A Tool for Extracting Leak-Detecting Smart Balls from Pressurized Lines

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Pipeline Pigging and Integrity Management Conference

February 12-16, 2024

Organized by
Clarion Technical Conferences

https://doi.org/10.52202/072781-0074

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Abstract

PHMSA has mandated that operators of hazardous liquid pipelines implement at least two technologically complementary forms of leak detection on all pipelines by October 1, 2024. This includes sections not part of high-consequence areas (HCAs). In-line acoustic leak detection multi-sensing inspection balls (MSIBs) are a popular complement to conventional pressure monitoring because, with the right pipeline operational conditions, they can detect very small leaks that conventional pressure monitoring systems may miss. Further, MSIBs do not require a pipeline shutdown and require little to no modification of existing lines. This talk presents a patent-pending tool for extracting MSIBs from an operating pipeline without shutting down the line or reducing its flow rate. This tool extracts the MSIB through a pressure-balanced 4-inch lateral tee, avoiding the expense and complexity of installing and operating a pig trap or pigging valve.

Overview

Multi-Sensor Inspection Balls (MSIBs), like Ingu's Piper Ball and Xylem's SmartBall, are a versatile addition to the pipeline inspection and maintenance toolbox. These devices contain multiple sensors that capture various conditions as they travel through the pipe. Not only can MSIBs detect leaks with enough precision to identify the location within one or two joints, but they can also be used for pipeline mapping and for screening the pipe in advance of an ILI run. Since MSIBs are smaller than the pipe's diameter, they are not pushed along by a pressure differential like pigs. Instead, they are free-floating and are swept along by the flow of the fluids in a liquid line. Although they can be attached to pigs for use in gas lines, this application is outside the scope of this paper. This paper introduces an inexpensive and easy-to-use tool for retrieving MSIBs from operating liquid lines.

MSIBs are an attractive tool because they are so easy to use. They feel familiar because they can take advantage of existing pigging infrastructure. They can be launched and retrieved using permanent or temporary pig launchers and receivers. Pigging valves are a compact solution well-suited for launching and retrieving these small devices. Although MSIBs can take advantage of these installations, simpler solutions are just as effective for pipes where this pigging infrastructure is unavailable.

An MSIB can be dropped into any line fitted with a tee large enough for the MSIB to pass through by building a double-valved chamber on this tee. These chambers operate as an airlock that allows an MSIB to pass from ambient pressure outside the pipe into the fluid flow at the pipe's operating pressure. To launch a device, first open the ball valve at the top, drop in the MSIB, close the top, open the bottom, and away it goes. These simple launchers make MSIBs attractive candidates for monitoring difficult-to-inspect and proportionally expensive-to-inspect smaller pipes in challenging and cost-sensitive environments like gathering fields.

A question that is often asked is, is there a method of retrieving MSIBs that is as easy as dropping them through a double-valve chamber? Such a device might look like a net that passes through a similar airlock to pluck the MSIB from the flow. Upstream Vee, LLC (USV) developed such a device, called the Small Inspection Device (SID)-Sucker, with the guidance of Chevron's Technical Center.

The USV SID-Sucker can operate on any liquid pipe between 4 and 12 inches in diameter that can be fitted with a 4-inch flanged tee near the end of an MSIB inspection run. The SID-Sucker is

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temporarily bolted to a 4-inch full port ball valve permanently attached to this tee. It is a portable pressure chamber with an integrated net that can reach into an operating pipe and pluck out an MSIB as it passes. This net is laterally compliant so that it collapses into the chamber and is axially stiff to resist the high Reynolds number flows of fast-moving or viscous fluids. The SID-Sucker weighs less than 50 pounds and is intended to be moved from line to line to retrieve MSIBs from multiple pipes.

The SID-Sucker is easy to operate. After bolting the device to the 4-inch ball valve, the operator equalizes the pressure by opening a bleed valve at the chamber's top. After opening the ball valve, the SID-Sucker's collapsed net may be lowered into the pipe by pulling on a rope. As it lowers, the net expands across the pipe to wait for one or more MSIBs to arrive. Once all MSIBs have been captured, releasing the rope raises the net back into the chamber. After equalizing with the outside air, the SID-Sucker may be unbolted and moved to the next pipe. Moving the SID-Sucker reveals the captured MSIBs at the bottom of the net.

The SID-Sucker is licensed to the operator as hardware-as-service (HAAS). It may also be purchased outright. Each device is configured to a specific nominal pipe diameter and "stack height," which is the distance from the top flange of the ball valve to the top of the target pipe. The standard stack height is 16 inches. The nets can accommodate a range of wall thicknesses for a given diameter. Multiple nets may be required to cover the entire wall thickness range.

Using a SID-Sucker

The SID-Sucker is a dip net lowered through an airlock into an operating pipe to wait for one or more MSIBs. Once they have all arrived, the net with collected MSIBs is drawn back into the airlock, which is sealed, drained, and returned to atmospheric pressure. As the SID-Sucker is moved to the next pipe by unbolting it from the ball valve, the MSIBs may be retrieved for data analysis. This is a very simple system, both conceptually and in its implementation. Figures 1 and 2 illustrate the SID-sucker net in the raised and lowered positions.

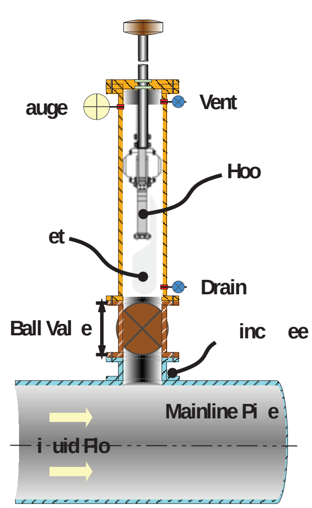

Figure 1. Retracted position

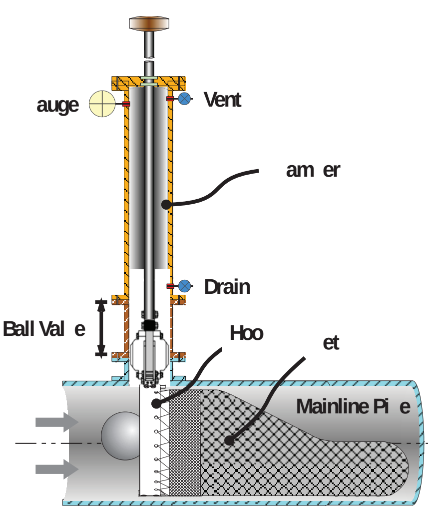

Figure 2. Deployed position

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The SID-Sucker is shipped and stored mostly assembled in a protective, hard-sided case. It weighs less than 50 pounds and is about 3 feet (1 meter) long when compressed for transport. It will easily fit in the cab of a truck. The net's hoop is sized according to a pipe's nominal diameter and wall thickness. As shown in Figure 2, the shaft extends 3 feet above the chamber, so the total height is about 6 feet (2 meters) when it is in the extended position. An assembled SID-Sucker attached to a ball valve can be rather tall. With this in mind, the primary points of human interaction are placed low on the device. For many installations, this means the operation of the SID-Sucker takes place directly in front of the operator at waist or chest height.

Installation of the SID-Sucker at the MSIB extraction site begins by attaching a net. This is done by pinning it to the shaft with two pins. These pins establish a chain of orientation that allows the operator to know where the front of the net is during operation. Next, the shaft is raised to the top of its range. This draws the net into the chamber. With the net out of the way, the SID-Sucker can be lifted to mate with the flange on the ball valve. This is done safely with a hoist and wire rope harness that attaches to lift points built into the chamber lid. An optional collapsable tripod lifting hoist, weighing only 50 pounds, is ideal for use in remote locations, allowing one to avoid the logistics of a forklift.

Figure 1 illustrates a SID-Sucker in the raised position immediately after it was secured to the ball valve. At this point, the device is fully installed and ready for operation. The chamber is full of air and is isolated from the pipe by the closed ball valve. The next step is to equalize the pressure in the chamber with the pressure in the pipe. This is done by opening the ball valve into the pipe and, at approximately the same time, opening the bleed valve, labeled as "vent" in the figures. Once equalized, the bleed valve is closed, and the net can be deployed.

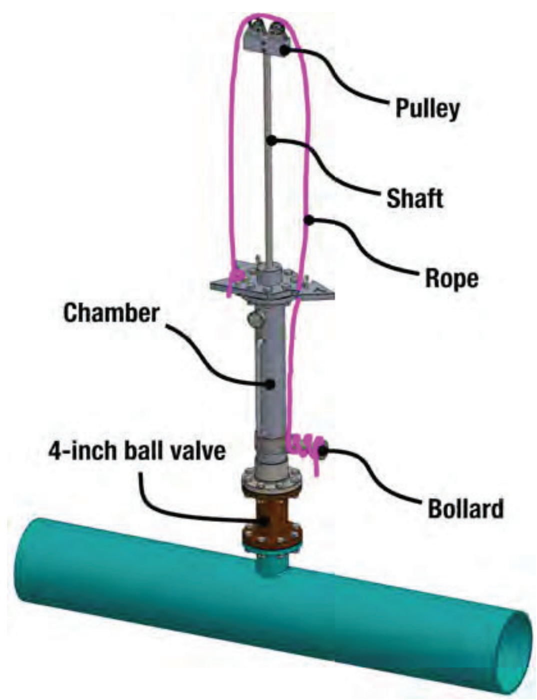

Figure 3. Deployment rope

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With the ball valve opened, the net does not just fall into the pipeline below. The pressure in the pipe makes the net act like a piston that wants to be forced up and out of the chamber. This means it takes a downward force to move the net into the chamber. This force is applied with a soft, synthetic, conductive rope running over a pulley secured to the top of the shaft and anchored by a bollard just above the ball valve. The rope is conductive to dissipate static charge. The pulley mounted on the shaft supplies a 2:1 mechanical advantage. This mechanism is illustrated in Figure 3, where the pink line is the rope.

The bollard is the key element of this arrangement. Its large diameter allows the operator to direct the rope's pull in an optimum direction for the operator's height relative to each installation. A tall user can pull up on the rope. Other users may pull out. Others may need to pull down. Combining the bollard with some simple rigging can boost the mechanical advantage to 3:1 or 5:1, as required by the pipeline's operating pressure. For extreme pressures, adding a manual or drill-powered wench gives the operator even more options. Additionally, wrapping a few loops of rope around the bollard supplies friction that can retain downward progress or gently release the net back to a raised position when the capture phase is done. Finally, an integrated cleat on the bollard, used like tying off a boat at a dock, gives a simple way to secure the net in the pipe while waiting for MSIBs to arrive.

Figure 2 shows a SID-Sucker in its deployed state. As the net and hoop are lowered into the operating pipeline, the weighted long end of the net catches the current, allowing it to unfurl without tangling as it is swept downstream. Upon lowering the net further, the non-marring nose of the hoop makes contact with the inside of the pipe wall. This contact forces the spring material in the hoop to bow outwards. When fully deployed, the hoop spans the full pipe bore, exposing the net to the current. Soft feet on the hoop protect internal pipe coatings while the SID-Sucker waits.

When retrieving the SID-Sucker, the operator lets the rope slip around the bollard, controlling its ascent while line pressure ejects the net from the pipe. A mark on the rope indicates that the net is entirely within the chamber. Once the net is out, the ball valve may be closed. This isolates the pressurized chamber from the pipe. The chamber may now be depressurized and drained by opening both the vent and the drain.

Before unbolting the SID-Sucker from the ball valve, safety requires the operator to ensure there is no pressure in the chamber. After checking the pressure gauge, the operator is confronted with a fail-safe. Several bolts securing the SID-Sucker to the valve use an unusual star-head bolt. An impact wrench socket for these special bolts is attached to the handle of the drain valve. To free it, the drain valve must be opened. If the drain valve is open while there is still pressure on the chamber, it will discharge safely and noticeably from the open port. This serves as a warning for the operator to address the situation before proceeding with the unbolting.

Once the SID-Sucker has been safely unbolted, it can be raised by the hoist to retrieve the captured MSIBs. This is shown in Figure 4, which shows a retrieved Ingu Piper in an early version of the SID-Sucker net.

The SID-Sucker is intended to be used on multiple pipes. Once it has completed its mission on one pipe, it may be moved directly to another.

Comparison of methods

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This section compares some common methods for retrieving MSIBs from an operating pipeline. These methods include pigging traps, pigging valves, and strainers. Table 1 compares these methods.

While all the methods listed here can retrieve multiple MSIBs from the same line, only the SID-Sucker and temporary pig traps are designed to be moved from line to line. Of the two, a temporary pigging trap incurs the full cost each time it is used. In contrast, the SID-Sucker requires a 4-inch tee and a ball valve to be installed once on any target line. Once a line has been so equipped, the SID-Sucker may be used routinely. The cost of the tool can be spread across the multiple lines upon which it is used. This makes the real cost of a SID-Sucker significantly less than any other option.

Table 1 is arranged in order of decreasing installation costs as estimated for a 10-inch line. These broad cost estimates, which are order of magnitude approximations for comparison, include the cost of both the extraction device and the installation. For example, installing a pig trap is expensive because the trap is expensive, and the infrastructure and heavy equipment required for the installation are expensive. As another example, although a strainer is a normal part of pipeline startup and operation, using one to retrieve MSIBs is not. Retrieving the captured inspectors requires either shutting down the line or installing a bypass so that the line can continue to operate during retrieval.

Table 1. Comparison of MSIB retrieval methods

	Install Cost (for 1)	**Install Impact**	**Lines**	**Operating Cost**	**Operating Impact**
Pig Trap	$900K	Very High	1	Very High	Low
Pigging Valve	$150K	Med	1	Med	Low
Temporary Trap	$30K	Med	∞	High	Med
Strainer	$20K	Low	1	Low	Low
SID-Sucker	$4K**	Very Low	∞	Low	Very Low

**Does not include tool cost

The third column in Table 1, called "Install Impact," compares the relative disruption to a line when each corresponding MSIB retrieval method is installed. It is well known that it is very disruptive to install a pig trap. It requires a new or expanded facility. The impact of installing a pigging valve is much smaller. It requires a bypass line and an expensive piece of equipment. Using a strainer to retrieve MSIBs requires the installation of a bypass line. As already mentioned, installing a SID-Sucker has a very low impact on a line since all that is required is to install a tee and a valve.

The operating cost column reflects the number of people required to operate a device and the level of training for each step. Further, it reflects equipment that may be required each time a method is used. For example, a temporary pig trap requires specialized training and the use of a crane or forklift to support the trap. In contrast, since opening a bypass line and unbolting two flanges is a routine pipeline operation, retrieving an MSIB from a strainer has a low impact on a pipeline's operation. Using a SID-Sucker is new and will require training. On the other hand, this training is simple and intuitive; only one individual is required to operate the device. Further, since the tool cost can be spread out across several lines, the operating cost is low.

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The final column compares the overall impact each method has on the line. It reflects how much flow restriction a method imparts and if the flow rate must be altered. Most methods are routine and can be performed with little impact on the line. A temporary trap may have more impact than other methods because these devices are sensitive to too high pressures. The SID-Sucker is listed as "very low" because its low-drag net and solo operation have very little impact on the pipe's overall operation.

Case study

When Chevron's Technical Center Integrity Team SMEs performed their first trials of the Ingu Pipers at the PRCI test loop in Houston, they envisioned retrieving MSIBs in much the same way that corrosion coupons are inserted into and then later withdrawn from an operating pipe. A corrosion coupon holder uses a shaft to move a coupon through a single block and bleed chamber into and out of a pipeline. The idea was that if the corrosion coupon were replaced with a net, this could be an effective tool for retrieving MSIBs.

Upstream Vee LLC committed time and resources to develop a device to fulfill the original idea and have it ready by the Ingu trial. For the trial, they supplied a laterally compliant but axially stiff collapsable net that was designed to resist high Reynolds number flow. They deployed the net through a 6-inch tee and used the actuator from a coupon holder to move the net into and out of the pipe. The test was low-pressure, and the flow in the test loop was shut down to retrieve the MSIB after each test.

At these trials, the SID-Sucker was able to catch Pipers consistently. Figure 4 shows the crew removing a Piper from the net after a successful retrieval. A video of these trials is available on YouTube at https://www.youtube.com/watch?v=oFyAHhJ-iOM. The SID-Sucker can be seen at time stamps 1:41, 2:17, 3:09, and 3:22.

Figure 4. Retrieving the MSIB

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Additional information

The SID-Sucker is available for pipes between 4 and 12 inches in diameter. Since the net capacity is a function of the chamber size, and the chamber size was kept small to keep the device from being heavy and unwieldy, the larger sizes can collect fewer MSIBs. At the limit, the 12-inch net has room to collect three medium-sized MSIBs.

The suggested location to install a SID-Sucker is immediately upstream of a sieve. While this is not a requirement, having a sieve as a backup provides added confidence that nothing will get lost in the pipeline.

As a final note, Technology Readiness Level (TRL)[1] is a concept developed by NASA to evaluate the maturity of a new technology. This scale ranges from a "good idea" at the low end, given a value of 1, to a high-end value of 9, given to a mature commercial product with a long history of various deployments. The SID-Sucker is currently at TRL 6. This means that the critical elements have been tested under simulated but realistic conditions.

Upstream Vee is ready to move to TRL 7, where a complete tool has been tested in a real operating environment. This step takes us from a prototype to a commercially available system. To that end, USV has several pre-production tools available for lease. We hope to move to TRL 8, which describes a new commercially available product, by the end of 2024. To do this, we need several operators who see this approach's value and are eager to try it.

Summary

Upstream Vee's SID-Sucker is an intuitive way to extract Multi-Sensor Inspection Balls (MSIBs) from an operating pipeline with minimal impact on other operations. "SID" stands for "Small Inspection Devices," which hints at a future where these small inspectors may take other shapes besides spheres.

Preparing a line to use a SID-Sucker is as routine as installing a 4-inch tee and topping it with a full port ball valve. Once prepared in this way, a SID-Sucker with a properly sized net can be used repeatedly on that pipe. Further, this same SID-Sucker can be used on all pipes of the same diameter that have been fitted with a tee and valve.

Operating the SID-Sucker is simple and safe. Pull a waist-high, static-safe rope toward the pipe to engage the net. Release the rope to have the net exit the pipe. This simplicity is what makes it portable. This portability is what makes is a great value.

Unlike other MSIB extraction technologies, which require larger capital investments and are restricted to a single line, the cost of a SID-Sucker can be amortized across several lines. For a single, price, one SID-Sucker can be deployed across multiple pipes. This makes the SID-Sucker a cost-effective solution no matter what the price.

[1] https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/ and https://api.army.mil/e2/c/downloads/404585.pdf

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