NAXSA North American Excavation Shoring Association

TIPS FROM THE TRENCH

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PIPE TESTING WITH HIGH PRESSURE PLUGS

Safety and Operating Instructional Supplement
by Tim Markonich

Objective: We will examine the design differences between low-pressure and high-pressure test plugs and review essential safety principles for the proper use of high-pressure plugs.

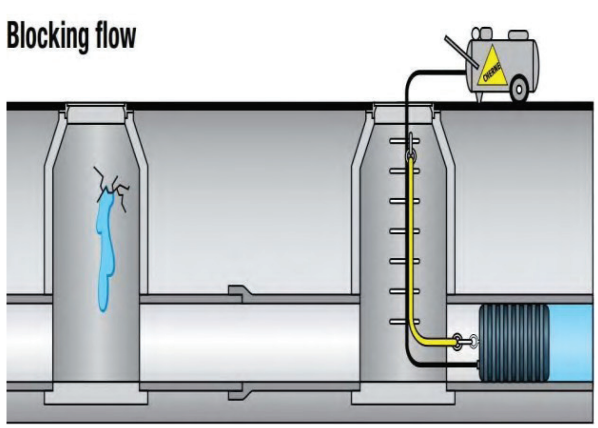
Disclaimers: These instructions are intended as foundational guidance rather than a comprehensive resource, aimed at assisting users in the safe operation of high-pressure test plugs. Ensuring plug safety is a collaborative effort between the manufacturer, distributor, and the end user. Adhere to all safety instructions outlined in OSHA and federal, state, and local regulations. Do not use the plug if any conditions may compromise the safety of personnel or property. For confined space entry, comply with all applicable federal, state, local, and/or company requirements.

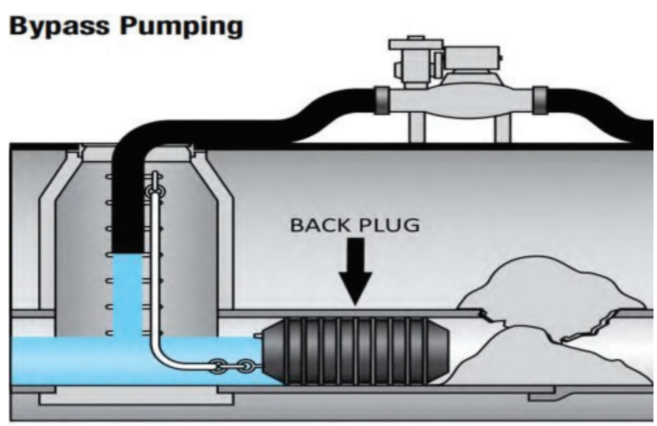
Additional Safety Resources:
NAXSA: https://www.naxsa.org/page/resources
Lansas Products: https://lansas.com/downloads-videos/
Cherne Industries: https://www.cherneind.com/safety
Plug Technologies: https://plugtechinc.com/safety-info/

STEP ONE: UNDERSTANDING THE PRODUCT

Low-Pressure Plugs

To grasp the nuances of high-pressure test plugs, it's essential to first understand the design differences between low-pressure and high-pressure plugs. Most wet utility contractors, municipal workers, and sales representatives are well acquainted with low-pressure plugs. These plugs typically feature a narrow profile and are primarily constructed from natural rubber, which offers excellent flexibility. They can be inflated to accommodate various pipe diameters, making them versatile for a wide range of applications, including those illustrated below:





LOW-PRESSURE PLUG DESIGN

Low-pressure plugs are designed to maintain pressure by forming a secure seal when the plug's bladder and sealing ribs or ring come into contact with the inner surface of the pipe wall. This seal is achieved by inflating the plug to the precise pressure specified by the manufacturer.

LOW-PRESSURE PLUG PRESSURE RATING

Manufacturers of low-pressure plugs determine their pressure ratings by installing new plugs into clean, dry, appropriately sized iron pipes and applying back pressure until the plug shifts. This process is repeated multiple times to establish the lowest pressure at which movement occurs. A safety margin is then applied, and the maximum back pressure rating is published based on these findings.

Plug with sealing ribs

Plug with sealing ring (yellow)

EXAMPLE: BACK PRESSURE DATA TABLE BY SIZE OF PIPE

PLUG SIZE	PIPE DIAMETER																	
	4"	6"	8"	12"	15"	18"	20"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	84"	96"
15"-32"		-	-	-	18.6 psi	17.6 psi	17.2 psi	16.6 psi	15.4 psi	12.2 psi	-	-	-	-	-	-	-	-	-
20"-40"		-	-	-	-	-	-	13.6 psi	12.5 psi	11.2 psi	10.2 psi	8.7 psi	-	-	-	-	-	-	-
24"-48"		-	-	-	-	-	-	-	15.2 psi	13.9 psi	12.8 psi	11.4 psi	10.1 psi	-	-	-	-	-	-
24"-60"		-	-	-	-	-	-	-	15.6 psi	15.2 psi	14.8 psi	14.0 psi	12.6 psi	9.6 psi	6.0 psi	-	-	-	-
40"-60"		-	-	-	-	-	-	-	-	-	-	15.0 psi	13.0 psi	11.0 psi	8.7 psi	-	-	-	-
48"-72"		-	-	-	-	-	-	-	-	-	-	-	7.2 psi	6.8 psi	6.4 psi	6.2 psi	6.0 psi	-	-
54"-96"		-	-	-	-	-	-	-	-	-	-	-	-	7.3 psi	7.2 psi	6.9 psi	6.8 psi	6.6 psi	6.4 psi

EXAMPLE: BACK PRESSURE DATA ON SPEC TABLE

PART NUMBER	RANGE OF USE: MINIMUM PIPE DIAMETER	RANGE OF USE: MAXIMUM PIPE DIAMETER	REQUIRED INFLATION PRESSURE	MAXIMUM BACK/TEST PRESSURE	PRODUCT DIMENSIONS: LENGTH	PRODUCT DIMENSIONS: DEFLATED DIAMETER	PRODUCT DIMENSIONS: WEIGHT
050-46	3.5"	6.25"	30 psi	15 psi	9.5"	3.5"	1 lbs.
050-610	5.3"	10.25"	30 psi	15 psi	9.7"	5.0"	4 lbs.
050-812	7.3"	12.25"	25 psi	15 psi	0.0"	7.0"	8 lbs.
050-1016	9.5"	16.25"	25 psi	15 psi	0.0"	9.30"	19 lbs.
050-1218	11.5"	18.25"	25 psi	15 psi	0.0"	11.0"	29 lbs.
050-1224	11.5"	24.25"	25 psi	15 psi	1.0"	11.0"	33 lbs.
050-1530	14.0"	30.25"	20 psi	8 psi	55.0"	13.0"	48 lbs.
050-1530RP	14.0"	30.25"	20 psi	8 psi	55.0"	13.0"	50 lbs.
050-2036	19.0"	36.25"	20 psi	8 psi	64.0"	18.5"	71 lbs.
050-2036RP	19.0"	36.25"	20 psi	8 psi	64.0"	18.5"	73 lbs
050-2448	22.0"	48.25"	15 psi	8 psi	84.0"	21.5"	102 lbs.

POINT OF EMPHASIS:

The performance of a plug in a clean, dry iron pipe can differ significantly from its behavior in a wet plastic pipe, potentially eliminating the safety margin entirely or even reducing the back pressure rating. It is essential for competent personnel to carefully consider all jobsite and testing conditions before selecting and using a pipe plug to ensure safe and effective application. For example – using a pipe plug in a corrugated pipe drops the back pressure rating by 50%.

SAFETY CONSIDERATION:
While low-pressure plugs are designed to hold back pressure independently, it is recommended to secure them with a safety line and wire rope cable to prevent loss down the line in case of unexpected deflation. Additionally, backup safety measures should be considered to mitigate the risk of injury or property damage in the event of an unexpected plug failure.

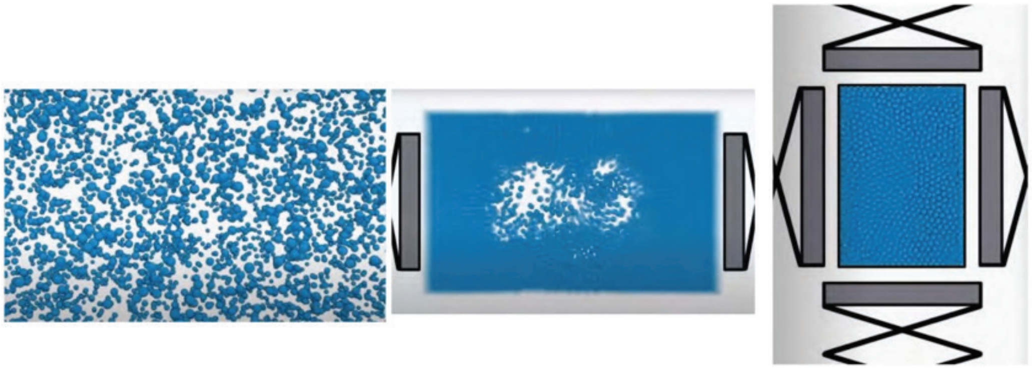
High-Pressure Plugs

HIGH-PRESSURE ROLLUP PLUG DESIGN
The plug is designed to endure and withstand high pressures, but it is not intended to independently hold them back. Blocking and bracing must be installed in conjunction with a high-pressure plug to ensure it remains securely in place. Below is an example of a 42” high-pressure plug:

EXPLANATION:
High-pressure plugs feature more robust construction with more advanced material which can withstand higher pressures without deforming. They typically incorporate additional layers of such material for extra strength, such as aramid or other high-strength fibers. For example, Kevlar is a high-strength and well-known example of a synthetic aramid fiber developed by DuPont in the 1960s that is commonly used in body armor, aerospace, automotive, and more products.

A high-pressure plug is exceptionally durable and can endure high pressures, but it isn’t designed to contain the pressure on its own. Instead, it relies on an external bracing system to keep it securely in place and resist the force trying to push it out. When inflated to the designated pressure, the bladder of the high-pressure plug forms a tight seal against the pipe wall, akin to glue. However, the internal pressure of the test exerts a force that pushes the metal core of the high-pressure plug outward, much like squeezing toothpaste from a tube. Therefore, the external bracing is crucial to maintain the plug’s secure position under pressure.

Safety Consideration: Inflation & Test Mediums – Air vs. Water



Does 1 PSI of air pressure equal 1 PSI of water pressure?

Yes, in terms of pressure measurement, 1 PSI (pound per square inch) of air pressure is equivalent to 1 PSI of water pressure. However, the dynamics of how these pressures behave are fundamentally different:

When air is suddenly released, it can be much more dangerous and violent than water due to a few key factors related to its compressibility and behavior under pressure:

1. **Compressibility:** Air is highly compressible, which means it can be compressed into a smaller volume under pressure and then expand rapidly when released. This rapid expansion can cause a sudden and forceful burst of energy. In contrast, water is only slightly compressible, so it doesn't expand or contract as dramatically under pressure.
2. **Rapid Expansion:** When high-pressure air is suddenly released, it expands quickly to reach atmospheric pressure. This rapid expansion can generate a powerful shockwave or blast effect, creating a significant and potentially dangerous force. For instance, a high-pressure air tank bursting can result in a violent explosion.
3. **Energy Release:** Compressed air stores a significant amount of energy. When this energy is released suddenly, it can cause a powerful and potentially dangerous force. This is because the air, once released, quickly seeks to equalize with the surrounding atmospheric pressure, releasing a large amount of energy in the process.
4. **Volume:** Air, when compressed, occupies much less volume than it does at atmospheric pressure. When released, it suddenly occupies a much larger volume, which can contribute to a dramatic and violent effect.
5. **Speed of Sound:** The speed of sound in air is relatively high compared to the speed of pressure waves in water. This means that the effects of a sudden release of air can propagate quickly and with significant force.

Overall, the combination of air's compressibility, rapid expansion, and stored energy makes its sudden release more dangerous and potentially violent compared to water, which is less compressible and doesn't expand as drastically when pressure is suddenly released.

See NAXSA Video demonstration: https://www.youtube.com/watch?v=fRPwjqIEr1Y

STEP TWO: UNDERSTANDING THE FORCE

High-Pressure Plugs

To ensure safety and proper planning with high-pressure plugs, it is absolutely essential to accurately determine the amount of force you're dealing with by calculating the pounds of force that will be exerted onto the plug. This calculation is critical as it provides the Competent Person, Supervisor, or Certified Engineer with vital information about the amount and type of blocking material required. Proper assessment of the pounds of force will directly impact the choice of materials and the overall safety of the operation. Understanding this force and how to brace a high-pressure plug to withstand the force exerted is essential for choosing appropriate materials and ensuring safety during the job.

CALCULATING POUNDS OF FORCE:

The pounds of force can be calculated using the formula:

$$\text{Pounds of Force} = \pi \times r^2 \times \text{PSI}$$

Where:

- π (Pi) is approximately 3.14159.
- r is the radius of the area where the pressure is applied (in inches).
- PSI is the pressure in pounds per square inch.

Steps to Calculate:

1. Measure the radius of the area where the pressure is applied.
2. Square the radius (r^2).
3. Multiply the squared radius by π (Pi).
4. Multiply the result by the pressure in PSI.

This will give you the total pounds of force being exerted. Understanding this force is essential for choosing appropriate materials and ensuring safety during the job.

Let's examine several examples to demonstrate how variations in pipe sizes and test pressures impact the total pounds of force generated.

EXAMPLE 1: 8" PIPE, 3 PSI TEST

For an 8-inch pipe under a 3 PSI test pressure, the pounds of force exerted can be calculated as follows:

1. **Determine the radius:** The radius r of an 8-inch pipe is four inches (since radius is half of the diameter).
2. **Calculate the area:** Area = $\pi \times r^2 = \pi \times (4 \text{ in})^2 = \pi \times 16 \text{ in}^2 \approx 50.27 \text{ in}^2$
3. **Calculate the pounds of force:** Pounds of Force = Area × PSI = $50.27 \text{ in}^2 \times 3$ PSI ≈ 150.72 lbs

So, the force exerted is approximately **150 pounds**.

This is roughly equivalent to the weight of a high school student or a small dirt bike standing on your bracing. Thiscomparison helps underscore the importance of properly assessing and accounting for the force toensure that the bracing material and system are adequate and safe.

EXAMPLE 2: 36” PIPE, 3 PSI TEST

For a 36-inch pipe under a 3 PSI test pressure:

1. **Determine the radius:** The radius r of a 36-inch pipe is 18 inches.
2. **Calculate the area:** Area = $\pi \times r^2 = \pi \times (18\ \text{in})^2 = \pi \times 324\ \text{in}^2 \approx 1{,}018.60\ \text{in}^2$
3. **Calculate the pounds of force:** Pounds of Force = Area × PSI = $1{,}018.60\ \text{in}^2 \times 3$ PSI ≈ 3,052.08 lbs

So, the force exerted is approximately **3,052 pound**s.

This force is roughly equivalent to the weight of a 2024 Toyota Corolla sitting on top of your bracing. While this is a significant amount of force, wood may be adequate for this load depending on the specific type of wood and its condition. However, it’s essential to assess the strength of the wood and the bracing system to ensure safety. If there’s any uncertainty, consulting a structural engineer or using more robust materials is recommended.

EXAMPLE 3: 36” PIPE, 13 PSI TEST

For a 36-inch pipe under a 13 PSI test pressure, the pounds of force exerted are calculated as follows:

1. **Determine the radius:** The radius r of a 36-inch pipe is 18 inches.
2. **Calculate the area:** Area = $\pi \times r^2 = \pi \times (18\ \text{in})^2 = \pi \times 324\ \text{in}^2 \approx 1{,}018.60\ \text{in}^2$
3. **Calculate the pounds of force**: Pounds of Force = Area × PSI = $1{,}018.60\ \text{in}^2 \times 13$ PSI ≈ 13,225 lbs

So, the force exerted is approximately **13,225 pounds**.

This is roughly equivalent to a fully grown 10-foot tall male African bush elephant standing on your bracing. Given the magnitude of this force, wood alone is unlikely to be sufficient for bracing. Engineering-grade bracing would be required to safely support this force.

EXAMPLE 4: 36” PIPE, 150 PSI TEST

For a 36-inch pipe under a 150 PSI test pressure:

1. **Calculate the pounds of force:** Pounds of Force = Area × PSI = $1{,}018.60\ \text{in}^2 \times 150$ PSI ≈ 152,604 lbs

So, the force exerted is approximately **152,604 pounds**.

This force is comparable to the combined weight of 12 African bush elephants or approximately eight school buses. Such an immense load underscores the need for heavy-duty, professionally engineered bracing systems to ensure safety and structural integrity.

STEP THREE: PLUG INSTALLATION

A plug installation plan should be constructed by the end user specific to each installation due to the countless jobsite variables that vary from job to job.

Here's a step-by-step checklist that can assist an end user in the proper use and installation of a plug in a pipe:

1. **Check Plug Usage Range Against Pipe ID:** Verify that the plug is suitable for the pipe's internal diameter (ID). The plug should fit securely within the pipe to ensure a proper seal.
2. **Check Plug Length Against Pipe Length:** Ensure the plug length matches the length of the pipe available. The plug should not be too short or too long for the pipe.
3. **Prepare the Pipe:**
   - Ensure the pipe is in good condition: clean, dry, and free of any sharp edges or openings.
   - The pipe should be cleaned thoroughly to remove any debris, rust, or contaminants that could affect the seal.
4. **Inspect the Plug and Accessories:**
   - Ensure the plug and all accessories are in good condition and have been tested.
   - Check for any signs of wear, damage, or defects.
5. **Insert the Plug:**
   - Fully insert the plug into the pipe, ensuring it is positioned correctly.
   - If needed, install some pre-bracing to hold the plug in place temporarily.
6. **Inflate the Plug:**
   - Inflate the plug to the required pressure, as specified for your application. Ensure that it inflates uniformly and maintains a tight seal against the pipe wall and did not shift or become cockeyed during inflation.
7. **Block, Brace, Restrain:**
   - Implement blocking, bracing, and restraining measures to secure the plug in place and resist any forces pushing it out.
   - Ensure that the bracing system is designed and installed according to safety guidelines, and that it effectively holds the plug in position.

BRACING GUIDELINES:

1. **Multiple Points of Contact:** Ensure that the bracing system has multiple points of contact with the plug. All points of contact should be equidistant from the plug to ensure even distribution of force.
2. **Stability:** The plug should remain completely stationary, with no movement allowed, even by ¼ inch. This is crucial for maintaining a secure and effective seal.
3. **Design and Engineering:** The design of the bracing system should be determined by an experienced

and competent individual. It is essential to have the design reviewed and validated by a certified engineer to ensure it meets safety and performance standards.

4. **Material Appropriateness:** Select materials that are suitable for the calculated pounds of force. Consider factors like:
   - **Metal vs. Wood:** Assess whether metal or wood is more appropriate based on the load requirements and environmental conditions.
   - **Thickness:** Ensure the materials are thick enough to handle the force without deformation or failure.
   - **Grade and Origin:** Choose materials based on their grade and county of origin, as these can affect strength and durability.
5. **Safety Margin:** It’s important to factor in a safety margin. Bracing should be designed to handle loads well beyond the calculated force to account for unexpected stresses or weaknesses.
6. **Consultation:** There are engineering firms that specialize in consulting for framework design. Engaging with these professionals can help you build a robust and reliable bracing system tailored to your specific needs.

First Attempt (failed)

Second Attempt (passed)

STEP FOUR: HYDROSTATIC PRESSURE TESTING

Typically, these tests involve both a high side and a low side. The test pipe should be filled and tested from the low side, while air is bled off from the high side.

Most high-pressure plugs feature two through-ports: a smaller ¾" offset pipe/port and a larger 2" port located in the center of the plug.

The plug on the high side should always be installed with the ¾" offset bypass pipe positioned at the "APEX" or 12 o'clock position set up with a bleed hose and valve. This setup allows the maximum amount of air to be expelled from the pipe before conducting the test, as trapped air can compromise the accuracy of the test.

To conduct the test:

1. **Fill the Pipe:** Use the center port to fill the pipe until it is completely full.
2. **Pressurize:** Once the pipe is full, use the hydrostatic test pump connected to the ¾" port to pressurize the test area.

This process ensures that the test is conducted accurately without interference from trapped air.

Allow Air to Vent: You must permit air to vent back into the pipe as you drain off the water. Failing to do so can create a vacuum effect that pulls the plug into the pipe, potentially damaging the test plug frame and/or bladder.

Prevent Vacuum Formation: As you drain the water from the test area, keep the high-side ports open to allow air to enter. Also, open the valves on the low-side plug. This prevents a vacuum from forming that could compromise the integrity of the plug and test setup.

Drain and Deflate: Once the test area is fully drained and no more water is leaking from the high-side ports, you can proceed to deflate the plugs. Ensure that there is no residual back or test pressure behind the plugs before deflating them.

Remove Bracing and Plugs Safely: Deflate the plugs while the blocking and bracing systems or structures are still in place to ensure the safety of your workers and crew. After deflation, remove the blocking/bracing structure and then remove the plugs.

NOTE FROM THE AUTHOR:

Selecting a pipe plug without first acquiring details about the pipe size and test pressure is comparable to choosing shoring without assessing the trench width or soil type. Such oversight increases the risk of failure, equipment damage, or more severe consequences.

Furthermore, providing a high-pressure test plug without ensuring that the end users comprehend the design differences between low-pressure and high-pressure plugs can result in disastrous outcomes. It is crucial to gather all pertinent details and ensure that end users are thoroughly informed to prevent issues and guarantee the safe and effective use of the equipment.

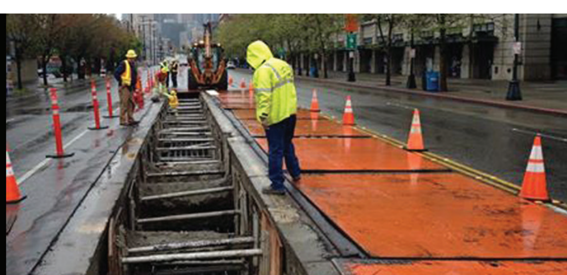
If there is a single take-away from this article regarding the use of high-pressure test plugs it would be:

BRACING IS KEY!

66" high-pressure test plug set up for inflation and test through via hydropump

66" high-pressure test plug set up for fill via water pump (not pictured) and inflation and test via hydropump

Disclaimer: This document does not provide or address all information, laws, standards, regulations, codes, requirements, and safety procedures applicable to excavations, trench protection, and shoring options. Readers should comply with all such measures.



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