#G-003a

Cleanroom facility safety and process training

Outline:

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Perspective

This document is a compilation of works from various authors over several years. The bulk of the content was initially targeted to a cleanroom short course designed mostly for nontrained members of the business community. Reference to companies in this document are held over from that time.

The current document has been revised to address more specifically the student and staff employees of LCI as the majority of the work done in the facility is currently done by these people.

The this document is meant to be a general resource and supplement to cleanroom training, cleaning gowning training, specific equipment training, and general lab safety training. This document is not intended to be a self-help book and is not intended to be used to bypass any of the required training necessary for safe and effective work in the LCI cleanroom.

Anyone who uses the cleanroom must go through proper training for all aspects of their work and will be responsible for conducting themselves in a proper manner and will be expected to follow all specific and general work practices and safety protocols during their time in the facility.

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Why Cleanrooms?

Overview

In this section, you will be introduced to cleanrooms, their importance in LCD manufacturing and your relationship to the cleanroom and the processes. The first section will discuss what industries use cleanrooms and why they use these special clean environments. The next section addresses the question, "What makes a cleanroom clean?" The third section will focus on the major sources of "contamination" that reduce the yield in LCD fabrication facilities. This section will also discuss the operator's and engineer's role in contamination reduction. An important observation will be that **you are a very important part of both contamination control and the manufacturing process.**

Objectives

Upon completion of this section, you should be able to:

1. Explain why cleanrooms are used in manufacturing.
2. Define contamination.
3. List the major sources of contamination.
4. Explain particulate contamination.
5. Explain what the class number of a cleanroom refers to and what class numbers are appropriate for LCD manufacturing.
6. Explain the relationship between the people in cleanrooms and contamination.

What industries use cleanrooms?

Cleanrooms are not new. They have continuously evolved and been manufactured since early in the space program when it was found that dust from a normal environment could cause devices to fail in space. Today, the list of companies that use cleanrooms is rather large. We will mention just a few. The electronics industry manufactures printed circuit boards from which electronic devices are constructed in cleanrooms. More fundamentally, the semiconductor industry has been an industry leader in cleanroom technology; in fact, all the most advanced semiconductor devices are manufactured in cleanrooms. The consumer electronics industry including the manufacturing of CD players, cell phones, CD's, optical systems and the semiconductor laser industries also use cleanrooms. While, they do not occur in obvious ways in many common products, the crystal growth industry needs the cleanliness provided by cleanroom to manufacture high quality crystals that are used in many behind the scene ways. The aerospace and military components industries also need such environments. The pharmaceutical and biotechnology industries are also large scale users of cleanrooms. In these areas not only is the room clean but it is often also sterile. Even some fairly "low-tech" industries use cleanrooms. For example, automobile ignition systems and some automobile parts are manufactured in cleanrooms. Old "stodgy" industries such as the soap and garment industries also use these environments. This list could get rather long; suffice it to say that many industries including, most importantly for the present purpose, the LCD industry find cleanrooms essential to the production of their products. A more complete list as well as interesting articles about cleanrooms and related topics can be found at the cleanroom magazine site (http://cr.pennnet.com/home.cfm).

These companies use such a special manufacturing environment for a number of reasons. The primary reason is that these industries find that they can manufacture unique products in a clean environment that they can not manufacture in a non-clean environment. They also obtain improved yield of the products they make. It is not unusual for quality and performance to improve when manufacturing is moved to a cleanroom.

What makes a cleanroom clean?

Cleanrooms are clean because they are a controlled environment that is designed to reduce/eliminate contamination. Contamination in the cleanroom community has a special definition. **Contamination is anything that interferes with the production and/or operation of the product.** Contamination comes in many types, shapes and sizes.

Types of contamination

There are six major contaminants. All of these are treated in a clean environment to reduce the level of contamination that they cause. These major contaminants are:

1. Air
2. The production facility
3. The production personnel
4. Process water and chemicals
5. Process gases
6. Static electric charge

This is a rather impressive list that appears to cover almost every common substance or phenomena that in any way impacts manufacturing of LCDs. In fact, this is true, and that is why cleanrooms are so important. We will come back to each of these contaminating agents during this discussion. For now we will focus on those contaminants that are particularly critical in LCD production. From this perspective, these three questions are particularly important:

1. What contaminants are particularly critical to LCD failure and lower yield and must be reduced?
2. How are levels of these critical contaminants reduced?
3. What is the production person's role in keeping the manufacturing environment uncontaminated (more correctly minimally contaminated)?

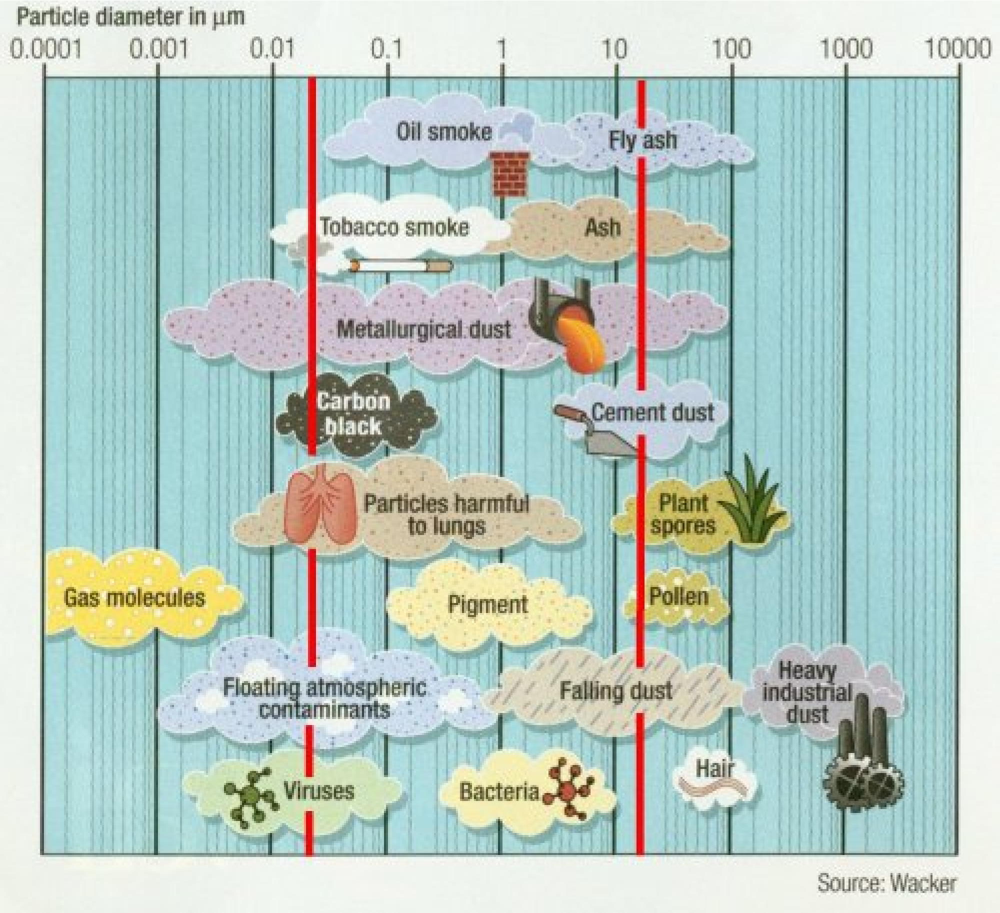
In the manufacturing of liquid crystal displays all of the contaminants listed above may present problems. However, the two major sources of contamination are particulates and chemicals. In some instances, bacteria may also be a serious problem. These three types of contamination now will be discussed in greater detail. Later, the role and reduction of all these contaminants will be discussed.

Particulate Contamination

The following table lists the major sources of particulate contamination and some common types of these particulates.

Source of particulate contamination	Examples
The room itself	dust and aerosols in the air
The operator	hair, skin flakes, bacteria, clothing fibers, finger prints
The equipment	flecks of dried processing chemicals, dust, paint flakes, fiber dust, wiper dust
Glass or plastic dust	fragments of glass or plastic from when they are cut
Dirty solvents	particles in water, cleaning solvents, and the like

Most of these seem rather small and somewhat minor. Why do we care? A typical LCD has a cell gap of between 3 and 20 microns. A micron is a metric unit of length and is one millionth of a meter. 25.4 microns equals 0.001 inches. Thus, most displays have gaps that are less than 1 thousandth of an inch in size. To see how this compares to everyday particulates consider the following figure.



First, observe that the scale across the top of this chart is not linear like a ruler. Factors of ten are separated by equal amounts. The left-hand most line corresponds to particles 100 million times smaller than those at the right-hand most line. Next observe that this chart has just about every common particulate contaminant you can name off the top of your head. Next, notice the two red (wider) lines that extend from the top to the bottom of the figure. The right red (wider) line is near the maximum cell gap of an LCD. The left line is somewhat arbitrary. However, it represents the smallest size particle that can **"significantly"** inhibit the operation of an LCD. This line could certainly be moved further to the left. This line is spaced more than 100 times smaller than the smallest LCD cell gap commonly used today.

Now note those types of particulates that are to the right of the **right-hand** red line. That is, particles larger than the largest cell gap. These particles are generally too big to get into a display. Furthermore, should they become attached to a substrate they are so big that they would be clearly visible. Generally hair, plant spores, and plant pollen are too large to be contaminants. However, other particulates attached to these may be a problem. Fortunately the large particles can be removed via cleaning, or the substrate can be pulled out of the fabrication line so that it undergoes no further processing. Particles that are to the left of the **left-hand** red line are very small. In fact, they are so small that they are not significantly impeding the current LCD technology.

The important area is the region between the two red lines. Particles in this size region can have a major impact on LCD manufacturing yield and performance. Consider the top entry —oil smoke. This is the common type of smoke produced by homes and cars. It is next to impossible to avoid. The next entry is tobacco smoke. Once more this is a near universal problem. Metallurgical dust is common in heavy manufacturing areas. This may be a bigger problem in some locations than others. Carbon black and cement dust are next in line. Cement dust is a common side product of construction, while carbon black is a common pigment and is used in tires. ‘Particles harmful to the lungs’ is a catch-all for many substances such as asbestos and similar materials. Pigments are common in paints, make-up colored pens and the like. They are almost perfectly positioned to destroy LCDs. It is for this reason that make-up is not allowed in cleanrooms. Falling dust and floating contaminants are the normal suspects in dust such as flour dust and the like. Although this area also includes aerosols (a suspension of solids or liquid particles in a gas; usually air). Finally, note that bacteria are of the correct size to destroy LCDs. In short, many common substances and activities produce particles that are of the correct size to destroy LCDs. This means, that at the very least, the air in an LCD fabrication facility must be very heavily filtered to remove these particulates from the facility.

Chemical Contamination

A remarkable number of chemicals are used in LCD manufacturing. These include the chemicals used in the lithographic (generally photolithography) process that forms the electrodes and active regions of the display, the chemicals and water used to clean the substrate, the chemicals used in the formation of alignment layers, the glue used to hold the substrates together and seal the filled display and the liquid crystal itself. With such a wide array and large number of chemicals it is easy to understand how they might accidentally get mixed together during manufacturing of an LCD. Chemical contamination generally occurs when unwanted chemicals get <u>accidentally</u> added to the desired processing materials. The amount that gets added is often a very small or "trace" amount. Under normal circumstances this would seem to be of minimal important. However, due to this thin film nature of alignment layers and the small volume of liquid crystal in displays these trace amounts can have significant effects on LCD yield and performance. A particularly insidious source of contamination, both particulate and chemical may be the processing water that is used in manufacturing.

Bacteria Contamination

The third major source of contamination in LCD manufacturing is bacteria. Bacteria are a natural part of the environment and may act as either a chemical or a particulate contaminant, or in the worst case both. While a clean environment minimizes the number of bacteria that are initially in the air, this ignores potential operator contributions of bacteria to the clean environment. For example, a sneeze or a cough will generally put both bacteria and aerosol particles into the air. Bacteria are on everyone's skin and scratching exposed skin will place both skin flakes and bacteria into the air. Another problem is the ability of bacteria to mutate; thus it is not uncommon for bacteria to grow in water systems and the like. In light of their size, it is not surprising that bacteria are particulate contaminants. But, how are they chemical contaminants? Recall that they are alive and contain a vast array of chemicals. Included among these chemicals are electrically charged molecules called ions. These ions may play havoc with the performance of the completed display.

Problems Caused by Contamination

Why has this discussion made such a big deal out of contamination? The reason is contamination lowers yield, and generally raises the cost of producing the desired LCD. Thus, contamination greatly affects the bottom line. The first place contamination affects yield is in the manufacturing of the display. This contamination induced problem is often caught in production; however, the loss of materials and labor drives costs up. The second place contamination affects yield is in the performance testing that occurs before the display is shipped. Here contamination can greatly affect the alignment of the liquid crystal and cause unacceptable problems with the optical performance. Contamination may also affect the time response of the displays; this will also be caught in the performance testing step. Catching defects at this stage is much better than not catching them and shipping the display. Nevertheless, these problems are caught at the end of the manufacturing process and thus are more costly in labor and materials than problems caught during manufacturing. The third problem caused by contamination can be the most serious. Contamination may lower the lifetime of the display. This is especially bad, because it generally occurs while the display is "in the field"—the display performed at specification in the final test. Thus, the display's problem was not initially apparent. Failure via this mode may require a warranty replacement. This is bad because it represents the loss of the cost of the replacement display as well as potential harm to the company's reputation and future sales.

Sources of Contamination

The discussion will now focus on the sources of contamination encountered in LCD manufacturing, and briefly discuss some of ways that these contaminants are minimized and why this minimization is important. The major sources of contamination in LCD manufacturing are:

- The air in the facility
- The personnel in the facility (including things brought into the facility with them).
- The water used to process the displays
- The chemicals and gases used to process the displays
- Static electric charge
- The production facility and equipment in the facility

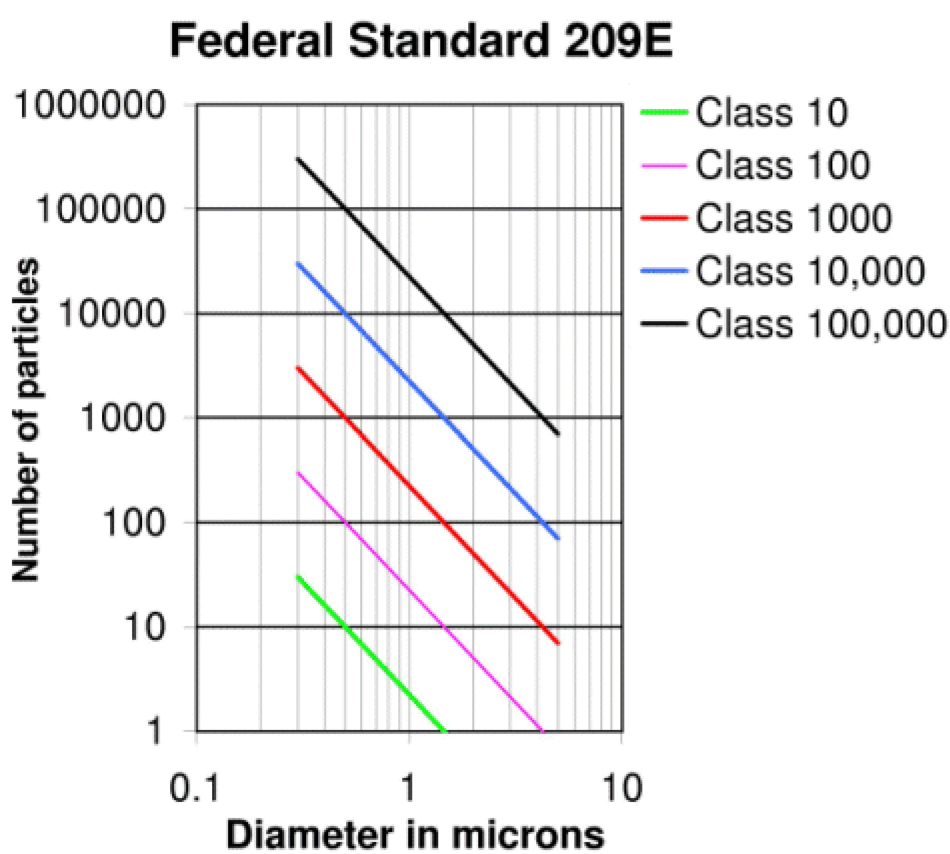
Each of these contaminants requires special control techniques.

The major approach to minimizing contamination in the work environment is to have the manufacturing done in a cleanroom. This is a special room with **treated** air, personnel containment clothing, filtered water, high purity chemicals, and specially designed equipment.

Air

The contaminants in the air are a major problem. The particulates and aerosols in the air do not behave in the same way as large particles. This is critical because the particles are very small, and thus have a large surface area. This area is available for chemical reactions with other substances as well as physical effects such as electrostatic attraction. The particles that are critical contaminants in air do not behave similarly to large particles. For example, a large particle, say a paper clip, when dropped from ones hand falls to the ground. The situation with very small particles is different, they randomly move around and execute "Brownian motion"—they float in the air for a long time. Fortunately, a large fraction of the particles in the air in a cleanroom are removed via HEPA (high-efficiency particle attenuation) filters. These are typically 99.99+% effective. Thus, at least in the absence of new sources of contamination, only the smaller of the small particles remain in the air. These typically are removed by colliding with other particles until they are so large that they are removed by other means or they stick to surfaces and are removed in this way. This is a bit like dust in a room; large aggregates of dust form "dust bunnies" that "hide" under furniture and the like, while other dust just sticks to the tops of the furniture.

You will hear of cleanrooms being of some class "number." For example, class 100 cleanroom, class 1000 cleanroom and so forth. This is a way to identify air cleanliness in terms of particle diameter and density (number per unit volume). The standards in this area are evolving. The outdated U.S. Federal Standard 209E (FS209E), which has regulated cleanroom operations since 1963, was replaced as of November 2001. Stricter regulations, set forth by the International Organization for Standardization (ISO), have been adopted by the European Union, the U.S., and across much of the industrialized world. ISO's new standard, ISO 14644-1, defines the criteria that cleanrooms must meet to stay competitive in today's global business environment.. (http://www.cleanroom.com) This 209e standard specified cleanliness levels down to class 1. It also defined class numbers at the 0.5 micron diameter level, and measured particle density in number per cubic foot of air. We will abbreviate cubic foot by the collected symbols: ft^3. Higher densities are allowable for smaller particles and lower densities for larger particles. The following graph is based on this standard.



Basically, the class number is the allowed number of 0.5 micron particles per cubic foot. This is illustrated in the following table that is deduced from the above graph.

class name	0.1 micron particles/ft^3	0.3 micron particles/ft^3	0.5 micron particles/ft^3	5 micron particles/ft^3
10	350	30	10	-
100	-	300	100	-
1,000	-	-	1,000	7
10,000	-	-	10,000	70
100,000	-	-	100,000	700

The new ISO 14644-1 standard is based on modern high tech demands and needs, and due to the overall and general shrinkage of feature sizes in modern displays, the new standard defines particle count at the 0.1 micron level, much more stringent than counting particles at the 0.5 micron level according to the old 209e standard.

At this stage, you may be wondering, "What are typical class numbers for various environments?" While hard and fast numbers are not to be obtained for some environments the following numbers are typical, based on the former 209e standard. Outside, the class number is greater than 500,000. In areas of heavy manufacturing, it will easily exceed this number. A room in a house typically is about class 100,000. Obviously, in those situations where filters are used this number may be lower. An important number for the present purpose is what class number is needed in LCD fabrication plants. The answer depends on the process. However, typically class 100 to class 1000 is needed for high yield LCD manufacturing. In certain **non-critical** areas the class number could be as high as 10,000. LCD fabrication plants often include microenvironments called laminar flow hoods where low class numbers can be obtained even in the presence of a high class number outside the hood.

The Personnel

It would seem that the filtered air in a lower class number cleanroom is rather free of particulates, so where does particulate contamination come from? It turns out that nearly everything that comes into the cleanroom brings in contamination. Moreover, while they are essential to the program and process, **people are a large source of contamination** .

You are undoubtedly aware that bloodhounds and other specially trained dogs can find missing or lost people because they can smell the trail of dead skin cells, hair and so forth that are part of every person's life. This shedding does not disappear in a cleanroom. For example, while sitting in a cleanroom an operator can give off between 100,000 and 1,000,000 particles per minute. This is made worse by movement. Walking at 2 mph generates 5,000,000 particles per minute. Furthermore, faster motion makes the situation worse. At 5 mph (a fairly good pace) 10,000,000 particles per minute are shed. Everyday activities also increase the number of particles shed. A sneeze increases the number of particles shed by a factor of twenty.

Of course we also wear clothes so this is not the whole story. Normal clothes add millions of particles to the air even when they are under a cleanroom garment. This is a sufficiently serious problem that wool, cotton or high collars may be prohibited in certain areas. This is not a control issue but a yield issue. Human breath is also a problem. In climates where the temperature falls to near freezing, it is common to see a white cloud of condensing water vapor when people breathe and it is cold. This water vapor is always there, however, we rarely see it. This water vapor from everyone's breath may also be a problem. Furthermore, smokers' breath contains five times more particulates than that of non-smokers. In summary, **every person entering a cleanroom is a source of contamination.**

You are probably aware of how the personnel contribution to contamination is **minimized**. First, you cover up as much as possible with low contamination clothing. Since our heads and feet are among the worst offenders it is standard to have shoe coverings and head coverings of some sort. Furthermore, our faces are sources of contamination; thus, masks and safety glasses with side shields are required for more than the very important safety reasons. Lastly, gloves are generally required because our hands are a great source of oils, and other contaminants. It is good practice to dress from the top down. This subject will be discussed in greater detail during the discussion on cleanroom basics.

Water Contamination Issues

The substrates that the display is built upon are often glass or plastic, although silicon is also used in some displays. These substrates spend large amounts of time in water. This is because water is used both for cleaning (both with added surfactants and in the absence of added surfactants) and for rinsing before or after cleaning with other solvents. For this reason, water purity is critical. It is not uncommon to hear of pure spring water, or pure tap water. From the view point of manufacturing LCDs these are extremely impure. The water used in LCD manufacturing is treated to remove the following contaminants: dissolved minerals and salts, particulates, bacteria and organics. Organics are best described as substances that contain carbon, but this is not really sufficient. For now think of them as greasy or oily substances and most common solvents. Each of these contaminants can cause serious reductions in overall yield of LCDs.

Since the incoming tap (or well) water is not sufficiently pure, the water entering the plant must be further purified before it can be used in manufacturing of LCDs. The technology is well known and generally uses several methods to remove the minerals and salts, filtration to remove the particulates and various treatment cartridges to remove organic contaminants. The details are not critical to those not involved in producing this water. This water is almost always tested for removal of salts and minerals via measurement of the *resistivity* of the water. The best one can do in this area is to obtain a resistivity of 18,300,000 ohms-cm. This is called 18 or 18.3 meg-ohm water. While a high resistivity is indicative of minimal ionic (electrically charged) contamination, it does not indicate the level of organic contamination. This can be monitored by measuring the surface tension of the water or spectrographic techniques. In spite of this, high resistivity water is critical. The following table is from O'Mara's book *(Liquid Crystal Flat Panel Displays, William C. O'Mara (Van Nostrand Reinhold, NY 1993))* and shows the effect of water resistivity on the number of particles on a 4x4 inch substrate.

Resistivity meg-ohm-cm	Initial particle count	Post rinse particle count
7.5	7	10
1	2	5
0.15	5	328
0.01	14	6356

Observe that a resistivity of at least 1 meg-ohm-cm is necessary.

Process Chemical Contamination

A fairly large number of chemicals are used in the production of LCDs. The list includes acids, photoresist, alignment layer materials and solvents to name a few. Since each may be a source of contamination this may be a serious problem. The major contaminants in these are metallics—atoms of metals that exist as ions (electrically charged entities), particulates, and unwanted chemicals. This last class of contaminants is new to this discussion and includes chemicals that are not desired. They may cause non-uniformities in the complete displays and reduce yield. To minimize the effects of this type of contamination requires a change in thinking. For example, a chemical may be 99.9% pure. This is certainly very pure, but it means there is 0.1% something else, and what we don't know may hurt the yield. You should train yourself to think of the 0.1% first and the 99.9% second. Since chemicals and vapors from these chemicals can easily mix this is not just a management issue. **Everyone must work to minimize contamination of the process chemicals and contamination of the LCDs by these same chemicals.**

Since this issue goes beyond the cleanroom we will briefly summarize how to keep chemicals clean. First and foremost, start with pure particulate free chemicals. These are expensive. The isopropyl alcohol that costs less than $1 a pint at the drug store costs over $50 a gallon when purified to the levels needed for LCD manufacturing. The container that the material is shipped in is clean, if the material is poured into another container make certain that the inside of the secondary container is clean, and has minimal particulate contamination. Some of the chemicals that are used are sufficiently strong, that they may dissolve the materials that constitute some containers. Therefore, use containers that do not dissolve in the solvent. Paper can be a source of particulates, for this reason use particulate free labels. These four considerations are most important to those who buy and dispense chemicals. The next two are critical to all personnel. One should always be careful to not add particles during transport, pouring into new containers and the like. All personnel that use chemicals should also be careful not to cross-contaminate or accidentally mix different chemicals.

Process Gases

Gases such as compressed nitrogen or air are used to blow particulates off substrates and equipment. The gas used and the quality of the gas may be important. Why might the gas used be critical? Suppose a chemical reacts with oxygen (from air) in an oven. If this is undesired, then nitrogen or argon would be a better choice as a gas. What are the quality issues? The primary issue is purity. Generally, there are small amounts of gases besides the major constituent in all gases (no gas is 100% pure). These trace gases may react with the chemicals that are used to manufacture the LCD. Among these trace contaminants in gases water vapor and particulates are particularly insidious. They will be discussed in the next paragraph. However, water vapor content is important since some operations, chemicals, or contaminants may interact with water to produce unwanted structures or chemicals. Particulates from gas are as bad as particulates from liquids. They must be minimized to the greatest extent possible. A fourth contaminant to gas may be metallic ions. These contaminants are minimized by using high quality gases. It is common to have gas purities between 99.99% and 99.999999%. The purity of the gas is expressed by the number of 9's to the right of the decimal point. Thus, 99.99% pure is called two 9's pure.

Water vapor and particulates are both potential contaminants in gas. As mentioned above, water vapor can react with other molecules to produce unwanted contaminants. This is made worse because water droplets may contain various ions (electrically charged atoms or molecules) that will remain behind after the water has evaporated. These ions can cause shorts in the electrical pattern or poor response due the extra conductivity they add to the liquid crystal. Particulates in a gas have the same effect as in liquids. However, a wild spray of gas may stir up significantly more particles than spilled liquid. Gases are often filtered through 0.2 micron filters to reduce the particulates.

Equipment

A whole range of contaminants have been mentioned. It seems that almost everything that goes into a cleanroom adds contamination. This is essentially true. In fact, even the equipment can be a source of contamination. They are especially good sources of particulate contamination. A major source is dried processing chemicals. These may be knocked loose and become floating particulates. Equipment may also have nooks and crannies for dust to hide and later dislodge itself. In this respect loading stations are particularly bad since many parts are being moved around and this can both generate and stir up particulates. A further contaminating aspect of the equipment is that it often applies a static electric charge to components. The components then act like sweaters in a dryer and attract dust particles in the same way that a sweater attracts socks and other clothes. For this reason it is not uncommon for certain pieces of equipment to have static reduction equipment attached.

Summary: Where do we go from here?

After this discussion you know what contaminants are particularly critical to LCD manufacturing: particulates and chemicals. You are aware of how contamination can reduce yield, and how LCD manufactures try to reduce/minimize contamination by using special chemicals and fabricating LCDs in cleanrooms. From the point of view of being a minimally contaminating employee you must now learn two things before you enter the cleanroom. These are how to dress for the cleanroom, and the rules of how to work in the cleanroom. Once this is understood, you can proceed to learn how LCDs are fabricated and where a given step that you may be working on fits into the total picture. As we move forward it is important for you to realize that the cleanroom rules were not arbitrarily devised and to obtain high yield you must follow the rules.

Cleanroom Basics

Overview

This very important section discusses the basics of cleanrooms. Four topics will be covered. First, a cleanroom will be described in greater detail than the cursory view of the last section. Included in this description will be a discussion of how the elements of a cleanroom contribute to minimizing contamination. Then, the most critical part of the discussion will be presented: how to work in a cleanroom. This sub-section will include the basic rules of working in cleanrooms, a discussion of restricted materials, and the cardinal rule of all cleanrooms. There are particular ways to dress and behave that must be followed in order to minimize personnel caused contamination. This will be the third topic discussed. The discussion will conclude with a section on "housekeeping," the all important part of keeping a cleanroom clean.

Objectives

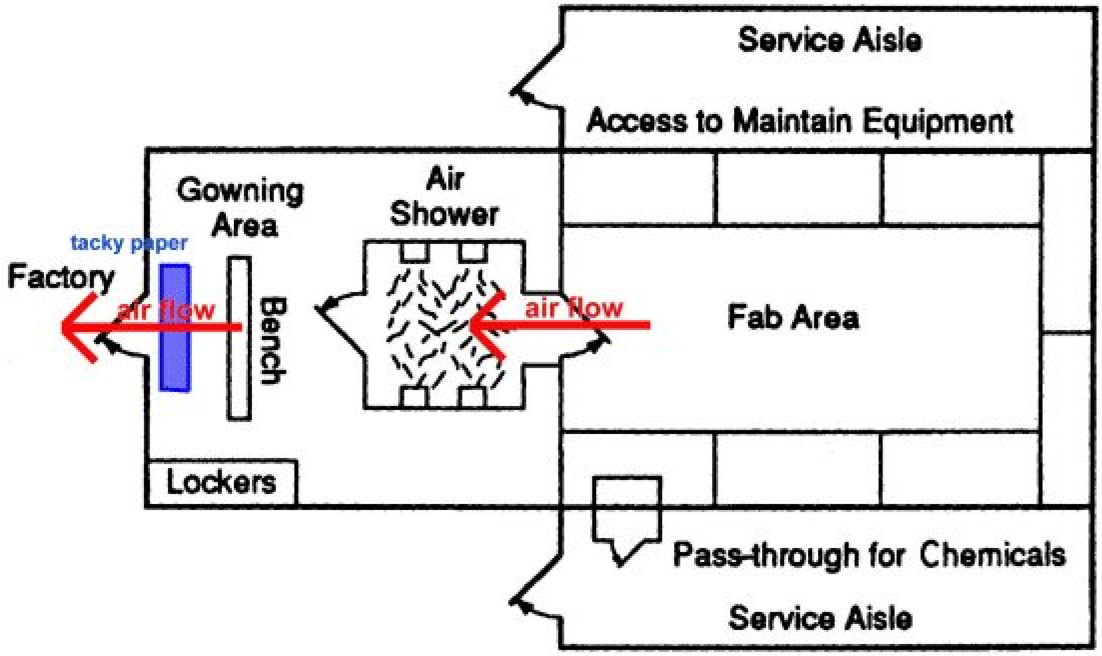
Upon completion of this section, you should be able to:

1. Explain the parts of a cleanroom that minimize contamination.
2. Know and explain the rationale for the cardinal rule of cleanrooms.
3. List and rationalize the garmenting procedure for a class 10,000 to class 100 fabrication facilities.
4. Explain how to clean a cleanroom table.
5. Understand and explain why a cleanroom is only as clean as its dirtiest worker.

What is a cleanroom?

A cleanroom is a <u>controlled</u> environment in which all incoming air, water, and chemicals are filtered and purified to meet high standards of purity and freedom from particulates. The cleanroom environment is also characterized by control of temperature, humidity and air pressure. This rather fragile environment can easily be contaminated. For this reason great care is taken to keep a cleanroom from becoming contaminated.

The following figure shows a "typical" cleanroom floor pattern.



Fab area with gowning area, air showers, and service aisles.

There are a number of features of this floor pattern that show elements of the clean environment that contribute to reducing contamination in the **"Fab Area".** The fab area, which is short for Fabrication Area is where the critical processes of the fabrication or manufacturing process take place. First, notice that one does not directly enter the fabrication area from the factory floor. Instead all people enter the cleanroom through the **Gowning Area**. In fact, a closer inspection of the figure shows that even this is not the whole story. Upon entering the gowning area all people are required to walk over, and walk in place on a **tacky mat**. This is a disposable tacky material that removes particles from the bottom of all entering person's shoes. The idea is to minimize the contamination coming in on people's shoes. This is often further reduced by having people wear either special cleanroom shoes or shoe covers after they have walked on the tacky mat. This helps insure that the gowning area is cleaner than the factory, although not as clean as the fab area. Benches and mirrors are provided so that personnel may change into cleanroom garments and make certain that they have put the garments on correctly. This room is setup so that minimal contamination of the cleanroom garments occurs in this room.

The next part depends on the actual facility; however, it is not uncommon to have an **air shower**. This is a room with two doors connected by an interlock. This way the doors to the gowning area and the fab area can not be open at the same time, and it is difficult for contamination to move directly through from the gowning area to the fab area. This arrangement is called a double-door pass-through. In the air shower, upon entering the room from the gowning side a sensor turns on streams of air that knock off many of the larger particles that are on the outside of cleanroom garments. You should note that air showers are not 100% effective in removing external particulates from garments. Some LCD facilities do not have air showers, and individuals move directly (possibly through a double-door arrangement) from the gowning area to the fab area.

Contamination in the fab area is further reduced by other features of the cleanroom. Typically the air pressure in such a facility is not constant. The air pressure is often higher in the fab area than in then gowning area which in turn is higher than the balance of the factory. This leads to air flow in the direction of the red arrows in the figure. This means that there is a natural air flow out of the fab area. This helps contribute to minimal contamination; for a particle to move from the factory to the fab area it must move "up-hill." However, high air pressure is not the answer to all problems, and there are cases were lower pressure may be desirable. Two other features are critical to the contamination reduction ability of a cleanroom. First, note near the bottom middle there is a **"pass-through for chemicals."** This is a double door pass-through for getting small items, chemicals, and the like into the cleanroom without them going through the gowning area. The other items to note are the **"service aisles."** These are areas that are cleaner than the factory that allow access to the equipment for maintenance and the like without entering the fab area proper.

Of course, the above steps are not sufficient to keep contamination at a minimum. **The whole manufacturing process, from beginning to end, must be run in a manner that minimizes contamination.** For this reason a number of other elements are optimized to minimize overall contamination. For example, the process equipment and materials can supply contamination. For this reason, companies use equipment and materials that have a <u>low enough</u> level of chemical and particulate contamination. The operators, must also be careful to avoid cross contamination, where by one item is contaminated by another, such as fingerprint on a substrate. Another key to minimizing contamination is to optimize processes so that the minimal amount of material is needed and the by-products of processes are minimal. However, it is still critical that the housekeeping rules and cleanroom procedures be followed. There is little room for a free spirit in a cleanroom. This helps ensure that contamination is cleaned and not continually transferred from one place to another. The final element is almost obvious but is often forgotten, and this is **keeping dirty processes outside of the cleanroom**.

The basics of working in a cleanroom

A thorough understanding and commitment to following the rules of this sub-section is critical to you being a minimally contaminating employee and hence contributing to high product yield. We will begin by asking six sets of questions. These questions will be answered and the rationale behind them explained in subsequent paragraphs.

- What may be taken into a cleanroom?
- What am I allowed to wear under a cleanroom garment?
- How does one gown? Why is it done in a particular way? Why does this matter?
- Are there special rules for working in a cleanroom? If so, what are these rules?
- How do you clean a cleanroom?
- How do you clean up a mistake in a cleanroom?

Cleanroom Restricted Materials (What may be taken into a cleanroom?)

There are a large number of items that should not be taken into a cleanroom. The company you work for may be more or less strict regarding the guidelines discussed here. When in doubt **always err on the side of being too strict. That is, if you don't know if an item is allowed, assume that the item may <u>not</u> enter the cleanroom.** In fact, the first and foremost or cardinal rule of all cleanrooms is:

The Cardinal Rule:

Never bring anything into a cleanroom unless it absolutely needs to be there.

There are a number of materials and personal items that are restricted for <u>all</u> classes. The following list includes the most **commonly restricted items. These are not allowed in all classes of cleanrooms.**

- No jewelry. This includes watches, pins, rings, piercings and other jewelry. A plain wedding ring under a glove may be acceptable in some fabrication plants.
- No cosmetics.
- No food or drink.
- No lit cigarettes, pipes, etc. (smokers may not re-enter cleanroom for 30 minutes)
- No cardboard. foam, standard (non-cleanroom) paper or unsealed wood.
- No external (topical) medications.
- No aerosol products.
- Wearing an incorrectly fitted cleanroom garment is not allowed.
- Things that disturb air flow (fans, audio speakers)
- Cell phones

Why is this list so long and inclusive? First, the items on this list were not included because management wants employees to be unhappy, constrained or "controlled." All items on this list are included because they are sources of contamination and hence reduce yields and can lead to device failure. Second, the items on this list have continuously been evaluated for their contamination producing abilities and have always been found to be contaminating — this is a tried and true list.

Consider the first item, no jewelry. Jewelry is not allowed because it has been found to be a source of particulate contamination. In particular, the fine details, and small pores in jewelry are great places for skin flakes, dust and bacteria to hide. Some jewelry has sharp edges and protrusions; these may (accidentally) cut through gloves or garments allowing contamination contained by the garment or gloves to then contaminate the cleanroom. Some facilities allow jewelry to be put into an inside shirt pocket, others provide lockers, and yet others want you to simply leave the jewelry at home. For this reason know your company's policy.

One woman once jokingly suggested that the no cosmetics rule existed because management (or management's wives!) wanted ugly employees. The reason behind this rule is not that sinister. Cosmetics contain small particulates and metal compounds. These particles are of the correct size (.1 to 20 microns) to substantially reduce yields of LCDs. Furthermore, they are on people's faces which often puts the source of contamination too close to the products being made. When cosmetics slough off people they also have the potential of carrying off bacteria and skin flakes. The particles that are in the cosmetic can also affect quality and reliability. Cosmetics commonly contain significant amounts of, iron, aluminum, titanium, magnesium, potassium, sulfur and carbon all of which may cause a problem.

Anyone who has worked in a cleanroom for more than a few minutes knows that in spite of efforts to keep them comfortable, one often becomes thirsty and ready for a snack after an hour or two. One could easily argue that providing snacks and drinks in the cleanroom would improve employee moral and productivity. The reasons why food and drink are not allowed must be rather strong to outweigh these arguments. In fact, they are. First, the food and beverage must be taken into the clean environment. This will without a doubt bring in contamination. Even if "clean" cans of soda and bags of cookies could be brought in the items themselves would contaminate. Consider all the crumbs that would result from eating almost anything, and ask yourself how can they be eliminated? Carbonated drinks contribute aerosols to the air. In summary, there is no way to keep food or beverages from contaminating the cleanroom.

Lit cigarettes, pipes, cigars and the like are prohibited from cleanrooms because the smoke is an obvious source of contamination. In fact, even several minutes after smoking a cigarette, a smoker's breath contains many times the number of particles of a non-smoker. While personal behavior during off work hours can not be controlled by the company, some companies may have non-smokers rules for certain processes.

The reason for no cardboard, foam, standard paper and unsealed wood are all the same. First, they contain small cavities that are wonderful holding stations for small particles, viruses and bacteria that may leave the cavity at anytime. Furthermore by their very nature these materials are sources of particles even in the absence of external particles attaching to them. Lastly, these are most often manufactured or processed in a non-clean environment, meaning that even if the above problems did not exist, they would still be a potentially significant source of contamination.

The rationale for no external (exposed) topical medications is two-fold. First, suppose that the medication was not applied. Then the person would have an open cut, sore, or other partially healed external injury. These injuries are potential sources of bacteria, various human cells, and scabs that may fall off and contaminate the environment. Clearly, this situation is not consistent with minimal contamination. Now suppose the medication is applied. Then, the above problems no longer exist, but now, the medication can contribute contamination in place of the open wound.

In the section "Why Cleanrooms" the potential problems associated with aerosols was discussed. Briefly, recall that aerosols are of the correct size to present problems to LCD manufacturing and may contain chemicals that are especially harmful to displays. Naturally occurring aerosols, such as human breath, are difficult to avoid. However, it is important to avoid adding man-made aerosols to the clean environment. For this reason, aerosol spray products should not be used in the cleanroom. Furthermore, those activities that require using aerosols, such as solvent application of spacers, should be done in a hood or other isolated environment within the cleanroom.

Lastly, one should wear properly fitting cleanroom garments. Too small of a garment is a problem because it has the potential to rip (often when least expected) and hence expose the cleanroom to the contamination that is normally within the suit. The rationale for not wearing too large of a suit is more subtle. A suit which is too large will tend to billow in and out as a person moves. In the process of moving, gaps may appear near the various openings. These gaps, in conjunction with the air movement inside the garment can create a "particle smokestack" that will pour out and spread contamination everywhere the person goes in the cleanroom.

Some materials are allowed in only certain classes of cleanrooms. This list of restricted materials is somewhat smaller than the above list.
The following are **not** allowed in cleanrooms between class 1 and class 10,000:

- **No writing instruments except special ball point pens (many LCD cleanrooms also allow markers such as "Sharpies").**
- **No paper except cleanroom paper.**

The following are **not** allowed in cleanrooms between class 1 and class 1000:

- **No <u>uncovered</u> outside clothing is allowed in the cleanroom.**
- **Some types of clothes such as wool sweaters, cotton garments and high collars (such as turtle necks) may not be allowed.**

What is one allowed to wear under a cleanroom garment?

The clothing that is worn under a cleanroom garment is to some extent dependent on the employer. Some companies have operators wear special garments under the cleanroom garments, while others allow normal street clothes. Still others let people wear "normal clothes" but only of a particular type such as nylon. The policy is dependent on the level of the cleanroom. However, it is important for the employee to realize that some types of clothing may not be acceptable because they tend to be contaminating. Anyone who has cleaned the lint trap on a dryer is aware that certain clothes produce more lint (particles) than others. It is for this reason that cotton, wool or other materials may not be allowed. It is important to follow your company's policy in this area. Furthermore, there should be **no exceptions allowed**. (Automobile industry, spray paint booth example, BWall)

How do I gown?

By now you realize that people are a source of contamination in cleanrooms. Furthermore, you are aware that the purpose of cleanroom garments is to protect the product that is being manufactured from the contamination produced by operators. However, this needs to be repeated:

All people who enter a cleanroom are sources of contamination.
The purpose of the cleanroom garments is to protect the facility and process items from contamination produced by the employee and employee's clothes.

With this in mind we begin by asking, "What are the two major sources of contamination from people?" The answer is your feet (look at a floor connecting to the outdoors during the winter) and your head (those flaky dandruff shampoo commercials). For this reason, from the start of the gowning process contamination of clean areas by dirty areas is minimized.

Shoes are a major source of contamination. One cleanroom company claims that 80% of the contamination that enters a cleanroom comes in on feet and wheels. While they sell tacky mats and have an interest in this number being high, this is still worth noting; minimize the incoming contamination that comes in on people's feet. This is usually done, in several ways. First, facility users must cover their street shoes with plastic shoe covers prior to entering the facility. Secondly, there are adhesive, sticky mats at the entrance to the gowning area. This helps remove particles from the bottoms of shoes covers. The operator may also put on special "cleanroom shoes" that are only worn in the cleanroom to help reduce the influx of contamination into the facility.

As noted above, our heads are another source of contamination. The next step after covering ones feet is to then cover one's head. In fact, as a *general rule*, cover your shoes with shoe covers and then gown from the top down. Generally, our eyes and faces are a major source of fluid particles, particulates and bacteria. Furthermore, some of the solvents that are used in LCD manufacturing are potentially dangerous. For this reason, **goggles or safety glasses with side shields are required** in cleanrooms. These eye covers solve both the safety problem and the contamination problem in one step.

The following paragraphs list standard procedures for gowning for different class cleanrooms. In all cases we are assuming that the cleanroom is not sterile. More importantly, **your company may have some variations from these rules**.

Gowning for class 100,000 cleanrooms

The following items are put on in the order listed. In all cases it is assumed that shoe covers, gloves and safety glasses are being worn.

- Hair cover
- Smock

Gowning for class 10,000 cleanrooms

The following items are put on in the order listed. It is assumed that shoe covers, gloves and safety glasses are being worn.

- Hair cover
- Face mask
- Smock

Gowning for class 100/1000 cleanrooms

The following items are put on in the order listed. It is assumed that shoe covers and safety glasses are being worn.

- Hairnet
- Gowning gloves (These are gloves that are placed on prior to gowning, and reduce the contamination that is added to the cleanroom garment while gowning. Some LCD fabrication plants do not use these.)
- Hood
- Face mask
- Coverall/gown
- Boots
- Production Gloves

Notice that in the above lists we have been very specific about the order in which items are put on. Is this just to give you something else to worry about? No, the orders shown were picked for very specific reasons. First, remember that the goal of the process is have a person in the cleanroom who is minimally contaminating. Thus in short, we want to minimize contamination. We start at those places that can potentially cause the most contamination, and cover them up so that they can not contaminate later steps in the process. To present an everyday analogy, when you wash a car or a dirty floor you usually start at the cleaner parts (the roof of the car, away from the entrance to the room) and work towards the dirtier parts. You do this because you don't want to take the dirty water (say from the tires and hubcaps) and use it to "clean" the windows or roof.

Note: Throughout the gowning procedure, care should be taken to not let the garments touch the floor and to not let your hands touch the floor or the bottoms of your shoes and garment boots.

What order do you take cleanroom garments off? Take them off in the exact opposite order that you put them on. Don’t let garments touch the floor while degowning. Hang everything up on cleanroom hangers for use next time.

Special rules for working in a cleanroom (Restricted activities)

Since the major goal of this section is to describe the techniques needed to work as a minimally contaminating employee, you might guess that there are some activities that are forbidden because they cause too much contamination. This subsection will follow the same format as the earlier subsection on restricted materials. We will begin with a list, and then explain why these activities are restricted. **Many of these restricted activities are not very natural. In fact, we commonly perform these restricted activities. You must develop the habit of not engaging in these very natural, everyday activities while in the cleanroom. Furthermore, you must also help remind/inform your coworkers to minimize their activities also.**

- No fast motions
- No sitting or leaning on equipment
- No writing on equipment or cleanroom garments (Asymtek, VPI)
- No removing items from under cleanroom garments (cell phones, keys)
- No wearing of cleanroom garments outside the cleanroom and adjacent gowning area
- No wearing of soiled or torn garments
- No touching or scratching of exposed hair or skin
- No coughing or sneezing over work areas
- Don't wear contaminated gloves (gloves should be changed outside the main facility, except under emergency situations)

Fast motions are not allowed in a cleanroom. This can be difficult, all projects are behind schedule, everything is needed yesterday, and if you needed something later you would not be going to get it now. The rationale for this restriction comes from studies of how people disturb the air flow in a cleanroom. When movements (walking, moving arms, etc.) are slow enough the air flow in the cleanroom is only minimally disturbed, and the flow quickly returns to its pre-agitated state. When rapid movements are executed turbulence is produced. This can cause large scale motions of particles and can take a long time to relax back to the non-turbulent state. The turbulence that is produced by rapid motion generally include vortices that sweep up particles and then deposit them on surfaces, often the substrates that are being worked on. The best advice that can be given in this area is to just move along slowly and calmly, and perform all operations as if it were the hottest summer day. The work must be completed, but rushing can produce more problems than it solves.

While in a cleanroom you should not sit or lean on equipment. This too is very unnatural. How often do we place a hand on a table and lean on it, or how often do we lean against a wall or a kitchen countertop. In informal settings it is not uncommon for people to sit on desks or tables. Thus, for most of us this is a standard mode of behavior which must be suppressed. Furthermore, it is not uncommon for operators to spend hours in the cleanroom and really want to take a load off of ones feet. Once more, the rationale for this rule is to minimize contamination. By leaning or sitting on equipment you can easily remove contamination such as settled particles from the equipment as well as your cleanroom garment. Furthermore, you might catch part of your garment on a protuberance and rip the garment leading to more widespread contamination. Lastly, such behavior might upset the alignment of some of the equipment and lead to further problems. Cleanroom stools are present for sitting, but care must be taken when using them. Do not spin on these chairs or zoom across the floor, both activities which would result in severe air disturbance in the room. Also, the stool seats are slippery to cleanroom garments. Care must be taken when sitting down to avoid having the stools slip out from under you, causing you to land on the floor.

Writing on equipment or garments is prohibited for a number of reasons. However, once more this can be difficult to avoid. Suppose a piece of equipment has just been adjusted, and the numbers or procedure needs to written down. The time taken to go get a cleanroom notebook, or paper may seem to be too excessive because the numbers are only needed for that piece of equipment. Why not have them where you need them? Suppose a supervisor tells you to remember to get or do something later. You don't want to forget so why not write it on a glove or a garment sleeve where you can not forget? All of these rationalizations for not following the rules seem reasonable; however, they ignore the potential contamination that can occur by writing on equipment or garments. This rule exists because the writing on equipment may not stay and it may well then become so much particle contamination. Furthermore, the writing may rub contamination off the equipment, but provide nothing to pick it up. Similarly writing on garments or gloves generally will produce some contamination, remove some contamination, and worst of all possibly tear or rip these important contaminant reducing clothes.

How often do you reach into a pocket to remove something; for instance a billfold from a back pocket? During the winter, or when wearing a raincoat, it is common to reach inside one garment to get something out of another. This is so common we usually don't think of it in the terms just described. Now suppose you want to do the same thing while in a cleanroom wearing a cleanroom garment. You must undo the garment, get what you want, and then redo the garment. While doing all of this, what happens? Contamination from your clothes and the inside of your garment gets spread all over. Then what ever was under the garment, which has not been in a clean environment will add its own contamination to the mix. The only acceptable place to open a cleanroom garment and get something from under it is in the gowning area. Furthermore, objects should be removed only at the correct step of gowning or degowning. To open a cleanroom garment while in a cleanroom is the same as not dressing for the cleanroom at all.

One should not wear a coverall/gown outside the cleanroom or gowning area. Once more, this is not natural. How often do we run outside without a coat, because it will only be for a few moments? It takes time to put on and take off the cleanroom apparel, and I will only be outside for 5 seconds. Why can't I run out and run in? The rationale for this rule goes back to why we dress for the cleanroom in the first place. Recall that we dress in the special cleanroom apparel to protect the product we are making from us. This is the exact reverse of why we wear clothes, shoes and coats, which is to protect ourselves from external elements. Once a cleanroom garment has been worn outside a cleanroom (or the adjacent gowning area) it has become contaminated. To bring it back into the cleanroom is to bring that contamination into the cleanroom, and to some extent contaminate the cleanroom. This violates the reason for the cleanroom in the first place.

The rule to not wear soiled or torn garments follows from the cardinal rule to not bring anything into a cleanroom that is not absolutely necessary. A soiled garment brings in the materials on the garment. These can easily contaminate the cleanroom environment. Similarly, a torn garment fails to protect the products from the employee so it is useless. In this area it is important to remember that people rarely put torn garments on except by accident. If you notice a coworker wearing a torn garment (usually in back where it can not be seen) you should tell them about the tear immediately, or if a part of the garment is being worn improperly..

The rule to not touch or scratch exposed hair or skin seems obvious enough. However, in practice it is not so easy. It is very common to push ones hair over while talking, wipe ones brow, or scratch an arm during everyday activities. Recently, someone observed that the best way to get an itchy nose is to put a face mask on. So once more you are being asked to avoid performing a common, everyday activity. The rationale behind this rule is that scratching exposed skin, hair, or even a cleanroom garment puts a large number of contaminants into the air. When hair and skin are scratched, bacteria, skin flakes and other particulate matter are removed from ones skin and randomly put into the air. Furthermore, how do you slowly scratch? Scratching through a cleanroom garment may dislodge particles and other contaminants that may be on the outside of the suit.

The no coughing or sneezing over work areas is obvious once it is mentioned, but many people do not think about it until it is mentioned. Sneezing or coughing puts particles and aerosols into the air. These can easily contaminate a work piece. Obviously, you are not expected to not sneeze or cough; however, you should **turn away from the work area when you sneeze, cough, or talk to another person**. The talking rule is mentioned here for the same reason. Even exhaling or working directly over a work piece should be avoided during critical operations, particularly wet coating steps.

Lastly, one should not continue to use contaminated gloves. Suppose one turns away from a workbench and sneezes into a glove. The aerosols and particles from the sneeze are now not only in the air, but also on your glove. At this point you are probably somewhat tempted to wipe your hand on the outside of your cleanroom garment. This is poor practice, and you know why. You could get a cleanroom wipe and wipe your hands. This is clearly significantly better than the first option. However, upon reflection, the best thing to do is to get a new glove (or pair of gloves). This will minimize further contamination of work pieces. When gloves become very contaminated with chemicals or other materials, they should also be thrown out and replaced with clean gloves. A pair of cleanroom gloves is substantially less expensive then producing many defective displays.

Activity Induced Contamination

Recall from the section entitled "Why Cleanrooms?" that activities increase the number of particles that are shed by people. This section on activities that are restricted in the cleanroom concludes with a brief summary of these points.

An operator sitting at a workstation after an air shower will give off between 100,000 and 1,000,000 particles per minute. Any activity will cause an increase above this background level. For example, a sneeze increases the particle load by 2000%. Stamping on the floor increases the load by 5000% (50 times!). Just walking will increase the particle load by 200% as will rubbing your hands on your face. The point here is that an operator is a contamination source, and you must work in such a way as to minimize the extra contamination that you generate.

Cleaning the cleanroom

How do I clean a cleanroom?

Cleaning a cleanroom is more difficult than cleaning, say, a dirty window. In large part this is because in many cases you are cleaning dirt that you can not see, and are not even certain you are removing the contamination via cleaning. Most readers of these notes will not clean cleanrooms professionally; nevertheless, you should know something about such cleaning. Like many other procedures associated with cleanrooms, the typical sequence for cleaning a cleanroom is not arbitrary, and has been chosen to reduce contamination and the spread of contamination. The sequence for filters in the ceiling is the following:

- ceiling
- walls and doors
- equipment
- floor, wheels and feet of equipment

You should observe that you are working from the top down, so contamination that is knocked off the higher areas will be removed at a later stage. Recall that when the HEPA filters for input air are on the ceiling, and return vents are on the floor, airflow in the facility is vertical and downward. Also observe that you are following the general rule of cleaning the dirtiest parts last. Clean walls, then equipment, then table tops, all down to waist high. Then clean everything below waist height, and do the floor last. Also make sure you clean wheels on equipment and don't walk on mopped floors.

The preferred method of cleaning is to first vacuum the surface with a cleanroom certified vacuum cleaner. Then mop the area. Then wipe the area, and lastly vacuum the area a second time. The wiping technique is not like cleaning a car or a floor. The following procedure is for strict particle control. Begin by folding the cleanroom wipe that will be used into eights. Then squirt some isopropyl alcohol onto the area to be cleaned. **Using a clean part of the wipe, clean by wiping in one direction one time only**; do not use a back and forth motion. After the first pass turn the wiper over or unfold it so that a clean (unused) part of the cleanroom wipe is used for the next pass over the alcohol covered surface. Wipe the surface in the same direction as the first wipe, making sure that the two wipes overlap. Repeat this until all sides of the cleanroom wipe have been used, and then start a new cleanroom wipe. For noncritical areas, wipes can be used less rigidly to clean equipment and surfaces. **Do not reuse wipers, wring them out like a sponge, or use a back and forth or circular motion to wipe down surfaces**.

During times of general facility cleaning, no processing work should be allowed as cleaning disturbs the cleanliness of the room severely. As part of the general cleaning process, after all the bulk cleaning has been done, a pressurized air line may be used to flush out hard to reach places on equipment and difficult surfaces such as utility shut off valve handles, etc. Then the room can be cleaned thoroughly from top to bottom. After many cycles of this practice, the nooks and crannies of the facility will be flushed out to the point where many places will cease being significant particle generators.

How do I clean up a mistake?

It is not uncommon to spill materials or make a mistake that results in a spill. One of the most common places for a significant, noncontained spill in our facility is during photoresist syringe loading and reloading. Many of the materials in the cleanroom can not be wiped with acetone, photoresist's solvent of choice. The best measure is to load syringes carefully and avoid spills. In the event of a photoresist spill, excess material should be wiped up right away in such a way as to not spread the resist material around. Acetone can not be used on the black borders of the flooring tiles.

The procedure for cleaning spills is straight forward. For liquid spills simply use the cleaning procedure described above to wipe up the spill. If there is broken glass, you must consider the situation. If a bottle of a liquid is dropped and becomes broken, the spill should be treated as a chemical spill. If there is no liquid, carefully pick up or vacuum up the broken pieces of glass.

Summary

This has been an important section that has far too many 'thou shalts' and 'thou shalt nots.' These rules are far too numerous and in some cases specific for a first time reader to remember all of them. However, the bottom line is clear. Every person who enters the cleanroom is a source of contamination. Movement and sloppy technique make this contamination even worse. Every person must modify their behavior so as to minimize contamination of the cleanroom. And lastly, the minimization of contamination within a cleanroom is **everyone's** responsibility. The following figure helps remind us of this communal responsibility as well as our individual contribution to creating the problem.

A cleanroom is only as clean as its dirtiest worker

However, this is not an impossible task as the following figure helps us recall.

But...there is hope for everyone!

Safety

Overview

This is a relatively short section that discusses two important issues that are related to safety. The first issue is simply a description of general rules of safety. The second topic is a brief description of Material Data Safety Sheets (MSDSs). These data sheets, supplied by chemical manufactures, detail safety issues and the properties of various chemicals. They will be illustrated by two examples.

Objectives

Upon completion of this section, you should be able to:

1. Explain the general rules of safety
2. Explain what is in a MSDS.
3. Explain why care is needed in interpreting an MSDS.

The general rules of safety (in a lab, production facility, cleanroom, etc.)

There are a number of safety rules that are true regardless of your job within the fabrication facility.
There may also be special safety rules for specific chemicals or procedures.
The following will be true regardless of what you work on.

- If you don't think something is safe, say so! Moreover, don't perform any activity that you believe may be dangerous or that you do not fully understand.
- Follow all rules and standard operating procedures.
- Wear goggles or safety glasses. (no contacts may be worn)
- Wear gloves. (two pair, one for gowning, one for pinhole protection)
- Wear hairnets or pull long hair back. (no jewelry)
- Don't wear loose clothing for jobs in which it might become stuck in machinery.
- Avoid contact with all chemicals.
- Don't smell chemicals.
- Label equipment that is in use with a tag indicating the time the equipment will become available to others, your name and any special precautions such as to leave any utilities on, door closed, lights off, etc.

Many of these rules seem to be common sense; nevertheless, failure to follow these rules can lead to both safety and health issues. The rationale for each of these rules will now be explained. The first rule is very important; while no (reasonable) company wants you to do something that is intrinsically dangerous, a lack of knowledge may cause you to perform a relatively safe activity in a dangerous way. If the way you want to do the job seems dangerous, make sure you are doing the job correctly. The second rule, "to follow the rules," is clearly self-referenced. Nevertheless, a correctly established rule and well thought out and tested standard operating procedures have safety as a prime concern. The rule to wear goggles or safety glasses is no different than the minimal contaminating rule from cleanroom basics. However, glasses can become uncomfortable, or fog. You might not be working in a low class number cleanroom or the like. The rationale for these items is to protect your eyes from chemicals and other foreign matter. The glove rule is similarly a repeat; in this case it is to protect your hands from chemicals, detergent and other materials. The hairnet/ponytail rule is also a carry over from how to dress for a cleanroom. In this case it is to keep your hair out of chemicals, and keep your hair from splashing chemicals about. There may be places in the facility where a cleanroom garment is not required. In these places you do not want to wear loose clothing that may get stuck in machinery. The last two rules are related and explicitly state that some of the chemicals used in manufacturing LCDs may be harmful your skin, or lungs. The harm caused by these materials may be no more serious than dry skin; however, this may not be the case, so the best policy is to minimize your contact with chemicals and chemical vapors.

Glass (broken or not) should be relatively clean if possible before discarding. Glass can only be discarded in appropriate glass/sharps containers. Nonglass items should not be placed in these containers, including wipers, bottle caps, plastic syringe bodies, syringe filters, etc. All vials and bottles that are not broken should be rinsed before discarding. Needles and razor blades should also be discarded in appropriate receptacles for this purpose. Glass, razors and needles should not be disposed of in regular trash.

Emergency response:

It is required that all personnel, student, faculty and staff, permanent or temporary, take a one-day, university-run safety program. In addition, our department runs a department-specific program once a year as well. And lastly, our cleanroom facility runs a facility-specific safety and training program for new users, and for equipment/process-specific operations periodically as the needs arise, but no less than once per academic year. No one is permitted to use the cleanroom facility unless they have passed the university safety course, and have taken and passed cleanroom training.

Cleanroom training for all processes and equipment use must be performed by cleanroom facility staff ONLY. Cleanroom users are not permitted to train other users.

If a hazardous chemical contact happens in the facility, even if one is suspected, react immediately. Once you have a potential personal health hazard, correcting the problem becomes top priority over all things. You do not need to stop timers, leave the facility, degown, stop running equipment, turn off utilities, etc. You need to fix the problem. If you have a chemical splashed into your eyes somehow, take off your safety glass, walk to the eye fountain and flush your eyes with water. Don't worry about the mess. Don't worry about anything but getting your eyes flushed out. If you experience a chemical breach in your gloves or cleanroom suit of a serious nature (strong corrosive, acid, base, skin absorbed toxic) take off your contaminated gloves, suit parts, clothes whatever has become contaminated and rinse your skin thoroughly. Do not worry about contaminating the room by taking off gloves, suit parts, etc. Protect yourself. The room will recover after proper cleaning. If you experience a chemical exposure of a less serious nature, it might be acceptable to leave the facility to correct. For example, getting a common solvent on your suit that you can feel (due to it feeling cold or wet) does not usually require immediate flushing, but should not go uncorrected either. Leave the facility, remove suit, gloves, etc., and make sure the solvent evaporates or change your clothes. It is impossible to design a firm policy for each incident since they vary in degree of potential risk, severity and area affected. But, never anything above personal safety. When in doubt, correct the problem and do not worry about the facility.

Lastly, an incident must be reported to the cleanroom facility managers after emergency measures have corrected the main problem, so that additional recommendations may be made to ensure complete correction of the exposure. Effective reporting is required by university policy to better serve the practical needs of the campus work force and to help tailor additional educational programs to the needs of specific facilities.

Material Safety Data Sheets (MSDSs)

An MSDS is a "sheet" (usually several pages long) that is specific to each material, and may vary slightly from manufacturer to manufacturer. This sheet details the properties, disposal, safety and health related issues of the material. This sheet also includes exposure limits, fire fighting information and references to literature on the various topics. There should be a MSDS on file for every chemical that is used in the fabrication of LCDs at you plant. Furthermore, you should be able to read or obtain copies of MSDSs for all materials that you use or are exposed to in your job. Having said that, **Don't get/study copies of MSDS unless needed.** The reason is that these sheets are part scientific and part legalistic. The company that issues the MSDS form has a vested interest in making certain that they never face litigation over the any aspect of the use of the material. Therefore, it is not uncommon for some to go overboard. This will be illustrated in the examples. (Steroid example)

Most of the chemicals used in LCD manufacturing can be used safely with minimal risk when used with the proper precautions. Some chemicals (HF, Ammonium bifluoride) always carry higher associated risk than other chemicals. Always know the necessary handling and exposure prevention measures of all the materials with which you will work. Also, there may be real health issues, even when all precautions are taken. This is because although precautions are taken, small levels of exposure will undoubtedly occur. If you can smell it, you have been exposed. Whether or not this is a problem depends on the chemical and the size of the exposure dose. Some people are more sensitive to lower exposure limits than others. For example, pregnant women (or women thinking of getting pregnant) should talk to their doctor about the chemicals they are using at work, and follow the doctor's advice. However, all employees should follow this general rule:

Never let any of the chemicals used in LCD fabrication come in contact with your skin, eyes or mouth.

Two examples of MSDSs will be presented. The first will be for sucrose, which is the same as normal table sugar, only more pure. The second example will be acetone, a chemical commonly used for substrate cleaning in LCD manufacturing. It is also commonly used in fingernail polish remover.

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MSDS Safety Information
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FSC: 6810
MSDS Date: 01/01/1999
MSDS Num: CJRPV
LIIN: 00N092415
Product ID: D(+)-SUCROSE ACS FOR MICROBIOLOGY, 84100
MFN: 01
Responsible Party
Cage: 63181

Review Ind: Y
Published: Y
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Contractor Summary
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Cage: 63181

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Ingredients
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Cas: 57-50-1
RTECS #: WN6500000
Name: SUCROSE. LD50:(ORAL,RAT) 29,700 MG/KG.
LD 50 means lethal dose for 50% of a test group of rats is 29.7 grams per 1000 grams of body weight. This would correspond to about three pound for a 100 pound person. Almost all of us would stop well before eating that much.
Percent by Wt: 100.
OSHA PEL: 15 MG/M3
ACGIH TLV: 10 MG/M3
ACGIH STEL: NOT ESTABLISHED
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Health Hazards Data
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LD50 LC50 Mixture: SEE INGREDIENT ∓mp; TOXICOLOGICAL INFO.
Route Of Entry Inds - Inhalation: YES
Skin: YES
Ingestion: YES

These three lines mean that it can get into your
body via inhalation (breathing of sucrose dust) ingestion (eating)
and that such dust can irritate your skin and if it gets in your
eye will bother your sight.

Carcinogenicity Inds - NTP: NO
IARC: NO
OSHA: NO

These three lines mean three governmental organizations
tested and found it does not cause cancer.

Effects of Exposure: ACUTE: MAY BE HARMFUL BY INHALATION, INGESTION OR SKIN ABSORPTION. MAY CAUSE EYE IRRITATION. MAY CAUSE SKIN IRRITATION. MATERIAL MAY BE IRRITATING TO MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT.

Signs And Symptoms Of Overexposure: SEE HEALTH HAZARDS.

First Aid: EYES: IMMEDIATELY FLUSH WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES. SKIN: IMMEDIATELY WASH WITH SOAP AND COPIOUS AMOUNTS OF WATER. WASH CONTAMINATED CLOTHING BEFORE REUSE. INHALATION: REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. INGESTION: WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS. CALL MD.

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Handling and Disposal

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Spill Release Procedures: WEAR PROTECTIVE EQUIPMENT. SWEEP UP, PLACE IN A BAG AND HOLD FOR WASTE DISPOSAL. VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

Waste Disposal Methods: DISSOLVE IN WATER. DILUTE TO 5% SOLN. CHECK PH ADJUST IT TO 7 IF NEC.***(necessary)*** POUR SOLN DOWN DRAIN W/RUNNING WATER CONTINUE TO FLUSH DRAIN SYS FOR 10 MINS, PROVIDED THAT RULES AT YOUR PLACE OF EMPLOYMENT/LOC, STATE & FED GUIDELINES ALLOW YOU TO DO SO. IF YOU ARE UNABLE TO FLUSH SOLN DOWN DRAIN/IN DOUBT ABOUT SUITABILITY OF METH USE A (SUPP DATA)

This is clearly over done. We routinely use sugar and don't
worry about all of this. This is why a chemist or someone familiar with
the chemical should always discuss the sheets with non-experts.

Handling And Storage Precautions: DO NOT BREATHE DUST. DO NOT GET IN EYES, ON SKIN, ON CLOTHING. KEEP TIGHTLY CLOSED. STORE IN A COOL, DRY PLACE.

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Fire and Explosion Hazard Information

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Extinguishing Media: WATER SPRAY, CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.

Fire Fighting Procedures: USE NIOSH APPROVED SCBA AND FULL PROTECTIVE EQUIPMENT (FP N).

Unusual Fire/Explosion Hazard: EMITS TOXIC FUMES UNDER FIRE CONDITIONS.

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Control Measures

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Respiratory Protection: NIOSH APPROVED RESPIRATOR IN NON-VENTILATED AREAS AND/OR FOR EXPOSURE ABOVE THE ACGIH TLV.

Ventilation: MECHANICAL EXHAUST REQUIRED.

Protective Gloves: COMPATIBLE CHEMICAL-RESISTANT GLOVES.

Eye Protection: ANSI APPROVED CHEMICAL WORKERS GOGGLES (FP N).

Other Protective Equipment: ANSI APPROVED EYE WASH & DELUGE SHOWER (FP N).

Work Hygienic Practices: WASH THOROUGHLY AFTER HANDLING.

Supplemental Safety and Health: MANUFACTURER'S INFORMATION ON INGREDIENTS: MF: $C_{12}H_{22}O_{11}$. EC NO: 200-334-9. -- WASTE DISP METH: LICENSED WASTE DISPOSAL COMPANY. OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

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Physical/Chemical Properties

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Melt/Freeze Pt: =185.C, 365.F

Appearance and Odor: WHITE POWDER.

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Reactivity Data

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Stability Indicator: YES
Stability Condition To Avoid: HEAT.
Materials To Avoid: STRONG OXIDIZING AGENTS.
Hazardous Decomposition Products: TOXIC FUMES OF: CARBON MONOXIDE, CARBON DIOXIDE.
Hazardous Polymerization Indicator: NO
Conditions To Avoid Polymerization: WILL NOT OCCUR.
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Toxicological Information
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Toxicological Information: TO THE BEST OF MFR'S KNOWLEDGE, THE CHEMICAL, PHYSICAL AND TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED. TOXICITY DATA: LD50:(ORAL,RAT) 29,700 MG/KG - TXAPA9 7,609,1965. LD50:(IPR, MUS) 14,000 MG/KG - PCJOAU 15,139,1981. ONLY SELECTED REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES (RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR COMPLETE INFORMATION.
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Ecological Information
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Ecological: DATA NOT YET AVAILABLE.
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MSDS Transport Information
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Transport Information: CONTACT INFORMATION.
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Regulatory Information
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Federal Regulatory Information: REVIEWS, STDS ∓mp; REGS: OEL=MAK. ACGIH TLV - NOT CLASSIFIABLE AS HUMAN CARCIN; TWA 10 MG/M3 - DTLVS* TLV/BEI,1997. MSHA STD:NUISANCE PARTICULATES - DTLWS* 3,28,1973. OSHA PEL (GEN INDUS): 8H TWA 15 MG/M3, TOTAL DUST; 8H TWA 5 MG/M3, RESPIRABL E DUST - CFRGBR 29,1910.1000,1994. OSHA PEL (CONSTRUC): 8H TWA 15 MG/M3, TOTAL DUST; 8H TWA 5 MG/M3, RESPIRABLE DUST - CFRGBR 29,1926.55,1994. OSHA PEL (SHIPYARD): 8H TWA 15 MG/M3 TOTAL DUST; 8H TWA 5 MG/M3 RESPIRABLE DUST - CFRGBR 29,1915. 1000,1993. OSHA PEL (FED CONT): 8H TWA 15 MG/M3 TOTAL DUST; 8H TWA 5 MG/M3 RESPIRABLE DUST - CFRGBR 41,50-204.50, 1994. OEL-AUSTRALIA, BELGIUM, (OTHER INFO)
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Other Information
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Other Information: FEDERAL REGULATORY: FRANCE, UNITED KINGDOM: TWA 10 MG/M3 JAN 1993. OEL IN BULGARIA, COLOMBIA, JORDAN, KOREA, NEW ZEALAND, SINGAPORE, VIETNAM - CHECK ACGIH TLV. NIOSH REL TO SUCROSE: RESPIRABLE FRACTION-AIR: 10H TWA 5 MG/M3; TOTAL DUST-AIR: 10H TWA 10 MG/M3 - NIOSH* DHHS #92-100,1992. NOHS 1974: HZD 81515; NIS 101; TNF 12044; NOS 86; TNE 121005. NOES 1993: HZD 81515; NIS 108; TNF 15179; NOS 110; TNE 368912; TFE 169962: EPA GENETOX PROGRAM 1988, INCONCLUSIVE: MAMMALIAN MICRONU CLEUS. EPA TSCA SECTION 8(B) CHEMICAL INVENTORY. EPA TSCA SECTION 8(D) UNPUBLISHED HLTH/SAFETY STUDIES. EPA TSCA TEST SUBMISSION (TSCATS) DATA BASE, JUNE 1998.
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HAZCOM Label
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Product ID: D(+)-SUCROSE ACS FOR MICROBIOLOGY, 84100
Cage: 63181

Label Required IND: Y
Date Of Label Review: 11/03/1999
Status Code: A
Origination Code: F
Eye Protection IND: YES

Skin Protection IND: YES
Signal Word: WARNING
Respiratory Protection IND: YES
Health Hazard: Moderate
Contact Hazard: Slight
Fire Hazard: Slight
Reactivity Hazard: None
Hazard And Precautions: ACUTE: MAY BE HARMFUL BY INHALATION, INGESTION OR SKIN ABSORPTION. MAY CAUSE EYE IRRITATION. MAY CAUSE SKIN IRRITATION. MATERIAL MAY BE IRRITATING TO MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT. CHRONIC: NONE LISTED BY MANUFACTURER.
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-- **ACETONE** ACS REAGENT, A4206

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MSDS Safety Information

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FSC: 6810
MSDS Date: 07/01/1999
MSDS Num: CJTSF
LIIN: 00N092611
Product ID: ACETONE ACS REAGENT, A4206
MFN: 01
Responsible Party
Cage: 21076

Review Ind: Y
Published: Y

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Contractor Summary

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Cage: 21076

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Ingredients

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Cas: 67-64-1
RTECS #: AL3150000
Name: ACETONE LD50: (ORAL, RAT) 5800 MG/KG
This is substantially lower than sucrose. From the practical point of view you would not want to even taste acetone.
Percent by Wt: 100.
OSHA PEL: 2400 MG/M3;1000 PPM
ACGIH TLV: 1780 MG/M3;750 PPM
ACGIH STEL: 2380 MG/M3;1000 PPM
The previous three lines are exposure limits. They indicate that the maximum amount in rats about 1000 parts per million (ppm).
EPA Rpt Qty: 5000 LBS
DOT Rpt Qty: 5000 LBS

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Health Hazards Data

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Route Of Entry Inds - Inhalation: YES
Skin: YES
Ingestion: YES
Carcinogenicity Inds - NTP: NO
IARC: NO
OSHA: NO

Effects of Exposure: ACUTE EFFECTS: MAY BE HARMFUL BY INHALATION, INGESTION, OR SKIN ABSORPTION. CAUSES SEVERE EYE IRRITATION. CAUSES SKIN IRRITATION. MATERIAL IS IRRITATING TO MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT. CAUSES DERMATITIS. TARGET ORGANS: LIVER, KIDNEYS. SEE ALSO TOXICOLOGICAL INFORMATION.

Dermatitis ***is dry skin and can easily occur by splashing acetone onto ones hands. A small amount on a finger will leave a white residue due to the oils it has removed from your skin.***

Signs And Symptoms Of Overexposure: SEE HEALTH HAZARDS.
First Aid: EYES: IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES. ASSURE ADEQUATE FLUSHING OF THE EYES BY SEPARATING THE EYELIDS WITH FINGERS. SKIN: FLUSH SKIN WITH WATER. INHALATION: IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. INGESTION: IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS. CALL A PHYSICIAN. REMOVE AND WASH CONTAMINATED CLOTHING PROMPTLY.

Unlike sucrose this is serious. Acetone vapors can suffocate a person.

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Handling and Disposal

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Spill Release Procedures: EVACUATE AREA. SHUT OFF ALL SOURCES OF IGNITION. WEAR NIOSH APPROVED SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES. COVER WITH AN ACTIVATED CARBON ABSORBENT, TAKE UP AND PLACE IN CLOSED CONTAINERS. TRANSPORT OUTDO ORS. VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE. WASTE #U002.

This is very serious and must be followed! Acetone is highly flammable as well.

Waste Disposal Methods: BURN IN A CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER BUT EXERT EXTRA CARE IN IGNITING AS THIS MATERIAL IS HIGHLY FLAMMABLE. OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS. RCRA WASTE NUMBER: U002.

Handling And Storage Precautions: KEEP TIGHTLY CLOSED. KEEP AWAY FROM HEAT, SPARKS AND OPEN FLAME. STORE IN A COOL, DRY PLACE.

Other Precautions: DO NOT BREATHE VAPOR. DO NOT GET IN EYES, ON SKIN, ONCLOTHING. AVOID PROLONGED OR REPEATED EXPOSURE. WASH THOROUGHLY AFTERHANDLING. SEVERE EYE IRRITANT.

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Fire and Explosion Hazard Information

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Flash Point: =-17.2C, 1.F

Autoignition Temp: =465.C, 869.F

Lower Limits: 2%

Upper Limits: 13%

Extinguishing Media: CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM. WATER MAY BE EFFECTIVE FOR COOLING, BUT MAY NOT EFFECT EXTINGUISHMENT.

Fire Fighting Procedures: USE NIOSH APPROVED SCBA AND FULL PROTECTIVE EQUIPMENT (FP N) TO PREVENT CONTACT WITH SKIN AND EYES.

Unusual Fire/Explosion Hazard: EXTREMELY FLAMMABLE. VAPOR MAY TRAVEL CONSIDERABLE DISTANCE TO SOURCE OF IGNITION AND FLASH BACK.

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Control Measures

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Respiratory Protection: NIOSH APPROVED RESPIRATOR.

Ventilation: MECHANICAL EXHAUST REQUIRED.

Protective Gloves: COMPATIBLE CHEMICAL-RESISTANT GLOVES.

Eye Protection: ANSI APPROVED CHEMICAL WORKERS GOGGLES (FP N).

Other Protective Equipment: EYE WASH AND DELUGE SHOWER MEETING ANSI DESIGN CRITERIA (FP N). FACESHIELD (8-INCH MINIMUM).

Supplemental Safety and Health: STATE REG INFO: EPA TSCA TEST SUBMISSION (TSCATS) DATA BASE, DECEMBER 1998. NIOSH ANALYTICAL METH, 1994: KETONES I, 1300. NIOSH ANALYTICAL METH, 1996: VOC, 2549, NTP TOXICITY STUDIES, RPT# TOX-03, NOVEMBER 1998. OSHA ANALYTICAL METHOD #ID-6 9.

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Physical/Chemical Properties

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Boiling Point: =56.C, 132.8F

Melt/Freeze Pt: =-94.C, -137.2F

Vapor Pres: 184 MM 20C;400 MM 39.5C

Vapor Density: 2

Spec Gravity: 0.791

Appearance and Odor: COLORLESS LIQUID.

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Reactivity Data

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Materials To Avoid: BASES, OXIDIZING AGENTS, REDUCING AGENTS.

Hazardous Decomposition Products: TOXIC FUMES OF: CARBON MONOXIDE, CARBON DIOXIDE.

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Toxicological Information
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Toxicological Information: RTECS #: AL3150000 ACETONE. IRRITATION DATA: EYE-HMN 500 PPM JIHTAB 25,282,1943. SKN-RBT 395 MG OPEN MLD UCDS 5/7/1970. SKN-RBT 500 MG/24H MLD 85JCAE -,280,1986. EYE-RBT 20 MG SEV AJOPAA 29,1363,1946. EYE-RBT 20 MG/24H MOD 85JCAE -,280,198 6. TOXICITY DATA: UNR-MAN LD50: 1159 MG/KG 85DCAI 2,73,1970. ORL-RAT LD50: 5800 MG/KG JTEHD6 15,609,1985. IHL-RAT LC50: 50100 MG/M3/8H AIHAAP 20,364,1959. IVN-RAT LD50: 5500 MG/KG NPIRI 1,1,1974. ORL-MUS LD50: 3 GM/KG PCJOAU 14,162,1980. I HL-MUS LC50: 44 GM/M3/4H CUTOEX 1,47,1993. IPR-MUS LD50: 1297 MG/KG SCCUR -,1,1961. ORL-RBT LD50: 5340 MG/KG FAONAU 48A,86,1970. (OTHER INFO)
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Ecological Information
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Ecological: DATA NOT YET AVAIL. OTHER INFO: CONTRACTION OR SPASTICITY). LUNGS, THORAX OR RESPIRATION (RESP DEPRES; OTHER CHANGES). KIDNEY, URETER, BLADDER (RENAL FUNCT TESTS DEPRESSED). EFTS ON FERTILITY (POST-IMPLANTATION MORTALITY). ONLY SELECTED REG ISTRY OF TOXIC EFTS OF CHEM SUSBTANCES (RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR COMPLETE INFO. FED REG INFO: (GEN INDU): 8H TWA 1000 PPM (2400 MG/M3) CFRGBR 29,1910.1000,1994. OSHA PEL (CONSTRUC): 8H TWA 1000 PPM (2400 MG/M3) CFRGBR 29,1926.55,1994. OSHA PEL (SHIPYARD): 8H TWA 1000 PPM (2400 MG/M3) CFRGBR 29,1915.1000,1993. OSHA PEL (FED CONT): 8H TWA (TRANSPORT INFO)
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MSDS Transport Information
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Transport Information:
ECOLOGICAL INFO: 1000 PPM (2400 MG/M3) CFRGBR 41,50-204.50,1994.
OEL-AUSTRALIA:TWA 500 PPM (1185 MG/M3); STEL 1000 PPM JAN 1993.
OEL-AUSTRIA:TWA 750 PPM (1780 MG/M3) JAN 1993. OEL-BELGIUM:TW A 750 PPM (1780 MG/M3); STEL 1000 PPM JAN 1993.OEL-DENMARK:TWA 250 PPM (600 MG/M3) JAN 1993.
OEL-FINLAND: TWA 500 PPM (1200 MG/M3); STEL 625 PPM (1500 MG/M3) JAN 1993.
OEL-FRANCE:TWA 750 PPM (1800 MG/M3) JAN 1993. OEL-GERMANY:TWA 1000 PPM (2400 MG/M3) JAN 1993. OEL-HUNGARY:TWA 600 MG/M3; STEL 1200 MG/M3 JAN 1993.
OEL-INDIA:TWA 750 PPM (1780 MG/M3); STEL 1000 PPM (2375 MG/M3) (SARA REG INFO)
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Regulatory Information
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Sara Title III Information: N/P. TRANSPORT INFO: JAN 1993. OEL-JAPAN:TWA 200 PPM (470 MG/M3) JAN 1993. OEL-NETHERLANDS:TWA 750 PPM (1780 MG/M3) JAN 1993. OEL-PHILIPPINES:TWA 1000 PPM (2400 MG/M3) JAN 1993. OEL-POLAND:TWA 200 MG/M3 JAN 1993. OEL-RUSSIA:TWA 200 PPM; STE L 200 MG/M3 JAN 1993. OEL-SWEDEN:TWA 250 PPM (600 MG/M3); STEL 500 PPM (1200 MG/M3) JAN 1993. OEL-SWITZERLAND:TWA 750 PPM (1780 MG/M3) JAN 1993. OEL-TURKET:TWA 1000 PPM (2400 MG/M3) JAN 1993. OEL-UNITED KINGDOM:TWA 1000 PPM (2400 MG/M3); ST EL 1250 PPM JAN 1993. OEL IN BULGARIA, COLOMBIA, JORDAN, KOREA CHECK ACGIH TLV. OEL IN NEW ZEALAND, SINGAPORE, VIETNAM CHECK ACGIH TLV. (STATE REG INFO)
Federal Regulatory Information: EUROPEAN INFO: EC INDEX NO: 606-001-00-8. HIGHLY FLAM. IRRITANT. R 11 HIGHLY FLAM. S 9 KEEP CNTNR IN WELL-VENTD PLACE. S 16 KEEP AWAY FROM SOURCES OF IGNIT - NO SMKNG. S 23 DO NOT BREATHE VAP. S 33 TAKE PRECAUTIONARY MEASURES AGAINST STATIC DISCHARGES. REVIEWS, STDDS ∓ REGS: OEL=MAK. ACGIH TLV-NOT CLASSIFIABLE AS HUMAN CARCIN DTLVS TLV/BEI,1997. ACGIH TLV-STEL 1782 MG/M3 (750 PPM) DTLVS TLV/BEI, 1997. ACGIH TLV-TWA 1188 MG/M3 (500 PPM) DTLVS TLV/BEI,1977. EPA FIFRA 1988 PESTI CIDE SUBJECT TO REGISTRATION OR RE-REGISTRATION FEREAC 54,7740,1989. MSHA STANDARD-AIR:TWA 1000 PPM (2400 MG/M3) DTLVS 3,3,1971. OSHA PEL (ECOLOGICAL INFO)
State Regulatory Information: N/P. SARA REG INFO: NIOSH REL TO ACETONE-AIR: 10H TWA 250 PPM. NIOSH DHHS #92-100,1992. NOHS 1974: HZD 02820; NIS 350; TNF 99713; NOS 188; TNE 1287794. NOES 1983: HZD 02820; NIS 358; TNF 97342; NOS

215; TNE 1740164; TFE 540313. EPA GENETOX PROGRAM 1988, NEG: SHE-CLONAL ASSAY; CELL TRANSFORM-MOUSE EMBRYO. EPA GENETOX PROGRAM 1988, NEG: CELL TRANSFORM-RLV F344 RAT EMBRYO. EPA GENETOX PROGRAM 1988, NEG: IN VITRO CYTOGENETICS-NONHUMAN. EPA GENETOX PROGRAM 1988, NEG: HISTIDINE RE VERSION-AMES TEST; IN VITRO SCE-NONHUMAN. EPA TSCA SECTION 8(B) CHEM INVENTORY. EPA TSCA SECTION 8(D) UNPUB HLTH/SFTY STUDIES ON EPA IRIS DATABASE. (SUPDAT)

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Other Information

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Other Information: LABEL PRECAUTIONARY STATEMENTS: FLAM (USE). HIGHLY FLAM (EU). IRRITANT. IRRIT TO RESP SYS ∓ SKIN. RISK OF SERIOUS DMG TO EYES. TARGET ORGANS: LIVER, KIDNEYS. KEEP AWAY FROM SOURCES OF IGNIT - NO SMKNG. KEEP CNTNR TIGHTLY CLSD IN COOL, WELL -VENTD PLACE. IN CASE OF CNTCT W/EYES, RINSE IMMED W/PLENTY OF WATER ∓ SEEK MED ADVICE. WEAR SUITABLE PROT CLTHG. TOXICOLOGICAL INFO: SKN-GPG LD50: >9400 UL/KG TXAPA9 7,559,1965. TARGET ORGAN DATA: BRAIN ∓ COVERINGS (RECORDINGS FROM SPECIF IC AREAS OF CNS). SENSE ORGANS ∓ SPECIAL SENSES (OTHER OLFACTION EFTS; CONJ IRRIT). BEHAVIORAL (GEN ANESTH; MUSCLE WEAK; MUSCLE (ECOLOGICAL INFO)

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HAZCOM Label

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Product ID: ACETONE ACS REAGENT, A4206
Cage: 21076

Label Required IND: Y
Date Of Label Review: 10/28/1999
Status Code: A
Origination Code: F
Eye Protection IND: YES
Skin Protection IND: YES
Signal Word: DANGER
Respiratory Protection IND: YES
Health Hazard: Moderate
Contact Hazard: Moderate
Fire Hazard: Severe
Reactivity Hazard: None
Hazard And Precautions: FLAMMABLE. ACUTE EFFECTS: MAY BE HARMFUL BY INHALATION, INGESTION, OR SKIN ABSORPTION. CAUSES SEVERE EYE IRRITATION. CAUSES SKIN IRRITATION. MATERIAL IS IRRITATING TO MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT. CAUSES DERMATITIS. TARGET O RGANS: LIVER, KIDNEYS. CHRONIC: NONE LISTED BY MANUFACTURER.

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The following discussion of dermatitis was sent out by Lab Safety April, 2001.

CONTACT DERMATITIS: THE INDUSTRIAL WORKERS' DILEMMA

Skin takes a beating in industrial workplaces. It is knocked, scrapped and jabbed. It comes into contact with all kinds of harsh substances--- chemicals, heavy grease, oils, dirt and bacteria. The everyday activities of an industrial worker can compromise the skin's system of renewal and protection, leaving the body vulnerable to infections and diseases. Inflammation that occurs when an irritating substance comes into contact with the skin is known as contact dermatitis. How serious a problem is contact dermatitis in the workplace? The National Institute for Occupational Safety and Health (NIOSH) believes that occupational skin diseases have been severely under-reported in the past and that the rate of new cases may be much higher than documented. NIOSH invested approximately three million dollars in contact dermatitis research during year 2000. Contact dermatitis is one of the most common skin problems afflicting workers in industrial facilities. There are no formal government standards or guidelines relating specifically to skin protection in industrial settings, but NIOSH research indicates practices which employers and workers can follow to help prevent contact dermatitis. Here are some recommended measures:

- Identify irritants and allergens in the workplace.
- Whenever possible, find substitute chemicals/materials that are less irritating or allergenic.
- Use effective engineering controls to eliminate or reduce contact with harmful substances.
- Use appropriate personal protective equipment, such as gloves and protective clothing.
- Emphasize personal and occupational hygiene.
- Educate employees to increase their awareness of irritants and allergens in the workplace.
- Provide a system for monitoring, evaluating and reporting dermatological diseases.

Keeping skin healthy is important for both employers and employees. Workers want to stay safe and healthy, and employers want their workers on the job, not at home with an illness or injury. Dry, damaged, itchy or irritated skin is an all too common sight in many workplaces, and isn't just unsightly; it can lead to accidents and infections. Employers can promote productivity by motivating their employees to increase the frequency and effectiveness of skin care, and by teaching proper hand washing techniques and providing skin care products that are effective and pleasant to use.

For more information on contact dermatitis, visit the NIOSH Web site.
(http://www.cdc.gov)
(http://www.cdc.gov/search.do?action=search&queryText=contact+dermatitis&x=11&y=6)

Summary

What does this all mean? A significant lesson is that the MSDSs may not be too useful to a non-chemist. Having said that, MSDSs do indicate that **the chemicals used in LCD manufacturing may be hazardous if used incorrectly or in the wrong environment**. For instance, acetone should be used in a fume hood or an area where the fumes are caught so that the fumes do not spread and fill the whole facility. Another significant point is that these chemicals can get into your body through a number of different pathways, including the mouth (ingestion), the lungs (inhalation), and the skin. In the cleanroom environment, the skin pathway is extremely difficult because of the cleanroom garments, the mouth pathway is similarly constrained by facemasks, or hoods. However, special care should be taken to avoid breathing the vapors of the chemicals used in the cleanroom. Many of these solvents are irritating to the eyes. Fortunately, safety glasses or goggles, which are required in the cleanroom, minimize this potential hazard. **This does not mean that you can be sloppy! The best routes to safety are care, diligence, and well constructed standard operating procedures.** While it might seem trite, safety is no accident; it must be part of the manner in which a facility is run.

From the point of view of an employee, the best safety advice is still:

Never breath the vapors of any of the chemicals used in LCD fabrication and don't let them come in contact with your skin, eyes, or mouth, and,

When in doubt, stop, ask, or get out..