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Vintage Power Plants: Environmental Characterization, Decontamination, & Demolition

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Vintage Power Plants: Environmental Characterization, Decontamination, and Demolition

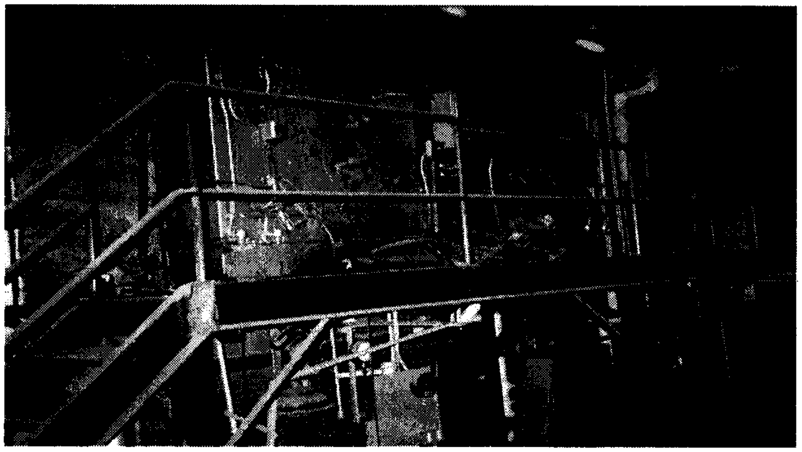
Introduction

Decontamination and demolition of buildings can be a regulatory and financial abyss. Numerous regulations apply to the identification, characterization, removal, and disposal of contaminated materials and building debris, and project assessments and contract language can leave building owners wide open for contractor add-ons. These projects can vary greatly in complexity depending upon the nature and use of a building. The decontamination and demolition of vintage power plants presents a significant challenge to the owner, consultant, and contractor. However, through a detailed assessment of the building systems, an understanding of the nature and location of contaminants and their associated regulations, and through explicit contract documents and oversight, projects can be completed on time and within budget. Obviously every site is different, and there are no guarantees, but a consistent due diligence process combined with astute contract management will mitigate liabilities. This document describes systems and important features of vintage power plants, includes methodologies for evaluating them, and provides suggestions for decontamination/demolition contract language and contract management strategies.

As illustrations, portions of this paper refer to two vintage power plants located in Connecticut. They include 1920s (low-pressure) boiler houses and high-pressure (1940/50s) boilers. The plants were originally coal fired, but were converted to fuel oil or co-burning plants. One facility has been demolished and the site is awaiting redevelopment, highlighting its strategic waterfront location. The other plant's hazardous materials and asbestos survey has been completed.

Building Systems and Operations

Each building offers its own unique architecture, operations, history, and secrets. The first step taken toward decontamination and demolition is the completion of a detailed building assessment which identifies the nature and location of building activities and operations, both past and present, especially those involving the use or storage of chemicals/oils. It also seeks to understand the individual building systems and how they operate in concert. This provides key insight into the actual or potential distribution of contaminants such as polychlorinated biphenyl (PCB) contaminated compressor oils or floor drain sediments. An assessment of building structural systems and materials is also essential to the completion of demolition plans and specifications.



Low-pressure boiler firing deck

Vintage power plants are a labyrinth of catwalks, alleys, pumps, and pipes, especially to those unfamiliar with power plant operations. Tours guided by facility personnel who know building operations and systems are critical to laying the foundation for a detailed hazardous material survey. Weeks of sampling activities can be expected in order to produce a thorough assessment of hazardous materials at the facility; however, this time is well spent as it promotes a thorough understanding of the building layout and operations. Facility maps and drawings are also critical for understanding the building systems and revealing interior areas of boilers and other equipment that are hidden from sight. Some plans may specify the use of asbestos insulation or mercury switches that may otherwise be overlooked during a survey.

Thorough, field-verified base maps must be generated and reviewed before the survey begins. These maps provide the road map that will guide the survey and direct the inspector throughout the survey. Any historic data may also prove useful to the inspector and should be included on the base maps.

The following presents a brief summary of the major systems and processes located within vintage power plants, as well as some associated constituents of concern.

Coal Systems

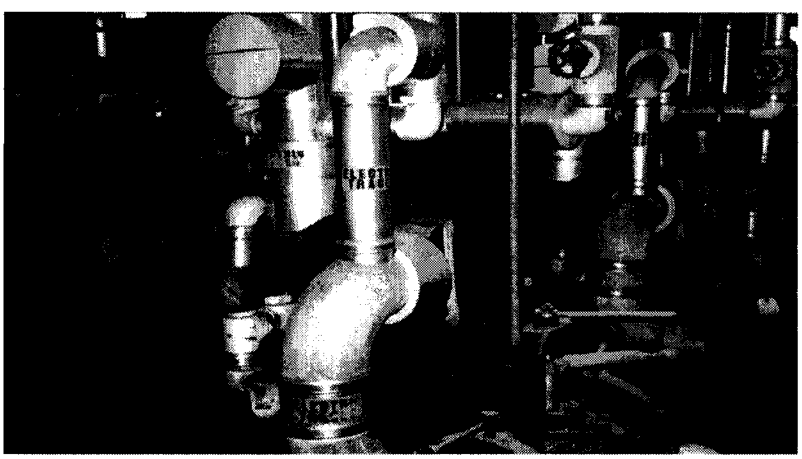
Coal is usually delivered to power plants by either water or rail, and can be offloaded by cranes attached to on-site elevated rail systems (i.e., traveling cranes). The coal is usually stockpiled outdoors and adjacent to the power plants, and is handled with heavy equipment such as bulldozers or crane systems. Conveyor systems bring the coal from the exterior of the plant to interior storage silos. Very early plants used human or mechanical stokers to deliver coal to the fire, while more modern plants fired by pulverized coal use internal


Internal coal conveyor above low-pressure boilers

feeders to bring the coal from the silos directly to stoker-fired boilers. In the case of pulverized-coal boilers, the feeders deliver coal to coal pulverizers associated with individual boilers or groups of burners. The pulverized (to the fineness of talcum powder) coal is transported to the boiler burners through pipes or ducts by means of hot pressurized air.

At the facilities, use of the coal delivery systems was abandoned when the boilers were subsequently modified to burn fuel oil. Outside each plant, much of the coal delivery systems have been removed, and only foundations of the old conveyors and crane systems are visible. Inside both plants, the coal conveyor systems remained in-place and both plants also had low-pressure stoker-fired boilers as well as pulverized-coal-fired high-pressure boilers.

The heavy equipment storage and maintenance area may be suspect for fuel storage and maintenance chemicals, and conveyor and crane systems require heavy grease for the many moving parts. The coal itself is relatively innocuous, although groundwater monitoring can be required for coal stockpile areas due to issues potentially resulting from coal leachate.


Fuel oil pump room

Fuel Oil Systems

Bunker C/No. 6 Fuel Oil (commonly referred to as Heavy Oil) is typically the main source of fuel oil consumed at these types of power plants. However, most boilers which operate on Heavy Oil require the use of a lighter grade fuel oil during the initial firing stages of boilers. This No. 2 Fuel Oil (or Light Oil) is used to bring the internal temperature of the boilers up to the levels necessary to properly burn the Heavy Oil. Light Oil is typically stored in aboveground or underground storage tanks, with storage capacities varying depending on the demand of each power plant. Heavy Oil is usually stored in large aboveground storage tanks (bulk oil tanks). Storage capacity requirements for Heavy Oil are significantly more than those for Light Oil, and can often exceed 1 million gallons. The locations of these tanks are a considerable distance from the power plant, necessitating aboveground and underground oil transfer piping and oil pump houses. Some Heavy Oils are not readily flowable under cool temperatures, therefore steam coils are usually used within the large storage tanks, and steam or electric heat tracing along transfer piping exterior to the power plant. This fuel/steam piping is also insulated. Oil is usually directed into a central pump room area where it is heated (usually by steam) and perhaps mixed with fuel oil additives before being pumped to the boilers. A variety of steam and electricity-driven pumps move the oil through the transfer piping up to the boilers. In older plants, fuel oil pumps may serve one or more boilers, but in newer plants each boiler may have its own pump. Redundancy in power plant systems is essential for minimizing down time. Fuel lines run from the pump rooms through the plant and to the boiler firing decks, where they are injected into the burners of the boilers.

It is not uncommon to find chlorinated solvents, metals or low levels of polychlorinated biphenyls (PCBs) within fuel and fuel systems. This may be the result of cross-contamination or disposal of wastes (from other areas/operations at the plant) into the fuel oil storage tanks or fuel systems. Fuel and steam pipe insulation may also contain asbestos.

Boilers

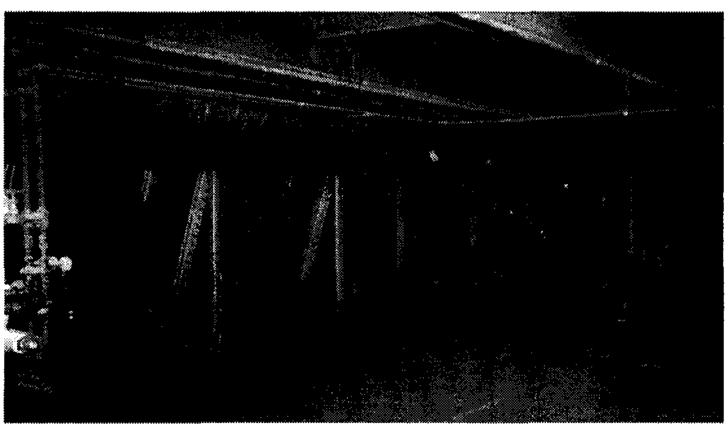
Power plant boilers are huge and ominous creatures; however, through careful study and review of plans, they can be understood by the layman. Power plant boilers can be several stories in height and are surrounded by a labyrinth of catwalks and open stairs that access equipment and machinery on various levels. Fresh, condensed, and chemically treated boiler feed water is directed into tubes inside the boiler. In the furnace section of the boiler, the flame directly heats the water in the boiler tubes. After leaving the furnace section, the hot gases continue through the boiler, further giving up heat to the steam and water in the boiler tubes. As the heated water inside the tubes turns to steam, the steam is separated from the water in a large horizontal tank called the steam drum. From the drum the steam is piped to other sections of the boiler (called superheaters) where it is further heated. A continuous circulation of steam exiting the boiler and cooler makeup water entering the boiler takes place. Old (cooler) water inside the steam drum is also re-circulated back through the boiler.

There are numerous asbestos applications in the construction of older boilers. Boiler cross-section plans may specifically reference asbestos products as a thermal jacket, between expansion joints, as door insulation, boiler brick, between channels, etc. Again, plans, drawings or blueprints can prove quite useful for assessing hidden areas within boilers. With or without plans, one must assume all boiler gaskets and other insulating materials contain asbestos unless proven otherwise through testing. Therefore, boilers must be disassembled and cleaned to remove asbestos components. In some instances, it may prove more cost effective to simply dispose of entire portions of the boiler as asbestos-containing building material (ACBM). Boilers also contain numerous gates, valves, and air dampers, often controlled by hydraulic or pneumatic cylinders. These lines must be identified and drained/cleaned during boiler disassembly. Boiler hydraulic oils can potentially contain PCBs, and certain associated switching assemblies may be operated by mercury switches.

Ash Handling Systems

The combustion of coal and fuel oil inside the boilers produces ash that must be handled continuously throughout steam production. Boilers produce two types of ash, called bottom ash and fly ash. Bottom ash is heavy; it accumulates below the furnace (fire ball) area of the boiler and tends to be a coarse, hard material. Flyash is light and is carried away from the furnace by the flue gas; it tends to be a very fine material. Both coal and oil produce both types of ash.

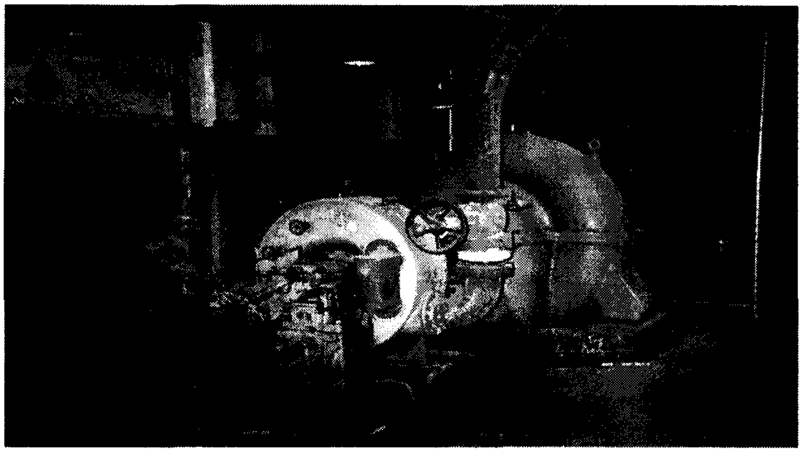
Bottom ash is usually handled as a bulk material, using equipment such as chain/gear or hydraulic ash gates, carts or conveyors, or hoist mechanisms (called skip hoists). The ash would then be transported into a storage area (usually silos) for future disposal.



Bottom ash collection hoppers

Fly ash is carried by flue gases to equipment that removes it. Older boilers recovered some fly ash material as the boiler gases cooled as they traveled to the chimney; however, much of it was released into the atmosphere. More recent pulverized-coal boilers produced more fly-ash material and less bottom ash, and have better systems for removal of fly ash. Systems include electro-static precipitators, which use high-voltage electric fields to remove the fly ash from the flue gases and cyclone separators, which use an air swirl to separate the ash. Other ash handling equipment includes ash vacuum systems and associated vacuum piping, and ash silos.

By and large, bottom and fly ash are relatively innocuous. However, they can contain heavy metals and some heavy oil ash contains valuable vanadium. Traces of semivolatile organic compounds are also in the ash. As part of the decontamination and demolition procedures it may be wise to follow the ash disposal methods that the facility has been using for years. This may eliminate costly ash characterization which may, in turn, lead to a more expensive disposal as a contaminated waste. The ash conveyance systems are straightforward mechanical units that require oil, greases and gaskets. The electrostatic precipitators have numerous associated transformers and other electrical components that could contain PCB-containing insulating oils and asbestos containing building materials (ACBMs).



Steam-driven condenser pump

Steam and Condensate Systems

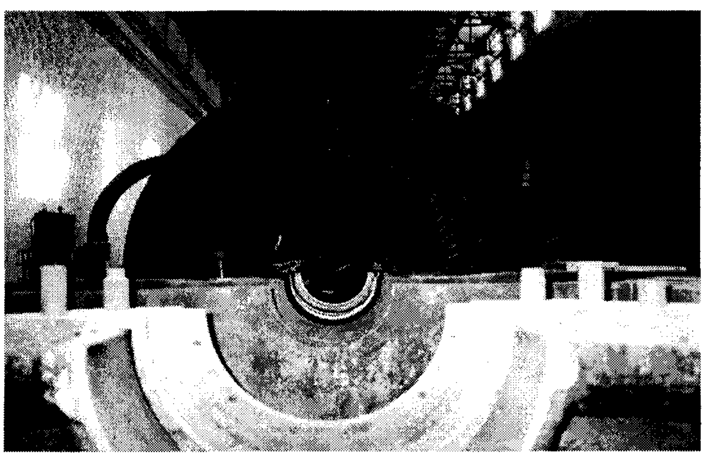
High-pressure steam lines from the boilers travel through the boiler room and enter the turbine room. A single steam delivery pipe typically accesses each turbine and one or more boilers are required for each turbine. At the facilities there were more than 10 low-pressure boilers that supplied more than five low-pressure turbines, but there was one high-pressure boiler for each high-pressure turbine. Steam lines must maintain pressure, and therefore temperature: they are nearly always insulated with asbestos. Steam enters the turbine under immense pressure (200 to 600 pounds per square [psi] for older low-pressure equipment, 600 to 1,200 psi for equipment 40 to 60 years old, and up to 5,000 psi for new plants) and exits the turbine with a negative pressure (strong vacuum, in fact). Nearly all of its energy is dissipated by the action of turning the turbine at speeds of up to 3,600 revolutions per minute (rpm). There are other applications for the steam being produced by the boilers. It is directed throughout the plant through smaller steam lines for functions such as heating feedwater, heating fuel oil lines, and driving pumps and fans.

Open end of condenser unit

Once steam exits the turbines, it is directed to condensers that cool the steam back into water. This is typically done using sea or river water as the cooling agent, although some older units used cooling towers with air blowers. The low-pressure turbine condensers at one of the facilities consisted of cylinders approximately 25 feet long and 10 feet in diameter. These were filled with horizontal tubes about 1 inch in diameter. Steam was condensed around these tubes as the river water was directed through them. Large pumps pump the condensed steam (condensate) back on the journey to the boiler room. Numerous feedwater heaters and booster pumps also raise the temperature and pressure within the condensate return lines as it is pumped to the boiler.

The cooling water (from a nearby river or sea) is obtained through tunnels commonly referred to as "intake structures." Screen houses remove large items from the water, such as shellfish and litter which would obstruct the flow of cooling water to the condenser units. The cooling water is pumped through the condensers and exits the plant via discharge tunnels or canals. One intake/discharge may serve several turbines or there may be one for each turbine.

Steam and condensate lines contain "pure" water and are not an issue with regard to contamination other than asbestos insulation and gaskets. The pumps that serve these systems utilize lubricating oil and grease, which may potentially contain PCBs. Intake/discharge tunnels may contain contaminated river/sea sediments since these facilities are typically located in industrial areas. The same discharge tunnels may also receive other stormwater-type discharges from other portions of the plant. Mercury-containing switches can potentially be found on any of the support equipment (i.e., pumps, tanks, heaters, etc.) associated with the condensate or steam systems.



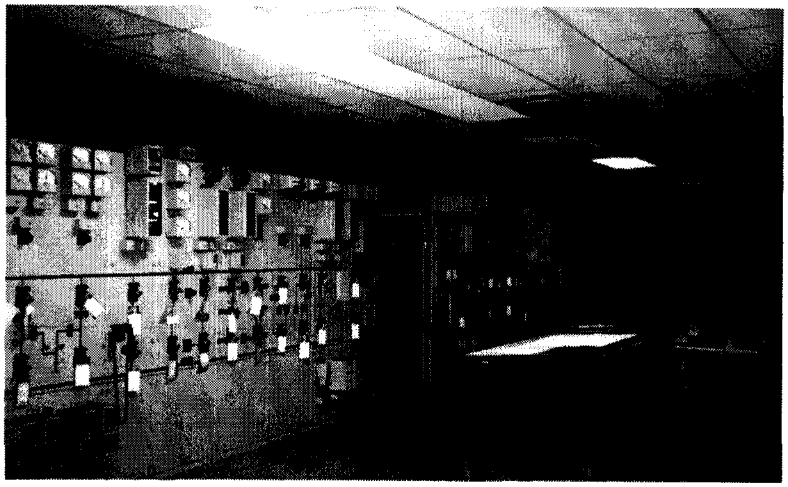
Stripped low-pressure turbine

Turbines and Rotors

The steam generated by the boilers is directed to turbines which turn the electric generator rotor. As the massive, magnetized rotor turns at 1800 to 3600 rpm within the wound copper casing (stator), voltage is generated as magnetic lines of force are cut by the windings. The electrical frequency (60 cycles per second) generated depends on the speed at which the rotor turns. Lubrication, balance and cool temperature are all critical for proper operation of the turbine. A network of passages through the turbine rotor is provided that permits the continuous flow of lubricating oil and, for some generators, hydrogen for cooling.

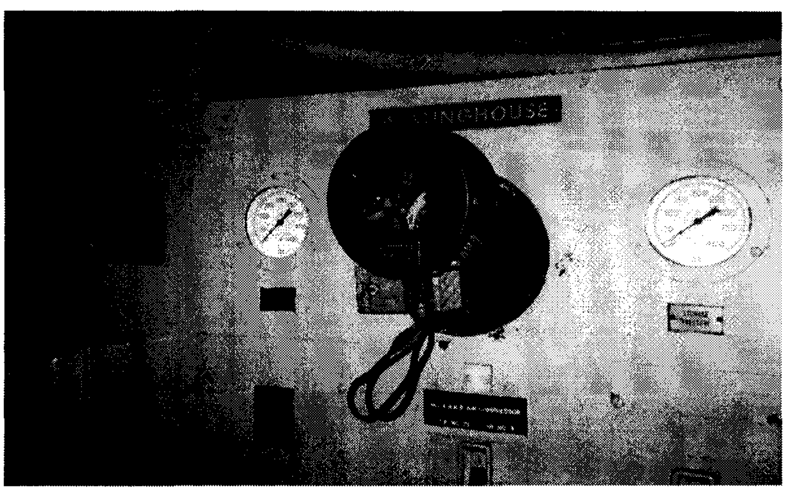
Turbine oil lubrication systems are potential sources of PCB-containing oils. Also, various asbestos applications for thermal and electrical insulation are common.

Electrical Switchgear and Equipment/Control Rooms



Control Room

Motor-controlled, oil-immersed circuit breakers (switchgear) are used to control the alternating current circuits produced by the turbines. They are typically located on the opposite side of the turbines from the boilers. They are placed within electrically insulated boxes so no short circuiting can occur between phases. The breakers are usually in long banks and stacked two or three high and are below or adjacent to the control room. Reactors, capacitors, and transformers also serve to regulate the flow and voltage of electricity within the plant as well as power transmission from the plant. The control rooms are the brains of the operation. They contain the sensors that indicate the output levels of each turbine and provide the necessary information for the operators so that flow can be switched or regulated. The control rooms also maintain some responsibility for distribution of electricity from the plant to the surrounding area. The temperature- and humidity-controlled rooms consist of panels of switches, lights, meters, and dials, as well as office space. Back-up power supply consisting of batteries of lead-acid cells will also probably be present near the control room.



Mercury switch in control room

At the facilities, the observed electrical switchgear and equipment and meter control rooms were similar to the conditions described above. Of particular note was the application of an asbestos-containing surface coating to the upper half of all four surrounding walls at the switchgear room. Climate control equipment was also observed in-place throughout much of the switchgear and electrical conduit rooms at the facility.

Oil-bath circuit breakers, reactors, capacitors and transformers are potential sources for PCB-containing insulating fluids. Mercury switches may be present on pressure-related switchgear. Certain rooms requiring climate control equipment may also have mercury-containing equipment. Potential ACBMs include insulated circuit breaker paneling and switch equipment, fire-rated doors, floors, ceilings and walls.

Floor Drains, Pits and Sumps

Due to the large volume of water required to operate these plants, their proximity to water bodies, and the presence of high voltage, the rapid shedding of water from the plant interior is critical to operations. Many plants have flood shields for doorways to keep high water/stormwater out. Also, extensive floor drain systems and sumps are located throughout the plants. Floor drain systems will discharge to collection areas such as sumps and may be pumped to the local sewer system or on-site treatment facility. Historically, stormwater and surface drainage discharged to a cooling water outfall or some other discharge point directly to the water body. Sumps are also located strategically throughout the plant to receive overflow waters/drainage and have similar discharge scenarios. These drainage systems can be extensive and complicated. As such, they are also an important part of the survey and should be included as accurately as possible on the inspector's base maps. Drain pipes should be clearly identified to depict which utility system they serve (sanitary, condensate, intake water, storm sewer).

Most drains and sumps contain sediments that likely include some level of petroleum products, metals, and PCBs. Sump water may also contain contaminants. Also, it is possible that concrete bottoms and sides or walls may contain PCBs and solvents if drain sediments have these constituents.

In many cases, these pit and sump areas are defined as confined spaces and may contain explosive or otherwise hazardous environments. Only properly trained personnel with the proper monitoring and personal protective equipment should enter these areas.

Machine Shops and Maintenance Areas

Power plants and nearly all large industrial endeavors, especially in the days of old, needed to be self-reliant with respect to repairs and maintenance. Unless a specialized part was required, materials were often fabricated or repaired on site. Plant machine shops will have a variety of metal working devices, including lathes, drill presses, abrasive grinding and cutting wheels, torches for cutting and welding, and other equipment required to carry out metal fabrication and repair work. Cutting oils, grease, and cleaning solvents were also typically used and stored in the machine shops. Other plant maintenance operations also included painting, cleaning, and regular servicing of equipment. Maintenance chemical/material storage areas could be found in various areas of the plant.

Bermed chemical storage area

At one facility, the machine shop remained intact and in good condition. Much of the machinery, tools, and equipment mentioned above were present, along with stock rooms for parts and equipment. Plans on file for this facility also showed an area formerly used as a machine shop. Although this former machine shop area was subsequently renovated for a different use, its past uses resulted in a closer inspection and sampling of this area.

Potential contaminants of concern in machine shops include oils and degreasing agents, caustic and alkaline solutions, and heavy metals. The potential exists for PCBs to be present in some oils as well. Sample floor drains/trenches in these areas, floors, equipment pads, stands, etc. would also be suspect.

Chemical Storage Areas

Designated chemical storage areas can often include diked or bermed areas, and can be located in various areas throughout the plant. It is important to be aware of the fact that the location of chemical storage areas may have changed throughout the life of a plant. Facility plans may show former storage areas. Lubricating oils and grease, breaker bath oil, cutting oils, cleaning solvents, gas cylinders, and boiler treatment chemicals may be located in these areas. Separate boiler treatment chemical handling areas may also be present. These areas would include mechanisms for mixing various boiler chemicals and pumping them into the condensate stream. Typically these treatment chemicals include acids and bases and anti-scaling materials.

Power plants also included material testing laboratories where boiler water was tested to ensure that the chemical properties of the boiler water were optimal in the generation of steam and pressure. Tests were run regularly to assess boiler chemistry. The laboratory usually contains relatively small quantities of testing chemicals.

Walls, floors, berms, and drains within or near chemical/oil storage areas are suspect. Potential types of contaminants would include oil and solvents, laboratory chemicals, and caustic and alkaline solutions/products. PCBs may have been used in some of these oils.

Structural Systems

Understanding the building structural systems is critical to developing an approach for demolition. Although the specifics of dismantling are often best left to the demolition contractor, the contract documents must provide the contractor with enough information to form the basis of his/her bid. Understanding information regarding structural systems is integral to determining scenarios and costs for both decontamination and possible demolition. For instance, PCB-contaminated concrete within a bermed station transformer area may extend several inches into the concrete or all the way through it. The thickness of the concrete, the presence of rebar or other structural materials, drains, electrical lines, or conduits beneath the floor are also important to know to assess the extent and nature of concrete removal. Also, if the contract calls for the removal of all building footings, details regarding the depth and construction of the footings would have to be provided, unless the facility owner chooses to bid this work on a time and materials basis.

Potential contaminants of concern include lead-based paint. Plans for one facility made reference to painted steel with "red-lead paint." Other sources of environmental concern include asbestos-containing packing and gasket material found in structural applications. The potential also exists that asbestos-containing electrical conduit piping may be set within concrete floors. Early identification of these lines prior to demolition is critical in minimizing project delays. A conceptual vintage power plant layout is provided as Figure 1, provided in Exhibit 1.

Building Characterization

The foundation of building characterization activities relative to the presence of hazardous/ regulated materials is based on an understanding of building systems and operations, and the use of chemicals/oils. Understanding the function of equipment/machinery will aid in focusing on what types of contaminants may be present. For instance, it is not practical to analyze concrete chip samples from a PCB-containing transformer enclosure for contaminants other than PCBs and perhaps petroleum hydrocarbons, unless information regarding the use of the area suggests otherwise. Similarly, if 10 "reciprocating dry vacuum pumps" are identified within the facility, it is not practical to sample the lubricating oil out of all ten units. Machinery should be consolidated into separate systems (i.e., steam-related equipment, condensate-related equipment, etc.), and then grouped together based on function. However, several variables need to be considered in grouping together similar equipment/machinery, including manufacturer type and design, construction history, shared systems, accessibility limitations, and health and safety concerns. No protocols have been established regarding the appropriate number of samples that need to be collected from similar equipment/machinery. Therefore, a representative number of samples should be collected as determined by the inspector in the field.

One facility was constructed in four different time periods (commonly referred to as generations). The installation of equipment and machinery during the first two generations was based around sharing equipment and machinery. Twelve low-pressure boilers were constructed to supply steam to six turbines. Centrally located switchgear would receive and manage electricity from the six turbines and subsequently distribute it to appropriate substations. Each of the six turbines also had its own condenser unit for cooling. Cooling water for the six condensers was received and shared from two water intakes (one cooling water intake was constructed during each of the first two generations). One screen house was also constructed at each intake. Cooling water from the six condensers was discharged through one centrally located discharge tunnel, completed during the first generation of installed equipment. Turbine lubrication oil was shared and recycled throughout the six turbines. Conversely, the third and fourth generation equipment installations saw a movement from shared systems to individually operated systems. The third generation boiler and turbine operated together; steam for this turbine was not supplied from any other boiler source. New switchgear, a new condenser (and associated pumps), and a new cooling water intake and discharge were all installed concurrent with the third generation boiler and turbine. All of these systems operated only with the third generation boiler and turbine. Installation of the boiler, turbine, condenser and switchgear comprising the fourth generation of construction mimicked this single-system dependency. However, one exception to this was the presence of a second, centrally-located turbine lubrication and recycling system for the third and fourth generation turbines. Only after all of these variables in building systems (containing both shared and dedicated equipment/machinery) were identified could an accurate sampling strategy be developed.

In addition to the above-noted recommendations on sampling methodologies, federal regulations governing the identification and characterization of ACBMs and PCB-impacted building materials and equipment/machinery have been established and must be followed.

Organization and Approach

Perhaps one of the most important tasks of building characterization is the organization of data. Knowing the exact location of a specific sample, and being able to relocate it in the field, is more complicated than in a typical two-dimensional outdoor field program. Access to detailed facility plans, again, is critical to locating yourself within a building and accurately plotting your sample points. Without plans, the inspector is relegated to developing drawings/sketches and creating elaborate descriptions of sample locations which can very easily be misinterpreted by others. At one of our Connecticut facilities, reams of plans and cross-sections, all in a digital format, were made available; however, while this was ideal, it was also atypical.

Depending on the amount of information available for review, it can take several days to organize plans and become familiar enough with a plant for the inspector to begin accurately referring to the names of particular areas of the building (low-pressure turbine room, bus room, second floor high-pressure area rear office, etc.). Consistently using the correct terminology (some terms may need to be developed in the field if none are designated) is important for staff communications and sample location descriptions. Also, a consistent sampling and supervising staff of equal familiarity with the plant is also important in order to maintain smooth progress.

We have found that conducting the asbestos survey first provides the most thorough review and understanding of equipment, machinery and systems within a power plant. The asbestos survey will generally require more time than the hazardous material survey due to the nature and extent of asbestos applications in power plants. The asbestos surveys are far more detailed and require more sampling than the sampling of other materials. Trying to perform both asbestos and hazardous material surveys simultaneously usually leads to confusion and mistakes. Focus and organization are the keys to a good survey.

We also have found it best to complete the asbestos survey for a particular building system before moving onto the next. This is done primarily to avoid confusing the multiple systems. For instance, one facility was separated into two areas: low-pressure side and high-pressure side. Within each area, three subareas were developed: boiler rooms/areas, turbine room/areas, and switchgear equipment and machinery. The survey commenced on the ground floor of the boiler room for the low-pressure boilers, including boilers, water tanks, and coal/oil delivery systems. The survey continued to other, higher floors, but remained within the low-pressure boiler room until the entire room/system was completed. Once completed, the survey progressed to the turbine area (commonly referred to as the turbine hall). The condenser units (low-pressure side only) were surveyed first, as they were on the ground floor of the turbine hall. The low-pressure turbines were surveyed after completing the condensers because they were located on the floor directly above the condensers. After the turbines, focus was centered on switchgear equipment. Again, the survey began on the ground floor and went upwards until all functional systems and equipment/machinery (including reactors, oil bath circuit breakers, bus rooms, electrical conduit rooms, electrical switchgear, and the main control board room) were reviewed. Once these areas were completed, the screen houses for the low-pressure side were surveyed. These structures represented the last major functional area relative to the low-pressure side. Only after all equipment and machinery associated with the low-pressure side had been completed, did the survey progress to the high-pressure side. The survey then continued in much the same fashion as described above, concentrating on high-pressure side equipment and machinery only.

Each sample location must be added to the base map, described in a written table, and marked in the field. This allows for the confirmation of sample locations and allows others (i.e., contractors/regulator, etc.) to find the sample collection point. Time lapses or personnel changes between the execution of the survey and subsequent abatement or decontamination are common. If the inspector's data cannot be easily recreated, it becomes useless.

Asbestos Sampling

Conducting a complete asbestos survey of a vintage power plant is probably the most complex type of asbestos survey. Thermal systems insulation abounds (quantifying it is more critical than sampling it), surfacing materials are applied often in discrete areas, and the miscellaneous materials, especially those associated with electrical components, are complex and sometimes dangerous to sample. In order to conduct a complete survey that will leave little room for add-ons and regulators to question asbestos characterization during abatement, an Asbestos Hazard Emergency Response Act (AHERA) style survey must be completed by a licensed Asbestos Inspector.

We will not repeat every detail of the AHERA protocols; however, several important facts should be revealed to prepare an owner for the nature of these surveys. They are as follows.

1. It is important to review all available information pertaining to known or documented ACBMs within the power plant prior to commencing the asbestos survey. This will avoid characterizing previously tested materials and reduce the length of time to conduct the survey. The information should include all previous asbestos work, including abatement, testing, and asbestos management plans.

2. Anything that could potentially contain asbestos must be assumed to be an ACBM unless it is sampled, analyzed, and shown not to contain asbestos.

3. In most cases AHERA requires that three samples of each suspect material must be collected and analyzed to determine asbestos content. If one of the three indicates asbestos present at greater than 1%, the material is considered an ACBM. You may save some analytical costs if you instruct the laboratory to stop on the first positive result.

4. The number of asbestos samples collected as part of a typical AHERA-type asbestos survey will vary from facility to facility; however, between 1,500 and 2,000 asbestos samples for a vintage power plant would not be uncommon.

5. In some cases severely damaged asbestos materials are present within buildings, and are subject to disturbance during building characterization/contractor walk throughs. These areas should either be abated to mitigate exposure hazards, or designated as restricted to trained personnel with appropriate personal protective equipment. Air monitoring during occupation of these areas would also be required to satisfy Occupational Safety and Health Agency (OSHA).

6. A good asbestos survey should be able to be incorporated directly into the project decontamination specifications.

7. Power plants often are built in stages concurrent with the demand for electricity. This translates to the construction of multiple interconnected buildings with different construction dates. In general, the greater the amount of building add-ons, the greater the length of time required to complete the asbestos survey. At one facility, the low-pressure boilers (older construction) were not covered by an exterior asbestos insulating jacket. However, the high-pressure boilers (newer construction) contained a fully encompassing asbestos jacket. Different construction time periods dictated different insulating requirements. With regard to roofing materials, each roofing system can generally be defined by the rooftop over a separate building. However, a single rooftop can contain several separate roofing systems (multiple layers) or may have been constructed in phases. This was the case over one turbine hall. Appearing as one uniform roofing system (only one roof elevation was evident), there were three additions

to the turbine hall completed throughout the course of its history; a total of four separate roofing systems were suspected. Field observations and laboratory analysis confirmed these suspicions; although the surface of the rooftops appears to be covered with similar materials, materials beneath the surface were not uniformly distributed throughout the four separate roof areas. Varying degrees of asbestos were identified in select materials at all four roof area locations. Given these variabilities, it is not uncommon to find 30 or more roofing systems at a power plant. One facility had over 40 separate roofing systems identified on the main power plant building; over 75 separate systems were identified if you incorporated the secondary buildings, ancillary equipment, and aboveground storage tanks.

Miscellaneous Contaminants Assessments

As indicated in the beginning of this section, knowing where to sample for impacted materials and what to analyze requires some prioritization and strategic planning. It is a delicate balance between spending too much time and money sampling and undercharacterizing a building and leaving the contract open to add-ons. Perhaps a place to start is by evaluating the systems described in the first section of the paper. Completing the hazardous material survey in much the same manner as described for the asbestos survey would also aid in accurately identifying hazardous and regulated materials. By reviewing the various systems and functions within the power plant, and by grouping equipment and machinery into functional areas (i.e., low-pressure side, high-pressure side, etc.), thorough sampling strategies can be developed.

The following table summarizes various approaches to these systems.

Table 1

Example Sample Strategies for Power Plant Systems

System/Operation	Potential Contaminants	Sampling Strategies
Coal Delivery	Petroleum, PCBs	1. Sample conveyor system lubrication oil and grease
Fuel Delivery and Storage	Metals, PCBs, solvents, and asbestos	1. Sample storage tank sludges 2. Sample fuel lines 3. Sample release areas 4. Sample fuel oil product where available 5. Sample pipe and tank insulation
Compressed Air Lines	PCBs	1. Sample oil residue in compressor lines
Boilers	PCBs, asbestos, mercury	1. Sample hydraulic lines 2. Assess presence of asbestos 3. Inventory mercury switches
Ash Handling Systems	Petroleum, SVOCs, PCBs, metals	1. Sample conveyor/lift oils and grease 2. Sample ash residue (check for varying types)
Steam and Condensate Systems	Asbestos, mercury	1. Assess presence of asbestos 2. Inventory mercury switches (on associated tanks and pumps)
Turbines and Rotors	PCBs, asbestos, mercury	1. Sample lubrication oils and grease 2. Sample insulating materials for asbestos 3. Inventory mercury switches
Switch Gear/Control Rooms	PCBs, asbestos, mercury	1. Sample oil and grease 2. Assess presence of asbestos 3. Inventory mercury switches
Transformers/ Rectifiers	PCBs, mercury	1. Sample oil 2. Sample underlying floor (note oil staining, if present) (delineate if required) 3. Inventory mercury switches
Floor Drain Pits and Sumps	Metals, organic compounds, PCBs, mercury	1. Sample sediment (review data and conduct additional sampling/delineate if required) 2. Sample sump water 3. Sample concrete bottoms
Machine Shops and Maintenance Areas	Metals, organic compounds, PCBs, mercury	1. Sample floors and drains 2. Inventory containers/contents
Chemical Storage Areas	Metals, organic compounds, PCBs, mercury	1. Sample floors and drains 2. Inventory containers/contents
Structural Systems	Lead paint, chemical spattering/leakage	1. Core sample painted materials and analyze using Toxicity Characteristic Leaching Procedure (TCLP) 2. Inspect all areas (floors, walls, ceilings) of plant for evidence of chemical or fuel spattering/leakage

*Note: Not a complete list; will vary by plant.

PCBs

There are specific regulations governing the assessment of PCB-contaminated materials. These regulations differ between applications. The sampling methodology is described below. It is important to bear in mind the physical capabilities of PCBs, especially in concrete. They travel readily though concrete and into soil or steel below. They typically extend further than expected.

"PCB remediation waste" is waste containing PCBs as a result of a spill, release, or other unauthorized disposal, at the following concentrations:

- Materials disposed of prior to April 18, 1978, that are currently at concentrations >50 ppm PCB, regardless of the concentration of the original spill

- Materials currently at any volume or concentration where the original source was >500 ppm PCB beginning on April 18, 1978, or >50 ppm PCB beginning on July 2, 1979

- Materials are currently at any concentration if the PCBs are from a source not authorized for use under this part

Thus, whether contaminated material falls within the definition of PCB remediation waste and must be cleaned up under EPA requirements depends on the concentration of PCBs at the time of the spill.

To conduct a self-implemented cleanup under §761.61(a) for PCB remediation waste, you must characterize the cleanup site and provide your proposed post-cleanup verification plan to the EPA before site cleanup begins. The separate sampling requirements for characterization and verification are included in the regulations and must be adhered to. The regulatory community is allowed 30 days to review the plan; however, substantially more time for this review process should be allowed.

There are no requirements as to when self-implemented site cleanup under §761.61(a) must be initiated or when it may be terminated. It is one of several options for the cleanup of PCB remediation waste. However, any cleanup activities not in direct compliance with the requirements for self-implementing cleanup do not qualify for the deregulatory benefits of §761.61(a). If PCB levels at a site meet the cleanup levels at §761.61(a)(4), no additional cleanup is necessary, but the owner or operator of the site must notify the EPA under §761.61(a)(3) to qualify the site as clean under the self-implemented option.

Subpart N (which contains the site characterization procedures for self implementing cleanups) for most sites requires the use of a grid-based system of 3 meters to select sample locations. There are also sample selection protocols specified for small or irregularly shaped sites and the EPA can approve alternative procedures for larger sites (generally greater than 1 acre) or special situations. The grid system must overlay the entire release area and a sample must be collected at each grid point. A minimum of three samples must be collected from each release area. A core sampler having a diameter >2 cm and <3 cm is required to collect samples. Under these procedures samples are to be collected to a maximum depth of 7.5 cm. Sample extraction and analysis methods referenced are either method 3500B/3540C or 3500B/3550B, and method 8082, respectively, in EPA SW-846. All analytical results are required to be reported on a dry weight basis. EPA Region I draft procedures for sampling concrete allow for the use of a carbide drill bit to collect fine concrete powder for analysis rather than collecting a core sample using a core drill. The carbide drill method is substantially quicker and provides the laboratory with a more representative and homogenous sample.

Animal Waste

Pigeon and raccoon droppings resulted in costs exceeding $50,000 at one GEI decontamination project. The difficult-to-access locations of these materials often increase cleanup and disposal costs. The health effects of animal waste can be serious and they should be assessed prior to every decontamination project.

Contaminant Delineation

Another nebulous area regarding building characterization is delineation. Again, enough information to make assumptions is usually adequate in most cases. However, a review of analytical data and an assessment of the potential extent of contamination is advisable. For example, if a floor-drain sediment sample is found to contain PCBs in excess of 1,000 ppm and that floor-drain system includes several hundred feet of sediment and a sump that was not sampled, some additional characterization is warranted, including analysis of the sump and drain bottoms (usually concrete). Additional sampling may also be required to locate the source of the PCBs. Ample delineation of contaminated areas will provide for better cost estimates associated with the decontamination of the area.7

General Health and Safety

Given the nature of a power plant, health and safety issues abound around each corner. From confined-space entry permits, to lock-out-tag-out procedures, health and safety is a significant part of the daily operation of a power plant. It also needs to be an integral part of the asbestos and hazardous material survey, especially since the inspector is not as familiar with the plant as actual plant employees.

Obviously, in operational plants the electrocution hazard is high, especially in switchgear areas. If equipment cannot be locked and tagged, then assumptions regarding hazardous materials/asbestos must be made. It is important to communicate with the owner as to what areas and systems need to be accessed and sampled so that appropriate shutdowns can occur.

As indicated previously, rooftop sampling is required to assess asbestos-containing building materials. Other high-elevation sampling inside the building may also be required. All safety precautions should be utilized to avoid fall injuries. It is important to delineate and communicate all unsafe areas of buildings to avoid injuries. Radio communication between personnel while in and around the plant is essential. Whenever possible, it is best to work in two-person teams.

Some areas or equipment may be inaccessible due to space constraints or other health and safety issues. Contract language should provide for the assessment of these materials as part of the demolition.

Urban wildlife, including rats and seagulls, are a problem at some sites. Seagulls were a particular nuisance on the rooftops of one plant.

Contract(or) Management

Contract management takes on various forms and can include close, daily project oversight by an owner's representative, direct management by the owner, little or no oversight, and everything in between. Multimillion-dollar decontamination and demolition projects contain great potential liabilities for an owner and therefore require close management to ensure that applicable regulations are being followed, contract documents are being properly and fairly interpreted, add-ons are being controlled, and a good working relationship between the owner/representative and the contractor is being developed. This relationship, one in which all parties feel fairly compensated, is the key to the successful completion of the project.

Most qualified contractors who will bid on these types of projects have substantial experience in recognizing inadequate building characterization (inviting add-on work), bidding documents that leave them open to financial liability (avoiding add-on work), and/or an owner/representative who appears uninformed or inexperienced with these projects. An owner/representative who is confident, informed, and willing to answer or find answers to contractors' questions, and learn from them, will quickly win confidence and respect from the field of contractors.

If issues of characterization or contract language are raised by a contractor (remember they probably have more experience than you do), listen closely, document and investigate these issues with the owner and consultants. Then, issue an addendum to address these issues, and/or possibly postpone the bid date if more time is required to resolve them. Don't be too proud of your contract documents; they can easily be amended with a one page addendum. Again, responding to contractors will help instill confidence and will foster a good working relationship with the chosen contractor. The contractor's confidence in completing the project in a timely manner with few surprises, and/or surprises that are fairly resolved, will be reflected in the bid price.

Pre-Qualification

It is important to ensure the qualifications, insurances, and bonding of contractors prior to allowing them to bid on any projects. Narrowing the field to six or eight bidders is recommended. An initial pre-qualification process should occur that simply consists of a qualification statement "questionnaire" to evaluate contractors' experience with similar projects and some of the above points. References are also recommended.

Pre-Bid Meeting

At the risk of laboring over every aspect of bidding a job, there are a few points that should be discussed about the pre-bid walk-through.

It takes a lot more time than a two-hour walk-through to absorb the vast amount of information a contractor needs to evaluate the cost and scope for the decontamination and demolition of a power plant (the contract documents can only do so much). The owner/representative should be as sympathetic and helpful to this point as possible by organizing a detailed walk-through and by having on hand the individual or individuals most familiar with the plant to answer questions. (Document all contractors' questions and answers during the walk-through and distribute this information afterwards). Allow contractors to conduct their own independent surveys of buildings after the initial walk-through. This offers them the opportunity to become very familiar with the site at their own pace.

In addition to physical safety hazards associated with walk-throughs, an assessment of environmental exposure concerns should be conducted. This could be assembled quickly by the environmental inspector. Typically, the most critical concern is damaged asbestos. One set of plans and specifications previously prepared included an area where the asbestos was in such deteriorated condition on one floor that only asbestos-trained personnel with appropriate respiratory protection could enter. This obviously limited contractor inspection of the area.

It is important to consider the environmental effect of 30 or 40 people walking through an area at one time. Provisions for smaller groups, individual inspections, and environmental exposure should be considered.

Contract Documents

Clearly, compiling all the building assessment information and integrating it with language providing for regulatory compliance, bonding, insurance, costing, and schedule, while also providing legal and cost protection for an owner is a challenge. However, standard contract language is developed and used and then modified to meet the needs of a particular project. Sections or sentences based on project experiences are also added or deleted, as applicable.

Decontamination and demolition contract documents can be simple and short. For example, one sentence could suffice, as follows, "The contractor shall remove and dispose of all power plant structures to the elevation of 10 feet above mean sea level in accordance with all applicable local, state and federal regulations, on a Lump Sum basis." Of course, more language regarding bonding, insurances, and site restoration is usually required. This type of contract obviously puts a tremendous burden on the contractor to evaluate the nature and extent of the project, resulting in very high bids to complete the project.

A good set of contract documents will provide a contractor with confidence that the scope of the project is well defined and/or there are adequate and fair provisions for unforeseen circumstances. These contracts usually yield good competitive bids. The contracts should provide the assessment information in a user-friendly format and may provide provisions for unit costing for removal and disposal where the extent of contamination may not be fully defined or where it was unforeseen. The contract may also request a complete listing of the contractors' services on a unit cost basis so that add-on work may be negotiated from a fixed starting point.

Also, we have found that the use of standard engineering scales on plans (versus architectural scales) are more user-friendly in the field.

Subcontractor Control

On more than one occasion, clients have selected an excellent contractor who brings in a less desirable subcontractor. Often a subcontractor will arrive unannounced, blend in with the rest of the workers, and start performing tasks without the knowledge of the owner/representative and without the supervision or control of the contractor. Contract documents should include provisions for the bidding contractor to reveal his/her subcontractors and their qualifications.

Asbestos Abatement

A complex decontamination task associated with these projects is the removal of asbestos. The close, daily oversight of asbestos abatement contractors by an asbestos-licensed representative of the owner is strongly advised since the regulatory, disposal, and health and safety issues associated with improper asbestos abatement and abatement documentation are great. Improper removal of asbestos can result in the contamination of the project waste stream and can put untrained workers at risk of asbestos exposure. Also, asbestos abatement is the decontamination/demolition activity most closely scrutinized by regulatory agencies. It can set the tone for the entire project.

The contractor/subcontractor should be required to prepare an asbestos abatement plan that would be subject to review by the owner's representative All state and federally required documentation should also be provided for review, including licenses, certifications, health and safety monitoring, and training certificates. All paperwork should also be reviewed at the start of each work day to ensure that all asbestos workers have the required paperwork on site. It is common for a variety of abatement workers to work on one large job; therefore, consistent enforcement of regulations and policies is a must.

For demolition jobs, where asbestos abatement areas will not be re-occupied by contractors, no final air clearance is required. However, for these projects, where interior salvage (e.g., metal piping, equipment, etc.) and additional decontamination would likely be required, final air testing must be completed before the areas can be reoccupied by untrained/unprotected personnel. Final air testing is relatively inexpensive and should be conducted by the owner's representative instead of the contractor. It should be noted that in order for an area to pass air testing, all surfaces must be wiped clean and be free of any visible dirt and debris. This obviously is a labor-intensive endeavor that the contractor must consider in the bid price.

Federal regulations require that the owner maintain asbestos abatement records for a period of 30 years. Final payment of the contractors should be provided only after all appropriate records have been reviewed by the owner's representative and have been determined to be in compliance with the regulations.

Decontamination

The appropriate removal of contaminants other than asbestos, lead paint, and PCBs is subject to interpretation. With regard to decontamination and demolition, the purpose of the removal of contaminants from building materials is to minimize the disposal volume/costs of those materials classified as contaminated or hazardous. By removing a section of contaminated flooring, the disposal of the entire floor as contaminated is avoided. Analytical documentation or visual confirmation must be provided that indicates whether the material being shipped to the disposal facility is contaminated or construction/demolition debris (C&D). There is a fine line between paying the contractor to decontaminate and paying the disposal facility for contaminated waste. At times, it may actually be more cost-effective to dispose of an entire building component as contaminated waste than to segregate the contaminated waste from the C&D (i.e., a roofing system with one layer of ACM).

The contract documents should specify the limits of removal of contaminated materials including area and depth, or provide for unit cost removal and disposal. The owner/representative should be responsible for conducting final inspections of areas and/or conducting confirmation sampling to ensure that all contaminants have been removed to the extent/concentrations desired.

Salvage Items

A building owner may consider conducting an inventory of building components and equipment that may have salvage value. This value may not always be monetary. It may be historic, aesthetic, or sentimental. The building owner, in being related to the industry, may also be able to utilize industry connections to find buyers for specific, specialized equipment. Some equipment utilized in power plants may also have other applications, including compressors and pumps. These may be useful to other industries. Critical to the evaluation of salvage value is the fact that an experienced demolition contractor will consider salvage in their demolition price. Therefore, an owner should not necessarily spend the time and effort to salvage materials that would otherwise lower the cost of demolition. Unless, of course, he/she can do better than the contractor on salvage.

Another consideration is the fact that some salvage items may require decontamination prior to removal from the building. This may also add to the cost of owner salvage and be included in the contractor overall price for decontamination. One client wished to salvage cut stone from a burned building site. However, the building debris contained asbestos and only asbestos contractors could handle the material. This proved to mitigate the salvage value of the stone and the stone's value was much greater when left to the overall project, which included complete site decontamination.

Blower renovation plans reviewed for one plant specified that the contractor to reimburse the owner for the salvage value of removed equipment. This procedure may reduce a contractor's motivation to offer a lower bid price.

Documentation

Complete project documentation, especially dealing with environmental decontamination and disposal, is critical to the owner. The contract documents must specify the mechanisms under which the documents are transferred from the contractor, reviewed by the representative, and provided to the owner.

As previously indicated, owners must maintain asbestos abatement records for 30 years (the latency period for asbestosis). In Connecticut, the records are specified to include the names of all those who entered the abatement areas, the abatement methods, and the final air clearance methodology and results among others. The contract documents should specify that the contractor compile all abatement, decontamination, and disposal records for the project. This "close-out documentation" should be provided for review by the owner's representative before the final payment.

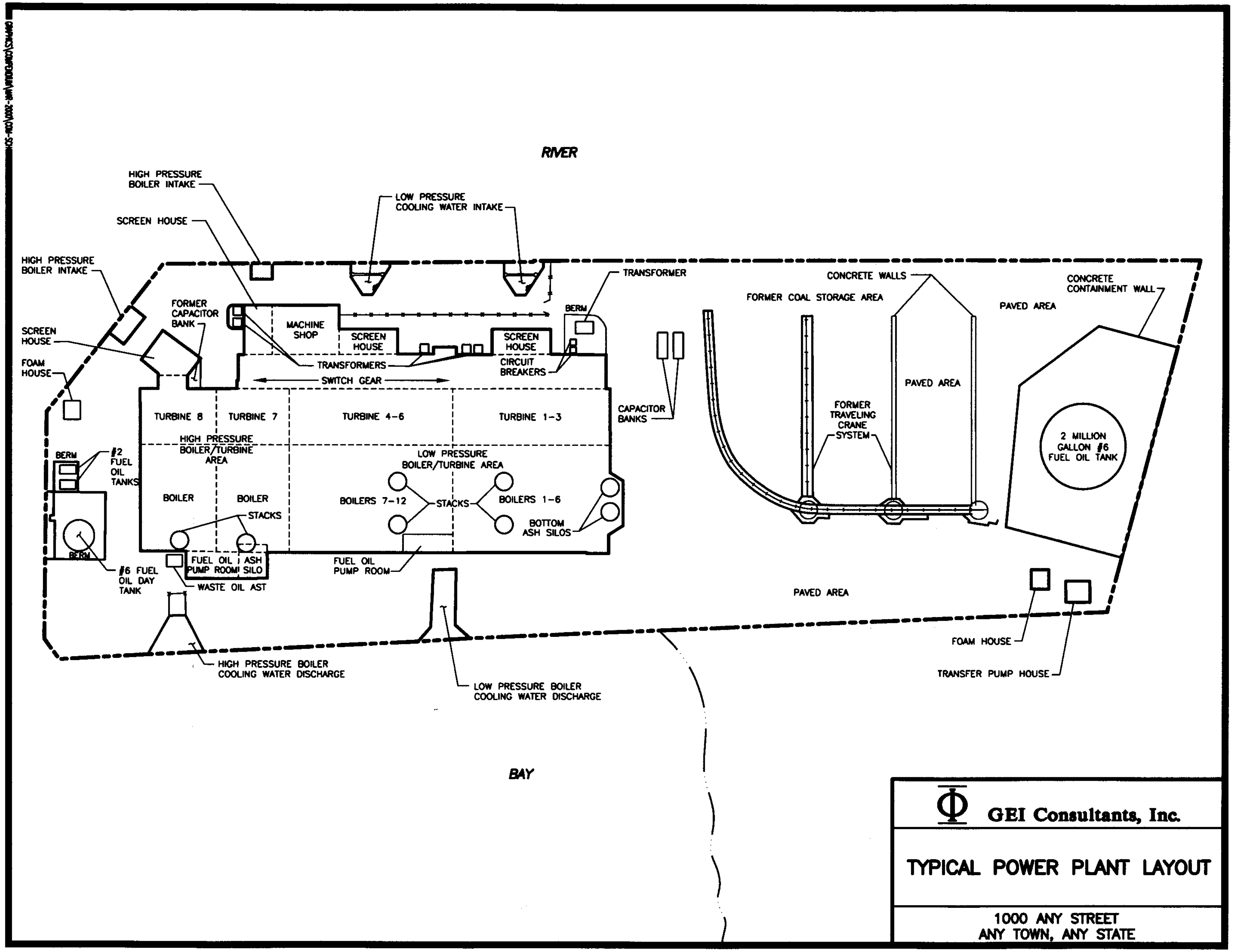
All disposal facility permits, all transporters' insurance and licenses, and all specialty workers' certifications and licenses should be reviewed by the owner's representative prior to the start of work, when any changes are made during the project, and at the end of the project. This should be stipulated in the contract documents.

Conclusions

This paper has provided some technical information relative to vintage power plant systems, has provided some explicit regulatory details, and has included suggestions for sampling protocols and contract management. It is important to remember that your project has never been done before. Every building is uncharted territory. While some regulatory boundaries must be strictly followed during these projects, the order of operations, the site restrictions, the weather, the building configuration, the location within the community, and the contaminant distribution are different for every site. Therefore, extremely thorough inspections of each building must be conducted and all project-specific concerns must be identified and addressed. Also, we must share our knowledge, be open-minded, and fair.

Exhibit 1

Conceptual Vintage Power Plant Layout


RIVER
HIGH PRESSURE BOILER INTAKE
LOW PRESSURE COOLING WATER INTAKE
SCREEN HOUSE
HIGH PRESSURE BOILER INTAKE
TRANSFORMER
CONCRETE WALLS
FORMER COAL STORAGE AREA
CONCRETE CONTAINMENT WALL
PAVED AREA
FORMER CAPACITOR BANK
BERM
MACHINE SHOP
SCREEN HOUSE
SCREEN HOUSE
SCREEN HOUSE
FOAM HOUSE
TRANSFORMERS
CIRCUIT BREAKERS
SWITCH GEAR
PAVED AREA
TURBINE 8
TURBINE 7
TURBINE 4-6
TURBINE 1-3
CAPACITOR BANKS
FORMER TRAVELING CRANE SYSTEM
2 MILLION GALLON #6 FUEL OIL TANK
HIGH PRESSURE BOILER/TURBINE AREA
LOW PRESSURE BOILER/TURBINE AREA
BERM
#2 FUEL OIL TANKS
BOILER
BOILER
BOILERS 7-12
STACKS
BOILERS 1-6
STACKS
BOTTOM ASH SILOS
BERM
FUEL OIL PUMP ROOM
ASH SILO
FUEL OIL PUMP ROOM
#6 FUEL OIL DAY TANK
WASTE OIL AST
PAVED AREA
FOAM HOUSE
TRANSFER PUMP HOUSE
HIGH PRESSURE BOILER COOLING WATER DISCHARGE
LOW PRESSURE BOILER COOLING WATER DISCHARGE
BAY
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