

The Tuned Pulse Source in layman's terms

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ABSTRACT

Pneumatic seismic sources, commonly known as airguns, have been serving us well for decades but there is an increasing need for sources with improved low frequency signal and reduced environmental impact. LISS developed a new pneumatic source which we call Tuned Pulse Source™. The TPS™ operates with lower pressures and larger volumes than air guns. By larger volume we mean much larger! At this stage we are seeking to permit a sea trial with TPS up to 26.5 thousand cubic inches, albeit at lower pressure. 26.5 thousand cubic inches at 1000 psi releases almost three times as much air than a typical airgun array of 5 thousand cubic inches at 2000 psi. The reason we want to release more air is that we want to create larger bubbles with longer bubble-periods. Longer bubble periods produce lower frequency signal. Low frequency signal is needed to improve the quality of seismic data to enable less risky and lower cost exploration and production of the remaining oil and gas which in mature sedimentary basins, such as offshore the USA are deep and often under salt and basalt in reservoir that are increasingly more difficult to image with airguns. The point in this paper is that environmental impact is not measured by the volume of the seismic source. It is the high frequency energy and not the low frequency energy that impacts the environment. TPS emits less high frequency waves than airguns. The release of the air from a TPS is tuned so that the rise-time is longer than the rise-time of an Airgun. The sound pressure level (SPL) of the TPS and the slope of the SPL are lower than those of airgun arrays. Certain engineering features improve safety and reduce cavitation. Although the volume of TPS is 100 times larger than most single airguns, and 4 times larger than an array of airguns, the total energy released by the TPS we want to deploy in a sea trial is about the same as the airgun array because the air guns will go more often than the TPS.

INTRODUCTION

When air guns were introduced in the 1960's, they brought significant safety and environmental improvements over the explosives that had been used. At the time the industry was happy with the geophysical quality of dynamite data and demanded that safer replacement sources that would geophysically be "just like dynamite". Therefore, air guns were designed with a shuttle that travels a certain acceleration distance before their ports start opening, so that the ports would open rapidly and quickly expose high-pressure air to ambient pressure water and produce a short rise time. Furthermore, in order to be similar to dynamite, airguns were deployed in arrays of a large number of small guns, rather than arrays of few-large-guns. Such arrays of many-small-guns at high pressure of 2000 psi, and with an acceleration distance, produce source signatures characterized by a large initial peak with a short rise-time. The sharp rise of the SPL (in BarM per millisecond) has an environmental impact that we want to reduce.

The TPS is designed to operate at 1000 psi or less, with no acceleration distance, and to be deployed in either single element or arrays of few-large-TPSs. LISS has built one TPS and tested it in ponds and lakes. The data recorded confirms that it performs as hoped. We are now offering this new unusual technology to the seismic industry for sea trials.

TPS DESIGN COMPARED TO AIR GUNS

As can be seen in Figures 1 and 2, the TPS is larger than a typical airgun. The low pressure of the TPS enables large volumes with acceptable weight. The TPS internal design, shown in Figure 3, is very different from the airgun design. In addition to the elimination of the acceleration distance, the TPS airflow is into the firing and operating chambers in parallel with a check valve that eliminates the risk of auto-fires and accidental fires and enables quick filling of large firing chambers. In comparison, the Airgun airflow method is via the operating chamber and the shuttle, which limits the volume that can be filled between shots, carries the risk of accidental fires, and is prone to auto-fire when draining the air. Also, the acceleration distance is eliminated in the TPS. Thanks to the low pressure, the cup shaped flange, and the elimination of the acceleration distance we expect the TPS to eliminate or at least significantly reduce cavitation generated by thin jets of water and air produced by current airguns. The length of the firing chamber tunes the rise time of the first peak. The longer firing chamber increases the rise time, which decreases the slope and the high frequency content.

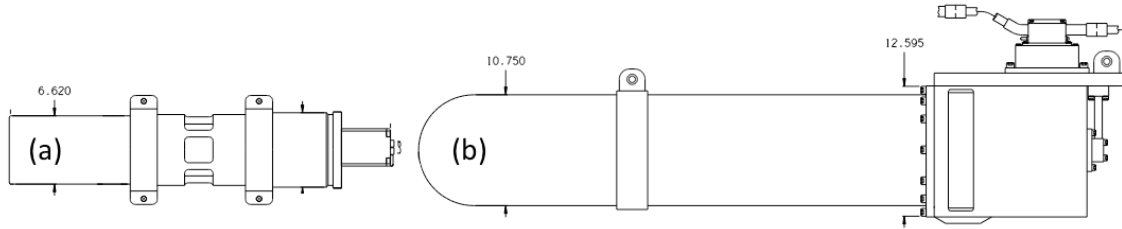


Figure 1. (a) An Airgun with a 350 in³ firing chamber. (b) A Tuned Pulse Source with a 4000 in³ firing chamber drawn on the same scale. Larger chambers can be mounted. We have so far tested the TPS up to 20600 in³.

Four thousand cubic inches chamber shown above in Figure 1 is shown so that it would fit together, drawn at the same scale with an Airgun with a typical firing chamber of 350 cubic inches. However, the TPS is designed for much larger volumes. In Figure 2 we show some of the volumes we tested.



Figure 2. Various volumes of firing chamber that we mounted and tested with the single TPS that we manufactured. Shown here are chambers with 2.4, 4.8, and 20.6 thousand cubic inches.

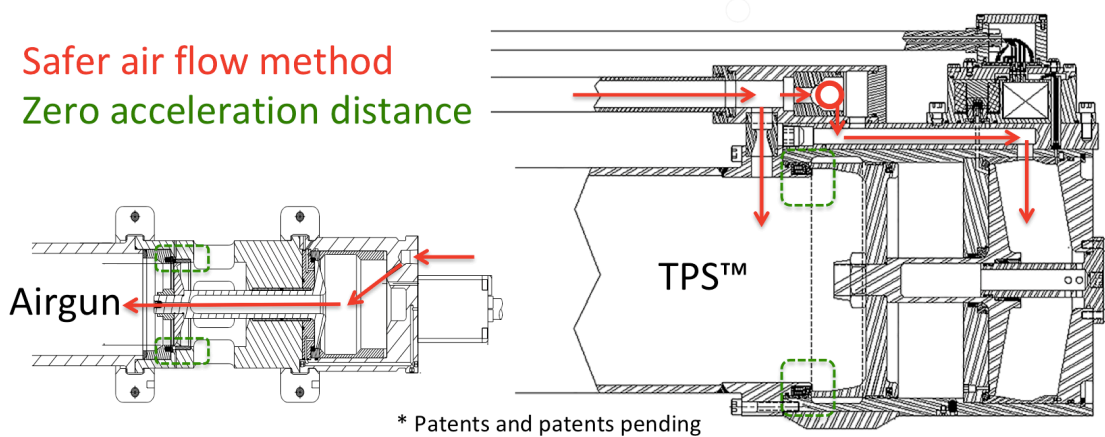


Figure 3. A comparison of the different internal designs of the TPS and the airgun. Out of a number of different design features, two are highlighted here. The safer airflow method (in red) and the zero-acceleration distance (in green).

SAFETY

When airguns replaced explosives, safety was greatly improved. There have been far fewer accidents with airguns than with explosives. However, there have been some accidents because airgun tend to auto-fire when the air pressure is draining out. The air flow design of the TPS includes parallel filling of the two chambers and a check valve that eliminates the risk of auto-fires while draining.

DUTY CYCLE AND ENERGY COMPARISON OF TPS AND AIRGUNS

The compressor capacity on seismic vessels is what is limiting the energy that their sources can emit. For the sea trial we wish to permit, we will deploy the TPS on an airgun source vessel, relying on the compressors already on the vessel. We will therefore not emit more energy in acoustic waves. For example, to shoot a 6650 cubic inch airgun array at 2500 psi, they need to compress at least 2700 cubic feet per minute (CFM). To shoot 26500 cubic inches at 1000 psi every 30 seconds we need to compress 2200 CFM. The TPS we want to test offshore will release less energy per minute than a large airgun array.

ENVIRONMENTAL IMPACT

The air pressure in the TPS, a factor of 2 to 3 lower than in airguns, generates lower peak sound pressure levels (SPL). As significantly, the long firing chambers generate long rise times. These reduce the slope and the high frequency content. The TPS increases the low frequency content (below 5 Hz). 5Hz, and under are well in the range of infrasound. We claim that increase in the infrasound does not increase environmental impact. From 5 to 7Hz, TPS emits about the same amount of energy as airguns. Above 7Hz TPS emits significantly less energy than Airguns. By significantly we mean factor of more than 30!

Marine Vibroseis sources have lower SPL and lower slope than TPS, but longer duration and higher duty cycle. TPS is therefore in between Air Guns and Marine Vibes (Figure 4).

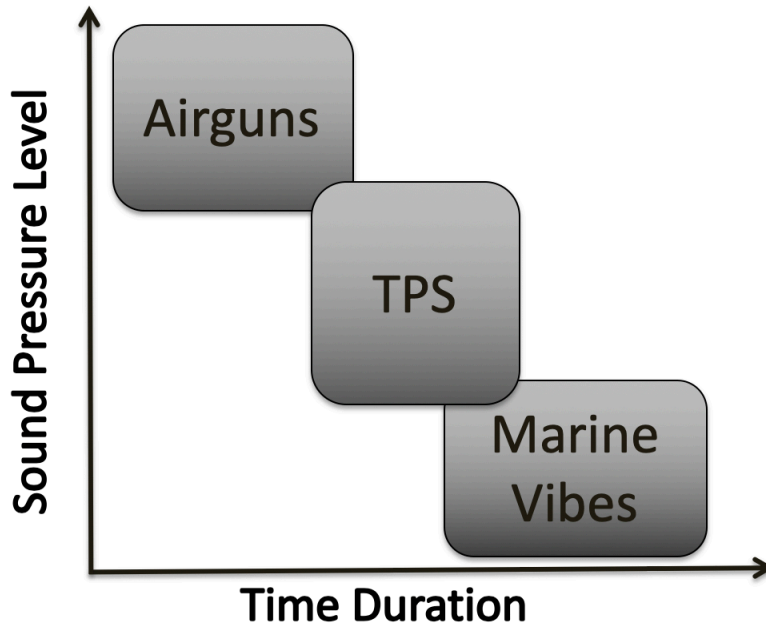


Figure 4. The TPS has lower SPL than Airguns and lower time duration than Marine Vibes.

Airguns use the first pulse as the signal generator. The TPS makes more use of the bubble pulses and radiates its acoustic energy over a longer time. Not as long as Marine Vibes, but longer than Airguns.

SOURCE SIZE AND LOW FREQUENCY CONTENT

Environmental impact of seismic sources should not be measured in source volume. For example, let us calculate the volume of a marine vibe which has a cylindrical shape with a radius of 3 feet and a length of 12 feet. The volume of such a cylinder is almost 60 thousand cubic inches. Yet, if it emits waves only as infrasound, such a large source will not have any environmental impact.

Similarly, the impact of musical instruments on our ear drums is not proportional to their size (Figure 5). 30 violins may have the same volume as on bass, but 30 violins playing together have a higher impact on our ear drums. If there was an ultra-low bass whose frequency we can't hear, that is below 20 Hz, then it would not have any impact on us no matter how large it must be to emit less than 20 Hz audio.



Figure 5. Musical instruments' size is associated with their size. To achieve low frequency, they must be big. However, their volume does not mean that their impact is larger. The volume of one bass may be the same as the volume of 30 violins. Will the environmental impact of one bass be the same as the environmental impact of 30 violins playing at the same time?

FREQUENCY CONTENT AND ENVIRONMENTAL IMPACT

If we listen to an audio sinusoid at 200 Hz, and the to an audio sinusoid at 2 kHz we can then feel their different environmental impact (Figure 6).

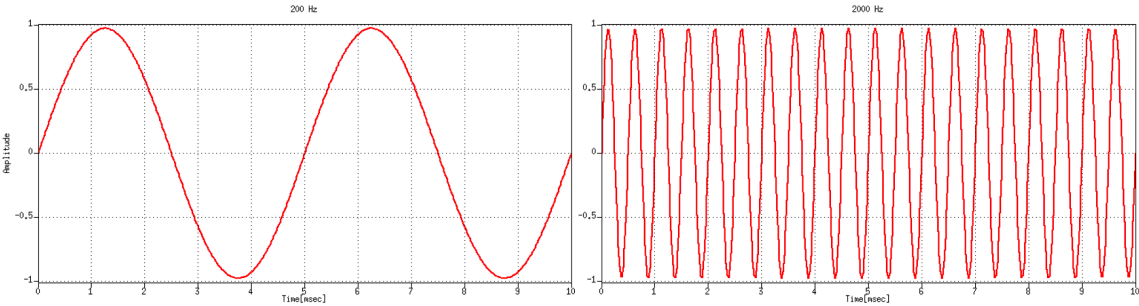


Figure 6. <http://seismicsources.com/sine200hz.wav> vs <http://seismicsources.com/sine2000hz.wav> on the right. The two sinusoids have the same amplitude but the 2 kHz frequency sinusoid has tens time the slope, ten times the acceleration, and ten times the force on our ear drums.

DATA FROM LAKE TESTING

Testing of TPS with small firing chambers in a quarry in New Hampshire (Figure 7) shows that the time it takes for the pressure to reach the first peak (the “rise-time”) is longer with increasing volume. Shorter rise time means more high frequency content which puts less energy in infrasound and more into sound. More significant than the rise-time is the slope. The slope is how much the pressure changes in a certain time. The slope is the most important factor for environmental impact because the acceleration associated with acoustic waves is proportional to the slope. The proportion factor is the acoustic impedance of water. For example, if the pressure of an acoustic wave changes by one Bar in one millisecond, the associated acceleration is 6.7 g where g is the earth gravity acceleration. Acceleration (in g) is used to measure impact on equipment, pilots, passengers, and all creatures great and small.

An alternative explanation for why slope is important is pressure changes experienced by divers (in water) or by people in airplanes and elevators. If the pressure changes happen too fast for equalization they are damaging. For divers, one Bar is the change in ambient ocean pressure over a depth of 10 meters. One Bar per millisecond is like diving 10 meters in a millisecond. This can never happen because it is supersonic. But it might be useful to note that if a whale descends or ascends 10 meters a second, it experiences a slope of one millibar per millisecond.

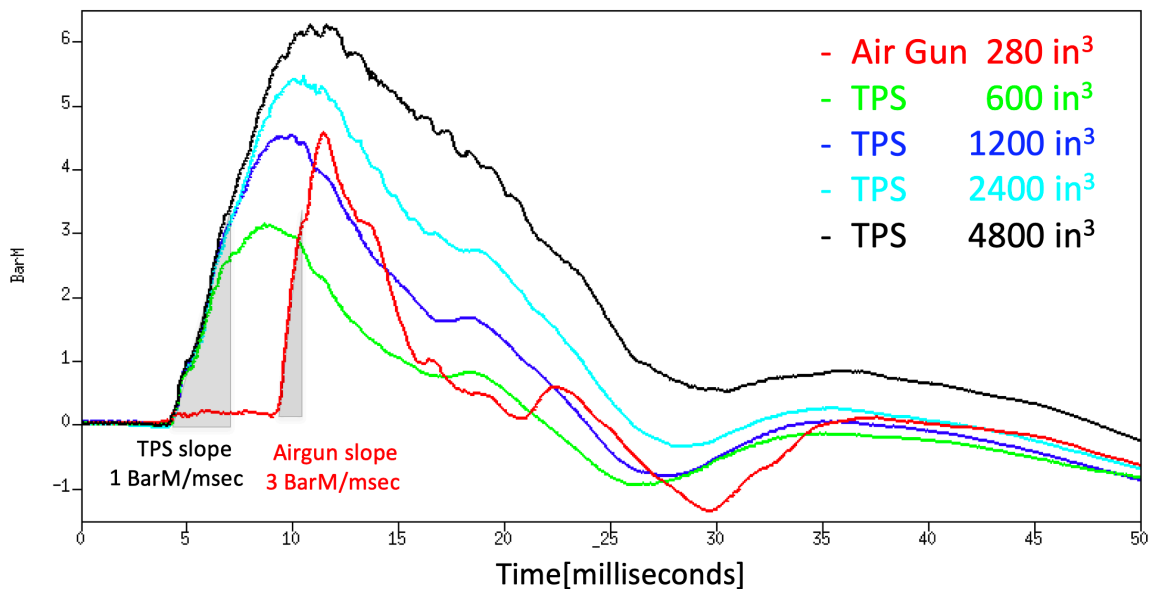


Figure 7. Time domain comparison of a conventional Airgun (red) to TPS with different volumes. The slope of all TPS is 1 Bar/msec regardless of volume. The slope of the airgun is 3 BarM/msec.

We tested TPS in a lake (High Test Virginia) up to 20600 cubic inches. We overlay the signatures in the time (Figure 8) and the frequency (Figure 9) domains.

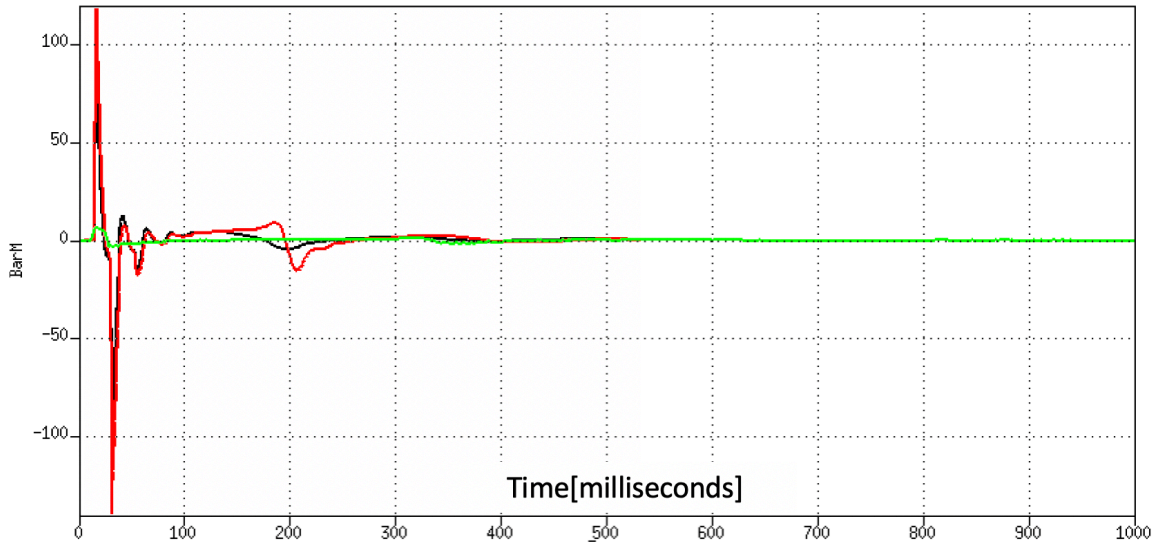


Figure 8. Time domain comparison of TPS (green) to a conventional airgun array (in black) and to an enhanced airgun array (in red). The TPS has lower SPL, lower slope, less sound and ultrasound energy than airguns.

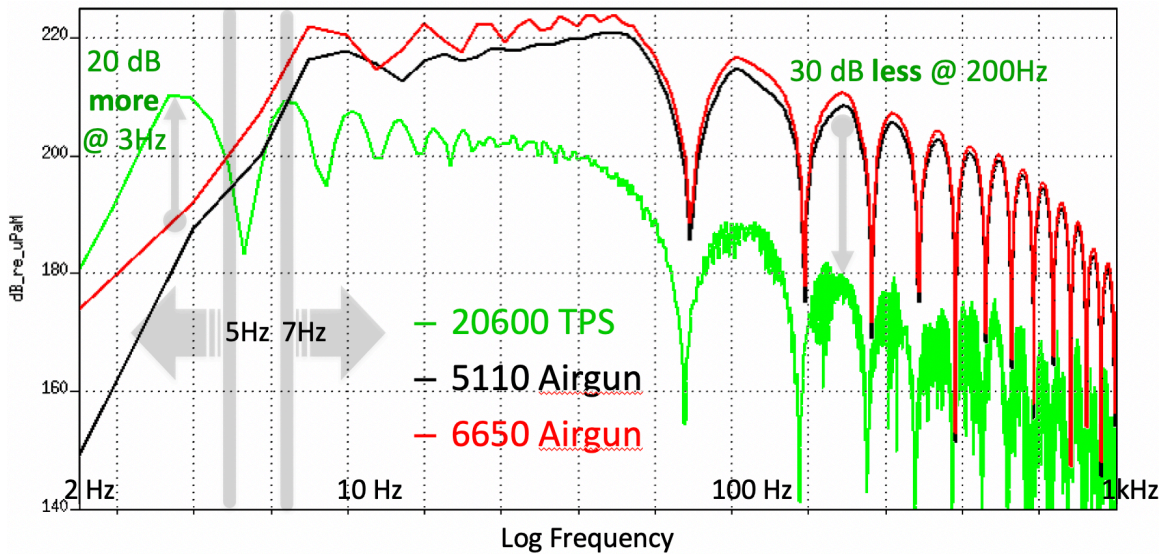


Figure 9. Frequency domain (spectral) comparison of TPS (green) to a conventional airgun array (in black) and to an enhanced airgun array (in red). The TPS generates much less infrasound energy above 7 Hz. 30 dB happens to be a factor of about 31.6. 20 dB is a factor of exactly 10. Infrasound for humans is below 20 Hz. For a creature than can hear lower frequencies down to 7 Hz, infrasound is below 7 Hz.

Table 1 compares the main features derived from the data. Time domain features are that TPS has lower SPL by a factor of about 20, lower slope and lower acceleration by a factor of 100 than airguns. Frequency domain features are that the TPS emits less sound and ultrasound energy than airguns but more infrasound energy below 5 Hz.

Source	5110	6650	TPS	Units
Volume	5.1	6.7	20.6	K in3
Pressure	2	2.5	1	K PSI
P2P SPL	200	250	11	BarM
Slope	75	100	1	BarM/msec
Acceleration	5	7	0.07	g at 100m
Infrasound	0	+10	+32	dB
Sound	0	+2	-20	dB
Ultrasound	0	+	-	dB

Table 1. SPL is Sound Pressure Level. P2P is peak to peak which is the maximal swing in pressure. For example, 100 meters under a 250 BarM source, the pressure swing would be 2.5 Bars. The slope is given in units of BarM per msec and is proportional to acceleration. 100 meters under the 100 BarM/msec the acceleration would be 6.7g. 100 meters under the TPS, the acceleration would be 0.067g.

ENVIRONMENTAL IMPACT OF INCREASED INFRASOUND

While the direct impact of infrasound on creatures may be an area of biological research, the indirect environmental impact of better seismic data is well known. To the oil industry, increased infrasound provides better seismic data. Better seismic data leads to better information which reduces the environmental impact of the oil industry because it reduces drilling in general and the risk of drilling into formation with unexpected high pressure in particular.

SUMMARY

There is a pressing need to improve existing marine seismic source technology in order to meet the dual goals of improved low frequency content for imaging more challenging targets and to reduce the high frequency noise to minimize the environmental impact of active seismic surveys. Based on lake data, we expect the Tuned Pulse Source to answer this pressing need. In addition to the direct benefit of lower environmental impact than airguns, the TPS will provide higher quality geophysical data that will reduce the cost of energy to the economy and mitigate the risk from hazards associated with more drilling into formations with not very well-known pore-pressure.

We seek a permit to take TPS offshore on sea trials with a volume of 26.5 thousand cubic inches. The TPS we seek to test offshore will release less energy per minute than a large airgun array. Moreover, this energy will be released as infrasound and generate acceleration that is 100 times less than a large array of airguns.