PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Nonstructural Loss Estimation: The UC Berkeley Case Study

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ABSTRACT

Compared to structural systems, there is little basic research on the performance of nonstructural systems and building contents, and little empirical data on damage to specific systems, from past earthquakes. This report describes approaches to nonstructural hazards mitigation at the University of California, Berkeley, and focuses on design and cost estimates for anchoring the contents of laboratories. Research equipment is grouped into five categories: (1) tanks and cylinders, (2) unique equipment and experimental setups, (3) heavy equipment, (4) storage elements, and (5) benchtop items. Illustrative anchorage details are based on a combination of commonly available products and engineered standard details. The details serve as a basis for estimating the cost of installation in five prototypical university laboratories including two from biological science, and one laboratory each from computer science, chemistry, and physics. The direct costs for anchoring the contents in these laboratories ranged from $10 to $16 per square foot. Additional anchoring for ceiling systems, and mechanical, electrical, and fire suppression systems could add $1 to $6 per square foot, depending on existing building conditions. To answer whether or not the anchoring of laboratory contents is a worthwhile expenditure will depend on the impact of such anchoring on building downtime together with dollar losses avoided.

Keywords:

Nonstructural, mitigation, cost, laboratory contents, equipment, nonstructural systems, anchoring, PEER, performance engineering.

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EXECUTIVE SUMMARY

The damage to the nonstructural systems and building contents has become a critical component in the process of estimating potential capital losses and downtime resulting from an earthquake. Compared to structural systems, there is little basic research on the performance of nonstructural systems and building contents, and little empirical data on damage to specific systems from past earthquakes. However, PEER researchers recognize the need to incorporate nonstructural systems and contents into performance-based earthquake engineering, and a program of design investigations and testing is under way. This research project describes approaches to nonstructural hazards mitigation at the Berkeley campus of the University of California, and focuses on designs and cost estimates for anchoring the contents of laboratories.

The central campus of the University of California at Berkeley has 114 buildings on 177 acres, with about 5 million net square feet of classrooms, libraries, offices, research laboratories, and other specialized facilities (such as food service and performing arts). The Hayward fault crosses the eastern end of the campus and serves as a continuous reminder of the vulnerability of the campus buildings. Libraries and research laboratories hold 78% of the \$3.2 million in contents value, and 17 laboratory buildings house 75% of annual sponsored research. Given the concentration of equipment and research value in the laboratories, loss reduction methods could be applied there.

This study details the types of equipment and contents in typical university laboratories, provides prototypical designs for anchoring, estimates the cost of anchoring the equipment and contents, and applies the results to five prototypical laboratories. The critical contents in most university laboratories can be cataloged in the following five categories: (1) tanks and cylinders, (2) unique equipment and experimental setups, (3) heavy equipment, (4) storage elements, and (5) benchtop items. Anchoring and bracing of the heavier contents can mimic techniques used for building service systems, employing concrete anchors and steel sections. For lightweight and benchtop equipment, many companies have developed systems using adhesives, friction material, Velcro™, nylon tapes and buckles, and other easy to employ anchorage devices. Although testing data is not generally available, the applicability and adequacy of these devices are obvious in many situations.

We designed illustrative details based on a combination of standard anchorage materials commonly available and engineered standard details. Each of these details is keyed to the variety of contents in the five categories. The design details served as the basis for estimating the cost of installation. For example, in the Tanks and Cylinders category, an individual cylinder (detail T1) can be attached to the wall with commonly available hardware for about $100, while a permanent tank of less than 250 pounds (detail T3) can be attached to the wall with an "engineered standard detail" for about $180.

With these details and costs, we document two biological science laboratories, and one laboratory each in computer science, physics, and chemistry. Each case study is accompanied by drawings, photos, and equipment lists. The direct costs for anchoring the contents in these laboratories ranged from $10 to $16 per square foot. If the work were to be done by an outside contractor, it would be necessary to add 25% for contractor overhead and profit. Although the costs appear high, it should be noted that these laboratories are densely occupied because space is at a premium on the UC Berkeley campus, and most researchers work in relatively crowded laboratories. In addition, this estimate is for the anchorage of every piece of equipment in the laboratory. In any individual laboratory retrofit, only a subset of the most important or valuable equipment may need to be anchored, bringing down the overall costs per square foot.

We considered the overall cost to retrofit laboratory equipment in all the laboratory spaces in buildings on the UC Berkeley campus. Using a range of $10 to $15 per square foot, the total costs for such a program would range from $11 to $16 million. However, many of the spaces designated "research laboratory" in the campus space database are teaching labs and preparatory spaces without research equipment. A more realistic estimate of costs to retrofit laboratory space in 29 research buildings ranges from $8 to 12 million.

In the case of laboratories, most of the value and risk are represented by the contents; however, there is a significant interdependence between the potential losses and downtime caused by damage to contents and the physical conditions surrounding the laboratory in the structure and building service systems. As part of the study, we estimated the costs to anchor ceiling systems, and to mechanical, electrical, and fire suppression systems in laboratory buildings. These costs range from $1 to $6 per square foot of laboratory space, depending on the building and system conditions. It was beyond the scope of this report to develop cost/benefit models for contents and nonstructural seismic improvements. However, the costs of anchoring contents, as described in this report, represent only a 10% to 15% increment over the typical costs of structural retrofits.

The final determination of whether the anchoring of laboratory contents is a worthwhile expenditure will depend on the impact of such anchoring on building downtime together with dollar losses avoided. With further research on designs for building-specific contents anchoring, and with testing of the behavior of contents anchors, we will be able to better assess the efficacy of such nonstructural retrofits.

Introduction

The spiraling costs associated with large urban earthquakes have pushed policy makers, businesses, institutions, and private property owners to seek a reduction in societal and economic losses beyond the standards for prevention of life-loss and injury. The Pacific Earthquake Engineering Research Center (PEER) research into Performance-Based Earthquake Engineering (PBEE) attempts to provide quantitative tools for characterizing and managing these risks. The PEER Center approach is aimed at improving decision making about seismic risk by making the choice of performance goals and trade-offs they entail apparent to facility owners and society at large.

To meet this aim, our understanding of building performance needs to incorporate reliable loss estimates for nonstructural building components as well as design solutions for mitigating nonstructural hazards in existing and new buildings. The need for better loss data and design techniques has been recognized for more than 20 years. A review of the nonstructural literature demonstrates that seismic restraint "handbooks" for furniture, equipment, and supplies were developed for the Veterans Administration and the Armed Services by practicing engineers after the San Fernando Earthquake [Rutherford and Chekene, 1976; Reid and Tarics Associates, 1981]. Robert Reitherman wrote the first practical guide to reducing the risk of nonstructural damage for the Southern California Earthquake Preparedness Project (SCEPP) in 1983. This guide has been reprinted several times by the Federal Emergency Management Agency (FEMA) and the California Office of Emergency Services.

Some testing of partitions and a limited number of other building components has been done over the years, and some limited data on nonstructural losses have been collected after the Northridge and Kobe earthquakes. Another recent compendium of research on the design, retrofit, and performance of nonstructural components was published by the Applied Technology

Council, ATC 29-1, the proceedings of a seminar on the subject [ATC, 1998]. The most recent publication to include an inventory and summary of past analytical and experimental research on nonstructural building components is a PEER report, *Guidelines, Specifications, and Seismic Performance Characterization of Nonstructural Building Components and Equipment* by Filiatrault et al., 2001. Unfortunately, the attempts to define the nonstructural problem leave many questions unanswered.

There is neither a taxonomy of nonstructural building components nor a priority list of the most vulnerable components. Loss data are often anecdotal. No systematic quantification of nonstructural losses has ever been done after a major earthquake. Similarly, there has been little engineering design or testing of most of the proposed mitigation solutions for anchoring mechanical systems and sprinklers, ceiling systems, curtain walls, facades, partitions and other building components, or contents.

For PEER to incorporate nonstructural building components into an overall performance framework will require a more systematic approach to nonstructural loss data and an equally systematic approach to quantifying performance characteristics of nonstructural components through analysis and testing.

This research project looks at building contents on the UC Berkeley campus. Extensive structural evaluations of 114 buildings on the central campus were done in 1997 by Degenkolb Engineers, Forell-Elsesser, and Rutherford and Chekene [UC-PSE, 1997]. Detailed reviews of nonstructural building components and contents, together with an assessment of building uses and numbers of occupants, were completed by the author as part of a comprehensive study of potential earthquake losses and economic impacts to the campus [Comerio, 2000]. That study suggested that significant losses and downtime could be attributed to nonstructural damage, particularly to the contents of libraries and research laboratories. This research builds on the campus database and focuses on establishing costs for mitigation of nonstructural contents hazards.

The objective of this research is threefold: (1) to estimate the value of nonstructural losses in classroom, laboratory, office, and library spaces in a university setting; (2) to design appropriate loss reduction measures for typical space types; and (3) to estimate the cost of nonstructural mitigation measures for contents. Overall, the goal of the research is to begin to measure the contribution of nonstructural mitigation measures to loss reduction and continued operations, in the context of measures established to evaluate the performance of structural systems.

This report is not intended to provide precise design and construction details to individual spaces or equipment on the UC Berkeley campus. The intent is to evaluate typical nonstructural conditions in campus spaces, suggest mitigation solutions for these typical conditions, and to evaluate the cost of those solutions as well as the impact that mitigation could have on reducing campus losses and shortening recovery times.

Initially, we intended to identify three prototypical spaces for each of the four major space-types (classrooms, libraries, offices, and laboratories). The plan was to review the nonstructural conditions in these prototypical spaces as representative of typical space and occupancy conditions. In tours of campus spaces, we found that prototypical elements or conditions were common among classrooms, libraries, offices, and laboratories. So instead of selecting 12 rooms on the campus for the case studies, we chose to evaluate the prototypical contents common to most campus spaces.

In addition, some spaces on the Berkeley campus have had some degree of nonstructural bracing. For example, in some classrooms, projectors and monitors have been anchored or replaced, and many hazardous light fixtures have also been replaced. For office spaces, a program called Q-Brace provides matching funds to various departments to anchor furniture, computers, equipment, etc. Similarly, the architect for the campus library system is evaluating the need for seismic upgrades to library shelves as part of the campus building retrofit program.

Given that some mitigation experience and cost data were available for libraries, classrooms, and office spaces, we felt that the focus of this investigation should be on laboratory contents and their interaction with building conditions and building systems. As a result, we maintained our original objectives, but reorganized project tasks 1–3 to reflect availability of data on classrooms, offices, and libraries, and the need for more focused attention to laboratory contents. Thus, the tasks outlined in the proposal have been changed to reflect the focus on laboratories:

- Task One: Survey nonstructural conditions in campus space and identify prototypical contents conditions in laboratory spaces across the campus.

- Task Two: Review and itemize nonstructural conditions and approaches to mitigation in classroom, office, and library spaces.

- Task Three: Prepare existing conditions drawings of the five example case study laboratory spaces.

- Task Four: Conduct literature and design reviews of accepted methods for nonstructural mitigation measures and document these findings.

- Task Five: Prepare conceptual design drawings for nonstructural mitigation for the general conditions as well as the five sample laboratory spaces.

- Task Six: Prepare cost estimates for the nonstructural designs for the laboratory conditions, and cases, and document costs in other campus spaces.

- Task Seven: Estimate total costs for the aggregation of nonstructural measures.

- Task Eight: Evaluate the potential loss reduction of such measures.

- Task Nine: Evaluate the nonstructural loss reduction measures in the context of building structural performance objectives, and compare the cost of nonstructural measures to that of structural retrofits.

- Task Ten: Prepare a final report presenting the findings and conclusions.

The report is organized as follows: Chapter 1 describes the existing UC Berkeley campus programs to mitigate nonstructural hazards in classrooms, offices, and libraries, and includes a summary of costs based on recent program experience. The section also includes a description of the value of research to the UC campus and the critical nature of the laboratory contents.

Chapter 2 provides a general discussion of nonstructural elements in buildings, distinguishing between building systems, building services, and building contents. This chapter describes five categories of typical laboratory contents and discusses the issues associated with the seismic protection of laboratories. The five categories are (1) tanks and containers; (2) unique research equipment (either because the equipment needs vibration isolation or because the equipment itself is research in progress); (3) heavy machines, including refrigerators, and freezers; (4) storage for chemicals, experiments, equipment, tools, parts, etc.; and (5) benchtop equipment.

Chapter 3 provides schematic design solutions for the conditions described in Section 2 and estimates of the costs for each. This section also includes drawings and documentation of five prototypical laboratories in order to document the cost of solutions necessary to improve the performance of the laboratory contents. In addition, mitigation costs are estimated to include other improvements in the building systems, such as mechanical, electrical, and plumbing systems.

Chapter 4 concludes the report with an assessment of nonstructural mitigation measures in the context of building performance and specific directions for PEER in continuing research into the performance of nonstructural conditions. Scientific progress in developing an understanding of nonstructural losses can have a great impact not only on life safety, but also on the reduction of downtime and repair costs.

1 Nonstructural Hazards Mitigation and the UC Berkeley Campus

Universities are unique and specialized in terms of their physical facilities, which serve both research and teaching. They are somewhat self-contained communities with housing, food services, small businesses, performance and recreational spaces, and hospitals in addition to their academic space. Universities have concentrated value, not only because of their facilities and specialized contents, but also because of the public investment they represent in terms of students and research. Universities play a role in the economic well-being of a community (in the traditional mode of employment/wage, goods, and services benefits), and also in the sorting function of bringing talented individuals from out of state, then "retaining" them for jobs in the regional economy.

The University of California, Berkeley, is a worldwide leader among universities in research, education, and public service. The central campus houses over 40,000 students, faculty, and staff in more than 100 academic departments and research units. The central campus has 114 buildings on 177 acres, with about 5 million net square feet of classrooms, libraries, offices, research laboratories, and other specialized facilities. The annual campus operating budget is about $1 billion dollars, and the sponsored research awards average about $400 million per year.

UC Berkeley has done more than any other campus in the nation to address the threat of earthquakes. The campus has had a seismic corrections program in place since 1978. After a 1997 re-evaluation of building conditions, the campus committed to spend about $20 million per year for the next 20 years to improve the structural conditions of campus facilities. Another study [Comerio, 2000] addressed the economic impact of potential losses under various earthquake scenarios. In addition to the cost of repairs, it considered the time needed for repairs to make the campus habitable and operational. Even in a moderate earthquake, the study estimated that 19% of laboratory space could need more than 20 months for repair. In a magnitude 7.0 earthquake on the Hayward fault, the estimates ranged from 30% to 50% of all spaces needing more than 20 months for repair.

Space on the campus is not evenly divided among uses. Only 6% of the net square footage is allocated to classrooms, while 30% is to laboratories, 29% to offices, 16% to libraries, and 19% to other spaces such as the student union, food service, performance space, and storage. This allocation of space is not significantly different from other universities because classrooms are shared throughout the day, but labs and offices belong to individual researchers and students.

University buildings have large numbers of occupants for many hours per day, and they also have very special contents—books, artwork, artifacts, and research equipment (see Table 1). In value, books are more than half of the $3 billion dollars in scheduled non-building assets. Equipment and art are each valued at more than 20% of total. As in the case of space use, these assets are not distributed evenly on the campus. The majority (two thirds) of the library collections are housed in four main buildings. The art and artifacts are in three other buildings. Fifty percent of the research on the UC campus is conducted in seven buildings, 75% in 17 buildings [Comerio, 2000]. Twenty-nine of the 114 buildings on the main campus have contents valued at greater than $5 million [UC Berkeley, 2000].

TABLE 1

Berkeley Campus Insurable Asset Values for Year 2000

Item	Value	Percent
Contents	$593,157,455	18.4%
Non-Capital Equipment	$83,042,046	2.6%
Library	$1,829,321,229	56.7%
Fine Art	$708,621,134	22.0%
Vehicles	$9,354,023	0.3%
TOTAL	$3,223,495,887	100%

Source Comerio 2000

The Comerio study demonstrated that despite the commitment to improvement of life-safety hazards, the UC Berkeley campus remained vulnerable to earthquake loss. Overall, the potential loss to buildings and contents could represent as much as 30% to 40% of replacement value, and the disruption to teaching and research, even if only partial closures were required, would be unacceptable. The study recommended that the campus consider operational needs in planning for building improvements, develop business resumption plans for all units, and enhance nonstructural mitigation programs across the campus.

This research project builds on the findings of the campus loss estimation studies and is focused on the techniques and costs involved in reducing losses to building contents and other nonstructural hazards.

1.1 DEFINING NONSTRUCTURAL CONDITIONS

The nonstructural components of a building include the exterior finishes (cladding and glazing), interior finishes (partitions, lights, ceiling systems), all mechanical, electrical, and plumbing systems, and the contents (furnishings and equipment). Although there are limited data on the extent of loss in nonstructural systems from previous earthquakes, the types of damage are documented for ceiling systems, sprinklers, storage racks, library shelves, and equipment. However, though the earthquake engineering research community has some understanding of the types of failures in nonstructural components, the statistics on the failures of any particular type are inadequate.

Most efforts to address seismic design for nonstructural components fall into two categories: (1) changes in the building code for nonstructural design force coefficients, and (2) guidebooks with details for anchoring furniture and contents. Although there has been an effort to identify the nonstructural problem, there has been very little engineering design or testing of anchoring details for building components or for contents. Most of the solutions proposed and used may be better than doing nothing, but the reliability and performance of many nonstructural anchoring details have not been studied. This is a problem with details in publicly available guidebooks, with many products sold as "seismic restraints," and in details adopted and used by UC programs.

1.2 UC PROGRAM EXPERIENCE

The University of California, Berkeley, has three existing programs to mitigate nonstructural hazards in campus buildings. The programs are focused on furnishings and ceiling conditions in libraries, classrooms, and office spaces. The library system reviews the conditions of library shelves, and makes recommendations to include shelf strengthening whenever a library is part of a building seismic retrofit. As part of the campus plan for building seismic improvements, some funds were allocated to review the life-safety conditions in general assignment classrooms. Here, light fixtures were replaced and monitors and projectors were anchored or replaced in the most vulnerable classrooms. In the third program, called Q-Brace, the central campus administration made matching funds available to departments to anchor furniture and equipment. Although a general set of design guidelines was issued with the furniture program, the specific design details and the installation were left to the individual units.

1.2.1 Libraries

Library shelving is a structural system designed to carry heavy loads. The failure of library shelves in earthquakes can be a very serious hazard for building occupants. These failures have been noted over many years. Although there are no good statistics on the percentage of shelf failures, every earthquake reconnaissance report contains descriptions of shelves tipped over with books piled on the floor. In addition to the labor in reshelving the books, some portion will have broken spines that need repair. Even in the recent Nisqually earthquake in the Seattle-Tacoma region, where the damage was relatively light, the engineering library at the University of Washington was closed due to failure of the library shelving system.

The UC Berkeley campus library system includes the Doe main library plus 18 branches. Additionally, there are 20 other special-use libraries on the campus that are not part of the main library system. The library system employs an "in-house" architect to work with the architects and engineers on new buildings and most existing building renovations when a library is in the building. For example, the Doe library was renovated and a major new building was constructed underground. In this case, a combination of new compact shelving and upgraded standard metal shelving was used. In the case of Moffett Undergraduate Library, the building was seismically upgraded, but the existing shelving was not improved.

The decisions to seismically upgrade or replace library shelving are made on a project-by-project basis, based on a number of factors. The project budget and the need for other code improvements in the library space are often dominant. The cost of seismically improving a typical library shelf unit (36 inches by 12 inches by 90 inches tall) is $150, half the cost of a new shelf. The work involves the addition of a triangular gusset plate on the sides of the shelf unit and an "x" brace on the back. It is a labor-intensive project, given the hundreds of shelves in any given library.

The strengthening method must be designed for the particular shelf unit and the design work is typically done by the manufacturer of the shelving unit. Obviously, there is a great deal of variation among the basic shelf design, depending on the age of the product, so it is important to have the manufacturer involved. Unfortunately, there does not appear to be a clear uniform engineering standard for the design solutions proposed by manufacturers, even though some research has been conducted by Rihal and Gates [ATC 29-1, 1998]. As such, it is very hard to evaluate the effectiveness of completed library shelf retrofits at UC Berkeley.

1.2.2 Offices

The Quake-Bracing Assistance Program (Q-Brace) was instituted at UC Berkeley in 1999 to provide matching funds to campus departments to address nonstructural seismic safety hazards. At the same time that the campus had begun a major program of seismic building retrofits and infrastructure improvements across the campus, the administration wanted to provide some funds to campus units to anchor bookshelves, file cabinets, and other equipment that could cause injuries during earthquakes. The administration has made about $100,000 available each year since 1999 for this purpose.

The Q-Brace program is administered by staff from Environment, Health and Safety (EH&S), although the review of existing spaces and needs as well as the actual bracing are left to the individual departments. Inspection sheets and bracing guidelines were developed by a structural engineer, and a cost estimation sheet for labor and materials was provided by Physical

Plant-Campus Services. EH&S staff are typically not trained in structural engineering, so there is little oversight of the construction details. The EH&S staff administers the program and sees that work is completed, but cannot provide quality assurance.

The Q-Brace program includes two basic categories of seismic improvements. The first is for bracing of computer monitors, printers, and benchtop equipment all under 50 pounds. For these items, the program recommends simple strapping devices available from a variety of manufacturers. These can be installed by anyone. In the second category is furniture over four feet tall, equipment over 50 pounds, furniture drawers or cabinet doors without latches, and some lab items such as unsecured gas cylinders. For these items, a set of generic details is available. Most departments use carpenters and other skilled labor from the Academic Facilities Office or Physical Plant-Campus Services to estimate the costs of labor and materials, and to do the actual installation. In some cases, the departments do the work with their own staff or graduate students.

The cost for the materials for the computers or benchtop equipment, and for the hardware needed for the furniture and door latches typically runs between $10 and $20. There is no labor cost for the computers and lightweight equipment. For furniture and heavier equipment, the typical estimate is between one and two hours, depending on the complexity of the job. A cabinet with multiple drawers, a freezer, or gas cylinder will take somewhat longer than a simple bookcase. Using campus personnel, the labor cost is estimated at $50 per hour. Departments using their own staff typically estimate labor at $20 per hour. Overall, the anchoring for a simple piece of furniture ranges from $40 to $70. A gas cylinder, a freezer, or other larger equipment may range from $150 to $300 because these typically involve $70 to $80 in materials and the remainder in labor (see Table 2).

TABLE 2

Range of Costs for Bracing Furniture and Equipment[1]

Item	Cost Range[2]
Computer	\$10.00–\$20.00
Furniture over 4' in Height	\$50.00–\$95.00
Drawer Latch	\$5.00–\$35.00
Cabinet Door Latch	\$20.00–\$75.00
Bookcase/File Cabinet	\$35.00–\$45.00
Refrigerator/Freezer	\$155.00–\$300.00
Gas Cylinder	\$175.00–\$200.00

Notes:

[1] Based on actual estimates for recipients of Q-Brace funding 2000–2001.

[2] Cost range includes labor and materials. Costs vary with the scale of the work order and the labor rate. For UCB the typical campus staff labor rate used here is \$50.00/hr. Typical materials cost is 25–30% of total cost.

The Q-Brace program has provided the funding for approximately 80 campus units to anchor bookcases, furnishings, computers, and some lab equipment. The program is popular with departments and can clearly make a significant impact on preventing falling hazards for very little cost. As in the case of the library, the overall effectiveness is hard to evaluate, primarily because there is no engineering standard for the anchoring details. The individual carpenters, or in some cases graduate students, are expected to select the hardware and install the anchor based on their own judgment. Although we have seen excellent work done throughout the campus, we have also seen numerous cases of inadequate anchors and inappropriate attachment to floors and walls. The program could be more effective if an engineer were available to monitor designs and installations.

1.2.3 Classrooms

Typically, classrooms are fairly empty spaces except for the furnishings, ceiling lighting, and projection equipment installed in some larger lecture halls. Over the last three years, the staff managing the general assignment classrooms on campus have surveyed classroom conditions and worked with the Capital Projects office to replace hazardous light fixtures or to simply remove glass lenses on older light fixtures in about 70 of the 240 general assignment classrooms.

Staff in the Office of Media Services (OMS) has also looked at limiting the dependence on ceiling mounted monitors and anchoring those that must remain.

As with most nonstructural improvements, the costs vary because the anchorage needed depends on the condition of the ceiling or wall. When possible OMS has tried to eliminate old TV monitors in classrooms and use mobile equipment instead. As part of an instructional improvement program, it is replacing some of the old monitors with a sophisticated overhead projection system that will include VCR and data inputs. These systems still require a ceiling mounted projector (using a detail called a Mongor mount™), a smart panel and an input box in the wall. Overall these systems cost $22,000 to $25,000 per room.

The costs for these projects vary widely because each is based on the conditions in each building. One very unusual coffered ceiling in the Inter-Library Loan Department was braced for $6.90 per square foot. More commonly, the campus has added bracing cables to existing light fixtures at a cost of $50 to $80 per fixture. In cases where the light fixtures are replaced, the cost is $350 per fixture.

A more detailed discussion of the ceiling systems is presented in Section 3. We should note that art objects, musical instruments, and other highly specialized contents have not been included in this review of libraries, offices, and classrooms. The efforts undertaken on the Berkeley campus to improve nonstructural conditions have been a remarkable first step, but the next step needs to include better engineering design and a better understanding of the performance of nonstructural components and contents.

1.2.4 Laboratories

Some effort has been made by individual researchers and/or building managers to anchor critical pieces of equipment or those that might pose a life-safety hazard. Overall, there has not been a systematic effort to anchor laboratory contents. Very little in the literature on nonstructural mitigation addresses the design of anchoring for lab equipment, nor have the costs for such mitigation efforts been explored. Given the value and importance of university research, this is clearly an area of concern for university administrators and faculty.

Research on the UC Berkeley campus averages almost $400 million per year, and the funds are distributed to almost 200 units or departments. In the study of the economic impact of earthquakes on the UC Berkeley campus, Comerio and her colleagues identified the top-ranked research units and evaluated how much work took place on the central campus and in what buildings. The intent was to tie the research output to the various buildings in which the research is undertaken. The study found that 74% of all sponsored research dollars are expended in central campus buildings, with 72% concentrated in twenty-five research units, primarily in science and engineering.

The most significant finding of the study was the concentration of research in a few buildings. Of all sponsored research, 25% takes place in just two central campus buildings with only 5% of the net square feet of campus space. Only five other buildings, with 7% of the net area, comprise the next 25% of all sponsored research. Another ten buildings with 22% of the net area comprise the third increment of 25% of sponsored research (see Table 3).

TABLE 3

Core Buildings Top 20 Annual Research Value

Fiscal years 1994–1999 (average) in 1999 dollars

Use Type	Research $ Value	Rank in $ Research Value
Computer Science	$31,120,270	1
Biological Science	$21,527,387	2
Biological Science	$17,056,740	3
Computer Science	$12,729,357	4
Health Science	$7,783,766	5
Health Science	$7,741,480	6
Biological Science	$7,416,637	7
Computer Science	$7,257,629	8
Physical Science	$6,868,029	9
Health Science	$6,021,151	10
Physical Science	$5,363,345	11
Physical Science	$4,163,232	12
Physical Science	$4,136,461	13
Biological Science	$3,857,235	14
Physical Science	$3,622,805	15
Physical Science	$3,297,751	16
Physical Science	$3,009,765	17
Health Science	$2,881,592	18
Health Science	$2,580,493	19
Physical Science	$2,289,343	20

Source Comerio 2000

Overall, 75% of all sponsored research occurs in only 17 central campus buildings, with a cumulative 33% of central campus floor space. In a magnitude 7.0 earthquake, 11 of the 17 buildings could be closed for a substantial period of time for repairs (see Table 4). Although the aggregate of lost research output depends on the downtime associated with each building, and the extent to which research could be moved to other facilities, the study estimated that in a M 7.0 earthquake scenario, the research disruption cost would be approximately $87 million, and in a M 7.25 scenario could reach $122 million.

TABLE 4

Percent of Space Needing > 20 Months for Repairs

Conditions in 1999[1]

Use	Scenario O	Scenario R	Scenario VR[4]
Classroom	5%	44%	78%
Laboratory	19%	52%	66%
Office	9%	50%	72%
Library	4%	28%	38%
Telecom	2%	46%	50%
Other	11%	36%	50%

Conditions in 2006[2]

Use	Scenario O	Scenario R	Scenario VR[4]
Classroom	0%	26%	61%
Laboratory	1%	26%	40%
Office	5%	38%	59%
Library	1%	23%	33%
Telecom	1%	45%	49%
Other	7%	31%	45%

Conditions in 2011[3]

Use	Scenario O	Scenario R	Scenario VR[4]
Classroom	0%	3%	38%
Laboratory	0%	13%	26%
Office	2%	15%	36%
Library	0%	6%	16%
Telecom	1%	11%	16%
Other	0%	14%	29%

(1) Buildings under construction in 1999 were rated as if they were finished.
(2) Based on projections that 10 additional main campus buildings will have completed seismic repairs by 2006.
(3) Based on projections that 15 additional main campus buildings will have completed seismic repairs between 2006 and 2011.
(4) O represents an "occasional" earthquake scenario with moderate damage.
R represents a M 7.0 rare earthquake scenario.
VR represents a M 7.25 very rare earthquake scenario.
Source: Comerio, 2000

Laboratories constitute 30% of the overall campus space. The value of contents is estimated at $676 million, or 21% of the total insured assets. The estimate is based on the reporting of equipment valued at over $1500 by all campus units to a central equipment inventory. Although not a perfect system, it does provide a conservative estimate of contents value, since some purchases may be unreported, while others depreciate rapidly. Equally important is the inestimable value of the research itself. Refrigerators and freezers contain irreplaceable specimens. Computer hard drives store data for research in progress. These are the knowledge bases of the university.

Laboratories represent a concentration of research (as measured by annual funding) and a concentration of valuable contents and equipment. For example, the case study laboratories are located in five major laboratory buildings on campus. These five buildings each have 60 to 80% of their space in dedicated laboratories and together they comprise 24% of the total laboratory space on campus. These five buildings house equipment worth $165 million dollars. In these buildings, the typical content value would be about $200 per square foot (see Table 5). By comparison, in a typical office space, the average value of the contents is about $25 per square foot.

TABLE 5
Contents Values Per Square Foot in Five Case Study Buildings

Building	ASF	Lab ASF	%Lab	Contents Value In 2000	Contents VAL/SF Lab
Lab 1 Biological Science	122,022	73,375	60%	$19,500,000.00	$265.76
Lab 2 Biological Science	91,533	75,879	83%	$10,500,000.00	$138.38
Lab 3 Computer Science	125,257	71,688	57%	$89,200,000.00	$1,244.28
Lab 4 Physics	90,918	51,165	56%	$13,300,000.00	$259.94
Lab 5 Chemistry	115,864	74,311	64%	$13,300,000.00	$178.98

The potential loss of building operations is a serious issue for the university. However, the dollar value of the equipment, computers, and other contents in laboratories, the priceless nature of experiments in progress, the value of research supported annually, and the immeasurable value of the contribution to knowledge represented in university laboratories make them an obvious focus for mitigation of nonstructural hazards.

Existing Conditions: Illustration 1

Library 1

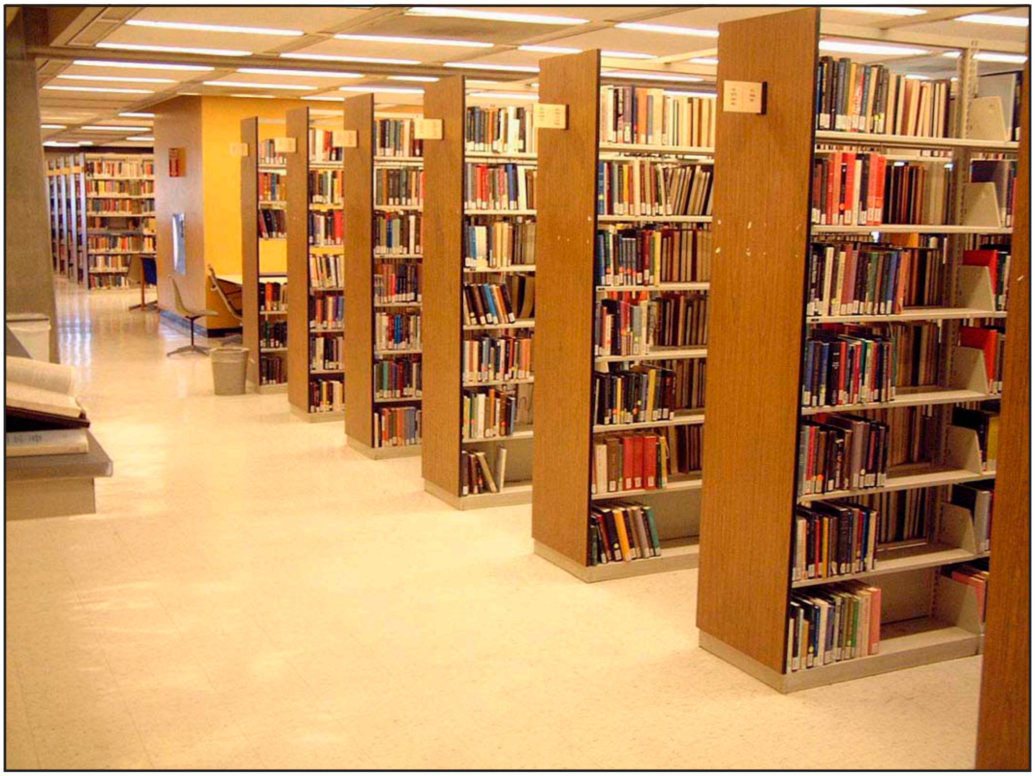

Photo Code: DSC8

Library 2

Photo Code: DSC2

Photo Code: DSC6

Office 1

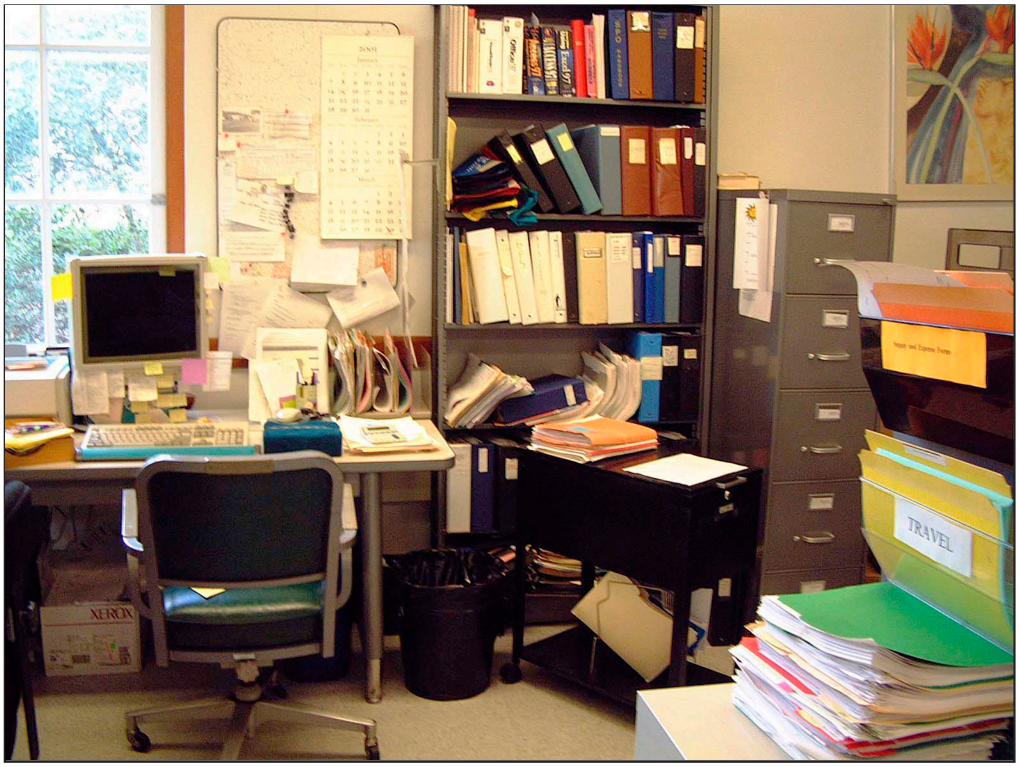

Photo Code: DSC4

Office 2

Photo Code: DSC7

Classroom 1

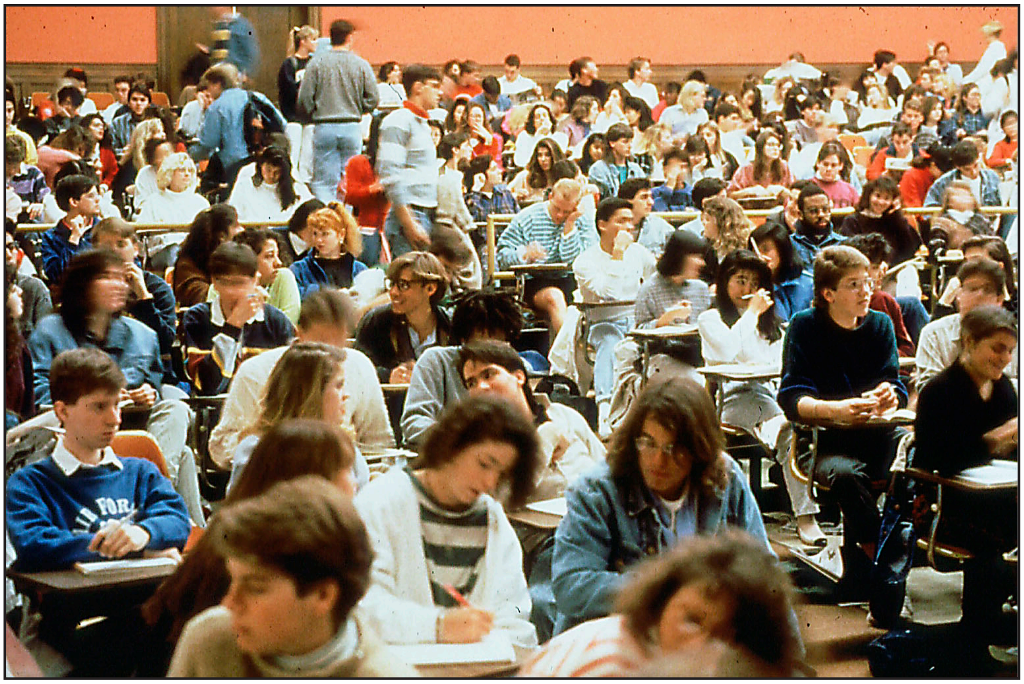

Photo Code: 009_9

Classroom 2

Photo Code: 2-5

Laboratory 1

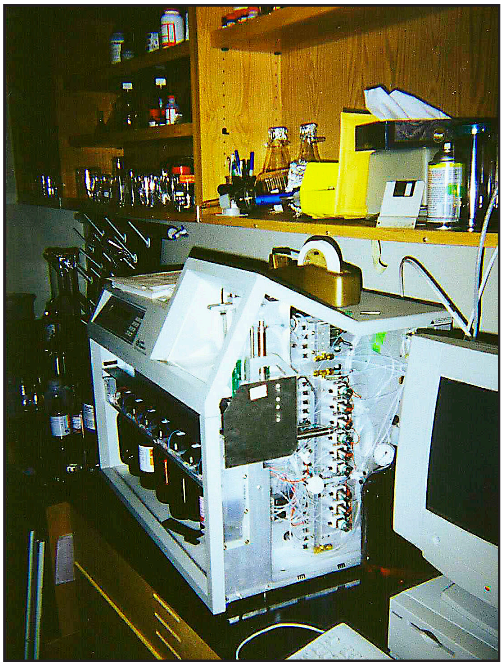

Photo Code: 3-108

Laboratory 2

Photo Code: 3-130

Library Damage 1 and 2: Cal State University Northridge Library, 1994

Photo Code: 001a_1

Photo Code: 013_13

Library 3: University of Washington, 2001

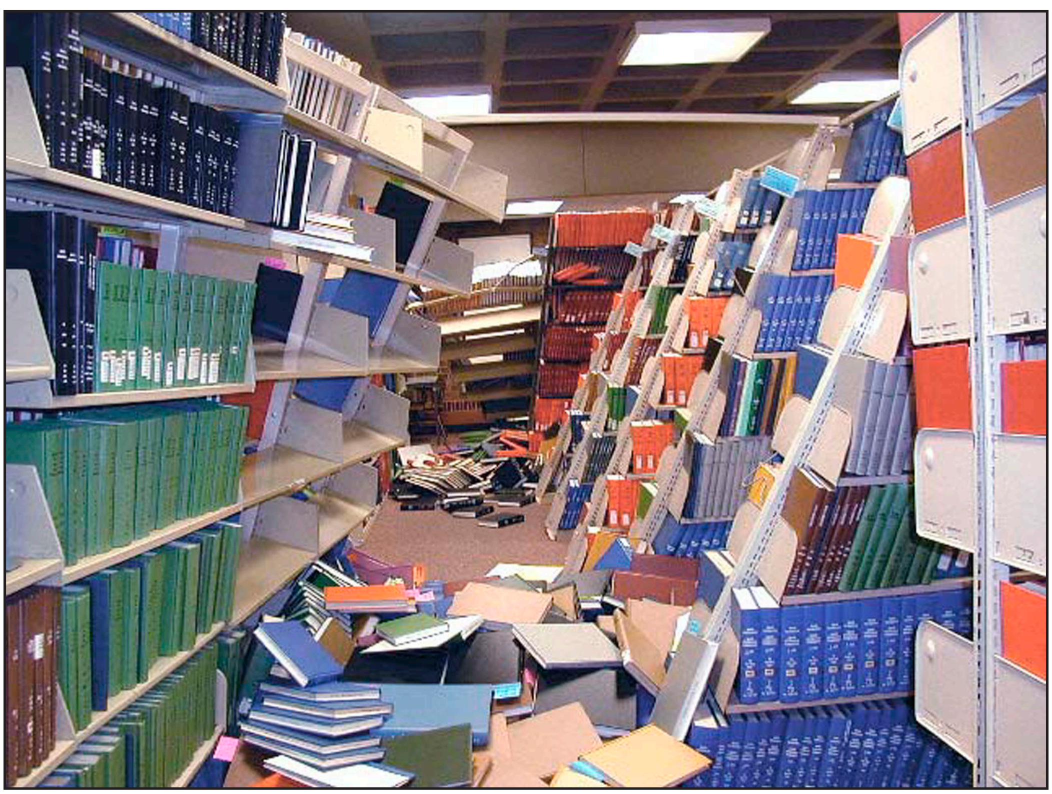

Photo Code: Engr34-30101

Office Damage 1: CSUN, 1994

Photo Code: 002_2

Office Damage 2: CSUN, 1994

Photo Code: 007_7

Office Damage 3: CSUN, 1994

Photo Code: 013a_13

Office Damage 4: CSUN, 1994

Photo Code: 015_15

Tank 1

Photo Code: 011_11

Unique Equipment 1

Photo Code: 004_4

Unique Equipment 2

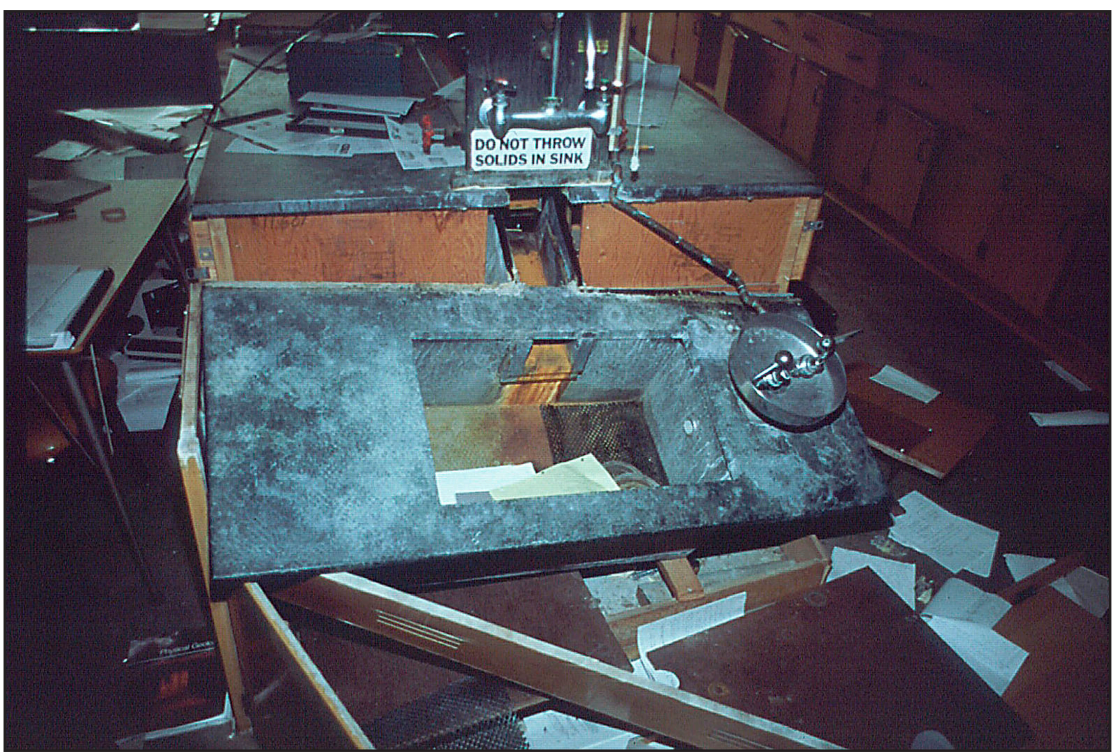

Photo Code: 009a_9

Heavy Machinery 1

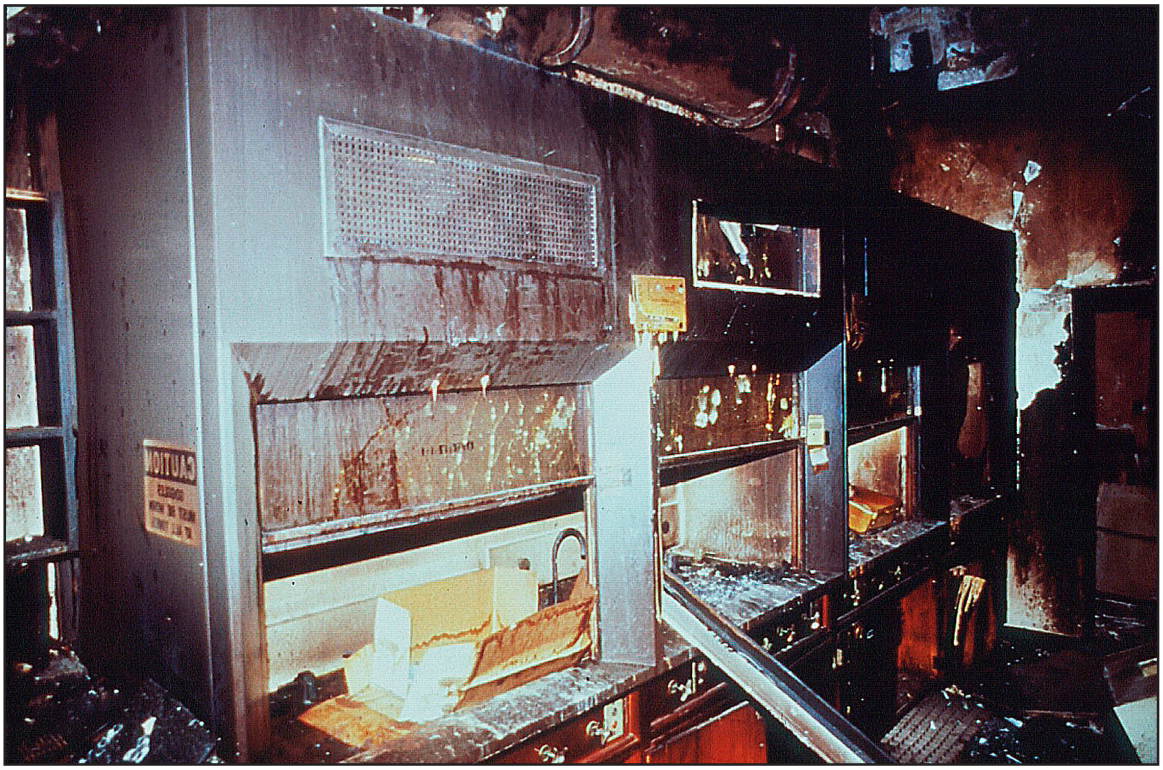

Photo Code: 006_6

Storage 1

Photo Code: 005_5

Storage 2

Photo Code: 008_8

Benchtop Equipment 1

Photo Code: 012_12

Benchtop Equipment 2

Photo Code: 014_14

Benchtop Equipment 3

Photo Code: 001_1

Benchtop Equipment 4

Photo Code: 011_11

Ceiling Damage 1

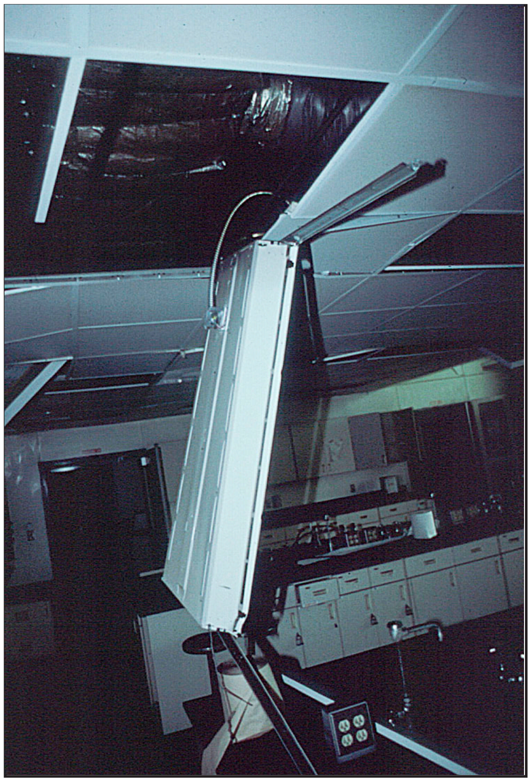

Photo Code: 010_10

Ceiling Damage 2

Photo Code: 06_Third_N

2 Nonstructural Elements and Contents in Laboratories

2.1 GENERAL

For the purpose of discussing seismic behavior of "nonstructural" elements in buildings, a further categorization is required. The most common distinction is made between "building service systems" that are part of the building systems, and often installed at the time of original construction or major remodel, and "contents," most often furnished and controlled by the user. Building service systems include mechanical, electrical, and plumbing (MEP) equipment and distribution systems required to heat, cool, and otherwise service the spaces, as well as semi-permanent partitions, casework, ceilings, and light fixtures. Contents include furniture, portable equipment, and supplies (for Veteran's Administration hospitals, a formal category of Furniture, Equipment, and Supplies (FES) was created for the purposes of procurement protocol as well as for providing seismic protection). Large, relatively permanent "user equipment" such as medical equipment in hospitals, biological safety cabinets in laboratories, or kitchen equipment fall in between and are often placed in their own category. In California hospitals, "permanent" equipment that requires code-type anchorage is identified by permanent connection to the building's wiring or plumbing systems.

Nonstructural elements in buildings can be damaged in earthquakes in two ways:

1. Acceleration-related damage: Damage due to the inertia forces generated by the building motion. Damage is caused by swinging, sliding, or overturning of unanchored elements, or when it occurs only to the restraints or the restrained element. Examples include damage to floor or counter-mounted equipment or damage to ceiling and light fixture systems.

2. Displacement-related damage: Damage due to distortion of an element caused by building drift. Examples include damage to partitions, glass, and stairways due to building drift.

Displacement-related damage is relatively straightforward: stiff buildings (shear wall, braced frames) with small inter-story drifts are less vulnerable than more flexible buildings (moment frames). On the other hand, acceleration-related damage is dependent not only on the absolute value of acceleration on a floor, but also on the entire time history of motion. Unrestrained items may slide slightly back and forth in place, may "walk" considerable distances, or may overturn, depending on the characteristics of the floor motion. Restrained or anchored elements will respond with an intensity determined by their dynamic properties, much as buildings respond to ground motions. Flexible buildings will have larger floor to floor drifts and lower floor accelerations, and stiff buildings larger accelerations and smaller floor to floor drifts. Nonstructural damage, of course, will depend on how well the systems have been designed for the various building motions. Ironically, recently completed buildings will have a tendency to be stiffer, but with no commensurate increase in acceleration resistance of the nonstructural systems, particularly contents, which will probably lead to increased nonstructural damage.

2.2 BUILDING SERVICE SYSTEMS

The Uniform Building Code (UBC) has contained provisions for seismic anchorage of certain building service systems for some time. Requirements began to expand in 1973 following the San Fernando earthquake, and the 1988 UBC [International Conference of Building Officials, ICBO, various years] covered all building service systems as described above, including "major" distribution elements. The code requirements have traditionally been implemented by requiring a design for lateral loads in the range of 20%–30% of the weight of the element. Recently, the introduction of strength design increased the basic load to 45%; in addition, the 1997 UBC changed the basis of design such that lateral loads on elements vary depending on the position in the building, and anchorage loads depend on the ductility of the fastener.

Techniques to provide improved seismic protection of building service systems are well established and the first line of defense is simply to anchor and brace elements to prevent uncontrolled movement, and to provide for building structural drift. Anchorage and bracing materials generally involve traditional materials such as concrete anchors, steel angles and other steel sections, and a few commonly available specialty products such as aircraft cable and strut channels (*Unistrut*, for example). Several pre-designed systems to provide anchorage and bracing are available, developed primarily to satisfy California hospital regulations, including the Sheet Metal and Air Conditioning Contractors National Association, [SMACNA, 1998], and the National Uniform Seismic Installation Guide, [NUSIG, 1997]. Although the individual details of these systems are competently designed, there are implementation issues, such as employment of the correct detail for the field situation, provision of details in conditions excluded from the system, and field inspection.

It is difficult with most buildings, including hospitals, to provide assurance that critical machinery or equipment, properly anchored, will continue to operate after severe shaking from an earthquake. The cost and time required to "qualify" equipment as operational after strong shaking, coupled with the relatively rare failures of properly anchored equipment in buildings, have discouraged regulations that require such qualification. This issue, as it applies both to building service systems and laboratory equipment, may be important in some cases such as where extremely hazardous materials are handled, or one-of-a-kind experimental setups are at risk.

In fact, code-required seismic protection of nonstructural systems is poorly, or at best inconsistently, provided. Owing to its direct dependence on structural design, consideration of building drift is common, but enforcement of special drift-tolerant details for interior partitions, if provided, is rare. Owing to the availability of prescriptive requirements, seismic anchorage of hung ceiling and light fixture systems and sprinkler piping are in the current construction standard of practice in California. Anchorage of large equipment and snubbing of vibration-isolated building service systems equipment are common, but not universal. Bracing of piping, ducting, and cable-trays is unusual. Other than in acute care medical buildings covered by the California Hospital Seismic Safety Act, anchorage of large "user equipment" is more dependent on the manufacturer's packaging and instructions than on the desire for good seismic performance by the design team or the owner. There are no code requirements covering restraint of contents, so lack of awareness, cost, marginal loss of convenience and functionality, and difficulties in administration make installation of such protection personalized and unusual, and systematic employment rare.

2.3 OVERALL PHYSICAL CONDITIONS AFFECTING SEISMIC PROTECTION OF LABORATORIES

In the specific case of laboratories, most of the value and risk is represented by the contents. Exotic and sometimes heavy equipment, potentially hazardous materials, and ongoing experimental setups are often susceptible to costly and dangerous direct damage and have the potential to create ongoing losses from laboratory downtime. There is a wide range of measures that can be taken to reduce the risk of damage to contents and resulting downtime which will be discussed later, but there is also a significant interdependence between the potential losses and downtime caused by damage to the contents and the physical conditions created by the structure and the building service systems, as outlined below.

Structure: A building's structural system will influence the impact to other systems and contents in an earthquake. Obviously, a poorly performing structural seismic system will supersede any local seismic protection provided within the laboratory environment. It is therefore assumed in this study that the structural performance is not the controlling factor in improving seismic performance of laboratories. (Although not the subject of this study, structural performance of older buildings and some poorly designed new buildings may very well cause closure of laboratory buildings, and in some cases directly cause damage to laboratories due to excess drift or collapse.) Assuming a building has a structural performance level that allows the building to remain open, the dynamic characteristic of the structure can directly affect nonstructural damage. In certain cases of laboratories representing extreme hazard or value, dynamic studies of the structure to determine probable floor motions may be justified to aid in designing protection for the contents.

Location: In addition to the stiffness and other dynamic characteristic of the structure, the location of the laboratory, principally the floor level, will also affect internal shaking levels. Beginning with the 1997 UBC, the code required levels of design for nonstructural elements to vary with height within the building.

Floor type: It is assumed that, due to fire safety requirements, laboratory floors will be concrete. However concrete floors can vary from 2½″ thickness (over metal deck) to 10″–12″ of solid concrete, and from lightly reinforced to heavily reinforced or even to post tensioned. The ease, effectiveness, and cost of anchorage to these floors can vary considerably. Most labs are also required to have an impermeable floor. In most cases, impermeability can be maintained by use of epoxy-installed anchors, rather than mechanical devices. However, this requirement may increase the importance of slab thickness.

Structure above: Some bracing of building service systems as well as contents will require anchorage to the structure above. This surface can vary from flat concrete slabs to waffle slabs to beam and slab to fireproofed steel beams and steel decking. Similar to floor surfaces, the ease, effectiveness, and cost of anchorage to these systems can vary considerably.

Walls/ partitions: The stability of wall-mounted cabinetry and the adequacy of a multitude of wall-mounted seismic anchorage devices are dependent on the strength, stiffness, and local attachment capability of the walls themselves. Clay tile partitions, found in some older buildings, would generally be found unsuitable for such anchorage. At the other extreme, structural concrete walls would allow anchorage and attachment limited only by interference from existing reinforcing. The adequacy of steel stud and gypsum board partitions for anchorage is determined by the stud size, height, and top support, as well as the availability of adequate backing plates or stud flanges for local attachment.

Lab bench shelving: Many types of labs incorporate standard layout of bench and shelving systems, either one-sided (against walls), or two-sided (freestanding). The shelving systems can be given a wide range of inherent stability in earthquake shaking. This stability becomes more important as shelving contents and benchtop equipment are provided with seismic restraints.

Ceiling: "Hard" ceilings of plaster or gypsum board will present an impediment to installation of braces or anchorage to the structure above. Panelized ceilings, if not installed to latest code requirements, are very susceptible to damage themselves and could cause secondary damage to lab contents below.

Lights: Similar to ceilings, light fixtures are susceptible to damage, in some cases by falling and creating both a risk of injury and of secondary damage to contents. Appropriate mounting or retrofit measures can prevent this damage.

Mechanical, electrical, plumbing (MEP) systems above: Mechanical ducts, electrical conduits, pressure water and steam pipes of various kinds, waste piping, and gas piping are installed in various levels of intensity over laboratory spaces. These systems, if not appropriately suspended and/or braced, are susceptible to damage that could make them inoperable, and thus shut down the lab itself. It is also possible, but less likely, that parts of these systems could fall and cause secondary damage to the lab contents. Perhaps most likely, as observed in recent earthquakes, are leaks or breaks to pressurized water pipes that will result in secondary water damage.

Fire sprinklers: Fire sprinklers are a subcategory of MEP systems. However, fire sprinkler systems are very common in laboratory spaces, and unless installed recently (and correctly), have proven to be relatively likely to cause water damage.

MEP supply equipment: Assuming that the local laboratory environment is protected from nonstructural damage by appropriate protection of the building service systems and contents, lab spaces or the entire building can be made non-functional by failure of equipment and distribution systems within MEP rooms. Over and above normal service, the continuity of some experiments may be dependent on certain utilities. Anchorage and/or bracing would therefore need to be provided in MEP rooms to ensure protection equivalent to that provided in the laboratories. Of course, even if a given building is evenly protected, the utilities serving the building could also fail and cause shutdown. Other than recommending back-up service of critical utilities within individual buildings, performance of utility systems is beyond the scope of this study.

2.4 CONTENTS

In order to study seismic protection of the wide variety of contents found in laboratories, it is convenient to create a few broad categories. Categorization could be based on configuration, location, use, similarity of anchorage conditions, value, risk to life safety, vulnerability, or other characteristics, and is somewhat arbitrary. Since a primary goal of this study was to estimate costs of improving seismic protection of laboratories, we placed a high priority on development of representative details that could be employed. Thus categories of contents primarily consider similarity of anchorage conditions. A listing of typical contents based on a walk-through of many UC laboratories led to the creation of the following categories of contents:

- Tanks and cylinders
- Unique equipment and experimental setups
- Equipment that is heavy or large, but of boxy configuration
- Storage elements and contents
- Benchtop items

Anchorage and bracing of many of these contents can parallel techniques used for building service systems, employing concrete anchors and various steel sections. In many cases, however, their light weight, the lack of concrete anchoring media, or the required mobility of elements may preclude use of traditional structural materials. To fill this gap, several companies have developed systems using adhesives, double-backed tape, high friction material, Velcro™, nylon tapes and buckles, and other easy-to-employ and mobile anchorage devices. Some testing data for the materials used have been assembled by the manufacturers, and some testing of assemblies has been carried out, but adequate, comprehensive test data are generally not available. Issues include lack of load qualification of full assemblies, lack of consideration of eccentricities inherent in most connections, lack of data on application to various connecting substrates, lack of control of the strength of anchoring surfaces, and lack of comprehensive information on the effects of aging and exposure to light or chemicals. Nevertheless, the applicability and adequacy of these devices are obvious in many situations.

Based on the typical conditions represented by the categories described above, and a non-comprehensive review of available proprietary hardware, a set of conceptual seismic protection details was developed. These details are described and discussed in Table 8, and are illustrated in Chapter 3. Three categories of details are listed:

- **SD:** Standard Detail—elements available from one or more proprietary suppliers, or standard in industry (no detail drawn).
- **ESD:** Engineered Standard Detail—generic detail sketched for this project; minor adjustments from typical case shown may be needed when employed.
- **Custom—**no generic detail applies and restraint/anchorage must be developed for each case.

For the purposes of this study, these details have been universally applied to inventories of contents in five prototypical laboratories, as described in Chapter 3. Another dimension can be applied to the assignment of details by considering additional characteristics of each element, such as risk to life-safety, value, and user needs. Considerations of risk to life safety and potential loss of value are independent, and either could govern the priority of providing seismic protection or the selection of anchorage detail.

One way to systematize these considerations is to use matrices that combine the two most important parameters affecting the consequences of failure. For example, considering direct life safety (direct life safety refers to risk of injury from impact of an object; indirect life safety refers to risk from release of hazardous material or fire), the combination of weight and location of an object most heavily influences its risk. The matrix below (Table 6) demonstrates how the priority and importance of an element will increase systematically from upper left to lower right. The locations that qualify as low, medium, and high risk must be defined for consistent application. For example, low risk might be floor-mounted with a low aspect ratio while high risk could be defined as directly overhead.

TABLE 6
Life-Safety Priority/Importance Levels

	Risk of Location		
Weight[1]	low	medium	high
< 20#	A[2]	B	C
20# - 400#	B	C	D
> 400#	C	C	D

1. The weight cutoffs are arbitrary and must be set by judgment. Those shown here are weights used for similar priority setting in codes.
2. Importance Levels:
   A: No specific anchorage requirement; low priority
   B: Anchorage using a standard detail installed by users or maintenance staff; moderate priority
   C: Anchorage using a standard conceptual detail customized by trained staff or professionals for the particular condition; high priority
   D: Anchorage designed by professionals for the specific situation; highest priority

TABLE 7
Value / Priority / Importance Level

Weight	Value/ Importance		
	low	medium	high
< 10#	A	B	C
10-50#	Controlled by LS	C	D
> 50#	Controlled by LS	C	D

See Table 6 for notes.

A similar, but independent, relationship can be developed when considering the value or importance of items (see Table 7). Weight is also used as a parameter in this chart because of a presumed higher reliability when anchoring lighter items. The value or importance could be defined by replacement value, replacement time, or by the potential for indirect life-safety risk or damage.

2.5 ISSUES ASSOCIATED WITH SEISMIC PROTECTION OF LABORATORIES

An important issue affecting some laboratory contents is the lack of a permanent location. Simple and small benchtop devices can be restrained by proprietary devices that are easily detachable. However, most of these devices require a permanent wall or counter anchor to which the removable anchor can be attached. Unless a "universal" system is provided with such anchors available everywhere, it is unlikely that these relatively convenient systems will be used. Larger and heavier equipment on carts or wheels must have more permanent "docks" at selected locations. If such locations can not be determined, successful restraint is unlikely. In all cases, the need for mobility must be weighed against the overall value of the element and its vulnerability to damage (or its risk to life safety).

As previously discussed, it is unusual to go beyond anchorage and restraint of equipment to require limited internal damage after strong earthquake shaking. Such qualification of equipment is difficult to achieve without costly testing, although standards for such testing are available from the electric power and nuclear industries. If continued operation is required of a piece of equipment, the cost of qualifying testing must be balanced against the potential losses from damage. The probability of interruptions to power, water, and other external utilities must also be considered in such cases.

Many laboratories employ equipment that is sensitive to vibration. The floor structure of new laboratories is almost always designed to minimize vibrations. Although most reciprocating equipment, such as compressors in refrigerators, is internally isolated, rigid anchorage increases the risk of overall building vibration. This is not only true concerning local lab equipment, but also when rigidly anchoring building service equipment and distribution systems.

Current codes for many types of laboratories require "impervious" floor systems, presumably to contain spills within the lab. Drilled in expansion-type concrete anchors are not compatible with this requirement, although anchors set in epoxy can maintain the impermeable layer. Obviously, epoxy-set anchors are more problematic to install than expansion-types (particularly for a non-expert) and epoxy also creates fumes that must be investigated for acceptability in each lab.

2.6 SAMPLE CONDITIONS IN LABORATORIES

At the end of this chapter are photos representing the conditions in many of the laboratories at UC Berkeley. Each photo is accompanied by an assessment of the item in terms of life safety and value. In some cases, such as an electronics rack or a storage cabinet, the high or low ranking for either life safety or value will vary with the contents. Each photo also includes a suggested mitigation solution based on the recommendations outlined above and summarized in Table 8.

2.7 PROTOTYPICAL ANCHORING SOLUTIONS FOR LABORATORY CONTENTS

For each category of equipment Table 8 provides a breakdown of the specific applications of each detail. For example, in the Tanks and Cylinders category, there is a differentiation between "individual" cylinders, tanks on legs, dewars on wheels, etc. Each item is assigned a detail number (T1, T2), and each detail is qualified as to whether it is a Standard Detail (SD), available from various suppliers, an Engineered Standard Detail (ESD), or a Custom detail. Illustrations for each of the Standard and Engineered Standard Details are included in Appendix A.

The sample conditions and the prototypical anchoring details are exemplary of the contents within laboratories at UC Berkeley, and provide a basis for estimating the costs of anchoring in typical laboratories in the next chapter. While these details serve as a prototype, and are based on actual lab conditions, the generic details were developed to understand the costs involved in a contents retrofit. The details should not be applied without specific review of the conditions in a building, with details appropriate to specific wall, floor, ceiling, and structural system existing conditions.

TABLE 8

Anchorage Methods for Laboratory Contents

Category	Item	Detail No	Type[2]	Description	Comment
Tanks/ Cylinders	Individual cylinders.	T1	SD	Wall rack or chain. Commercial wall or floor-mounted holder.	Attachment to concrete wall or to stud. Compare freedom for movement with flexibility of connecting hoses.
	Multiple cylinders.	T2	SD	Wall "corrals." Commercial racks.	Attachment to concrete wall or to stud. Compare freedom for movement with flexibility of connecting hoses.
	Other permanent tanks without legs< 250# at wall.	T3	ESD	Strap to wall @ 2/3 height.	#12 screw into stud min. The limit is the connection to the wall. Can develop more screws or use spreader for larger load.
	Other permanent tanks without legs; diam > 2/3 height not at wall.	T4	ESD	Perimeter "keeper" angle bolted to floor (no attachment to tank) or 5 individual angles.	No overturning problem. If no attachment to surroundings and on floor, consider no anchorage.
	Other permanent tanks without legs diam < 2/3 height not at wall.	T5	ESD	2- strongbacks[1] and containment band at 2/3 height.	
	Tanks on legs.	T6	Custom	Custom.	Anchorage of legs may be inadequate.
	Dewar on wheels.	T7A	ESD	Wall dock.	No adhesive attachments. Heavy nylon strap or chain restraint. Attachment to wall needs special consideration. Locking wheels will create overturning problem.
		T7B	ESD	Custom floor dock if locations can be determined.	
Unique Equipment	Vibration-isolated equipment.	U1	ESD	Install snubber device from wall, floor, or strongback.	Find locations where support elements will not inhibit use.
	Built-up equipment.	U2	Custom	Completely custom. Often strongbacks from floor or counter will work.	Find locations where elements will not inhibit use.
Heavy Equipment	Permanent equipment on floor with breakable connections to other elements except refrigerators.	H1	ESD	Anchor bolts to floor. May need large angles and 2-bolt connections to floor. Connection to equipment may vary.	Do not use commercial leveling foot brackets. Do not use adhesive either to structure or to equipment. Consider similar to medical equipment.
	Self-contained equipment with only flexible connections (e.g., plug) and w > 2/3 h.	H2	ESD	If life-safety or high-value issue, similar H1. Otherwise, may not need anchorage.	
	Freestanding.	H3	ESD	2 strongbacks and attachments. May be adhesive in some cases.	Distinction is that no wall is available. Some equipment may default to H2.
	On wheels at wall.	H4A See T7A	ESD	If stable, install wheel locks or docking station. If tall, tightly restrain docking station.	No adhesive. Attachment to wall needs special consideration. Equipment >250# may need spreader bar on stud walls.

Table 8 *continued*

Category	Item	Detail No.	Type[2]	Description	Comment
Heavy Equipment cont'd.	On wheels no wall	H4B See T7B			
	Lighter equipment.	H5	SD	Commercial devices.	Adhesive anchorage equipment. Screws to walls, bolts to floor. What is wt limit or eccentricity limit?
	Refrigerators/freezer A small or not critical.	H6	SD	Commercial straps to wall. Adhesive to unit, screws to wall.	Option available with Velcro for cleaning.
		H6a	SD	Door latch.	
		H6b	SD	Special contents trays.	
	Refrigerators/freezer B large, critical, or life safety.	H7	ESD	Anchor to wall or floor with screws or bolts to casing or frame.	Issue of how to attach to item. Issue of wall strength.
		H7a	SD	Door latch.	
		H7b	SD	Special contents trays.	
	Refrigerator/ freezer: Floor/wall support Not Good.	H8 See H3	ESD	Floor to ceiling side supports. See also H8a, and b.	If no wall is available and no attachment is possible at bottom.
	Electronic-type racks: wheels, no wheels at wall.	H9a	ESD		Issues include need for mobility, wheeled or not, adequacy of rack itself.
	Without wall.	H9B	ESD		
	Wheeled banks of racks.	H10	ESD	Anchor with tight cables to structure above.	
Storage	Shelving at walls.	S1	SD	Anchor to wall.	
		S1a	ESD	Stabilize shelves.	
		S1b	SD	3" commercial clear lips for items < 6".	x depends on reliability desired against coming off shelf. 3" probably provides 2.25" barrier reliable for 4.5-5" items.
		S1c	SD	Items > 6' : taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall; also strap trac (hinged bar).	Compartmented bins with friction bottoms.
	Book shelving.	S2	SD	Grip strip.	Commercial material.
	Closed cabinets at walls.	S3	SD	Anchor to wall.	
		S3a	SD	Positive latch.	
		S3b	SD	Protection for glass front	Film. Or inside protection mesh, etc.
	Freestanding.	S4	ESD	Stabilize.	Anchor at bottom, struts across top, floor to ceiling elements.
		S4a	ESD	Internally strengthen.	Cross braces etc.
		S4b	SD	Restrain contents.	Lips, friction pads, restraining bars, individual item holders, etc.
	Carts.	S5A	SD	Wall docks.	No adhesive.
	Cart without walls.	S5B	SD	Floor dock.	Similar H9B with one post.
		S5Aa	SD	Contents security measures.	Compartmented bins with friction bottoms? Lips, etc.
	Metal cabinets.	S6	SD	Typical office solutions.	UC Typical or commercial.

Table 8 *continued*

Category	Item	Detail No.	Type[2]	Description	Comment
Benchtop	Large and heavy "built-in" equipment (hoods, etc.).	B1	ESD	Develop anchorage to benchtop framing or walls.	Treat similar to built-in medical equipment.
	Other large and heavy > 250#.	B2	ESD	Anchorage to counter, back wall, or counter to ceiling elements.	No adhesive.
	< 250#	B3	SD	Commercial adhesive devices, but screwed to back splash, wall, or counter.	
	< 50#	B4	SD	2 commercial adhesive devices.	
	Stacked components.	B5	SD	Velcro pads and cable ties to tie together, with other tie to wall or counter. May need counter to ceiling elements.	

Notes:

1. Strongback: steel tube, unistrut, or channel running floor (or countertop) to structure above to provide lateral support for element.

2. Type of detail for estimating purposes:

SD: Standard Detail—No detail. elements available from one or more proprietary suppliers, or standard in industry.

ESD: Engineered Standard Detail—Generic detail sketched for this project; minor adjustments may be needed.

Custom—No generic detail applies and restraint/anchorage must be developed for each case.

Compressed Gas Cylinder Storage

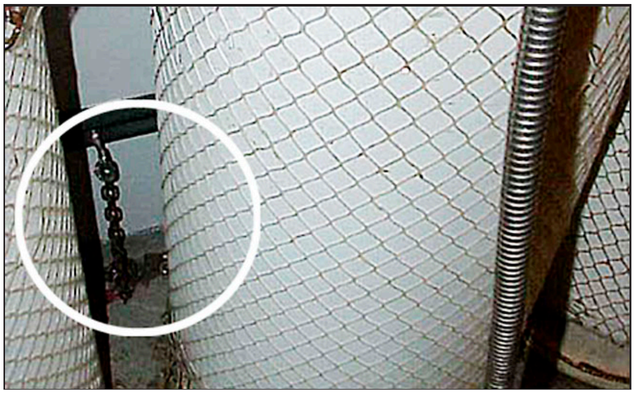

Photo Code: 3-92

	High	Low
Value		✓
Life Safety		✓

Solutions: T1 - SD

Description: Wall rack or chain. Commercial wall or floor-mounted holder.

Comments: Attachment to concrete wall or to stud. Compare freedom for movement with flexibility of connecting hoses.

Compressed Gas Cylinder Storage — Existing Anchorage

Photo Code: 3-6

	High	Low
Value		✓
Life Safety		✓

Solutions: T2 - SD

Description: Wall “corrals.” Commercial racks.

Comments: Attachment to concrete wall or to stud. Compare freedom for movement with flexibility of connecting hoses.

Unanchored Liquid Nitrogen Storage Tank

Photo Code: 3-35

	High	Low
Value		✓
Life Safety	✓	

Solutions: T6 - Custom

Description: Custom.

Comments: Anchorage of legs may be inadequate.

Unanchored Liquid Nitrogen Storage Tank (Dewar)

Photo Code: 3-51

	High	Low
Value		✓
Life Safety	✓	

Solutions: T7 - ESD

Description: Wall dock or custom floor dock if locations can be determined.

Comments: No adhesive attachments. Heavy nylon strap or chain restraint. Attachment to wall needs special consideration. Locking wheels will create overturning problem.

Microscope on Pneumatic Table

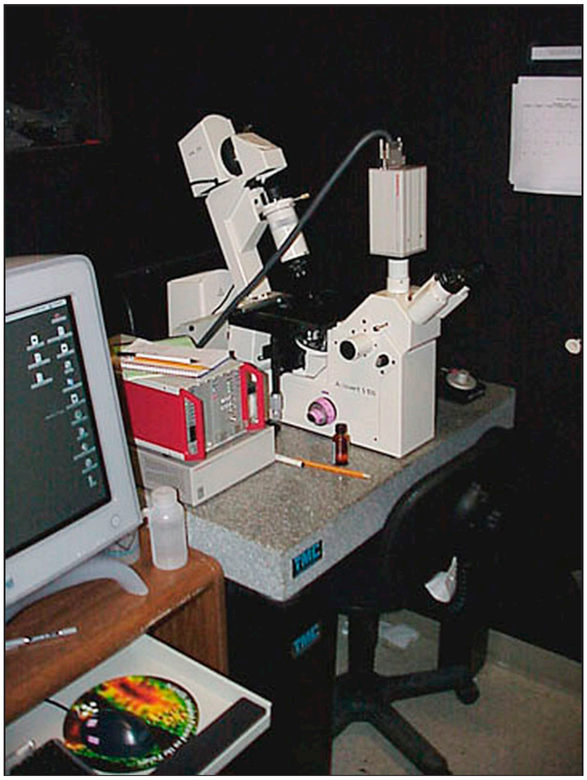

Photo Code: 3-126

	High	Low
Value	✓	
Life Safety		✓

Solutions: U1 - ESD

Description: Install snubber device from wall, floor, or strongback.

Comments: Find locations where support elements will not inhibit use.

Laser Table

Photo Code: 3-26

Photo Code: 27 Leg Detail

	High	Low
Value	✓	
Life Safety	✓	

Solutions: U1 - ESD

Description: Install snubber device from wall, floor, or strongback.

Comments: Find locations where support elements will not inhibit use.

Unanchored Electron Microscope

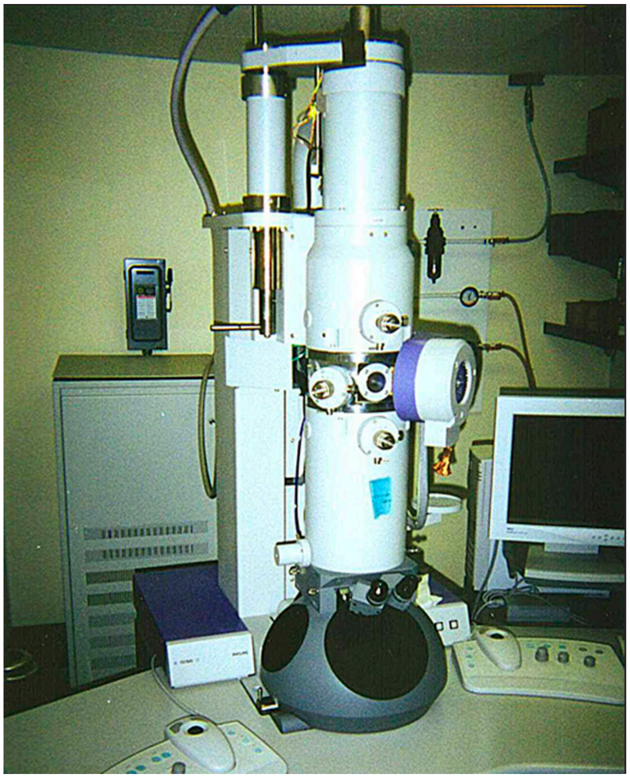

Photo Code: 3-109

	High	Low
Value	✓ ✓	
Life Safety		✓

Solutions: U2 - Custom

Description: Completely custom. Often strongbacks from floor or counter will work.

Comments: Find locations where elements will not inhibit use.

Scanning Tunneling Microscope under Construction

Photo Code: 3-52

	High	Low
Value	✓ ✓	
Life Safety	✓	

Solutions: U2 - Custom

Description: Completely custom. Often strongbacks from floor or counter will work.

Comments: Find locations where elements will not inhibit use.

Typical Physics Experimental Apparatus

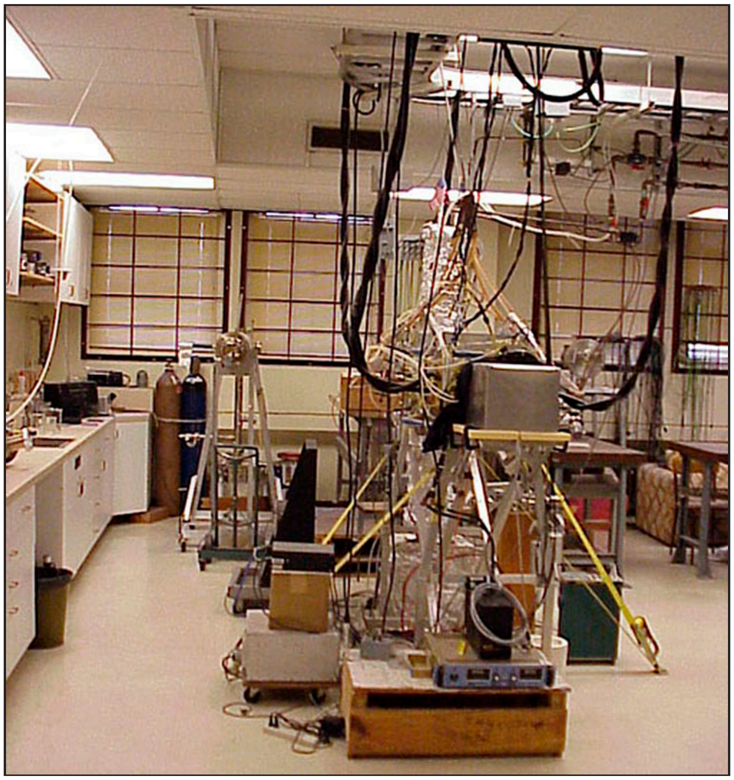

Photo Code: 3-34

	High	Low
Value	?	?
Life Safety		✓

Solutions: U2 - Custom

Description: Completely custom. Often strongbacks from floor or counter will work.

Comments: Find locations where elements will not inhibit use.

Dilution Refrigeration Apparatus

Photo Code: 3-43

	High	Low
Value	✓	
Life Safety	✓	

Solutions: U2 - Custom

Description: Completely custom. Often strongbacks from floor or counter will work.

Comments: Find locations where elements will not inhibit use.

Cage Washing Machine

Photo Code: 3-58

	High	Low
Value	✓	
Life Safety		✓

Solutions: H1 - ESD

Description: Anchor bolts to floor. May need large angles and two-bolt connections to floor.

Comments: Do not use commercial leveling foot brackets. Do not use adhesive. Consider similar to medical equipment.

Gas Chromatograph

Photo Code: 3-84

	High	Low
Value	✓ ✓	
Life Safety	✓	

Solutions: U2 - ESD

Description: Anchor bolts to floor. May need large angles and two-bolt connections to floor.

Comments: Do not use commercial leveling foot brackets. Do not use adhesive. Consider similar to medical equipment.

Superspeed Refrigerated Centrifuge

Photo Code: 3-129

	High	Low
Value		✓
Life Safety	✓	

Solutions: H2 - ESD

Description: If life-safety or high-value issue, similar to H1. Otherwise, may not need anchorage.

Mobile Lab Hood

Photo Code: 3-68

	High	Low
Value		✓
Life Safety	✓	

Solutions: H4 - ESD

Description: If stable, install wheel locks or docking station. If tall, tightly restrain docking station.

Comments: No adhesive. Attachment to wall needs special consideration. Equipment >250# may need spreader bar on stud walls.

Unanchored Tissue Slicer for Microscope Slides

Photo Code: 3-63

	High	Low
Value	✓	
Life Safety		✓

Solutions: H6 - SD

Description: Commercial straps to wall. Adhesive to unit, screws to wall.

Comments: Option available with Velcro for cleaning.

Typical Refrigerator

Photo Code: 3-133

Refrigerator Contents

Photo Code: 3-134

	High	Low
Value	✓	✓
Life Safety	✓	✓

Solutions: H6, H6a, H7b - SD

Description: Commercial straps to wall. Adhesive to unit, screws to wall. Door latch, special contents trays.

Comments: Option available with Velcro for cleaning.

Stacked Equipment

Photo Code: 3-140

	High	Low
Value		✓
Life Safety	✓	

Solutions: H7 - ESD

Description: Anchor to wall or floor with screws or bolts to casing or frame.

Comments: Issue of how to attach to item. Issue of wall strength.

Unanchored Refrigerators

Photo Code: 3-112

	High	Low
Value		✓
Life Safety		✓

Solutions: H7, H7a, H7b, H6 - SD

Description: Commercial straps to wall. Adhesive to unit, screws to wall. Door latch. Special contents trays.

Comments: Option available with Velcro for cleaning.

Large Unanchored Refrigerator

Photo Code: 3-78

	High	Low
Value		✓
Life Safety	✓	

Solutions: H7 - ESD

Description: Commercial straps to wall. Adhesive to unit, screws to wall.

Comments: Option available with Velcro for cleaning.

Typical Unanchored Refrigerator

Photo Code: 3-12

	High	Low
Value		✓
Life Safety	✓	

Solutions: H7, H8 - ESD

Description: Commercial straps to wall. Adhesive to unit, screws to wall. Floor to ceiling side supports. See H3.

Comments: Option available with Velcro for cleaning. Use ceiling supports if no wall or floor attachment is possible.

Pneumatic Optics Table and Racked Equipment

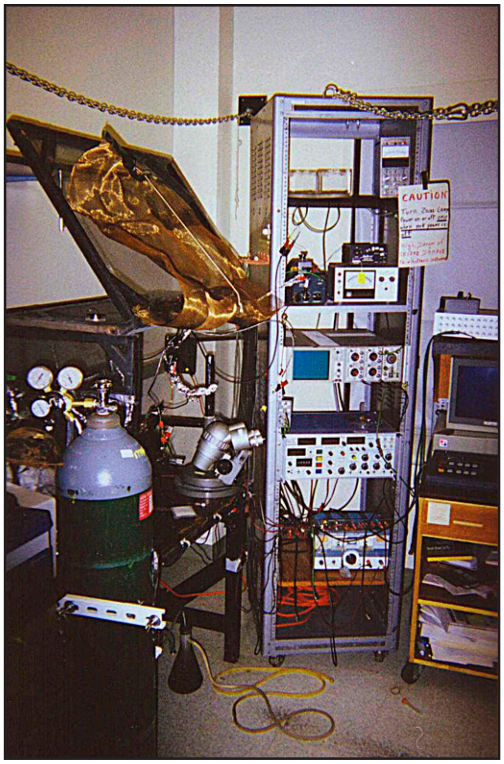

Photo Code: 3-101

	High	Low
Value	✓	
Life Safety	✓	

Solutions: H9 - ESD/Custom

Comments: Issues include need for mobility, wheeled or not; adequacy of rack itself.

Typical Racked Electronic Equipment

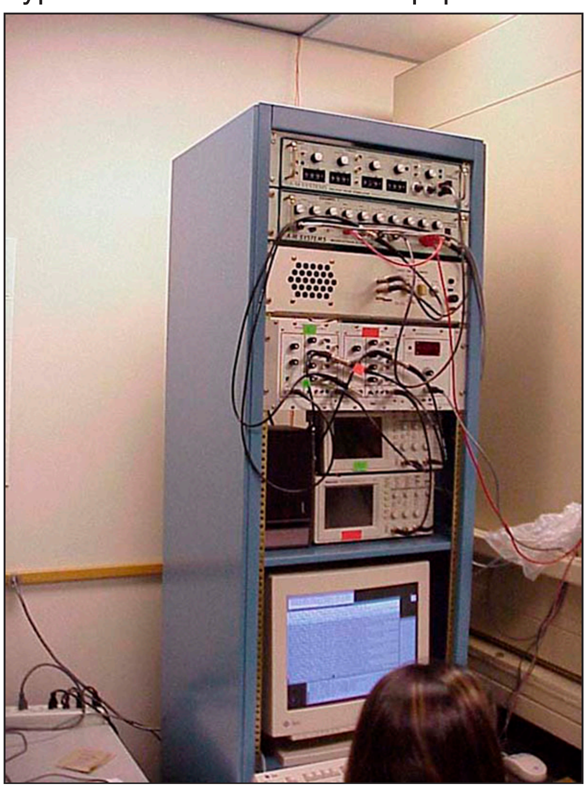

Photo Code: 3-61

	High	Low
Value	✓	
Life Safety	✓	

Solutions: H9 - ESD/Custom

Comments: Issues include need for mobility, wheeled or not; adequacy of rack itself.

Unanchored Lab Apparatus

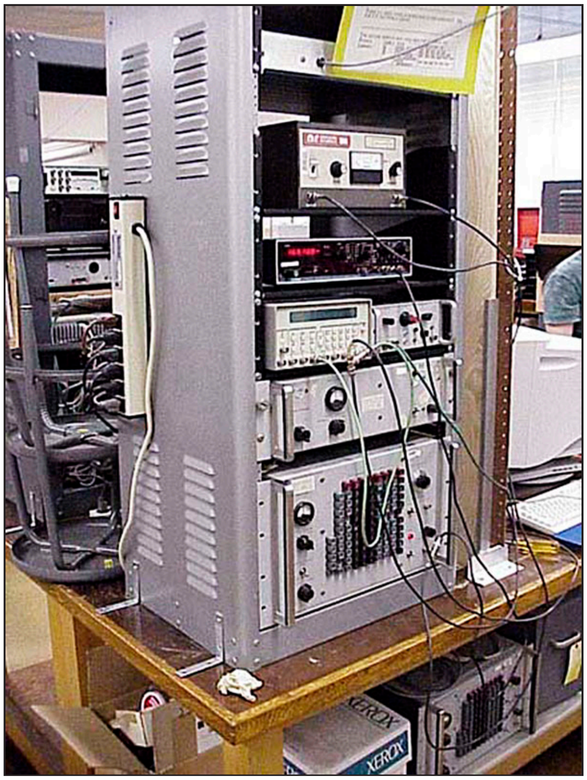

Photo Code: 3-42

	High	Low
Value		✓
Life Safety		✓

Solutions: H9 - ESD/Custom

Comments: Issues include need for mobility, wheeled or not; adequacy of rack itself.

NMR Magnet

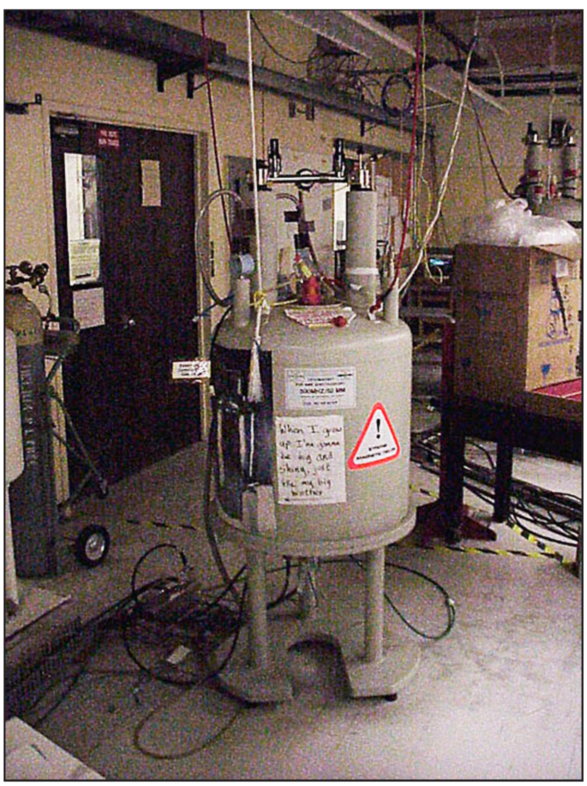

Photo Code: 3-29

	High	Low
Value	✓	
Life Safety	✓	

Solutions: Custom

Description: Anchor with non-metallic cables to structure above.

X-Ray

Photo Code: 3-79

NOTE: Some campus labs have medical equipment that should be detailed according to the California Hospital Seismic Safety Act.

Surgery Room

Photo Code: 3-74

Cold Room

Photo Code: 3-105

	High	Low
Value		✓
Life Safety		✓

Solutions: S1a, S1b, S1c-SD

Description: Stabilize shelves, 3″ commercial clear lips for items<6″. Items >6″: taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall: also strap trac (hinged bar).

Typical Lab Shelf

Photo Code: 3-11

	High	Low
Value		✓
Life Safety		✓

Solutions: S1a, S1c -SD

Description: Stabilize shelves. Items >6″: taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall: also strap trac (hinged bar).

Comments: Highly variable depending on nature of shelving system.

Small Cage Room

Photo Code: 3-65

	High	Low
Value	✓	
Life Safety		✓

Solutions: H10, S1b-ESD/SD

Description: 3″ commercial clear lips for items <6″, anchor with tight cables to structure above.

Comments: Depends on reliability desired against coming off shelf. 3″ probably provides 2.25″ barrier, reliable for 4.5–5″ items.

Typical Lab Shelving with Shelf Lip

Photo Code: 3-2

	High	Low
Value		✓
Life Safety		✓

Solutions: S1c - SD

Description: Items > 6″: taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall: also strap trac (hinged bar).

Comments: Compartmented bins with friction bottoms.

Typical Lab Bench

Photo Code: 3-102

	High	Low
Value		✓
Life Safety		✓

Solutions: S1c - SD

Description: Items > 6″: taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall: also strap trac hinged bar).

Comments: Compartmented bins with friction bottoms.

Specimen Room

Photo Code: 3-98

	High	Low
Value	✓ ✓	
Life Safety		✓

Solutions: S1c - SD

Description: Items > 6″: taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall: also strap trac (hinged bar).

Comments: Compartmented bins with friction bottoms.

Cold Room Bench

Photo Code: 3-82

	High	Low
Value	✓	✓
Life Safety		✓

Solutions: S2, S3 - SD

Description: Grip strip, anchor to wall.

Comments: Commercial material.

Unanchored Surgical Equipment/Supply Cabinet

Photo Code: 3-72

	High	Low
Value		✓
Life Safety		✓

Solutions: S3, S3a, S3b - SD

Description: Anchor to wall, positive latch, protection for glass front.

Comments: For glass front: film or protection mesh, etc.

Storage Cabinets with Glass Fronts without Latches

Photo Code: 3-39

	High	Low
Value		✓
Life Safety		✓

Solutions: S3a, S3b - SD

Description: Positive latch, protection for glass front.

Comments: For glass front: film or protection mesh, etc.

Unanchored Storage Cabinets in Electronics Shop

Photo Code: 3-48

	High	Low
Value		✓
Life Safety		✓

Solutions: S4 - ESD

Description: Stabilize.

Comments: Anchor at bottom, struts across top, floor to ceiling elements.

Aquarium Racks

Photo Code: 3-111

	High	Low
Value	✓	
Life Safety	✓	

Solutions: S4, S4b - ESD, SD

Description: Stabilize, restrain contents.

Comments: Anchor at bottom, struts across top, floor to ceiling elements. Lips, friction pads, restraining bars, individual item holders, etc.

Rolling Carts outside Glass Washer Room

Photo Code: 3-15

	High	Low
Value		✓
Life Safety		✓

Solutions: S5 - SD

Description: Wall docks.

Comments: No adhesive.

Biological Safety Cabinet

Photo Code: 3-139

	High	Low
Value		✓
Life Safety		✓

Solutions: B1 - ESD

Description: Develop anchorage to benchtop framing or walls.

Comments: Treat similar to built-in medical equipment.

Unanchored Load Cell

Photo Code: 3-94

	High	Low
Value		✓
Life Safety	✓	

Solutions: B2, B7 - ESD

Description: Anchorage to counter, back wall, or counter to ceiling elements.

Comments: No adhesive.

Unanchored DNA Sequencer

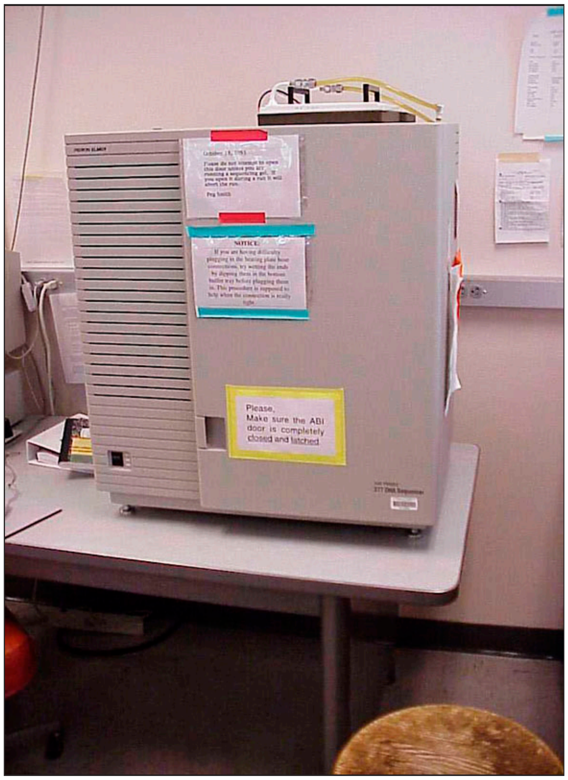

Photo Code: 3-87

	High	Low
Value	✓	
Life Safety		✓

Solutions: B2, B3, B7 - ESD,SD

Description: Anchorage to counter, back wall, or counter to ceiling elements. Commercial adhesive devices, but screwed to back splash, wall, or counter.

Unanchored Benchtop Centrifuge

Photo Code: 3-10

	High	Low
Value	✓	
Life Safety		✓

Solutions: B3 - SD

Description: Commercial adhesive devices, but screwed to back splash, wall, or counter.

Unanchored Protein Sequencer

Photo Code: 3-14

	High	Low
Value	✓	
Life Safety		✓

Solutions: B3 -SD

Description: Commercial adhesive devices, but screwed to back splash, wall, or counter.

Incubators

Photo Code: 3-121

	High	Low
Value		✓
Life Safety		✓

Solutions: B3a, B4a - SD

Description: Commercial adhesive devices, but screwed to back splash, wall, or counter.

Printer

Photo Code: 3-131

	High	Low
Value		✓
Life Safety		✓

Solutions: B3 - SD

Description: Commercial adhesive devices, but screwed to back-splash, wall, or counter.

Microscope

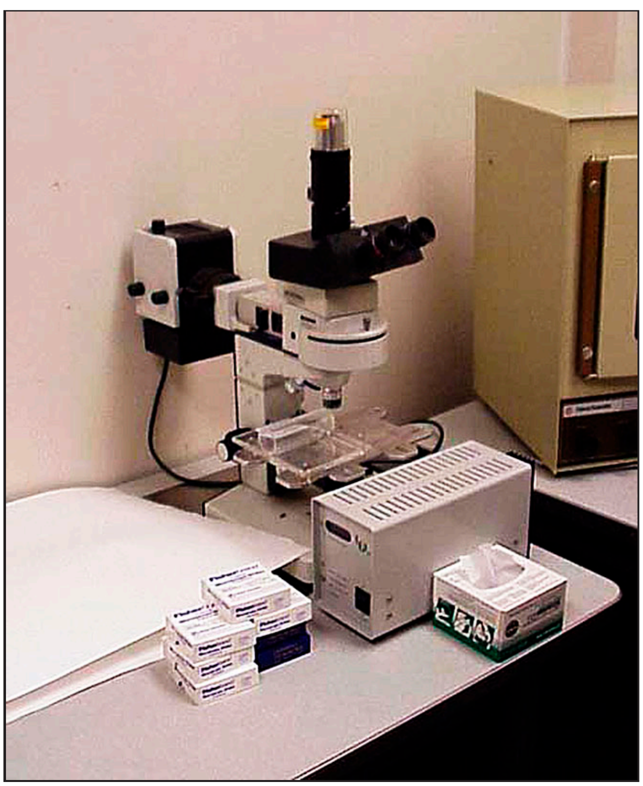

Photo Code: 3-64

	High	Low
Value		✓
Life Safety		✓

Solutions: B4 - SD

Description: Two commercial adhesive devices.

Computer Monitor

Photo Code: 3-118

	High	Low
Value		✓
Life Safety		✓

Solutions: B4 - SD

Description: Two commercial adhesive devices.

Mass Comparator

Photo Code: 3-95

	High	Low
Value		✓
Life Safety		✓

Solutions: B4, B6 - SD

Description: Two commercial adhesive devices.

Vertical Unanchored Protein Sequencer

Photo Code: 3-13

	High	Low
Value	✓	
Life Safety		✓

Solutions: B5 - SD

Description: Velcro pads and cable ties to tie together, with other tie to wall or counter. May need counter to ceiling elements.

Unanchored Liquid Chromatograph

Photo Code: 3-22

	High	Low
Value	✓	
Life Safety		✓

Solutions: B5 - SD

Description: Velcro pads and cable ties to tie together, with other tie to wall or counter. May need counter to ceiling elements.

3 Case Studies of Five Prototypical Laboratories

3.1 SCHEMATIC DETAILS AND DEVELOPMENT OF UNIT COSTS

In the previous chapter, a series of conceptual seismic solutions to the anchoring of laboratory equipment is outlined in Table 8. The schematic details shown here follow the order of conditions in Table 8. These details are not intended as design specifications for the various conditions described in the previous section, but were developed to demonstrate the type of solution necessary, and to provide sufficient information on the construction detail to estimate a unit cost.

To estimate the unit costs, the project team worked in consultation with Peter Morris, principal of Davis Langdon Adamson (DLA), a well-known construction cost-estimating and management firm with significant experience working with the UC system. Together with Peter Morris, the team reviewed the costs for Q-Brace and other nonstructural seismic anchoring projects on the UC Berkeley campus. We reviewed the product costs from various purveyors of standard details, and we carefully reviewed the materials and labor necessary for the engineered standard details.

Peter Morris provided the team with a breakdown of direct costs (including both labor and materials) for the components of each Standard Detail (SD) and Engineered Standard Detail (ESD). These are shown in Table 9. Table 10 provides a list of total costs for each item, or component item. For example, detail H6 shows an anchorage for small refrigerators and the cost of the anchorage is $250. H6a is a door latch and H6b represents contents trays. These are additional items that may or may not be needed, depending on the requirements of the researcher or the fragility of the contents of the refrigerator. Thus, when estimating the costs in a particular laboratory, the team could decide whether to apply these additional details to specific circumstances. The same logic applies to the "S" Storage details: S1 or S4 describe the basic unit of equipment, and the "a, b, c" designations are additional details to be used as needed in various situations.

TABLE 9

Breakdown of Costs for Anchoring Contents by Detail Type

Tanks and Cylinders						
T1	Individual cylinders					
	Attachment to wall	1	EA	60.00	60
	Chain/rack	1	EA	40.00	40
					$100
T2	Multiple cylinders					
	Attachment to wall	1	EA	60.00	20
	Rack system	1	EA	250.00	250
					$370
T3	Permanent tanks, <250#					
	Attachment to wall	2	EA	60.00	120
	Chain/rack	1	EA	60.00	60
					$180
T4	Permanent tanks, diam > 2/3 ht					
	Attachment to floor	#	EA	90.00	900
	Angle brackets	5	EA	35.00	175
					$1,075
T5	Permanent tanks, diam < 2/3 ht					
	Strongbacks	2	EA	600.00	1,200
	Containment band	1	EA	150.00	150
					$1,350
T6	Tanks on legs				Custom
T7	Dewars on wheels					
a	Wall dock					
	Attachment to wall	2	EA	60.00	120
	Dock assembly	1	EA	400.00	400
					$ 520
b	Floor dock					
	Attachment to floor	4	EA	90.00	360
	Dock assembly	1	EA	400.00	400
					$760

Table 9 *continued*

Unique Equipment					
U1	Install snubber device				
	Strongbacks	4	EA	600.00	2,400
	Snubbers	4	EA	150.00	600
					$ 3,000
U2	Built-up equipment				Custom
Heavy Equipment					
H1	Permanent equipment on floor				
	Attachment to floor	8	EA	90.00	720
	Angle brackets	4	EA	35.00	140
					$ 860
H2	Self-contained with only flexible connections				N/A
H3	Freestanding				
	Strongbacks	2	EA	600.00	1,200
	Attachment	1	EA	150.00	150
					$ 1,350
H4A	On wheels, at wall				
	Wall dock				
	Attachment to wall	2	EA	60.00	120
	Dock assembly	1	EA	400.00	400
					$ 520
H4B	On wheels, floor dock				
	Attachment to floor	4	EA	90.00	360
	Dock assembly	1	EA	400.00	400
					$ 760
H5	Lighter equipment				
	Commercial attachments	1	EA	250.00	250
					$ 250
H6	Refrigerators/freezers — small, not critical				
	Commercial attachments	1	EA	250.00	250
					$ 250
H6a	Refrigerators/freezers — small, not critical, door latch				
	Door latch	1	EA	150.00	150
					$ 150
H6b	Refrigerators/freezers — small, not critical, contents tray				
	Contents trays	3	EA	75.00	225
					$ 225
H7	Refrigerators/freezers — large, critical				
	Attachment to floor	4	EA	90.00	360
	Strap attachment	1	EA	400.00	400
					$ 760
H7a	Refrigerators/freezers — large, critical, door latch				
	Door latch	1	EA	150.00	150
					$ 150

Table 9 *continued*

H7b	Refrigerators/freezers — large, critical, contents tray					
	Contents trays	6	EA	75.00	450	
					$ 450	
H8	Refrigerators/freezers — no wall/floor support					
	Strongbacks	2	EA	600.00	1,200	
	Strap attachment	1	EA	400.00	400	
	Door latch	1	EA	150.00	150	
	Contents trays	6	EA	75.00	450	
					$ 2,200	
H9A	Racks, at wall					
	Attachment to wall	2	EA	60.00	120	
	Dock assembly, commercial attachment	1	EA	150.00	150	
	Grip strip	#	LF	4.00	96	
					$ 366	
H9B	Racks, freestanding				Custom	
	Strongbacks	2	EA	600.00	1,200	
	Dock assembly, commercial attachment	1	EA	150.00	150	
	Grip strip	#	LF	4.00	96	
					$ 1,446	
H10	Wheeled racks					
	Ceiling structural attachments	2	EA	400.00	800	
	Strap attachment	1	EA	200.00	200	
					$ 1,000	
Storage						
S1	Shelving at walls					
	Attachment to wall	1	EA	35.00	35	
	Bracket	1	EA	10.00	10	
					$ 45	
S1a	Shelving at walls — stabilize shelves					
	Stabilize shelves	1	LS	50.00	50	
					$ 50	
S1b	Shelving at walls — commercial lips, 3"					
	3" commercial lips	6	EA	30.00	180	
					$ 180	
S1c	Shelving at walls — commercial lips, >3"					
	3" commercial lips	6	EA	30.00	180	
	Compartmented bins	#	EA	25.00	250	
					$ 430	
S2	Bookshelving					
	Grip strip	#	LF	4.00	72	
					$ 72	

Table 9 *continued*

S3	Closed cabinets at walls				
	Attachment to wall	1	EA	35.00	35
	Bracket	1	EA	10.00	10
					$ 45
S3a	Closed cabinets at walls, provide positive latch				
	Positive latch	1	EA	50.00	50
					$ 50
S3b	Closed cabinets at walls, protect glass door				
	Protection for glass front	#	SF	15.00	270
					$ 270
S4	Freestanding cabinets				
	Attachment to floor	1	EA	90.00	90
	Overhead attachment	1	EA	150.00	150
					$ 240
S4a	Freestanding cabinets, stabilize shelves				
	Stabilize shelves	1	LS	50.00	50
					$ 50
S4b	Freestanding cabinets, restrain contents				
	Contents trays	6	EA	75.00	450
					$ 450
S5A	Carts, wall dock				
	Attachment to wall	2	EA	35.00	70
	Dock assembly, commercial attachment	1	EA	75.00	75
					$ 145
S5B	Carts, floor dock				
	Strongbacks	1	EA	600.00	600
	Dock assembly, commercial attachment	1	EA	75.00	75
					$ 675
S5Aa	Carts, wall dock, restrain contents				
	Contents trays	3	EA	75.00	225
					$ 225
S6	Metal cabinets				
	Attachment to wall	1	EA	35.00	35
	Bracket	1	EA	10.00	10
					$ 45

Table 9 *continued*

Benchtop						
B1	Large and heavy built-in equipment					
	Attachment to wall	4	EA	35.00	140
	Strap attachment	1	EA	600.00	600
					$ 740
B2	Other large and heavy equipment > 250#				
	Attachment to wall	4	EA	75.00	300
	Strap attachment	1	EA	800.00	800
					$ 1,100
B3	Other large and heavy equipment < 250#				
	Commercial attachments	1	EA	150.00	150
					$ 150
B4	Other large and heavy equipment < 50#				
	Commercial attachments	1	EA	50.00	50
					$ 50
B5	Stacked components				
	Commercial attachments	1	EA	75.00	75
					$ 75

In the case of T7, Dewars, H4, Equipment on wheels, H9, Equipment racks on Wheels, and S5, carts on Wheels, the capital letters “A” and “B” following the detail designate alternate methods of anchoring the equipment to the wall, floor, or ceiling. No costs are assigned to two custom conditions, T6, Tanks on legs, and U2, Unique built-up equipment. However, in laboratory cases where these details exist, the engineer can make a judgment on the local conditions and estimate an approximate cost based on component costs from other details.

The costs of anchoring represented in Tables 10 and 11 assume union labor rates and retail pricing of supplies. Obviously, if large quantities of materials were purchased for a series of installations, the cost of materials could be reduced. Similarly, labor costs assume the work is to be done on a small group of rooms. If an entire floor of a building, or other large aggregation of space were scheduled for nonstructural seismic repairs, an efficiency of scale would apply to labor rates as well.

The study assumes these are direct costs for in-house work by campus physical plant staff. If a general contractor were engaged to do the work, an 18 to 25% contractor profit and overhead markup would need to be added to the project estimate. Similarly, if a general contractor were involved and the project were managed by the campus Capital Projects Office, as with other building construction projects, a 20 to 30% markup would be added for project management. The percentage for contractor overhead and profit is common to the industry, and both overhead and construction management markups are common to UC projects.

3.2 EXAMPLE COSTS FOR FIVE PROTOTYPICAL LABORATORIES

Five campus laboratories were chosen to demonstrate the application of the cost methodology in different settings. Two of the labs are used for research in the biological sciences. These spaces are typically dominated by the presence of lab benches with storage above. The benches hold numerous densely packed pieces of equipment—small centrifuges, stirring machines, and microscopes—as well as heavy and expensive equipment such as a protein sequencer. Labs in the biological sciences also characteristically have numerous refrigerators and freezers for samples.

The third lab is in computer science. Here the space is dominated by computer work-stations, machine tools, and space for the building of specialized computer-driven products. The fourth lab is in physics, where most of the equipment is large and custom made for the purpose of experiments. As with most physics labs, the equipment itself is a work in progress, and the research is supported by a supply of tools, electronic parts, fume hoods and other more conventional equipment. The fifth lab is in chemistry. Typically these labs are similar to those in the biological sciences, in terms of the use of benches and benchtop equipment. Often however, these labs have other unique features such as specializing piping and other mechanical services.

TABLE 10

Summary of Costs by Detail Type

	Detail	Description	Direct Cost
Tanks and Cylinders	T1	Individual cylinders	$100
	T2	Multiple cylinders (6)	$370
	T3	Permanent tanks, <250#	$180
	T4	Permanent tanks, diam > 2/3 ht	$1,075
	T5	Permanent tanks, diam < 2/3 ht	$1,350
	T6	Tanks on legs	Custom
	T7A	Dewars, Wall dock	$520
	T7B	Dewars Floor dock	$760
Unique Equipment	U1	Install snubber device	$3,000
	U2	Built up equipment	Custom
Heavy Equipment	H1	Permanent equipment on floor	$860
	H2	Self-contained with only flexible connections	N/A
	H3	Freestanding	$1,350
	H4A	Wheels, wall dock	$520
	H4B	Wheels, floor dock	$760
	H5	Lighter equipment	$250
	H6	Refrigerators/freezers — small, not critical (anchor)	$250
	H6a	Door latch	$150
	H6b	Contents trays (3)	$225
	H7	Refrigerators/freezers — large, critical (anchor)	$760
	H7a	Door latch	$150
	H7b	Contents trays (6)	$450
	H8	Refrigerators/freezers — no wall/floor support	$2,200
	H9A	Racks (electronic type, wheeled or not) at wall	$366
	H9B	H9 freestanding	$1,446
	H10	Wheeled racks	$1,000
Storage	S1	Shelving at walls (anchor)	$45
	S1a	Stabilize shelves	$50
	S1b	3" lips	$180
	S1c	> 3" lips	$430
	S2	Bookshelving	$72
	S3	Closed cabinets at walls (anchor)	$45
	S3a	Positive latch	$50
	S3b	Protection of glass front	$270
	S4	Freestanding	$240
	S4a	Internally strengthen	$50
	S4b	Restrain contents	$450
	S5A	Carts, wall dock	$145
	S5B	Carts, floor dock(1 post)	$675
	S5a	Restrain contents (3)	$225
	S6	Metal cabinets	$45

Table 10 *continued*

Benchtop	B1	Large and heavy built-in equipment	$740
	B2	Other large and heavy equipment > 250#	$1,100
	B3	Other large and heavy equipment < 250#	$150
	B4	Other large and heavy equipment < 50#	$50
	B5	Stacked components	$75
Other Nonstructural Elements (cost/sf for typical lab densities)			
		Ceilings	$2.00
		Plumbing	
		Pipes over 2" diam	$0.50
		Pipe racks	$0.60
		Primary equipment	$0.10
		HVAC	
		Main Ducts	$0.20
		Piping over 2" diam	$0.10
		Primary equipment	$0.40
		Electrical	
		Conduit over 2" diam	$0.20
		Panelboards	$0.60
		Primary equipment	$0.40
		Fire protection	
		Piping over 2" diam	$0.60

3.3 LABORATORY PLANS AND COST ESTIMATES

Each of the five prototype labs is described with a floor plan, and an inventory of equipment contents in Appendix B. The inventory list is coded on the plans, with each item listed as A, B, C, etc. Examples of typical equipment are shown in the accompanying photos. The photos are keyed to the inventory list. The inventory list also includes the type of schematic engineering detail needed for seismic bracing and the cost of each item. For these five case study laboratories, details are used primarily for cost-estimating purposes. Some equipment may require a custom design for its anchoring but our estimate will list a detail that is comparable in cost. The total direct cost for equipment bracing is summed on each inventory list, and a 25% overhead fee is added to show the costs if contractor overhead and profit is included. Of course, these are preliminary estimates, and the prices could vary plus or minus 15%. Table 11 summarizes the direct costs and the costs per square foot in the five prototypical laboratories.

TABLE 11

Cost of Anchoring in Five Case Study Buildings

Laboratory	Direct Cost	Area in Sq. Ft.	Cost/ Sq. Ft.
Lab 1: Biology	$15,425	1,567	$9.84
Lab 2: Biology	$41,655	2,604	$16.00
Lab 3: Computer Science	$28,929	1,845	$15.68
Lab 4: Physics	$11,920	1,137	$10.48
Lab 5: Chemistry	$2,965	310	$9.56

The project team believes these estimates provide a reasonably accurate assessment of the cost of anchoring laboratory equipment. Two issues influence the final cost. First, it is important to note the density of equipment in these labs. Space is at a premium on the UC campus and most researchers are working in relatively crowded labs. Second, this estimate includes anchoring of all equipment in each lab. If an importance factor were assigned to each piece of equipment—representing either the importance to continuity of research or the difficulty in replacing special equipment—then estimates might be made for the cost of anchoring only a subset of the equipment.

3.4 PHYSICAL CONDITIONS AFFECTING FIVE PROTOTYPICAL LABORATORIES

The physical conditions that can affect seismic protection of laboratory environments, as discussed in Chapter 2, are documented, to the extent practicable for this project, for the five prototype labs in Tables 12 and 13. Several noteworthy issues are discussed below.

TABLE 12

Repairs in Three Scenario Earthquakes for Five Case Study Buildings

Building	Value of Repairs			Downtime in Months		
	Occ.	Rare	V. Rare	Occ.	Rare	V. Rare
Lab 1 Biological Science	$ 7,700,000	$ 16,300,000	$ 24,700,000	1	2	3
Lab 2 Biological Science	$ 6,000,000	$ 14,000,000	$ 22,600,000	2	4	6
Lab 3 Computer Science	$ 24,000,000	$ 42,000,000	$ 55,800,000	6	24	24
Lab 4 Physics	$ 10,500,000	$ 20,700,000	$ 30,000,000	3	24	40
Lab 5 Chemistry	$ 16,500,000	$ 24,700,000	$ 103,500,000	24	40	40
5 BUILDINGS	$ 51,000,000	$ 87,400,000	$ 189,300,000			

*SOURCE: Comerio, 2000

Two buildings housing prototype labs are expected to have poor seismic structural performance, and one is rated as only fair. Although structural retrofits for the poor buildings are under way, the condition emphasizes that overall seismic performance of labs, measured by life safety, direct damage, and downtime is dependent on both structural performance and the performance of nonstructural systems and contents.

The floor, overhead structure, and walls of the five labs selected for study do not appear to have problems with serving as anchorage media for building service systems or contents. However, for anchorage of larger loads, the exact size and configuration of the steel studs that make up the partitions should be determined.

The typical shelving that is part of the bench casework in Lab 1 and 2 appeared flexible and weak. These should be tested both for their adequacy to carry the load developed in an earthquake by heavy restrained items and as an adequate anchorage medium for equipment. For example the shelf unit may not be adequate to carry the combined load (due to earthquake motion) of all its contents. In addition, it may not be possible to anchor heavy items adequately to the shelf.

TABLE 13

Summary of Physical Conditions in Five Case Study Buildings

Lab ID	Floor	Structure	Floor Type (1)	Structure Above	Walls/ Partitions (2)	Bench Shelving (3)	Ceiling	Lights	MEP Above	Fire Sprinklers (4)	MEP Supply Equipment (5)
Lab 1 Biological Science	3rd	1985 6-story concrete shear wall. GOOD	Con.	Concrete beams and slabs	Concrete or floor to floor steel stud	Central post with cantilevered shelf supports. Assumed OK	None	1'x4' surface mounted to unbraced unistrut trapezes; Or to separate runners?	On unbraced trapezes	Bracing probably assumed by unistrut trapezes	Incomplete anchorage and bracing
Lab 2 Biological Science	1st	1987 5-story concrete shear wall. GOOD	Con.	Large-sized waffle slab	Concrete or floor to floor steel stud	Center and outboard small diameter tubes. Potentially weak	None	1'x4' pendants to structure or to suspended unbraced unistrut grid system	On unbraced unistrut grid system	Bracing probably assumed by unistrut system	Incomplete anchorage and bracing
Lab 3 Computer Science	3rd	1950 5-story concrete shear wall. FAIR	Con.	Concrete slabs	Corridor steel stud with every 3rd stud to floor above. Transverse floor to floor.	None	2x4 lay-in with complying bracing	Complying with ceiling system	Unbraced	Heads not braced in accordance with NPFA	Poor anchorage and bracing
Lab 4 Physics	1st	1924 4-story concrete pier and spandrel exterior wall POOR. (Retrofit in design)	Con.	Beams and slabs covered with acoustical tile	Floor to floor steel stud	None	2x4 lay-in with complying bracing	Complying with ceiling system	Unbraced unistrut trapezes. Mechanical equipment braced with cables.	None	Poor anchorage and bracing
Lab 5 Chemistry	8th	1963 11-story concrete shear wall/ moment frame. POOR. (Retrofit in const.)	Con.	Flat slab	Floor to floor steel stud	Unistrut system tied to ceiling system. Very flexible.	None	Supported on suspended unbraced unistrut grid system with no bracing	Unbraced unistrut ceiling grid	New system being installed to code	Incomplete anchorage and bracing

Notes:

1. Thickness of concrete is important for anchorage. Thickness not determined here. Impermeability of floor with or without anchorage is also an issue.

2. Allowable support by partitions depends on stud size, height and top support; specific details in these rooms not determined except for checking for continuity to floor above.

3. Shelving lateral strength is highly variable. Restrained contents may place high lateral loads on freestanding central shelving systems.

4. Sprinkler lines have proven to be vulnerable to breaks and leaks due to placement incompatibility of various pipe runs and sizes. Bracing required by NFPA 1994 or later is best, but may not prevent leaks.

5. Comprehensive review of mechanical rooms was not performed as a part of this project. General rating taken from *The Economic Benefits of a Disaster Resistant University*.

The building mechanical, electrical, and plumbing distribution systems in general, do not have comprehensive seismic bracing. On the other hand, none appears to present exceptional or obvious risks. Water damage from leaks or breaks in the pressurized water systems, including sprinklers, is probably the most significant threat to the lab contents.

The dependence of lab experiments on the availability of services from the MEP systems, or the possibility that experiments could be destroyed by short-term outages, has not been determined as part of this study. If such interdependence exists, the bracing of distribution systems and supply equipment becomes critical. In such cases, the reliability of externally supplied utilities after an earthquake must be considered and, when necessary, backup provided.

3.5 TYPICAL COSTS FOR UPGRADE OF BUILDING SERVICE SYSTEMS

The seismic anchorage costs described above apply only to laboratory contents. If additional nonstructural retrofits were recommended for a given building, the cost for that work would be added to the total project costs. As discussed in Chapters 2 and 3, ceilings, mechanical systems, and fire protection systems are the building elements most likely to be damaged in an earthquake. Additionally, damage to these nonstructural elements is likely to cause further damage and/or force a building closure. After the Northridge earthquake, the "state-of-the-art" new Veterans Hospital was closed for several days as a result of water damage from broken sprinkler pipes.

A detailed assessment of the performance of the mechanical systems, ceilings and other elements in the five case study buildings was beyond the scope of this research. However, we did include the typical costs to brace mechanical, electrical, plumbing, fire protection systems, and ceilings in laboratory buildings (Table 9). The bracing of all these nonstructural elements would be less than $6.00 per square foot in direct costs.

To brace all these components in the case study laboratories would increase the price of nonstructural mitigation from the base of $10.00 to $16.00 per square foot by an additional charge of up to $6 per square foot. In some recently constructed buildings, there will be no need to brace ceilings and mechanical systems. In other buildings, only a subset of these mitigation measures may be necessary. We include the information on the cost of these particular elements to exemplify the range of incremental costs for a variety of common nonstructural mitigation measures which may be needed in some laboratory buildings.

The five case study labs are representative of most of the typical laboratory spaces on the UC Berkeley campus. The only notable exception is the civil engineering laboratory, which has large machines and heavy equipment bolted to the floor and/or the structural system. The range of costs described here, from \$10 to \$16 per square foot, is typical for the densely inhabited laboratories on the UC Berkeley campus. The cost of bracing other nonstructural elements such as ceilings and mechanical systems could add an additional \$1.00 to \$6.00 per square foot to the base cost. Given the various building conditions on any campus, there is likely to be a range of costs for individual buildings, with some below and some above the estimates developed here.

4 Conclusions

If a university or corporate park wants to limit earthquake damage and the time needed for repairs, efforts to identify and protect key aspects of the operation are critical. These institutions may decide to invest in performance engineering and nonstructural mitigation — efforts beyond code minimum requirements.

At UC Berkeley, administrators have funded small programs aimed at limiting nonstructural damage, particularly where the elements are known to be a life-safety hazard. The Q-Brace program for bookcases and office equipment provides a preliminary understanding of the costs involved in anchoring furnishings and small equipment. Similarly, the campus experience with the upgrade of library shelves, and the anchoring of light fixtures suggests that the decision to retrofit or replace the equipment must be based on cost, function, useful life of the fixture, and other building location factors. Nonstructural upgrades are not universally inexpensive, and must be evaluated in the context of the life-safety, building conditions, and programmatic needs.

As with most universities, UC Berkeley's labs represent about 30% of the net floor space in the university. These spaces house expensive and unique equipment along with data and samples. The laboratories themselves are critical to the continuity of funded research. For this study, the team cataloged typical research equipment and described typical design solutions for anchoring each type.

In the five laboratories studied, direct costs ranged from $10 to $16 dollars per square foot. Although these estimates may appear to be expensive, it is important to note that the laboratories shown are densely packed with equipment, and the estimates are for anchoring every object in the space. The next logical step (one which is beyond the scope of this project) would be to assign an importance factor to the laboratory equipment and estimate the costs of upgrading only the most critical in terms of life safety or protection of research.

The research team also looked at the physical conditions of the building structure and building systems in an attempt to identify the issues or conditions that would add cost to a nonstructural upgrade, but would be important to the protection of research. We estimated the cost to brace other nonstructural elements such as ceilings, mechanical, electrical, and fire protection systems, in a range of costs between $1.00 and $6.00 per square foot, depending on building and system conditions. It was beyond the scope of this report to develop cost/benefit models for nonstructural upgrades or to provide an analysis of the variation in costs for different combinations of systems and contents upgrades; however, these are important for individual building evaluations.

To provide an overall assessment of the cost to the campus for anchoring of contents in the laboratories, one can multiply the average cost for mitigation by the net area of laboratories on campus. Table 14 provides an estimate of costs on the UC Berkeley campus at $10.00 and $15.00 per square foot. This is calculated for all spaces designated as a research laboratory in the campus space management system, and for the laboratory space in the subset of buildings that are predominantly laboratory buildings (i.e., buildings where the majority of space is laboratories). For the buildings in which the dominant use is laboratories, the cost to anchor all the contents could range from $8 to $12 million.

TABLE 14

Estimated Range of Costs for Seismic Improvement to Laboratory Contents on the UC Berkeley Campus

Space	Net Area	Cost/ Sq. Ft.	Total in Millions
All research space	1,125,400	$10.00	$11.3
All research space	1,125,400	$15.00	$16.9
Dominant lab buildings	810,950	$10.00	$8.1
Dominant lab buildings	810,950	$15.00	$12.2

In general, the range of costs presented in this report provides a first cut at understanding the magnitude of effort in comparison to other building costs. For example, the cost of anchoring laboratory contents represents only a 10 to 15% increment over the cost of structural retrofits.

Whether the anchoring of laboratory contents is a worthwhile expenditure, that is, whether it would substantially reduce building downtime or reduce dollar losses will require a review of conditions on a building by building basis, including the interaction between the structural performance, building systems, and contents. Future PEER research projects will evaluate the structural and nonstructural performance of a specific university-based laboratory building. This research will provide a better understanding of the potential losses (in dollars and downtime) resulting from nonstructural damage, and will provide a more refined understanding of the costs and benefits of nonstructural mitigation measures.

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White, George, and et al. Selecting Public Buildings for Seismic Strengthening: Lessons Learned from San Francisco's Earthquake Safety Program. 1994. In proceedings *Fifth US National Conference on Earthquake Engineering, July 10–14, 1994, Chicago, Illinois: Earthquake Awareness and Mitigation Across the Nation.* Vol. 3, pp. 955–64. Berkeley, Calif.: Earthquake Engineering Research Institute.

Appendix A: Schematic Details for Anchorage of Laboratory Contents

This appendix contains details for seismic mitigation of lab equipment. Some are products available for purchase. Others are generic engineered standard details (ESD) developed by the research team for cost-estimating purposes. When proprietary products are used as examples, the manufacturer's claims regarding performance and application are indicated in italics.

Appendix A: Solutions Key

Anchorage Methods for Laboratory Contents

Category	Detail No.	Item	Type[2]	Description	Comment
Tanks/ Cylinders	T1	Individual cylinders	SD	Wall rack or chain. Commercial wall or floor-mounted holder.	Attachment to concrete wall or to stud. Compare freedom for movement with flexibility of connecting hoses.
	T2	Multiple cylinders	SD	Wall "corrals." Commercial racks.	Attachment to concrete wall or to stud. Compare freedom for movement with flexibility of connecting hoses.
	T3	Other permanent tanks without legs< 250# at wall	ESD	Strap to wall @ 2/3 height.	#12 screw into stud min. The limit is the connection to the wall. Can develop more screws or use spreader for larger load.
	T4	Other permanent tanks without legs; diam > 2/3 height not at wall	ESD	Perimeter "keeper"- angle bolted to floor (no attachment to tank) or 5 individual angles.	No overturning problem. If no attachment to surroundings and on floor, consider no anchorage.
	T5	Other permanent tanks without legs diam < 2/3 height not at wall	ESD	2- strongbacks[1] and containment band at 2/3 height.	
	T6	Tanks on legs	Custom	Custom.	Anchorage of legs may be inadequate.
	T7A	Dewar on wheels	ESD	Wall dock.	No adhesive attachments. Heavy nylon strap or chain restraint. Attachment to wall needs special consideration. Locking wheels will create overturning problem.
	T7B		ESD	Custom floor dock if locations can be determined.	
Unique Equipment	U1	Vibration-isolated equipment	ESD	Install snubber device from wall, floor, or strongback.	Find locations where support elements will not inhibit use.
	U2	Built-up equipment	Custom	Completely custom. Often strongbacks from floor or counter will work.	Find locations where elements will not inhibit use.
Heavy Equipment	H1	Permanent equipment on floor with breakable connections to other elements except refrigerators	ESD	Anchor bolts to floor. May need large angles and 2-bolt connections to floor. Connection to equipment may vary.	Do not use commercial leveling foot brackets. Do not use adhesive either to structure or to equipment. Consider similar to medical equipment.
	H2	Self-contained equipment with only flexible connections (e.g., plug) and w > 2/3 h	ESD	If life safety or high value issue, similar H1. Otherwise, may not need anchorage.	
	H3	Freestanding	ESD	2 strongbacks and attachments. May be adhesive in some cases.	Distinction is that no wall is available. Some equipment may default to H2
	H4A See T7A	On wheels at wall	ESD	If stable, install wheel locks or docking station. If tall, tightly restrained docking station.	No adhesive. Attachment to wall needs special consideration. Equipment >250# may need spreader bar on stud walls.
	H4B See T7B	On wheels no wall			
	H5	Lighter equipment	SD	Commercial devices.	Adhesive anchorage equipment. Screws to walls, bolts to floor. What is wt limit or eccentricity limit?
	H6	Refrigerators/freezer A—Small or not critical	SD	Commercial straps to wall. Adhesive to unit, screws to wall.	Option available with Velcro for cleaning.
	H6a		SD	Door latch.	
	H6b		SD	Special contents trays.	
	H7	Refrigerators/ freezer B—Large, critical, or life safety	ESD	Anchor to wall or floor with screws or bolts to casing or frame.	Issue of how to attach to item. Issue of wall strength.
	H7a		SD	Door latch.	
	H7b		SD	Special contents trays.	

Appendix A: Solutions Key

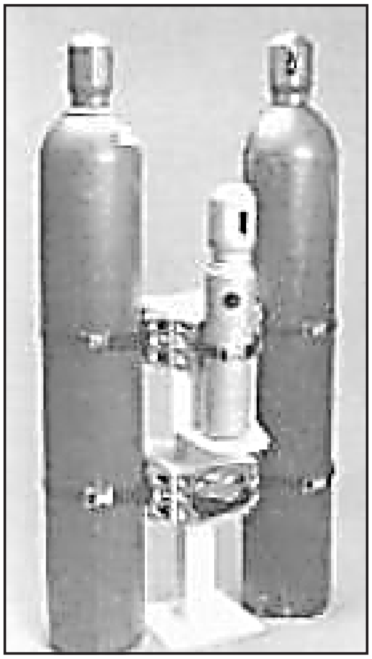
Heavy Equipment cont.	H8 See H3	Refrigerator/freezer: Floor/wall support Not Good	ESD	Floor to ceiling side supports. See also H8a, and b.	If no wall is available and no attachment is possible at bottom.
	H9a	Electronic type Racks: wheels, no wheels at wall	ESD		Issues include need for mobility, wheeled or not, adequacy of rack itself.
	H9B	Without wall	ESD		
	H10	Wheeled banks of racks	ESD	Anchor with tight cables to structure above.	
Storage	S1	Shelving at walls	SD	Anchor to wall.	
	S1a		ESD	Stabilize shelves.	
	S1b		SD	3" commercial clear lips for items < 6".	x depends on reliability desired against coming off shelf. 3" probably provides 2.25" barrier reliable for 4.5-5" items.
	S1c		SD	Items > 6' : taller lips, closed cabinets, or individual item holders with no-slip pads or tethers to wall; also strap trac (hinged bar).	Compartmented bins with friction bottoms.
	S2	Book shelving	SD	Grip strip.	Commercial material.
	S3	Closed cabinets at walls	SD	Anchor to wall.	
	S3a		SD	Positive latch.	
	S3b		SD	Protection for glass front.	Film. Or inside protection mesh, etc.
	S4	Freestanding	ESD	Stabilize.	Anchor at bottom, struts across top, floor to ceiling elements.
	S4a		ESD	Internally strengthen.	Cross braces etc.
	S4b		SD	Restrain contents.	Lips, friction pads, restraining bars, individual item holders, etc.
	S5A	Carts	SD	Wall docks.	No adhesive. Attachment to wall needs special consideration. Equipment >250# may need spreader bar on stud walls.
	S5B	Cart without walls	SD	Floor dock.	Similar H9B with one post.
	S5Aa		SD	Contents security measures.	Compartmented bins with friction bottoms? Lips, etc.
	S6	Metal cabinets	SD	Typical office solutions.	UC Typical or commercial.
Benchtop	B1	Large and heavy "built-in" equipment (hoods, etc.)	ESD	Develop anchorage to benchtop framing or walls.	Treat similar to built-in medical equipment.
	B2	Other large and heavy > 250#	ESD	Anchorage to counter, back wall, or counter to ceiling elements.	No adhesive.
	B3	< 250#	SD	Commercial adhesive devices, but screwed to back splash, wall, or counter.	
	B4	< 50#	SD	2-Commercial adhesive devices.	
	B5	Stacked components	SD	Velcro pads and cable ties to tie together, with other tie to wall or counter. May need counter to ceiling elements.	

Notes:
1. Strongback: steel tube, unistrut or channel running floor (or countertop) to structure above to provide lateral support for element.
2. Type of detail for estimating purposes:

SD: Standard Detail— No detail. Elements available from one or more proprietary suppliers, or standard in industry.
ESD: Engineered Standard Detail— Generic detail sketched for this project; minor adjustments may be needed.
Custom— No generic detail applies and restraint/anchorage must be developed for each case.

Compressed Gas Cylinder Storage System

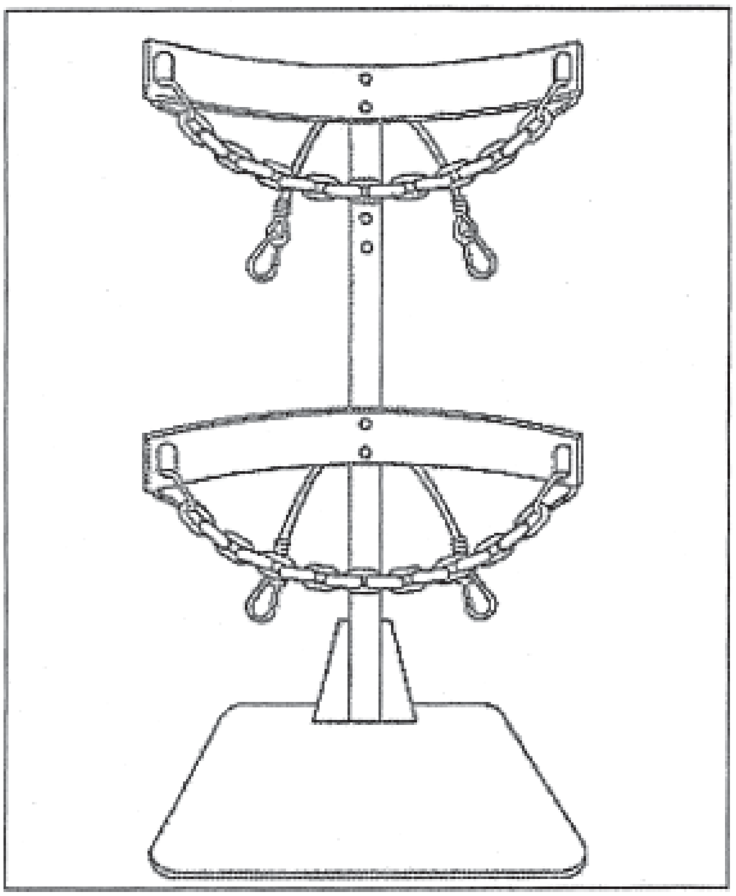
http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441



British Columbia's new April 1998 WCB regulations require secure storage and transport of compressed gas cylinders. Safe-T-Rack Systems Inc. offers a range of storage and restraint systems for all types of compressed gas tanks. These patented systems meet NFC, UFC, UB, Seismic Regulations and OSHA Requirements in the U.S.

Compressed Gas Cylinder Storage System

http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441



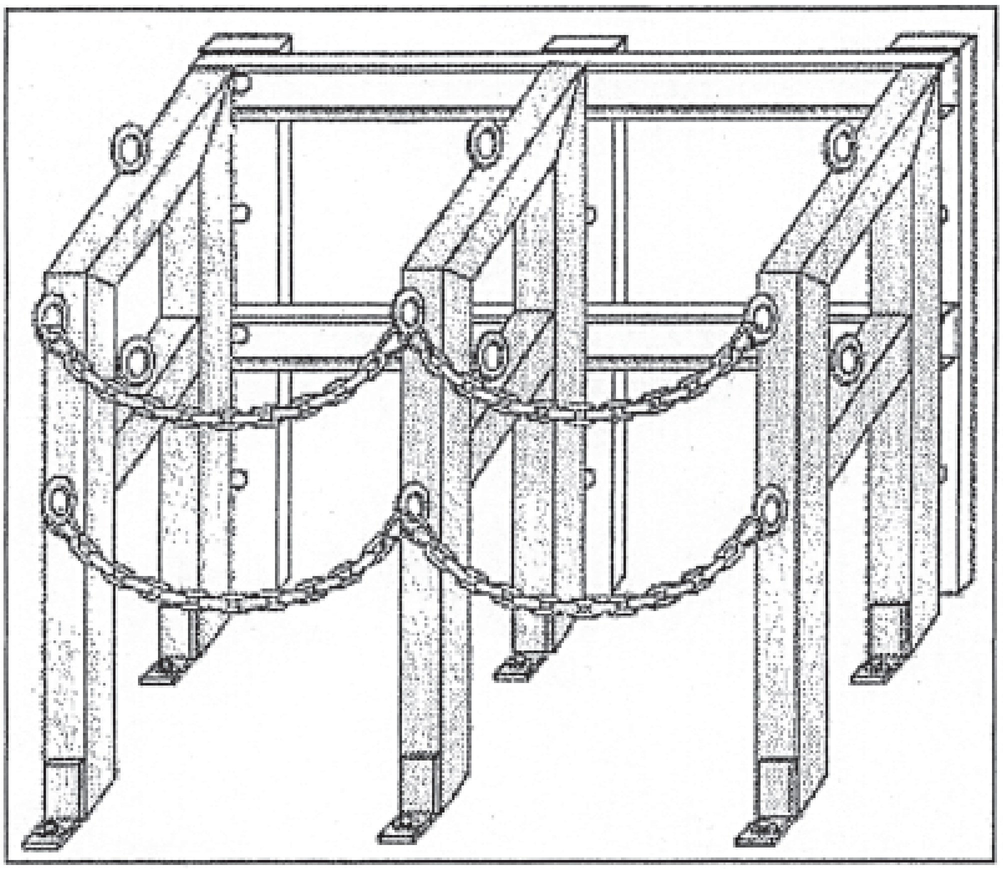
Front View

Seismic Cylinder Restraint **Detail** 5/20/01 **T1**

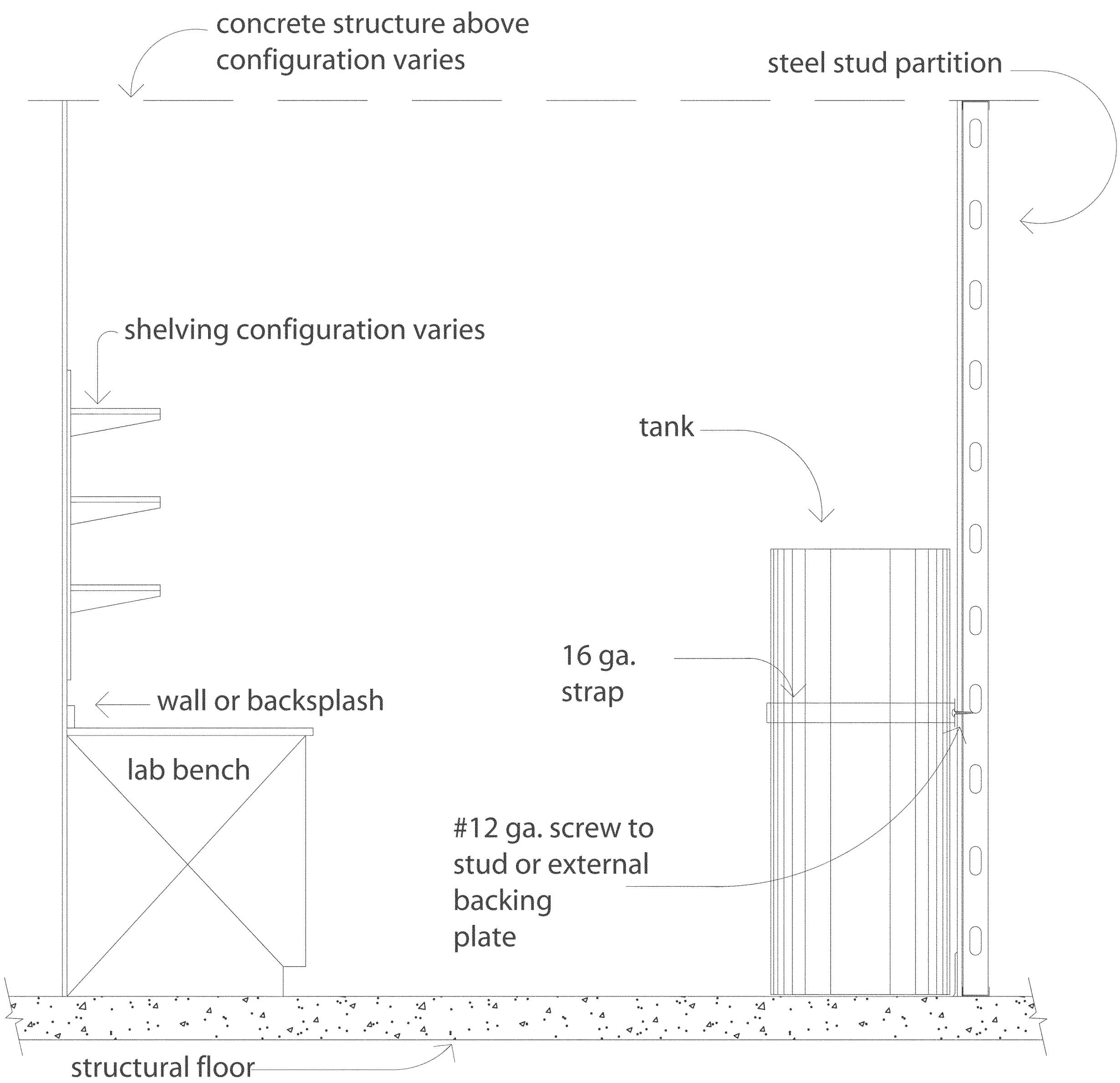
PEER Nonstructural Loss Study NOTE: This is one example of a range of products available from a variety of manufacturers.

Compressed Gas Cylinder Storage System

http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441



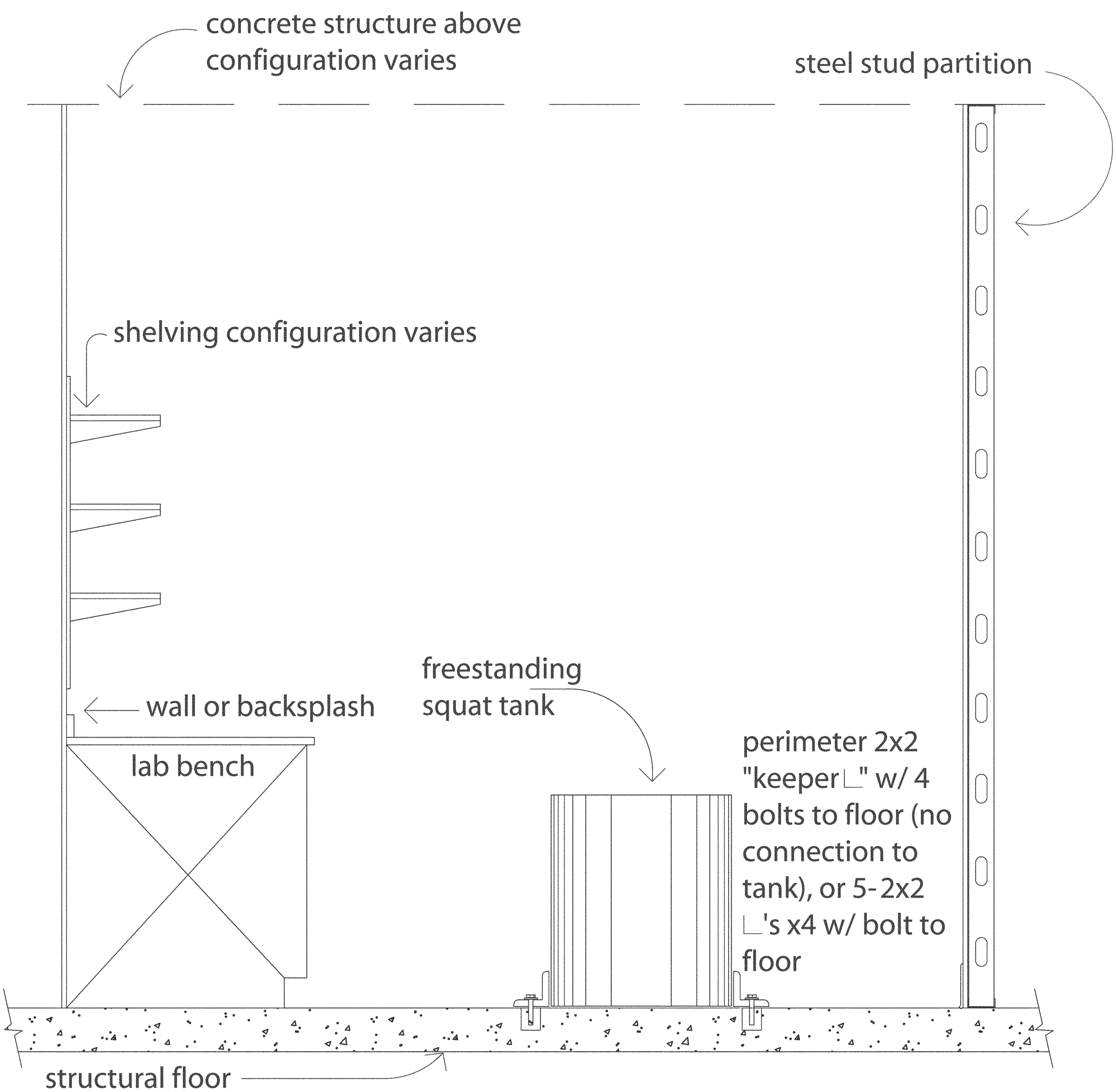
Front View



Tank Restraint

T3

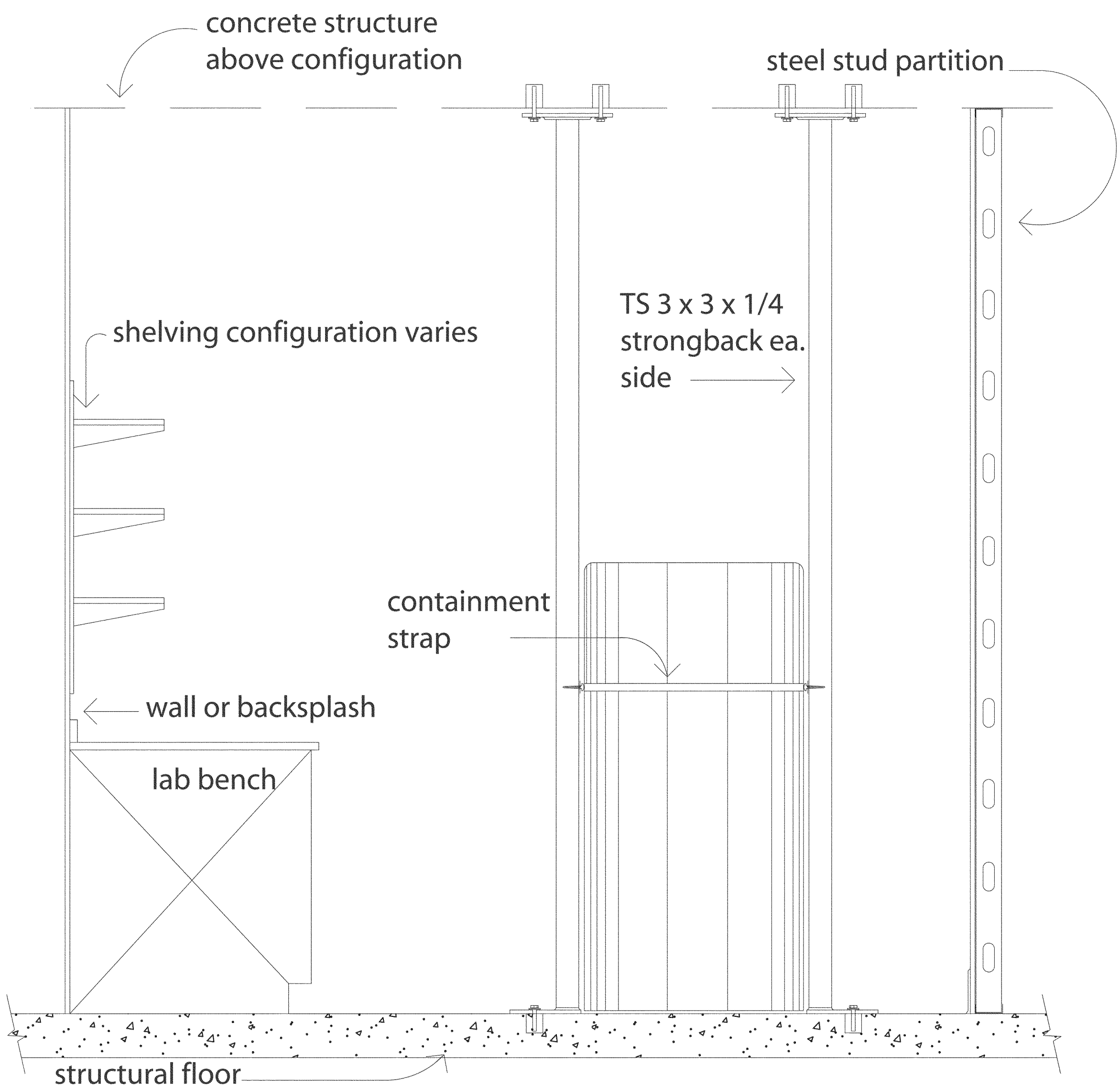
PEER Nonstructural Loss Study



Tank Restraint

T4

PEER Nonstructural Loss Study



Tank Restraint

T5

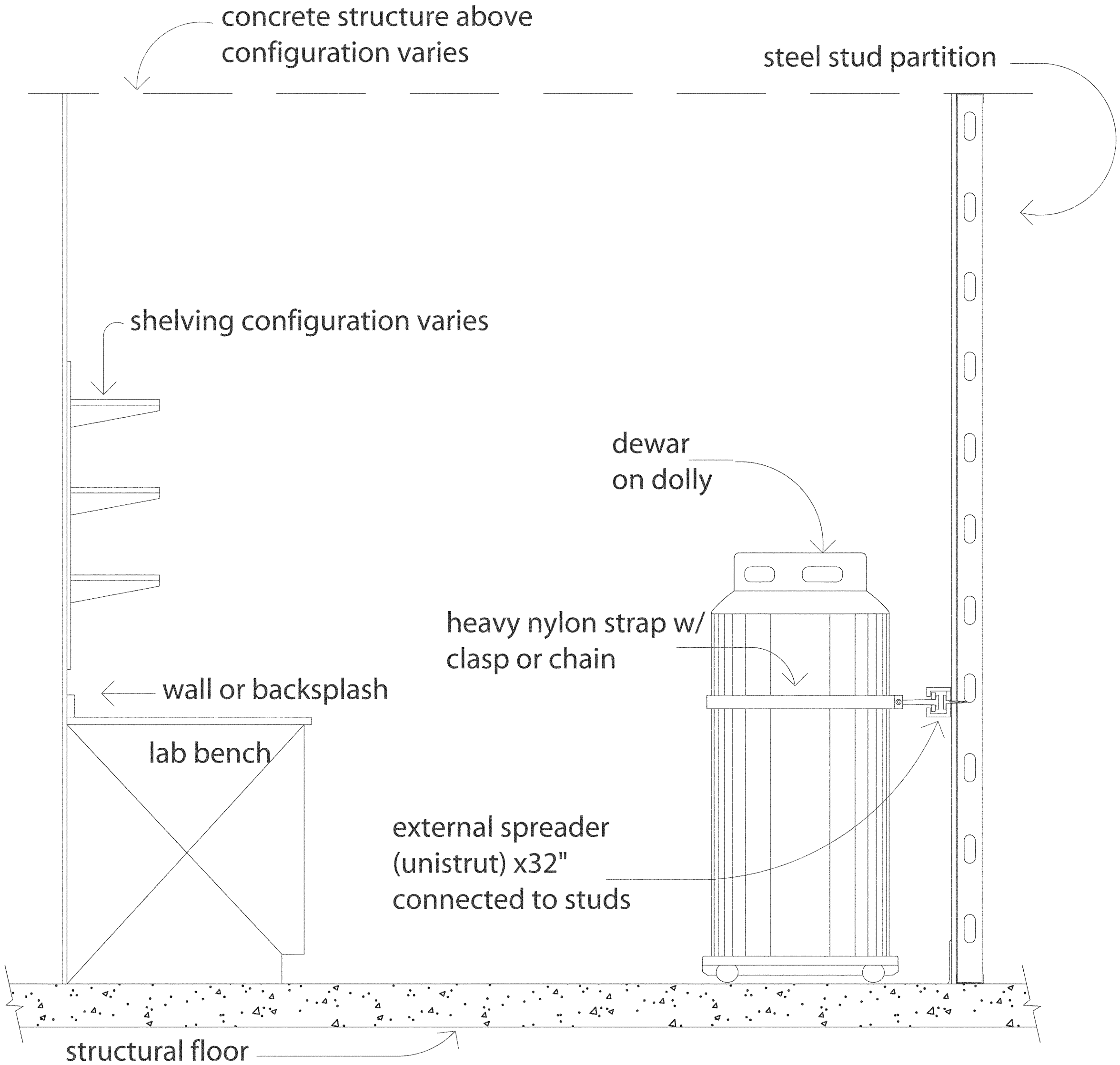
PEER Nonstructural Loss Study

Custom Detail Requiring Engineering

Tanks on Legs

PEER Nonstructural Loss Study

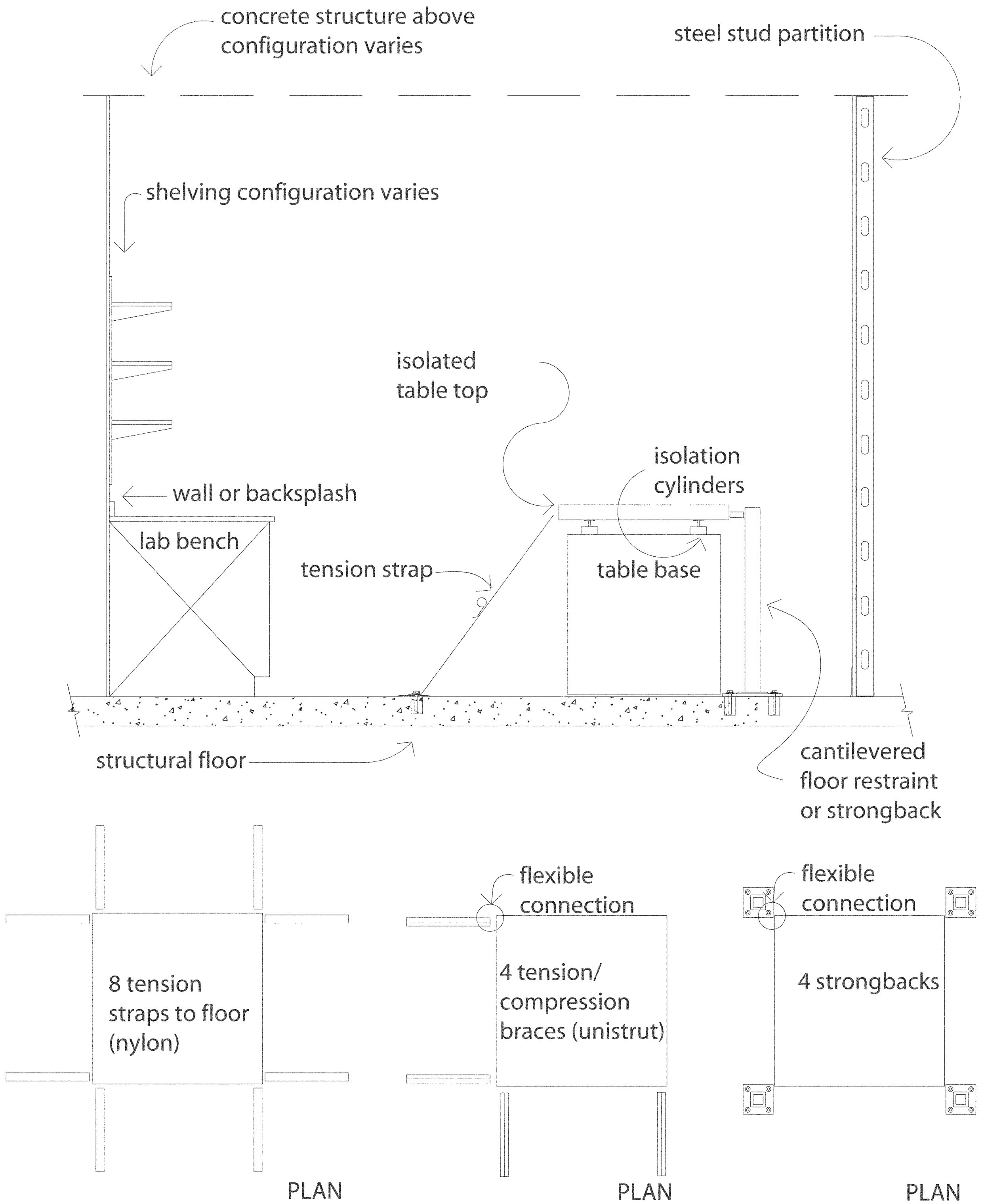
T6



Dewar Restraint

T7

PEER Nonstructural Loss Study



Vibration-Isolated Table Restraint | **Detail** | **U1**

PEER Nonstructural Loss Study

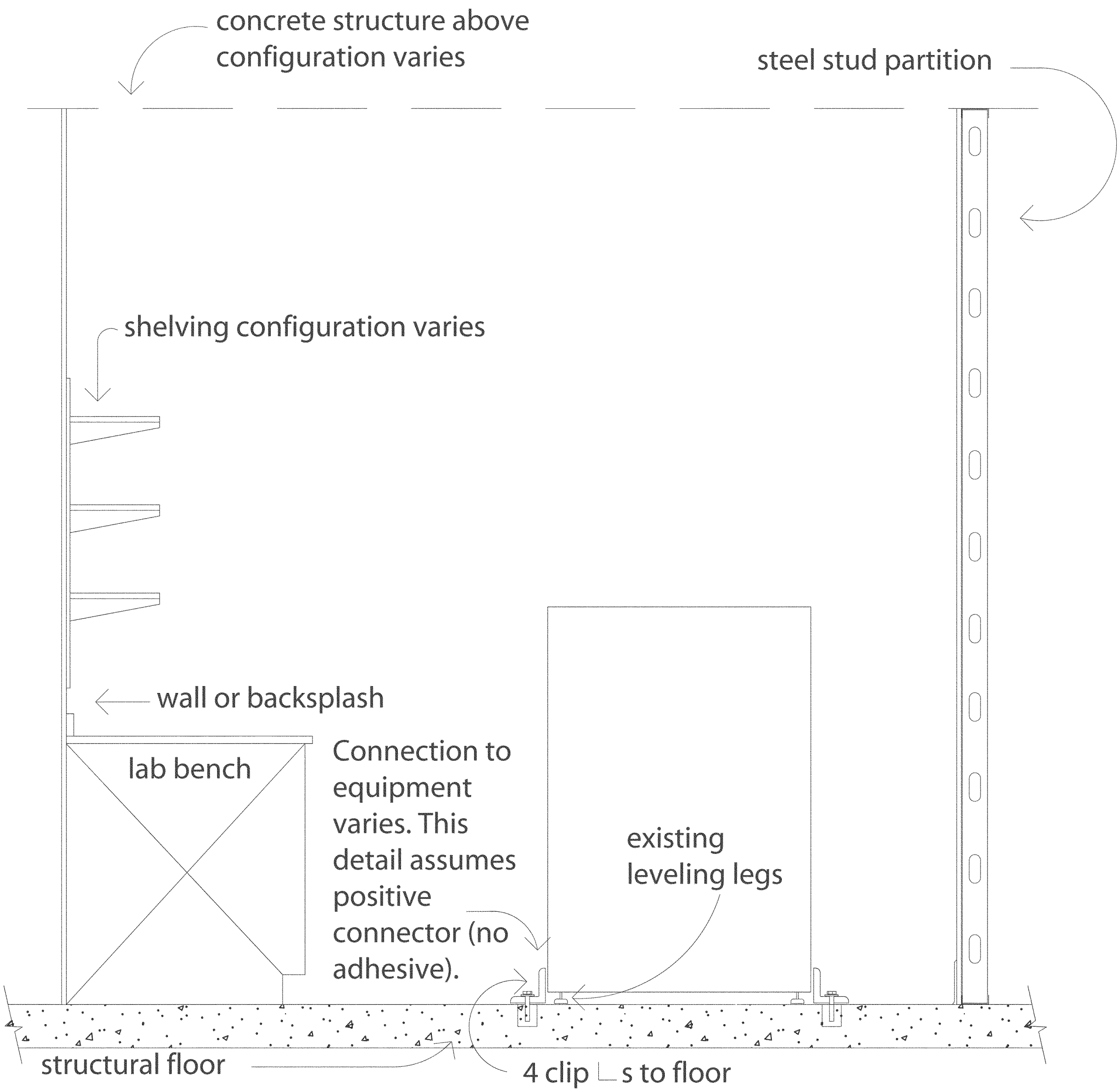
Custom Detail	**U1**
PEER Nonstructural Loss Study	

Custom Detail Requiring Engineering

Specialized or Built-Up Equipment

PEER Nonstructural Loss Study

U2



Heavy Equipment with Leveling Legs

H1

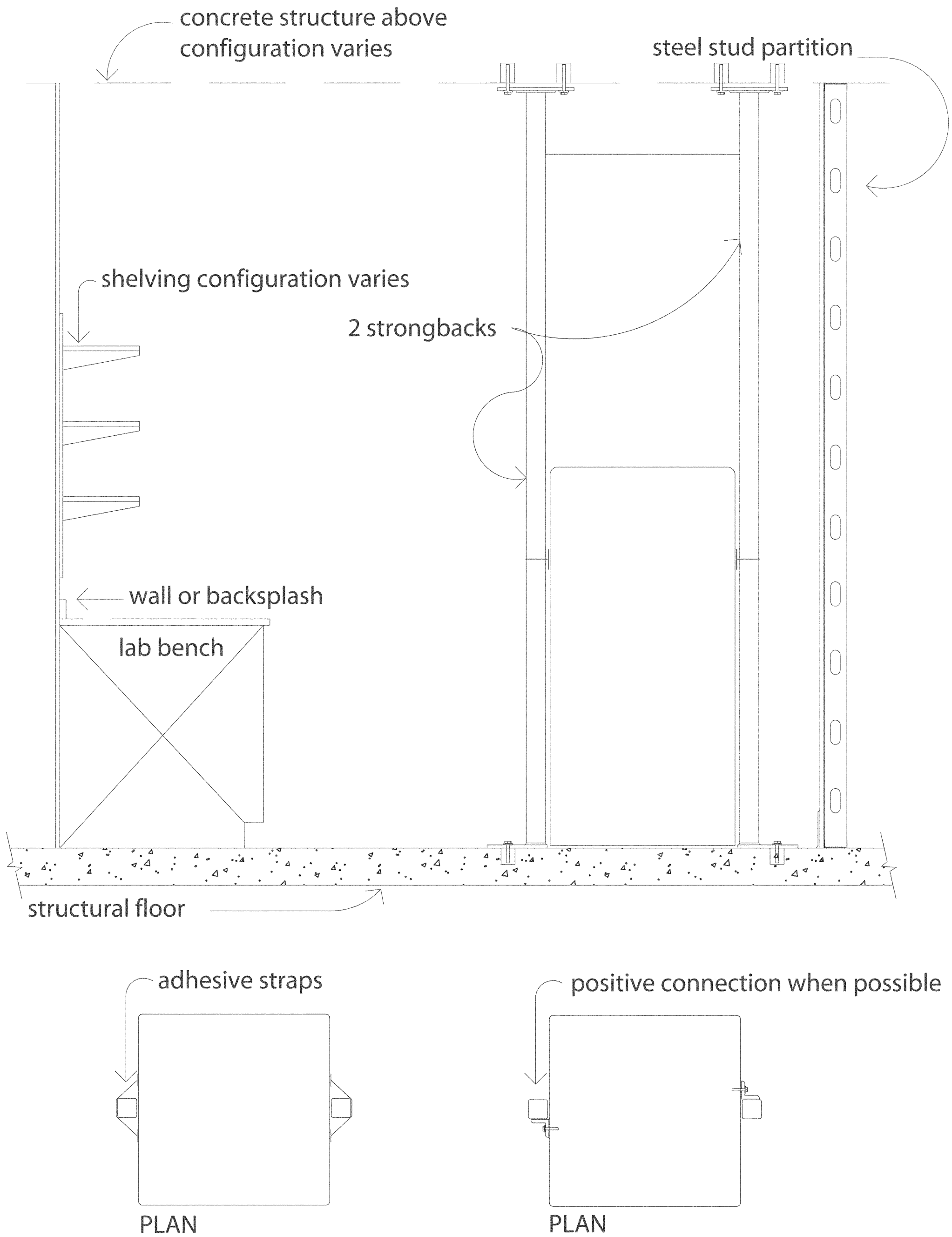
PEER Nonstructural Loss Study

Similar to H1

Self-Contained Equipment with Flexible Connections

PEER Nonstructural Loss Study

H2



Freestanding Heavy Equipment **Detail** **H3**

PEER Nonstructural Loss Study

See S5 or H9

Equipment on Wheels

PEER Nonstructural Loss Study

H4

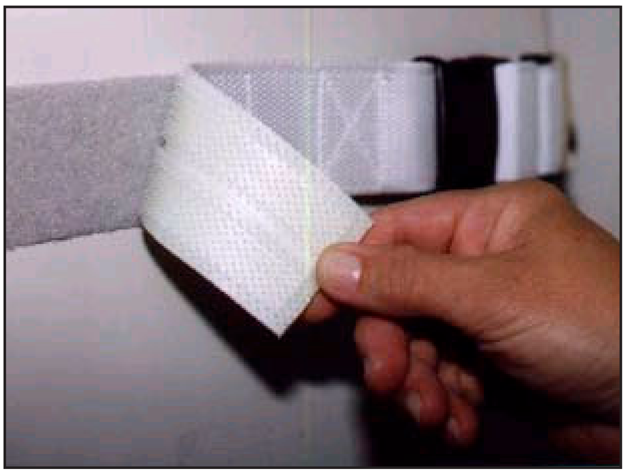
Similar to H6

Lighter Equipment	**Detail**	**H5**
PEER Nonstructural Loss Study		

Refrigerator / Vending Machine / Appliance Fastener

Source: Pacific County Emergency Management Agency
http://www.co.pacific.wa.us/pcema/earthquake/

http://www.safe-t-proof.com/index1.htm
1-888-6772338
General information about Safe-T-Proof: info@safe-t-proof.com
Michael Essrig, President & CEO: messrig@safe-t-proof.com



*2 sets of nylon straps,
each with Velcro® brand hook & loop fastener and
a quick-release buckle; mount on sides and/or top.
Used for refrigerators, vending machines, stoves and
other appliances.*

*#500-30-WH-02 (white);
#500-30-BK-02 (black).*

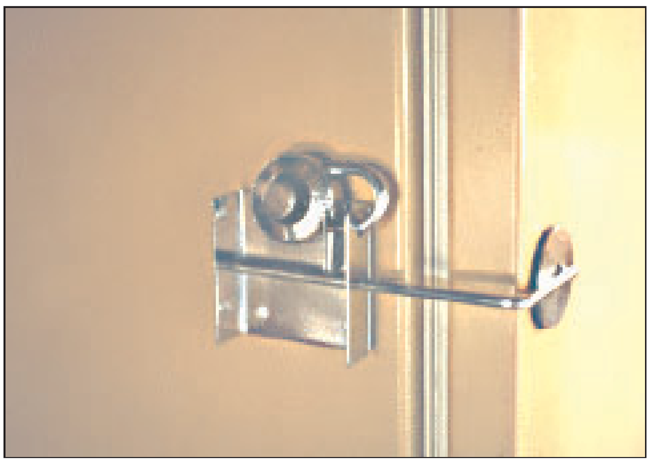
*Price
White $21.95
Black $21.95*

Standard Mounting: Side Mounting

http://www.sciline.com/earthquake_hold%20downs.html
tom@scline.com

1-800-622-3010
FAX 1-877-SCILINE (Toll Free)

SciLine Products
PO Box 6423
Whittier, CA 90609



#SL-518-PL
Padlock Latch $12.95
Dimensions: 3" X 3" base plate; 1" high flanges; retaining rod extends out 3" from front flange and down 3"; padded disc is 2′ in diameter.

#SL-518-2R
Non-Padlocking Latch $11.50
Dimensions: same as above

#SL-518-2M
Non-Padlocking Latch $9.95
Dimensions: Base plate is 3" X 1 1/2" wide.
All other dimensions are the same.

Photo Code: 3-1

Refrigerator Door Latch

Detail

H6a

PEER Nonstructural Loss Study

NOTE: This is one example of a range of products available from a variety of manufacturers.

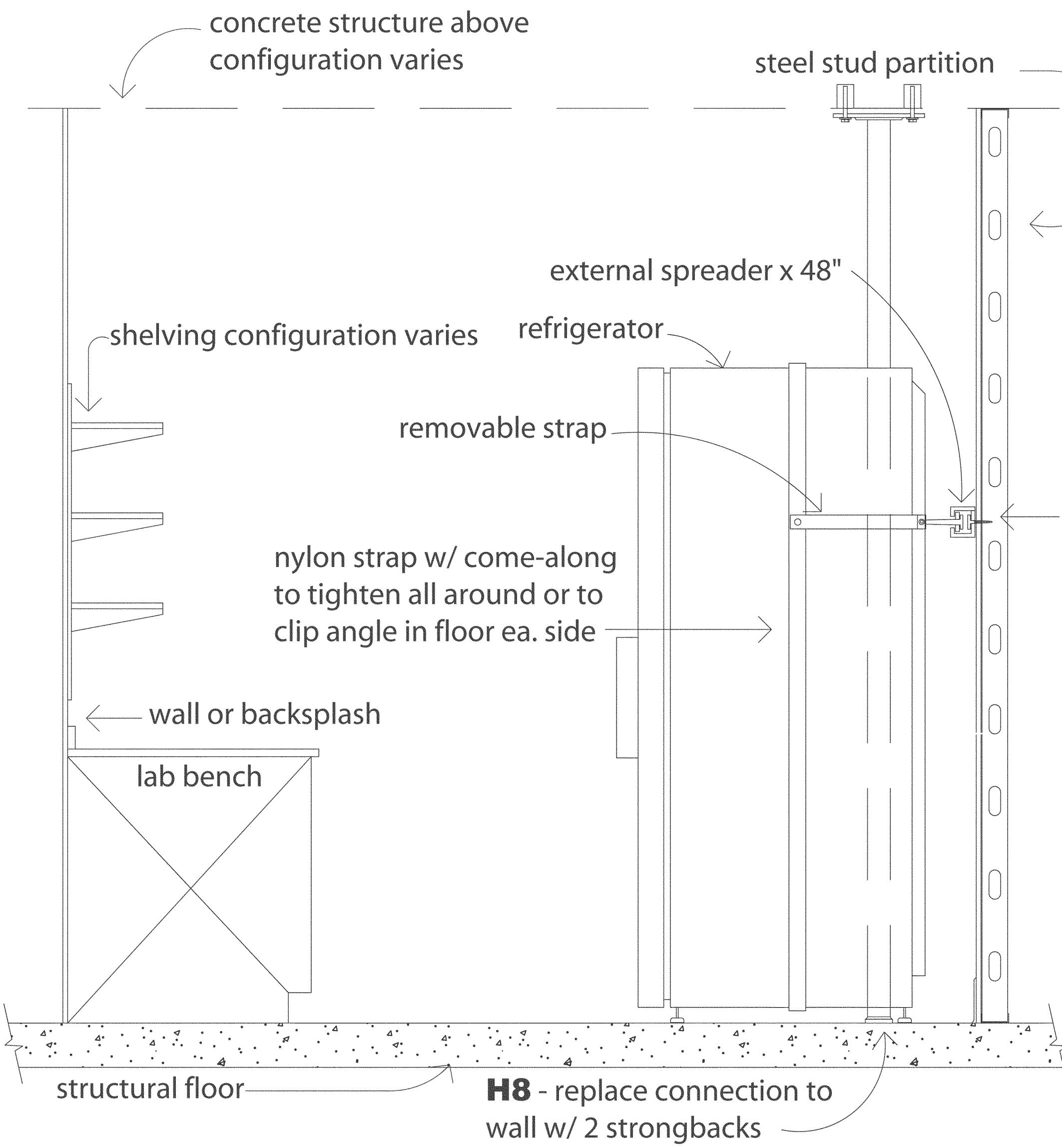
Photo Code: 3-67

Handle on Sub-Zero Freezer

Detail

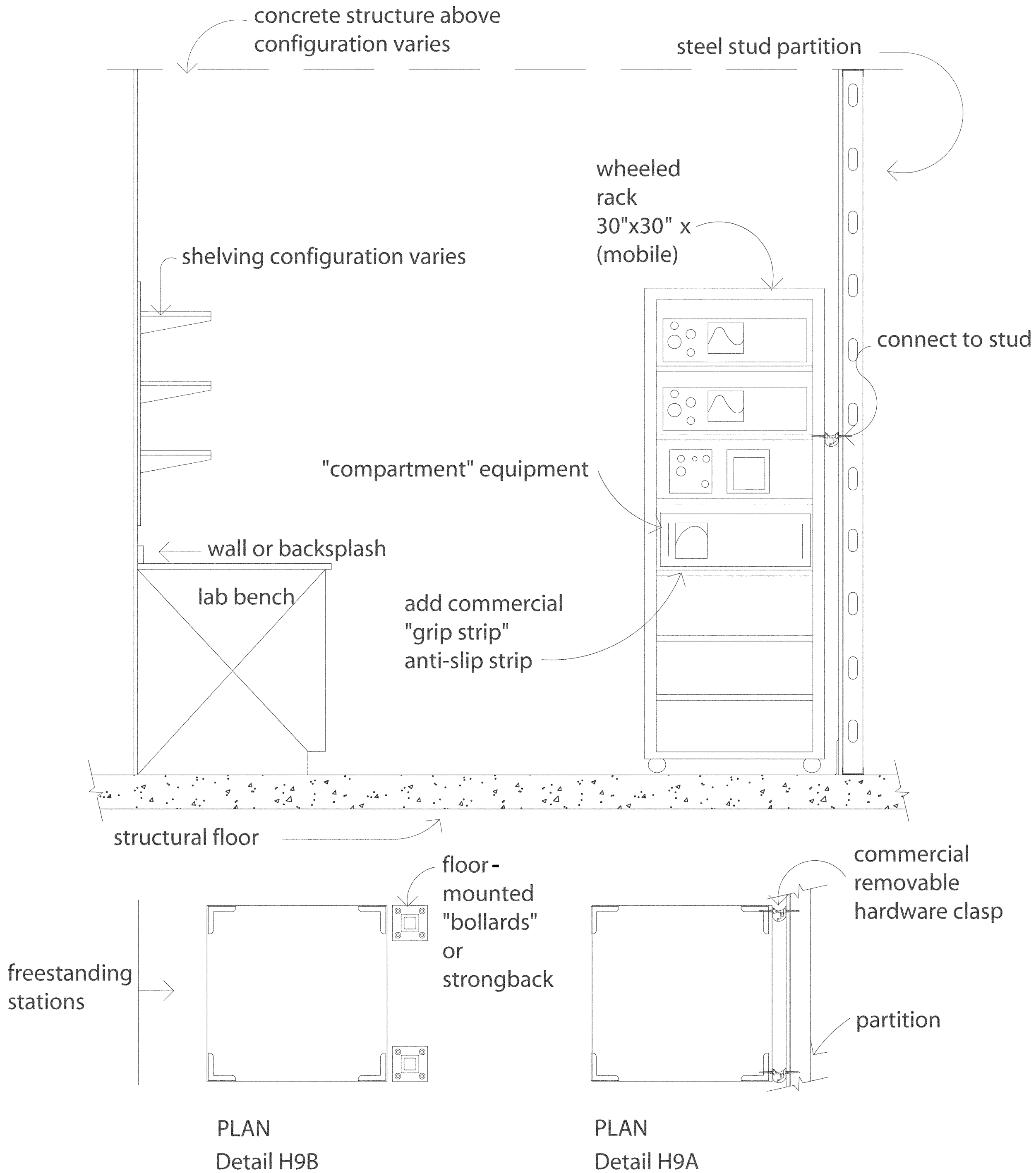
H6a

NOTE: This is one example of a range of products available from a variety of manufacturers.



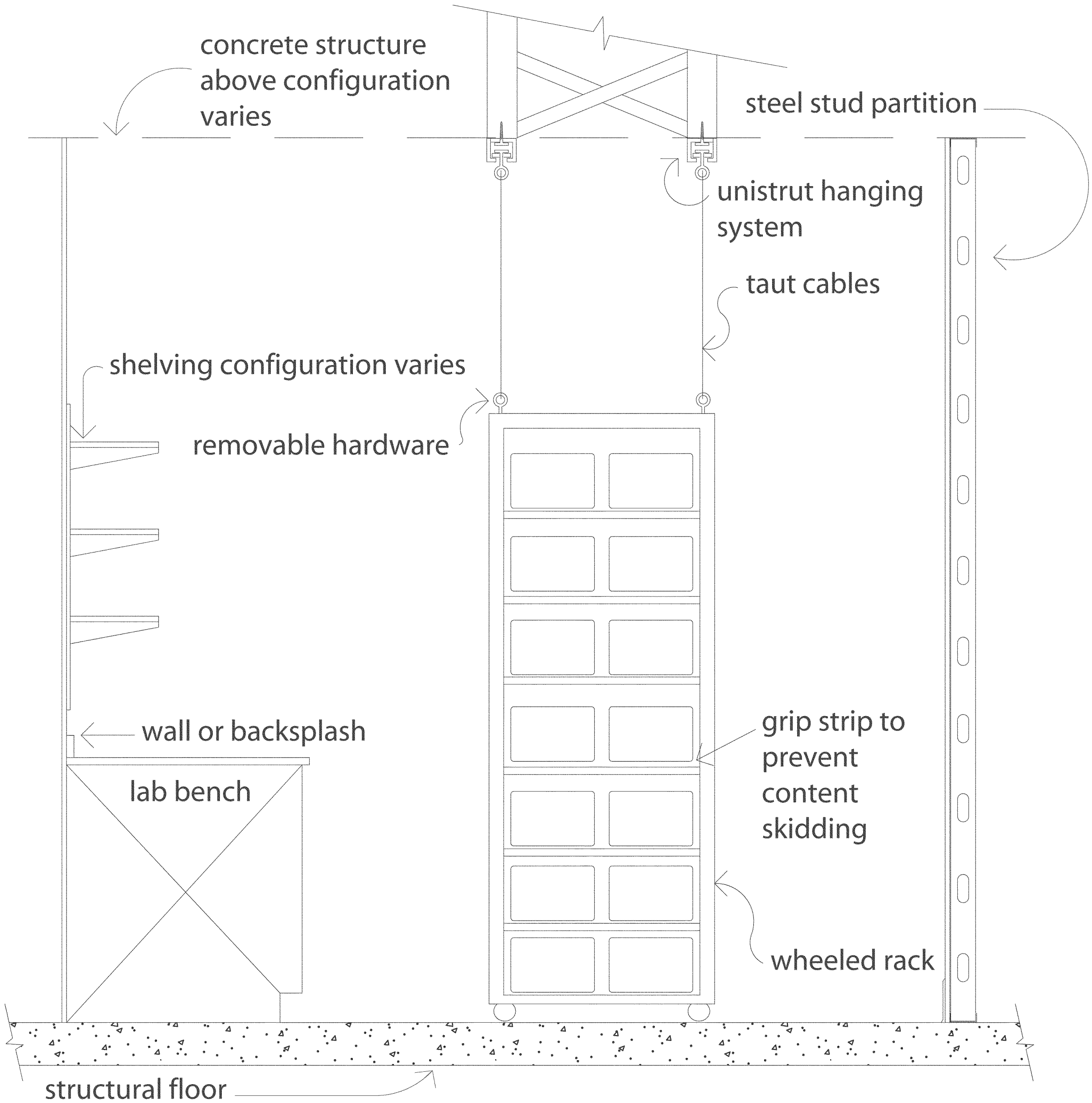
NOTE:
Tight restraint of refrigerator/freezer may cause unacceptable floor vibrations. This condition must be investigated and considered on a case-by-case basis.

Refrigerator Restraint	**Detail**	**H7 / H8**
PEER Nonstructural Loss Study		

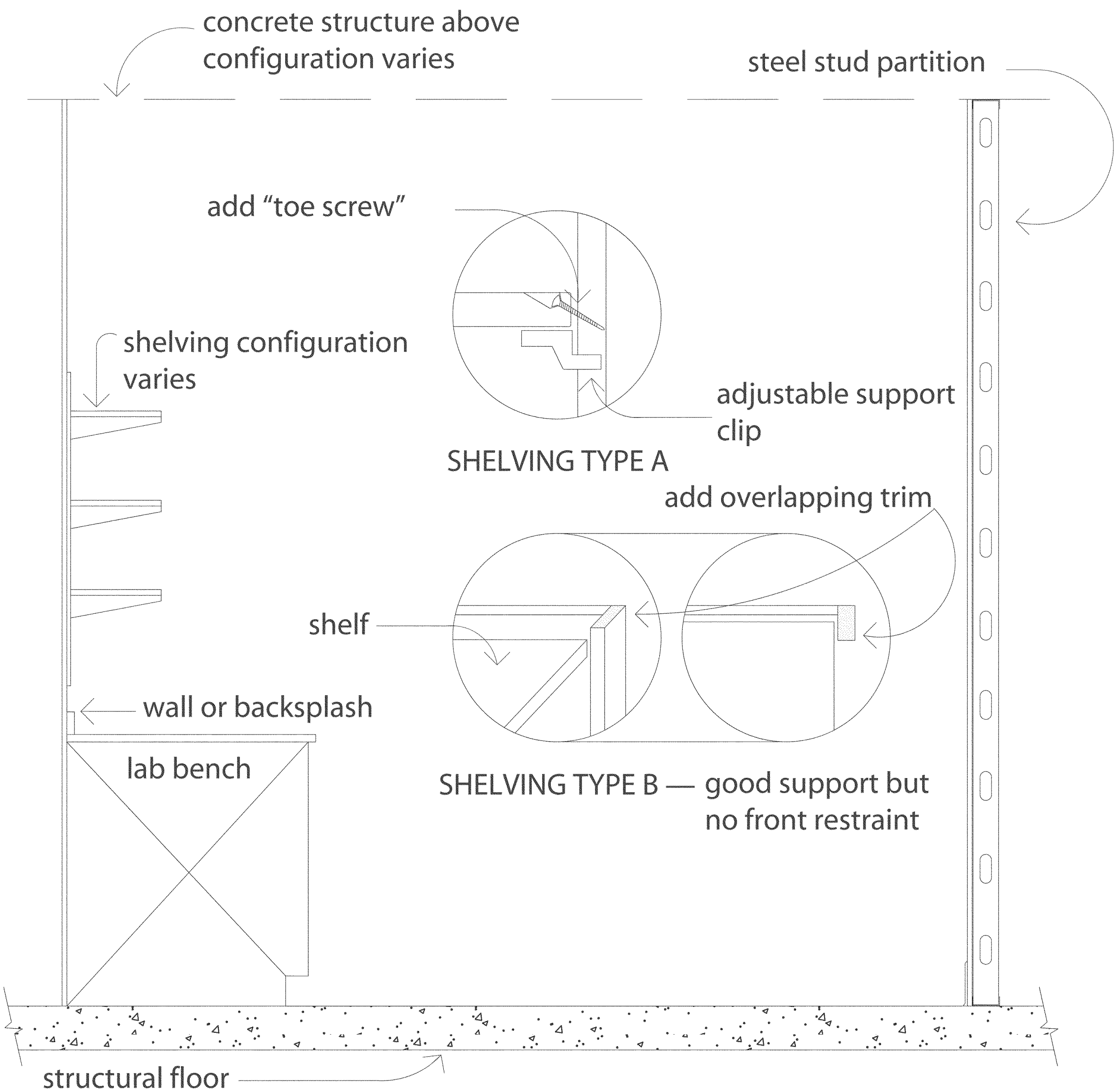


Wheeled Rack Restraint | **Detail** | **H9**

PEER Nonstructural Loss Study



Rolling Storage Rack	**Detail**	**H10**
PEER Nonstructural Loss Study		



Shelf Restraint **Detail** **S1a**

PEER Nonstructural Loss Study

Shelf Barriers

http://www.sciline.com/earthquake_hold%20downs.html
tom@scline.com
1-800-622-3010
FAX 1-877-SCILINE (Toll Free)
SciLine Products
PO Box 6423
Whittier, CA 90609

UC Berkeley

2" High , Double Stainless Steel, Rod Barriers in place 1" Above Shelf Level in BioChem Stockroom. Both Stainless Steel & Acrylic Barriers are used in this UC Stockroom. This 4' Wide Barrier is supported at each End by Side-Wall Mounted Brackets and In Between by Sciline's "L" Brackets with Adjustable Barrier Supports.

The pictured 2" High X 1/4" Thick, Clear, Acrylic Barriers are supported and held in place at each end and in the center by Sciline's Self-Adhering, Stainless Steel "SAFE-SHELF " brackets. These brackets can be affixed to the shelf itself or to the shelving unit side-walls at or above shelf level by means of 3M VHBTM (Very High Bond) Double-Sided, Tape Adhesive. This Adhesive is rated by 3M at 80 lbs Per Square Inch of Shear Resistance. This gives Each of Sciline's Brackets 160 lbs of Shear Resistance. Bracket Anchoring Feet are also Pre-drilled for Screws for added Holding Strength when deemed necessary.
Center Support Brackets can be supplied adjustable to conform to Vertical Positioning of the End Brackets on Side Walls (Pictured at Left) or Standard for Horizontal, On-Shelf Positioning. "Safe-Shelf" End Brackets are 2" Wide X 2" High with 1/4" ID Channels and 1" X 2" Anchoring Feet with Pre-drilled Screw Holes
Custom Sizes are also Available
No Tools Needed for Installation. Just Peel & Position

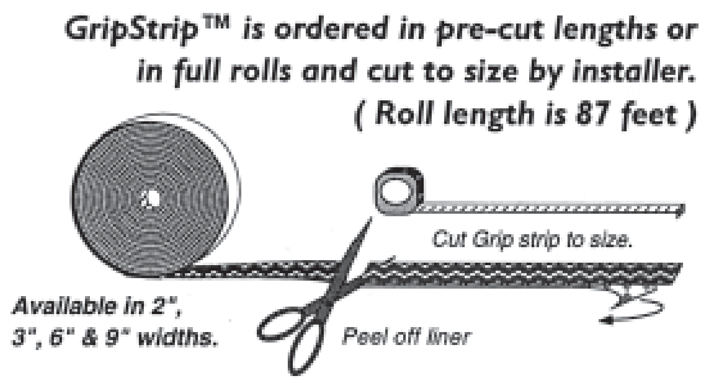
Major San Diego Research Facility

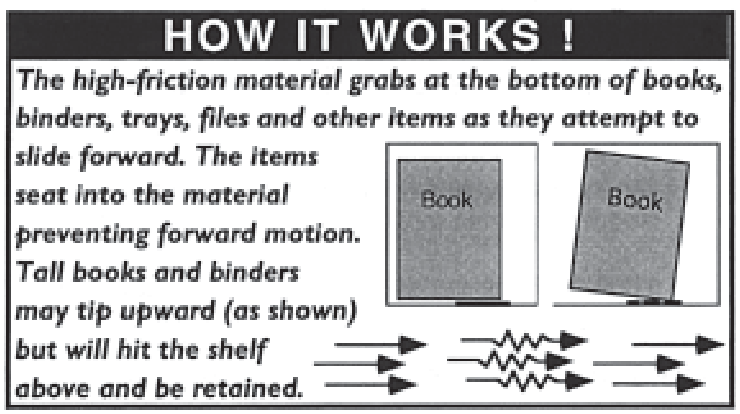
Pictured at left are acrylic barriers held in place by Sciline's stainless steel, single channel brackets in research lab refrigerator. Sciline's self-adhering brackets will adhere to most clean glass, metal and wood surfaces.
These barriers have been placed to separate trays of samples from other refrigerator items. Barriers are easily removed & replaced as required.

NOTE: This is one example of a range of products available from a variety of manufacturers.

Grip Strip

http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441





Grip Strip | **Detail** | **S2**

PEER Nonstructural Loss Study

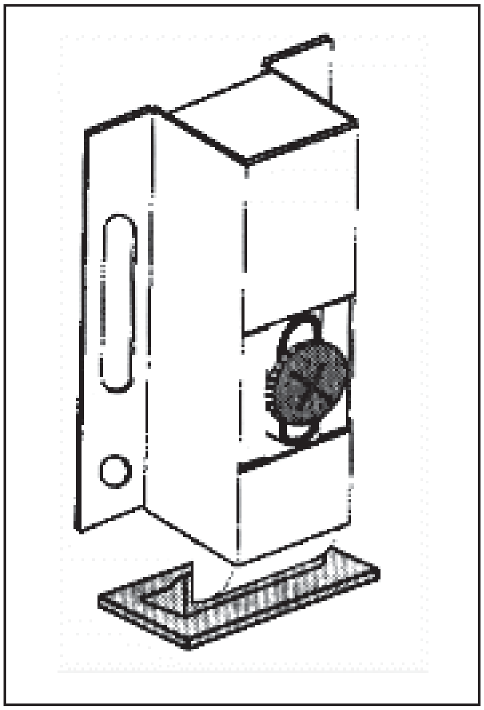
NOTE: This is one example of a range of products available from a variety of manufacturers.

Cabinet Restraint: Pull Feature

http://www.parkin-sec.com/
(ph) 1-408-255-4564
1-888 931-9900
(fx) 1-408-255-8222

Parkin Security Consultants
staff@parkin-sec.com

7258 Bark Lane
San Jose, CA 95129

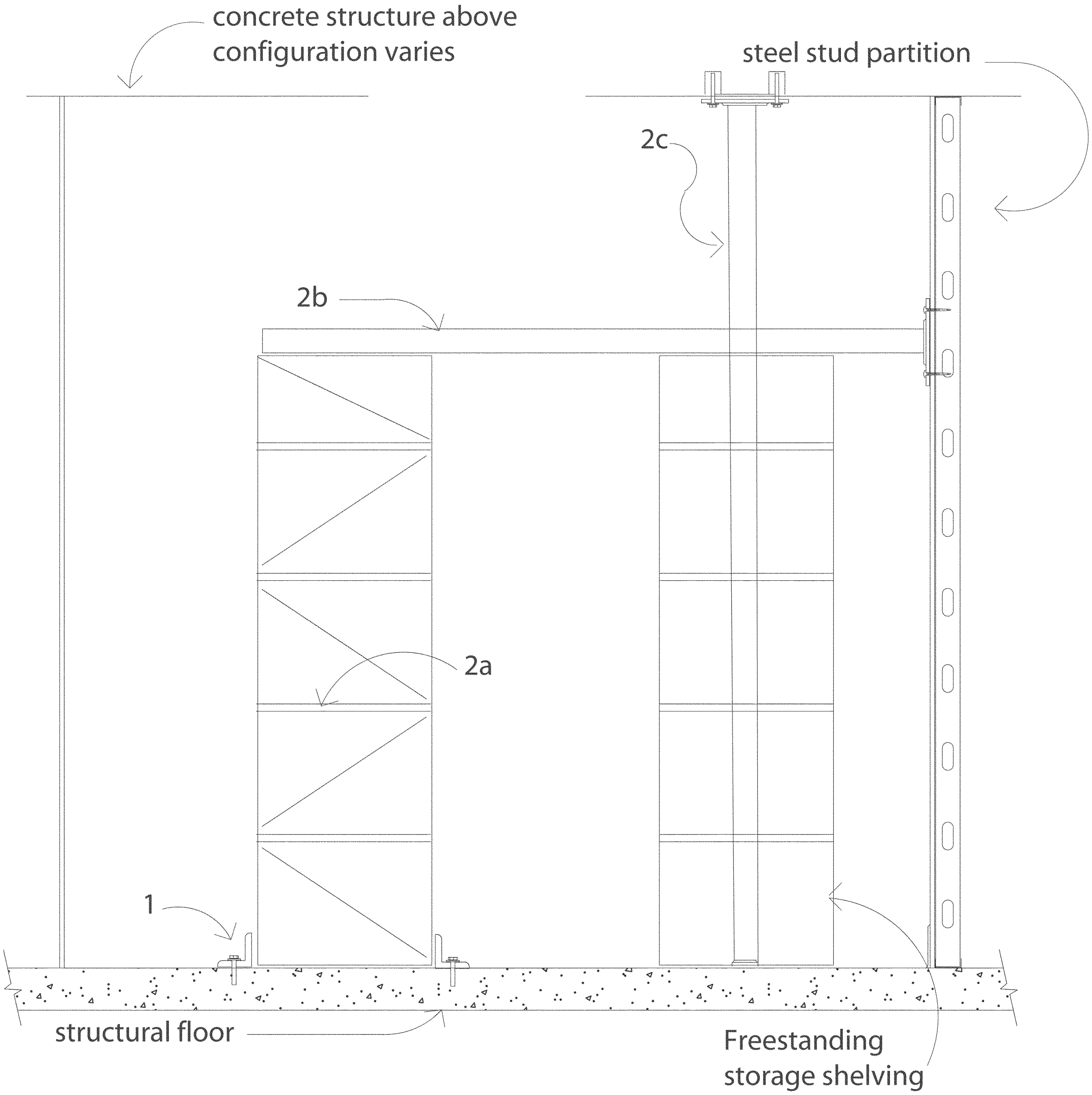


Cabinet Restraint
Ideal for cabinets containing heavy items or glassware.

Positive Locking cabinet latches have a locking mechanism that refrains the cabinet door from opening unless the locking mechanism is triggered by pushing or pulling. Positive locking latches are user-friendly, and do not require a series of motions like child-safety latches.

Our "pull the knob" latch attaches inside the cabinet door and opens when the knob is pulled.

It works with any standard 8/32" thread-style knob.



1. If racks strong enough, anchor to floor
2. If racks weak, add
   a. x-braces or end planks
   b. top cross members to studs or concrete walls
   c. strongbacks
3. longitudinal direction similar

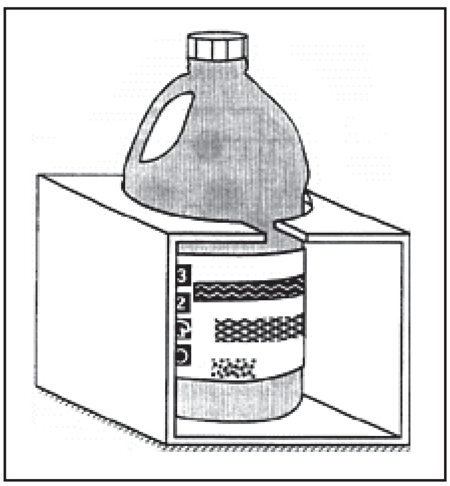
Freestanding Storage Restraint	**Detail**	**S4, S4a**
PEER Nonstructural Loss Study		

Lab Gallon Glass Jug and Plastic Bottle Holders

http://www.parkin-sec.com/
(ph) 1-408-255-4564
1-888 931-9900
(fx) 1-408-255-8222

Parkin Security Consultants
staff@parkin-sec.com

7258 Bark Lane
San Jose, CA 95129



LabTrac™ Gallon Glass Jug and Plastic Bottle Holders

For one-gallon chemical bottles commonly used in laboratories.

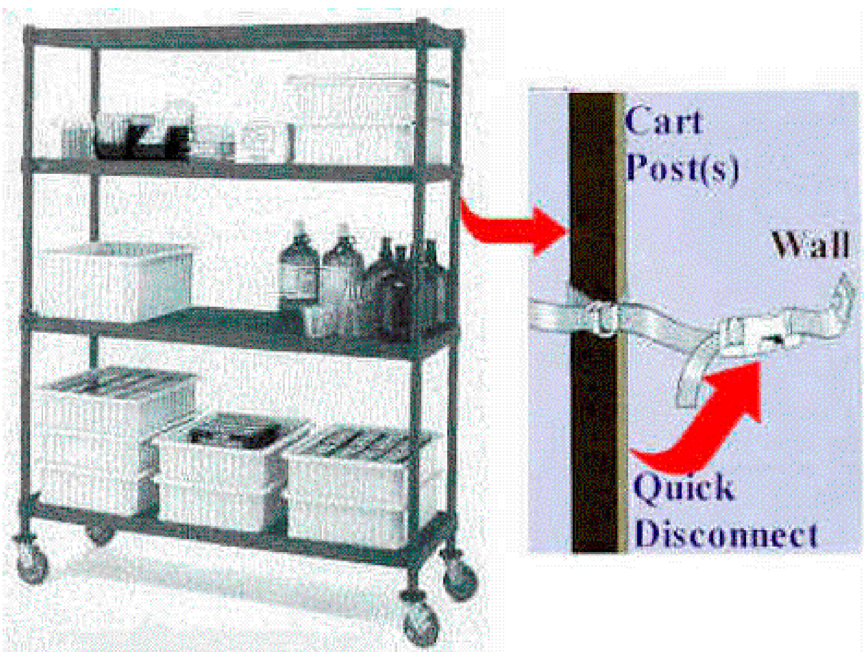
These stainless steel racks are designed to hold bottles of solvents and reagents (& other hazardous chemicals). Bottles can only be pulled out from above, keeping the bottles captive on all sides, yet leaves two of the sides open for content label visibility.

The stands come with GripStrip™ high-friction tape on their base, which prevents the item from sliding on the counter top (handles all standard one-gallon size bottles). Stands can also be permanently attached to the counter top with adhesives or screws, and/or tethered to the wall or counter top with our SeismaLok™ strap and buckles.

Cart Restraint

http://www.sciline.com/earthquake_hold%20downs.html
tom@scline.com

1-800-622-3010
FAX 1-877-SCILINE (Toll Free)
SciLine Products
PO Box 6423
Whittier, CA 90609



Anchor Strap

Strap Provides Secure Link
Between Cart and Wall with Quick Disconnect
to Free Cart on Demand
Strap can be Adjusted between 10" & 24"

$9.95/Kit

Each Kit Contains: 1 (14") Strap with 2 D rings; 1 (10") Strap with Quick Disconnect Buckle; 1 Wood Stud Screw; 1 Washer; Instructions.

This solution could use S5A Wall, or S5B Floor anchor sim. to H9 w/ a single post.

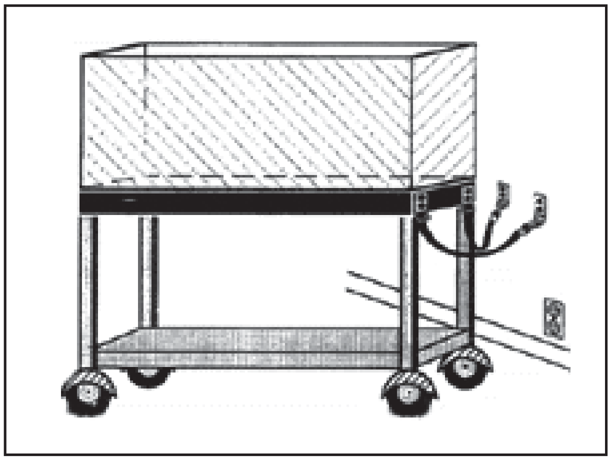
Cart Restraint	**Detail**	**S5**
PEER Nonstructural Loss Study	NOTE: This is one example of a range of products available from a variety of manufacturers.	

Lab Utility Cart and Hospital Incubator Straps

http://www.parkin-sec.com/
(ph) 1-408-255-4564
1-888 931-9900
(fx) 1-408-255-8222

Parkin Security Consultants
staff@parkin-sec.com

7258 Bark Lane
San Jose, CA 95129



Laboratory Utility Cart and Hospital Incubator Straps

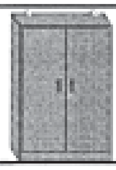
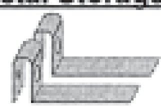
Removable earthquake safety straps for wheeled carts and equipment.

These heavy-duty nylon straps tether wheeled carts to the wall where they usually rest when not mobile. Each strap has "quick-release" snap hooks that easily connect and disconnect the cart strap to the wall.

NOTE: This is one example of a range of products available from a variety of manufacturers.

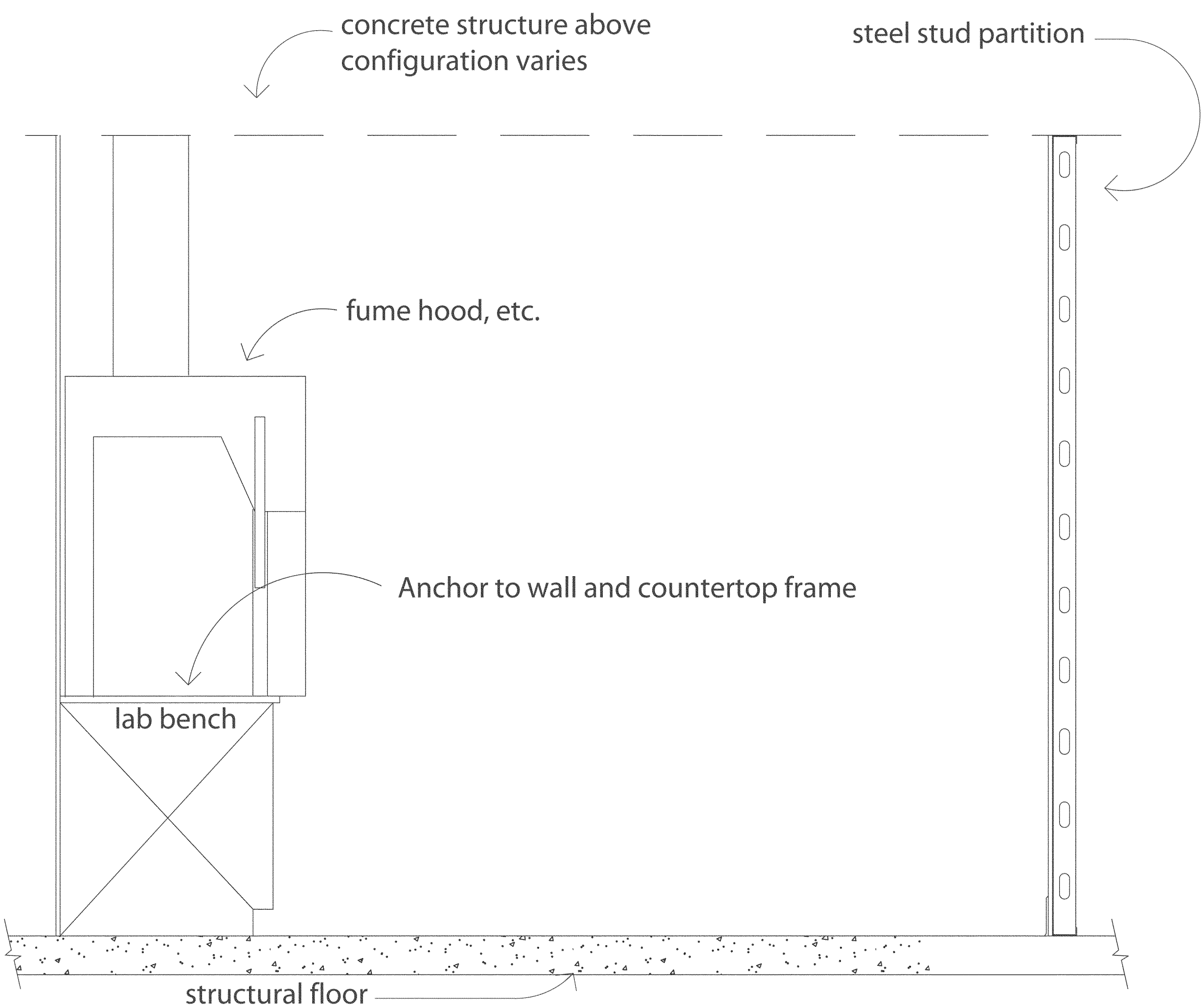
Metal Storage Cabinet

http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441

	Metal Storage Cabinet	SF 680	SeismaFlex short 0" to 2" away from wall
		SF 686	SeismaFlex long 2" to 4" away from wall
	Total Items_____@ $	=	Total $

Metal Storage Cabinet **Detail** **S6**

NOTE: This is one example of a range of products available from a variety of manufacturers.

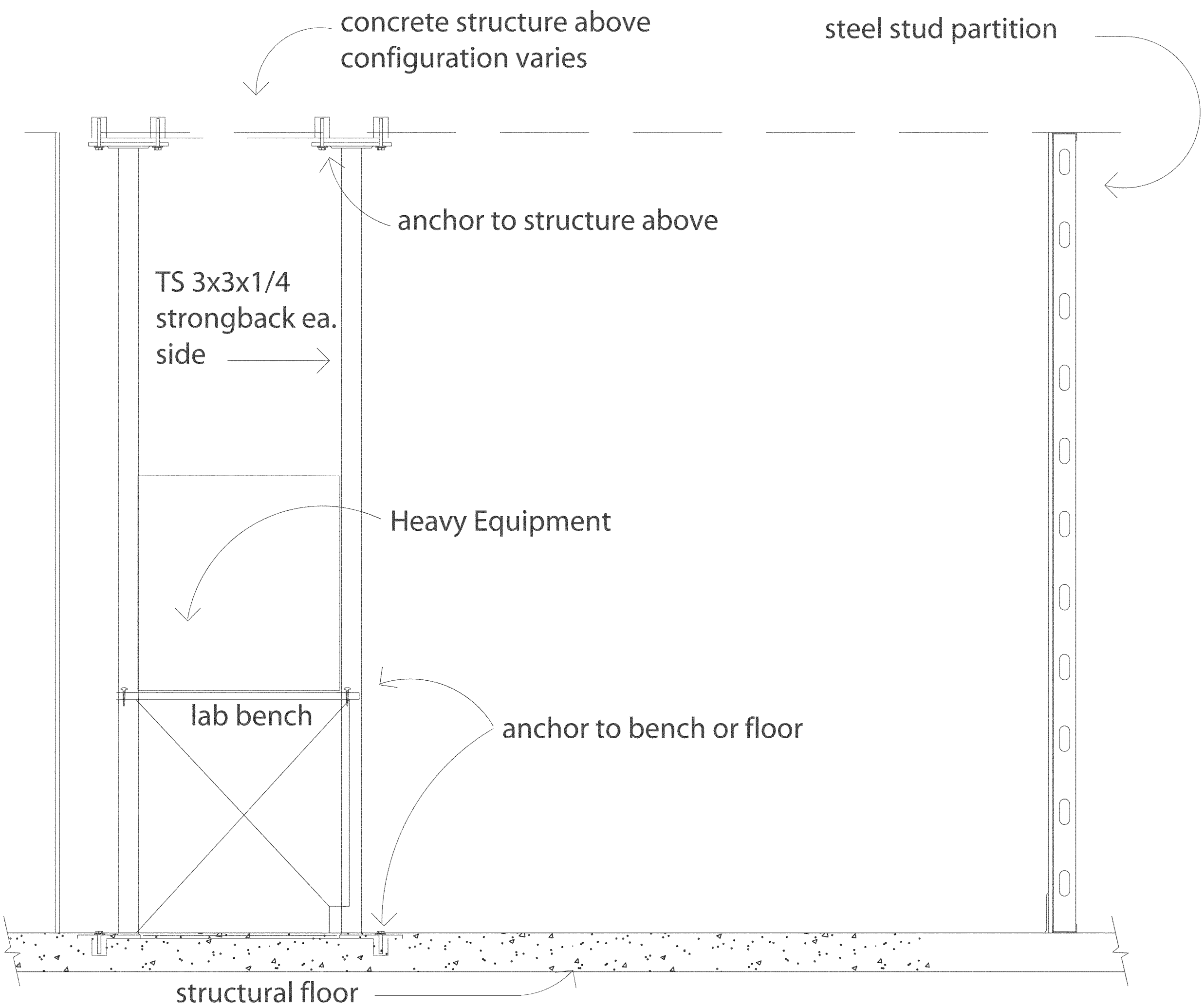


NOTE

1. This suggested detail assumes original installation was inadequate. Original plans or shop drawings and field conditions must be reviewed prior to retrofitting.
2. The actual method of retrofitting, if necessary, will vary from case to case, but can be represented as typical for costing purposes.

Benchtop Heavy Equipment	**Detail**	**B1**
PEER Nonstructural Loss Study		

Solutions: Heavy Equipment



Large Equipment > 250 lbs.	Detail	B2
PEER Nonstructural Loss Study		

File & Storage Cabinet Fastener

http://www.safe-t-proof.com/index1.htm
1-888-6772338
General information about Safe-T-Proof: info@safe-t-proof.com
U.S.A. Offices
Michael Essrig, President & CEO
messrig@safe-t-proof.com

File & Storage Cabinet Fastener. For file cabinets and tall storage cabinets. Available in black or putty color; 1 fastener per pack. Wood stud fastener: #250-12-BK-01 (black) or #250-12-PY-01 (putty); Metal stud fastener: #250-24-BK-01 (black) or #250-24-PY-01 (putty). We recommend 1 fastener for standard file cabinets and 2 fasteners for lateral files and storage cabinets.

Price
Cabinet Fastener (for WOOD studs;Black) $6.95
Cabinet Fastener (for WOOD studs; Putty) $6.95
Cabinet Fastener(for METAL studs; Black) $8.95
Cabinet Fastener (for METAL studs; Putty) $8.95

Benchtop Instrument Fastener

http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441

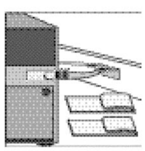
PRODUCT SPECIFICATIONS

LAB INSTRUMENT COUNTERTOP FASTENING
MODEL # LT 1224S LAB TRAC™ KIT

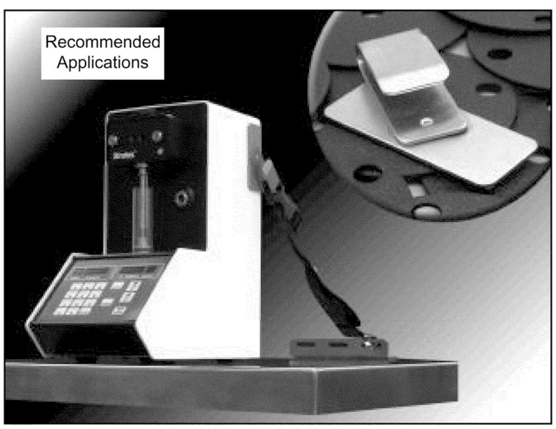
Product Drawing

Design Abstract: LT 1224S

The LabTrac™ fastening system is designed to secure countertop lab instruments, yet allow movement of the item quickly and easily for service or relocation. The series begins with a track plate that is positioned near the back edge or on the backsplash of the lab table. Straps w/ snaphook ends attach to the track plate, with the opposing attaching via adhesive to the sides of the instrument. The straps can be easily adjusted to proper length and allow quick detachment.The straps can also be easily detached from the track should relocation of the item be necessary.



Recommended Applications



Lab Instrument Countertop Fastening

Detail

B4

NOTE: This is one example of a range of products available from a variety of manufacturers.

Benchtop Instrument Fastener

http://www.worksafetech.com
http://www.counterquake.net/cgcss.html
Work Safe Technologies
ncsales@worksafetech.com
(408) 255-5441

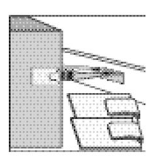
PRODUCT SPECIFICATIONS

LAB INSTRUMENT COUNTERTOP FASTENING
MODEL # LT 1224B LAB TRAC™ KIT

Product Drawing

Design Abstract: LT 1224B

The LabTrac™ fastening system is designed to secure countertop lab instruments, yet allow movement of the item quickly and easily for service or relocation. The series begins with a track plate that is positioned near the back edge or on the backsplash of the lab table. Straps w/ snaphook ends attach to the track plate, with the opposing attaching via adhesive to the sides of the instrument. The straps can be easily adjusted to proper length and allow quick detachment.The straps can also be easily detached from the track should relocation of the item be necessary.



Recommended Applications

Lab Instrument Countertop Fastening **Detail** **B4**

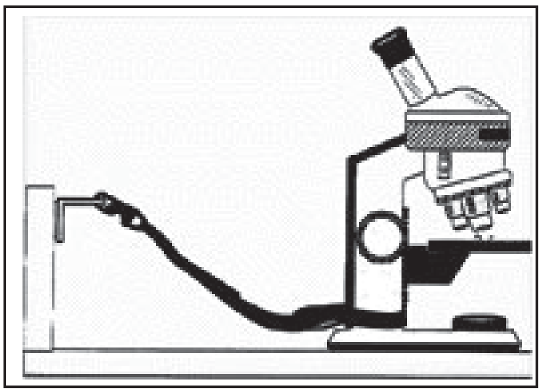
NOTE: This is one example of a range of products available from a variety of manufacturers.

Lab Equipment Fasteners: Light Instrument Lasso

http://www.parkin-sec.com/
(ph) 1-408-255-4564
1-888 931-9900
(fx) 1-408-255-8222

Parkin Security Consultants
staff@parkin-sec.com

7258 Bark Lane
San Jose, CA 95129



LabTrac™ Microscope and Light Instrument Lassos

Lasso straps wrap around an item's neck or base and connect it to a Trac plate (mounted to the backsplash or countertop). These tether straps allow the item to be moved around the countertop, yet restrict the item from moving or falling past the table edge.

Straps made of chemical and bacterial resistant plastic.

Light Instrument Lasso	Detail	B4
PEER Nonstructural Loss Study	NOTE: This is one example of a range of products available from a variety of manufacturers.	

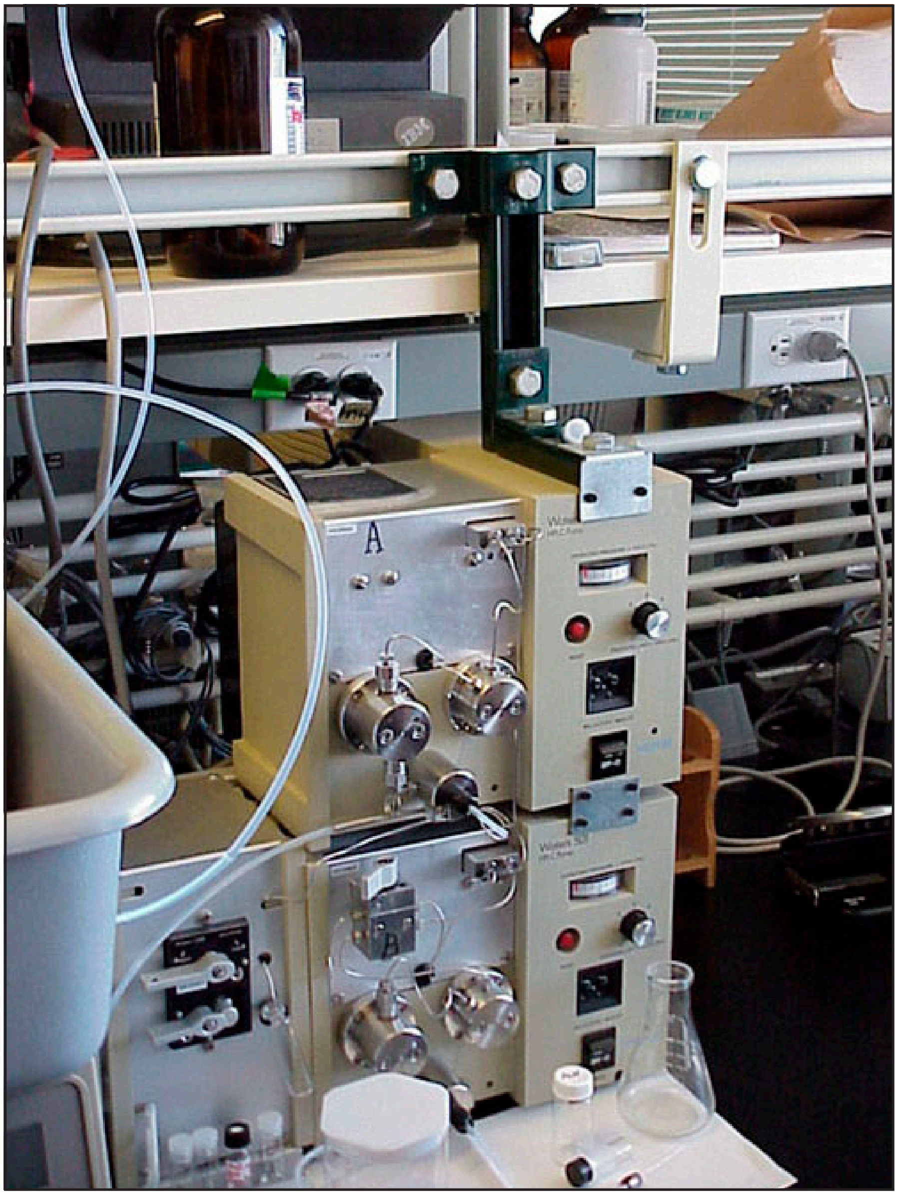


Photo Code: 3-23

Shop-Made Equipment Anchorage

Detail

B5

PEER Nonstructural Loss Study

NOTE: This is one example of a range of products available from a variety of manufacturers.

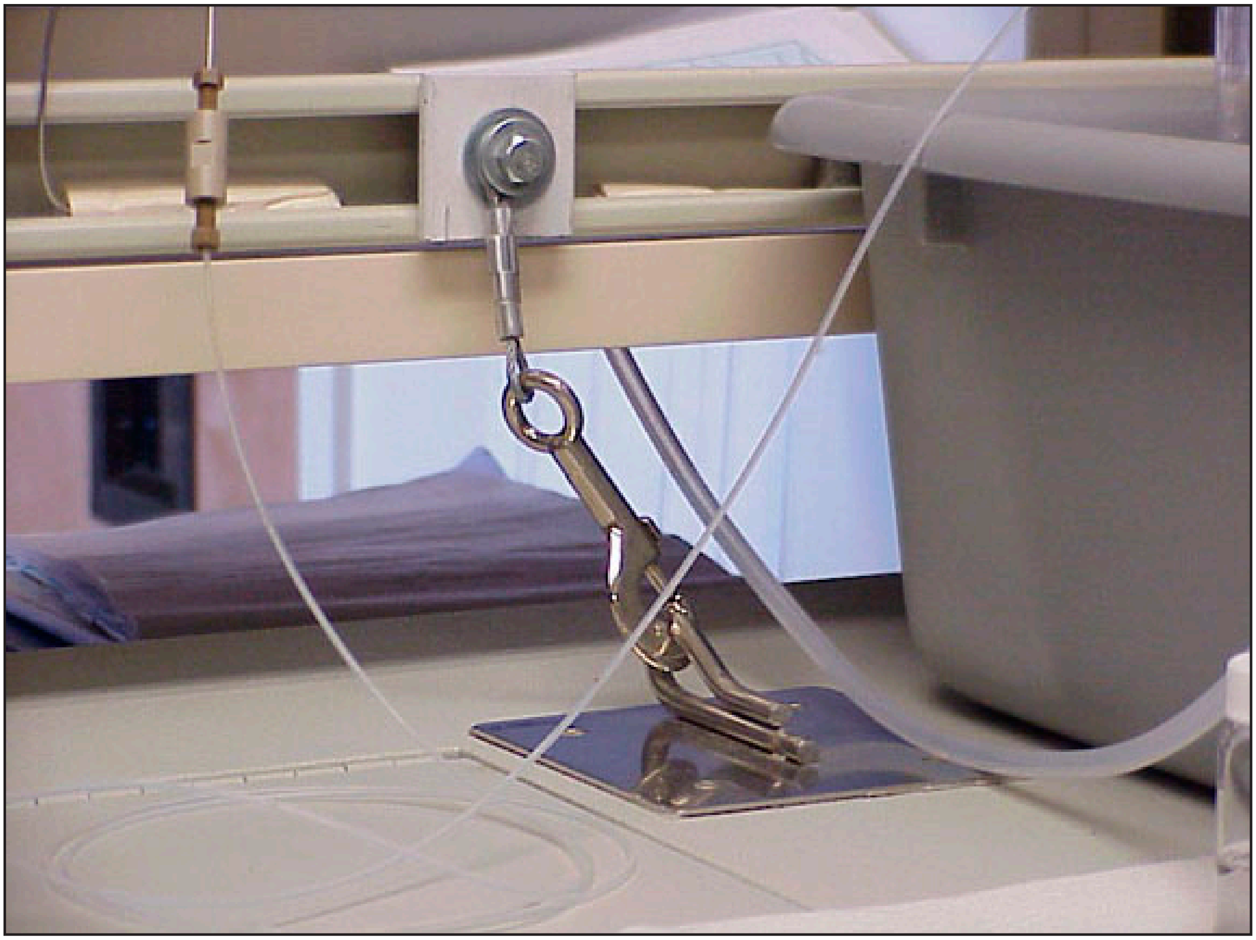


Photo Code: 3-33

Unistrut

Detail

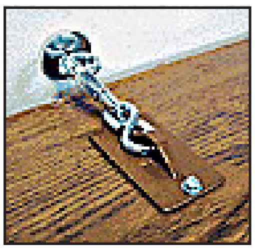
B5

PEER Nonstructural Loss Study

NOTE: This is one example of a range of products available from a variety of manufacturers.

Furniture Fastener

http://www.safe-t-proof.com/index1.htm
1-888-6772338
General information about Safe-T-Proof: info@safe-t-proof.com
U.S.A. Offices
Michael Essrig, President & CEO
messrig@safe-t-proof.com



Furniture Fastener. 2 fasteners per pack. For bookcases, china cabinets, entertainment centers, etc.; incl. mounting hardware; can be hidden.

Available in 2 colors.
Wood stud fastener: #201-15-BK-02 (black) or #201-15-BR-02 (brown);
Metal stud fastener: #201-18-BK-02 (black) or #201-18-BR-02 (brown).

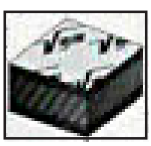
Price
Furniture Fastener (for WOOD studs;Black) $10.95
Furniture Fastener(for WOOD studs;Brown)$10.95
Furniture Fastener(for METALstuds; Black)$11.95
Furniture Fastener(for METALstuds; Brown)$11.95

Versa Blocks

http://www.sciline.com/earthquake_hold%20downs.html
tom@scline.com

1-800-622-3010
FAX 1-877-SCILINE (Toll Free)

SciLine Products
PO Box 6423
Whittier, CA 90609



VersaBLOCKS™

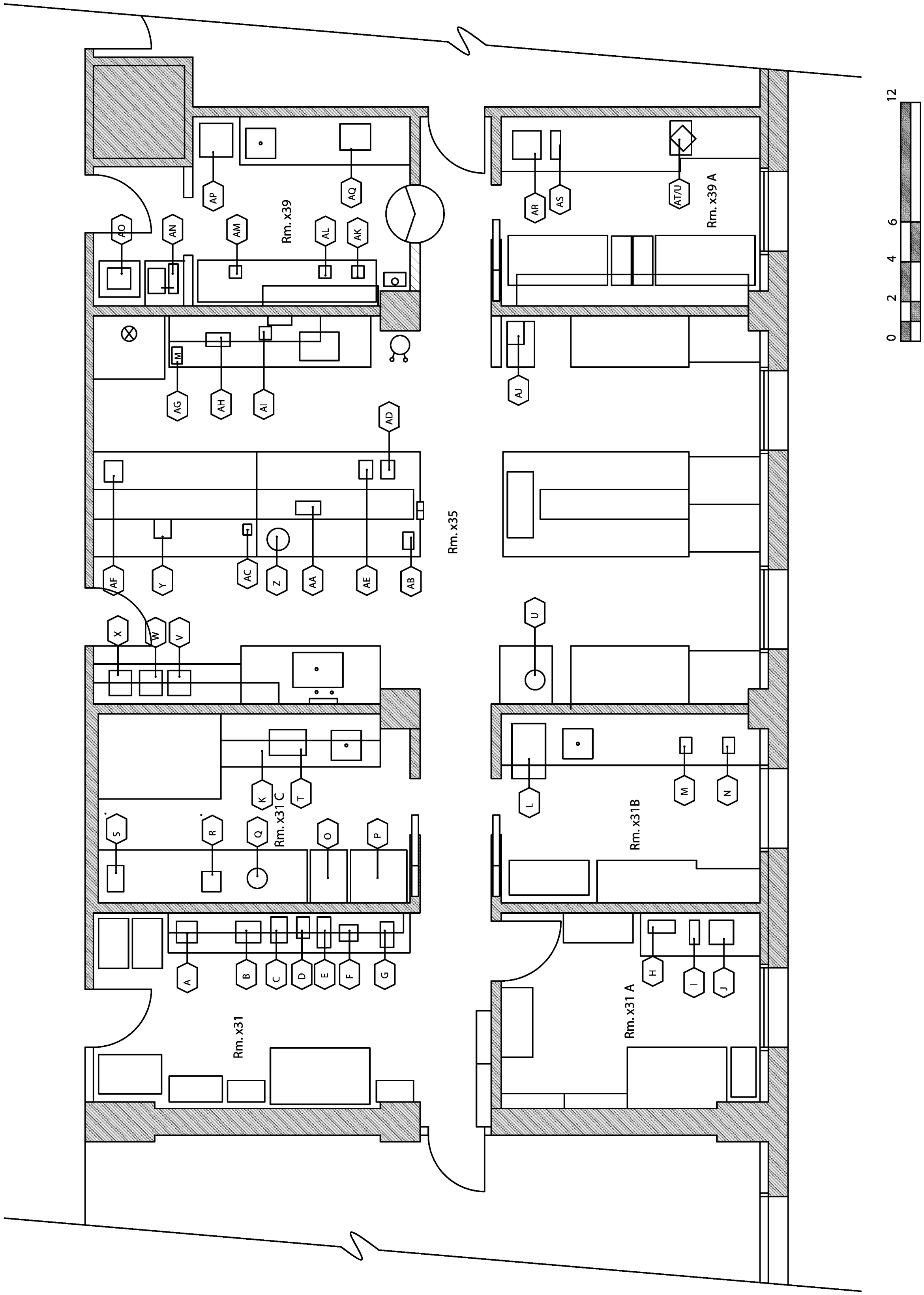
Provide Strong, Out-of-Sight, Bond between Bench Top, Desk Top and Equipment.
4 Blocks with Velcro on Both Sides/Kit

2150 1" X 1" X 3/8" For Items up to 30lbs $7.95/Kit
2200 1" X 2" X 5/8" For Items up to 60lbs $9.95/Kit
2300 2" X 2" X 5/8" For Items up to 100lbs $11.95/Kit

NOTE: This is one example of a range of products available from a variety of manufacturers.

Appendix B: Case Study Laboratories

This appendix contains drawings, equipment inventory tables, and photos for the five laboratories used as examples in this report.



LAB 1: BIOLOGICAL SCIENCES Floor Plan 1567 Sq. Ft.

DATE: 04/02/01
DRAWN BY: SL

PEER Nonstructural Loss Study

Lab 1 Biological Sciences Equipment List

Rm #		Equip. Key	Equipment Name	Photo Example	MITIGATION DETAIL	COST
x31		A	Printer		B3	$150
x31		B	Monitor		B4	$50
x31		C	CPU		B4	$50
x31		D	Printer		B3	$150
x31		E	CPU		B4	$50
x31		F	Monitor		B4	$50
x31		G	Scanner		B4	$50
x31	a	H	CPU		B4	$50
x31	a	I	Monitor		B4	$50
x31	a	J	Printer		B3	$150
x31	c	K	Refrigerator		H6	$250
					H6a	$150
x31	b	L	Refrigerator		H6	$250
x31	b	M	Microscope	1	B4	$50
x31	b	N	Microscope		B4	$50
x31	c	O	Refrigerator	2	H7	$760
					H7a	$300
					H7b	$450
x31	c	P	-22 Freezer		H7	$760
					H7a	$150
					H7b	$450
x31	c	Q	Centrifuge		H3	$1,350
x31	c	R	Centrifuge		H3	$1,350
x31	c	S	Incubator		B3	$150
x31	c	T	Reciprocal Shaking Bath	3	B3	$150
x35		U	Refrigerator		H7	$760
					H7a	$150
					H7b	$450
x35		V	L-C Incubator	4	B3	$150
x35		W	Incubator		B3	$150
x35		X	Incubator		B3	$150
x35		Y	Incubator		B3	$150
x35		Z	DeWar		T4	$1,075
x35		AA	UV Stratalinker		B4	$50
x35		AB	Centrifuge		B3	$150
x35		AC	Auto Densi-Flow		B3	$150
x35		AD	Mass Comparator		B4	$50
x35		AE	Balance		B4	$50
x35		AF	PCR Machine		B4	$50
x35		AG	Constant Power Supply		B4	$50
x35		AH	EC Apparatus EC 135		B4	$50
x35		AI	Constant Power Supply		B3	$150
x35		AJ	Centrifuge	5	H1	$860
x39		AK	Microscope		B4	$50
x39		AL	Microscope		B4	$50
x39		AM	Microscope		B4	$50

Lab 1 Biological Sciences Equipment List

Rm #		Equip. Key	Equipment Name	Photo Example	MITIGATION DETAIL	COST
x39		AN	CPU & Monitor		B4	$100
x39		AO	Microscope	6	B2	$1,100
x39		AP	Refrigerator, Freezer		H7	$760
					H7a	$150
					H7b	$450
x39		AQ	Incubator for "eggs"		B3	$150
x39	a	AR	Monitor		B4	$50
		AS	CPU		B4	$50
		AT/U	CPU/ Monitor		B4	$100
			Food Refrigerator		H6	$250
			and Microwave		B4	$50
			Total Direct Cost			$15,425
			GC OHP (25%)			$3,856
			Total			$19,281
			Lab Sq. Ft.			1,567
			Direct Cost Per Sq. Ft			$9.84
			Total Cost Per Sq. Ft.			$12.30

Lab 1

Sample Condition 1

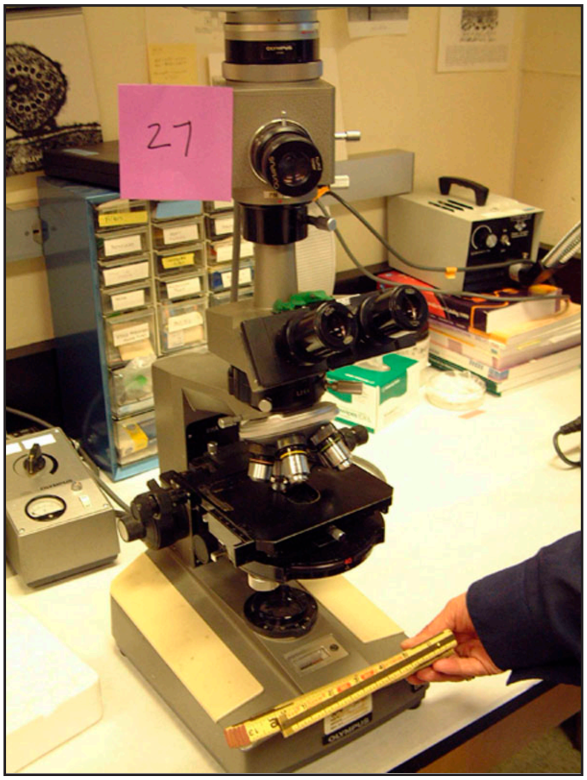


Photo Code: 27

Solutions: B4

Sample Condition 2

Photo Code: 20

Solutions: H7

Lab 1

Sample Condition 3

Solutions: B3

Photo Code: 26

Sample Condition 4

Solutions: B3

Photo Code: 2

Lab 1

Sample Condition 5

Photo Code: 12

Solutions: H1

Sample Condition 6

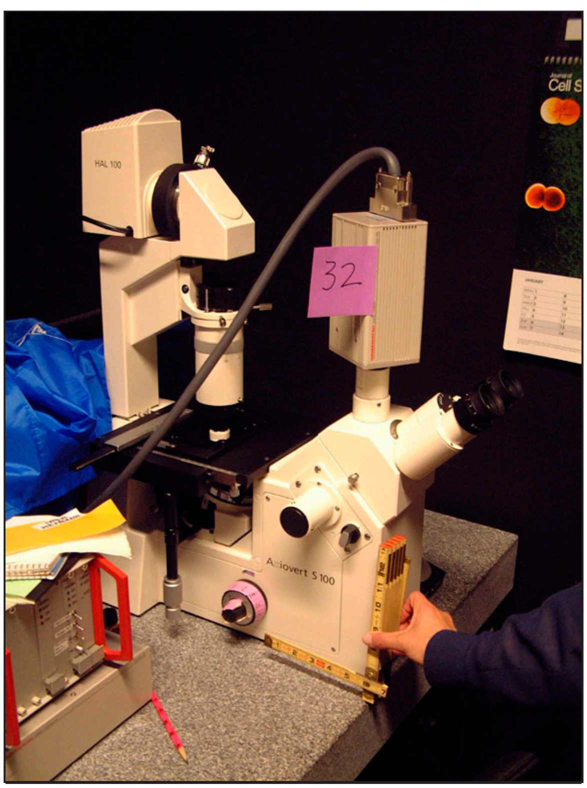
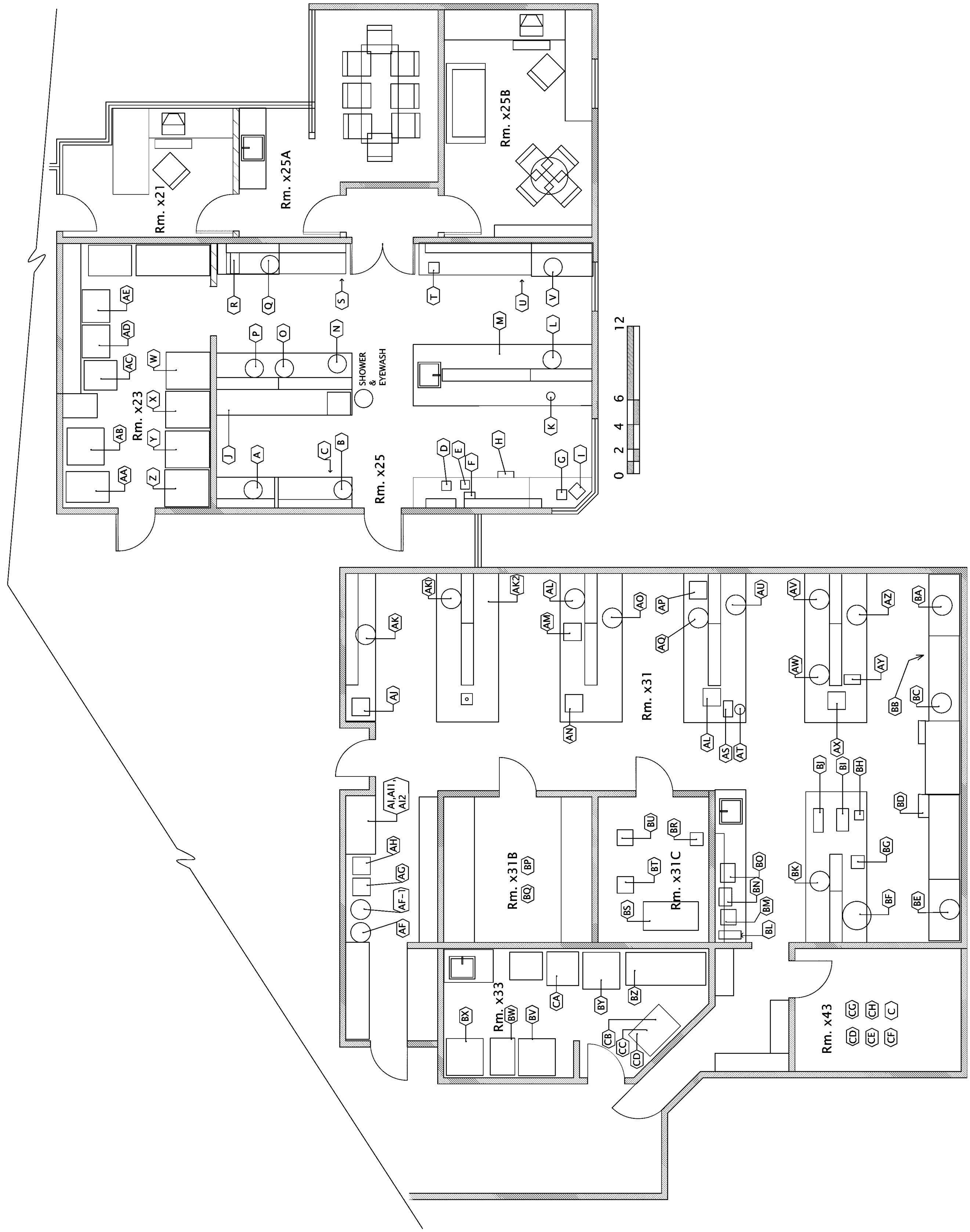


Photo Code: 32

Solutions: U1 at cost B2



LAB 2: BIOLOGICAL SCIENCES Floor Plan 2604 Sq. Ft.	**DATE: 04/02/01**
PEER Nonstructural Loss Study	

Lab 2 Biological Sciences Equipment List

Rm #		Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x25		A	Microscope	1	B4	$50
x25		B	Gell Electro		B3	$150
x25		C	Undercounter Refrigerator		H6	$250
					H6a	$150
					H6b	$225
x25		D	Centrifuge		B2	$1,100
x25		E	Stirer		B4	$50
x25		F	BIO-Dancer		B4	$50
x25		G	Microscope		B4	$50
x25		H	Undercounter Refrigerator		H6	$250
					H6a	$150
					H6b	$225
x25		I	I-Mac		B4	$50
x25		J	Typical Microscope		B4	$50
x25		K	Microscope		B3	$150
x25		L	Typical Microscope		B4	$50
x25		M	Misc. Shakers, Stuff		B4	$50
x25		N	PCR CDNA/ Machine		B3	$150
x25		O	Old Centrifuge		B2	$1,100
x25		P	Typical Microscope		B4	$50
x25		Q	Microscope		B3	$150
x25		R	Tower CPU/ Monitor		B4	$50
x25		S	Undercounter Refrigerator		H6	$250
					H6a	$150
					H6b	$225
x25		T	Centrifuge		B2	$1,100
x25		U	Undercounter Refrigerator		H6	$250
					H6a	$150
					H6b	$225
x25		V	Microscope		B3	$150
x25		W,X,Y,Z	Incubator		H7	$760
					H7a	$150
					H7b	$450
x25		AA	-86 Freezer		H7	$760
					H7a	$150
					H7b	$450
x25		AB	25 Deg. Incubator		H7	$760
					H7a	$150
					H7b	$450
x25		AC	-20 Freezer		H7	$760
					H7a	$150
					H7b	$450
x25		AD	3 Degree Freezer		H7	$760
					H7a	$150
					H7b	$450
x25		AE	Shaking Incubator		H8	$2,200
					H7a	$150
					H7b	$450
x31		AF, AF-1	Dewars	2	T7A	$520

Lab 2 Biological Sciences Equipment List

Rm #		Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x31		AG	Refrigerator		H7	$760
					H7a	$150
					H7b	$450
x31		AH	Freezer, Refrigerator		H7	$760
					H7a	$150
					H7b	$450
x31		AI, AI-1, AI-2	Small equip, mass comparator & balance		B4	$50
x31		AJ	PCR Machine		B3	$150
x31		AK, AK-1, AK-2	2 Typical Microscopes		B4	$50
x31		AL	Microscope		B3	$150
x31		AM	Centrifuge		B2	$1,100
x31		AN	Centrifuge, Refrigerated	3	B2	$1,100
x31		AO	Microscope		B4	$50
x31		AP	Power PC		B4	$50
x31		AQ	Microscope		B4	$50
x31		AR	Microwave, Conv. Oven	4	B4	$50
x31		AS	Water Bath	4	B4	$50
x31		AT	Centrifuge	4	B3	$150
x31		AU	Microscope		B4	$50
x31		AV	Microscope		B4	$50
x31		AW	Centrifuge		B2	$1,100
x31		AX	Centrifuge, Refrigerator		B2	$1,100
					H7a	$150
x31		AY	PCR Machine		B3	$150
x31		AZ	Microscope		B3	$150
x31		BA	Microscope		B4	$50
x31		BB	Undercounter Refrigerator		H6	$250
					H6a	$150
					H6b	$225
x31		BC	Centrifuge		B2	$1,100
x31		BD	Undercounter Refrigerator		H6a	$150
			(assume anchorage ok here)		H6b	$225
x31		BE	Undercounter Refrigerator		H6a	$150
					H6b	$225
x31		BF	Undercounter Refrigerator		H6a	$150
					H6b	$225
x31		BG	Stirer		B4	$50
x31		BH	Stirer		B4	$50
x31		BI	PCR Machine		B3	$150
x31		BJ	Spectrophometer		B2	$1,100
x31		BK	Microscope		B4	$50
x31		BL	Power PC Tower, Monitor	5	B5	$75
x31		BM	Bio-RAD	5	B3	$150
x31		BN	Oven	5	B2	$1,100
x31		BO	Centrifuge		B3	$150
x31	b	BP	G4s, Monitors		B4	$50

Lab 2 Biological Sciences Equipment List

Rm #		Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x31	b	BQ	Printer		B4	$50
x31	b		Printer		B4	$50
x31	b		Silicon Graphics Unit		B4	$50
x31	c	BR	Microscope	6	B3	$150
x31	c	BS	Microscope, Computer Parts	6	B2	$1,100
x31	c	BT	Microscope		B4	$50
x31	c	BU	Axioplan Microscpe		B2	$1,100
x33		BV	Sorvall Centrifuge	7	H1	$860
x33		BW	Incubator Refrigerator		H7	$760
					H7a	$150
					H7b	$450
x33		BX	minus 80 upright freezer/ bottom compressor		H7	$760
					H7a	$150
x33		BY	Chiller unit Microscope		B3	$150
x33		BZ, BZ-1	minus 80 freezer chest		H7	$760
					H7a	$150
x33		CA	Refrigerator, upright, single door		H7	$760
					H7a	$150
					H7b	$450
x33		CB	Particle Delivery System	8	B3	$150
x33		CC	Sonicator & Probe		B3	$150
x43		CD	Axiovert 135 w/ injection system		B2	$1,100
x43		CE	Microscope		B3	$150
x43		CF	Axioplan, G4		B3	$150
x43		CG	Tank		T1	$100
x43		CH	Chiller		H6	$250
x43		CI	Microscope		B4	$50
			Total Direct Cost			**$41,665**
			GC OHP (25%)			$10,416
			Total			**$52,081**
			Lab Sq. Ft.			2,604
			Direct Cost Per Sq. Ft.			$16.00
			Total Cost Per Sq. Ft.			$20.00

Lab 2

Sample Condition 1

Solutions: B4

Photo Code: DSC1

Sample Condition 2

Solutions: T7A

Photo Code: DSC4a

Lab 2

Sample Condition 3

Photo Code: DSC5

Solutions: B2

Sample Condition 4

Photo Code: DSC6

Solutions: B4/B4/B3

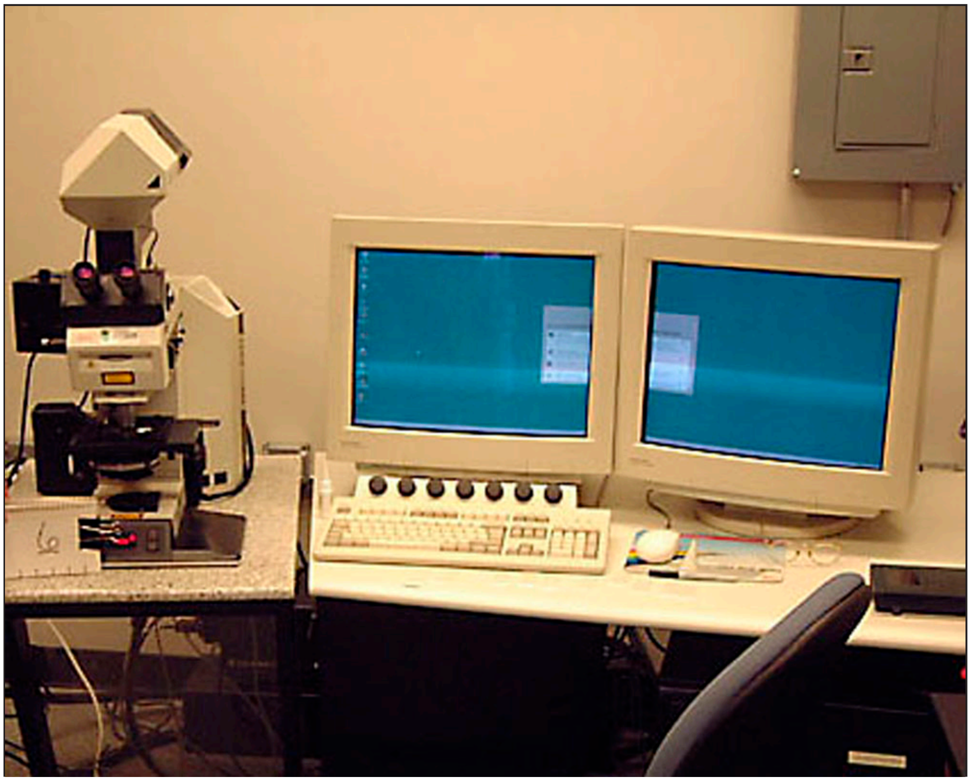
Lab 2

Sample Condition 5

Solutions: B5/B3/B2

Photo Code: DSC7

Sample Condition 6



Solutions: B3/B2

Photo Code: DSC8

Sample Condition 7

Photo Code: DSC12

Solutions: H1

Sample Condition 8

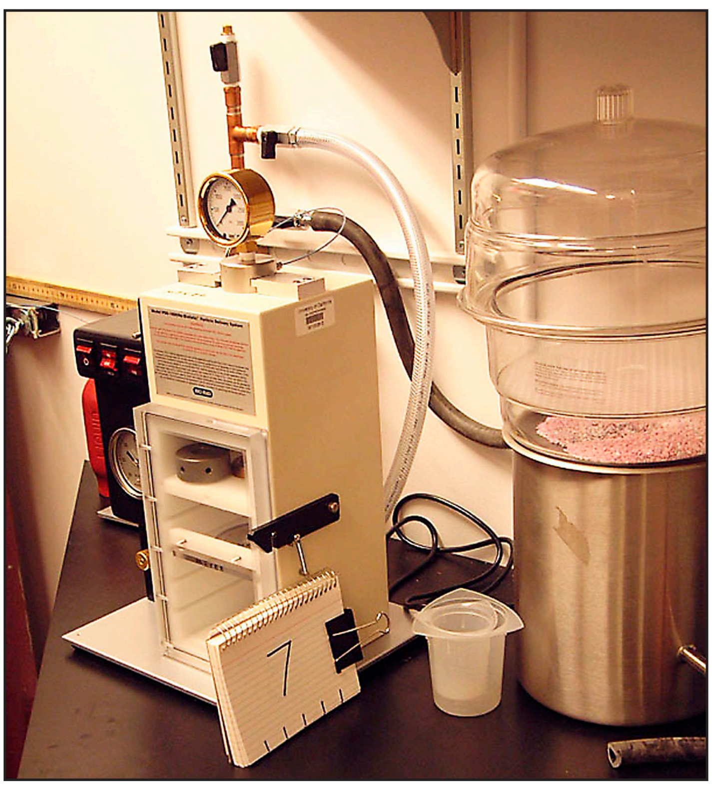
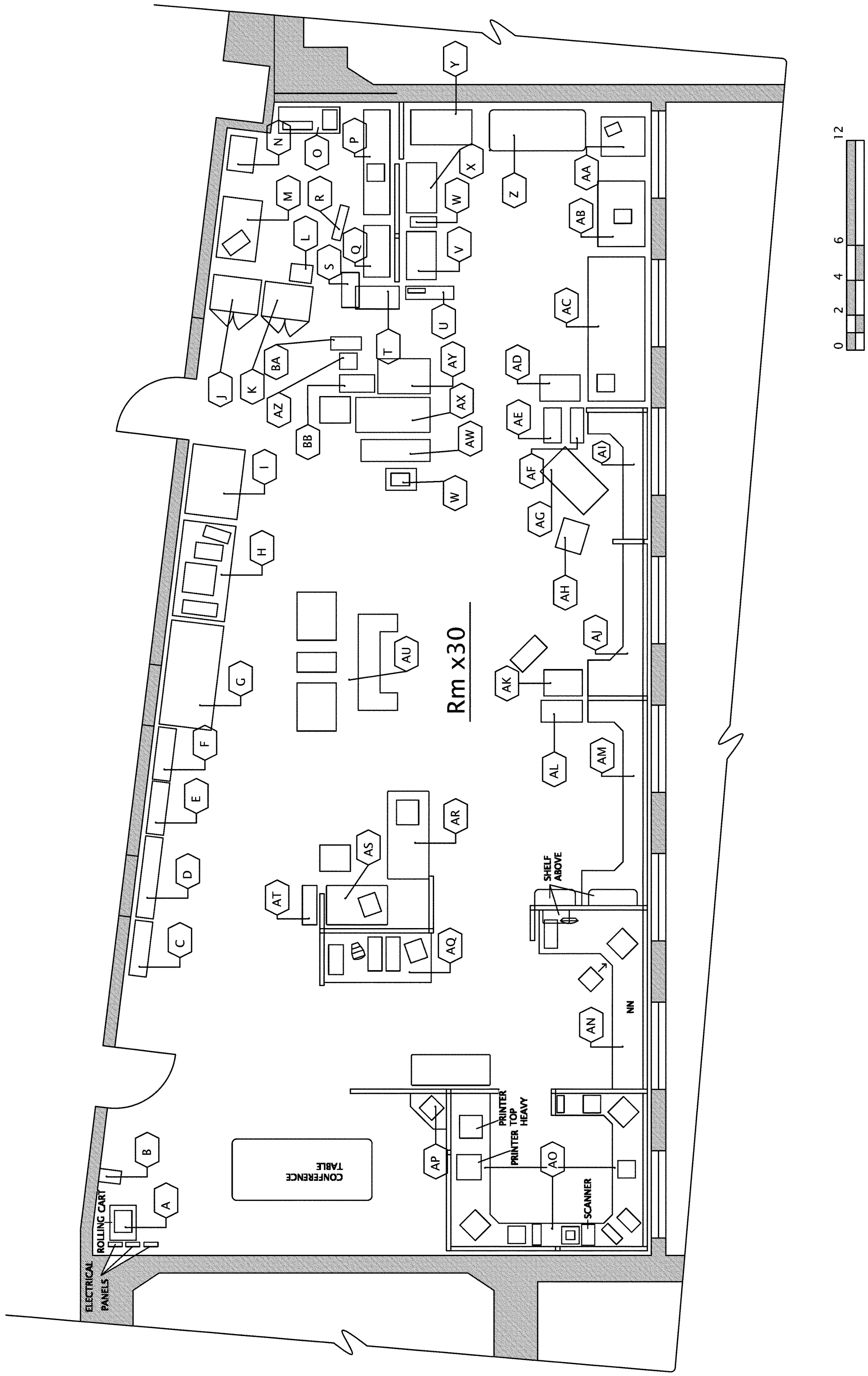


Photo Code: DSC11

Solutions: B3



LAB 3: COMPUTER SCIENCE Floor Plan 1845 Sq. Ft.

DATE: 04/02/01
DRAWN BY: SL

PEER Nonstructural Loss Study

Lab 3 Computer Science Equipment List

Rm #	Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x30	A	TV on Rolling Cart		S5A	$145
				B4	$50
x30	B	Video Projector		B4	$50
x30	C	Metal Bookshelf		S2	$72
x30	D	Wood Shelf		S1	$45
				S1b	$180
x30	E	Metal Shelf		S1	$45
				S1b	$180
x30	F	Metal Shelf		S1	$45
				S1b	$180
x30	G. G-1	Workbench w/ Helicopter Robot		B2	$1,100
x30	H, H-1, h-2	Workbench w/ 2 Tower CPU, 2 Monitors		B4	$200
x30	I	Workbench w/ small electronic tools		S3a	$200
		shelving		S1	$45
		equipment and storage		B4	$300
x30	J	Metal Cabinet w/ electronic parts		S6	$45
				S3a	$50
				S4b	$450
x30	K	Metal Cabinet w/ electronic parts		S6	$45
				S3a	$50
x30	L	Parts Cabinet		S6	$45
x30	M, M-1	Metal Workbench w/ drillpress, small tools		B2	$1,100
x30	N	Metal Tool Cabinet		S5A	$145
				S5Aa	$225
x30	O, O-1,O-2	Workbench w/ metal lathe, desktop CPU/ Monitor	1	B2	$1,100
				B4	$50
x30	P, P-1	Workbench w/ milling machine		B2	$1,100
x30	Q	Desk Shelf w/ numerous electronic amps & parts	2	S1	$90
				S1a	$100
				S3a	$50
				B4	$500
x30	R	Band Saw		H1	$860
x30	S	Cabinet w/ chemicals & Electronic Parts		S4b	$450
				S4a	$50
				S3a	$50
x30	T	Wooden Flat File, sectioned for parts		S3a	$50
x30	U, U-1	Metal Bookshelf w/ freestanding parts drawer on top		S4	$240
				S4a	$50
				S4b	$450
x30	V	3-D Thermojet, Solid Object Printer	3	H1	$860
x30	W	Tower CPU		B4	$50
x30	X	Desk w/ parts		S3a	$50
x30	Y	Flat File w/ parts		S3a	$50

Lab 3 Computer Science Equipment List

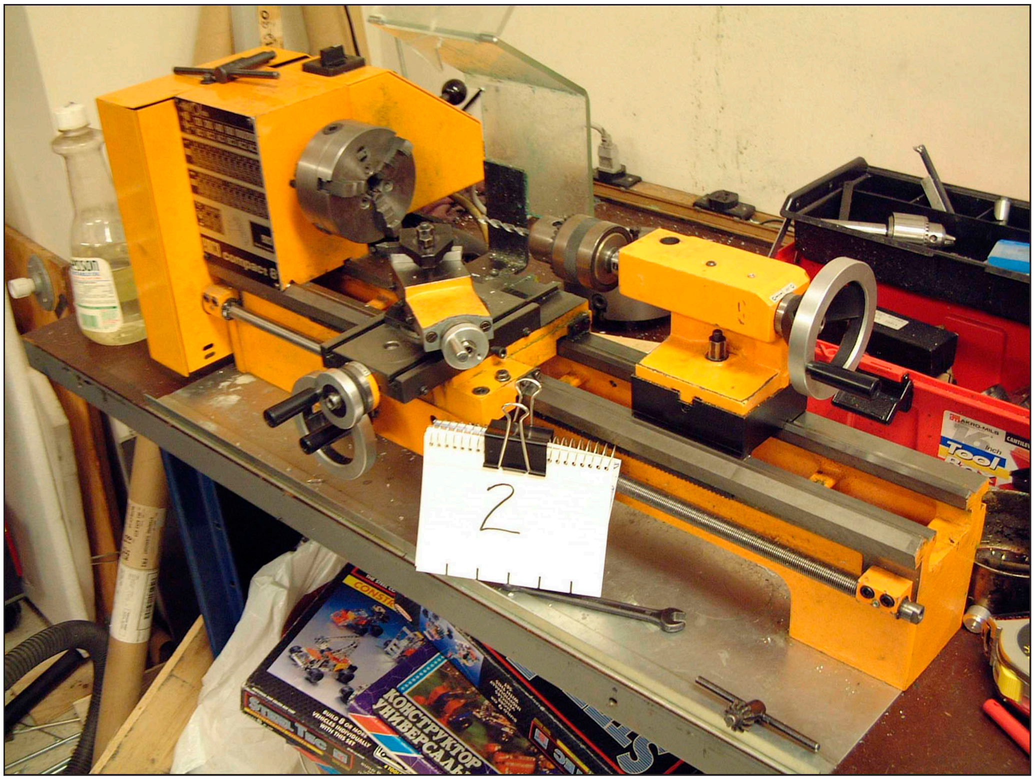
Rm #	Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x30	Z, Z-1	Metal Desk w/ 3 Monitors		B4	$150
x30	AA	Table w/ tower CPU & Electronics		B4	$200
x30	BB	Pneumatic table w/ camera, microscope & robot	4	U1	$3,000
				B4	$150
				B5	$75
x30	CC	Workbench		na	$0
x30	CC-1	Vacuum Oven	5	B2	$1,100
				S5B	$675
x30	DD	Metal Rack w/ Books		S4	$240
				S4b	$450
x30	EE	Tool Cabinet		H4B	$760
x30	FF	4 Drawer File		S6	$45
x30	GG	Cart w/ computer & 2 arm robot on wheels	6	S5B	$675
				S5Aa	$225
x30	HH	Cart w/ compressed 4 gas cylinders		S5B	$675
x30	II, II-1, 2	L Desks w/ 2 tower CPU/ Monitor, w/ stuff		B4	$250
x30	JJ	1 Monitor, CPU w/ shelf		S1	$45
				B4	$100
x30	KK	Equipment Cart		S5B	$675
				S5Aa	$225
x30	LL	Desk w/ Monitor		B4	$50
x30	MM	Furniture Module w/ 3 Monitors & Tower CPUs		B4	$300
				S1	$45
				S1b	$180
x30	NN-1,2,3,4	Furniture Module w/ 2 tower CPUs, Monitors & 2 Robots		B4	$200
				B3	$300
				S1	$45
				S1a	$50
x30	OO	Furniture Module w/ 6 CPU, Monitors, 3 Printers, 1 Scanner		B4	$750
				B3	$150
x30	PP	TV on Rolling Cart		S5A	$145
				S5Aa	$225
x30	QQ	Module w/ 2 silicon graphics tower & 2 monitor and sun sparc station		B4	$200
				B3	$150
x30	RR	Metal Desk w/ 2 CPU/ Monitor		B4	$200
x30	SS	Metal Desk w/ 1 CPU/ Monitor		B4	$100
x30	TT	5 Drawer File		S6	$45
x30	UU	2 armed surgical robot		S5B	$1,350
x30	VV	electronics rack w/ monitor		H9B	$1,446
x30	WW	Workbench		na	$0
x30	XX	Table w/ electronic gear incl. 2 CPUs		B4	$300

Lab 3 Computer Science Equipment List

Rm #	Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x30	YY	Desk w/ CPU & electronics		B4	$300
x30	ZZ	Electronics Rack		H9B	$1,446
x30	AAA	Metal Desk		na	$0
x30	BBB	5 Drawer File		S6	$45
		Total Direct Cost			**$28,929**
		GC OHP (25%)			$7,232
		Total			**$36,161**
		Lab Sq. Ft.			1,845
		Direct Cost Per Sq. Ft.			$15.68
		Total Cost Per Sq. Ft.			$19.60

Lab 3

Sample Condition 1



Solutions: B2

Photo Code: 2

Sample Condition 2

Solutions: S1

Photo Code: 4

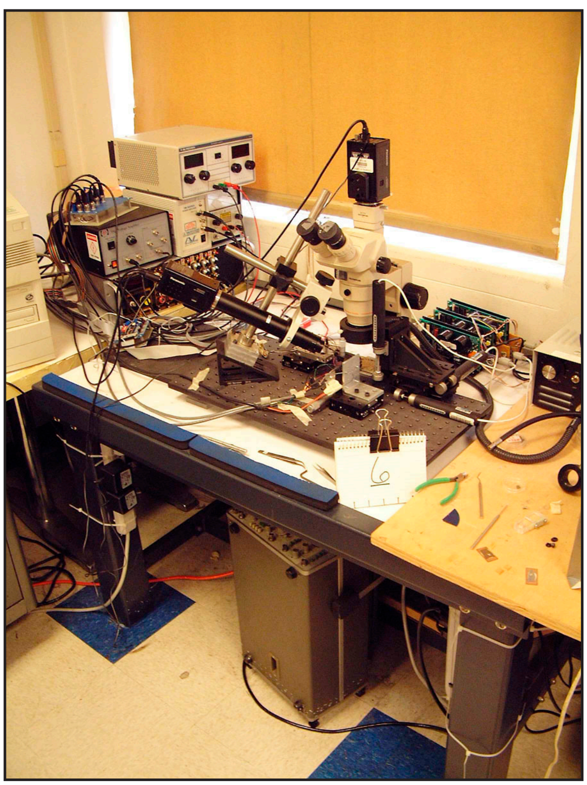
Lab 3

Sample Condition 3

Solutions: H1

Photo Code: 5

Sample Condition 4



Solutions: U1

Photo Code: 6

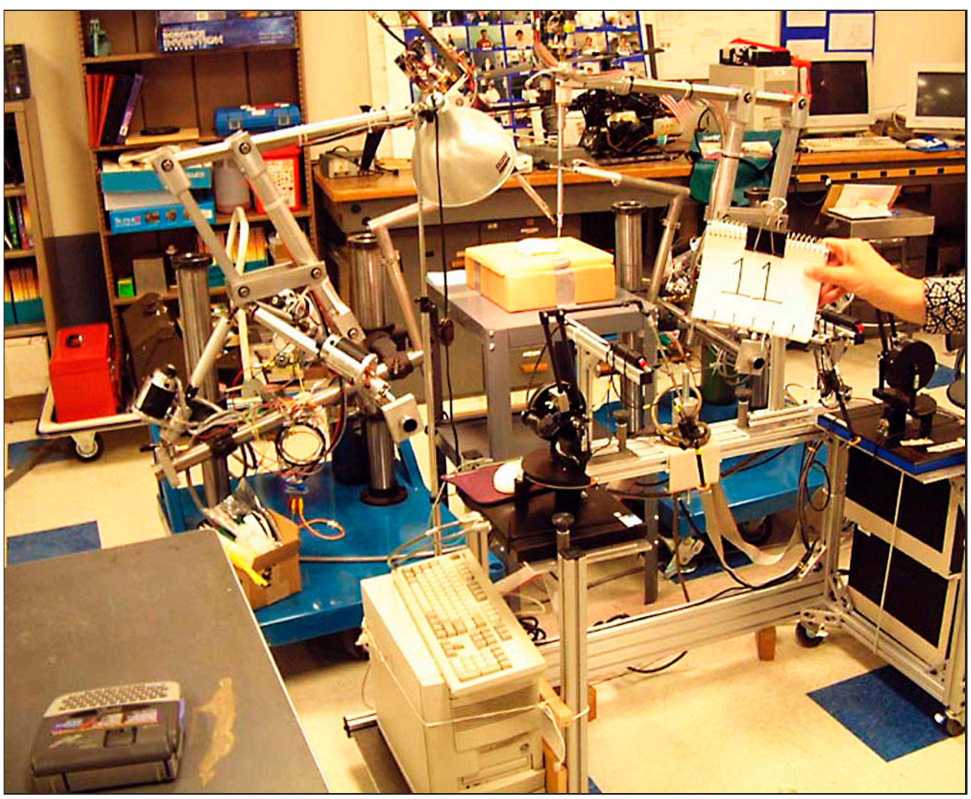
Sample Condition 5

Solutions: B2

Photo Code: 7

Sample Condition 6

Solutions: S5B



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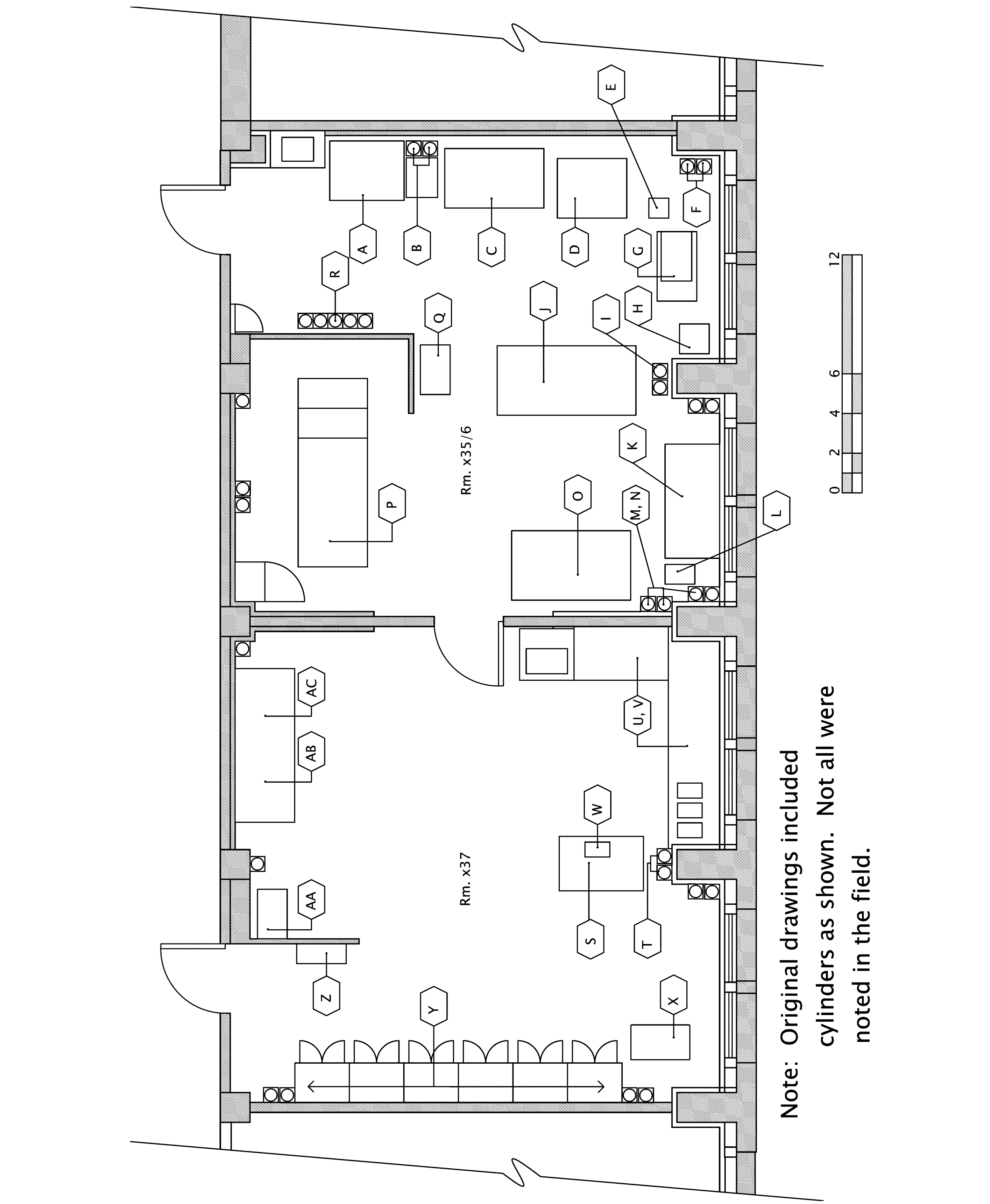


LAB 4: PHYSICS Floor Plan 1137 Sq. Ft.

PEER Nonstructural Loss Study

DATE: 04/02/01
DRAWN BY: SL

Lab 4 Physics Equipment List

Rm #	Equip. Key	Equipment Name	Photo Example	DETAIL	COST
x35/6	A	Laminar flow bench		B2	$1,100
x35/6	B	Gas Cylinders	1	T2	$370
x35/6	C	Evaporator		H1	$860
x35/6	D	Evaporator	2	H1	$860
x35/6	E	Equipment		H5	$250
x35/6	F	Gas Cylinders		T2	$370
x35/6	G	WorkBench		na	$0
x35/6	H	Electronics Rack	3	H5	$250
x35/6	I	Gas Cylinders		T2	$370
x35/6	J	Ion mill	4	H1	$860
x35/6	K	WorkBench		na	$0
x35/6	L	Electronics Rack (assumed wheels)		H4b	$760
x35/6	M	Gas Cyliders		T2	$370
x35/6	N	Gas Cylinders		T2	$370
x35/6	O	Nobium Sputterer (custom/use H10)	5	H10	$1,000
x35/6	P	Laser Apparatus		H1	$860
		add		S4	$240
x35/6	Q	Part Cabinet	6	S5A	$145
x35/6	R	Gas Cylinders		T2	$370
x37	S	WorkBench		na	$0
x37	T	Gas Cyliders		T2	$370
x37	U	WorkBench		na	$0
x37	V	WorkBench		na	$0
x37	W	Microscope (like B5)		B5	$75
x37	X	Flammables Cab.	7	S3	$45
x37	Y	Cabinets		S3	$45
x37	Z	Metal Cabinet		S6	$45
x37	AA	wire bonder		B4	$50
x37	AB	Laminar flow bench w/ Acids Base	8	B2	$1,100
		add		S6	$45
x37	AC	Fumehood		B1	$740
		Total Direct Cost			**$11,920**
		GC OHP (25%)			$2,980
		Total			**$14,900**
		Lab Sq. Ft.			1,137
		Direct Cost Per Sq. Ft.			$10.48
		Total Cost Per Sq. Ft.			$13.10

Lab 4

Sample Condition 1

Solutions: T2

Photo Code: 4

Sample Condition 2

Solutions: H1

Photo Code: 3

Lab 4

Sample Condition 3

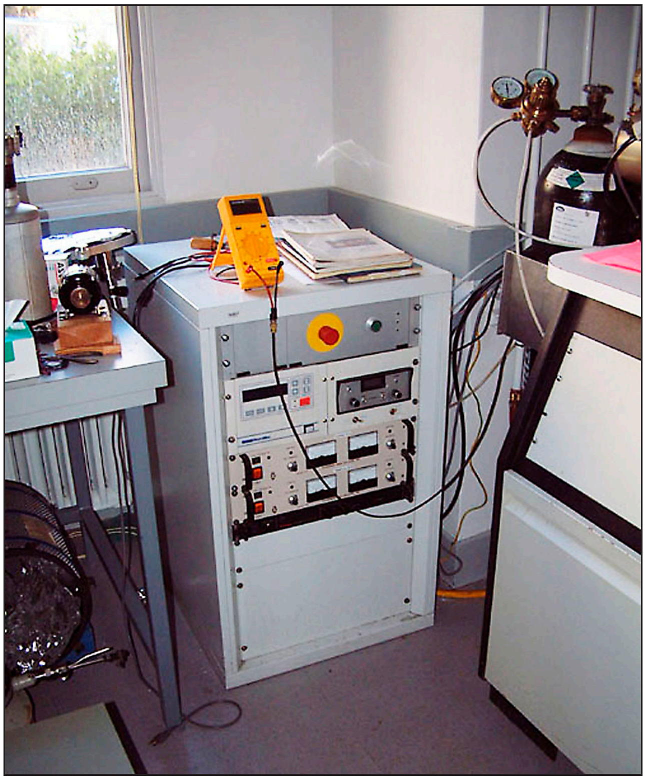


Photo Code: 6

Solutions: H5

Sample Condition 4

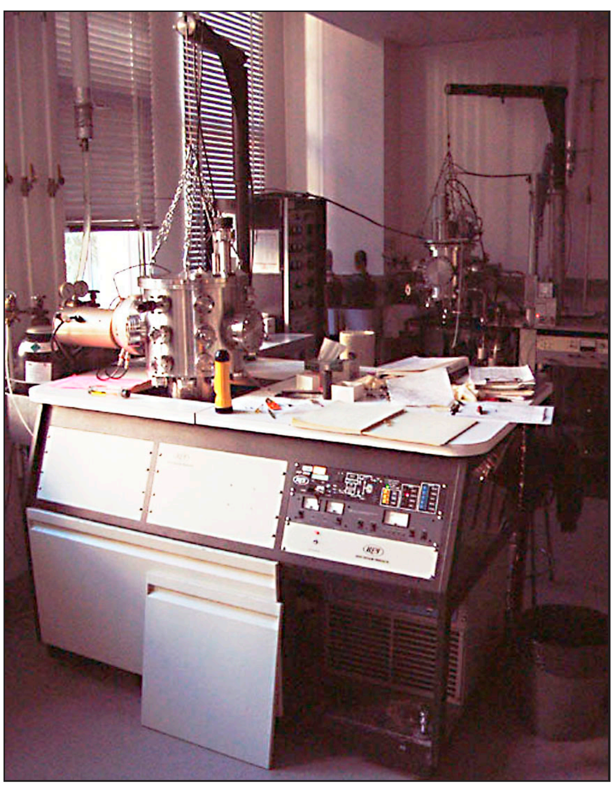


Photo Code: 7

Solutions: H1

Lab 4

Sample Condition 5

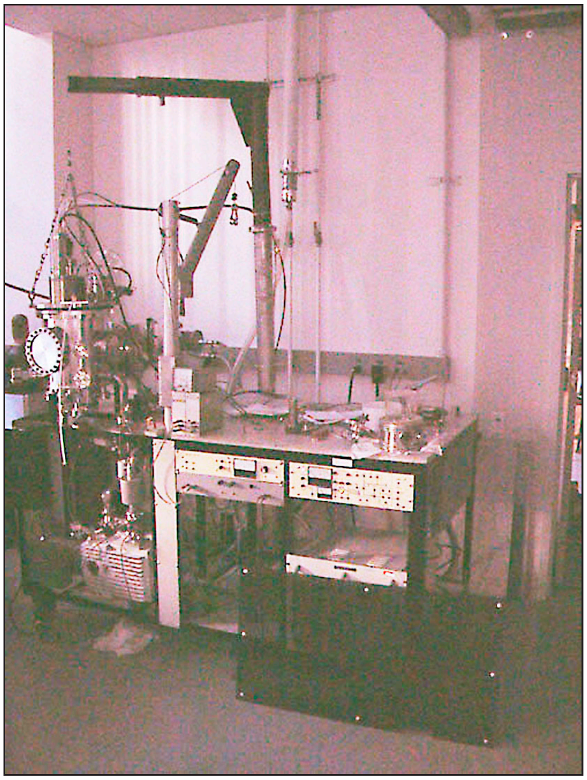


Photo Code: 10

Solutions: H10

Sample Condition 6

Photo Code: 12

Solutions: S5A

Lab 4

Sample Condition 7

Solutions: S3

Photo Code: 137-4

Sample Condition 8

Solutions: B2

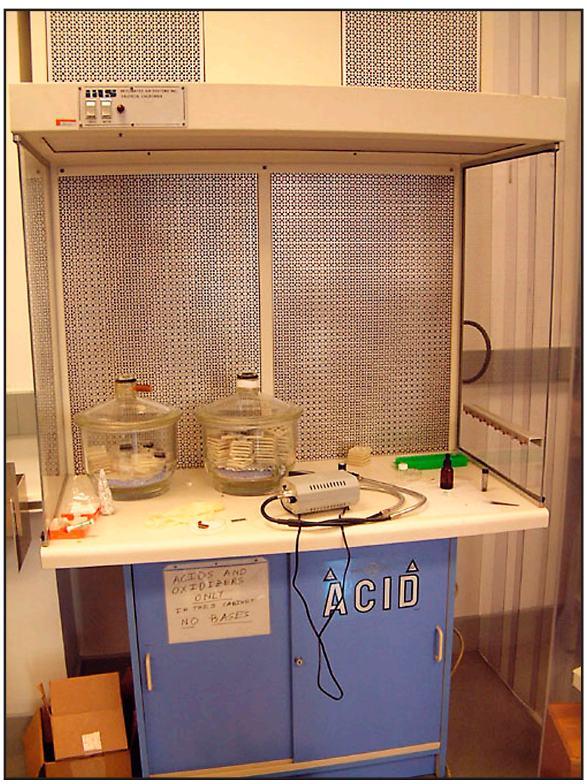
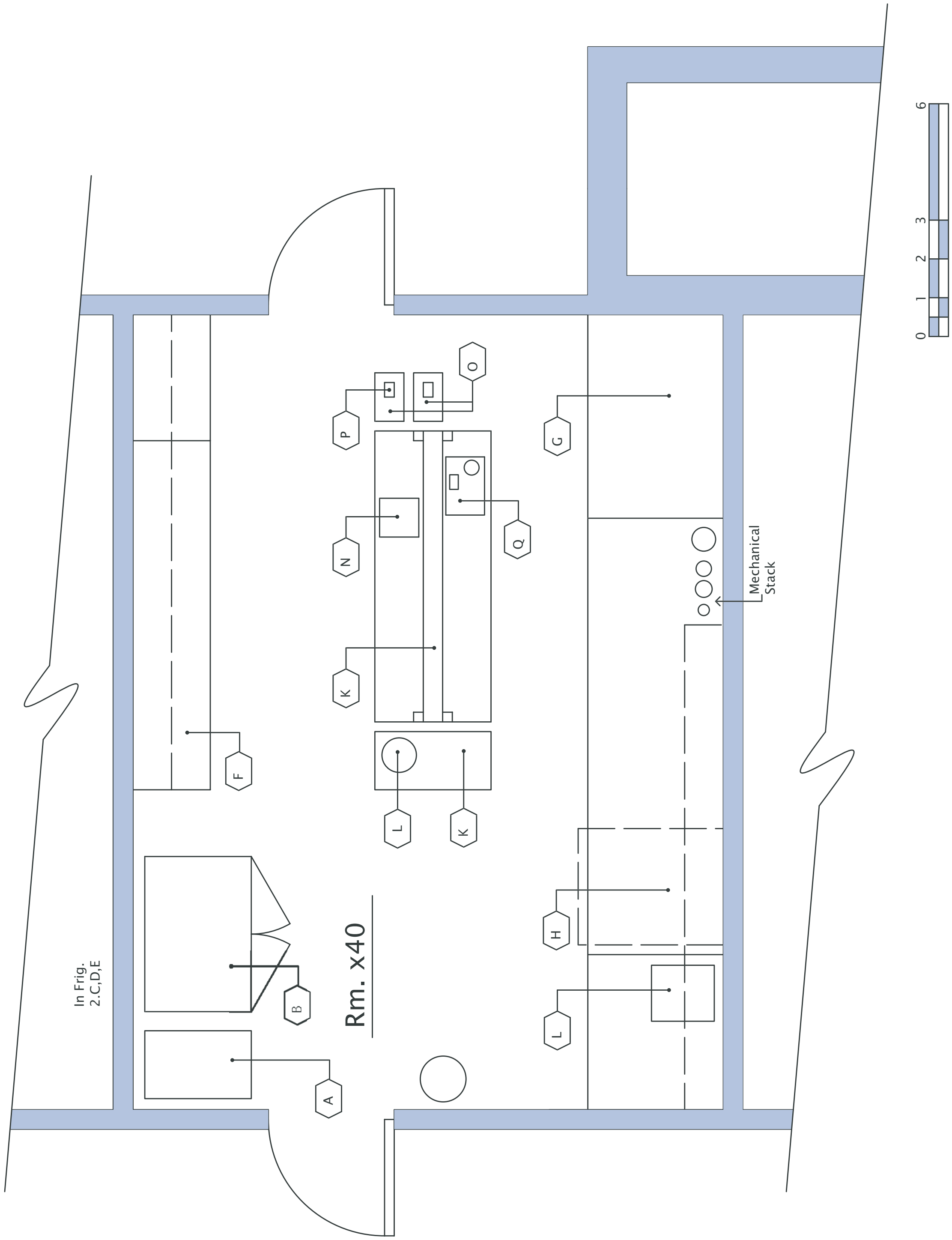


Photo Code: 137-6



LAB 5: CHEMISTRY **Floor Plan** **310 Sq. Ft.**

DATE: 04/02/01
DRAWN BY: SL

PEER Nonstructural Loss Study

Lab 5 Chemistry Equipment List

Rm #	Equip. Key	Equipment Name	Photo Example	DETAIL	Direct COST
x40	A	Cart w/ wheels		S5A	$145
x40	B	Deli Fridge	1	H7	$760
x40	C (in B)	Econo-Pump		na	$0
x40	D(in B)	Centrifuge		na	$0
x40	E(in B)	Chemical Pump		na	$0
x40	F	Lab Bench w. shelves (sim S1)	2	S1	$45
x40		Base cabinet drawers & doors w/no latches		S3	$45
x40	K	Flammables Cabinet		S3	$45
x40	L	Capilary malting apparatus		B4	$50
x40	M	Experiment Rack w/ mechanical	3	S4	$240
x40	N	Marathon Micro H		B4	$50
x40	O	2-2 Drawer Files		S6	$45
x40	P	2 Balances		B4	$50
				B4	$50
x40	G	Fume Hood	4	B1	$740
x40	H	Lab Bench		NA	$0
x40	I	Under Counter Refrigerator		H6	$250
x40	J	Imac		B4	$50
x40	R	Minus 20 Under Counter Refrigerator	5	H6	$250
x40	Q	Roto-Bath	6	B3	$150
		Total Direct Cost			**$2,965**
		GC OHP (25%)			$741
		Total			**$3,706**
		Lab sq. Ft.			310
		Direct Cost Per Sq. Ft.			$9.56
		Total Cost Per Sq. Ft.			$11.96

Sample Condition 1

Photo Code: 1

Solutions: H7

Sample Condition 2

Photo Code: 2

Solutions: S1

Lab 5

Sample Condition 3

Photo Code: 8

Solutions: S4

Sample Condition 4

Photo Code: 4

Solutions: B1

Lab 5

Sample Condition 5

Solutions: H6

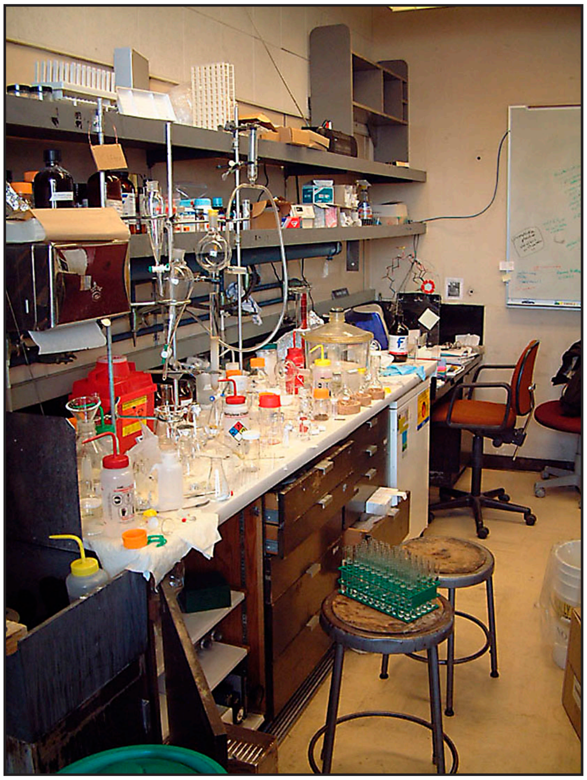


Photo Code: 7

Sample Condition 6

Solutions: B3

Photo Code: 5