ANEJO PARA GUIA DE EVALUACION

DIVISIONES PERMANENTES	% PARA CADA ELEMENTO
Bloques de arcilla o yeso	10.0
Bloques de concreto	9.1
Tornillos de metal	10.0
Panel de yeso/tornillo de metal	9.1
Madera	9.1
Panel sólido de yeso o mezcla	8.3
Divisiones de metal en baños	20.0
Divisiones de mármol en baños	20.0
Rejillas metálicas en baños	20.0

DIVISIONES DESMONTABLES

Paneles de metal	9.1
Metal y cristal	9.1
Madera	9.1
Madera y cristal	9.1
Misceláneo	9.1

DIVISIONES DE ALTURA PARCIAL

Panel de metal	11.1
Metal y cristal	11.1
Madera	11.1
Madera y cristal	11.1
Yeso o mezcla	9.1
Misceláneos (no fijo)	20.0

SISTEMAS DE RECUBRIMIENTO

Mezcla	10.0
Panel de yeso	8.3
Bloques de concreto	10.0
Panel de metal	10.0

TERMINACIONES DE DIVISIONES

Losas de cerámica	14.3
Paneles de madera	14.3
Cubierta en vinil	25.0

SISTEMA SUSPENDIDO	% PARA CADA ELEMENTO
Paneles ocultos	11.1
Paneles expuestos	11.1
Panel de metal	11.1
Mezcla	10.0
Paneles de yeso	9.1
Sistema de iluminaria	11.1

SUPERFICIE APLICADA AL SISTEMA	
Losa pegada a la estructura	20.0
Panel de yeso	16.7
Mezcla de yeso	20.0
Mezcla de cemento	20.0

inevitables.

Daños en el equipo interior del edificio

La mayoría del equipo de oficina es adquirido (comprado) como sistemas generales más que sistemas específicamente manufacturado para un proyecto. Las características particulares de tal equipo son establecidas por sus manufactureros y determinan las probabilidades de daños a esperarse. Los terremotos han causado una cantidad considerable de daños en elementos no estructurales como equipo mecánico (motores), equipo eléctrico (sistemas de enfriamiento), materiales peligrosos (rotura de líneas de gas, etc.. En el equipo de computadoras las probabilidades de daños extensos son muy grandes, sin embargo, algunos elementos no estructurales de este tipo se pueden asegurar en bases que permitan alguna vibración o con materiales menos costosos como el velcro. Para reemplzar el equipo ya existente en el edificio por razones puramente sísmicas se debe clasificar que equipo es necesario para proveer servicios esenciales luego de un terremoto.

Daños Misceláneos

Un gran número de otros elementos no estructurales pueden sufrir daños por un terremoto de alta magnitud. Estos representan consideraciones relativamente menores con respecto a la probabilidad de un daño total. A continuación se desglosa un listado parcial de algunos elementos no estructurales que sufren daños de este tipo.

1. equipo de laboratorio como los envases de vidrio
2. objetos colgando en paredes como cuadros de pinturas, placas o anuncios
3. daños en equipo de oficina como archivos de más de tres gavetas
4. roturas en tuberías

Historia de daños

En la Apéndice C se muestran los tipos de daños que han sido identificados y registrados en cada elemento no estructural luego de un terremoto. Se puede observar que los elementos con daños más frecuentes incluyen sistemas de techo acústico, lámparas flourescentes, divisiones y elevadores. De todos los sistemas de techo acústico los sistemas tipo T con paneles incrustados y los sistemas suspendidos de yeso desarrollaron un comportamiento más pobre comparado con otros sistemas de techo acústico. El mejor comportamiento fue obtenido en sistemas de techo acústico de paneles expuestos y fijos a la estructura. La mayoría de los daños en sistemas de techo acústico se notaron más en oficinas o salones donde las divisiones de estos actuaron contra el sistema de techo acústico. Estos daños incluyen pandeo del sistema suspendido, el desplome de los paneles del acústico y divisiones de yeso.

Los tipos de lámparas que más daños sufrieron incluyen las lámparas colgantes, las flourescentes y las incandescentes las cuales no estaban soportadas directamente a la estructura. Las lámparas que fueron instaladas en filas largas de un extremo a otro del salón u oficina sufrieron más daños que las instaladas de forma separada con el daño causado por el choque de unas con otras debido a la acción de oscilación durante el evento. Las lámparas que desarrollaron un buen comportamiento fueron aquellas que estaban soportadas directamente a la estructura o a paredes reforzadas.

Todos los sistemas de divisiones sufrieron daños. Las divisiones de bloques ya sean de arcilla, concreto o yeso sufieron daños en las juntas en la división o fallas por compresión en la parte superior de la división que se debió a la acción de la estructura sobre ellas. Otros tipos de daños fueron desplazamiento horizontal y fallas en las esquinas. Los pasadores de las divisiones de altura completa sufrieron daños cuando soportaron los movimientos sísmicos (esfuerzos) de las losas estructurales. Los pernos que soportaron hacia o justo sobre el techo acústico fueron

. Basic data on the building which relates to seismic performance, including all site exposure and response predictions, structural response spectra, and objectives for post-earthquake operations.

a. Site Inspection

A site inspection is recommended to verify all data on non-structural components as well as to accumulate information on the following:

. Method of support, anchorage and bracing of all components including all material sizes;

. Major characteristics of the components which may relate to seismic performance, such as lenses in light fixtures, glass stops in metal/glass partitions and lateral bracing;

. Variety of installation methods for similar components;

. Locations of major equipment in the building, such as cooling towers, boilers, major air handling equipment and tanks;

. Quality and capability of components to continue performing the required purposes, not considering seismic objectives (i.e., if the equipment is old and not worth repairing, etc.).

During the site inspection, an inspection guide is proposed for use. This guide is presented in Figure 3-1 shown below.

b. Photographs

It is recommended that photographs be taken of critical or unusual component assemblies in order to supplement the inspection guide. These photographs should be keyed to the guide form for future reference.

3. Phase II (EVALUATION OVERVIEW)

This phase is intended to be a rational method for reviewing, evaluating and predicting the performance of in-place non-structural components when they may be subjected to a major seismic event. The proposed approach consists of a Sensitivity Matrix Evaluation System which makes use of a two-part guide as follows in Figure 3-1 (pages 42a thru 42f) and Figure 3-2 (pages 42g thru 42j).

Component	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	Percentage of Risk										
Partitions-Permanent											
Clay or Gypsum Block	4	4	4	4	3	3	2	1	1	1	1
Concrete Masonry	4	4	4	3	2	2	1	1	1	1	1
Metal Stud/Plaster	4	4	4	3	3	2	2	1	1	1	1
Metal Stud/Gypsum Board	4	4	4	4	3	3	2	2	1	1	1
Wood	4	4	4	4	4	3	3	3	2	2	1
Solid Gypsum Board or Plaster	4	4	4	4	4	3	2	2	1	1	1
Toilet Partitions											
Metal	4	4	4	4	3	3	2	2	2	1	1
Marble	4	4	3	3	2	2	2	1	1	1	1
Metal Screens	4	4	4	4	3	3	3	3	2	2	2
Partitions-Demountable											
Full Height (To Ceiling)											
Metal Panel	4	4	4	3	3	2	2	1	1	1	1
Metal and Glass	4	4	4	3	2	2	1	1	1	1	1
Wood	4	4	4	3	3	3	2	2	1	1	1
Wood and Glass	4	4	4	3	2	2	1	1	1	1	1
Miscellaneous	4	4	4	3	3	2	2	2	1	1	1
Partial Height Screen											
Metal Panel	4	4	4	4	3	4	3	3	2	2	1
Metal and Glass	4	4	4	4	3	3	3	2	2	1	1
Glass	4	4	4	3	3	3	2	2	1	1	1
Wood	4	4	4	4	4	3	3	3	2	2	2
Wood and Glass	4	4	4	4	3	4	3	3	2	2	1
Gypsum Board or Plaster	4	4	4	4	4	3	3	2	2	1	1
Miscellaneous not positively anchored	4	4	4	4	4	4	3	3	2	2	2
Furring Systems											
Plaster	4	4	4	4	3	3	3	3	2	2	2
Gypsum board	4	4	4	4	4	3	3	3	2	2	2
Concrete Masonry	4	4	4	3	3	3	2	2	2	1	1
Metal Panel	4	4	4	4	3	3	3	2	2	2	1
Partition Finishes											
Ceramic Tile	4	4	4	4	4	4	3	3	3	3	2
Wood Paneling	4	4	4	4	4	3	3	3	2	2	2
Vinyl Wall Covering or Fabric Wall Covering	4	4	4	4	4	4.	4	4	3	3	3

Figure 3-2
SENSITIVITY SCALE FOR IN-PLACE COMPONENTS

Component	Percentage of Risk										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Ceiling Systems											
Suspended Systems											
Concelaed Spline	4	4	3	3	2	2	1	1	1	1	1
Exposed Spline	4	4	3	2	2	1	1	1	1	1	1
Metal Pan	4	4	3	2	2	1	1	1	1	1	1
Plaster	4	4	4	3	3	2	2	2	1	1	1
Gypsum Board	4	4	4	4	3	3	2	2	1	1	1
Surface Applied Systems											
Tile, Glued to Structure	4	4	4	3	3	2	2	2	1	1	1
Gypsum Board	4	4	4	4	3	3	2	2	2	1	1
Gypsum Plaster	4	4	4	3	3	2	2	2	1	1	1
Cement Plaster	4	4	4	3	2	2	2	1	1	1	1
Special Ceilings											
Luminous Systems	4	4	3	2	2	1	1	1	1	1	1
Electrical System											
Bus Duct	4	4	4	3	3	3	2	2	2	1	1
Conduit	4	4	4	3	3	3	2	2	2	1	1
Panels	4	4	3	3	3	2	2	2	2	2	1
Transformers	4	4	3	3	3	2	2	2	1	1	1
Switchboards	4	4	3	3	3	2	2	2	1	1	1
Emergency Generator	4	4	4	4	3	3	3	2	1	1	1
Fuel System	4	4	4	4	4	3	2	2	1	1	1
Battery Racks	4	4	4	3	3	3	2	2	1	1	1
Motor Starters	4	4	3	3	3	3	2	2	1	1	1
Lighting Fixtures											
Fluorescent Ceiling Fixtures											
Recessed	4	4	3	2	2	2	1	1	1	1	1
Semi-Recessed	4	4	4	3	2	2	1	1	1	1	1
Surface Mounted	4	4	4	3	2	2	1	1	1	1	1
Stem Mounted											
Single Stem	4	4	3	2	1	1	1	1	1	1	1
Two Short Stems	4	4	4	3	3	2	1	1	1	1	1
Two Long Stems	4	4	3	2	1	1	1	1	1	1	1
End to End Assemblies	4	4	4	3	2	1	1	1	1	1	1
Chain Hung											
Separate Fixtures	4	4	3	2	2	1	1	1	1	1	1
End to End Assemblies	4	3	2	2	1	1	1	1	1	1	1

Figure 3-2
SENSITIVITY SCALE FOR IN-PLACE COMPONENTS

Component	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
					Percentage of Risk						
Incandescent Ceiling Fixtures											
Recessed	4	4	4	4	3	3	2	2	1	1	1
Surface Mounted	4	4	4	3	2	2	2	1	1	1	1
Stem Mounted (Globe)	4	4	3	2	2	1	1	1	1	1	1
Chain Hung	4	4	4	3	3	2	1	1	1	1	1
Ornamental Chandelier	4	4	4	3	3	2	2	1	1	1	1
Track Lighting	4	4	4	3	2	2	1	1	1	1	1
Wall Fixtures											
Surface Mounted	4	4	4	3	3	3	2	2	1	1	1
Recessed	4	4	4	4	4	3	3	2	2	2	1
Emergency Lighting											
Battery Powered	4	4	4	4	3	3	3	3	2	2	1
Exit Lights	4	4	4	4	4	3	3	3	2	2	1
Furniture and Furnishings											
Open Shelving											
Floor Mounted Over 6' high	4	4	4	3	2	2	1	1	1	1	1
Floor Mounted Under 6' high	4	4	4	3	3	3	2	2	1	1	1
Wall Mounted	4	4	4	3	2	2	2	1	1	1	1
Storage	4	4	3	2	2	1	1	1	1	1	1
Floor Mounted (Laboratory)	4	4	3	2	2	1	1	1	1	1	1
Wall Mounted (Laboratory)	4	3	2	2	1	1	1	1	1	1	1
Bookcases	4	4	4	3	3	3	2	2	1	1	1
Storage Cabinets											
Floor Mounted	4	4	4	4	3	3	3	2	2	2	1
Wall Mounted	4	4	4	3	3	2	2	1	1	1	1
Files											
Lateral or Standard	4	4	4	3	3	3	2	2	1	1	1
Plan or Map	4	4	4	4	3	3	3	2	2	2	1
Motor operated	4	4	4	3	3	2	2	1	1	1	1
Desk Top Revolving	4	4	4	3	3	3	2	2	2	1	1
Wall Mounted	4	4	3	3	2	2	1	1	1	1	1
Desks											
Wall Mounted	4	4	3	3	2	2	1	1	1	1	1
Floor Supported	4	4	4	4	4	3	3	3	2	2	2
Vital Furniture	4	4	4	3	3	2	2	2	1	1	1
Computer Equipment											
Wheel Mounted	4	4	4	4	3	3	3	2	2	1	1
Stationary	4	4	4	3	3	3	2	2	1	1	1
Tape/Disc Storage	4	4	4	4	4	3	3	2	2	1	1

Figure 3-2
SENSITIVITY SCALE FOR IN-PLACE COMPONENTS

Component	Percentage of Risk										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Elevator Systems											
Traction (Geared)	4	3	3	2	2	2	1	1	1	1	1
Traction (Gearless)	4	3	3	2	1	1	1	1	1	1	1
Hydraulic - Personnel	4	4	4	3	3	2	2	2	1	1	1
Hydraulic - Freight	4	4	4	3	3	3	3	2	2	1	1
Dumbwaiter (Geared)	4	4	4	4	4	3	3	3	3	2	2
Dumbwaiter (Gearless)	4	4	4	4	4	3	3	3	3	2	2
Mechanical, Plumbing and Fire Protection Equipment											
Boilers	4	4	3	3	2	2	2	1	1	1	1
Chillers	4	4	4	4	4	3	3	3	2	2	2
HUAC Pumps	4	4	4	4	4	3	3	3	2	2	2
Storage Tanks	4	4	4	3	3	2	2	2	2	1	1
Treatment & Expansion Tanks	4	4	4	4	3	3	2	2	1	1	1
Fans	4	4	4	4	4	3	3	2	2	2	2
Coils	4	4	4	4	4	3	3	2	2	2	2
Domestic Water Pumps	4	4	4	4	3	3	3	3	2	2	2
Fire Pumps	4	4	3	2	1	1	1	1	1	1	1
Hot Waterheaters	4	4	4	4	4	3	3	2	2	2	2
Water Softeners	4	4	4	4	4	3	3	2	2	2	2
Pneumatic Tanks	4	4	4	4	3	3	3	3	2	2	2
Plumbing Piping											
Cold Water	4	4	4	4	3	3	2	2	2	1	1
Hot Water	4	4	4	4	3	3	2	2	2	1	1
Drainage	4	4	4	3	3	2	2	2	2	2	1
Sanitary Vent	4	4	4	3	3	2	2	2	2	2	1
Gas	4	4	3	3	2	2	2	1	1	1	1
Compressed Air	4	4	4	4	3	2	2	2	2	2	2
Vacuum	4	4	4	4	3	2	2	2	2	2	2
Mechanical and Fire Protection Piping											
Standpipe-Wet and Dry	4	4	3	3	2	2	2	2	1	1	1
Sprinkler-Wet and Dry	4	4	3	2	2	2	2	1	1	1	1
Chilled Water	4	4	4	3	3	3	3	2	2	2	2
Hot Water	4	4	3	3	2	2	2	1	1	1	1
Condenser Water	4	4	4	4	3	3	3	2	2	2	2
Steam	4	4	3	3	2	2	2	2	1	1	1
Condensate	4	4	3	3	2	2	2	2	1	1	1
Buried Pipe	4	4	4	3	3	3	2	2	2	1	1

Figure 3-2
SENSITIVITY SCALE FOR IN-PLACE COMPONENTS

. Risk Percentage Inspection/Evaluation Guide, which is used to determine the likelihood of any component being damaged by a major seismic event and is expressed in terms of comparative percentages of risk (see Figure 3-1).

. Sensitivity Scale, which is used to indicate the potential hazard to building occupants that would result from earthquake damage to components and is expressed in a scale of values from one to four (see Figure 3-2).

The Sensitivity Matrix provies an opportunity to evaluate all components and arrive at action proposals for each component with some factual basis on the relative urgency for such improvements. This evaluation system is planned to reduce judgment decisions to a minimum and to provide a procedure that can be used by a varied staff if building siting is dispersed.

The primary assumption for the Matrix System approach is that any installed component may include certain characteristics which would tend to resist seismic forces. These seismic characteristics may include:

- Support devices
- Bracing and Sway damping features
- Reinforcement
- Safety devices, such as face bars on shelves
- Special arrangements of components

The likelihood of damage is determined by the nature of the component itself, together with the particular characteristics of the installation system utilized. This is expressed in terms of a *risk percentage*. The danger to occupants of a building (sensitivity) is considered from the viewpoint of the relative occupant density of that building in the immediate vicinity of a component which might be damaged.

The factor of lifesafety based on occupant density is suggested since the overall intent of these nonstructural guidelines is related to the possible hazards in high density office buildings, as opposed to primarily storage or other types of low occupant density buildings. In such office building areas, it is impractical to consider every component as having equal likelihood of injurying occupants. Further, this occupant hazard provides an effective weighing system towards determining overall hazard levels.

4. MATRIX RECORDING SYSTEM

Figure 4-1, see page 44a, presents a graphic representation of the proposed Matrix Evaluation System. As can be seen, the overall product of this system is the recommended actions to be taken for upgrading components in existing buildings. These actions are defined in terms of alternate sensitivity ratings as well as overall seismic and nonseismic objectives for the particular buildings. Sensitivity scale ratings arise from the component risk percentages (from a Risk Percentage Inspection/Evaluation Guide) and from a level of minimum uncontrollable damage.

5. RISK EVALUATION GUIDE

The Risk Evaluation Guide (see Figure 3-1) is the first of two forms which comprise the overall Matrix Evaluation System. Figure 3-1 presents this guide for the inspection and risk evaluation of in-place components to determine the installed seismic characteristics and to assign risk percentages for potential earthquake damage. As can be seen, components are separated into system groups with common characteristics for each group. The eight systems include:

- Partitions
- Ceilings
- Electrical system
- Light fixtures
- Elevators
- Furniture
- Equipment
- Piping

For all eight groups there are a total of 125 different components listed. The number of characteristics for each group ranges from 15 for partitions to 8 for both furniture and equipment. For any one component, the number of characteristics varies between 2 and 11. The characteristics that do not apply to a particular component in the group have been blanked out.

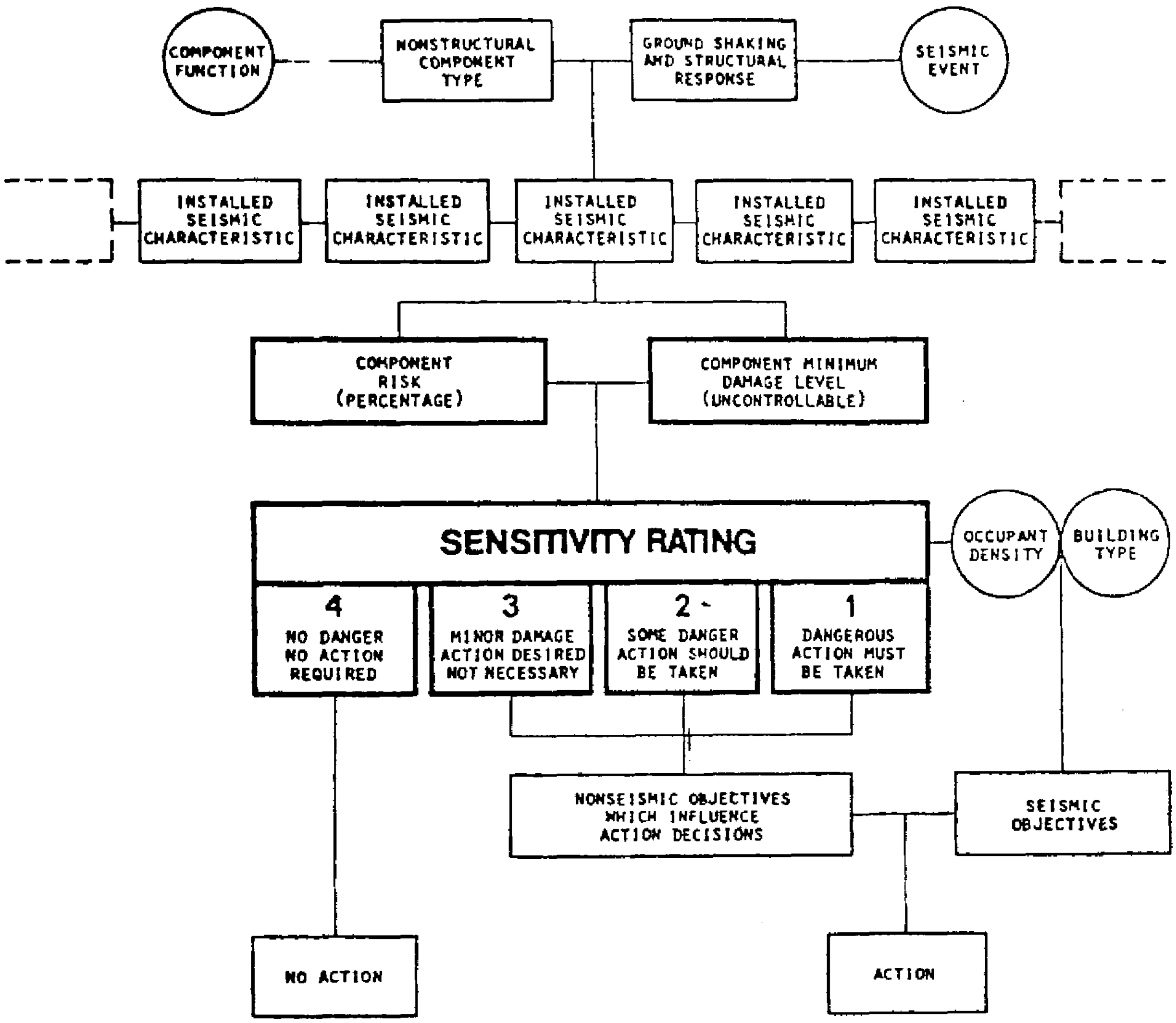

Figure 4-1
MATRIX EVALUATION SYSTEM

The intent in this guide is to provide a directly usable format which can be taken to a building site and marked by an inspector, with percentage calculations added to the same form. For this reason, each form sheet also contains space for the building name and number, the date of the inspection and space for inspection notes and special conditions.

These evaluation forms are used to calculate risk (damage potential) percentages in the following manner:

. As an inspection is made of the components in a building, the list of applicable characteristics to each component is reviewed.

. A check mark is placed in each column opposite a component name if the characteristic statement applies to that installation.

. The total number of check marks is added across to the right and placed in the column titled Number of Items Checked.

. The number of checked items is multiplied by the Percent of Risk that has been established for each characteristic and which has been printed in the next column.

. The product would indicate the Total Percentage of Risk for each component.

The percentages of risk totals may be averaged for each component group separate from other groups in a building to provide an overview.

This guide provides one space for each type of nonstructural component that may be found in a typical GSA office building. It is assumed, based on the survey of buildings, that only one method is generally used for installing a component type within an entire building. For those buildings which have more than one type of installation method for single component types, duplicate sheets of the applicable guide page should be used to record the risk percentages for the alternate installation. To keep track of these additional sheets, space has been provided on each sheet for the page numbers.

6. SENSITIVITY SCALE

Figure 3-2 (Sensitivity Scale for In-place Components), is the second form in the matrix evaluation system. This form establishes an occupant hazard scale and consists of a list of the 125 components which were included from the previous form, with a range of percentages for each component in 10 percent increments from 0 to 100 percent. These percentage increments represent the possible range of calculated *Total Percentage of Risk* for each component from the Risk Percentage Evaluation Guide.

Below each percentage increment, there are numbers ranging between 1 and 4 representing sensitivity-action priority statements as follows:

Code	Action
1	Dangerous: action must be taken
2	Somewhat Dangerous: action should be taken
3	Action desirable but not urgent
4	No action required.

For any possible risk percentage, there would be corresponding action priority recommended, which indicates also the potential danger to building occupants.

As can be seen, the danger potential (sensitivity) and the priority number may vary among components for equivalent risk percentages. These variations exist for the following reasons:

. Many components are inherently more dangerous than others (a falling light fixture is more dangerous than the separation and failure of a vinyl wall covering).

. The number of seismic characteristics that are applicable for each component may vary widely. For a component with three characteristics, each would represent 33.3 percent of risk, so sensitivity numbers could only be recorded at 30-40 percent of 60-70 percent levels. For a component with 10 characteristics, the sensitivity could be applicable at each of the 10 percent increments.

. Some components have a long history of continuous damage from even minor earthquakes, such as suspended exposed tee ceilings and pendant hung fluorescents. The action priorities for these have been given greater weight to account for this evidence.

. Damage to some components may not be dangerous in itself, but may cause other damage which would be dangerous.

7. MINIMUM ACCEPTABLE DAMAGE

Many components are inherently subject to damage which tends not to be controllable. Further, the decision not to improve the performance of components which were not clearly scored as hazards would result in a level of *minimum acceptable damage*.

Uncontrollable damage is generally minimal in effect and would consist of such areas as plaster cracking, overturning of some furniture or light partitions, and minor damage to such items as laboratory glassware or material, file drawers, equipment, etc. The specific types of damage, together with indications as to the alternative improvement options, are presented in the succeeding paragraphs.

a. Plaster Cracks and Spalls

Plaster is a very brittle finish material and if subjected to relatively minor bending or shearing forces, will crack or spall out of the supporting lath. This is particularly true in cases of plastic surfacing on structural elements such as shear walls, columns and beams. The structural elements, twisting or bending through designed limits, will cause cracking in the surface plaster in all but the most rigid of building systems. Such cracking is not necessarily expensive to repair subsequent to the event and further is not a major life hazard problem, except when on ceiling surfaces where spalls can cause injury. Isolation of the furring from structural elements may aid in the resistivity but since the repair costs are relatively minimal, a decision to have existing plasterwork remain unchanged until after an event may be a more practical decision. On ceilings, where the hazard is higher, replacement is recommended.

b. Tile and Masonry Joint Failures

Damage to these elements in most cases is due to unreinforced partition conditions. If other seismic resistive characteristics are accommodated, including adequate compression joints, control and expansion joints, then cracking will be more of a nuisance than a hazard. Repair of mortar or grout joints may be necessary following an event.

c. Overturning of Movable Furniture and Furnishings

Resistivity in components is achieved primarily through positive anchorage to the structural frame. This anchorage is not desirable for such items as chairs, tables, desks, and other similar furniture. The result would be some overturning or displacement during events. The selection of alternate furniture should consider stability, but this again is a minor consideration. Storage furniture such as bookcases, storage shelving, files, cabinets and the like, should always be positively anchored and braced to prevent overturning or movement. The important consideration with regard to moveable furniture is that any overturned furniture should not obstruct means of egress such as corridors, stairways, and doors. Interior planning should consider this as one factor in the layout of space. Improvements to existing space should consist of anchorage of any furniture which is not expected to be relocated, and providing closed storage cabinets for the majority of items which can be thrown about during an event.

d. Partition Failures to Unanchored Systems

Some newer interior planning approaches utilize nonanchored partition systems relying upon the weight, corners, or spread bases to supply stability. These partitions are more susceptible to overturning than anchored systems when subjected to seismic forces. Decisions on their use should take into account the flexibility of such systems and their ease of installation, as opposed to the possible danger of overturning during earthquakes. Of particular importance in this regard are those systems which utilize hanging furniture or storage systems as are part of the partition system. Those partitions which are lightweight screens may not necessarily cause injury if overturned. Some systems, on the other hand, are denser and heavier than full height stud-and-gypsum board walls. The weight and stability of these systems should be given careful consideration in high seismic exposure zones.

e. Ceiling Tile Cracks or Falls

Many types of ceiling tile are very brittle and will crack if stressed by deformation of the ceiling suspension system during an earthquake. Further, deformation can also cause separations in the suspension system, which may cause the tiles to fall. Bracing of the ceiling system can reduce these effects, but would not eliminate them altogether in the case of exposed spline systems.

f. Shear Cracking of Surface Finishes Near Doors and Windows

Although this type of damage is most common in plaster surfaces, other materials such as gypsum board and ceramic tile are also subject to cracking from movements of walls in relation to openings. Post-earthquake repairs in these instances, are relatively inexpensive and is almost unavoidable.

g. Internal Equipment Damage

Most equipment is purchased as package systems rather than manufactured specifically for the project. The particular characteristics of such equipment which are established by the manufacturers, determine future damage probabilities. Earthquakes have caused a considerable amount of damage to such items as motor rotors, fan blades, switch assemblies, housings and internal wires or pipes. For computer equipment, the possibilities of expensive damage are very great, although many internal items tend to be mounted on rocker-arm assemblies which allow for some vibration damping. For existing equipment, however, replacement is not warranted for purely seismic reasons, except for that equipment or in such buildings which provide essential post-event services. Recommendations for computer equipment are discussed in the Volume I dealing with new construction.

h. Miscellaneous Damage

A number of other items will probably be damaged by a major earthquake. These represent relatively minor considerations with respect to total damage probability. The following is a partial list of such types of damage:

. Laboratory items such as glassware, portable equipment, and other items;

. Art objects, graphics, paintings, signs and other items hung on walls;

. File drawer damage through inadvertant opening or falling;

. Piping material, damage to cast iron drainage piping, cast iron pipe fittings and others.

i. Historical Damage

Figure 7-1, shown on page 49a, shows types of damage to each nonstructural component or system which have been recorded and identified after past earthquakes. As can be seen, the most frequently damaged components included ceiling systems, light fixtures, partition systems, and elevator systems. Of all ceiling systems, suspended T systems with lay-in acoustic tiles and suspended plaster systems performed more poorly than other ceiling systems. Better performance was obtained with concealed spline systems and surface mounted ceilings. For all suspended systems, damage was more noticeable at room perimeters, where the enclosing partitions acted against the ceiling system. Perimeter damage included buckling of the suspension system and falling ceiling tiles, plaster, or gypsum board.

Light fixture types which sustained the most frequent damage included pendant or chain-hung fluorescent and incandescent fixtures as well as recessed fluorescent fixtures which were not supported directly from the structure. Fixtures which were installed in long rows end to end were damaged more frequently than were installed separately, since damage was

System	Components	Recorded Damage
Partitions	Permanent - masonry and tile	Cracking of units; horizontal drift; unit losses or compression failures at top of partitions, joint failures; overturning.
	Permanent - stud and gypsum board or plaster	Overturning associated with ceiling failures adjacent to partitions; finish cracking; horizontal drift; delamination of finish from studs.
	Demountable - metal, wood, metal and glass	Separations at top and bottom channel; compression breaks; overturning; fixed glass cracking or separating from partition body.
Furring	Plaster or gypsum board	Cracks in finish; separation failures from furred structural element due to movement of structure.
Ceilings	Suspended lay-in tile system - exposed splines	Unwinding or breakage of hangers; separation of tiles from suspension system; compression bending of system at room perimeters, breakage at building seismic joints; shear breakage in suspension interconnections.
	Suspended concealed spline systems	Failures similar to exposed spline, except less tiles separating from suspension system.
	Suspended plaster or gypsum board	Plaster spall from lath; shear cracks in finish; suspension system sustained similar damage as other suspended systems; gypsum board separation from supports.
	Surface applied tile, plaster or gypsum board	Generally performed better than suspended systems; plaster cracks and spalls due to structural movement; adhesive failures in ceiling tile.
Light Fixtures	Lay-in fluorescent (recessed and semi-recessed)	Racking of ceiling suspension caused fixtures to separate from suspension system and fall. Where fixtures were supported separately from ceiling system, they performed better. Failures within fixtures included separation of diffusers, lenses, and lamps from housing.
	Stem hung fluorescent and chain hung fluorescent	Separating of stem at structural connection point; twisting of fixture caused breakage in stems and chain breakage. Multiple fixtures installations (end to end) were most commonly damaged due to interaction of fixtures with each other. Long stem fixtures sustained more damage than short stem units. Internal damage was similar to lay-in fixtures.
	Surface mounted fluorescent	Ceiling fixtures performed similarly to lay-in fixtures. Wall fixtures performed better than ceiling fixtures except in instances of wall failure. Internal damage similar to others.
	Stem hung incandescent	Performance similar to stem hung fluorescent fixtures except that incandescent fixtures were usually hung with a single flexible stem. Damage was due primarily to fixture swaying and encountering other structural and nonstructural components. Internal damage consisted of lenses and globe separation, as well as lamp breakage.
	Surface mounted incandescent	Ceiling fixtures performed similarly to surface mounted fluorescent. Wall fixtures performed well.
	Ornamental fixtures	Chandeliers and other fixtures of a similar nature failed similarly to other stem hung fixtures. Internal damage due to multiple moving elements interacting with each other.
Doors and Frames	Wood, hollow metal, metal and glass	Frame warp from enclosing wall movements, doors occasionally deformed hinges.

Figure 7-1
QUALITY OF NONSTRUCTURAL DAMAGE RECORDED DURING PAST EARTHQUAKES

System	Components	Recorded Damage
Furnishings	Store shelving and bookcases	Overturning, dislodging of stored items horizontal movement. Better performance obtained when unit bolted to floor and laterally braced at top.
	Laboratory shelving	Similar performance as other shelving or storage units
	Cabinets - wall hung	Doors unlatched, units fell from walls where gravity support hooks were utilized. Damage to walls by cabinet loading.
Mechanical Equipment	Rigidly mounted equipment such as boilers, chillers, generators, tanks	Generally performed well where there was no damage to structural base. Some shearing of attachment devices and corresponding horizontal displacement; tall tanks overturned; support failures. Greatest damage was to equipment which rested on structural base without positive anchorage, overturning and horizontal movement severed connection lines and pipes.
	Vibration isolation mounted fans, pumps, air handlers, etc.	Devices failed, causing equipment to fall. Some damage due to unrestrained shaking on vibration isolation device. Suspended equipment failed more often than floor mounted equipment.
Piping	Water, stream, sprinkler, gas, waste and others	Large diameter rigid piping failed at elbows and bends. Joint separations. hanger failures. Small diameter piping performed better than larger piping due to bending without resulting breakage. Single failures of hanger assemblies frequently caused progressive overloading and failures at other hangers and piping supports. Piping performed better in vertical runs where there were lateral restraints, than in horizontal runs where there was no lateral bracing. Failures at building seismic joints due to differential movements.
Ducts	Rectangular, square and round ducts	Breakage was most common at bends. Supporting yokes failed; long runs failed as a result of large amplitude swaying.
Electrical Equipment	Panels, transformers, ducts, switchboards, distribution system	Tall equipment overturned where not bolted at base or braced at top. Many instances of panels performing better than enclosing partitions. Horizontal movement of large equipment. Rigid conduit failures with structure support.
Elevators	Counterweights, Guiderails	Separation of counterweights from rails. Damage from counterweights included structural beams, cables, and cabs.
	Motor generator sets	Sheared off vibration isolation devices.
	Controller panels	Overturning when unanchored at bases. Hinged panels thrown open.
	Cars - Guiding systems	Generally performed well.
	Hoistway doors	Some doors jammed or fell outwards.
	Hydraulic elevator systems	Generally performed well. Some cylinders shifted out of plumb.
Escalators		Generally performed well. Some treads damaged by falling debris.
Emergency Equipment	Generators	Generally performed well when bolted securely to structural bases
	Communications equipment and lighting equipment	Performed similarly to other electrical equipment. Some battery racks collapsed. Unsecured battery powered emergency lighting and fell.
	Exit corridors, doors, lighting	Many exit doors deformed and jammed. Exit corridors blocked with other debris. Exit lights performed well
	Battery packs	Most remained in place where strapped to walls.

Figure 7-1
QUALITY OF NONSTRUCTURAL DAMAGE RECORDED DURING PAST EARTHQUAKES

caused by the swaying action of the fixtures against each other during an event. The light fixtures which performed well included surface mounted fixtures and recessed fixtures which were supported directly from the structure or from rigid permanent partitions.

All partition systems sustained some damage. Block type partitions including clay tile, concrete masonry, or gypsum block were damaged by joint failures in the partition or by compression failures at the top due to the action of the structure on the partition. Other damage included horizontal movement and corner failures. Metal stud partitions, when carried full height between structural floors were damaged similarly in that structural vibration caused bending in the studs. Studs, carried to or just above the ceiling system, were overturned by lateral action of the ceiling system on the partitions. Some separations were evident between the studs and carrying channels, both at the top and bottom. The partition systems which performed well included metal demountable partition systems and drywall partitions. Partitions which crossed building seismic joints were particularly susceptible to damage due to differential structural movement across the joints. Partitions which contained buried piping or rigid conduit also sustained some damage due to the interaction of the piping and the partition body.

Page 2 of Figure 7-2 on the following page, shows the elevator damage which was recorded in a study following the San Fernando Earthquake of 1971. This exhibit illustrates the types of damage which were sustained, and the numbers of instances of each type of damage.

As can be seen, the most common damage was to the counterweights, brackets, and guide rails. Other types of significant damage included motor generators and cable damage.

8. COMPONENT INSPECTION AIDS

Aides for making the initial Phase I (see par. 2 above) inspections of Nonstructural components are presented in Figure 8-1 in the form of Do/Don't Statements. Figure 8-2 to 8-10 depict desirable ways in which several of these type components should be constructed. Observed deviations from these idealized construction suggestions defined in these figures would, of course, downgrade the earthquake resistive capability of the component being reviewed. While the desirability of these construction approaches would generally be evident upon review, amplifying comments on a few are as follows:

. Figure 8-2 shows a detail for the proposed installation of recessed lighting fixtures. As can be seen, positive anchorage of the fixture body to the support is shown, as well as typical safety devices such as chairs to prevent the diffuser from falling and retainer clips to restrict the movement of acoustical tile.

. Figure 8-3 shows a proposed detail for conduit and bus duct crossing a building seismic joint. As can be seen, the rigid conduit and bus duct are terminated on either side of the joint and flexible conduit installed across the joint. This flexible conduit would allow for structural movements in all three directions.

. Figure 8-4 shows a proposed guide rail safety shoe which would constrain the movement of an elevator counterweight in the event of severe vibrations. During the normal operation of the elevator, this shoe would not be in contact with the rail.

Partitions	DON'T	DO
General	Cross building seismic joints with partitions unless special provision for deflections are built in.	In buildings with flexible frames, anchor partitions to only one structural element with separations from all other.
		The internal conduit and piping to same structural element as partition, with openings reinforced and large enough for pipe vibration.
	Use hanging furniture systems unless seismic Force Factor (C_p) adds the weight of such system to partition.	Provide lateral bracing for partition at top - either independently or from ceiling system.
Masonry		Reinforce partitions.
	Tie partitions to multiple structural elements.	Separate partition from structure with large joints.
		Use relatively close spacing of control joints.
Stud-drywall or Plaster	Brace with ceiling system unless designed for.	Provide expansion connections at columns and other structural elements coordinated with designed structural drift limits.
Demountable Full Height	Use a system which utilizes only gravity or friction connection of panel with top and bottom channels.	
	Use hanging furniture systems unless seismic Force Factor (C_p) adds the weight of such system to partition.	Use higher values of C_p in design assembly.
Demountable Screens		Anchor to structural element

Figure 8-1
DESIGN SUGGESTIONS

	DON'T	DO
Ceiling Systems	Use clips for attachment of elements to each other.	Design ceiling system for added weight of lighting fixtures or support independently.
		Gypsum board ceilings should be installed using large head nails.
	Support light fixtures or brace partitions with ceiling system unless separately designed.	Brace and separate suspended systems from walls in large rooms.
	Use lay-in tiles in exit corridors.	Coordinate ceiling system design separations with structural.
	Use ceiling system as a supply plenum.	Positively connect all elements together.
Light Fixtures	Use multiple lengths of fluorescent fixtures unless adequately braced at all points along length.	Provide adequate sway provision and damping in pendant fixtures.
		Separate pendant fixtures sufficiently so that sway arcs do not intersect.
	Use long rigid stems for supporting fixtures unless adequate sway is designed in hanger.	Use safety chains or positive attachment of lenses to fixtures.
	Use double stem fixtures with stems close together since rotation would tend to break items.	Use plastic lenses on fluorescent fixtures as opposed to glass.
		Design all fixture attachment systems utilizing engineering analysis and laboratory shaker table testing.
Furniture and Furnishings	Use open shelving for vital equipment or supplies.	Anchor all storage racks at base and laterally brace at top.
	Use glass shelves or glass display cases in public areas unless glass is tempered and securely fastened.	

Figure 8-1
DESIGN SUGGESTIONS

	DON'T	DO
	Use filing system with no system for latching drawers or doors.	Provide safety face bars on rails for open shelving where practical. Attach or brace all vital equipment for damage prevention.
<u>Piping Systems</u>	Anchor parts of the system. Cross structural seismic joints at all possible, except at lower building floors. Support pipes from each other.	Tie each line run to a single structural system. Where pipe runs across structural change, provide moveable joint. System should be designed as a rigid element - all elements should have some degree of freedom. Install sprinklers as per NFPC standards. Provide large openings on pipe sleeves to allow for movement.
<u>Ducts</u>	Anchor ductwork from multiple structural elements in long spans. Hang ducts from piping or other nonstructural elements.	Install flexible duct connections in semi-folded conditions to allow for future deflections. Laterally brace long hangers or support for ductwork. Provide earthquake values on gas lines and other critical service or hazardous piping.
<u>Mechanical Equipment</u>	Locate noisy equipment near critical occupancy so that vibration isolation may be avoided. Locate heavy equipment on upper floor of building if possible. Use inertia blocks under equipment mounted on vibration isolators.	Laterally brace all equipment including suspended equipment. Provide restraints on vibration isolators to limit excessive movement.

Figure 8-1
DESIGN SUGGESTIONS

Elc ical Equipment	Cross building seismic joints with rigid conduit and bus ducts except at lowest floor where unavoidable.	Anchor all transformers, switchboards and control panels to building. Use flexible connections where movement may occur. Provide separate grounds for conduit runs crossing seismic joints.
Elevator Systems		Provide restraints on vibration isolators under motor generators to withstand excessive movement. Bolt panels to floor where possible and brace at top. Design counterweight rails and supports to withstand earthquake forces. Provide for emergency communication ventilation, and lighting of elevators. Design hoistways and area to prevent distortion.
Emergency Power and Lighting System		Provide emergency generators in all buildings. Strap or anchor all batteries on racks.

Figure 8-1
DESIGN SUGGESTIONS

Figure 8-3
PROPOSED DETAIL FOR CONDUIT AND BUS DUCT
CROSSING SEISMIC JOINT