Earthquake Hazard Reduction for Life Support Equipment in Hospitals

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EXECUTIVE SUMMARY

After many years of providing seismic designs for essential facilities such as hospitals, we as a society, have still not succeeded in adequately protecting the public during and after a damaging earthquake. While building codes throughout the United States require new hospitals to remain operational after an earthquake, most building designers simply provide for the aseismic design of the structural components of hospitals while virtually ignoring the equipment within the hospital. Hospitals are simply not shells alone. There are many critical and noncritical items that a hospital will be hard pressed to operate without in the aftermath of a disaster.

Of paramount importance is critical hospital equipment that has been termed Life Support Equipment (LSE) by the authors. Life Support Equipment is defined, for the purposes of this report, as equipment that directly maintains the life functions of a patient. Some of these items may be in use at the time of the earthquake, while others may not be required until after the earthquake. Notably absent from the LSE items are building systems, such as emergency power supply systems. These items are undergoing study by others.

This report is written primarily for those involved in the manufacture, specification, and installation of owner-supplied hospital equipment. It may also be useful to architects, engineers, and insurance companies that have a vested interest in designing and maintaining hospitals.

This report builds on the experience and conclusions of previous works by the authors and others. The report discusses the effects of earthquakes within hospitals, defines seismic categories in detail and how they are used and discusses the various methods available for seismic qualification. Seismic categories are a method of identifying the relative importance of a particular piece of equipment. We have used letters from "A" through "E" to designate five separate seismic categories. The more important equipment required for continued hospital function will be categorized as "A" and "B" items. Less important pieces of equipment will be categorized as "C", "D," or "E" items. LSE items are by definition classed in seismic category "A".

During this study, the authors visited two hospitals to identify typical equipment found in hospitals. One of the hospitals is a private institution; the other is a major government facility. In all, the authors examined several hundred equipment items. Of these, only fifteen were identified as required for life support. These LSE items are:

1. Anesthesia Gas Machine
2. Cart, Emergency (and contents)
3. Defibrillator
4. External Pacemaker
5. General Surgical Instruments
6. Heart-Lung Machine
7. Hyper-Hypothermia Unit
8. Infant Care Unit
9. Infant Isolation Incubator
10. Infusion Pump
11. Kidney Dialysis Unit
12. Oxygen Cylinder with Flow Meter
13. Suction Apparatus, Portable
14. Surgical Table
15. Ventilator/Respirator

These items are discussed in detail in Chapter 6 of this report. The authors found that most of the LSE items lacked seismic protective measures in the case study hospitals and other hospitals that the authors visited. Previous works have, however, provided designers with some means of protecting equipment in the form of seismic details for restraint. Representative restraint details have been reproduced in Appendix 2. In addition to this, we have provided seismic categories for approximately 160 other equipment items in

Appendix 1. The user of the report should consider these seismic categories as generic and may wish to further refine the categories as they may apply to a specific hospital.

Significant issues that remain include the need for physical seismic testing of some items identified as LSE. This will provide a reasonable level of assurance that the LSE will remain operational after a significant earthquake. These testing programs should be fairly generic in nature so that the equipment can be qualified for the widest range of seismic environments possible, at minimal expense.

This report also offers some suggestions for further study. As an example, an issue that can be posed is whether seismic qualification might not be out-dated, with the possible future widespread introduction of building base isolation systems, such as those used in the San Bernardino County Law and Justice Building in Southern California.

The testing of LSE should be conducted where the equipment is to be used in facilities that are base isolated, as the base-isolation systems leave little protection against vertical displacement generated by earthquakes.

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Robert J. Barnecut, a longtime advocate of earthquake protection of health facility building systems and contents was instrumental in preparing much of the material for this report until he passed away. We are grateful for the opportunity to have known and worked with him over the years.

In addition to Mr. Barnecut's many contributions, we are grateful to Woodward-Clyde Consultants, Valley Memorial Hospital and Tom Andrews, the Jerry L. Pettis Memorial Veterans Administration Hospital, Wyle Laboratories; Gene Marshall, for photography; and Patricia Wolf, for editing the draft and final manuscripts.

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INTRODUCTION

Earthquakes have strong shaking characteristics that are capable of seriously damaging buildings. The Chinese studied earthquakes and used seismographs thousands of years ago. The Greeks used some aseismic design features in some of their early temples, also thousands of years ago. Little quantitative thought has, however, been given to widespread aseismic design until recent decades.

Now, consideration is given to earthquake-resistant design for the structural components of buildings. However, minimal consideration is given to the nonstructural components and equipment within those buildings. In facilities with essential functions to perform, this lack of concern can lead to the inability to function after an earthquake.

Hospitals are at the forefront of facilities that must remain in operation immediately after an earthquake. Studies by the American Institute of Architects Research Corporation have indicated the need for essential services can be expected to increase by 300 to 700 percent immediately after a disaster, such as a damaging earthquake.

Hospitals rendered nonfunctional, not as a result of structural damage, but as a result of the failure of the nonstructural components or equipment, should not be tolerated. This requirement will come at great expense, especially if the requirements are imposed on existing hospitals as well as new construction.

There are many classifications and types of nonstructural components and equipment found within a hospital. This report will study, in detail, those equipment items that are directly required for the life support of patients. Several hundred equipment items were examined during the course of this study. The analysis showed that there are fifteen Life Support Equipment (LSE) items that are likely to be found in a well-equipped hospital.

This report does not address nonstructural items, such as walls and emergency power supply systems, because the authors wished to limit the focus of study to owner-supplied equipment that are directly related to patient life support. Equipment such as emergency power supply systems are being studied by other researchers in detail. These studies will complement this research effort.

Recent advances in the study of earthquake-resistant design, mainly for the nuclear power industry have made it possible for hospitals to remain operational after an earthquake. We have the technology available to protect hospitals.

More than 10 years ago codes were adopted that required essential buildings to be operational following a disaster. There has, however, been little effort by regulating agencies to enforce this operational requirement because many do not know what actually constitutes "operability". The exception to this rule has been in California, where new hospitals are now required to physically anchor fixed equipment. Unfortunately, much of the owner-supplied equipment is not considered to be fixed, and it escapes this requirement. The anchoring of equipment does not guarantee operability for there are many items that will fail through an operability mode rather than a more simple mechanism such as sliding or overturning. An operability mode of failure can be explained as a failure that is due to the non-operation of some component in the equipment. These sub-components are responsible for the continued operation of the equipment. Examples of such failures might include switches that produce false signals through accidental tripping, circuit boards that back out, etc. In addition, there are many items that are not "fixed" but require some form of restraint and/or seismic qualification. The potential for the "operability mode of failure" of equipment has not received attention by any codes that regulate the operation of hospitals. The technology currently exists to provide the aseismic qualification of LSE that will assure that hospitals will be able to perform their necessary functions immediately after an earthquake.

Socioeconomic questions need to be addressed: Just how important are hospitals in the aftermath of a regional disaster? Do we consider hospitals essential facilities? As long as we allow hospitals to remain vulnerable through a lack of seismic qualification, it would appear that we do not consider them essential.

This report has been prepared for hospital designers, administrators, and equipment manufacturers. Unfortunately, the recommendations of this report are likely to be carried out when agencies enforce the operability requirements now in place. We are not likely to see this in the immediate future. This will likely only affect new construction. Backfitting existing facilities will probably not be required by any enforcing agencies until after an earthquake in which many existing hospitals will be needlessly left inoperable. Then, the public outcry will force agencies to enforce and/or reform the regulations.

General Earthquake Effects on Buildings and Equipment 2

GENERAL EARTHQUAKE EFFECTS ON BUILDINGS AND EQUIPMENT

Throughout history, man has lived in fear of earthquakes. We fear being trapped inside a building that collapses. This was once a justified fear. Now, with modern building codes and building materials, we are freed from some of these fears, at least in this country. Many places do not have the luxury of modern building codes or quality field inspection during construction. Either codes are nonexistent, woefully lacking, or, as we have seen in many recent examples where codes are available, they are bypassed as shown in Figure 2.1. The result is a damaged building, or worse yet, total collapse and loss of life.

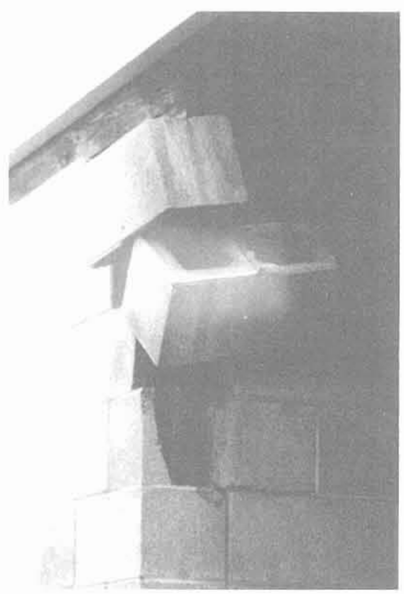


Figure 2.1 — Masonry construction damaged in an earthquake as a result of grout not being placed in the hollow masonry cavities. The local building codes require the grout, but a lack of quality on-site building inspection allowed the contractor to skip this requirement, which guaranteed the failure of the building during a moderate earthquake.

The effect of an earthquake on any given building depends on a variety of factors including:

1. Size of Earthquake
2. Distance from Hypocenter and/or Fault Plane
3. Duration of Strong Ground Shaking
4. Regional Geology
5. Local Soil Conditions
6. Building Structural Type
7. Building Configuration
8. Age of Building (Effect of previous earthquakes)

The effect of the earthquake on the contents of a building also has a long list of variables. These include the above list as well as the following:

1. Location of Equipment Within the Building
   (Basement or upper floors)
2. How Equipment is Mounted or Not Mounted
   (Is the equipment restrained, resting on a tabletop?)
3. Likely Failure Mode
   (Sliding/overturning as opposed to operational failure)
4. Power or Other Utility Requirements

The actual effects on equipment within buildings can vary significantly, even within a single building and during a particular earthquake. Examples abound where one space such as a laboratory, will suffer little or no damage in an earthquake. In contrast to a lab in another wing, or on a different level that will suffer greatly. Each case needs to be examined in detail. Often the answers are simple and straightforward such as:

1. Different Ground Types between Building Wings
2. Building Configuration
3. Owner-Initiated Seismic Protection Measures

In other cases, the answer might be more obscure and require an in-depth investigation by a specialist familiar with earthquake engineering for both building structures and contents.

There are several ways hospital equipment can fail during an earthquake. Excluding equipment failure as a result of building collapse, we can identify the following types of failure:

1. Sliding or Rolling
2. Toppling, Overturning, or Falling
3. Loss of Utilities
4. Struck by Other Equipment
5. Internal Component Failure
6. Flooding or Contamination

These mechanisms can individually cause the failure of a particular piece of equipment or they can act collectively.

Some of the most common failures in an earthquake are simply nuisance failures. Examples might include bottles toppling from shelves, or the ejection of files from cabinets. Both of these failures will only hinder the continued functioning of the hospital because the hospital staff will be required to spend some time cleaning up. If proper protective measures are taken this will not occur. In other cases, failure is the same as that described in the previous example, only with more drastic results. An example here could be a defibrillator that might topple from an emergency cart. In this case, the equipment is both expensive and is required for efficient hospital operation as well as life support. Again, the equipment could have been easily protected.

Common Misconceptions

There are many misconceptions about the effects of earthquakes. One of the most common is that if a building is designed to meet the earthquake codes, then that building is "earthquake-proof". This is simply not the case. There is no building constructed that is not susceptible to some form of earthquake damage. Buildings do have varying degrees of earthquake resistance, but they are simply not earthquake proof. Even if a building is designed to meet the codes in force, these codes are minimum standards. Buildings that are not damaged as a result of an earthquake are not examples of earthquake-proof structures. They were simply designed appropriately for that particular earthquake.

The authors commonly discuss the earthquake problem with design professionals as well as the public. All are convinced that because their building was not damaged in the "last big one," that they have found the secret to earthquake design. The United States hasn't had a great earthquake since 1964 (Alaska Richter Magnitude 8.4). What people commonly refer to as large earthquakes are usually fairly moderate in size (Sylmar 1971, Imperial 1979, Coalinga 1983). These earthquakes were all approximately Richter Magnitude 6 and are the size many areas in the United States can expect on a regular basis. The more devastating earthquakes are quite rare.

Although it isn't exactly proper to compare earthquake magnitudes to energy, it can serve as a useful example. Using Richter's text, "Elementary Seismology," as the basis for discussion, we assume his analysis for the comparison of magnitude to energy release. Richter has written that for every full increase in Richter Magnitude, there is an increase in energy release of approximately 31 times. Therefore, the Alaskan earthquake of 1964 was approximately 960 times larger (in energy release) than the Sylmar earthquake of 1971.

Some design professionals believe their buildings have met the earthquake challenge because their buildings were not damaged by an earthquake that has an epicenter 60 or 70 miles away. This would be like assuming that your ear drums can't be broken by a jet engine blast when your only experience with a jet engine has been to see one flying overhead at an altitude of a half mile or so. The effect of the moderate earthquake and the jet blast have been attenuated due to distance. Distance alone is not a safety factor. Many factors come into play, as we have previously noted. On the question of distance, it is interesting that the epicenter for the 1964 Alaskan earthquake was approximately 100 miles from Anchorage and the epicenters for the Mexican earthquakes in September 1985, were several hundred miles from Mexico City. Both cities received considerable damage as a result of these distant earthquakes.

We are fortunate in this country to have modern building codes. It is fairly common to read or hear an account of a small earthquake (say Richter Magnitude 5) that kills thousands of people because some nations do not have any enforceable earthquake codes. Small earthquakes can easily kill more people if basic, safe, building practices are not followed.

Another misconception is that we shouldn't worry about designing for a specific size earthquake simply because any earthquake we design for can be exceeded. We must design for the earthquake that is reasonably expected so that we do not expose human life to needless loss. We can easily see that our earthquake codes have saved many lives as opposed to countries which do not enforce or have building codes.

Many people are unaware of the shaking characteristics of an earthquake. The building codes in this country, for example, do not recognize that earthquakes have three components of shaking (two horizontal and one vertical).

The vertical shaking component is continuously ignored. Some state that buildings are designed to stand up under normal gravity loads and that earthquakes are not likely to exceed gravity. This is not the case. Recent moderate earthquakes have shown that vertical free field accelerations (measurements taken by a seismograph outside of a building or other man made structure) can exceed gravity even where the fault mechanism is strike-slip (consisting of horizontal movement) in nature. For this reason, the Nuclear Regulatory Commission requires vertical seismic examination. Figure 2.2 shows a lathe that has experienced vertical and horizontal displacement in a recent earthquake. We need to give consideration to equipment for vertical shaking if we expect essential facilities to remain operational.

Figure 2.2 — Lathe in a school showing vertical displacement that occurred during the Coalinga earthquake. Note the shavings under the previous location of the base that were not disturbed when that part of this heavy equipment item was displaced in the earthquake.

Another common misconception is that because the building is designed structurally to meet the codes, the building contents are equally well protected. The design for structural response to an earthquake does not guarantee that the equipment will survive. Even where the building structure is designed with all the best principles in mind, if the components are not separately protected, they will run the risk of failing. It is false to assume that a facility will be capable of operating after an earthquake because the building was constructed to meet the latest structural codes.

One common misconception is that earthquakes have different effects on equipment of various sizes and weights. Earthquakes do not necessarily make a distinction for the size of the equipment. Large heavy items are just as prone to displacement as smaller, lighter items. Figure 2.3 shows a large item that was moved.

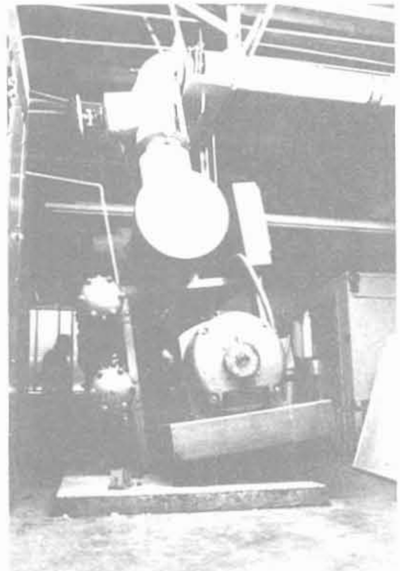


Figure 2.3 — Large chiller that was significantly displaced as a result of a moderate earthquake. **Photo by William Harris, NBS**

While it is true that anchoring the base of building equipment will protect most items, it will not guarantee the operation of equipment that has an operational mode of failure. The misconception that equipment can be protected solely by anchoring its base is one of the major premises of this report.

Specific Earthquake Effects on Equipment

It may be useful to describe the outcome of a moderate earthquake on a hypothetical hospital so the reader can learn what can happen to hospital equipment in a building that does meet the latest codes.

If we were to walk into most hospitals in the United States, we would see what appears, on the surface, to be an organization capable of meeting the challenges of virtually any disaster. People are working with a calm purpose, equipment is stored ready for immediate use.

Imagine, however, standing in the hallway of a major hospital hearing a low growl that grows in intensity to the point normal conversation is no longer audible. Simultaneously, the building begins to shake in a violent way. Not only is the floor moving erratically in horizontal directions, but it is violently displaced vertically to the point that an oberver can see waves ripple through the building.

By this time, the building is no longer groaning, it is screeching and dust is belching from cracks in the walls. The shaking is so violent that we find ourselves thrown to the floor. We have no immediate understanding why we can't stand up. We'd like to seek cover, but our movements are restricted by our inability to balance ourselves. Now we notice that others are in the same position as we are. What is it that keeps us down? Why the sudden feeling of uncontrolled nausea? Now other noises are filtering into our consciousness, the screams of others or ourselves. A fire extinguisher crashes through its glass cabinet door and rolls aimlessly through the halls. Lights flicker and finally go out all together. In the ensuing darkness, the building noise and screams of human anguish are frightening.

Again, the lights begin to flicker, this time coming back on, only they are quite dim. The emergency power supply has begun to operate and at this point we come to realize that we are in the midst of an earthquake. It is an earthquake that seems to be ripping virtually everything in the building apart. We'd get out of the building if we could only stand up even though we know we shouldn't.

Small explosions also continue, only they are no longer a mystery in the darkness. They are fluorescent light tubes being thrown as projectiles from the light fixtures and breaking on impact in white clouds of powdered dust and tiny shards of glass. Ceiling tiles are falling all around in the dim light. With the lights back on it is possible to see portable X-ray machines on their sides, crash carts wandering and bouncing around, files spewing across the floor and other people lying on the floor as precariously as we are.

When will it end? It has only begun! The time lag between the first low growl that we heard in the hallway and the flickering of the lights was only a few seconds. This hypothetical earthquake will last between 30 and 40 seconds. It is a moderate earthquake of approximately Richter Magnitude 6.5. We say it's moderate, but we will remember it as the most terrifying experience of our lives. We are fortunate to have been in a hospital at the time of the earthquake; there are many building collapses as a result of this moderate earthquake. The hospital that we are in does not collapse, having been designed to meet the modern code requirements. It withstood the strong shaking but it is useless as a functional hospital.

How can a building that survived the earthquake essentially intact with only cosmetic damage be useless? Easily. It will take the hospital staff days to clean the work spaces.

The emergency power supply is operational, but there is no water available. Our hypothetical hospital had a fresh water tank and a fresh water well in the basement. Unfortunately, the emergency water supply tank was not anchored even though the tank manufacturer provided predrilled holes in the tank skid for anchor bolts. During the earthquake, the tank slid approximately 18 inches and severed an adjacent well head. What designer would have ever thought that a large emergency water tank would have been capable of sliding a foot and a half? Unfortunately, all too many designers are not aware that this is exactly what can happen.

Other such problems abound throughout the hospital. Some items are taken care of, however, others are woefully lacking. In the laboratories, equipment items that were used on countertops are on the floor. Many of these items are sensitive to motion for calibration purposes and are no longer useful to the laboratory staff. Many functions that were automatically performed by Coulter Counters, etc. must now be performed manually. This is certainly not an efficient use of the hospital staff in an emergency. Adding to this, the laboratories have lost all of the blood bank refrigerators due to toppling. There have been significant chemical spills, some caused noxious fumes that fill the laboratories.

Throughout the rest of the hospital, the scene is much the same. Equipment that was restrained has, in general, fared better. As always, there are exceptions to this observation. In some cases, restrained equipment has been damaged by sliding or rolling equipment that was not restrained. In other cases equipment that appears to be undamaged is in fact inoperable due to internal failures.

Serious consideration needs to be given to seismically qualifying the equipment that can be classified as Life Support Equipment. The failure of this equipment can have life-threatening consequences. We have the architectural details and scientific technology to restrain equipment in hospitals during an earthquake. Unfortunately, seismic restraints will not always provide the level of protection required. Again though, we do have the technology available today to make certain that LSE will remain functioning. An example of the need for qualifying LSE equipment would be in the operating suite. There are many instances when an operation cannot be immediately terminated. For the safety of the patient, the equipment required for the operation must work during and after the earthquake. The utilities required for the operation of the equipment must also remain on line for the safety of the patient. These equipment items will be discussed in detail in Chapter 6 of this report.

The thrust of this report is directed toward LSE. The reader may wish to consult other works that discuss in detail some of the other equipment items that can render a facility inoperable if proper seismic considerations are not in force at the time of an earthquake. Five works that the authors suggest for further reading include the following:

1. **Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide**
   by Robert Reitherman,
   California Seismic Safety
   Commission, SCEPP, 1983.

2. **Earthquake Protection of Essential Building Equipment: Design, Engineering, Installation**
   by Gary L. McGavin, AIA,
   John Wiley and Sons, Inc. 1981

3. **Seismic Restraint Handbook for Furniture, Equipment & Supplies**
   Reid & Tarics Associates
   Veterans Administration

4. **Study to Establish Seismic Protection Provisions for Furniture, Equipment & Supplies for VA Hospitals**
Stone, Marraccini & Patterson
R. Barnecut and G. Austin
Veterans Administration, 1976

5. **Nonstructural Earthquake Hazards Mitigation for Hospitals**
by Robert Reitherman,
Scientific Service, Inc.,
Prepared for Federal Emergency Management Agency
Contract No. EMW-C-5-2065, 1986

Equipment Seismic Categories
3

EQUIPMENT SEISMIC CATEGORIES

One of the first steps in qualifying hospital equipment is to determine the need for a particular system or individual piece of equipment in an emergency situation. We must keep in mind that entire systems are sometimes required to perform a specific function. The failure of any one piece of equipment within the system can render the entire system inoperable. Examples might include the CT scan suite. There is more than the scanner that must be protected. The computer system, power unit, and cooling units are examples of additional items that are needed to make this equipment operate as a complete system.

The authors have in past works established a Seismic Category system that is applicable for this report. The following discussion draws heavily from "Earthquake Protection of Essential Building Equipment: Design, Engineering, Installation," by Gary L. McGavin, AIA, Published by John Wiley and Sons, Inc., NY, NY, Copyright 1981.

Seismic Design Categories allow the design team and owner to rationally specify methods of achieving seismic protection for various types of building equipment. The Seismic Categories that we propose include the following:

1. **Category A** — Critical systems or equipment that are required for the operation of the facility or patient life support or where failure will directly and adversely affect the function of other critical systems or equipment.

2. **Category B** — Support systems or equipment required for support functions. The facility can operate on a limited basis if a failure occurs.

3. **Category C** — Support systems or equipment required for prolonged operation of the facility on a day-to-day basis.

4. **Category D** — Portable systems or equipment not in Seismic Category "A".

5. **Category E** — Convenience or miscellaneous systems or equipment.

We have by definition listed all LSE items in Seismic Category "A". We have listed approximately 160 pieces of equipment in Appendix 1 and have provided suggested Seismic Categories for each of these pieces of equipment. In some cases, individual hospitals may wish to review this list to see if it is consistent with their individual operating policies. Changes can easily be made to the suggested Seismic Categories for specific cases.

Following this procedure will help the hospital staff determine exactly what pieces of equipment must be in order to remain operational after an earthquake.

Employment of the Seismic Category philosophy is one step toward meeting the building codes and keeping essential facilities in operation following an earthquake.

Seismic Qualification Techniques 4

SEISMIC QUALIFICATION TECHNIQUES

There are several seismic qualification techniques available to assure that hospitals remain operational after an earthquake. These techniques are:

1. Seismic Test
2. Mathematical Analysis
   - — Simple
   - — Complex
3. Past Experience
4. Design Team Judgment
5. Combined Qualification Approaches

A general discussion of each of these techniques follows. The reader may wish to refer to McGavin's book on *Earthquake Protection of Essential Building Equipment*, 1981. This text gives a much fuller account of the techniques that are available.

Seismic Testing

The use of the seismic test is actually an outgrowth of the aerospace testing programs that were established during the 1950s and 1960s. These tests were conducted mostly with giant solenoids that produced high-frequency and high-gravity loads to simulate the vibratory environment that aircraft and spacecraft would experience during service. The late 1960s saw a significant decline in the requirements for aerospace testing. On the horizon, however, were several programs that would need extensive vibration testing requiring lower frequencies and lower accelerations. These were the Corps of Engineers programs for nuclear war readiness, programs such as Safeguard, nuclear power plants, and the Alaska Pipeline. The latter two specifically required testing for an earthquake environment. While the structures did require some testing for these programs, the majority of the testing requirements were for systems and equipment that were shown to be required for the safe operation of the facilities.

When it was discovered that vibration testing was required, laboratories began to research the technology for conducting these tests. The aerospace test equipment was largely unsatisfactory for simulating the earthquake environment because the displacements were too small, the frequencies were too high, and the accelerations were too large. Eventually, most labs settled on the electro-hydraulic shaker'systems. These hydraulic rams could be coupled to a shaking table that would impart the many different waveforms required for seismic testing. In the beginning, time histories were most often employed. A time history is a recording of a previous earthquake. As computers became more sophisticated, laboratories were to be able to manufacture their own earthquakes that would more accurately simulate the shaking characteristics of a specific site. Additional earthquake waveforms that are used include sine sweeps, sine beats, and decaying sines. Each waveform has a specific function and a complete seismic test will often employ more than one waveform in different parts of the test.

Originally, seismic test machines were capable of testing only one direction at a time. Earthquakes shake in three mutually perpendicular axes simultaneously. As the technology expanded, testing in two axes became possible and today testing in three axes is possible to a limited extent. Many biaxial (capable of testing in two axes simultaneously) test machines are actually uniaxial shakers because they rely on vector biaxial shaking. Figure 4.1a and b show the difference between these two shaking machine philosophies.

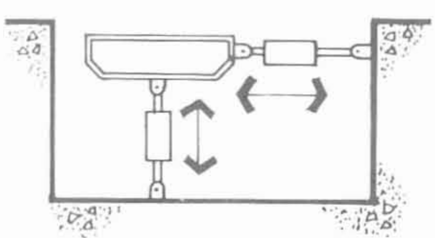


Figure 4.1a
True biaxial-independent simultaneous input motion for both the horizontal and the vertical directions.

Figure 4.1b
Vector biaxial-single direction of input motion at an angle to the test table.

Shake-table testing is an expensive proposition and should only be required for equipment that cannot be qualified by simpler, less expensive methods. The main justification for seismic testing is to seismically qualify equipment that has an operational mode of failure that cannot be qualified with a simpler method, such as mathematical analysis. Seismic testing should not be used to qualify base anchorage. This is a waste of time and money. Testing as seen in figure 4.2 is well suited to showing that a piece of equipment is capable of operating during and after an earthquake of given characteristics.

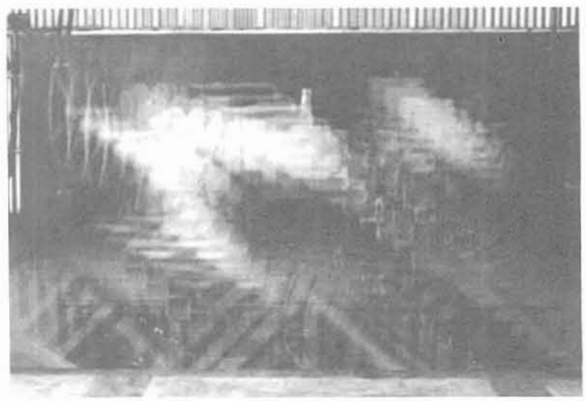


Figure 4.2 — Seismic test table. **Photograph courtesy Wyle Laboratories, Gene Marshall.**

Seismic testing, except for academic endeavors should, in general, only be performed on hospital equipment that is in Seismic Category "A". It is not necessary to test equipment for base anchorage. Equipment in other Seismic Categories can usually be qualified with less expensive methods. Seismic Testing allows the equipment to experience the next best thing to a real earthquake. Axes of shaking can be modeled, as can displacement, acceleration, and frequency, as close as possible to an expected earthquake at a specific site. In some cases, it might be wiser to perform a "fragility test" that examines equipment to the point of failure. This type of test could qualify equipment for any seismic environment at any location in the United States. This would obviously be a savings over retesting equipment for each location.

Any useful seismic testing program would need the full cooperation of the equipment manufacturers. In our research, we have not been able to obtain the help of the major equipment manufacturers. The authors assume that some of the equipment has been supplied to the United States Navy for shipboard use. The Navy would likely have required testing for the dynamic shipboard environment. Qualification for the shipboard environment may have led to design changes in the equipment that would be roughly equivalent to redesigning for the seismic environment. This could occur even though the dynamic motions of the shipboard installation are not identical to a seismic event.

It is our opinion that if manufacturers were to cooperate with future research efforts, equipment could be qualified for many installations throughout the United States and go a long way toward reducing future loss of life.

The following section identifies laboratories that are available to perform seismic testing in the United States. The capabilities of the individual laboratories are, as they have been reported to us, also listed. Manufacturers may find this section useful when they need to test their equipment.

Seismic Test Laboratories

Since the early 1970s, laboratories have been developing and filling the need for seismic testing.

This report has identified laboratories with seismic testing capabilities. About 38 laboratories were contacted. Of these, 13 responded with enough information to examine their seismic-test capabilities. Table 4-1 below lists the laboratories contacted in alphabetical order, their addresses, and seismic capabilities as reported by the respondents.

TABLE 4-1

LABORATORIES CONTACTED

LABORATORY	ADDRESS	SEISMIC TESTING
1. AKO, INC.	108 BROAD BROOK ROAD P.O. BOX 2283 ENFIELD, CT 06082	NO
2. ANCO ENGINEERS, INC.	9937 JEFFERSON BLVD. CULVER CITY, CA 90230	YES
3. AERO NAVY LABORATORIES, INC.	14-29T 112TH STREET COLLEGE POINT, NY 11356	NO
4. AEROSPACE RESEARCH CORP.	5450 JAE VALLEY ROAD ROANOKE, VA 24014	NO
5. AMERICAN ELECTRONIC LABORATORIES, INC.	P.O. BOX 552 LANSDALE, PA 19446	NO
6. APPLIED RESEARCH LABORATORIES	5371 - T.N.W. 16 1ST. STREET MIAMI, FL 33014	NO
7. ASSOCIATED TESTING LABORATORIES, INC.	53 SECOND AVENUE BURLINGTON, MA 01803	NO
8. BREWER ENGINEERING LABORATORIES	P.O. BOX 288 513 MILL STREET MARION, MA 02738	NO
9. CONSTRUCTION ENGINEERING RESEARCH LABORATORY (CERL) U.S. ARMY CORPS OF ENGINEERS	P.O. BOX 4005 CHAMPAIGN, IL 61820	YES
10. CORNELL UNIVERSITY	ITHACA, NY 14850	YES
11. ETL TESTING LABORATORIES, INC.	INDUSTRIAL PARK CORTLAND, NY 13045	NO
12. EARTHQUAKE ENGINEERING RESEARCH CENTER	COLLEGE OF ENGINEERING UNIVERSITY OF CALIFORNIA BERKELEY, CA 94720	YES
13. EAST-WEST TECHNOLOGY CORP.	119-T CABOT STREET WEST BABYLON, NY 11704	YES

TABLE 4-1 cont'd.

LABORATORY	ADDRESS	SEISMIC TESTING
14. ENVIRON LABORATORIES, INC.	9725-T GIRARD AVENUE MINNEAPOLIS, MN 49503	NO
15. ENVIRONMENTAL DYNAMICS INC.	1234-T NORTH MAIN STREET P.O. BOX 7209 ANN ARBOR, MI	NO
16. ENVIRONMENTAL SCREENING TECHNOLOGY, INC.	285 KOLLEN PARK DRIVE HOLLAND, MI 49423	NO
17. FOAMFAB, INC.	409 OAKLAND STREET MANSFIELD, MA 02048	NO
18. GAYNES TESTING LABORATORIES	1652 WEST FULTON STREET CHICAGO, IL 60612	NO
19. INDUSTRIAL TESTING LABORATORIES, INC.	637 N.W. IONIA DRIVE SUITE B GRAND RAPIDS, MI 49503	NO
20. JOHN A. BLUME EARTHQUAKE ENGINEERING CENTER	STANFORD UNIVERSITY PALO ALTO, CA 94305	YES
21. METCUT RESEARCH ASSOCIATES, INC.	3990 ROSSLIN DRIVE CINCINNATI, OH 45209	NO
22. MINER ENTERPRISES, INC.	P.O. BOX 471T 1200 EAST STATE STREET GENEVA, IL 60134	NO
23. NATIONAL TECHNICAL SYSTEMS (NTS) SCIENTIFIC SERVICES GROUP	26525 GOLDEN VALLEY ROAD SAUGUS, CA	YES
24. NEW YORK TESTING LABORATORIES	81-T URBAN AVENUE WESTBURY, NY 11590	NO
25. RUSSELS TECHNICAL PRODUCTS	363 EAST 6TH STREET HOLLAND, MI 49423	NO
26. SEXTON INDUSTRIES, INC.	133 HARRISON AVENUE ZEELAND, MI 49464	NO

TABLE 4-1 cont'd.

LABORATORY	ADDRESS	SEISMIC TESTING
27. SMITHERS SCIENTIFIC SERVICES, INC.	425 W. MARKET STREET DEPARTMENT TR2 AKRON, OH 44303	NO
28. STATE UNIVERSITY OF NEW YORK AT BUFFALO	DEPARTMENT OF CIVIL ENGINEERING 212 ENGINEERING WEST R-8 BUFFALO, NY 14260	YES
29. TELEDYNE RYAN AERONAUTICAL	2701 HARBOUR DRIVE SAN DIEGO, CA 92138	NO
30. TORVICO ELECTRONICS, INC.	HIGHWAY 70 LAKEWOOD, NJ	NO
31. UNIVERSITY OF CALIFORNIA LOS ANGELES (UCLA)	SCHOOL OF ENGINEERING AND APPLIED SCIENCE LOS ANGELES, CA 90024	YES
32. UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN	DEPARTMENT OF CIVIL ENGINEERING 1245 NEWMARK C.E. LAB 200 N. ROMINE STREET URBANA, IL 61801	YES
33. UNIVERSITY OF WASHINGTON	1400 NE CAMPUS PARKWAY SEATTLE, WA 98195	YES
34. VIBRATION SPECIALTY CORP.	100 GEIGER ROAD PHILADELPHIA, PA 19115	NO
35. VIBRATION TEST SYSTEMS, INC.	10246 CLIPPER CIRCLE AURORA, OH 44202	NO
36. VIKING LABORATORIES	440 BERNARDO AVENUE MOUNTAIN VIEW, CA 94043	NO
37. WESTINGHOUSE ELECTRIC CORP.	P.O. BOX 10864 PITTSBURGH, PA 15236	YES
38. WYLE LABORATORIES	1841 HILLSIDE AVENUE NORCO, CA 91760	YES

Of the 38 laboratories identified, only 13 had seismic capabilities. Table 4-2 compares the following characteristics between the 13 laboratories:

1. Number of Facilities
2. Number of Test Tables
3. Size of Test Table
4. Axial Characteristics of Test Table
5. Allowable Specimen Weights
6. Test Table Strokes
7. Frequency Ranges of Test Table
8. Activator Types
9. Maximum Acceleration of Test Table
10. Maximum Displacement of Test Table
11. Available Wave Forms
12. Utilities Available for Test Specimens (water, electricity, etc.)

A seismic test is not the only means to qualify equipment. The following sections will address other methods in which equipment can be qualified for the seismic environment.

Mathematical Analysis

In general, there are two types of mathematical analyses. The first is relatively simple and consequently inexpensive. It is a Static Coefficient Analysis that is generally only good to determine base anchorage requirements. The second is more complex and can be used for a variety of purposes such as determining the natural frequency of the equipment, the various modes of vibration of the equipment, frame displacements, mass modeling, etc. This type of analysis has varying degrees of complexity and therefore varying levels of expense. In general, the Complex Mathematical Analyses should be left to the specialists who are versed in earthquake engineering techniques for building equipment.

Static Coefficient Analysis

This form of analysis is in its simplest expression, Newton's law of physics that states:

Force **(F)** = Mass **(m)** times Acceleration **(a)**

$$F = ma$$

In many instances, building codes substitute the weight of the equipment for the equipment mass. This is incorrect. Engineers have done this by convention from the earliest attempts at writing codes for earthquakes. The definition of earthquake formulas using "static equivalents" are at their best, only rough approximations of the complex dynamic motions that actually occur in an earthquake. Clearly, in America, engineers are not as accustomed to converting weight back into mass prior to conducting mathematical manipulations as physicists. Realizing that the static equivalent is not a precise science, engineers have opted for using weight by convention. Even though using the weight is an improper application of the laws of physics, the equipment may not be any more prone to measurable damage.

The equipment weight is equivalent to the static vertical force due to gravity. Substituting the equipment weight for the mass in the earthquake equations creates a meaningless equation. Remember that most codes require the examination of the earthquake in two "horizontal" directions. The equipment can simply not have any "horizontal weight" until an acceleration is applied in a horizontal direction. Therefore, the equipment is weightless in the horizontal directions until an acceleration is applied to the object. Then, the object's horizontal weight is the product of its mass and its horizontal acceleration.

In addition to this, many building codes such as the Uniform Building Code published by the International Conference of Building

Officials, add modifiers to the basic Newtonian equation that in effect reduce the acceleration levels. This would seem to be in deference to the recent acceleration levels that are being found in earthquakes.

The building codes are basically in error, in our opinion, because they fully ignore the vertical shaking component in an earthquake. Generally, the stated reason for ignoring the vertical earthquake component, is that the equipment is inherently designed to withstand the ambient condition of 1g acceleration due to the earth's gravitational field. The misunderstanding here is twofold. First, the normal pull of gravity is static. When an earthquake occurs, the earthquake accelerations are added to the earth's gravitational field. Therefore, the equipment actually sees more than 1g in all earthquakes where upward motion is experienced. By way of illustration, imagine a piece of equipment resting on a scale in an elevator. Before the elevator begins to move, the equipment has a weight that can be read from the scale due to gravity. Now, when a button is pushed to take the elevator to the building's upper floors, the elevator begins to accelerate upward. If we were to look at the scale, we would see the equipment weight increase! This is simply the result of the Newtonian equation listed previously. An earthquake is the same thing, in reality. We're simply riding an "earth elevator" when the ground moves up. The force applied to the equipment as a result of this vertical acceleration will always be in addition to the earth's ambient gravitational field. In contrast to this, the downward motion of our example elevator will result in the reduction of the equipment weight. It is true that the equipment is designed to stand up under its own weight. Any upward vertical earthquake motion will in effect increase its weight. It appears that equipment survives the vertical earthquake environment not because it is designed to stand up under its weight, but because it has been designed to resist additional weight. But, how much additional weight? Each piece of equipment will have a different factor of vertical safety.

The second point missed by those who dismiss the vertical component of earthquakes, lies in the response of the equipment due to its configuration. As with building structures themselves, pointed out by Arnold's book on Building Configuration, 1982, equipment is also subject to eccentric loading and couples transforming motions. These lead to torsional responses that the equipment is not able to withstand, even with its safety factor.

The most recent Uniform Building Code static coefficient formula employed for lateral forces on elements of structures and nonstructural components is as follows:

Force **(F)** = Seismic Zone **(Z)** times Importance **(I)** times Equipment Horizontal Force Coefficient **(C_p)** times Equipment Weight **(W_p)**

$$F = ZIC_pW_p$$

Let's look at a hypothetical example using the two formulas noted above to determine the amount of basal force in order to anchor a piece of equipment. We will make the following assumptions about our example equipment:

1. Equipment to be located in UBC seismic zone 4: **Z** = 1
2. Equipment weight W_p = 3000 pounds
3. Equipment mass **m** = 93.214 slugs (converting at 60 degrees north latitude)
4. Importance factor **I** = 1.5 for essential facility
5. Equipment coefficient C_p = 0.3 equipment required for operation
6. Assumed acceleration **a** = 1g = 32.174 ft/sec/sec

   F = **ma** (horizontal examination)

   F = 93.214 x 32.174 = 3000 pounds Note: in the example earthquake, the lateral (horizontal) acceleration of 1g makes the final force equal to the equipment weight.

   Where:

   1 slug (mass) = 14.5949 kg

   1 kg = 2.205 lbs @ 1g

The total base force needed to be designed for is actually 3000 pounds, using Newtonian physics. If we had anchors at each of four corners, each anchor would need to resist 750 lbs of shear. If, on the other hand, we use the Uniform Building Code equation we find the following:

$$\mathbf{F = ZIC_pW_p}$$

$$F = 1 \times 1.5 \times 0.3 \times 3000$$
$$= 1350 \text{ pounds}$$

The Uniform Building Code has in this case under-designed this equipment for total base shear.

The reader may wish to refer to and review the Veterans Administration report "Study to Establish Seismic Protection Provisions for Furniture, Equipment & Supplies for VA Hospitals", by Stone, Marraccini & Patterson, Robert Barnecut and Georgeann Austin, 1976 and "Earthquake Protection of Essential Building Equipment" by Gary L. McGavin, AIA, 1981. This reading will enhance the reader's understanding of the static coefficient method of design. Both of these works approach static coefficient design from the UBC basic approach rather than from the Newtonian physics point of view and thereby have examples that do not agree with the method shown here.

Complex Mathematical Analysis

There are other methods of mathematically analyzing equipment. In general, these methods are fairly complex and, for the protection of equipment, should be left to specialists with specific expertise in earthquake engineering. Some equipment is so complex in itself, that it can not easily or accurately be mathematically modeled. If this is the case, then the equipment may require a combination of analysis and seismic tests. This is, however, not usually the case. In any event, mathematical analysis cannot guarantee equipment operation after an earthquake if the equipment has an operational failure.

The complex mathematical analysis can fairly accurately predict the resonant frequencies of the equipment if the equipment is modeled correctly. The mathematical model simply breaks the equipment down into mass-spring relationships for quantitative analysis. If the equipment is analyzed to have a natural frequency of twenty hertz (20Hz) or greater, the equipment is considered rigid. If the natural frequency is less than twenty hertz (<20Hz), the equipment is considered flexible. In general, it is the equipment in the low frequency ranges that are of most concern during an earthquake.

One of the first requirements in the more complex mathematical model analyses is to determine the type of model to be used. If the system is fairly simple, it might be modeled as a single degree of freedom system (SDOF); if it is fairly complex, it might be modeled as a multiple degree of freedom system (MDOF). Equipment shown in Figure 4.3 is an example of a SDOF piece of equipment while Figure 4.4 is an example of the more complex MDOF equipment.

Often, complex mathematical analysis will result in higher base shear requirements than those found by using the standard code approaches. The complex methods don't ignore Newtonian Physics as the static equivalent approaches have chosen to do. Table 4.3 lists some of the requirements for mathematical analyses:

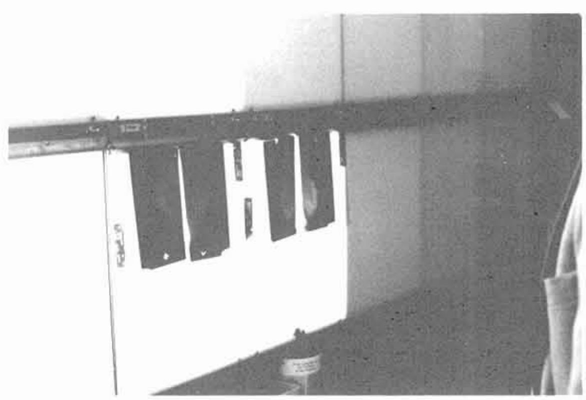


Figure 4.3 — Example of SDOF equipment. Wall mounted X-ray viewer is restrained by the wall and can only move in one direction.

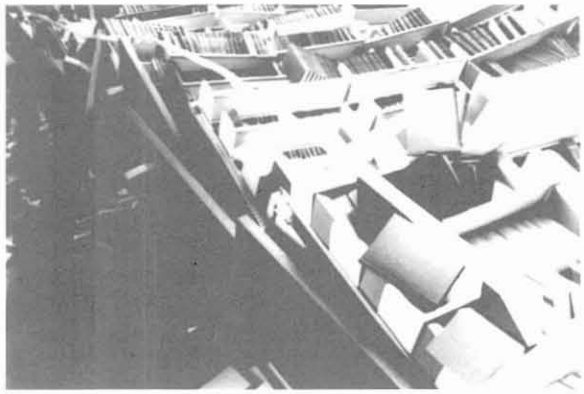


Figure 4.4 — Example of MDOF equipment. Library stacks that failed in an earthquake because they weren't anchored. **Photograph by William Harris, NBS.**

TABLE 4.3 Mathematical Analysis Required

If the Equipment is:	Analyze for:	By Using:
Rigid with high center of gravity	Overturning	Simple overturning & pullout of base anchors
Rigid with low center of gravity	Shear failure of base anchors	Static coefficient method for shear of base anchors
Flexible equipment (simple)	Natural frequency, velocity, displacement, acceleration, and base anchorage	Simple dynamic math model using response spectrum and base shear methods
Flexible equipment (complex)	Natural frequency, velocity, displacement, acceleration, and base anchorage	Complex dynamic math model using response spectrum, computer solutions, and base shear methods

Reproduced from "Earthquake Protection of Essential Building Equipment: Design, Engineering, Installation," by Gary L. McGavin, AIA, Published by John Wiley and Sons, Inc., NY, NY, Copyright 1981.

The phrase response spectrum is mentioned in the above table. The concept of the response spectrum has been extremely valuable to those designing for earthquakes. Unfortunately, it has not been widely used for the protection of equipment. This is true except for the nuclear power industry and for major projects, such as the Alaska Pipeline. Most have used the response spectrum for the dynamic analysis of building shells for the earthquake environment. The response spectrum approach can be reviewed in detail in works such as the Earthquake Engineering Research Institute Monographs "Earthquake Spectra and Design" by Nathan M. Newmark and William J. Hall, and "Earthquake Design Criteria" by George W. Housner and Paul C. Jennings.

Past Experience

In some cases, equipment may be considered qualified as a result of past experience. Past experience does not mean that because a piece of equipment survived a moderate earthquake in a hospital that is scores of miles away from the area of strong shaking, that it is considered "earthquake ready". Past experience is more accurate when an individual piece of equipment has undergone a seismic qualification test for another installation that can be documented. The previous seismic qualification program must equal or exceed the requirements for the new validation. As an example, a piece of equipment may have qualified for use at a military hospital. The use of the past experience category might, in some cases, be stretched to include equipment that has been qualified for use on a Naval hospital ship. Testing for the dynamic ocean environment may in some cases exceed the requirements for earthquake qualification. This is an avenue worth pursuing in future research. It would be valuable to determine if the shipboard environment is similar to the earthquake environment.

Design Team Judgment

Although it is not likely a viable seismic qualification technique for LSE, design team judgment can be a useful technique throughout the hospital for other pieces of equipment. Design team judgment does not require any sophisticated analyses. It relies solely on the designer, which may often include the hospital maintenance staff, and their innate understanding of the effects of an earthquake. There needs to be the simple recognition that things can and will move violently in an earthquake. Consequently if the hospital technical staff is expected to be able to perform in the emergency aftermath, loose items should be protected from being thrown to the floor. Examples of design team judgment might include the base plate for the microscope shown in Figure 5.18. This base plate was designed and installed to prevent theft, but will also adequately perform in an earthquake by not allowing the microscope to be dislodged. Other examples include adding shelf parapets for shelved items, tilting shelves to the rear, and other common sense approaches such as not placing heavy items on upper shelves. Numerous examples have been given by Reitherman, 1983, McGavin, 1981, Reid and Tarics, 1982, and Reitherman, 1986. Refer to Appendix 4 for an example base plate available for purchase.

Combined Approaches

In some cases, it may be advantageous to combine two or more of the qualification techniques discussed above for a comprehensive qualification program. In some cases, it may cost less to qualify LSE systems by analyzing some portions of the systems while physically testing other portions that have a likely operational failure mode.

Case Study Hospitals
5

CASE STUDY HOSPITALS

Two hospitals were selected as case-study hospitals. These case-study hospitals were toured, the staffs were interviewed, and the equipment was photographed in order to assist in defining Life Support Equipment (LSE) items.

The two hospitals selected were Valley Memorial Hospital in Livermore, California and the Jerry L. Pettis Memorial Veterans Administration Hospital in Loma Linda, California. The former is a private nonprofit hospital in a rural Northern California setting. The latter is a large government hospital in suburban Southern California.

The purpose of the project was to identify LSE items for further study. The authors have chosen to broaden the scope of the project and have provided an appendix that lists equipment and likely locations for the equipment. We have also provided suggestions for seismic categories. Ultimately the authors hope that this identification will be employed by the operators of hospitals so that the facilities will be able to perform their required functions after an earthquake.

Touring both hospitals left the clear impression that in the event of a damaging earthquake, both hospitals would be spending valuable time cleaning up rather than devoting staff time to emergency care. There is little doubt that many of these problems could be easily solved. The authors found few seismic protective measures for the identified LSE items.

Valley Memorial Hospital was built in 1969, which is prior to the California Hospital Seismic Safety Act of 1973. It may be presumed that earthquake-induced equipment movement may be greater than that of a post-1973 building. This hospital has in fact withstood a small earthquake (January 1980 Richter Scale Magnitude 5.5) with only minor problems. The outside communications were out of service as a result of P.T. & T. switching emergency communications lines in favor of Lawrence Livermore Laboratory. It should be pointed out that Lawrence Livermore Laboratory did sustain damage to equipment as a result of earthquake motion.

The Veterans Administration Hospital was constructed after the

Sylmar Earthquake of 1971 and employed many features such as a building configuration that should assist in reducing damage to both the structure and the equipment. The reader may wish to refer to Arnold and Reitherman's book on Building Configuration for a review of the merits of building configuration in aseismic design.

The tours and interviews indicate that the bulk of the functions at the two hospitals would be maintained in the aftermath of an earthquake if items are secured and storage patterns for immediate access to supplies are considered.

This doesn't provide the total answer for LSE. This specialized equipment will require additional considerations.

The following is a brief discussion of some of the major areas toured at the case-study hospitals on a unit-by-unit basis.

Administration

Although the hospital will need an administrative function after a moderate or a major earthquake, the loss of equipment in this area will not seriously impair hospital functions. There are no LSE items in the administrative areas. Damage will likely be confined to spills from table-top items, books from book shelves, filing cabinets, etc. Past experience has shown that office workers have been trapped in administrative spaces due to fallen filing cabinets that blocked doors.

Emergency

There are several LSE items in the emergency suites including the defibrillators and emergency carts. The emergency carts are portable but since they are classified as LSE items, they are listed in Seismic Category "A" rather than "D". The authors have commonly heard explanations as to why portable equipment must remain loose and cannot be secured (immediate need, etc.). At the Veterans Administration Hospital, the emergency carts are physically locked to the wall as shown in Figures 5.1 and 5.2 The locks have been installed by the hospital to prevent theft of the drugs in the carts. The emergency room staff indicated that the emergency cart locks do not hinder access to the carts. In fact, the staff said that the locks solve

Figure 5.1
Emergency cart. Note the locking box to the left of the cart.

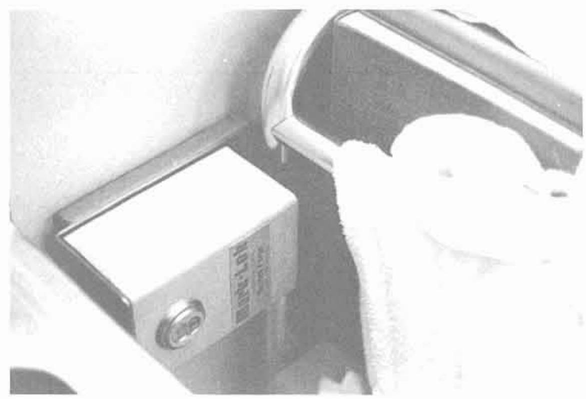


Figure 5.2
Detail of emergency cart lock box.

Figure 5.3
Defibrillator mounted on top of an emergency cart. This equipment is seldom secured to the emergency cart.

the problem of having to look for a cart when an emergency arises. The defibrillators are commonly mounted on top of the emergency carts as shown in Figure 5.3 and they run the risk of being thrown from the cart and rendered inoperable. The defibrillator is one of the few LSE items that does not need a sophisticated protective approach due to their solid state types of construction.

Throughout the rest of the emergency suite, Figures 5.4 through 5.8, are monitors, ventilators, portable EKG units, patient beds, I.V. stands, etc. These items are likely to be pitched to the floor and broken since they are normally not anchored. Patient monitors, which include cardiac and respiration monitors as well as strip-chart recorders in this unit and others, are usually on brackets attached to the walls and are likely to remain operational after an earthquake as long as they are attached to their mounting brackets. In some cases, they are left sitting on shelves unattached. Simple parapets such as that shown in Figure 5.9 have been able to prevent monitors from being thrown to the floor during an earthquake.

Pharmacy

There are no LSE items in the pharmacy. The major problems will arise from shelved items spilling and the possibility of containers breaking in the fall. This could result in mixing chemicals that can cause toxic and or volatile fumes. This probably isn't as likely in the pharmacy, however, as it is in the laboratory storage areas. Still, pharmacy medicines can easily be protected by simply tilting shelves back, adding shelf parapets, etc. Figure 5.10 shows a university pharmacy that employed such measures prior to an earthquake. The pharmacy as a whole should be considered in Seismic Design Category "A" because there are some medicines that will be immediately needed after an earthquake.

Medical Records Storage

The medical records of patients will be needed for the long-term operation of the hospital. This area does not contain any LSE items. The major dangers will be stored items shaken from their shelves and the possibility of the shelves themselves collapsing. The collapse of the shelves could pose a threat to those working between

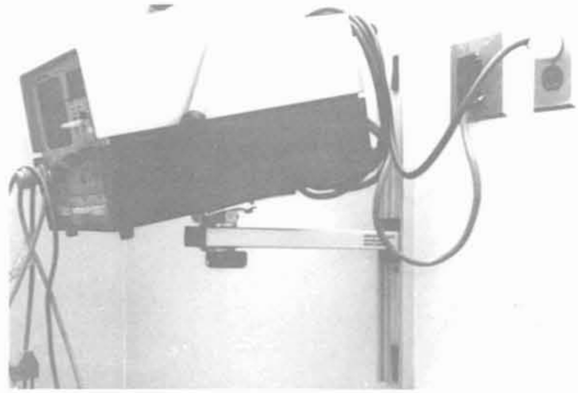


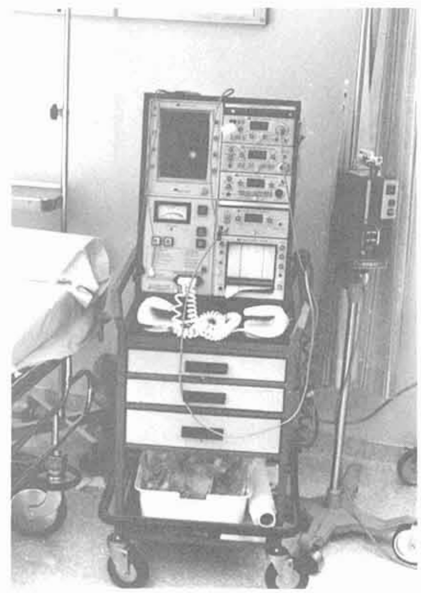
Figure 5.4
Wall mounted monitor. Wall bracket is rated for maximum equipment weight.

Figure 5.5
Portable ventilator. Wheel locks are not provided on this example.

Figure 5.6
Portable EKG machine. Wheel locks are not provided on this example.

Figure 5.7
Emergency room patient bed.

Figure 5.8
Wheeled cart with unsecured monitor on top. The cart does not have any wheel locks. The tall slender monitor is subject to toppling off of the cart.



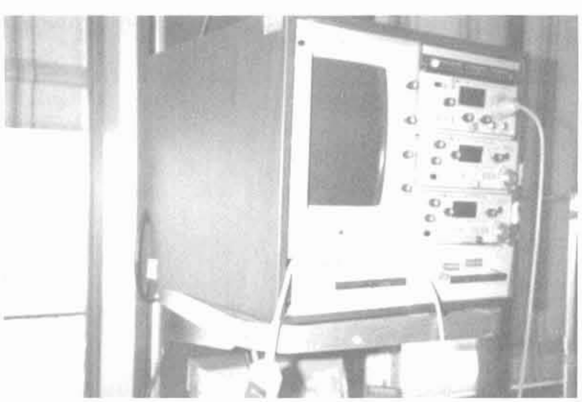


Figure 5.9
Monitor resting on a fixed shelf. The monitor is not restrained to the shelf but is protected by a shelf parapet.

the shelves at the time of the earthquake. These items are easily protected against earthquakes with shelf parapets and by interlocking the filing cabinets themselves. Figures 5.11 through 5.13 illustrate some medical record storage conditions and failures during recent earthquakes.

Hemodialysis Unit

The equipment in this area is generally wheeled and does contain LSE. A typical kidney dialysis unit is shown in Figures 5.14 through 5.17. These units are wheeled and sometimes are provided with wheel locks. The wheel locks were not found to be in use in the case-study hospitals. Conversations with the staff indicated that they would not object to having the units loosely fastened to the patient beds. The unit would then be prevented from rolling away from the patient, thereby disconnecting the equipment from the patient during an earthquake. In addition, this unit contains emergency carts, defibrillators, infusion pumps, respirators, etc.

Laboratories

The laboratories run the risk of being hardest hit during an earthquake. There are many equipment items that we have classified as Seismic Category "A" in the laboratories that are not LSE items. Most of the equipment in the laboratories is counter top mounted and much of it will be thrown to the floor even in a minor earthquake. See Figures 5.18 through 5.35.

Most of the equipment in the laboratory can be protected by installing restraints. Examples of restraints can be found in Appendix 2 of this report, the VA Research Study Report for the protection of furniture and equipment by Stone, Marraccini, & Patterson; Robert Reitherman's book for SCEPP; McGavin's book on the protection of essential building equipment; and Reid & Tarics' VA study. The reader should know, however, that some of the heavier items such as the blood banks, blood analyzers, and large centrifuges will require the attention of engineers for seismic protection. Inadequate or improper anchorage connections to these items may do more harm than good by pulling down walls or lifting counter tops. Not protecting the laboratories will lead to possible hospital contamin-

Figure 5.10
Photograph of shelved pharmacy bottles. Note top shelves tipped back and lower shelf with elastic cord restraining the bottles.
Photo credit: Richard Miller

Figure 5.11
Filing cabinets with medical records or other items stored on top of the cabinets are quite common.

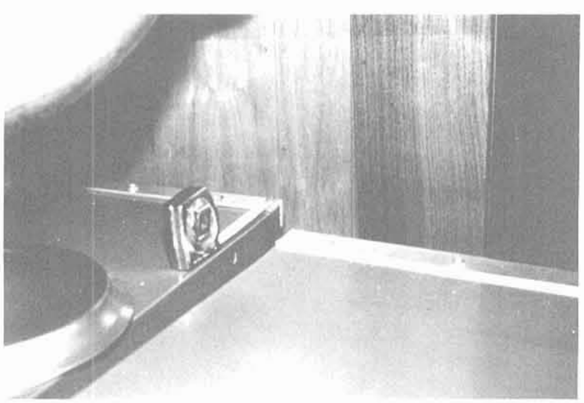


Figure 5.12
In an attempt to keep their filing cabinets upright and together, this facility used some angle aluminum which is too brittle and failed in an earthquake. Angle steel would have worked better.

Figure 5.13
Lightweight shelving that failed in an earthquake as a result of being overloaded with medical records.

Figure 5.14
Hemodialysis suite showing upright wheeled equipment. Wheel locks are not provided on this piece of equipment.

Figure 5.15
View of open back of hemodialysis unit. Horizontal shelf slides very easily and is susceptible to falling out. There are no cover plates on the back of this particular piece of equipment.

Figure 5.16
Detail of sliding shelf shown in Figure 5.15. If the shelf slides out too far, some of the plastic tubes containing deionized water can be pulled out possibly allowing air to be sucked into the system.

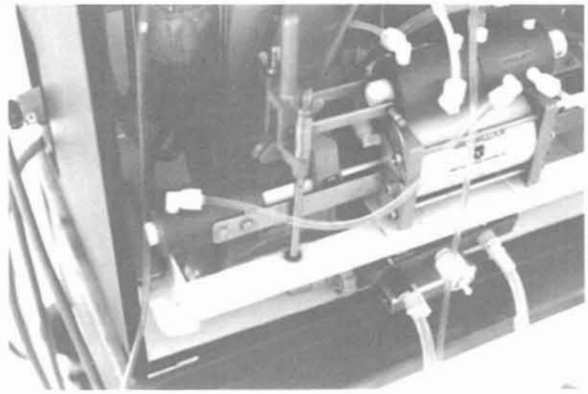


Figure 5.17
Detail of electronic control module of hemodialysis. Note small mechanical switches at the lower left. These switches are subject to flopping during an earthquake, thus creating false signaling.

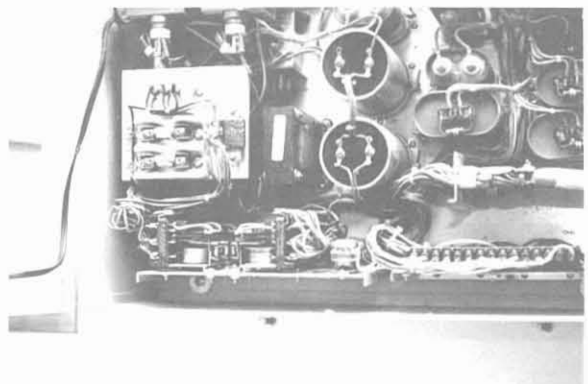


Figure 5.18
Laboratory microscope that has been fixed to the countertop to prevent theft. This will also prevent the microscope from falling to the floor during an earthquake.

Figure 5.19
Laboratory refrigerator that has been anchored to the wall.

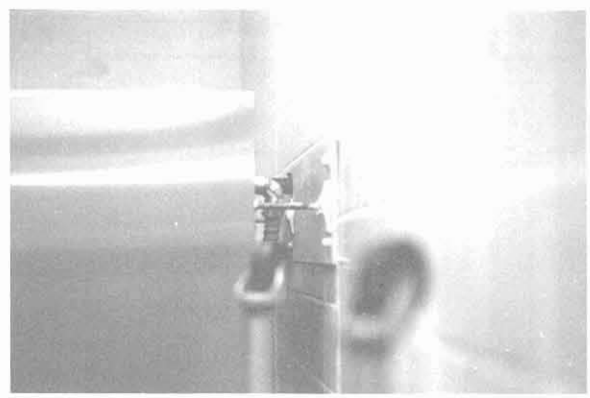


Figure 5.20
Detail photograph of refrigerator anchorage.

Figure 5.21
Unanchored laboratory refrigerator.

Figure 5.22
Unanchored laboratory culture incubator.

Figure 5.23
Laboratory counter with culture solutions. While the counter is anchored, there is nothing to prevent the solution containers from falling to the floor and spilling/mixing.

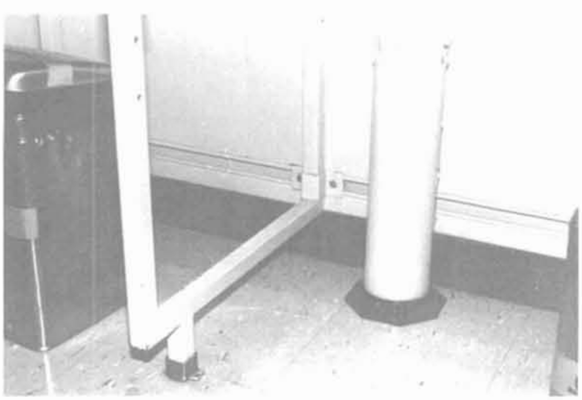


Figure 5.24
Detail of laboratory counter anchorage to both the floor and the wall behind the counter.

Figure 5.25
Many items in the laboratory are left unrestrained on shelves and countertops such as this centrifuge and the glass bottles on the shelf.

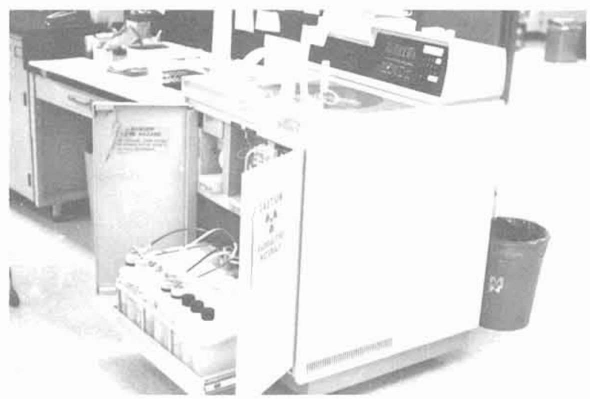


Figure 5.26
Laboratory analyzers such as this are seldom anchored. This unit has doors with magnetic latches which easily open in earthquake. The bottom tray is on rollers that can easily roll out and possibly spill the solutions.

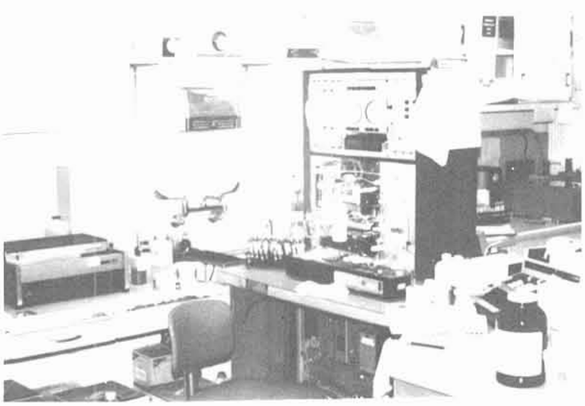


Figure 5.27
A countertop analyzer that can easily fall on the operator in an earthquake if it isn't restrained properly.

Figure 5.28
Front view of an analyzer. The equipment is located on a countertop and is not restrained.

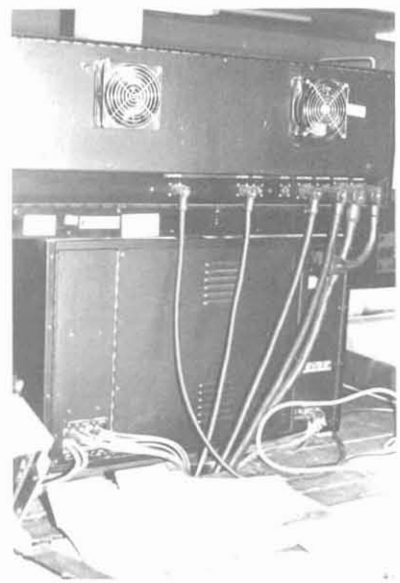


Figure 5.29
Rear view of the analyzer shown in Figure 5.27.

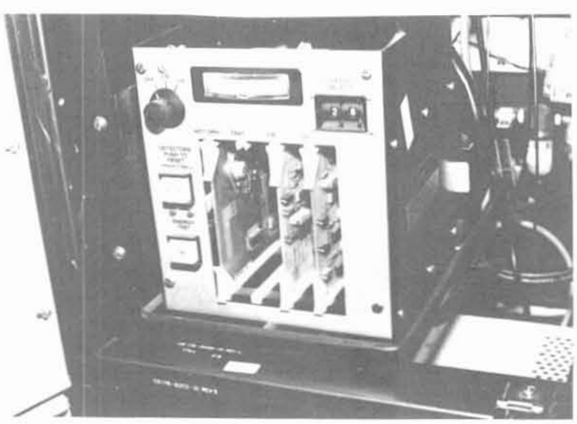


Figure 5.30
Detail of analyzer circuit boards. Note that each board is restrained by two positive latches.

Figure 5.31
Large floor mounted laboratory analyzer. This unit is unanchored.

Figure 5.32
Rear view of the analyzer shown in Figure 5.30. Note that there is nothing to prevent the solution bottles from sliding out of the analyzer.

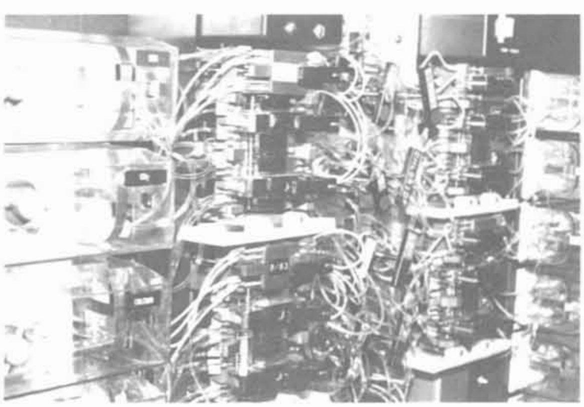


Figure 5.33
Detail of analyzer shown in Figure 5.31. Note the glass and plastic tubes that are susceptible to pulling out or breaking in an earthquake.

Figure 5.34
Compressed gas cylinders that are strapped together. These cylinders can easily fall and break off their tops. If the bottles are full or nearly full, they could do serious damage to the inside of a hospital.

Figure 5.35
Compressed gas cylinders that have heavy duty safety chains. If these chains are too loose, the bottles can slide to the floor. Base shoes would prevent this.

Figure 5.36
Adjustable X-ray table. This table is anchored to the floor.

ation through a variety of mechanisms, and at a minimum, will require valuable personnel to focus on cleanup rather than saving lives. In addition, some tests that would normally be conducted automatically, must be performed manually after a damaging earthquake if sensitive equipment is knocked out of calibration by banging around or toppling to the floor. The hospital in Coalinga suffered this. The laboratory was fine except for the counter-top equipment that was broken as a result of falling. It takes more manpower to run the necessary tests by hand than it does to have them run automatically.

Radiography

The X-ray suites are not likely to fare well in an earthquake, due to the nature of the equipment mountings. Most hospitals will likely rely on the portable X-ray units rather than the large fixed units in the suites. The fixed equipment in the suites needs to be considered as a system rather than as individual pieces. The X-ray equipment has not been classified as LSE, however, it is suggested that it be considered in Seismic Category "A" to best protect a hospital. Figures 5.36 through 5.45 show examples of X-ray equipment.

Surgical Suites

The bulk of the LSE that has been identified in this report is located in the surgical suites and similar spaces such as trauma, etc. Surgical suite LSE includes the following:

1. Anesthesia Gas Machine
2. Defibrillators
3. External Pacemakers
4. Heart-Lung Machines
5. Hyper-Hypothermia Unit
6. Infusion Pumps
7. Surgical Table
8. Ventilator

Figure 5.37
Adjustable X-ray table. The table is shown in the fully cantilevered position.

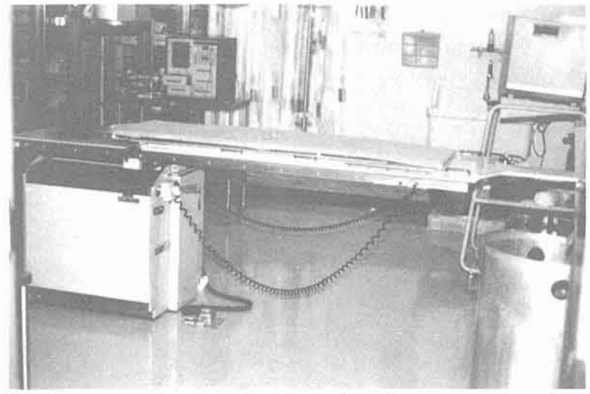
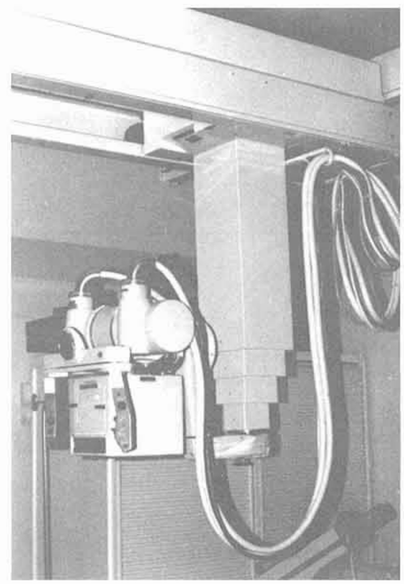


Figure 5.38
Suspended X-ray camera. These cameras are difficult to protect from earthquakes.



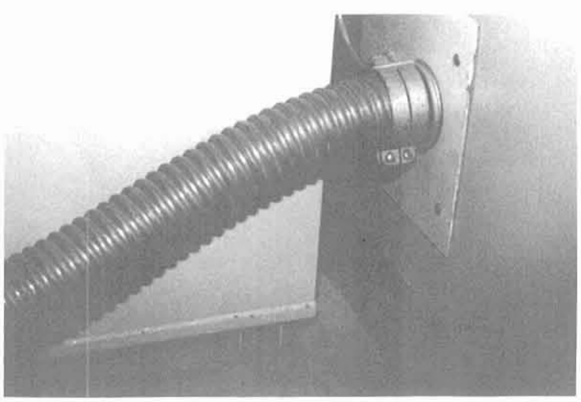


Figure 5.39
X-ray power unit. Note the flexible conduit that will aid in surviving an earthquake. Also note that the manufacturer has supplied a predrilled hole in the skid, but no anchor bolts have been installed.

Figure 5.40
X-ray film developing equipment is not anchored. The solution tanks are sitting loosely atop pedestals and will likely spill their contents.

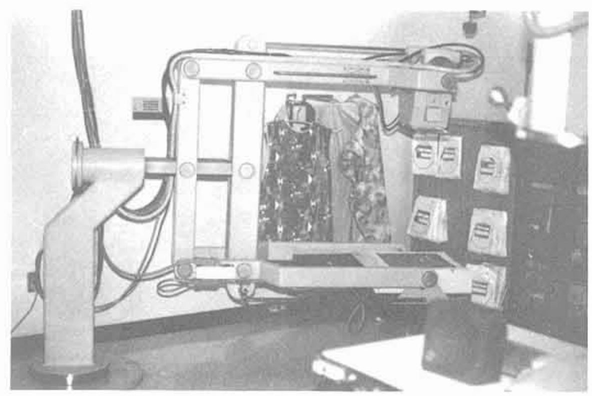


Figure 5.41
Specialized X-ray cameras such as this must be anchored due to their geometry.

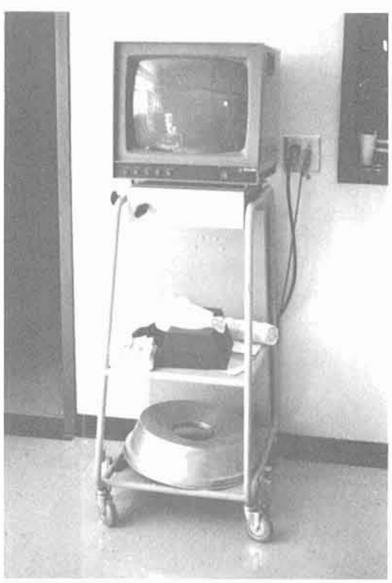


Figure 5.42
Remote-viewing CRT in the radiography suite. This type of equipment will most likely topple in an earthquake.

Figure 5.43
Portable gamma camera could possible tip or roll in an earthquake. The camera is heavy and could cause serious injury or damage.

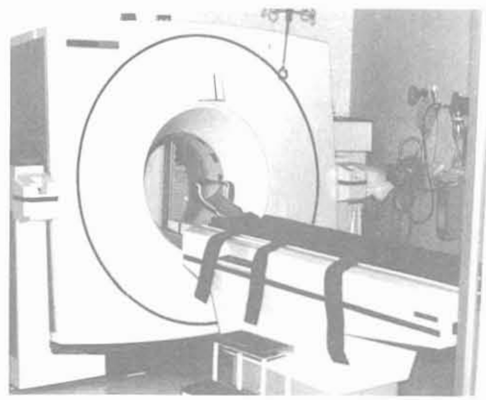


Figure 5.44
C.T. Scanner. This system should be considered for seismic protection due to its expense.

Figure 5.45
C.T. Scanner control console.

Figures 5.46 through 5.54 show typical surgical suites and associated equipment. It is easy to see that the area around the patient is quite cramped. Seismic protection of the equipment in the surgical suites will be difficult at best. Therein lies a dilemma. The highest concentration of LSE is found in the most difficult space to protect. In fact, most of the equipment can be easily protected when it is not in use.

The LSE designations have been assigned, in many of the cases, due to the danger to a patient if an operation is in progress at the time of the earthquake. There are many operations at which there is a point of no return, where the surgical team cannot simply back out of the operation. The operation must progress to a point where the procedure can be safely aborted. Unfortunately, some of the equipment for these procedures must be readily available to the surgical team and cannot be restrained. Possibly, some of the critical equipment can be fixed through suction cups or some other means that could be quickly disconnected. This would allow for some protection for the equipment. Future research should be conducted to determine the reasonableness of such protection. Other measures might include lowering the center of gravity of the equipment or some such other passive qualification that does not require the surgical staff to devote time and effort to protecting the equipment during an operation. Many of the LSE items are sensitive to dynamic motions and will likely fail if moved violently while in operation. This is a little easier to provide protection for. The equipment can be examined and strengthened from the inside. This form of qualification will be passive, as far as the surgical team is concerned, and will not interfere with the team's duties. Aside from the LSE items, there are numerous items that we have suggested for Seismic Category "A".

A serious problem that we noted in the surgical suites was a lack of storage space for sophisticated equipment. With the lack of storage space, which is usually the first space to be cut from a building as a cost-saving measure, much of the equipment that is needed on an intermittent basis was left in the circulation space. Some of this equipment is quite expensive and will likely sustain considerable damage since it is left unrestrained. This equipment could easily be protected.

Figure 5.46
Hospital operating room. Surgery is in process.

Figure 5.47
Anesthesia cart. The cart is mobile and is not provided with wheel locks. There are several parts of the cart that sit very high or hang off of the cart lending to a decrease in stability.

Figure 5.48
Base of an operating table. Tables are not always built-in as in this example.

Figure 5.49
Sterile instrument storage in the operating room.

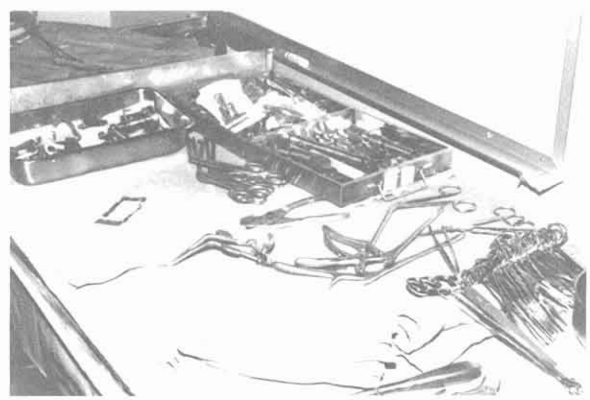


Figure 5.50
Sterile instrument table in the operating room. The table is not restrained.

Figure 5.51
Sterile instrument cart storage. These carts are provided with wheel locks and the locks were on. These carts are kept ready as an emergency back-up measure.

Figure 5.52
Cantilevered CRT in the operating room. This unit is designed to swing, swivel, and tilt. It is likely to do all of this in an earthquake.

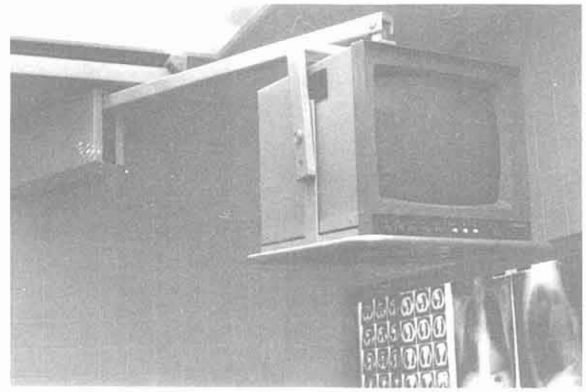


Figure 5.53
Wire cart for medicine and supplies. The cart has wheel locks. There is no protection for the contents of the cart which can easily fall off.

Figure 5.54
Hallways are commonly used for storage as seen here in the surgical suite. This situation will likely slow the emergency response after an earthquake while the equipment is uprighted and put back into place, out of the path of travel.

Central Computer

The computer system can only be considered a critical item in special conditions. For the most part, it contains financial and administrative data. Qualification of computer systems more complex than personal computers should be referred to engineers versed in earthquake protection of equipment. The computer should be qualified as a complete system rather than by individual pieces.

Patient Rooms

Patient rooms do not usually contain LSE. Exceptions could include ventilators. There are, however, monitors, etc. that do need consideration for the seismic environment. Items in the patient rooms can be qualified using the methods described for equipment in other areas.

Nursing Stations

While nursing stations do not usually contain any LSE items, they often contain equipment that we have recommended for Seismic Category "A". This includes patient monitors, alarms, and medication stations. Nursing Stations also contain filing cabinets that if unprotected, will only contribute to wasted manpower in the aftermath of an earthquake by requiring excessive clean up. Figures 5.55 through 5.57 illustrate typical nursing stations.

Miscellaneous Spaces

There are many other spaces that are included in the comprehensive health care facility. Spaces such as post-operative care, CCU, ICU, dietetics, physical therapy, morgue, nurseries, supply, processing, distribution, building maintenance, engineering, warehouse, clothing, etc. are all important to the continued function of a hospital. Units that have critical equipment, and in some cases LSE such as the ICU, CCU, and nurseries generally have the type of equipment that can be protected like equipment that has already been described.

Figure 5.55
Nursing station monitors built into the casework.

Figure 5.56
Nursing unit with unrestrained monitor on shelf.

Figure 5.57
Medicine carts stored and locked at the nursing station. Note lock boxes.

Identification of Life Support Equipment 6

IDENTIFICATION OF LIFE SUPPORT EQUIPMENT

Approximately 160 major hospital equipment items have been examined in the course of this research. Of these, approximately one-half have been assigned to Seismic Category "A" of which 15 have been further classified as Life Support Equipment (LSE). LSE items have been defined for the purposes of this report as equipment that is necessary for the continued life support of a patient. We have purposely excluded some building systems such as emergency power supplies due to the work that others are currently undertaking.

The approximately 160 or so equipment items that we examined for this project are but a mere fraction of the equipment items that are part of a comprehensive hospital. We selected the equipment for study as representative of the equipment that would be found in a hospital. We do feel fairly confident that the following list of LSE items is relatively complete for the hospital in operation today. The following table of equipment items lists the Seismic Categories and whether or not the equipment is classified as LSE. The LSE items are then discussed in detail.

TABLE 6.1

EQUIPMENT	SEISMIC CATEGORY	LSE
Analyzers		
1. Automatic Clinical	C	NO
2. Blood Cell	B	NO
3. Blood Gas	B	NO
4. Calcium	B	NO
5. Chloride	B	NO
6. Glucose	A	NO
7. Hemoglobinometer	A	NO
8. Sequential Multiple	C	NO

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
Surgical Instruments		
1. Arthroscope	C	NO
2. Bronchoscope	C	NO
3. Cardioscope	A	NO
4. Cautery	B	NO
5. Craniotome	B	NO
6. Cytoscope	B	NO
7. Ear Tray	B	NO
8. Eye Tray	B	NO
9. General Surgery Instruments	A	YES
10. Nephroscope	B	NO
11. Neurosurgical	B	NO
12. Orthopedic Frames	A	NO
Carts		
1. Cardiopulmonary/Resuscitation	A	NO
2. Electrocardiograph	B	NO
3. Emergency ("Crash")	A	YES
4. Endoscopy	B	NO
5. Isolation	A	NO
6. Medication	A	NO
7. Surgical Dressings	B	NO

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
Beds		
1. Adjustable	A	NO
2. Bassinets	A	NO
3. Fracture	A	NO
4. Infant Care Unit	A	YES
5. Infant Isolation Incubator	A	YES
6. Rotating	A	NO
Cabinets		
1. Bedside	B	NO
2. Catheter	B	NO
3. Combination Medicine	B	NO
4. Instruments	A	NO
5. Medication Dispensing Trays	B	NO
6. Surgical Instrument and Dressing	A	NO
7. Treatment	B	NO
8. Warming	C	NO
Operating Tables		
1. Fracture (Orthopedic)	A	NO
2. Surgical	A	YES
3. Urological	B	NO
Hemodialysis Apparatus		
1. Deionizer (Fixed)	A	YES
2. Kidney Dialysis Unit	A	YES

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
Communications		
1. Alarm Systems	A	NO
2. Annunciator	A	NO
3. Batteries	A	NO
4. Call Recorder	A	NO
5. Computer System (Information/Financial)	E	NO
6. Console	A	NO
7. Input/Output	A	NO
8. Power Packs	A	NO
9. Tape Drives	A	NO
10. Telautograph	C	NO
11. Teletype	C	NO
Respiratory Apparatus		
1. Croupette	A	NO
2. Humidifier	B	NO
3. Infant Incubation	A	NO
4. Inhalator	A	NO
5. Oxygen Cylinder with Flowmeter	A	YES
6. Percussor (Pulmonary Drainage)	B	NO
7. Respirator	A	YES
8. Respirometer	B	NO
9. Ventilator	A	YES

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
Surgery Equipment		
1. Anesthesia Gas Machine	A	YES
2. Autoclaves	B	NO
3. Blood Recovery Transfusion (Autotransfusion Pump)	B	NO
4. Hemorrhage Control Apparatus	A	NO
5. Hyper-Hypothermia Unit	A	YES
6. Infusion Pump	A	YES
7. Instrument Table	B	NO
8. I.V. Fluid Containers	A	NO
9. I.V. Stands (Trees)	A	NO
10. Irrigation Apparatus	A	NO
11. Operating Lights — fixed	A	NO
12. Operating Light — portable	A	NO
13. Restraints	A	NO
14. Solution Basin	C	NO
15. Solution Stand	C	NO
16. Sterilizer	B	NO
17. Suction Apparatus, Portable	A	YES
18. Table, Surgical	A	YES
19. Work Stations	B	NO

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
Imaging Equipment		
1. Automatic Film Developer	A	NO
2. Cassette Holder	B	NO
3. Cardiovascular Catheter	A	NO
4. Collimator	C	NO
5. CT Scanner	B	NO
6. Diagnostic Ultra Sound	C	NO
7. Fixed Fluoroscopic Unit	B	NO
8. Gamma Camera	C	NO
9. Geiger Counter	B	NO
10. Magnetic Resonance Imaging	B	NO
11. Radiation Shielding Screens	B	NO
12. Radiographic Unit (fixed)	A	NO
13. Radiographic Unit (mobile)	A	NO
Laboratory Apparatus		
1. Biological Safety Hood	B	NO
2. Blood Bank Refrigerator	A	NO
3. Cleaner, Ultrasonic	C	NO
4. Coulter Counter	B	NO
5. Hematocrit	A	NO
6. Hemoglobinometer	A	NO
7. Microscope, Electron	C	NO
8. Oximeter	A	NO

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
9. pH Meter	A	NO
10. Refrigerator, Biologicals	B	NO
11. Washer, Glassware	C	NO
Cardiovascular Equipment		
1. Defibrillator	A	YES
2. Heart-Lung Machine	A	YES
3. Magnetic Tape Recorder	C	NO
4. Resuscitator	A	YES
5. Pacemaker — External	A	YES
6. Pressure Transducer	B	NO
Patient Care Equipment		
1. Chart Rack	C	NO
2. Computer Monitoring	A	NO
3. Electrocardiograph	B	NO
4. Electrocardioscope	A	NO
5. Examination Lights	B	NO
6. Examination Table	B	NO
7. Illuminator	B	NO
8. Medical Gas Cylinders	A	NO
9. Oxygen Outlet	A	NO
10. Oxygen Tank (bulk)	A	NO
11. Shelving	A to E	NO
12. Sphygmomanometer	B	NO

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
13. Unit Dose Packaging Machine	C	NO
MISCELLANEOUS EQUIPMENT		
Administration		
1. Communications Console	A	NO
2. Computers (Information, Financial)	E	NO
3. Desks and Chairs	E	NO
4. Filing Cabinets	E	NO
5. Shelved Storage	E	NO
Alcoves		
1. Gurneys	D	NO
2. Wheelchairs	D	NO
Patient Rooms		
1. Bedside Cabinets	E	NO
2. Chairs and Tables	E	NO
3. Interval Clock	B	NO
4. Patient Lockers	E	NO
5. Portable Toilet	E	NO
6. Table, Over Bed	D	NO
7. TV — usually wall mounted	E	NO
Food Preparation and Serving		
1. Blenders	E	NO
2. Coffee Urn	E	NO
3. Deep Fryers	E	NO

TABLE 6.1 (continued)

EQUIPMENT	SEISMIC CATEGORY	LSE
4. Dish and Glass Dispensers	E	NO
5. Food Carts	D	NO
6. Food Cutters/Slicers	E	NO
7. Food Racks	E	NO
8. Freezers	E	NO
9. Hot/Cold Serving Line	E	NO
10. Hot Plate	E	NO
11. Ice Machines	E	NO
12. Juice Extractor	E	NO
13. Kettles	E	NO
14. Microwave Ovens	E	NO
15. Milk Dispensers	E	NO
16. Ovens	E	NO
17. Peelers	E	NO
18. Preparation Tables	E	NO
19. Refrigerators	E	NO
20. Stoves	E	NO

The decision to place a particular piece in the LSE category is by its very nature somewhat subjective. There are many cases where a particular piece of equipment could in some cases have a life support function, but due to the short duration of the life support function, or the low probability that the equipment would be in use during an earthquake, the equipment has been excluded from the LSE category. It may still, however warrant the Seismic Category "A" due to the eventual demand for the equipment. In other cases, some equipment is only used for diagnostic purposes and can not be classed as LSE. It too may be classed in Seismic Category "A". Table 6.1 actually tallies nineteen "yes" responses to the LSE question. This is a result of duplication of equipment in more than one category in some cases such as operating tables, and breaking systems down into individual pieces of equipment in other cases. We have identified fifteen separate LSE items.

The next data pages in this chapter list the following data about each of the fifteen pieces of LSE that we have identified in the table above:

1. Seismic Category: by definition, all of the LSE items are included in Seismic Category "A".
2. Seismic Code Imposed: any codes which impose specific requirements for individual pieces of equipment
3. Projected Damage to Unprotected Equipment: matrix form compares earthquakes of both moderate and severe intensity
4. Recommended Seismic Qualification Method: seismic test, math analysis, etc. are suggested
5. Physical Restraints Suggested: the VA Seismic Restraint Handbook details have been referenced and are included in the appendix for the reader's reference . . . other references are made where appropriate
6. Alternative Precautions: other possible methods for achieving the same results rather than to qualifying the equipment
7. Representation Photographs: shows a generic piece of equipment
8. Functional Description: description of how the equipment operates
9. Probable Locations: where the equipment is likely to be located within the hospital
10. Utility Support Required: utilities required for the equipment's continued operation
11. Miscellaneous Remarks

ITEM NAME: ANESTHESIA GAS MACHINE

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
●	●	Impact by external objects.
	●	Displacement of internal components.
	●	Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic and Seismic Test

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

See Remarks

ALTERNATIVE PRECAUTIONS:

See Remarks

ITEM NAME: ANESTHESIA GAS MACHINE

REPRESENTATIVE PRODUCT:

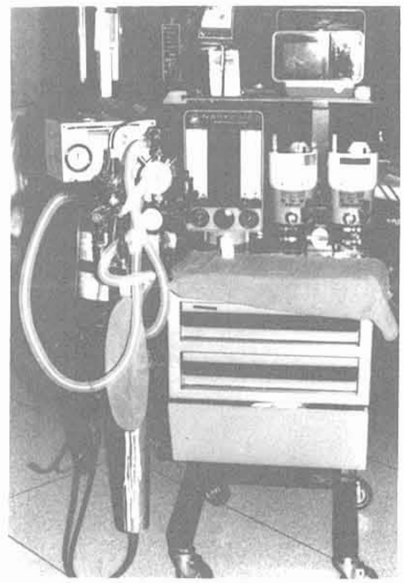


Figure 6.1

FUNCTIONAL DESCRIPTION:

Used to administer anesthetic agents to patient during surgical procedures.

PROBABLE LOCATIONS:

Operating Room, Delivery Room, Trauma Room.

UTILITIES SUPPORT REQUIRED:

Electrical:	120V.
Medical Gas:	Oxygen; Air; Nitrous Oxide.
Mechanical:	Venting.

REMARKS:

When in use, anesthesia machine is located away from walls or structural support. Wheel brakes or floor anchoring would provide limited protection due to physical configuration of these units. Some ceiling suspended units available in the European market are now marketed in America, but are not currently in wide use.

ITEM NAME: CART, EMERGENCY

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity Moderate	Earthquake Intensity Severe	
●	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Static Coefficient (Wall Anchor)

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL; S2.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup supplies in casework nearby.

ITEM NAME: CART, EMERGENCY

REPRESENTATIVE PRODUCT:

Figure 6.2

FUNCTIONAL DESCRIPTION:

Contains supplies, medications, and instruments required for life support and resuscitation procedures during cardiac arrest or fibrillation (Heart attack).

PROBABLE LOCATIONS:

Critical Care Units, Emergency Rooms, Operating Rooms, Intensive Care Nurseries, Inpatient Units.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V.

REMARKS:

Defibrillator often located on top of this item and should be attached. Cart can be secured when in stand-by mode. When in use can be in any location or position however.

ITEM NAME: DEFIBRILLATOR

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity Moderate	Severe	
	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
●	●	Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Static Coefficient (anchor to cart)

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: AP, HL1.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.61.

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup equipment in protected location.

ITEM NAME: DEFRIBILLATOR

REPRESENTATIVE PRODUCT:

Figure 6.3

FUNCTIONAL DESCRIPTION:

Produces electrical stimulation to heart muscle to start or modify electro-muscular activity.

PROBABLE LOCATIONS:

Operating Rooms, Delivery Rooms, Emergency Rooms, Intensive Care Units, Inpatient Units, Cardiology, Post-anesthesia Recovery.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V. (Some units battery operated w/recharger).

REMARKS:

Often placed on top of portable cart without attachment. Battery-operated units would be more likely to be usable in a post-earthquake situation.

ITEM NAME: EXTERNAL PACEMAKER

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity		
Moderate	**Severe**	
		Impact by external objects.
		Displacement of internal components.
	●	Internal component failure probable.
●	●	Overturn, displacement, disconnection.
	●	Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic and Seismic Test

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: AP; HL1; S1.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.61.

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup equipment in protected location.

ITEM NAME: EXTERNAL PACEMAKER

REPRESENTATIVE PRODUCT:

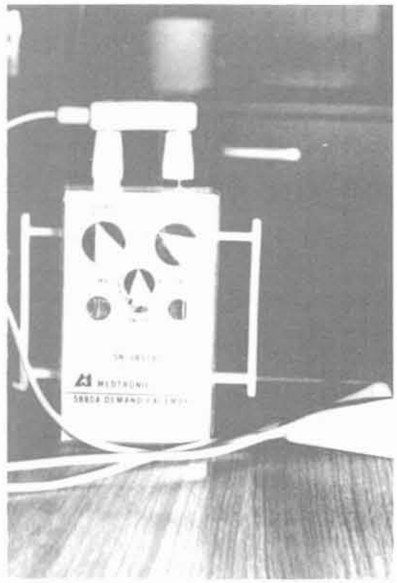


Figure 6.4

FUNCTIONAL DESCRIPTION:

Electrically stimulates heart muscle to restore and maintain normal function.

PROBABLE LOCATIONS:

Intensive Care Unit, Operating Rooms, Trauma Room

UTILITIES SUPPORT REQUIRED:

Electrical: 120V.

REMARKS:

Also has theraputic applications which are not for life support, but unit should be protected for use in emergency situations.

ITEM NAME: GENERAL SURGICAL INSTRUMENT SET

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
		Impact by external objects.
		Displacement of internal components.
	●	Internal component failure probable.
	●	Overturn, physical displacement, disconnection.
●	●	Falling from support mounting.
●	●	Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Static Coefficient and Design Team Judgement

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: S3.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.20; 4.61.

ALTERNATIVE PRECAUTIONS:

Sterile backup sets.

ITEM NAME: GENERAL SURGICAL INSTRUMENT SET

REPRESENTATIVE PRODUCT:

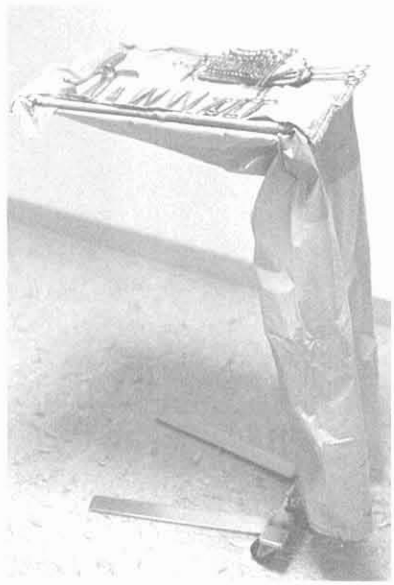


Figure 6.5

FUNCTIONAL DESCRIPTION:

Used to perform surgical procedures. Set must be sterile before and during use.

PROBABLE LOCATIONS:

Operating Room, Delivery Room, Trauma Room.

UTILITIES SUPPORT REQUIRED:

None.

REMARKS:

When in use, sets are located away from walls or structural support usually placed on portable table or stand. Wheel brakes or floor anchoring would provide limited protection due to physical configuration of such units. Set must be restrained from falling off stand or table during major surgical procedures. Composition of instrument set varies according to surgical procedure, but most often held in tray for sterilization, transport, and case preparation.

ITEM NAME: HEART-LUNG MACHINE

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
	●	Impact by external objects.
●	●	Displacement of internal components.
	●	Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
●	●	Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Seismic Dynamic Testing
Mathematical Analysis: Dynamic

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

None

REPRESENTATIVE PRODUCT:

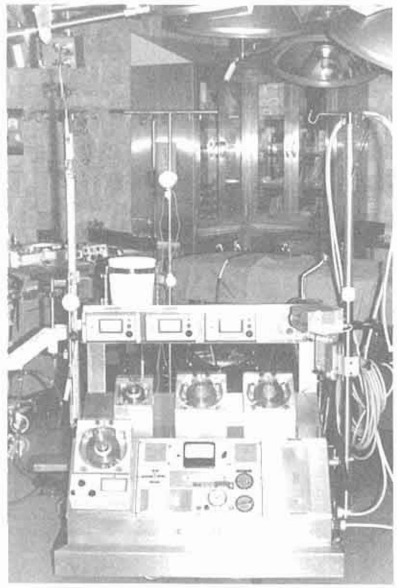


Figure 6.6

FUNCTIONAL DESCRIPTION:

Circulates, oxygenates and controls temperature of patient blood supply.

PROBABLE LOCATIONS:

Operating Room.

UTILITIES SUPPORT REQUIRED:

Electrical:	120V.
Lighting:	Ambient.
Plumbing:	Cold Water (selected models).
Medical Gas:	Oxygen.

REMARKS:

When in use unit not located near wall or structural support. Use of wheel brakes or floor anchors would improve protection.

ITEM NAME: HYPER-HYPOTHERMIA UNIT

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
●	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic and Seismic Test

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

ALTERNATIVE PRECAUTIONS:

Cooling can be accomplished with ice or cold packs if available, on an emergency basis. Heating can be accomplished with warmed blankets or heating pads on an emergency basis.

ITEM NAME: HYPER-HYPOTHERMIA UNIT

REPRESENTATIVE PRODUCT:

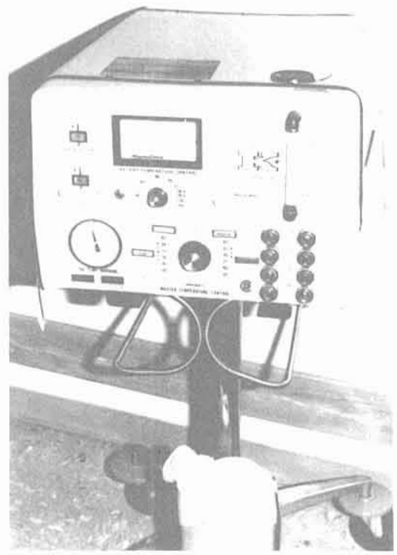


Figure 6.7

FUNCTIONAL DESCRIPTION:

Heats or cools surgical or critical patient using circulating liquid contained in vinyl pads. Combination refrigeration and heating pump.

PROBABLE LOCATIONS:

Operating Room.

UTILITIES SUPPORT REQUIRED:

Electrical:	120V.
Plumbing:	Cold Water (selected models).

REMARKS:

Life support device during coronary arterial bypass surgical procedure and certain critical patient care conditions. Other applications may not be life support situations.

ITEM NAME: INFANT CARE UNIT

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
●	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

None.

REPRESENTATIVE PRODUCT:

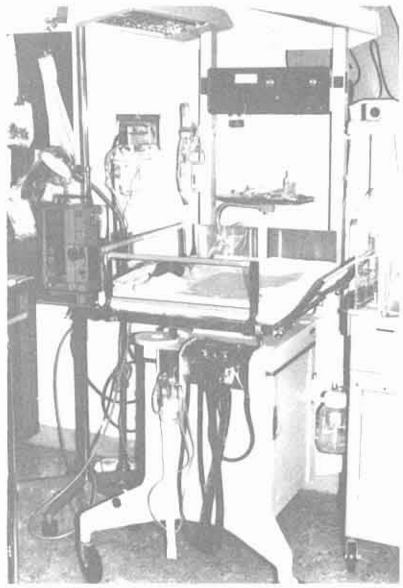


Figure 6.8

FUNCTIONAL DESCRIPTION:

Provides temperature control, therapeutic lighting and equipment support for newborn infants.

PROBABLE LOCATIONS:

Delivery, Nurseries, Emergency.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V.
Lighting: Emergency.
Medical Gas: Oxygen.

REMARKS:

Often located away from walls or structural support when in use. Vertical design suggests counterweight may improve stability.

ITEM NAME: INFANT ISOLATION INCUBATOR

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
●	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

None

REPRESENTATIVE PRODUCT:

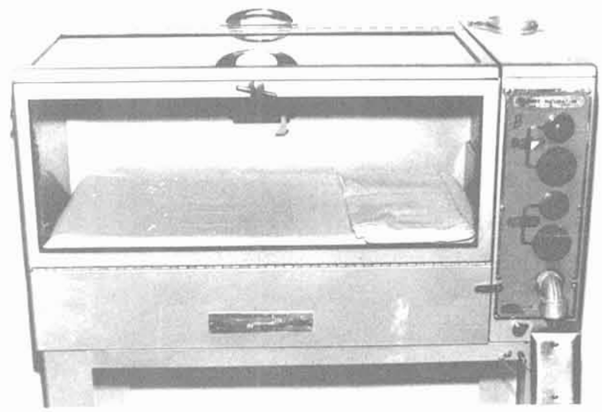


Figure 6.9

FUNCTIONAL DESCRIPTION:

Provides enclosed controlled environment chamber for newborn infants.

PROBABLE LOCATIONS:

Nurseries

UTILITIES SUPPORT REQUIRED:

Electrical:	120V.
Lighting:	Emergency.
Medical Gas:	Oxygen.

REMARKS:

Counterweight would improve stabillity. Use of wheelbrakes or floor anchors would provide improved protection. When in use, unit is often not at wall or structural support.

ITEM NAME: INFUSION PUMP

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None, unless wall mounted, then UBC, NBSIR812195

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
●	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Static Coefficient (Wall Mount)
Dynamic (on pole).

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: S5.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.68.

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup equipment
Wall mount in locations where functionally feasible.

REPRESENTATIVE PRODUCT:

Figure 6.10

FUNCTIONAL DESCRIPTION:

Controls or meters the administration of intravenous fluids and medications.

PROBABLE LOCATIONS:

Any Inpatient Unit, Post-anesthesia Recovery, Critical Care Unit, Operating Rooms, Labor Rooms, Emergency Rooms, Nurseries.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V. (Some models battery operated w/recharger).

REMARKS:

Can be wall mounted rather than I.V. Pole mounted. This option should be considered in areas such as Critical Care, Labor Rooms, Nurseries, and Inpatient Units.

ITEM NAME: KIDNEY DIALYSIS UNIT

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity Moderate	Severe	
●	●	Impact by external objects.
	●	Displacement of internal components.
	●	Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
	●	Flooding by spilled fluids.
●	●	Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Static Coefficient (Dynamic) and Seismic Test

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

Backup portable unit stored in protected location.
Transfer patients to unaffected facility.

REPRESENTATIVE PRODUCT:

Figure 6.11

FUNCTIONAL DESCRIPTION:

Pumping and filtering device to externally remove waste materials from circulating blood (artificial kidney).

PROBABLE LOCATIONS:

Hemodialysis Unit, Dialysis Center.

UTILITIES SUPPORT REQUIRED:

Electrical:	120V.
Lighting:	Ambient.
Plumbing:	Pure Water; Waste (selected models).

REMARKS:

Acute patients require continuous support. Chronic patients can tolerate limited disruption of service. Units often part of piped system for central dialysate preparation. All components of such systems become life support items and must be protected accordingly.

ITEM NAME: OXYGEN CYLINDER W/REGULATOR, CART

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required. (For critical patients).

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity Moderate	Earthquake Intensity Severe	
	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support mounting.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Static Coefficient

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: CR, S5.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.59.

See Remarks

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup equipment for emergencies
Medical Oxygen central system, if operable.

ITEM NAME: OXYGEN CYLINDER W/REGULATOR, CART

REPRESENTATIVE PRODUCT:

Figure 6.12

FUNCTIONAL DESCRIPTION:

High pressure storage for medical breathing oxygen, with pressure reduction and flow regulator for administration. Essential to back up central piped system or to support patients not located near piped oxygen outlet.

PROBABLE LOCATIONS:

All inpatient locations, Post-anesthesia Recovery, Surgery, Respiratory Therapy, Engineering, Critical Care Units, Emergency, Nurseries.

UTILITIES SUPPORT REQUIRED:

None.

REMARKS:

These portable carts transport and hold cylinders and are used when piped system is not operable, or when patient is not near a piped system outlet. Such devices are difficult to protect when in use.

ITEM NAME: SUCTION APPARATUS, PORTABLE CHEST/THORACIC

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
●	●	Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
	●	Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic and Seismic Test

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL; HL1.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup equipment in protected location.
Optional wall mount assembly operated by central medical vacuum system.

ITEM NAME: SUCTION APPARATUS, PORTABLE CHEST/THORACIC

REPRESENTATIVE PRODUCT:

Figure 6.13

FUNCTIONAL DESCRIPTION:

Provides low negative pressure suction for draining fluids from patients chest cavity or lungs.

PROBABLE LOCATIONS:

Intensive Care Units, Post-anesthesia Recovery.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V.

REMARKS:

Wall mounted vacuum driven units require continued operation of the central vacuum system. Electric models are usually portable design not readily converted to wall mounting.

ITEM NAME: SURGICAL TABLE

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity: Moderate	Earthquake Intensity: Severe	
		Impact by external objects.
		Displacement of internal components.
		Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

ALTERNATIVE PRECAUTIONS:

None

ITEM NAME: SURGICAL TABLE

REPRESENTATIVE PRODUCT:

Figure 6.14

FUNCTIONAL DESCRIPTION:

Support and positioning of patient during all surgical procedures.

PROBABLE LOCATIONS:

Operating Room, Emergency Trauma Room.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V. (If powered).

REMARKS:

Most surgical tables are portable with caster brake or braking mechanism. A protocol to set brake would be useful for preventing horizontal travel. Cantilever design of most tables require weighted base to prohibit overturning.

ITEM NAME: VENTILATOR, RESPIRATOR

SEISMIC CATEGORY:

A Life support equipment: Continuous immediate functioning required.

SEISMIC CODE IMPOSED:

None

PROJECTED DAMAGE TO UNPROTECTED EQUIPMENT:

Earthquake Intensity Moderate	Severe	
●	●	Impact by external objects.
	●	Displacement of internal components.
	●	Internal component failure probable.
●	●	Overturn, displacement, disconnection.
		Falling from support surface.
		Flooding by spilled fluids.
		Contamination from external materials.

RECOMMENDED SEISMIC QUALIFICATION METHOD:

Mathematical Analysis: Dynamic and Seismic Test

PHYSICAL RESTRAINTS SUGGESTED:

"V.A. Seismic Restraint Handbook" Detail: FL.

"Earthquake Protection of Essential Building Equipment"
Figure: 4.69.

ALTERNATIVE PRECAUTIONS:

Maintain on-site backup equipment in protected location.
Some models can be wall mounted.

ITEM NAME: VENTILATOR, RESPIRATOR

REPRESENTATIVE PRODUCT:

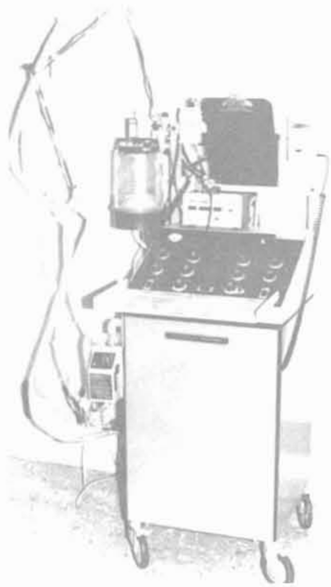


Figure 6.15

FUNCTIONAL DESCRIPTION:

Manages critical patient respiration process.

PROBABLE LOCATIONS:

Operating Rooms, Post-anesthesia Recovery, Critical Care Units, Emergency-Trauma, Intensive Care Nurseries.

UTILITIES SUPPORT REQUIRED:

Electrical: 120V.
Medical Gas: Oxygen, Air.

REMARKS:

Ventilator must often be transported with patient if relocation is required. Use of wheel brakes or floor anchors would provide only limited protection. Counterweight may improve stability.

Conclusions and Recommendations 7

CONCLUSIONS AND RECOMMENDATIONS

This report has examined equipment necessary for the continued operation of hospitals and for the continued life support of patients both during and after an earthquake. This is called Life Support Equipment (LSE). In addition to examining LSE, this report has discussed qualification methods available for the seismic protection of all hospital equipment.

During the course of this research, approximately 160 pieces of equipment were examined. Out of these, we have identified 15 as LSE. Approximately one-half of all the equipment items examined are classified as Seismic Category "A". Seismic Categories have been defined as letters from "A to E". The Seismic Category is based on the relative need for a particular piece of equipment. For example, category "A" equipment is needed for the immediate and continued operation of a hospital, whereas category "C" equipment is only needed for the long-term operation of a hospital. In general, equipment in either category "A" or "B" requires more protective measures for earthquake survivability. All of the LSE items fall into Seismic Category "A" by definition.

The following equipment items have been determined to be LSE by the authors:

1. Anesthesia Gas Machine
2. Cart, Emergency
3. Defibrillator
4. External Pacemaker
5. General Surgical Instrument Set
6. Heart-Lung Machine
7. Hyper-Hypothermia Unit
8. Infant Care Unit
9. Infusion Pump

10. Infant Isolation Incubator

11. Kidney Dialysis Unit

12. Oxygen Cylinder with Flowmeter

13. Suction Apparatus, Portable

14. Surgical Table

15. Ventilator/Respirator

While examining the LSE items, we found that most of these items were not protected from seismic activity. Many are wheeled equipment items which some say are more difficult to qualify. This is not necessarily the case. Restraints can be used when the equipment is not in use as seen with the crash carts that were locked to the wall in the Jerry L. Pettis Memorial Veterans Administration Hospital in Loma Linda. Locking devices such as these are commercially available. The restraints on the crash carts were not provided for seismic protection, but to prevent theft since the carts contain drugs. Nevertheless, these restraints will assure that the crash carts will be immediately available after an earthquake when they are needed. The staff reported that the locking devices are not a hinderance when the carts are needed in an emergency. In fact, some staff members said the locking devices guarantee that the equipment will be in a known location when an emergency arises.

Many LSE items are likely to have operational modes of failure (failure by the inability to operate rather than sliding or overturning, etc.). None of the LSE in the two hospitals was found to have been previously qualified or received any protective measures to guard the equipment against earthquakes. Representative equipment manufacturers were contacted to determine if they had previously qualified their equipment for earthquakes under any program. All of the manufacturers stated that, due to legal problems, they could not discuss any measures that they had or had not taken to qualify their equipment for the earthquake environment. To the authors, this is a sad commentary when the fear of legal reprisal dictates the pursuit of knowledge.

This report has left many questions unanswered. We would suggest that future researchers consider the following topics for further study:

1. What effects building base isolation systems will have on building contents. Possibly, full scale or scale model tests could be conducted at seismic testlaboratoriesto determine the effects. The vertical component of earthquakes should not be ignored.

2. Generic seismic qualification of LSE should be conducted for equipment that has a likely operational mode of failure. Seismic tests may need to be conducted in order to protect these equipment items. This may be difficult due to the legal position of the equipment manufacturers.

3. Seismic test programs to determine what effects an earthquake will have on the following:

   - Wheeled equipment without wheel locks in place.
   - Wheeled equipment with wheel locks in place.
   - Wheeled equipment that is tethered.
   - Tabletop equipment that is tethered.

4. Determine if equipment has been previously qualified for similar environments, such as shipboard conditions.

5. Examine the feasibility of seismic legislation for mandating the continued operation of hospitals both during and after an earthquake. The legislation should consider both fixed and portable equipment.

6. Provide programs that educate the hospital staff in the necessity of maintaining operations during and after an earthquake. This type of program is currently in progress for FEMA by Reitherman and Scientific Service, Inc. These types of programs should be continued.

7. The building codes need to be examined to determine if they are adequate for protecting equipment. Conditions that must be met include:

- Provide for vertical shaking.
- Provide more realistic protection methods rather than simple equivalent static coefficient (i.e. dynamic analysis and seismic testing where appropriate).
- Provide that the static equivalent acceleration levels are appropriate.
- Provide static equivalent formulas with mass relationships rather than weights.

Pursuit and implementation of these conditions will help make certain that hospitals are equipped and ready for operation both during and after an earthquake. This is a necessary task in order to meet the dictates of the current codes and for the continued operation of essential facilities.

Appendix 1

APPENDIX 1

Appendix 1 has been provided to assist the reader in identifying equipment locations, functions, and to present the author's suggestions for seismic categories. The latter was also presented in table 6.1. This information has been included here so that the reader does not need to reference between the two tables.

The following abbreviations have been used in this appendix:

Admin	=	Administration
Burn	=	Burn Center
Cath	=	Cardiac Catheterization Lab
CCU	=	Coronary Care Unit
CVO	=	Cardio-vascular Operating
Cysto	=	Cystoscopy Room
ER	=	Emergency Room
Hemo	=	Hemodialysis
ICN	=	Intensive Care Nursery
ICU	=	Intensive Care Unit
Lab	=	Laboratory
NSY	=	Nursery
NUR	=	Nurses Station
OB	=	Obstetrics
OPD	=	Out Patient Department
OR	=	Operating Room
PED	=	Pediatrics
RAD	=	Radiology

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
Analyzers		
1. Automatic Clinical — used for multiple tests of a single substance	Lab	C
2. Blood Cell — evaluates relative amounts of red & white blood cells	Lab	B
3. Blood Gas — measures oxygen and carbon dioxide tension in arterial blood	Lab	B
4. Calcium — analyzes undiluted body fluids	Lab	B
5. Chloride — analyzes undiluted body fluids	Lab	B
6. Glucose — measures sugar content in blood	Lab	A
7. Hemoglobinometer — measures hemoglobin	Lab	A
8. Sequential Multiple — used for sequential testing of multiple items	Lab	C
Medical Surgical Sets		
1. Arthroscope — knee joint exam	OR, ER	B
2. Bronchoscope — lung exams	OR, ER	C
3. Cardioscope — displays cardiac pulse tracings on CRT	OR, ER	A
4. Cardiovascular Catheter — small tube passed into heart chambers to measure pressure and detect inappropriate blood mixing	OR, ER, OB, CVO	C
5. Cautery — heated instrument to remove tissue or stop bleeding	OR, ER, OB, CVO	B
6. Craniotome — cutting device for surgery of the cranium	OR, ER, OB	B
7. Cytoscope — urinary exams	OR	B
8. Ear Tray — ear surgery	OR, ER	B

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
9. Eye Tray — eye surgery	OR, ER	B
10. General Surgery — general, dental, and experimental surgery	OR, ER, OB, CVO	A
11. Nephroscope — kidney exams		B
12. Neurosurgical — brain and nervous system surgery	OR	B
13. Orthopedic Frames — attached to patient bed to support broken bones	Nur	A
Carts		
1. Cardiopulmonary/Resuscitation revives heart/lung patients	OR, ER, OB, CVO, Nur	A
2. Crash — provides prompt availability of reanimative gas, drugs, biologicals, serums, and resuscitative measures to patients in extreme emergencies	OR, ER, OB, CVO, ICU, CCU, Burn, Nur	A
3. Electrocardiograph — used to analyze heart action	OR, ER, OB, CVO	B
4. Endoscopy — exams of organ interiors	OR, ER, OB	B
5. Isolution — serves clinically isolated patients, stores solutions, gowns, masks, supplies, etc.	Nur, ICU, CCU Burn	A
6. Medication — used to dispense drugs, biologicals at bedside	Nur, ICU, CCU, Burn	A
7. Surgical Dressings — changing bandages at bedside	Nur, ICU, CCU, Burn	B
Beds		
1. Adjustable — rest, therapy, recuperation, treatment	Nur, ICU, CCU, Burn	A
2. Bassinets — newborn/infant rest and general treatment	Nsy, ICN	A

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
3. Fracture — provides bed with heavy webbing and springs for patients with broken bones	Nur, ICU, CCU, Burn	A
4. Infant Incubator — maintains proper temperature and humidity environment for premature infants	Nsy, ICN	A
5. Isolette — equipped with plastic hood to maintain controlled environment to separate infants suspected of having infectious conditions	Nsy, ICU	A
6. Rotating — alters patients position to relieve pressure points	Nur, ICU, CCU, Burn	A
Cabinets		
1. Bedside — used as mounting base for respirators, monitors, suction apparatus, etc.	Nur, ICU, CCU, ICN, Nsy	B
2. Catheter — contains probes for cardiovascular procedures, urinary procedures, etc.	OR, ER, OB, CVO	B
3. Combination Medicine — has narcotic locker in upper section and refrigerator in enclosed base . . . counter worktop is provided	ICU, CCU, ICN, Burn, Nur	B
4. Instruments — for storage of surgical sets	OR, ER, OB, CVO, Cysto, Hemo, OPD	A
5. Medication Dispensing Trays — advanced preparation and storage of medicines	ICU, CCU, ICN, Burn, Nur	B
6. Surgical Instrument and Dressing — for ready storage of surgical instruments and materials in sterile conditions	OR, ER, OB, CVO	A
7. Treatment — base section only, with counter top for preparation of materials at work station	ICU, CCU, ICN, Nur, ER, OPD	B
8. Warming — used for warming of solutions, blankets, bedpans, etc.	OR, ER, OB, CVO, ICU, CCU, Burn, Nur	C

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
Operating Tables		
1. Fracture (Orthopedic) — adjustable for fracture reducing positions	OR, ER	A
2. General Surgery — pedestal mounted, adjustable sectional top	OR, ER, OB, CVO	A
3. Urological — adjustable for all urological positions	OR	B
Hemodialysis Apparatus		
1. Deionizer — provides water purification component of the hemodialysis system	Hemodialysis	A
2. Dialyzer — impurities, chemicals, and liquids are removed from the blood through membranes into dialysis solution, returning purified blood to the patient	Hemodialysis	A
Communications		
1. Alarm Systems — signalling devices for alerting staff to existing and pending emergencies	Admin, OR, ER, OB, CVO, ICU, CCU, ICN, Nur, Burn, Hemo, Nsy	A
2. Annunciator — patient to nurse intercom	ER, OR, OB, CVO, ICU, CCU, ICN, Nur, Burn, Hemo, Nsy	A
3. Batteries — system emergency power source	Engineering	A
4. Call Recorder — records significant communications	Admin, ER, OR, OB, CVO, Nur, Nsy, ICU, CCU, ICN, Hemo, Burn	A
5. Computer — patient data base	All Areas	E
6. Console — command post for guiding the implementation of a disaster plan	Communications	A
7. Input/Output — used for patient records	Admin, Lab, Rad, CCU, Pharmacy	A
8. Power Packs — power stabilizer	Communications	A

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
9. Tape Drives — computer peripheral	Data Processing	A
10. Telautograph — reproduces written notes (e.g. drug prescriptions) at a distance from the source	Pharmacy, Lab, Nur	C
11. Teletype — reproduces typed notes	Pharmacy, Lab, Communications	C
Respiratory Apparatus		
1. Aspirator — used to clear liquids from nose or throat	ICU, CCU, ER, OR	A
2. Croupette — relieves breathing by introducing atomized solutions	ICU, CCU, ER, OR	A
3. Humidifier — inhalation therapy apparatus	ICU, CCU, ER, OR	B
4. Inhalator — device for treating patient by mixture of gas to assist breathing	ER, OR	B
5. Laryngoscope — blade inserted beyond tongue to assist throat exam	Nsy, Ped, ICN, ICU, ER, OR, CCU, Nur	A
6. Mixing controller — used to control proper air/oxygen ratio	ER, OR, ICU, CCU, Nur, Burn	A
7. Percussor (Pulmonary Drainage) used to free mucus deposits deep in the chest cavity with percussion waves	ER, OR, Respiratory Therapy	B
8. Respirator — artificial breathing device.	ER, OR Respiratory Therapy	A
9. Respirometer — measures breathing capacity	ER, OR Respiratory Therapy	B
10. Ventilator — administers oxygen through nasal catheter	ER, OR, ICU, CCU, Nur, Respiratory Therapy	A
Surgery Equipment		
1. Autoclaves — sterilizer	OR, ER, OB, CVO	B
2. Blood Auto-Transfusion Unit —simultaneous recovery filtration and transfusion of blood lost at operative site	OR, ER, OB, CVO, Recovery	B

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
3. Body Restraints — Positions patient for surgery	OR, ER, OB, CVO	A
4. Hemorrhage Control Apparatus — mobile device used in emergency treatment of internal bleeding	OR, ER, OB, CVO	A
5. Instrument Table — table with surgical sets and individual instruments	ER, OR, OB, CVO	B
6. Irrigation Apparatus — device for delivering controlled jet of water to irrigate a wound	OR, ER, OB, CVO, ICU, CCU, Nur, Burn	A
7. I.V. Fluid Containers — glass containers of blood/fluids	OR, ER, OB, CVO, ICU, CCU, Burn, Nsy	B
8. I.V. Stands (Trees) — used to suspend or support I.V. fluid containers	OR, ER, OB, CVO, ICU, CCU, Burn, Nsy	A
9. Medical Gas (Anesthesia Cart) — mobile cylinder cart for anesthesia gasses	OR, ER, OB, CVO, ICU, CCU, Nur, Nsy, Burn	A
10. Operating Light — portable floor lamp	OR, ER, OB, CVO, ICU, CCU, Burn	A
11. Operating Lights — ceiling suspended light	OR, ER, OB, CVO, ICU, CCU, Burn	A
12. Solution Basin — contains treatment liquids used in surgery	OR, ER, OB, CVO, ICU, CCU, Burn, Nsy	C
13. Solution Stand — supports solution basin	OR, ER, OB, CVO, ICU, CCU	C
14. Sterilizer — apparatus for sterilizing surgical instruments with boiling water	OPD	B
15. Suction Apparatus — removes foreign matter from body cavities by suction	Recovery, OR, ER, OB, CVO, ICU, CCU, Nsy, Nur	A
16. Work Stations (Critical) — preparation of materials in surgery	OR	B

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
Imaging Equipment		
1. Automatic Film Developer — automatic dry processing of X-ray film	Rad, OR, ER	A
2. Cassette Holder — holds X-ray film	Rad, ER, OR, OPD	B
3. Collimator — Component of scintillation camera	Nuclear Medicine	C
4. CT Scanner — computer assisted multi-element apparatus for imaging	Scanner Suite	B
5. Diagnostic Ultra Sound — detects clogged viens via ultra sound waves	Ultra Sound, Rad, OPD	C
6. Fixed Fluoroscopic Unit — anatomical exam by imaging on a fluoro screen	Rad	B
7. Gamma Camera — component of scintillation camera	Nuclear Medicine	C
8. Geiger Counter — detecting and measuring intensity of radioactive substances	Nuclear Medicine	B
9. Magnetic Resonance Imaging — provides computerized video image of body	Mag Res Suite	B
10. Radiation Sheilding Screens — shields patient from scattered radiation	Rad	B
11. Radiographic Unit (fixed) — used for radiographically examining anatomical conditions	Rad	A
12. Radiographic unit (mobile) — used for radiographically examining anatomical conditions	Nur, OPD, ICU, CCU, ER OR, CVO	B
Laboratory Apparatus		
1. Biological Safety Hood — used to maintain positive exhaust of toxic gasses	Lab	B

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
2. Blood Bank Refrigerator — blood plasma preservation	Lab	A
3. Cleaner, Ultrasonic — used to clean instruments	Lab	C
4. Coulter Counter — counting, classifying, and totalizing different types of blood cells	Lab	B
5. Hemoglobinometer — used for measuring oxygen-carrying pigment in blood	Lab	A
6. Hematocrit — separation of liquids from solids or liquids of different densities	Lab	A
7. Microscope, Electron — used to examine objects at great magnification	Lab	C
8. Oximeter — provides photo record of oxygen saturation of blood	Lab	A
9. pH Meter — used for measuring hydrogen ion concentration in blood	Lab	A
10. Refrigerator, Biologicals — preservation of blood serums surgical and autopsy specimens	Lab	B
11. Washer, Glassware — cleans laboratory glassware	Lab	C
Cardiovascular Equipment		
1. Defibrillator — used for counteracting irregular heartbeat	ER, OR, CVO, Nur	A
2. Heart-Lung Machine — multi-element process used as substitute heart during cardiac surgery	CVO	A
3. Magnetic Tape Recorder — used for audio records during surgical process	CVO, CV, Cath, ER, OR	C
4. Pacemaker External — stimulates contraction of heart muscle	CV, Cath, CCU	A

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
5. Pressure Transducer — provides data on structure in and around heart with sound waves	CV, Cath, CCU	B
6. Resuscitator — assists in reviving breathing, heartbeat and blood pressure	ER, OR, CVO, OB, Nur	A
Patient Care Equipment		
1. Chart Rack — holds patient medical records	Nur, Nsy, ICU, CCU, ICN, OPD, Burn	C
2. Computer Monitor	ICU, CCU, Par	A
3. Electrocardiograph — assists in analysis of heart condition	OPD, ER	A
4. Electrocardioscope — device providing video and audio display of anatomical conditions	In all patient areas of hospital	A
5. Examination Lights — used for diagnosis and treatment illumination	Nur, Nsy, ICU, CCU, ICN, OPD, Burn	B
6. Examination Table — used for nonsurgical diagnosis and treatment of patients	OPD, Nur	B
7. Illuminator — backlight panel for viewing X-rays	In all patient areas of hospital	B
8. Medical Gas Cylinders — portable containers of pressurized oxygen and other gasses	Service Department	A
9. Oxygen Outlet, wall mounted	Nur, Nsy, ICU, CCU, ICN, OPD, Burn	A
10. Oxygen tank (bulk) — source of piped oxygen	Service Yard	A
11. Shelving — storage of supplies instruments, chemicals, medical sets, etc.	In all patient areas	A to E
12. Sphygmomanometer — used to measure blood pressure	Nur, Nsy, ICU, CCU, ICN, OPD, Burn	B
13. Unit Dose Packaging Machine — used to fill drug Rx	Pharmacy	C

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
MISCELLANEOUS EQUIPMENT		
Administration		
1. Communications Console	Admin, Nur	A
2. Computers	Admin, Nur	E
3. Desks and chairs	Admin, Nur	E
4. Filing Cabinets	Admin, Nur	E
5. Shelved Storage	Admin, Nur	E
Alcoves		
1. Gurneys	Throughout patient areas	D
2. Wheelchairs	Throughout hospital	D
Patient Rooms		
1. Bedside cabinets	Patient rooms	E
2. Chairs and tables	Patient rooms	E
3. Interval Clock — sweep second hand activated at time of cardiac arrest	Patient rooms	B
4. Patient Lockers	Patient rooms	E
5. Portable toilet	Patient rooms	E
6. Table, Over Bed	Patient rooms	D
7. TV — usually wall mounted	Patient rooms	E
Food Preparation and Serving		
1. Blenders	Kitchen	E
2. Coffee Urn	Cafeteria	E
3. Deep Fryers	Kitchen	E
4. Dish and Glass Dispensers	Cafeteria	E

EQUIPMENT NAME & FUNCTION	LOCATION	SEISMIC CATEGORY
5. Food Carts	Kitchen	D
6. Food Cutters/Slicers	Kitchen	E
7. Food Racks	Kitchen	E
8. Freezers	Kitchen	E
9. Hot/Cold Serving Line	Kitchen	E
10. Hot Plate	Kitchen	E
11. Ice Machines	Kitchen/Cafeteria	E
12. Juice Extractor	Kitchen	E
13. Kettles	Kitchen	E
14. Microwave Ovens	Kitchen/Cafeteria	E
15. Milk Dispensers	Kitchen	E
16. Ovens	Kitchen	E
17. Peelers	Kitchen	E
18. Preparation Tables	Kitchen	E
19. Refrigerators	Kitchen	E
20. Stoves	Kitchen	E

Appendix 2

APPENDIX 2

Appendix 2 has been provided so that the reader might have reference details available for the seismic protection of hospital equipment. There are several publications readily available that might also be consulted for additional details. These include:

1. **Reducing the Risks of Nonstructural Damage: A Practical Guide**
   by Robert Reitherman, California
   Seismic Safety Commission, SCEPP, 1983

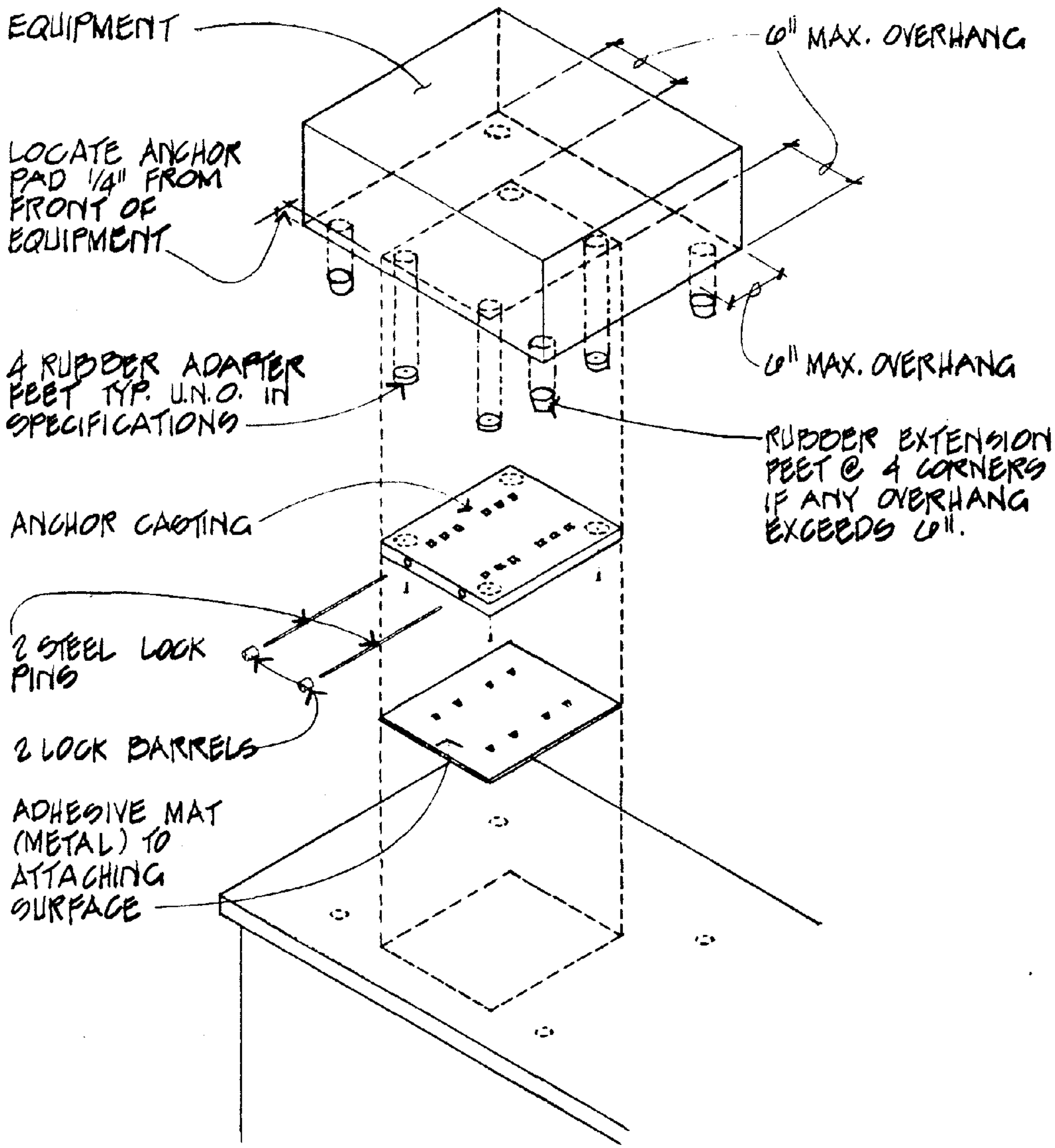
2. **Seismic Design for Buildings**
   Tri-Services Manual No. 5-809-10, 1982

3. **Study to Establish Seismic Protection Provisions for Furniture, Equipment, & Supplies for VA Hospitals**
   by Stone, Marraccini, & Patterson
   R. Barnecut and G. Austin
   Veterans Administration, 1976

4. **Earthquake Protection of Essential Building Equipment: Design, Engineering, Installation**
   by Gary L. McGavin, AIA
   John Wiley and Sons, Inc., 1981

All of the details reproduced in Appendix 2 are from **Seismic Restraint Handbook for Furniture, Equipment & Supplies,** by Reid & Tarics Associates for the Veterans Administration. These details were chosen for reproduction because they were written specifically for hospitals and because they cover a relatively wide range of situations and installations in a minimal number of drawings.

Seismic design for equipment is a relatively new field of study. The reader should consult with an engineer knowledgable in the protection of equipment for the seismic environment when protecting critical or heavy equipment.

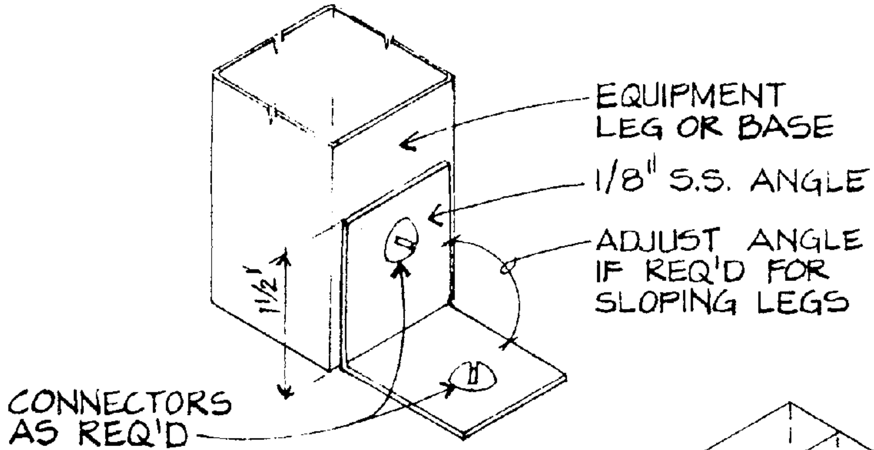


COMPONENTS:

Manufactured Item
Consisting of:
1. A self-adhesive mat.
2. Anchor Pad which is mechanically fastened to FES.
3. Steel Rods interlocking Anchor Pad to Mat.

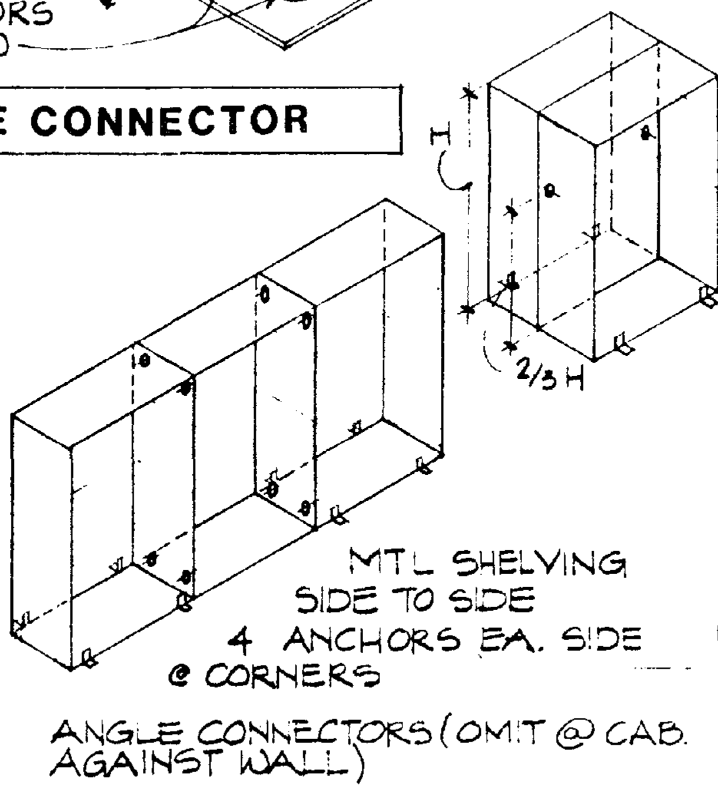
See Specifications to match Anchor Pad type to FES type.

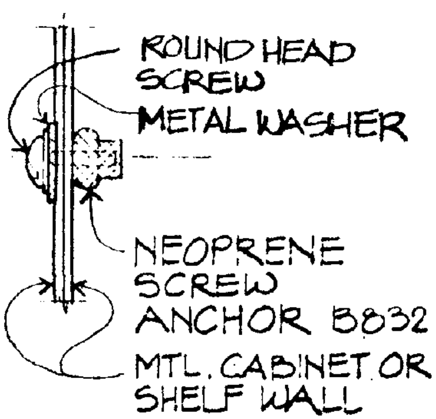
ANCHOR PAD | BASIC DETAIL **AP**



FOR DIETETIC EQUIP. USE SET SCREW TO LEG, NEOPRENE GASKET & 3/8"Φ ADHES. ANCHOR AS FOR PIPE SHOE

ANGLE CONNECTOR





MTL. SHELVING & CABINET ANCHORS

VARIATIONS

B1 Groups of Free-Standing Cabinets with Angle Connectors

4 Connections to cabinets side by side,
2 Connections to cabinets back to back,
4 Angle connections at end cabinets and every other intermediate cabinet to attaching surface.

B2 Equipment to Surfaces Direct Bolt

2 Connections for wall restraints.
4 Connections for floor restraints.

B3 Equipment to Surfaces with Angle Connectors

2 Connectors for wall restraints.
4 Connectors for floor restraints.

- Fasteners to Use

(all restraints to be 10 gauge except use 3/8" diameter for equipment over 200 pounds)

Toggle Bolts to plaster or gypsum board walls.

Nut & Bolt, or Neoprene Screw Anchor & Bolt to metal.

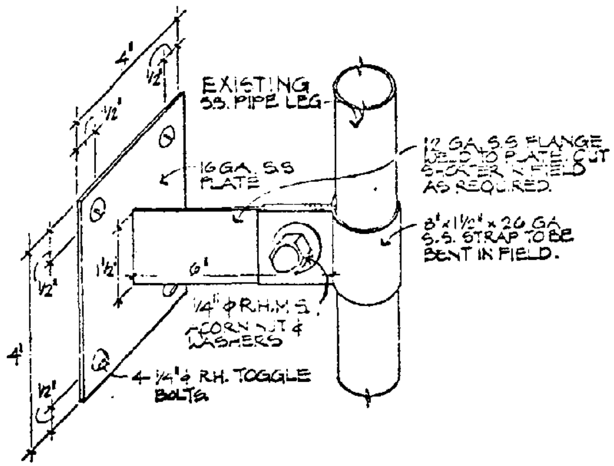
Wood Screw to wood or plastic laminate.

Expansion Anchor to concrete or soapstone.

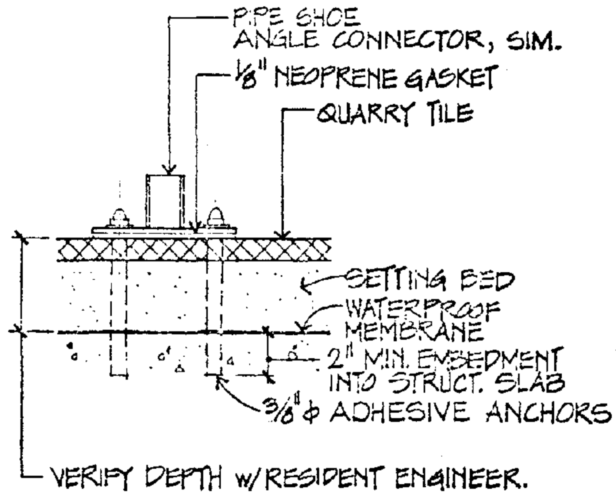
Adhesive Anchor to ceramic tile floor.

SHEET 1 OF 2

BOLTED CONNECTION | **BASIC DETAIL B**



WALL PIPE CONNECTOR

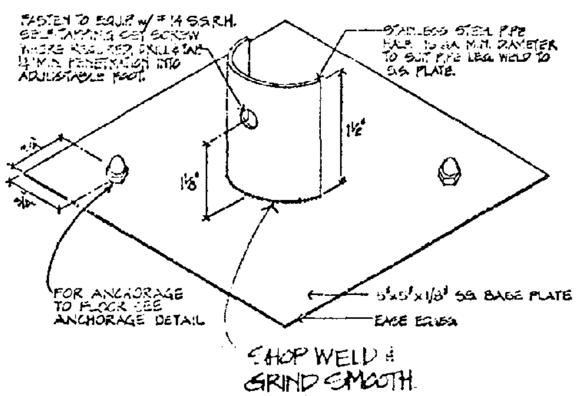


ANCHORAGE FOR DIETETIC EQUIPMENT

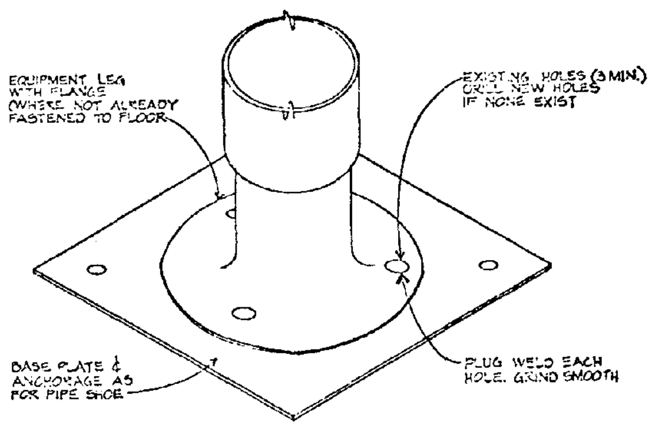
B4 Dietetic Equipment

Base Plates,
Pipe Shoes,
Angle Connectors, and/or
Wall Pipe Connectors.
] To Suit

4 Connections minimum.
Connections required @ all corners.
Connections @ 10'-0" max.



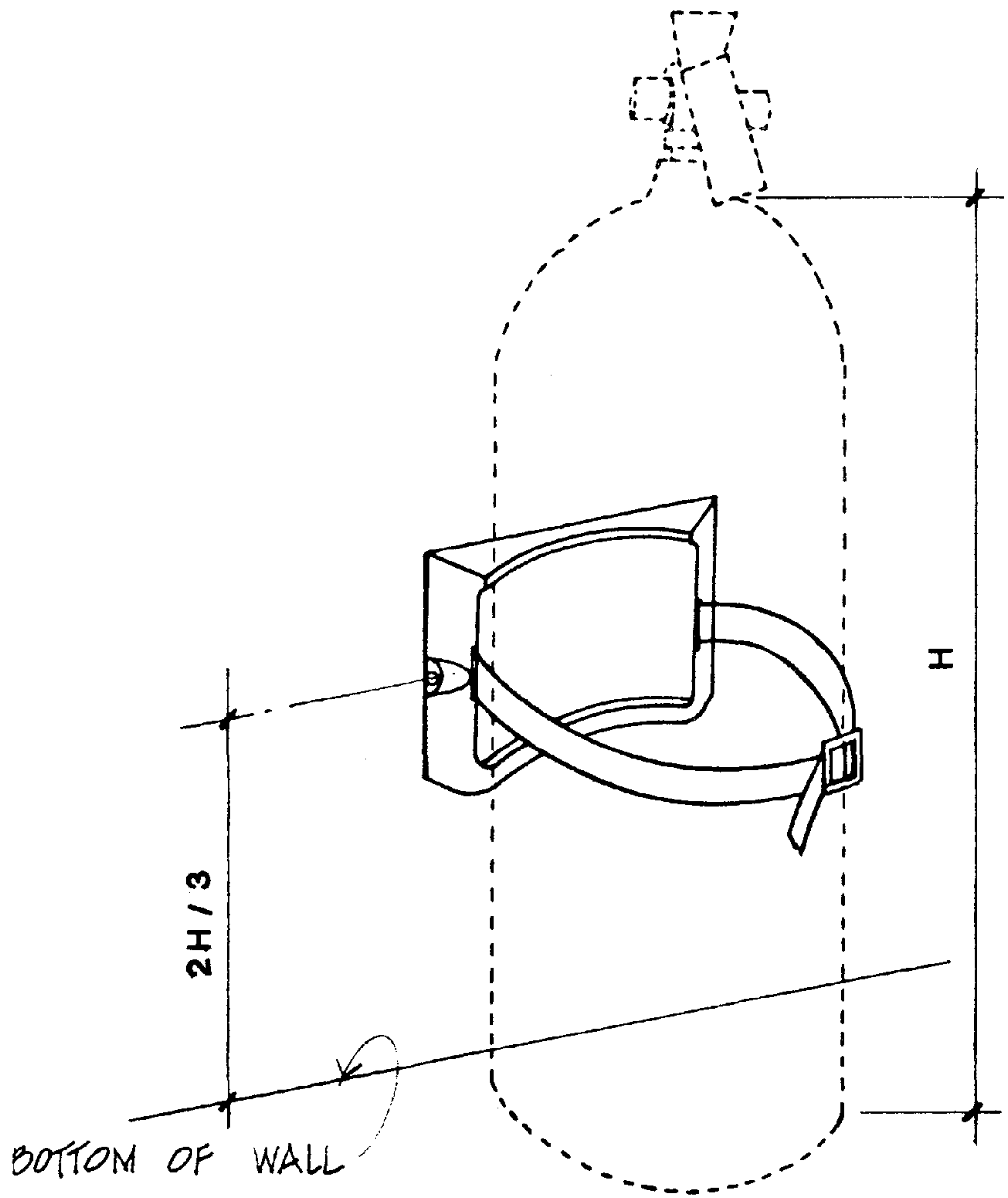
PIPE SHOE



BASE PLATE

SHEET 2 OF 2

BOLTED CONNECTION | **BASIC DETAIL B**



ISOMETRIC

COMPONENTS

1. Cylinder Restraining Device w/ Straps (Manufactured item)

2. Fasteners - see below (Size as recommended by manufacturer).

- Fasteners to Use

Toggle Bolts to plaster or gypsum board walls.

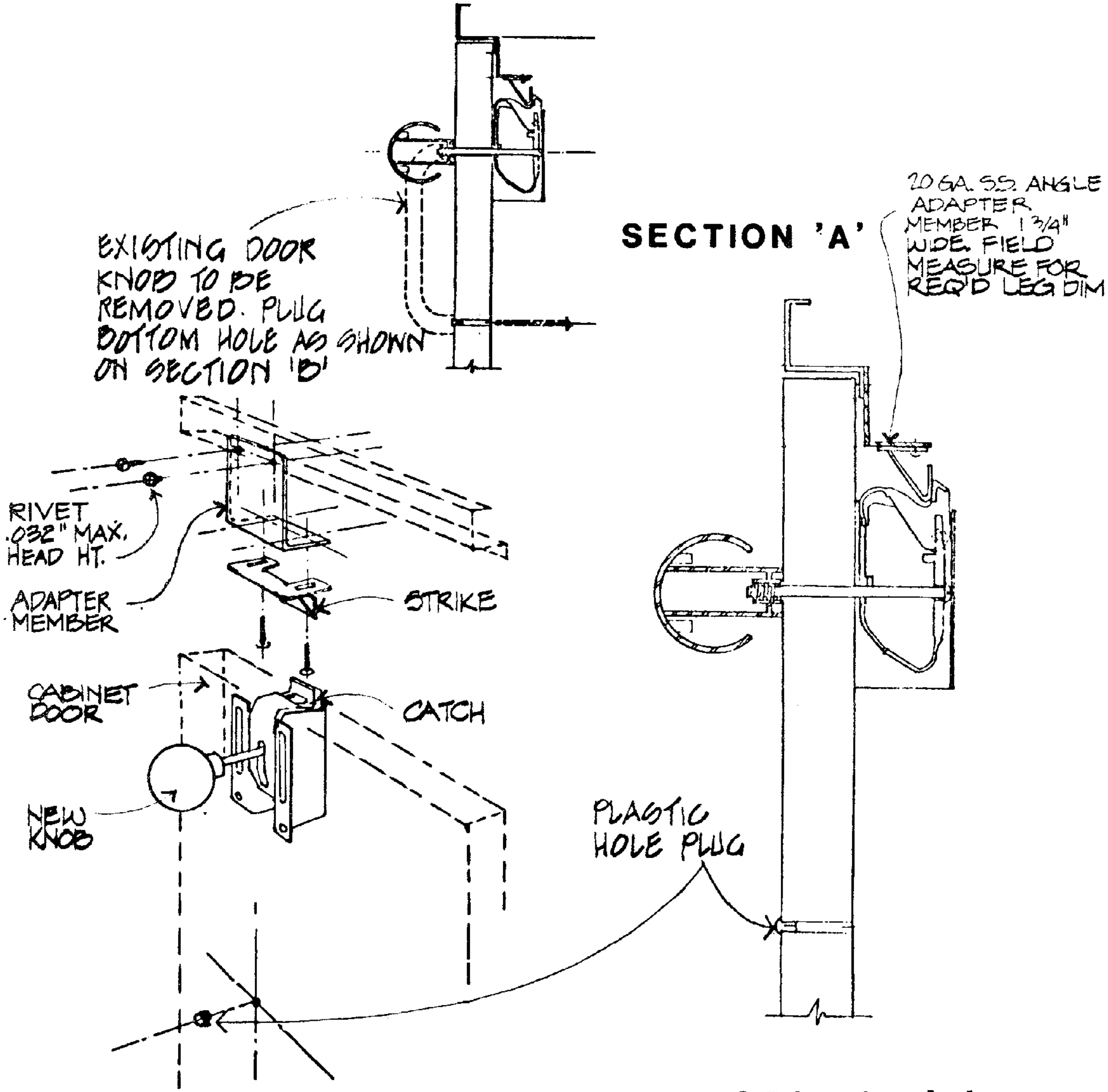
Nut & Bolt, or Neoprene Screw Anchor & Bolt to metal.

Wood Screw to wood or plastic laminate.

Expansion Anchor to concrete.

CYLINDER RESTRAINT

BASIC DETAIL **CR**



SECTION 'B'

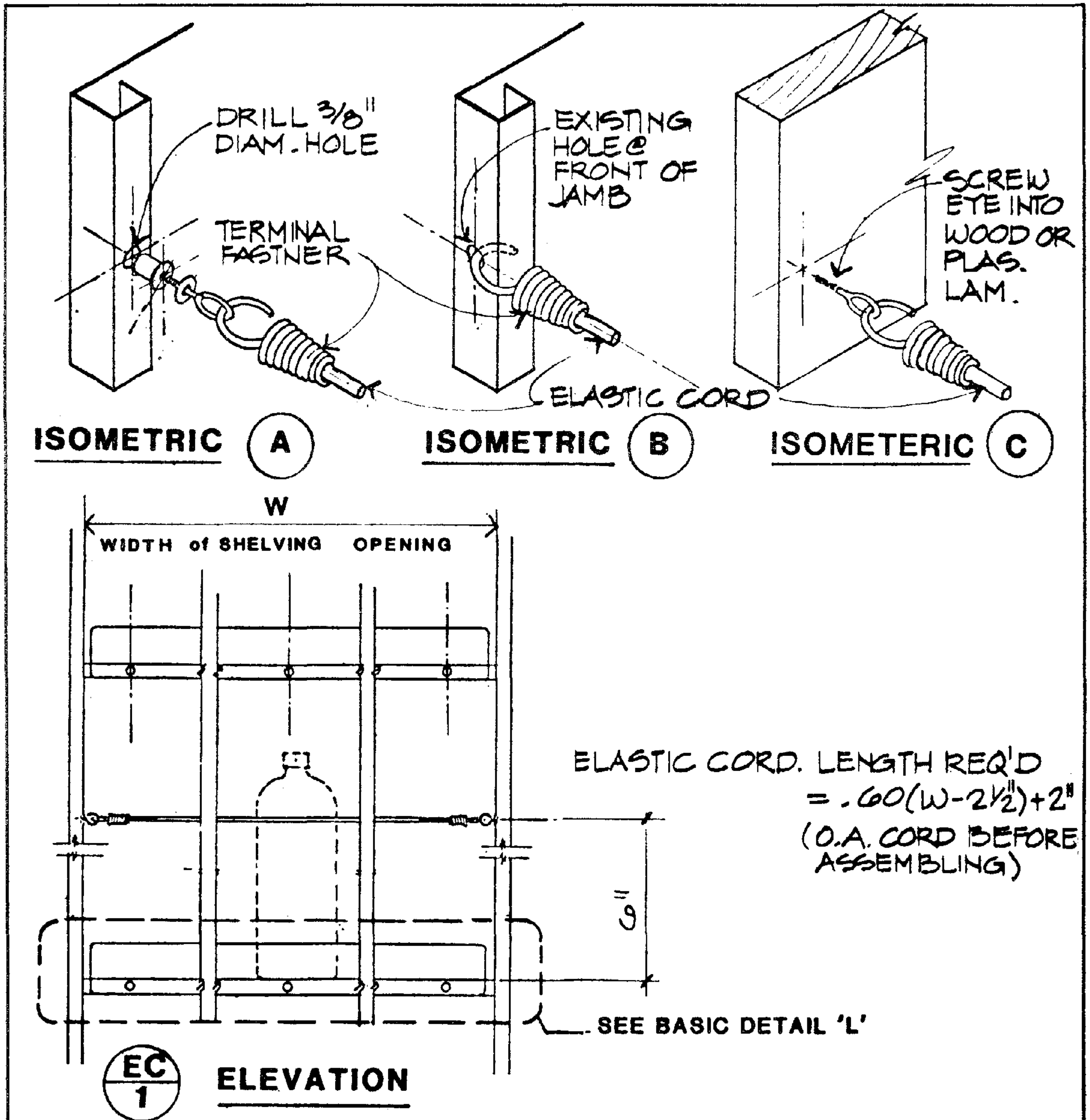
COMPONENTS

1. Catch & Strike Assembly (Manufactured item).
2. Knob (Manufactured item).
3. Plastic Hole Plug (Manufactured item).
4. Adapter Member (Fabricated).

Note:

Provide additional blocking or adapter members for mounting strike if required. Members shall be metal for metal cabinets and wood for wood or laminated plastic cabinets.

DOOR LATCH, CABINET	BASIC DETAIL	DL



COMPONENTS

1. Elastic Cord w/ Terminal Fastener.
2. Eyebolt Fastening Assembly for metal cabinet consisting of:
   - A. 8/32 x 1-5/8" Eyebolt (Cut to 1" length).
   - B. #8 Steel Washer.
   - C. Neoprene Screw Anchor.
3. Eye Screw Fastening for plastic laminate and wood cabinet use #109 screw eye .

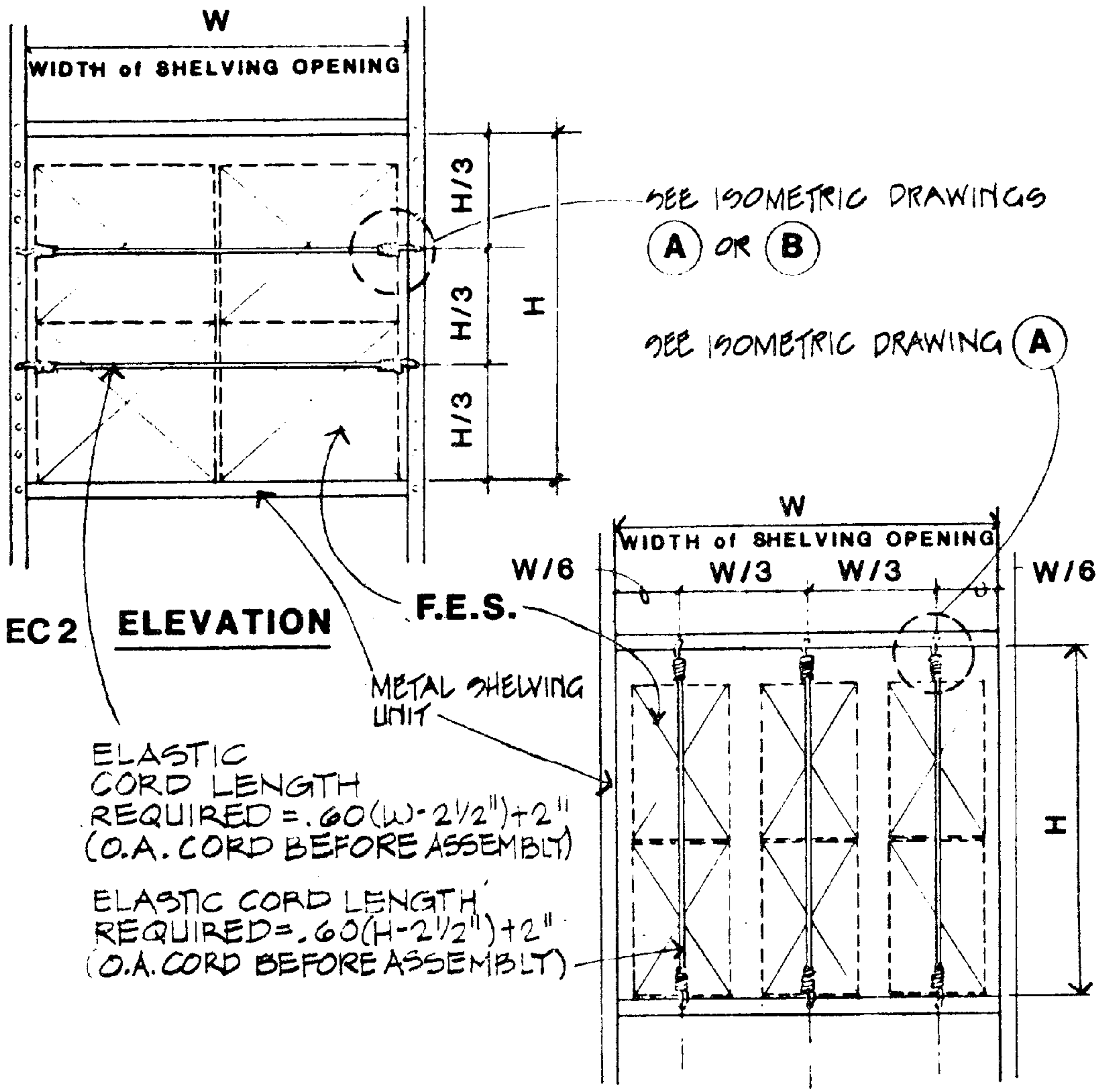
VARIATIONS

EC1 Set of 1 Elastic Cord and 2 Eyebolt Assemblies installed horizontally.

EC2 Set of 2 Elastic Cords & 4 Eyebolt Assemblies installed horizontally.

EC3 Set of 3 Elastic Cords & 6 Eyebolt Assemblies installed vertically.

ELASTIC CORD | BASIC DETAIL **EC**

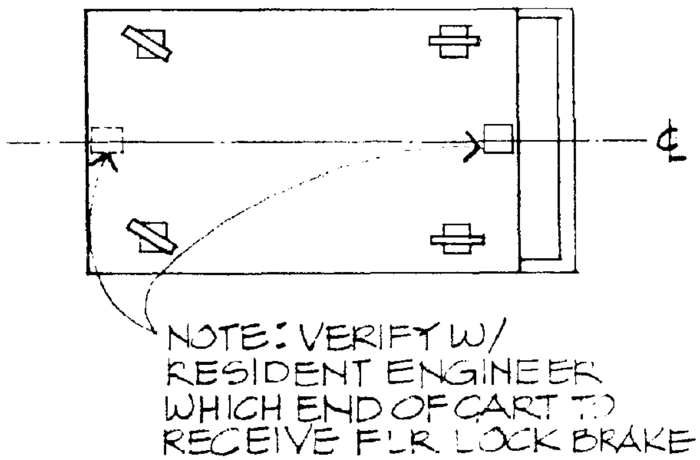


EC2 ELEVATION

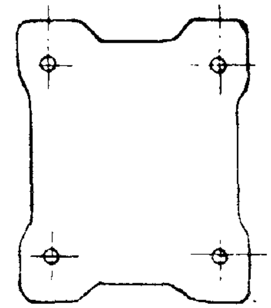
EC3 ELEVATION

SHEET 2 of 2

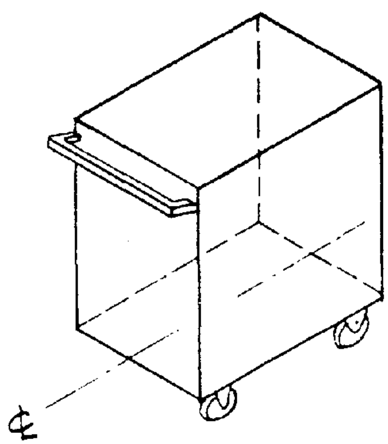
ELASTIC CORD | BASIC DETAIL **EC**

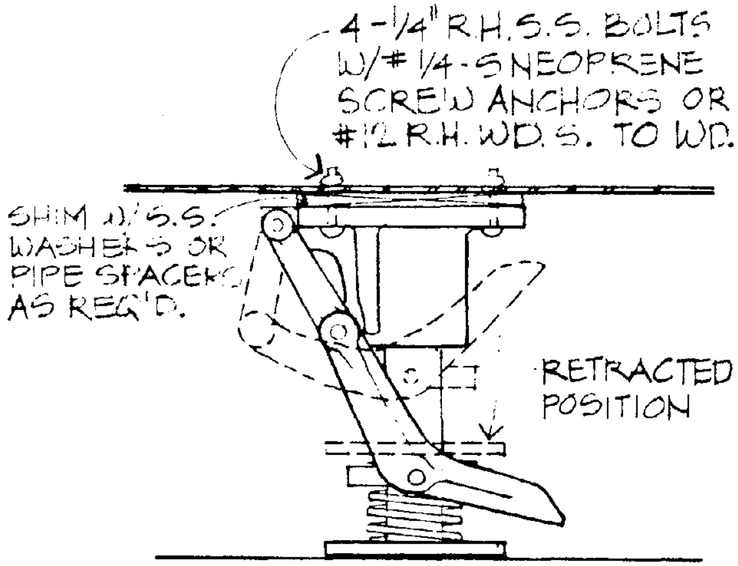


PLAN-bottom of cart



PLAN





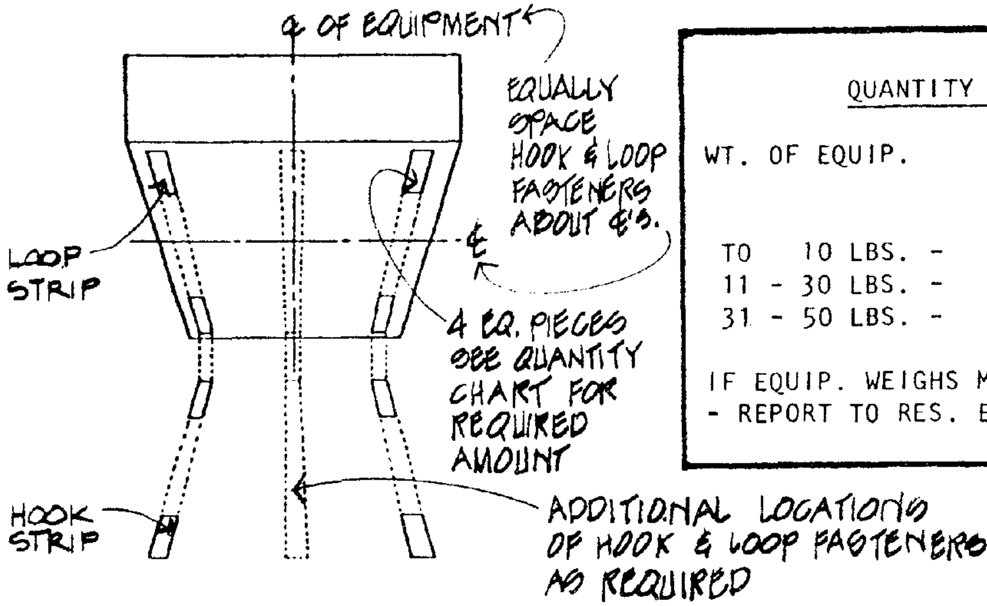
SECTION

COMPONENTS

Manufactured item.

FLOOR LOCK BRAKE

BASIC DETAIL **F L**

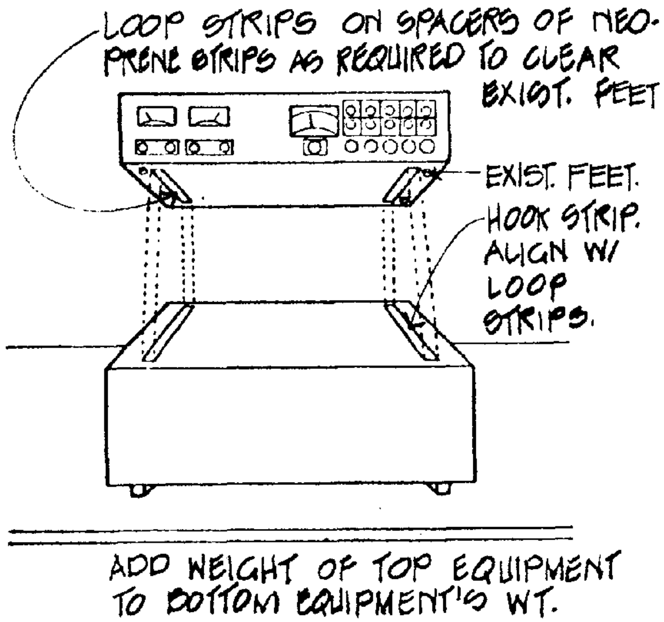


QUANTITY CHART

WT. OF EQUIP.	LENGTH OF H & L FASTENER.
TO 10 LBS. -	6"
11 - 30 LBS. -	18"
31 - 50 LBS. -	30"

IF EQUIP. WEIGHS MORE THAN 50 LBS. - REPORT TO RES. ENG.

POSITIONING & QUANTITY of HOOK & LOOP FASTENERS



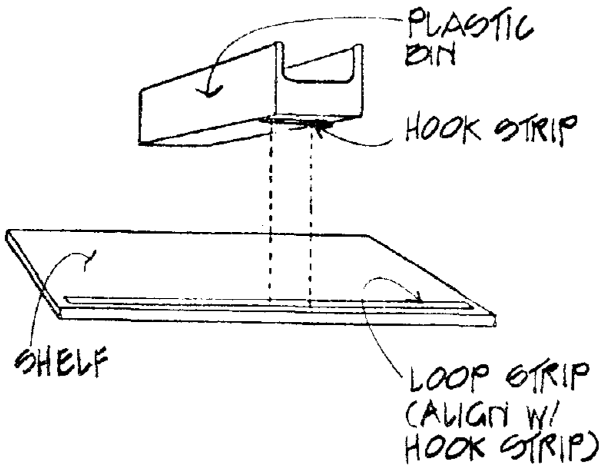
HL 1 EQUIPMENT TO EQUIPMENT OR COUNTER

COMPONENTS

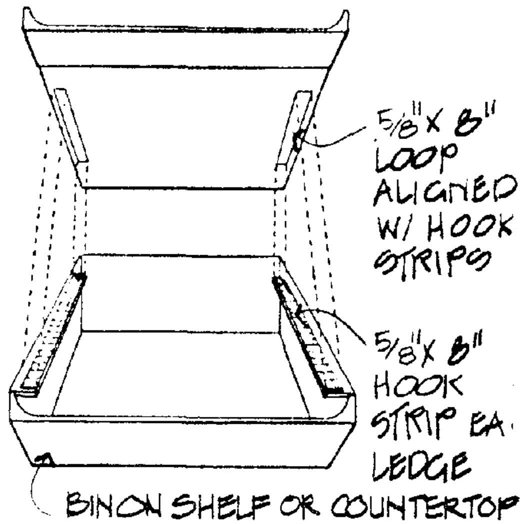
1. Self-adhesive Hook & Loop strip assembly. (Manufactured item).
2. Neoprene Spacer.

SHEET 1 OF 2

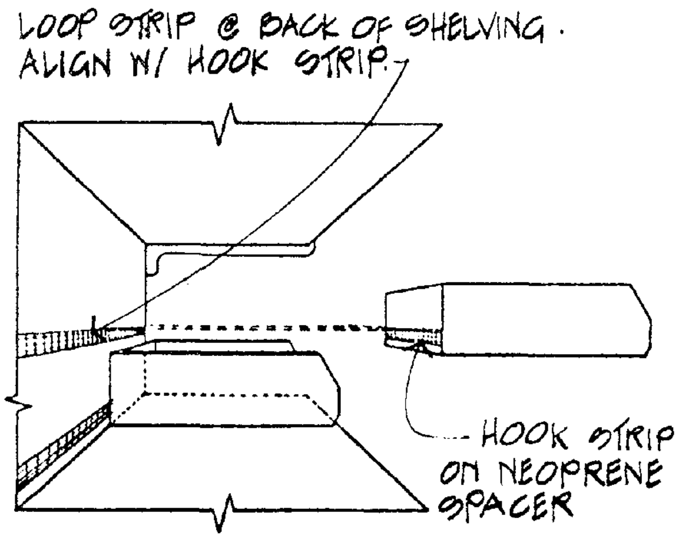
HOOK & LOOP FASTENERS | BASIC DETAIL **HL**



HL2 BIN TO SHELF OR COUNTERTOP



HL2 LARGE STACKED BINS



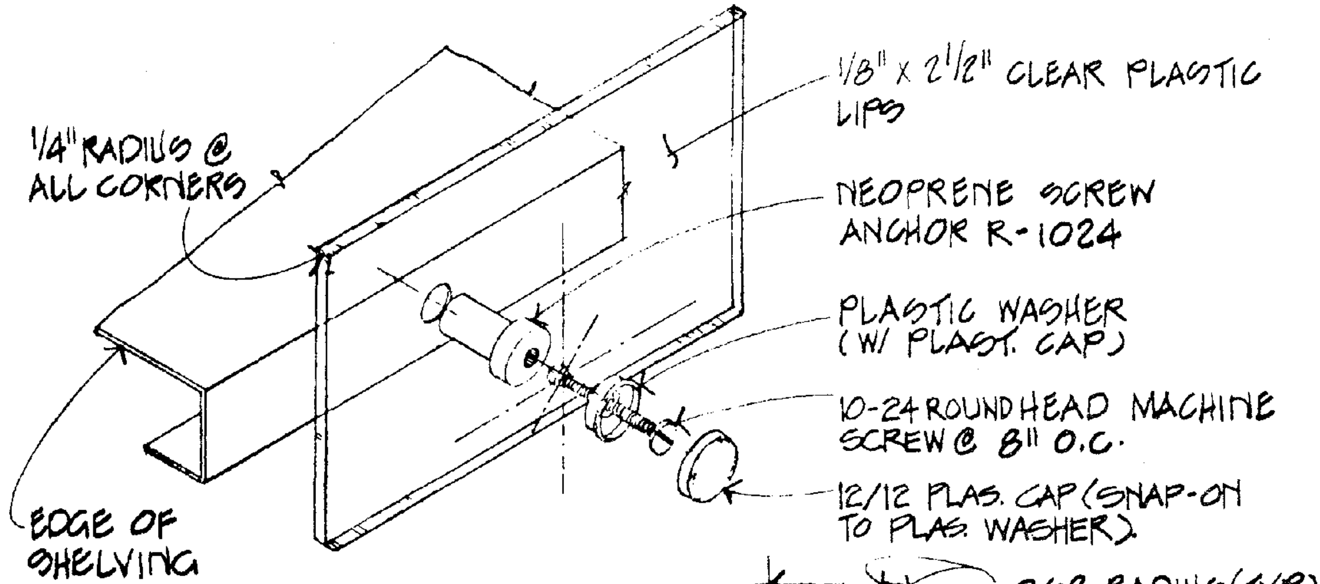
HL2 STACKED BINS AND BINS TO CABINET BACK

COMPONENTS

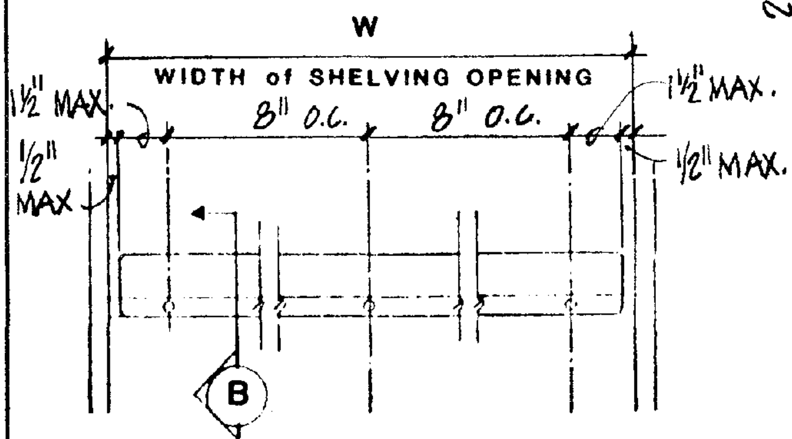
1. Self-adhesive Hook & Loop strip assembly. (Manufactured item).
2. Neoprene Spacer.

SHEET 2 OF 2

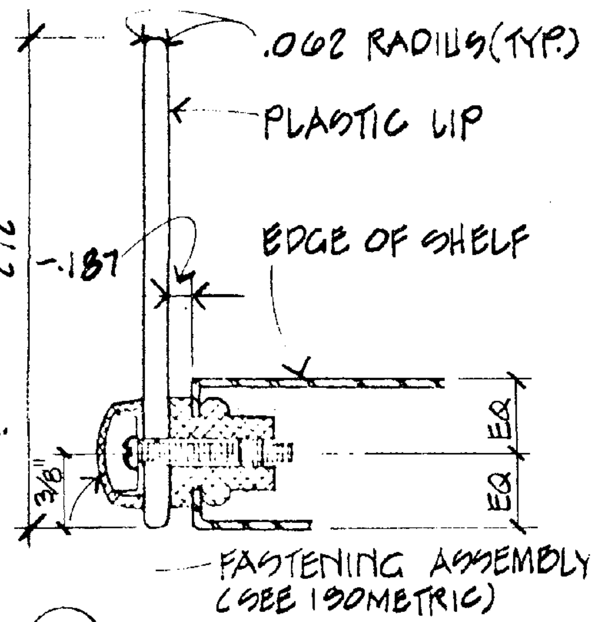
HOOK & LOOP FASTENERS | BASIC DETAIL **HL**



ISOMETRIC



(A) ELEVATION



(B) SECTION

VARIATIONS

L As shown.

L1 Substitutions for shelves at cabinets with glass doors: 10-S Neoprene screw anchors, 10-32 round head screws.

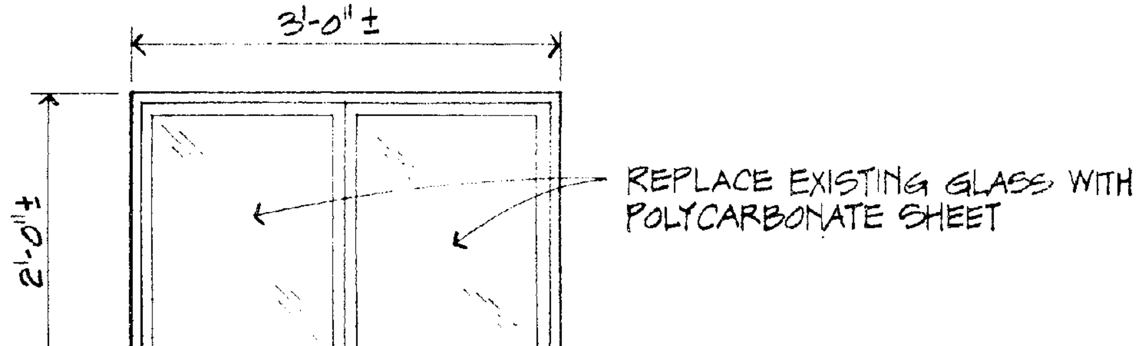
L2 Substitutions for 1/2" thick shelves: E-632 Neoprene screw anchors plus size "0" flat Neoprene faucet washer, 6-32 round head screws, 8/8 plastic snap caps.

Notes:

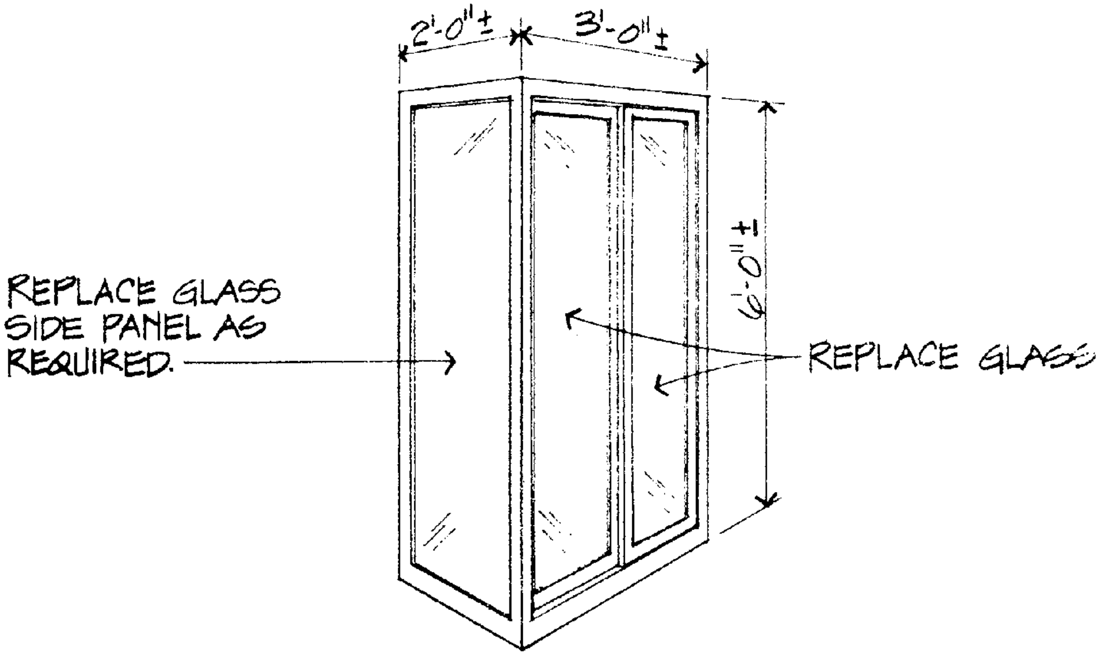
1. Where ends and/or backs of shelves are open, install Lips on all open edges.

2. For plastic laminate or wood shelves, use equivalent pan head sheet metal screw with size "0" neoprene faucet washer in lieu of neoprene screw anchor.

LIPS, PLASTIC | **BASIC DETAIL L**



UPPER CABINET DOORS



FULL HEIGHT CABINET DOORS & SIDES

VARIATIONS

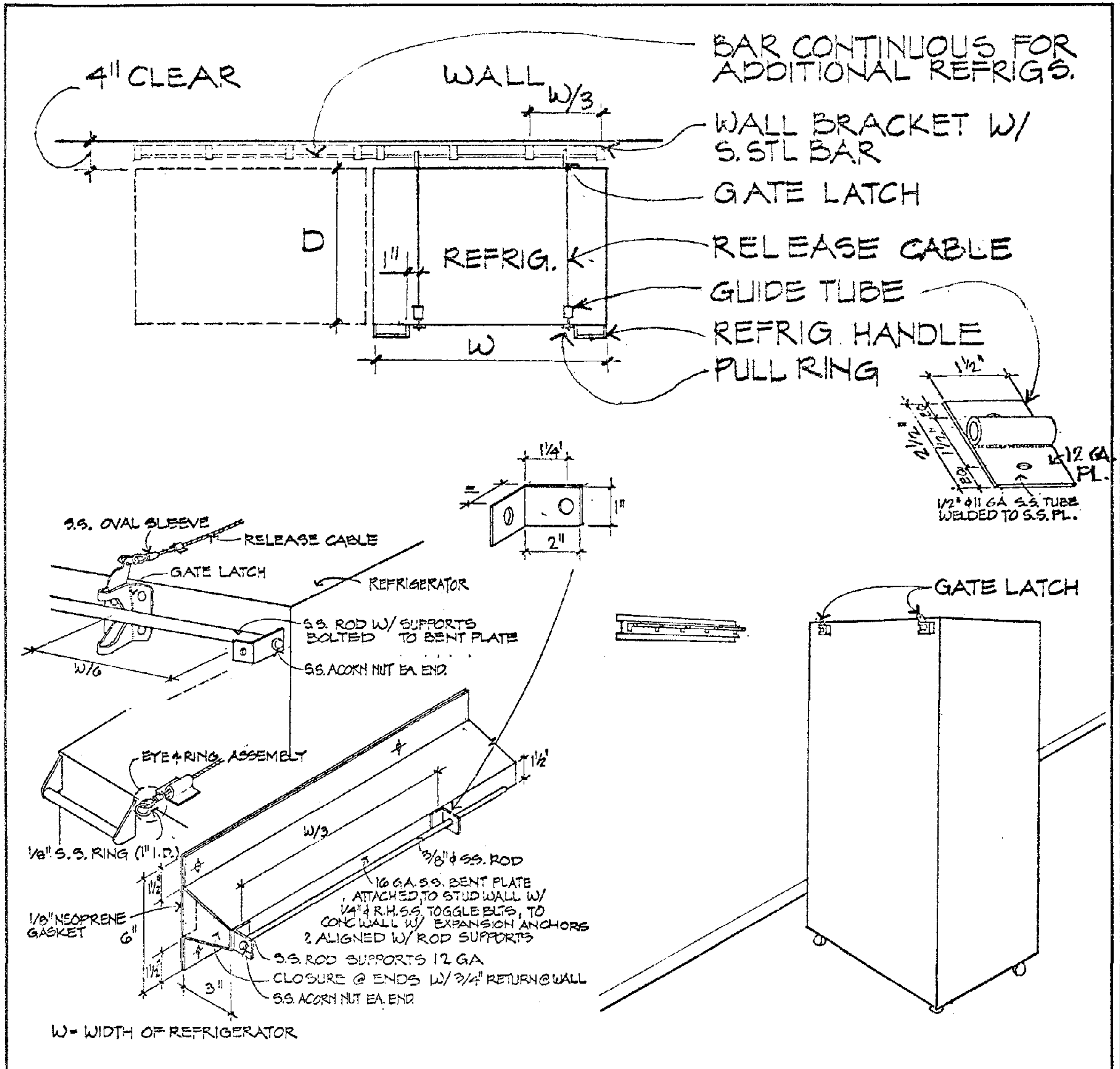
Replace existing glass with polycarbonate sheets.

RG1 Reglaze upper cabinet doors.

RG2 Reglaze full height cabinet doors.

RG3 Reglaze full height cabinet doors and cabinet sides.

REPLACE GLASS	BASIC DETAIL RG

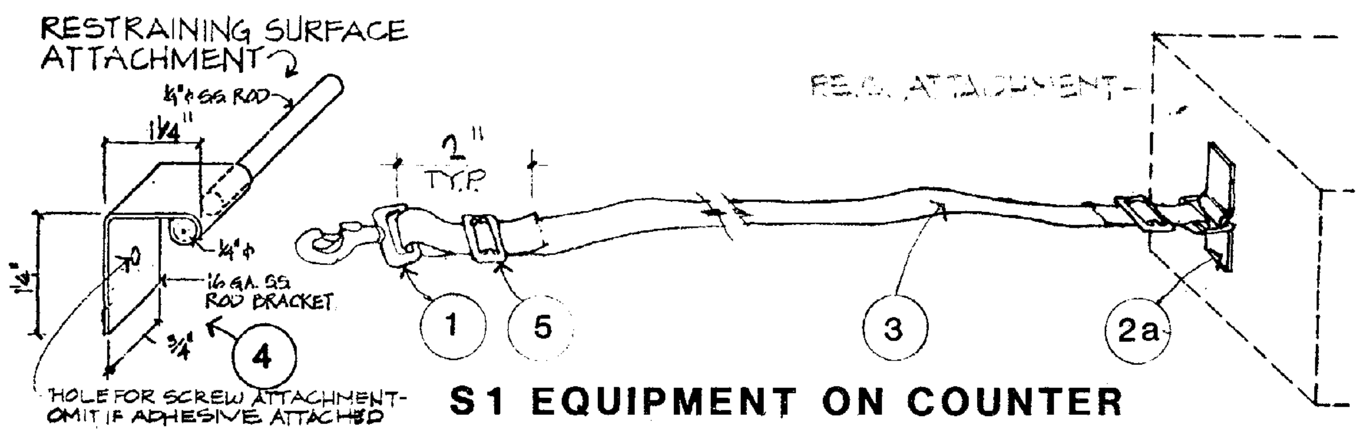


Dietetics Refrigerators

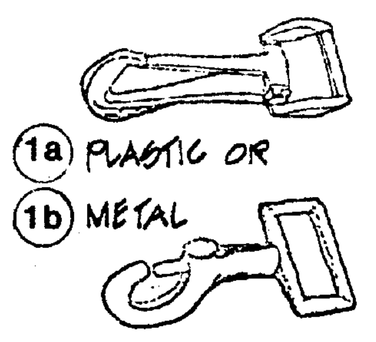
2 Gate latches/Refrig.
2 Guide tubes/Refrig.
2 Release Cables with eye and ring assembly/Refrig.
1 S.S. bent plate/Refrig. L=W
1/8" Neoprene gasket as indicated.
4 S.S. rod supports/Refrig.
1 S.S. rod/Refrig.
8 R.H. S.S. fasteners to wall/Refrig.

DIETETIC REFRIGERATOR ANCHORING

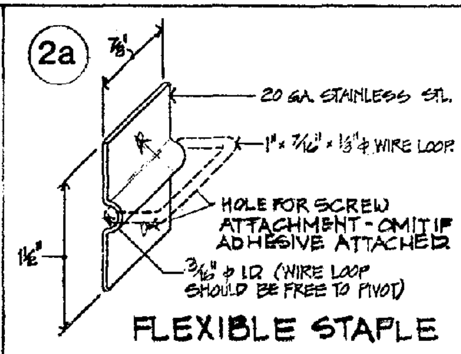
ROD & LATCH | BASIC DETAIL **RL**

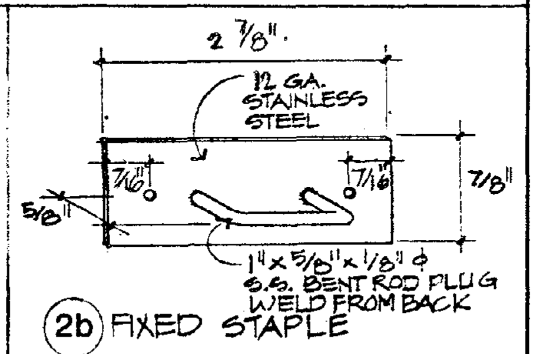


S1 EQUIPMENT ON COUNTER

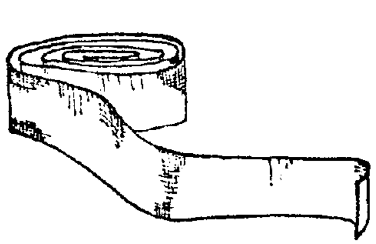


1 SNAPS

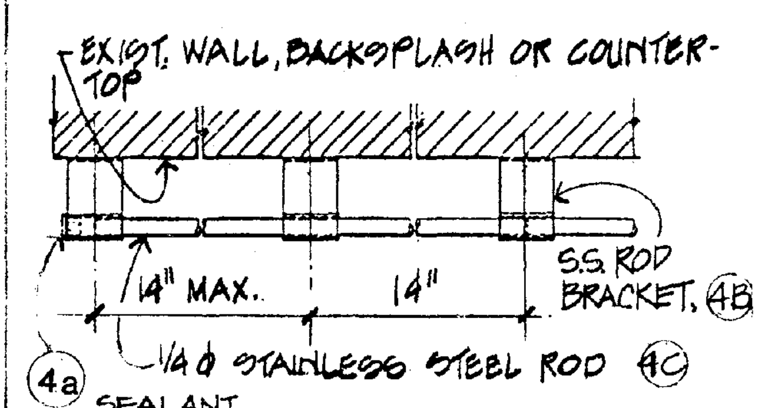




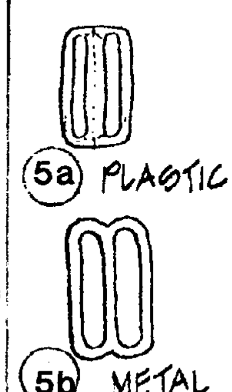
2 STAPLES



3 STRAPS



4 ROD & BRACKET



5 SLIDES

Note:

Use 2" fold-over on each end of straps, typical (as shown in assembly at left).

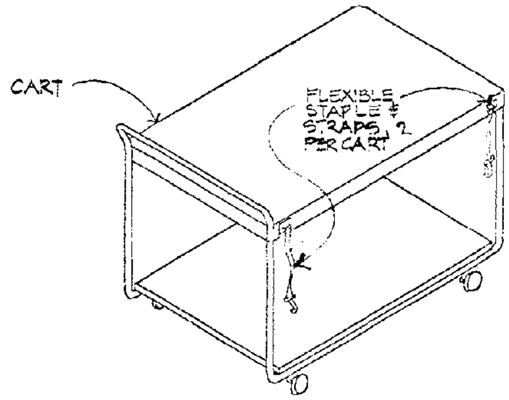
VARIATIONS

S1 Equipment on Counter

- 2 Straps (24" O.A.)/Equip. (Adjust length of strap to prevent equipment from falling off counter. Trim strap as required.)
- 1 Plastic Snap/Strap.
- 2 Plastic Slides/Strap.
- 2 Flexible Staples/Equip.
- 1 Rod & Bracket (24")/Equip (one piece continuous for equipment side by side)

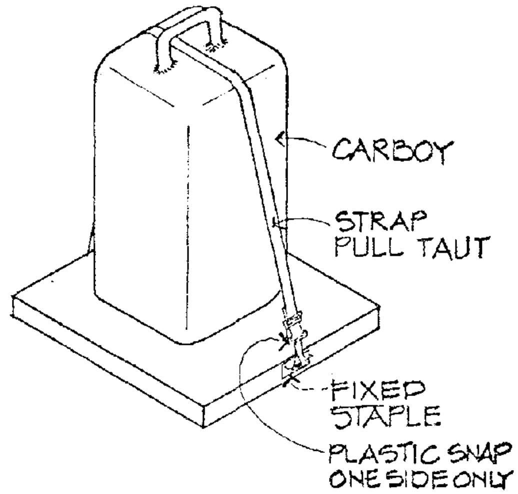
SHEET 1 OF 5

STRAP	BASIC DETAIL S

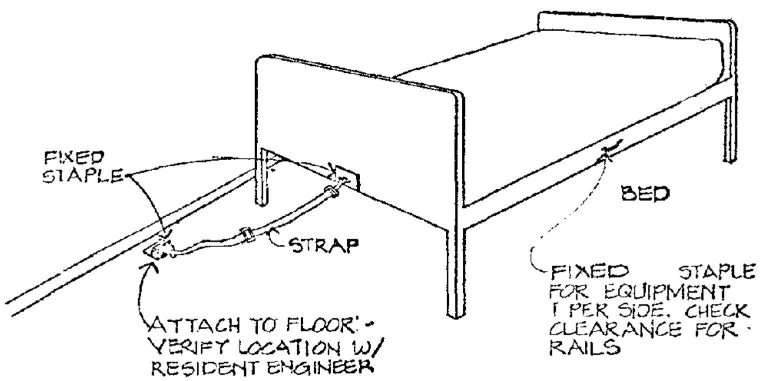


VERIFY LOCATION OF STAPLES WITH RESIDENT ENGINEER.

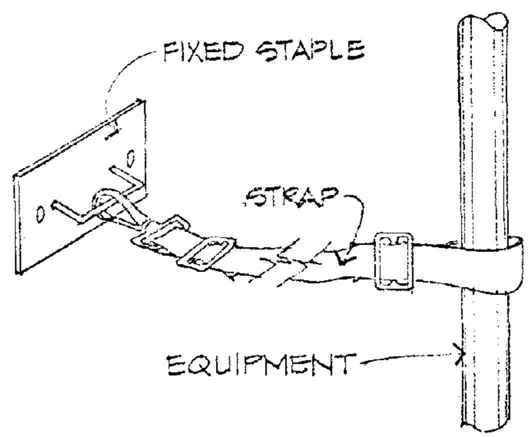
S2 CARTS



S3 TIE-DOWN STRAPS



S4 BEDS



S5 SINGLE STRAP

VARIATIONS

S2 Carts

- 2 Straps/Carts (10" O.A.)
- 2 Flexible Staples/cart
- 2 Plastic Slides/Strap.
- 1 Plastic Snap/Strap.
- 2 Fixed Staples (to attaching Surface).

S3 Tie-Down Strap

- 1 Strap (48" Average).
- 2 Plastic Slides/Strap
- 1 Plastic Snap/Strap
- 2 Fixed Staples.

S4 Bed (Bedside Cabinet Similar)

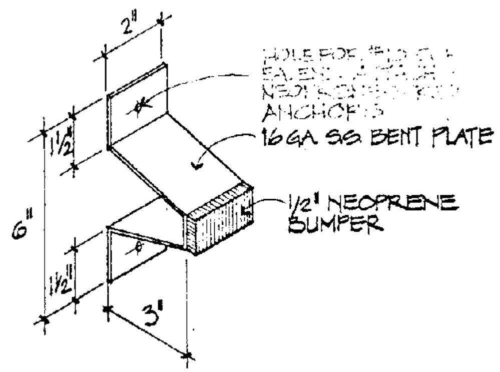
- 1 Strap (24" O.A.)
- 2 Metal Snaps/Strap.
- 2 Metal Slides/Strap.
- 1 Fixed Staple to bed.
- 1 Fixed Staple to floor.
- 2 Fixed Staples to bed for equipment.

S5

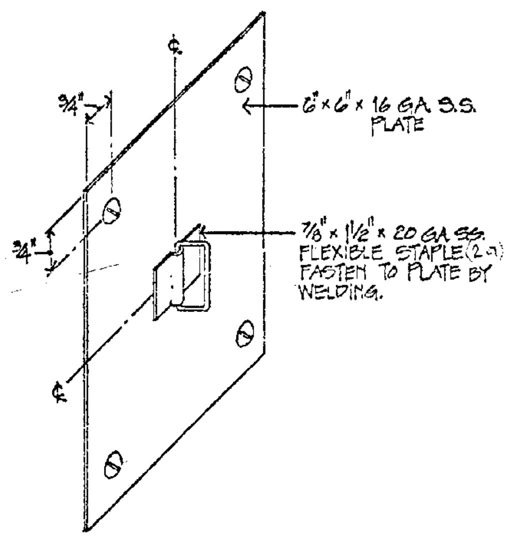
- 1 Strap (10" O.A.)/Item.
- 2 Plastic Slides/Strap.
- 1 Plastic Snap/Strap.
- 1 Fixed staple (to attaching surface)

SHEET 2 OF 5

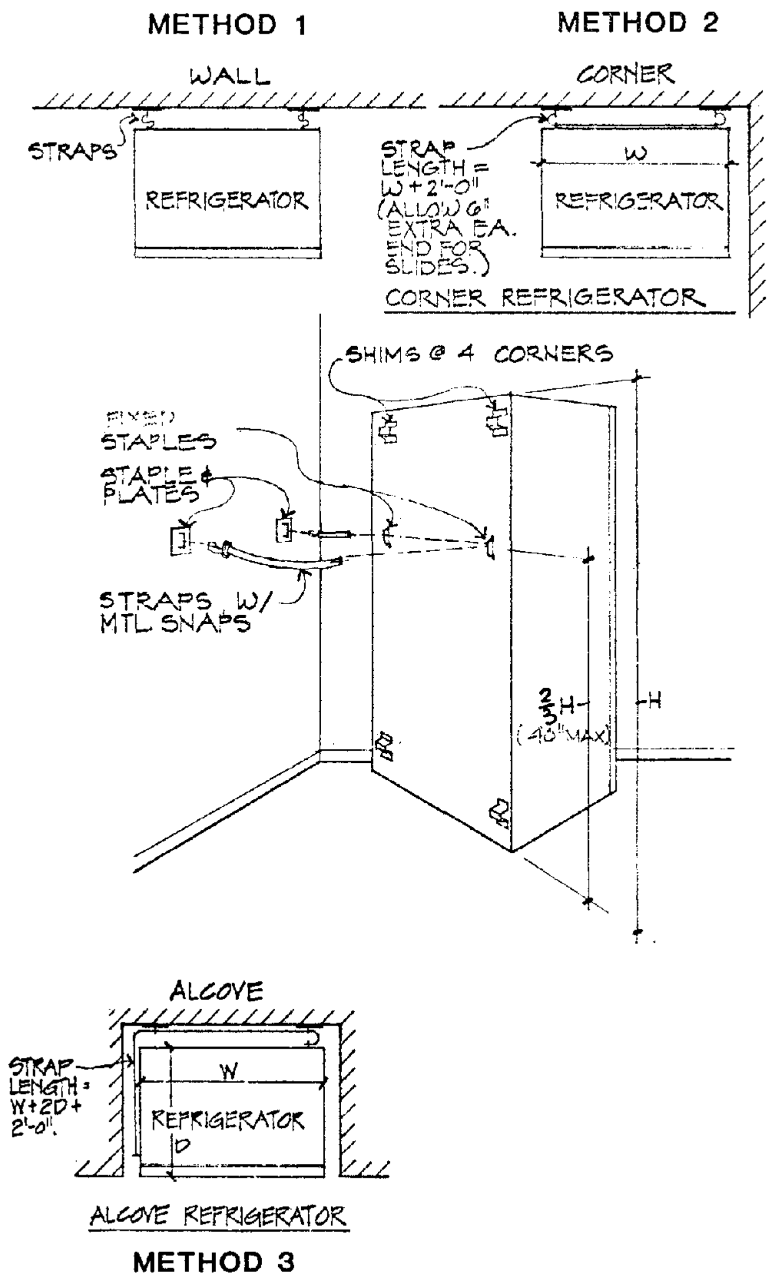
STRAP | BASIC DETAIL **S**



SHIM



STAPLE & PLATE



S6 REFRIGERATOR ANCHORING

VARIATIONS

S6 Refrigerator Anchoring

Method 1
Refrigerator to Wall

- 2-12" O.A. Straps/Refrig.
- 1 Metal Snap /Strap.
- 2 Metal Slides/Strap.
- 2 Fixed Staples/Refrig.
- 2 Staple & Plates/Refrig.
- 4 Shims/Refrig. (if needed to protect projecting coils, etc.)

Method 2
Refrig. to Wall @ Corner

- 1 Strap (L=W+24" O.A.)/Refrig.
- 1 Metal Snap /Strap.
- 2 Metal Slides/Strap.
- 2 Fixed Staples/Refrig.
- 2 Staple & Plates/Refrig.
- 4 Shims/Refrig.

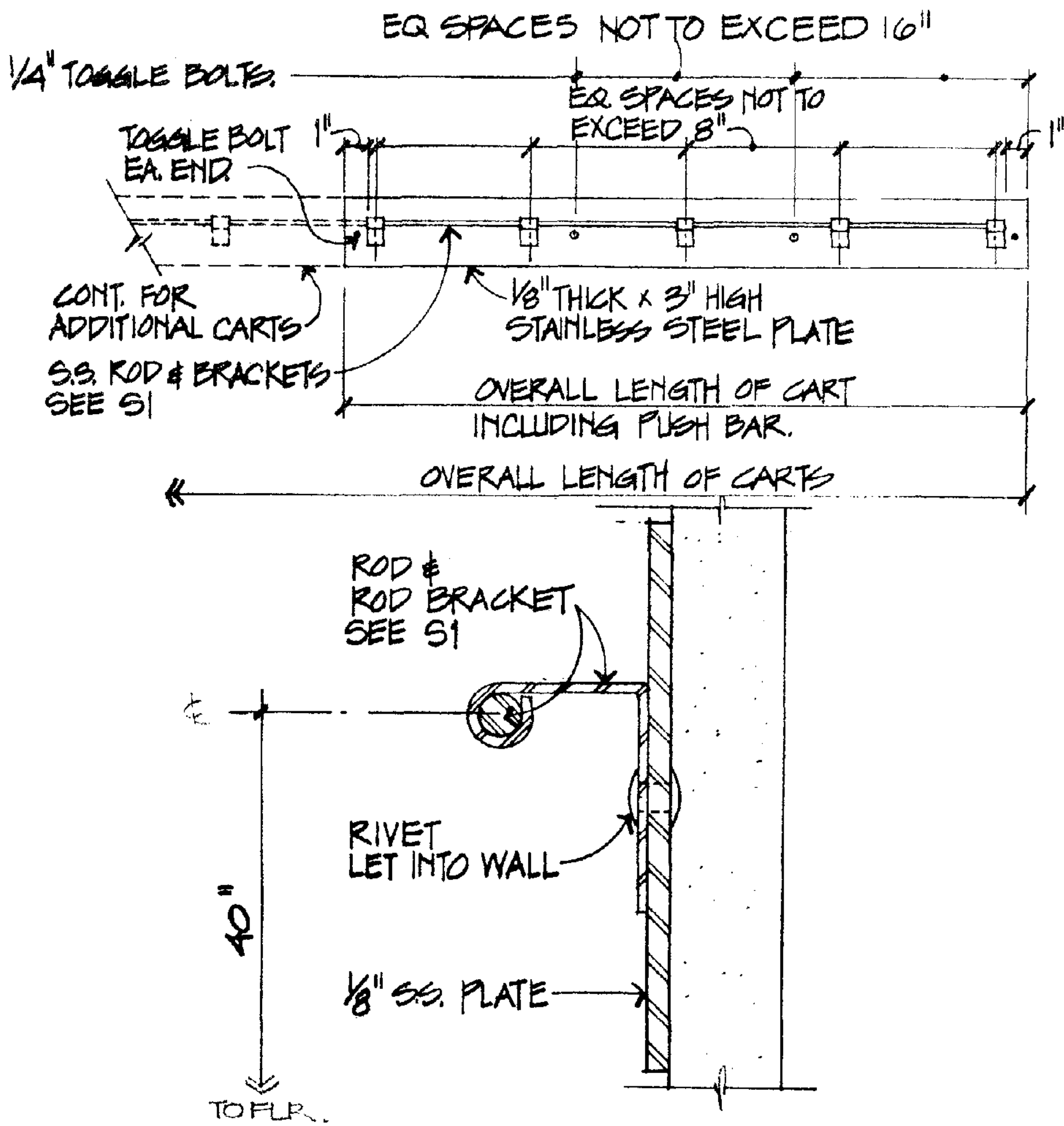
Method 3
Refrig. to Wall in Alcove

- 1 Strap (L=W+2D+24" O.A.)/ Refrig.
- 1 Metal Snap /Strap.
- 2 Metal Slides/Strap.
- 2 Fixed Staples/Refrig.
- 2 Staple & Plates/Refrig.
- 4 Shims/Refrig.

S7 Same as S1 except use 2 Fixed Staples instead of Rod & Brackets.

STRAP

BASIC DETAIL **S**



VARIATIONS

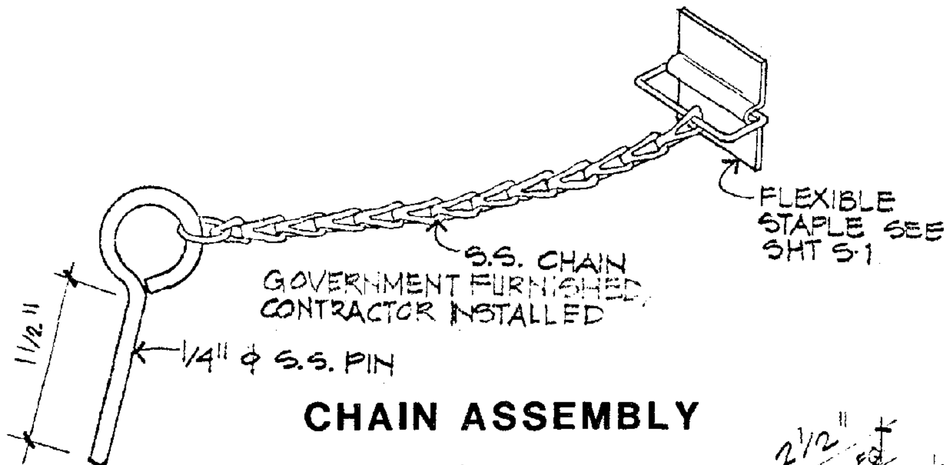
Same as S2 except with Rod, Rod Brackets, and Stainless Steel Plate.

Note: Strap length may vary.

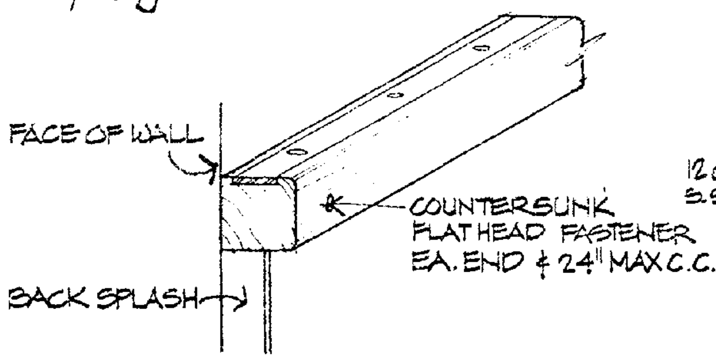
S8 CARTS

STRAP

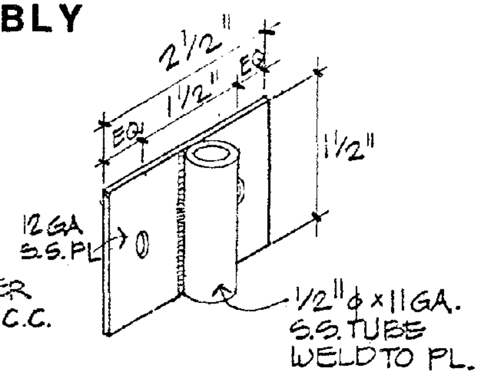
BASIC DETAIL S



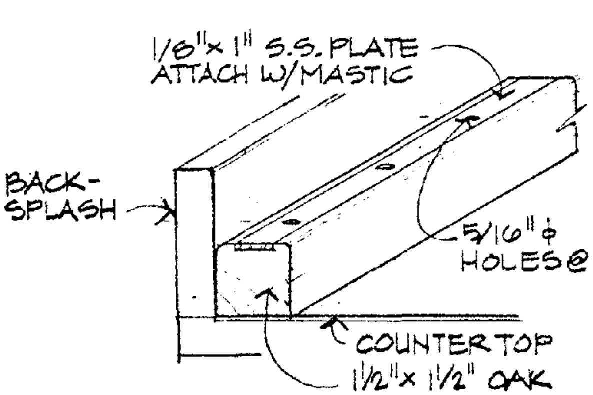
CHAIN ASSEMBLY



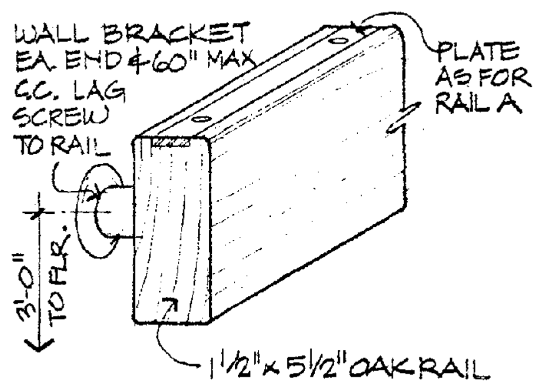
RAIL A @ top of splash



PIN SOCKET



RAIL A @ countertop



RAIL B

VARIATIONS

S1A Equipment on Counter:

1 Rail A (24")/Equip. (1 piece continuous for equipment side by side)

2 Chain Assemblies/Equip. Adjust length of chain to prevent equipment from falling off counter.

S2A Carts:

2 Pin Sockets/Equip. to Attaching Surface.

2 Chain Assemblies/Equip. (6" long chain).

S7A Same as S1A except 2 pin sockets instead of rail.

S8A Same as S2A except 1 Rail B/Cart, overall length of rail to be same as overall length of cart including push bar (1 piece continuous for carts side by side).

SHEET 5 OF 5

S1A, S2A, S7A, S8A - ALTERNATE STRAP DETAILS

STRAP | BASIC DETAIL **S**

Appendix 3

APPENDIX 3

Appendix 3 has been included to illustrate what the State of California is doing about the protection of hospital equipment. This appendix includes some of the history of seismic protection in California as well as listing some of the quantifiable information such as California's Level I and II seismic categories.

SEISMIC SAFETY OF HEALTH FACILITIES IN CALIFORNIA

I. BACKGROUND

The Hospital Seismic Safety Act of 1983 (HSSA), an amended version of the original act in 1973, mandates that structural resistance to earthquakes be provided in hospital buildings. HSSA is implemented by detailed regulations in Title 24 of the California Administrative Code.

The law and regulations cover the architectural, structural, mechanical, and electrical systems involved in new construction, additions, and alterations, as well as anchorages of fixed equipment and other non-structural building components. A complete assessment of the nature of the hospital site and potential for earthquake damage based on geologic and engineering investigations is also required.

It is the intent of the Act that hospital type buildings that house patients having less capacity to protect themselves, and which must be reasonably capable of providing services to the public following a disaster, shall be designed and constructed to resist the forces generated by earthquakes, gravity, and winds.

The Act designates the Office of Statewide Health Planning and Development (OSHPD) as the state agency responsible for implementing the intent of the Act.

OSHPD has named its Division of Facilities Development and Financing (DFDF) as the program supervising authority.

DFDF supervises the policies and procedures of its Architectural and Engineering Section (A/E) in the implementation of HSSA's intent, by reviewing plans and observing related construction of all but State-owned health facilities.

A/E has reviewed plans of health facilities for compliance with construction standards in Title 17, California Administrative Code, since 1946 — a service relating to the intent of the Hospital Licensing Act of 1946 and its later amendments.

The Office of the State Fire Marshal (SFM) has assisted A/E since 1946 by reviewing the fire safety features of health facilities design and construction, and advising A/E of its findings. The Office of the State Architect, Structural Safety Section (OSA), has assisted A/E since 1973, the year of the original HSSA enactment, in reviewing the structural systems of hospital plans, and the observation of the related construction.

OSHPD is the coordinator of hospital design review and construction observation, and preempts the authority of local building jurisdictions with respect to hospital type buildings. The Act permits OSHPD to conduct research directed toward the reduction of earthquake hazard in health facilities; to enter hospital buildings and inspect them to enforce the provisions of the law and regulations; to stop construction that is being performed contrary to state standards; and to order the vacating of any structure found to have been in violation of the standards. Following any earthquake OSHPD studies any health facility damaged within the area involved.

The Building Safety Board, in the Office of Statewide Health Planning and Development, is established by the Hospital Seismic Safety Act to advise the Office on matters of seismic structural safety, and to act as a board of appeals on any questioned code enforcement actions of A/E. The Board members are appointed by the Director of OSHPD with the advice of the Department of General Services. Selection of appointed members is made from candidates recommended by their professional organizations.

Of the appointed members, two are structural engineers, two are architects, one is a soils engineer, one is an engineering geologist, one is a seismologist, one is a mechanical engineer, one is an electrical engineer, and one is approved at large from among the above listed professions; also, one is a hospital administrator, and three are members of the general public.

Additionally, ex-officio (non-voting) members provided for in the Act are the director of OSHPD, the State Architect, the State Fire Marshal, the State Geologist, the Chief of DFDF, and the Chief Structural Engineer of the Structural Safety Section of OSA, or their officially designated representatives. Other ex-officio members are appointed by the director of the OSHPD, with the advice of the board chairperson.

The law requires that only architects and engineers, duly licensed to practice in the State of California, may prepare hospital plans.

Applications for health facility building permits are addressed to OSHPD, and are accompanied by drawings, specifications, structural calculations, site geotechnical reports, and fees. Currently, the required fee is 1.5 percent of the cost of construction. An additional fee is required for the review by A/E of fixed equipment anchorages.

OSHPD headquarters office is in Sacramento where A/E reviews projects of the northern counties. A Los Angeles branch of A/E reviews plans and construction of hospital projects in Los Angeles and Orange Counties. Sub-area A/E offices perform "over-the-counter" and small project reviews by the Sacramento staff at five locations throughout the state.

The standing committees of the Building Safety Board are:

Architectural Committee
Structural Committee
Mechanical/Electrical Committee
Geotechnical Committee

Members are professionals practicing in the fields stated in the above titles.

Ad hoc subcommittees, whose titles and functions are shown below, perform detailed investigations on specific items; reporting their conclusions to the board in public meetings.

II. Projects

Subcommittees are established, each chaired by an appointed Board member, to investigate areas of seismic concern in hospital structures, equipment anchorages, and related statutory requirements. These subcommittees are titled:

Essential Functions: Identify services that are essential to a licensed hospital. Identification to include the anchorages of fixed equipment and utilities.

Geotechnics: Study and develop guidelines regarding waiver of soils reports where such would not benefit seismic safety.

Earthquake Policy: Develop guidelines for survey of structural conditions of exisiting hospitals particularly in the Southern California uplift area.

Preemption: Pursuant to Hospital Seismic Safety Act consult with local building jurisdictions regarding statutory preemption of such by the state.

The specific objectives of the above bodies have been achieved. The panels, however, have been kept intact to consider new projects that are spin-offs from the original committee assignments. For example: the development of a list of departments that are basic to a general hospital operation gave rise to a recommendation of a statewide structural survey of health facilities. The survey, based upon experience gained in the Southern California Uplift program, would establish a timetable of structural improvement or discontinuance of hospital usage.

The subcommittees on Earthquake Policy and Essential Functions, through joint meetings, developed a six-category list of structural quality levels that would determine improvement/discontinuance decisions:

III. OTHER ACTIVITIES

The value of proposed construction shown in plans reviewed by A/E, SSS, and SFM in 1985 is $800,000,000. In addition to this plan check routine, A/E provides staff services for the Building Safety Board and its committees.

Soon to be initiated are the following:

- Standardized computation patterns for anchorages of fixed equipment and other non-structural components under various conditions.

- Structural requirements of surgical centers. These out-patient facilities are particularly well-suited to the provision of emergency services following an earthquake.

- Structural examination of all hospitals statewide. The Structural Safety Section will conduct this investigation.

- Discussions with private mechanical engineers regarding the placement (location upstream vs. downstream) of filters in air intake ducts. Currently, A/E requires both locations per Part 4, Title 24, CAC.

- Post-earthquake evaluation of damaged hospitals.

- Adoption of 1985 Uniform Building Code (Structural).

- Review of new Special Studies Zone (Seismic) proposed by the California Division of Mines and Geology.

- Review of requirements of isolated power centers.

- Review of OSHPD appeals procedures.

The following information has been reproduced from the Essential Functions Subcommittee of the State of California Hospital Building Safety Board.

PROPOSED RETROACTIVE REQUIREMENTS FOR HSSA

All hospital structures housing essential functions listed in Table 1 below shall be made to fully comply with the seismic requirements of Title 24 prior to a time 40 years from the Base Date. The exact time allowed for removal of essential functions from non-complying buildings or for structural strengthening shall be determined as follows:

A structural **Code Compliance Priority Rating,** P, will be established for each structural entity. Each structure or portion of a structure that will act independently during seismic motion due to physical separations at its boundaries shall be considered a separate structural entity.

By, Y, the year under consideration in the future, the Code Compliance Priority Rating for any structural entity shall be made equal to or less than,

$$P_{max} = \frac{900}{(Y\text{-Base Year})^2}$$

The Code Compliance Priority Rating shall be defined,

$$P = DER$$

where D = Structural Deficiency Index

E = Essential Function Exposure

R = Use Extension Factor

The **Structural Deficiency Index**, D[1] shall be a measure of the ability of the structure to successfully resist lateral forces:

D = 9.0 for buildings with no recognizable lateral force resisting system.

D = 2.25 for buildings with lateral force resisting systems that will resist code forces using an I less than 0.75.

D = 1.00 for buildings in substantial compliance with the code using an I of .75.

D = 0.0 for buildings in full compliance with Title 24.

1.The Structural Deficiency Index will require additional definition and possibly more categories in its final form. The range from 1 to 9 is meant to be a bracket.

The **Essential Function Exposure**, E, shall be a measure of exposure of essential functions to disruption due to poor structural performance:

$$E = 0.5 + \Sigma e_i$$

Where e_i represents an importance factor on each essential function as listed in Table 1 and Σe_i is the sum of the factors for the functions housed in the structural entity under consideration.

The **Use Extension Factor**, R, shall discourage, but not prohibit, life extending remodels to essential functions in non-complying buildings. The factor shall consider the cumulative total of all such extensions of use starting at the Base Date.

$$R = 1 + \Sigma r_i$$

where r_i is related to the e_i of the essential function remodeled as follows:

$$r_i = (D^{1/2})(e_i)$$

Remodels[1] must significantly extend the useful life of the existing function or be a part of 1 a plan to extend the useful life of the function to be assigned an r_i.

[1]Criteria will have to be developed to define such remodels.

ESSENTIAL FUNCTION	IMPORTANCE FACTOR, e_i PER FUNCTION
GROUP 1 Emergency Surgery O.B. Critical Care Beds: each 12 beds or fraction thereof	0.2
GROUP 2 Laboratory Radiology	0.15
GROUP 3 Beds other than Critical Care: each 50 beds or fraction thereof	0.10
GROUP 4 Pharmacy Required General Storage Area Dietary	0.05
GROUP 5[1] 5A Emergency Generator	0.2[2]
5B Boilers Medical Gas Transformers, Main Switchgear	0.05[2]

1. Group 5 categories include ancillary elements required for operation but do not include distribution systems.
2. The e_i listed shall be tripled for equipment not anchored in compliance with Title 22.

TABLE 1. ESSENTIAL FUNCTION IMPORTANCE FACTORS

Following are meeting notes of the "Essential Services Ad-Hoc Subcommittee" of March 7, 1979.

I. BACKGROUND: (Items mentioned but not discussed to conclusion)

1. In part, the provisions of the Hospital Seismic Safety Act are interpreted to mean that hospital buildings housing *one* or more "essential" departments (services) shall be designed and constructed in a manner that will permit the continued operation of necessary functions during and following an earthquake.

2. Current considerations propose that certain departments (services) which are parts of a hospital complex but are separated from the main hospital building and which contain *no essential* departments and equipment may be subject to the Department's less stringent review of seismic safety features under certain conditions.

3. "Certain Conditions"

   a) Single story, wood frame, one-hour fire resistant Level 2 buildings shall meet the design and construction requirements of Chapter 23 of the Uniform Building Code for hospital buildings, and shall be subject to the Department's review.

   b) Separate Level 2 (see below) buildings shall be located at a distance from the main hospital building equal to or greater than the height of the least-structurally-stable building. Connecting passageways with appropriately located seismic joints are permitted.

II. MEETING NOTES:

1. Discussion of degrees of essentiality resulted in the adoption of two categories (after discarding a "three-category" theory):

   LEVEL 1: Services and equipment which are indispensable to the continued operation of a hospital during and following an earthquake.

LEVEL 2: Services and equipment which, if use is curtailed through earthquake damage, will not inhibit the continued operation of the hospital during and following a disaster.

2. Agreement was reached on assigning the Basic Services set forth in Title 22 to Level 1, excepting the Pharmaceutical Service. Thus Medical, Nursing, Anesthesia, Surgical, Radiology, Laboratory and Dietetic Services and supporting equipment are considered to be indispensable to the performance of a hospital.

   Withdrawal of the Pharmaceutical Service from the essential category is based on: 1) a four day supply of drugs can be made available in each nursing unit, and 2) there is little likelihood of drug compounding being performed during a disaster. Thus the Pharmaceutical Service assumes a "warehouse" function in which plumbing, heating, ventilation, power and lighting are not dire necessities.

   However, subsequent discussions with Facilities Licensing indicates that a four day supply of drugs on each nursing unit is unrealistic and not now required and therefore the Pharmaceutical Service has been included under Level 1. Outpatient pharmacies may be located under Level 2.

   Additionally, Title 22, California Administrative Code lists a number of hospital services which are not hospital licensing requisites. The Panel determined, however, that certain licensure non-essentials become disaster-oriented necessities. Accordingly, the following Level assignments are recommended for an acute general hospital:

LEVEL 1	LEVEL 2
Medical Service Space	Administration Space
Nursing Service Space	Morgue
Surgical Service Space	Employees Dressing
Anesthesia Service Space	Housekeeping
Clinical Laboratory	Laundry
Radiological Service Space	Chronic Dialysis
Pharmaceutical Service Space	Dental
Dietetic Service Space	Nuclear Medicine
Acute Respiratory Care	Occupational Therapy
Basic Emergency Medical, Physician on Duty	Outpatient
Burn Center	Physical Therapy
Cardiovascular Surgery	Podiatric
Comprehensive Emergency Medical	Radiation Therapy
Coronary Care	Rehabilitation Center
Intensive Care Newborn Nursery	Respiratory Care
Pediatric Service	Social Service
Perinatal Unit	Speech Pathology and/or Audiology
Psychiatric Unit	Storage
Renal Transplant Center	
Standby Emergency Medical	
Storage	

Following are OSHPD approvals (R-number) for equipment anchorage.

NO.	TITLE	CONTACT	DATE (1)
R-0003	Superstrut Seismic Restraint System	Midland-Ross Corporation, P.O. Box 857 Oakland, CA 94604	03/26/84
R-0008	Seismic Anchorage for ROLM CBX Cabinets (2)	ROLM Telecommunications 4900 Old Ironside Drive Santa Clara, CA 95050	08/20/84
R-0010	SMACNA "Guidelines for Seismic Restraints of Mechanical Systems & Plumbing Piping Systems"	The Sheet Metal Industry Fund of Los Angeles, or The Plumbing & Piping Industry Council, Inc., Los Angeles	02/10/82
R-0011	Herman Miller Free Standing & Wall Hung Laboratory Units	Herman Miller, Inc. 8500 Byron Road Zeeland, Michigan 49464	03/18/84
R-0012	Isolator Restraints (RJEQ)	California Dynamics Corp. 5572 Alhambra Avenue Los Angeles, CA 90032	03/30/82
R-0016	Technicare Delta Systems 2060, 2020, 2010, 2005, 50 FS, 100	Technicare Corp. P.O. Box 5130 Cleveland, OH 44101	08/02/82
R-0018	American Telecom Focus Elite PABX Cabinets (2)	American Telecom, Inc. 3190 Mira Loma Avenue Anaheim, CA 92806	12/10/82
R-0021	Technicare DR-960 System	Technicare Corp. 29100 Aurora Road Solon, OH 44139	12/07/82
R-0024	U.T.C. Communications DBX Cabinet, Power Frame Cabinet, Battery Frame	United Technologies Corp. 1475 So. Bascom, Suite 113 Campbell, CA 95008	09/29/82
R-0030	Herman Miller Low Profile Furniture Partitions (3)	Space Design, Inc. 2490 Charleston Road Mountain View, CA 94043	09/19/83

NO.	TITLE	CONTACT	DATE (1)
R-0031	Isolator Restraints (SSLFH)	Mason Industries, Inc. 708 North Valley Street Suite K Anaheim, CA 92801	11/25/83
R-0040	Numerous Items of Diagnostic Imaging Equipment	Picker International 595 Miner Road Cleveland, OH 44143	10/17/84
R-0041	GTE OMNI SII/SIII PABX Cabinet	GTE Business Communication Systems, Inc. 12502 Sunrise Valley Drive Reston, VA 22091	05/03/84
R-0042	Lexar Digital PABX Cabinets	United Technologies Lexar 31829 La Tienda Drive Westlake Village, CA 91362	11/16/84
R-0043	Technicare Corporation HPS CT Scanner Equipment	Technicare Corporation P.O. Box 5130 Cleveland, OH 44101	08/23/84

NOTES

(1) This is date of approval or latest renewal. Approvals are valid for a maximum of three (3) years.

(2) Approved for maximum ZICp of 0.5.

(3) Approved for use only in non-patient, administrative, office areas.

Appendix 4

Bibliography

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