Pneumatic and Hydraulic Cylinder Presses

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Introduction

Pneumatic and hydraulic cylinder presses are some of the most common machines used in manufacturing. They are used to assemble or form products from wiring harnesses to metal parts and even press fit ROSS valve internal assemblies. They are relatively simple machines consisting of a cylinder, a control valve, and a method to actuate the valve. They are popular because they are simple yet can produce a lot of force to perform a great deal of work with a small table-top machine reaching up to 13,000 lbf. This also makes them potentially hazardous machines that require a safety control system to prevent motion when an operator requires access to the point of operation.

Standards

Pneumatic Press Safety; ANSI B11.2:2013, CSA Z142:10, & ISO 16092-4:2017

Because these machines are very specific and hazardous there are C Type standards for pneumatic and hydraulic cylinder presses. This means that the machine has specific minimum requirement that typically cannot be reduced or circumvented through the use of risk assessment and risk reduction methods. This is not to say that risk assessment and risk reduction is not needed as they will be required when the machine is integrated into a more complete system.

Established in 1921, ROSS is headquartered in Troy, Michigan and is ISO certified. ROSS designs and manufactures pneumatic & hydraulic valves, control systems, and is universally recognized as a global leader in fluid power safety solutions and poppet valve technology. ROSS provides standard products and customized ROSS/FLEX® solutions for machinery and automation.

The specific C Type standards are:

- ANSI B11.2:2013 Safety Requirements for Hydraulic & Pneumatic Power Presses
- CSA Z142:10 Code for power press operation: Health, safety, and safeguarding requirements
- ISO 16092-4:2017 Machine Tool Safety – Presses – Part 4: Safety requirements for pneumatic presses
- ISO 16092-3:2017 Machine tools safety – Presses – Part 3: Safety requirements for hydraulic presses

Specific C Type standards include ANSI, CSA & ISO

ANSI REQUIREMENTS

ANSI requires that the fluid power circuits that control hazardous motion meet section 8.8 "Performance of the Safety Related Function(s)". It requires that when a single failure occurs that the safety function shall:

- prevent initiation of hazardous motion
- initiate a stop command and prevent re-initiation, or
- prevent re-initiation at the next stop command.

This system must be control reliable as defined in B11.19 or meet Category 3 Performance Level d at a minimum.

Both ANSI & CSA require control reliability in the safety system

CSA REQUIREMENTS

CSA is nearly identical stating Hydraulic/pneumatic circuits used for press cycle initiation and controls that affect operator safety at the point of operation shall meet the requirements of Clause 8 which states that "Safety-related control systems and their parts shall be designed, constructed, and applied in such a manner that:

(a) a single fault in any part does not lead to loss of the safety function;
(b) a single fault is detected at the time of failure. If such detection is not practicable, the fault shall be detected at the next demand upon the safety function;
(c) when a single fault occurs, the safety function is always performed, and a safe state is maintained until the fault is corrected; and
(d) all reasonably foreseeable faults are detected.

It also has some more specific references for pneumatic presses:

7.1.4.11.3 Pneumatic presses

Interlocks or monitoring circuits shall be provided to prevent or stop slide/ram/platen motion if:

(a) power to a safeguarding device fails; or
(b) the valves that control the hazardous motion fail.

CSA also includes specific pneumatic press & multiple-cylinder system references

7.3.3.2 Multiple-cylinder systems

Where there is a risk of injury due to unintended gravity falls and press tonnage is developed with the use of two or more cylinders, at least two of the cylinders shall be independently controlled by a cyclically monitored valve capable of independently holding the slide/ram/platen/die combination in the event of a mechanical or hydraulic/pneumatic failure of a cylinder. If the cylinders are not capable of independently holding the slide/ram/platen/die, at least one of the following shall be provided:

(a) a monitored mechanical restraint device(s); or
(b) a monitored hydraulic restraint device(s).

The restraint devices shall operate automatically and shall be effective throughout all portions of the stroke/cycle during all times that operators have access to the tools, pinch points, or danger zone. Each restraint device shall be individually capable of holding the slide/ram/platen and all of its attachments.

ISO 16092-4 REQUIREMENTS

ISO 16092-4 starts with similar recommendations regarding gravity issues.

ISO 16092-4 has specific PL requirements based on input device and hazardous movement

5.3.7 Prevention of unintended gravity fall during production (down-stroking press)
5.3.7.2 The restraint device shall consist of one or more of the following measures, provided that they are capable of holding up the slide/ram:

a) return spring
b) clamping device
c) two pneumatic restraint valves, one of which is fitted as close as possible to the cylinder outlet, using flanged or welded pipework, capable of holding the slide/ram.

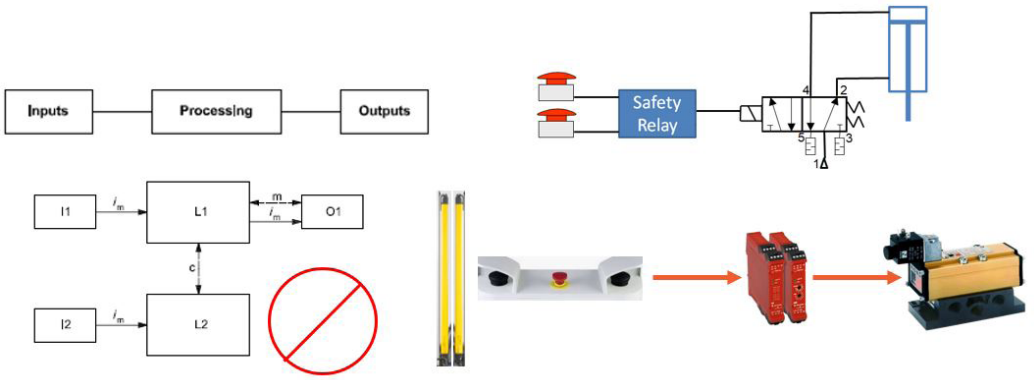
It then prescribes the performance level required based on the hazard and safety control systems being used as described in a series of tables. In summary, a PL d or e is required for the working stroke when using safety systems that do not prevent access to the hazard by a locking mechanism. This includes safety systems using non-locking interlocks, light curtains, scanners, and two hand control devices.

ISO 16094-4 Table 1

Main safety system	Hazardous movement	Safety function	Minimum required PL (PLr) for safety function and I, L and O	Basis for the design of input, output of safety function			
				Requirement for category of Input, Logic and Output[a]	I-Input (sensor area)	L-Logic (control)	O-Output (pre-actuator)
Two-hand control device [see ISO 16092-1:2017, 5.3.2.1 g) and 5.3.2.12]	Movements (e.g. closing stroke) of the slide and die cushions	Stop and cycle initiation for pneumatic presses with a stroke length equal or less than 30 mm and a maximum press force of 1000N or less (see 5.4.1.8)	PL d[b, d]	Cat 3	Push buttons of two-hand control device[g,h]	Safety-related logic	Pneumatic system (e.g. air valves)
ESPE using AOPD (see ISO 16092-1:2017, 5.3.2.1 f and 5.3.2.11)	Movements (e.g. closing stroke) of the slide and die cushions	Stop by AOPD	PL e[c]	Cat 4	AOPD	Safety-related logic	Pneumatic system (e.g. air valves)
		Muting (see ISO 16092-1:2017, 5.4.2)	Same as the safety function on which muting is acting[q]	–	Position signal or suitable alternative	–	–
	Movements of work-piece ejector and transfer systems	Stop by AOPD	PL e[c]	Cat 3	AOPD	Safety-related logic	Electrical, hydraulic or pneumatic system
		Muting (see ISO 16092-1:2017, 5.4.2) Not alowed for transfer system	Same as the safety function on which muting is acting[q]	–	Position signal or suitable alternative	–	–
	Movements of the slide, die cushions, work-piece ejector and transfer systems	Prevention of restart by an additional safeguarding by AOPD [see ISO 16092-1:2017, 5.3.2.11 c)	Pl d	Cat 3	AOPD	Safety-related logic	Logic control shall act on the appropriate part of the electrical control system

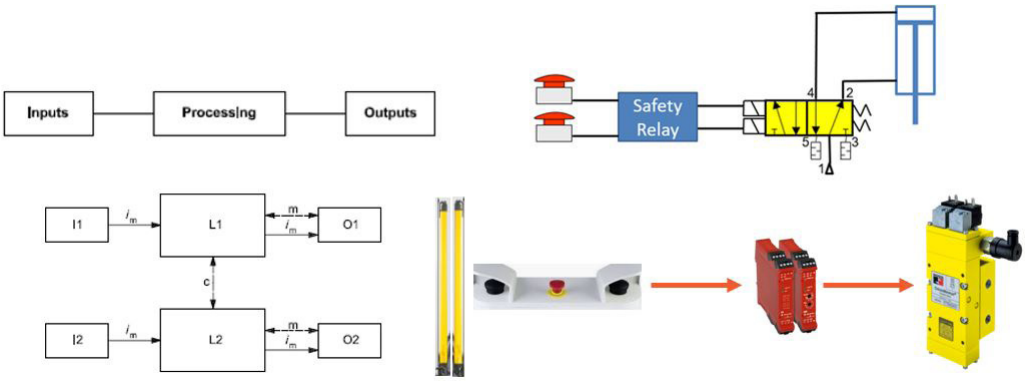
Knowing that we need a control reliable or Category 3, PL d system is just the first step in determining the most effective safety system. This control reliability must include the inputs, logic, and outputs. Using a single channel valve can result in the loss of the safety function through the failure of single component such as solenoid, spring, or internal component. Choosing the best safety rated system and output device will depend on the complete machine specifics and the risk assessment of that machine that utilizes the cylinder press.

Category 1, PL c installation with standard valve



If a single channel valve is used a single failure such as broken spring or sticking spool can lead to the loss of the safety function.

Category 4, PL e installation with safe return valve



When the risk is broken bones or amputation the system must be control reliable or Category 3 PL d. This requires redundancy in the system including the inputs, logic, and outputs.

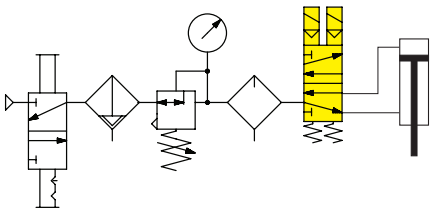
Risk Assessment & Solution

Considerations during the risk assessment of a cylinder press application to determine the most appropriate solution should include:

Considerations during risk assessment

- Stopping time and safe distance calculations
- Force calculations
- The effect of gravity
- Failure modes of the cylinder press and automation

The typical cylinder press will simply go down when actuated and return up when de-actuated. The primary risk is having a hand in the point of operation during the downstroke. This up and down function is accomplished with a 5/2 valve function in which port 2 is pressurized during de-energization and port 4 during energization. For a safety rated system this can be accomplished with a safety rated dual 5/2 Category 4, PL e valve.



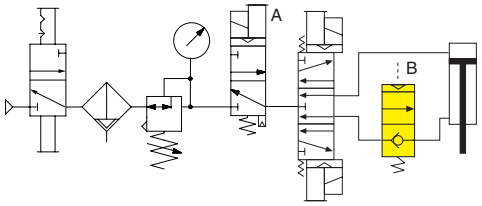
Cat 4 Safe Return

The most basic safety control system will simply require two safe outputs to control the valve's main solenoids if using an internally monitored valve. This may have some form of feedback should a fault occur that can be used to prevent the reset of the safety system. If the safety system has the capability of actively monitoring sensor feedback, then an externally monitored dual 5/2 valve can be utilized. The residual risks in this type of system are the motion of the return stroke which should not create any pinch points and the risk of gravity due to the loss of supply pressure. These can be mitigated with the use of a check valve on the supply or through mechanical means on the cylinder.

Reversing the cylinder can create potential hazards

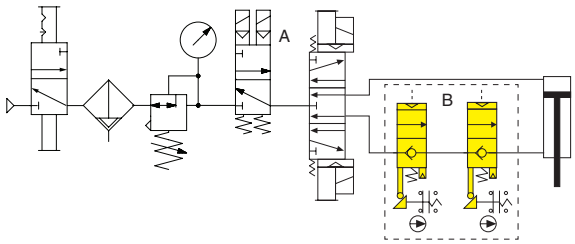
In some cases, reversing the cylinder can create potential hazards due to the work being done. A common risk is parts under load being ejected if the reversal occurs prior to the work being completed. The machine would typically use guarding to protect the operator but if an interlock is opened and power lost during the cycle the safest outcome could be the cylinder stopping. This stopping of a cylinder can be accomplished a few ways depending on the exact risk.

If the risk is largely due to gravity the most effective solution for stopping may be to have a safety rated exhaust valve supplying the standard Category 1 cylinder control valve and utilize a pilot operated check, mechanical device, or combination of the two. A key aspect of risk assessment is that it is iterative. You provide a solution that will leave residual risk which can then be addressed. In this case the main risk at the point of operation with full force on the cylinder. The safety rated exhaust valve eliminates that risk, but the residual risk is due to gravity which could be minimal requiring a simple Category 1 check valve.



Cat 1 Non-monitored Load Holding

If the gravity risk is substantial, then Category 3 pilot operated checks or safety rated mechanical catchers or brakes or a combination of those for diversity and redundancy.



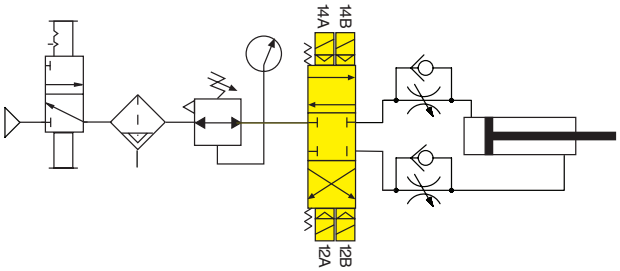
Cat 3 Monitored Load Holding

Monitoring of those devices is crucial in obtaining the needed diagnostic coverage to meet the requirements for a Performance Level d system. Simple redundancy and or diversity will not meet the requirements. Frequently monitoring of the machine function is referenced as the diagnostic coverage. The end positions of the cylinder stroke will provide feedback showing that the cylinder is functioning correctly. This is actually monitoring the single channel control valve and not the safety function which is designed to stop the machine in mid-stroke. It is advisable that this function be periodically tested.

Many mechanical devices used on cylinders are not designed to stop a moving cylinder

Additionally, it should be noted that many mechanical devices used on cylinders are designed to hold a stopped cylinder, not stop a moving cylinder. These often will contain a disclaimer stating it is not intended as a safety device. There are devices available that are certified for use in presses.

If the risk is not only gravity but a machine that must remain in compression during the work function such as assembling a spring loaded type of device, pressure will need to be trapped on both ends of the cylinder and there must be a method to safety relieve this pressure if necessary. A safety rated 5/3 closed center valve can be used for Category 3 or 4 PL d or e applications. This valve will use dual internals to redundantly control the supply to each end of the cylinder and dual internals to redundantly control the air exhausting out of the end of each cylinder. Similar to a safe return valve, this valve handled the control function in a safety rated manner. This is only available with position sensors for external monitoring and therefore requires a programmable safety controller to perform the safe monitoring function.



Cat 4 Safe Control & Load Holding

Summary

There are many factors to consider when assessing/designing and implementing cylinder press solutions that include press force, stopping times and the effects of gravity. There are also several standards that apply so users need to know where the machine is going and how it is going to be used in order to select the correct safety solution. ROSS Controls can help guide users through the selection and design process to help users implement effective solutions that meet the requirements of the standards.