MITIGATING CONSTRUCTION AND DEMOLITION VIBRATION DAMAGE ON STATIONARY BATTERIES AND ELECTRONIC SYSTEMS: WHAT TO DO WHEN SOMEONE ROCKS YOUR WORLD

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ABSTRACT

Construction and demolition activities can generate potentially damaging levels of vibration to telecommunications equipment, computer or data center systems or utility control systems and other sensitive electronic systems and their stationary battery systems. Low frequency high amplitude mechanical energy sources like building implosions, pile drivers, wrecking balls, hydraulic rams, vibratory compactors, tampers and the like can cause a phalanx of electrical problems such as:

Battery issues:

- Active material shaking off of battery plates
- Cracks to battery jars, plates or other conductive structures.
- Loosening of intercell connections
- Dust or debris entering the cells through explosion-proof vents

Vibration issues for electronic systems may include:

- Circuit packs “walking” out of their sockets
- Loosened electrical connections
- Arcing damage
- False operation or “bouncing” of relay contacts or thermostat contacts disrupting normal system operation
- Dust generation that may contaminate sensitive electronic circuitry or cause false operation of laser dust-spot type fire detection systems
- Internal stress or metal fatigue damage to electronic parts such as integrated circuit “chips” or other components
- Head crashes on computer drives
- Abrasion damage to cables
- Misalignment of directional antennas such as microwave dishes or cellular telephone antennas

This paper is based on casework experienced during nearby demolition activities in the author’s telco Maintenance Engineer career and will delve into what sources of heavy vibration are most likely to cause problems, how local soil conditions affect transmission or propagation of mechanical energy and how equipment placement in a building can amplify or dampen mechanical energy. Covered also are how much vibration is too much and what steps can be taken to reduce the risk of potential damage. Various methods of demolition will be discussed in terms of their characteristic vibratory impact. The paper will identify mitigation steps that can be taken in the facility and when to ‘raise a flag’ with construction or demolition contractors who plan to work near the facility.

Because the most reliable of seismic standards for telecommunications systems are the Network Equipment Building Systems (NEBS) standards, typical data published by the US Department of the interior on construction and demolition vibration will be compared with NEBS criteria to develop safe working distances and acceptable vibration levels.

Generally speaking the lower the frequency of the mechanical energy the more likely it is to propagate through soil, rock and building structures where it may cause equipment problems. Further, the softer the soil the more likely it is to conduct vibration energy with peat or swampy soil or poor grade alluvium being about the most active of the conductors and having the potential for the most circuit equipment damage. Further, since building height tends to amplify vibration fairly linearly, equipment on upper floors may be exposed to more vibration than equipment on or near the ground floor.

HOW MUCH VIBRATION IS TOO MUCH?

As a general rule of thumb, if you can feel vibration with your body it is exceeding safe levels for equipment. So if touching a frame or cabinet produces vibration that you can feel or if you can feel it in your feet from the floor slab it's time to do something about the problem before failure or damage occurs.

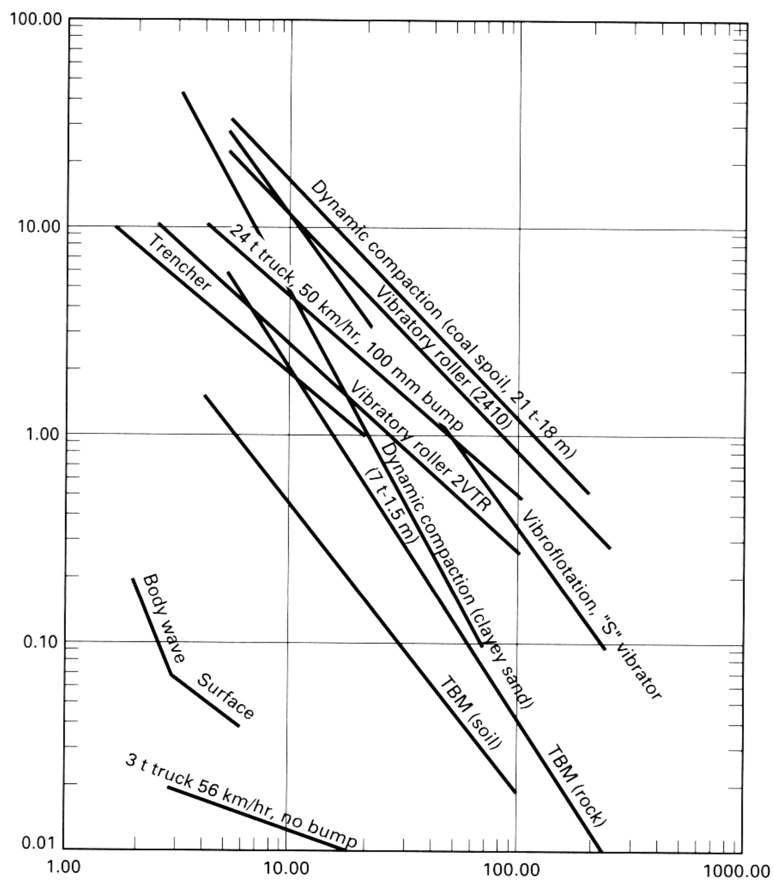

Figure 1. Excerpt from Construction Vibrations: Charles Dowding showing the effect of distance on vibration levels.

Site	Soil Type	Energy Source/ Description	Energy or Power	Frequency Range (Hz)
M1	Sand	Drop weight/ 15 tons, 80 ft drop	2,400,000 ft-lb[b]	5–10.5
M2	Clay	Drop weight/ 6 tons, 30 ft drop	360,000 ft-lb	8.5–17
M3	Sand	Vibroflot	100 hp	31
			30 hp	31
M4	About 20 ft soil over bedrock	Diesel pile hammer, 700-lb hairpin	18,200 ft-lb 2,500 ft-lb	18–33 40–44
M5	Clay	Drop weight 13 ft. below G. S./1.5 tons, 1 ft and 2 ft drop	6,000 ft-lb 3,000 ft-lb	12–33 30–48
M6	Sand	Pump-generator	—	11–60
01	Clay	Drop weight/ 8 tons, 30 ft drop	480,000 ft-lb	9–12
NC1	Sand	Drop weight/ 300 lb, 5 ft drop	1,500 ft-lb	20–40
NC2	Sand	Dump truck driving over 3-in. high plank	7,000 ft-lb (loaded) 2,500 ft-lb (unloaded)	10–40

Figure 2 Impact of various construction or demolition events *Construction Vibrations*: Charles *Dowding*

SCRANTON, PENNSYLVANIA

A 5-story central office building in Scranton Pennsylvania found itself in the path of redevelopment. The telephone building occupies most of a city block in Scranton, a former coal mining and railroad city about two hours north of Philadelphia. The redevelopment plan called for the demolition of The Casey, an 11-story hotel dating from approximately 1911. The central office is built only 14-1/2 feet across a narrow alley from the doomed hotel. A number of one and two story buildings across the street from both the central office and the hotel were to be razed to provide parking for a new convention hotel to be built on the site of the original Casey Hotel, as was another building behind the central office.

The soil below both the Casey Hotel and the central office is unstable bog soil and alluvium some thirty feet deep as was determined by core borings. Such soil transmits vibration very easily and is a little like building on a bowl of Jell-O. The developer wanted to demolish the Casey Hotel using an implosion because that means is faster than a conventional demolition using a wrecking ball etc. Both methods cost approximately the same and implosion is just a faster process. The other buildings were scheduled for conventional demolition. Given the weight of the building materials in the eleven-story Casey, an implosion would drop those materials producing a calculated 1.2 billion foot-pounds of energy! By calculation, it would take 63 feet of separation between the Casey and the central office in order to remain below the maximum tolerable vibration level of 0.5 Inches per Second of Horizontal Particle velocity and there was only 14 feet of separation.

Figure 3. The Casey Hotel before demolition.

While many areas for concern were addressed, from a battery standpoint some protection was in order, especially for battery strings close to the condemned building. While the demolition contractor was hanging tires and plywood to the outside of the building, it was prudent to provide additional protection inside in case a mass of falling bricks etc. penetrated the exterior plywood and window glass. A temporary wall of ¾" plywood on a frame of 2 x 6 lumber provided a shield for the battery and bus (Figure 5). Supplies of clay absorbent were purchased and the battery stand was equipped with a vibration measurement accelerometer, one of many that were wired to a computer arranged to provide notification if vibration limits exceeded a preset safe limit. Additionally, each cell in the battery was inspected to assure that excessive sediment wasn't present and that electrical connections were within micro-Ohmic limits. Dust caps were installed on all explosion-proof vents.

Negotiation (often spirited) with the developer and the city government was necessary in order to back them down from their implosion plan and the hotel was taken down with a wrecking ball with only one minor incident of damage to the telco building. There was no significant impact to telecommunications services.

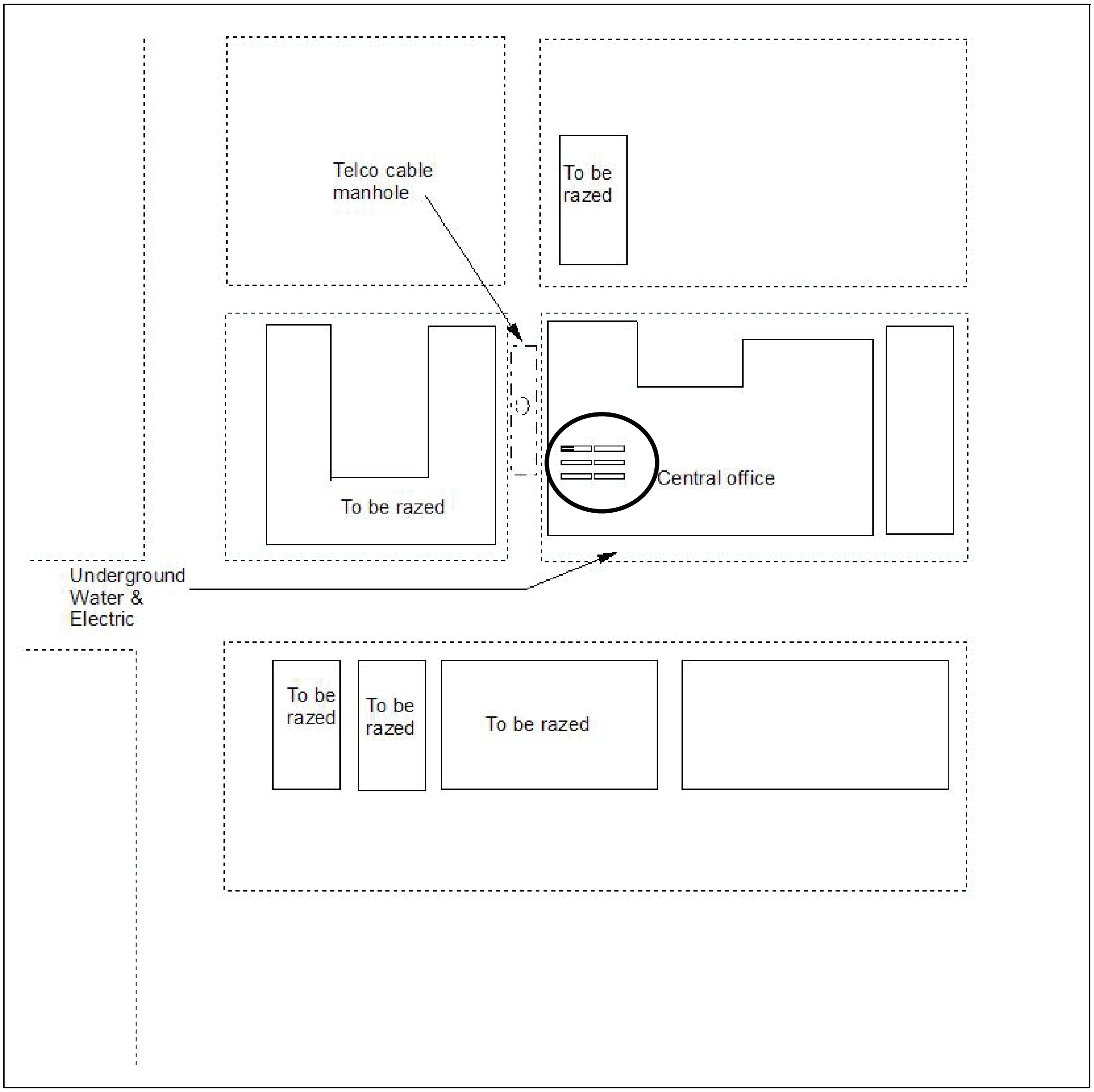

Figure 4. Scranton Central Office surrounded by buildings scheduled for demolition.
Note that battery strings (circled) for critical systems are very close to the doomed hotel.

Apart from battery protective measures already covered and negotiating a conventional demolition, the proactive facility management measures taken by the telco included:

- Single point of contact established with General Contractor
- Back up system restore tapes & drives often in case a restoral effort was needed due to a drive crash or other event.
- Seismic monitoring established in the telco network equipment space
- Maintained standby engine fuel tanks at or near topped-off
- Extra fuel filters on-hand
- Emergency portable generator prearranged
- Add prefilters to HVAC air intakes
- Positive air pressure of all C.O. spaces placed.
- Exterior chiller piping protected
- Tires and plywood on C.O. roofs
- Manhole sandbagged
- Alley above manhole plated
- Telco building windows protected

- Telco building doors closest to demo site off limits during the demolition phase
- Tacky-mats (Sticky door mats) placed on floor at all doors in use
- Hotel pre-cleaned of HazMats (Disease control for Histoplasmosis and Hantavirus from bird and rodent droppings)
- Water spray for dust control during demolition
- Particle counters placed and monitored in network equipment spaces
- More frequent cleaning of network equipment spaces
- Strict enforcement to keep equipment cabinet doors closed (dust control)
- Exterior of building photographed in case evidence needed for damage claims.

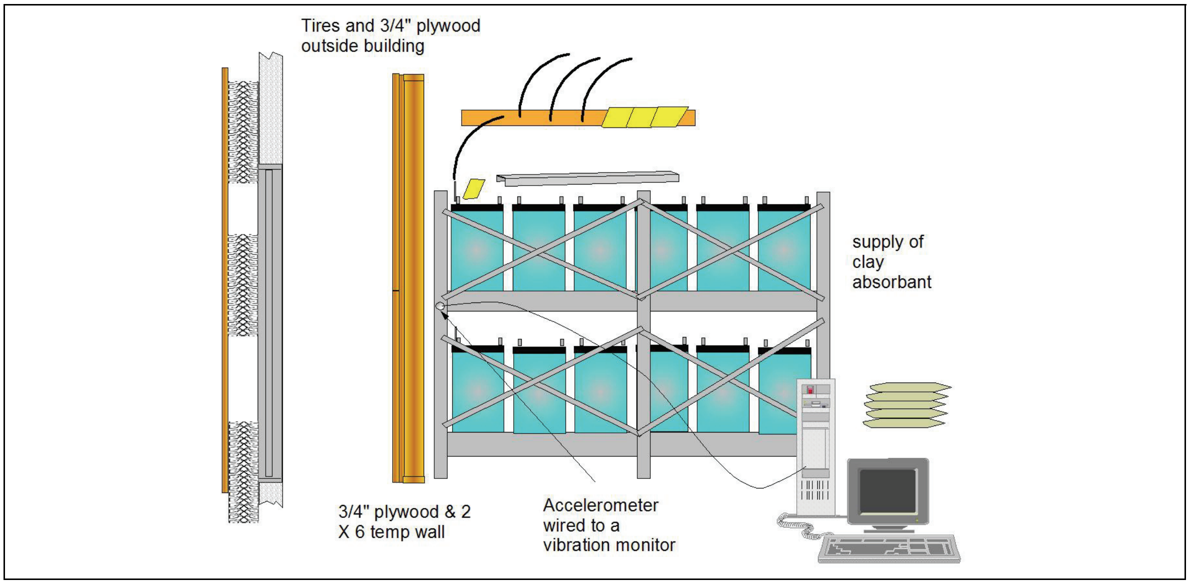

Figure 5. Battery protection for strings close to the demolition area.

ALLENTOWN, PENNSYLVANIA

As may be seen in Figure 6, an office building about a city block from a multistory telecommunications central office building was in need of demolition after a sinkhole caused the structural failure of one corner of the building. Due to the proximity of nearby structures the means chosen for demolition was a “pancake” type of implosion technique. Because the telephone building is 367 feet from the nearest edge implosion site there was no sufficient risk of vibration damage from the explosive blast or the impact of the building remains pummeling the ground.

- From a battery perspective, proactive measures included:
- Ohmic measurement of the intercell connectors and battery cables
- Ensuring that all explosion-proof vents were covered against dust ingress
- Visually inspecting all cells for evidence of sediment that might suddenly result in a shorted cell
- Ensuring that “Battery on Discharge alarms were functioning
- Ensuring that absorbent materials were on hand
- Testing the standby engine start battery to ensure that the system would serve if needed.

In this case most preparatory measures were to the building. HVAC systems were placed in a Recirculation mode and all outdoor louvers closed to prevent the ingress of dust from the implosion. Additionally, photographs were taken of the telephone central office walls and windows in case evidence was needed to support a damage claim. Fortunately, prevailing winds carried the massive dust cloud away from the central office and once the cloud passed, the event was over, the HVAC system was made normal again. Until all debris was trucked from the site, particular attention was placed on the HVAC system to maintain positive pressurization inside the building and air filter maintenance. System level proactive measures included:

- Back up system restoration tapes & drives to handle a drive crash event
- Top off standby engine fuel tanks to cover a prolonged run
- Alert Network Operations Center in case of unusual events or alarms

- Close off fresh air dampers during the implosion to avoid the ingress of dust
- Maintenance Engineers on-site to aid in an emergency restoration if needed

Figure 6. This photo is taken from the snow covered roof of a telephone central office in Allentown, Pennsylvania, where a pair of video cameras will record the implosion of a damaged 8 year-old office building. A sinkhole caused the structural failure of one corner of the building, as can be seen by the partial collapse.

PHILADELPHIA, PENNSYLVANIA – THIS ONE NEARLY WENT BADLY

During a severe snowstorm, fire broke out in an abandoned 8-story building that was only 12-1/2 feet from an 11 story telecommunications hub in Philadelphia's Chinatown community (Figure 7). Because the telephone company building overlooked the burning structure, the Philadelphia Fire Department opted to use the fire standpipe system in the telco building in order to direct hose-lines from the roof of the telco building to the burning building in fighting what became an 8-alarm fire.

The threats to telephone service were that a collapse of the burning structure might destroy critical systems on that side of the telco building and also, that smoke would enter through the air intakes that – unfortunately – were on the same side of the building. To reduce smoke incursion all HVAC systems were placed in the Recirculation mode. All fresh air dampers on that side of the building were closed. Later, it was determined that some smoke still was entering past the closed air dampers and so manual steps were taken to close the fire dampers associated with those dampers. Because of the amount of water splashing around from hose-lines through cracks in window glass on that side of the building, it was necessary to go from floor to floor in the telco building blotting up water before it could cause equipment problems. What we almost missed was water incursion on the 4th floor, where a critical UPS system was located. At first no one realized that water had gotten below a raised floor where the UPS electrical junction boxes (480V 3 PH) were mounted. The placement of large fans and blotting water from the Junction box and from the flooded battery string that fed the UPS helped dry the area. Despite the magnitude of the event, thankfully no significant service problems occurred.

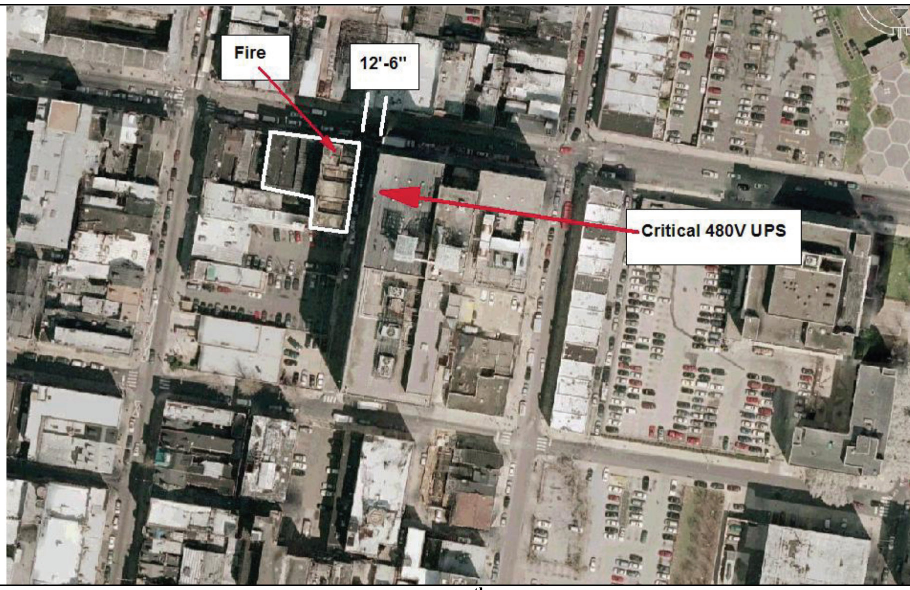

Figure 7. A pre-fire aerial image of the 9th and Race Streets telephone building.
Note that a critical 480V UPS was located just inside the West wall on the 4th floor.

CONCLUSIONS

Construction and demolition are a fact of life. Poorly managed, the vibration, dust, smoke etc that could impact a network equipment installation could be disastrous and expensive. Such expenses might take the shape of shortened service life or increased ongoing maintenance cost. By taking a Risk Management approach and appointing someone or even a team of people to serve as an advocate for equipment safety, reliability and operational readiness, telcos can minimize the threats to their critical services. If a telco needs consulting services to cover some of these bases, there are enough experienced former telco people or Bellcore/ Telcordia disaster recovery people in the US to make outsourcing feasible. The bottom line is that it's a telco's job to assure telephone service, reliably and cost effectively despite threats to those services. So what's a telco guy to do?

1. **Assess the situation and be assertive**
   If the demolition or construction site is fewer than several hundred feet from your network equipment or if it is an addition to your building someone must act as an advocate for service. Meet with the General Contractor and address vibration and dust issues. Assert that telco equipment is more sensitive even than most hospital equipment and that vibration levels experienced at the ground level of a telco network facility cannot exceed 0.3 inches of horizontal particle velocity. Expect that he or she will balk at this figure and keep asserting it doggedly. Remember that the cost of telecom equipment is a very minor figure compared to the losses experienced when that equipment is not in service. Also, the contractor probably doesn't realize the level of interconnection between one central office and others. Assert that damage in one central office could have widespread impact and even isolate major portions of the US. Make it clear that if necessary your company would seek injunctive relief because of the public safety aspects of telephone services. Assert that if equipment damage took a week to fix that the total losses are very large. Don't be afraid to toss around numbers like "losses could reach a half-billion US dollars." Potentially staggering Figures like that generally get a contractor's attention and respect and the fact is that in many instances a potential for such losses do in fact exist given the right network conditions.

2. **Negotiate for lower vibration levels**
   If the contractor wanted to use a ram to break concrete or rocks and that impact is felt in your equipment frames, there are other less low-frequency rich means to do the job. Jackhammers or concrete saws do the same job without jarring your systems. For excavating rock, there are chemical expanders that are sometimes used in quarry work that when poured into holes drilled into rock will expand and apply pressure, breaking the rock in the same way that explosive charges would and they pose no risk to network systems. Insist that the contractor protect your building from flying debris if necessary. Provide vibration monitoring equipment in the network equipment space to alert you if the vibration exceeds a safe threshold.

3. **Get a "big picture" of the risks**
   Put aside your equipment engineer's hat or Operations hat and look at the scope of work from a Risk Management perspective. If you don't have those kinds of skills in-house outsource for them. You want to limit vibration, dust, and you want to assure that heavy truck or other equipment won't damage underground power feeders, fuel tanks, telephone cables or water and sewer lines. Each of these items must be addressed to assure that adequate protection is in place.

4. **Control dust**
   Dust is a killer to electronic systems. Many construction dusts have the capacity to accumulate on circuit boards and electrically short-circuit electronic circuits especially if higher than normal humidity levels are experienced. Identify the relative positioning of your building air intakes with respect to the construction / demolition dust source. Find ways to increase the air pressure in your equipment spaces with respect to other spaces or the building exterior. This so-called "Positive Pressurization" tends to push dust away from doors etc and therefore minimize the incursion of dust. If the construction or demolition will go on for weeks and months it's prudent to place a particle counter in the network equipment space to alert if there is too much dust in the room air.

5. **What about nearby fires?**
   Sometimes fires break out near central offices and the chief threat is smoke. Smoke incursion is a very serious threat to network equipment as soot accumulations on circuit boards are electrically conductive. Usually the best thing to do in such cases is to shut all outside air dampers and place the building's HVAC system on recirculation if that is at all possible. Try to limit people from entering or leaving the building using doors that are in the path of the smoke. If you experience soot damage there are a couple of reliable companies across the USA that are experienced at cleaning away such contamination.

6. **What about water?**
   If, due to firefighting efforts, pipe leaks, flooding or other causes equipment cannot be kept dry, the most proactive measure you can take is to shut down and depower the equipment. When energized circuit boards become wet, an irreversible corrosion cycle begins and such equipment cannot be salvaged. Often, if equipment was deenergized before it got wet, specialized cleaning and drying are possible to restore the equipment to service.

7. **Do not allow anyone to place so-called Odor Eater or Smoke Sponge units.**
   Such products claim to absorb smoke or odors. Those claims are blatant lies. The fact is that these products are evaporative sponges that absorb nothing but perfumes. These perfumes then evaporate or "boil-off" invisible cloud-like plumes of fruity smells with hydrocarbon chemicals such as limonene etc. Such chemical plumes deposit Volatile Organic Compounds (VOCs) that form deposits on equipment. When deposits of VOCs experience vibration such as from fans etc, the VOCs undergo a process called frictional polymerization that create a "goo" that works its way into sockets to form an insulating layer between pins and socket parts.