# Design Considerations for a PCB Facility

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n the initial planning phase for the construction of a new PCB manufacturing facility, numerous factors have to be taken into account. Obviously, the planner must first determine the circuit boards to be manufactured and how to best implement production. The production rate goals for initial and future growth patterns should be carefully defined, including the need for lowvolume prototype services. Diversification, such as multilayer and flex film circuitry or employing the newer substrate materials, must be anticipated so the facility can keep abreast of changing technology.

The planner must next determine the optimal location for the facility based on the availability of a skilled labor force, zoning restrictions, the possibility of financing from the Industrial Revenue Board (IRB), access to transportation routes, and other considerations.

The political atmosphere of the target area must also be surveyed so the planner can assess the likely level of environmental regulation and the impact these regulations will have on the overall construction budget. Issues such as the availability of sewerage systems and whether local or municipal effluent discharge requirements will be more stringent than federal statutes must be looked into prior to committing to any location. New EPA pretreatment regulations affecting municipal sludge disposal and effluent bioassays will increasingly affect industries tied into those local sewerage systems.

## **PROCESS DEFINITION**

Once the location for the plant has been selected, the planner must define and lay out the process to be used in the new facility.

The manufacturing plant's general layout should be primarily determined by material work flow patterns. Efficient use of space can minimize delays between process operation steps and thus contribute to the long-range success of the Facility.

The layout of wet processing operations is equally important. Process bath chemistries should be evaluated for their potential effects on waste treatment requirements, air pollution control technology, hazardous waste storage or treatment needs, and Occupational Safety and Health Act (OSHA) acceptability. Provisions for the segregation of incompatible materials, spill control, and passive secondary containment must be considered for how they will impact material flow.

Contingency planning for line growth due to production rate expansion, implementation of in-process source reduction waste treatment technologies, and product staging should also be part of the process layout. Beyond the wet process, the layout must accommodate process support and environmental services.

#### PROCESS WATER PRETREATMENT

Water is one of the most critical raw materials used in PCB manufacturing operations. Rinsing operations that foil w certain wet chemistry cleaning, developing, stripping, plating, and etching processes, as well as bath makeup, may require higherquality water than is available from the local municipality or the facility's private source. In the design phase of the project, the facility's process water quality, source water quality, and possible seasonal variations should be thoroughly investigated.

Depending on the need for higherpurity water, the facility's planner should determine whether total facility process water conditioning and treatment with on-site regeneration capability s are warranted or whether point-of-use water treatment via a service contract to an outside vendor will suffice. A review of the potential for water reuse from the treated wastewater system effluent should be conducted. The decision should consider factors such as floor space availability, initial capital vs. long-term operation and maintenance costs, system life expectancy, and susceptibility to adverse impacts caused by the facility's influent plant water.

# VENTILATION AND AIR-POLLUTION CONTROL

The primary function of an industrial exhaust system is to protect workers against potentially toxic airborne contaminants generated in the workroom. Also, a properly functioning exhaust system will prolong the life of corrosion-susceptible plant components and production equipment. The exhaust ventilation system should be designed according to the guidelines that are recommended by either OSHA or the American Conference of Governmental Industrial Hygienists (ACGIH).

Air pollution control for new or modified plating exhaust systems is regulated by the individual states. Some of the states mandate and enforce specific emission limitations while other states require the design to be in accordance with standards of good engineering practice. Accordingly, applicable regulations and restrictions should be well defined prior to initiating design.

Gases, vapors, and mists from the work area are most efficiently captured at the point-of-generation by tank- or station-mounted ventilation hoods. Typically, each open surface tank is provided with an individual hood. However, the exhausts from most, if not all, of the process baths can usually be combined into a common duct network leading to a single scrubber and exhaust fan combination. Hood design and the necessity for push-pull local exhaust ventilation should be reviewed. The information on chemical fume compatibility, prepared during the process definition phase of the project, should be used to define central or segregated system requirements.

The exhaust ductwork system should be designed to efficiently transport pollutant-laden mists and gases from the connected workstations to the air pollution control device. Since corrosive fumes are being transported, the systems are usually constructed of PVC, FRP, or polypropylene.

Solvent usage in the process will dictate the use of metallic ductwork.



These m aterials are combustible to varying degrees, and certain insurante un derwrites may impose restriction on their design, such as internal sprinkler systems or collapserated P VC to inhibit flame spread. The plan ner should be aware of these possible restrictions at the outset of the proj ect to avoid costly redesign later.

Packed bed, countercurrent wet air scrubbers are the most efficient type of air pollution control device for the PCB ind ustry. Their design provides a large surface area for gas-liquid contact, which enables nearly complete ca pture of mists and soluble gases. T hese systems normally employ a s crubber liquid recirculation system t at neutralizes airborne acid mists and absorbs metal contaminants. D ue to the eventual build-up of the contraminant, some of the recirculating flu id is bled to in-house industrial was tewater treatment (IWWT) facilities.

As with the purchase of any piece of major equipment, the initial cost should be only one of many factors considered when purchasing or designing air pollution control equipment. Matching the nature of the pollution problem with the most suitable technology is critical. Expected operations and maintenance costs, service life, and performance are other important factors. Volatile organic compound (VOC) control technology also needs to be reviewed should the facility plan to use solvent or organic material in the production process.

#### MAKEUP AIR

The air that is removed from a workplace by the exhaust ventilation system must be replaced, either passively through infiltration or actively through a makeup air supply system. Because infiltration is almost never sufficient in providing the needed replacement air, well-designed and energy-efficient makeup air systems that provide tempered air to the facility are typically used with exhaust ventilation systems.

Makeup air is usually supplied by a roof-mounted supply fan equipped with air filters and some method of heating the air. Direct fired heating of the influent air with natural gas is usually the method of choice because of its relative efficiency and lower cost in comparison with other fuels. Steam can also be used as a heat source, but winter freeze-up problems and slow responses to changing air temperatures present disadvantages.

The distribution of makeup air in the workplace is important for worker comfort and for the exhaust ventilation system to work properly. Crossdrafts over the tops of vented process tanks can significantly affect the effi-



ciency of the exhaust system and should be avoided by using adjustable louver arrangements at the injection points of the duct diffuser system.

Heat recovery from exhaust air and recirculation of interior air to the makeup air system are generally not recommended for the PCB manufacturing industry. Exhaust fumes and mists can corrode heat exchangers, and air recirculation can reintroduce airborne contaminants into occupied areas. In facilities employing heat recovery and recirculation systems, the maintenance and equipment replacement costs that are associated with corrosion usually convert initial economic feasibility into a long-term headache.

# ELECTRICAL CONSIDERATIONS

As previously mentioned, the use of tic conduit should be used for racecorrosion-resistant materials in all ways. Local disconnects should be

wet manufacturing areas of the facility can be an important factor in the useful life of capital equipment and support services, particularly electrical devices. PVC or other thermoplastic conduit should be used for racevays. Local disconnects should be housed in fiberglass or other NEMA (National Electrical Manufacturing Association ) 4X rated enclosures, and lighting fixtures should be specially selected.

A worst-case design approach, in spite of the, attention given to exhaust ventilation makeup air systems, may result in higher initial construction costs, but the long-term operation and maintenance costs will be minimized.

## SPILL PROTECTION

With all of the attention that is currently being given to ground water quality and environmental protection in general, more new facilities employing wet processes are incorporating passive spill control and secondary containment provisions into the designs of their buildings. Though capital appropriations for these controls may be difficult to extract from the facility budget, the initial expense is minor compared with the cost of a remedial ground water cleanup project made necessary by an uncontrolled release of chemicals through the building floor slab.

Wet processing areas should be contained **by** either bermed exterior walls or by a network of subslab drainage trenches for spill collection. Specially designed FRP or epoxy protective floor coatings should be used throughout wet manufacturing areas. The type of material selected for these coatings should be specific to the service conditions anticipated, for example, spills, immersion, or drips. Though floors should be designed for operation in dry conditions, contingency planning is the best insurance against future liability.

Beyond passive containment control, active spill response measures may be used for additional protection. Automatic spill detection alarms can be incorporated into the facility design to alert a trained emergency response team that an event has occurred and that expeditious cleanup **activities** are required. If the proper cleanup materials are always available, the impact of an event such as this can be minimized.

## CHEMICAL AND HAZARDOUS WASTE STORAGE

The storage areas for process support chemicals and waste by-products should be designed into the facility layout during the planning phase. Too often, these considerations are given low priority compared to the primary goal of the manufacturing operation. Segregation of incompatible chemistries, such as acids and alkalis, should be carefully planned; each designated area should be given OSHA, safety, spill control, and secondary containment considerations. Bulk chemical storage vs. drum chemical storage should be decided early in the planning phase since the chemical storage

area layout and material movement within the area will be accordingly affected.

Storage of organics must be considered separately since red-label flammable storage will require special structural, architectural, and fire protection system designs. Outdoor, underground, organic spill containment vaults, used in conjunction with exterior wall- or roof-mounted blowout panels and high-density sprinkler systems may be implemented as state-ofthe-art design. The facility insurance underwriter should be involved with any decision for on-site flammable organics storage from the initiation of project planning.

The industrial wastewater effluent from a newly constructed or acquired PCB facility is required, at a minimum, to meet federal Pretreatment Standards for New Sources (PSNS) or New **S**ource Performance Standards (NSPS). The new facility must meet the former standard if the discharge is made indirectly to a locally owned mun icipal treatment plant, and the latter standard if the discharge is made directly to a receiving surface water treatment plant.

In addition to the minimum federal requirements, the local municipality may impose more stringent limitations, which may affect the type and extent of IWWT technology used or even dictate the selection of an alternate site. More stringent local limitations are an increasingly common occurrence as local sewer authorities come under federal surveillance.

Knowing the regulations that will apply to t e new facility, the planner should conduct a thorough inventory of all of the process manufacturing operational that will contribute to the influent wastewater stream. The design of an IWWT system should begin with in-process controls to minimize the volume of waste generated. Source reduction considerations should be implemented in the process definition phase, and benefit and cost justification for implementing pointof-generation pollution abatement or recovery technologies should be completed to assess economic feasibility.

Treatment can be categorized as in-process treatment, using source reduction or in-line recovery methods, or as end-of-pipe treatment, using advanced or conventional technologies. Whether end-of-pipe conventional or advanced technology is used will depend on regulatory limitations and facility needs. Conventional systems employing chemical precipitation technology and clarification or filtration will meet federal and certain local limits. However, more stringent local limits would necessitate advanced technologies, such as ion exchange and carbon adsorption.

An alternative is waste minimization. Waste minimization can take the form of source reduction, recycling and reuse, and some forms of alternative treatment. In-process segregation of selected metal-bearing waste streams affords the opportunity to use metal reclamation and sludge reduction techniques, like electrolytic recovery, ion exchange, reverse osmosis, and electrodialysis.

The best way to approach wastewater pretreatment requirements for the facility is to prepare a comprehensive database of process operations and chemical characteristics and to work in constructive cooperation with local, state, and federal regulatory officials. Treat these officials as part of your project team, rather than as adversaries. Be forthright, discuss your problems openly and honestly with them and negotiate solutions. Follow up on a periodic basis and keep them informed of any changes to the construction n and start-up schedules. Cooperate and encourage their participation, where appropriate, in commissioning activities subsequent to construction n. Such an approach initially will pay for itself many times over in the course of the facility's residence in the community.

To illustrate the impact of properly planning environmental controls for wet manufacturing operations, Table 1 shows, on a percentage of the total construction basis, the cost of implementing a variety of elements. The figures that are presented were developed from actual projects recently completed! The table does not inelude, however, the costs associated with the actual building construction (walls, slab, roof) since architectural features vary greatly from job to job.

The hi gher cost of process water pretreatment at Company A can be attributed to its location in the southwestern U.S. where the influent plant water con tained between 350 and 400 mg per 1 (CaC03) of hardness. The pretreatment system comprised filtration, carbon adsorption, reverse osmosis, and ion-exchange softening with on-site regeneration capabilities. The second facility employed only canister-type point-of-use ion-exchange water pretreatment under a service contract to a local vendor.

The second point of interest between the two companies is the cost of LEV and AP (local exhaust ventilation and air-pollution) control systems. Capital and installation costs for the systems employed at the facilities were **essentially** equivalent. However, since the scope of the second project was about half that of the first, the comparable costs for the air **pollution control** system at the second facility was twice that of the first.

In either case, only about one-fifth of the total construction budget allocated for wet manufacturing operations was spent on process-related hardware. The remainder was distributed to environmental control support services and installation.

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