

Fluid Injection Injury – A Surgical Emergency

The
Lethal
Strike!

A Guide to Properly Managing
and Preventing Injection Injuries

Presented by
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F P S I
FLUID POWER SAFETY INSTITUTE™

www.fluidpowersafety.com

The Hand consists of . . .

- 29 major and minor bones
- 29 major joints
- At least 123 named ligaments
- 34 muscles, which move the fingers and thumb
- 48 named nerves
- 3 major nerves
- 24 named sensory branches
- 21 named muscular branches
- 30 named arteries, and nearly as many smaller named branches



The Hand . . .

- Easily damaged if injured
- Exceedingly difficult to repair

DO EVERYTHING POSSIBLE
TO PROTECT THEM!



Abstract

This document examines the factors that influence the background, symptoms, treatment and likelihood of fluid injection injuries – specifically identifying people who are most at risk and how such an injury should be treated.

All people who work on and around fluid power systems are at risk of suffering a fluid injection injury. The people most at risk include those who maintain, service, repair, and troubleshoot fluid power systems, assembly line workers, diesel engine technicians, and workers who operate hydraulic-powered tools.

Abstract

A number of factors cause, or contribute to, the reasons why people who work on, and around, fluid power systems are at high risk of suffering liquid injection injuries:

- Fluid power is not recognized as an occupational hazard by Federal (OSHA and MSHA) and state agencies, which means people who work on and around fluid power systems are not required to undergo any type of safety training in fluid power, moreover, less than 1% of companies provide it.
- Licensed safety professionals only receive training in those jobs that are recognized by OSHA and MSHA as occupational hazards thus they typically do not have the skillsets needed to introduce vital safety guidelines needed to protect workers.
- Without OSHA or MSHA oversight and/or regulations regarding the safe release of hydraulic energy, there are no safety design standards for the safe release of stored hydraulic energy.
- Without integrated safety devices to safely remove stored energy from fluid power systems workers routinely expose themselves to hazardous conditions.

What is Pressure?

DEFINITION: A measure of a force's intensity

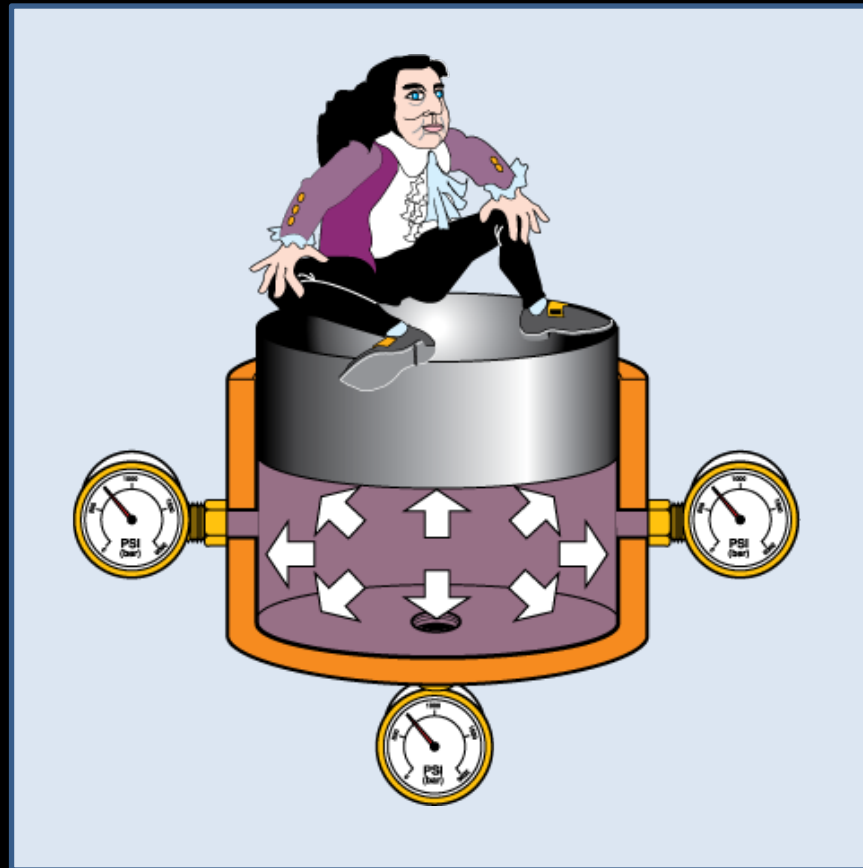
FORMULA: $\text{PRESSURE} = \text{FORCE} \div \text{AREA}$



What is Liquid Pressure?

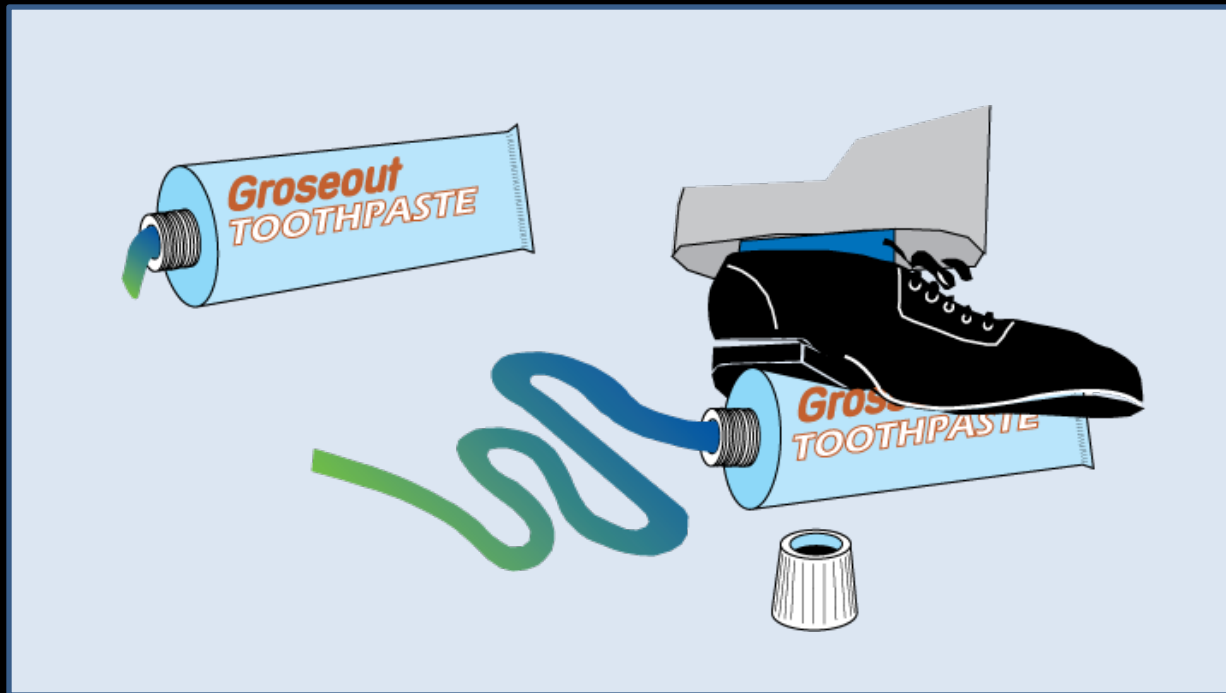
“Fluids in a closed container, receiving pressure over any area of that container, transmit this pressure throughout the system undiminished and equal in all directions.”

BLAISE PASCAL
(1623-1662)



Pressure Difference Affects Flow -

THE GREATER THE PRESSURE DROP ACROSS AN ORIFICE THE GREATER THE FLOW RATE



What is a Subcutaneous Injection?

An injection delivered via a hypodermic needle.



What is a “Jet-Injector” Device?

Believe it or not, there is actually a device that is designed to give a person a liquid injection: it's called a “jet injector”

A jet injector device is a mechanism that delivers a controlled, tiny, high-pressure jet of medication into the skin without the use of a hypodermic needle.

What is a “Jet-Injector” Device?

However, there are four key differences between being injected with a “jet injector” medical device and being injected with an industrial device.

A “jet injector” will:

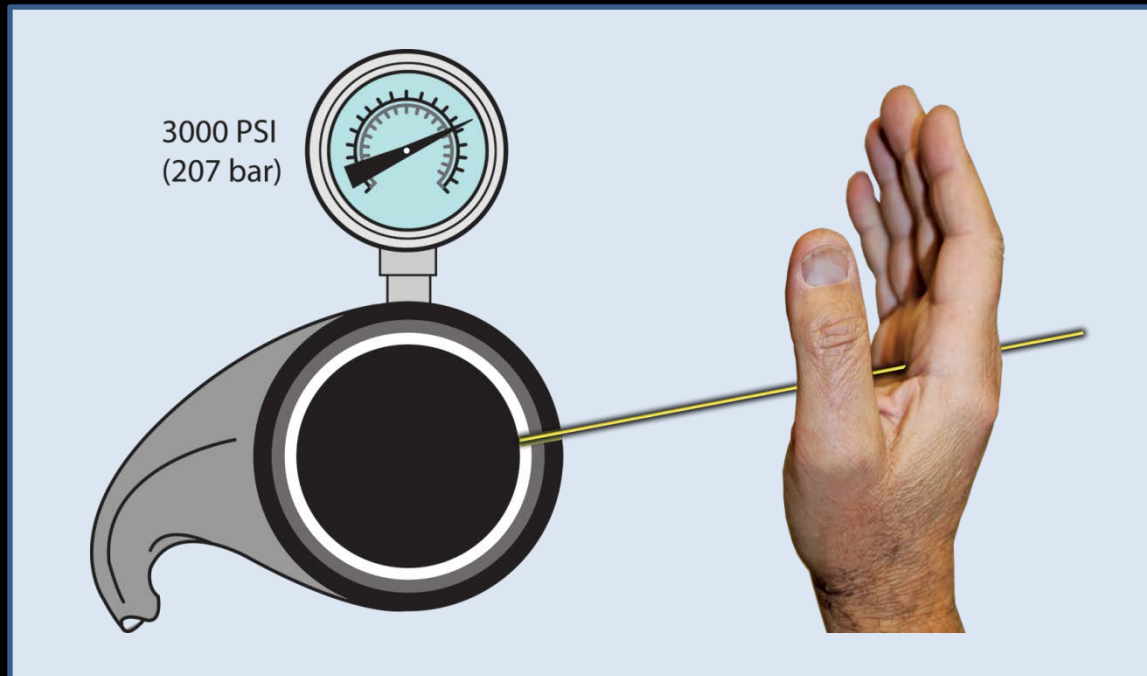
- Deliver a substance that will improve your health.
- Deliver a pre-determined amount of medication.
- Deliver it to a pre-determine location in the body.
- Be administered by a medical professional.

On the contrary, an industrial device will:

- Deliver a substance that will maim or kill you.
- Deliver an uncontrolled amount of the substance.
- Deliver it to an arbitrary part of the body.
- Be administered unexpectedly by a machine.

How a typical substance injection injury occurs:

Here is an illustration of the cross-section of a flexible hose.
The pressure within the hose is 3000 PSI (207 bar).



A pinhole leak appears in the wall of the hose and releases a “jet” of oil, which heads for the hand and effortlessly breaches the skin.

Do You Work With Any of the Following Devices?

Are you aware of the operating pressures of those devices? Here are some examples:

Device type	Typical operating pressure(s)	Device type	Typical operating pressure(s)
Hose pipe	35 PSI to 75 PSI (2.4 to 5.2 bar)	Hose crimping machine	5,000 PSI (345 bar)
Air brakes (truck)	120 PSI (8.3 bar)	Hydraulic system	1,000 to 10,000 PSI (69 to 690 bar)
Airplane hydraulic system:		Hydraulic fracturing (fracking)	Up to 15,000 PSI (1,034 bar)
• Boeing 737	3,500 PSI (241 bar)	Nitrogen pumping	5,000 PSI (345 bar)
• F16 fighter jet	5,000 PSI (345 bar)	Pesticide sprayer	45 to 560 PSI (3 to 39 bar)
Bolt torque devices	up to 10,000 PSI (690 bar)	Porta-power	10,000 PSI (690 bar)
Diesel fuel system:		Pressure washer (water)	3,000 to 5,000 PSI (207 to 345 bar)
• Pre-common rail	2,250 PSI (155 bar)	Paint spray gun:	
• Common rail	Up to 44,000 PSI (3,034 bar)	• Air compressor operated	15 PSI to 45 PSI (1 to 3 bar)
Drive through car wash	1,000 to 2,500 PSI (69 to 172 bar)	• Air assisted type	300 to 3,000 PSI (21 to 207 bar)
Forklift hydraulic system	Up to 3,000 PSI (207 bar)	• Airless type	300 to 7,500 PSI (21 to 517 bar)
Grease gun:		Paint-ball gun	3,000 to 5,000 PSI (207 to 345 bar)
• Needle-point type	250 to 6,000 PSI (17 to 414 bar)	Water jet cutting machine	Up to 95,000 PSI (6,552 bar)
• Lever operated type	Up to 15,000 PSI (1,034 bar)		
• Air or battery operated	Up to 5,800 PSI (400 bar)		
• Central lube system	Up to 5,800 PSI (400 bar)		
• Lube system rail industry	Up to 4,000 PSI (276 bar)		

If you do, and you are not properly trained, you are at high risk of severe injury or death. You MUST receive training in safety and fundamental fluid power before working on and around pressurized systems.

Introduction

High pressure injection injuries are rare, occurring in an average of 1 in 600 cases of hospital reported hand injuries (Louisville Manual for Hand Surgery - Outline). One study showed that large surgical hand centers have on average 1 to 4 injection injury treatments every year (Verhoeven & Hierner 2008).

This study is supported by Dailiana et al (2008) who cited that 8 patients were treated with injection injuries in a 5 year period in the Department of Orthopedic Surgery of Larissa University Hospital. conditions.



Introduction

The first recorded high pressure injection injury in the UK occurred in the 1930s (Loveday 2007), the first published case of an injection injury to the hand was in the German literature by Hesse 1925 by (Wermeling and Kasdan). There were 150 reported cases in the 50 years to 1984 in the UK (New South Wales Government, 2002). Gelberman (1975) reported that most injuries occur to people who have been working in a new job for less than 6 months.

Research concurs that injury typically involves pressures in excess of 100 psi (6.9 bar) punching a hole in the skin and soft tissue (Dailiana et al, 2008, Louisville Manual for Hand Surgery-Outline, Loveday 2007, Verhoeven & Hierner 2008). Unless having direct contact with the skin, pressures below 100 psi (6.9 bar) are unlikely to have sufficient energy to cause an injection injury unless skin has previously been broken, or is healing from a recent injury.



Introduction

Grease is the material most often injected, followed by paint, water, wax, paint thinner, cement, plastic, oil and hydraulic fluid. Injection pressures are generally 2,000 – 10,000 psi (138 – 690 bar), (Makhene 2012).

Dependent on the entry pressure, injected fluid can travel a significant distance from the initial site of entry, this results in more widespread tissue damage.

The high pressure injection of a fluid such as oil constitutes a medical emergency and requires rapid access to appropriate specialist surgical care. The injury is often worse than it will appear and all medical personnel, (including First Responders) must be aware of the seriousness of the patient's condition. Prompt recognition of the injury and early treatment are essential to avoid a poor outcome.



The People Most at Risk -

The people who are at risk are those who work on, and around hydraulic powered machinery: mobile and industrial, hydraulic test benches, assembly line workers, diesel fuel systems: particularly common rail, grease guns, hydraulic powered tools, water jet machines, spray paint equipment, military equipment, robotics, pneumatic machinery, power washers, steam, and aviation.

**Remember you can also be in the
wrong place at the wrong time**

The age range of the patient varies between studies, 21 to 59 years (Flotre 1992) with the average being around 36 (Verhoeven & Hierner 2008).

At present there are no gloves currently available to protect people against fluid injection injuries to the hand.

The Material Injected, Site of Injection and Likelihood of Amputation -

The toxicity of the injected material is dependent upon its chemical composition, lipid soluble (insoluble in water) causes greater tissue damage than grease – even when not under pressure. Paint solvents are more toxic than either paint, or diesel fuel.

One study showed that amputation was needed in 80% of the cases when paint solvent was injected. In the same study amputation was needed in 20% of the cases where grease was injected (The Louisville Manual for Hand Surgery-Outline).

The Material Injected, Site of Injection and Likelihood of Amputation -

Grease and oil often cause no reaction for the first two days but then cause extensive fibrosis, oleogranuloma formation and draining sinuses (Flotre 1992).

Water and air injuries may cause further complications due to fungal or other chemicals (for example sewage, or oil lubrication). Clean water injection injuries require superficial debridement (which can be performed under local anesthetic), broad-spectrum antibiotics, and elevation – close observation will also be required (Makhene 2012).

High energy gas injection can cause serious injury and gas embolism (air bubbles in the bloodstream) and death have been reported (The Louisville Manual for Hand Surgery-Outline).

Fluid viscosity also has a direct bearing on the extent of the injury. The more viscous the material, the less it will spread. Paint does not disperse as far as paint solvent which, therefore, affects a greater volume of tissue (The Louisville Manual for Hand Surgery-Outline).

The Material Injected, Site of Injection and Likelihood of Amputation -

The most common site of injection is the non-dominant hand on which the thumb, index and middle fingers are the most commonly injured digits (this is because the device is most often held in the dominant hand whilst the device being worked on, or in the case of a paint spray gun, the nozzle is being adjusted by the other hand).

(In a study, five of the nine patients with amputations had paint injection injuries). This supports other studies, (including those by Verhoeven & Hierner 2008) which concluded that the injection of paint into the hand results in more cases of amputation than other materials, for example oil (solvents resulted in amputation in 50-80% of the cases, whereas other materials resulted in amputation in 16-55% of the cases). Gelberman's studies concluded that prompt surgery does not guarantee a satisfactory result (but is likely to improve the outcome).

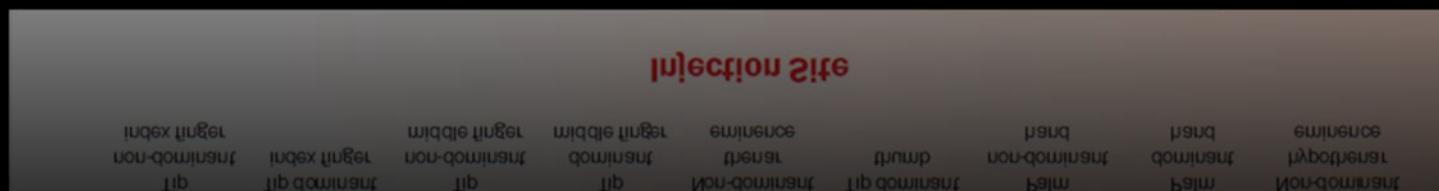
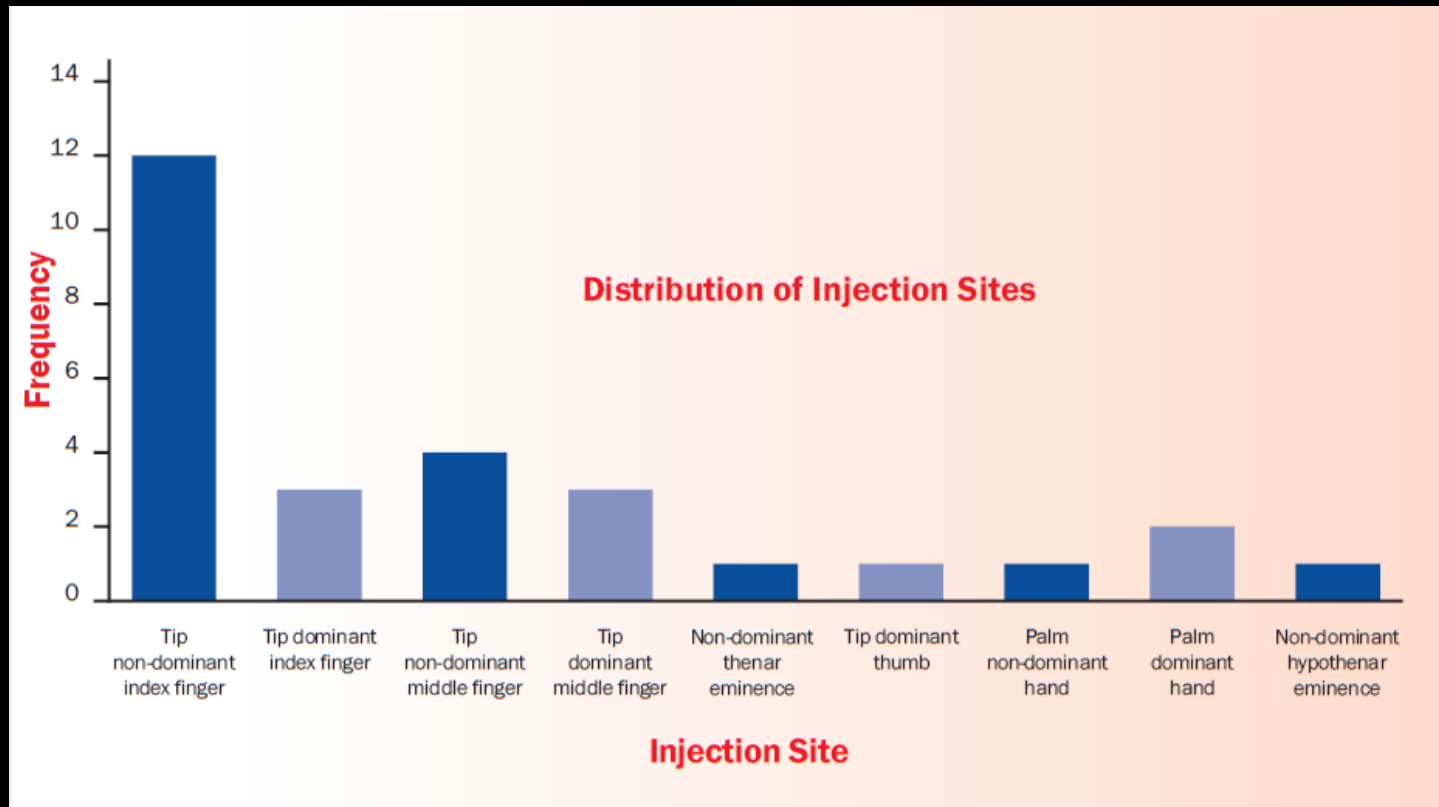
The amputation risk is lower if wide surgical debridement occurs within 6 hours of the injury (Dailiana et al 2008). However, Loveday's (2007) research found that the average time between high-pressure injection injury and emergency department attendance is eight hours.

The Material Injected, Site of Injection and Likelihood of Amputation -

80% of people injured by paint and paint thinners required amputation (Louisville Manual for Hand Surgery-Outline). Verhoeven & Hierner (2008) cited that, (irrespective of the material injected) where the pressure was more than 6,900 psi (490 bar) amputation risk is extremely likely.

Distribution of Injection Sites -

This graph shows the distribution of fluid injection injuries by site based on a 10-year review of high-pressure injection injuries to the hand by Lewis, Clarke, Kneafsey and Brennen, (1998).



The Symptoms -

(1 to 5 inclusive, Queensland Ambulance Service 2011)

1. The point of entry may look very small and may not bleed, (*)
2. The area of injury will usually be on the working surface of the hand, however it may be located on any body area.
3. Initially the patient may not complain of pain but may feel a numbness or increased pressure within the affected part.
4. Damage in the early stages is normally related to the physical injury as well as damage from the chemicals in the injected material.
5. The affected body part will progressively become increasingly irritated, with the patient complaining of throbbing pain.
6. The injected material may cause additional injury (for example burns).

(*) In his research Loveday (2007) cited an example of a man who, after being struck by a high-pressure water jet, received severe internal abdominal injuries even though his skin was not pierced. In his paper, High-pressure injection injuries of the hand, Flotre (1992) gave an illustration of a 30-year old man who had been using an airless paint sprayer at home attempted to clear a blockage at the tip of the spray gun with one hand while depressing the trigger of the sprayer with the other hand. As a result, white paint was injected into the tip of his left index finger. Initially, the finger felt stiff. The patient only realized the injection had occurred when a drop of white paint spurted out of his fingertip when he bent his finger.

Treatment -

(refer to Appendix 1)

First aid treatment is very limited, being mainly restricted to comforting the casualty until qualified medical assistance can be obtained.

Any fluid injection injury must be treated as a medical emergency, it requires prompt and accurate diagnosis and treatment – this often requires surgery.

The patient **MUST NOT** be taken to a local GP, they **MUST** be taken to an emergency department, preferably one which is able to treat injuries to the hand surgically.

The time to receiving treatment is critical in order to give the patient the best possible chance of having a positive outcome and chance of recovery.

In one study (Dailiana et al 2008) the total number of surgical procedures required following a fluid injection injury was 2 to 5 (the average being 2.7).

Infection may occur even if antibiotics have been prescribed. Many patients are given antibiotics but reported infection rates vary from 11.5-60% (Louisville Manual for Hand Surgery-Outline).

For injuries to the hand splinting is used to reduce joint contracture and provides the best position from which to mobilize. Night splinting may need to continue for some months following surgery (Louisville Manual for Hand Surgery-Outline).



Outcome -

As a result of suffering a fluid injection injury of the hand only a small percentage (not quantified within the material which was reviewed whilst writing this document) of the patients can resume their original work.

In one study 92% of the patients returned to work (of some type), 50% of those who required amputation had changed their occupation (Louisville Manual for Hand Surgery-Outline).

The same document goes on to explain that in comparison to the uninjured hand, grip strength was decreased by 15%, lateral key pinch by 23%, chuck grip by 25% and dynamic muscle power was reduced by 27%.



WARNING!

DISTURBING IMAGES AHEAD



Outcome -

In his research Loveday (2007) identified that 40 percent of patients who required amputation in one emergency department had been assessed inadequately at initial presentation.

The studies by Verhoeven & Hierner (2008) noted that the outcome following a fluid injection injury to the hand include permanent complaints of the patient amongst others are hyperesthesia (abnormal increase in sensitivity around the area injured), continuous pain, cold intolerance, contracture and reduced sensitivity. Amputation and aesthetic problems are two other complications.



Photo courtesy of Dailiana H.Z.

Conclusion -

Oil injection injuries to the hand are not common but should they occur they **MUST** be treated as a medical emergency, they require prompt and accurate diagnosis and treatment – this often requires surgery. The patient **MUST NOT** be taken to a local GP, they **MUST** be taken to an emergency department, preferably one which is able to treat injuries to the hand surgically.

The time to receiving the correct treatment is critical in order to give the patient the best possible chance of having a positive outcome and chance of recovery.



Photo courtesy of Dailiana H.Z.

Further studies show -

- Fluid at pressure punctures and penetrates the skin and body tissue.
- Injected substance passes rapidly through the subcutaneous tissue and enters the tendons and deep spaces of the hand/body.
- A pinhole leak in a hydraulic hose that is under pressure can release toxic fluid at a speed of 600+ feet (183m) per second, this is close to the muzzle velocity of a gun.
- This is sufficient to penetrate protective equipment depending upon velocity.
- Penetration distances recorded up to 4" (10cm) between fluid source and skin show that:
 - 100 psi (6.9 bar) is sufficient to puncture the skin
 - < 2,000 psi (138 bar) – 40% chance of amputation
 - > 2,000 psi (138 bar) – 50% chance of amputation
 - < 7,000 psi (483 bar) – non-prognostic
 - > 10,000 psi (690 bar) – amputation extremely likely



Photo courtesy of Dailiana H.Z.

Checking for oil leaks -

Injection typically occurs when a person is looking for a leak in a bundle of hoses. When examining hoses for damage or searching for a leak, it is vital that the hands (and indeed any other part of the body) are kept away from equipment which is under pressure.

The image shows the incorrect way of doing this.



Checking for oil leaks -

The safest way to find a leaking hose in a hose bundle is through the use of a pressure/leak test using a Safe-T-Bleed® MicroLeak detector.



Always Be Aware! -

When working around hydraulics and pneumatics it is vitally important that people are aware of the potential risks involved. Everyone within an organization where hydraulics and pneumatics are used should be aware of the risk, this includes (but is not limited to): First Responders, Occupational Health, Operators, Engineers, Maintenance Personnel, Supervisors and Managers/Directors. In addition to being aware of the risk we also need to know how to manage a fluid injection injury/suspected fluid injection injury.

People who are most at risk from these types of injury are those people who undertake pressure testing of product (particularly those who are required to make adjustment to equipment whilst the equipment is under pressure/has flow).



Always Be Aware! -

While we at the FPSI™ are not qualified to stipulate how a fluid injection injury should be treated, our view is that any fluid injection injury (or indeed any suspected fluid injection injury) must be treated as a medical emergency.

This would mean the person injured should be referred to the Emergency Department of a hospital.

If the injury is to the hand, or lower arm it is preferable that the hospital has a hand trauma unit as the injury may well require surgery.

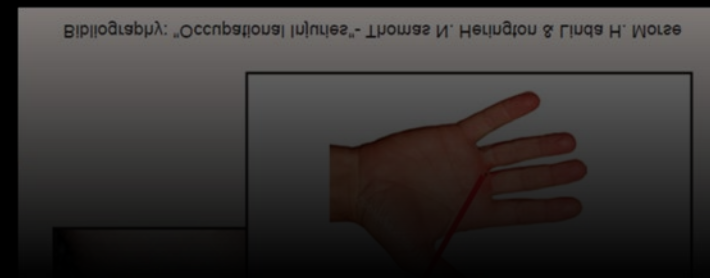
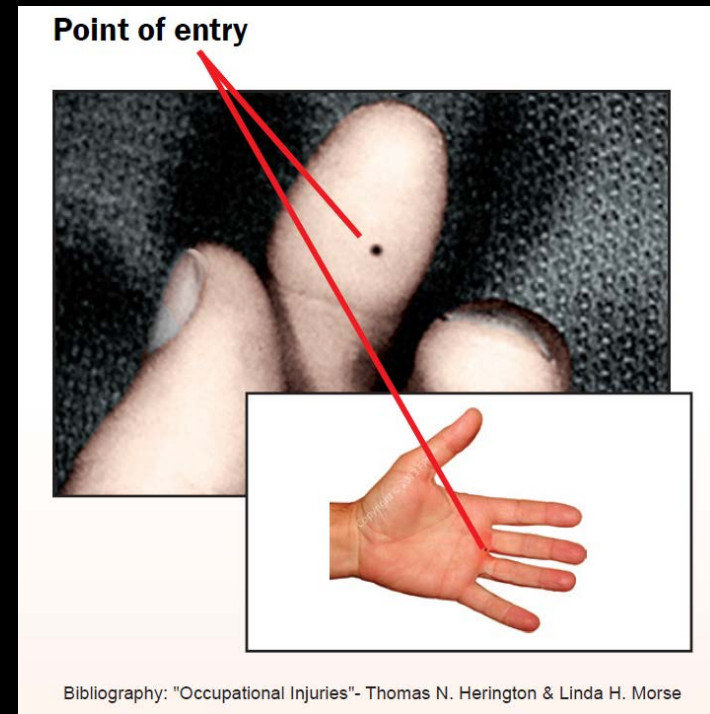
It is strongly recommended that employers consult their local hospital to ascertain if they, or indeed an alternative hospital further away can treat this type of injury.



How to Treat a Fluid Injection Injury -

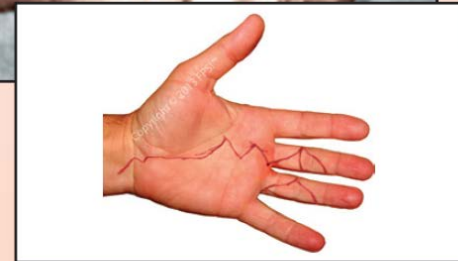
Any person who receives (or may have received) a fluid injection injury, no matter how minor it may appear must follow the procedure detailed below:

- 1) The person should, if possible, make the area safe to prevent other people receiving a fluid injection injury.
- 2) Call for an ambulance to transport the patient to the hospital. After this there may be a requirement for someone else to take over the responsibilities and duties of the patient (for example if the patient was operating a mobile van on-site). This falls outside the scope of this procedure.
- 3) The next of kin should be told of the injury and that they must await further news.
- 4) First aid treatment should be given. This would include gentle cleaning of the injured part, immobilizing and elevating the affected limb to a comfortable position. The patient should rest to avoid anxiety. The patient should NOT be given food or fluid as they may require surgery.
- 5) The following information should be made available for when the ambulance arrives: Material Safety Data Sheet (MSDS) for the injected material, details showing the site where the fluid was injected, a completed copy of the 'Injection Injury Patient Information Sheet' (found in this booklet). All of this information should be attached to the patient, a copy should also be given to the ambulance crew.



How to Treat a Fluid Injection Injury -

- 6) The employee must not be left alone or allowed to drive themselves to the hospital.
- 7) Upon arrival at the hospital the medical staff must be given a copy of the completed appendices from this booklet (Appendix 2 and 3), they should also be made aware of and preferably given a copy of Appendix 4 and 5.
- 8) If the patient is referred to the general waiting room within an Emergency department medical personal must be made aware that fluid injection injuries should be treated as a medical emergency and that immediate treatment is required in order to give the patient the best chance of having a positive outcome.
- 9) The employer must be made aware of the treatment given to the patient.
- 10) Once the patient arrives back at work the incident must be fully documented and procedures reviewed and put into place to reduce the likelihood of a repeat incident.



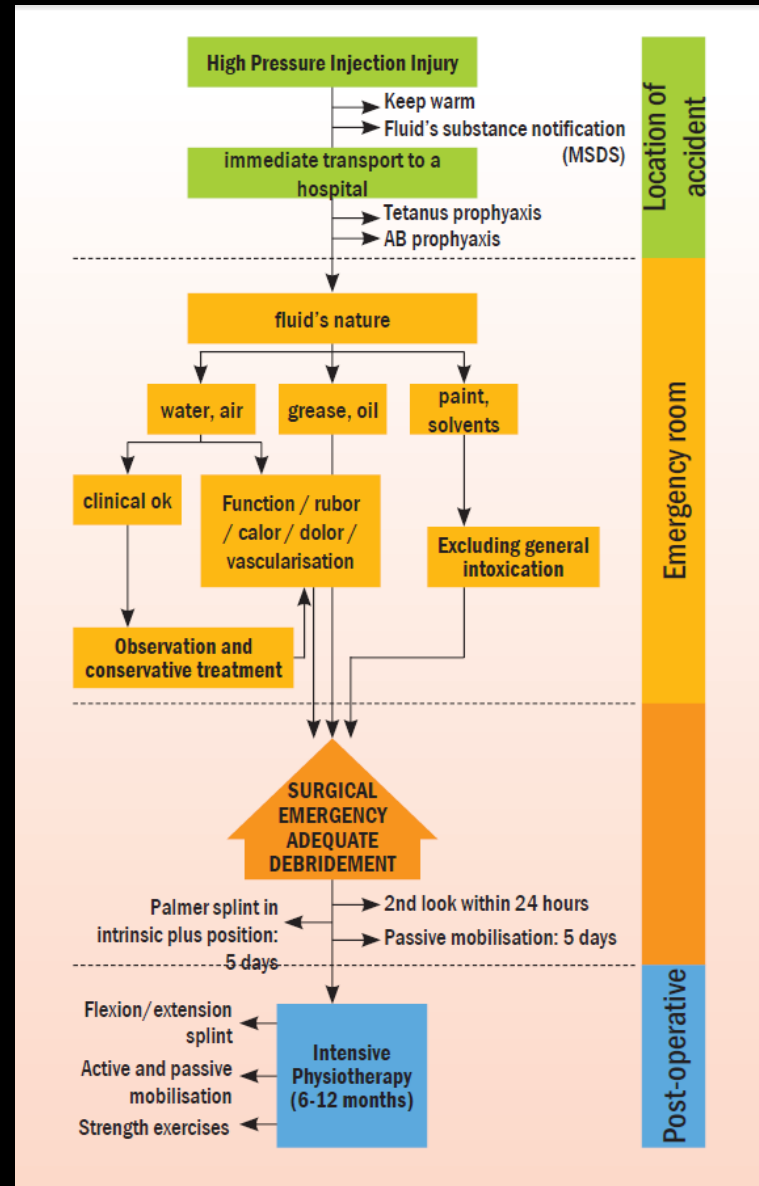
Bibliography: "Occupational Injuries"- Thomas N. Herington & Linda H. Morse

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Procedure and Process Flow – How to Treat a Fluid Injection Injury

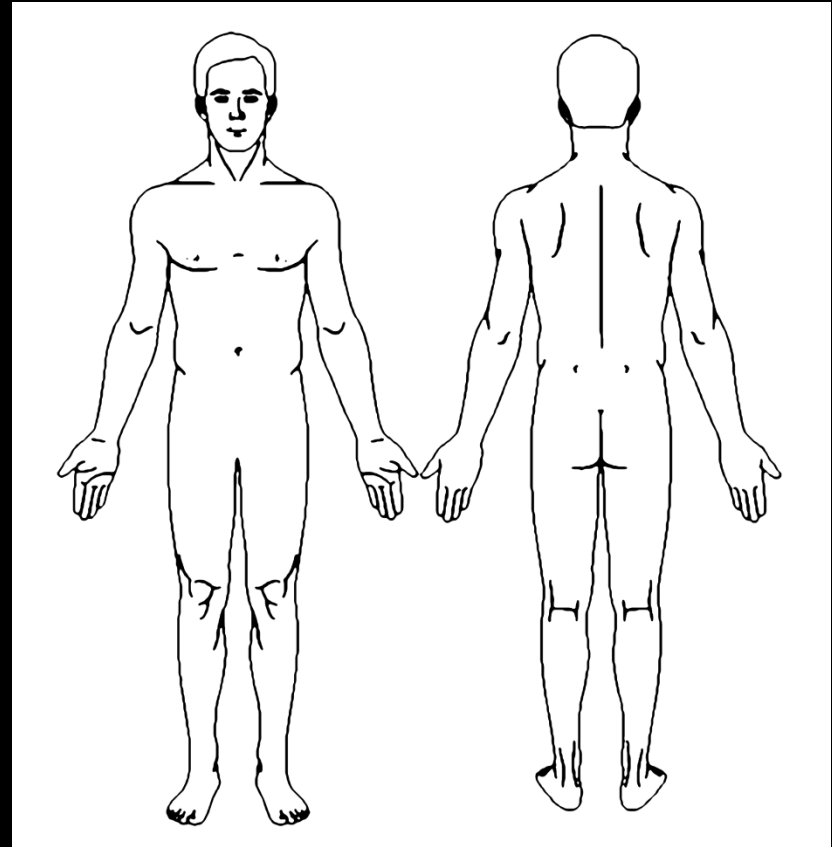
Algorithm for the treatment of high-pressure injection injuries on the base of nature of the fluid (Verhoeven & Hierner 2008).



Appendix 2 – Site of Injection

The images shown should be used to identify the area where the fluid injection occurred. If the patient has suffered a hand injury then this must be recorded on the following page.

This information must then be taken with the casualty as it will help the medical team treating the patient.



Appendix 2 – Site of Injection

The images shown should be used to identify the area where the fluid injection occurred. If the patient has suffered a hand injury then this must be recorded on the following page.

This information must then be taken with the casualty as it will help the medical team treating the patient.



Appendix 3 – Injection Injury Patient Information Sheet -

This information must be taken with the casualty as it will help the medical team treating the patient.



Dear Medical Practitioner,

Date _____
Current Time _____
Patient's Name _____
Date of Birth _____
Company's Name _____
Company Contact _____
(including phone no.) _____
Company Address _____

We believe that the above person has suffered a high pressure fluid injection injury.

The injury occurred at _____ (am/pm) on _____

The injection material is _____

We have included a copy of the MSDS sheet

Yes / No (mark as appropriate)

We believe that the above person last had something to eat / drink at approximately _____ (am / pm)

The following observations were made by the Ambulance crew:

Pulse: _____

Blood pressure: _____

Temperature: _____

The patient is complaining of:

IMPORTANT: Any delay in the urgent and correct treatment of this injury WILL have a negative effect on their outcome.

Appendix 4 –

Three phases that define the natural history of high pressure injection injuries -

Acute

- The immediate symptoms resulting from the injection of the foreign material are swelling, numbness and vascular insufficiency.
- This distention of the tissues may cause a pressure buildup that exceeds hydrostatic pressure, limiting tissue perfusion similar to that in compartment syndrome.
- The chemical injury caused by the substance itself may result in tissue destruction and an inflammatory reaction (which leads to more swelling, which may further compromise the tissue perfusion).
- Infection may occur in the necrotic tissue or from contamination from the substance injected.
- Initially, the patient may complain only of mild pain and may even continue working, leading to a delay of care. The injured area may at first seem inconspicuous, presenting as a small pinprick, and caregivers who may not be familiar with this injury may regard it as insignificant. The finger eventually becomes painful, numb, bloated, edematous, tense, pale and cold.
- Radiographs may help assess the extent of the spread of the injected material, which may present as air in the soft tissue, or as radiopaque material in other cases.

Appendix 4 –

Three phases that define the natural history of high pressure injection injuries -

Intermediate

- Oleomas often develop following the acute phase. These are nodular “tumors” that develop as a result of a foreign body reaction to the injected material.
- Oleomas may remain unchanged for years, but fibrosis often occurs with them, leading to loss of function. Because of this, oleomas should be excised completely along with any fibrosis associated with them.

Appendix 4 –

Three phases that define the natural history of high pressure injection injuries -

Late

- Skin overlying the untreated oleoma may breakdown. This may lead to ulcer and draining sinus formation.
- The skin becomes thick and pitted.
- The ulcers and draining sinuses may become infected.
- Development of squamous epithelioma in the sinuses have been reported.

Appendix 5 –

Suggested guidelines for optimal treatment (for the medical professional) -

- Early medical evaluation, including radiographic studies.
- Prompt surgical consultation. Patients treated properly within 10 hours of injury had much better outcomes than those treated in a delayed fashion.
- Administration of tetanus prophylaxis and intravenous antibiotics.
- Elevation and splinting before and after surgical exploration. Do not use cooling packs to control edema because their use may further compromise tissue perfusion.
- Surgical exploration using general anesthesia or axillary block. Digital and local blocks may contribute to tissue edema and are associated with worse outcomes.
- Use of an extremity tourniquet to establish a bloodless operative field after exsanguinating the arm by elevation. Esmarch bandage exsanguination may cause further spread of the injected toxins into tissue planes or compartments.

Appendix 5 –

Suggested guidelines for optimal treatment (for the medical professional) -

- Wide surgical exploration, including decompression of tissue compartments, debridement of nonviable tissue, and high-volume saline irrigation. Particular attention should be directed toward fluid tracking around neurovascular bundles. Flexor tendon sheaths are less likely to be involved.
- Wound cultures when appropriate to direct antibiotic therapy.
- Consider leaving the wound open, with a planned second look operative irrigation and debridement.
- Consider early amputation of a cool or poorly perfused digit.
- If edema is significant, consider administering 100 mg of hydrocortisone intravenously every 6 hours until improvement is observed. Change to 25 mg of oral prednisone daily and taper over 3 to 5 days. Restart hydrocortisone if edema, erythema or pain worsens.
- Frequent post-operative reassessment and return to the operating room if indicated.
- Early post-operative hand therapy to maximize functional outcome.



*Typical debridement -
Photo courtesy of Dailiana H.Z.*

Appendix 6 –

Preventing Injection Injuries - SCOPE OF WORK

There are two methods to safely isolate a pinhole leak in a flexible hose without having to put your hands, or body, in harms way:

1. Static test - hose assemblies can be individually tested without removing them from the hydraulic system. A Safe-T-Bleed® MicroLeak detection kit is needed to perform a static test.
2. Dynamic test - an actuator stall/load cycle test can be used to isolate a leak.

WARNING

These procedures must be performed by authorized personnel who have been trained in Fluid Power Safety and Fundamental Hydraulics. Performing these procedures without the proper training can cause severe injury, death, or substantial property damage.

Appendix 6 –

Preventing Injection Injuries - SCOPE OF WORK

How to perform a static test to isolate a pinhole leak in a flexible hose assembly:

Wheeled vehicle pre-test procedures:

NOTE: *If the hydraulic system is in a stationary application there will likely be a puddle of oil on the floor, which will mark the approximate location of the concealed leak from above.*

- If the vehicle is wheeled, there is evidence of a leak somewhere in the hydraulic system if there is a puddle of oil on the ground when it is parked or, if the hydraulic oil reservoir needs constant replenishment.
- If the vehicle is in constant motion, due to high operating frequency, park the vehicle in the repair shop, if available, or on a flat surface. Apply the brakes and chock the wheels. Place a tarp under the vehicle to prevent oil from contaminating the ground.

Appendix 6 –

Preventing Injection Injuries - SCOPE OF WORK

WARNING

Before climbing underneath any vehicle while the engine is running take these life saving steps:

- Appoint an observer that will stand in a position that gives him/her clear vision to both you and the vehicle operator.
- Inform the operator that he/she must not take their eyes off the observer while you are out of sight under the machine.
- Inform the observer that he/she must not take their eyes off the person under the vehicle.
- The three parties must agree on a hand signal that the observer will use to signal the vehicle operator to shut the engine off should an emergency situation arise.
- Start the engine and operate the vehicle's hydraulic system(s). Oil must be at normal operating temperature. Where possible, stall, or cycle, all actuators in both directions of travel.
- Turn the engine off and apply the park brake.
- Chock the wheels.

Appendix 6 –

Preventing Injection Injuries - SCOPE OF WORK

- Climb under the vehicle and look for signs of oil on the shop floor, or on the tarp. The location of the oil on the ground will usually mark the approximate location of the oil leak above.

NOTE: *Be aware that oil can also be dripping from one hose onto another (or the frame), and due to the inclination of the hose it may cause oil to run along the outside of hose (or frame) before it finally drips onto the ground. This situation may mask the exact location of the leak. This is another reason why hands must never be used to find leaks.*

- Before proceeding lockout and tagout the machine.
- De-energize the hydraulic system before loosening any connectors.
- If the source of the oil leak appears to be coming from a bundle (two or more) of flexible hoses, proceed with the pressure/leak test with the Safe-T-Bleed® MicroLeak detector to isolate the leak.
- Use the hydraulic schematic to identify the connection points of the hoses contained in the bundle.
- Perform a MicroLeak test on one hydraulic hose assembly at a time.

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- Remove the hose end from the connector. Use the appropriate MicroLeak fitting to plug the end of the hose.
- Remove the opposite end of the hose from the connector and install the appropriate MicroLeak fitting.
- Connect the MicroLeak detection pump to the test fitting.
- Operate the MicroLeak pump and continue pumping until the hydraulic hose is full of oil. Keep pumping until the pressure builds up to approximately 1000 PSI (69 bar) and stop. The pressure should hold at 1000 PSI (69 bar) indefinitely.
- If pressure does not build up at all, or if the pressure rises but quickly decreases, the hose is leaking.
- If the hose assembly passes the MicroLeak test, remove the test connectors and re-install the hose. Tighten the hose connectors to the torque value specified by the manufacturer.

WARNING

To avoid inadvertently switching hoses, perform the MicroLeak test on one hose assembly at a time. Switching hoses can lead to an accident which could result in severe injury or death.

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How to perform a dynamic test to isolate a pinhole leak in a flexible hose:

- Perform the test with the hydraulic oil at normal operating temperature (approximately 130°F [54°C]).
- If there is a puddle of oil on the floor below the vehicle or machine clean it up before proceeding with the test.

WARNING

Before climbing underneath a wheeled vehicle, place the implements on the ground, apply the park brake, shut the engine off, and chock the wheels.

NOTE: *If, for example, there are six hydraulic hoses in the bundle there are probably three actuators (two hose assemblies per actuator).*

- Start the prime mover.

NOTE: *Perform this test on one actuator at a time. If the actuator is double acting (cylinder) or reversible (motor) perform the test in one direction of operation at a time.*

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How to perform the test with a cylinder -

Activate the directional control valve and stall the cylinder IN ONE DIRECTION ONLY. Pause and look to see if the test created an oil puddle on the ground.

CAUTION

If it is necessary to climb under a vehicle to inspect for leakage apply the brakes and chock the wheels..

- If there is no evidence of leakage, stall the cylinder in the opposite direction and inspect the ground for leakage.
- Repeat this procedure on all cylinders.

The leaking hose will be identified when, for example, while stalling a cylinder in the rod extend position a puddle of oil forms on the ground. If this occurs, the hose connected to the closed end of the cylinder is leaking and must be replaced.

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How to perform the test with a motor -

- If there is no evidence of leakage, stall the cylinder in the opposite direction and inspect the ground for leakage.
- Repeat this procedure on all cylinders.

The leaking hose will be identified when, for example, while stalling a cylinder in the rod extend position a puddle of oil forms on the ground. If this occurs, the hose connected to the closed end of the cylinder is leaking and must be replaced.

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2.0 Develop a Risk Assessment for working on and around pressurized systems, including inspection, troubleshooting and testing.

Foreword:

The fluid power industry is unique in that less than 1% of its maintenance workforce is properly trained in safety, maintenance, repair and troubleshooting as it pertains to fluid power systems and components. This problem must be considered when assessing risks associated with working, on and around, pressurized systems – particularly hydraulic systems.

Untrained maintenance personnel and machine operators advance risks because they routinely haphazardly alter critical system and component operating parameters, which puts them and their colleagues in imminent danger.

Consequently, risk assessment with respect to pressurized systems is three-pronged: the untrained person is at risk. Also, the untrained person creates risks by performing arbitrary and unauthorized system/component modifications. These can be referred to as human risks. The pressurized system thus becomes the material risk.

Human risk must be dealt with swiftly because it creates most of the risk by putting both the untrained person and his or her colleagues at risk. Personnel who are not properly trained in pressurized systems should be prohibited from performing any type of work on these systems until duly trained and authorized. Training must include: Pressurized systems safety; fundamental principles and laws associated with pressurized systems, with a heavy emphasis on pressure, flow and velocity; safe and proper uses of instrumentation; safe and proper diagnostics prohibiting inherently dangerous “test to atmosphere” procedures, which are unfortunately more often than not recommended by machinery and equipment manufacturers.

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2.1 Risk assessment for working on and around pressurized systems:

2.1.1 Human risk:

- a) Is the person properly trained in pressurized system safety and theory?
- b) Is the person trained to properly use specialized tools and instrumentation?

2.1.2 Material risk:

- a) Is the source of the leak visual?
- b) Is the source of the leak concealed?
- c) If the liquid is flammable, is there an ignition source in close proximity to the leak?
- d) Is the leak causing harmful vapor due to liquid atomization?
- e) Is the apparent source of the leak in a confined space?
- f) Is the liquid classified as hazardous material?
- g) Could the leak cause hazardous material to find its way into a sewer?

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2.1 Risk assessment for working on and around pressurized systems:

2.1.3 Training:

People who work on and around pressurized systems face a wide variety of unique risks. The most profound element of risk reduction or elimination is training. When people who work on and around hydraulic systems are properly trained, they are empowered to recognize potential risks, avoid taking risks, avoid creating risks and perform their work without risk. With respect to pressurized systems training must cover pressurized system safety, fundamental laws and principles associated with high-pressure systems (with a heavy emphasis on pressure, flow, and velocity) and how to safely and effectively use diagnostic instrumentation and equipment.

2.1.4 Test apparatus and instrumentation:

Diagnostic equipment and instrumentation are the conduits through which a person communicates with a pressurized system. Personnel must know how and where to safely tap into a system, what the various operating parameters should be, how abnormal operating parameters affect machine safety and reliability, and what action to take to mitigate a problem.

The company (or employee) must acquire suitable diagnostic equipment and instrumentation, which must be available to authorized employees at all times.

Untrained personnel must be restricted from using diagnostic instrumentation and special tools until they are properly trained and authorized.

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2.1 Risk assessment for working on and around pressurized systems:

2.1.5 Pressure/leak detection tools and instruments:

Concealed leaks in transmission lines can be safely detected with pressure/leak detection equipment. Special tools and instruments must be made available to maintenance personnel. In turn maintenance personnel must be trained on how to safely and properly use the equipment.

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3.0 Evaluate and recommend industry best practice for safe leak detection.

Industry best practices for safe concealed leak detection are:

- a) The person conducting the procedure must be properly trained in fluid power safety.
- b) The person conducting the procedure must know how to safely and effectively use pressure/leak detection apparatus and instrumentation to accurately detect leaks in transmission lines without any risk.
- c) The person conducting the procedure must wear all safety PPE, including safety glasses with side shields and a full-face shield.
- d) The machine must be locked and tagged in accordance with the company's lockout protocol.
- e) The person conducting the procedure must identify and isolate all zones of stored (potential) energy within the system. The isolation must be verifiable.
- f) The person must have the proper tools and instrumentation to safely detect the leak?
- g) The person must be able to safely and properly install pressure/leak detection connectors on each suspect transmission line and perform pressure/leak testing until the defective transmission line is found.

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4.0 Evaluate and develop training module for pressurized system safety.

Training curriculum for teaching personnel pressurized system safety:

- a) Pressurized system safety.
- b) Fundamental laws and principles pertaining to fluid power.
- c) How pressure differential affects flow through an orifice.
- d) The relationships of pressure, flow, and velocity.
- e) Hydraulic hose safety.
- f) How to safely and correctly make hydraulic hoses assemblies.
- g) How to clean, handle and store hydraulic hose assemblies.
- h) Proper routing techniques for hydraulic hoses.
- i) How to safely and correctly use pressure/leak-testing techniques to locate hidden leaks in hydraulic transmission lines.
- j) Common causes of hydraulic hose failure.

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4.0 Evaluate and develop training module for pressurized system safety.

Training curriculum for teaching personnel pressurized system safety:

- k) Troubleshooting and analyzing hydraulic hose failures.
- l) How to safely and effectively make steel tubing assemblies – bending, flaring, flat-face (SAE J1453) and flare-less.
- m) Proper installation procedures for steel tubing assemblies – includes correct mounting and clamping techniques.
- n) Common causes of tube assembly failures.
- o) How to troubleshoot and analyze steel tubing failures.
- p) How to safely and effectively make steel pipe assemblies – threading and flaring.
- q) Proper installation procedures for steel pipe assemblies – includes correct mounting and clamping techniques.
- r) Common causes of steel pipe assembly failures.
- s) How to troubleshoot and analyze steel pipe failures.
- t) International thread identification: How to identify all types and designs of thread configurations (metric and imperial) used in the fluid power. This section also covers connector pressure and flow ratings.

Fluid Injection Injury – A Surgical Emergency

The Lethal Strike!

A Guide to Properly Managing
and Preventing Injection Injuries



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