Gus Velasquez, Allan Rienstra SDT

Ultrasound – Beyond Fixed Assets

Introduction

Ultrasound as a predictive maintenance tool is used successfully in many industrial applications in industries of all kinds. It is used as an inspection tool for detecting positive and negative pressure leaks such as those found in compressed air systems or vacuum pumps. Some industrial processes use ultrasound to identify failed steam traps and all facilities derive safety benefits from its ability to find electrical faults. Most recently PdM professionals have opened their eyes to the benefits ultrasound offers as a predictive technology giving early alert that an impending problem is developing in a bearing or helping to optimize the lubrication of rotating equipment.

All of these valuable applications contribute to billions of dollars saved in downtime, energy efficiency, and improved product quality. Perhaps most interesting of all is that most of these inspections are carried out on fixed assets. However in many companies such as mines, cement production, quarries, civil engineering contractors, industrial farms, commercial fleets, and oceanic vessels the production cycle depends on heavy vehicles, loaders, off road vehicles, and seagoing ships.

These vehicles have a wide range of applications such as moving goods from land points to sea ports and beyond, plant, maintain, and harvest crops, excavate earth and move thousands of tons of raw materials in quarries and open pit mines.

Although their size can varied between 30 to more than 350 MT, they all have in common an internal combustion engine to provide the power to move the vehicle. Most have a cabin to keep the operator safe, dry, warm, or cool while others have storage volumes which must be weather tight at the least, and hermetically tight in the case of chilled container transports. And in many cases compressed air systems are used for breaking and suspension systems.

To protect the investment in these mobile assets preventative and predictive maintenance is performed on a regular basis. Most fleet managers rely on oil analysis for predictive maintenance while other PdM technologies (Ultrasound, Vibration, Infrared) are seldom considered. Additional investment in these technologies is not a priority. However there are several important applications that can be served with ultrasound technology, but not currently understood. These apps fit the PdM tool box perfectly for any maintenance department responsible for keeping a commercial fleet running flawlessly.

The purpose of this paper is to educate about some important applications where the combination of ultrasound testing and oil analysis can predict major premature engine failures and speed up the inspection time required to find problems. This paper also discusses some secondary applications that address issues related to safety of these vehicles, protection of cargo, and comfort for the operator. Please read on to learn the important role that ultrasound technology serves for fleet maintenance managers and mechanics.

Ultrasound Testing – What is it? How does it work?

Many people in maintenance department of factories responsible for fixed assets know that the principle source of ultrasonic waves is turbulent flow, friction and discharge related to electrical problems. They also know that ultrasound waves are sound waves vibrating over 20,000 Hz, which is impossible for humans to hear without the help of special instrumentation such as the SDT170 Ultrasonic Measurement Instrument.

Image 1 - Ultrasound Testing plays a huge role in predicting failures in factories, refineries, and on other fixed assets.

The SDT170 detects potential problems that can lead to shut down of a process or factory. The SDT170 also detects sources of energy waste and issues that impact negatively on product quality. Early stage problems produce ultrasonic signals that are transmitted from the source as ultrasound pressure waves. The SDT170 detects these waves and translates them into an audible signal that can heard by the inspector, all the while measuring the ultrasound signal so that it can be compared and trended to determine gradual deterioration. If that sounds complicated, its really not.

To date there are thousands of trained ultrasound inspectors working in factories with fixed assets who are extremely sharp and creative when it comes to detecting sources of ultrasound inside their processes and fixing their findings.

A growing demographic of qualified and skilled ultrasound inspectors is poorly represented in the mobile maintenance shop where the technology is virtually unknown, and sadly, many cost saving applications have not been revealed. If you are working in the maintenance department responsible for mobile asset maintenance you will be pleasantly surprised by the applications revealed in this paper.

Applying Ultrasound Inspection to Mobile Fleets

- Diesel engines
- Hydraulic cylinders
- Air braking systems operate by air
- Air suspension
- Cabin tightness

Diesel Engines

Internal combustion engines burn fuel and regardless of size they require air; preferably clean. The air we breathe is the same air engines breath. No matter where we are on the planet air contains particles in suspension. Some of these particles are harmless but others represent a serious danger. Silica ranks as one of the hardest elements on earth, only surpassed by topaz, corundum, and diamond. Silica is very damaging if it reaches the inside of the engine. Silica also ranks as one of the most abundant elements on earth and ever present in dirt and dust which is made airborne in the conditions where mobile machines operate. Engines are therefore equipped with high efficiency filtration systems to prevent silica and other contaminants from reaching the combustion chamber.

Image 2 - Typical Turbo Charger System

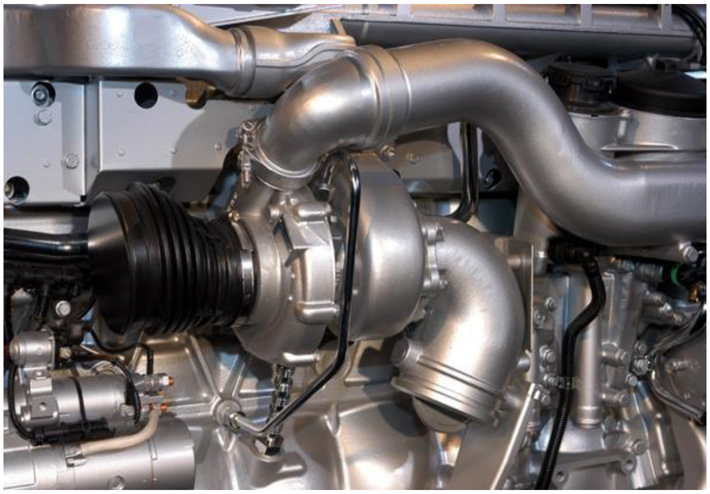

Image 3 - Typical Air Breather System on Heavy Trucks

All diesel engines have primary and secondary filters fitted between the air intake vents and the turbocharger (Image 2). When the engine is operational a negative pressure is created in the air intake system and any leaky orifice (loose clamps, cracked hoses, thinned metal, pin holes) downstream of the filters means the engine is breathing without filtration. This means air full of silica can reach the pistons, rings, sleeves and other engine components causing damage and premature failure. Depending on how much silica is ingested, the life of the engine is dramatically reduced, sometimes lasting only a few days!

Oil analysis is used as a predictive tool comparing the metal content and silica in parts per million (PPM) found in the oil sample against limit values set according to the engine manufacturer. The acceptable silica content is very low ranging from 15-50 PPM. When a sample shows values over the limit the source of the contamination needs to be found quickly and the mobile asset must be removed from service to avoid further costly damage. This introduces the added cost of downtime and lost productivity.

Finding the leaks calls for an exhaustive visual inspection of the entire air intake system. This can take several hours to inspect and it's not uncommon after the inspection to have found nothing. The next oil sample will still show high silica levels and increasing wear metal values indicating the problem is getting worse. As a companion to visual inspection, ultrasound testing to find the leak will net results much faster, and is also useful to confirm the repairs to the leak were done correctly. Progressive mobile mechanics use ultrasound inspection after any service work is made on the air intake system.

There are two methods for finding problems in the air intake system with the SDT170.

- Inspection with the engine running
- Inspection with the engine turned off

Inspection with the engine running

Using this method of inspection is based on the premise that any turbulent flow from a potential leak produces ultrasonic sound pressure waves which are detected with the SDT170 ultrasonic detector. Turbulent flow is produced between two adjacent volumes when those volumes have a) differential pressure, and b) a leak path. Turbulent flow will exist at the leak path for so long as there is differential pressure between the volumes.

Start the engine and leave it to idle. With noise attenuating headphones in place adjust the sensitivity of the SDT170 according to the ultrasound sources near the engine. Using the flexible sensor for safety (if you have that accessory) inspect the entire intake system starting from the air breather and ending at the turbocharger. Any air ingress will produce an ultrasonic signal that sounds like the hissing, swooshing sound you know from a compressed air leak. A well trained ear will pick this sound quickly despite competing noises that may come from the engine itself. Additional training teaches ultrasound inspectors how to deal with parasite noise and harsh environments and is highly recommended for mobile mechanics that are adopting ultrasound testing symbiotically with oil analysis. Techniques known as "shielding", "covering", "blocking", and "positioning" are learned keys that assist inspectors in high noise areas.

Image 4 - Typical Air Breather on Heavy Truck

Inspection with the engine turned off

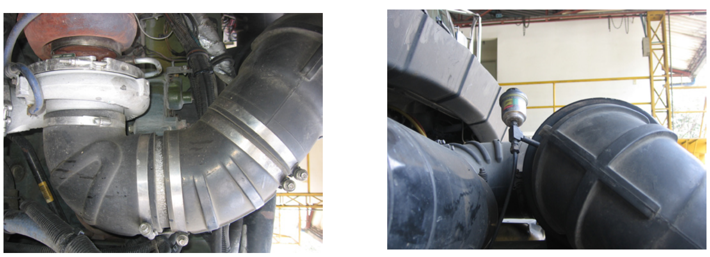

Image 5 - Potential Leak Sites on piping between air breather and turbo charger

The air intake system can also be inspected for leaks when the engine is not running. In fact this may be a more desirable method if the parasite noise from the engine is too much.

When the engine is off there is no differential pressure and consequently no turbulent flow. No turbulent flow means no natural ultrasound signals are present at any leak sites. In lieu of turbulent flow we can generate artificial ultrasound signals in the air breather system. This is done by means of an SDT 200mW Bi-Sonic Transmitter, a small accessory that generates a 40 kHz signal powerful enough to fill small volumes. The ultrasound signal can be heard and measured directly through the various membranes that make up the air breather system. Wherever the possibility of air ingress exists the signal will be significantly louder. This is noted in the headphones of the SDT170, and also in the measured decibel on the SDT170 display.

A large mining company in northern Canada recently shared their experience inspecting the air intake on a LeTourneau production loader. In Response to very high levels of Silica & Iron from Oil samples on 546 Production Loader an attempt was made to determine if there were any leaks in the breather system of the loader which would cause severe dusting. A visual inspection of the breather system failed to produce any definitive results. A second check of the breather system was conducted using airborne ultrasound with an SDT170.

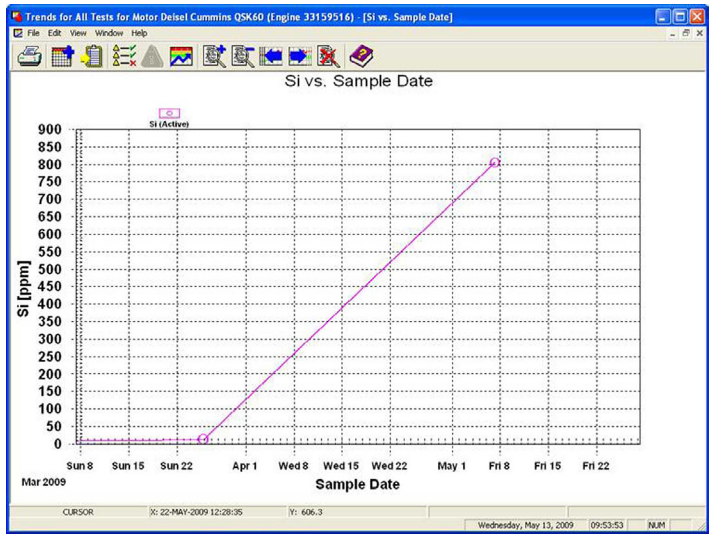

Image 6 - Silica levels are 800 PPM indicating motor dusting

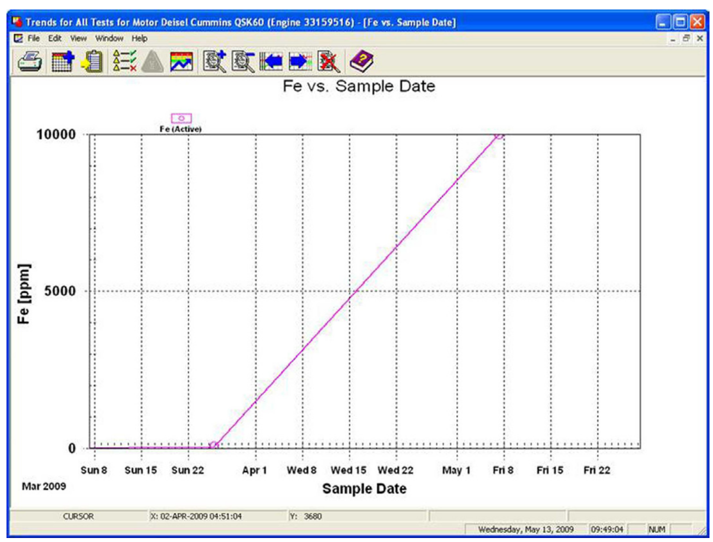

Image 7 - Iron levels are 10000 PPM indicating motor dusting

Finding the leaks was easy the mining company reports. A 200mW Ultrasonic Transmitter was placed inside the inner air filter. Both air filters were replaced and the breather system was sealed up. The entire breather system from the filters to the engine was probed with the SDT170 ultrasonic receiver (Image 8). All locations along the breather piping and joints displayed ultrasound readings from 20 to 24 dBμV. One location, inside

Image 8 - Scan the breather system from filters to turbo charger with SDT170

a clamp on the right hand side of the loader gave readings of 34 to 38 dBμV. That is an increase of 14 decibels. 38 decibels is 5 times louder than 24 decibels. This is a strong indication of thinned metal combined with the possibility of pinhole leaks under or around the clamp. Images taken with a digital camera indicate where baseline ultrasound readings of 20-24 dBμV were registered versus anticipated leak sites where 34-38 dBμV were observed.

Image 9 - An area around the clamp was welded previously, but still leaking

The mechanics at the mobile repair shop reported that the fix was relatively simple once the leaks were discovered. And finding the leaks with ultrasound inspection was far quicker than any other method previously used. It was clear the pipe had been patched previously. It was removed and the existing patch inspected and re-welded. The pipe was reinstalled on the loader, filters replaced and it was recommended that the loader return to operations for a 12 to 24 hour period, at which time fresh oil samples would be taken again and the results analyzed for further dusting problems.

The production loader's oil was re-sampled on May 22, 2009, after approximately 48 hours operating in the field, and test results were received back from the lab on six days later. All indications of dusting had disappeared from the oil sample results. As can be seen in comparing the samples shown, Substantial drops in Aluminum, Nickel, Chromium, Iron, Copper, Lead, & Silica were observed, indicating the air leak had been patched successfully, and was indeed the cause of the dusting. It was suspected that the contaminants in the initial samples were a combination of dusting ingress and wear particles from engine components.

Test info	diagnosis	diagnosis
Al	3	11
Ni	<1	9
Cr	<1	83
Fe	4	>9999
Cu	<1	59
Pb	2	15
Sn	<1	<1
Si	4	805

Image 10 - Oil Analysis Report

Ultrasound inspection of air intake systems is now standard practice at this Canadian mine site, as are other applications yet to be discussed in this paper.

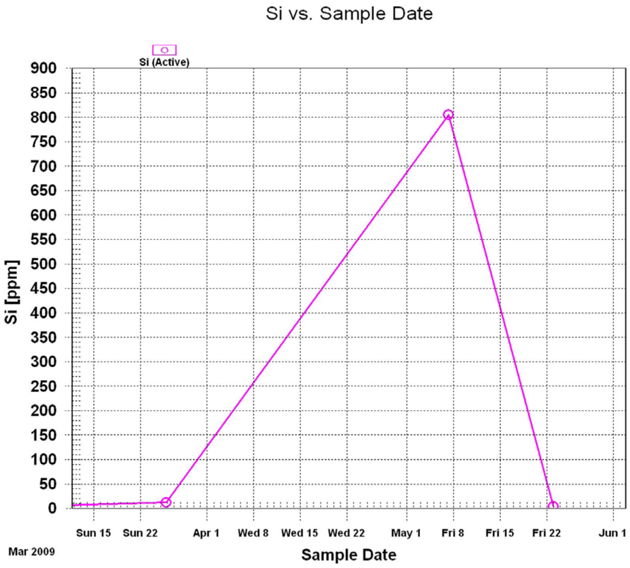

Image 11 - Silica samples showed normal after 48 hours in service

Hydraulic Cylinders

Hydraulic cylinders, also called a linear hydraulic motor are widely used in fixed and mobile hydraulic systems. They provide linear force through a linear stroke. The cylinder operation is based on Pascal's Law which states that if you apply pressure to fluids that are confined then the fluids will transmit the same pressure in all directions at the same rate. Hydraulic cylinders are an efficient way to multiply force and move heavy loads.

Image 12 - Typical Hydraulic Cylinders on Shovel Loader

Seals are one of the most important components in hydraulic cylinders. They create a barrier between the high pressure chamber and the low pressure chamber. When the integrity of seals is compromised the cylinder no longer transmits its full force potential.

Symptoms of Problems in Cylinders

A sure symptom that the cylinder has problems is a loss of power and or slow operation. In severe cases the cylinder can stall even under light loads. An increase in pump noise and temperature is also a sign of leaking cylinders. The leading cause for hydraulic system failures is contaminated hydraulic fluid. Hard contaminants in the fluid such as silica wear out the barrel and the seals making it hard for the hydraulic pump to maintain the necessary pressure.

How to Troubleshoot the System

A conventional method to check for leaks in hydraulic cylinders requires an operator to run the piston to one end of its stroke and leave it stalled in this position under pressure (Image 13). Then, he cracks the fitting at the same end of the cylinder and checks for fluid leaks which would indicate hydraulic oil has passed the wiper seal. After checking, the fitting is re-tightened and the procedure is repeated on the other end, and the middle of the stroke. This procedure is time consuming and requires the asset to be out of service for a longer time than necessary.

Ultrasound can speed the time required for the inspection, and in many instances the inspection is performed in the field avoiding the cost and delay to float the equipment back to the repair bay. This has added benefit if the inspection reveals a leak and that leak can be repaired in the field.

Using ultrasound the inspector places the contact sensor or magnetic sensor over the barrel near to the piston (Image 14). The system is put under pressure and the sensor scans around the barrel 360o while listening for the characteristic sound produced for a leak when the fluid pass from the high pressure to low pressure chamber. This sound could be that made by small bubbles of oil bursting on the non-pressure side of the wiper. In the case of larger leaks the sound is more like a squishing sound as oil is forced across a small orifice in the seal. The point where the signal is most intense indicates the integrity breach of the seal.

Image 13 - Hydraulic cylinders blocked in open position at end of stroke

Image 14 - Place sensor on barrel of cylinder near piston

Air Operated Brake Systems

Air break systems are primarily used in all type of trucks, buses and rail cars. For an efficient and safe operation the system must be absolutely tight. Brake systems manufacturers establish guidelines for pressure and under all circumstances this working pressure must be maintained.

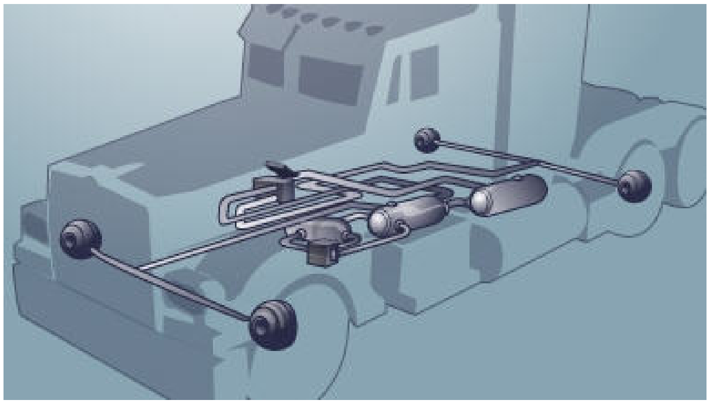

Image 15 - Typical air brake system on heavy truck

Air break systems have several parts including the compressor, an air dryer, valves, air reservoir tank, pipes, fittings and the brake system itself. All these components are susceptible to leaks. The compressor is designed to run loaded up to 25% of the engine's running time but air leaks can cause the running time to increase, adding operation costs in the form of fuel and maintenance. Of course this is not as important as the fact that leaks cause the braking system to be an unreliable safety risk.

Trouble Shooting the Brake System

Finding leaks in the compressed air system in any mobile equipment is easy and fast. In fact many manufacturers, including Volvo Trucks and Mack Trucks already use SDT170 detectors on the assembly line to ensure leak free brake systems. Start the engine and let the compressor run until the required pressure is reached in the system. Turn off the engine and using the SDT170 with the flexible sensor scan from the compressor side to the brakes in the wheels. The hissing sound of the any leak will be easily heard, and because its ultrasonic it is directional and therefore easy to localize.

Air Suspension Systems

Air suspension systems provide a much smoother ride which can add protection to cargo that is sensitive to transportation shocks. The air spring is basically a bellow filled with compressed air and run off the same compressor that the braking system uses. Leaks in the air suspension system affect the smooth ride, but also can draw on the brake system making it unreliable,

Image 16 - Typical air suspension system

and therefore unsafe. There is of course the added risk for a vehicle transporting several tons of cargo. When the air spring loses its pressure there is the chance of balance loss and tipping.

Troubleshooting air suspension systems is essentially the same procedure as that used for braking systems.

Cabin Tightness

A final, but equally important application where ultrasound inspection is usefully employed ensures the tightness of cabins and cockpits. In smaller vehicles tightness is important to prevent noisy interiors from wind noise and water leaks. On larger mobile assets like loaders and tractors keeping micron sized dust particles out of the cabin is a comfort and health issue for the operators.

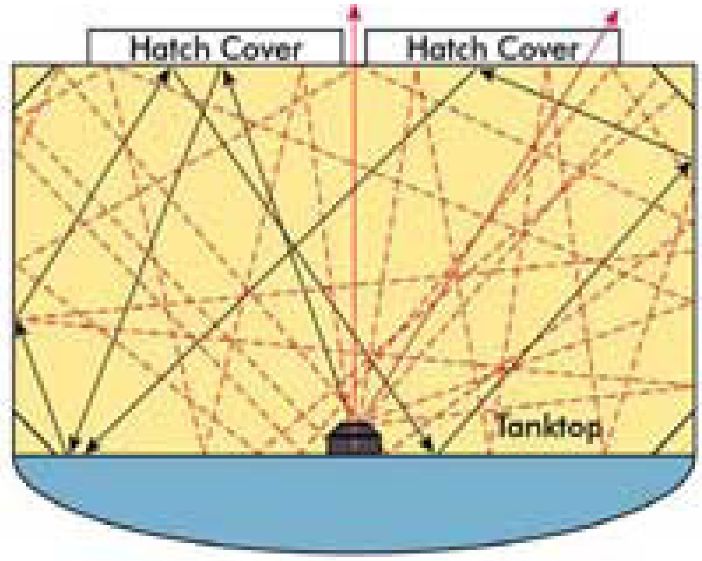

Image 17 - Typical configuration of ultrasonic transmitter in ship hatch

Ultrasound Inspection - Beyond Fixed Assets: Diesel Motors, Hydraulic Cylinders, Air Brakes, Cabin Tightness

Gus Velasquez, Allan Rienstra SDT

The inspection is as simple, and similar as the procedure used for inspecting air breather system with artificial ultrasound. Place the 200mW tone generator inside the cabin and close all windows, doors, and vents. Using the SDT170 and flexible sensor scan the outside seals on all windows and doors. The artificial ultrasound source is powerful enough to fill the entire cabin, but it is also powerful enough to transmit directly through glass and steel. Follow this procedure to understand the difference between a leak and non-leak.

1. *Set the 200mW transmitter inside the cabin*
2. *Take a dBμV reading through an open door or window. That is your OHV (open hatch value)*
3. *Now close the doors and windows and take a dBμV reading at an area where there could not possibly be any leak (the middle of the door glass will suffice). That is the CHV (closed hatch value)*
4. *Now scan around doors and seals with the flexible sensor. The baseline reading will hover around the CHV. Listen in the headphones and when you hear a signal louder than CHV observe it. Does it approach the OHV? If so you have found a potential leak path.*

Image 18 - Ultrasound inspector checks for tightness of tractor cab at SIAC do Brasil with his SDT170 and SDT08 ultrasound transmitter

This white paper covers what we believe are four major reasons to implement ultrasound inspection for major fleet maintenance centers. The inspections discussed have positive impact for cost reduction through faster inspections as compared to traditional methods. They also aid in the prevention of premature failure in diesel engines which can run costs in the hundreds of thousands of dollars. Ultrasound inspection already shares a symbiotic relationship with vibration and infrared inspection of fixed assets. Our examples here cite an excellent argument for marrying ultrasound and oil analysis data for better control of internal combustion engines. Hydraulic issues are time consuming. If ultrasound inspection can be used to isolate leakages in the wiper seals it only makes sense to implement the technology to win more inspection time. Finally, inspecting cabins for tightness enhances comfort and safety for the operators. Tightness of refrigeration units means less drain on the refer compressor motor and better fuel efficiency. Tightness of hatches on cargo carrying ships means dry cargo arriving in port.

While great progress has been made applying ultrasound to inspections on fixed assets, we have learned from this paper that there are equal wins to be gained from applications on mobile assets. As ultrasound technology proliferates around the globe I can't help but wonder what other simple applications exist that will help save the next million dollars.

About the Authors

Gustavo Velasquez

Gus Velasquez

gus@sdtnorthamerica.com

Gustavo has more than 20 years professional experience working for several Companies in Latin-American and Canada such as Mobil Corporation, Saybolt Consultores, Lubrication Engineers of Canada, Battenfeld Grease Canada, LubriSupport, and lately as Account Manager for Latin-American Region with SDT North America.

Gus is a member of STLE and SMRP. He lives in Cobourg, Ontario with his wife and two daughters.

Allan Rienstra

Allan is the CEO of SDT Ultrasound Systems. He has been involved with airborne ultrasound methods for nearly two decades and has helped thousands of ultrasound inspectors achieve inspection greatness through his unique coaching techniques.

Allan Rienstra

allan@sdtnorthamerica.com

He is co-author of two certification training manuals, founder of the SDT certification training and implementation guide. His writing appears in maintenance journals around the world. He lives in Cobourg, Ontario Canada with his wife and two sons.