HETA 2000-0268-2812
Southwest Airlines San Antonio Reservations Center
San Antonio, Texas

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Preface

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Acknowledgments and Availability of Report

This report was prepared by Kristin K. Gwin and Richard J. Driscoll of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Field assistance was provided by Gregory A. Burr. Analytical support was provided by P&K Microbiology Services, Inc. Desktop publishing was performed by Robin Smith. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Indoor Air Quality at the San Antonio Reservations Center

In June 2000, NIOSH investigators conducted a health hazard evaluation at Southwest Airline's San Antonio Reservations Center (SRC). We assisted OSHA in evaluating indoor air quality, ventilation, and health symptoms at the reservations center.

What NIOSH Did

- We made a visual inspection of the building's interior and exterior, and the ventilation system.
- We took bulk insulation samples from interior insulation in a supply duct, bulk dust samples from carpeted areas, and tape samples from beneath restroom sinks to look for microbial growth.
- We collected temperature, relative humidity, and carbon dioxide measurements, checked for moisture in the walls and floor, and looked for mold between the walls of quadrant A and B using a boroscope.
- We made airflow measurements to see if areas were maintained under positive, negative, or neutral pressures.
- We talked with some employees about their symptoms and health concerns.

What NIOSH Found

- We saw only limited evidence of microbial growth during inspection of the building (beneath restroom sinks).
- One bulk dust sample from a carpeted wall in quadrant B showed increased fungal concentrations when compared to the other samples. Two of the five tape samples from beneath the sinks in the restroom showed fungal growth.
- Average temperatures in the SRC were within the recommended summer comfort range (73°-79°F), with the exception of a few areas which varied by only 1°-2°F.
- Average relative humidity within the SRC was withinthe recommended comfort range (30%-60%).
- Carbon dioxide measurements were well below 800 ppm, indicating an adequate amount of outdoor air is being supplied.
- Allergy-like symptoms were reported by workers; however, it did not appear that the symptoms were related to exposures unique to the workplace.

What Southwest Airlines Managers Can Do

- Replace the carpeting on the walls of the quadrants with a non-carpeted, acoustical material that will be easier to keep clean and to dry when water leaks occur.
- If an alternative acoustical material is not used on the walls, then the new carpet should be HEPA-vacuumed on a weekly basis to prevent buildup of dust and debris.
- Replace the moldy plywood beneath the sinks in the restrooms.
- Prior to any renovation, controls should be instituted to protect both the workers and the adjacent environment (see full report for further details.)
- Water leaks should be fixed immediately, and water-damaged materials either dried (within 24-48 hours) and properly cleaned, or replaced (see full report for further details).

What the Southwest Airlines Employees Can Do

- Employees with health concerns should see their health care provider to determine the cause and proper treatment.

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National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 2000-0268-2812
Southwest Airlines San Antonio Reservations Center
San Antonio, Texas
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SUMMARY

In April 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Occupational Safety and Health Administration (OSHA) for assistance in the evaluation of potential microbial contamination in the Southwest Airlines San Antonio Reservations Center (SRC), San Antonio, Texas. A similar request had been previously received by NIOSH from Southwest Airlines management. Employees in the SRC believed their health problems, which included upper respiratory infections, asthma, fatigue, headaches, chemical sensitivity, and loss of concentration and short-term memory, were related to working in this building.

On June 28-30, 2000, NIOSH investigators conducted a site visit at the reservations center. A walk-through inspection was made of the building interior, exterior, and roof. Bulk material samples were collected from interior insulation in a supply duct above quadrant A, and bulk dust samples were collected on carpeted areas to assess microbial contamination. Surface samples using sticky tape were also collected beneath sinks in a women's restroom. Measurements to detect moisture incursion and general indoor air quality comfort parameters were collected, and a qualitative ventilation assessment was also performed. Confidential medical interviews were conducted to assess health concerns.

Fungal concentrations from two bulk material samples of interior insulation in the supply duct above quadrant A ranged from less than the detectable limit (<758 colony forming units per gram of material [CFU/g]) to $7.1x10^4$ CFU/g. *Cladosporium cladosporioides* was the fungi detected. Bacterial concentrations from the two bulk insulation samples were not detected (ND) (<758 CFU/g in one sample and <893 CFU/g in the other). Bulk dust samples yielded fungal levels ranging from $1.4x10^3$ to $1.45x10^5$ CFU/g. *Pencillium*, *Acremonium*, *Cladosporium*, and *Alternaria alternata* were the predominant fungi identified. One of the six bulk dust samples revealed increased fungal concentrations of *Penicillium* when compared with the other samples. Dust characterization showed samples consisted mainly of mineral crystals, skin flakes, and cellulose fibers. Sticky tape samples taken beneath the sinks in the women's restroom (closest to the break room) revealed mostly wood fibers with paint. However, fungal growth was observed in two of the five samples. This indicates that microbial growth is present.

Temperatures were within the range recommended by the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE), with the exception of a few areas which varied by only 1°- 2°F above or below the recommended range (73°-79°F). Relative humidity measurements were also within the range recommended by ASHRAE; however, almost half of the measurements closely approached the

recommended upper limit. All carbon dioxide measurements were well below 800 parts per million (ppm), a level indicating an adequate amount of outdoor air is being supplied to the quadrant and office areas.

Confidential interviews were conducted with 13 employees to assess their symptoms and health concerns. The most common symptoms reported by the employees were itchy watery eyes, runny nose, chronic sinus infections, headaches, and fatigue.

Based on the information and measurements obtained during this Health Hazard Evaluation, NIOSH investigators conclude that a health hazard was not present at the time of the site visit, and that there is limited evidence of the presence of microbial growth in the SRC. There was no evidence that the health problems reported by employees were, on the whole, related to an exposure unique to the work environment. Recommendations addressing the carpet on the quadrant walls, the humidity levels, housekeeping procedures, and future water incursion incidents are included in the report.

Keywords: SIC 4729 (Arrangement of Passenger Transportation, Not Elsewhere Classified), airline reservations center, indoor air quality, microbial contamination, *Penicillium*, *Cladosporium*, *Acremonium*, asthma.

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INTRODUCTION

In April, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Austin Area Office of the Occupational Safety and Health Administration (OSHA) for help in the evaluation of potential microbial contamination in the Southwest Airlines San Antonio Reservations Center (SRC), San Antonio, Texas. A similar request from Southwest Airlines management was received by NIOSH a few weeks earlier. Employee health concerns included upper respiratory infections, asthma, fatigue, headaches, chemical sensitivity, and loss of concentration and short-term memory.

On June 28-30, 2000, NIOSH investigators (including two industrial hygienists and an epidemiologist) conducted a site visit to the Southwest Airlines SRC. An opening conference was held with building management, the facility maintenance specialist, International Association of Machinists and Aerospace Workers (IAM) union stewards, Southwest Airlines Corporate Counsel, and an industrial hygienist from the Austin area office of OSHA. Information was obtained relating to the building and the history of the concerns involving microbial contamination. A walk-through inspection was made of the building interior and exterior. Attention was focused on the four quadrants where customer sales representatives work, and the heating, ventilating, and air-conditioning (HVAC) units located in mechanical rooms. Bulk material and dust samples were collected from interior insulation in a supply duct above quadrant A and on carpeted areas to assess microbial contamination. Sticky tape surface samples were collected from beneath sinks in a women's restroom. Measurements to detect moisture incursion and general indoor air quality comfort parameters were also collected. Confidential interviews were conducted with employees to determine the extent of their health concerns and to determine whether symptoms were consistent with work place exposures. A closing conference was held on June 30, 2000, during which preliminary findings and recommendations were discussed.

BACKGROUND

Building Description

The Southwest Airlines SRC is a one-story brick structure with approximately 31,000 square feet (ft^2) of indoor floor space. The building, which is owned by Southwest Airlines, has been used as a reservations center since it was built in 1981. It is occupied 24 hours a day, 7 days per week with variable work shifts. There are approximately 617 employees at the reservations center. Building occupancy varies daily depending on work load and overtime. During the 2-day NIOSH site visit, the average daily occupancy was approximately 185 employees.

The work stations of the reservations agents are arranged concentrically and divided into four quadrants, A-D (see figure 1). There are six to seven rows of workstations in each quadrant. Workstations are separated by connecting, carpeted cubicle dividers approximately four feet in height. At the center of the quadrants is a console area where supervisors work. There is a gradual incline in the floor, extending from the console up to the back of each quadrant. The cubicles are equipped with video display terminals and keyboards, and are occupied by the customer sales or customer care representatives. The majority of enclosed offices, the break room, and the training room are located in the area behind quadrant D. Six enclosed offices and a conference room are located behind quadrant C. The entire building is carpeted, with the exception of the break room and the restrooms. The walls in each quadrant are also carpeted for acoustical attenuation. This carpeting was replaced during the summer of 1995. Pesticides are sprayed around the interior and exterior of the building on a monthly basis.

Ventilation System

A designated indoor smoking area is located adjacent to the break room. It is segregated by walls and two doors, one leading to the break room and one leading into a perimeter hallway. This smoking area is ventilated by an exhaust fan that exhausts the air directly outside, thus preventing it from mixing with return air from other areas of the building and being dispersed into the rest of the reservations center. One Trane® HVAC unit in the mechanical room behind quadrant D services this room, the non-smoking portion of the break room, and the training room. An electrostatic precipitator air cleaner was mounted on the ceiling of the room approximately one year ago. Filters in the air cleaner are replaced monthly.

The remaining ventilation systems at the SRC consist of six large Trane® HVAC units housed in four mechanical rooms. One Trane® unit is dedicated to servicing each individual quadrant, and the remaining two service the smoking and non-smoking break rooms, training room, and the main offices. However, the air is mixed, recirculated, and returned through ducts in the area above the drop ceiling. This allows for mixing of air throughout all areas of the building (except the designated smoking room). Four outdoor air (OA) intakes and six exhaust fans are located on the roof of the building. Two of the exhaust fans are dedicated to the restrooms and are located at least 25 feet from the OA intakes. The temperature and amount of OA introduced into the building is regulated using electronically controlled fan-powered variable- or constant air-volume box dampers. The former is utilized in office areas and the latter is utilized in the quadrants. Carbon dioxide (CO_2) sensors, with a 1,000 part per million (ppm) set-point, control the OA intake dampers based on the levels of CO_2 detected within the building. When CO_2 levels rise, a greater amount of OA is brought into the building. The ventilation consultant reported that, on average, between 10%-20% of OA is brought into the building. OA enters the mechanical rooms housing the AHU and mixes with the air in the room before it enters the AHU. Filtration utilized prior to air entering the AHUs consists of a 30% efficient, 2" pleated pre-filter and a 65% efficient secondary filter. The pre-filters are replaced monthly basis and the secondary filters are replaced quarterly. Two water chillers provide a chilled-water cooling system. The discharge water temperature is electronically maintained at 44-45°F. After the air is dehumidified, terminal electric re-heaters warm the supply air to 70°F.

In 1999, a ventilation design company conducted an overhaul of the HVAC system at the SRC to bring the system back to design specifications for the building. The inside of the AHUs, including the evaporation coils, were pressure washed. The old condensate pans were removed and replaced with stainless steel pans fabricated to enhance drainage and prevent standing water. Access doors were installed to allow visual inspection of the evaporation coils and interior of the AHU. Interior insulation lining supply ductwork was removed where possible and replaced with exterior insulation. The interior insulation left in place was cleaned with a vacuum equipped with a High-Efficiency Particulate Air filter (HEPA). After cleaning, a biocide was applied in an effort to inhibit microbial growth. In addition, ultraviolet (UV) lights were installed upstream of the cooling coils in an attempt to remove any microbial contaminants that may be present in the airstream and to promote cleaning of the evaporation coils. Remediation of the AHUs also included replacing worn mechanical equipment.

Inducer fans were installed at the OA intakes to actively bring OA into the building. Filtration efficiency was greatly improved when the filter section of the AHUs was replaced with filter housings capable of handling higher-efficiency filters. All pneumatic controls were replaced with electronic controls. The building was pressurized to maintain a positive pressure relative to the outdoors. Furthermore, a test and balance of the HVAC system was performed in the spring of 2000 (after modifications) to bring the performance of the equipment back to the original operating specifications. This was to ensure that air would be properly distributed according to original design specifications of the system, which were determined when the building was built.

Prior Building Surveys

Indoor air quality (IAQ) surveys were previously performed by private consulting firms at the request of Southwest Airlines. NIOSH received copies of consultant reports performed on the following dates: October 6, 1995; August 16, 1996 (with a follow-up survey by the same company on October 22, 1996); May 8, 1997; February 22, 1998; and November 2, 18, and 19, 1998. All of these surveys focused on IAQ issues in the reservations center, with the exception of the survey conducted on May 8, 1997, which concentrated on asbestos. Due to the number of surveys performed in the last five years, only the most recent survey performed prior to the NIOSH site visit will be discussed.

On November 2, 1998, a private consultant conducted an initial site visit at the SRC, during which a visual inspection of the building took place and limited environmental samples were collected. Based on the initial site visit, a sampling protocol was designed for a more comprehensive IAQ survey at the building. The sampling protocol included the following: air monitoring for volatile organic compounds (VOCs), microbial VOCs, fungi, mold spores, formaldehyde and other aldehydes, and endotoxin; bulk dust and material samples for determination of potential fungal or endotoxin sources; direct reading measurements of CO_2, carbon monoxide (CO), temperature, relative humidity (RH), airborne particles; and an inspection of the HVAC system components. Air sampling revealed no amplification of airborne fungal levels in the indoor environment when compared to levels in outdoor air. It was also reported that air sampling revealed levels of VOCs, microbial VOCs, mold spores, formaldehyde and other aldehydes, and endotoxin to be within acceptable limits for indoor environments. Bulk dust and material samples had non-detectable to low levels of cockroach and dust mite allergens, and endotoxin levels were typical of those expected in building dust. Cat allergens measured in the samples revealed levels close to the action level of concern for people allergic to cat dander. Settled building dust revealed the presence of fungi, such as *Cladosporium*, *Aspergillus*, *Penicillium*, and *Eurotium*. In addition, bulk dust and material samples from the HVAC system, including internal insulation, revealed *Cladosporium*, *Aspergillus*, and *Pencillium*. Direct reading measurements for CO_2, CO, temperature, RH, and airborne particles were within acceptable limits or recommended ranges, with the exception of some locations that exceeded 60% RH. Inspection of the HVAC system components revealed a minimal amount of OA being brought into the building, inefficient filtration, drain pans with standing water, and mechanical rooms being used as storage rooms (this was before the ventilation overhaul that began in 1999). The consultants recommended improved housekeeping procedures; identifying sources of water intrusion, repairing water leaks, and replacing water-damaged materials; determining if the HVAC system should be redesigned; further testing to verify the extent of fungal colonization on HVAC airstream surfaces, maintaining sanitary conditions in the mechanical equipment rooms where the AHUs are located; ensuring the drain pans allow for complete drainage; increasing filter efficiency; and modifying the system so that outdoor air could be properly dehumidified. They also recommended that designated smoking areas be separately ventilated and negatively pressurized. They also stated that any visible mold growth, such as that found in the "cold room" (a former computer room), should be removed according to mold remediation protocols.

After the consultant's survey, however, OSHA continued to receive health complaints from employees working at the SRC. A request for NIOSH to conduct a health hazard evaluation (HHE) was generated by management in April

2000. When NIOSH learned that OSHA was currently conducting an investigation at the building, OSHA was contacted and it was decided that OSHA would also submit a request for NIOSH's assistance so that all concerns would be addressed.

METHODS

Industrial Hygiene

A walk-through inspection of the building interior and exterior was conducted immediately following the opening conference. NIOSH investigators inspected the interior and exterior of the building for evidence of water damage and fungal contamination to identify potential sources of microbial contamination and pathways for moisture vapor intrusion into the building. The six large Trane® HVAC units, located in mechanical rooms both inside and outside out of the building, and the roof were also inspected.

Two bulk material samples were collected from the interior insulation in a supply air duct above quadrant A to determine if microbial growth existed on an airstream surface. The bulk samples consisted of an approximate two-square-inch section cut from the insulation. Additionally, six bulk dust samples were collected by micro-vacuuming three-square-foot sections of carpet on the walls and floor in quadrant B, C, and D, the floor of the hallway between quadrant C and D, and the floor in a private office. The samples were split and the dust components of the six surface vacuum samples were then microscopically characterized. Dilutions were also made of the contents from the surface vacuum samples. These dilutions were then placed onto two different nutrient media, malt extract agar (MEA) and cornmeal agar (CMA), to determine fungal genera concentration.

Five sticky tape surface samples were collected from visibly contaminated areas under sinks in the women's restroom near the break room. Clear adhesive tape was lightly pressed against the area of suspected growth. The tape sample was then removed and mounted (in the field) to a glass slide for subsequent optical analysis. The tape contained a portion of the fungal sample intact on the adhesive surface. All bulk material and tape samples were placed in clean polyethylene bags and sent to an environmental microbiological laboratory to quantitatively and qualitatively determine bacterial and fungal species and evaluate the presence of fungal spores/hyphae.

Indicators of occupant comfort were measured in various locations throughout the reservations center and outdoors. Real-time CO_2, temperature, and RH measurements were taken using a TSI Q-Track®, Model 8550, hand-held, battery-operated IAQ monitor. This portable monitor uses a non-dispersive infrared absorption (NDIR) sensor to measure CO_2 in the range of 0-5000 ppm, with an accuracy of ±3% of reading ±50 ppm at 25°C. It is capable of measuring temperature in the range of 32 to 122°F, with an accuracy of 1°F. This instrument also measures RH in the range of 5 to 95%, with an accuracy of ±3%. Temperature and RH measurements were also collected and logged for a continuous 24-hour period using the Q-Track and HOBO H8 Pro Series loggers. These battery-operated loggers use an internal temperature sensor and external RH sensor. The operating range is -22 to 122°F and 0 to 100% RH. Moisture incursion measurements were collected using a Delmhorst Instrument Company Moisture Tester, Model BD-9, battery-operated detector. This meter provides direct readings for moisture content in the range of 8 to 50% on wood. A reference scale is used for comparative readings on non-wood materials. This portable instrument uses the amount of electrical conductivity in the material being tested to determine its moisture content. Moisture readings were also collected using a battery-operated Tramex Moisture Encounter for non-destructive moisture detection.

An Instrument Technology, Inc., Model no.125010, rigid boroscope was used to look inside the wall between quadrant A and B to inspect interior drywall for any signs of visible contamination. The boroscope was equipped with a 150W light source.

Qualitative airflow measurements were performed using ventilation smoke tubes to determine airflow patterns throughout the building. These measurements determined whether areas were maintained under positive, negative, or neutral pressures. Airflow measurements were made at all building entrances, restroom entrances, and enclosed offices and rooms within the building.

Medical

Confidential interviews were conducted with workers to assess the types of health concerns they have been experiencing. Workers were asked to describe health concerns and symptoms that they experienced, when these symptoms first occurred, and how long these symptoms had persisted. Workers who participated in the confidential interviews were selected by union representatives as workers who believed they had been most affected by work-related exposures. In addition, union representatives announced that interviews were available to any worker who wished to participate.

EVALUATION CRITERIA

NIOSH investigators have completed over 1,200 investigations of the occupational indoor environment in a wide variety of non-industrial settings. Almost all of these investigations have been conducted since 1979. Overall, the symptoms and health complaints reported by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. Symptoms frequently reported include headaches, unusual fatigue, itching or burning eyes, skin irritation, nasal congestion, dry or irritated throats, and other respiratory irritations. Typically, the workplace environment has been implicated because workers often report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[1,2,3,4,5] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] Among these factors are imprecisely-defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[8,9,10,11,12,13] Design, maintenance, and operation of HVAC systems are critical to their proper functioning and provision of healthy and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

Other studies have shown that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than any measured indoor contaminant or condition.[14,15,16] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[16,17,18,19]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, and carbon monoxide poisoning. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel-burning appliances.

Environmental problems NIOSH investigators have found in the non-industrial indoor environment have included the following: poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from office furnishings, emissions from office machines and from structural components of the building and its contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and RH conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these indoor environmental problems could not be directly linked to the health effects reported by the building's occupants.

Standards specific for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH), have published regulatory standards or recommended limits for occupational exposures to specific chemical and physical agents.[20,21,22] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[23, 24] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[25]

Measurements of indoor environmental contaminants have generally not proved to be helpful in determining the cause of symptoms and complaints, except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and variable mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature, and RH, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[26] This manual suggests that indoor environmental quality (IEQ) is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: (1) a source of odors or contaminants; (2) a problem with the design or operation of the HVAC system; (3) a pathway between the contaminant source and the location of the complaint; and (4) the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems. Information about exposures and health effects relevant to this investigation is given below.

Microorganisms

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an adequate supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells, or in association with soil or dust particles or water droplets. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In a "normal" indoor environment, where there is no unusual source of microorganisms, the level of microorganisms may vary somewhat as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency), with consistently similar ranking among the microbial species.[27,28]

The current strategy for on-site evaluation of environmental microbial contamination involves a comprehensive inspection to identify sources (reservoirs) of microbial growth and potential routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples may be collected to document the presence of a suspected microbial contaminant. Airborne dissemination (characterized by elevated indoor levels relative to outdoor levels, and an anomalous ranking among the microbial species) associated with occupant health effects suggests that the contaminant may be responsible for the health effects.

Penicillium

The blue-green molds of *Penicillium* are common contaminants of indoor environments. Exposure to *Penicillium* can occur as a result of contaminated humidifier water and moldy HVAC systems. Inhalation of airborne spores is the major route of human exposure. These molds are common contaminants of agricultural commodities, and some of the mycotoxins produced by these species are also produced by fungi common in house dust.[29] *Penicillium* infections of clinical importance are very rare, although this mold has been associated with asthma and hypersensitivity pneumonitis.[30] Presently, *Penicillium* mycotoxins are not known to be a serious health threat in water-damaged buildings.[31]

Carbon Dioxide

CO_2 is a normal constituent of exhaled breath, and if monitored at equilibrium concentrations in a building, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The American National Standards Institute (ANSI)/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, 15 cfm/person for reception areas, classrooms, libraries, auditoriums, and corridors, and 60 cfm/person for smoking lounges. Maintaining the recommended ASHRAE OA supply rates when the OA is of good quality, and there are no significant indoor emission sources, should provide for acceptable IAQ.

CO_2 is not considered a building air pollutant, but CO_2 concentration is used as an indicator of the adequacy of outside air supplied to occupied areas. Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). ASHRAE Standard 62-1989 recommends 1000 ppm as the upper limit for comfort (odor) reasons.[23, 31] When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[32] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual level when the measurements are made.

Temperature and Relative Humidity

Temperature and RH measurements are often collected as part of an indoor environmental quality investigation because these parameters affect the perception of comfort in an indoor environment. The perception of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures.[33] Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. The ASHRAE Standard 55-1992, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[24] Assuming low air movement, 60% RH and sedentary job tasks, the temperatures recommended by ASHRAE range from 68-74°F in the winter, and from 73-79°F in the summer. ASHRAE also recommends that RH be maintained between 30 and 60%.[23] Excessive humidity can support the growth of microorganisms, while low RH could possibly cause the eyes and upper respiratory tract to dry which may result in irritation.

RESULTS

Industrial Hygiene

Visual Inspection

Visible fungal growth was not observed on building materials during the walk-through inspection of the interior of the building, with the exception of in the women's and men's restrooms near the break room. Evidence of water damage was not observed in the building, with the exception of a few ceiling tiles located in the cold room. Building maintenance was in the process of replacing damaged tiles at the time of the NIOSH site visit. Small areas of carpet on the walls of quadrant A and B were peeled back to check the underlying drywall for visible signs of water incursion or microbial growth. No evidence of past water incursion or visible microbial colonization were observed in these areas. However, lack of maintenance and housekeeping on the carpeted walls in all four quadrants was apparent. An accumulation of dust and dirt was observed on these surfaces.

Areas where moisture incursion would likely occur (along exterior walls, carpeted floors, and around windows and entrances) were probed with a moisture meter to qualitatively assess residual amounts of water suggesting past water incursion problems. No moisture problems were detected in these areas. One area around the large rectangular windows in the reception area showed evidence of water damage, however no moisture was detected in the wood surrounding the windows. Areas in the break room, where water damage or leaks had been reported to occur (beneath the sinks, inside the cabinets, and along the interior and exterior drywall), were also checked for moisture content. These areas showed a minimal, if any, amount of moisture content. The plywood beneath the sinks in the women's restroom (closest to the break room) revealed some moisture content in the same areas of the visible mold (this was reportedly due to water leaking between the sink and the sink cutout). Areas where wallpaper was peeling at the seams were also checked for moisture. No moisture was detected. The carpeted walls and floors were also checked. The quadrant walls consisted of two layers of drywall covered by carpet. The original layer of drywall on a wall in quadrant A (the wall that separates quadrant A from quadrant B) showed a minimal amount of moisture in a small area.

Inspection of the interior drywall of the wall separating quadrant A and B using the rigid boroscope did not reveal any evidence of visible microbial colonization. The interior of the walls was inspected from above the ceiling, as well as at a few locations along the floor spanning the length of the partition wall. This particular wall was investigated at the request of employees and union representatives due to health complaints originating from employees who sat in these two quadrants.

The ventilation blueprints and balance test results were reviewed, the OA intakes were visually examined, and the condition of the air filters, coils, drain pans, and other interior components of four randomly selected Air Handling Units (AHUs) were checked. The test and balance report showed that the system had been properly balanced back to original performance specifications earlier in the year. OA is now actively pulled in using both induction fans and the fans in the AHUs. Protective covers have been placed over the intakes to prevent water or debris from collecting around the intake. This had been prompted by construction of apartment buildings that was taking place behind quadrant A and D at the time of our site visit.

Inspection of the interior components of the HVAC units servicing the reservations center did not reveal any evidence of microbial contamination. The interior of the AHUs appeared dry. No mineral deposits were observed on the interior insulation of the AHUs, which would indicate recent water damage. The condensation drip pans appeared in good condition with proper drainage. There were no observable water marks that would indicate a problem with standing water. The pre- and secondary filters fit properly, minimizing the amount of air that can flow around the filters and enter the AHU without proper filtration. The sewer vents on the roof of the building were inspected, and all were clear of debris with the exception of one which was clogged with leaves. Building maintenance was aware of the problem and intended to clear the vent. NIOSH was also informed by building management that new sewer vent covers had been ordered to replace the old ones that had deteriorated.

Bulk Sample Analysis

Tape samples taken from plywood beneath the sinks in the women's restroom near the break room revealed mostly wood fibers and paint and skin flakes, with no obvious sign of fungal growth. However, two of the five sticky tape samples suggested fungal growth. One tape sample revealed a few yeast cells, and the other revealed a few fungal hyphae and a few loose fungal spores of unidentified fungi. Fungal concentrations from analysis of two bulk material samples of interior insulation taken within a supply duct above quadrant A ranged from non-detectable (ND) to 7.1×10^4 colony forming units per gram of material (CFU/g). The bulk insulation sample taken within the supply air duct close to the wall separating quadrant A and B had ND (< 758 CFU/g) fungal concentrations when cultured in 2% MEA and ND bacterial concentrations (< 758 CFU/g) when cultured in tryptic soy agar (TSA). The bulk insulation sample taken from within the same supply air duct at an area above the center aisle in quadrant A revealed a fungal concentration of 7.1×10^4 CFU/g when cultured in an MEA medium. *Cladosporium cladosporioides* was the only species detected. When TSA media was used to culture the same sample, a ND (< 893 CFU/g) bacterial concentration occurred.

Dust component results from the six bulk dust samples that were microscopically characterized are presented in Table 1. Mineral crystals, skin flakes, and cellulose fibers were the predominant components in all six surface vacuum samples, ranging from 5% to 70% of total matter detected. Trace elements of fungal matter were detected in all six samples.

The fungal genera and concentrations resulting from the bulk dust sample culture analysis are presented in Table 2. Results are shown separately for the two nutrient media used during analysis, CMA and MEA. Fungal concentrations ranged from 1.4×10^3 CFU/g to 1.5×10^5 CFU/g on the CMA nutrient media, and from 1.5×10^3 CFU/g to $1.2x10^5$ CFU/g on the MEA nutrient media. The predominant fungal genera identified on both nutrient media were *Penicillium*, *Acremonium*, and *Cladosporium*. The bulk dust sample taken from the carpeted wall in quadrant B in an area close to the front of quadrant revealed a *Penicillium* concentration of $1.3x10^5$ CFU/g when cultured on CMA and $1.1x10^5$ CFU/g when cultured on MEA.

Comfort Parameters

Measurements taken in the morning (using the Q-track) indicated an overall mean temperature in the reservations center of 74°F. Temperatures ranged from 71° to 76°F. The overall mean RH in the reservations center was 50%, and ranged from 44% to 53%. OA temperature was 79°F, and outdoor RH was 80%, when measured at 10:00 a.m. The overall mean CO_2 level in the building was 573 ppm, with a range of 530 to 650 ppm, in comparison with the measured outdoor CO_2 level of 350 ppm. Temperature measurements taken in the smoking room, break room, and training room were 1° to 2°F cooler than the range recommended by ASHRAE (for comfort purposes in the summer months) in Standard 55-1992.

Afternoon temperature measurements (taken with the Q-track) indicated an overall mean temperature of 73°F in the building. Temperatures ranged from 72° to 74°F. The overall mean RH in the reservations center was 50%, ranging from 43% to 53%. The overall mean CO_2 level in the building was 598 ppm, with a range of 550 to 680 ppm. Temperature measurements taken in the smoking room, break room, and training room were 1°F cooler than the comfort range recommended by ASHRAE in Standard 55-1992. None of the RH measurements exceeded the range recommended by ASHRAE in Standard 55-1992, and none of the CO_2 measurements exceeded the NIOSH recommendation of 800 ppm. The overall mean temperature, RH, and CO_2 remained relatively consistent throughout the day.

Figures 2-11 graphically illustrate the temperature variations at 5-minute intervals over a 24-hour period at different locations in the reservations center and outdoors. The locations are as follows: (1) quadrant A; (2) quadrant B; (3) quadrant C; (4) quadrant D; (5) console area; (6) front reception area; (7) break room; (8) first aid room; (9) Q & A office; (10) union shop steward's office; and (11) outdoors. The temperature varied from less than 1°- 3°F in the four quadrants. Quadrant B had the coolest temperature (72.5°F), measured from approximately 8:30 p.m. to 8:30 a.m. This corresponds to the times that the quadrant is unoccupied (8:30 p.m. to 8:00 a.m.). Figure 8 shows the most variation in temperature (approximately 73° to 77°F) in comparison with the other locations. This data logger was placed in the break room on top of a drink machine by the television. Although the temperature range only spanned approximately 4°F, the temperatures peaked at the upper and lower extremes in a continuous pattern from approximately 8:45 a.m. on June 29, 2000, through 8:51 a.m. on June 30, 2000. The offices around the perimeter of the quadrants exhibited more variable temperature patterns than those measured within the quadrants. The first aid and Q&A office (see figure 9 and 10) showed warmer temperature trends when compared with the remaining locations (up to 80°F), however the temperatures dropped and were within ASHRAE's recommended comfort range between 8:00 a.m. and 4:00 p.m. Temperatures logged in the shop steward's office (see figure 11) also showed more variation than within the quadrants, but the temperature range was approximately 4°F cooler than the other offices. All of the offices are serviced by one AHU. The instrument placed outdoors was directly in the sun in the afternoon, most likely causing the very high temperature readings (see figure 12).

Medical

Thirteen workers were interviewed during the two-day site visit. Four of 13 workers reported itchy watery eyes and a runny nose, 4 workers reported chronic sinus infections, 4 reported headaches (in some cases self-described as migraine), 3 reported sore throat, 3 reported fatigue, and 2 persons reported shortness of breath. Five persons noted that their symptoms were aggravated when sitting in quadrant A. In addition, at least 2 employees described chronic debilitating conditions of unknown etiology that are being managed by their personal physician.

DISCUSSION AND CONCLUSIONS

Microbial growth and proliferation requires a nutrient source, adequate moisture, and an appropriate temperature. All of these factors must be present to achieve optimum conditions for microorganisms to grow. However, limited evidence of water accumulation or moisture incursion was observed during the site visit (a few damaged ceiling tiles, beneath the sinks in a women's restroom, and by windows in the front entrance/reception area). Visual inspection of building materials in the reservations center did not reveal the existence of microbial reservoirs. In addition, moisture incursion measurements did not reveal moist conditions which would be needed to sustain growth of microorganisms.

The visible mold observed beneath the sinks in the women's restroom near the break room was confirmed in two of the five tape samples collected. Although the fungi could not be identified, the yeast cells and fungal hyphae and spores detected suggested fungal growth was present. This is most likely due to water leaks between the sink and sink cutout due to deteriorating caulking.

No accumulation of dust or dirt, or any evidence of microbial growth was observed, in the interior insulation in a supply duct above quadrant A. However, one of the two bulk material samples of interior insulation taken from within the supply duct identified *Cladosporium cladosporioides*. Water spray from air movement over the cooling coils results in a marginal amount of water deposition in supply ducts downstream of the cooling coils. Thus, it is not unexpected to see small counts of this type of fungi. But the low concentration detected in the sample, and the lack of grossly apparent contamination do not suggest the need to replace the insulation in the supply ducts.

The predominant fungal genera identified through culturable analysis of the bulk dust samples included the allergens *Penicillium*, *Acremonium*, and *Cladosporium*. Although found in varying concentrations, one of these species was either the predominant or second most predominant species in all six of the bulk dust samples. However, no other evidence was found that would suggest that an amplifying source of microbial growth existed beneath the carpeted walls or floors in the any of the four quadrants. Although carpeting provides an organic nutrient source, a continuous source of moisture must be present for microbial growth to thrive. No evidence of moisture incursion was found through visual inspection and testing with the invasive and non-invasive moisture meters. A definitive explanation addressing the origin of the *Penicillium* can not be given because there are many possible explanations. For example, it is possible that the colonies of *Penicillium* detected were residual growth from a previous moisture incursion event. It is also possible that the fungi could have been carried through the air, possibly originating from the ventilation system before it was remediated, and deposited on the carpet. However, regardless of the origin, it is difficult to conclude that a marginal reservoir identified in one out of six samples is indicative of a microbial growth problem.

Qualitative smoke tube tests indicated that the building was maintained under a positive pressure with respect to the outdoor environment. This will ensure that unconditioned and unfiltered air does not leak into the building through cracks and other entry points. Positive pressure in the building will also maintain zone control and decrease temperature fluctuations. Smoke tube tests also indicated that the smoking break room was under negative pressure. This should keep cigarette smoke from entering other areas of the reservation center. However, cross-drafts introduced through opening doors could disrupt the airflow and allow some smoke to escape the area if the negative pressure is not strong enough to overcome the cross-drafts. Thus, it is important that this room be maintained under strong negative pressure relative to its surroundings at all times to prevent migration of cigarette smoke into non-smoking areas.

Measured temperatures in quadrant B, the front reception area, the Q&A office, and the shop steward's office were from 2°F below to 1°F above ASHRAE's recommended range for the summer months (73-79°F). However, with the exception of the shop steward's office, these slight variations outside the recommended range occurred during either unoccupied, or low occupancy times of the day. Temperatures in the remaining locations measured were within the range recommended by ASHRAE Standard 55-1992. Temperature patterns in the reservations center were fairly consistent, with the exception of the temperature fluctuations illustrated in the break room. This is most likely due to the frequency of outside air being introduced into the break room when employees enter or exit the outdoor break area, which is accessible through a door in the break room. Certain areas of the reservations center remain occupied for 24 hours and, as a result, temperature patterns should be uniform and remain stable at all times. RH measured in the building indicated that maximum levels were approaching the upper limit recommended by ASHRAE Standard 55-1992. This factor suggests that the current ventilation system is not sufficiently conditioning the intake air before it is delivered to the building.

CO_2 measurements below the NIOSH guideline of 800 ppm indicate that the HVAC system is providing adequate amounts of outdoor air to the occupied areas. This indicates that the remediated HVAC system is capable of maintaining outdoor air supply rates of at least 20 cfm/person for office spaces, the amount recommended by ASHRAE Standard 62-1989.[23] The current AHUs utilize direct electronically controlled variable and constant air volume boxes to control temperature and the amount of OA brought into the building.

The health effects described by the interviewed employees were, on the whole, not suggestive of a shared exposure in the SRC. The symptoms described by some of the workers were consistent with exposures to allergens. These symptoms included itchy watery eyes, headache, and fatigue. Although these symptoms were reported at work, they were not exclusive to the work environment (some of the workers indicated that these symptoms occurred both at work and away from work). The environmental evaluation of the building did not identify an obvious source of mold in the building. Furthermore, this building is located in a climate where seasonal allergies are common. With no obvious source of allergens unique to the work environment, it is most likely that the allergic symptoms described by workers are the result of exposure to antigens in the external environment. However, building conditions can be a problem for those who have a history of allergies, especially during periods when the building is being repaired or renovated and steps should be taken to keep work areas clean and minimize dust migration during renovation work.

In conclusion, the limited evidence of visual microbial colonization (one area); lack of water incursion evidence; and proper operating condition of the HVAC system in the Southwest Airlines SRC indicates that a microbial growth problem did not exist in this building at the time of the NIOSH site visit.

RECOMMENDATIONS

1. The carpeting on the walls of the quadrants should be replaced with a non-carpeted, acoustical material that will be easier to keep clean and to

dry in instances of water incursion. Highly porous materials, such as carpet, can act as a sink for materials found in the air that may deposit there, creating an organic nutrient source. However, if an acceptable alternate to the carpeting can not be found, then special care must be given to the new carpet to reduce the possibility of microbial growth. The carpeting on the walls should be HEPA vacuumed (used to prevent re-entrainment of debris into the air) on a weekly basis, at a minimum, to prevent buildup of dust and debris, which can act as a nutrient source for microbial growth. In addition, any episodes of water incursion should be dealt with immediately and water should immediately be removed from the carpet. Heat fans should be used within 24-48 hours to dry the carpets. If they can not be dried within 24-48 hours, they should be replaced. Steam or other water-based cleaning methods which add moisture to the environment must be used with extreme care and are not recommended. Any soft materials, including carpeted areas, that become wet with sewage-contaminated water should be promptly discarded. A written program for dealing with these incidents, proper training of personnel, and the ready availability of the necessary equipment would help reduce the likelihood of future problems from events of this nature (these guidelines are applicable to all porous materials, including furnishings and construction materials). In all situations, the underlying cause of water accumulation must be rectified or the possibility of fungal growth occurring, or reoccurring, will be greatly increased.

2. Renovation of the carpeting on the quadrant walls will result in the disruption of dust, dirt, and any other debris on the carpet. The airborne dissemination of these aerosols is an exposure concern for the workers completing the task and the occupants of the building. Additionally, these aerosols can be spread to other areas of a building, increasing exposure concerns for the remaining occupants and adding to the difficulty of clean-up. Therefore, it is important that all renovation activities be conducted with an awareness of the potential exposures and with minimal disturbance of the materials.

3. Prior to any renovation, controls should be instituted that protect both the workers and the adjacent environment. Preferably, the work area should be unoccupied, and persons having undergone recent surgery, immune suppressed people, or people with chronic inflammatory lung diseases (e.g., asthma, hypersensitivity pneumonitis, and severe allergies) should be vacated from spaces adjacent to the work area. The work area should be isolated from surrounding areas before renovation begins. Covering the area with plastic sheeting and sealing with tape should help contain dust and debris. The carpet should also be HEPA-vacuumed before removal begins to reduce dispersion of any dust, debris, or other contaminants. The ventilation ducts/grills in the work area and directly adjacent areas should also be sealed with plastic sheeting. Once the carpet is removed from the wall it should be wrapped in plastic before being removed from the building to prevent dissemination of debris into other areas. The work area and areas used by remedial workers for egress should be HEPA vacuumed after disposal of the carpet.

4. The moldy plywood beneath the sinks in the women's and men's restroom near the training room, and in the other restrooms, if needed, should be replaced. The restrooms should be made inaccessible to employees during the remediation process. Although in this instance containment of the work area is not necessary, contaminated materials should be removed from the building sealed in plastic to prevent any dissemination into other work areas. After remediation the restroom floors should be cleaned with a damp cloth and/or mop and a detergent solution. The work areas used by remedial workers for egress should also be cleaned with a HEPA vacuum if the flooring is carpeted. All areas should be left dry and visibly free from contamination and debris. After the plywood is replaced, caulking between the sink and sink

cutout should be properly applied to ensure that water leakage through this area does not occur. Any faucet leaks, or other plumbing leaks, should also be fixed to prevent water from accumulating around the sinks.

5. A few water-damaged ceiling tiles were observed in the reservations center, specifically in the cold room. The facility maintenance specialist was reportedly in the process of replacing all damaged ceiling tiles. Although no visible signs of mold were seen on the damaged tiles during the NIOSH inspection, if mold is observed during removal, special precautions must be taken during non-occupied hours or at times during the least amount of occupancy. The tiles should be carefully removed from the ceiling grids and individually bagged inside polyethylene or sturdy plastic to contain any release of mold spores when the materials are removed from the building. Applying thin sheets of clear plastic with an adhesive backing to mold-contaminated sections of wallboard or ceiling tiles can help to contain spores on the side of the wall board that the adhesive plastic is attached.

6. RH in the reservations center must be maintained at levels below 60% to inhibit mold growth.[24] Although this was the case at the time of the NIOSH site visit, measured RH in some areas was approaching 60%. RH levels in the upper end of the acceptable range may be due to the fact that the cooling coils are over capacity for the maximum heat load and not capable of properly cooling the amount of OA being brought in. The capacity of the cooling coils should be checked. For chilled-water systems, temperatures above design specifications may result in insufficient dehumidification and reduced cooling capacity. HVAC engineers recommend chilled water temperatures be maintained below 55°F. Chilled water temperatures at the time of the NIOSH site visit were well below 55°F and regularly scheduled maintenance checks should ensure proper temperature regulation.

7. Sewer drains should be periodically checked to ensure that they do not dry up, allowing sewer gas vapors to escape and subsequently causing an odor problem. This is especially important during dry periods. Mineral oil can be added to infrequently used drains if there is a problem with water evaporating too quickly.

8. According to NIOSH policy, smoking in a work area should not be permitted. To facilitate elimination of tobacco use in the workplace, management and labor should work together to develop appropriate nonsmoking policies.[34] However, until that is achieved, employers can designate separate, enclosed areas for smoking with separate ventilation. Smoking areas should also have negative pressure to ensure airflow into the area rather than back into the airspace of the workplace.[23] The smoking break room was under negative pressure at the time of the NIOSH site visit, however it was reported that prior to the NIOSH site visit this room was under positive pressure. It is important that this room constantly remain under a strong negative pressure to ensure that smoke does not migrate to other areas of the workplace. The outdoor break area is also designated as a smoking area. Although outside, it is a common area to both non-smoking and smoking employees. Thus, according to NIOSH policy this area should be non-smoking. Smoking should only be permitted in areas designated as strictly smoking areas.

9. The current service agreements addressing the housekeeping program and routine operating inspections, repair services, and annual preventive maintenance on the building should be diligently followed and updated as needed. All carpeted areas should be HEPA-vacuumed on a weekly basis, at a minimum, to prevent buildup of dust and debris, which can act as a nutrient source for microbial growth. A HEPA vacuum should be used to prevent re-entrainment of aerosols into the air. The supply and return grills should be cleaned on a regular basis to prevent dust and debris accumulation from entering the airstream. Cleaning activities that introduce moisture into the building, such as steam cleaning carpets, should not be performed in a way that leads to excessive moisture in porous materials.

10. Although the HVAC system appeared in good condition at the time of the NIOSH site visit, the condition of the HVAC system should be routinely checked and annual preventive maintenance should be diligently followed to ensure proper performance continues. This includes inspection of interior components of the AHUs, such as cooling coils, condensate drip pans, and porous internal HVAC duct liners for accumulation of dust, dirt, or other contaminants, as well as evidence of water damage. Preventive maintenance should also include inspection of outdoor air damper systems and exhaust vents. Any future HVAC upgrades or modifications require that accurate heat load calculations be obtained to ensure proper sizing of equipment. A complete test and balance of the system should also be performed to ensure that the system operates as intended and that design goals are met.

11. Communication between management and employees should be increased to facilitate the exchange of concerns about environmental conditions in the building. Employees should be made aware of the problems with the building and decisions that must be made by building managers to address those problems. Forming a safety committee consisting of members of management, the union, and employee representatives to act as a liaison between management and the staff is recommended.

12. Employees who have health concerns such as rhinitis, asthma, and sinusitis should consult their health care provider to determine the cause and proper treatment.

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Table 1
Characterization of Bulk Dust Samples
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 28-30, 2000

Sample Location	Dust Component	Percentage (%)
Bulk 1 (from the carpeted wall separating Quad A and B; on Quad B side)	cellulose fibers	5
	fiber glass	trace
	fungal matter	trace
	mineral crystals	20
	miscellaneous	3
	plant matter/trichome	1
	pollen	trace
	skin flakes	70
	starch grains	1
Bulk 2 (from carpeted wall separating Quad C and main hallway; on Quad C side)	cellulose fibers	15
	fiber glass	trace
	fungal matter	trace
	mineral crystals	10
	miscellaneous	3
	pollen	trace
	skin flakes	70
	starch grains	1
	synthetic fibers	1
Bulk 3 (from carpeted rear wall in Quad C)	cellulose fibers	40
	fungal matter	trace
	mineral crystals	5
	miscellaneous	3
	plant matter/trichome	1
	pollen	trace
	skin flakes	50
	starch grains	trace
	synthetic fibers	1
Bulk 4 (from carpeted floor in hallway between Quad C and D)	cellulose fibers	25
	fungal matter	trace
	mineral crystals	35
	miscellaneous	7
	pollen	trace
	skin flakes	30
	starch grains	2
	synthetic fibers	1

Table 1
Characterization of Bulk Dust Samples
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 28-30, 2000

Sample Location	Dust Component	Percentage (%)
Bulk 5 (from carpeted floor halfway up the center aisle in Quad D)	cellulose fibers	5
	fungal matter	trace
	mineral crystals	50
	miscellaneous	4
	pollen	trace
	skin flakes	40
	starch grains	trace
	synthetic fibers	1
Bulk 6 (carpeted floor in union steward's office)	cellulose fibers	25
	fiber glass	trace
	foam particles	trace
	fungal matter	trace
	mineral crystals	15
	miscellaneous	6
	plant matter/trichome	1
	pollen	trace
	rubber	1
	skin flakes	50
	starch grains	1
	synthetic fibers	1

Table 2
Microbiological Bulk Dust Sample Results
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 28-30, 2000

Sample Location	Fungi (MEA†)		Fungi (CMA‡)	
	CFU/g	**Taxa (%)**	**CFU/g***	**Taxa (%)**
Bulk 1 (from the carpeted wall separating Quad A and B, on Quad B side)	$2.0x10^3$ $9.8x10^2$ $2.0x10^3$ $2.0x10^3$ $1.1x10^5$ $2.0x10^3$	*Acremonium* (2) *Aspergillus niger* (<1) *Aspergillus versicolor*(2) *Cladosporium* (2) *Penicillium* (93) sterile fungi (2)	$1.3x10^4$ $1.3x10^5$ $9.8x10^2$ $9.8x10^2$	Myrothecium (9) *Penicillium* (90) *Rhizopus stolonifer* (<1) sterile fungi (<1)
	Total: $1.2x10^5$		**Total: $1.5x10^5$**	
Bulk 2 (from carpeted wall separating Quad C and main hallway, on Quad C side)	$7.5x10^3$ $5.0x10^3$	*Aphanocladium* (60) *Penicillium* (40)	$1.3x10^4$ $1.3x10^4$	*Aphanocladium* (50) *Penicillium* (50)
	Total: $1.3x10^4$		**Total: $2.5x10^4$**	
Bulk 3 (from carpeted rear wall in Quad C)	$1.3x10^3$ $6.6x10^2$ $1.3x10^3$ $6.6x10^2$ $1.3x10^3$ $4.6x10^3$ $6.6x10^2$	*Alternaria alternata* (13) *Botrytis* (6) *Chaetomium globosum* (13) *Nigrospora* (6) *Penicillium* (13) *Phoma* (44) sterile fungi (6)	$1.3x10^3$ $6.6x10^2$ $1.3x10^3$ $6.6x10^2$ $6.6x10^2$ $1.3x10^3$ $6.6x10^2$ $6.6x10^2$	*Alternaria alternata* (18) *Aureobasiduim pullulans* (9) *Chaetomium globosum* (18) *Exophiala* (9) *Mucor* (9) *Phoma* (18) *Rhodotorula (9)* sterile fungi (9)
	Total: $1.0x10^4$		**Total: $7.2x10^3$**	

Table 2
Microbiological Bulk Dust Sample Results
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 28-30, 2000

Sample Location	**Fungi (MEA†)**		**Fungi (CMA‡)**	
	CFU/g	**Taxa (%)**	**CFU/g***	**Taxa (%)**
Bulk 4 (from carpeted floor in hallway between Quad C and D)	$5.9x10^3$	*Acremonium* (7)	$4.1x10^4$	*Acremonium* (37)
	$1.2x10^4$	*Alternaria alternata* (15)	$5.9x10^3$	*Alternaria alternata* (5)
	$1.5x10^3$	*Aspergillus flavus* (2)	$1.5x10^3$	*Aspergillus sydowii* (1)
	$1.5x10^3$	*Aspergillus niger* (2)	$3.0x10^3$	*Aspergillus ustus* (3)
	$1.5x10^3$	*Aureobasidium pullulans* (2)	$1.5x10^3$	*Chaetomium globosum* (1)
	$2.7x10^4$	*Cladosporium* (33)	$2.5x10^4$	*Cladosporium* (23)
	$3.0x10^3$	*Curvularia* (4)	$4.4x10^3$	*Curvularia* (4)
	$4.4x10^3$	*Epicoccum nigrum* (6)	$1.5x10^3$	*Drechslera* (1)
	$7.4x10^3$	*Penicillium* (9)	$7.4x10^3$	*Penicillium* (7)
	$3.0x10^3$	*Rhodotorula glutinis* (4)	$3.0x10^3$	*Phoma* (3)
	$3.0x10^3$	sterile fungi (4)	$4.4x10^3$	*Rhodotorula glutinis* (4)
	$1.0x10^4$	yeasts (13)	$3.0x10^3$	sterile fungi (3)
			$8.9x10^3$	yeasts (8)
	Total: $8.0x10^4$		**Total: $1.1x10^5$**	

Table 2
Microbiological Bulk Dust Sample Results
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 28-30, 2000

Sample Location	Fungi (MEA†)		Fungi (CMA‡)	
	CFU/g	Taxa (%)	CFU/g*	Taxa (%)
Bulk 5 (from carpeted floor halfway up the center aisle in Quad D)	$1.6x10^2$	*Acremonium* (11)	$1.6x10^2$	*Alternaria alternata* (11)
	$2.0x10^2$	*Alternaria alternata* (13)	80	*Aureobasidium pullulans* (6)
	40	*Aureobasidium pullulans* (3)	$4.8x10^2$	*Cladosporium* (34)
	$2.8x10^2$	*Cladosporium* (18)	$2.4x10^2$	*Curvularia* (17)
	$2.8x10^2$	*Curvularia* (18)	40	*Myrothecium* (3)
	40	*Nigrospora* (3)	80	*Penicillium* (6)
	40	*Penicillium* (3)	80	*Phoma* (6)
	$1.6x10^2$	*Phoma* (11)	40	*Rhodotorula glutinis* (3)
	80	*Rhodotorula glutinis* (5)	40	sterile fungi (3)
	$1.2x10^2$	sterile fungi (8)	$1.6x10^2$	yeasts (11)
	$1.2x10^2$	yeasts (8)		
	Total: $1.5x10^3$		**Total: $1.4x10^3$**	
Bulk 6 (carpeted floor in union steward's office)	$1.6x10^3$	*Aspergillus nidulans*(5)	$1.6x10^3$	*Acremonium* (5)
	$2.9x10^4$	*Penicillium* (95)	$1.6x10^3$	*Aspergillus flavus* (5)
			$3.0x10^4$	*Penicillium* (86)
			$1.6x10^3$	sterile fungi (5)
	Total: $3.1x10^4$		**Total: $3.4x10^4$**	

*Concentration is (CFU/sample) if sample amount is non-detectable.
†MEA-2% malt extract agar
‡CMA-cornmeal agar

Figure 1
Floor Plan of the San Antonio Reservations Center
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 28-30, 2000

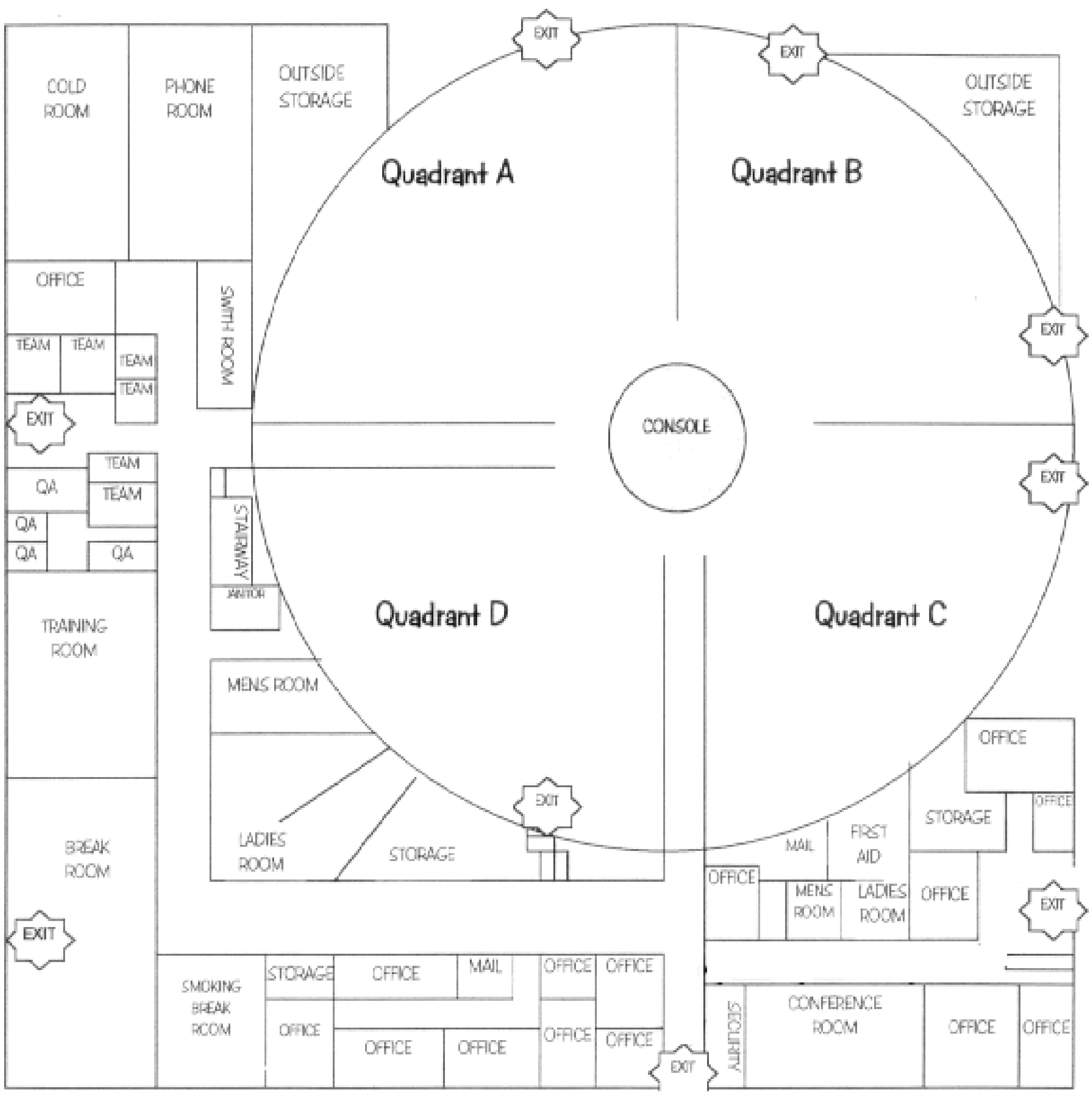


Figure 2
Temperature Variations in Quadrant A
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

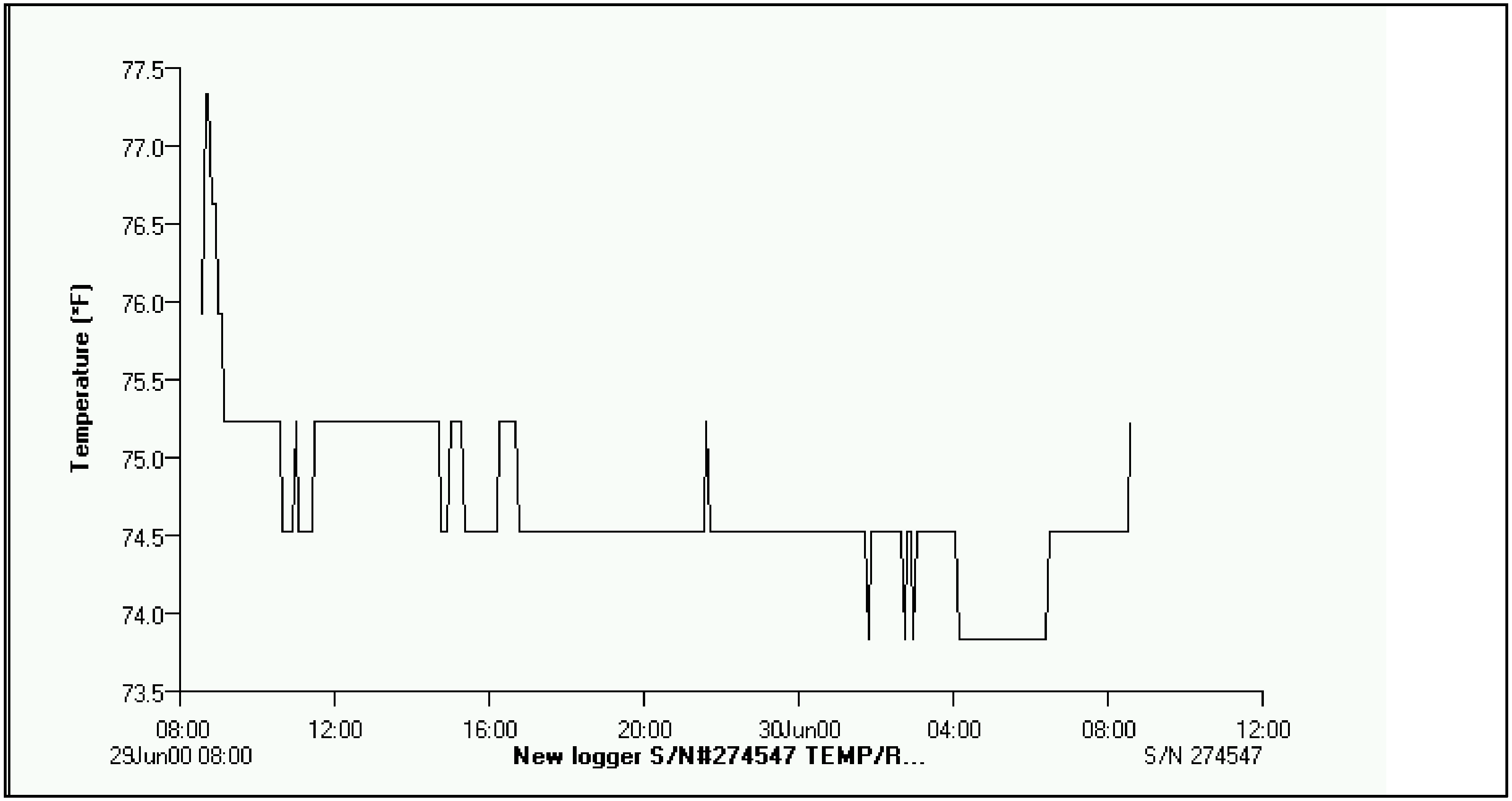


Figure 3
Temperature Variations in Quadrant B
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

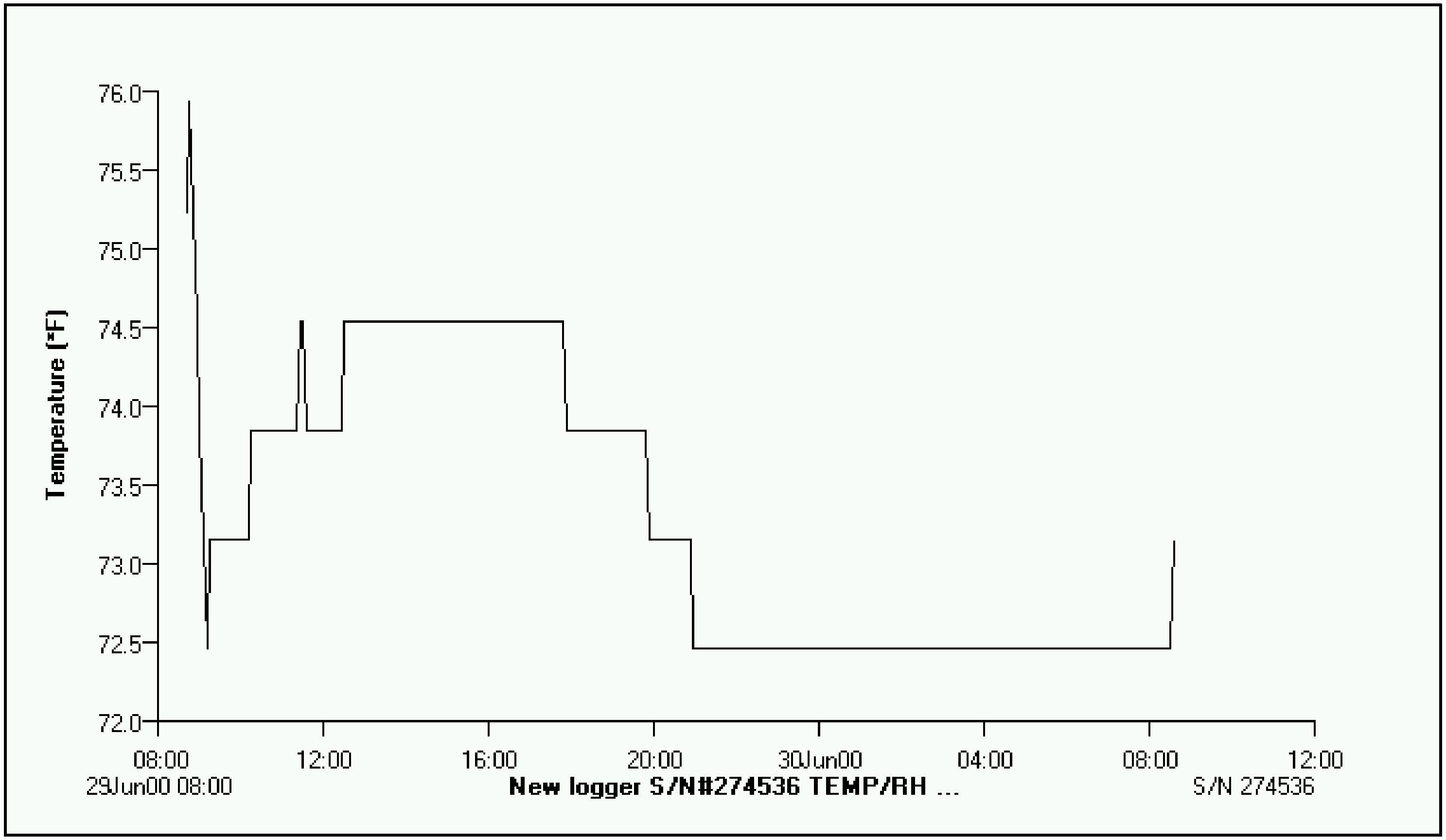


Figure 4
Temperature Variations in Quadrant C
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

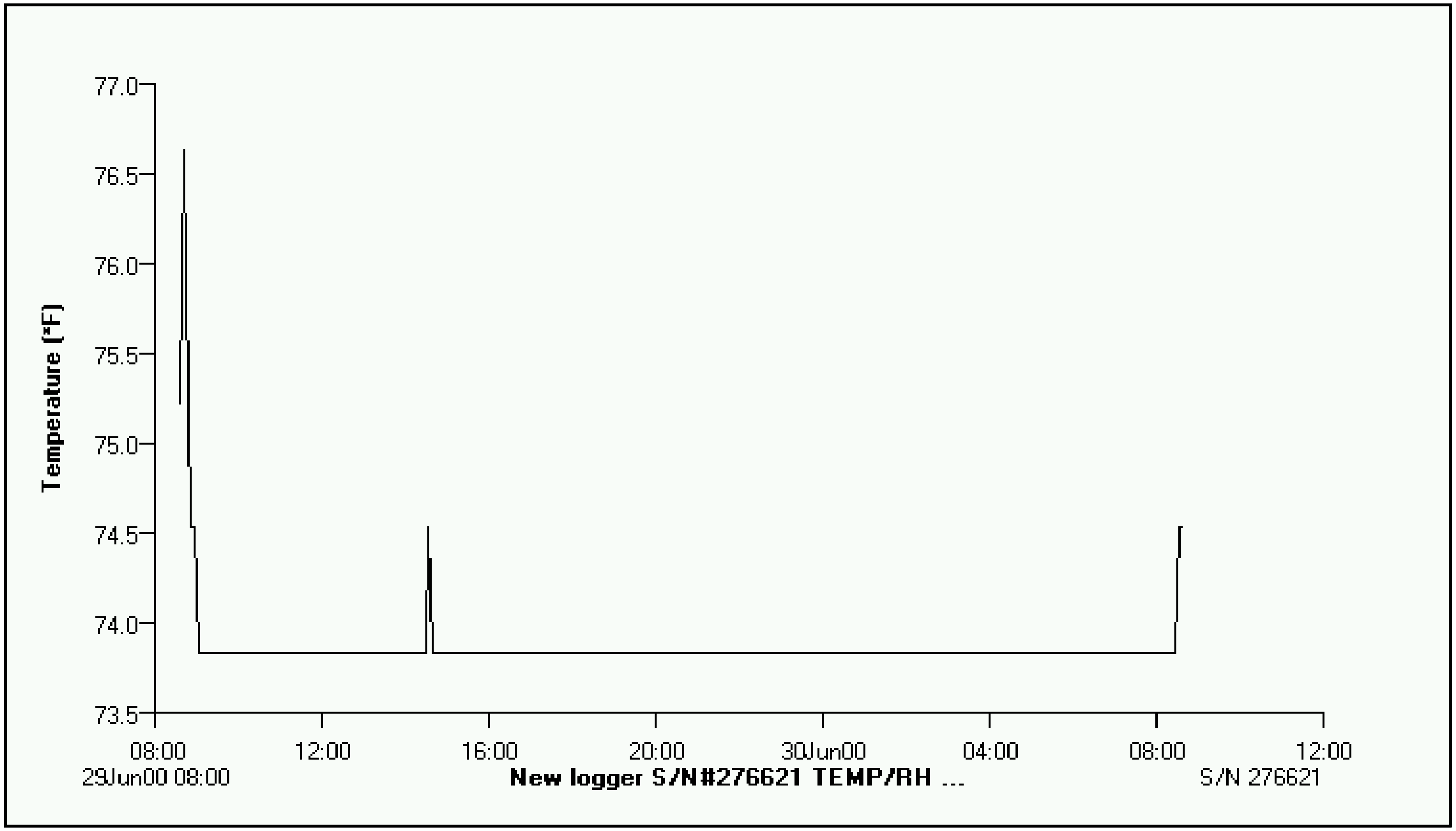


Figure 5
Temperature Variations in Quadrant D
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

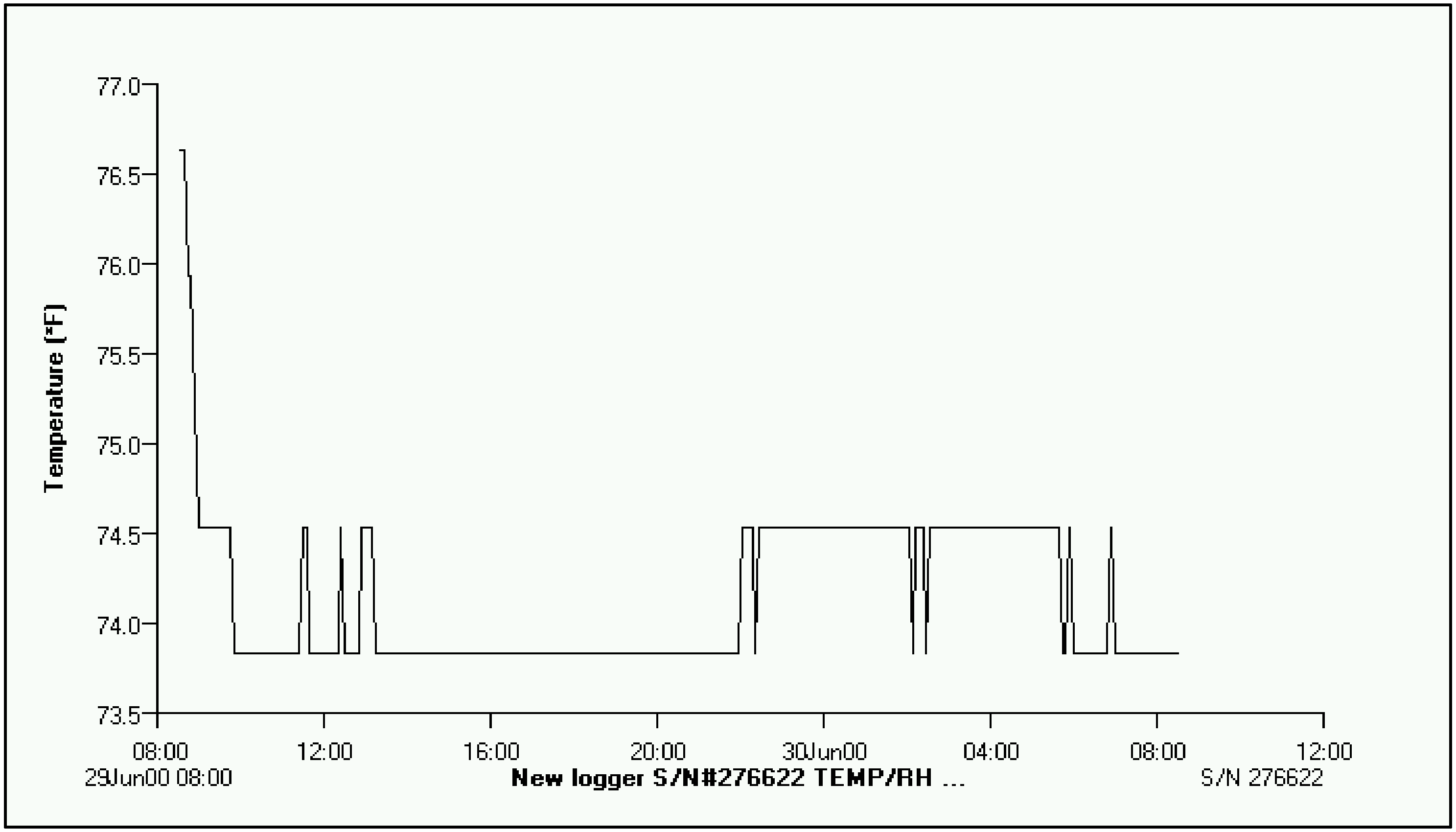


Figure 6
Temperature Variations in the Console Area
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

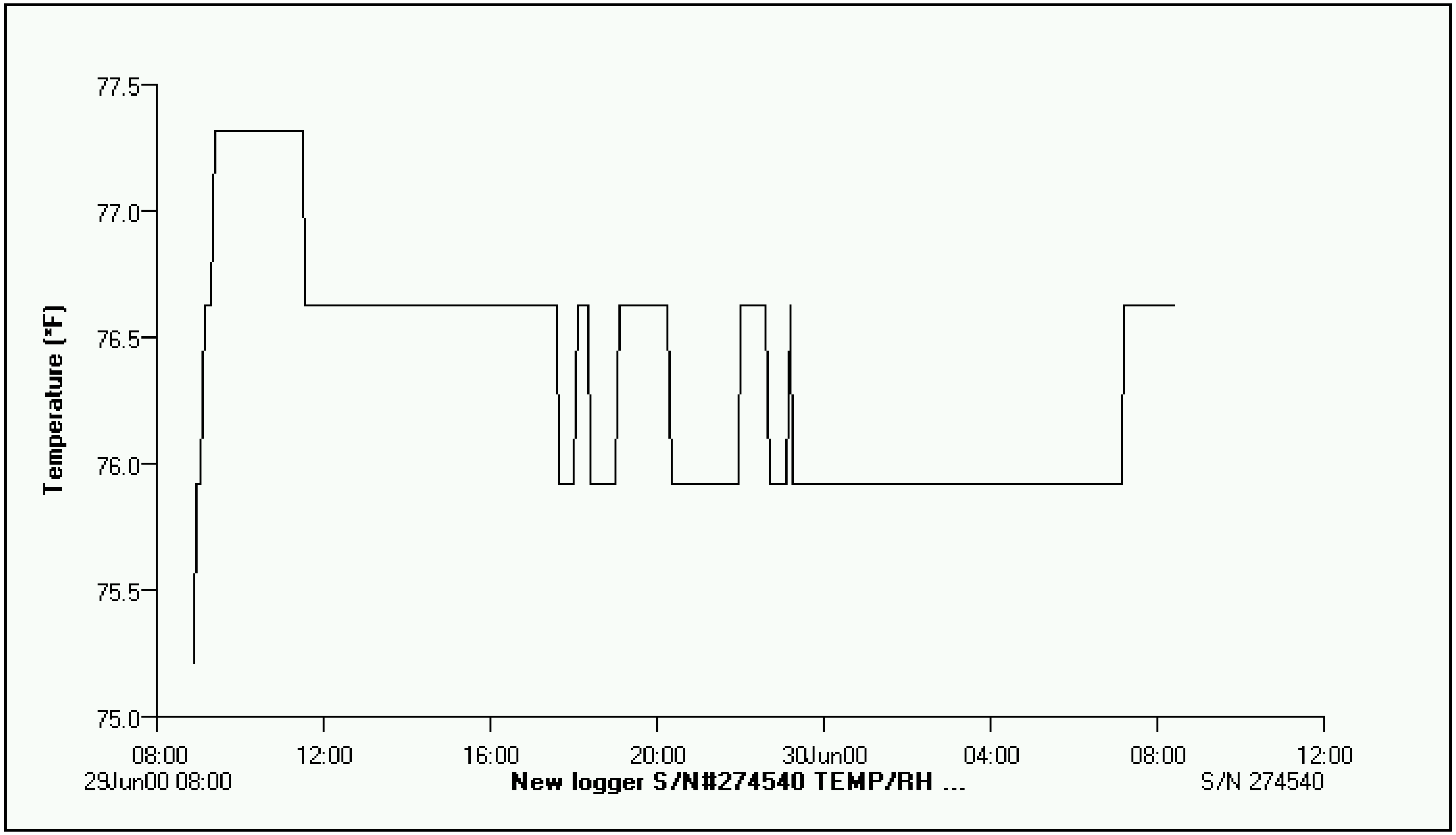


Figure 7
Temperature Variations in the Reception Area
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

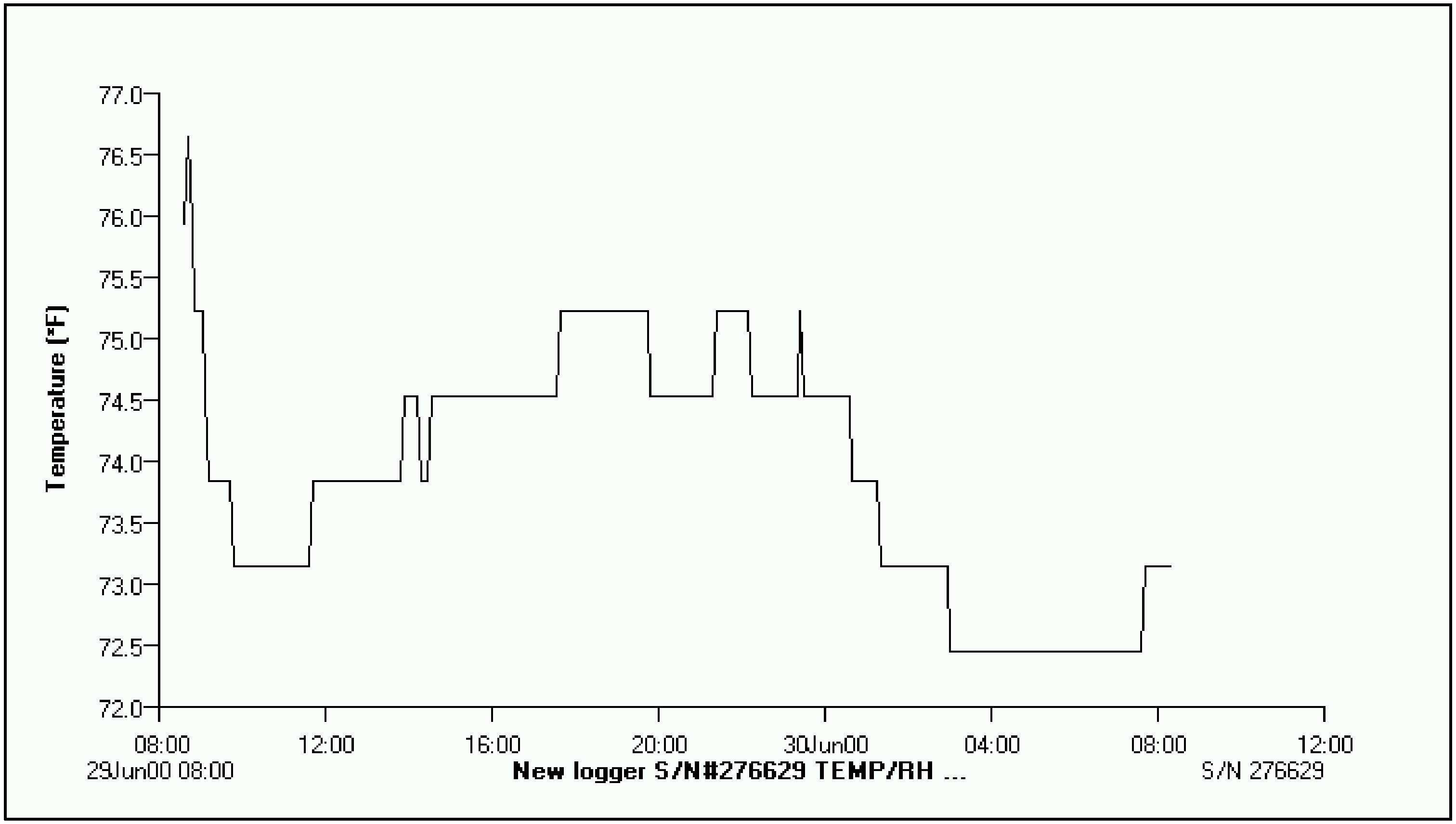


Figure 8
Temperature Variations in the Break Room
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

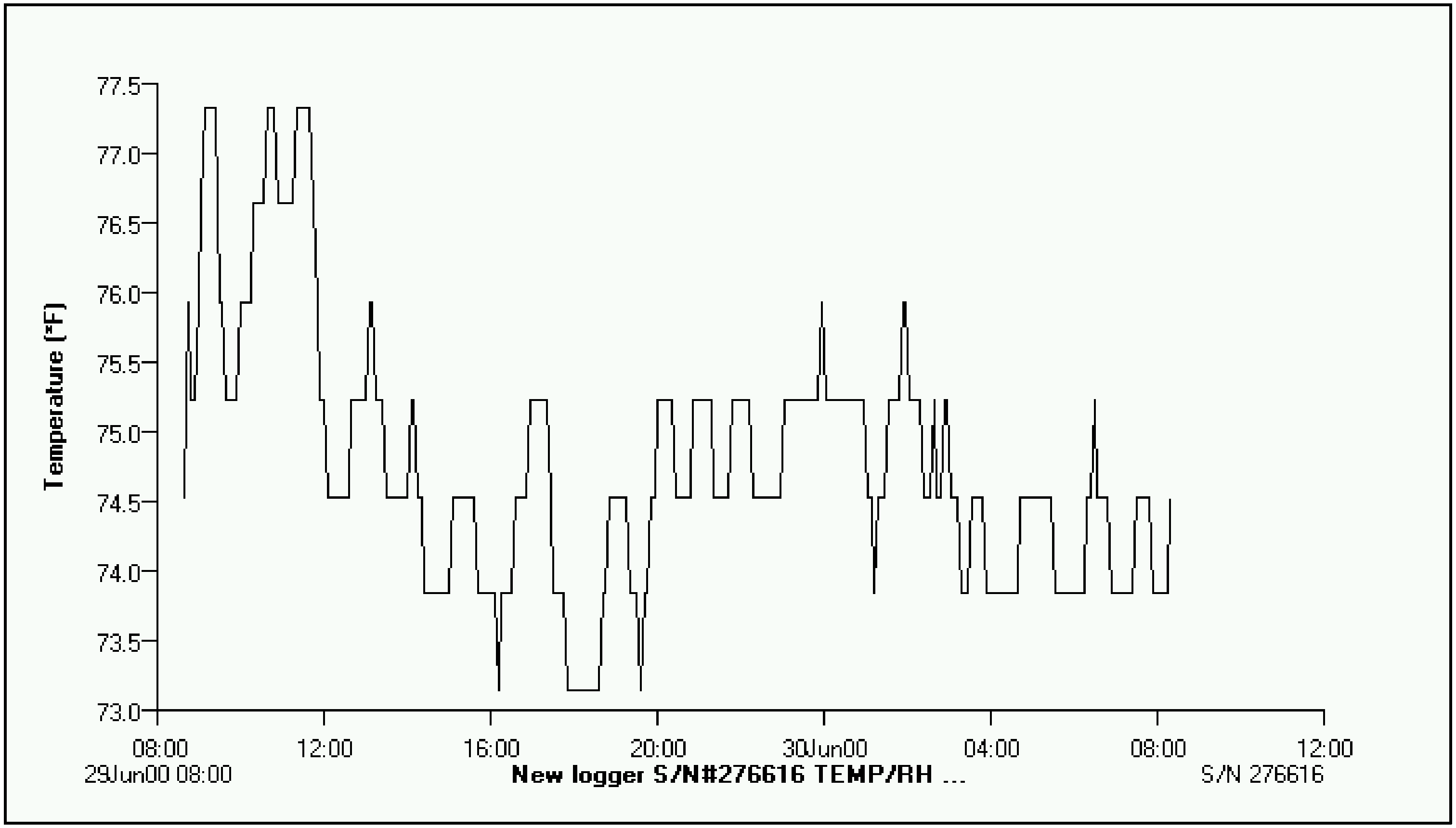


Figure 9
Temperature Variations in the First Aid Room
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

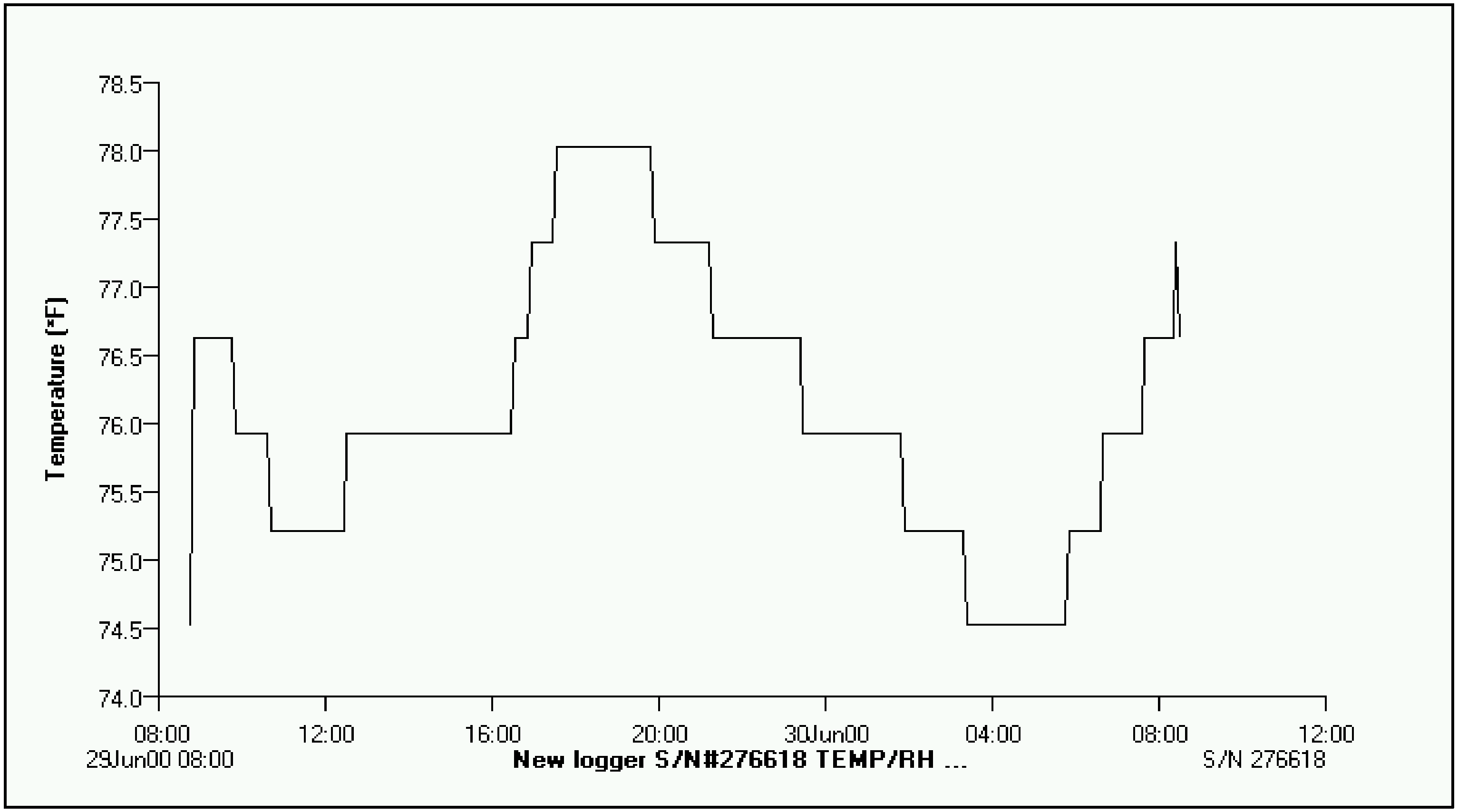


Figure 10
Temperature Variations in the Q & A Office
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

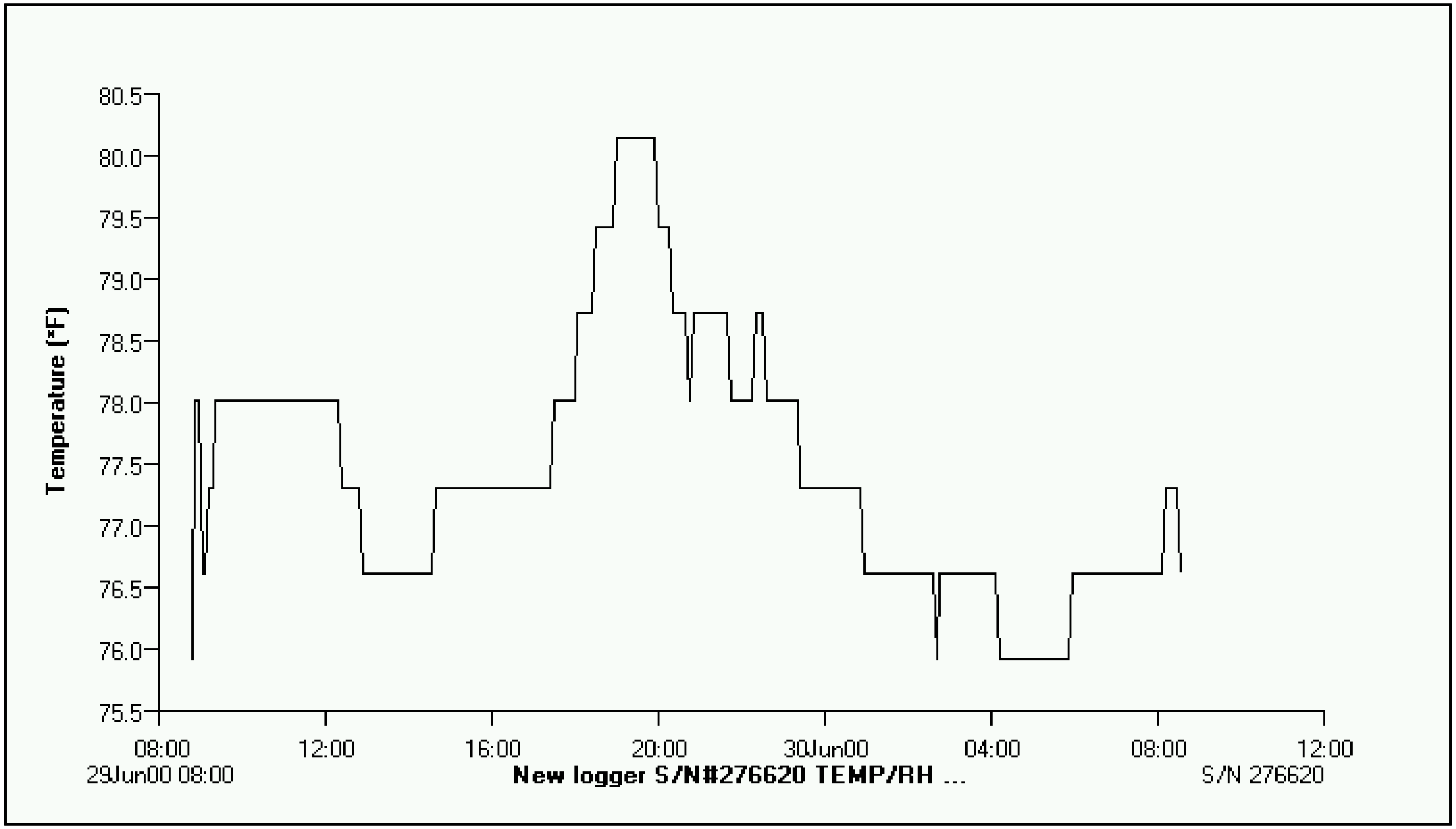


Figure 11
Temperature Variations in the Shop Steward's Office
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000

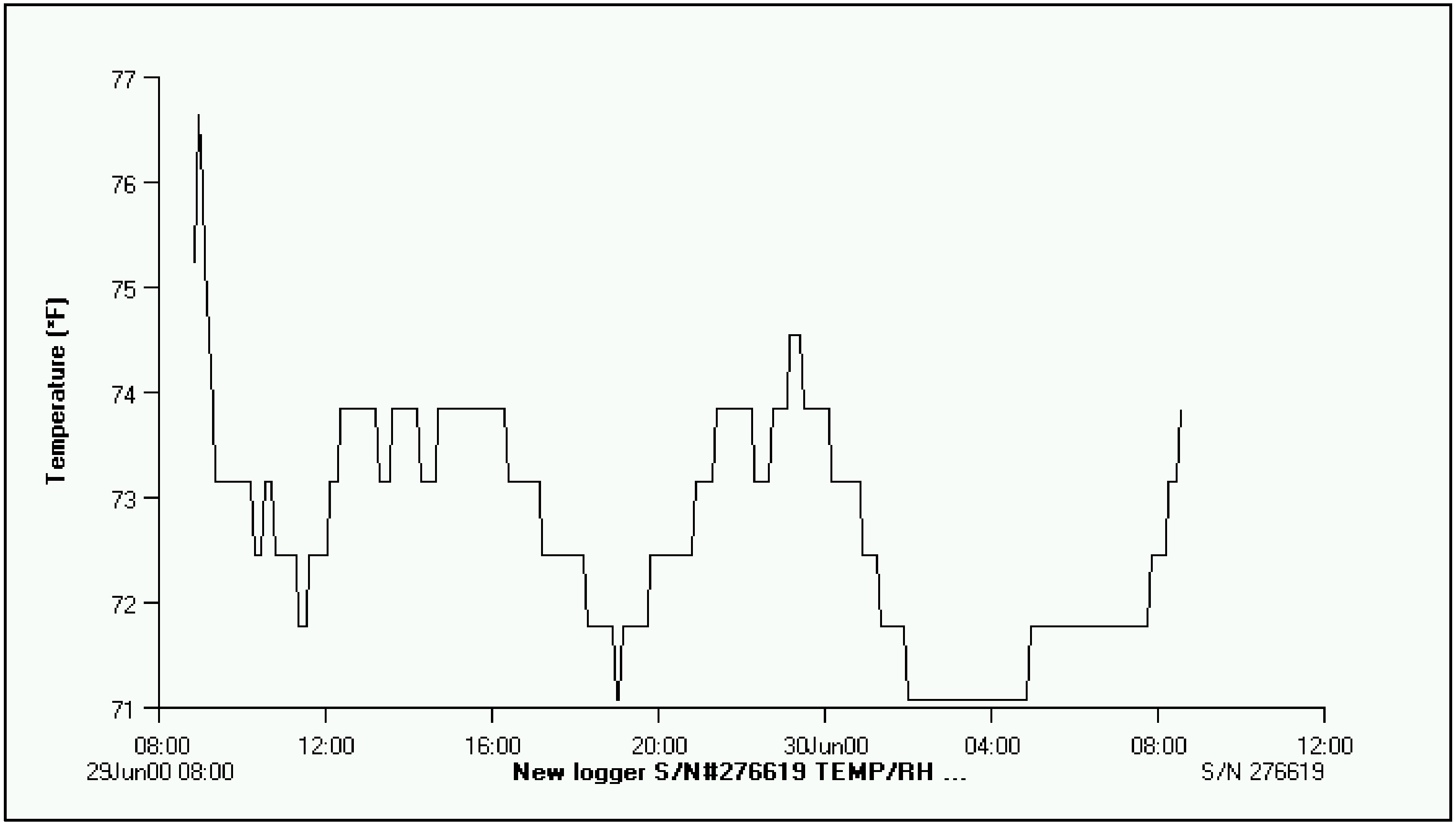
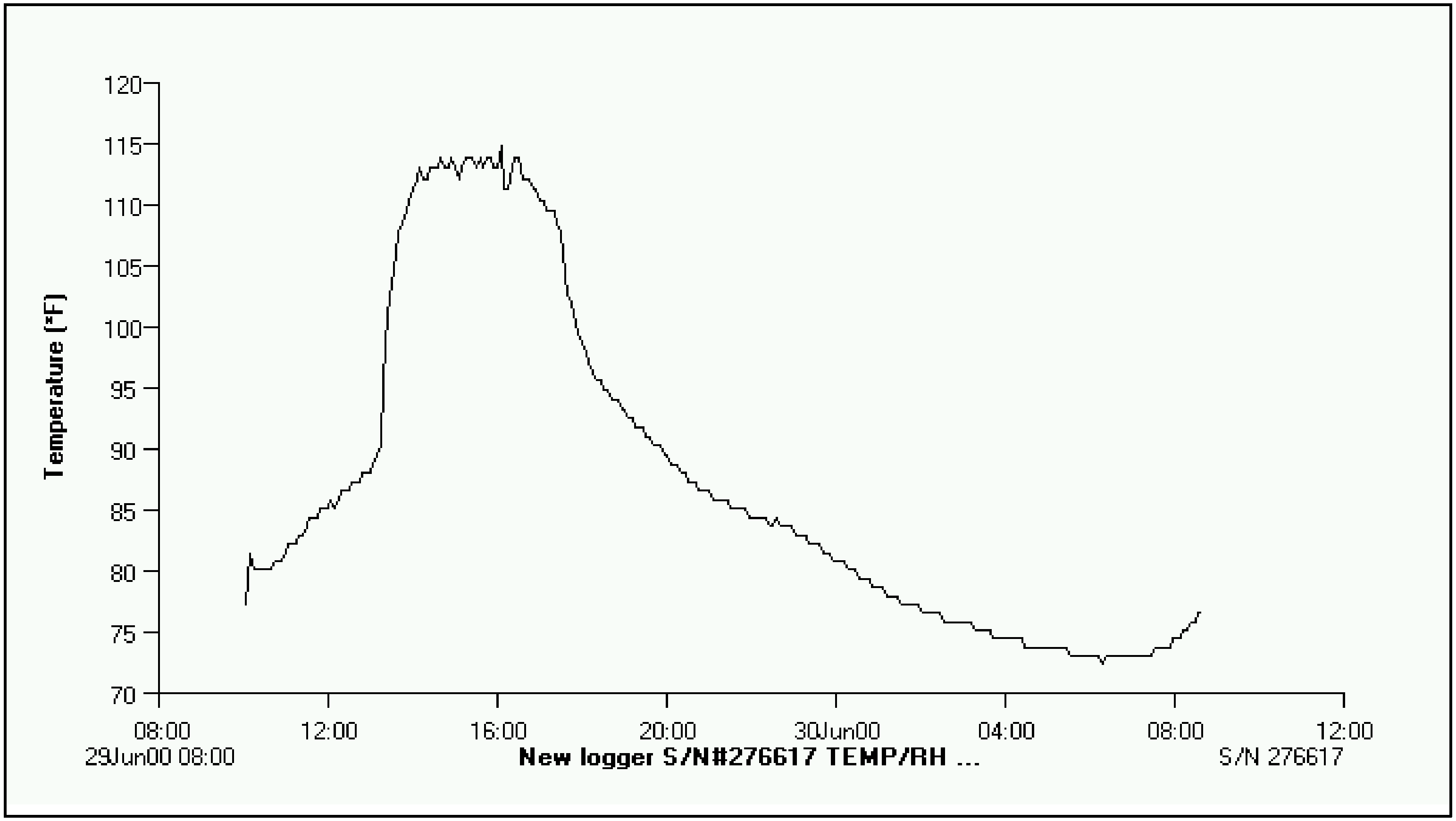


Figure 12
Temperature Variations Outdoors
HETA 2000-0268
Southwest Airlines San Antonio Reservations Center, San Antonio, TX
June 29-30, 2000



For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh