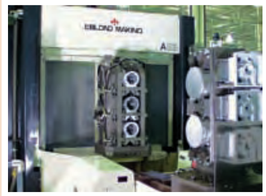
Quality products at competitive prices make Hytec the hydraulic power work-holding brand you can depend on!..........................*And we can prove it.*

- Precisely controlled clamping forces...proven reliability of component systems
- Continuous pressure, stall-type systems increase safety
- Reduced vibration of workpiece and tooling for increased quality
- Faster feeds and speeds...longer tool life
- Reduced scrap and rework
- Faster load/unload cycles
- Fully automated systems capability
- Fully adaptable to multi-station hydraulic clamping applications
- Designed for simple installation in your present or planned fixtures
- Improved ergonomics



Hytec is ready to help you set up hydraulic power workholding systems to fit your specific applications. With the Hytec CAD Graphics Library, Tracing Template Kits, Free Seminars, and Technical Advisors available to answer your questions, you have the support you need.

To serve our customers, Hytec has a policy of continuous product improvement. While all technical data in this catalog is believed to be correct at the time of printing, we cannot be liable for errors and omissions or product changes.

Contact our Technical Services Workholding Specialists for assistance in the application of Hytec products in your particular situation.

LIFETIME MARATHON WARRANTY

All Hytec products and parts, with the exception noted below, are warranted against defects in materials and workmanship for the life of the product or part.

Hytec's warranty is expressly limited to persons who purchase Hytec's products or parts for the resale or use in the ordinary course of the buyer's business. This warranty does not cover any product or part that has been abused, worn out, heated, ground or otherwise altered, used for a purpose other than that for which it was intended, or used in a manner inconsistent with any instructions regarding its use.

Hytec's electronic products are warranted against defects in material and workmanship for one year. All electric motors are separately warranted by their manufacturer under the conditions stated in the separated warranty.

THIS WARRANTY IS EXCLUSIVE, AND HYTEC MAKES NO OTHER WARRANTY OF ANY KIND WHATSOEVER, EXPRESSED OR IMPLIED, WITH RESPECT TO THE PRODUCTS MANUFACTURED AND SOLD BY IT, WHETHER AS TO MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR ANY OTHER MATTER. No agent, employee or representative of Hytec has any authority to bind Hytec to any affirmation, representation, or warranty concerning Hytec products or parts, except as stated herein.

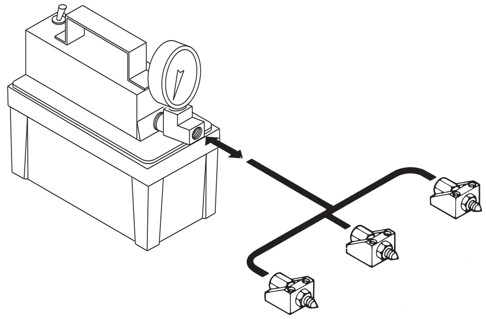
SPX HYTEC LIFETIME MARATHON WARRANTY ISO 9001 CERTIFIED

To qualify for warranty consideration, return the Hytec product, freight prepaid, to a Hytec authorized repair center or to the Hytec factory. If any product or part manufactured by Hytec is found to be defective by Hytec, in its sole judgement, Hytec will, at its option, either repair or replace such defective product or part and return it via best ground transportation, freight prepaid. THIS REMEDY SHALL BE THE EXCLUSIVE REMEDY AVAILABLE FOR ANY DEFECTS IN THE PRODUCTS OR PARTS MANUFACTURED AND SOLD BY HYTEC OR FOR DAMAGES RESULTING FROM ANY OTHER CAUSE WHATSOEVER, INCLUDING WITHOUT LIMITATION, HYTEC'S NEGLIGENCE. HYTEC SHALL NOT, IN ANY EVENT, BE LIABLE TO ANY BUYER FOR CONSEQUENTIAL OR INCIDENTAL DAMAGES OF ANY KIND, WHETHER FOR DEFECTIVE OR NON-CONFORMING GOODS, NEGLIGENCE, ON THE BASIS OF STRICT LIABILITY, OR FOR ANY OTHER REASON.

The purpose of this exclusive remedy shall be to provide the buyer with repair or replacement of products or parts manufactured by Hytec found to be defective in materials or workmanship or negligently manufactured. This exclusive remedy shall not be deemed to have failed of its essential purpose so long as Hytec is willing and able to replace said defective products or parts in the prescribed manner.

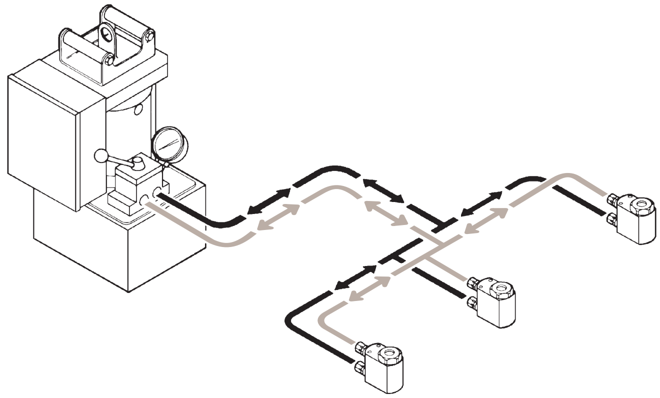
Application A

Among the simplest systems, single-acting spring return actuators can be operated with a single pressure line from this 58219 air/hydraulic pump or any Hytec constant pressure pump with a 9504 pump-mounted valve.



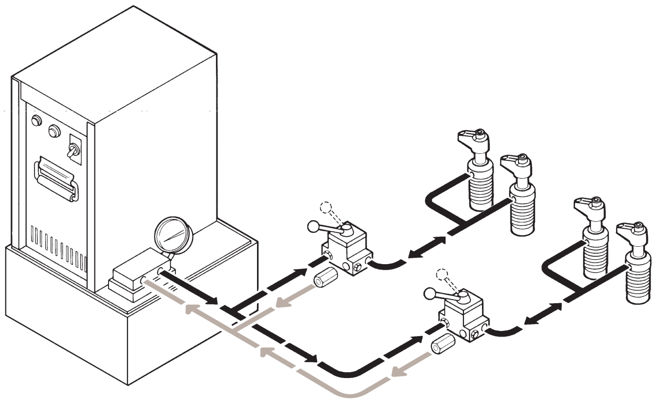
Application B

Multiple double-acting actuators can be operated simultaneously, powered by a pump with a 9504 pump-mounted manual control valve.



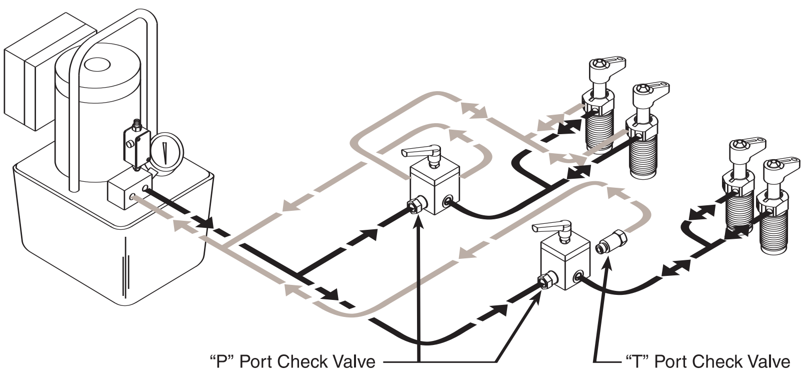
Application C

Two pairs of single-acting actuators are independently operated by 9503 remote mounted control valves and powered by one pump. Check valves prevent return line pressure fluctuations from affecting released clamps. Pressure port "P" check valves are built into the 9503 control valve.



Application D

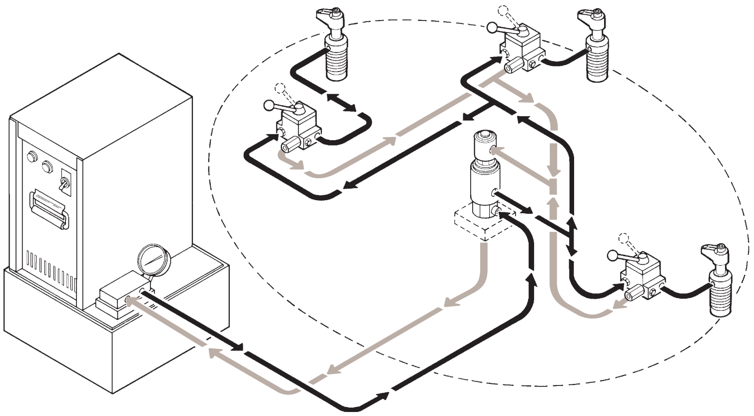
Similar to Application C, one pair of single-acting actuators and one pair of double-acting actuators are independently controlled by 100969 directional control valves. When using more than one directional valve in one circuit, "P" port check valves 500174 are required to prevent loss of clamping pressure in one circuit while actuating another. "T" port check valves 500173 should be used in single-acting circuits where return line pressure fluctuations may affect released clamps.



Power Workholding Systems

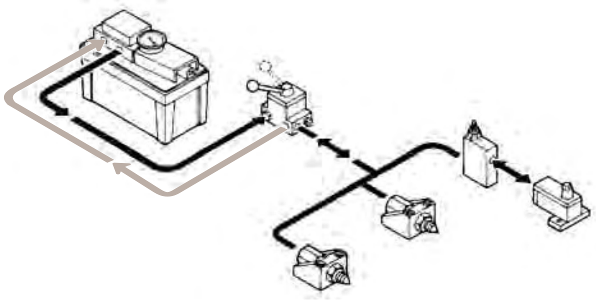
Application E

Rotating unions are used to connect pressure and return lines on applications where fixture rotation does not allow fixed plumbing. Here, three single-acting actuators are independently operated by three, 9503 remote mounted control valves. Each valve is connected to the rotating union which in turn, is connected to a single pump.



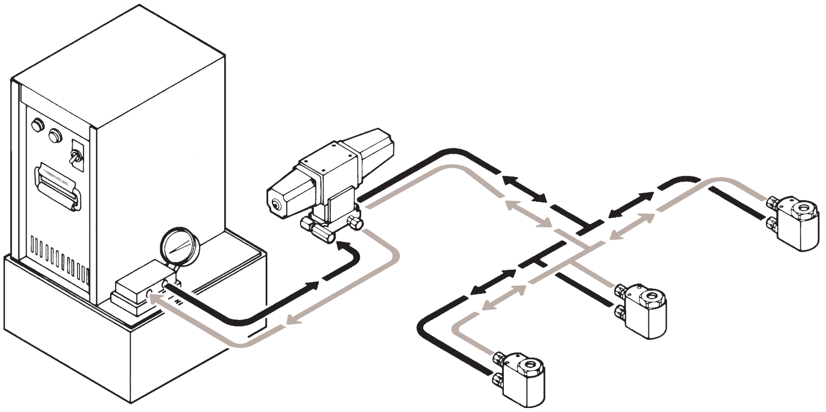
Application F

Two single-acting actuators operate simultaneously, controlled by a 9503 remote manual valve. A sequence valve insures that the workpiece is clamped before the work support is locked.



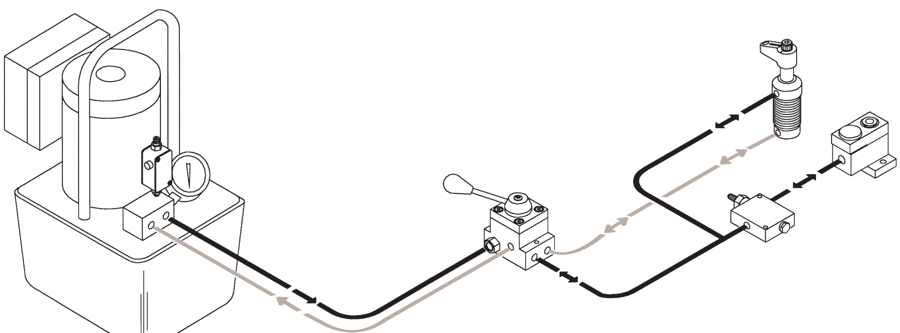
Application G

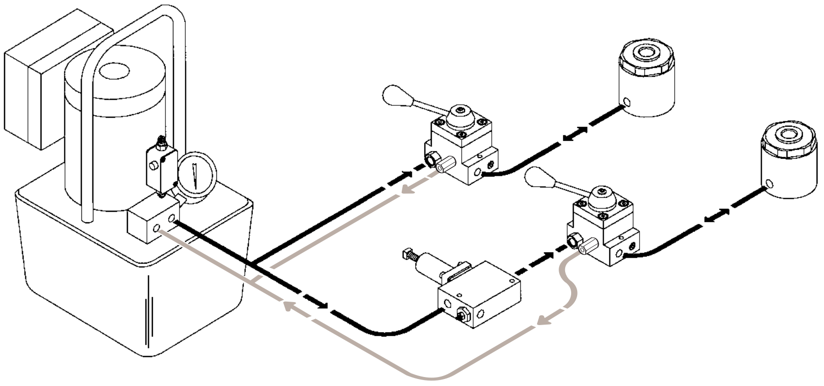
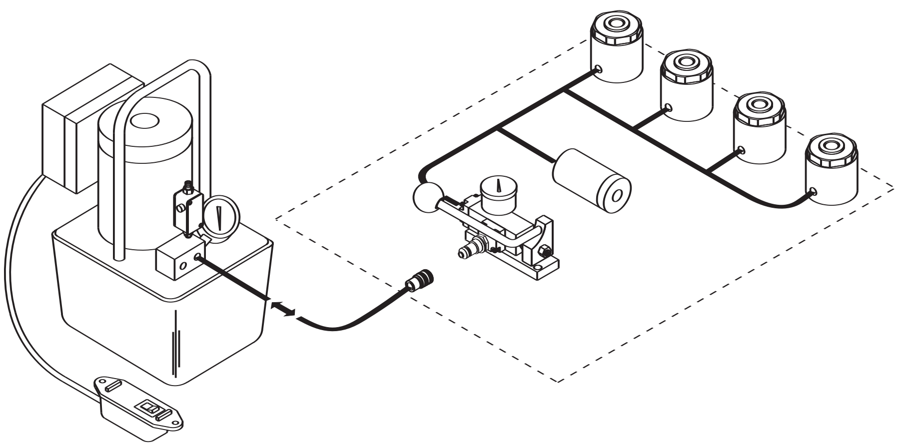
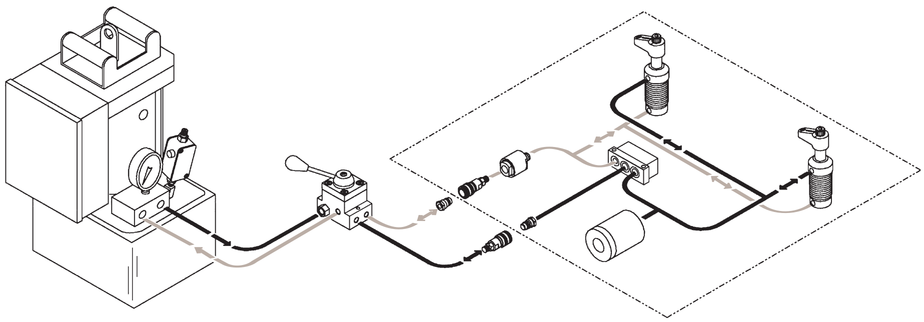
Similar to Application B, the three actuators are operated by a remote mounted control valve. This type of valve allows the pump to be located away from the workstation. The valve can be manually operated or, as shown, a 9612 electrically operated remote control valve is used. This valve can be used to give the operator push-button convenience or fully automated control by the machine tool.



Application H

Similar to Application F, a double-acting swing clamp is actuated before sequencing a work support. When released, the work support drains back through the sequence valve's internal check valve.



Application I Like application C, two single-acting systems are independently operated by remote mounted control valves. Here the pressure reducing valve allows each system to have its own maximum pressure. The cylinder on the left operates at the pressure of the power source and the one on the right can be set at a lower pressure by adjusting the pressure reducing valve.	
Application J Hytec's Manual Pallet Valve is the simplest way to disconnect the power source from a pressurized pallet. For use only with single-acting actuators, it provides an automatic, leak free shut-off. An accumulator makes up for temperature changes and minor leakage. Built-in filtration protects this valve from contamination.	
Application K For pallets using double-acting actuators, Hytec's double-acting pallet valve system uses a pilot-operated check valve to maintain pressure on the pallet. The three position directional valve (100843) mounts at the operators workstation instead of the pallet. Any of Hytec's standard, constant pressure pumps operate the system. An accumulator makes up for temperature change and minor leakage.	

Design Information

PLANNING

The most important and cost effective part of the fixture design process is planning. All facets of the project should be considered, and questions answered before fixture designing begins.

- How many operations are required?
- What machine will be used?
- What is the expected cycle time?
- How many parts will be run? How often?
- How fast must the workpiece be changed?

The answers to questions like these will help determine the relative cost/benefit of the clamping system chosen for the fixture.

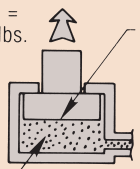
The following information will help prove that a hydraulic power clamping system can be a cost effective fixturing alternative.

HYDRAULIC FORCE

A basic principle of hydraulics states that pressure applied to a confined fluid is transmitted equally in all directions. This principle allows the transmission of pressure through tubes and hoses to remotely located actuators where that pressure is converted to usable force.

The simplicity of hydraulic power clamping can be summed up in one small equation:

FORCE = Pressure X Area



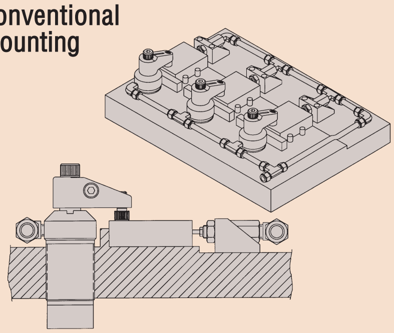
In the cylinder above, the fluid pressurized at 2000 psi is acting on the 3 sq. in. piston. As the formula says, 2000 psi times 3 sq. in. yields a force of 6000 pounds.

This same concept applies to all hydraulic actuators.

PLUMBING OPTIONS

The method used to route the pressure to the actuators on the fixture should be determined early in the planning stages. The plumbing is an essential part of the fixture and should never be left as an afterthought. There are two basic plumbing methods; conventional and manifold mount.

Conventional Mounting



Conventionally mounted components have threaded ports which accept fittings for tubing and hoses. Many different types of fittings are available, giving you several options for customizing your design. Since most of these components are commonly available, conventional mounting will typically be the lower cost option.

The threaded ports are usually one of two designs, NPT tapered pipe threads or SAE O-Ring boss.

NPT tapered pipe threads depend on the interference of the mating thread forms. This thread form has been in use for general plumbing applications for many years. Consequently there is a wide selection of fittings available for even the most unique applications. However, the thread form is the same whether the application is a household water supply or a high pressure hydraulic workholding system. It is important to specify only fittings that are rated for the maximum pressure to be seen in your application. The plastic, copper and iron pipe fittings are not acceptable alternatives.

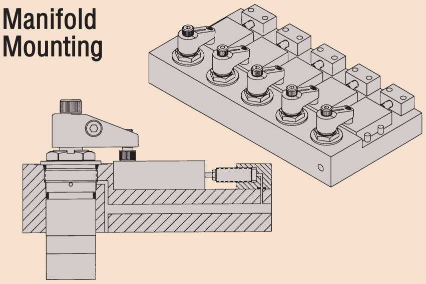
Straight thread, O-Ring boss ports per SAE J514 are common in both industrial and mobile hydraulic systems. Because this system of ports and fittings depends on a simple, replaceable o-ring for sealing instead of the interference of perfectly formed threads, the chance for leakage is greatly reduced.

Systems can be disassembled and reassembled numerous times with no additional make-up required. Fittings will always be in the exact same place and elbows will always point in the right direction. There is never the need to over or under-tighten elbows to properly align them in your system.

Pipe sealants and teflon tapes that can contaminate your system are not required. The torque needed to properly tighten these fittings is less, too.

All of Hytec's newest products have the SAE ports and a line of fittings and adapters is available in our catalog. In addition, we have made many of our other products (originally designed with NPT threads) available with SAE ports. Where available, this is noted on the product description page.

Manifold Mounting



Manifold mounted components eliminate the need for external fittings, tubing, and hoses because the fluid passages are machined directly into the fixture. Securing the workholding component to the fixture automatically makes the hydraulic connection.

Manifold mounting:

- Provides no-tool hydraulic connections
- Saves valuable fixture space
- Eliminates tubes, hoses, or fittings that disrupt coolant flow and collect chips
- Simplifies post-machining fixture cleaning
- Reduces assembly and maintenance time
- Improves performance
- Means fewer hydraulic connections resulting in fewer potential leak points
- Results in a cleaner, more professional looking fixture

PLUMBING SIZING

When designing and assembling your hydraulic system, keep in mind that your choices of size and length of plumbing lines can significantly change the performance of your fixture. The back-pressure created by fittings, tubing and hoses can slow the operation of your system, especially single-acting systems. Larger diameter plumbing runs with a minimum number of bends and fittings will reduce this back pressure.

When sizing hydraulic lines, make sure you look at the inside diameter. 1⁄4" hose is not the same as 1⁄4" tubing. Hose is specified by its inside diameter. Hydraulic tubing is usually specified by the outside diameter. 1⁄4"O.D., .035" wall tubing has an inside diameter of .180", a flow carrying capacity of only 50% of that of the hose.

Single acting clamps can develop only a limited amount of pressure to force hydraulic fluid out of the clamp and allow it to retract. When the return fluid from multiple clamps must share the same hydraulic line, back pressure can easily become excessive and slow the clamp's retraction.

When connecting multiple clamps, you can use either a "daisy chain" or "home run" configuration. In a daisy chain, you use a tee at each clamp and run tubing from the first clamp to the second and then to the third and then the fourth, etc. When using a home run configuration, you begin at a manifold and run hydraulic lines all the way from the manifold to each clamp.

The daisy chain method uses less tubing so it might appear that this would minimize back pressure. However in the daisy chain, the fluid from all of the clamps must pass through a single hydraulic line. In the home run, while there may be longer runs, each line only has to accommodate flow from one clamp.

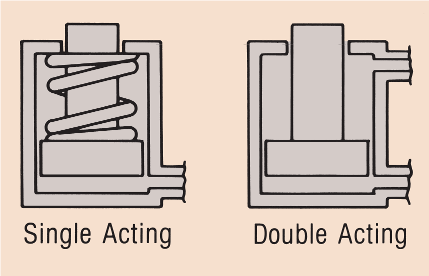
The viscosity of the hydraulic fluid used will also affect back pressure. Viscosity is affected by temperature. Contact the factory to discuss applications running below room temperature. We recommend using only Hytec fluids. Other fluids may have different viscosities or other characteristics that can adversely affect system operation.

SINGLE- vs. DOUBLE-ACTING

Another decision to be made early in the planning stage is whether to use single- or double-acting components.

Single-acting components are typically actuated using hydraulic pressure. When released, the pressure is removed and the actuator is returned by a spring which forces the hydraulic fluid back into the pump reservoir. This type of system is usually the most cost effective because each actuator needs only one pressure source connection for operation. Single-acting actuators should be vented to clean atmosphere whenever appropriate. Remember, double the plumbing for double-acting systems. This does, however, use more valuable fixture space and adds to the cost.

Nevertheless, there are good reasons to use double-acting systems. The larger and/or more complex the circuit design, the greater the potential for return restrictions which will slow the return of the single-acting actuators. Double-acting actuators are ideal



for applications which require both pushing and pulling or returning clamps with heavy, custom designed attachments. They work well for powering linkages which require fast actuation in both directions. Double-acting clamps are often used in automated systems where coordinating the action of the clamp with that of the rest of the system requires fast, positive, predictable cycle times. By installing pressure switches in both the pressure and return lines, the status of the clamp can constantly be monitored.

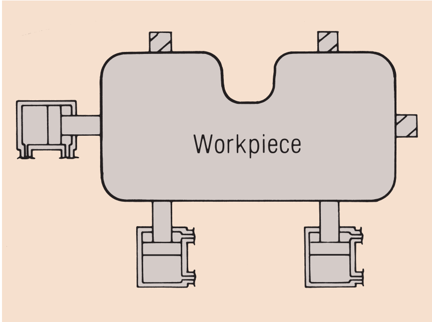
AUTOMATION

Hydraulic power clamping provides varying degrees of automation. During the planning stage, the method of actuating the fixture must be considered. The simplest systems use manually operated valves where the operator turns a handle to clamp and unclamp the fixture. In totally automated systems, the machine tool itself can be programmed to control the clamping and unclamping functions through the use of electric solenoid valves.

POSITIONING vs. CLAMPING

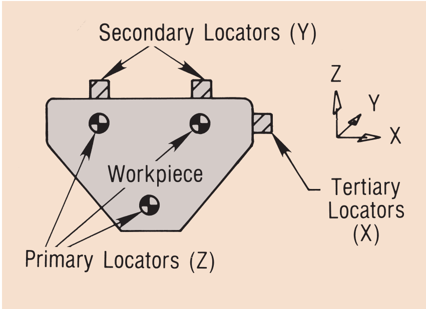
Hydraulic actuators are typically used on a fixture to perform one of two functions: positioning or clamping. Positioning actuators' primary purpose is to push the workpiece against the solid positioning stops built into the fixture. Clamping actuators hold the workpiece in position during machining.

With a properly designed fixture, all the operator needs to do is to place the workpiece into the fixture. The positioning actuators (typically cylinders) will move and correctly orient the workpiece against the stops, and hold it there while the clamps are sequenced, thus securing the part to resist machining forces. While clamps are always needed to hold the part, positioning actuators are sometimes optional depending on the workpiece, fixture design, and the level of operator involvement.



3-2-1 LOCATING PRINCIPLE

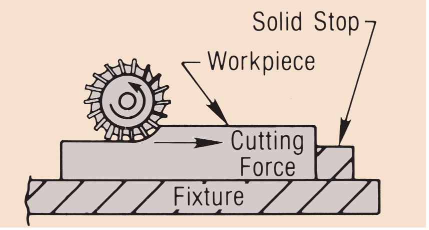
One of the most basic concepts of work-holding is referred to as the 3-2-1 locating principle. To repeatedly locate (or reference) a workpiece, it must be oriented and positioned in three planes: X, Y, and Z.



Thinking of a typical fixture where the workpiece is loaded and gravity holds it in place during clamping, start with the Z axis. Knowing that three points define a plane, it follows that any rigid object in the fixture is technically being supported at only three points regardless of shape. With the part supported in this manner, the workpiece is prevented from moving in the Z direction, but is still free to rotate or slide in the X and Y directions. To prevent rotation and position the workpiece in the Y direction, two stops are used. With the part contacting three stops in the Z axis, and two stops in the Y axis, the only direction the part can move is in the X direction. A single stop is all that is needed to prevent this motion. Always use three locators as the primary (Z) locators, two secondary (Y) locators, and one tertiary (X) locator; thus the name 3-2-1 principle. In rigid parts, these are the only solid stops required to locate the part. Any more are a duplication and can affect repeatability from one part to the next.

RESISTING FORCES – STOPS vs. CLAMPS

When designing the solid stops for a fixture, it is usually best to locate them so that they directly resist the machining forces.



If the cutting tool forces are resisted by solid stops, the workholding clamps need only hold the part in position and can typically be much smaller, saving money and valuable fixture space.

TORQUE vs. TENSION

A user's first introduction to hydraulic power workholding is often the replacement of the nut on a typical strap clamp with a center hole cylinder.

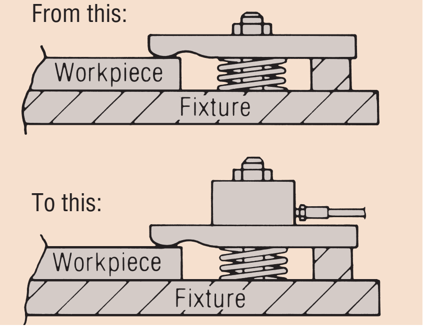
If the torque of the nut is known, the resulting tension on the bolt or stud can be easily approximated.

$$\frac{\text{Torque (In. Lbs.)}}{\text{Nominal thd. size (In.) X .12}} = \text{Tension (Lbs.)}$$

For example, a ½-13 UNC nut is torqued to 300 inch pounds. The resulting approximate tension would be:

$$\frac{300}{.5 \text{ X } .12} = 5000 \text{ lbs.Tension}$$

The most accurate way to determine that the hydraulic power clamping system is exactly duplicating the mechanical system is to place the center hole cylinder over the stud or bolt and replace the nut loosely over the cylinder. Use the hydraulic system to partially extend the cylinder until it contacts the nut. Use a torque wrench to torque the nut to its original value while monitoring the system pressure gauge. When the nut is properly torqued, the gauge will indicate the exact system pressure setting for this application.



OPERATING PRESSURES

Most Hytec workholding components are rated at 5000 psi. When designing, it is a good rule of thumb to choose components for your fixture that will give you the forces you need at a pressure of about 3000 psi. This gives you plenty of latitude to adjust the system pressure both up and down when fine tuning the fixture on the machine tool. Operating at lower pressures, while sometimes necessary, does not make the most efficient use of these components. Higher pressures allow the use of smaller components, saving cost and fixture space.

DESIGN STROKE LENGTH

Clamps and cylinders should never be designed into a fixture at their rated full stroke. Always use something less than full stroke to make sure that all tolerances and variations in the workpiece, workholding device and fixture can be accepted, insuring that the workpiece is properly clamped.

VOLUME CALCULATIONS

The total volume required to actuate a circuit should be checked to make sure that the power source chosen has enough usable fluid capacity. The fluid volume required to fully actuate each clamp and cylinder is listed in the charts on each product page. By totaling this value for each component, you know the maximum fluid volume that could possibly be used in this fixture. Even the smallest Hytec pumps have enough fluid volume for most applications.

Since the fixture is designed to use less than the full stroke of the actuators, the actual fluid volume will be less. If it becomes necessary to get an exact figure, it can be easily calculated using the following formula:

Effective Area (Sq. In.) X Stroke (In.) = Fluid Capacity (Cu. In.)

The effective area of the actuators (from product chart) multiplied by the stroke used (not total stroke) will result in the fluid volume. For example, if a cylinder has an effective area of 2 square inches, and an actual stroke of 3 inches, its fluid volume will be 2 x 3 or 6 cubic inches. (For easy reference, 231 cubic inches = 1 gallon.)

SYSTEM CARE AND MAINTENANCE

The single most important factor in determining the life of a properly designed system is the effort taken to keep the fluid clean.

System Flushing

During assembly, make sure all fluid-carrying components are flushed with clean solvent and blown dry. Hydraulic tubing is particularly notorious for the amount of contaminant's found inside. If not removed, this debris will quickly damage seals and score precision-fit metal parts. The contamination will also clog passages in pumps and control valves.

After fixture assembly, the entire system should be flushed to remove any contamination created during assembly. Use only hydraulic fluid for this procedure. Solvents may become trapped in the system, contaminating the fluid.

Once the fluid in the system is clean, be sure to keep it that way by changing the fluid on a regular basis and making sure that extreme care is taken whenever the system is disconnected or disassembled so that new contaminant's are not introduced.

System Bleeding

Air trapped in the hydraulic system is the most common cause of erratic operation and slow return times. The most common way to bleed a system is to pressurize the circuit and carefully loosen a fitting just enough to let fluid escape. The trapped air will usually be flushed out with the fluid. With conventionally mounted components, the fittings required for connection provide ideal bleeding locations. Since manifold mounting eliminates external fittings and lines, the fixture designer/builder no longer gets bleeding points by default and must now consciously plan for system bleeding.

As workholding hydraulic systems become more sophisticated, compact and automated, proper bleeding becomes increasingly important. Air trapped in the system is most often revealed by the slow retraction of single acting (spring return) components. To understand why, picture the following example:

- Single acting actuators - return springs develop 15 psi
- Flow required to clamp - 1 cubic inch
- System pressure - 3000 psi

Return time for this application is dictated by the time it takes to force 1 cubic inch of fluid through all of the return line restrictions at 15 psi.

Take the same example with 1 cubic inch of air (at atmospheric pressure) trapped anywhere in the system:

When pressurized, this "bubble" compresses and becomes 200 times smaller or .005 cubic inch. This means that .995 cubic inch of oil must be pumped into the system just to compress the bubble. Now when the clamps are released, 1.995 cubic inches of fluid must leave the system - nearly double that of the same system without air.

HYTEC

CALCULATING MACHINING FORCES

To help you choose the right cylinders, clamps, and work supports, it is important to know how much clamping or supporting force is necessary.

There are numerous ways to calculate the approximate forces that the cutting tool places on the workpiece. **Please note that the results of these calculations are estimates and must never replace experience, common sense, and caution.** In addition, these results indicate only the magnitude of the force, not the direction. Depending on the specific application, the direction of the force may vary significantly from the beginning to the end of the cut.

MILLING, TURNING, AND BORING

A rough estimate of cutting tool force—if the horsepower required to make the cut is known—is the result of the following equation:

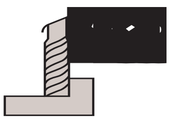
$$\text{Cutting Force (Lbs.)} = \frac{\text{HP} \times 24{,}750}{\text{Cutting Speed (SFPM)}}$$

For example, an operation is expected to take 5 horsepower with a cutting speed of 150 surface feet per minute.

$$\frac{5 \times 24{,}750}{150} = 825 \text{ lbs. Cutting Force}$$

Where horsepower is not yet known, a value called unit power comes into play. Unit power is the horsepower required to remove one cubic inch of material in one minute. (Refer to Table A.)

MILLING



Depth of Cut (In.)
Feed per Tooth (In.)
Number of Teeth
Unit Power

___X___X___X___ X 125,950 = _____ lbs. Cutting Force

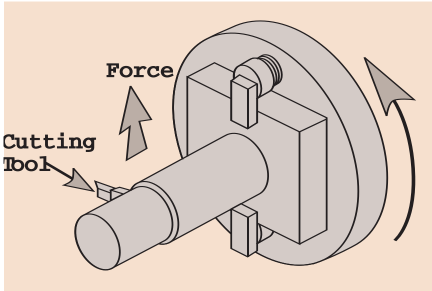
Example: a 4-flute end mill is used to machine aluminum. The cut is ½" deep and the feed per tooth is .002". From the table the unit power value is 0.4. So the cutting force transferred to the workpiece is:

$$.5 \times .002 \times 4 \times .4 \times 125{,}950 = 202 \text{ lbs. Cutting Force}$$

Note that this calculation assumes a full width cut. Applications using less than the full cut may reduce the calculated force by the percentage of the full cut being taken.

TURNING AND BORING

A similar calculation applies to turning and boring. Note that the cutting force is usually perpendicular to the cutting tool but since the tool or workpiece is rotating, the direction of the force relative to the work piece is constantly changing.



Depth of Cut (In.)
Feed per Revolution (In.)
Unit Power

____X____X____X 396,000 = _____ lbs. Cutting Force

number of drill styles available, the thrust varies tremendously. Torque is somewhat less variable and can be estimated as shown:

$$\text{Feed (IPR)} \times (\text{Drill Dia.})^2 \times \text{Unit Power} \times 49{,}500 = \text{Drilling Torque (In. Lbs.)}$$

For example, drilling a ¾" diameter hole in magnesium (unit power .2) with a feed rate of .010" per revolution gives a result of:

$$.010 \times .75^2 \times .2 \times 49{,}500 = 56 \text{ in. lbs.}$$

FRICTION COEFFICIENT

Now that an estimate of the amount of cutter force being transferred to the workpiece is available, we must determine how much clamping force is necessary to resist the cutter force. This depends on the amount of friction between the workpiece and the fixture, commonly referred to as the friction coefficient.

Typically, if an object is lying on a surface, the amount of force required to slide it sideways will be considerably less than the weight of the object. It follows then that when clamping a workpiece to resist machining forces, the clamping force will need to be much higher than the machining force. The following chart shows approximate friction coefficients:

Static Friction Coefficients for Steel on Various Materials

Material	Friction Coefficient	
	Clean	Lubricated
Brass	0.35	0.19
Bronze	–	0.16
Bronze, Aluminum	0.45	–
Bronze, Phosphor	0.35	–
Bronze, Sintered	–	0.13
Carbon, Hard	0.14	0.11-0.14
Copper-Lead Alloy	0.22	–
Graphite	0.10	0.10
Iron, Cast	0.40	0.21
Steel	0.80	0.16
Tungsten Carbide	0.4-0.6	0.1-0.2

mping force is divided
riction coefficient and
suitable safety factor
total clamping force

$$\frac{\text{Machining Force (Lbs.)}}{\text{Friction Coefficient}} \times \text{Safety Factor} = \text{Total Clamping Force (Lbs.)}$$

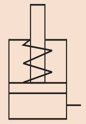
Example: A steel workpiece on steel rest buttons is being machined using coolant. The estimated machining force is 300 lbs. From the table the friction coefficient for steel on steel (lubricated) is .16. After choosing an appropriate safety factor (usually about 2), the estimated total clamping force would be:

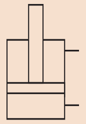
$$\frac{300}{.16} \times 2 = 3750 \text{ lbs. Total Clamping Force}$$

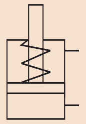
This total clamping force may now be divided by the number of clamps holding the workpiece, which equals the clamping force needed for each clamp.

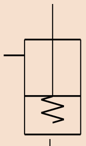
TABLE A		Unit Power hp/in³/min		
		Turning	Drilling	Milling
Material	Hardness Bhn	HSS & Carbide Tools	HSS Drills	HSS & Carbide Tools
STEELS Plain Carbon Alloy Steels	85-200 35-40Rc 40-50Rc 50-55Rc 55-58Rc	1.4 1.7 1.9 2.5 4.2	1.3 1.7 2.1 2.6 3.2	1.4 1.9 2.2 2.6 3.2
CAST IRONS Gray, Ductile & Malleable	110-190 190-320	0.9 1.7	1.2 2.0	0.8 1.4
STAINLESS STEELS	135-275 30-45Rc	1.6 1.7	1.4 1.5	1.7 1.9
TITANIUM	250-375	1.5	1.4	1.4
NICKEL ALLOYS	80-360	2.5	2.2	2.4
ALUMINUM ALLOYS	30-150 500kg	0.3	0.2	0.4
MAGNESIUM ALLOYS	40-90 500kg	0.2	0.2	0.2
COPPER ALLOYS	10-80Rb 80-100Rb	0.8 1.2	0.6 1.0	0.8 1.2

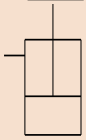
Cylinder Symbols


Cylinder, Single-Acting

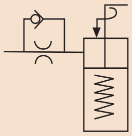

Cylinder, Double-Acting

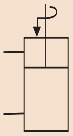

Cylinder, Single or Double-Acting

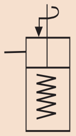

Pull Cylinder, Single-Acting, Spring Return

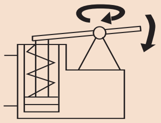

Pull Cylinder, Single-Acting

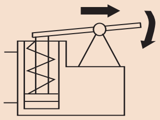
Clamp Symbols


Swing/Pull Clamp, Single-Acting
w/Flow Restrictor Valve

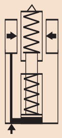

Swing/Pull Clamp, Double-Acting


Swing/Pull Clamp, Single-Acting

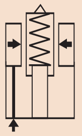
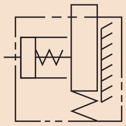

Swing Clamp, Single or Double-Acting

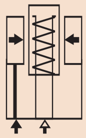
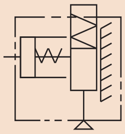

Retract Clamp, Single or Double-Acting

Work Support Symbols


Work Support, Fluid Advance

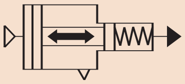
Work Support Symbols

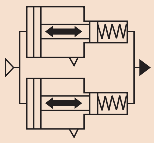


Work Support, Spring Advance

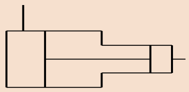


Work Support, Air Advance

Power Source Symbols

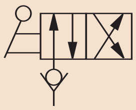
Electric/Hydraulic Pump

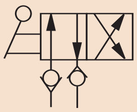

Air/Hydraulic Pump, Reciprocating

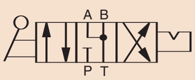

Air/Hydraulic Pump, Reciprocating 2-stage


Intensifier

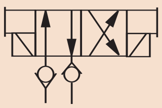
Control Valve Symbols

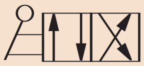

Directional Control Valve, Manual 4-Way,
2-Position w/Inlet Check Valve


Directional Control Valve, Manual 4-Way,
2-Position w/Inlet and Outlet Check Valves



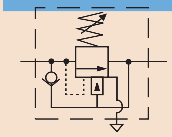
Directional Control Valve, Manual 4-Way,
3-Position Detented

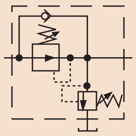

Directional Control Valve, Electric 4-Way,
2-Position w/Inlet and Outlet Check Valves
w/Manual Override

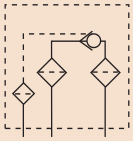

Directional Control Valve, Manual 4-Way,
2-Position

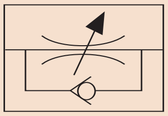
HYTEC

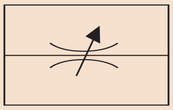
Control Valve Symbols


Pressure Sequence Valve, Adjustable w/Reverse Free-Flow Check Valve

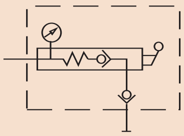

Pressure Reducing Valve, Adjustable w/Reverse Free-Flow Check Valve w/Over-Pressure Relief Valve

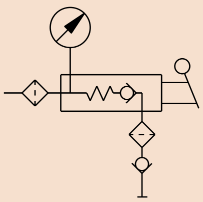

Check Valve, Pilot Operated w/Filters


Flow Restrictor, Adjustable w/Reverse Free-Flow Check Valve

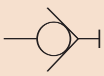

Flow Restrictor, Adjustable

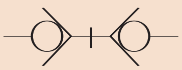
Pallet Coupling Symbols


Manual Pallet Valve w/Gauge and Male Coupler


Manual Pallet Valve With Filters, Gauge and Coupler

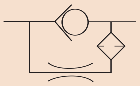
Accessory Symbols

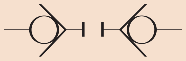

Hydraulic Coupler, Half-Male or Female


Hydraulic Coupler Set, Coupled

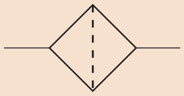
Accessory Symbols

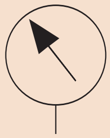

Check Valve

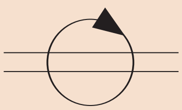

Flow Restrictor, Fitted w/Reverse Free-Flow Check Valve w/Filtered Orifice

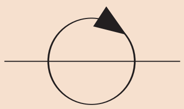

Hydraulic Coupler Set, Uncoupled

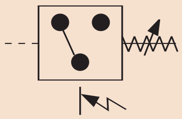

Accumulator, Gas Charged

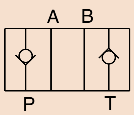

Filter


Pressure Gauge

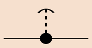

Rotating Union, Dual Circuit


Rotating Union, Single Circuit


Pressure Switch, Adjustable



Check Valve Sub-Plate


Air Bleed Valve


Ball Valve

Conversion Formulas

SI* Conversion Formulas

APPROXIMATE CONVERSION				
MULTIPLY	BY	TO GET OR MULTIPLY	BY	TO GET
SI* UNIT	CONV FACTOR	NON-SI UNIT	CONV FACTOR	SI* UNIT
LENGTH				
millimeter (mm) (1 inch = 25.4 mm exactly)	X 0.03937	= inch	X 25.4	= mm
centimeter (cm) 10 mm	X 0.3937	= inch	X 2.54	= cm
meter (m) 1000 mm	X 3.28	= foot	X 0.305	= m
meter (m)	X 1.09	= yard	X 0.914	= m
kilometer (km) 1000 m	X 0.62	= mile	X 1.61	= km
AREA				
millimeter^2 (mm^2)	X 0.00155	= inch^2	X 645	= mm^2
centimeter^2 (cm^2)	X 0.155	= inch^2	X 6.45	= cm^2
meter^2 (m^2)	X 10.8	= foot^2	X 0.0929	= m^2
meter^2 (m^2)	X 1.2	= yard^2	X 0.836	= m^2
hectare (ha) 10,000 m^2	X 2.47	= acre	X 0.405	= ha
kilometer^2 (km^2)	X 0.39	= mile^2	X 2.59	= km^2
VOLUME				
centimeter^3 (cm^3)	X 0.061	= inch^3	X 16.4	= cm^3
liter (l)	X 61	= inch^3	X 0.016	= l
milliliter (ml)	X 0.034	= oz-liq	X 29.6	= ml (1 ml = 1 cm^3)
liter (l) 1000 ml	X 1.06	= quart	X 0.946	= l
liter (l)	X 0.26	= gallon	X 3.79	= l
meter^3 (m^3) 1000 l	X 1.3	= yard^3	X 0.76	= m^3
MASS				
gram (g)	X 0.035	= ounce	X 28.3	= g
kilogram (kg) 1000 g	X 2.2	= pound	X 0.454	= kg
metric ton (t) 1000 kg	X 1.1	= ton (short)	X 0.907	= t

APPROXIMATE CONVERSION				
MULTIPLY	BY	TO GET OR MULTIPLY	BY	TO GET
SI* UNIT	CONV FACTOR	NON-SI UNIT	CONV FACTOR	SI* UNIT
FORCE (N = kg • m/s^2)				
newton (N)	X 0.225	= pound	X 4.45	= N
kilonewton (kN)	X 225	= pound	X 0.00445	= kN
TORQUE				
newton meter (N•m)	X 8.9	= lb. in.	X 0.113	= N•m
newton meter (N•m)	X 0.74	= lb. ft.	X 1.36	= N•m
PRESSURE (Pa = N/m^2)				
kilopascal (kPa)	X 4.0	= in. H_2O	X 0.249	= kPa
kilopascal (kPa)	X 0.30	= in. Hg	X 3.38	= kPa
kilopascal (kPa)	X 0.145	= p.s.i.	X 6.89	= kPa
megapascal (MPa)	X 145	= p.s.i.	X 0.00689	= MPa
Bar	X 14.5	= p.s.i.	X .0689	= Bar
POWER (w = J/s)				
kilowatt (kw)	X 1.34	= hp	X 0.746	= kw
kilowatt (kw)	X 0.948	= Btu/s	X 1.055	= kw
watt (w)	X 0.74	= ft. lb/s	X 1.36	= w
TEMPERATURE				
°C = (°F - 32) ÷ 1.8	°F = (°C X 1.8) + 32			
FLOW				
cu. cm./min.	X .061	= cu. in/min.	X 16.4	= cu. cm./min.
liters/min.	X .2642	= GPM	X 3.785	= liters/min.

* System International (Modern Metric System)

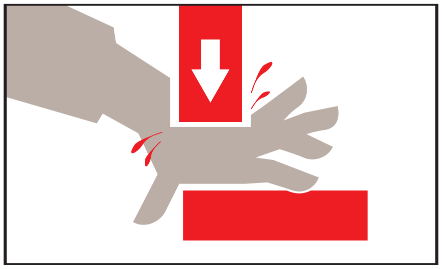
Decimal & Millimeter Equivalents

	DECIMALS	MILLIMETERS		DECIMALS	MILLIMETERS		DECIMALS	MILLIMETERS
1/64	.015625	— 0.397	23/64	.359375	— 9.128	45/64	.703125	— 17.859
1/32	.03125	— 0.794	3/8	.3750	— 9.525	23/32	.71875	— 18.256
3/64	.046875	— 1.191	25/64	.390625	— 9.922	47/64	.734375	— 18.653
1/16	.0625	— 1.588	13/32	.40625	— 10.319	3/4	.7500	— 19.050
5/64	.078125	— 1.984	27/64	.421875	— 10.716	49/64	.765625	— 19.447
3/32	.09375	— 2.381	7/16	.4375	— 11.113	25/32	.78125	— 19.844
7/64	.109375	— 2.778	29/64	.453125	— 11.509	51/64	.796875	— 20.241
1/8	.1250	— 3.175	15/32	.46875	— 11.906	13/16	.8125	— 20.638
9/64	.140625	— 3.572	31/64	.484375	— 12.303	53/64	.828125	— 21.034
5/32	.15625	— 3.969	1/2	.5000	— 12.700	27/32	.84375	— 21.431
11/64	.171875	— 4.366	33/64	.515625	— 13.097	55/64	.859375	— 21.828
3/16	.1875	— 4.763	17/32	.53125	— 13.494	7/8	.8750	— 22.225
13/64	.203125	— 5.159	35/64	.546875	— 13.891	57/64	.890625	— 22.622
7/32	.21875	— 5.556	9/16	.5625	— 14.288	29/32	.90625	— 23.019
15/64	.234375	— 5.953	37/64	.578125	— 14.684	59/64	.921875	— 23.416
1/4	.2500	— 6.350	19/32	.59375	— 15.081	15/16	.9375	— 23.813
17/64	.265625	— 6.747	39/64	.609375	— 15.478	61/64	.953125	— 24.209
9/32	.28125	— 7.144	5/8	.6250	— 15.875	31/32	.96875	— 24.606
19/64	.296875	— 7.541	41/64	.640625	— 16.272	63/64	.984375	— 25.003
5/16	.3125	— 7.938	21/32	.65625	— 16.669	1	1.000	— 25.400
21/64	.328125	— 8.334	43/64	.671875	— 17.066			
11/32	.34375	— 8.731	11/16	.6875	— 17.463			

1 mm = .03937"
.001" = .0254 mm

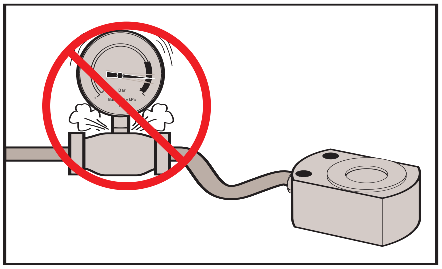
... a note on SAFETY

Safety means paying attention to the smallest details. A hastily assembled workholding system can result in a hazardous operator environment. Hydraulic workholding is not a generic technique where most anything will work nor is there one right or best answer for all situations. Each application is different and can be approached in many different ways. Because of this versatility, there is no rule-of-thumb to follow to guarantee safety. Knowledge, careful fixture design and common sense are likely the key to avoiding injuries.



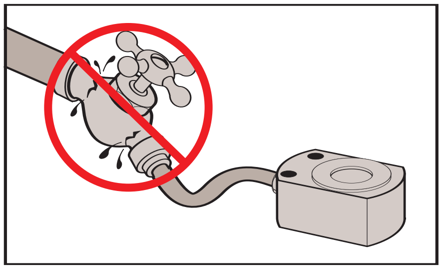
Plan your fixture installation with the operator's safety in mind. By nature, most clamping devices have pinch points. Many times the fixture can be designed to shield the operator from a pinching hazard. Often the placement of the clamping device in the fixture can minimize the gap between the clamp and the workpiece thus reducing or eliminating the pinch point. Perhaps the clamping control valve or switch can be located such that the operator cannot reach the fixture and the control at the same time. Dual palm buttons on electrically actuated systems serve the same purpose.

Don't require the operator to hold the workpiece in position during the clamping operation. Make sure that the workpiece is self supporting and self locating so that the operator's hands can be out of danger when the hydraulic system is actuated. Often a simple spring plunger is all that is necessary.

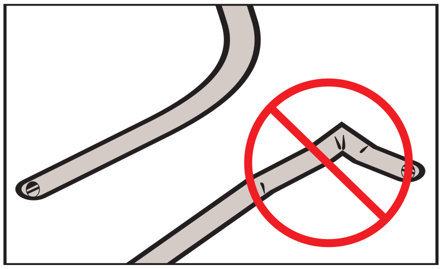


The **lowest** pressure rating of any component in the clamping system sets the **maximum** pressure rating for the entire system.

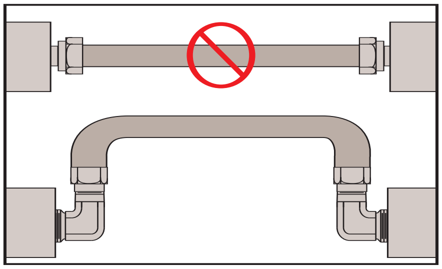
Most Hytec hydraulic workholding components are rated at 5,000 psi maximum. However, some components are rated at less than 5,000 psi. The maximum pressure is listed on each product page of this catalog. **Never exceed this rating.**



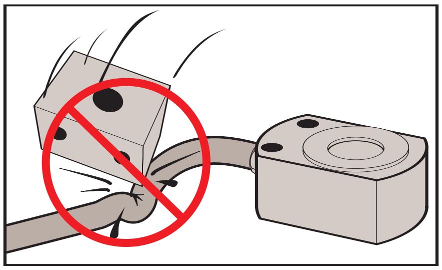
Just having a clamp that is rated at 5,000 psi is not enough. Every hose, fitting, valve, adapter and tube exposed to pressure must be rated at or above the maximum hydraulic system pressure. Most "hardware store" fittings are intended only for low pressure plumbing. Never use water pipe fittings or copper tubing and brass fittings for hydraulic service.



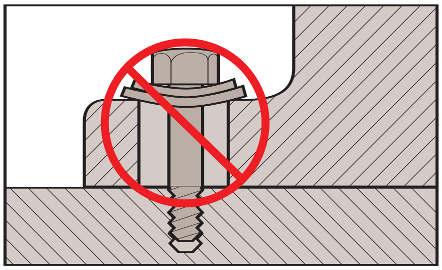
Use proper tools when bending tubing and maintain proper minimum bend radii for hoses and tubing. If a hose or tube is ever kinked, replace it. Don't risk a rupture. Fluid escaping under high pressure is dangerous. The resulting loss in pressure could release the workpiece from the fixture and cause serious injury and equipment damage by being ejected from the machine or breaking tooling.



Tubing and hoses do flex when pressurized. Allow for that movement by supporting the fluid lines away from surfaces which could abrade the surface and eventually cause damage. Avoid straight lengths of hose and tubing. A bend will allow for this deflection without putting too much stress on the line.



Even if proper hydraulic tubing and fittings are specified, be sure to protect them from abuse. Components damaged from abrasion or accidental dropping of a workpiece will no longer have the strength and safety originally designed.



Use proper mounting hardware when installing workholding clamps and other components. Always use the largest bolt available to fit in the mounting hole. In many cases, the recommended cap screw or thread is specified on the product page of this catalog. Sometimes the mounting hardware is included with the component. Always use supplied hardware.