INTRODUCTION

As part of its ongoing mission to strengthen the fluid power industry, the National Fluid Power Association (NFPA) serves as a vital forum for collaboration among its members, OEMs, and technology partners. Within this framework, the NFPA launched a *Leak Prevention Task Force* in December of 2023, recognizing the importance of minimizing external leakage to improve hydraulic system efficiency, safety, and sustainability.

The *Leak Prevention Task Force* was tasked with producing a comprehensive report to:

1. Summarize current best practices for preventing leaks,
2. Assess the prevalence of those practices across the industry, and
3. Estimate the potential for improvement based on actionable strategies and challenges identified through industry input.

To achieve these objectives, the task force conducted a survey of NFPA members, encompassing a broad range of stakeholders in the fluid power industry, including suppliers, manufacturers, distributors, machine builders, and end-users. The survey explored perspectives on the impact of external leakage, the root causes of leakage, and the strategies deemed most effective for leak prevention. The results are presented below:

SURVEY QUESTIONS AND DEFINITIONS

The survey consisted of targeted questions designed to capture the diverse viewpoints and experiences of NFPA members. Questions addressed organizational roles, market focus, and specific challenges and strategies related to external leakage. Respondents were also asked to evaluate the consequences and financial impacts of leaks on their operations.

Survey questions for Leak Prevention Task Force:

1) What is the primary role of your organization in Fluid Power Industry
    a. Component Manufacturer
    b. Equipment Manufacturer
    c. Distributor
    d. System Integrator
    e. User/other
2) What is your primary role in our organization?
    a. Executive management
    b. Sales or marketing
    c. Engineering
    d. Information technology
    e. Other

3) My organization serves the following markets?
    a. Mobile
    b. Industrial
    c. Both

4) Is external leakage a problem for your organization?
    a. Yes
    b. No

5) How significant are external leakage for your organization
    a. Low -> High in 5 increments

6) Which of these consequences of external leakage have the financial impact on your organization
    a. Downtime for repair
    b. Spill cleanup
    c. Safety (e.g. slips and falls)
    d. Fluid replacement and disposal
    e. Warrantee service

7) Which components are most susceptible to external leakage (please rank)
    a. Adapters and connectors
    b. Cylinders
    c. Hoses
    d. Manifolds
    e. Motors and Pumps
    f. Tubes

8) What are the most common mistakes people make that result in external leakage?

9) What is the greatest challenge to eliminating external leakage?

10) What strategy has the best potential for eliminating external leakage?

SUMMARY OF SURVEY RESULTS

The survey respondents primarily consisted of component (46%) and original equipment manufacturers (34%), with engineers making up the majority (63%) of participants. Nearly all organizations served mobile markets (98%), while 37% also operated in industrial markets.

External leakage was reported as a problem by 76% of respondents, with its significance rated an average of 2.8 on a 1-to-5 scale.

The most common cost impact was on customer satisfaction (95%), followed by downtime and repair costs (58%) and warranty expenses (53%). Connectors (68.4%) and hoses (47.4%) were identified as the components most frequently affected by leakage. These findings reveal that leak prevention is essential for customer satisfaction and market acceptance of fluid power technology.

COMMON MISTAKES LEADING TO EXTERNAL LEAKAGE

Respondents indicated that improper use of torque wrenches during assembly and repair, poor conductor routing and support, use of outmoded connectors, and failure to minimize connection points were common mistakes that lead to external leaks. Several noted that early intervention during the design phase, such as collaborating with sealing solutions companies and ensuring design-for-assembly principles, can significantly reduce leakage. On its face, all these common mistakes are preventable.

BARRIERS TO SOLVING LEAKAGE PROBLEMS

Respondents identified several key barriers to addressing leakage problems, with many emphasizing the importance of proper training, including educating technicians on correct installation practices, torque specifications, and system maintenance. Design challenges were frequently mentioned, such as ensuring seal integrity, improving system design to withstand vibration, and minimizing connection points in confined assembly areas.

Material and component issues were also highlighted, including the durability of seals, quality of casting, and proper selection of system-rated hydraulic components. Several respondents pointed to systemic issues, such as cost-driven decision-making over technology, adherence to entrenched industry standards, and insufficient integration of advanced sealing technologies.

Additionally, respondents noted challenges in troubleshooting and diagnostics, such as identifying the root cause of leaks, verifying system integrity before shipment, and addressing customer misconceptions about leakage sources. Other barriers included external factors, such as contamination ingress, increasing duty cycles, and the high cost of implementing improved technologies.

These insights underline the need for better training, improved design practices, and strategic use of advanced components and materials to effectively mitigate leakage challenges.

STRATEGIES WITH THE BEST POTENTIAL FOR ELIMINATING EXTERNAL LEAKAGE

Respondents emphasized education and training as critical strategies, including better maintenance training, operator-independent assembly techniques, and enforcing the use of torque specifications in assembly and service manuals. Improved design practices were also highlighted, such as eliminating NPT and O-rings face seals in favor of bore-sealing joints.

Other strategies focused on preventing errors and damage, including eliminating installation damage, ensuring correct part usage, and using gland drains to monitor seal performance. Respondents also stressed the importance of clear communication and documentation, such as obtaining detailed technical data sheets and assisting customers in applying appropriate specifications.

These strategies collectively suggest that a combination of education, design optimization, and process standardization holds the greatest potential for reducing external leakage.

RAW SURVEY RESULTS

1. Forty-one (41) respondents.
    a. Component manufacturer: 46%
    b. Equipment Manufacturer: 34%
    c. Distributor: 7%
    d. System integrator: 7%
    e. User/other: 5%

2. Role in organization
    a. Engineer: 63%
    b. Sales/marketing: 20%
    c. Executive management: 12%
    d. Other: 5%

3. Markets served
    a. Mobile: 98%
    b. Industrial: 37%

4. Leakage a problem for your organization?
    a. Yes: 76%
    b. No: 24%

5. Significance on a scale of 1 to 5:
    a. 2.8

6. Cost impact
    a. Customer satisfaction: 95%
    b. Downtime/repair: 58%
    c. Warrantee costs: 53%
    d. Safety/compliance: 29%
    e. Spill cleanup: 21%
    f. Fluid replacement: 16%

7. Components most effected
    a. Connectors: 68.4%
    b. Hoses: 47.4%
    c. Tubes: 44.7%
    d. Cylinders: 36.8%
    e. Manifolds: 36.8%
    f. Pumps/Motors: 31.6%

8. What are the most common mistakes people make that result in external leakage?
    a. Improper training
    b. Foundry design reviews. Seal design reviews.
    c. Reduce the amount of connection points and switch to connections with soft seals rather than mechanical seals.
    d. Not sure, perhaps a computer vision system of some sort, to properly identify when and where external leakage is happening.
    e. Push-to-connect is great but costly
    f. Most effective seems to be handled at initial design. Designs that allow for easy implementation of best installation practices seem to reduce leak issues.
    g. Systematic Standard Engineering.
    h. Timely & Proper training to be provided to the Hydraulic fitter.
    i. Critical Assembly areas & High-Pressure system to be taken care with intervention of trained supervisor.
    j. Not sure
    k. use the most appropriate/reliable fitting and ensure proper training
    l. Preventive Maintenance
    m. The biggest complaint I have seen regarding leakage is from the suction hose on refuse trucks. Contamination build up on the suction strainer will cause cavitation that may collapse the suction hose causing the tank to drain out onto the street.
    n. Partnering with sealing solutions companies from the design phases.
    o. Internal copper gaskets on tapered fittings.
    p. I find that a lot of external leakage can be eliminated if there is a detailed review before the system is implemented and started - as all it takes is a single loose item to cause a mess.
    q. Design for assembly.
    r. Upgrading O-ring technology and installation torque.
    s. Proper work instruction, Correct design/selection of components

9. What is the greatest challenge to eliminating external leakage?
    a. High quality green sand castings. Seal design.
    b. Having a full understanding of the system and how it will be used.
    c. End of line verification, prior to shipment.
    d. consistent tightening of connections
    e. greatest challenge is component integrity over time. Continuous vibration can eventually cause components to leak.
    f. Following Proper standards based on applications & Hydraulic system parameters.
    g. Use of System Rated Hydraulic Components based on requirement.
    h. Systematic Engineering Before Integration of hydraulic system.
    i. Skilled labor in Hydraulic fitter at assembly area
    j. Troubleshooting shaft seals. Leaking shaft seals are difficult to figure out why.
    k. Proper training and use of the proper fittings

l. Shutting down the application to correct the problem.
m. Avoid using NPT fittings and use hose guards or sleeves to protect from wear potential injury due to a leak.
n. Mindset. "If it leaks, the seal is the problem". The problem can be somewhere else. Design engineers should worry about their end product and leave the sealing design to the expert companies.
o. Adequate combination of seal & torque
p. In most cases it is something which can be easy to fix in the field, and it is done and we are notified after. others, the customer is not as hands on - and it is a flight or warranty claim for something seemly simple.
q. The greatest challenge for us is more on the side of regaining reputation than cleaning oil spill
r. Finding the root cause
s. Increasing duty cycles on machines.
t. Education on true cost of leakage
u. To avoid unscrewing due to vibrations and high pressure without compromising the structural resistance of components
v. Proper installation of connectors, fittings, flanges, adaptors, pipe/hose runs....etc. The technology exists to reduce the occurrence of external leaks; however, often the decision on components d cost driven, not technology driven. Improperly tuned systems which experience shock contribute to external leaks
w. Keeping out external contamination
x. Training and materials
y. Customer always following specs products are designed for
z. Proper training of assembly and repair technicians to use torque wrenches, not just eyeball it.
aa. Durability of sealing components
bb. Preventing ingress of contaminating particles (which destroys seals)
cc. Increased cost of improved technology and entrenched industry standards.
dd. Understanding application's maintenance challenges and what can be done to prevent damage or misuse in application.
ee. personnel experience
ff. We mfr components. This is more of an integration issue.
gg. Convincing customers that torque values are important.
hh. Human assembly processes
ii. Access and torque
jj. There are too many connections in a small area when assembling equipment so it is difficult to properly torque connectors

10. What strategy has the best potential for eliminating external leakage?
    a. Precise determination of torque - for components producers the limit is to know the manifold material in the final application
    b. Tell them, tell them, tell them, and tell them again. Presumably, with few exceptions, technology exists to minimize external leaks, but "quick & dirty", or "it only needs to survive the original warranty" design decisions likely do not take full advantage of technical solutions readily available.
    c. Eliminating installation damage and eliminating the possibility of using the wrong part
    d. Better maintenance training
    e. Always get technical data sheet from applications to make sure all pressure, flow and oil type/temperature are communicated to our engineering for product specification
    f. Not sure
    g. Reminding customers to list torque specs in their assembly and service manuals and then enforcing the use of these documents.
    h. Adding gland drains to know when primary seals are starting to fail. Eliminating NPT port connections.
    i. Elimination of face seal o-rings and gaskets in favor of bore sealing o-ring joints.
    j. Apply a failure mode analysis of some degree to each application, assist the customer in this process.
    k. Proper documentation and training
    l. Education
    m. Teaching.
    n. Operator independent assembly
    o. Improved routing and reducing connections
    p. Some way of doing push to connect that is serviceable

DEFINITIONS:

In fluid power systems, power is transmitted and controlled through a fluid (liquid or gas) under pressure within a circuit.

Connector: a device that connects tubes, hoses or pipes to each other or to other components

Conductor: tube or hose that conveys fluid between connectors

Crimped hose fitting: hose fitting attached to the hose by permanent deformation of one end of the hose fitting

Cylinder: actuator that provides linear motion

Hose: flexible conductor usually made of reinforced rubber or plastic

Leakage: fluid flow of a relatively small quantity that does no useful work and causes energy losses

Lip seal: seal that has a flexible sealing projection; fluid pressure acting on one side of the lip holds the other side in contact with a suitable surface against which to make the seal

Maximum working pressure: highest pressure at which a system or sub-system is intended to operate in steady-state operating conditions

O-ring: molded elastomeric seal that has a round cross section in the free state

Packing: sealing device consisting of one or more mating deformable elements usually subjected to adjustable axial compression to obtain effective radial sealing

Pressure: normal force per unit area exerted by a fluid against its confinement

Piping: any combination of connectors, couplings, tubes and/or hoses which allows fluid flow between components

Tube: rigid or semi-rigid conductor used to transmit fluid