SEISMIC DESIGN FOR POLICE AND FIRE STATIONS

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16. Abstract (Limit: 200 words)

This project attempts to explore, define, and develop seismic design consideratons to be used by the architectural and public safety professions in the planning, design, construction, and operation of police and fire stations so that they can remain functional in the event of an earthquake. Specific objectives are to identify past and potential damage to police and fire facilities and their operation during earthquake disasters; identify and assess present and future facility requirements and equipment needs relative both to normal and disaster operations; identify and develop specific design considerations and alternatives for mitigation of earthquake damage/failure; and develop specific conceptual seismic design solutions for police and fire facilities. The text evaluates police and fire stations in terms of disaster operations, site design, building form, functional space criteria, nonstructural systems and components, equipment, and future trends. Emergency Operating Centers (E.O.C.)are discussed in terms of definition, program functions, program models, and analysis of a fire station/police station as an E.O.C. Also discussed are seismic renovation and multi-hazard design.

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Design
Earthquake resistant structures
Hazards
Design criteria
Design standards

b. Identifiers/Open-Ended Terms

Fire stations
Police stations
Emergency Operating Centers (E.O.C.)

c. COSATI Field/Group

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PREFACE

> *"It is important for post-disaster recovery that critical facilities such as police and fire stations, hospitals, dams and reservoirs, power facilities, and emergency communication systems remain operative after an earthquake."*

Seismic Safety Plan
City of Los Angeles, California
September 1975

There is no such thing as an earthquake-proof building. It is neither economically nor technically feasible to design a building that will sustain no damage after a major earthquake. But designers can go beyond the old tenet — preventing building collapse — to a consideration of damage control. This is especially true when designing critical facilities that should remain operational during a disaster.

Police and fire services are among the most critical services that a local government can provide to its community during an earthquake disaster. To ensure the capability to perform these services, individual police and fire stations should be designed, constructed and operated to remain functional during the earthquake disaster period.

This report is not applicable to each and every station throughout the country; nor is it a "how to" manual. It does discuss the many issues that should be considered during the design of police and fire stations in areas susceptible to earthquakes. There will be a wide range of local variables, including differing decisions concerning budget allocations and the degree of risk to be accepted. Each situation is unique and will dictate what can or should be done in the project under consideration. Architects and public safety professionals must be aware of these earthquake issues if they are to fulfill their responsibilities to the public. In the past the public has not been prepared to evaluate the delivery of police and fire services during major disasters. This may not be true in the future.

It is hoped that this report will contribute to earthquake disaster planning and response of these vital public safety services. Local police and fire departments will benefit from the reduction of disruption and risk associated with earthquake disasters. Design professionals will benefit from having information available to them concerning seismic design of police and fire stations. The public will benefit from increased assurance that these critical emergency services will be able to provide assistance during an earthquake disaster.

We should neither overestimate nor underestimate the potential seismic threat to our police and fire stations. To overestimate can lead to unnecessarily expensive and rigorous seismic design strategies, with the result that other important considerations are neglected. On the other hand, to underestimate the potential risks and hazards can lead to disruption or loss of these critical services for the community after an earthquake, with increased loss of property and life.

CONTENTS

EARTHQUAKE RISK

Earthquakes can be one of nature's most terrifying and devastating events. They have destroyed countless cities and killed literally millions of persons throughout history. The 1976 earthquake in China alone killed more than 600,000.

The very size and strength of an earthquake is difficult to express in common terms. The energy released from an earthquake can be enormous. For example, the earthquake in Alaska in 1964 released an amount of energy equivalent to 100 nuclear explosions of 100 megatons each. But this comparison has very little meaning, since the force of even one such explosion is difficult to comprehend. Since the 1906 quake was the largest in California for which we have extensive records, its energy is often estimated. Two frequently quoted comparisons state that the energy released during that single earthquake was equal to the force needed to raise a cubic mile of rock 6,000 feet, or to run a battleship at full speed for 45,000 years.

It is sobering to realize that some of the most heavily populated regions of the world, including Japan, Central and South America, China, Turkey, Iran, the nations around the Mediterranean and the U.S., are located in areas exposed to the most violent of earthquakes.

This nation has historically assumed that earthquakes are primarily confined to the west coast. As is evident from the following figures, earthquakes have occurred and continue to occur in the majority of states across the entire country. More than 70 million people in 39 states live in areas of moderate to high seismic risk. Montana, Illinois, Tennessee, Georgia, New York, South Carolina and Massachusetts are included, in addition to California, Alaska, Washington and Hawaii.

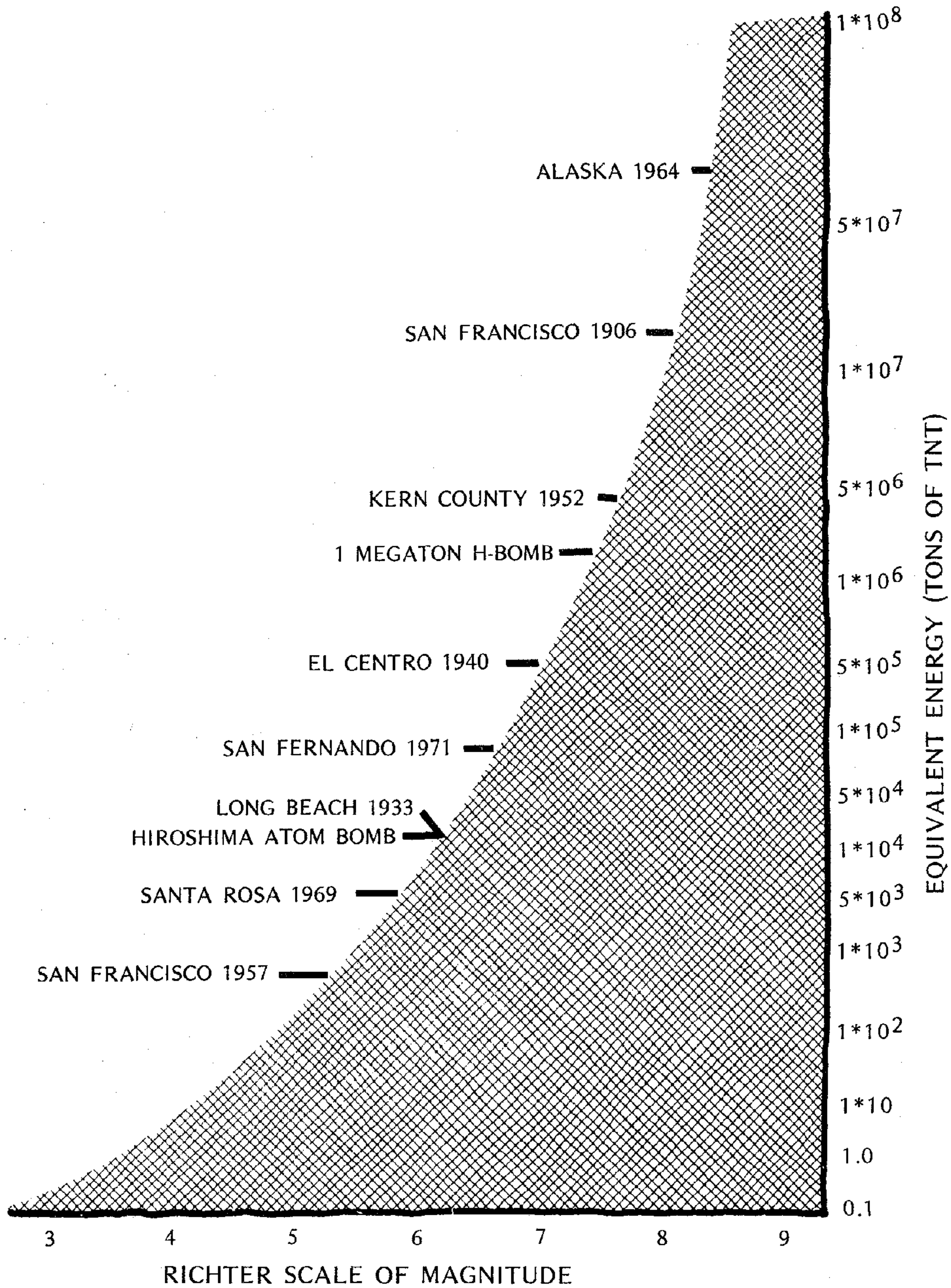
The architect, as the design team leader, plays a major role in determining a building's site location, shape, form, configuration, basic structural system, materials, architectural systems/components and basic mechanical/electrical systems. The decisions made by the architect can determine the overall success or failure of the building's performance during an earthquake or the additional cost of designing specific systems to be earthquake-resistant.

CRITICAL NATURE OF POLICE AND FIRE STATIONS

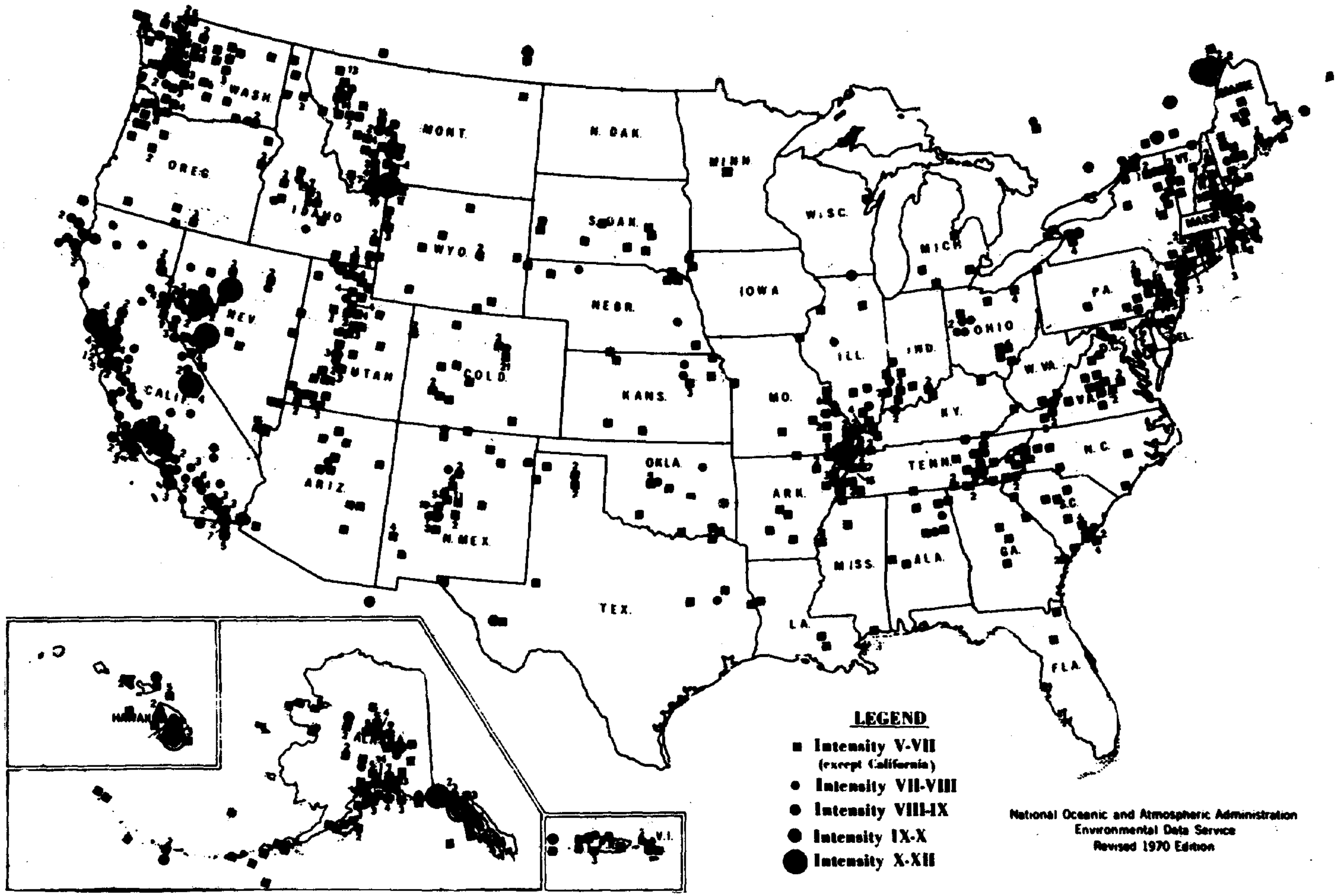
Certain community facilities and operations must be depended upon in an earthquake disaster to provide critical public services such as rescue, fire suppression and medical assistance. This especially applies to the police and fire services. In fact, in the San Fernando Earthquake of 1971, the need for major services increased 300-700%.

Spurred by the recent earthquake activities around urban centers throughout the world, seismic design of critical facilities has been receiving increasing attention from local officials, governmental agencies and the public. Such facilities have included nuclear power plants, hospitals, schools and other structures whose structural integrity impacts directly on the lives and well-being of large numbers of citizens. However, no specific earthquake design guidelines address the additional life loss and property damage that can ensue from the loss of the specialized functions of police and fire stations.

During a major earthquake disaster the police and fire departments will find themselves exceedingly taxed to perform the critical services expected of them. The amount of stress



MAGNITUDE—ENERGY COMPARISON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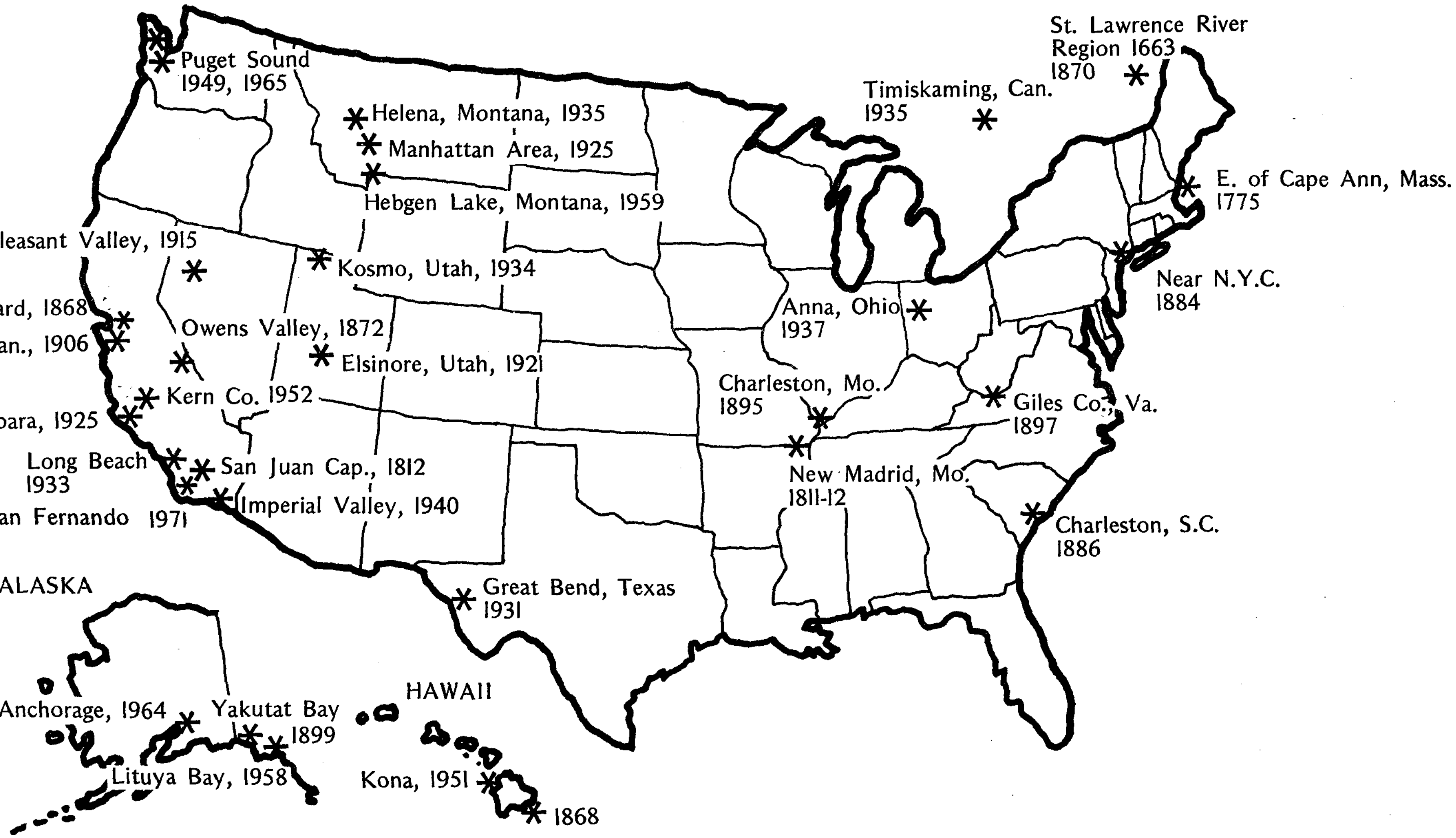
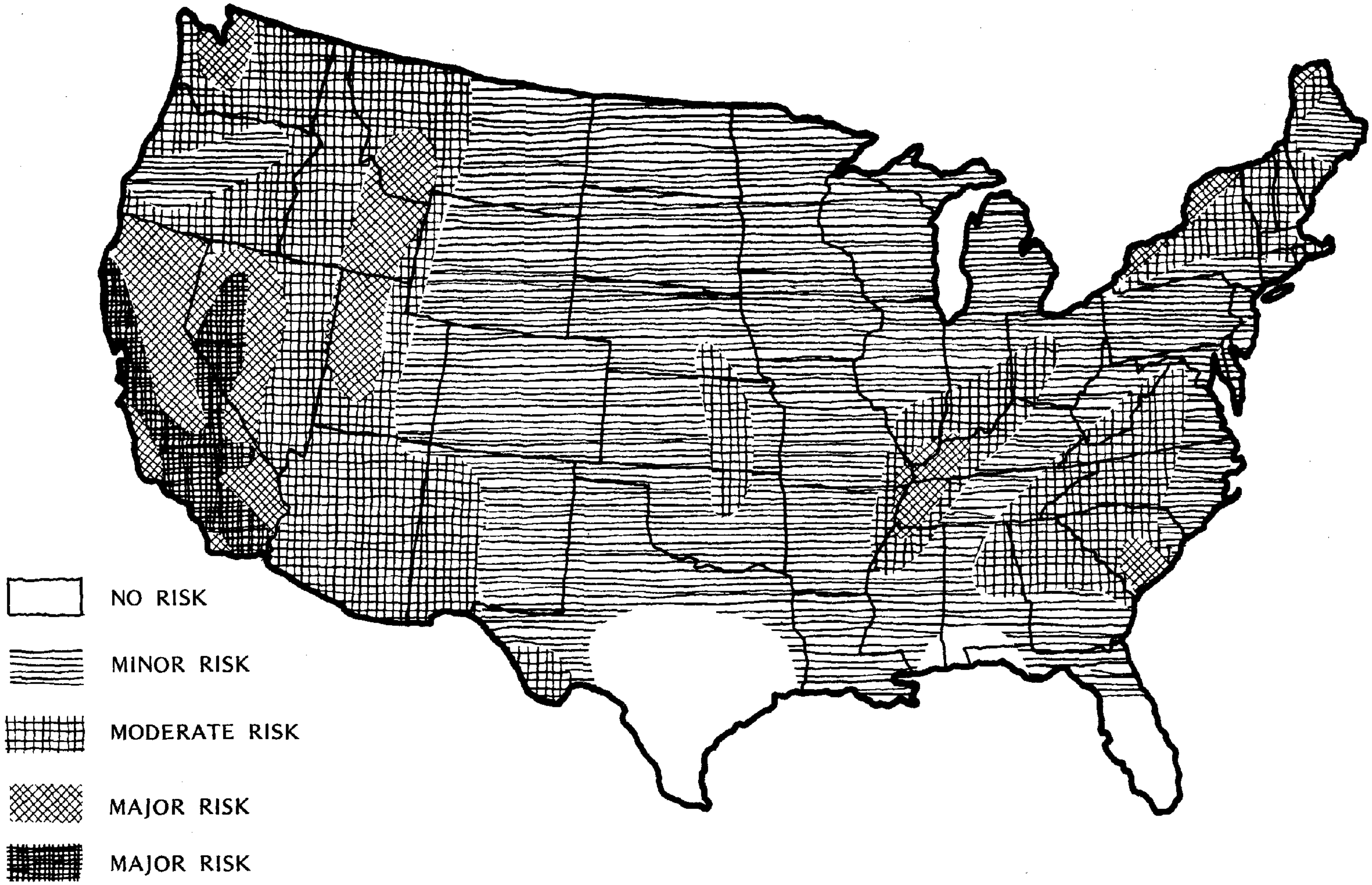


MAJOR NORTH AMERICAN EARTHQUAKES



SEISMIC RISK-COTERMINOUS U.S.
U.B.C. 1976

will depend on many variables, over some of which the departments will have no control. The extent of damage and destruction, the number of injured/dead, the size of affected area and the availability of community resources are some of the variables that will determine such stress. These variables will depend on the earthquake itself (magnitude, intensity, time of day, etc.), as well as on the community (public awareness, response planning, building codes, land use, etc.).

However, there are several conditions that aid the operational capacity and performance of the police or fire organization.

- Police and fire departments are operated 24 hours every day. This will provide a large number of personnel (including auxiliary forces) beyond that needed for a normal duty shift.

- Since these departments are on duty 24 hours every day, they have the capability for an immediate response to the disaster.

- Police and fire personnel work daily with individual emergencies and their operation has been organized to provide immediate critical services.

- Police and fire personnel are trained and experienced in making critical decisions based on priorities.

- During a disaster situation, the performance of these organizations will drastically increase because of the critical circumstances and the short time span of the immediate earthquake disaster.

- Intra-organization communications are well developed and used constantly in emergency situations.

- Emergency equipment and resources are available and personnel are well trained in their use.

In reviewing these issues, it becomes apparent that if police or fire departments are to utilize their strengths to the optimum during an earthquake disaster, their resources (operation, personnel, equipment) must remain functional. This means that police and fire stations must be designed, constructed and operated to remain functional during the disaster. This does not mean that all fire and police stations throughout the country should be designed to withstand the same potential earthquake disaster. But, while the earthquake potential can vary, the definition of a station that is functional during and after an earthquake does not change.

To remain totally functional, the police or fire station should

- provide protection to personnel;

- provide protection to essential or critical equipment;

- allow personnel and equipment to exit the station in order to respond to the disaster;

- be able to serve as a center of activity (medical, communications, etc.) for disaster efforts.

There are several additional factors that should be considered by the architect and building owner/user.

- The seismic risk, building function and cost implications should be analyzed to determine the desired performance criteria for the building.
- The public inside and outside the building should be protected during an earthquake.
- Not only should the building design provide safe egress from the building; ingress into the building by rescue workers should be considered as well.
- The amount of capital investment to be protected (building/equipment) should be determined.

PAST EARTHQUAKE DAMAGE TO POLICE AND FIRE STATIONS

A few examples of damage and disruption of police and fire stations from this country's most recent moderate earthquake, the San Fernando, California, earthquake of 1971, can give an idea of what might be expected during future larger damaging earthquakes. Although of moderate magnitude and confined to a relatively small area, this earthquake nevertheless caused disruption of the area's fire and police services.

The immediate effect of the earthquake was a blackout of practically all of the San Fernando Valley and a portion of downtown Los Angeles, with scattered interruptions throughout the entire area. Damage to water distribution and supply facilities involved pipe of every type and description, valves and fittings, water storage facilities of both steel and concrete construction, large conduits, tunnels, wells, pumps, and pump stations.

The Country Fire Department had some $400,000 damage to structures. The two fire stations in the City of San Fernando were severely damaged. The Burbank Fire Stations received minor damage. Apparatus in the two fire stations in the Sylmar area were also rendered temporarily inoperative due to the obstruction of apparatus room doors by damaged equipment and racking. Electrical power failure in other locations necessitated the manual operation of many apparatus doors normally activated by motorized units, causing minor delays. In two or three cases fire department automotive apparatus had either been permanently or temporarily shifted by the earth movement, damaging or impinging upon the apparatus floor doors. In one instance, apparatus moved laterally as much as five feet, as well as longitudinally, with damage to both itself and the fire station apparatus room. One county fire station was so severely damaged that it took nearly 30 minutes to extract the department's pumper from the building following removal of obstructing debris (including the fire alarm system control panel) and freeing of the apparatus floor doors.

Three fire stations were damaged to the extent that demolition of the structures was necessary. Apparatus room doors experienced binding of rollers with guides, failure of a door retraction spring, and general binding, in addition to damage by shifting automotive apparatus. In one station all on-duty firemen were thrown from their beds, were hit by articles and falling plaster, and sustained cuts, scratches, and minor bruises.

Of the City of Los Angeles Fire Department's 105 stations none actually collapsed, although five received major damage. Minor building or equipment damage occurred at 53 other stations.The San Fernando City police station emergency generator experienced a six-hour outage due to physical damage. At the Los Angeles County Juvenile Hall, the electric doors jammed, and 350 young inmates had to be rescued individually through the second story windows of their rooms. Eighty inmates escaped when a part of a wall collapsed.

POTENTIAL EARTHQUAKE DAMAGE TO POLICE AND FIRE STATIONS

Recent studies[1] have indicated that there exists a high potential for earthquake damage and disruption to police and fire stations, even on the West Coast where seismic code requirements are enforced.

In the Los Angeles metropolitan area, for instance, a survey of 155 city and county fire stations and 32 city and county police facilities indicated that an earthquake of magnitude 8.3 along the San Andreas fault would leave 36 (23%) of the fire stations and 5 (16%) of the police facilities nonfunctional, while an earthquake of 7.5 along the nearby Newport-Inglewood fault would leave 55 (35%) of the fire stations and 10 (31%) of the police facilities nonfunctional.

In the San Francisco metropolitan area, an earthquake of magnitude 8.3 along the San Andreas Fault would cause an estimated 10 (23%) of the 44 surveyed fire stations to be nonfunctional in the city of San Francisco alone. The same magnitude earthquake along the Hayward Fault would leave an estimated 5 (19%) of 27 surveyed fire stations nonfunctional in just the city of Oakland.It is also estimated that in an earthquake of 7.5 along the Wasatch Fault in the Salt Lake City, Utah, area, 43 (50%) of the 85 city and county fire stations surveyed would be nonfunctional. In addition, 29 (55%) of the 52 surveyed police stations would be nonfunctional.

It should be noted that although these areas follow earthquake code requirements, the codes emphasize structural requirements, and a police or fire station can become damaged or disrupted enough to become nonfunctional without an actual building collapse. This should not be taken as an indication that the present codes are not satisfactory, but that there are considerations and guidelines that can be used by designers that go beyond mere code provisions in designing a police or fire station to remain functional during an earthquake disaster.

It should also be emphasized that in areas susceptible to damaging earthquakes that do not utilize earthquake requirements the percentage of police and fire stations that could be expected to be nonfunctional or actually collapse would be much higher.

PROJECT SCOPE

The goal of this project is to explore, define and develop seismic design considerations to be used by the architectural and public safety professions in the planning, design, construction and operation of police and fire stations so that they can remain functional in the event of an

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1. Algermissen, S. T., et al. *A Study of Earthquake Losses in the Los Angeles, California Area.* Federal Disaster Assistance Administration: Washington, D. C. 1973; Algermissen, S. T., et al. *A Study of Earthquake Losses in the San Francisco Bay Area.* Office of Emergency Preparedness: Washington, D. C. 1972; Rogers, A. M., et al. *A Study of Earthquake Losses in the Salt Lake City, Utah Area.* U. S. Geological Survey: Washington, D. C. 1976.

earthquake.

In order to accomplish this goal, four specific objectives have been identified. They are to

- Identify past and potential damage to police and fire facilities and their operation during earthquake disasters;

- Identify and assess present and future facility requirements and equipment needs relative to both normal and disaster operations;

- Identify and develop specific design considerations and alternatives for mitigation of earthquake damage/failure;

- Develop specific conceptual seismic design solutions for police and fire facilities.

It is felt that possible benefits of this project would be to

- Assist jurisdictions in considering the need for seismic design measures for police and fire facilities;

- Provide greater responsiveness and operability of fire and police services in time of earthquake disaster;

- Provide a useful starting point for architects and local officials who are considering seismic safety in new and existing police and fire facilities;

- Provide a common basis for discussions between architects and local governments on this problem;

- Improve the quality and reduce the study cost of local government efforts to achieve seismic safety for the community.

It was felt from the beginning of the project that several elements were necessary to the success of this final report.

- Because both designers and local government officials are potential users of the document, both groups should be involved throughout its development in order to ensure consideration of the full range of issues.

- The report should be usable by architects, technical personnel within local governments, general city management and elected officials. Besides the design professions it is important that general management and elected officials be assisted in considering the need for seismic safety in police and fire stations. This is especially important for achieving utilization of the design considerations. The management summary serves to briefly explain to elected officials the overall scope and applicability of the document to emergency facilities design. The design document covers in depth the needs, possible solutions and potential trade-offs to be considered when applying seismic design criteria to police and fire stations.

- The report should apply to police and fire stations, paramedic facilities, communications centers, and emergency operating centers located in police or fire facilities. Cities may find that other public facilities also need seismic attention, but fire and police stations are among the most important, and are interrelated.

- The report should focus on design *considerations* for seismic design — not *standards* for design. It would be unrealistic to talk of mandatory standards when there exist major variations in risk, geography, station design, public safety service operating procedures, and local and regional disaster plans. It should be usable by all communities and regions of the country regardless of differing earthquake risks and potentials.

- Design considerations should apply to both urban and low density or rural situations.

- Both new facilities and renovation of existing facilities should be addressed.

- The report should be objective in discussing possible seismic safety solutions. In particular, it should not push architectural solutions where procedural, planning, operations, or other non-architectural solutions can yield better or less expensive results.

- Major changes have been occuring in both the police and fire services with resultant impacts on facility needs. Material should be included in the report to assist the architect in understanding these trends and in designing a facility which can respond to the changing needs of the community.

- The report should include information to assist local communities and their architects in making preliminary estimates of the cost impact of seismic safety.

- The report should relate seismic design considerations to design considerations for other types of disasters or major disturbances. Overlapping issues of disaster preparedness may justify seismic criteria in certain instances in which seismic risk alone is insufficient to cause their inclusion in a new facility design.

- The major emphasis of the design considerations should be to protect public safety responsiveness, resources and critical functions. In almost no earthquake situations will all normal systems be functional. However, a high degree of responsiveness is a realistic goal. Protection of the facility is of importance because the operational capacity of the facilities will affect responsiveness of fire and police services during an earthquake disaster.

2 POLICE AND FIRE STATIONS

DISASTER OPERATIONS

INTRODUCTION

The police or fire department may undergo changes in organizational structure and operations in order to meet the demands that arise during an earthquake disaster. Even the facility that is efficiently designed for normal operations may be logistically inadequate during a disaster. The changes that may be anticipated during an earthquake situation and that should be considered by architects and police and fire officials during the planning of both facility design and emergency operations are discussed in the following section.

DESIGN CHECKLIST

1. What are the safety and functional needs of the police or fire station in the event of an earthquake?

   Safety of personnel ☐

   Safety of personnel and use of certain critical apparatus/equipment ☐

   Safety of personnel and use of most critical apparatus/equipment ☐

   Safety of personnel, critical apparatus/equipment and continued operation of station ☐

2. What operations will or might occur in the police or fire station during an earthquake disaster?

   Normal police/fire operations ☐

   Distribution/emergency aid center ☐

   Staging/coordination center ☐

   Communications/operations center ☐

   Other ☐

   ____

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3. What changes in functional interrelationships of the station will or might occur during an earthquake disaster?

Interactive Areas

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Disruptive Areas

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The following questions can be used to identify those specific areas and resources that are critical to the continued operations of the police or fire station during an earthquake disaster.

4. What communications operations will be needed during the disaster?

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5. What types of reconnaissance operations are planned or will be needed during the disaster?

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6. What search and rescue operations will be initiated during the disaster period?

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7. What types of first aid assistance or Emergency Medical Services (EMS) will the department or station provide?

8. What services might be required for a mass evacuation of certain areas threatened by secondary hazards during the disaster period?

9. What fire suppression services will be provided by the fire department during the disaster?

10. What crowd control, traffic control or security services will the police provide during the disaster?

11. What administrative services will the police and fire departments provide during a disaster?

12. What contamination control operations are planned?

13. Will the police or fire department use auxiliary personnel during the disaster?

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14. How will off-duty personnel be activated?

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Other services that may be provided by the police or fire services and that might also be considered for any design ramifications include the following:

Debris Removal
Marine Operations
Transportation of Injured
Hazardous Materials Control
Removal and Disposition of Dead
Dispensing Supplies
Mutual Aid

COMMENTARY

1. The architect should learn, from the police or fire department, the operational needs of the station during the disaster period. Such information will determine the overall protection philosophy of the individual station under design. For instance, if each station were programed to become the disaster coordination center for its district the protection level for that station would be substantially increased over that of a station whose only requirement was to provide for the safe exit of personnel and apparatus.

2. During an earthquake disaster the individual police and fire station will suspend some of its normal operations while initiating certain new operations to respond to the special demands of the disaster. The station may provide disaster services to the public that require only the continued operation of the station for typical fire- and police-related services. But the station may also serve as a local communications center or the base of operations for the police or fire department or civilian authorities. Such an operation would require certain spaces in which to perform the new functions, increased operations space, and restrictions on the public's normal use of the station.

   The station may, instead, become a distribution/emergency aid center. Such a station would require large spaces in which to provide such services, as well as increased public use and accessibility. The police or fire station may even be the location of a staging or coordination area requiring large open areas and spaces for storage of arriving equipment and dispensing of such equipment. Other police stations might become detention centers for the central relocation of prisoners. Such a station would need increased prisoner processing and short-term detention areas, with suitable security requirements.

   The architect must be aware of any dual or new functions the police or fire station may have in a disaster situation. Only then can the facility be designed to operate effectively during normal times as well as maintain the flexibility to take on new functions during the disaster.

3. Certain functional interrelationships can change as a result of modified or new functional requirements in the fire or police station. The facility which is efficiently designed for effective normal operations may run into functional or logistical problems in disaster activities. It is the architect's responsibility to identify the potential conflicts and design the facility not only to operate effectively during normal times but to be flexible enough to operate effectively during a disaster. At the minimum, it should be ensured that identified conflicts are not designed into the building.

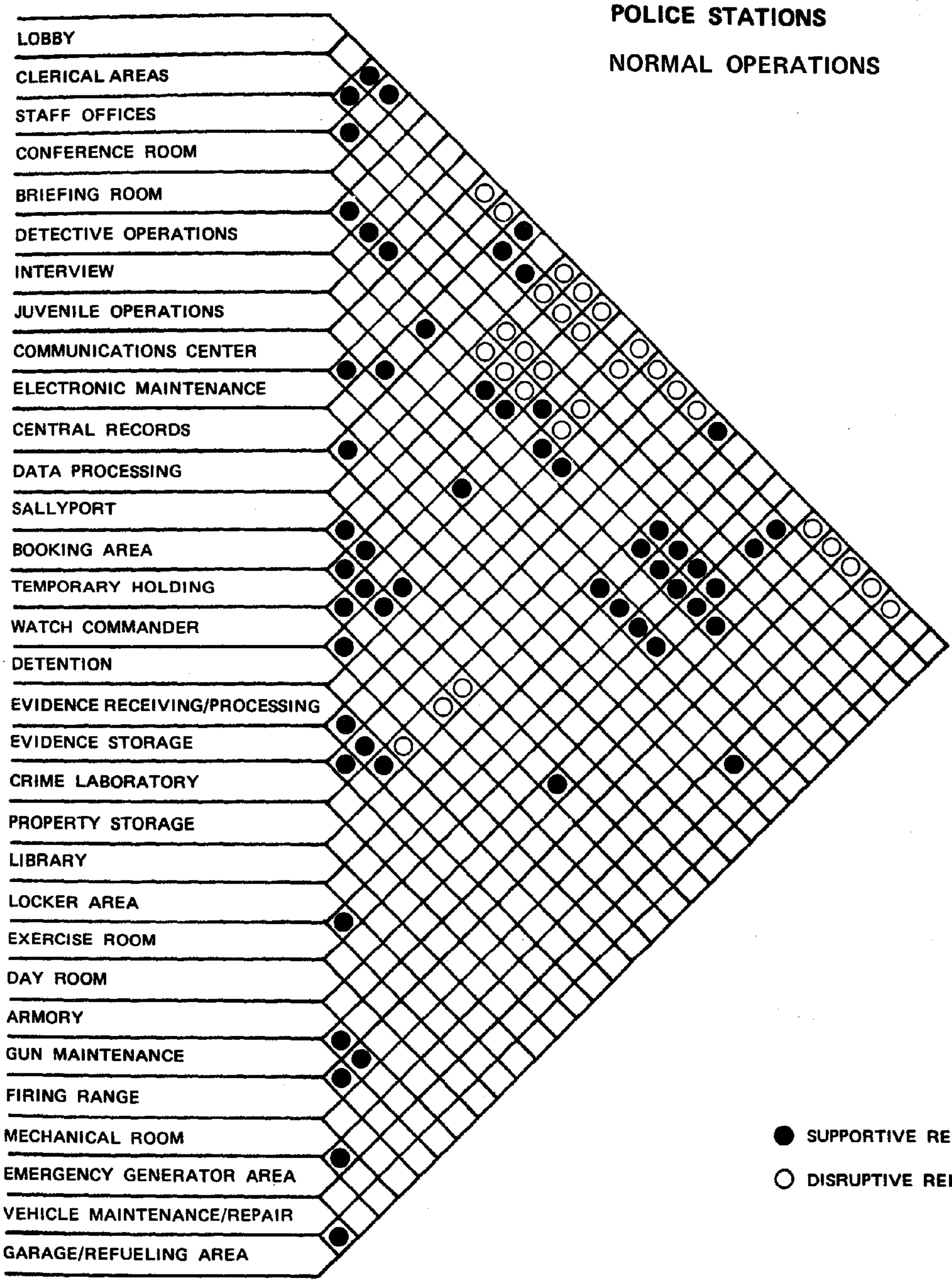
   For example, a police station serving as an operations center during a disaster would require the flexibility to be able to enlarge its communications room and make it the hub of activity. During normal operations, the records center may be the logistical hub, and designed as a large, centrally located, space, while the communications room may be smaller and located in a relatively isolated part of the station. A possible design solution would be to design adjoining records and communications areas, separated during normal operations but with the flexibility to merge during disaster operations through the use of normally locked doors, removable partitions, etc.

   The following matrices display functional and disruptive relationships between certain areas in police and fire stations during normal and disaster operations. The disrupting or interactive relationships can be used to identify potential dual or conflicting functional interrelationships.

FUNCTIONAL INTERRELATIONSHIPS

POLICE STATIONS

NORMAL OPERATIONS



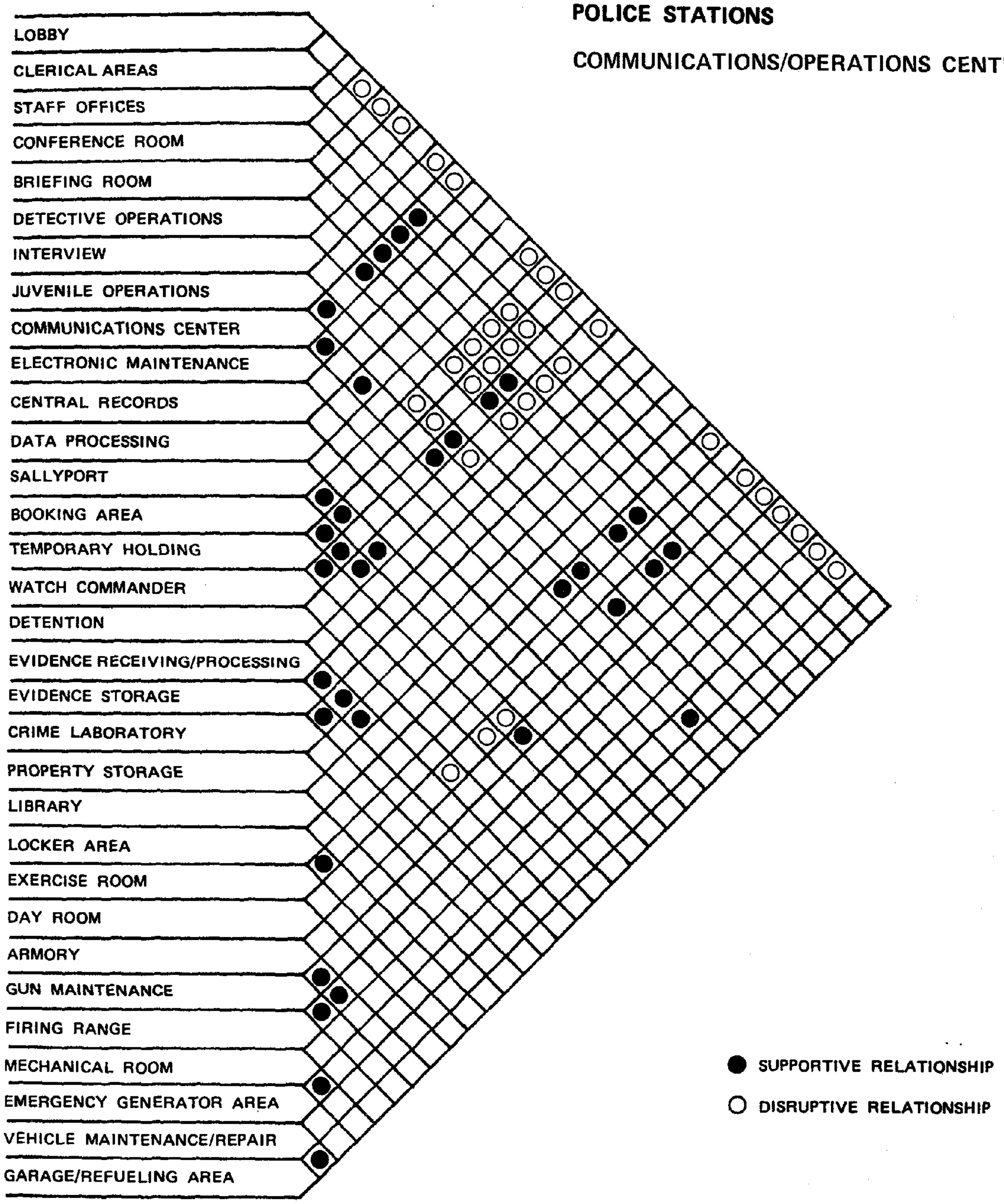
● SUPPORTIVE RELATIONSHIP

○ DISRUPTIVE RELATIONSHIP

FUNCTIONAL INTERRELATIONSHIPS

POLICE STATIONS

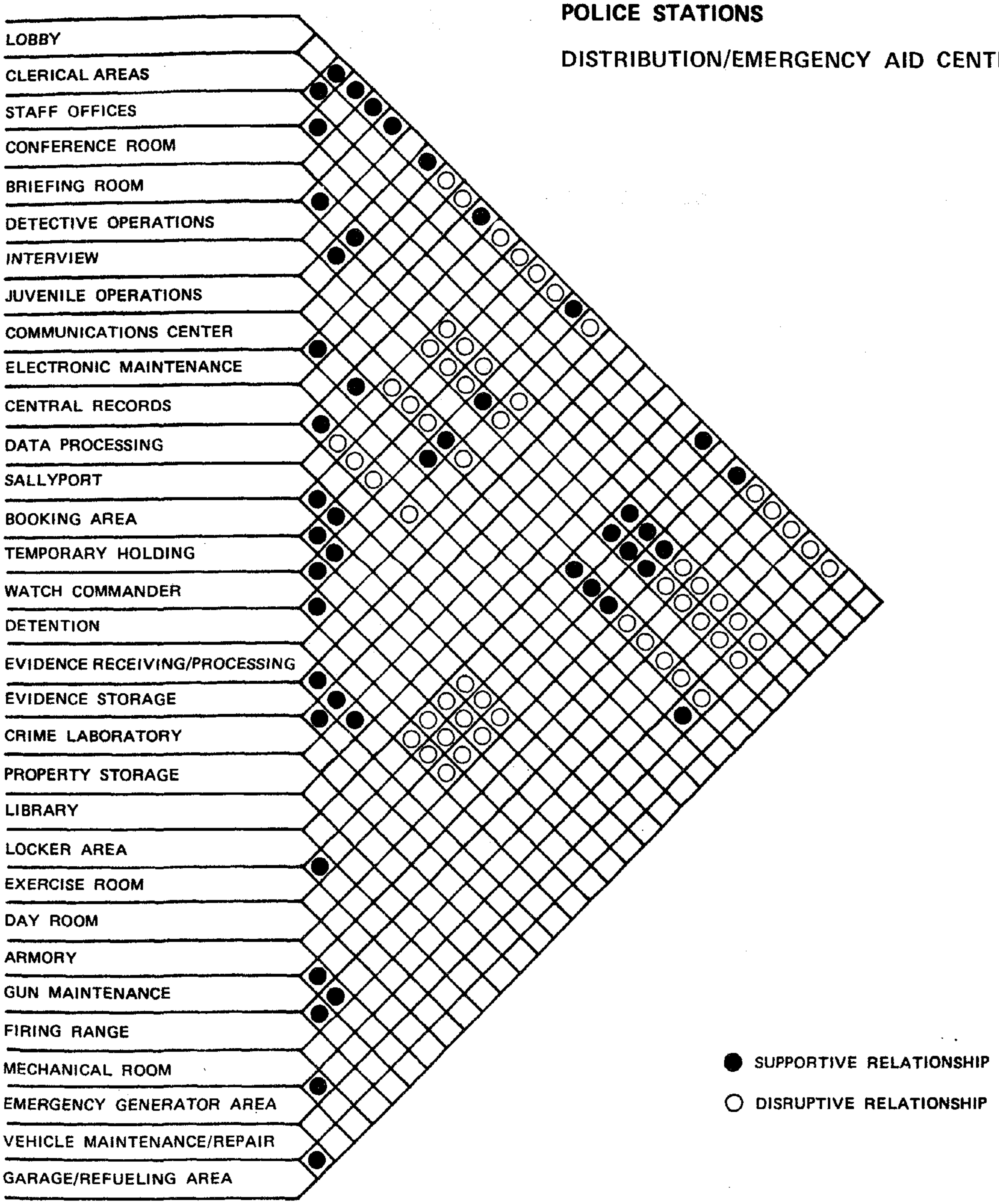
COMMUNICATIONS/OPERATIONS CENTER



FUNCTIONAL INTERRELATIONSHIPS

POLICE STATIONS

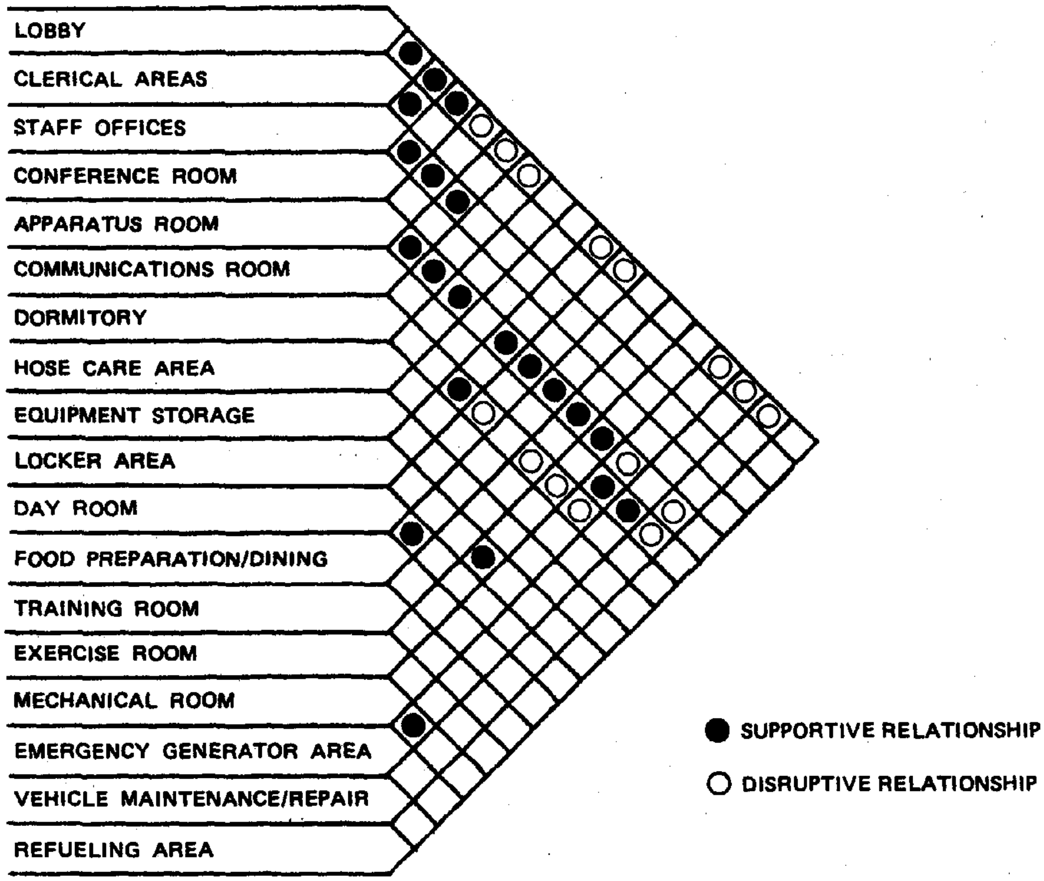
DISTRIBUTION/EMERGENCY AID CENTER



FUNCTIONAL INTERRELATIONSHIPS

FIRE STATIONS

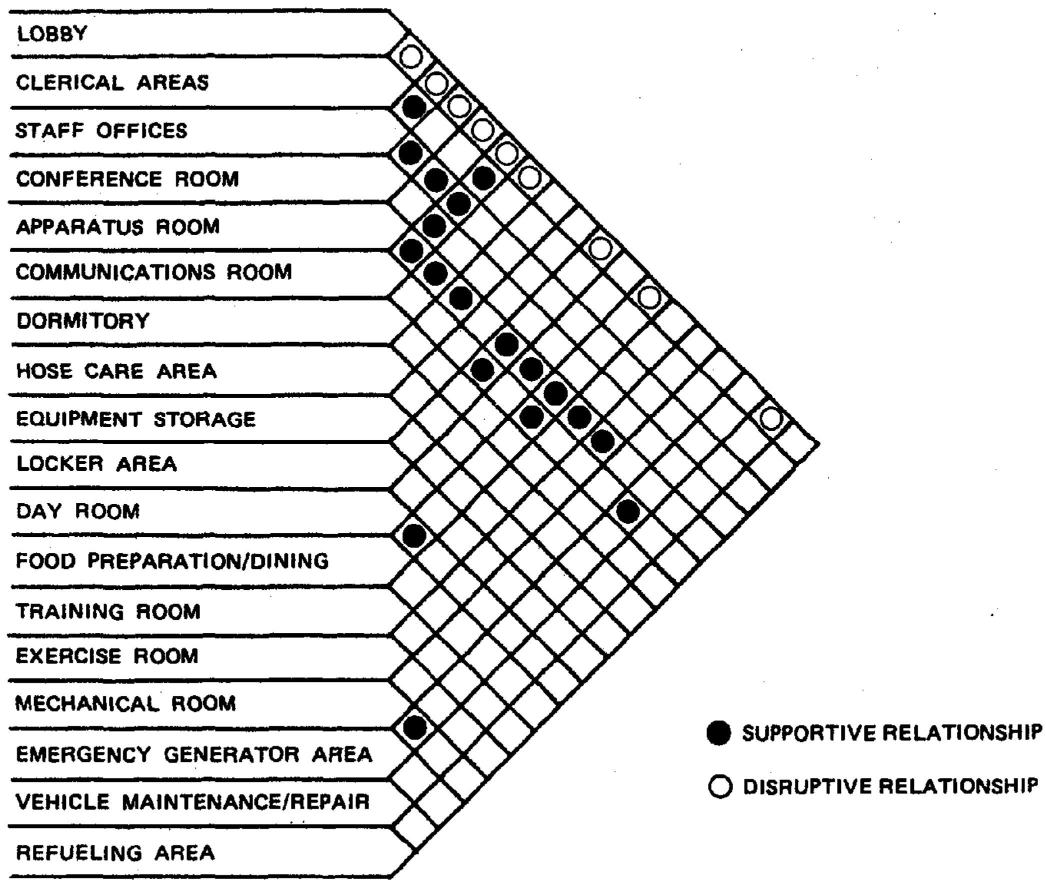
NORMAL OPERATIONS



FUNCTIONAL INTERRELATIONSHIPS

FIRE STATIONS

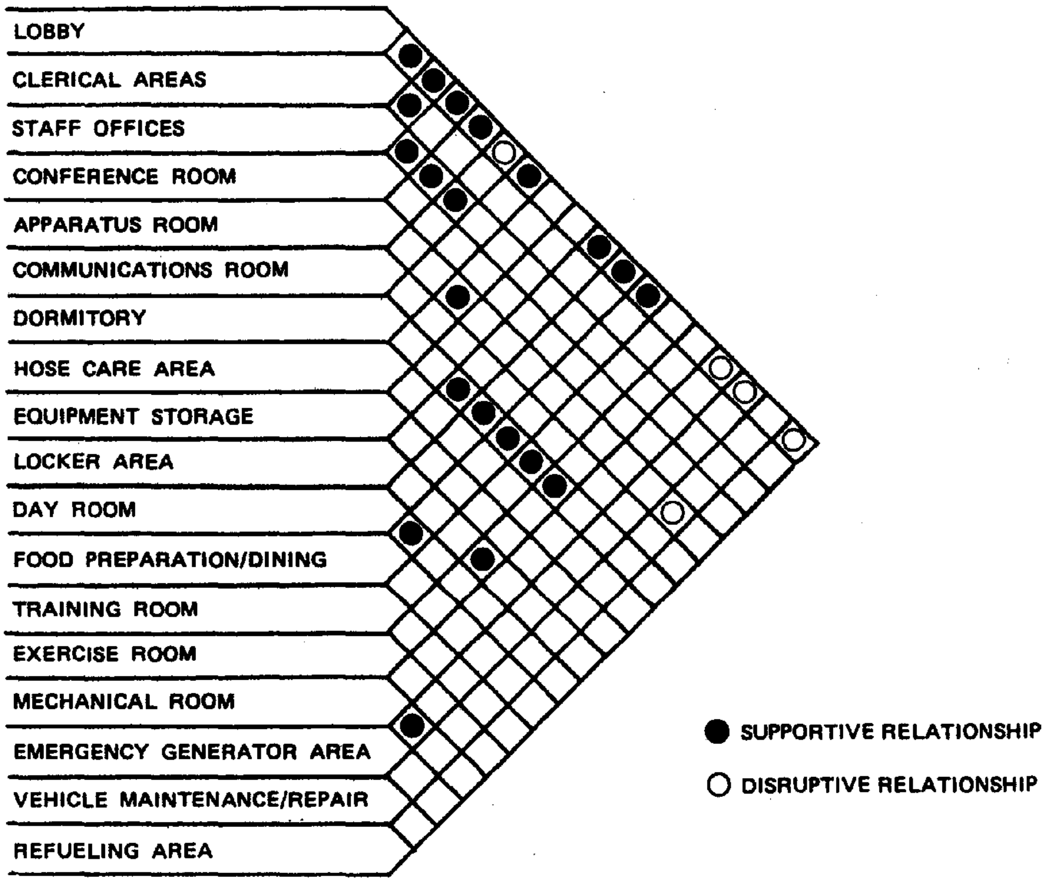
COMMUNICATIONS/OPERATIONS CENTER



FUNCTIONAL INTERRELATIONSHIPS

FIRE STATIONS

DISTRIBUTION/EMERGENCY AID CENTER



4. Communications will likely be one of the most important functions for the continued operation of a police or fire station. It is to be expected that during a major earthquake large portions of the community's communication network will be disrupted, if not destroyed. Police and fire stations may be expected not only to provide intra-agency communications, but also to serve as vital inter-agency and inter-community links. The importance of protecting the areas and equipment needed for the station's communications function cannot be overemphasized.

   A dispatching capability for the station can be critical in the event central dispatching services are disrupted. Stations may require no dispatch capability during normal operations if their personnel and apparatus are dispatched from a central headquarters. Such an addition to the station's receiving/monitoring capability for emergency use should be considered.

5. Reconnaissance will be an extremely critical service during the initial phase of the disaster. Because of their communications capabilities and "on the street" status, police and fire personnel will probably be the first "official" participants of a visual survey of damage to the community. The use of helicopters is extremely useful in performing this function, and the need for a landing pad or area should be considered. Special care must be taken in the placement of helicopter facilities, both to protect the helicopter itself from earthquake damage and to provide a secure landing and refueling area after the earthquake. Pilots may hesitate to land on a rooftop pad, for instance, for fear that the earthquake has left the building unable to support the helicopter's weight. Thus an alternate landing and refueling area should be considered.

6. Police and/or fire departments may perform search and rescue operations after an earthquake. In some cases search and rescue operations might require the temporary use of stations to house injured persons. All equipment needed to provide search and rescue services should be protected in the station. Such equipment may include emergency lights, penetration equipment, portable generators, etc.

7. In certain communities police or fire departments may be increasing their roles in providing emergency medical services (EMS) to the community. Fire fighters in many cities are cross-trained as paramedics and police officers usually receive first-aid training. EMS services during an earthquake disaster will probably be triage, field treatment and transportation of the injured. Protection of all first-aid supplies and equipment, including EMS equipment, is required.

8. If mass evacuation from an area is required it can be a major and critical undertaking by the police or fire services. The police may have to evacuate persons from actual or potentially hazardous areas to reloaction areas. The service may also include receiving and caring for the evacuees at the reloation areas, especially during the initial disaster phase, before other agencies or organizations are mobilized. Although evacuation will probably be primarily a police function, fire personnel may be expected to initiate evacuation procedures when areas are threatened by conflagration. The architect should determine any special equipment or supplies that the police or fire services will need for evacuation procedures so that the design can help ensure their protection.

9. Fire suppression and containment will be the major activity of the fire department following an earthquake disaster. Although the basic objective will remain to extinguish and curtail fires, the means of accomplishing this objective may change during a mass disaster. Since fire equipment may be in almost constant use, it may return to the station

only for maintenance, refueling and supplies. The fire station must be designed to protect the apparatus, not only from the building and building components, but from other apparatus as well. There are several practical ways to minimize the problem of apparatus shifting across the floor. Concrete curbs can be provided for the sides and rear (if only one exit is provided) to restrict shifting, and floor finishes can be chosen to provide good friction. Protective curbing can also be provided at the base of critical elements with which the apparatus might have contact during shifting, such as gas pumps, columns, walls or equipment cabinets.

10. The public may consider security services one of the most essential after a disaster. This would include protection of damaged and vacated buildings and their contents, as well as the protection of other critical or essential facilities and supplies. Perimeter control, including barricading and cordoning off affected areas, is also likely to be required. The police may also be required to enforce new ordinances established during the emergency, such as imposed curfews. The police may also need to assist and control crowds. This may include controlling a mass exodus from crowded facilities or from densely populated areas. Traffic control may be extremely critical in vehicular-oriented segments of the stricken area. The police may be needed to control vehicular movement of the public and to expedite and assist the movement of emergency units. The protection of equipment or resources necessary to provide these services, such as weapons in the amory, should be considered.

11. Certain administrative services will be needed during the disaster operation. While these services, including duplication, data processing and recording the details of disaster activities, may necessarily receive low priority, they are nevertheless important. The protection of equipment and areas for such activities should be considered.

12. Local services may be needed to provide contamination control for the stricken area. This may include not only identifying and limiting access to contaminated areas but actually identifying released contaminants and their threat. If the police perform this function equipment and materials necessary to the identification of contaminants may be located in the crime laboratory, and should be protected.

13. Certain police and fire departments may depend on the use of auxiliary personnel during a major disaster. An identification of the potential numbers and uses of such personnel would give a hint of any increase in space or other needs that would arise during an earthquake disaster.

14. Police and fire departments may have primary and alternate methods of activating off-duty (and auxiliary) personnel for an emergency operation. The protection of such activation equipment or systems should be ensured.

SITE DESIGN

INTRODUCTION

Regional and specific site conditions must be considered in both the siting and the planning of police and fire stations. Everyone who participates in the decision-making process — local officials, architects, engineers and planners — must be aware of the unique earthquake potential and problems for each facility. Regional and specific site conditions will determine the kinds and degrees of earthquake-resistant design and operational planning that architects and fire and police officials will select when planning the facility.

If the specific state does not require regional seismic risk maps and geological data, preliminary information may be determined from maps available from several federal and state geologic agencies. The U.S. Geological Survey (USGS), for example, provides seismic risk maps and isoseismal maps. The Nuclear Regulatory Commission provides Safety Analysis Reports (SAR), which contain the results of detailed seismic studies covering areas within 200 miles of every nuclear power station. Several sources of information are considered in determining the seismicity of a region. These include

- historical records of earthquake damage;
- frequency of earthquake occurrence;
- magnitudes of previous earthquakes;
- epicenter location of previous earthquakes.

Actual site selection for police and fire stations is dependent on factors such as economics, overall operational methods, high risk areas, travel time, security, visibility, image, flexibility and efficiency. Site selection criteria may include the following elements:

- Service Delivery — the type of services and speed of response needed. Operational concerns, service area composition and industry criteria such as contained in the Insurance Services Office (ISO) Grading Schedule tend to become major determinants of design and equipment of fire stations.

- Geographical Center — the center of the recognized service delivery area, such as a neighborhood or district.

- Accessibility — access to freeways and streets to ensure quick response to calls, as well as accessibility to the public by public or private transportation.

- Helicopter Accessibility — including the effect on surrounding neighborhoods of helicopters as well as the actual overhead accessibility of the location.

- Site Conditions — including geological conditions, terrain, land availability, proximity to hazardous sites and structures.

- Explansion Flexibility — including provision for growth of the facilities or future operational changes.

- Cost — including land, construction and maintenance cost at a particular site.

- Surrounding Area — including the compatibility with and proximity to related agencies, the surrounding land uses and community acceptance.

- Security — including the desired security level for the facility.

- Future Change in Surrounding Area — neighborhoods change, with potentially significant impact on all of the preceding factors. Consideration should be given to the planned or possible future of the site and surrounding area.

In addition to these selection criteria, specific geologic conditions of potential sites should be carefully studied before one is selected for the facility. A qualified consultant in geology, seismology or soils engineering can investigate potential sites to determine, among other things, site characteristics (soil structure, depth to bedrock, faulting and ground water level), ground failure potential, and ground motion potential.

DESIGN CHECKLIST

1. Have the geologic or seismologic conditions of the site been investigated?

Geologic Conditions

____

____

____

____

Ground Failure Potential

Differential Settlement

____

Liquefaction

____

Landslide

____

Faulting

____

Ground Motion Potential

____

____

____

____

2. If the site is located on land fill, what design strategies will be used to reduce the danger of settlement during an earthquake?

Piles

___

Basement

___

Excavation

___

Re-compaction

___

Other

___

3. If the site is located on a shoreline or adjacent to a body of water that may pose water hazards in an earthquake, what design mitigation strategies are contemplated?

Elevated Facility

___

Dikes, Flood Walls

___

Fill

___

Flood Shields

___

Controlled Flooding

___

Other

___

4. If the site is located near a river or on a dry river bed, what measures have been taken to reduce the potential damage from liquefaction?

Piles

___

Basements

___

Soil Stabilization

___

Pre-consolidation

____

Other

____

5. If the site straddles an active fault or is located in an active fault zone, has the fault been marked so that the building and utility lines (if possible) will not cross it?

____

____

____

____

6. If the site is on a hill or bluff, what mitigation strategies are being used to reduce the threat of landslide?

Slope Elimination

____

Retaining Walls

____

Tie-backs

____

Water Table Reduction

____

Other

____

7. Are there adjacent potential earthquake-generated fire risks that could threaten the station?

Structures Housing Hazardous Contents

____

High Voltage Substations

____

Gas Mains

____

Fuel Storage Areas

____

Fire-prone Buildings

____

Others

---

8. Does the condition of the adjoining streets offer the likelihood of safe and unobstructed egress and access following an earthquake?

   Location

   Size

   Hazardous Conditions

   Potential Obstacles

   Other

9. What are the type and location(s) of utility services, and has their protection been considered?

10. What type and condition are adjacent buildings?

    Types of Adjacent Buildings

    Condition of Adjacent Buildings

11. What other adjacent elements might be hazardous to the station in the event of an earthquake?

    Overhead Utility Lines

    ____

    Poles, Antennae

    ____

    Signs

    ____

    Others

    ____

COMMENTARY

1. Specific geologic conditions of the site should be carefully studied before the actual design of the facility. A qualified geo-technic consultant can investigate the site to determine the soil structure, depth to bedrock, faulting, ground water level, ground failure potential, and ground motion potential. This information will identify possible problems and allow the architect the opportunity to design or site the facility so as to mitigate these problems. Historical records show, for example, that deep deposits of soft soils tend to produce ground surface motion with longer period ground characteristics, while shallow deposits of stiff soils result in shorter period ground motions. Because of the potential for resonance to increase the motion imposed on the building, more rigid buildings would probably perform better on soft soils, while more flexible buildings would perform better on stiffer soils.

2. Settlement by compaction is a densification of generally loosely consolidated, cohesionless deposits due to vibration during the earthquake. Ground settlement, although rarely causing complete collapse, can render a facility completely inoperative. Land fills and other loose soil deposits are extremely susceptible to settlement. Strategies open to the architect if such a site has already been selected are the use of piles to provide support on a more reliable strata, use of basements to reduce the net pressure on the supporting soil, or, if the fill is sufficiently shallow, excavation and re-compaction.

3. Buildings located near bodies of water are threatened by a number of hazards that can be generated by earthquakes. Inundation or flooding may be caused by tsunamis (seismic sea waves), seiches (waves along lakes and bays), or the failure of dams. Beyond relocation there are several options available to mitigate these hazards, including elevating the facility or using dikes and retaining walls. The facility might also be sited on natural or artificial fill above the flood level. Flood shields can be used to keep water from entering the building through windows and doors. Conversely, controlled flooding could be provided by intentionally flooding the first floor to balance the external flood pressure on the facility.

4. Liquefaction is the transformation of granular material from a solid state into a liquified state. The materials prone to exhibit this effect are soft soils with high water tables, such as old river beds or sites near rivers, lakes or bays. When the soil is subjected to vibration the resulting upward flow of water can turn the ground into a composition similar to quicksand. Stategies open to the designer include using piles, providing basements, grouting the ground under the building with chemicals to stabilize the soil, or pre-consolidating (densifying) the soil material.

5. The most obvious earthquake hazard to a building is the fault rupture. If at all possible critical facilities should not be located across an active fault. Major damage to the building during fault rupture will be all but unavoidable. Of course, utility lines into the station may necessarily cross faults, but the use of loops and flexible joints can provide enough displacement to take the movement without rupture.

   Fissures or tension cracks may form in the ground after an earthquake. This does not pose a major problem as long as the foundation is tied together to provide the tension strength needed to hold the building together.

6. During shaking, the shearing stresses in the soil increase and the friction to resist these stresses decreases, causing landslides in hills or bluffs. Susceptibility increases when there are marked differences in soil conditions on sloping sites, such as clay soils or sloping fills. Stategies to reduce this hazard can be expensive, and include elimination of surface slopes, addition of retaining walls or tie backs, or reduction of water in the ground to increase friction. It is worth noting a facility is threatened by a hill or bluff adjacent to it as well as one on which it may be sited.

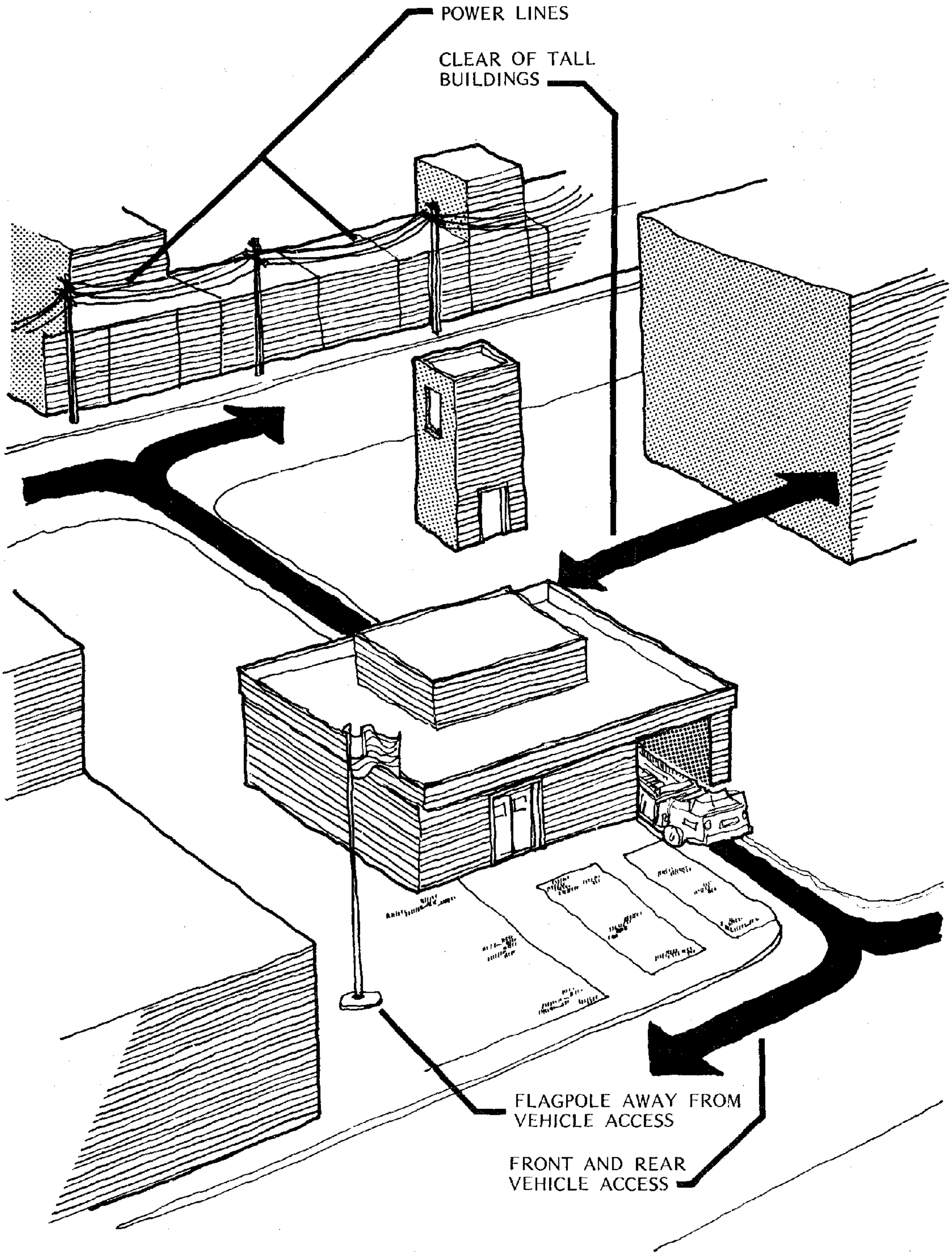
7. Potential fire hazards near the fire or police station should be identified and attention given to mitigating their threat to the functioning of the station. These include nearby buildings storing or manufacturing hazardous or flammable materials, high voltage substations, major gas mains, fuel storage areas, etc. Walls and fire breaks can be used if site conditions permit. Fire breaks or open spaces near the station can also be used as "safe" or staging areas for equipment and personnel in the event of an earthquake.

8. Whenever possible the architect should provide emergency vehicles with more than one exit from the facility in order to lessen the possibility that obstruction of one exit by debris and street damage would make it impossible for these vehicles to perform their disaster functions. If possible, exits should feed into adjoining streets that are wide enough not to be blocked by autos, collapsed building and other debris. Older buildings, utility lines and major gas mains pose potential dangers to egress routes.

9. Redundancy can be provided to the police or fire station's critical power source by two or more independent utility lines, connections and power sources. Certain nearby non-municipal utility sources might be utilized as back-up systems. Closed circuit utility systems in a grid pattern can promote maximum flexibility, since a break in the line will not put the system completely out of service.

10. Attention should be given to the possibile disadvantages of locating fire and police stations near other critical-use facilities such as hospitals because of the heavy congestion around these facilities following a disaster. If it is necessary to locate a station near one of these facilities multiple access routes can often provide access and exit from the station outside the service envelope of the other critical or high-use building.

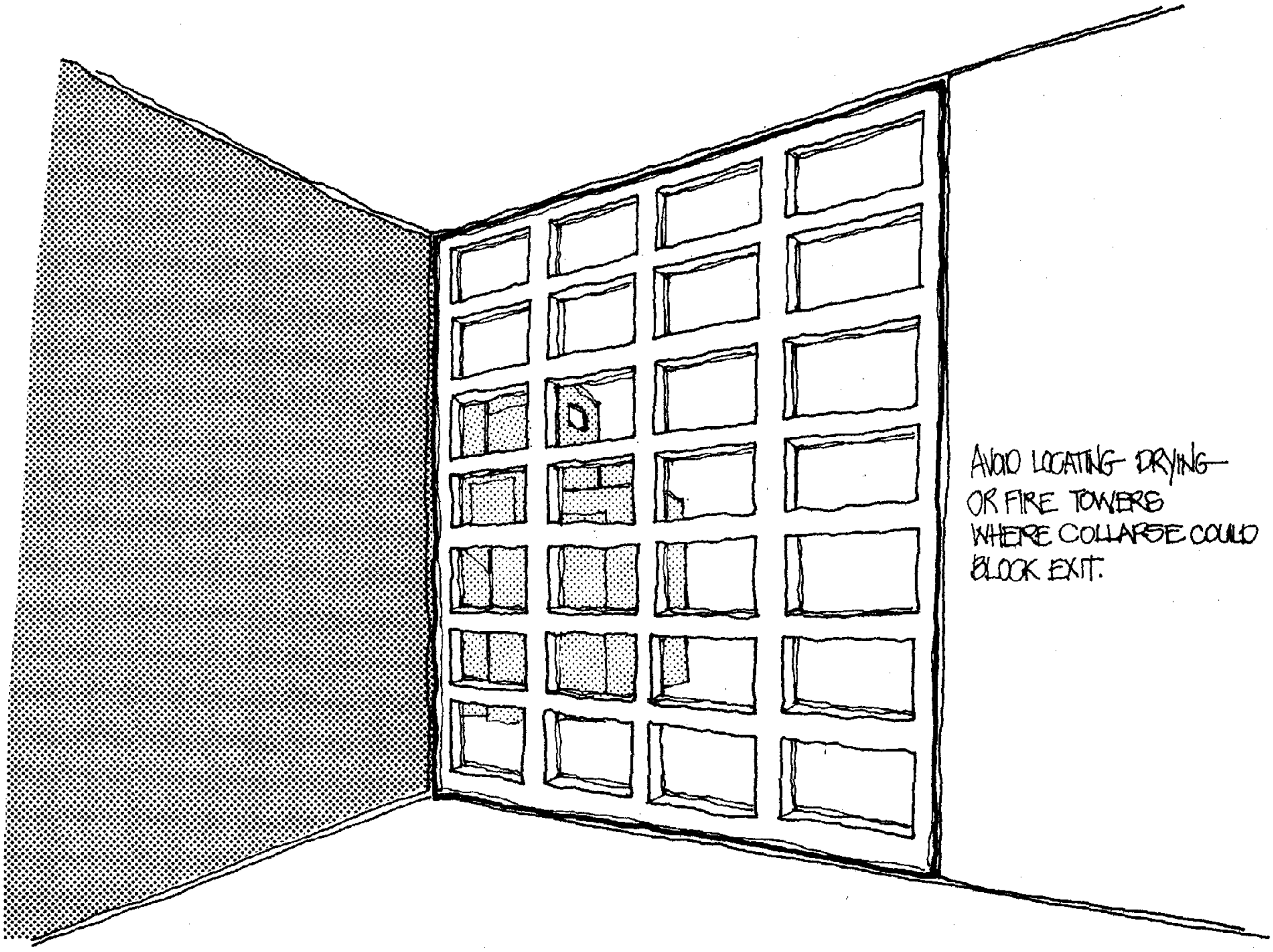
    Adjoining buildings, especially older and taller structures, may collapse, drop debris on or



FIRE STATION SITE SELECTION

pound the station during an earthquake. If an adequate distance cannot be provided between the station and such buildings the architect should consider providing the station with increased protection (especially the roof). The location and design of any fire tower or hose drying tower should also be such as not to pose a risk to the station.

11. The location of other surrounding elements should be considered during site planning and design of the station. Overhead utility lines, antennae, poles and large signs should not be allowed to pose a hazard to the station or to block its exits or egress routes.


AVOID LOCATING DRYING
OR FIRE TOWERS
WHERE COLLAPSE COULD
BLOCK EXIT.

SITE DESIGN

BUILDING FORM

INTRODUCTION

One of the decisions most critical to the ability of the police or fire station to withstand earthquakes and remain operational is the design of the basic form and configuration. Since the shape of the site, functional requirements, aesthetics and client wishes may present constraints to an optimal form for seismic safety, it is important that the architect understands how the station's form and structural configuration affect the building's seismic performance. Seismic design should be incorporated at the start of the design process, and a structural engineer knowledgeable in earthquake engineering should be an early member of the design team.

DESIGN CHECKLIST

1. How does the basic form of the station achieve symmetrical qualities?

2. How does the selected structural system respond to the desired seismic performance of the station?

3. How will the selected materials and structural system of the station promote uniform behavior during an earthquake?

4. How do the structural system and materials utilize or achieve ductility and good damping characteristics?

5. How has the weight of the station been effectively reduced to provide a decrease in the applied earthquake forces?

____

6. How has the diaphragm of the station been designed and used to effectively provide the proper transfer of lateral forces?

____

7. How has redundancy been designed into the structural system of the building?

____

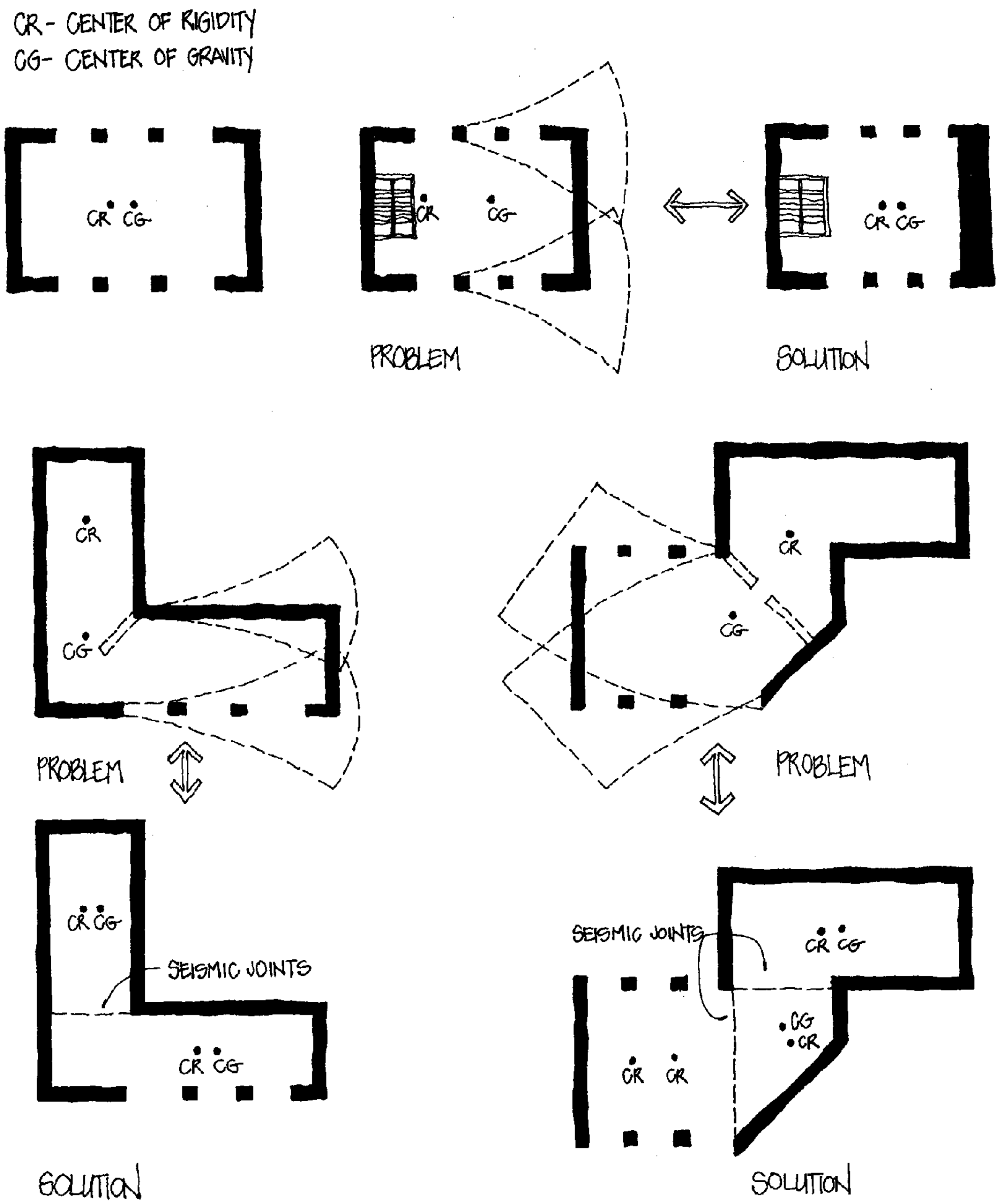
8. How have connections and joints been designed so that the building will act together as a total unit during ground motion?

____

COMMENTARY

1. Past experience has shown that buildings that are unsymmetrical in plan or elevation have greater susceptibility to earthquake damage than symmetrical structures. In any building in which the center of gravity of the lateral forces fails to coincide with the center of rigidity of the vertical resisting elements, major torsional moments are generated during an earthquake. Another important aspect of symmetry is the general undesirability of reentrant corners because of high-stress concentrations in these areas.

   Pure symmetry of outer form does not necessarily produce lower torsional effects, however, as can be seen in a relatively symmetrical police station with a stiffer (more rigid) core located off-center in the plan and elevation, which causes the center of rigidity to move from the center of gravity. Thus, instead of pure symmetry what is really required is a coincidence of the mass, strength and stiffness of the building.



TORSIONAL EFFECTS

The fire station apparatus room that has three of its walls either solid or with minimal openings, while the other wall is open, can produce major torsional forces. When shaken by an earthquake, the solid walls remain rigid while the front wall is flexible, causing the roof to twist. Any increase in the length of the building beyond the depth will cause a rapid increase in the torsional deflections.

There are several strategies open to the architect in the conceptual design phase to provide this basic "symmetry."

- The architect can design a completely symmetrical building, both in plan and elevation.

- Distinct units may be separated out of an irregularly shaped facility by the use of seismic joints at the junctions. Several problems can be created by this strategy. The joint should proceed through the entire building, so any nonstructural systems such as partitions or service lines will not be damaged if also provided with joints of flexibility. Water penetration or fire problems may be created by the joints. Most importantly, pounding of the adjacent units during the earthquake may create major damage potential.

- If an asymmetrical form or layout is required the architect may design and locate certain structural or nonstructural elements in the building to bring the centers of gravity and rigidity closer. Such a strategy requires the technical assistance of the structural engineer in locating and designing such elements.

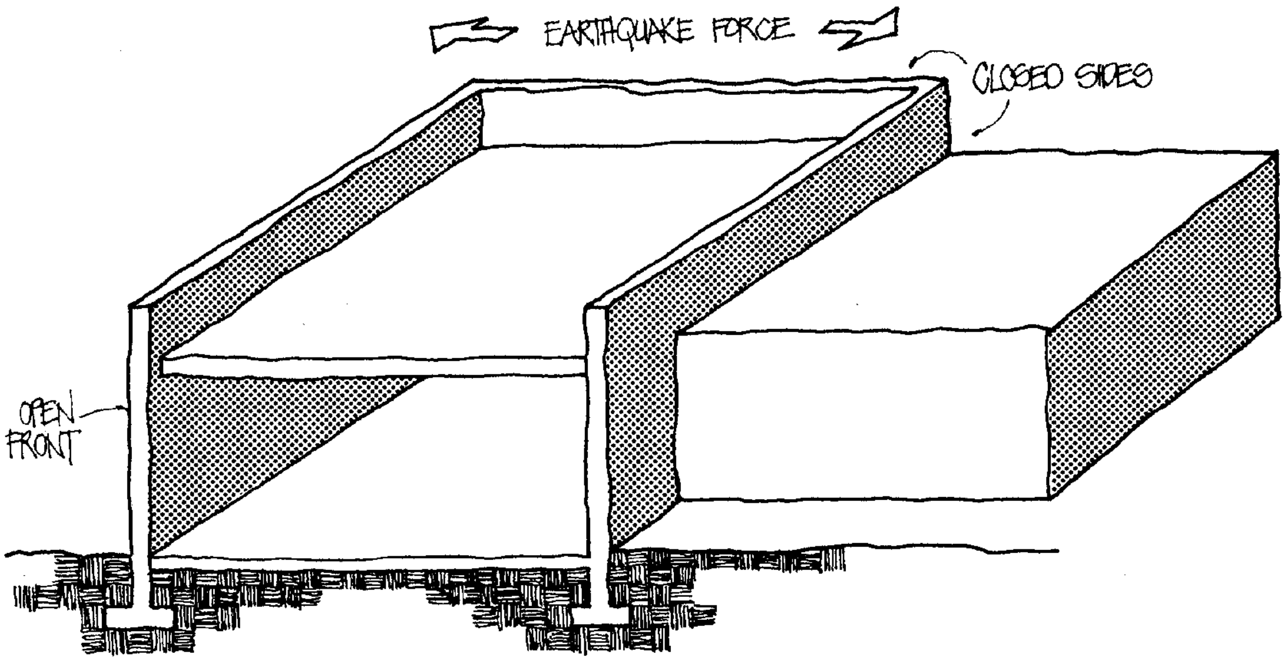
2. The basic flexibility or rigidity of the facility will determine the mode of response of the building during an earthquake. If the local ground motion is in the frequency range of the natural frequency of the building, the resulting resonance will cause maximum punishment to the station. Softer soils will produce longer period ground motions that correspond with the natural period of vibration of more flexible buildings, increasing the damage probability. Conversely, more rigid (shorter period) buildings will correspond more closely to periods produced by firm soils.

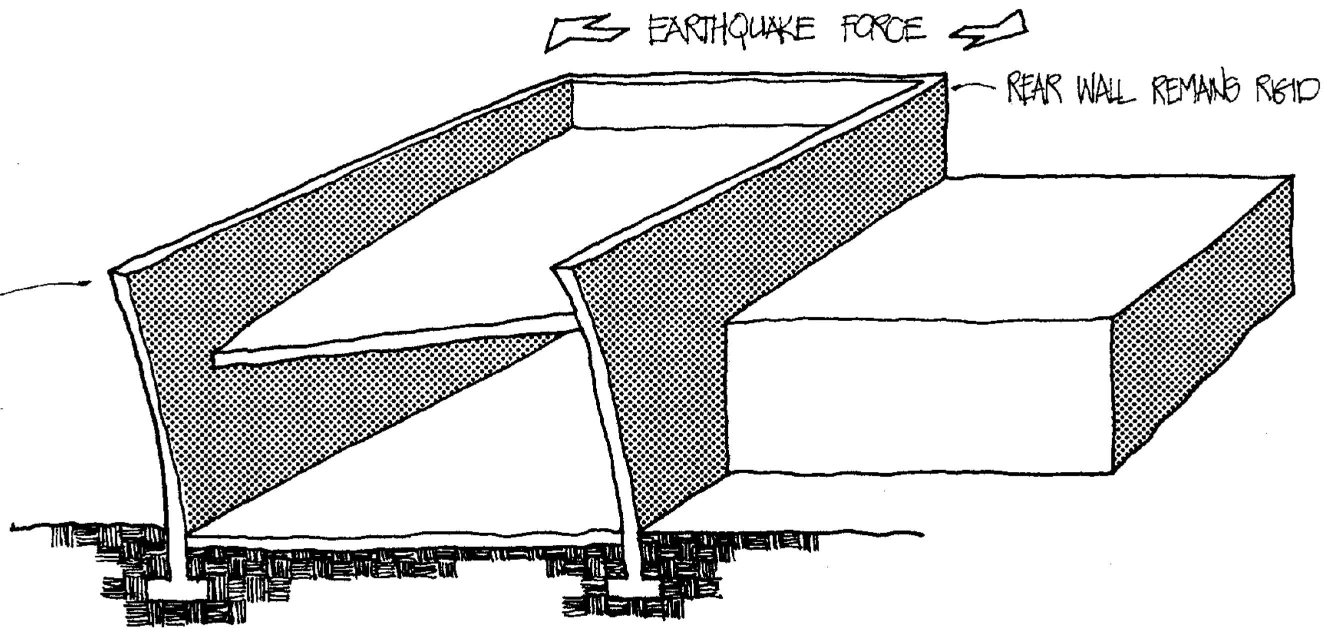
Nonstructural damage can also be dependent upon the relative rigidity or flexibility of the building. Flexible structures, because of their relative movement during an earthquake, will impose greater deformations and damage potential to nonstructural elements and systems. More rigid buildings have experienced less damage to nonstructural elements because of their opposition to deformation.

In essence, stiffer or more rigid buildings respond better on soft soils with less nonstructural damage. More flexible buildings respond better on firmer ground, but will increase the nonstructural damage potential and respective design costs.

Calculation of the natural frequency of the building can be quite difficult, especially for complex buildings. There is also the disadvantage that the structure must be designed before the frequencies can be determined. Once the site characteristics are determined, the architect can determine what type of structural system would be most appropriate.

Most fire and police stations (except fire apparatus rooms) will be relatively rigid buildings, as opposed to the varieties allowable in higher-rise buildings. Nevertheless, there is a range of rigidity/flexibility open to the designer through the use of structural systems or materials.





TORSIONAL EFFECTS

A modified system can be designed by incorporating rigid shear walls into a frame structure. The architect must understand that when using shear walls the number and size of openings in the wall will decrease the resistance of the wall dramatically. In a fire station, for example, the shear wall, when broken up by large openings close together, in effect becomes a frame structure.

Either stiff or flexible structures can be made to work through proper engineering analysis and design, but the architect should consider the advantages and disadvantages of both systems to select the most optimum concept.

The architect can select a more rigid structure based on several considerations.

- Suitability for long period (soft soils) sites
- Less nonstructural damage potential
- Easier nonstructural details to prevent damage

A more flexible building may be selected based on several other considerations.

- Suitability for short period (firm ground) sites
- Easier achievement of ductility (energy absorption)
- Usually a lighter structural system

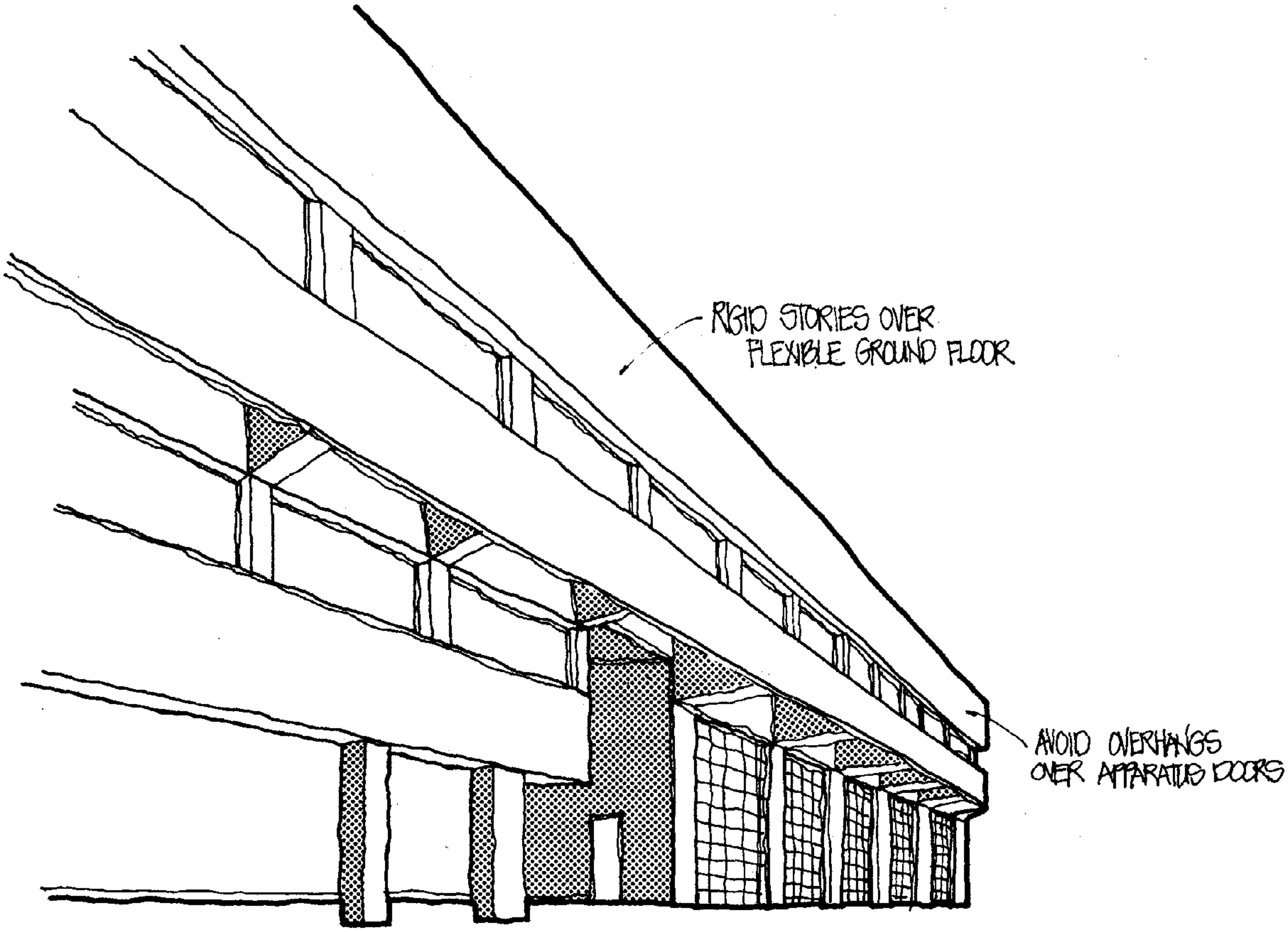
3. Since different materials, structural systems and sizes of members react differently during ground motion, it is apparent that, in any building, incorporating a range of materials, structural systems and member sizes can have disastrous consequences because of the differing reactions of the various elements.

   It has been proposed from time to time that a rigid structure could be protected from short period vibrations by making the bottom story relatively flexible (non-uniformity of structural systems). However, experience in earthquakes has shown the opposite.

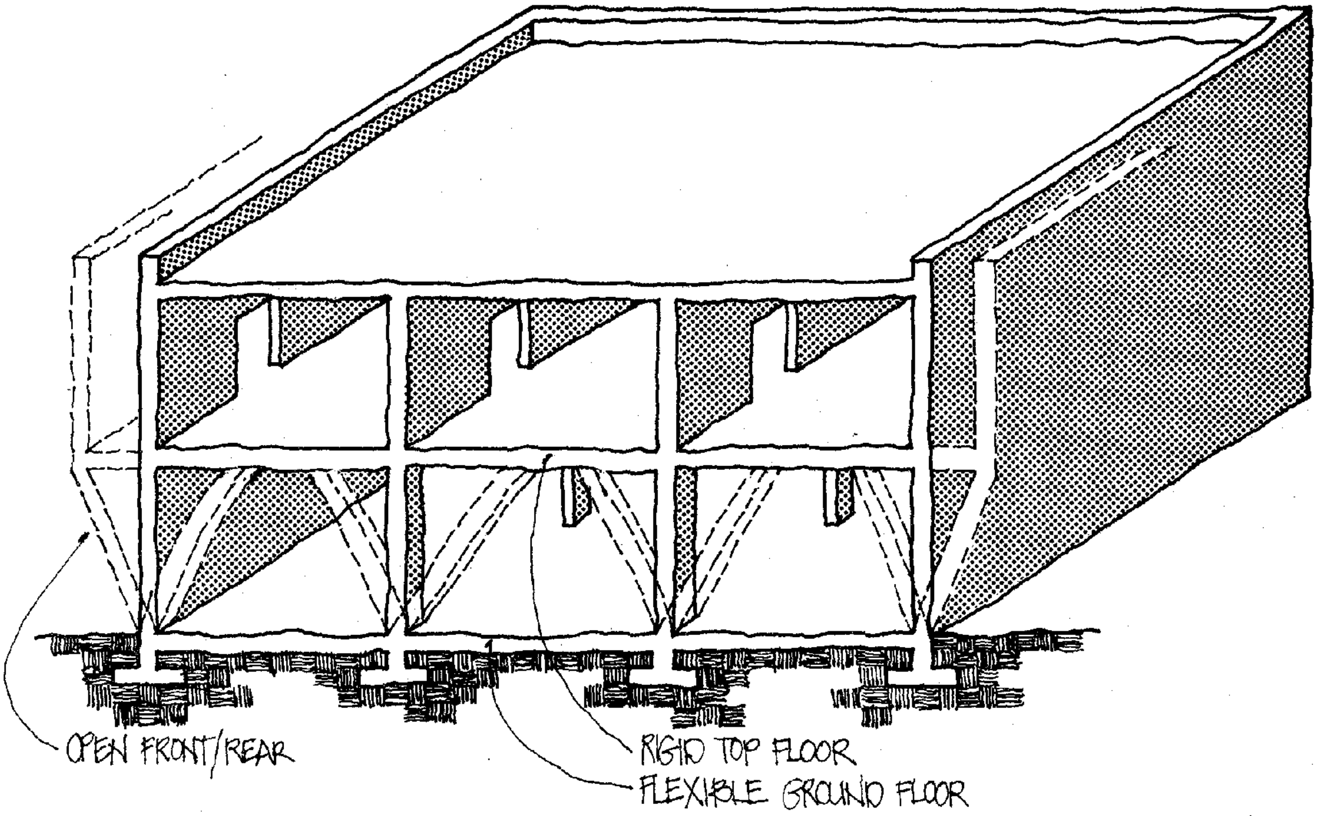
   For example, a police or fire facility with rigid vertical resisting elements above a beam and column lower story could create an adverse dynamic response. The discontinuity of stiffness in height will cause the building to respond to ground shaking like an inverted pendulum, and the flexible portion (offering less resistance) will receive maximum punishment. This situation can be common in fire station design when placing dormitory space above the apparatus room or when designing police facilities with an open first floor parking arrangement.

   Uniformity must also be considered in plan as well as elevation. The location of a flexible structural system such as the apparatus room (long span beams/column) in a fire station or exercise area or gym (long span steel joists) in a police station can be very important when the rest of the station is a more rigid structure. Such separate structural systems will react differently under dynamic conditions, causing damage between the different systems through torsional forces and pounding.

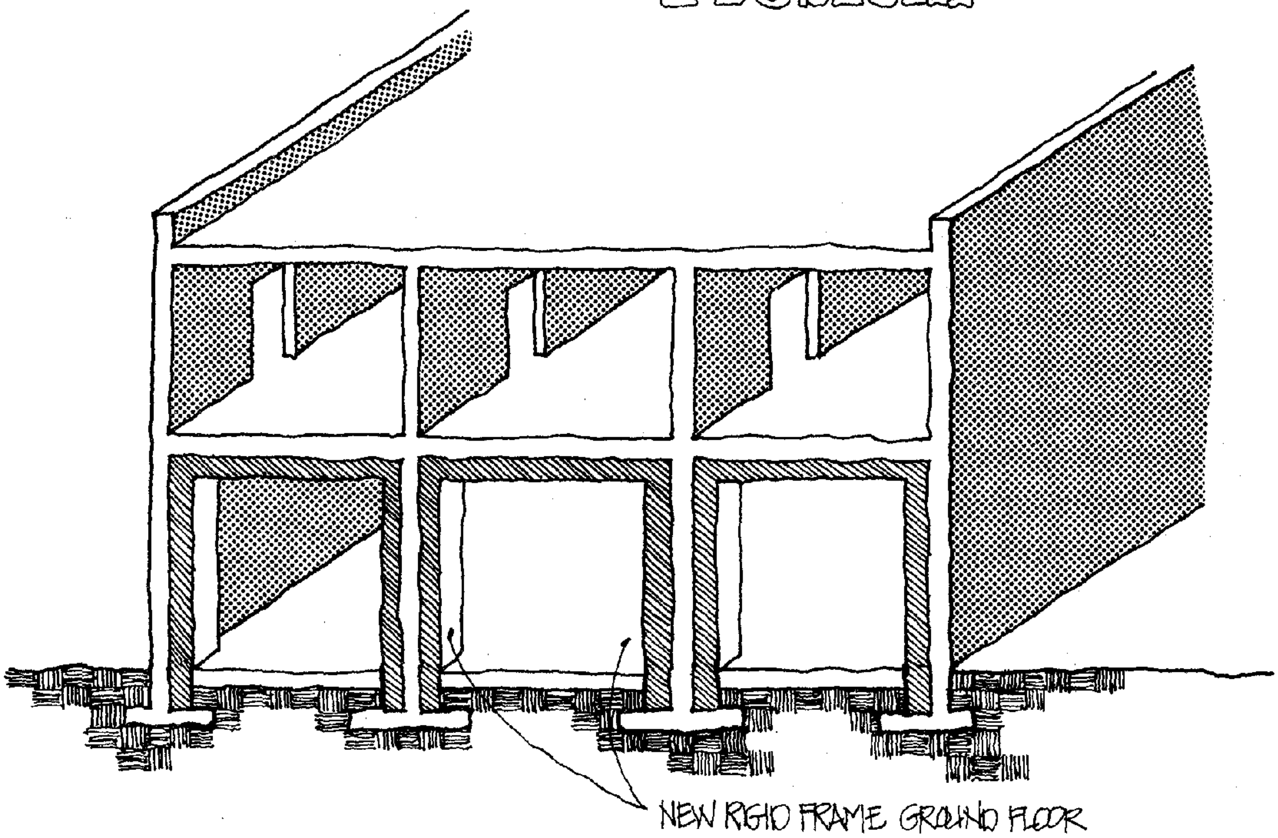
   Even in a facility using a uniform system throughout the building, the use and location of certain "nonstructural" elements may actually change the response of certain structural elements. This in effect changes a uniform system into a collection of systems, each acting differently. For instance, the location of a rigid element (stairs, infill masonry) adjoining or connected to a flexible element will change the performance of that element. Many times the structural elements are analyzed and designed before the location of these


RIGID STORIES OVER FLEXIBLE GROUND FLOOR
AVOID OVERHANGS OVER APPARATUS DOORS

UNIFORMITY



Problem



Solution

elements is determined. Thus, if a column is designed for a full height deflection, and because of the location of a rigid element it becomes a "shorter" column, it will actually carry a larger portion of the lateral forces than assumed.

The architect has several strategies available to provide uniformity in the station.

- The architect can design a facility that is uniform in the design and use of structural system and materials.

- If this is impossible because of other design concerns, non-uniform segments of the facility can be located to provide some compatibility. An example would be the possible location of a long span section (gym, firing range) within the more rigid facility to provide an increased degree of stiffness to the flexible portion.

- The architect can design the different systems to become more compatible. For instance, the open end of a flexible apparatus room in a fire station can be given an increased degree of stiffness to make it more compatible with more rigid adjoining dorm/office spaces.

- The non-uniform sections of the facility can be separated from the rest of the facility through the use of seismic joints.

- The architect can use certain nonstructural elements (stairs, infill, partitions) to increase the stiffness of certain structural elements to increase their uniformity. Conversely, the architect must ensure that the locations of stiffening "nonstructural" elements are considered in the structural analysis of the building.

4. Ductility can be thought of as the quality of toughness that, to a large extent, determines the building's survival during an earthquake. Ductility is the energy absorption capacity of the structure in the inelastic range. The ductility of a structure depends on the type of structural members, their connections and the construction materials used.

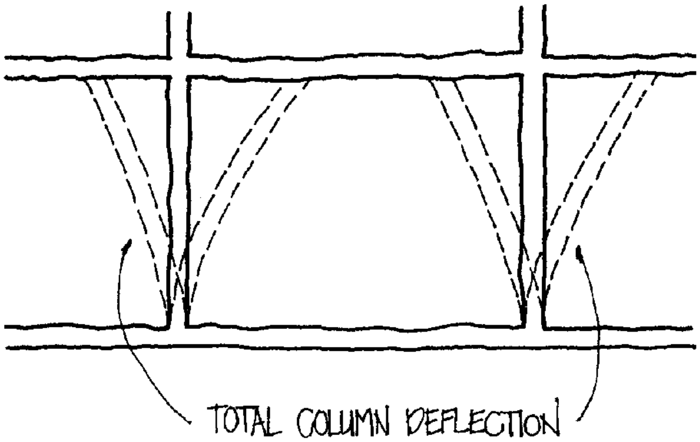
   In brittle materials cracking will occur and, as more and more displacement occurs with continued applied force, strength rapidly deteriorates. Ductile materials can undergo a limited number of cycles of loading while maintaining the energy absorption capability.

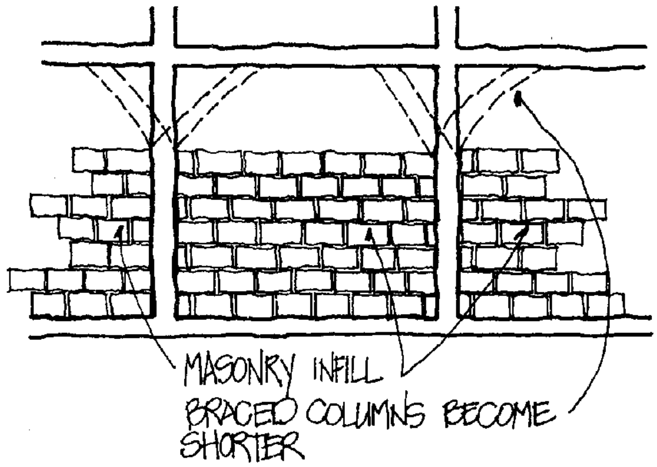
   Ductile building systems include steel frames, ductile concrete frames and wood diaphragm construction. Brittle materials, such as concrete and masonry, can be given an element of ductility through the proper use of reinforcement and containment of materials.

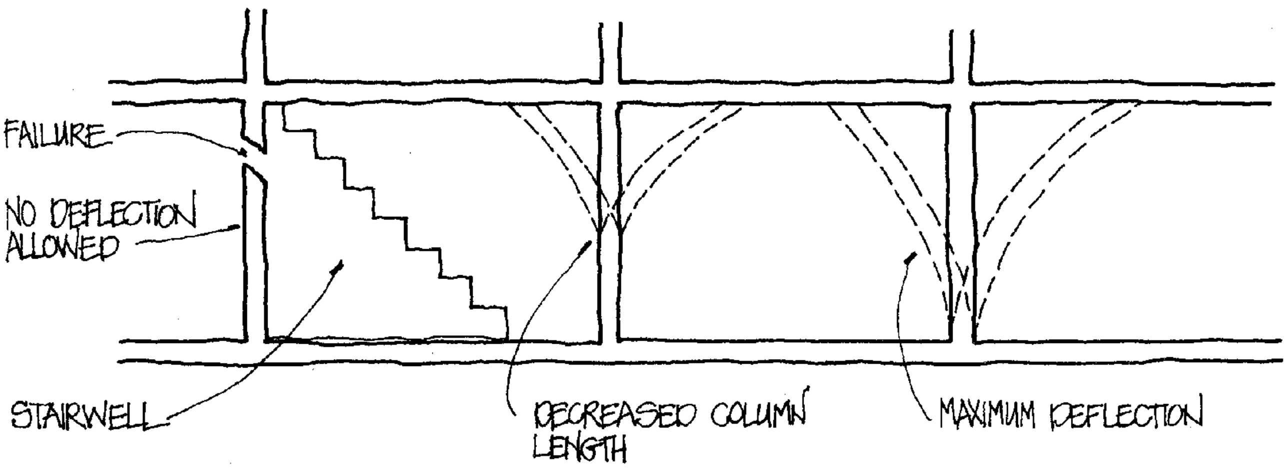
   One point should be made about the use of filler walls between frames. Because the building becomes stiffer with the introduction of filler or shear walls, the ductility of the system consequently decreases.

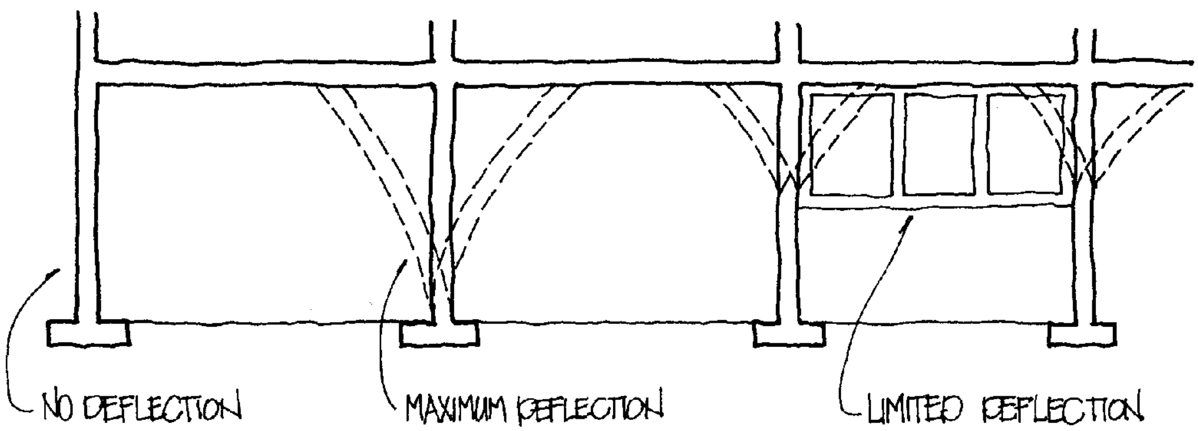
   Damping is the rate at which natural vibration decays as a result of the absorption of energy. Thus, the damping characteristics of the structural system will significantly reduce the maximum deflections due to resonant response.

   The architect has several strategies to increase the basic ductility and damping


TOTAL COLUMN DEFLECTION


MASONRY INFILL
BRACED COLUMNS BECOME SHORTER


FAILURE
NO DEFLECTION ALLOWED
STAIRWELL
DECREASED COLUMN LENGTH
MAXIMUM DEFLECTION


NO DEFLECTION
MAXIMUM DEFLECTION
LIMITED DEFLECTION

UNIFORMITY

characteristics of the building.

- A structural system and materials can be selected that are inherently ductile.
- Less ductile systems can be designed and detailed to increase their ductility.
- Certain energy absorbing or damping devices can be considered to absorb or dissipate energy by inelastic deformation, friction or heat transfer. Examples include the use of friction dampers and visco-elastic layers.

5. The force of an earthquake on a more or less rigid building is equal to the mass of the building times the ground acceleration. The higher acceleration and or mass, the greater the resultant force. The ground acceleration cannot be controlled, but the weight of the building can be, to varying degrees, by the architect. Lightweight construction materials and systems will minimize seismic forces, although other considerations such as energy conservation, fire resistance and cost must be considered.

   The architect may, for instance, decide to use lightweight concrete rather than normal-weight concrete. Such a decision will not only lower the weight of the building, but can also provide better fire safety, since lightweight concrete retains more strength during heat build-up, has a lower coefficient of thermal conductivity and seems more resistant to spalling during fire.

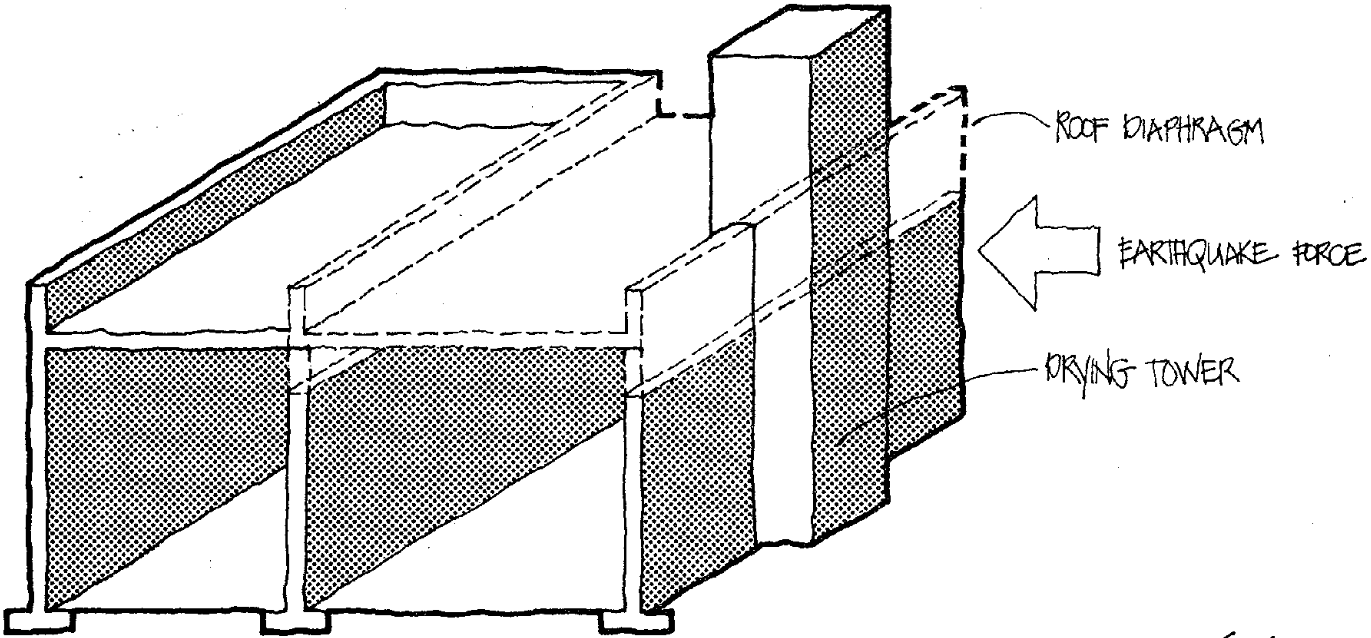
   Another example of an opportunity for the architect to design a lighter-weight building is the use of security steel for detention areas. Security iron can increase the overall weight of a police facility dramatically. Savings in both weight and dollars can be made by not over building security and detention areas beyond actual needs, or by using detention and security concepts that require less steel.

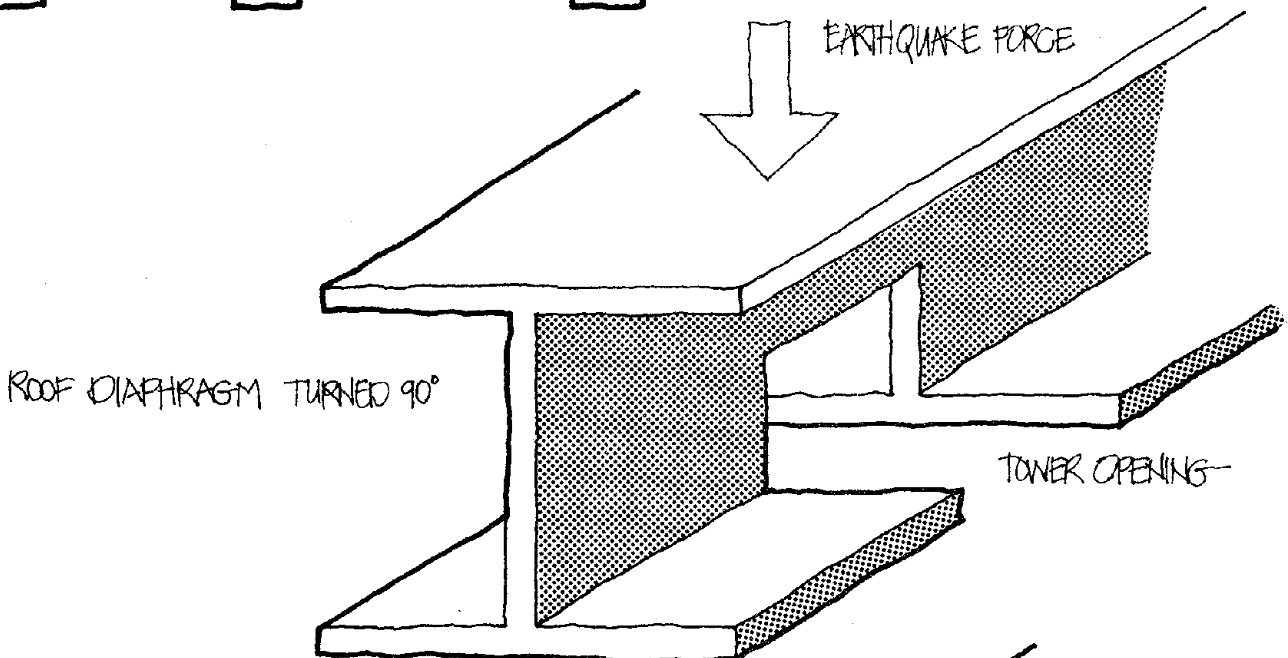
   A helicopter pad on the roof of a police station is an efficient use of land and space. However, the helicopter and the pad itself increase the weight of the building. If this is considered along with the possibility that the pad may be unusable because of damage, or the uncertainty of damage, following an earthquake, it may seem more beneficial to locate the pad on adjacent land, if available and within economic limits.

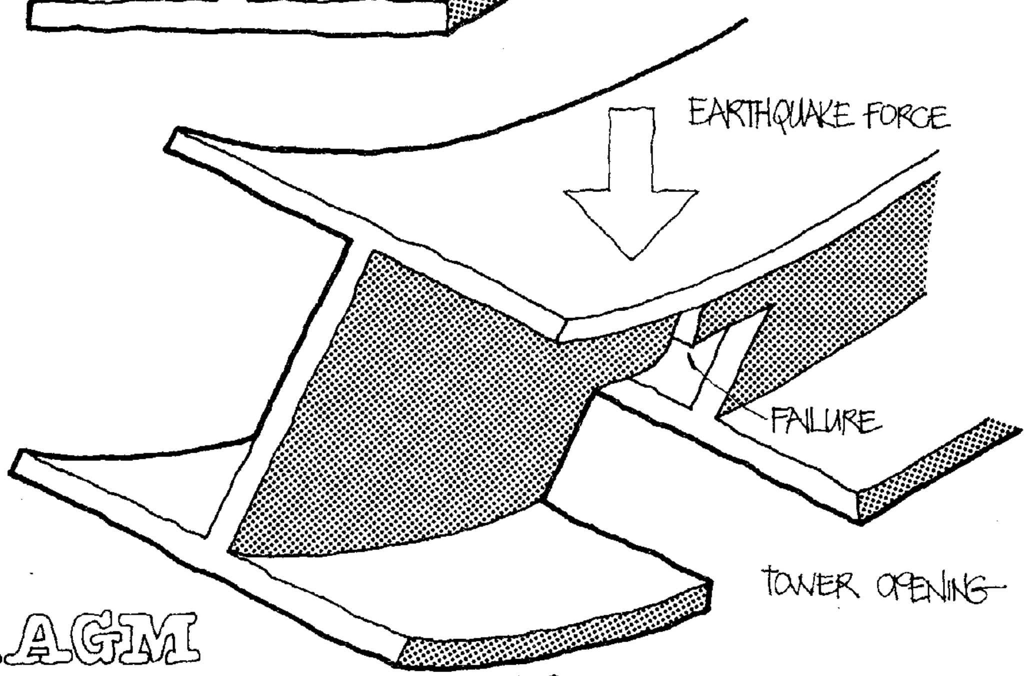
   It should be pointed out that any decrease in weight through the selection, use and design of the structural system and materials must be weighed with the needs for redundancy in the structural system.

6. During an earthquake the total shear at any level in the building will be distributed to the various vertical elements of the lateral force resisting system in proportion to their rigidities and the rigidity of the diaphragm. In more rigid diaphragms the force will be distributed in larger proportion to those vertical members having greater relative rigidity. In more flexible diaphragms the force is distributed in larger proportion to those vertical members having lower relative rigidity. The common assumption that a diaphragm is infinitely stiff in comparison to the vertical resisting elements is not necessarily true. The differences in relative rigidity between the diaphragm and vertical elements must be considered, especially when heavy shear walls are used. Thus, the type of vertical resisting elements affects the selection of the diaphragm.

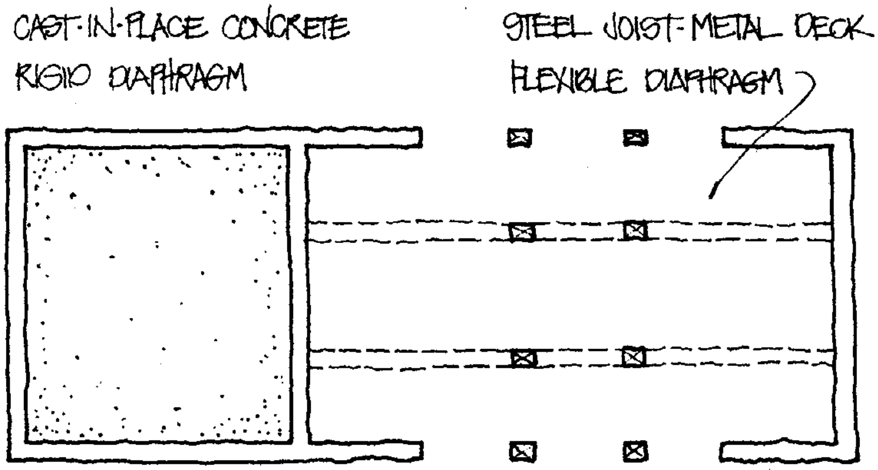
   The rigidity of the diaphragm is important, since very flexible diaphragms could give insufficient support for the wall elements, permitting the walls to fail as cantilevers. In

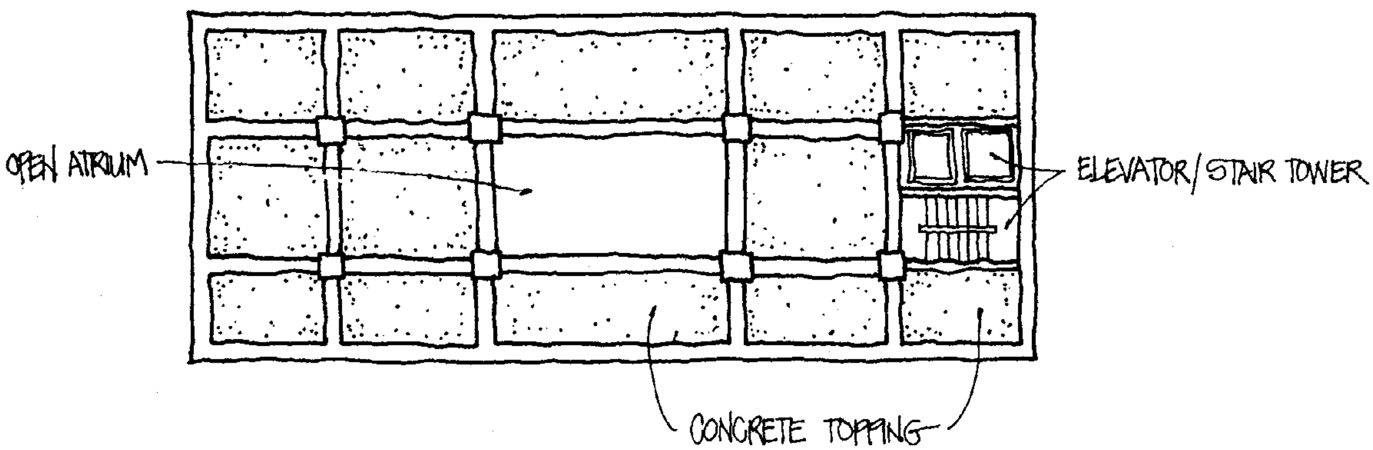

ROOF DIAPHRAGM
EARTHQUAKE FORCE
DRYING TOWER


EARTHQUAKE FORCE
ROOF DIAPHRAGM TURNED 90°
TOWER OPENING


EARTHQUAKE FORCE
FAILURE
TOWER OPENING

DIAPHRAGM





DISCONTINUITY IN DIAPHRAGM STIFFNESS

addition, when rigid diaphragms are used the effect of unsymmetrical forms and structural elements will be reduced, since rigid diaphragms can develop considerable torsion. Also, more flexible diaphragms will permit portions of the building to vibrate out-of-phase with the rest of the structure, creating major torsional and displacement problems.

Diaphragms act as deep beams with the decking (web) carrying shear and the spandral beams or walls (flange) resisting bending. Boundary members at diaphragm perimeters must be designed to resist tensile strength as well as compressive stresses. This requires continuous structural chords at the perimeter of the diaphragm to provide tension and compression strengths.

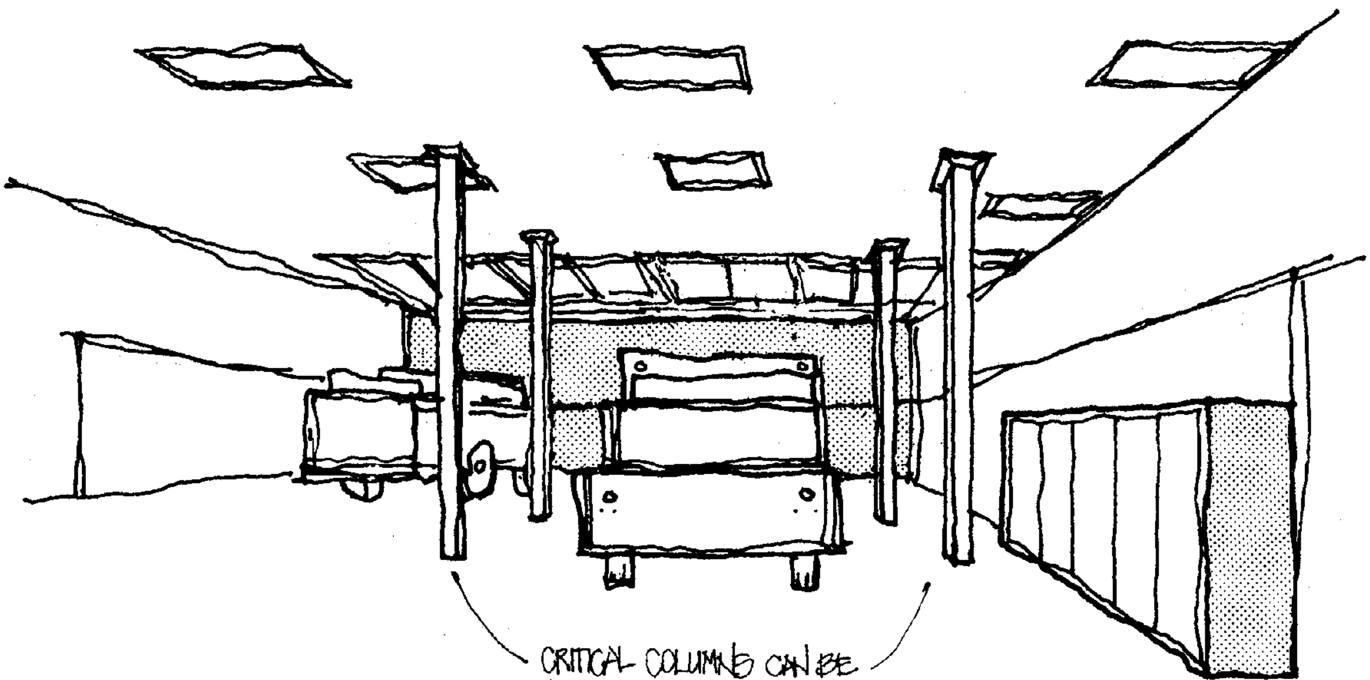
The location of large openings in the diaphragm is in reality cutting a hole in the web of the beam. These openings can come in the form of stairs, elevator cores, atriums, skylights and access routes to helicopter pads.

Horizontal diaphragms must be adequately reinforced to transfer all lateral leads to the vertical resisting elements. This means not only tying the diaphragm together but also tying it to the vertical element to develop the adequate diaphragm action.

The following classes of diaphragm rigidities are given.

Rigid:	Diaphragm of cast-in-place concrete.
Semi-rigid:	Metal deck diaphragms with structural concrete topping. Metal deck systems made up of one fluted element and one flat element. Pre-cast concrete elements with structural concrete topping. Horizontal steel bracing. Steel deck systems with insulating concrete fill.
Semi-flexible:	Well blocked and nailed plywood. Double diagonal sheathing or straight sheathing plus diagonal sheathing. Metal decks with fluted elements only.
Flexible:	Unblocked plywood. Diagonal wood sheathed floors or roofs. Straight wood sheathed floors or roofs. Corrugated iron roofing (screw fastened).

7. Redundancy in the structural system of the building can be that second line of defense that makes the difference between survival and collapse. The police or fire station should be designed so that a failure of any one element would not cause the failure of the system. And, the failure mode of the element should not be viewed only in the traditional sense of failure from the lateral earthquake force. In a fire station apparatus room containing only four columns and walls, for instance, the loss of only one of the columns could cause progressive collapse. The failure might result from the earthquake force itself or from apparatus being displaced a few feet by the earthquake force and colliding with the column.



REDUNDANCY

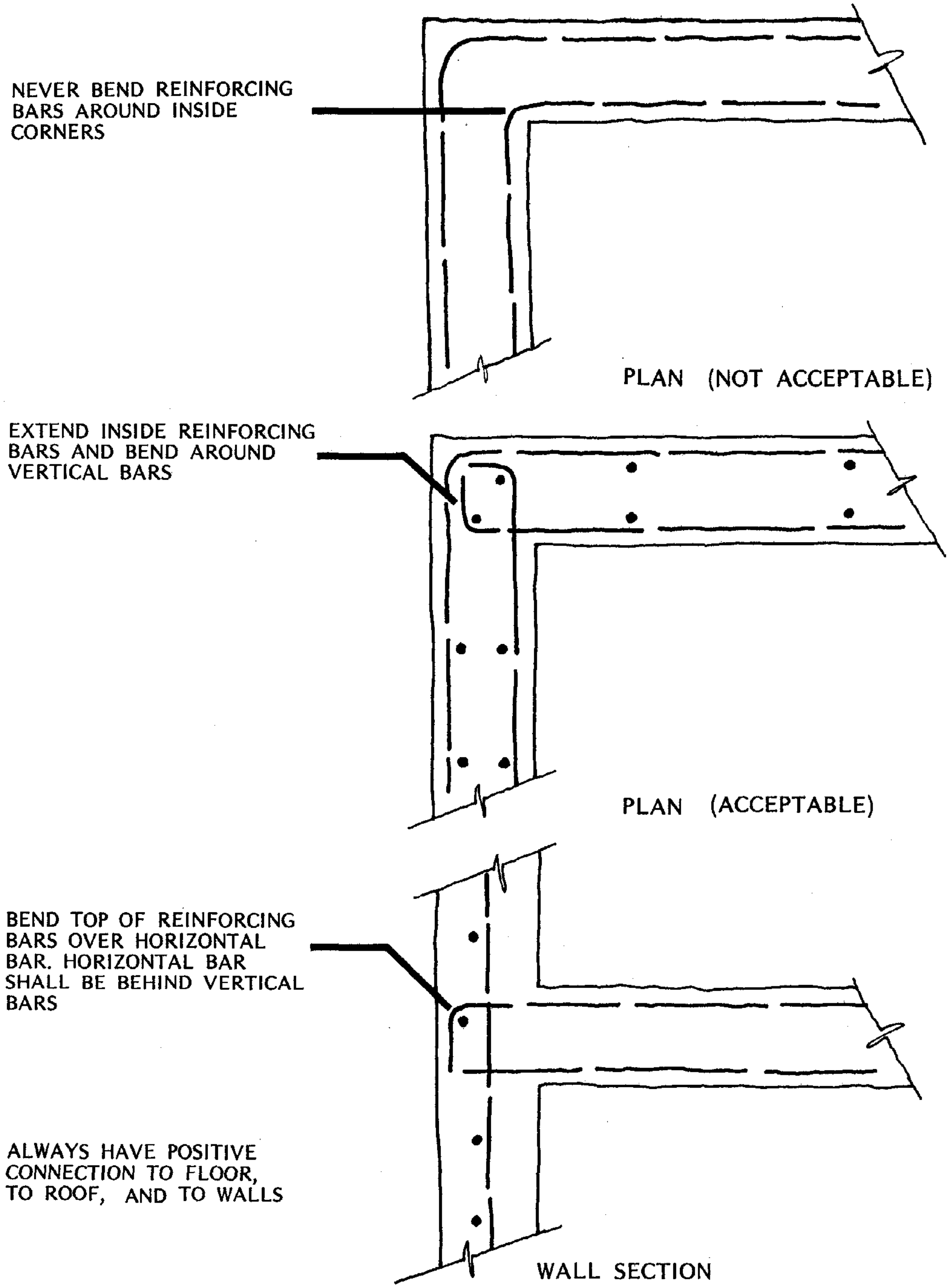
It can be economically and functionally preferable to have one definite means of resisting a given load. In seismic design, however, multiple systems should be used when the damage to one element could cause complete failure. This can be in direct conflict with the philosophy of using only one type of structural system in order to provide for a more uniform reaction to the earthquake forces. Redundancy, however, can be accomplisheed by increasing the number of existing elements (columns, shear walls) as well as by adding new elements, such as steel cross frames, to the existing system.

Moreover, by slight adjustments some elements can be given a second, redundant function. For instance, a masonry shear wall may also be used as a bearing wall with a small increase in the size or reinforcement bars.

The architect has several options available to ensure that the failure of any one structural element would not cause the complete failure of the building.

- The architect can ensure that there are no single critical elements in the structural system.
- If this is not possible, the architect can review the location of those necessary critical elements to ensure that they are not susceptible to damage from nonstructural elements.
- The more critical elements can be designed to increase their seismic resistance beyond code requirements.
- These elements can be increased in number to ensure that no one element becomes crucial to the entire building.
- New elements or systems can be included with the primary structural system, taking extreme care that the seismic interactions of the dual systems are considered.

8. Foremost among the requirements vital to earthquake-resistant design is the necessity of tying the structure together to act as a unit. Obviously, a structural element cannot transmit shears, moments and torsions in excess of the connections used to join the element. The seismic resistance of the facility should depend on the ultimate strength of the building elements, and not just the connections.



WALL SECTION

FUNCTIONAL SPACE CRITERIA — POLICE STATIONS

INTRODUCTION

The police station serves as a point of departure, arrival and coordination of police personnel, vehicles and equipment. Though the majority of police personnel are in the field, the station must be designed to accomodate large numbers of personnel during specific times of the day. In addition, the police station should provide easy access for the public's transactions of police business. In fact, one city of 700,000 experiences an average of 4,000 persons visiting the city's stations monthly, in addition to processing an average of 5,000 arrestees and detained persons. Combined with the number of police and civilian personnel on duty in the station, it is readily apparent that the station must be designed to function efficiently in a minimum amount of space while also maintaining the capacity to accomodate increased numbers of persons during certain times of the day.

Different police stations have different space and design needs, depending, among other things, on the organization of the community's police operations. Cities may centralize all police operations into one building, creating a large, complex facility. Others may centralize some operations and place other overall operations into various precincts and districts. These stations may be major facilities delivering services to all districts and precints, or they may be smaller facilities serving defined areas as in the case of district stations. A police station may also be a neighborhood or "storefront" station, which is more community-oriented and provides convenience, social and municipal services in an informal setting. Another city may have police operations that are a mixture of all three concepts. Coupled with the inherent differences between urban and rural police service delivery, a universally accepted definition of a police station is, in reality, nonexistent. Each department develops and responds to local conditions, variables, constraints, etc., creating a unique police delivery system. Even district stations vary within and between cities. The population that a police district serves may range from a few thousand to hundreds of thousands, and the service delivery area may range from a few square miles to over a hundred square miles.

The location of functional activity areas within the police station should be planned to facilitate efficient operations. This includes locating certain activities adjacent to others that require strong task interrelationships (e.g., booking area adjacent to temporary holding area), as well as separating certain functions that may have disruptive effects on other activities (e.g., booking area separate from lobby/reception area).

The following categorization is a listing and description of possible functional activity areas in a police station. A discussion of seismic design concerns related specifically to each area is given. These areas are not programatic in the sense that all or even a majority of stations would require each area. Some areas might be eliminated, combined or added, depending upon the individual department's program requirements.

DESIGN CHECKLIST

1. What performance and protection criteria are attached to the individual functional areas of the police station?

   Particularly Vulnerable Areas

   ____

   ____

   ____

   Areas Housing Critical Equipment

   ____

   ____

   ____

   Critical Operational Areas

   ____

   ____

   ____

   Secure Areas

   ____

   ____

   ____

2. What design strategies have been developed for the protection of the public and police personnel in the Administrative Areas?

   Lobby/Reception Area

   ____

   ____

   ____

   Clerical Areas

   ____

   ____

   ____

Staff Offices

Restrooms

3. What seismic design consideration has been given to protecting the personnel in the Operations Areas or to using the space for disaster operations?

Briefing Room

Detective Operations Area

Interview/Detention Area

Juvenile Operations Area

4. How have the Communications Areas been designed and planned to ensure their operational capability during the disaster period?

Communications Center

Electronic Maintenance Area

5. What design strategies have been used to protect the important contents housed in the Records Area?

Central Records

Data Processing System

6. What seismic design consideration has been given to the protection of prisoners confined in the Prisoner Processing Areas?

Sallyport

Booking Area

Temporary Holding Area

Detention Area

7. How does the seismic design of the Evidence Areas protect the important contents located in these areas?

Evidence Receiving/Processing Area

Evidence Storage Area

Crime Analysis Lab

Recovered Property Storage Area

8. What seismic design strategies have been used in the Support Function Areas of the police station?

Library/Reading Room

Locker Area

Exercise Room

Day Room

9. What protection strategies have been developed for the hazardous elements located in the Weapons Areas of the station?

Armory

Firing Range

10. How have the Mechanical Areas of the station been designed to ensure that they remain in service during an earthquake disaster?

Mechanical Room

Emergency Generator Area

11. How has adequate earthquake protection been provided to the Vehicle Areas?

Vehicle Maintenance Area

___

___

___

Motor Court/Refueling Area

___

___

___

12. Have the Circulation Systems been designed and planned so that they can be safely used during the disaster period?

Corridors

___

___

___

Doors/Exits

___

___

___

Stairwells

___

___

___

Elevators

___

___

___

COMMENTARY

1. Seismic considerations can have significant impact, not only on the structural design, but also on the basic planning of a police facility. All building types share a vulnerability to structural damage from an earthquake, but police facilities face disruption of operations that are critical to the safety of the community. To ensure the capability for emergency operations, certain key areas of the police facility should remain functional. The concept and organization of areas within the building envelope will be influenced by this need to protect and coordinate the core disaster relief functions. Four major criteria are important in the seismic evaluation of the functional areas in a police station.

   - Areas that are particularly vulnerable to seismic damage.
   - Areas that house critical or important equipment/items that should be protected.
   - Areas that are critical to continued police operations during a disaster.
   - Areas that need to remain secure during and after an earthquake.

   The following charts display these criteria in relation to the functional areas that may be found in the police station.

2. Police facilities contain certain areas allocated for the combined use of administrative personnel and the general public. The reception area, most administrative offices, training rooms and conference rooms all serve as space for interactions between the department and the public. These areas should not only be well organized and easily accessible by the public; serious thought should be given to the public's protection in the event of an earthquake.

   The Lobby/Reception Areas serves as the public entrance and waiting area. A bright, cheerful and uncluttered appearance, coupled with acoustic control and easy accessibility, should make these area responsive to and usable by the public. Good visibility into this area for police personnel, as well as distinct boundaries to demarcate it from restricted areas, should be provided. The ramifications of certain security strategies should be considered in the event of an earthquake. A power loss during an earthquake may lock electrically controlled lobby doors, impeding exit from the station. Limiting the number of exits for controlled access may hamper mass evacuation after an earthquake. Limiting the number of windows in a station may, in a power failure, result in lighting and ventialation loss. Because of the potential for injury and panic of the public, the lobby area should receive particular attention. Large ornamental plaques and lighting fixtures, heavy furniture and glass trophy/display cases should be restrained by bracing or anchors.

   The Clerical Areas provide space for clerical duties, duplication services and office supplies storage for the station. The clerical area creates noise that should be contained or isolated from surrounding areas. Expansion and flexibility should be designed into the area. The large number of unrestrained pieces of heavy office equipment (desks, file cabinets), coupled with the number of personnel, could make this area extremely hazardous during an earthquake. In addition, unrestrained partial-height partitions could create hazards if they collapsed or were flung across the working area.

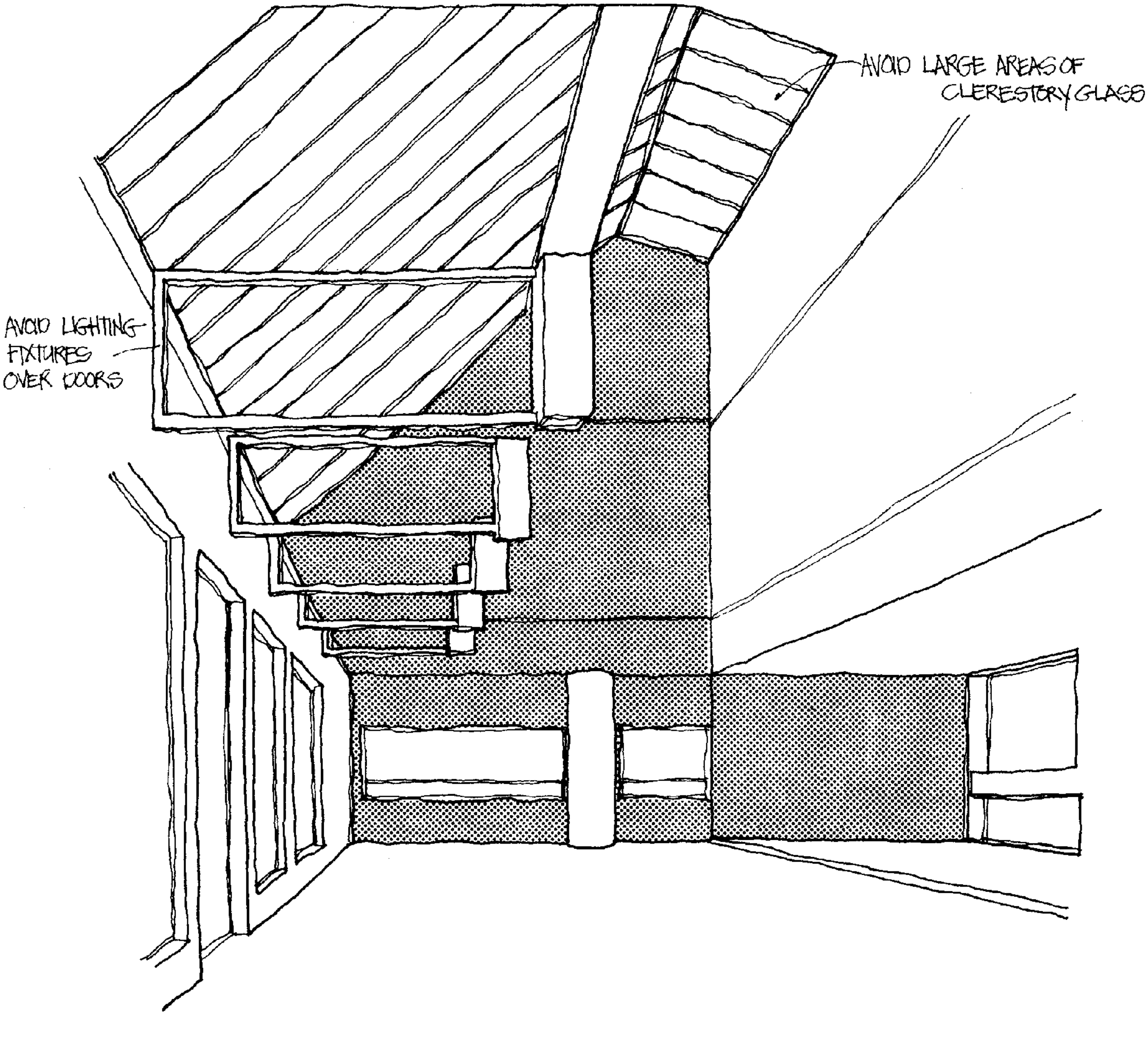
   The Staff Offices serve many differenct activities that occur within the police facility. The functions can include the commander's office, training office, crime prevention offices,

SEISMIC CRITERIA

POLICE STATION FUNCTIONAL AREAS	VULNERABLE TO SEISMIC DAMAGE: STRUCTURAL DAMAGE	ELECTRICAL DISRUPTION	HVAC DISRUPTION	PLUMBING DISRUPTION	EQUIPMENT DISRUPTION	SPECIAL RISK TO OCCUPANTS	PROTECT CONTENTS	CONTINUE FUNCTION: CRITICAL	HELPFUL	NO NEED	KEEP SECURE	RANK: VULNERABLE	PROTECT	CRITICAL	SECURE
ADMINISTRATION (AD)															
Lobby/Reception	●	●	●			●				●		●			
Clerical Area	●	●	●			●				●		●			
Staff Offices	●	●	●							●					
Conference Room	●	●	●							●					
Toilets	●	●	●	●						●					
OPERATIONS (OPS)															
Briefing Room	●	●	●			●			●			●			
Detective Operations	●	●	●			●				●		●			
Interview/Detention	●	●	●							●					
Juvenile Operations	●	●	●			●				●		●			
COMMUNICATIONS (CO)															
Communications Center	●	●	●		●	●	●	●			●	●	●	●	●
Electronic Maintenance	●	●	●		●		●	●			●	●	●	●	●
Switching Equipment	●	●	●		●		●	●			●	●	●	●	●
RECORDS (REC)															
Central Records	●	●	●			●	●			●	●	●	●		●
Data Processing	●	●	●		●	●	●			●	●	●	●		●
PRISONER PROCESSING (PP)															
Sallyport	●	●			●				●		●	●			●
Booking	●	●	●						●		●				●
Temporary Holding	●	●	●		●	●	●		●		●	●	●		●
Detention	●	●	●		●	●	●	●			●	●	●	●	●
EVIDENCE (EV)															
Receiving/Processing	●	●	●		●					●	●				●
Evidence Storage	●	●	●		●		●			●	●	●	●		●
Crime Laboratory	●	●	●		●	●	●		●		●	●	●		●
Property Storage	●	●	●		●		●			●	●	●	●		●

SEISMIC CRITERIA

POLICE STATION FUNCTIONAL AREAS	VULNERABLE TO SEISMIC DAMAGE						PROTECT CONTENTS	CONTINUE FUNCTION			KEEP SECURE	RANK			
	STRUCTURAL DAMAGE	ELECTRICAL DISRUPTION	HVAC DISRUPTION	PLUMBING DISRUPTION	EQUIPMENT DISRUPTION	SPECIAL RISK TO OCCUPANTS		CRITICAL	HELPFUL	NO NEED		VULNERABLE	PROTECT	CRITICAL	SECURE
SUPPORT FUNCTIONS (SF)															
Library	●	●	●			●				●					
Resource Center	●	●	●			●				●					
Locker Areas	●	●	●	●						●					
Exercise Room	●	●	●							●					
Day Room	●	●	●	●						●					
WEAPONS (WE)															
Armory	●	●	●		●	●	●	●			●	●	●	●	●
Gun Maintenance	●	●	●							●	●				●
Firing Range	●	●	●		●		●			●		●	●		
MECHANICAL (ME)															
Mechanical Room	●	●	●		●		●	●			●	●	●	●	●
Emergency Generator Area	●	●	●		●		●	●			●	●	●	●	●
VEHICLE (VE)															
Vehicle Maintenance/Repair	●	●	●		●	●	●	●			●	●	●	●	●
Garage	●				●		●			●		●	●		
Gas Pumps	●	●			●	●	●	●			●	●	●	●	●
Fuel Tanks	●				●	●	●	●			●	●	●	●	●
Helicopter Pad	●				●		●		●		●	●			●
EXITWAYS															
Halls/Stairs	●	●	●			●	●	●				●	●	●	
Exits	●	●				●	●	●			●	●	●	●	●
Elevators	●	●			●	●			●			●	●		



POLICE STATION LOBBY

planning and research offices, press and community relations areas and interview rooms. General protection from broken glass, furniture, ceiling systems and air diffusers should be considered. In addition, any critical equipment, such as two-way radios, located in these rooms should be protected by restraints or anchors.

The Conference Room is used for operations planning meetings, administrative meetings and briefings. In addition, the space may be made available for meetings of community groups that the police may be involved with. Large interior glass panels are sometimes used in conference rooms to integrate the space with other public use or administrative spaces. Smaller panels of glass or the use of plastic glazing materials may serve the same purpose while providing more protection.

Restrooms, because of their water and waste disposal service systems, deserve special attention. Pipe failures can flood the immediate area and damage adjacent areas unless precautions are taken, such as the use of automatic shut-off valves and the location of plumbing service lines where pipe breaks will not flood essential areas.

3. The Operations Areas of the station are typical office-type layouts where the day-to-day in-house operational duties are performed. Their size, location and layout offer the possibility of dual use during an earthquake disaster. These areas could serve as expansion or spill-over space for the increase in operations and services that might be provided by or at the police station.

The Briefing Room or squad room is a restricted public-use area used for the daily briefings that precede each shift and for training sessions. The briefing room is usually located near the other operations areas as well as the locker area. The protection of this area becomes important because of the need for briefing areas during the disaster period, when personnel are reassigned to new duties. In addition, the briefing room may contain large numbers of officers during the earthquake were it to occur during shift changes; attention should be given to ceiling systems and mechanical equipment over the occupants and to the restraint of seating elements.

The Detectives Operations Area provides spaces for the interview and interrogation of suspects, informers and victims, as well as for the preparation and review of investigation reports. The area should be flexible enough to accomodate expansion, while providing visual and acoustical privacy for report writing and interviews. The area should have easy access to the prisoner processing areas, while also providing private access for victims and informers. The number of unrestrained pieces of office equipment and furniture and the number of personnel could make this area extremely hazardous during an earthquake. Detective operations may be curtailed and officers assigned to other duties, thus possibly opening the area to use for other disaster-related functions.

The Interview/Detention Area is sometimes located in the operations area of the police station. The area provides space for the detention and interviewing of suspects and interviewing of informants and victims. Sufficient security and privacy is needed for these functions. The use of heavy-duty and vandal-proof furniture and fixtures in these spaces provides good seismic resistance and protection.

The Juvenile Operations Area should provide an optimal setting for conferences and counseling between police officers and juveniles and/or parents. The area should be separated from other operational areas and provide public access without the need to pass through other areas of the station. The earthquake concerns are generally the same as in the Detective Operations Area.

4. The Communications Center is the nerve center of the police station. The area is a very high security space that provides communications receiving and dispatching services as well as the monitoring of calls and updating the status or location of personnel. Since police response in an earthquake disaster will be directly related to the reliability and operational capacity of the communications system, maximum attention should be given to the earthquake protection of this area. The communications center should be designed so that it is expandable and flexible enough to permit an efficient increase in communications functions in a disaster. Radios, consoles and other communications equipment should be secured and restrained. Protection of back-up communications equipment is also essential. Some communications areas have securable visitor galleries for viewing the center. Large panels of glass located in such a gallery may be hazardous to the communications center and personnel during an earthquake. Smaller panels or relocation might give the same degree of visibility with greater protection.

   Stations using central dispatching services might have the capability to receive and monitor, but not transmit, messages. Consideration might be given to using trans-receivers to provide flexibility in case the central dispatching center is disrupted. Emergency power must be provided to the communications center, including all radio equipment, telephone switchboard lights, electrical outlets and alarm systems.

   The Electronic Maintenance Area provides for the repair and maintenance of communications equipment. Repair of damaged communications equipment becomes a critical task during a disaster. Equipment may be in short supply and all repairable equipment should be put back into use quickly. Built-in shelving for storage of spare parts must provide restraint and protection. Repair equipment and other electronic instruments found in this area should be anchored or restrained.

5. Central Records houses the personnel and equipment for the preparation, storage and retrieval of records. The area is a high security space that should be adjacent to both the operations and administrative areas, as well as providing accessibility to the public. Because of the importance of records to the judicial system, care should be taken to protect the contents of this area. They should also be protected from water damage due to broken pipes. Although information and records computer systems may not be operable during an earthquake because of electrical disruption, continued security is essential. The computer and retrieval systems should be protected to preserve the capability to use the information once normal operations are resumed.

   The Data Processing Area provides equipment and staff for data processing and computer services. The protection and restraint of this expensive equipment will present a unique set of seismic design problems. Raised computer room floors, for instance, may present stability problems during an earthquake.

6. The Sallyport is the secure garage or carport area used for the rapid transfer of suspects and prisoners from police vehicles to prisoner processing. Overhead doors in the sallyport should be designed to prevent racking or failure. Consideration should be given to restraining the door runners from lifting out of guides due to the vertical forces of an earthquake. Electrically-operated doors will not work during a power failure. Glass skylights sometimes used in sallyports to provide high illumination levels could be hazardous to the area.

   The Booking Area provides space for processing, fingerprinting and photographing arrested persons. The area is restricted and isolated from public areas. The area has a high potential for confrontation; as a result, furnishings should be secured, providing good seismic resistance. However, the booking area may have central control panels for the alarm system, electric doors and closed circuit television sets, the protection of which during an earthquake must be considered.

The Temporary Holding Area provides space for the dentention of suspects up to four hours. Although the area should be vandal-proof and eliminate the possibility of escape, the security features should be built-in unobstrusively. The vandal-proof furnishings and fixtures will allow for good seismic resistance.

If the police station has a Detention Area, adequate separation of holding spaces for inmates of one classification from those of another classification must be provided. This high security area must be capable of being monitored (audio/visual) while assuring the privacy of the inmates. Security monitors, such as sensors and closed-circuit teleivision, should be restrained and anchored to protect these expensive pieces of equipment. Cells should be designed to withstand the vertical forces of an earthquake. Consideration should be given to how prisoners are to be protected and controlled, especially if cell doors should rack or electric locks become inoperable.

7. Because of the judical importance of criminal evidence, maximum consideration must be given to its protection during an earthquake.

The Evidence Receiving/Processing Area provides space for the initial processing of evidence. This space is a maximum security area and should have the only entrance into the evidence storage vault.

The Evidence Storage Area is used for storing evidence for indefinite periods of time, and requires maximum security at all times. The area is usually provided with constant-level temperature and humidity control for the preservation of evidence. Expansion and flexibility requirements should also be considered, since this area has a high potential for overcrowding. Because of the importance of maintaining the exact original condition of evidence, shelves and cabinets should be anchored, pieces of evidence restrained, and the area protected from water damage from broken piping.

The Crime Analysis Laboratory provides space for the investigation, analysis and testing of evidence, and can include equipment for chemical analysis, ballistics, fingerprint analysis, photographic services, etc. This high security area can contain expensive equipment that should be protected. In addition, potentially hazardous and toxic substances, many in breakable containers, are usually located in this area, and should be restrained or protected.

The Recovered Property Storage Area houses impounded and stolen property that is not being held as evidence. Again, stored objects can be secured with restrainers or shelves tilted backwards.

8. The support areas of the police station provide space for a wide range of services and functions that support the operation of the station. Although these areas are not critical to the operational capabilities of the station, they do contain hazardous elements that should be considered in the total seismic design of the station.

The Library/Reading Room and Resource Center provide space for reading to supplement other in-service training. The protection of this area is the same as the seismic protection in any library. Heavy book cases can be anchored and secured to prevent their toppling over during an earthquake.

The Locker Area provides space for lockers in which police officers store clothes and personal belongings while on duty, as well as uniforms and equipment. The area should be located near a staff entrance, the briefing room and the exercise room. Although changing areas are not critical, locker areas can house personnel equipment and arms that must be accessible. Therefore, lockers and benches should be restrained or anchored and configured to provide stability.

The Exercise Room provides the space and houses the equipment for police officers to develop and maintain their physical fitness. The area needs good acoustical, humidity and ventilation control. The exercise area has the potential for being a dangerous area during an earthquake because of the heavy unrestrained exercise equipment. Consideration should be given to restraining large, stationary items, as well as smaller pieces, when not in use.

The Day Room provides a lounge area for relaxation or eating. Consideration should be given to anchoring heavy kitchen equipment such as refrigerators or microwave ovens.

9. The danger posed by the weapons areas of the police station in any disaster situation is obvious.

   The Armory and the Gun Maintenance Area are restricted areas that provide space for the storage of weapons and emergency equipment and the repair of firearms. This area has a particular danger of fire and explosion, and should be designed to prevent both the destruction of the items and potential danger to the station.

   The Firing Range provides the space for training and practice for police officers to increase their firearm skills. The basic design decisions in firing ranges involve safety, noise reduction, convenience and efficiency. Design should include seismic protection and resistance of the expensive equipment located in this area, such as the control system, communications system and shooting separators.

10. The Mechanical Room houses HVAC and other mechanical equipment for the station. Because of the station-wide importance of this equipment, its expensive nature and its fire potential, this area should receive maximum seismic design attention. Equipment such as boilers, HVAC equipment and electrical panels can be anchored or braced to resist lateral forces. Special cut-off valves for gas and water lines can be used to reduce the potential for fire or flooding.

    The Emergency Generator Area may or may not be located in the mechanical room. The emergency generator will provide the power necessary to operate the station in the probable event of power disruption in an earthquake. Consideration should be given to which areas the generator must service in order to maintain the operational capabilities of the station. Areas serviced by the generator should include, at the minimum, all emergency systems (fire alarms), emergency corridors, exits and stairs, detention areas, the emergency command center, if applicable, and the communications center.

    Emergency generators should be restrained from excessive movement or overturning during an earthquake and should start automatically when there is a power interruption or loss. An alternate source of fuel for the generator should be provided if there is a possibility that the primary fuel (e.g., natural gas) will be interrupted. Emergency generators should have flexible wiring connections and supply lines, as well as shock mounting with seismic features.

11. The vehicle areas of the station should provide adequate protection of vehicles, repair services and refueling facilities.

    The Vehicle Maintenance Area provides space for repair and maintenance services on police vehicles. The repair of damaged or inoperative vehicles may become a major task during a disaster period. Vehicles may be in short supply and all repairable vehicles may need to be put back into use quickly.

    The Motor Court Area can contain the garage or parking area and the refueling area. Provision must be made for the protection of fuel tanks and pumps and for operable fire control equipment, as this area could endanger the entire station. Consideration must also be given to the functional capabilities of refueling facilities after an earthquake. Canopies, if located over fuel pumps, should be designed to resist the lateral forces of an earthquake. Fuel pumps should be able to be manually operated in case of electrical power loss.

    The Helicopter Pad serves as the landing and take-off area for police helicopters. The pad is often located on the roof of the station. The helicopter is the most logical reconnaisance vehicle for disaster operations. If the pad is to be located on the roof of the station, alternate landing areas might be considered, since the structural integrity of the station's roof will probably be in question after a damaging earthquake.

12. Safe emergency routes should be planned in corridors and halls so personnel can proceed to vehicles and work stations or egress the station in minimum time with minimum obstruction. These routes should be equipped with emergency lighting powered by the generator or batteries. Partitions that enclose these routes and exits are critical components for egress or movement, and should be designed as such. Glass, ornamentations, poorly supported ceilings, pendant light fixtures, etc., should be avoided along emergency circulation routes.

    The reasons for door and frame failure in earthquakes are obvious. The door assembly must function with normal frame-to-door clearance required for fire protection, while the wall that it is attached to will be subject ro racking and bending. Door frames should be structurally sound to prevent racking. Breakaway internal doors might be considered.

FUNCTIONAL SPACE CRITERIA — FIRE STATIONS

INTRODUCTION

The fire service provides three basic services to the public: fire prevention; rescue and life safety; and fire suppression. Although cities may place varying degrees of emphasis on centralization or decentralization of administrative activities, the nature of the fire service demands that stations be distributed throughout the neighborhoods of the city.

Traditionally, the basic unit of the fire department is the "fire company." A company may range in size from 3 to 8 or more persons. In general, a company is assigned one or more major pieces of apparatus, although in small communities a single company may operate all apparatus in the fire station.

One or more companies are housed in each fire station. More than 70% of the communities in the U.S. have fire departments with only one or two companies. About 6,000 fire departments in the United States and Canada (25% of the total) have at least three companies, and a small number of these have up to five companies. The fire station thus must be designed not only to accomodate present pieces of apparatus and related equipment, but also to provide flexibility for future expansion or changes in operational focus.

Fire station activities can be separated into four distinct categories: administration, fire prevention, operations, and support functions. Administration provides for the control and management of fire service activities. Fire prevention includes investigative, inspection and informational services to prevent fires and fire damage. Operations provide the field services needed for actual fire suppression and/or emergency medical services. Support services provide all related activities or services that support the accomplishment of fire service operations. In addition, there is an increasing movement to give fire stations the responsibility for housing emergency medical services (EMS). This service, however, is often a discrete function. The station must be designed to accomodate these functions and at the same time allow flexibility for future changes in operations and programs.

Probably most critical to the design of the station is that it facilitate the safest and quickest response of the personnel and fire suppression apparatus. This involves uncomplicated floor plans and the most logical and efficient egress routing possible. Response at any time of day or night, response time required, and the number of personnel responding are some of the issues that must be considered when designing optimal use and configuration of space in a fire station. Some areas of the fire station will be in use 24 hours a day, others only 8 hours and others only at night. The design must consider these use times to properly reduce disruptive interrelationships. For instance, the noise from the watch room or communications area should not disturb personnel sleeping in the dormitory, nor should personnel wishing to go to the apparatus room from other parts of the station have to pass through the sleeping area at night.

An important consideration in daily operations is that of security. In the past the "public good will" enjoyed by the fire services did not generally require that architects and fire officials be particularly concerned about station security. This situation has changed in some areas, and because of the potential risk of vandalism or damage when fire stations are left unoccupied, many departments are increasing security measures at their station houses.

During an earthquake disaster the fire department, like the police, will be expected to undergo changes to meet the demands of the situation. Architects and fire officials must consider this fact when planning fire facilities in order to provide the flexibility required for these organizational and operational changes.

DESIGN CHECKLIST

1. What performance and protection criteria are attached to the individual functional areas of the fire station?

Particularly Vulnerable Areas

____

____

____

Areas Housing Critical Equipment

____

____

____

Critcal Operational Areas

____

____

____

Secure Areas

____

____

____

2. What design strategies have been developed for the protection of the public and fire personnel in the Administrative Areas?

Lobby/Reception Area

____

____

____

Clerical Area

____

____

Staff Offices

Conference Room

3. How have the Operations Areas been designed to ensure their protection and operational capability during the disaster period?

Apparatus Room

Communications Room

4. What earthquake design strategies have been used to protect occupants and equipment in the Support Function Areas of the fire station?

Dormitory

Locker Area

Hose Care Area

Equipment Storage

Day Room

Food Preparation/Dining

Training Room

Exercise Room

5. How have the Mechanical Areas of the station been designed to ensure they remain in service during an earthquake disaster?

Mechanical Room

Emergency Generator Area

____

____

____

6. How has adequate earthquake protection been provided to the Apparatus Maintenance and Refueling Areas?

Maintenance/Repair Area

____

____

____

Refueling Area

____

____

____

7. Have the Circulation Systems been designed and planned so that they can be used safely during the disaster period?

Circulation Routes

____

____

____

Exits

____

____

____

Stairways

____

____

____

COMMENTARY

1. Seismic considerations can have significant impact, not only on the structural design, but also on the basic planning of a fire facility. All building types share a vulnerability to structural damage from an earthquake, but fire facilities face disruption of operations that are critical to the safety of the community. To ensure the facility's capability for emergency operations, certain of its key areas should remain functional. The concept and organization of areas within the building envelope will be influenced by this need to protect and coordinate the core disaster relief functions. Four major criteria are important in the seismic evaluation of the functional areas in a fire station.

   - Areas that are particularly vulnerable to seismic damage.

   - Areas that house critical or important equipment/items that should be protected.

   - Areas that are critical to continued fire operations during a disaster.

   - Areas that need to remain secure during and after the earthquake.

   The following charts display these criteria in relation to the functional areas that may be found in fire stations.

2. The Lobby/Reception Area of a fire station is used as a primary reception area for the general public. Its location should be obvious from the outside and easily accessible and should direct public traffic away from the operations areas of the station.

   Inside a cheerful atmosphere, perhaps with informational displays, should be provided, and the receptionist's center and usual office-type furniture should be arranged to allow casual circulation for the public. Should an earthquake occur, shifting furniture, falling ceilings and broken glass from doors, wall panels or skylights could produce many unnecessary injuries. Serious consideration should be given to securing shelves, display cases and other special equipment, such as decorative or general lighting fixtures, to minimize damage and injuries.

   The Clerical Area provides space for the handling and storage of records and other daily clerical duties. As this room is potentially a high-noise area, special consideration needs to be given to acoustic design features. The most obvious potential for seismic damage comes from heavy office equipment, files, shelves and typewriters, which can shift or topple. Any special features, such as landscape-type furnishings or large wall storage units, should be securely anchored in place. Although this is not a critical area for disaster operations, protection of the records housed in this area may be important for resumption of normal duties.

   Various Staff Offices can be included in the fire station, including Chief's office, training office, fire prevention/inspection office and others. The primary function of these offices is administrative in nature, and seismic considerations given to standard furniture need to be applied here in particular.

   The Conference Room is used not only for daily meetings of the staff, but for meetings of various public groups as well. The seismic ramifications of the location and types of glass overhead or in wall panels should be considered.

SEISMIC CRITERIA

FIRE STATION FUNCTIONAL AREAS	VULNERABLE TO SEISMIC DAMAGE						PROTECT CONTENTS	CONTINUE FUNCTION			KEEP SECURE	RANK			
	STRUCTURAL DAMAGE	ELECTRICAL DISRUPTION	HVAC DISRUPTION	PLUMBING DISRUPTION	EQUIPMENT DISRUPTION	SPECIAL RISK TO OCCUPANTS		CRITICAL	HELPFUL	NO NEED		VULNERABLE	PROTECT	CRITICAL	SECURE
ADMINISTRATION (AD)															
Lobby/Reception	●	●	●			●				●		●			
Clerical Area	●	●	●			●				●		●			
Staff Offices	●	●	●							●					
Conference Room	●	●	●							●					
OPERATIONS (OP)															
Apparatus Room	●	●	●	●	●	●	●	●			●	●	●	●	●
Communications Room	●	●	●		●	●	●	●			●	●	●	●	●
SUPPORT FUNCTIONS (SF)															
Hose Care Area	●	●	●	●	●		●		●			●	●		
Equipment Storage	●	●	●		●		●			●	●	●	●		●
Dormitory	●	●	●			●	●			●		●	●		
Locker Area	●	●	●	●		●				●		●			
Day Room	●	●	●						●			●			
Food Prep/Dining	●	●	●	●		●			●			●			
Training Room	●	●	●							●		●			
Exercise Room	●	●	●			●				●		●			
MECHANICAL (ME)															
Mechanical Room	●	●	●		●		●	●			●	●	●	●	●
Emergency Generator Area	●	●	●		●		●	●			●	●	●	●	●
VEHICLE (VE)															
Maintenance/Repair	●	●	●		●	●	●	●			●	●	●	●	●
Gas Pumps	●	●			●	●	●	●			●	●	●	●	●
Fuel Tanks	●				●	●	●	●			●	●	●	●	●
Motor Court	●				●		●		●				●		
EXITWAYS															
Halls/Stairs/Poles	●	●	●			●	●	●				●	●	●	
Exits	●	●					●	●			●	●	●	●	●

3. The Apparatus Room is the primary operational area of the fire station. It must receive special seismic attention to protect the vital equipment housed there. Without this equipment fire services will be virtually nonexistent during a disaster. The apparatus room may also be used during a disaster as a distribution center or shelter.

Access to the apparatus room should be quick and direct from any point in the station. Flexibility for future expansion and versatile storage space for changing and expanding equipment are important. Good lighting, adequate heating and ventilation and alarm and communications systems are all of utmost importance. Detail considerations, such as skid-resistant floors, drainage and noxious gas removal, are equally important.

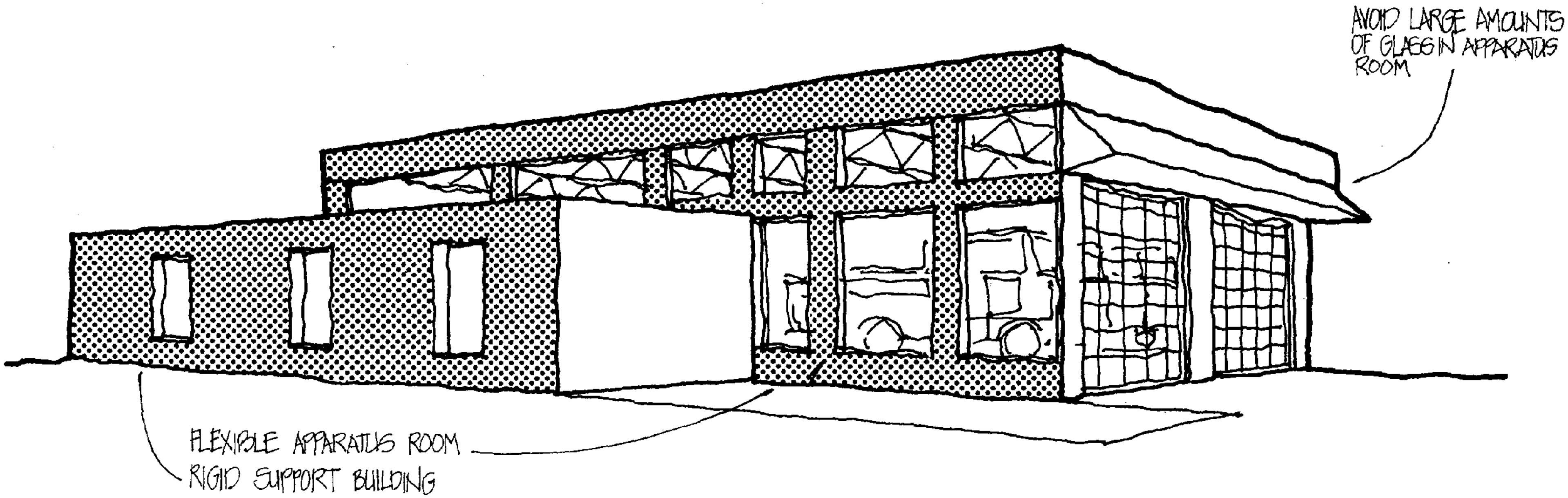
Because of the open atmosphere and display of apparatus sought in the design of some fire station, they may have large amounts of glass in clerestories and skylights in the apparatus room. This can cause a serious situation during an earthquake, and consideration should be given to protecting personnel and apparatus from broken or falling glass.

Many apparatus doors also contain large amounts of glass, posing not only hazardous conditions if the glass is broken by earthquake forces but also the potential for injury to station personnel if the doors become inoperative and apparatus has to be driven through the doors. Breakaway doors, such as fiberglass, would be safer in the event doors rack and jam shut. Apparatus doors should have a manual operational capability, and consideration must be given to strengthing door frames to prevent racking and to eliminating the potential for doors to slip off the runners during earthquake movement.

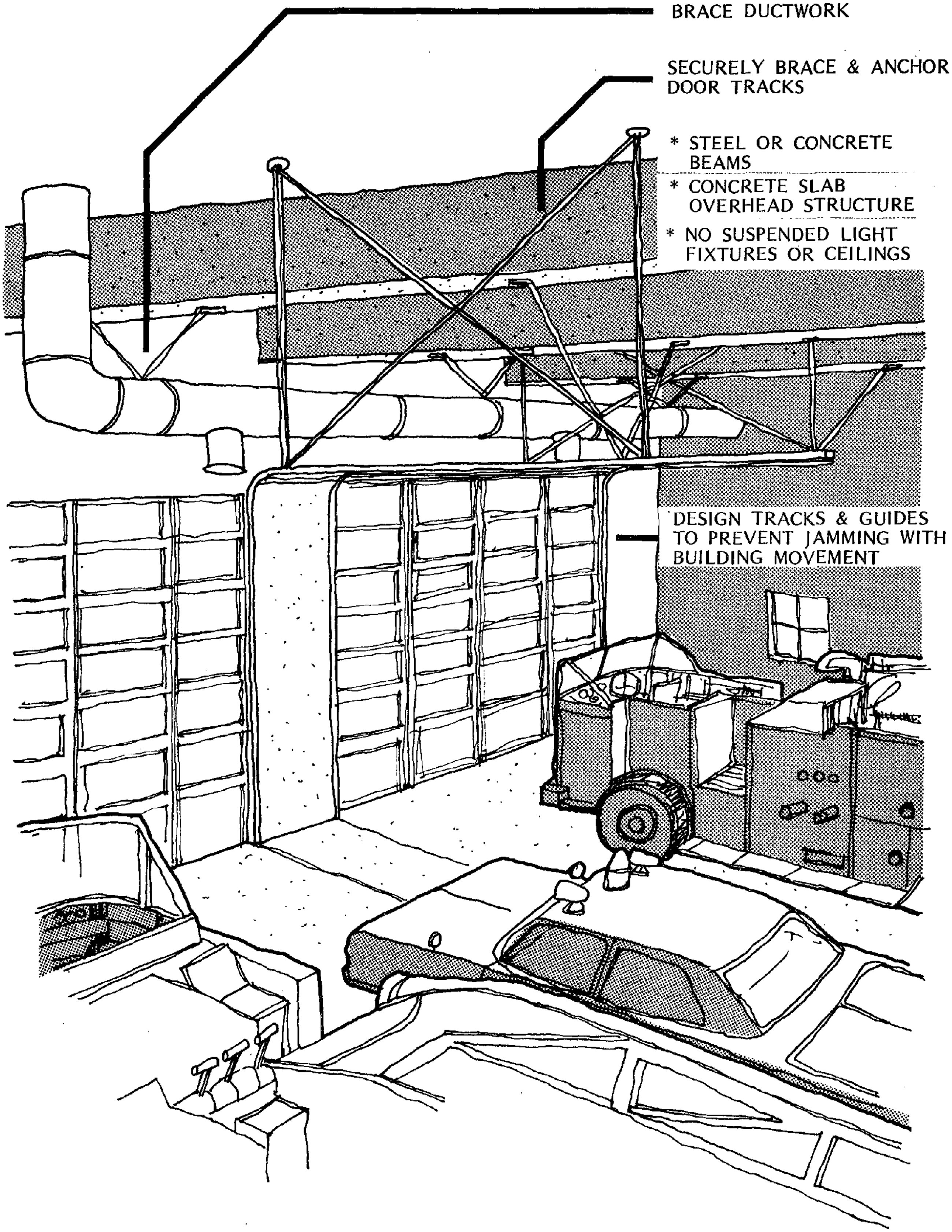
Sliding poles into the apparatus room should receive attention to ensure that they do not bend or actually collapse due to excessive lateral forces. The use of alcoves for storing large pieces of equipment, such as hose racks, might prevent their damage or hazardous movement during an earthquake. Some stations use hung plastic ceilings in the apparatus room because of their convenient maintenance and cleaning; there is always the danger that hung ceilings will fall during an earthquake, inflicting injuries and damage. Hung heating and ventilation equipment can be braced and secured to prevent their falling on apparatus and personnel.

The Communications Room or Watch Room is the nerve center of the fire station. Usually located next to the apparatus room, it performs the alarm and communications functions of the station. Fire response in an earthquake disaster will probably be directly related to the reliability of the communications system. Because of the critical nature of this area, its protection should be given the utmost attention. The communications center should be designed so that it will not become overcrowded by the increased personnel likely to be needed during a disaster. Watch rooms sometimes have large amounts of glass to allow visual surveillance of the public entrance, response route and apparatus room. Some may even be enclosed by three sides of glass, increasing the potential for injury and disruption due to glass breakage. Consideration should be given to the reduction and/or protection of glazed areas.

Communications and data processing systems are prominent in the trend toward greater use of electronic systems in fire operations. In the event of an earthquake, sophisticated equipment can present particular hazards in the form of fire, electrical shock or explosion. Radios, consoles and other communications equipment should be anchored and braced to prevent damage. Damage to the equipment from sources such as ceilings, mechanical systems, lighting, etc., should also be considered. Protection of back-up communications equipment is also essential. The emergency power system should connect to all of the communications area, including electrical outlets, alarm systems and telephone



APPARATUS ROOM



FIRE STATION SEISMIC CONSIDERATIONS

switchboards.

4. The Dormitory provides sleeping accomodations and personal storage for the firefighters in the fire station. The area should be isolated from noise (mechanical, other station areas, street) and have direct access to the apparatus room. Personnel in dormitory areas should be protected from falling lockers, chests, light fixutres and, especially, the wardrobe units some stations use to divide sleeping areas in the dormitory. The dormitory's seismic design is extremely critical since the majority of the station's force could be disabled in this area if an earthquake were to occur at night.

   The Locker Area provides shower, dressing and storage facilities for fire station personnel. The locker area is usually located near the dormitory and the exercise room. The operation of this area, although not critical during a disaster, would be useful in accomodating the large numbers of personnel that would be based at the station throughout the period. Lockers and benches can be restrained, anchored and located to provide seismic resistance.

   The Hose Care Area and Equipment Storage Area provide space for cleaning, drying and storage of hoses and storage of hose-related equipment and supplies. At present, the philosophy of hose care is controversial, and particular seismic attention must be given to the method chosen. If a mechanical washer and/or dryer is used, these expensive pieces of equipment should be secured and anchored to prevent damage. If a drying tower is used, it should be located so as not to endanger the station should it be damaged or collapse.

   The Day Room in the fire station provides space for lounge and study activities. The room should have direct access to the apparatus room, while maintaining privacy from the general public. It may also be adjacent to or combined with the food preparation/dining area.

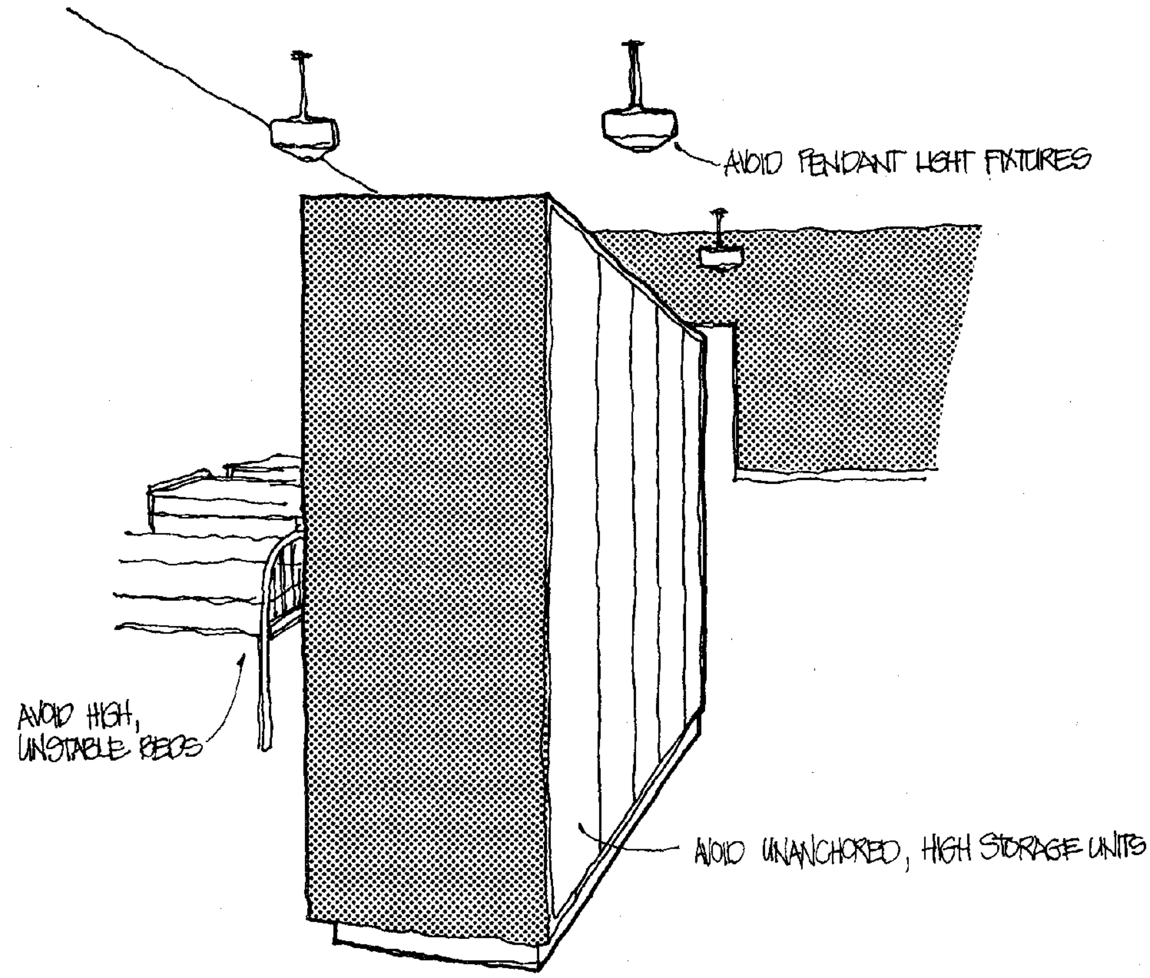
   The Food Preparation/Dining Area houses the food service and dining facilities for the station. In addition to providing meals to personnel, this area might serve as a small community feeding facility for the homeless during the emergency period. Consideration should be given to anchoring and bracing kitchen equipment. Failure of piping in this area could flood the immediate area unless durable piping and shut-off valves are used.

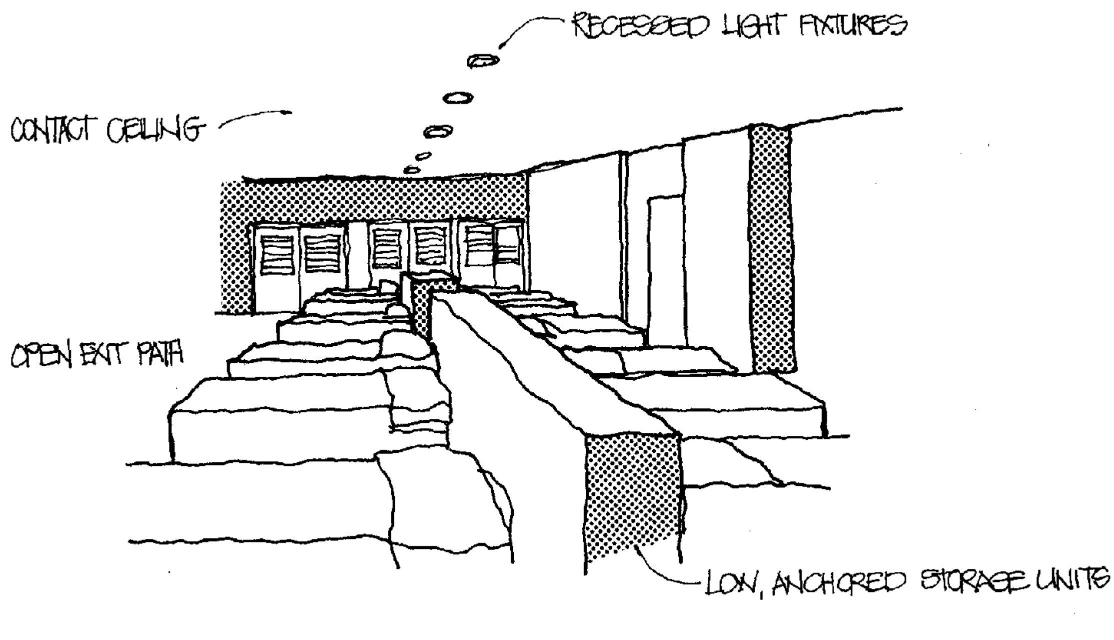
   The Training Room provides space for education, demonstration and briefing activities. The protection of this area would provide a possible briefing area for operations personnel during the emergency.

   The Exercise Room is used to develop and maintain the physical fitness of fire officers. Good acoustic, humidity and ventilation control is important. The exercise room may be a dangerous area during an earthquake because of the heavy unrestrained equipment located there.

5. The Mechanical Room houses HVAC and other mechanical equipment. Because of the station-wide importance of this equipment, it expensive nature and its fire potential, the mechanical room should receive maximum seismic design attention. Equipment such as boilers, HVAC equipment and electrical panels can be anchored and braced to resist lateral forces. Special cut-off valves for gas and water lines can be used to reduce the potential for fire or flooding.

   The Emergency Generator Area may or may not be located in the mechanical room. This generator will provide the power necessary to operate the station in the probable event of


AVOID PENDANT LIGHT FIXTURES
AVOID HIGH, UNSTABLE BEDS
AVOID UNANCHORED, HIGH STORAGE UNITS


RECESSED LIGHT FIXTURES
CONTACT CEILING
OPEN EXIT PATH
LOW, ANCHORED STORAGE UNITS

DORMITORY

a power disruption in an earthquake. Consideration should be given to which areas the generator must service to maintain the operational capacity of the station. Areas serviced by the generator should include, at a minimum, emergency systems (fire alarms), emergency corridors, exits and stairs, the emergency command center, if applicable, and the communications center.

Emergency generators should be restrained from excessive movement or overturning during an earthquake and should start automatically when there is a power interruption or loss. An alternate source of fuel should be provided against the possibility that the generator's primary fuel, e.g., natural gas, should be disrupted during an earthquake. Emergency generators should have flexible wiring connnections and supply lines, as well as shock mounting with seismic features.

6. The vehicle areas of the station should provide adequate protection of the fire apparatus, repair services and refueling facilities.

   The Maintenance Area provides space for repair and maintenance of fire apparatus. The repair of damaged or inoperative apparatus may become a major task during a disaster period. These critical vehicles may be in short supply and all repairable apparatus may need to be put back into use quickly.

   The Refueling Area poses an extreme fire hazard to the entire station, and it is essential that provision be made for the protection of fuel tanks and pumps from the direct effects of earthquake forces as well as from the danger of shifting apparatus. Pumps should be protected by curbs and railings and provision should be made for operable fire control equipment. Consideration must also be given to the importance of these refueling facilities after an earthquake. Canopies, if located over fuel pumps, should be designed to resist the lateral forces of an earthquake, and the fuel pumps should be able to be manually operated in case of electrical power loss.

   The Helicopter Pad serves as the landing and take-off area for helicopters. The pad is often located on the roof of the station. The helicopter is the most logical reconnaisance vehicle for disaster operations. If the pad is to be located on the roof of the station, alternate landing areas might be considered, since the structural integrity of the station's roof will probably be in question after a damaging earthquake.

7. Safe emergency routes should be planned in corridors and halls so firefighters can proceed to apparatus or work stations in minimum time with minimum obstruction. These routes should be equipped with emergency lights powered by the generator or batteries. Partitions that enclose these routes and exits are critical components for egress or movement, and should be designed as such. Glass, ornamentation, poorly supported ceilings, pendant light fixtures, etc., should be avoided along the emergency circulation routes.

   The reasons for door and frame failure in earthquakes are obvious. The door assembly must function with normal frame-to-door clearances required for fire protection, while the wall that it is attached to will be subject to racking and bending. Door frames should be structurally sound to prevent racking. Overhead door tracks can be braced, and restraints used to prevent rollers from lifting out of tracks. Breakaway internal doors might be considered.

NONSTRUCTURAL SYSTEMS AND COMPONENTS

INTRODUCTION

Many of the building systems and components of police and fire station facilities are the same as for other building types. However, there are many potential "weak points" in these systems that could easily become damaged or fail, creating problems for a critical facility in terms of its continued ability to conduct emergency operations. These weak points that would affect critical facility operations must be identified, studied and given special design consideration by the architect. The value of the assistance of qualified structural, mechanical and electrical engineers from the beginning of the design process cannot be overemphasized. The engineering consultants should be involved in the detailing of components that must withstand lateral forces. Due to the general simplicity of the problems involved, this could consist of a general discussion at the beginning of design work and a review session when working drawings are started. One system of the building should not be designed and detailed by only one discipline without taking into consideration design of other systems and their interactions. If a dynamic analysis is done for the structure, it should be used for the determination of load on equipment.

Adherence to building code requirements concerning nonstructural seismic design will not in itself ensure that the code's provisions will be properly applied by the design team or installed by the contractors. Most of this problem stems from the traditional divisions of responsibilities between design professionals and a construction industry that does not require careful detailing of nonstructural elements.

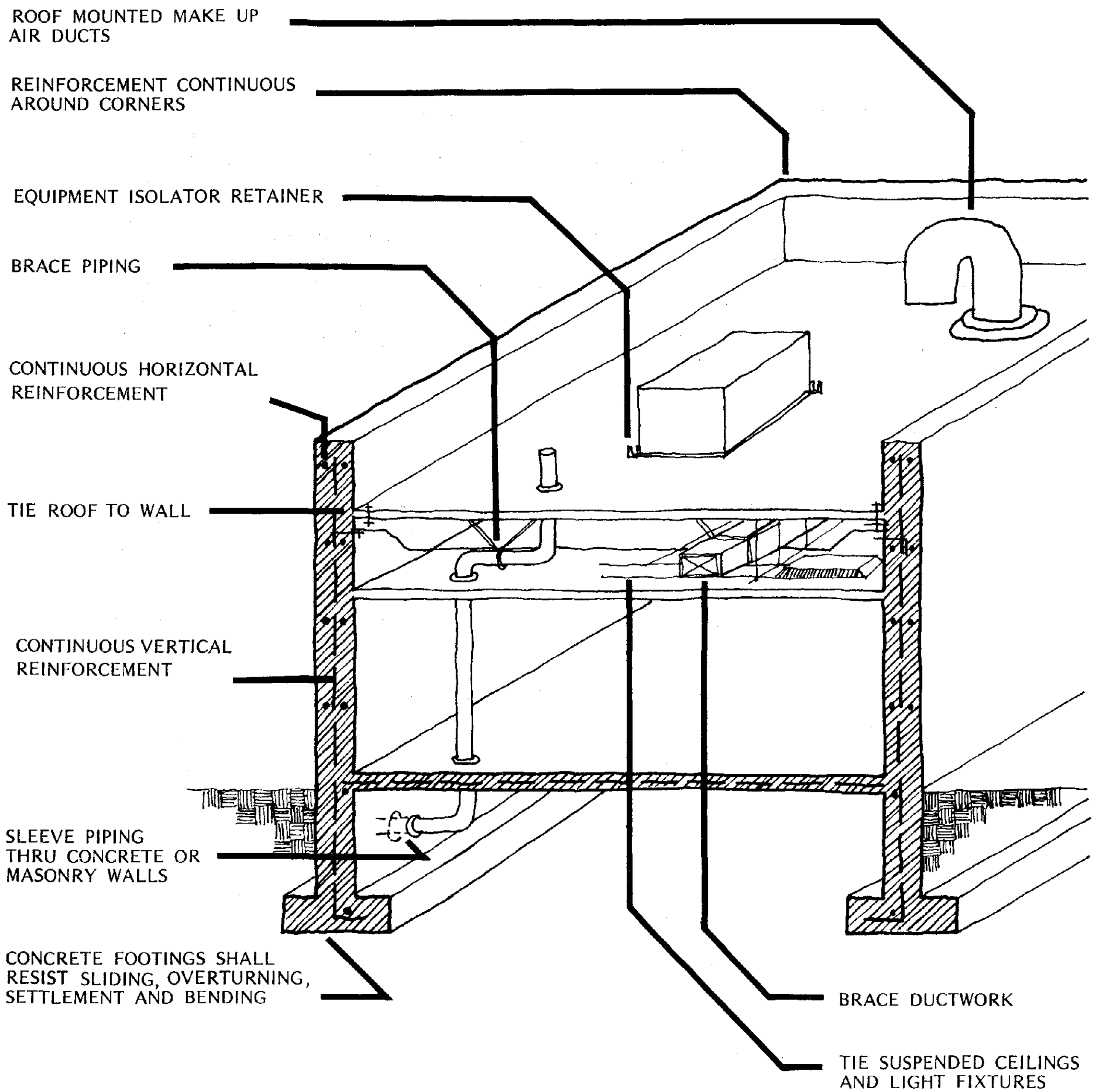
The total cost of possible damage of nonstructural systems and components in an earthquake of moderate or major intensity cannot be measured in dollars and cents alone. Damage may include loss of life, injury and, in the case of police and fire stations, reduction of their operational capabilities at a time when they are vital to their communities.

Virtually every nonstructural system is subject to damage, and we do not have sufficient knowledge of earthquakes or how to prevent damage to nonstructural systems and their components. The architect, engineer and client must make a decision as to what system should continue to function or to what limit damage can be tolerated.

Several nonstructural systems and components must be given utmost attention in designing for seismic resistance because they are critical to the continued operation of police and fire facilities during a disaster operations.

- Fire Protection System
  - Standpipes
  - Sprinklers
  - Extinguishers
  - Smoke and Fire Detectors

- Communications System
  - Dispatching/Receiving Radios
  - Alarm System
  - Telephones
  - Computer Terminals
  - Electrical Raceways



SEISMIC DESIGN BUILDING ELEMENTS & SYSTEMS

- Emergency Generator System
  - Generator
  - Fuel Sources, Batteries
  - Cooling System
  - Switchgear, Panels
  - Conduits
- Hazardous Components
  - Elements that have the potential to injure personnel or damage critical systems and essential equipment.
- Essential Equipment
  - Items that are essential to providing necessary services after an earthquake.

DESIGN CHECKLIST

1. Do any exterior elements of the station present a potential hazard to the operation of the station?

   Cornices ☐

   Signs ☐

   Overhangs ☐

   Roof Mechanical Systems ☐

   Communications Antennae ☐

   Utility Poles/Transmission Lines ☐

   Other

   ____

2. Have exterior veneers been designed and detailed to resist damage or failure from the earthquake?

   Anchorage Details ☐

   Ductile Materials ☐

   Deformation Ability ☐

   Other

   ____

3. Are the interior partitions susceptible to earthquake damage? Does their failure pose major threats to the occupants or continued operation of the station? Have the partitions been designed to resist lateral forces?

   Reinforcement ☐

   Lateral Bracing ☐

   Seismic Joints ☐

   Separation Gaps ☐

   Stable Configuration (partial-height partitions) ☐

   Deformation ☐

   Other

   ____

4. Has the ceiling system been designed to resist lateral and upward vertical forces? Would its collapse pose a hazard to critial resouces in the station?

   Lateral Bracing ☐

   Compressional Bracing ☐

   Separation from Walls ☐

   Positive Connections/Attachments ☐

   Other

   ____

5. Are the lighting systems in the station designed to resist earthquake forces?

   Independent Support/Restraint ☐

   Positive Connections/Attachments ☐

   Other

   ____

6. Are the glazing systems in the station properly selected and fitted to withstand lateral forces? Does their location pose serious hzards in case of failure?

   Proper Location ☐

   Safety Glass ☐

   Proper Mounts and Fitting ☐

Separation from Wall ☐

Other

---

7. Are circulation and egress/access routes protected and free of hazards?

   Proper Planning of Routes ☐

   Free of Hazards in Routes ☐

   Door and Frame Design ☐

   Stairwell Design ☐

   Other

---

8. Are the emergency systems of the station well protected from earthquake damage or disruption?

   Emergency Generator System
      Redundant Fuel Sources ☐

      Anchorage/Bracing ☐

      Flexible Connections ☐

   Fire Protection System
      Anchorage/Bracing ☐

9. Are the mechanical/electrical systems protected and designed so as not to pose hazards to personnel or critical equipment within the station?

   Proper Location ☐

   Consistent Degrees of Movement ☐

   Flexible Connections ☐

   Lateral Bracing/Support ☐

   Other

---

10. Will station contents become hazardous to personnel and critical equipment during an earthquake?

   Stability ☐

Anchorage ☐

Restraints ☐

Other

COMMENTARY

1.

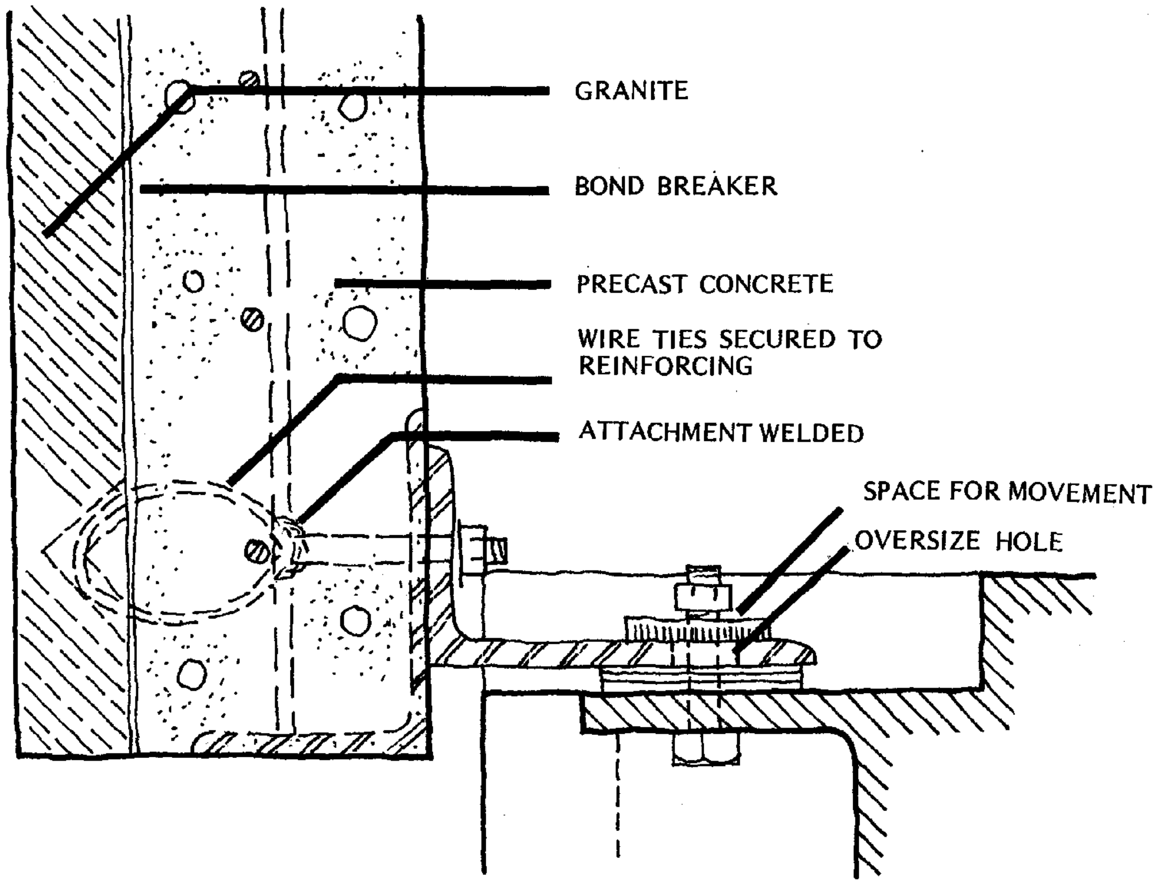
- Consideration should be given to avoiding heavy exterior elements, such as projecting cornices, signs, tall parapets, heavy overhangs, etc.
- Any mechanical systems or equipment, such as solar panels or air conditioning, should be securely anchored away from the perimiter of the roof.
- Locating exits where elements such as poles, transmission lines or adjoining building elements might fall across them should be avoided.
- Communications antennae should be well guyed and mounted in the center of the roof or, if mounted on the side of the station, should extend along and be attached to the entire wall.

2.

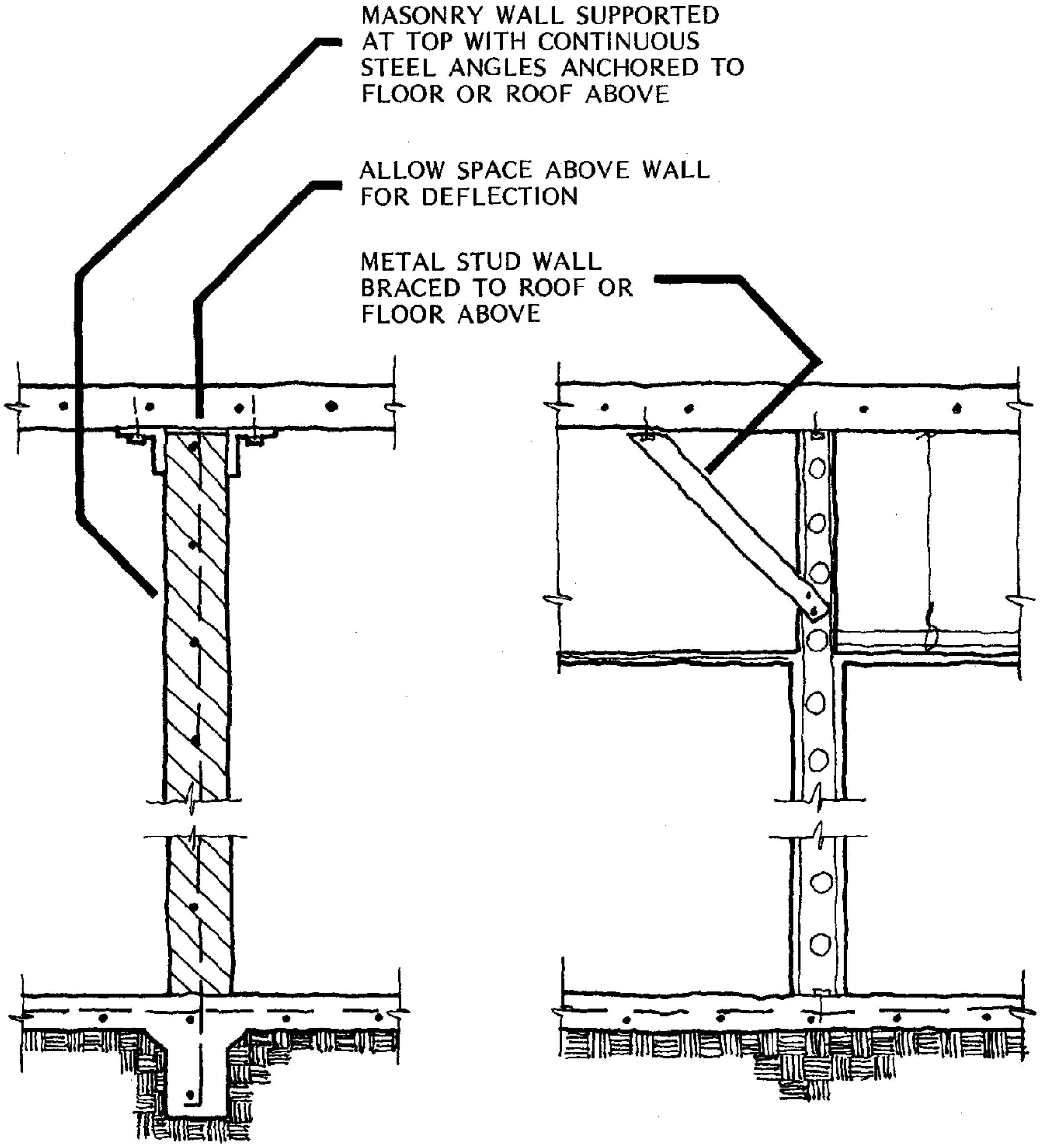
- Damage to veneers on the exterior enclosure system, especially veneers of brittle materials, can be extensive during an earthquake. This is principally due to differential movement between the supporting element and the veneer. Experience seems to indicate that a larger number of smaller wire anchors are better than a few larger ones. Veneers can also be anchored to rigid panels that in turn are anchored to the structure in such a manner that allowance can be made for movement.

3.

- The use of unreinforced concrete masonry, even for nonstructural partitions, should be avoided.
- All partitions, including non-load bearing ones, should be braced laterally for stability.
- Consideration should be given to anchoring furniture or equipment to a structural element instead of to partitions. If this is not desirable, the partition should be constructed to assume the added seismic lateral load caused by the furniture or equipment. The amount of furniture found in the prisoner processing area of a police station that is anchored may be hazardous if not properly anchored to a structural element or a partition that can take the added load during an earthquake.
- Seismic joints should include partition construction details to provide a continuous separation through the floor, walls and ceiling. The large number of divided areas that can be found in police and fire stations may cause extensive cracking (which is expensive to repair) if not properly detailed.



ATTACHMENT OF VENEERS



INTERIOR WALL BRACING NON STRUCTURAL WALLS

- Interior partitions and fire-rated walls that have floor-to-floor connection require careful design consideration if drift damage is to be minimized. Details should support nonstructural walls against out-of-plane seismic forces, yet allow freedom for interstory drigt in the plane of the walls. Problem areas are corners and tee-junctions of walls, as well as the junction of walls with columns. The selection of compressible filler material for the clearance gaps should meet fire and/or acoustic requirements.

- Police and fire operations change, making it desirable to have flexible spaces. Open space planning and office landscape systems have helped departments gain this flexibility. Open office landscaping may be used for large work areas (clerical, detective) because of more effecient communication, lighting, heating, ventilation and flexibility. Open planning may present a potentially hazardous condition in the event of an earthquake. Good configuration stability control (e.g., "L"-shape) and good anchorage to a structural element should be explored when using partial-height partitions.

4.

- The potential for ceiling collapse should be investigated, especially for rooms and areas that can house large numbers of personnel (police briefing room, fire dormitory) or critical equipment (communications area). Suspended ceiling systems are damaged during earthquakes because they are usually free to swing on their suspension systems and batter against adjacent walls. They are also subject to pounding movement from light fixtures and mechanical equipment.

- Ceiling collapse is most likely to occur at the perimeters of rooms, due to the deflection and drift of the enclosing walls. The ceiling system can be isolated from the walls, but it must be recognized that this may leave travel routes for fire, smoke and noise. Conversely, fire-rated corridors and rooms that are built solidly from floor to ceiling may rack to the point where the ceiling falls and the doors will not open.

- The ceiling system should be braced to resist lateral forces, with rigid vertical bracing to prevent upward movement. Hung ceilings can be attached directly to a structural element using positive connections.

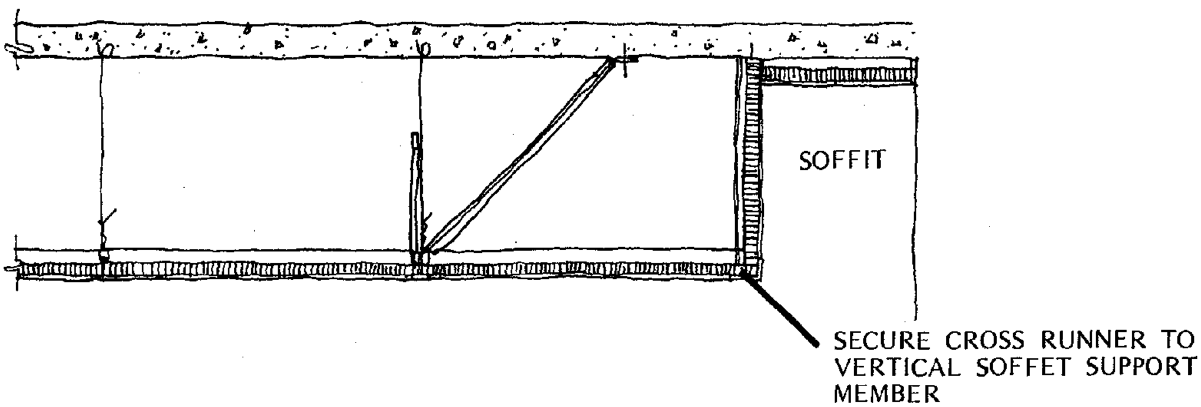
- Exposed tee-bar hung ceilings can lack rigidity and support. Concealed syspension systems are usually more stable. Ceilings attached directly to the slab using, for example, high strength adhesive, are usually less susceptible to failure.

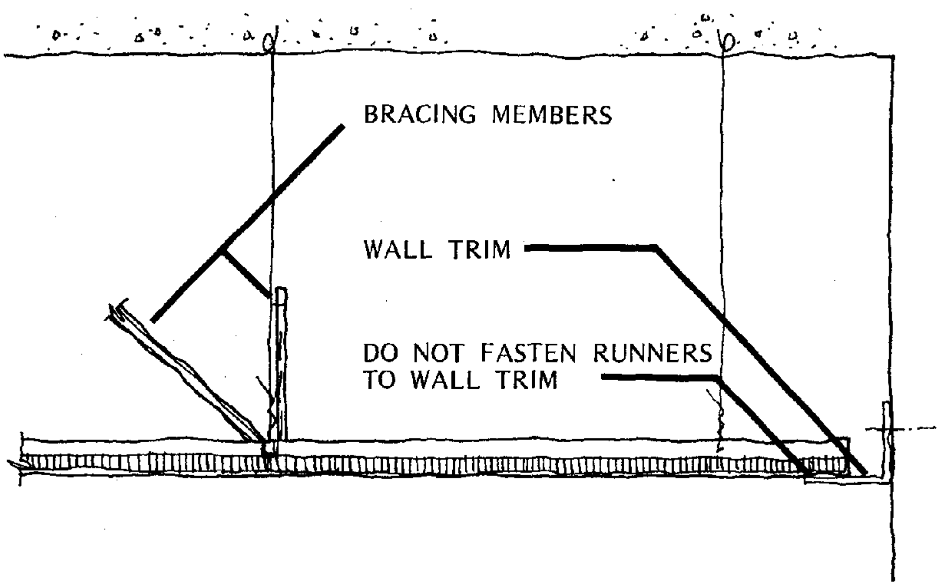
- Because of the instability of most ceiling systems, elements such as light fixtures should not be attached to them. If this is not possible, the ceiling system should be designed to support the fixtures during an earthquake.

- Although it may seem desirable to place work stations along the building periphery to take maximum advantage of natural lighting, this area can be a most hazardous one during an earthquake.

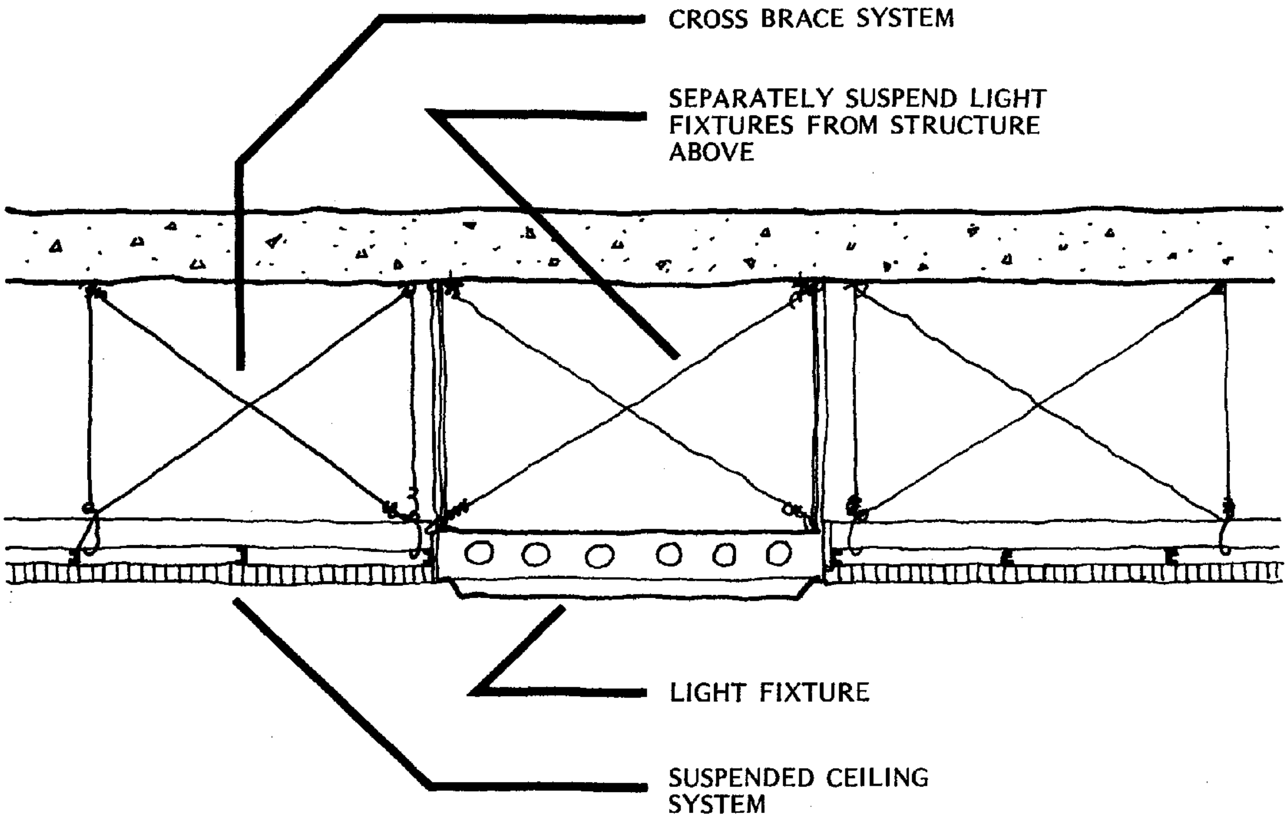
5.

- Pendant-hung lighting fixtures are more susceptible to earthquake failure than recessed or surface-mounted fixtures. If pendant fixtures are used, there are several techniques for reducing earthquake damage: a restraining device to support the stem during excessive motion; separation between fixtures to eliminate contact during swaying; and avoiding rigid stems. Multiple fluorescent fixtures placed end-to-end are very susceptible to damage through pounding.

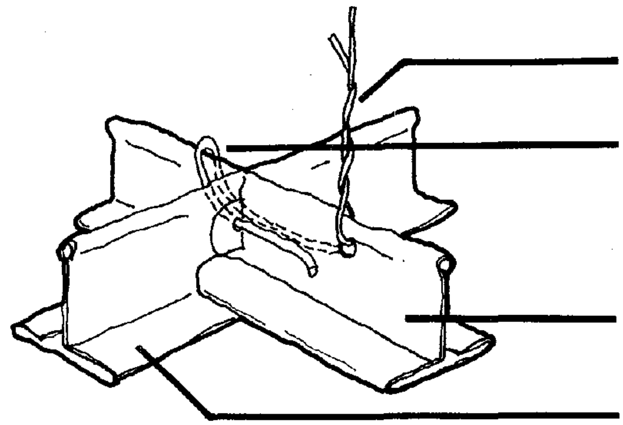


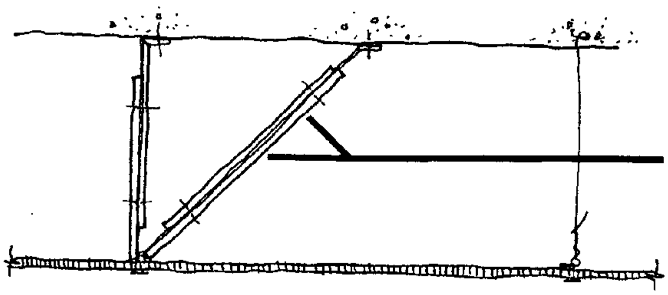


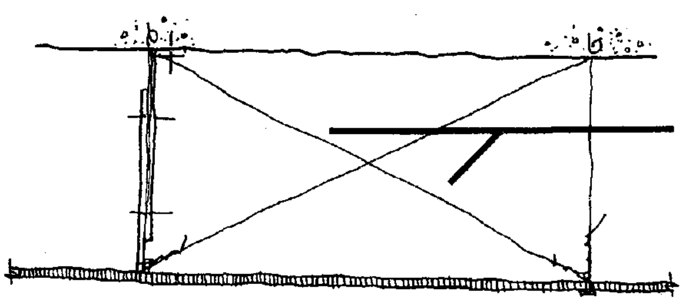
SEPARATION OF CEILING & WALL



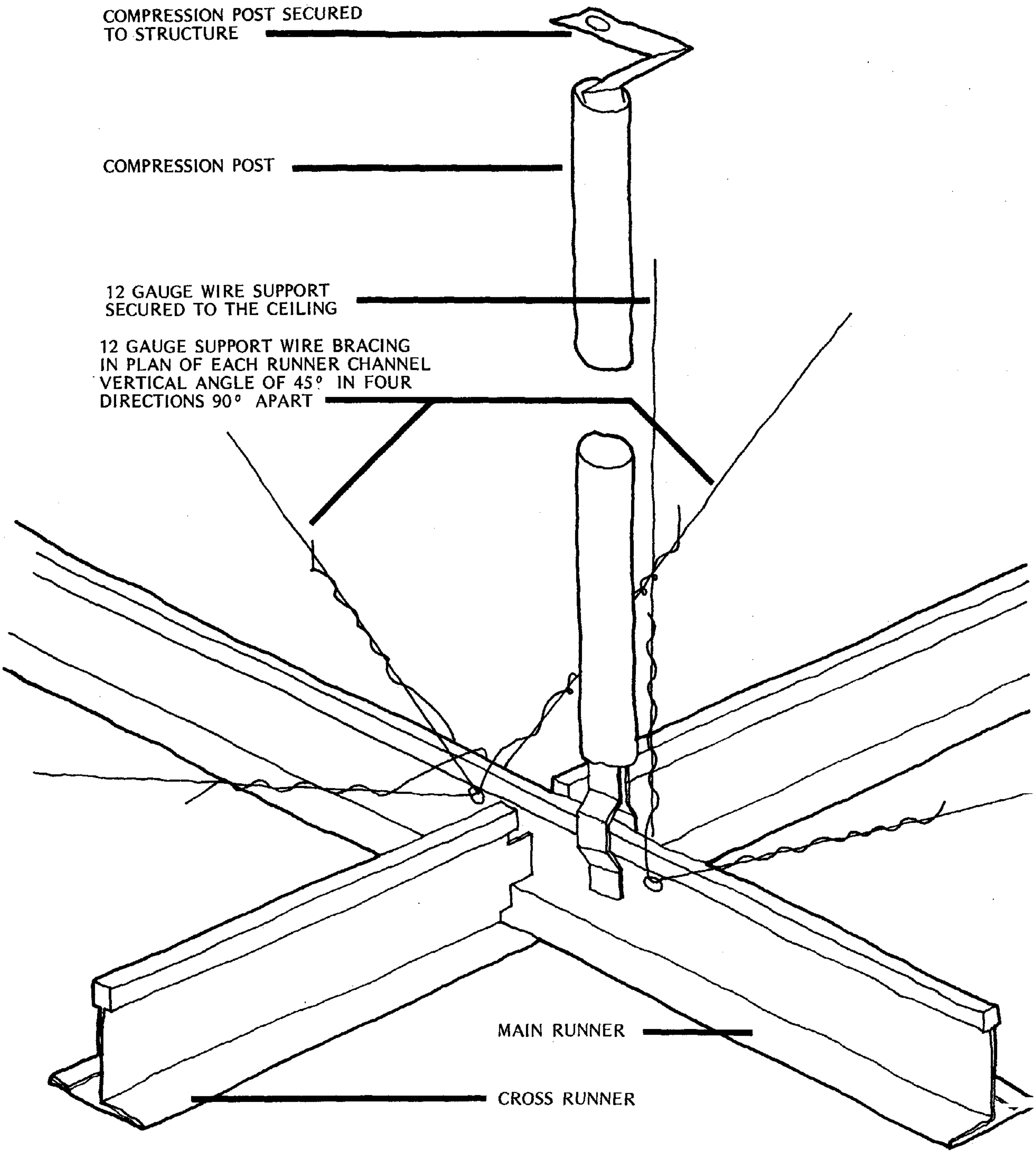
CEILING SUPPORT







BRACING OF SUSPENDED CEILING



ACOUSTICAL CEILING COMPRESSION MEMBER

- When recessed or surface fixtures are used, they should be equipped with positive attachments at the corners and should be attached to a structural element. Recessed light fixtures supported by exposed tee-bar ceiling systems are potential personnel hazards. Each fixture must have at least two independent hanger wires per fixture at diagonal corners that are anchored to the floor slab above.

- The positive attachment of batter-powered emergency lighting to the structure is often neglected in building design specifications.

- Lay-in lighting, which is used for increased flexibility, often has stability problems.

- Plastic lenses can be used on fixtures in place of glass, and held in place with metal clips screwed in place.

6.

- Large glass areas can have a high damage potential, as well as possible security and energy problems. Interior glazed areas that should receive consideration include the communication areas, police prisoner processing areas and fire apparatus rooms.

- Tempered glass, laminated safety glass or plastic windows can be used in areas where breakage could cause injury due to broken shards of glass. This includes glass doors.

- Resilient mounts for glass panels with sufficient space around the frame for glass displacement can be used. Gaskets or sealants that do not lose their resiliency with age or exposure are recommended. Flexible sealants or rubber seals allow the glass to rotate within the frame to provide additional frame distorting without imposing a diagonal force on the glass.

- Although skylights may be used for natural illumination, they pose a hazard in the event of an earthquake. Plastic panels, properly secured, can be used.

- Windows located high in walls may create the hazard of glass falling on personnel and equipment during an earthquake. Windows slanted outward from the top would be less likely to harm building occupants should the sash break.

- Ceilings and curtain pockets adjacent to window assemblies can be braced, and proper clearance for building movement provided, to avoid damage to windows.

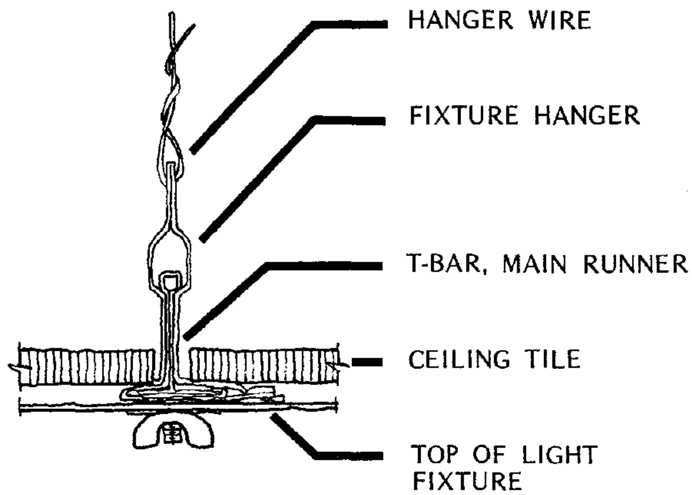
7.

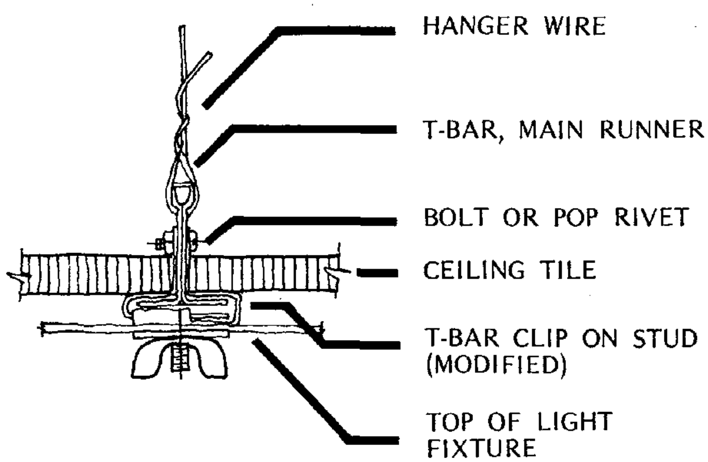
- Safe circulation/exit routes should be planned so that personnel can proceed to apparatus and stations or egress the station in minimum time with minimum obstruction. Corridors or routes should be equipped with emergency lighting powered by the generator or batteries.

- Partitions that enclose exit routes are critical components for easy egress and should be designed as such.

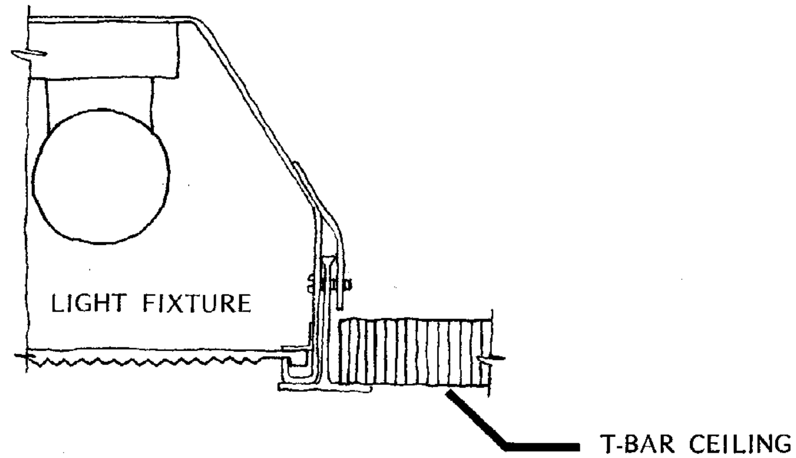
- Avoid glass, ornamentations, poorly supported suspended ceilings, pendant light fixtures, etc., along routes and exits.

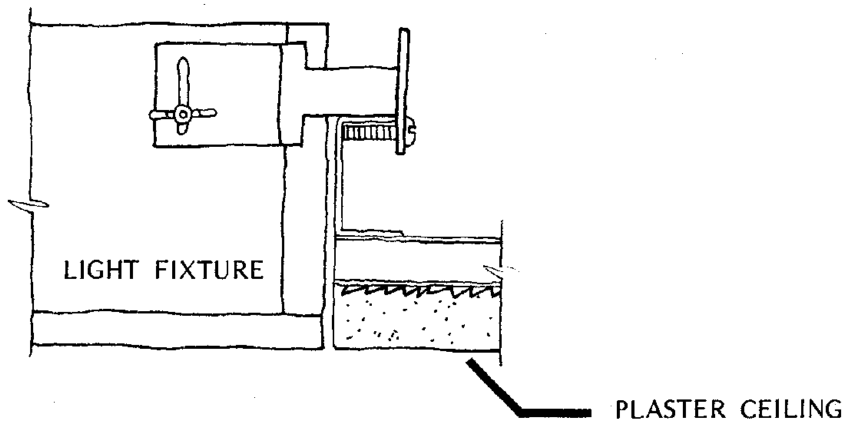
- The reasons for door and frame failure in earthquakes are obvious. The door assembly must function with normal frame-to-door clearances required for fire protection while the wall that it is attached to will be subject to racking and bending.

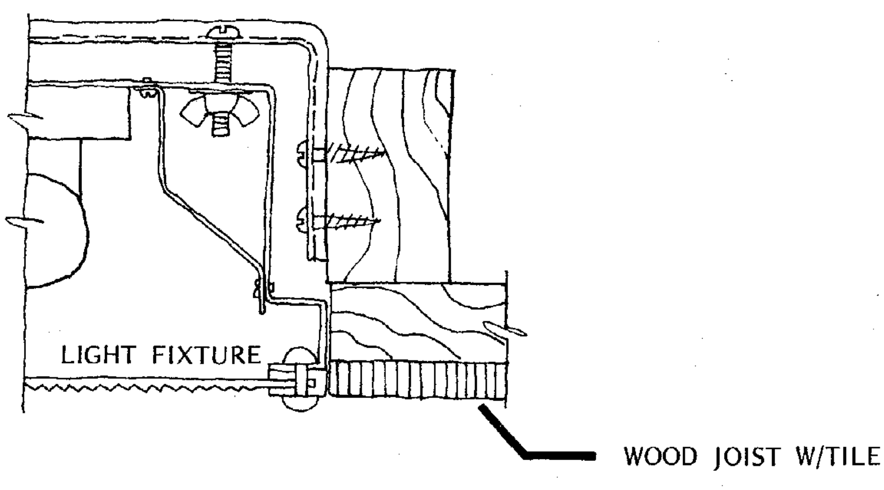




POSITIVE LOCKING DEVICES FOR SURFACE MOUNTED FIXTURES







RECESSED LIGHT FIXTURES

- Fire apparatus room doors are highly susceptible to damage. The frame should be strengthened and the roller assembly restrained. Apparatus room doors must be manually operable when power systems or automatic operating devices fail.

- Critical access door frames should be specially braced to prevent jamming. Consideration can be given to access panels in critical doors.

- Security considerations may require police and fire stations to have a limited number of exits. This could contribute to panic and injury in an earthquake disaster. Advance planning for timely and controlled exit from the facility could help alleviate this problem.

- Emergency exits, which are often bolted or padlocked for security reasons, should be designed to be both secure and operable for quick exit at the time of an earthquake or similar disaster.

- Lobby doors designed for security should also be designed not to jam and impede exiting.

- The design of stairwells, which can be critical when emergency egress from buildings is necessary, should be structurally sound. The stairwells and all exit corridors should be equipped with emergency lighting powered by the generator or batteries.

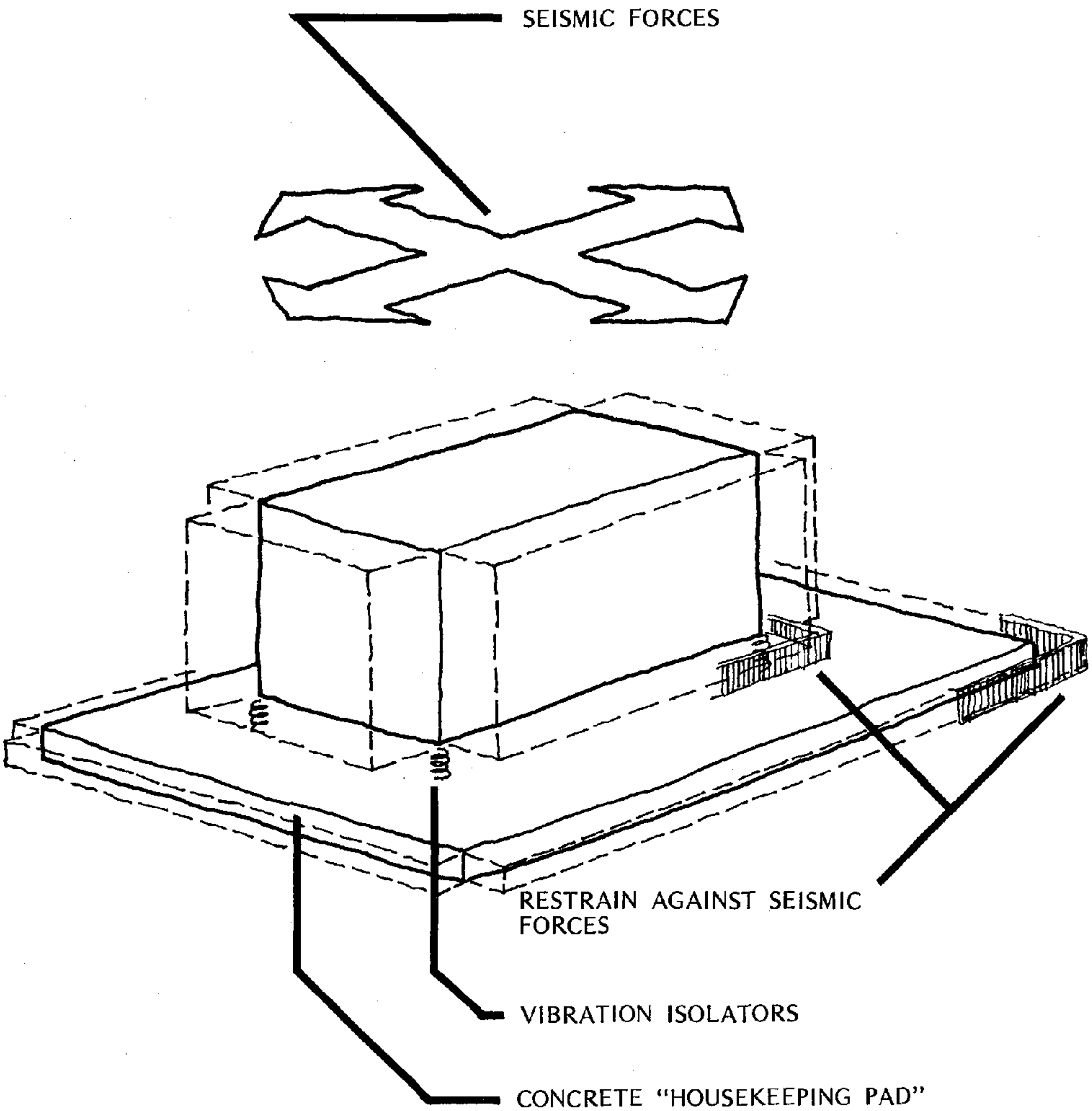
- The behavior of stairs within an enclosed stairwell which is distorted by building drift is critical. Stairs tend to act as diagonal bracing between floors, and can have damaging loads induced in them by inter-storv deflections. One possible solution is to design stairs as two flight or three flight free-standing staircases, spanning from the floor above to the floor below as a self-contained structure, without any outside support to the landing. The flexibility for inter-story movement at right angles to the main flights must be checked. Another arrangement is to put a separation gap through the mid-story height landing, so that each half of the landing is connected to only one flight of stairs. The support for the vertical load of the landing is warranted so that the landing is free to move laterally. Such support can be by flexible hangers, flexible struts or sliding support on a beam. Where a stairway consists of single flights between floors. each flight can be fixed at one end by a movement gap and sliding support, or freed at the top by providing flexible strut support. Separation gaps can be covered by metal plates with provision for sliding.

8.

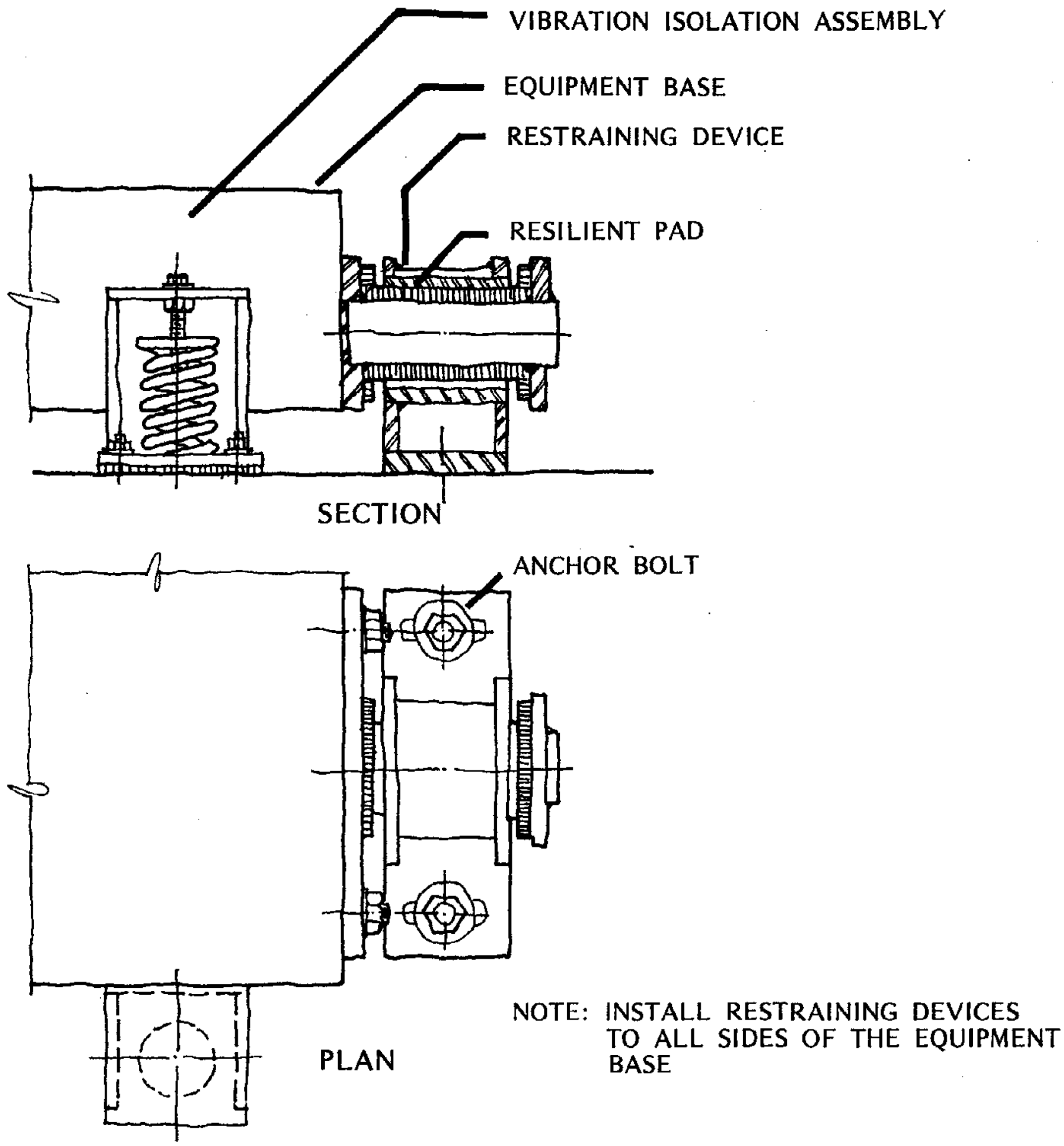
- Redundant fuel lines, piping and circuits can be used for emergency equipment. These lines should be kept as short as possible.

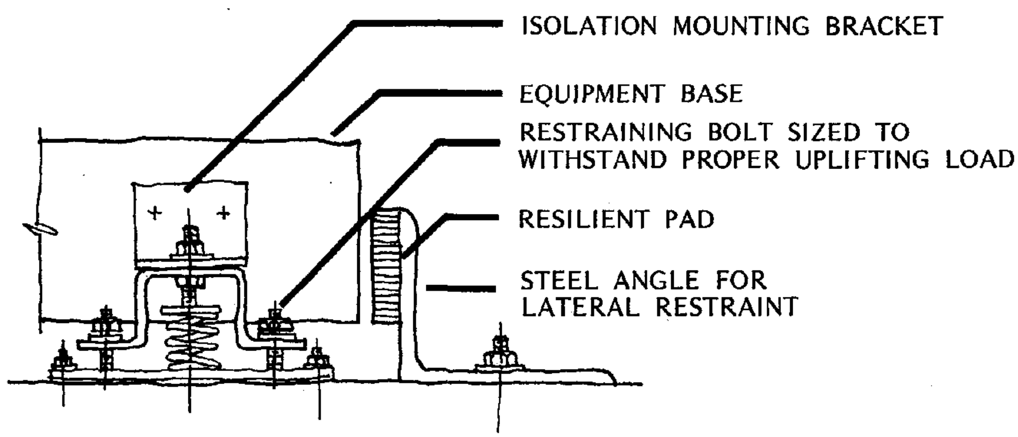
- Emergency generators should start automatically when there is a power interruption or loss prior to complete power failure. Master starters for emergency generators can be provided with undervoltage relays to void damage caused by low service voltages after an earthquake.

- It is worth noting that "old" fuel is a common reason for failure to start. Use of a compatible shelf life additive and maintenance of a fresh fuel replacement program are desirable. If existing gas lines are used to supply the emergency generator, an alternate source of fuel should also be provided.



EQUIPMENT SUPPORT





RESTRAINTS FOR VIBRATION ISOLATION MOUNTS

- Dual carburetors that switch fuels are useful on standby emergency generators. Diesel is one of the dependable fuels, and most generators are diesel-powered.

- Batteries should be securely strapped in racks.

- Fuel tanks can be located underground and as close to generators as is safely possible. Small day-tanks can be used to provide a few hours of fuel if lines are broken.

- Emergency generators should have flexible wiring connections and shock mounting with seismic features.

- Emergency generators should be located in areas with good ventilation. Separation between generator and furnace will help prevent heat buildup and damage from equipment collapse.

- All fuel supply lines and exhaust systems should have flexible connections at the generator.

- The building's fire suppression system (e.g., sprinklers, standpipes) must be protected. Fire extinguishers must be supported in ways that resist lateral earthquake forces.

9.

- Consistent degrees of freedom of movement should be used between piping piping/ductwork and connected equipment.

- The use of flexible connections at piping/equipment connections should be explored. The piping leading to connections should be guided to confine the degree of movement.

- The use of kinetic couplings at tees and other changes of pipe direction, especially at the bottom of risers, should be explored. Non-rigid duct connections can be used at bends. Consideration should be given to the combustibility of materials used.

- Horizontal pipes are usually more susceptible to damage than vertical piping.

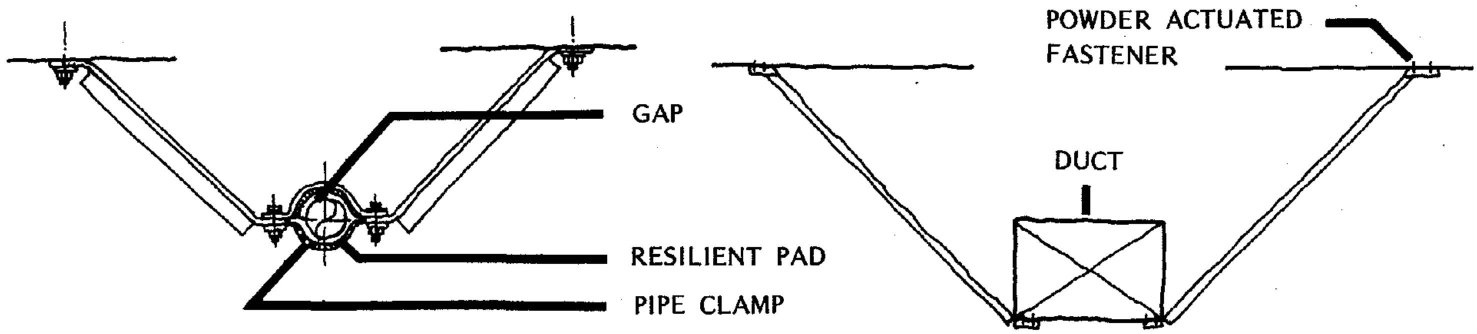
- Supports should be provided at all pipe joints.

- Whenever possible, service lines should not be located where line breakage can reduce other functions (e.g., water pipe break that floods basement mechanical equipment area).

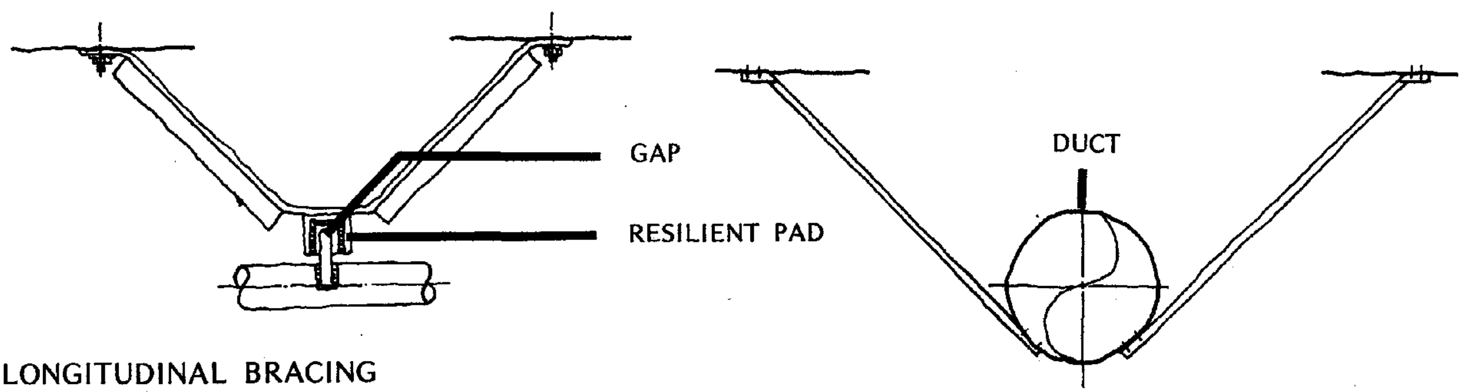
- Spreaders can be located between adjacent pipes to prevent contact during earthquake movement.

- Although locating equipment rooms and heavy equipment on the roof can reduce unwanted heat gain and heat loss in the building, it can reduce the seismic resistance of the building if not designed properly.

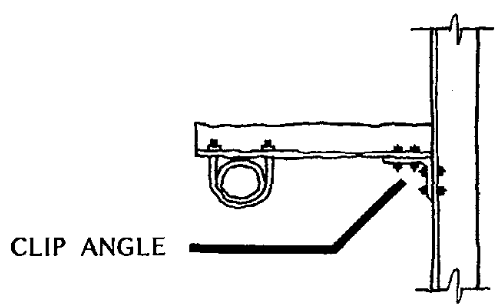
- Mechanical equipment rigidly mounted to a structural element (floor) usually performs better than equipment mounted on vibration isolation supports. Thus, noisy equipment should be located away from certain areas. If vibration isolators are used, they should be restrained in all directions.



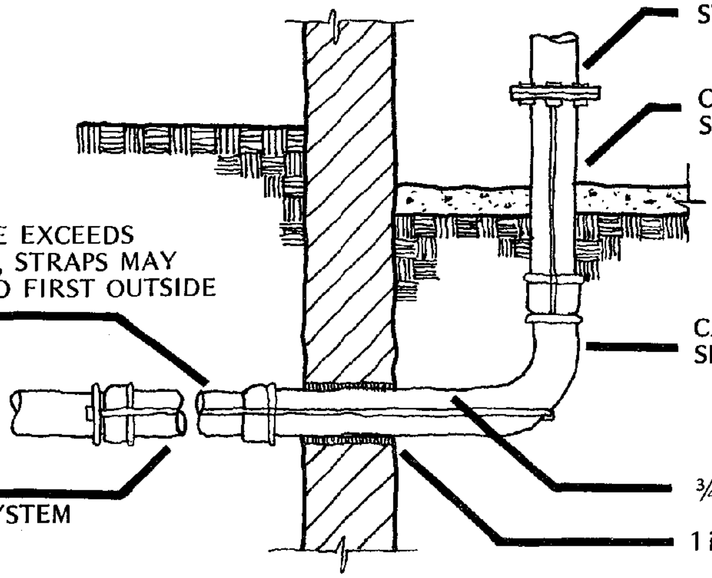
TRANSVERSE BRACING



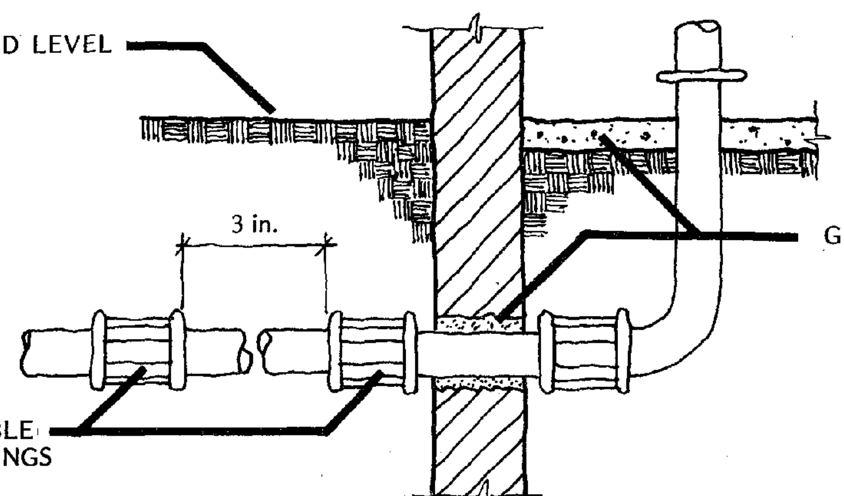
LONGITUDINAL BRACING



BRACING FOR PIPES/DUCTS



UNGROUTED PIPE



PIPE GROUTED IN WALL

ACCEPTABLE SEISMIC DETAILS PIPING ENTERING BUILDING

- A vast majority of mechanical equipment within a building is supported on vibration isolation mounts to eleminate noise transmission through the structure. All major manufacturers of vibration mounting offer "earthquake mount" or "earthquake snubber' restraints that prevent overstress of spring mounts.

- When solar energy systems are used, roof panels, tanks and related equipment should be anchored and otherwise safeguarded. Water tanks above ground offer considerable problems.

- Hot water heaters and tanks can be anchored and strapped to structural elements to prevent overturning.

- The heating system should have emergency power in stations located in cold climates.

- Piping crossing seismic building joints should be avoided. If this is not possible, loops should be used when crossing joints.

- Piping, especially chemical supply, can have a movement-sensitive shut-off valve.

- Pipe sleeves should be large enough to allow piping movement, as well as be lined with vibration damping material.

- Piping installed within partitions should be tied to the same structural element as the partition to ensure consistent movement during an earthquake.

- Screwed fittings are more vulnerable to earthquake failure than welded or soldered fittings. Also, threaded pipes that are used as equipment legs are susceptible to stripping and failing.

- Sway bracing in two directions can be provided to all piping following the recommendations of the National Fire Protection Association's 'Standard for Installation of Sprinkler Systems." Lateral bracing can be used for suspended ducts, expecially long runs.

- Long pipe runs can be reduced by minimizing the length of dead runs such as those connecting faucets. Shorter duct runs not only save energy by reducing friction, they are also more seismically safe.

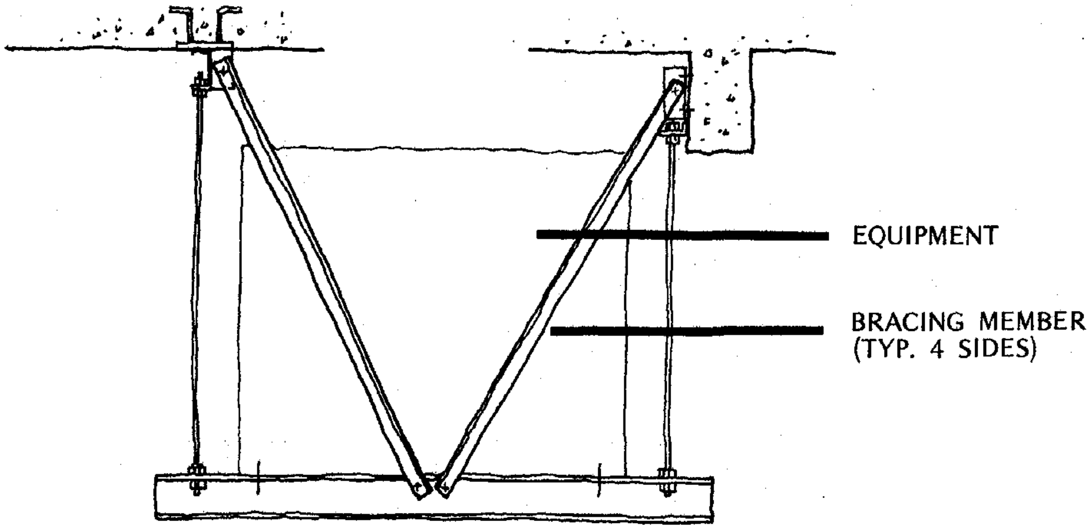
- Hanging ducts from other nonstructural components (e.g., piping) should be avoided. Ductwork should be anchored to the same structural element as the supply equipment to provide consistency of movement.

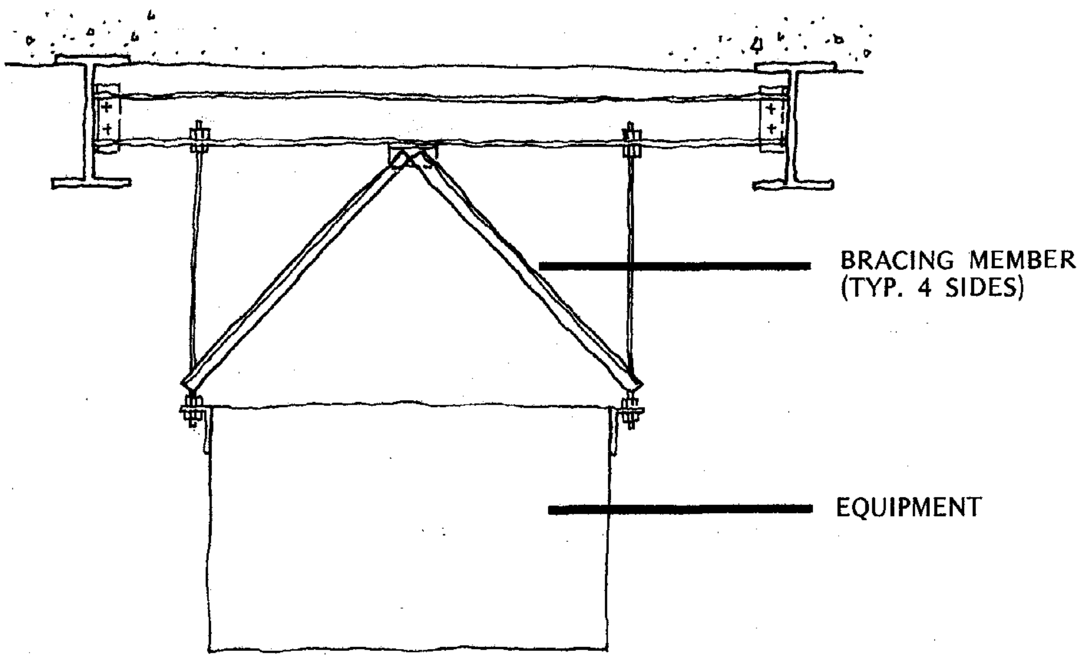
- Grills and diffusers can be lightweight and equipped with safety chains.

- A structural restraining frame should be provided around suspended heavy equipment.

- If unit heaters, like those often used in apparatus rooms, are suspended, they should be anchored and braced against seismic forces.

- Panels and switch boards should be bolted to a structural element and braced to resist lateral forces.





BRACING FOR SUSPENDED EQUIPMENT

- Multiple crossing of seismic building joints with conduits should be avoided. When this is impossible, loops in conduits can be used for more flexibility.

- Crossing seismic building joints with conduits should be avoided. When this is impossible, flexible conduits can be used.

- A separate ground conductor for a conduit run across seismic building joints should be considered, since the grounding system could be broken.

- Additional pull boxes can be located to relieve the tension that occurs along conduit runs during earth movement.

- Branch circuits, when possible, should be reduced in length by proper location of the power distribution centers.

- Flexible braided connections can be used in place of rigid copper busses.

- The swinging door of the electrical panel should be secured, and free-standing panels should be bolted to the wall.

- Electric fuel pumps should be connected to the emergency generator. The fuel pump for the generator itself should also be manually operated.

- Certain high efficiency lighting (HID lamps) starts slowly, and should be avoided in critical areas that will need immediate lighting. Backup emergency battery-operated lighting (with built-in charger) should be used for critical operational areas.

- Clean, break-away mothods (non-twist locks) help prevent damage to mechanical/electrical connectors.

- Electrical distribution and motor control equipment is usually placed within sheet metal enclosures. The specification and anchoring of such equipment requires careful attention. Often, the most significant source of flexibility in equipment enclosures is local deformation of the equipment base near the anchor points.

10.

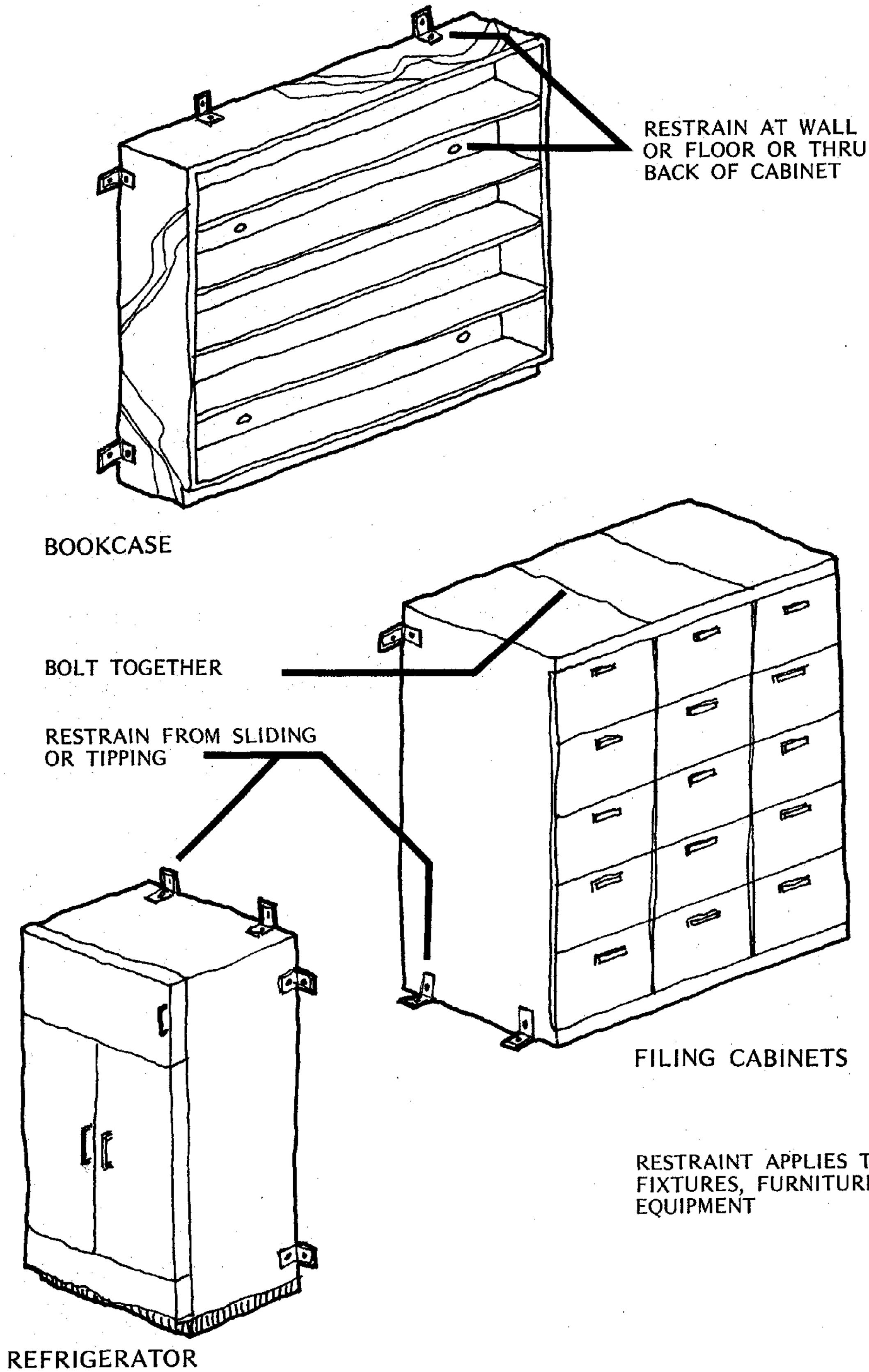
- Maximum attention should be given to increasing the stability of free-standing, tall furniture, such as bookcases and filing cabinets. Free-standing cabinets, lockers and shelving should be configured to increase stability. Units can be attached to each other and to the floor to prevent "walking" and overturning.

- Heavy equipment and furniture can be anchored at the base and braced laterally at the top.

- Free-standing items, especially tall, heavy equipment, can be anchored to a structural element.

- Furniture with a low center of gravity and widespread leges is less likely to overturn. Wheeled items should have wheels as large as feasible.

- Restraining rods, pins, straps or magnets should be considered for heavy equipment that is frequently moved.



RESTRAINT APPLIES TO HEAVY FIXTURES, FURNITURE OR EQUIPMENT

FURNISHINGS & EQUIPMENT

- Elastic straps, covers, face bars, restraining lips, metal angles and shelves that tilt backwards should be considered for restraining containers and items on shelves.
- Alcoves in which heavy wheeled equipment can be stored when not in use should be considered.
- Large, heavy items, such as containers, are most safely stored on the lowest shelves.
- Latching devices can be used on drawers, especially those not in frequent use.
- Glass containers for chemicals, etc., in police crime laboratories or storage areas should be avoided.
- Recessed trays or bolts can be provided to anchor typewriters and other heavy small equipment.
- Small dangerous items, such as tools, are more safely stored in storage bins.
- Supplies should be stacked so as to increase the stability of the pile (e.g., reverse the axis of each level in the stack).

EQUIPMENT

INTRODUCTION

In designing for protection of equipment from seismic forces, the codes as well as general standards of engineering practice encourage the use of dynamic analysis. Such an analysis takes into account the specific dynamic properties of the earthquake (the duration, frequency content, acceleration of the ground motion, etc.) and the building (its period, relative movements of various structural elements, damping, rigidity of support, etc.). The equivalent static force method, which is spelled out in the texts of codes, tries to take the complex dynamic interrelationships into account by the use of formulae such as Fp=ZICpSWp. This formula method is easier and faster to use, and can generally be relied on as long as good judgement is used, and as long as the case at hand is not atypical in any relevant way.

The following provides an example of how the design force for a typical piece of equipment would by computed according to the 1976 Uniform Building Code.

Z	=	Geographic Factor	=	1	Maximum value, applies to most buildings in California (Fig. 1, Chapter 23)
Cp	=	Coefficient taking into account dynamic factors and also importance	=	.5	"Equipment or machinery required for life safety systems or for continued operation of established facilities" (Table 23-J)
I	=	Importance Factor	=	1.5	(Table 23-K)
S	=	Soils Factor	=	1 1.5	Minimum Maximum (2312-d)
IxS	=	Importance x Soils	=	1.5	I(s) $\leq$ 1.5 (Table 23-J, note 5)
Wp	=	Weight of Object			Includes contents of shelves, etc. (Table 23-J, note 3)
Fp	=	Lateral Force			

Fp = [Z x Cp x (I x S)]x Wp (2312-g)

Fp = [1 x .5 x 1.5]x Wp

Fp = .75 x Wp Lateral Force = ¾ g = ¾ weight

Subscript "P," as in Cp and Fp, refers to fact that it is the C coefficient or F force for a part of a building.

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The more essential the structure or equipment, the more reason there is to use a full dynamic analysis. Note that merely increasing the force factor for essential equipment is not necessarily enough. The current Structural Engineers Association of California's *Blue Book*, for example, contains this important warning:

> It is emphasized that the SEAOC Seismology Committee does not subscribe to the philosophy that better performance is totally equated to increasing the design force level. The basic concepts and configurations of the lateral resisting system may be more important than the design force level but considerations impractical to codify are involved. The lateral resisting system in whole, and in part, must be well detailed to accomodate seismic demands.
>
> Increasing the design force level may not necessarily minimize damage to non-structural building elements, contents, equipment and utilities. Those responsible for such elements must design, specify and detail them to provide good seismic performance. Such consideration is especially important for vital systems of essential facilities if the latter are to remain operable after an earthquake. (SEAOC, *Recommended Lateral Force Requirements and Commentary*. 1975.)

DESIGN CHECKLIST

1. Have the major pieces of equipment been considered as to their importance, hazard and worth?

    Essential Equipment

    ____

    ____

    ____

    Hazardous Equipment

    ____

    ____

    ____

    Expensive Equipment

    ____

    ____

    ____

2. Have problems induced by the building design been considered in the protection of the equipment?

____

____

____

3. Has the rigidity or flexibility of the piece of equipment and its mount been considered in its seismic protection?

____

____

____

4. Has increased attention to seismic protection been given to unusually heavy equipment?

____

____

____

5. Has consideration been given to the equipment's location within the station?

____

____

____

6. Has the housing of the equipment been designed or selected to provide an improved response to lateral forces?

____

____

____

7. Has the relative movement of the structure during an earthquake and its interaction with the piece of equipment been considered?

____

____

____

8. Do the equipment specifications take into consideration the resistance and protection of the equipment during an earthquake?

____

____

____

9. Communications equipment is extremely important for the continued operation of the station after an earthquake. Have the various elements and pieces that make up the communications system been located, designed, selected, and attached to increase their seismic protection?

____

____

____

COMMENTARY

1. Police and fire stations contain specialized equipment that should be protected during an earthquake. This equipment generally falls into three categories.

    - Essential equipment is that equipment that is essential to the operation of the police or fire station in an earthquake disaster. Essential equipment could also include items or materials that, although not essential during the disaster, would be essential to normal operations and could be irreplaceable if destroyed in the earthquake.

    - Hazardous equipment is that equipment that might be hazardous to essential equipment or personnel during an earthquake.

    - Expensive equipment is that equipment that is extremely expensive and would be very costly to replace after a disaster.

2. Lack of symmetry, unusual flexibility, a mixture of structural materials and structural systems, unusual soils conditions or any other atypical condition in the building itself will introduce problems into the design of equipment supports.

3. The stiffer the equipment, the better. Bolted down equipment can be so stiff that its period can be much less than the predominant period of the ground motion, which is usually between .1 sec. and several seconds. Flexible equipment can begin to resonate, and

SEISMIC CRITERIA

POLICE STATION EQUIPMENT	ESSENTIAL	HAZARDOUS	EXPENSIVE
Communications Equipment	●	●	●
Emergency Generator	●	●	●
Data Processing/Computer	●***	● *	●
Furniture (table, chairs, display cases)		● *	
Office Equipment (filing cabinets, lockers, etc.)		● *	
Gas Pumps	●	●	
Vehicles	●		●
Maintenance/Repair Equipment	●	● *	
Laboratory Equipment		●	● **
Security Equipment (TV monitors, etc.)	●		● **
Evidence/Records Equipment	●***		
Photographic Equipment		● *	● **
Armory Items		●	
Exercise Equipment		●	
Special Equipment (surveillance, etc.)		●	● **
Duplicating Equipment		● *	● **

* DEPENDS ON ROOM LOCATION
** CERTAIN ITEMS
*** REQUIRED AFTER DISASTER

SEISMIC CRITERIA

FIRE STATION EQUIPMENT	ESSENTIAL	HAZARDOUS	EXPENSIVE
Communications Equipment	●	●	●
Emergency Generator	●		●
Furniture (beds, chairs, lockers, etc.)		● *	
Office Equipment (filing cabinets, desks, etc.)		● *	
Apparatus Doors	●		
Hose Care Equipment		● *	
Fire Poles	●		
Gas Pumps	●	●	
Apparatus/Vehicles	●	●	●
Kitchen Equipment		● *	
Maintenance/Repair Equipment	●	● *	
Exercise Equipment		●	
Miscellaneous Equipment (small pumps, hose, lights, etc.)	●		
EMS Equipment (supplies, respiratory equipment)	●		● **

* DEPENDS ON ROOM LOCATION
** CERTAIN ITEMS

as a result experience a great load. The extent of amplification can be known accurately only through a specific analysis. The UBC states, for instance, that "[f]or flexible and flexibly mounted equipment and machinery, the appropriate values of Cp shall be determined with consideration given to both the dynamic properties of the equipment and machinery and to the building or structure in which it is placed...."

Equipment on vibration isolation mounts, generally only mechanical equipment, requires special attention. Positive anchorage must be retained while still allowing for the isolation assembly's function. Vibration isolators are designed for rapid, mechanical vibration; slower, earthquake-induced motions are amplified by the isolators, not reduced by them.

Electronic equipment that at first sight looks quite rigid may actually be rather flexible. Most communications and computer equipment takes the form of metal boxes or cabinets, but often the "shear wall" sheet metal panels are poorly attached to the corner angles. Metal cabinets with one or more open sides should be designed so that the remaining sides can carry the shear, torsion and bending moments for the entire cabinet. The bottom should also be strong enough to transfer the forces to the anchor bolts or connections.

Smaller electronic pieces of equipment, about the size of ordinary stereo components, are generally quite stiff and strong, and the only problem is their anchorage. Larger cabinets may be inadequate. Electronic equipment is generally in metal cabinets, which usually have flexibility problems, as compared to wooden cabinets and lockers, which are usually stiffer. If equipment is mounted in a frame, rather than in a cabinet box, special care must be taken to be sure the frame is stiff enough.

4. The military's *Seismic Design For Buildings* takes special note of pieces of equipment that weigh more than 15,000 lbs. or weigh more than one-fifth of the dead load on the floor where the equipment is located or more than one-tenth the total dead load of the building. Such equipment cannot be assumed to have a negligible effect on the response of the building; conversely, the response of this equipment is highly dependent on the response of the building.

5. Equipment mounted on two different floors of a building will experience two different earthquakes. Acceleration is greater at the top of a flexible tower, for instance, and less at the ground level.

   The draft version of the TITLE 24 provisions for California hospitals states that "[e]mergency equipment should be located where there is the least likelihood of damage due to earthquake. Such equipment should be located at ground level...," and reductions in the seismic load factor are permitted for equipment mounted on a slab or foundation on grade. In the design of the new Veterans Administration hospital at Loma Linda, California, communications equipment in the basement or on the first floor was designed for a lateral load factor of 1; at the second floor, 1.5; and on the roof, the design load was twice the equipment's weight (and the building was a four-story, low profile, shear-walled structure; in a more flexible building the loads might have been raised even more for upper floors).

   Most fire and police stations are one or two stories high; it is preferable to put essential, hazardous or expensive equipment on the ground level. Central stations or combined-service municipal facilities may be taller buildings and in these the problem becomes worse because it may be functionally or operationally necessary to place such equipment on upper floors. Antennae are often roof-mounted by necessity and require special attention.

6. Equipment with eccentrically loaded or irregularly framed housing can experience excessive seismic stress caused by torsion or unevenly distributed response load; the same principles apply to buildings. Thus, equipment can be considered little buildings sitting inside larger buildings.

7. Flexibile equipment is to be avoided for two reasons. As already noted, the degree of flexibility is the key characteristic that determines the response of a structure to an earthquake; varying the flexibility varies the force level. Second, flexibility obviously affects how much objects move during earthquakes, and if the motions of pieces of equipment, walls or floors are imcompatible failure is imminent. Stiffness is desirable in both cases, for it moderates the response for equipment (for buildings, it is not always true that stiffer is better) and it reduces the amount of motion that must be handled.

   In the case of fire and police equipment, which is typically furniture-sized boxes of electronic gear sitting on the floor, planners should allow several inches of space between the back and/or side of equipment and the walls to enable the floor-plus-equipment rigid assembly (once the equipment is bolted down) to move one way while the wall moves another. The amount of space allowed should equal or exceed the amount of potential motion calculated. For the purpose of detailing equipment, drift is significant because it can cause room contents to undergo incompatible motions. The equipment can tolerate the drift that will occur between two adjacent floor levels as long as it is not structurally connected to both floor and ceiling.

   Wall-mounted equipment (unless it is small components installed in shelving) often also touches the floor, which could create incompatible relative motions during an earthquake because the floor and wall may not form a right angle during a quake.

   If a piece of equipment is to be installed onto one of the room surfaces only, the best choice is probably the floor. This is the lowest, stiffest and strongest structural element available, and the failure mode would be sliding or overturning, rather than the more hazardous and destructive falling that would occur if mounted on a wall or ceiling. Partitions can be adequate if properly designed for lateral loads, and ceiling-supported components, which necessarily usually include lights, ducts, diffusers, etc., can be adequately supported as well, but more care should be taken.

   For retrofitting purposes, it is usually easy to ascertain whether the floor is strong enough to support equipment loads (lateral and vertical), whereas walls and ceilings are investigated with more difficulty and less certainty.

   The racking of the open, garage door front of a fire station is a good example of the problem presented by the buildings/equipment interaction. In the design of the building, the flexibility of this structural element should be minimized, while at the same time the door assembly should be specified and detailed so that it can withstand the amount of movement that can occur in an earthquake.

8. If the electronic hardware inside a properly secured cabinet fails during an earthquake, the system becomes inoperative. It is difficult to ascertain the flexibility of some pieces of equipment just be looking at them and for more precise analyses, damping and period values may require shake table tests. Manufacturers who supply equipment for nuclear power plants are accustomed to supplying this data. The threat to the public posed by a police or fire station incapacitated by an earthquake, however, has not been considered sufficient to warrant the cost and effort spent on ensuring the reliability of nuclear power plant equipment. Even on a project as large as the Alaska pipeline, there were difficulties in developing a process with manufacturers for specification, quality control and purchasing to ensure the fulfullment of seismic criteria.

   Yet, more could economically be done to upgrade the seismic standards of fire and police equipment, in particular the communications components. Fire and police professional associations or governmental organizations could develop standards for the equipment involved. If fire and police stations are being designed to remain operational, market forces should encourage the production of better equipment. To buy a cheaper unit that will need time-consuming retrofit work to secure batteries, reinforce frame, or provide connection flanges, rather than to buy a more expensive unit that has such features factory-installed would not be economical. Such improvements can be rather cheaply made in the factory. Optional welded base flanges, for instance, could come with the "seismic" model, and the added cost would almost certainly be less than retrofit work in the field.

9. Police and fire dispatch centers depend on radio as the operational link between the headquarters and the field. Backup base stations, repeaters, emergency radio bands, state links, etc., are used to ensure constant service. The total communications system contains many necessary subsystems, all requiring careful planning. These systems include radio, intercom, closed-circuit TV, alarms, recorders, CRT computer terminals, status systems for cars and people, etc.

   Communications systems require careful consideration of their power requirements. For example, digital-dialing (pushbutton) phones require an external AC power source to function. If intrabuilding telephone communication is considered necessary during an emergency, a battery/inverter system should be considered to supply the required AC power.

   If a city is large enough, its fire service probably has a central communications station, which receives the phone call from a person reporting a fire, sends an alarm message to a branch fire station, and communicates with vehicles in the field. (This may be performed by a single facility in a smaller jurisdiction or in a rural area.) Communication between a central station and its fire houses is usually by telephone lines (including teletype and former telegraph systems, which are also cable systems). Communication between a station and vehicles, and between vehicles, is by radio. Both cable and radio require electricity.

   The essential elements of central station-fire house communication are the electronic transmitting and receiving components; the local electrical system or stand-by generator or batteries; and the local telephone system.

   The normal radio system for communication with vehicles, and the backup radio system for station-to-station communication if the telephone system fails, also have their electronic components, similar in size to the cable-dependent ones, connected to the local electrical system or backup power. Instead of the cable network, the transmitter and receiver are linked via antennae. (The design and anchorage of antennae is a specialized field of its own, beyond the scope of this report, but it is important to note that they are as necessary to the system as the radio set itself. Microwave units are often used to send signals, sometimes in relays, to or from a desirable location from which they are generally broadcast. If the microwave dishes are moved out of alignment, the signals will "miss the target," even if the dishes are not actually damaged. An antenna tower on top of a building is more problematic than a tower on the ground. The structural consultant should handle the design of antenna towers, or review the specification of a factory-built unit.)

As a backup to this system there is the self-contained radio communication capability between vehicles. However, transmitting range may be limited and vehicles from different jurisdictions may be incompatibly equipped and unable to communicate with each other. Power, transmitting and receiving capabilities and antennae are basically similar on the vehicle. Since these components undergo motions in the course of daily work, and have performed well in past earthquakes, the vehicle communication equipment and its anchorage can be considered adequate.

The police station communications set-up resembles that of the fire station. Central station/branch station and central station/vehicle communication is similar. The primary system, in the stations, is the telephone system. Computer terminals are present in many police stations, providing access to license plate numbers, criminal records, etc. The computer portion of the system may be housed in a different municipal building and might also be used by the water and power department for billing customers or by the social services department for sending welfare checks. Yet it is still part of the same system that the police rely on. If temporary disruption of computer services is accepted as tolerable, this portion of the system might be considered less essential than, for example, radio equipment. (However, careful anchorage of equipment in the computer room may be warranted simply because of the equipment's expense.) Like the terminals in the stations, the computer facility is dependent on electricity. In the usual windowless room, the heat gain from the machines makes continued operation of the air conditioning system essential, which in turn requires both electricity and water, and a whole array of pumps, fans, chillers, etc., in operable condition.

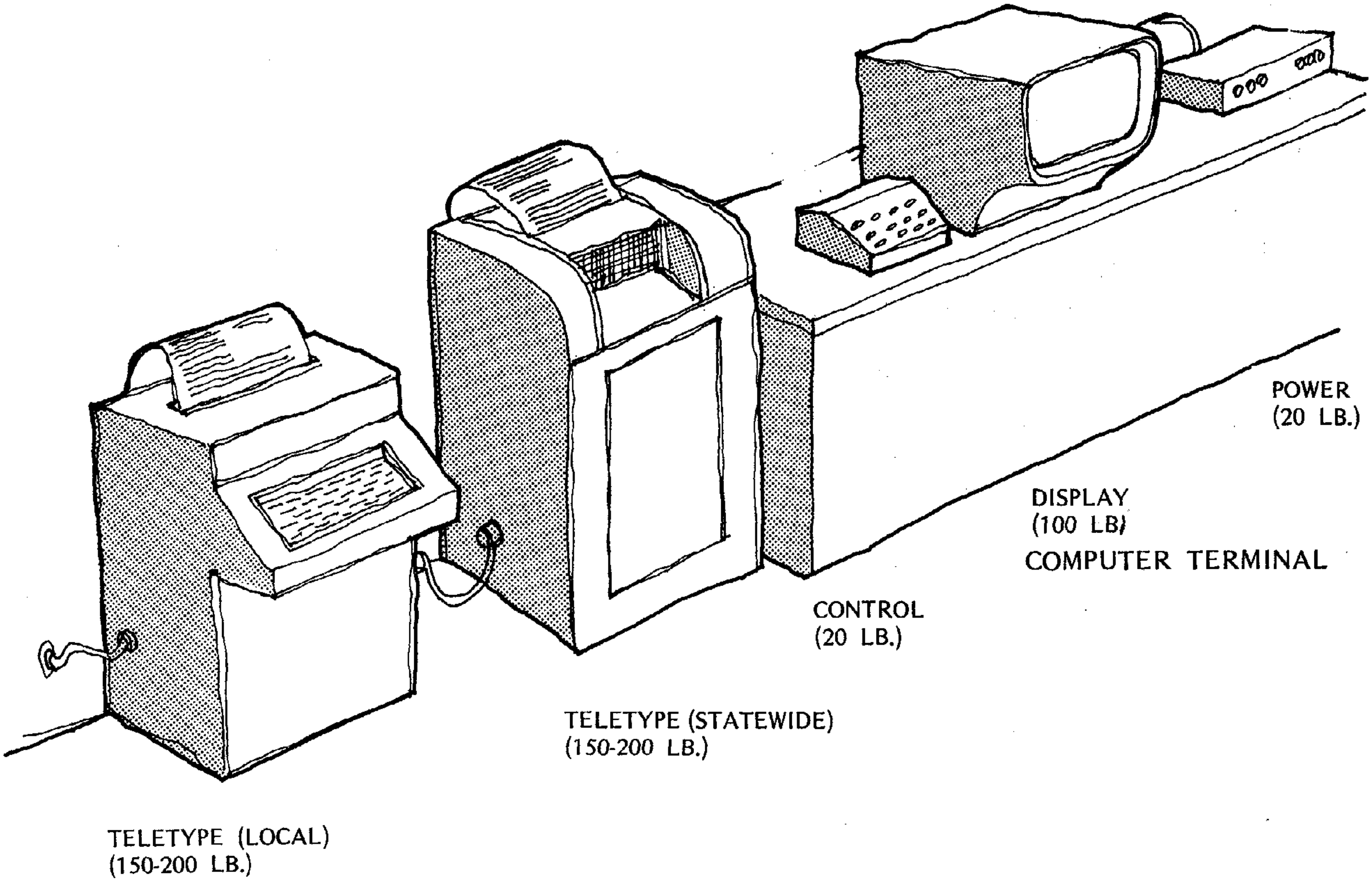
- Radio equipment housed at the station, both base station and portable types, should be securely mounted or stored and readily available. The backup radio base stations should be remotedly located from the main unit.

- The communications dispatch center should be located in the most secure part of the station and as protected as possible from damage by an earthquake.

- Attention should be given to the stability of the raised electrical floor sometimes used in the communications or computer room.

- The phone lines can lead into the building by an underground service. The antenna cable can be protected at the antenna pole by running a steel conduit at least ten feet up the exterior of the pole. Antenna cable should not be placed on the interior of a monopole.

The following examples display specific pieces of equipment in police and fire stations and design strategies for their earthquake protection.



POLICE STATION COMMUNICATIONS SYSTEM

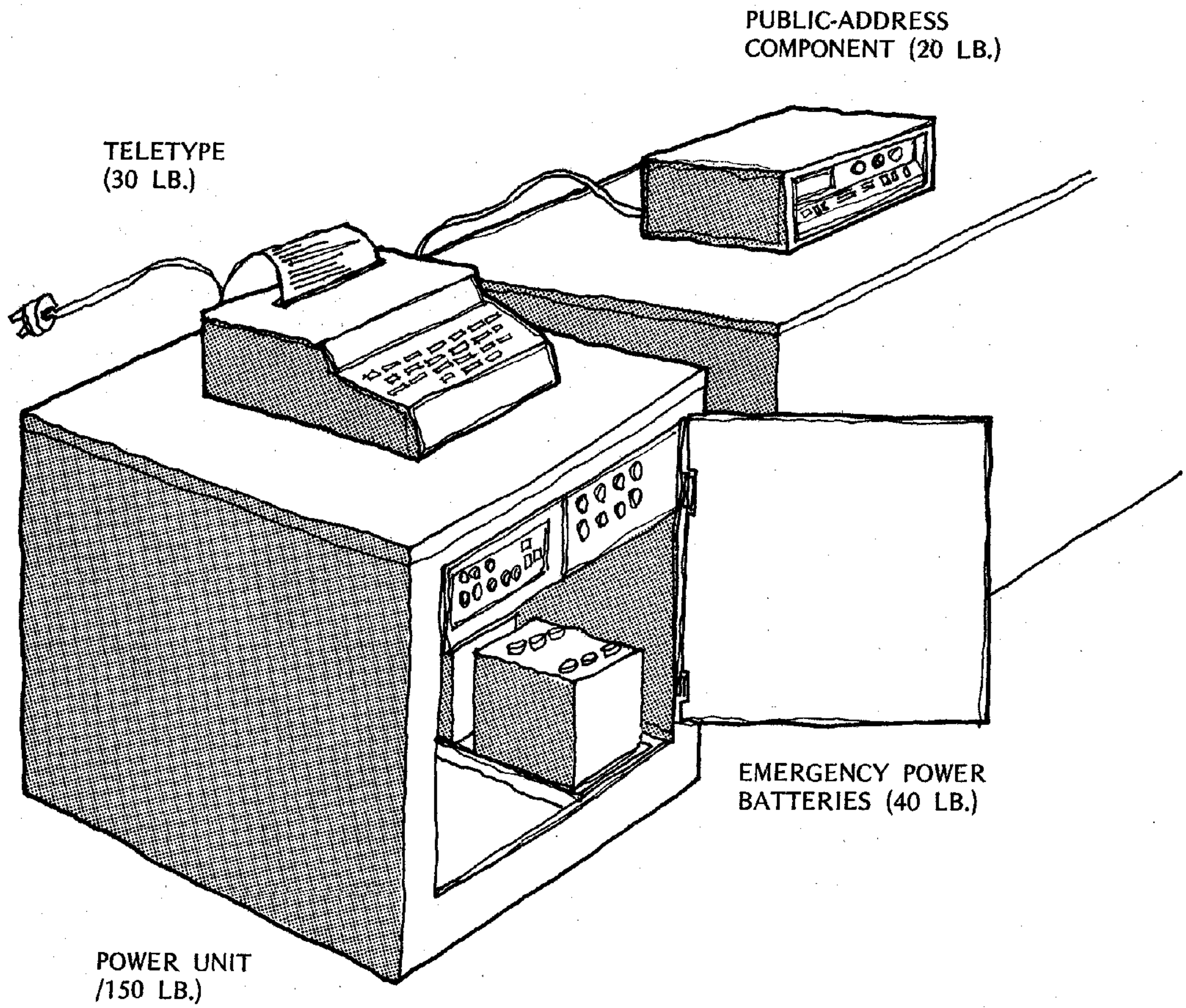
IMPORTANCE: Essential Equipment

FUNCTION: All components have the role of extracting information from, or feeding information into, central data systems. Some of these systems provide linkage with other law enforcement agencies, and some service the local jurisdiction's data only; some are computerized, some are not. Radio backup can provide the communications function but cannot provide ready access to data.

SUPPORTING INFRASTRUCTURE: Local telephone system (signals travel via cables). Electrical system (or emergency generator). Data processing facilities with which these components connect.

VULNERABILITY Phone company's service could be interrupted. Same for electrical service; backup generator and its fuel source must then be used. Components could overturn, slide off counter, suffer pounding damage; cabinets themselves could fail. If computer facility in another building is damaged, these components will be inoperable even if they remain undamaged.

SOLUTION: Provide positive anchorage for all components. Reinforce cabinets if necessary on larger pieces. Anchor generator and provide self-contained fuel system (should not rely on natural gas hook-up). Data processing facilities elsewhere must be similarly designed.



FIRE STATION COMMAND & CONTROL CONSOLE

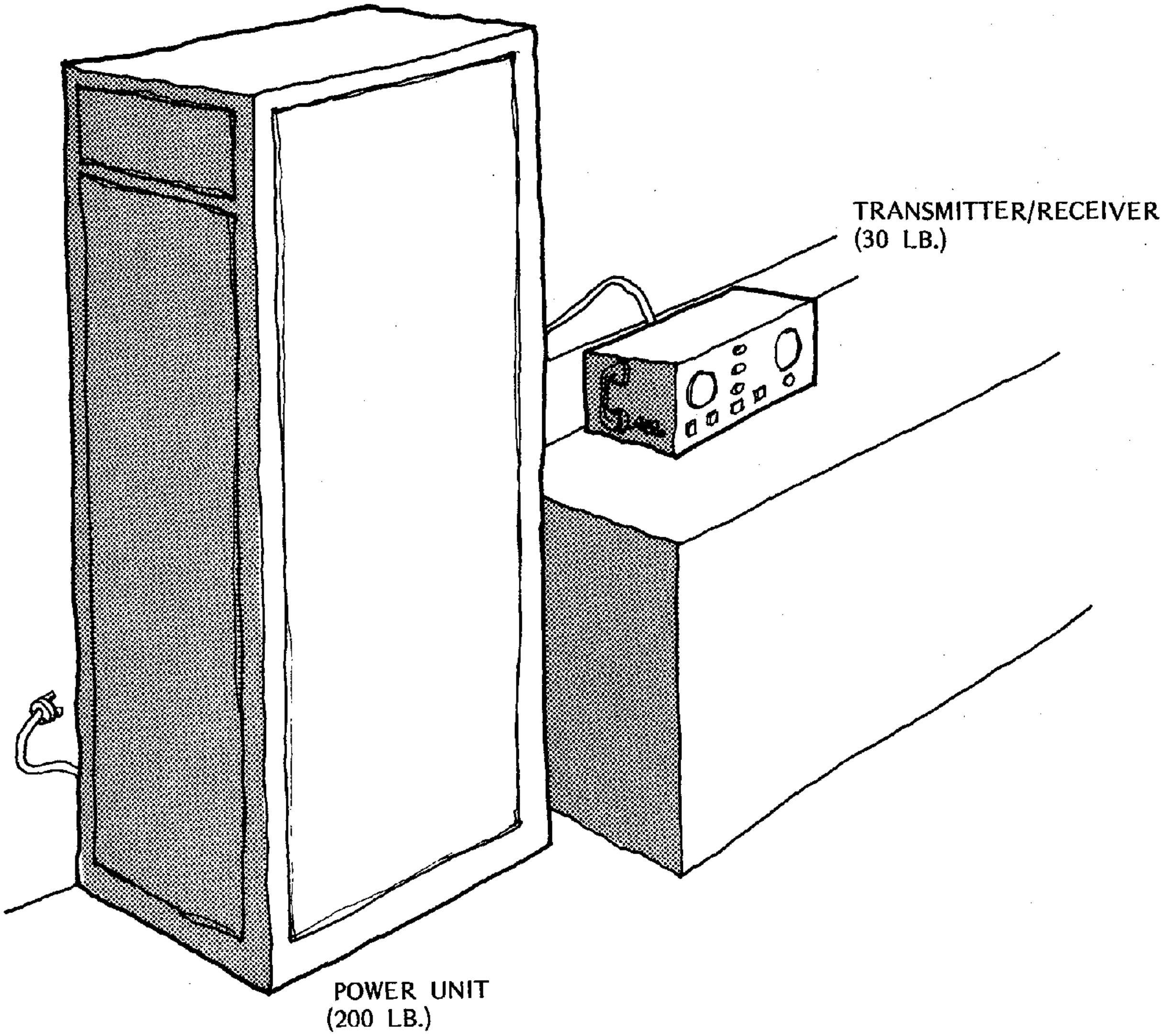
IMPORTANCE: Essential Equipment

FUNCTION: Alarm messages from central station are recorded on teletype and broadcast throughout fire station over P.A.

SUPPORTING INFRASTRUCTURE: Local telephone system (communication signals travel via cables). Electrical system (with stand-by power from generator or, as above, batteries).

VULNERABILITY: Phone company's service could be interrupted, teletype and P.A. could be thrown to floor, power unit could overturn, cabinet structure itself could fail (note opening, which increases flexibility and introduces torsion). Even if power unit remains upright and intact, unattached batteries (or other components inside) could suffer pounding damage.

SOLUTION: Bolt all units to floor, cabinet top or counter top. Strap down batteries. Add bracing to cabinet structure.



FIRE STATION RADIO SYSTEM

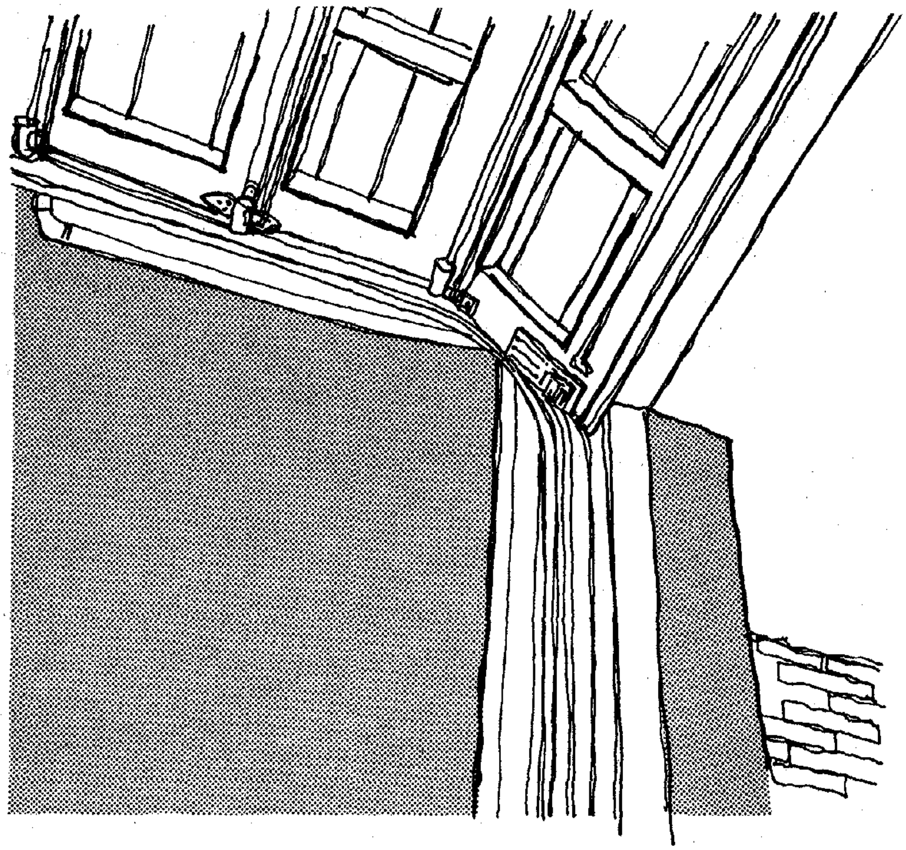
IMPORTANCE: Essential Equipment

FUNCTION: Provides communication with vehicles and central station if cable-dependent teletype and telephone are inoperable; radios in vehicle are possible backup.

SUPPORTING INFRASTRUCTURE: Electrical system (or emergency generator or batteries or, in the above case, capability of plugging into generator on vehicle).

VULNERABILITY: Transmitter/receiver could fall off counter. Power unit is a poor shape and relatively heavy. If it didn't overturn, its inertial force could cause its own cabinet to fail. Light frame and removable sheet metal panels make the cabinet neither strong nor stiff. (Lack of stiffness increases period, which may increase resonance, increasing the applied load.)

SOLUTION: Bolt transmitter/receiver to counter. Attach power unit to wall or counter (rather than attaching at base and expect it to perform as cantilever). Straps around cabinet preferable, rather than single point connections. Brace cabinet structure.



FIRE STATION APPARATUS DOORS

IMPORTANCE: Essential Equipment

FUNCTION: Provides for exit of apparatus and personnel from fire station. Encloses and protects apparatus room from elements and vandals.

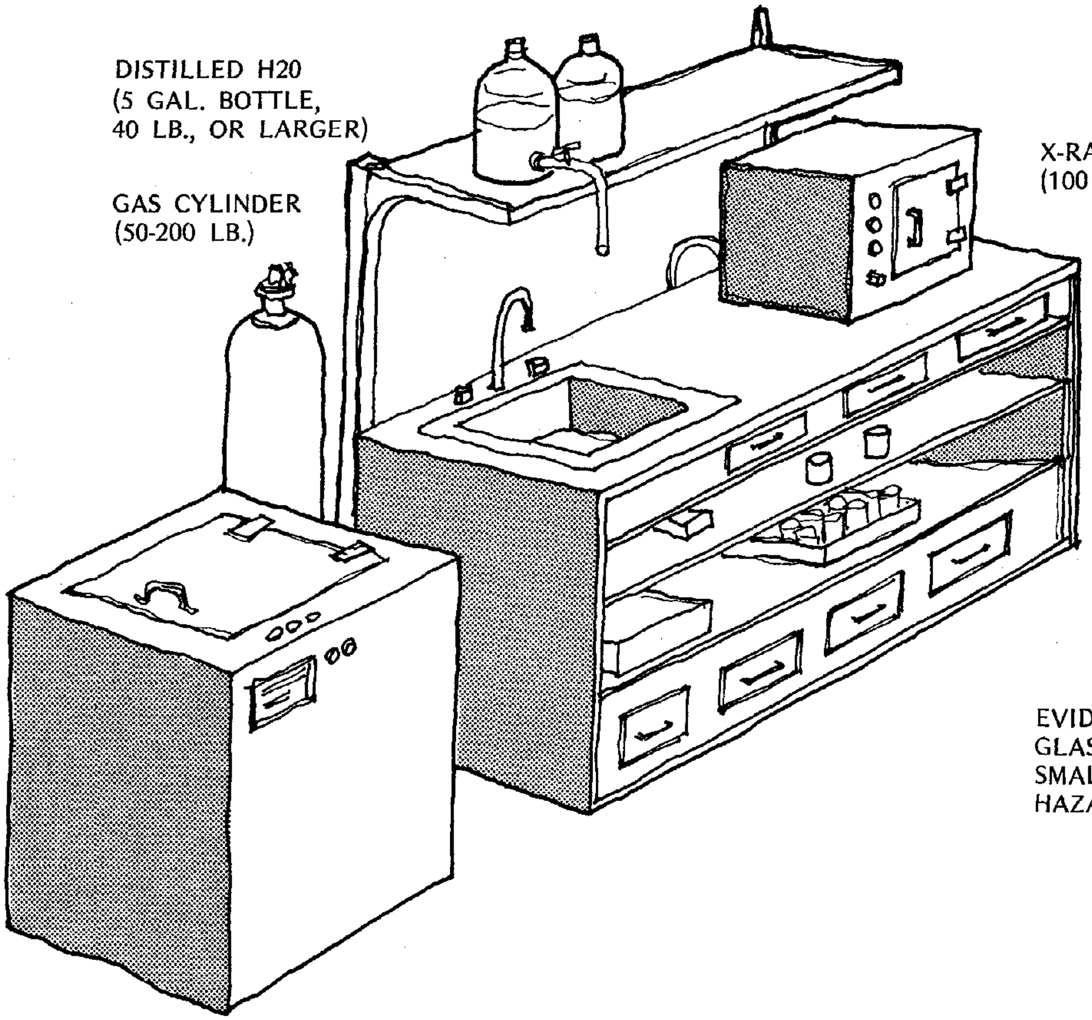
SUPPORTING INFRASTRUCTURE: Electrical system

VULNERABILITY: Electrical system may be disrupted. Door frames or door may rack and jam. Roller tracks can rack and twist, cause the door to become inoperable. Rollers may jump the tracks because of uplift from vertical forces.

SOLUTION: Manual override should be provided for door operation. Door frames and roller tracks can be strengthened. Roller tracks can be laterally braced and restraints provided to prevent the rollers from uplifting out of the tracks. Consideration can be given to either strengthening the door or providing a break-through capability to the door.

In an earthquake, the large open bay at the front of a typical fire station would quite predictably move more than the other solidly-walled faces. Historically, such shapes have proven to be problems and this basic configuration is one prime example of the general rule that unsymmetrical shapes provide poor seismic resistance.

Even if the structure is adequately designed, there is still the problem that if the front opening racks, the door may jam. Springs break and tracks get bent even under normal use. Normal use at a fire station can be very heavy use, compared to a residential garage where the door goes up and down only once or twice a day. The specification of the door and the design of its mounting should provide for seismic response.



POLICE CRIME LAB

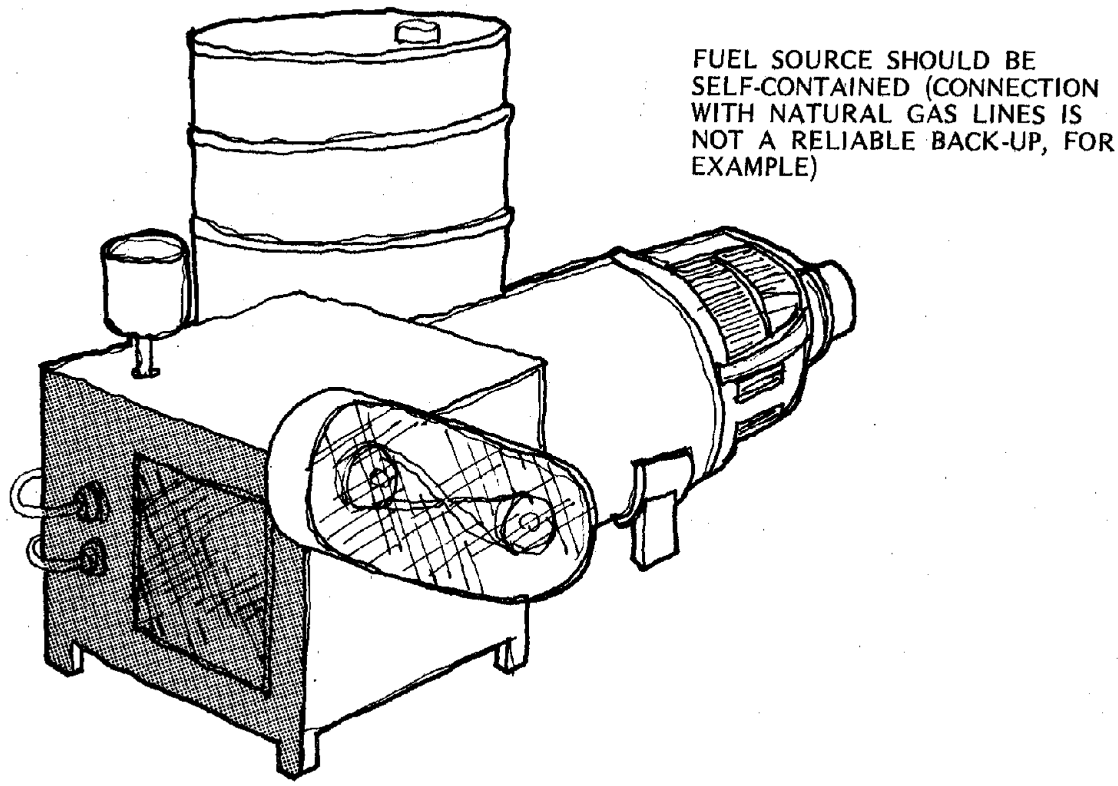
IMPORTANCE: Long-term essential but not needed during disaster. Equipment is typically expensive. Many hazardous objects.

FUNCTION: Scientific investigation of physical evidence. Documentation and recording of data.

VULNERABILITY: Lab equipment could overturn, fall off shelves, etc.; expensive to replace, poses unusually severe hazard to occupants. Destruction or disorganization of evidence and data files could void prosecutions. Labs contain hazardous liquids and gases, as well as the objects shown.

SOLUTION: Objects bolted or strapped down, cabinet doors latched, restraining rails on shelves, glassware in "egg cartons," etc. The Veterans Administration's *Study to Establish Seismic Protection Provisions* has applicable suggestions for anchoring gas cylinders, equipment on rollers and other types of laboratory apparatus.

Usually, hazard-protection measures also take care of the essential aspects of the physical preservation of evidence, as well as the organization of its documentation. For instance, to prevent the hazardous overturning of file cabinets, the base can be anchored and drawers specified to latch when shut; this then ensures against disorganization of the records.



STAND-BY GENERATOR

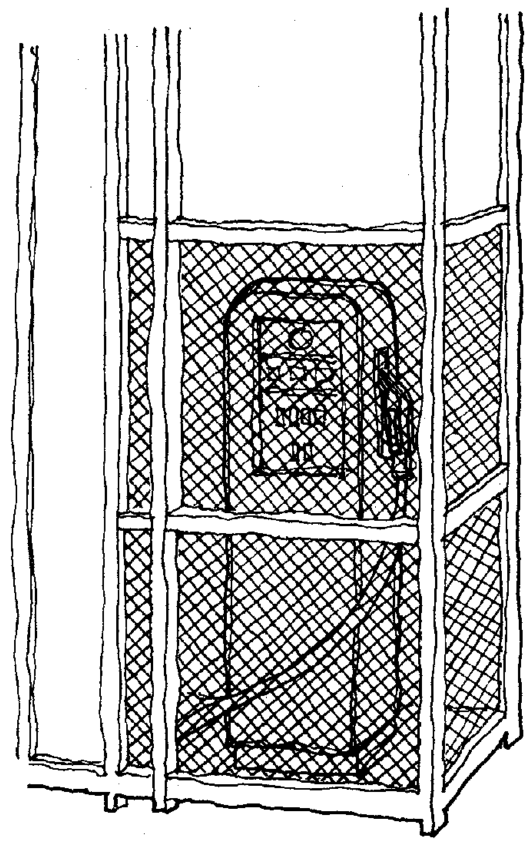
IMPORTANCE: Essential Equipment

FUNCTION: Provides electricity when usual service interrupted.

SUPPORTING INFRASTRUCTURE: None (if it has self-contained fuel system, as it should).

VULNERABILITY: Sliding or overturning.

SOLUTION: Bolt generator and fuel tank, if separate, to floor. Positive connection is needed, even with vibration isolators. (Current good practice for mechanical equipment offers various restraining details.)



FUEL PUMP

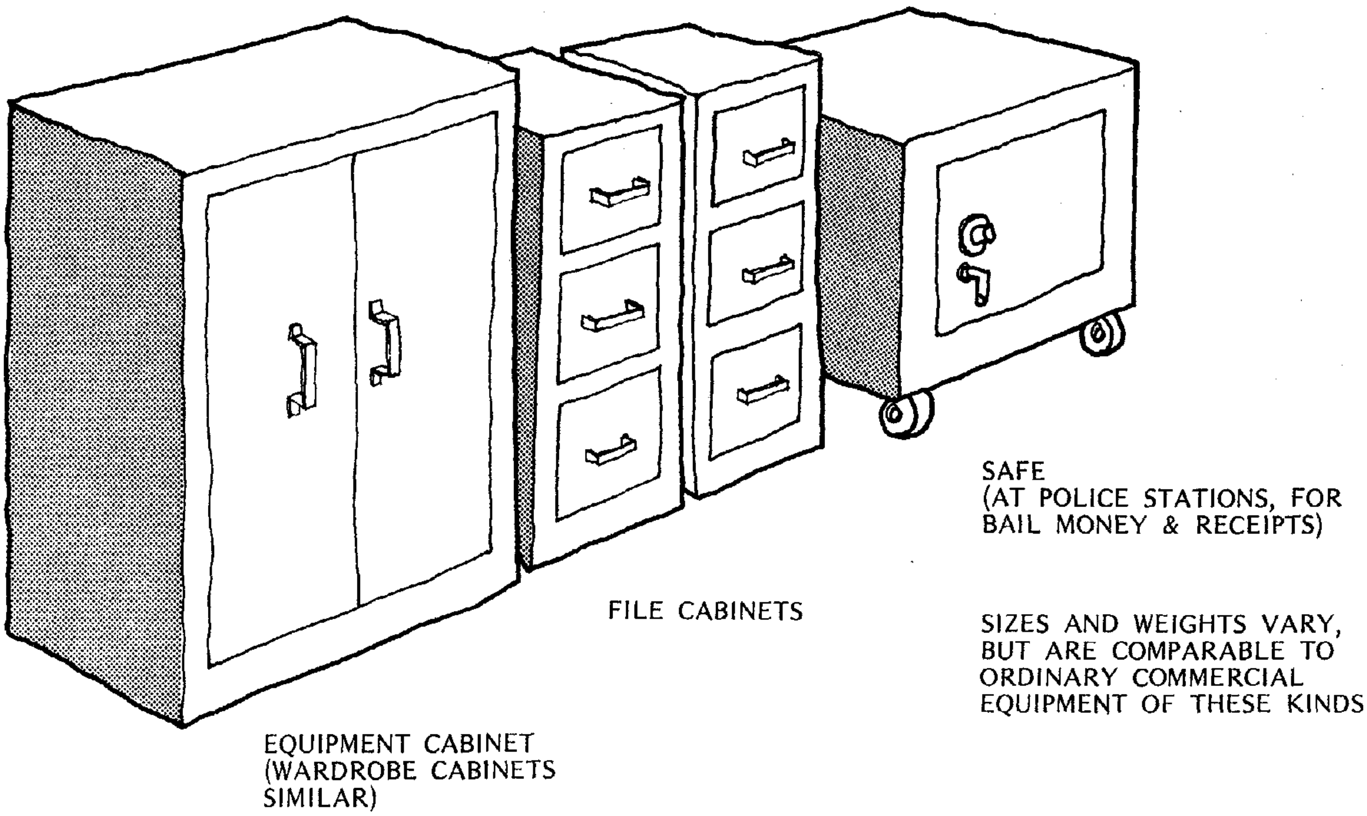
IMPORTANCE: Essential/Hazardous Equipment

FUNCTION: Refuels various vehicles, apparatus and other equipment.

SUPPORTING INFRASTRUCTURE: Electrical service system. Fuel storage tanks.

VULNERABILITY: Danger of fire or explosion that could damage the station. Disruption of operational capacity of pump due to damage, overturning or loss of power.

SOLUTION: Fuel pumps could be located so as not to be a hazard to the station. Pumps can be protected from damage from adjacent components or vehicles by designing curbs or barricades. Pumps can be laterally braced and supported. Fuel pumps should be manually operable and attached to the emergency power system.



MISC. FIRE & POLICE STATION FURNITURE

IMPORTANCE: Hazardous. Files containing information on disaster procedures are essential; other files are long-term essential.

FUNCTION: Storage

SUPPORTING INFRASTRUCTURE: None

VULNERABILITY: Furniture could overturn, or contents spill out. Safes on casters at police station could roll into things.

SOLUTION: Provide latches on cabinet doors (prevents spillage as well as lessening chance of overturning in the case of file cabinets). Anchor cabinets to floor or wall. Anchor safe to floor (safe is probably heaviest object in fire or police station other than mechanical equipment or vehicles).

The equipment in fire station dormitories should be considered. The living quarters of a fire station can look like ordinary group dormitory facilities. Fire personnel keep only a few personal effects with them at the station during their shifts, so the living quarters are unusually spare and quite orderly. Because of the occupancy potential, especially at night, this portion of the fire house can pose more than normal seismic problems. Tall wardrobe cabinets, bunk beds, etc., can overturn if unattached.

FUTURE TRENDS

INTRODUCTION

It is worthwhile to look at the overall trends and anticipated developments that may affect the general design concerns for emergency facilities. Often these can affect the seismic design requirements. Knowledge of innovative trends and advancements can aid in developing facilities that satisfy today's needs and are flexible enough to be altered for tomorrow's changes. In this period of technological innovation, tomorrow is often not far off.

Many recent developments and trends in the police and fire services have strong implications for station facilities. Technological innovations have improved the apparatus and equipment for the services. Studies have produced new strategies for administering fire and police protection. Legislation in Congress has resulted in research that has improved the capabilities of local departments.

The period of the 1960's and 1970's has produced very important improvements in equipment, techniques and research data. Emergency Medical Services as a distinct function has had a significant impact in some jurisdictions. The cost of energy today is becoming an increasing concern of all public service agencies, including fire and police departments.

Today the criteria for determining what is adequate local fire and police protection are being evaluated. The future could bring important changes to the equipment and facilities that make up these services. Introduction of new equipment has altered manpower needs and functions in many departments. These changes in manpower, equipment or services will alter the needs for facilities and their design requirements.

The following trends and developments may produce many of the fire and police facility changes of the future. Such changes will not affect all departments. Many changes will depend on the goals of local communities and their special protection requirements.

DESIGN CHECKLIST

1. What are some of the changes in police, fire or Emergency Medical Services (EMS) operations that are presently taking place or are envisioned in the future?

   Expansion/Reduction of Services

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   ____

   ____

   Centralization/Decentralization of Services

   ____

   ____

   ____

Future Changes in Services

Others

2. What are future community demands that may be made of the police or fire station?

Increased Public Interaction

Changes in Community

Others

3. What future changes may be required because of reduced budgets?

Restructured Operations

Facility Additions

Leased Facilities

Contract Services

Others

4. What are possible future security requirements for the police or fire station?

Minimized Access

Controlled Access

Electronic Security Measures

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Others

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5. What changes might be brought about by an increased union influence on the police, fire or EMS service?

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6. What changes will be brought about by the increased use of women in line duty positions?

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7. Is there any consideration of a combined public safety force in the future?

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8. Is there are consideration of consolidating or unifying police services with neighboring departments in the future?

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9. What future strategies or concepts might be employed for energy conservation?

Increased Mass

Offsets

Overhangs

Tightness

Other

10. What new equipment might be used in the facility in the future?

Communications Equipment

Computer Equipment

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Fire, Police, EMS Equipment

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Other

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COMMENTARY

1. Higher rates of certain types of crime (or increased reporting) have made sophisticated police services and prevention methods a necessity. Increasing urban and suburban densities are forcing police departments to develop and expand facilities and services. Facilities increasingly contain more elaborate investigative, laboratory and communications equipment requiring new spaces. These new areas and equipment will need new protection considerations because of their high cost and/or critical function during and after disasters. Some cities may centralize all police operations into one or a few buildings, while others may decentralize their operations into neighborhood stations. Such changes in operations will dramatically affect the risk to the community. The functional loss of the one centralized police station would be disastrous to the community.

   Questions of firefighter productivity have increased greatly in the current atmosphere of budgetary conservation and increased community demands for new services. Firefighters in some jurisdictions offer hazard awareness, fire safety inspections and other educational programs to the community. Building inventory programs, prefire planning and smoke detector information are also becoming part of the duties of firefighters. These and other non-emergency duties are considered to contribute to effective and efficient use of manpower. New stations will need to be flexible enough to provide space for these emerging functions.

There may be changes from volunteer departments to all-paid departments. The facility impacts of this trend can include reduction of recreation spaces used by volunteers and changed requirements for dormitories and kitchens. Some jurisdictions are changing from longer hours to eight-hour shifts. Such changes may significantly change the normal needs for dormitories, kitchen and other personnel facilities. Differences between such normal service delivery (reduced dormitory/kitchen needs) and disaster operations (increased dormitory/kitchen needs) should be considered.

Emergency Medical Service provisions are changing. Some fire departments are increasing their budgets for EMS services, while others are eliminating the service. Many fire stations now providing EMS services have been modified to accomodate EMS vehicles. The growing EMS service can change the operational roles and responsibilities for providing medical services during a major disaster. A primary trend in EMS in some jurisdictions is the increasing movement from basic EMT (Emergency Medical Technician) care to full paramedical care and advanced life support. Paramedical teams require more specialized and sophisticated equipment. Such equipment, although usually portable and rugged, must be given special storage protection.

EMS services may change during major disasters. EMS personnel may staff field hospitals, which may of necessity be located at fire stations. Such possibilities should be anticipated, and appropriate facility flexibility considered to accomodate them.

2. In many communities, police are increasing their visibility as a deterrent to crime and to reassure citizens of police vigilance. One impact on the station is the addition of citizen "walk-ins," which help personalize local police services. The designed openness and inviting atmosphere of community-oriented police stations may result in public convergence on them for aid in a disaster situation. These "walk-in" or storefront police stations are sometimes located in older existing buildings, which may be very susceptible to damage from an earthquake.

   Urban development patterns can have major effects on fire station needs. Shifting populations, changing mix of buildings, newer taller buildings and local annexation can mean major changes in a community's fire protection needs.

   As the concept of master planning of fire protection, which is being developed and promulgated by the National Fire Protection and Control Administration, develops, it may have major effects on fire station needs. Changes brought on by master planning are potentially tremendous, but the direction they will take is not yet clear. These changes may have major implications for the provision of critical services during emergency situations.

   Where EMS is well developed, there has been a trend toward heavy emphasis on EMS during comprehensive disaster exercises as a disaster service for the community.

3. Some departments have had serious problems increasing or even maintaining current levels of services because of tightening budgets. Often, significant restructuring of operations and reassessment of priorities is necessary to maintain or increase productivity. Operational restructuring may have good or bad effects on disaster functions. Equipment that may be nonessential for normal operations and, therefore, eliminated for budgetary reasons may, during a disaster, be crucial to the station's emergency capabilities.

   New additions may be added to existing stations in lieu of completely new facilities for financial reasons. This can prolong the use of older, less safe buildings and may even increase the risk of damage to the building.

Local police officials are also looking for methods to achieve the best new facilities at reduced costs. The search for quality for less cost will probably continue and will stimulate the building industry, architects, engineers and the research community to produce effective alternative products and construction methods to solve this growing problem. It can also lead officials to try alternatives to the traditional police or fire facility.

Several police departments have leased facilities for both temporary and permanent quarters at lower initial costs. Leasing reduces a department's responsibilities from those of facility ownership; attention nevertheless must be given to ensure the operational capability of the station after an earthquake.

Certain cities have contracted with private firms to provide fire and EMS services for their communities. These cities have found this approach to be more economical than providing their own force. This frees local governments from the burden of buying equipment, providing personnel training and housing apparatus and crews. This approach, however, may create difficulties in linking up regional disaster mitigation networks when both public and private agency cooperation is required. The city may want more seismic protection (beyond code compliance) for the station than the private organization provides.

4. Recent incidents of vandalism and crime against police and fire stations have prompted retrofit and design modifications to stations for increased security. Obvious changes have included reduced window areas, offset entrances, electric lock systems and security bars. Certain security measures may not only reduce the sense of a facility's fitting into a community but may also conflict with seismic safety concerns. Controlled access and egress, for instance, may hamper exit from the station after an earthquake. Electric locks may fail from power disruption. Minimal window areas may leave the station unusuable if emergency lighting systems fail. Seismic safety and special security concerns may be of equal or unequal importance, but innovative solutions will be necessary to provide for both at a reasonable cost.

5. Labor union involvement in the public safety profession has increased recently. New staffing levels and new facility and equipment requirements will reflect union concerns. Union concern for the protection of members during disasters may promote new safety standards.

6. Women are being accepted into regular line positions in many police, fire and EMS forces in a trend that will continue and expand in the future. Stations must provide facilities for women in various areas whenever a distinction must be made.

7. In an attempt at an answer to the issues of productivity and the rising costs of fire and police services, a few jurisdictions have combined police and firefighting functions under a single job description. The public safety organization concept provides for the cross-training of personnel to assume either fire or police and, possibly, EMS duties as needed. A potential for cutting manpower, equipment and facility costs may exist in certain instances. Many jurisdictions that have an EMS service combine it with either the police or the fire department, but usually as a separate corps. In contrast, EMS as a third public service separate from police or fire departments has been tried in several communities.

The potential earthquake failure of a facility housing both fire and police functions would be of increased risk to the community. Such combinations of public safety services and facilities will require extensive planning to ensure the necessary separation and delivery of proper levels of response during an earthquake disaster.

8. Inter-community consolidation of public safety services can take several forms. Specific services needed by several communities may be operated by one for the use of all under a contractual agreement, or service may be transferred from one jurisdiction to another, better equipped one by cooperative agreement. Under another approach a regional authority can be developed to provide the protection for several communities with similar needs. Mutual aid agreements are also becoming more common. In mutual aid a jurisdiction may contract with a neighboring jurisdiction to provide additional assistance for special emergency situations, such as an earthquake disaster. Mutual aid and unification programs may have major impacts on the size, location, staffing and equipping of police and fire facilities. There may also be serious implications for the delivery of emergency services during a major disaster that affects a large area.

9. Many police and fire department are becoming very cognizant of energy use. Facilities are being designed or retrofitted to be more energy-efficient. Certain energy conservation strategies may create design safety conflicts when changes that save energy and dollars reduce security or protection against natural hazards. For instance, facilities with increased thermal mass can increase the weight and thus the seismic forces the building must withstand. Heavy offsets, overhangs and parapets used to shade portions of a building are very susceptible to failure as vertical or horizontal cantilevers. The reduction of spaces or gaps between glass doors, mechanical piping and ducts and partitions to reduce unwanted air infiltration may limit the movement of such components during an earthquake, increasing deformation and potential failure in the elements. The seismic protection of solar collectors is an area that has previously received little attention.

10. Recent communication technology developments have had a major effect on police and fire facilities. New types of equipment in the communications networks of many departments may even reduce the redundancy in communications systems that can be so beneficial during an earthquake. Careful attention to the protection of new sophisticated communications equipment is necessary.

    A significant and growing number of departments are using computers to streamline many areas of police, fire and EMS services, from administrative functions and central dispatching to monitoring unit status. The secure and often substantial spaces required for computer equipment and operations will require special seismic protection to ensure emergency operating capabilities.

    Helicopters, already in use in many jurisdictions for a variety of functions, are sure to come into increased use in police, fire and EMS services. Helicopters can perform invaluable functions in earthquake disasters, especially reconaissance and preliminary damage assessment. The helicopter and landing pad on top of the facility can be very susceptible to earthquake damage. Consideration should be given to alternate landing areas, as a roof landing pad may not be usable after an earthquake.

    Technological innovations that make possible new types of fire, police and EMS equipment can increase both the viability and cost of such equipment. These new and oftentimes expensive pieces of equipment must be protected from damage because of both their critical nature and their replacement costs.

A federal standard for EMS vehicles was developed in 1974. Some states have already adopted the standard and are enforcing its design requirements. This may call for facility alterations in some cases. EMS vehicles are essential equipment during a disaster, and must be protected.

The U.S. Department of Transportation has adopted a policy of uniform quality for EMS services, both urban and rural. Although this concept is in its exploratory stages, the Department's approach is to make the most of technology in order to provide rural areas EMS services of a quality equal to that available in urban areas.

11. The establishment of the Law Enforcement Assistance Administration in 1968 began a new federal initiative in improving the quality of police services. LEAA programs support law enforcement training and administration improvements through grants to states, municipalities and others. Evaluations and research leading to improved departmental administration, increased use of technology and changes in equipment standards can be expected to continue.

    The National Fire Prevention and Control Administration, authorized by Congress in 1974, has a mandate to bring about major reductions in fire losses. Areas of special interest to NFPCA include master planning, equipment, firefighter training, public awareness and building design. Changes in each may eventually have major facility impacts, especially in relation to designing for disaster protection and operation.

CASE STUDIES

INTRODUCTION

The following case studies illustrate the seismic design of a police and a fire station and the seismic protection of an essential piece of equipment.

These designs are not prototypical solutions; they are actual design solutions by architectural firms that go beyond seismic code requirements. They serve only as examples of how the information presented in this document can be used to design police or fire stations to ensure their operational capability after an earthquake.

CASE STUDY – POLICE STATION

Architect: Gruzen & Partners
New York, New York

Application of seismic criteria to the design of a police station may result in a different configuration, as well as a more resistant structural design. Seismic design has long been considered to be solely a structural problem, but for essential community resources, such as police stations, the basic design will be affected by the need for the facility to operate during a seismic disaster.

One specific police station will be examined to explore and find the most practical approach to its seismic design and to uncover general seismic design considerations. The case study approach allows an evaluation of an actual design and program from which we can document general seismic issues. Choosing an existing police station design as a test case also minimizes the temptation to color either the non-seismic or seismic scheme to make a point.

The Case Study police station is located in an urban area of approximately 60,000 people in New York State, in seismic zone 1. Seismic design is not a consideration in that area, so we assume this facility to be a non-seismic scheme. For seismic consideration we assume that the station will now be located in a seismic risk area and the local citizens will be dependent on the police to provide some immediate disaster relief operations. Modifying a non-seismic scheme to a higher level of resistance makes it possible to note the organizational and nonstructural changes.

The station is the central police and public safety facility for the city. The police department occupies approximately 70% of the building. City Courts, District Attorney and Public Safety offices occupy the remaining 30%. Although not totally police functions, police facilities like this are part of a trend toward multi-purpose municipal facilities. Mixed use buildings raise the issue of whether it is necessary for the entire police facility to function during an earthquake emergency or whether some areas can be given less consideration. The activities of the offices and police administration could take place elsewhere if that facility were damaged.

As part of the municipal center complex, the Case Study police station is surrounded by a public plaza, with parking underneath. The police building has two exits from the garage. For seismic protection, the exits should emerge to the outside as quickly as possible. In the original scheme the garage exitways are covered for a substantial distance, something the designer would try to avoid in a seismic scheme because of the danger of blockage from falling debris (i.e., the plaza).

The basic building envelope for the original scheme is a 4 story plus garage building with a rectangular plan. While the structural shape and plan are suitable for earthquake resistance, the exterior wall does not follow the column line. The lower floors are set back, and the upper floors overhang the column line. Long unsupported columns, such as are used here, would be very unsuitable if used for a seismic design. With the exterior walls in line with the columns, the building envelope of this case study police station would be a good vehicle for investigating our hypotheses. Since the building shape is suitable for seismic resistance, changes in the configuration will be responsive to the need for emergency services to continue during an earthquake emergency.

Seismic criteria applied to this station program are useful input to the evaluation of any police station. It is possible to identify vulnerable, critical and secure areas and to establish a seismic priority for all activity areas. Although the names of the spaces may differ, certain police operations take place in the majority of stations. Prominent among them are the following:

- Prisoner Processing
- Communications
- Records

Having different local conditions and different law enforcement systems, individual stations may provide these services on widely different scales, but seismic evaluation of the functional areas is still necessary. In general, the key functional areas for conducting police operations in an emergency situation are the same as those in a normal situation. The importance of these is intensified because of the higher level of police activity and the severe physical strains put on the law enforcement facilities in a seismic emergency.

After seismic evaluation, the functional areas that were considered critical in the case study police station were found to be grouped generally in the original scheme.

- Booking, Intake and the Communications Center, all considered critical to continued police operations, are already grouped together in the original scheme.
- Equipment support functions, which are together on the garage level, are also directly underneath the communications center.

A close physical proximity is desirable for functions that provide 24-hour services. To save energy, zoning together all areas that must have mechanical service 24 hours a day is the most economical way.

- In this urban police station, all the critical functions operate 24 hours a day. In addition, there are several areas, such as detectives, that are not considered critical to continue in a seismic emergency, but which operate all the time. For energy conservation to be effective, they would have to be included in a mechanical zone with the critical functions.

In a police station of greater size than the case study, with more support and administrative functions, the detective area might be grouped in a seismic structure with the critical functions, thus enabling HVAC zoning of all 24-hour operations.

Security measures also suggest that critical areas be grouped together. A limited number of access points that can be kept under surveillance will reduce security risk and allow operation with limited manpower. Certain areas of the building could be closed off altogether at night or in the case of an emergency. Although the normal operational relationships of the critical functions are similar for an emergency situation, the physical relationships are modified with this concept.

With a program of the complexity of the case study police station, structural separation of critical functions implies a multi-story building. Taking several bays on each floor to become the seismic structure, as done here, suggests an equal amount of critical functions on each floor. The normal relationships between spaces do not lend themselves to this. In this case, addition of some noncritical areas to the seismically resistant structures helps to balance each floor and maintain operational proximities. It is impossible to impose a rigorous physical form on some areas of a whole without making some compromises in relationships.

- Separation of Gym and Lockers: Because of limited area per floor in the critical functions building, it was found to be impossible to keep Lockers and Briefing on the fourth floor with the Exercise Room. With a complete redesign of the building, mechanical equipment might be moved to the lowest floor, allowing the Exercise Room and Lockers to be on the same floor.

- Horizontal connection of Courts and Detention: Detention areas are typically located above courtroom facilities with an elevator connected directly to the holding room off the courtroom. The direct vertical connection is impossible. Redesign of the court support spaces to provide for a separate and secure prisoner corridor could solve this problem.

To get larger floor areas for the critical functions, it is possible for the seismic structure to have fewer stories than the noncritical structure, although this presents several problems. Access from the upper floors of the noncritical structure would be circuitous. The roof of the critical function structure would have to be designed for impact loading to protect it from falling debris from the noncritical building. For a less complex program it may be possible to protect one portion of the building seismically without modifying any functional relationships.

The effectiveness of this seismic concept lies in the ability to consolidate critical functions for a given building. For this type of solution, each section of the concept must be large enough in proportion to make it a viable "building." In this case study the ratio was approximately 60/40 (40% were critical/secure functions).

An urban precinct station, for example, may not contain enough support or administrative areas to break off from the critical functions into a separate structure. But the concept is viable for an urban police facility such as this one, espcially if it contains some other municipal functions. This concept definitely should be considered when local fiscal pressures preclude designing for the highest level of seismic resistance for the entire building.

Functional areas of the urban police station that have been cited as critical by seismic criteria have strong task interrelationships, even during normal police operations.

- Equipment interconnections demand close proximity of the Communications Center to the Electronic Maintenance, Switching and Telephone Equipment Rooms.

- The prisoner booking process encompasses the Sallyport, Intake/Booking and Detention. Criminal Identification, which must be kept secure in an emergency situation, is a support function.

- Communications Center and the Booking desk are core functions. Police units are dispatched by the Communications Center as a result of complaints received at the Booking desk. The Booking desk should be able to visually survey Intake, Holding and the Lobby.

Clustering critical areas into a physical unit within the building can provide a higher level of seismic resistance for the entire group. Links between the functional areas, whether they be service lines for equipment or passageways for people, are less likely to be disrupted if the areas are physically close. During an emergency situation, concentration of activity and personnel in a tight core will promote smoother operations and increased security control. If the critical functions are grouped together, special structural and mechanical consideration can be given to this area. Noncritical areas can be designed to an appropriate level for occupant safety, but need not be able to function.

Areas that are critical to police emergency operations and areas that must be kept secure make up approximately 45% of the net square footage of the building. Police service areas that are critical during an earthquake emergency are the following:

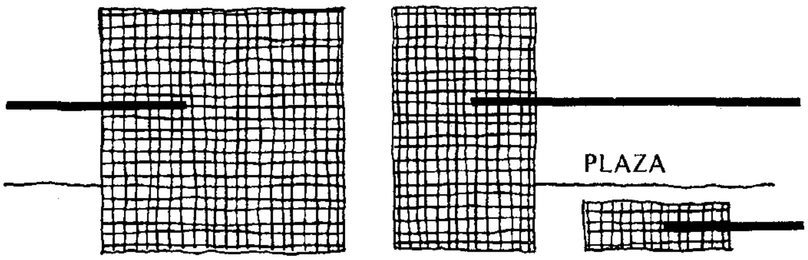
- Communications Center (Command Control)
- Intake/Booking
- Briefing and Lockers
- Armory
- Mechanical Equipment
- Electronic Equipment
- Emergency Vehicle Parking
- Vehicle Maintenance

The following areas must remain secure during seismic disaster, but are not critical to disaster functions:

- Records
- Criminal Identification
- Evidence Storage
- Data Processing
- Ammmunition for pistol range

In regrouping these areas to create a more distinct package, every attempt was made to make changes only for seismic reasons. As few compromises as possible were made in special relationships. Functions were moved from one floor to another only when necessary. To measure the impact of seismic criteria on design of this urban police station, the new scheme should be the same building — with modifications dictated by seismic considerations. Design changes for any other reason will obscure any seismic conclusions.

The structural concept for this urban police station is a three-building scheme.



SECTION

The critical functional areas and those that must remain secure are grouped together in one structure, which is designed to a high level of seismic resistance. The structural and mechanical design must enable the activities and equipment to continue functioning during an earthquake emergency. Emergency vehicle parking and maintenance bays are removed from the lowest story of the building and put in a separate garage under the plaza. In a critical situation, getting the emergency vehicles into the field is of prime importance. Construction of a specially protected and separate garage further minimizes the risk of damage to vehicles or to exitways from falling debris. Noncritical police facilities are grouped together in a third structure that uses conventional seismic criteria to protect the lives of the occupants. The three sections of the police station are structurally independent, but functionally continuous. Each section has its own structural system appropriate to the degree of seismic resistance required.

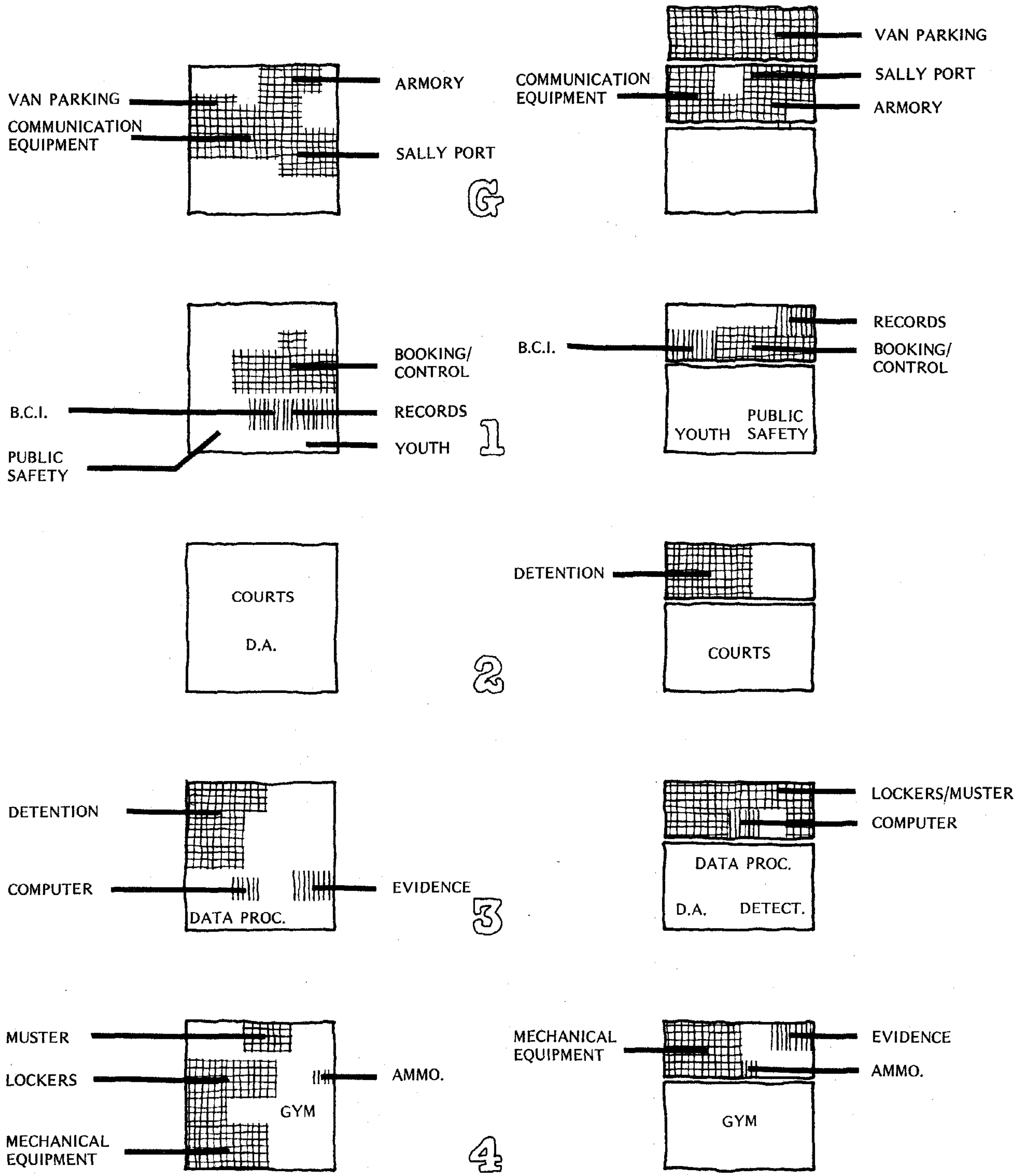
Essentially, there are three buildings within one building envelope. Free access between them can exist on all levels. For security reasons, we have chosen to limit accessto one or two points on each floor. It is then possible to close off the critical function building for security if the adjacent structure is damaged. The building sizes of the two schemes are similar, although the structural concept of the seismically resistant building is different from that of the original. The original building has a structural frame of five bays in one direction by four bays in the other. The lower floors are set back from the perimeter column line, while the upper floors overhang. Unsupported columns as shown in the original scheme are inappropriate for seismic design. The seismic scheme is also five bays by four bays, but the spans have been reduced slightly to be more seismically credible. The exterior building wall coincides with the perimeter column line on all floors above grade. Overall floor area is approximately the same as that of the original scheme.

On the Garage level, the bays for emergency vehicle parking and maintenance have been moved from their location in the original scheme to the separate garage structure in the seismic scheme. The other functional areas are located in the critical function structure. Staff parking only is located in the structure for noncritical functions. An additional means of access has been added so that the new garage area has two vehicle exits leading directly outside.

The functional areas located on the Plaza level are the same for both the original and seismic schemes. The locations of the following have been moved to the critical function structure:

- Communications Center (Command Control)
- Intake/Booking

ORIGINAL SCHEME | SEISMIC SCHEME



SUMMARY DIAGRAMS

- Records
- Criminal Identification (BCI)
- Lobby
- Administrative Areas

The police administrative area is not required to function in an earthquake emergency, but proximity to the Communications Center is necessary for normal operations.

The Second Floor in the original scheme, consisting of Courts and District Attorney, has no critical functions. In the seismic scheme, Detention is now located on the second floor in the critical function structure to be adjacent to the courts and directly above Intake/Booking. The District Attorney is moved to the third floor. Detectives, Data Processing and District Attorney are located in the noncritical structure on the third floor. The computer room from Data Processing is in the protected structure with direct access from other Data Processing areas. The Lockers and Briefing room originally on the fourth floor are the critical functions located on the third floor in the seismic scheme.

The Fourth Floor in both schemes has the mechanical equipment for the building. In the seismic scheme mechanical equipment, as well as Evidence storage and Ammunition, are located in the critical function structure. Ammunition, used for the pistol range only, is in the protected structure, directly adjacent to the pistol range, which is located in the noncritical structure. Other police patrol support areas remain in the noncritical portion of the fourth floor.

In order to retain the essential function of the building during emergencies, the structural design should follow the guidelines set down below for the different sections.

The parking structure for emergency vehicles, being underground, will be a well-reinforced concrete, boxlike structure, consisting of roof slab (plaza slab), basement slab and outside walls. Because of its proximity to the multi-story control portion of the building, the plaza slab (or roof slab) of the garage must be designed for impact loading to protect it from falling debris from the adjacent building, and the open exit from the garage must be moved sufficiently far away from the building to avoid any obstruction. The walls of the garage must be designed for the extreme earth pressures that have been observed acting against foundation walls during earthquakes.

- For seismic protection, it would be ideal to have the emergency parking located outside of the building altogether, with no covering that could collapse. Security reasons, however, necessitate protection against possible vandalism to valuable emergency vehicles.

The critical function portion of the building, being the most vital one, should be framed by a ductile, moment-resisting steel structure, which is best suited to resist forces experienced during earthquakes and gives the most assurance against structural failure. The floor slabs and walls of this portion of the building should be as light as possible, preferably of metal deck, in order to reduce the mass that could be activated by seismic ground accelerations. The steel skeleton of this portion of the building, because of its ductile design and ductile detailing, might very well be appreciably more expensive than conventional steel framing, the excess weight depending to a large extent on reduction of the dead weight.

The noncritical function portion of the building that houses Public Safety and City Courts could be designed as a conventional concrete structure, taking into account the rules of seismic design but using the shear walls as the most economical bracing system, which should increase the conventional construction cost by only a negligible amount. Consistently with the critical portion, the noncritical structure could also be framed in structural steel with braced steel frames very efficiently.

Separate mechanical systems are most appropriate for the critical and noncritical functional areas in this ssismic scheme. A separate system operating only in the seismically resistant structure can be protected against disruption from an earthquake.

There is no one type of HVAC system best for seismic design. A system should be chosen to be appropriate for the area's climatic conditions and fuel availability. A properly anchored system is likely to remain operable no matter what the system.

If the choice of system is unimportant to the seismic design, the connections are not. Connections are the weak points in the system. Ductwork and piping must be braced, and flexible joints must be used when passing through building joints. Mechanical equipment must be rigidly mounted to the structure or mounted on vibration isolators that are completely restrained.

Mechanical ventilation and air conditioning must be provided for some areas. Working conditions, even in emergency situations, can become intolerable in interior rooms with high sensible loads, such as the radio and communication rooms. Air conditioning should be provided when the outside design temperature exceeds 85°F. Ventilation and air conditioning, run on emergency power, should be provided for these areas:

- Communications Center
- Booking/Intake
- Electronic Maintenance
- Armory

Other areas, such as Detention, will require ventilation if they are not designed to allow natural ventilation. Air distribution systems in the critical function areas should be designed for low static pressure losses to minimize emergency power requirements. The heating system must be capable of operating from on-site fuel reserves in the event that normal utility connections are disrupted.

An emergency water supply and sewage holding tank should be provided for the critical function building in the event that utility services are severed. The water reserve tank and sewage holding tank should each be 15,000-gallon capacity based on 24 employees each of three shifts and 18 inmates in detention. This would provide emergency operation of sanitary facilities for 14 days. The underground tanks should be part of the structure to maintain the integrity of the connections to the tanks.

All equipment and piping must be adequately supported to limit damage. The water distribution systems must be designed so that all nonessential use can be valved off during emergency operations, and pumps must be connected to the emergency power supply.

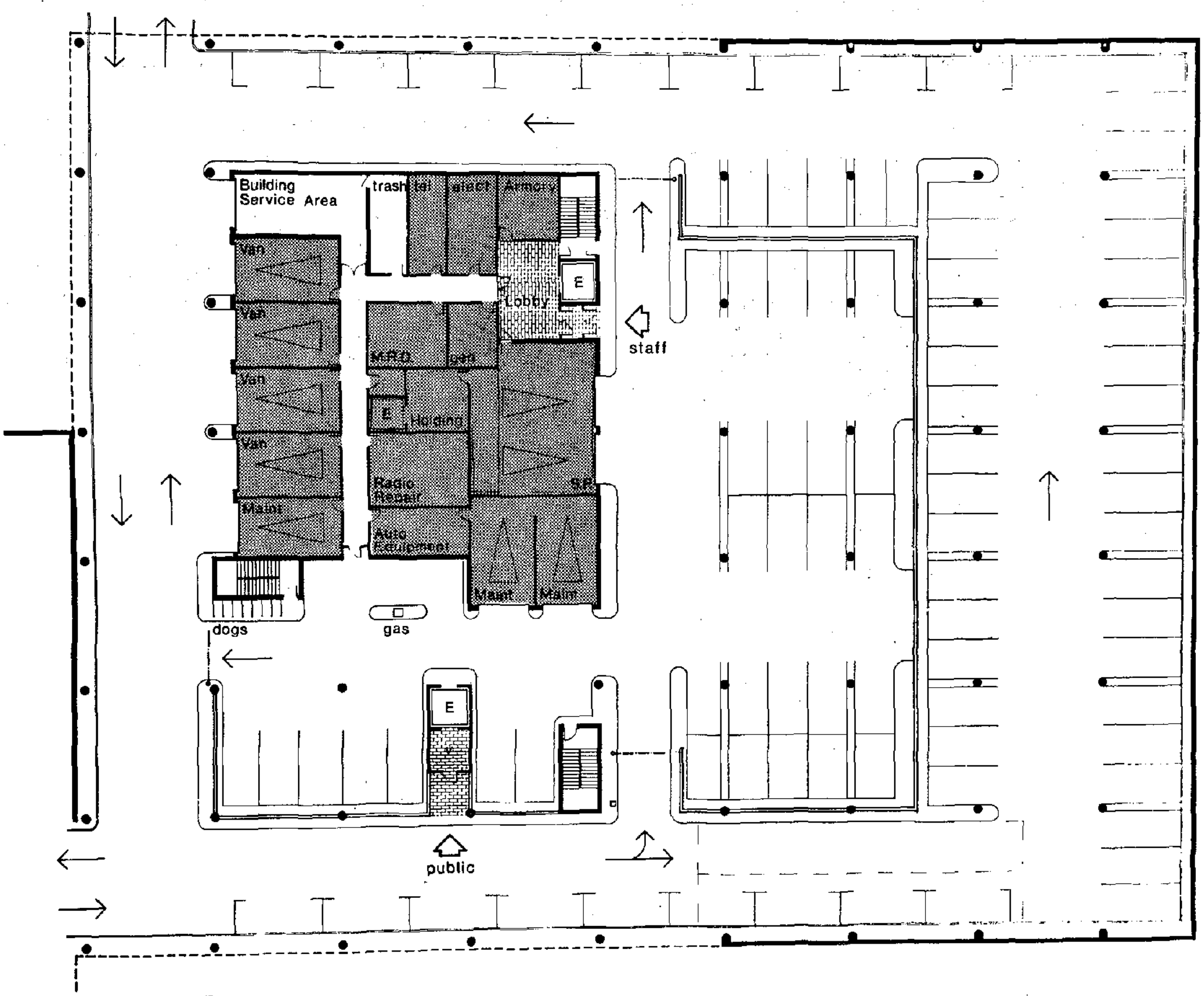
Emergency power must be provided to carry about 2/3 of the normal load for the building. Communications equipment, some mechanical equipment, lighting, elevators and electric doors will depend on the emergency power system.

- The emergency generator should be approximately 60 KW to operate the critical functions (50 KW for critical function building plus 10 KW for emergency exit lights in the noncritical function building). For a normal building of approximately the same size, the emergency generator would be 20 KW.

The underground fuel oil tank should be a part of the structure to protect the connections.

Lighting should be designed to provide minimum acceptable task lighting and should be circuited and switched to limit power consumption during emergency operation. For elevators, additional supports and restraints for motor-generators, elevator drives and control cabinets are necessary, as well as more rigorous structural design for the cab and counterweight rails. Electrical systems for the noncritical function building could be similar to the systems for the original scheme. Standard systems and a normal power supply would be required. Following minimum life safety requirements, normal equipment supports, air system fire dampers and protection of evacuation routes are provided. Emergency power, which is supplied by the generator in the critical building, is needed only to operate essential life safetv equipment, emergency exit lights and to position elevators at a safe level.

Original Scheme



Garage Floor

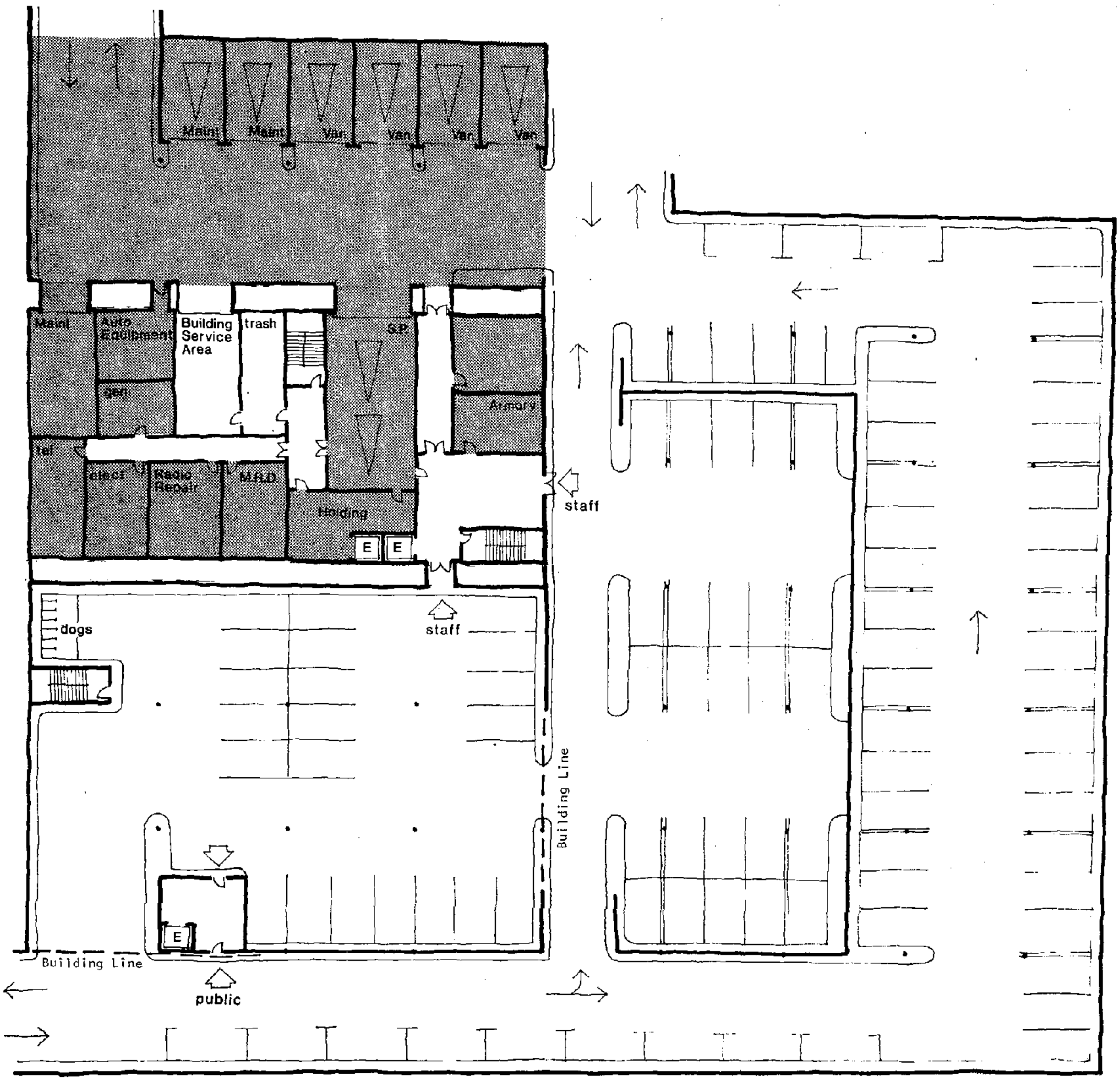
Critical Areas
Secure Areas

0 5 15 25'

ARCHITECT: GRUZEN & PARTNERS NEW YORK, NEW YORK

ENGINEERS: SEVERUD ASSOCIATES SYSKA AND HENNESSY

Seismic Scheme



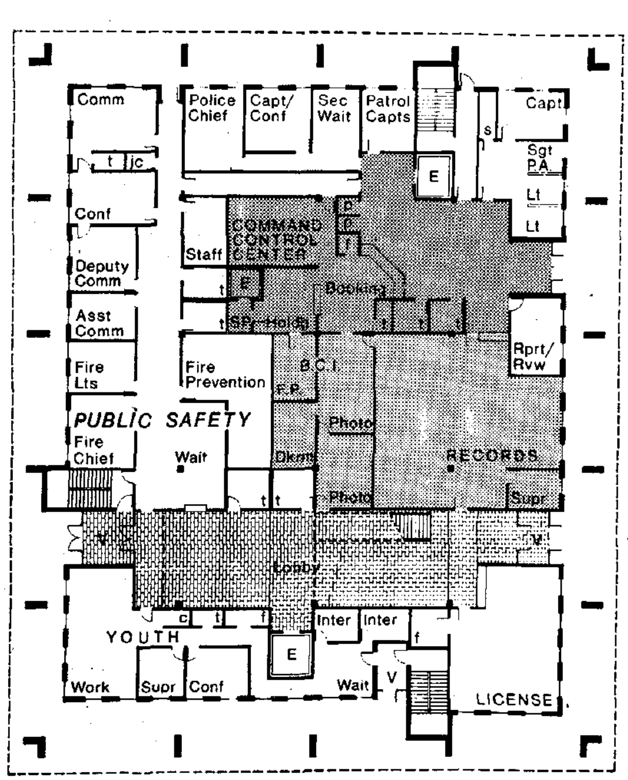
Garage Floor

Critical Areas

Secure Areas

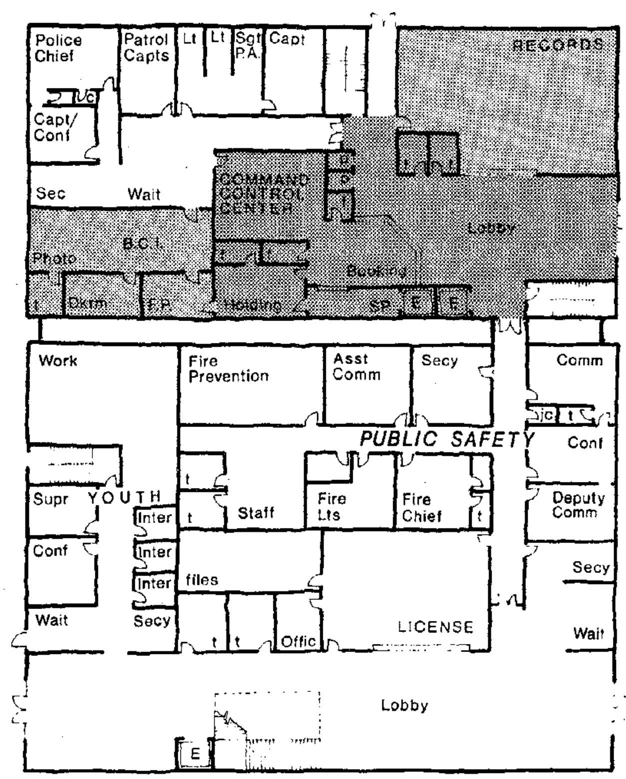
0 5 15 25'

Original Scheme



Plaza Floor

Seismic Scheme



Plaza Floor

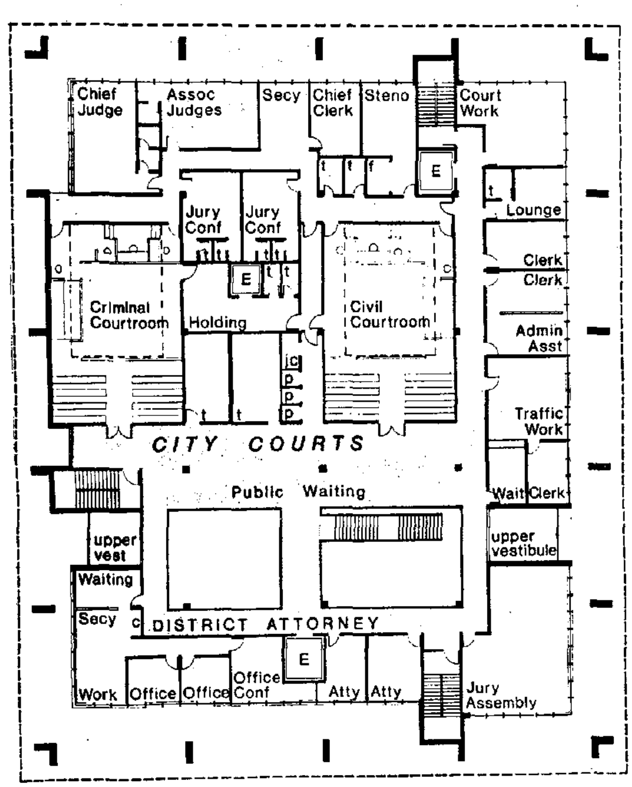
Critical Areas

Secure Areas

0 5 15 25'

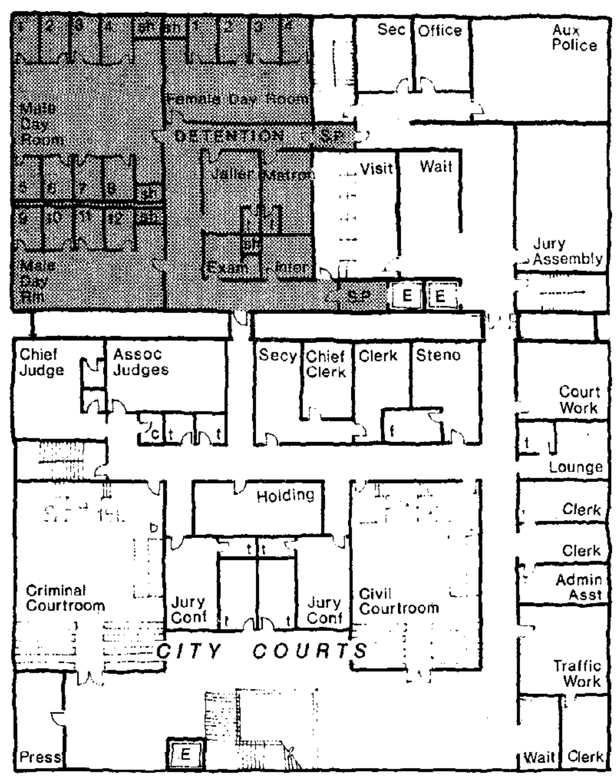
152

Original Scheme



Second Floor

Seismic Scheme



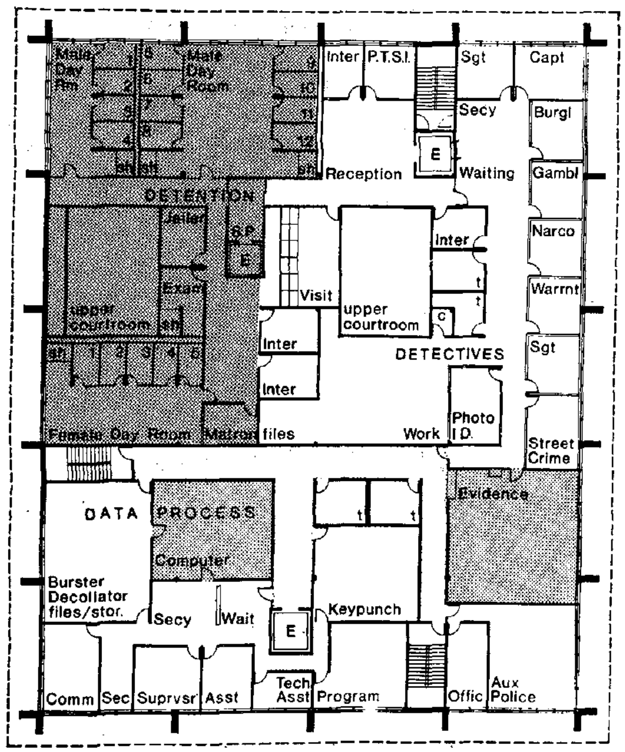
Second Floor

Critical Areas

Secure Areas

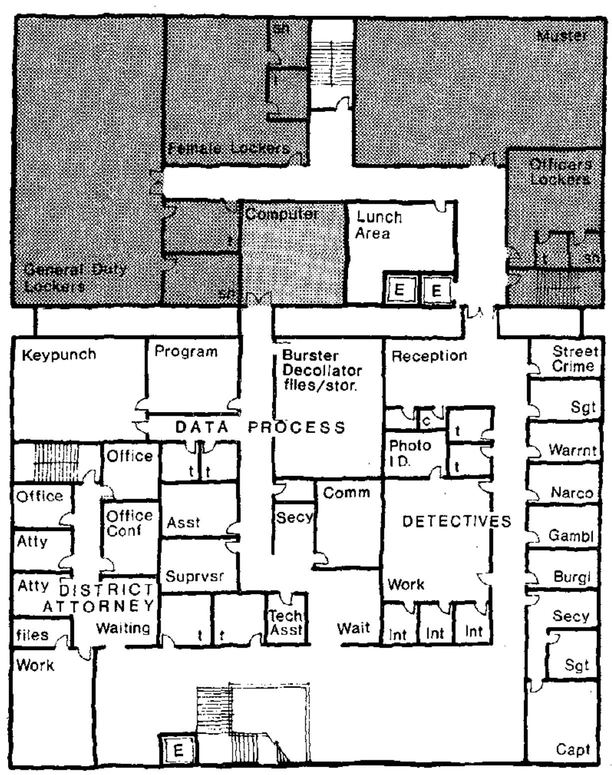
0 5 15 25'

Original Scheme



Third Floor

Seismic Scheme



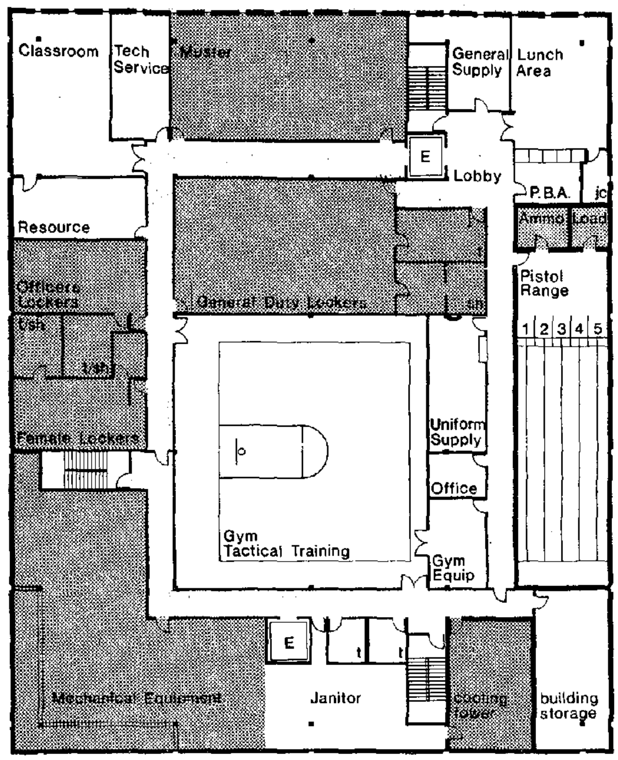
Third Floor

Critical Areas

Secure Areas

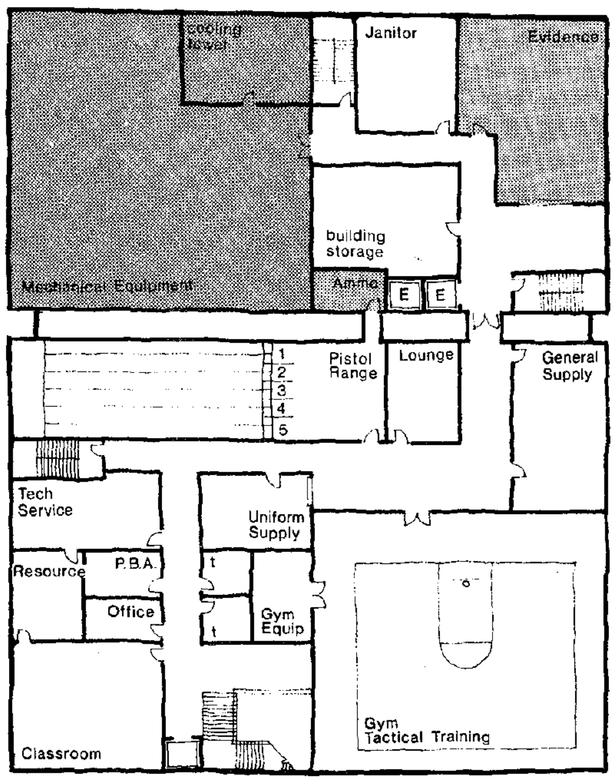
0 5 15 25'

Original Scheme



Fourth Floor

Seismic Scheme



Fourth Floor

Critical Areas

Secure Areas

0 5 15 25'

COST DATA

TOTAL AREA: 93,000 S.F.

COMPONENT	ORIGINAL COST	REVISED COST	PERCENT CHANGE
ARCHITECTURAL	3,304,300	3,304,300	0%
STRUCTURAL	1,096,000	1,301,760 GARAGE 130,560 CRITICAL 480,000 NON-CRITICAL 691,200	18.8%
MECHANICAL	945,700	1,171,700 SEPARATION OF SYSTEMS SPECIAL SUPPORTS/RESTRAINTS STORAGE TANKS	23.9% 13.7% 5.0% 5.2%
ELECTRICAL	640,000	800,000 SEPARATION OF SYSTEMS SPECIAL SUPPORTS/RESTRAINTS EMERGENCY SYSTEM EXPAND	25.0% 5.0% 5.0% 15.0%
ELEVATORS	100,000	125,000 SPECIAL SUPPORTS/RESTRAINTS	25.0% 25.0%
TOTAL COST	$6,086,000	$6,702,760	10.1%

NOTE:
It should be noted this percentage can be considered a maximum increase because of the complexity of the facility, its original design in a non-seismic risk area, and the need for separating the facility into basically two buildings with independent systems.

CASE STUDY – FIRE STATION

Architect: Boyd A. Blackner Architect and Associates
Salt Lake City, Utah

The following case study identifies design parameters and develops conceptual solutions for mitigation of earthquake damage and disruption by analyzing a specific design for a Salt Lake City, Utah, fire station through a value engineering process.

The original design represents a fire station that meets all seismic code requirements for emergency facilities in seismic zone 3. The revised design optimized through the value engineering process the overall disaster operation capability of the facility. The value engineering process included a workshop of the project design team (architects, structural, mechanical, electrical engineers), a critique team (architect, structural, mechanical, electrical engineers), a cost/construction consultant and fire service officials.

The seismic safety design parameters developed during the workshop include special consideration of the architectural, structural, mechanical and electrical components to maintain the operational status of the facility in an earthquake disaster. The following process was used during the value engineering workshop:

Information Phase

- Establish broad information base for making best decision in expenditure of resources.
- Define functional requirements.

Speculative Phase

- Create, develop innovative alternatives.
- Record all suggestions.

Analytical Phase

- Evaluate basic functions.
- Evaluate functional alternatives.
- Determine Costs.

Proposal Phase

- List optimum solutions.
- Finalize solutions.
- Document and present solutions for positive action.

During the interdisciplinary discussion an image of the fire station as an emergency node for its district during and immediately after the earthquake emerged. With the possibility of utilities out, roads blocked, water supplies questionable and possible health threats, the station may become the neighborhood kitchen, shelter, communications center and emergency hospital without losing its essential function as a firefighting facility. The roof could become an emergency heliport and the stair towers extend up to the roof for access.

In what follows, elements of each area (architectural, structural, mechanical, electrical) were evaluated, based on certain specific criteria. Each criterion was given a weight shown in the summary of the Criteria Weighting Process. Each criterion was then ranked against the others, producing a raw score of the total preference points each received. The Analysis Matrix shows the grades given for the various criteria to a number of particular design elements. The grade received by each design element is then multiplied by the weight of importance for each criterion. The resulting scores represent appraisals of the design elements considered.

ARCHITECTURAL ANALYSIS SUMMARY

Architectural elements were evaluated based upon six criteria: cost, aesthetics, maintenance, fire resistance, function, and seismic performance.

As shown in the analysis matrix, precast and poured-in-place structural systems were of nearly equal preference, with a slight advantage for a poured-in-place system. The matrix also showed that lightweight interior and exterior partitions as well as an added remote stair exit should be considered seriously for design implementation.

Architectural Workshop

- Architectural Expression — Too heavy a structural expression, inappropriate to surrounding area? A flexing of seismic structural muscles?

- Structural — Should precast possible be changed to poured-in-place? Can the building be completely integral like a ship or car?

- Site — Possible relocation? Develop an adequate secondary exit. Is electrical substation proximity a danger or advantage?

- Fuel Storage, Utilities — Create a basement fuel storage area. Is it a hazard if within the building? Locate pumped storage for solid waste sewage. Consider roof location for storage of fuel, water, utilities for gravity flow. Structural problems? Add storage tanks for vehicle fuel.

- Emergency Community Center — Plan for fire station to be a shelter, hospital and community kitchen.

- Materials — Omit hung ceilings. Anchor lockers, use floor-mounted toilets, secure as much equipment and furnishings as possible. Use plastic instead of glass glazing. Masonry infill is too heavy and hazardous. Use lightweight panels on the exterior and steel studs and vinyl-covered sheet rock on the interior.

- Locate another remote exit within building.

CRITERIA WEIGHTING PROCESS

ARCHITECTURAL

CRITERIA	WEIGHT	RAW SCORE
A. COST	4	4
B. AESTHETICS	1	2
C. MAINTENANCE	5	6
D. FIRE RESISTANCE	8	10
E. FUNCTION	1	2
F. SEISMIC PERFORMANCE	10	14
G.		
H.		
I.		

EVALUATION SCALE

4 major preference
3 medium preference
2 minor preference
1 letter/letter - no preference, each score one point

CRITERIA SCORING MATRIX

	B	C	D	E	F	G	H	I
A	A-3	A/C	D-3	E-2	F-4			
B		C-2	D-3	B-2	F-3			
C			C/D	C-2	F-3			
D				D-2	D/F			
E					F-3			
F								
G								
H								

ANALYSIS MATRIX

ARCHITECTURAL

EVALUATION SCALE

5 excellent
4 very good
3 good
2 fair
1 poor

	DESIRED CRITERIA	A COST	B AESTHETICS	C MAINTENANCE	D FIRE RESISTANCE	E FUNCTION	F SEISMIC PERFORMANCE	G	TOTAL
	Weight of Importance (0-10)	4	1	5	8	1	10		
1.	PRECAST STRUCTURE w/MASONRY PANELS	16 / 4	3 / 3	20 / 4	40 / 5	3 / 3	40 / 4		122
2.	POURED IN PLACE w/MASONRY PANELS	12 / 3	3 / 3	20 / 4	40 / 5	3 / 3	50 / 5		128
3.	LIGHT WEIGHT EXTERIOR PANELS	20 / 5	3 / 3	25 / 5	24 / 3	3 / 3	40 / 4		115
4.	ADD HELICOPTER PAD ON ROOF	8 / 2	2 / 2	15 / 3	24 / 3	5 / 5	40 / 4		94
5.	ADD REMOTE EXIT/STAIR	8 / 2	2 / 2	15 / 3	40 / 5	5 / 5	50 / 5		120
6.	CHANGE SITE	12 / 3	3 / 3	15 / 3	24 / 3	3 / 3	40 / 4		97
7.	BASEMENT AREA FOR FUEL/WATER STORAGE	4 / 1	2 / 2	5 / 1	8 / 1	2 / 2	30 / 3		51
8.	LIGHT WEIGHT INTERIOR PARTITIONS	20 / 5	4 / 4	25 / 5	32 / 4	4 / 4	30 / 3		115
9.									
10.									

STRUCTURAL ANALYSIS SUMMARY

Structural components were evaluated based upon five criteria: cost, weight distribution, rigidity, fire resistance, and construction time.

The structural matrix revealed a strong preference for a poured-in-place concrete frame. The floor and roof would remain precast double tees, but the matrix suggests adding a new column and beam for the second floor tees and turning the floor tees 90° to the roof tees to facilitate a more even distribution of loads on the perimeter foundation. Also, a brick shear wall may be considered for stiffness, as may be necessary for seismic requirements.

Structural Workshop

- Use precast floor and roof elements.
- Provide option of cast-in-place *or* precast frames for *all* walls as well as interior frames.
- Use interior columns as shown in alternate solutions first floor only.
- Span roof the 72-ft. to north and south wall frames.
- Place interior beam in north/south direction at floor level.
- Frame floor with precast elements in east/west direction spanning 32 ft.
- This recommended system would place more even loads at foundation level around perimeter of building.
- Investigate use of a massive brick shear wall at first floor level under interior beam at wall between exercise room and apparatus room.
- Use of haunches would significantly increase stiffness of frames in both directions.

CRITERIA WEIGHTING PROCESS

STRUCTURAL

CRITERIA	WEIGHT	RAW SCORE
A. COST	3	3
B. WEIGHT DISTRIBUTION	2	2
C. ADEQUATE RIGIDITY - DUCTILITY	10	11
D. FIRE RESISTANCE	8	8
E. CONSTRUCTION TIME	1	1
F.		
G.		
H.		
I.		

EVALUATION SCALE

4 major preference
3 medium preference
2 minor preference
1 letter/letter - no preference, each score one point

CRITERIA SCORING MATRIX

	B	C	D	E	F	G	H	I
A	A-2	C-2	D-2	A/E				
B		C-3	D-3	B-2				
C			C-3	C-3				
D				D-3				
E								
F								
G								
H								

ANALYSIS MATRIX

STRUCTURAL

EVALUATION SCALE

5 excellent
4 very good
3 good
2 fair
1 poor

DESIRED CRITERIA	COST	WEIGHT DISTRIBUTION	ADEQUATE RIGIDITY	FIRE RESISTANCE	CONSTRUCTION TIME			
	A	B	C	D	E	F	G	TOTAL
Weight of Importance (0-10)	3	2	10	8	1			
1. PRE-CAST COLUMNS, BEAMS AND TEES	12 / 4	4 / 2	40 / 4	40 / 5	5 / 5			101
2. POURED IN PLACE FRAME w/TEES	6 / 2	4 / 2	50 / 5	40 / 5	3 / 3			103
3. ADD FIRST FLOOR COLUMNS AND SPAN FLOOR TEES PERPENDICULAR TO ROOF TEES	6 / 2	10 / 5	50 / 5	40 / 5	3 / 3			109
4. BRICK SHEAR WALL	6 / 2	6 / 3	50 / 5	40 / 5	2 / 2			104
5.								
6.								
7.								
8.								
9.								
10.								

MECHANICAL ANALYSIS SUMMARY

Mechanical elements were evaluated based upon six criteria: cost, energy efficiency, maintenance, reserve resources, equipment anchorage, and seismic performance.

The originally proposed mechanical system of rooftop units and unit heaters in the apparatus room proved to be a viable system through the matrix analysis. Emergency systems that the matrix indicated should be considered were use of a heat recovery system with the emergency generator, and a flow through pressure storage water tank.

Mechanical Workshop

- Consider possibly providing heat exchanger and heat recovery from emergency generator for providing heating for building. Would cut down fuel storage.
- Consider use of an auxiliary domestic water pressure tank. Provide a pump (connected to the emergency power supply) to furnish pressure.
- Consider water storage tanks and pumps for fire protection. Attaching domestic water supply to the storage tank would help ensure an adequate water supply.
- Alternative on domestic water would be to use water from storage tank on a periodic basis, for apparatus use with fire pump.
- Provide fuel storage for trucks for ten days: gasoline, unleaded gas, diesel.
- Avoid cast iron boiler.
- Note: Securing equipment not difficult because lightweight units are selected for Apparatus Room.

CRITERIA WEIGHTING PROCESS

MECHANICAL

CRITERIA	WEIGHT	RAW SCORE
A. COST	1	1
B. ENERGY EFFICIENCY	7	7
C. MAINTENANCE	3	3
D. RESERVE RESOURCES	7	7
E. EQUIPMENT ANCHORAGE	4	4
F. SEISMIC PERFORMANCE	10	11
G.		
H.		
I.		

EVALUATION SCALE

4 major preference
3 medium preference
2 minor preference
1 letter/letter - no preference, each score one point

CRITERIA SCORING MATRIX

	B	C	D	E	F	G	H	I
A	B-2	A/C	D-3	E-2	F-3			
B		B-2	B/D	B-2	F-2			
C			D-2	C-2	F-3			
D				D/E	F-2			
E					E/F			
F								
G								
H								

ANALYSIS MATRIX

MECHANICAL

EVALUATION SCALE

5 excellent
4 very good
3 good
2 fair
1 poor

DESIRED CRITERIA	A: COST	B: ENERGY EFFICIENCY	C: MAINTENANCE	D: RESERVE RESOURCES	E: EQUIPMENT ANCHORAGE	F: SEISMIC PERFORMANCE	G	TOTAL
Weight of Importance (0-10)	1	7	3	7	4	10		
1. ROOF TOP UNITS, w/UNIT HEATERS IN APPARATUS ROOM	1 / 5	21 / 3	12 / 4	28 / 4	8 / 2	40 / 4		110
2. PROVIDE HEAT RECOVERY FROM EMERGENCY GENERATOR	2 / 2	35 / 5	9 / 3	35 / 5	12 / 3	40 / 4		133
3. USE CAST IRON BOILER	1 / 1	14 / 2	6 / 2	14 / 2	4 / 1	10 / 1		49
4. DOMESTIC WATER STORAGE RUN WATER THROUGH PRESSURE TANK	2 / 2	21 / 3	6 / 2	35 / 5	12 / 3	30 / 3		106
5.								
6.								
7.								
8.								
9.								
10.								

ELECTRICAL ANALYSIS SUMMARY

Electrical components were evaluated based upon seven criteria: cost, communications, energy efficiency, maintenance, anchorage, automatic features, and seismic performance.

Considerations for electrical items shown in the analysis matrix would be to omit hung ceilings and to circuit emergency items separately on a panel with an automatic throw over switch to the emergency generator, with a recommended battery backup for about six hours. Also, the use of flex conduit should be implemented wherever feasible, while avoiding casting conduit into structural elements.

Electrical Workshop

- Special Structural Considerations — Pad mount transformer, bolt down. Panel anchorage, bolt through. Communications cabinet, anchorage.
- Fixtures, Mounting — Lens vs. Open. Positive lens latching. Avoid lay-in.
- Conduit Locations — Avoid cast in conduit into structural elements. Flex - conduit.
- Emergency Fixtures — Separate circuit, emergency panel on automatic throw over switch from generator.
- Dual Emergency System — Battery backup to generator. Six hours. Insurance to get generator going.
- Underground Service Desirable.
- Emergency Generator — Automatic switching. Fuel, diesel vs. oil. Size, 20 KW. Battery start. 10 KW adequate if no heat required. Priorities: communication (amplifier, etc.) radio; fuel pumps; emergency lighting; heat source, to avoid freezing. Must emergency generator handle entire building load for 10 days?
- Manual Overrides in case of Failure — gas pumps, fuel storage, water, doors.

CRITERIA WEIGHTING PROCESS

ELECTRICAL

CRITERIA		WEIGHT	RAW SCORE
A.	COST	1	2
B.	COMMUNICATIONS	8	10
C.	ENERGY EFFICIENCY	2	3
D.	MAINTENANCE	1	2
E.	EQUIPMENT ANCHORAGE	8	10
F.	AUTOMATIC FEATURES	10	12
G.	SEISMIC PERFORMANCE	10	12
H.			
I.			

EVALUATION SCALE

4 major preference
3 medium preference
2 minor preference
1 letter/letter - no preference, each score one point

CRITERIA SCORING MATRIX

	B	C	D	E	F	G	H	I
A	B-4	C-2	A-2	E-3	F-4	G-3		
B		B-2	B-2	B/E	F-3	B/G		
C			C/D	E-2	F-2	G-3		
D				E-2	D/F	G-3		
E					E/F	E/G		
F						F/G		
G								
H								

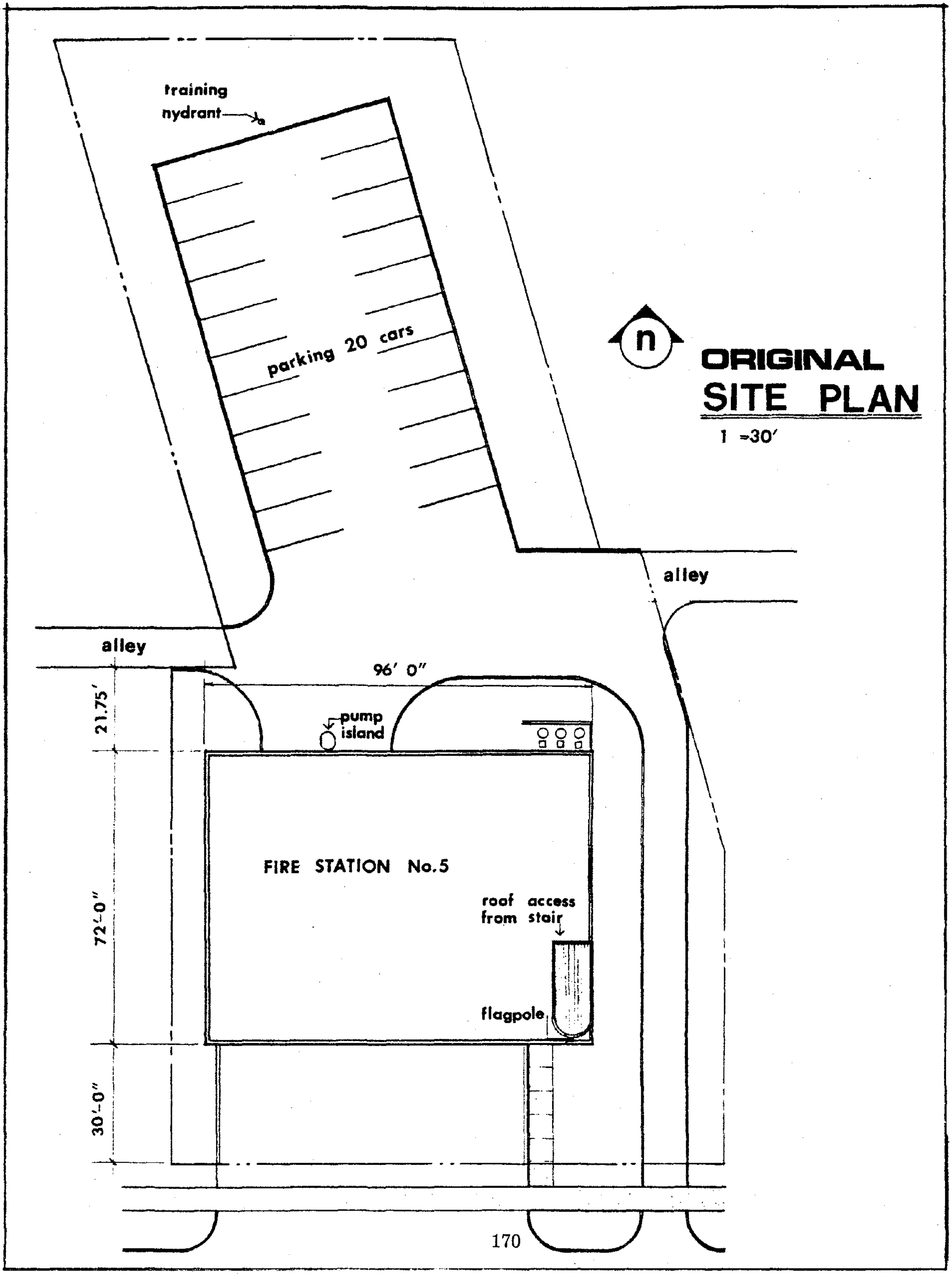
ANALYSIS MATRIX

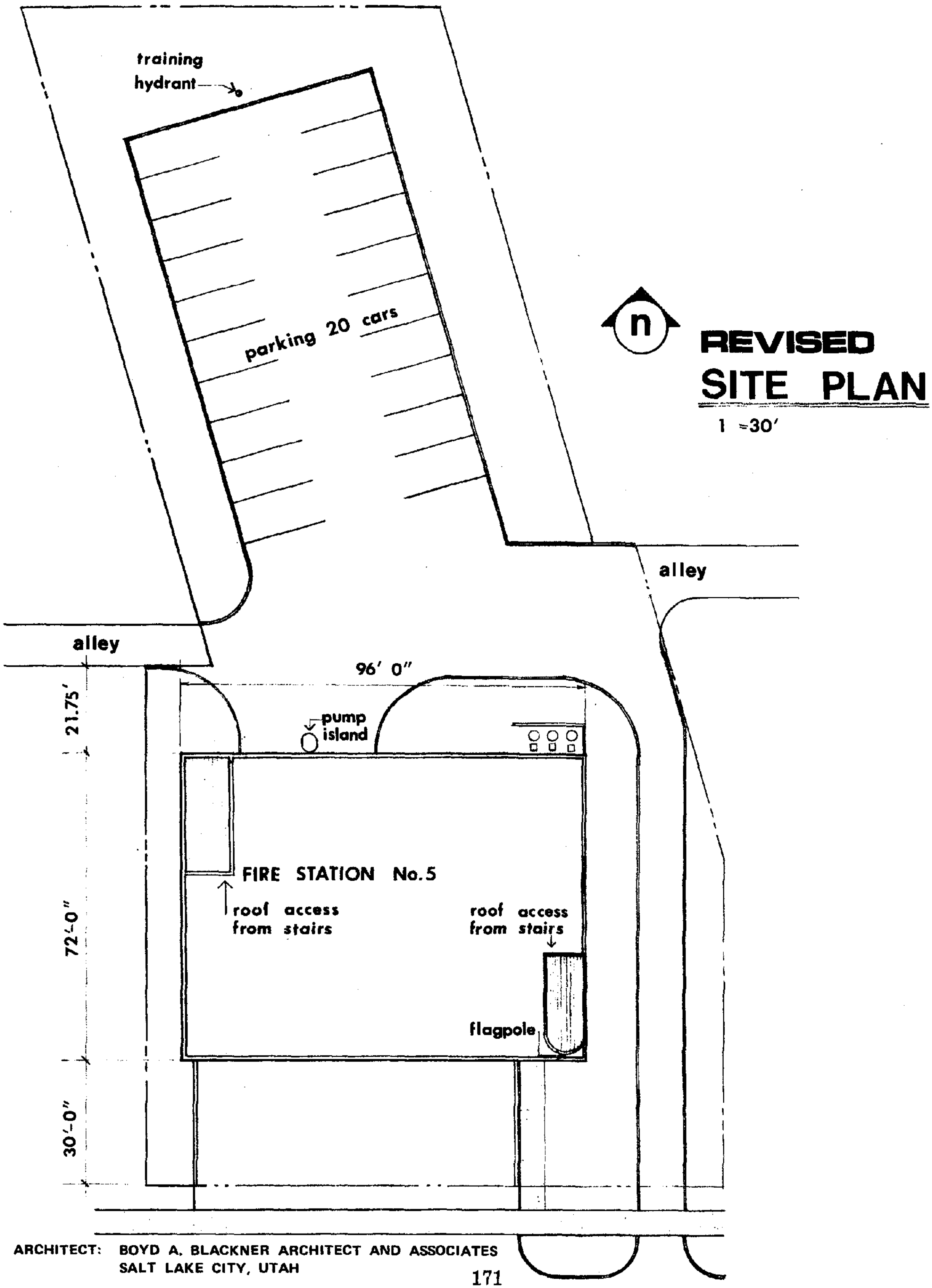
ELECTRICAL

EVALUATION SCALE

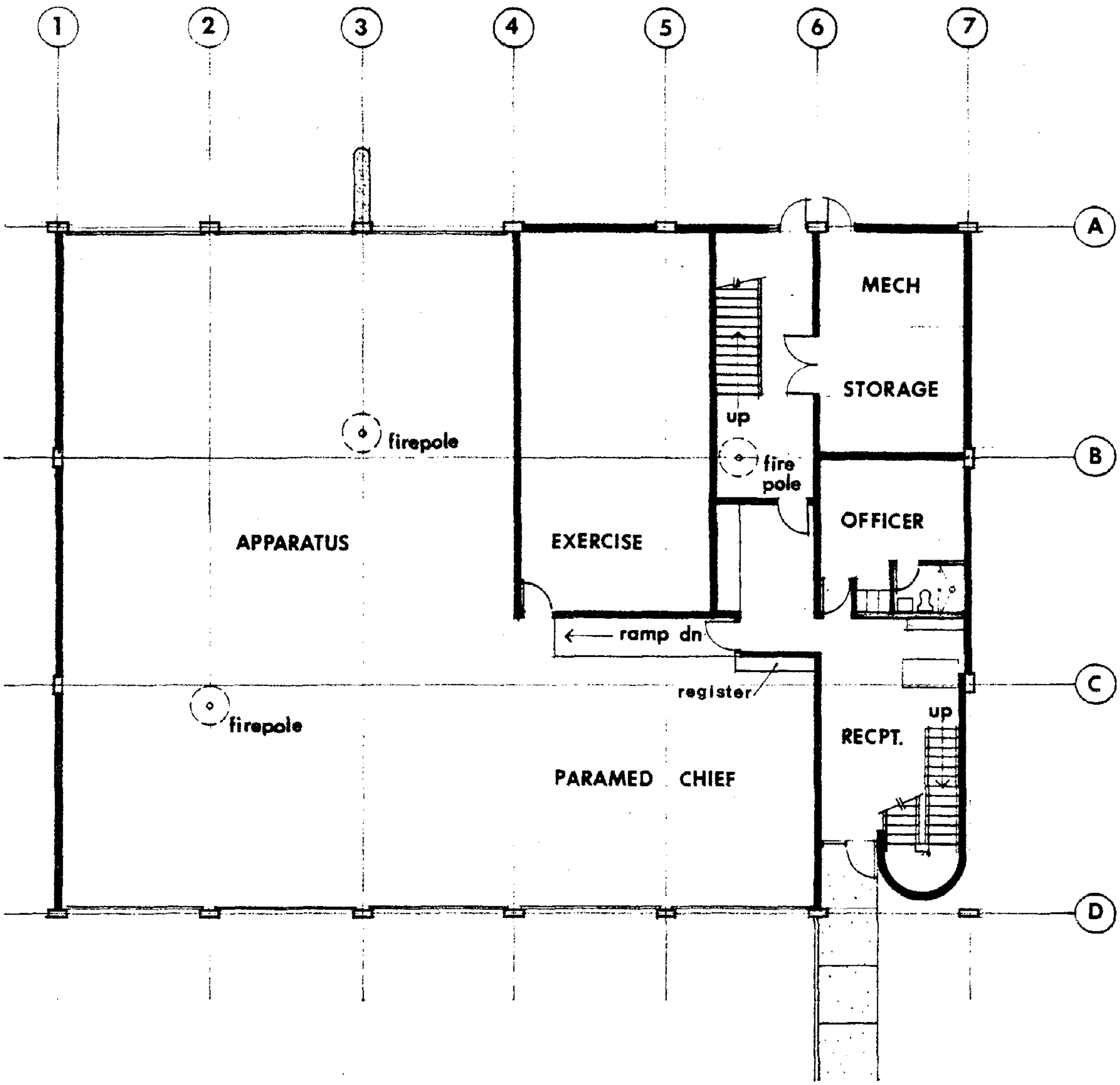
5 *excellent*
4 very good
3 good
2 fair
1 poor

DESIRED CRITERIA	COST	COMMUNICATIONS	ENERGY EFFICIENCY	MAINTENANCE	EQUIPMENT ANCHORAGE	AUTOMATIC FEATURES	SEISMIC PERFORMANCE	
	A	B	C	D	E	F	G	TOTAL
Weight of Importance (0-10)	1	8	2	1	8	10	10	
1. LAY-IN CEILING WITH RIGID CONDUIT SYSTEM	2 / 2	32 / 4	6 / 3	4 / 4	8 / 1	10 / 1	10 / 1	72
2. EMERGENCY CIRCUITS ON SEPARATE PANELS w/AUTOMATIC SWITCHING	2 / 2	40 / 5	6 / 3	4 / 4	24 / 3	50 / 5	50 / 5	176
3. USE FLEX CONDUIT, AND AVOID CONDUIT CAST INTO STRUCTURAL ELEMENTS	1 / 1	24 / 3	6 / 3	4 / 4	40 / 5	30 / 3	50 / 5	155
4. PROVIDE MANUAL OVERRIDES ON ALL EQUIPMENT	2 / 2	32 / 5	6 / 2	4 / 2	16 / 2	20 / 4	20 / 4	100
5. BATTERY BACK-UP FOR ALL SYSTEMS FOR 6 HOURS	2 / 2	40 / 5	4 / 2	2 / 2	16 / 2	40 / 4	40 / 4	144
6. OMIT LAY-IN CEILING	5 / 5	24 / 3	2 / 1	2 / 2	32 / 4	30 / 3	50 / 5	145
7.								
8.								
9.								
10.								


training
nydrant
parking 20 cars
n
ORIGINAL
SITE PLAN
1 =30′
alley
alley
96′ 0″
21.75′
pump
island
FIRE STATION No.5
roof access
from stair
flagpole
72′-0″
30′-0″



ARCHITECT: BOYD A. BLACKNER ARCHITECT AND ASSOCIATES
SALT LAKE CITY, UTAH

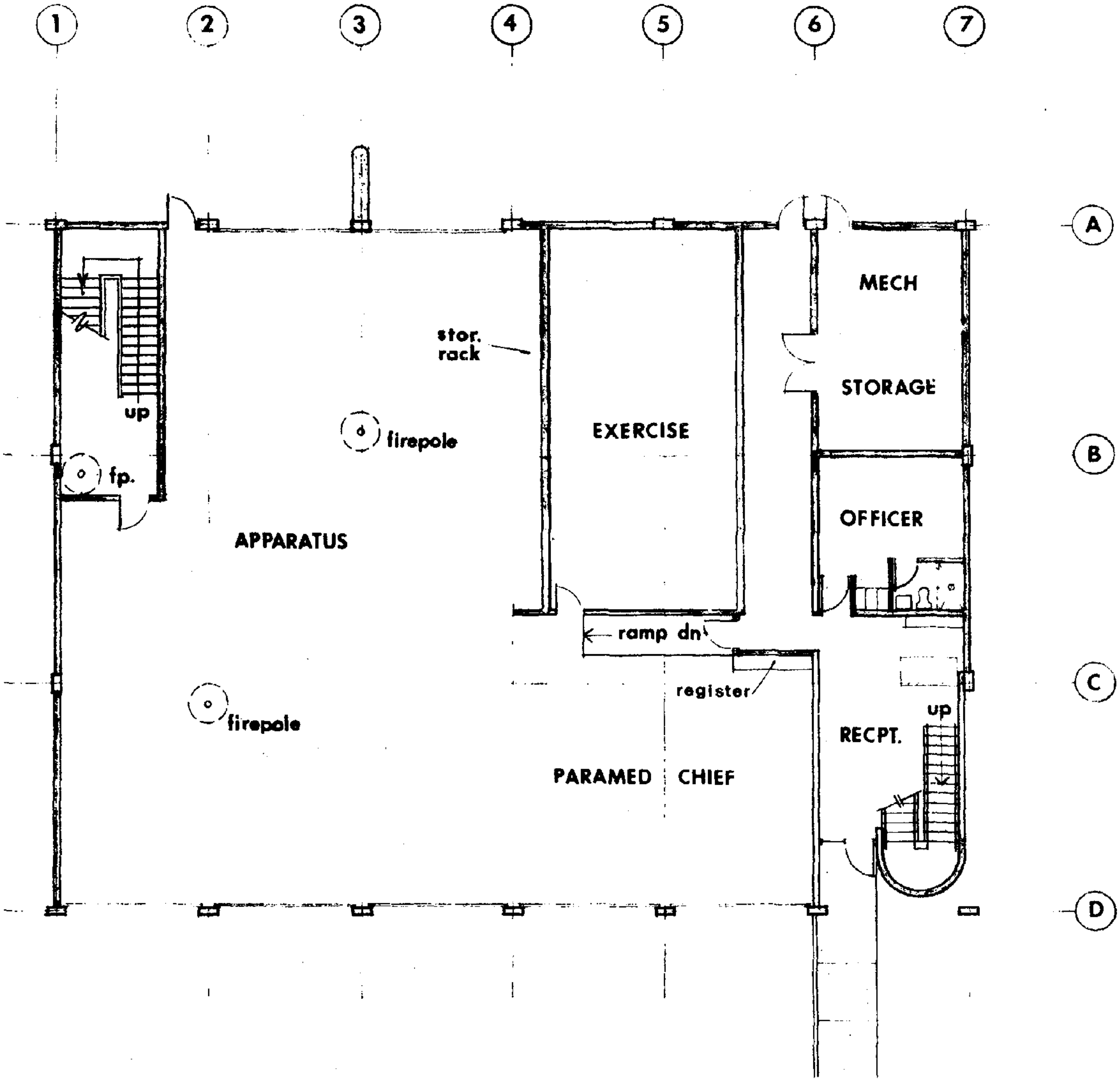


ORIGINAL
FIRST FLOOR PLAN

1" = 16'-0"

AREA SUMMARY

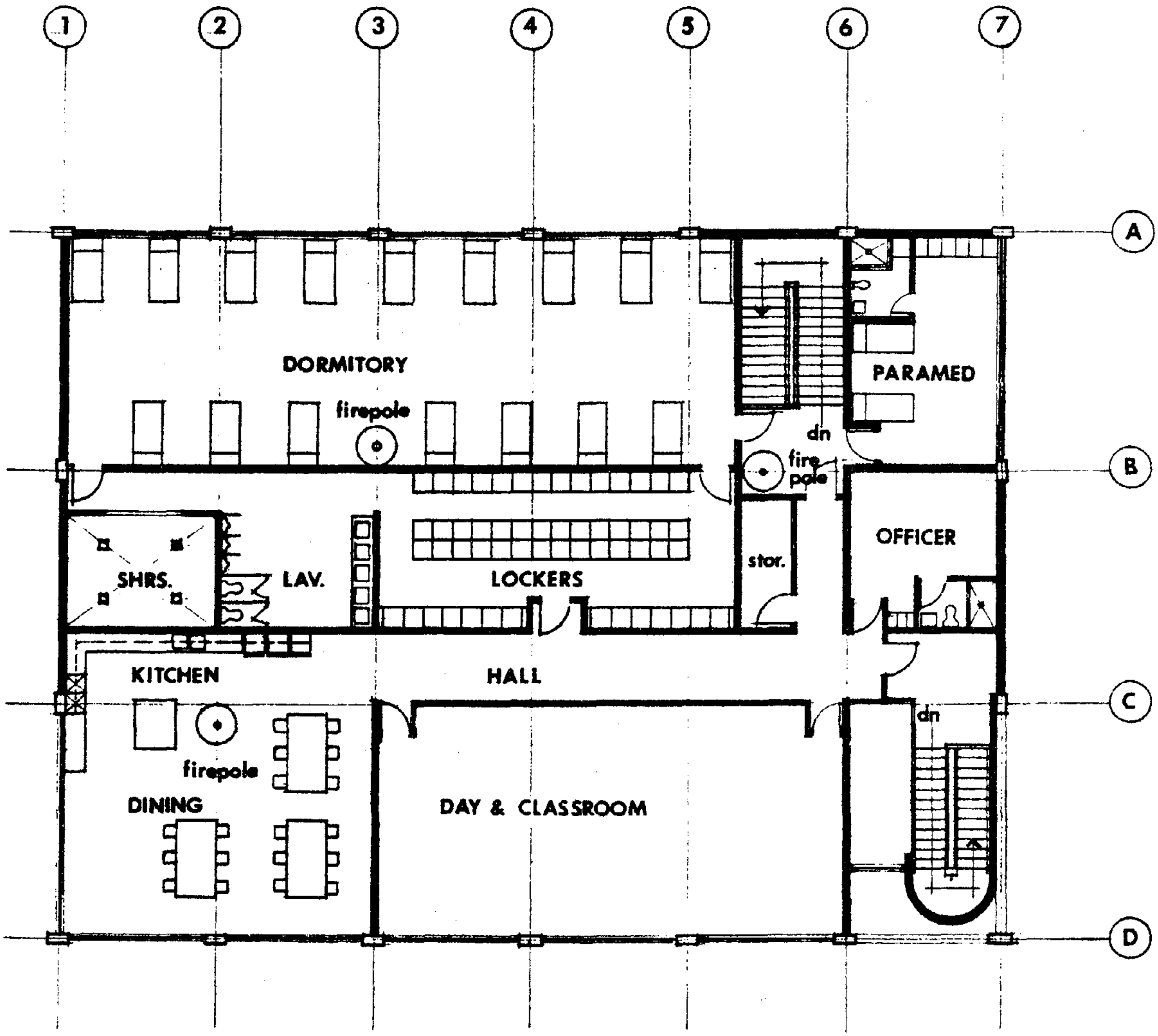
first floor	6912 sq. ft.
second floor	6912 " "
TOTAL	13824 sq. ft.



REVISED
FIRST FLOOR PLAN
1" – 16'-0"

AREA SUMMARY

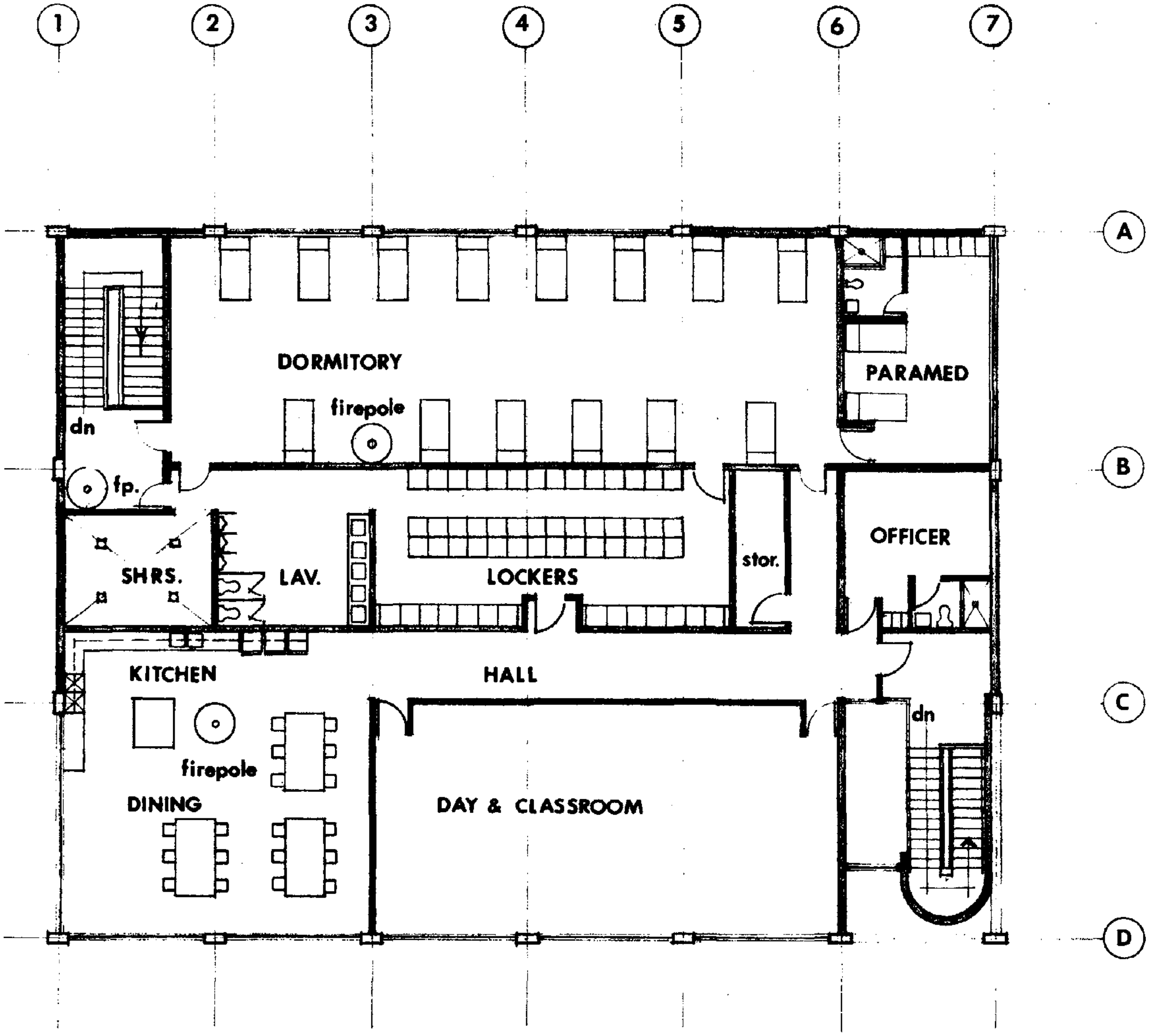
first floor	6912sq. ft.
second floor	6912 " "
TOTAL	13824 sq. ft.



ORIGINAL

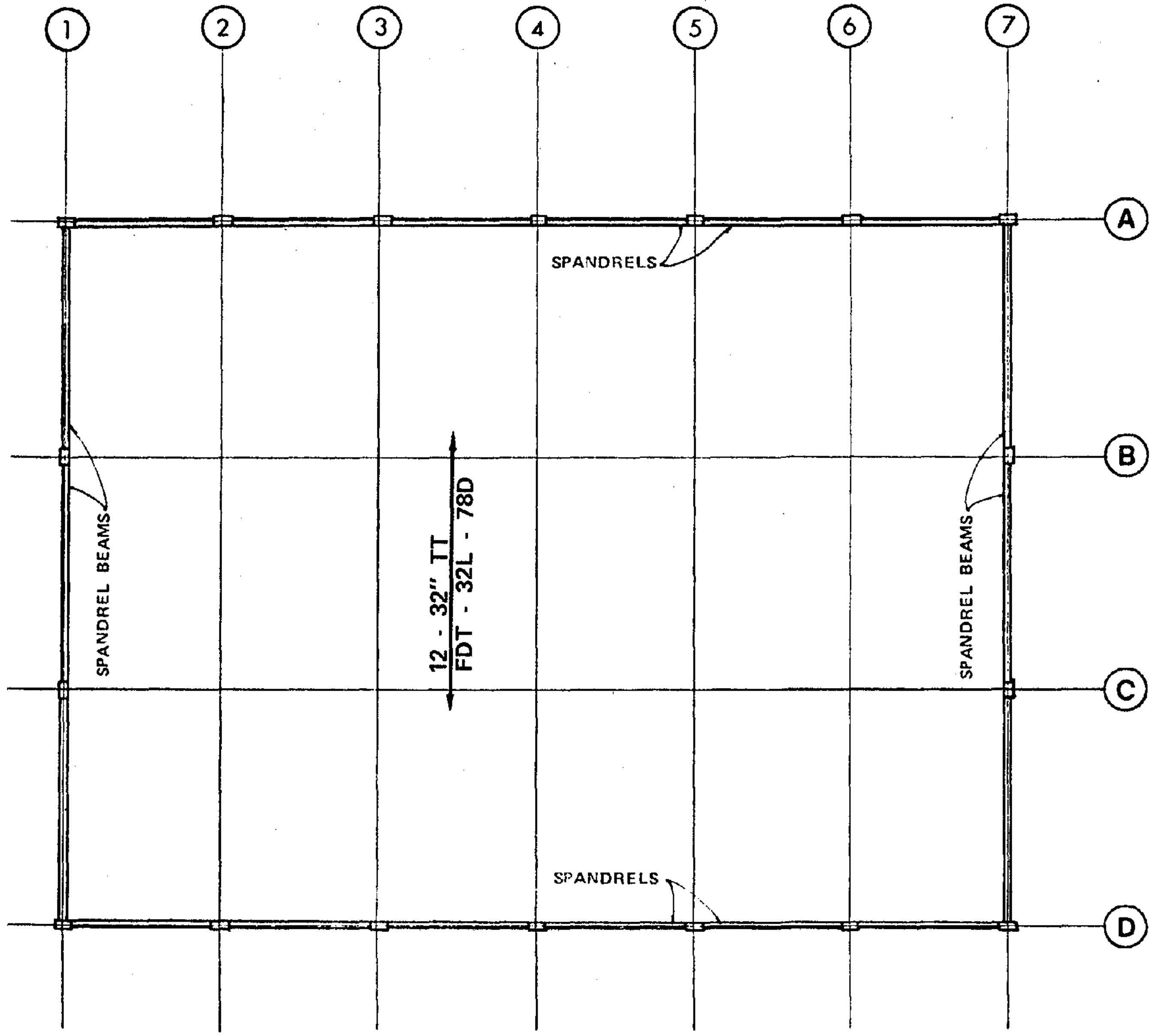
SECOND FLOOR PLAN

1" = 16'-0"



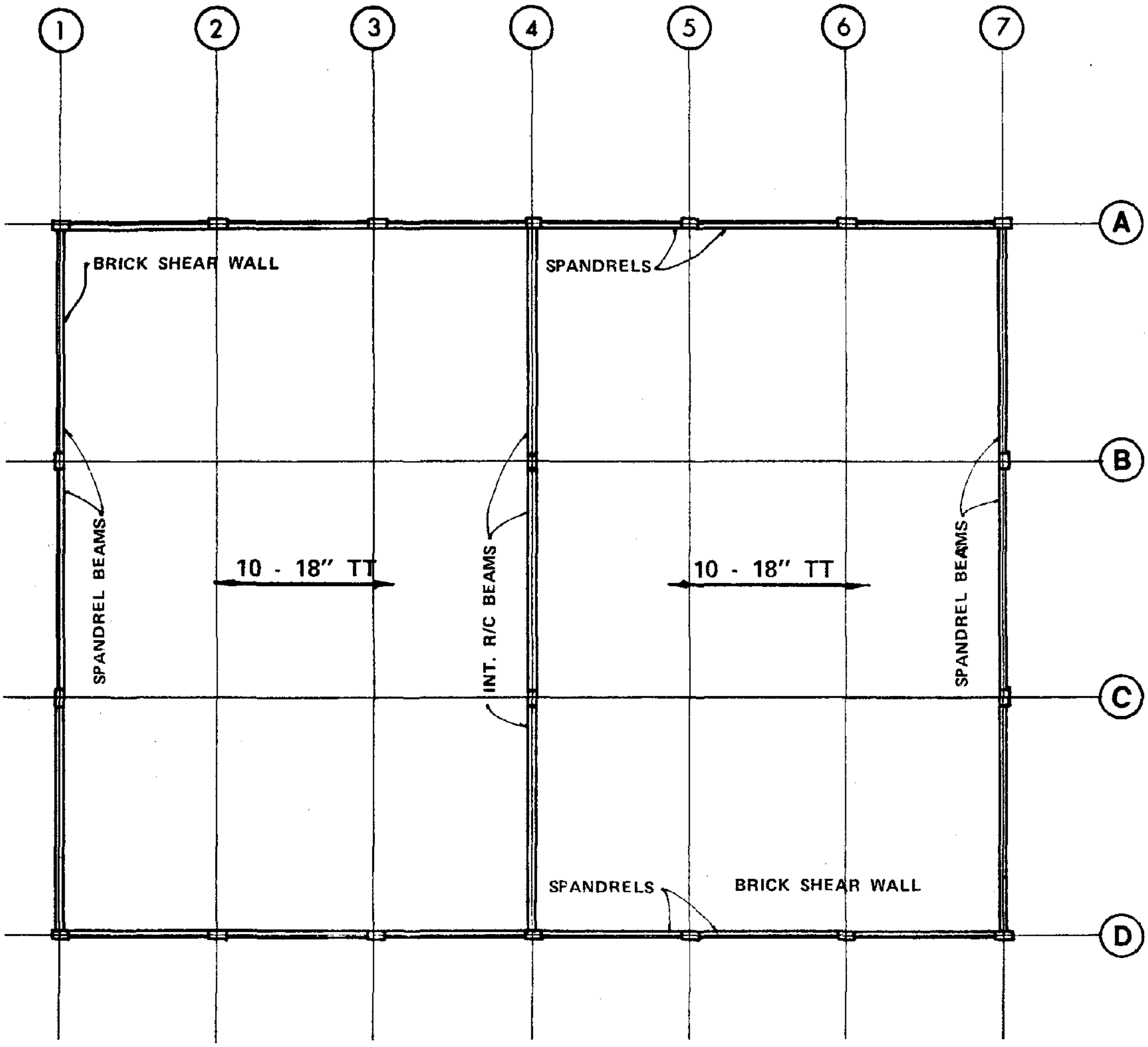
REVISED SECOND FLOOR PLAN

1" = 16'-0"

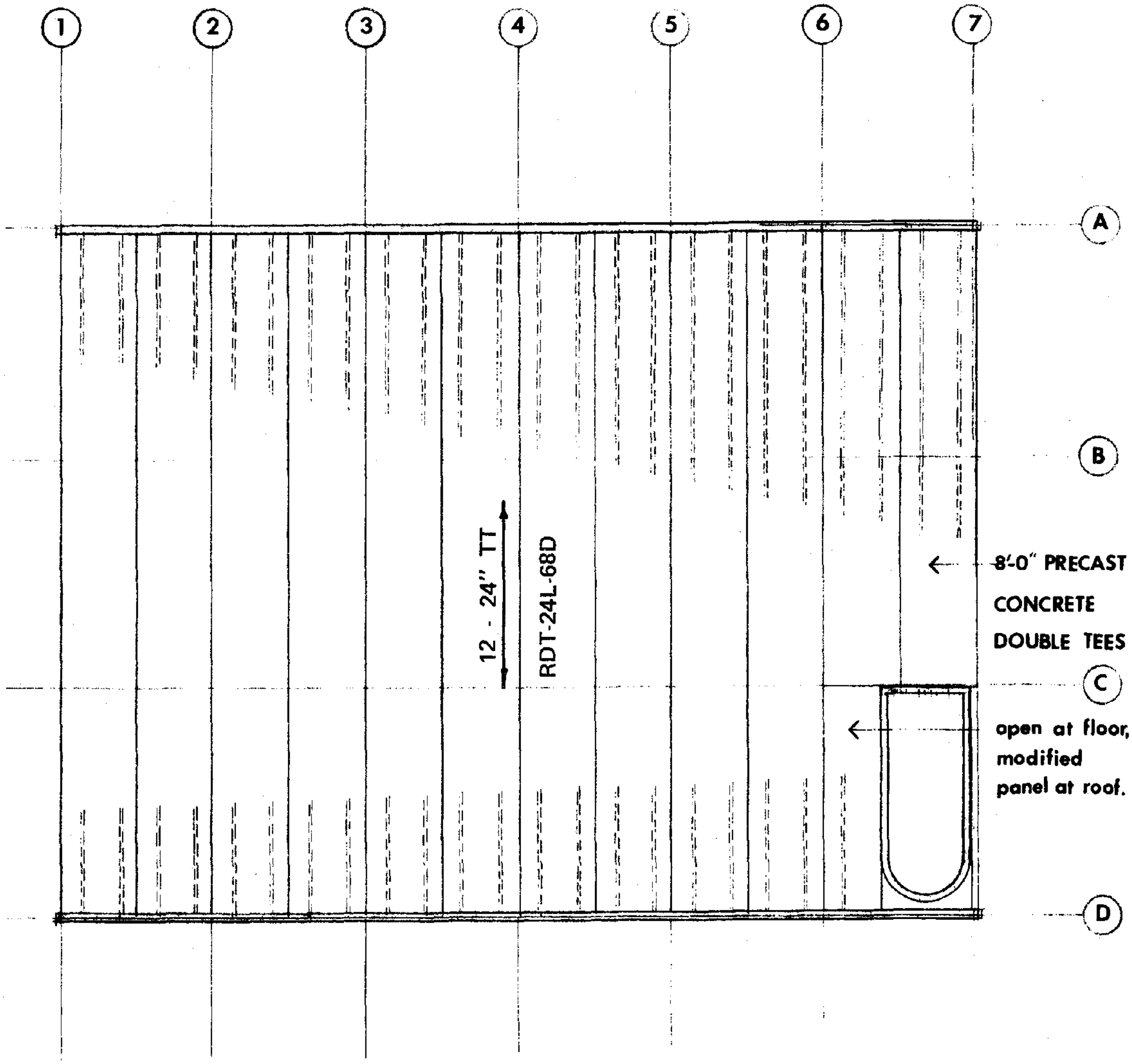


ORIGINAL
SECOND FLOOR FRAMING PLAN

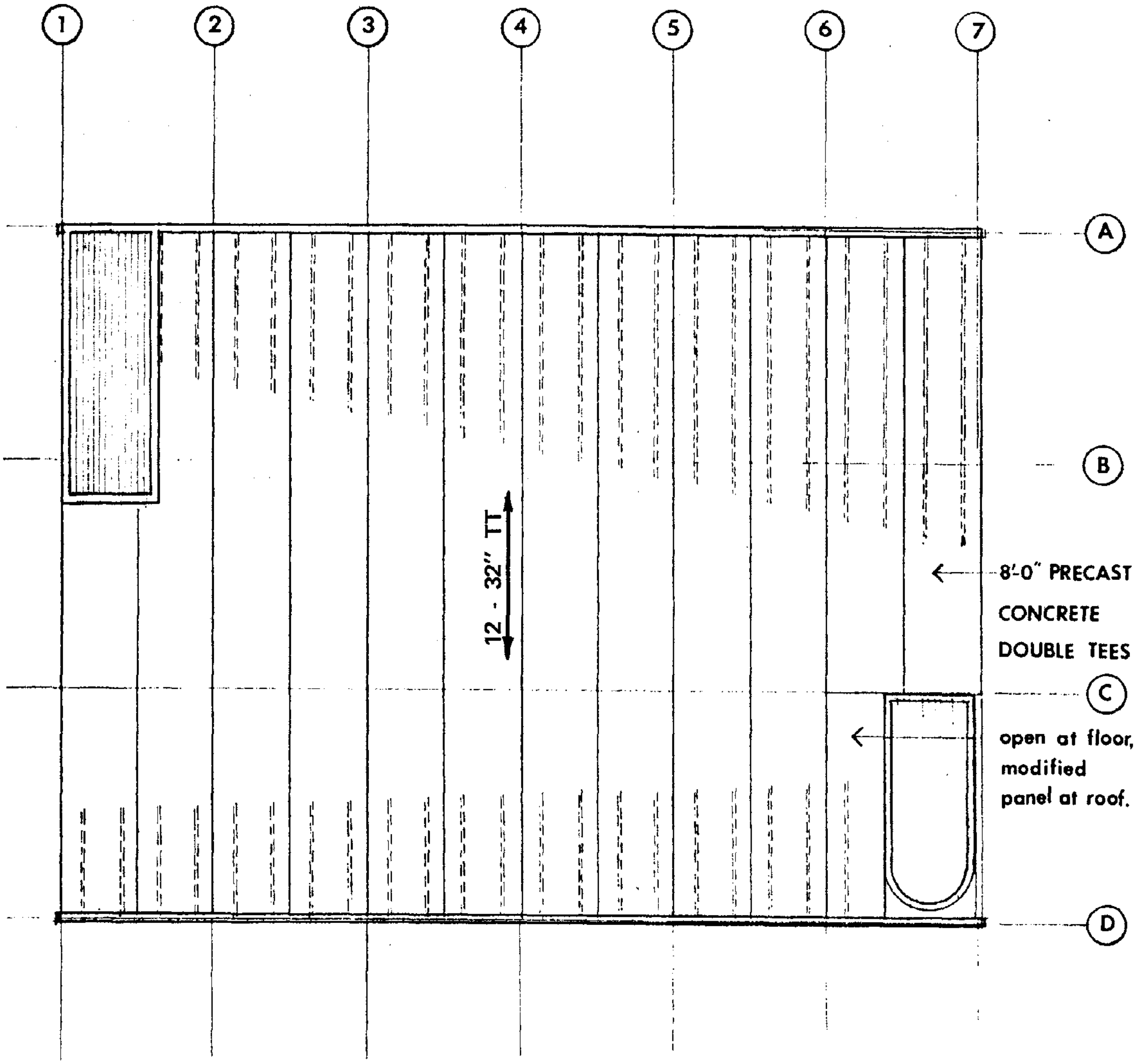
1" = 16'-0"



REVISED
SECOND FLOOR FRAMING PLAN
1" = 16'-0"

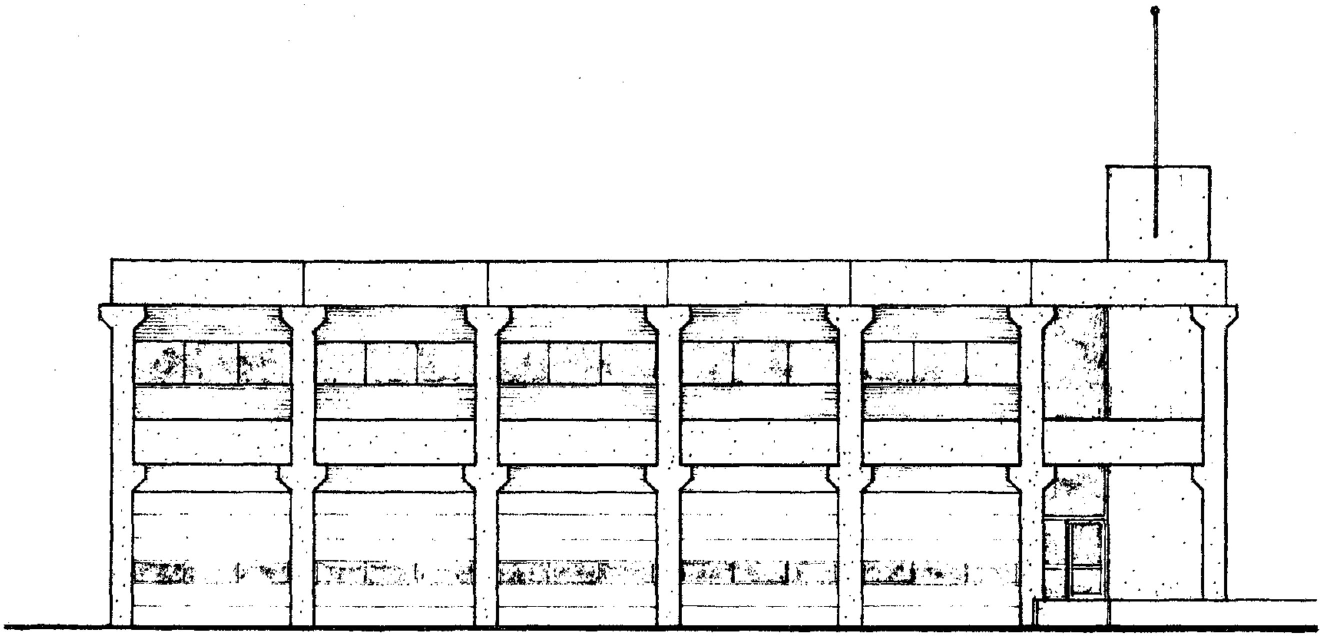


ORIGINAL
ROOF FRAMING PLAN
1"-16'-0"



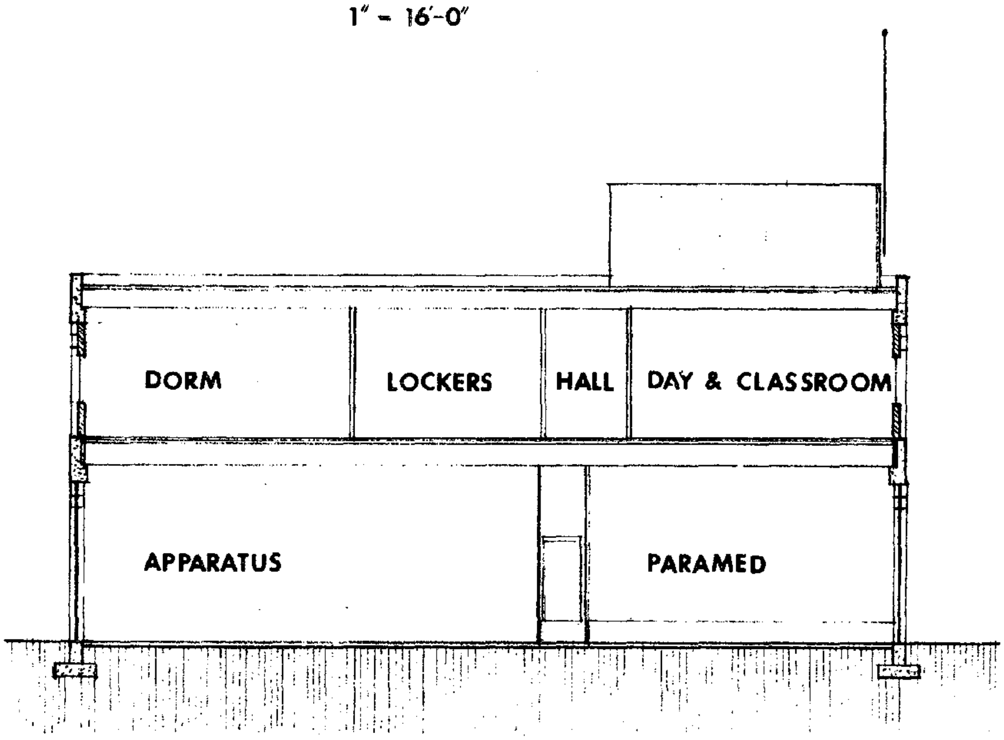
REVISED
ROOF FRAMING PLAN

1"-16'-0'



SOUTH ELEVATION

1" - 16'-0"



SECTION

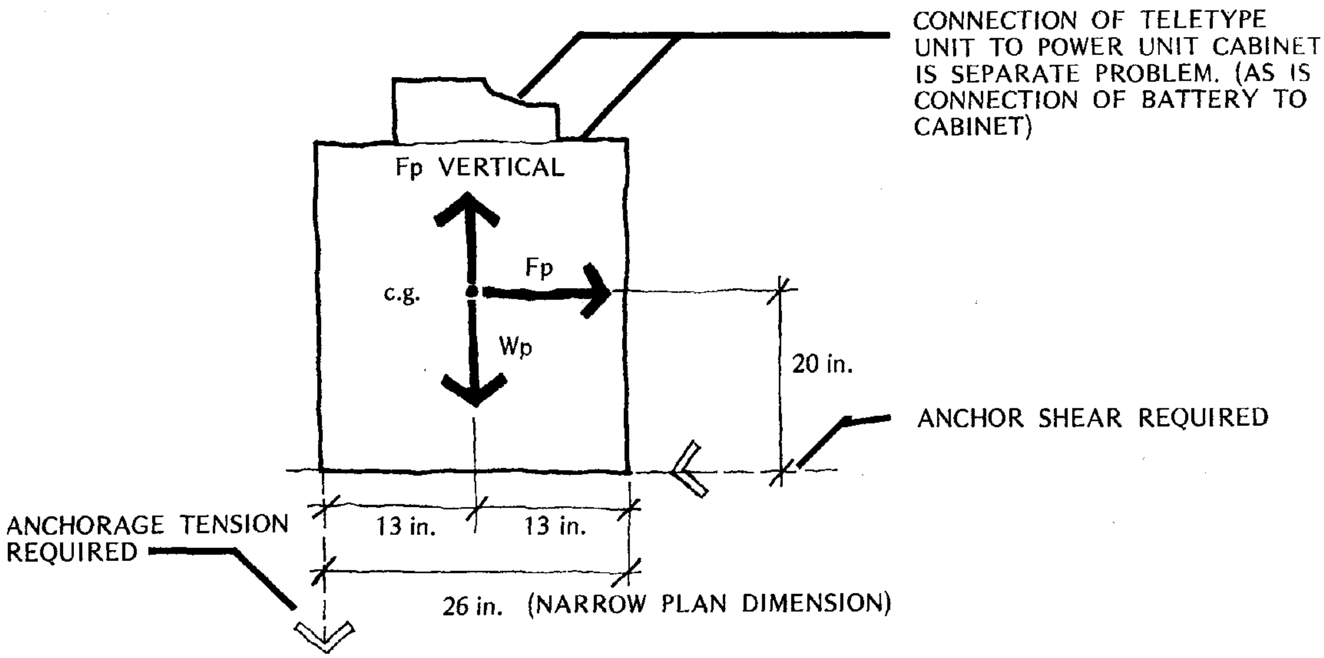
COST DATA

TOTAL AREA: 13,824 S.F.

COMPONENT	ORIGINAL COST	REVISED COST	PERCENT CHANGE
ARCHITECTURAL	138,458	140,508	1.5%
		SUPPORTS/RESTRAINTS	.5%
		HELICOPTER PAD	6.1%
		CHANGE EXTERIOR WALLS	0%
		CHANGE INTERIOR WALLS	- .8%
		OMIT HUNG CEILING	-4.3%
		RELOCATE STAIR	0%
STRUCTURAL	146,860	147,360	.3%
		REDUCE BEAMS/TOPPING	3.3%
		ADD COLUMNS/BEAMS	-3.0%
MECHANICAL	94,221	97,871	3.8%
		SUPPORTS/RESTRAINTS	.8%
		PRESSURE TANK LOOP	.6%
		EMERGENCY HEAT RECOVERY	2.4%
ELECTRICAL	51,756	56,656	9.5%
		SUPPORTS/RESTRAINTS	1.4%
		SURFACE MOUNT FIXTURES	2.4%
		EXPAND EMERGENCY SYSTEM	4.5%
		MANUAL OVERIDES	1.2%
TOTAL COST	$431,295	$442,395	2.6%

Architect: Building Systems Development International
San Francisco, California

The following case study illustrates a solution for seismic connection/anchorage details for a teletype-power unit.



There are three forces acting on the piece of equipment: a gravitational force and the horizontal and vertical earthquake forces.

Fp-vertical could act downward, but that is not the significant case for overturning (vertical strength is probably adequate for downward Fp added to Wp).

Wp = Weight = 200 lb.

Fp - Horizontal EQ force = 2 (Wp) = 400 lb. A high value is chosen as the factor to apply to the weight, to see the implications of conservative assumptions. Code values range from 3/4 to 1-1/8 (with working stress design). Comparison will be made at the end with these lower values.

Fp Vertical = 1/2 Fp. This exceeds code value of 1/3 Fp, and with a value of 2 x W for Rp, in effect cancels out the vertical gravitational force. Again, a conservative assumption.

Hence, the only applied force is Fp = 400 lb.

Overturning moment = 400 lb. (20 in.) = 8000 in-lb.

Assume this will be resisted by tie-downs at the four corners.

Anchorage Tension = Moment/Depth ÷ 2 anchorages on this side.

T = 8000 in-lb/26 in ÷ 2 = 154 lb. each anchor

Anchorage Shear -- 400 lb./4 anchors (Neglect Friction) V = 100 lb. each Anchor

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For comparison, use UBC:

Fp Max	=	1-1/8 Wp	
Vertical Fp	=	1/3 Wp	
Fp	=	169 lb.	
Fp Vertical	=	56 lb.	Subtract from Wp; Net Wp = 144 lb., or 36 lb. each corner
Moment	=	169 lb. (20 in.) = 3380 in-lb.	
M/D	=	3380/26 = 121 lb.	Divide by 2 anchors: 61 lbs. each. Subtract the amount supplied already, Net Wp at each corner: 61 lb. − 31 lb. = 30 lb.

Anchorage Tension = 25 lb.

Anchorage Shear = 42 lb. = Fp/4

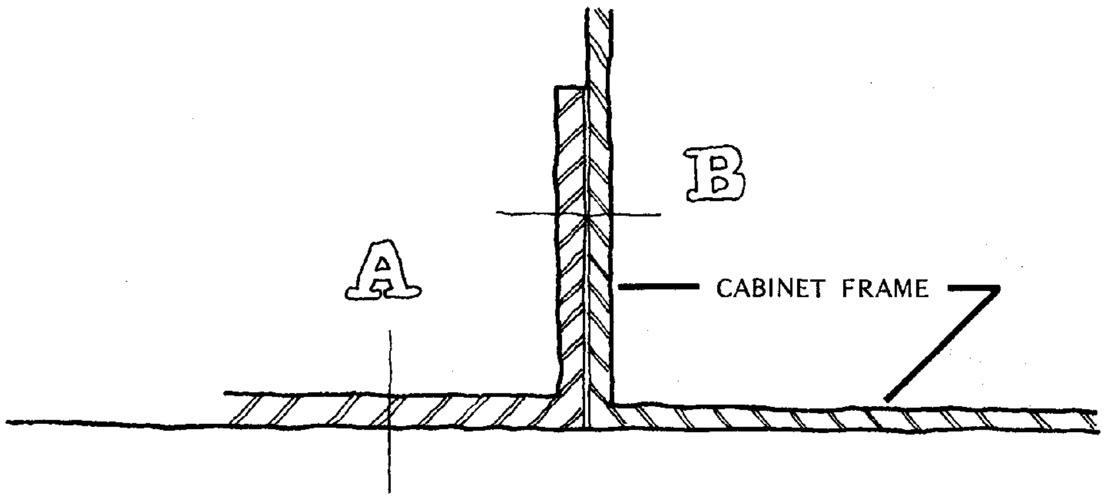
For comparison, use Title 24 California Hospitals Code (Draft Version)

Fp Max	=	3/4 Wp	
Fp Vertical	=	1/3 Fp	
Fp	=	150 lb.	Net Wp = 150 lb. = 38 lb. each corner
O.M.	=	150 lb. (20 in.) = 3000 in-lb.	
M/D	=	3000 in-lb/26 in. = 115 lb.	Divide by 2 anchors = 58 lb. each; less 38 lb. = 20 lb.

Anchorage Tension = 20 lb.	This code prohibits 1/3 stress increases for EQ loads	T = 27 lb.
Anchorage Shear = 38 lb.		V = 51 lb.

Obviously, using a lateral force factor of 2, rather than 1-1/8 or 3/4, produces larger tension and shear values. For an object of this mass, the forces are not significantly different, when it is seen that the same hardware can handle all three cases. It is interesting to note, however, especially with regard to heavier objects, that the assumption concerning the vertical Fp is quite significant. If it is assumed that there is no vertical earthquake force, the object may compute out as stable with no attachment at all. (This is just about the case with the above example using 3/4 g). In this example, if Fp Vertical = 1/3Fp (the usual code-prescribed value) the shear force is about twice the tensile force, on the anchors. If the Fp Vertical is 1 g, negating the helpful downward force of gravity, the tensile force is a third *more* than the shear force. This is significant, because if a thru-bolt connection cannot be used, as for instance with threaded inserts or expansion bolts in concrete or screws in wood, the connection will fail in tension (the bolt or screw pulling out of the concrete or wood) before it would fail in shear.

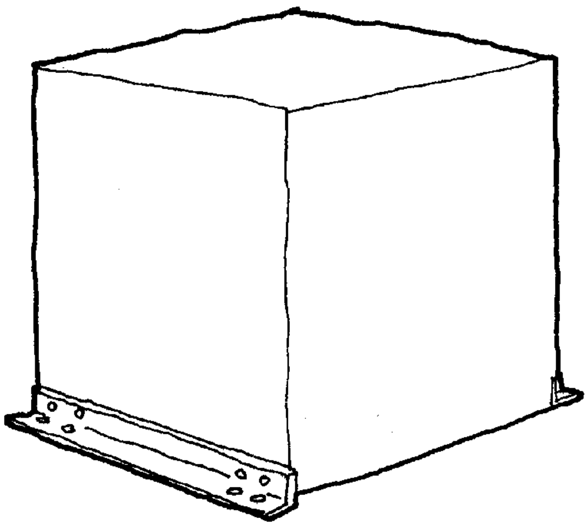
If, as in this example, a conservative assumption can be made at insignigicant cost, it would be wise to make it.



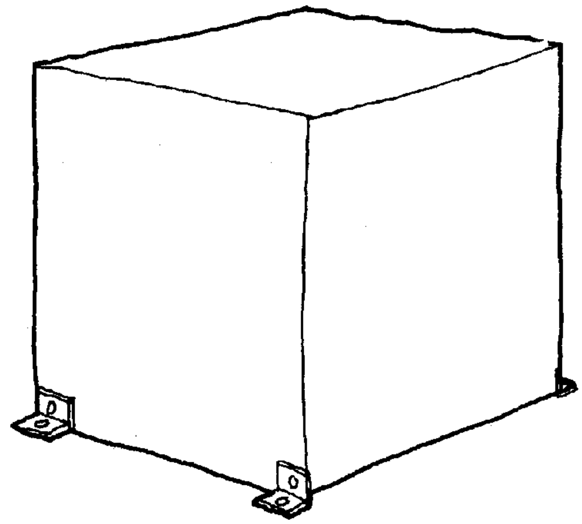
Connection A, Angle to Floor

Following sizes shown are for the worst case above, Fp = 2(Wp); 154 lb. Tension, 100 lb. Shear. It should be noted that expansion bolts are usually 1/4 in. minimum diameter, so the other two design assumptions would result in the same detail. If one size larger bolt had been required, it would have been at a minimal cost.

If an expansion bolt is used (rather than a cast-in-place insert), or if a screw is used in a wood floor (rather than a thru bolt), the designer should note that these methods are not generally recommended, and a second line of defense should be sought. For instance, the attachment angle could be run along the base in one piece, rather than using two short pieces. Two expansion bolts or screws could be placed at each corner.



INHERENTLY SAFER



FAILURE OF ONLY ONE
CONNECTION CAUSES SUCCESSIVE
FAILURE OF OTHERS

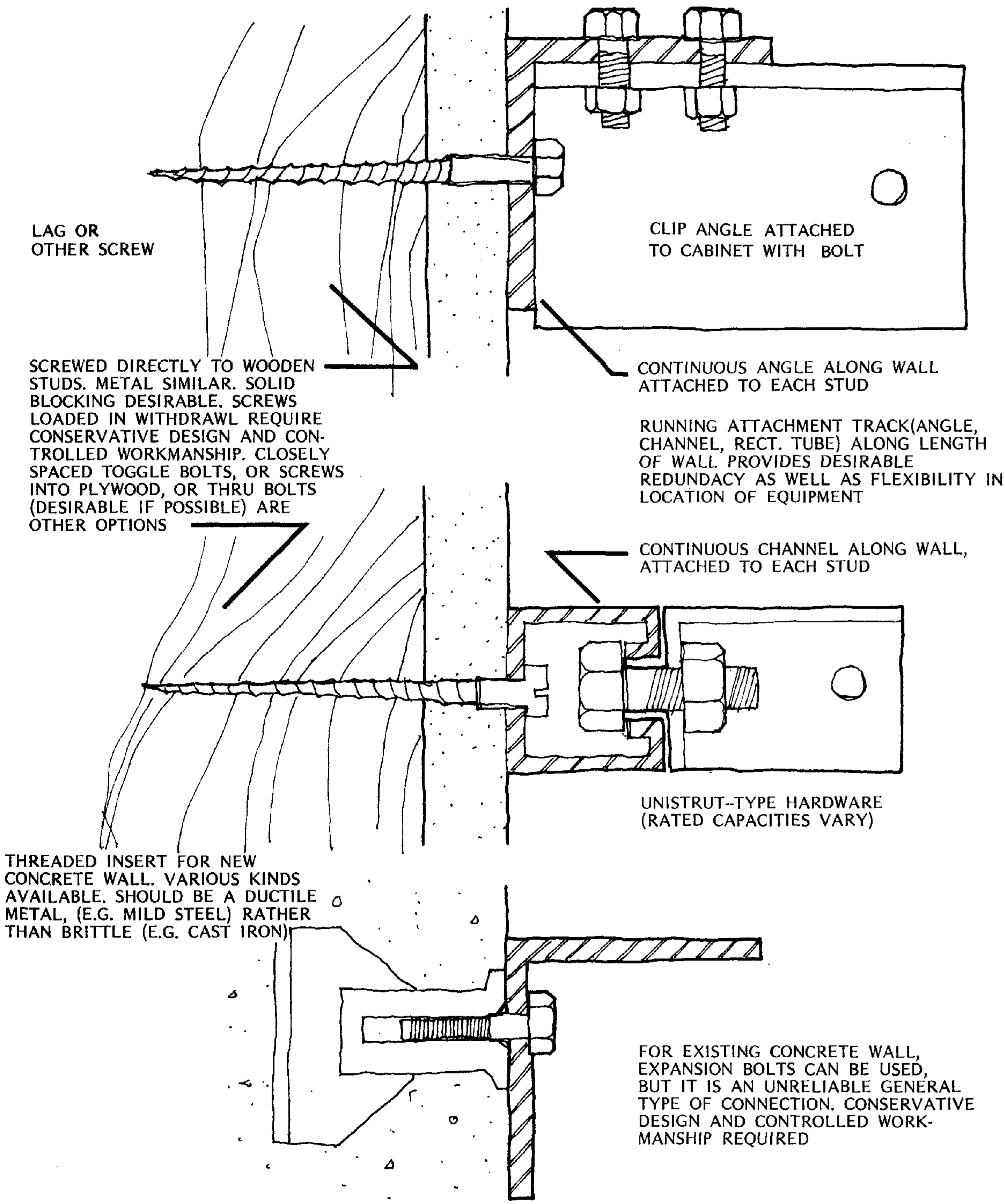
Connection B, Angle to Cabinet

A thru bolt must take 154 lb. in vertical shear (due to uplift) and 100 lb. in horizontal shear to provide the horizontal reaction to keep the box from sliding at the same time. Or, when forces reverse and work along the other axis, the horizontal reaction is provided via tension, and the uplift is resisted in shear.

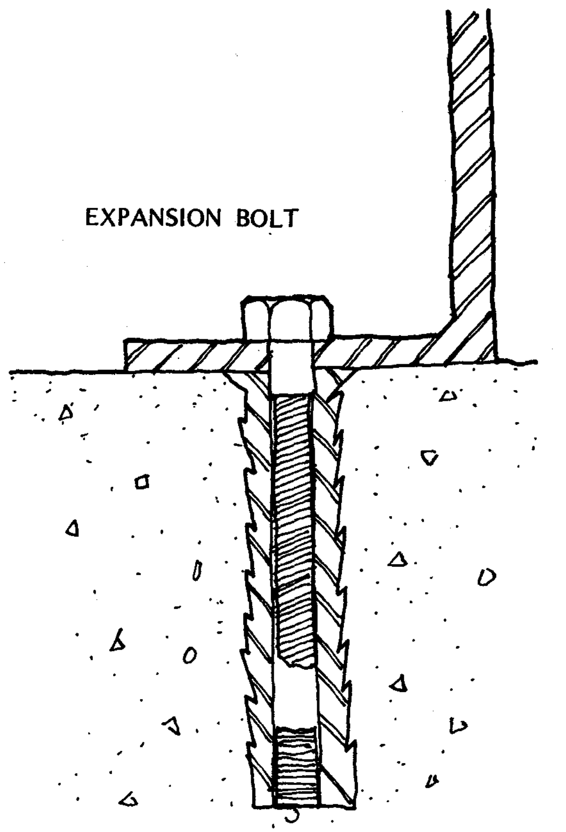
A 1/4 in. bolt is adequate.

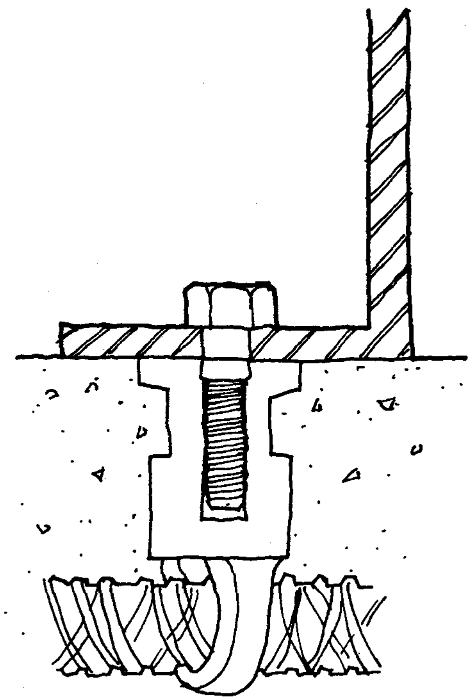
Use a 2 in. x 2 in. x 3/16 in. angle.

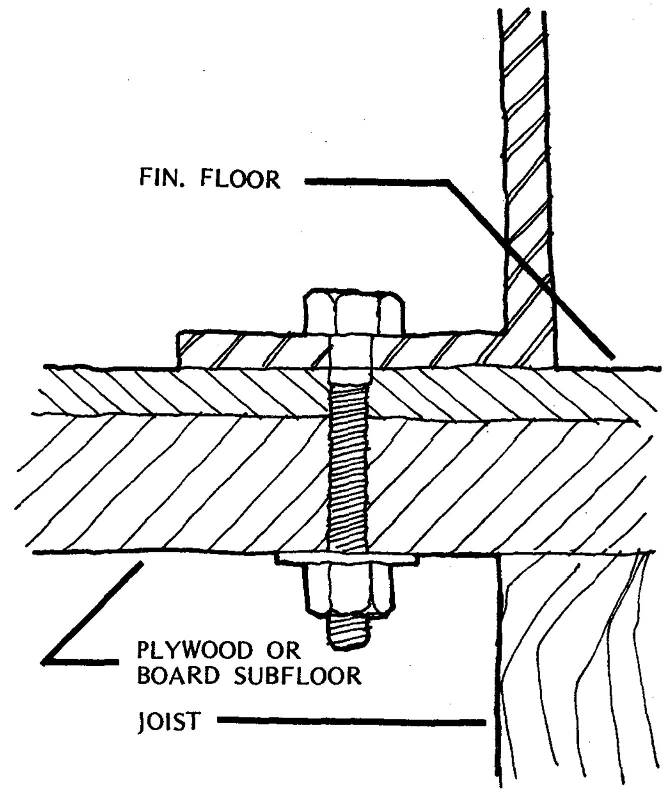
Attach to edge framing member (typically an angle) of cabinet (rather than sheet metal wall).



POSSIBLE WALL ANCHORAGE CONDITIONS







EXPANSION BOLT
(EXISTING CONCRETE FLOOR)

PROPRIETARY KINDS AVAILABLE.

SELF-DRILLING TYPE PREFERABLE SINCE IMPRECISE DRILLING OF HOLE DRASTICALLY REDUCES LOAD CAPACITY.

NOTE: THIS GENERAL TYPE OF CONNECTION IS UNRELIABLE (ESPECIALLY WHEN LOADED IN WITHDRAWL). CONSERVATIVE DESIGN AND CONTROLLED WORKMANSHIP REQUIRED.

THREADED INSERT
(NEW CONCRETE FLOOR)

PROPRIETARY KINDS AVAILABLE.

COULD BE PLUGGED WITH FLAT HEAD STOVE BOLT WHEN NOT IN USE.

RECOMMENDED FOR NEW CONSTRUCTION (RATHER THAN EXPANSION BOLT).

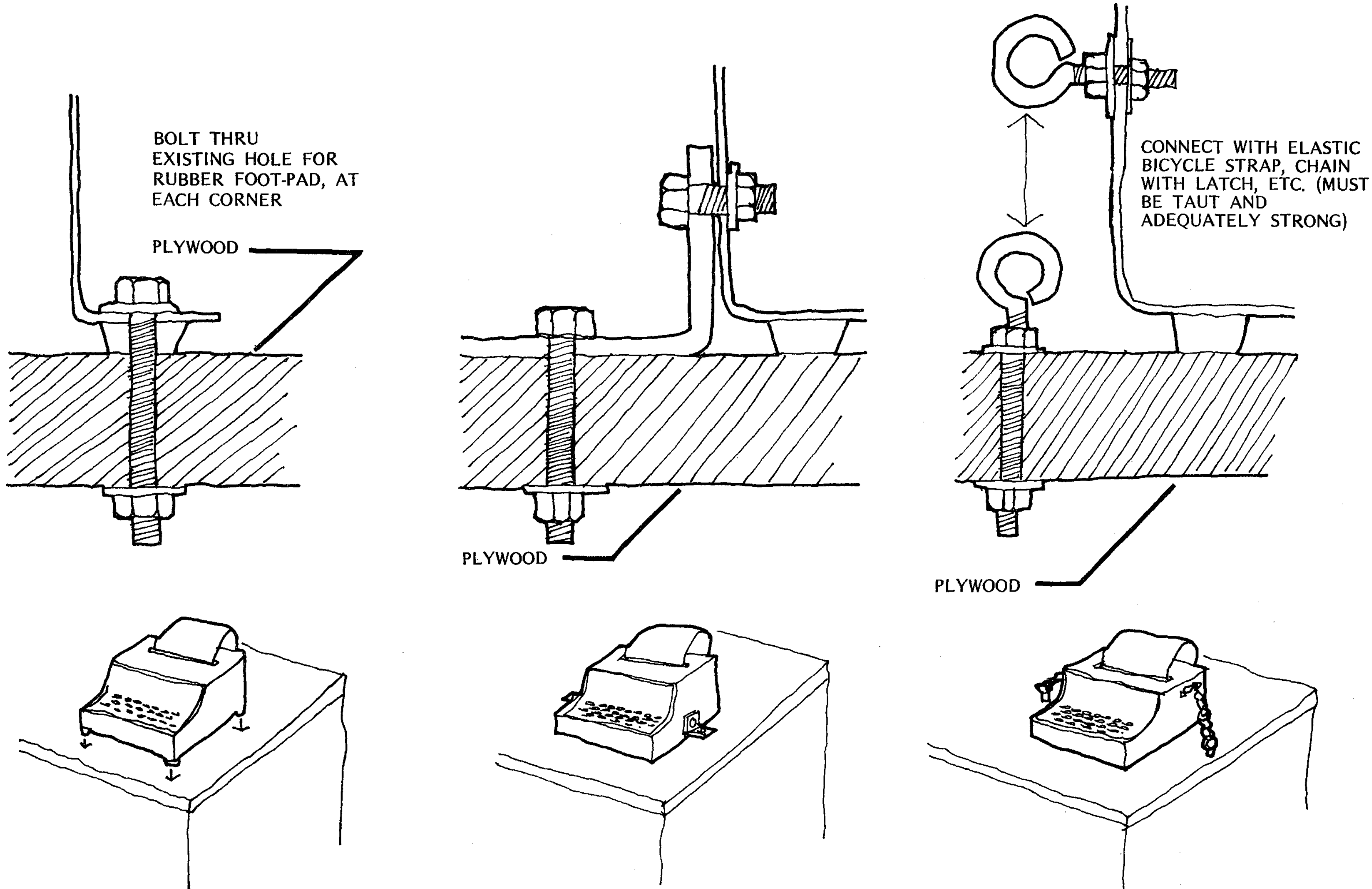
METAL SHOULD BE DUCTILE (E.G. MILD STEEL), RATHER THAN BRITTLE (E.G CAST IRON).

THRU BOLT
(NEW OR EXISTING WD. FLOOR)

WOOD SCREWS CAN BE USED WHEN UNDERSIDE OF FLOOR IS INACCESSIBLE, BUT ARE NOT RECOMMENDED FOR SAME REASON AS CAUTIONARY NOTE FOR EXPANSION BOLT.

TOGGLE BOLT OF KNOWN CAPACITY IS ANOTHER ALTERNATIVE.

POSSIBLE FLOOR ANCHORAGE CONDITIONS



POSSIBLE COUNTER TOP ANCHORAGE

3 EMERGENCY OPERATING CENTERS

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INTRODUCTION

This chapter discusses program guidelines for the planning and design of Emergency Operating Centers (EOC) in fire and police stations with a multi-disaster response capability. Many communities have developed operational plans for responsing to emergency conditions such as earthquakes or nuclear attack, but there exists little program information to enable architects and emergency service officials to design buildings to house and facilitate the resultant response functions. Because of the unpredictability of these disaster situations, and because of the costs involved in building the EOC structure, communities have found it necessary to either retrofit an existing facility or to design a new fire or police station to contain an EOC. Fire and police stations are critical elements in emergency response planning and as such should remain operational under a variety of predictable and unpredictable disaster conditions.

It is necessary, therefore, that architects and emergency operations officials become more aware of the programing and design problems involved in developing police and fire facilities that can accomodate the functions of an EOC and, at the same time, survive the destructive effects of such a disaster. Fire and police stations must combine the normal program requirements of their building type with the program requirements of the emergency operating staff during disaster conditions. An analysis of how this may be accomplished will be discussed.

This chapter examines those characteristics of EOC's and fire and police stations that will be important to the initial programing and conceptual design of a new facility. The principal considerations will be the following:

- Functional relations of individual program elements
- Size of program elements
- Design characteristics of program elements
- Relative costs of various program decisions

DEFINITION OF AN E.O.C.

INTRODUCTION

An Emergency Operating Center is generally degined as the place in which the direction and control of municipal civil government is carried out in the event of a large scale disaster that significantly disrupts the normal operation of government and community life. In such emergencies, civilian government requires a central place from which to coordinate the various responses necessary to deal with the disaster and to return order and continuity to the community. The EOC normally provides the space, facilities, and protection necessary for the following broad functions:

- Collection, evaluation, display and dissemination of damage assessment.
- Coordination and control of shelter operations, including movement to and from the EOC.

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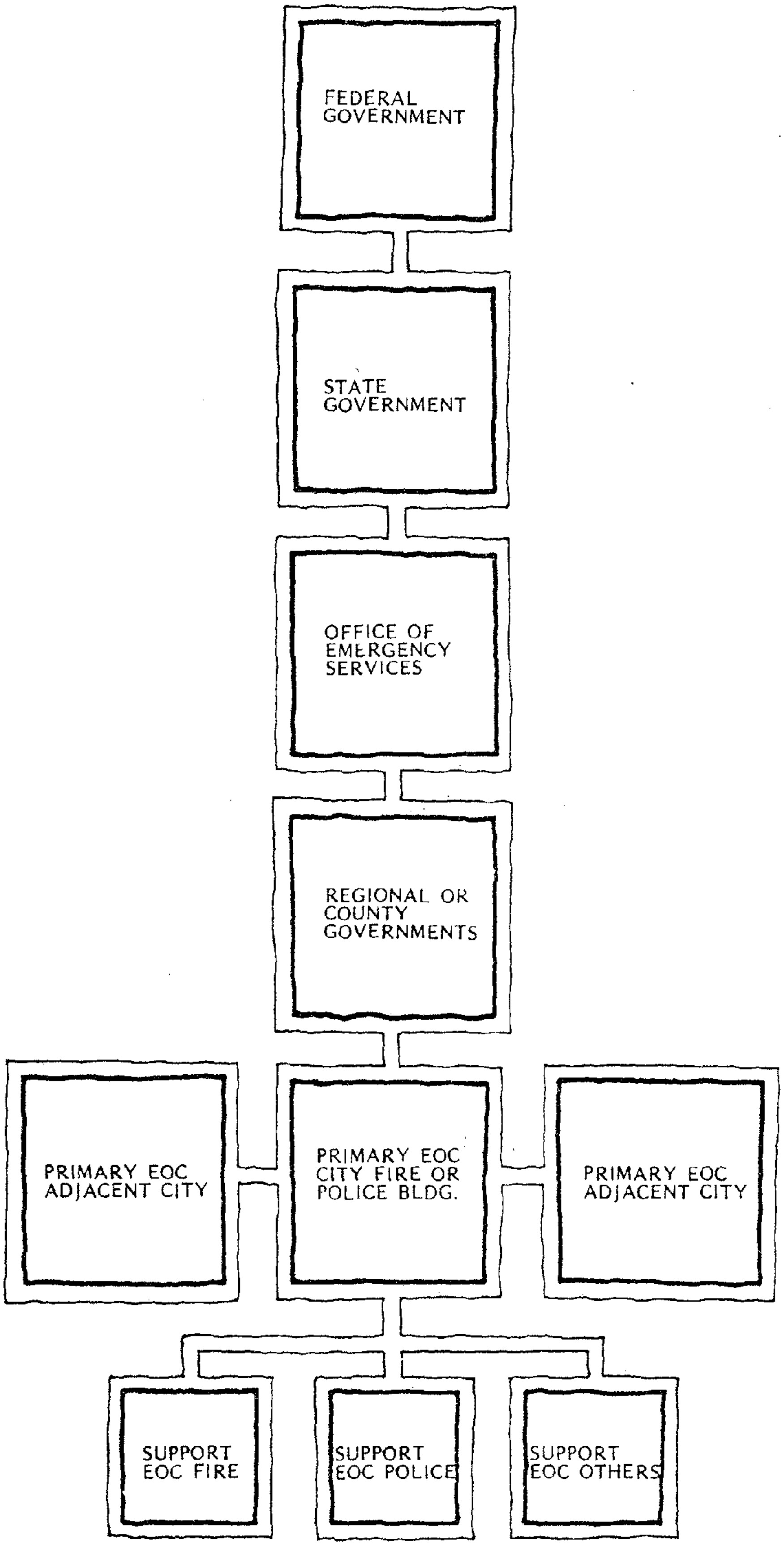


EOC CHAIN OF COMMAND

- Provision of emergency information, warnings and instructions to the general public.

- Direction of all emergency planning and operations, including location and direction of all community resources not sheltered within the EOC.

The following tasks may be typically carried out at an Emergency Operations Center:

- Coordination of agencies

- Policy making

- Operations

- Information gathering

- Information dissemination

- Visitor housing

The accompanying figure explains the relationships between a primary municipal EOC and its support facilities and the higher levels of government. In communities under 300,000, the functions of an EOC can generally be accomodated within a facility that during normal conditions operates as a public safety building — a fire or police station — or, in some cases, within a city hall, a library or a judicial building. Normal requirements of a fire or police station can lend themselves to easier and less costly conversion to an EOC during times of disaster. In larger cities, the complexities of government are such that EOC's are often independent buildings or are so highly complicated that specific programs must be developed to accomodate the greater number of government operations. The design and programing guidelines discussed here are not intended to specifically cover the large, independent EOC.

TYPES OF DISASTERS

The programing and design of an EOC depends largely on the predictability of a future disaster and the degree to which a municipal government intends to respond to emergency conditions that arise. The proper level of response needed for natural disasters can often be evaluated according to the history of local conditions. The predictability of man-made disasters is much more subjective and will require more sensitive evaluation of the costs necessary to provide proper protection and response in view of the likelihood that such situations will arise. The following list broadly defines the possible disasters that can influence the design and programing guidelines for an EOC:

Natural Disasters

- Earthquake
- Flood, Tsunami and Seiche Action
- Fire
- Strong Wind

Man-Made Disasters

- Nuclear War
- Nuclear Accident

- Conventional War
- Civil Disorder
- Major Accidents or Incidents

It is obvious that to design a facility that offers complete protection from all these possible disaster conditions could be very expensive. EOC designers, however, must make qualitative decisions as to the conditions and the degree of response for which the facility is being designed. This should be the first step in programing a new facility.

Existing federal government guidelines for EOC design are directed principally toward providing protection against the effects of nuclear war. While such protection can in some cases be provided easily and economically, the disaster postential from direct blast, radioactive fallout, electro-magnetic pulse and thermal radiation can make complete protection a costly requirement.

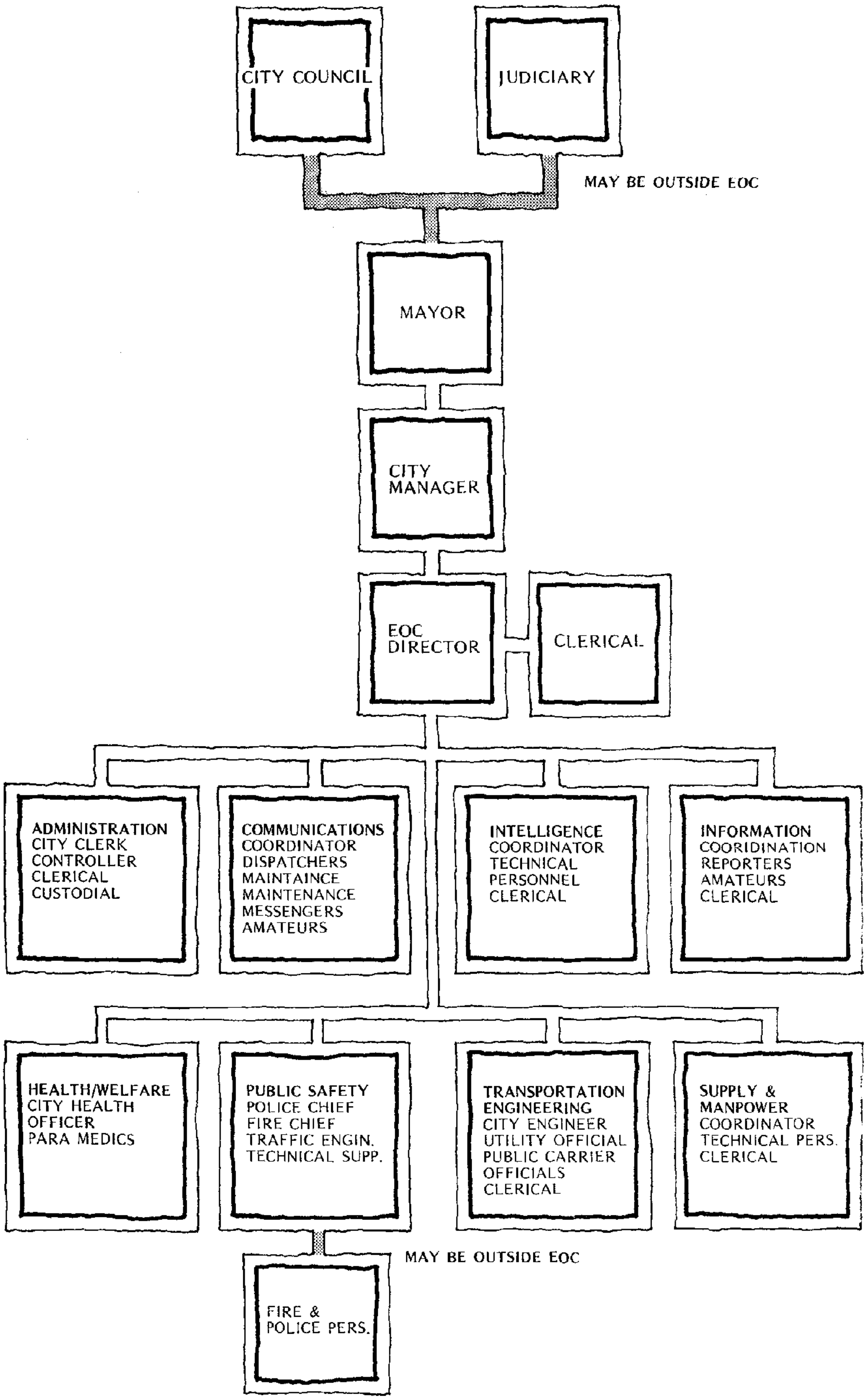
The guidelines presented here are intended to address the most predictable kinds of disaster conditions and to suggest program responses that can easily and effectively be incorporated into a new building without substantial cost. Generally, provision for protection against one hazard can be multi-beneficial, providing some advantage in dealing with other disasters as well. Thus the program guidelines have been directed to the normal operational needs of fire and police facilities when subjected to predictable multi-disaster conditions.

PRIMARY E.O.C.

Under emergency conditions, it is necessary that the emergency operations staff of the city and the city's top level professional departmental heads be brought together in one central location to direct city government. This location is generally called the primary EOC. When this EOC function is located in a fire or police station, the program for the building (and its parking facilities) must be capable of accomodating personnel in substantially greater numbers than during normal operations. The accompanying figure on EOC personnel outlines the range of persons that may occupy the building during a disaster. The great variety of organizational structures within municipal governments makes it a difficult task to program accurately the precise area requirements needs for any given size of city. The EOC designer should obtain from the city/client during the program phase a definitive organizational description of the city's emergency operation plan giving (1) number and title of each person assigned to the EOC under disaster conditions, (2) general function of each person, (3) normal working location of each staff position. This information will enable the designer to compare the emergency operations spatial needs with the normal operations spatial needs and to adjust the building program accordingly if there exists a significant conflict.

Some emergency operations plans may direct that elected officials such as the City Council or judicial functionaries be accomodated within the primary EOC. Other emergency operations plans suggest that these individuals be located elsewhere. Local city legislation will define whether such persons must be accomodated withing the EOC. The designer should verify this condition if space requirements become restrictive. In larger facilities this will generally not be a problem. In smaller facilities, it may be critical. A lack of space, overcrowded conditions, noise and lack of privacy may sometimes require that a secondary EOC be established during the disaster operations. Provisions should be made for the location of the secondary EOC.

Of critical importance is the development of provisions for the relocation of the primary EOC should it become unusable.



EOC PERSONEL

SUPPORT E.O.C.'s

Cities greater than 50,000 to 75,000 population tend to become large enough in land area that they require branch fire and police stations to serve the community adequately. These buildings generally cannot become primary EOC's in disaster situations because of their smaller size and more remote location. However, it will be necessary that these facilities remain operational as they will form a vital communications link to the primary EOC, as well as performing their emergency response and law enforcement functions. Therefore, many general guidelines proposed apply to both primary and support EOC's. Program guidelines such as space allocations and communications capability are directed specifically toward fire and police stations as primary EOC's.

THE NEED FOR AN E.O.C.

Communities faced with the decision of whether to incorporate an EOC into a new fire or police station should consider carefully the results of not providing such a facility. In areas of high seismic risk or in areas where tornadoes or hurricanes are common occurrences, the need for an EOC is easily justified. Parts of nearly every state in the country have experienced earthquakes, and over 2/3 of all the states contain risk areas that may incur at least moderate damage from an earthquake. Every part of the country is vulnerable to tornadoes. Between 1971 and 1975, every state was struck except Alaska, causing nearly 700 deaths and 15,000 injuries. Fires, flooding, civil disorders and nuclear disasters are possible in all parts of the country.

Should a disaster strike a community that does not have a functional EOC the following problems may occur:

- Community decision-makers may be separated from each other. The designated place of assembly may not survive a disaster and another, less satisfactory location may have to be found from which to direct the community response.

- Time and lives may be lost in the confusion caused by inadequate communications capabilities or the lack of other facilities.

- An inadequately planned EOC may cause internal disorder and crowding that will delay the efficient return of order to the community.

All communities, regardless of size, should maintain and regularly rehearse a disaster response plan. While the probability of a totally disabling disaster may be small, the damage effects of even a minor disaster that cannot be managed adequately from an efficiently functioning EOC will certainly be magnified.

FEDERAL E.O.C. PROGRAM

The federal government has a program for assisting local communities in the design, construction and financing of Emergency Operations Centers. This program is administered through the Defense Civil Preparedness Agency (DCPA). The purposes and criteria for the program are discussed in *Federal Assistance Handbook (CPG 1-3)*, available from DCPA. The program is intended to encourage local communities to develop EOC's in existing buildings or as improvements or modifications to new building programs. Basically, the government will pay 50% of the cost of the following:

- That portion of the building shell that is necessary to "convert" the basic shell into an EOC meeting DCPA protection factor criteria for a rating of 100 (basically a basement condition or earth berm construction).

- Items necessary for operation of the EOC, including internal partitions, HVAC systems, electrical systems, plumbing systems, floor materials, emergency electrical and water systems, display equipment, food preparation equipment and communications equipment.

The DCPA will not pay for construction costs for an EOC with a protection factor of less than 100. Below this level only equipment items can be funded.

In addition, the EOC space must be used on a daily basis by emergency service personnel, such as fire or police staff, who are assigned to the EOC. The EOC space must have dual-use, as may be accomplished in a fire or police station, and may not be built solely as an independent space within the building. The DCPA also requires certain ventilation, operational and protection standards consistent with good design practice for this type of facility. DCPA engineers will work with architects and community officials to develop the EOC design to the required standards.

An often cited criticism of this program is that the paperwork involved in adjusting the building design to the federal guidelines is very time-consuming and costly. An initial review with DCPA officials prior to beginning design will aid in the establishment of mutually satisfactory program requirements.

PROGRAM FUNCTIONS OF AN E.O.C.

SITE SELECTION

At the onset of a disaster situation, the fire or police station housing the EOC will undergo many organizational changes. When an emergency is declared and the department staff is notified that the EOC will become operational, personnel from outside the building will begin arriving. These people, as the decision-making heads of the community, will conduct the coordination and communication activities that will mobilize the various emergency response agencies. In addition, persons from outside the local government will arrive to act as liaison to the higher levels of government (state, federal). As a command post, the EOC site should have the following characteristics:

- Good Accessibility — A central location within easy reach from the various parts of the community. EOC staff will originate from many locations as well as city hall or the principal municipal buildings. During working hours, most staff will probably originate near city center. During other times, people will come from their homes in the different parts of the community. Quick access over roads most likely to be open is desirable.

- Unobtrusive Location — In a disaster, many citizens will seek aid and assistance from the source most prominent and accessible. Conspicuously-sited public buildings with prominent entries and easy access may become congested with persons wishing to see authorities or wanting direct aid. The fire or police station may be prepared to dispense such aid, but not at the expense of hampering EOC operations unnecessarily. The EOC should have direct, private access for authorized personnel without introducing unnecessary conflicts from outside persons seeking assistance and information.

- Good Communications Location — The EOC's principal functions will involve broadcasting and receiving information. It must have a good line-of-sight to its main antenna and not be dependent on land lines or internal secondary communications systems. If the primary antenna must be located remote from the building, good communications will depend on proper siting of the building.

- "Protected Site" Requirements — The site should be free from all natural or man-made impediments to its operations. The following should be avoided:

  - Areas of known earthquake faults, possible landslides, flood plains, inundation paths from damaged reservoirs or utility lines, land fill, tsunami, high water tables or tall, unstable trees.

  - Sites adjacent to tall buildings, buildings not resistant to earthquakes and fire, or structures that may be bombing targets.

  - Sites adjacent to large health care facilities, schools or other buildings of high predictable traffic congestion.

E.O.C. PROGRAM ELEMENTS

The various program elements have been divided into three areas for analysis: the Operations Room, the Communications Room and the Secondary Spaces that support these two areas. The Operations and Communications Rooms are the two most important areas of the EOC. These areas must be programed for the projected number of personnel to be assigned directly to them during an emergency situation.

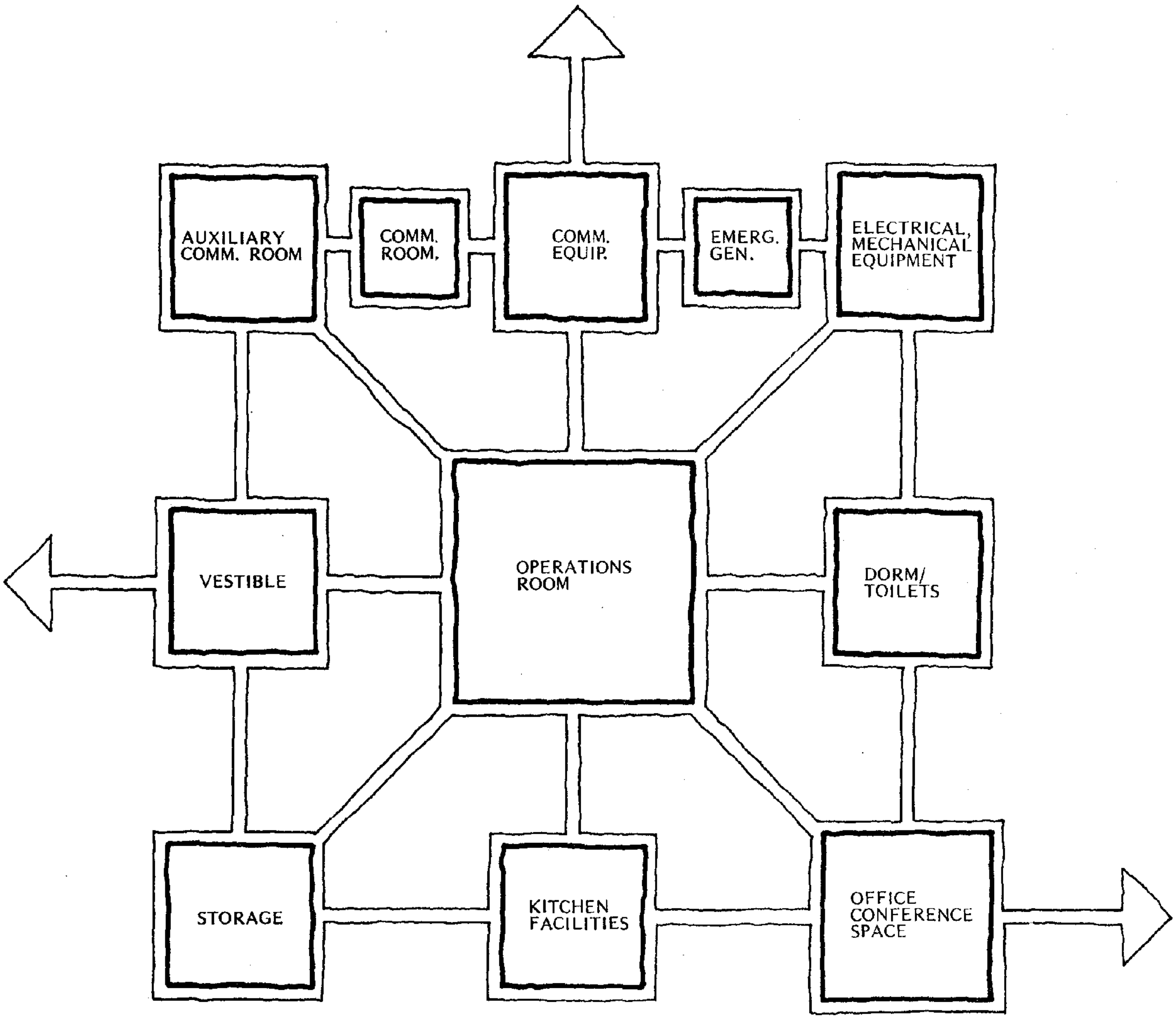
These two areas must be analyzed independently of the other areas of the building. When comparing the EOC program requirements with the normal operating requirements of the various spaces in a police or fire station, as will be done later in this chapter, the common characteristics of each should be evaluated. From this evaluation, the building program for an EOC within a fire or police station can be more objectively derived.

OPERATIONS ROOM

The principal functions of an EOC during an emergency situation are coordination and communication of information in order to maintain and restore civil order. As such, the various program elements are organized around a common space designed to facilitate rapid, direct personal communication among the decision-makers who have been gathered together. This space is generally termed the Operations Room. It is the center of the EOC and, as such, must be the first space programed into the normal operational building program of the fire or police station.

The operations room is actually a multi-use space that should have the flexibility to be rearranged into a number of configurations, depending on the personnel and emergency operation plans being used by the city. Additionally, it should have the following characteristics:

- Ample display areas for maps, logs and various status boards, which would be stored for normal use and assembled for emergencies.



EOC PROGRAM ELEMENTS

- Acoustical treatment to minimize the impact of internally generated noise during emergency conditions. Acoustical ceilings and/or carpeted floors are recommended. The level of background noise can affect the operation of the EOC significantly. High levels can result from adjacent radios or consoles. Acoustical partitions strategically placed may alleviate this problem.

- Storage closets to house portable telephones, tables and chairs, display panels and emergency operation paper supplies.

- Direct access to the communications room and adjacent, independent office spaces.

- Simple room configuration to facilitate orientation toward a display center or stage area. Sufficient flexibility in configuration to allow multiple arrangements of work tables. Space allowing several other furniture groupings.

- Variable-intensity general illumination, with spot lighting of display areas.

- Flexible telephone jack system in ceiling, in addition to normal operating system for principal department heads and operations personnel. (This system offers greater flexibility than floor outlets, which may mean entangled cords. Adequate support should be provided in ceiling space.)

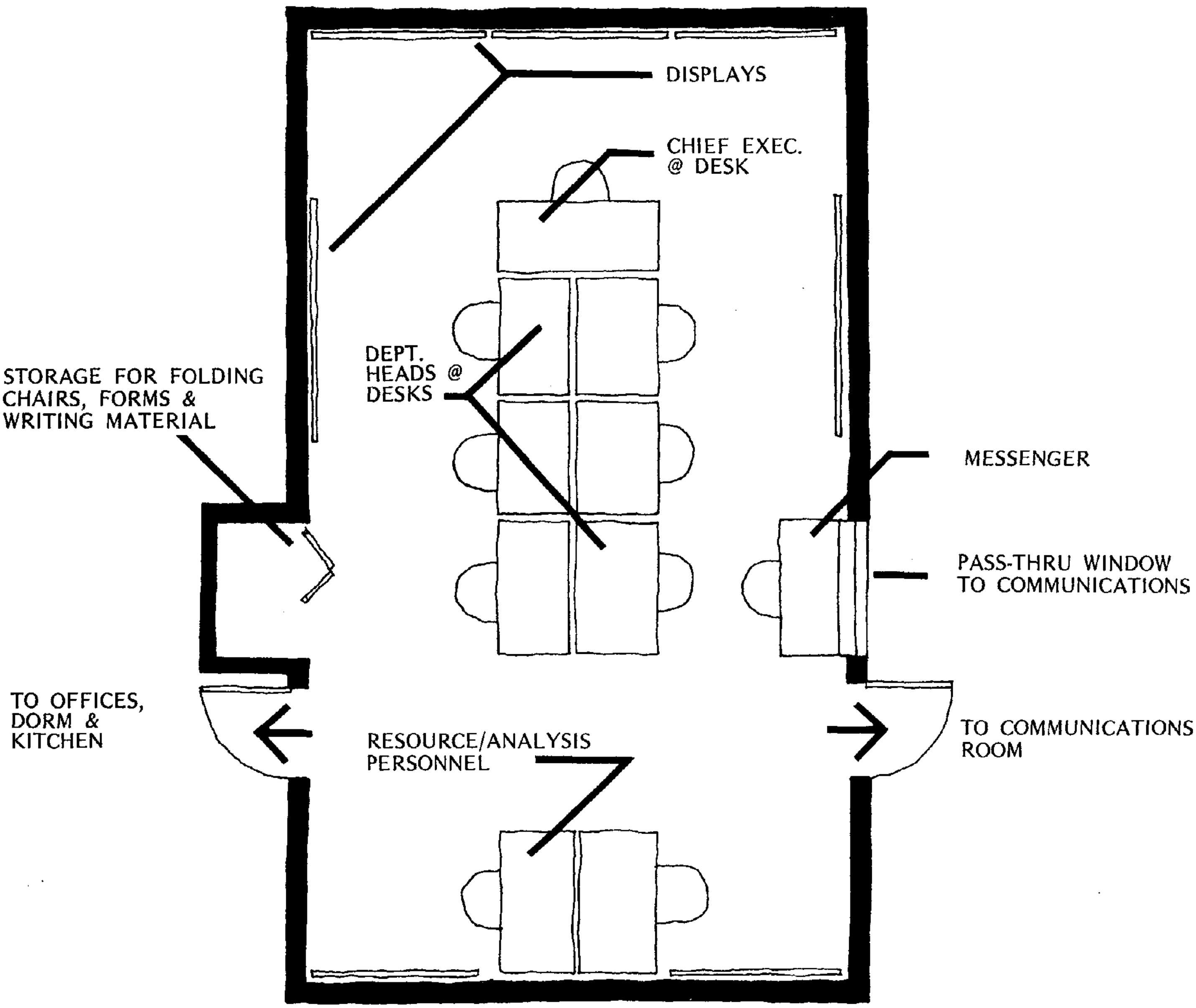
Space allocations for operations rooms must be considered carefully. Operations rooms in fire and police stations will vary considerably according to the emergency response programs developed by each community and the size of each community. Because the operations room is the heart of the EOC, it is critical that its program space needs be analyzed in relation to the normal function of the designated room. The following guidelines have been developed to program the operations room according to generally recommended ranges of staffing for disaster situations for various sizes of communities. The room capacity has been calculated by dividing the total staff necessary for the EOC operations room in half, assuming two 12-hour shifts per day. Additional space must be provided because this room will periodically become more crowded, depending on the degree of crisis. The recommended sizes should be considered minimums.

OPERATIONS ROOM SPACE ALLOCATIONS

City Population	Total Operations Staff	Shift Staff	Area/Occupant	Net Room Size
50,000	20-28	12	35 s.f.	420 s.f.
150,000	35-45	20	40 s.f.*	800 s.f.
300,000	40-50	23	40 s.f.**	920 s.f.

* Higher figure based on assumption that more flexibility is required in larger facilities to accomodate more messengers and resource personnel foı contingency situations.

** Range determined from Department of Defense's "Emergency Operating Center Operations, Organization and Staffing for Municipalities and Counties with less than 300,000 Population." The range was compared with several existing community plans and in discussions with several EOC administrative officials.



OPERATIONS ROOM

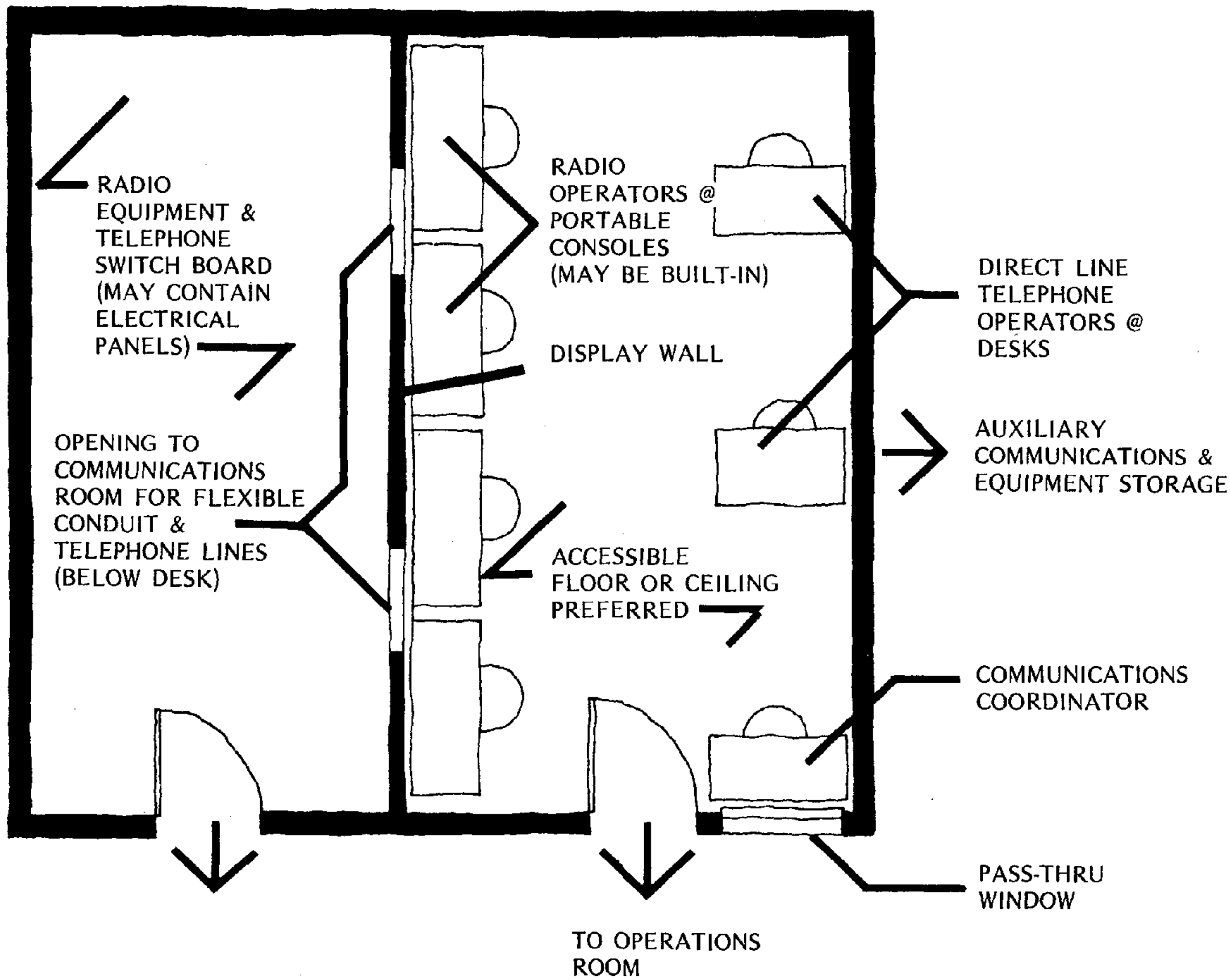
COMMUNICATIONS ROOM

The other central area of the EOC is the communications space. Contained within this area are the radio and telephone dispatch and receiving functions normally accomodated within a police station and larger fire stations. Under disaster situations, the space will usually be occupied by additional communications operators operating portable communications equipment not normally in use. In addition, one or more supervisory personnel and messengers may be expected to occupy the space. Also, the greater influx of communications during a disaster will require more time to keep logs. These additional personnel burdens will require that the communications area have a high degree of flexibility to accomodate different arrangements of communications personnel.

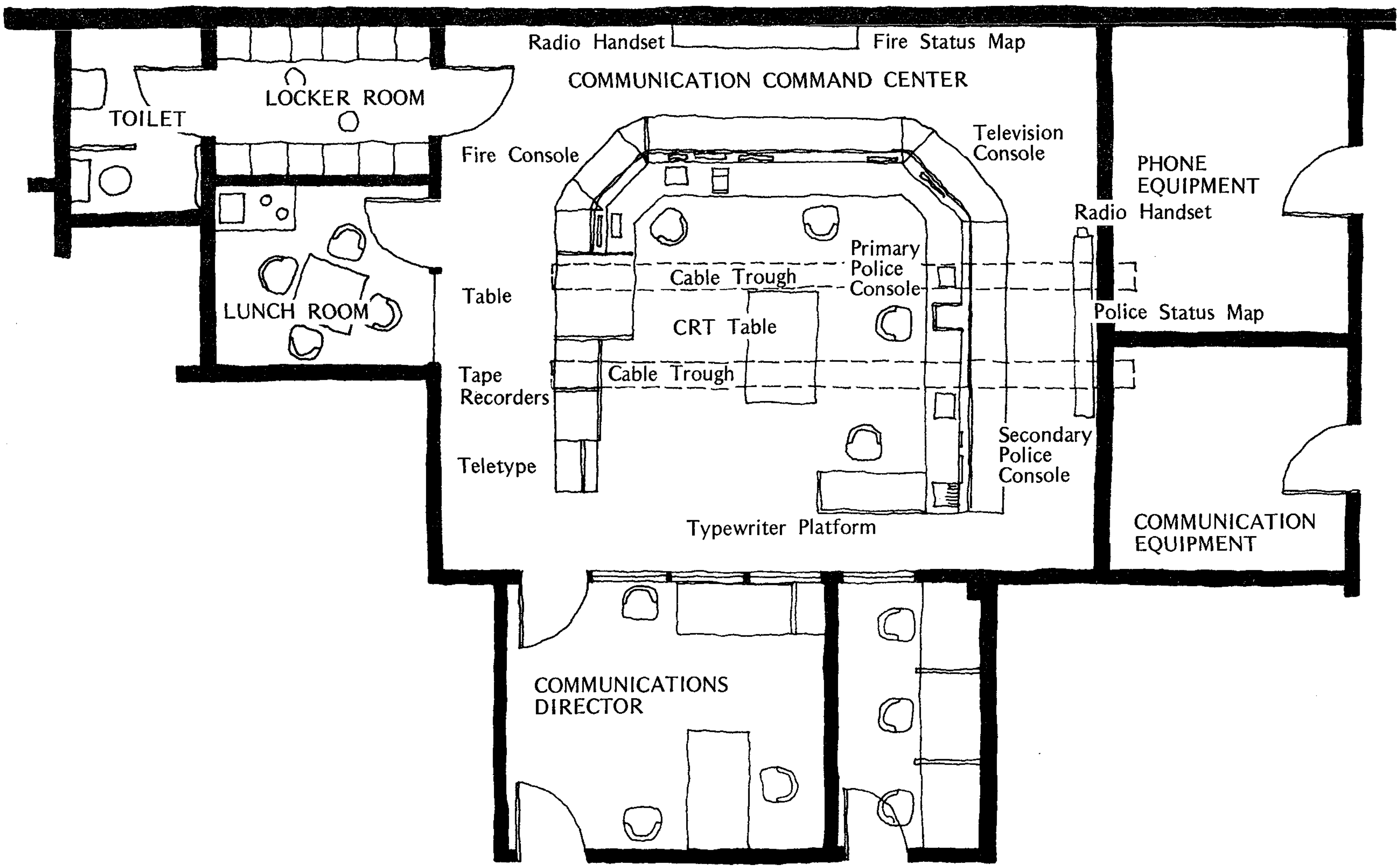
The fire or police station will probably contain a communications room for normal operations. The EOC communications room should be considered a separate room. To combine the emergency communications equipment with the normal operating equipment may lead to overall confusion and conflict. The normal communications room will continue to be used for command and control of fire or police even during emergency conditions. It will be staffed by the dispatchers normally assigned to that duty. The EOC communications room will be staffed by separate personnel, either off-duty dispatchers or fire and police personnel trained for the position.

The communications room should have the following characteristics:

- Ample display walls for permanently mounted maps and status boards.
- Acoustically treated walls and ceilings and carpets to minimize the impact of internally generated noise as well as noise transmitted into the room from surrounding spaces.
- Additional unused wall space for the set-up of portable communications equipment and desks. Direct tie-in to stand-by communications equipment in the equipment room through walls, floors or ceiling. Flexible systems desirable.
- Variable-intensity general illumination, with spot lighting of console and display walls. Indirect lighting systems reduce undesirable glare.
- Space for communications console. Console cabinet and internal equipment should be securely fastened to a structural wall. Conduit and cable connections should be flexible with sufficient slack to absorb impact loads from earthquakes. All storage units adjacent to the console and all equipment in the communications equipment room should be securely fastened to a structural wall.
- Communications room should be as close as possible to its equipment room to minimize length of conduit and potential disruption of circuitry. The equipment room containing the transmitting and receiving equipment should be close to the antenna. A secondary antenna should be stored nearby. Non-rigid or remote antennae are preferable.
- Window to operations space or direct convenient access. Polycarbonate plastic glazing desirable.
- Auxiliary space located adjacent to main communications room for secondary communications set-up. In many disaster situations, volunteer CB and amateur radio



TYPICAL COMMICATIONS ROOM



COMMUNICATIONS COMMAND CENTER

operators may be used to supplement the professional staff. Portable equipment on desks may be used, or equipment may be permanently installed if the space is used by citizen operators under normal conditions.

Space allocations for communications room must be considered carefully. Communications rooms in fire and police stations represent a large initial investment in a building program. Because of the inherent need to maintain flexibility to accomodate rapidly developing changes in equipment technology, sufficient expansion space should be built into the normal conditions building program. Therefore, the room sizes recommended include additional space for this purpose, and can also accomodate added personnel under disaster conditions. Room capacity has been calculated using two 12-hour shifts per day. The room sizes given in the following guidelines should be considered minimums.

COMMUNICATIONS ROOM SPACE ALLOCATIONS

City Population	Total Comm. Staff	Staff/Shift Comm. Room	Area/Occupant	Net Comm. Room Area	Staff/Shift Aux. Comm.	Net Add'l ** Room Area
50,000	4-12*	6	40 s.f.	240 s.f.	3	120 s.f.
150,000	10-28*	8	40 s.f.	320 s.f.	5	200 s.f.
300,000	16-50*	12	40 s.f.	480 s.f.	8	320 s.f.

* Upper staff limit is a generous maximum for particularly severe of prolonged disaster conditions. If the upper limit of staff is programed for the EOC, the communications room should be designed as one principal space with transmitting and receiving capability and secondary rooms for telephone operators, citizen band operators, Red Cross and public utilities.

** Because of the great potential for fluctuation of communications personnel, depending on the duration and severity of the disaster, it is recommended that the communications room be provided additional space. This space should be a minimum of 1/2 to 1/3 the main room requirement. The communications equipment room is generally 1/3 to 1/4 the size of the communications room, but usually not less than 100 s.f. The size of the equipment room should be programed according to the actual equipment to be located in it.

SECONDARY SPACES

Most of the other program elements necessary to support an EOC will require less additional space than the operations and communications functions. The EOC personnel reporting to the station in an emergency will generally require office and sleeping facilities in addition to those needed by the station for its normal operations. Other EOC support needs, including food preparation, toilet and storage facilities, and mechanical and electrical systems, can usually be provided for by the same equipment and in the same space that are required for the station's normal needs. However, the location and protection of these support functions can be critical. If only the area within the perimeter of the EOC portion of the station is expected to survive the anticipated level of disaster, planners must ensure that these support functions are within the perimeter. If conflicting design considerations make this impossible, a certain amount of duplication of space and equipment may be necessary.

- Additional Office Space — A minimum of two small office spaces should be provided adjacent to the operations room for all EOC's, regardless of size. This space will be used by operations personnel for conferences, quiet spaces, or as overflow space if the operations room becomes crowded. These office spaces ideally should be located as close as possible to the operations room. Other than flexibility, there are no special technical requirements for this space. Inclusion within the protected shell of the EOC is desirable.

- Sleeping Areas — Assuming 12-hour shifts during emergency conditions, half of the entire staff will be off-duty at any one time. In many disaster situations personnel will not be required to stay within the inner core of the EOC, but will enter other parts of the building or may even return to their homes. The provisions for sleeping within the building should remain flexible. By providing temporary beds for half of the maximum anticipated emergency staff, this requirement will generally be met. Most dorm spaces should be flexible and have few built-in pieces of equipment and a simple configuration. If floor space for sleeping is limited because of restrictions of the normal building program, hammocks or even mattresses on tiers of wide shelving designed for the purpose can be used. In larger EOC's, it will be desirable to program separate areas for men and women. In crowded sleeping rooms, ample air circulation and ventilation should be provided.

- Food Preparation Facilities — In some disaster situations personnel may be allowed to leave the protected EOC. Minimal kitchen facilities should be provided, however, within the EOC perimeter. A double sink, cooktop, small refrigerator, and a microwave oven will generally be sufficient. Food stored within the EOC should be dried, canned, powdered or otherwise preserved to last for long periods of time and should require minimal preparation. Federal guidelines suggest a 14-day supply of food and water for all personnel. A 20-80 square foot storage pantry should be sufficient for food. Disposable cups and plates can be used. In addition, an area within the EOC core should be designed to accomodate a 14-day accumulation of garbage and trash.

- Toilet Facilities — Separate men's and women's toilets, with 2 lavs, 2 W. C.'s and 1 shower for each sex, should be provided within the EOC perimeter. (In very small EOC's one fixture each may be sufficient.) A gang-type wash down shower for 4-6 people may be desirable adjacent to the entry for decontamination.

- Storage Rooms — In addition to the storage functions mentioned under each area above, the following items should be stored within the EOC core:

  - Medical Supplies — Paramedical personnel on the EOC staff should have a complete first-aid cabinet for treatment of burns, cuts, respiratory ailments and other medical problems. These supplies should be in sufficient quantity to treat the EOC and station personnel. Gas masks and temporary clothing for fallout victims are other considerations.

  - Personal Effects — Space should be allowed for the outer clothing and personal items of the EOC staff, especially in non-temperate climates.

  - Furniture Storage — Space should be allowed for folding tables, desks and chairs for added EOC staff if the normal building program does not provide these in sufficent numbers.

- Mechanical and Electrical Equipment Spaces

  - Reserve Water Tank — A fiberglass or steel tank with a 14-day capacity of fresh water, estimated at 10 gallons per day per person, and and accompanying mechanical requirements, should be provided. It should be buried underground to protect it from possible damage. A well is a possible alternative.

  - Emergency Generator — Provision should be made for a generator with dual fuel capability with sufficient capacity to power the entire EOC and the police or fire station's mechanical air conditioning systems, all communications and alarms systems, all conveying systems, and all critical lighting in the normal operations area, including exits, corridors and special function areas. The generator should be shock mounted and located entirely within the EOC protected perimeter in a room designed to be acoustically isolated. Space requirements for most medium to large generators are 150-200 square feet.

  - HVAC Systems — Mechanical equipment should be secured and located in a protected space, free from potential damage from the effects of wind-carried debris, falling objects, fallout, etc. Interior locations are preferred over rooftop or exterior ground locations. Secure mountings are necessary. Fresh air intakes should be carefully designed to screen out biological and chemical impurities and removed from potential sources of fire and smoke. Inverted or gooseneck vents should be used to eliminate fallout infiltration. The HVAC equipment is best located in the EOC shell and, if possible, a separate system of supply and control should be provided for the EOC portion of the building.

  - Electrical Systems — The lighting, power, signal, and control systems of the EOC should be functionally independent of the rest of the building. Cost considerations may make this impossible; however, as a minimum emergency power should be supplied to the EOC even though conduit and cables may be shared with other portions of the building. All electrical panels, telephone panels, switching, and monitoring equipment for the EOC should be protected within the EOC shell.

  - Mobile Communications Unit — As an extension of the communications function of the EOC, a mobile van equipped with communications equipment may be available as a secondary command post. Many fire and police departments have a unit of this type that acts as a mobile command post for the department in its own normal operations. Should the EOC communications system be damaged, a mobile van can serve as backup. Ideally, it should be parked in a protected location independent from the EOC.

  - Exits and Entrances — The EOC should be tightly secured to control access by unauthorized personnel. The EOC should be connected to the other fire or police spaces at a minimum number of points, and should have at least two controlled access points directly to the exterior. The doors should have a construction consistent with the protection requirements of the EOC shell. All access doors should be lockable and monitored. The nature of the security measures should also be designed according to the normal operations program of the building, and will differ with the design of each building.

  - Interior Protection Systems — The EOC should be equipped with a fire protection system. Sprinkler systems will protect the building and EOC shell, but may damage essential equipment. Halon and CO_2 systems will not damage equipment, but will require that occupants vacate the area while the system is operating. A more practical approach is a complete smoke and heat detection system with localized manual dry chemical and standpipe systems for extinguishing. Because an EOC within a fire or police station will be staffed 24 hours a day, immediate response to any fire can be expected. Localized extinguishing can prevent inadvertent damage to equipment not threatened by fire.

The secondary areas space allocations guidelines that follow are for additional offices and sleeping areas. Food preparation, storage and mechanical and electrical spaces are not included. These should be programed for the normal operations space requirements and compared for compliance with the needs of each individual EOC.

SECONDARY AREAS SPACE ALLOCATIONS*

City Population	On-Duty Office Staff	Area/Occupant	Net On-Duty Office Area **	Off-Duty Staff	Area/Occupant	Net Off-Duty Area ***
50,000	4-6	75 s.f.	375 s.f.	20-26	40 s.f.	920 s.f.
150,000	8-12	75 s.f.	750 s.f.	40-50	40 s.f.	1800 s.f.
300,000	12-16	75 s.f.	1050 s.f.	58-68	40 s.f.	2520 s.f.

* These space requirements are for additional offices and sleeping areas. Food preparation, storage and mechanical and electrical spaces are not included. These should be programed for the normal operations space requirements and compared for compliance with EOC needs.

** Total area is the net interior room area for additional office space.

*** The majority of this space should be considered sleeping or lounging space. Total off-duty area is a general guideline only. This space may be provided outside the EOC protected area.

SPACE ALLOCATION SUMMARY

Federal guidelines have identified the normal range of EOC program areas as 50 square feet per occupant gross to 85 square feet per occupant gross. Based on the space allocation study of each EOC program element, it appears that 60 square feet per occupant gross (using a 70% efficiency factor for circulation and unassigned space) is a reasonable allowance for the entire EOC. For preliminary design purposes, this figure can be used to approximate the minimum size of the protected shell of the EOC. For detailed design purposes, the total EOC area will be adjusted in each case to accomodate the building configuration and the normal fire or police functions.

The critical areas in each EOC are the operations room, communications room and the equipment spaces. Historically, most instances in which an EOC has been activated have been for emergencies that did not directly endanger the occupants of the EOC or were of relatively short duration (1-2 days). During these types of emergencies, building occupants will be free to leave the building or to occupy other parts of the building because complete protection is not absolutely necessary. The primary consideration in programing an EOC is that the communications and operations rooms, because of their critical nature, should not be undersized.

E.O.C. PROGRAM MODELS

The designer of critical facilities such as fire and police stations is often asked to resolve several conflicting design requirements. Because of the necessity that fire and police stations remain operational during disaster conditions, it is important that various protective measures be taken to mitigate the many potential disaster effects upon the building perimeter, the structural system, the mechanical, electrical and communications systeems, and the various other building elements.

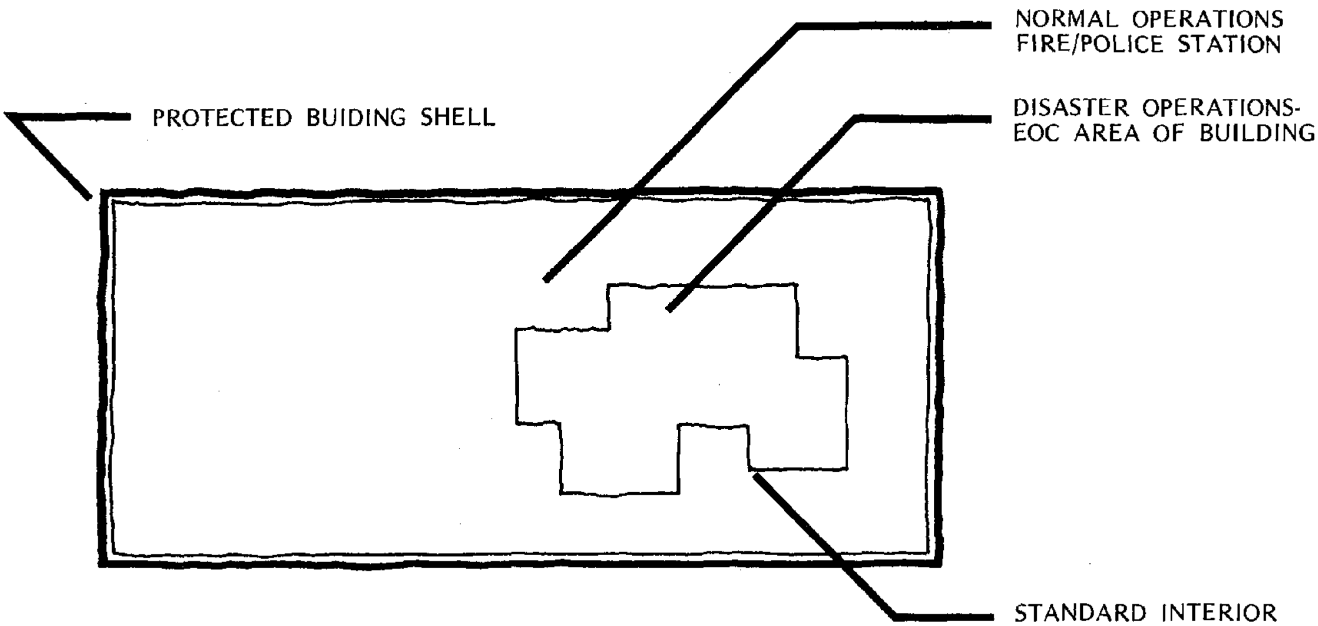
However, it is not often possible or even desirable to design a completely protected multi-disaster Emergency Operating Center. Often, the cost of such a structure, weighed against the relative unpredictability of certain disaster conditions, such as an earthquake, may devalue the importance of many protective measures. Second, the community's image and its concern for the exterior character of the architecture may further limit the effectiveness of other obvious protective measures, as well as introducing certain liabilities. An example might be a design requirement for a wood exterior on a new police station at the expense of more protective materials such as reinforced masonry or concrete. Also, the availability of sites offering natural protection is often limited. Sites may be chosen that do not maximize the protective capability of the building program.

It is helpful to describe two models for EOC design, the Protected Perimeter model and the Protected Core model, which differ in the degree of protective capability they provide. In the Protected Perimeter design approach, the entire building shell is designed to offer maximum protection from reasonably anticipated multi-disaster conditions, including nuclear attack. To combine protection against nuclear fallout, earthquakes and fire in the building shell, the structure will most likely need to be constructed of cast-in-place concrete, reinforced unit masonry, or either of these in a bermed or below-grade structure. The building configuration will generally need to be less complicated and more regular, and a full measure of protection must be extended to the roof structure. Thus, complicated forms and large continuous openings in the building shell will tend to undermine the earthquake resistance of the structure. To compensate for the increased mass of the shell walls, the roof must also be more rigid, usually increasing the cost of the structure substantially. A building with a full basement is better able to absorb ground movement. In addition, the smaller exposed profile will be an advantage against the effects of wind, fallout and blast.

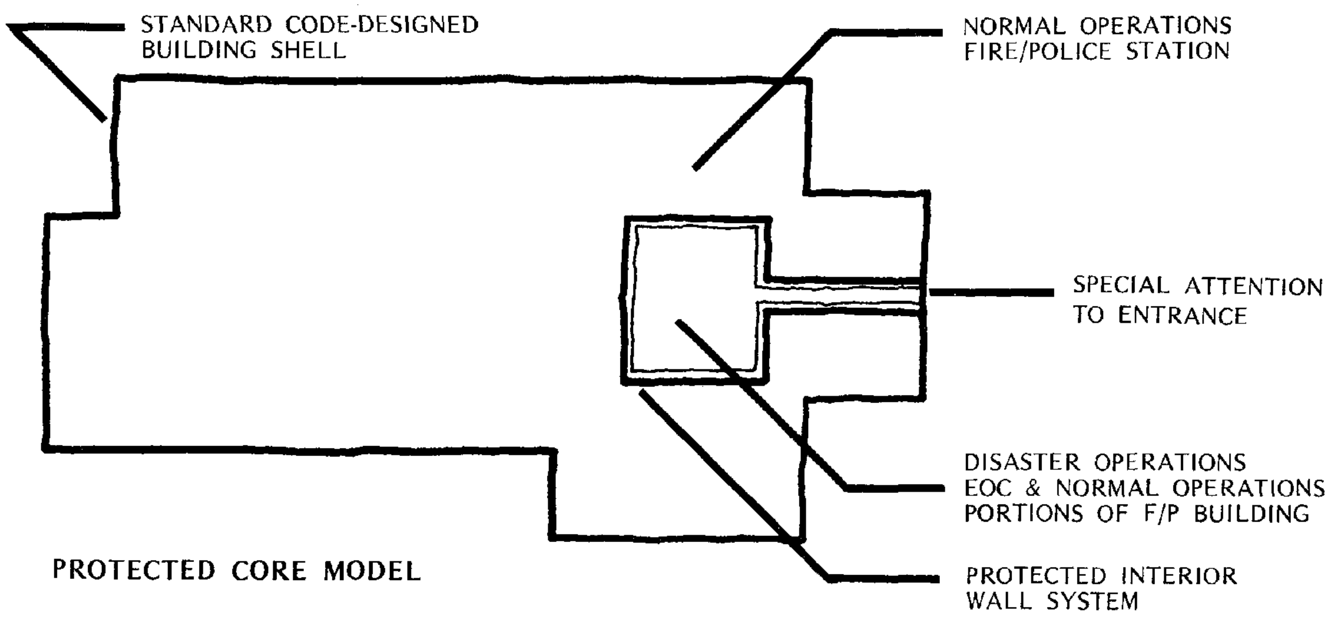
The protected perimeter apprach tends to be costly and to limit exterior design flexibility. It does, however, offer several advantages:

- The entire building, its personnel and equipment, is less vulnerable to disaster conditions.
- The building will generally offer better fire protection and less vulnerability to break-in and civil disorder.
- The more massive structure may be more energy-efficient.
- Interior spatial organization of the building, including the location of an EOC, can be more flexible.

With the Protected Core design approach the normal operations building program can be given primary emphasis in the exterior design of the facility. Independent of the building perimeter, a separate portion of the interior is designed with additional protection. This part of the building operates in a normal manner except during disaster conditions, when it becomes an



PROTECTED PERIMETER MODEL



PROTECTED CORE MODEL

ALTERNATE EOC PROGRAM MODELS

EOC. The protected core approach has the following advantages:

- The EOC may be less costly to build than a similarly programed protected perimeter facility.

- The building exterior will be more free to respond to the requirements of the site and the desired architectural character.

- The building will generally offer better protection to the EOC from wind damage and fallout because of its additional layer of exterior wall enclosing the inner core.

- The building will generally be easier to expand.

- The protected core minimizes the organizational conflicts that may occur when a building changes from normal operations to disaster operations by defining and controlling the EOC functional space.

A common variation on the protected core model is a building containing a full basement. The protection offered by the earth against the basement walls and by the overhead mass will give sufficient protection against fallout to fulfill the relevant federal requirements, as well as good protection against wind, fire and civil disorders. Also, the design of a building with full basement will provide a more firm foundation from which to design a lower-height, earthquake-resistant building. The cost of such a structure will not be significantly more than a building totally above grade and may be less expensive, depending on subgrade conditions.

In the protected core building, complete protection from fire may be more costly. Although local building codes will dictate the minimum fire-resistant construction of the building, a building shell that is burning will offer no operational capabilities to an inner core of superior fire resistance. The building shell must be the first line of defense against fire.

A steel or heavy timber frame, however, provides excellent earthquake resistance without substantial cost penalties. If the necessary exterior fire protection can be economically achieved, a rigid frame structure with a rigid, concrete-protected core containing the EOC function will generally offer excellent multi-disaster protection, as well as architectural design flexibility.

The question of which EOC design approach to adopt depends very heavily on local conditions and the size of the projected facility. Smaller support EOC/fire or police stations can be protected perimeter models. Large facilities can more frequently be designed with protected cores or with fully protected basements where feasible. The probability of various emergency conditions should be defined at an early design stage with the city's emergency operations officer and the building's primary users. The protection standards agreed on will then limit the design alternatives to those systems appropriate to the needs of the local community.

The protected perimeter model has these principal characteristics:

- Fire-resistant exterior materials

- Fire-resistant structural system

- Simple exterior building configuration

- Heavy, massive walls or earth berms on exterior

- Minimum roof area and simple roof profile

- Flexible interior building systems

The protected core model has these principal characteristics:

- Fire-resistant exterior materials (combustible systems may be used, but are not recommended) according to minimum code requirement.

- Fire-resistant or other structural system according to code requirement.

- Exterior openings according to normal requirements (including seismic) of building design.

- Building configuration according to normal requirements (including seismic) of building design.

- Lightweight walls on exterior according to normal requirements (including seismic) of building.

- Roof design according to normal requirements (including seismic) of the building.

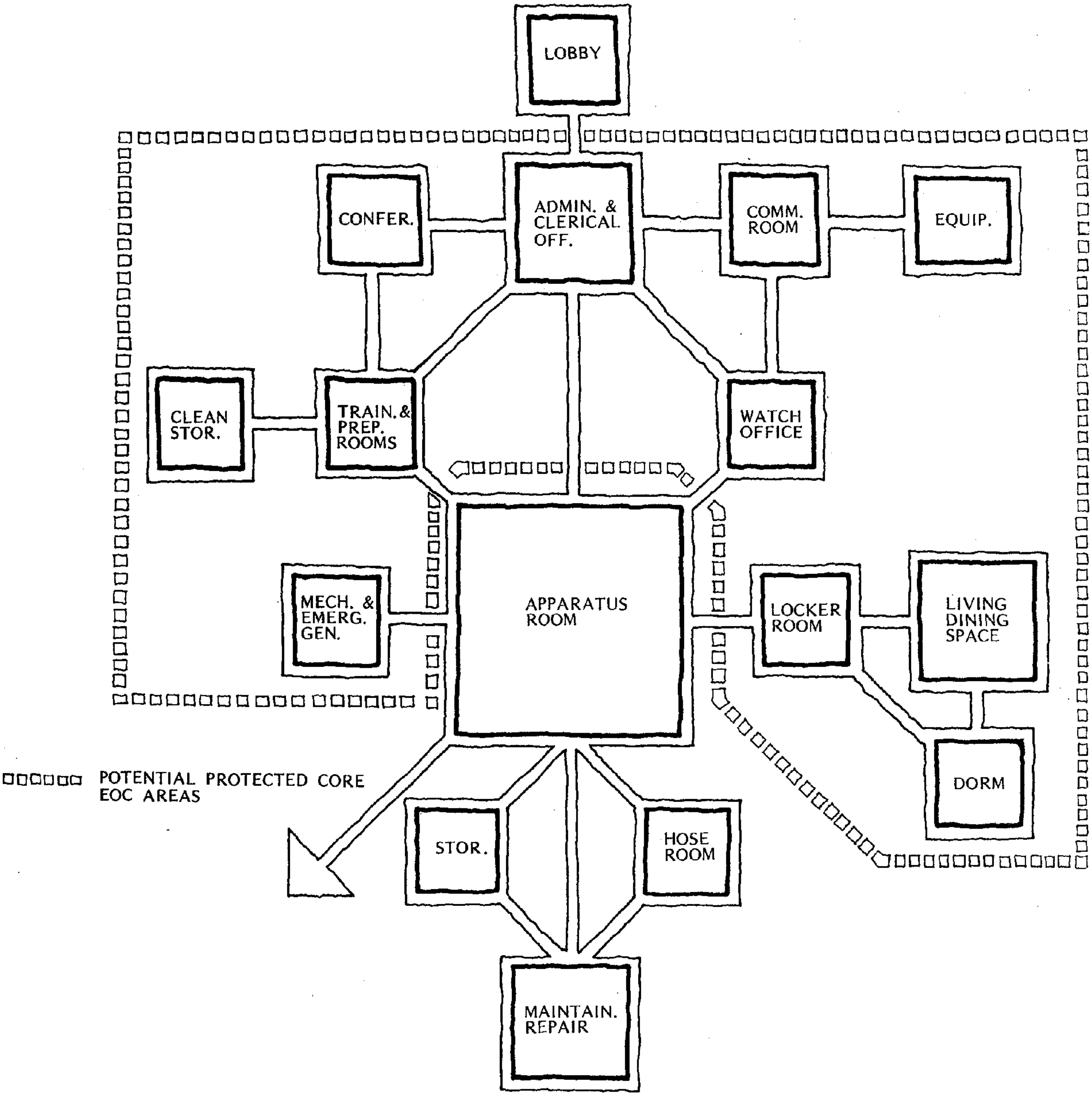
- Heavy, massive and fire-resistant core on interior containing normal operations and EOC functions. Core has independent exits, mechanical systems, and few openings into other portions of the building.

ANALYSIS OF A FIRE STATION AS AN E.O.C.

There may be more fire stations than police facilities in most urban areas. Because the range of fire fighting service is closely linked to response time from a stationary point (the fire station) rather than a mobile unit, as are the police (the squad car), the fire station as a building type is more likely to be smaller than the police facility. When fire stations are programed and designed as EOC's, they may be support facilities following the protected perimeter model. This is because it may be uneconomical and not functional to introduce a protected core into a branch fire station.

Communities of 50,000 or more will generally have more than one fire station, with the training and administrative functions located in a larger central facility. The central municipal fire station may thus have a sufficiently large normal operating capacity to serve as a community's primary EOC. In such an instance, certain organizational changes will occur in the building during emergency conditions that will need to be accomodated. These changes require that the normal operating functions of the fire station be designed and programed to support the EOC functions. Fire station program elements are analyzed below to evaluate their adaptability and liability as emergency operating components within the building.

The operational characteristics of the fire department make the fire station a good candidate for use as an EOC. Fire department personnel are generally trained in many duties in addition to firefighting, enabling them to respond to various emergency situations. Most fire personnel, including administrators, are trained to work in the field dispensing direct aid. During disasters, most fire personnel may not be in the building or will return for only brief periods. Thus, the "evacuation" of the building of firefighters will enable EOC personnel to operate more efficiently within the building with minimum operational conflicts. This contrasts with police



FIRE STATION PROGRAM ELEMENTS

departments, which may require more "in-house" operations to support the outside personnel, introducing the potential for increased operational conflicts between police and EOC.

ADMINISTRATIVE AREA

In larger stations, the administrative offices together with the training room can accomodate the EOC program. Generally, however, the requirement for offices with natural lighting will place most of these spaces on an outside wall. The training room usually functions well as an interior space, and may accomodate the EOC operations room requirements. The watch room, which is the center of normal operations, may become the EOC communications room. In fire stations that have a central communications room with full receiving and dispatching capabilities this space would automatically continue its normal function. The watch room could then be used for auxiliary communications personnel.

APPARATUS AND MAINTENANCE AREA

The EOC function should be separated from the apparatus room/operations portion of the building with a protective wall. Apparatus rooms and maintenance areas are the most frequent source of fire damage in fire stations, and may be a source of potential damage to adjacent parts of the buildings under certain disaster situations. The apparatus room, while a critical element in the emergency response capability of a city, nevertheless performs a different function than an EOC, and should be separated from the EOC with its own protective shell. The EOC should be protected from the hazards presented by glass overhead doors in an apparatus room. Any repair or storage functions using flammable or volatile materials should be isolated from the EOC area, including hose drying rooms, hose towers and shops. Drive-through apparatus rooms, which give additional vehicle operating flexibility, are ideal as a means to isolate these functions from the EOC.

LIVING AREAS

Larger fire stations will usually have sleeping and living areas sufficient to accomodate several EOC program functions. Sleeping areas may be designed without windows as interior space. Kitchen and dining areas may be located on the interior or with minimal outside exposure. These facilities can easily be adapted to the EOC program. Some departments have adopted 8-hour shifts, thus eliminating the dormitory as a separate and independent space. These dormitories are becoming more multi-use rooms, serving as day rooms or dining facilities in off-hours. This duplication of function is consistent with the requirements of an EOC.

MECHANICAL AND ELECTRICAL AREAS

Mechanical, electrical and emergency generator rooms ideally should be located within a protected area away from the apparatus room. Internal utility zoning should be designed to provide for independent operation of the EOC portion of the building.

STORAGE AREAS

Medical and general building supply storage should be located within the EOC area. Material storage for maintenance and repair, including paint, chemicals, and parts, are better located adjacent to the apparatus room outside the EOC perimeter.

STAGING AREAS

Fire stations, whether they contain an EOC or not, may attract citizens in need of information or direct aid. This contingency should be anticipated in the design of a fire station. A protected and paved exterior area should be available for the assembly and organization of private citizens and professional staff for functions such as the distribution of supplies and services, vehicle repair and care of the injured.

OTHER AREAS

Exercise rooms are often included in fire station programs. These spaces are well suited to inclusion within the EOC, provided some provisions for storage of equipment can be made.

ANALYSIS OF A POLICE STATION AS AN E.O.C.

Police facilities are generally larger and have more complicated program requirements than fire facilities. Police stations should be able to accomodate easily the various program requirements of a primary EOC because of both their larger size and their generally more extensive communications capabilities. In addition, the accessibility of police buildings may be better than that of fire stations because of police stations' central location within the city. EOC staff might normally be able to reach the police facility more easily than they would a branch fire station serving a particular outlying district of the city.

An additional consideration that suggests that the EOC is functionally adapted to a police facility is the greater outreach potential available to the police. Patrol cars not only act as sources of communication and intelligence during emergency conditions, but can also facilitate the transportation of staff and supplies to the EOC if necessary. This advantage suggests that the operations capability of the police department during disasters is generally consistent with the communications and coordination response that is a primary requirement of the EOC.

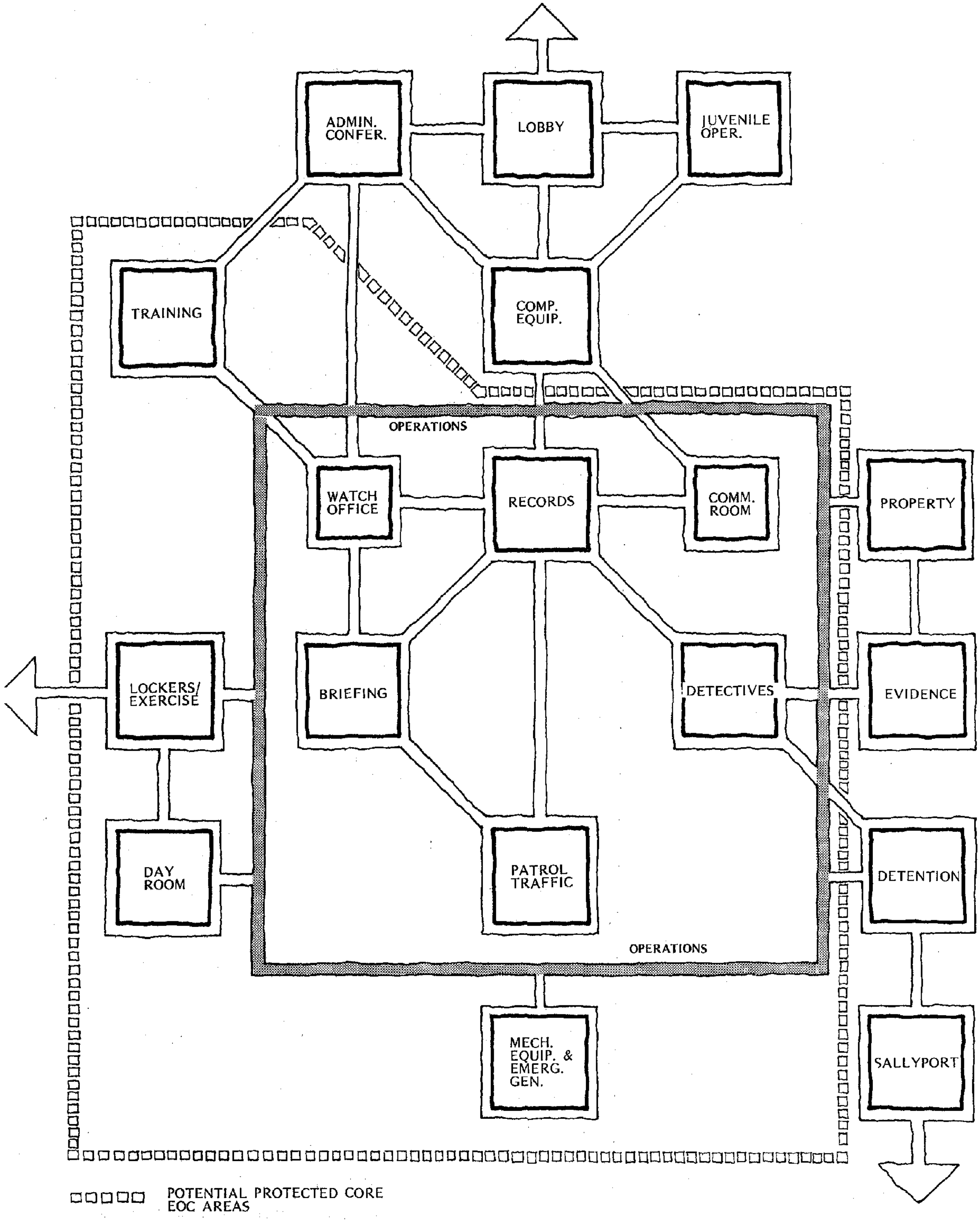
A disadvantage of a police station as an EOC is the potential operational conflicts that may occur with the influx of EOC personnel into the police building. In some departments police staff can be divided almost equally between persons working within the building and those working in the field. This means that a high proportion of the police building is occupied during most of a 24-hour day. During emergency situations these people may be displaced, which will impose operational conflicts on the police department, or they must be programed into the EOC staff and assigned duties as part of the disaster response team. This conflict should be considered and planned for in the EOC program.

The program elements for normal operations discussed below can be used to evaluate how a police station can be designed to accomodate the EOC program.

OPERATIONS AREA

Within the operations section of the building there are several areas that can act as the EOC operations room: the briefing room, the detectives area, or, in larger departments, the traffic operations room. These rooms are generally large, flexible, multi-purpose spaces with sufficient area to handle large numbers of persons. Additionally, because these areas are occupied only occasionally, they can often be designed without windows and within the interior of the building.

- Briefing Room — During emergencies, this room might easily be rearranged to become a central command station. It can be located near the communications room. A potential problem may be the size of the room, which is sometimes programed for an assembly seating space allocation.



POLICE STATION PROGRAM ELEMENTS

Although the room capacity is large, it may prove inadequate. However, it would serve very adequately as a briefing and conference room for legislative officials or standby resource personnel during an emergency. No personnel would be displaced from this area in a disaster.

- Detectives Area — This area is very well suited to be used as an EOC operations room. The area is generally divided into a large detective pool area furnished with desks and chairs that could be easily rearranged into an emergency operations room. (If this is to be done, flexible telephone and power systems should be designed to facilitate rearrangement.) Adjacent to the pool area is usually a command office and several small, quiet interview rooms. This suite could act as an operations center with adjacent communications rooms. The principal design problem would be to provide duplicate, portable communications equipment within the area that could be stored nearby. The detectives area is usually a somewhat self-contained section of the police department and thus offers obvious potential for a simply-designed protected core EOC. During disaster situations the detectives themselves would probably be displaced to other sections of the building or be assigned to field intelligence work.

- Traffic Operations — In smaller departments this room will be too small to serve as an EOC operations room. In larger departments it may have characteristics similar to the detectives area.

- Juvenile Operations — The current trend in juvenile services is to provide an open, inviting area of the building relatively independent of other police functions. It is not generally designed to project the image of maximum security that is often characteristic of protected EOC design. In many cases it would probably be incompatible to design the juvenile operations area as part of the EOC.

OPERATIONS SUPPORT

- Training Room — In some facilities, the training room is also a community room. As such it may be the largest space in the building and large enough to serve as an EOC operations room. Normally it is an independent space, not functionally dependent on other departmental offices. However, as a community space with a direct relationship to the front lobby, the protection of the room may be difficult. Protecting it will conflict with the accessibility and visibility requirements of a community room.

- Day Room/Lounge — This room may be functionally independent of most other building spaces, but is usually close to the locker and exercise rooms. A day room normally has a kitchen facility. Under EOC emergency conditions this space could logically act as the food preparation and dining area of the building. It may be located on the building interior and thus could be easily protected.

- Lockers and Exercise Room — These spaces are better designed for both disaster and normal operations as interior spaces. The exercise room is often furnished with movable exercise equipment. It may serve as an EOC dormitory sleeping area by rearranging the equipment or by providing a storage closet for cots, which could be exchanged for the equipment as needed. In smaller facilities, this may not be practical. In larger exercise rooms, the amount of space for floor exercises and mats should provide sufficient space to accomodate at least partially the sleeping space requirements of an EOC. The lockers located adjacent to the exercise room would contain sufficient toilet facilities for emergency conditions. A locker/toilet room located adjacent to the patrol entry can easily accomodate a fallout shower to provide this additional protection.

- Records Room and Storage — The records room under normal operations will contain clerical and data processing activities. It is furnished with large and immobile file cabinets, reproduction machines, microfilm tables and other data storage and retrieval equipment. Under disaster conditions personnel record storage and retrieval becomes a secondary function. The inflexibility of the space also becomes detrimental to its utility in the EOC. The records area is, however, a very important organizing element of the normal operations program for the building. As a result, it will be centrally located, adjacent to many of the more functional EOC spaces. Because of its critical storage function, its protection should be equal to the rest of the EOC core.

- Communications Room — This space is the central receiving and dispatching location within the building. It contains the console and personnel who monitor the building systems and the daily radio and telephone communications between the community and the police. This room may also handle fire communications and dispatch as well. In many building programs this room is functionally independent of most other rooms in the building. Many communities have taken this function out of the police building entirely and coordinated the entire daily emergency response function in another building. Where this is desirable or necessary a separate EOC communications room must be established within the building.

  A common design relationship in some communities is to have the communications room personnel act as reception and records backup personnel on swing and graveyard shifts. This requirement means a direct visual relationship must be provided between the public entry and communications room. The protection of the communications room is thus compromised, as its location is fixed near the public entry. This may require that a supplementary communications room be set up within the protected EOC core adjacent to the designated operations room. This space should be adjacent to the main building communications equipment room with flexible protected conduit extended to the main console location, which may be outside the EOC core. Portable transmitting and receiving equipment, which can be set up in the EOC communications room, would thus be protected and functionally located to facilitate emergency communications. In addition, the primary base station would be protected inside the EOC core.

ADMINISTRATION

The administration portion of the police station is usually composed of the chief's office, conference space, offices for senior management personnel, clerical and administrative offices, and the complaint counter/reception area. Usually the administrative portion of the building is in use only 8 hours a day and does not receive as intensive use as, for example, the operations area. The administrative area is generally designed with natural light and may be oriented to take advantage of views. Daily face-to-face contact with operations personnel is not a necessary requirement. Thus the administrative area can generally be designed as an independent element not functionally dependent on the operational areas of the building.

Access to the administrative area is usually controlled at the complaint counter. The public has access to police administrators only through locked doors or secondary reception personnel within the administrative area. This security requirement may further separate the administrators from other police areas. For this reason, and because of the strong requirement for exposure to the exterior, the administrative area should probably not be considered a potential EOC area. The normal operating requirements of the police program will take precedence in most cases. By itself, the administrative area may not be large enough to support the full EOC program.

If the administrative area can be designed without windows and organized in the protected interior of the building without detriment to the normal operations requirements of the building it has greater potential as an EOC. Functionally, the administrative offices will not be occupied for most of the 24-hour day. This will mean a minimum of disruption to police emergency activities if the administrative section became an operational EOC. An administrative pool area could be used as an operations room, and an office suite could become a communications room with the use of portable equipment.

PRISONER PROCESSING

This area normally consists of the secure sallyport, booking and identification area, and holding rooms. In many municipal police stations, detainees are held for a maximum of four hours for booking and interviewing prior to transfer to the detention facility or release. Normally, food service and overnight accomodations occur only occasionally or are entirely prohibited. The prisoner processing area is generally a series of tightly controlled small rooms with good internal surveillance capabilities.

As an EOC, the prisoner processing area has several liabilities:

- The total area will normally be smaller than that recommended for the EOC program.

- The transfer of prisoners to other facilities during early emergency situations will be an operational problem.

- The prisoner processing area may require heavier use during emergencies such as wind storms or earthquakes, when looting and civil disorder may become an increased problem.

- Normal programs will contain no area large enough to act as an operations room.

- Storage of necessary furnishings and equipment will be difficult to provide.

While the security requirements of the prisoner processing area offer advantages to using the space as an EOC, the difficulty of communication between the various small spaces, and the severe character of the rooms, will significantly detract from this advantage. Keying of rooms and interior circulation will also be difficult for people unfamiliar with the area.

The one significant advantage is the relative isolation and increased protection possible in the prisoner processing area. Because it is functionally remote from most other sections of the building, it is possible to design the area with controlled access at the rear of the building, without natural light, and with protective building materials. This advantage will probably outweigh the disadvantages only in smaller facilities where the operational demands on the prisoner processing area are not high and alternative detention arrangements can easily be made, either in the building or elsewhere in the community.

PROPERTY/EVIDENCE

The evidence lab, evidence processing and storage, inactive records, and property constitute the normal program elements of this area. This area of a police building is generally a crowded storage and processing space with little flexibility for accomodating an EOC. During an emergency this space will not experience heavy use. Because of its non-critical emergency function and its relative isolation in the building, this area would seem to have little use as part of an EOC.

OTHER AREAS

- Firing Range — A highly specialized function with heavy protection capability, the firing range could possibly be used as a dormitory. Some police stations may not be able to afford the expense of including this function in their building program.

- Armory — This area, which provides for storage of weapons and ammunition, may be highly used during an emergency. It has no functional advantage within an EOC, but should be protected to prevent additional damage to the building in a disaster.

- Mechanical and Electrical Areas — Space for this equipment ideally should be located within the protected area designated as the EOC. Interior utility zoning should be designed to provide for independent operation of the EOC portion of the building.

- Emergency Generator — The generator should be protected as part of the EOC.

- Staging Areas — Police stations, whether they contain an EOC or not, may attract citizens in need of direct aid in an emergency. This contingency should be anticipated in the design of a police station. Therefore, a protected and paved exterior area should be available for the assembly and organization of private citizens and professional staff for various functions such as distribution of supplies and services, vehicle repair or care of injured.

CASE STUDY

Architect: Rockrise Odermatt Mountjoy Associates
San Francisco, California

The following is an illustrative example of a protected core Emergency Operating Center located in a combined police/fire station in a town with a population of 27,000. The following design elements should be noted:

- No windows in core area
- Direct access to outside from operations room (training room)
- Most of core on an inside wall
- Reinforced concrete block walls and concrete roof
- Internal mechanical and electrical rooms
- Minimal conflict with normal operating portions of building
- Separation from hazardous spaces (apparatus room and storage)
- Direct access to sallyport for vehicular access

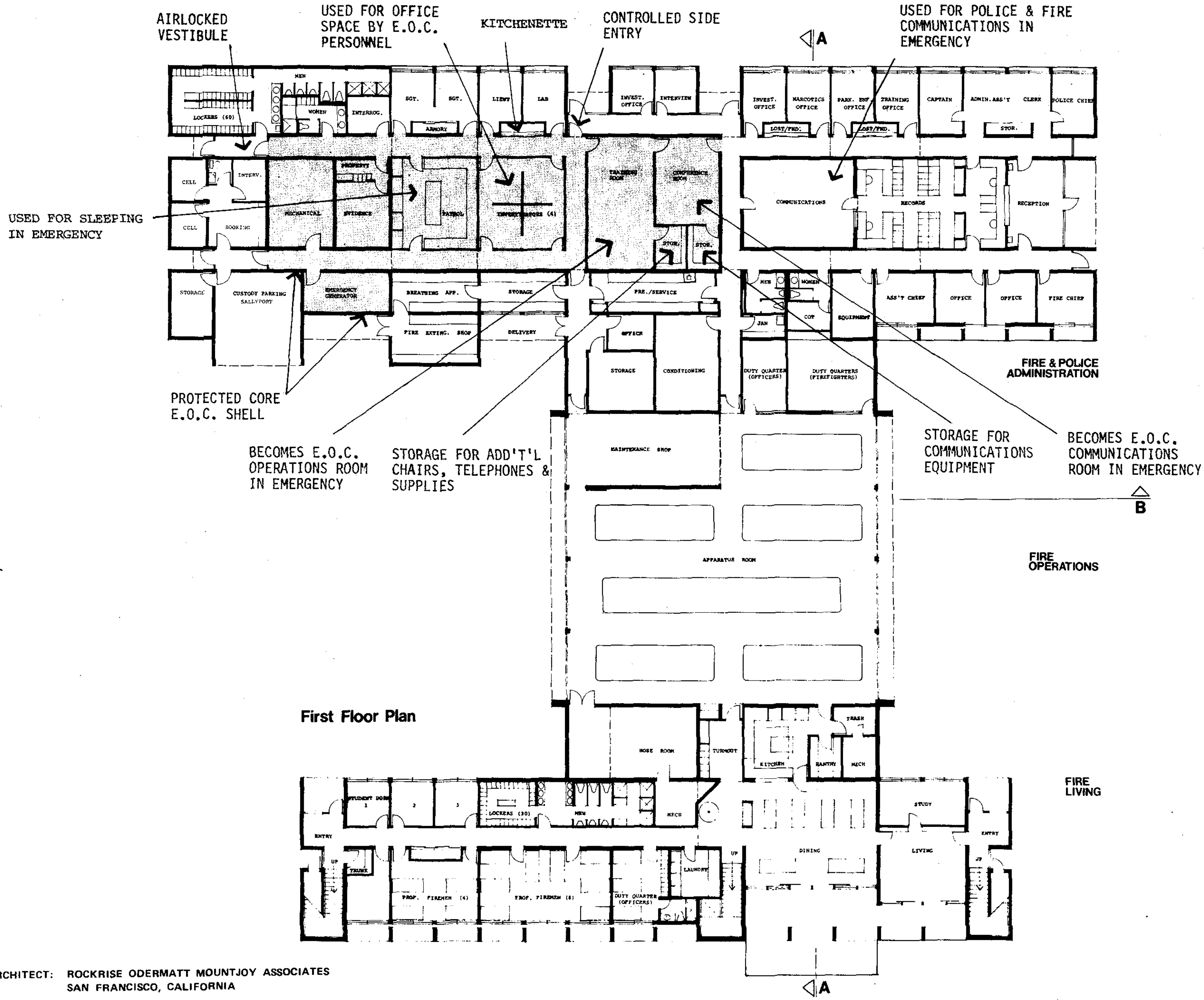
The cost of an EOC within a new fire or police building can be estimated in two ways:

- The cost of all necessary modifications to the normal building program. This includes shell protection, equipment, partition modifications and mechanical and electrical service systems that allow the dual use of the building as a fire or police facility and, during emergencies, as an EOC. Calculated in this manner, much of the building cost will be included in the ordinary costs of building a fire or police facility for a small or medium community. EOC's that share this space with normal fire or police functions will thus contribute only a fraction of the total cost of the building.
- The cost of the total EOC area of the building. This includes building shell, partitions, finishes and all mechanical and electrical service systems. Estimated in this way, the EOC is considered an independent area of the building with no dual-use capability. A basement EOC would be an example of this type.

Because of the many ways in which an EOC can be programed and designed and the range of sizes of EOC's, it is difficult to establish precise guidelines for the cost of a new EOC. The guidelines presented here represent average or normal ranges for the costs involved. The design of sophisticated protection systems or elaborate communications equipment will easily alter the figures used. Before establishing a project budget for a new EOC, a complete program defining the project should be established and cost estimated prior to beginning design.

COMMUNICATIONS EQUIPMENT

Communications equipment system costs for a small to medium-sized city's fire, police and public works network is generally in the range of $50,000 to $200,000, including consoles, wiring and antenna systems. The costs of adding an EOC backup communications system consisting of portable or desk-type base stations, receivers, additional telephones and standby antennae, plus hook-up to the main system, will be 50% to 100% of that of the basic system. The exact increase will depend on the function of the equipment, the EMP protection requirements, and the number of standby pieces of equpment. A broad range of judgemental decisions by local emergency planning officials regarding individual system capabilities make the establishment of specific guidelines a difficult task.



First Floor Plan

ARCHITECT: ROCKRISE ODERMATT MOUNTJOY ASSOCIATES
SAN FRANCISCO, CALIFORNIA

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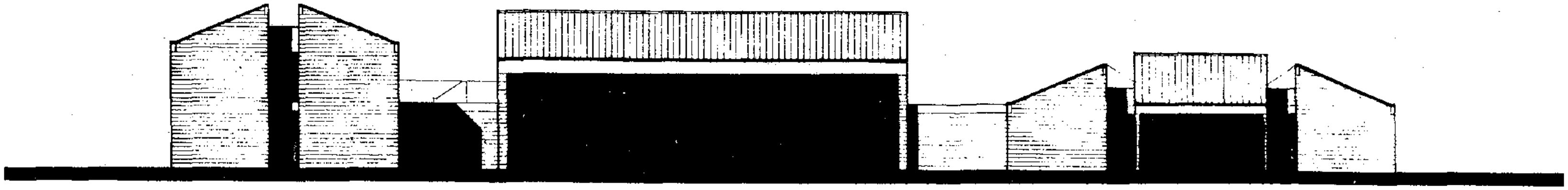
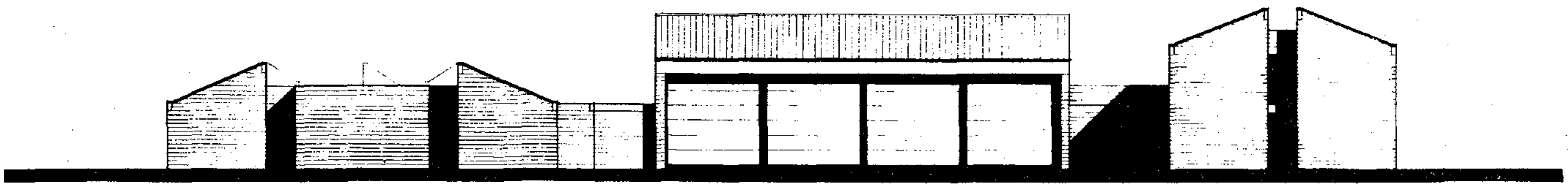


East Elevation

South Elevation



West Elevation

North Elevation

COST DATA

DUAL USE EOC		TOTAL AREA: 25,000 SF
BASIC BUILDING COST	22,000 S.F. x $60/SF	$ 1,320,000
EOC COST	3,000 S.F. x ($60/SF + $45/SF)	315,000
TOTAL COST		1,635,000
COST/S.F.		65.40

As a dual-use space including additional building shell protection, added partitions, HVAC systems and controls, emergency generator, and emergency water supply, the total additional cost to install an EOC is currently estimated to be $20-85/sq. ft. The median cost is about $45/sq. ft. This represents an additional cost of 30%-125%/sq. ft. of EOC space more than what the building would cost without an EOC. The median cost increase would be about 75%/sq. ft. of EOC space more than the same building without an EOC (assuming an average police and fire station cost on the West Coast of $60/sq. ft.).

INDEPENDENT EOC		TOTAL AREA: 28,000 SF
BASIC BUILDING COST	25,000 S.F. x $60/SF	1,500,000
EOC COST	3,000 S.F. x ($60/SF + $30/SF)	270,000
TOTAL COST		1,770,000
COST/S.F.		63.20

As an independent portion of a fire and police building without dual-use capability, the above figures can be reduced slightly. This is because an independent EOC that does not function as another space can be designed more simply and with less redundant systems than a dual-use space. The median cost would be about 50%/sq. ft. of EOC space more than the same building without an EOC. This percentage reduction from the first example is offset, however, by the total additional cost of the EOC that is an independent addition to the normal building program and has no other function within the building.

4 SEISMIC RENOVATION

INTRODUCTION

During the next several decades the bulk of safety and emergency public services will be housed in and supplied from facilities that are existing today. Many of these facilities have been designed and built with little or no regard to their remaining operational during an earthquake disaster. This situation presents both a potential problem and a potential opportunity to upgrade these facilities.

The problem lies in the potential for damage and disruption of services during a time at which the demand for emergency services can be at a maximum. By retrofitting/renovating its existing public service facilities, a community can reduce many of the potential hazards that might render the emergency services inoperational. This opportunity provides what is perhaps the most immediate and cost-effective means of ensuring that critical services and staff could remain in operation during and after an earthquake.

In order to improve the existing facilities, the design team must have a comprehensive picture of their present condition, where the potential problems exist and what alternative solutions exist, with relative costs involved. Presented on the following pages is an approach to the seismic evaluation of existing police and fire facilities, an evaluation form and accompanying commentary, and an evaluation of a case study facility.

THE APPROACH

The potential for hazardous conditions in police or fire facilities appears to fall into three problem areas: access/egress, human safety, and operations safety. Of course, all are interrelated, but each area is more strongly related internally.

The access/egress deals with hazards to both pedestrian and vehicular traffic external to the building and the site. If the approach paths are blocked, the facility may become useless, even if it survives the disaster undamaged. Access/egress hazards include geological conditions such as soil failure and geographic conditions such as susceptibility to flooding from broken dams or stream blockage or to tsunamis or seiches. If any of these hazards threatens, serious thought should be given to abandoning the facility rather than attempting to bring it to current standards. Access/egress hazards also include man-made hazards, such as power lines, flag poles, parapets, canopies, signs and adjacent structures, any of which, in failing, could inflict damage or block access. In addition, traffic blockage at a major intersection could render a fire facility useless. Because of the nature of vehicles and short reponse time desired, traffic tieups due to confusions and/or power failure could prevent effective service. Many of these man-made hazards can be corrected when identified. The study of individual cases will determine if the cost of correction is warranted.

The area of human safety is self-explanatory. Special attention must, however, be given to problems that grow out of the facility's unique functions, its around-the-clock occupancy and, in the case of some police stations, forced confinement. Many solutions to these problems have been found in fire exit treatments; however, one unique problem is the blockage by rubble generated by building movement.

Operations safety deals with maintaining utility services, stabilizing and protecting necessary equipment, and protecting circulation spaces and other critical areas so that the facility can function during the emergency period.

The evaluation form and commentary that follow use these three areas as a framework and emphasize those elements that can pose the greatest risk to the operations that will be crucial after a natural disaster. These techniques and guidelines are concerned with adapting existing, functioning facilities, rather than either planning totally new facilities or restoring damaged facilities. This approach presents two unusual variations from most seismic investigations.

First, since the facilities currently exist, the construction type and the planning has already been established. This is an additional set of constraints not present in new construction, but which, for economy, is a part of renovation or retrofit planning.

Second, since damage has not yet occurred, the existing hazards must be surveyed for potential damage before choices can be made as to which conditions should receive attention and how much can reasonably be spent for changes.

All architects will easily recognize the need and desirability of consulting experienced and competent engineers when dealing with an evaluation for seismic renovation. A renovation of this nature may be valued at greater than 50% of the value of the building. If this is the case, most codes will require complete code compliance for the renovated facility. Since it is obvious that improvement is the intent of the work, the building official may be persuaded to accept the proposed work, even without assurance of total compliance. If not, then the building cannot be completely retrofitted, and the owner will have to choose between a partial upgrading and a new structure. In either case, the procedure outlined here will be of value, as it provides the information required to make the best choice intelligently.

THE EVALUATION FORM

If the objective is to retrofit or renovate an existing facility for police or fire services or to evaluate a facility as to the feasibility of such retrofitting, the professional should first read and understand the commentary associated with the Evaluation Form.

The facility should then be surveyed using the Evaluation Form to ensure that all information is obtained. If possible, one or more safety service professionals from the facility should accompany the surveyor to answer questions and escort him through sensitive areas. The commentary supplements the Evaluation Form during the survey. Solutions, including accepting the existing risk or changing procedures, should be proposed and a judgement made as to which solution most fully meets the conditions of the client's needs. With these solutions established, rough cost estimates can be made, priorities set to allocate the budget to satisfy the most important requirements of the problem, or a determination made to obtain a different facility.

Once the solutions have been decided on, the usual contract documents, perhaps including other, non-seismic considerations, can be prepared, bids taken, and construction contracts awarded.

SEISMIC RENOVATION EVALUATION FORM

1. Facility ______________________________ Fire___ Police____

2. Address ______________________________ City ______________

3. Local Official ____________________ Surveyor ________ Date ______

4. Plans Available ____________________ Seismic Zone ______________

   Building Code ______________________________

5. Plans Location ____________________ Obtained______ Returned ______

6. Remarks:

Site Conditions

7. Foundation Condition: Bedrock___Dry___Wet___Cohesive___Non-cohesive___

   Other ______________________________

8. Site Location: On or below a bluff___In flood plain___Hilly terrain___

   Other ______________________________

9. Man-made Hazards: Adjacent tall structures___Power lines___Major intersection___

   Other ______________________________

10. Remarks:

Structure

11. General Description: No. of stories___(Sketch plans and attach)

    Basement/crawl space___(Sketch plans and attach)

12. Construction Types: Skeleton frame___Material__________ Damage____________

    Bearing Wall___Material________ Large Openings________(Sketch elevations and attach) Anchorage______Damage_________ Other types: Describe, sketch and attach

13. Floor Construction: Materials__________(Note on plans) Large Openings________ (Note on plans) Damage____________ (Note on Plans) Anchorage______________

14. Roof Construction: Materials ____________(Note on plans) Large Openings________ _____ (Note on plans) Damage__________(Note on plans) Anchorage_____________

15. Foundation: Type___________(Note on plan) Wall material__________________

Heights, above grade___________ below grade ______ (Note on elevations)

Thickness___________Reinforcing__________ Damage________ (Note on Plan or Elevation)

16. Towers/Parapets:______________ Materials_____________Damage_______________ (Note on plans) Attachment ______________________

17. Roof-Mounted Equipment: Sketch on plan

18. Stair Towers: Construction of Walls ___________________ Construction of Stair_________________________Construction of Roof________________________

Damage_________________________(Note on plans) Attachment_______________

19. Remarks:

Exterior Architectural Conditions

20. Walls: Materials__________________________ Anchorage ______________________

21. Fenestration: ___________________________________

22. Previous Damage: ________________________________

23. Roof: Materials _________________________ Anchorage ______________________

Finish ___________________________ Anchorage ___________________________

24. Miscellaneous Hazards: Power entry___ Parapet___Flag Pole___ Sign___ Canopy .__

Other ____

Interior Architectural Conditions

25. Structural Walls: Materials__________________ Anchorage ____________________

Finish ___________________________ Anchorage___________________________

26. Non-Structural Walls: Materials______________ Anchorage______________________

Finish ___________________________ Anchorage ___________________________

27. Floors: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

28. Ceilings: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

29. Remarks:

Exit Path Conditions

30. Corridor Walls: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

31. Corridor Floors: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

32. Corridor Ceillings: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

33. Exit Doors: Materials ______________ Anchorage ______________

Direction of Swing ______________ Other ______________

34. Stairway Walls: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

35. Stair: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

36. Exit Lighting: Materials ______________ Anchorage ______________

Lens/Globe ______________ Anchorage ______________

Emergency Type: ______________ Anchorage ______________

37. Remarks:

Fire Protection

38. Natural Gas Valves: Accessible ___Marked___ In a vented space___ Exterior___
Earthquake cut-off ___

39. Natural Gas Piping: Flexible sleeves through walls___ Flexible Joints at Equipment___
Anchored to structure ____

40. Hazardous Liquids and Gases: Containers protected___ Remarks ____________________

41. Detection System Types: Smoke___ Heat___ Anchorage ____________________________
Emergency power ___________________________________

42. Extinguishing System Types: Automatic___Anchorage ____________________________
Manual __ Anchorage _______________________________

Water and Sewer Piping

43. Standard Systems: Flexible Sleeves __Flexible Joints___Anchorage _________________

44. Emergency: Water________________________ Sanitary ___________________________

Lighting and Electrical Systems

45. Standard Electrical System: Latch Covered Panels___Panel Anchorage ______________

46. Emergency System: Outlets marked___ Battery system___ Generator___Generator Automatic start___ Generator anchored___ Batteries and Racks Anchored _________________
Flexible Wiring and Fuel Lines___Backup Fuel for Natural Gas___
Power Detectors___Fuel Tanks Anchored _____________

47. Standard Lighting: Recessed/Surface___ Indirect___ Lay-In___ (Positive Suspension___)
Continuous or Track___Stem Mounted___Safety Lenses/Globes___Rapid Start___

48. Emergency Lighting: Generator-Powered___ Individual Battery___ (Anchored___)
Locations: Mass Assembly___Detention/Dormitory___ Exit Path___ Watch Room/Communications Room___ Apparatus Room___ Lockers___ Accessible Hand Lights ________

49. Remarks:

Mechanical Equipment

50. Equipment: Anchored___ Flexible connections to: Electrical supply___ Piping___ Ductwork___ Fan on emergency circuit___

51. Ductwork: Anchored___ Flexible connection through: Walls___ Ceilings___ On vertical ducts___ Across expansion/earthquake joints___

Elevators and Dumbwaiters

52. Machine Room: Anchored generator___ Flexible electrical connection___ Flexible hydraulic connection___ Cable guide___

53. Shafts: Counterweight reinforced___ Guide rails anchored___ Non-brittle shaft wall___

Maintenance/Repair/Garage/Apparatus Room

54. Floors: Materials ____________________ Finish ____________________

55. Walls: Materials ____________________ Anchorage ____________________
    Finish ____________________ Anchorage ____________________

56. Ceiling: Materials ____________________ Anchorage ____________________
    Finish ____________________ Anchorage ____________________

57. Lighting: Mounting ______________ Lenses ____________________
    Emergency ______________

58. Extinguishing System ______________ Detection System ____________________

59. Unit Heater: Anchorage ____________ Piping Anchorage ____________________
    Piping Flexible ______________ Flue Anchorage ____________________

60. Cabinets: Anchorage ______________ Positive Latches ____________________
    Shelf Rails _________ Unbreakable Containers ______ Heavy Items Low __________

61. Fixed Equipment: Anchorage _________ Flexible Connections ____________________

62. Movable Equipment: Restrained _______ Types ____________________

63. Doors: Swing into Apparatus Room___Break Away (O.H.)___Manual Operators (O.H.)

___Jambs Reinforced ___

64. Other Hazards: ________________________________

Detention/Dormitory/Locker Room

65. Floor: Materials ______________________ Finishes ____________________

66. Walls: Materials ______________________ Anchorage ____________________

Finishes: ______________________ Anchorage ____________________

67. Ceiling: Materials ______________________ Anchorage ____________________

Finishes ______________________ Anchorage ____________________

68. Lighting: Mounting __________ Lenses __________ Emergency ____________________

69. Extinguishing Systems ______________ Detection Systems ____________________

70. Doors: Type ______________________ Direction ____________________

71. Furnishings: Anchorage ________________________

72. Other Hazards ________________________________

Communications/Watch Room

73. Floor: Materials ____________________ Finish __________ Raised ______________

74. Walls: Materials ______________________ Anchorage ____________________

Finish ______________________ Anchorage ____________________

75. Ceilings: Materials ______________________ Anchorage ____________________

Finish ______________________ Anchorage ____________________

76. Lighting: Mounting ________ Lenses __________ Emergency ____________________

77. Extinguishing System ______________ Detection System ____________________

78. Cabinets: Anchorage ______________ Positive Latches ____________________

Shelf Rails ________ Unbreakable Containers __________ Heavy Items Low ____________

79. Fixed Equipment: Anchorage ______________ Flexible Connections ______________

80. Movable Equipment: Restrained ______________ Types ______________

81. Room Enclosed ______________ "Hardened" ______________ Brittle Material ______________

82. Emergency: Ventilation ______________ Maps ________ Chief's Radio ______________

83. Other Hazards: ______________

Briefing/Day Room

84. Floor: Materials ______________ Finish ______________

85. Walls: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

86. Ceiling: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

87. Lighting: Mounting ______________ Lenses ______________ Emergency ______________

88. Extinguishing System ______________ Detection System ______________

89. Cabinets: Anchorage ______________ Positive Latches ______________

Shelf Rails ______________ Unbreakable Containers ______ Heavy Items Low ________

90. Fixed Equipment: Anchorage ______________ Flexible Connections ______________

91. Movable Equipment: Restrained ______________ Types ______________

92. Other Hazards: ______________

Evidence Storage/Records/Emergency Supplies Storage

93. Floor: Materials ______________ Finish ______________

94. Walls: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

95. Ceiling: Materials ______________ Anchorage ______________

Finish ______________ Anchorage ______________

96. Lighting: Mounting ______________ Lenses ______________ Emergency ______________

97. Extinguishing System ______________ Detection System ____________________

98. Cabinets: Anchorage ____________________ Positive Latches ________________

Shelf Rails ___________ Unbreakable Containers ________ Heavy Items Low ______

99. Fixed Equipment: Anchorage ______________ Flexible Connections ____________

100. Movable Equipment: Restrained ____________ Types ______________________

101. Water/Sanitary Piping __________________ Gas Piping ______________________

102. Other Hazards: _______________________________

Armory

103. Floor: Materials ________________________ Finish ________________________

104. Walls: Materials ________________________ Anchorage ____________________

Finish __________________________ Anchorage _________________________

105. Ceiling: Materials ________________________ Anchorage ___________________

Finish __________________________ Anchorage _________________________

106. Lighting: Mounting ____________ Lenses ____________ Emergency __________

107. Extinguishing System ______________ Detection System ____________________

108. Cabinets: Anchorage ____________________ Positive Latches ________________

Shelf Rails __________ Unbreakable Containers ________ Heavy Items Low _______

109. Exhaust to Outside ____

110. Other Hazards: _______________________________

COMMENTARY ON EVALUATION FORM

LINES 1 THROUGH 6, IDENTIFICATION: used to identify the building that was evaluated. The facility can have any or all of the functions and may also include city or county services or Civil Defense Offices. Availability and location of plans will be desired during retrofit.

LINE 7, FOUNDATION CONDITIONS: may have to be investigated by geological/soils testing services. Preliminary information may already exist. Check the testing services, state geological societies and coast and geodetic surveys (U.S. Geological Survey). Wet, non-cohesive soil, either as a total situation, or in lenses, is subject to liquefaction. This condition is not correctable and can cause excessive settlement and slides. Any attempt to upgrade a facility on such foundation material may be unfeasible. A facility on variable foundation materials may be subject to unequal settlement. Upgrading such a facility may also be economically unfeasible.

LINE 8, SITE LOCATION: conditions existing near and around the site that could threaten the facility. A bluff could collapse, threatening a facility below it with a slide or undermining a facility above it. The facility on a traditional flood plain could be threatened by water either from a broken dam or reservoir or by the backing up of a waterway, if dammed downstream by a slide. Proximity to a large lake or ocean shore threatens the facility with a seiche or tsunami (waves generated by an earthquake).

LINE 9, MAN-MADE HAZARDS: deals with immediately adjacent threats. Any high structure, if toppled, could damage the facility. The taller, heavier, and older (i.e., non-seismically designed) the structure, the greater the hazard. Live power lines across pedestrian or traffic pathways are a threat. A major intersection, especially if controlled by an automatic signal, is a likely point of congestion during a disaster, and poses the threat of blocking the dispatch of emergency vehicles. The collapse of a bridge, highway overpass, viaduct, or rail trestle could block a vehicle access pathway. Many of these hazards can economically be mitigated or bypassed.

LINE 10, REMARKS: allows space for any additional information about the site. Fault zones pass through many urban and suburban areas. No building can survive if it is spanning a fault. More frequent hazards are the existence of mine tunnels or utility tunnels, the collapse of which can undermine the structure or sever utilities. Storm sewers can collect volatile liquids, such as gasoline, from underground tanks that may be ruptured. Sanitary sewers, if the flow is halted, will generate methane gas, which can explode.

LINES 11 THROUGH 19, STRUCTURE: deals primarily with the structure. Heavy reliance on field sketches and/or existing drawings will be necessary so that the structure can be documented. Each item on the list will affect the structure's resistance to seismic loading. Of special importance are the anchorage and steel reinforcing. If the anchorage and reinforcing are not immediately visible, destructive investigation may be required. Also of importance are the size and location of any openings in bearing walls, floors, or roof, and the attachment and support of towers, parapets, penthouses and roof-mounted equipment. All of this information will be required before a structural design can be properly evaluated.

LINE 20, EXTERIOR ARCHITECTURAL CONDITIONS: shows brittle material, such as structural clay tile, ceramic or glazed tile, cement-asbestos board, and glass which, under seismically induced movement, may shatter and spray the pedestrian access pathways with sharp rubble. The anchorage of heavy materials, such as brick or precast concrete, may fail, allowing the finish to fall.

LINE 21, FENESTRATION: includes sunscreens, which can separate and fall on alternate exit paths.

LINE 22, PREVIOUS DAMAGE: notes existing damage. This may have been caused by normal deterioration, previous earthquakes, fire, vandalism or other causes.

LINE 23, ROOF: material and finish are not usually hazardous. Potential problems can be caused by heavy roof material, such as concrete fill, or finish, such as slate or tile. However, these are usually considered in the structural design. Improper anchorage can cause finishes to fall, threatening pedestrians near the building. Any heavy finished, sloped roof should be inspected and proper anchorage verified.

LINE 24, MISCELLANEOUS HAZARDS: are on the building or site and threaten the same as off-site hazards explained under line 9. Recurrent hazards have been unreinforced parapets and cornices, entrance canopies (especially of concrete) and building signs. Other hazards include display cases, sculptures, light fixtures and fountains.

LINES 25 THROUGH 29, INTERIOR ARCHITECTURAL CONDITIONS: are concerned, generally, with elements selected by the architect. Most damage to these elements is caused by the different earthquake motion response of each part. Structural and nonstructural walls of stiff materials are susceptible to cracking. The cost of restricting movement to an amount that does not cause cracking in concrete block or gypsum board may be sufficiently expensive (especially in retrofit or renovation situations) that repairable and nonhazardous failures are usually accepted as the most reasonable alternative to corrective work. However, if cracking of the wall brings hazard, the wall should receive corrective work. The hazard will usually come in the form of a heavy wall toppling or a brittle material, such as structural clay tile or glass, shattering. Correction should include properly anchoring and reinforcing heavy walls and replacing brittle ones with non-brittle materials, such as gypsum board on steel studs.

The major hazard from wall finishes comes from brittle finishes shattering under stress and spraying the surrounding areas. These materials, such as ceramic tile, can be removed.

There is very little hazard in resilient floor materials and finishes. Ceramic tile and other brittle materials are the only exceptions. It can be replaced in critical areas. Terrazzo will show cracks due to movement and is difficult to successfully repair; however, it is not very hazardous. Smooth surfaces may be hazardous if leaking pipes cause wet areas in critical function areas.

Ceilings constitute perhaps the greatest general hazard. Floors can more different amounts and even different directions during seismic activity. Ceilings are usually attached to the floor above and walls attached to the floor below. The difference in the two movements usually occurs where the ceiling and wall meet. If the stress or movement is not allowed, the ceiling can fail at this point, dropping debris onto the occupants below and destroying the fire rating if the ceiling provides one. Historically, exposed grid lay-in acoustical tile are most susceptible to this failure. Some tile panels are heavy, and thus hazardous; light fixtures using the same grid for support can fall if the grid fails. The usual support for gypsum board ceilings is sufficiently strong to take most seismic loads in most rooms. Decorative ceiling panels are usually not properly anchored.

LINES 30 THROUGH 37, EXIT PATH CONDITIONS: concentrates specifically on an area critical to occupant safety. During and immediately after a seismic occurence, this area should be substantially undamaged both for life safety and for proper functioning of the facility.

The comments given above relate to the corridor walls, floors and ceilings, but maximum attention should also be given to removing all potential hazards from these areas.

Exit door anchorage and direction of swing are typical of any exit requirement. However, all doors should be checked for hazardous materials, especially in older buildings that may have been built before the requirement for safety glazing in glass doors became widespread.

Stairways should also command careful attention. The level changes inherent in stairwells make even minor amounts of debris extremely hazardous, and any material that shatters and any finish that could separate from its support should be removed. The stair itself presents an almost unique hazard in that it spans from level to level and can restrain the variation in movement between levels. The stair is almost never strong enough to successfully accomplish this; as a result, something must fail, and usually the stair flight itself buckles, cracks or separates and falls. Allowing a slip joint at one end of each flight that can operate both parallel and perpendicular to the flight allows the different levels to move without damaging the flight.

Exit lighting should be furnished, even if glazing is used to introduce daylight, since these facilities can operate 24 hours a day. The type of light fixture will often vary in the stairway from the rest of the building. Check these for anchorage to eliminate failure as well as malfunction. The normal lighting is not on the emergency circuit. Other emergency illumination should be furnished, and properly anchored. Unprotected lenses or bulbs can be eliminated.

LINES 38 THROUGH 42, FIRE PROTECTION: is important in that destruction/disruption can be caused by fire, which can follow an earthquake. Check for proper anchorage of fire extinguishers, sprinklers and fire detection systems. Heavy damage to pipes allows both gas and water to leak. One of the first measures that should be taken after a natural gas line break is to shut it off. If it is shut off automatically, a fire may be prevented.

Historically, piping damage can occur where piping passes through walls and where the appliances are connected to the system. This is due to the difference in earthquake response between the piping and the walls or the equipment. Flexible joints in the piping can be used at the wall sleeves and at the equipment. Oversized sleeves packed with compressible material can be a less expensive alternative to flexible joints at walls. Damage to pipes can also be caused by the pendulum action of piping. If not braced against sway, the piping may easily be damaged.

Volatile liquids and gases are not usually piped, except natural gas. Welding gases and paints and chemicals may be stored in the building. These can be protected from damage by using unbreakable containers and positively anchoring them. In larger police facilities, laboratory reagents should also be protected.

Fire detection systems should be installed, anchored and connected to the emergency power system.

Extinguishing systems can be automatic or manual. Fire extinguishers and fire hoses should be positively anchored. Cabinets and gravity hooks cannot restrain the tanks and hoses during earthquakes. Automatic systems have two different damage possibilities. First, the suspension of piping should be braced against sidesway, or elbow joints may be damaged. The other problem is that the ceiling often moves at a different rate and direction than the supporting structure above. Since the sprinkler head must extend through the ceiling this movement may damage the ceiling or may shear off the sprinkler head. The ceiling damage removes the fire protection and shearing the head creates water damage and removes the fire extinguishing capability. The water damage can cause the ceiling to fall.

LINES 43 and 44, WATER AND SEWER PIPING: has the same problems as the natural gas piping. Flexible sleeves or piping can be used through walls, flexible joints can be used at attachment to equipment, and piping suspension can be braced against sway. Emergency supplies of water, and facilities for sewage, must be provided if the facility is to continue to function. These may be furnished under civil defense supplies if these supplies are stored within the facility.

LINES 45 THROUGH 49, LIGHTING AND ELECTRICAL SYSTEMS: are critical to continued functioning of the facility. The standard electrical distribution system historically has sustained little damage as long as supporting structures do not fail. This is because the system is generally very flexible and can withstand differentials of displacement. Damage has occurred to rigid electrical bus bars and to free-standing panels. Bus bars can be replaced by heavy cables and free-standing panels, being light, can be anchored easily, so these precautions can be taken relatively inexpensively.

The emergency electrical system is vital for continued communications, lighting, and ventilation of critical spaces. Batteries can handle most of these loads, but an emergency generator will handle much more and will allow the load to be carried indefinitely, assuming access to fuel is maintained. The generator's starting system should be protected. Usually this means protecting a battery by strapping it to the generator or to an adjacent structure. Fuel can be supplied by an integral tank, a buried tank or a separate tank. The separate tank should be properly anchored to the structure. Flexible fuel lines can be used from non-integral tanks. Refill cans for a small integral tank may be used in lieu of a day tank or buried tank. Since this is a hazardous liquid it should be positively attached to the structure, away from fire hazards. The electrical connection should be flexible.

The generator itself is a heavy piece of equipment, and its uncontrolled movement can do extensive damage. It should be anchored to the structure. Historically, isolation pads have not provided proper anchorage without restraint from all directions. If isolation pads are to be used, the generator can be surrounded with a substantial curb to restrict its movement. The generator should exhaust to the outside. Flexible sleeves through the wall should be provided or sufficient flexibility in the exhaust pipe itself will be required to eliminate the possibility of breaking the pipe. If the generator is fueled by natural gas, a two-fuel carburetor and backup fuel supply should be arranged to protect against loss of generating capacity due to failure in the natural gas supply system.

It is highly desirable that the emergency system be investigated to locate outlets that can be used while under emergency operation and to ensure that the fire detection system remains operational. If detectors and outlets in all areas are not a part of the emergency system, some consideration should be given to rewiring the system to provide them. Those outlets that are on the emergency system should be marked so that they may be located without test equipment.

Lighting fixtures can be a major source of debris. Stem mounted lights can sway far enough to damage themselves and adjacent fixtures. Lay-in fixtures in acoustical tile ceilings can fail with the tiles and grids unless they have separate, positive attachment. Continuous and track mounted fixtures also are easily damaged. Glass lenses and globes are easily shattered. Recessed and surface mounted individual fixtures may offer better protection if the ceiling retains its integrity. Indirect and cove lighting is especially good because it will contain the bulbs if they shatter and does not usually contain lenses to shatter or fall. Total reliance on high efficiency lights should be avoided because of long re-start times required.

Emergency lighting can be a part of the standard lighting system and wired to the emergency electrical system or individual battery lights. Both types should be designed and anchored to prevent damage. The most heavily occupied spaces should have emergency lights. Handlights should be readily accessible so that spaces not serviced with emergency lighting can be checked and materials removed from them if needed.

LINES 50 AND 51, MECHANICAL EQUIPMENT: will usually remain operational following an earthquake if properly anchored and furnished with flexible connections to ductwork, electrical service and piping. If equipment is mounted on unrestrained isolation pads, a curb of sufficient strength to limit movement can be installed. Suspended equipment such as unit heaters and air handlers can be braced to prevent sway. Ventilation fans, expecially for the most critical areas, should be on the emergency electrical system.

Ductwork is susceptible to the same types of damage as automatic fire extinguishing systems, and for the same reasons. All ductwork can be braced against sway to preserve joints. Flexible sections can be installed wherever the ductwork passes through floors, ceilings or walls, where it crosses building expansion or special earthquake joints and where there is a change in the structural member supporting it.

LINES 52 AND 53, ELEVATORS AND DUMBWAITERS: have requirements similar to those of mechanical equipment. Flexible connections can be made for electrical or hydraulic lines. Steel guides for hoist cables can be mounted near the sheaves to keep them in their grooves.

The shafts themselves should not be of brittle material such as structural clay tile. Historically, the counterweight guide brackets have been insufficient to restrain the counterweights. If the elevator is vital to continued operation, these brackets should be reinforced.

LINES 54 THROUGH 64, MAINTENANCE/REPAIR/GARAGE/APPARATUS ROOM: is importance to continued police operation and vital to fire stations. Floors are almost never a hazard, but should be checked for cracks, which may often point to soil problems or previous earthquake damage. Wall finishes are also not normally a hazard unless the wall includes large amounts of glass. Many walls are of heavy material, such as concrete block, that can do extensive damage if not properly anchored. This space is often taller than adjacent parts of the structure. Buildings can fail at the point in a wall where a change in height occurs. This condition should be mitigated, especially in apparatus rooms.

Ceilings, if they exist, are often exposed grid acoustical tile, which has a poor survival record. While the grid itself does little damage, it must be cleared to allow the space to be effectively used. Some of the water-resistant types of tiles are heavy and can damage equipment. Even the lightest tiles and grids can injure personnel.

Lighting is the most dangerous part of the ceiling. Stem mounted lights, continuous strips and improperly supported lay-in fixtures should be removed or braced against movement. High efficiency light fixtures should be supplemented with rapid-starting types so that no delay in response is caused by a temporary loss of electrical service, especially in fire station apparatus rooms.

Extinguishing and detection systems may not be furnished in these areas, since the areas are continually in use. However, because of the petroleum products located in this space, and because the personnel will be called away from the facility immediately after an earthquake, installation of such systems is desirable.

Unit heaters are often used in these spaces. They should be specifically checked for anchorage and flexible connections and, if found lacking, should be retrofitted with them.

Cabinets may be used for storage of equipment not normally left on vehicles. Failure of doors or of positive stops on shelves may throw this equipment around the room. Anything breakable will shatter, leaving debris of glass and contents. Cabinets not anchored may "walk."

Fixed equipment such as tool benches, welding equipment and compressors can be anchored to prevent movement. Any connections should be flexible to allow differential movement.

Movable equipment, jacks and hose racks should be restrained in such a way as to prevent toppling or displacement.

Doors in fire station apparatus rooms should be investigated to ensure their continued operation after an earthquake. Overhead doors are especially vulnerable. Loss of electrical power will require manual override of the door operator. The size of the openings makes them vulnerable to racking and permanent distortion. If this occurs, the door should be such that equipment can drive through it or that it can be removed in very little time. Doors with removable panels or breakaway doors could be considered.

Other potential hazards to investigate include the roof drainage piping and pumper fill piping, both of which must be braced against sway. Hose drying towers, with a substantial change in height and hanging equipment should be checked as an additional hazard, and reinforced (or eliminated) to alleviate the threat of collapse.

LINES 65 THROUGH 72, DETENTION/DORMITORY/LOCKER ROOM: detention or dormitory space with its associated toilet and/or locker spaces is a critical space in both police (jail/detention) and fire (dormitory, toilet and lockers) stations. This is because the space is heavily occupied.

Fire personnel occupy the dormitory during the night. If an earthquake occurs during the night they may awaken without light in a damaged environment. The additional hazard of falling debris, moving furnishings or shattered glass may incapacitate many before they can respond to the emergency.

The legal burden of providing physical protection in detention facilities lies with the government. The prisoners should be neither automatically freed nor incarcerated so effectively as to make evacuation difficult or impossible.

Floor materials and finishes do not usually present a hazard unless wet, in which case rapid movement may be hazardous. Cracking in flooring and finish can point to previous earthquake damage and should be checked.

Walls also do not normally constitute a hazard unless they contain high glass windows, which should be safety glazed or slanted out. Heavy partitions that are not properly anchored can topple, causing injury. The typical cell block for jails protects the prisoners from almost all potential hazards associated with falling debris, with the possible exception of glass.

Ceilings in dormitories can fall, especially the exposed grid lay-in acoustical types. The tiles themselves are a minor hazard, but the grid and other metal parts of the ceiling system (lights, air conditioning registers) can do great injury, as well as making movement difficult. Ceilings in detention facilities are not usually a hazard, due to the nature of the cell block construction.

Light fixtures can be very hazardous. Continuous strips and lights mounted on short stems are the most prone to falling, and surface mounted or recessed (not lay-in) being the least. These two types usually can stay with the ceiling; if the ceiling stays up, so do they. Emergency lights, especially battery-operated lights, are frequently only hung or placed on shelves. In a major tremor they may fall and be damaged.

Doors should be fire-resistant in case fire breaks out in adjacent spaces, and should swing out in the direction of exit travel, especially to the apparatus room in fire stations. Furnishings in detention blocks are usually anchored. It is unusual to find anchorage in dormitory space or in the locker space. This is a major hazard to personnel. High pieces such as lockers can topple, and low pieces (bed, benches and dressers) can "walk," causing injuries.

Other hazards would include the locking of detention cells. If they are electrically operated, they could either free all prisoners or trap them when fire or imminent collapse might make immediate evacuation necessary. Manually operated locks controlled from outside the cell block are best, as they do not depend on a continuing source of power.

LINES 73 THROUGH 83, COMMUNICATIONS/WATCH ROOM: is the nerve center of the police or fire facility. If this area becomes inoperable for any reason the facility immediately becomes basically ineffective. To avoid discontinuity of service, this area should be brought up to current standards, even if other areas are neglected. Many governmental agencies are combining different communications centers for emergency services into a single communications center to take advantage of a unified emergency telephone number and the improvement in equipment utilization and service made possible by pooling resources. If such a facility exists, it should be inspected as if it were the communications room in the police or fire station.

Floors are not a critical factor; however, it is recommended that the floor be accessible to allow wiring of new pieces of equipment as the facility is expanded and its equipment upgraded. An alternative would be a wire trench just in front of the equipment line around the walls. A horizontal wire chase behind the equipment would be preferred to wiring running across the floor, but access would be limited and require the removal of some equipment while work is being done.

Walls of communications centers and watch rooms can be partly glazed. Watch rooms should have safety glazing to prevent glass breakage. Before work is done, an investigation should be made of the effect changing the glazing type would have on the fire exit conditions.

Ceilings should be inspected and renovated as necessary to prevent collapse. Suspended ceilings should be removed or braced for lateral movement. Acoustical tile can be freed from direct contact with the wall or removed. Flexible connections can be made in sprinkler heads, ventilation grills and registers.

Lighting fixtures should be treated as required. Lay-in fixtures should be independently suspended from the structure. Surface mounted fixtures should be verified for positive anchorage. Consideration should be given to replacing stem mounted fixtures with surface mounted fixtures. Emergency lights should be installed if not presently in place and positive attachments should be made. Gravity hooks or placement on shelves is not sufficient to prevent damage.

Extinguishing systems should be checked closely. Fire extinguishers should be non-electric.

Doors should be fire- and impact-resistant. Swing should be in the direction of exit.

An earthquake can damage/disrupt the radio equipment and records stored in this room if not properly secured. File cabinets can have latches and be anchored. Card cabinets can also be anchored and latched. Most communications equipment is placed on shelves. These should be bolted in place or the shelf should have a rail to prevent equipment's falling.

Most fixed equipment items have flexible connections to electrical systems, but may not have flexible connections to other utilities, such as gas or water. These can cause fire or may short-circuit electrical equipment.

Movable equipment is almost never anchored. A typewriter can become a missile during an earthquake, as can any other heavy, loose piece of equipment, including telephones, books, microphones, etc.

An enclosed room that resists damage from the outside, whether from civil disorder or from loose objects or collapse in adjacent spaces, is necessary to protect the operators and equipment. Brittle materials, glass and tile can shatter into missiles during an earthquake. Injury to the station's staff during the initial stages of an earthquake can make the facility ineffective just as easily as damage to its equipment.

This area may be inhabited for long periods of time during a disaster. With outside utilities cut, emergency ventilation may be required.

Other hazards would include proximity to furnace room or gas piping (fire and explosion) and proximity to water piping (damaged equipment).

LINES 84 THROUGH 92, BRIEFING/DAY ROOM: deal with the briefing room in police facilities and the day room in fire stations, which have a high occupancy rate, either in volume or duration. The personnel here must be protected from the same types of hazards as previously described.

LINES 92 THROUGH 102, EVIDENCE STORAGE/RECORDS/EMERGENCY MEDICAL STORAGE: concerns storage areas that should be protected from damage. Here less attention can be paid to the ceiling and lighting, but more must be paid to protection from fire and moisture. Evidence and records will be extremely important when operations return to normal.

LINES 103 THROUGH 110, ARMORY: concerns the police armory. Because of the materials stored here, fire or explosion is a great threat. If the material is ignited, ammunition can injure people in adjacent spaces, and gas released by gas containers can make the immediate area uninhabitable. An exhaust to the outside will clear smoke and gases without upsetting operating spaces.

CASE STUDY

Architect: Fischer-Stein Associates
Carbondale, Illinois

The facility evaluated in the case study is the city hall of a midwestern town with a population of 15,000. The city hall houses the city government, including civic and water department offices, and both the police and fire services. The building itself was constructed in 1958, and is located in an area designated as zone 3 seismicity. It has been subjected to several minor seismic occurences, which it survived reasonably well. The survey of the facility revealed both strong and weak points and is thus a fairly representative case study. It must be emphasized that this case study should not be used as an example of correct solutions; it is only an illustration of the evaluation of one particular facility.

GENERAL DESCRIPTION

Although the site conditions were not checked as fully as an actual job would require, the site seemed to pose no insurmountable obstacles. The general area has been mined for coal, but not extensively, so it was assumed that no mine tunnels threaten the structure. This would need to be verified by mine maps. Soil testing was not done, but experience in the area indicates a cohesive soil, clay silts underlain by clays, shales, sandstone and coal, with little chance of liquefaction potential. A few power lines pass across the exit path of the fire apparatus.

The exterior walls are either brick with concrete block back-up or glass in aluminum framing. The power entry crosses the street sidewalk, a condition that can be alleviated only by underground service. One access to the building is under a light-weight steel canopy supported on steel columns, with one glass wall of the building paralleling the walk.

Interior architectural details in general are suspended concealed spline acoustical tile with surface mounted light fixtures; painted plaster on masonry or gypsum board on studs; steel deck and joists with concrete fill and vinyl asbestos tile; steel deck and joists with built-up roofing. A basic seismic problem is that the building has two different structural systems — steel beams and columns on one side and bearing masonry on the other. Part of the steel framing is two story and part one story; the height of the masonry is halfway between the two.

The exit path is primarily a stairway that extends from basement to second floor in four flights. It is steel pans with concrete fill and surrounded with gypsum board and plastic opaque panels.

There is no fire detection system, but the facility is staffed constantly. The only firefighting devices are the hoses and extinguishers in the fire department area. The natural gas valve is outside and easily accessible, but has no automatic earthquake cut-off and is not well marked. The gas piping has many elbows, and is fairly flexible; it is also self-bracing to some extent, but not well braced. There are no unusual materials in the building that could be a hazard except gasoline in the tanks of the fire trucks and in gasoline tanks for an emergency generator. Small quantities of paint products are kept in a cabinet in the fire department's apparatus room.

Water and sewer service has poor seismic resistance and threatens flooding in the apparatus room and basement.

Lighting and electrical service is very good. Not only are the light fixtures surface mounted, but an emergency generator exists that can and has operated the entire building. The generator is not an automatic-starting type. The output of the generator feeds into a panel by a manual transfer switch. The generator is not anchored, nor is the starting battery or the auxiliary fuel supply, which is kept in gasoline cans. This system allows all outlets to be emergency outlets, all light fixtures to be emergency fixtures (but not for quick, fire exit capacity), and ventilation and communications connections to be on emergency power; all highly desirable for continued operations.

Mechanical equipment is not properly anchored, nor is the ductwork. The electrical connection is flexible and the gas connection fairly flexible due to the number of elbows in the piping. The ductwork is not flexibly connected.

There are no elevators or dumbwaiters.

The apparatus room has a sealed concrete slab on grade, painted concrete block walls, and steel deck on steel joists. The roof joists are not anchored to the walls. The flourescent light fixtures are mounted to the bottom of the steel joists, but have exposed tubes. Unit heaters are suspended from the steel, but are not laterally braced. The gas piping is not properly anchored nor does it have flexible joints. The flue is not braced.

The major cabinet in the space is a hose dryer. It is not anchored, nor are the doors furnished with positive latches. A paint cabinet is next to the hose dryer — a possible fire hazard. Its doors are not positively latched, but most containers are cans, not bottles. Fixed equipment consists of wall mounted telephones, which are a minor hazard; a small refrigerator, not anchored; and the emergency generator discussed above. Movable equipment is minor — ladders, exhausted fire extinguishers, etc., but none is anchored in any way. Apparatus doors are of wood and glass and manually operated. The jambs are not specially braced.

The dormitory furniture and equipment is not anchored. The toilet room is finished in ceramic tile. The lockers in the kitchen/dining area are not anchored.

Communications is part of the police facility. Room finish is vinyl asbestos tile flooring, painted gypsum board walls and concealed spline acoustical tile. There is a large expanse of glass in the curtain wall between the communications and the entry sidewalk. The lighting is exposed tube, surface mounted flourescent. There are no automatic or manual extinguishing systems or fire detection systems. The floor is not raised, and electrical wiring runs adjacent to cabinets and walls or is otherwise exposed. File cabinets for records are latched, but card file drawers are not. Other cabinets have shelving with no restraining lip; radio sets, microphones, telephones and other equipment are not restrained.

There is no assembly room specifically for police or fire personnel, as both departments are small enough not to require large spaces, so offices or day rooms serve for meetings. If a larger room were required, the city council space could be used, but it has no more protection than any other space in the building.

The fire department's day room is of similar finish as the rest of the building. It has substantial glazing and unanchored furnishings. Ambulance service vehicles, stored on the site, are covered with a light steel canopy. Records are stored in the police communications area.

The armory has no special shielding. No guard rails or restraining devices are in place and no ventilation is provided.

The structure of the fire apparatus room and council chamber is bearing masonry, brick and block. The fire apparatus doors break the symmetry of shear walls in that area. The rest of the building is steel beams and columns. All floors and roofs are steel deck and bar joists, with concrete fill on the floors. One side of this steel frame has been filled with masonry, breaking uniformity and probably introducing considerable eccentrically produced torsion in an earthquake. The joists are not connected to the bearing walls, leaving in doubt the horizontal resistance of all connections.

The following is an evaluation of the facility using the Evaluation Form to document the hazard potential, possible solutions and the recommended solution or solutions for this specific building. Different buildings, different functions and different locations can all change the importance of any item, requiring that professional judgement be used in the evaluation. One comment about costs. Some items could be very expensive to do alone, and correcting all seismically related items would still be expensive, due to the small, almost detailed scope of the work involved. If major remodeling is planned, however, even of a cosmetic nature, most of these solutions could be carried out at reasonable cost.

EVALUATION

Site Conditions

Power lines parallel to the street across the pedestrian and vehicular accesses, judged to be a minor hazard due to small number and standard voltage. Possible solutions would be to move the lines to the opposite side of the street, perhaps at next pole replacement (cost borne by power company, not too expensive), place lines underground (expensive for electrical work) or leave lines as they exist. The recommendation is to leave the lines as they are at the moment (no cost) but to encourage the power company to shift the lines at the next pole replacement (no cost to city; moderate cost to power company).

Structure

The facility is a partial two story structure with a partial basement. A portion of the existing one story room has been designed for a future second floor, although plans have not been made for using this area. The first floor of the building is "H"-shaped in plan, with one side of the "H" larger than the other (see page 259). The basement of the building occupies the narrower portion of the "H" and the cross-over area. The second floor occurs over the cross-over portion of the "H."

The construction of the basement, all below grade, is hollow concrete masonry units (CMU) for exterior foundation walls; unreinforced, interior CMU bearing walls; concrete columns; and steel columns. The footings are of poured unreinforced concrete.

The first floor construction over the basement area is open web steel joists, bearing on hollow concrete masonry unit walls or steel beams with corrugated steel centering on a 2-1/2 in. concrete slab. The remainder of the first floor, the Fire Department apparatus room and Council room, are 4 in. thick concrete slabs-on-grade.

The second floor construction consists of open web steel joists bearing on CMU walls and steel beams. The beams are supported on steel tubular columns with a 2-1/2 in. thick concrete slab on corrugated steel centering. The roof over the narrower portion of the "H" is of similar construction, while the roof over the apparatus room and Council room consists of steel open web joists with 22 gauge steel roof deck. The joists in this area are generally bearing on masonry walls. The roof over the second floor area consists of open web steel joists supported by steel beams on tubular steel columns with a 1-1/2 in. deep 22 gauge steel deck roof.

Drawings were available on this structure, but they were not detailed to show positive connnection of the various structural elements. Although a visual inspection of this building was made, it was impossible without some destructive removal of finishes, ceilings, wall and the like to verify connections and anchorages. It was found that the steel roof joists in the apparatus room roof were not anchored down to the masonry bearing walls.

The inspection of the basement walls did not reveal any serious structural movements due to either settlement or movement from previous earthquakes. The CMU masonry walls appeared sound. The basement slab was relatively free of cracks. The first story masonry walls, generally of face brick and CMU back-up, were in good structural condition, with only minor cracking noted.

The first floor construction on steel joists appeared rigid and no ruptures in the floor finish — which would indicate excessive movements — were found. The slab-on-grade of the apparatus room was also in good structural condition.

The second floor and roof construction is inaccessible without some destructive removal of finishes.

The drawings did not indicate connections or anchorages of the structural elements. It appeared, however, that the steel beams are connected to cap plates on top of the columns. The construction of the second story roof structure appeared similar in design. Since destructive investigation of specific problem areas was not performed, certain structural assumptions were made.

- Steel deck roofs are welded to steel joists.

- Steel joists are welded to structural steel supports.

- Steel joists of roof bearing on masonry walls are not anchored.

- Steel joists of the second floor and first floor bearing on and encased in masonry walls have standard government-type anchors.

- Steel centering on steel joists for concrete slabs is welded to steel joists.

- Concrete slab on steel joists, where joists are parallel to walls, are anchored into walls.

- Beam connections to steel columns are bearing on cap plate over columns with bottom flanges bolted to cap plate with 2 bolts and a splice plate at the beam webs over the column.

- Steel deck is an "A" type, 1-1/2 in. deep, 22 gauge painted deck with standard weld pattern. Due to the complicated plan configuration of the building and the fact that it is basically a one story structure, the analysis of the distribution of seismically induced loadings was made on the basis of load distribution by tributary areas and not by stiffnesses of resisting elements. Most of the diaphragms are in the flexible to semi-flexible range.

From the visual inspection of the building and the use of the existing drawings it was evident that certain problem areas existed.

- The second story is poorly braced against shear load movements and its integrity will largely depend on the rigidity of the panel wall system.

- The steel joists of the roof on masonry walls are not anchored to the walls to resist either lateral movement or uplift. These joists are spaced 6 feet o.c., which causes the shear capacity of the A-Type metal deck to have a low value.

- Concrete masonry unit foundation walls have not, historically, performed well in earthquakes of major intensity.

- The light steel beam and column construction of the narrow portion of the "H," designed as a future floor, is unbraced and would provide a poor resisting element to seismic movement in the long direction.

- The total masonry box system of the Council room would be a rigid element in the plan of the total building in all directions, while the apparatus room, with masonry walls on all sides except at the double door end, would be rigid in one direction and weak in the other — *if* the roof structure is properly anchored to the walls.

- There is a high variation of rigidities in the various elements of the total building plan and an absence of a separating joint between such dissimilar units. Such conditions would most probably create disastrous effects at the joining of the various portions of the building.

From an analysis based on the assumptions given above (which would require verification in an actual renovation project) the following items of structural retrofit would be needed.

- Roof joists should be anchored to masonry walls in the Council room and apparatus room. This may be accomplished in a number of ways, two of which are shown on page 259. The solution on the left, although more economical than the other, may produce an aesthetically poor appearance. Since the building is approaching 20 years of age the roofing probably needs replacing. This work could be coupled with the replacement of roofing and flashings, the installation of additional insulation, and the anchorage of the joists.

- The open double door end of the apparatus room requires added rigidity inasmuch as only wood framing attached to a steel joist exists above the door heads to the roof. A rigid steel frame of three columns and continuous steel beams could be installed in the opening — well tied to masonry walls and steel roof deck. This would be an improvement, although it would be virtually impossible to provide stability to these walls and allow distribution of shear loads to this end of the building to reduce torsional loads.

- The second story dormitory's roof structure is weakest in the east-west direction. To provide for safety of personnel in this area, a masonry shear wall could replace the panel wall construction of the south wall. The shear wall could be built up from the concrete slab to the underside of the steel angle fascia — securely anchoring the new wall to the roof structure and corner columns. The structure is capable of supporting this wall. The north end has a partial masonry wall. Removing the small windows, adding the required masonry, and grouting and anchoring the two walls together would provide adequate shear walls for the roof structure in the east-west direction. An alternative would be to install exposed X bracing with proper anchorage.

  In the north-south direction, although it is doubtful that total collapse would occur, the lack of rigidity in connections casts serious doubt on the integrity of the structure without depending on the panel to provide some measure of stability. It is difficult to provide stiffness in the structure in this direction. One possibility would be X bracing, exposed on the interior. Another possibility would be to stiffen the beam-column connections, requiring removal of part of the ceiling and column covers. With these structural revisions and additions the second story would be safe from collapse.

- Another deficient area of the building, the south narrow portion of the "H," requires attention. The concrete roof slab offers a stiff diaphragm but also adds a considerable amount of mass/weight to the structure. There exists little structural ability to resist seismic loadings in the north-south direction. A possible solution would be to remove the roof edge at the east wall, grouting and reinforcing the existing masonry wall, and adequately anchoring the roof structure to the wall. At the west end, a similar solution would be possible with the exception of a portion of the wall which is a window panel wall. Be removing this window panel wall, replacing it with masonry, and tying it into the existing masonry and roof structure, a portion of the resistance required for the wing in this direction would be provided.

  At the cross-over of the "H" from this wing a double steel joist and steel beam exists in line with the west wall of the apparatus room and the east wall of the Council room. In the north direction, the beams could carry loads from the cross-over and narrow "H" portion into the walls. However, to derive any assistance from these two walls in the south direction, anchorage of these beams to the walls should be provided. This would involve cutting through walls and ceilings, drilling through walls, and grouting the anchors.

  In the east-west direction, due to the beam-column connections, the structural elements would not adequately resist major earthquake forces. Two possible options exist. The first entails removing the ceiling, partitions, column covers, etc., for access to the column-beam connections. This would be very expensive. The second appears to be less expensive and disruptive. In the first structural bay, window panel walls on the north and south walls would be removed and a grouted reinforced masonry shear wall installed.

- There exists one additional area exhibiting a serious problem. This is the portion of the building that connects the narrow and wide part of the "H" along the south wall of the Council room. The roof at the connection is lower than the roof of the Council room, causing a horizontal load to be imposed somewhat below the top of the Council room wall. This would cause a bending moment in the wall greater than its ability to resist. Since we have recommended anchoring the Council room roof joists to the wall (item 1), cutting into the top of this wall would allow access not only for that work, but also for the grouting of the masonry and the installation of vertical reinforcing bars.

Exterior Architectural Conditions

Glass in curtain wall frames at entry path is judged to be a major potential hazard. The glass is not safety glazing and almost all access passes along this material for an extensive distance. Possible solutions would be to replace the glazing with safety glazing (about 30% of the cost of replacing the entire window wall, or 40% more than replacing with plate glass); blocking up the existing window wall with masonry (60% of the cost of replacing the entire window wall or 20% more than changing to safety glazing); or doing nothing (no cost now). Due to the hazard of flying glass, it is recommended that the glass be replaced. The least expensive alternative is safety glazing, either tempered glass or plastic glazing.

The broadcast tower adjacent to the building is a minor hazard due to its light weight and excellent guying. Solutions are to move the tower to a far corner of the lot (cost would be equivalent to a new installation) or leaving it as it is. The recommendation is to leave it as it is (no cost).

Interior Architectural Conditions

No major or moderate architectural hazards in general.

Exit Path Conditions

Rigid stair connection at the second floor is judged to be a hazard. Although the steel stair braces the second floor steel framing, it is probably not sufficient to prevent movement during a major earthquake. Failure of the stair will be by the stringer buckling, so the stair will probably be usable, although damaged. Solutions are to rework the connection to allow horizontal movement both parallel and perpendicular to the stair (at a fairly high cost) or to accept the potential damage and make no change (no cost). Since the damage does not prevent emergency access and the cost of changing it may be high, the recommendation is to make no change.

Fire Protection

Unmarked natural gas cut-off valve, since it is outside and easily accessible, is a very minor hazard, especially since the fire department is in the building and aware of the valve's location. Solutions are to do nothing at no cost or to place a sign at very little cost. The recommendation is to place a sign since the cost will be small.

Lack of an automatic earthquake motion valve is also judged to be a very minor hazard for the same reasons. Solutions are to add the valve (cost of the valve) or do nothing (no cost). The recommendation is to do nothing.

Rigid gas pipe sleeves are a moderate hazard, as damage at this point will require shutting down the heating system during repairs. Solutions include cutting around pipe to give 1 in. of movement room and packing with sealant (fairly costly, due to the hand work involved), inserting flexible piping on both sides of the sleeve (at a fairly small cost), or doing nothing. The recommendation is to install flexible piping on both sides of the wall. The installation of accordian-type sleeve or a series of flexible elbows would allow movement horizontally both parallel and perpendicular to the wall.

Lack of automatic fire detection system is judged to be a minor hazard since the building is occupied 24 hours a day, 7 days a week. Solutions are to add an automatic smoke and fire detection system throughout the building (costly), establish a regular routine patrol of all sections of the building during office hours (inexpensive), or do nothing (no cost). The recommendation is to establish a regular routine patrol by existing personnel.

Lack of firefighting systems is a moderate hazard, as the fire vehicles carry portable equipment and will usually be available. Solutions are to install an automatic sprinkler system (cost about 5% of total building replacement), furnish and install fire extinguishers in clamp-type holders (moderate cost; about $40 each), or do nothing. The recommendation is to install fire extinguishers, especially in the highly critical areas of communications room, dormitory, armory and apparatus rooms.

Water and Sewer Piping

Non-flexible sleeves and joints are judged to be a moderate hazard. Failure of these systems would not threaten life or operation of those in the building, but would create physical damage and inconvenience. Solutions are the same as those listed under rigid gas pipe sleeve in the fire protection section above. The recommendation here is to install the flexible connections even though they would involve some cost.

Lack of emergency water and sewer facilities is judged to be a minor hazard. Solutions are to stock water and camp sanitary systems or do nothing. The recommendation is to stock water and/or other liquids, but only in quantities sufficient for the operating staff for a short period, perhaps a day.

Lighting and Electrical Systems

Bare tube flourescent fixtures are a minor hazard due to their installation as surface mounted fixtures. Solutions are to replace the fixtures with new ones (about $90 each), add a wire mesh over the tubes (small cost), or do nothing. The recommendation varies with the function of the room. If the room is not critical or used infrequently, do nothing. If the room is heavily used or critical, install new fixtures. If the room is not a finished room but critical, such as the apparatus room, guard the tubes with a wire mesh to protect the occupants from broken shards of glass. Page 261 illustrates one possible way of achieving this and still allowing reasonable re-lamping ability.

The emergency generator and its accessories are not properly anchored, which is judged to be a major hazard. This generator is currently set up to provide emergency power and has been used in this manner. If damage to this generator prevents its operation, the ability of police and fire services to respond will be greatly decreased. Solutions are to install new mounts (10% to 20% of the value of the generator), anchor the existing mounting (small cost), or do nothing. The recommendation is to anchor the existing generator and furnish proper and anchored racks for the accessories and gasoline storage cans. Page 262 shows several approaches for anchoring a generator of this type.

Mechanical Equipment

Unanchored heating equipment is judged to be a moderate hazard, as its failure does not prevent the functioning of the facility. Solutions are to anchor the equipment (relatively inexpensive) or do nothing. The recommendation is to anchor the equipment. Page 261 shows several possible details to achieve this.

Unanchored piping is judged to be a minor hazard, except in the case of gas piping. Solutions are to add diagonal bracing or to do nothing. The recommendation is to add diagonal bracing to all gas piping to diminish the possibility of leaking gas. It is also recommended that bracing be added to all other easily accessible piping. These braces are inexpensive compared with replacing the damaged pipe and cleaning up damage.

Inflexible ductwork is a minor hazard since repairing the duct is the same as changing it, and damage will probably not incapacitate the facility (which is in a temperate area), although it could cause injuries. Solutions are to add flexible duct connections (minor cost) or do nothing. The recommendation is to add flexible connection at the equipment, but this is not as important as mitigating many other hazards. So if funds are not currently available, the recommendation would be to do nothing.

Unanchored ductwork is also judged to be a minor hazard for the same reasons as the unanchored piping. The solutions and recommendations are the same.

Elevators and Dumbwaiters

There are no elevators or dumbwaiters.

Equipment Repair/Garage/Apparatus Room

Equipment repair and garage facilities are not located at this facility. In the apparatus room the bare flourescent tube fixtures are judged to be a minor hazard. The solutions are discussed under lighting and electrical systems, above, and the recommendation is to install wire guards as on page 261.

Lack of fire extinguishers is a moderate hazard as discussed under fire protection, above. The recommendation was to install fire extinguishers with clamp mountings.

Lack of fire detection system is judged to be a minor hazard as discussed under fire protection, above. The recommendation was to establish a routine patrol of the building. Preferably the patrols would be made by someone other than a member of the fire department.

Unbraced unit heater is judged to be a major hazard, due to the possibility of movement shearing the gas piping and the heater igniting the gas. Solutions are to brace the heater, piping and flue, or do nothing. Since the hazard threatens a major element of the building, the fire apparatus, the recommendation is to brace the unit, piping and flue. Methods of bracing piping are shown in the Nonstructural Systems section of this report.

The flue can also be braced in the same way. Flexibility should also be introduced, especially in the gas piping. Bracing the unit itself depends on its suspension system. See page 261 for trapeze-hung equipment. This is ideal for equipment that must be isolated from the structure because of vibration; the trapeze can be braced and the isolated equipment mounted on the trapeze. If the unit heater is suspended as on page 261, then the additional braces must be connected directly to the cabinet, making vibration isolation more difficult, especially if the braces are under tension. Direct brace connections can be similar to brace connections to the trapeze shown on page 261.

Unanchored cabinets and fixed equipment is judged to be a moderate hazard since equipment and personnel could be threatened. Solutions are to add anchorage to these items or to do nothing. The recommendation is to anchor the equipment. Anchorage devices such as illustrated on page 261 could easily be used, as could anchorage for furnishings such as illustrated on page 260.

Unrestrained movable equipment is judged a minor hazard because of its small size (tools and extinguishers to be recharged) and the variable nature of their placement within the space. Solutions are to provide bins, shelves and racks for these items or do nothing. Due to the fluctuating quantity, type and location of these items, the cost in money and space would be considerable. Therefore, the recommendation is to do nothing physical, but to encourage the replacement of such items that are normally stored in cabinets. An attempt should be made to provide mooring for large, portable pieces of equipment, such as jacks and hose racks.

Detention/Dormitory/Locker Room

There are no detention facilities in the building. In the dormitory, unanchored furnishings are judged to be a moderate hazard, as the station is mostly staffed by volunteers and the occupancy of the dormitory is very light. If the station becomes a full-time staffed station, the occupancy of this room becomes heavy and the hazard would be considered major. Solutions are to anchor the furnishings or do nothing. The recommendation is to anchor the furnishings, as this can be done very inexpensively, as shown on pages 260 and 261, with those on page 260 being simpler, cheaper and visually more acceptable.

Unanchored lockers are especially in need of anchoring, as they are tall and therefore prone to toppling. They should be braced at the bottom as shown on pages 260 and 261 and at the top as shown on page 260. Note that the latter illustration is based on the assumption that the lockers back up to a wall or partition. If they do not, the locker tops must be braced to the ceiling or horizontally to each other.

Tile walls and floor in the toilet room are judged to be a moderate hazard due to the low occupancy. If the facility changes to a full-time staff the hazard would be considered major. Solutions are to cover the tile with a new finish, remove the tile, or do nothing. The recommendation would be to do nothing unless the facility changes to a full-time staff, when the tile should be removed, an expensive and lengthy process. If it is possible to bond some tear-resistant material, such as vinyl fabric, to the tile in such a way that it does not lift, this would be the ideal compromise and the recommendation for both volunteer and full-time staff modes. For a relatively low cost the hazard of flying tile shards is removed.

Communications/Watch Room:

In the communications room of the police department the unraised floor is judged to be a very minor problem as the raised floor is recommended to allow easy changes in the electrical connections for communcations systems. Solutions are to install a commercially available accessible floor (very expensive), a plywood raised floor (fairly expensive and time-consuming), or to do nothing. The recommendation is to do nothing unless the communications requirement expands greatly. In that case, a new communications room will be required to furnish the necessary space. This should then be furnished with an accessible floor.

Bare tube flourescent fixtures are judged to be a moderate hazard, as their failure can harm the occupants and possibly damage the equipment. Solutions are to replace the existing fixtures, put wire mesh guards on the fixtures, or do nothing. The recommendation is to replace the existing fixtures with new fixtures having anchored plastic lenses (cost about $90 per fixture), since this is a critical area.

Lack of fire detection and extinguishing systems is judged the same as discussed above, with the same solutions and recommendations. The staff of the communications room would seem a logical choice for the fire detection patrol routine.

Lack of anchorage for cabinets and communications equipment is judged to be a major hazard. The equipment can be easily damaged by overturning or by being struck by heavy, sliding objects. The operators can be injured by flying and sliding objects. Movement of equipment can sever electrical wiring creating an electrical hazard. Solutions are to anchor and brace cabinets, add shelf ledges, anchor equipment, or do nothing. The recommendation is to do everything possible to anchor and brace the equipment, including shelf ledges. Pages 260 and 261 show possible methods of anchorage for low equipment and page 260 shows possible methods of anchoring the tops of higher equipment such as consoles and file cabinets. If a wall is not accessible to brace the top, as is not unusual for reception counters or radio consoles, positive anchorage as shown on page 261 can resist overturning. Shelves can be made safer by adding a lip, such as a quarter round strip, to the top, front edge, to prevent items stored on them from sliding off. All of these details are inexpensive, and when the cost of replacing the equipment is considered it is obvious that all communications equipment should be anchored.

Lack of hardening for the enclosure is judged to be a moderate hazard. Although ease of access to the area can be a great threat to the equipment and operators, historically, the locale has had extremely good relationships with the police, and the safety professionals are not greatly concerned with this risk. Solutions are to block in the area between the public and communications area with masonry (about $5 per square foot of wall), add an aluminum frame with safety glazing between these areas (about $15 per square foot of wall), or do nothing. The recommendation would be very difficult here due to the conflicts between cost, appearance and the need as seen by the police department and the city. If cost and need controlled, the recommendation would be to block in the area. If appearance and need controlled, the recommendation would be to install the aluminum frame. If cost and appearance controlled, the recommendation would be to do nothing.

Briefing/Day Room

There is no specific briefing room. In the day room, the lack of furniture anchorage is judged to be a minor hazard, due to the volunteer nature of the department. Solutions are to anchor the furnishings or do nothing. The recommendation is to anchor the furnishings as shown on page 260, since the cost of these details in time and materials is small.

The glazing is judged to be a moderate hazard. The volunteer nature of the department keeps the occupancy low, but flying shards can do great injury. If the department goes to full-time staff the hazard would be major. Solutions are to replace the existing glass with safety glass or do nothing. The recommendation is to replace the existing glass with safety glass, especially if the staff becomes full-time.

Evidence Storage/Records/Emergency Medical Storage

The lack of latches on some file cabinets is judged to be a minor hazard as the dumping of their contents does not greatly hinder operations, and in their present location would not cause injuries. Solutions are to add latches to the drawers or do nothing. The recommendation is to add latches as a continuing process of upgrading. As new files are required, they should be obtained with integral positive latches. Unfortunately card files are not available with these latches. For these files, and for older, non-latched file cabinets, a pivot-type latch can be installed to prevent the drawers from opening. These latches are not fast operating, so they will probably be added only to low-usage files. One type of pivot is shown on page 260.

Armory (Police Station)

Lack of protection for adjacent spaces is judged to be a major hazard. If, during a fire or explosion, the armory were to be detonated, the adjacent personnel, including the communications operators, would be injured, and equipment damaged. Solutions are to shield the room, including ceiling (cost of several thousand dollars), relocate the armory (cost of new shelving, but less convenient location), or do nothing. The recommendation is to relocate the armory, since there does exist a satisfactory space (old detention cells no longer in use).

Lack of ventilation is also judged a major hazard. If the ammunition did explode, tear gas grenades and powder smoke would be trapped in the armory, leaking slowly into adjacent spaces and making them unusable until the gas has dispersed. Solutions are to provide forced ventilation (cost $150 to $200, depending on wall or roof access), provide natural ventilation (cost $50 for new louver in existing opening), or do nothing. The recommendation is to provide natural ventilation in the new armory location.

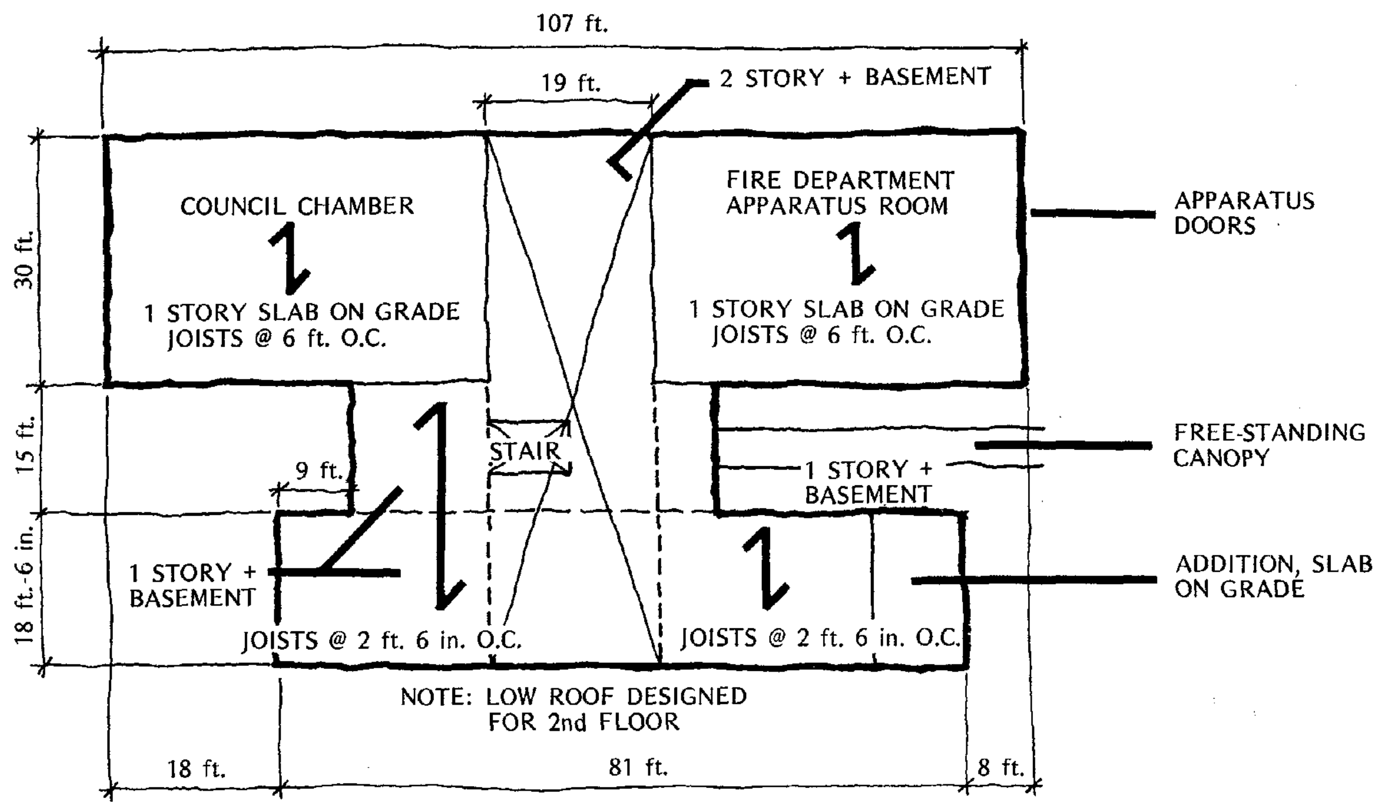
CONCLUSION

It is not to be assumed that the recommendations outlined above will provide a facility that fully complies with all requirements for seismic design. Nor should it be assumed that the building so retrofitted will not sustain serious damage under a major earthquake. The recommendations are an attempt to provide a minimum of safety to the personnel and equipment of this critical building during an earthquake and to allow functioning of the required fire and police services.

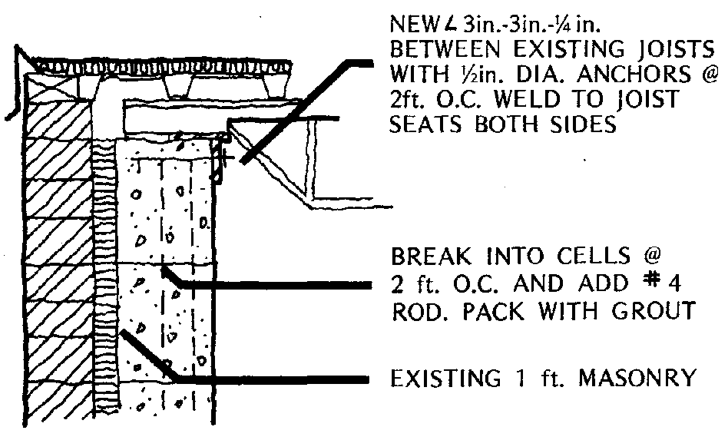
It is also not to be presupposed that the total renovation would be economically feasible. To provide an evaluation of the feasibility it would be necessary to develop a detailed economic study including computing the cost of a new facility. This cost would be compared with the detailed cost of a renovation. From this detailed information, a decision can be made by the owner or by the public.

It may be unlikely that all problems would be corrected except in the case of a major renovation. If the work is primarily for seismic renovation, a priority list should be presented to guide the owner in allocating the budget. The initial priority list for this case study would be as follows:

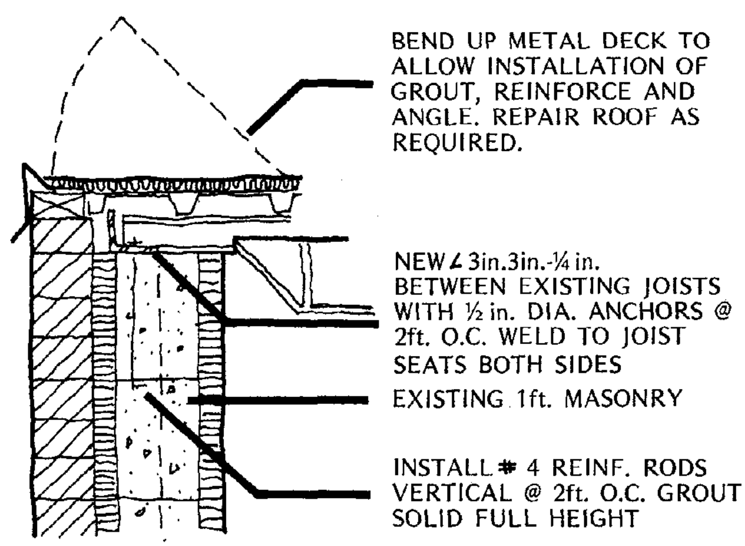
1. Communications Room — Cabinet and equipment anchorage. Structural corrections.
2. Armory — Relocate and provide ventilation.
3. Apparatus Room — Brace unit heater, piping and flue. Structural corrections.
4. Other major hazards such as anchorage of emergency generator.
5. Other hazards.



1st FLOOR PLAN

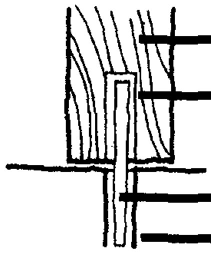


JOIST CONNECTION IF THE ROOF CAN NOT BE REMOVED

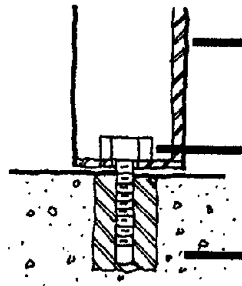


JOIST CONNECTION IF THE ROOF CAN BE REMOVED

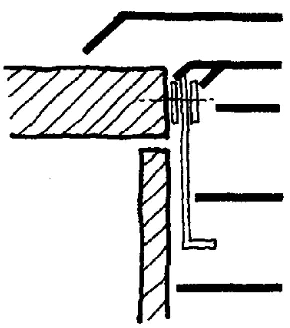
CASE STUDY: SEISMIC RENOVATION



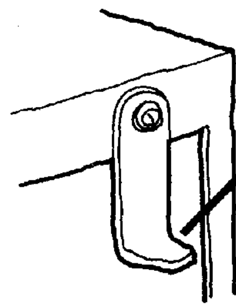
WOOD OR TUBE FURNISHINGS



METAL ANGLE FURNISHINGS



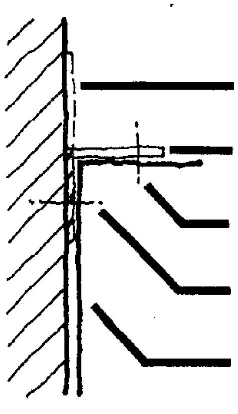
SECTION



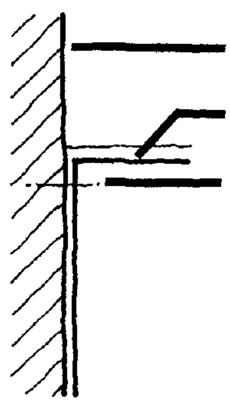
PERSPECTIVE

RETROFIT STOP FOR NON-LATCHING FILE DRAWERS

NOTE: MOST APPLICABLE TO LOW FREQUENCY USAGE CABINETS

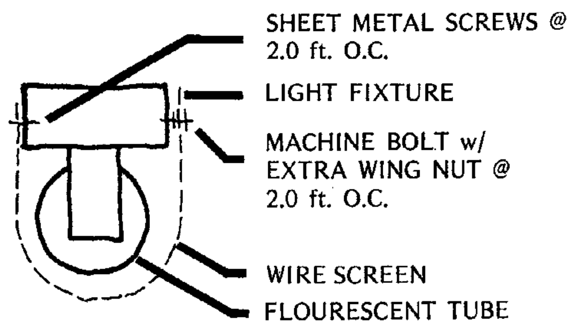


NON-CONTINUOUS STRUCTURE

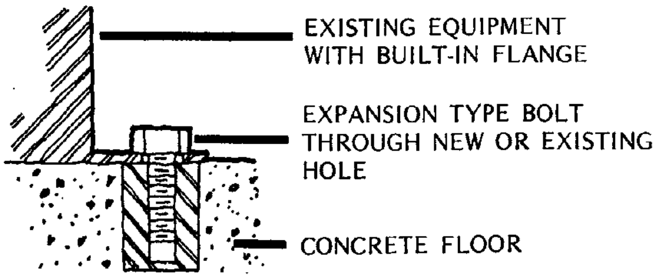


CONTINUOUS STRUCTURE

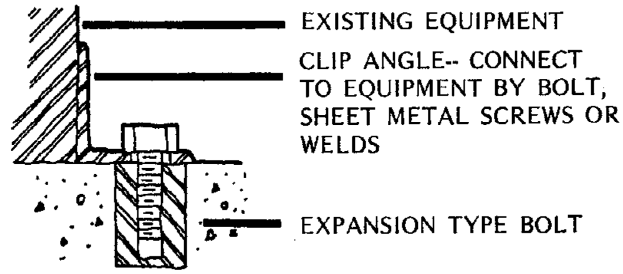
ANCHORAGE/CONNECTIONS FOR FURNITURE & EQUIPMENT



SCREEN GUARD FOR BARE TUBE FIXTURES

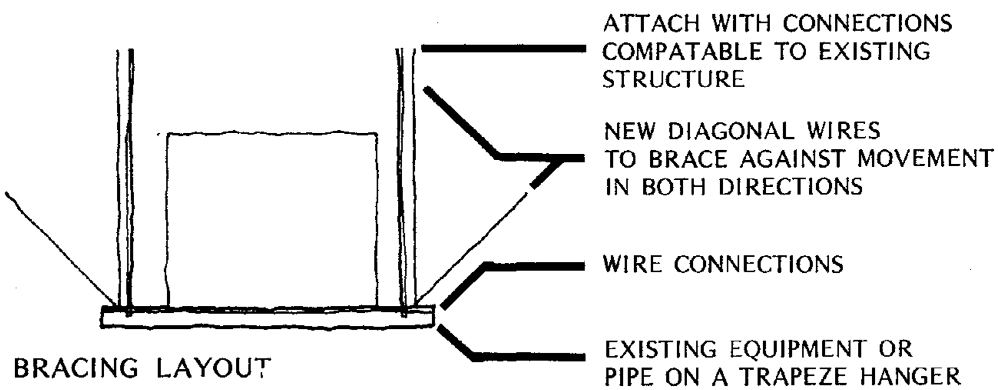


WITH A BUILT-IN FLANGE

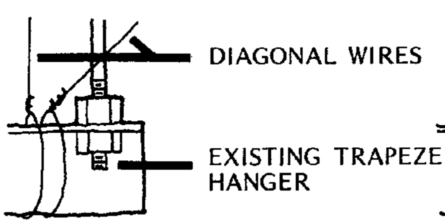


WITHOUT A FLANGE

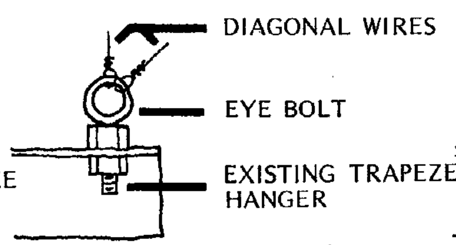
EXISTING EQUIPMENT ANCHORAGE



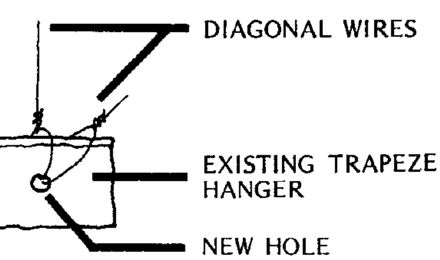
BRACING LAYOUT



WRAPPED CONNECTION



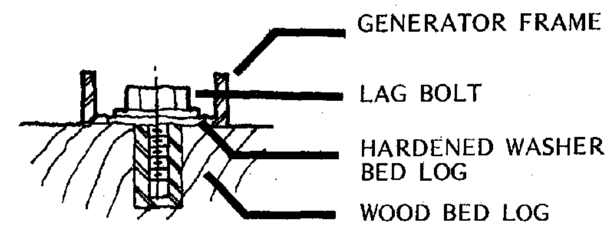
EYE BOLT CONNECTION



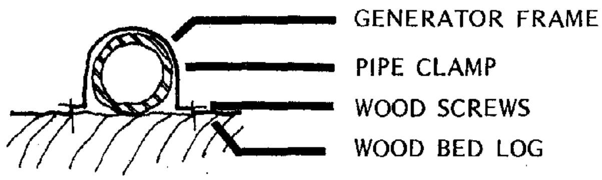
DRILLED HOLE CONNECTION

SUSPENDED EQUIPMENT BRACING

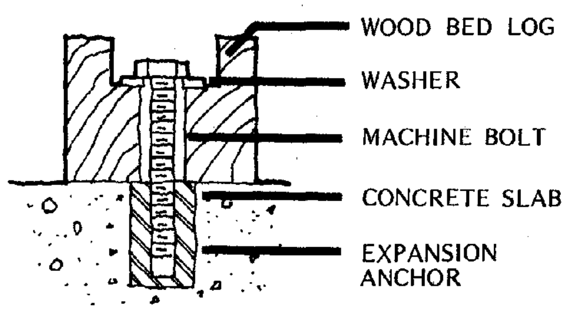
EQUIPMENT ANCHORAGE BRACING



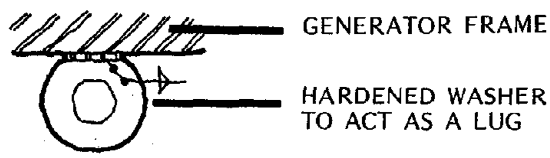
HEAVY GENERATOR ATTACHMENT



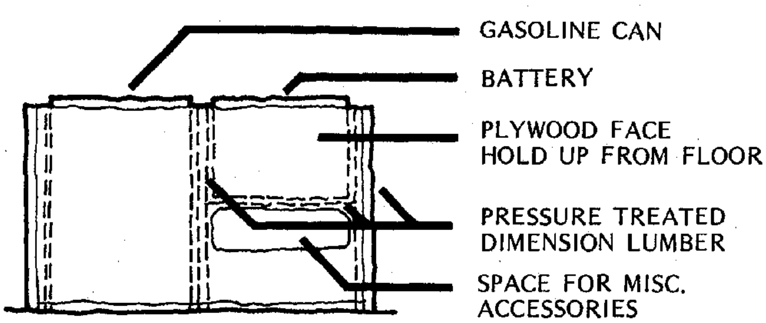
LIGHT GENERATOR ATTACHMENT



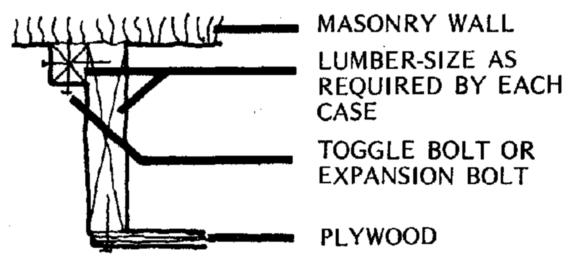
WOOD BED LOG ATTACHMENT



LUG ADDITION DETAIL



FUEL AND BATTERY RACK



FUEL RACK ATTACHMENT

EMERGENCY GENERATOR DETAILS

5 MULTI-HAZARD DESIGN

INTRODUCTION

Life safety is an issue that is gaining increasing attention from the public as well as from design professionals. Shocking disasters such as the San Fernando Earthquake in 1971 have dramatically demonstrated the need for more effective strategies for disaster mitigation.

Recent earthquake research has gone beyond improvement of structural design techniques. As a result, attention is being focused on critical institutions and agencies such as fire departments, police departments and hospitals, which provide critical disaster services. Higher protection standards are being specified for these building types and designers are looking for better ways to protect critical resources and services to ensure their continued operational capability during disasters.

In high risk seismic zones, the lessons of experience usually come with sufficient frequency to reinforce the need for seismic protection. In the vast moderate risk areas, public officials and design professionals alike often must defend such expenditures to a public that can more clearly see current needs than future possibilities. The potential for tragedy is very great if a community is unprepared for a disaster such as an earthquake.

A basic premise of this chapter is that provision of seismic protection in all risk zones can be made more "acceptable" to public officials and taxpayers if additional benefits can be shown for these design features.

This leads to consideration of how seismic design features can provide protection against other natural and man-made hazards. This is referred to as a "multi-hazard design approach."

The development of hazard protection standards has been the focus of much attention in recent years. The correlation of these standards, however, has been relatively unexplored and is one of the focuses of this chapter. It is an area that is prime for future in-depth investigation.

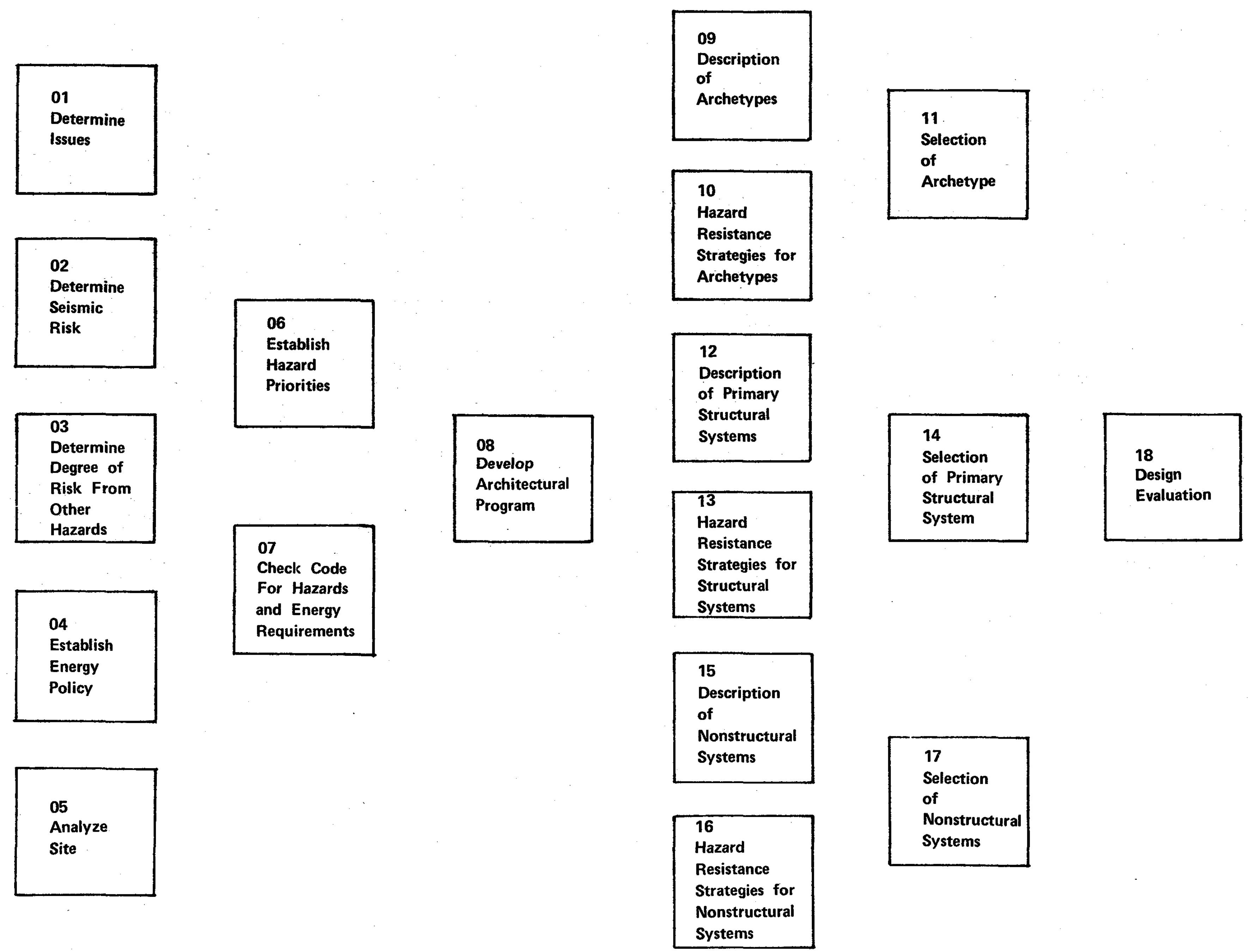
The principal focus of this chapter is the development of a design process and tools to aid the designer in applying and integrating locally relavent multi-hazard design standards into the conceptual design of a fire or police facility. It is felt that the cost and difficulty of developing hazard protection in a building will be greatly reduced if the designer is able to develop basic multi-hazard resistance during the early design phases rather than relying on engineering corrections made after the architectural design concept has been developed.

Design can be considered a process of creating or discovering alternative design concepts and solutions to problems and then analyzing them in order to select the one best suited to the needs of the individual problem. A major facet of the design process thus becomes an act of "selection." The concept selected will not be the "solution" to the problem but rather will provide the starting point or the initial direction for the development of the design, which must be adapted to local needs and conditions. The better the selection, the fewer the functional and financial compromises that will be required in the later design stages to compensate for initial concept inadequacies.

Achievement of a high quality design product that "fits" the needs of the client does and always will require an enlightened and interested client and a skilled design team. Nevertheless, design quality and degree of "fit" of the design will be enhanced by, first, clarification and expansion of the criteria used for selection among the competing concepts, and, second, expansion of the range of potential solutions under consideration.

Clarification and expansion of criteria are probably self-evident; clearly defined goals facilitate

MULTI-HAZARD DESIGN PROCESS



the solution. When the range of potential solutions is expanded, the likelihood of finding a solution that is a "good fit" is increased. The logic is that the better the "fit" of the concept to all the contextual problems, the fewer the corrective and compensating design features that will be required during later detailed design stages.

MULTI-HAZARD DESIGN PROCESS

The process recommended for multi-hazard design is shown in the accompanying schematic work plan. Each of the eighteen steps is discussed below.

01. DETERMINE ISSUES

Procedure:

1. Study the design problem.
2. Ask the six fundmental questions of "task analysis."

   What has to be done? (needs)

   Why has it to be done? (reason)

   When has it to be done? (time)

   Where has it to be done? (place)

   By what or whom has it to be done? (means)

   How has it to be done? (method)

3. Provisionally identify the needs that the design is to satisfy. Which of the needs are critical? — very important? — important? — desirable?
4. Identify and analyze the "Primary Functional Need" (the need that if not properly satisfied makes the fulfillment of all the other needs pointless).
5. Identify the expectations of the client and his rationale.

Resources:

Association of Washington Cities. *Design of Fire Stations.* Seattle: University of Washington, 1965.

International Fire Service Training Association. *Fire Department: Facilities, Planning and Procedures.* Oklahoma State University, 1970.

National Clearinghouse for Criminal Justice Planning and Architecture. *Guidelines for the Planning and Design of Police Programs and Facilities.* Champaign: University of Illinois, 1973.

The Circul-Air Corporation. *Fire Station Design.* 1740 W. Big Beaver, Troy, Michigan 48084, various issues.

Fire Station Design is a compilation and publication of recent fire station designs submitted by architects. Typically, each fire station is illustrated by a facade photograph and a scale floor plan plus descriptive text. The text is basically descriptive and not critical as is the case with the University of Washington publication listed above. The published examples use Circul-Air hose dryers and so this selection of designs will not provide examples or illustrations of various methods for handling hose towers or other less energy-intensive hose drying methods. The greatest strength of this publication is that it provides a substantial collection of recent station designs that may be critically analyzed to explore alternative planning approaches.

National Fire Protection Association. *Fire Stations Bibliography*, research reports and books.

National Fire Protection Association. *National Fire Codes*, 13th Edition (see section 10, chapter IV for design criteria for the fire station).

02. SEISMIC RISK

Procedure:

1. Determine the degree of seismic risk in the project locale. Review general and local seismic risk maps. Additional information sources are listed below.

2. Identify special roles or functions that the fire or police station might assume during a seismic disaster. This information will be incorporated into the architectural program in the design process step 8.

Resources:

Building Codes.

Environmental Protection Agency. *Environmental Impact Analysis for Nuclear Power Plants.*

Detailed seismic risk data may be obtained from the EPA. An extensive grid of nuclear power plant sites exists in many regions. Environmental analysis of a 200-mile radius is required.

Local State Department of Civil Defense. *Hazard Analysis* [for the state].

Each State Department of Civil Defense is required to prepare an analysis of natural and man-made hazards in the state.

The Veterans Administration. *Soils Investigation Reports for VA Hospitals.*

Detailed geologic and soil investigations have been prepared for all VA hospital sites. If one exists in the project locale, it may provide a more detailed indication of local conditions when interpreted by an expert. VA has also developed seismic risk maps for the entire U.S.

03. DETERMINE DEGREE OF RISK FROM OTHER HAZARDS

Procedure:

1. Determine the degree of risk to the project from other natural and man-made hazards, e.g., high winds, fire, explosion, flood, civil disorder (security), and radioactive fallout. Additional information sources are listed below.

2. Identify special roles or functions that the fire or police station will assume during the disasters identified above. This information will be incorporated into the architectural program in the design process step 8.

Resources:

Building Code.

Defense Civil Preparedness Agency. *High Risk Areas for Civil Preparedness for Nuclear Defense Planning Purposes, Manual TR-82.* Washington, D. C.: DCPA, April 1975.

Defense Civil Preparedness Agency. *Multi Protection Design, Manual TR-20 (Vol. 6).* Washington, D. C.: DCPA, December 1973.

Local Fire Department

The local fire department will be able to provide data on local fire risk factors and can help make useful projections.

Local State Department of Civil Defense. *Hazard Analysis* [for the state].

A general overview of a variety of natural and man-made hazards. Risk maps are included. Prepared by each state and available from each State Department of Civil Defense.

04. ESTABLISH ENERGY POLICY

Procedure:

1. Define the energy conservation goals, needs or requirements for the project. There are a variety of ways for stating this goal. Some examples follow:

    Building "energy budget" based on users, functional requirements, location, etc.

An annual fuel and power budget based on fuel price assumptions.

General goal statements such as "obtain as much heating and cooling as feasible by use of solar technology" and "incorporate as many 'passive design' energy conservation features as feasible."

2. Describe any requirements for energy self-sufficiency during normal and/or disaster situations. List any alternative methods for satisfying that needs.

Resources:

American Institute of Architects. *AIA Energy Notebook.* A continually updated information service.

AIA Research Corporation. *Energy Conservation in Building Design.* Washington, D. C.: Government Printing Office, 1974. Available from the AIA Publications Marketing Department, 1735 New York Avenue, N. W., Washington, D. C. 20006.

AIA Research Corporation. *Solar Dwelling Design Concepts.* Washington, D. C.: Government Printing Office, 1976. Available from the AIA Publications Marketing Department, 1735 New York Avenue, N. W., Washington, D. C. 20006.

Griffin, C. W. *Energy Conservation in Buildings.* Washington, D. C.: American Institute of Architects, 1975.

National Solar Heating and Cooling Information Center, P. O. Box 160, Rockville, Maryland 20850.

U.S. Department of Energy, P. O. Box 62, Oak Ridge, Tennessee 37830.

Note: This design concern is currently undergoing dramatic changes and there exists a large amount of information and documents, and new resources are being added constantly.

05. ANALYZE SITE

Procedure:

1. Select the building site.

2. Analyze the building site.

Resources:

American Insurance Association, formerly the National Board of Fire Underwriters, Engineering and Safety Service. *Fire Department Stations and Companies — Location, Distribution and Response. Special Interest Bulletin No. 176*, Revised February 1975.

Lynch, Kevin. *Site Planning*, 2nd Edition. Cambridge, 1972.

Local geological and soils investigations.

06. ESTABLISH HAZARD PRIORITIES

Procedure:

1. Review the risk factors for the various hazard types. Review energy policy.
2. Rate each in terms of local needs and priorities.

PRIORITY FACTOR

HAZARD	PRIORITY FACTOR
EARTHQUAKE	
FIRE	
EXTREME WINDS	
FLOOD	
SECURITY	
HIGH SOUND	
RADIOACTIVE FALLOUT	

07. CHECK CODE FOR HAZARD AND ENERGY REQUIREMENTS

Procedure:

1. Identify all applicable building codes and local requirements.

2. Identify all applicable mandatory standards and suggested guidelines issued by governmental, financial, regulatory or insurance organizations.

3. Assemble these materials and correlate them with other project requirements that will be assembled in the architectural program in step 8.

4. General comments: Building codes are adopted by state and/or local governments. They prescribe minimum building standards to protect health, safety and property. It is recommended that codes applicable to each project be identified early in the project and that building officials be contacted in order to benefit from their assistance in interpreting the standards for each particular application.

   Codes are sometimes general and are usually minimum standards. Sometimes they are incomplete and do not provide design standards for protection against known or discovered hazards in a particular area. In such a situation appropriate design standards or guidelines must be identified. Some suggestions are listed below.

Resources:

American National Standards Institute. *Building Code Requirements for Minimum Design Loads in Buildings and Other Structures*, ANSI A 58.1. See the latest edition.

International Conference of Building Officials. *Uniform Building Code*. Whittier, California: ICBO, see the latest edition.

Local Building Officials.

   It is recommended that local building officials be contacted early in the project in order to benefit from their assistance in interpreting the standards for a particular application.

National Fire Protection Association. *National Fire Codes*, in 16 volumes. Boston: NFPA, see the latest edition.

08. DEVELOP ARCHITECTURAL PROGRAM

Procedure:

1. The materials and decisions that have been developed in the previous design steps will now be assembled into a comprehensive description of the problem(s) to be solved. Emphasis has been on the investigation of non-traditional roles and requirements related to the key

role played by the fire and police departments during seismic and other disasters. This information has traditionally been recorded by the architect in a document known as the "architectural program," which should be prepared at this time.

2. Check for omissions. Because of the vast amount of information contained in an architectural program, it is very useful to develop a clear, comprehensive index of materials. This will serve as a check list to ensure that all necessary areas of inquiry have been covered. The materials noted below are very useful for this purpose.

3. Check emphasis. Not all things are of equal importance in a project. Priorities should be rechecked with the police and fire departments.

Resources:

Koberg, Don and Bagnall, Jim. *The Universal Traveler*. Los Altos, California: William Kaufmann Inc., 1974.

Pena, William M. and Focke, John W. *Problem Seeking: New Directions in Architectural Programming*. Houston: Caudill Rowlett Scott, Architects and Engineers, 1969.

White, Edward T. *Introduction to Architectural Programming*. Tucson: Architectural Media (P. O. Box 466A, Tuscon, Arizona 85717), 1972.

09. DESCRIPTION OF ARCHETYPES

Procedure:

1. Develop sketch plans for the project based on the archetypes.

2. Rank the archetypes in terms of functional suitability for the particular project.

Definitions:

Archetype — An archetype can be defined as "a conceptual model after which other similar things are patterned." Archetype is used in the present context to describe different patterns for organizing the various functional areas of the building.

Archetype Variations — If an examination is made of a large number of building plans for a building type such as a fire or police station the variety of solutions presented can be overwhelming. These plans can, however, be simplified by ignoring the complicated arrangements of rooms and focusing on the functional blocks of spaces. It is quickly apparent that all of the diverse plans can fit into basic planning patterns. Each of the plans thus represents a variation on one of the archetypes. These variations involve things such as room arrangement details, but within an archetype family there are common characteristics. These common characteristics serve as the basis for the multi-projection analysis of archetypes presented later in this chapter.

The Archetype as a Design Tool

Each client is unique. It would be a rare occurrence to find clients with identical needs, modes of operation, size of operations, attitudes toward the environments or site conditions. Each building is thus unique to the degree that it takes into account these individual differences. Both architects and clients alike reject "planbook" schemes because they cannot take into account unique local conditions or situations.

The design method presented here should not be confused with the "planbook" method, in which a design choice is made from a narrow range of predetermined solutions. The archetypes that are presented here are used to describe a range of conceptual beginnings for the design process, and are not presented as designs from which to choose. The archetypes are used to explore broad concepts and their important implications prior to tackling the detailed issues that can have a tendency to obscure the larger conceptual issues.

Fire Station Archetypes

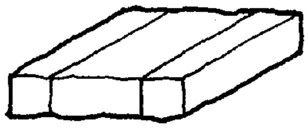
The fire station archetypes discussed below were developed from a review of existing fire station designs. During the analysis, recurring patterns in the organization of the major functional elements of the building (the apparatus room, dormitory, operational support areas, administrative offices, etc.) were identified.

Three key organizational variables were defined and used to classify the archetypes:

- Plan Organization — Are there two functional blocks set one next to the other, or is there one functional area sandwiched between two others? Several basic patterns emerge for each building type.
- Functional Zoning — Are the functional components of the building stacked vertically or spread out horizontally in reference to one another, or is the pattern a combination of both?
- Apparatus Circulation — Apparatus make special demands on fire station organization. Two basic approaches were identified, drive-through and back-in.

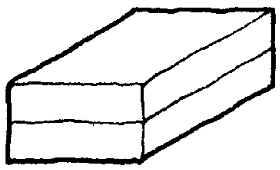
After analyzing approximately 150 fire station plans, five basic planning patterns or concepts emerged. Archetypes and their descriptions follow.

"Sandwich"



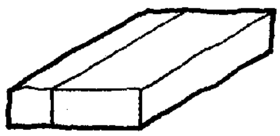
Plan Organization: Operational and living areas are located on both sides of the apparatus room.
Functional Zoning: Horizontal.
Apparatus Circulation: Drive through. Can also be used for back-in parking.

"Over and Under"



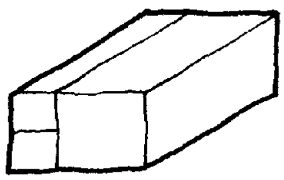
Plan Organization: Operational and living areas are located above apparatus space.
Functional Zoning: Vertical.
Apparatus Circulation: Drive through. Can also be used for back-in parking.

"Side-by-Side"
One-Story



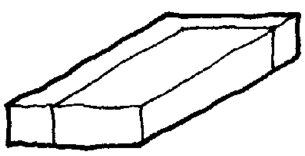
Plan Organization: Operational and living areas are in a single story block located at one side of the apparatus room.
Functional Zoning: Horizontal.
Apparatus Circulation: Drive through. Can also be used for back-in parking.

"Side-by-Side'
Two-Story



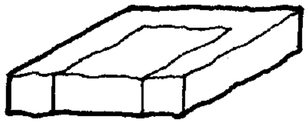
Plan Organization: Operational and living areas are in a two-story block located at the side of the apparatus room.
Functional Zoning: Horizontal and vertical.
Apparatus Circulation: Drive through. Can also be used for back-in parking.

"L-Plan"



Plan Organization: Operational and living areas are wrapped around two sides of the apparatus room.
Functional Zoning: Horizontal.
Apparatus Circulation: Back-in only.

"U-Plan"



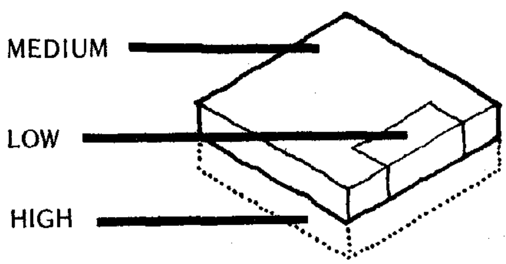
Plan Organization: Operational and living areas wrap around three sides of the apparatus room.
Functional Zoning: Horizontal (typically).
Apparatus Circulation: Back-in only.

Police Station Archetypes

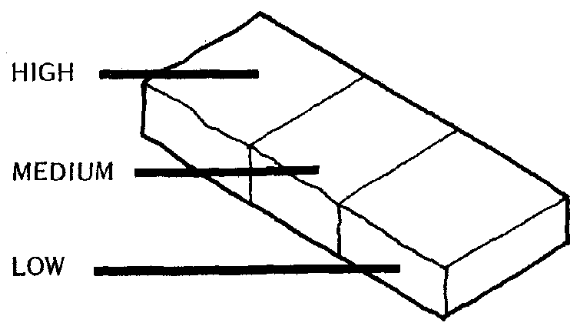
The police station archetypes were derived from the various possibilities of grouping the three major components of a police station: the low security, medium security and high security areas.

In the schematic design phase, it is necessary to identify archetypes that describe the range of conceptual approaches to the police station design. Based on a review of the literature, four archetypes for police stations were identified.

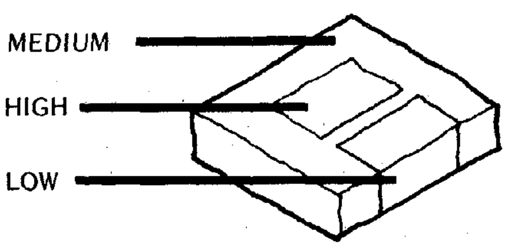
DEGREE OF SECURITY



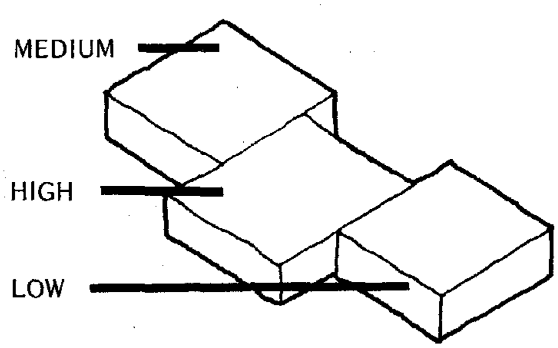
OVER & UNDER/COMPACT



LINEAR/SEMI-COMPACT



DOUGHNUT/COMPACT



BROKEN LINEAR/COMPLEX

10. HAZARD RESISTANCE STRATEGIES FOR ARCHETYPES

Procedure:

1. Evaluate each archetype in terms of form and organization characteristics.
2. Identify potential earthquake resistance strategies for the archetypes.
3. Evaluate the archetypes in terms of overall hazard resistance.

Form and Organization Characteristics of the Archetypes

The "form and organization characteristics" used were derived from a study of police and fire stations as building types and from a recognition of the politive or negative consequences of having or not having certain features in the building design. These characteristics are the following:

1. Symmetry — Building form that reduces the torsional effects on the structure.
2. Uniformity — Building form that reduces the need for non-uniform segments or areas within the building.
3. Massing — Building form that reduces the need for recesses, reentrant corners, offsets, etc.
4. Continuity — Building form that effectively increases the potential for continuity of structure and non-structure throughout the building.

SEISMIC DESIGN STRATEGIES

HAZARD RESISTANCE STRATEGIES

ARCHETYPES	SYMMETRY	UNIFORMITY	MASSING	CONTINUITY							
FIRE STATIONS:											
SANDWICH	○	●									
OVER AND UNDER	●			○							
SIDE BY SIDE ONE STORY	○	○									
SIDE BY SIDE MULTI–STORY	○										
L PLAN	○										
U PLAN	○										
POLICE STATIONS:											
OVER AND UNDER COMPACT	●	●	●	●							
DOUGHNUT/COMPACT	●		●								
LINEAR/SEMI COMPACT		●	●	●							
BROKEN LINEAR											

● HIGH POTENTIAL STRATEGIES

○ POSSIBLE STRATEGIES

MULTI-HAZARD POTENTIALS

ARCHETYPES

HAZARD RESISTANCE STRATEGIES	EARTHQUAKE	FIRE	EXTREME WINDS	FLOOD	SECURITY	HIGH SOUND	RADIOACTIVE FALLOUT
SYMMETRY	●	○	●		●		
UNIFORMITY	●					○	○
MASSING	●	○		○	○	○	●
CONTINUITY	●	●	●		●	●	●

● MUTUAL BENEFITS

○ POSSIBLE BENEFITS

✶ CONFLICTS

11. SELECTION OF ARCHETYPE

Procedure:

1. Review the results of step 9. The various archetypes have been evaluated in terms of functional suitability and adaptability to local needs, priorities and site conditions.

2. Review the results of step 10. The various archetypes should be evaluated in terms of potential hazard resistance strategies, with consideration of local hazards and priorities.

3. The archetype selection can now be made by client and architect on the basis of established priorities and findings.

Discussion:

Schematic design is an extremely important step in the design process. The physical planning or design concept that is developed or adopted at this point sets the stage, establishes the logic, and fixes the limits within which detailed space and equipment planning must take place. The concept should "fit" the needs of the project. A "bad fit" can be overcome through compensating changes during the design development and later stages; however, this may mean a more expensive and less effective solution.

12. DESCRIPTION OF PRIMARY STRUCTURAL SYSTEMS

Procedure:

1. Develop conceptual plans for the project based on the primary structural systems.

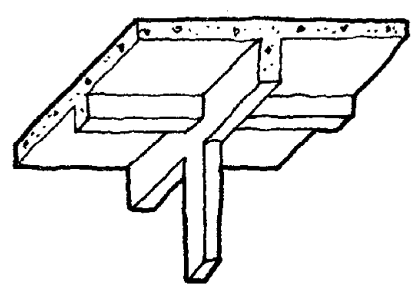
2. Rank the primary structural systems in terms of functional and economic suitability for the particular project.

Discussion:

The following nine structural systems have been chosen for detailed examination. They have been selected as representative of common options available and in use today.

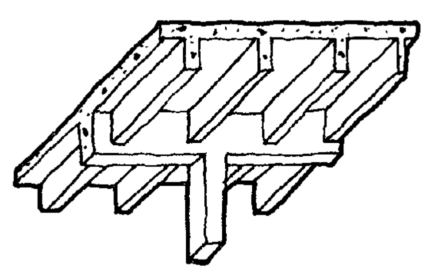
SYSTEM 1. HEAVY CONCRETE

Floor and roof-reinforced slab (2-way), beams, girders and columns.



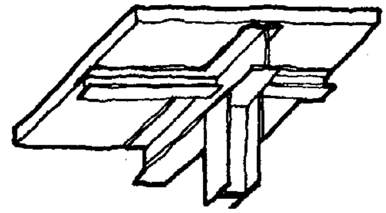
SYSTEM 2. CONCRETE

Concrete pan joist one-way ribs, reinforced concrete girders and columns.



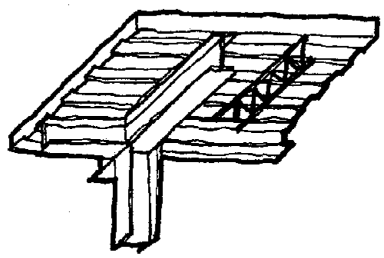
SYSTEM 3. HEAVY STEEL

Steel composite floor deck with 2-way reinforced concrete slab, structural steel beams, girders and columns.



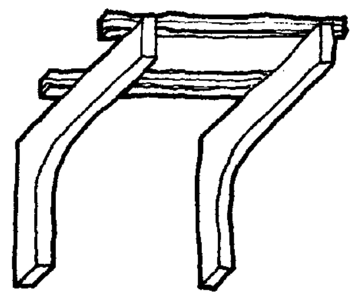
SYSTEM 4. LIGHT STEEL

Steel columns and beams with open-web steel joists supporting a metal floor deck with concrete wearing surface and a metal roof deck with insulation board covering.



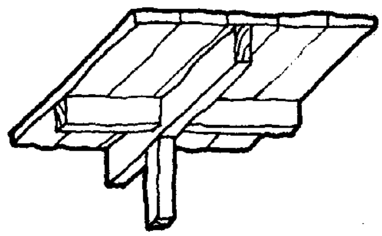
SYSTEM 5. STEEL RIGID FRAME

Steel rigid frame, steel purlins and steel roof deck with insulation board covering.



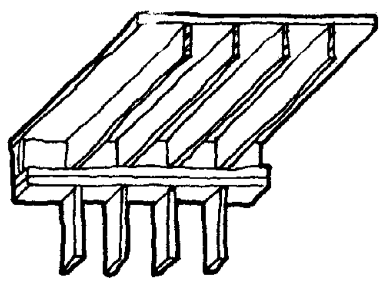
SYSTEM 6. HEAVY TIMBER

Heavy timber beams, girders, columns, and floor deck.



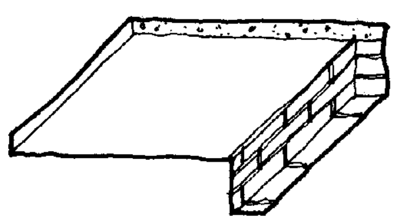
SYSTEM 7. LIGHT WOOD

Wood joists and stud bearing walls.



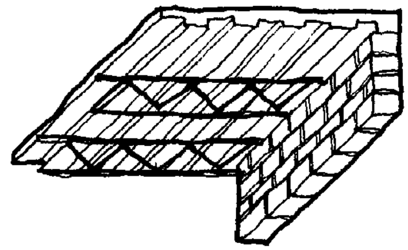
SYSTEM 8. REINFORCED MASONRY

Walls are vertically and horizontally reinforced and detailed to provide structural continuity with floors and roofs which are 2-way reinforced concrete slabs.



SYSTEM 9. MASONRY

Walls, ordinary construction with reinforcement every third course. Floors-open web steel joists, steel deck and concrete wearing surface. Roof as floor, except insulation board instead of concrete.



13. HAZARD RESISTANCE STRATEGIES OF SELECTED STRUCTURAL SYSTEMS

Procedure:

1. Evaluate each structural system in terms of the selected characteristics.
2. Identify potential earthquake resistance strategies for structural systems.
3. Evaluate the structural systems in terms of overall hazard resistance.

Characteristics of the Structural Systems

The structural system characteristics used were derived from a recognition of certain positive and negative consequences of having or not have certain qualities in the selected structural system. These characteristics are the following:

1. Reduced Mass — A reduction in mass decreases the inertial force that must be resisted.
2. Uniformity — The structural system performs in a uniform manner, not as independent systems or elements.
3. Continuity — The structural system provides a degree of continuity throughout the building.
4. Ductility — The structural system has the ability to absorb repeated loadings from the ground motion.
5. Redundancy — The structural system minimizes critical elements that could cause collapse if they failed.
6. Diaphragm — The structural system provides a proper transfer of loads to the vertical resisting members.
7. Connectivity — The structural system acts as a total unit through proper connection and joint design.

SEISMIC DESIGN STRATEGIES

STRUCTURAL SYSTEMS	REDUCED MASS	UNIFORMITY	CONTINUITY	DUCTILITY	REDUNDANCY	DIAPHRAGM	CONNECTIVITY				
	HAZARD RESISTANCE STRATEGIES										
CONCRETE, HEAVY		●	●		●	●	●				
CONCRETE		●	●	○	●	●	●				
STEEL	○		○	○	●	●	○				
STEEL, LIGHT	●		○	●	●		○				
STEEL, RIGID FRAME	●	○	○	●	●		○				
TIMBER, HEAVY	●	●	●	●	●	○	●				
WOOD, LIGHT	●	●	●	●	●	○	●				
MASONRY, REINFORCED	○		○		○	●					
MASONRY	○				○						

● HIGH POTENTIAL STRATEGIES

○ POSSIBLE STRATEGIES

MULTI-HAZARD POTENTIALS

STRUCTURAL SYSTEMS

HAZARD RESISTANCE STRATEGIES	EARTHQUAKE	FIRE	EXTREME WINDS	FLOOD	SECURITY	HIGH SOUND	RADIOACTIVE FALLOUT
REDUCED MASS	●	✷	✷		✷	✷	✷
UNIFORMITY	●		○				
CONTINUITY	●	●	●	●	●	○	●
DUCTILITY	●		○		○		
REDUNDANCY	●	●	●	○	●		
DIAPHRAGM	●	○	●		○	○	○
CONNECTIVITY	●	●	●	●	○		

● MUTUAL BENEFITS

○ POSSIBLE BENEFITS

✷ CONFLICTS

14. SELECTION OF PRIMARY STRUCTURAL SYSTEM

Procedure:

1. Review the results of step 12. The various structural systems are presented and described.
2. Review the results of step 13. The various structural systems should be evaluated in terms of potential hazard resistance strategies with consideration of local hazards and priorities.
3. The structural system selection can now be made by client and architect on the basis of established priorities and findings.

Discussion:

Additional criteria influencing the selection of the primary structural system and the relative priorities of those criteria should be developed by client and architect for the needs of each project.

15. DESCRIPTION OF BUILDING SUBSYSTEMS

Procedure:

1. Classify building subsystems into generic areas.
2. Develop descriptions of desired subsystem characteristics relative to each hazard.

Discussion:

There are a number of existing models that can be used as a guide to classifying the building subsystems. Among them are the following:

1. Construction Specification Institute (CSI) Index
2. General Services Administration (GSA) Classification
3. see *The Interaction of building Components During Earthquakes.* San Francisco: McCue Boone Tomsick, 1976.

The following is one example of a possible classification system:

Enclosure Systems:

Walls	Curtain Wall Masonry Bearing Wall

Finish Systems:

Partitions	Permanent Relocatable

Service Systems:

Lighting	Pendant Recessed

16. HAZARD RESISTANCE STRATEGIES OF NONSTRUCTURAL SYSTEMS

Procedure:

1. Identify potential hazard resistance strategies for nonstructural systems.
2. Evaluate each nonstructural system according to the desired characteristics for each hazard.

Characteristics of the Nonstructural Systems

The nonstructural system characteristics used were derived from a recognition of certain negative and positive consequences of having or not having certain qualities in the selected nonstructural system. These characteristics are the following:

1. Flexibility/Deformation — Ability to distort or deform with the earthquake forces.
2. Anchorage — Connected to a suitable element to resist independent movement.
3. Bracing — Supported to resist lateral forces.
4. Stability — Configured to provide a degree of inherent resistance to forces.
5. Strengthening — Internal rigidity or bracing to provide increased damage resistance.
6. Separation/Isolation — Separation of the element from the damage mechanism.
7. Slip/Control Joints — Ability to move independently to limit the transfer of energy.
8. Reduced Mass — Reduced mass or weight, reduces the earthquake force imposed on the element.
9. Containment — Enclosure of the element to provide a barrier to energy transfer.
10. Incorporation — Incorporation of the element into a more resistive element or system.
11. Location — Locating the element to reduce its vulnerability or hazard.

SEISMIC DESIGN STRATEGIES

NONSTRUCTURAL SYSTEMS	FLEXIBILITY/DEFORMATION	ANCHORAGE	BRACING	STABILITY	STRENGTHENING	SEPARATION/ISOLATION	SLIP/CONTROL JOINTS	REDUCED MASS	CONTAINMENT	INCORPORATION	LOCATION
	HAZARD RESISTANCE STRATEGIES										
EXTERIOR ELEMENTS		●	●		●			●	○	○	●
ENCLOSURE SYSTEMS	●						●	●		●	
FINISHES/VENEERS	●	●					○	●			
PARTITIONS	○					●	●				
CEILING SYSTEMS		●	●		○	●		○		●	
LIGHTING SYSTEMS		●	●		○	○				○	
GLAZING	●				●	●					●
TRANSPORTATION SYSTEM					●	●	●				●
MECHANICAL SYSTEMS	●	●	●					●			●
FURNISHINGS/EQUIPMENT		●		●	●			●			

● HIGH POTENTIAL STRATEGIES

○ POSSIBLE STRATEGIES

MULTI-HAZARD POTENTIALS

NONSTRUCTURAL SYSTEMS

HAZARD RESISTANCE STRATEGIES	EARTHQUAKE	FIRE	EXTREME WINDS	FLOOD	SECURITY	HIGH SOUND	RADIOACTIVE FALLOUT
FLEXIBILITY/ DEFORMATION	●		○				
ANCHORAGE	●		●	○	●		
BRACING	●		●		●		
STABILITY	●		●		○		
STRENGTHENING	●		●		●		
SEPARATION/ ISOLATION	●	✷				✷	
SLIP/CONTROL JOINTS	●						
REDUCED MASS	●		✷				
CONTAINMENT	●		●		●		
INCORPORATION	●	○	○		○		
LOCATION	●	●	○		●	●	

● MUTUAL BENEFITS

○ POSSIBLE BENEFITS

✷ CONFLICTS

17. SELECTION OF BUILDING SUBSYSTEMS

Procedure:

1. Review the results of step 15. Nonstructural systems should be classified into generic areas.

2. Review the results of step 16. The various nonstructural systems should be evaluated in terms of possible hazard resistance strategies with consideration of hazards and priorities.

3. The specific type of each nonstructural system can be selected by client and architect on the basis of established priorities and findings.

18. DESIGN EVALUATION

Procedure:

The basic question is, To what extent have the project goals been realized?

1. Functional Evaluation

   a. Review criteria, standards, codes, etc. Compare with the design.
   b. Review the original and any revised project objectives and priorities. Compare with project attainment.
   c. Develop scenarios for functional testing of the design.
   d. Evaluate and compare "Alternative design concepts."
   e. If possible, use external, independent experts to assess goals versus accomplishments.
   f. Involve users and staff representatives of various functional levels in reviews.

2. Hazard Evaluations

   a. Use the design guidelines and aids as evaluation instruments.
   b. Use the engineer to critique the design from a hazard resistance point of view.
   c. Invite civil defense, fire, police, code and local officials to critique the project from their respective vantage points.

3. Criticism Evaluations

   Assess the criticisms and determine the extent, nature and strategy(s) for incorporating these findings and suggestions into the design.

CASE STUDY

Architect: Koehler-Woodfin Partnership
Muncie, Indiana

In order to demonstrate the developed multi-hazard design process, the process has been applied to the design of a fire station. It must be emphasized that this design remains quite theoretical because it only reflects a concern for hazard and functional requirements. An architectural solution is actually much more complex because of the necessity to consider the scale, pattern, texture, materials, community and many other factors.

01. DETERMINE ISSUES

The goal of the conceptual design is to demonstrate the application of the design process to the creation of a seismically resistant fire station while developing as much resistance capacity as practical against the other identified hazards.

02. DETERMINE SEISMIC RISK

Since this design of the fire station is a demonstration exercise, no specific site was chosen. It is assumed to be located in a high risk area.

03. DETERMINE DEGREE OF RISK FROM OTHER HAZARDS

In conformity with the established goals, it is assumed that there is equal exposure to all hazards (an unrealistic assumption).

04. ESTABLISH ENERGY POLICY

The design goal was to take advantage of energy-saving design options whenever possible.

05. ANALYZE SITE

No restricting site conditions are considered.

06. ESTABLISH HAZARD PRIORITIES

Since maximum hazard exposure is considered, the degree of concern for all hazards is equally high.

07. CHECK CODE FOR HAZARD AND ENERGY REQUIREMENTS

Requirements of the Uniform Building Code are considered.

08. DEVELOP ARCHITECTURAL PROGRAM

Programatic requirements were developed and an architectural program established (it is not presented here because of space). In summary, it represents a Central Fire Station with administration, four apparatus bays and one repair bay. The communications center is located elsewhere, based on the assumption that the city combines fire, police and civil defense communications.

09. DESCRIPTION OF ARCHETYPES

For this exercise, all archetypes were assumed to be functionally acceptable.

10. HAZARD RESISTANCE STRATEGIES FOR ARCHETYPES

Potential hazard resistance strategies are identified for earthquake design and benefits or conflicts identified in terms of overall hazard resistance.

11. SELECTION OF ARCHETYPE

Since all archetypes were assumed to be functionally equal, an archetype was selected as the design concept to be used as the basis for detailed design studies. There are two major factors that make the design of this fire station somewhat unique. First, since this is a hypothetical project, there are no site or contextual constraints limiting or directing design development. Second, the assumed program of functional requirements for this building calls for a repair bay. The repair bay is usually not found in the fire station, and it is not found in any of the archetypes. It posed special problems and conflicts, such as the need for physical separation from other spaces and a need to prevent access by unauthorized personnel. The strategy used to incorporate the two story repair bay was to group it with the two story apparatus spaces, separated with a relatively non-stiff fire-rated wall, to flank these two story spaces with two story support spaces on either side and then to cover these with a third floor level consisting of living and administrative spaces. This arrangement provided good access from services spaces to apparatus, provided symmetry in plan, section and elevation for seismic purposes, provided overhead protection for apparatus from high wind damage and provided a compact, simple configuration suitable for the shell concept structure and with a good enclosure to volume ratio for energy efficiency.

12. DESCRIPTION OF PRIMARY STRUCTURAL SYSTEMS

For this exercise, all selected primary structural systems were assumed to be functionally and economically acceptable.

13. HAZARD RESISTANCE STRATEGIES FOR PRIMARY STRUCTURAL SYSTEMS

Potential hazard resistance strategies are identified for earthquake design and benefits or conflicts identified in terms of overall hazard resistance.

14. SELECTION OF PRIMARY STRUCTURAL SYSTEM

Based on the data provided in step 13, two systems perform well: the concrete system with beams, girders, columns and slab; and the reinforced masonry system with vertically and horizontally reinforced walls and reinforced concrete slab. The reinforced masonry system is selected. The rigid shell or box approach is appropriate for low-rise buildings where the relatively high mass is not overly critical. The major advantage is that because of the limited movement of the primary structure, during an earthquake, the nonstructural parts are less susceptible to extensive damage than they would be in the context of a more flexible primary structure.

Inherent in the shell principle is the requirement that the designer maintain continuity of wall surface. The larger an opening, the more wall area needs to remain solid around it. However, openings can occur independent of specific modules, allowing a great degree of freedom in the placement of wall openings. This principle is a major design determinant for the articulation of the facades. The design includes the use of a massive enclosure shell and two massive stiffener partitions, separating the two story apparatus and repair spaces from the flanking service spaces.

15. DESCRIPTION OF NONSTRUCTURAL SYSTEMS
16. HAZARD RESISTANCE STRATEGIES FOR NONSTRUCTURAL SYSTEMS
17. SELECTION OF NONSTRUCTURAL SYSTEMS

Because of the hypothetical and conceptual nature of this example, these steps were not considered.

18. DESIGN EVALUATION

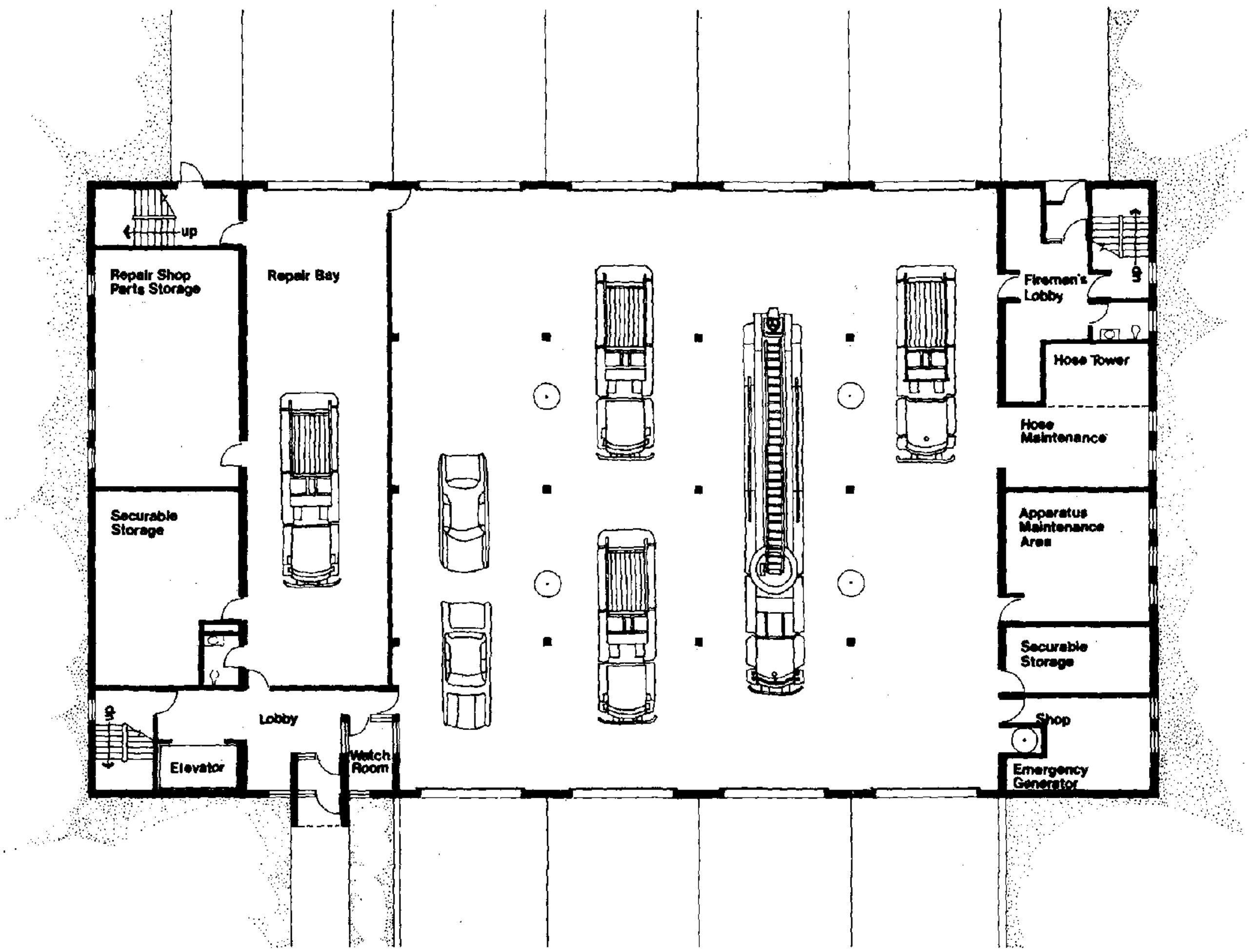
The design solution described above and illustrated in the following drawing was achieved during the design evaluation step. In the first trial solution, the repair bay was separated from the apparatus space by one of the two story support spaces flanking the apparatus room. In evaluating the first design, it was found that the separation of the apparatus repair bay was not acceptable, because it violated the important seismic consideration of building symmetry. The desirability of the drive-through feature for the repair bay stated in the original architectural program was reevaluated. Since the apparatus remains in the repair bay for longer periods of time, the convenience of the drive-through concept was found to be not as critical as it is for the frequently used apparatus room. The architectural program was changed to eliminate the mandatory drive-through requirement for the repair bay. This was an important development because it now became functionally possible to group the two story repair bay with the two story apparatus space, while controlling access to the repair bay, and while permitting free access to the apparatus room from service spaces on both sides. The seismic advantage in grouping the repair and apparatus bays was in the achievement of symmetry in plan, section and elevation.

SUMMARY

The design of a building is a complex process involving a large number of interdependent factors of varying degrees of importance. For essential buildings such as fire and police stations the need for full operational capabilities in case of a disaster is greater than for the vast majority of other buildings. For that reason, special emphasis needs to be placed on disaster resistance during the design process of these facilities.

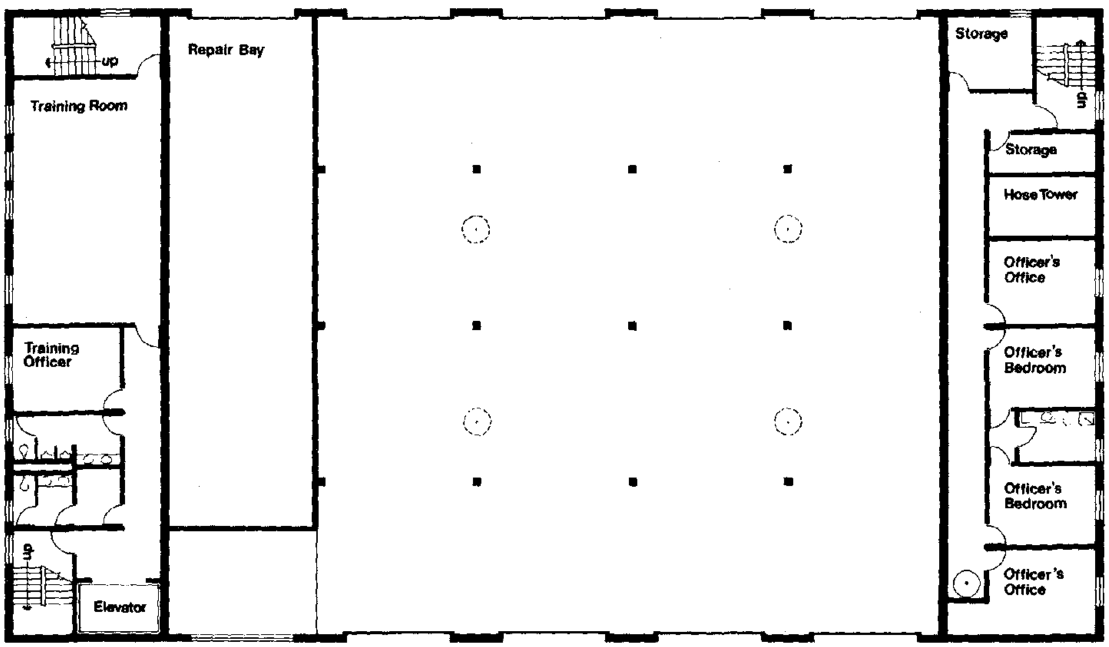
Based on the observation that certain design features that make a building earthquake-resistant can also result in good performance during other disasters, this design process was developed to identify and highlight those features. The correlation of such findings is essential to the development of a comprehensive approach known as "multi-hazard design."

A "multi-hazard design process" was developed and demonstrated to assist the architect in easily and economically attaining higher protection levels for a range of hazards in the design of police and fire stations. It perhaps should be emphasized here that design guidelines must be seen as a frame of reference and a resource. They are based on generalizations and abstractions. Therefore, the user must maintain an active, innovative and critical role during the use of the process.

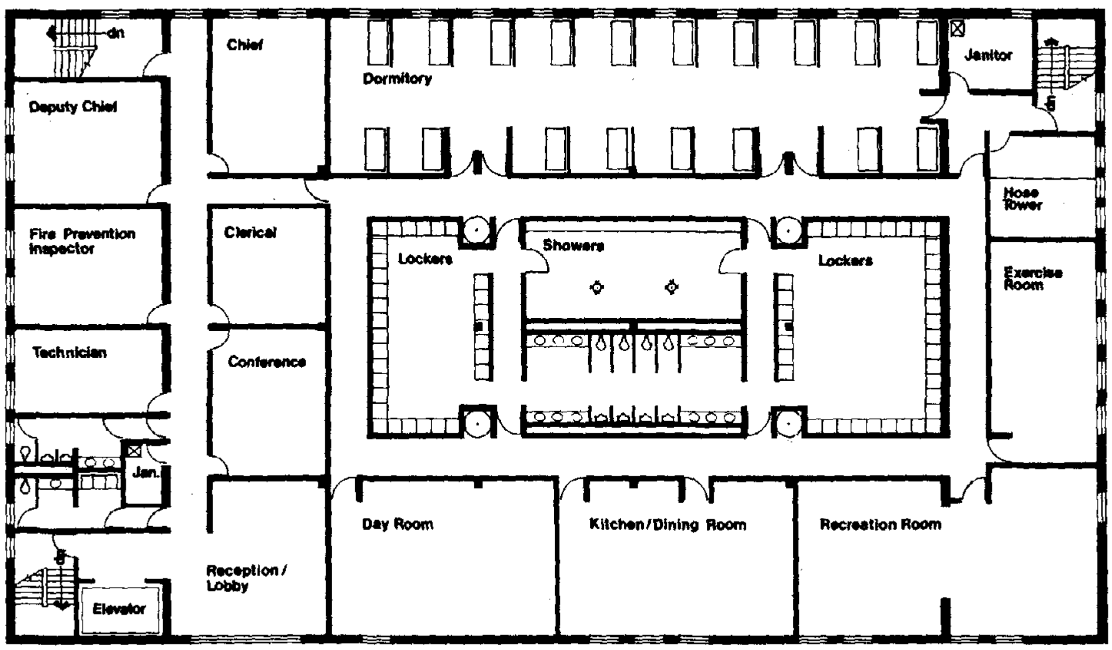


GROUND FLOOR PLAN

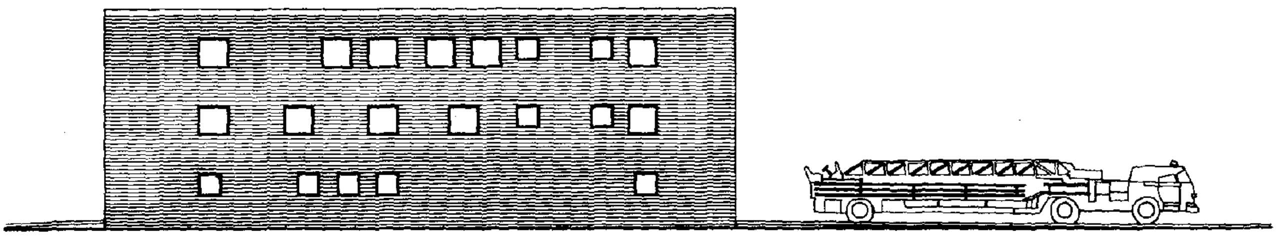
ARCHITECT: KOEHLER-WOODFIN PARTNERSHIP
MUNCIE, INDIANA



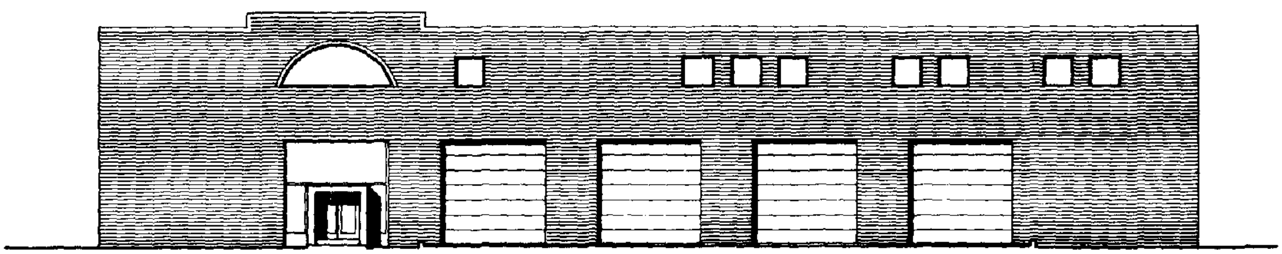
MEZZANINE FLOOR PLAN



THIRD FLOOR PLAN



WEST ELEVATION



SOUTH ELEVATION

0 5 10 20 40

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   - ☐ Previous interest in seismic design
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