SAFE by DESIGN

“Hydraulic safety doesn’t just happen, it has to be pursued!”™

- Safety MUST be the nucleus of hydraulic system design.
- The responsibility of safe design must be vested in the design engineer.
- If an engineer does not possess the background, education, and training to design a safe hydraulic system he/she must assign the responsibility of safe design to a suitably qualified person or committee.
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Proto-type Testing:

- Engineers must oversee the design and construction of the first article.
- Engineers must also test every operating parameter on the first article as prescribed by the component manufacturer.
- There is overwhelming evidence that engineers are not confirming component manufacturers maximum and minimum operating parameters.

Examples:
Evidence suggests many engineers aren’t aware of vital operating parameters:
- Real-time temperature drop across heat exchangers.
- Real-time pump inlet restriction specifications.
- Real-time case pressure specifications.
- One of the most vital functions of prototype testing is to establish reliable component/system operating parameters.
- The observed operating parameter MUST be compared with the component manufacturers maximum and minimum operating parameters.
Proto-type Testing:

Evidence of a disconnect between prototype testing and the component manufacturer’s specifications lies within the covers of machinery and equipment manufacturer’s service manuals.

For example, a piston pump manufacturer recommends a maximum pump inlet restriction of 4” Hg (mercury).

The manufacturer fails to compare real-time inlet restriction values with the manufacturer’s specifications. The manufacturer photocopies the pump manufacturer’s service literature and inserts in the service manual. The service manual reflects the pump manufacturer’s specifications and precludes the actual specifications.

The designer must be responsible for determining the point-of-reference (POR) for all component operating parameters.
What can engineers do to make sure the person constructing the hydraulic system works as safely as possible?

Assembly line workers are responsible for constructing the hydraulic systems engineers’ design. They rely on drawings, hydraulic schematics, and specifications engineers compose to insure the systems are constructed correctly.

1. Safe-by-design – Assembly drawings
   • Correct and clear component port identification.
   • Correct connector torque values
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What can engineers do to make sure the person constructing the hydraulic system works as safely as possible?

2. Safe-by-design – Pre-start procedures

- Provide specific information about status of brakes, wheel chocks, engine kill switch, lockout and tagout.
- Provide assistance if assembly line workers are not suitably qualified to perform pre-start procedures.
- Include specific information about valve settings.
- Include specific information about pump and motor pre-fill procedures.
- Include specific instructions for correct pump adjustment.
- Include specific information about critical pump and motor alignment specifications and procedures.
- Provide bolt and fitting torque specifications.
- Provide specific information about insuring pump displacement control valve linkages and electrical connections are disconnected before initial start-up.
What can engineers do to make sure the person constructing the hydraulic system works as safely as possible?

2. Safe-by-design – Pre-start procedures
   - Provide specific information about purging pump intake transmission lines.
   - Provide specific information about what diagnostic instruments are needed, and where to install them for initial start-up observation.
   - Provide specific instructions about prime mover speed and how long to run the system before pressure must be observed, e.g. charge pressure in hydrostatic drive.
   - Provide specific instructions about critical post-start procedures.
   - Provide specific instructions about correct component/system air-bleeding procedures.
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What can engineers do to make sure the person operating the machine is as safe as possible?

A machine operator’s primary responsibility is operating a machine, be it a production or mobile machine. Machinery and equipment operators are not only responsible for their own safety, but also the safety of those around them.

I recently investigated an accident in which a 47,00 pound (21,319 kg) asphalt paver with hydrostatic drive unexpectedly ran away on a public roadway. During the investigation I determined the machine was so poorly designed that a machine runaway was inevitable, if the fluid coupling breached.

Here are some of my findings:

• The park brake was poorly designed - exposed driveline disc brake was bathed in asphalt residue.
• Service brake was poorly designed - exposed disc brakes were bathed in asphalt residue.
• Manufacturer relied on hydrostatic drive for primary braking system - defied hydrostatic pump manufacturer’s warnings about depending on the hydrostatic drive for the primary braking system on the machine.
• Manufacturer opined that operator “failed to ‘test’ service brakes.” Service brakes could not be tested independently of the hydrostatic drive and hydrostatic drive was powerful enough to “drive-through” both service and park brakes.
• Instrument cluster was 54” (86.4cm) away from operator’s eyes.
• Critical operational gauges were ignored, i.e. hydraulic oil temperature and hydraulic oil pressure.
What can engineers do to make sure the person operating the machine is as safe as possible?

Operator survey yields disturbing results:
A survey of machinery and equipment operators conducted by FPTI™ yielded some extremely disturbing findings.

- Ten operators were surveyed. They were asked ten (10) questions about the hydraulic systems on the machines they operated:

- Ten out of ten could not answer questions about critical operating parameters: specifically temperature and pressure, because they did not have gauges.

- They also had no idea what the normal operating pressures and temperatures of their respective machines should be.
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What can engineers do to make sure the person operating the machine is as safe as possible?

1. **Safe-by-design – Training**
   Operator training must include, in addition to machine operation, fundamental hydraulics, and hydraulic safety.

2. **Safe-by-design – Instrumentation**
   - Machine operator must know and be able to observe hydraulic fluid temperature.
   - Machine operator must know and be able to observe hydraulic pressure.
   - Color-coding analog gauges is highly recommended.

3. **Safe-by-design – Emergency procedures**
   - Machine operator must know limitations of reserve power, e.g. one full turn left and right steering.

4. **Safe-by-design – Pre-start/op checks**
   - Machine must be designed to facilitate checks that must be made by the machine operator, e.g. brake test. If the machine is equipped with a hydrostatic drive it must be possible to perform the service brake test independently of the hydrostatic transmission’s dynamic brakes.
What can the engineer do to make sure the person that services, maintains, and troubleshoots the system works as safely as possible?

1. Safe-by-design – Stored energy
   Maintenance technicians face the ultimate safety challenge when performing service, repair, maintenance, and troubleshooting on hydraulic systems.

   The most egregious problem maintenance workers face is the fact that “hydraulics” is not recognized as an occupational hazard by any institution in the U.S.A. The most notable include:
   - Occupational Safety and Health Administration (OSHA)
   - Mine Safety and Health Administration (OSHA)
   - State safety agencies
   - American Society of Safety Engineers (ASSE)
   - National Fluid Power Association (NFPA)

   • There are so many people working on hydraulic systems without the proper training that engineers should take it into account when designing hydraulic systems.
   • For example instead of specifying adjustable pressure control valves, specify pre-set, non-adjustable valves.
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What can the engineer do to make sure the person that services, maintains, and troubleshoots the system works as safely as possible?

2. Safe-by-design – Pump performance testing
   Quick-connect/disconnect valve at inlet port of return line filter
   **Advantages:**
   - Facilitate safe pump performance testing.
   - Uncontaminated oil filling.

3. Safe-by-design – Non-invasive pressure test port
   - Never have to “open” system for pressure testing.
   - Avoids burn injuries.
   - Never have to worry about stored energy.
   - Environmentally friendly.

4. Safe-by-design – Flow meter insertion points
   - Flow meter insertion points.
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5. Safe-by-design – Mobile machine power isolation
   - Prevents unexpected machine start-up under trying conditions.
   - Will not create a hazardous situation if starter wires are inadvertently arced.

6. Safe-by-design – Thermal expansion
   - Rule-of-thumb – each 1°F (-17°C) = pressure rise of 50 - 60 PSI (3.5 - 4.1 bar).
   - Skid mounted equipment with quick connect valves.
   - Agricultural implements with quick connect valves.
   - Pilot-operated check w/out thermal expansion.

7. Safe-by-design – Ball valves for safety isolation
   - Not a fail-safe device.
   - No protocol for handle orientation.
   - NEVER plug return line.
   - MUST not be used for lockout isolation.
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8. Safe-by-design – Hydraulic oil temperature sensors
   • Tradition puts them in the reservoir – provides false positive when there are design issues, e.g. no separation of suction and return lines in reservoir.
   • Should be monitoring temperature at the inlet side of heat exchanger.
   • Hydrostatic drives – loop is the critical “reservoir.” Sensors must be in loop.

9. Safe-by-design – Pressure-compensated with external pressure relief valves
   • Pressure margins are too close contributing to system overheating.

10. Safe-by-design – Horizontal filter mounting
    • Environmental disaster.
    • Contaminates machinery.
    • Environmental challenges in the field, e.g. changing filters in environmentally sensitive areas.
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11. **Safe-by-design – Sharing of case drain lines**
   - Major shaft seal problems on pumps and motors.
   - Not properly tested – worst case scenarios/extreme cold.

12. **Safe-by-design – Case pressure testing recommendations incorrect**
   - Pressure gauge in case drain line monitors drain line pressure only.

13. **Safe-by-design – External drain motor vertical mount**
   - Manufacturers guidelines often ignored. Premature shaft seal and bearing failure due to unavoidable oil air pressure chamber.

14. **Safe-by-design – Failure-to-warn – Setting a pressure relief valve with a hand pump**
   - In cases where very unusual circumstances are employed to set, for example, pressure relief valves, it is critical to provide specific warnings about uniqueness of procedure.
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What can the engineer do to make sure the person that services, maintains, and troubleshoots the system works as safely as possible?

15. Safe-by-design – Normal operating parameters
   • Screenprint all the normal operating parameters of a given hydraulic system on a plate and affix them to the machine.

16. Safe-by-design – Service manual inconsistencies
   • Refrain from photocopying component manufacturer’s specifications and inserting them in service manuals - the specifications are pertinent to the components, not the machine. ALL operating parameters should be monitored and recorded in real-time and compared against manufacturer’s specifications. If acceptable, the accurate specification must be shown in the service manual.

17. Safe-by-design – Avoid conflicting safety warnings
   • If the cautions and warnings stated in the service manual warn against the consequences of discharging hydraulic oil to atmosphere, refrain from providing “test” procedures for testing components that recommend testing to atmosphere, e.g. cylinder testing, and case flow testing.
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18. **Safe-by-design – No industry standards for cartridge valve port identification makes the need to show port numbering and manufacturer vital**
   - Cartridge valve manufacturers typically utilize numbers for port reference.
   - There is no industry standard for numbering.
   - Assembly line workers and maintenance personnel cannot rely on the numbers e.g., “1” may reflect the inlet port on one manufacturer’s valve, and the outlet port on another manufacturer’s valve.
   - Hydraulic schematics MUST indicate numbers and manufacturer to avoid accidents.

19. **Safe-by-design – Temperature drop across heat exchanger**
   - It is vital that maintenance personnel observe, on a routine maintenance basis, oil temperature across the heat exchanger. In the vast majority of cases this procedure is ignored because it cannot be executed safely (mobile machinery).
What can the engineer do to make sure the person that services, maintains, and troubleshoots the system works as safely as possible?

20. **Safe-by-design – Oil sampling**
   - Oil sample ports should be located at the inlet port of the system’s return line filter.

21. **Safe-by-design – Pressure intensification**
   - Quick connect/disconnect valves and cylinders must be rated for two times pressure relief valve setting to avoid a serious outcome should a person forget to make the live end connection.
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