Reducing Earthquake Risk in Hospitals

from Equipment, Contents, Architectural Elements and Building Utility Systems

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety
GeoHazards Society India
Swiss Re


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Authors: Janise Rodgers, Veronica Cedillos, Hari Kumar, L. Thomas Tobin and Kristen Yawitz of GeoHazards International

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Dr.R.K Chadha, Hindu Rao Hospital, New Delhi
Dr.L.M Chandana, Former CDMO, Bhuj Hospital
and Hospital Administration Department, All India Institute of Medical Sciences.

Contributors of images and technical material
Applied Technology Council, BFP Engineers (Bertero, Fierro, Perry), California Office of Statewide Health Planning and Development, Degenkolb Engineers, Earthquake Engineering Research Institute, Indian Institute of Technology Kanpur, Indian Institute of Technology Roorkee, Mason Industries, Melvyn Green and Associates, National Information Centre of Earthquake Engineering (Indian Institute of Technology, Kanpur), National Information Service for Earthquake Engineering (Earthquake Engineering Research Center, University of California, Berkeley), Multidisciplinary Center for Earthquake Engineering Research (University at Buffalo, State University of New York), National Geophysical Data Center, Rutherford & Chekene, University of California, Berkeley, U.S. Federal Emergency Management Agency, U.S. Geological Survey and Dr. Shakti Kumar Gupta.

Vice Chairman
National Disaster Management Authorit
Government of India

FOREWORD

1. National Disaster Management Authority has prepared National Guidelines for various types of disasters including man-made disasters as a part of its mandate under the Disaster Management Act, 2005. The intent of these guidelines is to develop a holistic, coordinated, proactive and technology-driven strategy for the management of disasters through a culture of prevention, mitigation and preparedness. Along with the guidelines, NDMA is also supporting numerous awareness generation and capacity building/training materials in various languages for ensuring sustainable risk reduction in the Country.

2. We are happy to encourage the efforts of Swiss Re, GeoHazards International and GeoHazards Society in the preparation of this manual for 'Reducing Earthquake Risks in Hospitals from Equipment, Contents, Architectural Elements and Building Utility Systems, as 2009 is being observed as year of 'Safe Hospitals . This manual is a comprehensive tool with numerous practical and graphic details to enable all hospital administrators and departmental in-charges to initiate safety measures within their area of influence.

3. I acknowledge the contribution of experts from around the Country and abroad who have given valuable technical inputs in the development of this manual.

New Delhi
08 December 2009

General NC Vij
PVSM, UYSM, AVSM (Retd)

Lt Gen (Dr) J R Bhardwaj
PVSM AVSM VSM PHS (Retd)
MD DCP PhD FICP FAMS FRC Path (London)
Member
(Status : Union Minister of State)

सत्यमेव जयते

National Disaster Management Authority
Government of India
NDMA Bhawan
A-1, Safdarjung Enclave
New Delhi - 110029
Tel. : 011-2671778 Fax : 011-26701804
E-mail : jrb2600@gmail.com

Message

Hospitals have expensive medical equipments and vital support systems that have to remain functional following a disaster to ensure the continuity of medical services. Securing these vital equipments and systems will greatly reduce damages and avoidable consequences such as loss of life and functionality of the Hospital. The manual 'Reducing Earthquake Risks in Hospitals from Equipment, Contents, Architectural Elements and Building Utility Systems' brought out by Swiss Re, GeoHazards International and GeoHazards Society is a comprehensive guide that will help hospital administrators reduce the earthquake risk to their hospitals. In particular, the manual will help them identify and mitigate hazards in various parts of the hospitals including ICUs. Operation theatres and other critical areas.

All hospitals in the country are advised to undertake actions as detailed in this manual as it will help reduce one of the major sources of earthquake-related damage and losses: the hospital's medical equipment and supplies, contents, architectural elements, and building utility systems. I am sure this manual will go a long way in helping heath facilities in the country get prepared so that they continue to function and serve the community when it needs it the most. I am pleased to place on record my sincere appreciation for the detailed technical inputs that have gone into the preparation of the manual.

Lt. Gen (Dr.) J R Bhardwaj

Executive Summary

Hospitals provide life-saving medical care on a daily basis to the communities that they serve. Your community expects your hospital and its staff to save lives in an emergency and to care for community members, if they are severely injured or become seriously ill. Your hospital has an additional responsibility to keep patients and staff safe. In particular, critical care patients, the very ill and the very young will require protection: they will not be able to protect themselves or to evacuate, if disaster strikes.

Earthquakes threaten your hospital's ability to carry out it's responsibilities to care for the ill and injured. Past earthquakes around the world have destroyed hospitals or damaged them so that they could not function. These hospitals failed their communities in their hour of greatest need.

You can take reasonable measures to reduce your risk of earthquake damage and losses and to keep your hospital functioning after an earthquake. This manual will help you to reduce one of the major sources of earthquake-related damage and losses: your hospital's medical equipment and supplies, contents, architectural elements, and building utility systems. Damage to these items has caused deaths, injuries, building functional loss, and economic loss in past earthquakes, even in cases in which the building structure itself was essentially undamaged. This manual outlines measures for anchoring and bracing items properly to reduce risk; these steps, however, form only one part of the comprehensive approach that you need to take, in order to keep your hospital safe from earthquakes. Your hospital buildings might be at risk of severe damage or even collapse in a major earthquake, but you can strengthen them, if needed, with the help of engineers and building professionals. Your staff may not know what to do if an earthquake strikes, but you can train them, so that they do know how to respond.

You can start to reduce your hospital's earthquake risk today. The first step is to create a hospital emergency preparedness committee, if you do not already have one. This committee will develop a plan to ensure that (a) your hospital's buildings are safe and will not collapse during an earthquake; (b) medical equipment and supplies, contents, architectural elements, and building utility systems will not fall or fail and injure patients or endanger critical functions; and (c) your staff will be prepared to keep themselves, their patients and their families safe if an earthquake strikes. The hospital emergency preparedness committee can use this manual to get started.

The next step is to pass this manual along to your hospital's maintenance or engineering department head and to direct them to begin anchoring and bracing critical equipment and building utility systems. This manual provides guidance for maintenance personnel and engineers, as well as references to additional technical information. Most anchoring and bracing can be done using low-cost, readily available parts and tools.

Preparing your hospital is a process that takes time to complete. By starting today, you demonstrate your commitment to be there for the community after a major earthquake strikes.

Table of Contents

Bhuj Civil Hospital

On the morning of January 26, 2001, people throughout Gujarat were just starting their day of celebrations for the Republic Day holiday. Schoolchildren were putting on special programmes and marching in parades. At the Civil Hospital in Bhuj, also known as the GK General Hospital, which serves as the district hospital for Kachchh district, the staff continued its daily routine of providing care for the sick. Dr. L. M. Chandana, the Civil Surgeon for the hospital and Chief District Medical Officer at the time, provided the following eyewitness account of what happened next:

I was in charge of the Bhuj Civil Hospital, which had been built in the late 1940s. On Jan 26, 2001, I left my quarters at 8:00 a.m. and took the ten minute walk to the hospital as I normally do, stopping by at the temple on the way. I had a surgery lined up for the morning, but the patient had not come. My colleagues in the OT were having coffee and invited me for a cup, but I refused as I had breakfast just before leaving home. Besides, I also had to attend two flag hoisting ceremonies, this being Republic Day. The surgery patient came just then and I asked her to come after 11 a.m., by when I expected to have hoisted the flag at our hospital. I was informed by my ward boy that a vehicle was waiting downstairs to take me to the grounds where the district's flag hoisting would take place.

I came down to the ground floor and was about to get into the car when there was this tremendous noise like a jet plane about to take off. Those were the days of India-Pakistan tensions and being close to the border, I assumed that it was a missile attack. Then I saw parts of the fort opposite the hospital fall, and there was dust everywhere, and it seemed like I was in the middle of a cyclone. Buildings were swaying and collapsing all around me, and I knew then that it was an earthquake. I went back in, if you could call it going 'in,' and found that my colleagues in the OT, my own staff nurse and ward boy were no more. We lost 17 staff and 197 patients and relatives at the hospital that day. On the South side, the building had not collapsed completely, and some staff members could escape. The main building (which houses the OT), maternity ward, the out-patient department were all dust.

Within 15 minutes, people started coming in with patients (and even the dead), without realising that the hospital had collapsed. As in any government hospital in those days, we were not prepared for such a disaster. And to add to that, the loss of the main buildings and staff traumatised us. After about 30 minutes, we started organising ourselves in the campus of the hospital and treating the injured. Luckily, our pharmacy had just been stocked, and we had stocks of medicine worth about 40 lakh rupees. The pharmacy was largely undamaged, except for the collapse of a corner. We arranged for necessary physical support to be given to the pharmacy roof slab and started organising treatment in the campus. Doctors from the surrounding area also joined in. Whatever cots we could salvage were brought out to the open, and we started treatment, including surgery, in the open. Doctors from other parts of the country came by evening, but they had been pulled out of wherever they had been that day and were largely unprepared. Many had not even eaten their lunches when they were put on the flight, and I had trouble trying to make arrangements for them. Finally, I could arrange some broth and a tent to stay for them. For eleven months, we worked from tents. When the Prime Minister's office decided to rebuild the hospital, I was still in charge and all drawings have my signature.

As a result of the Gujarat earthquake, 13,805 people lost their lives. The city of Bhuj was hit especially hard—thousands of people died, and the city center was devastated. The Civil Hospital was not there when the city needed it most.

A year later, a new hospital was built to replace the collapsed Civil Hospital. This hospital was built on special sliders, called seismic isolators, to allow it to survive a strong earthquake with minimal damage. The hospital and community now understand the importance of earthquake preparedness and how valuable it is to have a safely built hospital—it can save thousands of lives. The community feels more at peace with its new earthquake-safe hospital. This new hospital will prevent people from dying in the next Gujarat earthquake. That is why it is so important to build new hospitals that will be able to function after an earthquake and to strengthen existing hospitals before the next earthquake strikes somewhere in India—perhaps in your city or district. The question is, are you prepared? Or could your hospital fail the community, like Bhuj Civil Hospital did?

Photo credits: EERI 2001 Bhuj, India Earthquake Reconnaissance Report

Introduction

Hospitals are critical institutions that community members rely on to save lives in an emergency. Regrettably, many hospitals around the world have failed their communities after major earthquakes, in times of dire need. This manual will help you to take steps to prevent that from happening to your hospital. Let's begin by reviewing what can happen in an earthquake, based on the experience of a hospital located here in India.

An earthquake can cause damage to the hospital building itself and, in cases like that of the Bhuj Civil Hospital, could cause all or part of the building to collapse. Building collapse is the greatest threat to life safety in most earthquakes. Protect your patients, your staff and colleagues, and yourself by having a qualified engineer evaluate your buildings to determine if they need to be strengthened (i.e., seismically retrofitted).

Building safety is crucial to saving lives during an earthquake, but objects within a building can be a great hazard as well. Hospitals house a large number of objects that are required for operational and functional purposes. Some people refer to these objects as “non-structural” components because they are not part of the building structure that resists forces. Falling objects and damage to building systems and equipment have caused deaths, injuries, building functional loss, and economic loss in past earthquakes, even in cases where the building structure was essentially undamaged. In many cases, facilities were unusable for weeks or even months, due to earthquake damage to objects and building utility systems. Even smaller earthquakes that do not damage the building itself can break water pipes and damage equipment. This manual will help you to develop and carry out a plan to reduce the hazards posed by the major groups of objects found in hospital buildings: medical equipment and supplies, architectural elements, furnishings, and building utility systems and equipment. This plan should be part of a larger plan to reduce your hospital's earthquake risk.

Why Your Hospital Needs to Function After an Earthquake

Damage to your hospital's utility systems and equipment, architectural elements, and medical equipment may prevent the hospital from functioning, even if the building structure itself is undamaged. It is essential to address the safety hazards that these items pose, for the following reasons:

- **The community needs you.**

Hospital buildings play a vital role in communities, especially right after an earthquake, when there is a sharp increase in demand for medical services. Numerous earthquake victims will come to the hospital, seeking medical assistance. The community will expect the hospital to provide immediate medical care to the injured, as well as help to those people who are suffering from the traumatic experience. Your hospital may need to provide these additional services for weeks or months after an earthquake.

- **Some patients cannot protect themselves or evacuate.**

Patients already in the hospital could be injured, if these hazards are not addressed. Many patients will be unable to take protective actions, such as getting under sturdy furniture, during an earthquake or to evacuate afterwards; therefore, reducing falling hazards is crucial to their safety. Medical and emergency personnel need to be able to enter the building after the earthquake, in order to care for these patients.

- **Moving critical care patients can be difficult and dangerous.**

It is in the hospital's best interest to avoid transferring their critical care patients to another hospital after an earthquake, because this transfer could be dangerous for the patient, as well as difficult and expensive. Patients could also be easily separated from their medical records during the transfer, making it difficult to identify and to provide the correct care for each patient.

- **Earthquakes disproportionately affect the poor.**

Earthquakes cause the most suffering among those segments of population that live below the poverty line. These people are injured or killed in an earthquake more often than are other groups, because they tend to live in more vulnerable types of buildings, due to a lack of resources. The poor also rely heavily on government and private charitable health facilities for routine care and do not have the resources to travel elsewhere for care, if the government facilities can't function. Lengthy closures of these facilities will compound the suffering of the poor.

Why Earthquake Damage Affects Hospitals More Severely Than Other Buildings

Earthquakes can have numerous consequences, ranging from minor to life-threatening. Unprepared hospitals tend to experience more serious consequences from earthquake damage than other buildings do, for the following reasons:

- **Hospitals have complex systems that are crucial to maintaining services.**

Hospitals tend to be more complicated than other buildings, in terms of their components and systems (i.e., medical equipment, electrical and heating, ventilation and air conditioning systems, medical gas distribution systems, emergency power systems). Many of these systems are crucial to preventing the spread of infection, while others, such as life support systems, are necessary for keeping patients alive. Earthquake damage could interrupt the function of these vital systems, which could result in loss of life and disrupted hospital services.

- **Hospitals contain expensive medical equipment.**

Studies have shown that the cost of components (i.e., equipment, furniture, partition walls) relative to the entire building cost is much higher for hospitals than for other buildings. This is chiefly due to hospitals' expensive medical equipment, such as scanning and imaging machines. Preventing damage to hospital equipment can greatly reduce the economic losses from earthquakes.

- **Hospitals house patients who may be incapacitated or reliant on life support.**

Many of the patients in a hospital may not be able to protect themselves during earthquake shaking or to evacuate on their own after an earthquake. Earthquake damage that could cause minor injuries to, or merely inconvenience, healthy people might cause severe injury to incapacitated hospital patients. Patients on life support can die if life support systems fail during an earthquake.

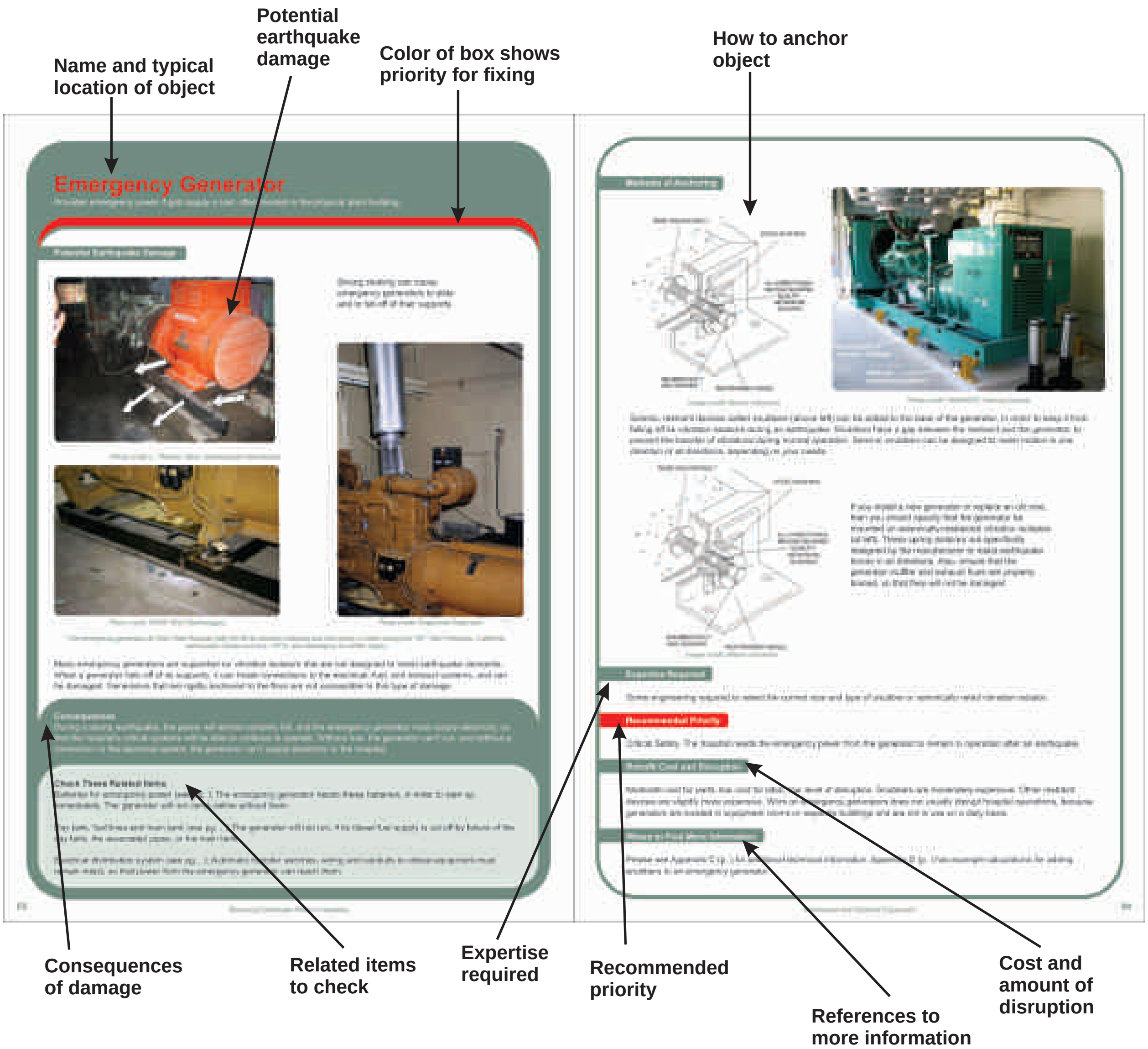
Securing items that could fall, slide or topple during an earthquake will greatly reduce damage and its consequences.

How this Manual Can Help

This manual is intended to help hospital administrators reduce their hospital's earthquake risk, including earthquake damage to their hospital's equipment systems and furnishings. In particular, the manual shows readers how to identify hazards, how to understand the various options available to mitigate these hazards (such as anchoring and bracing medical equipment), and outlines the level of difficulty and estimated cost for each option. With these tools in hand, administrators can decide how to prioritize mitigation efforts and how to assign responsibilities based on the hospital's staffing, conditions and budget. This manual only covers one of several aspects, however, of hospital earthquake preparedness. A full preparedness program would include checking the structural safety of your building, forming a hospital emergency preparedness committee, developing evacuation routes, making an earthquake preparedness plan, and conducting periodic drills, in addition to carrying out the recommendations in this manual.

What Types of Information the Manual Includes and Where to Find It

The section on Objects Typically Found in Major Rooms, which begins on page 16, gives a quick reference guide to the location of anchoring and bracing information for objects in eleven major rooms. If you want to anchor the objects in your work area, then this section is a good place to start, after you read the introductory sections.
The section on Anchoring and Bracing Information for Specific Objects, which begins on page 51, gives information about each object on two facing pages, so that you can see everything at once. The first page describes an object's potential damage from an earthquake and the consequences of that damage, while the opposite page discusses solution options, costs, and expertise required. The illustration on the following page shows what these two pages look like for a sample object, and where you can find the information you need.



Detailed information and/or engineering drawings required for various objects are included in the appendices and are referenced in the corresponding sections.

How to Determine Your Hospital's Earthquake Risk

Reducing earthquake risk begins with determining what is at risk. What could happen to your hospital in a damaging earthquake? The next two sections will help you to understand the severity of earthquake shaking to expect, based on your hospital's location, and what could happen to your hospital during that shaking.

How Earthquakes Can Damage and Affect Hospitals

Earthquakes can cause building damage or collapse, damage to equipment and objects inside the hospitals, and secondary effects, such as fires or spills of hazardous materials.

Building Damage

As the story of the Bhuj Civil Hospital shows, strong earthquakes can destroy hospital buildings that were not designed to resist earthquakes. Taller, more modern buildings can be just as vulnerable as older buildings. In the 1985 Mexico City earthquake, thirteen hospitals over six stories high either collapsed or were severely damaged, and the city lost approximately one-quarter of its hospital beds, as a result. Over 900 doctors, nurses, and other hospital personnel were killed, greatly reducing the city's ability to deal with the disaster.

Collapsed Hospital Juarez (left) and Hospital General (right) Mexico. Photo credits: E.V. Leyendecker and Mehmet Çelebi, USGS.

During a strong earthquake, some buildings collapse, while others suffer very little damage. How can you determine what will happen to your building? To use a medical analogy, the only way to know for certain is to consult a “building doctor”–a structural engineer. Like the patients in your hospital, each building is unique and warrants a “check-up” from an engineer. However, there are some general principles that engineers use to “diagnose” earthquake vulnerabilities in buildings. The severity of earthquake damage that your building could suffer depends on the building's shape and size, the quality of its construction, its age, the type of materials used in construction, and the earthquake shaking intensity at that location. Refer to the section “How to Determine Your Earthquake Hazard” on page to determine whether or not your hospital is located in an area of high seismic hazard (Seismic Zones IV and V on India's seismic hazard map), where the strongest ground shaking is likely to occur.

New buildings, built to comply with the latest building codes, are unlikely to collapse. If your building was built before 2002, when the latest building codes were adopted after the Gujarat earthquake, then you should have a structural engineer evaluate your building for earthquake resistance. Not all older buildings are likely to collapse in a strong earthquake, but past earthquakes have shown that some types of buildings are prone to collapse. If your building is a brick or stone bearing wall building without reinforcing steel or “bands” at the lintel (the top of the windows and doors), then it is crucial that you contact an engineer to evaluate its condition and to suggest ways to improve it. If your building is a reinforced concrete building with more than three storeys that was built before 1980, it is also very important that you consult an engineer to determine whether or not your building might collapse. Preventing the collapse of your hospital's buildings in an earthquake should be your top priority in reducing earthquake risk.

Damage to Equipment, Contents, Architectural Elements, and Building Utility Systems

This manual focuses on preventing damage to equipment, conduits, partition walls, ceilings, and other objects. Damage to these components can result in many adverse effects, including death, injuries, loss of function, and economic losses. The following account illustrates why securing objects is crucial to keeping a hospital functional.

Olive View Medical Center

On February 9, 1971, a magnitude 6.6 earthquake struck the San Fernando Valley, near Los Angeles, California. Old buildings and highways were damaged, and some collapsed, but even more concerning was the severe damage to a new hospital. Olive View Medical Center had just opened a month before the earthquake struck. In that earthquake, the main hospital building's first story leaned alarmingly and was near collapse, and two stair towers collapsed. The first floor of the psychiatric building also collapsed; luckily, the patients and staff were on the second floor and survived. The ambulance canopy collapsed and crushed the parked ambulances beneath it.

The main building was so severely damaged that it had to be demolished. All of the damaged and collapsed buildings had met the technical requirements of the building codes in force at the time of their construction. Yet all had features that left them especially vulnerable to earthquake damage. After the San Fernando earthquake, engineers changed the building code, to prevent this type of damage from happening in the future. The damage to Olive View Medical Center was one of the main reasons that the State of California passed a law, the Hospital Seismic Safety Act, mandating that hospitals be designed, built, and inspected according to strict earthquake safety standards.

Damage to old main building (left); water damage in new main building (right). Photo credits: NiSEE and FEMA 74.

For years following the 1971 San Fernando earthquake, patients of Olive View Medical Center had to be treated at an interim facility nearby. The hospital was carefully redesigned and in 1987, the new hospital was completed, exceeding the requirements of the new Hospital Seismic Safety Act. Seven years later, Olive View Medical Center was again put to the test. The Magnitude 6.7 Northridge earthquake hit the San Fernando Valley on January 17, 1994, causing damage throughout the region. The structural design of the hospital worked magnificently – there was little to no damage to the building itself. However, the new building's stiff and strong structural system transferred very high earthquake accelerations. This, combined with inadequately anchored equipment and architectural features, caused many unexpected problems. The earthquake accelerations broke the chiller water lines on the roof, causing flooding in portions of the top floors. Several lifts were severely damaged and unusable. Numerous pipes broke, causing leaks throughout the hospital.

Due primarily to water damage, the hospital decided to transfer all 377 of its resident patients, including patients in critical condition, to other facilities. Damage to building components and systems forced the hospital to shut its doors for 41 hours even though there was virtually no structural damage. Once again, the Olive View Medical Center was not operational at the community's time of greatest need.

Consequences from earthquake damage

Consequences from earthquake damage vary widely. In order of importance, they are:

Loss of life
People can be killed or injured by objects that fail and/or fall. Falling objects are especially dangerous for patients who do not have the ability to protect themselves from falling debris during an earthquake. Falling objects that have caused injuries and deaths in past earthquakes include heavy furniture or equipment that toppled and pieces of masonry that fell. Just as serious, if certain equipment, such as life support equipment, fails, then that failure can lead to injuries and deaths.

Loss of function
It is also possible that many of the systems, equipment and supplies necessary to run a hospital will be heavily damaged and will render the hospital unusable or will reduce its functionality for a period of time. For example, serious damage to the operating or surgery rooms might prevent a hospital from using those facilities, until they were repaired and/or replaced. Damaged sterilizers, laundry facilities and air circulation systems might create an unclean environment, where disease can easily spread, making the hospital unusable.

Loss of property/money
Property including building components such as furniture, equipment, partitions, and windows can be severely damaged during an earthquake. Hospitals are especially vulnerable, since they contain very expensive medical equipment that is not easy to replace. Additionally, their electrical and mechanical systems are more complex than in standard buildings and therefore, more expensive to fix.

Loss of community confidence
If the hospital is not functional following the earthquake, then the population it serves can lose confidence in the hospital as a trusted, reliable institution. Private hospitals could lose patients to competitors who appear more reliable.

All of these losses can be caused either directly or indirectly by an earthquake. For example, a water pipe that breaks on the top floor might cause flooding in the building. Although direct costs only include replacing the pipe, indirect costs include fixing the flooding problem and repairing or replacing any components that were damaged, as well as downtime losses. Another example would be the failure of an emergency generator. Although the direct loss would only be functional, the lack of power might lead to deterioration of services to the critically ill and, in some cases, to death.

The following are earthquake damage examples of hospital objects that either failed or fell. The consequences of the fall or failure are indicated for each example.

Loss of Life
If someone were sitting at this desk, then that person would be likely to be seriously injured.

Photo credit: FEMA

Loss of Function
If emergency generators are not properly anchored, then they can fall off their supports and lose function after an earthquake, when they are needed most.

Photo credit: NiSEE (Karl Steinbrugge)

Loss of Property/Money
Expensive equipment can be damaged in an earthquake and can become unusable. Repairing or replacing this equipment can be very costly. The X-ray machine below was damaged in the 1971 San Fernando, California earthquake.

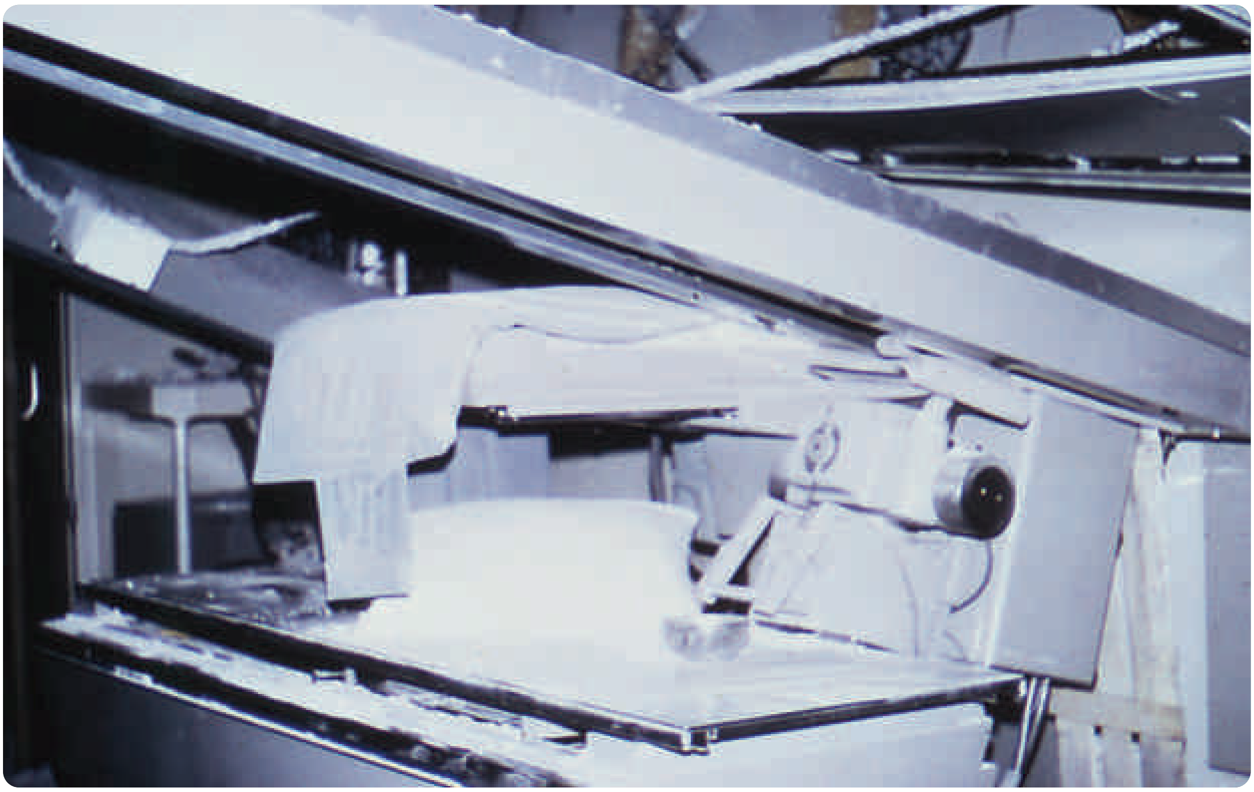


Photo credit: FEMA

What causes damage?

Earthquakes affect objects in a building in two primary ways. The ground motion shakes the building, and the building shakes everything that is either inside it or attached to it. Engineers call this motion acceleration. Objects can fall, slide or break due to the back-and-forth shaking. For example, tall and top-heavy cupboards are likely to tip over because of acceleration.

The second way that the earthquakes affect objects in a building is by causing the building to bend, as it sways back and forth. Engineers call this motion deformation. Objects that are connected to two different floors get stretched, and they can crack, bend, or break. For example, deformation often causes damage to partitions and pipes, because they must endure the movement between different building elements and across joints.

What factors affect damage?

In general, the level of earthquake damage caused by objects depends on various aspects of the object. The main factors affecting how likely an object is to fail/fall are an object's:

- **Shape, Size, and Weight.** An object that is tall and narrow is more likely to overturn. A good rule of thumb is that if an object is more than one and a half times taller than it is wide, it could topple. If the object is also top-heavy, it is even more likely to topple. You should anchor and/or brace an object of this type, if at all possible.

- **Location within Building.** Objects located on upper floors are more exposed to strong shaking than those closer to the ground floor. Equipment on the top floor of a hospital will experience higher accelerations than that on the ground floor. This is important to keep in mind when prioritizing mitigation actions, especially in tall hospital buildings.

- **Relative Location.** Heavy objects should be placed closer to the floor, whenever possible. For example, heavy books or electronics on shelves should be moved to the lower shelves. This prevents objects from falling and possibly hurting someone.

- **Anchorage/Bracing Condition.** Bracing or anchoring an object helps to reduce the likelihood that it will slide, overturn, or fall. However, the way that an object is braced/anchored and what it is braced/anchored to are crucial: inadequate anchorage designs can fail and cause major damage. For example, an object might be anchored, but if the anchor bolts are not long enough, then they can possibly pull out during an earthquake.

- **Connection to the Building.** Even if an object is adequately anchored/braced, if it is not connected to a strong component of the building, then the object might still fail or fall. For example, a braced object might fall, if the brace connects it to a weak partition wall.

- **Pounding/Impact Possibility.** Although an object might be properly braced, other inadequately restrained objects nearby can potentially pound against it or impact it during earthquake shaking, possibly damaging it and making it unusable. Different parts of one building or two adjacent buildings can also pound against each other unless there is a large enough gap (called a seismic separation or joint) between them.

- **Interconnected Equipment/Systems.** Although the object of main concern might be properly restrained, if the interconnected systems and equipment necessary to make it function are not taken into consideration, then the object might not be useable after an earthquake. For example, an emergency generator might be properly anchored, but if the connection to its diesel fuel supply fails during an earthquake, then the emergency generator becomes useless.

- **Earthquake Shaking.** How much and for how long an earthquake shakes an object obviously affect that object's likeliness to fail. A hospital located in an area where strong earthquakes are expected should expect to suffer more damage than a hospital that is located in an area affected only by small or distant earthquakes.
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The soil underlying the hospital also helps to determine how strong the shaking will be. Soft soils tend to amplify shaking a lot, while hard rock does not amplify shaking much. These factors are important when analyzing several hospitals and determining which one should be the first priority in terms of mitigation work. It is also important in helping you to understand how important earthquake mitigation work is for your hospital. To determine your earthquake-shaking hazard, read the section “How to Determine Your Earthquake Hazard.”

How to Determine Your Earthquake Hazard

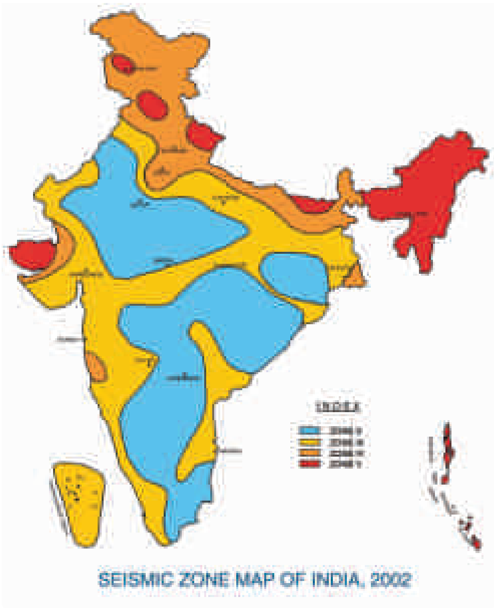


Image Credit: BMTPC

India's current seismic zoning map divides the country into four Seismic Zones that show how severe earthquake shaking is likely to be. Zone V (in red) is the area of very high risk, Zone IV (in orange) is the area of high risk, Zone III (in yellow) is the area of moderate risk, and Zone II (in blue) is the area of low risk. There is no Zone I (no risk), because all of India is at some risk of earthquakes. Very strong, destructive shaking is expected in Zones IV and V, with more moderate but damaging shaking expected in Zone III, and mildly damaging shaking expected in Zone II.

Use this map or the more detailed maps for each state found in the Vulnerability Atlas of India, available from the Building Materials & Technology Promotion Council (BMTPC), to determine in which zone your hospital is located. The BMTPC website (http://www.bmtpc.org/disasterandmitigation.htm) also contains detailed maps that you can freely view and download.

The map shows that northern India along the Himalayas, the Northeast, parts of Gujarat, and the Andaman and Nicobar Islands are the areas most at-risk for earthquakes. The reason for this is that the Indian and Eurasian tectonic plates collide here, creating one of the world's most seismically active areas, which stretches in India alone from Kashmir to the Northeast, and down to the Andaman and Nicobar Islands. This plate collision formed the Himalayas, the world's tallest and fastest growing mountain range. As the tectonic plates collide, they flex, storing energy like a spring. When the plates' margin finally slips, then energy is released in the form of an earthquake. Earthquakes from the Himalayas can be very strong, greater than magnitude 8 in some cases, and can affect areas in India that are quite far from the Himalayan foothills. The tectonic collision in the Himalayas also causes the Indian plate to buckle, resulting in earthquakes away from the plate boundary.

What to Expect After an Earthquake

After a severe earthquake, people in an unprepared community will be in a state of shock and won't be able to function normally. People will probably have been killed, and a much larger number will be injured and seeking immediate medical assistance at your hospital. Their injuries will vary from minor to severe, and those trapped in the debris and rescued will be likely to have suffered crush injuries, which require special attention. The affected population will also need psychosocial support/psychiatric help.

Inside the hospital facility, doctors, hospital staff and patients might be injured and/or trapped and will require medical attention themselves. To make matters worse, your hospital will probably have a shortage of staff – some might be killed, others might be injured, and some might be trapped within collapsed buildings. Hospital employees will want to ensure the safety of their own family members and might consider rushing home. Those at home may have difficulty getting to the hospital because of damaged roads and bridges, or streets blocked by debris. The hospital might suffer significant damage directly from the earthquake or indirectly, through fires or flooding. Medical equipment might be damaged and stop working. The power will almost certainly fail. Medical supplies might fall and become unusable, or the stock of the supplies might not be adequate to meet the post-earthquake needs.

Communications will be interrupted. Cell phones will stop working. Aftershocks might cause even more destruction. Evacuations might be necessary, making it difficult to keep records of patients and their conditions. Damage to roads and bridges might make it especially difficult for emergency responders and relief supplies to reach the hospital.

The level of your hospital's preparedness will determine how severe the consequences will be. If your hospital is prepared, then much of the damage will be prevented, backup power will keep most medical equipment functioning, and prepared employees will remain calm and know how to react. If you aren't prepared, then your hospital will find itself in crisis, rather than responding to the needs of the community.

How to Manage Your Hospital's Earthquake Risk

Managing a hospital's earthquake risk can be overwhelming. However, if done incrementally and carefully, it is something that any hospital can accomplish. In fact, managing your hospital's risk is not a one-time event but something that requires periodic assessments.

Here are some simple steps that can help you to get started:

Set up a Hospital Emergency Preparedness Committee

Forming an emergency preparedness committee is essential to ensure that your hospital will be prepared for earthquakes and other disasters and to continue risk reduction activities in the future. To avoid confusion and duplication of efforts, you should have one committee responsible for planning for all of the hazards that the hospital faces. The committee should develop a basic response plan with sections that deal with the specifics of each hazard response. The committee can have subcommittees for earthquakes, fires, floods, and any other hazard that the hospital faces, or the whole committee can address each hazard in turn. This committee should represent various functioning units of the hospital and should include a representative from each of the following groups or departments: hospital administrators, nurses (including the chief nursing officer), doctors, engineering/maintenance, security, transport, pharmacy, central supply, and environmental services. The members of the committee should develop Standard Operating Procedures (SOPs), assign specific duties and meet periodically to discuss issues and progress. The committee should also prioritize mitigation activities, develop emergency plans, and organize evacuation drills. The committee should coordinate the hospital's plan with disaster response plans for the city or district.

Conduct a Hazard Hunt

Identify hazards in your hospital by conducting a hazard hunt. This activity involves walking through your hospital and determining which objects might fall and/or fail in an earthquake. Note objects that are located close to patients' beds and to staff office desks, as well as objects that might block an exit. For example, bookshelves along a corridor leading to an exit are a hazard, since they might topple and block the exit. See Appendix A for a checklist to use during your hazard hunt.

Determine How to Fix Each Hazard

The two main options for fixing a hazard are:

1. **Relocate.**

Some hazards are eliminated simply by relocating furniture, contents and equipment. For example, furniture can be placed so that it would not block an exit, if it were to tip over during an earthquake.

2. **Anchor/Brace/Secure.**

Although relocating objects can eliminate many hazards, some objects present a hazard regardless of their location and must be secured, in order to prevent damage. To fix those hazards, you can:

- ***Do It Yourself.*** Many furnishings and contents can be secured without the need to consult an engineer. For example, with the help of this manual, anyone can anchor a bookshelf or secure medical contents to keep them from falling and possibly hurting someone. Another easy example would be to place heavy objects closer to the ground. As an alternative, a handyman can also easily anchor items labeled in this manual as Do It Yourself.

- ***Consult an Engineer.*** You will need to consult an engineer to determine how to anchor and brace objects heavier than 100 kilograms, sensitive medical equipment, containers of hazardous materials, and building utility systems. Most of the typical heavy equipment found in hospitals is covered by this manual, which provides pre-engineered solutions for some of the equipment. Your hospital's facilities engineers can use this manual and the documents that it references to fix many of these typical hazards. Certain equipment and systems, such as lifts, will require consultation with an external engineer with specialized expertise. The following are examples of when you will need to consult an engineer:

  - Anchoring/bracing objects that are heavier than 100 kilograms.
  - Hazards that reoccur throughout the hospital. A good example would be window-mounted coolers that need to be anchored. This type of hazard would require a customized solution.
  - Sensitive medical equipment, such as imaging equipment. You will need to consult the equipment manufacturer, in addition to an engineer. Many manufacturers provide guidance on how to seismically anchor their products.

- Containers of and supply lines for hazardous materials, such as medical gas pipes.
- Battery packs for essential machinery. For example, the batteries for the emergency generator need to be properly anchored.
- Lifts. Lift systems are among the most complicated systems to protect against earthquake damage. You will need to consult a structural engineering specialist with experience in designing earthquake retrofit measures specifically for lift systems.
- Large architectural features. These would include stairways, sunshades and brick partitions.

The section on Anchoring and Bracing Information for Specific Objects identifies options for fixing hazards and the level of expertise required to implement the different solutions.

Estimate the Cost

The cost of fixing hazards varies significantly. The cost depends mostly on the level of expertise needed and the specific device used to fix the hazard, as well as the costs of materials and hardware in your area. For a summary of devices, see Appendix B.

Determine Possible Consequences for Each Hazard

For each hazard that you find, determine the worst consequence that it can cause: in the worse case scenario, could that hazard cause loss of life, loss of function, or loss of property/money? Important questions to keep in mind include:

- Would it seriously hurt someone?
- Would it interrupt life support?
- Would it risk a patient's health?
- Would it prevent the use of the emergency room and the operating room?

Refer to the pages for each object in the section Anchoring and Bracing Information for Specific Objects for more information on the consequences of a specific failure.

Prioritize Your Hazard Reduction Activities

The list of mitigation activities might seem overwhelming. Understanding how to prioritize activities is important in managing the work. If your hospital has a limited budget, then start with the hazards that are the most inexpensive within the critical safety category below. If the budget allows, then make it a goal to brace all of the objects in one of the following categories, depending on what is reasonable for your hospital's conditions. Assuming that your buildings suffer only minor damage, then bracing all of the objects in that category will allow your facility to achieve that level of performance.

- **Critical Safety** Objects and systems most critical to life safety and to allowing for evacuation are properly secured. This includes securing objects that might fall and kill/injure people, objects whose failure would interrupt life support, and objects that might obstruct exits. Objects that should be secured in order to achieve the critical safety level of performance are indicated in the manual by a red box around the title.

- **Essential Services** Critical Safety requirements are met. In addition, objects in critical care areas are properly secured. A hospital in this category is expected to be able to care for its existing critical patients in place after the earthquake and to provide emergency care for earthquake victims. Objects that should be secured in order to achieve the essential services level of performance are indicated in the manual by an amber box around the title.

- **Continuous Service** Essential Services requirements are met. All other hazards are properly secured, including expensive equipment that would be costly to replace. The hospital can provide care to existing patients in place and can admit earthquake victims if needed. Objects that should be secured in order to achieve the continuous service level of performance are indicated in the manual by a green box around the title.

Implement

Implementing hazard reduction activities is a gradual process and is best managed when a good plan is set from the beginning. Even small activities can have a life-saving effect during an earthquake. As mentioned previously, it is recommended that you form an earthquake safety committee and give the committee the responsibility of overseeing and managing long-term hazard reduction activities. The most important thing to keep in mind is that simply starting helps to reduce your community's earthquake hazard.


MEDISERVE
MEDIVOLS
6
NICU
6.1.07

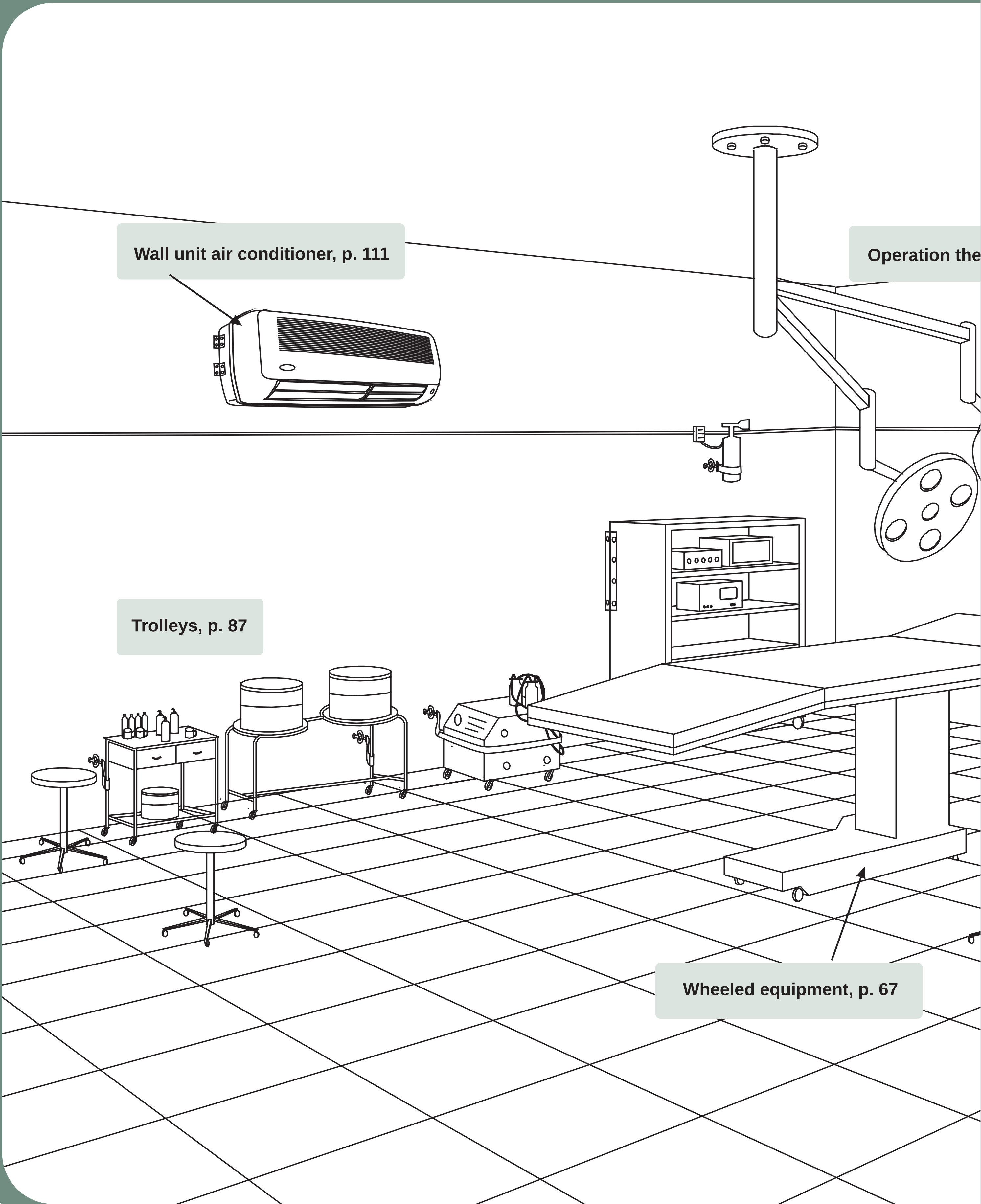
Where to Find Information about Specific Objects

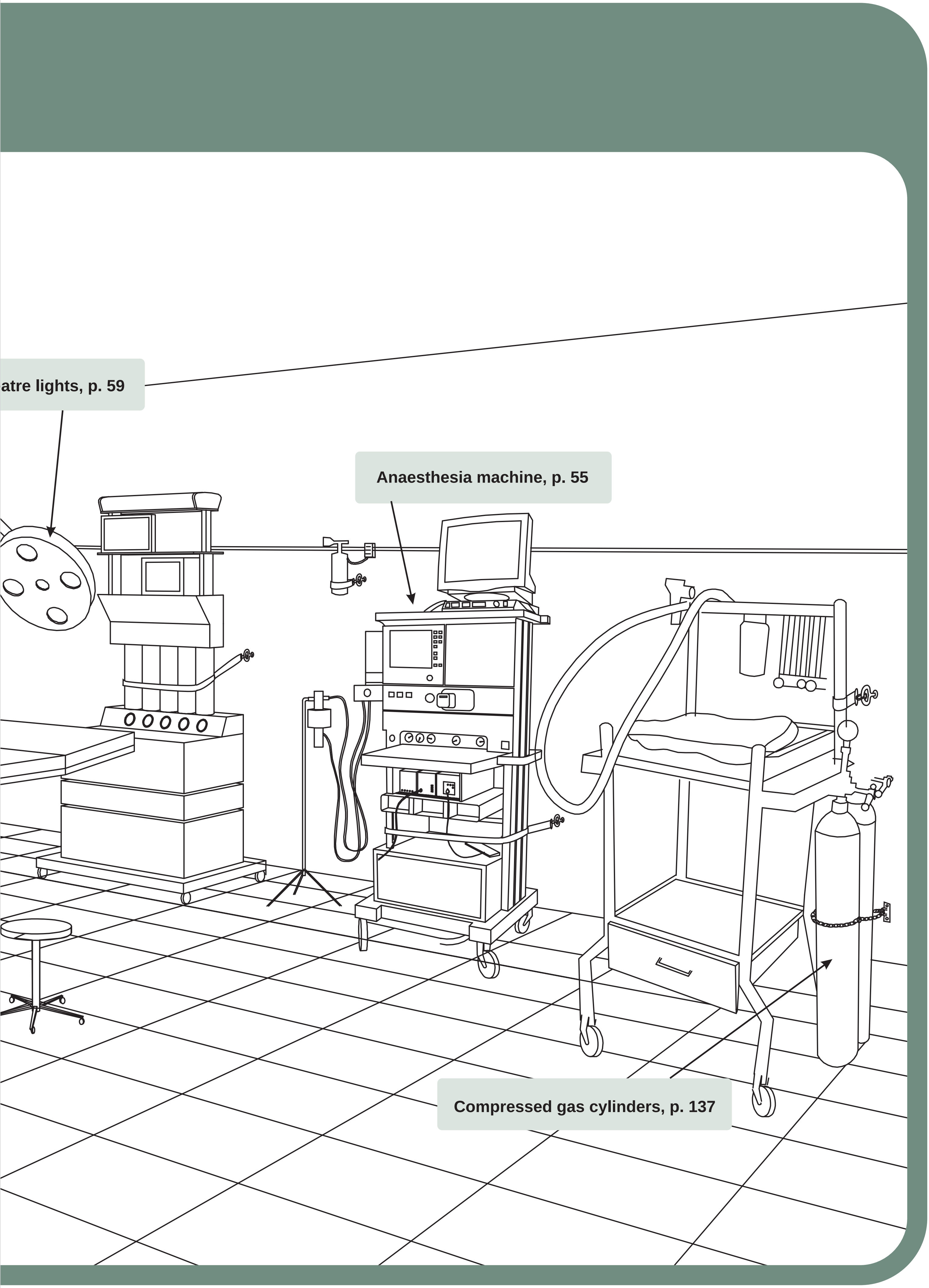
The following pages show major rooms in the hospital and the typical objects found in each one that can pose a hazard. For each object, there is a reference to the pages where you can find more information about what could happen to that object during an earthquake (and to the hospital, as a result), and how you can anchor or brace the object, in order to keep that from happening.

Objects Typically Found in Major Rooms:

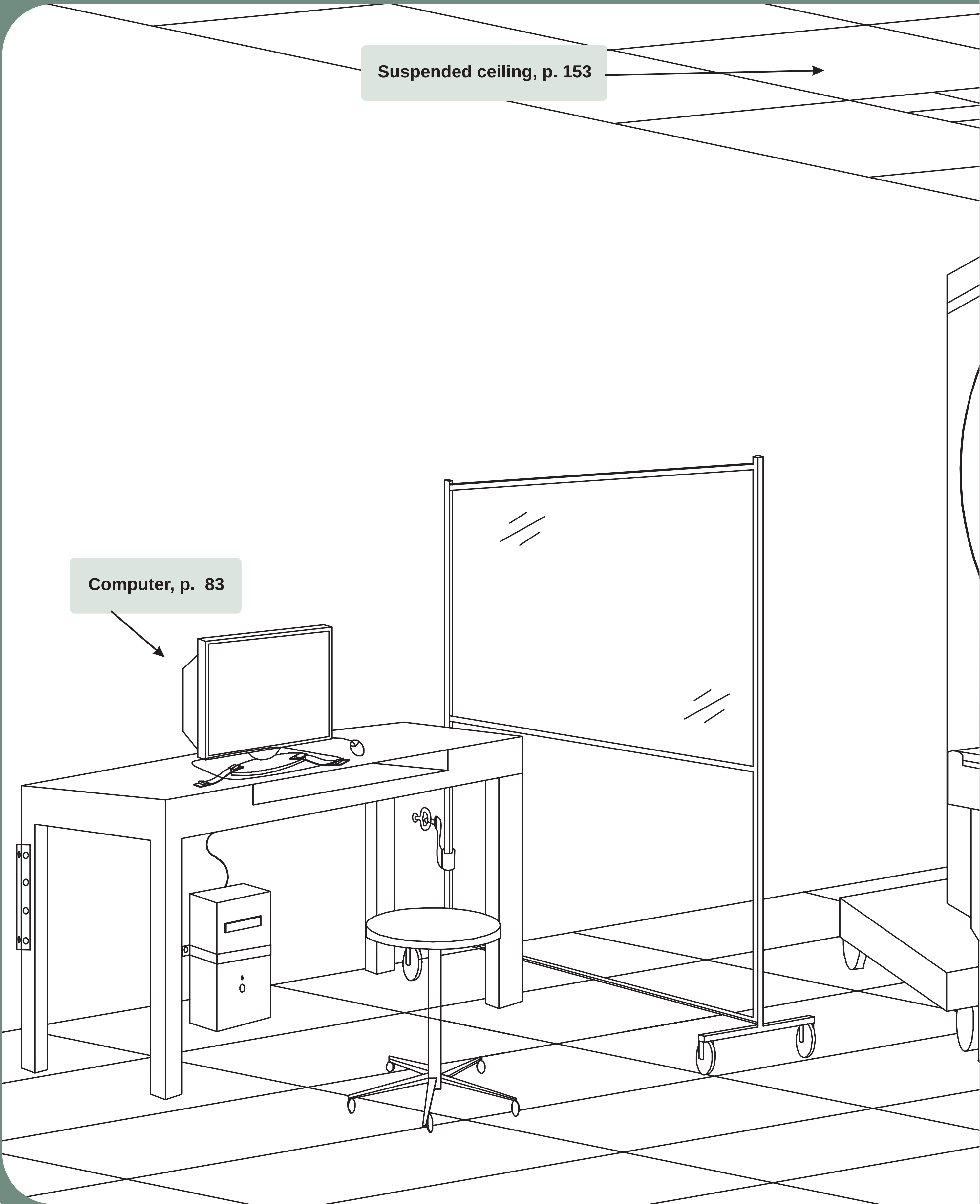
Following the drawings of typical rooms, potentially hazardous or fragile objects are organized into separate sections by type:

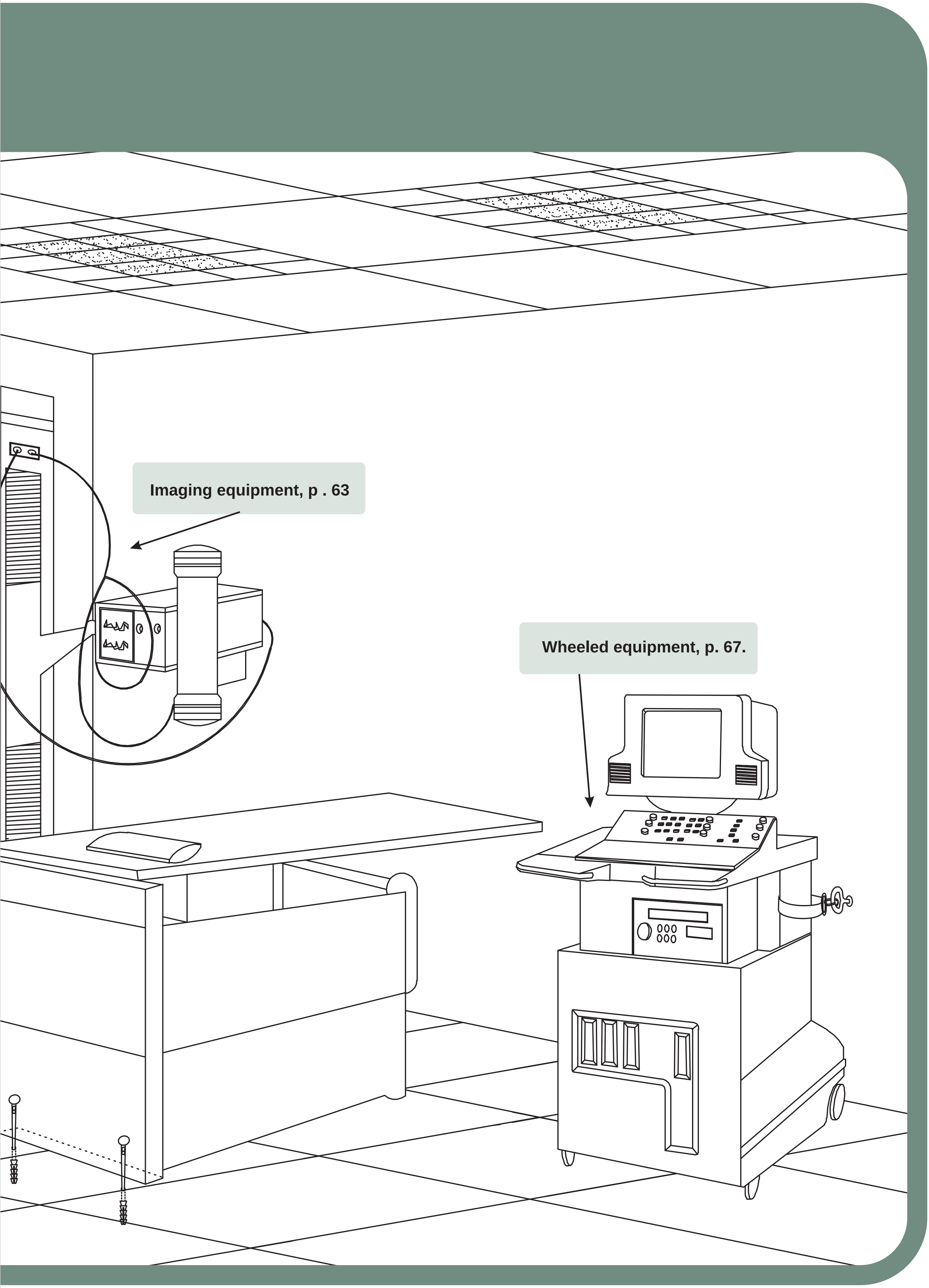
Operation Theatre



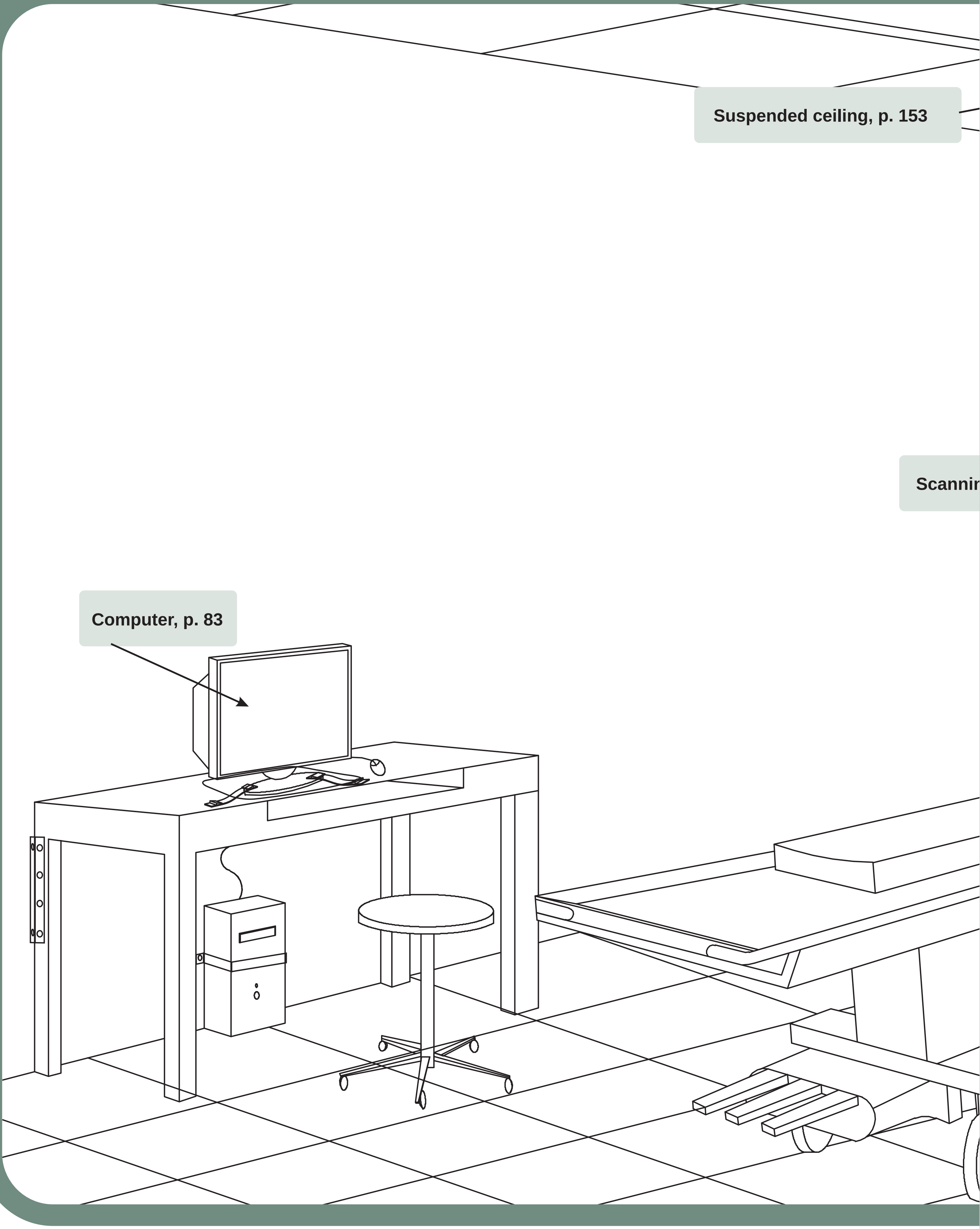

atre lights, p. 59
Anaesthesia machine, p. 55
Compressed gas cylinders, p. 137

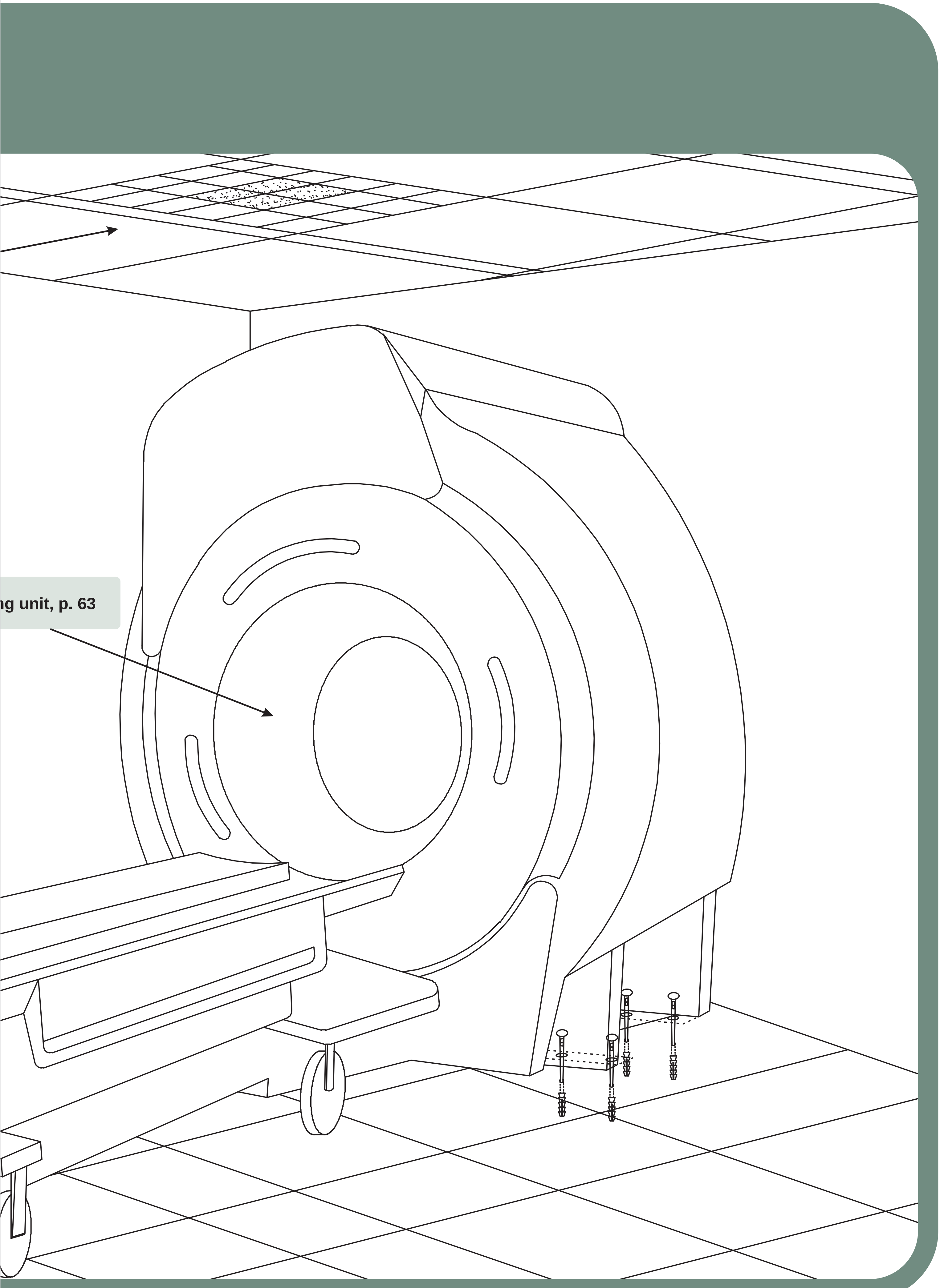
Radiology Department



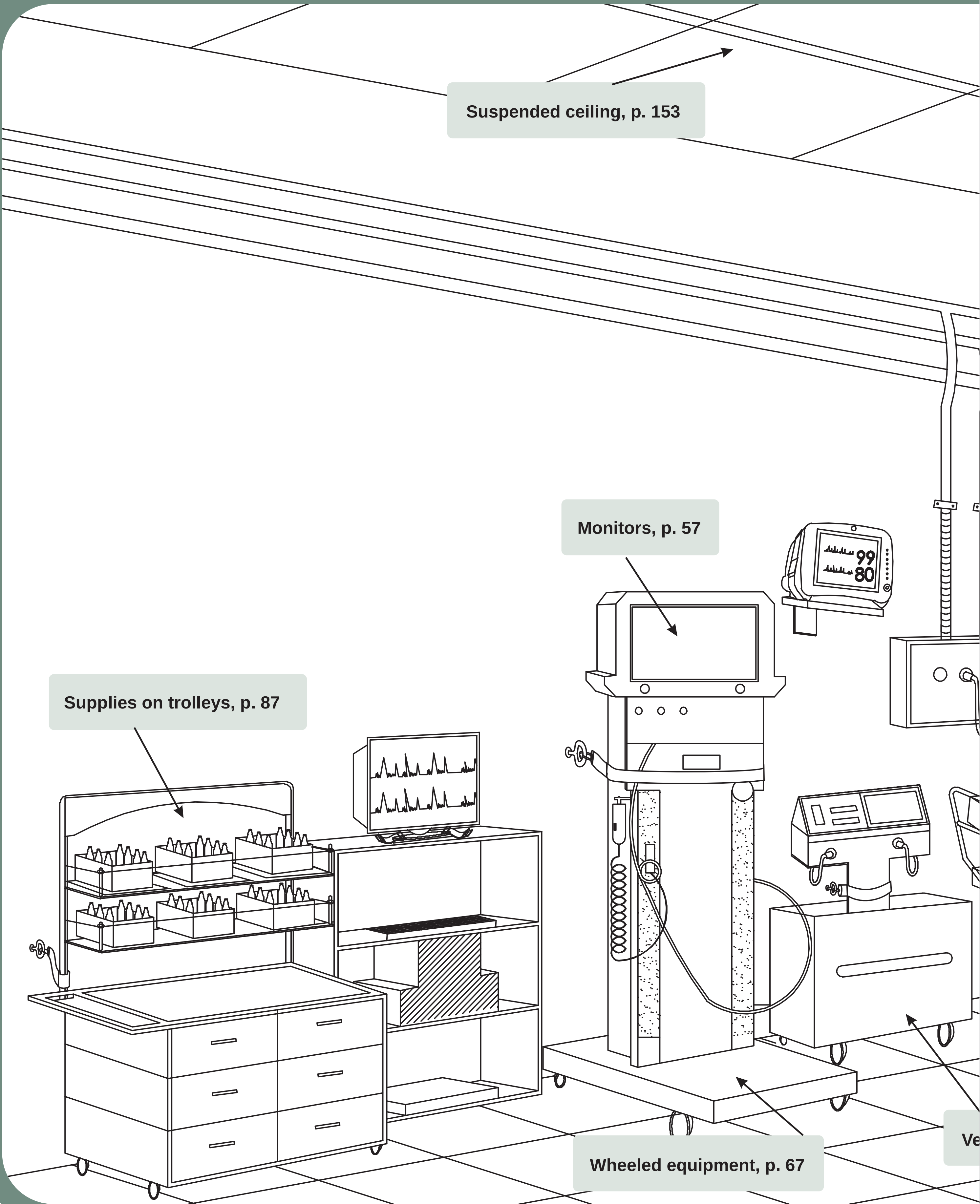

Imaging equipment, p . 63
Wheeled equipment, p. 67.

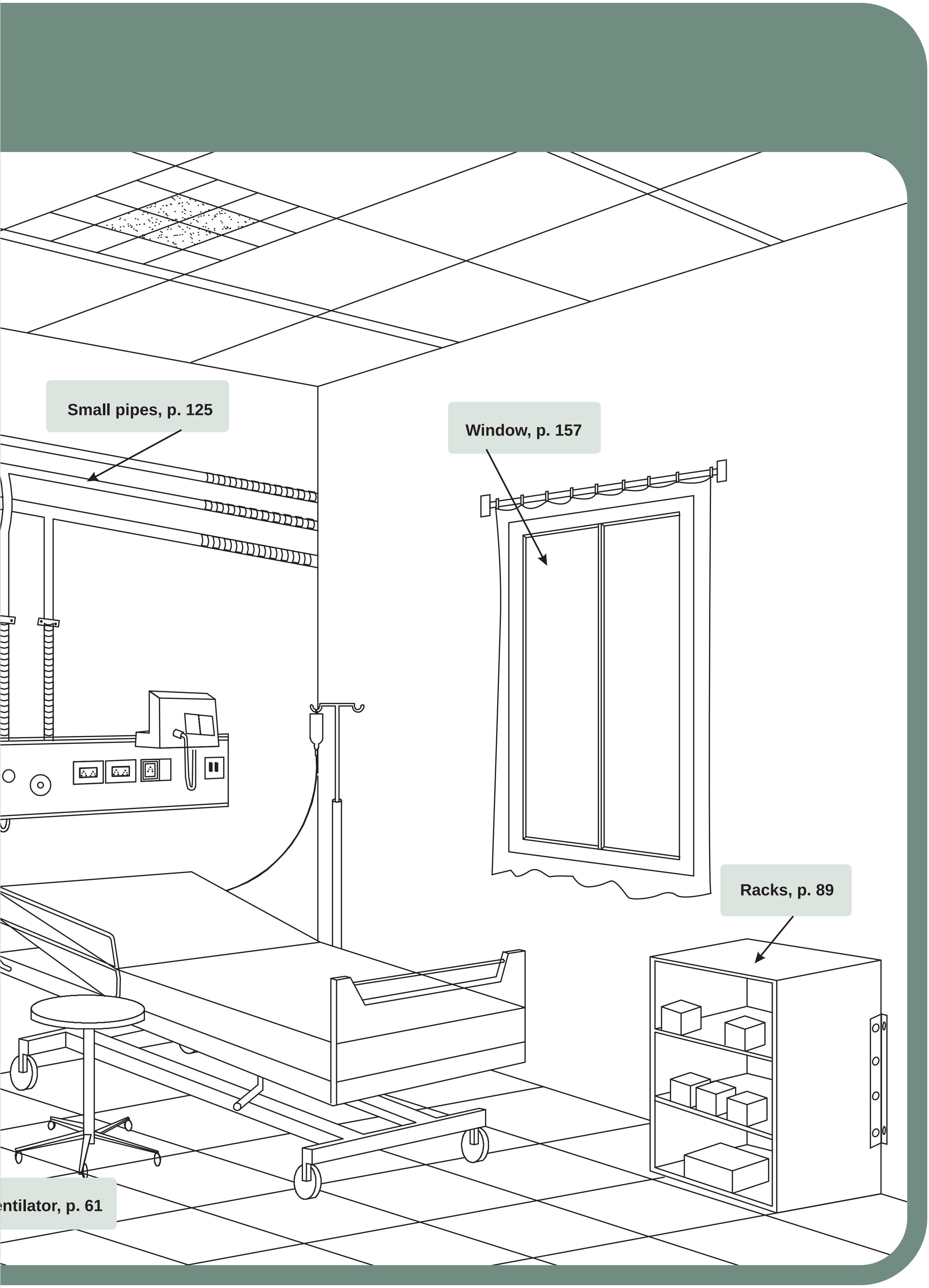
Radiology Department



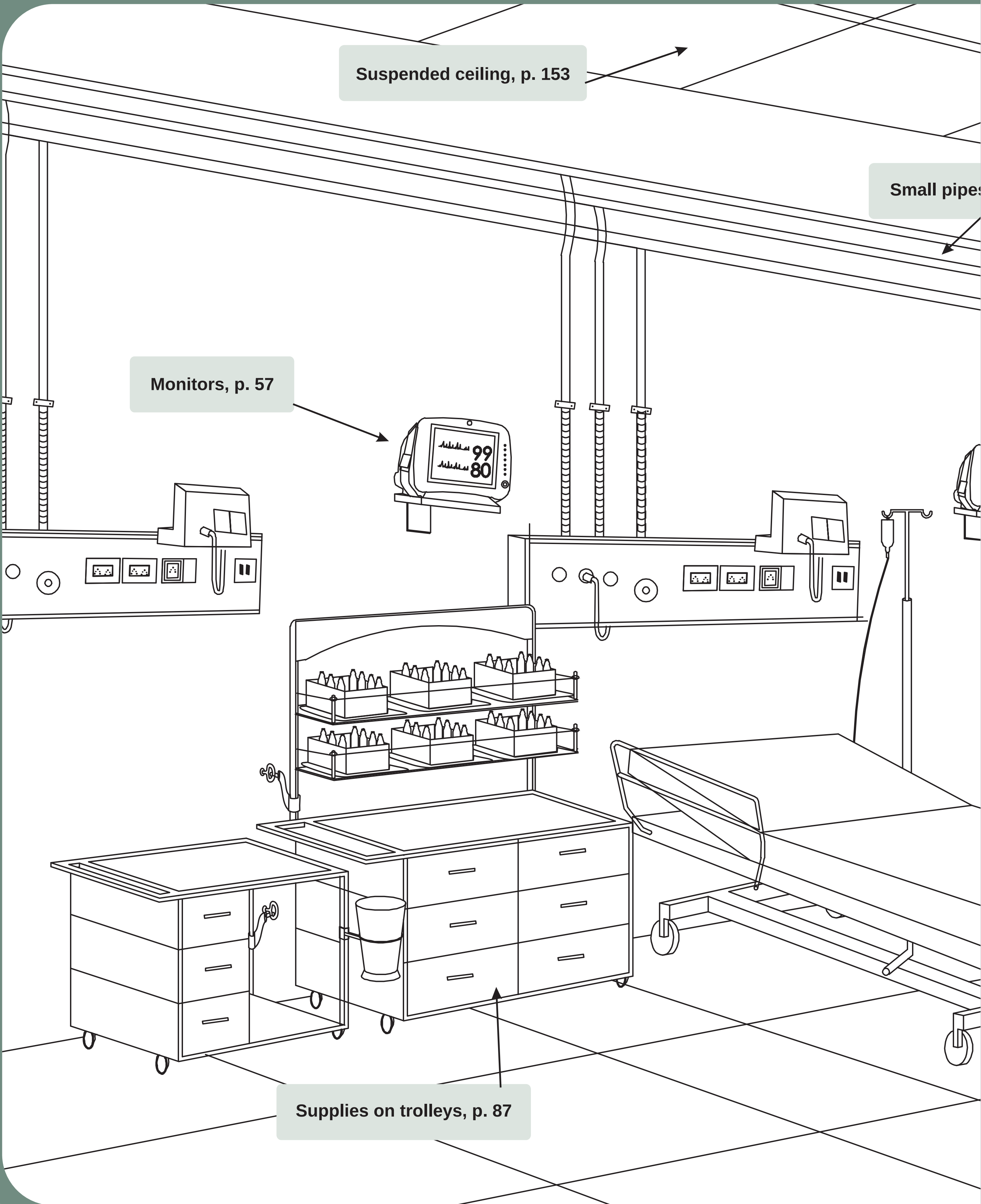

ng unit, p. 63

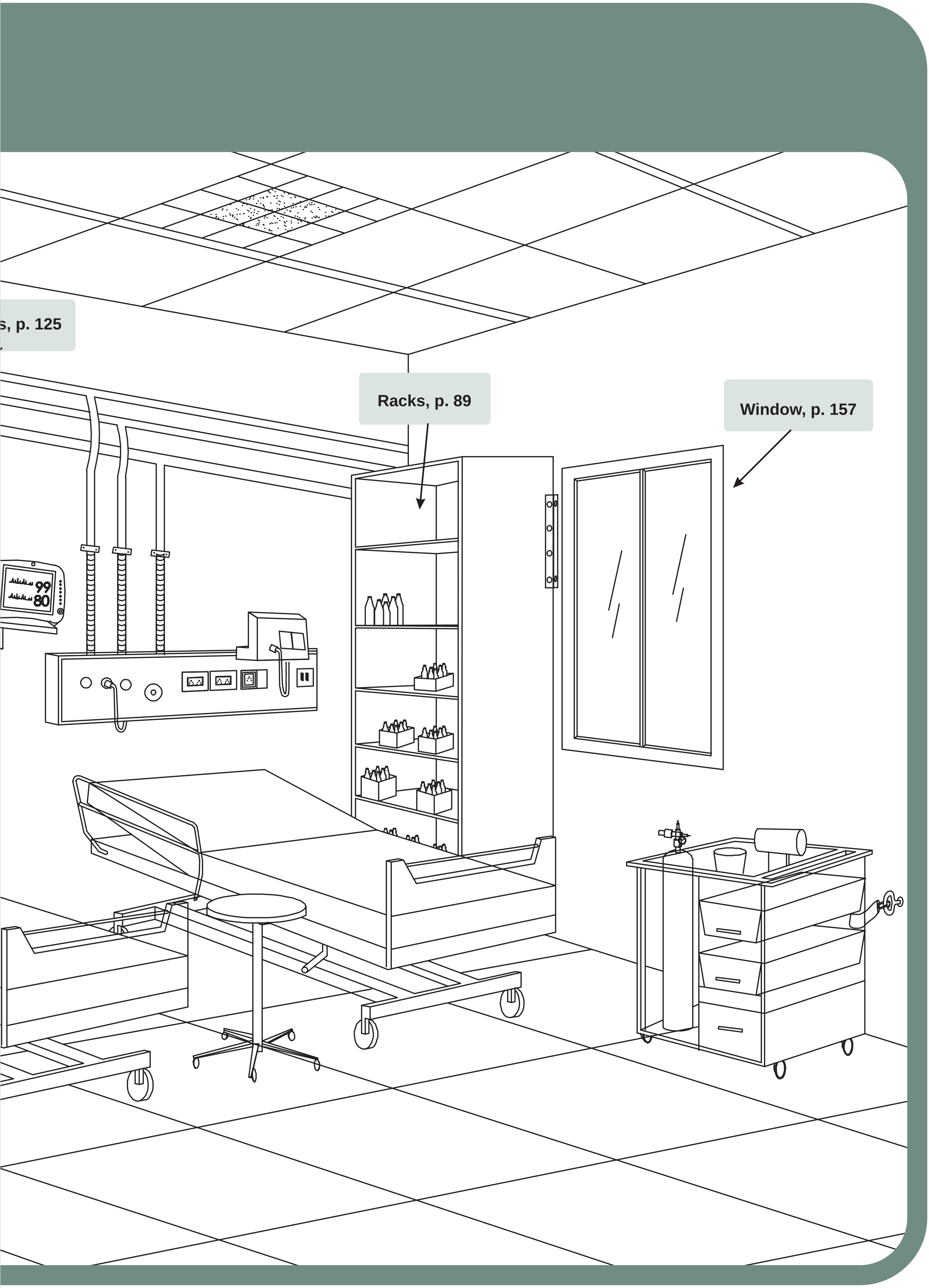
Intensive Care Unit (ICU)



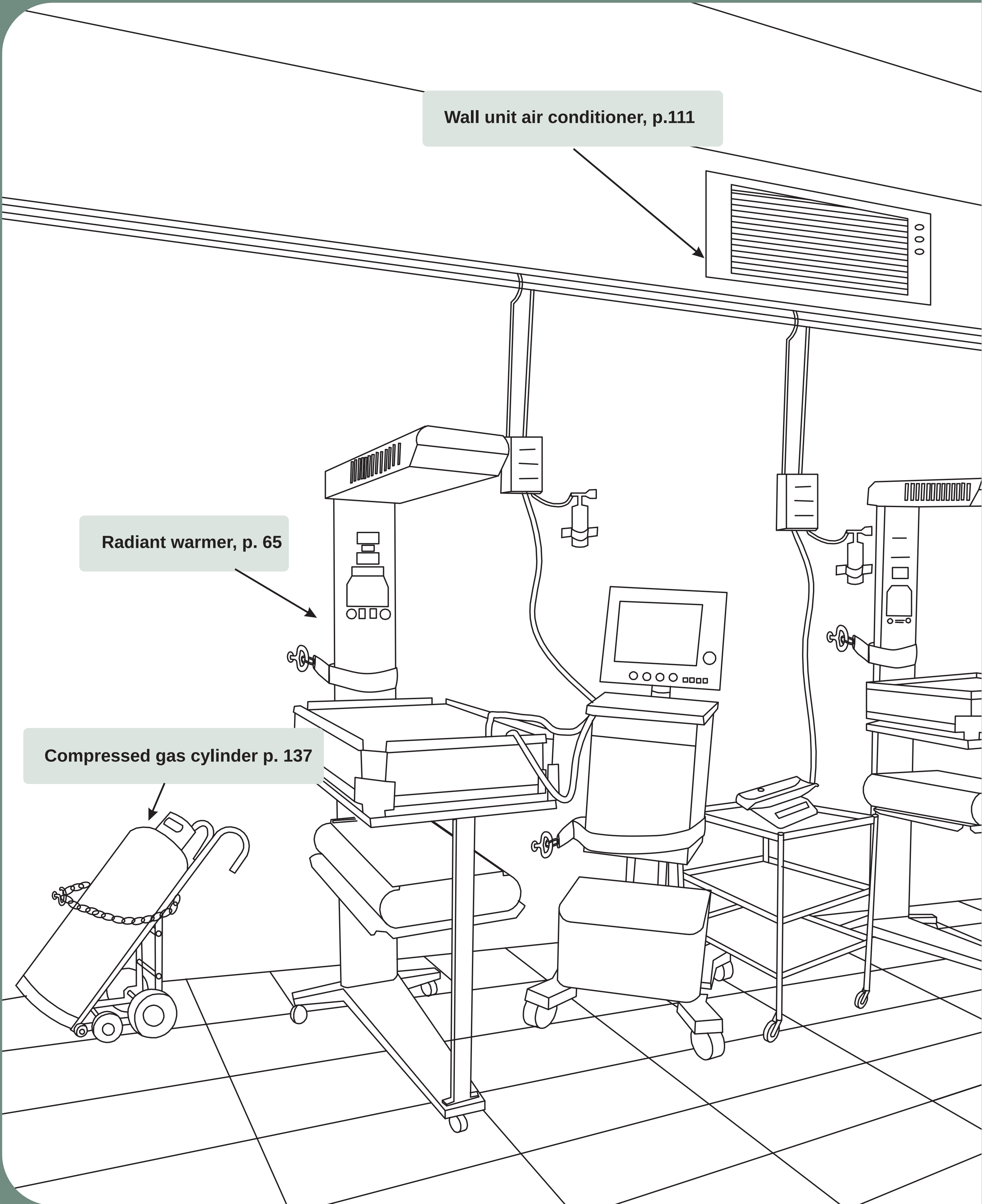

Small pipes, p. 125
Window, p. 157
Racks, p. 89
entilator, p. 61

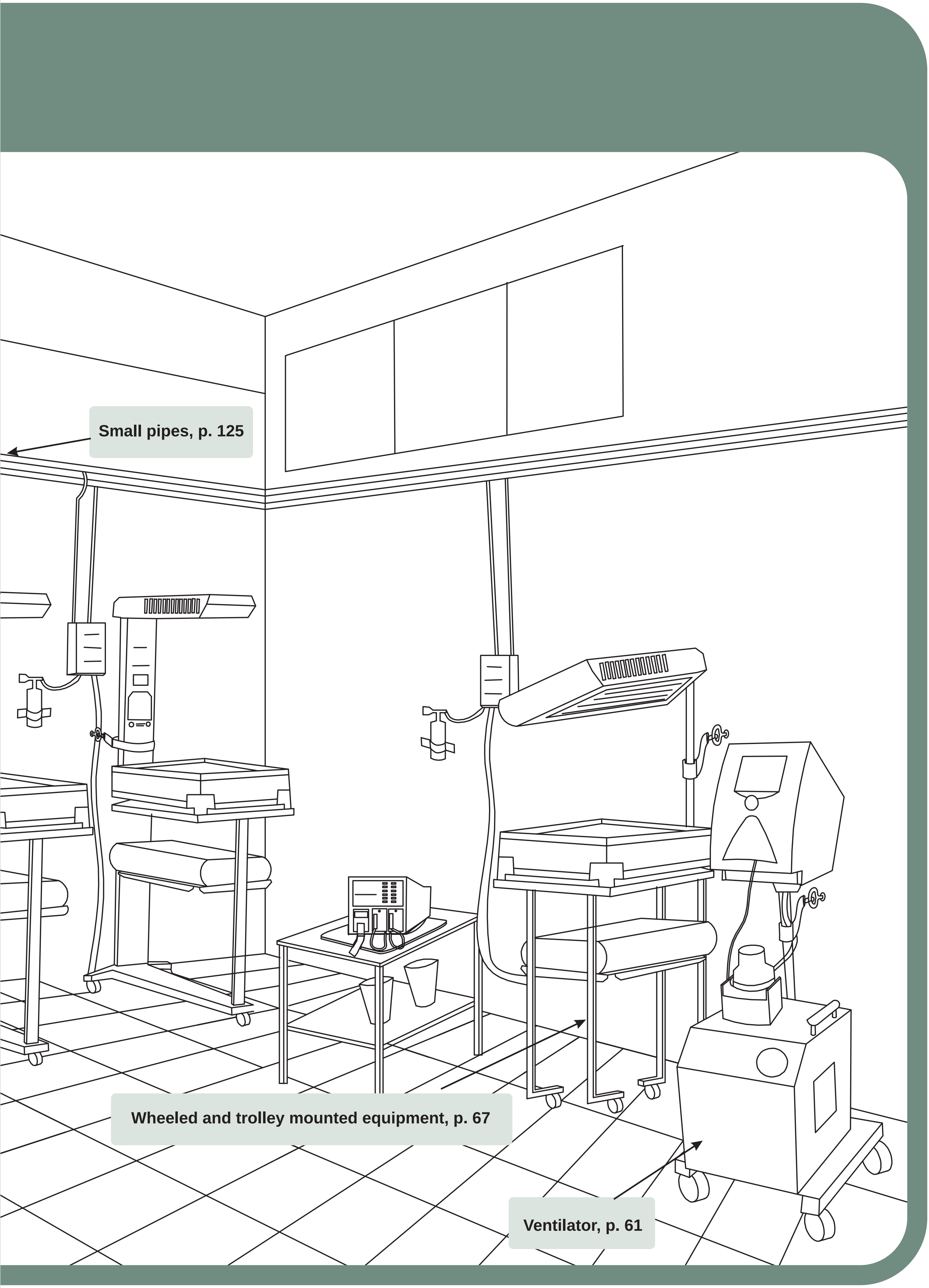
Emergency Ward



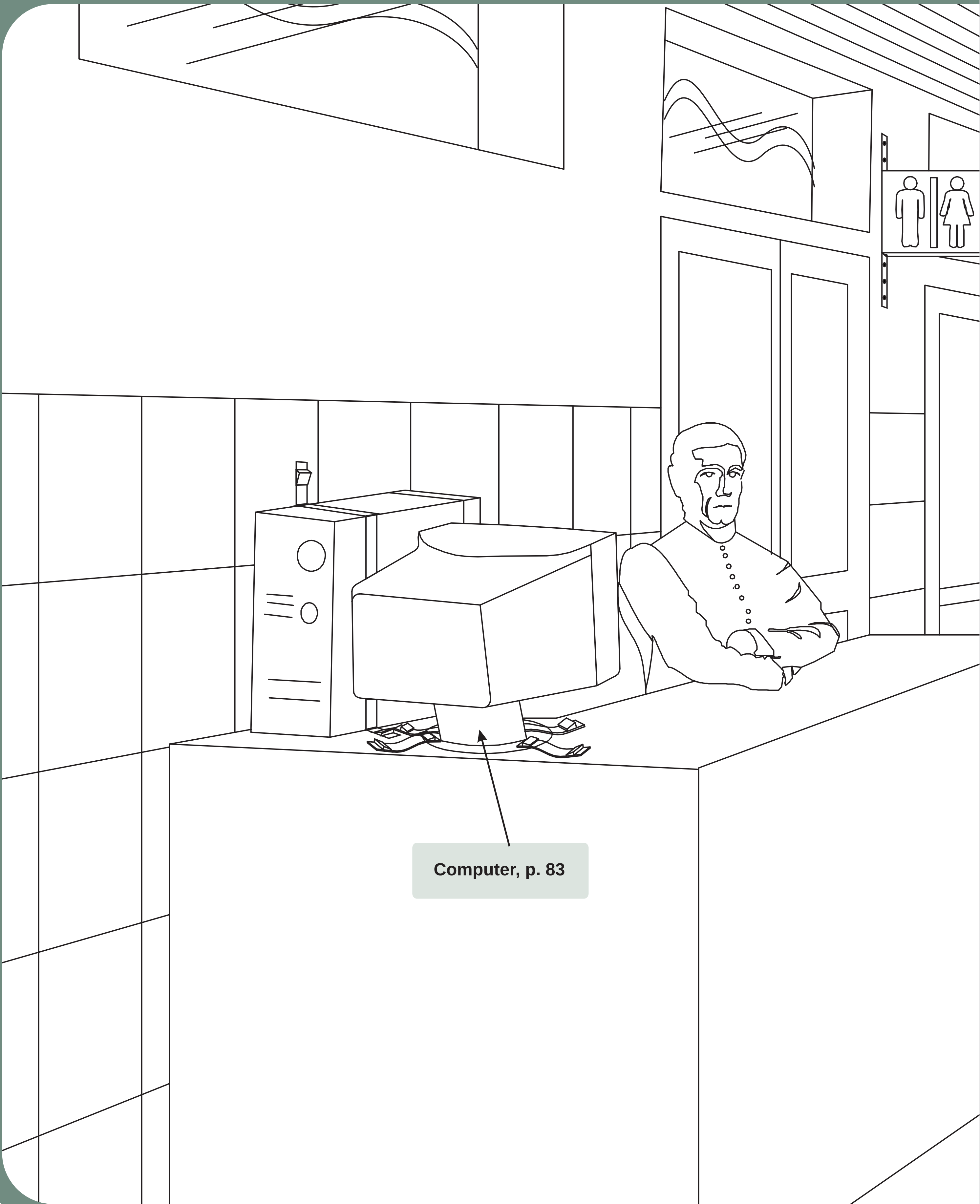

s, p. 125
Racks, p. 89
Window, p. 157
99
80

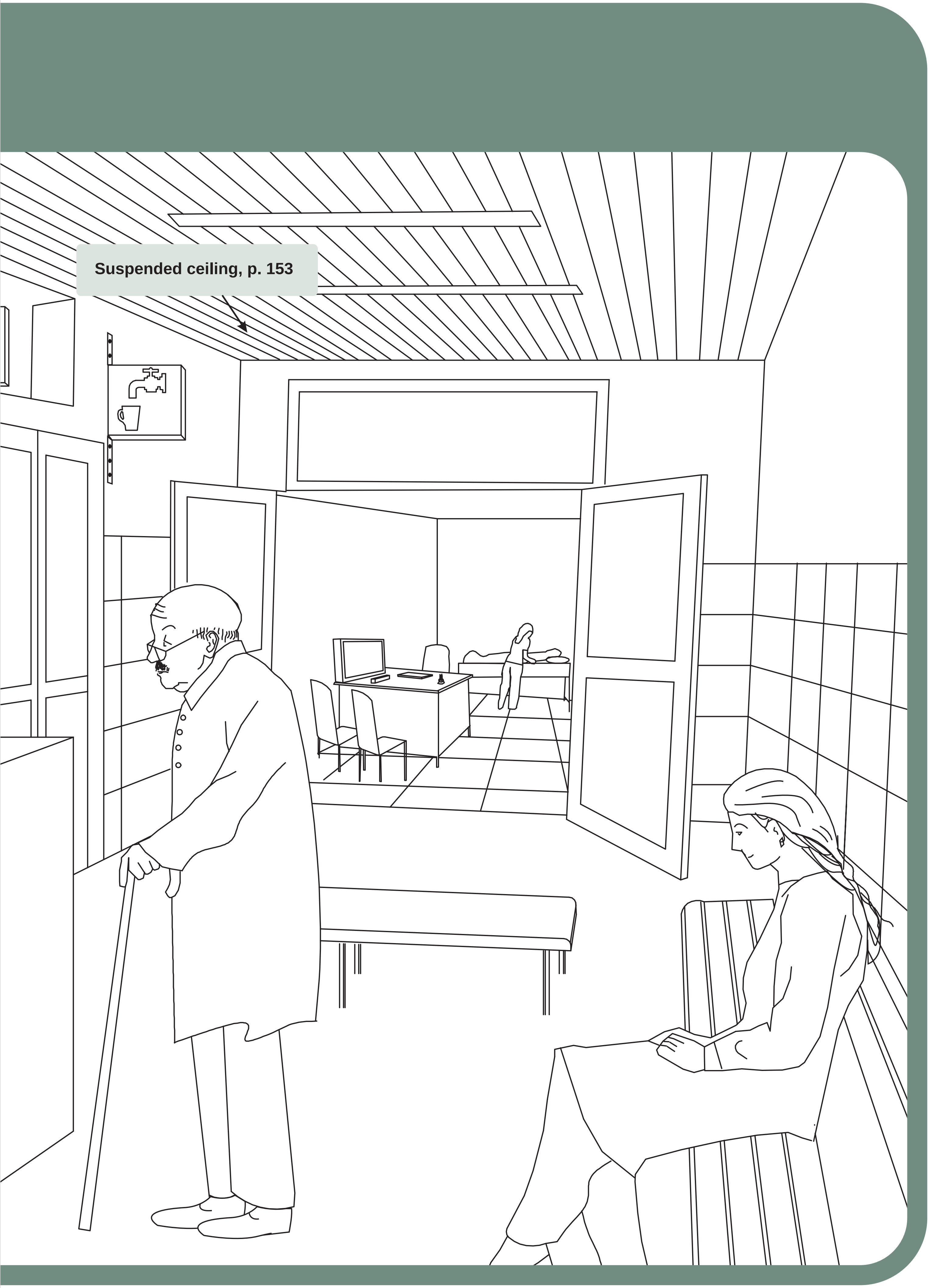
Neonatal Intensive Care Unit (NICU)



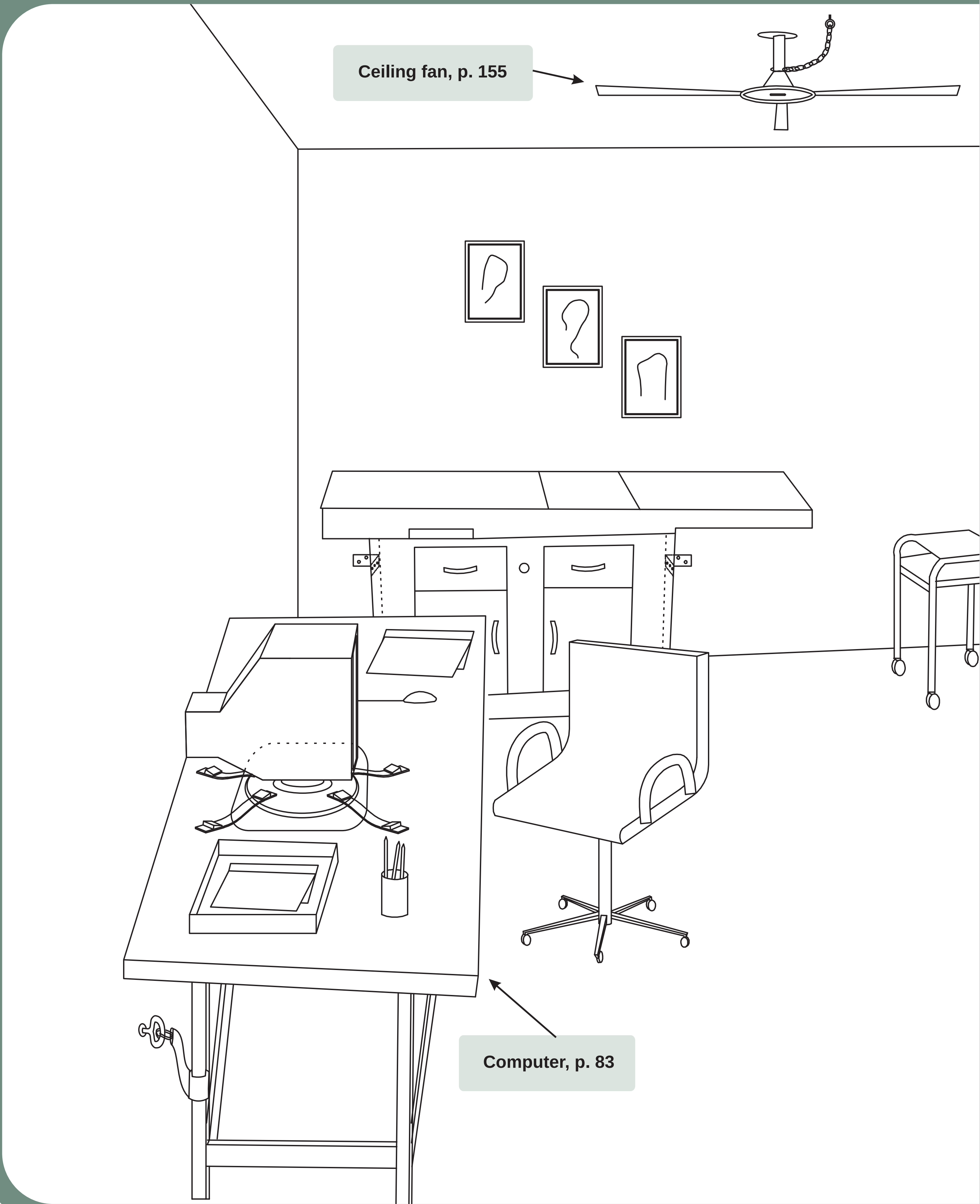

Small pipes, p. 125
Wheeled and trolley mounted equipment, p. 67
Ventilator, p. 61

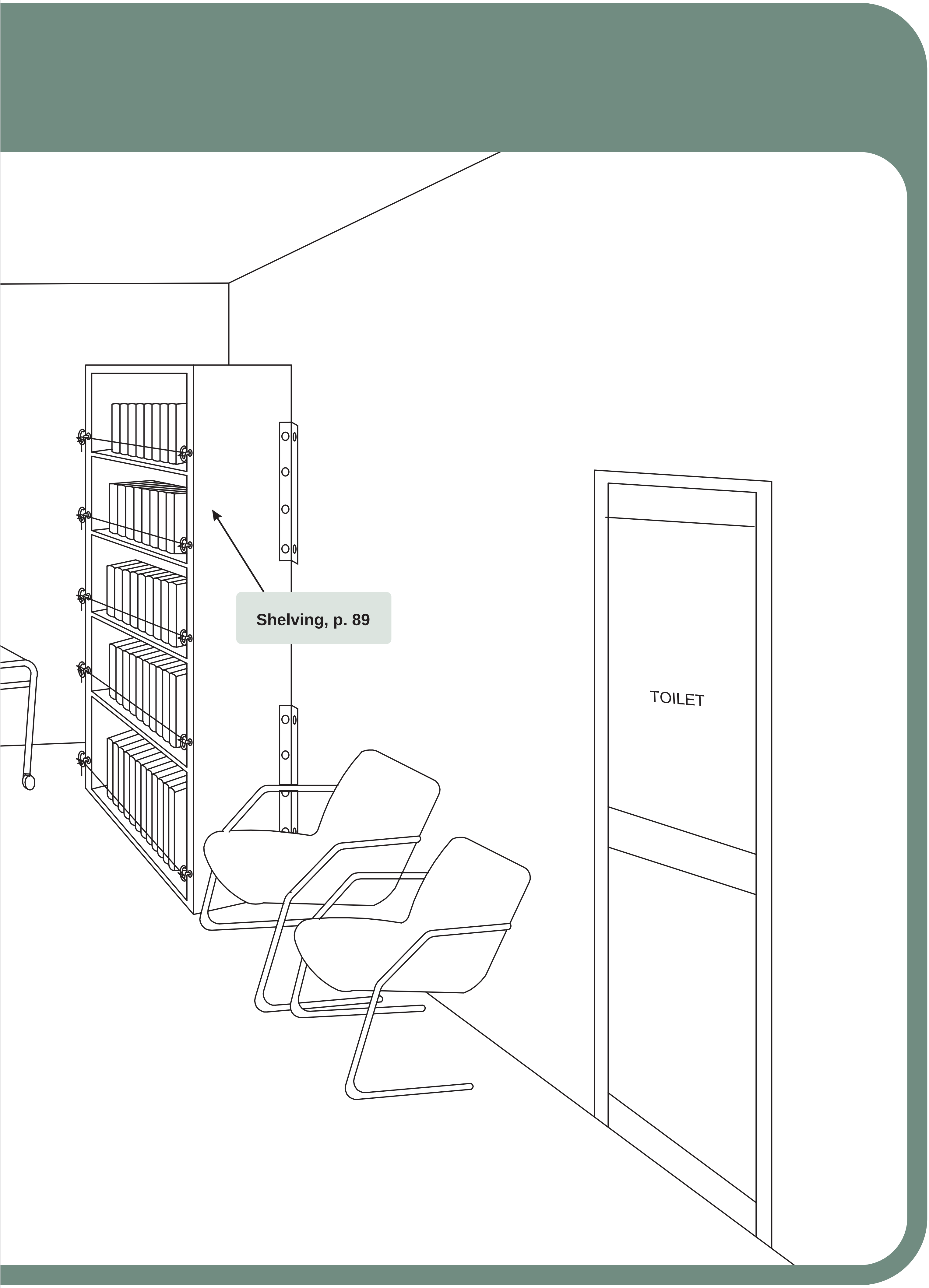
Outpatient Department (OPD)



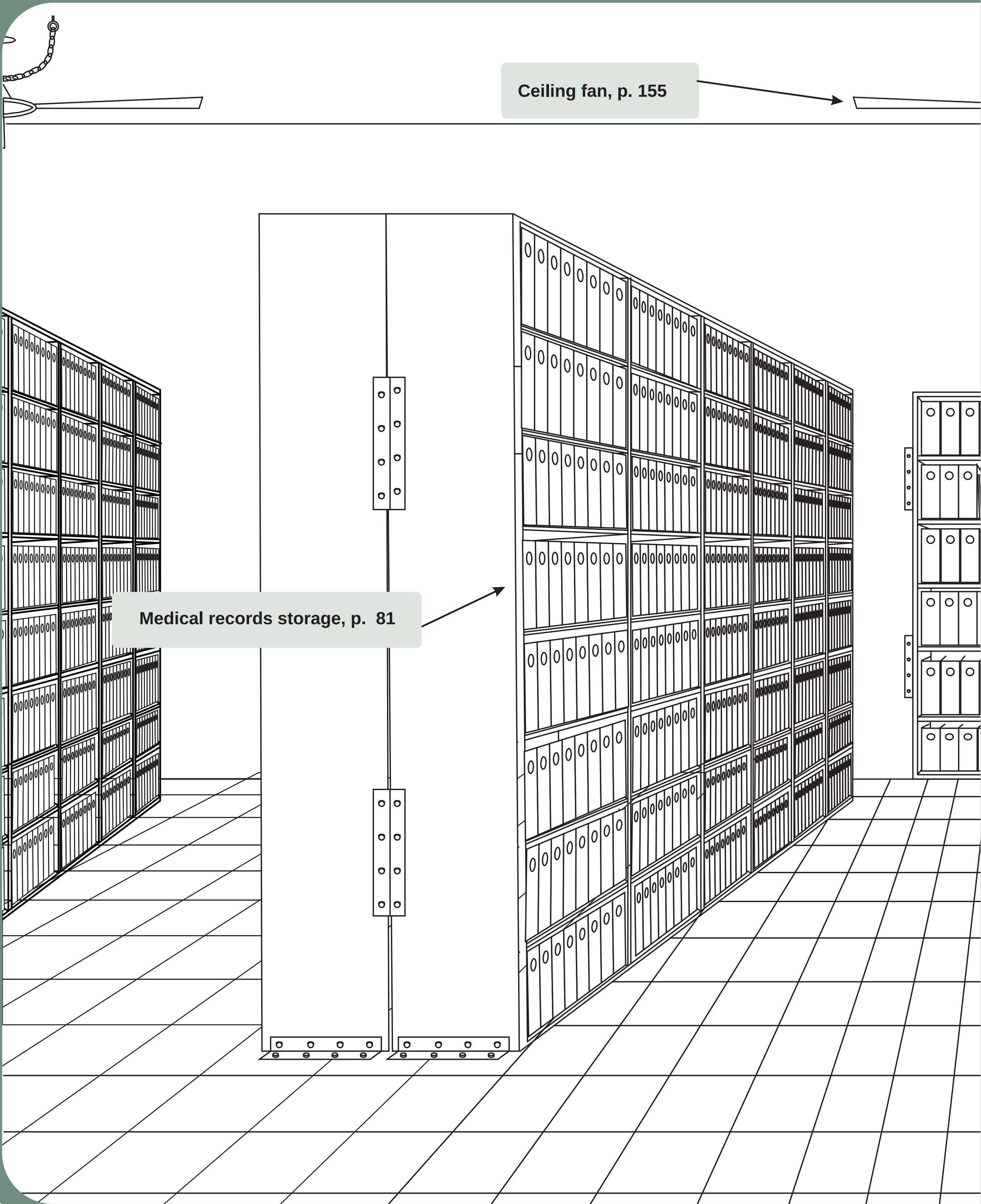

Suspended ceiling, p. 153

Doctor's Office



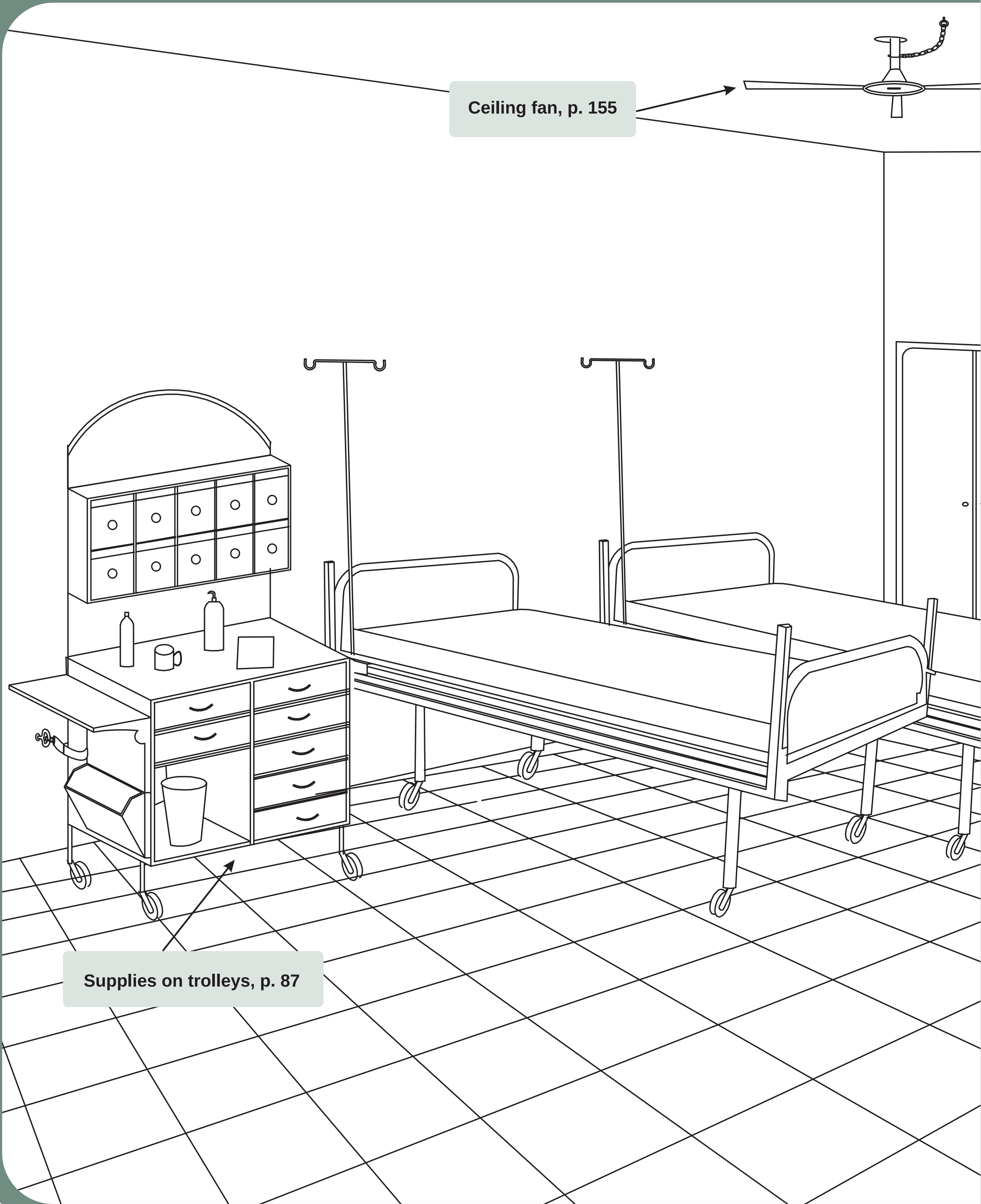

Shelving, p. 89
TOILET

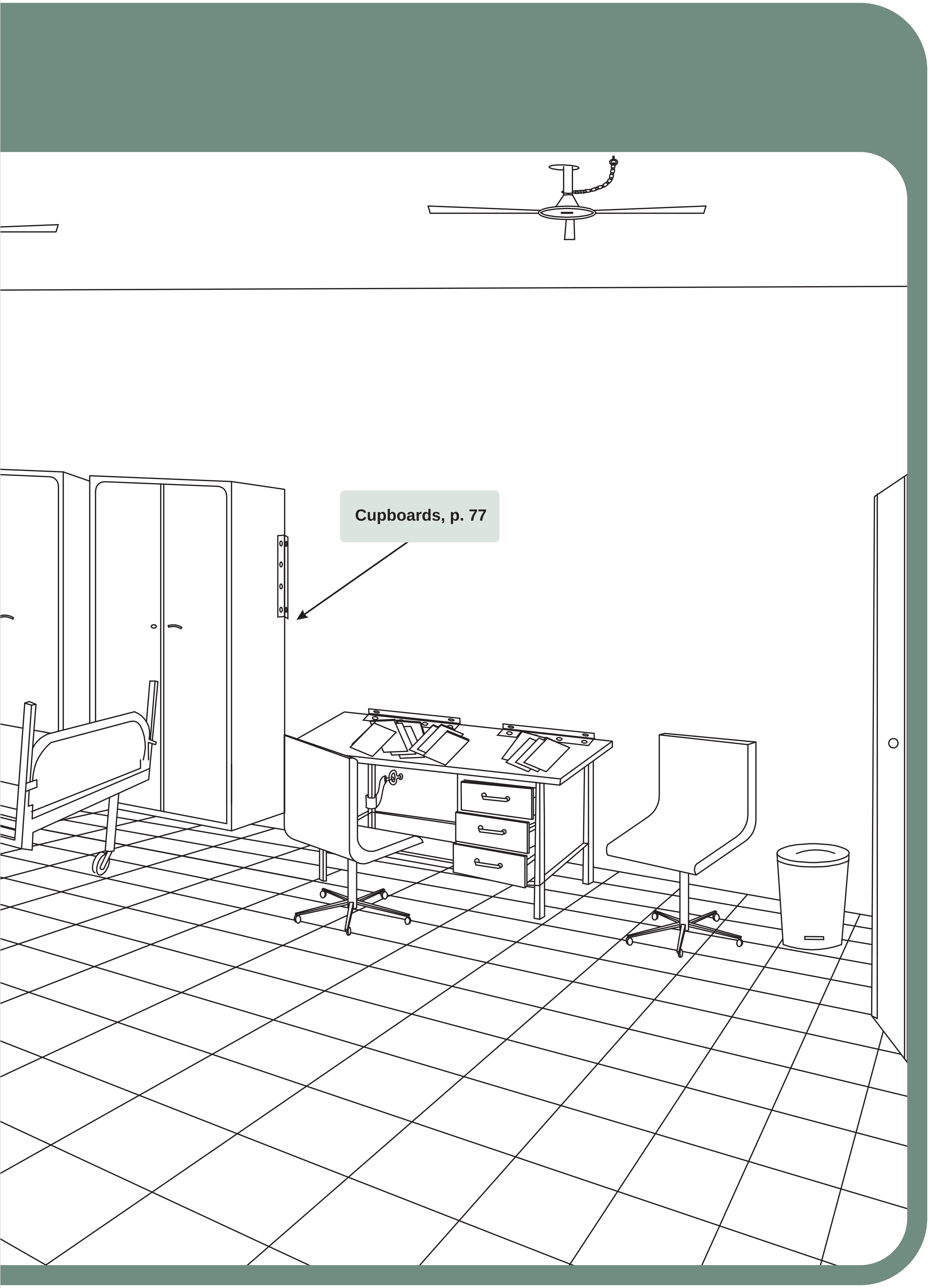
Medical Records Room



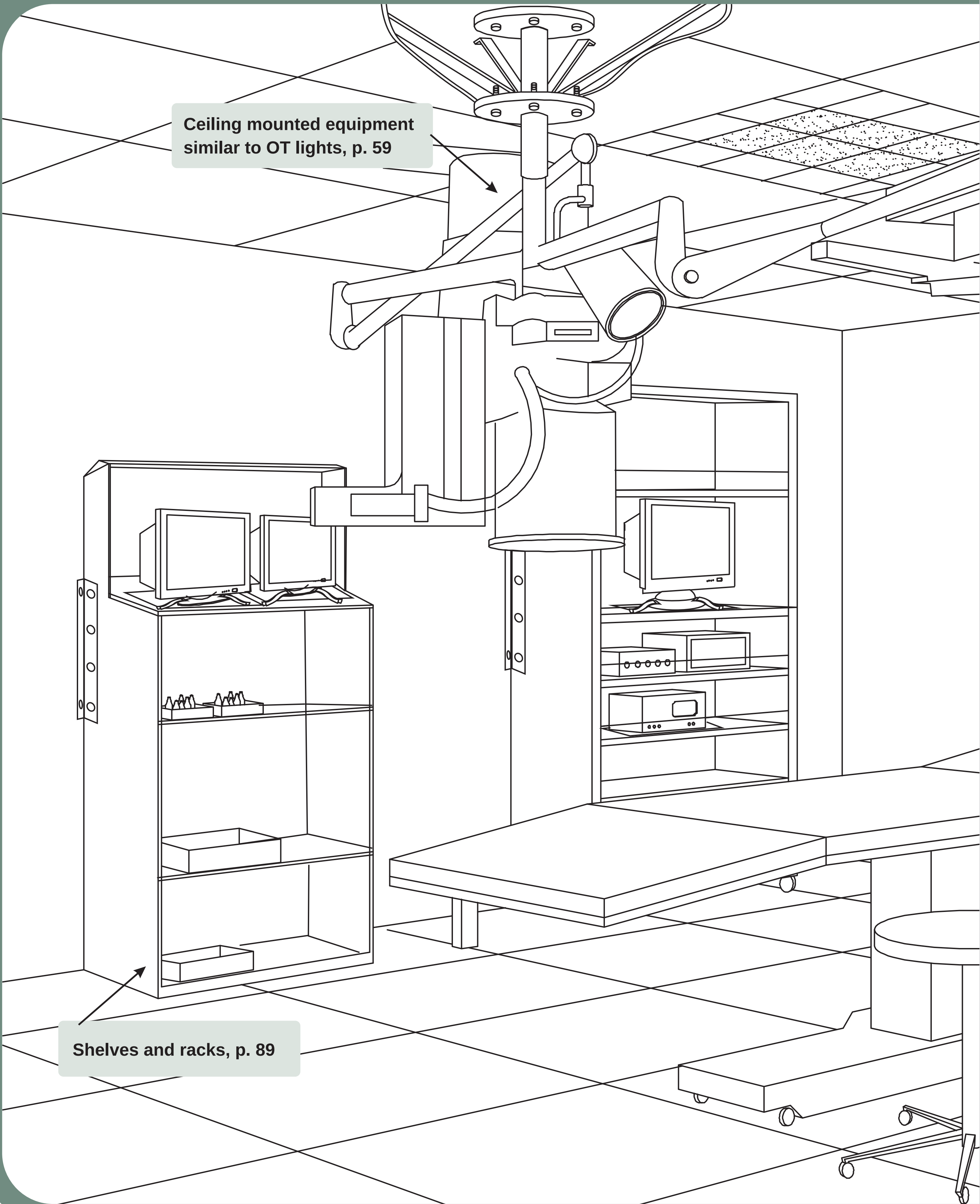

Computer p. 83

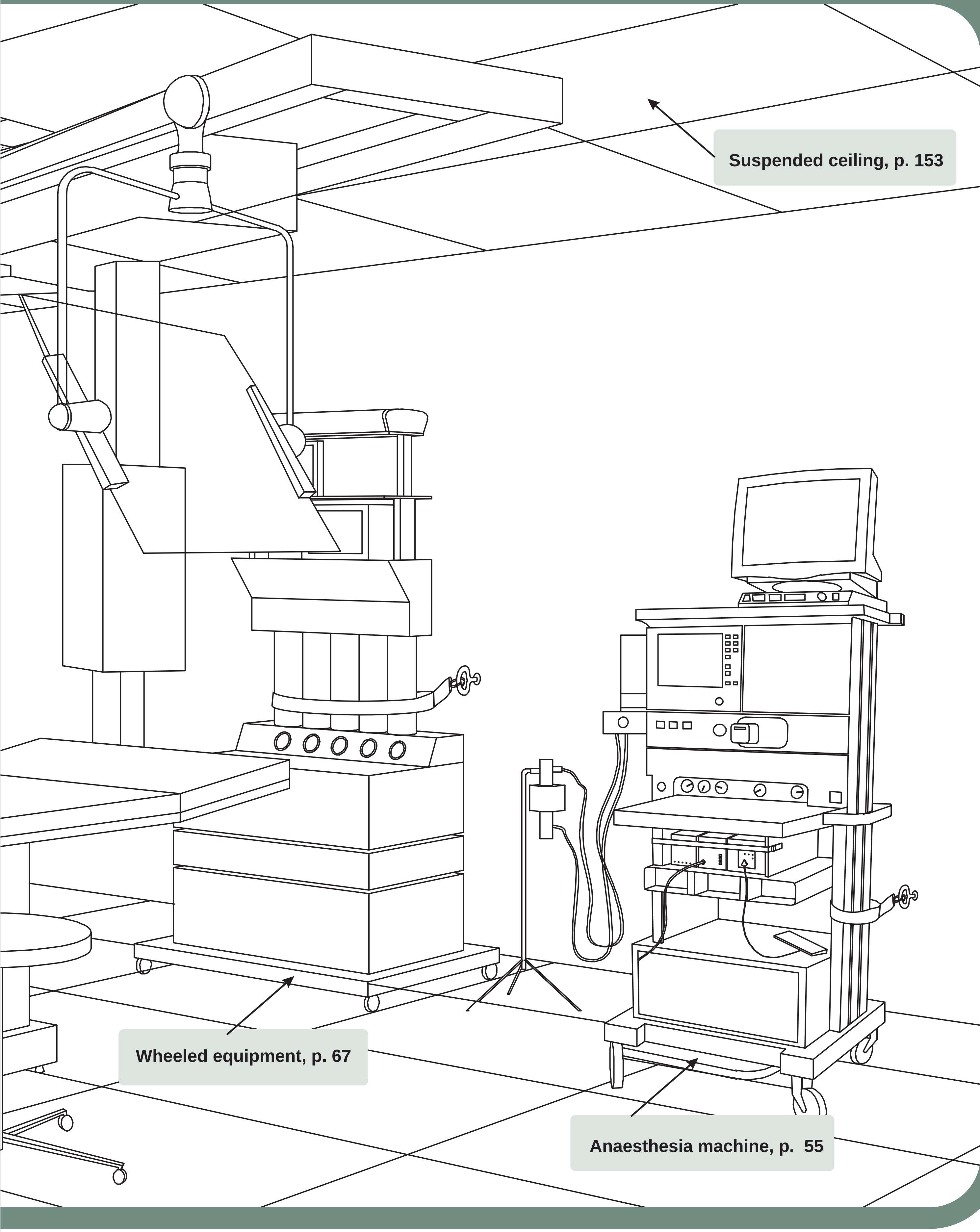
Nurses' Station




Cupboards, p. 77

Cardiac Catheterisation Laboratory

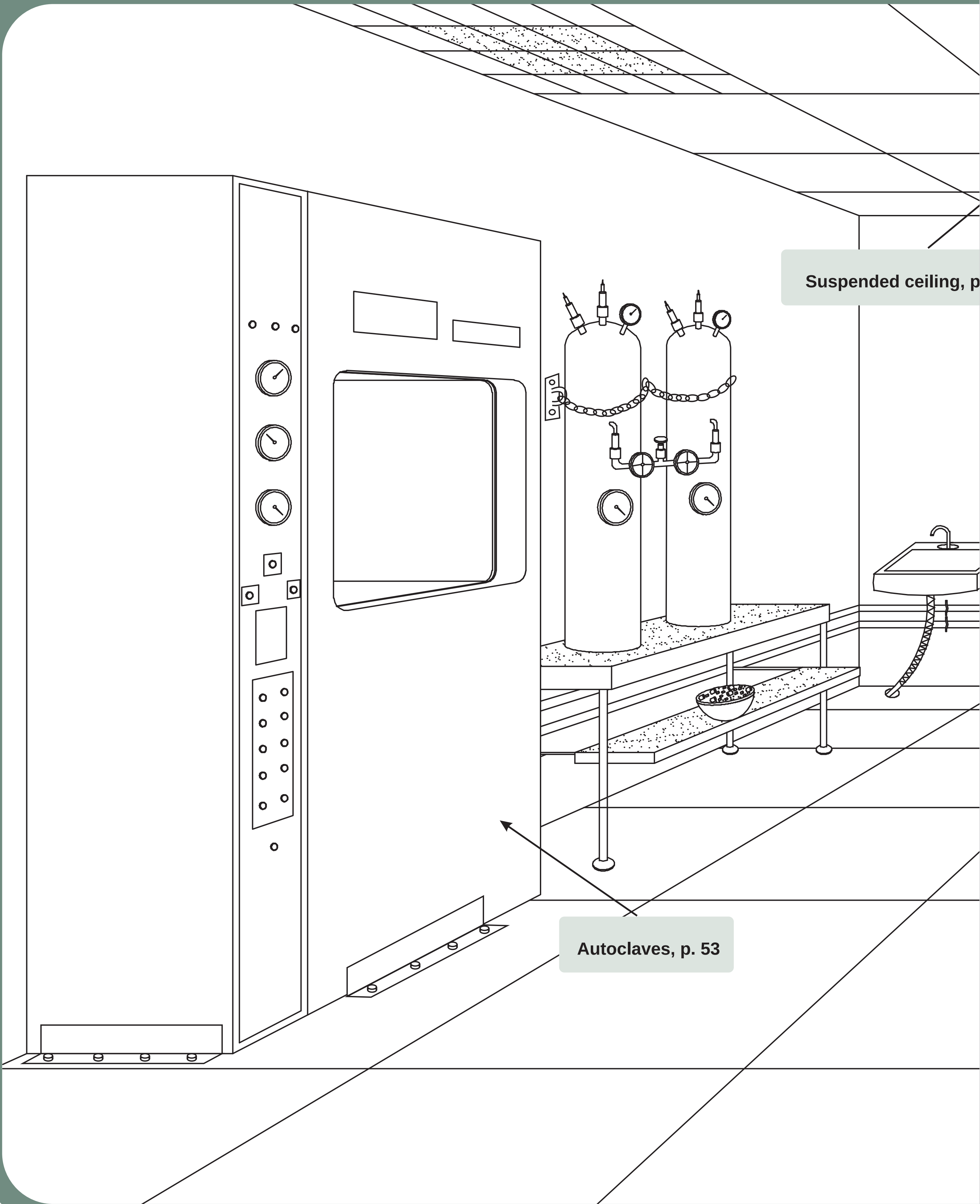


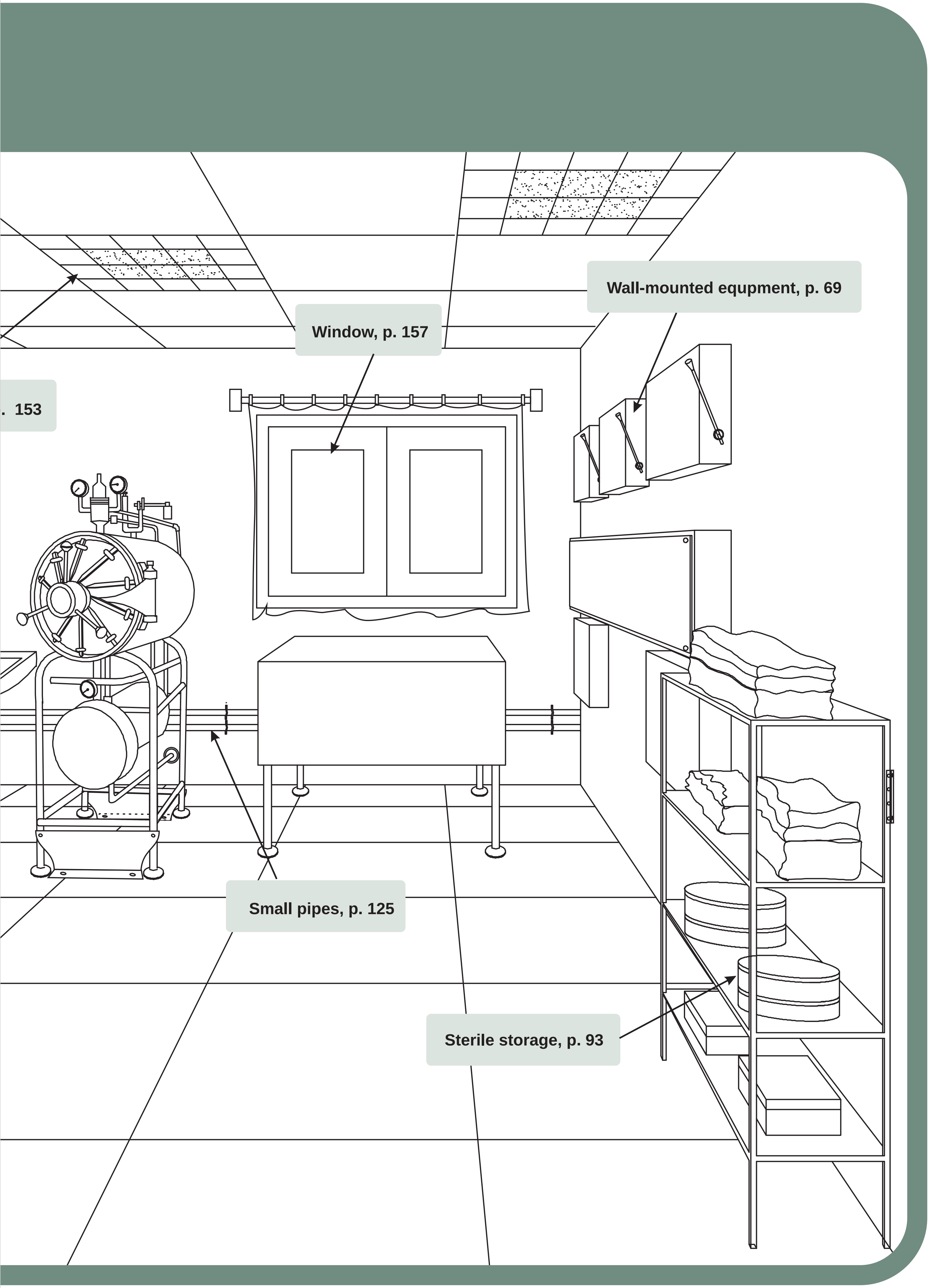

Suspended ceiling, p. 153
Wheeled equipment, p. 67
Anaesthesia machine, p. 55

Laboratory

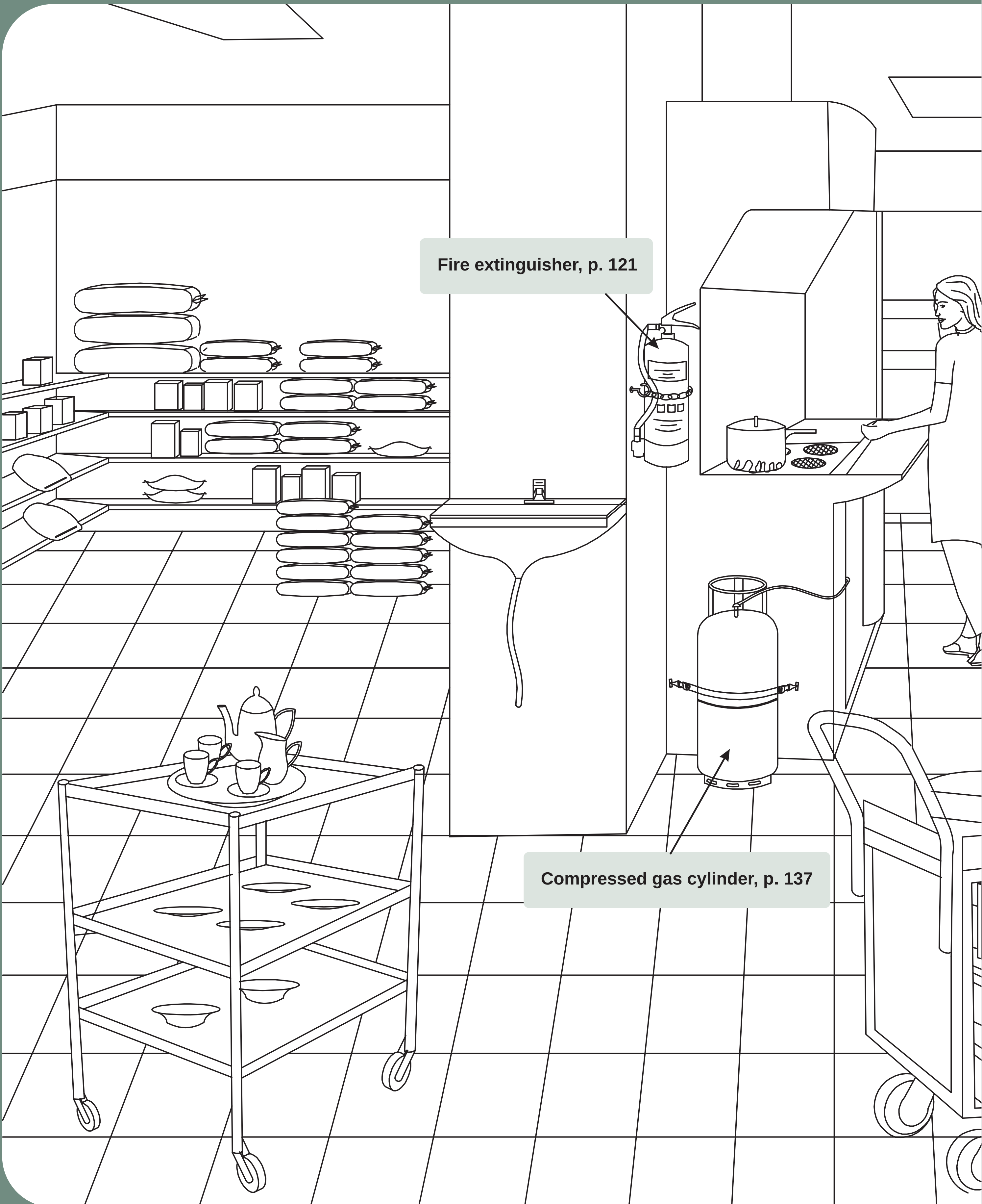

Compressed gas cylinders, p. 137
Computer, p. 83
Laboratory bench-mounted equipment equipment, p. 71

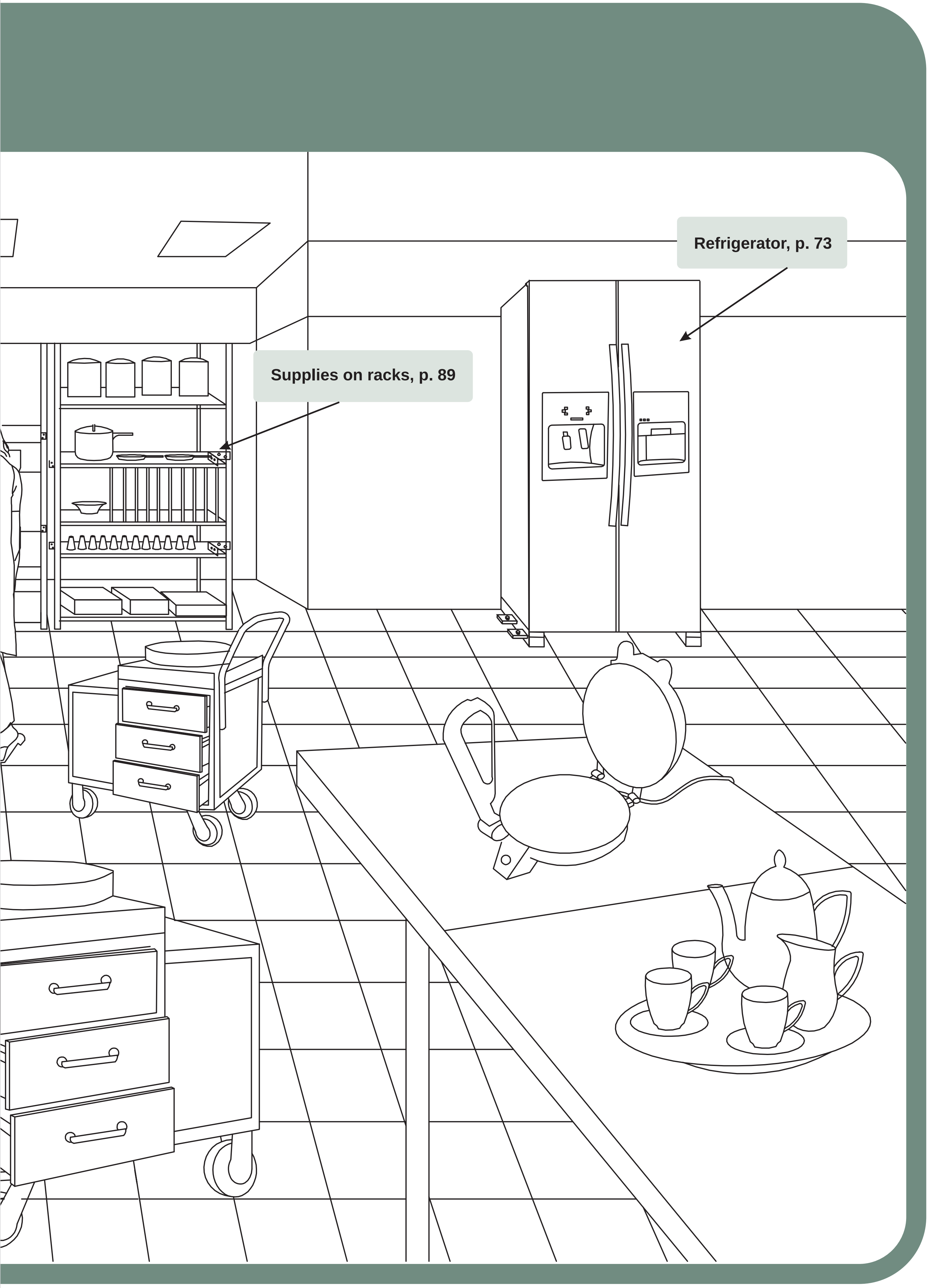
Sterilisation Room



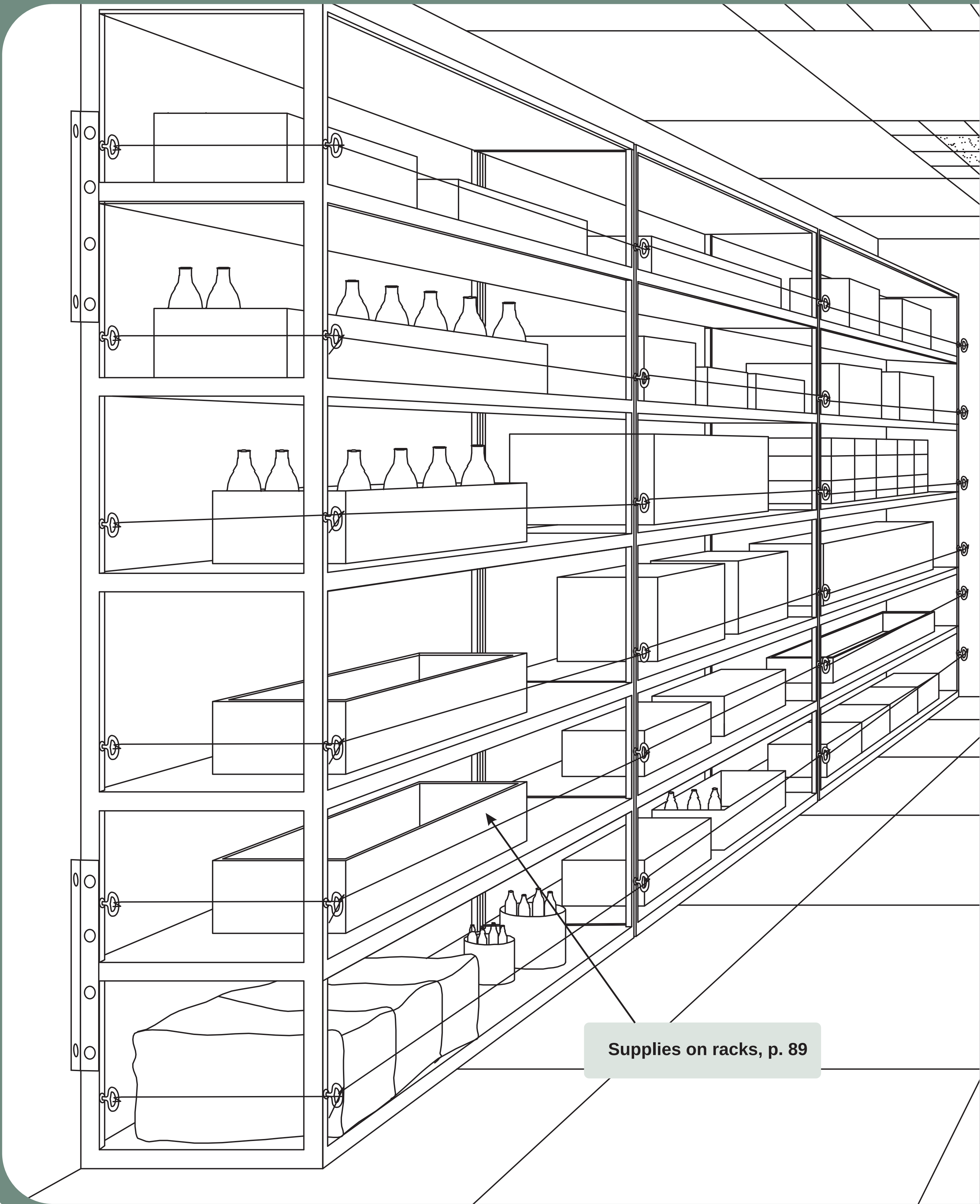

Wall-mounted equipment, p. 69
Window, p. 157
. 153
Small pipes, p. 125
Sterile storage, p. 93

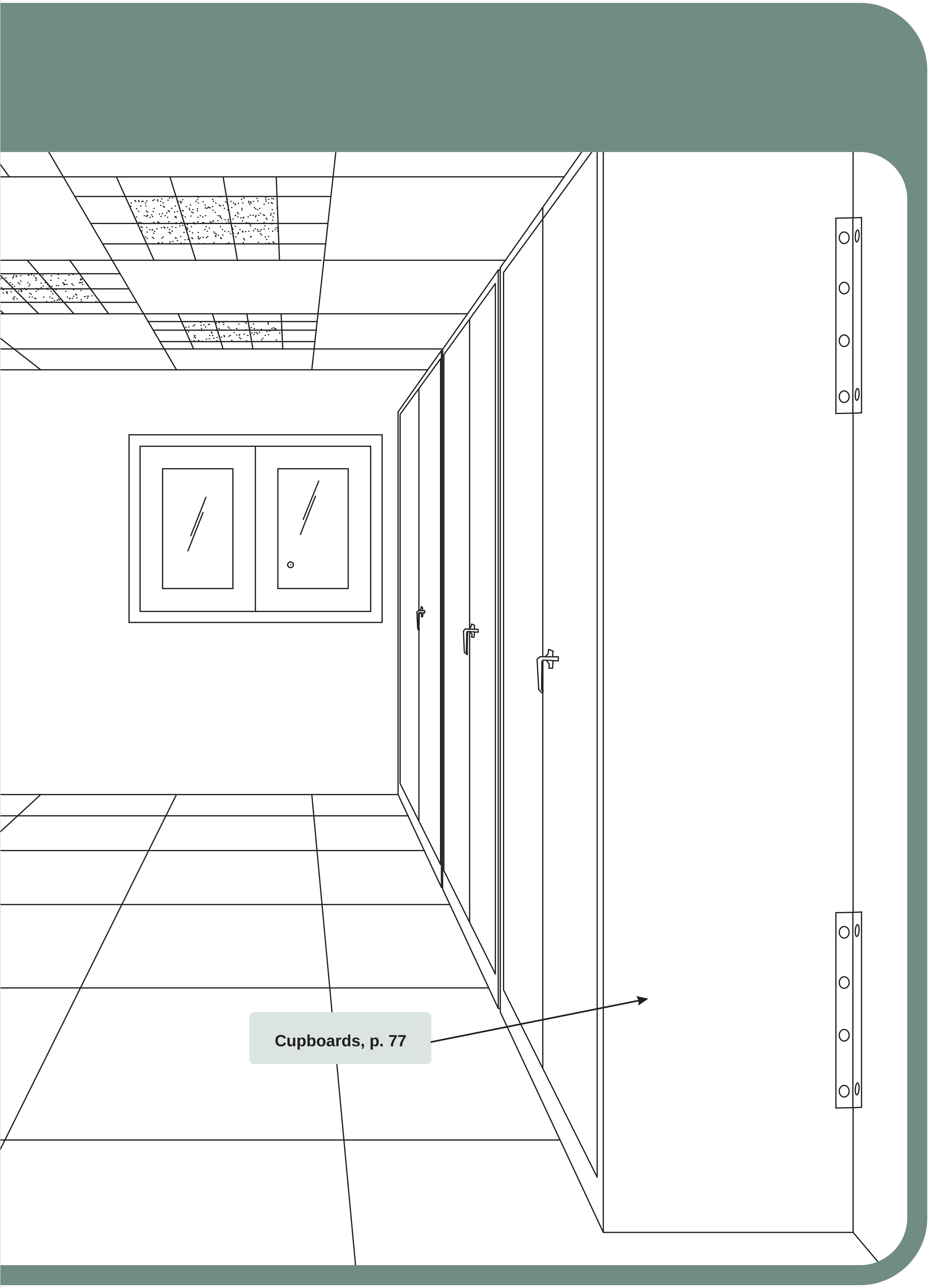
Kitchen



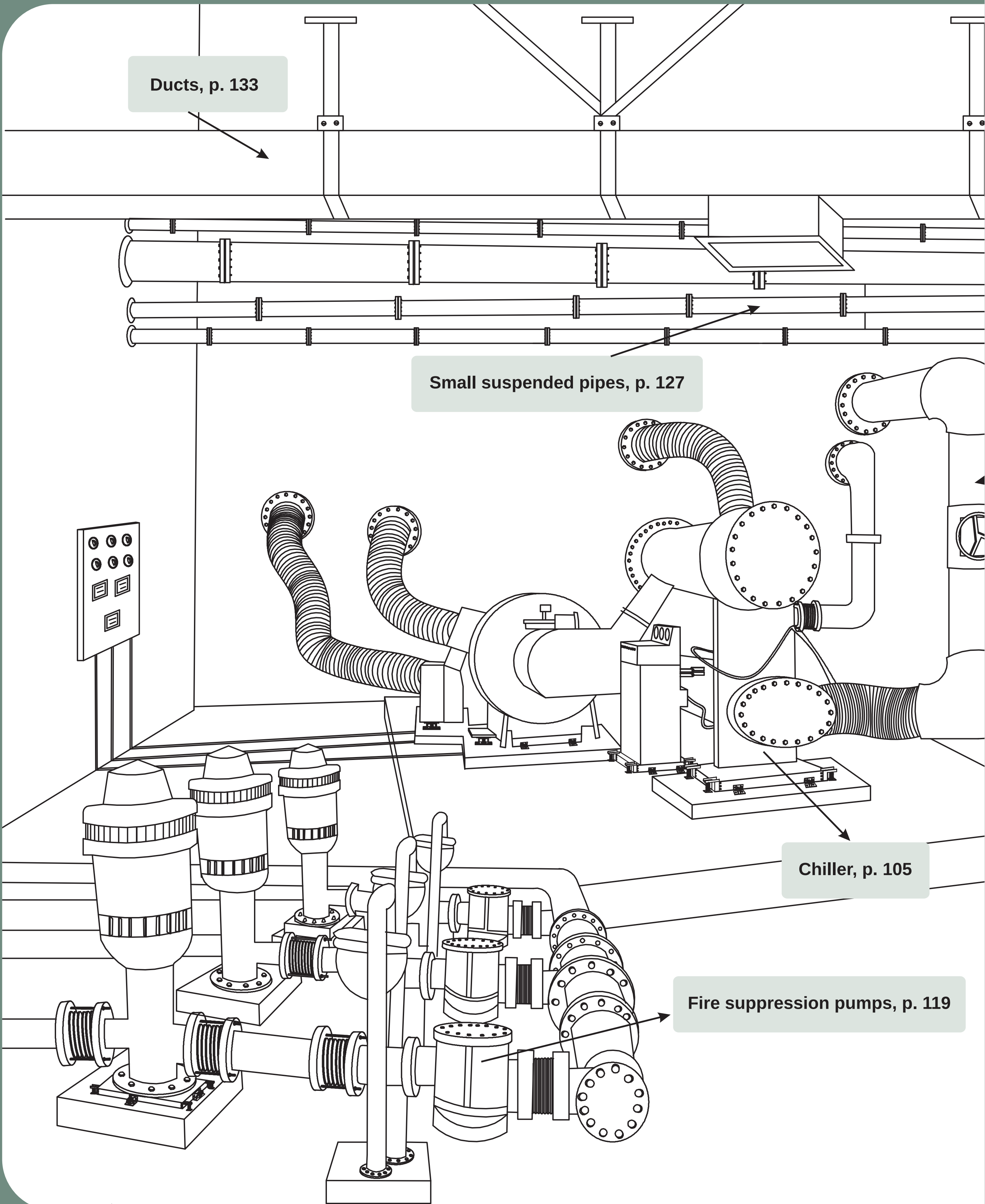

Refrigerator, p. 73
Supplies on racks, p. 89

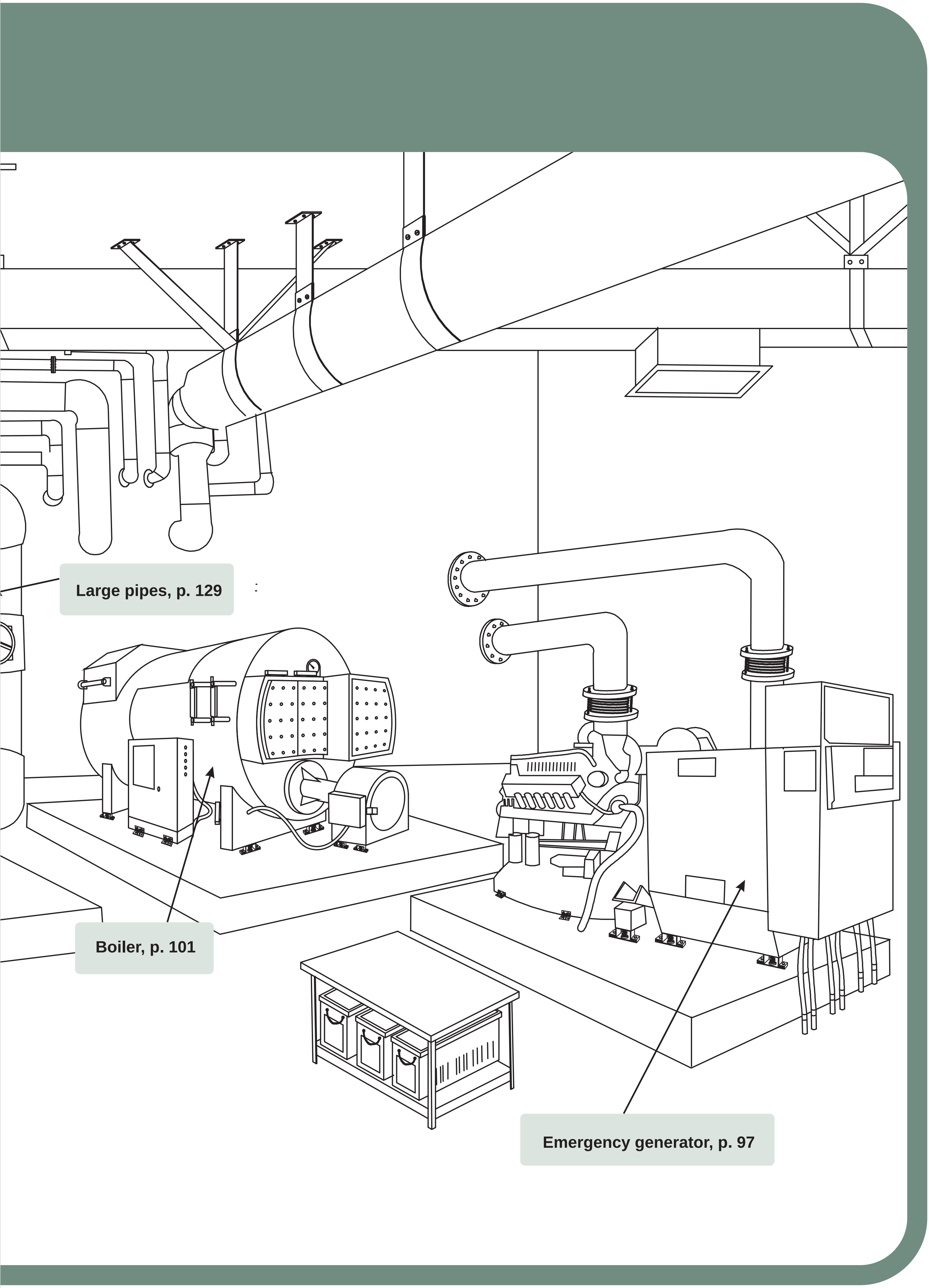
Store Room



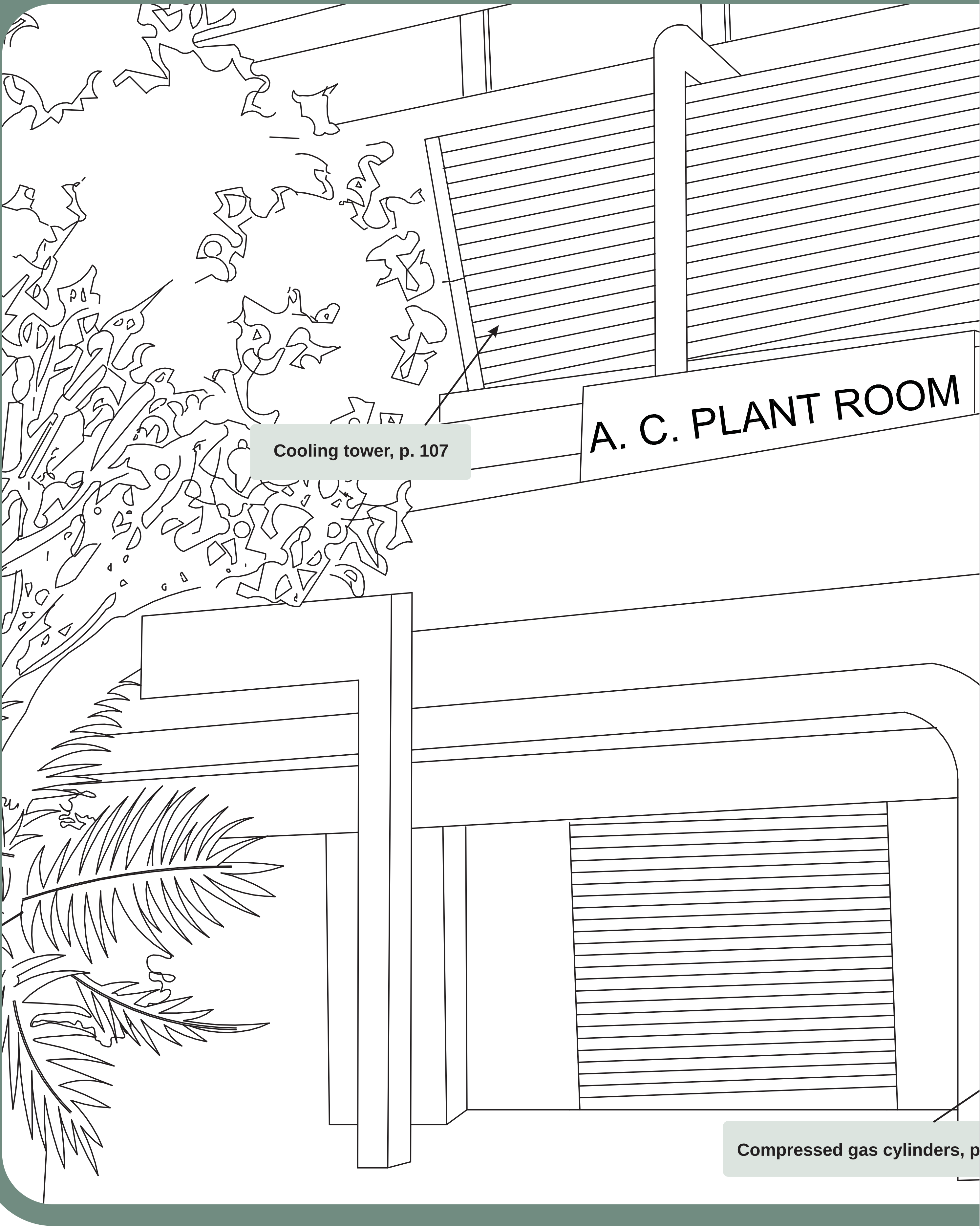

Cupboards, p. 77

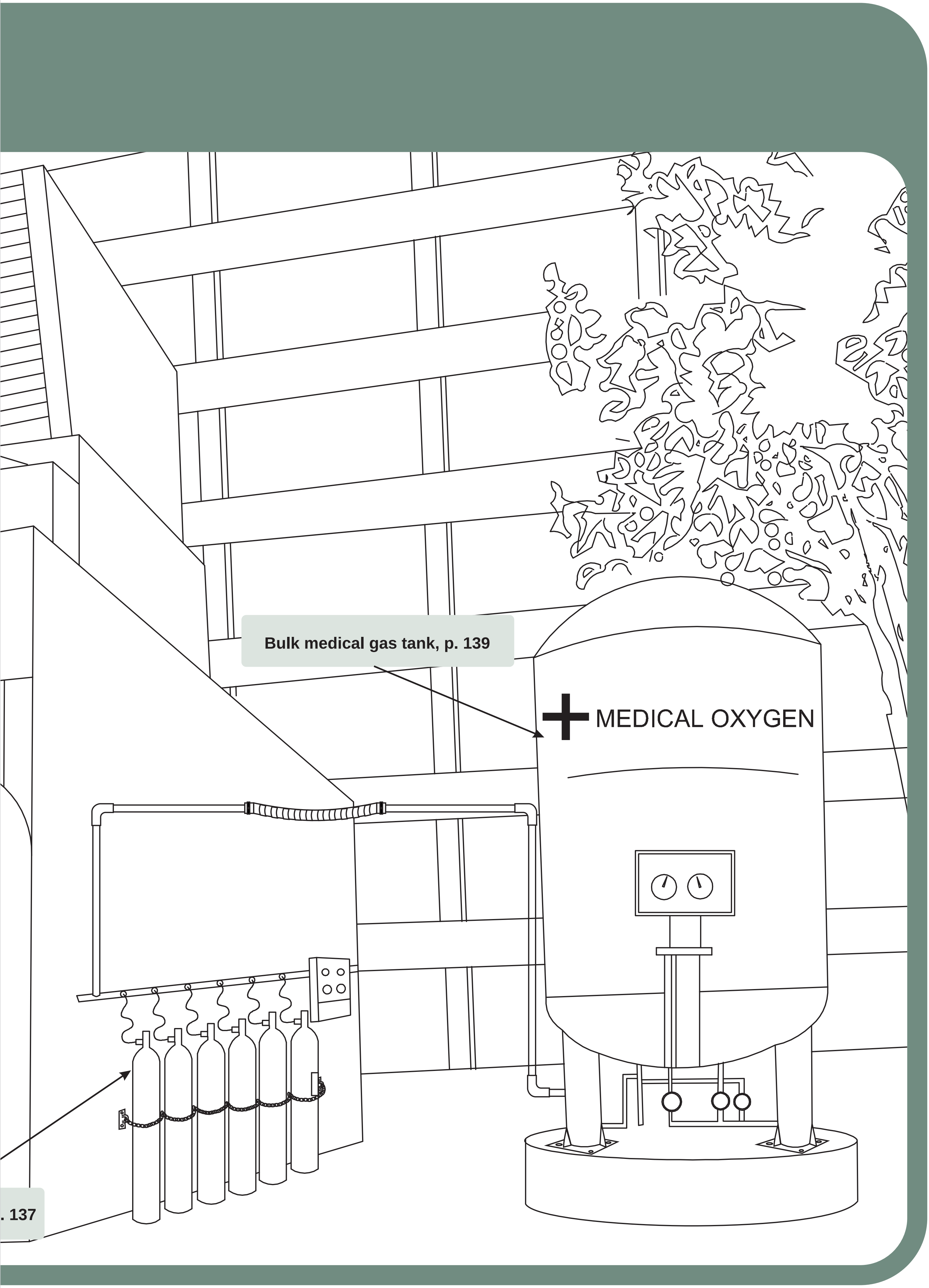
Physical Plant




Large pipes, p. 129
Boiler, p. 101
Emergency generator, p. 97

Physical Plant




Bulk medical gas tank, p. 139
MEDICAL OXYGEN
. 137

Medical Equipment

Doctors and hospital staff rely on medical equipment to provide care to patients. If an earthquake damages medical equipment, then that equipment is not available when needed in the post-earthquake period. It also may be costly to replace.

This section contains information on how to anchor the following types of medical equipment:

Consult the manufacturer or an engineer for information on how to anchor other types of large or very sensitive medical equipment. When purchasing new equipment, ask the manufacturer to supply seismic restraints along with the equipment. Manufacturers that sell medical equipment in areas (such as California) that have regulations regarding the seismic anchorage of equipment will be able to provide seismic restraint details for the equipment that they sell. These details may need to be modified for your hospital's conditions.

Certain types of equipment are not very vulnerable to earthquake damage or must be moved often for functional reasons. GHI does not recommend anchoring this equipment, which includes: roller mounted suction machines, operating tables, or roller mounted equipment with a height to base ratio of less than 1.5. Equipment anchorage should take into account each piece of equipment's necessary functions. Equipment that must be moved often cannot be anchored in the same way that stationary equipment can, and it may not be able to be anchored at all.

Autoclaves

Sterilise surgical instruments and laboratory equipment; located in sterilisation room.

Potential Earthquake Damage

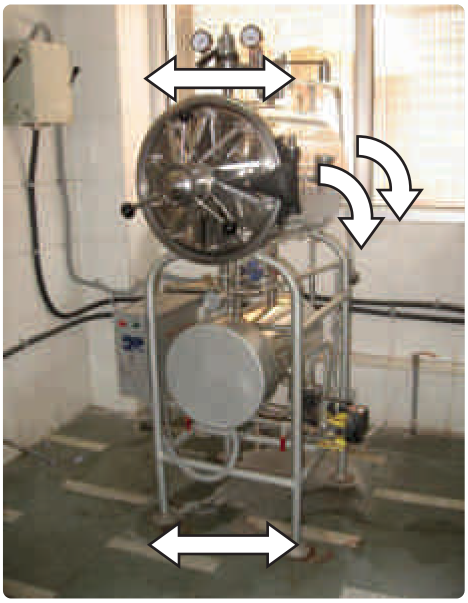


Photo credit: Kanchan Sabnis, GeoHazards Society

Strong shaking can cause autoclaves to topple.

Photo credit: NiSEE

Photo credit: Degenkolb Engineers

Overturned tank with aspect ratio similar to autoclave (left); damaged equipment similar to autoclave (right).

Autoclaves are tall and narrow and are susceptible to toppling, unless they are properly anchored. Water lines to autoclaves can break, leaving the autoclaves without the water that they need to generate steam for sterilising.

Consequences

Toppling is likely to damage autoclaves. Without autoclaves, the hospital will not be able to sterilize the instruments that doctors need to perform surgeries on earthquake victims.

Check These Related Items

Sterile storage (see pg.93): The sterile storage area should remain functional, so that the hospital can continue its sterilization procedures and can keep doctors supplied with the instruments that they need.
Electrical distribution system (see pg.131): The autoclave needs electricity in order to function.

Water supply pipes (see pg.127): The autoclave needs water in order to function. Autoclaves in Kobe, Japan were rendered useless by the loss of city water supply after the 1995 earthquake.

Methods of Anchoring

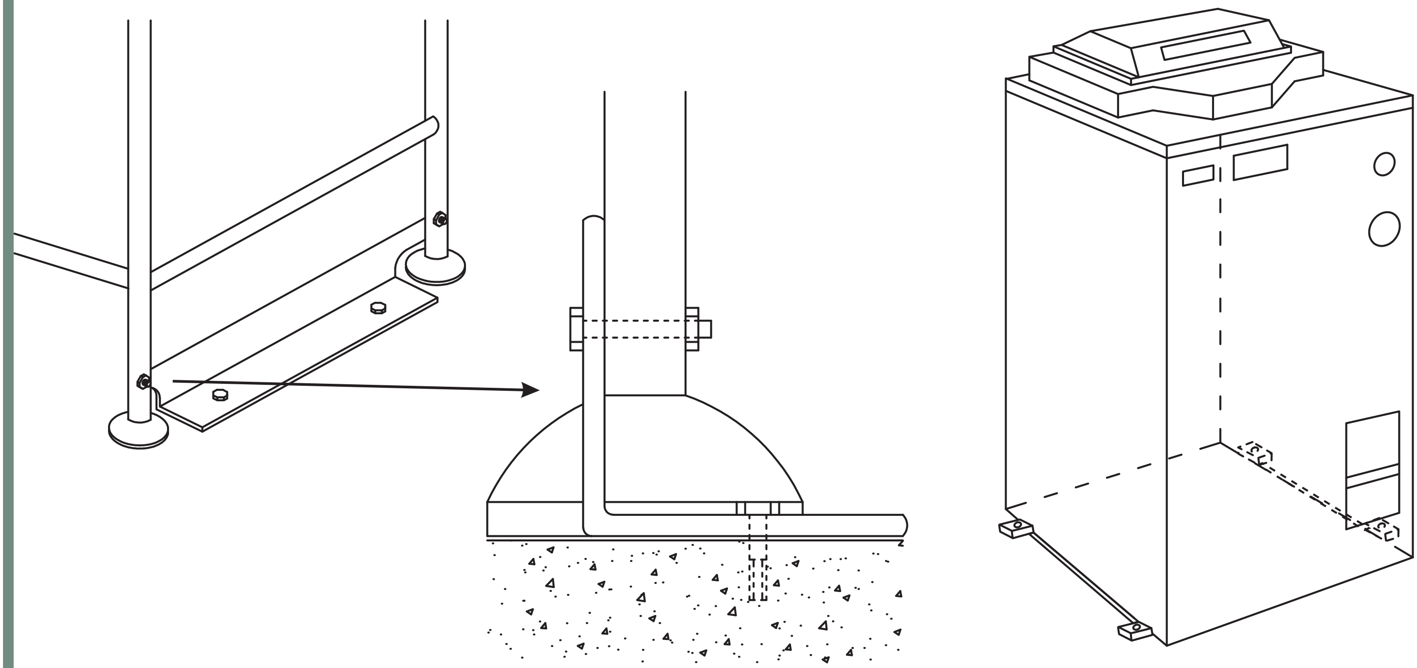


Photo credit: Janise Rodgers, GeoHazards International

Anchor freestanding autoclaves to the floor as shown above. You can anchor autoclave legs with either circular steel collars or L-brackets bolted to each leg and to the floor, or by concreting the legs at the base. If you are using concrete, then be sure to connect the new reinforced concrete pad to the existing floor using dowels. Anchor large chest-type autoclaves to the wall or the floor. You can use some of the same anchoring techniques as for blood bank refrigerators, which are found on p73

When anchoring a large chest-type autoclave to the wall, be sure to have an engineer check that the wall is strong enough to resist the earthquake forces generated by the autoclave. The engineer will also need to select the correct size anchoring devices. Make sure that pipes are connected to the autoclave using flexible connections, like those shown at left. Consider having a plumber install an alternate connection valve, so that you can supply water to the autoclave from a local source (a jug or jerry can) if pipes break, or if the hospital does not have a backup water supply.

Expertise Required

Some engineering required to design anchorage for autoclaves and to provide flexible connections.

Recommended Priority

Essential Services. The hospital needs the autoclave to sterilize instruments in the post-earthquake period, when many trauma patients will need surgery.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, moderate level of disruption. The parts used to anchor an autoclave and to install flexible connections are inexpensive. Anchoring will require that the autoclave be taken out of service for a period of several hours, so advance planning is required.

Where to Find More Information

Please see Appendix C, page 173 for more information.

Anaesthesia Machines

Supply anaesthetics; located in operation theatres, catheterization labs and radiology.

Potential Earthquake Damage

Strong shaking can cause anesthesia machines and associated equipment to slide or topple off of the trolley.

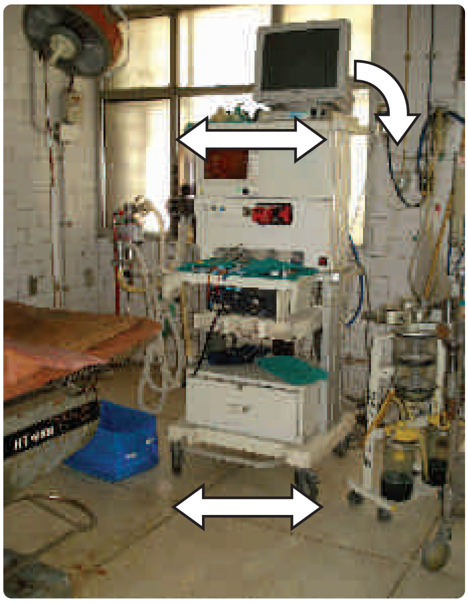


Photo credit: Manisha Dharan, THOT Designs

Photo credits: MCEER

Medical electronic equipment similar to that in anesthesia machine fell (left) and shifted (right) during earthquake simulation test in an engineering laboratory.

Anaesthesia machines are typically located on trolleys, along with related equipment and supplies. These trolleys can be tall and narrow, and equipment could slide or topple off of the trolley, especially from the higher shelves.

Consequences

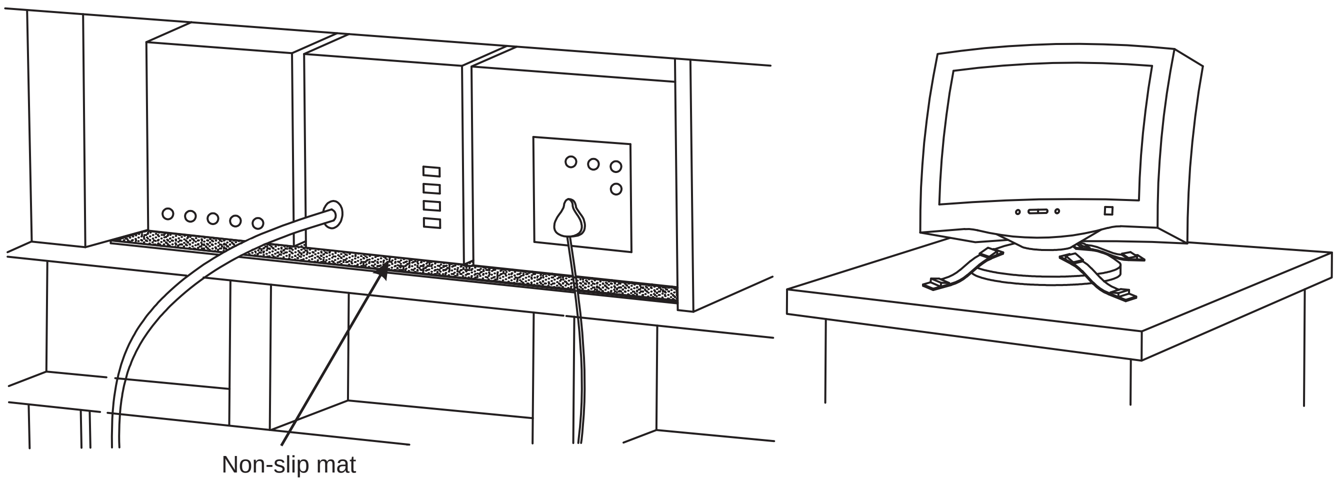
Equipment that falls can break and will not be available when needed after the earthquake. The equipment can also be expensive to replace. Falling equipment could also injure staff and/or patients.

Check These Related Items

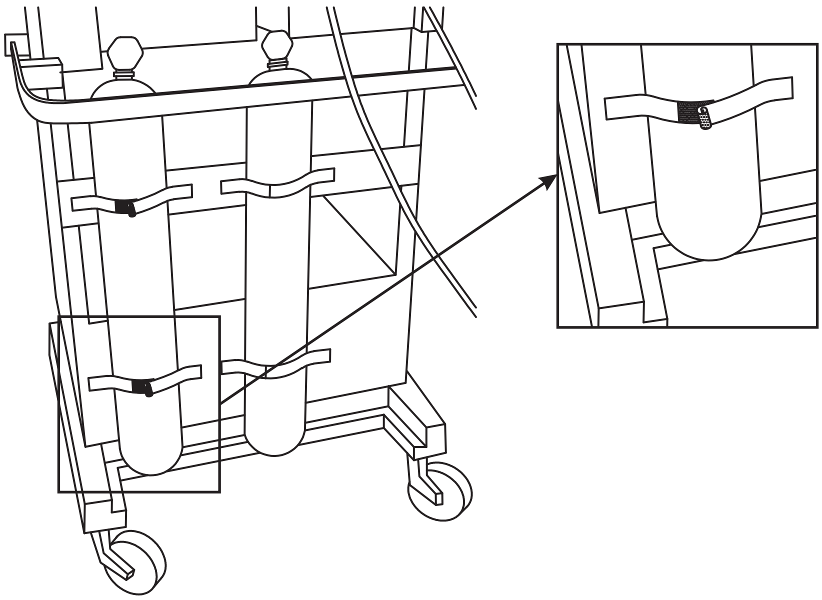
Electrical distribution system and connections (see pg.131): The anaesthesia machine needs electricity in order to function; some machines have battery backup, but the battery does not last long.

Medical gas supply (see pg.139 for pipes, pg.141 for tanks and pg.137 for cylinders): The anaesthesia machine needs medical gases in order to function. These are supplied by pipe or by local cylinders.

Methods of Anchoring



Attach box-shaped equipment to the trolley using straps or hold-downs like those used for computers, or provide a non-slip mat to keep the equipment from sliding off. Place heavy equipment on the lowest possible shelf of the trolley. Anchor heavier equipment, such as monitors, that needs to be at eye level. Provide support for attached cylinders, in addition to the mounting connection; this connection may not be strong enough on its own to resist earthquake forces.



Consider what would happen if the medical gas distribution system ceased to function: have spare cylinders available. Also, when purchasing a new anesthesia machine, look for one with equipment that is integrally attached to the trolley and that is not too tall and narrow; tall and narrow machines can overturn.

Expertise Required

Some maintenance assistance required. You can attach straps yourself but may need maintenance staff to attach shelf restraints or rails.

Recommended Priority

Essential Services. The hospital needs the anaesthesia machines in the post-earthquake period, when many trauma patients will need surgery.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring an anesthesia machine is inexpensive. Work can be done when the machine is not in use (for instance, when no surgeries are scheduled) to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for more information on installing restraints.

Monitors

Monitor patients' vital signs; located anywhere that patients need to be monitored.

Potential Earthquake Damage

Photo credit: Kanchan Sabnis, GeoHazards International

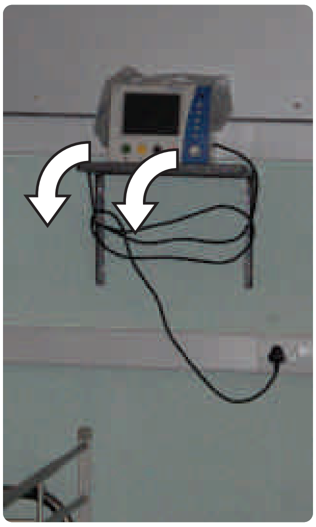


Photo credit: Janise Rodgers, GeoHazards International

Strong shaking can cause unanchored small monitors to fall from shelves, wall mounts, or carts and to break.

Photo credit: MCEER

Photo credit: Khalid Mosalam, University of California, Berkeley

Monitor fell from support bracket during earthquake simulation test in an engineering laboratory (left); monitor fell from shelf, 2009 L'Aquila earthquake (right).

Monitors are often placed on shelves or trolleys a meter or more above floor level; they can easily slide or fall off, if not anchored. Some monitors are mounted on walls and can fall, if the attachment is not strong enough to withstand earthquake forces. A fall from this height is likely to break the monitor.

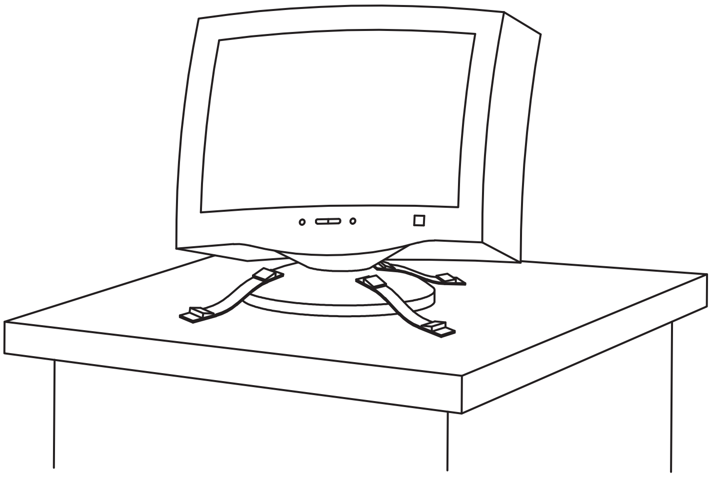
Consequences

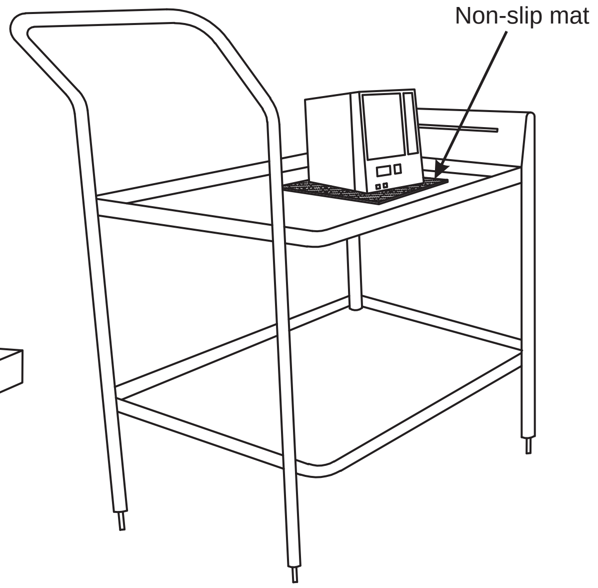
If the monitor falls and breaks, then it no longer provides hospital staff with vital information on the status of the patient, and the patient could be in danger. The hospital will not have the option of using the monitor for other critical patients who arrive after the earthquake. Monitors located over beds could fall and injure patients, especially babies and small children. The monitor may also be expensive to replace, and replacements may not arrive for some time, since the transportation system in the area may be disrupted after the earthquake.

Check These Related Items

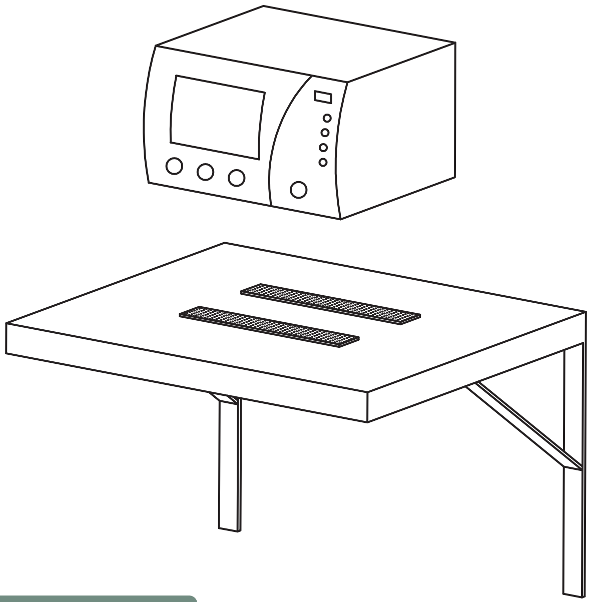
Electrical distribution system (see pg.131): The monitor will not function if power from the emergency generator cannot reach it, because the electrical distribution system is damaged.

Methods of Anchoring





Monitors can be easily anchored to counters, shelves, or trolleys using hook and loop tape (eg. Velcro) straps or small L-brackets. You could also use a trolley with rails or could install a shelf restraint, in order to keep the monitor from sliding off. Small monitors on wide shelves can be placed on non-skid mats, so that they will not slide off.



Overhead or wall-mounted monitors are often mounted using commercially available brackets. The monitor should be properly anchored to the bracket, so that it cannot fall during an earthquake. The bracket also has to be properly anchored to the wall and be able to withstand earthquake forces without breaking.

You can also relocate monitors that could fall onto patients, especially babies and small children.

Expertise Required

Do it yourself. Nearly anyone can anchor monitors or relocate them.

Recommended Priority

Continued Service. For most monitors.
Critical Safety. For monitors that can fall onto patients, especially onto particularly fragile ones.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring monitors is very inexpensive. Relocating costs virtually nothing. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for more information on installing restraints.

Operation Theatre Lights

Provide bright light for surgical procedures; located in operation theatres.

Potential Earthquake Damage

Photo credit: Janise Rodgers, GeoHazards International

Strong shaking can cause lights to sway, break off their supports, and fall.

Photo credits: MCEER

Operation theatre light broke off arm and fell to floor during an earthquake simulation test at an engineering laboratory (left) and (right).

Many sets of operation theatre lights are not connected to the ceiling with mountings that are able to resist lateral forces, as well as gravity. These weak connections can break during an earthquake, and the entire light assembly can fall down and break.

Consequences

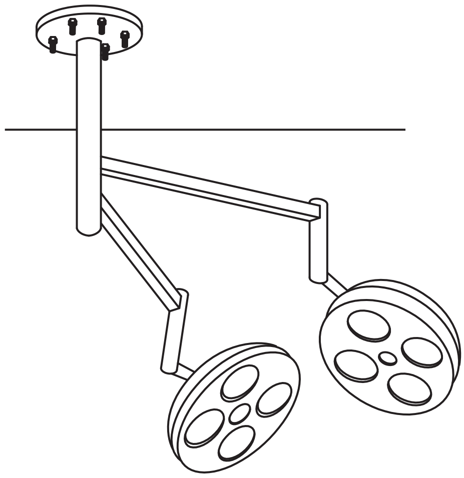
After an earthquake, there may be many trauma patients who need surgery, and the operation theatres need to be functional. Surgeons need bright lights in order to perform surgeries safely, so the operation theatre will not be functional, if its lights have fallen/damaged.

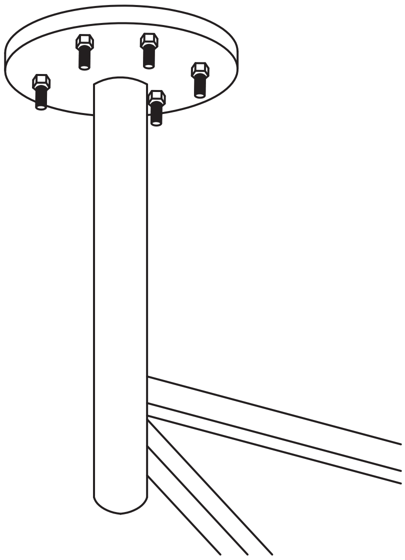
Check These Related Items

Electrical distribution system (see pg.131): Wiring and conduits to the emergency power system must remain intact, so that power from the emergency generator can reach the operation theatre.

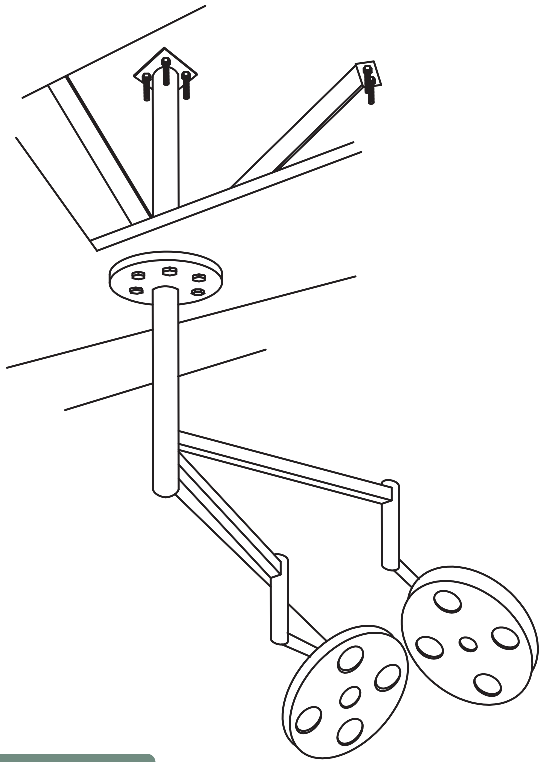
Suspended (false) ceilings (see pg.153): If the lights are located in a false or suspended ceiling, then they can sway and cause parts of the ceiling to collapse.

Methods of Anchoring





Operation theatre lights should be anchored securely to the reinforced concrete ceiling using bolts. Have an engineer determine the anchor bolt size and anchorage arrangement required to resist earthquake forces.



If you have a suspended (false) ceiling in your operation theatre, then you will need to brace the lights back to the structural ceiling as shown at left. The suspended ceiling will not be strong enough to prevent the lights from swinging and falling.

Expertise Required

Some engineering required to select the correct size bolts or braces.

Recommended Priority

Essential Services. Doctors need to be able to perform operations after an earthquake.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Bolts are typically inexpensive. Bracing systems are more expensive. Work on operating theatre lights can be done at night, when no surgeries are scheduled, so as not to disrupt hospital operations.

Where to Find More Information

Please see Appendix C, page 173 for more information.

Ventilators

Provide respiratory support to patients; located in intensive care units.

Potential Earthquake Damage

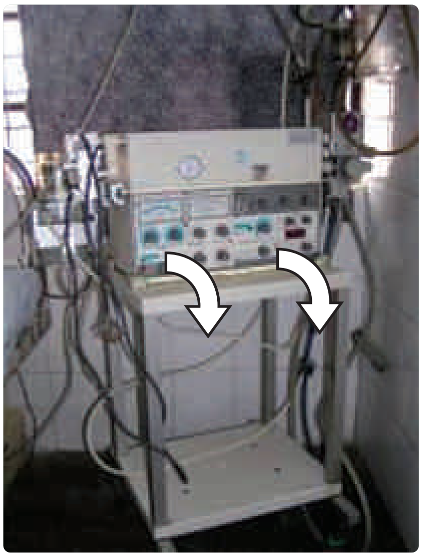


Photo credit: Kanchan Sabnis, GeoHazards International

Strong shaking can cause ventilators to topple from stands or trolleys.

Photo credit: NiSEE (Robert Reitherman)

Photo credit: Khalid Mosalam, University of California, Berkeley

Damage to equipment with similar aspect ratio to shelf mounted ventilators during the 1994 Northridge, California earthquake (left) and 2009 L'Aquila, Italy earthquake (right).

Ventilators are often placed on trolleys or stands at patients' bedsides in ICUs. They can slide or topple, if they are not anchored. Bottom-heavy ventilator units on wheels, or ventilators attached the wall are not very vulnerable to earthquake damage.

Consequences

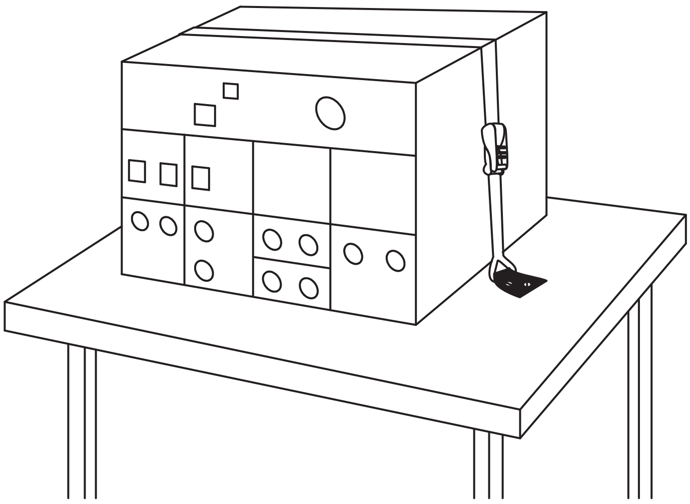
If the ventilator on a stand or trolley falls, then it could be damaged or break. It may also break connections with supply systems. The patient using the ventilator will have to be manually ventilated using a bag, which requires tremendous amounts of staff time and effort.

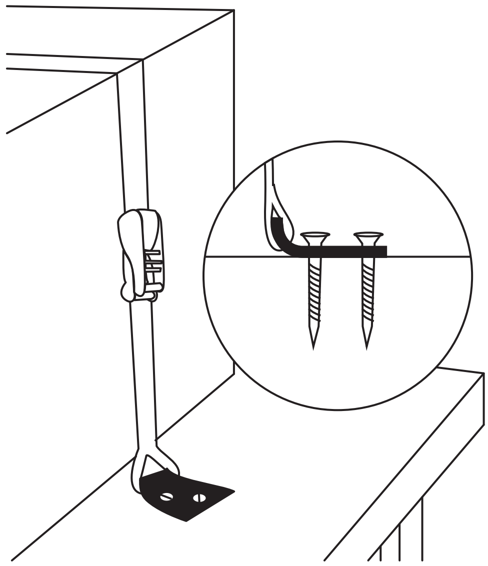
Check These Related Items

Electrical distribution system (see pg.131): Wiring and conduits in the emergency power system must remain intact, so that power from the emergency generator can reach the ventilator.

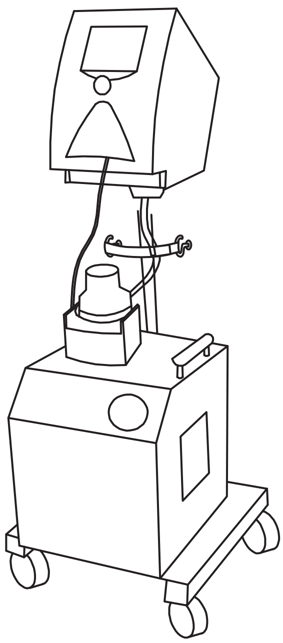
Medical gas supply (see pg.125 for pipes, pg.141 for tanks and pg.137 for cylinders): The ventilator needs oxygen, which is supplied by pipe or local cylinders, in order to function.

Methods of Anchoring





Anchor ventilators to trolleys or stands using straps. You can use straps similar to those used for computers and other equipment. Ensure that the ventilator has flexible connections to the oxygen supply, especially if the supply is from a pipe that is rigidly mounted to the wall.



When purchasing new ventilators, buy those that can be easily anchored or that are resistant to toppling. Ventilators built into or firmly anchored to the wall are the most resistant to earthquake damage. Ventilators on wheels should be bottom-heavy.

Expertise Required

Do it yourself. You can place straps on a ventilator, in order to anchor it to a stand.

Recommended Priority

Essential Services. Without the ventilator, patients that need help breathing will have to be manually ventilated, which takes a tremendous amount of staff time and effort.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Bolts are typically inexpensive. Bracing systems are more expensive. Work on operating theatre lights can be done at night, when no surgeries are scheduled, so as not to disrupt hospital operations.

Where to Find More Information

Please see Appendix B, page 167 for more information on installing restraints

Imaging and Scanning Units

Provide medical imaging; located in radiology. Includes X-ray machines, CT scanners, and others.

Potential Earthquake Damage

Strong shaking can cause imaging units, which include X-ray machines, CT scanners, to slide, topple, or break.

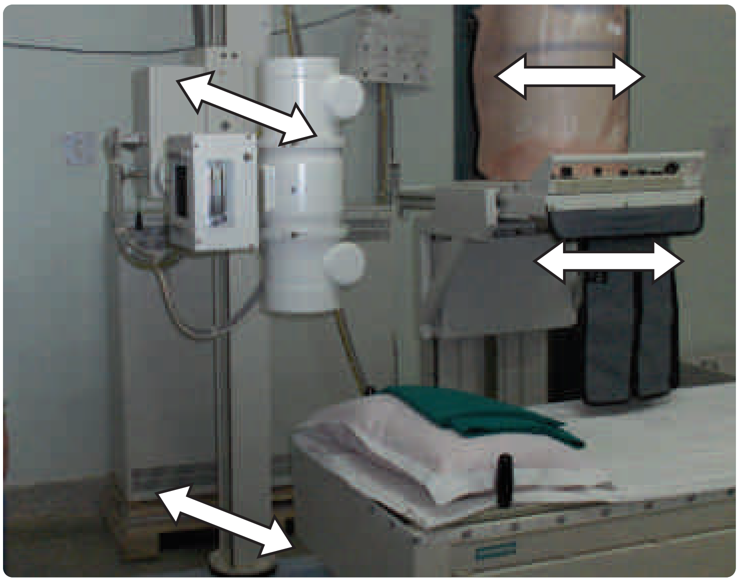


Photo credit: Kanchan Sabnis, GeoHazards International

Photo credit: FEMA

Photo credit: California OSHPD

Badly damaged X-ray machine, 1971 San Fernando, California earthquake (left); imaging unit drum moved 75 cm, as indicated by the dark circle on floor, 1983 Coalinga, California earthquake (right).

The equipment can either slide or, in the case of equipment that is tall and narrow, topple during strong earthquake shaking. The unsupported arms or extended parts of some imaging equipment can vibrate excessively, leading to damage or breakage.

Consequences

Broken imaging equipment will not be available to use to help to diagnose trauma injuries after an earthquake, when it will be needed. Broken equipment can also leak radiation, which is a serious health hazard.

Check These Related Items

Electrical distribution system (see pg.131): Scanning units need electricity from the emergency power system, in order to function.

Methods of Anchoring

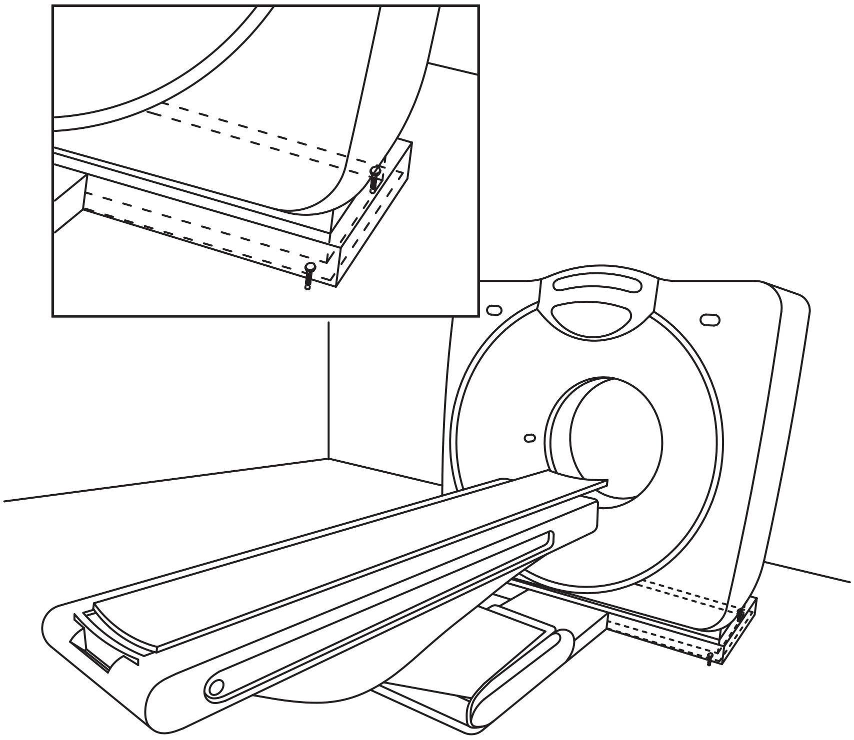


Photo credit: California OSHPD

First, consult the manufacturer of the equipment to see if it can provide seismic restraint devices or details. Manufacturers that sell equipment in areas of high seismicity, such as California or Japan, should be able to provide seismic restraints for their products. If the manufacturer can't provide seismic restraint information, then you will need to hire an engineer. Manufacturer-provided restraint information could be as simple as alerting you to the location of holes, where the equipment should be bolted to the floor. Your maintenance department could then bolt the equipment to the floor. Other restraint designs could be more complicated. Follow manufacturer's instructions carefully, in order to avoid damaging the equipment or voiding the warranty. Some imaging equipment is already well-attached to the floor, so that it can withstand the forces imposed by normal operations. Have an engineer check to see if this attachment is strong enough to resist the expected earthquake forces. If the manufacturer does not make seismic restraints for your imaging equipment, then you will need to anchor it yourself. A very simple anchoring solution (a chain) saved the imaging equipment at above right from damage during the 1995 Kobe, Japan earthquake. For large and heavy equipment such as CT scanners or MRI machines, consult an engineer, if the manufacturer does not provide restraints. Discuss the engineer's design with the manufacturer to be sure that it will work as intended.

Expertise Required

Some maintenance assistance and engineering required. You will need to consult an engineer to design the anchoring system. You will need maintenance help to install either the manufacturer's or your engineer's system.

Recommended Priority

Essential Services. The hospital needs imaging equipment in the post-earthquake period to diagnose injuries.

Retrofit Cost and Disruption

Low to moderate cost for parts, moderate cost for labor, moderate level of disruption. Anchoring imaging equipment can be relatively inexpensive, if you only need to bolt it to the floor or tether it to the wall. Strengthening an existing anchorage or providing a custom-designed anchorage solution will be more expensive. The machine will have to be taken out of service while work is done, so advance planning is required.

Where to Find More Information

Contact your equipment's manufacturer, and see Appendix C, page 173 for more information.

Radiant Warmers

Keep premature or ill babies warm and monitor them; located in neonatal intensive care unit.

Potential Earthquake Damage

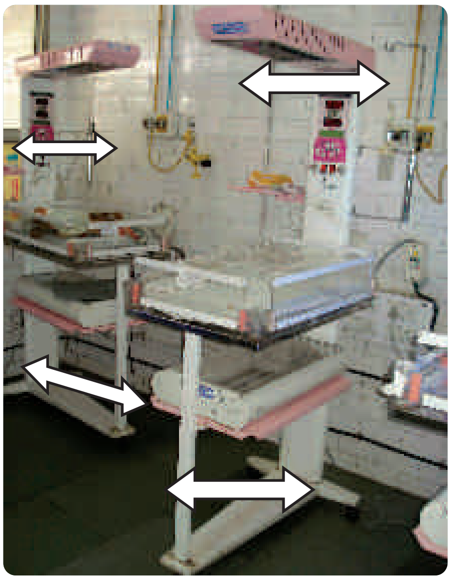
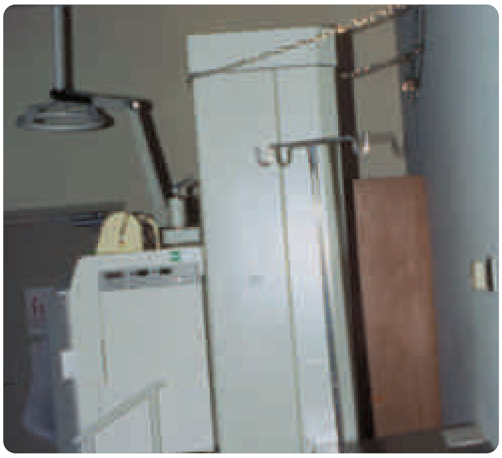


Photo credit: Manisha Dharan, THOT Designs

Strong shaking can cause radiant warmers to topple or roll and to break connections.



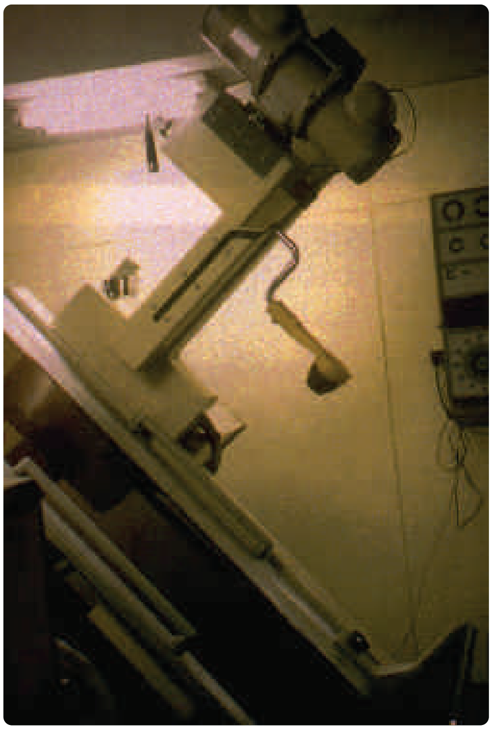


Photo credits: California OSHPD

X-ray equipment tall and narrow like a radiant warmer saved from damage by a tether during the 1995 Kobe, Japan earthquake (left); another similar piece of equipment toppled in the same earthquake (right).

Radiant warmers can rock and possibly topple. Equipment on the warmer's shelves could slide or topple. Since the warmer is on wheels, it could also roll far enough to break the connections with medical gas lines or electrical power.

Consequences

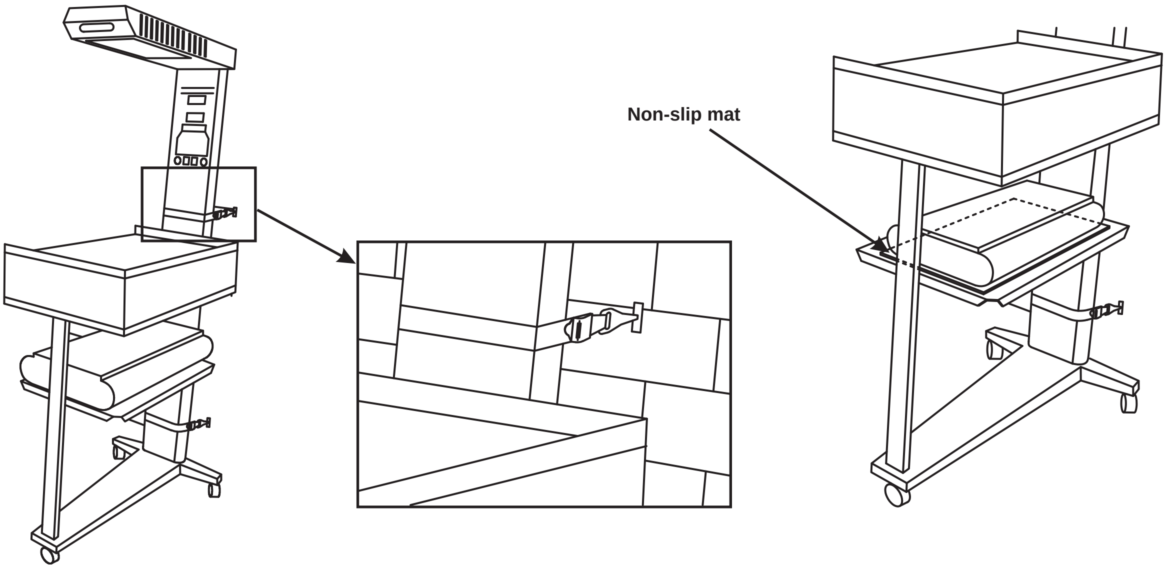
Fragile babies could be injured or could even die from a disruption in electrical power or medical gas supplying a ventilator, or from a fall to the ground, if the warmer overturns.

Check These Related Items

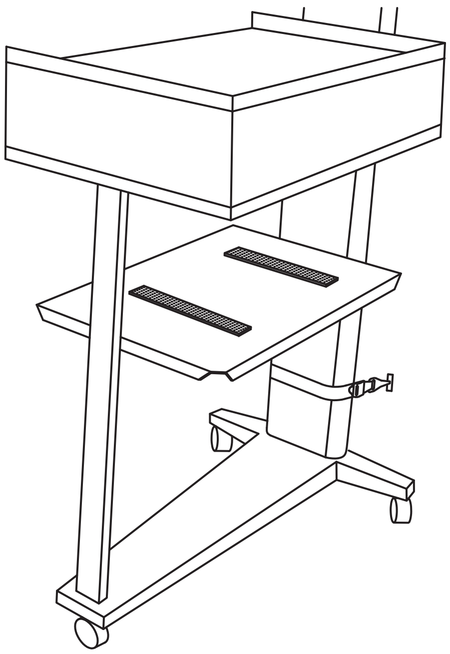
Electrical distribution system (see pg.131): Wiring and conduits in the emergency power system must remain intact, so that power from the emergency generator can reach the warmer.

Medical gas supply (see pg.139 for pipes, pg.141 for tanks and pg.137 for cylinders): Warmers often have equipment that supplies oxygen to help babies breathe. This supply must not be interrupted.

Methods of Anchoring



You can keep radiant warmers from toppling by attaching a tether at the top, as shown above. You should be able to detach the tether quickly, to move the incubator if needed. Another option is a magnetic latch; this relies less on staff to remember to reattach the tether. Make sure that the latch is not positioned where it could interfere with electrical equipment.



Anchor other equipment located on the warmer's shelves using non-slip mats or hook and loop tape. Place such equipment as low to the floor as possible, to help the warmer to resist toppling. Try to keep wheels clean so that they roll easily, because this will also help the warmer to resist toppling.

Expertise Required

Do it yourself. Anyone can install a tether.

Recommended Priority

Essential Services. Radiant warmers provide essential care for very small or sick babies.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring radiant warmers is inexpensive. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Please see Appendix B, page167 for more information on installing a tether or other restraint.

Wheeled or Trolley-mounted Equipment

Varies; located throughout hospital.

Potential Earthquake Damage

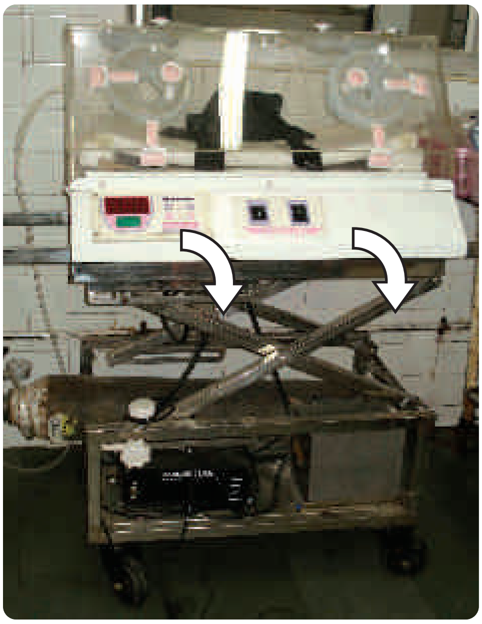


Photo credit: Manisha Dharan, THOT Designs

Strong shaking can cause tall and narrow wheeled equipment to topple and equipment on trolleys to fall off of the trolley.

Photo credit: California OSHPD

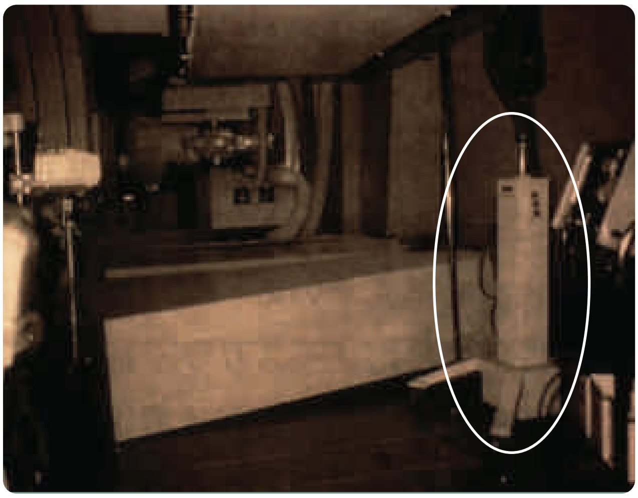


Photo credit: Degenkolb Engineers

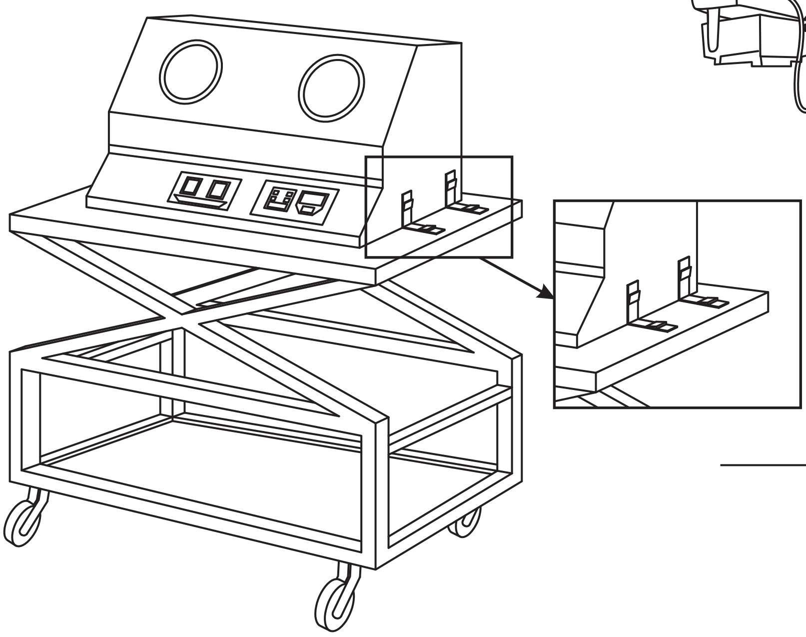
Wheeled hospital kitchen equipment rolled and damaged other items, 1983 Coalinga, California earthquake (left); undamaged bottom-heavy wheeled equipment next to toppled cupboards in radiology department, 1995 Kobe, Japan earthquake (right).

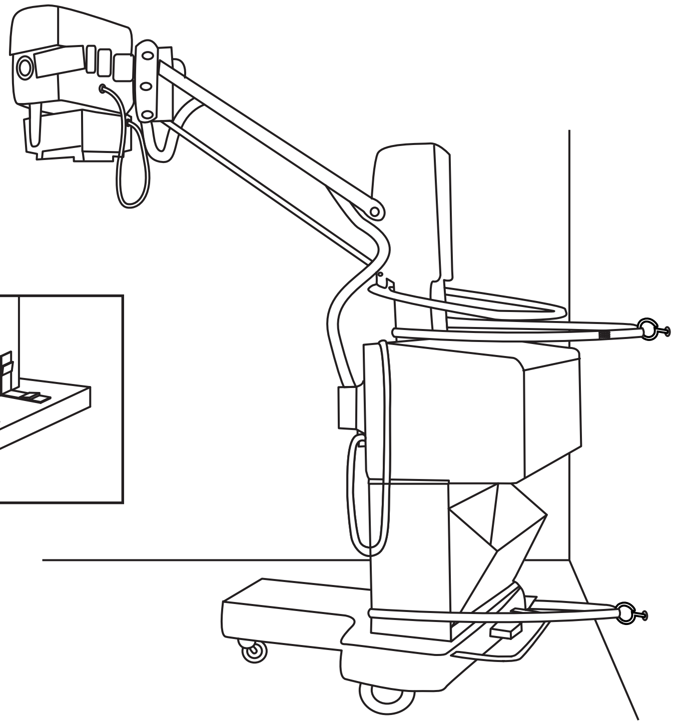
Tall and narrow wheeled equipment can topple and break. Improperly anchored equipment on trolleys can fall to the floor and break.

Consequences
The broken equipment will not be available for use and could be expensive to replace. Damage to equipment used to care for critically ill patients could disrupt the care of those patients or could endanger their health.

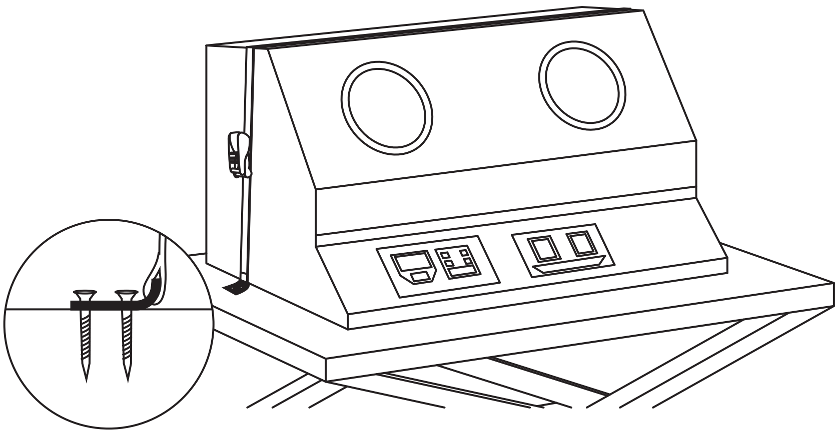
Check These Related Items
There are no related items to check.

Methods of Anchoring





Anchor equipment on trolleys using straps or provide rails or shelf restraints to keep the equipment from sliding or toppling off of the trolley. Wheeled equipment is difficult to secure, because it is frequently moved. You can design a “garage” or parking location for the heavy wheeled equipment when it is not in use, where the equipment can be anchored to a wall or post. For some equipment prone to toppling, you may have to accept the possibility that the equipment could break during earthquake shaking. For smaller or less expensive equipment, you could keep a properly anchored spare in storage.



When purchasing new wheeled equipment, try to find equipment that is either bottom-heavy or relatively short and squat. These types of wheeled equipment are less prone to toppling. You can test the toppling resistance of light wheeled equipment with a colleague. Have your colleague stand next to the equipment, ready to catch it if it starts to topple. Carefully give the equipment a sharp shove at the top. If it rolls instead of toppling, it is not likely to topple in an earthquake.

Expertise Required

Do it yourself. You can secure equipment to a trolley yourself.

Recommended Priority

Continued Service. The hospital needs wheeled and trolley-mounted equipment to care for patients.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring equipment to trolleys is typically inexpensive. Wheeled equipment can be more expensive to anchor, because solutions may be more complex, in order to account for functional requirements. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for information on installing restraints.

Small Wall-mounted Equipment

Varies; located throughout hospital.

Potential Earthquake Damage

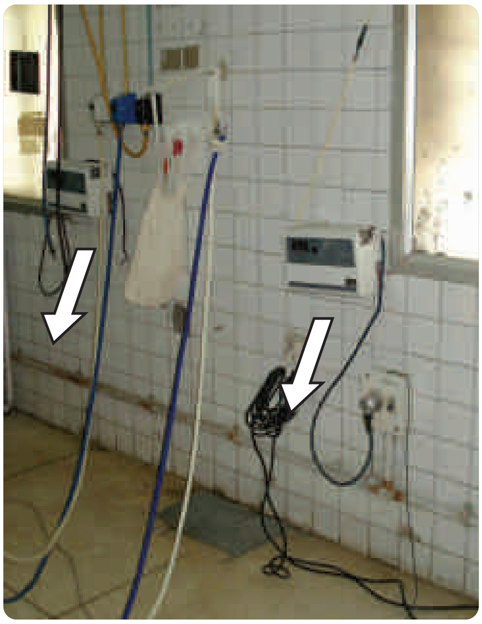


Photo credit: Manisha Dharan, THOT Designs

Strong shaking can cause bench-mounted equipment in laboratories to fall.

Photo credits: MCEER

Laboratory damage, 1994 Northridge, California earthquake (left) and (right).

Laboratories typically have an array of small and medium-sized equipment located on benches or tabletops. If not anchored, then these pieces of equipment can slide or topple from benches and break.

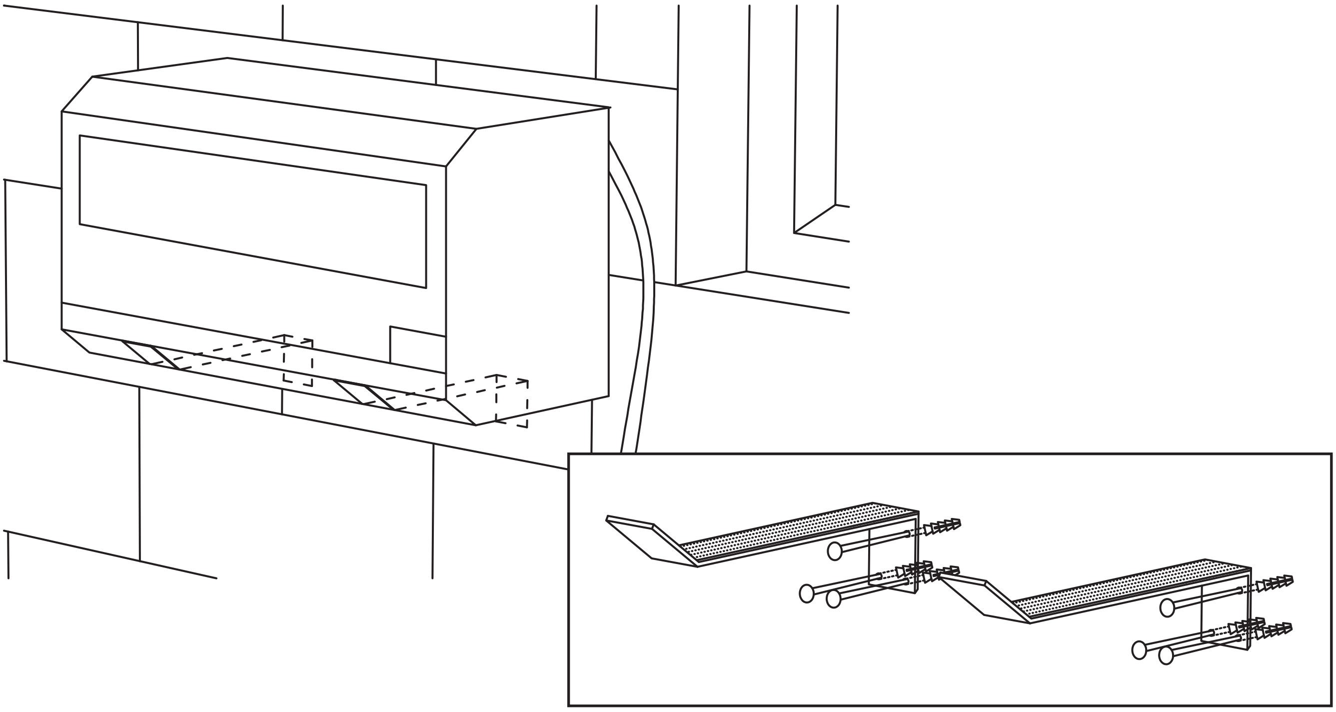
Consequences

If laboratory equipment breaks, then the hospital will lose vital diagnostic capabilities. The equipment may also be expensive to replace.

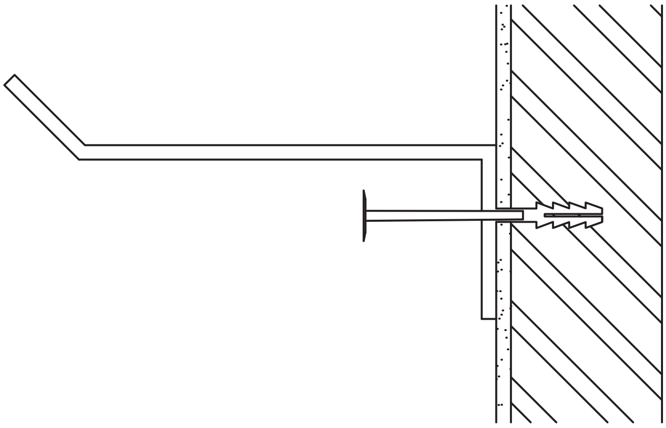
Check These Related Items

Electrical distribution system (see pg.131): Laboratory equipment typically needs electricity, in order to function.

Methods of Anchoring



Small wall-mounted equipment can be fixed to the wall using brackets or bolts. Some electronic equipment might require specialized mounting hardware. Several manufacturers produce mounting hardware. Some existing anchorages may be adequate for the expected earthquake forces.



When installing new wall-mounted equipment, be sure to anchor it properly. You may need to consult an engineer about how to anchor particularly heavy or sensitive equipment. The manufacturer may also be a good source of information about seismic anchorage, particularly if it sells the equipment in other high earthquake hazard areas like California and Japan.

Expertise Required

Do it yourself. Most wall-mounted equipment can be properly anchored by users following manufacturer's instructions.

Recommended Priority

Continued Service. The hospital needs the equipment to function normally.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring wall-mounted equipment properly is typically inexpensive. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Consult the manufacturer, and see Appendix B, page 167 for more information on anchoring equipment to walls.

Laboratory Bench-mounted Equipment

Used to perform laboratory tests; located in laboratory.

Potential Earthquake Damage

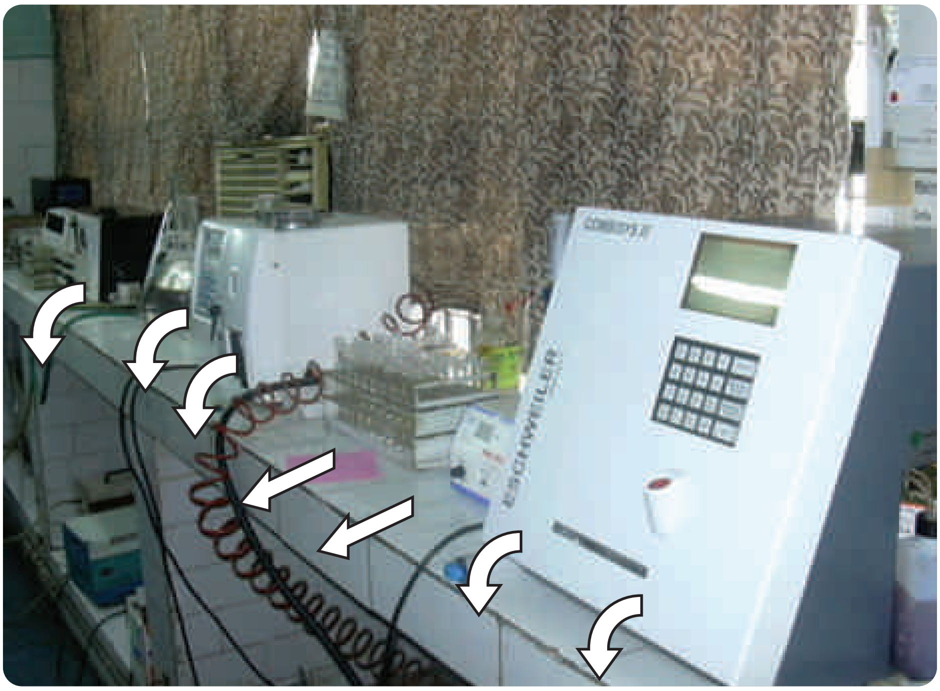


Photo credit: SEEDS

Strong shaking can cause inadequately anchored wall-mounted equipment to fall to the floor.

Photo credit: California OSHPD

Photo credit: California State University, Northridge Emergency Management

Wall-mounted monitor fell (left) after screws in attachment bracket sheared off (right) during an earthquake simulation test at an engineering laboratory.

Improperly anchored wall-mounted equipment can fall to the floor and break.

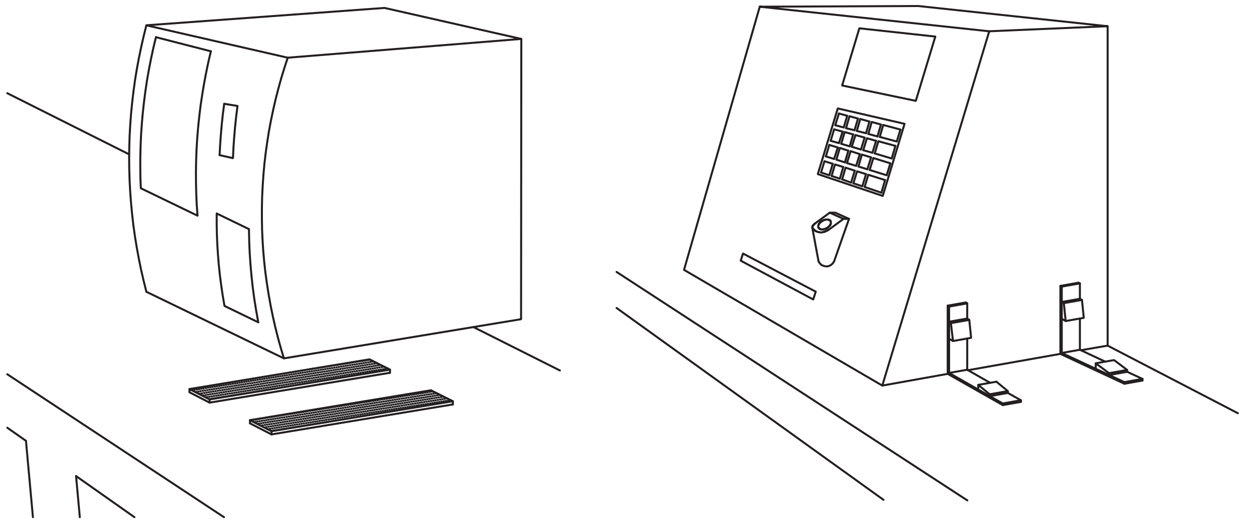
Consequences

The broken equipment will not be available for use and could be expensive to replace.

Check These Related Items

Electrical distribution system (see pg.131): Equipment typically needs electricity in order to function.

Methods of Anchoring



Laboratory equipment that does not need to be moved should be bolted to the bench/table through holes in the equipment itself or using an L-bracket, as shown below. Anchor other laboratory equipment using hook and loop tape (i.e. Velcro), or specially designed straps or tethers. Several manufacturers sell anchoring devices specifically made for use in laboratories.

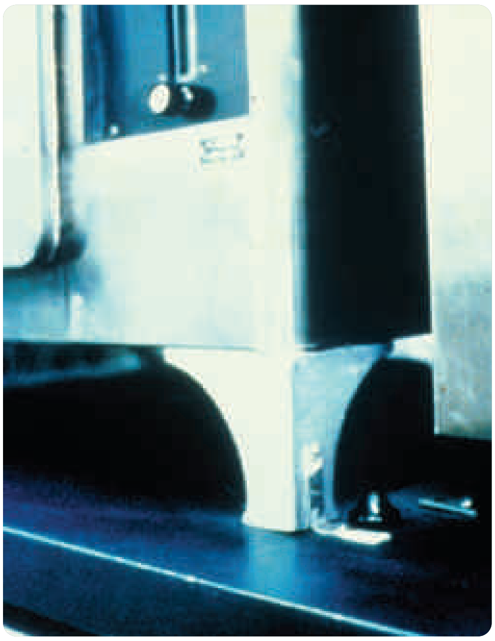
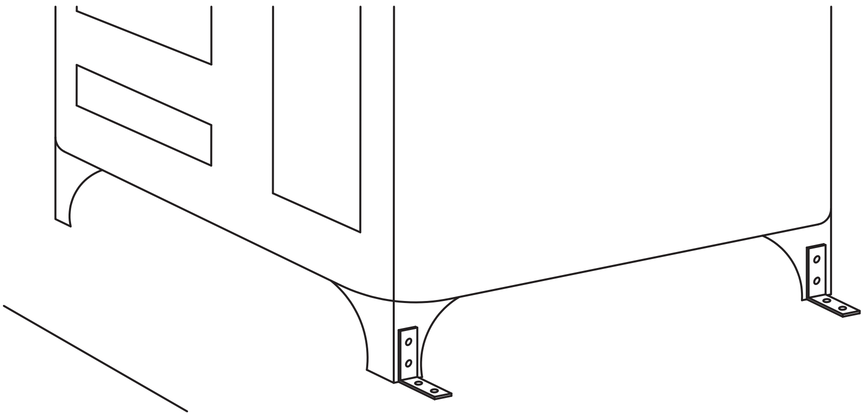


Photo credit: California OSHPD



Expertise Required

Do it yourself. Follow the manufacturer's instructions to install the restraint device.

Recommended Priority

Continued Service. The hospital needs its laboratory facilities to function normally.

Retrofit Cost and Disruption

Low to moderate cost for parts, low cost for labor, minor level of disruption. Anchoring bench-mounted laboratory equipment is typically inexpensive, though some anchoring devices can be moderately expensive. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Consult your equipment's manufacturer, and see Appendix B, page 167 for more information on installing restraints.

Blood Bank Refrigerator

Stores blood for transfusions; located in blood bank.

Potential Earthquake Damage

Photo credit: SEEDS

Strong shaking can cause blood bank refrigerators to slide or topple.

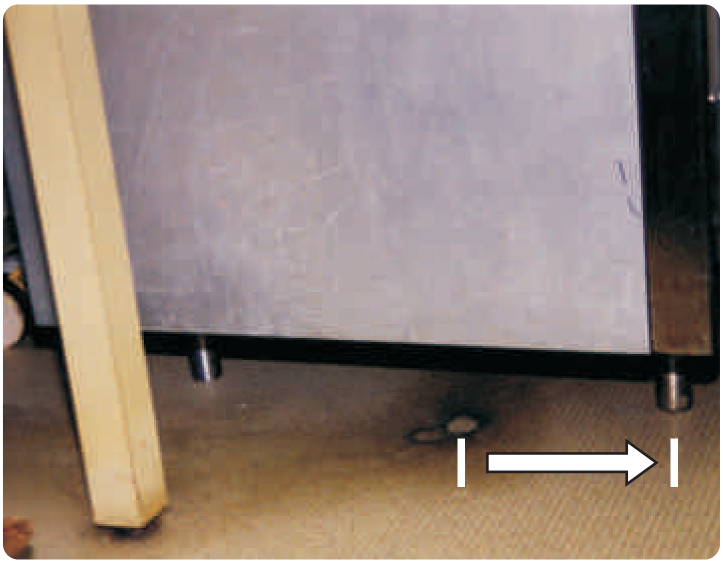


Photo credits: California OSHPD

Blood bank refrigerator moved approximately 100 cm during in the 1994 Northridge, California earthquake. Close-up of leg showing movement (left); overall view of refrigerator (right).

Blood bank refrigerators could slide or topple during strong earthquake shaking and could break their electrical connections. Some blood banks use ordinary refrigerators intended for home use; these refrigerators do not typically have door latches, and the door is likely to come open in an earthquake. If the door does open, then blood bags could fall out onto the floor.

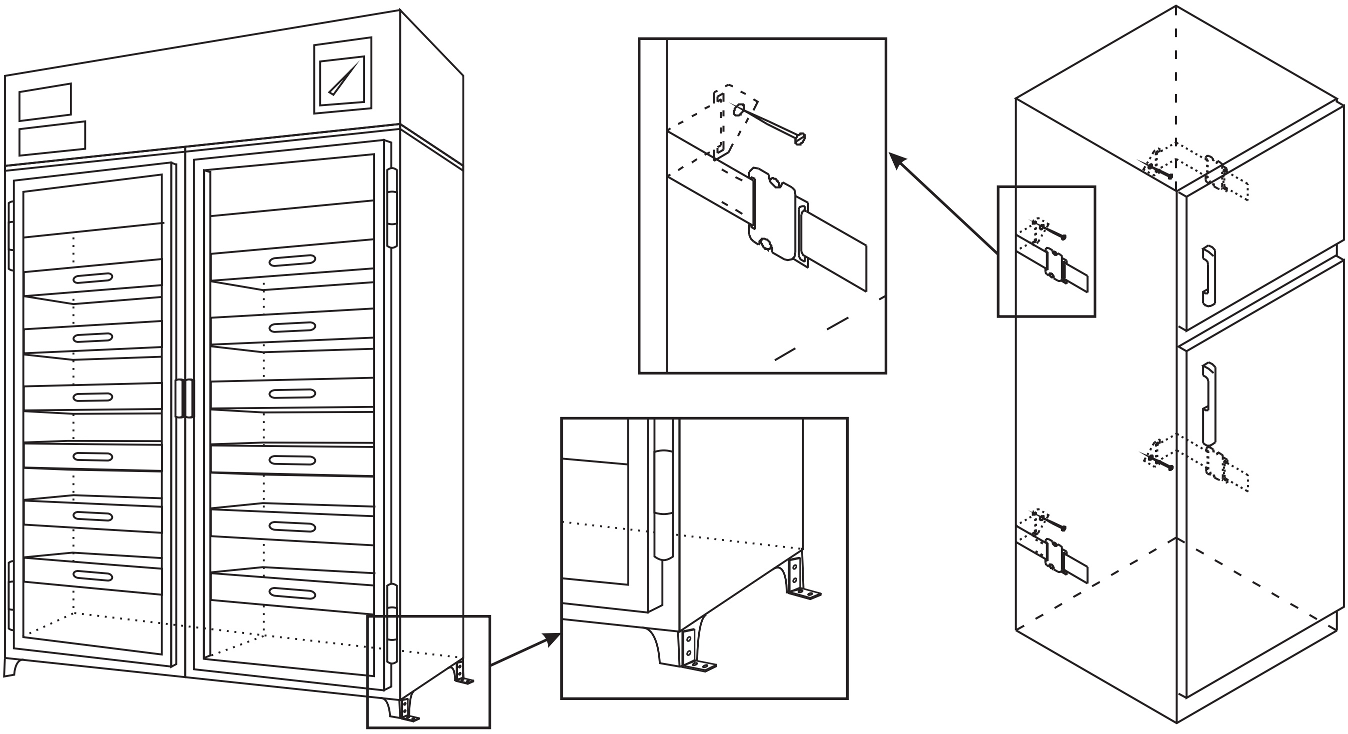
Consequences

Toppling could damage the refrigerator and cause it to lose power. Blood is highly perishable and will go bad if not promptly refrigerated again. Spilled blood bags could go bad, if they are not immediately retrieved and refrigerated. Blood will also be in high demand immediately after the earthquake.

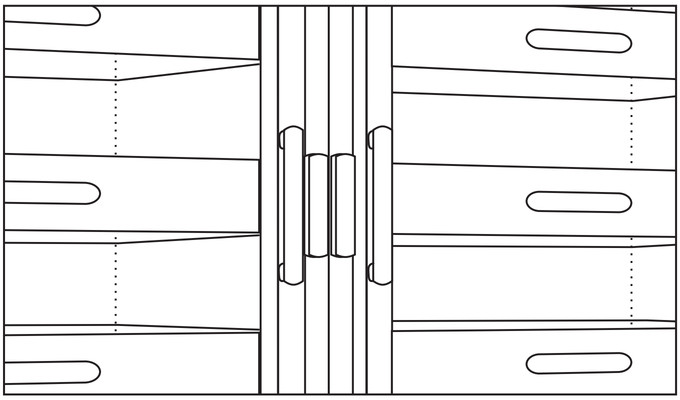
Check These Related Items

Electrical distribution system (see pg.131): Blood is highly perishable, and the refrigerator needs electrical power from the emergency power system to continue functioning.

Methods of Anchoring



Keep refrigerators from toppling by fastening the legs to the floor. The restraints are not actually connected to the refrigerator body (so they do not disturb the installation or void the warranty) but keep it from toppling. For smaller refrigerators, you could provide straps or connect the top of the refrigerator to the wall with a steel angle.



If your blood bank refrigerator does not have a door latch (but most commercial blood bank refrigerators do), then install one. A latch will keep the door from coming open and blood bags from falling out onto the floor. A proper latch will also ensure that the door is fully closed, which is essential to maintaining the proper temperature.

Expertise Required

Do it yourself. You can install most refrigerator anchorages and latches yourself. You will need an engineer to design the restraints if you decide to anchor the refrigerator at its base.

Recommended Priority

Essential Services. The hospital will need blood to treat those injured by the earthquake.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring refrigerators is inexpensive, if you use straps or top restraints. Base restraints are more expensive. Latches are very inexpensive. Work can often be done while the refrigerator is in operation, but blood should be temporarily shifted to another refrigerator during installation of restraints, if anchoring at the base.

Where to Find More Information

Please see Appendix B, page 167 for more information on installing anchors.

Furnishings and Hospital Administrative Systems

Furnishings such as shelving and cupboards can topple during an earthquake, possibly causing injuries and blocking exits. The resulting loss of medical records or items needed to administer the hospital can also lead to confusion and can endanger patients.

This section contains information on how to anchor the following types of furnishings and elements of hospital administrative systems:

Cupboards

Store medical supplies; located in stockrooms, offices, wards, and sometimes other spaces.

Potential Earthquake Damage

Photo credit: Kanchan Sabnis, GeoHazards International

Strong shaking can cause unanchored cupboards to slide or topple. If the doors are open or fall open during the earthquake, then the contents can fall out.

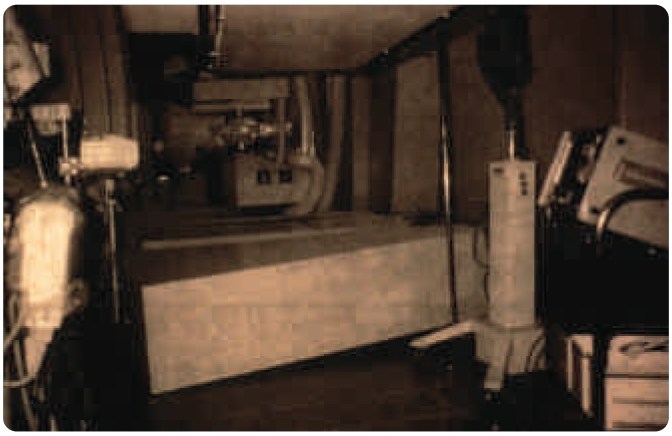


Photo credit: Degenkolb Engineers, FEMA 74

Photo credit: EERI 2003 Bam Iran Reconnaissance Report

Overturned cupboards in radiology department, 1995 Kobe, Japan earthquake (left); overturned cupboards in a hospital in the 2003 Bam, Iran earthquake (right).

Tall and narrow cupboards can topple in an earthquake, and more squat cupboards can slide. If the cupboard door is not latched, then it can open, and contents can spill. Even if the door stays closed, bottles or other fragile containers inside the cupboard can be tossed about and break during strong ground shaking.

Consequences

Hospital and staff can be injured by toppling or sliding cupboards. Cupboards located in corridors or near doorways can block exits. If the cupboard door opens, then chemicals, medicines or hazardous substances inside it can spill or mix, creating a hazard.

Check These Related Items

Items on shelves (see pg.89): If the cupboard contains chemicals or medicines on shelves, then those bottles need to be in bins or other containers to keep them from breaking and mixing.

Methods of Anchoring

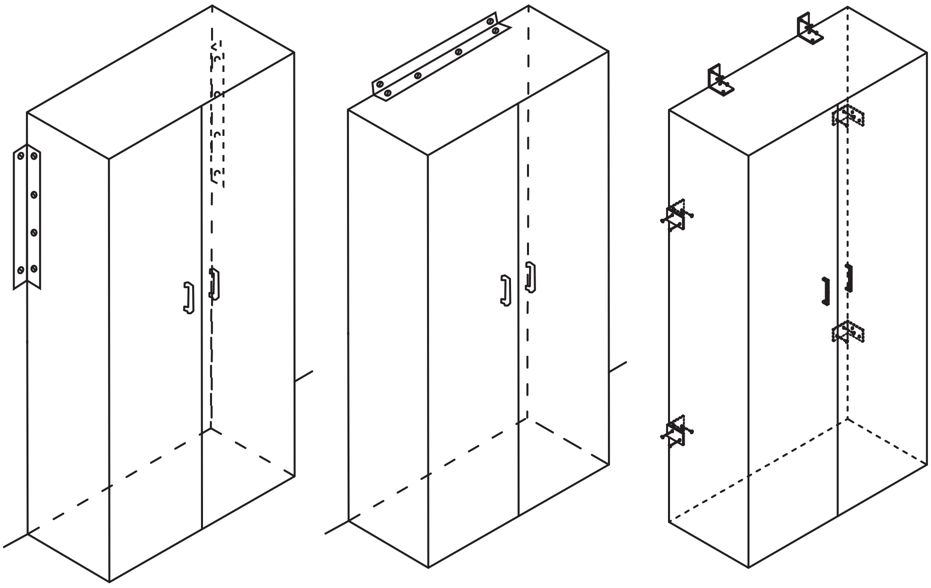
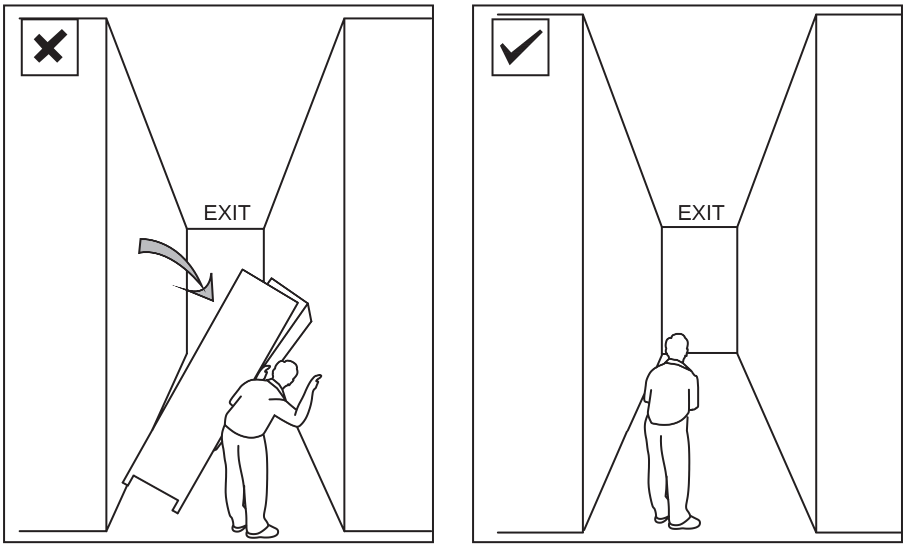


Photo credit: FEMA/ATC Training Course

Steel or wooden cupboards can be easily anchored to the wall using L-brackets or an angle bracket, masonry plugs or concrete screws (depending on the type of wall), and a drill machine. You can use two L-brackets at the top of the cupboard, and two more L-brackets each on the left and right sides, as shown above. For large cupboards (1 m x 2m x 0.5 m or larger), use larger L-brackets. Alternatively, you can use a single long angle bracket across the top of the cupboard. Keep the door latch closed, so that the contents won't fly out during an earthquake. Place breakable contents in separate padded bins.



Cupboards can also be relocated away from doors and out of corridors, so they will not block exits. They can be moved away from patient areas and work areas, where they could fall on someone. However, even if cupboards are relocated, you should anchor any cupboards that contain items that would cause problems, if they were to spill.

Expertise Required

Do it yourself. Nearly anyone can relocate cupboards or learn to use a drill machine.

Recommended Priority

Continued Service. For most cupboards that store supplies not easily damaged.
Critical Safety. For cupboards that can block exits or fall on patients or staff members.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring cupboards to the wall is very inexpensive. Relocating cupboards costs virtually nothing to do. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for information on installing fasteners.

File Cabinets

Store records and information; located in offices.

Potential Earthquake Damage

Strong shaking can cause unanchored file cabinets to topple, or drawers to slide out. Contents can fall out.

Photo credit: Dr. Shakti Gupta, AIIMS

Photo credit: National Geophysical Data Center

Photo credit: FEMA74

Overturned filing cabinets in the 1980 Livermore, California earthquake (left); filing cabinets damaged by the 1994 Northridge, California earthquake (right).

Drawers can slide out and/or cabinets can topple over.

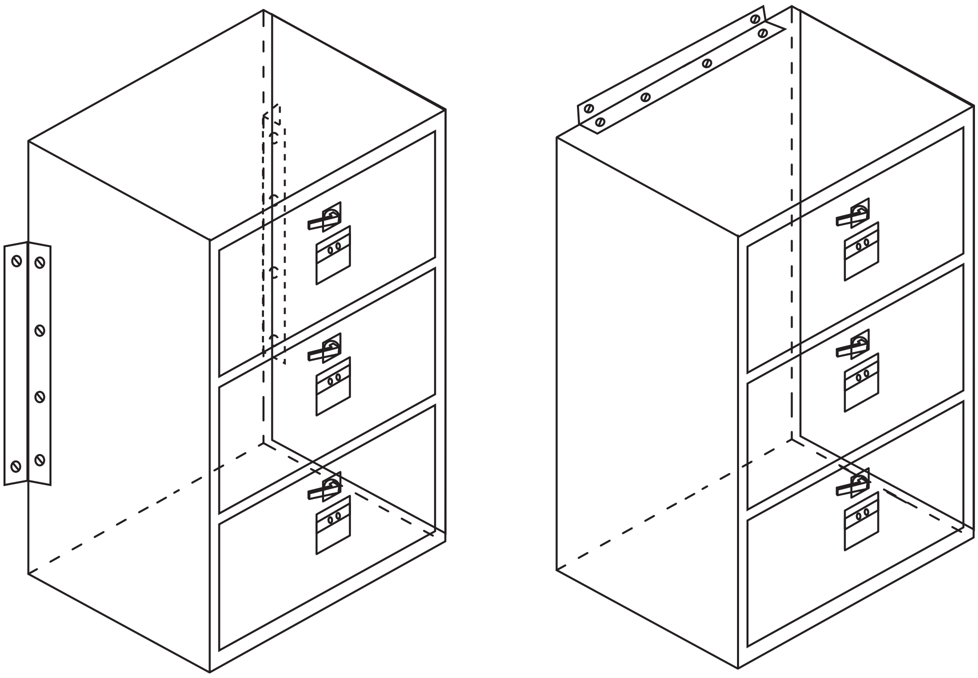
Consequences

Hospital staff working near filing cabinets can be injured by toppling file cabinets or by file drawers sliding out. File contents can be mixed up, if they spill out of drawers.

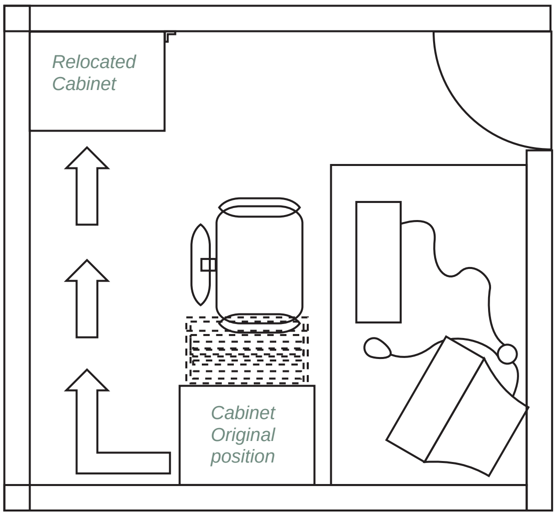
Check These Related Items

There are no related items to check.

Methods of Anchoring



File cabinets can be easily anchored to the wall using L-brackets, angles, masonry plugs or concrete screws (depending on wall type), and a drill machine. You should use two L-brackets at the top of the cabinet, and two more L-brackets each on the left and right sides, as shown above.



File cabinets can also be relocated away from doors and out of corridors, so that they will not block exits. They can be moved away from work areas, where they could fall on someone.

Expertise Required

Do it yourself. Nearly anyone can relocate file cabinets or learn to use a drill machine.

Recommended Priority

Continued Service. For most file cabinets.
Critical Safety. For file cabinets that can block exits or fall on staff members.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring file cabinets to the wall is very inexpensive to do. Relocating file cabinets costs virtually nothing. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for information on installing fasteners.

Medical Records Storage

Stores patient medical records; located in central storeroom, with smaller units elsewhere.

Potential Earthquake Damage

Photo credit: Hari Kumar, GeoHazards International

Strong shaking can cause unbraced shelving to deform or topple. Unrestrained files containing paper or film records can slide off of shelves.

Photo credits: California OSHPD

Workers stand atop piles of medical records more than one meter deep that spilled during the 1994 Northridge, California earthquake (left); toppled X-ray records cabinet, 1983 Coalinga, California earthquake (right).

Unbraced shelves can collapse or topple, spilling the files that they contain. Individual records can fall out of files and become mixed up with other records.

Consequences
Hospital staff working in the medical records storage area can be injured by toppling shelving. The medical records storage areas contain critical information for patient care, and such information will not be available, if the files fall from the shelves and can't be readily located.

Check These Related Items
There are no related items to check.

Methods of Anchoring

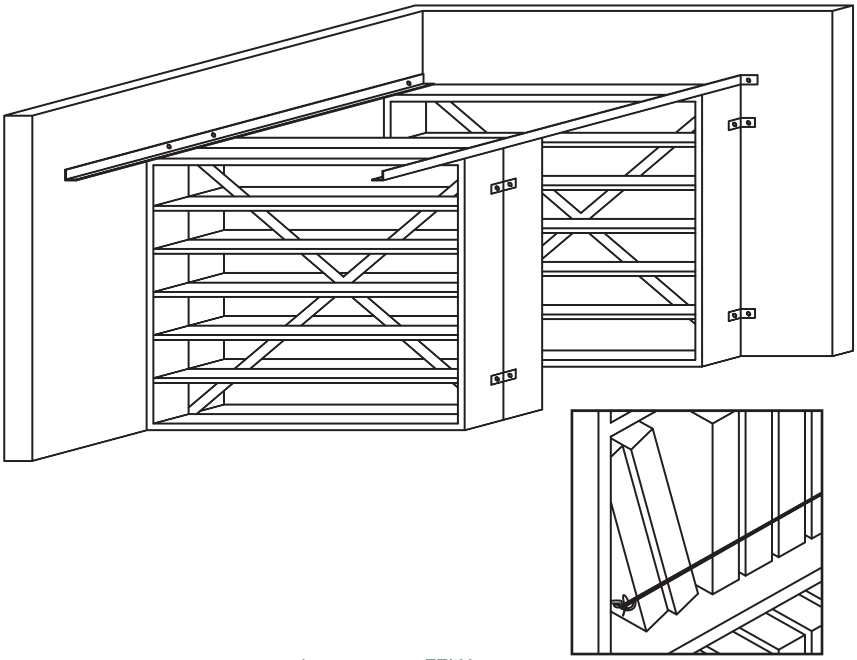


Image source: FEMA

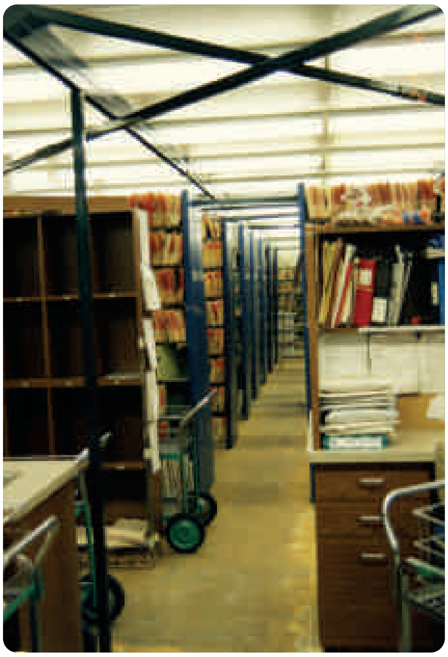


Photo credit: California OSHPD

Shelving for medical records can be attached securely to the wall or floor, or can be connected with bracing across the top to prevent the shelves from toppling. Restrain shelves in both directions. If shelves are open racks without a back, then brace shelving units with cross bracing to keep the units themselves from failing.

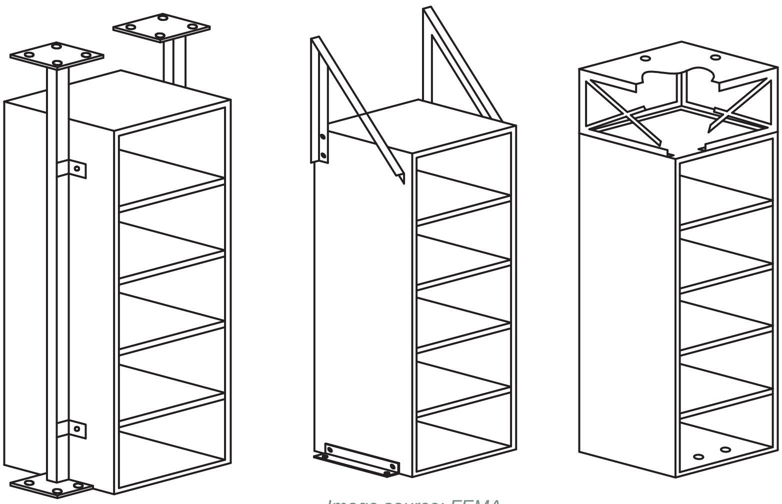


Image source: FEMA

You can keep records from falling out by installing lips on the shelves or shelf restraints such as elastic cords (shown above, inset). Ask the medical records staff for input on the shelf restraint system to use; a system that makes it difficult for them to work will likely be removed. Alternatively, you can make sure that the individual record sheets inside files are securely attached to the file, so that they will not get mixed up, if the file falls. If you choose this method, then be sure to designate some people to reshelve records after the earthquake.

Expertise Required

Some engineering required. An engineer will need to design the bracing for the shelving system.

Recommended Priority

Continued Service. The hospital needs medical records to document care provided to patients and for reference.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Bracing systems for shelving can typically be built from inexpensive, readily available components. Work can be scheduled to minimize disruption. Files will need to be shifted one section at a time, as each shelving unit is braced.

Where to Find More Information

Please see Appendix B, page 167 for more information on shelf restraints.

Computers

Store patient and administrative information; located in offices and patient registration areas.

Potential Earthquake Damage

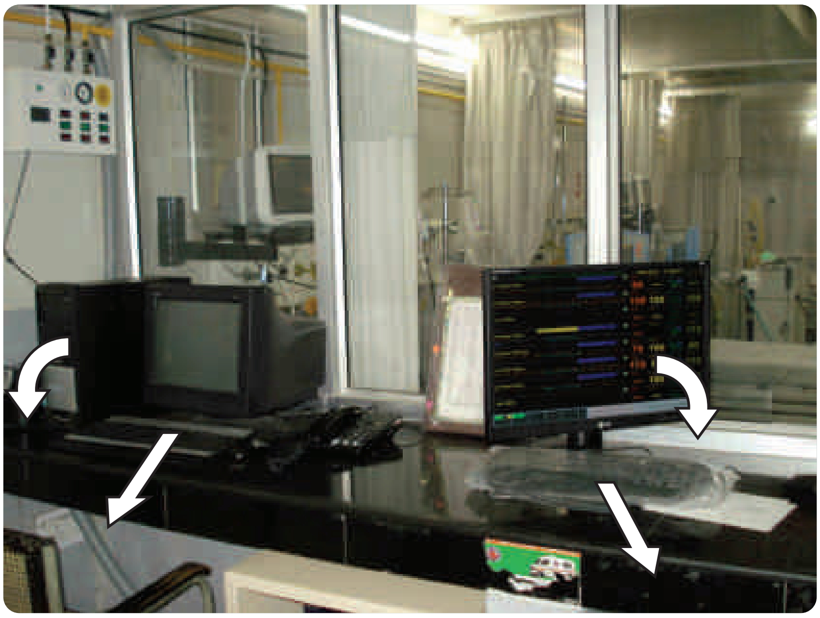


Photo credit: Manisha Dharan, THOT Designs

Strong shaking can cause unanchored computers and monitors to slide or topple off desks and stands.

Photo credit: NiSEE (Robert Reitherman)

Photo credit: Khalid Mosalam, University of California, Berkeley

Monitor fell from desk during the 1994 Northridge, California earthquake (left); equipment similar in size to monitors and printers toppled from shelf and broke in the 2009 L'Aquila, Italy earthquake (right).

Computers, monitors, and peripheral hardware such as printers can slide or topple off of desks or stands. The impact can damage the computer or break the computer monitor screen.

Consequences

Computers contain vital data and records. These can be lost (or can be very expensive to retrieve), if the computer breaks due to impact from a fall, and if the data are not backed up offsite. If computers used to monitor patients should break, then medical staff will have much less information about the patient's current condition. The computer, monitor, and peripheral equipment may also be expensive to replace.

Check These Related Items

Offsite backup: Vital information stored on your hospital's computers should be backed up regularly to an off-site location. This is a good practice, even if you are not in earthquake country – many other things, from computer viruses to hardware malfunctions, can cause a computer to lose data or to break down without warning.

Methods of Anchoring

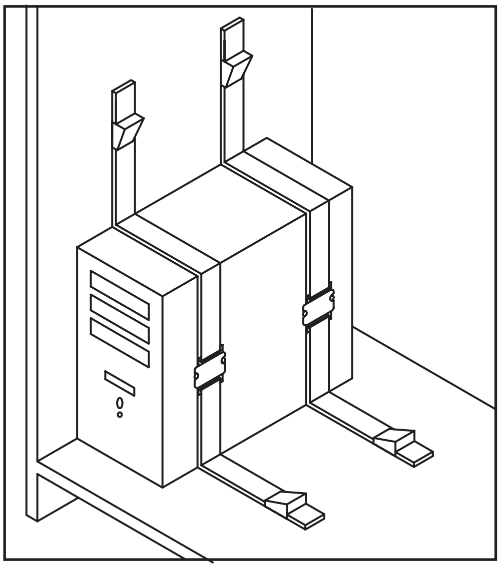
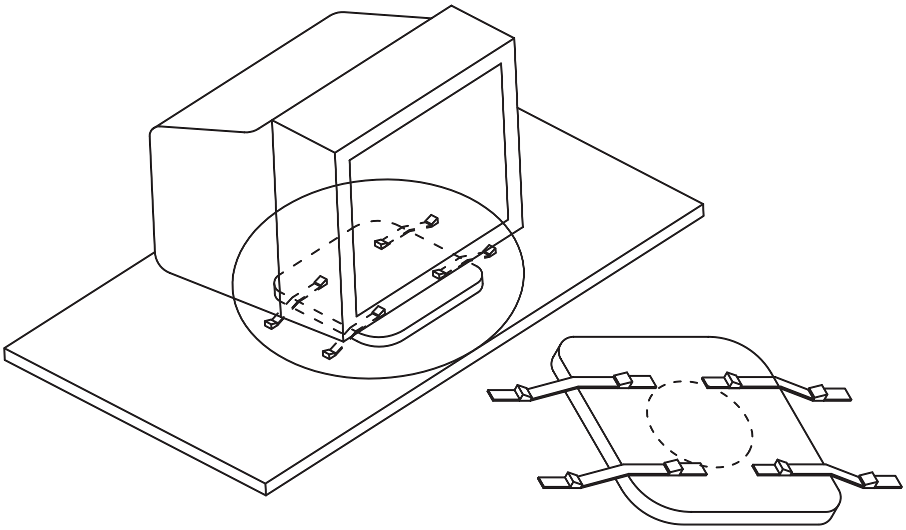


Photo credit: Rebekah Green, Western Washington University

Computer central processing units (CPUs) and monitors can be anchored using special, commercially available straps designed to anchor computers. Many of these straps and clips are self-adhesive. Anchor the CPU to the desk as shown. Anchor tower CPUs placed on the floor to the side of a desk or table. Anchor the monitor to the desk, stand, or CPU. Clean the surfaces very well with rubbing alcohol before using any type of adhesive fasteners. Self-adhesives are convenient to install but can start to peel off after a year or so. You can use self-adhesive tape from a hardware store if the original self-adhesive wears out.



If using self-adhesive clips, instruct hospital staff to check these clips as part of a yearly maintenance program and to replace either the self-adhesive or the entire clip, when it starts to peel off and whenever the electronic equipment is moved to a new location. In addition, your hospital should develop and practice back-up operating procedures as part of the emergency response plan, in case you lose all computers (i.e. revert to manual forms for admissions and records, etc.).

Expertise Required

Do it yourself. Nearly anyone can anchor a computer to a desk.

Recommended Priority

Continued Service. Hospitals need the critical data and information on computers to continue normal operations.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minor level of disruption. Anchoring computers to desks is inexpensive. Work can be done quickly and can be scheduled to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for information on anchoring computers.


SURGICARE
SURGICA

Supplies

A hospital can't deliver medical care, if it does not have supplies. After an earthquake, it will be doubly important to have undamaged supplies ready to use, because demands will be greater, and normal supply distribution will be disrupted.

This section contains general information on how to seismically protect the following supplies:

Cupboards used to store supplies are found on p.77, while refrigerators used to store the blood supply are found on p. 73.

Supplies on Trolleys

Include bandages, instruments, and pharmaceuticals; located throughout hospital.

Potential Earthquake Damage

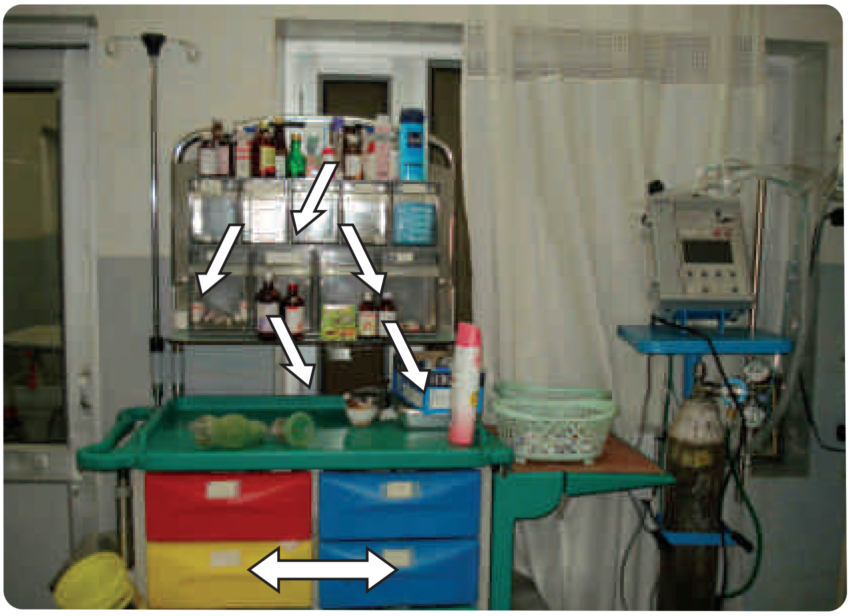


Photo credit: Manisha Dharan THOT Designs

Strong shaking can cause trolleys to roll, and if they impact other objects, then unanchored items on them could fall or slide.

Photo credit: Degenkolb Engineers, FEMA 74

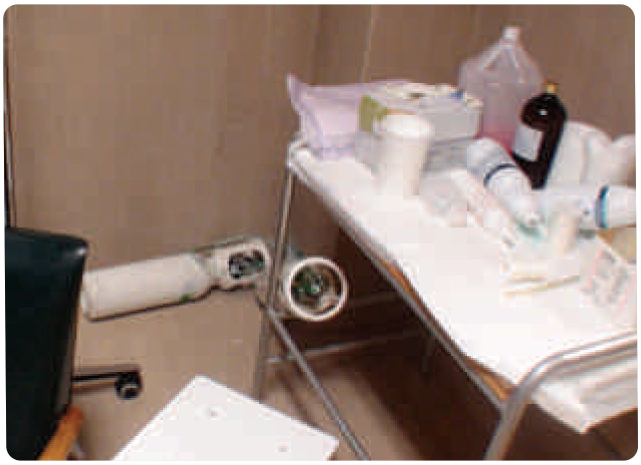


Photo credit: Khalid Mosalam, University of California, Berkeley

Chemical spill in a hospital due to fallen bottles, Costa Rica earthquake (left) ; spilled items on top shelf of trolley and fallen canisters, 2009 L'Aquila, Italy earthquake(right).

Trolleys are designed to be mobile, and may roll during strong shaking. Rolling tends to limit the earthquake forces that are transferred into the trolley itself but could cause the cart to impact another object. If the objects on the trolley aren't either fastened to the trolley, restrained, or contained in bins, then they could fall or slide due to the impact.

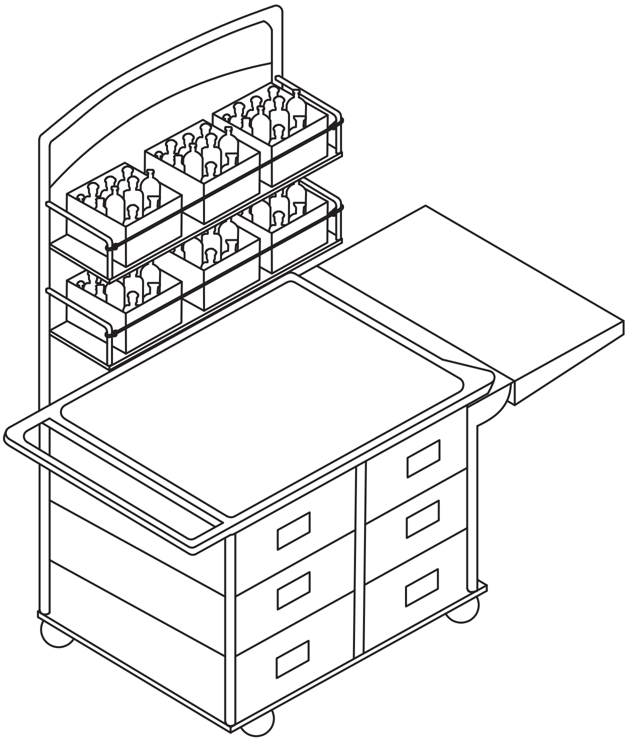
Consequences

Unanchored equipment on trolleys could fall and break. Items on certain trolleys, such as crash carts, must be accessed quickly in emergency situations. The cart could be rendered unusable, if emergency drugs spill and mix, or if emergency equipment falls off of the cart and breaks. Sterile instruments and supplies that fall to the floor are no longer sterile.

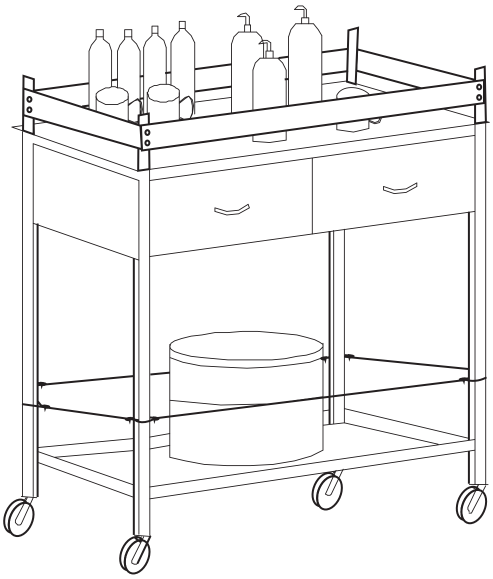
Check These Related Items

There are no related items to check.

Methods of Anchoring



Trolleys themselves cannot be anchored because they must move, in order to function. You could place trolleys in a "docking station" on the wall when not in use, but this requires additional staff effort to restrain the trolley. Instead, consider restraining the objects on the trolley so that they do not fall or slide off, if the trolley impacts another object. Many trolleys have rails or a lip on the shelves that will keep many items in place, but these are not always included on all four sides. Also, if there is no lip, then small items can slide between the rail and the shelf. Placing smaller items in bins could prevent this. Larger equipment that is tall enough to topple over the rails or lip should be anchored to the trolley using straps or other devices.



Pay particular attention to breakable glass bottles, especially those that contain chemicals or medicines that could mix or create a hazard, if they were to spill. Broken glass on the floor is also a hazard. Restraining objects on the trolley will also help to protect against spills and breakage due to accidental collisions during routine usage. Also, if the hospital is badly damaged in an earthquake, then a trolley with properly restrained items will be ready to be pulled outside and used to treat patients there.

Expertise Required

Do it yourself. Anyone can anchor equipment with straps or can place supplies in bins.

Recommended Priority

Continuous Service. Items on trolleys are an integral part of normal hospital operations.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minimal level of disruption. You can place supplies on trolleys into bins very easily and cheaply. This can be done during normal restocking of supplies and does not need to disrupt operations.

Where to Find More Information

Please see the Appendix B, page 167 for more information on installing restraints.

Supplies on Racks

Includes supplies on open racks or shelves; located in storage rooms or elsewhere as needed.

Potential Earthquake Damage

Photo credit: D.K. Paul, IIT Roorkee

Strong shaking can cause the contents of racks to slide out and fall to the floor and can cause racks themselves to topple, if they are tall and narrow.

Photo credit: Khalid Mosalam, University of California, Berkeley

Photo credit: Degenkolb Engineers

Supplies in rack at left toppled and spilled; supplies in rack at right were in bins and did not, 2009 L'Aquila, Italy earthquake (left); supplies in a medical office fell from shelves, 1994 Northridge, California earthquake (right).

Many important supplies are stored on open racks. During an earthquake, these supplies can slide from shelves and fall to the floor, or unanchored racks can topple.

Consequences

Breakable supplies, such as glass bottles of laboratory chemicals and medicines, could break and spill, creating a chemical hazard. The fall from shelves could damage other supplies and render them unusable. The increased demand for services and the likely disruptions in normal supply deliveries after an earthquake will make any loss of supplies unacceptable. Hospital personnel will lose valuable time sorting and re-shelving items that fall off of racks, even if those supplies are not damaged.

Check These Related Items

There are no related items to check.

Methods of Anchoring

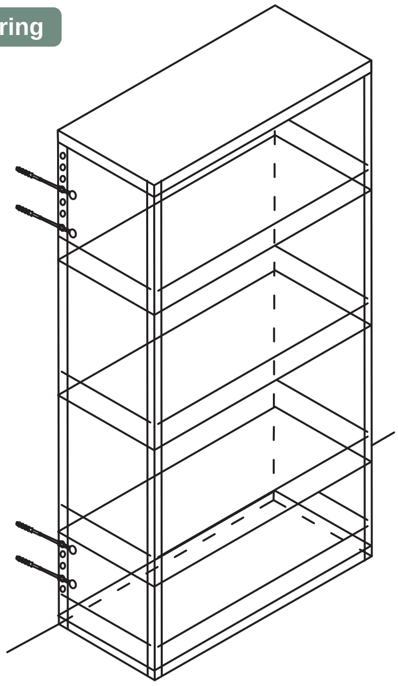
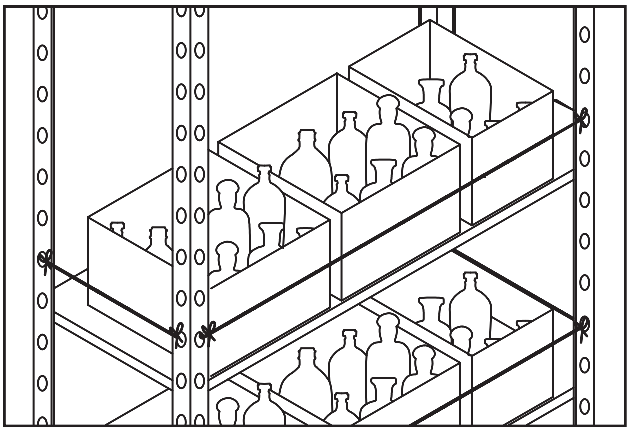


Photo credit: Rebekah Green, Western Washington University

First, anchor the rack to the wall with L-brackets, steel angles, cables, or chains to keep it from toppling. This is especially important for tall racks. Next, provide shelf restraints to keep the items on the shelves from sliding out and falling. There are several different options for shelf restraints, including elastic cord (shown above); metal springs; and clear plastic, wood, or metal strips. Bottles that could break and cause the chemicals inside to spill or mix should be placed in bins that are restrained with shelf restraints (below right), or in custom restraints (below left). Consult with the staff who work in the supply area to decide on a system of shelf restraints that will not impede their work; otherwise they are likely to remove the restraints.

Photo credit: FEMA 370



Expertise Required

Do it yourself. Virtually anyone can anchor racks and install shelf restraints.

Recommended Priority

Continuous Service. The hospital needs supplies on racks to continue functioning during the post-earthquake period.

Retrofit Cost and Disruption

Low cost for parts, low cost for labour, minimal level of disruption. The parts required to anchor racks are very inexpensive. Shelf restraints range from very inexpensive to moderately expensive (for custom systems). Anchoring the racks and installing shelf restraints can be done between normal restocking and should not disrupt hospital operations.

Where to Find More Information

Please see Appendix B, page 167 for information on installing fasteners.

Pharmacy

Storage and dispensing of pharmaceuticals; located in a central pharmacy and other locations.

Potential Earthquake Damage

Photo credit: Shakti Gupta, AIIMS

Strong shaking can cause glass to break, and pharmaceuticals to fall and possibly to spill.

Photo credit: U.S. National Geophysical Data Center (G. Reagor)

Photo credit: NiSEE (Robert Reitherman)

Fallen bottles and merchandise in a chemist shop, 1979 Imperial Valley, California earthquake (left); items fell off pharmacy shelves, 1994 Northridge, California earthquake (right).

Unrestrained containers of pills can fall from shelves and can potentially spill or mix. Bottles of liquid medicine can also spill or mix, creating a potential chemical hazard.

Consequences

Pills that spill from their containers may no longer be conclusively identifiable and may need to be discarded. Even if pills do not spill, picking up and reorganizing the containers can be a major undertaking, at precisely the time when the pharmacists most need to keep the hospital supplied with life-saving drugs.

Check These Related Items

There are no related items to check.

Methods of Anchoring

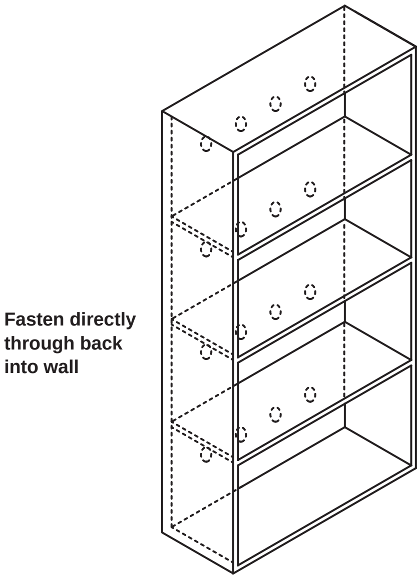
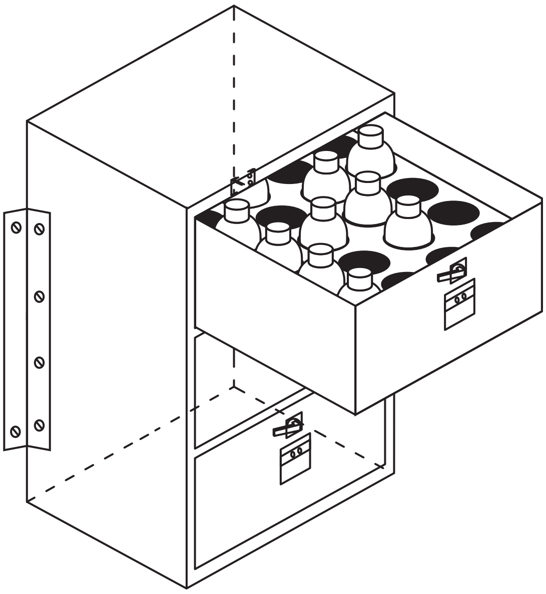
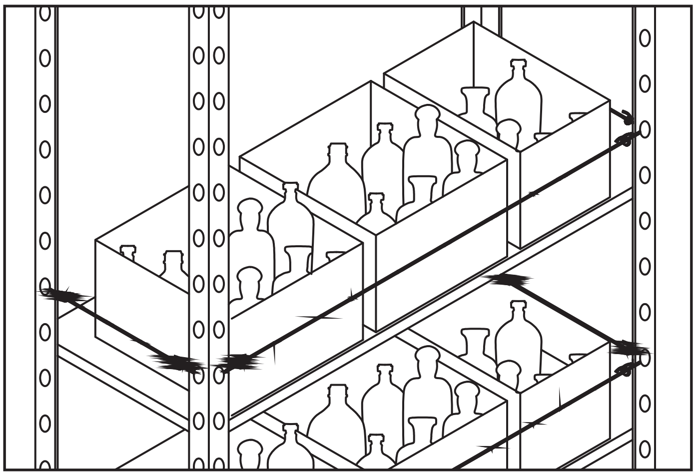


Photo credit: Degenkolb Engineers, FEMA 74

Anchor shelving, racks and cabinets in the pharmacy to the wall using the option above, L-brackets, or steel angles. Provide shelf restraints, such as the Plexiglas lip shown at above right, to keep pharmaceuticals on shelves. The clear lip allows the pharmacy staff to see the medicines. The shelf lip can also hold labels to help to track and organize pharmaceuticals. Be sure to consult with the staff who work in the pharmacy to decide on an appropriate system of shelf restraints that will not impede their work.





Expertise Required

Do it yourself. Virtually anyone can anchor racks and shelving and install shelf restraints.

Recommended Priority

Continuous Service. The hospital needs pharmaceuticals, in order to continue functioning after an earthquake.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minimal level of disruption. Anchoring pharmacy shelves and providing shelf restraints is inexpensive. Work can be scheduled for less busy periods (such as when the pharmacy is closed to the public) and can be phased to minimize disruption.

Where to Find More Information

Please see Appendix B, page 167 for information on installing fasteners.

Sterile Storage

Sterile items; located in sterilization room and distributed as needed.

Potential Earthquake Damage

Photo credit: Shakti Gupta, AIIMS

Strong shaking can cause unanchored racks storing sterile items to topple, and sterile items can fall from shelves.

Photo credit: California OSHPD

Photo credit: University of Washington

Toppled light-gage racks in hospital, 1995 Kobe, Japan earthquake (left); books fell and light-gauge racks similar to those in sterile storage areas were damaged in the 2001 Nisqually, Washington earthquake(right).

Unanchored racks containing sterile items could topple, or the sterile items could fall from shelves.

Consequences

Sterile items that fall to the floor are no longer sterile. Damage to sterile storage can leave the hospital without enough sterilized instruments, precisely when the demand for surgery and trauma care will be highest.

Check These Related Items

Autoclaves/sterilisers (see pg.53): There won't be anything to store, unless the sterilisers are working.

Methods of Anchoring

Photo credit: FEMA 74

Anchor racks and shelves for sterile storage to the wall or floor using L-brackets or smooth cables. The moveable rack at left is anchored to the floor with removable eye bolts and connected to the adjoining rack, which is also anchored to the floor. The angled lip at the front of the shelves and dividers keep contents from falling or getting mixed up. The racks below are connected together and anchored to the floor. Ensure that the anchoring hardware and shelf restraints can be easily cleaned and will not readily trap dust or dirt.

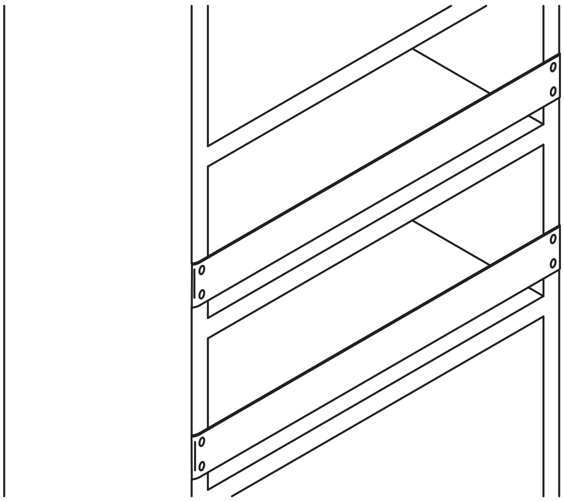


Photo credit: FEMA 74

Expertise Required

Do it yourself. Virtually anyone can anchor racks and shelving and install shelf restraints.

Recommended Priority

Continuous Service. The hospital needs sterile storage, in order to continue functioning after an earthquake.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minimal level of disruption. Work on sterile storage racks is very inexpensive and need not disrupt hospital operations. Sterile items can be placed in temporary sterile locations, such as on trolleys, while the shelves are being anchored and shelf restraints are being installed. The local area will need to be re-sterilized after holes are drilled in the walls, since this generates dust.

Where to Find More Information

Please see Appendix B, page 167 for information on installing fasteners.

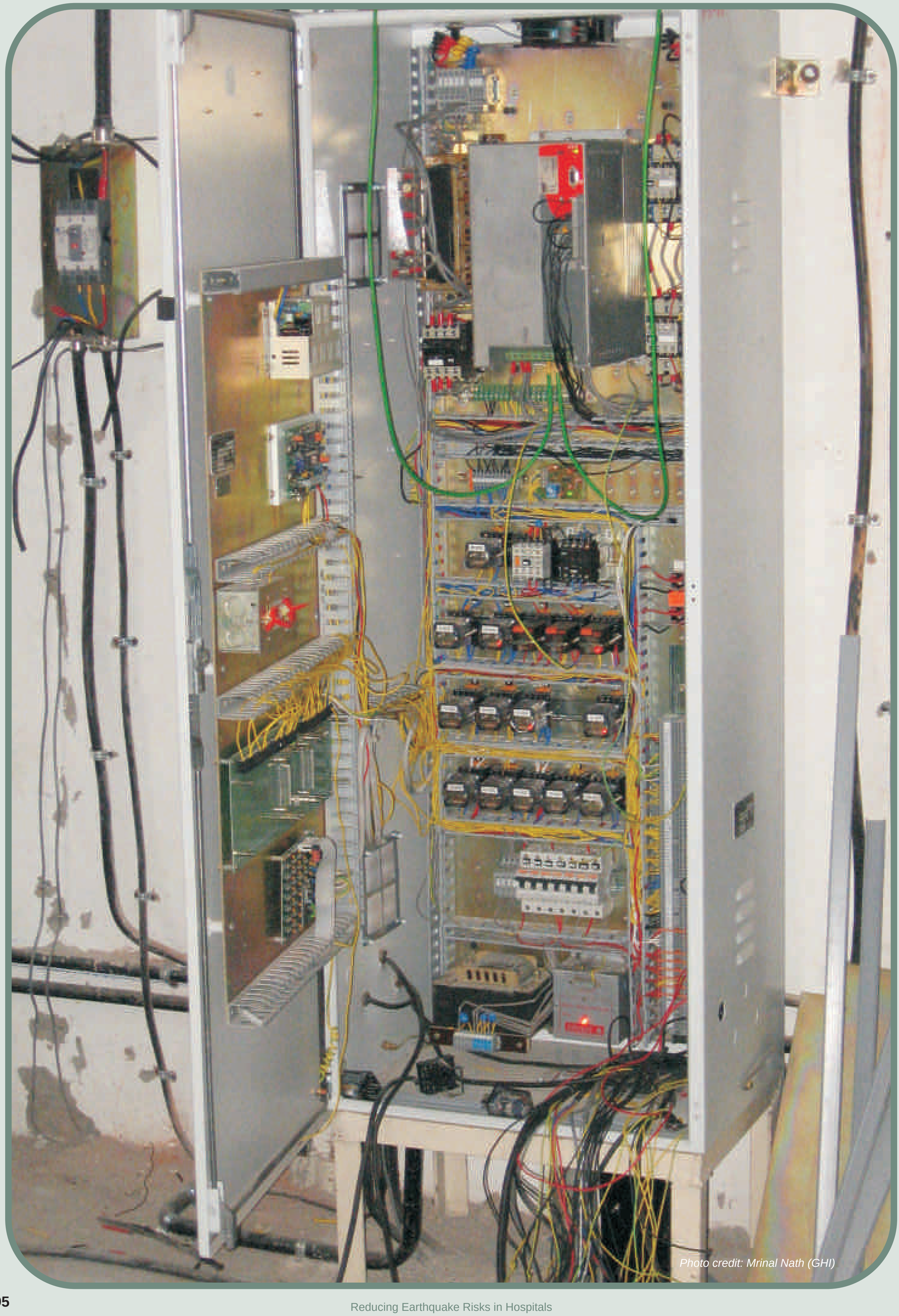


Photo credit: Mrinal Nath (GHI)

Mechanical and Electrical Equipment

Mechanical and electrical equipment keep the hospital's systems functioning. Equipment provides electricity, heat, air conditioning, domestic water (i.e., not fire-fighting water) and fire protection to the hospital. If an earthquake damages equipment or renders it inoperable, then the hospital will not be able to operate normally. The potential consequences of equipment damage can range from mild discomfort (due to failure of the air conditioning system) to death (due to loss of life support systems caused by failure of the emergency generator). However, most equipment can be properly anchored to be able to resist earthquake loads, at a low to moderate cost and with minimal disruption to hospital operations.

This section contains information on how to anchor the following types of mechanical and electrical equipment:

For rigidly-mounted mechanical equipment that is not listed here, follow the anchoring methods for boilers. For equipment on vibration isolators that is not listed here, follow the anchoring methods for emergency generators. For roof-mounted equipment, follow the anchoring methods for air handling units. For suspended equipment and other configurations not common in most hospitals, please see FEMA-74, Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide, for more information.

Communications racks and cabinets can be anchored using the methods for electrical cabinets on p115 For large roof-mounted communications equipment, you will need to consult an engineer.

Emergency Generator

Provides emergency power if grid supply is lost; often located in the physical plant building.

Potential Earthquake Damage

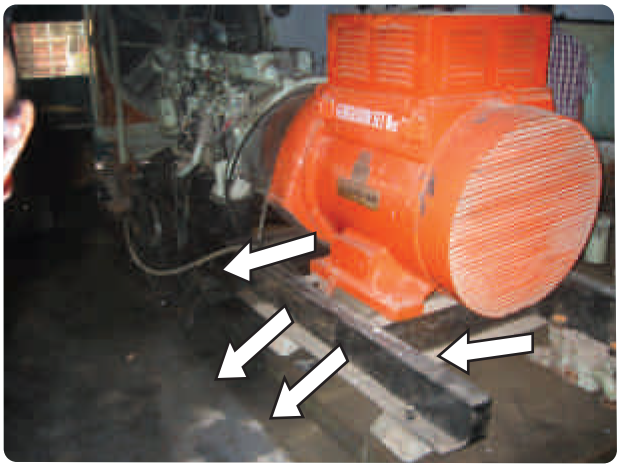


Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause emergency generators to slide and to fall off of their supports.

Photo credit: NiSEE (Karl Steinbrugge)

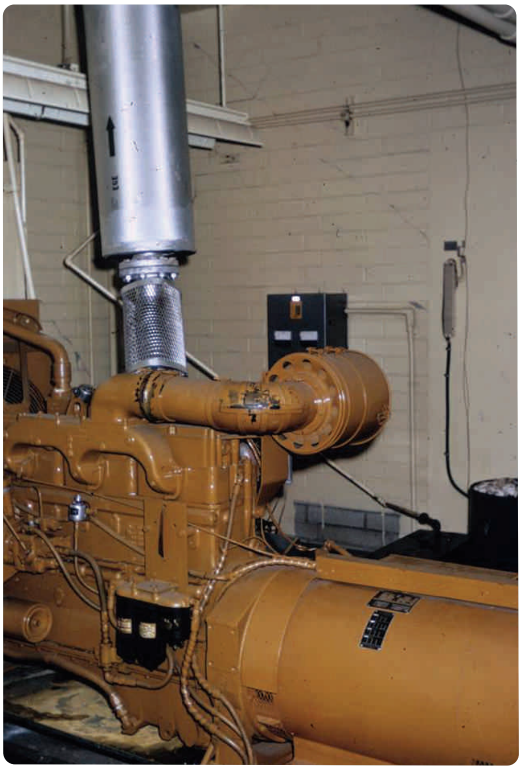


Photo credit: Degenkolb Engineers

The emergency generator at Olive View Hospital (left) fell off its vibration isolators and slid nearly a meter during the 1971 San Fernando, California earthquake (Ayres and Sun, 1973), also damaging its muffler (right).

Many emergency generators are supported on vibration isolators that are not designed to resist earthquake demands. When a generator falls off of its supports, it can break connections to the electrical, fuel, and exhaust systems, and can be damaged. Generators that are rigidly anchored to the floor are not susceptible to this type of damage.

Consequences

During a strong earthquake, the power will almost certainly fail, and the emergency generator must supply electricity, so that the hospital's critical systems will be able to continue to operate. Without fuel, the generator can't run, and without a connection to the electrical system, the generator can't supply electricity to the hospital.

Check These Related Items

Batteries for emergency power (see pg.99): The emergency generator needs these batteries, in order to start up immediately. The generator will not come online without them.

Day tank, fuel lines and main tank (see pg.125, pg.143): The generator will not run, if its diesel fuel supply is cut off by failure of the day tank, the associated pipes, or the main tank.

Electrical distribution system (see pg.115, pg.131): Automatic transfer switches, wiring and conduits to critical equipment must remain intact, so that power from the emergency generator can reach them.

Methods of Anchoring

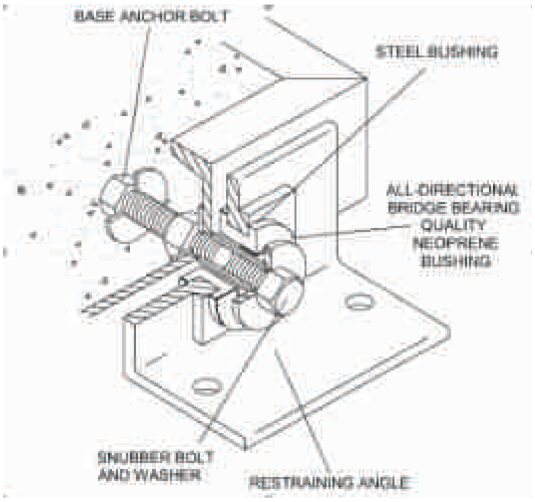


Image credit: Mason Industries

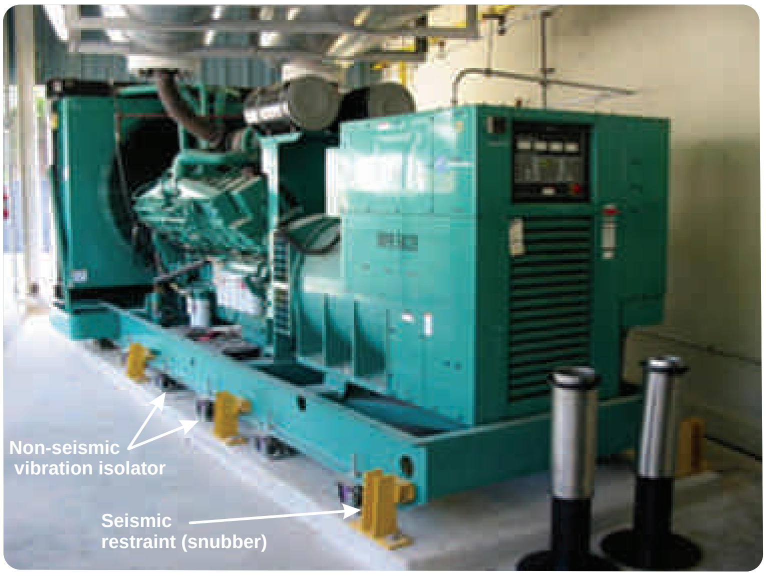


Photo credit: FEMA/ATC Training Course

Seismic restraint devices called snubbers (above left) can be added to the base of the generator, in order to keep it from falling off its vibration isolators during an earthquake. Snubbers have a gap between the restraint and the generator, to prevent the transfer of vibrations during normal operation. Seismic snubbers can be designed to resist motion in one direction or all directions, depending on your needs.

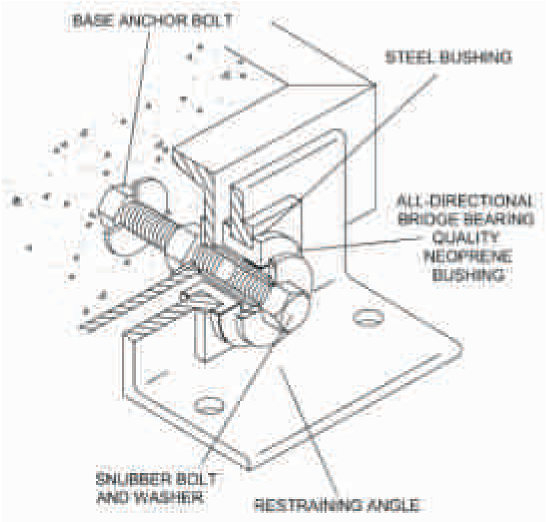


Image credit: Mason Industries

If you install a new generator or replace an old one, then you should specify that the generator be mounted on seismically-restrained vibration isolators (at left). These spring isolators are specifically designed by the manufacturer to resist earthquake forces in all directions. Also, ensure that the generator muffler and exhaust flues are properly braced, so that they will not be damaged.

Expertise Required

Some engineering required to select the correct size and type of snubber or seismically rated vibration isolator.

Recommended Priority

Critical Safety. The hospital needs the emergency power from the generator to remain in operation after an earthquake.

Retrofit Cost and Disruption

Moderate cost for parts, low cost for labor, low level of disruption. Snubbers are moderately expensive. Other restraint devices are slightly more expensive. Work on emergency generators does not usually disrupt hospital operations, because generators are located in equipment rooms or separate buildings and are not in use on a daily basis.

Where to Find More Information

Please see Appendix C, page173 for additional technical information. Appendix D, page179 has example calculations for adding snubbers to an emergency generator.

Batteries for Emergency Power

Provide uninterrupted power if grid supply is lost; often located near equipment they power.

Potential Earthquake Damage

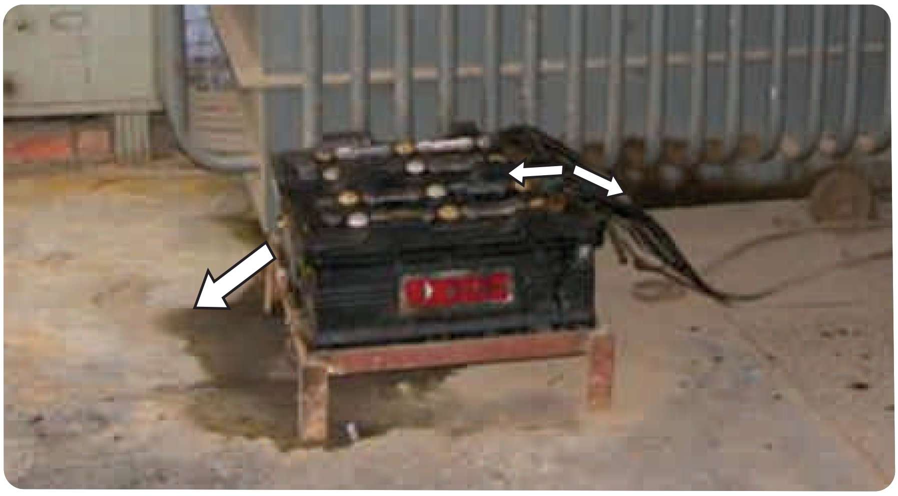


Photo credit: D.K. Paul, IIT Roorkee

Strong shaking can cause batteries to topple from their racks and become disconnected from the power system.

Photo credit: Degenkolb Engineers

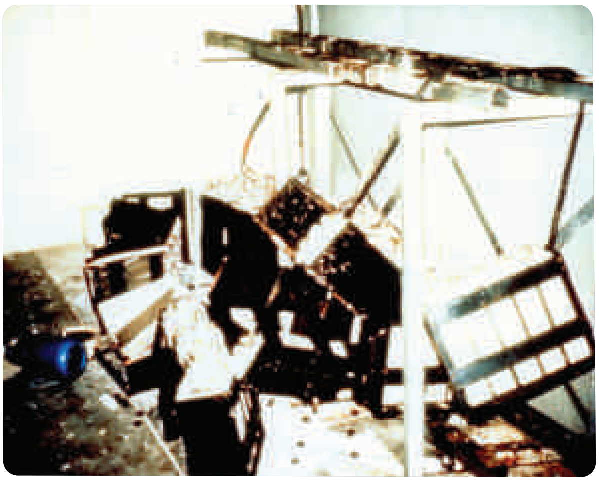


Photo credit: FEMA 74

Failed battery racks, 1971 San Fernando earthquake (left) and (right).

There are two types of batteries in the emergency power system. The first type supplies uninterrupted power from the moment when grid power goes out, until the emergency generator starts. These batteries are stored in racks that can topple. The second type starts the emergency generator. These batteries can slide and become disconnected from the generator.

Consequences

During a strong earthquake, the power will almost certainly fail. Life support systems need the uninterrupted power that is supplied by the batteries. The emergency generator also needs batteries to start, so that it can supply electricity to the hospital's critical systems.

Check These Related Items

Emergency generator (see pg.97): The emergency generator needs to be mounted on seismically-rated vibration isolators or else, to be kept from sliding by snubbers.

Electrical distribution system (see pg.131): Wiring and conduits to critical equipment and systems must remain intact, so that power from the batteries can reach them.

Methods of Anchoring

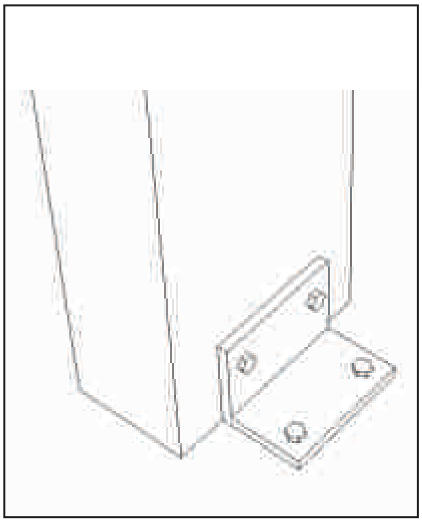


Photo credit: Eduardo Fierro, BFP Engineers (Bertero, Fierro, Perry)

Provide a strong rack, which will not collapse, for the hospital's batteries. Anchor the rack to the floor or wall, so that it will not topple. Shorter racks, such as the ones shown above, are less susceptible to toppling than tall ones are. Restrain the batteries within the rack, so that they cannot topple out of it.

Photo credit: Eduardo Fierro, BFP Engineers (Bertero, Fierro, Perry)

Anchor batteries for emergency generators by providing a tie-down to keep them in their rack or by anchoring them within the emergency generator housing.

Expertise Required

Some engineering required to select the correct size and type of bracing or anchorage.

Recommended Priority

Critical Safety. The hospital needs the emergency power from the batteries to keep critical systems in operation after an earthquake.

Retrofit Cost and Disruption

Moderate cost for parts, low cost for labor, low level of disruption. Work on emergency battery systems does not usually disrupt hospital operations, because batteries are located in equipment rooms or separate buildings and are not in use on a daily basis.

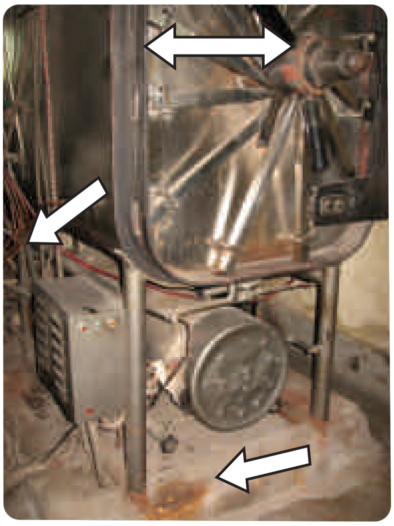
Where to Find More Information

Please see Appendix C, page173 for additional technical informationsnubbers to an emergency generator.

Boilers

Provide heat; often located in the physical plant building.

Potential Earthquake Damage



Strong shaking can cause boilers to slide off of their supports and to break water and fuel connections.

Photo credit: Hari Kumar, GeoHazards International

Photo credit: NiSEE (Andrew Whittaker)

Photo credit: Degenkolb Engineers

Boiler slid off its supports during the 1999 Izmit, Turkey earthquake (left); one end of Olive View hospital boiler slid 1 m in the 1971 San Fernando, California earthquake, breaking pipe connections (right).

Boilers are large and heavy and can slide off of their supports if not bolted to a concrete pad or the floor. The movement can cause them to break their connections, which include water, steam, and fuel connections. Broken fuel connections can cause fuel to spill.

Consequences
The hospital will not have heat without the boiler, which could present problems in the case of a winter earthquake in a cold region. Fuel spills are a fire hazard.

Check These Related Items
Pipes and connections (see pg.127): The pipes that supply hot water must remain intact, so that hot water from the boiler can reach critical locations in the hospital.

Ducts (see p.133): The ducts that distribute steam and hot air from the boiler and heating system to the hospital must remain intact, so that the heat can reach the hospital.

Fuel system and connections (see pg.125): Connections to the fuel system must remain intact, so that the boiler can function.

Methods of Anchoring

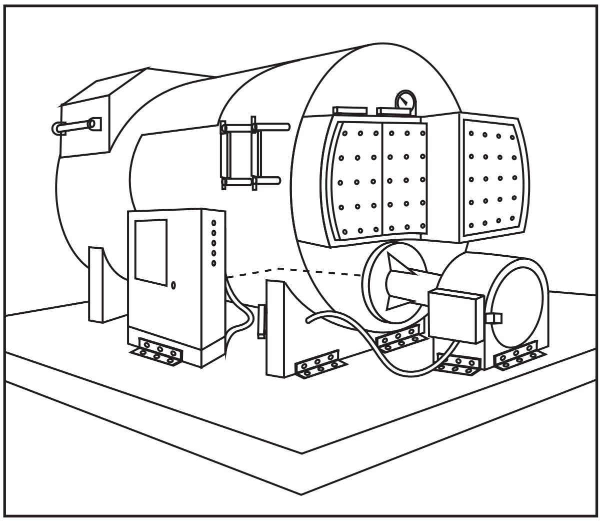


Photo credit: Janise Rodgers, GeoHazards International

Boilers are typically rigidly-mounted, and should be bolted to a concrete pad or to the floor. If bolted to a pad as shown above, then the pad should be properly reinforced and connected to the floor as shown below at right. Poorly anchored pads can be reinforced against sliding, as shown below at left. Provide flexible connectors to all pipes. Flexible connectors must be designed for the expected motion and to limit forces on the pipes and boiler.

Photo credit: Eduardo Fierro, BFP Engineers (Bertero, Fierro, Perry)

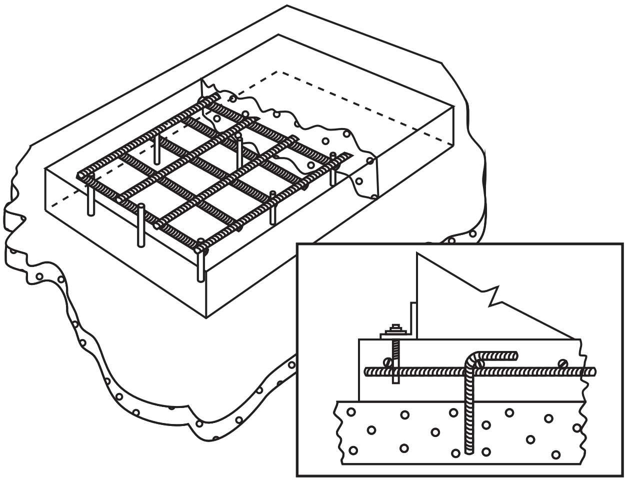


Image credit: FEMA 412

Expertise Required

Some engineering required to design anchorage system for boilers.

Recommended Priority

Essential Services. Hospitals in cold regions need the heat provided by the boiler, in order to maintain acceptable temperatures in critical patient areas during winter.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring a boiler and attaching flexible connections are relatively inexpensive and can be done with minimal disruption to hospital operations. Boilers are located in equipment rooms or separate buildings, and the work can be scheduled (for example, for warmer periods when heat is not needed).

Where to Find More Information

Please see Appendix C, page173 for additional technical information.

Geysers

Provide hot water, if central hot water not provided; located in various rooms.

Potential Earthquake Damage

Photo credit: D.K. Paul, IIT Roorkee

Strong shaking can cause geysers to topple from their wall mounts and to break water connections.

Photo credit: Mason Industries

Photo credit: NiSEE

Toppled hot water heaters (left) and tank (right) similar in shape to geysers.

Geysers are typically mounted on walls at a height of 1.5 to 2 meters, so if they are not properly attached to the wall, then they create a falling hazard. Toppling geysers can also break connections and leak hot water. Most geysers have flexible connections, but these are not very long and will break before the geyser falls all of the way to the floor.

Consequences

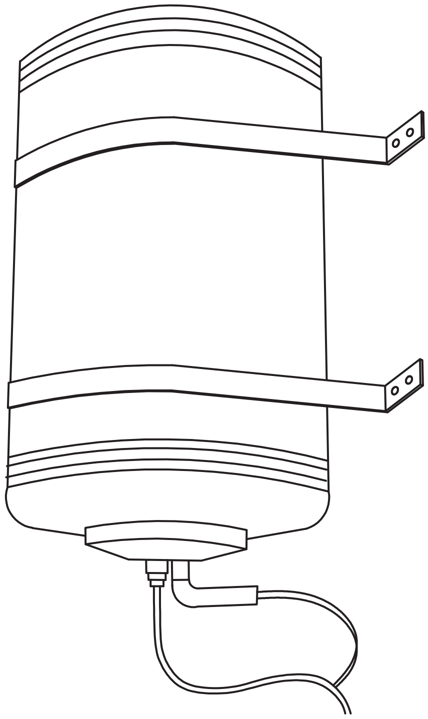
A falling geyser could injure someone, and hot water could spill on someone and scald that person. Most geysers are not located near patient beds or other areas where people congregate; however, some are located in bathrooms.

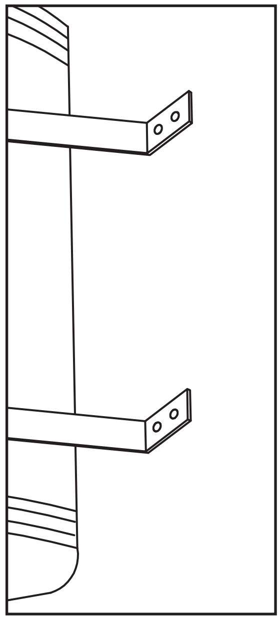
Check These Related Items

Pipes and connections (see pg.127): The pipes that supply water to the geyser must remain intact, so that the geyser can function.

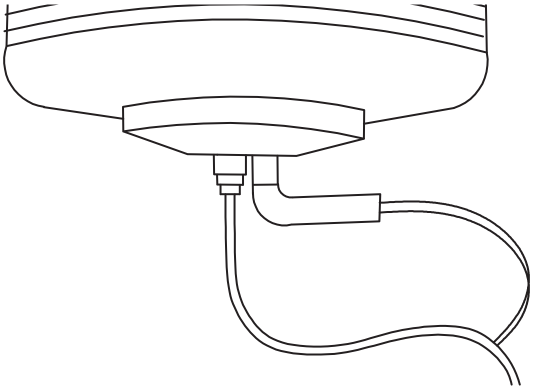
Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the geyser can function.

Methods of Anchoring





Geysers should be anchored to the wall with bolts that are sized to resist the horizontal forces caused by the expected level of earthquake shaking. The geysers should have straps around the top and bottom that attach to the bolts. These bolts must be properly installed, so that they will not pull out, and the wall must be strong enough to resist the forces from the geyser without failing.



Geysers should have flexible connections to the water lines. Check to make sure that your geyser has flexible connections.

Expertise Required

Some engineering required to select appropriate bolts and straps.

Recommended Priority

Continuous Service. The hospital needs the hot water from the geyser for hand-washing and sanitation.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring a geyser and attaching flexible connections can be done with minimal disruption to hospital operations. You can properly anchor geysers one at a time, to reduce disruption.

Where to Find More Information

Please see Appendix C, page173 for additional technical information.

Chillers

Provide cold water for air conditioning; often located in the physical plant building.

Potential Earthquake Damage

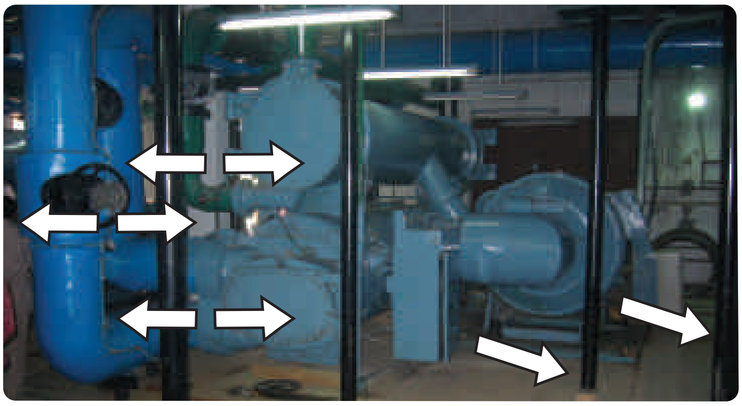


Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause chillers to slide off of their supports and to break water and other connections.

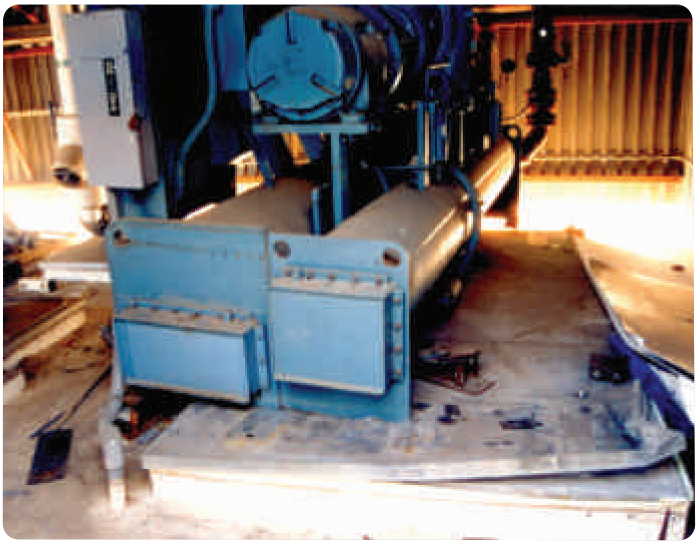


Photo credit: FEMA 74

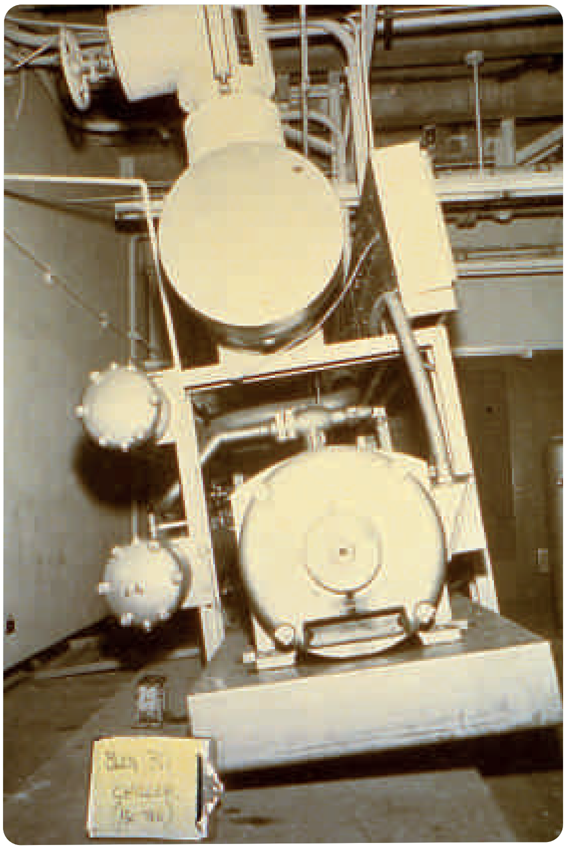


Photo credit: FEMA, Making Hospitals Safe in Earthquakes

Chiller mounts failed due to inadequate uplift resistance during the 1994 Northridge, California earthquake (left); chiller at the old Olive View Hospital slid off its supports in the 1971 San Fernando, California earthquake (right).

Unanchored chillers can slide off of their supports, which can damage the chiller and break water pipes or other connections. Chillers on vibration isolators are particularly at risk.

Consequences

Damaged chillers prevent central air conditioning systems from working. Broken water pipes could cause local water damage or flooding, depending on the location of the chiller.

Check These Related Items

Pipes and connections (see pg.127): The pipes that supply water to the chiller must remain intact, so that the chiller can function.

Ducts (see p.133): The ducts that distribute cool air from the air conditioning system to the hospital must remain intact, so that the cool air reaches the hospital.

Fuel system and connections (see pg.125): Connections to the fuel system must remain intact, so that the chiller can function.

Methods of Anchoring

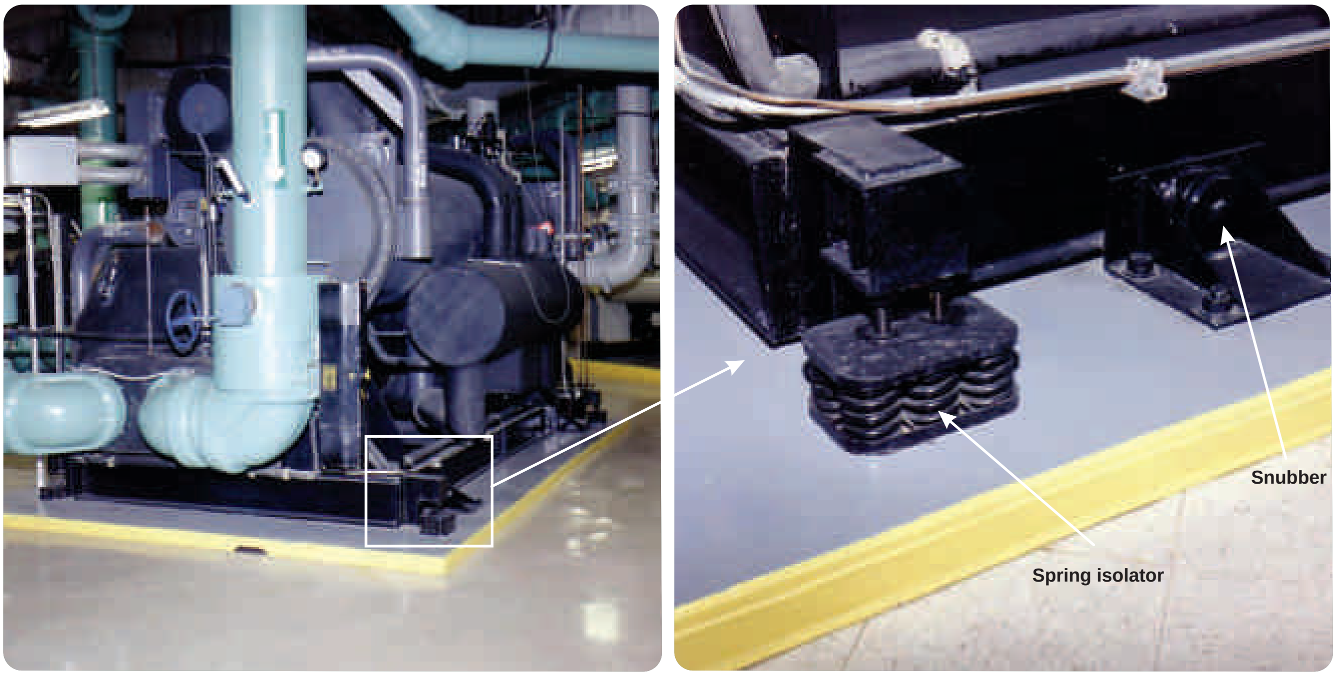


Photo credits: Mason Industries

Vibration-isolated chillers should be restrained with special seismic restraint devices called snubbers or with seismically restrained spring mounts. Using spring isolators without snubbers or without seismically restrained housing will actually increase earthquake forces and cause the springs to fail. The chiller above is mounted on spring isolators and restrained with snubbers. The photo at right shows a chiller on seismically restrained spring mounts. Provide flexible connections for all pipes.

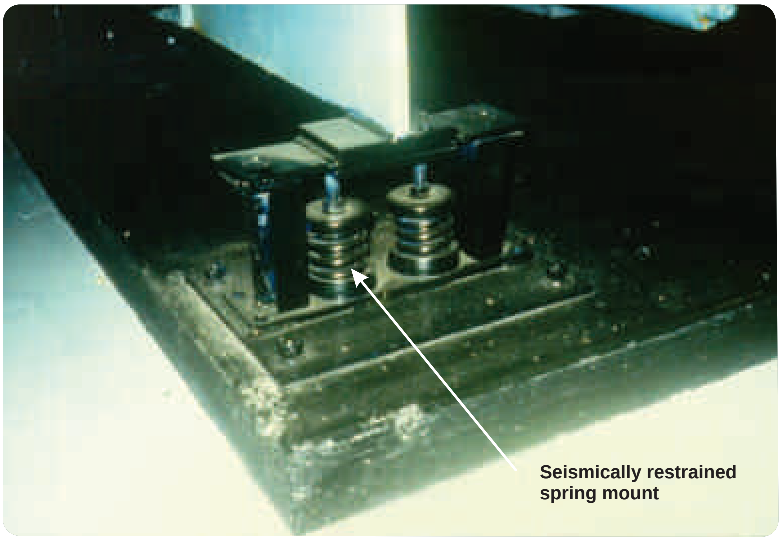


Photo credits: Mason Industries

Expertise Required

Some engineering required to design anchorage for chillers.

Recommended Priority

Continuous Service. The hospital needs the cool air from the chiller to maintain temperatures for patient comfort during hot weather

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring a chiller and attaching flexible connections can be done with minimal disruption to hospital operations. Chillers are located in equipment rooms or separate buildings, and the work can be scheduled (for example, for cooler periods when air conditioning is not needed).

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Cooling Towers

Provide cooling for air conditioning; often located on the roof.

Potential Earthquake Damage

Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause cooling towers to slide off their supports and to break water and fuel connections.

Photo credit: Mason Industries

Photo credit: NiSEE (Halil Sezen)

Failure of support frame for rooftop cooling tower due to inadequate cross-bracing during the 1994 Northridge earthquake (left); complete collapse of large cooling tower (in foreground), 1999 Izmit, Turkey earthquake (right).

Cooling towers can slide off their supports during strong shaking or be damaged by high accelerations, especially if located on the roof. Differential movement can break water connections.

Consequences

Without the cooling tower, the central air conditioning system won't work. Broken water pipes can cause flooding and water damage, particularly if the cooling tower is located on the roof.

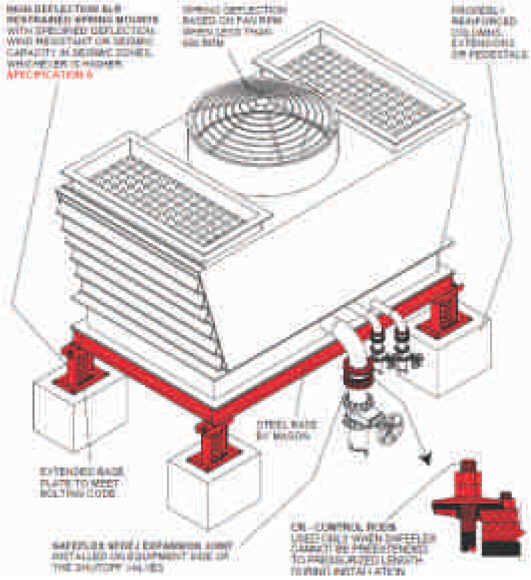
Check These Related Items

Pipes and connections (see pg.127): The pipes that supply water to the cooling tower must remain intact, so that the cooling tower can function.

Ducts (see p.133): The ducts that distribute cool air from the air conditioning system to the hospital must remain intact, so that the cool air reaches the hospital.

Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the cooling tower can function.

Methods of Anchoring



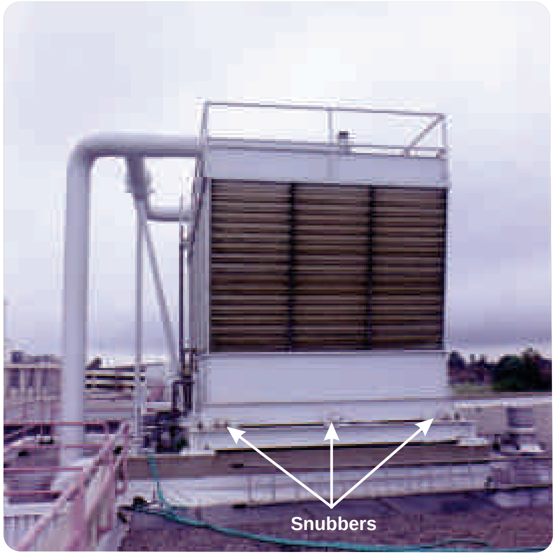
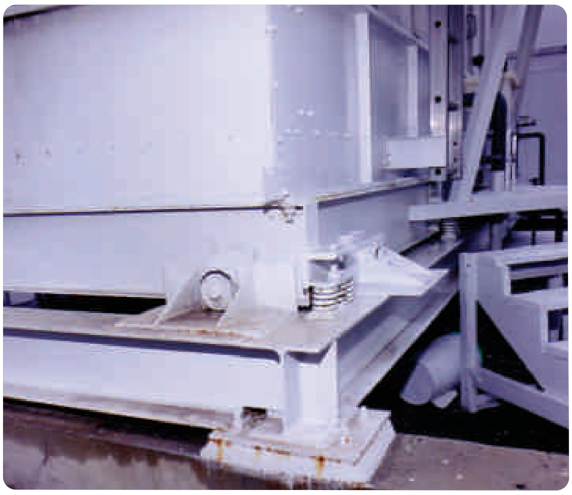


Photo and image credits: Mason Industries

Have an engineer check to see if your cooling tower is adequately anchored. The engineer will need to check the adequacy of the supports and their connections to both the cooling tower and the roof or concrete pad. Reinforce inadequate anchorages by adding new bolts, angles or support members. The cooling tower at above right was reinforced with seismic snubbers. The photo below shows the details of the support frame.



You should also consider having an engineer check the structural integrity of the cooling tower itself, especially if it is located on the roof. In this location, the seismic forces can be very high, and the cooling tower will need to be able to resist them without damage. If the cooling tower isn't strong enough to be point-supported on piers, then you can strengthen it by placing a support frame around it to help it resist the forces.

Expertise Required

Some engineering required to design anchorage systems for cooling towers.

Recommended Priority

Continuous Service. The hospital needs the cool air from the cooling tower to maintain temperatures in critical patient areas during hot weather.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring a cooling tower and attaching flexible connections can be done with minimal disruption to hospital operations. Cooling towers are often located on the roof, and the work can be scheduled (for cooler periods when air conditioning is not needed, for instance).

Where to Find More Information

Please see Appendix C, page 173 for additional technical information. Appendix D, page 179 has example calculations for anchoring a cooling tower.

Curb-Mounted Rooftop Units

Circulate air for ventilation and air conditioning; located on the roof.

Potential Earthquake Damage

Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause inadequately supported rooftop units to slide off their supports and break supply connections.

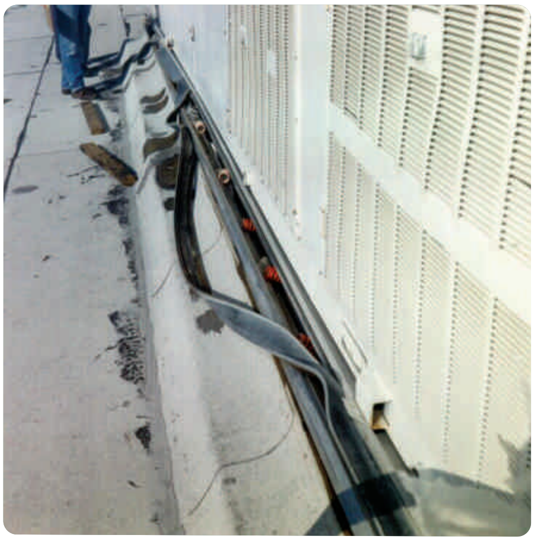


Photo credits: Mason Industries

Damaged curb-mounted isolation system, 1994 Northridge, California earthquake (left); independent rails without cross-bracing twisted and failed, 1994 Northridge, California earthquake (right).

Rooftop curb mounting units (also called packaged air conditioning units) can be subjected to high seismic forces transmitted by the building, and their supports can fail. Units on vibration isolators without properly designed support systems are especially vulnerable. When the support system fails, it can break supply connections and damage ductwork.

Consequences

The hospital's central air conditioning system won't work properly without the rooftop unit.

Check These Related Items

Ducts (see p.133): The ducts that distribute cool air from the air conditioning system to the hospital must remain intact, so that the cool air reaches the hospital.

Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the air handling unit can function.

Methods of Anchoring

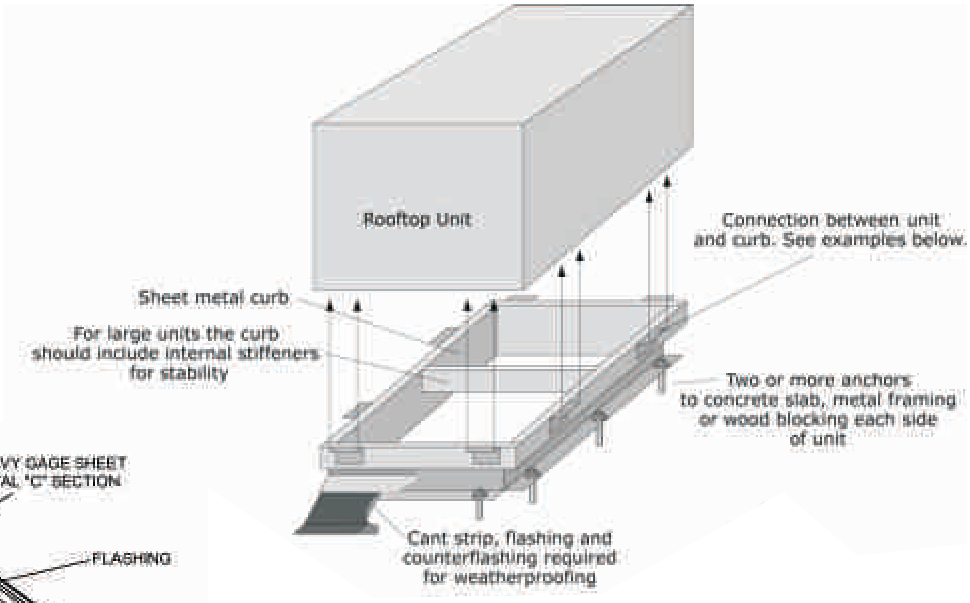


Image credit: FEMA 74

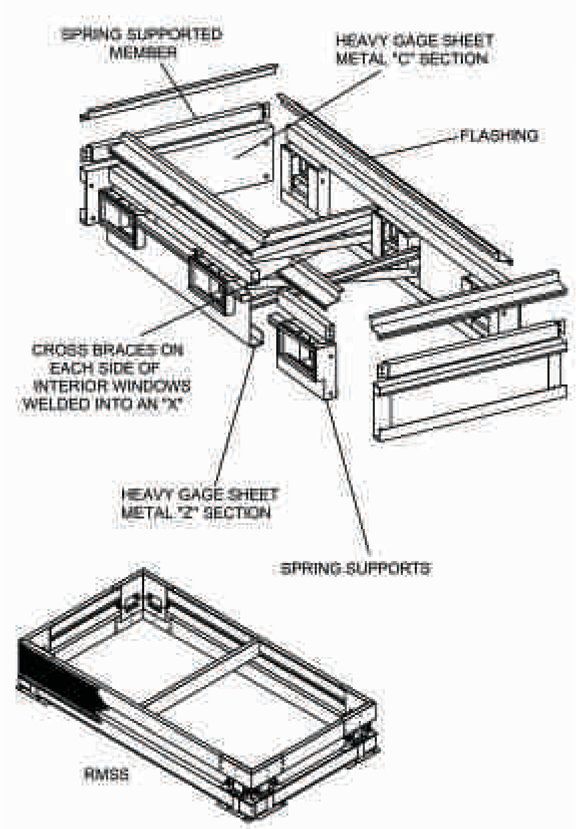


Image credit: Mason Industries

Most rooftop units are mounted on curbs supplied by the manufacturer. Do not add a separate system of aluminum rails to the top of the manufacturer's curb; this is what caused the failures shown on the facing page. Instead, use a complete steel curb with spring isolators designed for seismic loads, as shown above. Where vibration isolation is not required, use reinforced curbs with cross-bracing and design the attachments of the equipment to the curb and the curb to the building for seismic forces.

Expertise Required

Some engineering required to design anchorage system for rooftop units.

Recommended Priority

Continuous Service. The hospital needs the cool air from the air conditioning system to maintain temperatures in critical patient areas during hot weather.

Retrofit Cost and Disruption

Moderate cost for parts, low cost for labor, low level of disruption. Anchoring a rooftop unit and attaching flexible connections can be done with minimal disruption to hospital operations. Units are located on the roof, and the work can be scheduled (for example, for cooler periods when air conditioning is not needed).

Where to Find More Information

Please see Appendix C, page173 for additional technical information.

Window or Wall Unit Air Conditioners

Provide air conditioning for a single room; located in various rooms.

Potential Earthquake Damage

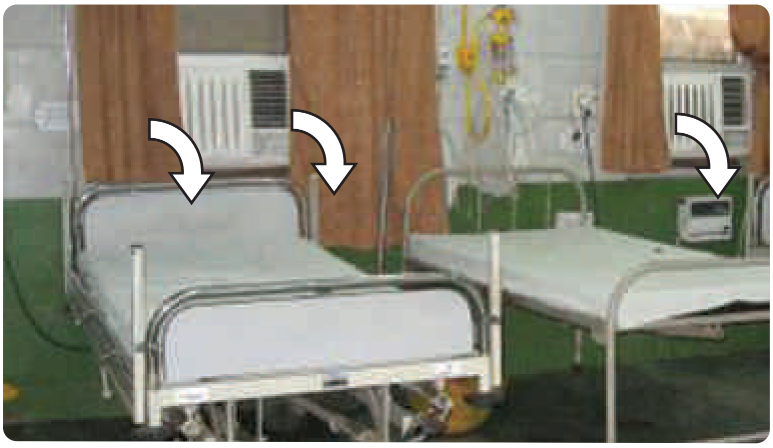


Photo credit: Kanchan Sabnis, GeoHazards Society

Strong shaking could cause window or wall unit air conditioners to fall into the room.

Photo credit: NiSEE (Ralph Tower Taylor)

Photo credit: California OSHPD

Air conditioner similar in size to window unit dislodged, 1952 Kern County, California earthquake (left); earthquake forces from window unit pulled window frame away from wall, 1994 Northridge earthquake (right).

Window or wall unit air conditioners are typically mounted at window height or in specially made wall penetrations closer to the ceiling, so they can create a falling hazard, if they are not properly attached to the wall. These air conditioners are often larger in dimension inside the building than outside it, making them more likely to fall into the room than outside onto the ground.

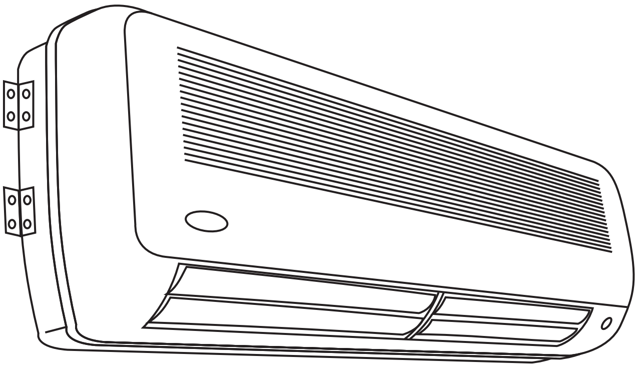
Consequences

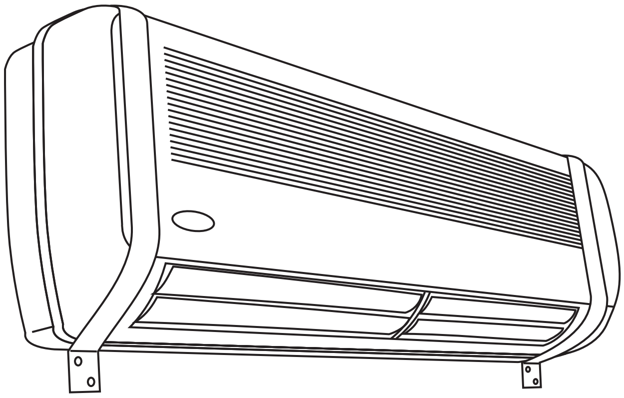
A falling air conditioner could injure a staff member or patient below it. The air conditioner will likely break due to the impact and won't be able to provide cool air to the room.

Check These Related Items

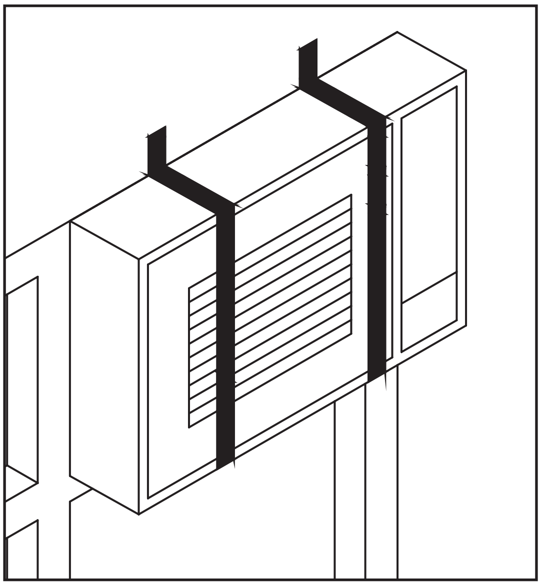
Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the air conditioning unit can function.

Methods of Anchoring





Window unit air conditioners should be anchored to the wall or a frame with bolts that are sized to resist the horizontal forces caused by the expected level of earthquake shaking. These bolts must be properly installed so that they will not pull out, and the frame and wall must be strong enough to resist the forces without failing.



Alternatively, you can keep the air conditioner unit from falling into the room by providing two restraint straps or cables (depending on the configuration of the unit) across the face of the air conditioner, and securely attaching the straps to the window frame or wall on both sides. Provide straps on the outside for window units that can slide out of the opening and fall outside.

Expertise Required

Some engineering required to properly anchor window or wall unit air conditioners.

Recommended Priority

Continuous Service. The hospital needs the cool air from the window unit to maintain patient and staff comfort.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring window or wall unit air conditioners can be done with minimal disruption to hospital operations. You can properly anchor units one at a time, to reduce disruption.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Window Unit Air Coolers

Provides evaporative cooling for a single room; located in various rooms.

Potential Earthquake Damage

Photo credit: Janise Rodgers, GeoHazards International

Strong shaking could cause window unit air coolers to topple off of their support frames and to fall from the exterior of the building.

Photo credit: L. Thomas Tobin, GeoHazards International

Photo credit: Khalid Mosalam, University of California, Berkeley

Relatives of patients gather in a courtyard underneath the air coolers shown above (left); equipment with similar size, shape, and supports fell from shelf during the 2009 L'Aquila, Italy earthquake (right).

Window unit air coolers are typically mounted on light metal support frames or shelves outside windows. Air coolers are heavy and create a serious falling hazard for anyone near the exterior of the building. At many hospitals, the family members of patients gather in courtyards and other open spaces near buildings with numerous air coolers in the windows above them.

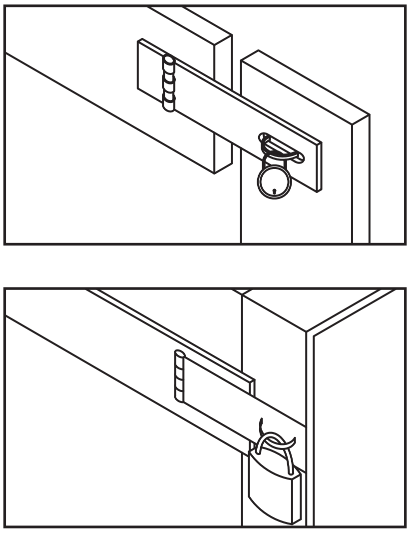
Consequences

A falling air cooler could injure or kill anyone below it. Air coolers could also fall during aftershocks, when areas near the building's exterior may be in use to treat mass casualties.

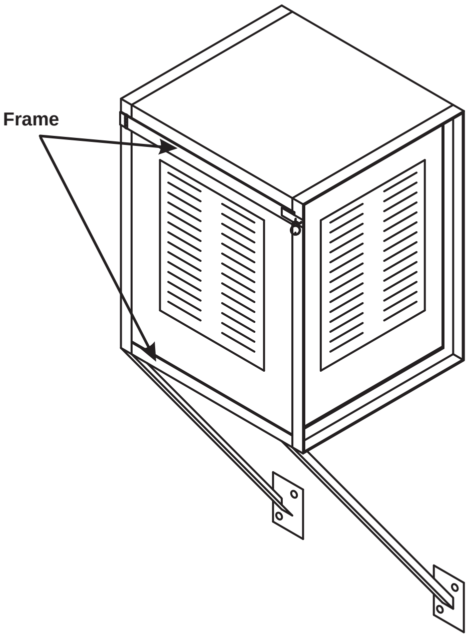
Check These Related Items

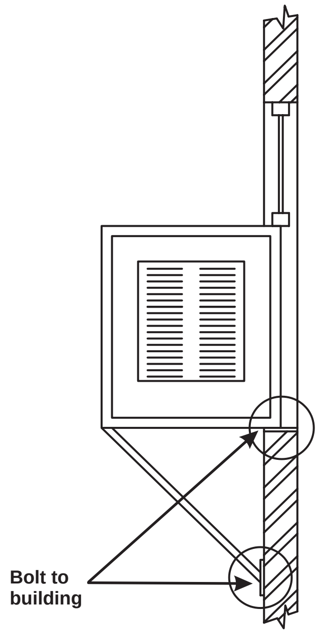
There are no related items to check.

Methods of Anchoring

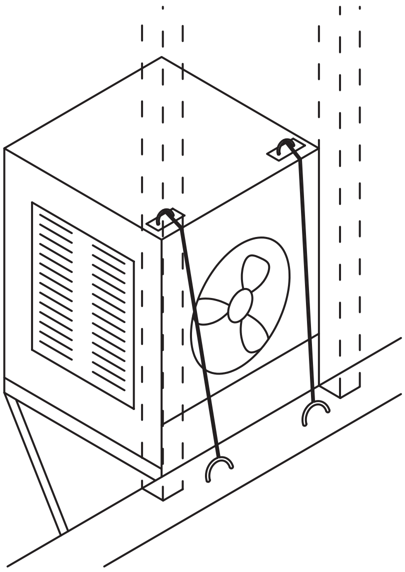


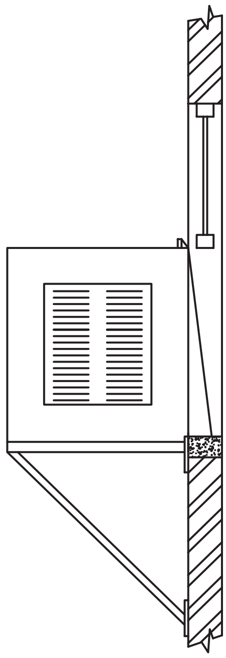
Latch options





Window unit air coolers should be supported on a special frame (above) or fastened to the building with cables (below). Attach cables to the steel grill or to strong portions of the window or wall. Security measures designed to prevent the theft of air coolers can be adapted to prevent toppling. Since a typical hospital has many air coolers that must be installed and removed seasonally, the engineering staff should develop a detail that can be used for all coolers.





Expertise Required

Some engineering required to keep window unit air coolers from falling.

Recommended Priority

Critical Safety. Air coolers are a major falling hazard and can injure or kill people outside the building near the façade.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring window unit air coolers can be done with minimal disruption to hospital operations. The retrofit can be done at the time when air coolers are installed.

Where to Find More Information

Please see Appendix C, page173 for additional technical information.

Electrical Cabinets

House various types of electrical equipment; located in the physical plant and elsewhere.

Potential Earthquake Damage

Photo credit: Janise Rodgers, GeoHazards International

Strong shaking could cause tall and narrow electrical cabinets to topple over.

Photo credits: Degenkolb Engineers, FEMA 74

Toppled electrical cabinets, 1985 Mexico City earthquake (left); toppled cabinets and damaged equipment (right).

Tall and narrow electrical cabinets could topple, if they are not secured. Damage to electrical cabinets has not been particularly widespread in past earthquakes, in cases where the cabinets were anchored.

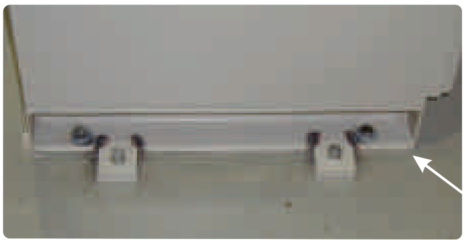
Consequences

Toppling could damage the equipment in the cabinets and create an electric shock hazard or fire hazard. In addition, the equipment could be expensive to repair or replace. This could cut off electricity to some parts of the hospital.

Check These Related Items

Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the air cooler unit can function.

Methods of Anchoring



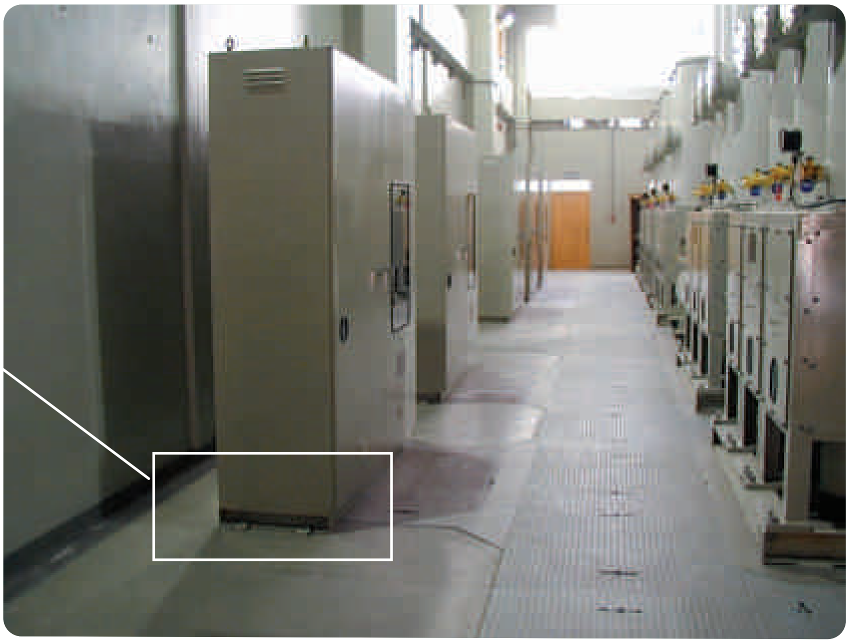
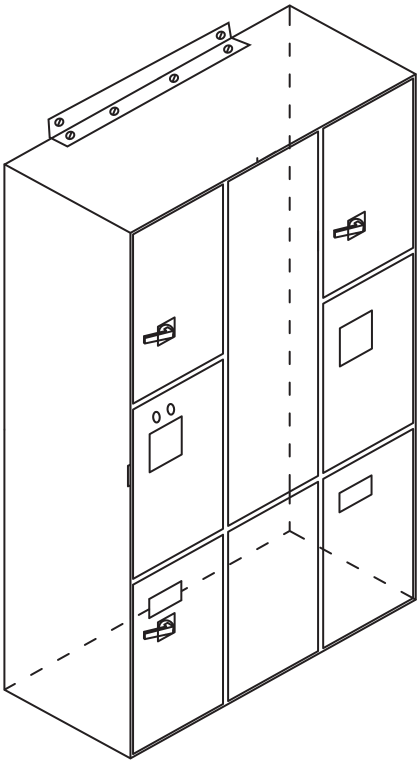


Photo credits: Eduardo Fierro, BFP Engineers (Bertero Fierro Perry)



Anchorage at the base can prevent lightweight electrical cabinets from overturning. Bolt the base to the floor, or use steel angles. Heavier cabinets may need restraints at the top, as well.
As with any electrical installation, use caution when designing solutions for and working on electrical cabinets.

Expertise Required

Some engineering required to design the anchorage for electrical cabinets.

Recommended Priority

Critical Safety. Cabinets containing equipment needed to operate the emergency power system must remain functional. Give lower priority to cabinets containing less critical equipment.

Retrofit Cost and Disruption

Low cost for parts, moderate cost for labor, moderate level of disruption. Electrical cabinets can be anchored with simple, inexpensive parts. Anchoring electrical cabinets can be done with some disruption to hospital operations. Ensure that you turn off electrical power to the cabinet during installation of restraints, to prevent electric shock.

Where to Find More Information

Please see Appendix C, page173 for additional information. FEMA 413, freely downloadable from www.fema.gov, provides additional information on anchoring electrical equipment.

Transformers

Convert high-voltage electrical power for building use; often located outside the building.

Potential Earthquake Damage

Photo credit: D. K. Paul, IIT Roorkee

Strong shaking could cause transformers to slide and break their connections.

Photo credit: NiSEE (Halil Sezen)

Damage at base of transformer (left); large transformer overturned in the 1999 Izmit, Turkey earthquake (right).

Transformers are large and heavy, and they can slide. They are not typically susceptible to overturning, because they are usually short and wide. However, sliding can break a transformer's electrical connections.

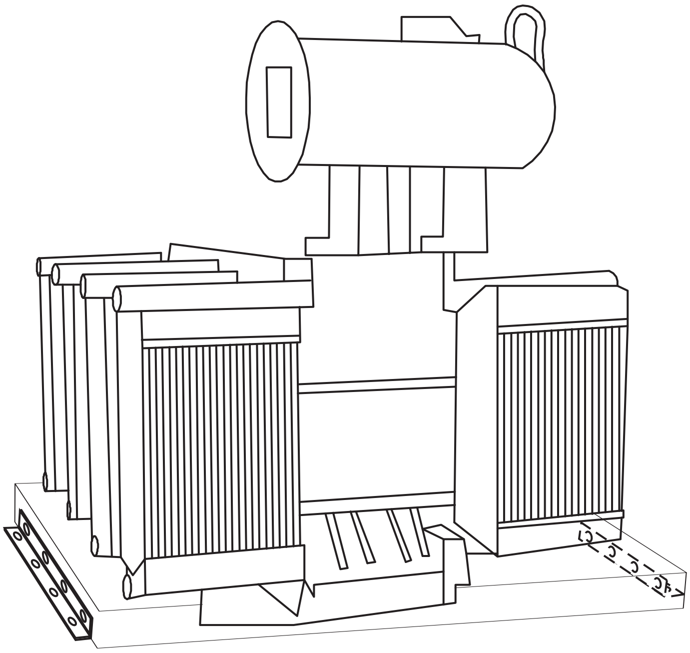
Consequences

The hospital can't receive power from the grid, if the transformer is not functioning or has broken its connections. The hospital will want to use grid power as soon as it is available, because it may be difficult to keep the emergency generators supplied with diesel fuel for long periods of time.

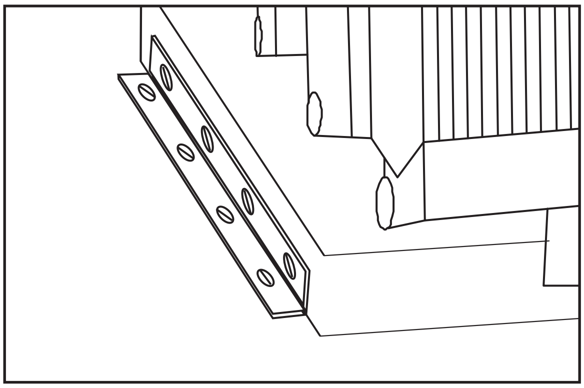
Check These Related Items

Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the transformer can function.

Methods of Anchoring



Anchor transformers at the base to prevent them from sliding. The type of restraint used will depend on the type of transformer and on its size and location. Possible restraints include angle brackets, snubbers, bolts, and welds. Large transformers require specialized engineering and electrical expertise.



Working on high-voltage equipment such as transformers is extremely hazardous. Be sure to consult both an electrician and an engineer to arrive at an appropriate anchoring solution. Shut off power to the transformer and take appropriate safety measures before starting work.

Expertise Required

Some engineering required to design the restraint system. Also, consult an electrician to make sure that the restraint system is electrically safe.

Recommended Priority

Continuous Service. The hospital needs the transformer to be able to receive power from the grid, once it is restored.

Retrofit Cost and Disruption

Low cost for parts, moderate cost for labor, low level of disruption. Anchoring a transformer can normally be done with readily available parts, but it requires an electrician and an engineer. Anchoring may require some disruption to hospital operations. Electrical power to the transformer will need to be turned off during installation of restraints, to prevent electric shock.

Where to Find More Information

Please see Appendix C, page 173 for additional information. FEMA 413, freely downloadable from www.fema.gov, provides additional information on anchoring electrical equipment.

Fire Suppression Pumps

Supply water for fighting fires; typically found in the physical plant.

Potential Earthquake Damage

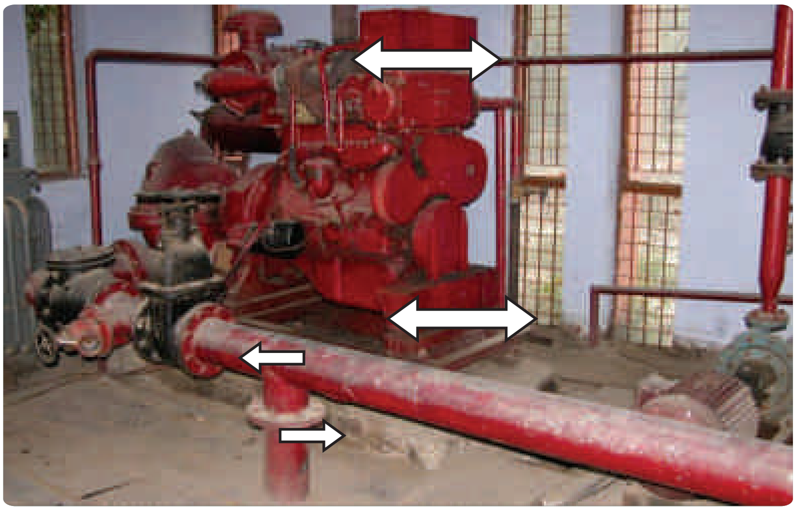


Photo credit: D. K. Paul, IIT Roorkee

Strong shaking could cause improperly anchored pumps to slide and break their connections.

Photo credits: Mason Industries

Damage to water pumps during the 1994 Northridge, California earthquake. Flexible connections on the pump at left prevented valve damage.

Fire suppression pumps can slide off their supports and break water lines and other connections.

Consequences

Failure of the fire suppression pump means that the hospital's fire suppression systems won't work. Broken pipe connections can cause local flooding and will drain the fire-fighting water out of the system.

Check These Related Items

Pipes and connections (see pg.127): The pipes that supply fire-fighting water to the hospital must remain intact, so water can reach the location of the fire.

Electrical system and connections (see pg.131): Connections to the electrical system must remain intact, so that the pump can function.

Electrical cabinets (see pg.115): The electrical panel that controls the pump must remain intact, so that the pump can function.

Methods of Anchoring

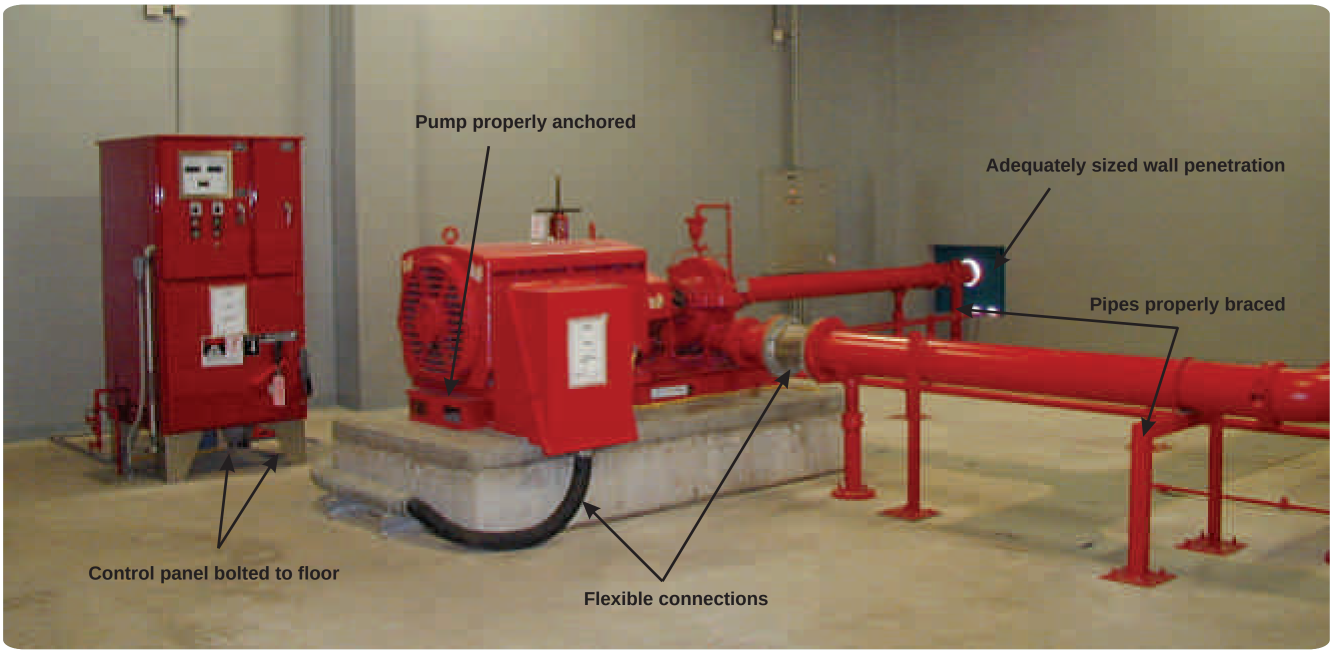
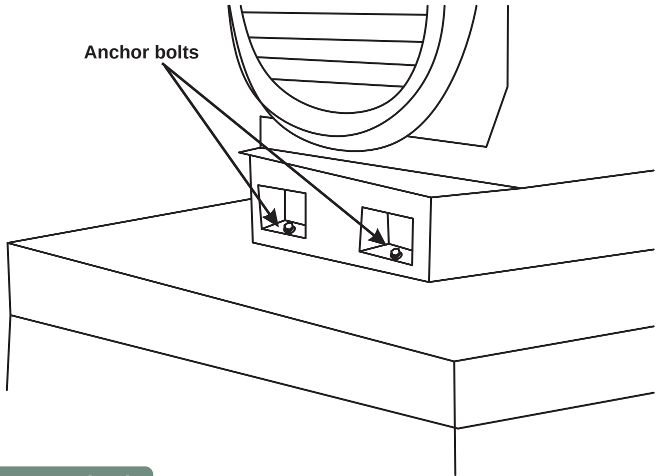


Photo credit: Eduardo Fierro, BFP Engineers (Bertero Fierro Perry)

The properly anchored fire suppression pump and associated piping and controls were not damaged in the 2001 Peru earthquake. Fire suppression systems are governed by relevant codes published by Bureau of Indian Standards.



Seismic protection of fire suppression systems requires several actions. The fire suppression pump must be properly anchored to its concrete pad or to the floor. The pump must have flexible connections, and fire water pipes must be braced. For pipes that penetrate masonry walls, the penetration must be large enough that relative motion during the earthquake won't damage the pipe or wall.

Expertise Required

Some engineering required to design the anchoring system for the fire suppression pump and associated pipes.

Recommended Priority

Critical Safety. The hospital needs its fire protection system in the event of a fire after the earthquake.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring requires minimal disruption of hospital operations. Fire protection pumps are typically located in the physical plant, where work will not interfere with hospital operations. The fire protection system may need to be taken off-line temporarily, during work to install restraints and flexible connections. Develop a backup fire-fighting plan with the fire service, in case there is a fire while the system is off-line.

Where to Find More Information

Please see Appendix C, page for additional technical information.

Fire Extinguishers

Put out small fires before they spread; distributed throughout areas without fire sprinklers.

Potential Earthquake Damage

Photo credit: D. K. Paul, IIT Roorkee

Strong shaking could cause improperly mounted extinguishers to fall from their mountings and roll.

Photo credit: OSHPD

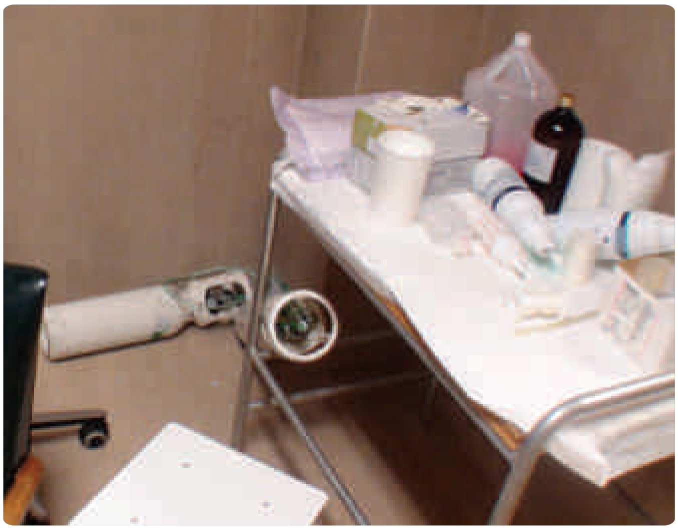


Photo credit: Khalid Mosalam, University of California, Berkeley

Anchored fire extinguisher in hospital maintenance room did not fall during the 1983 Coalinga, California earthquake (left); fallen cylinders similar in size to extinguisher canisters, 2009 L'Aquila, Italy earthquake (right).

Improperly mounted or unmounted fire extinguisher canisters can fall and roll.

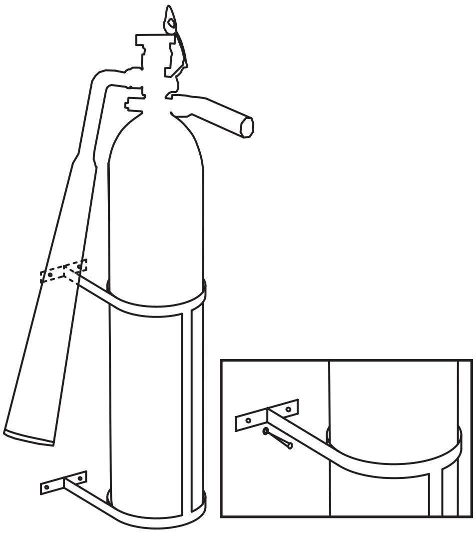
Consequences

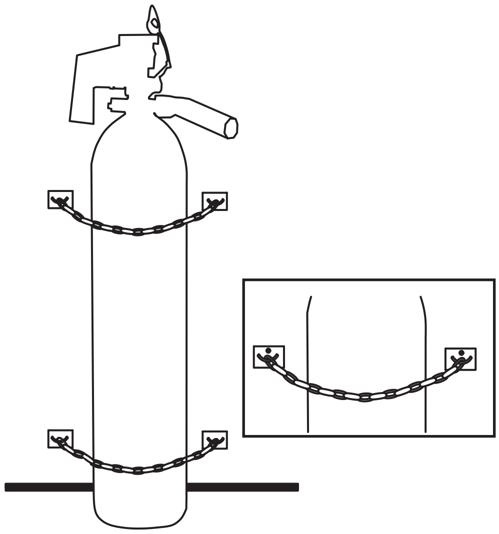
The impact could damage the canister and prevent it from working properly. The canister could also roll under other items and not be readily available when needed. Hunting for a fire extinguisher that is not where it should be wastes valuable time. During the time that it takes to locate the extinguisher, the fire could spread from something small enough to be put out with the extinguisher to something larger and more difficult and dangerous to extinguish.

Check These Related Items

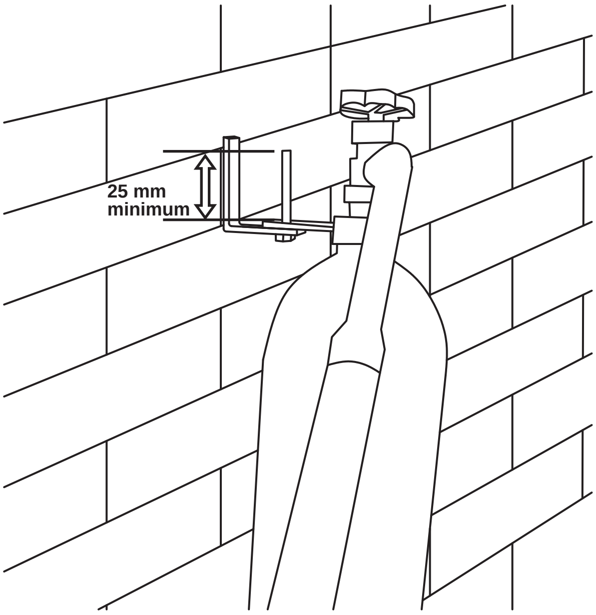
There are no other items to check.

Methods of Anchoring





The canister's attachment to the wall must be strong enough to resist the lateral forces from the fire extinguisher's movement. The canister will swing back and forth. The attachment can permit motion but must not allow the canister to fall. Canisters can also be placed in small wall-mounted cabinets.



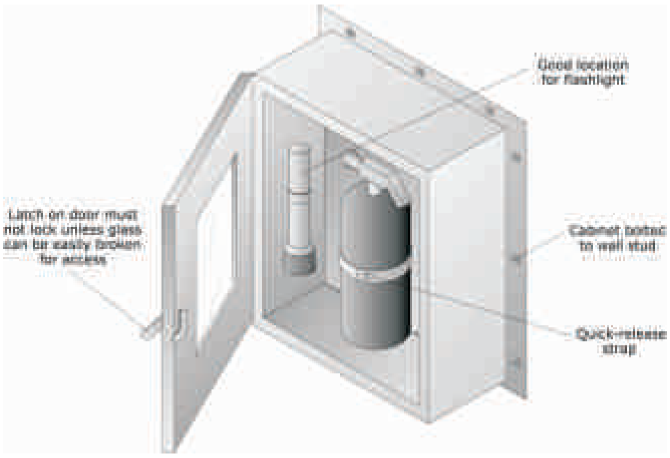


Image credit: FEMA 74

Expertise Required

Do it yourself. Anyone can install a proper attachment for a fire extinguisher.

Recommended Priority

Critical Safety. Fire extinguishers need to remain in the locations where people expect them to be. Fires spread quickly – looking for a fire extinguisher wastes precious time.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Anchoring fire extinguishers is very inexpensive and requires minimal disruption of hospital operations.

Where to Find More Information

Please see Appendix B, page for information on installing fasteners.

Pipes, Ducts and Conduits

The distribution systems for building utilities such as electricity, water, medical gases, cool air, steam, or telecommunications are vulnerable to earthquake damage. Leaks from water pipes in particular can cause damage or can even flood portions of the hospital. Leaks from medical gas pipes can be a fire hazard. Damage to electrical conduits can shut down power to portions of the hospital or cause a fire hazard. Damage to telecommunications conduits can shut down communication systems.

This section contains information on how to seismically protect the following:

For the purposes of this manual, small pipes are those with nominal pipe size of 50 mm or less.

Small Rigidly-Attached Pipes

Distribute water, medical gases, and other utilities; attached to walls throughout the hospital.

Potential Earthquake Damage

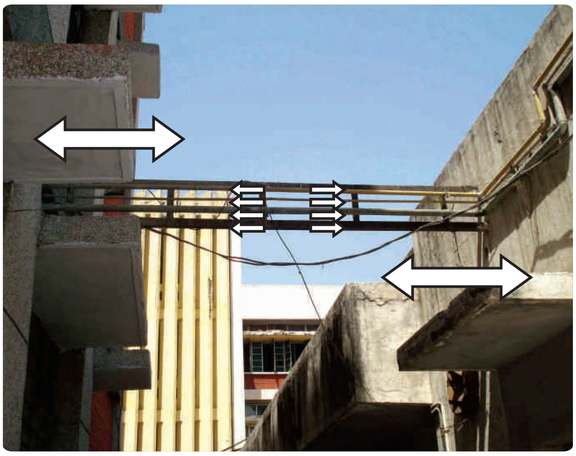


Photo credit: Manisha Dharan, THOT Designs

Strong shaking can cause portions of the building or of separate buildings to move differently, which can damage or break pipes.

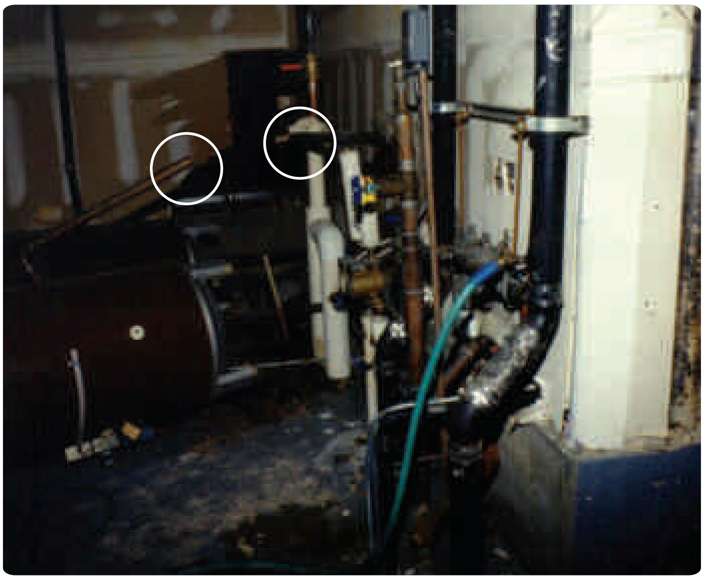


Photo credits: Mason Industries

Broken pipes and damaged pipes, 1994 Northridge California earthquake.

Rigidly attached pipes are often attached directly to walls near the ceiling. These pipes must be able to move with the walls during an earthquake. At expansion joints, building separations, and other locations where the pipe is connected to two walls that can move differently, the pipe can break, as it is pulled in different directions by the two different walls. The top photo shows medical gas pipes rigidly connected between two buildings.

Consequences

Pipe breaks cause whatever is in the pipe to leak. For water pipes, a break could cause localized flooding and water damage. Hospitals have had to be evacuated before, due to pipe breaks. For medical gas pipes, a leak can cause a major safety hazard.

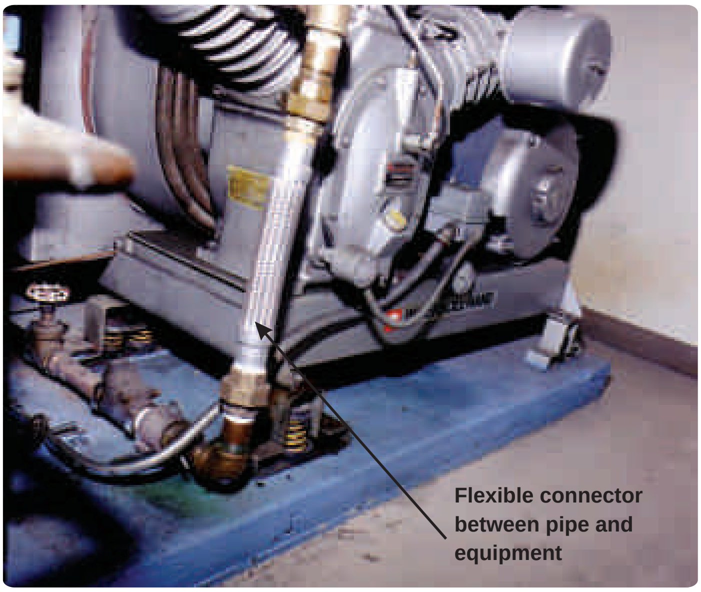
Check These Related Items

Connected equipment and tanks: Anchor equipment, tanks and cylinders that are connected to pipes. Provide flexible connections between pipes, equipment, and tanks. Flexible connections must be designed for the anticipated differential motion and to minimize forces on pipes, equipment and tanks.

Methods of Anchoring

Photo credit: FEMA 74

The best way to prevent breaks in pipes that are rigidly attached to walls is to install flexible connections in those locations where you expect differential movement. These locations include all expansion joints and building separations. Also, be sure to install flexible connections wherever pipes connect to equipment, even if the equipment is properly braced. Flexible connections must be designed for the anticipated differential movement, and to minimize forces on pipes and connected equipment or tanks.



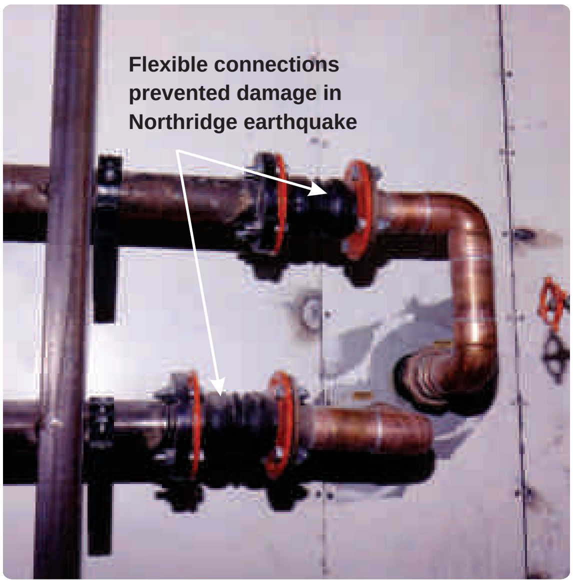


Photo credit: Mason Industries

Expertise Required

Some engineering required to select flexible connectors.

Recommended Priority

Continuous Service. The utility distribution systems are necessary for the hospital to function normally.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, moderate level of disruption. Having a plumber or maintenance staff install flexible connectors is inexpensive. The distribution system being worked on will have to be shut off during the installation, so advance planning will be required, especially for medical gas pipes. You can use cylinders to provide gas during that time.

Where to Find More Information

Please see Appendix C, located on page , for additional technical information and types of flexible connectors. FEMA 414, freely downloadable from www.fema.gov, is a good resource for information on pipes and includes additional flexible connection details.

Small Suspended Pipes

Distribute water, medical gases, and other utilities; located throughout the hospital.

Potential Earthquake Damage

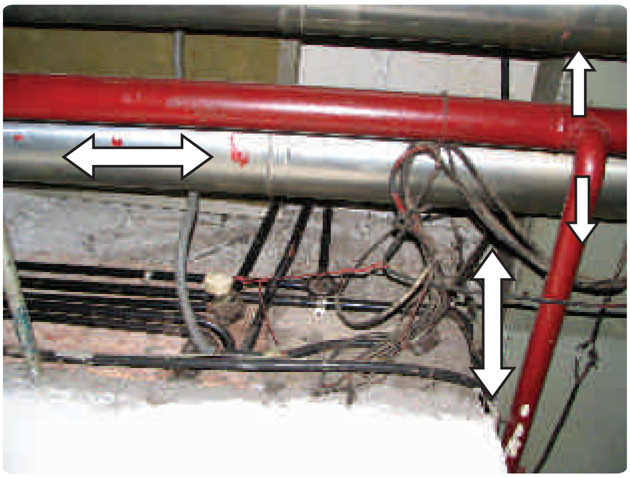


Photo credit: Melvyn Green, Melvyn Green & Associates

Strong shaking can cause suspended pipes to swing, which can damage or break pipes at joints.

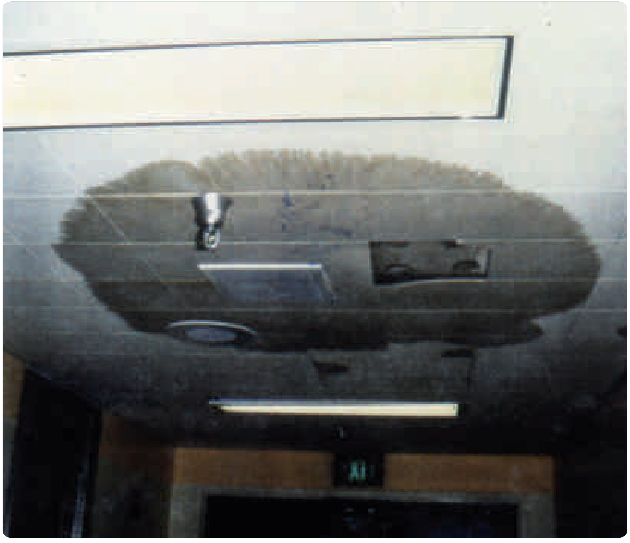


Photo credit: Degenkolb Engineers, FEMA 74

Photo credit: Mason Industries

Water damage to ceiling due to a pipe break (left); inadequately braced fire water pipe moved and bent, 1994 Northridge, California earthquake (right).

Suspended pipes that are not braced can swing and break or be damaged, especially at joints. They can impact other pipes or ducts in the same area. At expansion joints and building separations, the pipe can break, as it is pulled in different directions by the two different floor slabs or walls to which it is attached.

Consequences

Pipe breaks cause whatever is in the pipe to leak. For water pipes, a break could cause localized flooding and water damage. Hospitals have had to be evacuated before, due to pipe breaks. For medical gas pipes, a leak can cause a major safety hazard.

Check These Related Items

Suspended (false) ceilings (see pg.153): Suspended pipes are often located in the space above suspended ceilings. These ceilings can swing and impact the pipes during earthquakes.

Connected equipment and tanks: Anchor equipment, tanks and cylinders that are connected to pipes. Be sure to provide flexible connections between pipes, equipment, and tanks.

Methods of Anchoring

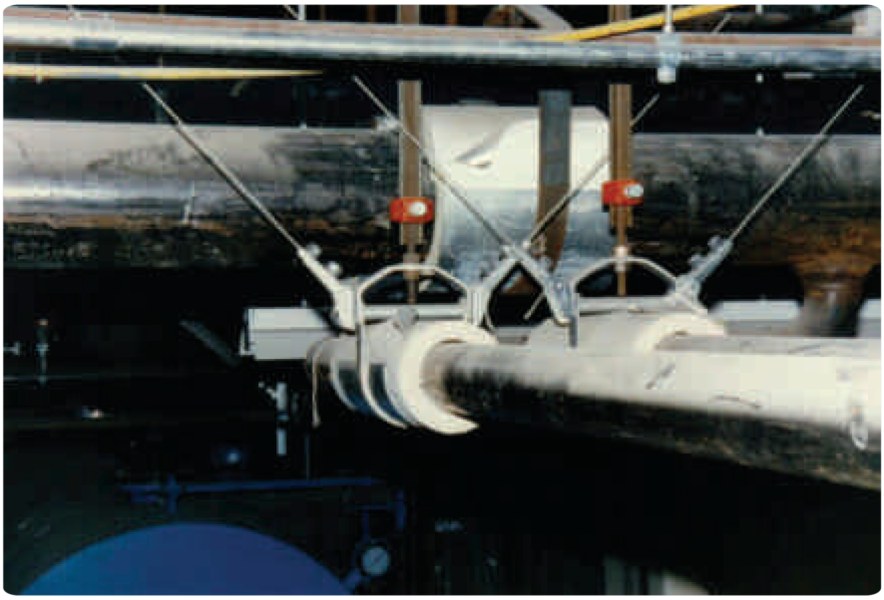


Photo credit: Mason Industries

Anchor suspended pipes either with special clamps or with other special hardware called clevises, which hold the pipe. Use cables (shown at left), angle braces (shown below right), or an equivalent locally-designed system to brace the pipe. Brace the pipe at regular intervals in all three directions: transverse, longitudinal, and vertical. Many manufacturers make hardware to seismically anchor pipe systems, or an engineer can design a system using locally available components. Provide properly designed flexible connections at building separations (below left) and equipment connections.

Photo credits: Mason Industries

Expertise Required

Some engineering required to design bracing/ anchoring systems and to select proper flexible connectors.

Recommended Priority

Continuous Service. The utility distribution systems are necessary for the hospital to function normally. Prioritize installing flexible connections and bracing pipes that supply the most important areas.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, moderate level of disruption. Having a plumber or maintenance staff install flexible connectors is inexpensive. Installing bracing systems for pipes is moderately expensive. The distribution system being worked on will have to be shut off during the installation, so advance planning is necessary.

Where to Find More Information

Please see Appendix C, page for additional technical information and types of flexible connectors. FEMA 414, freely downloadable from www.fema.gov, is a good resource for information on pipes.

Large Pipes

Distribute water or steam to or from equipment; typically located in the physical plant.

Potential Earthquake Damage

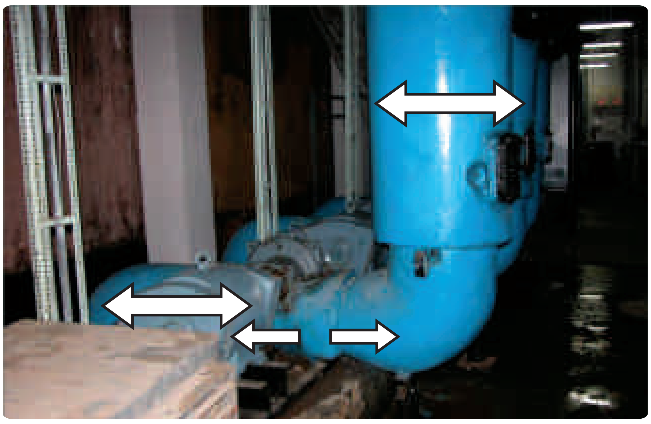


Photo credit: D.K. Paul, IIT Roorkee

Strong shaking can cause large pipes to move and break at joints or at connections to equipment.

Photo credits: Mason Industries

Large iron pipe elbow joint (left) and cast connector between large pipe and equipment (right) fractured due to differential movement between equipment and pipes, 1994 Northridge, California earthquake.

Large pipes that are not braced can vibrate excessively and break at joints or at connections with equipment. Large pipes are much heavier than small pipes and can generate large seismic forces. Standard cast connectors have often broken in past earthquakes.

Consequences

Pipe breaks cause whatever is in the pipe to leak. For water pipes, a break could cause local flooding and water damage.

Check These Related Items

Connected equipment and tanks: Large pipes often connect to large equipment. Be sure to anchor equipment and provide flexible connections between pipes and equipment that are able to accommodate the expected relative displacement. Rigid, cast connectors are very vulnerable to breakage.

Methods of Anchoring

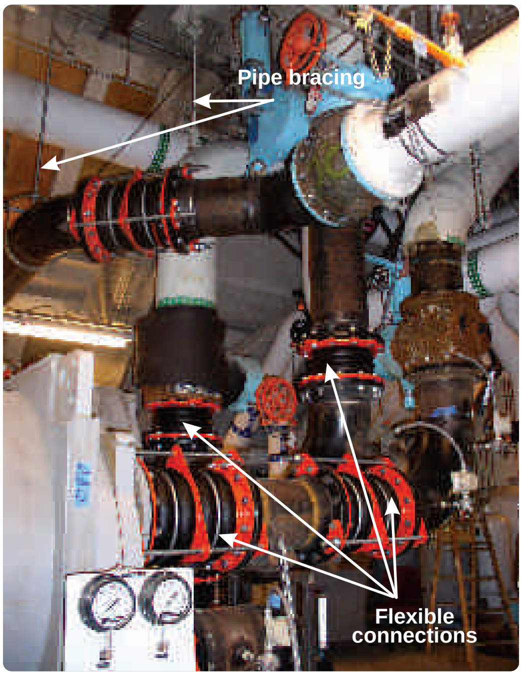


Photo credit: Mason Industries

Anchor large pipes to special support members or to the structural framing. Provide flexible connections at those places where pipes connect to equipment or to the structure. Flexible connections are very important for large pipes, which are less flexible than smaller pipes. Large pipes connected to both the ceiling and floor-mounted equipment will experience the full relative displacement between the floor and ceiling, which can be larger than many conventional, non-seismic flexible connectors can accommodate. Several manufacturers produce flexible connectors such as those at left that can accommodate these large relative displacements.

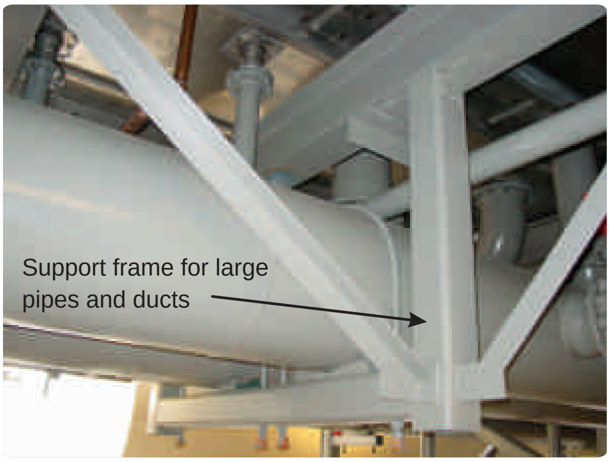


Photo credit: Janise Rodgers, GeoHazards International

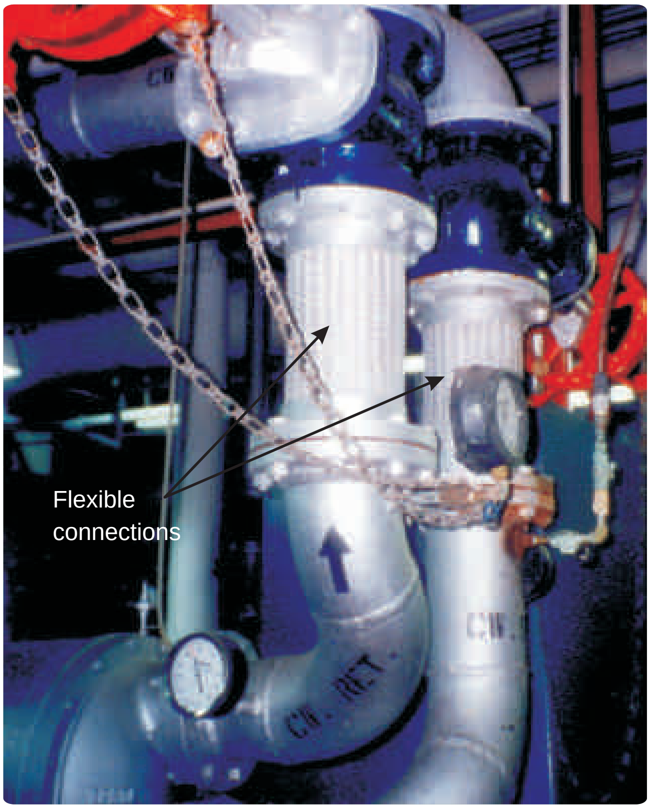


Photo credit: FEMA 74

Expertise Required

Some engineering required to design bracing and flexible connections.

Recommended Priority

Continuous Service. The utility distribution systems are necessary for the hospital to function normally.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, moderate level of disruption. Having a plumber or maintenance staff install flexible connectors is moderately expensive. Installing bracing systems for pipes can be expensive. The distribution system being worked on will have to be shut off during the installation, so advance planning is necessary.

Where to Find More Information

Please see Appendix C, page for additional technical information and types of flexible connectors. FEMA 414, freely downloadable from www.fema.gov, is a good resource for information on pipes and includes additional flexible connection details.

Conduits and Electrical Distribution

Distribute electrical wires and communications lines; located throughout the hospital.

Potential Earthquake Damage

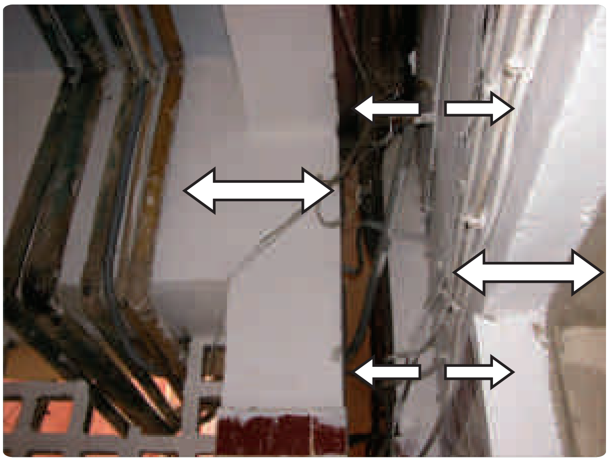


Photo credit: D. K. Paul, IIT Roorkee

Strong shaking or differential motion across expansion joints can cause conduits to fall or separate at the couplings.

Photo credit: Mason Industries

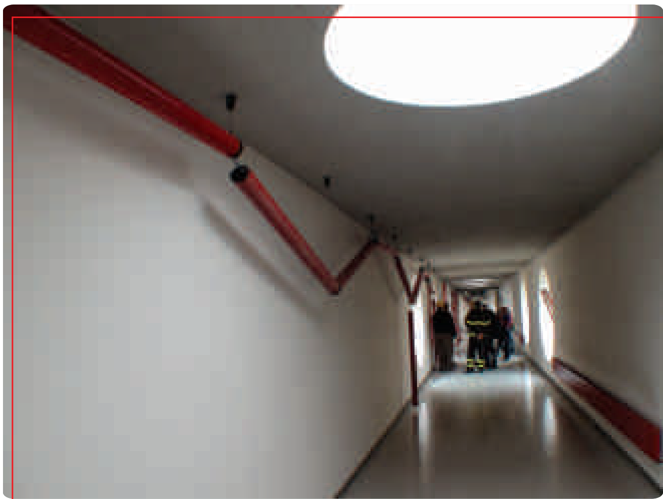


Photo credit: Khalid Mosalam, University of California, Berkeley

Fallen electrical conduit, 1994 Northridge, California earthquake (left); conduit in a hospital separated at couplings during the 2009 L'Aquila, Italy earthquake (right).

At expansion joints and building separations, the conduit can separate at the couplings, as it is pulled in different directions by the two different floor slabs or walls to which it is attached. Poorly anchored conduits can fall. Conduits carry electrical wiring and telecommunications lines that can be damaged by a conduit break.

Consequences

Broken electrical wires can cause parts of the hospital to lose power, and they can be a fire hazard. Broken telecommunications lines can shut down parts of the hospital's communication system.

Check These Related Items

Electrical cabinets (see pg.115): The electrical cabinets connected to conduits should be properly anchored to prevent them from toppling.

Telecommunications racks (see pg.115): The telecommunications equipment connected to conduits should be properly anchored to keep the communications system functioning.

Connected equipment: Anchor equipment connected to conduits. Provide flexible connections between conduits and equipment.

Methods of Anchoring

Photo credit: California OSHPD

The best way to prevent breaks in conduits that are rigidly attached to walls is to install flexible connections in locations where you expect differential movement to occur. These locations include all expansion joints and building separations. The conduit shown at left has a flexible connection across a building separation. The part of the building on the right is on sliders, called base isolators, while the part on the left is not. The two sides will move differently in an earthquake, so a flexible connection that has been properly designed for the expected displacement is necessary, in order to keep the conduit from breaking. The conduit's couplings must also be installed properly to keep the conduit from separating. You can have the conduits in your hospital inspected to determine if couplings were properly installed.

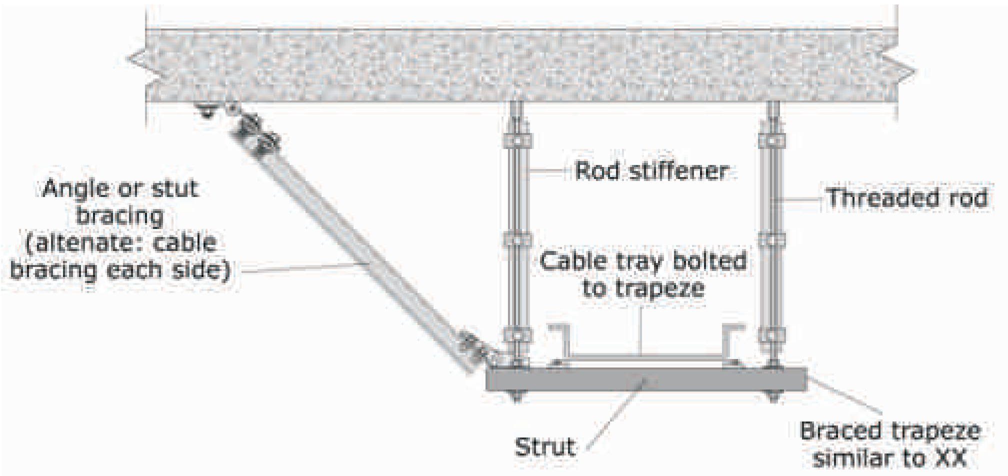


Image credit: FEMA 74

Suspended conduits require bracing similar to that used for suspended pipes. Raceways and cable trays should be braced in all three directions using cables, angle braces or an equivalent bracing system.

Expertise Required

Some engineering required to design bracing system for conduits and select flexible connectors.

Recommended Priority

Continuous Service. The electrical and telecommunications distribution systems are necessary for the hospital to function normally.

Retrofit Cost and Disruption

Low cost for parts, moderate cost for labor, moderate level of disruption. An electrician will need to install flexible connections for conduits, and power will need to be shut off to the area while they are installed. This requires some advance planning.

Where to Find More Information

Please see Appendix C, page for additional technical information.

Ductwork

Distributes cool or hot air; typically located in centrally cooled or heated areas.

Potential Earthquake Damage

Strong shaking can cause ducts to swing, separate at joints and fall.

Photo credit: Melvyn Green, Melvyn Green & Associates

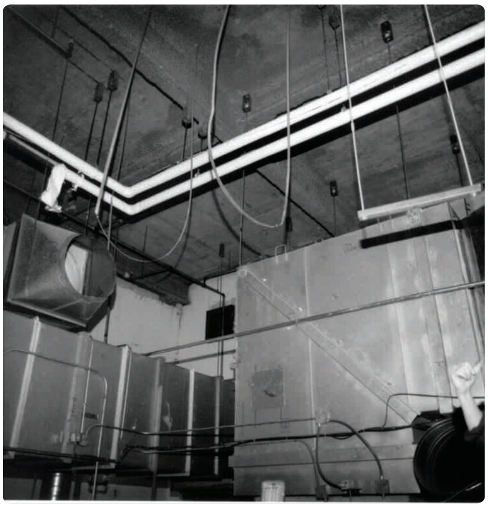


Photo credits: Mason Industries

Fallen ductwork (left) and (right); duct crushed by swinging pipes (center) 1994 Northridge, California earthquake.

Suspended ducts that are not braced can swing or move and might separate at joints. Separated pieces might fall. Ducts can also impact swinging pipes or other objects, which might damage or crush the duct's lightweight walls. Smaller ducts are less prone to damage than larger ducts are. Proper duct construction has prevented damage in past earthquakes.

Consequences

Disconnected or crushed ducts will no longer deliver cool or hot air to the hospital or circulate air properly. Ducts are not usually falling hazards, because they are relatively lightweight and are not usually located where they can fall on people.

Check These Related Items

Suspended pipes (see pg.127): Brace suspended pipes in the vicinity of ducts, so that they will not swing and damage the ducts.

Connected equipment: Pay attention to connections between ducts and equipment, because separations can occur due to differential movement.

Methods of Anchoring

Brace large suspended ducts with either cable or angle bracing in all three directions: longitudinal, transverse, and vertical, as shown below. Construct ducts in accordance with accepted standards. For instance, ducts constructed to Sheet Metal and Air Conditioning Contractors National Association (SMACNA) standards have performed reasonably well in earthquakes in the United States.

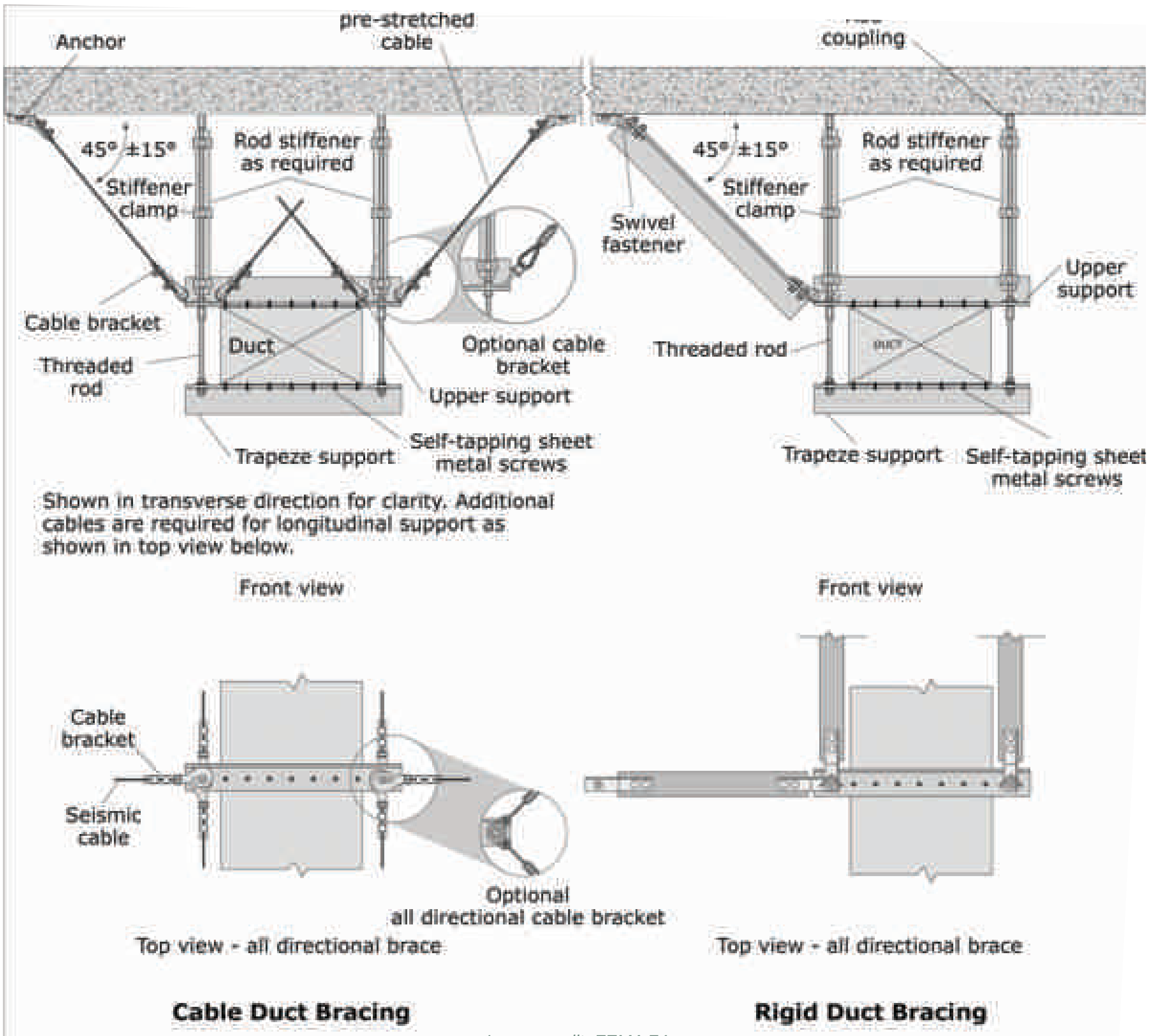


Image credit: FEMA 74

Expertise Required

Some engineering required to design bracing system.

Recommended Priority

Continuous Service. The hospital needs the ducts to circulate cool or hot air.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, moderate level of disruption. Installing bracing systems for ducts is moderately expensive. The distribution system being worked on may need to be shut off during the installation, so advance planning is necessary.

Where to Find More Information

Please see Appendix C, page for additional technical information. FEMA 414, freely downloadable from www.fema.gov, is a good resource for information on ducts.

Tanks and Medical Gases

Medical gas, supplied by bulk medical gas tanks or individual compressed gas cylinders, is critical for surgery, life support, and other important hospital functions. Medical gas storage systems have been shown in past earthquakes to be among the most vulnerable systems, if tanks and cylinders are not properly anchored. Most hospitals also have several other kinds of tanks that serve important functions, including rooftop water tanks and diesel fuel day tanks for emergency generators.

- This section contains general information on how to seismically protect tanks and medical gases:

Other tanks:

Compressed-gas Cylinders

Store nitrogen, oxygen or other medical gases; located in a central room and on carts.

Potential Earthquake Damage

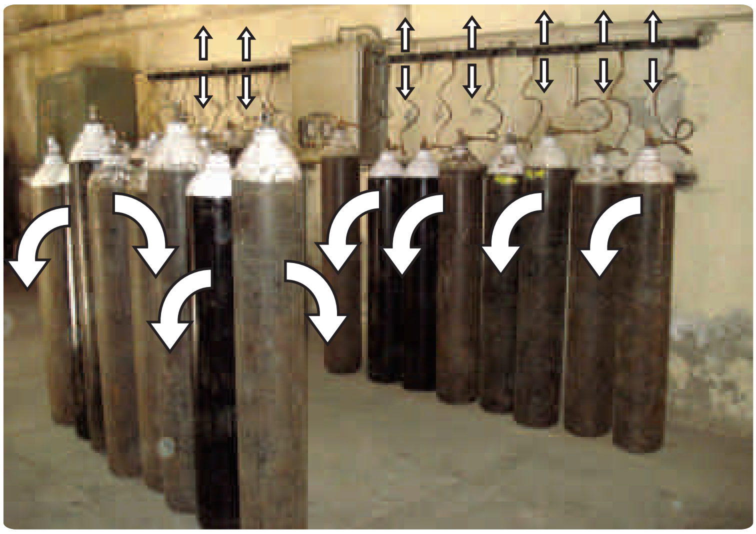


Photo credit: Manisha Dharan, THOT Designs

Strong shaking can cause unrestrained cylinders to topple. Cylinders connected to manifolds can break their connections.

Photo credit: FEMA 370

Photo credit: California OSHPD

Toppled cylinders (left); cylinders anchored with chains did not topple, but unanchored cylinders did in the 1983 Coalinga, California earthquake (right).

Cylinders provide necessary medical gases such as oxygen, nitrogen and nitrous oxide, and are often attached to manifolds. In hospitals without bulk medical gas tanks, cylinders are the sole means of providing medical gases. During an earthquake, unrestrained cylinders can topple and break their connection with the manifold, which is not strong enough to hold the cylinder upright. Cylinders on carts inside the hospital can fall and break connections, if they are not properly anchored to the cart. Cylinders with broken connections can leak gas.

Consequences

If cylinders break free from manifolds, then the supply of medical gas will be interrupted. This could pose a danger to patients. Medical gas leaks can be dangerous, especially inside the hospital building.

Check These Related Items

Rigidly attached pipes (see pg.125): Medical gas distribution systems must also remain intact, in order for gases from the cylinders attached to manifolds in yards to reach the patients that need them.

Methods of Anchoring

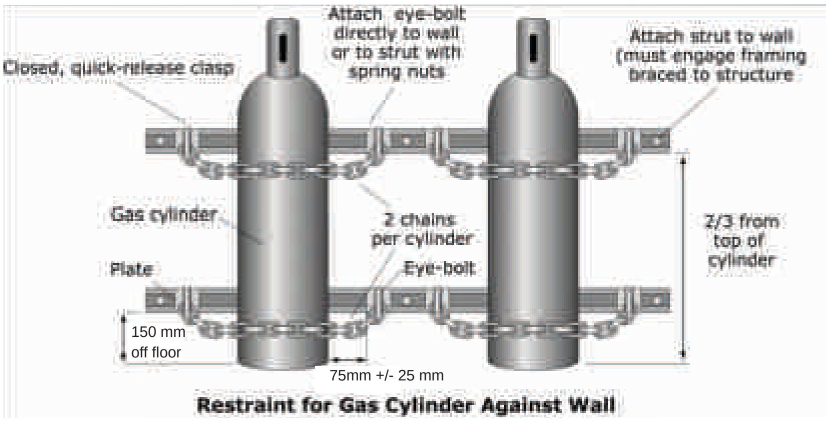


Image credit: FEMA 74

Anchoring compressed-gas cylinders is easy and inexpensive. Install chains with quick-release clasps to struts (light channel sections shown at left) or angles that are fastened securely to the wall. Place one strut at two-thirds the height of the cylinders, and the other near the bottom of the cylinders. Fasten the chains around the cylinders. Confirm that the wall is strong enough to resist the forces that the cylinders generate. Anchor cylinders on carts using chains in a similar manner.

Another option is to install a special rack for the cylinders, as shown at right. The manifolds are built in to the rack, and the rack is secured to the wall. The cylinders are firmly anchored to the rack but can easily be removed by loosening the wing nut and turning the restraint ninety degrees. The rack of nitrogen cylinders at right was undamaged during the 2001 Peru earthquake. This approach is more expensive, but cylinders can be spaced much more closely than when using the chain and strut solution.

Photo credits: Eduardo Fierro, BFP Engineers (Bertero Fierro, Perry)

Expertise Required

Some maintenance assistance required. A handyman will need to install the struts/ channels and cut the chains to length. Special racks need to be designed by an engineer.

Recommended Priority

Critical Safety. Interruptions in medical gas supply could lead to death for critical patients. Leaking medical gas is a hazard.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, low level of disruption. Chains and struts are very inexpensive. Racks are more expensive but can be fabricated from commonly available, inexpensive parts. Cylinders are commonly located in a separate building or yard (open area near building), so work on them will not disrupt hospital operations.

Where to Find More Information

See Appendix C, page for additional technical information.

Bulk Medical Gas Tanks

Provides storage for bulk medical gas; often located outdoors.

Potential Earthquake Damage

Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause bulk medical gas tank supports to fail, and the tank can topple.

Photo credit: California OSHPD

Photo credit: NiSEE

Medical oxygen tank overturned due to inadequate anchorage in 1994 Northridge, California earthquake (left); similar failure of liquid nitrogen tank in 1971 San Fernando, California earthquake (right).

Most medical gas tanks are tall compared to their diameter (a height to base ratio of 2.5 is typical), which generates large forces on the supports, when the tank tries to move during earthquake shaking. Often, the anchor bolts holding the tank to the concrete or the support frame are too weak to resist these forces, and the tank topples.

Consequences

When a tank topples, it typically breaks connections to the medical gas distribution system. This cuts off the supply of medical gas to the hospital and could cause a leak. Many medical gas tanks supply oxygen. Patients with breathing difficulties or on life support could die without the oxygen supplied by the bulk medical gas tank. Leaking oxygen is also a fire hazard, and the area might need to be evacuated.

Check These Related Items

Rigidly attached pipes (see pg.125): The medical gas will not be able to reach the hospital, if the supply system pipes or their connections to the tank are damaged.

Methods of Anchoring

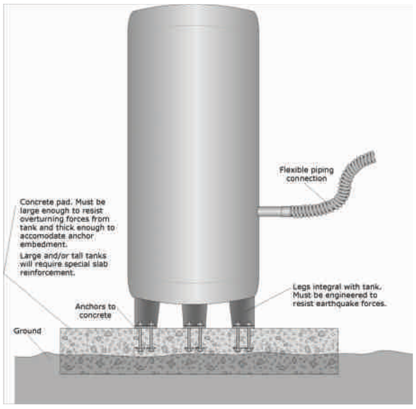
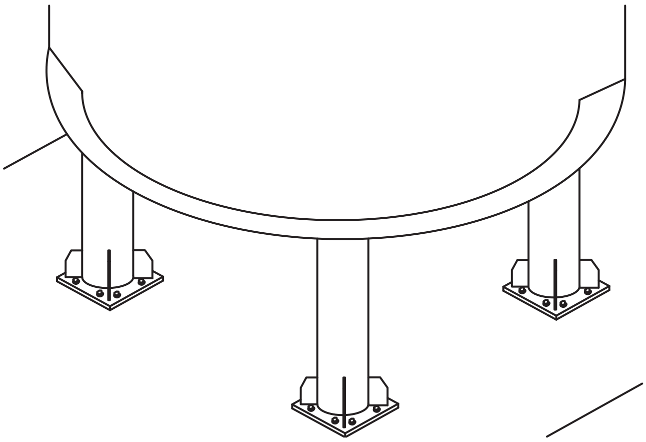


Image credit: FEMA 74



First, have an engineer determine if the tank's support system is strong enough to resist the expected level of earthquake shaking. The engineer should check the anchor bolts, the tank legs themselves, and the welds that connect the legs to the tank. Strengthen tanks with undersized or non-existent anchor bolts by adding new, properly sized bolts able to resist the expected seismic forces. If the existing bolt holes are not adequate, then weld clip angles to the tank legs and bolt them to the slab. In some cases, you may need a stronger foundation, which increases costs. You may also need to reinforce the tank legs or support frame, as shown below, if they are not strong enough. In all cases, replace rigid connections to the supply system with flexible connections.

Photo credit: Eduardo Fierro, BFP I Engineers (Bertero Fierro, Perry)

If you install a new tank or replace an old one, you should specify that the tank be properly anchored with bolts and a support frame designed by an engineer to resist earthquake forces in all directions. All connections to the supply system should be flexible connections.

Expertise Required

Some engineering required. An engineer will need to check the tank's anchorage and support system and design strengthening measures if needed.

Recommended Priority

Critical Safety. Interruptions in medical gas supply could lead to death for critical patients. Leaking medical gas is a hazard.

Retrofit Cost and Disruption

Low cost for parts, moderate cost for labor, minimal disruption. Bolts and steel members used to reinforce tank supports are readily available and thus, relatively inexpensive. Work on bulk medical gas tanks requires planning to provide another supply of gas (such as cylinders), if the tank will be disconnected from the supply system. Tanks are usually located in areas where work does not disrupt other hospital operations.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Rooftop Water Tanks

Store water for domestic use; located on the rooftop.

Potential Earthquake Damage

Photo credit: Melvyn Green, Melvyn Green & Associates

Strong shaking can cause rooftop water tanks to break their supply pipe connections. Unanchored plastic tanks can slide and break their connections or fall from the roof, if located close to the edge.

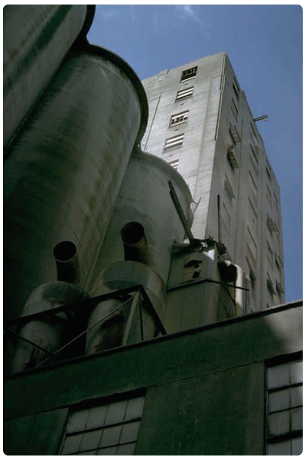


Photo credits: NiSEE (Karl Steinbrugge and Harold M. Engle)

Wooden rooftop water tank fell from high roof (left) and damaged grain silos and ruined grain at a flour mill (center), 1965 Puget Sound, Washington earthquake; building front damaged by falling rooftop water tank, 1933 Long Beach, California earthquake (right).

There are two major types of rooftop water tanks: cast-in-place reinforced concrete tanks, and smaller flat-bottomed fibre-glass or plastic tanks. Cast-in-place tanks must be designed for seismic forces per the building code, so if the building was built to code recently, then the tank is probably adequately anchored. However, the connections to water supply pipes can break. Fibre-glass or plastic tanks are often unanchored and may be perched at the edge of the building, to provide simpler plumbing. These tanks can slide and break their connections or fall from the roof, if located too close to the edge. An unreinforced brick parapet will not be strong enough to keep a full water tank from toppling off the roof.

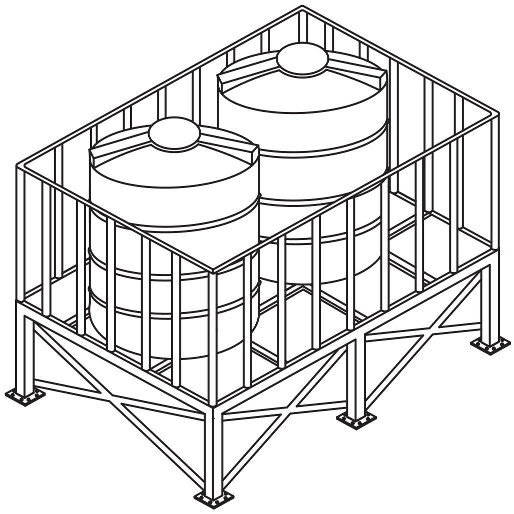
Consequences

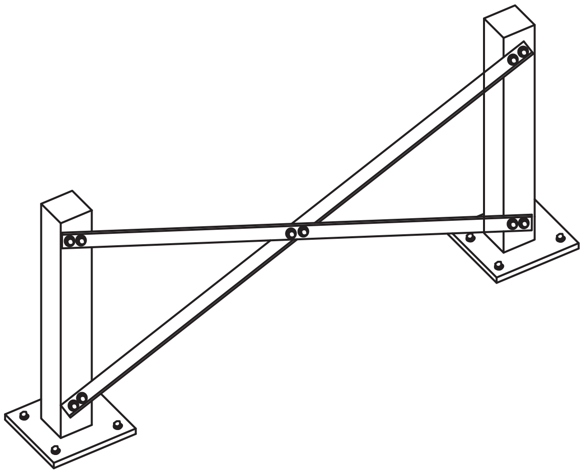
Breaks in water pipe connections allow the water in the tank to leak and potentially to flood areas of the hospital. This happened in hospitals in both the 1994 Northridge, California and 1995 Kobe, Japan earthquakes. Plastic tanks falling from the roof are a major falling hazard.

Check These Related Items

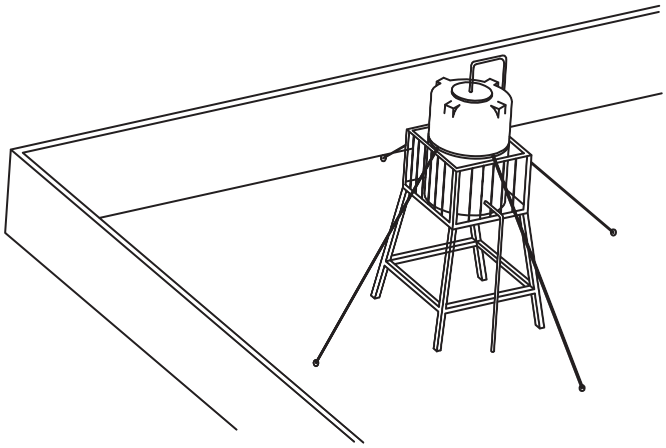
Rigidly attached pipes (see pg.125): Water distribution systems must remain intact, in order for water from the rooftop tanks to reach the hospital.

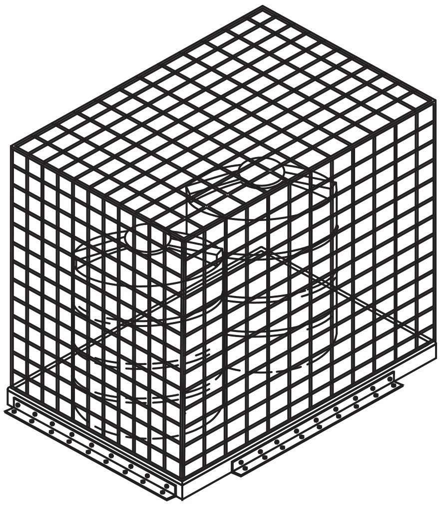
Methods of Anchoring





Have an engineer check the strength and condition of reinforced concrete tanks. Over time, the steel reinforcement in tank supports can corrode. Anchor fibre glass or plastic water tanks by surrounding them with steel enclosures or rails. If you already have cage-type enclosures designed to keep monkeys out of the water tanks, then have an engineer check them – they may not now be strong enough to keep the tank from sliding or toppling, but they could be reinforced to become so. Keep in mind that some plastic tanks are more likely to slide than to topple, because their height to base ratio is 1.5 or less. Do not anchor tanks to parapets – unreinforced parapets are not strong enough and will often fail on their own during an earthquake, even without additional forces from a heavy tank.





Expertise Required

Some engineering required to design the anchorage system for plastic tanks.

Recommended Priority

Continuous Service. For most water tanks. The hospital needs water to continue functioning during the post-earthquake period.
Critical Safety. Plastic water tanks located close to the edge of the roof can fall and kill anyone below.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, minimal level of disruption. Steel enclosures or rails to keep plastic tanks from sliding can be constructed from inexpensive, readily available parts. Work on rooftop water tanks does not typically disturb hospital operations, except perhaps during drilling, when doweling anchors into the roof slab.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Horizontally-Oriented Cylindrical Tanks

Store fuel, water, or other fluids; located in physical plant or yards.

Potential Earthquake Damage

Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause tanks to fall from their supports and break their connections.

Photo credit: California OSHPD

Photo credit: Degenkolb Engineers

Tank shifted off of support curb at Granada Hills Hospital in 1994 Northridge, California earthquake (left); tank slid on its supports and broke pipe connections (right).

Day tanks are smaller tanks that contain a supply of diesel fuel to power the emergency generator for a short period of time. The day tank must remain connected, in order for the emergency generator to function. Other types of tanks include water treatment tanks and storage tanks. Horizontal tanks can still topple about their longitudinal axis, as shown above, or slide off their supports and break supply connections.

Consequences

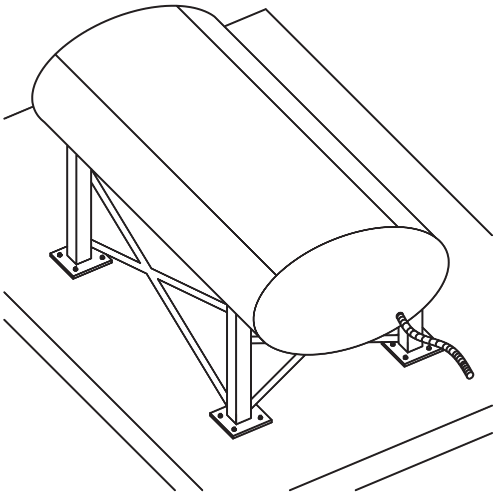
Failure of a day tank or its connections will prevent the emergency generator from functioning, because it will not have a fuel supply. The failure of other types of tanks will keep the systems such as water purification or hot water systems that those tanks serve from working properly. Broken connections can also cause hazardous fuel spills or water damage.

Check These Related Items

Rigidly attached pipes (see pg.125): Distribution systems into and out of tanks must remain intact, in order for the tank to perform its function.

Emergency generator (see pg.97): The emergency generator must be properly anchored and have flexible connections, so that it will remain connected to the fuel supply system.

Methods of Anchoring



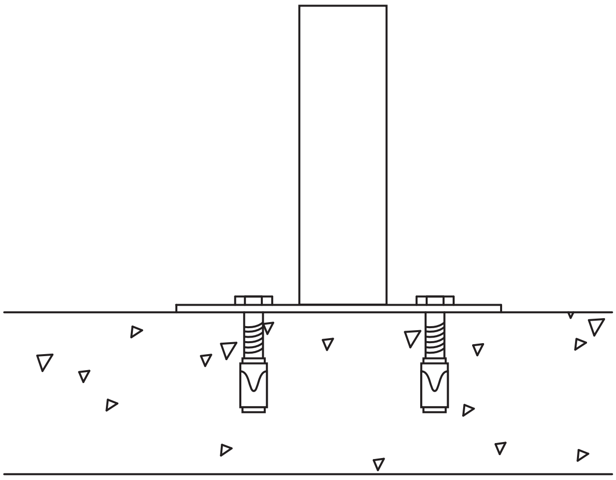


Image credit: FEMA 74

Anchor day tanks and other tanks by providing a structural support frame that can resist earthquake forces and is bolted to the floor or foundation. The photos below show one option for increasing the strength of an existing support system. The anchorage system should protect against both overturning and sliding. Provide flexible connections to all supply lines and pipes.

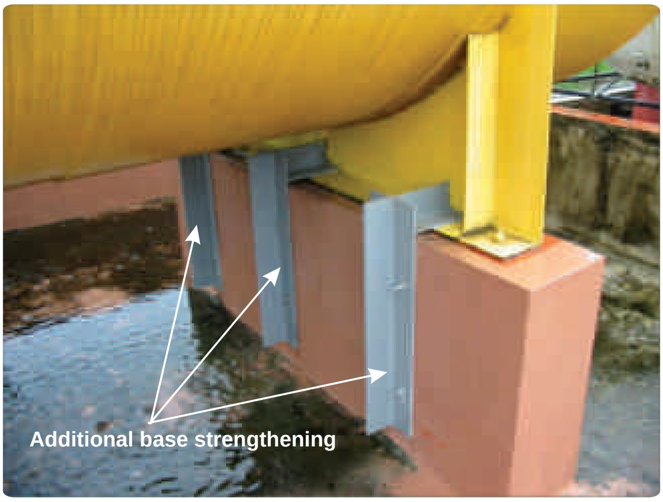


Photo credits: FEMA/ATC Training Course

Expertise Required

Some engineering required. An engineer will need to evaluate and strengthen the tank's anchorage if needed.

Recommended Priority

Critical Safety. For day tanks that power the emergency generator.
Continuous Service. For other tanks.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, minimal level of disruption. Work on day tanks takes place in the physical plant, where it will not affect hospital operations. Provide a backup fuel connection to the emergency generator while working on the day tank. Work on other types of tanks will disrupt the system that the tank is part of, but this can be managed with advance planning.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Architectural Elements

Hospital buildings have a number of architectural elements that are an integral part of the building but that don't resist loads in the way that the structural “backbone” of the building does. These elements enhance the functionality, comfort, and aesthetics of the building.

This section contains general information on how to seismically protect the following types of architectural elements:

Other exterior architectural features such as balcony walls can be evaluated and strengthened using techniques similar to those used for sunshades and parapets. Consult an engineer for guidance on strengthening particularly large or heavy elements, such as entrance canopies. Decorative masonry elements (jalies) are generally not a cause for concern, unless they are larger than 1 m by 1 m in size. For decorative ceramic tiles applied as a veneer attached to wall plaster, determine whether falling tiles could injure someone or block the exit. If so, then consider either replacing the tiles in these areas with properly anchored veneer or removing them.

Parapets

Provide a safety wall and hide equipment from street-level view; located at roof edges.

Potential Earthquake Damage

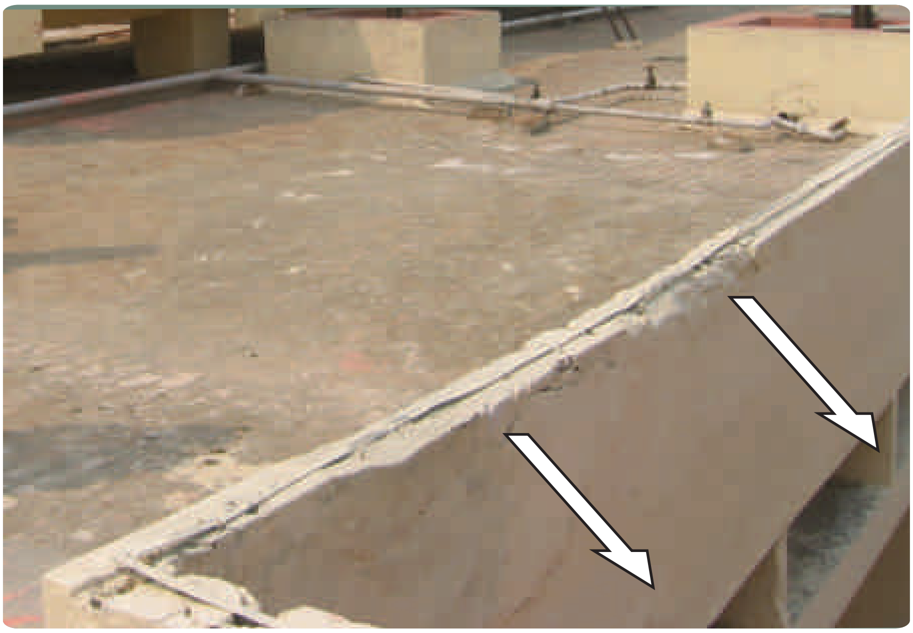


Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause unbraced brick parapets to topple from the roof edge onto whatever lies below.

Photo credit: Rabindra Vasvada

Photo credit: National Geophysical Data Center

Fallen parapet, 2001 Gujarat, India earthquake (left); car crushed by fallen parapet, 1992 Petrolia, California earthquake (right).

Unbraced, unreinforced brick or stone parapets with height to thickness ratios of 1.5 to 1 (meaning they are one and a half times as tall as they are thick) or more in Seismic Zones IV and V, or with height to thickness ratios of 2.5 to 1 in Seismic Zones II and III, are likely to topple. Unbraced parapets have fallen in many small earthquakes. The bricks or stones often fall several storeys from the edge of the roof.

Consequences

Unbraced brick parapets are one of the greatest falling hazards: they can kill anyone outside who is near to the building's walls. They can also crush cars or mechanical equipment located in the fall zone. Parapets have fallen in many small earthquakes and killed people. People on sidewalks and those who try to run out of buildings are particularly at risk.

Check These Related Items

There are no related items to check.

Methods of Anchoring

Photo credit: FEMA 74

Parapets must be braced back to the roof to prevent them from toppling. Steel braces spaced along the parapet length are the most common solution. An engineer will need to design the braces to resist the forces that the masonry applies under the expected level of earthquake shaking. Connect the braces to the parapet by drilling a hole through the masonry and then inserting a bolt first through the parapet and then through a steel plate. The steel plate spreads out the earthquake forces. You can use a plate with decorative motifs or a plate color that blends with the brick, as shown below, to improve the exterior appearance.

If you can't brace the parapet right away, you can provide landscaping that discourages pedestrians from standing near the walls where they could be hit by a falling parapet. Maintaining the landscaping and making it uninviting to pedestrians are very important. Grassy areas are likely to attract people, not to keep them away from the walls. Choose shrubs, bushes or taller plants instead.

Expertise Required

Some engineering required. An engineer will need to design the bracing system.

Recommended Priority

Critical Safety. Falling parapets can kill.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, minimal level of disruption. Parapets can be braced with steel braces at reasonable cost; installing a new parapet is significantly more expensive. Disruption is minimal, because work takes place on the roof, and all buildings systems can remain in operation. Coordinate the drilling of holes in the parapet with the users in the storeys below the parapet, as drilling causes both noise and vibrations.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Sunshades

Reduce sunlight, heat and glare entering the windows; located on exterior façade.

Potential Earthquake Damage

Photo credit: *Melvyn Green, Melvyn Green and Associates*

Strong shaking can cause the sunshades to fall from the building's exterior.

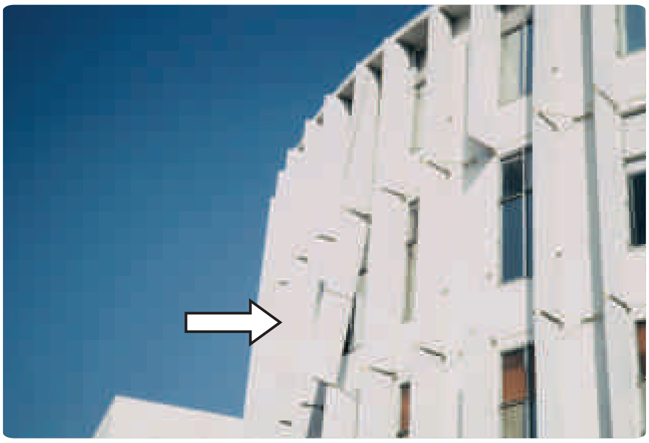


Photo credit: California OSHPD

Photo credit: Degenkolb Engineers, FEMA74

Displaced sunshade now hanging by one attachment, 1994 Northridge, California earthquake (left); concrete panel similar to a sunshade that fell and killed one pedestrian, 1987 Whittier Narrows, California earthquake (right).

Sunshades that are not properly anchored to the building could detach and fall during strong earthquake shaking. Deterioration of sunshades and corrosion of reinforcing steel can cause pieces of the sunshade to fall, even if the entire sunshade does not.

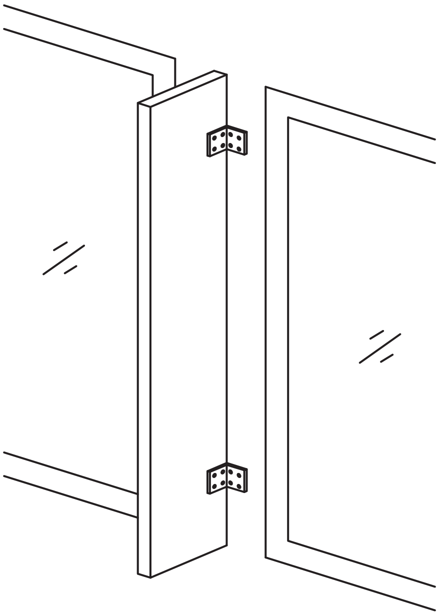
Consequences

Falling sunshades could kill people outside the building near the walls, and could possibly block the exits.

Check These Related Items

There are no related items to check.

Methods of Anchoring



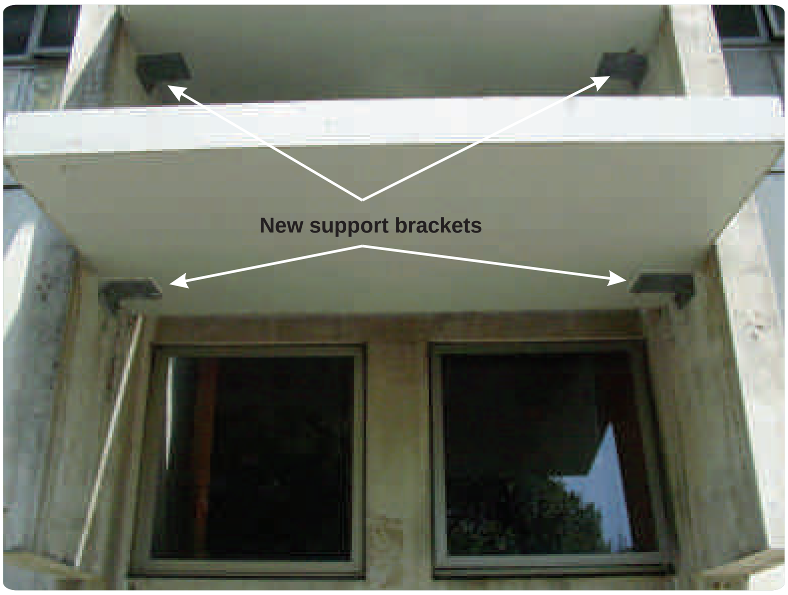


Photo credit: Janise Rodgers, GeoHazards International

An engineer will need to check the anchorage details of sunshades to determine whether or not the anchoring mechanism can withstand the expected earthquake forces. If sunshades are not well anchored, then you can provide supplementary support brackets like those shown above. You can also create a landscaped area near the building, in order to keep pedestrians away from the area where sunshades are likely to fall. Maintaining the landscaping and making it uninviting to pedestrians are very important. Grassy areas are likely to attract people, not to keep them away from the walls. You can also reinforce the canopies over exits (or can install new canopies), so that falling sunshades will not block the exits.

Photo credit: Jorge Meneses

If sunshades have been damaged by exposure to the elements, then you might replace them with new, properly anchored sunshades. Sunshade replacement can drastically improve a building's appearance, but it is expensive. The sunshades on the building at left were replaced as part of a rehabilitation project.

Expertise Required

Some engineering required. An engineer will need to check the anchorage and condition of sunshades and to design any strengthening measures.

Recommended Priority

Continuous Service. Falling sunshades are a hazard.

Retrofit Cost and Disruption

Low cost for parts, moderate cost for labor, moderate level of disruption. Adding support brackets to sunshades is moderately expensive, because scaffolding and special safety measures will be required. Sunshade replacement can be expensive. Work on sunshades can be disruptive, due to noise and vibrations, even though the work takes place on the exterior of the structure.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Masonry Partition Walls

Non-loadbearing walls that divide rooms; located throughout concrete frame buildings.

Potential Earthquake Damage

Photo credit: *Melvyn Green, Melvyn Green and Associates*

Strong shaking can cause masonry partition walls to crack or to fall into rooms.

Photo credit: NiSEE (Halil Sezen)

Photo credit: California OSHPD

Collapsed infill walls and column damage, 1999 Izmit, Turkey earthquake (left); Cracked masonry partition in a patient room, 1994 Northridge, California earthquake (right).

Unreinforced brick partitions that are only one brick thick can crack and fall into rooms or outward to the ground outside, as the building moves back and forth in an earthquake. Bricks, large portions of the wall, or even the whole wall can topple into rooms, if the wall is not anchored to the concrete beams and columns in some way. Thicker partial-height masonry walls can cause the adjacent concrete columns to fail. Column failures are considered major structural damage. Engineers refer to this type of failure as the “short column” or “captive column” effect, because the walls restrain a portion of the column from moving. As a result, all of the deformation has to occur within a short segment of the column. Most columns aren't designed to withstand these demands and often fail.

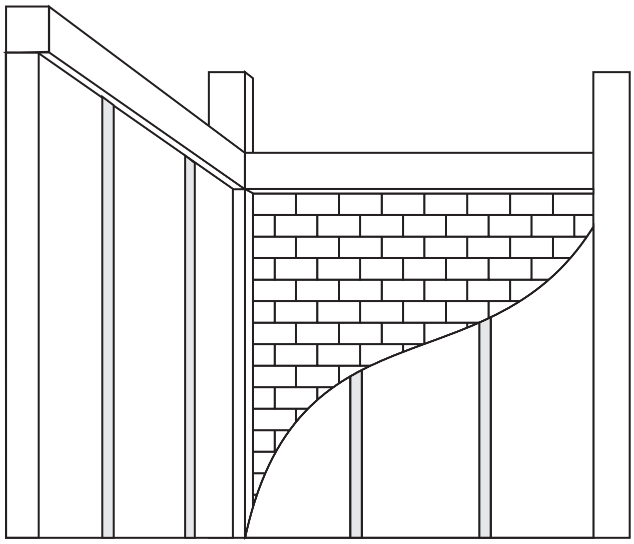
Consequences

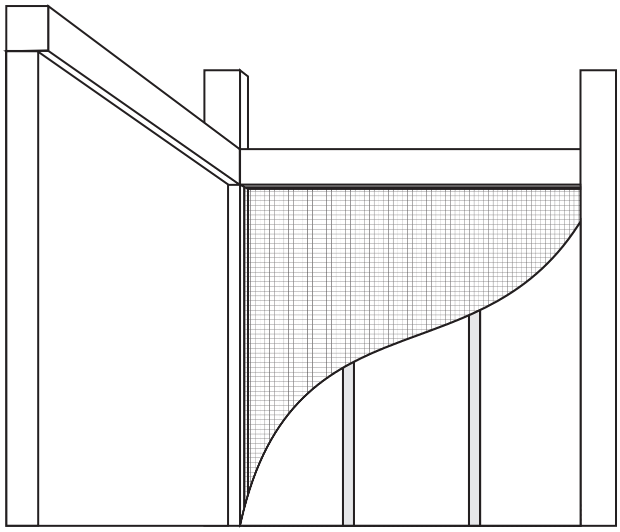
Falling bricks could injure or kill people next to the wall. Bricks that fall in stairwells could prevent people from safely exiting the building after the earthquake. Partial-height masonry walls can cause major structural damage that could make the building unsafe.

Check These Related Items

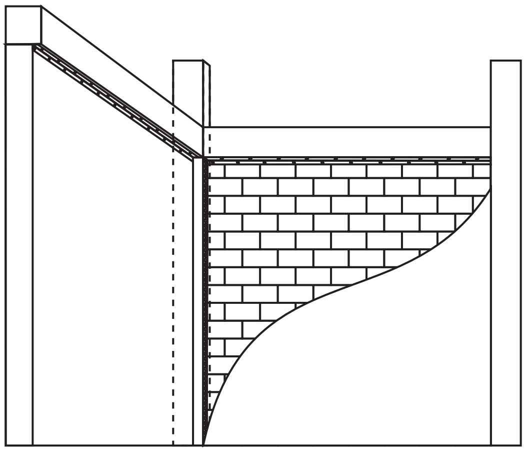
There are no related items to check.

Methods of Anchoring





Anchor partition walls using steel members connected floor to ceiling, shown above at left. Another option is to provide a fiber-reinforced polymer or microconcrete (with woven wire mesh reinforcement) overlay, shown above at right. Full-height partitions can also be detached from the columns, and a steel angle used to connect the top of the wall to the ceiling to prevent toppling. However, this is disruptive, and gaps in walls raise fire protection concerns that will need to be addressed. Partial-height partitions should be detached from the columns, however, because they can cause major structural damage due to the “captive column” effect.



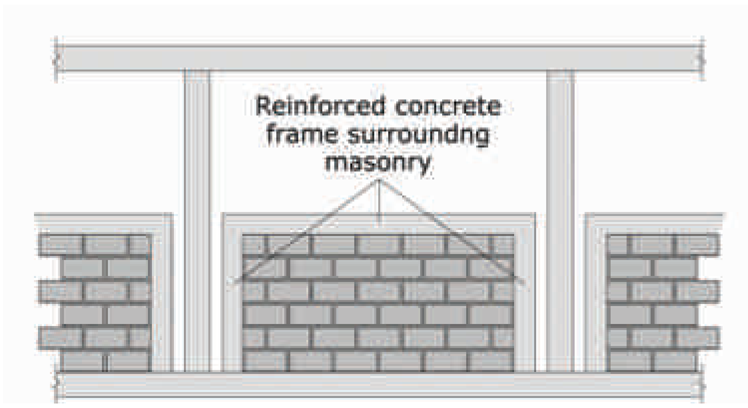


Image credit: FEMA 74

Expertise Required

Some engineering required. An engineer will need to design the restraints for the walls.

Recommended Priority

Continuous Service. Fallen infill walls can prevent the hospital from functioning after an earthquake. Fixing all partitions is very disruptive and not recommended as a standalone project. Consider anchoring partitions in critical areas only.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, high level of disruption. Work on masonry partition walls is very disruptive, because there are typically large number of partitions located throughout the hospital Work on partitions must be phased. Work may also be more economical and less disruptive, if it is done in conjunction with a remodel or structural retrofit.

Where to Find More Information

Please see Appendix B, page 167 for more information on anchoring to partition walls, and Appendix C, page for additional technical information.

Suspended (False) Ceilings

Can be a suspended grid or metal panels; often located in centrally air conditioned spaces.

Potential Earthquake Damage

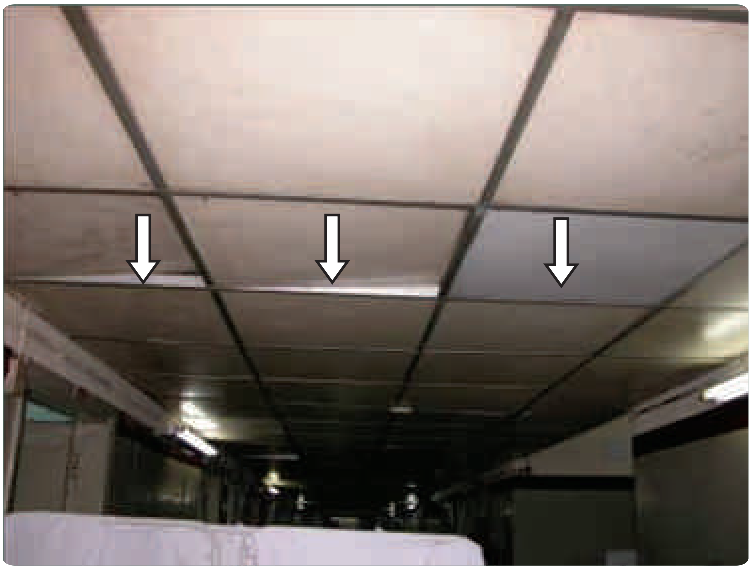


Photo credit: D. K. Paul, IIT Roorkee

Strong shaking can cause panels in suspended grid ceilings to fall and metal panels to buckle.

Photo credit: William T. Holmes, Rutherford & Chekene

Photo credit: EERI 2003 Bam, Iran Earthquake Reconnaissance Report

Damage to an operation theatre ceiling at Kona Community Hospital, 2006 Hawaii earthquake (left); buckled panels in a hospital corridor suspended metal panel ceiling, 2003 Bam, Iran earthquake (right).

Suspended grid ceiling panels can fall out during earthquake shaking, though these panels are lightweight and typically don't injure anyone. Light fixtures supported by the ceiling system could fall. Metal panels are much less likely to fall, though they may bend and twist.

Consequences

Falling ceiling panels will drop accumulated dust down into clean or sterile spaces such as operation theatres. Fallen panels in corridors could partially block the exit pathway.

Check These Related Items

There are no related items to check.

Methods of Anchoring

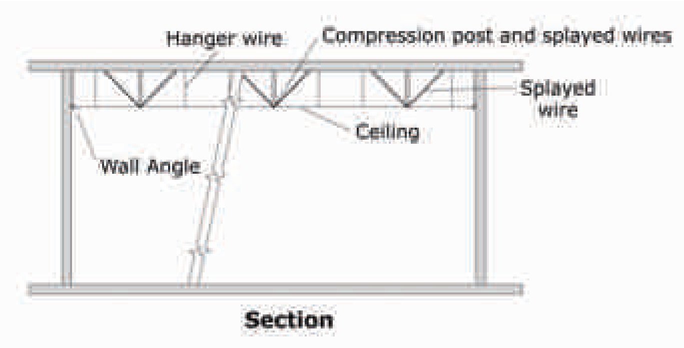


Image credit: FEMA 74

Photo credit: FEMA 74

Anchor suspended grid systems by adding bracing wires and compression struts from the ceiling grid to the floor slab or beams above. The recommended layout of the braces and struts is shown in section view above. Connect the bracing wires and hanger wires to the concrete slab as shown below. GHI does not recommend retrofit of suspended metal panel ceilings, because panels are unlikely to fall and attaching them to their supports would impede access to the ceiling space.

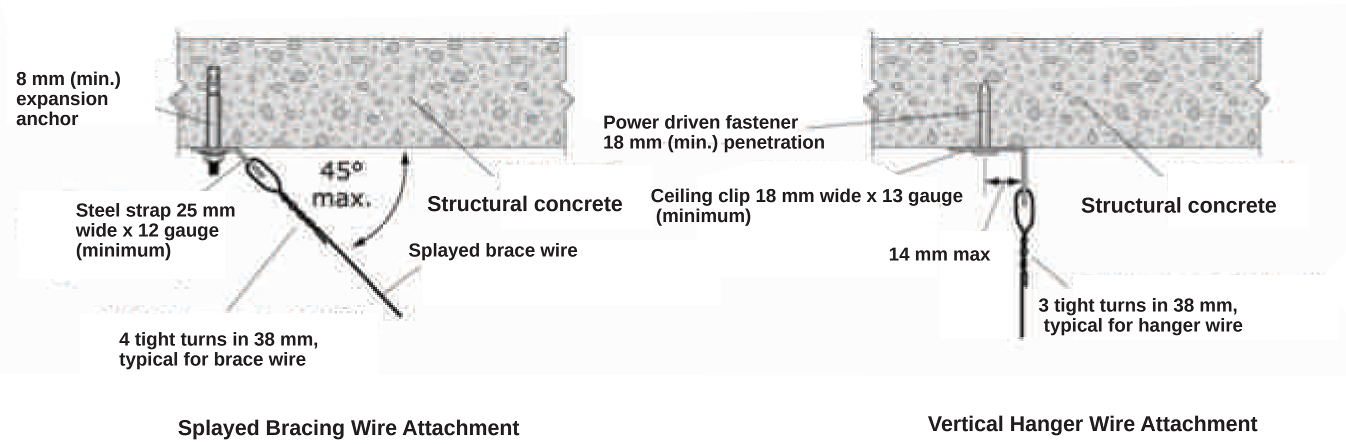


Image credit: FEMA 74

Expertise Required

Some engineering required to design the spacing and orientation of the wire braces for suspended grid ceilings.

Recommended Priority

Continuous Service. The hospital's operations will not be impaired by ceiling damage, except in operation theatres, critical care/sterile areas, and exit corridors.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, moderate level of disruption. Suspended grid ceilings are often found in operation theatres and critical care areas that are centrally air conditioned. Disturbing these areas to brace the ceiling grid requires careful planning to minimize disruption.

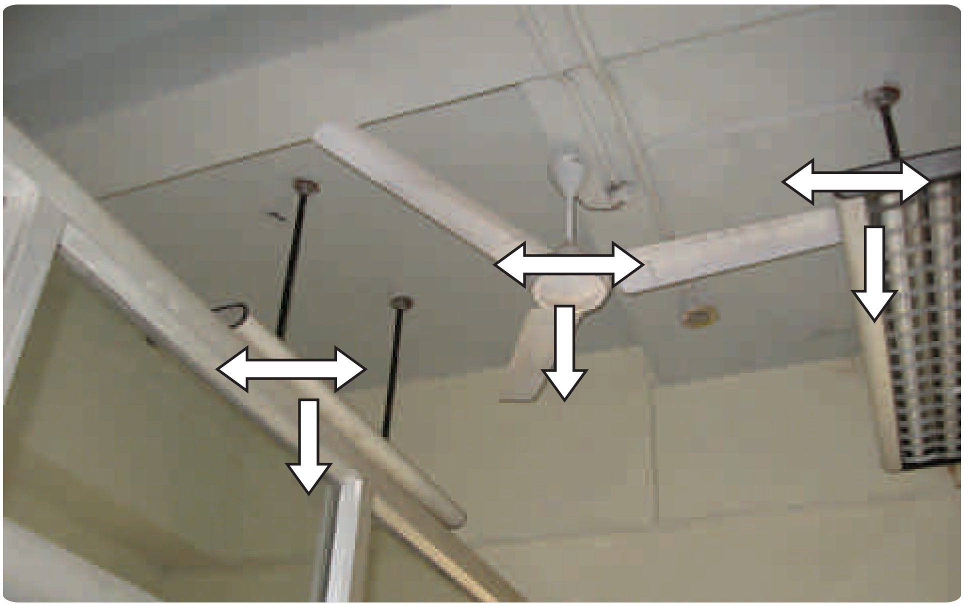
Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Pendant Light Fixtures and Ceiling Fans

Provide lighting and air circulation in many rooms; hang from ceiling.

Potential Earthquake Damage



Strong shaking can cause weakly attached pendant light fixtures and ceiling fans to swing, break their connections, and fall.

Photo credit: Hari Kumar, GeoHazards International

Photo credit: FEMA

Photo credit: National Geophysical Data Center

Failed pendant light fixture hanging dangerously over patient beds, 1971 San Fernando, California earthquake (left); fallen pendant light, 1983 Coalinga, California earthquake (right).

Pendant light fixtures and ceiling fans on rods will swing and can break the connection at the ceiling. Light fixtures and fans on chains, wire rope, or cables are safe, provided that the chain/rope/cable is attached securely with a closed circle hook or other device, so that it can't slip off.

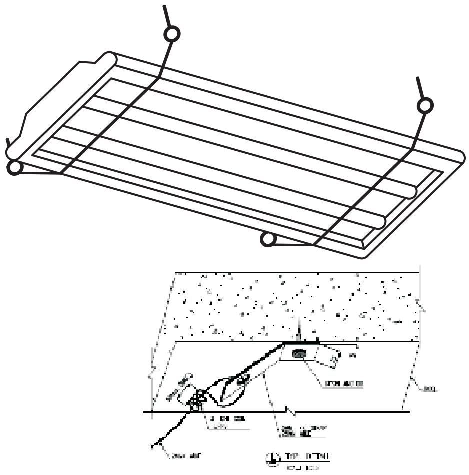
Consequences

Lights often have sharp metal parts that can cut people as they swing and fall. Fluorescent tubes can fall out of light fixtures and break, and people can step on the shards and cut themselves. Fans are heavy and can be particularly dangerous, if they are spinning rapidly when they fall.

Check These Related Items

There are no related items to check.

Methods of Anchoring



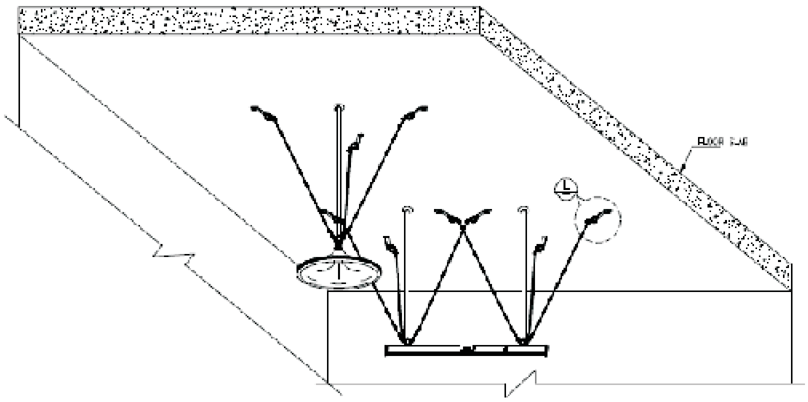
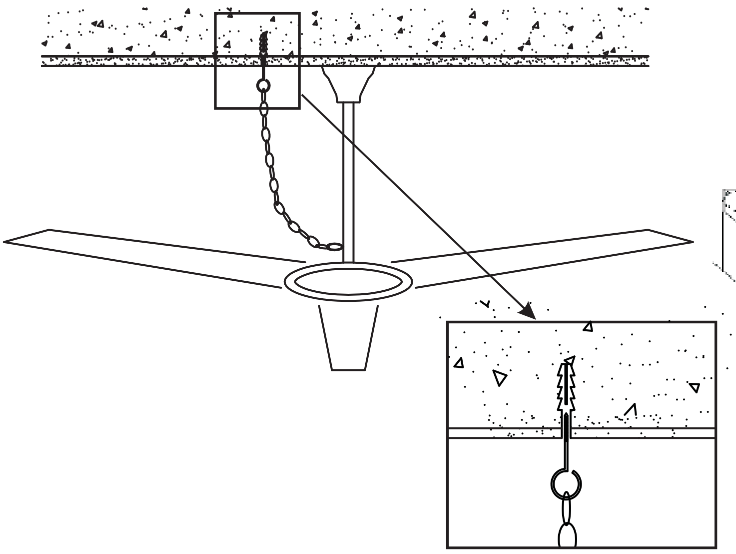


Image credit: Ahuja Consultants Pvt. Ltd.

You can limit the swing of a light fixture or fan on rods by providing wires that attach the light or fan body to the ceiling. This should prevent the connection at the ceiling from failing. Alternatively, you can replace the rod with a chain, wire rope, or cable and allow the light to swing. Swinging will not harm the light, if the fluorescent tubes have restraint devices like the wires around the fixture shown above right, to keep them from falling out. Screw-in globe bulbs do not need additional restraints.



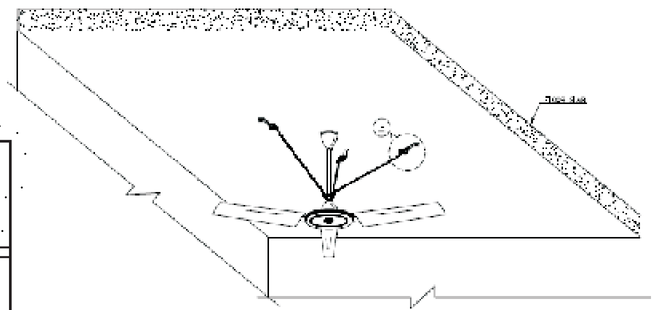


Image credit: Ahuja Consultants Pvt. Ltd.

Expertise Required

Maintenance/tradesman support required. An electrician from the maintenance department will need to assist in replacing rods with chains, wire ropes, or cables.

Recommended Priority

Continuous Service. The hospital needs lights to continue functioning after an earthquake. Fix the pendant lights in the most critical areas first.

Retrofit Cost and Disruption

Low cost for parts, low cost for labor, moderate level of disruption. Work on light fixtures should be phased and scheduled to minimize disruption. However, there are typically a large number of pendant light fixtures in a hospital, so addressing them will cause some level of disruption.

Where to Find More Information

Please see Appendix B, page 167 for additional information on anchoring devices.

Windows and Glass

Includes windows, glass doors, and glass partitions; located on exterior and interior.

Potential Earthquake Damage

Strong shaking can cause glass that is not annealed or tempered to break into sharp shards that fall out of the frame.

Photo credit: Janise Rodgers, GeoHazards International

Photo credit: EERI 2003 Bam, Iran Earthquake Reconnaissance Report

Photo credit: FEMA 74

Shattered glass door in a hospital, 2003 Bam, Iran earthquake (left); shard of untempered glass that fell from a broken window, 1994 Northridge, California earthquake (right).

There are several types of glass used in windows, doors and other glazing. Plain glass shatters into sharp shards that can fall from the frame. Annealed, tempered, and safety glass do not, and are much safer.

Consequences

Glass falling from upper story windows is very hazardous for anyone outside the building below. In addition to the falling hazards, broken glass on the ground or floor can cause major cuts to the feet of people who are not wearing sturdy shoes. Glass on the ground at exit doors can slow or stop people who are trying to exit.

Check These Related Items

There are no related items to check.

Methods of Anchoring

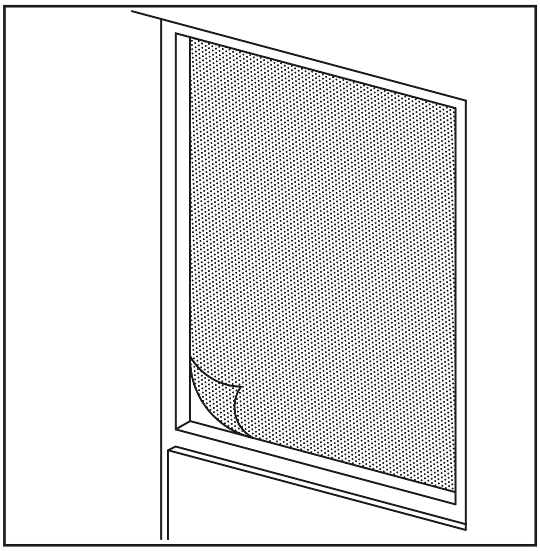


Photo credit: FEMA 74

GHI recommends replacing or placing film over large panes of glass that are directly above or at exits. It is very expensive to replace all plain glass with tempered, annealed, or safety glass, or even to apply film to all glass, and these options are not recommended. For large panes of glass on the exterior of the building, you can provide landscaping that discourages pedestrians from loitering or congregating where glass shards could fall. Ensure that such landscaped areas are uninviting to pedestrians by planting dense shrubs, bushes, or tall plants such as those shown at above right.

Photo credit: NiSEE (Karl Steinbrugge)

When installing new glass, be sure that it is tempered glass, annealed glass, or safety glass. These types of glass are also much safer, if glass is accidentally broken or vandalized.

Expertise Required

Do it yourself. You can arrange for the maintenance staff to apply film to glass, or make sure to order the right type of glass for new installations.

Recommended Priority

Continuous Service. The hospital needs for exits to be free and clear of glass shards, so that people can exit the building safely after an earthquake, if needed.

Retrofit Cost and Disruption

Moderate cost for parts, low cost for labor, minimal level of disruption. Film is moderately expensive. Replacement glass costs more; the cost depends on the size of the glass panel and the difficulty of installation. Film can be installed quickly and scheduled during less-busy times, to minimize disruption to entrances and exits.

Where to Find More Information

Please see Appendix B, page 167 for more information on protecting glass.

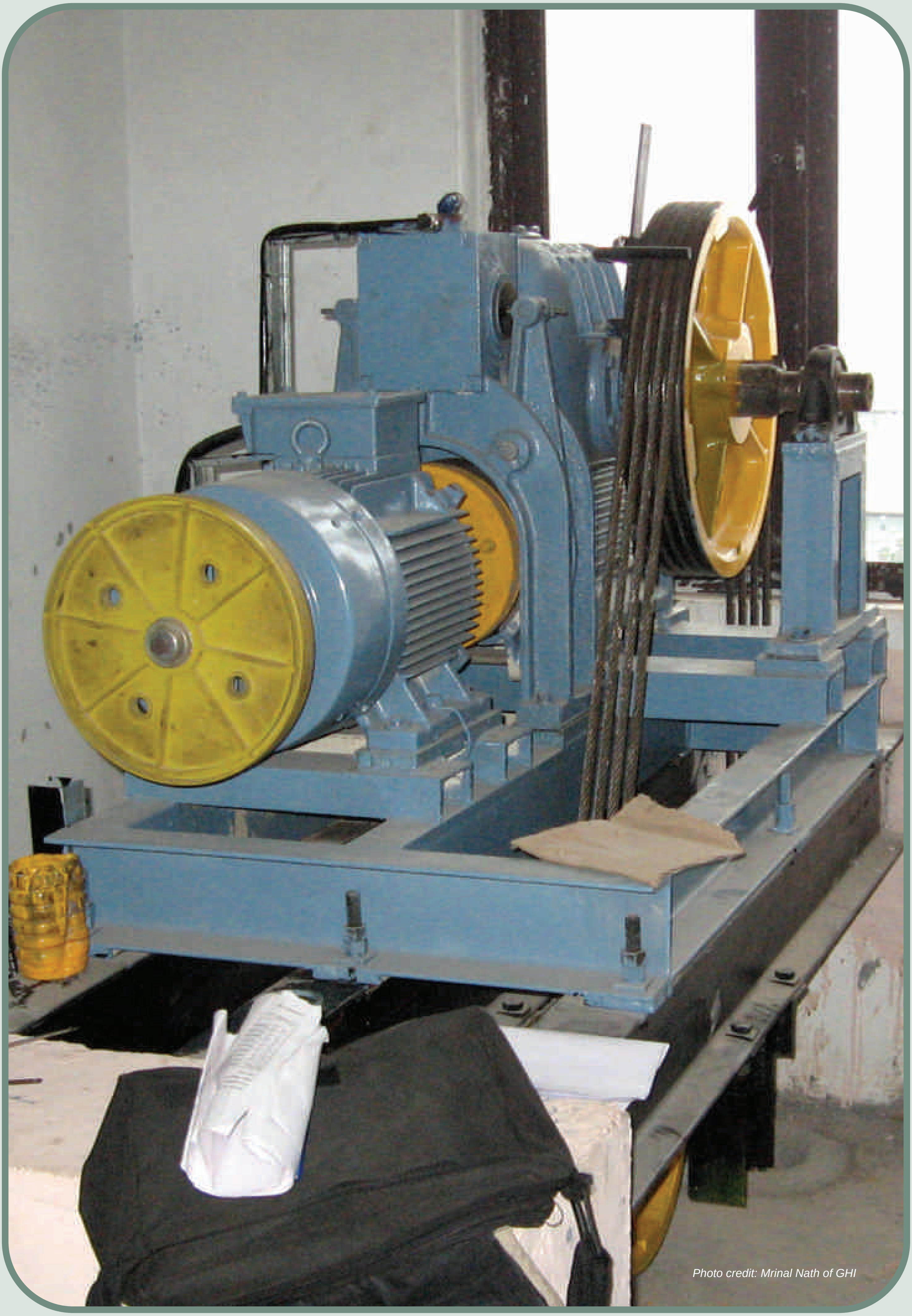


Photo credit: Mrinal Nath of GHI

Lifts

Lifts are one of the most complex equipment systems found in a hospital. They are also highly vulnerable to earthquake damage. The design of earthquake protection measures for existing lift systems should be handled by a specialist with specific structural engineering experience in the seismic strengthening of lift systems.

This section contains general information on how to seismically protect the following portions of lift systems:

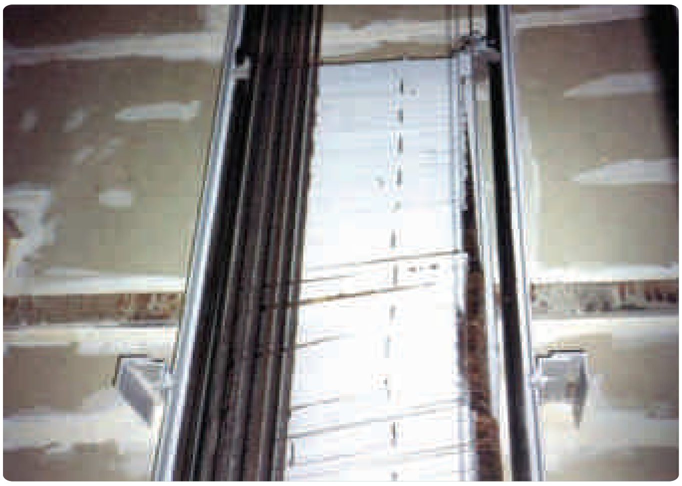
Information on how to anchor lift electrical and control panels can be found in the Electrical and Mechanical equipment section under Electrical Cabinets, on page . Lift electrical and control panels are similar to other types of electrical cabinets and switchgear; an ordinary engineer can anchor them properly. You do not need a specialist.

Lift Rail Systems

Guide lift cars and counterweights; located in lift shafts.

Potential Earthquake Damage

Strong shaking can cause lift and counterweight guide rails to deflect excessively and can cause counterweights to derail.



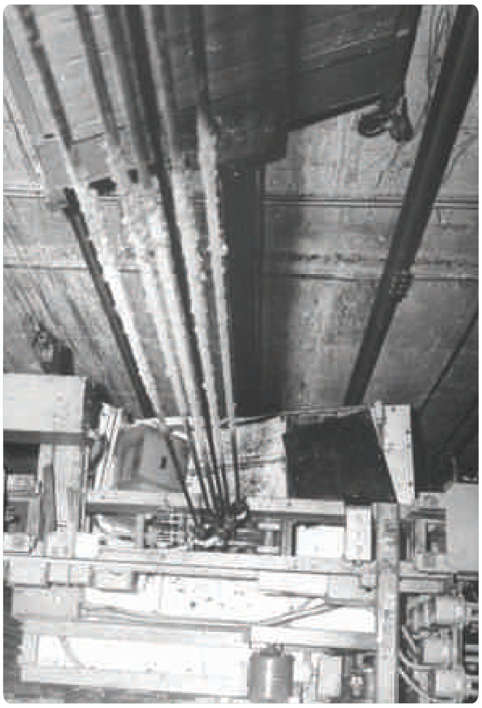


Photo credit: California OSHPD

Photo credit: NiSEE (Ayres and Sun)

Derailed counterweights in new Olive View Hospital, 1994 Northridge earthquake (left). The counterweights in this lift derailed in the 1971 San Fernando earthquake (right) and impacted the top of the car (Ayres and Sun, 1973). (right).

Lift and counterweight guide rails are often not properly designed to withstand seismic forces. Lift guide rails are typically designed for some lateral forces, due to the forces applied when the lift is in operation. They are constructed from larger sections and are less prone to damage than counterweight rails, which are often designed for no horizontal forces at all.

Consequences

Counterweights can derail due to excessive deflection of the rails. If the lift is restarted without anyone first checking for damage, then the counterweights can collide with the lift car, inflicting further damage and possibly injuring anyone in the car. In the case of derailed counterweights, the lift will not operate properly. Damage to the lift system can be expensive to repair.

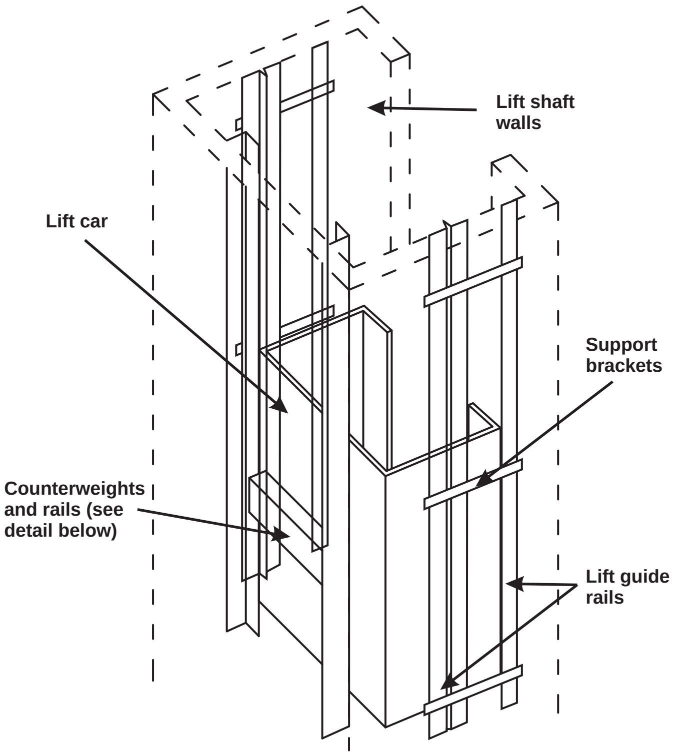
Check These Related Items

Lift motors and generators (see pg.163): The lift will not work, if its motor and generator are not also operational.

Lift electrical and control panels (see pg.115): The lift will not function, if the control panel is not working.

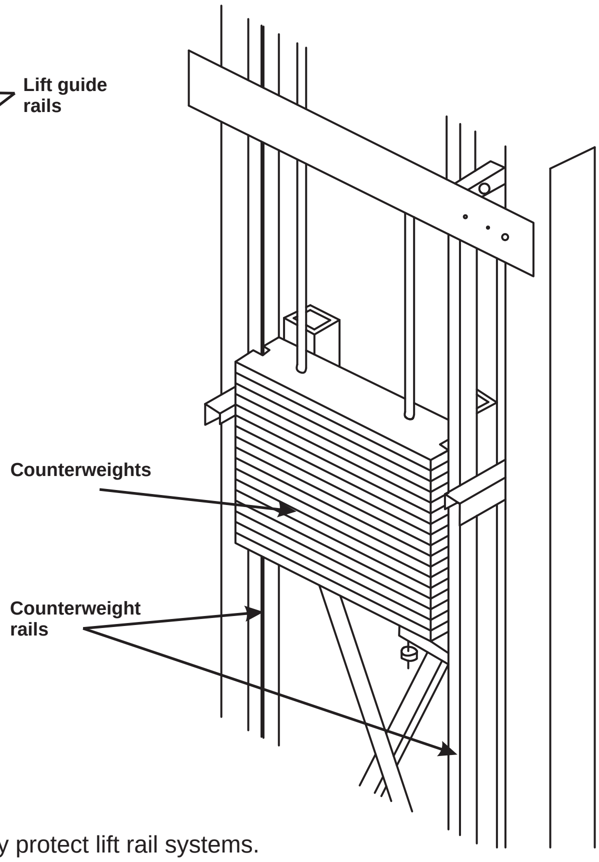
Electrical distribution system (see pg.131): Wiring and conduits to the lift motor and controls must remain intact, so that emergency power can reach them.

Methods of Anchoring



Lift rail systems are typically retrofitted (strengthened to better resist earthquake forces) by adding new support brackets to the rails and by strengthening existing support brackets to resist earthquake forces, as well as by providing safety brackets (also called guide rail retainer plates) to keep the lift car from derailing. The walls in the lift shaft must be examined to determine if they can withstand the earthquake forces imposed by the lift cars and the counterweights, once anchored; if not, then the walls will need to be strengthened. A structural engineering specialist should design the retrofit measures for the lift system. This specialist will need to evaluate the strength of the lift enclosure and to properly design strengthening measures for both the shaft and lift rail system, if necessary.

If you install a new lift or replace an old one, then you should specify that the entire system be seismically designed for the level of shaking expected in your area. New systems can be equipped with sensors to detect derailment or to shut down the system in the event of an earthquake. If your new lift system has an automated seismic shutoff feature, then be sure to have a procedure in place to restart the lift quickly, so that normal operations can continue post-earthquake.



Expertise Required

Specialized engineering expertise required to seismically protect lift rail systems.

Recommended Priority

Continuous Service. The lift system is necessary for transferring patients, unless the hospital has ramps that service all levels.

Retrofit Cost and Disruption

Moderate to high cost for parts, moderate to high cost for labor, high level of disruption. Lift systems can be among the most costly and disruptive systems to retrofit. If the lift shaft requires retrofit, then the lift and surrounding areas will be out of service for some time. If only the lift rails need retrofit, the lift will still be out of service for a limited time.

Where to Find More Information

Please see the Applied Technology Council's report ATC-51-2, Recommended US-Italy collaborative guidelines for bracing and anchoring nonstructural components in Italian hospitals, pages 83-94, for a design example of a lift system retrofit.

Lift Motors and Generators

Operate lifts; typically located in mechanical penthouse above lift shaft.

Potential Earthquake Damage

Photo credit: L. Thomas Tobin, GeoHazards International

Strong shaking can cause lift motors and generators to slide off of their supports.

Photo credits: California OSHPD

Broken electrical connections resulted from large displacement of an improperly anchored lift generator (left); view of one of four generators moved from anchorage, 1994 Northridge, California earthquake (right).

Lift motors and generators that are not well-anchored can slide off their supports and prevent the lift from operating. The lift motor and generator are often installed on vibration isolators to keep vibrations from normal operation from shaking the building. Vibration-isolated equipment is particularly vulnerable to damage, unless the isolators are seismically rated. Most are not.

Consequences

If the lift motor slides off its supports, then the lift cannot function. If the lifts are not working, then the hospital staff will have difficulty moving patients or evacuating them if needed, unless the building has ramps that service each floor.

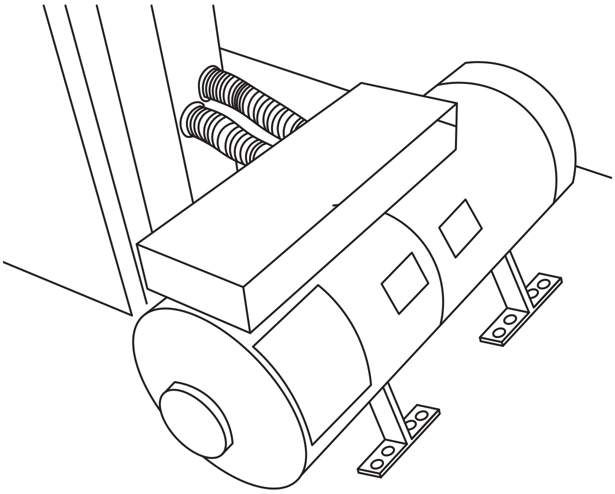
Check These Related Items

Lift rail systems (see pg.161): The lift will not operate properly, if the counterweights have derailed or if the rails have suffered other damage.

Lift electrical and control panels (see pg.115): The lift will not function, if the control panel is not working.

Electrical distribution system (see pg.131): Wiring and conduits to the lift motor and controls must remain intact, so that emergency power can reach them.

Methods of Anchoring



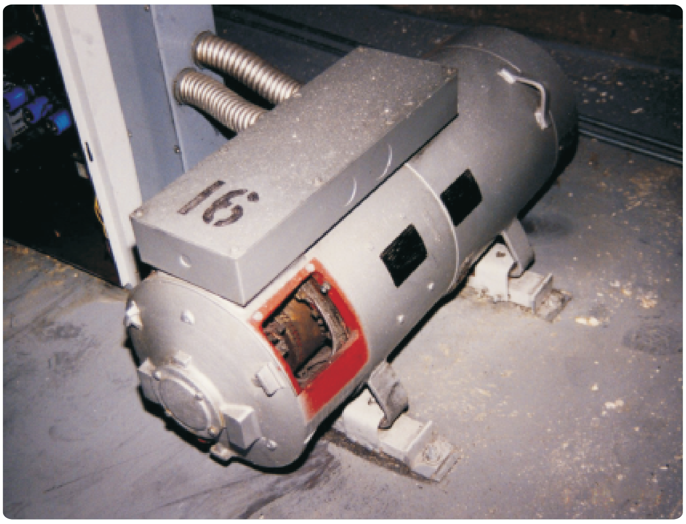
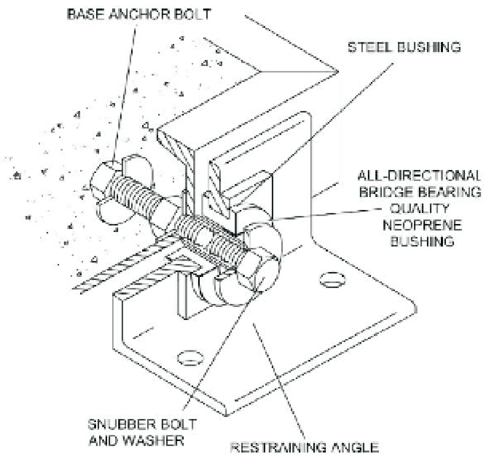


Photo credit: California OSHPD

Anchor fixed-base lift motors and generators by bolting them securely to the floor or the supporting steel base. The properly anchored lift motor above was undamaged in the 1994 Northridge earthquake. An engineer will need to calculate the number of bolts needed (use no fewer than four, with one located at each corner), based on the weight of the equipment and the expected earthquake shaking for your area. Anchor vibration-isolated lift motors and generators by installing special seismic restraints called snubbers (below left), or replace the isolators with new, seismically restrained spring mounts (below right).



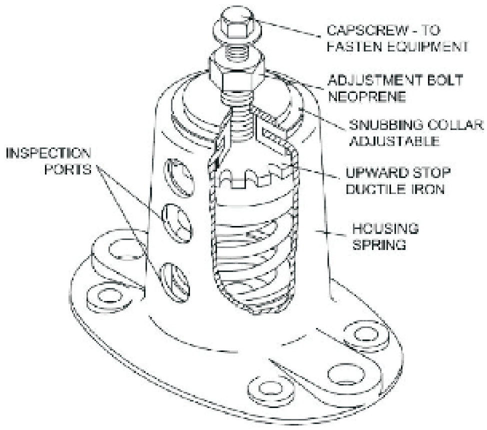


Image credits: Mason Industries

Expertise Required

Some engineering required to select the correct size and type of anchorage. Lifts must be inspected after an earthquake before usage.

Recommended Priority

Continuous Service. The hospital needs the lifts to perform normal functions, such as transporting patients to and from surgery. Lifts are also very helpful if the hospital must be evacuated.

Retrofit Cost and Disruption

Moderate cost for parts, moderate cost for labor, high level of disruption. Work on lift systems can be very disruptive to hospital operations. If the hospital has multiple lifts, then you can minimize disruption by working on one lift at a time. If the hospital has ramps, then you can use these to move patients, while the lift is out of service.

Where to Find More Information

Please see Appendix C, page 173 for additional technical information.

Hazard Hunt Checklist For Hospital Safety
For Hospital Safety

Section/ Block:	Date of Hazard Hunt:
Room Number/Use:	**Hazard Hunt Conducted By:**

Potential Hazards	Check if item is present	Total no. of units	Does item need to be		Engineer-ing required?	Supplies and tools needed
			Moved	Anchored		
Medical Equipment						
Autoclaves	☐		☐	☐	☑	
Anesthesia machines	☐		☐	☐		
Monitors	☐		☐	☐		
Operation theatre lights	☐		☐	☐	☑	
Ventilators	☐		☐	☐		
Imaging and scanning units	☐		☐	☐	☑	
Radiant warmers	☐		☐	☐		
Wheeled or trolley-mounted equipment	☐		☐	☐		
Small wall-mounted equipment	☐		☐	☐		
Laboratory bench-mounted equipment	☐		☐	☐		
Blood bank refrigerators	☐		☐	☐		
Other:	☐		☐	☐	☑	
Furnishings and Hospital Administrative Systems						
Cupboards	☐		☐	☐		
File cabinets	☐		☐	☐		
Medical records storage	☐		☐	☐	☑	
Computers	☐		☐	☐		
Other:	☐		☐	☐	☑	
Supplies	☐		☐	☐		
On trolleys	☐		☐	☐		
On racks	☐		☐	☐		
Pharmacy	☐		☐	☐		
Sterile storage	☐		☐	☐		
Other:	☐		☐	☐	☑	

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety

Potential Hazards	Check if item is present	Total no. of units	Does item need to be Moved	Anchored	Engineer-ing required?	Supplies and tools needed
Mechanical and Electrical Equipment						
Emergency generators	☐		☐	☐	☑	
Batteries for emergency power	☐		☐	☐	☑	
Boilers	☐		☐	☐	☑	
Geysers	☐		☐	☐	☑	
Chillers	☐		☐	☐	☑	
Cooling towers	☐		☐	☐	☑	
Air handling units	☐		☐	☐	☑	
Window unit air conditioners	☐		☐	☐	☑	
Window unit air coolers	☐		☐	☐	☑	
Electrical cabinets and switchgear	☐		☐	☐	☑	
Transformers	☐		☐	☐	☑	
Fire suppression pumps	☐		☐	☐	☑	
Fire extinguishers	☐		☐	☐		
Other:	☐		☐	☐	☑	
Pipes, Ducts and Conduits						
Small rigidly-attached pipes	☐		☐	☐	☑	
Small suspended pipes	☐		☐	☐	☑	
Large pipes	☐		☐	☐	☑	
Conduits and electrical distribution	☐		☐	☐	☑	
Ductwork	☐		☐	☐	☑	
Tanks and Medical Gases						
Compressed-gas cylinders	☐		☐	☐		
Bulk medical gas tanks	☐		☐	☐	☑	
Rooftop water tanks	☐		☐	☐	☑	
Horizontally oriented cylindrical tanks	☐		☐	☐	☑	
Vertically oriented cylindrical tanks	☐		☐	☐	☑	
Other tanks:	☐		☐	☐	☑	
Architectural Elements						
Parapets	☐		☐	☐	☑	
Sunshades	☐		☐	☐	☑	
Masonry partition walls	☐		☐	☐	☑	
Suspended (false) ceilings	☐		☐	☐	☑	
Pendant light fixtures and ceiling fans	☐		☐	☐		
Windows and glass	☐		☐	☐		
Jalies larger that 1mX1m	☐		☐	☐	☑	
Entrance canopy	☐		☐	☐	☑	
Other:	☐		☐	☐	☐	
Lifts						
Lift rail systems	☐		☐	☐	☑	
Lift motors and generators	☐		☐	☐	☑	
Lift control panel/cabinet	☐		☐	☐	☑	

Notes:

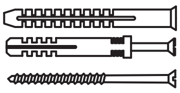
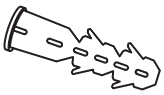
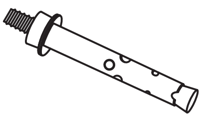
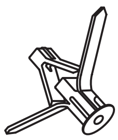
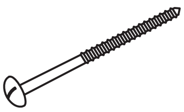
Appendix B

Do It Yourself Resources

The information in this appendix will help you anchor and brace the items labeled “Do It Yourself” in the main body of the manual. You can also use this information to instruct a handyman to properly anchor and brace “Do It Yourself” items. This appendix contains information on anchoring and bracing hardware, parts, and supplies, as well as guidance on how to properly install fasteners.

Common Fasteners

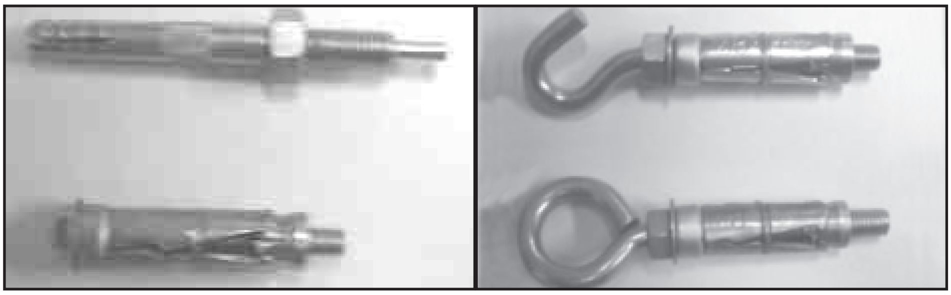
The table below provides guidance on which fasteners to use, depending on the type of wall to which you are anchoring and the weight of the object to be anchored.

How heavy is your object?	What is the wall or other structural element made of? Select appropriate anchors.				
	Brick masonry		Concrete	Gypsum board	Timber
	 Plastic Masonry Wall Plugs	 Standard Wall Plugs	 Expansion bolts	 Winged Gypsum Wall Plugs	 Wood Screws
0-5 kg	For light objects use size 6 Standard Wall Plugs			Size 2 or 3	4 mm x 60 mm
5-50 kg	Size 6	Size 7	Size 6	For items this heavy, attach directly to studs or use a wall bridge.	4 mm x 60 mm
50-100 kg	Size 8	Size 8	Size 8		6 mm x 80 mm
100 + kg	Consult an engineer for proper anchorage.				
Notes:			Leave a 16 cm space between expansion bolts	Use Size 2 for 10 mm board; Size 3 for 12 mm board	

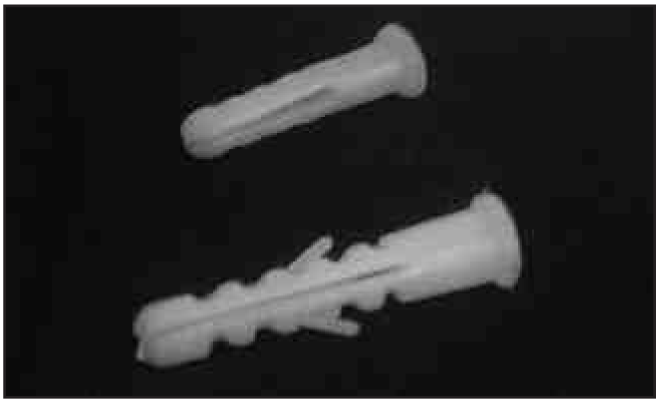
Photographs of Common Fasteners

L-brackets

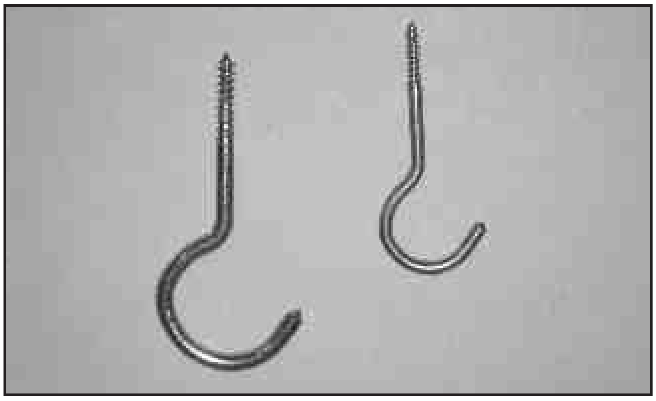
Expansion anchors (bolts)



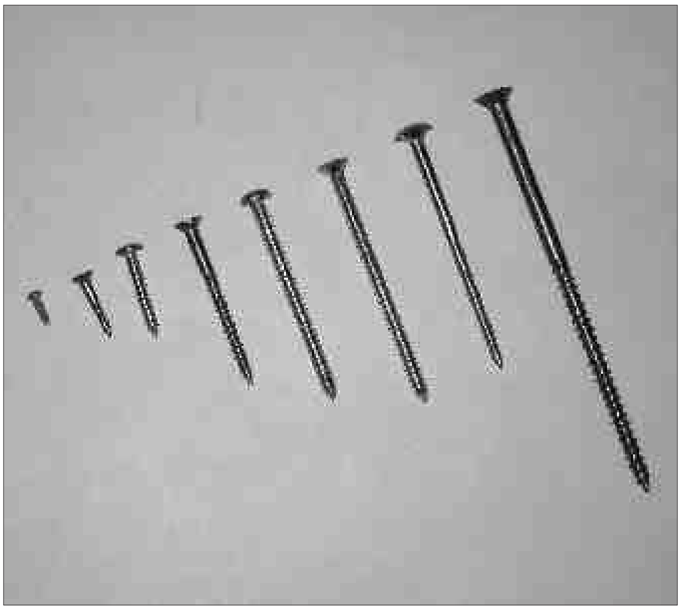
Plastic dowels



J-hooks

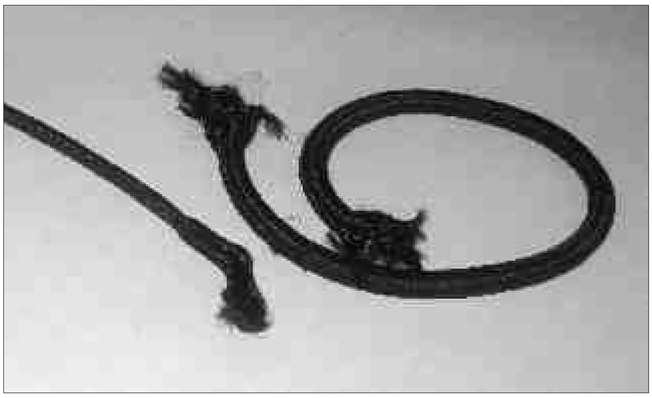


Screws

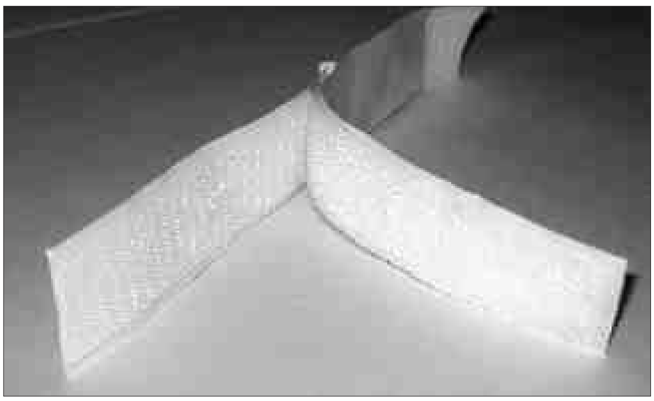


Chain and carabiner link

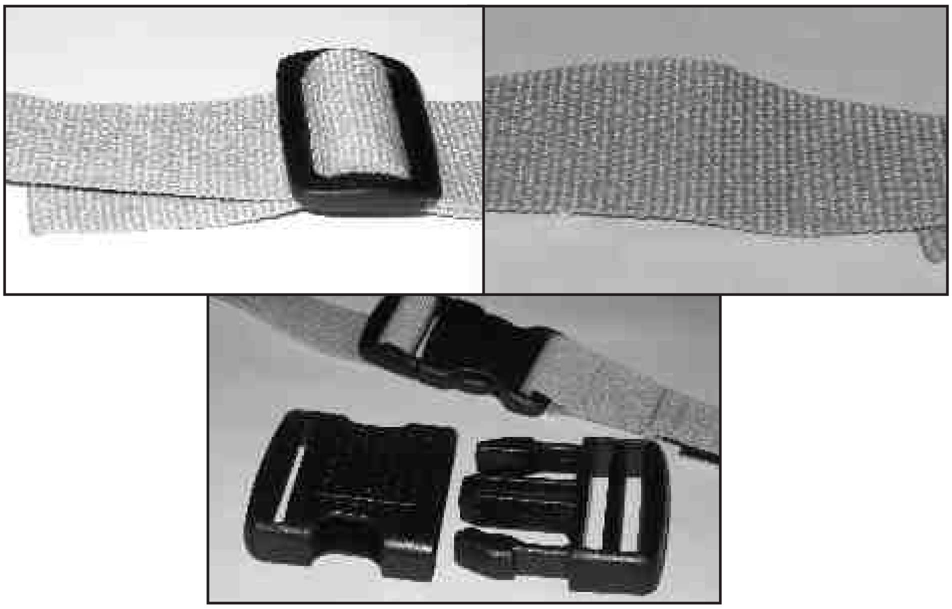
Elastic cord



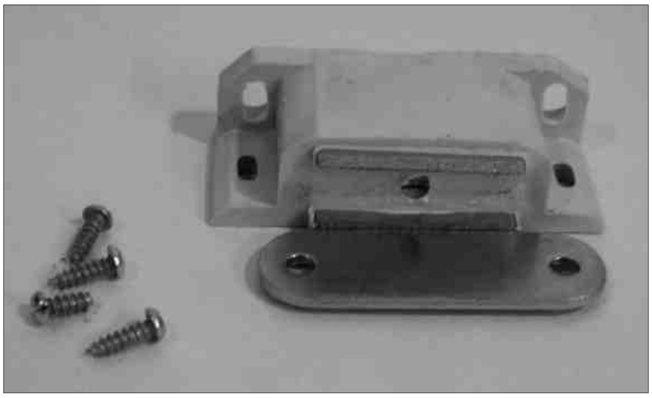
Loop tape



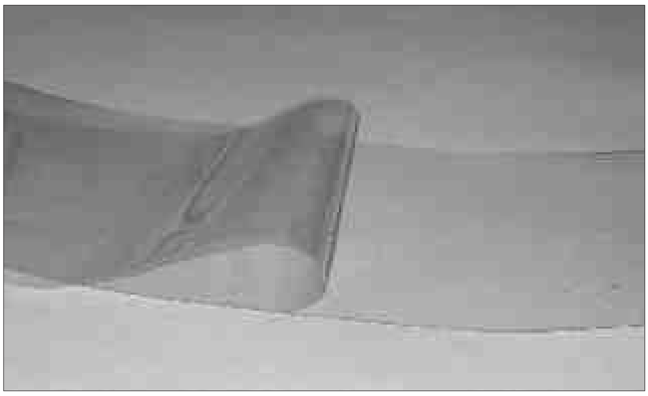
Clips and woven straps



Magnetic latch



Polyester film



Non-slip mat (EVA sheet)

How to Properly Install Fasteners

If you are installing fasteners into concrete or brick walls, then you will need to follow these steps:

1. Drill a hole of the correct size and depth for the fastener that you are using. Drill the hole straight, using a smooth motion. Drill a few practice holes in a scrap piece of concrete or brick before trying to drill a hole in a wall. When drilling in reinforced concrete, avoid drilling into rebar.

2. Clean the hole following the manufacturer's instructions for the type of anchor that you are using. The most common methods of cleaning the hole are using compressed air or a wire brush. You can use a shop vacuum or industrial vacuum to clean most of the dust out of the hole first to avoid getting dust everywhere.

3. Line up the hole on the L-bracket or equipment. For some anchors that use a nut to attach the bracket or equipment, this should be done after you insert the anchor. Read the manufacturer's instructions for details.

4. Insert the anchor following the manufacturer's instructions. Most anchors other than adhesive (i.e., epoxy) anchors need to be tapped in carefully using a hammer.

5. Align the bracket or equipment, set the anchor and tighten. The method for setting the anchor will vary with the type of anchor. Follow the manufacturer's instructions very precisely.

It is best not to drill into reinforced concrete floors or beams yourself. Have maintenance/engineering personnel or specialty contractors use a special piece of equipment called a rebar locator to find the rebar in the area where you want to drill; in this way, they will make sure that they don't hit the reinforcing steel. If the floor is pre-stressed or post-tensioned concrete, then DO NOT let anyone drill into it without first consulting an engineer and specialty contractor to locate the post-tensioning strands. Otherwise, you could jeopardize the structural safety of the building.

FEMA 412, Installing Seismic Restraints for Mechanical Equipment, contains a section (starting on p. 96) that explains the proper installation of various types of anchors in concrete, brick, and concrete block in more detail. Manufacturers of anchors also provide detailed instructions on how to install their products properly.

How to Determine if a Wall is Strong Enough to Use for Anchoring

In buildings with masonry walls, anchor objects that are less than 100 kg to walls that are at least two bricks thick (225 mm or more). For heavier objects, you will need to consult an engineer to determine whether the wall is strong enough to anchor to or not. Anchor only very lightweight objects (10 kg or less) to partition walls that are only one brick thick (110 mm). Ensure that you insert masonry anchors into the bricks themselves, rather than into the mortar joints.

Before you anchor an object, check the condition of the wall to which you plan to anchor. Brick walls should be in good condition, with sound brick and mortar. If the mortar is exposed and you can scrape it away with your fingernail or a coin, then it is not sound. If the wall is not sound or is not thick enough, then anchor the object to the floor instead, or consult an engineer to reinforce the wall.

For walls with timbers (such as dhajji-dewari construction), anchor items to vertical timbers spanning from floor to ceiling (where possible) using wood screws. Before anchoring, check to ensure that the timbers are in good condition and have not deteriorated, due to rotting or insect attack.

In general, anchoring to random rubble stone masonry walls is not recommended. Anchoring to dressed stone walls is possible, but it may be difficult to drill holes into the stone. If the stones are thicker than about 250 mm, then you may be able to anchor to a wall with a single wythe of stones. It is always better to anchor to double wythe stone walls, though. Check double-wythe walls to see if there are cross-stones that connect the two wythes together. Otherwise, you will be anchoring to what is essentially a single wythe wall, because the two wythes act independently, if they are not connected. Also, consult an anchor manufacturer to ensure that you select the proper anchor for the type of stone in your wall.

How to Properly Install Restraints for Computers

Follow the manufacturer's advice for installing self-adhesive clips used to anchor computers. Ensure that surfaces are very, very clean before using the self-adhesive on the clips. Rubbing alcohol is the most appropriate cleaner. Leave some length of straps outside the clips, so that the restraint can be re-fastened after cleaning.

You can re-install a clip after moving the computer by replacing the self-adhesive on the clip with double sided self-adhesive tape (found in some hardware supply shops). The original self-adhesive may also wear out, and you can repair the restraint using the same self-adhesive tape. Instruct hospital staff to check clips for wear as part of a yearly maintenance program and to replace the self-adhesive or the entire clip when it starts to peel off and whenever the electronic equipment is moved to a new location.

Appendix C

Further Information and Technical Resources for Engineers

This appendix contains additional information on anchoring mechanical equipment, electrical equipment, major medical equipment, pipes, conduits, ducts, and concrete pads.

Codes and Standards

The Indian Standard for earthquake-resistant design, IS 1893, does not currently have provisions for anchoring and bracing equipment and other nonstructural items, except for cast-in-place rooftop tanks. Some draft provisions have been proposed, but none have yet been adopted. These draft provisions can be found in a paper by Mondal and Jain in the October 2005 issue of the Indian Concrete Journal entitled, “Proposed draft for IS 1893 on design of non-structural elements.” The paper can be obtained from the National Information Centre of Earthquake Engineering at Indian Institute of Technology, Kanpur. The design examples in Appendix D are based on the draft provisions outlined in this paper.
For more general information on earthquake-resistant design of buildings and other structures, the National Information Centre of Earthquake Engineering (NICEE) at Indian Institute of Technology, Kanpur has produced commentaries on current Bureau of Indian Standards (BIS) codes. These commentaries, produced in partnership with the Gujarat State Disaster Management Authority (GSDMA), explain the code provisions. NICEE also produced Earthquake Tips that explain basic principles of earthquake resistant design. Both the commentaries and Earthquake Tips can be downloaded from the NICEE website at www.nicee.org.

Additional Information on Installing Anchors and Concrete Pads for Equipment

FEMA 412, Installing Seismic Restraints for Mechanical Equipment, contains a section (starting on p. 96) that explains the proper installation of various types of anchors used for mechanical equipment. FEMA 412 also has a special section on how to reinforce, construct, and install concrete pads (also called housekeeping pads) for equipment, beginning on p. 135. This section is for new installations only; to strengthen an existing pad, you can install a reinforced concrete beam around the perimeter, which is doweled into the underlying slab. FEMA 413, Installing Seismic Restraints for Electrical Equipment, contains a section (starting on p. 104) on how to install the types of anchors used for electrical equipment and conduits. FEMA 414, Installing Seismic Restraints for Duct and Pipe, also contains a section (starting on p. 107) on the proper installation of anchors used to brace pipes, ductwork, and in-line equipment. All three documents can be downloaded for free from www.fema.gov.

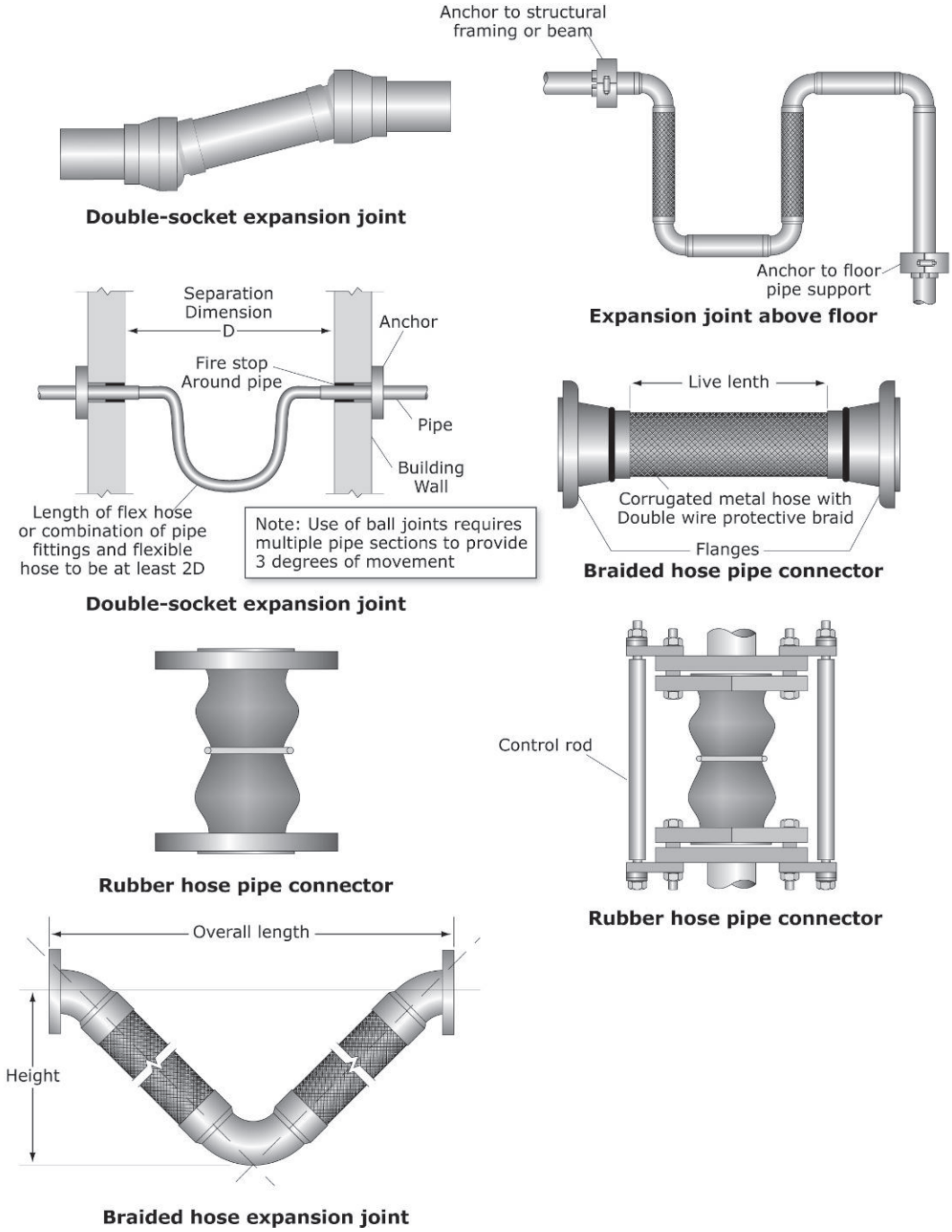
Additional Information on Anchoring Vibration-Isolated Equipment

FEMA 412, Installing Seismic Restraints for Mechanical Equipment, contains a section with more information on anchoring vibration-isolated equipment, beginning on p. 77.

Additional Information on Flexible Connectors

There are a number of types of flexible connectors, shown below, that you can use to connect pipes across expansion joints or building separations, or to connect pipes to equipment. If these connectors are not available in your area, then you can substitute equivalent flexible connectors.

Be sure to provide a connector that will accommodate the amount of differential movement that you expect. For pipes that cross separations between buildings, you will need to calculate how much the buildings will move with respect to each other. The maximum differential displacement will be the sum of the displacements of each building at the level of the pipe. Flexible connections for pipes attached to the ceiling and to equipment near the floor should be designed for the amount of relative deformation between the ceiling and the floor. Calculate this deformation by subtracting the building displacement at the ceiling level from the building displacement at the floor level.

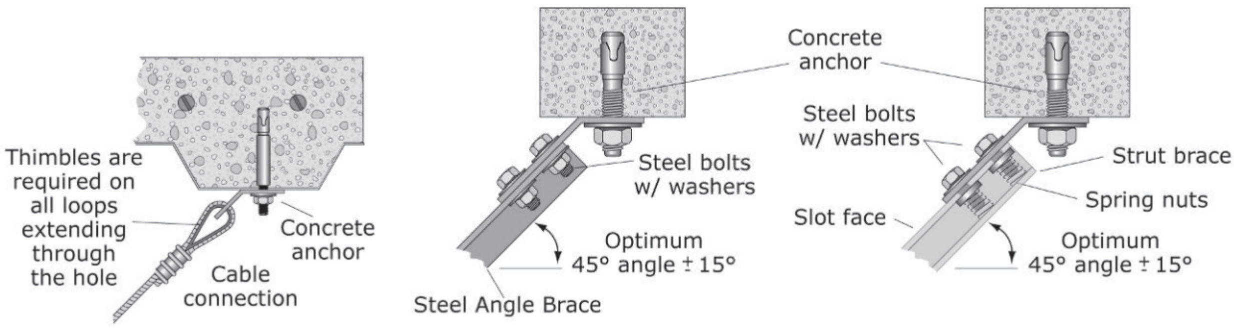


Types of flexible connectors

Image credit: FEMA 74

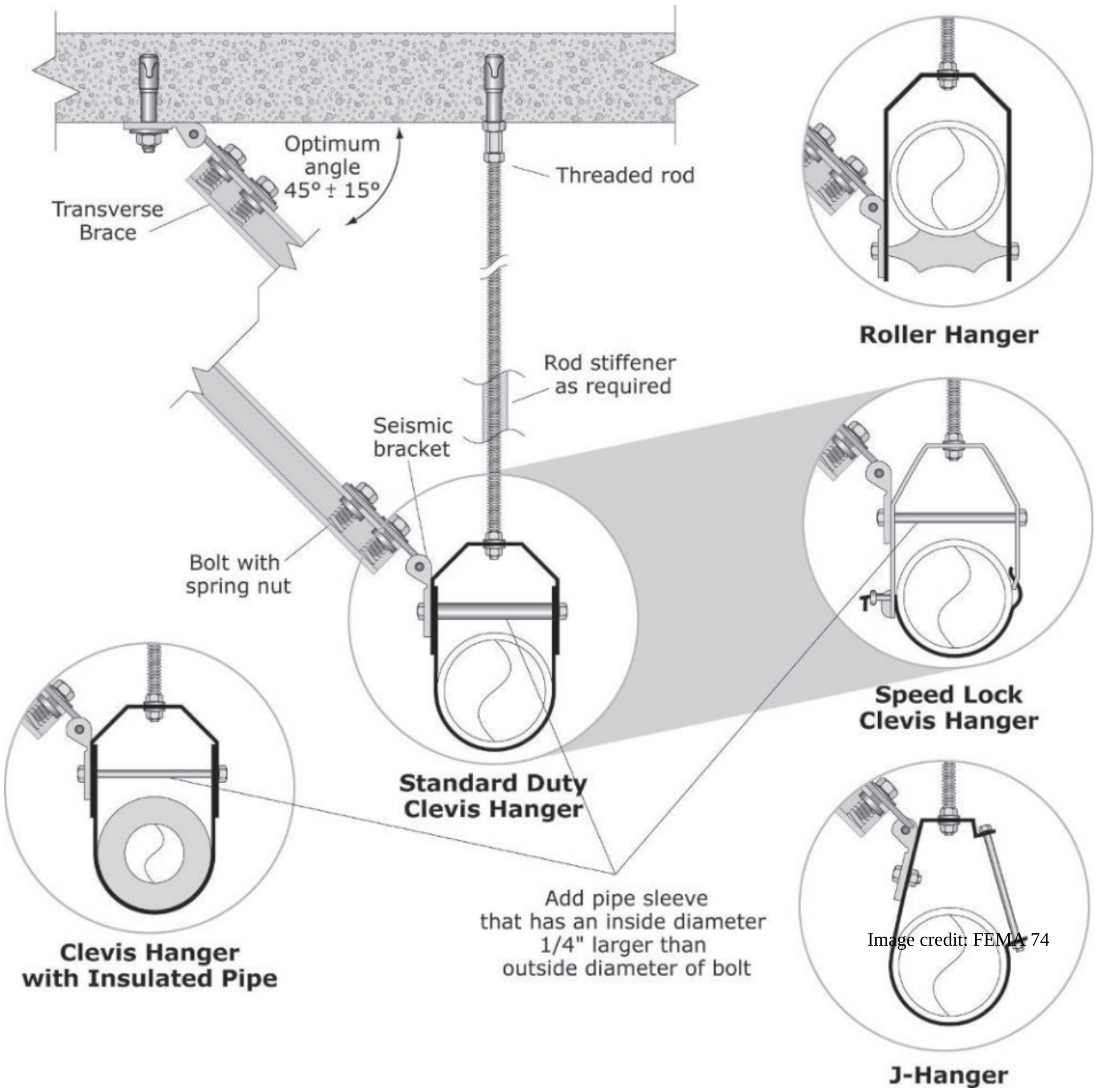
Additional Information on Bracing Suspended Pipes, Ducts and Conduits

The following drawings from FEMA 74 show conceptual designs for bracing suspended pipes and conduits. You can also use other designs that brace the pipes to prevent them from swaying and breaking, such as small moment frames constructed from steel angles. For more information on bracing pipes and ducts, see FEMA 414, Installing Seismic Restraints for Duct and Pipe, which contains a large amount of additional information on bracing both suspended and rigidly mounted pipes, as well as ductwork. The document covers seismic restraints for valves and other plumbing components that may be installed in-line with pipes, and suspended equipment that may be installed in-line with ducts. For more information on bracing electrical and communications conduits, raceways, and cable trays, see FEMA 413, Installing Seismic Restraints for Electrical Equipment, which contains a large amount of additional information on bracing conduits as well as all manner of electrical equipment. FEMA 413 and 414 are freely downloadable from www.fema.gov



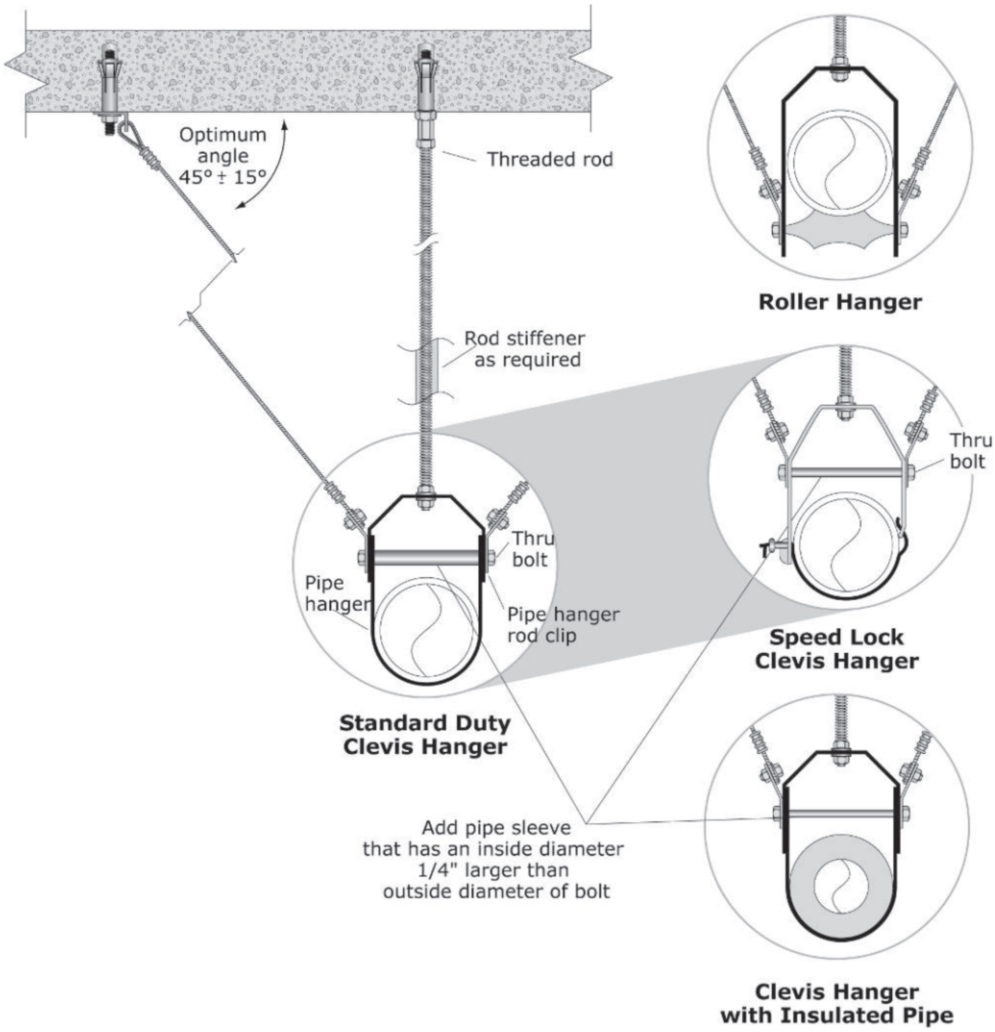
Anchorage for cable and rigid bracing

Image credit: FEMA 74



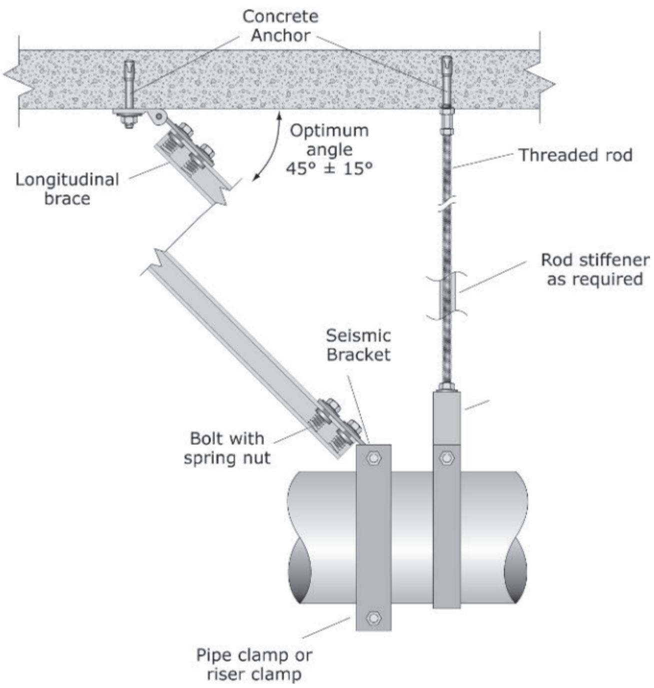
Types of suspended pipe hangers for bracing a single pipe in the transverse direction with rigid bracing

Image credit: FEMA 74



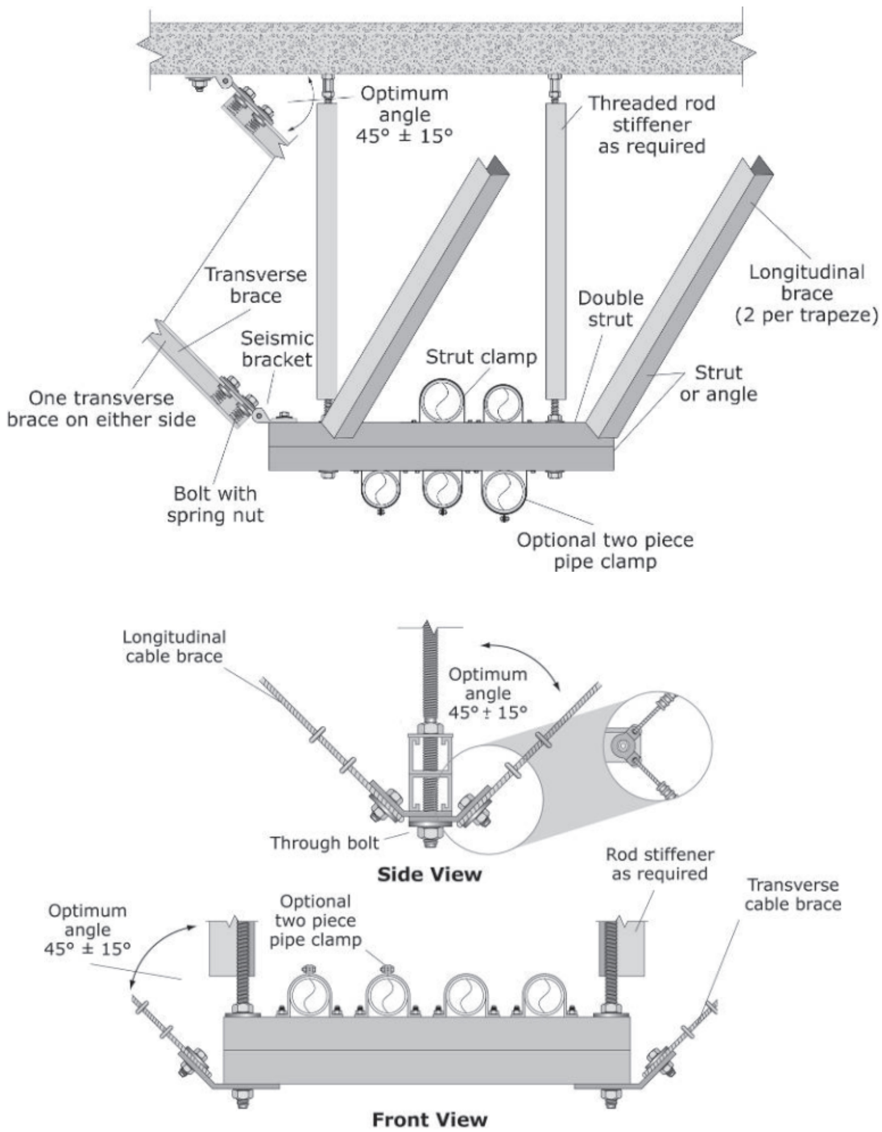
Types of suspended pipe hangers for bracing a single pipe in the transverse direction with cable bracing

Image credit: FEMA 74



Rigid bracing for a single pipe in the longitudinal direction

Image credit: FEMA 74



Rigid and cable bracing options for trapeze-supported pipes and conduits

Image credit: FEMA 74

California Office of Statewide Health Planning and Development (OSHPD) Pre-Approval Index

The U.S. State of California requires that certain types of equipment and building utility systems be anchored or braced against earthquake forces. All newly installed equipment must meet these requirements, and eventually, existing equipment must as well. The Office of Statewide Health Planning and Development (OSHPD) maintains an index of anchoring and bracing details that its engineers have certified meet these requirements. The details are proprietary, meaning that you will have to get permission to use them, and you may have to pay to use them. However, they can be a useful resource for certain specific types of equipment. The list of pre-approvals can be downloaded from the following website: http://www.oshpd.ca.gov/FDD/Pre-Approval/OPAIndex.pdf. New pre-approvals are continually being added. This list includes major medical equipment, such as CT scanners and other imaging equipment. The index lists the name, product number, and manufacturer of the equipment being anchored, as well as the company that designed the pre-approved detail. Manufacturers sometimes provide pre-approved details for the equipment that they sell, as part of their marketing efforts. Any company that sells major equipment to California hospitals (i.e., most major medical equipment manufacturers) will likely have pre-approved details for anchoring their equipment. You can use the OSHPD pre-approval index to find out whether a solution already exists for a piece of equipment that you need to anchor. If your hospital is buying new equipment, then be sure to tell the manufacturer that the equipment needs to be seismically anchored when it is installed, so that they can supply you with anchorage details.

Details and Guidelines Provided by Manufacturers and Others

There are a number of companies that manufacture and sell devices to seismically restrain equipment, building utility systems, and other items. These manufacturers provide design drawings and example calculations for how to use their products. These can be very helpful references. These manufacturers include:

- Mason Industries publishes Seismic Restraint Guidelines for Suspended Piping, Ductwork and Electrical Systems and for Floor Mounted Equipment, which can be downloaded for free from www.masonindustries.com. Also available at the website are complete seismic anchorage specifications for various pieces of equipment and a report on causes of earthquake damage to mechanical equipment.
- Unistrut provides drawings and specifications for rigid bracing systems for pipes and conduits at www.unistrut.com.

Several other helpful resources exist, but you will have to order and pay for them. These include:

- Applied Technology Council report 51-2, Recommended US-Italy collaborative guidelines for bracing and anchoring nonstructural components in Italian hospitals. Contains engineering details for common items, recommendations, and design examples. Available from the Applied Technology Council, 201 Redwood Shores Parkway, Suite 240, Redwood City, California, 94065 USA; www.atcouncil.org.
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), “Seismic and Wind Restraint Design” in Applications Handbook. Available from ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329 USA; www.ashrae.org. Also available on a CD with A Practical Guide to Seismic Restraint and Seismic Restraint Manual: Guidelines for Mechanical Systems.
- A Practical Guide to Seismic Restraint. Available from ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329 USA; www.ashrae.org.
- Sheet Metal and Air Conditioning Contractors National Association, Seismic Restraint Manual: Guidelines for Mechanical Systems. Available from SMACNA, 4201 Lafayette Center Drive Chantilly, Virginia 20151-1209 USA.

Appendix D

Example Calculations for Engineers

This section contains two examples of calculations required for anchoring equipment. These calculations are based on draft provisions for IS 1983 in a paper by Mondal and Jain in the October 2005 issue of the Indian Concrete Journal entitled, "Proposed draft for IS 1893 on design of non-structural elements." The paper can be obtained from the National Information Centre of Earthquake Engineering at Indian Institute of Technology, Kanpur.

Example 1: Design for anchorage of a cooling tower

Problem Statement

A 50 kN cooling tower, shown in Fig. 1, will be installed on the roof of a one-story air conditioning plant building in seismic zone IV. It is attached by four anchor bolts, one at each corner of the cooling tower, embedded in the roof concrete slab. The height of the building is 5.0 m. Determine the shear and tension demands on the anchor bolts during earthquake shaking.

Solution

Zone factor, Z = 0.24 (for zone IV, Table 2 of IS 1893 (part 1): 2002)

Height of pont of attachment of the cooling tower above the base of the building, x = 5.0m

Height of the building, h = 5.0m

Cooling tower is not listed table3, however it can be considered as a stack.

Amplification factor of the cooling tower, a_p = 2.5 (stack, Table 3 of Mondal and Jain)

Response modification factor R_p = 2.5 (Table 3 of Mondal and Jain)

Importance factor I_p = 1.0 (not life safety component, Table 4 of Mondal and Jain)

Weight of the cooling tower, W_p = 50kN

The design seismic force, $F_p = \frac{Z}{2}(1+\frac{x}{h})\frac{a_p}{R_p} I_p W_p$

$$= \frac{0.24}{2}(1+\frac{5.0}{5.0})\frac{2.5}{2.5} \text{ X1X } 50\text{kN}$$

$$= 12\text{kN}$$

The minimum design seismic force, $F_{p.\ min} = 0.1W_p = 5.0$kN

Hence, the design seismic force, for the cooling tower

F_p = 12kN

The anchorage of equipment to the building must be designed for twice this force (Clause 1.3.4).

Shear per anchor bolt:

$$V = \frac{2F_p}{4}$$

$$= 2 \text{ X } \frac{12}{4} \text{ kN}$$

$$= 6.0\text{kN}$$

The overturning moment is1m

M_{ot} = 2.0 X 5.0kN X 1m

= 24kN.m

The resisting moment using 0.9D load combination from the weight of the unit is

0.9M_r = 0.9 X 50kN X 1.5m

= 67.5kN.m

M_{ot} < 0.9M_r

Hence, there is no tension in the anchor bolt.

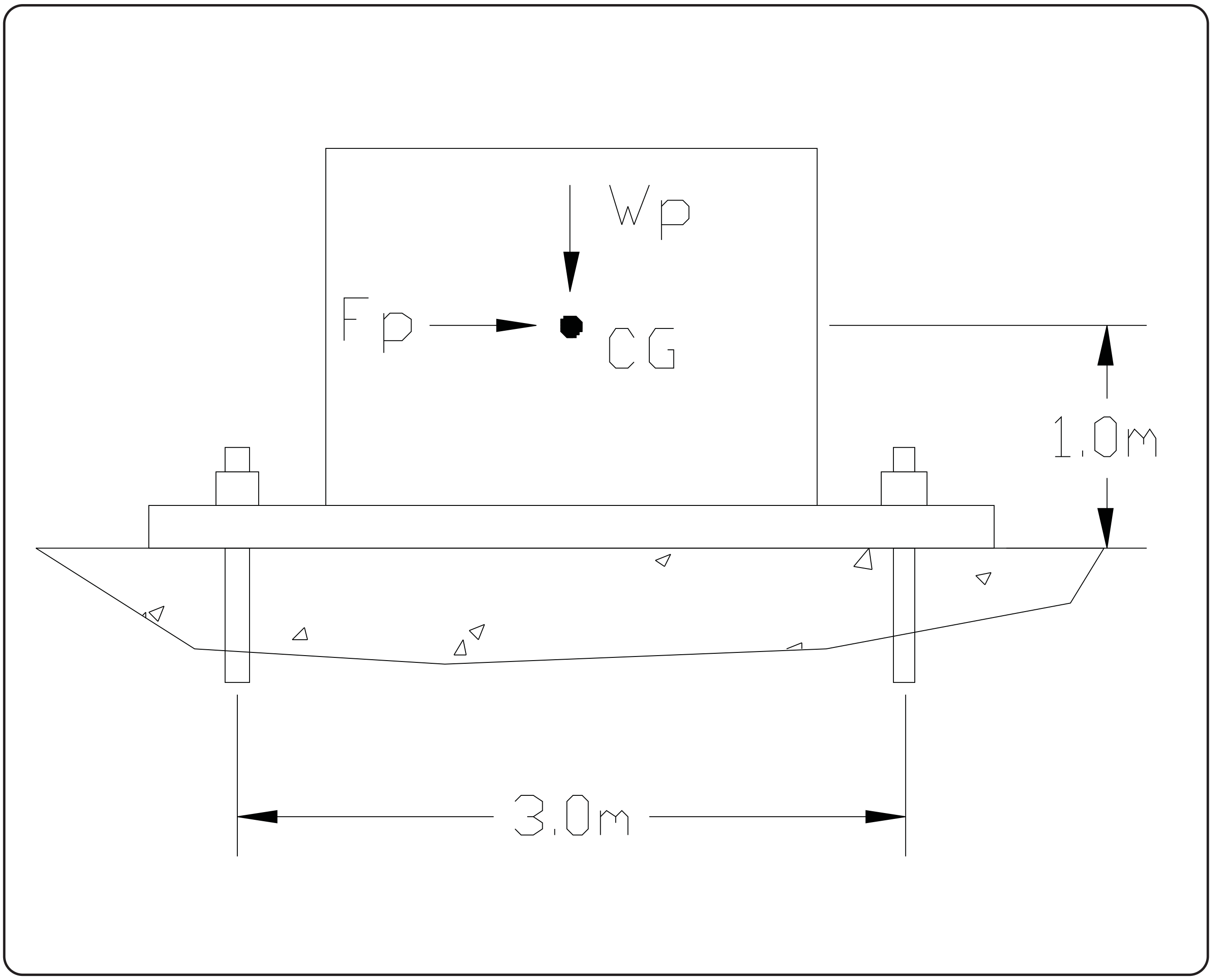


Fig. 1. Cooling tower installed at roof

Example 2: Design anchorage for an emergency generator supported on open springs

Problem Statement

An existing emergency generator is located at ground level in a single-storey physical plant building in Zone V. It is mounted on six open springs, one at each corner of the unit and one at the midpoint of each side, to damp the vibrations generated during operation. The medical superintendent has given an urgent order that the generator be restrained with snubbers so it will not fall off its supports during the expected earthquake. You have proposed that the snubbers be located as shown in Fig. 2. Now, you need to determine the shear and tension demands on the bolts that will anchor the snubbers to the concrete pad, and the compression demand in the spring supports.

Solution

Zone factor, Z = 0.36 (for zone V, Table 2 of IS 1893 (part 1): 2002)

Height of point of attachment of the emergency generator above the base of the building, x = 0.0m

Amplification factor of the emergency generator, a_p = 2.5 (flexible component, Table 3 of Mondal and Jain)

Response modification factor R_p = 2.5 (vibration isolated, Table 3 of Mondal and Jain)

Importance factor I_p = 1.5 (life safety component, Table4 of Mondal and Jain)

Weight of the emergency generator, W_p = 100kN

The design seismic force, $F_p = \frac{Z}{2}(1+\frac{x}{h})\frac{a_p}{R_p} I_p W_p$

$$= \frac{0.36}{2}(1+0)\frac{2.5}{2.5} \text{X}1.5\text{X } 100\text{kN}$$

$$= 27\text{kN}$$

The minimum design seismic force, $F_{p.\ min} = 0.1W_p$ =10kN

Hence, the design seismic force for the emergency generator is

F_p = 27kN

Since the generator is mounted on flexible spring supports, the design force is doubled per clause 1.3.3, that is,

F_p = 2 X 27kN

= 54kN

The anchorage of equipment to the building must be designed for twice this force (Clause 1.3.4).

By inspection the transverse direction loading will result in the worst-case demands for design.

For overturning forces, the compression forces will be resisted by the spring supports and the tension forces (if any) will be resisted by the snubbers and the associated anchor bolts.

The overturning moment is

M_{ot} = 2.0 X 54kN X 0.75m

= 81kN.m

The resisting moment using 0.9D load combination from the weight of the unit is

$0.9M_r$ = 0.9 X 100kNx1m

= 90kN.m

$M_{ot} < 0.9M_r$

Hence, there is no tension in the spring supports. Note that if tension forces are present, the snubber should be designed to resist the uplift force.

The compression force in the spring support is,

$$F_c = \frac{81kN.m}{1.0mX3} + \frac{100kN}{6}$$

$$= 43.7kN$$

The shear load will be resisted by the snubber on one side of the unit for each loading direction.

Since the shear force is applied to the snubber at an elevated position, the anchor bolts, which row is closest to the unit will experience both shear and tension forces, Fig 3.

With the proposed layout, the shear force will be resisted by 8 anchor bolts and tension force by 4 anchor bolts, Fig 2.

Shear per anchor bolt:

$$V = \frac{2F_p}{6}$$

$$= 2 X \frac{54}{8} kN$$

$$= 13.5kN$$

Tension per anchor bolt, assuming a moment arm of 2/3 times the distance from the center of the anchor to the edge of the snubber:

$$V = \frac{2 X 54kN X 15cm}{\frac{2}{3} X 33cm X 4}$$

$$= 18.4kN$$

Note that if tension force is present due to overturning moment of the unit, then the anchors will also need to be designed for the additional tension force.

Use the forces calculated above to design the snubbers out of steel angles as shown in Fig. 3, or select them from a manufacturer.

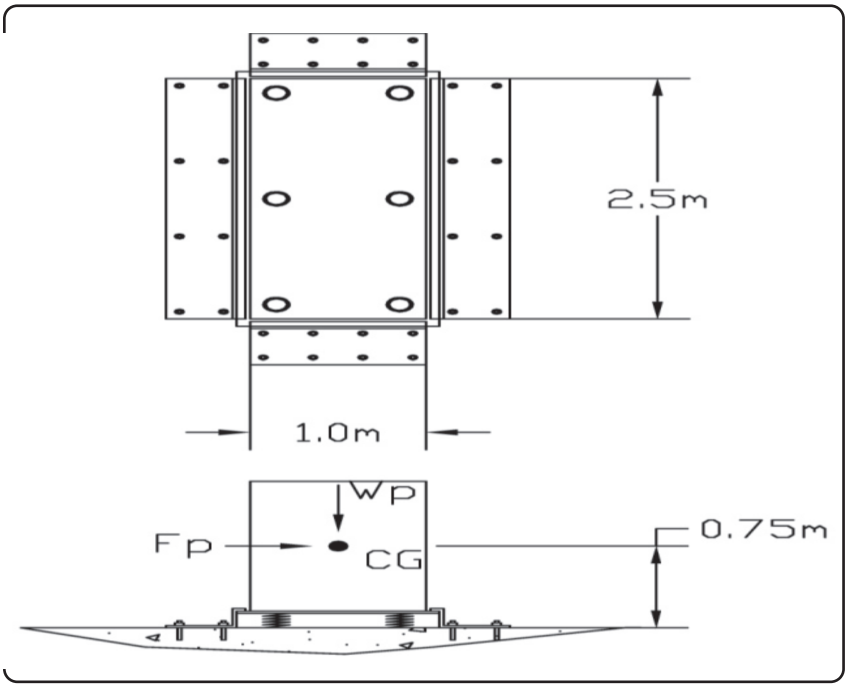


Fig 2: Emergency generator installed at ground level

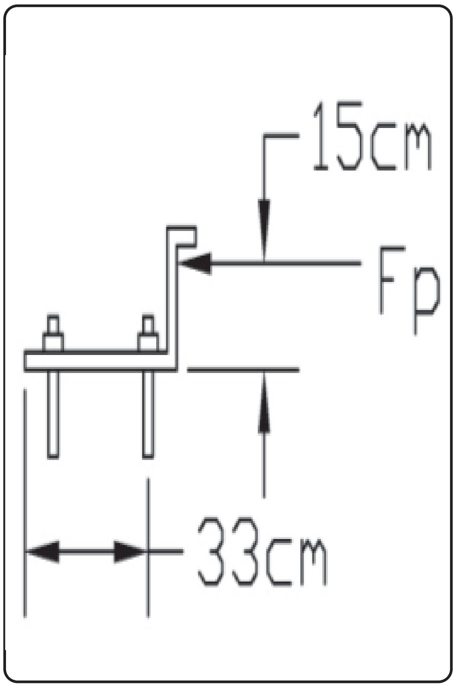


Fig 3: Snubber load diagram

Abbreviations and References

Abbreviations

ATC	Applied Technology Council
BIS	Bureau of Indian Standards
BMTPC	Building Materials & Technology Promotion Council
BU-KOERI	Bogaziçi University Kandilli Observatory and Earthquake Research Institute
CT	Computed Tomography
DDMA	Delhi Disaster Management Authority
FEMA	Federal Emergency Management Agency (United States)
GSDMA	Gujarat State Disaster Management Authority
GSI	Geological Survey of India
ICU	Intensive Care Unit
IIT	Indian Institute of Technology
IS	Indian Standard
MCEER	Multidisciplinary Center for Earthquake Engineering Research (University at Buffalo)
MRI	Magnetic Resonance Imaging
NDMA	National Disaster Management Authority
NICU	Neonatal Intensive Care Unit
NICEE	National Information Centre of Earthquake Engineering (IIT Kanpur)
NiSEE	National Information Service for Earthquake Engineering (University of California Berkeley)
OSHPD	Office of Statewide Health Planning and Development (U.S. State of California)
OT	Operation Theatre
USGS	United States Geological Survey

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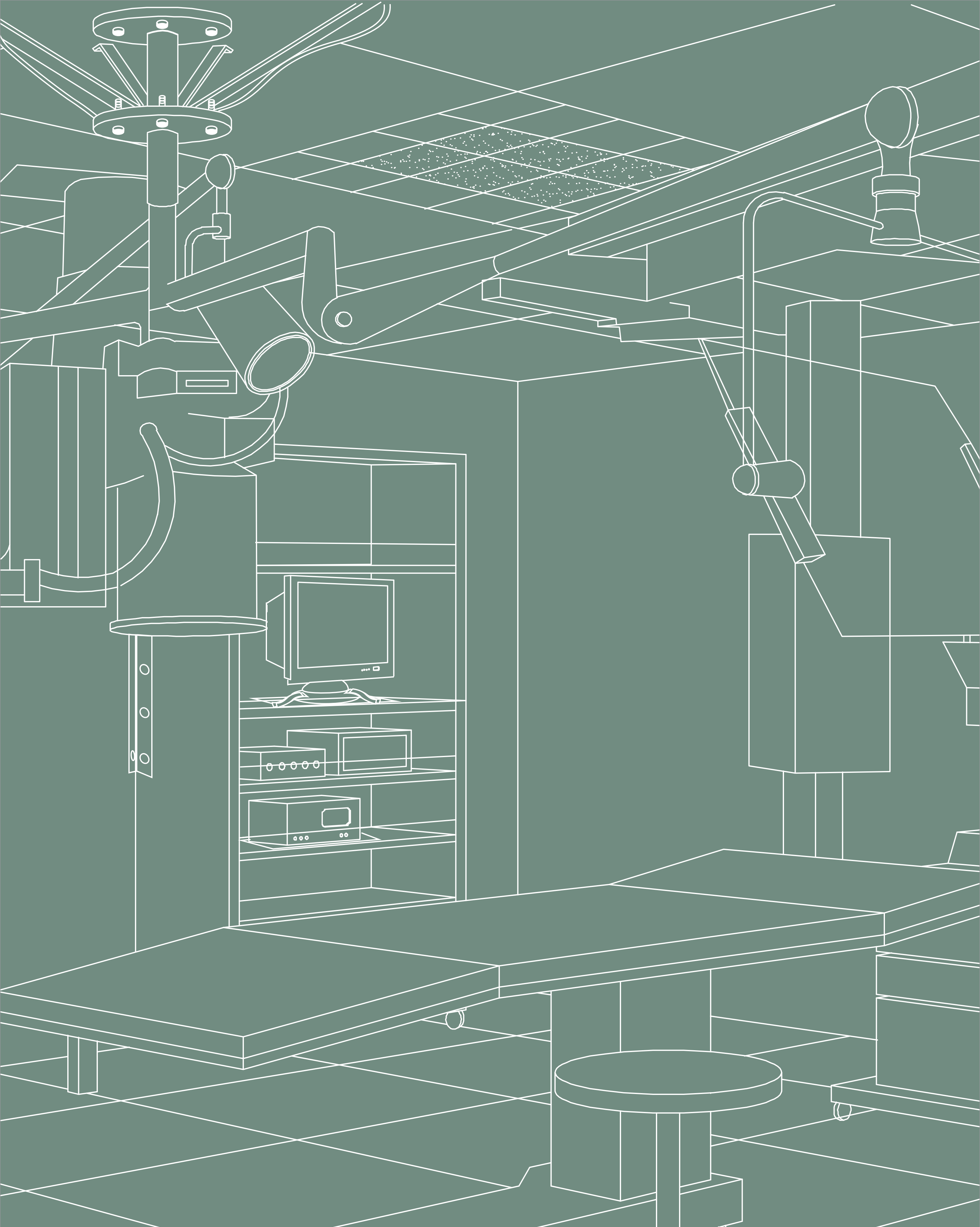
Index



GeoHazards Society: 71, B Floor, Vinobapuri, Lajpat Nagar-II, New Delhi-110024, India.
Tel: 91-11-46509848, 91-9810600821, email:hari@geohaz.org, www.geohaz.in, www.geohaz.org