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C Y Shaw, S A Barakat, G R Newsham, J A Veitch, J Bradley

Institute for Research in Construction, National Research Council Canada

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NRC INDOOR ENVIRONMENT RESEARCH FACILITY

C.Y. Shaw, S.A. Barakat, G.R. Newsham, J.A. Veitch and J. Bradley
Institute for Research in Construction
National Research Council Canada

Synopsis

This paper describes the new indoor environment research facility recently constructed at the Institute for Research in Construction, National Research Council Canada. This facility allows full-scale testing and physical modelling of office space lighting, thermal comfort, indoor air quality, airflow and contaminant-flow patterns, ventilation, acoustical characteristics, and occupants' reactions to these parameters. The facility consists of a test room, approximately, 12 m by 7 m by 2.74 m high, with adjustable interior partitions. The test area can range in size from a single large open area, to four identical single-office-sized test rooms.

The facility also has the option of including an exterior wall with windows to produce realistic boundary conditions created by wind and solar effects including daylighting. As well, the ceiling and floor are designed to allow the testing of different types and layouts of air diffusers and luminaires. To have an acoustically stable environment for special types of subjective experiments, noise from the HVAC systems and other external sources will not exceed NC 20 in the test rooms. Regulated and conditioned electrical power is available in the facility. Dedicated control systems provide a controlled environment for the test room and its various realistic boundary conditions.

Introduction

A significant ongoing challenge for building owners and managers is to balance the quality of office indoor environments against the savings in operating costs that are typically achieved through renovation and energy conservation programs. It is vital that energy savings not compromise occupant satisfaction and productivity, because the costs of lost productivity will always exceed the value of energy savings. Studies estimate that direct medical costs associated with indoor pollution in the US could range from US$500 million to over US$1 billion a year, while lost of productivity could cost tens of billions of dollars a year (Woods, 1989 and Leinster and Mitchell, 1992). Providing an acceptable indoor environment along with successful energy conservation depends on the performance of the building systems that heat, cool, ventilate, insulate and illuminate interior spaces. These systems must be properly designed and maintained in order to provide continuing comfort, environmental quality, and operating economy.

To help building owners and managers meet this challenge, it is necessary to develop techniques and measurement tools that can correctly diagnose shortcomings in any performance aspect, and can lead the building operator to correct them at the lowest cost. It is also necessary to explain the large difference between the occupants' perceptions and the physical assessment of a building's indoor air quality, acoustics and illumination. The best way to establish causal connections between physical parameters and human behaviour (e.g., perception, performance, mood) is to conduct systematic studies in a laboratory facility where each physical factor can be precisely varied, both individually and in combination, to assess its effect on the indoor environment and on the people in it. To facilitate such a study, the laboratory should be able to simulate offices and conference rooms of different sizes and layouts. It should also be able to simulate different ventilation system designs and operating conditions, lighting designs, and acoustical conditions.

Individual differences including age, gender, sensitivity, job satisfaction and job stress can also have significant effects on the occupant's perception of the indoor environment (e.g., Hedge et.al, 1992). Laboratory studies allow the researchers to examine the interactions of such personal characteristics and physical parameters in the workplace. Some of the social characteristics of workplaces can be created in the laboratory by having real office workers to serve as research subjects; this ensures results that are more representative of working organizations and their employees. This paper describes the indoor environment research facility constructed for this purpose at the National Research Council of Canada (NRC).

The Facility

The new facility is located at the west end of the second floor in a three storey laboratory-office building. It is the centrepiece of a multi-year research project on the indoor environment currently underway at the Building Performance Laboratory of the Institute for Research in Construction, NRC. It was designed to allow full-scale testing and physical modelling of office space lighting, thermal comfort, indoor air quality, airflow and contaminant-flow patterns, ventilation, acoustical characteristics, and occupants' reactions to these parameters. The architectural, mechanical and electrical designs are discussed in the following sections.

Architectural - Figure 1 shows that this facility consists of a test area, a control room and a reception area for the training and orientation of the test subjects. Inside the reception area, there is a visual acuity test room. The dimensions of the test area are 12 m by 7 m by 2.74 m high. The east, south and north walls are fixed internal walls with a sound transmission class of STC 55. The west wall is a double wall construction consisting of the exterior wall of the building and a removable interior wall. The exterior wall includes a removable panel to allow windows of different sizes and designs be installed for future investigations.

Partition walls of varying acoustical ratings can be installed to divide the test area into smaller spaces, ranging in size from a single large room to four identical single-office-sized rooms. At present, interior partitions for a five-zone configuration exist only above the suspended ceiling and below the raised floor (Figure 2). These partition tops and bottoms have an acoustical rating of STC 55. The remaining components of these interior walls can be installed with different acoustical ratings. Special fasteners have been installed in the tops and bottoms of the partitions above the ceiling and below the floor, to facilitate installation of these interior walls and to ensure that the required acoustical rating will be maintained at the joints. Also, the raised floor system can be removed completely to increase the ceiling height by 0.6 m for testing indirect lighting systems using suspended light fixtures.

Mechanical - The facility has a dedicated all-air, constant volume heating, ventilating, and air-conditioning (HVAC) system with multiple reheat. It consists of a supply air system and a return air system. The supply air system has an air pre-filter, a supply air fan, a chilled water cooling coil, a steam heating coil, a steam humidifier, and a high efficiency air filter (HEPA), all enclosed in the air handling unit (AHU). The AHU also has an internal by-pass to allow the supply air to by-pass all the components except the air filters. This feature will be particularly useful in assessing the contributions of these components to the overall contamination level in the test area.

The HVAC system is designed to provide the supply air to the test area at a constant flow rate adjustable between 0 and 1130 L/s or 15 air changes per hour, a constant temperature adjustable between 8°C and 30°C in the main supply air duct, and a constant relative humidity adjustable between 20% and 80%. It has the flexibility of using 100% outdoor air or a mixture of outdoor air and return air. Since the test area (Figures 1 and 3) can be divided into a maximum of five zones, the supply air system is divided into five zones, each with a steam reheat coil. Similarly, the return air system is also divided into five zones. There are two sets of the supply and return ducts for each zone: one set located in the ceiling space and the other set below the floor. The supply air can enter into each zone through either ceiling or floor mounted diffusers. As well, the return air can leave each zone through either ceiling or floor mounted air grilles. Balancing dampers and isolation dampers are installed in the ductwork to divert the airflows. The supply air diffusers and return air grilles can be installed in the removable panels in the ceiling and the floor. Using flexible ducts these diffusers and grilles can be placed anywhere in the ceiling or floor. Such a design will allow testing of almost any conceivable ventilation and air distribution systems intended for the office environment. An Energy Management and Control System (EMCS) is used to control and monitor the operation of the HVAC system.

Airflow control valves and dampers are used to control the airflow rates to and from each zone. As shown in Figure 3, all ducts to each zone have long and straight sections to facilitate installation of orifice plates for measuring the airflow rates in both the supply and return ducts of each zone.

Some acoustical experiments require that noise from the HVAC system and other external sources not exceed NC 20 in the test area. In addition to the STC 55 walls, duct silencers and vibration breakers are installed in the duct system. All ducts are acoustically lined with sound absorbing material which is wrapped completely with mylar film to prevent loose material from being released into the air stream. Also, no branch duct is used to serve more than one zone to avoid noise transmission from one zone to another through the air duct. The supply air flow to each zone can also be delivered through two diffusers, if needed, to lower the exit velocity to below 2.5 m/s or 500 ft/min. Furthermore, in tests where the subjective effects of varied ventilation noise levels are to be included, ventilation noises will be simulated in a controlled manner using loudspeaker systems located above the suspended ceiling of the test rooms.

Electrical - The electrical system allows installation and testing of almost all lighting designs suitable for the office environment. It has a dedicated, regulated power supply to ensure that the power supplied to the electrical systems being studied do not fluctuate uncontrollably with changes in the building electrical load. The regulated power supply provides power to four identical power source and dimmer sets: one for each of the four zones identified as test rooms. The fifth zone, the corridor area, can be connected to and supplied by any one of the other four zones.

Figure 4 shows the schematic diagram of one zone. Sixteen power outlets above the ceiling provide the power for ceiling or wall mounted lamp fixtures, and eight power outlets below the floor provide power for floor mounted lamp fixtures or task lamps for a total of 24 outlets per zone. There are eight dimmer switches, each with eight connectors. The 24 outlets can be connected to the 8 dimmers in any combinations. Thus, in each zone, it is possible to have eight groups of lamps, each with a different lighting level. Two sets of the dimmer switches are provided for each zone: one set located in the control room which is controlled by the researcher, while the other set located in the test room can be used by the test subject. The dimmer switch set in the control room also has an override controller which consists of five master switches to override the controls in individual test rooms. As shown in Figure 4, when the centre switch is engaged, the lighting level of all five zones will be the same. When one of the other master switches is engaged, the lighting level in the two adjacent zones controlled by the switch are identical.

Data Acquisition System - The facility has a 250-channel computerized data acquisition system for recording measured data. The flow rate, temperature and relative humidity are measured continuously in each duct using orifice plates, thermocouples and relative humidity sensors which have been installed in all supply and return ducts. The quality and amount of electrical power consumed by each lamp (and electrical appliance, e.g. computer display unit and printer) can be monitored continuously.

A computer controlled traversing system together with the data acquisition system will be used to measure and record the air temperatures, air velocities and turbulence intensities in the test area.

Research Plans

The first project to be conducted in this facility is a series of experimental investigations of lighting quality, preferences, and control effects on task performance and energy efficiency. The main objectives are:
(a) to characterize and quantify office lighting quality under different lighting designs, at lighting power densities relevant to existing and proposed codes and standards;
(b) to relate office worker task performance to lighting quality; and
(c) to determine the effect of the individual and automatic control over office lighting on worker satisfaction and performance.

The experiments will be carried out in this facility where subjects are exposed to various lighting conditions, and their preferences, mood, and task performance measured.

To make an efficient use of this facility, a five year research plan is being developed in consultation with a Steering Committee which includes representatives from government agencies and industry.

Summary

This paper describes the new indoor environment research facility recently constructed at the NRC. This facility allows researchers to assess the effects of the physical factors, either individually or in various combinations, on the occupant's task performance, mood, and perception of the quality of the indoor environment. These factors include illumination, building acoustics, ventilation, air distribution, thermal comfort conditions, and indoor air quality. It also enables the researcher to study systematically individual differences that can explain why some people are more affected than others by certain physical conditions.

This facility is the centrepiece of a multi-year research project on indoor environments currently underway at the Building Performance Laboratory, Institute for Research in Construction, NRC. The project's goal is to provide practical information to aid building owners and managers to satisfy the competing requirements for operating economy and occupant performance/productivity and comfort.

Acknowledgment

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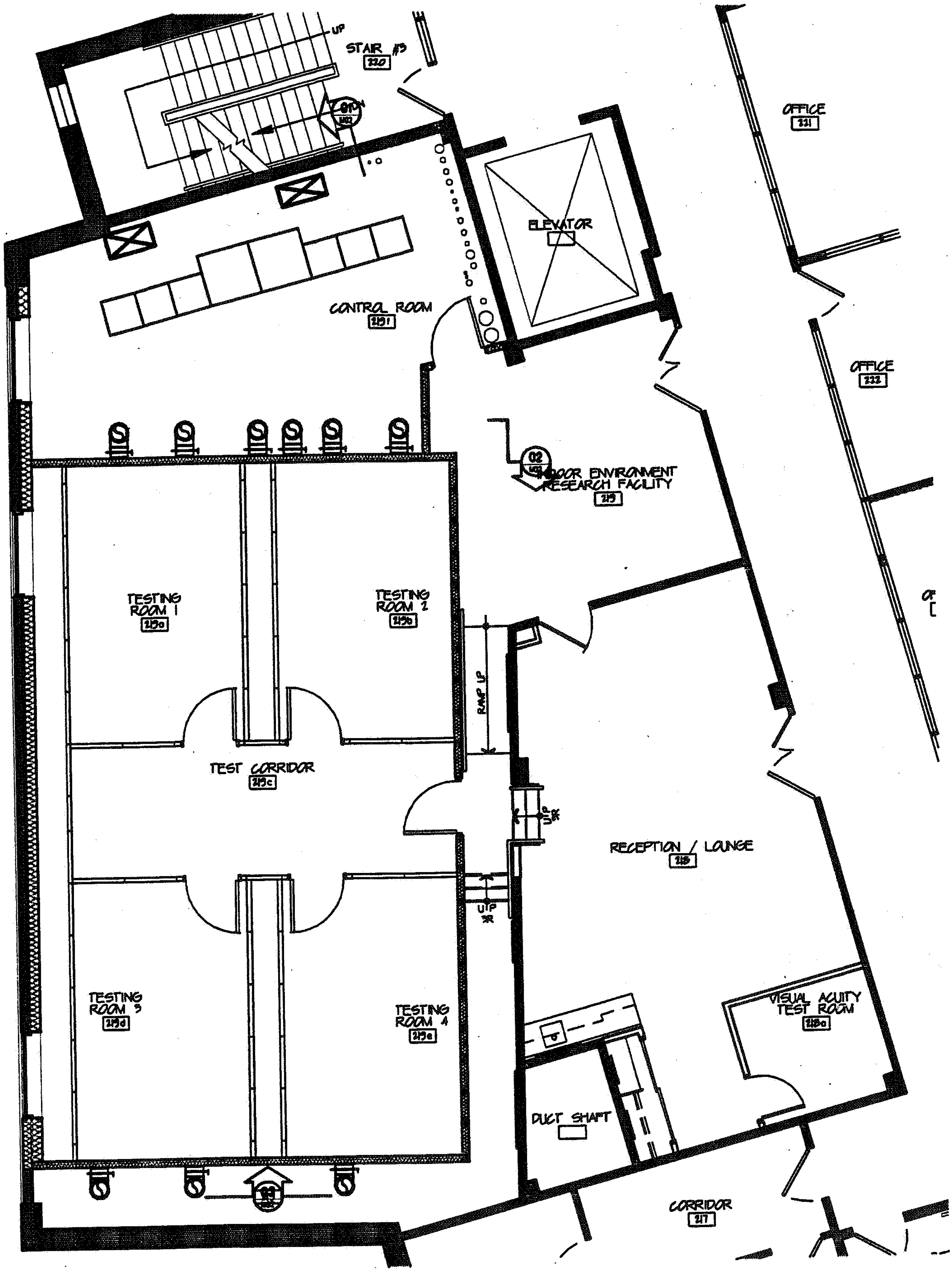

Figure 1 Floor plan

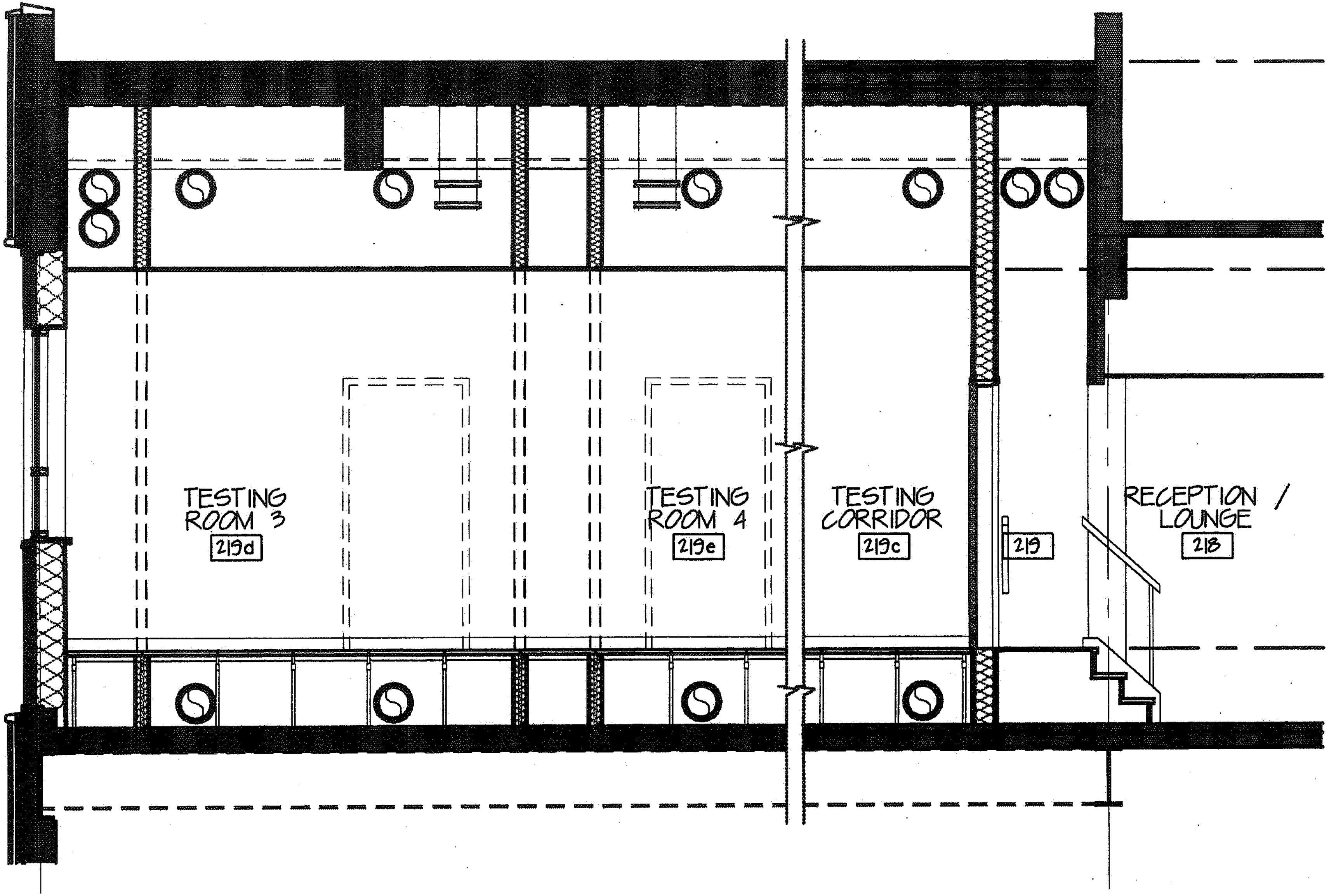

Figure 2 Elevation

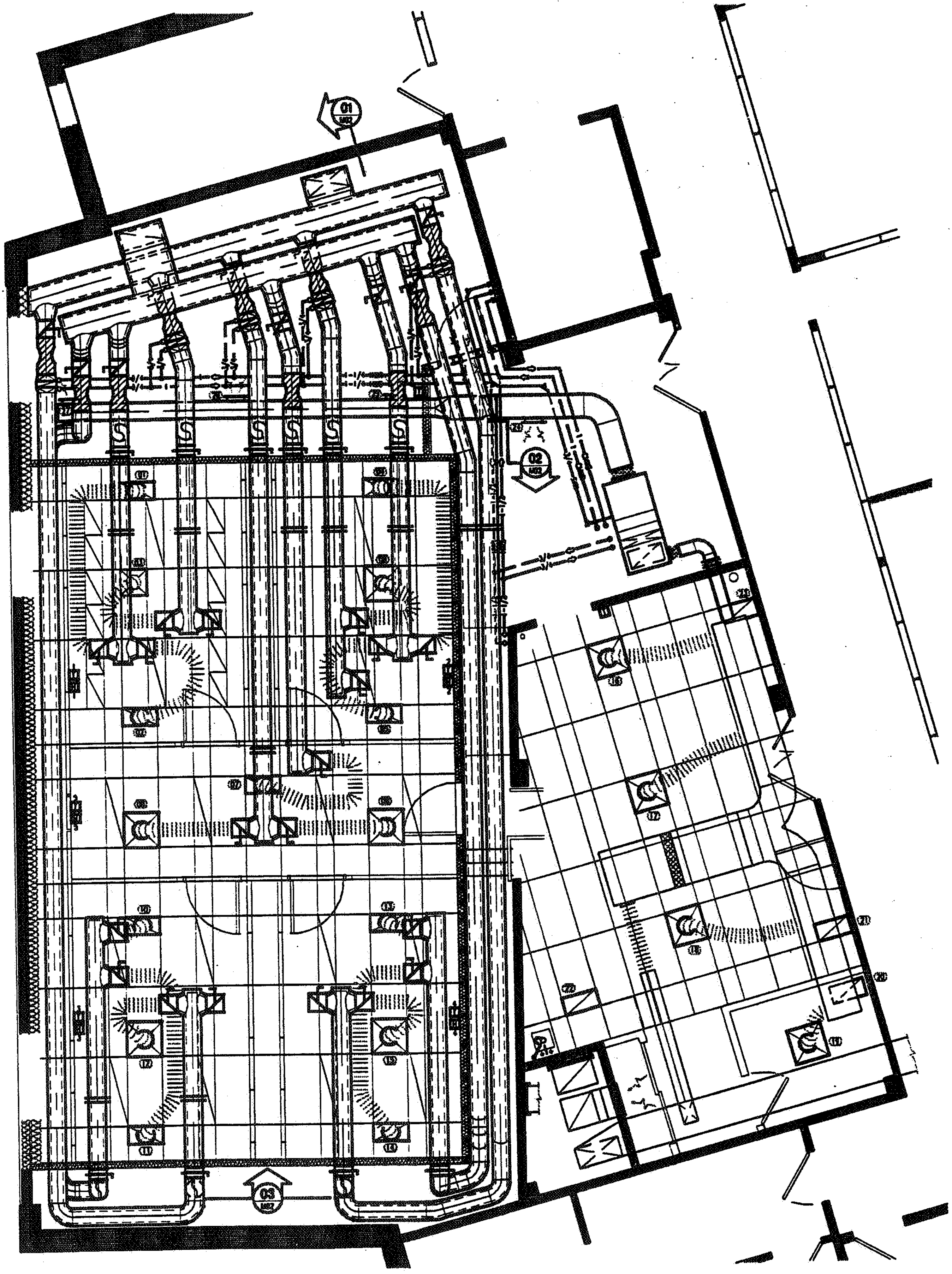

Figure 3 Schematic diagram of ductwork layout

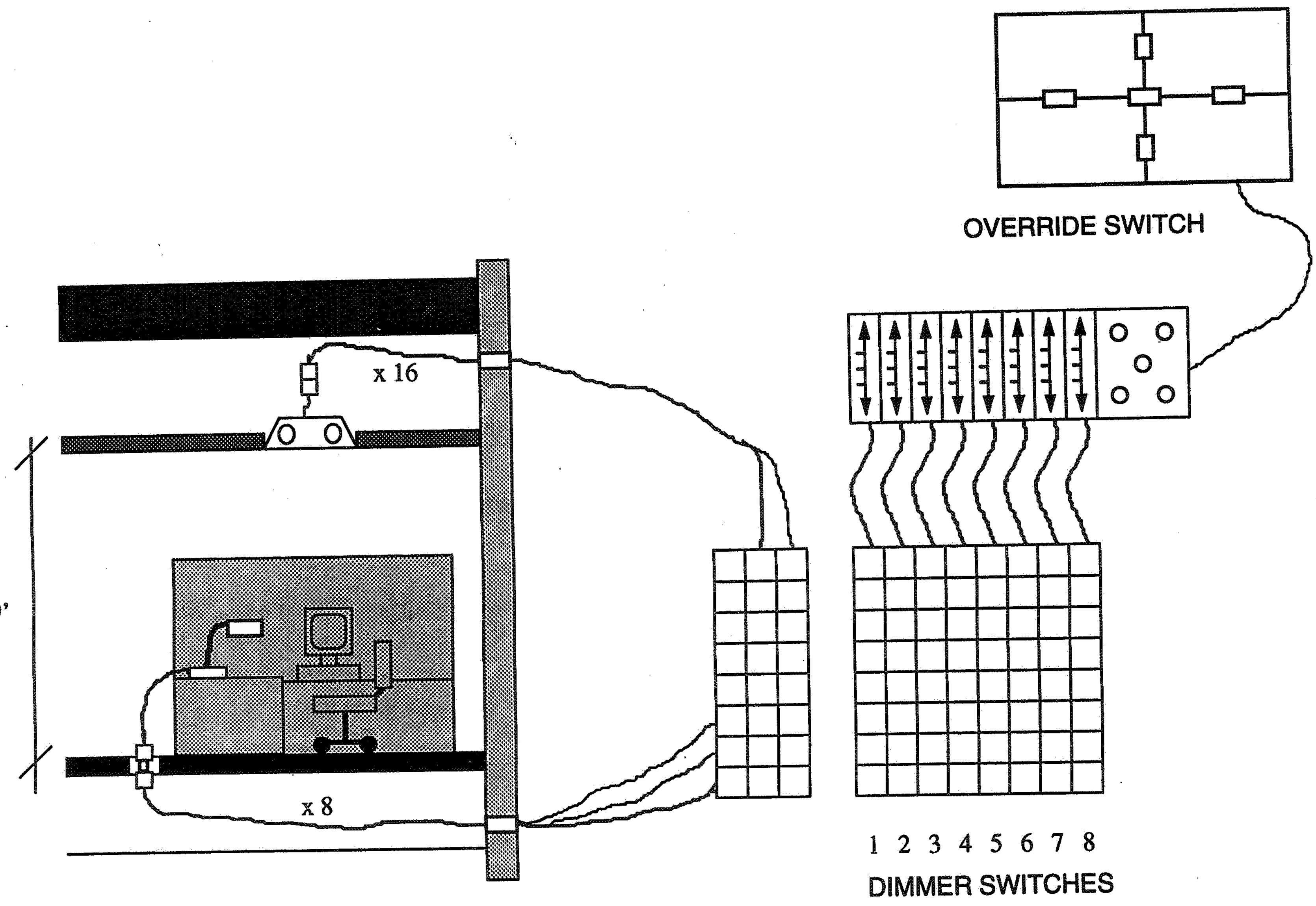

Figure 4 Schematic diagram of lighting controls