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Southwest Airlines Dallas Reservations Center
Grand Prairie, Texas

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Kristin K. Gwin, Kenneth F. Martinez, and Joel McCullough of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. 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 Dallas Reservations Center

In December 1999, NIOSH investigators conducted a health hazard evaluation at Southwest Airline's Dallas Reservations Center (DRC). We assisted OSHA in evaluating the 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 and tape samples from the interior of the air handling units to look for microbial growth.
- We collected temperature, relative humidity, and carbon dioxide measurements, and checked for moisture in the walls and floor.
- We checked the ventilation by releasing a "smoke" to see air flows.
- We talked with and administered a symptom questionnaire to some employees.

What NIOSH Found

- We did not see any fungal growth during inspection of the building.
- Bulk sample analysis of interior insulation in four of the air handling units showed high fungal concentrations and/or significant genera. Two of these four samples also showed high bacterial concentrations.
- Average temperatures in the DRC were within the recommended comfort range (68°-74°F in the winter). However, continuous measurements taken for 24 hours showed rapid temperature changes.
- Average relative humidity within the DRC were below the recommended comfort range (30%-60%).
- Some carbon dioxide measurements were greater than 800 ppm, indicating an inadequate amount of outside air.
- Air flow tests showed air moved from within the smoking break room and smoking customer service representative area out into the workplace.
- Most cases of asthma in DRC employees were non-allergic and do not appear to be related to exposures unique to the workplace.
- Most cases of adult onset runny and stuffy noses are unlikely to be caused by allergies.

What Southwest Airlines Managers Can Do

- Consult with a qualified engineering firm to determine if the current ventilation system is capable of servicing the building occupancy at the DRC.
- Replace the interior insulation in the air handling units, but avoid disturbing contaminated materials (see full report for further details).
- Until smoking is eliminated in the workplace, fix the ventilation in the smoking customer service representative work area and the smoking break room so these areas are under negative pressure with respect to surrounding areas.
- Water leaks should be fixed immediately, and water-damaged materials either dried 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 2000-0088-2809

Southwest Airlines Dallas Reservations Center
Grand Prairie, Texas
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SUMMARY

On December 7, 1999, 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 Dallas Reservations Center, Grand Prairie, Texas. A similar request had been previously received by NIOSH from employees of the reservations center. Health concerns included upper respiratory infections, fatigue, asthma, headaches, dry cough, and ear/nose bleeds.

On December 27-29, 1999, NIOSH investigators conducted a site visit at the reservations center. A walk-through inspection was made of the building interior and exterior. Bulk material and sticky tape samples of surfaces were collected from the interior of the air handling units (AHUs) to assess these areas for microbial contamination. Measurements to detect moisture incursion and general indoor air quality comfort parameters were also collected. Confidential medical interviews were conducted to assess health concerns.

Fungal concentrations from bulk material samples of interior insulation in the AHU units ranged from non-detectable (ND) to 1.8×10^7 colony forming units per gram of material (CFU/g). *Exophiala*, *Rhodotorula glutinis*, *Acremonium, Cladosporium sphaerospermum*, and *Cladosporium herbarum* were the predominant fungi identified. Four of the six bulk samples revealed high fungal concentrations and/or were identified with significant genera known to have irritant effects. Bacterial concentrations from the bulk insulation samples ranged from ND to 1.9×10^7 CFU/g. Gram negative bacteria were the most prevalent bacterial type detected and were found in the highest concentrations. Gram negative bacteria are commonly found in association with moisture. A tape sample taken from the laminated covering on the interior insulation within one of the AHUs revealed mostly dust, skin flakes, and glass fibers. No fungal growth was observed.

Although temperatures measured in the reservations center were within the range recommended by the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE), different temperature zones and fluctuating temperature patterns were observed on the first and second floors. Relative humidity measurements were generally lower than the range recommended by ASHRAE. Several carbon dioxide measurements exceeded 800 parts per million (ppm), a level indicating an inadequate amount of supplied outdoor air.

Based on medical interviews most of the cases of asthma began during childhood or were non-allergic in origin. Many workers reported symptoms suggestive of allergic upper respiratory diseases, however the characteristics of the symptoms suggest that a large proportion of the symptoms were non-allergic. Few workers had lower respiratory symptoms (cough, wheezing, shortness of breath) and did not have asthma. The diseases and symptoms reported are common in the population. There were no unique factors in this workplace that may cause worsening of allergic symptoms only in the workplace. Several workers reported

increased number of infections (primarily viral infections) since they began work at Southwest Airlines (SWA). This may be due to exposure to infectious agents in the workplace. Few workers complained of headache and fatigue. Among the nonsmokers (never smokers and former smokers), 82% stated that smoke in the workplace caused annoying irritant symptoms.

Based on the information and measurements obtained during this health hazard evaluation, NIOSH investigators conclude there is limited evidence of microbial contamination in the Dallas Reservations Center. Most of the health symptoms reported appear to be non-allergic in origin. There does not appear to be allergic diseases (including asthma) that can be attributed only to workplace exposures. There is evidence, however, that the heating, ventilating, and air-conditioning (HVAC) system may not be able to adequately service the building. Recommendations addressing the HVAC system, general ventilation concerns, cleaning 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, *Cladosporium*, *Aspergillus*, *Penicillium*, asthma.

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INTRODUCTION

On December 7, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Dallas Area Office of the Occupational Safety and Health Administration (OSHA) requesting help in the evaluation of potential microbial contamination in the Southwest Airlines Dallas Reservations Center, Grand Prairie, Texas. A similar request was received by NIOSH a few weeks earlier from employees of the reservations center. Health concerns included upper respiratory infections, fatigue, asthma, headaches, dry cough, and ear/nose bleeds.

On December 27-29, 1999, NIOSH investigators (including an industrial hygienist, an industrial hygiene engineer, and a medical officer) conducted a site visit to the Southwest Airlines Dallas Reservations Center. An opening conference was held with the Dallas Reservations Center management, the facility maintenance specialist, an International Association of Machinists and Aerospace Workers (IAM) union steward, Southwest Airlines Corporate Counsel, and two industrial hygienists from the Dallas area office of OSHA. Information was obtained relating to the building and the history of the concerns involving the microbial contamination. A walk-through inspection was made of the building interior and exterior. Attention was focused on the heating, ventilating, and air-conditioning (HVAC) units located on the roof and in the crawlspace underneath the building where water incursion earlier occurred. Bulk material and sticky tape surface samples were collected from interior insulation in the HVAC units to assess potential areas of microbial contamination. Measurements to detect moisture incursion and general indoor air quality (IAQ) comfort parameters were also collected. Confidential medical interviews were conducted to assess health concerns. A closing conference was held on December 29, 1999, during which preliminary findings were discussed.

BACKGROUND

Building Description

The Southwest Airlines Dallas Reservations Center is a 20-year-old, two-story brick structure with approximately 28,000 square feet (ft^2) of indoor floor space. The building is occupied 24 hours a day, 7 days per week with 10 to 15 variable work shifts. Beginning at 5:00 a.m., work shifts begin every 15 to 30 minutes until 9:15 p.m. There are a total of 615 customer sales and customer care representatives.

Building occupancy varies daily from approximately 175-250, depending on work load and overtime. A majority of the office space on both floors is open, divided by rows of carpeted cubicles approximately four feet in height. The cubicles are equipped with video display terminals and keyboards, and are occupied by the customer sales representatives. The open office space is surrounded by enclosed offices. The entire building is carpeted, with the exception of the break room and the restrooms. The property is located within a flood plain, and groundwater seepage underneath the building's foundation is controlled with French drains and two sump pumps (located at the northeast corner of the building and the northeast corner of the parking lot). However, when the sump pumps are not operating reservoirs of water accumulate in the parking lot.

A four-foot tall unfinished crawlspace is located underneath the building. During the late fall of 1999, management discovered that a damaged fire sprinkler line had leaked into the crawlspace for an undetermined period of time, flooding the area. At the time of the NIOSH site visit the leak had been repaired and the crawlspace appeared to be in good condition. The dirt floor was dry, the insulation lining the top had been replaced, and the rust on the metal joists had been removed before they were reprimed.

Ventilation System

There are two designated smoking areas on the second floor. Customer service representatives who smoke work in a separate area on the second floor segregated by walls and a door. This room is ventilated by two Dayton® exhaust fans mounted on the roof of the building and two recirculating electrostatic precipitator air cleaners mounted on the ceiling of the room. One of the York® HVAC units is dedicated to this room as well. The break room also has a separate smoking area segregated by walls and a door. This room is ventilated by one Dayton exhaust fan mounted on the roof of the building. One York HVAC unit on the roof of the building services this room and the non-smoking portion of the break room. Return air from the smoking areas is exhausted directly outside, preventing it from mixing in the return air plenum, and from being dispersed into the rest of the reservations center.

The Dallas Reservations Center ventilation system consists of two large Trane® and four zoned York® HVAC units mounted on the roof of the building. Each Trane unit serves separate floors. However, the air is mixed, recirculated, and returned through ducts in the area above the drop ceiling. This allows for mixing of air from both the first and second floors. Plenum return is utilized in the management offices located around the perimeter of the building on the second floor. The four York HVAC units are zoned as follows: (1) the break room and smoking break room; (2) the smoking customer service representative area; (3) the managers' offices on the second floor; and (4) the conference and training rooms. The temperature and amount of outdoor air introduced into the building is manually controlled by adjustment of the variable air volume box dampers. Pleated filters in the AHUs servicing the smoking areas are changed on a monthly basis, and on a bimonthly basis for the remaining units. Ultraviolet (UV) germocidal lights were installed upstream of the cooling coils in all six air handling units (AHUs) on the roof in an attempt to provide protection against microbial contaminants.

Prior Building Surveys

In response to continued health complaints from employees, an IAQ survey was performed by a private consulting firm on September 30 and October 1, 1999. The survey included air monitoring for fungi, endotoxins, nicotine, and carbon dioxide (CO_2), collection of bulk samples for fungi, bacteria, endotoxin and dust mite analyses, and temperature and humidity measurements. Air sampling revealed no amplification of airborne fungi levels in the indoor environment when levels in symptom and non-symptom areas of the building were compared to levels in outdoor air. Bulk material samples taken from suspect building materials revealed the presence of fungi, such as *Cladosporium*, *Aspergillus*, and *Penicillium*. In addition, one bulk sample (out of 15 total swab, bulk, and tape samples) of a dust mop head located in a first floor custodial closet revealed two isolated colonies of *Stachybotrys chartarum*. Bulk dust samples revealed non-detectable concentrations of dust mite allergens, and indoor airborne and bulk endotoxin concentrations were reported to be within acceptable limits. Comparative nicotine concentrations in the smoking and non-smoking areas indicated that cigarette smoke was confined to the designated smoking areas. Temperature and humidity measurements were within the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) guidelines for minimizing the growth of fungi and bacteria, however CO_2 concentrations greater than 1,000 parts per million (ppm) were detected. The consultants recommended repairing water leaks, cleaning or replacing water-damaged materials, upgrades in the HVAC system, and improved maintenance and upkeep of the building. They also stated that the presence of *Aspergillus* sp., *Penicillium* sp., and *Stachybotrys chartarum* in the Dallas Reservations Center represented a potential health hazard, and therefore recommended that all contaminated material either be thoroughly cleaned or removed from the building.

A follow up IAQ survey was performed at the reservations center by the same consulting firm on November 4, 1999. Air sampling using a *Stachybotrys chartarum* sensitive sampling media, airborne spore sampling, and swab samples were collected to determine if there was an amplification of this fungus in the reservations center since the initial survey. Air sampling revealed no airborne colonies or spores of this fungus. One of five swab samples identified low levels of *Stachybotrys chartarum* on a sheetrock wall in the second floor custodial closet where damp mops are stored. As a result, the consultants recommended cleaning the walls with a 1% Clorox® solution before painting the walls with Kilz® paint, followed by a latex interior paint. They also recommended placing Plexiglas™ between the wall hanging units where the mops are stored and the sheetrock walls to prevent contact. At the time of the follow-up survey the leak in the crawlspace had been discovered, and remediation efforts were in progress. The consultants recommended placing a 6-millimeter (mm) polyethylene vapor barrier over the crawl space floor to minimize moisture incursion from the ground into the crawlspace and possibly the building interior.

After the consultant's survey, however, OSHA continued to receive health complaints from employees working at the Dallas Reservations Center. A request for NIOSH to conduct a health hazard evaluation (HHE) was generated by employees a few months later. When NIOSH learned that OSHA was currently conducting an investigation at the building, OSHA was contacted and it was decided that OSHA would submit a request for NIOSH's assistance in order to expedite both investigations.

METHODS

Industrial Hygiene Evaluation

A walk-through inspection of the building interior and exterior was conducted immediately following the opening conference. NIOSH investigators inspected the inside and outside 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 two large Trane and four York HVAC units mounted on the roof of the building and the crawl space located underneath the first floor were also inspected.

Six bulk samples were collected from the interior insulation in the AHUs that were suspected of microbial contamination (based on visible assessment). The bulk samples consisted of an approximate two-square-inch section cut from the insulation. Additionally, a single tape sample was collected from the laminated surface covering the insulation in one of the AHUs. 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 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 parameters were measured in various locations throughout both floors of the reservations center. Real-time CO_2, temperature, and relative humidity (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 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 for temperature 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.

Medical Evaluation

Confidential medical interviews were conducted with employees. Customer sales and customer care representatives were chosen randomly from a computer screen that listed all employees who were present on the days of the NIOSH investigation. Also, employees who had health concerns were told of the NIOSH investigation, and were given the opportunity to participate. Participants were asked about symptoms typically associated with indoor environmental quality problems, as well as other symptoms reported among employees, especially asthma and allergic symptoms. In addition, self-administered questionnaires were sent after the visit to a union representative to distribute to employees who wanted to participate, but were not able to during the site visit. The questionnaires were returned to the NIOSH medical officer in individual NIOSH-addressed envelopes.

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 usually 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, 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. 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 IAQ 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.

Aspergillus

Aspergillus is a ubiquitous mold; there are over 600 species in the genus *Aspergillus*. Most *Aspergillus* species are found in soil, although many species can be found on a wide variety of substrates, including forage and food products, cotton, and other organic debris. *Aspergillus fumigatus*, the most common species, accounts for most disease attributable to *Aspergillus*, both allergic and infectious. Groups at higher risk of exposure to this fungus include farmers; bird hobbyists; workers in sawmills, greenhouses, cane mills or breweries; and people who work around mushroom, tobacco, or grain.[29,30,31,32,33,34] Workers who deal with compost piles, decomposing haystacks, or moldy grains may develop hypersensitivity responses.[33]

Aspergillus versicolor has the potential to produce sterigmatocystin, a mycotoxin closely related in structure and biological activity to another class of *Aspergillus* mycotoxins known as aflatoxins.[28] Aflatoxins are potent liver carcinogens and represent a risk to those who ingest them when they are present as contaminants in food products.[35] There are no reported cases of liver cancer associated with exposures to *Aspergillus* in office buildings.

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.[36] *Penicillium* infections of clinical importance are very rare, although this mold has been associated with asthma and hypersensitivity pneumonitis.[36] Presently, *Penicillium* mycotoxins are not known to be a serious health threat in water-damaged buildings.[37]

Endotoxin

Endotoxins are lipopolysaccharide substances contained in the outer cell wall of Gram-negative bacteria. The inhalation of endotoxin can induce a variety of biological responses including inflammatory, immunological, and hemodynamic activity. The pulmonary macrophage is extremely sensitive to the effects of endotoxins and a primary target cell for endotoxin induced pulmonary injury following respiratory exposure. Inhaled endotoxin causes a dose-related bronchoconstriction which develops 4 to 6 hours after exposure.[38,39] Exposures to endotoxin have been reported to cause acute fever, dyspnea, chest tightness, coughing, and decreases in pulmonary function. Illnesses possibly associated with endotoxin exposure include byssinosis, hypersensitivity pneumonitis (HP), asthma, and organic dust toxic syndrome (ODTS). There are no OSHA, ACGIH, or NIOSH standards or criteria for occupational exposures to endotoxin. The scientific literature contains research describing human threshold exposure limits for endotoxins. The lowest endotoxin exposure reported to cause adverse pulmonary response was measured in exposure studies among subjects sensitive to cotton dusts, 9 nanograms of elutriated endotoxin per cubic meter of air (ng/m^3). This concentration is equivalent to approximately 90 endotoxin units per cubic meter of air (EU/m^3). Threshold endotoxin exposures among healthy human subjects exposed to cotton dusts are reported by Rylander as approximately 1,000 to 2,000 EU/m^3 for an across shift acute pulmonary response (decline in FEV_1) and 5000 to 10,000 EU/m^3 for fever.[40,41,42] The Netherlands has recently adopted a recommended endotoxin exposure limit of 50 EU/m^3 based on inhalable dust sampling. This limit was established as about half of the 90 EU/m^3 level that induces measurable airways obstruction.[43]

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 outdoor air supply rates when the outdoor air is of good quality, and there are no significant indoor emission sources, should provide for acceptable indoor air quality.

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] When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[44] 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 IAQ 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.[45] 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]

Allergic Respiratory Disorders and the Office Environment

Rhinitis

Allergic rhinitis is characterized by episodes of sneezing, itching of the eyes and throat, nasal stuffiness, and rhinorrhea (runny nose). Approximately 40 million people in the U.S. suffer from the allergic type of rhinitis (10 to 20% of the general population), and the non-allergic types of rhinitis occurs with equal frequency. The mean age of onset of allergic rhinitis is between 8 and 11 years. The occurrence of the allergic form decreases with age; however the mean onset of non-allergic rhinitis is much later in life, generally after age 30.[46]

The difficulty lies in distinguishing rhinitis (inflammation of the mucous membranes in the nasal cavity) from normal nasal function (because the characteristic symptoms of rhinitis may occur occasionally in all individuals). Therefore clinical definitions focus on cases in which symptoms are severe enough to warrant treatment. Allergy is a common cause of rhinitis, but it is not the only one; nasal inflammation may arise from multiple factors. This condition can broadly be divided into four main groups: allergic, infective, structural, and amorphous.[47]

Differentiation of allergic and non-allergic forms of rhinitis is important because they have different causes and the treatments are different. Allergic rhinitis may be seasonal or perennial (continual). The most common seasons for worsening of symptoms are spring and autumn during periods of pollination. Chronic non-allergic rhinitis is usually perennial, but may also worsen during periods of weather changes, such as during late autumn and early spring. Most people with seasonal allergic rhinitis have a worsening of symptoms on exposure to allergens in the air, such as fresh cut grass or animal dander. Most people with non-allergic rhinitis have a characteristic worsening of symptoms with exposure to respiratory irritants, such as perfumes and cigarette smoke. Common causes of non-allergic forms of rhinitis are acute bacterial or viral infections, vasomotor, irritants, medications (e.g. birth control pills, blood pressure pills, psychiatric medication), cold air, and structural abnormalities in the nose. Itchiness of the nose and episodes of sneezing are more commonly found in allergic rhinitis. In addition, patients with allergic rhinitis often have other allergic illnesses, such as allergic eye symptoms (watery eyes, itchiness, redness), allergic skin symptoms (itchiness, hives, or swelling), or allergic asthma. There is usually a family history of allergic diseases in patients with allergic rhinitis.[47]

Asthma

Asthma is a disease characterized by variable airway obstruction, chronic inflammation of the airways, and excessive airway responsiveness to stimuli. In susceptible individuals, the inflammatory process can lead to recurrent episodes of wheezing, shortness of breath, chest tightness, and cough; these symptoms are persistent in some individuals. Asthma is very common; it is estimated that 4 to 5% of the US population is affected.[55] The onset of asthma occurs predominantly, but not exclusively in childhood. Asthma may be classified by the principal stimuli that incite or are associated with the acute episodes. One can describe two broad types of asthma: allergic and idiosyncratic or non-allergic.[48] Occupational asthma is a disease that is characterized by variable airflow limitation and/ or hyperresponsiveness due to causes and conditions attributable to a particular occupational environment and not to stimuli encountered outside the workplace.[49] In the medical literature, researchers have described "building-related asthma," but thus far the evidence of asthma caused by an office building environment has been linked to specific irritant chemical exposures[50] or based on responses on questionnaires,[51] which is an imprecise method to determine the prevalence of asthma.[52,53]

Allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath in response to bronchial (airways in the lung) narrowing in response to exposure to allergens in the air. Allergic asthma is often associated with personal or family history of allergic diseases such as rhinitis, wheals, and eczema.[54]

A significant fraction of asthmatics have no personal or family history of allergy. These individuals are said to have non-allergic or idiosyncratic asthma. With this type of asthma, many people develop typical symptoms of asthma upon contracting an infectious respiratory illness. The initial insult may be a common viral infection, but after several days the patient develops wheezing and shortness of breath that can last days to months.[54]

In addition, common respiratory and non-respiratory conditions can be confused with asthma. For example, the symptoms of bronchospasm can be superimposed on other chronic conditions, such as chronic bronchitis, bronchiectasis (chronic dilation of the bronchi in the lungs, usually due to infection), emphysema, and congestive heart failure (cardiac asthma).[55]

RESULTS

Industrial Hygiene

Visual Inspection

Visible active fungal growth was not observed on building materials (some was found in HVACs) during the walk-through inspection of the interior of the building. Evidence of water damage was observed on some ceiling tiles located in various areas throughout the building. Building maintenance was in the process of replacing damaged tiles at the time of the NIOSH site visit. Potential areas where moisture incursion would be likely to occur (along exterior walls and around windows and entrances) were checked for moisture content. One side of the bathroom cabinet in the second floor women's restroom revealed evidence of slight moisture content (this was reportedly due to a pipe leak under the sink that had been previously repaired). The carpet by the east entrance of the building had moderate moisture content, and the carpet against the east (exterior) wall of the health room was slightly moist. Moisture by the carpet in the entrance is most likely from occupants tracking in water from outside. Readings taken in the west wall of the electrical room showed slight moisture content. The moisture was probably due to condensation because the room was cold and the readings were taken in the exterior wall.

Inspection of the HVAC units on the roof of the reservations center did not reveal any apparent observable evidence of microbial contamination. The interior of the Trane and York HVAC units appeared dry. However, rust on the condensation drip pans and water marks along the bottom of some of the units (Trane unit 5 and York HVAC units 1, 3, and 4) indicated that standing water was previously present. Also, the drain tubes were installed into the sides (rather than the bottom) of the condensation drip pans; and as a consequence there would always be approximately ¼" of standing water present in the drain pan unless manually emptied. Dust agglomerated to the interior of the front panel in Trane unit 5 indicated a bad seal between the front panel of the unit and the pre-filter, due to improper filter fit. Mineral deposits on the insulation covering in two of the York HVAC systems (1 and 3) indicated recent water damage. However, the deposits in unit 3 were upstream of the filters, which would limit dissemination of any contamination, if it were present.

Inspection of the crawlspace revealed no visible active fungal growth. Water incursion into this area had previously occurred due to a continuous water leak in a fire sprinkler line. However, the leak had been repaired and the area had undergone remediation prior to the NIOSH site visit.

Bulk Sample Analysis

A tape sample taken from the laminated covering on the insulation in the York HVAC unit 4 revealed mostly dust, skin flakes, and glass fibers. Although a trace of loose fungal spores and fragments were detected, no visual sign of fungal growth was observed. The results from analysis of bulk samples of insulation taken within five of the AHUs are presented in Table 1. Fungal concentrations ranged from non-detectable (ND) to 1.8×10^7 colony forming units per gram of material (CFU/g). The fungal genera identified included *Acremonium*, *Exophiala*, *Basidiomyctes*, *Cladosporium*, *Fusarium*, *Tritirachium*, sterile fungi, and yeasts. Colonies of *Cladosporium herbarum*, *Cladosporium sphaerospermum*, *Penicillium citrinum*, *Rhodotorula glutinis*, *Alternaria alternata*, and *Aspergillus penicillioides* were also identified. Four of the six bulk samples revealed high fungal concentrations and/or were identified with significant genera.

The bulk sample taken from the interior duct lining of AHU 1 (downstream of the coils) had concentrations of unidentified yeasts, *Rhodotorula glutinis*, and *Exophiala* ranging from 2.9×10^6 to 6.8×10^6 CFU/g. These fungi are characterized as hydrophilic (moisture-loving) fungi, and their presence is consistent with the evidence that there may have previously been standing water or condensation in the AHU. *Acremonium* and *Cladosporium herbarum* were also identified in this sample, in concentrations of 1.8×10^6 and 1.0×10^5 CFU/g, respectively. High concentrations of Gram negative bacteria (1.8×10^8 CFU/g), which are normally found in association with large amounts of moisture, were also detected. Additionally, a bulk sample of insulation taken from the interior duct lining of AHU 2 (downstream of the coils) also revealed high concentrations of *Exophiala* and *Rhodotorula* sp. (4.6×10^6 and 1.2×10^6 CFU/g, respectively). A water mark indicated that there had previously been standing water in the unit. *Acremonium* and Gram negative bacteria concentrations ranging to 3.8×10^5 and 2.3×10^5 CFU/g, respectively, were also found in this bulk sample. A bulk sample of insulation from the fan box of AHU 4 revealed fungal concentrations of *Alternaria alternata* and *Cladosporium herbarum* (2.1×10^4 and 8.2×10^5 CFU/g, respectively). Additionally, a bulk sample of insulation downstream of the coils in AHU 6 revealed a significant fungal level of *Cladosporium sphaerospermum* (4.7×10^4 CFU/g).

Bacterial concentrations from the bulk insulation samples ranged from ND to 1.9×10^7 CFU/g. Gram negative bacteria were the most prevalent, detected in three of the six bulk samples. They were also found in the highest concentration when compared to the other bacterial genera detected. The highest total bacterial concentration (1.9×10^7 CFU/g) was found in the bulk sample taken from insulation downstream of the coils in AHU 1. Two of the bulk samples (both from AHU 6) revealed ND concentrations.

Comfort Parameters

In the early afternoon, overall mean temperature in the reservations center was 74°F. Temperatures on the first floor of the reservations center ranged from 62° to 77°F, with a mean of 74°F. Temperatures on the second floor ranged from 71° to 76°F, with a mean of 74°F. The overall mean relative humidity in the reservations center was 27%. It ranged from 22% to 31% (mean of 27%) and 24% to 29% (mean of 26%) on the first and second floors, respectively. The outside air temperature was 62°F, and outdoor relative humidity was 22%, when measured at 12:00 p.m.

The overall mean temperature in the reservations center in the late afternoon was 74°F. Temperatures on the first floor ranged from 70 to 77°F, with a mean of 74°F. Temperatures on the second floor ranged from 73 to 78°F, with a mean of 75°F. The overall mean RH was 25%. RH measurements ranged from 23% to 31% (mean of 26%) on the first floor and 24% to 26% (mean of 25%) on the second floor. Measurements taken outside at 4:30 p.m. revealed an air temperature of 70°F and a RH of 21%. Temperatures measured at both times during the day were within the comfort zone recommended in ASHRAE Standard 55-1982; however, RH was lower than the recommended range on both occasions.

Figures 1-10 graphically illustrate the temperature variations over a 24-hour period at different locations on the first and second floors. Figure 1 shows the wide variation in temperature (approximately 75 to 82°F) from a data logger placed in the north end of the first floor in between cubicles 018 and 025 (see Figure 11). This area receives a large amount of radiant heat from eight large windows located directly north of these cubicles. The greatest temperature variations occurred on the second floor. The data logger in the conference room illustrates the greatest variation, ranging from approximately 68 to 80°F (see Figure 5). However, this room is not occupied on a regular basis. Additionally, the break room exhibited variable temperature patterns, ranging from approximately 70 to 75°F (see Figure 6). Data collected in the smoking customer service representative work area also illustrated a variable temperature pattern (see Figure 10). Although the temperature range only spanned approximately 4°F, the temperatures peaked at the upper and lower extremes in a continuous pattern from 12:00 p.m. through 12:00 a.m. and then again from approximately 10:00 a.m. through 12:00 p.m. Both the break room and the smoking customer service representative work area are serviced by individual York HVAC units (see figure 12 for the 2nd floor plan of the Dallas reservations center).

During the early afternoon the mean CO_2 concentration in the 35 locations measured in the building was 884 ppm. Concentrations on the first floor ranged from 395 to 1146 ppm, with a mean of 931 ppm. Concentrations in five locations exceeded 1000 ppm, recommended as the upper limit in ASHRAE Standard 62-1989. CO_2 concentrations in 19 of 20 locations on the first floor exceeded the NIOSH guideline of 800 ppm. CO_2 concentrations on the second floor ranged from 651 to 998 ppm, with a mean of 821 ppm. Nine of fifteen locations on the second floor had CO_2 concentrations that exceeded 800 ppm. The outdoor CO_2 concentration at 12:00 p.m. was 395 ppm.

The mean CO_2 concentration in the 35 locations measured in the late afternoon was 766 ppm. Concentrations on the first floor ranged from 570 to 896 ppm, with a mean of 752 ppm. CO_2 concentrations in four of the 20 locations on the first floor exceeded 800 ppm Concentrations on the second floor ranged from 705 to 935 ppm, with a mean of 783 ppm. Five of 15 locations on the second floor had CO_2 concentrations that exceeded 800 ppm. The outdoor CO_2 concentration at 4:30 p.m was 389 ppm.

Medical

Health information was gathered from 41 of the approximately 150 Southwest Airline customer sales and customer care representatives present on the days of the NIOSH investigation. Thirty-one SWA employees were interviewed by a NIOSH investigator (25 selected randomly, no refusals), and an additional 10 employees completed a self-administered questionnaire. The mean age of the employees was 43 years, and the average length of time worked at SWA was 8 years. Fifty-three percent of the respondents worked primarily on the first floor, 44% on the second floor, and 3% worked on both the first and second floors.

The most common symptom reported among all participants was rhinorrhea (runny nose) (68%). Among those selected randomly, 60% reported a history of seasonal allergies before working at SWA, while 80% of the self-selected employees reported a history of seasonal allergies. Sixty percent of the randomly selected employees reported rhinorrhea, while 80% of the self-selected employees reported rhinorrhea. Approximately 20% of those with rhinorrhea reported concurrent allergy symptoms (red, itchy, watery eyes; sneezing; itchy, stuffy nose) in both groups. Twenty-two percent of the randomly selected employees believed that their upper respiratory tract symptoms (e.g., itchy, stuffy, scratchy nose; watery or scratchy eyes; scratchy throat; sneezing; or sinus problems) were made worse by workplace exposures, while 80% of the self-selected employees believed their symptoms became more adverse in the workplace.

Among those selected randomly, 20% of the employees reported that lower respiratory tract symptoms (e.g. cough, phlegm production, chest tightness, wheezing, shortness of breath) were worsened by workplace exposures, while 60% of the self-selected workers reported a worsening of lower respiratory symptoms in the workplace. Among those randomly selected, 25% reported developing allergies (principally nasal allergy symptoms) after starting work at SWA, while 60% of the self-selected employees reported the onset of allergies after employment at SWA. Sinusitis (inflammation of a sinus or sinuses) on at least one occasion was reported by 11 (26%) individuals while they were employed by SWA, and bronchitis was reported by 7 (17%) individuals. Two workers (5%) reported chronic sinus infections which began while employed by SWA. The production of blood-streaked mucous after an upper respiratory tract infection was reported by one employee.

Two employees who were randomly selected and seven self-selected employees reported they had asthma. Nine employees (22%) stated they had asthma, and seven (17%) stated they developed asthma as an adult and while employed at SWA. Those who developed asthma as a child do not have significant worsening of their symptoms since they started work at SWA. Four employees (10%) developed asthma after a respiratory viral infection or with bronchitis, one (2%) described emphysema from an unknown cause (emphysema is a chronic respiratory disease that has different characteristics than asthma), and another (2%) stated that asthma began after a chemical exposure. The cause of asthma in the three other cases (7%) is unknown (these three cases were not interviewed by the NIOSH investigator, but completed a questionnaire). The employees who developed asthma as a child reported their asthma did not worsen after they started working in this building.

The participants were asked about general symptoms that they associate with the workplace. Among the randomly selected participants, the most common was headache (20%). The participants generally associated their headaches with workplace stress. Fatigue was reported in approximately 6% of these participants. Among the self-selected group, 50% reported generalized stress without specific symptoms. Four employees reported they had more frequent infections (primarily viral infections) since starting work in this building. These employees believed the infections were caused by infectious material left behind by ill coworkers (employees on different shifts may share the same computer stations).

Employees were also asked about their impression of the conditions in the building. Few workers reported seeing dampness or mold growth in the building, but many complained of a stale moldy odor in the first and second floor bathrooms. Stale odors also were reported in the stairwells and in the front interior of the building. Only 26% of the participants felt that the general temperature of the building was comfortable. Four percent thought that the building was too hot, 34% believed it was too cold, and 29% believed it varied between being too hot and too cold at different times. Among the nonsmokers (never smokers and former smokers), 82% stated that smoke in the workplace caused annoying irritant symptoms.

DISCUSSION AND CONCLUSIONS

Industrial Hygiene

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, no areas of water accumulation or moisture incursion were observed during the site visit, with the exception of a few ceiling tiles. Prior to the site visit it appears that all of these factors may have been present in the crawlspace under the building; i.e., a reservoir of water (from a leaky fire sprinkler line), a suitable nutrient source (organic material in the dirt floor), and cool temperatures. However, remediation of the crawlspace had been completed at the time of the site visit and no evidence of microbial contamination was found. Although it is plausible that microbial growth was present in the crawlspace at one time, it is unlikely that a pathway existed for the dissemination of microbial contaminants into the building. The only entrance into the building from the crawlspace was through a covered opening in the floor of the electrical room. The crawlspace was found to be under both marginally negative and positive pressure with respect to the building, probably due to changing wind direction. Negative pressure would prevent contaminants from entering the building through this entry, and although positive pressure would allow dissemination into the building, the steel plate covering the entrance should have minimized this.

Significant levels and/or genera of fungi and bacteria were confirmed by bulk sample analysis of insulation in four AHUs (1, 2, 4, and 6). The fungal species identified in three AHUs (1, 4, and 6) included the allergens *Alternaria alternata* and *Cladosporium herbarum*. *Acremonium*, *Exophiala*, *Rhodotorula glutinis*, and unidentified yeasts were the predominate fungi identified in AHU 1 and 2. The results suggest that these two bulk samples (taken from AHU 1 and 2) were from a wet environment. Evidence was observed in both AHUs at the time of the inspection (such as water lines and rust in the bottom of condensation pans) that indicated there previously had been standing water in the bottom of these units. *Cladosporium herbarum* and *Cladosporium sphaerospermum*, two documented fungal allergens, were the dominate fungi identified in AHUs 4 and 6. Fungal species colonizing on the interior insulation, which is in contact with the air stream, could cause these fungi to become airborne. Therefore, these results indicate that microbial contaminants could potentially be disseminated into the air spaces supplied by these AHUs.

The survey conducted by the consultant prior to the NIOSH site visit found that airborne fungi levels indicated no amplification of microbial contaminants in the indoor environment when compared to outdoor air. However, the air sampling was conducted approximately three months prior to the NIOSH site visit, and because no bulk material samples of interior insulation in the AHUs were collected at the time air sampling was conducted there is no way to assess the condition of the AHUs at the time of the consultant's survey.

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. Smoke tube tests revealed that the building was maintained under a positive pressure with respect to the outdoor environment. Thus, contaminants from outdoors should not enter the reservations center through open doors, or any other penetrations in the building envelope.

Pressure tests indicated that the smoking break room and the smoking customer service representative area were under positive pressure. This finding is consistent with employee reports of irritating cigarette smoke in the building. It is important that both of these rooms be under strong negative pressure relative to their surroundings to prevent migration of cigarette smoke into non-smoking areas.

Although measured temperatures in the reservations center were within the range recommended by ASHRAE Standard 55-1981, data logged for 24 hours revealed different temperature zones throughout the first and second floors. Large and fairly rapid fluctuations in temperature throughout the 24-hour period were also observed in certain areas on the second floor (the conference room, break room, smoking customer service representative work area, and "La Mesa"). The reservations center remains occupied for 24 hours and, as a result, temperature patterns should be uniform and remain stable at all times. However, the results indicate that the AHUs are not able to continually sustain appropriate thermal conditions. RH measured in the building indicated that mean levels were below the lower limit recommended by ASHRAE Standard 55-1981. This factor reveals that the current ventilation system is not appropriately conditioning the intake air before it is delivered to the building.

Carbon dioxide measurements greater than the NIOSH guideline of 800 ppm indicate that the HVAC system is not providing enough outdoor air to the occupied areas. The HVAC system should be capable of maintaining outdoor air supply rates of at least 20 cfm/person for office spaces.[23] The current AHUs utilize manually controlled variable air volume boxes to control temperature and the amount of outdoor air brought into the building. Variable air volume boxes make it difficult to control both of these parameters due to manual control and imprecise adjustments of the HVAC dampers. A minimum damper setting needs to be established to ensure that an adequate amount of outdoor air is supplied at all times.

In conclusion, the significant levels and/or genera of fungi and bacteria found in four of the six AHUs, the inability of the HVAC system to sustain appropriate thermal and humidity conditions, and an inadequate amount of outdoor air supplied to the occupied spaces, indicate deficiencies in the ventilation system. The HVAC system currently in place may be unable to properly service the reservations center at the current occupancy load.

Medical

The reservation agents who were surveyed commonly reported upper respiratory symptoms, particularly symptoms of rhinorrhea or rhinitis. These nasal symptoms probably represent a combination of both allergic and non-allergic rhinitis. Some of the workers reported they had a history of allergy since childhood, which is common in individuals with allergic rhinitis. However, many of the workers reported developing rhinitis as adults, which is more common with non-allergic rhinitis. Also, most workers who were surveyed reported their rhinorrhea was not regularly associated with allergic symptoms of the nose or eyes, which decreases the likelihood of an allergic cause. In addition, the environmental sampling performed by NIOSH investigators showed limited evidence of allergens that may be unique to this workplace, so exposures in other environments should also trigger allergic symptoms in those who have an allergic cause for their symptoms. Thus, it is unlikely that rhinorrhea reported by some workers to occur only in the workplace, is caused by allergy. Most of the cases of asthma identified in this work force were non-allergic, and do not appear to be related to exposures unique to the workplace (from the medical history given by the workers).

Sinusitis was a common problem among the participants. The primary cause of sinusitis is obstruction or delay of transport time of mucous secretions out of the sinuses. Viral infection of the upper respiratory tract is the most common precursor of sinusitis. Allergic rhinitis and structural abnormalities also increases the risk of developing sinusitis.[56] When sinusitis fails to respond to medical therapy, or if the sinusitis clears only to be followed by a recurrence shortly thereafter, allergy, immunodeficiency, fungal infections, and structural abnormalities of the nose should be considered. It is unlikely that sinusitis among SWA employees is solely related to workplace exposures. If some employees are allergic to allergens in the workplace, these allergens are present outside the workplace as well. Thus, the allergy cannot be attributed to the workplace, or the outside environment.

Several employees reported they had an increased number of upper respiratory tract infections, such as colds, since they began working in the building. The increased number of infections was difficult to quantify. There is evidence that sharing office space may increase the risk of contracting viral infections, however the primary mode of transmission (airborne versus direct or indirect contact) remains controversial.[57] An elevated risk of viral infections was associated with having young children and having a history of hay fever.

The most common reports of health concerns in this workplace was exposure to second-hand cigarette smoke. Most complaints of second-hand smoke exposure occurred when walking near the smoking customer service representative work area or when near the door to the smoking breakroom. Smoke exposure typically did not occur for nonsmokers at their workstations.

RECOMMENDATIONS

1. Qualified mechanical engineering firms or original HVAC system designers should be consulted to determine if the AHUs servicing the HVAC system need to be replaced with upgraded units that are capable of servicing the building occupancy at the Dallas Reservations Center. The units must be able to supply at least 20 cfm of air per person. The unit servicing the smoking customer service representative work area must be able to supply 60 cfm of air per person. Units utilizing computerized control of temperature and RH parameters, rather than manually-controlled variable air volume boxes which are currently in place, are recommended to better stabilize these comfort factors in the recommended ranges.

2. At a minimum, the duct insulation in the AHUs needs to be replaced to prevent possible dissemination of microbial contaminants into occupied areas. The laminated covering on the duct insulation in some of the AHUs had become friable. Replacement of the insulation would also prevent fiberglass from becoming entrained in supplied air and affecting occupants of the building. During replacement, insulation should not be installed in the duct work downstream of the cooling coils; rather, exterior insulation can be used around the ducts. The cooling coils are the point at which the dew point is reached and, as a result, condensation and moisture accumulation can occur. Undersized AHUs, not capable of properly cooling the amount of outdoor air being brought in, also promote moisture accumulation. Another suggestion to reduce condensation would be to use double-walled ducts.

3. Remediation will result in the disruption of microbial reservoirs. The airborne dissemination of these bioaerosols is an exposure concern for the remediation workers and the occupants of the building. Additionally, these aerosols can be spread to uncontaminated areas of a building, increasing the hazard for the remaining occupants and adding to the difficulty of clean-up. Therefore, it is important that all remediation activities be conducted with an awareness of the potential bioaerosol exposures and with minimal disturbance of contaminated materials. Specifically, controls must be instituted, prior to remediation, that protect both the workers and the adjacent environment. Remediation workers should use personal protective equipment (PPE) appropriate for the hazards to which they may be exposed. Engineering controls should be applied at the source to minimize the disturbance of microbial reservoirs and to prevent dissemination of contaminants to other areas of the building. Firms specializing in microbial contamination removal and clean up should be consulted before any remediation work begins (see Appendix).

4. The pre-filters must fit properly so that a good seal can be maintained when the front panel of the AHU is closed. If this is not achieved, outdoor air coming through the intake will be pulled around the filter and unfiltered air will enter the system. During the inspection it was observed that some of the filters are not as wide as the housing unit, leaving approximately ¼" of space between the two. As an interim measure, a piece of foam or wood could be wedged between the current filters and housing units to temporarily tighten the fit.

5. The drain tubes are located on the side of the condensation drip pans and the condensation drip pans are set down too low in the bottom of the AHUs. As a result there will always be approximately ¼" of standing water in the bottom of the drip pans. The simplest way to accomplish proper drainage would be to raise the condensation pans.

6. The UV germocidal lights that were installed in the AHUs do not provide adequate protection against microbial contamination and are a safety hazard for anyone who opens the access door. Fungal spores are more resistant to UV light than bacteria, and it is unlikely the contact time the UV radiation has with the air stream is long enough to have an appreciable effect on any contaminants that may be present. Dirt in the AHUs also reduces the efficacy.

7. The ventilation system in the reservations center utilizes ducted return except in the area where the management offices are located on the second floor. The ventilation in this area utilizes plenum return. However, ducted return is preferable and should be considered if the HVAC system is upgraded.

8. Water-damaged ceiling tiles were observed throughout the reservations center (training room, break room, smoking break room, second floor janitorial closet, copy room, records 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. Workers should wear polyethylene or vinyl gloves to prevent skin contact.

9. 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.[58] 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 customer service representative work area and the smoking break room were under positive pressure at the time of the site visit. In order to achieve negative pressure in these locations, a greater amount of air must be exhausted than is supplied to the area. Some of the supply air to the smoking customer service representative work area is pulled from the general customer service representative work area. Ceasing to pull air from this space may achieve negative pressure in the area.

10. Installation of an exhaust fan is recommended in the second floor janitorial closet because chemicals are stored in this area.

11. The crawlspace should be under negative pressure with respect to the building so that it is taken out of the building envelope. Therefore, if any water incursion occurs in this area in the future, there will be a reduced possibility that contaminants could be disseminated into the building. This can be achieved by installing an exhaust fan in the crawlspace. Additionally, the polyethylene vapor barrier placed on the dirt floor of the crawlspace should be removed because it retains moisture and allows water reservoirs to collect on top. Moisture will naturally percolate over time and the barrier hinders this. However, a vapor barrier should be installed on the insulation lining the ceiling of the crawlspace to keep it dry.

12. A barrier should be installed within the front entrance canopy to prevent future bird nesting. The areas covered in bird droppings should then be pressure-washed and cleaned.

13. Any future episodes of water incursion should be dealt with immediately. Water should be removed immediately from porous, water-damaged furnishings, carpets, and construction materials. Heat fans should be used within 24 hours to dry carpets and other applicable surfaces. Steam or other water-based cleaning methods which add moisture to the environment must be used with extreme care. Any soft materials 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.

14. The current service agreements addressing the housekeeping program and routine operating inspections, repair services, and annual preventive maintenance of the HVAC system should be

diligently followed and updated as needed. Additionally, each workstation, including the keyboard, should be cleaned with a disinfecting solution after each shift to prevent the spread of germs between workers. The disinfectant should be a non-irritant, or diluted until it is no longer an irritant, that does not produce any noxious odors.

15. 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.

16. 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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APPENDIX

Building Cleaning – Visible or Suspected Microbiological Contamination

Visible or suspected microbial contamination requires remediation efforts, including the removal of the contaminated material and/or clean–up with a high efficiency particulate air filter (HEPA) vacuum and decontamination with an effective chemical agent (i.e., 5 to 10% solution of chlorine bleach). Remediation will result in the disruption of microbiological reservoirs. The airborne dissemination of these bioaerosols can pose a significant exposure concern for the remediation workers. Additionally, these aerosols can be spread to uncontaminated areas of a building, increasing the hazard for the remaining occupants and adding to the difficulty of clean–up. Thus, it is important that all remediation activities be conducted with an awareness of the potential bioaerosol exposures and with minimal disturbance of contaminated materials. Specifically, controls must be instituted that protect both the *worker* and the *adjacent environment*.

Remediation workers should use personal protective equipment (PPE) appropriate for the hazards to which they may be exposed. Such decisions require *a priori* awareness of potentially hazardous agents, significant exposure routes (e.g., inhalation, dermal contact, or ingestion), and possible concentrations of the biological materials. Remediation work on small, localized patches of mold growth on ceilings or walls should be conducted with appropriate respirators (i.e., a disposable N–95 NIOSH–approved respirator with a facepiece that fits tightly, ensuring that contaminants do not enter through leaks between the respirator and a wearer's face), eye protection, and gloves. Situations involving gross contamination with microorganisms that pose potentially significant health outcomes (e.g., infectious or toxigenic fungi), may require a higher level of PPE (e.g., full–face, powered air–purifying respirators, disposable protective clothing with hoods, gloves, and disposable shoe coverings). For respirator use, OSHA requires a respiratory protection program that includes the following components: written standard operating procedures, user instruction and training, cleaning and disinfection, storage, inspection, surveillance of work area conditions, evaluation of respirator protection program, medical review, and use of certified respirators.[1]

Given the level of disruption that may occur during microbiological remediation work, engineering controls applied at the source should be the primary control measure. Activities should be conducted in a manner that minimizes the disturbance of microbiological reservoirs. However, as the extent of the microbial contamination becomes larger, reservoir dissemination becomes unavoidable due to the activities of surrounding building material removal. Under these conditions, isolation barriers are required to contain airborne spores and other biological matter. Barriers alone disrupt the pathways between remediation zones and adjacent environments, but disseminated aerosols almost invariably find breaks in any barrier system. Therefore, negative pressure relative to adjacent areas is recommended to ensure containment. It is critical that the exhausted air streams be appropriately filtered (i.e., HEPA filters) to guard against the re–entry of microbially contaminated air back into the zone of remediation and/or to other areas that are considered uncontaminated. Specific control guidelines have been recommended for the remediation of toxigenic fungi from contaminated materials.[2]

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Table 1
Microbiological Bulk Sample Results
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

Sample Location Material	**Fungi (MEA†)**		**Bacteria (TSA‡)**	
	CFU/g	**Taxa (%)**	**CFU/g****	**Taxa (%)**
Bulk 1 (AHU #1)	$6.8x10^6$	*Exophiala* (38)	$1.8x10^7$	Gram negative bacteria and others (92)
insulation downstream of coil	$5.2x10^6$	*Rhodotorula glutinis* (29)	$8.1x10^5$	*Methylobacterium* (4)
	$2.9x10^6$	unidentified yeasts (16)	$4.1x10^5$	*Flavobacterium* (2)
	$1.8x10^6$	*Acremonium* (10)	$4.1x10^5$	*Micrococcus luteus* (2)
	$6.1x10^5$	*Clad.* sphaerospermum* (3)		
	$2.7x10^5$	*Penicillium citrinum* (1)		
	$2.7x10^5$	*Tritirachium* (1)		
	$8.2x10^5$	*Clad. herbarum* (<1)		
	$6.8x10^4$	*Fusarium* (<1)		
	$6.8x10^4$	sterile fungi (<1)		
	Total: $1.8x10^7$		**Total: $1.9x10^7$**	
Bulk 2 (AHU #2)	$4.6x10^6$	*Exophiala* (73)	$2.4x10^6$	*Methylobacterium* (91)
insulation downstream of coils	$1.2x10^6$	*Rhodotorula* (19)	$2.3x10^5$	Gram negative bacteria and others (9)
	$3.8x10^5$	*Acremonium* (6)		
	$5.8x10^4$	*Clad. sphaerospermum* (<1)		
	$2.9x10^4$	sterile fungi (<1)		
	Total: $6.3x10^6$		**Total: $2.6x10^6$**	
Bulk 3 (AHU #4)	$8.2x10^5$	*Clad. herbarum* (90)	$5.8x10^3$	*Bacillus* (79)
insulation from fan box	$6.4x10^4$	unidentified yeasts (7)	$1.0x10^3$	Gram negative bacteria (14)
	$2.1x10^4$	*Alternaria alternata* (2)	524	*Pseudomonas sp., non aeruginosa* (7)
	Total: $9.0x10^5$		**Total: $7.3x10^3$**	
Bulk 4 (AHU #5)	non-detectable		$1.6x10^4$	*Staphylococcus* (100)
insulation downstream of coils	**Total: <690**		**Total: $1.6x10^4$**	

Table 1
Microbiological Bulk Sample Results
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

Sample Location Material	Fungi (MEA†)		Bacteria (TSA‡)	
	CFU/g	**Taxa (%)**	**CFU/g****	**Taxa (%)**
Bulk 5 (AHU #6)	$1.0x10^3$	*Basidiomyctes* (40)	non-detectable	
insulation downstream of coils	524	*Aspergillus penicillioides*		
	(20)			
	524	*Cladosporium* (20)		
	524	sterile fungi (20)	**Total: <524**	
	Total: $2.6x10^3$			
Bulk 6 (AHU #6)	$4.7x10^4$	*Clad. sphaerospermum* (98)	non-detectable	
insulation downstream of coils	$1.1x10^3$	*Clad. herbarum* (2)		
	Total: $4.9x10^4$		**Total: <559**	

*Clad-*Cladosporium*
**Concentration is (CFU/sample) if sample amount is non-detectable.
†MEA-2% malt extract agar
‡TSA-tryptic soy agar

Figure 1
Temperature Variations on the 1st Floor of the Reservations Center (near cubicles 18 & 25)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

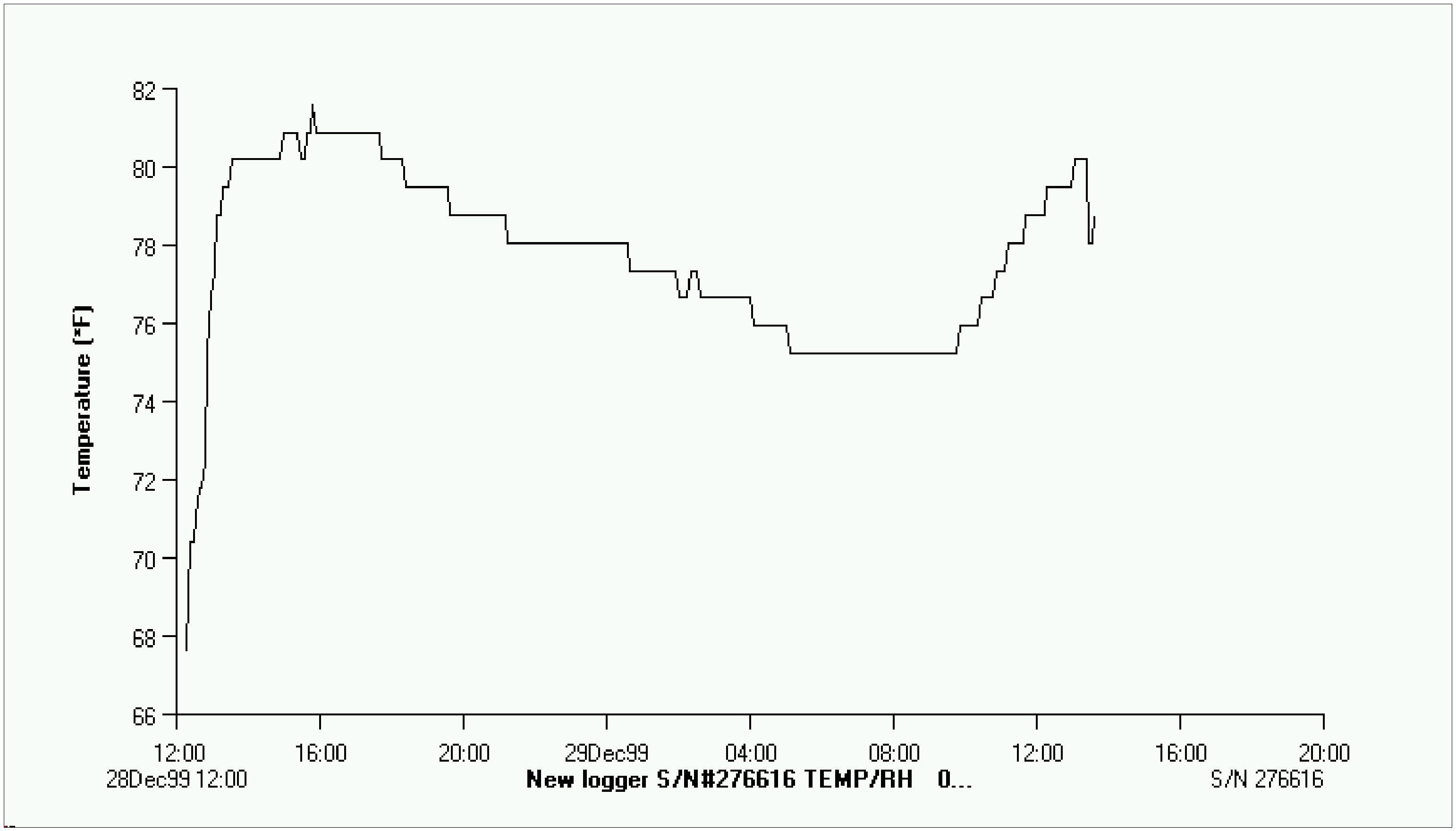


Figure 2
Temperature Variations on the 1st Floor of the Reservations Center (cubicles 106/107 & 96/97)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

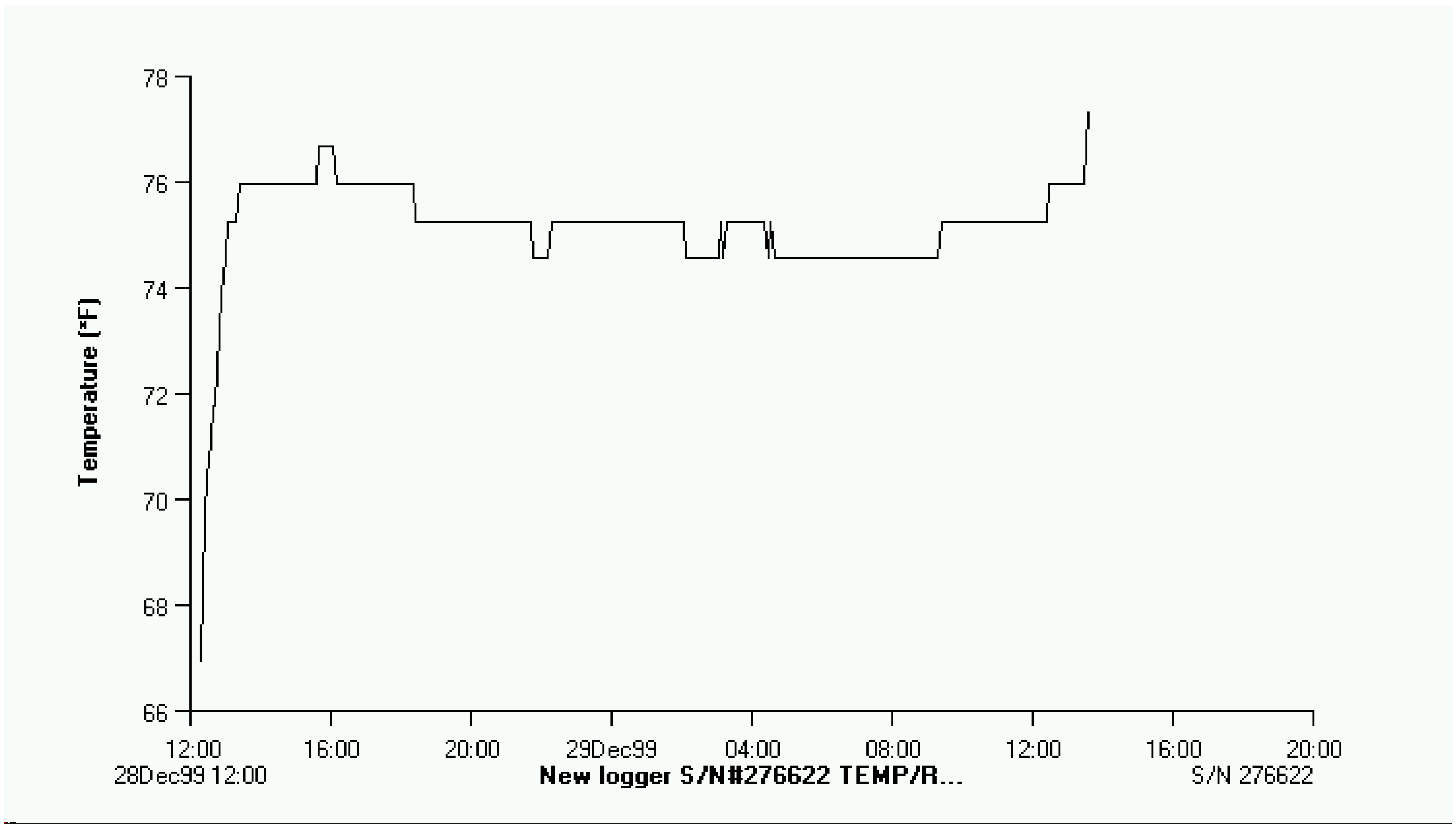


Figure 3
Temperature Variations on the 1st Floor of the Reservations Center (cubicles 189/190 & 183/184)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

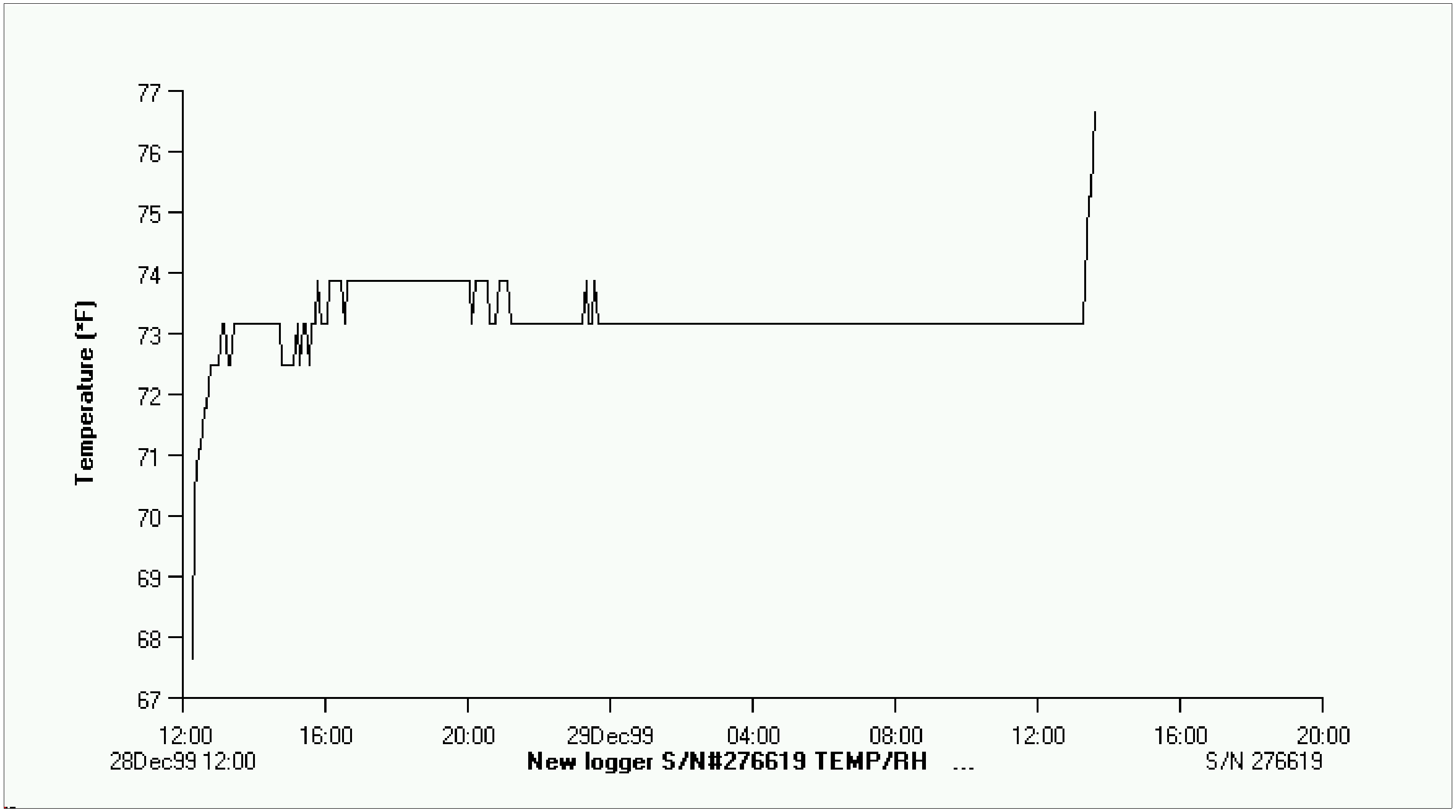


Figure 4
Temperature Variations on the 1st Floor of the Reservations Center (console area)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

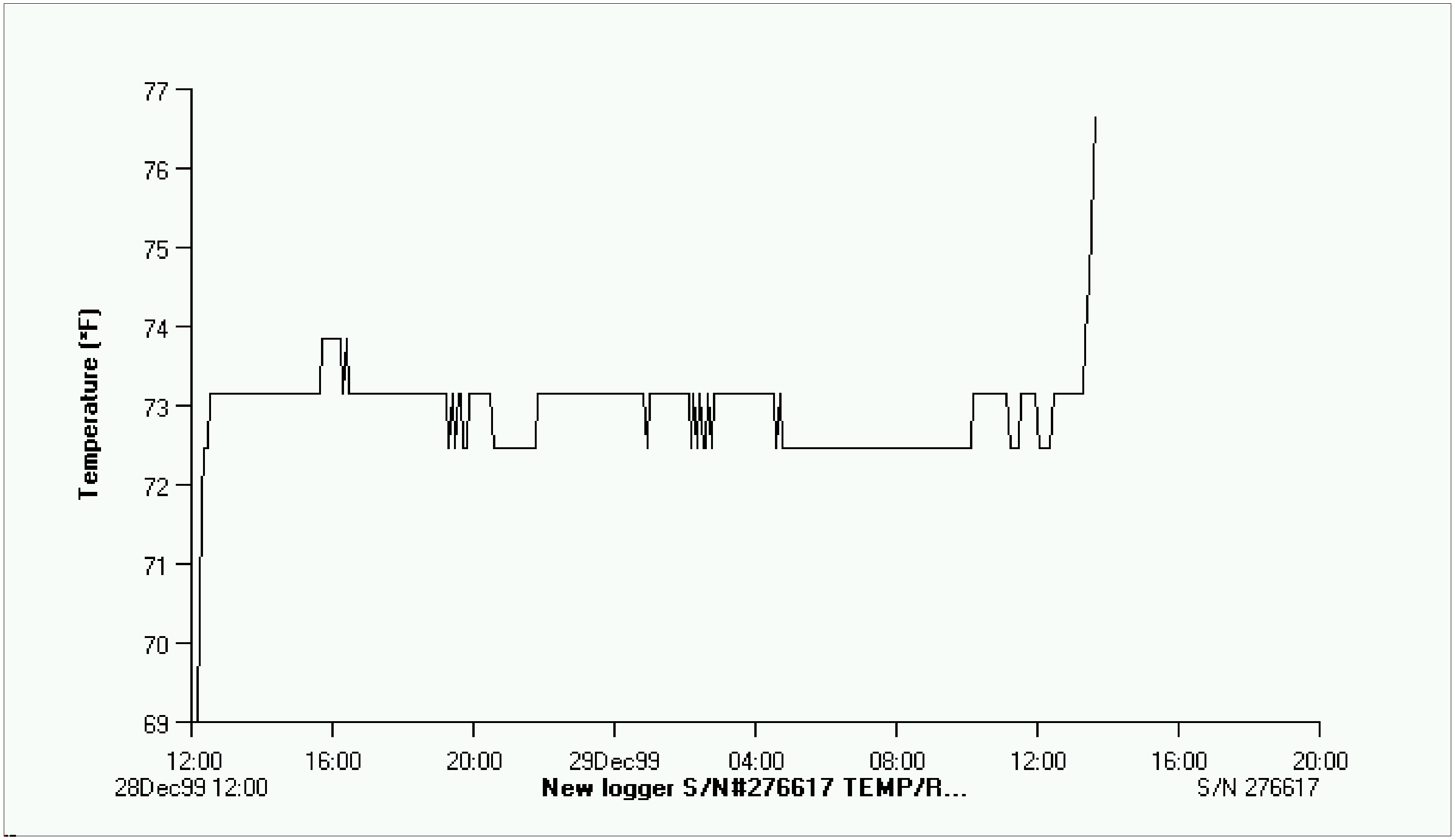


Figure 5
Temperature Variations on the 2nd Floor of the Reservations Center (conference room)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

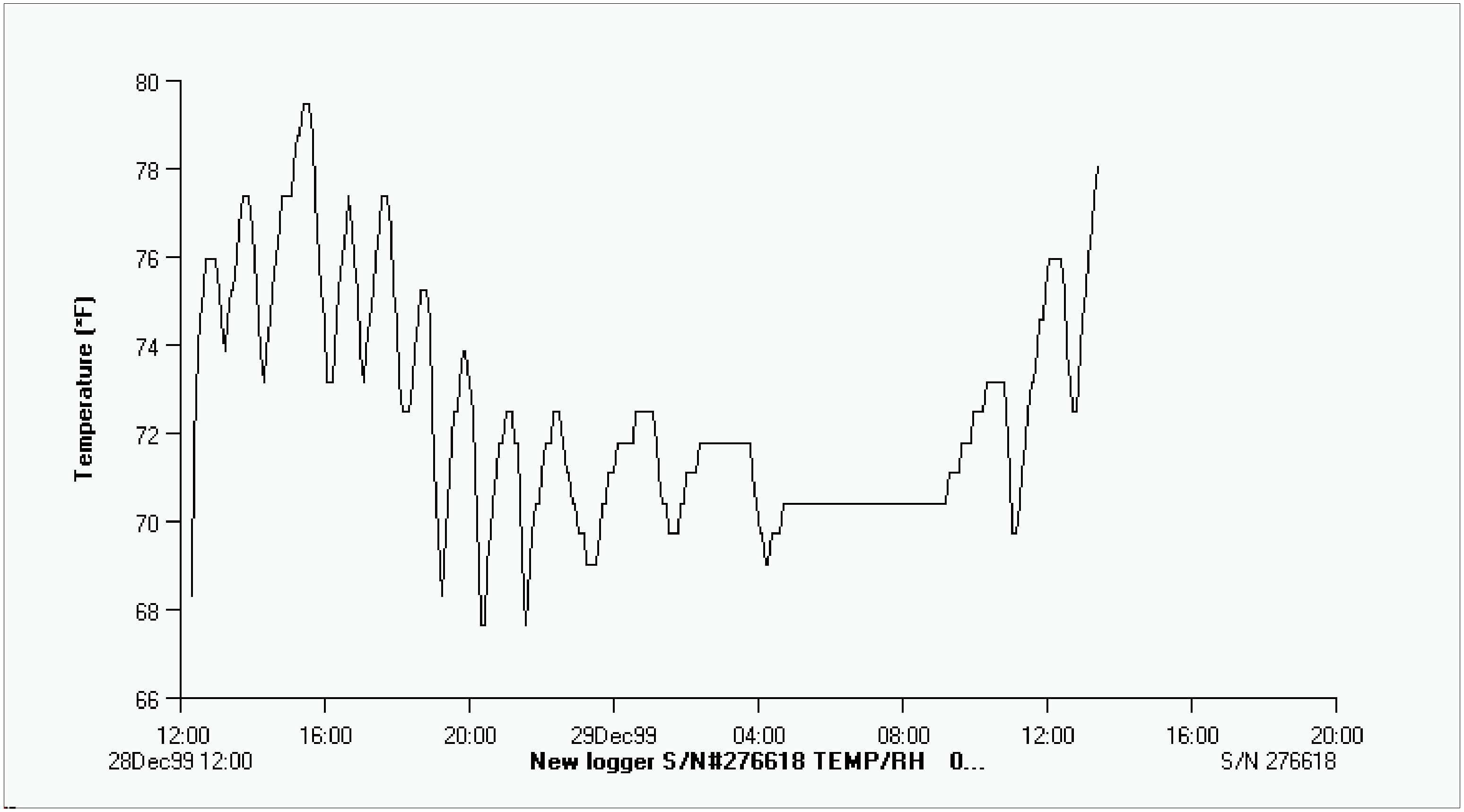


Figure 6
Temperature Variations on the 2nd Floor of the Reservations Center (break room)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

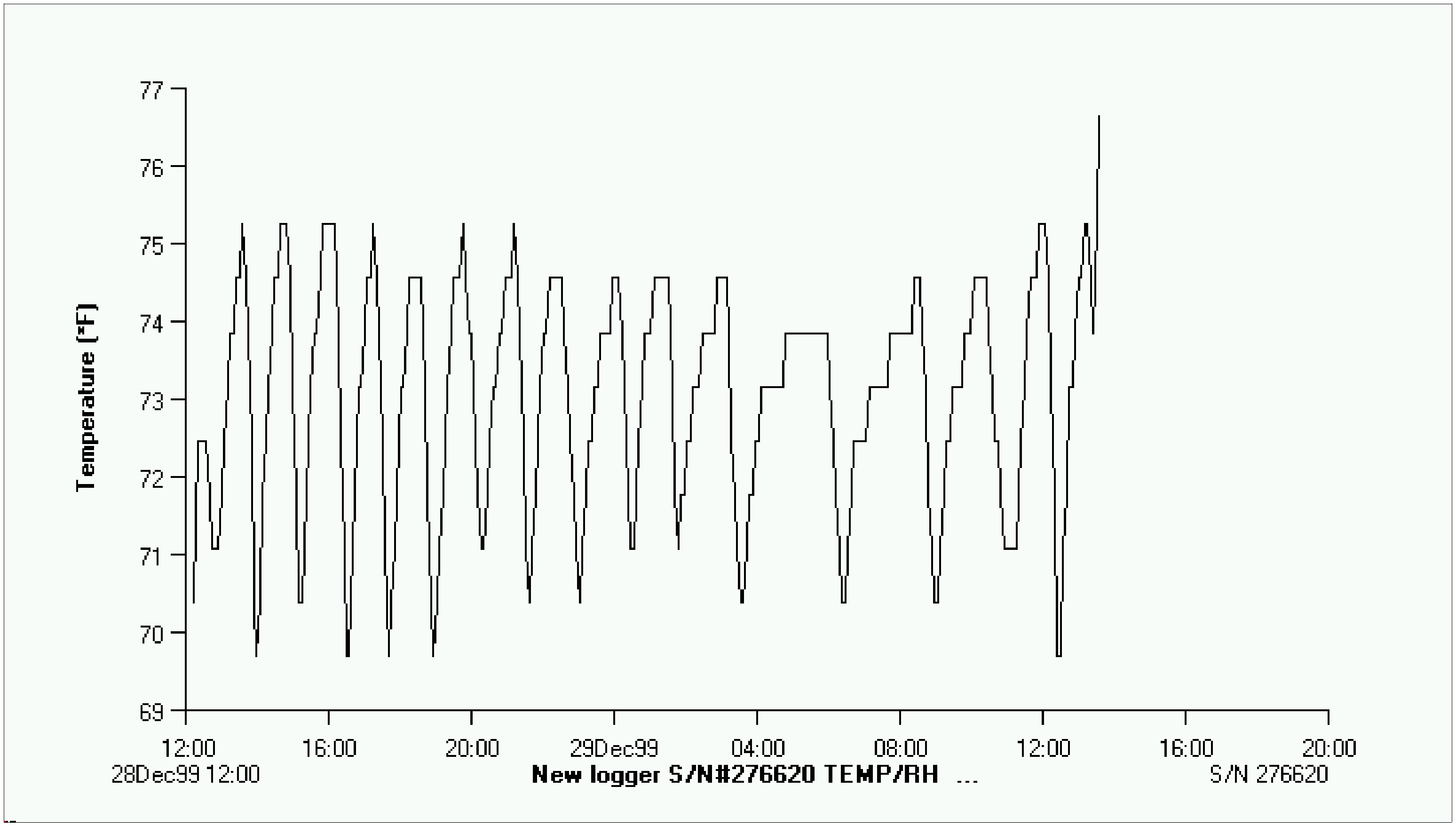


Figure 7
Temperature Variations on the 2nd Floor of the Reservations Center (cubicles 272/279)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

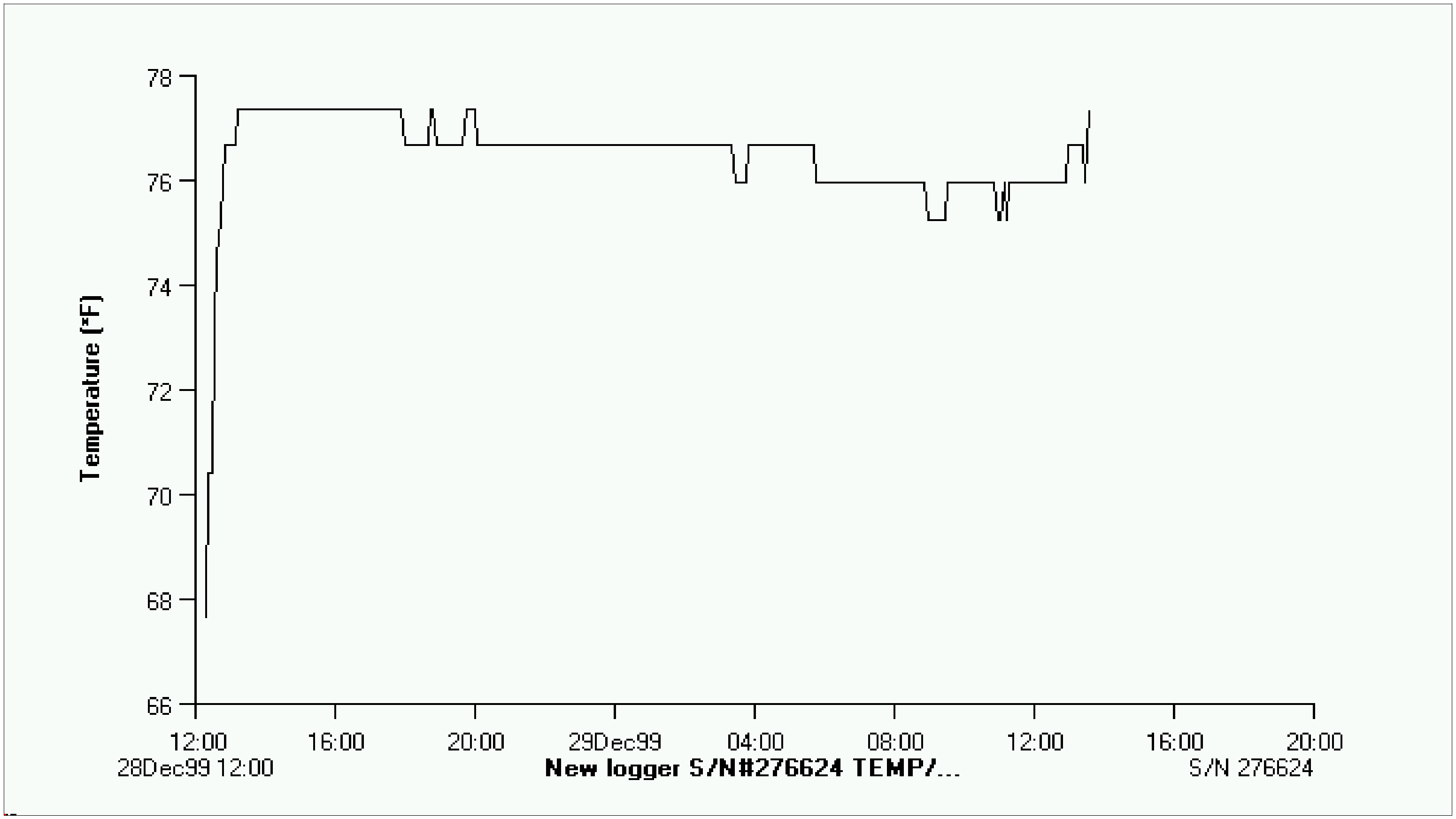


Figure 8
Temperature Variations on the 2nd Floor of the Reservations Center (cubicles 319/328)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

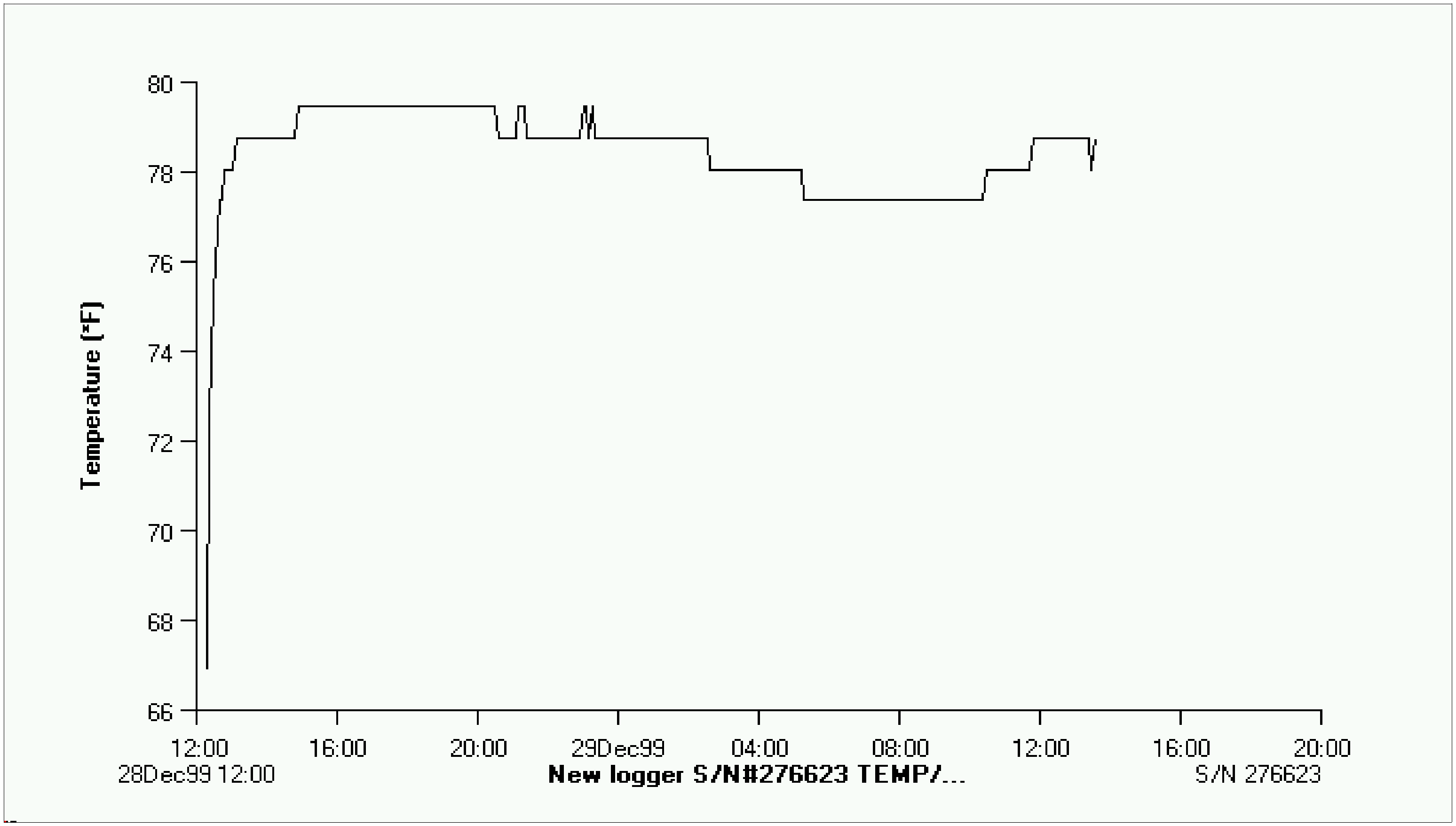


Figure 9
Temperature Variations on the 2nd Floor of the Reservations Center ("La Mesa")
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

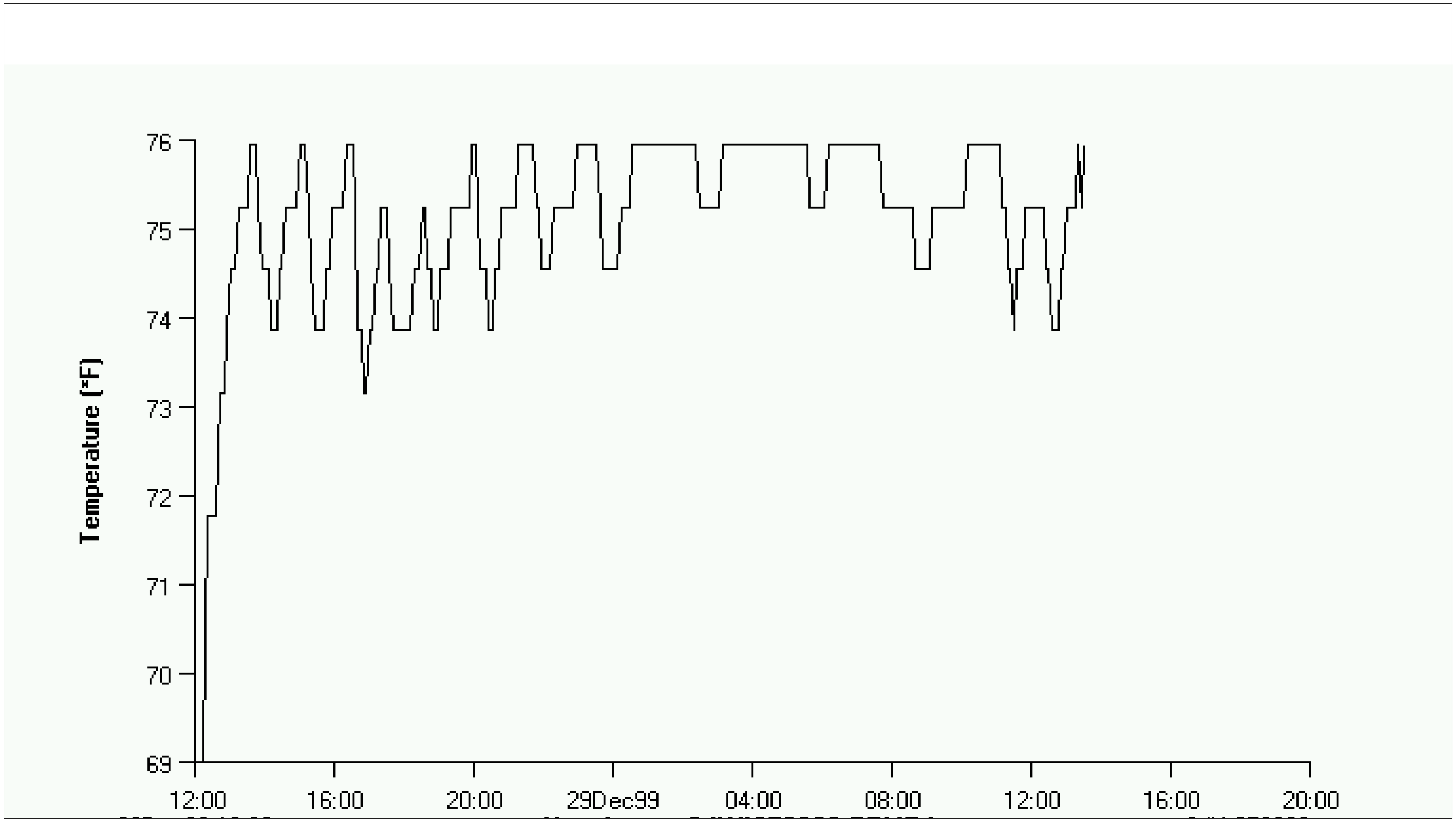


Figure 10
Temperature Variations on the 2nd Floor of the Reservations Center (smoking CSR area-cubicles 241/242 & 251/252)
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

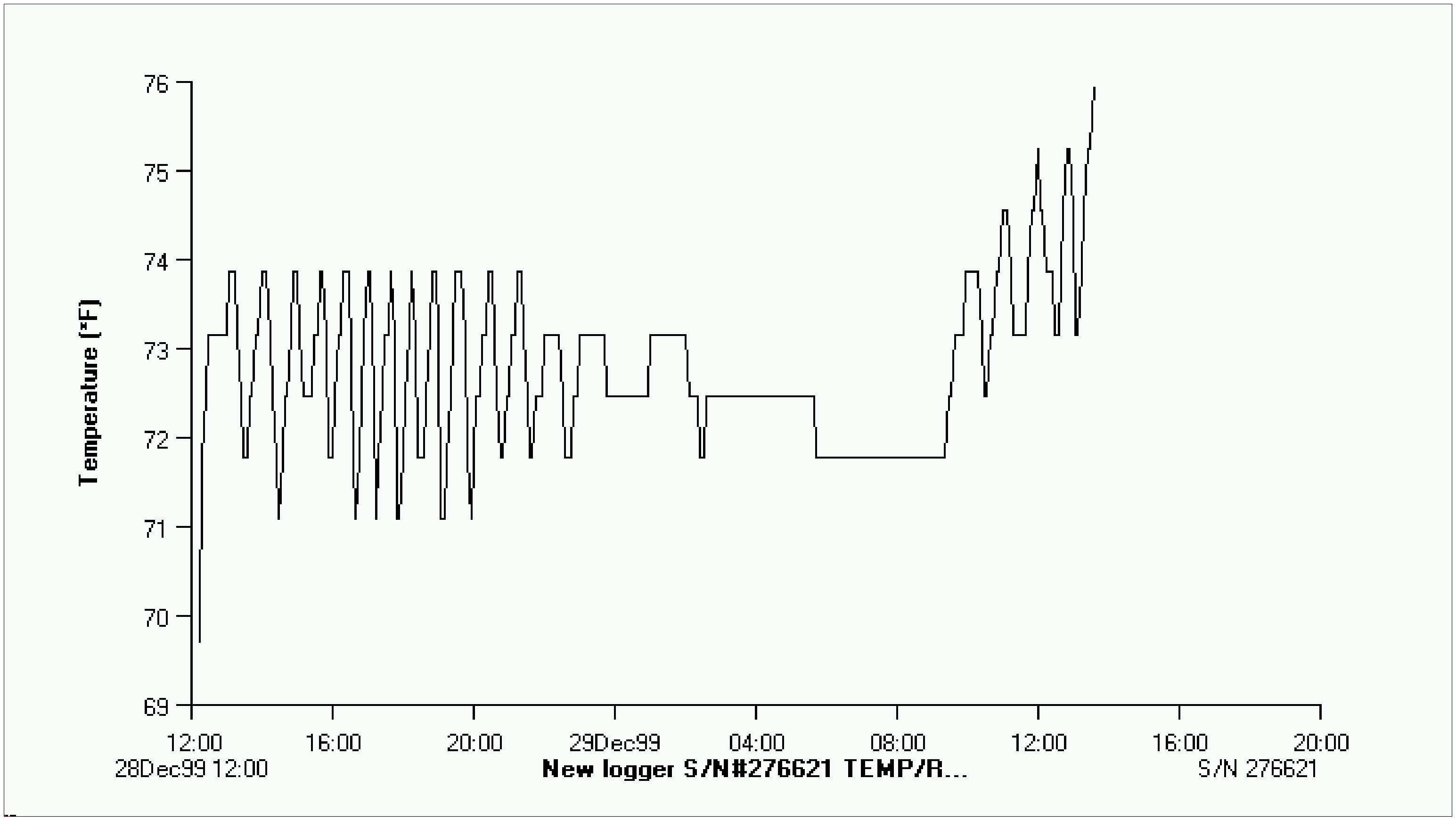


Figure 11
1st Floor Plan for the Dallas Reservations Center
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999

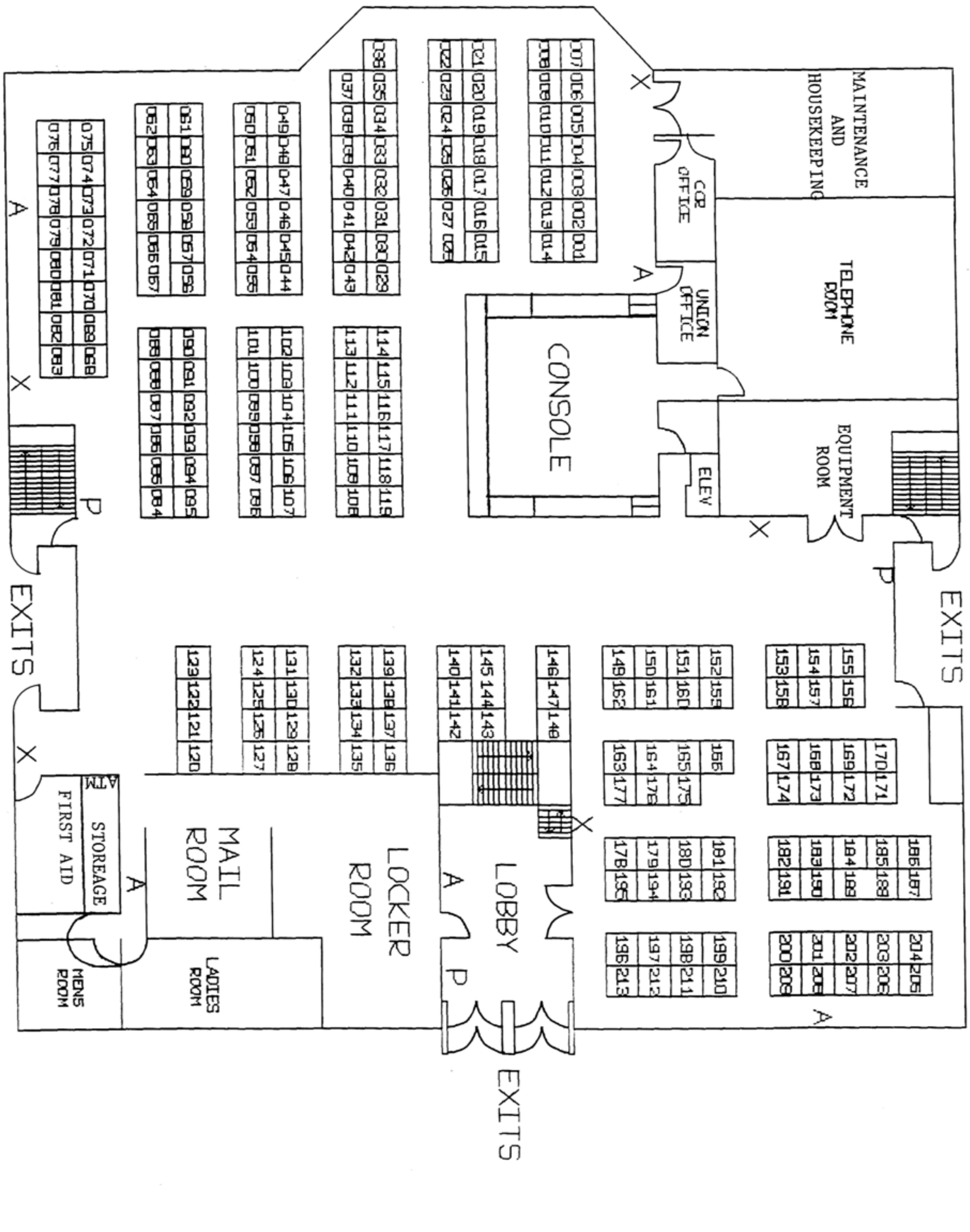
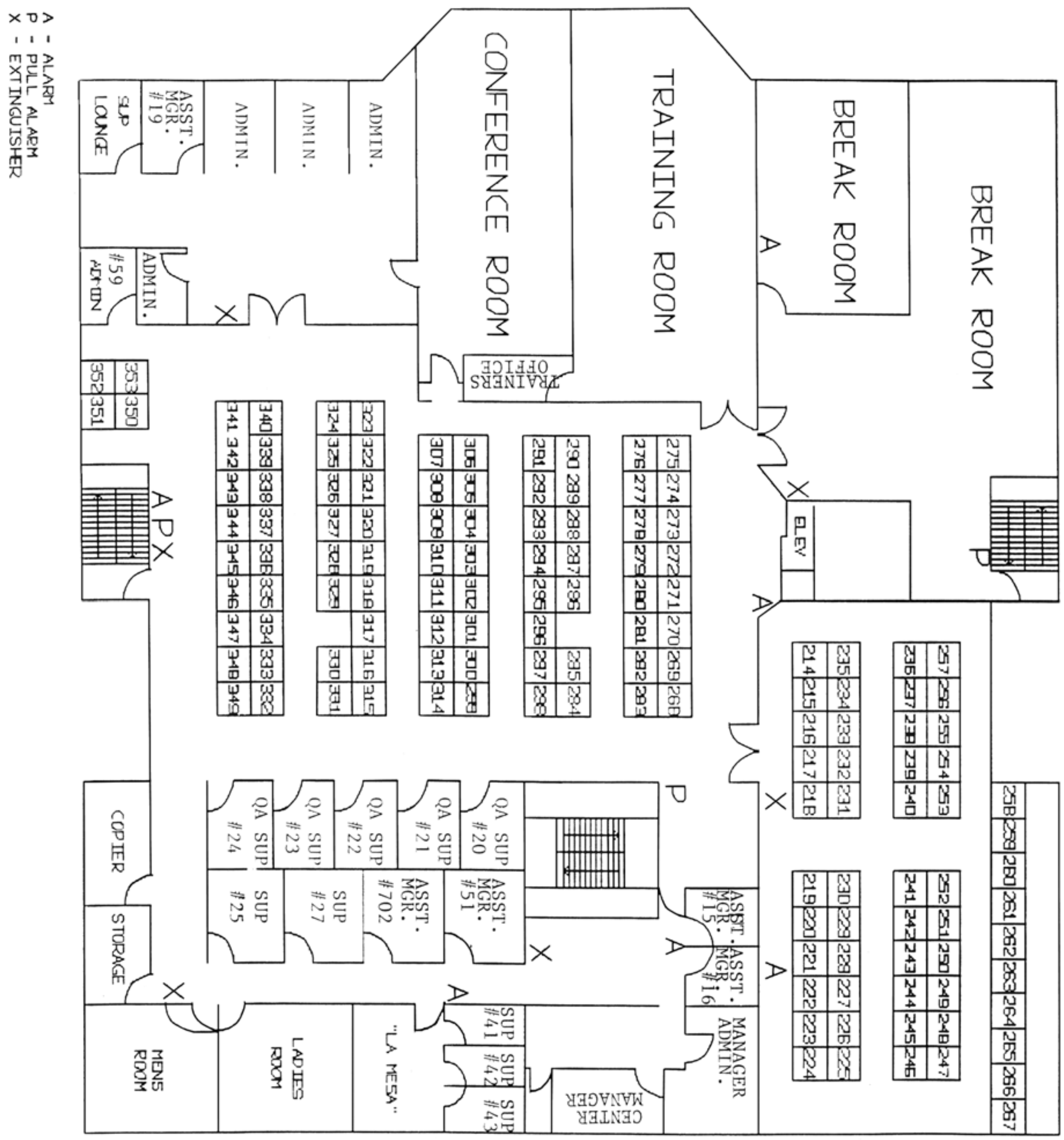


Figure 12
2nd Floor Plan for the Dallas Reservations Center
HETA 00-0088
Southwest Airlines Dallas Reservations Center, Grand Prairie, TX
December 27-29, 1999



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or visit the NIOSH Web site at:
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