Improving Elevator Performance by Monitoring Elevator Cab Volume

by James O'Laughlin

Learning Objectives

After reading this article, you should:

- ◆ Understand why some elevator applications have the problem of full elevator cabs stopping unnecessarily to service hall calls.
- ◆ Be able to describe several methods that help minimize the problem of full elevator cabs stopping unnecessarily to service hall calls.
- ◆ Recognize why camera technology provides a better solution for monitoring consumed elevator-cab volume.
- ◆ Know the application requirements for monitoring consumed elevator-cab volume using infrared camera technology.
- ◆ Obtain knowledge regarding the installation and operation of the CEDES ESPROS/VOL Camera sensor.

Optimal elevator system performance has always been a concern for facilities and building management. People expect that the elevator will arrive shortly after they press the hall call button. When the elevator arrives, people are disappointed when it is full, and they have to press the hall call button and wait for the next car. The delays and inconvenience caused by full cabs arriving to service hall calls are not appreciated. Equally annoyed are passengers currently in the elevator who are unnecessarily delayed as they stop for hall calls that cannot be serviced because the elevator cab is already full of passengers.

Several methods can be used to minimize the instance of full cabs responding to hall calls. Increasing the number of elevators is one possibility, but is generally cost prohibitive. Destination-dispatch systems can also help to alleviate this issue. However, destination-dispatch systems are best implemented in new installations, and also may be cost prohibitive for modernization applications. More cost-effective solutions include using load-weighing systems or camera-based monitoring to determine a threshold that corresponds to the consumed volume inside the elevator cab. Once the threshold value has been reached, the elevator control system can perform a bypass or an express run that minimizes or eliminates the unnecessary stops.

CEDES ESPROS/VOL camera installation (photo courtesy of New York Elevator)

However, load-weighing systems cannot improve elevator performance when the consumed elevator cab volume does not correspond to the measured weight. This is particularly true when elevator loads include

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passengers and other items such as luggage carts in hotels, gurneys and beds in hospitals, or wheelchairs in nursing homes. For these and similar types of circumstances, measuring the actual consumed volume inside the elevator cab provides the only real solution that addresses this challenge.

Camera-Based Volume Monitoring

The ESPROS/VOL is a camera-based system that can operate as part of a stand-alone system or with a load-weighing system to help determine when a "cab full" condition exists. This product is manufactured by CEDES AG in Landquart, Switzerland, and is an intelligent vision sensor that uses infrared complementary metal-oxide-semiconductor camera technology. The microprocessor inside the device provides a camera image of more than 100,000 gray-scale pixels. The internal software algorithm then compares the current pixel image against a reference image stored in its internal memory. When the percentage of pixels that have changed meets or exceeds the user-defined "cab full" threshold, an output is generated. The elevator operational control can then perform a bypass or an express run to the destination floors selected from inside the elevator cab without stopping unnecessarily for waiting hall calls.

Monitoring elevator cab volume consumption using an infrared-camera system includes the following application requirements:

- The elevator operational control system must have an electrical input that supports the bypass or express run function. The output from the ESPROS/VOL camera is 24 VDC when the percentage change required by the threshold value has been met or exceeded. Particular attention is required for hydraulic elevator applications when the bypass function is accomplished using fluid dynamics rather than electrical control.
- Infrared cameras rely on infrared light present inside the elevator cab. Halogen lighting provides an efficient means of fulfilling this requirement. However, when fluorescent lighting is the sole source of lighting in the elevator cab, an additional infrared light source may be necessary to ensure adequate ambient infrared light is available.
- Consistent lighting inside the elevator cab is also required. Lighting variation caused by direct or indirect sunlight showing through a glass window will impact system performance negatively. For non-glass enclosed elevators, this is generally not an issue as the pixel comparison used to determine whether or not the bypass threshold has been reached should occur when the elevator door is closed.
- The camera's field of view must be considered. Based on a 2.1-m (6.8-ft.) mounting height, the observed space inside the elevator cab for a field of view equal to 54° (i.e., ESPROS/VOL field of view) is 2.9 m X 2.2 m (9.4 ft. X 7.1 ft.) maximum. Areas larger than this can be addressed using two or more cameras, e.g. by series connection of signal relay contacts.
- Mirrored surfaces may result in "double counting." This results from counting the pixel changes caused by the actual load (e.g., person) and then counting pixel changes also reflected by the mirrored surface. This specifically occurs when the mirrored surface is within the camera's field of view.

When these application requirements are adequately addressed, an infrared camera-based monitoring system may be used for measuring the consumed volume inside an elevator cab and signaling that a bypass or express run condition has occurred.

Mounting Considerations

The mounting location and orientation of an ESPROS/VOL infrared camera is critical to performance. There are two model types: one for ceiling mounting (ESPROS/VOL-V) with a vertical view and one for wall mounting (ESPROS/VOL-A) with an angled view. The sensor may be inconspicuously mounted due to its small size (the housing is 126 mm long X 67 mm wide X 36 mm deep, or 4.96 in. long X 2.64 in. wide X 1.42 in. deep). However, the system will be most effective when the elevator cab floor is in full view.

The ideal position for ceiling-mounted applications is in the center

Figure 1: ESPROS/VOL images showing different levels of elevator cab volume consumption (l-r): 15% full; 50% full; 75% full

of the cab with a full view of the elevator cab floor. Figures 2-5 were captured in an elevator with a floor area of 1.2 m X 1.5 m (3.9 ft. X 4.9 ft.) at a mounting height of 2 m (6.5 ft.). The crosshair shown in Figure 2 shows the mounting position of the camera in the ceiling with respect to the elevator cab floor. Camera images are slightly rectangular (i.e., not square) as the view is larger for the housing length than for the housing width.

Care should be taken to avoid unfavorable mounting locations. Figures 3 and 4 show mounting locations that should be avoided when possible. The mounting location shown in Figure 3 only partially monitors the elevator cab floor. In this case, that part of the floor in the front of the cab is out of camera view.

The mounting location indicated by the crosshair shown in Figure 4 affects system performance by double counting pixels, once for an actual person or object and once for the associated reflection in the mirror. As more passengers or objects enter the cab, the double counting effect becomes worse.

The ideal position for wall-mounted applications is in the middle of the elevator on the wall directly above the elevator door. Figure 5 was captured in an elevator with a floor area of 1.2 m X 1.5 m (3.9 ft. X 4.9 ft.) at a mounting height of 2.1 m (6.8 ft.). The crosshair shown in Figure 5 shows the mounting position of the camera located on the wall above elevator cab door.

To mount the ESPROS/VOL, fasten the mounting plate provided with the device to the selected location in the elevator cab. Once the mounting plate has been secured, slide the ESPROS/VOL housing onto the mounting plate as shown in Figure 6 below.

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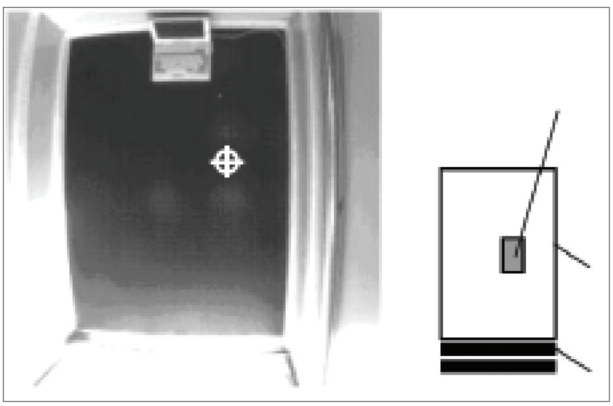

Figure 2: Correct mounting location for ESPROS/VOL-V in ceiling of elevator cab

Figure 3: Incorrect mounting location for ESPROS/VOL-V in ceiling of elevator cab (0.5 m from back of elevator cab)

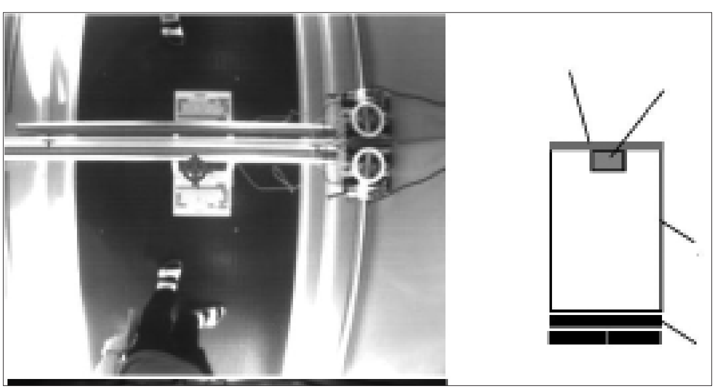

Figure 4: Incorrect mounting location for ESPROS/VOL-V in ceiling of elevator cab near mirrored back wall

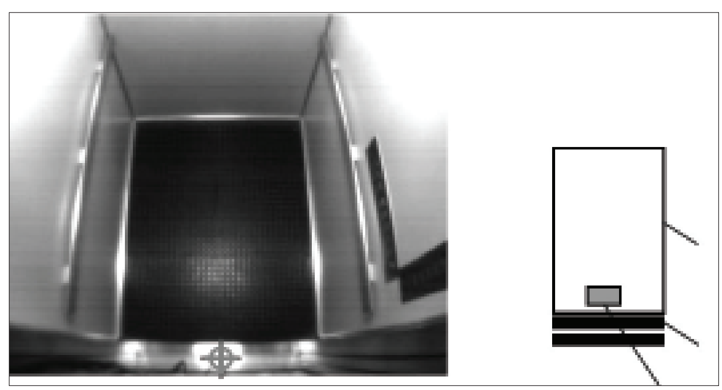

Figure 5: Correct mounting location for ESPROS/VOL-A on wall of elevator cab above elevator door

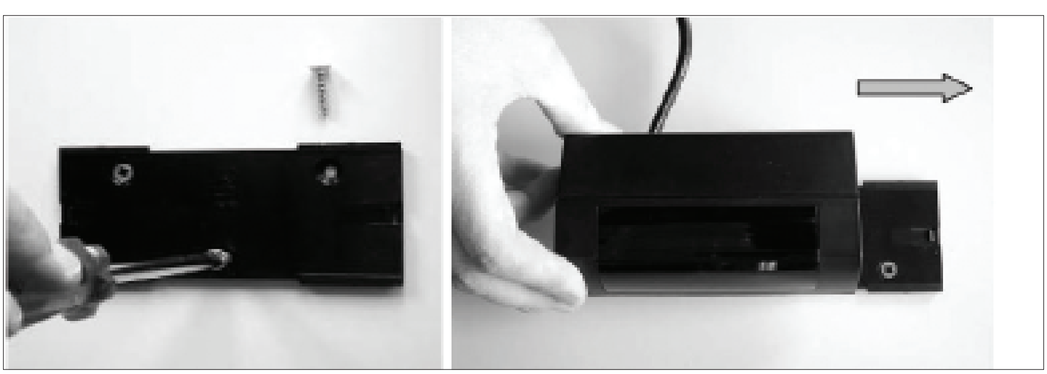

Figure 6: Fastening the mounting plate and then sliding the ESPROS housing on to the mounting plate

Device Connections

A single 11-conductor cable, 2 m (8 ft.) in length, provides connections for power, communication and relay outputs from the ESPROS/VOL camera. Power connections consist of a 24 VDC and Common. Connections for communication to a computer are RS-232 receive (Rx) and transmit (Tx) lines. These connections are used for communicating to the visualization software described later in this article. Relay outputs are available that provide indication of:

- When the user-configured threshold value has been reached (normally open and normally closed contacts)
- When the elevator cab is occupied (normally open and normally closed contacts)

It is important to note that the relay outputs should only be evaluated by the elevator control system when:

- The elevator door is shut.
- The light in the elevator cab is on.

Configurable Parameters

Configuration of the ESPROS/VOL is implemented using three potentiometers and one bank of digital image processing (DIP) switches. Figure 7 shows the location of these items. Potentiometer P1 configures the threshold value from 4% to 100%. Potentiometer P2 is used to turn a buzzer on or off when the current occupancy is greater than the threshold value. This is helpful for establishing which threshold value should be used. Potentiometer P3 defines the recalibration time from 20 to 120 seconds. When the camera image remains constant for the recalibration time period, that image becomes the stored reference image. This allows environmental changes within the elevator cab (e.g., a burned out light) to be taken into account.

The DIP switches are used to define additional recalibration parameters, darkness mode and relay properties. Darkness mode is used when the brightness of the elevator cab decreases suddenly (e.g., the elevator cab lighting is turned off when the elevator is not in operation). When darkness mode is activated and the brightness in the cab suddenly decreases, the camera no longer recalibrates the stored image. In this case, the relay output remains in the pre-darkness state, as determined through other DIP switch settings. The darkness mode ceases when the brightness inside the elevator cab returns to near its previous value.

Diagnostic Indicators

The ESPROS/VOL features several diagnostic indicators for ease of troubleshooting. The yellow power LED indicates when power is present on the device. If this LED is not illuminated, check the power connections and ensure that power is present. When the Relay Out 1 LED (green) is illuminated, the occupied floor space in the elevator car is higher than the threshold value set by potentiometer P1. When the Relay Out 2 LED (red) is illuminated, the elevator car is not empty. LEDs L1, L2 and L3 (all green) provide diagnostic information related to recalibration. In particular, when LED L3 is blinking, it indicates that the ESPROS/VOL device is operating properly.

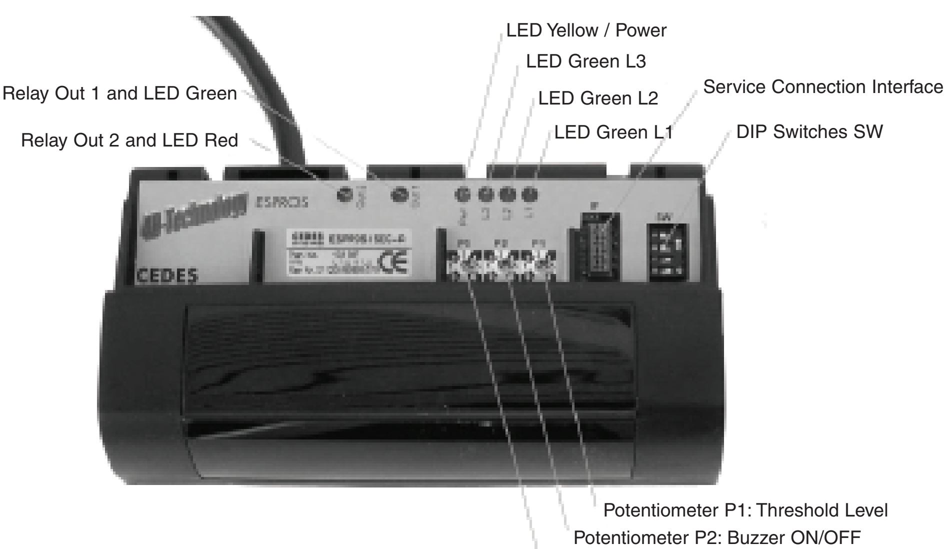

Figure 7: ESPROS/VOL indicators and configuration potentiometers/DIP switches

Visualization Software

Microsoft® Windows XP® or Vista® compatible software may be used to communicate status and current configuration information from the sensor using RS-232c communication. This is particularly useful for both troubleshooting and initial configuration. The software communicates to the ESPROS/VOL device using the RS-232c communication conductors (Rx, Tx and GND) available in the cable. If RS-232c is not available at the computer, the RS-232 signals can be converted to a universal serial bus signal using a conventional cable converter.

Figure 8 shows several examples of how the visualization software may be used for configuration and troubleshooting of the ESPROS/VOL camera system. The left picture shows an ESPROS/VOL system in which no passengers are present. Note that the occupancy is 0% and the Relay Out 1 and Relay Out 2 are both inactive (NC). The potentiometer values are also indicated (P1 = 64%; P2 = 0; and P3 = 79 seconds). The middle picture provides an example of a cab that is occupied, but has not yet reached the threshold set point. The potentiometer values have not changed, but now Relay Out 2 is active (NO). The right picture shows that the occupancy value has met/exceeded the threshold value. In this case, the potentiometer values have remained constant, but Relay Out 1 is active. This relay signal would be used to implement the bypass or express run signal in the elevator control system.

Startup Procedure

After the ESPROS/VOL camera is mounted in accordance with your

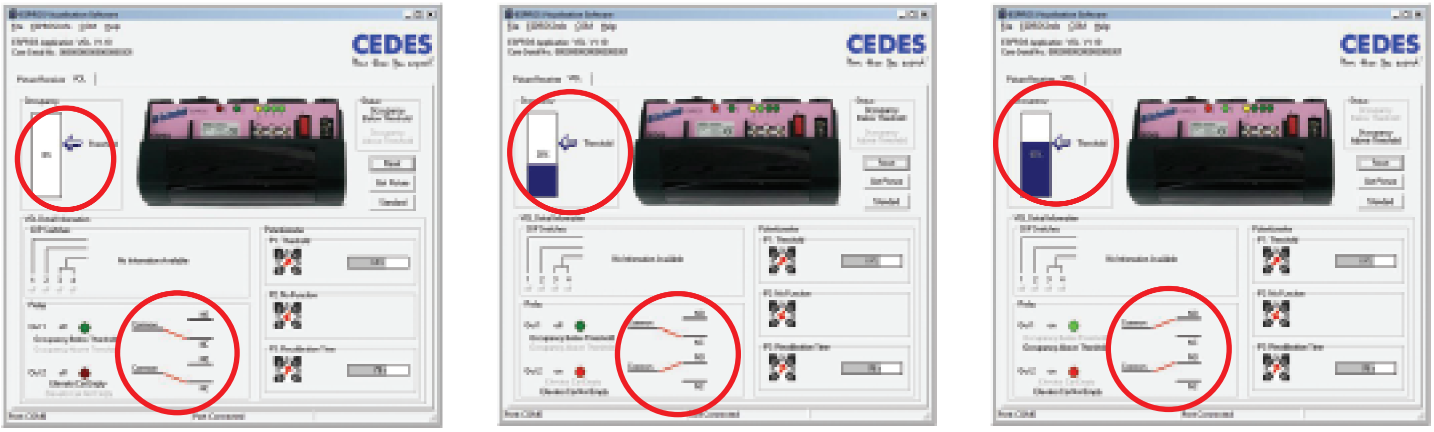

Figure 8: ESPROS/VOL visualization software tool screenshots

application requirements, the initial startup is straightforward. Begin by implementing the following steps:

- ◆ Make the necessary cable connections for power, relay outputs and communication.
- ◆ Configure the DIP switches in accordance with your application requirements.
- ◆ Ensure that elevator doors are closed.
- ◆ Ensure that the lights are turned on inside the elevator cab.
- ◆ Ensure that the elevator cab is empty.
- ◆ Cycle power to ESPROS/VOL camera.
- ◆ Wait five seconds for the internal power-up sequence to complete and a reference image to be taken.

At this point, the ESPROS/VOL camera is operational and you can configure parameters using the potentiometers. You may wish to consider adjusting the occupancy threshold value with the help of the buzzer (potentiometer P2 set to a value ≥ 2). When the buzzer is active, it will sound when the ESPROS/VOL detects that the percentage of pixels that have changed between the reference image and the current image has met or exceeded the configured threshold value. Once you have determined the occupancy threshold value (using potentiometer P1), set the buzzer configuration back to inactive (potentiometer P2 set to a value ≤1).

In the event that power cannot be cycled (i.e., turned off and then back on), the ESPROS/VOL will recalibrate the reference image based on its configuration settings (based on potentiometer P3 setting; factory default setting is 20 seconds).

When the power to the ESPROS/VOL is interrupted, the elevator control should ensure that the following has occurred before utilizing signals from the relay outputs of the ESPROS/VOL:

- ◆ The elevator door must be closed.
- ◆ The light in the elevator car must be on.

The ESPROS/VOL has cycled through the recalibration time.

Conclusions

Optimal elevator performance has and will continue to be a high priority for building and facility professionals. When an elevator cab is full but continually stops to service hall calls, the unnecessary delays and inconvenience lead to unhappy customers, patients, tenants and more. Load-weighing systems and camera-based technologies can assist with minimizing or eliminating this issue.

Camera-based monitoring provides an intelligent solution to load-weighing systems. It can accurately account for non-passenger loads that weigh significantly less than the amount of space that would be occupied by people. Examples include wheelchairs, hospital gurneys and luggage carts. That said, load-weighing systems may need to fulfill other elevator performance requirements (e.g., prevention of rollback) and cannot always be eliminated from the elevator control system. When this is the case, the best solution uses both camera-based monitoring with the load-weighing system to provide a clear picture of the current state of "fullness" in the elevator cab.

James O'Laughlin recently joined CEDES Corp. of America in Minneapolis as a product marketing manager. He received his BSEE from Mankato State University in 1988. He has specifically focused on the integration of safety technologies in industrial machinery over the past 10 years and has been engaged in engineering, sales and marketing roles within the industrial automation sector for the past 20 years.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 149 of this issue.

- ◆ Which methods can be used to improve efficiency of elevator systems during high-traffic periods?
- ◆ Which benefits does camera-based volume consumption monitoring offer compared to load-weighing monitor systems?
- ◆ What application requirements must be addressed for camera-based volume consumption monitoring?
- ◆ How do you implement a camera-based volume consumption monitoring system into an existing elevator cab?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Instructions:

- Read the article **"Improving Elevator Performance by Monitoring Elevator Cab Volume"** (page 73) and study the learning-reinforcement questions.
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1. Which of the following methods provides the most cost-effective and efficient improvement for elevator applications where non-passenger loads frequently occur?
   a. Destination-dispatch systems.
   b. Camera-based volume consumption monitoring systems.
   c. Load-weighing monitoring systems.
   d. Adding additional elevators.

2. What term is used to describe an "express run" condition in which the elevator-operation control ignores hall calls when the elevator cab is full?
   a. Circumvent.
   b. Circumnavigate.
   c. Bypass.
   d. Diversion.

3. The threshold value of the CEDES ESPROS/VOL camera-based volume consumption monitoring compares a stored reference image to the current camera image. The number of pixels that are compared is:
   a. 10,000.
   b. 50,000.
   c. 75,000.
   d. More than 100,000.

4. The most efficient and consistent light source that should be used with infrared cameras located inside an elevator cab is:
   a. Fluorescent lighting.
   b. Neon lighting.
   c. Halogen lighting.
   d. Direct sunlight.

5. When mounting a camera-based volume consumption monitoring system, it is important that the camera's image (camera view) is focused on the:
   a. Elevator cab floor.
   b. Elevator cab back wall.
   c. Elevator cab doors.
   d. Elevator cab ceiling.

6. The recalibration time of the CEDES ESPROS/VOL camera-based volume consumption monitoring is the amount of time required:
   a. For the camera relay output to return to its resting state.
   b. For the camera image to remain constant before it becomes the new reference image.
   c. For the elevator operation control to respond to the camera output.
   d. For the camera buzzer to start buzzing after the camera image reaches the user-defined threshold.

7. The CEDES ESPROS/VOL camera system supports communication from the camera to the visualization software via:
   a. CAN protocol.
   b. RS-232.
   c. RS-422.
   d. HART protocol.

8. When troubleshooting a CEDES ESPROS/VOL camera system installation, and the yellow LED is not illuminated, you should:
   a. Check to ensure that there is sufficient infrared light available inside the elevator cab.
   b. Make sure that 24-VDC power is connected to the device.
   c. Verify that RS-232 communication is occurring between the camera and a computer that has the visualization software.
   d. Make sure the image inside the cab does not change for the defined recalibration time.

9. What are used on the CESES ESPROS/VOL camera system to define additional recalibration parameters, darkness mode and relay properties?
   a. DIP switches.
   b. Potentiometers.
   c. Banks.
   d. Transmit lines.

10. Which is NOT a method that can be used to minimize the instance of full cabs responding to hall calls?
    a. Increasing the number of elevators in service.
    b. Destination-dispatch systems.
    c. Emergency-operations systems.
    d. Load-weighing monitoring systems.

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