# ETME 3120
# Maintenance of Mechatronic Systems

## Lesson 1: Introduction to Maintenance

**Suggested References:**


1. Productivity and Reliability-Based Maintenance Management, M. Stephens, 2010
2. Khalid Tantawi, I. Fidan, A. Tantawi "Status of Smart Manufactring in the United States", IEEE SoutheastCon. Huntsville, AL, 2019



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# Introduction

- Purpose of Maintenance Management:
  - Increase uptime and reduce downtime
  - Provide most efficient and effective use f facilities
- **Maintenance:** All activities necessary to keep a system and all of its components in working order, i.e to maintain the capability of the system while controlling the costs.
- **Failure:** Any deviation or change in the production system from its satisfactory condition to a condition below acceptable or operating standards.
- Components of cost:
  - Cost of maintenance labor and materials
  - Cost of production loss

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# Historical Background: Evolution of Manufacturing

| Table 2. Historical Evolution of the Manufacturing paradigms and models. | | |
|---|---|---|
| **Manufacturing Model / Paradigm** | **Development Date** | **Main Features** |
| **Lean Manufacturing** | 1940's | Waste management |
| **Flexible Manufacturing Systems** | 1970's | Flexible adjustments in processes |
| **Computer Integrated Manufacturing** | 1970's | Computer-controlled processes |
| **Sustainable Manufacturing** | 1990's | Environment friendly |
| **Holonic Manufacturing** | 1990's | Autonomy |
| **Agile Manufacturing** | 1990's | Customer satisfaction with reduced cost |
| **Cloud Manufacturing** | 2000's | Deploys IoT technology |
| **Smart Manufacturing** | 2010's | Artificial Intelligence |

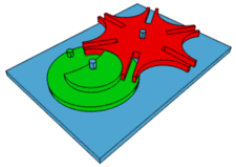
# • Industry 4.0 "Industrie 4.0"

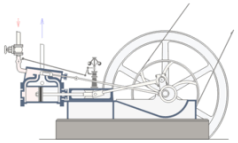
The term **Industry 4.0 came to existance in 2011**. It came to identify the technologies and practices of the fourth generation of industry.

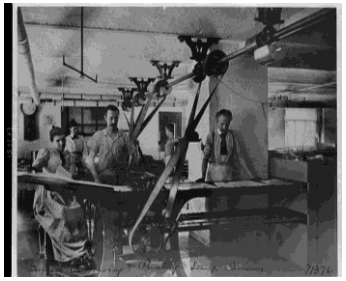
Many Industry 4.0 technologies are used in maintenance such as vision systems, augmented reality, and RF identification, and others.

**Mechanization** → **Automation** → **Computerized Automation** → **Artificial Intelligence**

## 1st Generation:
**Industry 1.0**
**1700's to 1910's**

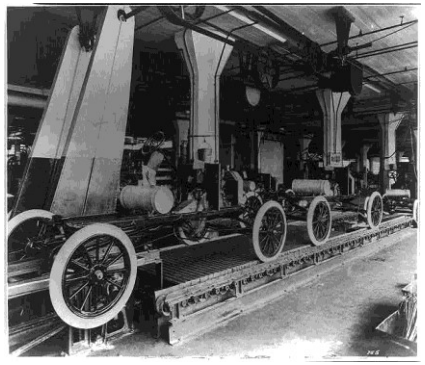






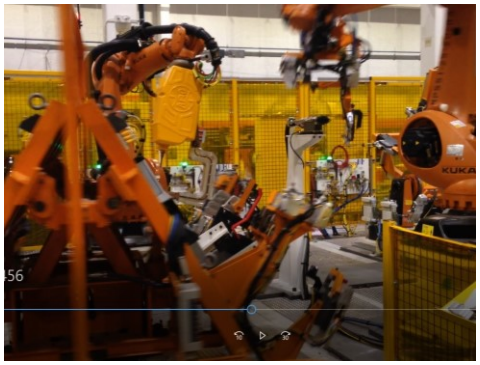
Steam-driven belt drives used in stamp gumming in 1895.
Source: Library of Congress

## 2nd Generation:
**Industry 2.0**
**1910's- 1970's**



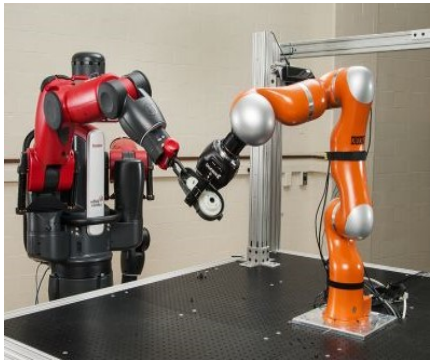
First automated assembly line, Ford Motor Company, 1913
Source: Library of Congress

## 3rd Generation:
**Industry 3.0**
**1970's- 2010's**



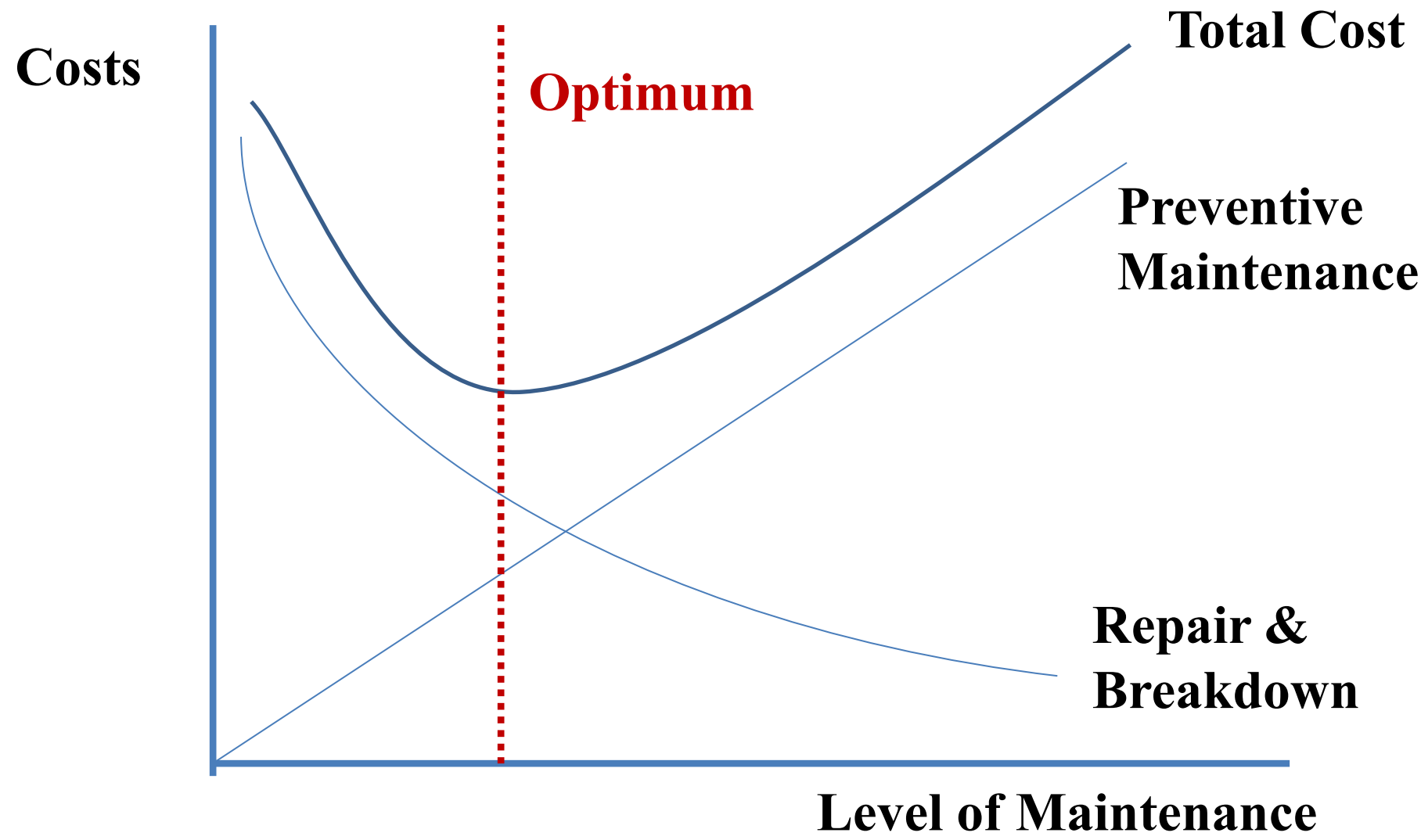
Industrial Robots in and assembly plant

## 4th Generation:
**Industry 4.0**
**2010's - now**



Source: NIMS (above), US Army (below)

# Cost vs. Maintenance Level



# Maintenance Objectives

- **Primary Goals:**
  - Maintaining existing equipment
  - Equipment inspection and lubrication
  - Equipment modification and installation
  - Utility generation, distribution, and management
  - Maintaining existing building and grounds
  - Building modification
- **Secondary Goals:**
  - Plant protection and security
  - Salvage of obsolete equipment and waste disposal
  - Pollution and noise control
  - ADA, EPA, OSHA, and other regulatory compliance
  - Other functions

# Typical Job Duties of a Level 1 Technician

1. **Reading schematics:** such as electrical, hydraulic, and pneumatic circuits, wiring diagrams, and machine drawings.
2. **Electrical measurements**: ammeters, voltmeters, ohmmeters ..etc
3. **Mechanical measurements**: such as calipers, scales, tachometers, levels.
4. **simple mathematics**: areas, circumferences, fractions, decimals, ..etc.
5. **Units:** understanding of common English and Metric units such as kg, pounds, meters, feet, kW, and horsepower.
6. operating AC and DC motors.
7. **Alignment techniques:** as straight edge alignment and correcting soft foot.
8. **Lubrication:** such as bearing lubrication, chain lubrication, ..etc.
9. **Mechanical Systems:** Understanding of ratios of systems mainly: a) gear drives, b) chain drives, c) belt drives and d) pulley systems.
10. Maintenance of bearings and gear drives.
11. Operating and maintaining hydraulic and pneumatic systems.
12. **Predictive** and **Preventive Maintenance:** Must be performed on shafts, bearing, hydraulic and pneumatic parts, and other parts.

# Management & Structure of Maintenance (slide 1)

- **Maintenance Management functions:**
  - Planning
  - Scheduling
- **Planning:** prioritizing activities, estimating time required for maintenance, determining type of equipment, and labor, providing labor development opportunities, and measure performance.
- **Scheduling:** executing the planned objectives
- Backlog: Accumulation of uncompleted maintenance work.
- Typically, a healthy backlog should be in the range 2-3 weeks.
- If the backlog is continuously decreasing: the maintenance workforce will be downsized to keep efficiency.
- If the backlog has a trend of increasing, the maintenance workforce is increased or more overtime is scheduled.

# Management & Structure of Maintenance (slide 2)

**Determining the crew size:**

$$Crew\ size = \frac{Scheduled\ labor\ hours\ per\ week}{Backlog\ \times Hours\ per\ week}$$

**Example:** What is the number of technicians needed if the scheduled maintenance work is 1250 hours per week, and a backlog of no more than two weeks is required, if the full-time employee works 40 hours per week?

Crew size = 1250/ (2 x 40) = 15.625 = 16 employees

# Computerized Maintenance Management Systems (CMMS): Software Packages:

- Computerized Maintenance Management Systems are software-based that can do functions such as:
  - Employ statistical methods and techniques
  - Determine allocation of resources (staff, event planning, and others) based on computer simulation
  - Track and control backlog
  - Tracking and updating equipment history

**Example:**

- When a maintenance task is performed on an equipment, it is documented in a software package.
- When the equipment fails, the operator can quickly review the history of preventative and corrective maintenance on the equipment, and a documentation of the parts that were changed to assess him/her in repairing the equipment.
- An example of a maintenance software is the **Infor EAM** software: (See this demo: https://www.youtube.com/watch?v=z0n6QkMY5ck )

# Total Productive Maintenance (TPM) (Slide 1)

- A strategy developed in Japan in the 1970's.
- Characterized by three features:
  - viewing maintenance as a vital **profitable** part of business and not a non-profit activity.
  - **Empowers operators** to take ownership of equipment and responsibility of basic routine maintenance
  - Reduce **six major losses**.

**Operator Responsibilities:**

- Housekeeping and organization
- Equipment Cleaning
- Protecting (covering) machines from dirt
- Lubrication
- Routine Inspection: loose parts, vibration, noise, ..etc
- Routine Adjustments

# Total Productive Maintenance (TPM) (Slide 2)

- The six major losses that affect efficiency f the production system [2]:
  1. Equipment Failure losses
  2. Setup and routine adjustment losses
  3. Idling and minor stoppage losses
  4. Reduced speed losses
  5. Defects and rework losses
  6. Startup losses

# Maintenance

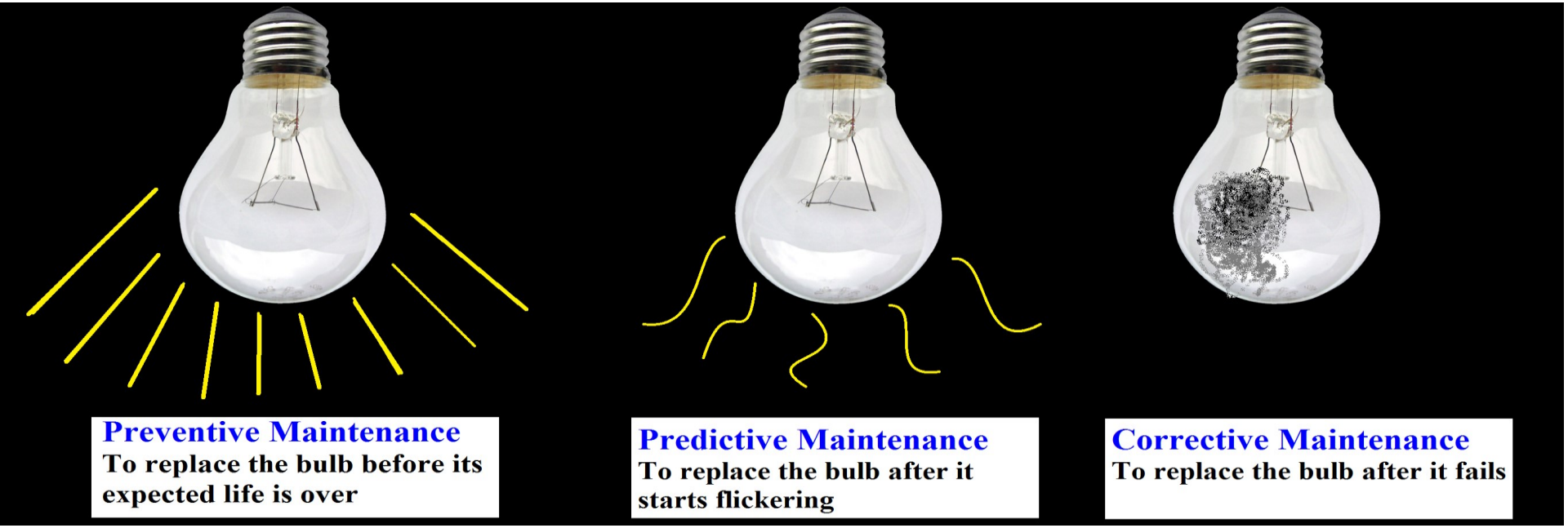
- **Main Target**: More **Uptime**, and less **Downtime** of equipment

- **Types of maintenance Activities**:

  - **Preventative maintenance**: Performing scheduled and unscheduled tasks on an equipment for optimization and preventing failure.
  - **Predictive maintenance**: condition monitoring of an equipment in comparison to a preset standard or baseline.
  - **Corrective (Reactive) maintenance**: performing maintenance after a part failure. The most expensive type of maintenance

**Example:** (Source: Wikipedia) If an operator bought a light bulb that has a life span of 3 years, then:

- **Preventive maintenance:** To replace the bulb with a new one just before the 3 years pass.
- **Predictive Maintenance:** At about 3 years, when the bulb starts flickering, the operator predicts that the bulb is going to fail very soon and replaces it for a new one.
- **Corrective maintenance:** The operator ignores the flickering bulb and only replaces the light bulb when the current one fails.



# Importance of Preventive Maintenance

- Importance of Preventive Maintenance and the significance of the cost saving that results from implementing it, can be viewed in the case study in the book. Please read the case study: Crash of Flight 261 on pages 16-18 in the textbook.

# Examples of Predictive maintenance

1. **Vibration analysis:**
   - Analysis of the oscillatory motion in a mechanical system.
   - Example: a change in the natural frequency of a structure can indicate a fracture in a shaft, or a slight misalignment in a pulley, the problem might be very small to notice, but as time progresses, it can cause failure. Thus vibration analysis is a predictive maintenance technique.
2. **Oil Analysis:** Investigation of the physical properties and presence of contaminants in oil samples.
3. **Thermography:** Analysis of the temperature of an equipment at different operating conditions.

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# The Ten Safety Rules

1. Wear safety glasses.
2. Remove watches, jewelry, rings, and ties.
3. If you have a long hair, you must tie it up or put it in a cap.
4. Wear tight-fitted clothes and remove jackets.
5. Wear short sleeves, or properly rolled-up long sleeves.
6. Wear heavy duty shoes.
7. Make sure the floor is dry before you start and stays dry during the lab session. Never start your lab session if the floor is wet or greasy.
8. Familiarize yourself with the location of the emergency stop buttons before you start your lab session.
9. Some labs may require wearing electrically-insulating gloves. Please be aware when they are needed.
10. Inform other students around you and your group members, if you are working in a group, before you plug in or operate, or turn on an electrical equipment, in particular electric motors, and make them aware of that.

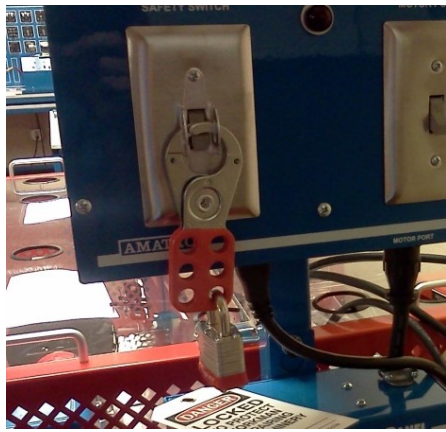
# Safety Procedures

## Lockout/Tagout Standard

- In effect since 1989 in the United States
- To control hazardous energy sources.
- **Lockout:** placement of a device that locks out the energy-isolating device.
- **Tagout:** placement of a tagout on the energy-isolating device.

# Lockout Requirements

1. Use a positive means to keep the energy-isolating device in the safe position.
2. The lockout device must be able to withstand the environment it is exposed to, such as excessive heat, radiation, freezing..etc.
3. The lockout and tagout devices must be standardized in the facility in size and/or color and/or shape.
4. The lockout device must be strong enough to prevent removal without excessive force.
5. Notification of employees before the application and after removal of the lockout/tagout.
6. Only the employee who applied it can remove the lock out device.



# Tagout Requirements

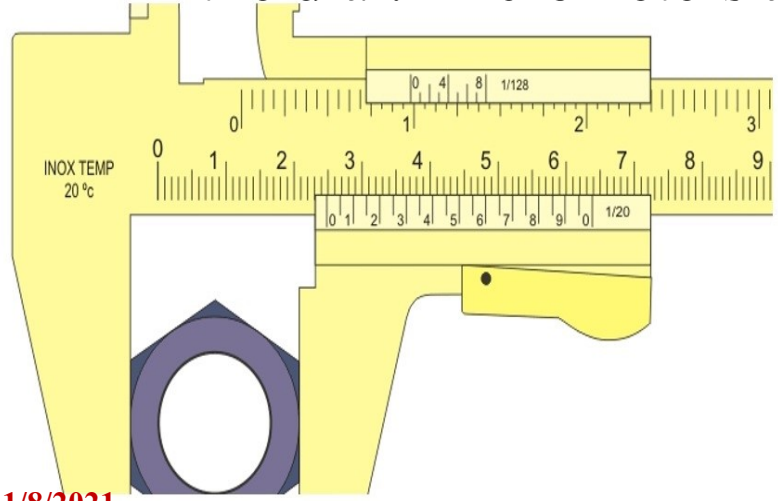
1. Must contain a clear warning. For example: Danger.
2. Must state clearly that moving the energy-isolating device from the safe mode is not allowed.
3. Must be placed in the place a lock device would be placed, or if not possible, as close as safely possible in a position obvious to anyone who attempts to operate the device.
4. Must be able to withstand the environment.
5. Must be standardized in the facility.
6. Must have a nonreusable type of attachment.

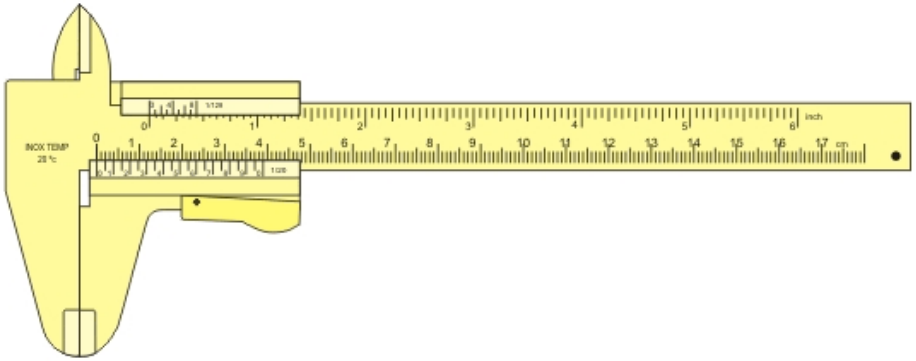
# Reading Calipers

- Vernier and Dial Calipers are high precision high accuracy length measurement tools
- To read the Vernier/dial caliper follow these steps:
  1. Notice the accuracy written on the vernier / dial caliper
  2. Read the measurement scale, then add to it the vernier scale reading, that is:

     **Final reading = main scale reading + vernier reading**
  3. the vernier scale reading is that of the first alignment of a tick mark on the vernier scale with a tick mark on the main scale.

**Note:** For a dial caliper the minor scale reading is read directly from the dial. Micrometers are more accurate than calipers.



Source: Wikimedia Commons by Joaquim Alves Gaspar

# Exercise Questions

1. The time when a machine or equipment is not functioning is called:
   a) Uptime
   b) Downtime
   c) Cycle Time
   d) Takt time
   e) Both b and d

2. Which statement is correct of the following:
   a) Only the lockout device is required to withstand the environment in which it is to be placed.
   b) Only the tagout device is required to withstand the environment in which it is to be placed.
   c) Either one of the two must withstand the environment in which it is to be placed, but not necessarily both.
   d) Both lockout and tagout devices must be able to withstand the environment.

## 3. Mark each statement below, in regards to Lockout/Tagout, as true or false :

a) When performing a Lockout/Tagout procedure, the tagout device must contain a clear warning such as "Danger " on it. **True**

b) A lockout device is acceptable as long as a child below the age of 12is not able to remove it. **False**

c) An affected employee can remove the lockout and tagout devices once maintenance work is done provided that the affected employee is a full-time managerial level employee in that department in which the lockout/tagout was applied. **False**

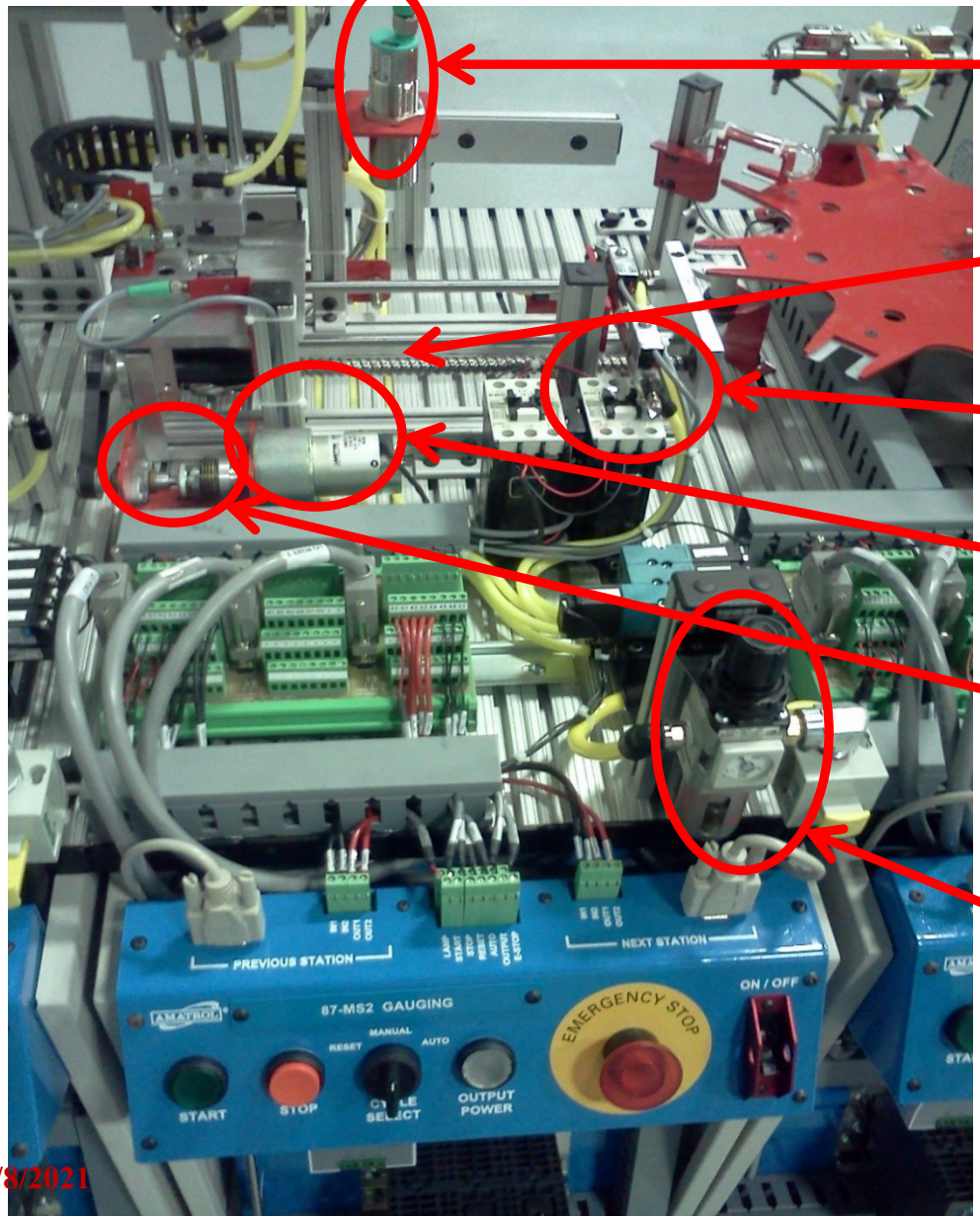
d) The Lockout device must use a positive means such as a mechanical lock to keep the energy-isolating device in the safe position. **True**

e) The protection provided by the tagout device is enough and eliminates the necessity of a lockout device. **False**

# Exercise:

**The picture shows two persons troubleshooting a station, what safety rule that is not followed in this picture?**

# Understanding a Mechatronic system with Blocks and Energy Flow Diagrams




Ultrasonic sensor

Ball Screw

Contactor

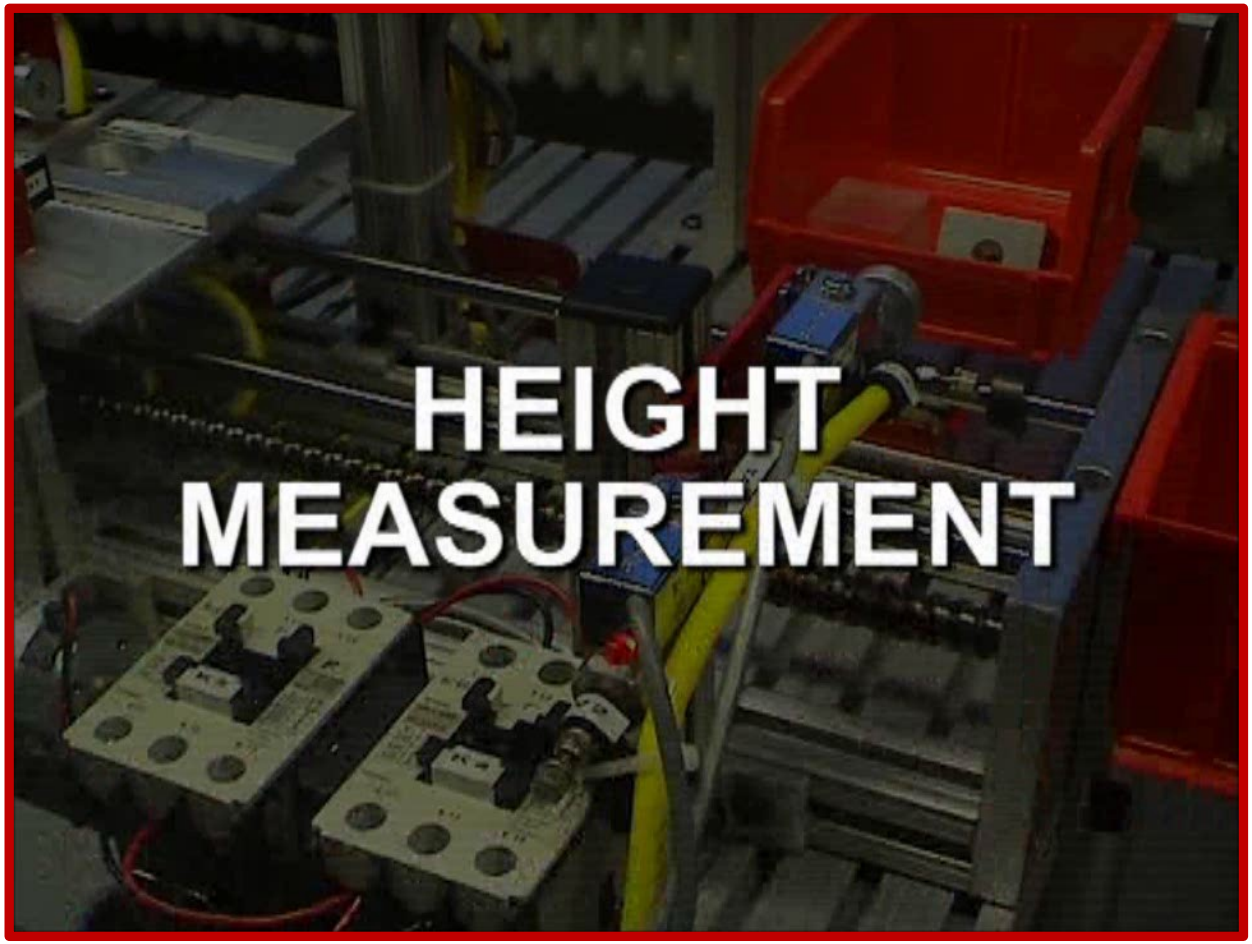
DC Motor

Slip clutch

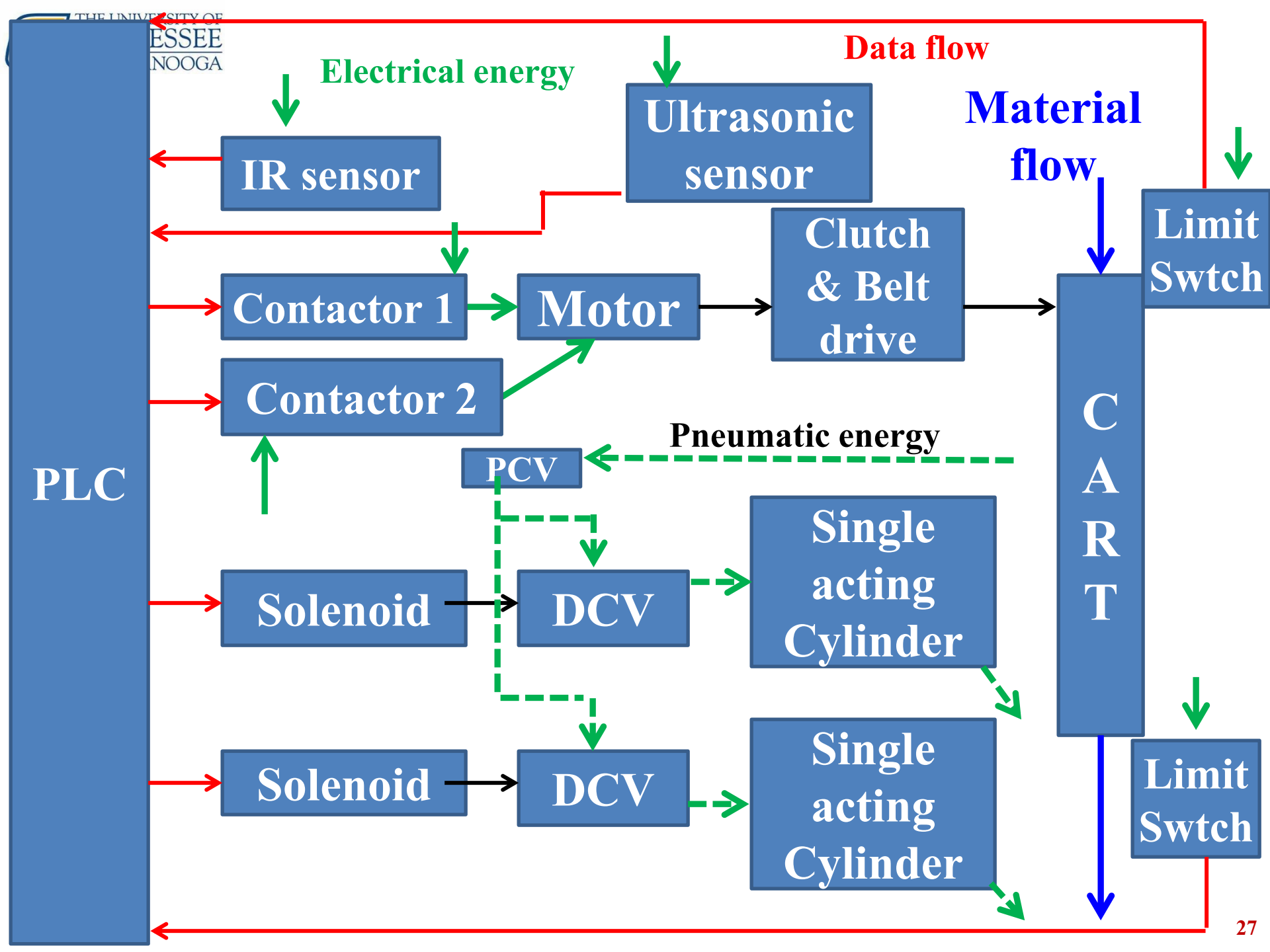
Pressure regulator

The first step in Maintenance is to familiarize yourself with the system running in operation.

You cannot troubleshoot a system that you never saw how it operates.




Video Source:
Siemens Technik Akademie-Berlin


Data flow
Electrical energy
Material flow
Ultrasonic sensor
IR sensor
Limit Swtch
Clutch & Belt drive
Contactor 1
Motor
Contactor 2
CART
Pneumatic energy
PCV
PLC
Single acting Cylinder
Solenoid
DCV
Solenoid
DCV
Single acting Cylinder
Limit Swtch

# U.S. Civil Aviation Accidents Involving Maintenance as a Cause/Factor

| Year | Number of Accidents | Accidents With Fatalities | Injuries | | | | | Total People Involved |
|---|---|---|---|---|---|---|---|---|
| | | | Fatal | Serious | Minor | None | Total | |
| 1995 | 150 | 25 | 62 | 49 | 70 | 200 | 181 | 381 |
| 1996 | 168 | 32 | 161 | 49 | 60 | 711 | 270 | 981 |
| 1997 | 149 | 26 | 47 | 41 | 85 | 487 | 173 | 660 |
| 1998 | 139 | 23 | 36 | 39 | 54 | 496 | 129 | 625 |