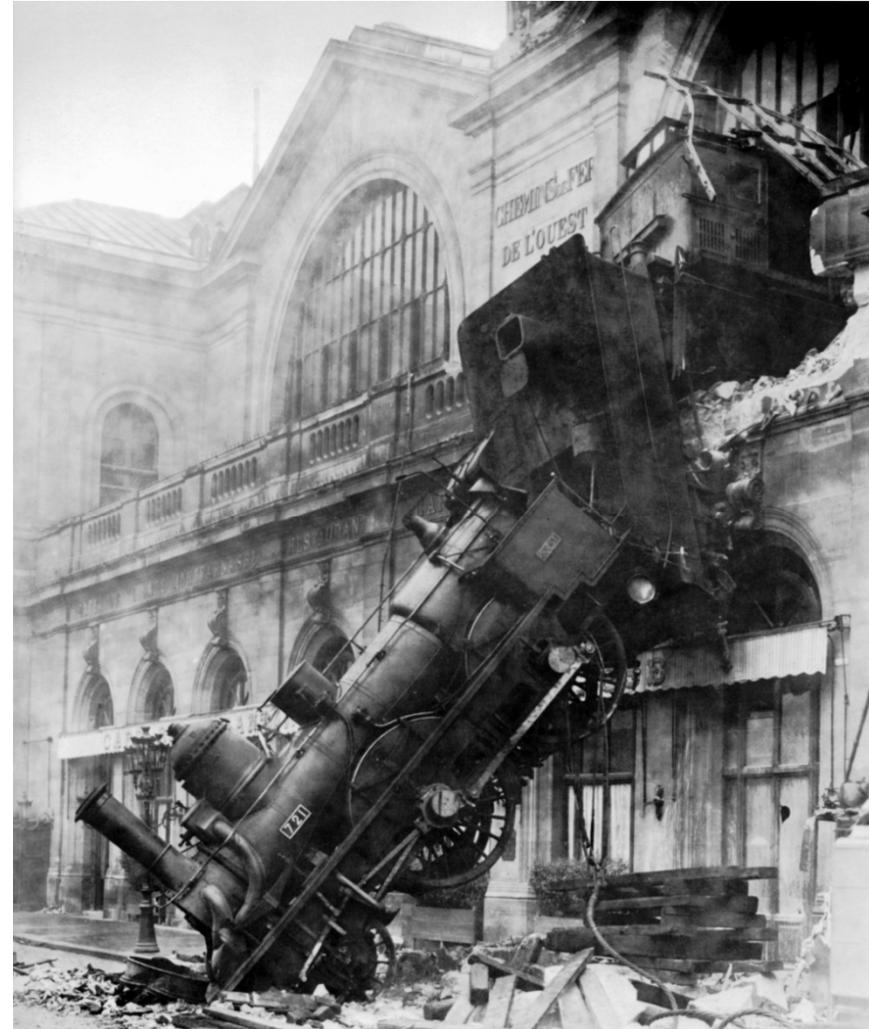


M_001 Mechanical Engineering General Safety Lecture



The Gare Montparnasse became famous for a derailment on 22 October 1895 of the Granville-Paris Express that overran the buffer stop. The engine careened across almost 30 meters (98 ft) of the station concourse, crashed through a 60-centimetre (24 in) thick wall, shot across a terrace and sailed out of the station, plummeting onto the Place de Rennes 10 meters (33 ft) below, where it stood on its nose. All on board the train survived, five sustaining injuries: two passengers, the fireman and two crewmembers; however, one woman on the street below was killed by falling masonry. The accident was caused by a faulty Westinghouse brake and the engine driver who was trying to make up for lost time. At the time of the accident the brakeman was doing paperwork.

Milton J. Shoup III
Mechanical Safety Officer
University of Rochester
Laboratory for Laser Energetics



Analysis of this accident clearly demonstrated that “people” were the primary cause of the accident



- **Establishing a timeline of the accident clearly demonstrates the contributing factors**
 - **Engineer driving too fast to make-up time (procedural violation)**
 - **Westinghouse brake fails**
 - **Back-up handbrake needs to be engaged, brakeman not at his station to actuate the brake (procedural violation caused failure to actuate safety system)**
 - **Buffer stop fails, train travelling too fast (procedural violation caused failure of secondary safety system)**

People cause accidents when they are hurrying, not following procedure, or not paying attention to their job. In short, “People are the primary cause of accidents.”

Summary

Safety is everyone's business and compliance with safety procedures is **MANDATORY**



- If an activity or practice seems unsafe, “Stop Work” and take the time to address concerns
- Situational Awareness – The best way to prevent an accident is to be aware of your surroundings
- All mechanical equipment modifications must be coordinated through Mechanical Engineering
- All gas systems must be inspected and approved by ME prior to first use
- Vacuum systems $> 0.4\text{m}^3$ must be inspected and approved by ME prior to first use
- Mechanical joints (including fasteners) may NOT be modified without the review and permission of Mechanical Engineering
- Only perform activities for which you are qualified
- Only use items for their intended purpose

Additional training is required for the activities and equipment listed below



- **Compressed gas safety (M_002)**
 - handling of any cryogenic liquids or working with any gas systems in excess of 150 psi
- **Overhead hoists (M_003)**
 - for the use of any overhead hoist
- **Overhead Rigging (M_004 and M_005)**
 - **Basic Rigging (M_004)** preparing loads from 120 to 500 lbs
 - **Advanced Rigging (M_005)** preparing any load in excess of 500 lbs
- **Fall Protection Equipment (M_006)**
- **Aerial work platforms (M_008)** for the use of any scissors or mast lift
- **Overhead crane operation (M_009)**
 - for the use of any overhead cranes

Numerous mechanical hazards exist in our work environment



- **General Mechanical Hazards include;**
 - **Tripping**
 - **Falling objects**
 - **Cutting/abrasion**
 - **Pinch points**
 - **Elevated work surfaces**
 - **Bump hazards**
 - **Noise**
 - **Slipping**
 - **and many more...**

Situational Awareness – The best way to prevent an accident is to be aware of your surroundings

Personal Protective Equipment (PPE) is provided by LLE and it's usage is mandatory when required



- There are areas within LLE that require the usage of PPE. Most of these areas have signs indicating the type of required PPE.
- Types of PPE relative to mechanical hazards include
 - Protective eyewear (laser glasses, safety glasses, goggles, etc.)
 - Hardhats
 - Protective footwear (i.e. steel toed shoes)
 - Face shields (must be used with safety eyewear)
 - Gloves
 - Ear plugs or earmuffs

Review PPE requirements with the work area supervisor if you are unsure what the requirements are.

Contact a Safety Officer to conduct a job hazard analysis and help select PPE for new or altered activities and processes.

Maintenance (cleaning) and care of PPE is the responsibility of the employee



- **Keep PPE clean and in good working order**
- **Check the PPE before each use**
- **Wear the PPE correctly**
- **PPE that is provided in a work area that is damaged or is not functional must be taken out of service by returning it to the work area supervisor who will dispose of it, have it repaired, or replace it**
- **PPE that is provided in specific areas or for specific tasks must NOT be removed from that area**
 - **For example: do not “upgrade” your laser safety glasses from another lab, the wavelengths may not be compatible**

When and where is protective eyewear required?



- From the OSHA Code of Federal Regulations (CFR), the two following sections govern the requirements for eye and face protection

1910.133(a)(1) The employer shall ensure that each affected employee uses appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation.

1910.133(a)(2) The employer shall ensure that each affected employee uses eye protection that provides side protection when there is a hazard from flying objects.

All protective eyewear used at LLE must have fixed side protection.

Users must wear protective eyewear in all locations where required by signs and in all locations where the hazards cited in OSHA paragraph 1910.133(a)(1) are present.

When and where protective footwear required?



- From the OSHA Code of Federal Regulations (CFR), the following section governs the requirements for protective footwear.

1910.136(a) General requirements. The employer shall ensure that each affected employee uses protective footwear when working in areas where there is a danger of foot injuries due to falling or rolling objects, or objects piercing the sole, and where such employee's feet are exposed to electrical hazards.

- All supervisors must complete G_008 LLE Safety footwear policy

Appropriate protective footwear must be worn at LLE by anyone moving items greater than 50 lbs; Electricians, machinists, mechanics, riggers, shipping and receiving personnel. Supervisors make final determination of need.

When and where are hardhats required?



- From the OSHA Code of Federal Regulations (CFR), the following section governs the requirements for hardhats

1910.135(a)(1) The employer shall ensure that each affected employee wears a protective helmet when working in areas where there is a potential for injury to the head from falling objects.

In general, hard hats must be worn anyplace another worker can be working directly overhead or required by signage.

Mechanical Engineering (ME) is responsible for ensuring the safety of mechanical equipment and its use



- **ME is responsible for**
 - **Performing analyses to confirm design integrity**
 - **Maintaining accurate CAD models**
 - **Insuring code compliance with agencies that have jurisdiction over LLE**
 - **University of Rochester (EHS)**
 - **New York State – DOL**
 - **Federal Agencies – OSHA, NIOSH ...**
 - **Standards Organizations – ASME, AWS, CGA, NFPA ...**

All equipment modifications must be coordinated through Mechanical Engineering

All equipment must be used properly and inspected prior to each use by the operator



- All commercial equipment must be used in accordance with manufacturers recommendations
 - Read the instructions or manual
- All LLE designed custom equipment must be used per the original intent
 - If users do not understand what custom equipment is intended to be used for they must contact ME for clarification
 - Failure to use custom equipment properly puts the user and the equipment at risk
- Verify that equipment is in good working order prior to using it

Improperly used equipment puts the user and the equipment at risk. If you are unsure contact the manufacturer or Mechanical Engineering

Stored energy is a common metric for evaluating the risk level associated with equipment and systems



- **Common stored energy sources within the laboratory include;**
 - **Gravity acting on any elevated mass**
 - **Springs**
 - **Compressed gases**
 - **Vacuum vessels**
 - **Pressure vessels**
 - **Motors/actuators (any rotating machinery)**
 - **Thermal sources**
 - **Heat**
 - **Cryogen**

The uncontrolled release of stored energy can cause personal injury and collateral damage to nearby equipment

Pressurized gas systems at LLE are classified into three categories



- All gas system sources are classified as either Low (<150 psi), High pressure (>150 psi), or Flammable
- ✓ Low pressure systems that use “house” air or nitrogen and commercial air compressors designed for <150 psi and when used in accordance with manufacturer's recommendations require only ME Safety Training
- High pressure gas systems consist of either bottled gas sources or commercial equipment capable of developing >150psi
- Flammable gas systems require extra safety measures and will be evaluated on a case-by-case basis by the LLE safety officers and the gas products supplier
- All bottled gas systems must have operating procedures and be operated by personnel who have completed compressed gas training

All gas systems must be inspected and approved by ME prior to first use.

All operators of high pressure, flammable gas, or bottled gas systems must have compressed gas system training.

Compressed air/nitrogen safety



- **Compressed air used for cleaning shall be limited to a maximum pressure of 30 psig with appropriate chip protection and PPE**
- **Do not use compressed air to clean clothing; the air jet tends to drive particles into the fabric, where they can cause skin irritation. Keep a clothes brush handy or, preferably, wear a lab coat**
- **Be sure no one is in the path of the air stream when using compressed air to dry mechanical parts. Always wear goggles to protect your eyes.**
- **Never apply air pressure to the body**
- **Unless an automatic shut-off coupling is used, attach a short chain (or equivalent) between a hose and an air-operated tool to prevent whipping in the event the coupling separates**
- **Unless an automatic shut-off coupling is used, vent the pressure in an air line before changing the nozzles or fittings**
- **Do not substitute compressed oxygen for air. Clothing saturated with oxygen burns explosively**

Vacuum systems can contain extremely large amounts of stored energy



- **All vacuum systems that have a potential stored energy in excess of 75,000 lbf-ft (101 kJ) must have a detailed engineering safety analysis performed by ME**
 - **75,000 lbf-ft (101 kJ) corresponds to a volume of 14.3 ft³ (0.4 m³)**
- **Potential energy of vacuum equipment in the OMEGA and EP systems**
 - **Target Chamber = 943k lbf-ft (1.27 MJ)**
 - **Grating Compressor Chamber = 57.7M lbf-ft (77.7 MJ)**
- **The load on vacuum ports scales with the area (radius squared)**
 - **4” and 24” diameter ports have 184 lbf and 6650 lbf respectively**

All vacuum systems with a volume greater than 0.4 m³ must be analyzed, inspected and approved by ME prior to operation

A safely-designed mechanical joint can be made unsafe by altering the joint configuration or operating conditions



- **Mechanical joints are created by joining multiple components by various methods;**
 - **Fasteners (nuts, bolts, rivets, etc.)**
 - **Adhesives**
 - **Welding**
 - **Brazing**
 - **Soldering**
 - **Crimping**
- **Proper joint design requires an understanding of the materials involved and all loads acting upon the joint. Alteration of the joint or a change in operating conditions can compromise the safety of the joint.**

No mechanical joints may be modified without the review and permission of Mechanical Engineering

Not all fasteners are created equal



- **Fasteners come in various sizes, materials (SST, steel, plastic, etc), grades (load ratings) and coatings (cadmium, zinc, silver, black oxide, galvanized, etc.)**
- **The permutations and combinations of materials, grades, and coatings available for fasteners is enormous**
 - **all silver bolts do not have the same strength, for example: aluminum vs. stainless steel**
- **The proper fastener selection for an application is essential to safety**
- **If there is uncertainty about fasteners, ask for help**

No fasteners may be substituted or altered without the review and approval of ME

In a bolted joint, the preload of the fastener is crucial to its mechanical performance (stiffness/strength)



- Determining the proper torque for a fastener is dependent upon the material, grade, coating, and lubrication
- Bolted joints that are critical to personnel safety usually have the torque specified on the assembly drawing
- Fasteners that are to be removed and reused should be torqued to 75% of their yield strength
- Fasteners that are to be installed once are torqued to 90% of their yield strength. A fastener torqued to this level must be thrown away if it is removed.
- Do NOT over-torque bolts because they can be damaged (distorted)
- Ask for help if you are unsure

Fasteners must be properly torqued (preloaded)

Materials must be selected based on their suitability for a particular environment and application



- **Selection criteria include mechanical, electrical, thermal, optical, and chemical properties, as well as vacuum compatibility and outgassing characteristics.**
- **Selection criteria differ depending on intended use (vacuum or clean room use, exposure to laser light, etc.)**
- **Surface finishes such as plating, anodizing, and painting are also subject to application dependencies (vacuum or clean room use, exposure to laser light, etc.)**

All materials used in the OMEGA and OMEGA EP clean room spaces and vacuum systems are subject to the approval of ME

Mechanical Engineering maintains a list of materials evaluated for use in vacuum or cleanroom applications where low outgassing is required



- **Materials or manufacturing processes that have not been previously approved can be put through a qualification process**

- **Qualification procedures exist and make use of**
 - **Mass spectrometry techniques for atmosphere and vacuum applications**
 - **Vacuum bake-out using an RGA (Residual Gas Analyzer) for subassemblies, full size components, circuit boards, cable assemblies, etc.**
 - **Sample processing through certified LLE cleaning processes and NVR (Non Volatile Residue) testing**

- **The materials database can be accessed through the ME website**
 - **<http://engineering.lle.rochester.edu/materials.php>**

Within LLE there is often a need to move sizeable pieces of equipment or materials



- Rigging/Material Handling is accomplished using jib, gantry, bridge cranes, and other specially designed equipment using overhead hoists



- Overhead bridge cranes in the OMEGA facilities can lift up to 10 tons
- Personnel must be trained and become qualified in the use of overhead bridge cranes before being permitted to lift any loads

Personnel must stay clear of overhead crane operations

There are two specific roles in moving materials overhead, hoist operators and riggers

- ***hoist operator:*** an employee who generally uses an overhead hoist as a tool to assist in the performance of their regular job
- ***rigger:*** At LLE a rigger is responsible for safely attaching payloads to the load hook of a hoist.



Moving material or equipment overhead is to be performed only by qualified personnel

For hoist operators and riggers there are multiple classes of qualification



- There are 2 classes of training for Hoist operators
 - Hoist operator (M_003) – for overhead vertical lifting with unpowered horizontal motion
 - Overhead Crane operator (M_009) – for overhead vertical lifting with powered horizontal motion
- There are 3 classes of training for riggers
 -  No training is required for payloads <120 lbs
 - Basic rigger (M_004) – for personnel attaching any loads from 120-500 lbs to any hoist
 - Advanced rigger (M_005) – for personnel attaching any load >500 lbs to any hoist

Rigging equipment must be inspected prior to each use to ensure that it is safe

The manual lifting of materials within LLE



- **The National Institute for Occupational Safety and Health (NIOSH) provides the guidelines for the manual movement of materials**
 - **The NIOSH maximum suggested lifting weight limit is 51 lbs under ideal conditions**
 - **The recommended weight limit is generally less, as determined by an equation that factors in:**
 - **vertical and horizontal motion, distance, frequency of lift, asymmetry of body position, and the control under which the weight is to be positioned**

When manually moving materials, use common sense. If it feels heavy or is marginally controllable, stop and get help

Precautions must be taken when working on ladders

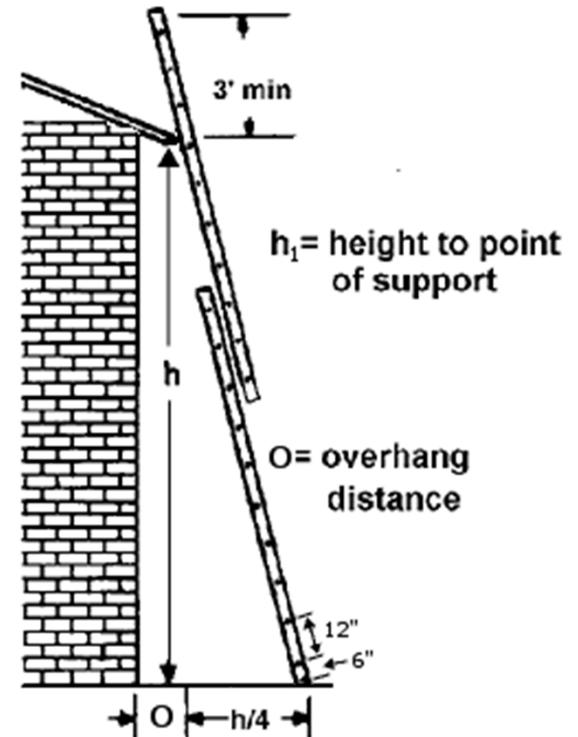


- **Ladder Do's**
 - **Read and follow all labels and markings on the ladder.**
 - **Avoid electrical hazards! – Look for overhead power lines before handling a ladder. Use ladders equipped with nonconductive side rails when working near power lines or exposed energized electrical equipment.**
 - **Always inspect the ladder prior to using it. If the ladder is damaged, it must be removed from service and tagged until repaired or discarded.**
 - **Always maintain a 3-point (two hands and a foot, or two feet and a hand) contact on the ladder when climbing. Keep your body near the middle of the step and always face the ladder while climbing.**
 - **Only use ladders and appropriate accessories (ladder levelers, jacks or hooks) for their designed purposes.**

Precautions must be taken when working on ladders

- **Ladder Do's**

- Ladders must be free of any slippery material on the rungs, steps or feet.
- Use a ladder only on a stable and level surface, unless it has been secured (top or bottom) to prevent displacement.
- An extension or straight ladder used to access an elevated surface must extend at least 3 feet above the point of support (see diagram). Do not stand on the three top rungs of a straight, single or extension ladder.
- The proper angle for setting up a ladder is to place its base a quarter of the working height of the ladder from the wall or other vertical surface



Precautions must be taken when working on ladders



- **Ladder Do's**

- **A ladder placed in any location where it can be displaced by other work activities must be secured to prevent displacement or a barricade must be erected to keep traffic away from the ladder.**
- **Be sure that all locks on an extension ladder are properly engaged.**
- **Store ladders in designated locations when not in use**
- **If the ladder is over six feet tall and stored vertically, the ladder must be chained securely in place**

Ladders are to be used in accordance with manufacturers recommendations

Precautions must be taken when working on ladders



- **Ladder Don'ts**
 - Do not use a self-supporting ladder (e.g., step ladder) as a single ladder or in a partially closed position.
 - Do not use the top step/rung of a ladder as a step/rung unless it was designed for that purpose.
 - Do not place a ladder on boxes, barrels or other unstable bases to obtain additional height.
 - Do not move or shift a ladder while a person or equipment is on the ladder.
 - Do not exceed the maximum load rating of a ladder. Be aware of the ladder's load rating and of the weight it is supporting, including the weight of any tools or equipment.
 - Do not allow personnel to work or pass under the ladder

Precautions must be taken when working on ladders



- **Ladder Don'ts**
 - Do not carry objects (loads) that could cause loss of balance and falling
 - Do NOT modify or repair a ladder

Ladders are to be used in accordance with manufacturers recommendations

Additional information on ladder safety can be found at the OSHA Publications website



- **Ladder Safety QuickCard**
 - https://www.osha.gov/Publications/portable_ladder_qc.html
- **Ladder Safety: Falling Off Ladders Can Kill: Use Them Safely**
 - <https://www.osha.gov/Publications/OSHA3625.pdf>
- **Ladder Safety: Reducing Falls in Construction: Safe Use of Extension Ladders Fact Sheet**
 - <https://www.osha.gov/Publications/OSHA3660.pdf>
- **Ladder Safety: Reducing Falls in Construction: Safe Use of Stepladders Fact Sheet**
 - <https://www.osha.gov/Publications/OSHA3662.pdf>

Use caution when working above floor level



- **Rolling stairs**
 - **Stay within the railings**
 - **When moving make sure that the path is clear of personnel and equipment**
 - **Use at least one hand to grasp the railing when climbing**

- **Aerial Work Platforms**
 - **Use of aerial work platforms require additional training**
 - **Do not cut across or stand in the path of a moving aerial work platform (do not assume the operator can see you)**

Rolling stairs and aerial work platforms are to be used in accordance with manufacturers recommendations. Use of aerial work platforms is restricted to qualified operators

Good housekeeping is everyone's responsibility and is essential to maintaining a safe work environment



- **Good housekeeping conditions shall be maintained at all times. Adequate aisles and passageways shall be maintained in all work areas.**
- **All staging platforms, ramps, stairways, walkways, aisles, and passageways shall be kept clear of all tools, materials, and equipment except that which is in use.**
- **Promptly remove all debris such as bolts, nuts, and similar material**
- **Hose and electric conductors shall be elevated over or placed under the walkway or working surfaces or covered by adequate crossover planks**

All personnel are required to maintain a clean and organized work environment to mitigate many potential safety risks

Good housekeeping is everyone's responsibility and is essential to maintaining a safe work environment



- **Slippery conditions on walkways or working surfaces shall be eliminated as they occur**
- **Maintain clear access at all times to all exits, fire-alarm boxes, and fire-extinguishing equipment**
- **Do not store equipment or materials in front of circuit breaker panels**
- **Do not store equipment or materials on electrical raceways**

All personnel are required to maintain a clean and organized work environment to mitigate many potential safety risks

Securing components used overhead is essential to preventing hazards from falling objects



- **All loose material or items must be stored in appropriate bins or containers**
- **All materials used at an elevation in excess of 4' off the ground must be appropriately secured to prevent them from becoming a falling object (An elevated deck surface is not the ground)**
- **Permanent or temporary attachments must be capable of withstanding all likely loads with a general purpose safety factor of 3X**
 - **Permanent attachments must include properly engineered joints**

All personnel are required to properly stow and secure all overhead items to help mitigate risks from falling objects

Securing components used overhead is essential to preventing hazards from falling objects



- **Temporary attachments (including tape and magnetic bases) should not remain in use for more than 30 days**
 - **Use of magnetic bases will depend upon the load being held, orientation of surface, and susceptibility to incidental loads (a bump). Use in Omega and Omega EP are subject to the approval of MSO (Mechanical Safety Officer).**
- **Tape must never be used to secure mechanical loads**
- **Tape may only be used to secure burn paper, instructions, procedures, etc.**

All personnel are required to properly stow and secure all overhead items to help mitigate risks from falling objects

All cable management in the Omega and Omega EP facilities must be engineered and documented by ME



- **Cable routing and the mounting of all electrical equipment in the Omega and Omega EP facilities must be engineered and documented**
 - **This pertains to ALL cables used in both facilities (data, network, fiber optic, power, etc.)**
- **The proper installation and strain relief of cables is required**
- **No ad-hoc mounts are permitted (including ty-wraps and tape dangling from cables)**
- **Cables that are run through air plenums must be “Plenum rated”**
- **Do not attach anything to the fire protection system**
 - **The fire protection system includes all piping, hangers and threaded rods and is required by code to be an exclusive system independent of all others**
- **Obtain permission from O&M before using threaded rod and Kindorf (used to support ductwork, chilled water, etc.) to support cabling systems**

General rules for cables in Omega and Omega EP



- **All cable installations will follow the rules outlined in OMEGA EP Cable Documentation And Labeling Specification E-CB-G-001**
- **The Electronics Shop is responsible for the engineering and documentation of cables and compliance with E-CB-G-001**
- **When running a cable from point A to point B, if there is no existing cable or wireway stop and get help from ME to get proper cable or wireways designed and installed**
- **Within LLE, the electricians are the most skilled individuals at performing cable installations**

Scientific and Fabricated Equipment/Instruments



- **Equipment that is designed internally or supplied by LLE Collaborators must comply with LLE instruction 7700**
 - **Requirements understood and documented**
 - **The design is reviewed at several stages by knowledgeable people**
 - **Procedures are written and released**
 - **Safety inspections performed following installation of the hardware and prior to use**

Equipment cannot be modified unless reviewed and approved by the appropriate Engineering group(s)

Hand tools and power tools are a necessary component of everyday laboratory work



- Use the proper tool for the job (i.e., the human hand is not a hammer)
- Use proper PPE (safety glasses, face shield, gloves, etc.)
- If you are uncertain how to use a tool properly (safely) get assistance by;
 - Reading the manual and using the tool in accordance to manufacturer's recommendations
 - Review the use with another qualified operator
 - ask for help in the machine shop from a machinist

The use of hand tools and power tools is permitted without specialized training when used in accordance with manufacturers recommendations

The Auxiliary Machine Shop is available for use by LLE personnel



- **Separate training (M_010) is required to work in the Auxiliary Machine Shop**
 - **Only qualified operators are permitted to use the equipment in the Auxiliary Machine Shop**
 - **Auxiliary Machine Shop operators are not permitted to use equipment in the LLE Machine Shop unless qualified**
 - **No machining of Beryllium or Lead**
- **Use of the shop is a privilege not a right. Users will likely be excused from the machine shop after one warning.**

Use of the machine shops is restricted to qualified users during posted hours

Equipment in the LLE Machine Shop falls into four categories and is available for limited use by LLE personnel



- **Single axis motion**
 - **Sheet metal equipment; shear, punches, break, etc.**
 - **Drill press, band saw, cut-off saw, etc.**
- **Two axis motion**
 - **Manual mill and manual lathe**
- **CNC**
 - **CNC Mills; Hardinge XR1000, Tree, CNC equipped Bridgeports**
- **Welding**

- **A list of qualified users is posted on the shop doors**

Qualified users must check in with the Machinist on Duty prior to the use of any equipment

Summary

Safety is everyone's business and compliance with safety procedures is **MANDATORY**



- If an activity or practice seems unsafe, “Stop Work” and take the time to address concerns
- Situational Awareness – The best way to prevent an accident is to be aware of your surroundings
- All mechanical equipment modifications must be coordinated through Mechanical Engineering
- All gas systems must be inspected and approved by ME prior to first use
- Vacuum systems $> 0.4\text{m}^3$ must be inspected and approved by ME prior to first use
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- Only perform activities for which you are qualified
- Only use items for their intended purpose