Reference Note 11

Personnel Sensors

Personnel sensors, also called "motion detectors" and "occupancy sensors," are devices that sense the presence of people within an area. Originally developed as security devices, personnel sensors have become an efficient method of controlling equipment that is needed only when people are present.

In appropriate applications, personnel sensors match the operation of equipment to space occupancy more accurately than any other method. At the same time, using personnel sensors can be tricky. Inappropriate or careless installation can waste energy, annoy occupants, and create safety hazards. This Note tells you how to select and install personnel sensors successfully.

Where to Use Personnel Sensors

The most common energy conservation application for personnel sensors is controlling lighting. For example, a lighting retrofit program for a large, diverse research hospital found personnel sensors to be the most efficient method of lighting control for a large fraction of the spaces in the hospital, including offices, laboratories, restrooms, etc. Lighting is well suited to control by people sensors because it is needed only when people are present. However, even with lighting, it is sometimes better to control with other methods. For example, sensor control is not appropriate for patient rooms in hospitals.

Personnel sensors can also be used to control other types of equipment that are related to occupancy, such as ventilation fans. Personnel sensors cannot be used to start equipment that needs a warm-up or cool-down period, but they may be an effective means of stopping such equipment in applications where occupancy ends at varying times. For example, timeclocks can be used to start heating and cooling equipment at the beginning of the day, while personnel sensors are used to control this equipment later in the day.

Do not expect to use one particular model of sensor or one particular mounting method throughout a facility. Typically, you will need three or four different models and many mounting configurations to cover a building of average size and complexity. Expect to tailor each personnel sensor installation to the space that it covers. Expect to spend a lot of time and effort on this.

Personnel sensor control has the potential of annoying people, and even of creating safety hazards. Experience shows that occupants do not object to personnel sensors that are installed with adequate attention to the considerations discussed below. In proper installations, occupants typically are amused by personnel sensors until they no longer notice them.

Types of Personnel Sensors

Various methods have been developed to detect the presence of people in a space. None of them can absolutely distinguish a person from another object, and none can absolutely detect the mode of behavior, such as remaining in a space or just passing through. You have to select the device, or combination of devices, that most reliably detects the person, object, or mode of behavior that is appropriate for your control application. The following are the main types being used to detect people, and objects associated with people.

■ Passive Infrared Sensors

Infrared sensors detect the long-wavelength heat radiation that is emitted by people or other warm objects. The sensor does not emit any radiation itself, so it is

"passive." For this reason, infrared personnel sensors are commonly called "passive infrared" sensors.

The world is full of warm objects that we do not want to detect, such as heating vents and coffee pots. To avoid being triggered by these objects, infrared personnel sensors exploit the fact that most of these objects are stationary. The device uses a grid and an optical system to sense the motion of people. Only a small amount of motion is needed by a person to trigger the sensor.

Infrared sensors have become the most common type of personnel sensor for energy conservation applications. Figure 1 shows a small ceiling-mounted model that could be used to control lighting, air conditioning, a security system, or other applications.

Infrared sensor models that are designed to replace existing light switches have become popular because of their low cost and ease of installation. Figure 2 shows a good example.

The number of configurations is growing, especially for lighting control. Passive infrared sensors are now commonly available as an accessory of exterior floodlight fixtures, and they are also installed in other types of light fixtures. For controlling existing lamps, an inexpensive infrared lighting control can be inserted between a light bulb and its socket. Portable infrared sensors are available with a power cord and a male/female plug that allow them to control any appliance.

■ Ultrasonic Sensors

Ultrasonic sensors function by radiating high-frequency sound waves and sensing the frequency shifts (Doppler effect) in the sound that is reflected back to the sensor by moving objects. They cannot distinguish between people and other objects, except by size and location. Ultrasonic sensors are commonly used to open automatic doors, for example. They function well in this application because they open the door for any moving object, whether living or not.

Ultrasonic sensors are used much less commonly than infrared sensors for detecting people inside a space. However, ultrasonic sensors designed for this purpose are available. Figure 3 shows an example.

■ Audible Sound Sensors

Sensitive microphones can be installed to sense the presence of people by the sounds they make. Sound detectors are rarely used for control of energy systems, primarily because there is too much background noise in most applications. They are used most commonly in security systems. However, audible sound detectors may be a good choice for controlling interior security lighting, for controlling lighting in very large spaces, and for other specialized applications.

■ Microwave Sensors

Microwave sensors fill a space with microwave radiation. They detect movement from the distortion of the reflected radiation. They are like the early type of non-directional radar. That is why the radar detector of your car may sound an alarm when you drive past a large building. Microwave sensors are common in security applications, but they are not generally used for control applications.

■ Tread Switches

A tread switch makes or breaks an electrical contact when someone walks on it or rolls equipment over it. For example, tread switches are commonly used to open automatic doors. They are not commonly used for sensing people in a space, because they cannot cover a large area. In principle, you could use a tread switch at the entrance to a space to turn on the lights in the space. However, the switch would not know when the space has been completely vacated. Thus, they are generally not useful for turning equipment off.

Unenco Electronics, Inc.

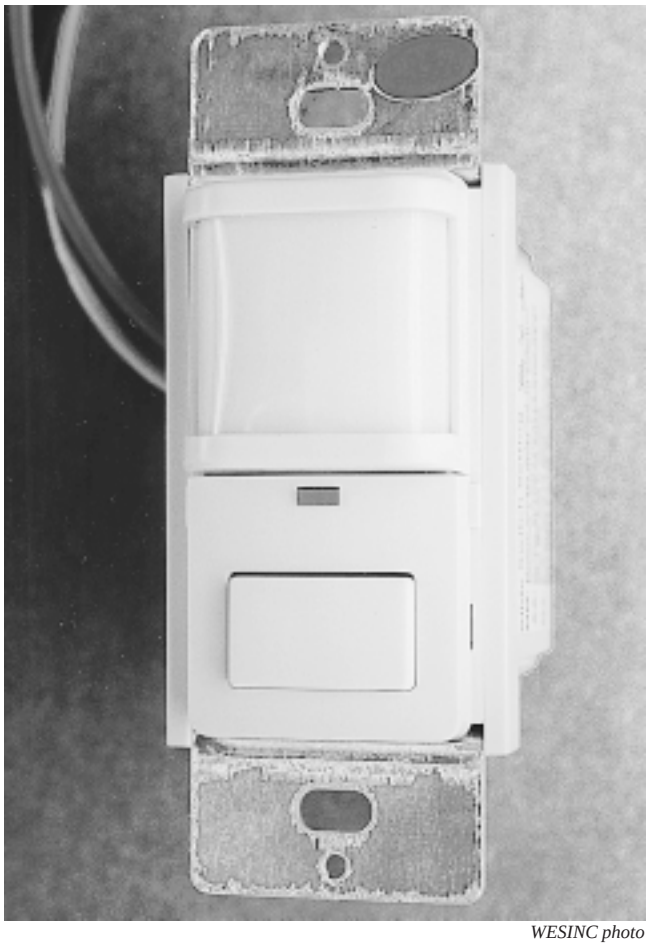
Fig. 1 Passive infrared sensor for ceiling mounting This unit sees in all directions. Installing it on the ceiling provides the most reliable coverage of the space. Settings are made with the tiny DIP switches, at the time of installation.

A tread switch may be a good way of conserving energy in a very localized application. For example, a tread pad can be used to turn off a machine tool when the operator is not standing on it.

■ Photoelectric (Light Beam) Switches

A light beam switch senses a person or object interrupting the light beam. A lamp is placed on one side of a path and shines a narrow beam into a photoelectric cell on the other side of the path. For example, light beam switches are commonly used as safety devices to keep automatic doors open when a person or object may be passing through the door.

This device is similar in application to tread switches, and it has similar weaknesses. Light beam switches are reliable and they are fairly inexpensive. In applications involving safety, they have the advantage of failing in a safe mode. For example, if the bulb burns out, the effect is the same as if a person crosses the light beam.



WESINC photo

Fig. 2 Passive infrared sensor for light switch location This type is inexpensive, easy to install, and easy to use. Its main weakness is the mounting location, which may not provide good coverage and may be easily obstructed. The details of this unit are shown in Figures 6, 7, and 8.

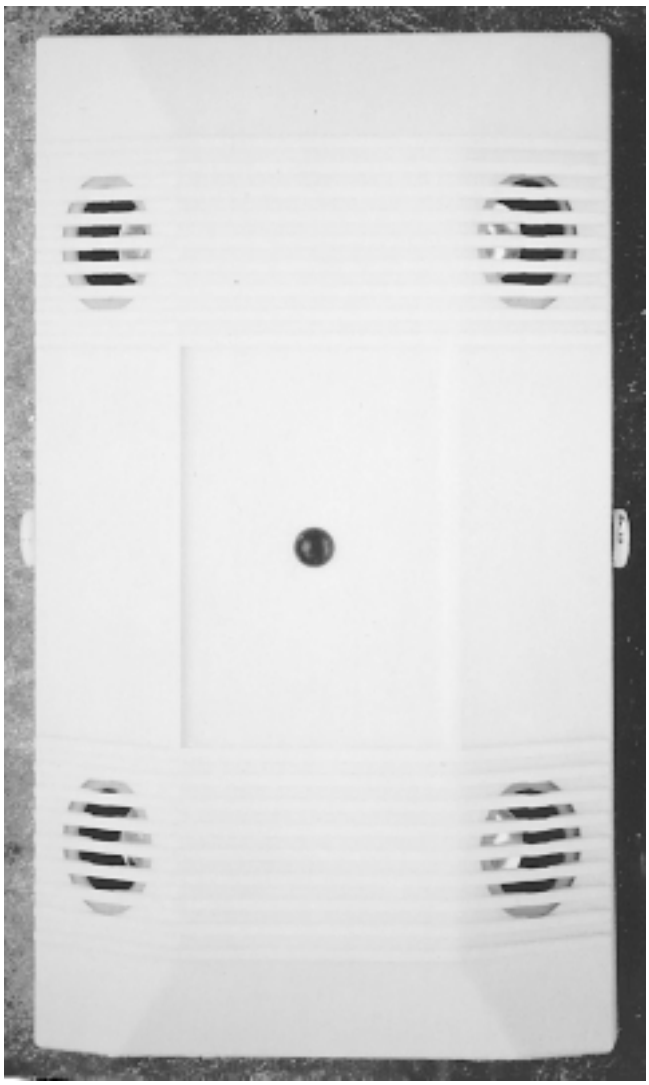
■ Interlocks with Other Controls

Any control that relates to the presence of people can be used as a personnel sensor. For example, the heating of a space may be controlled by the light switch for the space. Or, a contact switch can be installed on a door to turn on lights when the door is opened. Various Measures recommend these techniques where they are appropriate.

How to Select and Install Personnel Sensors

■ Safety

If you use personnel sensors to control lighting, take care to design the lighting layout so that a person will not be trapped in a darkened space if a personnel sensor fails to detect the person. For example, a personnel sensor controlling the light in the restroom may lose sight of a person who enters an enclosed stall. If the



Unenco Electronics, Inc.

Fig. 3 Ultrasonic motion sensor for ceiling mounting Ultrasound is directional, so this unit has four emitters to provide reasonably complete coverage. It is somewhat larger than a passive infrared unit.

person lingers there, the lights in the restroom may turn off, stranding the person.

The general solution to this problem is to provide enough continuous lighting to allow occupants to find their way safely to an exit. In most commercial buildings, this purpose is served by emergency lighting. If the facility operates only in the daytime, letting in some daylight may suffice.

Safety is also a major consideration where personnel sensors are used to control moving equipment, such as a conveyor belt in a factory. Design the controls to protect both equipment users and maintenance personnel from unexpected starts. The appropriate safeguards depend on the application, and may include warning signs, guards, interlocks, dead man switches, etc.

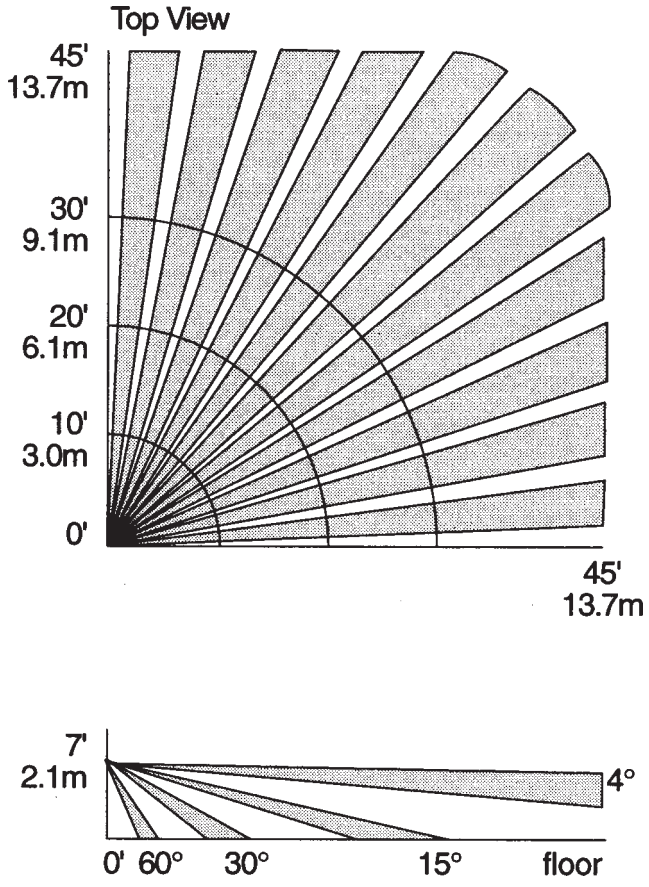
Ultrasonic sensors may be ineligible for some applications because of concern about their long-term effects on occupants. The fact that ultrasonic sensors remain on the market after years of use for opening doors indicates that no serious problems have been proven. However, it remains questionable whether ultrasonic controls should be installed where people will be exposed to them for long periods.

Do not use ultrasonic detectors in spaces containing animals that are sensitive to high-frequency sound, unless the animals are unwelcome.

■ Minimize the Perceived Delay in Turning On Lights

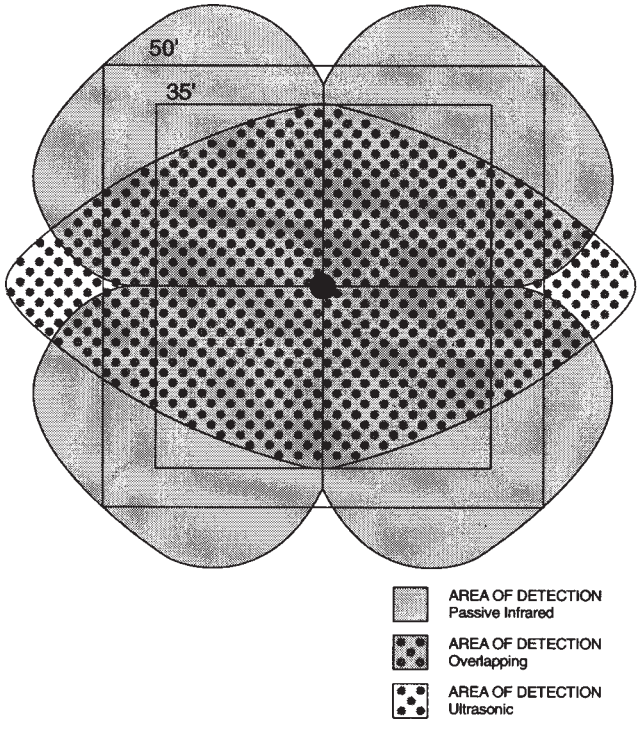
Locate sensors where they can immediately see a person entering a space, as when a person abruptly opens the door to a restroom with sensor lighting control. Otherwise, the person will have the unpleasant sensation of walking into a dark space. This problem is especially severe if persons are not familiar with the sensor control, for example, in public restrooms.

If the lighting is fluorescent, the problem is worsened by the starting delay of the lamp. The delay ranges from a fraction of a second for rapid-start lamps, to several seconds for preheat lamps. Most compact fluorescent lamps are preheat types, and many have a noticeable starting interval. Some compact fluorescent lamps take almost a minute to reach full brightness, and these lamps should not be used where instant light is required.



Unenco Electronics, Inc.

Fig. 4 Coverage pattern of an infrared sensor for corner mounting Infrared sensors use a lens system, so they can be made with any coverage pattern. Coverage can be uniform across the field of view, but sensitivity varies with background temperature.



Unenco Electronics, Inc.

Fig. 5 Coverage pattern of combined infrared and ultrasonic sensor This diagram does not tell the whole story, because each type of sensor is more sensitive in some ways than the other. For example, the IR sensor is most sensitive to motion across the field of view, but the ultrasonic sensor is most sensitive to approaching or departing motion.

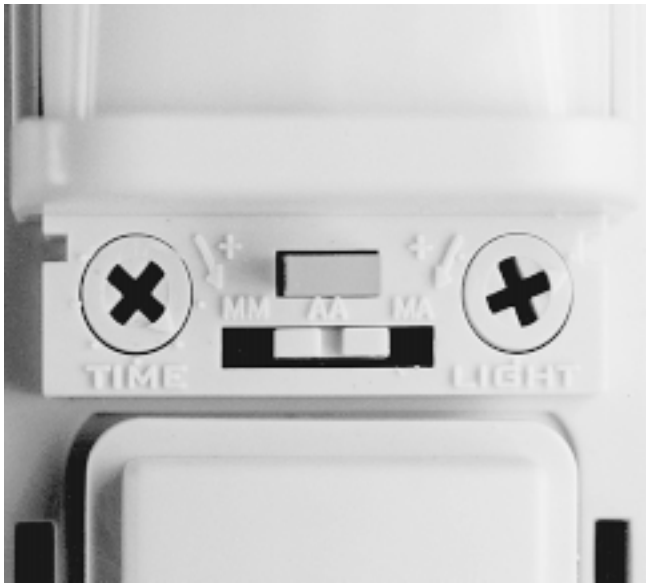
Do not use personnel sensors to control high-intensity discharge (HID) lighting. It has a very long delay in starting and restarting, of several minutes or longer.

■ Range, Coverage Pattern, and Sensitivity

Infrared personnel detectors typically have a range from 20 to 70 feet (6 to 20 meters). Detection is strictly line-of-sight. The coverage pattern, or field of view, depends on the geometry of the lenses that focus the heat radiation on the sensor. Ceiling-mounted sensors may have 360° coverage. Infrared sensors that replace existing wall switches may achieve almost 180° coverage against a flat wall. Figure 4 shows the coverage pattern of a model designed to be installed in a corner.

The range of infrared sensors varies with the magnitude of the temperature differential between the person's exposed skin and the background. Infrared sensors can detect remarkably small temperature differences, but it is conceivable that persons could become invisible to the sensors if the background temperature is close to skin temperature.

Infrared detectors sense motion across the sensor's field of view. Hence, the amount of motion required to trigger the unit depends on distance from the sensor. A unit installed close to a desk can sense a person nodding his head or moving his hand across a page, provided that this motion is across the detector's field of view.



WESINC photo

Fig. 6 A good set of features in an infrared sensor The screw on the right adjusts the daylight level that keeps lights turned off. The screw on the left adjusts the turn-off delay. Both require trial-and-error to set. The slide switch in the middle selects the override mode, explained in Figure 7. The switch plate must be removed to change any of these settings, which is an important safeguard. The little rectangular light amuses occupants by blinking when the sensor detects motion.

Ultrasonic detectors have about the same range as infrared units, or somewhat less. Their range depends on the person's size and direction of motion. Ultrasonic detectors sense motion primarily toward or away from the detector. They are generally less sensitive to motion than infrared detectors. As a result, they are limited to sensing large motions, such as people walking toward a door.

In order to get good sensing reliability, it may be desirable to combine the features of infrared sensing and ultrasonic sensing. Figure 5 shows the coverage pattern of a sensor that uses both types of technology in a single small unit.

Audible sound detectors have unlimited sensitivity potential. Their effective range is limited by the need to avoid false triggering from background noise. Occasional outside noises may be louder than typical human activity inside the space. Furthermore, human activity does not tend to be noisy on a continuous basis. Therefore, audible sound detectors are limited to applications where noise-producing activity is associated with the presence of people.

■ Mounting Location

Sensors must be mounted where they can reliably "see" people in the controlled area.

Infrared radiation is a form of electromagnetic radiation, like visible light. It has about the same penetration. If visible light cannot pass through something, infrared radiation cannot pass through it either. Furthermore, glass and other materials block heat radiation from people.

WESINC photo

Fig. 7 Override options This sticker explains the override modes that are selected by the switch in Figure 6. Option AA is the one to use in most applications. Option MA is efficient, but has few applications. Option MM abolishes the benefit of the sensor. The sticker becomes inaccessible, and hence useless, when the switch is installed.

Infrared sensors that replace wall switches are tempting with their low cost and ease of installation, but make sure that they provide adequate line-of-sight coverage of the space. This may be a problem, because light switches are mounted low on the wall, where the line of sight into the space may be obstructed by partitions, coat racks, etc.

This type of infrared sensor may be difficult to install in place of an existing toggle switch if the present switches are ganged, because the face plate of the sensor unit may be too wide for mounting alongside toggle switches. At least one manufacturer includes a replacement face plate to be used with double switch boxes. With larger numbers of ganged switches, you may need to install a separate junction box for the sensor.

Ultrasonic personnel detectors emit sound at very high frequency, which makes the sound directional. Ultrasound does not bend around objects very much. It does pass through lightweight objects, such as curtains and plants, and it reflects from the surfaces of the space, especially from hard surfaces. Thus, ultrasonic sensors are not limited entirely to line-of-sight detection. However, don't depend on this. Most ultrasonic detectors emit sound in a lobe pattern, with an effective pattern width around 50°. They are usually mounted high on a wall.

Audible sound detectors are non-directional, especially for sounds of lower frequency. This makes them worth considering where the other two methods cannot provide adequate coverage, provided that the environment is fairly quiet. Audible sound detectors can be installed almost anywhere, except that they should be installed away from any sources of noise that are not related to occupancy.

Wall-mounted sensors typically have self-contained override switches, sensitivity and delay adjustments, etc. Ceiling-mounted units either sacrifice these control options or they require separate control panels, which adds wiring cost.

■ Daylight Override

Sensors that are designed to control lighting may have a feature that detects the amount of daylight in the space. It keeps the switch from turning on the electric lights when sufficient daylight is available. This feature requires a setting to adjust the amount of daylight that is needed to deactivate the switch. Figure 6 shows the setting on a typical unit.

■ Turn-Off Delay

Virtually all personnel sensors have delay mechanisms to keep the equipment turned on for a period of time after the last motion or sound is detected. This delay feature compensates for lack of sensitivity. Extending the time delay makes it more probable that a person within the space will move enough to keep the equipment turned on. For example, even a person reading a book moves enough every few minutes to reactivate an infrared sensor.

The energy penalty of extending the turn-off delay is usually small. For example, if the equipment is kept running for ten minutes after the last person leaves the space, this does not waste much of the energy-saving potential in most applications.

In applications where people frequently enter and leave a space, the turn-off delay minimizes short-cycling of equipment, such as lamps, motors, compressors, etc.

Many delay options are available on different models. Some units have a single fixed delay period. Others have a choice of fixed delay periods. Many units provide a continuous range of delays, as in Figure 6. The latter type can be a nuisance to set, because the setting feature does not accurately indicate the delay. This requires wasting a lot time with trial and error.

■ Minimize False Triggering

Personnel sensors can be triggered by stimuli other than people, or by the wrong people. False triggering wastes energy and wears out equipment. To determine whether false triggering is occurring, observe the operation of the equipment during unoccupied periods. You can temporarily connect an inexpensive data logger to the controlled equipment for this purpose.

Infrared detectors may be triggered by equipment that turns on and off while the space is vacant. Examples are heating and cooling equipment, refrigerator motors and thermostatically controlled coffee pots. Infrared sensors are not triggered by the air from the conditioning units, but by surfaces that are heated or cooled rapidly by the air, including the surfaces of the conditioning units themselves. The same problem can be created by sunlight that enters through windows and skylights. Fortunately, window glass is opaque to heat radiation, which minimizes (but does not eliminate) false triggering caused by moving heat sources seen through windows.

Experience will teach you where to expect false triggering. Infrared control is line-of-sight, so you can usually prevent false triggering by installing shutters or blinders to keep the sensor from seeing the heated areas. Some infrared units include adjustable shutters to limit their field of view. Some infrared sensors have sensitivity controls that may avoid false triggering.

Ultrasonic personnel sensors may be triggered by moving objects within vacant spaces, such as machinery, exposed fans, blowing curtains, kinetic artworks, etc. They may also be triggered by transient sounds, such as thunder or an air conditioner turning on. Ultrasonic sensors may have sensitivity controls to limit unwanted triggering.

With audible sound detectors, it is virtually impossible to prevent some false triggering by sounds from outside the controlled space. Also, false triggering may be caused by equipment sounds that occur within

the space while it is vacant. Selecting the best mounting location and adjusting the sensitivity control are the ways to minimize false triggering.

■ How to Confine the Area of Control

Arrange the control layout so that people located in one area do not trigger sensors in other areas. You can do this by limiting the sensitive area of each sensor. For example, to provide individual lighting for a number of indoor tennis courts, install a sensor for each court and aim it at the center of its court. This may require adjusting shutters or installing blinders on the sensors.

The weakness of this technique is that people who are near the edges of controlled areas may not trigger sensors reliably. You can solve this problem, at increased cost, by installing a larger number of short-range sensors. For example, the lighting for each desk in an open office bay can be controlled by its own sensor.

Another approach is to install partitions. This may not be as expensive as it sounds. With infrared sensors, only lightweight visual screens are needed.

■ How to Control Large Areas with Few Sensors

Use clever sensor layout to minimize the number and cost of the sensors needed to provide coverage of a large area. For example, you may provide adequate control for lighting a basketball court by installing sensors near the basket, at the entrances, and at the front of the seating area.

If you use this "sampling" technique to control lighting, it is especially important to design the lighting so that safe egress is possible under all conditions.

Consider audible sound detectors for large areas that are sparsely or irregularly occupied, provided that the background noise is not too high. Audible detectors provide the advantage of complete coverage, avoiding the uncertainties of control on a sampling basis.

■ Accommodate Diverse Control Requirements

It may be desirable for equipment to respond differently to different types of occupancy. For example, the air conditioning unit in a room should start when the first occupant enters, but not when a security guard looks inside. One way to make this distinction is to mask out the portion of the space where unwanted triggering can occur. If this is not practical, consider subdividing the space into smaller controlled areas by using a number of sensors of limited range.

Cleaning crews deserve special attention because they go almost everywhere and they work at hours when the regular occupants are gone. For control of lighting, personnel sensors respond almost perfectly to cleaning crews. However, for control of conditioning equipment, they have just the wrong response. You may need to combine personnel sensors with other controls to keep equipment from starting as a result of the transient presence of people in an area.

(Permit a small sermon. Designers fail to account for operational factors like cleaning crews, window washing, light bulb changing, and equipment maintenance because they do not acquire experience in facility operations during the years they are in training. This is a glaring defect in our present way of training architects and engineers.)

■ Anticipate Changes in Space Configurations

Try to anticipate future changes in space configuration that may interfere with the operation of personnel sensors, such as relocation of furniture, addition of privacy screens, etc. Even small changes may mask the coverage of a sensor, such as placing a coat rack next to a wall sensor. Retrofit sensors that replace toggle switches are most vulnerable to changes because they are installed at a low height.

■ On and Off Override Switches

Personnel sensors cannot respond to all the conditions that may occur, so they may include a manual "off" switch, a manual "on" switch, or both. Figures 6 and 7 show an interesting combination of choices for selecting manual or automatic operation.

It is usually desirable to provide a manual "off" override, either on the sensor itself or separately. For example, in lighting applications, there is usually an occasional need to darken a space while it is occupied, e.g., to show slides in a conference room. Make the override switch easily accessible.

On the other hand, avoid sensors that include an "on" override. If the sensor has this feature, it is likely that someone will leave the switch in the "on" position, disabling its ability to turn equipment off. There should be no circumstances that require an "on" override. If a personnel sensor fails to turn on equipment automatically

WESINC photo

Fig. 8 Critical electrical information This infrared switch can control different kinds of electrical equipment, including motors, but the capacity ratings are different for each kind.

when it is needed, it is either installed improperly or it is not appropriate for the application.

■ Sensors with Three-Way Switches

Some wall-mounted sensors can act as a 3-way switch. These units are intended as replacements for existing 3-way toggle switches. These can be used in two ways. If all the manual switches are replaced with sensor switches, sensors in different parts of the space can control a single set of equipment. Or, if a single sensor switch is used in combination with manual switches, the manual switches can act as overrides to force the controlled equipment off.

■ Maximum Amperage or Wattage

The cost of electronic devices is related to the current they handle, so many personnel sensors are not designed to handle full circuit capacity. Be sure to check that the amperage or wattage rating of the sensor is adequate for the controlled load.

The amperage rating may be lower for incandescent lighting than for other types of loads. This is because incandescent lamp filaments have lower resistance when cold than at operating temperature, so they have high starting current.

If the sensor is rated by power, rather than by amperage, the rating may be lower for motors and fluorescent lighting. This is because motors and magnetic lamp ballasts have low power factor, which requires them to draw extra current for a given amount of power.

Figure 8 illustrates how a single sensor may have a number of different wattage and volt-amp ratings for different types of loads.

If you need to control a large amount of amperage or power, consider using a power relay instead of a more expensive sensor. Using multiple relays allows a single sensor to control as many circuits as desired. A relay also allows any sensor to control equipment of any voltage.

■ Minimum Wattage

An odd feature of some personnel sensors is that they require the controlled equipment to have a minimum wattage. For example, some lighting sensors cannot control lamps smaller than 40 watts. This is related to the switching characteristics of semiconductors.

■ Lamp Flicker

Some personnel sensors cause fluorescent lamps to flicker. This appears to be a problem associated with aged lamps. Also, high-efficiency fluorescent tubes are more susceptible to flicker than conventional tubes. The problem is most serious immediately after the lights are turned on. These problems suggest that the personnel sensors are lowering the peak voltage to the lamps.

For fluorescent lighting and other applications where the voltage and waveform of the power are critical, test candidate units to ensure that they do not cause problems.

Some electronic fluorescent lighting ballasts compensate for variations in input voltage, including variations caused by personnel detectors.

■ Grounding

Good grounding is especially important for reliable operation of semiconductor switching equipment, as well as for safety. It is good practice to ground the sensor units using separate ground wires attached to the boxes, rather than relying on the mounting screws for grounding. Trouble is likely to occur if the existing electrical system is not well grounded.

■ Placards

Even though personnel sensors are fully automatic, expect to install placards to inform occupants about them. Incomprehensible control operation is annoying, and people may respond in a manner that is wasteful or unsafe. See Reference Note 12, Placards, for details of effective placard design, materials, and installation. Placards about personnel sensors should explain the following:

- which equipment is controlled
- that the equipment responds to the presence of people in the space
- that the control will delay turning off the equipment for a short period after it ceases to sense people in the space
- how to operate the manual features of the control (if any)
- that the user should set the switch back to "automatic" after using any manual settings
- whom to contact in the event of malfunction.

Test Unfamiliar Situations

It is difficult to anticipate exactly how particular models of personnel sensors will work in any particular environment. In case of doubt, test a few candidate sensors in some typical spaces before purchasing large numbers.

Monitor Performance

For a period of several days after a sensor is installed, check with the occupants of the space to see whether the controls are causing any problems. Make any appropriate corrections.

Don't forget this step. If a dangerous or inconvenient situation is created by the sensor control, you want to know about it before trouble occurs.