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MICROELECTRONICS AND LIFE SCIENCES

With planning and teamwork, what seems to be impossible becomes possible.

Retrofitting and Upgrading OPERATIONAL CLEANROOMS

As contamination becomes of greater concern in all aspects of semiconductor and life sciences manufacturing, existing facilities need to be upgraded to tighter cleanliness levels, often while maintaining operations.

One of the toughest construction jobs is retrofitting, upgrading, or revamping a controlled manufacturing area. The task poses many challenges for the designers, construction managers, subcontractors, and facility managers, and personnel. The work presents a unique set of operational and construction issues which must be addressed in the planning stages. Addressing these issues up front ensures a minimum of unexpected events, which can affect budget, time, and operation of the facility.

This article will discuss specific issues that need to be addressed before and during construction, and present an operational outline to address these concerns, to successfully retrofit a clean manufacturing facility while maintaining operation and minimizing downtime.

Fitting more cleanroom space into existing production areas isn't always easy or quick. The keys to a successful retrofit project are planning, planning, and more planning. Why? Because nobody plans for a project not to succeed. Retrofitting existing clean manufacturing space can impede current production and yield. Retrofitting an existing operational cleanroom carries an uncommon set of issues and concerns. Addressing these issues prior to construction will insure a successful retrofit project while maintaining targeted production and existing yield levels.

While it is unrealistic to expect to maintain optimum production levels during retrofit, proper planning and sequencing of work will ensure a minimum of unexpected events which affect budget, time, and facility operation. Cost-versus-benefit analysis must be evaluated for each sequential step of work to evaluate its practicality. *Budget and schedule success cannot be evaluated by the lowest cost basis or shortest construction duration, but by the optimum compromise of schedule, cost, and lost production time and yield.* Careful up-front planning and scheduling must be foremost in mind. In many cases, retrofits are a better choice than new construction. Existing building space, workers, and the manufacturing supply chain are all available locally.

Specific Concerns

After the decision to retrofit has been made, the best place to begin is with the architect/designer and the construction manager/general contractor. Designing a retrofit plan and working out potential problems takes three quarters of the project's time. The quality of the design documents and the quality of the construction efforts is one issue, but supporting ongoing production is another.

The traditional concept of waiting for a design to be complete before soliciting the input of the construction team is not cost-, schedule-, or risk-effective. Getting the design and construction team on board and working together is the *only* prudent way to get the retrofit project off the ground successfully.

Owners want their retrofits to be completed as quickly and inexpensively as possible; having both the designer and contractor there from the beginning of the planning stage helps to save money and keep the project on schedule. Designing a retrofit project without understanding and incorporating the issues related to construction is a recipe for failure. For example, the seemingly obvious location for accessing utilities is often not the most appropriate, and choosing the wrong location can cause logistical issues that far exceed running a pipe a few extra feet. Designers design and constructors construct. A team effort minimizes "constructability" issues that are magnified tenfold when retrofitting.

The owner needs to collect specific information before the retrofit can begin. This begins with a utility list detailing equipment and its requirements for operating. Using this equipment list will also help identify all mechanical systems and infrastructure requirements for the retrofit.

Several items should be of foremost concern when con-

Before

Brewer Science (Rolla, MO) chose a design-builder for its retrofit project to minimize downtime. Customers were informed and production was increased prior to renovation in anticipation of customer needs. A daily schedule for the three-week shutdown was developed, with progress measured at the end of each day.

After

Because the cleanroom to be renovated shared a gowning area with another cleanroom running a production line which could not be interrupted, a temporary gowning area had to be created to ensure worker access to the second room. Limited lay-down area and lack of room for storage of production equipment required the renovation of three cleanrooms in sequential order, with equipment moving from one room to the next as the job progressed.

sidering any retrofit project:

- **Demolition and disposal of hazardous materials** may often be of concern in older facilities. Materials such as asbestos and items contaminated by process chemicals require disposal in compliance with local regulations.
- **Maintenance of fire exit conditions and sprinkler systems** during renovation often requires rerouting of piping systems, temporary disabling of sprinkler zones, and the construction of temporary egress corridors. Local codes and code officials should be consulted in the planning stages to determine which tasks can be completed during normal work hours, which must be accomplished during off hours, and what must be performed during shut down periods. Both Environmental/Health/Safety (EHS) and insurance requirements tend to dictate the extent of these temporary measures.
- **Material, equipment, and worker access** must be addressed in planning to ensure that production workers can access operational areas in a timely manner and that construction workers are not burdened with time-consuming access criteria to construction sites. Temporary access corridors and gown rooms often save significant time for production workers entering and exiting clean spaces. Separate construction entrances may seem to be a luxury during planning, but often pay for themselves in increased work production over a short period of time.

The Bottom Line

When retrofitting an existing facility, haste isn't necessarily the most prudent course and faster isn't necessarily better. Scheduling work around a production window of opportunity will ultimately, in many cases, have least impact on the bottom line. *To properly analyze the financial impact of a project, it is necessary to discard*

the preconceived notion that the lowest bid price is also the least expensive.

Laydown and storage space for materials and components must be integral to the renovation plan and schedule. Proper provisions for material handling will significantly cut labor cost and also the potential for the generation of contamination. Constant movement and shifting of materials risks damage and can even compromise a project's completion. Careful advance planning and construction management will allow for just-in-time deliveries and ease of staging of materials for installation, requiring the minimum amount of staging area and the maximum amount of flexibility.

Cost cannot be ignored in evaluating the upgrade of a facility. In the process of renovation while maintaining operation, cost is not necessarily equal to price. Actual cost must include price of the work along with lost production, potential for lost yield, and inconvenience. In reality, actual cost cannot be fully detailed until after the project is complete.

The only truly preventive steps that can be taken are to carefully select the contractor and base the decision not only on its price but also on its experience, reputation, proposed schedule, and operational plan to complete the work.

Production, cost, and space are all impacted when an existing operational cleanroom is retrofitted. It is unrealistic to expect to maintain optimum production levels during retrofit, but proper planning and sequencing of work can ensure minimum unexpected events that affect budget, time and facility operations. Renovations and retrofits are rarely cheaper than building new facilities, especially in semiconductor fabs, where tying into existing gas and chemical lines can be not only costly, but critical.

Renovating a clean manufacturing environment while production occurs drives the cost of the project up. Retrofit work schedules must be coordinated with production so that if a utility tie-in needs to be completed, the contractor knows when a work stoppage has been scheduled. The clean environment needs to be protected. In some cases, facilities are operating 24 hours per day, and any shutdowns can cause serious problems.

The Operational Plan

The first step in any renovation is a survey of the existing facility to determine how closely the plans reflect actual conditions. Identifying the level to which we can rely on the facility plans will significantly affect the aggressiveness of the schedule, material stock requirements, and loading. The existing facility may not have been built as designed, but a thorough analysis of the building's construction will help minimize unexpected surprises during renovation.

At the same time we are surveying the existing conditions, it is necessary to survey acceptable components in the marketplace to match existing facility conditions where required and understand their availability to meet schedule and performance requirements. Material selection may depend more on availability to meet the required schedule than on anything else. Performance criteria must be set, and price, product, and delivery issues prioritized.

A detailed sequence of work to be performed must be documented and incorporated into a preliminary schedule. The preliminary schedule must then be compared with the production requirements of the facility and with other events which will require scheduling flexibility. In areas of schedule conflict, the team must determine priorities and adapt requirements appropriately. This part of the work is the most critical to overall project success. Consideration must be given to squeezing or expanding the duration of construction tasks to match schedules and maintain a cooperative interface. Overall project duration must take into account holiday schedules, manpower availability, loading within a confined workspace, and, most important, continued operation of the facility.

A potentially significant cost issue that depends greatly on schedule flexibility and confidence in the documentation of existing conditions is excess material stock. What and how much excess material will be required must be weighed against the potential for restocking, any associated charges, and the critical nature of certain sequences along with lead time availability of potential shortfall products. Local sourcing of as many materials as possible must be achieved to properly plan for possible contingencies.

When planning is complete, it will be necessary to prepare for actual work in the facility. A proper build-clean protocol must be established to ensure that the generation of contamination is minimized. *In areas where construction workers interface with operating production areas, the cleanroom construction protocol must match the operating protocol.*

Construction area separation must be maintained at all times. Consideration should be given to areas above ceilings, in duct systems, plenums, return walls, conduit, and below floors to ensure that any contamination spread from demolition is not only minimal, but contained.

Once the window of downtime for work has opened, removal or protection of existing equipment and curtaining off of the actual construction area can begin. This must be performed with painstaking attention to detail to eliminate the potential for compromise of the existing operational facility. Whenever and wherever possible, equipment should be removed or isolated from the construction area.

Demolition should occur in accordance with a sequential plan, with materials removed from the controlled area and

properly discarded. A slow, deliberate process should be utilized to minimize the generation of contamination. Hazardous materials should be identified in advance and removed according to regulations.

Contamination-generating materials should be properly bagged upon removal and immediately removed from the critical environment. A staging area for outgoing and incoming materials should be established. Personnel should be badged and identified as critical environment workers or non-critical environment workers. The established protocol should be maintained at all times.

Items identified as salvageable and slated for re-installation or re-use should be identified immediately upon removal to the staging area and be cleaned and wrapped for storage. Before reinstallation, they should be unwrapped and cleaned in accordance with the protocol for incoming material.

With demolition complete, reinstallation of the salvaged materials and new material installation can begin. All materials should be treated as new and follow the incoming material protocol. Construction should occur under a build-clean protocol that is equal to or exceeds that of the operating facility. Final (super) cleaning should occur prior to the removal of temporary construction barriers. Equipment should then be moved in through the staging area under the incoming material protocol and set in place under operating protocol conditions.

Conclusion

- Put together a strong, experienced team whose members are committed to working together to meet the project goals.
- Research how operations will be affected during retrofit and plan for interruptions.
- Evaluate space needs and make sure work space layout and temporary protocol areas are anticipated.
- Investigate the facility and confirm that all parties involved have an accurate understanding of existing issues and conditions.

Proper planning is imperative to any cleanroom retrofit project and can minimize unforeseen occurrences which can negatively affect operation of the facility. The price of the work isn't necessarily the cost of the work. Selection of team members and open communication among all parties affected by the work is essential. There is no replacement for experience — and no excuse for not planning.

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