



Analysis of Various Lockout Tagout (LOTO) Devices used in Industrial Safety

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Abstract

Industries have equipment and processes which use hazardous energies like electrical, chemical, gravity, thermal, hydraulics etc. These hazardous energies are handled with utmost precaution and control of these hazardous energies ensures and enhances Safety. Factories Act-India, Occupational Safety and Health Administration, USA(OSHA) and others have defined a very detailed Hazardous Energy Control Program known as Lockout Tagout(LOTO) where these hazardous energies are controlled. These detailed LOTO procedures requires various LOTO devices to control the hazardous energies. These LOTO devices have many varieties (design, sizes, shapes etc.) based on the application. This paper aims to study various LOTO devices used for controlling various hazardous energies like electrical, mechanical, gravity, chemical, hydraulic, thermal, their specifications, application and limitations on a CNC Machining Centre. This will help in identification and use of most appropriate LOTO device for controlling specific hazardous energies. This can be very efficient in safety enhancement and reduction in safety related incidents.

Keywords: Hazardous Energy, Internet of Things(IoT), Lockout Tagout (LOTO), Safety and Accident.

1. Introduction

We use different type of hazardous energy[1,2] like electrical, pneumatics, hydraulics, chemical, potential etc. in our machines in Industries[3]. The person working with or near the machines or processes must be safe from the risk and use hazardous energy control procedure or Lockout Tagout (LOTO) procedure[4]. A wide variety of LOTO devices[5,6] is available for controlling different hazardous energies. Selection of right LOTO device is critical to ensuring safety as use of inadequate or wrong LOTO device may result in severe accident. As per National Crime Records Bureau (NCRB), India Accident and Death Data in 2015, accidental deaths due to electrocution (Year 1984-1,160 deaths to Year 2015-9,986 deaths) and other unnatural causes (Year 1984-130,387 deaths to Year 2015-336,051deaths) has increased[7].

2. Background and Significance of the Study

Occupational Safety and Health Association (OSHA), USA[4] and various other Safety organizations[8,9,10] in the world have well defined LOTO procedures. The person going to operate, repair or service of the equipment which has hazardous energy must follow these procedures. The person may meet with an accident if the procedure is not followed[11] with relevant LOTO device(s).

3. LOTO Procedures and its Application as per Various Codes and Standards

An exhaustive literature review was done to understand the theoretical significance of the concept and application of various LOTO devices[5,6,12]for effective Hazardous Energy Control Program.

3.1 OSHA specified LOTO procedure and The Factory Act 1948

OSHA have well defined Control of Hazardous Energy Program (LOTO) procedures [4]. As shown in Fig-1 The person going to operate, repair or service of the equipment which has hazardous energy must follow these steps defined in OSHA Standard Number 1910.147.App.A The steps marked with Red stars like notify Attach LOTO Device and Verify Lockout are the steps where the use of right LOTO device would ensure effective control.



★ LOTO (Lockout Tagout) devices are applied here
Fig. 1: OSHA defined LOTO Procedure, OSHA Standard Number 1910.147.App.A: Typical Minimal Lockout Procedure



Table 1: LOTO device(s) used in Industries for control of hazardous energies

Sl. No.	Type of Hazardous Energy	LOTO Device(s)	Salient Features	Limitations
1	Electrical	Electrical Panel Lockout	<ul style="list-style-type: none"> Higher Voltage 230V-440V AC Transparent cover improves visibility 	<ul style="list-style-type: none"> Non-Standard Fragile/Prono to Breakage Panel needs modification to fit these devices
2	Electrical	Electrical Panel Handle Lockout	<ul style="list-style-type: none"> Wide Voltage Range 0-440V AC and 0-24V DC Easy fitment and visible 	<ul style="list-style-type: none"> Non-Standard Arc Flash Hazard Prone Area Fragile/Prono to Breakage Panel needs modification to fit these devices
3	Electrical	Push Button Lockout	<ul style="list-style-type: none"> Regular Range 0-230V AC and 0-24V DC Customized for Emergency and Normal control Push Buttons Adjustable for oversize Push Buttons. 	<ul style="list-style-type: none"> Non-Standard Fragile/Prono to Breakage Mounting Surface needs modification to fit these devices
4	Electrical, Pneumatics, Hydraulics and Gravity	Cable Lockout	<ul style="list-style-type: none"> Multiple energy sources can be lockout Adjustable for many locations in single plane. 	<ul style="list-style-type: none"> Non-Standard Lengthy, Difficult to hand carry Damages other parts while lockout
Sl. No.	Type of Hazardous Energy	LOTO Device(s)	Salient Features	Limitations
5	Pressurized Water, Liquid, Oil, Gases, Compressed Air	Gate Valve Lockout	<ul style="list-style-type: none"> Multiple energy sources can be lockout Visible 	<ul style="list-style-type: none"> Can be broken or removed easily Gets damaged in open areas
6	Pressurized Water, Liquid, Oil, Coolant Compressed Air(0-7 Bar)	Ball Valve Lockout	<ul style="list-style-type: none"> Multiple energy sources can be lockout Visible 	<ul style="list-style-type: none"> Can be broken or removed easily Gets damaged if applied in open areas.
7	Pressurized Water, Liquid, Oil, Gases with High Flow >10LPM	Butterfly Valve Lockout	<ul style="list-style-type: none"> Multiple energy sources can be lockout Large in Sizes (> 150 mm Diameter) 	<ul style="list-style-type: none"> Can be broken or removed easily Gets damaged if applied in open areas.
8	Gas stored and used through Gas Cylinders	Gas Cylinder Lockout	<ul style="list-style-type: none"> Customized as per Cylinder Sizes Easy to apply 	<ul style="list-style-type: none"> Non- Standard Can be broken or removed Easily
9	Electrical	Electrical Plug Lockout	<ul style="list-style-type: none"> Regular Range 230V AC,440V AC Easy to Apply 	<ul style="list-style-type: none"> Non Standard Can be broken or removed easily
10	Compressed Air (0-7 Bar)	Air Service Unit (FRL) Lockout	<ul style="list-style-type: none"> Customized as per FRL size(s) Easy to Apply Some devices are with quick release features. 	<ul style="list-style-type: none"> Non Standard Can be broken or removed easily
11	Compressed Air (0-7 Bar) and Gases	Pneumatic Lockout	<ul style="list-style-type: none"> Customized as per tube size(s) Tube(s) life gets reduced due to folding for applying lockout 	<ul style="list-style-type: none"> Non Standard Can be broken or removed easily
12	Electrical	Circuit Breaker(CB) Lockout	<ul style="list-style-type: none"> Customized as per CB Wide voltage Range0-440V 	<ul style="list-style-type: none"> Non Standard Difficult to apply and Can be broken or removed easily

3.2 Definitions as per The Occupational Safety and Health Administration (OSHA) standard for The Control of Hazardous Energy (Lockout/Tagout), Title 29 Code of Federal Regulations (CFR) Part 1910.147(b)

a. Affected Employees –We have Employee or Employees whose job requires to use or operate the equipment or machine on which repair, servicing or maintenance is being performed under hazardous energy controlled condition or lockout or tagout, or work in an area in which such servicing, repair or maintenance is being carried out.

b. Authorized Employees- Employees needs to be trained, skilled and then authorized to carry out lockout or tagout. These employees are well trained to perform repair, service or maintenance of the equipment or machine.

c. Energized-It is a condition or state where machine or equipment is connected to an energy source(electrical, mechanical, chemical, thermal, hydraulic etc.) or connected to stored energy or containing residual energy.

d. Energy Isolation Devices-This is generally a mechanical device which is used to isolate source of energy and physically prevents the transmission or release of energy

e. Energy Source – Machine, equipment or processes requires energy sources like Mechanical, Electrical, Hydraulic, Chemical,, Thermal, Pneumatic , or Other energy

f. Lockout- This is a process of placing of a positive means such as lockout device on an energy isolating device, in accordance with an well-established, defined and approved procedure, ensuring that energy isolating device and equipment being controlled cannot be operated until lockout device is removed

g. Lockout Device- We need to use a device that uses a positive means such as a lock, either key or combination type, to hold an energy isolating device in the safe position and prevent the energizing of a machine or equipment Blank flanges and bolted slip blinds are also included as Lockout device.

h. Maintenance, Servicing and/or Repair- We need to perform many activities at our workplace with equipment, processes or machines such as Constructing, Installing, Setting up, Adjusting, Inspecting, Modifying, and Maintaining and/or servicing machines or equipment

i. **Tagout**-This is a process of placing of a tag (tagout device is generally good quality paper tag) on an energy isolating device, in accordance with an well-established, defined and approved procedure, ensuring that energy isolating device and equipment being controlled cannot be operated until tagout device is removed

3.3 Application of the Energy Control Procedure (Lockout)

1. **Prepare for shutdown**- Understand different on workplace or equipment hazards, Notify(inform as per defined procedure) to other workers of shutdown
2. **Shut down equipment**- Use the normal shutdown procedures, Turn all relevant switches, valves and devices to OFF/Neutral
3. **Isolate all energy sources**- Use energy isolation devices in accordance with established procedures to prevent release or transmission of energy,
4. **Apply Locks and Tags**- Apply Locks and Tags to Mechanical Valves, Breakers, electrical disconnects, Valves.
5. **Release Stored Energy**- Block/disconnect lines, Discharge capacitors, Block or release springs, Block elevated or extended parts, Drain fluids, Relieve system pressure , Vent gases, Allow system to be in safe temperature (or use PPE),Apply any additional locks and tags needed, Check that other workers are clear of potential hazards
6. **Verify equipment isolation**- Check that locking devices are secure at it's place, Attempt normal startup of the equipment or machine, Return control to OFF/Neutral
7. **Perform the task**- Perform repair, maintenance or service task.
8. **Release from Lockout**-Ensure Task has been completed and equipment or machinery is properly assembled and all tools(hand tools, tackles, instruments etc.) removed, Ensure that employees are in safe zone and outside of danger zones and are notified that lockout tagout devices are being removed, Remove Lockout Tagout (LOTO) devices by authorized employee who applied in.

4. Scope, Study, Experiment and Trials

4.1 Scope

We have defined the scope limited to study of widely used conventional Lockout devices on CNC Machine[14]which covers servicing, repair and maintenance of equipment and machine in which unexpected startup or energization or release of stored energy could cause accident, injury to employees refer OSHA1910.147(a)(1).

4.2 Study of Various Lockout Devices

There are different lockout device(s) [5,6,15,16,17] for different energy isolating devices. Systematic study has been carried out to study these devices, their usage, specifications, manufacturer, complexities etc.

4.2.1 Electrical Panel Lockout

Equipment have electrical panels with electrical supply 440V,230V,110V,24V,12V etc, These panels are fitted with various push buttons, emergency mushroom push buttons, switches, switches with lever etc. These needs to be lockout with correct Lockout devices.



Fig. 2: Electrical Panel Lockout Device (Make -Bradyid)

4.2.2 Electrical Panel Handle Lockout

Electrical Panels has handles for changing the position to on/off the equipment. These handle requires special handle lockout devices.



Fig. 3: Electrical Panel Handle Lockout Device(Make -Bradyid)

4.2.3 Push Button Lockout

Emergency Stop ,Mushroom Push Buttons, Normal push buttons are used more frequently by operators for different functions of the equipment and processes .These push buttons requires special lockout device.



Fig. 4: Push Button Lockout Device (Make -E Square)

4.2.4 Oversize Push Button Lockout

Some of the equipment is fitted with oversize Electrical Push Buttons on the electrical panels or on control stations. These requires special lockout device.



Fig. 5: Oversize Push Button Lockout Device (Make -E Square)

4.2.5 Lockout Pad Locks

These padlocks are applied on lockout device to lock the device. These locks can be opened with respective dedicated keys only.



Fig. 6: Lockout Pad Locks (Make –E Square)

4.2.6 Lockout Hasps

There are times when many people need to work on the equipment or multiple energy needs to be lockout. Safety lockout hasps are used when we need to use multiple or many padlocks by each authorized person to isolate one energy source. A hasp is placed through the relevant isolating point and closed, allowing each authorized person to place their padlock on it.



Fig. 7: Lock out Hasps for Multiple Locks and Group Lockout (Make –Bradyid)

4.2.7 Cable Lockout

These devices are used when different energy sources are at distance and coordinates. Cables are flexible and can be used in different applications.



Fig. 8: Cable Lockout Devices (Make –E Square)

4.2.8 Gate Valve Lockout

Equipment needs fluids and gases like pressurized water, compressed air, hydraulic oil, coolant oil and gases which can be very harmful. There are Gate Valves which requires to control flow of these fluids and gases. We need to lock out these gate valves with correct lockout devices.



Fig. 9: Gate Valve Lockout Devices (Make –E Square)

4.2.9 Ball Valve Lockout

Equipment needs fluids and gases like pressurized water, compressed air, hydraulic oil, coolant oil and gases which can be very harmful. There are Ball Valves(Shut Off Valves) which requires to control flow of these fluids and gases. We need to lock out these Ball Valves with correct lockout devices.



Fig. 10: Ball Valve Lockout Device (Make –LOTO)

4.2.10 Butterfly Valve Lockout

Equipment needs fluids and gases like pressurized water, compressed air, hydraulic oil, coolant oil and gases which can be very harmful. There are Butterfly Valves which require to control flow of these fluids and gases. We need to lock out these Butterfly valves with correct lockout devices. Butterfly valves are generally bigger than gate valves and ball valves. They control larger flow rate.



Fig. 11: Butterfly Valve Lockout (Make –E Square)

4.2.11 Gas Cylinder Lockout

Equipment and processes needs gases like Argon, Oxygen, Nitrogen LPG (liquefied Petroleum Gas), PNG (Piped Natural Gas) etc. These gases are pressurized and can be very harmful if not controlled. There are Gas Cylinder Lockout devices to apply lockout on cylinders.



Fig. 12: Gas Cylinder Lockout Device (Make –E Square)

4.2.12 Electrical Plug Lockout

Equipment and processes are fitted with electrical plugs. Many daily use appliances also have electrical plugs. WE need to lockout these plugs to be safe and avoid any harmful incident. Electrical Plug Lockout devices are used to lockout electrical plugs.



Fig. 13: Electrical Plug Lockout Device (Make –E Square)

4.2.13 Air Service (Filter- Regulator- Lubricator) Unit Lockout

Some Equipment and processes needs compressed air and fitted with FRL (Filter Regulator Lubricator) Unit. These units needs to be lockout to control hazardous energy.



Fig. 14: Air Service Unit (FRL) Lockout Device (Make –Festo)

4.2.14 Pneumatic Lockout

Some Equipment and processes needs compressed air, which flows through different pneumatic tubes and hoses. These hazardous energy (1-12 Bar pneumatic pressure) needs to be controlled with correct pneumatic lockout devices.



Fig. 15: Pneumatic Lockout Device (Make –E Square)

4.2.15 Circuit Breaker Lockout

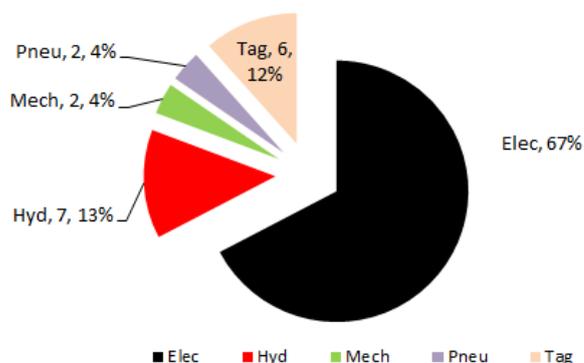
Most of the Equipment and processes requires electricity and fitted with Circuit Breakers[15] to control the electricity. These Circuit Breakers comes in many varieties. Most widely used Circuit Breakers are known as MCB (Miniature Circuit Breakers).Many lockout devices are available to lockout these circuit breakers.



Fig. 16: Circuit Breaker Lockout Device(Make –Bradyid)

4.3 Data Collection and Analysis of Lockout devices applied on a Machine

We have collected data in Oct 2017 from Makino CNC Machine (Model A81) for Gear Box Machining; This CNC Machine[14] uses various hazardous energies, lockout devices and activities. Total 52 Activities requires Lockout Tagout in which majority(67%) are electrical lockout followed by hydraulic lockout (13%).



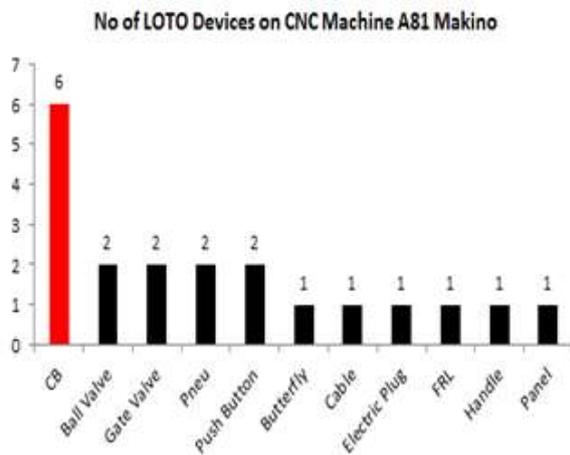


Fig. 17: Pie Chart of Lockout Tagout Activities and Bar Chart of LOTO devices on CNC Machine –Makino A81

- The machine has 16 different type of Lockout devices in which majorities are circuit breaker lockout device. Further Analysis of these 6 different CB(Circuit Breakers) has been done,
- There are 4 MCB(Mini Circuit Breakers) of different ratings which requires 4 different type of MCB(Mini Circuit Breakers) Lockout devices out of these 6 CB (Circuit Breakers)
- The above study and data reveals complexity of different lockout activities and devices. Specification and Type of MCB Lockout devices depend on specifications and type of MCBs. Further data were collected for different MCB and respective Lockout devices[16].

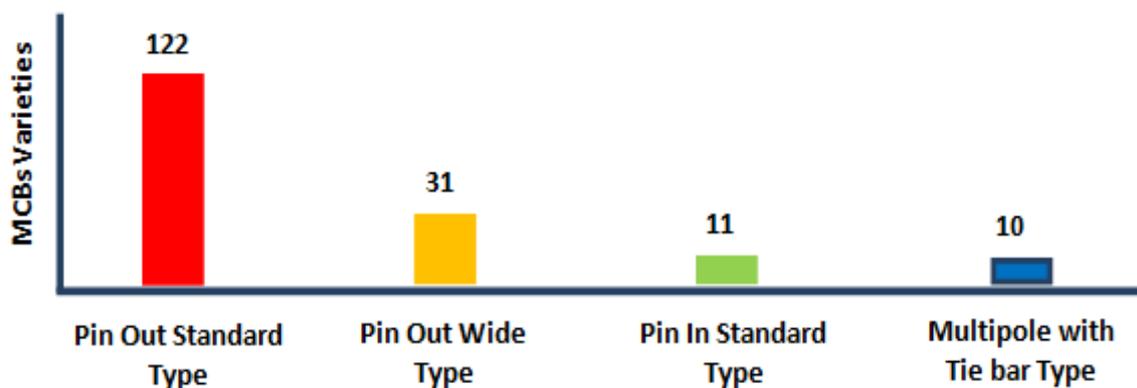


Fig. 18: Bar Chart for Different MCB Lockout Devices and various MCBs



Fig. 19: Manufacturer of Different Type of MCB Pin Out Standard Lockout Devices

4.3.1 Conclusion from Data Analysis and Study

Following conclusions can be made based on the data

- There are various energy sources and energy isolating devices
- There is variety of energy isolating devices in different specifications by different manufacturer
- Lockout devices do not have any specified standard, manufacturer makes customized devices.
- These devices do not have testing and endurance data which shows their life.
- The inspection of these devices is visual/manual.
- Sometimes these devices do not get right fitting on the energy source and can be removed easily.
- Some of these devices are bulky/heavy and cannot be hand carried.

- Lockout Tagout Procedure is standardized however the lockout devices are still custom made.

5. Recommendations and Future Scope

- Extensive theoretical and practical training required for each type of lockout device for respective energy isolating devices.
- The Lockout devices can be standardized for respective energy isolating device.
- Further studies can be made for other lockout devices based on identified hazard.

References

[1] E. Charlot, Sylvie Nadeau, Jean-Pierre Kenne, Optimal production, maintenance and lockout/tagout control policies in manufacturing

- systems, International Journal of Production Economics,107, 2007,435-450.
- [2] National Institute for occupational Safe, Guidelines for Controlling Hazardous Energy During Maintenance and Servicing, Bibilogov,2013
- [3] Hajji, A. , Gharbi, A. , Kenne, J.P. and Hidehiko, Y., Production and changeover control policies of a class of failure prone buffered flow-shops, Production Planning and Control, Vol. 20(8),2009,785-800
- [4] The Occupational Safety and Health Administration (OSHA) standard for The Control of Hazardous Energy (Lockout/Tagout), Title 29 Code of Federal Regulations (CFR) Part 1910.147
- [5] E-Square Alliance Private Limited, Lockout Tagout Catalogue, 2012-2013
- [6] Bradyid Lockout Tagout online Product Catalogue, <https://www.bradyid.com/en-us/category/lockout-tagout/200050498>, March 2018
- [7] NCRB, National Crime Records Bureau, Ministry of Home Affairs, Government of India, Accidental deaths and Suicides in India 2015,7-50
- [8] Philip P Purpura, safety in the workplace-security and the loss prevention: an introduction, Butterworth Hinemann, 2013.
- [9] Edward V. Grund, Lockout/Tagout: The Process of Controlling Hazardous Energy (Occupational Safety and Health), National Safety Council , 1995.
- [10] India, The Factories Act, 1948 (Act No 63 of 1948), Chapter IV Safety, Section 22 - Work on or near machinery in motion. Section 24- Striking Gear and devices for cutting off power.
- [11] Boulet, J.F. Gharbi, A. and Kenne, J.P. ,Multi-objective optimization in an unreliable failure-prone Manufacturing system, Journal of Quality in Maintenance Engineering, 15(4),2009,397-411.
- [12] Parker David, Yamin Samuel, Brosseau Lisa,Gordon Robert, MostIvan,Stanley Rodney, Findings from the national machine guarding program: A small business Intervention: Lockout Tagout, Journal, Journal of Occupational and Environmental Medicine,58,2016,61-68
- [13] Mark M. Moron, Lockout/Tagout Program: A Complete Compliance Program (Osha Compliance), Safetycertified.Com Inc; Reprint edition,1992.
- [14] Machine Maintenance Manual, Makino a81 Horizontal Machining Centre, Makino Japan, 2013.
- [15] Circuit Breaker Lockouts,<https://www.totallockout.com/online-store/electrical-lockout/circuit-breaker-lockouts/>,March 2018.
- [16] Circuit Breaker Lockout Reference Guide, Btadyid, https://www.bradyid.com/downloads?filename=Circuit_Breakout_Lockout_Brochure.pdf, March 2018.
- [17] KRM LOTO Mini Booklet, KRM Corporation, India, http://www.krmcorporation.com/images/download /KRM_LOTO_MINI_BOOKLET.pdf, March 2018