HILMA

application information

THE SAFE QUICK DIE CHANGE

Maximize Die Clamping Security, Minimize Die Movement Effort

Introduction

Many manufacturing concepts have changed in the last ten years or so. One way many metal stamping companies are attempting to remain competitive is by setting goals for reduced inventories. To help accomplish these aims, many are turning to shorter production runs, which require more frequent die changes.

The traditional method of using an assortment of strap clamps to accommodate various sizes of dies will not meet today's requirements for Just-In-Time manufacturing. Stampers are demanding faster and safer ways to move and clamp dies. A Quick Die Change system can help achieve these goals.

Many factors must be considered to ensure the new die change system will not only meet the company's goals of faster part-to-part die changeover times, but also provide for a safer work environment.

Die Movement

One facet of providing a safe die change environment involves moving and locating dies under controlled conditions with minimal effort. Moving a die in the traditional manner involves skidding metal against metal. The static or breakaway friction for a 1,000 lb. die requires up to 800 lbs. of force or 80 percent of the die weight to start the die in motion. Once the die is moving it can take up to 400 lbs. or 40 percent of the load to keep it moving.

Traditionally this has meant prying, pushing and pulling dies into and out of the press using fork lifts, chains, prybars and sledgehammers.

Moving a die this way requires more force than is necessary. If all of these tools and equipment were not needed, and only a fraction of the effort was required, wouldn't the alternate method also be safer? If this same die was supported on ball or roller lifters, it could safely and easily be moved, controlled and located by one person with a fraction of the effort.

Ball-type lifters riding in a nest of ball bearings can accommodate movement in any direction, while reducing the amount of force required to move the same 1,000 lb. die to 20 to 40 lbs., or about 2 to 4 percent of the die weight (**Figure 1**). A set of roller type lifters can allow movement in one or two directions and can reduce the effort required to move the same die to 10 to 30 lbs. of force, or about 1 to 3 percent of the die weight.

Some variations in the amount of force required, or rolling resistance encountered, can be attributed to the condition of a die surface that comes into contact with the balls or rollers. A lesser amount of force is required to move a die that has a smooth, hard surface and is free of holes or pockets. For roller-type lifters, die movement should be parallel with that of the roller direction.

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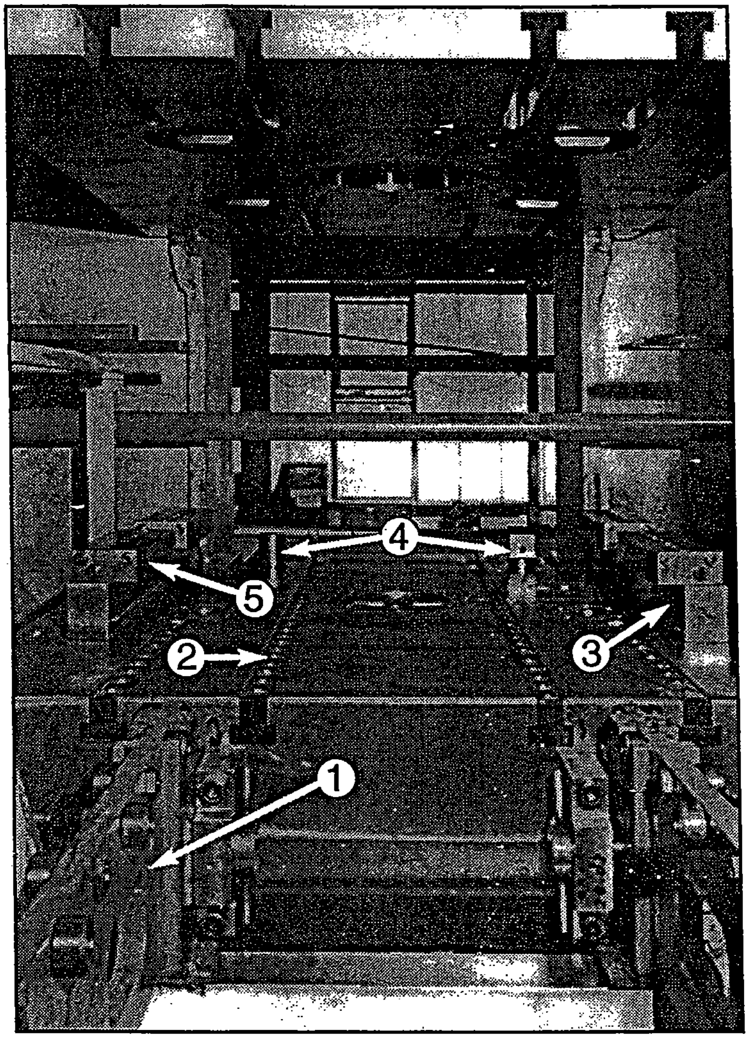

Figure 1. The effort to load and unload the die from the press is greatly reduced with ① die supports and ② ball lifters. The die is guided left to right with the ③ ledge clamp spacers. Final die location is achieved with a notch and V in the subplate which mate with the ④ two pins at the rear of the bolster. Each of the ⑤ ledge clamps is equipped with an integrated pilot-operated check valve.

Roller- or ball-type die lifters that are operated hydraulically must include a circuit relief valve to protect personnel and equipment from a potential pressure increase if the die lifters are overloaded. If die lifters are loaded beyond their rated capacity, the pistons that raise the rollers can act as pumps and generate higher pressure in the lift circuit. Without a safety valve to relieve the increased hydraulic pressure, components in the die lifter circuit can rupture, creating an unsafe condition at the press. With a circuit relief valve the increased pressure is simply dumped back to the tank.

Safe Clamping Force

With the die located in position, it must be safely clamped in place. The clamping force on the die must be sufficient to overcome its own weight, along with the acceleration, stripping and ejector forces working against the die clamps. The two most common ways to create this force is by manually torqued bolts and hydraulic clamps.

If the die is clamped manually, the T-Bolts must be torqued to provide a safe and consistent preload level. The tension in the bolt must be greater than any external loads applied against it (**Figure 2**). If a bolt is tightened to produce 5,000 lbs. of tension, an external load up to 5,000 lbs. can be applied without further elongating the bolt. Loads greater than this can affect the rigidity of the connection, and possible movement of the die.

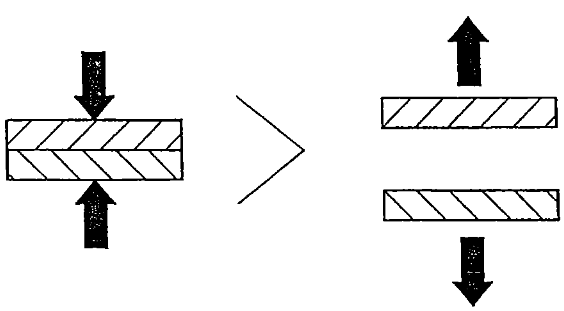

Figure 2. Clamping force must be greater than separation force.

High Bolt Preload

The higher the preload on the bolt, the greater the protection against:

- bolt fatigue and failure
- loosening during vibration
- joint relaxation
- die movement
- premature tool wear.

Bolt Fatigue

When the forces working against the preload on a bolt are greater than the existing preload, the bolt will stretch, cycle and fatigue. High preloads must be applied and maintained to protect the bolt against fatigue. Fatigue failures are more commonly related to too little preload rather than too much.

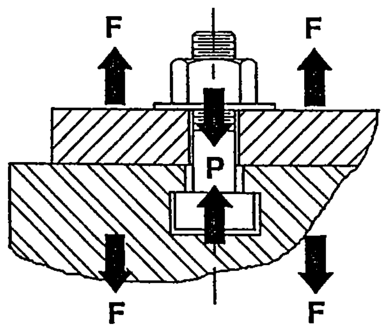

Figure 3. The higher the preload, the greater the protection.

Vibration

A bolt and nut stay in place due to the friction between the mating threads. The higher the preload, the greater the friction, and the less chance of the nut loosening during the stamping operation.

Joint Relaxation

Immediately after torquing the bolts the joint will relax with a loss of 2-11 percent of the initial bolt preload and for several days after fastening, the bolted joint "settles in" further, with an additional preload loss of 2-5 percent.

Metals under sustained load have a tendency to creep. That is, they continue to elongate without an increase of load. A heated die with elevated temperatures accelerates creep, and becomes a significant consideration.

Some of the ways to minimize joint relaxation are:

- Maximize clamping force.
- Clamp directly on the die through a U-slot.
- Use hardened washers. They distribute stresses and reduce the friction during the tightening of the fastener.
- Strap clamps split the force applied to the die. If they are used, keep the bolt as close to the die as possible and limit the number of layers or pieces being compressed – such as multiple spacers and shims.
- Contact surfaces should be smooth, flat and parallel.
- All surfaces must be free of slugs and scrap.
- As an extra level of security, retighten after a few minutes and retighten again after a few days.

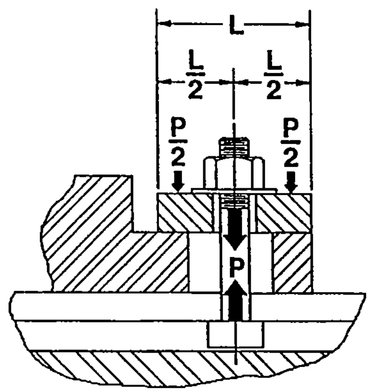

Figure 4. Strap clamps reduce the force applied to the die.

Die Movement/Tool Wear

A die that is not safely and securely clamped can be an accident waiting to happen. If there is die movement during the stamping operation the life of the tooling can be greatly reduced.

Proper Torque Levels

When tightening a bolt, the objective is to develop the correct preload. The torque applied is only an indicator of that preload. Due to the many variables there is no formula, method or device that guarantees that the application of a certain torque will develop a precise and uniform preload in a bolt.

Friction

When bolts are tightened they become stressed in tension. Of the torque applied:

- 50 percent overcomes the friction between the nut (or bolt head) and the joint surface.
- Another 40 percent overcomes friction between the mating threads.
- Only 10 percent develops useful tension or preload in the bolt.

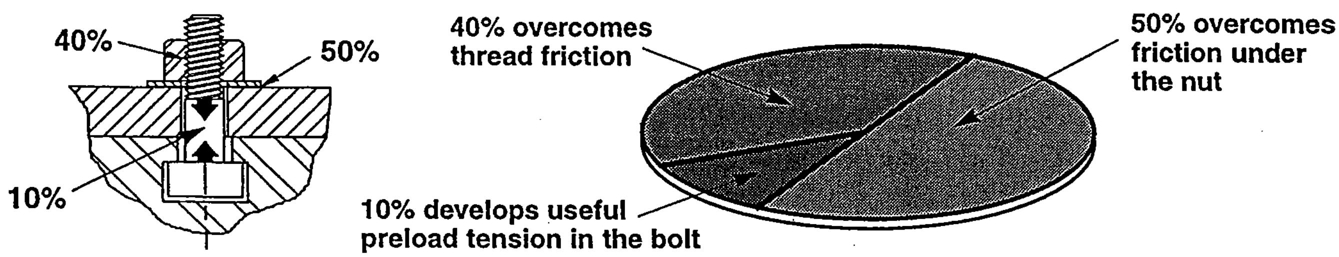

Figure 5. Torque applied to a nut.

Friction can be reduced by:

- lubrication
- care and attention to protecting the threads during storage and use
- replacing bolts with damaged threads
- hardened washers under the head of the nut.

Estimated Torque and Preload

To avoid vibration loosening or fatigue that can be caused by low clamp force problems, the maximum target torque should be 70 percent of the bolt's yield strength.

A well-accepted design equation for estimating torque can be stated as:

$$T = \frac{CDF}{12} \quad \text{or} \quad \left[F = \frac{T(12)}{CD}\right]$$

T = Torque applied (foot-pounds)
C = Constant (see table)
D = Diameter of fastener (inches)
F = Preload Force (pounds)
12 = Conversion to ft.-lbs.

Average C Factors for Steel Fasteners

Industrial Lubricant	C
As received, steel	0.20
As received, cad plate	0.19
Phosphate and oil	0.19
Parkerized and oiled	0.18
Moly grease	0.14
Fel-Pro 65A	0.13

Example 1: Based on this information, a new, unlubricated 1 in. grade 8, steel bolt torqued to 70 percent of its yield strength should produce a preload (F) of 55,860 lbs.

(79,800 lbs. x 70 percent = 55,860 lbs.)

D = 1.0 in.
C = 0.20 from table
F = 55,860 lbs.

$$T = \frac{CDF}{12}$$

$$= \frac{(.20)\ (1.0\ \text{in.})\ (55,860\ \text{lbs.})}{12\ \text{in./ft.}}$$

(torque) T = 931 ft.-lbs.

To create this optimum preload, 931 ft.-lbs. of torque are required.

Example 2: A more specific example may be to establish the minimum torque required for clamping the die in a 1,000 ton press. A total of sixteen 1 in. bolts are used, eight on the bed and eight on the slide. They clamp directly on the die through a U-slot.

A rule of thumb is that the total clamping force should be about 20 percent of the press capacity or:

- 10 percent clamping force on the slide
- 10 percent clamping force on the bed.

Clamping force required on the slide =

$$(1,000\ \text{ton press}) \times \frac{2,000\ \text{lbs.}}{\text{ton}} \times 10\ \text{percent} = 200,000\ \text{lbs.}$$

$$200,000\ \text{lbs.} \div 8\ \text{bolts} = 25,000\ \text{lbs. per bolt}$$

$$\therefore T = \frac{CDF}{12}$$

$$= \frac{.2\ (1.0\ \text{in.})\ 25,000}{12}$$

= 416 ft.-lbs. is the minimum torque required per bolt

Torque Measurement

The actual preload on a bolt can vary greatly due to estimating the friction factor of the bolt, manipulation errors and tolerance variation of the torque wrench.

Torque Measurement

Method of Preload	Preload Variation
Torque Wrench	±25% → ±43%
Impulse Tightening with torque wrench	±43% → ±60%

The Work Environment and the Human Factor

If all of the other factors that affect the actual clamping force on the die isn't enough, there is more to take into account – the work environment and the operator:

- Conditions at the press can make it difficult to properly torque the clamping bolts, such as when they are located overhead on the press slide and in holes, corners and pockets.
- The attitude, skill level and physical ability of each and every setup person can vary from day to day, thereby affecting the quality and integrity of the setup.

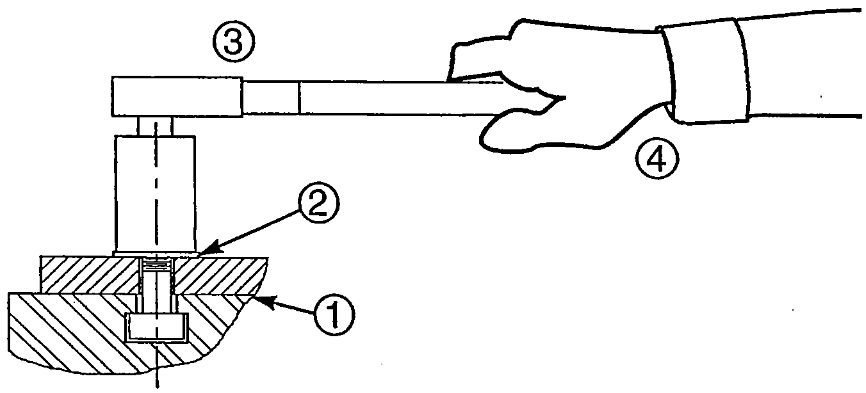

Figure 6. Clamping force can vary due to: ① joint relaxation ③ torque measurement ② bolt friction ④ work environment and human factors.

Using standard mechanical clamping methods and with all factors considered, it can be a very difficult task to ensure that the same high preload is applied by every bolt, every setup, every time.

Hydraulic Clamping

A properly designed hydraulic clamping system can provide the safety and security in ensuring that each clamp is creating the same measurable force at every point, at every die change. The same high clamping forces can be repeatedly applied to the die externally, internally, and in hard to get at places.

The force is created by the pressure applied to each hydraulic clamp. That pressure is monitored with a gauge and a pressure switch that are tied into the press's emergency-stop circuit. If a 20 percent drop in clamping pressure occurs, the press shuts down.

Clamp Location

A review of the present clamping methods and locations of the devices on the press will provide guidelines to safely hold the die in place and eliminate possible die deflection when a new clamping system is being considered. The number, size and location of the clamps should be evaluated so that the clamping forces can be placed as close as possible to those that they must overcome.

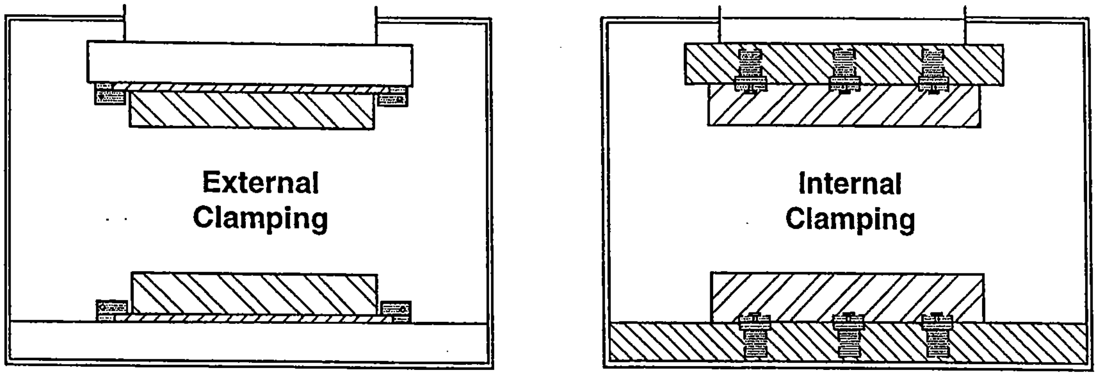

Figure 7. Clamps can be located internally or externally.

In many applications, clamps can be applied externally along the edge of the die. Others may require the installation of internal clamps if the loads are greatest internally.

Hydraulic Safety Circuits

Anyone working on or near stamping presses knows that unexpected events can occur. Those workers may ask questions such as "What if I loose power? What if I break a hydraulic line to a clamp? What if I break a hydraulic line from the press column to the slide that supplies pressure to all of my slide clamps? What if we loose the input power to the air or electric powered hydraulic pump?" If the clamping system has been designed with the appropriate safety circuits, a die will not move if any of those circumstances arise.

Clamping pressure can be maintained with zero leakage directional control valves, and pilot operated check valves. Pilot operated check valves allow flow through, but they lock pressure and fluid downstream until pressure is applied to a separate line to open the valve and release the pressure at the clamp. This in turn releases the clamp so the die can be removed.

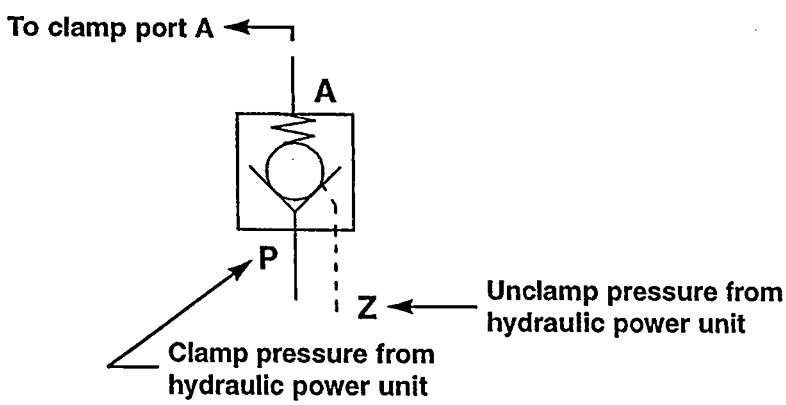

Figure 8. Pilot operated check valves have separate lines to pressurize and release die clamps.

Check valves can be provided for each clamp or they can be located in the bed and slide circuits near the clamps. Several methods are used to apply these safety devices in a clamp circuit and each offers a different level of safety and a different cost factor.

Hydraulic Safety Level "A"

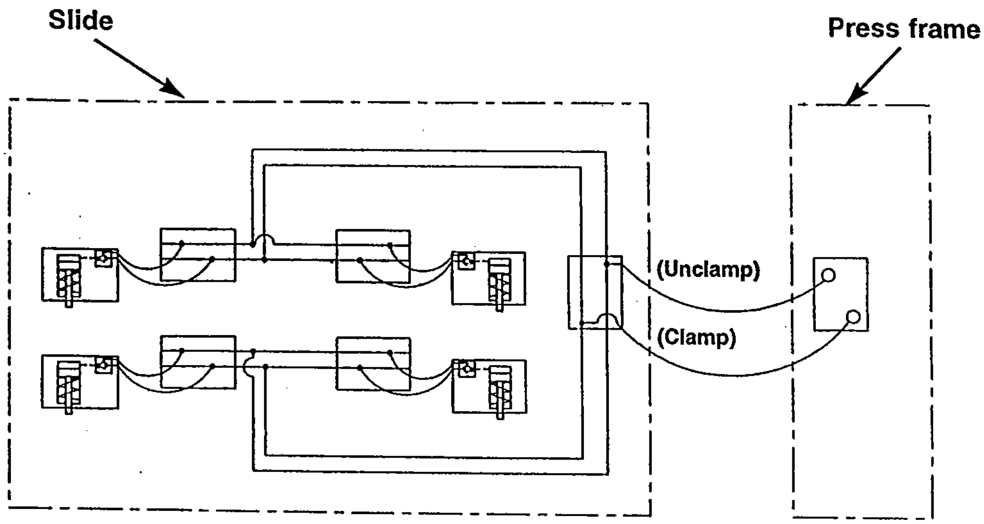

Figure 9. Integrated check valve in each clamp.

If the slide circuit of a press has four clamps, each equipped with integrated check valves, and a pressure line breaks at one clamp, the break is detected by a pressure switch at the pump and the press automatically shuts down. All four clamps remain locked in place to hold the die.

Hydraulic Safety Level "B"

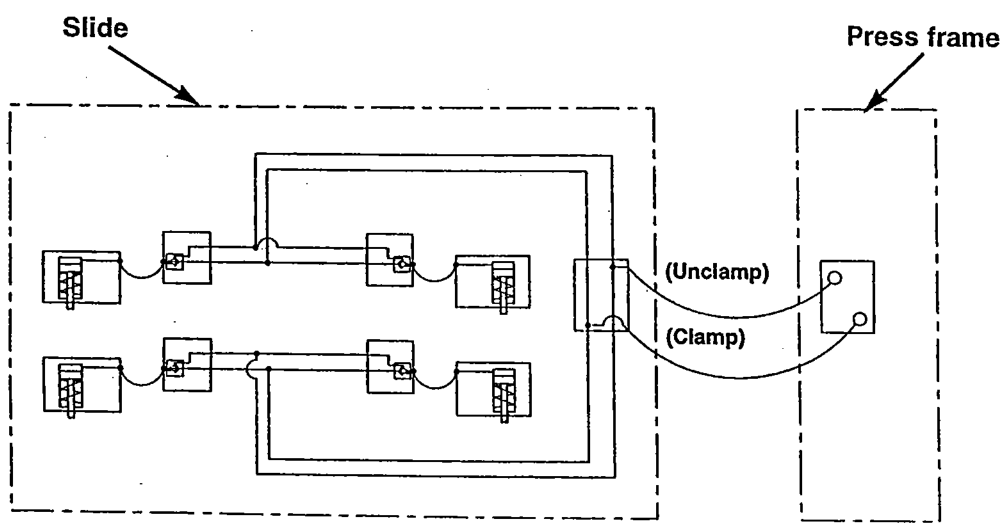

Figure 10. Remote check valves are located in separate blocks mounted near each clamp.

Another possible safety circuit is to provide a separate check valve for each clamp. Rather than integrating the valves into individual clamps, they are located in separate blocks attached to the slide or bed.

With this type of circuit, if the pressure line breaks at the clamp, the press will shut down and the die will be locked in place with three of the four clamps. One advantage to this system is the one hydraulic line rather than two runs to each clamp. This is an important consideration if the clamp is to be manually positioned.

Hydraulic Safety Level "C"

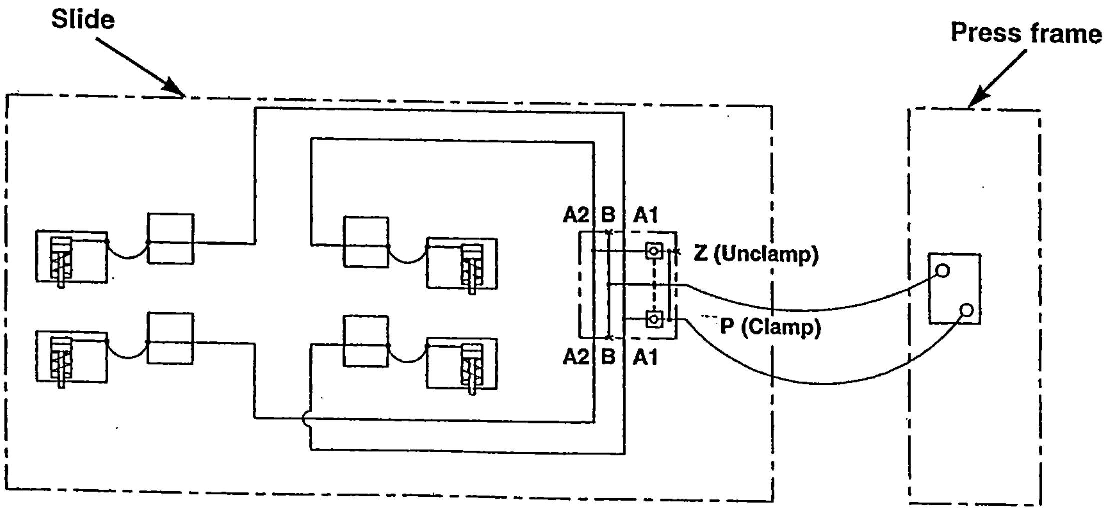

Figure 11. A diagonal clamping circuit with a dual check valve block mounted on the press slide.

If a check valve is not provided for each clamp, a diagonal clamping circuit with dual check valves can be used. In this circuit, one pressure line runs into a connection block mounted on the slide or the bed, where it splits past two pilot operated check valves to create two diagonal clamp circuits. Every other clamp is either on circuit A1 or A2.

If a hose to a clamp on circuit A1 fails, the pump pressure switch senses the break and shuts down the press, but the die is now held with two of the four clamps, those in circuit A2.

Hydraulic Safety Level "D"

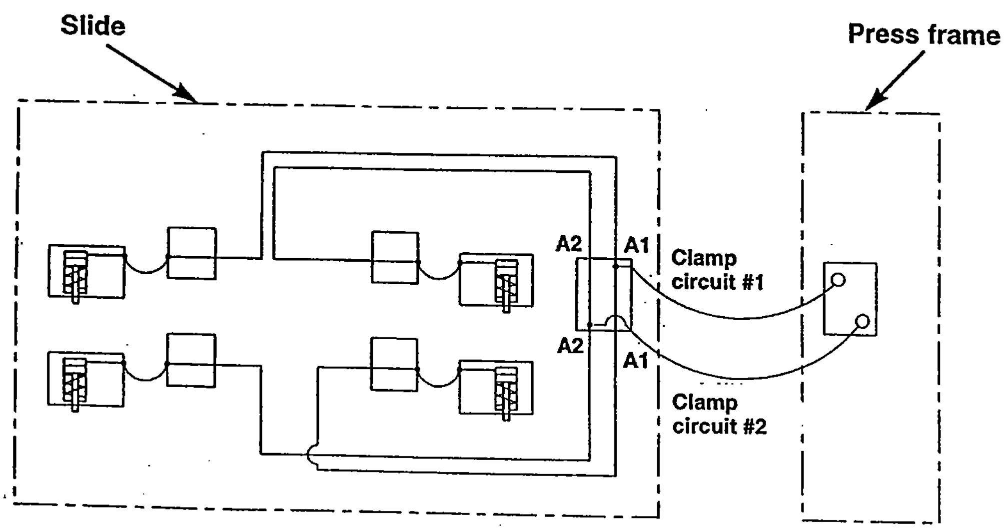

Figure 12. Dual diagonal clamping circuits without remote check valves.

A similar diagonal clamping circuit can be provided using two pressure lines to the slide, doubling the number of clamping valves at the pump. If a failure occurs in one circuit, the other circuit stays locked up with the pressure held at the pump control valves, rather than at the check valves on the slide. This solution is generally more expensive, while providing a lower level of safety.

Hydraulic Safety Level "E"
Clamping Without Pilot Operated Checks

If a clamp circuit is designed without safety checks, the clamping pressure must be maintained with the integrity of the hydraulic system, relying on zero leakage clamp seals and control valves. If there is a hose failure, pressure to all clamps in that circuit would be lost. Clamping like this may be considered for the bed circuit. This type of clamping system may also be suitable if used with hydraulically actuated and mechanically locking clamps.

Various types of mechanically locking clamps are available using the wedge lock principle. A hydraulic piston drives a tapered wedge inside such clamp, creating the clamping stroke and mechanically locking the clamp. A wedge lock clamp provides an extra level of safety.

Additional Hydraulic Protection for High Temperature Applications

If clamping on a press where the clamp temperature is expected to rise 50 degrees F or more, a pressure relief must be included in the hydraulic circuit. This is because the fluid in the sealed pressurized system can increase 80 psi per every increase of 1 degree F.

Electrical Controls and Safety Interlocks

Automating a die clamp system can help to provide additional levels of safety. Electrical controls, interlocks and sensors can help ensure that the various moving parts of the die change system are at the right place at the right time.

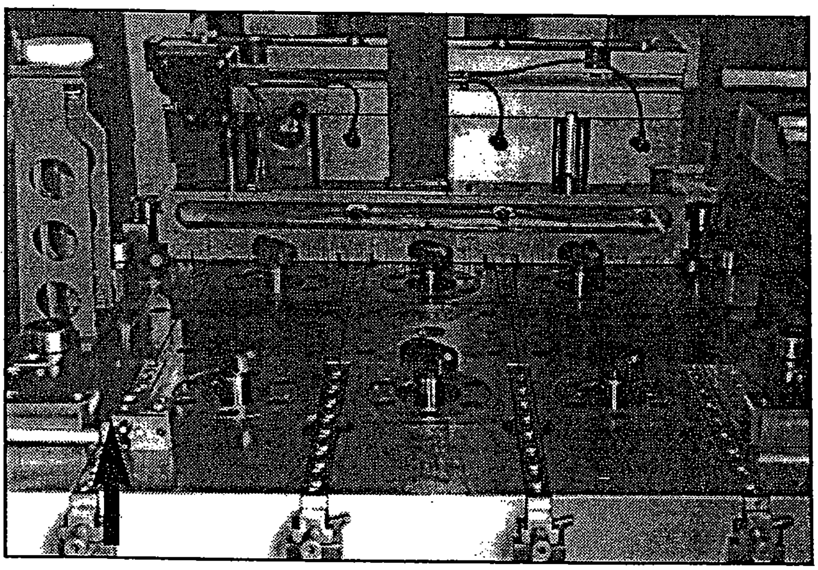

Figure 13. Tool-in position proximity switch provides press control feedback on this press. Swing sink clamps mounted in the bolster use dual check valve blocks in the bed clamp circuit.

Sensors can indicate, for example, whether a traveling clamp is at the die or at the home position, or whether a clamping piston is in the proper clamp or unclamp position. In a press, sensors can indicate that the press slide is down on the die, that the die is located horizontally and resting on the bed or that the slide is at bottom dead center.

Pressure switches signal that the valves are shifted and the clamping circuits are at proper pressure. Hydraulic reservoir sensors can monitor oil and temperature levels. Key operated clamp/unclamp switches are available, as are key locked pressure switches and pressure relief valves to ensure the pump pressure settings will not be reset without approval. Solenoid valves should be normally open, so they do not shift if a power failure occurs.

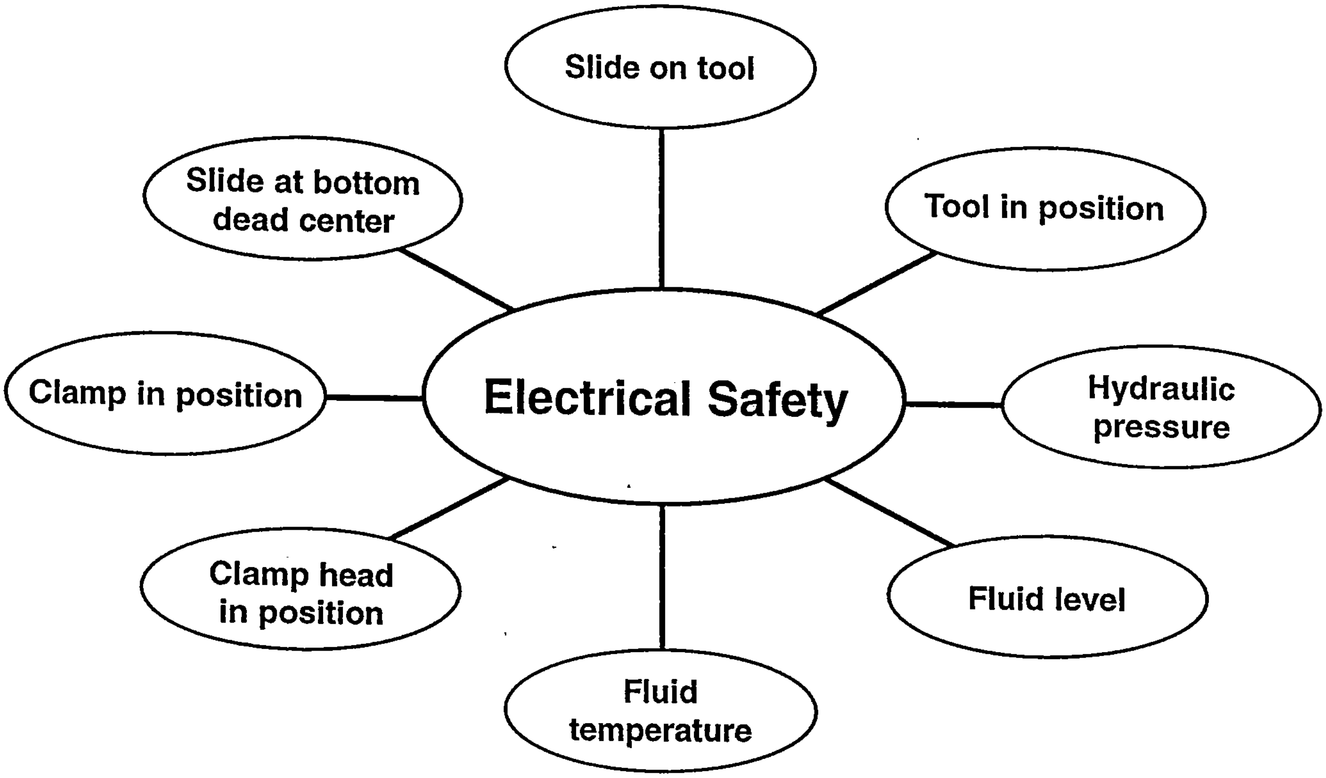

Figure 14. Electrical interlocks provide a safer clamp system.

Maintaining the Safety Level

If problems develop with a sensor, repairs should be made immediately. Although emergency jumpers are sometimes placed across proximity switches to keep a press running, this temporary "fix" can cause other problems in the clamping system. When sensors are bypassed, press controls do not know what is really happening inside a clamp.

If temporary jumpers must be used, operators should be warned to make certain that the function that had been monitored by the bypassed proximity switch, such as clamp location, operates properly.

A Quick Die Change system must be maintained to ensure that the level of safety meets expectations. Some companies have spent large sums of money to retrofit an existing press or buy a new press with a Quick Die Change package, only to have the equipment fail to perform properly or deteriorate due to a lack of personnel training and maintenance.

Achieving a Safe Die Change System

As plants and presses are updated, automated Quick Die Change systems can be incorporated to help achieve production goals and maintain competitiveness. In the process of reducing part-to-part die changeover times, higher safety levels in the plant can also be achieved with minimal additional cost.

If the Quick Die Change system on a press develops a problem, the press should be equipped so the *worst* possible result is that the press shuts down and production is delayed. When that is the case, the goal of incorporating a safe Quick Die Change system has been achieved.

January 22, 1998

Reference materials used or recommended to those desiring a more complete understanding of fasteners:

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pages M-52 to M-70 from "Manufacturer's Capability Guide" published in 1986 by Divisions 4 and 5 of Industrial Fastener Institute
2) Tool & Manufacturing Engineers Handbook, Third Edition, 1976
Edited by Daniel B. Dallas, Society of Manufacturing Engineers
3) "What Every Engineer Should Know About Threaded Fasteners"
by Alexander Blake, Marcel Dekker, Inc., 1986
4) "Bolt Torque: Getting It Right" article by John H. Bickford, published by *Machine Design* magazine June 21, 1990
5) Unbrako® Engineering Guide
Form 5519 20M 596 SPS
6) Bossard International, Inc., Technical Trading & Engineering 1993
7) *Stamping Journal* May/June 1997, "Safety Considerations for Quick Die Change Systems" article by David L. Fischer, excerpted.