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Laboratory Design for Today's Technologies

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At a glance ...

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Introduction

Rapid advancements in technologies and methodologies have rendered many existing labs inefficient. Today's laboratory managers must consistently monitor the productivity of their labs to ensure their status as lowest cost provider in their particular health care domain. Laboratory administrators must do more than respond to today's competitive circumstances. Laboratories must be prepared to adapt to changing market trends and technologies.

Incorporating new technologies can substantially alter demands placed on the laboratory environment. Physical alterations to the lab, including utilities, often accompany the inclusion of the new technologies. Flexibility and room for expansion in the floor plan and the mechanical systems are necessary.

As outpatient services continue to grow, laboratories have gained a new visibility as a vital part of health care market strategies. A well-designed lab that provides the health care community with efficient and state of the art service is viewed as a tool to attract physicians and HMO's to a facility.

The Design Process

The development of the project team is the primary step in the design process. (**Figure 1**) Each member of the team has an important role that reflects their expertise. The project manager must be the arbiter, consensus builder, organizer, communicator and ultimately the decision maker. The project manager can be a lab manager, a facilities coordinator, or part of the facility administration. Representation from the user groups is

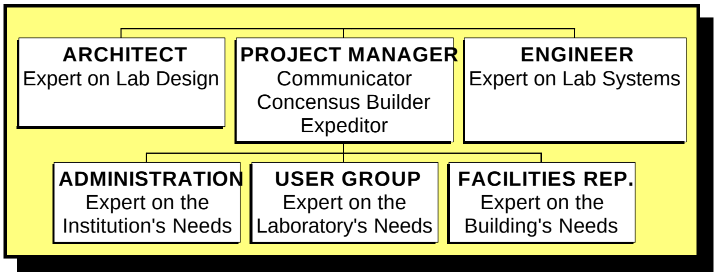

Figure 1 - The Project Team

necessary to ensure that laboratory methodologies are fully understood by all team members. The administrative and facility members of the team understand the long term goals of the overall organization, and the limitations imposed by physical and financial constraints. The architects and engineers are the experts in designing laboratories and the associated systems.

A construction project is organized as five successive stages. Each stage incorporates a goal that must be reached before the project team may advance to the next stage (**Figure 2**).

Project Design Phases

- Programming
- Schematic Design
- Design Development
- Construction Documents
- Bidding and Negotiation
- Construction

Figure 2

The Programming stage is where all issues that will affect the lab and the facilities are presented and evaluated. The more information that is evaluated in this phase, the better the new design will respond to the lab's needs. Areas such as equipment, personnel, existing conditions, and finances are used to develop goals for the project. We have found that an intensive meeting, lasting as much as a week, can provide information, ideas and an understanding between all the various members.

Schematic design translates these goals into a floor plan (**Figure 3**). Movement analysis of specimens, personnel and patients need to be incorporated to ensure maximum efficiency in the general layout. A series of meeting to review the plans are attended by the team members. Once satisfied that these preliminary designs fulfill the statement of the problem, the project may advance to the next phase.

Design development is the fleshing out of the schematic design (**Figure 4**). Casework elevations, equipment

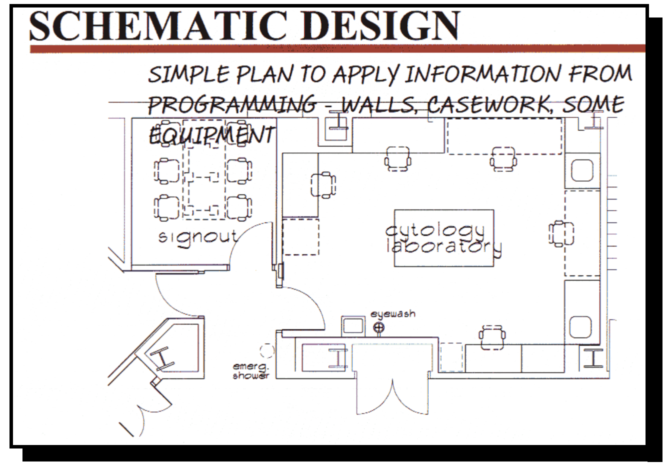

Figure 3

details, and engineering components are incorporated into the floor plan (**Figure 5**). Minor changes to the initial design often result requiring review by the project team. It is normally difficult for people to get a feel for

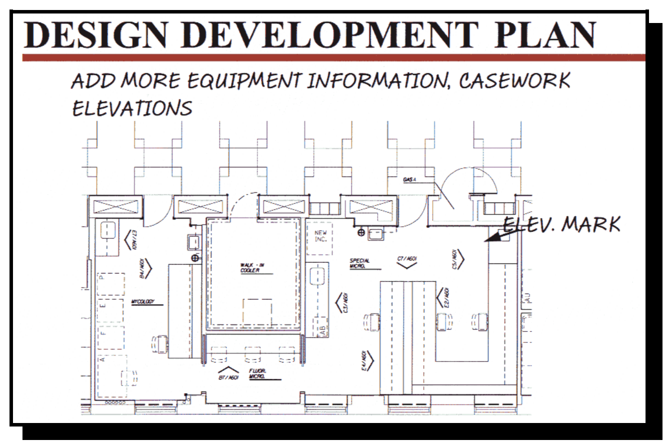

Figure 4

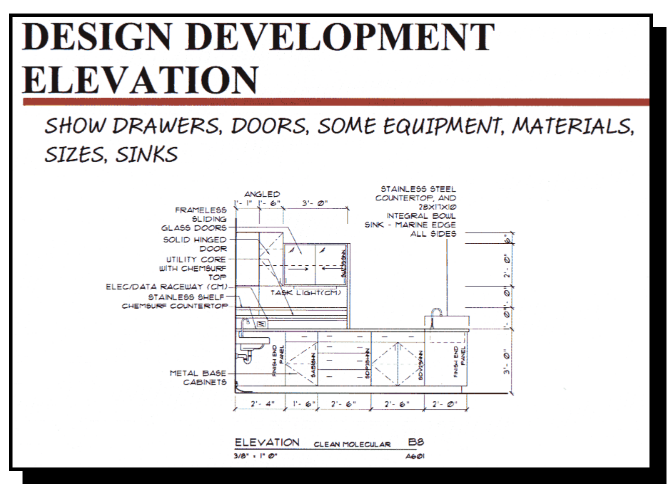

Figure 5

the actual space that the drawings are depicting. In the meetings ask the architect to relate sizes and spaces to areas that you know. Completion of design development completes the problem solving part of the construction project.

The construction document stage shifts the construction project into a technical mode (**Figure 6**). The drawings generated in the design development stage are detailed and materials are specified to prepare for construction. The architects and engineers are the only part of the design team that is involved in this stage. No major design changes should occur in this stage . The final drawings are considered contracts that must be adhered to by the contractor.

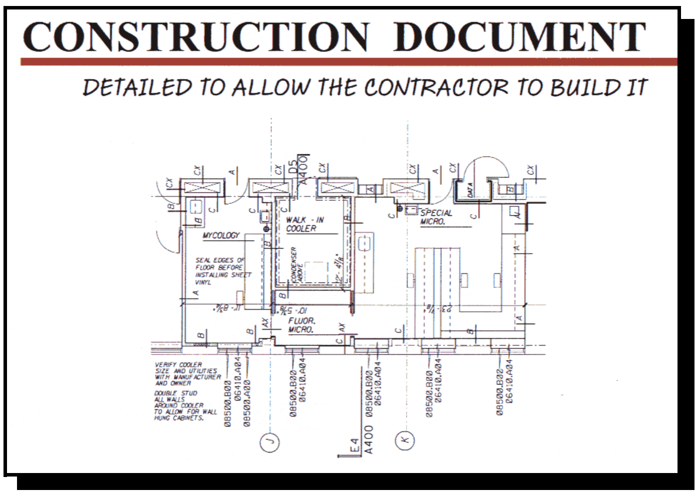

Figure 6

The construction documents are then sent to a selected list of contractors for bidding. The contractor will review the documents, contact subcontractors for prices, and tabulate a cost estimate for the project. A date is set for submission of these estimates and from these, the owners will select a construction company.

The project finally reaches fruition in the last phase; construction. The architects and engineers will act as liaisons between the contractors and the owners. They will answer questions, review compliance with the construction documents and generate change orders if necessary.

Understanding the responsibilities of the various members of a design team and the milestones that must be achieved during the design project allows everyone to be organized and efficient. A lack of organization, in the multifaceted laboratory project, will result in lost details and cause immediate and future problems.

Efficiency (See **Figure 7**)

Efficiency
- Functional Relationships
- Movement
- Flexibility
- Accessibility
- Energy Consumption

Figure 7

Architectural

Functional relationships are the relationships between the laboratory and the various areas of the facility that can affect patient, personnel and specimen movement. For example, functional relationships often exist between the laboratory and emergency, phlebotomy, surgery, and intensive care units. Not only can these relationships affect the efficiency of the lab and its personnel, they can also affect the nature of future expansion. An easy way to evaluate these relationships is through a bubble diagram (**Figure 8**). Using visual clues to organize and prioritize relationships the best location and orientation of the lab can be determined. In the same diagram, areas that can support future lab expansion, whether interior or exterior, should be included.

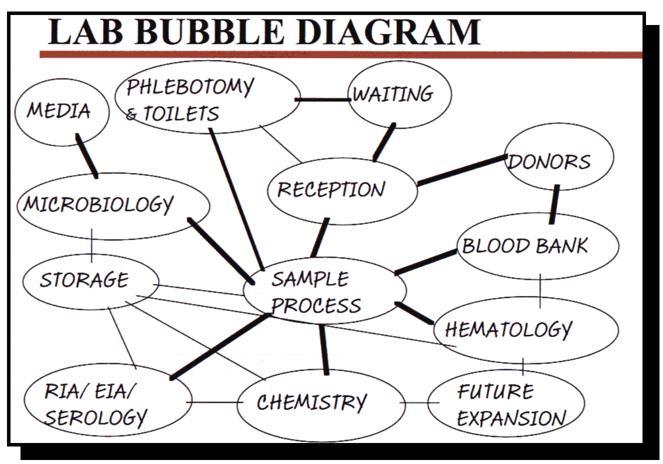

Figure 8

The evaluation of movement addresses three interrelated concerns; patients, personnel, and specimens. Patient use areas, including phlebotomy, donor areas, waiting and reception, and how they can best relate to the lab should be discussed. This could include phlebotomy, donor areas, waiting and reception. This establishes the separation between the lab and these areas as well as beginning an analysis of personnel movement with the specimen that has been obtained. Following the normal paths that are traveled as personnel do their jobs can show redundancy of movement and interferences. The third and most detailed of the movement analyses is specimen paths (**Figure 9**) this

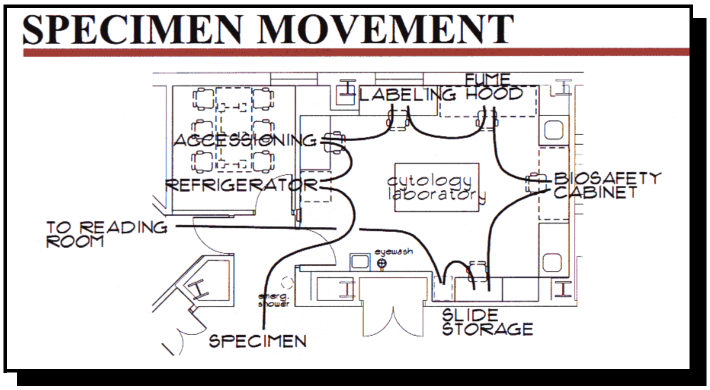

Figure 9

illustration of specimen movement provides visual clues to aid in the more efficient organization of the lab. In a recent project, in which we were designing a Cytology laboratory, we used the specimen movement diagram in the meeting to help the users to relate how they need the space to be set up. This same group used this method in reorganizing another lab that they had decided to add to the project. They were prepared for the next meeting.

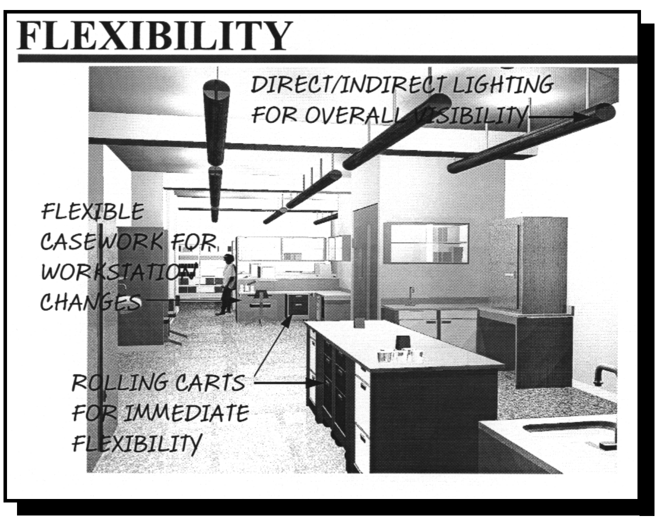

Figure 10

The laboratory must be designed to flexibly adapt to changes in technologies and marketplace (**Figure 10**).

With the rebirth of the core laboratory, an open center floor plan with casework situated around the periphery of the lab most easily adapts to the inclusion of new equipment and procedures. As the architectural design progresses, a balance between the amount of permanently mounted casework versus movable casework must be struck. Micro changes to individual workstations, counter areas that house equipment, and storage, can make the lab ready to accept procedures, equipment and personnel changes due to consolidations, technological advancements and cost containment. With today's necessary emphasis on facility flexibility comes one cautionary note; in the quest for design excellence, technologists and administrators must be prepared to abandon the "way we've always done things" and open their minds to new ways of organizing the lab. A Microbiology lab that was recently constructed made the level of flexibility a major issue in their design exploration. Several members believed that there was no need for any flexibility and a fixed casework plan, exactly like their previous lab, would be perfect. Other members, who had worked with flexible casework in other labs were strong advocates for their use. As the project progressed a decision was made to keep the perimeters fixed, but allow the peninsulas, where the workstations were located, to be flexible. This allows the easy addition of equipment that they are considering purchasing.

Mechanical

The proximity of existing air handlers, ductwork, risers, and plumbing should be evaluated to minimize

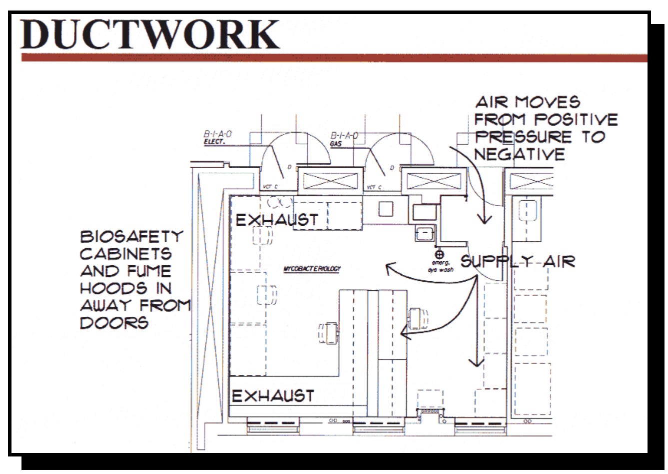

Figure 11

disruption and costs (**Figure 11**). Optimal location of mechanical components will lower material costs, allow more ceiling space, and reduce energy consumption. When the ideal location for the lab is a considerable distance from an existing air handler it may prove more efficient and less disruptive to add a new air handler to the project. Many facilities handle this situation by locating labs on upper floors to minimize the distance between the lab, the air supply and the exhaust area. It is important to locate areas that require many air changes, such as a BSL3 lab, close to risers. An example of the problems that this can create was a new BSL3 lab that was located in an existing wing of a facility that had no extra capacity on the air handler that fed that area. To add to this problem there was a very low floor to floor height, leaving little room for ductwork. The solution involved running ductwork from another wing down the outside of the building. This was very expensive, and not a pleasant addition to the exterior facade. The ductwork, coming into the lab, had to be brought through an existing window, as there was little space above the window to contain it.

In all projects, zones will be created depending on similar air and temperature demands and fire spread evaluations (**Figure 12**). These zones require separate ductruns and

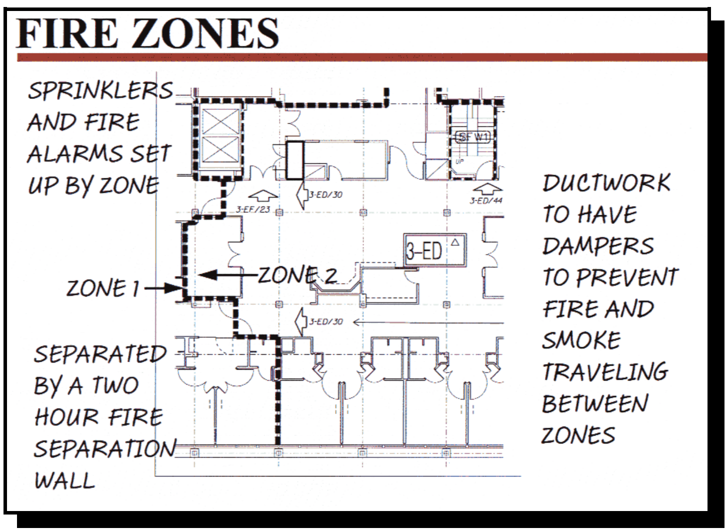

Figure 12

controls. The relationships between like spaces, such as all the Level 3 labs, should dictate the location of these spaces in the overall plan. This will minimize the amount of ductwork, and reduce the size of the ducts required in spaces that have lower requirements.

Flexibility in a mechanical sense refers to the ease of change and maintenance for plumbing, controls and ductwork. If access requires removing plaster ceilings, demolishing walls or digging into concrete floors, the disruption and costs that result will severely limit changes. By utilizing open or suspended ceilings more flexibility is achieved. Labeling the pipes and ductwork makes maintenance easier: an innovative solution that was reached in a Pennsylvania hospital to ease maintenance headaches. They paint the pipes in colors that announced their purpose. The fire protection piping was red, gases - yellow, and water - white. This also eliminated an ongoing problem of labels falling off.

Energy efficiency is important because of potential long term cost savings. In a lab project, that has such heavy dependency on air supply and exhaust, shorter duct runs are more efficient. Significant energy savings can be achieved by using well-insulated ducts that supply cooled or heated air and by updating windows and insulation. Evaluating lab equipment, a task that can fall to lab personnel, architects and engineers, or special equipment consultants, shows differences in consumption and life cycle costs. Life cycle information should include maintenance history, warranties, obsolescence and utilization projections.

Electrical/Communication

The locations and amounts of existing electrical and communication panels dictate wiring patterns. Often the addition of new panels and electrical closets is necessary due to increased amounts of specialized power and data. These panels and closets should be centralized in the lab for easy access and shorter wiring runs.

Accessibility applies to the wiring systems as it does to all engineering. Utilities may be organized and easily accessed when above ceiling cable trays are utilized. This feature occupies some ceiling space and must be designed in coordination with ductwork, lighting and plumbing. By designating specific above ceiling layers for each set of mechanical components, interferences can be reduced (**Figure 13**).

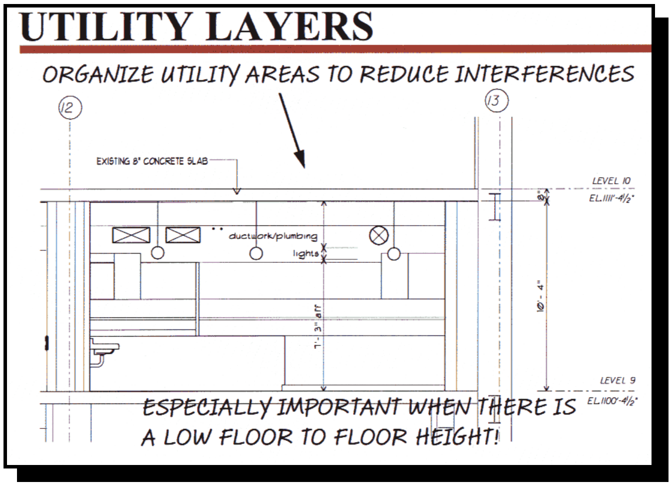

Figure 13

Outlets and lighting can be installed to allow flexibility. By using raceways that house both electrical and data wiring, outlets can be easily added, moved or eliminated. Task lighting should be switched individually and be movable with the use of simple tools. Good overall lighting in the lab, in addition to task lighting, will support most procedural and equipment changes. A problem that can be encountered, in relation to lighting, is the orientation of workspaces to the lighting. If during some minor changes the workstations become oriented parallel to lighting, as opposed to perpendicular, there can be shadows. The exception to this rule is Histology. In a histology lab there is special consideration necessary for the waterbaths used in cutting areas. Histologists that we have worked with have expressed preferences for lighting to be parallel.

Safety

Architectural

Laboratory safety is mandated through codes. Life safety codes have been issued and expanded over time by government, insurance companies and specialized regulatory agencies. Their basic premise is to protect personnel and patients. In laboratories, fire codes are frequently overlooked as space becomes strained. Boxes, refrigerators, trash cans, and equipment are often placed in exit corridors and in front of fire hose cabinets. Such space problems that actually interfere with the quality of work and the safety of personnel are College of American Pathologists (CAP) deficiencies. Having sufficient storage and flexibility in the lab helps limit future violations.

Hood locations can also cause egress code problems. If a hood is located next to an exit door, a second door must be supplied. This situation can cause problems in the hood itself if there is a lot of movement in and out of the door. The currents caused by such movement can interfere with the hood's air flow.

All materials that are used in the construction of a lab must meet codes for fire spread. Properly constructed walls and ceilings create a barrier to the spread of fire (**Figure 14**). Areas that house gases and large quantities (greater than 100 square feet) of dry storage must be separated by walls that retard the passage of fire and smoke for one or two hours. The location of fire extinguishers beside doors in areas that house flammables is a CAP requirement. It is prudent to have fire extinguishers next to the door in any lab that uses chemicals that could cause a fire.

Egress and construction requirements vary according to the amounts and types of chemicals stored in the lab. The National Fire Protection Association (NFPA) codes

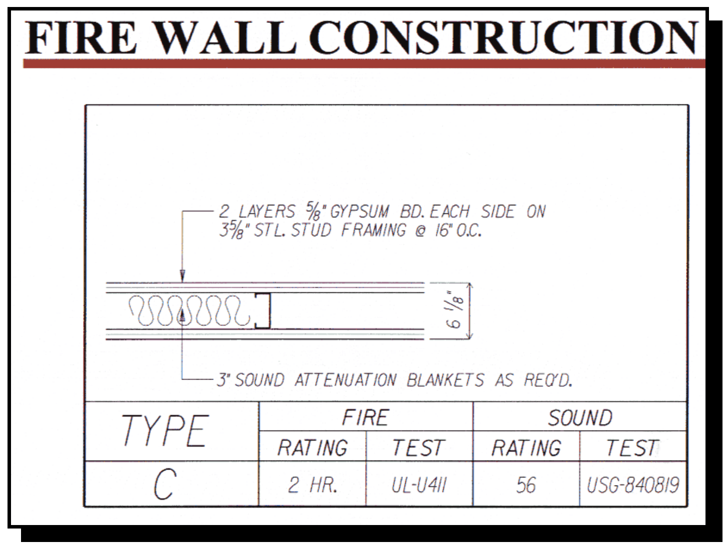

Figure 14

give three classifications for labs depending upon the amounts of flammable and combustible chemicals that are stored (**Figure 15**). It is generally acceptable in a typical clinical lab to have a sprinklered chemical storage space with a wall that can contain a fire for one hour. It is good practice to supply the project design team with a quantitative list of flammable and hazardous materials used and stored in the lab.

Emergency eye washes and showers are required where corrosive and toxic chemicals are used. These are

Laboratory Classifications

- **Class A**
  - High Hazard
  - 10 to 20 gal. of various flammable or combustible liquids allowed
- **Class B**
  - Intermediate Hazard
  - 5 to 10 gal. of various flammable or combustible liquids allowed
- **Class C**
  - Low Hazard
  - 2 to 4 gal. of various flammable or combustible liquids allowed

Figure 15

Emergency Eyewash

- water remains on without use of hands (hands to hold eyes open)
- goes from off to on in one second or less
- large and easy to operate controls
- delivers 0.4 gal of water per minute
- water nozzles 33 to 45 inches above floor
- visible sign
- checked and flushed weekly

Figure 16

Emergency Shower

- opens in one second
- water remains on without use of hands
- delivers 30 gal of water per minute
- easy to locate and accessible controls
- head at 84" from floor
- adjustable water supply
- visible sign
- checked and flushed weekly

Figure 17

chosen and located by the architect and the mechanical (plumbing) engineer. An eyewash must be a fixed unit that allows the users hands to hold both eyes open during operation, thus eliminating the use of squeeze bottles in labs. The basic requirement for both units is that it takes only ten seconds to reach the unit from the hazardous area. The distance that can be traveled in this time frame has been calculated to be 100 feet. However this should be evaluated on an individual basis to best protect technologists. The American National Standards Institute (ANSI) has specific performance requirements for both units (**Figures 16 & 17**). A common problem is the mess associated with the regular testing of the eyewash units. The fixed eyewashes with attached basins can be neatly tested if a cylinder is put over the unit before activating. This will direct all the water into the basin.

Biosafety levels are more important today with the expanding usage of DNA Amplification. The Center for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH) have categorized the requirements of the four levels (**Figure 18**). Levels 1 and 2 follow standard lab practices of safety. Handwash sinks, and cleanable surfaces are common to both. An emergency eyewash is required in Level 2 labs. Level 3 and 4 have progressively stricter requirements relating to emergency equipment, windows, cleanablity of surfaces, furniture and utilities minimizing contamination of people and facilities (**Figures 19, 20 & 21**).

Biosafety Levels

- **BSL 1 -** Infectious agents not known to cause disease in healthy adults
- **BSL 2 -** Infectious agents associated with human disease. Ability to infect through autoinoculation, ingestion, and mucous membrane exposure
- **BSL 3 -** Infectious agents with potential for aerosol transmission. Effects may be serious or lethal
- **BSL 4 -** Infectious agents which pose high risk of life-threatening disease, aerosol transmitted lab infections, or agents with unknown risk of transmission

Figure 18

ADA and ergonomic guidelines are easily accommodated in the lab design if considered early. Allowing adequate room for wheelchairs, some adjustable casework, and observing height requirements for light switches, outlets, and safety equipment will allow you to meet most requirements of a handicapped employee (**Figure 22**). Often overlooked in lab design is allowance next to doors for maneuvering space. It is recommended that 2'-0" clearance exists on the latch side of a door. Door sizes that are allowable for ADA

Facility Requirements for Biosafety Level 3

- Separate from traffic areas through two sets of self closing doors
- Hand-free handwash sink near door
- Interior surfaces water resistant and sealed
- Bench tops impervious to water, resistant to acids, alkalis, solvents and moderate heat
- Spaces between furniture and benches accessible for cleaning
- Windows closed and sealed
- Decontamination method available
- Directional ducted exhaust air provided
- HEPA filters in biosafety cabinets
- Eyewash facility

Figure 19

are often less than is necessary for movement of equipment. It is best if all the lab doors are four feet wide. Companies are developing equipment, such as biosafety cabinets, that is accessible to personnel with disabilities.

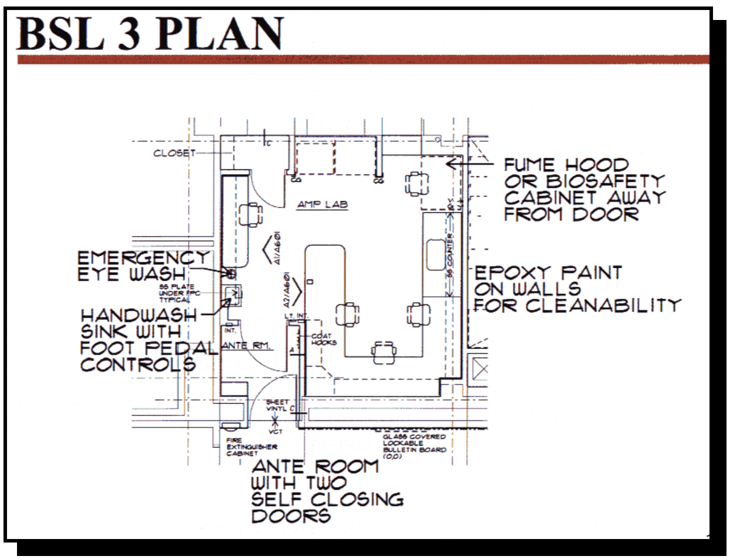

Figure 20

Ergonomics, designing to help prevent work-related musculoskelatal disorders, is addressed in several ways. Well designed and adjustable chairs, keyboard trays, and monitor arms allow personnel to keep from being frozen in a fixed position every day, and subsequently developing problems. Noise and vibrations, irritants known to cause mental and physical problems for employees, must be addressed, especially in situations where large amounts of equipment are used. For example, long periods of exposure to low levels of noise, called white noise, can cause fatigue, irritation and headaches. Laboratorians must stand to do phlebotomy or work on equipment. Antifatigue mats can ease back strain. A common ergonomic problem in labs is slippery footing. Areas with slip hazards, such as histology, should employ gripping surfaces instead of traditional flooring. Water spills can be controlled with mats at sink areas. Such mats are also beneficial in protecting flooring from spilled stains.

Facility Requirements for Biosafety Level 4

- Same as BSL 3 - plus ...
- Located in separate building or zone
- Floor drain; all surfaces able to be fumigated
- Constructed to minimize dust settling areas
- Doors lockable
- Double-door autoclave for exiting materials
- Decontamination method for non-autoclavable materials
- Heat treatment for liquid wastes to sewers
- Monitored differential pressure and directional airflow
- HEPA filtered exhaust
- Possible suit area with decontamination shower

Figure 21

ADA Guidelines

- Minimum door size - 32"
- Clear width for wheelchair - 36"
- Wheelchair turnaround space - 60" diameter
- Forward reach - 15" to 48" above floor
- Reach over counter - 44" maximum
- Kneespace - 30" wide
- Lavatory height - 29" to 34" above floor
- Countertop height - 34" maximum
- Apron height - 34" maximum

Figure 22

Mechanical

The passage of fire through ductwork, and openings in walls for pipes and ducts are addressed by NFPA. The code states that the passage of smoke, fire or vapors shall be prevented between fire rated floor or walls. This requirement, in practice, dictates the use of fire dampers. The best addition to any laboratory, to prevent fire spread and to protect personnel, is an automatic sprinkler system.

Protecting technologists and the patients they are associated with requires the addition of separate handwash sinks, either countertop or lavatory. The U.S. Department of Health and Human Services (DOH) regulations allow countertop sinks, designated for handwashing, to be used to dispose of nonhazardous waste. It is good practice, however, to designate a sink with foot pedal controls near the exit, for the sole purpose of handwashing.

Ventilation of vapors becomes more important as it is learned that many chemicals regularly used in labs are considered carcinogenic. In areas, such as histology, that use known carcinogens with regularity, a downdraft method of ventilation should be employed (**Figure 23**). This keeps the fumes of the xylene and formalin, known

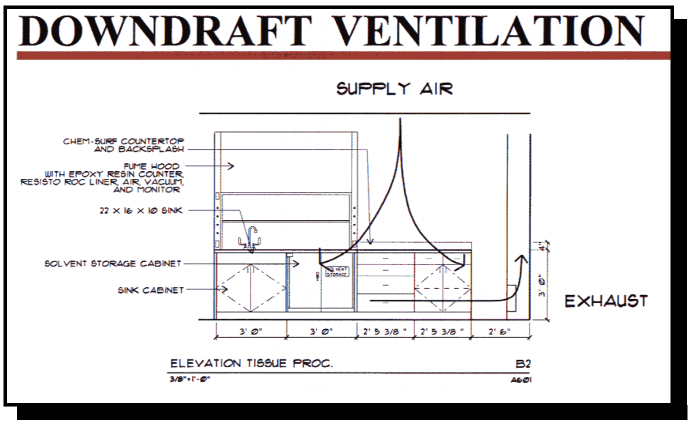

Figure 23

to be heavier than air, away from the technologist's face. It is required by the Occupational Safety and Health Act (OSHA), that work with carcinogens be performed in a properly functioning laboratory type hood , closed system or device that provides equivalent protection. Inside fume hoods the same downdraft design should be employed. Purchase a fume hood that pulls vapors directly back away from the users face.

Ventilation and exhaust from flammable storage cabinets is not required. The purpose of these cabinets is to separate chemicals from a fire. Venting these cabinets has not been proven beneficial. Venting flammable storage into a fume hood creates the potential of a flashback into the storage cabinet. If there is concern about combustion inside a cabinet it is prudent to install a sprinkler head inside.

Mechanical requirements associated with the Biosafety level 3 are noted in **Figure 19.** Levels 3 and 4 require directional air flow, meaning that air must move away from the doors towards the back of the room (**Figure 24**). This ensures that any contamination that may get

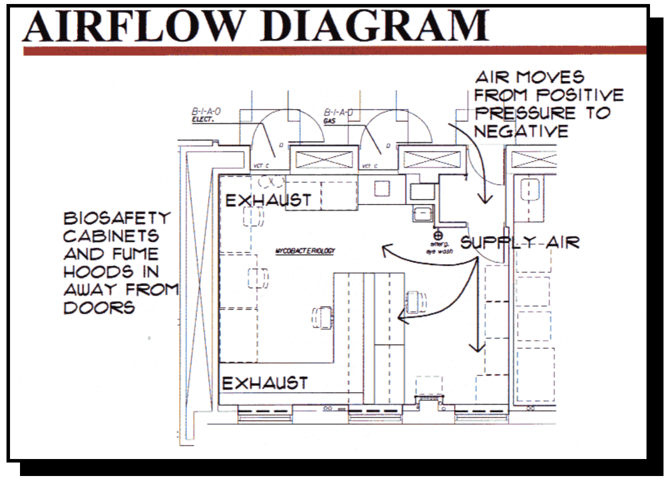

Figure 24

into the air will not pass into the ante room when the doors are opened. Another requirement for level 4 is differential pressurization. When a room is negatively pressurized, typical for most labs, isolation rooms and bathrooms, air moves into the room. This keeps contamination and noxious fumes from moving out into adjacent spaces. Positive pressurization, often used in clean rooms and reverse isolation, means that the air will move out of the room. In labs the majority of the spaces will be negatively pressurized in comparison with the corridors and offices. There is the occasion to positively pressurize lab areas that are sensitive to contamination from outside the space, but there must be nothing that is potentially harmful to people outside the space.

Electrical/Communication

Most of the codes regulating wiring, in relationship to fire prevention in labs, are universal. Fire alarms, connected to the sprinkler system, must be equipped with audible and visual signals. Equipment cords, often found in spaghetti like tangles on countertops and floors**,** should be controlled with wire management. Wires and cables interfering with traffic is considered a CAP deficiency. Controlling the cords necessitates the use of undercounter chases or hooks that keep excess wire off the floor. Including extra outlets for both data and electric eliminates long runs of cords, and so eliminates the potential hazard of extension cords and outlet adapters.

EQUIPMENT INFORMATION

MANUF. & DESC.	DEPT. RM. NO.	LOCATION	SIZE HxWxD	CLEAR	ELEC.	PHASE	PLUMBING	MECH.	MISC.
Baker biosafety cabinet	TB/Mycology	Floor	90"x53"x37"	2"	115 volts 22 Amps		hot and cold water cup sink	thimble	
MP Triple-Trak CO2 incubator	TB/Mycology	Floor	91"x53"x37"		120 Volts 11.7 Amps		floor drain		
Forma Model 3932 37C incubator	TB/Mycology	Floor	80"x42"x32"		120 Volts 60 Hertz			CO2	
Kelvinator double door refrigerator	TB/Mycology	Floor	[illegible]x54"x[illegible]		119 Volts				Special Plug emerg.
Precision low temp. incubator	TB/Mycology	Floor	73"x33"x29"		115 Volts 60 Hertz				emerg.
S/P multi-block heater	TB/Mycology	Counter	3.5"x8.5"x8"		110 Watts 0.83 Amps				
S/P multi-block heater	TB/Mycology	Counter	3.5"x8.5"x8"		110 Watts 0.83 Amps				
Epindorf microcentrifuge	TB/Mycology	Counter	11"x9"x11"		250 Watts				
Branson 1200 sonicator	TB/Mycology	Counter	10"x8"x9"		[illegible]3 Amps				
Boekel room temp. incubator	TB/Mycology	Counter	16"x13"x14"		120 Volts [illegible]0 Watts				emerg.
SteriGard Class II A/B3 biosafety cabinet	TB/Mycology	Floor	87"x76.5"x30"	4"	123 Volts 18.6 Amps		sink	CO2 thimble	hard wired
BacTec 460 TB instrument	TB/Mycology	Counter	19"x28"x35"		115 Volts 2.5 Amps			gas	emerg.
BacTec 460 TB instrument	TB/Mycology	Counter	19"x28"x35"		115 Volts 2.5 Amps			gas	emerg.
Lab LIne radiant heat CO2 incubator	TB/Mycology	Floor	93"x43"x34"		120 Volts 11.7 Amps			CO2	emerg.
Cold Spot -20C freezer	Freezer Room	Floor	60"x32"x30"		124 Volts				emerg.
IEC CU 5000R centrifuge	TB/Mycology	Floor	45"x26"x32"		115 Volts 20 Amps				special plug
Sunquest terminal with keyboard	Bacteriology	Counter	12"x13"x14"		1 Amp 50 Watts				[illegible] outlet
Labor Lux D fluorescent microscope	Fluor. Micro.	Counter	27"x8"x18"		100 Watts				no vibration has camera

DO PIPES STICK OUT?

SINKS?

GASES?

EMERG. POWER?

NEED CONNECT TO HVAC SYSTEM?

SPECIAL REQUIREMENTS?

Figure 25

Equipment

Architectural

New equipment technologies often create the need to redesign. In particular, robotics has had a profound effect on the layout of labs. In the past, automation has been departmentalized. In a robotic equipped lab, the chemistry, hematology, immunology and toxicology analyzers are together in one area, often directly linked with specimen preparation areas. Separating the equipment would be contradictory to the efficiency and cost of the robotics. The space allowed for robotics is dependent on the extent of the system and on the personnel changes that will be associated with the new procedures. Most often the lab will be designed with the anticipation of a robotics purchase. A core lab is developed with specimen preparation immediately adjacent. A space that allows for a linear orientation of the equipment is the most cost efficient. It is also important to allow space for the robotic system to expand. Areas, such as immunohematology and microbiology, still relying on extensive manual techniques and individual pieces of equipment, will become more and more automated and capable of connections to a robotics system.

Robotics and other individual pieces of equipment can stress existing structural systems. It is important to check statistics on each item related to weight and sensitivity to vibration. Of special concern are items with large point loads, a large weight set on a small area. An irradiator, for example, may necessitate augmentation of the existing supports in the floor, or placement in a space that can support the load. Point loads have also become important with liquid gas containers and sliding storage systems.

Acoustics is a problem in any area that houses large amounts of automation. In the large space required for robotics, a source of white noise, acoustics must be creatively handled. Open ceilings, tile floors and bare walls, often used in labs will reflect the noise and worsen the problem. Core labs must have acoustic panels in the ceiling. Different levels of sound absorption are available from various manufacturers. It is best to specify the most absorbent. One particular project, a renovation project that opened up into a core lab ready for robotics, experienced immediate acoustic problems. The solution was partial height movable panels placed behind the equipment. These are not only sound absorbent but can hide and control wires and plumbing lines running to the floor. Their movability allows easy access to the backs for maintenance. For large noise problems, wall panels and ceiling hung acoustic panels can be used.

With robotics come additional safety concerns. Special care must be taken to protect personnel from the tangle of wiring and drain lines that accompany such systems. Some systems have robotic arms that have the potential of causing injury. Floor pads that are electronically linked to the system can inactivate the arms. Equipment manufacturers are continually coming up with safer systems and more innovative ways of protecting users.

To facilitate the design process it is necessary to set up an organized system of equipment information (**Figure 25**). Manufacturers can provide catalog cuts that give specifications on sizes, power requirements, mechanical requirements, weights and special considerations. Users should individually look at these and determine what other requirements are necessary. This could include; clearances for pipes, wires and plugs, room to allow for regular maintenance, work space associated with the procedure and location. Is this a backup piece of equipment that is normally stored away, but needs to have space left for its occasional use? The sizes and weights are the first items looked at in design. This dictates floor space, countertop sizes, structural requirements, and orientation.

Mechanical

The amount of heat that is generated by individual pieces of equipment, when idle and in full operation, is very important in determining temperature and air requirements for the space. Without proper analysis of the total heat load, the equipment and personnel can be adversely affected. Fumes that may be generated, such as those from automatic stainers, are used in determining the location of vents, or addition of fume hoods.

Water lines and drains are often required for lab equipment (**Figure 26**). Types of water may include de-ionized, tap or filtered. Drains are added for those emergency situations when something overflows, or to empty wastes generated by analyzers. Drainage from

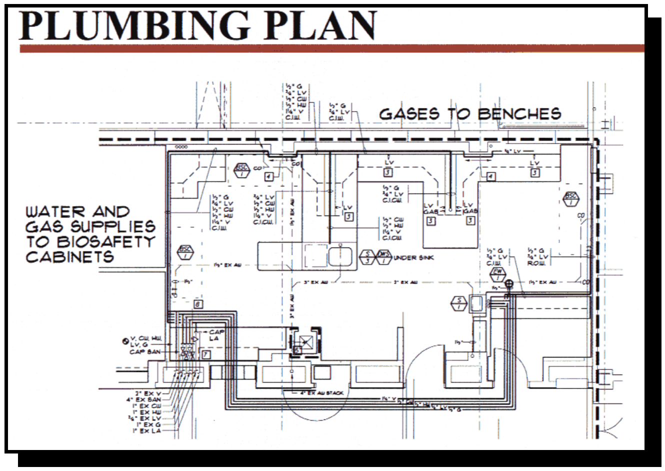

Figure 26

equipment may contain caustic or hazardous wastes. The system that will accept that waste must be evaluated by the engineers to ensure that it meets environmental codes and that the plumbing materials can handle caustics.

Gases, if required are to be included in mechanical information. CO_2, Nitrogen, Oxygen, Vacuum and other specialized gases can be connected into existing risers, nearby tank closets, or tanks located adjacent to the equipment. Locating any gases remotely from the equipment requires space, but is safer for the users.

An often overlooked addition to the mechanical information is the attachments from fume hoods and biosafety cabinets to the ventilation systems. New or additional thimble connections, and flexible pipes may be required. An additional ventilation concern that greatly affects the size and arrangement of ductwork is the air demands generated by hoods and biosafety cabinets.

Electrical/ Communication

Requirements for equipment and robotics include; power - normal, special and emergency, and data - networked or individual. Again, this information, excluding the need for emergency power, is normally included in the manufacturers specifications. Emergency power requirements must be evaluated individually. As a rule of thumb, if it is something that will immediately affect patient care, or cause a considerable financial crisis if down, then it should be on emergency power. Included may be refrigerators, incubators and stat testing equipment. Because the amount of emergency power in a facility is limited it is important to evaluate and prioritize needs carefully.

Lighting requirements are not normally thought of when looking into equipment information. Monitors that can have glare problems, waterbaths for tissue preparations that are subject to reflections, and correct lighting for reading agar plates and agglutination should be noted on equipment lists.

Software that is included in robotics is generally not a responsibility of the electrical engineers. However, even when all the necessary outlets, lights, and space requirements are provided the system may still not work because of software problems. The robotics manufacturers should provide software information and give recommendations before the purchase of the system. Depending on the manufacturer, an added expense may be incurred.

Design for Marketing

In today's evolving healthcare environment, hospitals must now compete for patients, physicians, and HMO's. Outpatient areas must be designed to be efficient and attractive to users. Patients, health care customers who are often hungry, sick, scared, or embarrassed, must be made to feel as comfortable as possible to assure their loyalty to your facility. Design inside the laboratory is important. A safe and pleasant laboratory environment will foster employee performance and satisfaction. Such an atmosphere can encourage physicians to visit the lab, resulting in increased interaction between the managers, technologists and doctors. A profound example was a laboratory that was recently renovated in a large university hospital. This is a teaching facility and wanted to be able to attract the best students possible. The new facility was so efficient and aesthetically pleasing that the directors found that they now could pick the best and most promising students, as every applicant wanted to train there. If a facility looks good and works well it reflects positively on doctors, employees, and the health insurance companies that recommend it.

Conclusion

Changing the physical plant of today's laboratories is necessitated by advancements in laboratory technologies and the adoption of more competitive business strategies. To survive in a competitive marketplace, labs must flexibly adapt to the inclusion of the new equipment and robotics, promote maximum production and efficiency, and provide the atmosphere and convenience demanded by an outpatient oriented marketplace. By following a systematic approach to planning, the design of the new lab can satisfy today's needs and be prepared for tomorrow.

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