SECTION 8

Industrial Facilities—Field Investigation

Types of Data to Be Collected and Recorded

Warehouses, manufacturing facilities, energy-producing facilities, and factories should be inspected for performance of structure and documentation of any interruption of service or utilities caused by the event. Special attention should be given to nonstructural elements such as anchoring of equipment and computers, performance of sprinkler systems, etc.

Categories of Damage

The damage categories delineated in Section 7, Engineered Buildings—Field Investigation, can be used to describe damage to most industrial facilities. However, investigation may indicate a need to modify these categories for some applications.

CHECKLIST

Industrial Facilities

The more common types of industrial facilities that may need investigation include:

smelters

refineries

tank farms

paper mills

cement plants

wineries

power generation plants

warehouses

electronic manufacturing plants

food processing and packaging plants

data processing centers

General Observations

1. When equipment or facilities are damaged, in addition to documenting the damage, attempt to determine:
   a. Failure mode(s).
   b. Factors that may have contributed to failure(s).
   c. Implications of the damage on the operation of the facility and system.
   d. Resources required to restore service, including person hours, support equipment, spare parts, and total time for restoration of service.
2. Attempt to gather sufficient details on the equipment and situation so that recommendations to improve the seismic response of the equipment or post-earthquake operations can be made.

3. Note what performed well in addition to what did not.
4. Pay particular attention to the performance, both good and bad, of new equipment types or designs and new installation practices.
5. If time is available after investigating damage, and if the site has experienced severe ground motions that can be quantified, identify equipment and facilities known to have been damaged in past earthquakes that performed well.
6. Did vertical acceleration affect the performance or anchorage of equipment?

Structural Performance

Heavy industrial structures are a special kind of structure, in terms of their size and design loads. Refer to Section 7, Engineered Buildings—Field Investigation, for the checklist. Note the differences represented by the large size of industrial facilities.

Fire Protection Systems

1. Note on-site fire system:
   a. Are there engine-driven fire pumps?
   b. Is there on-site fire water storage? How much?
   c. Are the fire lines buried or exposed?
   d. Are on-site personnel trained in firefighting?
2. How did the fire protection system operate?
3. Document occurrence and location of any failure in fire protection system. Was there failed fire piping, or earthquake-induced fire system actuation, without an actual fire?
4. Briefly describe each element of fire protection system and how well it performed. Document lack of damage as well as damage.
5. Was piping properly braced to prevent pipeline failure and water damage?

Hazardous Materials

If hazardous materials release created a need for emergency response procedures, refer to Section 12, Emergency Management and Response—Field Investigation, for applicable checklists.

1. Were hazardous materials stored in the facility? Name the materials and the volume stored on site.
2. How were hazardous materials affected by earthquake? If spilled, do the materials assume a gas or liquid form at ambient conditions? Was there a danger of chemical reaction of the spilled material mixed with water (such as rain water, fire-fighting water, or water from failed tanks or piping)?
3. Name the specific materials of the tanks and piping.
4. Did the hazardous materials create a danger to people? Equipment? The facility? The surrounding community? If so, what action was taken?
5. Did the site have a response plan for cleanup of a hazardous spill? Was the plan activated?
6. Were hazardous materials correctly stored?

Storage Tanks

1. Did they slosh? Did sloshing create damage?
2. Compare tanks full and partially full at time of earthquake.
3. Describe type of foundation and soils.
4. Examine tank shell contact with the footing. Was there evidence of vertical or lateral movement?
5. Examine piping connections to tank. Were connections flexible?
6. What is type of roof construction?
7. Was there any interaction between tanks tied together by catwalks at roof level?
8. Were there changes in leakage rates?
9. Examine elevated tanks, including bracing, columns, and foundations.
10. Did tanks maintain ability to function?
11. Were there berms that provided secondary containment? How well did they function?

Mechanical, Electrical, and Plumbing

Refer to Section 11, Architectural and Nonstructural Elements—Field Investigation, for checklist.

Identify the performance of nonstructural elements particular to industrial facitilities, including:

1. Vibration isolators: Did they fail? What part failed? Were snubbers provided? List number and type of isolators used and estimate equipment weight.
2. Check conduits, transformers, switch gear, panel boards, and noninterruptible equipment. Document any failures.

Damage from Fire

Refer to Section 9, Lifelines—Field Investigation, for checklist.

Equipment

1. Describe type of equipment in facility.
2. Was equipment damaged? Describe type and extent.
3. Did equipment failure affect ability of facility to continue operations? Describe.
4. Were storage racks anchored and/or braced? Was system effective?
5. Are storage racks independent of the building, supported by the building, or do they provide support for the building?
6. Note equipment restraint methods. Were they effective?
7. Were inventories of products or materials damaged or destroyed?
8. Note performance of elevators, counter weights, and controls.

Anchorage Systems

Refer to Section 11, Architectural and Nonstructural Elements, for checklist.

Control and Instrumentation

1. What was the type of control system (pneumatic, analog electronic, digital electronic)?
2. Was the control system centralized or local to specific equipment?
3. Were there problems with instrument calibration?
4. Were there problems with loss of instrument air supply?

Power Systems

The following section on power systems should be viewed as representative of the types of questions that could be asked at any industrial facility. It is not intended to suggest that only power systems should be investigated, or that they are the most important industrial facility. In the interest of saving space, such a list has not been created for each type of industrial facility, on the assumption that this checklist could be modified and used where appropriate.

In General

1. Look for interaction problems between the boiler support structure and the boiler.
2. Look for interaction problems between the turbine pedestal and the powerhouse operating floor.
3. Inquire whether or not the unit went off line. If so, determine why.
4. Are there any indications of turbine bearing damage?
5. Does there appear to be steam coming from the stack, indicating boiler tube damage?
6. In general, how is equipment anchored?
7. Check station batteries. Are they operational?
8. Were sudden pressure relays in transformers activated?
9. Did any protective relays change state? Which ones?
10. Were any relays reset after the earthquake before operations were resumed?
11. Loss of power on any lines into or out of the station?
12. Were there disruptions? What was cause? Duration?
13. Note performance of suspended ceilings.
14. Did anything fall from desks, tables, or shelves in the substation?
15. Was there any disruption in communications? If so, what types of communications are used and which were affected?
16. Have personnel that were on the site at the time of the earthquake describe the earthquake and their actions afterward.
17. Are personnel aware of any other effects that the earthquake had on the power system?
18. Did liquefaction occur nearby? If so, what was its effect on turbine operation?
19. Does the site manager know if there were any special foundation preparations at the site?
20. Estimate the percentage of failures for each type of equipment.

21. Be sure to get a card from the plant manager with his/her name and address.

Fossil Fuel and Hydroelectric Generating Plants

1. Document gas line breaks.
2. Document and analyze damage and lack of damage to transmission and distribution equipment.
3. Document and assess power generation distribution system performance (load flow, demand, etc.) immediately after the earthquake.
4. Evaluate loss of electricity on other lifelines.
5. Note any unnecessary gas shutoff. Did shutoff cause problems?
6. Evaluate performance of seismic gas shutoff valves.
7. Boiler and supporting frame:
    a. Evaluate boiler tubes, lining, equipment, and controls.
    b. Check backstays or lateral force stops.
    c. Check piping and duct work that is connected to the boiler and to the ground or support structure.
    d. Check main support structure for distortion, cracked welds, broken bolts, or rivets.
    e. Check footings for new cracks, spalled concrete, or exposed reinforcing.
    f. Evaluate auxiliary tanks and chemical feed systems.
    g. Document condition of fuel storage and transportation systems.
8. Did earthquake motion agitate sludge in fuel storage tanks? Did it cause generator to stop?
9. Circulating water system:
    a. Check pumps, gates, or other equipment.
    b. Check for cracks, spalled concrete, and exposed reinforcing.
    c. Note change in flow characteristics that might be indicative of damage.
    d. Look for wet spots on ground in vicinity of inlet piping that could indicate leaks.
    e. Look for muddy water that may indicate cracks in discharge lines.
10. Hydroelectric water supply:
    a. Note any change in seepage.
    b. Document distortions or cracks in cradles or footings.
    c. Note any decrease in flow capability of the conduit.
11. Turbines and generators:
    a. Were turbines or auxiliary equipment shut down? If so, ascertain from operating personnel the cause of shutdown and amount of shaft misalignment, if any.
    b. Inspect turbine pedestal for evidence of cracking, spalled concrete, or exposed reinforcing and determine consequences of interaction between pedestal and powerhouse floor.

c. Check for distortion and possible untracking of main crane beam or trolley.
d. Note distress of seismic uplift inhibitors, if present.
e. Was there any damage to turbine thrust bearings?

12. Control room:
    a. Did failure of control room equipment cause plant malfunction? If so, determine nature of the failure and type of mounting used.
    b. Did failure of auxiliary support systems, such as lighting, heating, or ventilation, cause control building to be inoperative?
    c. Evaluate condition and performance of battery and equipment racks.
13. Coal-fired plants: What was interaction between the boiler and boiler support structure and the coal handling equipment—particularly conveyers that carry coal into the plant?
14. Other structures and appurtenances:
    a. Check fuel oil and gas pipelines and operability of valves.
    b. Check attachments between structures, or between pipelines and tanks and structures.
    c. Evaluate smokestacks, including operability, overall condition, base connection, and conditions at two-thirds height and at breaching. Check for tilting.
    d. Determine operability of doors and windows. Check for cracked windows, buckled siding, and plumbing damage.
    e. Was there ground distortion or subsidence in yard areas?
    f. Note performance of light fixtures, ceilings, overhead vents, and equipment.

Geothermal, Gas Turbine, and Nuclear Power Plants

1. Determine whether or not there may have been changes in geothermal source.
2. Is there danger of incipient landslides adjacent to facilities?
3. Evaluate waste disposal facilities.

Internal Utilities

Refer to Section 9, Lifelines—Field Investigation, for checklist.

Field Investigation Form—Industrial Facilities

Note: Because of the diversity of information to be collected from any one site, and the variance among different types of industry, this form should be used for general guidance only.

Name of Investigator:_____ Date: _____

Building Information

Building type:

Address or location: When built:

Number of stories: Basement(s):

Vertical load system:

Lateral load system:

Condition of walls:

Condition of foundations:

Building configuration:

Evidence of torsional response:

Quality of construction:

Strong motion recording instruments present?

Site Information

Types of soils:

Site: Slope % Level

Sand boils present?

Ground faulting present?

Earthquake Damage to Structure

_____

_____

_____

_____

Total estimated loss:

Less than 10% 10–50% over 50%

Is building operational? Yes_____ No_____

If no, why not?

Were operations disrupted?

If so, for how long?

To what degree?

Current status of utilities:

Estimated dollar losses:

Casualties: Deaths Injuries Unknown

Estimated Modified Mercalli Intensity:

Does building warrant further investigation? Yes No

If yes, why?

Miscellaneous Data

Architect: Engineer:

Are plans available? Yes No

Where?

Photos: Yes No Roll #: Frame(s) #:

Use back of this sheet for sketches and additional notes.

Recommendations for Further Research on Industrial Facilities