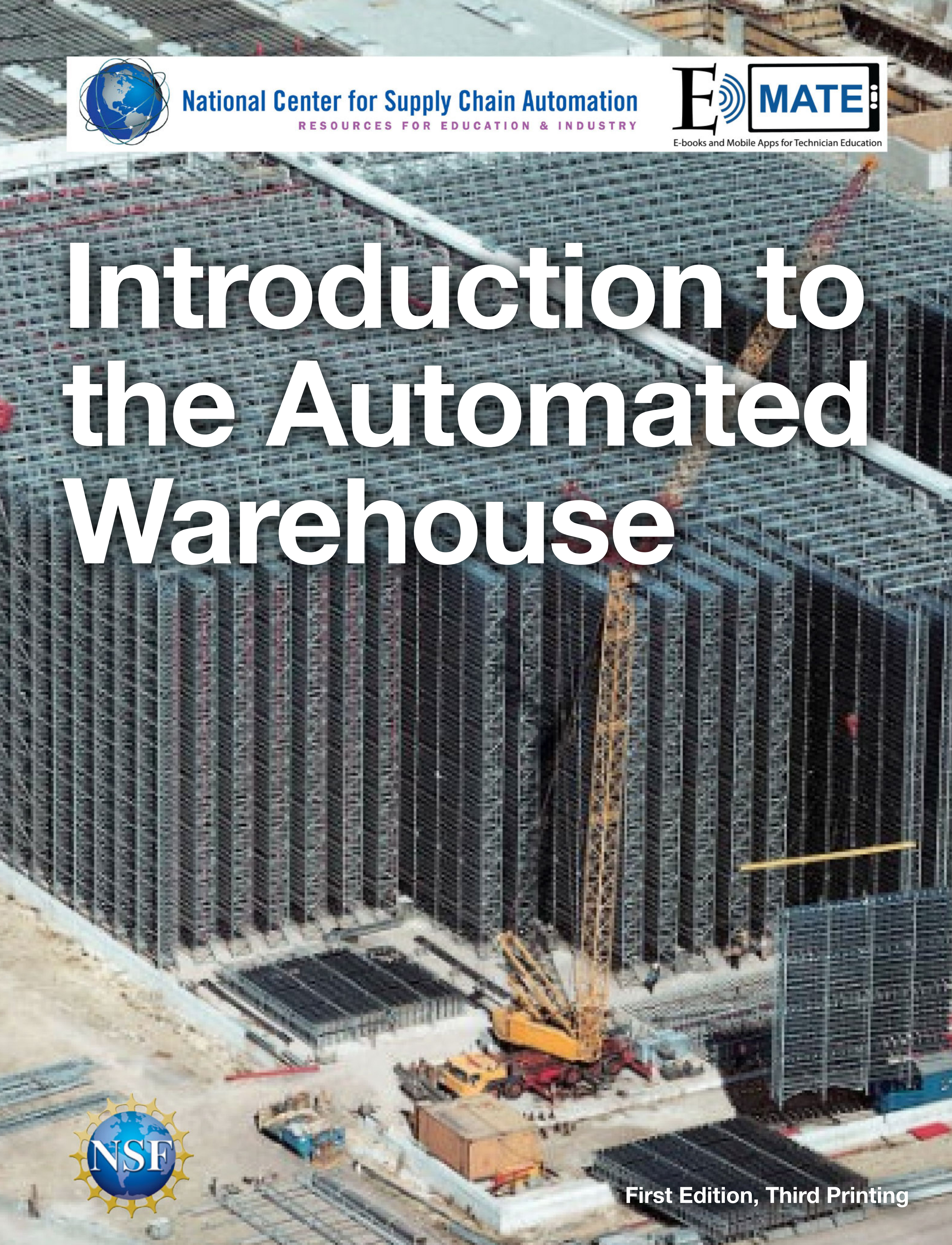

National Center for Supply Chain Automation
RESOURCES FOR EDUCATION & INDUSTRY

MATE
E-books and Mobile Apps for Technician Education

Introduction to the Automated Warehouse

First Edition, Third Printing

Preface

Through this exciting, interactive e-textbook, you will discover the Supply Chain Technician occupation, a high-wage job that is also sometimes referred to as Industrial Machinery Technician, Industrial Maintenance Mechanic and Electro-Mechanical Technician. Supply Chain Technician refers to a person who installs, operates, supports, upgrades or maintains the automated material handling equipment and systems that support the supply chain. The work involves a broad field of expertise that encompasses electrical and mechanical skills, robotics, optics, sensors and complex conveyor systems. If you enjoy working with your hands, the Supply Chain Technician occupation is for you!

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Copyright Information

Third Printing, November 2021

Interactive e-book content provided by the National Center for Supply Chain Automation, NSF ATE DUE Award #1601452. Interactive e-book created by E-MATE, E-books and Mobile Apps for Technician Education, NSF ATE DUE# 1205113.

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Forward

The National Center for Supply Chain Automation brought together technicians working in automated warehouses across the country to find out what a Supply Chain Technician does on a daily basis. What we discovered is that a Supply Chain Technician installs, operates, supports, upgrades or maintains the automated material handling equipment and systems that support the supply chain. With this new information, the Center created model curriculum and searched for a textbook to use in schools and colleges across the nation. This is where a gap between what existed and what was needed was found.

There are plenty of textbooks on electronics, welding, safety, material handling and the other topics covered in the “Introduction to Automated Warehousing” course; but none include all the topics in one comprehensive book. Plus, none are interactive, electronic, always up to date, and FREE! It was because of this gap that the National Center for Supply Chain Automation (SCA) decided to create this interactive, electronic book.

This e-book is the first of its kind as no single textbook existed that could be used in an introductory Supply Chain Technology course. This book integrates content with visual models to give students a comprehensive overview of the skills and abilities they will need to become well trained supply chain technicians. The language was written to provide students with the most up to date information possible. It is current. It is relevant. It is fun.

The first edition of Introduction to Automated Warehousing was created by E-MATE using content provided by SCA. Both organizations are funded by the National Science Foundations’ Advanced Technological Education

Program, which made it all possible. The goal of SCA is to increase the number of qualified supply chain technicians to meet the growing national need across the private and public supply chains.

The authors of Introduction to Automated Warehousing are all supply chain technicians who are in the field on a daily basis. They represent companies that want to hire you. They are industry associations that value the importance of emerging technologies which support the supply chain. There is a growing supply chain industry out there looking for talented technicians, and this e-book provides you with the foundational knowledge and skills you will need to be successful.

We know you'll enjoy using it, learning from it, and sharing it with others.

Feel free to share your thoughts and comments with us at infor@supplychainautomation.com.

Colleen Molko

Principal Investigator, SCA

Acknowledgements

Thank you to the National Science Foundation's Advanced Technological Education Program, the National Center for Supply Chain Automation, and E-MATE for making the creation of this eTextbook possible.

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This work is sponsored in part by the National Science Foundation's Advanced Technological Education Program under DUE Award #1601452. Any opinions, findings, conclusions or recommendations presented on our social media platforms are only those of the presenter grantee/researcher, author, or agency employee; and do not necessarily reflect the views of the National Science Foundation.

E-MATE, E-books and Mobile Apps for Technician Education is a project sponsored by the National Science Foundation's Advanced Technological Education Program under DUE Award #1205113.

Introduction

It’s an exciting time to be a supply chain technician! Logistics companies across the country continue to invest millions of dollars into new high tech distribution centers and to add new automation technology to optimize their capital investment in their supply chains. Automation technology in warehousing is advancing at a faster rate because the buying trends of today’s consumers are changing. Warehouses must be able to identify, locate and ship product instantaneously and with 100% accuracy. Without automation, this would be impossible. Labor costs are expensive and many companies struggle to hire enough workers to keep up with their needs. Automation enables companies to get more work done with equivalent or fewer operators, so even small companies are beginning to invest in systems with advanced technologies that were once only found in manufacturing sites or very large companies.

As these new engineered systems become more complex, the need to keep the equipment well maintained and fully functional becomes even greater. Supply chain technicians play critical roles in supply chain success, and there are ever-increasing demands for highly skilled workers that can learn new equipment and software. New systems offer exciting opportunities to work with the most cutting edge technologies in the market today, such as robotics, automated guided vehicles (AGVs), and automated storage and retrieval systems.

A supply chain technician has to be versatile and knowledgeable about all of the equipment inside their facility. It is not uncommon for technicians to routinely work on any and all of the equipment that their companies own and use. Ongoing education and continuous learning is essential to keep up with the fast-paced march of automation innovation. The more of these systems you understand, the more value you add to the facility.

This textbook introduces you to the career of a supply chain technician and the skills you will need to be successful. You will learn about warehousing and how it fits into a supply chain. You will have the opportunity to see firsthand the technology in use in an automated warehouse. You will meet experienced supply chain technicians and hear about the career from them directly. Finally, you will have the opportunity to read papers written by industry experts, many of which contributed to the writing of this textbook.

This textbook is divided into 13 chapters. The first part of the book focuses on the career awareness, industry certifications and the principles of the supply chain. You will learn the terminology of the industry and hopefully spend a good deal of time reflecting and asking simple questions related to the supply chain. The middle section of the book focuses on the skills you will need to learn to be successful. Although this course will not teach you these skills, you will know what these skills are, why you'll need to master them, and most importantly, which classes you'll need to take and where to find them. The last part of the book focuses on the importance of workplace communication and the need for technicians to clearly articulate their intentions as they work with others.

In the next chapter you will learn about the career of a supply chain technician. The chapter includes several videos, quizzes, and interactivity with technology. As you progress through this course you will have an opportunity to explore the industry on your own. The internet is a wonderful tool and should be used to fulfill your curiosity. Good luck and I hope you find the world of automation interesting and exciting.

Instructor's Manual An instructor's manual is available to assist in planning and organizing courses that use this E-text. The manual includes learning objectives, case studies appropriate for classroom discussions or homework assignments, additional supplemental exercises, sample syllabi and all E-text Review exercise solutions. To obtain a copy of the instructor's manual, please request it from Bob Sompolski at somplski@oakton.edu.

Chapter 1

Career Awareness

In this chapter you will learn what a supply chain technician is, what they do, and the education and training needed to be prepared for this exciting new career.

Section 1

Career Awareness

The career of a supply chain technician can be extremely rewarding. The successful technician will enjoy problem solving, learning new technology and taking responsibility. This chapter will introduce you to the career, outline the skills needed to be successful and show you all the resources you need to get started supporting our nation's supply chain as a highly skilled supply chain technician (SCT). This chapter will also give you insight into the day to day responsibilities of an SCT.

Many in the industry would describe this career as an industrial maintenance mechanic with expertise in the technologies and systems used in the 21st century's automated warehouses. That description is true. The Industry Leadership Team, providing guidance to the National Center for Supply Chain Automation, uses the following definition:

"A person who installs, operates, supports, upgrades or maintains the software, hardware, automated equipment and systems that support the supply chain."

As you read through this chapter you will have the opportunity to watch several videos, read relevant white papers, test your knowledge of the supply chain and create a list of resources you can use to plan your education.

Before you get started ask yourself these simple questions:

- How did the shoes that you are wearing get from the shoe manufacturer to your feet?
- How do you order something online right now knowing that it will get delivered to your home tomorrow?
- How many different types of soda are available for purchase?

Take a few minutes and write down the best answer you can. Think of all the steps necessary? How many people are involved? Why do consumers have so many choices? How far does a product have to travel? Where is it manufactured? The list of questions is infinite.

Now that you have thought about the scope of the supply chain, take a few minutes and watch this short video.

Movie 1.1 Material Handling as a Career

Tap to view a video

Now that you know there is a need for supply chain technicians, let's look at the different processes that occur in an automated warehouse.

Now that you have a better idea of the technology used in the automated distribution center, who is going to keep this automated equipment operating?

Movie 1.2 What is a Supply Chain Technician?

Tap to view a video

Now that you have spent some time researching the role of an SCT, you may be wondering why warehouses have become so advanced in recent years. To help you understand why so much automation is being added to warehouses, think for a moment about what is driving the need for this technology.

Here are 3 examples. You may have several more.

1. E-commerce
2. Accuracy & efficiency
3. Massive amount of available products

That's right! We are purchasing products online more and more every day. Businesses have to track your order from the moment you place the order to the time the delivery driver drops the package at your door.

Take a few minutes and read this paper written by industry expert Steve Harrington.

Interactive 1.1 Factors Driving the Adoption of Automation in the 21st Century Warehouse PDF

Tap to view PDF.

Now that you understand why we need supply chain technicians, you may be wondering what type of education you need to become successful. The National Center for Supply Chain Automation has put together an occupation profile that will help you get started. The occupation profile will help you answer the following questions:

- What do you need to know?
- What do you need to do?
- What skills do you need to have?
- How much money are you going to make?

Interactive 1.2 Occupation Profile PDF

Tap to view PDF.

The final section of the career awareness chapter focuses on what types of classes will you need to take to prepare yourself for this career. The Industry Leadership Team advising the National Center for Supply Chain Automation has agreed on a program of study that will meet the hiring criteria of most automated warehouses. Some locations have specific needs and put an emphasis on one skill over another. Some companies utilize specialists while other companies prefer someone with a more well-rounded skill set. In general, the skill sets listed in the sample program of study will prepare you for a career as an SCT.

Now that you have spent time learning about the role of an SCT, it's time to get started supporting our nation's supply chain as a highly skilled supply chain technician (SCT). Call or visit your local community college and ask them about the programs they have for this exciting field!

Interactive 1.3 Model Program of Study PDF

Tap to view PDF.

Chapter 2

Industry Certification

You will also have the opportunity to become familiar with some of the technical terms used in the industry standards underpinning current material handling certifications.

Industry Certification

The authors of this e-book believe industry recognized certification plays an important role in the success of our students. We encourage all of our students interested in supporting and improving our supply chain to become certified.

The Manufacturing Skill Standards Council (MSSC), a 501(c)3 non-profit, is an industry-led, training, assessment and certification system focused on the core skills and knowledge needed by the nation’s front-line production and material handling workers. The nationwide MSSC System, based upon industry-defined and federally-endorsed standards, offers both entry-level and incumbent workers the opportunity to demonstrate that they have acquired the skills increasingly needed in the technology-intensive jobs of the 21st century. MSSC offers two certifications for this workforce:

Certified Production Technician (CPT)

The CPT Certification addresses the core technical competencies of higher skilled production workers in all sectors of manufacturing. MSSC awards certificates to individuals who pass any of its Production Modules: Safety; Quality Practices & Measurement; Manufacturing Processes & Production; Maintenance Awareness; and Green Production and a full Certified Production Technician (CPT) Certification to those who pass all four original modules (NOTE: At this time, Green is not a requirement for full CPT certification). MSSC's Certified Production Technician (CPT) is the only manufacturing certification that is accredited by the American

National Standards Institute under International Organization for Standardization (ISO) Standard 17024. ISO is the authoritative quality standard used by industry globally.

Certified Logistics Technician (CLT)

The CLT Certification addresses the core technical competencies of higher skilled, front-line material handling and distribution workers in all supply chain facilities: from factories to warehouses, distribution centers and transporters. MSSC awards the foundational-level Certified Logistics Associate (CLA) certificate and the mid-level Certified Logistics Technician (CLT) certification. CLA is a prerequisite for CLT. MSSC's Certified Logistics Technician (CLT) is the only logistics certification that is accredited by the American National Standards Institute under ISO Standard 17024.

MSSC has developed, validated, piloted and deployed all the tools of a comprehensive system for both CPT and CLT Certifications: annually updated standards, courses, computer-based training materials, textbooks, instructor training, assessment center training, a national registry, assessments, credentials and diagnostic tools for employers. MSSC offers state-of-the-art, interactive, computer-based training courses to prepare students for the CPT and CLT certification assessments. These courses are delivered throughout the country at community and technical colleges, high schools and other training providers and help prepare students for CPT and CLA-CLT national certification assessments. If you are interested in learning more about this training and certification program to attempt these assessments, please visit their website at www.msscusa.org or contact them at info@msscusa.org.

CLT is the first step on a career and education pathway and will set you on a track toward becoming a Supply Chain Technician. CLT provides you with a foundational knowledge of the logistics industry at the frontline level. It will introduce you to the general principles of safety, quality, inventory management, standard warehouse and distribution center equipment and more. Below are the key work activities covered in the CLT program.

Certified Logistics Associate (CLA)

CLA is the foundational, entry-level certificate in the program. It introduces you to the world of logistics, the role of frontline employees in the global supply chain, the types of equipment used, etc. Individuals with a CLA certificate will be able to:

1. Demonstrate an understanding of the various roles in the global supply chain logistics life cycle
2. Demonstrate an understanding of the logistics environment
3. Operate and use equipment
4. Practice safety principles
5. Practice safety principles in the handling of materials and operation of equipment

6. Practice quality control principles
7. Employ good work communication practices
8. Practice teamwork and good workplace behavior to solve problems
9. Use relevant computer systems and applications to increase productivity

CLA is prerequisite for taking the CLT Assessment (see below) and for full CLT Certification.

Certified Logistics Technician (CLT)

CLT is a mid-level certificate. It includes the technical activities performed by employees as a product moves through the global supply chain. Individuals with a CLT certification will be able to:

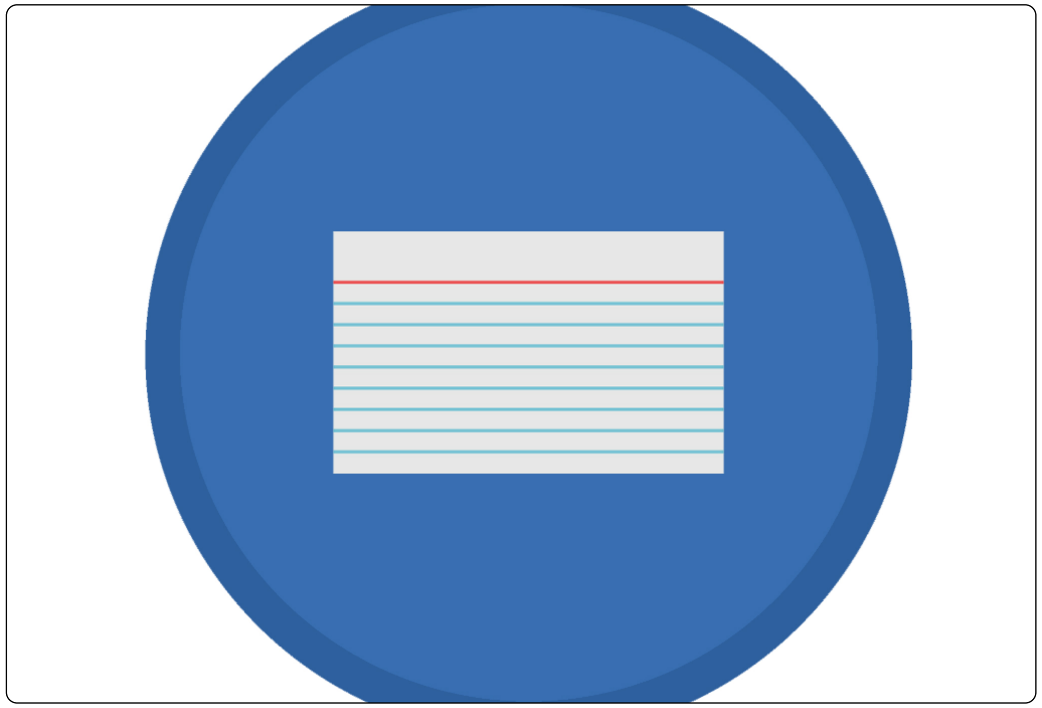
1. Receive products
2. Stock products
3. Process product orders
4. Prepare packages for shipment and ship products
5. Maintain control of inventory
6. Handle hazardous materials in a safe manner
7. Perform dispatch, routing and tracking operations
8. Understand U.S. measurements and metric system conversions

On the following pages you will find practice material to help you review the terminology covered in the CLT assessments. Earning your CLT is the first step in becoming the next 21st century industry athlete!

Review 2.1 Question Is . . . Round 1 (CLA-1)

Tap to test your knowledge.

Review 2.2 Flash Cards 1 (CLA-2)

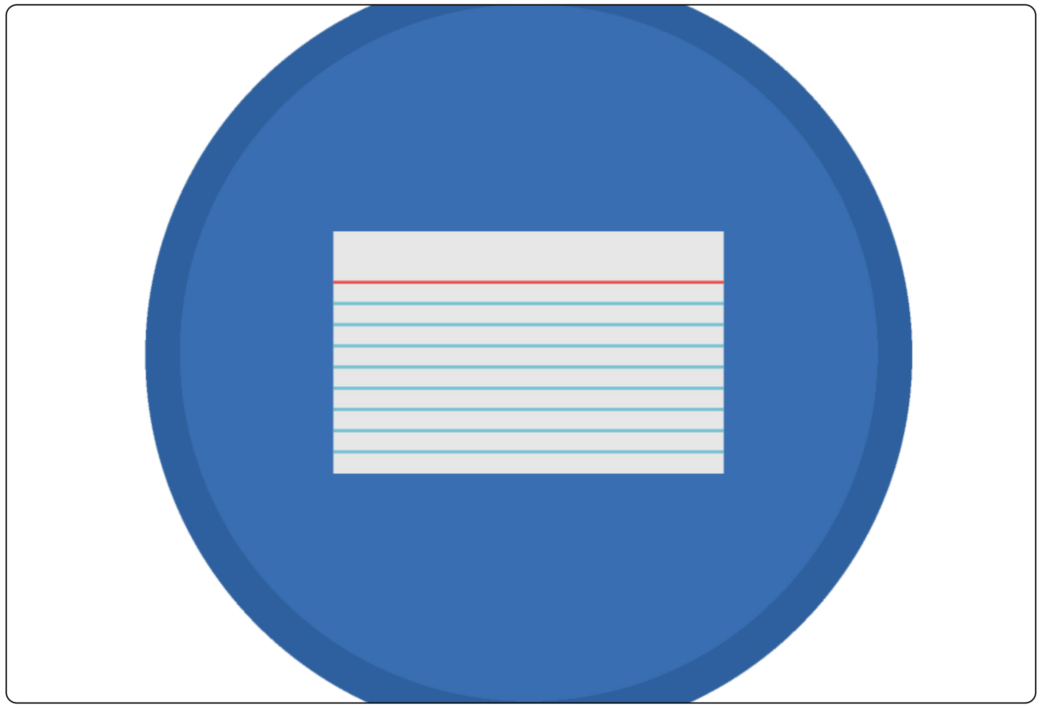


Tap to test your knowledge.

Review 2.3 Question Is . . . Round 2 (CLA-3)

Tap to test your knowledge.

Review 2.4 Flash Cards 2 (CLA-4)

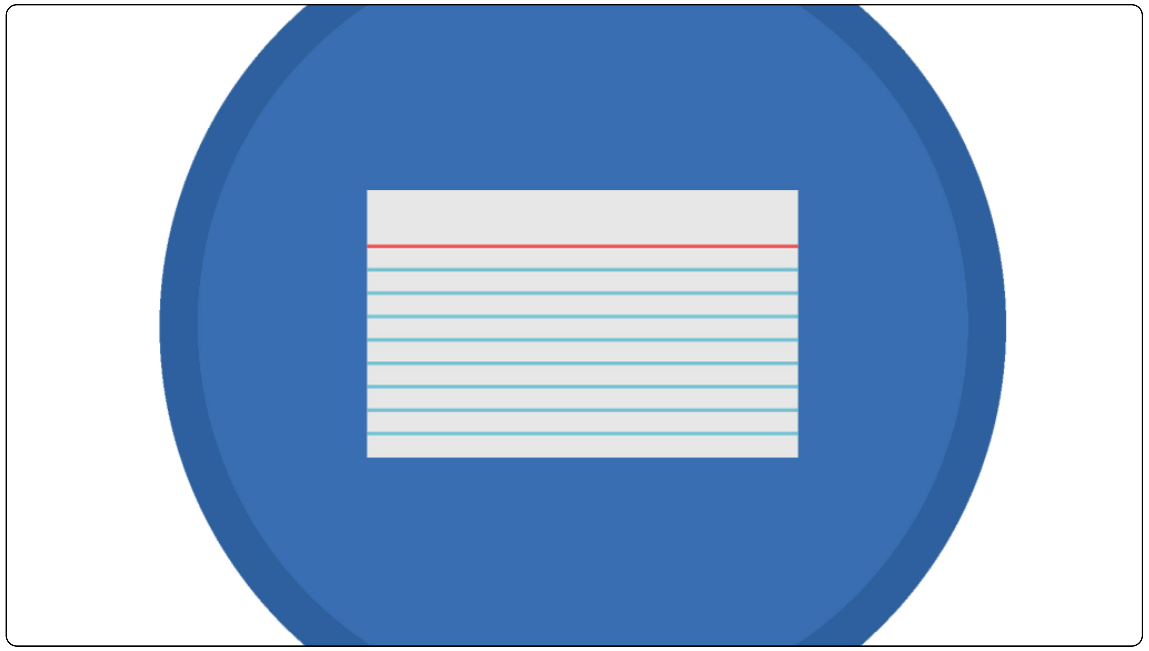


Tap to test your knowledge.

Review 2.5 Question Is . . . Round 3 (CLA-5)

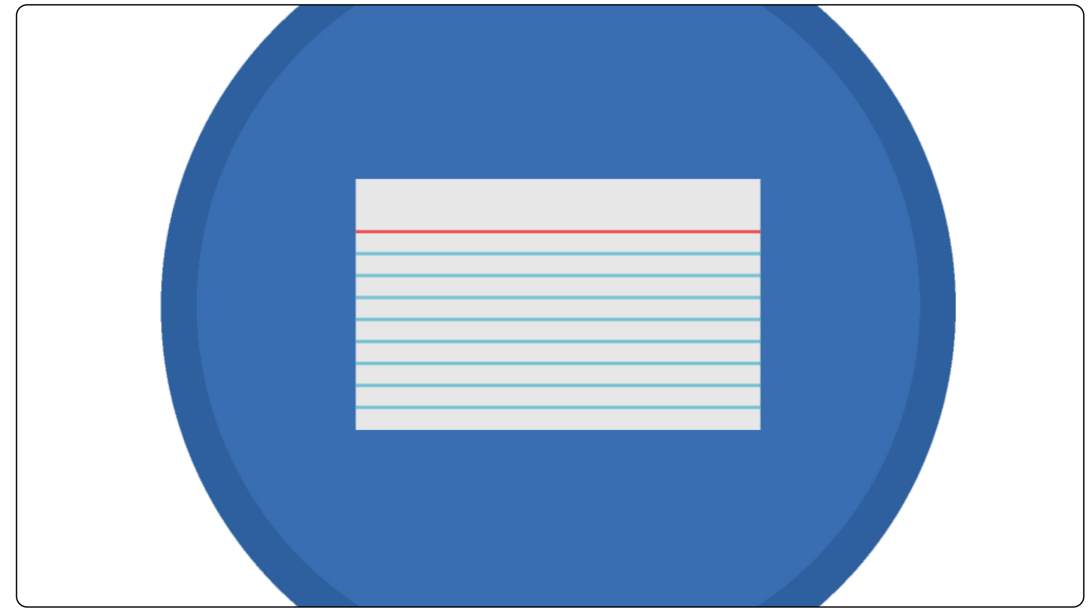
Tap to test your knowledge.

Review 2.6 Flash Cards 3 (CLA-6)



Tap to test your knowledge.

Review 2.8 Flash Cards 4 (CLA-8)



Tap to test your knowledge.

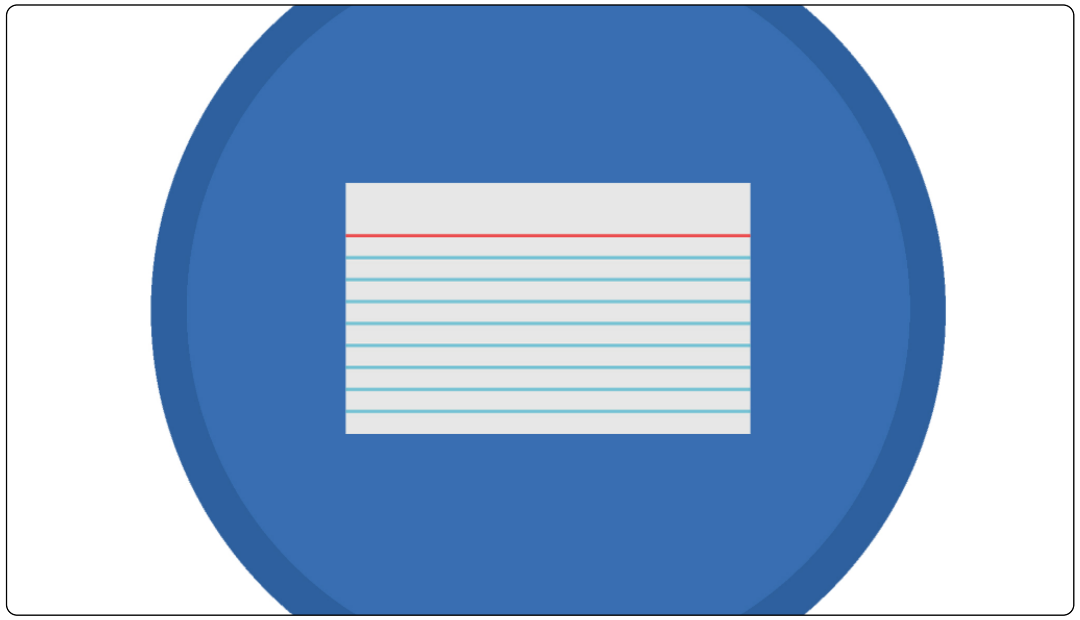
Review 2.7 Question Is . . . Round 4 (CLA-7)

Tap to test your knowledge.

Review 2.9 Question Is . . . Round 5 (CLA-9)

Tap to test your knowledge.

Review 2.10 Flash Cards 5 (CLT-2)

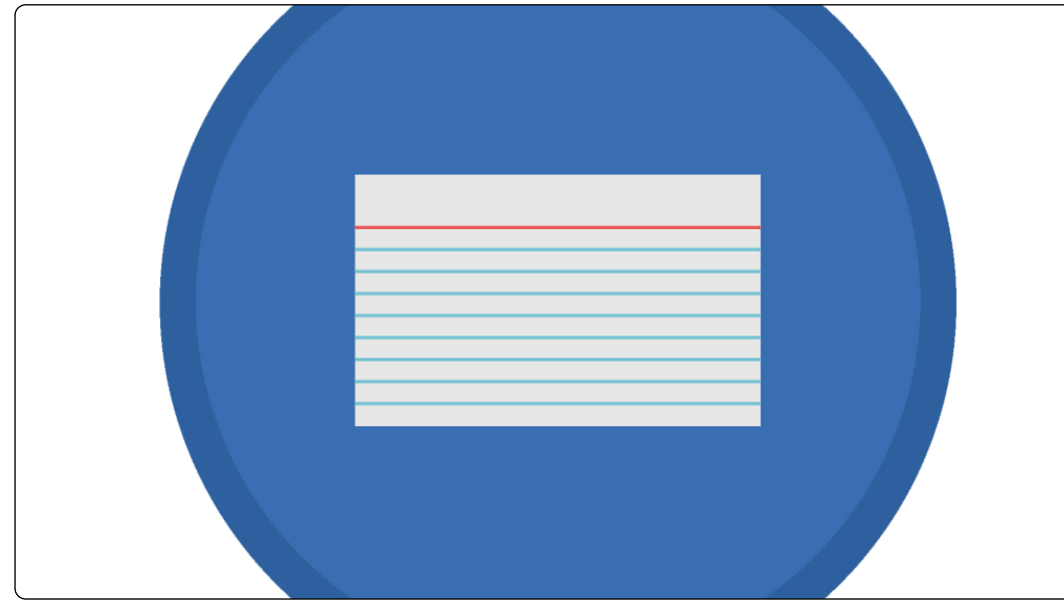


Tap to test your knowledge.

Review 2.11 Question Is . . . Round 6 (CLT-Comprehensive Final Round)

Tap to test your knowledge.

Review 2.12 Flash Cards 6 (CLT-4)

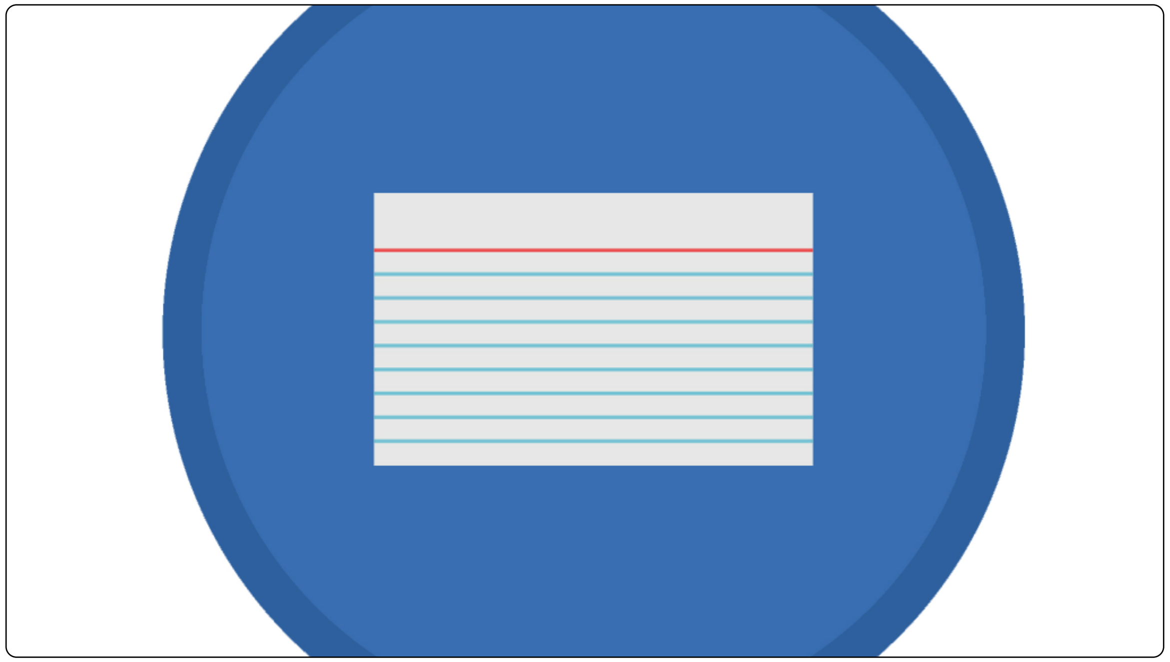


Tap to test your knowledge.

Review 2.13 Question Is . . . Round 7 (CLT-Comprehensive Round 1)

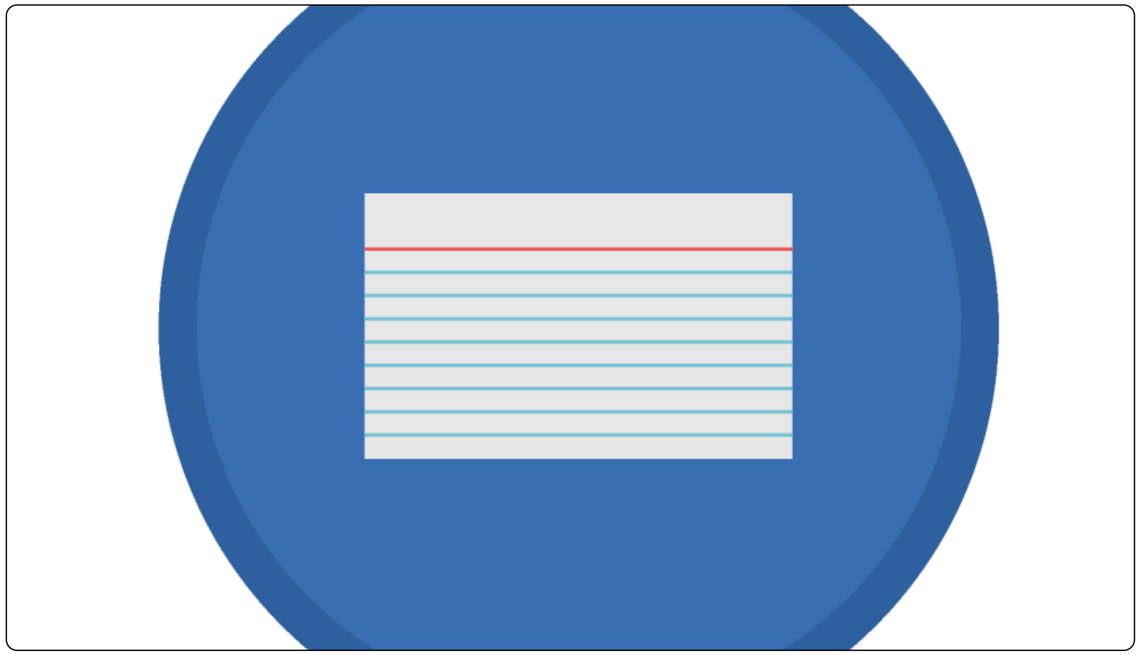
Tap to test your knowledge.

Review 2.14 Flash Cards 7 (CLT-6)



Tap to test your knowledge.

Review 2.15 Flash Cards 8 (CLT-8)



Tap to test your knowledge.

Chapter 3

Supply Chain Principles

This chapter will give you an overview of the supply chain, how the many components of the chain work together, and give you an opportunity to review several case studies to help you better understand our nation's supply chain.

Section 1

Supply Chain Principles

What is a Supply Chain?

One definition for Supply Chain is a network of manufactures, retailers, distributors, transporters, storage facilities, and suppliers that participate in the production, delivery, and sale of a product to the consumer. It is typically made up of multiple companies who coordinate activities to set themselves apart from the competition. Take a few minutes and think about the supply chain needed to sell new automobiles. Now consider the supply chain needed to sell every model by a single automobile manufacturer. Now think about every new car sold! The concept of a supply chain is simple; however, the complexity to make it efficient can be daunting.

What are some examples of a Supply Chain or companies that you know which have a Supply Chain?

Some supply chains are quite small. Think of the local farmer who grows tomatoes and sells them at the Farmers' Market in town. In this example, the Supply Chain goes directly from Grower/Producer to Customer and there isn't a "middle man" in between. However, some supply chains are large, global, complex, and a differentiating factor for organizations. Think of Target and the Supply Chain that is required to keep thousands of stores in stock with the right product at the right time.

The supply chain has 3 major components.

Supply focuses on the raw materials supplied to manufacturing, including how, when, and from what location.

- What are some examples of raw materials? Wood, Plastics, Leather, Cotton, Steel, Milk, Eggs, Flour

Manufacturing focuses on converting these raw materials into finished products.

- What are some examples of Manufacturing? Bakery, Facility where cars are made or goods are produced, Newspaper printing facility

Distribution focuses on ensuring these products reach the consumers through an organized network of distributors, warehouses, and retailers.

- What are some examples of Companies that have Distribution Centers nationwide? Wal-Mart, Target, Amazon, Barnes and Noble, Home Depot

While often applied to manufacturing and consumer products, a supply chain can also be used to show how several processes supply one another. The definition in this sense can apply to Internet technology, finance, and many other industries.   Take a few minutes and try to identify a process that isn't needed in some supply chain.

History of Supply Chain

In ancient times, transportation technology was basic and the cost of moving goods was an important determinant of the production and distribution of a product. Thus, goods were put together close to the source of raw materials. Then, these products made their way in a largely linear chain to their end consumer.

Ancient trade routes like the Silk Road through Central Asia and the Spice Route over the Indian Ocean were mostly linear chains that took a finished product to its ultimate destination. Moreover, given the high costs, long-distance trade was limited to high-value items such as spices, weapons and luxury goods.

It was only in the 18th century that shipping technology improved enough to allow the large-scale functioning of an international production network. Interestingly, the first product to be put together with a truly global supply network was rum. Slave labor was imported from West Africa to the Caribbean in order to grow sugarcane (a plant originally from India). Sugarcane molasses was then shipped to New England where distilleries in Massachusetts, Rhode Island and Staten Island turned it into rum.

All of these changes were complimented by improvements in ship design and, by the mid-19th century, the introduction of steamships. As a result of all of these innovations, a global supply network emerged that involved shipping cotton grown in the southern United States to the cotton mills in England. The finished cloth was then shipped out to the rest of the world.

Over the next century, transportation technology witnessed major breakthroughs that included the railways, trams, bicycles and the Suez Canal. By the time of World War I, we also had the Panama Canal, automobiles and even early airplanes. As a result, the cost of transporting goods dropped sharply. Ocean freight rates, for instance, fell 70% between 1840 and 1910.

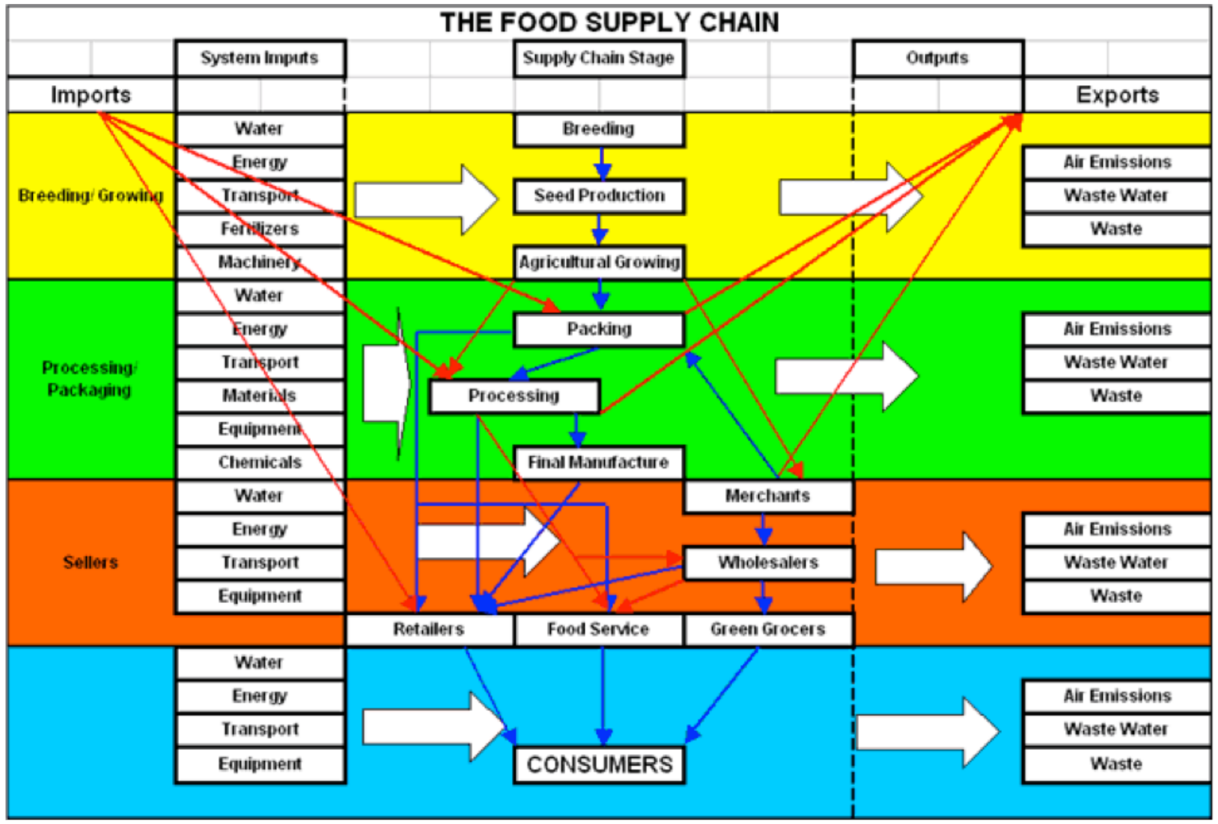
The Second World War witnessed the pinnacle of the Fordist production system. By 1950s, a new generation of technological changes began to alter the structure of global supply networks.

The combination of containerization (the loading of goods into Ocean Containers for transport) and telephones (and related technologies like the fax) caused the next shift in supply networks. Improved communications meant that it was possible to exactly specify components and products. Containerization meant that these components could be transported cheaply and be delivered "just-in-time."

Meanwhile, the efficiency gains of "just-in-time" and lean production were making their way downstream and being applied to distribution networks. One of the results of this change was the rise of hyper-markets like Walmart and Carrefour. By leveraging scale, logistics and lean inventories, they were able to bring down retail prices as well as provide consumers with unprecedented choice. It is very clear that the supply chain has become increasingly complex over the years. Think about today's supermarkets and unwind the retail progression. Before we had supermarkets we had standalone bakeries, meat markets, produce stands, bread trucks and milk men that delivered dairy products to your door. Now think about Super Target and Super Walmart and try to understand the retail progression that is taking place today. What's next?

Simple Supply Chain Example

Complex Supply Chain Example



Tap to zoom.

Distribution Center

Has anyone toured, worked in or known anyone who works in a Distribution Center?

A distribution center for a set of products is a warehouse or other specialized building which is stocked with products (goods) to be redistributed to retailers, to wholesalers, or directly to consumers. A distribution center is a principal part, the order processing element, of the entire order fulfillment process. Distribution centers are usually thought of as being demand-driven. A distribution center can also be called a warehouse, a DC, a fulfillment center, a cross-dock facility, a bulk break center, and a package handling center. The name by which the distribution center is known is commonly based on the purpose of the operation. For example a "retail distribution center" normally distributes goods to retail stores, an "order fulfillment center" commonly distributes goods directly to consumers, and a cross-dock facility stores little or no product, but distributes goods to other destinations.

Distribution centers are the foundation of a supply network, as they allow a single location to stock a vast number of products. Some organizations operate both retail distribution and direct-to-consumer out of a single facility, sharing space, equipment, labor resources, and inventory as applicable.

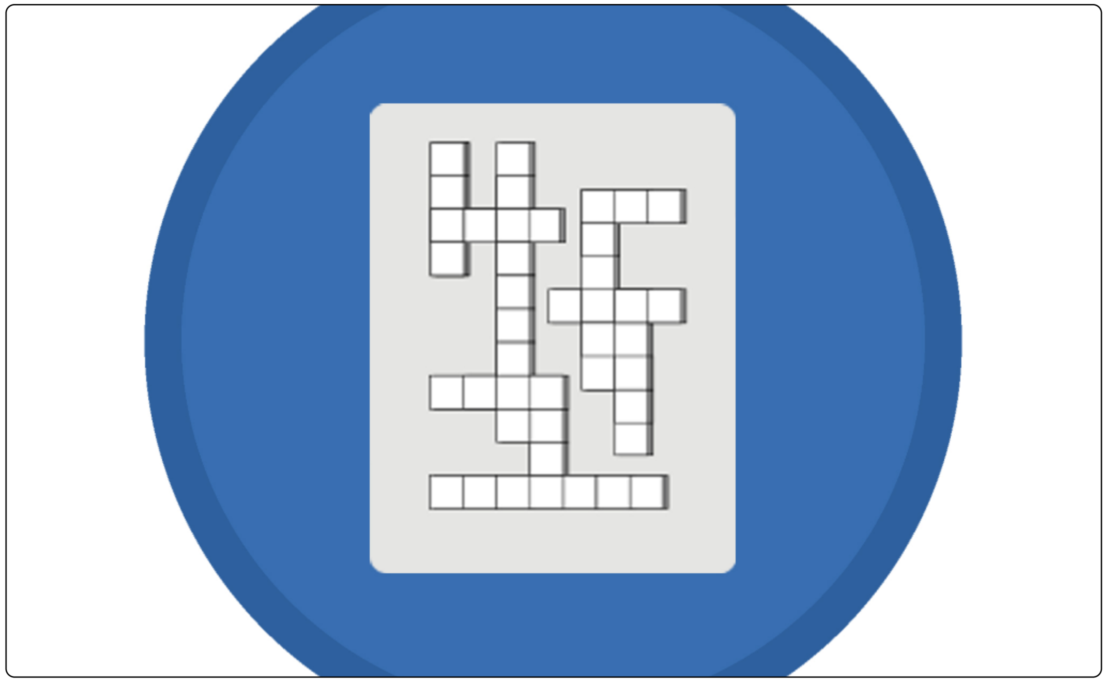
A typical retail distribution network operates with centers set up throughout a commercial market, with each center serving a number of stores. Large distribution centers for companies such as Wal-Mart serve 50–125 stores. Suppliers ship truckloads of products to the distribution center. The distribution center stores the product until needed by the retail location, then ships the proper quantity.

Since a large retailer might sell tens of thousands of products from thousands of vendors, it would be impossibly inefficient to ship each product directly from each vendor to each store. Many retailers own and run their own distribution networks, while smaller retailers may outsource this function to dedicated logistics firms that coordinate the distribution of products for a number of companies. A distribution center can be co-located at a logistics center.

Movie 3.1 Amazon Distribution Center

Tap to view a video

Review 3.1 Supply Chain Principles Crossword Puzzle



Tap to complete a crossword puzzle about supply chain principles.

Chapter 4

Safety

This chapter will explain the importance of safety in the automated warehouse and give you an opportunity to test your knowledge of safety best practices.

Section 1

Safety Planning, Accountability and Reporting

A safety poster keeps safety on the mind of all employees in a distribution center. The constant reminder is a proven method of controlling accidents.

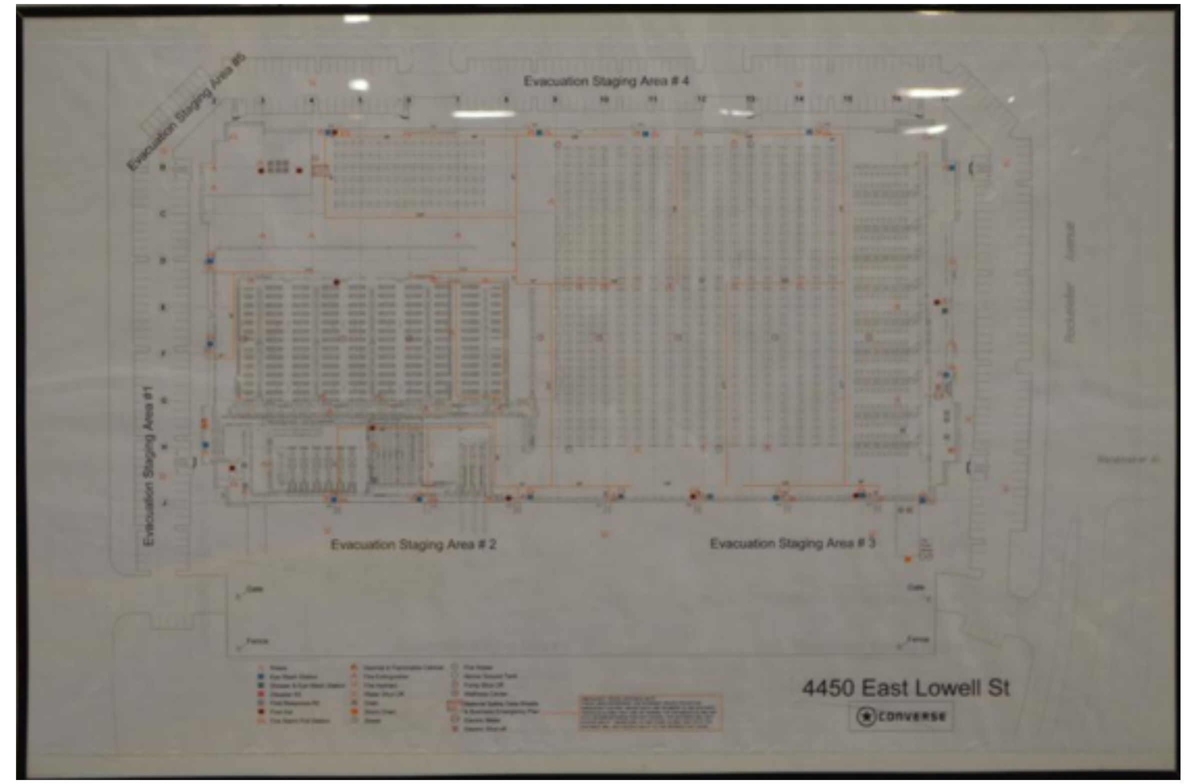
Working safely is the most important aspect of the working environment. Knowing the hazards and concerns of the workplace are a major part of all operations and tasks. Planning the task and identifying the hazards prior to the start of a project will minimize risk and make for a more efficient job completion. Documentation of the safety processes and activities are required for all employees and standardized forms need to be used. The complete and timely reporting of concerns is very important to expedite correction and eliminate future concerns.

Emergency Plan

Natural disasters and problems within the facility have to be planned for and practiced to make sure measures are taken to protect personnel and facilities. The overall crisis management plan must contain areas of responsibility, staging areas, personnel teams, and communication with inside and outside contacts and in most cases, security departments.

Evacuation Plan

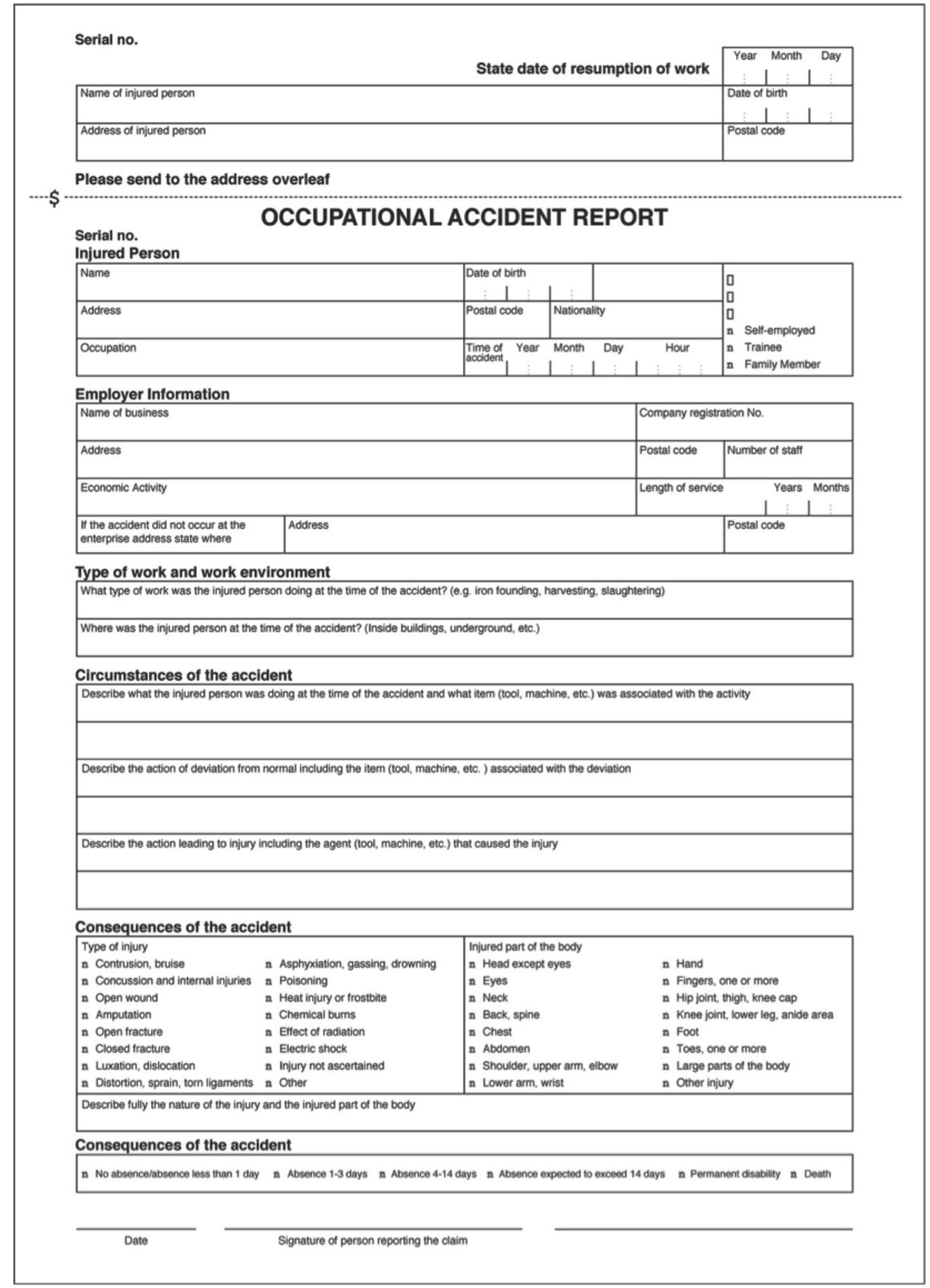
The written evacuation plan is a document that is posted so all employees have access to the information and understand where to go to exit the facility in a quick and safe manner. Included will be staging areas and people responsible for each group of people exiting the facility.



Evacuation plan that is posted on the wall at the entrance to a distribution center. It shows the current location and the escape route.

Injury Plan and Report Form

Recordkeeping is very important to create documentation of any injuries that take place during an incident. Procedures and common forms are used to create consistency in the process and to verify that all required information has been included. Input from everyone involved is also very important so interviews and fact finding will be done. This process needs to be completed as soon as it is practical.



Serial no.

State date of resumption of work — Year / Month / Day

Name of injured person | Date of birth

Address of injured person | Postal code

Please send to the address overleaf

$

OCCUPATIONAL ACCIDENT REPORT

Serial no.

Injured Person

Name | Date of birth

Address | Postal code | Nationality

Occupation | Time of accident — Year / Month / Day / Hour

n Self-employed
n Trainee
n Family Member

Employer Information

Name of business | Company registration No.

Address | Postal code | Number of staff

Economic Activity | Length of service — Years / Months

If the accident did not occur at the enterprise address state where | Address | Postal code

Type of work and work environment

What type of work was the injured person doing at the time of the accident? (e.g. iron founding, harvesting, slaughtering)

Where was the injured person at the time of the accident? (Inside buildings, underground, etc.)

Circumstances of the accident

Describe what the injured person was doing at the time of the accident and what item (tool, machine, etc.) was associated with the activity

Describe the action of deviation from normal including the item (tool, machine, etc.) associated with the deviation

Describe the action leading to injury including the agent (tool, machine, etc.) that caused the injury

Consequences of the accident

Type of injury		Injured part of the body	
n Contrusion, bruise	n Asphyxiation, gassing, drowning	n Head except eyes	n Hand
n Concussion and internal injuries	n Poisoning	n Eyes	n Fingers, one or more
n Open wound	n Heat injury or frostbite	n Neck	n Hip joint, thigh, knee cap
n Amputation	n Chemical burns	n Back, spine	n Knee joint, lower leg, anide area
n Open fracture	n Effect of radiation	n Chest	n Foot
n Closed fracture	n Electric shock	n Abdomen	n Toes, one or more
n Luxation, dislocation	n Injury not ascertained	n Shoulder, upper arm, elbow	n Large parts of the body
n Distortion, sprain, torn ligaments	n Other	n Lower arm, wrist	n Other injury

Describe fully the nature of the injury and the injured part of the body

Consequences of the accident

n No absence/absence less than 1 day n Absence 1-3 days n Absence 4-14 days n Absence expected to exceed 14 days n Permanent disability n Death

Date

Signature of person reporting the claim

Occupational accident report form that is used to account for and standardize the collected information.

Incident Reporting

Incident Reporting is the overall collection of information on an incident that has an effect on personnel, equipment or deliverables. The process includes accident reporting, statement forms, equipment review forms and property damage reports. This documentation allows for fact finding and planning for changes to operational processes to eliminate the problems in the future.

Accident /Incident Report and Investigation Form

Directions: Complete sections 1, 2, and 3 for all accidents and incidents. Accidents or incidents that require medical attention or lost or restricted work require the signature of the Divisional Vice President. Attach additional sheets as necessary. Send competed forms to the Director Of Human Resources.

1. EMPLOYEE INFORMATION

Name: ____________________ (First MI Last) **Social Security #** ___-___-___

Dept.: ____________________ **Job Title:** ____________________

Full Time ☐ **Part Time** ☐ **Student worker** ☐ **Other** ☐ ____________

2. ACCIDENT/ INCIDENT INFORMATION

Date of incident: ___/___/___ **Location:** ____________________

Time of incident ________ **AM/PM** **Time Employee began work** ________ **AM/PM**

☐ Check if time cannot be determined

Types of incident (check all that apply) ☐ **Accident** ☐ **Injury** ☐ **Illness** ☐ **Other** ____________

What was the employee doing just before the incident occurred? Describe the activity as well as the tools, equipment or materials the employee was using just before the incident.

____

What happened? Describe the incident. ____________________

Accident/Incident report and investigation report form is used for the collection of information from an incident that may be for equipment or process failures. They can also be a follow up to an injury report.

Section 2

Codes and Standards

Safety is the concern of all employees and maintenance technicians working within a distribution center. The best way to establish a safe working environment is to create codes and standards that can be applied and documented for consistent approaches in the workplace. These standards and codes can be local and apply to a single facility and established by the company or they may be established by national, state or local organizations of which all companies must comply. Most employers will use a combination of codes and standards that are both local and specific to a facility and yet meet the federal and state requirements.

Occupational Safety and Health Administration (OSHA)

OSHA website and logo

The Occupational Safety and Health Administration is the most comprehensive and recognized federal agency that deals with all aspects of workplace safety. The regulations they provide are the standards and codes that are the most widespread in use and most other regulatory organizations must abide by their requirements. They are the minimum standards established for all safety concerns and apply to all areas of industry workplaces. State and local agencies can require more complete and comprehensive standards.

American National Standards Institute (ANSI)

The American National Standards Institute is an organization that is a clearinghouse for guidelines to create conformity to enhance the competitiveness and safety within the global markets for US companies. Technical organizations create and recommend the standards which are then approved and co-published for use by all related industries. This allows for consistency and compatibility between products and guarantees quality. The American National Standards Institute is also the organization that represents US interests in the International Organization for Standardization that does the same work internationally.

ANSI logo

US Department of Transportation (USDOT)

The Department of Transportation has the responsibility of creating and enforcing the transportation regulations that are used to establish and improve the transportation system as it applies to health and safety. The application to distribution centers is that all goods are moved to and from the center by ship, rail, or truck, all of which must meet or exceed DOT standards. These standards produce a safe and healthy environment for everyone and consistency in requirements nationally.

US Department of Transportation (USDOT) logo

Section 3

Emergency Shut Off Devices

Electrical and mechanical devices in the distribution center will all have some sort of emergency shut off device. They range from electrical controls for panels to mechanical/electrical emergency stops on equipment. Some of the stops are automated using sensors to automatically stop operations. These stops are required and are located so as to provide direct access for employees.

Interactive 4.1 Emergency Shut Off Devices

Tap to view multiple images.

Section 4

Personal Protection Equipment

Personal Protection Equipment (PPE) is required whenever a working environment cannot be developed in such a way that creates a safe working condition for employees. These issues include any time an employee is put at personal risk of injury because of a situation requiring clothing, helmets, shoes, hearing, eyes, falling or hand and arm protection above normal dress and conditions. Some applications can also include chemical and electrical hazards that require specialty PPE.

Personal protection equipment used for battery service on lift trucks in a distribution center

Eye and Face

Safety Glasses

Safety glasses are the most common safety device used extensively in the working environment. They protect the eyes from liquid, particulate and impact damage. They are normally clear and made of a plastic lens and frame. Tinted lenses are used for outdoor use or in a light emitting area. In extreme applications such as chemical exposure, goggles may be required. Designs differ, but regulations dictate the protection in each type of application.

Face Shields

Face shields are required for both protection and comfort when the environment is more hazardous and safety glasses will not be adequate. They are normally a plastic lens mounted to a head band that covers the entire face and neck to protect the user from impact and particulate intrusion. They can be tinted for use when bright light is a concern. They can also be used with safety glasses to improve facial comfort and protection. Eye wash stations must be in all areas where specific risks such as chemicals are present.

Interactive 4.2 Personal Protection Equipment

Tap image to learn more about personal protection equipment.

Respiration Protection

Inhalation of hazardous gases or particles is especially damaging. The use of a respirator when at risk is a requirement. Respirators vary based on the materials and conditions under which the concern exists. They are worn to eliminate dust, liquid particulates, airborne chemicals and gases. The selection process for the type of device and the cartridges used is critical to a safe application.

Head Protection

Head protection (hard hat) is worn where a possibility of falling objects, electrical shock, flying items or bumping of the head puts the worker at risk for injury. Hard Hats are normally made of a plastic or composite material with suspension liners that distribute the impact so injury doesn't occur. Different classifications exist for determining the correct protection for the work environment. Another known value for requiring the use of head protection is that most workers see a commitment to safety by the employer and safety becomes a normal part of their job.

Hearing Protection

Hearing protection prevents initial occupational hearing loss, preserves and protects remaining hearing, and equips workers with the knowledge and hearing protection devices necessary to safeguard themselves. Employers are required to measure noise levels, monitor employees' hearing, and provide hearing protection and training. Research indicates that workplaces with appropriate and effective hearing protection programs have higher levels of worker productivity and a lower incidence of absenteeism.

Feet

Protecting feet during the performance of a task will require a level of footwear that is appropriate to the activity. Impact protection, slip resistance, foot support, chemical resistance and comfort are all part of the selection process. The most common requirement for safety shoes is for protection from impact or falling items. Working in an area of heavy materials and potential dropping or displacement of items requires a steel or composite toed shoe or boot for this type of protection.

Hands

Hand protection is usually in the form of gloves. Protection can be for chemicals, cuts, abrasions, heat, electricity and many additional risks. The selection of the proper gloves for the task is critical for the safety of the employee and may be influenced by the need for dexterity and protection.

Section 5

Hazardous Materials

Handling of hazardous materials in the workplace is the responsibility of employees and management. All authorized, qualified and competent people need to be trained in the laws, procedures and processes for the safe handling of materials to minimize accidents. The discarding of materials is controlled and monitored to address the issues within the environment.

Hazardous materials must be isolated, identified and contained. Secondary containment is normally provided to be sure no leakage is possible.

Hazardous Material Identification System (HMIS)

The Hazardous Material Identification System is a numerical rating that incorporates the use of labels with color-coded diamonds to define the type of hazard that is present and the degree of risk; the higher the number, the greater the risk. The four bars are used as symbols to identify different hazards: blue for health issues, red for flammability or fire issues, orange for physical hazards and white for personal protection. Each area includes a number system, ranging from 0-4, to identify the degree of risk.

Hazardous Material Identification System poster identifies the type of hazardous material so appropriate precautions can be taken. All materials must be identified. www.nfpa.org

Material Safety Data Sheets

All hazardous materials must be properly labeled, and information about each material must be posted on a Material Safety Data Sheet (MSDS). The sheet must include identification, and all chemical and physical properties, protective handling, explosive/fire hazard, incompatibility issues, health and medical issues, handling guidelines and spill/leak procedures. The sheets must be available at an easily accessed location for employees, safety officials and fire departments.

Material Safety Data Sheets are available for employee and public access for emergency responders and are normally kept in a binder for easy updating and changing.

MATERIAL SAFETY DATA SHEET
Metal Cleaner

Page: 1

HEALTH	3
FLAMMABILITY	1
PHYSICAL HAZ.	1
PPE	n

Revision: 11/27/1996

Printed: 12/01/2003
Date Created: 12/09/1996

1. Product and Company Identification

Product Code: DX579
Product Name: Metal Cleaner
Manufacturer Name and Address
Company Name: PPG Industries, Inc.
4325 Rosanna Drive
P.O. Box 9
Allison Park, PA 15101
Emergency Contact 1 Emergency Medical/Spill Info: (304)842-1300
Information Contact Technical Information (614)363-9610
Chemical Family: ACID

2. Composition/Information on Ingredients

Hazardous Components (Chemical Name)	CAS #	Percentage	OSHA TWA	ACGIH TWA	Other Limits
1. Ethanol, 2-Butoxy-	111-76-2	10.0 - 20.0 %	(S) 25 ppm	(S) 25 ppm	No data.
2. Diethylene glycol monobutyl ether	112-34-5	10.0 - 20.0 %	Not Estab.	Not Estab.	No data.
3. Phosphoric acid	7664-38-2	30.0 - 40.0 %	1 mg/m3	1 mg/m3	No data.

3. Hazards Identification

Emergency Overview
Harmful or fatal if swallowed. May be corrosive. This product contains a material which causes skin burns. This product contains a material which causes irreversible eye damage. May be harmful if absorbed through the skin. Vapor and/or spray mist harmful if inhaled. Vapor irritates eyes, nose, and throat. Vapor generated at elevated temperatures irritates eyes, nose, and throat.

Route(s) of Entry: Inhalation? No Skin? No Eyes? No Ingestion? No
Potential Health Effects (Acute and Chronic)

INGESTION: Harmful or fatal if swallowed.

EYE CONTACT: This product contains a material which causes irreversible eye damage.

SKIN CONTACT: May be corrosive. This product contains a material which causes skin burns. May be harmful if absorbed throught the skin.

INHALATION: Vapor and/or spray mist harmful if inhaled. Vapor irritants eyes, nose, and throat. Vapor generated at elevated temperatures irritates the eyes, nose, and throat. Repeated exposure to high vapor concentrations may cause irritation of the respiratory system and permanent brain and nervous system damage.

CHRONIC OVEREXPOSURE: Avoid long-term and repeated contact. This product contains an ethylene series glycol ether and/or acetate which has been shown to cause adverse effects on the kidneys, lever, blood and/or blood-forming tissue. This product contains diethylene glycol monobutyl ehter (DEGBE). DEGBE consumed in drinking water at low levels by rats for 30 days caused injury to either the liver, kidney, spleen, or testes.

 ANSI Format

Individual MSDSs include standardized information that is important to employee health, risks and emergency responders handling accidents or applying procedures.

Handling and Disposal

Proper handling and disposal of hazardous materials is the responsibility of all employees. Handling guidelines or regulations should be in place and everyone should abide by the processes. In many situations, outside venders are used for the disposal process since they are normally licensed, insured and better informed of the proper handling processes.

Section 6

Technician Safety

Lockouts and Tagouts

Lockouts and tagouts are a technique used to prevent operation or access to an area while maintenance or repairs are being done on facilities or equipment. Lockout is the placement of a lock or control device or can mean physically disconnecting the source of power. Tagout is the placement of a tag that informs people that the area or equipment is not to be activated, but it is not a physical barrier to use. Normally, the person activating the lockout/tagout should be the only person to remove the lock or tag and place the area or equipment back in service.

Fall Protection

Falls are among the most common causes of serious work related injuries and deaths. Employers must set up the work place to prevent employees from falling off of overhead platforms, elevated work stations or into holes in the floor and walls. OSHA requires that fall protection be provided at elevations of four feet or greater in general industry workplaces. In addition, OSHA requires that fall protection be provided when working over dangerous equipment and machinery, regardless of the fall distance.

Fall Arrest Systems

A personal fall arrest system is one option of protection that OSHA requires for workers in sites who are exposed to vertical drops of 6 feet or more. These systems can include lanyards, deceleration devices, harnesses and anchorage points. The systems vary with application, but all accomplish the same task of controlling a personal fall. In the distribution center, workers picking materials on lift equipment will be using harnesses and deceleration devices.

Guardrails

At any point with a drop of three feet or more, a guardrail is required. They are used as a safety device to stop a person from falling off a platform, steps or walkways. They are 42 inches in height depending on the application and must be solidly fastened to the base.

Interactive 4.3 Technician Safety Images

Tap to view images.

Section 7

Fire Safety and Prevention

Fire safety is the primary concern of most safety managers in the industrial setting. The development of fire safety training and a comprehensive plan is the responsibility of all employees and must be followed. Steps must be taken to prevent an environment where fire can start and propagate throughout a facility. An organized plan with good housekeeping at the forefront will minimize the possibility of a loss.

www.osha.gov/SLTC/firesafety/

Fire hoses are positioned around the distribution center to fight a fire if needed.

National Fire Protection Association (NFPA)

The National Fire Protection Association creates and distributes codes and standards to help minimize the risks of fire. Building materials, sprinkler systems, wall coverings, accessibility and item storage are a few areas addressed in the guidelines.

www.nfpa.org

Fire Types

The four types of fires are listed below:

1. Class A, general combustibles
2. Class B, flammable liquids
3. Class C, electrical fires
4. Class D, flammable metals (magnesium, aluminum oxide, sodium)

Types of Extinguishers

The three basic types are listed below:

1. Water, used on class A fires
2. Carbon Dioxide, used on all types but best on class B and C
3. Dry Chemical, used on A, B and C fires

Fire Safety Plan

The implementation of a Fire Safety Plan helps to assure effective utilization of life safety features in a building, to protect people from fire. The required Fire Safety Plan should be designed to suit the resources of each individual building or complex of buildings. Fire Safety Plans are intended to assist the facility with the basic essentials for the safety of all occupants, to ensure an orderly evacuation at the time of an emergency and to provide a maximum degree of flexibility to achieve the necessary fire safety for the building. The fire safety plan shall be reviewed as often as necessary, but at intervals not greater than 12 months, to ensure that it takes into account changes in the use and other characteristics of the building.

Dry chemical fire extinguisher for use on A, B or C fires. An employee may not use a fire extinguisher unless trained on its proper use by the employing company.

First Aid

Wall-mounted first aid kits are located throughout the distribution center.

First Aid and Emergency Medical Procedures

First aid is the providing of emergency care to an injured person to stabilize the injury before professional help arrives. A first aid plan or an emergency plan should be established and published so every employee knows the plan and how to implement it. Training and retraining are an important part of the plan and should be done on a regularly scheduled basis. It is a requirement of OSHA that employees be given a safe and healthy workplace that is reasonably free of occupational hazards. However, it is unrealistic to expect accidents not to happen. Therefore, employers are required to provide medical and first aid personnel and supplies commensurate with the hazards of the workplace. The details of a workplace medical and first aid program are dependent on the circumstances of each workplace and employer.

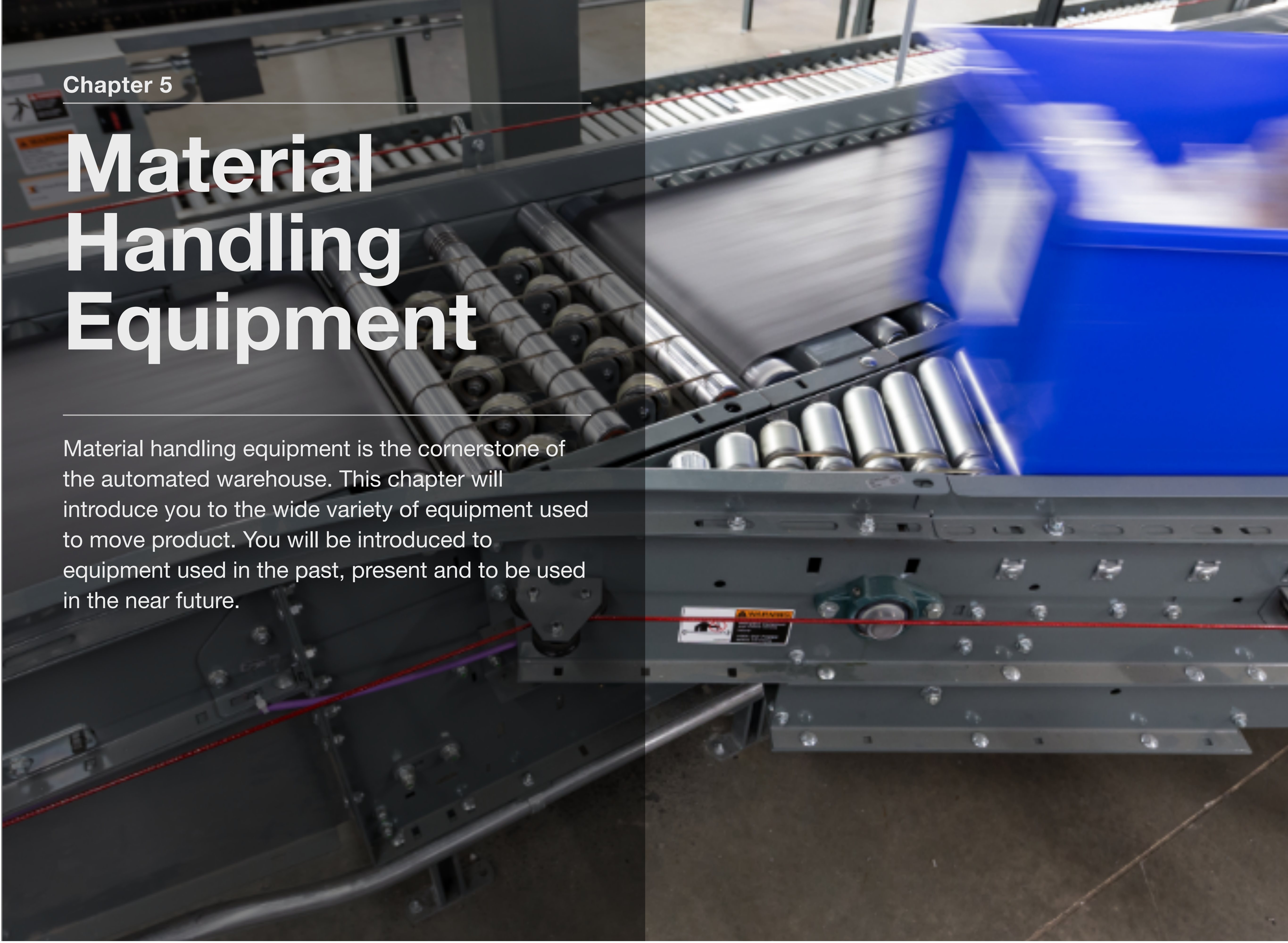
First Aid Kit Locations

Materials needed to provide first aid are normally in kits that would be distributed throughout the facility to allow for quick and easy access by employees. The medical supplies would be based on the needs for the types of activities that take place in the facility and can be simple or comprehensive. The kits are purchased from approved venders to meet local requirements and special needs in the facility. Kits must be refilled if supplies are used.

Chapter 5

Material Handling Equipment

Material handling equipment is the cornerstone of the automated warehouse. This chapter will introduce you to the wide variety of equipment used to move product. You will be introduced to equipment used in the past, present and to be used in the near future.



Section 1

Material Handling Equipment Overview

Material handling equipment (MHE) is equipment related to the movement, storage, control and protection of materials, goods and products throughout the processes of manufacturing, distribution, consumption and disposal. MHE is divided into the following areas within the supply chain:

Storage and Handling Equipment

Storage and handling equipment is usually non-automated storage equipment. Products such as pallet racking, shelving and carts belong to storage and handling.

Pallet Racking

Engineered Systems

Engineered systems are typically custom engineered material handling systems. Conveyors, robots, AS/RS, AGV and most other automated material handling systems are examples. Engineered systems are often a combination of products integrated into one system with common software. Many distribution centers optimize operations by using engineered systems such as pick modules and sortation systems.

Interactive 3.1 Engineered Systems Examples

Tap to view images.

Industrial trucks

Industrial trucks usually refer to operator driven motorized warehouse vehicles, powered manually, by gasoline, propane or electricity. Industrial trucks assist the material handling system with versatility; they can go where engineered systems cannot. Forklifts are the most common example of industrial trucks, but aren't the only examples. Their greatest advantage lies in the wide range of attachments available; these increase the trucks' ability to handle various types and shapes of material. OSHA requires industrial truck drivers be trained on them by the company by which they are employed.

Forklifts are the most common type of industrial truck.

Bulk Material Handling

Bulk material handling equipment is used to move and store bulk materials such as ore, liquids, and cereals. This equipment is often seen on farms, mines, shipyards and refineries. This type of equipment is associated with supply chain movement of products, however is not found inside supply chain facilities.

Cranes for maritime shipping containers

Movie 5.1 Nike Logistics Center

Tap to view the video.

Section 2

Industrial Trucks

A Distribution Center's (DC) purpose is the efficient handling of cartons, either for temporary storage or to trans-load freight from vendors to outbound trucks headed to stores or direct to customers. Similar cartons are frequently palletized for storage and handling, creating loads that are too heavy for lifting without machines, so DCs use forklifts. Different types of lifts are used to accomplish specific functions in the warehouse, such as lifting, transporting, or case picking. A typical DC might have dozens to more than a hundred forklifts, depending on the size of the facility. Even when the DC utilizes a complex automation system for pallet or case storage and handling, forklifts are typically used on the receiving and shipping docks for unloading and loading of pallets. Many DCs still use inexpensive high bay racking and forklifts to store pallets of freight when not needed for shipment.

Electrical Lifts

Electrically-powered lifts are predominantly used within distribution centers. They are quiet, maintain air quality without gas fumes, and can be powered by plug-in recharging. Forklifts are offered in both electrical AC and DC powered drives. They utilize large low voltage, lead acid batteries to provide power, as well as counter-balance the lifts to allow heavy weights on the forks. Characteristics of electrical motors also allow for efficient braking ("plugging") by reversing motor direction. Electrical forklifts are generally only used inside a building and are generally not designed to operate in inclement weather.

Interactive 5.2 Electrical Lifts

Tap to view images.

The batteries of electrical lifts discharge power during operation, requiring periodic replacement or recharging. In larger, multi-shift warehouses, a battery changer permits the storage and recharging of extra batteries, allowing operators to come in through the day and swap batteries. In lower usage facilities, the lift may be plugged in at end of shift to be ready for the next day.

Interactive 5ths Electrical Lift Batteries

Tap to view images.

Standup forklift in use

Standup forklift

A specialty clamp attachment for grabbing a heavy load by the sides

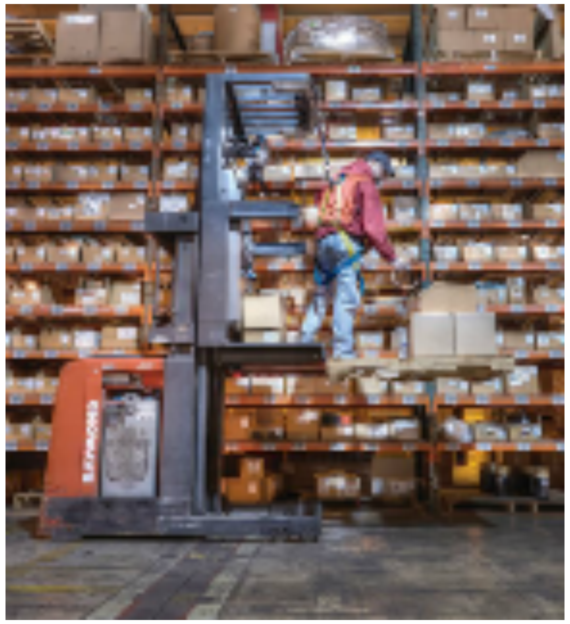
Forklifts

Electric forklifts are the workhorses of the distribution center. They permit quiet, fume-less heavy lifting and moving of pallets within the warehouse. If there was just one type of lift in the warehouse, this would be it. Although they cannot perform all of the necessary functions within the building, they are the most versatile, offering a variety of functions that are used to offload trailers on receiving docks and load trailers at shipping doors. Most trucks can lift individual or stacked pallets by counter-balancing the fork weight with the weight of their electrical batteries. They can be made more versatile with attachments that can clamp cases or pick up slip sheets to efficiently build pallets or layers for efficient storage in the warehouse.

Three views of reach truck operation

Reach truck in use

Order picker



Order picker

Operating the order picker

Reach Trucks

Reach trucks are forklifts with multi-stage masts that lift and lower heavy pallets into high bay storage racking above 30 feet in height. The operator remains at ground level in the compartment, raising the pallet on the forks up into the air above the lift. The operator uses a multi-function handle to extend the forks into the racking, shift the pallet horizontally to position it, or tilt the pallet to place pallet runners on rack beams. Reach trucks allow storage rack heights that allow efficient use of vertical space within the warehouse.

Reach truck

Turret/swing-reach truck

Order Pickers

An order picker is a powered lift that raises the operator in a compartment up to the level of pallets in high bay racking storage so that they can remove individual cases to fulfill less-than-pallet quantity orders. Individual cases are placed on pallets or carts that rest on forks at the back of the operator compartment. Operators can vary their height repeatedly through a rack aisle to pick numerous orders. Operators can individually steer the lift, or engage wire guidance systems in the floor (frequently used in very narrow aisle configurations).

Receiver using pallet jack

Turret/Swing-Reach Trucks

Turret trucks are hybrid lifts that combine characteristics of reach and order picker lifts, and put away or pick pallets inside very narrow aisle storage racking. The operator raises himself (in a compartment) and the pallet into the air to the desired put-away level. They swing the forks 90 degrees from direction of travel, and extend the pallet into the racking. Turret trucks allow rack aisles of smaller width by reducing pivot radii for the lifts. This allows denser utilization within rack storage areas. Turret trucks are very large and heavy, and take multiple batteries to provide necessary weight to counterbalance the heavier weights placed on the mast sections.

Tugger with flat carts

Train of cage carts

Pallet Trucks/Jacks

Forklift outdoor use

Powered pallet jacks (also known as electric pallet trucks, "walkies," or single/double/triple pallet riders are lifts that move individual or stacked pallets between different areas in a distribution center. The operator drives the forks into slots inside the pallets, raises the forks off the ground, and moves the pallet to a desired drop-off point. Pallet trucks are less costly than forklifts, and capable of more efficiently moving heavy pallet loads between receiving docks, storage areas, and shipping doors.

Forklift operator (gas powered)

Propane forklift in use

Transfer Tugs

Tuggers are the simplest types of powered lifts. They are used to tow “trains” of cage or flat carts for cost-efficient transportation of individual cases between areas within the warehouse. They can be used to pick individual orders at ground level, but are more frequently used to gather and move carts used by order pickers to fulfill numerous individual orders.

Articulating boom lift in use

Gas Powered Lifts

Forklifts that need to be used both inside and outside the DC are usually powered by fuels such as natural gas, diesel, or propane. Propane powered forklifts are the most common, due to low operating costs, easy change-out of cylinders, easy storage of replacement cylinders, and lower emissions than gas or diesel lifts. Careful maintenance is required to reduce emissions of carbon monoxide, making gas-powered lifts less desirable for frequent use within a restricted inside area. Gas powered lifts are also frequently used in smaller facilities because they do not require investment in multiple batteries, battery chargers, and other related infrastructure and labor costs associated with electrical forklifts.

Scissor lift in use

Specialty Equipment

Distribution centers also frequently have a variety of specialty pieces of rolling stock so that maintenance teams can perform various specialty functions that cannot be done well by conventional lifts. These may include:

Articulating Boom Lifts

Boom lifts are usually combination drives of electrical and propane. The battery power is quiet and has no emissions, and the propane power allows outside workability and redundancy.

Rider sweeper diagram

The multiple “joints” in the articulating booms give almost unlimited ability to stand-off and maneuver the work platform to where the base cannot move. They allow technicians to access

Rider sweeper

very high or difficult to access areas where they cannot use ladders or scissor lifts to change lights or access roofs or other elevated systems.

Scissor Lifts

Scissor lifts allow individual or groups of technicians to raise heavy drives or parts to elevated or ceiling-suspended conveyors, and then provide a stable work platform to do maintenance functions. They come in many different sizes of varying width and maximum elevation to best suit the work environment.

Industrial scrubber in use

They are an excellent choice when workers or materials need to be raised above ground level, without the obstructions caused by overhead cranes or machinery that lift the item from its side (such as forklifts). With a scissor lift, the entire lifting mechanism is contained beneath the lift platform or table, providing lifting capability with minimal footprint.

Safety with a scissor lift is very important. When the lift table is raised, there is a very high center of gravity, which can pose a tip-over hazard, if the lift is bumped. It is also important to look carefully all around and above when the lift table is raised because there are many different obstructions like pipes and

Schematic of scrubbing tank

cables and joists near roofs.

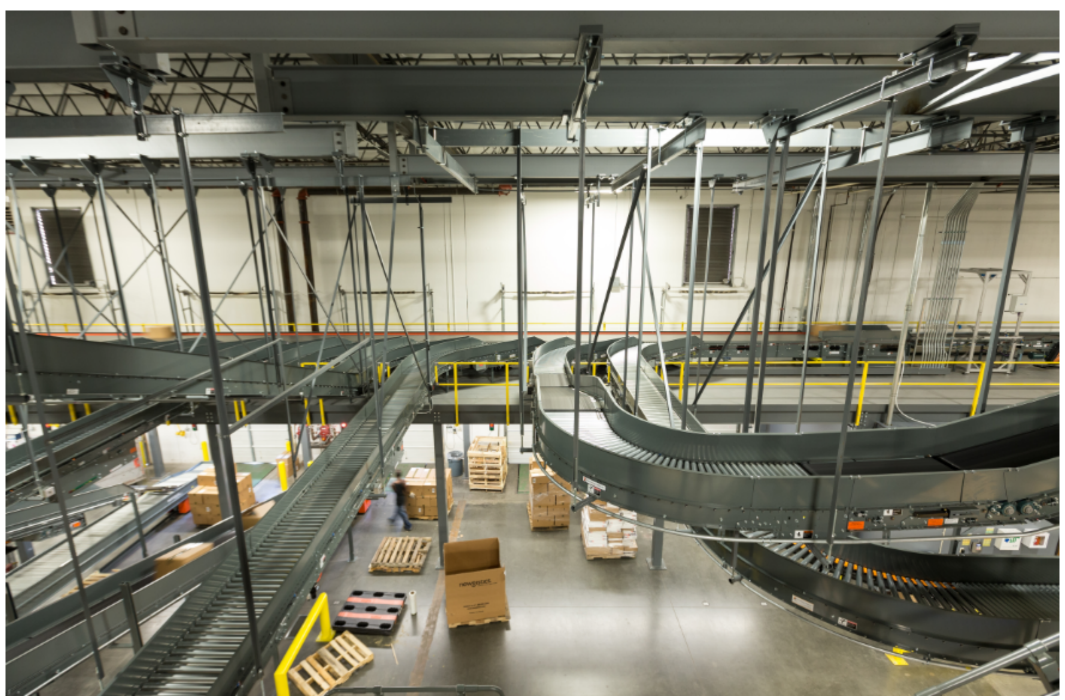
Section 3

Engineered Systems

Automated material handling systems (conveyors, sorters, AS/RS) are extensively used in DCs for a variety of reasons:

- Conveyor and sortation systems usually are less expensive over time on a cost per carton basis than manual handling because fewer operators are needed to process large volumes of freight.
- Automation can handle very high volumes of throughput that are not manageable with forklifts alone.
- Automation permits very dense storage options that efficiently utilize the entire vertical space of a DC (cubic footage), enabling greater storage capacity than high bay racking. Automated Storage/Retrieval Systems (AS/RS) cranes allow vertical storage heights in excess of 100 feet, allowing the use of smaller amounts of real estate for the needed capacity.
- Automation can handle freight in freezers or other conditions in which it would be difficult for people to work.
- Specialty automation such as shrink-wrappers and label printers are much more efficient than manual handling.

- Warehouse Control System (WCS) Software in modern material handling systems permit detailed control of freight flows (“waving”) that correctly time sequence freight to shipping doors for scheduled pick-ups.
- WCS software combines and integrates different types of automation technology to work together.
- Sequential use of integrated automation can efficiently handle virtually every aspect of handling and storage in a warehouse, with little human intervention.



An engineered system with conveyor and a sorter

As examples, the video below shows the associated automation used in a food distribution center by complex, specialized engineered systems used by several different grocers in the US and Canada.

Movie 5.2 SSI Schaefer Food Warehouse Video Showing Robots and Palletizing

Tap to view the video.

Belt Conveyors

Belt Conveyors are the most commonly used unit handling conveyor because they are usually the least expensive and simplest option to move a unit load from one point to another. They typically require the least amount of maintenance effort of any type of driven conveyor. They are used to convey unit loads in varying sizes, shapes, and weights. Since the conveying medium is a flat belt, these conveyors are capable of moving everything from well-formed boxes, cartons and totes to very flimsy bags and bundles.

Typically, belt conveyors are used to carry unit loads over long distances with a single drive motor, or to safely move them from one elevation to another. These are often referred to as incline belt conveyors when going from a lower elevation to a higher elevation, and as decline belt conveyors when going from a higher elevation to a lower elevation.

Belts must be correctly tensioned to turn correctly. The belting is typically centered on the rollers or slider beds underneath, but can be tracked more to a specific side to help position cartons better for subsequent turns or diverts to change carton direction of travel.

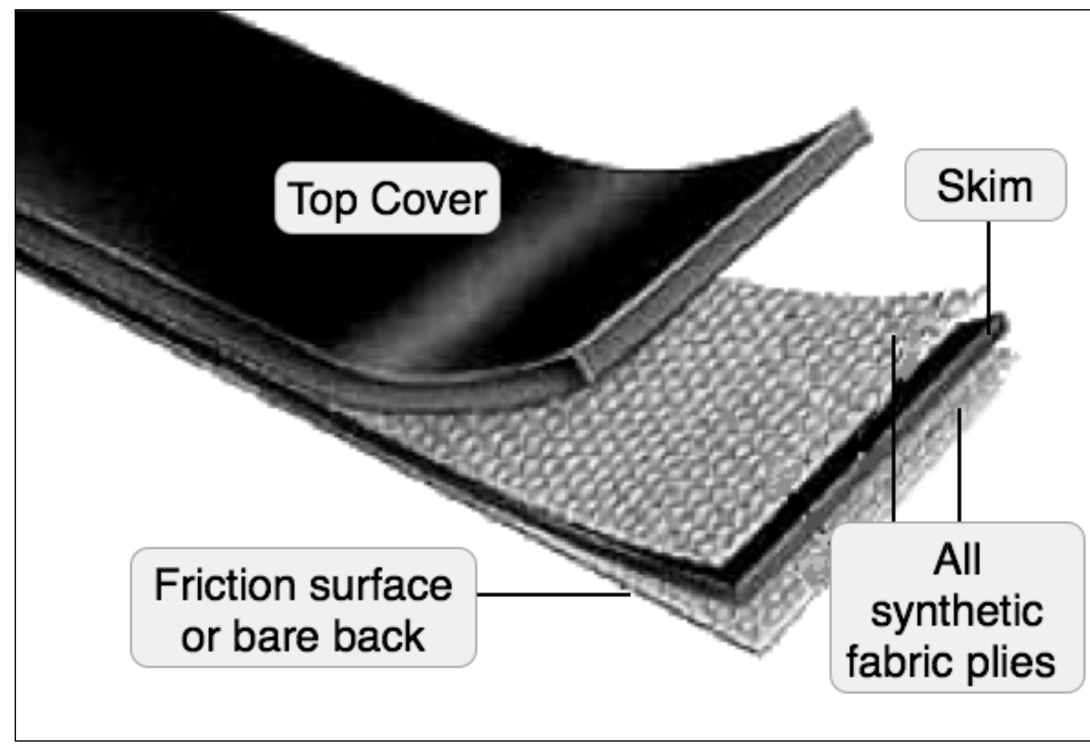
Belt Conveyors use the following components:

Belt Medium

The belt consists of one or more layers of material. They can be made out of rubber. Many belts in general material handling have two layers.

- An under layer of material, called a carcass, provides linear strength and shape. The carcass is often a woven fabric having a warp and weft. The most common carcass materials are polyester, nylon and cotton.

Interactive 5.4 Multi-Layer Belt Schematic



Tap label to zoom; tap label, home, or image to return.


Rough-top belting

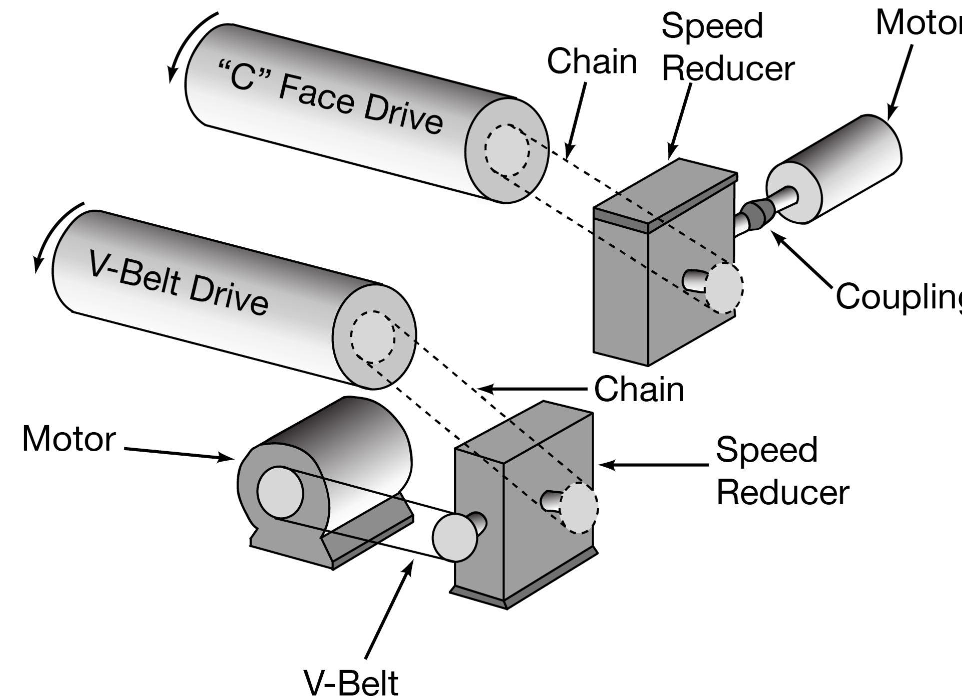

Standard belting

- An over layer is called the cover, and provides the desired surface to contact the conveyed material. The cover is often various rubber or plastic compounds specified by the use of the belt.

Drive (Gear Box and Motor)

Belt conveyors use a drive to provide power to the pulley. A drive is composed of both a motor and a gear box. Motors are typically 480 volt, three-phase powered.

Connected drive assembly

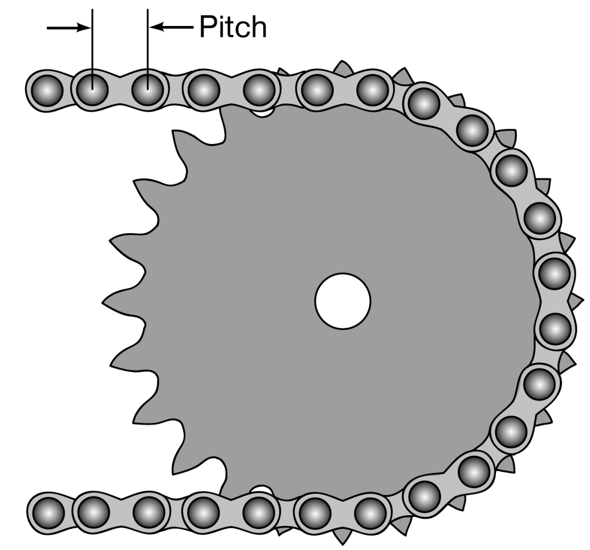


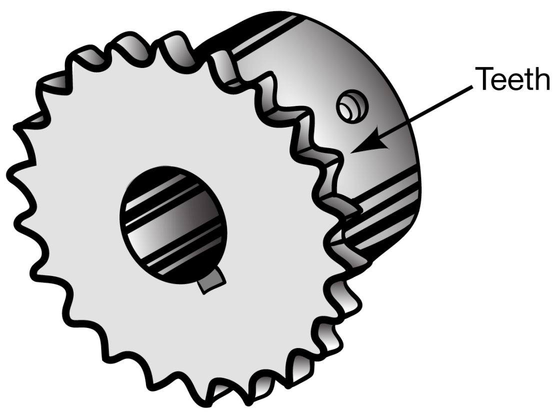
Schematic of two different ways motors and drives can connect to a drive pulley

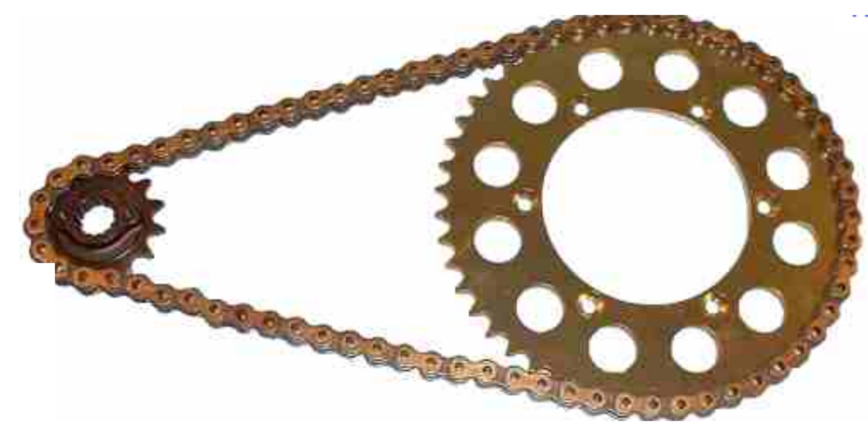
Because a motor turns much faster than the belt can move, a gear box (speed reducer) is added between the motor and the drive pulley to step down the speed. That is done inside the gear box by intermeshed metal gears of different diameters, similar to a car transmission. Lubricant oil inside the gear box ensures that the gears connect without metal to metal wear.

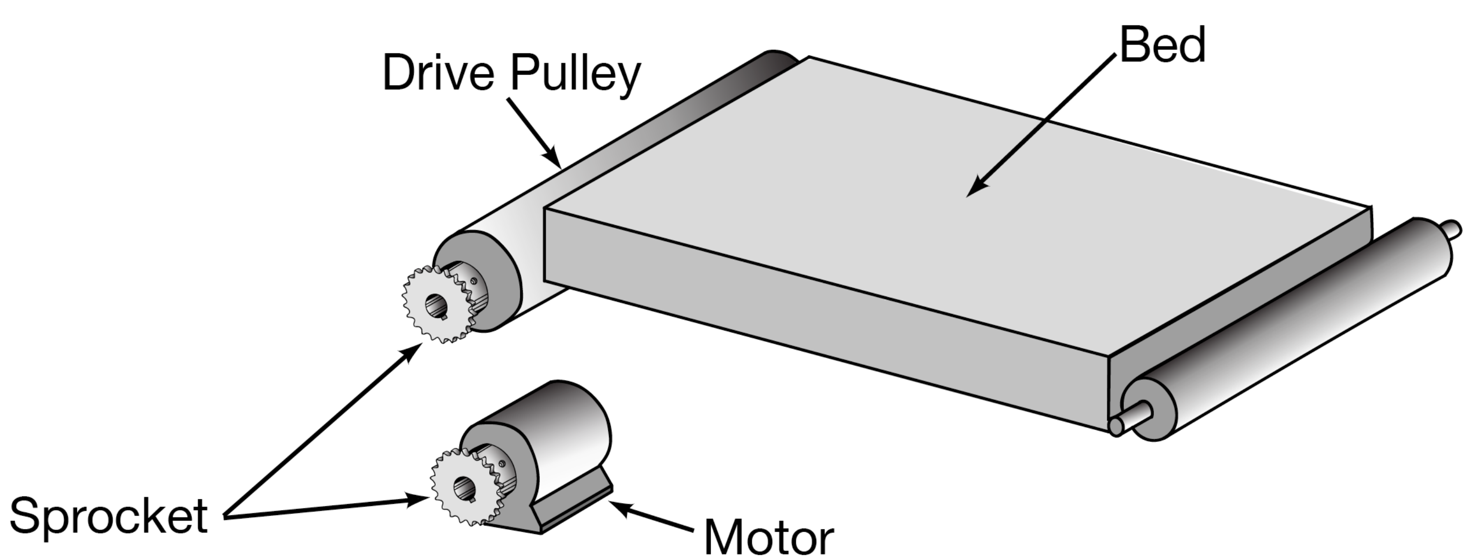
Sprockets

A sprocket is a metal "wheel" with "teeth" on the outside. The links of a chain ride over the teeth on the sprocket to turn the chain in the correct direction. When connected to the shaft on a pulley and a drive, a chain can be used to efficiently transmit torque to the pulley from the motor and drive.









Pulleys

Conveyor pulleys are the main elements providing the transmission of torque from the drive and ensuring that belts remain taut. Typical pulleys include:

Drive Pulleys

Drive pulleys (connected by chain and sprocket to the drive) are located at the end of the direction of travel of the belt or underneath in the center. Drive pulleys are typically “lagged,” or covered with vulcanized rubber to maintain friction and prevent the belt from slipping freely on the roller. A drive pulley is also frequently “crowned,” or slightly larger in the center than the ends to keep the belt tracked to the center instead of “walking” towards the sides.

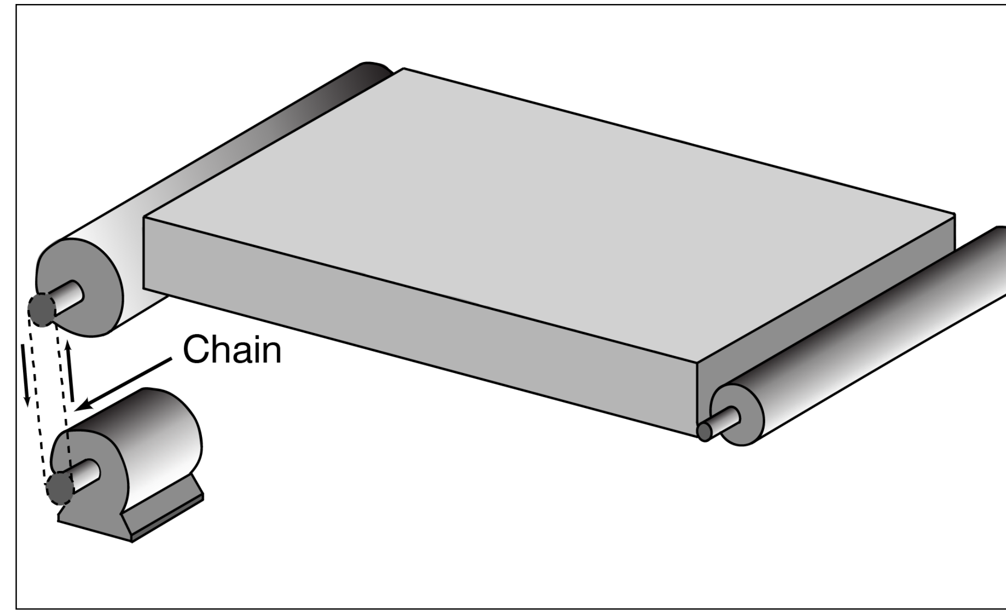
Tail Pulleys

Tail pulleys (typically un-driven) are located at the starting end of the conveyor, or at both ends of a center-drive. A tail pulley turns freely, and is adjustable to take-up belt stretch.

Take-Up Pulleys

Take-up pulleys maintain correct tension or bend the direction of belt travel for routing. Take-up pulleys are adjustable by screws to apply tension against the belting.

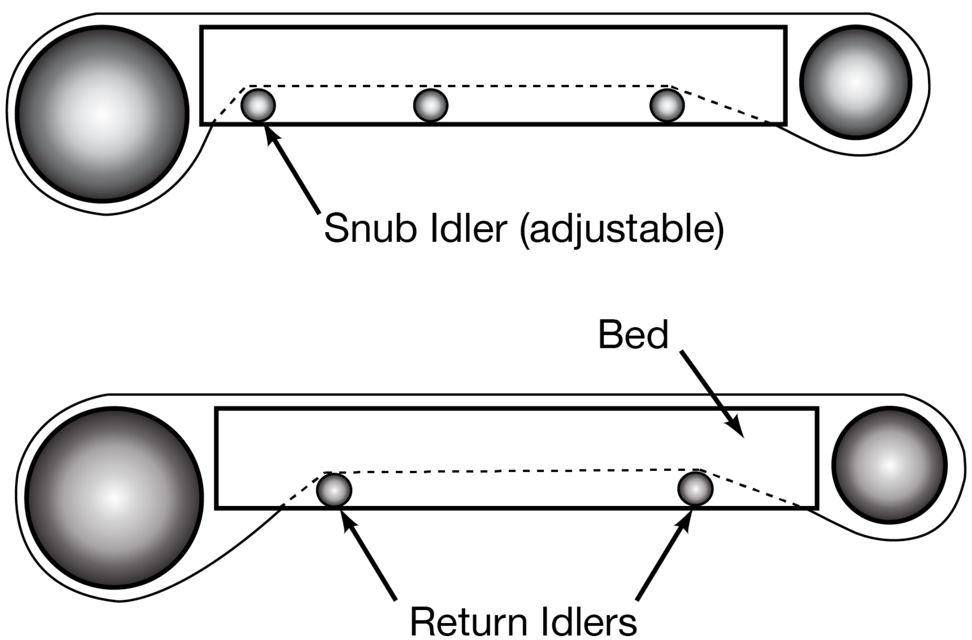
Interactive 5.5 Pulleys



Tap to view pulley graphics and images.

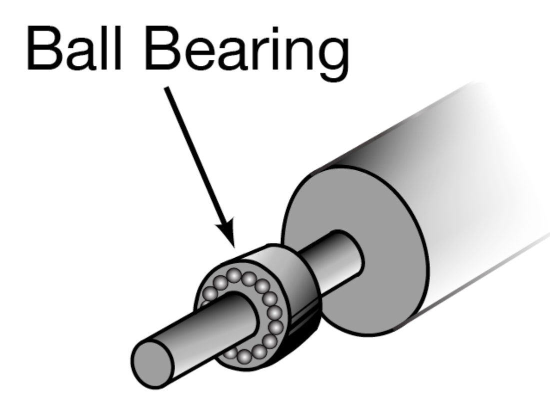
Snub Idler Rollers

A snub idler roller is located closer to a drive pulley to make the belt hug more of the drive pulley surface, increasing the drive efficiency. Regular idlers are simple un-driven rollers that the belts ride across to eliminate the danger of a hanging belt underneath the conveyor bed.



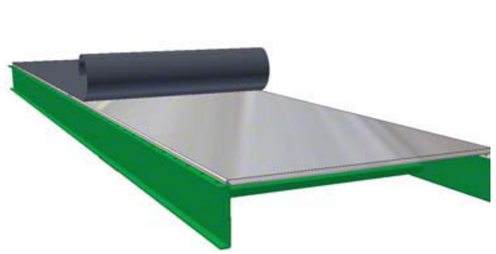
Bearings

When two pieces of metal touch each other, they cannot turn quickly and easily without bearings. Bearings are little steel balls that sit in a raceway to keep the pulley shaft and the conveyor bed from rubbing together. This allows the pulley's metal shaft to turn freely, but stay fixed in the same location.



Flat Belts

There are two typical types of flat belt conveyors: slider beds and belt on roller conveyors. A straight belt (frequently of rubber composition) rides on a series of rollers set at fixed intervals. Power comes from a motor and drive attached to a pulley at either the end or middle of the conveyor section.



Slider Bed Belt Conveyor

Belt on roller

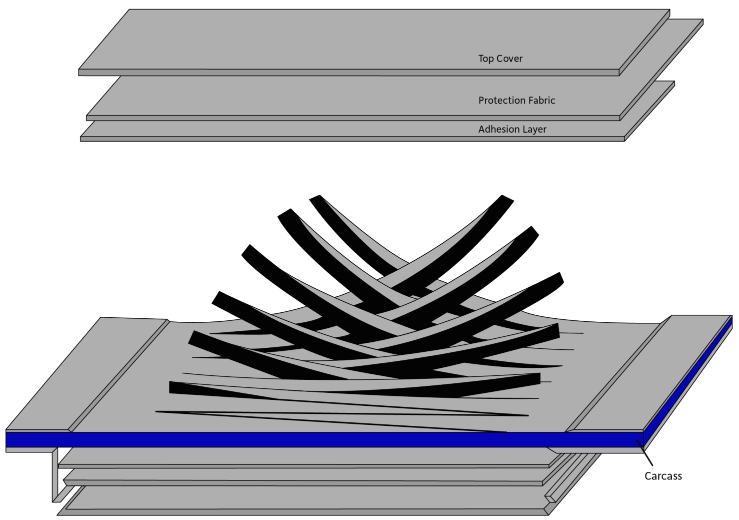
The belt is connected together by:

- A vulcanized heating process to fuse the ends
- Steel clipper lacing and pins to hold the two sections together.

To keep the belt tracked true, it is essential that the belt sections are cut perfectly perpendicular to the length so the two ends mate up correctly.

Flat belts tend to wear out or become separated over time. The belts are generally easily replaced with a comparable length of new belt, or in the case of a temporary repair, a small intermediate section (or “Dutchman”) can be spliced into the existing belt to replace a damaged section quickly.

Clipper lacing on belt



Schematic of vulcanized belt splicing

Interactive 5.6 Belt on Roller Conveyor

Tap to read about belt on roller conveyors.

Interactive 5.7 Brake Meter Belts

Tap to read about brake meter belts used for carton gapping.

Curved Belts

A curved belt conveyor permits change of direction for carton flow. They handle the same types of loads as a flat belt, and ensure that speed tracking and gapping is maintained throughout the curve by matching the speed of surrounding belted conveyors. Curved belts are used on spiral conveyors to move cartons between different levels over a short horizontal distance without cartons tumbling end over end.

Interactive 5.8 Curved Belts

Tap then swipe to view images.

Most curved belts use slider beds with low friction surfaces, although in special situations of heavy loads, a combination of roller and slider beds may be used. Belts on curved belt conveyors are precisely dimensioned and cut from the factory to turn smoothly without bowing or tearing apart from the twisting motion. The primary drive types available on belt curves are the friction drive, pinch drive and chain drive. The most frequently used configuration in DCs has a friction drive with guiding elements composed of a series of bearings on a guide bead.

Interactive 5.9 Roller Conveyors

Tap then swipe to view images.

Roller Conveyors

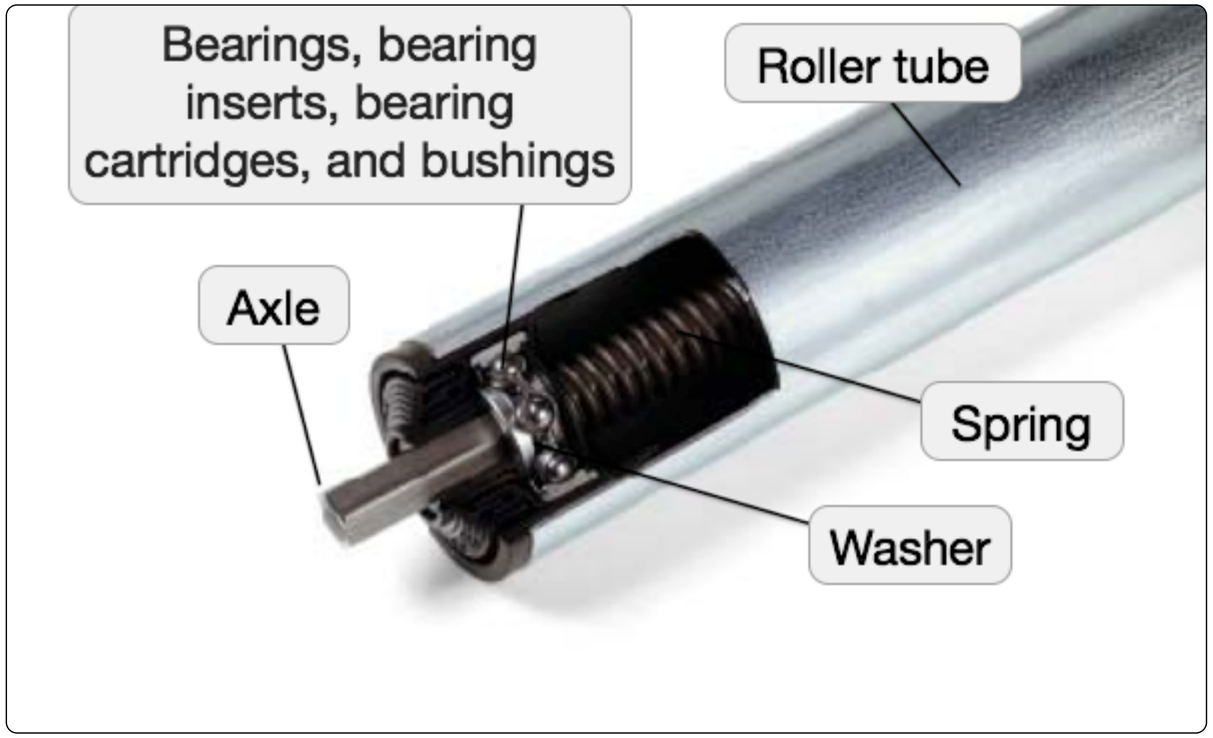
Some of the most prevalent conveyor types in distribution centers utilize many variants of rollers.

- **Heavy duty** rollers are used to slowly move wood or plastic system pallets. Speed is typically limited by the need to keep taller loads stable as they move on the conveyor.

- **Lighter duty** rollers are used to handle individual cases or containers (totes or trays), and are capable of handling tens of thousands of cartons per hour. Because individual cases or containers are considerably more stable, lighter duty rollers can run much faster, and designers can adjust speeds for specific control purposes.

Rollers are the most prevalent means of conveyor system in most facilities because they allow accumulation of lots of product throughout the entire system. Accumulation conveyors are used to temporarily stop, hold, and release material. This type of product flow management makes sure that boxes are transported as close as possible on the system. It allows efficiencies throughout the system by regulating flow for maximum utilization of downstream sortation. It allows flexibility to react to changing product volume in different areas of the facility without adversely reducing throughput or making people slow down or stop because of congestion.

Interactive 5.10 Roller Cross-Section Showing Components



In all roller conveyor variants, the rollers are composed of the parts detailed in the image above.

Different types of driven roller conveyors vary based on the drive mechanisms used to turn the rollers. Vendors use poly-vinyl driver pads, or various types of belts underneath the rollers, to engage specific sections of the conveyors to turn the rollers and to move product. Rollers can be skewed inside the side beds to move cartons from one side of the rollers to the other to set up subsequent changes in direction. Electro-mechanical controls activate sections of the conveyors as individual or grouped zones. Controls are also used to activate pneumatic systems, since air pressure is frequently used to selectively engage drive mechanisms and rollers.

System designers suit the component materials listed above to the types of freight to be conveyed. Roller tubes are typically steel or aluminum, of varying thicknesses based on the weight of the cartons or pallets. Plastic is sometimes used for food handling involving wash-downs. Rollers can be coated with rubber or poly-urethane for better grip and to provide more friction and control for a carton, especially in curves or after divert sorters.

The types of shafts and springs are suited to how rollers will connect with conveyor side rails. To work on drives, belts or chains used to turn the rollers, side rails must be notched to lift out the rollers, or the roller shafts must be spring-loaded on one or both sides so the rollers can be easily added or removed.

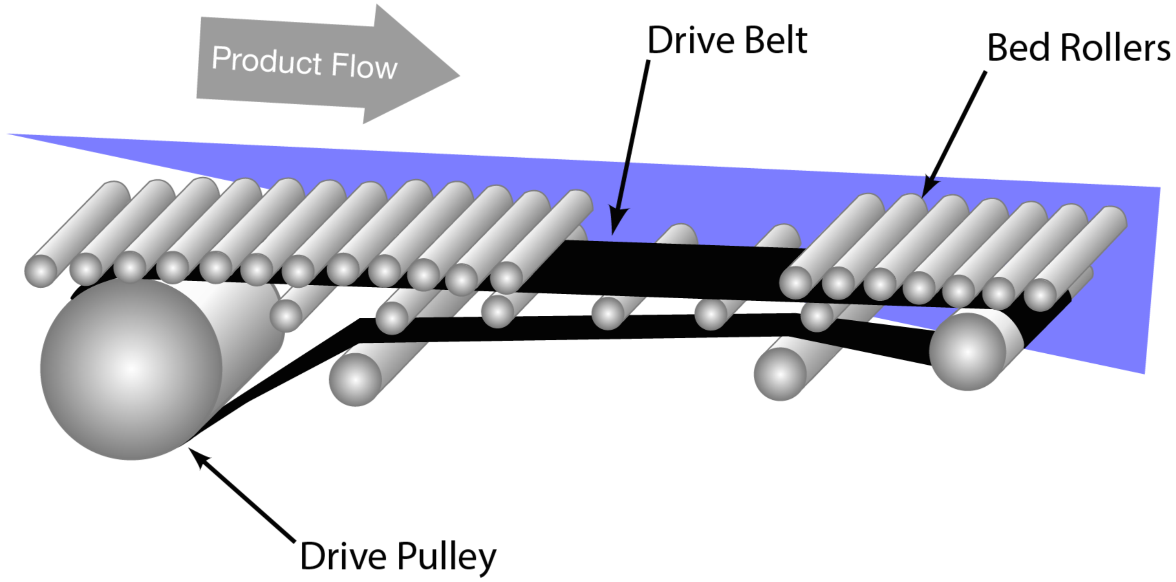
Various types of rollers

Bearings or bushings allow the shaft to stay fixed in the side rail while the roller turns. ABEC 1 precision bearings are most frequently used for carton handling rollers because they turn quickly and are quiet. Since individual rollers are relatively inexpensive, they are typically replaced when they wear or are damaged.

Drive belt on plastic sheaves

Belt-Driven Roller Conveyor

The belt-driven roller conveyor is driven by a narrow belt that runs beneath the roller bed, perpendicular to the rollers. As a motor drives the belt, the belt turns the rollers. The belt-driven roller is a good accumulator because it's easy to create zones. You can lower the belt away from the roller in any zone by reducing pneumatic pressure to create accumulation.



Movie 5.3 Belt Driven Roller NBC Accumulation Conveyor

Tap to view the video; the video has no sound.

Pallet-Handling Roller Conveyor

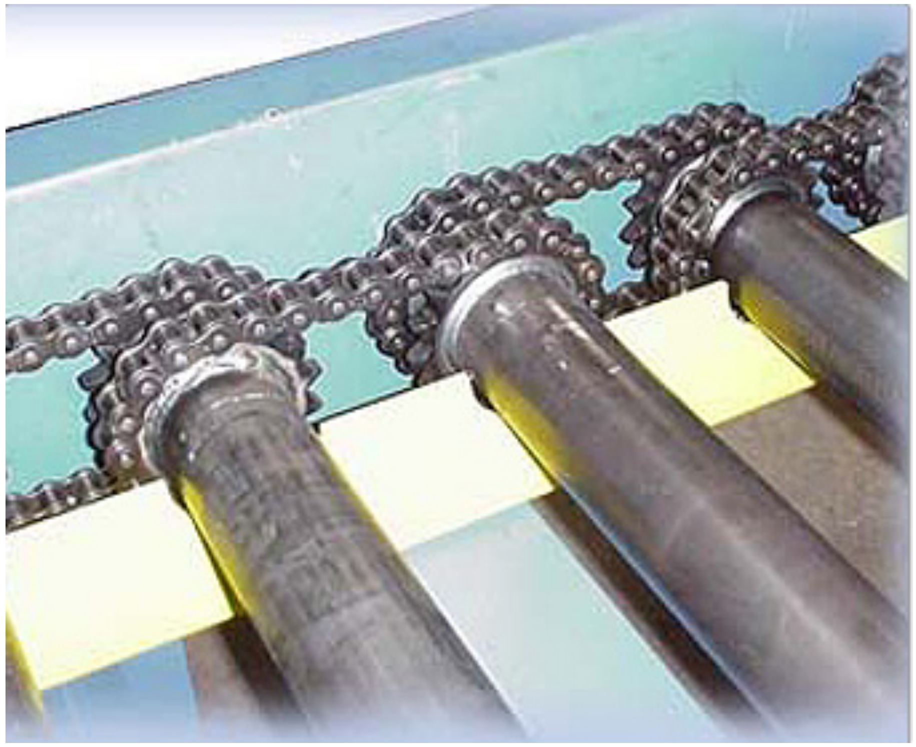
The Pallet-handling roller conveyor looks like the roller conveyor used for handling packages, but the rollers are wider and thicker to handle the additional weight. Most pallet-handling roller conveyors are chain-driven because the drive method (sprockets and chain links) provide the best torque without slippage. The heaviest pallets may incorporate roller guides to make sure the pallets are centered on the conveyor system.

Pallet conveyor

Pallet conveyors

Chain-Driven Pallet Conveyor

The chain-driven pallet conveyor works differently from the chain-driven package conveyor. Instead of running beneath the rollers, the chain runs along one side of the roller bed. Each roller is connected to the chain with a sprocket. The conveyor is divided into small segments, and each segment has its own AC induction motor. This segmentation allows for better control and allows some accumulation of pallets.



Chain-driven rollers coupler

Chain-driven rollers

Motorized Driven Roller Conveyor

Forms of conventional roller conveyors date back over a hundred years. The biggest change to conveyor technology in recent years has been the advent of motorized rollers. The innovative ways that they can be incorporated into new designs are making a big difference in enabling new technology in material handling.

The motorized roller is also known as internal motor or motor-driven roller (MDR) conveyor. The MDR conveyor, there is not an external powered motor and drive.

MDR Drive Roller Cross-section

A section of motorized roller conveyor is divided into small zones. At least one roller in each zone has an internal motor that turns the roller. The rollers in each zone are connected to each other by rubber O-rings so that the turning of the motorized roller turns all the rollers in that zone. Additionally, belts can go over the zones instead of O-rings, yielding the product handling benefits of a belted conveyor with the precise control of roller sections.

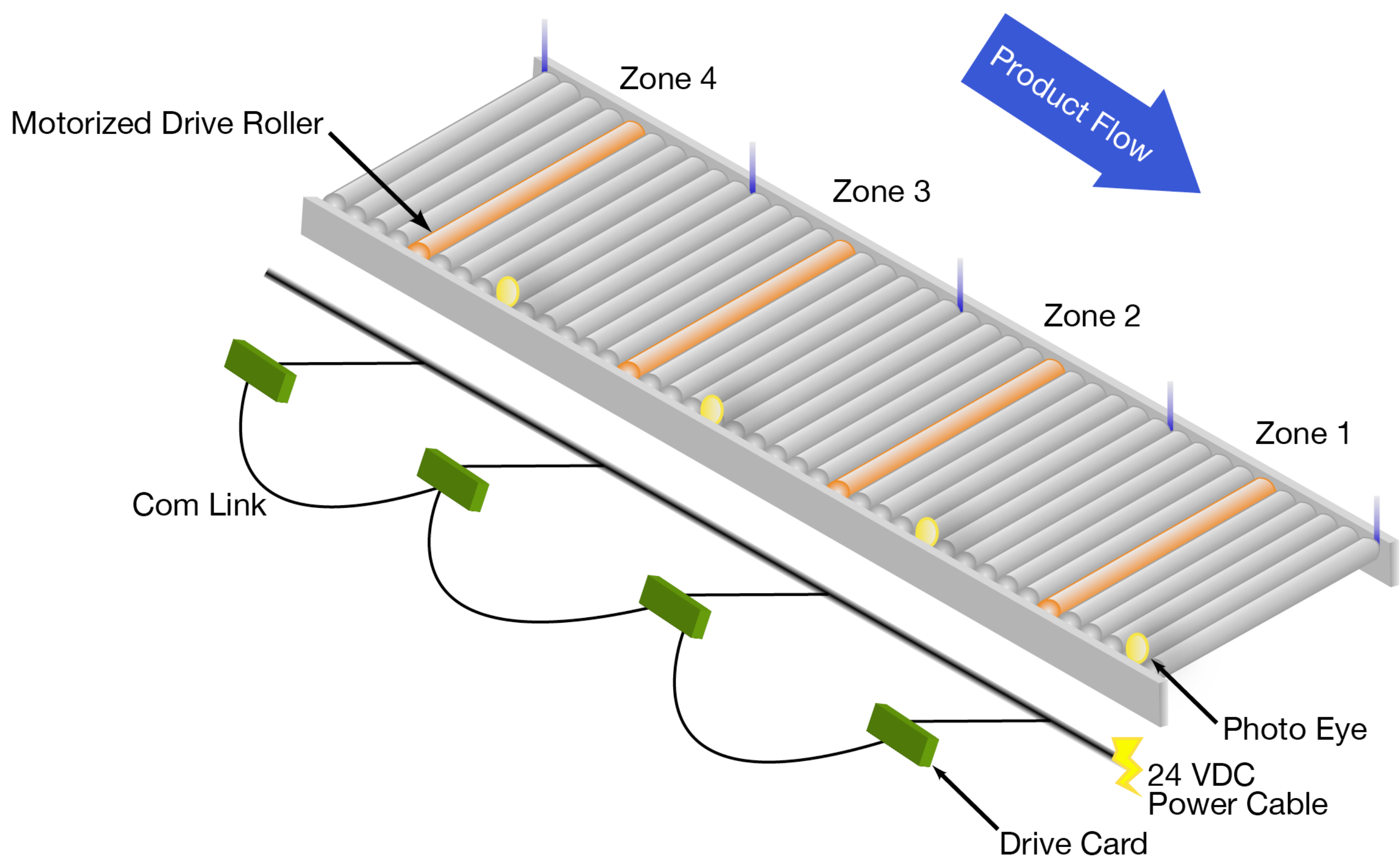
MDR conveyors provide good product control

The motors used in the motorized roller are usually 24-volt DC motors. These motors use less energy than the motors used to drive other forms of roller conveyors and they provide less torque, making them safer, too.

Because each zone of rollers is powered independently, the zones can be configured to run only when a package is present. This on-demand feature increases energy savings even further and decreases noise—both are important factors when the end user is addressing economics and ergonomics.

The motorized roller doesn't move as fast as the other forms of roller conveyor, because it's smaller, low-voltage DC configuration is designed to power only one zone, but it offers better product control and is easier to maintain.

With any roller conveyor, there's a basic rule of thumb: You want three rollers under your product at all times. Two rollers might create a wobble when the product hits a gap, but keeping the front, middle and back of a product supported will provide a smooth ride.



MDR conveyor with accumulation

Tapered Roller Curved Conveyor

A roller conveyor can be used to gently change the direction of carton flow by using sections with a degree of bend, usually in set turns like 45, 90, or 180 degrees. These conveyor sections use tapered rollers for use in a curve with end and intermediate diameter proportional to their distance from the center of curve. In cases where location and direction of orientation of the carton is important to maintain through the curve, the rollers can be lagged. The rollers are usually driven by v-belts or chains.

A lagged tapered roller

A tapered roller conveyor

Vertical Reciprocating Conveyors (VRCs)

Vertical Reciprocating Conveyors are used in factories, warehouses, DCs or industrial plants where products or supplies need to move from one level to another. They are sometimes used with multi-shuttle systems to quickly and efficiently bring cartons or trays up to rack levels without having to use numerous incline and decline conveyors that require lots of space.

Vertical Reciprocating Conveyors are not elevators. In fact, they have their own national code (ASME B20.1) and are specifically exempt from the national elevator code. Whereas elevators are highly regulated and most DCs outsource elevator maintenance to companies that specialize in elevators, maintenance technicians do frequently maintain and repair VRCs.

A VRC moving pallets between floor and mezzanine

Inside a VRC for raising cartons to different rack levels

Vertical Reciprocating Conveyors provide fast, efficient, convenient and safe access to/from mezzanines, balconies, basements, and between levels in multiple story buildings. They can be installed in through-floor, interior or exterior applications. The principal components of Vertical Reciprocating Conveyors include guide columns, a carriage and a mechanical or hydraulic actuating mechanism.

Directional Sortation

To separate and route items—such as parcels, boxes, cartons or parts—within a facility, you typically use a sortation system. The sorter merges, identifies, inducts and conveys products to specific destinations. Working in conjunction with fixed conveyors and automatic identification systems and controls, sortation systems transfer items off main conveyor lines to spur tracks. Sortation moves large volumes of material rapidly through a facility, allowing companies to ship or receive higher volumes with smaller storage space and lower labor costs. Typical sortation applications include the routing of cases, totes or palletized loads to and from static or automated storage systems, or from a picking area to packaging for shipping.

Sorter

Sortation line

Movie 5.4 Abel Womack, Inc. Sortation Video

Tap to view the video.

Chutes

Chutes are used as an inexpensive way to move products without drive or control. Chutes are often referred to as "gravity chutes" or "slides" because gravity provides the force to carry the load down the chute. Many different materials have been used for the surface of the chute to provide as little friction as possible, but cost and wear characteristics have driven most suppliers to steel or fiberglass.

Chutes are frequently used as a transition section from a powered sorter to a decline conveyor. In cases where a significant vertical decline must be done over a limited horizontal distance, a spiral chute may be used.

Gravity chute example

Spiral chute example

Sliding Shoe Sorter

A sliding shoe sorter is a continuous series of slats or tubes, on which rides a rubber block (or “shoe”). An electrical divert sends the shoe across the slat, making contact with the side of a carton. Multiple shoes can be actuated to match the length of the carton, gently pushing the carton at an angle into a chute, or onto another conveyor.

Shoe sorters are generally chain driven, but can also be driven by linear actuator motors along the length of the sorter that drive the slats by electrically induced magnetism. Oiler systems on chain driven systems are very important to reduce chain stretch and wear at very high speeds of potentially more than 600 feet per minute.

Sliding shoe sortation systems provide a very soft, positive divert (accurate) at high speed rates. Shoe sorters can be used where there are a wide variety of product sizes, shapes and weights being sorted. It is an excellent sortation choice when the product is fragile or easily damaged and requires a smooth and gentle movement from the sorter to the takeaway lane. Single and dual diverts are available and can be customized based on a particular conveyor system’s design.

Interactive 5.11 Sliding Shoe Sorters

Tap then swipe to view images.

Movie 5.5 Intelligrated Shoe Sorter Video

Tap to view the video; the video has no sound.

Movie 5.6 FKI Logistex Shoe Sorter Video

Tap to view the video.

Tilt Tray Sorter

A tilt-tray sorter is a high-speed, continuous-loop sortation conveyor that uses a technique of tilting a tray at a chute to slide the object into the chute. Tilt tray sorters are highly reliable, and when equipped with linear motor (LM) technology, very energy efficient and quiet. They are primarily used for sorting cartons, are frequently found in general merchandise DCs, and allow the highest throughputs in cartons per minute of any sortation type.

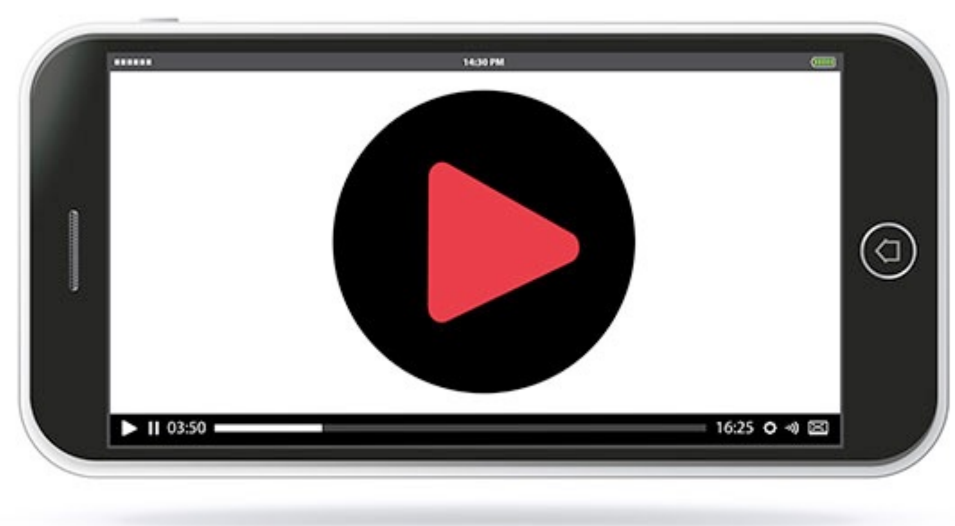
The continuous loop is composed of a “train” of interconnected carts that ride along a track. When the cart arrives at the sort location, controls activate an electrical solenoid that tips the tray over at an angle that allows the parcel to slide off into a chute. At various points along the rail, the trays are righted back to their horizontal position to receive a new parcel.

Older tilt tray sorters were driven by trains, but newer generation sorters frequently use linear motor technology, propelling the cart train by electrically induced magnetism.

Interactive 5.12 Tilt Tray Sorters

Tap then swipe to view images.

Movie 5.7 Intelligrated Tilt Tray Sorter Video



Tap to view the video; video does not have sound

Cross Belt Sorter

Cross Belt sorters are used to sort parcels, mail, apparel (in poly bags), and very small items, at high speed, that are difficult to sort, such as fragile or high friction items that would not easily slide off a tray or slat. Advantages of a cross belt sorter include tight divert centers for after-sort lanes that are close together or very narrow, and sortation rates in excess of 500 cartons per minute.

Cross belt sorters are used heavily in internet fulfillment centers.

In a cross belt sorter, each section (or tray) of the sorter has a motorized belt that runs perpendicular to the direction of the sorter. When the item comes to its correct destination, the motor turns on and runs the item off the side into the new direction of travel.

Movie 5.8 Bastian Solutions Cross Belt Sortation Video

Tap to view the video. This video has no audio.

Interactive 5.14 Cross Belt Sorters

Tap then swipe to view images.

Interactive 5.13 Pop-up Roller

Tap to read about overhead view of a pop-up roller sorter that just diverted a tote.

Pop-up/Skewed Wheel Sorter

A pop-up skewed wheel sorter is an in-line diverter conveyor that has wheels that pop up between the rollers of a powered roller conveyor or between belt conveyor segments and direct sorted items onto a powered take-away line. The take away line usually runs at a faster speed, and is sometimes equipped with rubber-lagged rollers to quickly take the carton away from its original direction of travel. These sorters are used most frequently to change a carton from one line to another within a warehouse.

A pop-up wheel sorter with raised wheel section to turn the direction of box travel

Section 4

Automated Storage and Retrieval Systems (AS/RS)

Automated Storage and Retrieval Systems, known as AS/RS are computer-controlled systems that put away, store and retrieve product in warehouses, distribution centers and manufacturing facilities. Retrieval of items is accomplished by specifying the item type and quantity to be retrieved. The computer determines where in the storage area the item can be retrieved from and schedules the retrieval. It directs the proper automated storage and retrieval machine (SRM) to the location where the item is stored and directs the machine to deposit the item at a location where it is to be picked up.

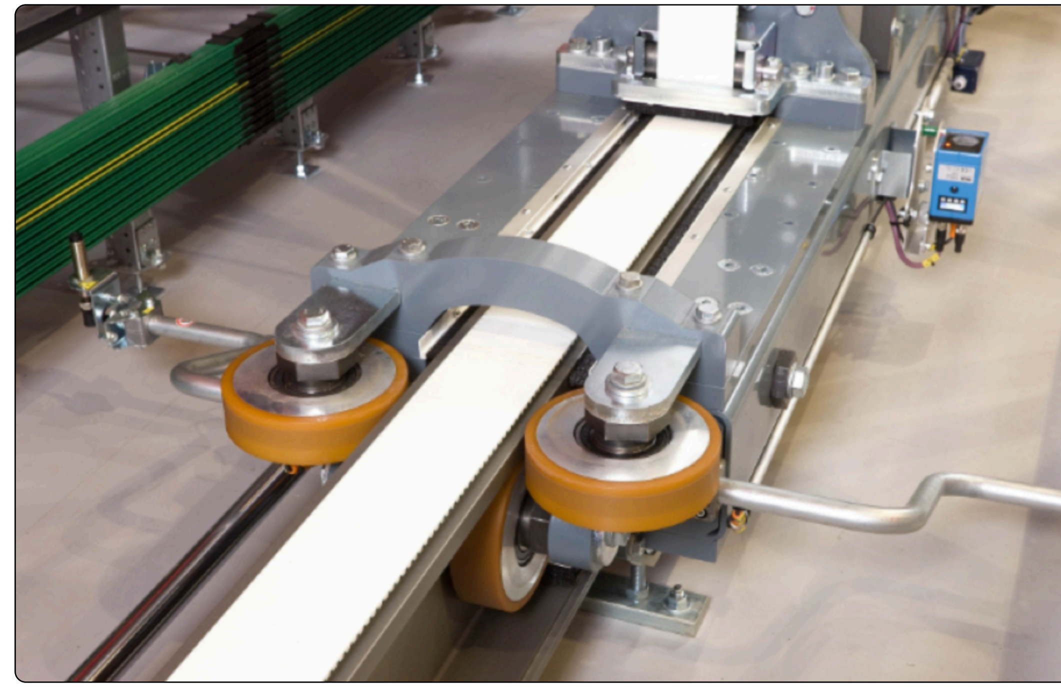
AS/RS systems usually fall in several categories: unit load cranes, miniload cranes, vertical lift modules and carousels, and multi-shuttles. AS/RS have several benefits, including controlled access to valuable inventory, increased accuracy and productivity, and reduced labor costs and risk to workers. For example, these systems are useful in freezers and other harsh environments that can be hazardous to people.

Storage Retrieval Machine (SRM) Cranes

Regardless of size, most AS/RS have the same configuration: Two rows of metal racks face each other with a narrow aisle in between. Down the center of the aisle is a raised metal rail. A tall mast travels through the aisle along the rail. When the mast reaches a designated storage location, a carriage travels up or down the mast to the level of the location. A load-handler mounted on the carriage then reaches into the storage location to put away or retrieve a load.

The mast, carriage and load-handler collectively are known as a Storage and Retrieval Machine (SRM), or crane. SRMs may have single or double masts. With a single-mast machine, the carriage is attached to the front of the mast. With a double-mast machine, the carriage rides between two masts, adding stability in very tall AS/RS or in systems that handle heavy loads.

Interactive 5.15 Storage Retrieval Machine (SRM) Cranes



Tap then swipe to view images.

Unit Load (Pallet) SRMs

Unit-load AS/RS cranes are designed to store large loads of 1,000 pounds or more, typically stored on pallets. They are large and slow to safely handle their loads. Unit load systems are extensively used for temperature controlled food storage. When used to store food in freezers with temperatures well below zero, special modifications to the equipment must be made.

While a unit-load AS/RS can reach 100 feet in height, a typical system is less than 40 feet high. A standard unit load AS/RS stores loads on rails designed specifically for automated systems. The rails run perpendicular to the rack aisles. (Standard pallet racks store loads on cross beams that run parallel to the aisles.) AS/RS racks can be configured single-deep, double-deep or as deep-lane racks with several pallets and stored one behind the other.

Movie 5.9 Swisslog Vectura SRM Video

Tap to view the video.

The load-handler for a unit-load AS/RS is usually a telescoping device, called a shuttle, that reaches into the storage location, slides under the pallet, then pulls it onto the carriage.

Interactive 5.16 Unit Load (Pallet) SRMs

Tap to view images.

Miniload SRMs

Miniload AS/RS handle lighter loads, usually less than 1,000 pounds, in containers such as trays, totes or cartons. Rack systems usually reach up to the ceiling, and storage is extremely dense, with only a few inches between individual levels.

Most miniload AS/RS look similar to unit-load systems with drive carriages, masts, and load handlers. Instead of using shuttles to pick up and retrieve loads, they use different load-handling devices, including extractors to grasp/pull handles on metal or plastic trays, vacuums to attach to corrugated cases, and robotic arms to grip plastic totes. Cartons and trays are frequently stored double deep, so miniload cranes can usually pick more than one load at once.

A typical mini-load stands between 10 and 40 feet tall. Because they do not carry heavy loads, miniload cranes can move extremely quickly. Many miniload AS/RS are used for small items and order fulfillment, replacing many order picker forklifts.

Interactive 5.17 Miniload SRMs

Tap to view images.

Movie 5.10 Daifuku Miniload Video

Tap to view the video.

Carousels and Vertical Lift Modules

Other storage technologies such as horizontal carousels, vertical carousels and vertical lift modules (VLMs) are also variants of AS/RS.

Horizontal carousels are like the equipment used by a dry cleaner, but instead of clothes hanging from the top rail, wire carriers are suspended from the rail. These carriers typically hold plastic bins containing small-sized products. They are often paired with pick-to-light and voice technology picking systems.

Vertical carousels are similar to a Ferris wheel. This technology uses shelves that rotate up and down inside a metal cabinet. The shelves can hold metal trays or plastic bins. When an operator requests a part from its computer system, the carousel rotates to deliver the correct shelf to an access window at the proper ergonomic level. Vertical carousels work well in situations where the inventory changes, but the product profile remains the same.

Vertical lift modules are a combination of vertical carousel and traditional AS/RS technology. While the outside looks like a vertical carousel, the inside stores trays located on both sides of a column. An extractor mechanism travels up and down the column, retrieves the trays and delivers them to the operator at an ergonomic work counter. VLMs are flexible, can change with operation’s changing requirements and optimize space tray density.

Interactive 5.18 Carousel and Vertical Lift Module Images

Tap to view images.

Multi-shuttles

Multi-shuttles are a newer version of AS/RS, sometimes replacing miniload-type SRM cranes. In an AS/RS that uses a single crane per aisle, throughput is driven by the speed of the crane as it performs movements back and forth within the aisle. When a crane is unavailable due to maintenance, you are unable to access the items inside the aisle. Multi-shuttle systems have evolved to address these shortcomings and increase throughput capability.

Multi-shuttles have smaller shuttles or “bots” on each level of an aisle, permitting simultaneous picking on all levels of an aisle at the same time. A vertical lift or a fixed miniload SRM mast raises and lowers cartons or totes to the different levels. Some multi-shuttle systems can move bots between aisles, or even change levels, increasing flexibility further.

Computer software controls the shuttles or bots, communicating wirelessly. A larger system can include dozens, or even hundreds of individual shuttles or bots. If a shuttle or bot breaks down, it can usually be easily removed from the racks for maintenance, allowing the system to continue to keep on working with little disruption.

Specialized rails are mounted on either side of the racks within the aisle, allowing the shuttles or bots to move quickly up and down the aisle. When the shuttle or bot comes to a stop, onboard load handlers reach into the racking to grab the cartons or totes, or put them away. Individual shuttles or bots can be powered by capacitive charging, receiving quick bursts of charge when they pick up or drop off their load, allowing the shuttle or bot to do its next assignment until it returns for a new charge.

Interactive 5.19 Multi-shuttle Images

Tap then swipe to view images.

Autonomous Bots

Autonomous bots are new versions of “goods to persons” systems, allow a system to pick goods and bring them to a person located at a fixed work station. Individual, or multiple bots working together, move along fixed routes (“ant trails”) or raised grids in the storage area, controlled wirelessly by a computer, grabbing totes or even entire shelves and transporting them to workstations along the periphery.

Similar to multi-shuttles, individual bots rapidly charge at stations along the edge, holding their charge in onboard low voltage batteries. Autonomous bots are very new to the material handling world, but show promise for rapid order fulfillment inside direct-to-customer fulfillment centers, due to their simple, scalable setups that fit in virtually any warehouse floor space.

Swisslog bots grab individual totes inside storage stacks

KIVA bot moving an entire shelf of items

Industrial Robots

Custom Pallet Building Robot

Robotic depalletizer singulating cases

Many material handling functions are tedious, dull and time-consuming for human workers. Several of them may require heavy or repetitive lifting that can cause injuries. These applications, once done only by people, are now being automated with robotic systems to increase production speed and safety levels. As robot costs progressively become more affordable, and programming becomes easier and more intuitive, it is likely that robots will become more prevalent in supply chain warehouses, and maintenance technicians will need to be familiar with how to repair and maintain robots.

A robot utilizes an end effector tool or End of Arm Tooling (EOAT) attachment to hold and manipulate items. A computer program controls the specific repeated movements and functions. A technician can also manually control the robot with an attachable control pendant.

There are many different functions that material handling robots can perform, but the most common function in supply chain facilities is palletizing and depalletizing.

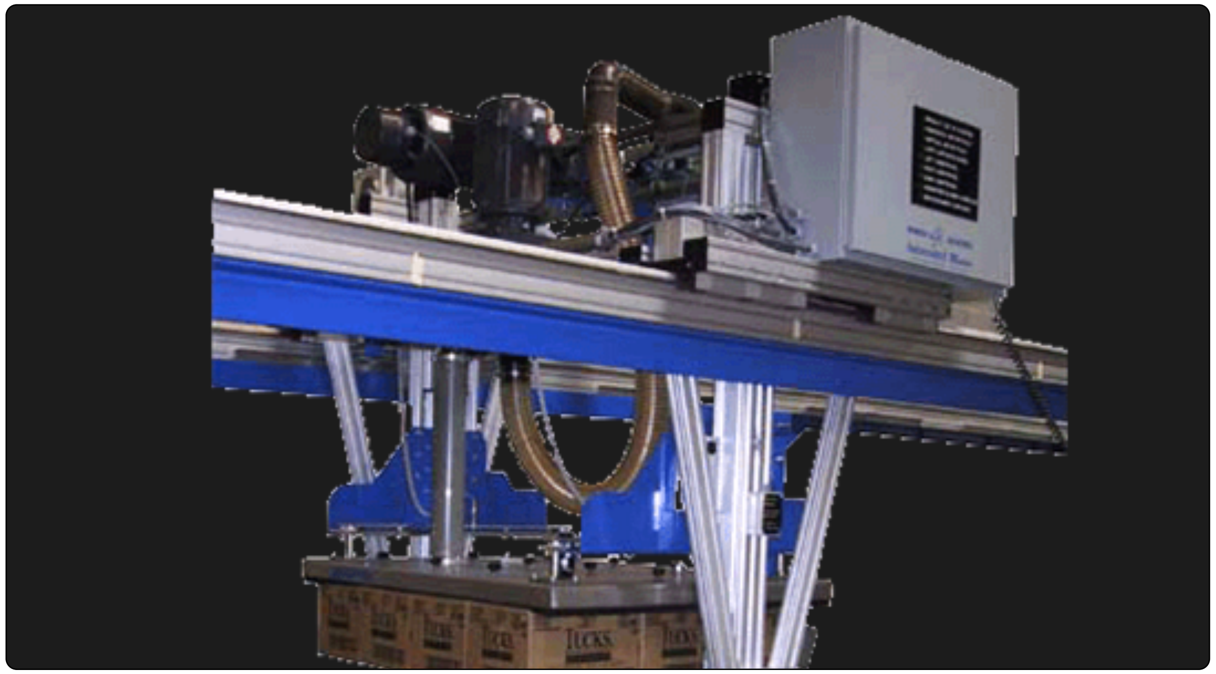
Palletizing/Depalletizing

Industrial robots load cartons or other packaged items onto a pallet in a defined pattern. Palletizing robots can stack cases layers higher and faster than a human can safely do at a sustained pace. Robotic palletizers are usually mounted either at a fixed position, or hanging from an overhead gantry (moving along an overhead rail). Special tooling interfaces with the individual load components, building simple to complex layer patterns on top of a pallet to maximize the load's stability during transport. There are three primary types of palletizing:

- Inline (layer forming)
- Depalletizing (unloading)
- Mixed case.

Robots can also do the process in reverse (delayering). Robots use specialized grippers (end effectors) to delayer tall pallets into individual layers or cases for dense storage or for individual case handling on conveyors.

Interactive 5.20 Palletizing/Depalletizing Images



Tap to view images.

Introduction to Robotics

Definition

According to the Merriam-Webster dictionary, “robotics” is a technology dealing with the design, construction, and operation of robots in automation. “Robot” is defined as a machine that looks like a human being and performs various complex acts, such as walking or talking. It is also defined as a device that automatically performs complicated and often repetitive tasks.

Robotics originated in a short story titled “Runaround”, written by Isaac Asimov, published in 1942. The word "robot" was popularized in 1920 when Karel Capek wrote the utopian stage play entitled "Rossum’s Universal Robots" in Prague. This gave the word "robot" popularity. The drama was almost an anticipation of modern science fiction: The robots seize power, kill nearly all humans, and destroy the secret of their construction. Only with the re-awakening of human feelings is life afforded a new chance.

The designation "robot" has its root in the German word "robat". This has survived in Polish and Czech as "robota" meaning "drudgery" or “servitude” and as ”robotnik” meaning “peasant” or “serf”.

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. The robot is a computer-controlled device that combines the technology of digital computers with the technology of servo control of articulated chains. It should be easily reprogrammed to perform a variety of tasks, and must have sensors that enable it to react and adapt to changing conditions. A robot is a device that sometimes resembles a human being and is capable of performing a variety of often-complex human tasks on command or by being programmed in advance.

The three fundamental characteristics of a robot are:

- Possess some form of mobility
- Able to be programmed to accomplish a large variety of tasks
- Operate automatically after being programmed

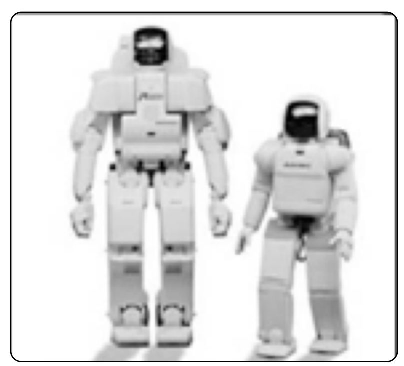
What Can Robots Do?

Robotics has been of interest to mankind for over one hundred years. However, our perception of what robots can do has been influenced by the movies and largely the media. A robot’s characteristics, as well as the way it looks, change depending on the environment it operates in.

According to the magazine of Melbourne PC User Group, some of these applications include:

- Outer Space – Manipulative arms that are controlled by a human are used to unload the docking bay of space shuttles to launch satellites or to construct a space station.
- The Intelligent Home – Automated systems can monitor home security, environmental conditions, and energy usage. Doors and windows can be opened automatically and features such as lighting and air conditioning can be pre-programmed to activate. This assists occupants regardless of their state of mobility.
- Exploration – Robots can visit environments that are harmful to humans. An example is monitoring the environment inside a volcano or exploring our deepest oceans. NASA has used robotic probes for planetary exploration since the early 1960s.
- Military Robots – Airborne robot drones are used for surveillance in today's modern army. In the future, automated aircraft and vehicles could be used to carry fuel and ammunition or clear minefields.

Interactive 5.21
Honda Humanoid Robots



Tap to read about Honda Humanoid Robots.

- Farms – Automated harvesters can cut and gather crops. Robotic dairies allow operators to feed and milk their cows remotely.
- Automotive Industry – Robotic arms that are able to perform multiple tasks are used in the car manufacturing industry. They perform tasks such as welding, cutting, lifting, sorting, bending, and assembly.
- Food Processing – Similar to the automotive industry but on a smaller scale, several applications are used for the food processing industry for the trimming, cutting, and processing of various meats such as fish, lamb, and beef.
- Hospitals – Under development is a robotic suit that will enable nurses to lift patients without damaging their backs. Scientists in Japan have developed a power-assisted suit which will give nurses the extra muscle they need to lift their patients and avoid back injuries.
- Disaster Areas – Surveillance robots fitted with advanced sensing and imaging equipment can operate in hazardous environments such as areas damaged by earthquakes by scanning walls, floors, and ceilings for structural integrity.
- Entertainment – Interactive robots exhibit behaviors and learning ability. SONY has one such robot which moves freely, plays with a ball, and can respond to verbal instructions.

History

Considering the technical progress in the course of the millennia, it could be said that this is due to the endeavors of mankind to find ways and means of reducing work. The wish to hand over arduous or repetitive actions to machines or devices dates back a considerable time. As far back as 2,000 years ago, procedures such as "set in motion" and "vary quantities" were achieved by means of mechanically controlled or adjustable appliances.

In approximately 230 B.C., Philon of Byzantium constructed an oil container which replaced the tedious refilling of lamps with oil by automatic topping up. Another impressive example is the automatic closing of temple doors achieved by Heron of Alexandria around 110 A.D. After lighting a sacrificial fire on top of a hollow altar, the temple doors shut themselves on their own. This made skillful use of the pneumatic effect from the temperature difference.

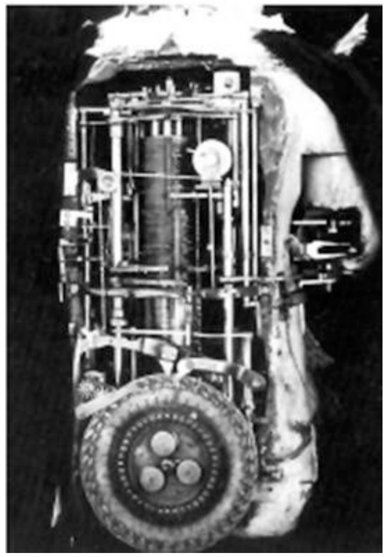
However, it was the ultimate dream of mankind to create something akin to man: an "android" (literally: "human like") which had to serve him. From sagas and literature, we know of many attempts to build androids such as Olympia the doll, Homunculus, and Frankenstein.

So-Called Robots

But even working appliances of humanoid shape were built. At the end of the 18th century, the watchmakers’ craft achieved particular distinction in western Switzerland. Due to the mastery of precision mechanics achieved at the time, the art of watch making still evokes high levels of respect. Pierre Jaquet-Droz built three "androids" around the year 1770 in Neuenburg. These were dolls capable of putting entire sentences on paper by means of writing quills. By changing an internal metal disk, other sentences could be written, so the device was considered to be "reprogrammable". Contemporaries expressed surprise and admiration for his work.

Aside from attempts to gain attraction at fairgrounds and popular festivals, there were also pure deceptions, such as an automatic chess player by Herr von Kempelen in 1783 which, in reality, concealed a dwarf who moved the pieces.

Writing doll by Pierre Jaquet-Droz, from the 18th century



Inside view of doll

The First Industrial Robots

The International Organization for Standardization (ISO) defines "industrial robot" as an automatically controlled, reprogrammable, multi-purpose, manipulative machine with several degrees of freedom which may be either fixed in place or mobile for use in industrial automation applications.

"Unimax", one of the first industrial robots of the 1960s

The first industrial use of robots came in the form of automated machinery. In 1801 Joseph Jacquard invented a textile machine which was operated by punch cards. In 1892 Seward Babbitt designed a motorized crane with a gripper to remove ingots from a furnace. In 1946 George Devol patented a magnetic process recorder which allowed for general purpose playback control of machines.

The mid-1960s introduced the first industrial robots when the American company, Unimation, launched "Unimax". This device was capable of executing simple motion sequences such as picking up workpieces with a tong-like device and rotating them. In addition, rotary movements around one horizontal and one vertical axis were possible. One of the first robots of this type was put to work in a Swedish foundry. Its task was to pick-up casting molds from which poisonous fumes were escaping and place them into a cooling station.

Although human-like appearance is not a criterion for the design and application of robots, there were often repeated attempts to create robots in human image. At the end of the 1920s, a robot called "Televox" was created in the U.S.A. It supervised water containers; switched a pump, light, and ventilator; and opened and shut doors and windows.

Honda was successful in creating two humanoid robots. The research for developing an "intelligent and mobile robot" started with the concept that the robot "should coexist and cooperate with human beings, by doing what a person cannot do and by cultivating a new dimension in mobility to ultimately benefit society." This provided a guideline for developing a new type of robot that would be used in daily life, rather than a robot purpose-built for special operations.

This is, however, not necessary, as any possible or desired complex movement can be divided into rotations and translations (longitudinal displacements) and thus be carried out by means of much simpler constructional arrangements.

Rationalization

Every type of industrial production is subject to the same requirements – the parts or products must be manufactured quickly, economically, and with uniform quality.

This initially brings to mind the revolutionary flow-line conveyor introduced by the Ford Motor Company early 1900s. However, in this instance only one among many operations was automated, the transport of the cars on a conveyor belt during the construction process. The workers had to carry out the same basic manual operations, at the preset pace of the conveyor belt.

With increasing mechanization, other possibilities were also pursued. Individual operations were carried out by appliances and workers could limit their intervention to the placement and removal of parts. Automation should encompass conveying as well as processing/machining. The idea envisioned a factory hall devoid of human beings – definitely no longer a utopia these days!

Economy

When serially manufacturing a certain component, production costs are to be reduced by various factors, including:

- Large batch quantity and short cycle times
- High reliability of the manufacturing process
- Constant high quality of the product

Wage costs form a very important component of the analysis for economic viability. In addition, worker satisfaction must be considered for workers who carry out monotonous and constantly repetitive operations. Even overlooking these two factors, a machine controlled manufacturing process merely supervised by humans is still most likely to provide the best solution to the three requirements specified.

Automation

Automation is a technology concerned with the application of mechanical, electronic, and computer-based systems to operate and control production with little or no human interaction. The word “automation” comes from the Greek word “automatos”, which means “self-acting”.

An automated system consists of three basic elements:

- Power to accomplish the process and operate the system
- A program of instructions to direct the process
- A control system to actuate the instructions

The decision to automate a new or existing production facility depends on the:

- Type of product to be manufactured
- Quantity and rate of production required

- Particular phase of the manufacturing operation to be automated
- Level of skill in the available work force
- Reliability and maintenance problems associated with automated systems
- Economics (labor cost versus equipment cost)

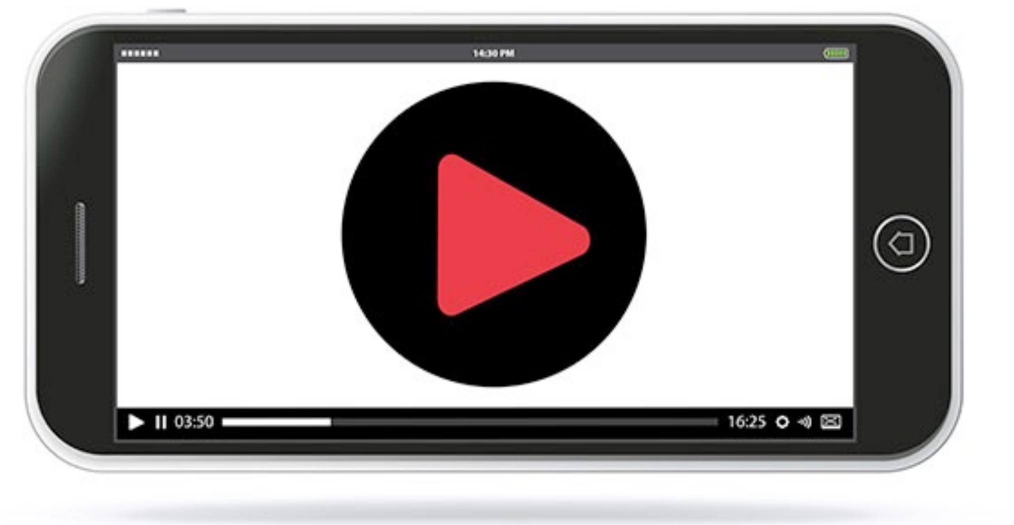
Some of the reasons used to justify automation are to:

- Increase labor productivity
- Improve quality
- Reduce lead time
- Reduce labor costs
- Mitigate the effects of labor shortages
- Reduce/eliminate routine manual and clerical tasks
- Improve safety
- Avoid the high cost of not automating

The application of automation offers various advantages:

- *Technical*: Uniform quality, constant and higher working speed
- *Economical*: Higher productivity, replacement of increasingly expensive human labor by machines
- *Social*: Relieving mankind of the burden of dirty, monotonous, difficult, or dangerous activities

Movie 5.11 Automatic Order-Picking System



Tap to view the video.

Types of Automation

Automation can be classified into three categories based on the level of automation and ease of making changes in the system:

- *Fixed* Automation*:* The sequence of processing steps is fixed by the equipment configuration.
- *Programmable* Automation*:* The production equipment is designed with the capability to change the sequence of operations in order to accommodate different product configurations. The operations are controlled by a program, which can be changed as product configuration changes.
- *Flexible* Automation*:* This is an extension of programmable automation, which is capable of producing a variety of products with virtually no time lost for changeovers. Computer numerically controlled machine tools, industrial robots, and programmable logic controllers are included in this category.

Robotic Safety

Safety around robots is particularly important. Robotic arms are extremely powerful and can quickly move heavy loads around. They do not sense the presence of surrounding objects, potentially causing injuries to surrounding people. Safety regulations call for controlled access robotic cells with safety fencing to prevent people from walking into the range of motion when the robot is in automatic mode. Maintenance technicians can only enter in the cells when the robot's energy source is removed (locked-out), or the robot is under individual manual control with a control pendant that permits them to emergency stop movement.

Robot safety cell with fencing

Robot control pendant with e-stop

Movie 5.12 Material Handling Robots Video

Tap to view the video.

Movie 5.13 KUKU Robot Video

Tap to view the video.

Section 6

Autonomous Guided Vehicles (AGVs)

An automated guided vehicle or automatic guided vehicle (AGV) is an unmanned mobile robot that follows markers or wires in or on the floor, or uses vision system camera technology or lasers to self-locate and move along a programmed route. Sometimes they are composed of regular forklifts equipped with add-on sensors and controls.

AGVs excel in applications with the following characteristics:

- Repetitive movement of materials over a distance
- Regular delivery of stable loads
- Medium throughput/volume
- When on-time delivery is critical and late deliveries are causing inefficiency
- Operations with at least two shifts
- Processes where tracking material is important

AGVs are one of the most exciting developments in the world of powered lifts, and new types of AGVs are regularly being introduced to potentially assume many of the functions previously done by manned forklifts. They are especially popular in food distribution centers.

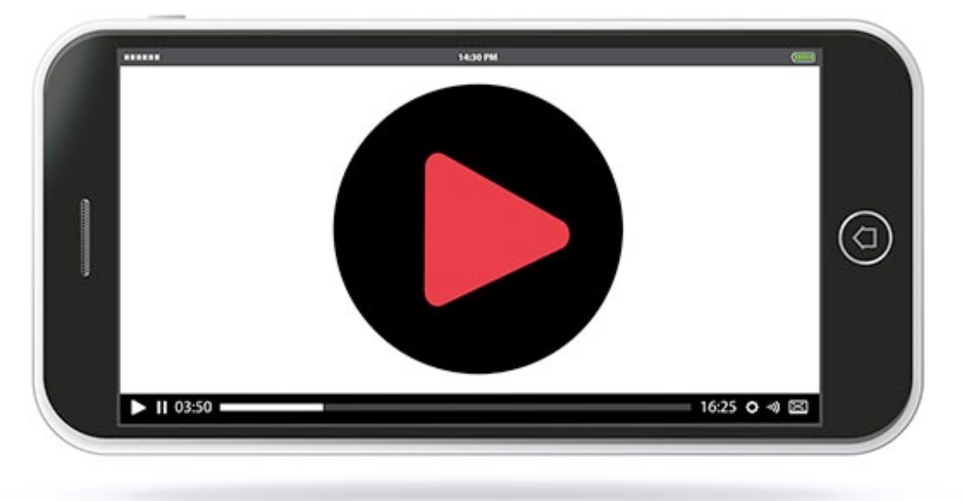
They are most often used to move product around a warehouse. They can be used to reduce labor requirements in a DC that are normally done using operators on forklifts. When AGVs are integrated with other automated material handling applications using Warehouse Management Systems (WMS) and Warehouse Control System (WCS) software, the system can automatically move the AGVs on pick routes through pallet rack aisles and stop automatically where product is located. A light can shine on the desired pallet, and a display will tell a human picker how many boxes to grab and load on the AGV.

Safety around unmanned AGVs is extremely important, and AGVs are typically equipped with numerous, redundant safety sensors to automatically stop the equipment if the AGV senses an object or person in its direction of travel or the AGV loses its location or path.

Movie 5.14 AGV Video

Tap to view the video.

Movie 5.15 Tugger AGV Video



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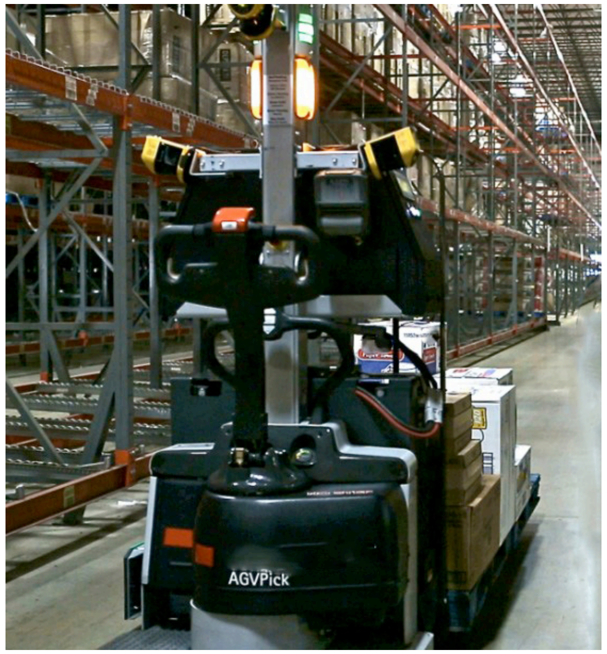


A pallet truck AGV used for product picking

Several AGVs moving pallets

Section 7

Maintenance Processes

Scheduled/Preventive Maintenance

Scheduled, preventive maintenance (PM) of equipment is an important part of keeping equipment available to run and extending the useful life of purchased equipment. In supply chain facilities, maximum use of equipment during scheduled production is critical to save the company money, so quality maintenance programs focus on ways to avoid costly breakdowns. The value of lost productive time may substantially exceed the value of the equipment itself. Timely preventive maintenance avoids failures, unnecessary production loss and safety issues. Technicians frequently spend much of their time performing scheduled maintenance.

Equipment manufacturers develop suggested maintenance procedures for each type of equipment with appropriate scheduled intervals, based on normal usage patterns. These are often put into Computerized Maintenance Management System (CMMS) software to schedule when to perform maintenance and to document the work performed. PMs usually look like checklists, but may include schematics or prints for the technician's reference.

Routine maintenance that technicians perform when doing PMs typically includes:

- Removing dust, excessive grease or debris
- Lubricating moving equipment like chains or bearings
- Verifying correct range of equipment motion and operational checks
- Checking tightness of connections
- Measuring or observing components or checking for excessive wear
- Checking chain stretch, belt tensions and tracking
- Checking alignment of components
- Measuring voltage, current, or resistance

Scheduled maintenance programs frequently include walk-through/observation PMs. These involve watching equipment for non-standard behavior, finding broken or missing components, listening for unexpected sounds, smelling for burnt odors, and detecting unwanted heat. These observations subsequently become follow-up work orders for repairs. Many potential break-downs can be identified and avoided before they turn into emergencies.

Interactive 5.22 Scheduled/Preventive Maintenance Images

Tap to view images.

Predictive Maintenance (PdM)

Predictive maintenance (PdM) techniques help determine the condition of in-service equipment to predict when maintenance should be performed. This approach offers cost savings over routine or time-based preventive maintenance, because tasks are performed only when warranted. The main value of Predictive Maintenance is to allow convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures.

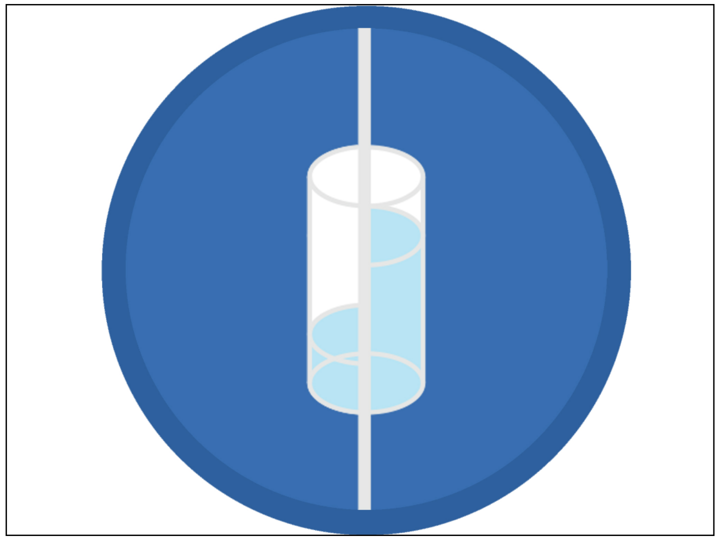
To evaluate equipment condition in supply chain facilities, maintenance technicians will sometimes use predictive maintenance, utilizing nondestructive testing technologies such as:

Infrared (IR) Thermography

Thermal imaging allows the detection of overloaded hot circuits, low integrity or high resistance connections, overrated wiring, and many other defective electrical parts before they fail, potentially catching fire to cause facility damage and/or production losses. Thermal photography (thermography) technology utilizes radiation emitted in the infrared light spectrum to image and measure thermal problems that are normally undetectable to the human eye. Without shutting down equipment or interfering with production, IR cameras can detect problems in electrical panels, motor controllers, switchgear cabinets, breakers, fuses, transformers, terminations, and equipment control panels that could easily result in electrical fires, mechanical breakdowns, or significant business interruption. The two key components are the IR camera and software to interpret the data and prepare reports.

Technician using IR camera to photograph switchboard

Interactive 5.23 Infrared Thermography Comparison

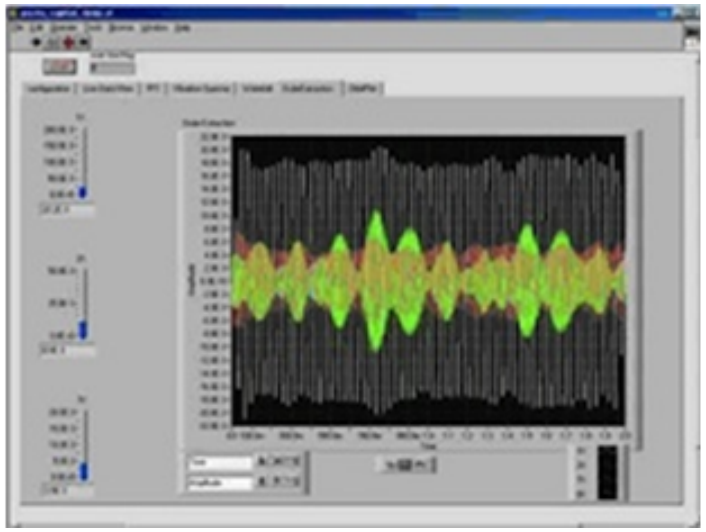


Tap to view a normal view of three-phased fuses and the IR view of the same fuses showing problem hot connection.

Vibration Analysis (VA)

Sensors applied to high speed equipment monitor and transmit records of wave forms and measure degrees of equipment vibration. Software interprets excessive or irregular vibration that might indicate developing problems and allows for scheduled replacement instead of breakdown.

VA sensors.



VA software interprets vibration wave forms

Oil Analysis

Maintenance technicians take oil samples from equipment and send them to a lab to measure contaminants in the lubrication to assess mechanical wear. Labs will frequently recommend replacement of oil or recommend inspection of internal components for machines if there is evidence of excessive contaminants.

Observing an oil sample for contamination

Drawing an oil analysis sample for testing purposes

Corrective Maintenance

Equipment sometimes breaks down or wears out, regardless of good preventive maintenance processes. Corrective maintenance is required when an item has failed or worn out in order to restore it to operating condition. Corrective maintenance usually involves:

- Troubleshooting to identify the root cause of the equipment failure or malfunction
- Disassembly of components
- Replacement of failed components with spares
- On the spot repairs of components
- Reassembly and restoration of service

Interactive 5.24 Corrective Maintenance

Tap then swipe to view images.

Section 8

Prioritization

A key part of being a good technician is being able to prioritize maintenance efforts. Equipment downtime in supply chain warehouses can quickly impair or stop business production and can be far more costly than the cost to repair the broken item. In some cases, multiple pieces of equipment may break down simultaneously. It is important for the technician to estimate the time necessary to perform the repair, assess the impact to production for the different equipment, inform leadership of the plan, and keep them informed of progress. The technician needs to understand the business that they support, and ensure they focus first on the repair that will best support the most important functions. This frequently involves:

- Teaming up with other technicians to maximize speed of effort
- Leaving less important work to wait while more important tasks are completed
- Performing temporary patches or repairs that allow the system to run until a better time is available to do a thorough repair

These types of repairs can be stressful, since many eyes turn to the technician for answers and many people's work depends on their results. The technician must keep a clear head to think about what they're doing, maintain safety awareness, and adapt their approach to changing circumstances. This is when a maintenance technician is invaluable, and sometimes the most important person in the facility.

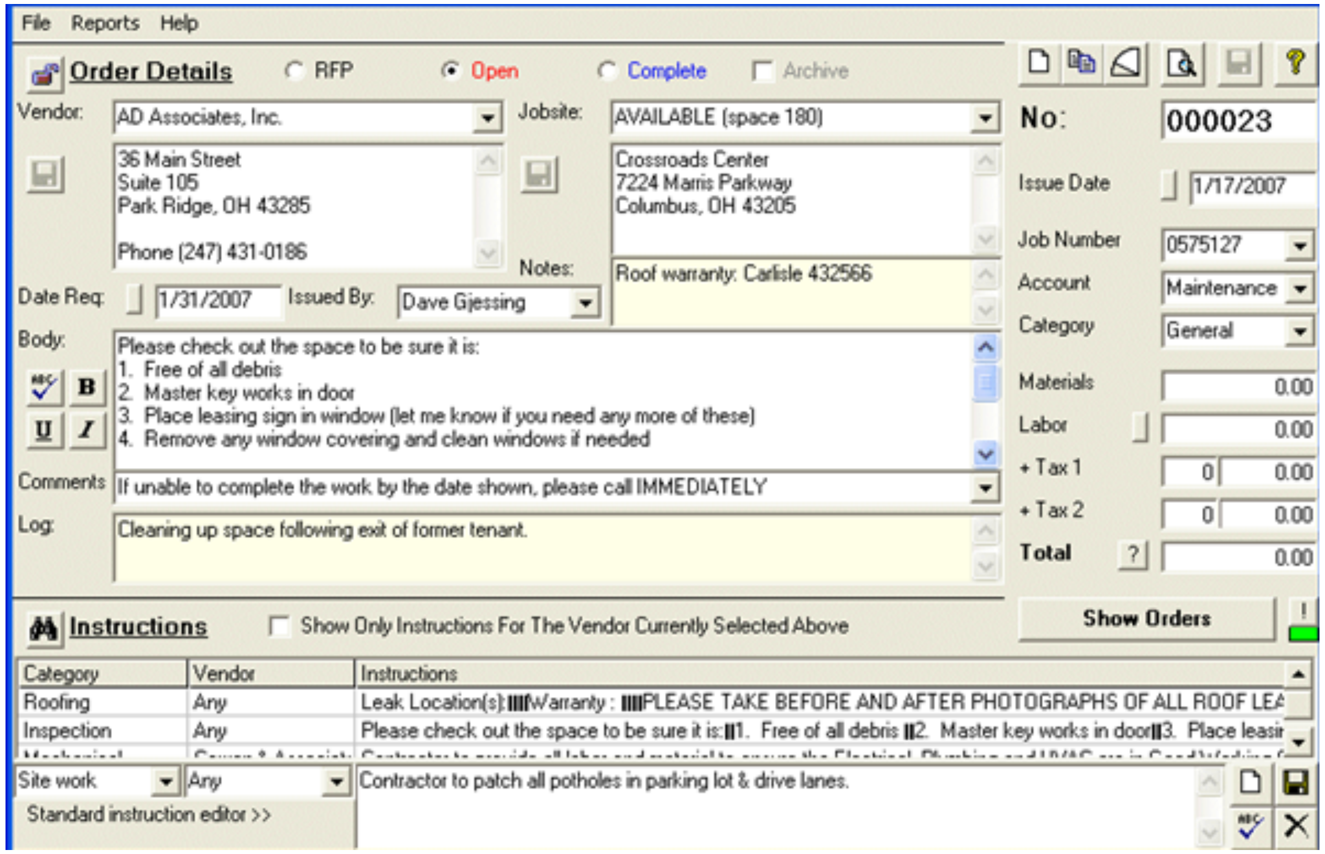
Section 9

Recordkeeping

Documentation and recordkeeping are routine parts of a technician's role. An industry standard practice is to assign work orders to all work performed by a technician. These work orders:

- Assign a tracking number
- Describe the problem or issue
- Track parts issued for repairs
- Track time spent to perform the task
- Record the problem, cause, and remedy (P/C/R).

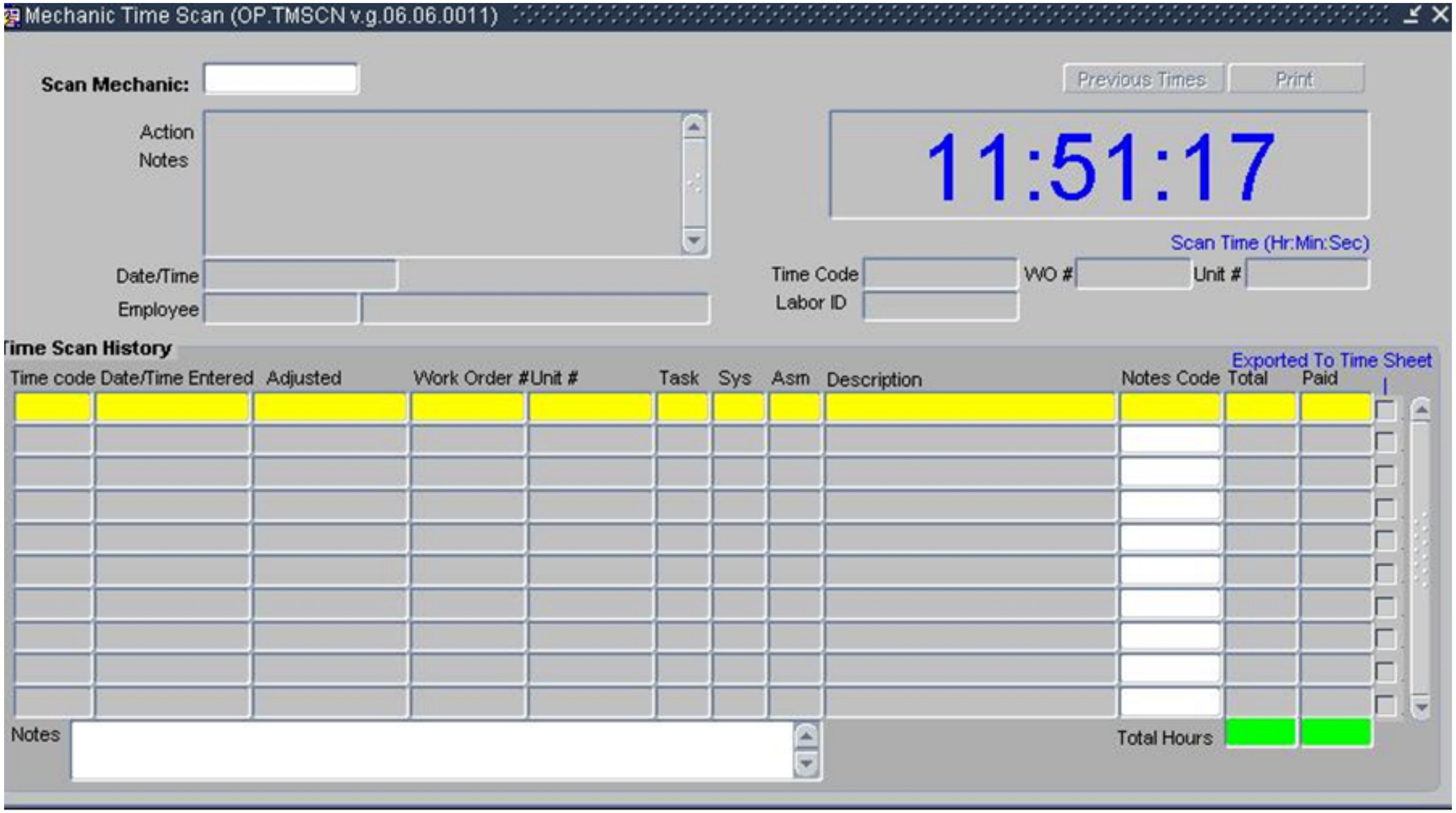
These work orders are often printed out from Computerized Maintenance Management System (CMMS) software. Some companies use hand-held devices that allow the technician to digitally interact with the CMMS.



An example of a digital work order in a CMMS program

Spare parts storage

Work order and CMMS processes allow the maintenance team to manage and order spare parts inventory, track trends of equipment performance, and accurately schedule technician work. Preventive Maintenance (PM) work orders usually have maintenance procedures and checklists to guide a technician through all the steps to perform a maintenance procedure.



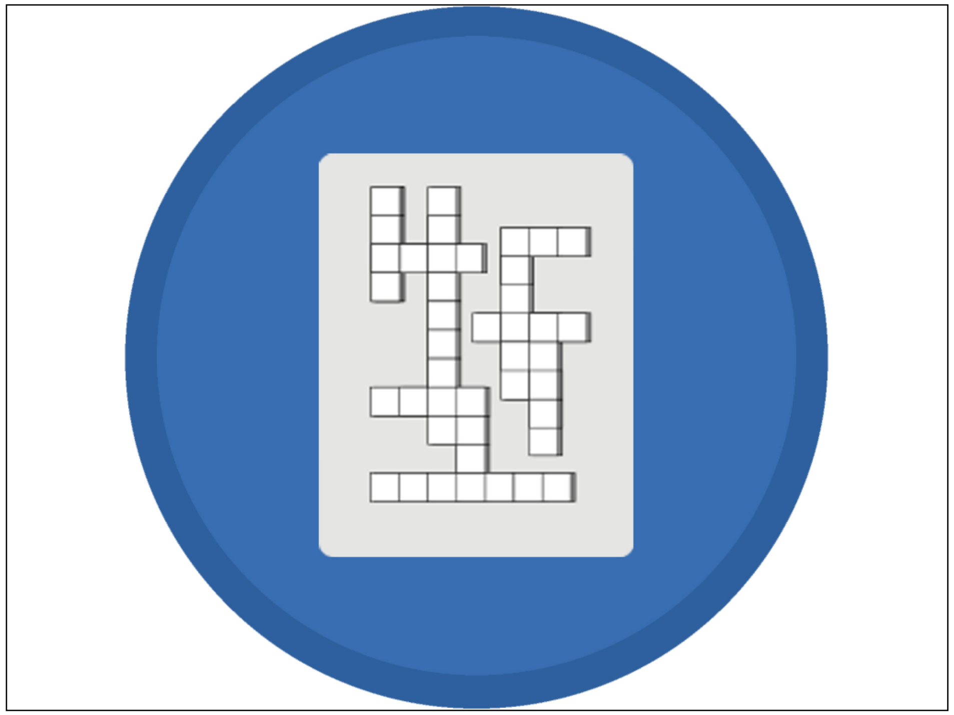
A digital version of a technician's time card

Sometimes, maintenance technicians fill out detailed time sheets accounting for their activities for a work shift. This allows maintenance managers to better understand how their staffing aligns with maintenance workload.

Detailed and accurate documentation is a professional expectation of a maintenance technician. Although documentation can be time consuming and tedious, it is an essential part of maintenance best practice. A technician relies heavily on good documentation to look at equipment history and trends to make a good diagnosis during troubleshooting.

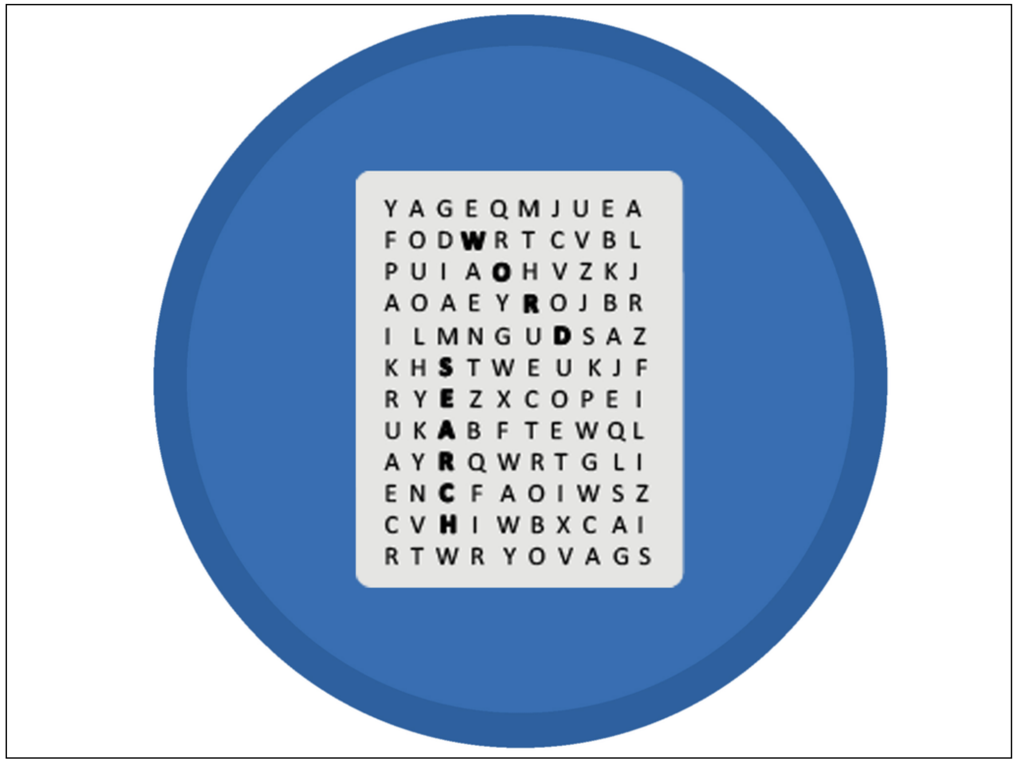
Activities

Review 5.1 Material Handling Equipment Crossword Puzzle



Tap to complete the crossword puzzle.

Review 5.2 Material Handling Terms Word Search

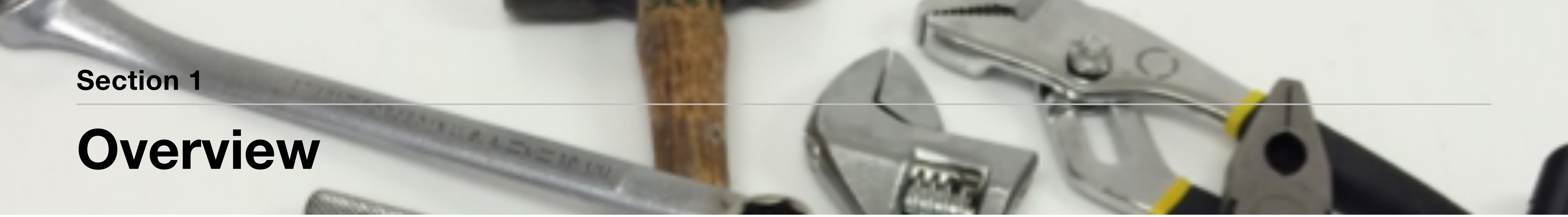


Tap to complete word search.

Chapter 6

Fundamentals of Mechanics

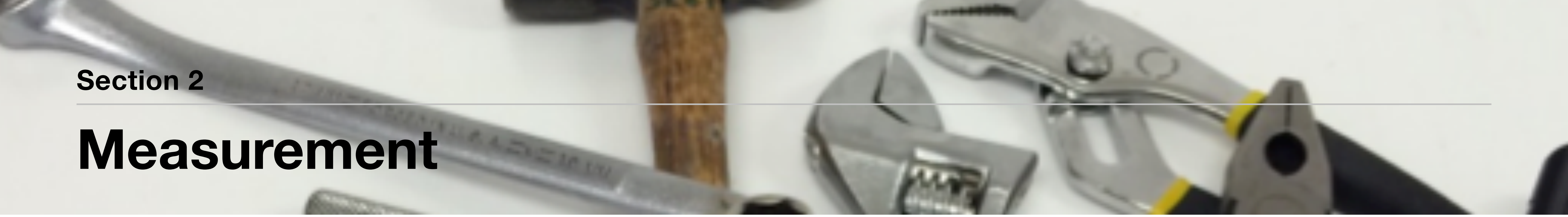
Having the ability to use the tools and equipment necessary to maintain the automated equipment is a mandatory skill for all supply chain technicians. This chapter will introduce you to the mechanical aspects of the automated warehouse.



Section 1

Overview

Mechanical systems drive the entire operation within the distribution center. The movement of product is done by robotics, conveyor systems, lifts, and controlled sorters which are all mechanical devices. The operation, maintenance and repair of this equipment is essential to reduce and prevent failure and maintain the efficiency of production.



Section 2

Measurement

Measurement of parts and components is required for operations to be accomplished by service technicians. Production, maintenance, construction and assembly all rely on measurement for consistent quality and control. The tools required are diverse and need to be organized and protected for maximum benefit and time savings. Quality measuring devices will last a lifetime if kept clean and protected from harsh treatment.

English/Metric Systems

The English (Society of Automotive Engineers, or SAE) system of measurement uses the basic units of inch and foot. This system is used almost exclusively in the United States. A foot is equal to 12 inches. Feet can be advanced into larger units which can be as long as a mile (5280 feet). Inches can be divided into smaller units that are represented as fractions of the whole; 1/2, 1/4, 1/8, 1/16, 1/32 or 1/64. The inch system can be presented as a fraction or as a decimal. The decimal is created by dividing the top fractional number by the bottom to arrive at a number that is a percentage of the inch system. This system is used extensively in precision measurement.

The metric system is based on the value of 10 and is the most common form of measurement in the world. The basic unit of the metric system is the meter (39.37 inches equals one meter). The meter is divided or multiplied by ten to increase or decrease the measurement size based on the unit needed. Prefixes are used to define the size. A kilometer is one thousand meters (1000) and a millimeter is one thousandth (.001) of a meter. The metric system is used extensively for international manufacturing and trade to standardize production.

Rules and Tape Measures

Rules and tape measures are used for measuring linear distances. Small rules are normally 6 or 12 inches in length and are used for more precise measurement. Tape measures can be as long as 100 feet but are normally between 6 and 12 feet and are used for less precise measurement. Rules are incremented into vertical lines representing a whole or a fraction of the whole. Most small rules are incremented with marks representing 1/64 of an inch but most long tape measures use 1/8 or 1/16 as the most accurate denomination. Many rules and tapes are incremented in both English and metric since the use of both systems has become so common. Rules are placed across or between the distance to be measured and the increments then represent a common size that anyone can compare and understand.

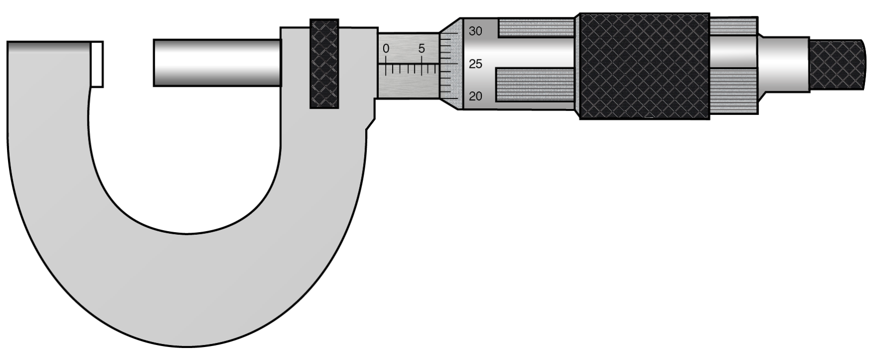
Tape measure and steel rules used for measuring

Precision Measurement

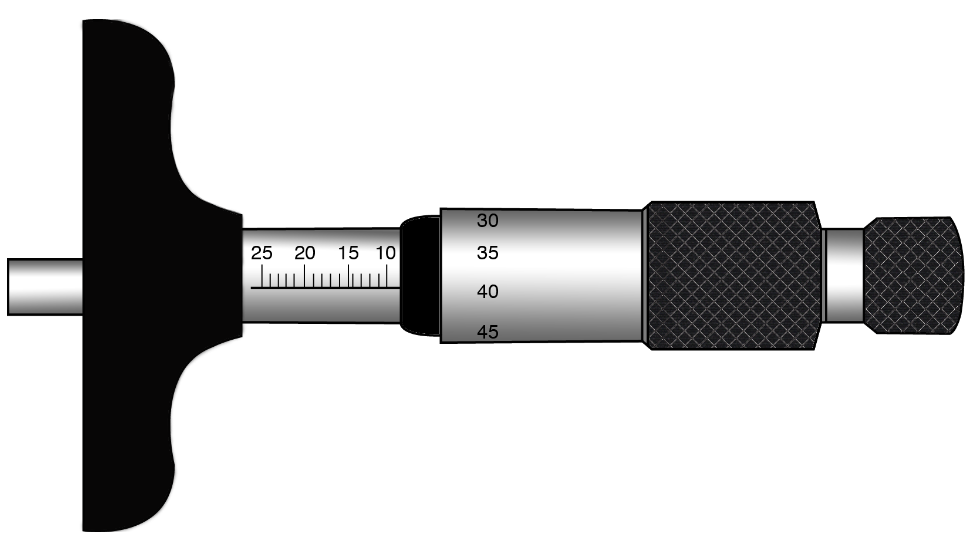
Precision measurement is critical when checking tolerances, verifying wear limits and selecting the proper parts for installation or repair. The accuracy on many components will determine if it is to operate effectively and reach an expected operating life. The tools and equipment needed for these measurements are very accurate and are designed to measure to one thousandths of an inch (.001) or one thousandths of a millimeter. Multiple tools will be needed to measure different configurations.

Micrometer

The micrometer is a hand tool used for accurate measurements. The standard micrometer will measure to one thousandth (.001) of an inch or, with the addition of a vernier, to one ten thousandths (.0001) of an inch. The tool is used for measuring thickness, diameter or any outside dimension. The micrometer head can also be adapted as a depth or inside measurement tool since the unit of measurement is the same. Micrometers are read by turning the thimble until the measuring points are snug on the device and reading the barrel increments to determine size. The numbered lines represent 100 thousandths (.100), the increments between represent 25 thousandths (.025) and the individual numbers on the thimble represent one thousandth (.001). The exposed markings are added to determine the total.



Outside micrometer used for precision measurement.



Depth micrometer used for precision measurement.

Dial Caliper

The dial caliper is a precision measuring tool that will measure inside, outside or depth linear measurements from 0 to 6 inches at an accuracy of one thousandths of an inch (.001).

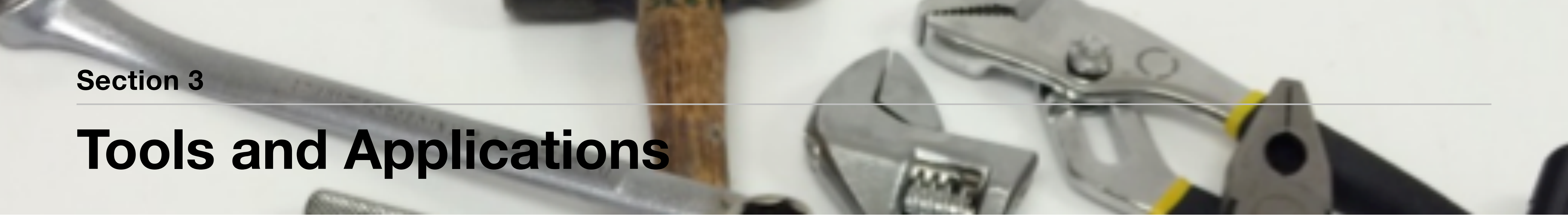
Dial Calipers used for inside, outside and depth precision measurement.

The dial caliper has a sliding head that works with the main beam to be very versatile in what it can measure. The tool is quick and easy to read. The main beam is incremented in inches and tenths of inches and the dial in one thousandth. To read the tool, it is snugged on the part and read as an addition of inches and tens of inches as exposed on the beam and individual thousandths on the dial.

Protractors

Protractor for measuring angles.

The accurate measuring of angles is done with protractors. Protractors are normally a semicircle incremented in degrees with a moveable pivoting arm. The flat or bottom surface is placed along a plane and the pivoting arm is positioned so it duplicates the angle, which is then shown as the exposed incremented line. Protractors are usually made of steel when used as an industrial tool but can be plastic when used in a drafting or engineering situation.



Section 3

Tools and Applications

The proper use of tools is essential for the performance of mechanical tasks; without tools productivity stops. The proper tool for the right job is also paramount for safety and quality. The right tool must be chosen for the right job.

Hand Tools

Hand tools are the lifeblood of maintenance technicians. They are used for all aspects of repair, maintenance and installation of equipment. The versatility and applications are endless and without them the process will not function and productivity will fail.

Hand tool set for service technicians

Miscellaneous tools used by service technicians

Hammers

Hammers are hand held striking tools with a head attached to a handle to allow control, leverage and strength. Hammers range in size from very small to very large depending on the application and design. Hammers can be used for shaping, riveting and bending metal or can be used in conjunction with other devices like punches and chisels to cut or press materials. Sledge hammers can be used for demolition or for applying large force to move an object.

Assorted hammers for applying blunt force power

Wrenches

Wrenches are used to apply twisting force to a bolt, nut, pipe or any item that requires torque. Open end, box end and combination wrenches are used in close quarters where access is limited. Sockets and drive devices (ratchet handles) are tools used to speed up the process and allow reach not possible with conventional wrenches. Pipe wrenches are used for twisting round objects, such as those used in plumbing, but they do have a tendency to damage the surface of the application. Adjustable wrenches allow for infinite sizes but lack some strength in the jaw and are bulky in use.

Interactive 6.1 Assorted Wrenches and Sockets

Tap then swipe to view images.

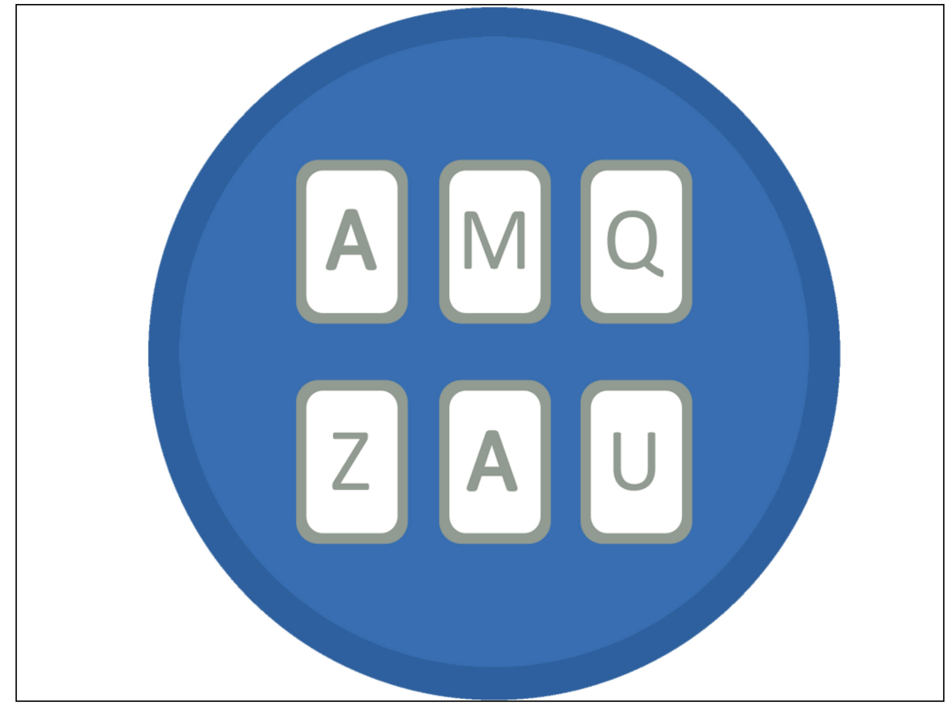
Screwdrivers

Screwdrivers are used for applying a twisting force to small threaded fasteners. Most screwdrivers are of the flat, phillips or captured type tips and come in varying sizes. The standard or flat tip is the most commonly used for many applications. The phillips design tip has an advantage that it will not allow the tip to slid out of the screw, which is common in the blade type tip. The captured tip can be of varying types to include allen, torx, clutch or fluted and are normally used with power tools.

Slotted screwdriver as commonly used by service technicians

Screwdriver set to cover most types and sizes

Review 6.1 Screwdriver Driver Types



Tap then match screwdriver drive types. Tap trash can to clear and repeat activity.

Pliers

Pliers are gripping tools with opposing handles and jaws that increase the leverage of the user's grip. They come in many different configurations to accomplish different tasks. Some pliers are adjustable by slipping the grooved jaws to change the jaw opening. Some pliers are locking jaw and can be used to hold work together as another task is being accomplished. Extended reach pliers allow the user to reach into areas that are either not accessible or unsafe to reach into. Pliers can also be used as cutting devices for small wire pins or nails.

Assorted pliers to apply griping and cutting force to a project

Power Tools

Power tools, when used in the appropriate manner, will lessen the workload and accomplish tasks much quicker. The use of electrically powered tools increases strength and versatility for the worker.

Drills

A power drill is a power tool that provides rotary motion to accomplish many tasks. They can be driven by wall current or battery power. It is used primarily for drilling holes in metal, wood or plastic but can also be used for drilling concrete or brick if used with the proper bits. Size (1/4", 3 /8", 1/2") and RPM can vary depending on the application. Drills can be fitted with different kinds of attachments which allow for screwing, grinding or buffing.

110 VAC drill motor

Saws

Cutting of materials is accomplished by saws. Portable circular saws are commonly used to cut wood or plastic and can be fitted with abrasive blades to cut metal. Reciprocating hand saws are used extensively for cutting all types of materials. They are versatile and can be used with many types of blades to accomplish multiple tasks.

Portable power saw for cutting wood or metal

Tool Safety

Tool safety is the most important consideration when using tools. Proper tool choice for the job is always a must. Organization and access to the proper tool will minimize the risk of using the wrong tool. Personal Protection Equipment (PPE) is always a consideration when working with tools so the worker is not placed at risk. Replace damaged or worn tools and have a tool replacement and purchase plan. When working with power tools make sure you understand their operation and the potential risks from electricity, chip removal, or torque concerns. Be in control of the tool by positioning your work where it is safe and secure. Think before you do the process and know the end result.

Section 4

Physical Properties

Angled components shown in a distribution center storage system to increase strength and stability

Formulas and calculations are used to determine the quantities and volume of applications. Linear units, volume, sizes and weights all play a role in the design, installation and maintenance of a distribution center. These properties need to be understood and correctly applied.

Conversions and Formulas

Formulas are the use of combined numbers to determine a needed value. The grouping of these numbers and mathematical applications become equations to determine the values. Examples of common formulas are area, volume, rise and unknown dimensions.

Angles

Angles are formed by the intersection of any two planes, lines or sides. Angles are measured in degrees, minutes and seconds. Different angle types have differing applications and will be used when installing equipment or structures. Some types include right, adjacent, supplemental, and obtuse.

Area

Area is the number of square units that make a flat surface. The configuration dictates what formula will be used to mathematically figure the total. Area is expressed as square inches, feet or a metric denomination such as square meters or millimeters. The applications of the formulas vary depending on shape and configuration.

Pressure

Pressure is the force created on a unit area. The inside of a tank or a pipe will contain pressure and its power is exerted against its sides. Pressure is expressed as atmospheric, gauge or absolute. Atmospheric pressure is outside air pressure which applies force to everything. Gauge pressure is internal to a system and is produced by a source. Absolute pressure is pressure above a perfect vacuum. Each has application but most of what will be used for a distribution center is gauge or enclosed pressure within a hydraulic or pneumatic system. This pressure is produced by compressors and pumps as a central system or as part of an individual piece of equipment.

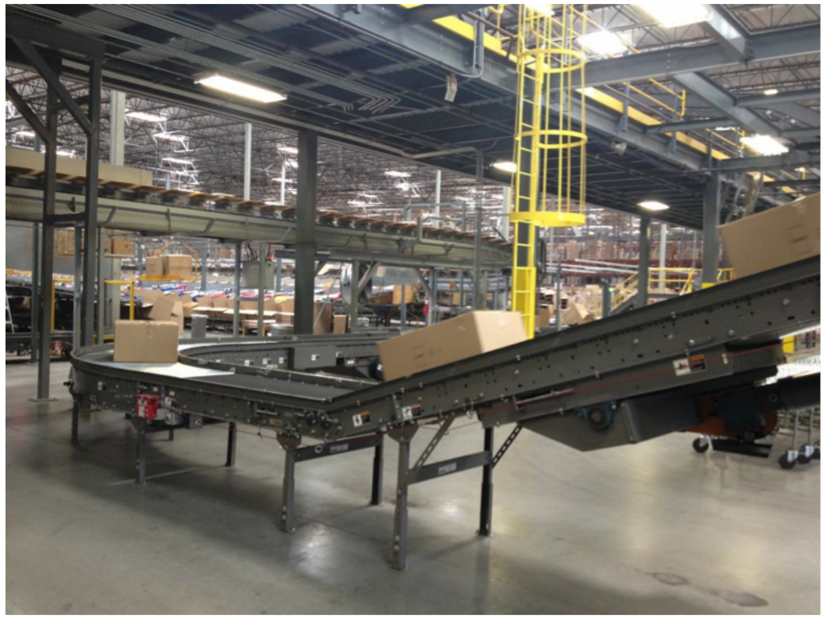
Industrial air compressor with a refrigeration drier

Pressure gauge indicated in PSI and metric systems (bar)

Section 5

Structures

The distribution center is made up entirely of structures. The distribution equipment from input to shipping is all supported by different structures that work together to allow flow and control of all items within the center. Maintenance and installation are part of the maintenance personnel's responsibility so an understanding of its function is important.



Distribution center structures

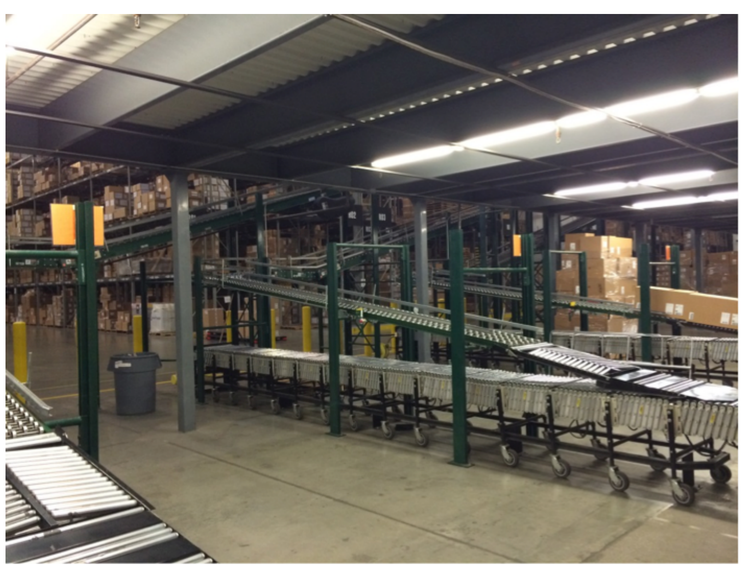
Stairways

Fixed industrial stairways are the standard for all distribution centers and must comply with the safety guidelines established by OSHA. Step design, width, hand rails and angles are part of the code, with all applications abiding by the guidelines.

Mezzanines

Industrial mezzanines are semi-permanent floor systems installed inside a building to create a secondary floor to increase floor space and expedite movement of materials.

The distribution center designs the system to increase productivity and volume and to maximize available space. Protection from falling product and personal safety concerns is part of the design. Most mezzanines are made of steel, supported by structural beams and anchored to the floor.



Ramps and mezzanines to increase floor space for better utilization

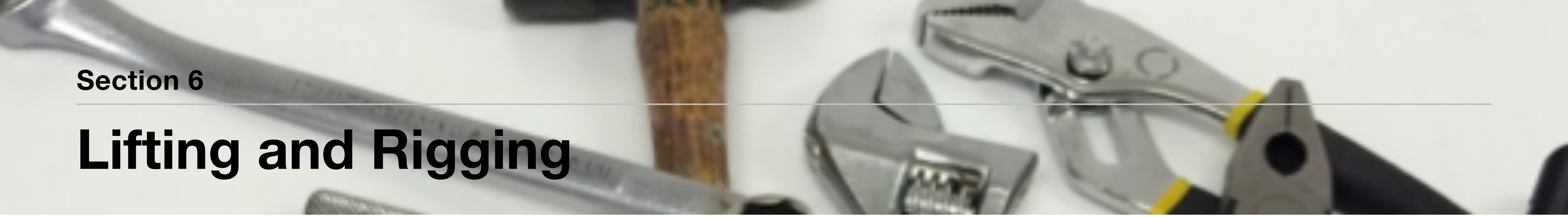
Racking

Distribution center racking is an extremely important part of the center. Efficiency is the primary issue in the design and application of racking systems. Racking can be as simple as pallet racks serviced by a lift truck or as complex as an automated storage and retrieval system. Volume and height are also a major part of the design so as to accommodate the merchandise that has to be distributed. Racks are built with cross supports to give structural rigidity and meet local building codes.

Storage racking

The distribution center conveyor system must progress to multiple elevations which is done by belt, rollers or lifts depending on the system design.

Most down movement is done by gravity on chutes or free rollers. The lifting of pallets during input and shipping is done by lift truck or moveable conveyors. The choice of processes depends on volume and cost effectiveness and if the center is designed to deal with pallets or individual items. Material lifting can be fully automated if the volume justifies the cost effectiveness of the initial expense. Automatic storage and recovery systems (AS/RS) are being used in most large distribution centers.



Section 6

Lifting and Rigging

Lifting and rigging is the safe movement of materials and equipment to a required height. Rigging is the securing of equipment for the preparation of lifting and the lifting is the use of hoists and cranes to accomplish the task. The needed equipment must be compliant and complete in order to accomplish the task in a safe and efficient manner. Straps, slings, hooks and cables are all used for different applications.

Rigging

The safe and effective process of lifting items during maintenance operations is critical to effective repair and replacement. Balance, security and strength all need to be evaluated effectively. A-frames or overhead hoists are a standard for lifting machinery and lifting jacks and platforms can be used when access and logistics allow.

Load Calculations

Estimating the weight of a load may be done by referring to the shipping weight of the replacement part or by using a material weight table. Large motors and gear boxes are some of the more difficult estimates to make without manufacturer specifications. The load also needs to be balanced, which requires the center of gravity to be considered when planning a lift.

Attachments

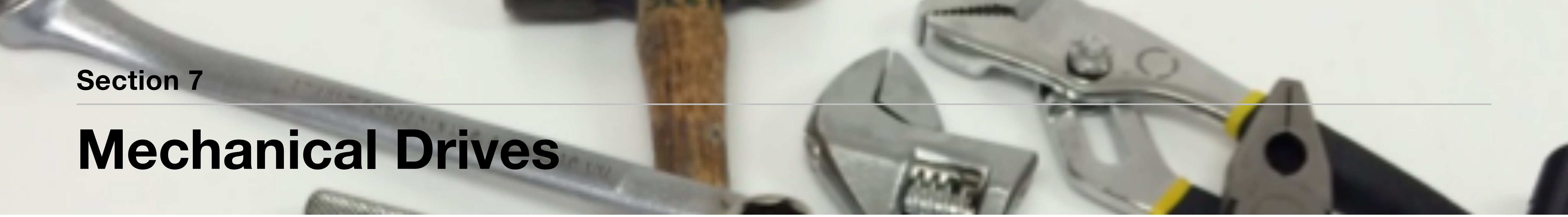
Attachments for rigging are normally steel hooks, shackles and lengths of chain or steel cable. The attachments can be gated or ungated and may use a swivel or a clevis to support the attachment. Shackles, as with all attachments, are of differing sizes to allow access to the rigging and to ensure appropriate strength for the load. Master links are also commonly used to allow multiple attachments to come together or to allow flexibility in the placement of the attachment.

Strapping/Slings

The choices of materials used for lifting range from rope to steel chain, and the options are dictated by the load. Rope is an inexpensive lifting tool that can be sized for a minimum weight or a very large weight. Webbing is also used and, as with rope, its strength is in relation to its width and thickness. The flexibility of webbing and its ability to grip on a component make it popular. Using steel rope or chain is common and again, its strength is dependent on the size.

Interactive 6.2 Lifts

Tap then swipe to view images.



Section 7

Mechanical Drives

The movement of distribution center items is done by a large, complex system of driven machinery. This power is delivered by mechanical drives. Gears, belts and direct electric motors provide torque and movement for all items. The supply chain technician is responsible for installation, service and maintenance of all moving equipment. Mechanical torque changes, speed changes and directional changes are all done by mechanical drives.

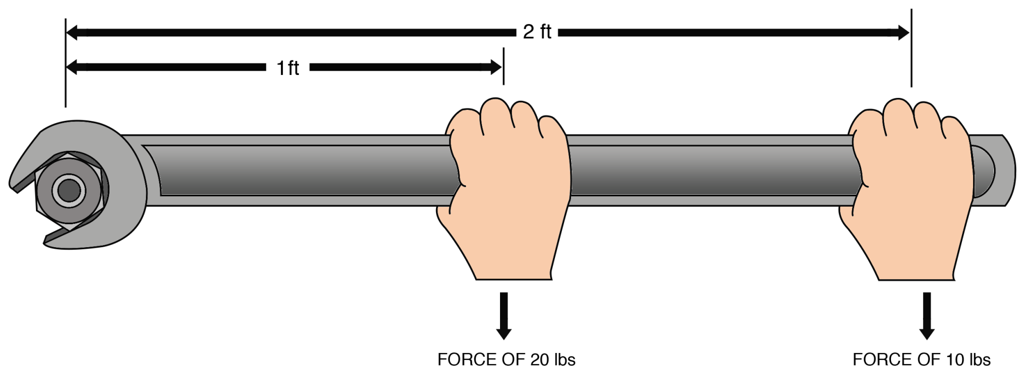
Energy Transfer

The transfer of energy is accomplished by mechanical means; this can be gear transfer or belts. The end product is the transfer, by a mechanical energy, from one source to a driven mechanism.

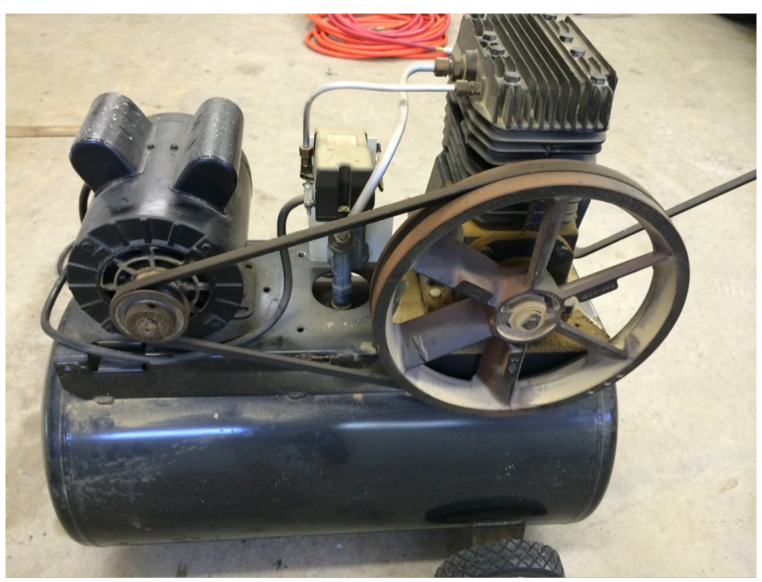
Gear set for changing torque and speed

Torque

Torque is the twisting force exerted on a shaft within a machine. Torque can be increased by going from a small drive device to a larger driven device. The multiplication of torque results in more power but less speed.



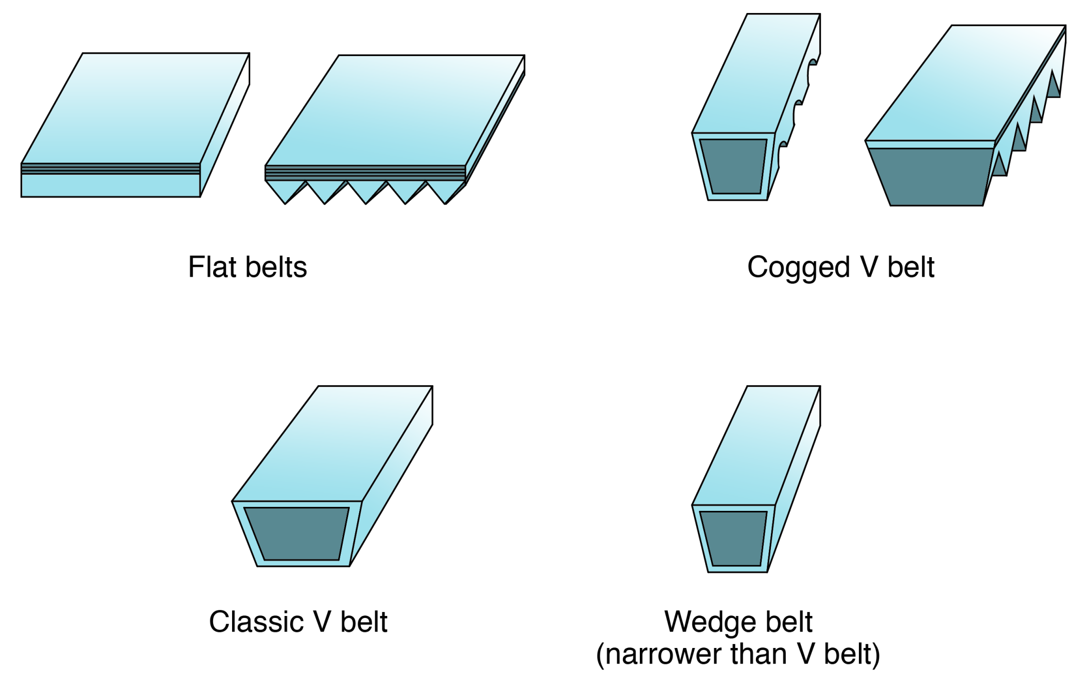
A wrench being used to multiply torque



Small sprocket driving a large sprocket to decrease speed and increase torque

Belt Drives/Pulleys

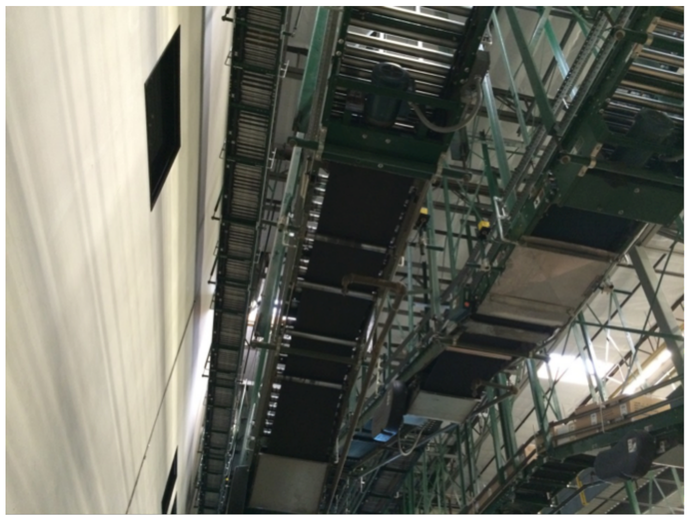
Belt driven systems use belts and pulleys to transfer power from a drive motor to a driven component. Belt drives create a convenient drive system that is quiet and forgiving. Belts normally have good useful life and can be easily maintained and serviced. They also have the advantage of not being a positive transfer, to minimize component breakage. Safety concerns are always present so make sure all guards are in place and the power is tagged off before work begins. Working around moving belts or pulleys should never be attempted.



Belt types

Flat Belts

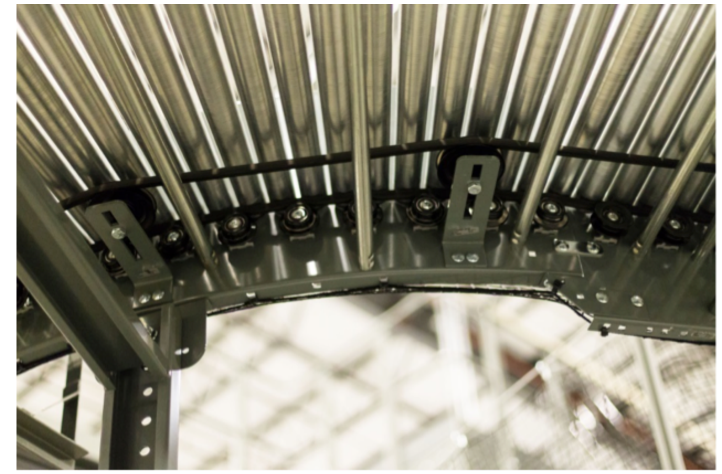
Flat or serpentine belts are used when the belt or tension system changes direction to drive multiple loads from both sides of the belt. The flexibility allows for small pulleys to be used without damaging the belt.



Flat belt in operation

V-Belts

V-Belts are the most common drive belt system for industrial applications. The belt has a large surface area to contact the pulley and is self-centering. Replacement, service and tensioning are simple and the costs are low. Larger power systems will use multiple groove pulleys and multiple belts to transfer torque and speed.



V-belt application for driving multiple rollers on a conveyor system

Cogged belt drive

Cogged Belts

Cogged belts are used to transfer high torque energy but they also index or time the pulleys if needed. Cogged belts allow no slippage so the transfer of energy is more controlled.

Gear Drives

Gear drives are used in distribution centers to increase torque and determine speed for driving conveyors or belts. The gears are housed in a gear box that is normally self-contained with an electric motor and gear train with lubricant for the gears in the sealed package. They are used for high torque applications and can be used to drive chains or belts, but are normally attached to high load equipment.

Straight

Straight cut or spur gears have gear teeth that are parallel to the direction of rotation. The advantage of this gear arrangement is that no side loads are placed on the gears and they transfer torque in the same plane to a driven gear. These gears are the most commonly used in industrial applications but produce substantial noise during operation.

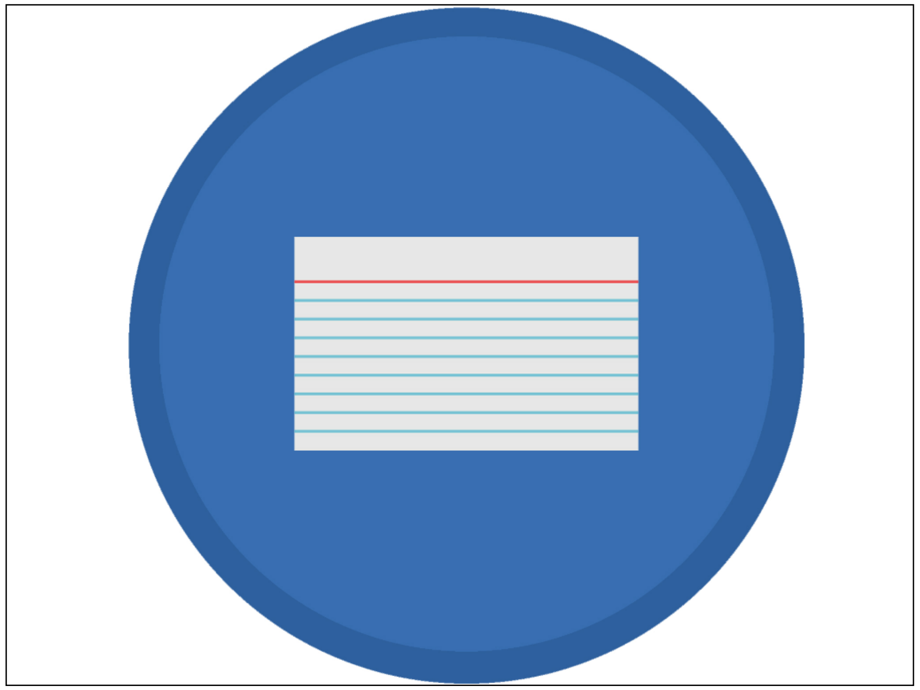
Bevel

Bevel gears are cone shaped so they can transfer torque and speed between shafts that are not in the same plane. Bevel gears produce heavy side thrusts on the gears so they must be used in a strong, well supported housing. They can be produced at different angles to provide additional applications. They can be produced with a spiral gear tooth to produce a quiet operation.

Worm

Worm gear sets are used for slow operation with high torque, speed reduction and a change in direction. The worm gear is on a shaft which drives a wheel gear in the perpendicular direction. Worm gear sets also lock the wheel gear in place when the drive worm gear is stationary.

Review 6.2 Different Types of Drive Gear Sets



Tap to test your knowledge of drive gear sets.

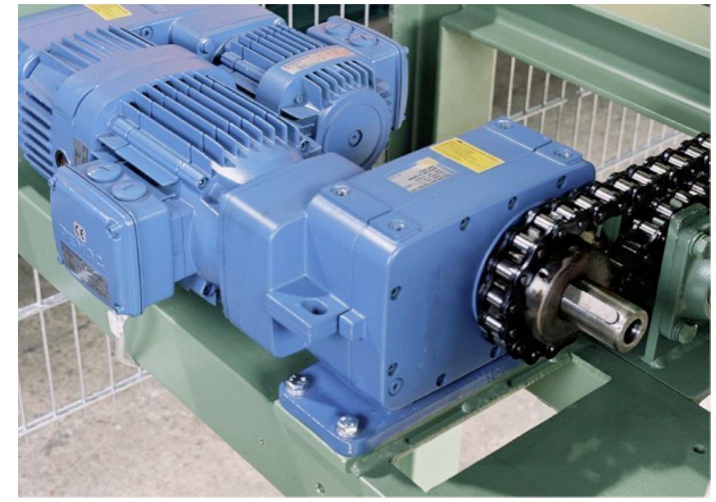
Chain Drives/Sprockets

Chain drives transfer energy in a controlled application. The sprocket teeth are in contact with the chain links so no slip is allowed and timing is achieved. These drives can be used in high torque applications. The meshing of the sprocket and chain create a positive drive system that is self-guiding.

Chain driven rollers for heavy-duty applications

Roller Chains

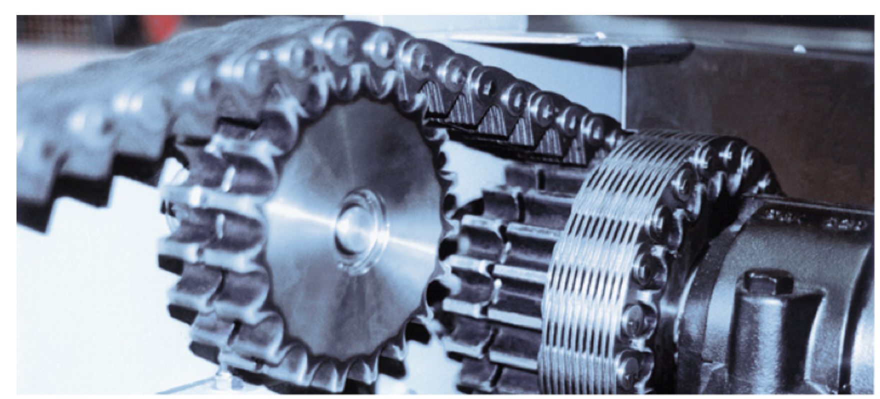
The roller chain contains a roller, pin and connecting links to make a flexible chain with internal lubrication. Roller chains come in different sizes based on torque requirements and function at moderate speeds with little or no lubrication.



Roller chain being driven by a gear box reduced drive motor

Silent Chain

The silent chain is made of a number of links pressed together on a pin which allows rotation. The edges or center link is not relieved so it will track on the sprocket. The advantage of the silent chain is less noise, longer operational life and greater efficiency.



Silent chain

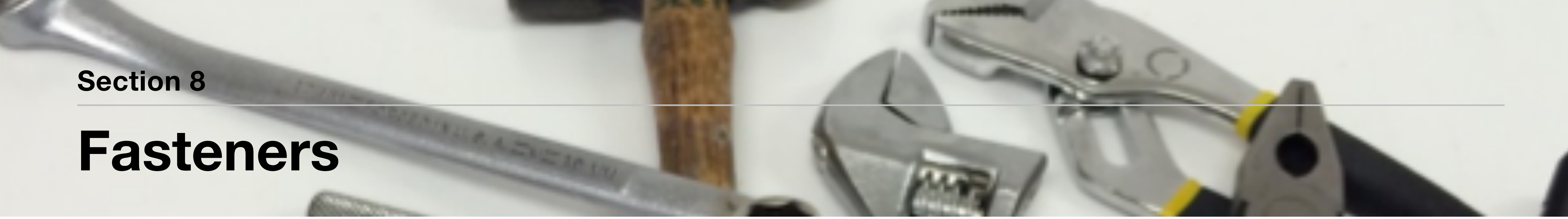
Ladder Chain

Ladder chains are used to create meshed sprockets that turn at a very low speed. It is normally used for position changes and control functions. It doesn't require lubrication and is inexpensive.

Ladder chain

Section 8

Fasteners



Most fabricated facilities today are held together with threaded fasteners. Threaded bolts and nuts are the most favored holding device since they are removable and can allow for easy maintenance and repair. Thread sizes differ based on application for size and strength. Bolts and nuts are rated for strength and can be produced with different drive types to fit individual needs. Wrenches and sockets are used to apply tightening force and automated power tools can be used to speed assembly or increase tension.

Nuts and bolts used for assembly processes

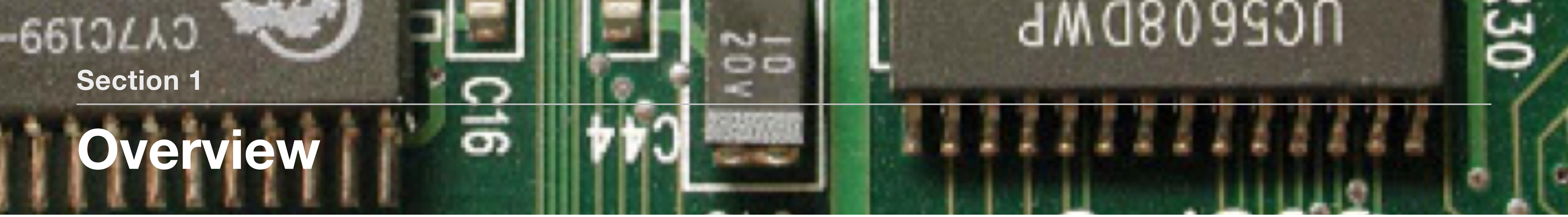
Anchoring

All equipment in a distribution center must be properly anchored to the floor or walls. This is done with anchor bolts and hammer drills that allow for future disassembly or repair. Permanent anchoring can be done during slab development but does away with the flexibility of anchor bolts.

Chapter 7

Electrical

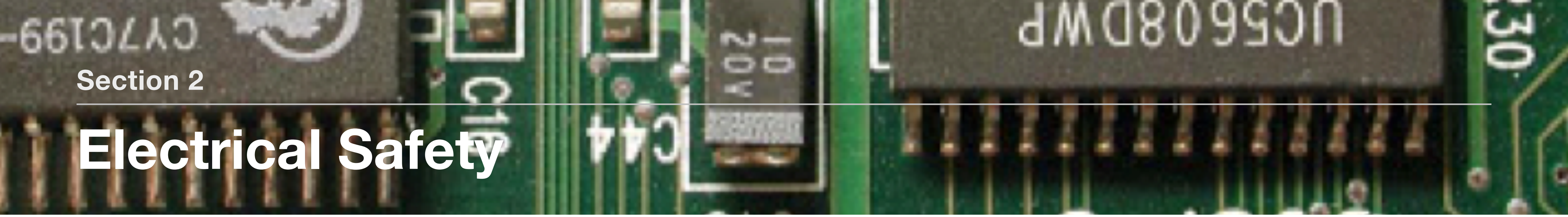
Every supply chain technician will need to know basic electronics. This chapter will introduce you to electrical theory, safety and the tools we use to diagnose, troubleshoot and repair electrical problems.



Section 1

Overview

Electricity is the movement of electrons from one atomic structure to another. The movement is accomplished by creating polarity changes in the atomic structure to force electrons to flow through a pathway made of conductive materials. The basic atomic structure is comprised of neutrons, protons and electrons. The neutrons and protons make up the core or nucleus with the protons being positively charged and the neutrons being neutral or having no charge. Electrons are free to orbit in shells around the nucleus and are negative in polarity and are held in position by opposing forces of centrifugal force and magnetic attraction. If the number of electrons and protons are the same in each atom the polarity is neutral and no movement of electrons is possible. If the number is different, the atomic structure can be of negative or positive polarity depending on which has the greater number. This is what forces electron movement or electrical energy and this movement of electrons is what does all work associated with electrical energy.



Section 2

Electrical Safety

Safety Codes and Organizations

Safety codes are procedures to follow and implement when working on electrical applications to protect the technician from injury and death. Organizations developing and setting uniform safety practices include the National Electrical Code (NEC), National Fire Protection Agency (NFPA) and the Occupational Safety and Health Administration (OSHA). These organizations require strict guidelines to include lock out/tag out procedures on equipment for safety to the technician for all electrical installs, repairs or preventative maintenance.

Each company will have governing electrical procedures and safety codes, however all companies are governed by safety in all operations, including electrical, from the agencies listed above. In industry there have been unfortunate injuries and deaths to technicians who have circumvented the procedures in place to either complete the job quicker or believe that skipping some safety procedures is acceptable. All procedures for electrical safety are in place to be able to do the job safely and effectively and must be followed at all times.

Personal Protection Equipment

PPE or personnel protection equipment is required for working on electrical applications live, an energized circuit. The requirements are set by the NFPA as determined by the types and amount of voltages and currents. As the voltages increase the amount of protection must also increase.


Protective clothing worn during electrical testing on a live circuit

Meter Safety

Meter safety falls into two categories. First ensuring the meter is properly protected with internal fuses in case of an error for checking voltages with the correct meter setting. Second ensuring the meter has been calibrated annually and is operable for reading accurate voltages.

Most importantly for meter functionality, understanding what the settings are on the Digital Volt-Ohmmeter (DVOM) allows for a level of confidence in the readings. Knowing the processes and how to check the various measurements for Amps, Volts and Resistance will ensure effective troubleshooting with safe practices.

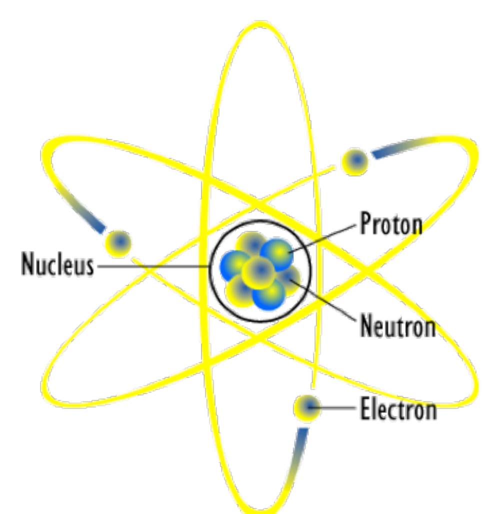
Overload Protection

The use of devices with fuses or circuit breakers provides protection that will open and deactivate the circuit if it is overloaded. This will protect devices or wiring within a circuit. Overload devices are important for protection during component errors such as a grounded hot wire, a malfunctioning component or overheating of a device. It is important never to bypass or use the incorrect rating of overload devices as this can lead to device damage and/or electrical fires.

Electrical Principles

Atomic Structure

The atom is a basic unit of matter that consists of a nucleus surrounded by a cloud of negatively charged electrons. The atomic nucleus contains a mix of positively charged protons and electrically neutral neutrons (except in the case of hydrogen). The electrons of an atom are bound to the nucleus by both electromagnetic force and centrifugal force. Likewise, a group of atoms can remain bound to each other by chemical bonds based on the same force, forming a molecule. An atom containing an equal number of protons and electrons in each atom is electrically neutral; otherwise it is positively or negatively charged and is known as a positive or negative ion. A negative ion has more negative electrons than positive protons so it will attempt to give off the extra electrons to become neutral. A positive ion has more positive protons than negative electrons so it will attempt to attract electrons to become neutral. The movement of these electrons from one atomic structure to another is electricity that does work.



Atomic structure as the basis for electricity

Voltage, Amperage, Resistance

Voltage is the electrical difference between two points of a circuit, or the difference in electric potential energy between two points. Voltage is indicated in units of volts (V). Voltage is the force pushing electricity (electron movement) to do work. It can be compared to water pressure in a pipe. The pressure on the water creates the potential to do work but the flow of water actually does the work.

Amperage is the movement of electrons through a circuit expressed and measured in amperes (A). Amperes are the component that is based on the movement of electrons through a conductor. The movement of electrons is what does the work. This could be the lighting of a light or the turning of a motor. The greater the volume of current the more work can be done. Amperage or current can be compared to the gallons of water flowing through a water pipe which can be said as doing all the work.

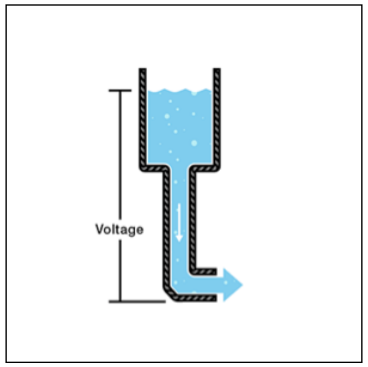
Electrical resistance is the opposition to the movement of electrons in an electric current through a conductor. The opposite is electrical conductance, the ease at which an electric current passes electrons. The unit of electrical resistance is the ohm (Ω). Electrical resistance is the control for electron flow. It can be compared to a valve in a water system as a closed valve being high resistance (no flow) and an open valve being no resistance (high flow).

Understanding the relationship of Volts, Amperage and Resistance in an electrical circuit is vital to understanding circuit applications and to effective troubleshooting. Once the relationships and roles of these parts of an electrical circuit are understood, the technician goes beyond guessing at the fix, but systematically isolating and identifying issues within electrical malfunctions.

Movie 7.1 What is Electricity

Tap to view the video.

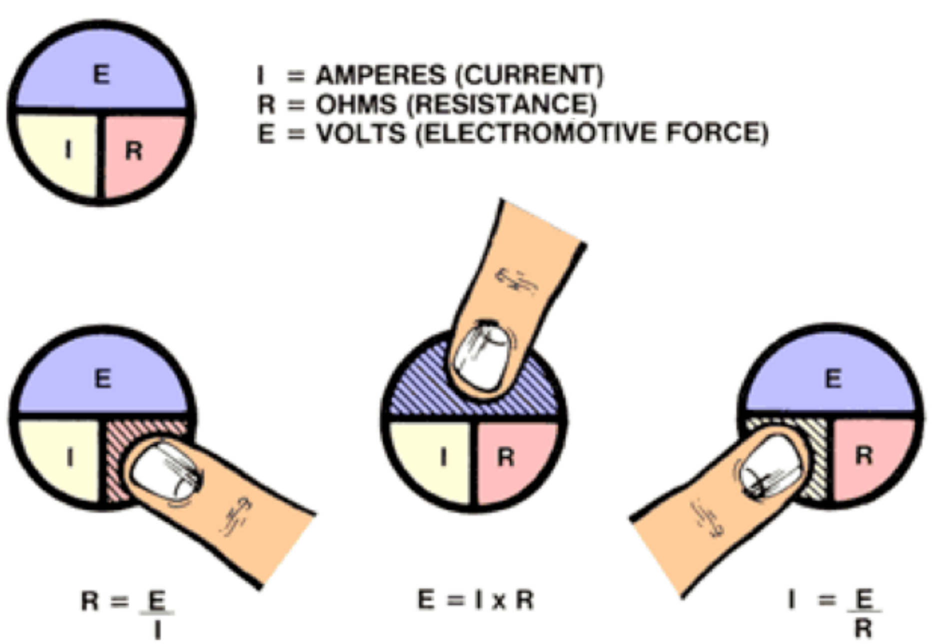
Interactive 7.1 Water flow demonstrating electrical properties



Tap image to view images of water flow demonstrating electrical properties.

Ohm’s Law

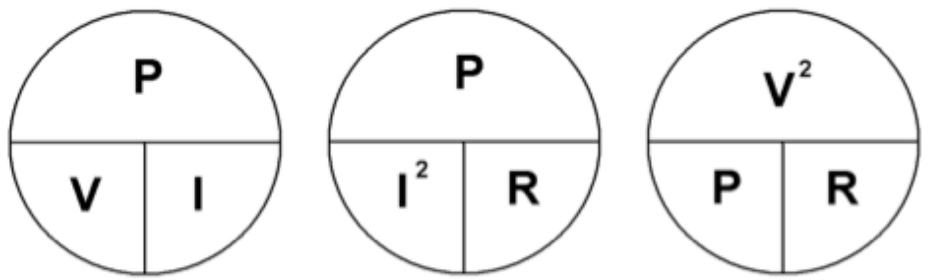
Ohm's law states that it requires 1 volt to push 1 ampere through 1 ohm of resistance. This is accomplished by the current through a conductor between two points being directly proportional to the potential difference across the two points. The mathematical formulas give order and understanding to the concepts of electricity. The most common method of applying the formula is called the ohms law pie where the unknown item is covered and it represents the formula for finding the unknown value.



Determining the unknown values by formulas for Ohm's Law

Power (wattage)

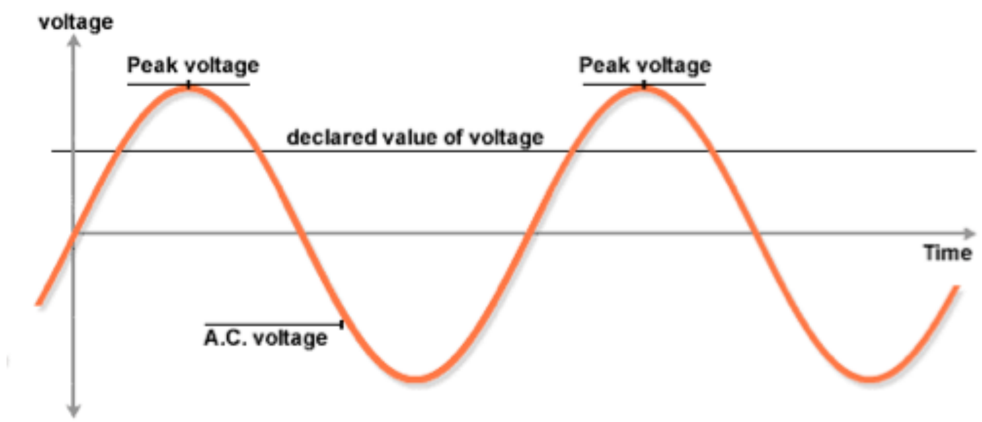
Power is the rate at which energy is transferred, used, or transformed. The unit of power is known as the watt (in honor of James Watt, the eighteenth-century developer of the steam engine). For example, the rate at which a light bulb transforms electrical energy into heat and light is measured in watts—the more wattage, the more power, or equivalently, the more electrical energy is used per unit time. The formulas for wattage are established by using the pie the same as the ohm’s law pie.



Power equation pie used to determine the amount of work that is being done and to help design a circuit so overloading doesn’t occur

AC/DC

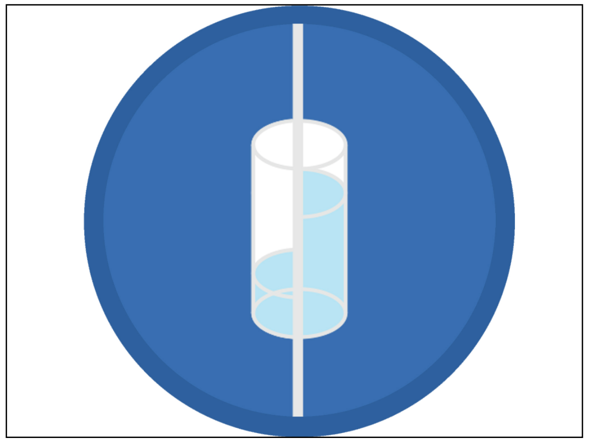
AC stands for “Alternating Current,” meaning voltage or current that changes polarity or direction over a given time. AC is the most common form of electrical energy used in industry because it is efficient to produce and transmit by suppliers over long distances. AC current is produced at a generating station and is then distributed to the automated warehouse. AC current can be used as single phase or three phase applications. Single phase at 120 or 220 volts is normally used on application below 5 horsepower and three phase 440 volts and above for larger energy applications.



Oscilloscope waveforms showing single phase AC

DC stands for "Direct Current," meaning voltage or current that maintains constant polarity or direction. DC voltage is used to power sensors, lights and communication networks at a low voltage of normally 24 volts. In the automated warehouse, all DC is rectified or produced by changing existing AC to DC through the use of a rectifier. DC voltage is also used extensively in low voltage control circuits and to power LED indicator lights.

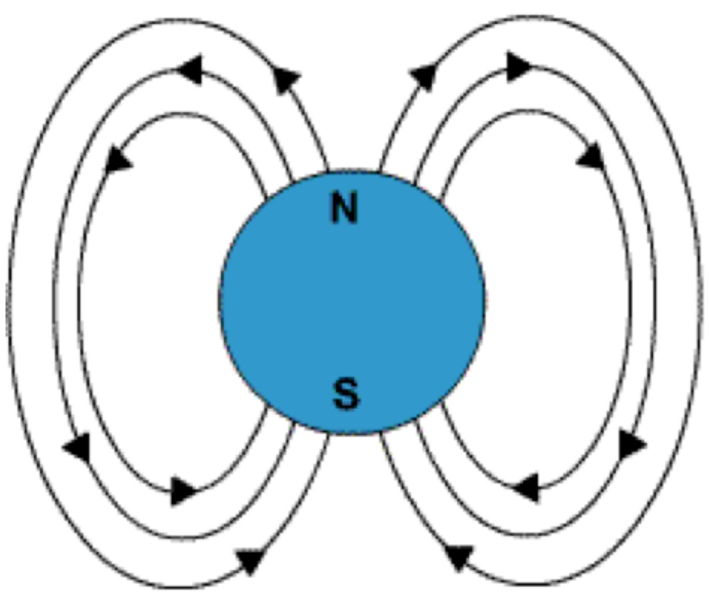
Interactive 7.2 Comparison of DC and AC oscilloscope waveforms.



Tap then slide bar to compare DC and AC oscilloscope waveforms .

Magnetism

A magnetic field consists of imaginary lines of flux coming from moving or spinning electrically charged particles. Examples include the spin of a proton and the motion of electrons through a wire in an electric circuit. What a magnetic field actually consists of is somewhat of a mystery, but we do know it is a special property of space. Magnetism is the property that propels motors, moves relays or any number of mechanical movements. Magnetic lines of flux move from north to south and “like” polarities will repel and “dislike” will attract. Most controllably, magnetism is produced by electricity since current flow will produce magnetism. Electricity is also produced by magnetism so the two interact to provide electricity and magnetism to do work. Some materials are permanently magnetic with constant polarity, some are magnetized by electrical current around them and some materials cannot be magnetized.



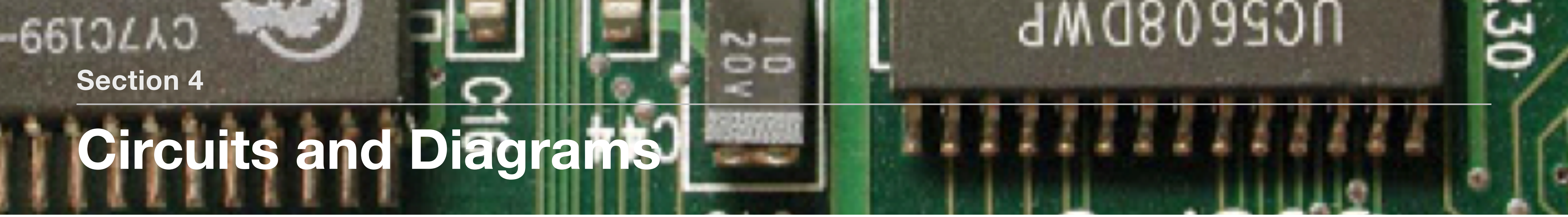
Magnetic field or lines of flux of a moving charged particle

Electric motor powering a hydraulic pump

Motors

Electric motors are devices that convert electricity into magnetism and produce mechanical energy or motion. An electric motor is a type of prime mover for a mechanical system.

Typically when motors are thought of in an automated warehouse environment, a gear set, chain and sprocket or a belt are included as driven devices. This is true of most motor applications, which are the core of many industrial control applications. Motors are also classified by the input power being AC or DC and can be rated by horsepower or wattage.



Section 4

Circuits and Diagrams

Series, Parallel, Combination

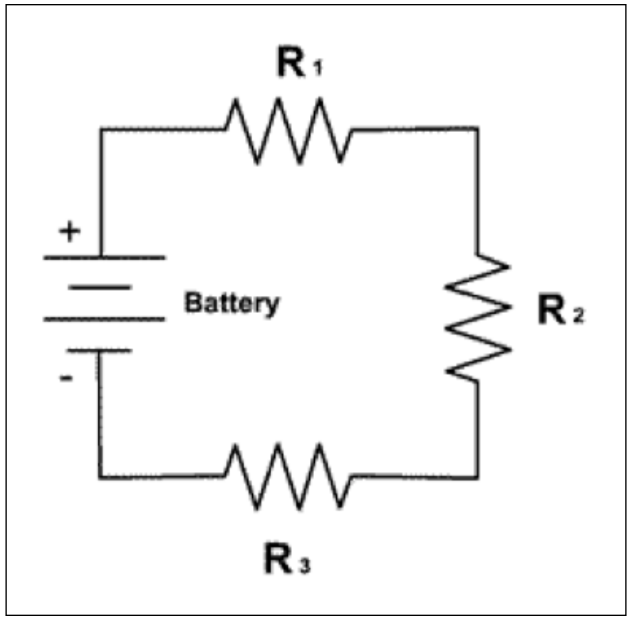
Components of an electrical circuit or electronic circuit can be connected in many different ways. The two simplest of these are called series and parallel circuits. Components connected in series are connected along a single path, so the same current flows through all of the components. Components connected in parallel are connected so the same voltage is applied to each component. Parallel circuits are the most common type of circuit used in a distribution center. A circuit composed solely of components connected in series is known as a series circuit; likewise, one connected completely in parallel is known as a parallel circuit.

In a series circuit, the current through each of the components is the same, and the voltage across the circuit is the sum of the voltage drops (voltage used) across each component. In a parallel circuit, the voltage across each of the components is the same and the total current is the sum of the currents through each component. Some circuits are a combination of both and will have the characteristics of both.

Understanding series, parallel or combination circuits are the basics for circuit design. Some components of a designed circuit will need varying voltages with the same amperage while other parts of the circuit will need consistent voltages with varying amperages for the electronic components. The components may be diodes, capacitors, resistors, memory chips, motors, actuators, etc. A circuit with these requirements would be designed as a series parallel circuit (combination).

For the technician, understanding the function, (voltages and amperages) of series–parallel circuits will give precise information when evaluating or troubleshooting a systems function by helping the technician know what to look for and why. These are skills needed to troubleshoot failures. The laws of circuits create a means for applying known values to find unknown values to troubleshoot a system. The basic laws are listed below.

Interactive 7.3 Series, Parallel, and Combination Circuits



Tap to view diagrams of series, parallel, and combination circuits.

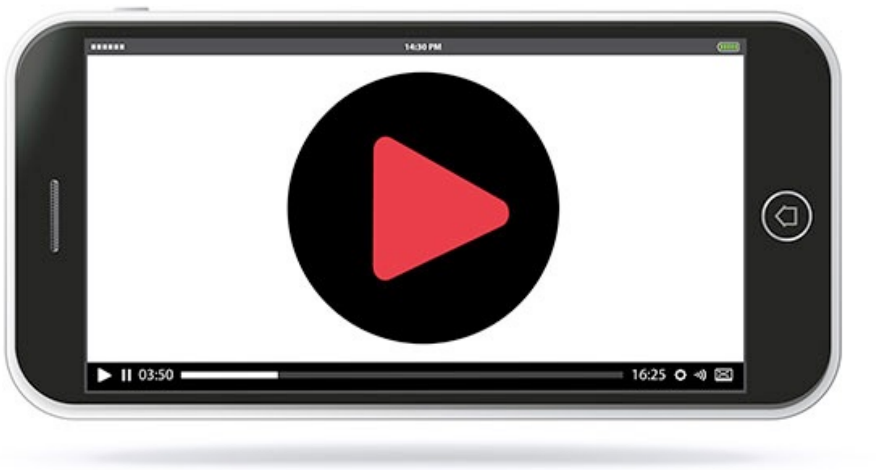
Series Laws

1. Total resistance of the circuit is the sum of the individual resistances
2. Current is the same at any point of the circuit
3. Voltage drops must add to the total voltage

Parallel Laws

1. Total resistance must be less than the value of the smallest resistor
2. Voltage is the same on each branch of the circuit
3. Total current is the sum of the individual branch currents

Movie 7.2 Voltage, Current, and Resistance



Tap to view the video.

Circuit Faults

Faults within a circuit will result in a specific error or operational failure. In digital circuitry this could be a signal or command error. Circuit faults can be simple or complex depending on the application and function. For example, the light doesn't work when the switch is turned on. Could it be a bad bulb or incomplete circuit where current, pushed by voltage, for some reason is not making it to the light or completing the circuit? The reasons for circuit faults could be as simple as a loose wire or connection to a room light, or a capacitor gone bad on a circuit board that is not providing direction for a PLC to control the light operation. More complicated circuit faults can be connected to digital electronics where operations and functions of the circuits are moved by correct digital signals to input or output correct voltages for circuit operations. The idea for the technician is to understand the basics of circuit faults in order to isolate the problem and make a quick repair. The circuit board design does not need to be mastered, just understanding the flow of electricity in and out for circuit operation.

Opens

An open circuit is an incomplete pathway within the circuit. It can be an open protection device (fuse or breaker), broken wire, open switching device, separated terminal or any number of other faults. An open in a series circuit will affect the entire circuit but in a parallel circuit it will only affect the faulted pathway. Testing for opens is done with a meter by doing voltage drop tests or measuring for available voltage on an active circuit or resistance testing on a denergized and disconnected circuit. Open faults never affect the protection devices since no current is available.

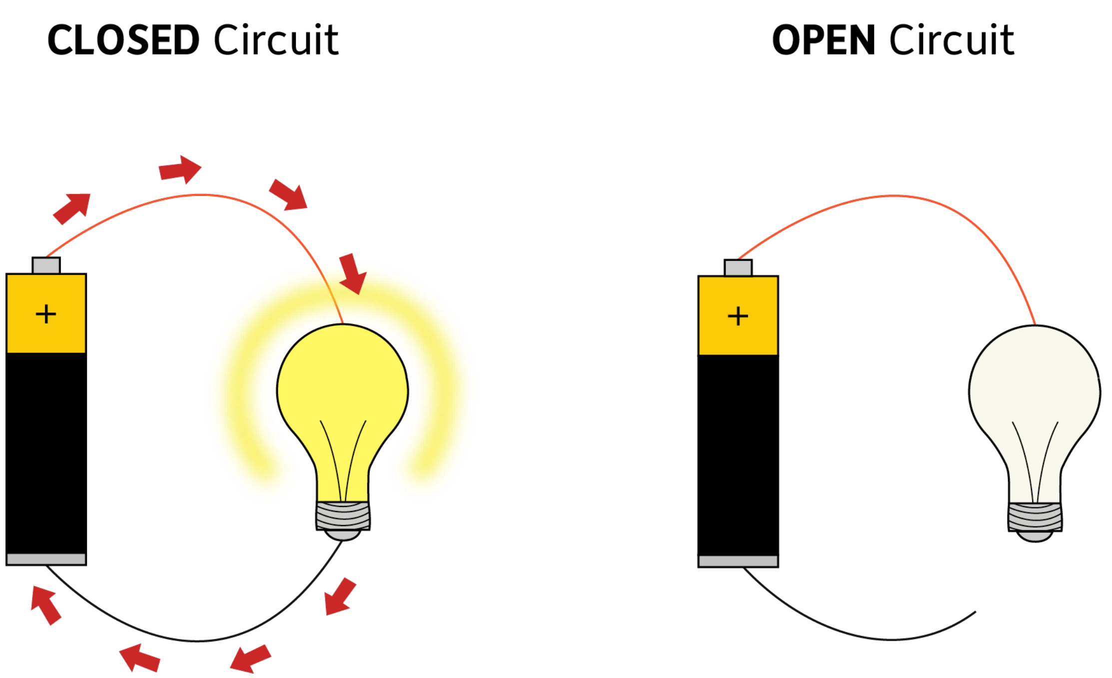


Diagram showing a closed or open circuit

Shorts

Shorts to Voltage

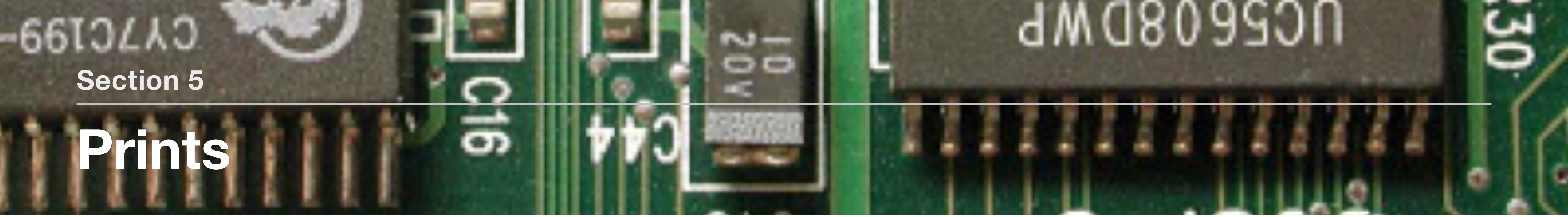
A short to voltage fault occurs when wires from one circuit are connected to power from another circuit. This failure will involve the power or supply side of the circuit. The circuit in question may be controlled by another circuit and in some cases can't be denergized easily. It may open the protection device depending on its position within the circuit and whether current is increased to a level of overload. Testing for this condition will normally require a meter and isolation of the wiring.

Shorts to Ground

A short to ground fault is when the current flow bypasses a load and goes directly to ground prior to the component. This fault will usually result in an open occurring at the protection device (fuse or breaker). This condition exists when a powered wire touches a ground or a component has an internal pathway to ground eliminating resistance. Testing can be done with a meter by doing voltage drops, voltage availability or a resistance check between the wiring and ground.

High Resistance

High resistance in a circuit is when the wiring or components are partially faulted, allowing less current to flow so less work is done. Examples of this fault could be dim lights, slower than normal motors, clicking of relays or solenoids or no operation of the circuit due to a lack of current. Corroded wiring and connections, undersized wiring during construction, loose connections or sockets are all examples of possible high resistance causes. High resistance can be tested with a meter to determine voltage drop across the fault or an ohmmeter in a circuit that is inactive.



Section 5

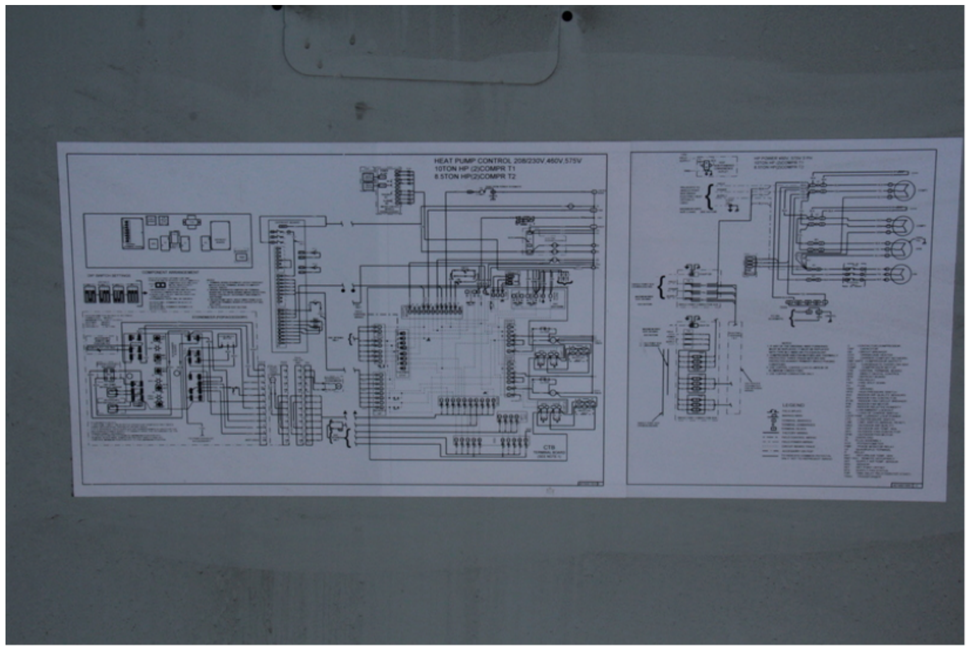
Prints

Diagrams

Diagrams are plans, sketches, drawings, or outlines designed to demonstrate or explain how something works or to clarify the relationship between the parts of an electrical system. Diagrams are maps for the installer or technician to use to see how components work together to function properly. Understanding diagrams can aid the technician in determining correct operation as well as noticing incorrect operations. Diagrams can offer physical locations for components to include wiring, safety interlocks, power and control inputs/outputs, internal connections and all extensions and associated devices connected to the equipment.

Schematics

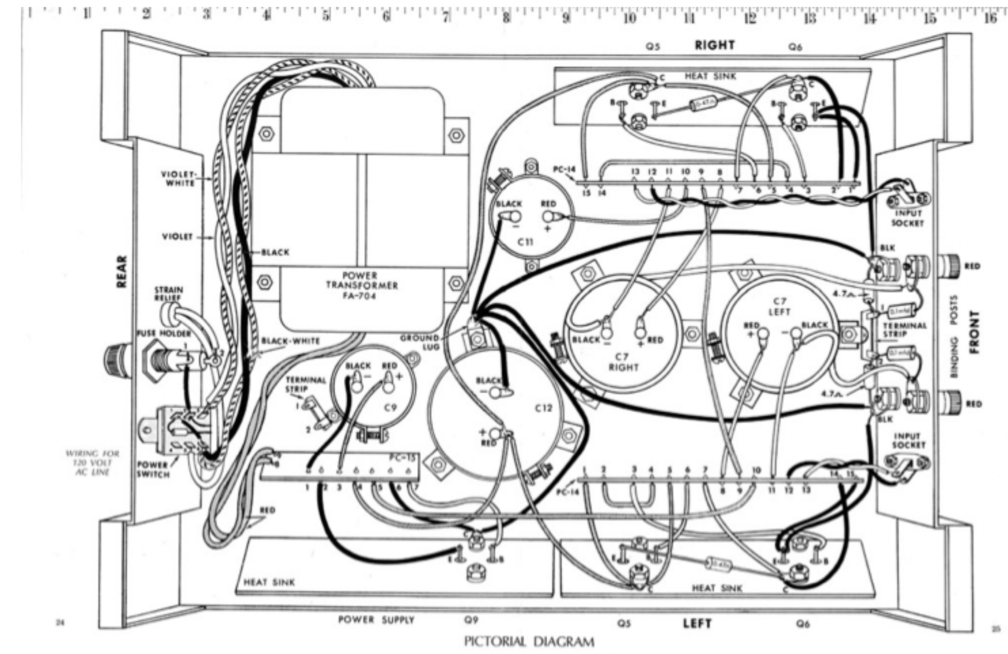
Schematics show the main parts of an electrical circuit usually in the form of a simple drawing or diagram. Schematics are drawings on paper or through an electronic medium of a physical object. Electrical schematics show all the components, electrically, for a piece of equipment, to include all the connections for the power and control inputs for a device. This includes the start and stop switches, power transformers, fuse ratings of a circuit, wire connection points at the terminal boards, all digital interfaces for the equipment, etc. The benefit to a technician learning to read and interpret schematics is it gives the technician greater ability to understand the operation of devices. By understanding schematics, simply learning the flow of electricity through their equipment, the technician will be an effective troubleshooter. Reading schematics will be used with a meter (DVOM) giving measurement information to compare with the schematic data.



Electrical schematic for understanding of a system

Pictorial

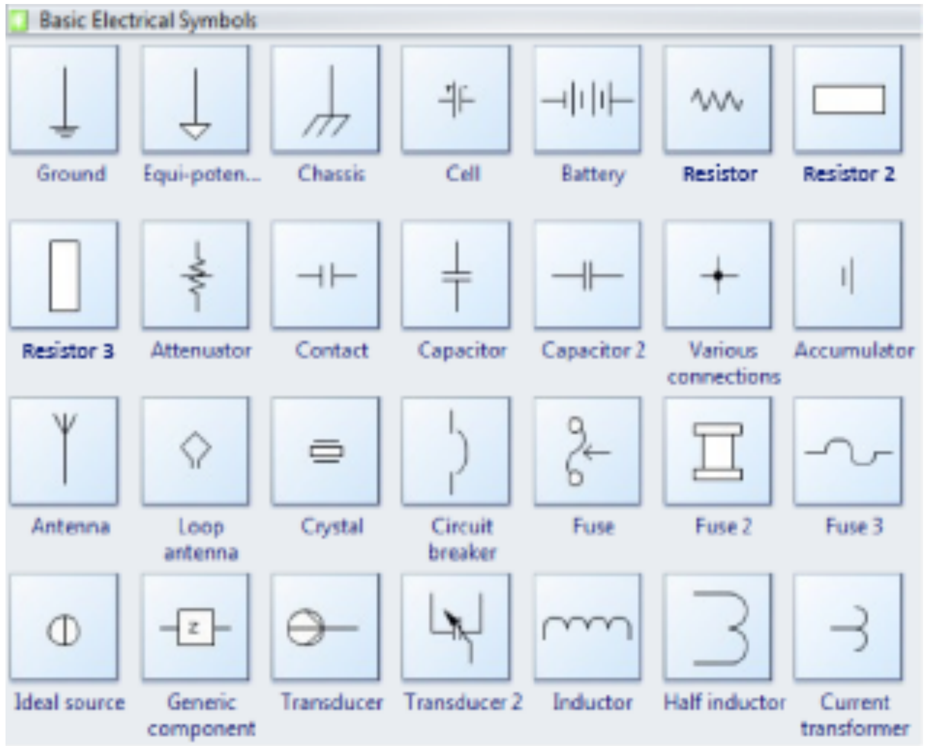
Pictorials are used for organizing the components of a system or component by using pictures. Pictorial diagrams can be useful in showing the location of a component, exactly what the component looks like and how it may be connected. Pictorials are not as accurate as wiring diagrams but are most important for identifying each component in a system and allowing a technician to find and isolate the component to allow repair.



Electrical pictorial used for identifying components and functions

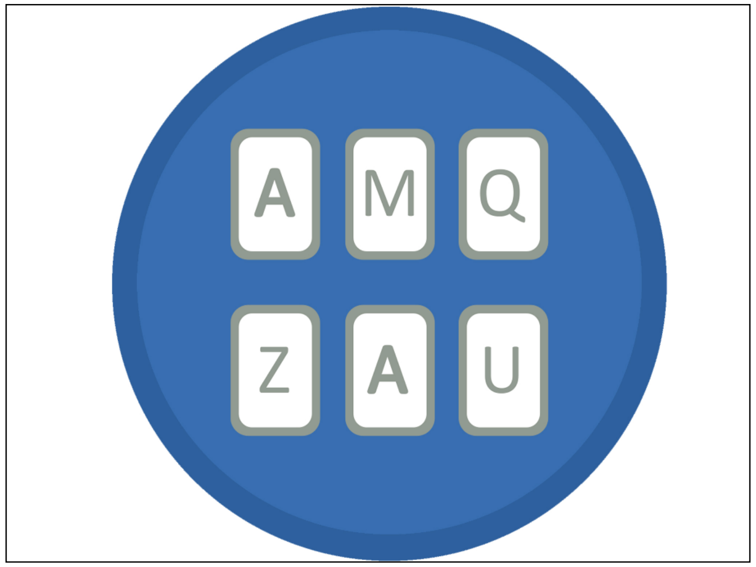
Symbols

Symbols are used to clarify or simplify a schematic or chart. In the world of electrical schematics, symbols are important to understand and interpret so the technician can understand quickly what the symbol or abbreviation stands for. All prints have a legend, which is a summary and description of the symbols, somewhere on the face of the drawing or as an attachment. The purpose of symbols is to use small objects to illustrate meanings or purposes of devices in a drawing. Writing the meaning of a symbol in the schematic may take up too much room and can vary from device to device and cause congestion within the prints.



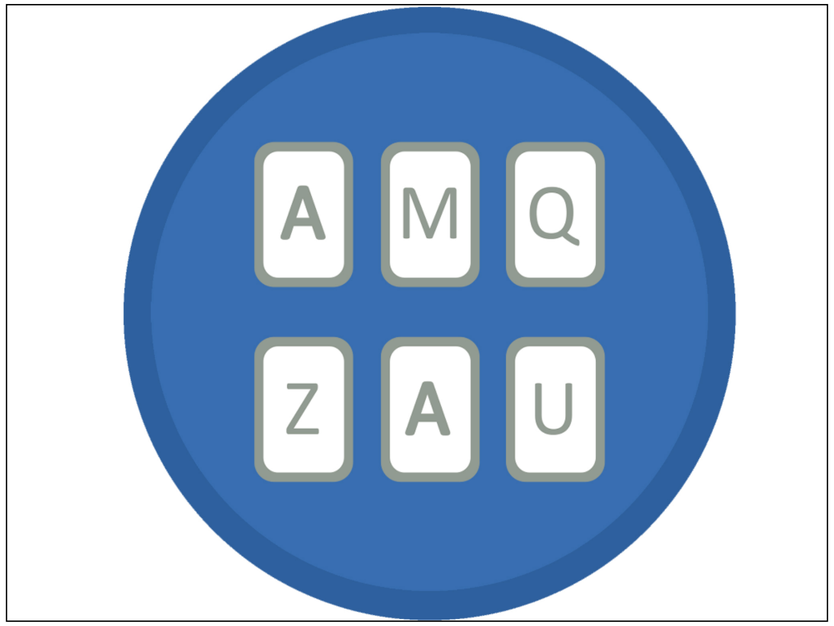
Symbols list used to identify parts on a schematic.

Review 7.1 Basic Electrical Symbols 1



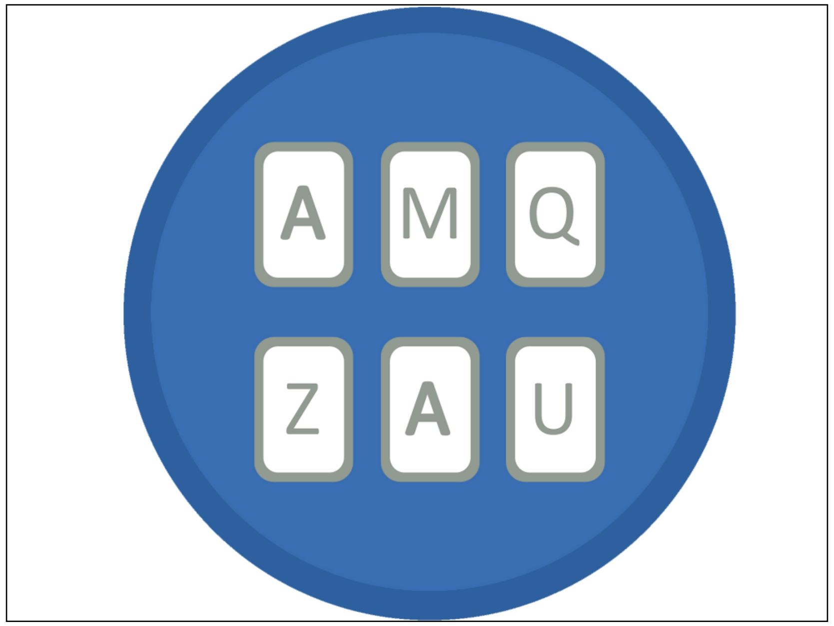
Tap image to begin pair matching activity. Tap symbol name and then the matching electrical symbol image.

Review 7.2 Basic Electrical Symbols 2



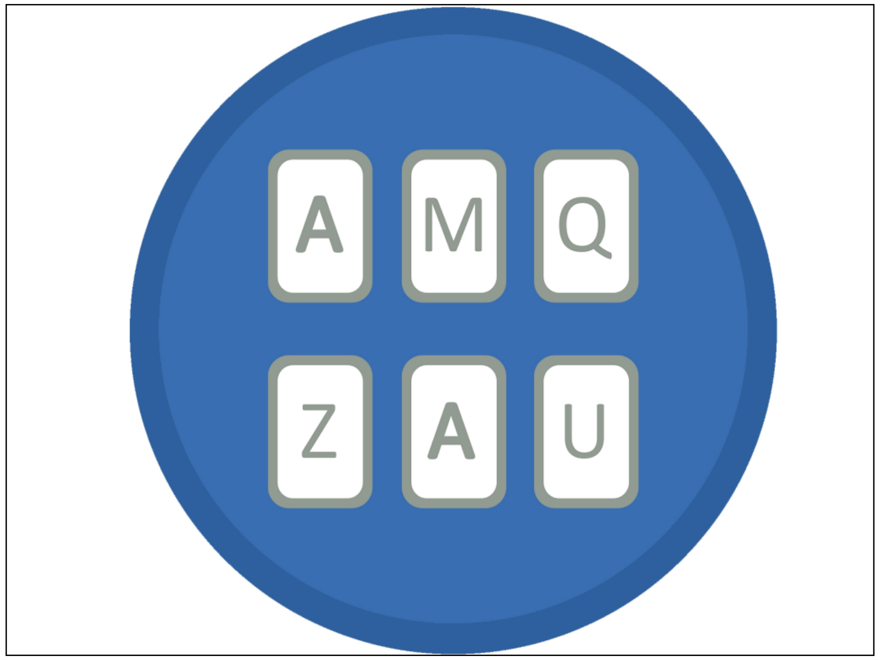
Tap image to begin pair matching activity. Tap symbol name and then the matching electrical symbol image.

Review 7.3 Basic Electrical Symbols 3

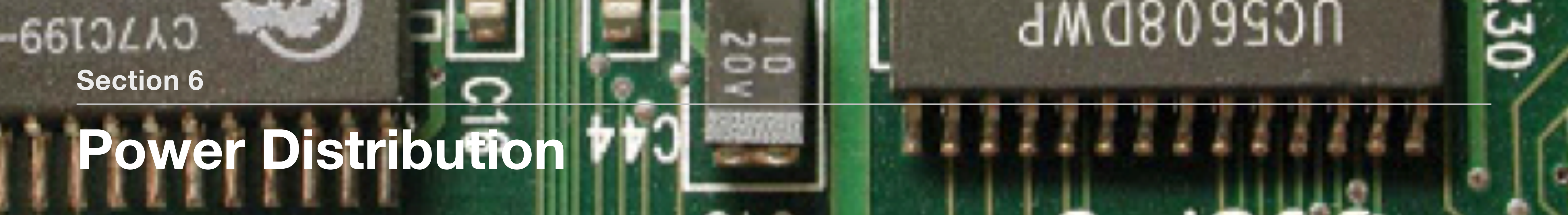


Tap image to begin pair matching activity. Tap symbol name and then the matching electrical symbol image.

Review 7.4 Basic Electrical Symbols 4



Tap image to begin pair matching activity. Tap symbol name and then the matching electrical symbol image.



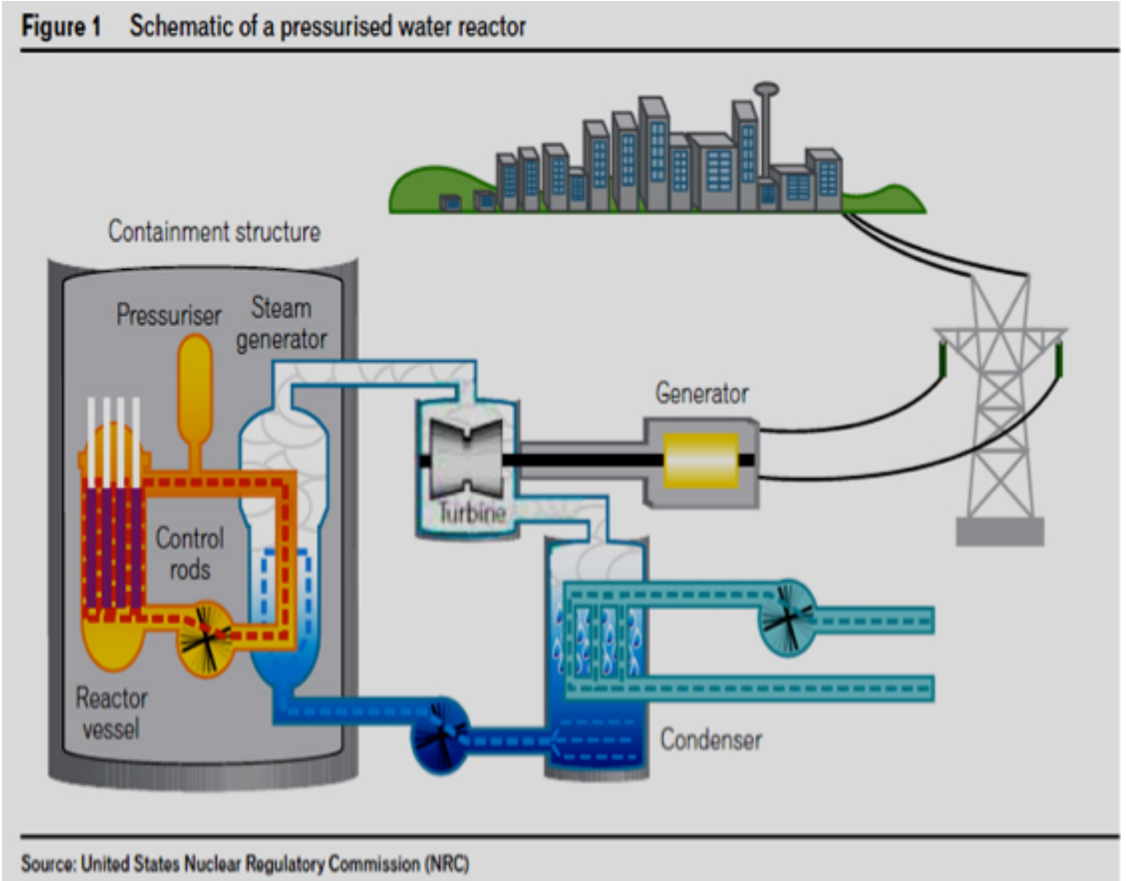
Section 6

Power Distribution

Power Generation

The production of electric power for industrial and residential use is described as power generation. Electric power generation generally comes from large-scale production of electric power at stationary plants designed for that purpose. The generating units in these plants convert energy from water flow (dams), coal, natural gas, oil, and nuclear fuels (heat production) to electric energy. Most electric generators are driven either by hydraulic turbines for conversion of water energy, or by steam or gas turbines for conversion of fossil fuel. Geothermal, wind and solar energy development is progressing in its various forms but these methods produce a small percentage of the total electrical energy that is produced and used.

Generating power is the key to providing electricity to everything in our lives. Power generation on a local level is regulated and provided by the utility companies and produced and distributed by them. It is important to understand the electrical energy that is supplying the distribution center to ensure proper safeguards are used during preventative maintenance, operations and troubleshooting. Different protections are required for different supply voltages. The technician must confirm that any equipment worked on is safe and the processes are understood, checked and verified.



Electricity generation by nuclear energy

Single and Three-Phase

Single-phase

A single-phase circuit is an alternating-current using only one sine wave current flow, a circuit that consists of three wires – live, neutral, and ground (earth). The main protection device in a single phase system is a single pole breaker, resembling the others in the panel and is rated at the required capacity.

Three-phase

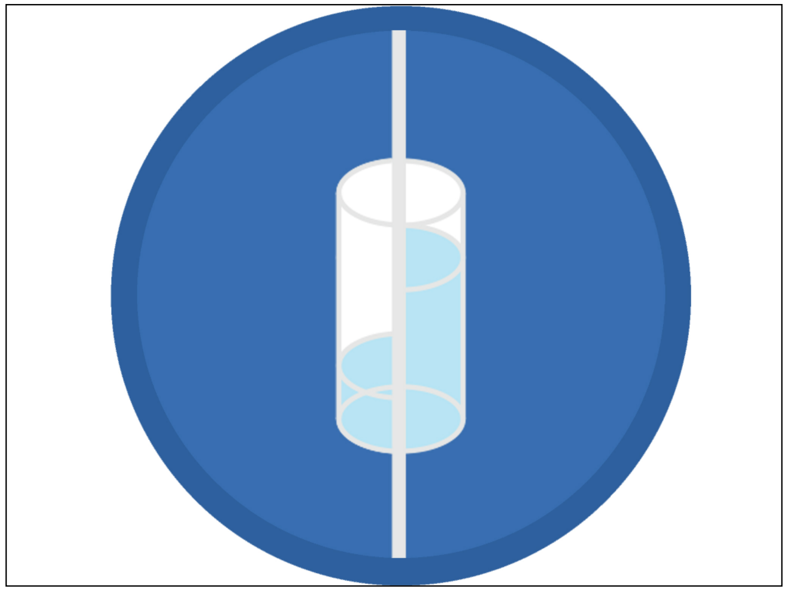
A three-phase circuit consists of three different sine wave current flows, different in phase by 120 degrees from each other. Three-phase is used for commercial applications and for demands for higher power. The main protection device is a double breaker at the rated capacity.

Single-phase and three-phase power are designed for different uses and purposes. Single-phase operates on one live conductor of electricity, 120 or 240 volts, within a 60-hertz cycle. Most residences operate on 120 volts for most appliances and power. Main panels built at residences have two 120 vac phases coming in to the home making the availability of single phase 240 vac for higher power applications such as swimming pool motor pumps or air conditioning compressors. The 240 vac power is derived from two 120-volt phases coming into the house. Single-phase systems are convenient for home residences.

Three-phase systems use three live conductors to operate equipment and machinery. Most three-phase systems in distribution centers operate on 480 volts. Three live conductors are used to power system motors for conveyors, transformers and other power distribution requirements. There are varying differences between three-phase power applications to single-phase power applications with advantages for either power structure.

For the technician, understanding the differences and functions for three-phase and single-phase power systems will increase their ability when troubleshooting and evaluating the overall operation of the equipment.

Interactive 7.4 Comparison of Single-Phase and Three-Phase Wave Forms



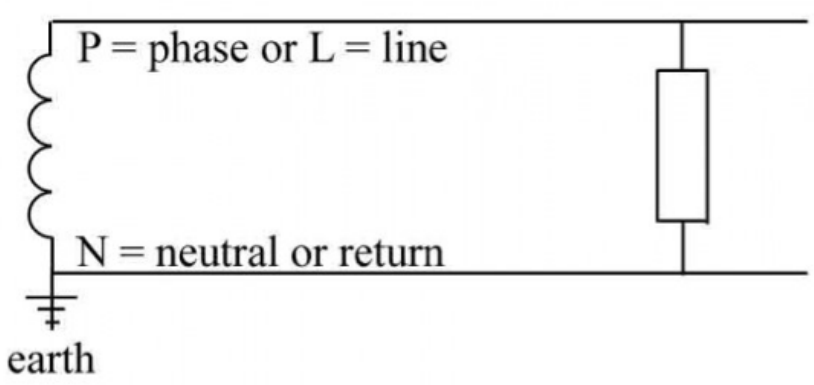
Tap then slide bar to compare diagrams of single-phase and three-phase wave forms.

Movie 7.3 Three-Phase Electricity Video

Tap to view the video.

Ground Circuits

The ground of a circuit is the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth. Ground circuits protect the equipment and operators of the equipment if there is a malfunction or electricity has no return path to a completed circuit. The ground circuit is connected to the exterior of the equipment, all sub panels and main panels, so in the event there is a pathway to the ground circuit, the voltage will follow the ground wire back to the main power panel dissipating the voltage through a pole drilled eight feet into the ground. It is important for the technician to ensure all equipment, panels, any power supply or devices providing or receiving power are grounded correctly for the safety of the operator and equipment.



Ground circuit diagram

Wiring

Wire is a slender flexible strand of metal, normally made of copper, usually insulated, and used to carry electricity throughout a system. Wires are the core of everything for the electrical world. Certainly there are wireless cell phones, remotes, car alarms and the list goes on, but these devices transmit signals, not voltage and can do little work. Wires are rated by the amperage they can carry. The greater the amperage and the longer the wire, the larger the wire needs to be. A wire that is a 6 gauge can carry more amps than a wire that is rated at an 18 gauge. This is because the 6 gauge wire is bigger with more copper than the 18 gauge wire. The technician does not need to memorize wire ratings, but needs to know where to verify and check if wire replacement is needed or an added load is being configured into an existing circuit.

Length	Current (amps)									
(feet)	5	10	15	20	25	30	40	50	60	70
15	16	12	10	10	8	8	6	6	4	4
20	14	12	10	8	8	6	6	4	4	4
25	14	10	8	8	6	6	4	4	2	2
30	12	10	8	6	6	4	4	2	2	2
40	12	8	6	6	4	4	2	2	1	1/0
50	10	8	6	4	4	2	2	1	1/0	1/0
60	10	6	6	4	2	2	1	1/0	2/0	2/0
70	10	6	4	2	2	2	1/0	2/0	2/0	3/0
80	8	6	4	2	2	1	1/0	2/0	3/0	3/0
90	8	4	4	2	1	1/0	2/0	3/0	3/0	4/0

American Wire Gauge (AWG)

Wire size application chart

Section 7

Test Equipment

Typical DVOMs (Fluke)

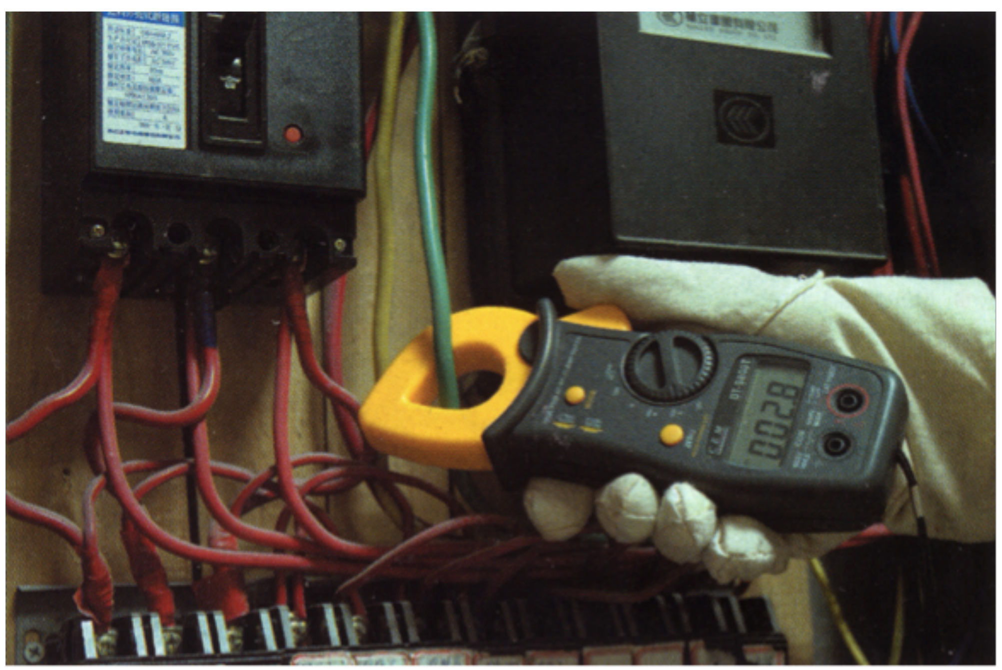
Digital Volt Ohmmeter (DVOM)

A multimeter, also known as a VOM (Volt-Ohmmeter) or DVOM, is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter would include basic features such as the ability to measure voltage, current, and resistance. Digital multimeters (DMM, DVOM) display the measured value in numerals, and may also display a bar of a length proportional to the quantity being measured. A multimeter is a hand-held device useful for basic fault finding and field service work. They can be used to troubleshoot electrical problems in a wide array of industrial applications such as electronic equipment, motor controls, appliances, power supplies, and wiring systems.

DVOMs are an electrical technician's most used device. When troubleshooting a circuit a DVOM provides all data needed to isolate the problem and to make repairs. The accuracy and the testing functions that the DVOM provides, allows a technician to quickly isolate and repair a problem.

Current Probe

In electrical troubleshooting or monitoring, a current clamp or current probe is an electrical device having two jaws which open to allow clamping around an electrical conductor (wire). The probe measures magnetic energy as created by current flow through the conductor. This allows current in the conductor to be measured without having to make physical contact with it or to disconnect it from the circuit. It also allows for measuring high currents with little or no safety concerns. When devices fail or are on the verge of failure, typically over or under normal current draws will be occurring. The ability to check the amperes in a circuit can prevent more damage to a device in a faulted state. Before the ammeter or current probe, circuits could still be tested for amperage with a DVOM being connected in series with a live circuit but only for low amperage circuits. Because the limits and danger of this test, DVOM in series, the amperage probe is much more versatile and safer as the probe simply clamps around the individual wires of the circuit without breaking the circuit. Learning this test is invaluable for the technician.

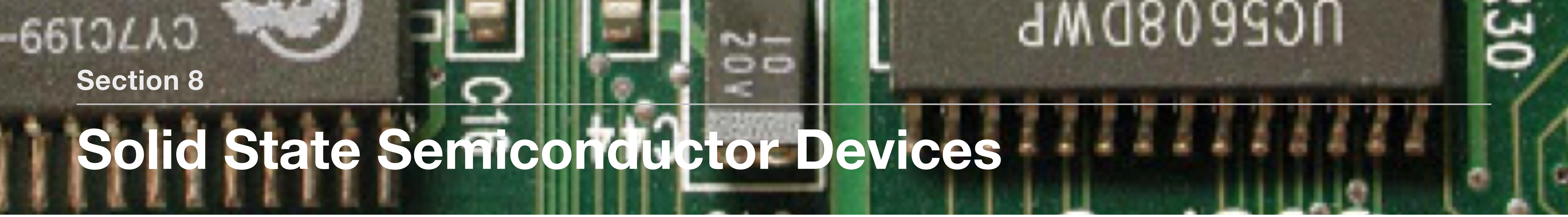


Using a current probe to test current draw

Testing Procedures

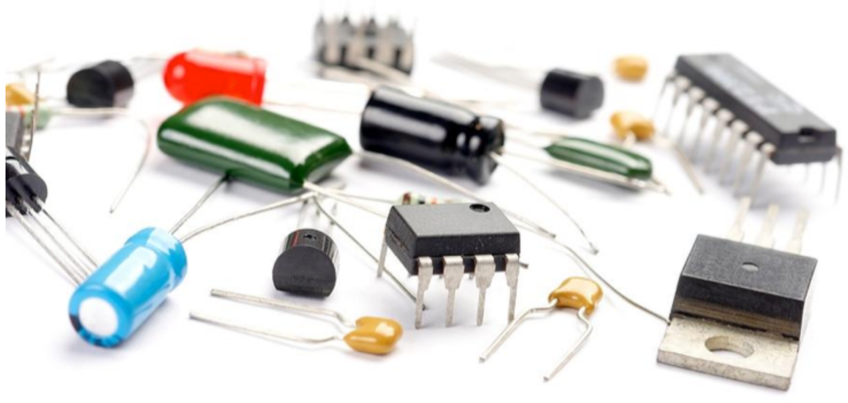
The testing procedures for electronics are many but the basics are checking for power, opens and shorts as related to the device as a system and at the component level. Checking for power is done by using a DVOM on the AC scale to test for normal operating voltages.

Testing for voltage



Section 8

Solid State Semiconductor Devices



Different types of semiconductors

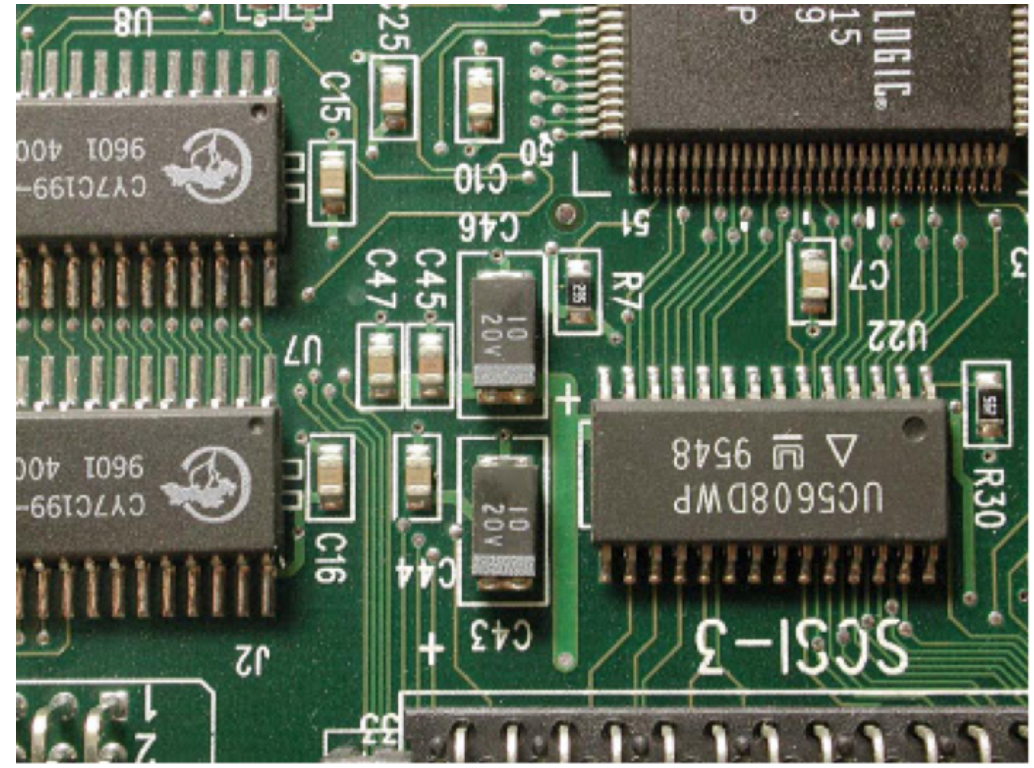
Principles

Semiconductors play a vital role in nearly every field of modern electronics, and they enable the production of everything from radios to computers and microprocessors. One of the most important applications for semiconductor materials involves their use in the creation of transistors, which are solid-state electron devices that form the basis for a vast range of electronic systems and equipment, particularly integrated circuits. The majority of semiconductor and transistor components are composed of silicon, which is highly useful for its distinct electron structure. By changing the electron arrangement in silicon or similar elements through the introduction of additional particles, it is possible to adjust the conductivity and resistivity levels of a material formed from these elements to create a semiconductor.

Semiconductors are the components of all electronics today. The ability to harness and manipulate voltages to precise specifications allows the creation of extreme electronic devices from microcomputers to varying robotics. For the technician, understanding the basic principles of semiconductor devices will aid in troubleshooting efforts to isolate failures in electronic boards or components. Some of these components include transistors, diodes, resistors, chips, and capacitors. Component or board level replacement, not individual semiconductor replacement, is the most common for the service technician but the isolation of the component or board requires an understanding of the operation.

Printed Circuit Boards

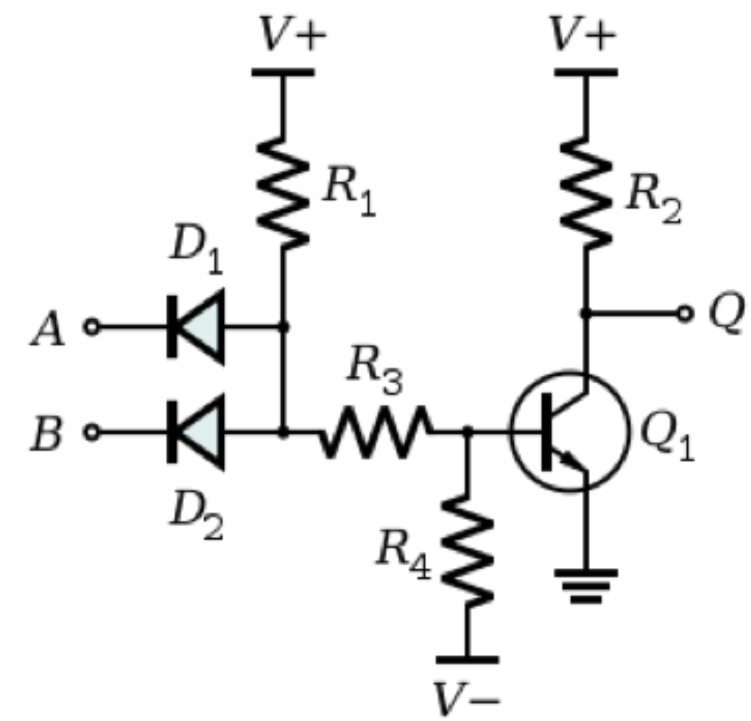
A printed circuit board is a flat plastic or fiberglass board on which interconnected circuits and components are laminated or etched. Chips and other electronic components are mounted on the circuits. Computers consist of one or more printed circuit boards, usually called cards or adapters. Printed circuit boards are typically attached to other boards providing some type of control or additional function to the device or unit. The printed circuit boards are interfaced with master boards to allow various functions for a device. For example, a computer may have an accelerated graphics board attached to the master motherboard giving more versatility of better graphics to the display monitor. Other boards could be for wireless Ethernet control and memory. For the most part technicians will troubleshoot to a bad board on a device. Troubleshooting to individual semiconductor level will typically happen at the manufacturer of the board. The goal is to isolate the board that has failed and replace that board so productivity in the distribution center is not compromised.



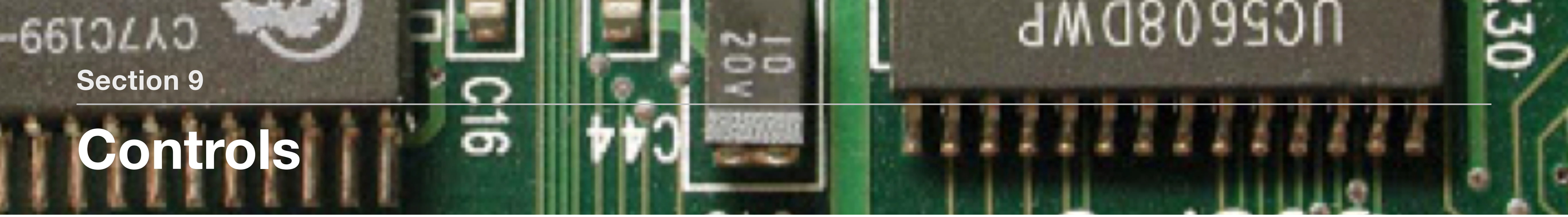
Integrated circuit board

Diode, Transistor

The diode is a two wire semiconductor that allows current to flow in one direction and block current flow in the other direction. The transistor is a three-wire semiconductor that allows voltage to flow through an electronic circuit when a signal has been received at the base. Most of this information is detailed at the engineering level, but the importance for the technician is to understand electronic fundamentals for troubleshooting. The idea is that no matter how technical a device gets with the electronics, there is always an output and an input, and if the technician can understand and isolate the basic principles of electronics, any device can be troubleshot.



Diode and transistor circuit



Section 9

Controls

Electrical controls command, direct, limit or regulate an electrical function which normally controls a machine. For electrical and electronic applications, control can be separated into two parts. Control by the user, including but not limited to start and stop functions, emergency stops and fault conditions of the equipment. The second control for machinery is control regulated by the design and process of either the application or the programing functions which is normally a Programmable Logic Controller (PLC). All electrical equipment operating at high voltages typically have voltages separated into two categories. Power volts and control volts.

Power Volts – Power volts is power actually used for the machinery or equipment to operate as designed. For example 480 vac are typical power volts for machinery of conveyor motors in automated supply chain distribution centers.

Control Volts – Control volts is power that regulates, manipulates or as programmed, delivers a smaller voltage to a unit or device, such as a Solid State Relay (SSR), motor contactor, and PLC board to open or close the passage for the power volts to operate the corresponding machinery as designed. Control volts are typical 120 vac or less to include DC voltage.

Testing

Electrical testing is a procedure for determining the root cause of a failure. The proper application of knowledge, judgment, and application of information and proper use of supporting test equipment are all parts of testing. Testing in relation to electrical processes is the ability to look at the system by electrical theory and function to determine proper operations through correct or incorrect measurements. These measurements can be conducted by a DVOM to find readings for Volts, Ohms, Amps, and continuity.

Electrical testing of low voltage control circuits

Preventive Maintenance

Preventive Maintenance is the care and servicing by personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition. This is done by providing for systematic inspection, detection, and correction of failures either before they occur or before they develop into major defects. Preventative maintenance is the process of inspecting and calibrating or cleaning equipment for normal operations and correcting impending failures during scheduled downtime to prevent failure or downtime of equipment during production operations. As with all imperfections, preventative maintenance will not prevent all breakdowns, but implementing this process has proven to improve production through longevity of equipment operation for optimal and consistent use.

Performing preventive maintenance

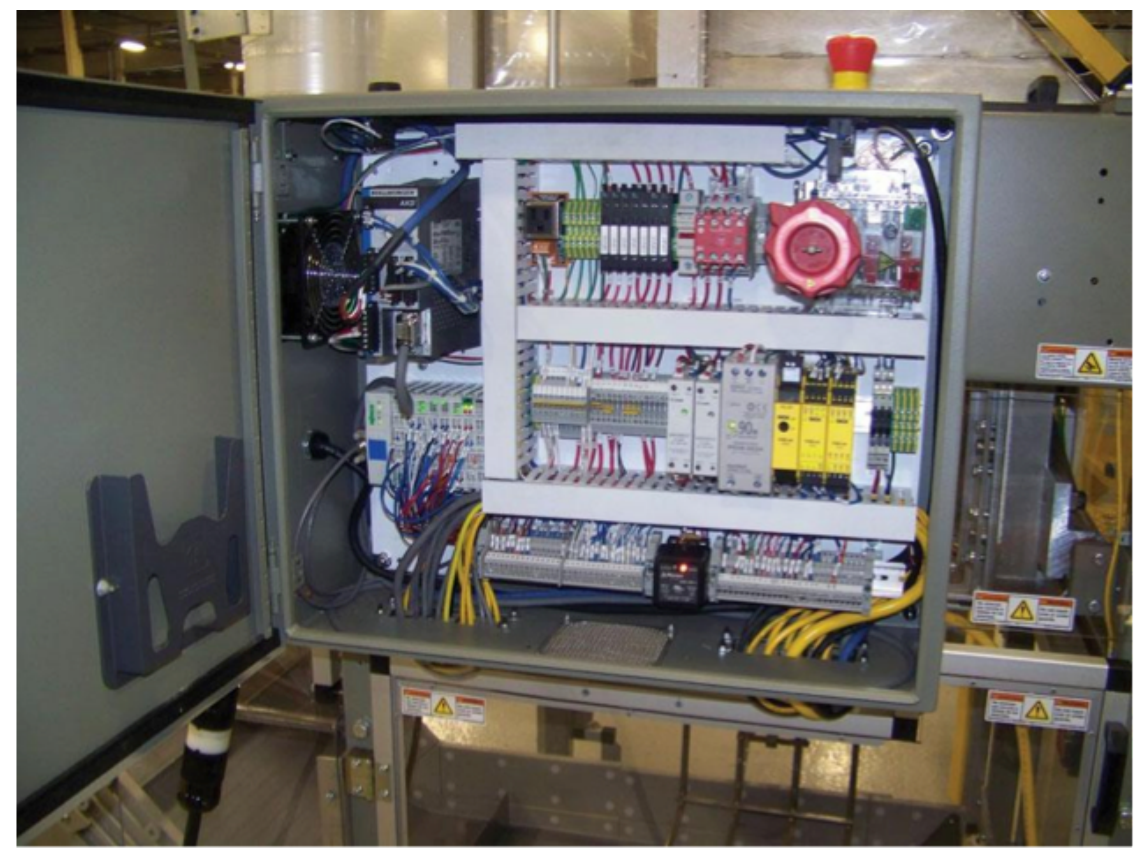
Motors

Motors are devices that are electrically powered to provide movement in a circular or linear motion to perform work. Motors are fundamentally involved in every aspect of automation. This includes operations for scanners, conveyors, forklifts and belt drives. Motors can be used in various types of drives. These include direct drives, connected directly to the equipment needing the energy; indirect drives, connected to a gear box or by chain that is attached to the equipment needing energy; and linear drives and linear induction drives, motors moved by magnetism requiring no moving parts, but driving the equipment needing the energy.

Electric motor attached to a gear box used to drive a chains or belt

Electrical Controls

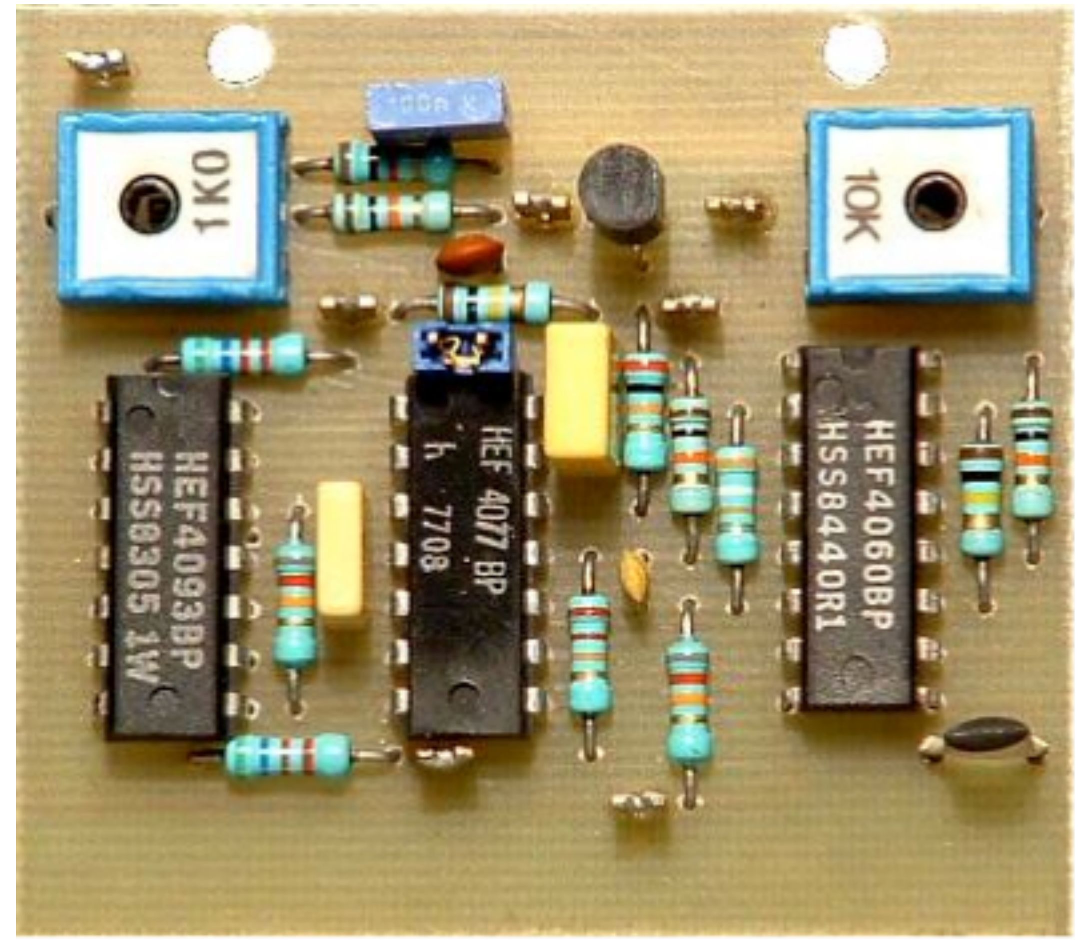
Electrical controls are any input device that controls the flow of current in a circuit. Control devices determine when equipment is energized or de-energized or may control the speed of an operation. Controls operate devices and equipment from remote locations for specific operations or functions of that equipment. Controls can include light switches, photocells, or energy management systems and software. At the electronic level, diodes and transistors, contactors, Programmable Logic Controls, inputs and outputs mange the system by controlling the functions. Control of devices allow for automated systems to operate as intended and equipment to operate for structured and specific design operations.



Electrical control panel

Electronic Components

Electronic components have the ability to amplify or control voltages or currents without mechanical or other nonelectrical command or they can switch currents or voltages without mechanical switches. Examples include electron tubes, transistors, and other solid-state devices. Components vary from device to device making up the basic structure for equipment operation and function. Components can include circuit boards, fuses, SSR (Solid State Relays), diodes, resistors, transistors, capacitors and much more. The importance of components for the technician is to know what components do what and how they are integrated within the equipment. Components that are important to the technician can be found in the equipment manual from the manufacturer. Some components are not end-user accessible and may be part of a bigger device. If the technician can identify the operation of the components for their equipment, the chances of a timely repair can be improved.



Components attached to a circuit board

Troubleshooting

Troubleshooting is the process of diagnosing the source of a problem. It is used to fix problems with hardware, software, and many other products. The basic theory of troubleshooting is that you start with the most general (and often most obvious) possible problems, and then narrow it down to more specific issues. In the world of industrial maintenance for specific skilled technicians, top rated technicians will be separated from average technicians by their ability to effectively troubleshoot. The differences show technicians replacing defective parts based on their tests compared to what they think, not related to the tests. Knowing a basic troubleshooting procedure will lead the technician to the problem, quickly allowing production to be down for a minimum time. As skill and knowledge increase, troubleshooting procedures will typically remain the same, specifically asking the right questions.

This module is focusing on Electrical applications, however there are several steps that can be applied to any process when troubleshooting to find and locate the fault. Below is a list of guidelines most technicians can follow, but every technician may have variances.

Troubleshooting Procedure

1) What is not working?

2) When was the last time it was working?

   a. Are there any visible evidence or smells?

3) Is it a power issue or mechanical issue?

   a. Power Issue?

      i. Does the equipment have power?

      ii. If not, is it a supply power or control power loss?

      iii. Possible problem, fuse, e-stop, logic process error? This will be defined by schematic interpretation.

   b. Mechanical issue?

      i. What mechanical device is not working?

      ii. If a motor, is the chain broken on the motor or is the motor seized by a bearing on the shaft?

      iii. If an electrical contactor, are the contacts binding mechanically?

4) Once step three has been verified, the next step is to isolate the problem. This example will suggest we have an electrical issue, specifically 120v loss to a contactor.

   a. Per the schematic and the technician using a DVOM for voltage check, where is the voltage reading at or not compared to where it should be or not in normal operation? This could identify open or shorted circuits.

b. Once the missing or irregular voltage has been determined in the circuit, what component is causing the error not allowing the electrical circuit to operate normally?

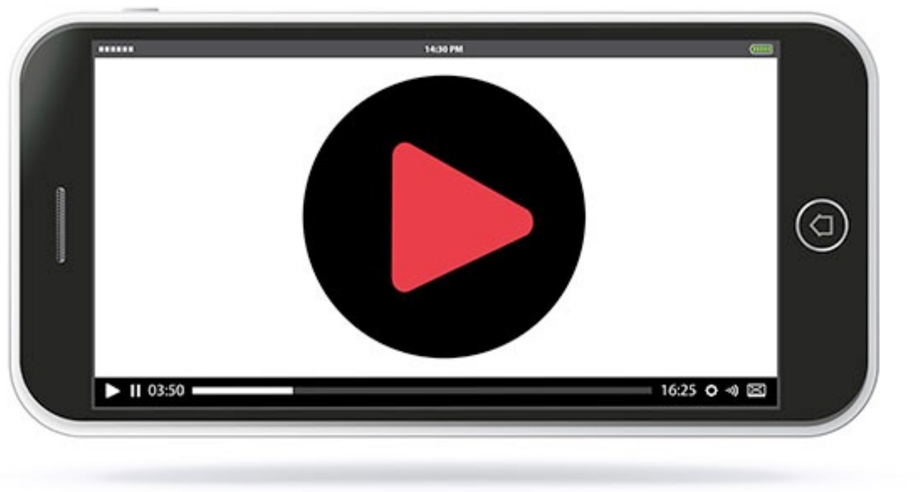
c. For example, if an estop, fuse, shorted diode or PLC control output error, circuit card error, etc., the troubleshooting procedure would move to the replacement of the faulty component or more questions, as defined in this troubleshooting procedure, would be considered in identifying the loss or irregular output of the 120v to complete the circuit.

5) Verify the faulty component and install a new part or correct the logic error.

6) Test the repair of the equipment for normal operation.

7) Monitor and reevaluate these steps to insure all processes associated with the faulty component are working normally.

Movie 7.4 Electrical Troubleshooting Video



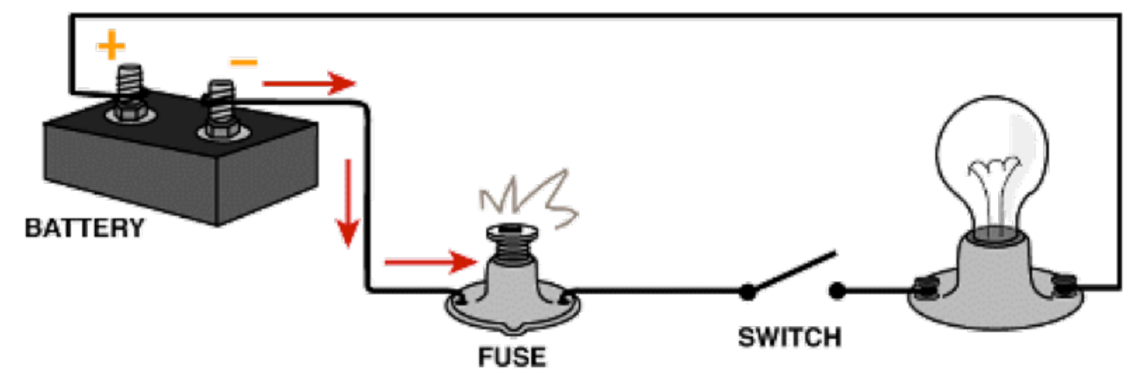
Tap to view the video.

Circuit Failures (Open, Short, High Resistance)

Circuit failures are errors of electrical flow from the source to the component for energy release then back to the source to ground to dissipate all energy not used by the component. Circuit failures can be from an open fuse to a shorted SSR – Solid-State Relay. Circuit failures can seem complicated by equipment design, but in the end the failures of all components are separated into two categories: open or shorted. High and low resistance can also be a factor, but are part of open and shorted circuits depending on equipment design.

Open

An open is an electric circuit in which the normal path of current has been interrupted. This is done by the disconnection of one part of its conducting pathways from another, or by the intervention of an electric component, such as a transistor. Open circuits prevent the flow of designed voltage and current from reaching components needing the energy to operate. The simple way to understand the open circuit is a break in the connection. Using a water hose as an example, if water is flowing out the end of the hose and suddenly stops, there is no water flowing due to a stop created by a break in the flow of water. It could be the water was turned off, the hose is kinked, or the hose is no longer connected to the water source. Thus there would be an open in the water circuit. Electricity operates on the same principle. Electricity travels through wires and components to make devices operate. If the device does not operate on the electrical side, it could be due to no power, a defective device or component or a break in the circuit. Understanding how to troubleshoot opens based on schematics and component operation will make the technician effective in problem isolation. An open circuit will not activate protection devices in the circuit since current flow is limited.



Open circuit with the switch open

Short

A short circuit is a faulty or accidental connection between two points of different potential in an electric circuit. This fault bypasses the load and establishes a path of low resistance through which an excessive current can flow. It can cause damage to the components if the circuit is not protected by a fuse. Short circuits will cause device non-operation or lack of control and will cause damage to the device. Simply understood, unlike an open circuit which does not deliver the voltage and current to a component, short circuits will send incorrect voltage to a component than cannot handle the voltage load, therefore destroying the component or device. For example, fuses are installed in many circuits to protect the wire and devices from shorts and incorrect voltage caused by shorts. Understanding the water hose concept, a short would be flow of water out of the middle of the hose through a defective section watering an area, not designated to be watered, decreasing pressure out of the end of the nozzle for the area needing a certain amount of water. Shorts sometimes can be identified more easily in a circuit due to component failure, but can also cause more destruction than open circuits.

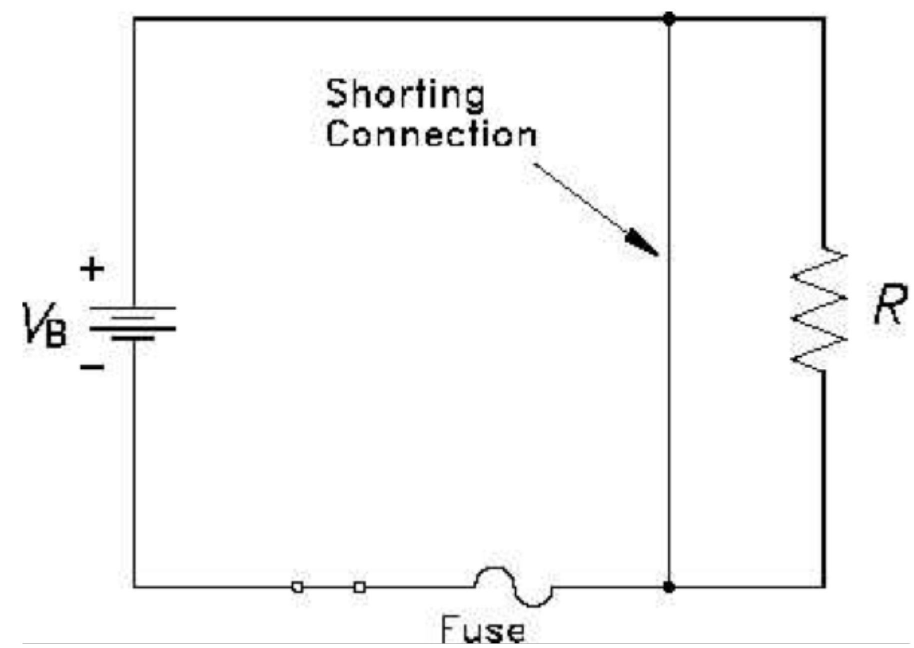
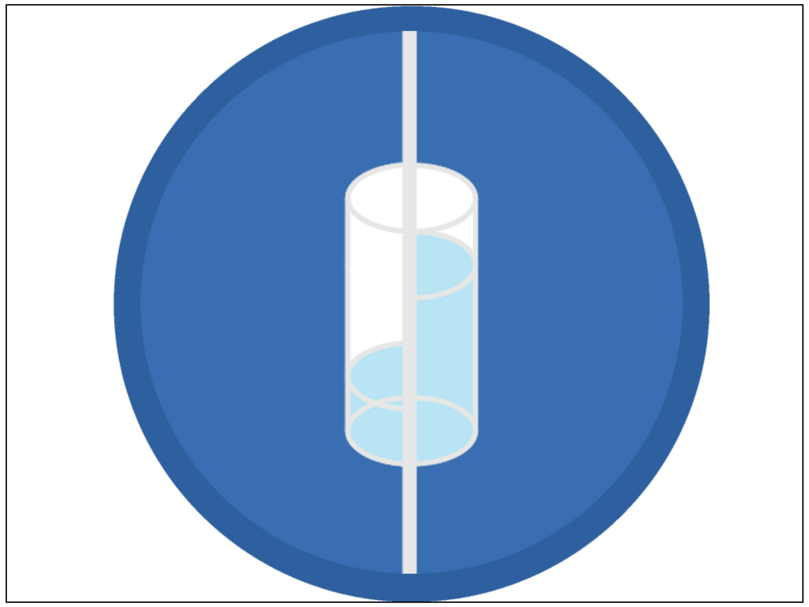


Diagram showing a short circuit

Component Failure

A defect in a component, circuit, piece of equipment, or system, which impairs operation significantly or that causes a failure is called a component failure or electrical fault. Component failures are the basis for any device not operating correctly. Component failures are the cause for open and shorted circuits and consistently will fail as all electronics fail at some point. Component failures include, open fuses, shorted diodes, open transistors, shorted bridge rectifiers, open electronic relays, open resistors, open contactor coils and so forth. Component failures are consistent, but technicians with strong troubleshooting skills and a solid knowledge base will be able to identify these issues and repair them quickly.

Interactive 7.5 Comparison of Resistor to Failed Resistor



Tap and then slide bar to compare images of working and failed resistors.

Chapter 8

Hydraulics/ Pneumatics

Fluid and air power are two critical sciences used in the automated warehouse. This chapter will give you an overview of the technology and show you how they facilitate the movement of product.

Section 1

Hydraulics Overview

History

The science of hydraulics goes back to prehistoric Egypt where canals and dams have been discovered. Water was moved or lifted by use of the Archimedes water screw and later by the piston pump to supply water from a lake or river to a community or agricultural area. In the 17th century Blaise Pascal discovered the principle that is the basis for modern hydraulic systems and is now called Pascal’s Principle. Pascal’s Principle states that in an undisturbed enclosed fluid, pressure is transmitted equally everywhere. This makes it possible to use enclosed systems to multiply applied forces and control movement.

Hydraulics as we use them today is the use of fluids to accomplish work and is used in automated equipment in a distribution center. The pressures and components of the system are designed to produce given movements and power outputs. The versatility of hydraulics allow for reliable operation and controllable and variable applications. Hydraulic fluid, normally mineral oil, is only slightly compressible so it maintains its volume, creating controllable and accurate movement in hydraulic components. Both pneumatics and hydraulics are applications of fluid power. Pneumatics uses an easily compressible gas such as air while hydraulics uses relatively incompressible liquid media such as oil. Most industrial pneumatic applications use pressures of about 80 to 125 pounds per square inch (550 to 690 kPa). Hydraulics applications commonly use between

1,000 to 5,000 psi (6.9 to 34 MPa), but specialized applications may exceed 10,000 psi (69 MPa).

Pressure

Three types of pressure affect the work that can be done. Atmospheric pressure is the pressure produced by the weight of the air mass around us. It varies with atmospheric conditions but is generally assumed to be 14.7 pounds per square inch (PSI) at sea level and creates a base pressure affecting everything. If you go to a higher elevation such as the mountains the pressure is less. Gauge pressure is the pressure within an enclosed system that is normally above atmospheric pressure and can be very high. Gauge pressure does the work creating mechanical movement of a hydraulic piston within a cylinder. Absolute pressure is the pressure above a perfect vacuum and is the total of atmospheric and gauge pressures. In the distribution center, gauge pressure is what is applied to the mechanics of operation and is the pressure the technician will be most concerned with.

Movement

Mechanical movement is produced by hydraulic pressure exerting force onto a sealed/sliding piston within a cylinder. This movement can be a lift for a pallet or a lift truck boom to pick merchandise. Most hydraulic applications in a distribution center are used for lifting or moving heavy items where control of the movement is critical.

Cylinders/Pistons

Hydraulic cylinders get their power from pressurized hydraulic fluid, which is typically oil. The hydraulic cylinder consists of a cylinder barrel, in which a piston connected to a piston rod moves back and forth. The barrel is closed on one end by the cylinder bottom (also called the cap) and the other end by the cylinder head (also called the gland) where the piston rod comes out of the cylinder. The piston has sliding rings and seals. The piston divides the inside of the cylinder into two chambers, the bottom chamber (cap end) and the piston rod side chamber (rod end / head end).

Common cylinder mounting options include flanges, trunnions, clevises and lugs. The piston rod also has mounting attachments to connect the cylinder to the object or machine component that it is pushing or pulling.

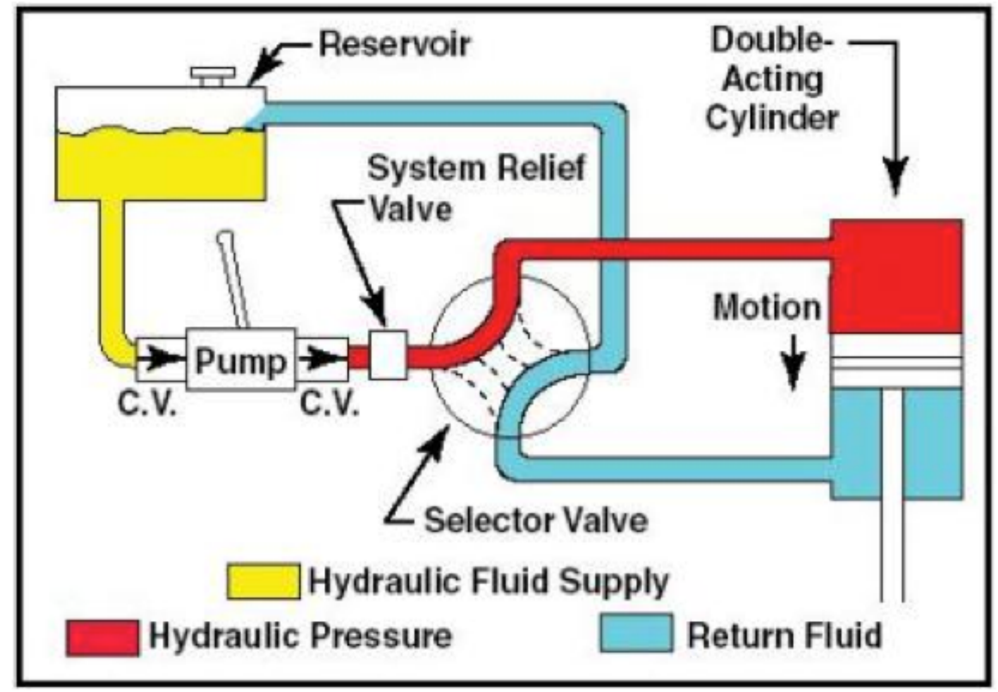
A dual action hydraulic cylinder cutaway

A hydraulic cylinder is the actuator or driven side of this system that does the work or movement. The drive side of the hydraulic system is the hydraulic pump, which brings in a fixed or regulated flow of oil to the hydraulic cylinder to move the piston with pressure and volume. The piston pushes the oil in the opposite chamber back to the reservoir. The movement or delivery of oil pressure is controlled by a hydraulic valve.

Hydraulic piston for fork movement on a lift truck

Diagrams

Pictorial diagrams are drawings and pictures that are used to show the relationships of components within the hydraulic or pneumatic system for fabrication, assembly or repair. They include each component and show the position and function. Cutaway diagrams show the internal detail of the system. This is the type of diagram that is used for the maintenance and repair of a system. The operation of the system can be determined by evaluating the cutaway. The graphic diagram is normally used during the design of the system and is characterized as line drawings using symbols to describe components and operation.



Cutaway drawing showing the internal motion of the piston and how it is controlled

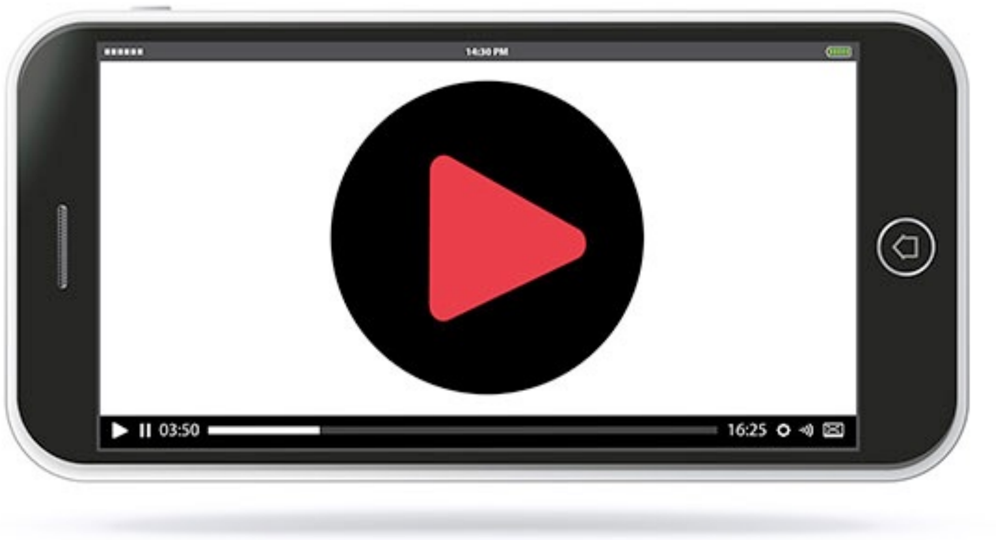
Applications

The most common applications for hydraulics in a distribution center are for lifting. Lift trucks and pallet lifting devices are the items service technicians will be required to maintain. Equipment that lifts product from one level to another will constitute a large percentage of the technician's service and repair work.

Interactive 6.1 Hydraulics Applications

Tap to view images of hydraulics applications in the automated warehouse

Movie 8.1 How Hydraulic Ram Works Video



Tap to view the video.

Pumps

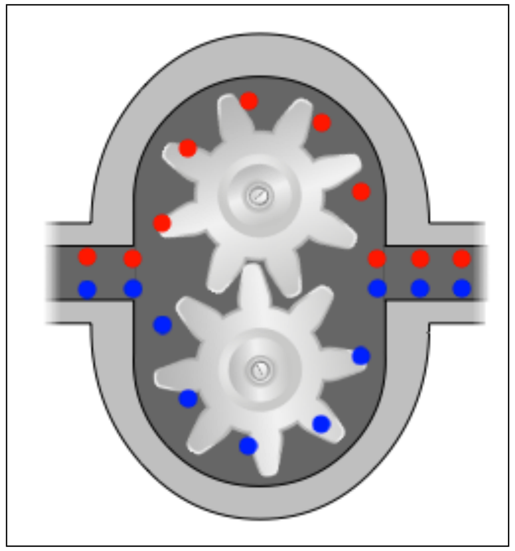
Hydraulic Pumps

Hydraulic pumps create the pressure and volume of hydraulic oil required to transfer and apply energy to a controlled component. Hydraulic pumps are used in hydraulic drive systems and can be hydrostatic or hydrodynamic. Hydrostatic pumps are positive displacement pumps while hydrodynamic pumps can be fixed displacement pumps, in which the displacement (flow through the pump per rotation of the pump) cannot be adjusted; or variable displacement pumps, which have a more complicated construction that allows the fluid flow and pressure to be adjusted.

Gear Pumps

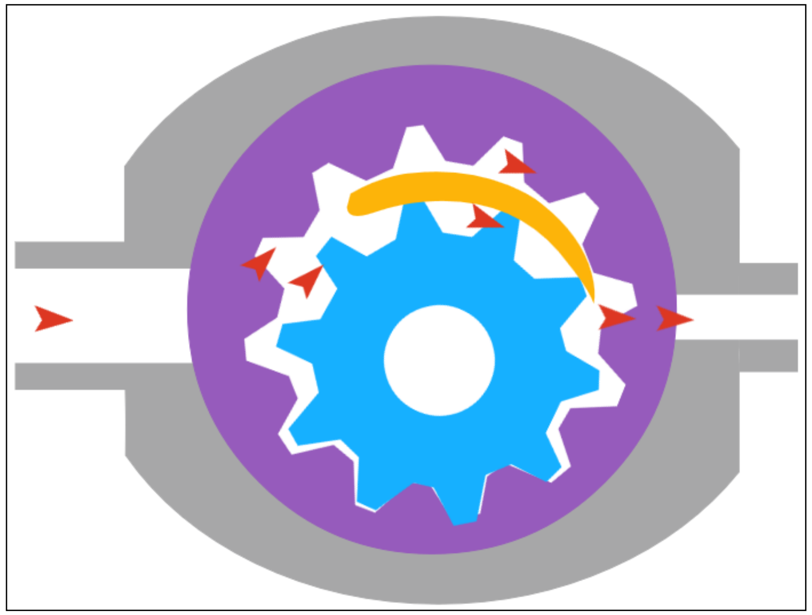
Gear pumps (with external or internal teeth) are simple and economical pumps. They have the lowest volumetric efficiency of all three basic pump types (gear, vane and piston pumps) and the lowest operating pressures (50 to 250 PSI). These pumps create pressure through the meshing of the gear teeth, which forces fluid around the gears to pressurize the outlet side. Some gear pumps can be quite noisy, compared to other types, but modern gear pumps are highly reliable and much quieter than older models. Another positive attribute of the gear pump is that catastrophic breakdown is a lot less common than in most other types of hydraulic pumps. This is because the gears gradually wear down the housing and/or main bushings, reducing the volumetric efficiency of the pump gradually until it is all but useless. This often happens long before wear causes the unit to seize or break down.

Interactive 8.1 Gear pump with external teeth - note the rotational direction of the gears



Tap to view demonstration of gear pump with external teeth. Note the rotational direction of the gears.

Interactive 8.2 Gear pump with internal teeth

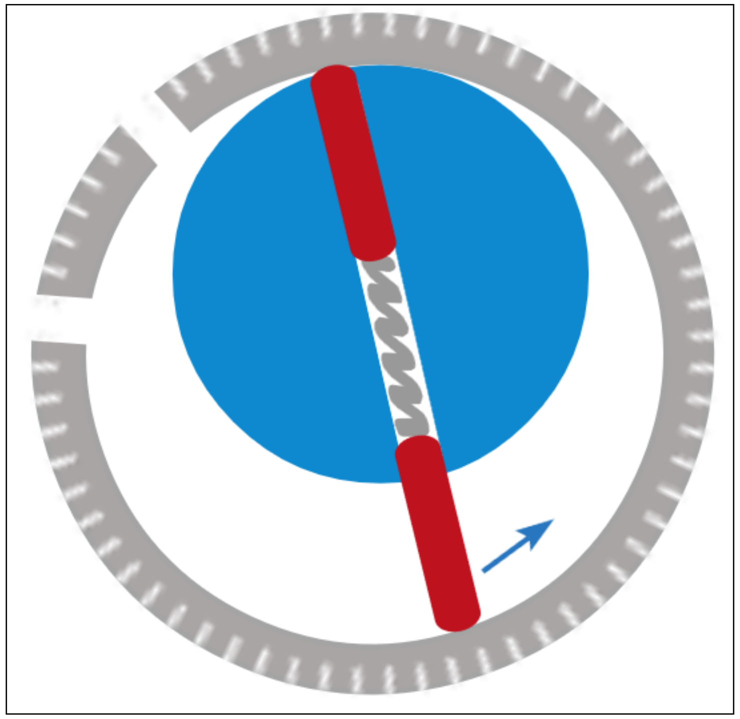


Tap to view a demonstration of a gear pump with internal teeth.

Rotary Vane Pumps

Rotary vane pumps (fixed and simple adjustable) have higher efficiencies than gear pumps, but are also used for mid pressures up to 2,640 PSI. Modern units can exceed 4,410 PSI in continuous operation, although vane pumps are not regarded as "high pressure" components. Some types of vane pumps can change the center of the vane body, so that a simple adjustable pump is obtained. These adjustable vane pumps are in general constant pressure or constant power pumps; the volume is increased until the required pressure or power is reached and subsequently the volume is decreased until equilibrium is reached. A critical element in vane pump design is how the vanes are pushed into contact with the pump housing, and how the vane tips are machined at this very point. Vane pumps are not as reliable as a gear pump due to the complexity of the pump.

Interactive 8.3 Fixed displacement vane pump



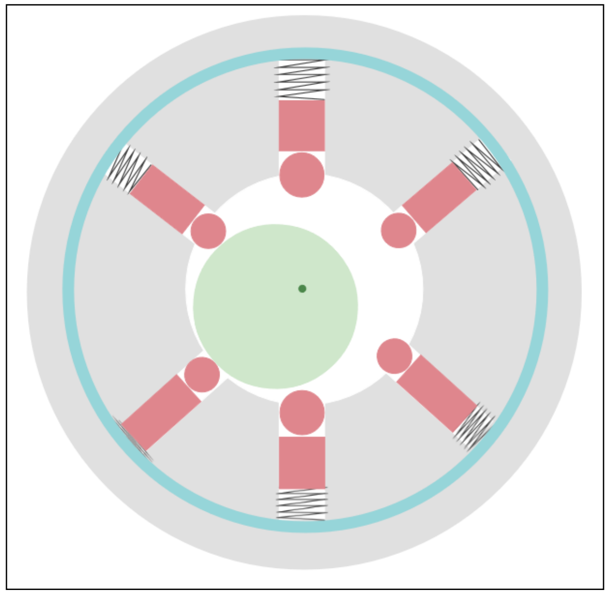
Tap to view demonstration of a fixed displacement vane pump.

Radial Piston Pumps

Radial piston pumps are used especially for high pressure and relatively small flows. Pressures of up to 10,000 PSI are normal. In fact, variable displacement is possible. The pump is designed in such a way that the plungers are connected to a floating ring. This floating ring can be moved horizontally by a control lever and causes an eccentricity in the center rotation of the plungers. The amount of eccentricity can be controlled to vary the discharge. The suction and discharge can be totally reversed seamlessly by shifting the eccentric to the opposite side. Hence both quantity and direction can be varied in a radial piston pump. Radial piston pumps are the most complicated and produce the highest pressures and therefore are not as reliable as the other type of pumps.

Self contained hydraulic pump assembly with reservoir that is used to power a single piece of machinery or a small area of the distribution center

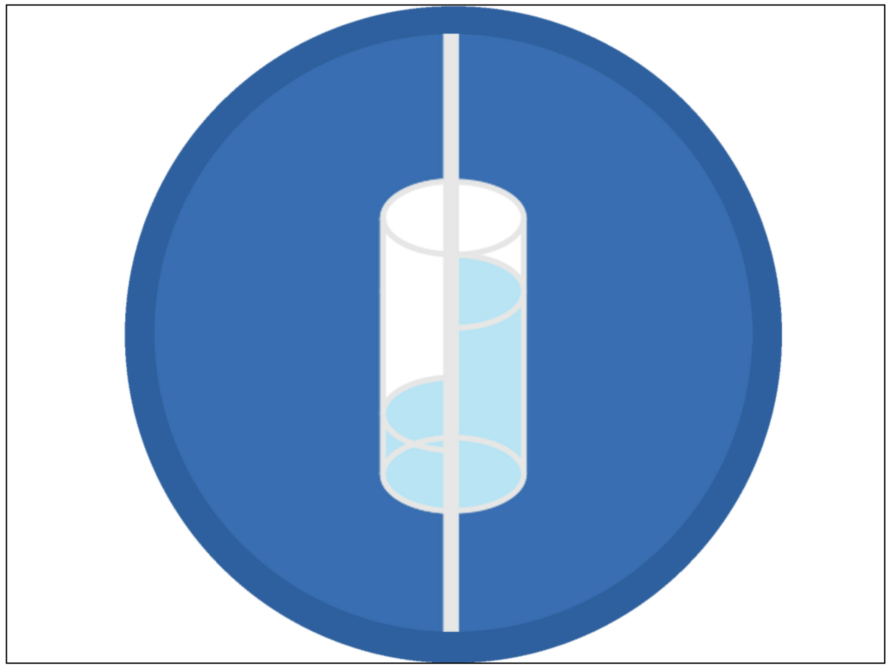
Interactive 8.4 Radial Piston Pump



Tap to view demonstration of a radial piston pump.

In a hydraulic system pressure control is normally achieved by using a mechanical valve that allows a controlled leakage of fluid to the reservoir at a given pressure. Since most hydraulic pumps are positive displacement this process is required to release the excess pressure and allow the pump to continue its operation. The valve is sprung and works with a check valve working against the spring which in some cases is adjustable.

Interactive 8.5 Comparison of Non-Adjustable and Adjustable Hydraulic Pressure Relief Valves



Tap and then slide bar.

Controls

Hydraulic controls direct the volume and pressure of the hydraulic fluid to the correct side of the cylinders to create movement and power. These valves are normally spool type valves that allow for positive control and little physical effort by the operator. Each valve may have multiple positions to allow a small number of valves to control multiple functions. This type of valve is simple and reliable with years of service life being the norm.

Interactive 8.6 Hydraulic Controls

Tap to view images of hydraulic controls

Filtering and Cooling

Hydraulic systems are closed systems so impurities should not collect in the system; settling reservoirs are a common method of removing any impurities that are developed in the system. If the system is under severe use such as a lift truck, filters will be installed in the fluid pick-up lines from the reservoir. Hydraulic systems under heavy use produce heat in the components and fluid. Some systems have coolers in the pick-up of the system to dissipate this heat.

Hydraulic fluid filter to remove impurities from the system

Pneumatics Overview

History

Pneumatics is the use of pressurized gas (air) as an energy source. A pneumatic system is a combination of components that makes a controllable, adaptable and varying power source from pressurized gas. Air pressure is the most common gas used and is normally produced by a central compressor and used throughout the distribution center. Pressurized gas can be used to move pistons to move product, activate control relays or power devices. The versatility of air pressure and ease of delivery throughout the facility makes it a popular design choice.

Early use of air pressure utilized bellows to add air to a fire to increase temperatures and improve the combustion process. Pressurized air systems today are used as a drive device in applications that require a clean and simple application such as medical or electronic applications where hydraulic or electrical hazards are a concern or are expensive.

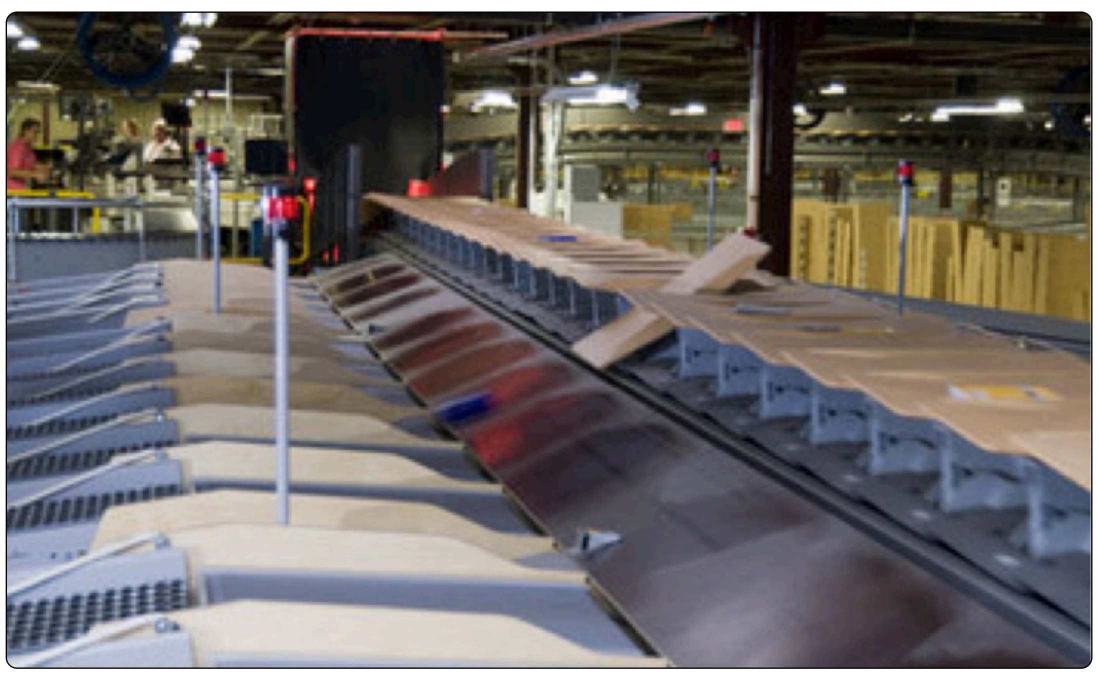
Pressure

Air pressure is developed by a compressor by forcing air closer together and regulated to the PSI that is needed for the individual application. Air is self-forming so it can flow freely through the entire system and can be controlled for both pressure and volume. During compression the air becomes heated and when it expands it cools so during the compression stage air may need to be cooled to get maximum benefit. Unlike hydraulic fluid, air is compressible so a constant supply is required within the enclosed system. Water or humidity within compressed air can be a problem to components and controls so most systems include a drier to remove the moisture and a filter to remove particulates.

Pneumatic Applications

Pneumatic motors are used to provide power for conveyors, as sliding pistons to move product during sorting or as control devices to activate components. They are also used as safety devices on conveyor lines or on components within the distribution center.

Interactive 8.7 Pneumatic Applications



Tap to view images of pneumatic applications in the automated warehouse.

Pneumatic Cylinders and Pistons

Pneumatic cylinders (sometimes known as air cylinders) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion or a rotary air motor for circular motion.

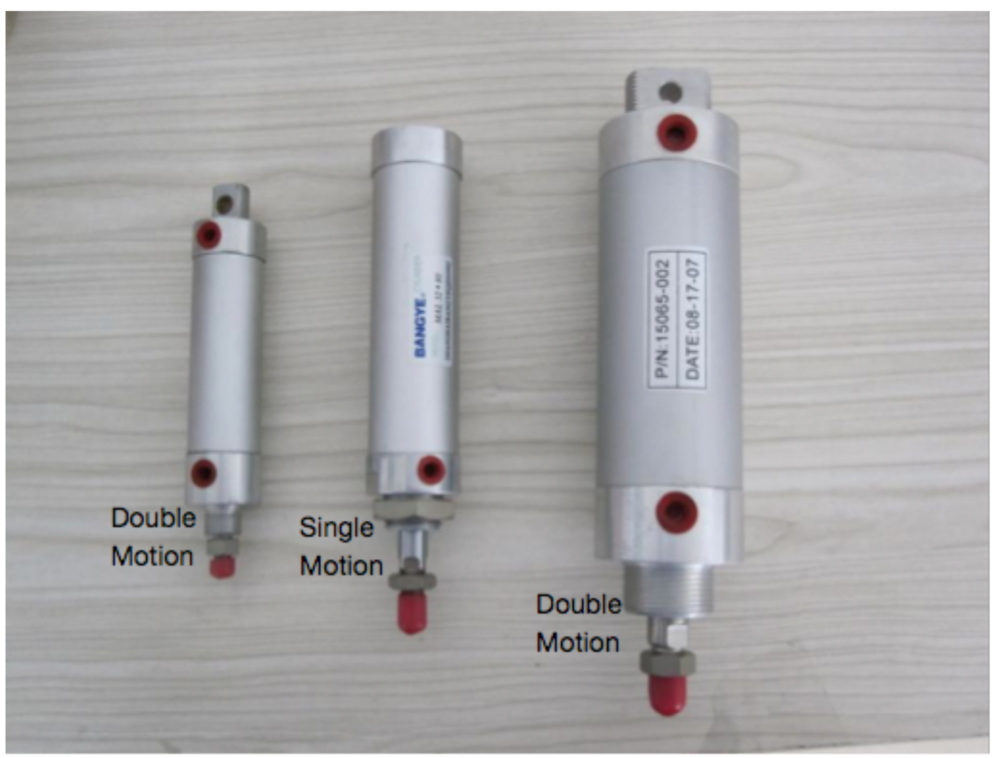
As with hydraulic cylinders, air pressure and volume forces a piston within the air cylinder to move in the desired direction. The piston is a disc sealed to the cylinder attached to a piston rod which transfers the force it develops to the object to be moved. Air motors use air pressure and volume to create twisting force or torque which can be used to provide power to drive components. Engineers prefer to use pneumatics sometimes because they are quieter, cleaner, and do not require large amounts of space for fluid storage. Because the operating fluid is a gas, leakage from a pneumatic cylinder is clean and will not contaminate the surroundings, making pneumatics more desirable where cleanliness is a requirement.

Single-Acting Cylinders

Single-acting cylinders (SACs) use the pressure of compressed air to push in one direction (usually out), and a spring to return to the original starting position. This type of cylinder has limited extension due to the space the compressed spring takes up. Another downside to SACs is that part of the force produced by the cylinder is lost as it tries to push against the spring. Because of those factors, single-acting cylinders are recommended for applications that require no more than 4 inches of stroke length.

Double-Acting Cylinders

Double-acting cylinders (DACs) use the force of air pressure to move in both directions. They have two ports to allow air in, one for push or extension and one for pull or contraction. When one side of the piston is being moved by air pressure the opposite side is exhausting the air. This is then reversed to allow movement in the other direction. Stroke length for this design is not limited; however, the piston rod is more vulnerable to buckling and bending as the movement increases in length.



Single and double motion pneumatic cylinders

Air Compressors

An air compressor is a device that converts power (usually from an electric motor in a distribution center) into energy by compressing or pressurizing air, which on command, can be released in quick bursts. There are numerous methods of air compression, divided into either positive-displacement or negative-displacement types. In a pneumatic system the pressure control is normally done by cycling the compressor on and off to control the pressure in the reservoir tank. The line pressure control to a local component is done with a local mechanical pressure regulator. Since air is compressible, available and is expended after use, the control of the pressure and volume is not as critical as in a hydraulic system. During the process of compressing and cooling the air humidity and moisture will accumulate in the reservoir tank or plumbing of the system. This water is damaging and must be removed by draining the reservoir and placing drying filters throughout the system prior to the air entering a component. Large pneumatic systems with high volume may use a refrigeration dryer that cools the compressed air as it flows through to condense and remove the water.

Piston Compressors

A reciprocating compressor or piston compressor is a positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure (125 PSI). The intake gas enters the suction manifold through a filter, then flows into the compression cylinder where it is compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged into a reservoir tank or directly to the system.

Two stage piston air compressor

Rotary Screw Compressors

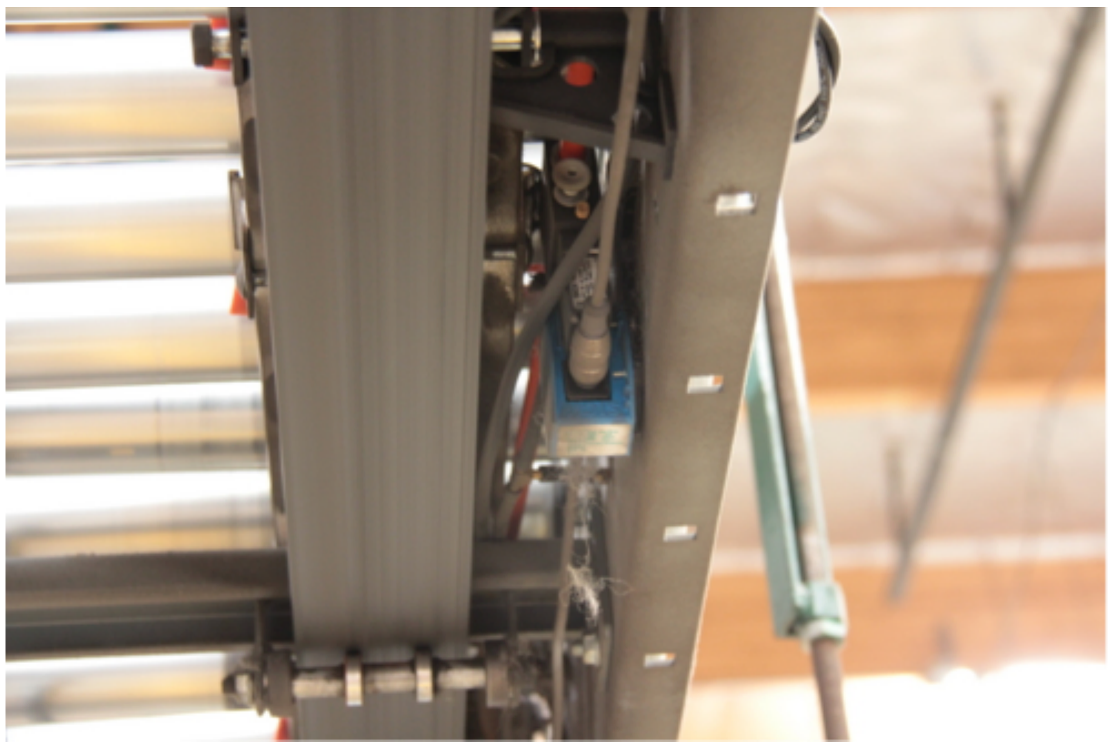
A rotary screw compressor is a type of air compressor which uses a rotary type positive displacement mechanism. They are commonly used to replace piston compressors where large volumes of high pressure air are needed, either for large distribution centers or to operate high-demand air tools. The gas compression process of a rotary screw is a continuous sweeping motion, so there is very little pulsation or surging of flow, as occurs with piston compressors.

Interactive 8.8 Compressor Images

Tap to view images

Directional Control Valves

Directional control valves direct pneumatic pressure and volume to an actuator or a cylinder and piston to produce movement. They are normally a spool type mechanical or electrical valve that controls flow into different passages. They can be two or three channel controls that have neutral and control positions. They can also be on/off valves that produce a quicker response to provide a surge of pressure and volume to an actuator to create movement. All of this control is normally done by an operating computer system that is directed through PLCs. Pneumatic systems are not as precise in their movement as hydraulic systems so they are normally directed to a full movement to mechanical stops.



Solenoid actuators converting electrical signals into air pressure control

System Maintenance

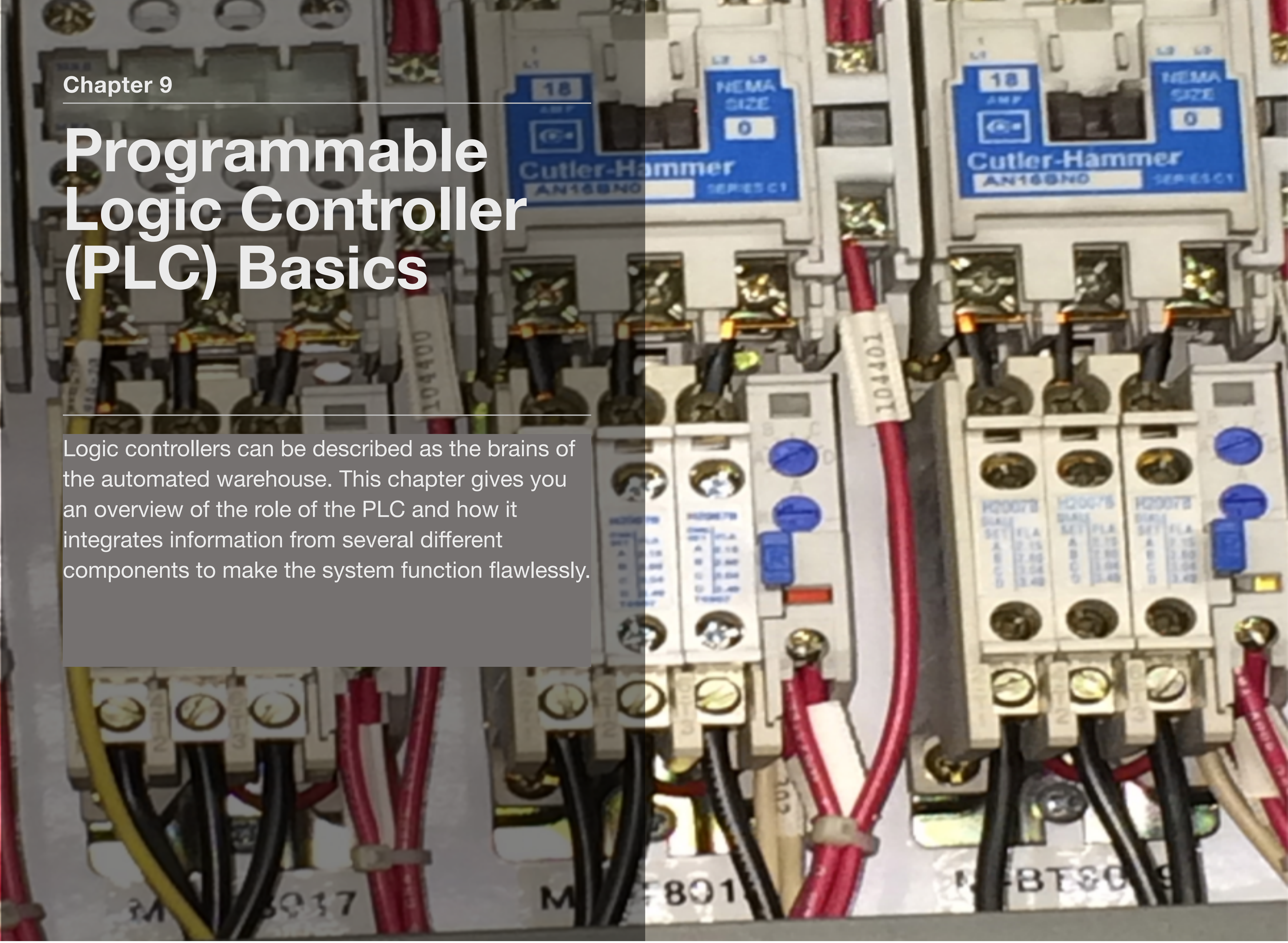
Hydraulic system maintenance is the process of timely replacement of filters and fluids or preventive rebuilding or replacement of components. Hydraulic systems require filter changes based on operating conditions and hours of operation. Scheduled replacement is best to limit failures and downtime. In hydraulic systems fluid changes are required, but the use of newer fluids has dramatically extended service intervals and in some cases fluids can last years without replacement. Monitoring of electrical devices that are used for driving motors or controls should be serviced based on the accumulated data for long-term reliability. Current draw and voltage drop tests can be done to test the operation of the devices. Monitoring pressures is a good indicator of the quality of the system and variations in outputs will indicate current or future problems.

Pneumatic systems have air filters at the inlet to remove impurities prior to the compression of the air and water filters are used after compression to eliminate any moisture that collects in the system. Large volume systems may use a refrigeration drier. Service or replacement of these devices is done on a scheduled basis. The draining of reservoir tanks and remote filter/driers is required often if not managed by an automatic system.

Chapter 9

Programmable Logic Controller (PLC) Basics

Logic controllers can be described as the brains of the automated warehouse. This chapter gives you an overview of the role of the PLC and how it integrates information from several different components to make the system function flawlessly.



Section 1

Programmable Logic Controller (PLC) Basics

Programmable logic controllers, commonly called PLCs or microprocessors, are used to automatically control various residential, commercial, and industrial electrical operations through programming logic in lieu of manual operations (turning switches on and off by hand). PLCs of today are in cars, energy management systems, supply chain operations, airplanes and any type of electrical control that can be imagined. PLC’s premise is based on receiving voltages as input signals and releasing voltages as output signals to control circuits based on the order of the signals received and program design of the logic for rendering outputs. PLCs are solid-state devices that are programmed to command operations using low control voltage, 5VDC, to control low power and high power voltage systems from 24VDC/120VAC to 277VAC/480VAC and greater. PLCs offer many benefits for automated control of electrical systems: low cost maintenance, easily replaceable input and output boards; quick diagnoses for troubleshooting and repair, including benefits of being reprogrammed for changes to existing equipment and production operations to increase efficiency. PLCs high speed, low cost, highly reliable small devices with diverse abilities that increase productivity and quality by linking multiple machines and operations into one integrated system for maximum support for supply chain operations. Learning and mastering PLCs from basic operations to intricate programming will give an edge to any technician in the supply chain support for operations.

PLCs provide warehouse efficiency by integrating hundreds of inputs and power sources to control hundreds of outputs by one central control scheme known as ladder logic, the brains of programmable logic control. Below are examples of PLCs.

Several types of PLCs exist and provide controlled automation for a main conveyor and all associated equipment. The first and the oldest is a PLC 5 built by Allen Bradley with programming by Rockwell software: RSLogix™ 5 Software with RSLinx™ communication software.

Input and Output boards for connections to a PLC, SLC 500 series

RS200 Sorter PLC controlled conveyor transporting product and sorting by movement of the conveyor shoes

The PLC is a master controller for all the outputs and inputs for the travel conveyor. The conveyors within the automated warehouse are controlled by a series of speed inputs, photo cell inputs and other electrical associations by the master PLC controller via ladder logic programming for streamlined operation. The master controller consists of a PLC rack which includes a power supply, master controller and a chassis to interface communications between the cards and controller inputs and outputs for operation. Also on the controller board is an external EPROM – an erasable programmable read only memory chip that retains information when power is switched off, which is inserted into the main controller.

Typically EPROMs in most PLCs today are internal unless otherwise designed. The main purpose of the EPROM is to retain the logic of the PLC program in case of a power loss. If the ladder logic is only in the RAM (Random Access Memory), once there is a power loss from control power to the PLC, all the contents (ladder logic program) will disappear.

Individual input and output boards are critical to ladder logic operations within the PLC's main controller. It is important to note that inputs and outputs in PLC controlled environments are simply voltages. The inputs from electrical peripherals (photo cells, switches, start buttons, etc.) and output voltages (motor contactors, status lights, start sirens, etc.) control the system. These voltages vary from 120VAC to smaller 24VDC as designed. The image on this page shows an example of a master controller station which allows the operator to control which inputs to the PLC are sent, thereby requesting a particular operation by the conveyor. Lights on the controller station are illuminated by outputs from the PLCs as input and output signals are received.

PLC 5 Master Controller with inserted EPROM, controlling the entire operation of a conveyor within a distribution center

This panel gives the operator manual control over PLC operations by turning inputs on and off when desired. The control the operator has in this case is the release of product from several conveyor lines into the merge area. Typically the auto control will run the conveyors, but at times due to physical errors on the conveyor, the operator may take control.

Operators' Control Station which can be used for manually switching and overriding PLC's Inputs or Outputs for operations indicated by illuminated lights

The lines of the conveyor will run one at a time for a set amount of seconds depending on each line's capacity and the logic in the PLC control. This creates a round robin cycle, allowing each conveyor to release product to the main conveyor in a timely and efficient manner.

It is important to note all PLC input wire markings are designated by 1 or 0. 1 is input and 0 is output. These numbers are the beginning number of PLC wire designations, sending voltage signals either going into a PLC module for input or exiting a PLC module as an output. Input boards have wires that are signal voltages coming in indicated by a 1 first and then followed by other numbers for wire circuit designation.

Merge of several conveyors moving product through timed intervals controlled automatically by the PLC controller and/or manually at the operators' control station

In addition to the wire markings for input and output, the SLC 500 series input and output module boards were designed to easily be replaced if an error occurred on the PLC board itself. The input wires would remain on the orange terminal block, which can be removed from this module by removing two screws: top and bottom. These screws do not have a wire connected to them. Once the screws are removed, the orange terminal strip will unplug from the PLC module. The PLC module can then be snapped out of the chassis for replacement or repair.

The SLC 500 series PLC is typically in one or two PLC racks to accommodate the size of the PLC system. This is dictated by the size and complexity of the automation.

PLCs are housed by two racks, providing a communication interface for all the modules. For descriptions of a PLC rack, refer to the image on the right. First is the PLC power supply being darker gray in color with one red light showing, which provides power to the PLC chassis. Next is a PLC adapter converting Ethernet connections for communications from other PLCs and the master controller. Next are the PLC modules labeled red for input and orange for output. These are the components on the PLC chassis.

PLC input board with wire markings beginning with 1 and followed by the circuit number

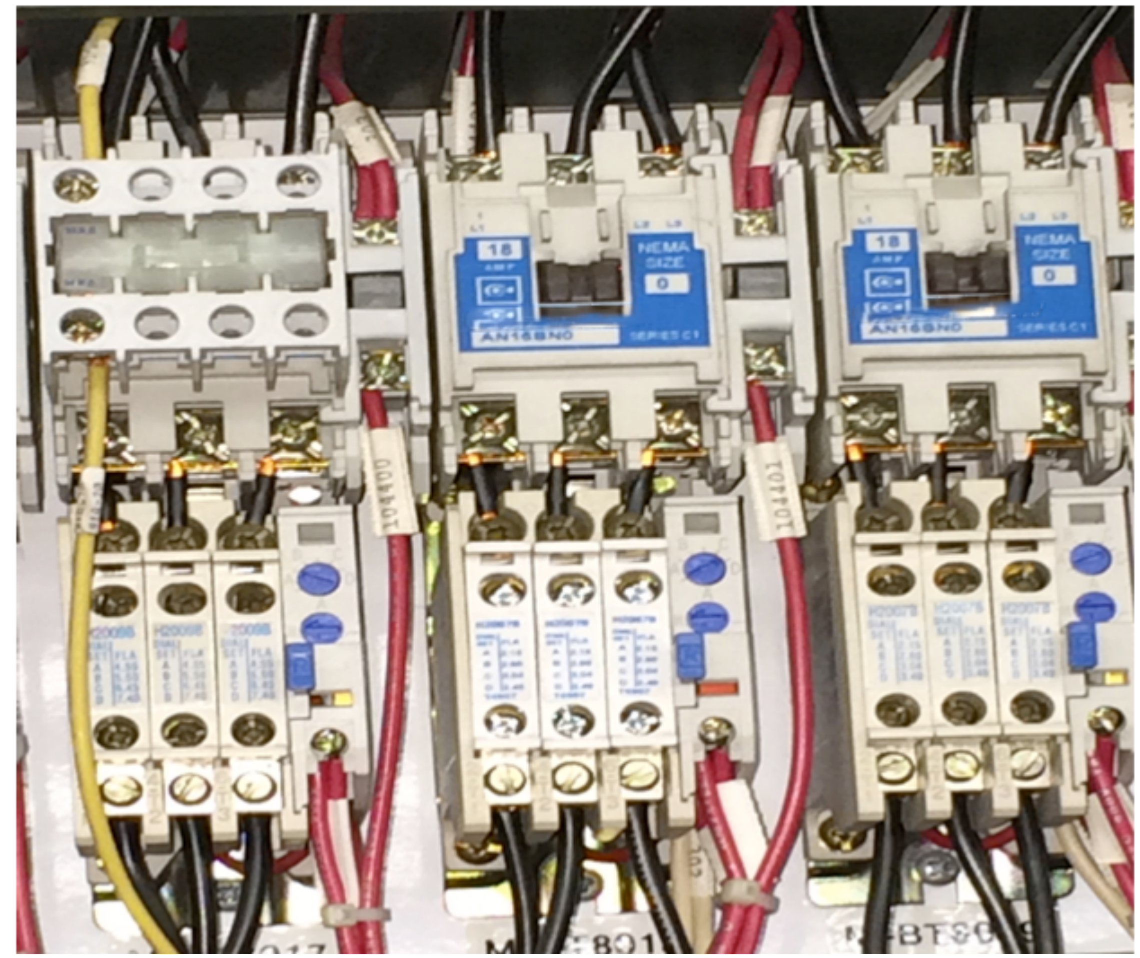

PLC rack of input and output boards

The lights on the output board, numbers 0 -17, illuminate when a signal indication for on is outputted. The logic of the PLC has been commanded to send voltage to an output device, such as a motor contactor. When the logic tells the output voltage to stop, the voltage will cease and the light will go out. Typically the lights give a true indication if voltage is present or not on the output terminal, however there are occasions where a light on or off may not indicate a true output on the terminal ID. In this case the output board is operating in error as the light should match voltage present or not on the terminal.

Output board Indicator lights to verify operational status

Motor starters provide 480VAC power to drive motors on the conveyor when energized. These starters receive their on signal, 120VAC, from PLC output boards when commanded by the PLC logic.

The input board status lights operate much the same as the output boards; the only difference, the signal, 120VAC, is coming into the PLC, not out.



Motor starters controlled by PLC outputs that activate a relay to provide current to start a motor

Input board indicator lights used to verify operational status

When an input device sends a signal to the PLC it will be indicated by an illuminated light for 0-17 terminal connections. Also note terminals 0-17 are separate input devices.

Within the PLC output device, a light “on” does not guarantee that 100 percent voltage is present on the input. These input and output module status lights operate on 24 volts DC and are controlled by internal relays on the PLC module itself. To completely verify a voltage signal is present on the PLC, a technician must check for the 120VAC with an approved DVOM, on the terminals for the designated connection to see if voltage is present. The internal relays on the modules will get stuck at times in the open or closed position whether or not the signal is present or not and in some cases give a false indication. The status lights are guidelines, not absolutes for voltage present or not.

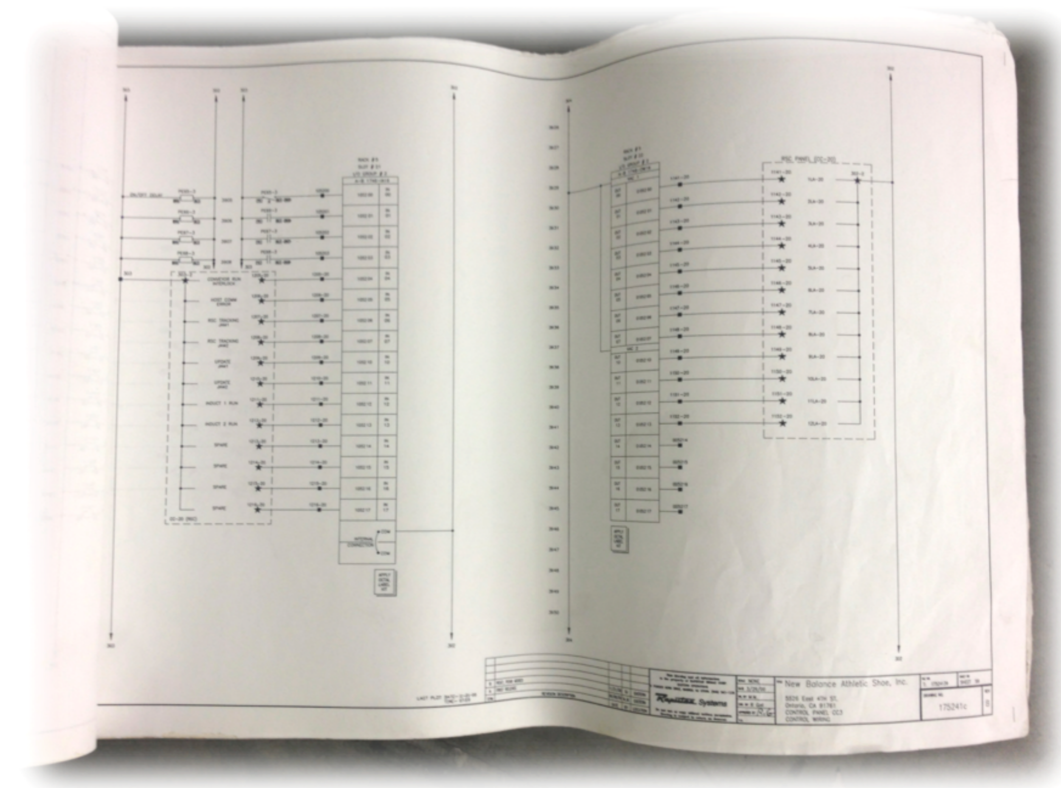
The photocell is an input device for PLCs. The signal for this photocell is 120VAC and it is sent to input modules when blocked by product. These photo eyes can be used for a variety of operations within the logic of the PLC. Examples are to hold product, indicate a jammed condition on the conveyor, stop a portion of the conveyor, etc.

Photo Eye 120 Volt input to PLC input modules

A Digital Volt Ohmmeter (DVOM) is the preferred tool for checking voltages on PLCs. Fluke is one of the most accurate meters on the market and is typically the standard. Being able to analyze PLCs using a DVOM is critical for effective and accurate analysis for proper operation and troubleshooting. Operation of the DVOM by technicians takes training and experience to be safe, knowledgeable, comfortable and quick with the use of the meter.

DVOM reading 117.5VAC

PLC prints are simplistic in nature. The rule is if voltage is going into the PLC module the print is an input. If voltage is coming out of the PLC module the signal is an output. The schematic diagrams beginning from the left are input prints and the schematic diagrams on the right are output prints. Learning to read and understand PLC prints are just as important as learning the PLC process and control of automation.



PLC prints for signals for inputs and outputs which are used for tracing each circuit and troubleshooting

MicroLogix is another type of PLC used in distribution centers. These PLCs are smaller in size and are typically used for smaller operations and to control stand-alone automations and machinery.

The big advantage of the smaller PLCs when compared to more complex PLC systems is that the inputs and outputs are all integrated into one unit. In the PLC 5 and SLC 500 they have a master controller and separate input and output modules. The MicroLogix controller is one simple unit. The input connections are on the top and the output connections are on the bottom. The MicroLogix controller, like the SLC 500 PLC, operates the internal relays operating on 24VDC. These relays switch the signal on and off, typically at 120VAC, as dictated by the PLC program turning on and off associated devices. These devices may be motors, mac valves, control power, etc.

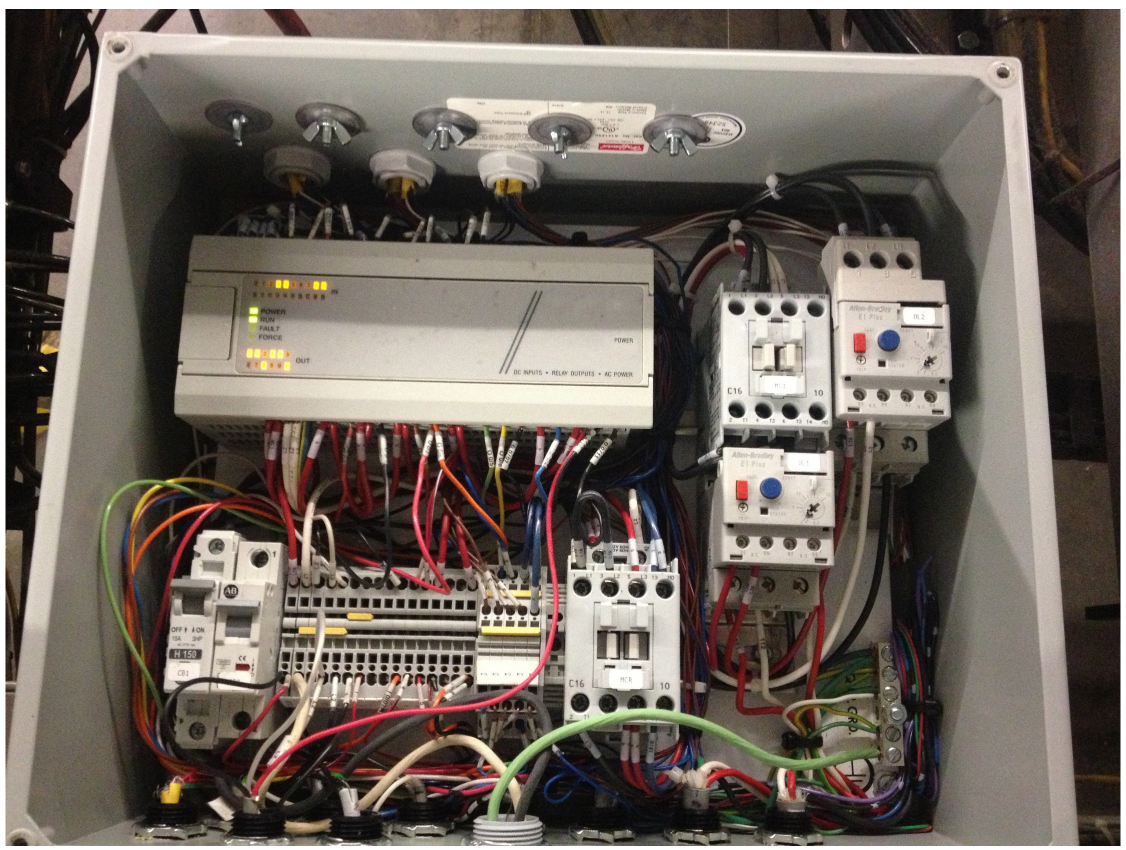
PLC Controller MicroLogix 1000

The panel cover for the output connections is in the open position, showing the terminals for devices that will receive the signal, a designated voltage, for the output device to operate as determined by the PLC logic. The input connections are at the top of the unit under the cover. The PLC 5 controller runs off RSLogix5 software and MicroLogix runs off of RSLogix500 software. Each PLC controller typically has proprietary software for the ladder logic that is not compatible with other PLC controllers from different manufacturers.

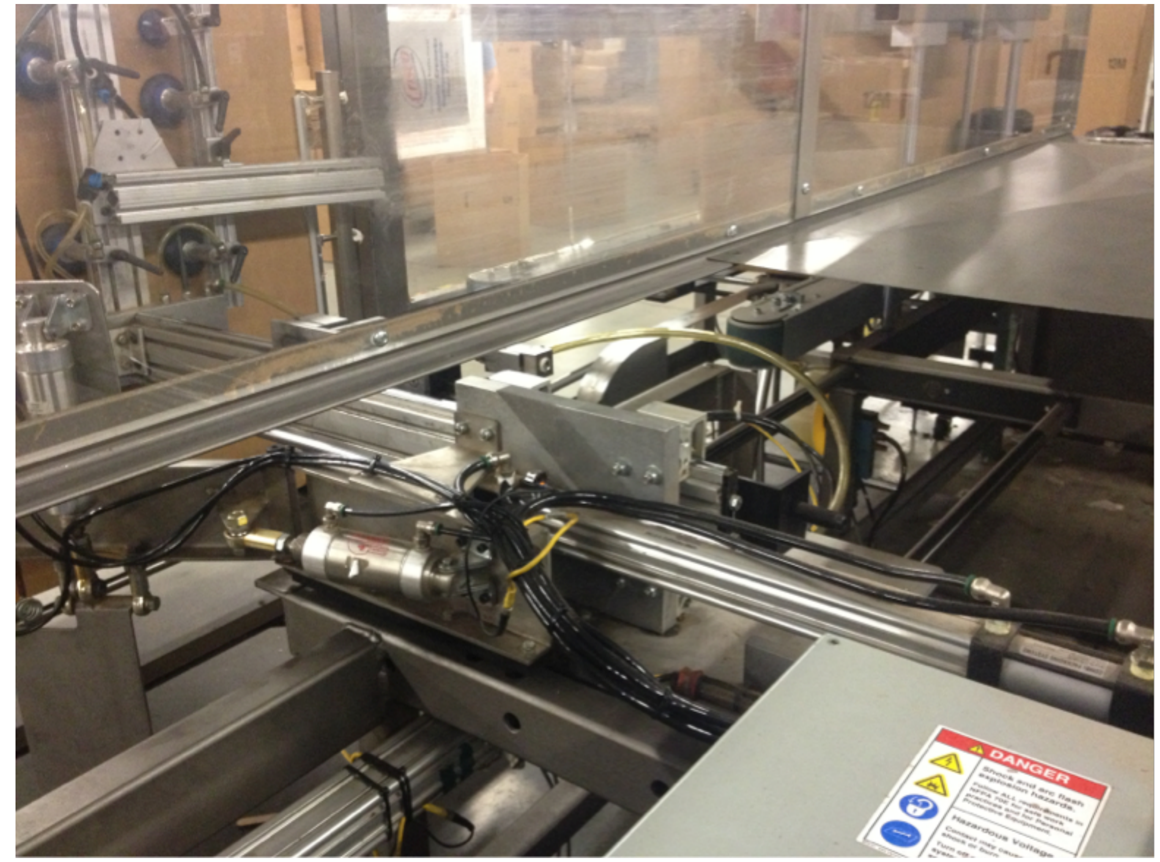
MicroLogix controller showing terminal connections for the outputs

The MicroLogix PLC controller is the central controller of the operation. In the example on the next page, a Combination Box Machine is making product boxes from flattened boxes on a stack. Some of the inputs are photocells, start switches and emergency stop buttons. The outputs are motors for belt rotation, Mac Valves controlling the output of air for cylinders, and other devices.

The combination box maker is completely controlled by PLC logic for full automation. In the picture on the right, the extend cylinder is reaching out to grab a box in the flat position from the stack and to pull it back to open it up into a formed box. This process is done by a series of compressed air cylinders controlled by Mac Valves and photocells controlled by the PLC logic in the MicroLogix controller.



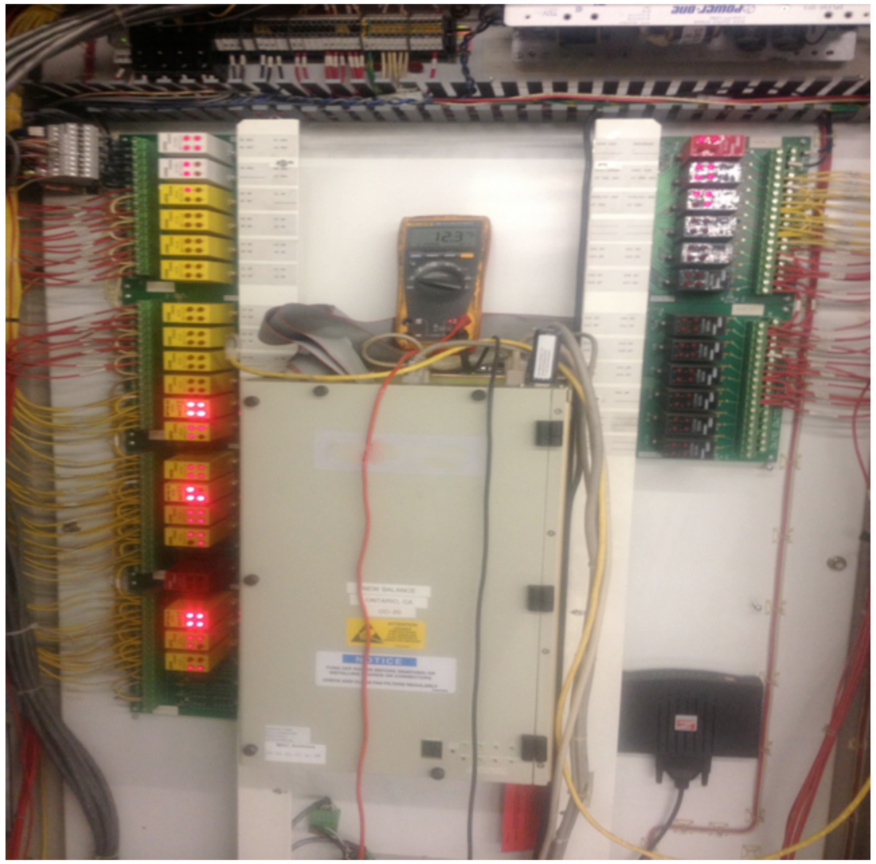
MicroLogix 1000 Controller for Combi Box machine



A box maker controlled by a MicroLogix Controller

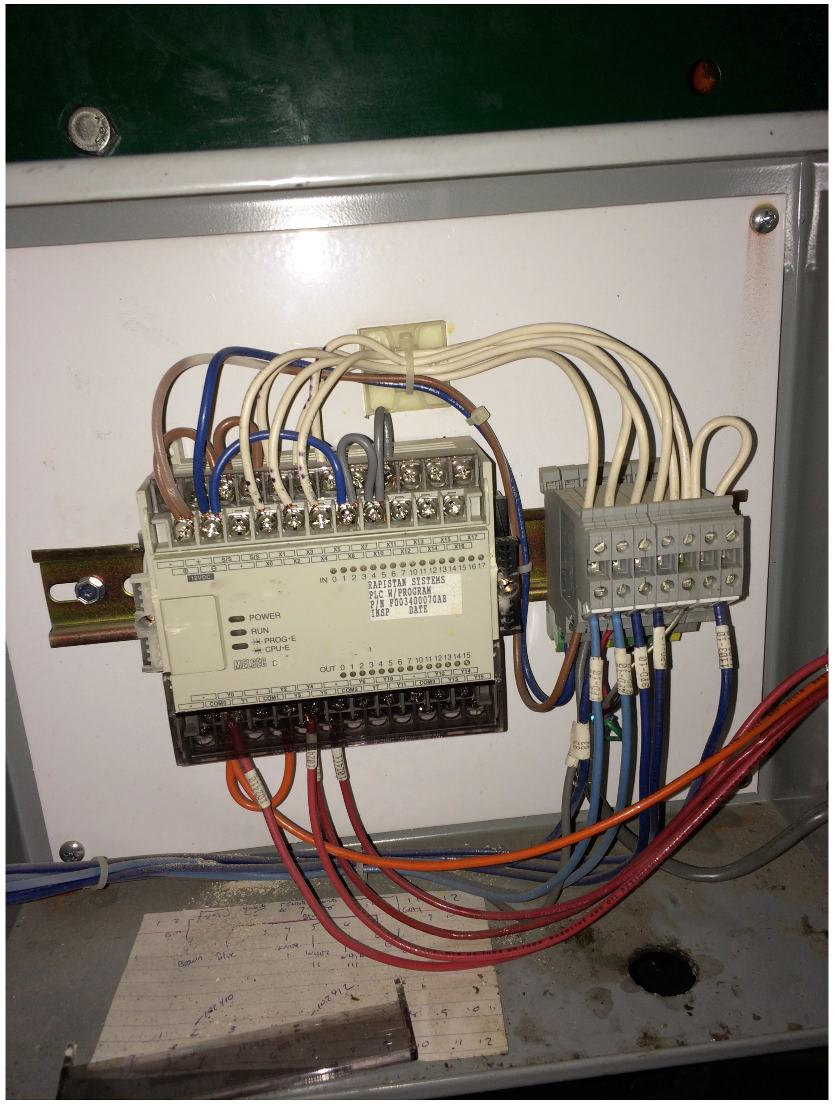
PLC Controllers often work with other computer controlled devices for automated operation. The computer controller receives inputs from various electrical peripherals, full photocells and update photocells to control product movement on the conveyor. Signals are sent to input devices called opto-blocks which covert a higher voltage signal to smaller voltages that a computer controller can process. The logic in the computer controller then sends a signal to an output block for an operation to occur.

This operation could be diverting product from a conveyor that is full to one that is not. The output device will also send signals to other controllers as inputs for the corresponding master PLC controller to allow another operation to occur. This process depends on the logic within the system and the complexity of the task, but is important to maintain movement of product and correct delivery of processes.



Computer controller with inputs and outputs

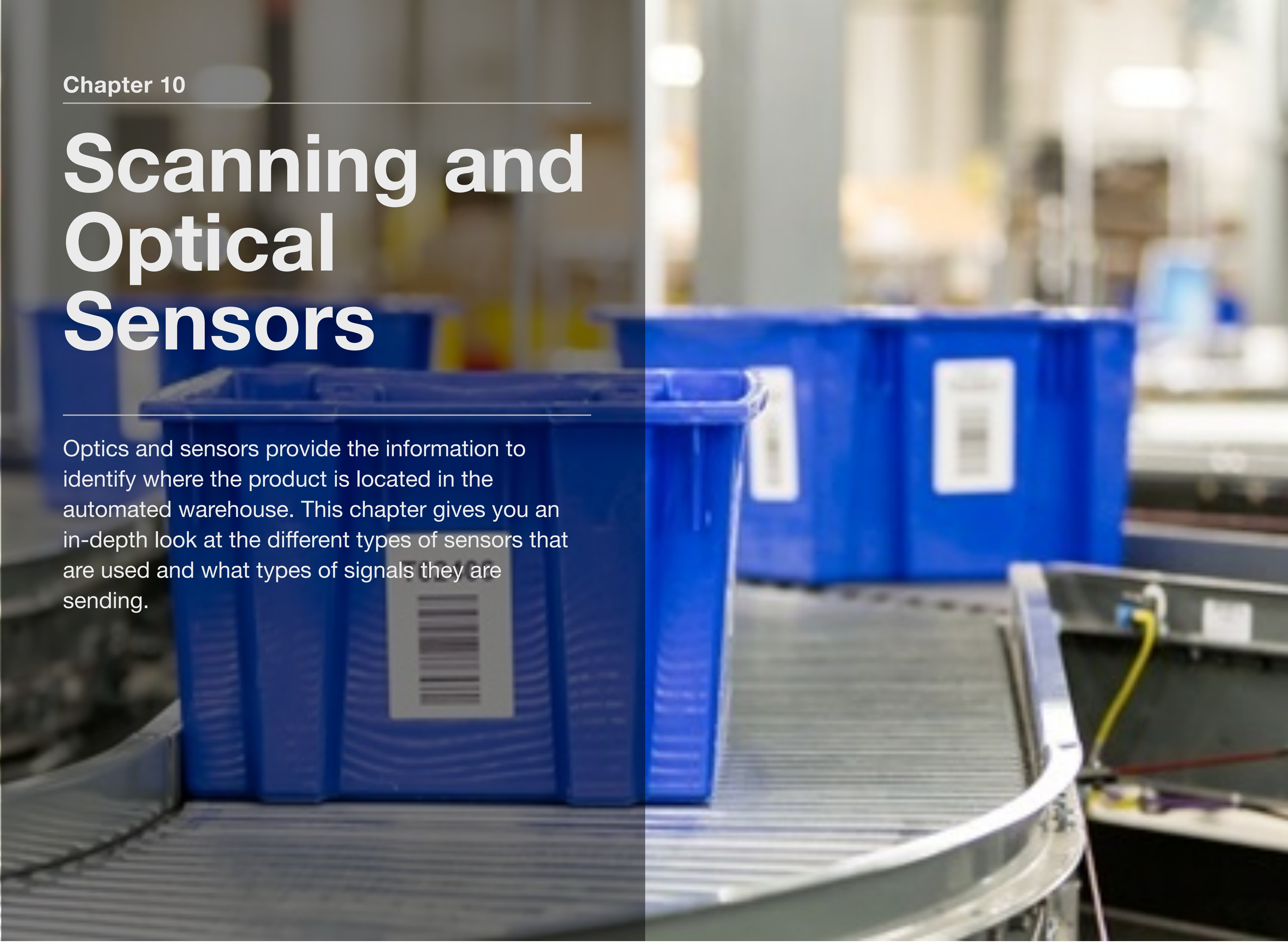
PLCs often work in unison with other PLCs even if the manufacturer is different. This versatility adds the capability of merging new technology with old without escalated costs.



A smaller PLC made by Mitsubishi, designed to work together with an Allen Bradley PLC 5 master controller

PLCs are the cornerstone of any automation operation. These examples are just a few of the operations inside an automated warehouse that are controlled by PLCs.

Overview of PLC-controlled automation



Chapter 10

Scanning and Optical Sensors

Optics and sensors provide the information to identify where the product is located in the automated warehouse. This chapter gives you an in-depth look at the different types of sensors that are used and what types of signals they are sending.

Section 1

Overview

Automated delivery systems require the use of sophisticated data input that is provided by different types of scanning devices. The use of barcodes and optical scanners has become the standard method used in today's distribution centers. Radio frequency identification is the wireless use of radio waves to transfer data so automatic tracking and identification of objects can be accomplished. This technology is growing in use and is being integrated into the supply chain system to promote better speed and accuracy. As the price declines it will become more prevalent in distribution centers. Used for counting, weighing, sizing, identifying or positioning, these devices are the basis for all processes within a distribution center. The installation, maintenance and repair of these sensors are a major task for supply chain technicians who require experience in troubleshooting, electronic signals and networking processes.

Section 2

Optical Sensors (Light)

Optical sensors in a distribution center are electronic sensors that convert a light beam, or a change in a light beam, into an electronic signal. They are used in many industrial and consumer applications. Light used can be red light, infrared light or laser light depending on the application.

The sensor measures the physical quantity of light and then converts it into a form that is readable as an input to a controlling computer system. An optical sensor is generally made of multiple components that integrate a source of light, a measuring device and the optical sensor. The sensor signal reacts to the change in the light signal within the light sensor. An optical sensor can measure the changes in one or several light beams. When a change occurs, the light sensor operates as a photoelectric switch which is used to create an on or off signal. An optical switch enables circuits to be switched selectively from one circuit to another without physically contacting the product.

Barcode Readers

Barcode readers or barcode scanners are an electronic device for reading printed barcode labels. They consist of a light source, a lens and a light sensor translating the light changes of the white and black bars into digital signals for identification. They normally use a laser as their light source to increase accuracy and dependability. Additionally, nearly all barcode readers contain circuitry analyzing the barcode's image data provided by the sensor and sending the barcode's content to the scanner's output port for use throughout the control system. Laser scanners use a laser beam as a light source and typically employ either a reciprocating mirror or a rotating prism to scan the laser beam back and forth across the bar code.

Interactive 10.1 Barcode Readers

Tap to view images of barcode readers.

Hand Held Barcode Readers

Hand held barcode readers as the name implies are portable and consist of a light source and photodiode that are placed next to each other on the tip of the device. To read the barcode, the person holding the reader must move the tip of it across the bars at a relatively uniform speed. The photodiode measures the intensity of the light reflected back from the light source as the tip crosses each bar and space in the printed code. The photodiode generates a waveform that is used to measure the widths of the bars and spaces in the bar code. Dark bars in the bar code absorb light and white spaces reflect light so that the voltage waveform generated by the photo diode is a representation of the bar and space pattern in the bar code. This waveform is decoded by the scanner in a manner similar to the way Morse code dots and dashes are decoded.

Interactive 10.2 Hand Held Barcode Readers

Tap to view images of hand held barcode readers.

Omni-Directional Scanners

Omni-directional scanners are most familiar to us as they are horizontal scanners in supermarkets, where packages are slid over a glass window. There are a range of different omni-directional units available, which can be used for differing scanning applications ranging from retail type applications with the barcodes read only a few inches away from the scanner to distribution center conveyor scanning where the unit can be from a few inches to 10 feet away from the barcode label. Omni-directional scanners are also better at reading poorly printed, wrinkled, or even torn barcodes.

Charge Coupled Devices

Charge coupled device (CCD) readers can be used in hand held or permanent mounts and use an array of hundreds of tiny light sensors lined up in a row in the head of the reader. Each sensor measures the intensity of the light immediately in front of it. Each individual light sensor in the CCD reader is extremely small and because there are hundreds of sensors lined up in a row, a voltage pattern identical to the pattern in a bar code is generated. The important difference between a CCD reader and the other bar code readers is that the CCD reader is measuring emitted ambient light from the bar code whereas other scanners are measuring reflected light.

CCD scanners are very fast so they read barcodes at any speed.

Position or Displacement Sensors

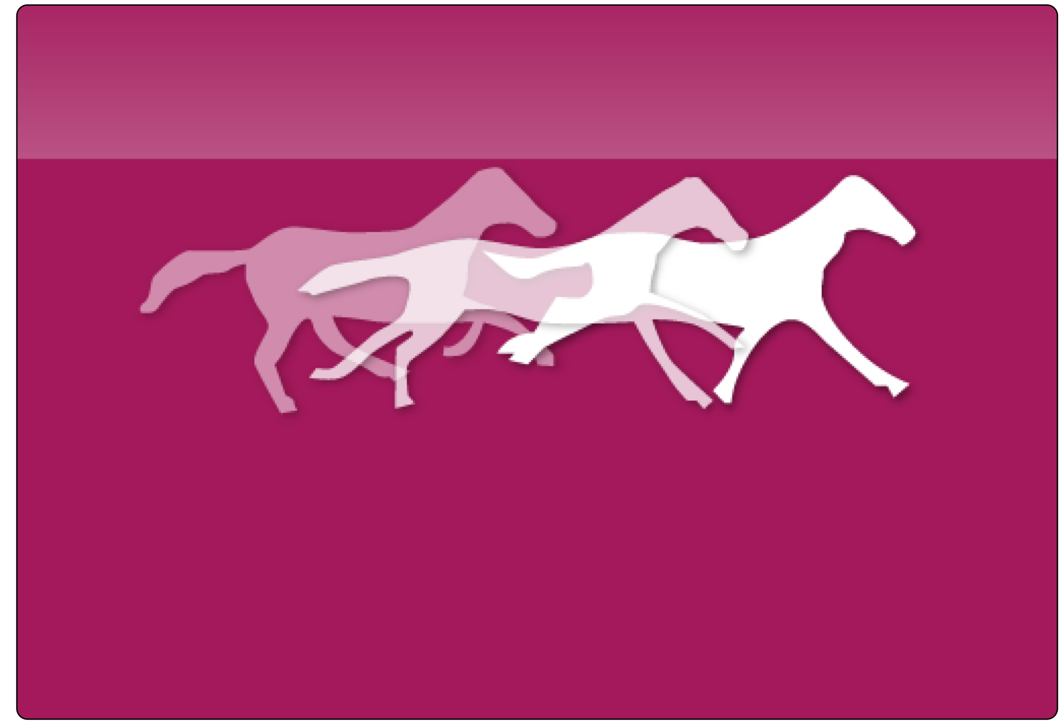
Photo sensors are used to respond to light or to a source of light which is part of the same circuit or system. They are normally used by allowing or blocking a light source to create an on/off switch which is used as an input for establishing presence of a box on a distribution system conveyer to control motion of the product. Photo sensors are also used to determine dimensions for the sizing of boxes as they are input into the distribution center during receiving operations. In most cases the light source is simply blocked by whatever item is being controlled to create a signal. The computer management system can then make decisions about the operation of the system. Safety controls and automatic safety shut offs may be controlled by photo sensors. An example would be if a person's hand or arm enters a dangerous area and blocks the light sensor. The system would stop to minimize risk to the operator.

Observe the sensors on each side of the conveyor system. The sensor could count, position or determine the speed of moving products.

Speed and Count Sensors

Optics can be used for measuring the speed of an operation by using photo sensors. The Warehouse Management System (WMS) can read the input information from the sensors and determine the speed or count the number of units during operation. This information is then used to manage the speed and delivery of product throughout the system.

Interactive 10.3 Speed and Count Sensors



Tap to view images of speed and count sensors.

Section 3

Hall Effect Sensors (Magnetism)

A Hall Effect sensor is a device that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity, switching, positioning, speed detection, and current sensing applications. Hall Effect technology did not begin to gain acceptance until the 1980s. This was because the voltage potential across the Hall element is minuscule, and may easily be influenced by outside forces, such as temperature and stresses. More recent devices incorporate advances in the ability to amplify the signal, which has allowed Hall Effect sensing technology to be employed even under extreme environmental conditions such as applications in distribution centers. Furthermore, the "non-contacting" operation of Hall Effect sensors gives the user a nearly infinite life and reliability with regard to actuation and switching. Most Hall Effect sensors are combined with circuitry that allows the device to act as a digital (on/off) signal as an output and may be referred to as a switch. The concept of operation is to create a signal when magnetism is present and remove the signal when the magnetism is removed. The sensors are very versatile and in a distribution center they can be used as position, speed or level controls.

Hall Effect proximity sensors are able to detect the presence of nearby objects without any physical contact. Proximity sensors emit electromagnetism or a beam of electromagnetic radiation (infrared, as an example), and look for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Some types of sensors use capacitive sensing, including sensors to detect and measure proximity, position, size or movement. This is done by the volume of the product changing or interrupting the magnetic field being produced by the sensor.

A Hall Effect sensor that can be installed in different applications

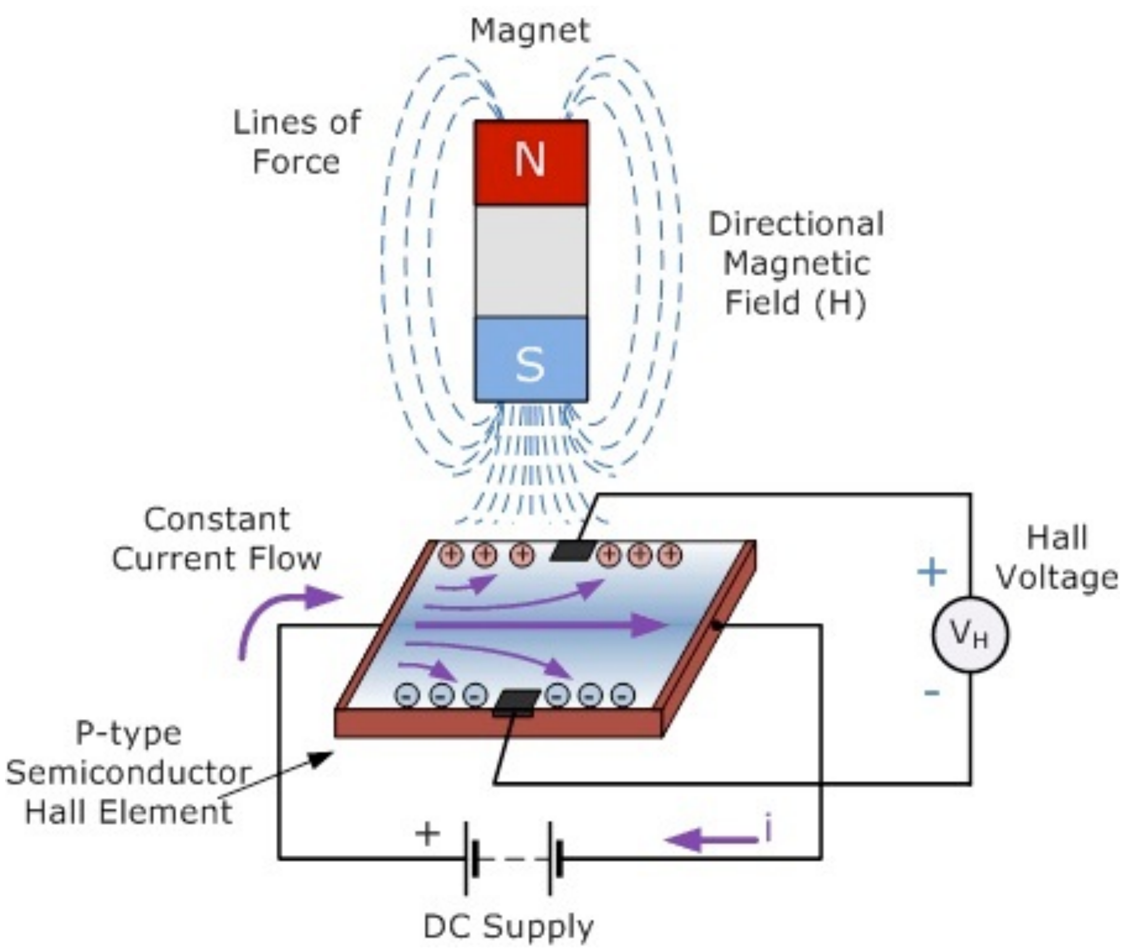


Diagram of the theory of a Hall Effect sensor. Magnetism allows a small voltage to flow through the plate.

Electricity carried through a conductor will produce a magnetic field that varies with current, and a Hall Effect sensor (current probe) can be used to measure the current without interrupting the circuit. This application is used for motor control electrical loads and data information for maintenance. Typically, the sensor is integrated with a wound core or permanent magnet that surrounds the conductor to be measured. These are commonly seen in distribution centers as speed controls for motors to control conveyor speed. They are also used in consumer equipment such as automotive speedometers and position inputs for conveyor systems.

Drive motor with a speed control box and start-up capacitor attached in the square box

Section 4

Radio-Frequency Identification (RFID)

Radio-frequency identification (RFID) systems use wireless radio signals to transfer data for the purposes of automatically identifying and tracking tags that are attached to boxes or individual items. The tags contain electronically stored information that will identify and track items as they flow through the distribution center. Some tags are powered by and read at short ranges (3 to 6 inches) via electromagnetic signals, and then act as a signal generator to give off radio waves at high frequencies. Others use a local power source such as a battery, and may operate at hundreds of feet away. Unlike a bar code, the tag does not necessarily need to be within line of sight of the reader, and may be embedded in the tracked object.

Tags

RFID tags can be passive, active or battery-assisted passive. An active tag has a small battery and periodically transmits an ID signal. A battery-assisted passive tag has a small battery on board and is activated when in the presence of an RFID reader. A passive tag is cheaper and smaller because it has no battery. However, to start operation of passive tags, they must be activated with a power level roughly three times stronger than for signal transmission. Tags may either be read-only, having a factory-assigned serial number that is used as a key into a database, or may be read/write, where object-specific data can be written into the tag by the user. Field programmable tags may be write-once, read-multiple. Blank tags may be written with an electronic product code by the user. A tag with no inherent identity is always vulnerable to manipulation.

An RFID reader transmits a radio signal to the tag. The RFID tag receives the message and then responds with its identification and any other information that it contains. This may be only a unique tag serial number, or may be product-related information such as a stock number, lot or batch number, production date, or other specific information.

An RFID chip that is compared in size to a grain of rice. The chip is embedded into a label and then attached to a product for identification.

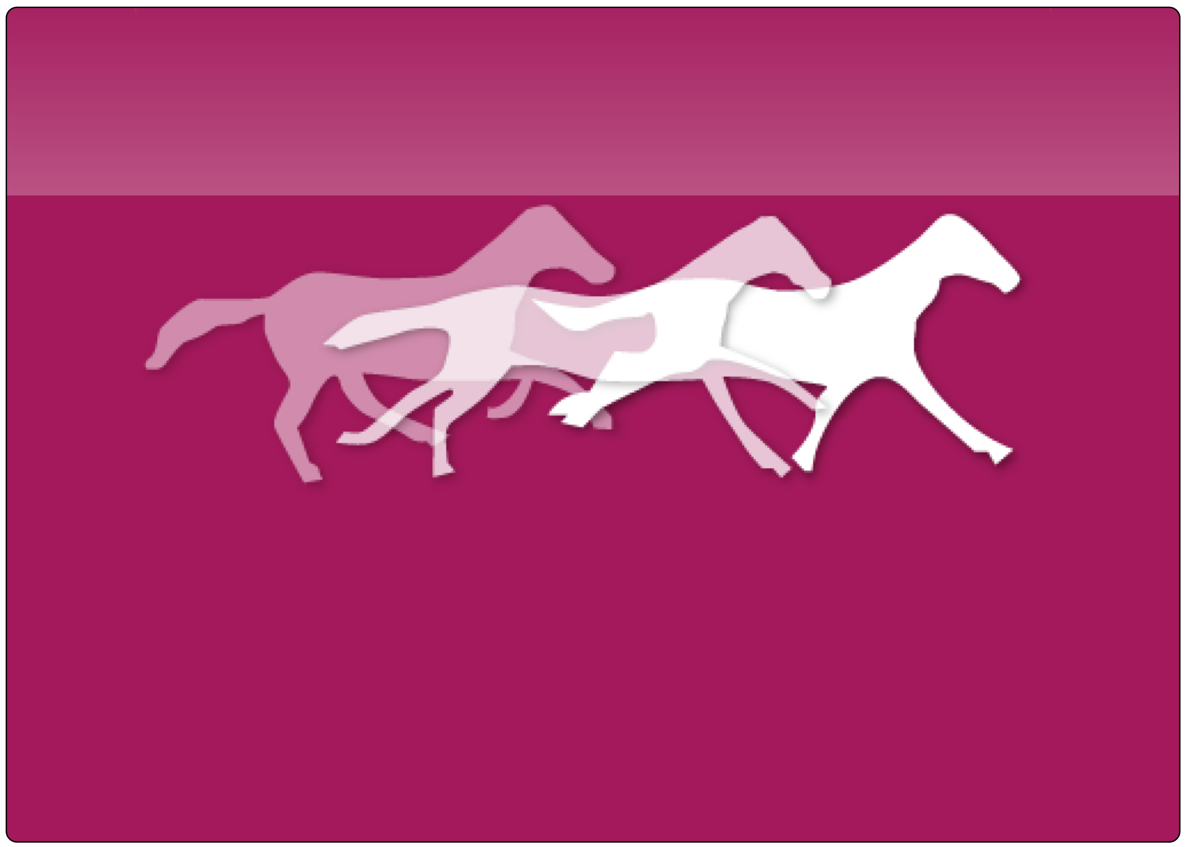
RFID Readers

RFID readers can be classified by the type of tag they read. A Passive system has a passive reader which only receives radio signals from tags that are periodically active. The reception range is up to 2,000 feet, allowing flexibility in applications such as theft protection and location of product. An Active system has an active reader, which transmits interrogator signals and also receives authentication replies from passive tags which are read periodically. An Active Reader system uses active tags initialized with an interrogator signal from the active reader, which allows the tag to be dormant until requested to activate. A variation of this system could also use a Battery-Assisted tag which acts like a passive tag, but has a small battery to power the tag's return reporting signal.

Fixed readers are set up to create a specific zone to actively read the tags, which can be tightly controlled. This allows a highly-defined reading area for when tags go in and out of the controlled zone. Mobile readers may be hand-held or mounted on carts or vehicles.

RFID is used in a small number of distribution centers to control product where extreme accuracy and accountability is needed. Health care, pharmacy and high value-items are a good application for RFID. Personal identification in keys and badges is a more common application for RFID in most distribution centers for area restrictions or access and security. They are very versatile and replace barcodes or magnetic strips. The biggest negative for general RFID use is the cost. The tags cost between $.50 and $25 each, making it difficult to compete with the inexpensive use of barcode labels. RFID readers are also substantially more expensive. As their use increases and technology improves, they may become more widely used.

Interactive 10.4 RFID Readers



Tap to view images of RFID readers.

Section 5

Piezoelectric

Vibration sensor using piezoelectric technology

A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure, acceleration, strain or force by producing a small electrical charge. Piezo refers to the production of small electrical signal as a result of compression or force on a material that is capable of giving off such signals. This process is normally used to weigh boxes or product. As the box or product is in place above the scale the compression on the piezoelectric material will give off an electrical signal based on the weight or stress on the material, which is then converted to a conventional weight. An advantage is that the scale doesn’t move or deflect very far during the process so making the scale part of the conveyor or movement system is easier.

Vibration sensors use the same technology and can be used to monitor possible failures or deterioration of equipment by converting the vibration into an electrical signal produced by a Piezo electric sensor input that can be monitored by a maintenance system. This process can inform distribution center technicians that maintenance is required.

Section 6

Troubleshooting

Interactive 10.5 Troubleshooting

Tap to view troubleshooting images.

Troubleshooting techniques for sensors requires the ability to isolate which component has failed. The use of a DVOM will allow the technician to isolate the cause of failure by determining if the sensor has input power, if required, and is producing output signals that are normal. Normally if the input is good but the output is not then a quick replacement of the sensor may save a lot of time and control the loss of productivity. If this is happening, then alignment of the optics or placement evaluation of the magnetic sensors will be required. If these conditions are normal, then establishing conduction of electricity in the wiring will follow. This level of repair will require a diagnosis of the system with a scan tool that can monitor the parameters. The key to this is, once again, to isolate the failure to a hard part or to a software control issue.

Chapter 11

Heating, Ventilation and Air Conditioning

Climate control is a critical need for many distribution centers. This chapter explains the theory behind refrigeration and heating and explains how this technology is used in today's warehouses.

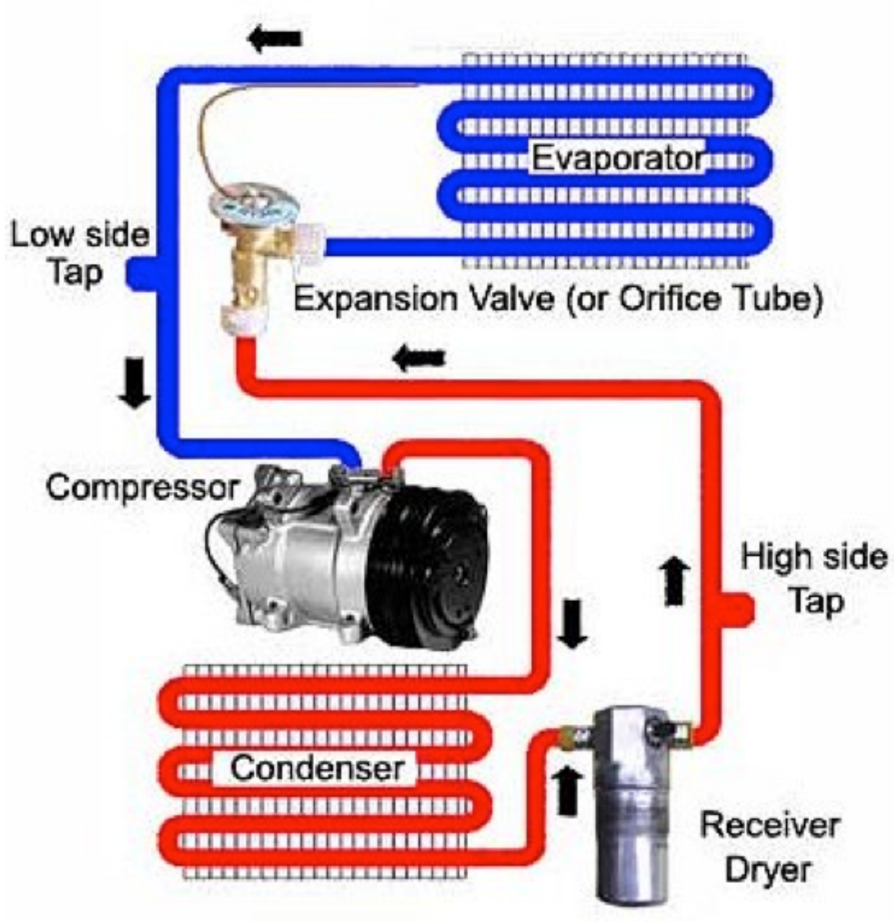
Section 1

Overview

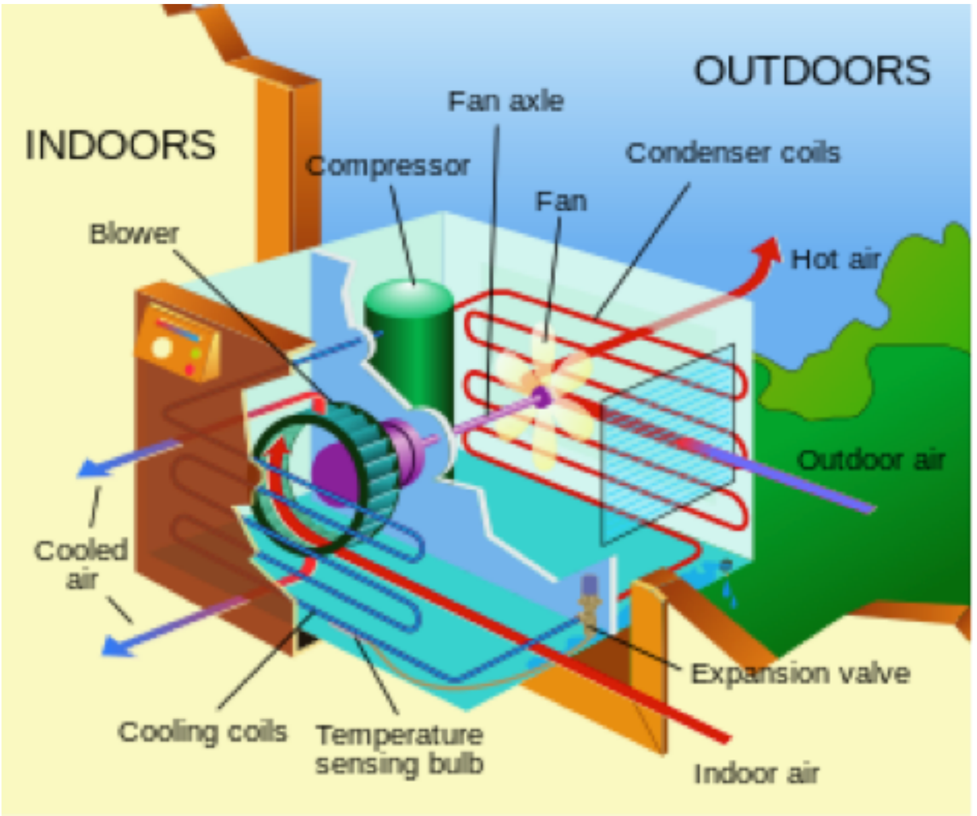
Heating, ventilation and air conditioning is the process of altering the properties of air (primarily temperature and humidity) to conditions that are more comfortable for people or the needs of products. More generally, air conditioning can refer to any form of technological cooling, heating, ventilation, or disinfection that modifies the condition of air.

An air conditioner is a major home appliance, system, or mechanism designed to change the air temperature and humidity within an area. The system is used for cooling and sometimes heating depending on the air properties required at a given time. The cooling is typically done using a simple refrigeration cycle, but sometimes evaporation is used, commonly for comfort cooling in buildings and motor vehicles. In construction, a complete system of heating, ventilation and air conditioning is referred to as HVAC.

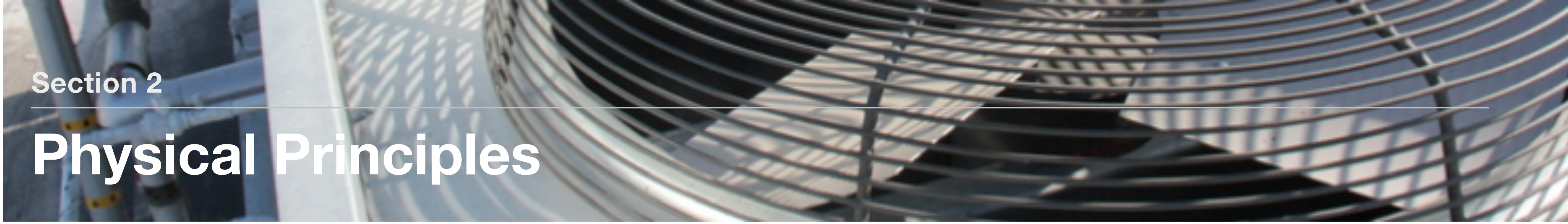
Air conditioning can also be provided by a process which uses pumps to circulate a coolant (typically water or a glycol mix) from a cold source (exterior system) to an entire building. These systems can create cold or hot liquids that circulate throughout the building and can have heat exchangers at different locations. These systems can have very high efficiencies and simplify the operation, making it more efficient. Large facilities like distribution centers or other large buildings use these systems.



Typical air conditioning system showing the components

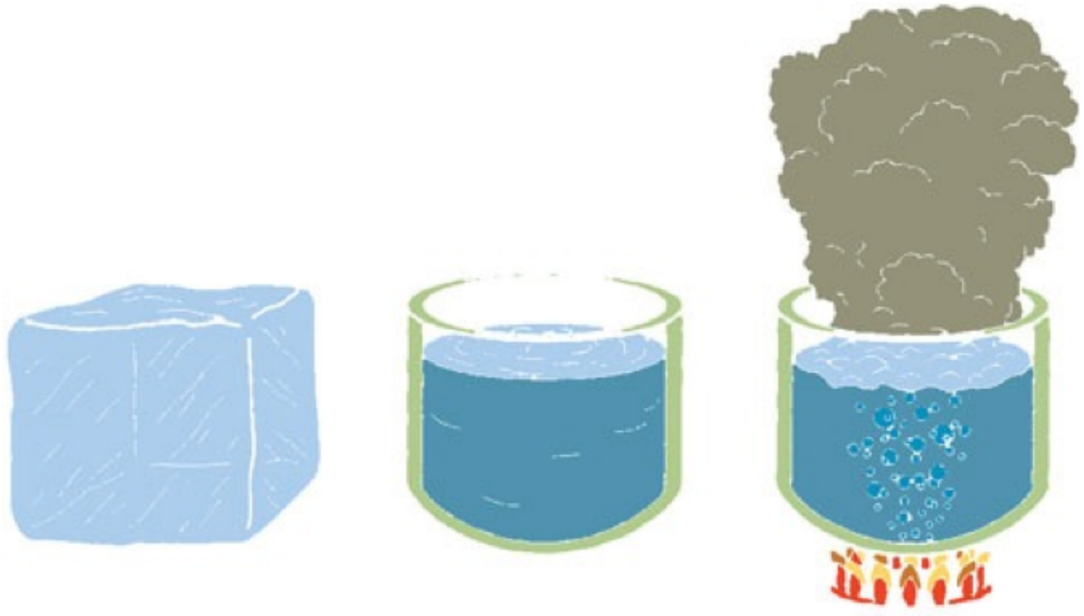


Window air conditioning unit



Change of State

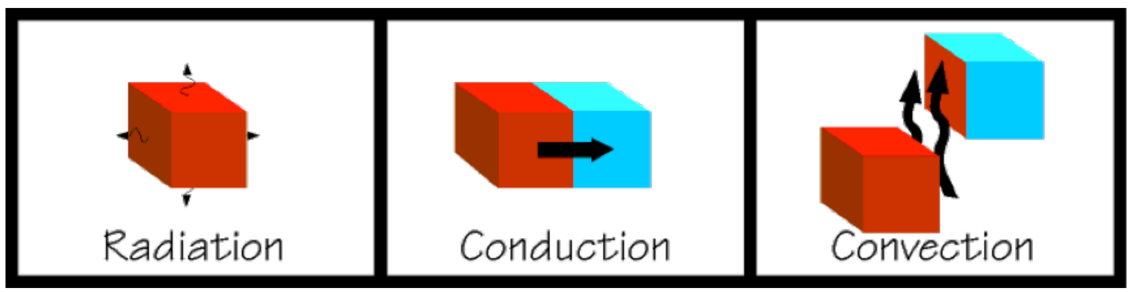
On earth, matter is found in one of three different phases or states: solid, liquid, or vapor (gas). The state depends upon the nature of the substance, the temperature, and the pressure or force exerted on it. Water occurs naturally in all three states: solid ice, liquid water, and water vapor, depending upon the temperature and pressure. Pure water below 32 degrees is a solid, 32 degrees to 212 degrees (at sea level pressure) is a liquid and 212 degrees or above (at sea level pressure) is a gas.



Three states of matter

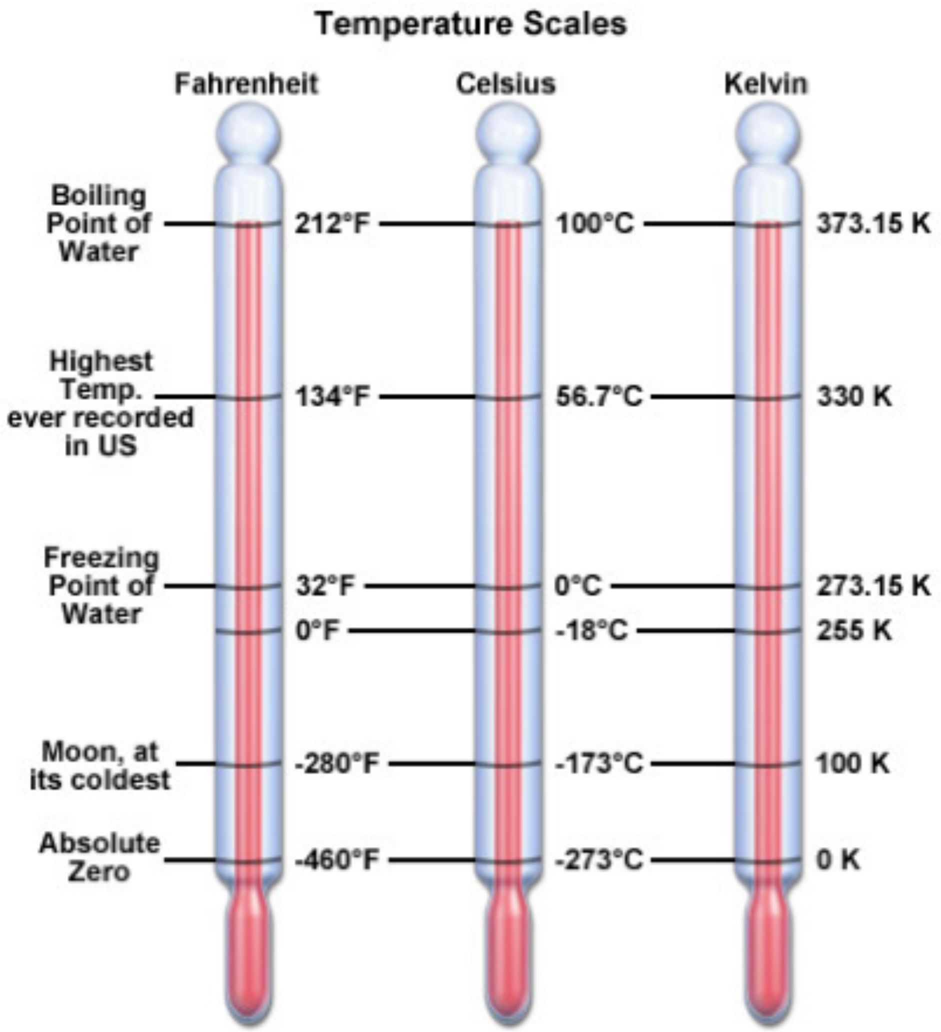
Heat and Temperature

Heat transfers by three processes: Radiation, Conduction and Convection. Heat will flow from the hot object into the cold object which is called conduction. When heat is transferred by a substance in the gaseous state, the process is called convection. When an object is cooling by removing heat to the surrounding area it is called radiating heat.



Heat transfer processes

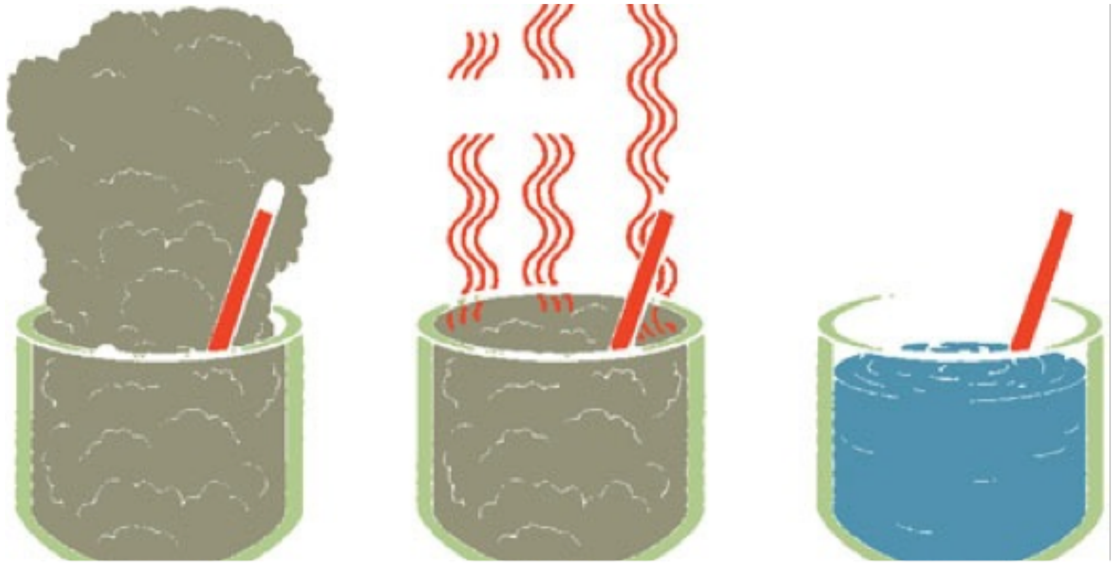
Molecules in a substance tend to vibrate rapidly in all directions, and this disorganized energy is called heat. The intensity of vibration depends on how much kinetic energy, or energy of motion, the atom or molecule contains. We measure the level of this energy as temperature. Heat and temperature are not the same. Temperature is measured in degrees. Heat is measured in calories (c). The calorie is a metric unit that expresses the amount of heat needed to raise the temperature of one gram of water one degree Celsius. Heat is also measured in British Thermal Units (BTU). One BTU is the heat required to raise the temperature of one pound of water 1°F at sea level. One BTU equals 252 calories.



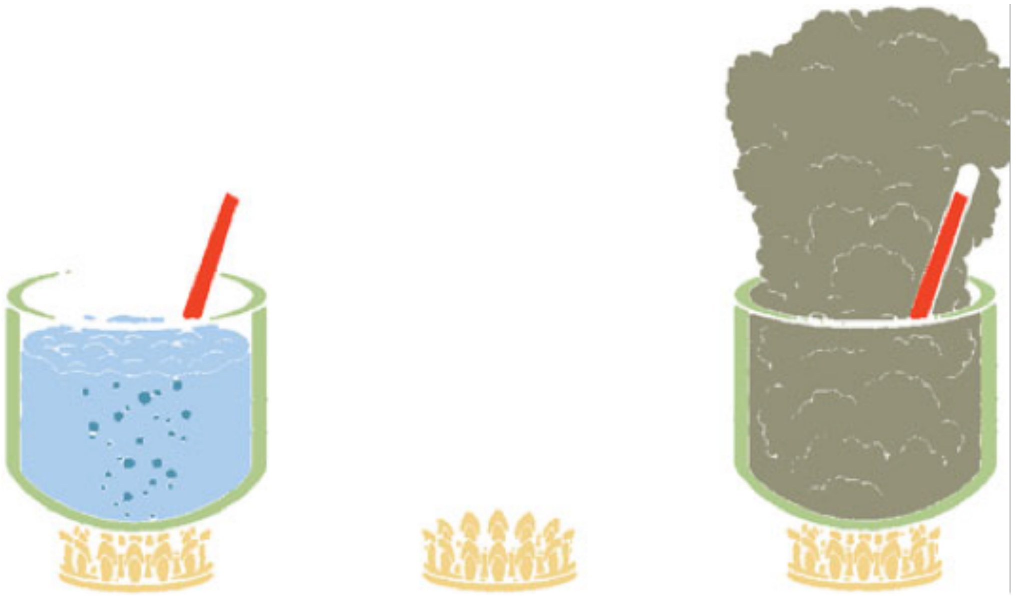
Temperature classification scales used for comparison

Latent Heat

Latent heat is heat that is needed to change a substance from one state to another. Imagine that a solid or a liquid is being heated on a stove. When the solid reaches its melting point, or the liquid reaches its boiling point, their temperatures stop rising. The solid begins to melt, and the liquid begins to boil. This occurs without any change in temperature, even though heat is still being poured in from the burner. This giving off and absorbing of heat energy is heat transfer that makes the HVAC system efficient. It is the change of state that allows the systems to work by absorbing large amounts of heart energy.



Heat is given off when converting a gas to a liquid, but the temperature can be the same.



Heat is absorbed to change the state from a liquid to a gas, but the temperature is the same.

Temperature/Pressure Relationship

The pressure on a substance will change the temperature required to change its state. As the pressure increases, the temperature required to change from a liquid to a gas (evaporation) increases. As the pressure decreases, less heat and a drop in temperature is needed to change from a gas to a liquid (condensation). During evaporation heat is absorbed and during condensation heat is given off. This pressure theory allows for controlling temperature in HVAC components by controlling the pressures, which then becomes the basic concept of temperature control in a given environment (room AC, freezer, and refrigerator). Refrigerant in an AC system is the heat transfer element and the change of state of the refrigerant absorbs and expels large volumes of heat energy. This is accomplished by the pressure on the refrigerant being controlled by the pressures within the system.

Refrigeration systems control the pressures within to control the temperatures at given places within the system. The temperature must be higher to give off heat to the surrounding air.

Temp °F	Pres R134	Pres R12	Temp °F	Pres R134	Pres R12	Temp °F	Pres R134	Pres R12
-60	21.6	19.0	29	25.3	27.7	70	71.2	70.2
-55	20.1	17.3	30	26.1	28.5	75	78.8	77.0
-50	18.7	15.4	31	26.9	29.3	80	86.8	84.2
-45	16.9	13.3	32	27.8	30.1	85	95.4	91.8
-40	14.8	11.0	33	28.6	30.9	90	104.0	99.8
-35	12.5	8.4	34	29.5	31.7	95	114.0	108.3
-30	9.8	5.5	35	30.4	32.6	100	124.0	117.2
-25	6.9	2.3	36	31.3	33.4	105	135.0	126.6
-20	3.7	0.6	37	32.2	34.3	110	147.0	136.4
-15	0.1	2.4	38	33.1	35.2	115	159.0	146.8
-10	1.9	4.5	39	34.1	36.1	120	171.0	157.7
-5	4.1	6.7	40	35.0	37.0	125	185.0	168.6
0	6.5	9.2	41	36.0	37.9	130	199.0	181.0
5	9.1	11.8	42	37.0	38.8	135	214.0	193.5
10	11.9	14.6	43	38.0	39.7	140	229.0	206.6
15	15.0	17.7	44	39.0	40.7	145	246.0	220.3
20	18.4	21.0	45	40.1	41.7	150	263.0	234.6
21	19.2	21.7	46	41.1	42.6	155	281.0	249.5
22	19.9	22.4	47	42.2	43.6	160	299.3	265.1
23	20.6	23.2	48	43.2	44.6	170	340.8	297.3
24	21.3	23.9	49	44.3	45.7	180	385.6	333.2
25	22.1	24.6	50	45.4	46.7	190	434.8	372.2
26	22.9	25.4	55	51.3	52.0	200	488.9	414.3
27	23.7	26.1	60	57.5	57.7			
28	24.5	26.9	65	64.1	63.8			
	inch Hg. Figures are Vacuum							

Temperature/Pressure chart for refrigerant

Humidity

Humidity plays a major role in personal comfort and efficiency of an air conditioner or refrigeration system. Humidity depends upon the amount of water vapor present in a volume of air and the temperature of that air mass. The amount of water vapor in the air tends to be higher near lakes or the ocean because more water is available to evaporate from their surfaces. In desert areas with little open water, the amount of water vapor in the air tends to be low. Relative humidity is the percentage of moisture is present in the air compared to how much moisture the air is capable of holding at that temperature. Humidity has an influence on heat transfer because energy is used to condense the humidity while not changing the temperature of the treated or cooled air, so the greater the humidity the less efficient an air conditioning system will be.

	Air Temperature (Degrees F)										
Relative Humidity	70	75	80	85	90	95	100	105	110	115	120
0%	64	69	73	78	83	87	91	95	99	103	107
10%	65	70	75	80	85	90	95	100	105	111	116
20%	66	72	77	82	87	93	99	105	112	120	130
30%	67	73	78	84	90	96	104	113	123	135	148
40%	68	74	79	86	93	101	110	123	137	151	
50%	69	75	81	88	96	107	120	135	150		
60%	70	76	82	90	100	114	132	149			
70%	70	77	85	93	106	124	144				
80%	71	78	86	97	113	136	157				
90%	71	79	88	102	122	150	170				
100%	72	80	91	108	133	166					

Humidity chart for comfort

Section 3

Air Distribution

Air distribution is normally accomplished when ducts are used for heating, ventilation, and air conditioning (HVAC) to deliver and remove air. Air flows include supply air, return air, and exhaust air. Ducts also deliver, most commonly as part of the supply air, ventilation or outside air. As such, air ducts are one method of ensuring acceptable indoor air quality as well as thermal comfort.

A duct system is often called ductwork. Planning, sizing, optimizing, detailing, and finding the pressure losses through a duct system, is called duct design.

Supply and Return Air

Most spaces that use climate control will be required to deliver supply air and return air. Supply air is delivered to a space after it has been cooled or heated by the system. The same amount or volume of air must be removed from the space to be returned to the system for retreatment and create a flow of air to continually control the temperature of the space. Most systems are of this recirculating air type. Exceptions to recirculating air are in areas where germs or bacteria are a concern such as hospital rooms and some food processing and storage facilities.

Interactive 11.1 Supply and Return Air Images

Tap to view supply and return air images.

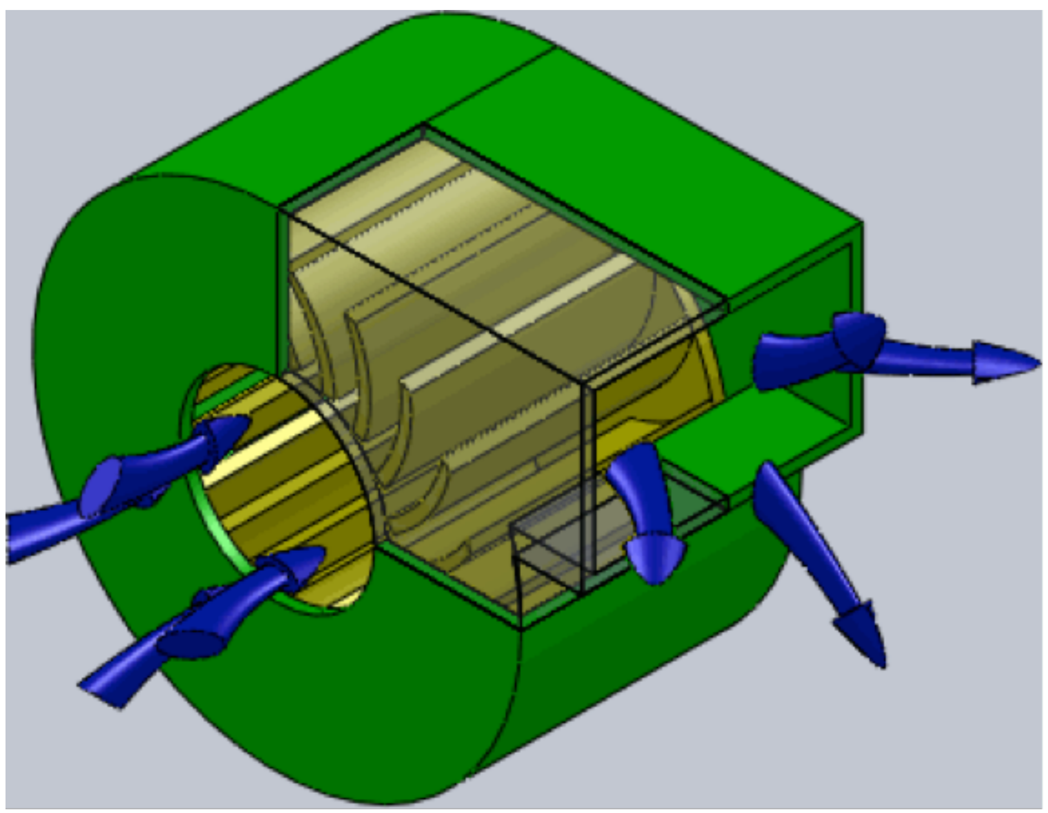
Blower motors

Electric blower motors are driven by 120 or 220 VAC, single or three-phase electricity, depending on the power rating. Motors under two horsepower or 1,500 watts will normally be driven by 120 VAC, with larger motors being driven by 220 VAC or higher. The motors are controlled by the system and may be of multiple or variable speed dependent on the application. The motor in operation with the fan will create pressurized supply air and suction side return air to complete the air flow through the controlled space.

Blower motor

Fans

Most air delivery fans to move treated air (evaporator fans) are of the squirrel cage design because they are very efficient and quiet. The size of the fan will be determined by the amount of air to be moved and its capacity will be rated in cubic feet per minute (CFPM) of air flow. Large spaces with high demands can have fans in excess of five feet in diameter, but most are about 18 to 24 inches in diameter. External heat dissipation fans (condenser fans) are normally of the blade design since noise is normally not a concern and vertical air flow is efficient.



Operation of a squirrel cage fan

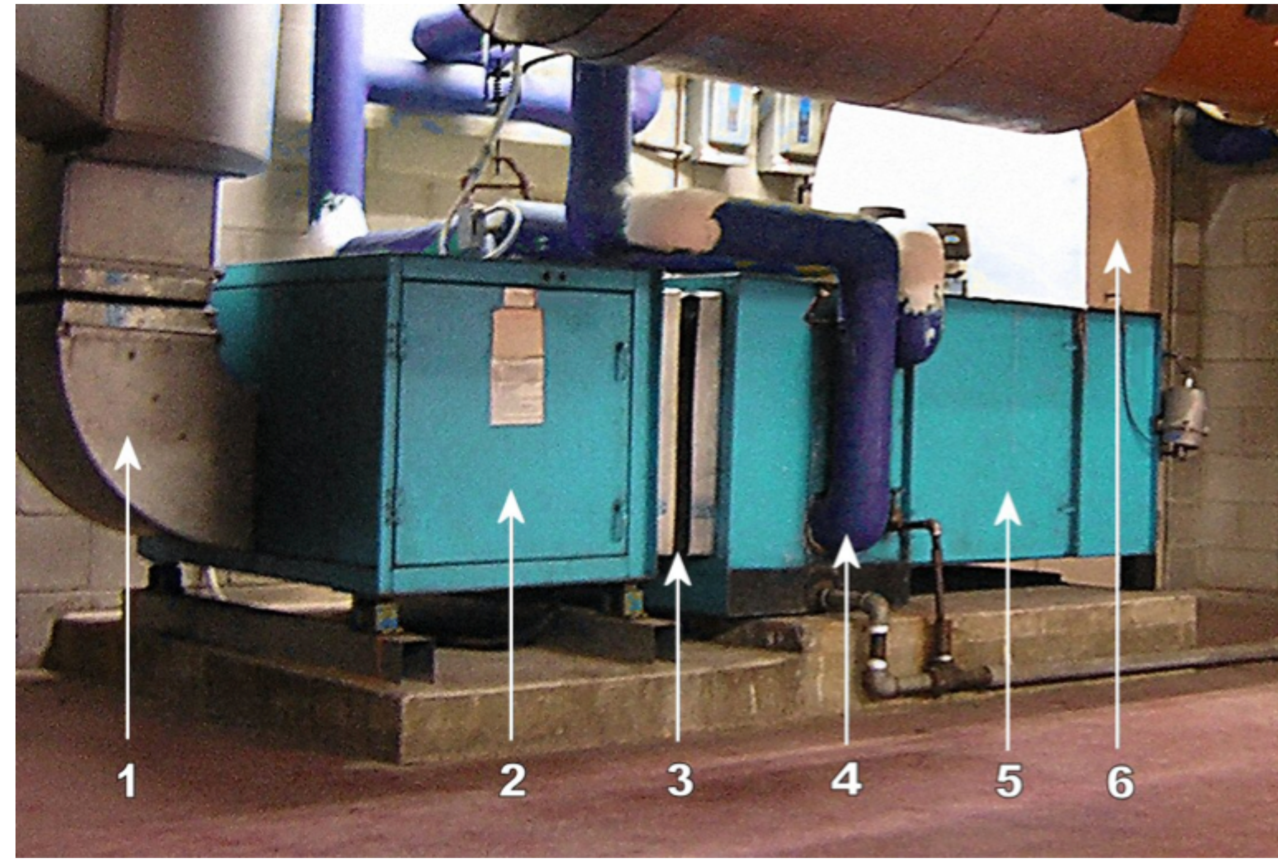
Interactive 11.2 Fan Images

Tap to view images of fans

Air Handlers

An air handler, or air handling unit (often abbreviated to AHU), is a device used to condition and circulate air as part of a heating, ventilating, and air-conditioning (HVAC) system. An air handler is usually a large metal box containing a blower, heating or cooling elements, filter racks or chambers, sound attenuators, and dampers. Air handlers usually connect to a duct work ventilation system that distributes the conditioned air through the building and returns it to the AHU. Sometimes AHUs discharge (supply) and admit (return) air directly to and from the space served without ductwork. Small air handlers, for local use, are called terminal units, and may only include an air filter, coil, and blower; these simple terminal units are called blower coils or fan coil units. A larger air handler that conditions 100% outside air, and no recirculated air, is known as a makeup air unit (MAU). An air handler designed for outdoor use, typically on roofs, is known as a packaged unit (PU) or rooftop unit (RTU).

Roof mounted package AC/Heating unit



Commercial Air Handler Parts

1-Supply duct

2-Fan compartment

3-Flex connector

4-Heating and cooling coil

5-Filter area

6-Return and fresh air duct

Filters

All air that is recirculated in the HVAC system or is brought into the system from outside must be filtered. The filters are paper or fiberglass replacement components that filter dust and dirt from the air before it is delivered to the conditioned space.

Paper (left) and fiberglass (right) element filters

Filter changing on roof units

Section 4

Heating

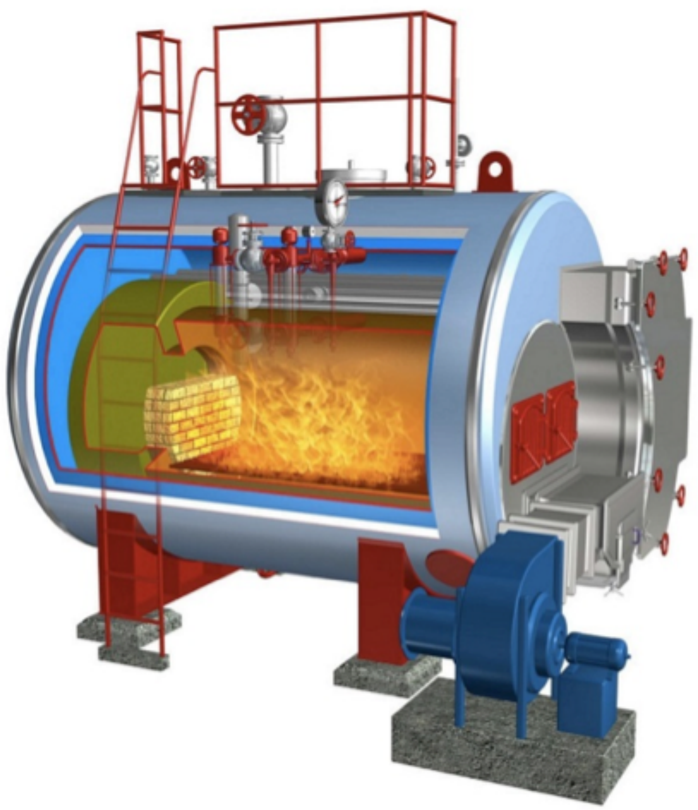
A heating system is a mechanism for maintaining temperatures at an acceptable level, by using thermal energy within a home, office, or other facility. Most often, heating is part of an HVAC system. A heating system may be centralized or distributed.

Heated Water System

A hot water or steam heating system uses heated water produced in a boiler or heated tank to circulate throughout a facility to heat spaces. A sealed hot water system provides a form of central heating in which the water used for heating usually circulates independently of the building's normal water supply.

An expansion tank contains compressed gas, separated from the sealed-system water by a diaphragm to allow expansion. This allows for normal pressure changes in the system. A safety valve allows water to escape from the system when pressure becomes too high, and a valve can open to replenish water from the normal water supply if the pressure drops too low. Sealed systems offer an alternative to open-vent air systems, in which steam can escape from the system, and gets replaced from the building's water supply via a feed and central storage system. The circulation of this heated water is pumped through insulated pipes throughout the facility and used with air flow devices to heat any space.

Expansion tank



Centralized hot water or steam boiler

Fueled Heating

The use of natural gas or oil has become the standard for most heating today. It can be used as a heater of water to transfer heat or can be used directly to heat air which is distributed to the space. Filters and blowers are used to direct and clean the air before it enters the controlled space. The use of different energy sources is dependent on the local area and the supply of energy sources.

Interactive 11.3 Fueled Heating Images

Tap to view fueled heating images

Electric Heating

Electric heating or resistance heating converts electricity directly to heat. Electric heat is often more expensive than heat produced by combustion appliances like natural gas, propane, and oil. Electric resistance heat can be provided by baseboard heaters, space heaters, radiant heaters, furnaces, wall heaters, or thermal storage systems.

Electric heaters are usually part of a fan coil which is part of a central air conditioner. They circulate heat by blowing air across the heating element, which is supplied to the furnace through return air ducts. Blowers in electric furnaces move air over one to five resistance coils or elements which are usually rated at five kilowatts. The heating elements activate one at a time to avoid overloading the electrical system. Overheating is prevented by a safety switch called a limit controller or limit switch. This limit controller may shut the furnace off if the blower fails or if something is blocking the air flow. The heated air is then sent back through the home through supply ducts.

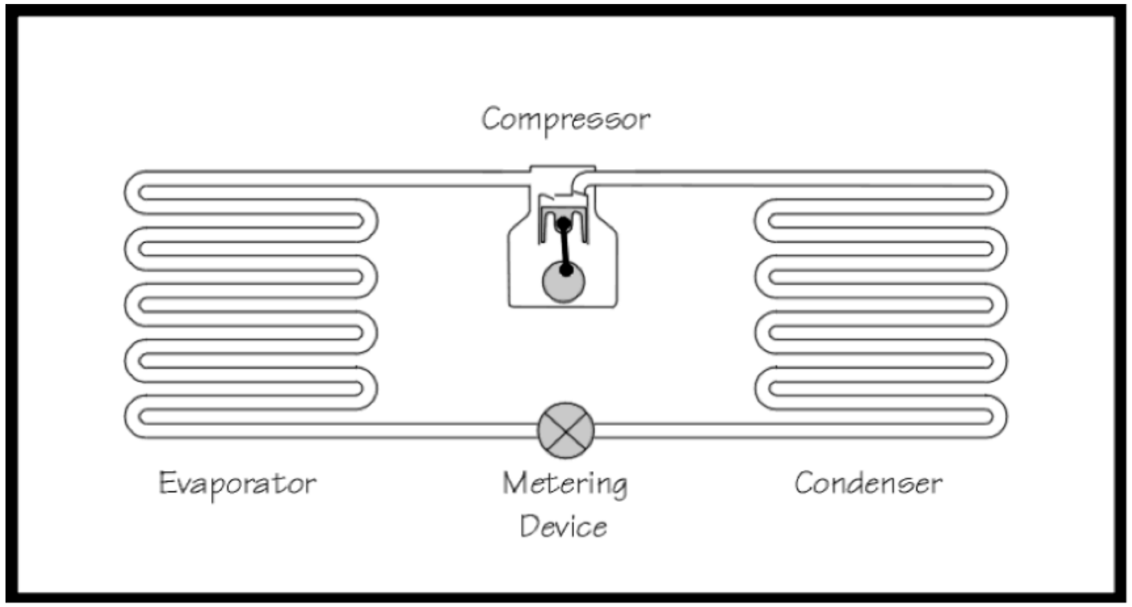
In larger commercial applications, central heating is provided through an air handler.

Electric space heater

Section 5

Refrigeration Cycle

The four main components in a mechanical refrigeration system are the compressor, condenser, metering device and evaporator. Any components beyond these basic four are called accessories. The compressor is a vapor compression pump, which uses pistons or some other method to compress the refrigerant gas and send it to the condenser. The condenser is a heat exchanger, which removes heat from the hot compressed gas and allows it to condense into a liquid as it gives off heat energy. The liquid refrigerant at slightly over outside air temperature is then routed to the metering device. This device restricts the flow by forcing the refrigerant to go through a small hole or control valve, which causes a pressure drop. As the pressure drops to a liquid, it lowers the boiling point and makes it easier to evaporate as it absorbs heat energy. When a liquid evaporates it will absorb heat from the surrounding area. This component where the evaporation takes place is called the evaporator. The refrigerant is then routed back to the compressor to complete the cycle. The refrigerant is used over and over again, absorbing heat from one area and relocating it to another. The definition of refrigeration is to remove and relocate heat.



Air Conditioning schematic of the four major parts of the refrigeration cycle

Compressors

Air conditioning compressors have two basic functions: to create pressure differences to recirculate refrigerant throughout the system and to increase and decrease pressures to allow for a flow of heat energy to a lower temperature to transfer heat. Four types of compressors are used: piston or reciprocating, scroll or centrifugal, vane and screw. Each type of compressor has advantages and the type used is dependent on volume and the size of the system. Compressors create high side pressures that heat the refrigerant above the outside temperature to make sure heat dissipation exists in the condenser and refrigerant changes from a gas to a liquid. The compressor also produces suction on the low side of the system at a much lower pressure, which allows the evaporator to absorb heat energy, changing the refrigerant from a liquid to a gas, which is used to cool the desired space.

Interactive 11.4 Compressor Images

Tap to view compressor images.

Components

Condensers

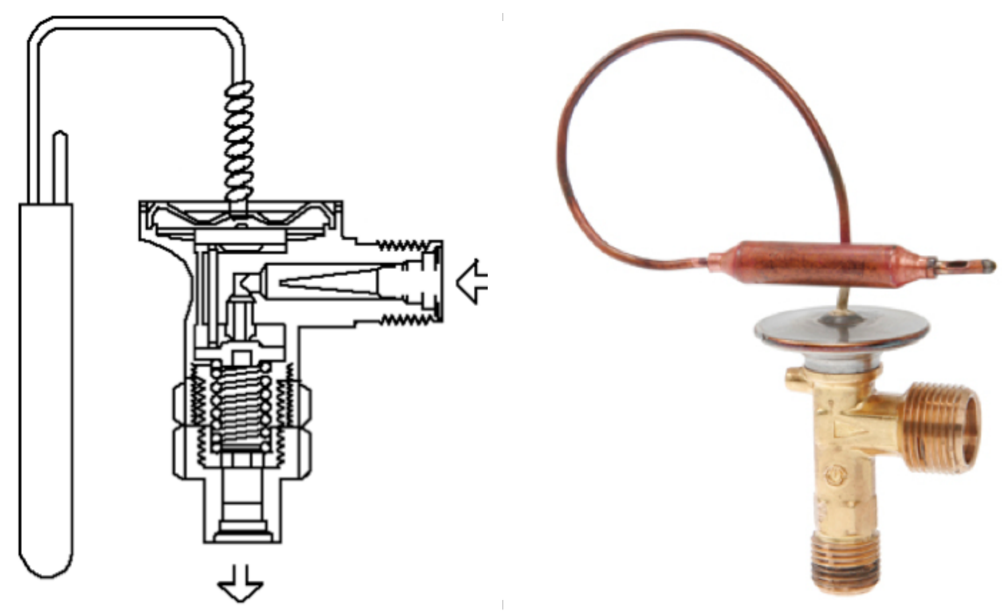
The condenser is a heat exchanger that gives off heat energy to the outside air and condenses hot gaseous refrigerant to a lower temperature liquid. It utilizes the principles of heat transfer to move heat from a high temperature to a lower temperature. The purpose is to dissipate heat so that the refrigerant gas can condense back into a liquid in preparation for a return trip to the evaporator. If the hot compressed gas is 135 °F and the outside air being sucked through the condenser fins is at 90 °F, heat will flow from high to low so heat is dissipated. Heat will have been removed from one place and relocated to another as the definition of refrigeration describes. As long as the compressor is running it will impose a force on the refrigerant to continue circulating around the loop and continue removing heat from the condenser.

Condensers with fans

Expansion Devices

The expansion valve removes pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator.

The high-pressure liquid refrigerant entering the expansion valve is quite warm. This may be verified by feeling the liquid line at its connection to the expansion valve. The liquid refrigerant leaving the expansion valve is quite cold. The orifice within the valve does not remove heat, but only reduces pressure. Heat molecules contained in the liquid refrigerant are thus allowed to spread as the refrigerant moves out of the orifice. Under a greatly reduced pressure the liquid refrigerant is at its coldest as it leaves the expansion valve and enters the evaporator.



Schematic and Pictorial view of an expansion valve

Evaporators

An evaporator is a heat transfer device that transfers heat from the recirculating air to the system refrigerant, lowering the air temperature. When the liquid refrigerant reaches the evaporator, its pressure has been reduced, dissipating its heat content and making it much cooler than the recirculating fan air flowing through it. This causes the refrigerant to absorb heat from the warm air and reach its low boiling point rapidly about (34 degrees). The refrigerant then vaporizes, absorbing the maximum amount of heat. This transfer of heat cools the space by removing the heat energy from the delivered air.

This heat is then carried by the refrigerant from the evaporator as a low-pressure gas through a hose or hard line to the low side of the compressor, where the whole refrigeration cycle is constantly repeated.

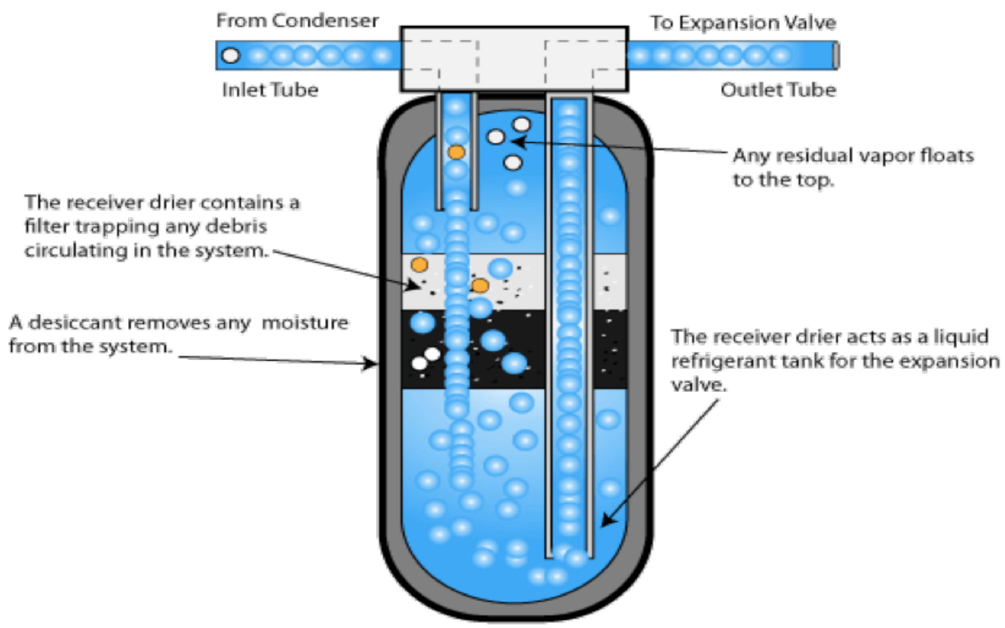
Evaporators for a commercial refrigerator

Receiver/Drier

The receiver/drier is a liquid storage tank for the refrigerant flowing from the condenser. This insures that the necessary liquid refrigerant is consistently supplied to the expansion valve under all operating conditions. At the most demanding times of the day, the opening expansion valve relies on this storage tank to provide the evaporator core its supply of liquid refrigerant.

The receiver drier also contains a desiccant capable of absorbing moisture from the refrigerant, and a filter that collects any unwanted debris in the system. Any time this desiccant is exposed to the atmosphere, it will absorb moisture and humidity from the air, and it must be replaced, so during service never leave a system open. Also, any time the compressor is replaced, the receiver drier must be replaced as well. This is because any debris in the system from the compressor is trapped in the filter located inside the drier.

Refrigerant from the condenser enters the receiver drier through the inlet port. The vapor rises to the top while the heavier liquid refrigerant drops to the bottom. It passes through the filter and desiccant and is then stored in the bottom of the tank. As the expansion valve opens and closes, the liquid refrigerant is drawn into the outlet port tube of the receiver drier, through the high pressure line, and into the expansion valve.



Receiver/drier diagram

Receiver/Drier in use

Chillers

A chiller is a machine that removes heat from a liquid via the refrigeration cycle. They work opposite of a heated water system used for heating. This liquid can then be circulated through insulated pipes throughout the facility to heat exchangers to cool air or equipment as required. In air conditioning systems, chilled water is typically distributed to heat exchangers, or coils, in air handling units or other types of terminal devices which cool the air in their respective space(s). The water is then recirculated back to the chiller to be cooled again. These cooling coils transfer sensible heat and latent heat from the air to the chilled water, thus cooling and usually dehumidifying the air stream.

Large volume chiller to distribute cold water

Section 6

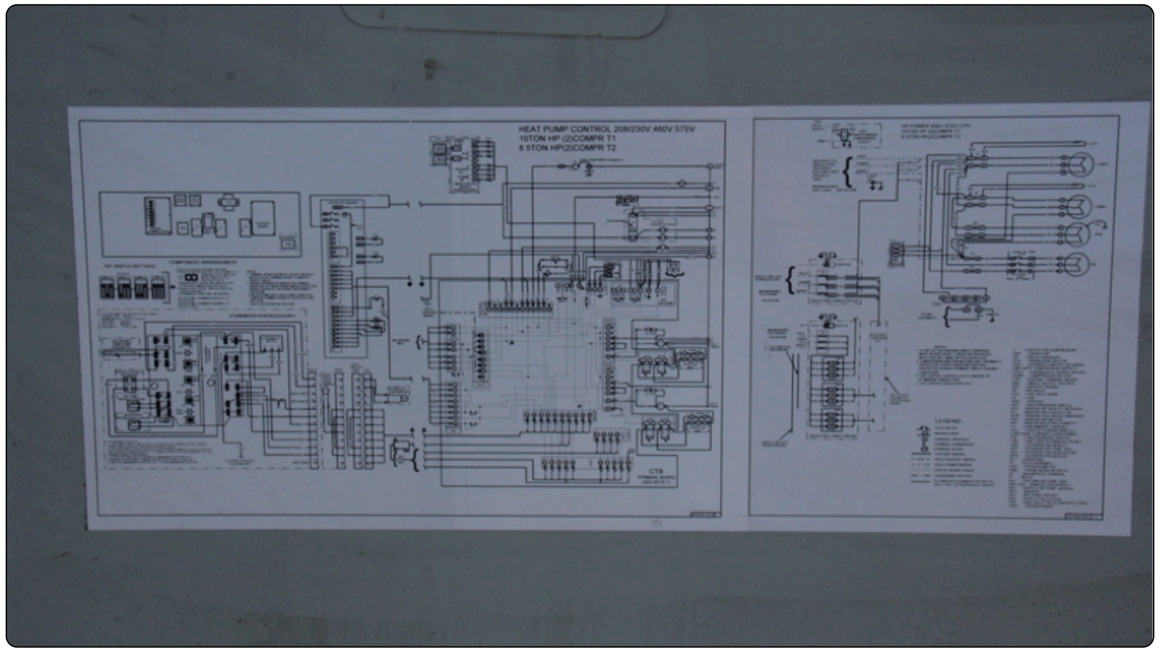
Controls

Controls for HVAC systems include electric/electronic, pneumatic, temperature sensing by pressure, space temperature sensing, flow control for cooling and heating and pressure sensors throughout the system. The design of the system will provide control for safety, temperatures and for self-diagnosis.

AC System Controls Schematic

Schematic diagrams of the control circuits are the roadmaps for technicians to evaluate the operation and troubleshoot any failures or operational concerns. They are developed by the supplier or installer, included with the equipment when installed and available on the equipment for easy access and in a central information data base of paper copies or computer memory.

Interactive 11.5 Controls Images



Tap to view images of controls.

AC System Controls

Thermostats

Thermostats are devices that maintain a selected temperature in the controlled space. They control the HVAC system by controlling the correct pressures within the refrigeration system, air flow in the distribution system and air temperatures.

A programmable thermostat is a thermostat, which is designed to adjust the temperature according to a series of programmed settings that take effect at different times of the day. Programmable thermostats may also be called setback thermostats or clock thermostats.

Heating and cooling losses from a building (or any other container) become greater as the difference in temperature increases. A programmable thermostat allows reduction of these losses by allowing the temperature difference to be reduced at times when the reduced amount of heating or cooling would not be objectionable.

Thermostatic control panel

Pressure Switches

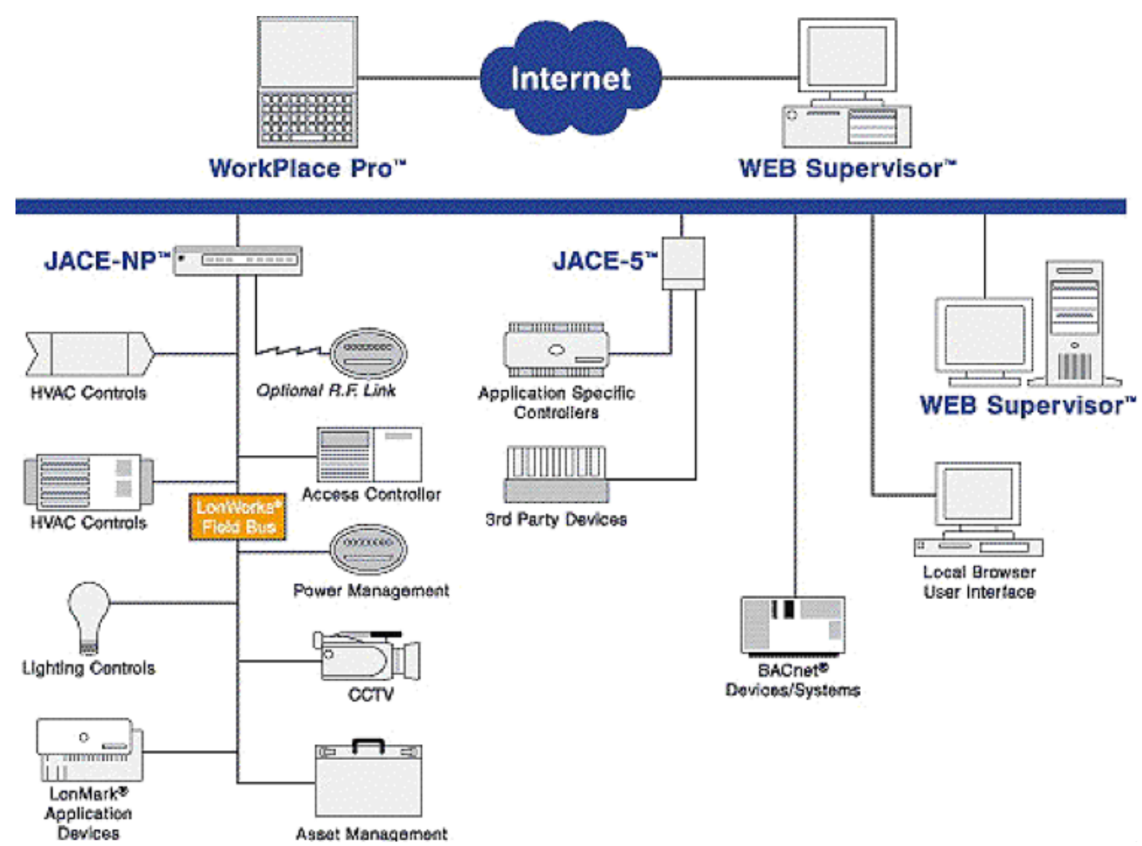
Pressure switches control temperatures in the evaporator by controlling the pressures within the system and the safeties installed on units to protect the unit, compressor, and anyone working on the unit. Pressure switch values vary from unit to unit and with the type of refrigerant in the unit. Usually, there are two types of pressure switches: high pressure switches (compressors, condensers) and low pressure switches (evaporators). It is important to remember that there are multiple causes for safeties tripping. A complete diagnostic of the refrigerant side of the system is necessary to determine the cause if the safety trips. Pressures are one part of the diagnostic, but amp draw of the compressor along with electrical diagnostics may be needed.

High and low pressure switch combination

Section 7

Automation Systems

Improvements in technology and computer controls have allowed for the development of fully integrated HVAC systems that have become accurate, cost effective and energy efficient systems. The total control and feedback delivered by these systems allow for constant monitoring of the system to control temperatures and to self-diagnose to make the automated warehouse the most productive it can be. Worker comfort and product temperature and humidity control create an environment for quality distribution and worker productivity.

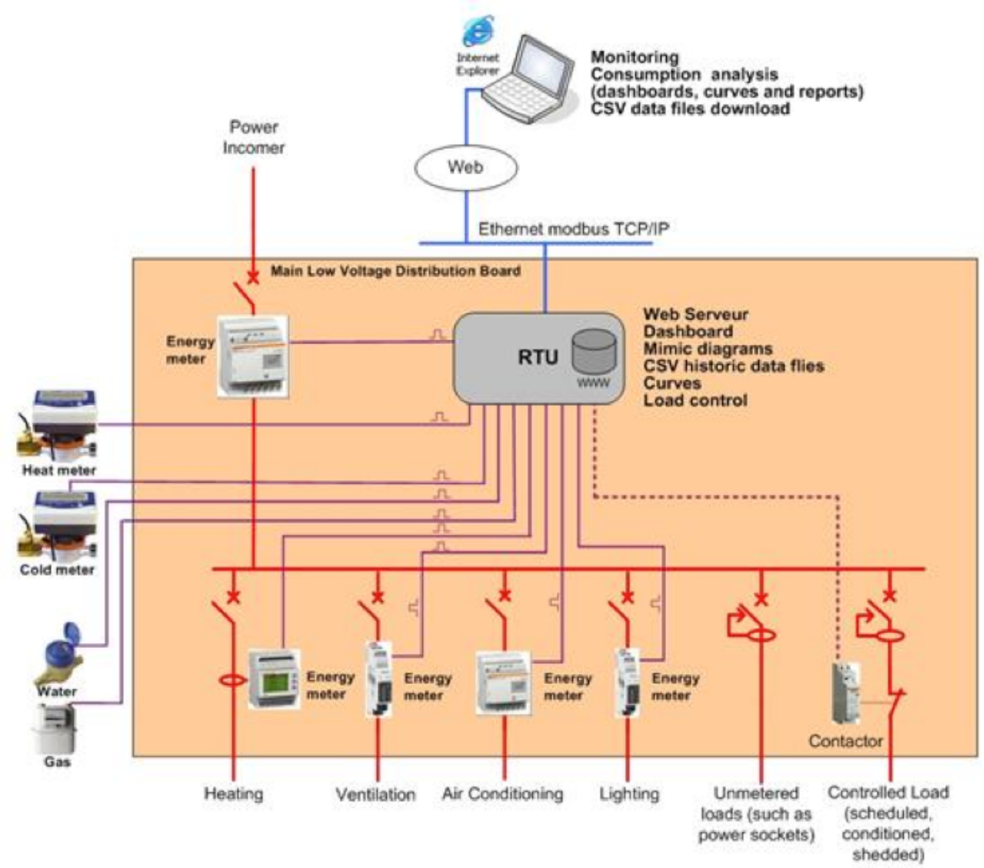


Pictorial view of an automated system

Section 8

Energy Management

HVAC is a large electrical energy consumer for a distribution center. Efficient operation of the system can be a major financial benefit to the company. Energy management includes planning and operation of all energy-related production and consumption units. Evaluating the systems and how they are operated will require a long range plan for design, purchase and operation of the HVAC system. Changes to the system and constant maintenance will help in controlling the costs and related failures.



Energy management system

Section 9

Maintenance

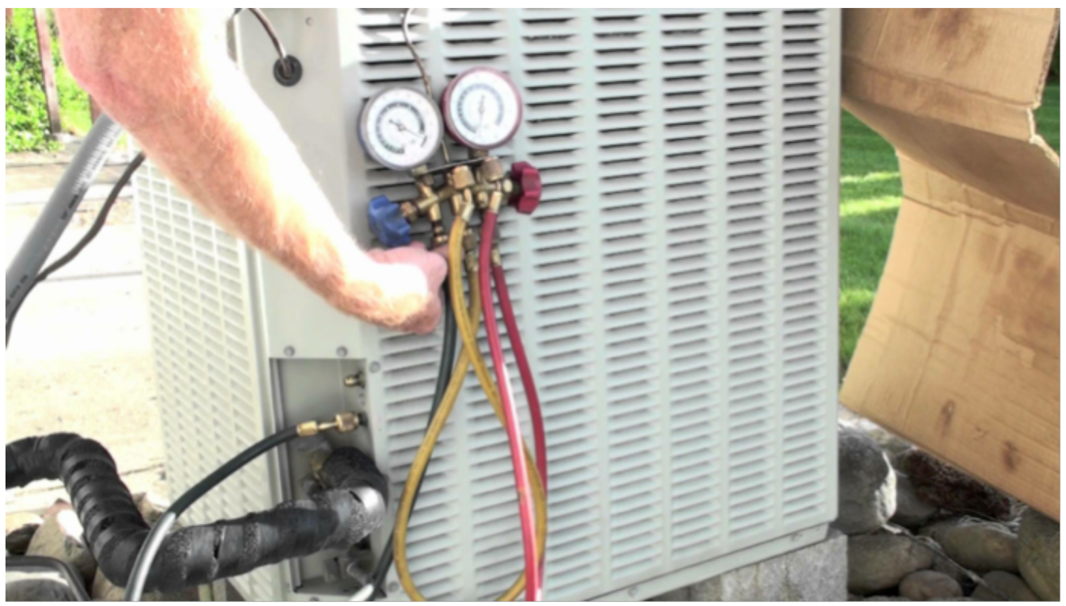
Scheduled Maintenance

The changing of filters and drive belts are the major replacement service items that are done as scheduled maintenance on an air conditioning and heating system. The cleaning of the condenser and evaporator are done periodically depending on the environment the system is operating in. Dirt and dust collecting on these items affect the efficiency of the system so cleaning needs to be done.

Changing filters

Pressure Monitoring

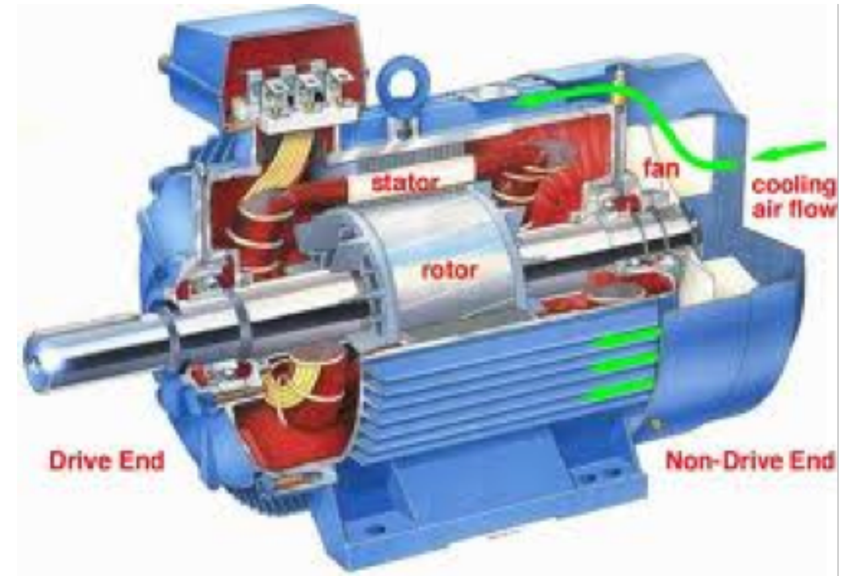
HVAC systems are trouble free and little maintenance is required when considering that most of the systems are in operation continuously. Monitoring refrigerant pressures is normally not required unless a temperature change exists, but this monitoring can expose a possible problem, such as a leak, before it becomes a failure.



Monitoring the high and low pressures

Motors and Belts

Motors to drive AC fans and compressors are reliable and require little or no maintenance. If they become noisy or fail to start, a problem exists and is a reason for repair or replacement. Supply voltage and current or electronic controls are usually the failure and not the motor.



AC motor for driving a fan or compressor

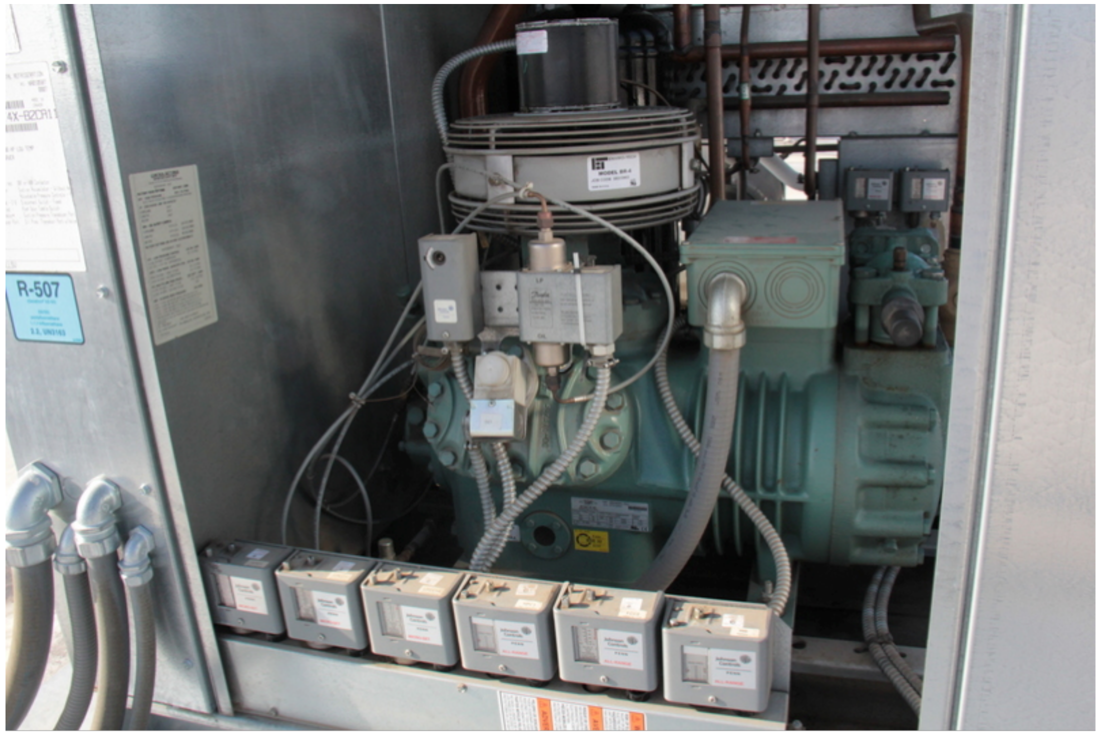
Most belt drives use standard V-belts, which have a trapezoidal cross section creating a wedging action on the pulleys. V-belts depend on friction as they are part of a wedging mechanical system.

V-belt drives can run as high as 95-98 percent efficient at the time of installation. They are manufactured in a wide variety of materials, cross sections, banded multiples, reinforcement styles, and constant and variable speed configurations. Low acquisition costs, wide availability, and quiet performance make them a popular power transmission solution. In most commercial applications the V-belt drive is the critical link and the only mechanism for mechanical transfer of power from the electric motor to the driven shaft/fan/blower.

Belt drive fan with reduction pulley

Compressors

Compressors are very reliable and when operation is critical, redundant and back-up systems are usually in place. Smaller compressors are normally not serviced or maintained but simply replaced. Larger compressors are maintained and can be rebuilt on a scheduled basis. This eliminates failure, which effects productivity.



Compressor with controls

Troubleshooting

Troubleshooting is done on the system when a failure of a component has occurred or the operation of the system is not producing proper temperatures. Isolating the problem normally involves diagnosing three different areas: non-operating systems, operating systems or control issues. If the system is not functioning the failure of a component or control is the probable cause. Use of electrical test equipment and pressure gauge sets will be the starting point for repair. If the system is operating, but not to the proper temperatures, the problem can be isolated by pressure checking with the gauge set and the ducting control for air flow.

Frozen evaporator due to low temperature in the evaporator

Repairing a condensing unit

Controls

Troubleshooting the controls for an air conditioning system will include the use of electrical test equipment to isolate where the failure has occurred. The lack of operation can be from sensors that have failed, supply voltages being lost, system direction not being delivered or safety switches disabling the system to avoid additional mechanical failure. The challenge for the technician is to isolate which area is causing the problem. This will require schematics and testing techniques and needs to be done quickly as to not compromise productivity or comfort. Newer systems will be part of the overall computer management system so interaction with the data base may be required.

Repairing AC controls

Air Handling

Air handling troubleshooting will include filter replacement or cleaning, verification that heating and cooling elements are open and allow air flow, blowers and fans are operational and that any baffles or directional valves are operational. The movement of air can be as simple as a direct duct to deliver supply and return air or as complex as a system with communication to the computer control device to vary speeds and volume depending on demand and location of the required cooling or heating.

Chapter 12

Welding

Welding and fabrication are skills many supply chain technicians possess. Having the ability to quickly and safely make repairs that require welding skills is critical to the efficiency and reliability of our nation's automated warehouses.

Section 1

Overview

Welder joining round tube

In many automated distribution centers the supply chain technician is required to know the foundations of basic welding and fabrication. Welders use several different types of equipment depending on the project being fabricated or repaired. In this section, you will review the different processes as well as the equipment needed to be successful.

Welding is a process used during fabrication or repair that joins metals by creating a bond from melted materials. This is done by melting a small area of the materials where they contact and adding a filler material to form a pool of molten material that when cooled becomes a strong joint to adhere the metals. Welding requires very high local temperatures (3,000 degrees minimum) which are produced by different energy sources. Energy sources include a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. Welding in support of a distribution center is used as a fabrication technique and for doing repair work and is usually a portable gas or electric arc welding process. Welding is a hazardous undertaking and precautions and planning are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation.

Section 2

Gas Welding and Cutting

Oxyacetylene welding and cutting are processes that use acetylene and oxygen blended in a torch to weld or cut metals. Pure oxygen, instead of air, is used to increase the flame temperature to allow localized melting of the material. The flame produced by the combination of acetylene and oxygen can reach temperatures above 3,500 degrees, which will melt most steels at a localized area. The size of the torch and mixing tips determine the heat produced and the size of the weld. Recently, gas welding has been less widely utilized in industrial applications as other specifically devised technologies have been adopted. It is still used for welding small pipes and tubes, as well as repair work. Oxyacetylene has an advantage over electric welding and cutting processes in situations where accessing electricity (using an extension cord or portable generator) would be more difficult. Gas welding and cutting is more self-contained making it more portable. Welding metal results when two pieces are heated in a small area to a temperature that produces a shared pool of molten metal to include both pieces to be joined that when cooled will join or adhere. The molten pool is generally supplied with additional metal called filler which is the same type of metal.

In oxyacetylene cutting, a torch is used to heat metal to its melting temperature. A pinpoint stream of pressurized oxygen is then sprayed through the liquid pool burning the liquid metal into a metal oxide that blows away from the material separating the joined pieces. This process is intense and can be dangerous without the proper equipment and planning.

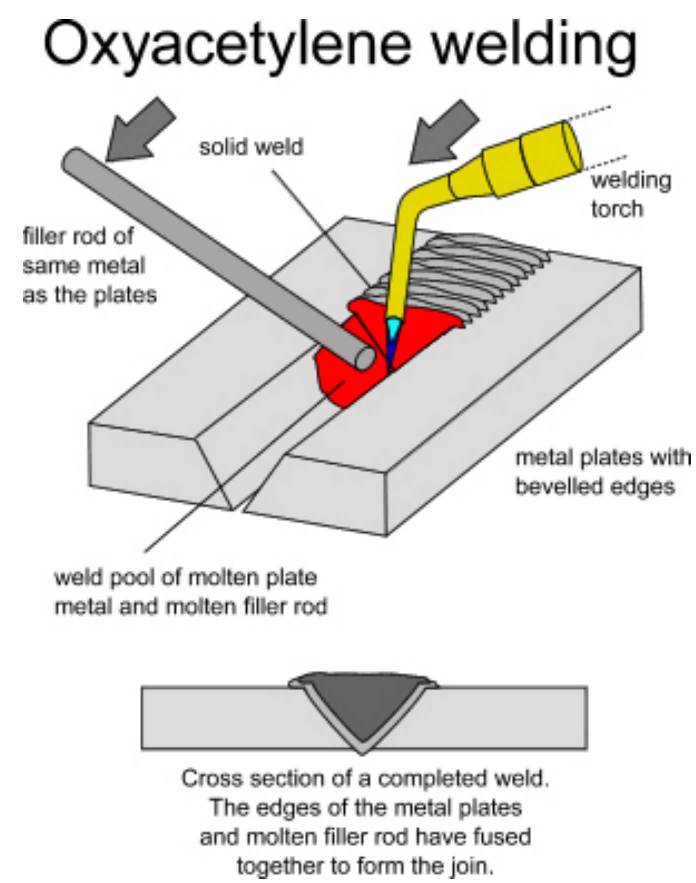


Diagram showing the oxyacetylene welding process

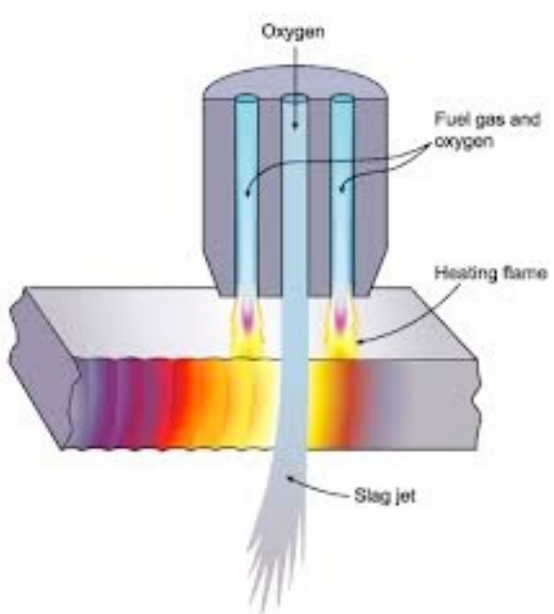


Diagram showing the oxyacetylene cutting process

Oxyacetylene welding and cutting equipment is normally portable and includes a cart with an oxygen bottle, acetylene bottle, controllable pressure regulators, hoses and an assortment of torches.

Oxyacetylene cutting

Portable oxyacetylene welding equipment

Section 3

Arc Welding

Arc welding is a type of welding that uses electrical power to create an electric arc between an electrode and the base material, which provides intense heat to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding gas, vapor, or slag to protect the weld from outside air which causes oxidation, weakening and porosity to the welded joint. Arc welding processes may be manual, semi-automatic, or fully automated but in support of the automated distribution center, manual processes are most common. First developed in the late part of the 19th century, arc welding became commercially important in ship building during the Second World War. Today it remains an important process for the fabrication of steel structures and repair work.

Arc welding equipment used for construction and repair is made up of a power source, conductive wires and material or rod holders. The equipment requirements change when more exotic processes and materials are used, but this is not as common in the automated distribution center.

Arc welding or “stick” welding is the most common type of welding done for fabrication and repair. This process uses a consumable rod and adjustable heat control to melt the material and provide additional filler material to feed the weld and is the most simple of welding processes. Wire feed welders of the flux core type or shielded gas type are used in manufacturing processes or in a controlled environment. Wire welding processes are faster and require less clean-up of the weld.

Interactive 12.1 Arc Welding Images and Diagrams

Tap to view arc welding images and diagrams.

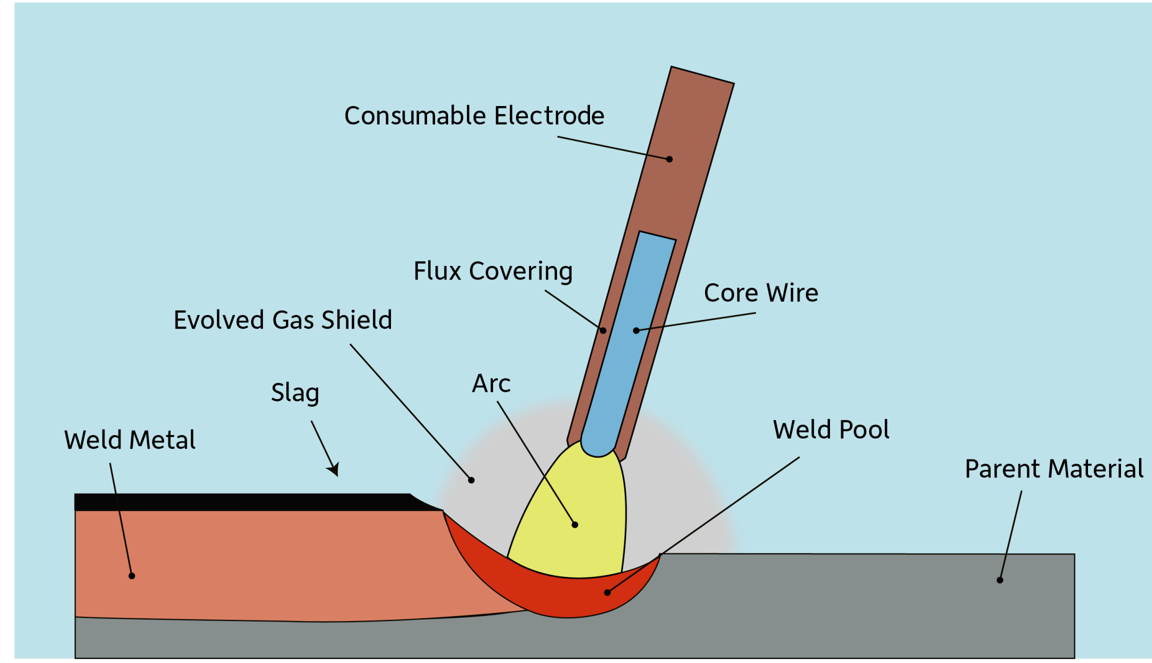
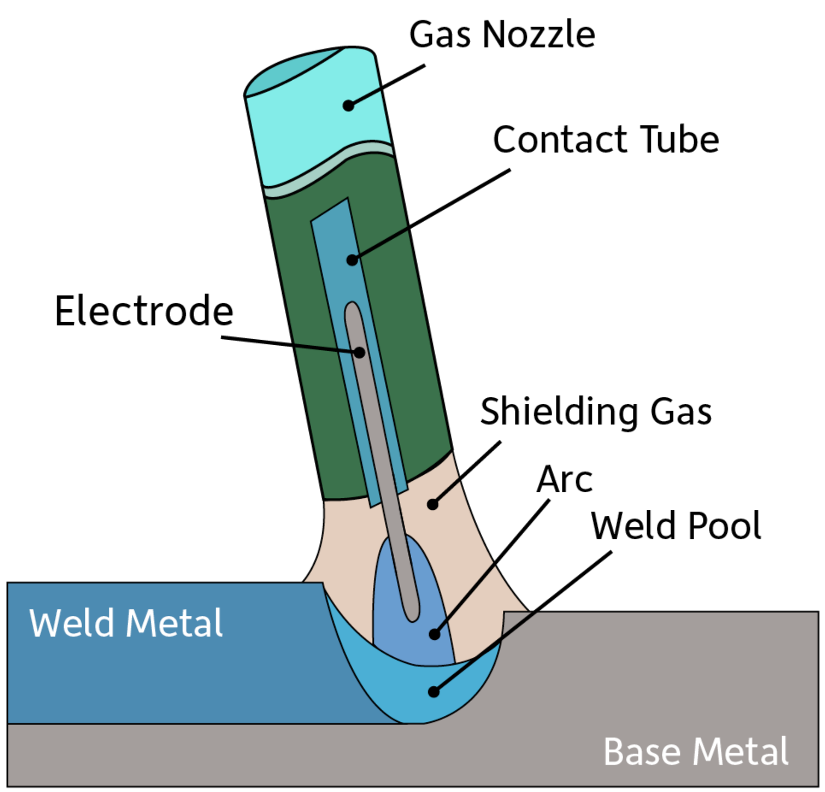


Diagram of the arc welding process

Section 4

Wire Feed Welding

The wire feed type of welding process (gas metal arc welding or GMAW) automatically feeds wire to the weld as filler at the same time it creates the arc to make heat. This type of welding is faster than conventional arc welding. Arc heat and wire feed speed is adjustable to fine tune the welding process.



Wire feed welding process (GMAW)

Arc welding that uses a non-consumable electrode (gas tungsten arc welding or GTAW) is used for materials that are more exotic (aluminum, stainless steel) and where quality control is critical. This process uses a hand feed filler rod to supplement the weld pool, which allows better control over the weld. The equipment used is more expensive and is becoming more common in today's automated distribution centers.

Wire feed welding

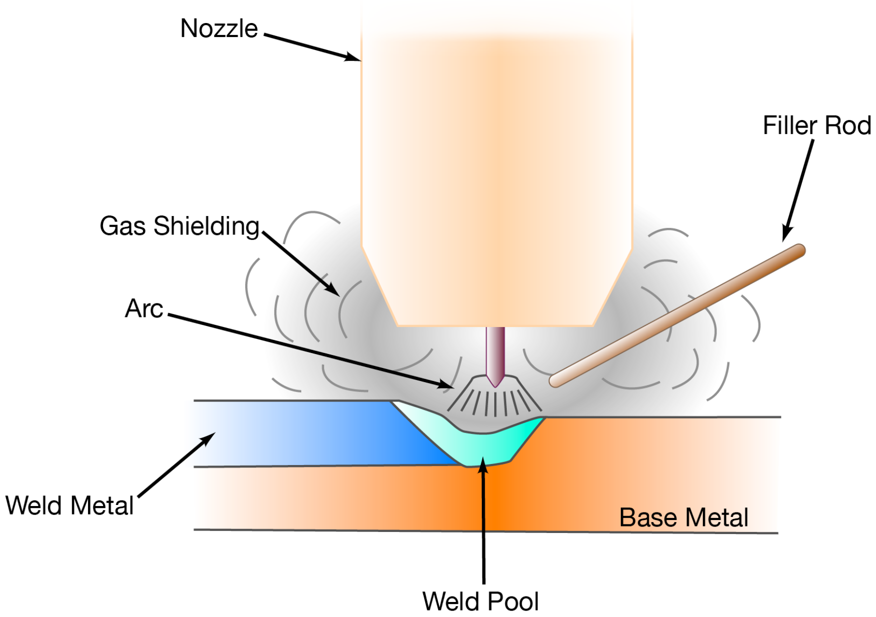
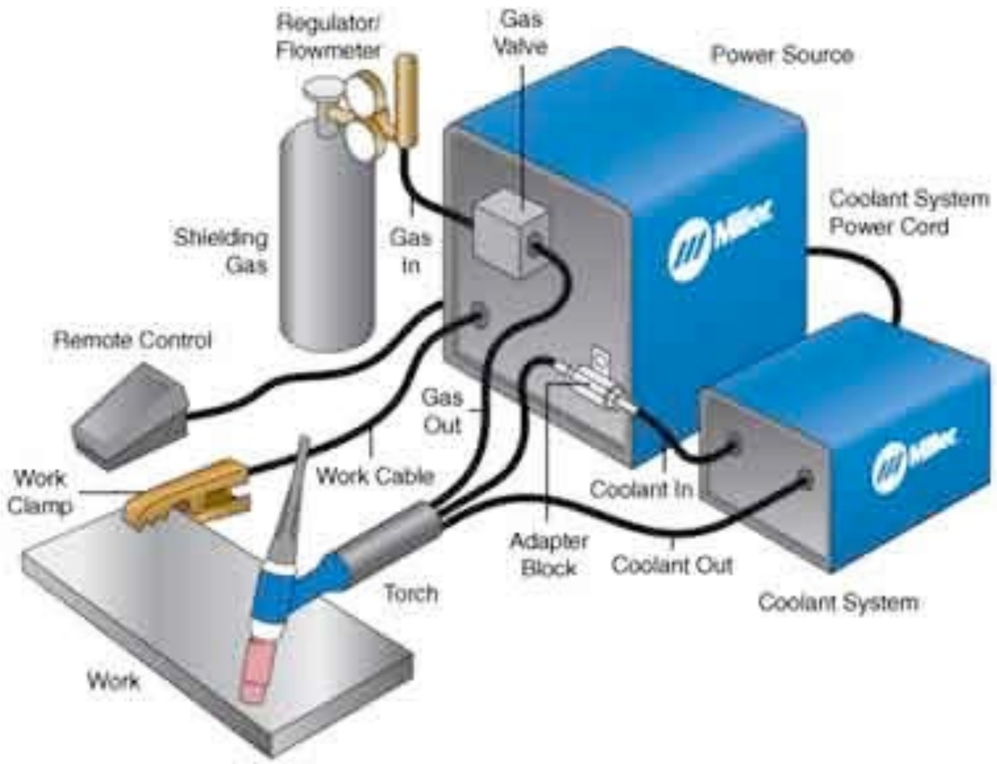


Diagram of the process of non consumable electrode welding



Non-consumable electrode welding equipment (GTAW)

Section 5

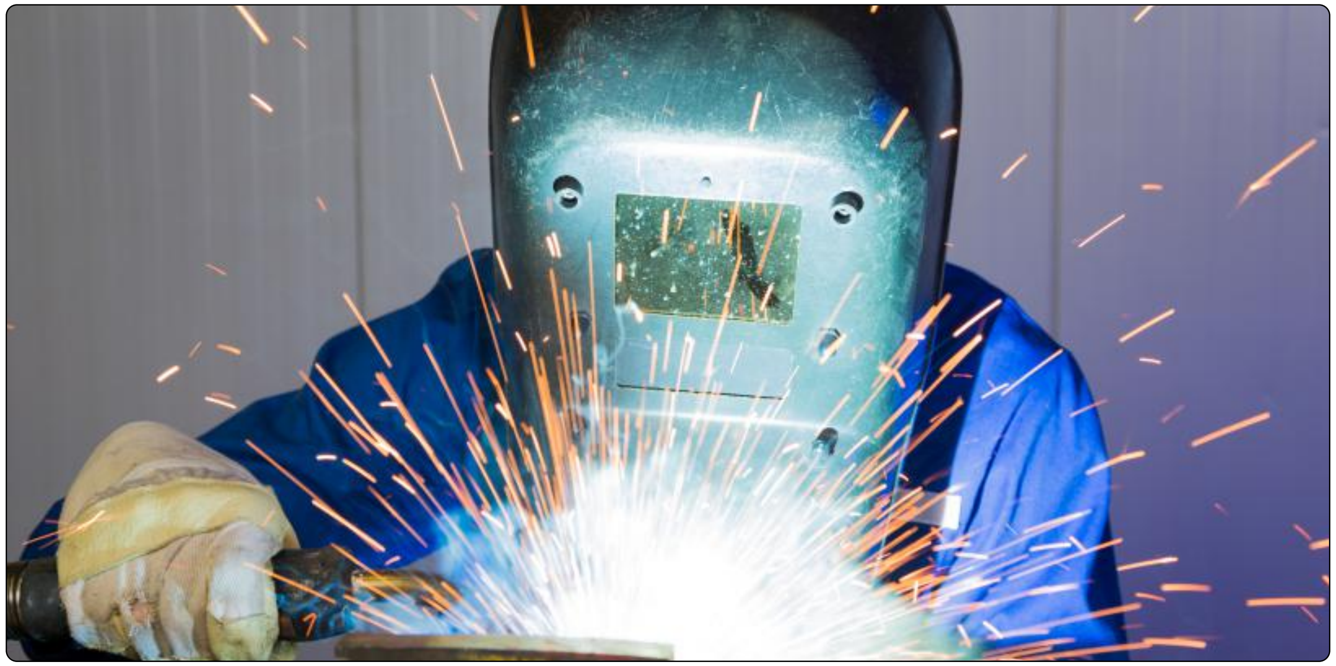
Welding Safety and Precautions

Welding, cutting and metal fabrication can be dangerous and unhealthy if the proper precautions are not taken. With the use of new technology and proper protection, risks of injury to personnel or to the surrounding facility can be greatly reduced. Since many common welding procedures involve extreme heat in the form of an open electric arc or flame, the risk of burns and fire is always a concern. To prevent injury, welders wear personal protective equipment in the form of heavy leather gloves and protective long sleeve jackets to avoid exposure to extreme heat and flames. Additionally, the brightness of the weld area leads to a condition called flash burn in which ultraviolet light causes inflammation of the cornea and can burn the retinas of the eyes. Goggles and welding helmets with dark UV-filtering face plates are worn to prevent this exposure. Since the early 2000s, some helmets have included a face plate which instantly darkens upon exposure to the intense UV light, which makes visibility easier prior to beginning a weld. To protect bystanders, the welding area is often surrounded with protective translucent welding curtains that don’t allow the harsh light to be damaging to the surrounding area.

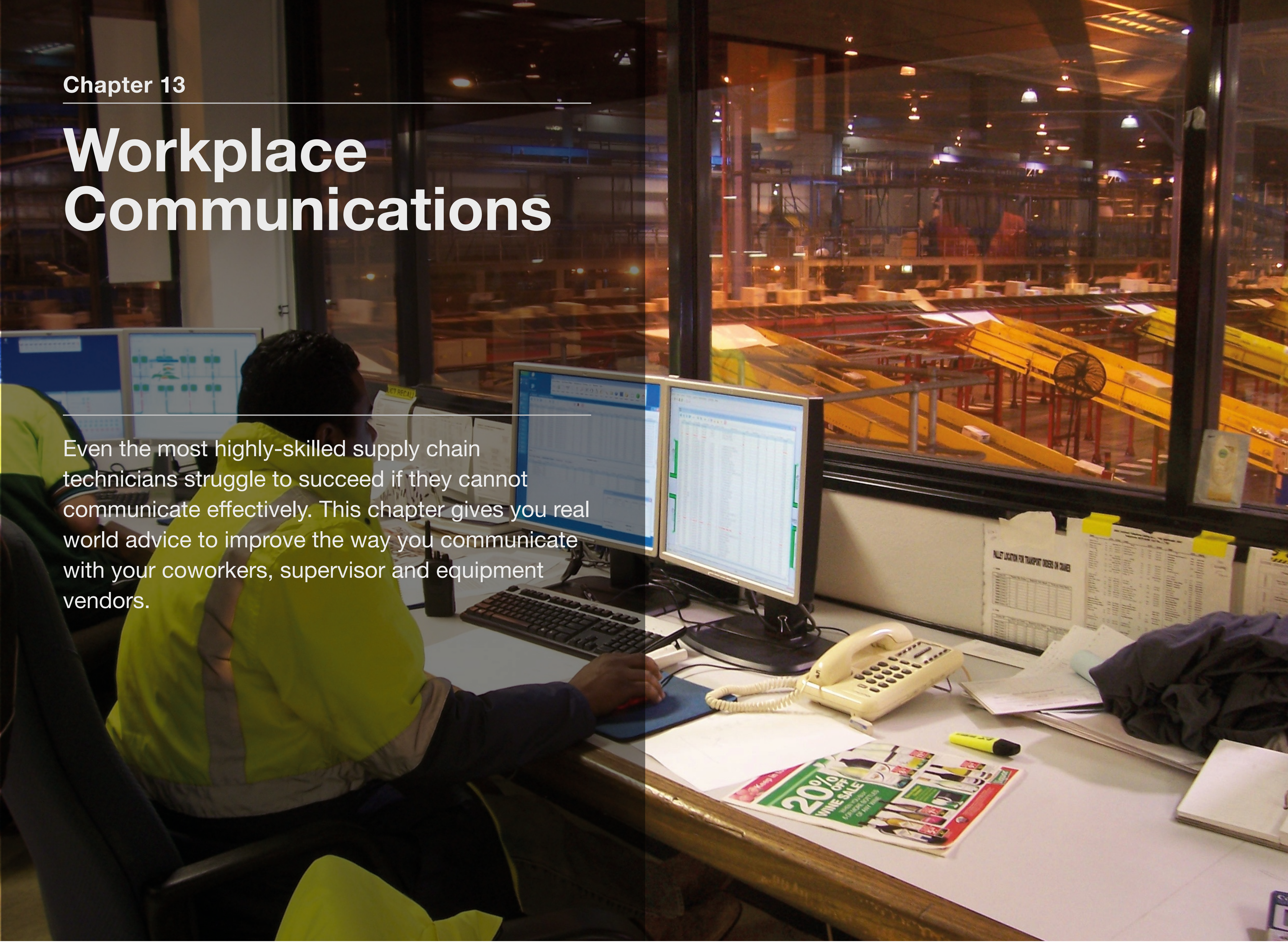
Welding personnel are often exposed to dangerous gases and particulate matter. Welding processes produce smoke containing particles of various types of hazardous materials. The size of the particles in question tends to influence the toxicity of the fumes, with smaller particles presenting a greater danger to the respiratory system. Gases, such as carbon dioxide, ozone, and fumes containing heavy metals, can be dangerous to welders lacking proper ventilation and training.

The use of compressed gases and flames in many welding processes poses an explosion and fire risk. Some common precautions include limiting the amount of oxygen in the air, and keeping combustible materials away from the workplace. Before any welding or cutting processes are started, proper planning is needed to minimize risks and to isolate the activity from the surrounding areas.

Interactive 12.2 Personal Welding Protection Equipment



Tap to view images of personal protection equipment for welding



Chapter 13

Workplace Communications

Even the most highly-skilled supply chain technicians struggle to succeed if they cannot communicate effectively. This chapter gives you real world advice to improve the way you communicate with your coworkers, supervisor and equipment vendors.

Workplace Communications

Introduction

Companies depend on supply chain technicians to service and maintain systems and equipment within tightly scheduled downtime to meet high demands and deadlines. Equipment failure and shut-downs are costly and often frustrating. While failures are often unforeseen and shut-downs necessary for long-term system operation and maintenance, the frustration of a system being off-line for repairs and maintenance may end up being directed at the supply chain technician. For this reason, it is critical that supply chain technicians practice quality customer service skills and clear communication in everyday workplace activities. In a recent National Center for Supply Chain Automation survey of supply chain firms, the need for supply chain technicians trained in soft skills and customer service ranked 4th out of 18 desired training needs. Implementing fundamental, yet essential, customer service and communication techniques will minimize operational frustration, increase productivity and positively impact your own performance and potential advancement within the industry.

The Essentials of Customer Service

Think back to an instance when you experienced outstanding customer service. What made it so great? Was it because they did something unexpected? Did they exceed your expectations? How about a time when you received poor customer service? What made it so bad?

Customer service occurs both internally and externally. When we think of customer service we often think of consumers interacting with a sales associate or a customer on the phone with a company representative. These types of interactions involve external customer service where the company or business is directly serving and interacting with the consumer or public. Internal customer service exists within the company or organization and is seen in the service and interaction between departments, such as the sales staff interacting and supporting the finance department at a new car dealer or supply chain technicians interacting and supporting the equipment operators. Both internal and external customer service are critical to the success and health of an organization.

To evaluate how well we are delivering customer service, we must consider five items: reliability, assurance, tangibles, empathy and responsiveness. Reliability in customer service is doing what you say you are going to do. Reliability is found in both internal and external customer service. Reliability is about keeping the service promise and doing what you say you will do for the customer or other department. If you don't keep these service promises you become unreliable and being unreliable will very quickly cause your customer to lose faith in your ability to deliver your product or service. For example, if you tell a co-worker in the morning you will get to the service repair he/she requested for a piece of equipment and by the end of the day you don't, then you become unreliable. Likewise, if you tell a vendor you will call back by 3:00 p.m. and you forget to, you will quickly become unreliable in your vendor's eyes. Make sure you follow-up and do what you say you will do.

Quality customer service also requires you to provide assurance. Customers (external) and co-workers (internal) want to feel assured that you know what you are doing. Have you ever walked into a store to make a purchase and realized you knew more about the product than the sales person? How did that make you feel? Have you ever asked a coworker to assist on a project or task and felt like they had no idea what they were doing? To project assurance to your coworkers, know your stuff! People will gain confidence and trust in you, and they will perceive you as being knowledgeable in your job. Make sure you know your equipment and systems well. Also know your organization and how your department fits within the rest of the company.

Since the actual maintenance and/or service you provide to the company will be hard to physically see, demonstrating tangibles is a little trickier. Understand, it is often very difficult for an operator to see the internal parts you replaced, for an operator to see a difference in operation due to routine lubrication, or for the operator to know the optical sensors were routinely calibrated last night. Your internal customers may not be able to see the actual service or repair you performed, however, they will see more of what you do in the extra details of your work. This extra detail is often the tangible component to service work. Your internal customers will notice when you take care of the details, even on a subconscious level. Special details like leaving the equipment cleaner than when you arrived to service it, paying attention to them and listening attentively when they are relaying a problem, being thorough in your written documentation, or returning service inquiries in a timely manner are all tangible examples of great customer service provided by the supply chain technician.

The last two components of customer service are empathy and responsiveness. Empathy means putting yourself in your customer's place. It means treating the customer as you would want to be treated and not seeing them as just a number. Remember that even your supervisor is a potential internal customer. Try to put yourself in their shoes and imagine how you would feel if you were them. Listening is the first step in empathy. Make sure you let the customer explain his/her needs without interruption. Listening tells a customer that you think what they have to say is important – which means you think they are important. Often customers just want a chance to vent their feelings. We will discuss listening in detail later in this chapter.

Lastly is timeliness and responsiveness. Today, timeliness is more critical to a person's view of customer service than ever before. Americans want things fast and they don't like to wait. It is evident in our ability to access information, how we shop and our access to people. Commerce is a prime example of timeliness. We can locate multiple suppliers of goods and services on the Internet, compare prices and previous reviews, and then have the item shipped instantly to our door the next day (this also validates the importance of supply chain technicians). Because this global need to quickly move products exists, supply chains are designed to run at the most efficient rate possible, thereby making responsiveness the most critically watched customer service trait of the supply chain technician. To maintain a high level of responsiveness, it is critical to only make a promise you can keep. If you don't, your customers will grow more frustrated not knowing how long the wait will be. Also make sure to acknowledge down times and make these down times known by ensuring your co-workers and supervisor know what is happening and how long they will need to wait for the equipment to be operational again.

In the end, great customer service is achieved when you make the service your priority and have a positive attitude. Being polite and enthusiastic will make you approachable to your co-workers. Make sure you follow these eight practices when you are dealing with your internal customers.

1. **Know your product or service.**
2. **Listen to the consumer and their complete story or problem.**
3. **If you do not understand something, ask questions to ensure understanding.**
4. **Maintain clear and effective communications.**
5. **Keep your customers informed and contact them if something changes.**

6. **Be certain to solve the problem.**
7. **Always follow-up because it demonstrates your concern.**
8. **Apologize and ensure it is sincere and timely. If the customer perceives you as insincere they will probably get even more upset!**

When providing quality customer service, do not wait to find out why there is a problem or what caused the problem before saying you are sorry. The sooner you apologize, the better. The solution to every problem, whether big or little, should start with a sincere apology. An apology is simply an acknowledgement that things aren't going right in your customer's eyes. It doesn't mean you're admitting you did something wrong. Often it is all the customer (internal or external) needs to hear. If you do not want to say "I'm sorry" because it feels like taking on too much of the blame, consider saying "Thank you for bringing this to my attention" instead. Lastly, do not blame others in your organization for a service breakdown.

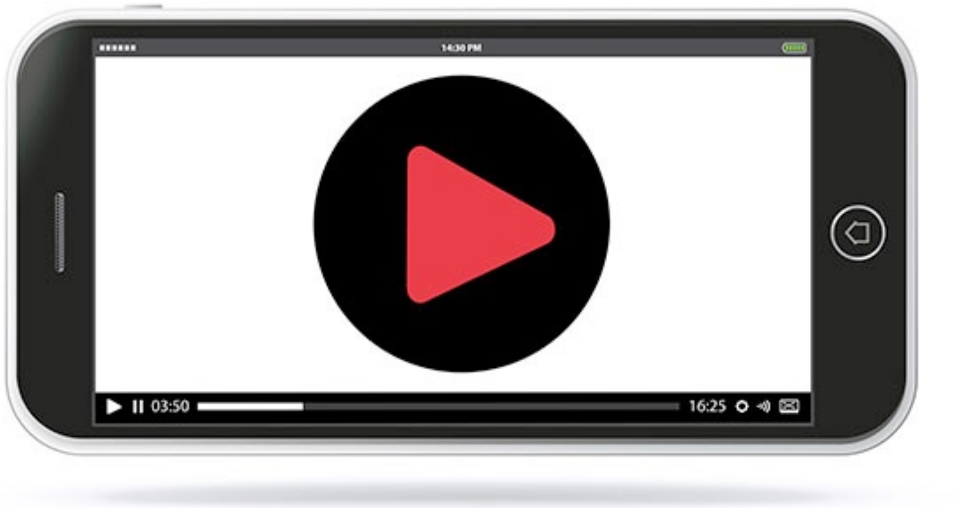
Barriers to Effective Communication

Dealing with an Upset Individual

Clear communication eliminates misunderstandings and reduces troubleshooting time. However, personnel issues may prevent a quick resolution of a maintenance problem and communication with an individual who is upset or frustrated can be very difficult to do. If you are unable to communicate the issues to a supervisor, then you will have to work it out with the aggravated person (who could be the supervisor anyway). This is best accomplished by remaining calm and listening carefully to an explanation of the problem without interruption. This will allow time for the individual to collect their thoughts and calm down. Emphasizing a willingness to work with the individual, as a team, will expedite finding a solution. Focus the efforts on the equipment problems and take clear notes during the conversation, as necessary. Avoid discussing related personnel issues and identify the specific steps to be taken and the time frame required to return the equipment to service. Then discuss the options and agree on the appropriate action to take.

It is important to understand that most communication problems stem from a misunderstanding. To humorously illustrate this point, watch this classic bit by two of the most iconic comedians ever to do stand up.

Movie 13.1 Who's on First Video

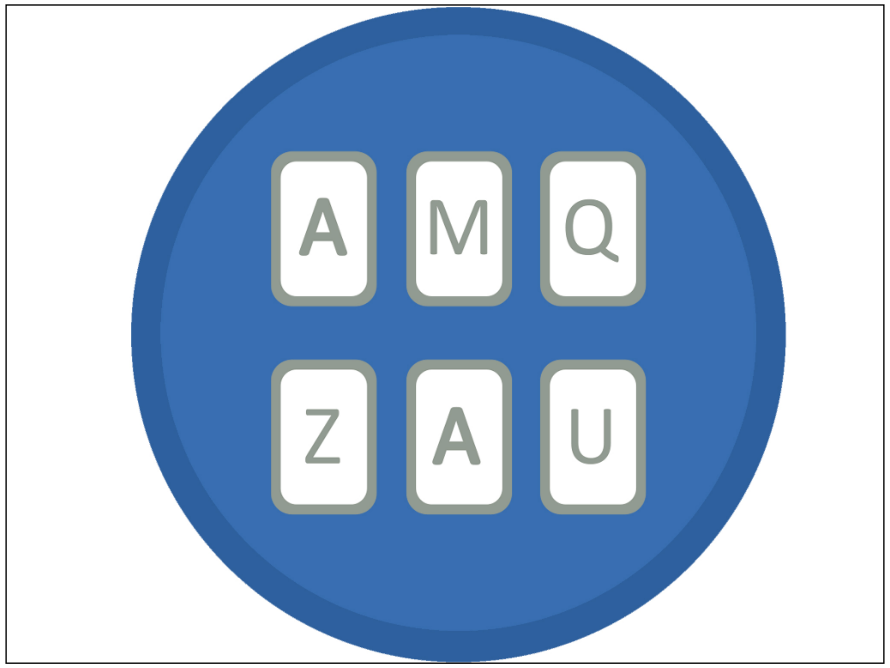


Tap to view the video.

Nonverbal Communication

At least 70% of what is communicated is done without speaking a word during face-to-face communications. This 70% is referred to as nonverbal communication. When nonverbal signals send a different message than the words we are communicating, those around us can become confused and skeptical of our motives and actions. Nonverbal communication can include voice signals, which puts emphases on certain words to change the meaning of what you say. Consider the following statement, "I didn't say you had a bad attitude." Depending on where you put the inflection or emphasis when it is spoken can completely change the meaning or the interpreted understanding. Putting the inflection on the word "I" in the sentence implies that I didn't say it, but somebody else did. Putting the emphasis on the word "bad" might communicate that one's attitude isn't bad, but something is wrong with it. Body signals are another form of nonverbal communication and can completely change the meaning of your spoken message.

Review 13.1 Understanding Body Signals



Tap to complete a matching exercise.

Additional nonverbal communications signals can include objects, space and time. You can indicate a tremendous amount about your willingness to communicate with others based upon how you place objects such as furniture, counters and desks. Regarding space, most North Americans prefer to maintain a distance of between a foot and a half and two feet between others when they are communicating. When we decide to eliminate that distance and huddle close to others to communicate it sends a very distinct nonverbal communication message to others who may be witnessing the conversation. What is it? It communicates secrecy and that others are not privy to hear what is being said.

Regarding time signals, consider what message someone sends when they are on time, not on time, when they keep someone waiting, or are not available/can't make time for someone? How you handle your time with others communicates messages non-verbally. For example, someone who is always late to a department meeting might communicate: "I don't think this meeting is very important." Or if someone never has the time to meet with you, it might communicate: "I don't want to spend any time with you because I don't like you."

Hierarchical Loss of Communication

Most organizations are shaped like a triangle. They usually have a CEO/President at the top, Vice Presidents, District Managers, Regional Managers, Managers, Leads, etc. Because of the layers within an organization, communication can become distorted, diverted and/or discontinued as it moves from one layer to the next. To illustrate, if during the communication chain someone makes the decision that the information does not need to be shared with the next level in the chain, communication discontinuance occurs. If a vital piece of information is omitted or perhaps information is added that did not need to be included, distortion of the communication occurs. Lastly, if the communication is delivered to the wrong persons in the organization (often due to a distortion of the communication earlier in the chain), diversion occurs and the intended recipient never receives the information.

You may have seen loss of communication in the workplace already or perhaps witnessed it in a church or other community-based organization. There is a good chance you even played a game as a child to see just how much communication can be distorted, diverted or discontinued within a communication chain. Do you remember playing the "gossip game" as a child, maybe in school? The teacher had everyone arrange themselves in a circle and then gave the first person in the communication chain a statement. This person then whispered the statement in the ear of the next person, and then they whispered it into the ear of the next person and so on. At the end of the chain the person would say out loud what they have been told. The result is often humorously different and even farther from the original statement as the communication chain gets longer.

Jargon

Jargon is a set of special words or expressions that are used by a particular profession or group and are difficult for others to understand. Their use is like a type of shorthand between members of a particular group of people; often jargon is meaningless outside of a certain context and unnecessarily complicated. It is more often than not, used to impress, rather than to inform, your audience.

Supply chain technicians will have their own jargon or "lingo." By learning the jargon for your industry, you will develop a deeper understanding of its culture and commonly used phrases. It is important to recognize that other departments in your organization may have their own jargon that you may not completely understand nor will they completely understand your technical jargon. It is critical that interdepartmental communication is kept as free from jargon as possible, unless the terms are used organization-wide. Technical terms are often very specific to certain teams within the organization. Be careful in their usage as it may decrease your customer service, cause delays in completing the task, cause frustration, or cause a mistake to be made.

Another reason to avoid jargon in communication is that in today's multicultural workplaces, differences in cultures and languages can hamper communication and using jargon will only increase misunderstanding. Cultural barriers can create a unique workplace environment where workers are expected to behave in a particular way to gain acceptance. Language barriers can result, not only when workers have different native languages but when others use jargon, buzzwords or terminology that is unfamiliar to non-native language speakers or even new employees. Therefore, when working with non-native language speakers and new employees, recognize that they may not understand what is being communicated and may be too embarrassed to ask for clarification. This lack of them seeking understanding could cause them to make a mistake on the job or provide the wrong service.

Listening Skills

Whether internal or external, to serve your customers within the supply chain you need to know the who, what, when, where, why and how. You must know who your customer is, what they want, when they want it, how they want it, where they expect to receive it, why they want it, how long they expect to wait, and what else they may be expecting along the way. Sound difficult? Well, the only way to understand these things about your customer is to listen to what they say and ask questions to ensure they say it. When you listen well to your customers, you…

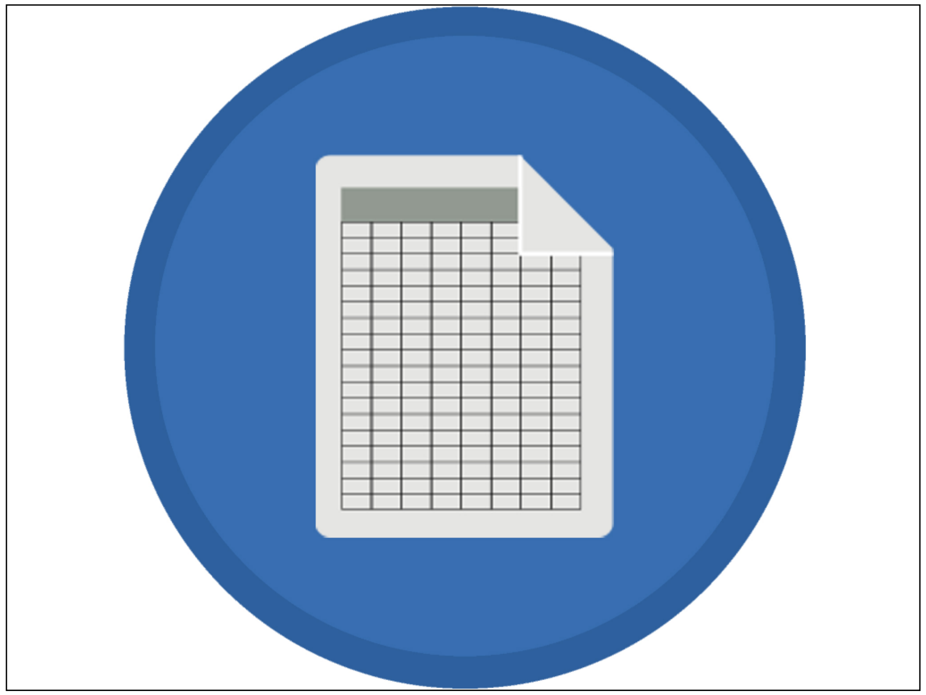
1. Figure out what the customer really wants and needs.
2. Avoid misunderstandings and mistakes.
3. Build long-term relationships.

Self-Assess Your Listening Habits

As a listener, how frequently do you practice the following listening behaviors? Complete the interactive Listening Habits activity to self-assess your listening habits and evaluate your overall listening skill.

One of the most important listening skills to develop is active listening. Active listening requires that you understand what is

Review 13.2 Listening Habits



Tap to learn more about your listening habits.

being communicated from the speaker's point of view and it requires you as the listener to concentrate on what is being said by the speaker and tune out the hundreds, if not potentially thousands, of distracting thoughts. It also requires that you listen with empathy and put yourself in the speaker's shoes. Additionally, you must practice acceptance and a willingness to take responsibility for getting the full-intended meaning from the speaker. By practicing acceptance you will listen objectively without judging what is being said. This is perhaps the hardest listening skill to master because we are easily distracted by content that we do not agree with.

So, for your customers, coworkers and supervisor to feel assured that you know what you are doing and that you will be able to help them, they need to feel like you are listening. Good body language, such as eye contact, leaning forward, not looking around or doing something else while they are talking (like checking text messages on your mobile phone) will assure them that you are listening. Asking questions and summarizing what they said can be great way to help them to feel assured.

Practice These Effective Listening Strategies

1. Take the time to listen.
2. Avoid doing most of the talking yourself.
3. Avoid distractions.
4. Act interested in what the other person says.
5. Ask questions.
6. Summarize.
7. Be empathetic.
8. Do not lose your temper.
9. Do not interrupt.
10. Jot down notes and review them.
11. Use active listening techniques.

How to Speak in the Positive

No one likes being around negative people. As a supply chain technician your job will be to keep the system running at maximum efficiency and capacity. You may often be the bearer of bad news regarding down times and expensive repairs. Do your best to bring bad news forward with a positive spin. Instead of saying, “the system will be offline for the next 24 hours,” say, “I pinpointed the failure and am having the replacement part shipped overnight, I’ll be in first thing tomorrow and will have it operational by noon.” Putting a positive spin on your communication will reduce the frustration your internal customers might experience.

Review 13.3 Speaking in the Positive

Tap to open interactive worksheet. Rewrite the negative phrases into positive phrases.

Written Communication

As a supply chain technician, a significant portion of your communication will be written. You will be tasked with filling out repair orders, work logs, equipment maintenance journals, incident reports and many other internal and possibly external forms. Preventative maintenance and repair orders will be a common form of your everyday communication and may be on paper or completed electronically through a computer software system. Regardless of the medium, it is critical your written communication is clear, complete and concise.

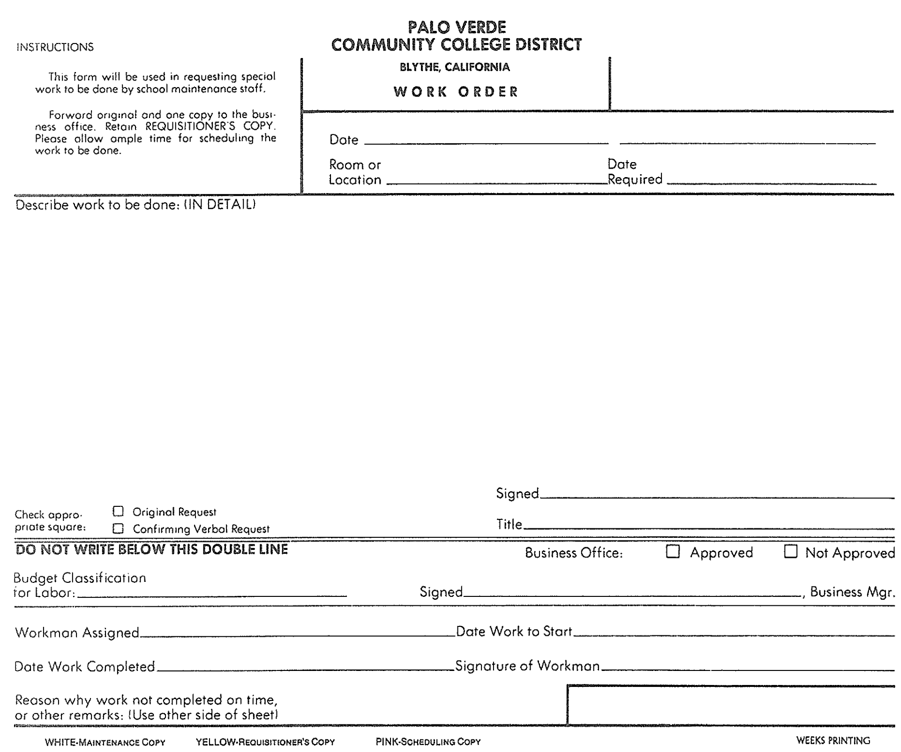
Incident Reports

For incident reports such as injuries or hazardous waste spills, you must ensure the forms required by your department, organization and/or oversight agency are filled out completely and properly. For these forms you are the reporter and recorder of the incident; you are identifying the what, when, and who. For these documents, be sure that all lines are filled in completely; you are printing legibly, pressing down hard enough if it has multiple copies, and giving just the facts. There is no need to inject opinion or your subjective assessment of the incident; doing so may lead to potential litigious action. It is important that these forms remain objective and list exactly what occurred.

Preventative Maintenance Work Orders/Logbooks

Preventative maintenance is scheduled work required to keep equipment and supply chain systems in peak operating condition.

The work is planned and scheduled for completion to minimize emergency repairs and to ensure efficient operation. Work orders and/or logbooks are used to organize and plan scheduled maintenance. These documents will detail specific tasks to be completed along with time, date, name, and location of the equipment, work detail, scheduled completion date/time, and sometimes future recommendations by the technician (such as additional service needed). When filling out these forms, ensure you are thorough and have recorded the information accurately. These forms will often serve as a basis for future maintenance and insufficient or missing information could lead to costly and unforeseen repairs.



INSTRUCTIONS

This form will be used in requesting special work to be done by school maintenance staff.

Forward original and one copy to the business office. Retain REQUISITIONER'S COPY. Please allow ample time for scheduling the work to be done.

PALO VERDE
COMMUNITY COLLEGE DISTRICT
BLYTHE, CALIFORNIA
WORK ORDER

Date ____________________ ____________________

Room or Location ____________________ Date Required ____________________

Describe work to be done: (IN DETAIL)

Signed ____________________

Title ____________________

Check appropriate square: ☐ Original Request ☐ Confirming Verbal Request

DO NOT WRITE BELOW THIS DOUBLE LINE

Business Office: ☐ Approved ☐ Not Approved

Budget Classification for Labor: ____________________ Signed ____________________, Business Mgr.

Workman Assigned ____________________ Date Work to Start ____________________

Date Work Completed ____________________ Signature of Workman ____________________

Reason why work not completed on time, or other remarks: (Use other side of sheet)

WHITE-MAINTENANCE COPY YELLOW-REQUISITIONER'S COPY PINK-SCHEDULING COPY WEEKS PRINTING

Sample work order form

Not all service work will be planned. Sometimes equipment breaks down and requires immediate attention. If this occurs, the supply chain technician will likely receive a Repair Order (RO) or Emergency Repair Order (ERO). These repair orders may or may not be different than the previously mentioned repair orders for scheduled maintenance. The biggest difference is that now the supply chain technician must be able to diagnose the failure and determine the best course of action to return the equipment to working order. Scheduled maintenance does not require a diagnosis by the supply chain technician.

Maintenance repair orders or service log books essentially require journaling the preventative maintenance once it is completed; however, repair orders for malfunctioning, broken or poorly operating equipment will require three major statements in order to be considered complete and thorough. Each of these repair orders must have a complaint statement, a cause statement, and a remedy statement. This is often referred to in the service industry as complaint, cause, remedy, or CCR. As a supply chain technician, you will be expected to write thorough and complete CCR statements.

Job Name		**Date**					
Unit Tag							
Model #		**Time**					
Serial #							
Full Load Design	Operating Condition						
	Operating Code						
	Last Diagnostic						
__________degF	LCHW Setpoint						
	Current Limit Setpoint						
	Start #						
	Run Hours						
__________Volts	Volts – AB						
__________Hertz	Volts – AC						
	Volts – BC						
	Amps L1						
	Amps L2						
	Amps L3						
	Amps AVG						
__________RLA	% of RLA						
	Oil Sump Temperature						
	Oil Temperature to Bearings						
	Oil Level						
	Low Oil Pressure						
	High Oil Pressure						
	Net Oil Pressure						
	Operating Purge Pressure						
	Operating Purge Oil Level						
	Purge Starts						
	Purge Run Hours						
_____PSID_____gpm	CHW PSID						
__________degF	CHW Temperature in						
__________degF	CHW Temperature out						
__________degF	CHW Temperature Differential						
	CHW Makeup Water						
	Evaporator Temperature						
	Evaporator Pressure						
_____PSID_____gpm	CW PSI Differential						
__________degF	CW Temperature in						
__________degF	CW Temperature out						
__________degF	CW Temperature Differential						
	Condenser Temperature						
	Condenser Pressure						
	Cooling Tower Makeup Water						
	CHW Makeup Water						
	Operator Initials						

Sample page from a logbook

Complaint

Most likely, the supply chain technician will not document the complaint. Instead, it will be documented by the supervisor or by the operator of the equipment. Nevertheless, that does not mean they should not be held to the standards of documenting a thorough complaint statement. This may be one of the most critical steps in ensuring a speedy diagnosis and repair of the equipment. The reason is that the complaint statement should be a guide to the technician, not a hindrance or diversion. The statement needs to include all the relevant information to allow the technician to narrow down and diagnose the equipment quickly. Consider these two complaint statements:

"Sorter #3 is not working properly. Check and repair sorter."

"The operator on shift three says Sorter #3 is not reading and sorting large parcels."

The second statement is much more complete and gives the technician an idea of what is going on. It also gives the technician a scenario to try and recreate to verify the equipment malfunction. Statement #1 is so vague that a technician may never know that it only messes up when large parcels are being processed. As a matter of fact, the technician may go look at the piece of equipment during the day and find it working perfectly fine, unless they happened to sort large packages that day. This is so important for a supply chain technician to do their job effectively that he/she may need to train the staff and/or supervisor writing the repair order to be very thorough when completing the complaint section.

Cause

The cause section is completed only by the supply chain technician and allows a place for the technician to document what exactly has occurred to produce the equipment failure. For potential warranty reasons, potential future litigious situations and internal budgeting, this section must be precise. Most importantly, it allows a place for the technician to put their expertise down in writing. Cause statements must include what happened and how it happened. Here are examples of two cause statements:

“no power to RFID” or “Open wire on Circuit 132, between junction block J3 and RFID control module”.

The second example gives a very clear image of what failed and allows the technician to make suggestions for repair. These suggestions must be classified by the supply chain technician as either a requirement or a recommendation. Understanding the difference between these two terms is critical and can save time and costly repairs.

Use the term “required” when:

- Part no longer performs intended purpose
- Part does not meet a design specification (regardless of performance)
- Part is missing

Use the term “recommended” when:

- Part is close to the end of its useful life (just above discard specifications, or weak; failure likely to occur soon, etc.)
- To address a customer need, convenience, or request (to stiffen ride, enhance performance, eliminate noise, etc.)
- To comply with maintenance recommended by the equipment’s Original Equipment Manufacturer (OEM)

Basically, when you use the term required, you are saying the repair must be done right now. However, when you use the term recommended, you are saying that it does not have to be done immediately, but it should be done soon.

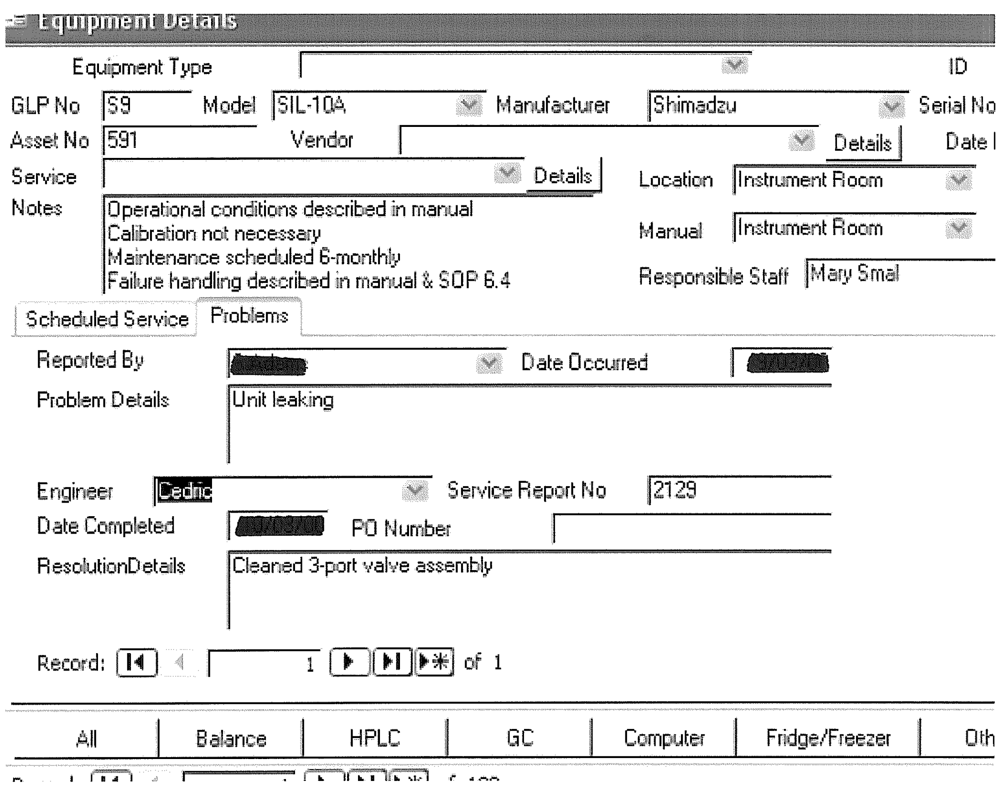
Remedy

The remedy section is a place where the supply chain technician records the action completed on the piece of equipment. Once again this section should be precise, thorough, and completed by the supply chain technician. Building on the statements in the cause section, compare these two remedy sections:

“Repaired open wire.”

" Replaced 36-inch wire section between junction block J3 and the RFID controller. Tested system with various size parcels and system operated as designed."

Repair Orders



Equipment Details

Equipment Type | ID

GLP No: S9 | Model: SIL-10A | Manufacturer: Shimadzu | Serial No

Asset No: 591 | Vendor | Details | Date I

Service | Details | Location: Instrument Room

Notes: Operational conditions described in manual
Calibration not necessary
Maintenance scheduled 6-monthly
Failure handling described in manual & SOP 6.4

Manual: Instrument Room

Responsible Staff: Mary Smal

Scheduled Service | Problems

Reported By: [redacted] | Date Occurred: [redacted]

Problem Details: Unit leaking

Engineer: Cedric | Service Report No: 2129

Date Completed: [redacted] | PO Number

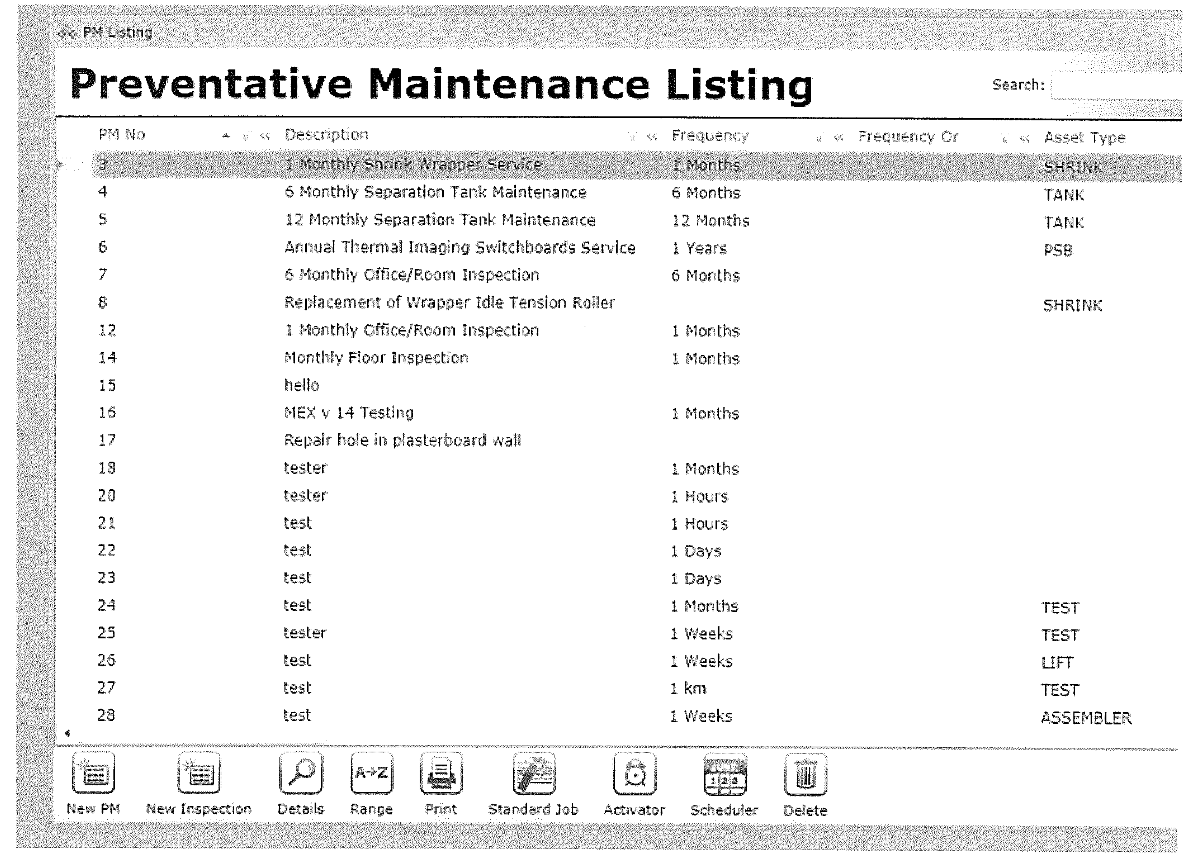
ResolutionDetails: Cleaned 3-port valve assembly

Record: 1 of 1

All | Balance | HPLC | GC | Computer | Fridge/Freezer | Oth

Sample repair order

Preventative Maintenance



PM Listing

Preventative Maintenance Listing

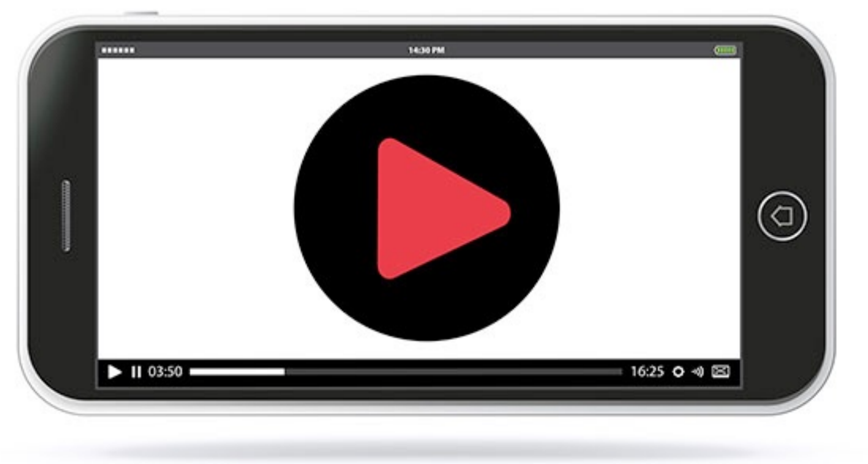
Search:

PM No	Description	Frequency	Frequency Or	Asset Type
3	1 Monthly Shrink Wrapper Service	1 Months		SHRINK
4	6 Monthly Separation Tank Maintenance	6 Months		TANK
5	12 Monthly Separation Tank Maintenance	12 Months		TANK
6	Annual Thermal Imaging Switchboards Service	1 Years		PSB
7	6 Monthly Office/Room Inspection	6 Months		
8	Replacement of Wrapper Idle Tension Roller			SHRINK
12	1 Monthly Office/Room Inspection	1 Months		
14	Monthly Floor Inspection	1 Months		
15	hello			
16	MEX v 14 Testing	1 Months		
17	Repair hole in plasterboard wall			
18	tester	1 Months		
20	tester	1 Hours		
21	test	1 Hours		
22	test	1 Days		
23	test	1 Days		
24	test	1 Months		TEST
25	tester	1 Weeks		TEST
26	test	1 Weeks		LIFT
27	test	1 km		TEST
28	test	1 Weeks		ASSEMBLER

New PM | New Inspection | Details | Range | Print | Standard Job | Activator | Scheduler | Delete

Sample preventive maintenance form

Movie 13.3 Six Common Customer Expectations



Tap to view the video.

Telephone Communication

Remember, whether you are interacting with someone inside or outside of your company, that person is your customer! Always remember that exceptional customer service is why people choose your company over another. In all your dealings, strive to employ these six key attributes:

1) Friendliness

2) Empathy

3) Accuracy

4) Professionalism

5) Promptness

6) Honesty

Electronic Communication

In today's electronic world, professional communication by email is critical to your success within your organization. Email is viewed by many as a "casual" form of communication, therefore people can often times come across as unprofessional when sending emails. It is important to remember that an email is a written form of communication and is a representation of your professionalism. Emails are easily forwarded, so it is important to be clear, organized, and professional when you send them out.

When communicating via email try to have the email bring closure to work, not create more work for you. Always ask yourself if calling or visiting the recipient would be a better way to communicate. If you do write an email, it should be short and whenever possible your point made in just the subject line or the space in the preview pane. Also, do not assume other people are staring at their screens, waiting for your email—it may take a day, two days or longer for them to respond. Lastly, regarding your personal time management, a good rule is to never spend more than five minutes dealing with an email. When you go over this limit, stop and make a phone call.

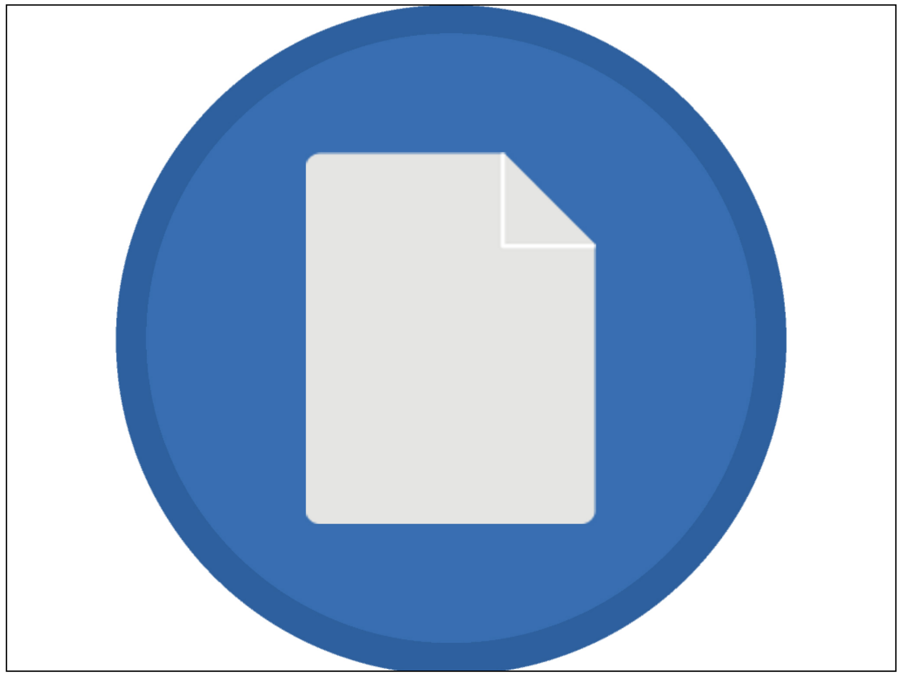
Review 13.4 Call Holds and Transfer Worksheet

Tap to test your knowledge of call holds and transfers.

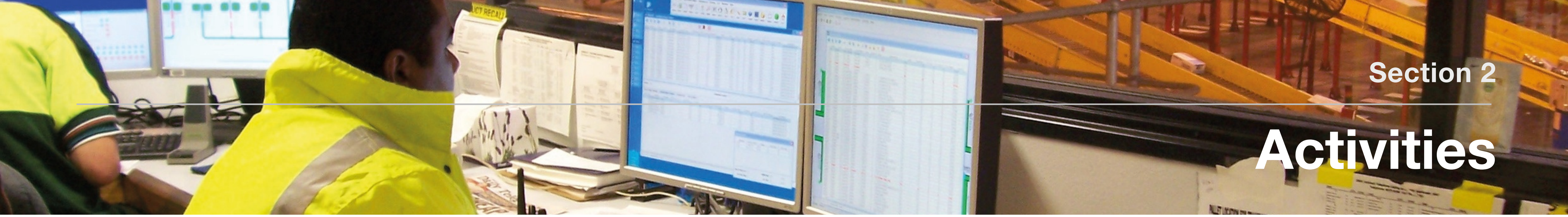
Review 13.5 Electronic Communication Worksheet

Tap to test your understanding of electronic communication in the workplace.

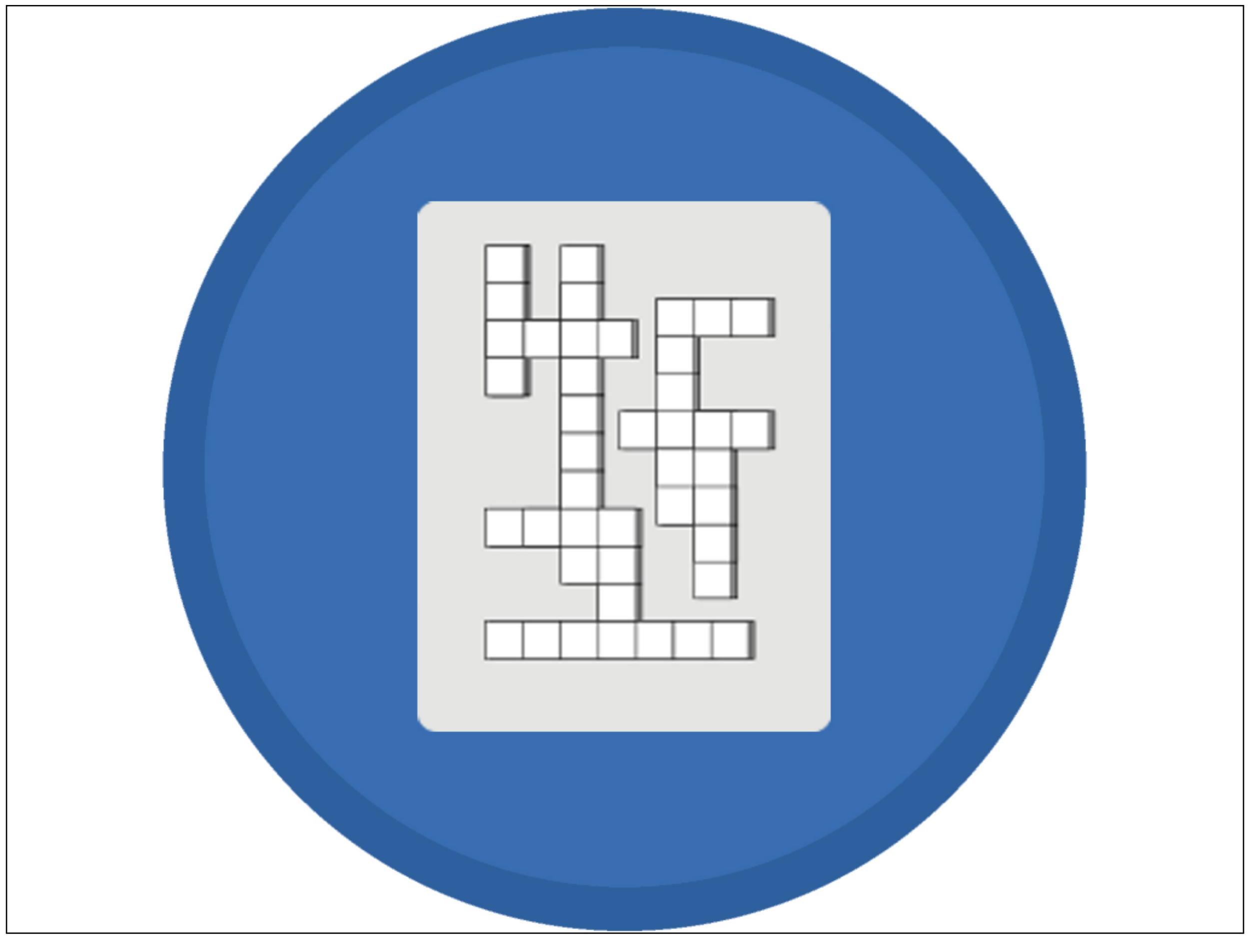
Interactive 13.1 Facilities Maintenance Work Order Procedures



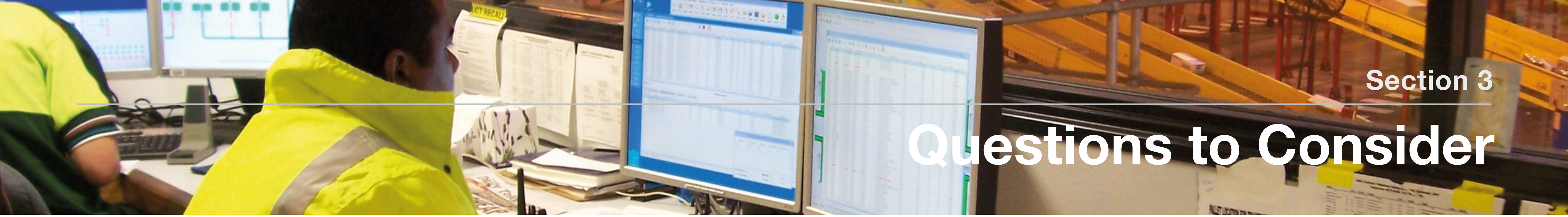
Tap for information related to facilities maintenance work order procedures.



Review 13.6 Communication Crossword



Tap to complete crossword puzzle.



Questions to Consider

My Personal Communication/Customer Service Action Plan

Students should respond to the following three statements as a written homework assignment or during a class discussion as directed by the instructor.

1. Three or more communication/customer service behaviors that I already do well are:

2. Three or more communication/customer service behaviors that I was reminded of during this class that I will begin to do again are:

3. Three or more new communication/customer service behaviors that I will begin doing when I return to my job are:

Glossary

AC

Alternating current is a type of electrical service that is provided into large buildings at 220/440 volts at 60 Hertz (cycles). This power is used for large motors and controllers of equipment.

AC/DC I/O Interface

A discrete interface that converts alternating current (AC) voltages from field devices into direct current (DC) signals that the computer can use. It can also convert DC signals into proportional AC voltages.

Accumulator

A container which stores fluid or air under pressure; used as an energy source or to absorb hydraulic and pneumatic shock. Common types are piston, bladder and diaphragm.

Accuracy

A measure of capability to repeat the same task multiple times without error.

Address Resolution Protocol (ARP)

Network protocol used to find the hardware or MAC address from an IP address

Aisle

The space between storage areas that provides access by material handling equipment and/or personnel.

Alignment

Positioning of a sensor so that the maximum amount of the emitted energy reaches the receiving sensing element.

American Standard Code for Information Interchange (ASCII)

Format for text files using 7-bit binary numbers for characters

Analog-to-Digital Converter (A/D)

A device that translates analog signals from field devices into binary numbers that can be read by the processor.

Anchoring

Attaching of a structure to the foundation or slab.

Angles

The intersection of any two planes, lines or sides.

Antenna

The tag antenna is the conductive element that enables the tag to send and receive data. Readers also have antennas which are used to emit radio waves. The RF energy from the reader antenna is "harvested" by the antenna and used to power up the microchip, which then changes the electrical load on the antenna to reflect back its own signals.

Artificial Intelligence (AI)

A subfield of computer science dealing with the development of computer programs that solve tasks requiring extensive knowledge.

AS/RS (Automatic Storage & Retrieval Systems)

An acronym that refers to a variety of systems under computer control for automatically depositing and retrieving goods from defined storage locations.

Atom

Basic structure of all matter.

Audio Video Interleave (AVI)

Multimedia format for audio and video data in a file for synchronous playback

Automated Dispenser

A series of vertical product dispensers which deliver individual units of products onto a conveyor.

Automatic Data Capture

The technology that support the identification and direct collection of data into a computer system or other micro-processor-controlled device without using a keyboard. Such technologies include bar code, radio frequency data communication, radio frequency identification and other emerging technologies.

Automatic Guided Vehicle System (AGVS)

AGV consists of one or more computer-controlled wheeled load carriers (normally battery powered) that runs on the plant floor (or if outdoors on a paved area) without the need for an onboard operator or driver. AGVs have defined paths or areas within which or over which they can navigate. Navigation is achieved by any one of several means, including following a path defined by buried inductive wires, surface mounted magnetic or optical strips; or alternatively by way of inertial or laser guidance.

Automatic Identification

A term that covers methods of collecting data and entering it directly into computer systems without human involvement. Technologies normally considered part of auto-ID include bar codes, biometrics, RFID and voice recognition.

Automation

A system that uses programmable equipment for production with less worker intervention. The equipment is capable of being altered and controlled by the program depending on the product.

Axis

The point that something, such as a tool, rotates around. The number of axes of a robot varies, but the majority of industrial robots are 4-axis or 6-axis.

Bar Code

A standard method of identifying product information of a particular item. The bar code is made as a label with bars and spaces representing numeric code that is input as data.

Bar Code Reader

A device used to identify and read a bar code symbol.

Battery Backup

A battery or set of batteries that will provide power to the processor's memory in the event of a power outage.

Bearing Life

The minimum expected life, in hours, of a group of bearings that are operated at a given speed and loading.

Bearings

Supporting devices that allow mechanical rollers to spin freely without load.

Benchmarking

A measurement process that establishes goals, operating targets and production expectations and can be used for comparison in an effort to achieve maximum efficiency of operation to include job evaluation, rating of performance, cost estimating and standards.

Broadband

The transmission of data where two or more signals share the same conductor. In more popular terminology, broadband is taken to mean high-speed data transmission.

Buffering

The process of storing "back-up" or reserve stock/inventory to absorb expected variations in usage between the time reorder action is initiated and the first part of new orders are received in stock.

Bumpers, Dock

Pieces of rubber or other resilient material located at the floor level of a dock opening to cushion and protect the building from truck trailer impact.

Cable Reel

An electrically, manually or spring-loaded device used to accumulate power cable on a reel so as to keep the cable from interfering with the piece of equipment to which the cable is bringing power.

Carousel

Carousels are a technology used to store items for eventual picking or retrieval in a circular motion (a type of AS/AR).

Carrier

Also known as a trolley. A unit that travels on the bottom flange of a monorail or patented track beam, jib crane or bridge girder to transport a load. Also refers to a trucking line used to transport materials to and from a distribution center.

Carts

Wheeled devices, generally made from plastic and/or metal, utilized to move items within a warehouse, distribution center or manufacturing facility.

Cavitation

Occurrence when air is being drawn into the suction side of a hydraulic pump which displaces fluid and becomes compressible.

Chain Conveyor

A form of powered conveyor used to transport heavy unit loads such as pallets and industrial containers.

Chocks (Wheel Chocks)

Triangular blocks of rubber, wood, or metal placed in front of, between or behind truck wheels to prevent accidental trailer movement.

Code

A collection of regulations related to a particular trade or environment. Computer language for programming operating parameters.

Collision Prevention

The use of sensors to detect the presence of objects and, through the use of integrated controls, prevent a collision between two objects from occurring.

Common Industrial Protocol (CIP)

Protocol for industrial automation applications

Compression

The creating of pressure on a gas.

Compressor

Device used to pressurize gases and rated by maximum pressure and volume.

Computer Aided Design (CAD)

A computer software system that allows the user to "draw" and design objects "on a screen" as opposed to the traditional method of drafting and prototyping.

Conductor Bar

Track mounted insulated bar used to transmit electric current to a vehicle.

Contrast (Optical)

The ratio of the amount of light falling on the receiver in the “light" state as compared to the “dark" state.

Controller

A device by means of which the operator controls the speed, acceleration, torque and/or direction of motor driven equipment.

Conveyor

A horizontal, inclined, or vertical device for moving or transporting bulk material, packages, or objects in a path predetermined by the design of the device, and having points of loading and discharge, fixed or selective.

Conveyor Belt

A belt used to carry materials and transmit power required to move the load being conveyed.

Cross Belt Sorter Conveyor

Another form of the tray sorter is where the tray is replaced by a short belt conveyor section with its direction of travel orientated perpendicular to the line of travel of the main train. At the proper moment the belt stepper motor is energized, propelling its load to either side and the desired takeaway lane.

Cross Docking

The process of moving merchandise from the receiving dock to shipping without placing it into storage locations. Information regarding the merchandise will be entered into the inventory and a transaction for shipping posted within one posting cycle.

Cubing

The amount of space occupied by an item or the volume within a system or building.

Cumulative Trauma Disorder

An injury that may be the result of stresses from repetitive motions such as twisting of the body during product movement or keyboard entry.

Current

Movement of electrons.

Cycle Time

A measurement of time required to order, fulfill, and deliver products and stock items. The two (2) major components of cycle time are order cycle and replenishment cycle.

Cylinder

A cylinder is a cylindrical tube that contains pressure allowing a sliding piston to apply force and motion.

Data Rate (Data Transfer Rate)

Speed in a radio frequency identification system, the rate at which data is communicated between transponder and the reader/interrogator, expressed in baud, bits or bytes.

Data Transmission

The use of sensors to transmit data via pulse-modulated light beam systems typically from host stations to mobile carriers such as AGVs or stacker cranes.

DC

In electrical terms, direct current (as opposed to AC which is alternating current). This very safe power is used to control sensors, motors, and manipulators for material handling.

Demurrage

A term associated with the charge (monetary) that can be levied against a shipper or consignee who detains a container, truck, ship or railroad car beyond the allotted time for loading and unloading of that piece of transport equipment. Such a monetary "penalty" is used to offset the loss to the carrier as a result of the delay. "Detention" is another word used for demurrage.

DIN Standard

Abbreviation for “Deutsches Institut fur Normung.” A collection of German industry standards that are recognized throughout the world.

Diode

Electronic one way check valve that controls the direction of current.

Dispersion angle

The degree of the angle of light.

Displacement

Size of a pump based on the volume of flow.

Distortion

Any disturbance that causes an unwarranted change in the form or intelligibility of a signal.

Domain Name System (DNS)

Naming system for computers, services, or other resources connected to the Internet or a private network

Drawing Legend

Information on a drawing providing a part or assembly number, a date, the name of the person who made the drawing with approvals, the scale, when it was first issued, and the current date and latest revision number.

Dryer

Device that removes moisture from fluids or gases.

Dunnage

Materials or devices used in the securing and/or bracing of products during shipments.

Duty cycle

The length of time an item is turned on or that a reader can be emitting energy.

DVOM (Digital Volt Ohm Meter)

Portable, hand held testing equipment used to test for voltage, amperage or resistance.

Earplugs

Personal protection device to protect and conserve hearing.

Extensible Authentication Protocol (EAP)

Point-to-point (P2P) wireless and local area network (LAN) data communication framework for authentication

Effective Beam

The usable beam diameter in photoelectric transmitted beam sensing which equals the lens diameter of the light source and receiver.

Electrification

The track mounted conductor system by which the moving equipment receives its electrical power. All of the electrical components that go into providing power to an electric overhead crane or jib crane. These components may include power bar, collectors, collector rings, pendent stations, and tagline/festooning.

Electronic Communication Network (ECN)

Forum or network for financial products trading outside traditional stock exchanges

Electronic Data Interchange

Communication of a data message, or messages, automatically between computers or information management systems, usually for the purposes of business transactions. A process by which the purchasing operation of one company is electronically linked with the order entry operation of another in order to "speed" ordering, reduce the amount of paperwork and keep errors to a minimum.

Emergency Stop

An equipment control that immediately stops motion and tasks of the system by cutting off the drive power.

End-Of-Arm Tooling (EOAT)

Application tools that are located at the end of the robot arm.

EPROM (Erasable Programmable Read-only Memory)

A type of nonvolatile, programmable, read-only memory.

Ergonomic

The design of working conditions to better accommodate the human body's capabilities and limitations (human factors). Ergonomics is also known as the study of work tasks with an emphasis on reducing to a practical minimum the physiological cost of doing the work.

EtherNet/Industrial Protocol (EtherNet/IP)

Protocol adapting the Common Industrial Protocol to standard Ethernet.

Failure Analysis

Using Maintenance Diagnostics tools, i.e. infra-red heat sensors, to locate hot spots in motors and controls, to locate the problems and repair before a fire could occur.

Feedback

A signal from equipment about conditions as they actually exist, rather than as the computer has directed them to exist.

Fiber Optics

Transparent fibers of glass or plastic used for conducting and guiding light energy. Used in photoelectrics as "light pipes" to conduct sensing light into and out of a sensing area.

File Transfer Protocol (FTP)

Protocol for computer files transfer on network

Filter

A device incorporated into a hydraulic or pneumatic system to remove contaminants from the oil or air.

Firewall

A firewall works as a barrier between networks, such as between a Local Area Network and the Internet. The firewall ensures that only authorized users are allowed to access the one network from the other. A firewall can be software running on a computer, or it can be a standalone hardware device.

First aid

Emergency treatment given to an injured person prior to professional medical care being available.

Fluid Power System

The transmission and control of power through the use of fluid pressure and volume.

Four-way fork entry

Openings on all four sides of a pallet or the base of a pallet container, which allow fork truck handling from any of the four sides.

Free Span

The distance between supports in a storage rack.

Frequency

The number of cycles a periodic signal makes in a unit of time. Usually expressed in Hertz (cycles per second).

Galling

The bonding, shearing, and tearing away of material from two contacting or sliding surfaces. Normally a result of lack of maintenance or part failure.

Gear Motor

A commonly used term that transmits power through a motor and gear reduction.

Gear Ratio

The comparison between the diameters of the drive gear or sprocket versus the diameter of the driven gear or sprocket.

Geometric Dimensions/Tolerances

A measurement technique that expresses position or form tolerances to establish construction sizes or repair tolerances.

Global Positioning System (GPS)

Developed for and managed by the United States military, GPS is a satellite navigation system. It consists of 24 satellites above the earth. They transmit radio signals to receivers placed on ships, trucks or other large assets that need to be tracked.

Graphics Interchange Format (GIF)

Bitmap format for images

Ground

Electrical reference point at which electrical circuit voltage can be measured or returned.

Harness

Distributes fall-arresting forces throughout the body.

Hazardous Motion

A possible dangerous or harmful motion.

Human-machine interface (HMI)

Hardware and software components for handling human-machine interactions

Hydraulic Motor

Motors that produce power that are driven by hydraulic pressure and volume that develop high torque and occupy a small space.

Hydraulic Pumps

Pump that pressurizes hydraulic fluids. They are rated by pressure and volume capacity.

Hypertext Transfer Protocol (HTTP)

Protocol for information systems where hyperlinks connect to hypertext documents

Hysteresis

The ratio of the distance the object travels between the points at which the sensor is turned on and off to the distance the object is from the sensor.

ID Filter

Computer software that compares a newly read identification (ID) tag or label with those within a database to establishing a match.

Industrial Trucks (Fork Lifts)

Wheeled vehicle used in the plant or distribution center, in the dock area (and in some cases also in the yard or on construction sites) to pick up, transport and deposit single loads. May be powered manually, by gasoline, propane or electrically.

Input Device

Any connected equipment, such as control devices (e.g., switches, buttons, and sensors) or peripheral devices (e.g., cathode ray tubes and manual programmers), that supply information to the central processing unit. Each type of input device has a unique interface to the processor.

Inputs/Outputs (I/O's)

The digital I/O's in a network is used to connect any device that can toggle between an open and a closed circuit. If, for example, a door switch is used as an input device, opening the door could trigger the upload and the sending of notification messages that the door is open. An output might, for example, be used to automatically start a siren when there is a motion detection trigger.

Inspection Tools

Calipers, micrometers, and other precision measuring tools to determine wear on parts.

Intelligent Reader

A term that is sometimes used to describe a reader that has the ability to filter data, execute commands and generally perform functions similar to a personal computer.

Interlock

The control of a device starting or stopping which is dependent upon the action of another device.

Intermediate System to Intermediate System (IS-IS; also written ISIS)

Routing protocol for moving information a network or connected computers or devices

International Standards Organization (ISO)

An organization established to promote the development of international standards.

Internet Control Message Protocol (ICMP)

Supporting protocol used by network devices for error messages and operational information with connecting to another IP address

Internet Protocol (IP)

Standard for directions as to where and how to go for packets over networks

Internet Relay Chat (IRC)

Protocol for text communication

Inventory Control

Maintaining specified product quantity to ensure product availability and planning needs.

Isometric Drawing

A three-dimensional type of drawing that shows both the horizontal and vertical sides of the object.

Joint Photographic Experts Group (JPEG)

Extension for image file

Just-In-Time (JIT)

The practice of timing inbound material flows so that they can arrive just in time before they are required. This results in smaller inventories. A JIT system requires close links among forecasting, production, scheduling, and purchasing groups as well as suppliers and carriers.

Kitting

The light assembly of component parts and sub-assemblies. Performed primarily by warehouse personnel.

Ladder Diagram

An industry standard line drawing for representing relay logic control systems.

Laser

An acronym for light amplification by the stimulated emission of radiation. Converts energy into laser light which, in turn, can be used to control the direction and movement of material handling equipment.

LED (Light Emitting Diode)

A semiconductor that emits a small amount of light when current flows through it in the forward direction. In photoelectric sensors, LEDs are used both as emitters for sensing beams and as visual indicators of alignment or output status.

Lever Type Limit Switch

A limit switch that uses a lever as the actuator for the purpose of coming into physical contact with the object to be detected.

Lifting Capacity

The rated load of a material handling lifting device (i.e., scissors lift, hoist) applied as uniformly distributed load.

Limit Switch

An electrical stop switch actuated by the motion of a machine or equipment.

Lockout/Tagout

An OSHA standard for the Control of Hazardous Energy. It addresses the practices and procedures necessary to disable machinery or equipment, thereby preventing the operation while employees perform servicing and maintenance activities. The standard describes limiting operation of equipment that is electrical, mechanical, hydraulic, pneumatic, chemical or thermal.

Machine Vision

A system which takes digital pictures of objects and codes and sends the pictures to a computer for interpretation.

Maintenance

Activities that are done at a regular or scheduled time to increase productivity and eliminate breakdowns.

Maintenance Diagnostics

A process by which the frequency, amount and cost of maintenance to buildings and machines is evaluated on an on-going basis.

Maintenance Log

A log that contains entries of machine breakdowns and repairs over a given time.

Manipulator

A movement assist device that is often equipped for handling different types of loads.

Material Handling

The movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal.

Memory

The part of a programmable controller that stores data, instructions, and the control program either temporarily or semi-permanently.

Mezzanine

Structural area that provides a secondary level to increase usable floor space in a distribution center.

Microprocessor

A silicon chip that is the heart of a computing system that is capable of performing the program execution, control, and data-processing functions of a central processing unit.

Moving Picture Experts Group (MPEG)

Alliance which sets standards for media coding, and file formats for various applications.

MSDS (Material Safety Data Sheet)

Acronym for the documents describing the hazard information about a given chemical or product.

National Electrical Manufacturers Association (NEMA)

NEMA standards are used to specify suitability of sensor and sensing system enclosures for various sensing environments.

Nestable pallet

A plastic pallet designed in such a way as to allow the pallet to fit or "nest" in another so as to facilitate better use of storage space. Pallets in which foot design is such that the pallets can stack within each other when empty.

Network News Transfer Protocol (NNTP)

Application protocol for sending Usenet news articles (netnews) between servers and posting and reading articles by end users.

Network Processing Engine (NPE)

Routing engine for the Cisco Universal Broadband Router

Nonvolatile Memory

A type of memory whose contents are not lost or disturbed if operating electrical power is lost.

Off-Line Programming

The ability to program computer operational parameters during operations so as to not stop production, but can be used as changes to the operation or as a back-up.

Ohm

A unit of measurement for resistance.

Open

A condition within a circuit without a complete pathway for current flow.

Open Shortest Path First (OSPF)

Link state routing protocol (LSRP) that uses the Shortest Path First (SPF) algorithm for the shortest connection path between devices

Order Picking

Order picking or order selection is the process of retrieving individual items (from storage locations) for the purpose of fulfilling an order for a customer.

Orthographic Projection

A drawing of a machined part or other object showing the vertical (frontal) plane, the horizontal (top) plane, and the profile (side) plane.

OSHA (Occupational Safety and Health Administration)

OSHA is an agency of the United States Department of Labor. OSHA's mission is to assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance.

Parallel

A type of electrical circuit that has more than one pathway for electrical current flow.

Personal Protective Equipment (PPE)

Refers to protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury.

Perspective Drawing

This type of drawing nearly presents an object as it appears to the eye or is seen in an actual picture.

Photoelectric

The development of electrical energy from a light source.

Photoelectric Sensor

A device which detects a visible or invisible beam of light and responds to a change in received light intensity to detect the presence or absence of a physical object.

Pick and Place Robot

A type of robot that moves parts from one place to another.

Pneumatic

The operation or powering of devices with the use of a gas.

Pneumatic Hoist

A motor driven hoist whose power is derived from pneumatically (compressed air or gas) powered motors. These hoists are often used in areas where electrical sparks are undesirable due to the possibility of explosion of fumes or materials.

Point-To-Point Motion

The user specifies points for the robot to follow along the path. The movement is point to point as opposed to a continuous motion.

Pressure

Hydraulic or pneumatic force developed by a pump and normally applied to a device.

Pressure: Maximum Rated

The maximum pressure at which a component should be operated on a continuous basis, usually the relief valve setting at maximum flow rate.

Preventative Maintenance

Periodically inspecting and repairing motors, conveyors, switches, forklifts, weight scales, etc. to insure these items are operational and accurate.

Procedure

A set of instructions to help guide activities and avoid harmful or dangerous situations.

Programmable Logic Controller (PLC)

industrial computer adaptation for manufacturing processes control; a solid-state control device that can be programmed to control process or machine operations. It consists of five basic components: the processor, memory, input/output modules, the power supply, and the programming device.

Proximity sensor

An electronic device that detects and signals the presence of a selected object. When used in association with a radio frequency identification system, the sensor is set up to sense the presence of a tagged or a transponder carrying object when it enters the vicinity of the reader/interrogator so that the reader can then be activated to effect a read.

Proximity Switch

This switch completes the circuit when a target comes close to the switch. It works over a short distance.

Pump

A device which converts mechanical energy into hydraulic energy to create pressure or movement of liquids. They may be either fixed or variable displacement.

Quality Control

The process of ensuring that the finished product, service, or system meets the specified criteria and constraints.

Queue

A wait or line of production.

R&D

Research and development

Radio Control

A communication medium through which motors, drives and controls receive direction over radio waves emitted from hand-held and equipment mounted transmitters.

Radio Frequency Identification (RFID)

A communication medium by which motor and controls are directed by means of high and low frequency radio transmission directives. RFID tags are labels with electronic chips embedded to allow for identification.

Radio Frequency Interference (RFI)

Interference caused by electromagnetic radiation at radio frequencies to sensors or to other sensitive electronic circuitry.

Random Access Memory (RAM)

A volatile, alterable memory that provides storage for the application program and data.

Receiving

The incoming process for supplied items from suppliers.

Refraction

The "bending" of light rays as they pass through a medium having one refractive index into a medium with a different refractive index. For example, as from air into water or from air into glass or plastic.

Reliability

A measure of the ability to perform similar operations multiple times based on similar operating conditions.

Repeatability

The variability of the position and orientation as the operation makes the same moves under the same conditions.

Reservoir

A container which stores the liquid in a fluid power system.

Resistance

The opposition to electrical current flow.

Respirator

Personal protection device used to filter breathing air of impurities.

Routing Information Protocol (RIP)

Protocol with hop count limit to prevent routing loops by implementing a limit on the number of hops allowed in a path from source to destination

Safeguard

Protects workers from hazardous situations through physical barriers or guidelines to follow.

Safety Procedure

A set of instructions to help avoid harmful or dangerous situations.

Sectional View

A drawing of a machined part or other object showing a cut-away view from inside the part.

Secure Shell (SSH)

Cryptographic protocol for operating secure operations over an unsecured network

Self-Guided Vehicle

A Self-Guided Vehicle (SGV) is an autonomous, self-directed robotic delivery system for the movement of product in diverse environments. An SGV operates independently to navigate around fixed and moving obstructions without the need for an external guide path network or sensors, such as buried wires or mounted magnetic or optical strips. Instead, an SGV uses on-board sensory inputs and navigational software to dynamically plot a path as the robot moves to each goal or task destination.

Semiconductor

Solid state device that is used in the application of electronics.

Sensor

An electronic device designed to detect a specific phenomenon, such as the presence or absence of a physical object, and used to affect control over a designated process.

Series

A type of electrical circuit that has a single pathway for current flow.

Server

A server is a computer program that provides services to other computer programs in the same or other computers. A computer running a server program is also frequently referred to as a server. In practice, the server may contain any number of server and client programs.

Shelf

A storage surface located above the floor level and usually contained in shelving systems or rack systems.

Shelf Life

The amount of time an item may be stored before it is unusable.

Shock

A physical condition where a person is traumatized by the effects of an injury.

Short

A condition within an electrical circuit that allows current flow through a faulty or accidental connection between two points of different potential.

Side Loader truck

An industrial lift truck with capabilities that can deliver a load to a storage rack in a sideways movement in each direction allowing for narrow aisles to save floor space.

Simple Network Management Protocol (SNMP)

Protocol for obtaining information about devices on IP networks and changing that information to change device operation.

Six Sigma

A process improvement initiative that troubleshoots operation concerns, locates problems, finds solutions, and reduces costs.

Smart Card

A card with a magnetic stripe to capture and present information.

Solenoid

A coil containing a moveable iron core that is used for transforming electrical energy to mechanical movement. The core moves as the electrical current moves through the coil.

Simple Network Management Protocol (SNMP)

Protocol for obtaining information about devices on IP networks and changing that information to change device operation.

Sprocket

The device that drives or is driven by a chain.

Standard

A collection of voluntary rules developed through consensus and related to a particular trade, industry or environment.

Stock (Storage)

Items that are held in inventory.

Storage

The process or act of positioning and placing items (cartons, packages, pallet unit loads, etc.) in area set aside for holding these items or staging these items for shipment.

Strain

The amount of deformation or flex a material undergoes with the application of load.

Strapping

A load stabilizing and securing method where a variety of materials can literally be used to wrap or tie down a load or individual item for movement and protection.

Stress

The load or force applied to a material.

Stretch Wrapping

Unitizing a load by stretching and wrapping a plastic sheet tightly around and over the load.

Supervisory Control and Data Acquisition (SCADA)

Computer control system architecture for network data and graphical user interfaces (GUI) for process management, including peripheral devices such as programmable logic controllers (PLC) and discrete proportional-integral-derivative (PID)

Supply Chain Management

Supply Chain Management is the integration and coordinated execution of all the business processes used to plan and execute the flow of material, goods, products and related information between the many sources and points of use throughout the supply chain.

Surface Hardness

The hardness of the outside surface of a material.

Surface Roughness

This is height value of the surface finish. Values range from 1 (super fine) through 1000 (extremely rough).

Symbols

Pictures or diagrams used to represent a function or component.

Teach Mode

The control state that allows the generation and storage of positional data points within a robotic operating system.

Tensile Strength

The maximum stress a material will withstand prior to failure.

Tensile Stress

The force per unit area that results in the application of tension forces.

Tension

The application of forces in opposite directions.

Three-way Valve

A 3 port valve (in, out and work) normally used with a single acting cylinder or uni-directional motor.

Time and Motion

A work measurement process that takes into consideration the time it takes to perform a task in a normal or variant effort or pace. The time and effort needed to accomplish a task.

Tool Safety

The proper procedures used when operating tools to minimize risks to personnel and equipment.

Torque

Twisting power or force.

Tracking Software

Software programs developed specifically to enhance the "tracking" or location of product, returnable containers, pallets and merchandise.

Transducer

A device used to convert physical parameters, such as temperature, pressure, and weight, into electrical signals.

Transistor

Three wire electrical semiconductor that allows voltage to flow through the circuit when a signal is received.

Transmission Control Protocol/Internet Protocol (TCP/IP)

TCP (transmission control protocol) and IP (Internet protocol) combination

Troubleshooting

The process of determining the basic cause of a failure so repairs can be accomplished.

Unshielded

An inductive proximity sensor configuration that requires a metal-free zone around the sensing face.

V – Belt

A flexible power transmitting device used with pulleys that is placed to drive a motor, pump, or other rotating motion device.

Valve

A device which controls fluid or gas flow rate, direction, or pressure.

Variable Frequency Drive (VFD)

An AC electrical input control that converts the 60 hertz (cycles) to both higher and lower cycles which increases and decreases motor RPM.

Viscosity

Thickness or resistance to flow of a fluid.

Voice Headset

Earphones and an attached microphone used by operators to interact with computer systems while keeping both hands free to simultaneously perform other tasks.

Voice Recognition

The ability to receive, recognize and/or understand voice commands. Usually associated with computer directed systems utilized for process control and data collection.

Volt

Unit value that represents voltage.

Voltage

Electrical pressure.

Walking Stacker

A power operated device controlled by an operator standing behind it, which lifts, stacks, and transports pallets.

Wattage

The unit value for power.

Waveform Audio File Format (WAVE or WAV)

File format for audio bitstream on PCs.

Welding

Any method of joining two materials by a cohesive fusion of the materials.

XYZ Coordinates

A reference to the most common names given to the lines forming a three dimensional solid. These coordinates are used for programming robots and other machine tools.

Yield Strength

The guaranteed minimum yield point stress of a material as specified by the supplier.