TGT

# ChorusX Ingredients

ChorusX is the sum of many parts that work in concert to deliver a range of important benefits to analysts and customers. Each ingredient is special in its own way, but the big gains occur when they are multiplied together.

## 8x Array sensors

**Eight nano-tuned sensors amplify the power of acoustics.**

Sensor arrays have delivered value across a wide range of measurement types and applications in many sectors. The multi-sensor array of nano-synchronised, high-sensitivity, calibrated sensors and data channels found in ChorusX underpins many of the new features and benefits delivered by this powerful diagnostic technology.

For example, the sensor array technology and associated processing are fundamental to the phase-shift computations and the new, high-precision flow answers provided by ChorusX.

Also, the simultaneous acquisition of high-resolution data from eight sensors brings significant efficiency, data density and redundancy gains compared with single-sensor platforms. This is particularly important in long horizontal or vertical well sections where intervals can be surveyed with greater ease, precision and data density. Two ChorusX tools can be combined, giving a total of 16 sensors, to achieve even greater efficiency gains.

In contrast to single-sensor technology, the multi-sensor arrangement means that ChorusX offers built-in redundancy. Phase measurements can be completed with as few as four operational sensors, and the power spectrum display will not be compromised by a single sensor failure.

## 3x Higher resolution

**30 cm precision takes clarity to a whole new level.**

Resolution is a crucial aspect of acoustic-based diagnostics and drives features such as accuracy, precision and visual clarity. These ultimately lead to clearer answers and better decisions.

The eight ChorusX sensors are spaced 30 cm apart. This provides a much higher-resolution measurement and a higher-density acoustic power spectrum than does single-sensor technology, which typically offers resolutions in the range 80–100 cm. This threefold improvement in resolution feeds through to the principal ChorusX outputs: the Acoustic Phase Map, the Acoustic Radial Map and, especially, the Acoustic Power Spectrum.

The ChorusX Acoustic Power Spectrum offers markedly higher-density, clearer and richer visual expression over a wider range of dynamic frequencies and amplitudes. This makes it easier to locate and characterise flow events, and even low-energy flows are visualised with greater clarity and precision.

The Acoustic Radial Map not only gives a clear radial indication of flow location, but can also pinpoint the depth of the flow event more accurately and precisely than the acoustic power spectrum.

The higher-resolution performance of ChorusX improves the delineation and mapping of active flow zones and flow points. This enables well operators to pinpoint flows such as leaks with greater precision and to discriminate between multiple flows that are in close proximity to each other, such as adjacent fractures or adjoining leak points in complex completions.

## 28x Phase measurements

**Breakthrough acoustic modelling leaves analysts unphased**

Acoustic phase modelling and processing, and phase-shift calculations are crucial enablers for the capabilities and benefits of ChorusX. This sophisticated methodology was developed by TGT and represents a significant advancement in acoustic science and the application of acoustics to well system flow diagnostics.

The combination of normalised, nano-synchronised, calibrated sensors and channels with acoustic field modelling enables the phase shift calculations. These calculations are the basis for two new principal answers from ChorusX: the Acoustic Phase Map and the Acoustic Radial Map.

The sensor measurements are synchronised to within 10 nanoseconds of each other, which enables a phase measurement accuracy of 10 milliseconds. There are 28 phase shift measurement permutations that determine the phase difference between acoustic signals received at 28 different combinations of sequential receivers.

The phase calculations are fundamental to the near–far proximity indicator and are displayed in the Acoustic Phase Map. The signature of the phase map as it switches from a negative to a positive shift provides additional verification of the active flow zone. The shape of the phase transition curve can be used to infer the type of flow, either localised or distributed. A sharp transition indicates a single localised flow such as a point leak, single fault or fracture, whereas a gradual transition indicates a distributed flow zone such as reservoir matrix flow.

## 2x Wider frequency range

**Wider frequency, richer sounds, sharper analysis.**

Frequency is an important characteristic of acoustic signals. Flows within the well system generate sound waves with frequencies ranging from a few hertz to more than 100 kHz. The frequency content of these waves is influenced by factors such as fluid type, pressure and fluid pathway. Analysts use frequency data to characterise the flow and its source. The acoustic recording systems used for well diagnostics must be able to record and display sound accurately and with uncompromised fidelity across a wideband frequency range.

The ChorusX recording system combines high-resolution sensors with eight wideband data channels and two low-frequency channels to capture flow-generated sound from 7 Hz to 120 kHz. This enables analysts to characterise flow and fluid type across a wide range of scenarios. In gas reservoirs, for example, the flow of gas through small pores often generates higher-frequency sounds than those caused by other fluids, whereas ‘near’ leaks in the completion usually have low-frequency sound signatures.

When displayed in the enhanced acoustic power spectrum, the extended frequency content captured by ChorusX facilitates advanced analysis and opens up the potential for new applications that are currently under development.

## 10x Extended dynamic range

**Recording the loudest flows, and the quietest.**

The sound waves generated by well system fluid flows vary across a wide range of amplitudes and carry vital information about the flow type and its source.

Low-energy, 'quiet' sounds within the well system, such as those from flows in its outer reaches, are challenging to detect and record accurately. Background noise can mask signals and louder, high-energy sounds can saturate inferior recording systems, creating distortion and inaccuracies in the data. Failure to record or display the sound accurately could result in crucial information being missed. Low-energy flows and leaks that could potentially undermine the integrity and performance of the well system could go entirely unnoticed. Consequently, acoustic systems used for well diagnostics must be able to capture and display sound accurately across a wide dynamic range of amplitudes and frequencies, without distortion.

Chorus technology provides outstanding fidelity and precision in sound reproduction, recording and displaying well system flow sounds both clearly and accurately. With a wider dynamic range, improved sampling and analogue-to-digital conversion, and high-definition recording modes, ChorusX takes the capability even further.

The dynamic range has been extended from 100 dB to 110 dB, representing a ten-fold improvement in sensitivity. This has been achieved by improving the dynamic recording range at the low energy end of the spectrum, thereby enhancing the detection of lower-energy flows. This extends the dynamic reach of Chorus diagnostics, both in terms of flow intensity and distance, to ensure a more complete assessment of flow dynamics in the well.

The breakthrough was achieved by lowering the noise floor of the acoustic sensors and A2D circuitry from 65 dB to 55 dB. The noise floor is the lower limit below which useful acoustic signals cannot be recorded by the system. With a quieter 55 dB noise floor, ChorusX can record and display a wider range of flows with greater clarity.

## 2x Radial proximity

**Near versus far takes analysis further.**

Flow-generated sound can travel long distances in and around the well, and through all well system media (steel, cement, fluids and rock), which makes it ideal for through-barrier diagnostics. Locating the precise depth of active flow zones, flow points and flow paths is possible with high-resolution sensing, but determining the radial distance of flow sources from the wellbore has long been a challenge for analysts. But not any more.

Until now, analysts have used single-sensor acoustics combined with other methods to locate flow sources radially and to distinguish between well completion flows and reservoir flows. This traditional approach has often led to uncertainties and inefficiencies in the interpretation and decision-making process.

ChorusX overcomes this challenge with its breakthrough Acoustic Radial Map and near-far index. By applying a unique and sophisticated phase-shift processing method, the radial map gives a clear indication of near versus far flow sources and a confidence level for the assessment.

This new approach makes identifying and locating the source of a flow much easier and more precise. ChorusX combines an exact depth with a radial proximity value to locate the flow with much greater accuracy than previously possible. In addition to distinguishing between completion flow and reservoir flow, the radial map complements the phase map in determining whether the flow is localised or distributed, thereby bringing additional clarity and insight to the analysis.

The radial map is particularly useful when reservoir flow sources coincide with completion leaks or ports such as inflow control devices and analysts need to determine whether the reservoir zone beyond the port is contributing. With single-sensor technology it would be virtually impossible to determine reservoir flow from port flow at the same depth using acoustics alone. ChorusX can answer difficult questions such as whether a fracture immediately behind a flow port is contributing to the flow.

## 4x Answer products

**Four new answers transform the professional workflow.**

Diagnosing and understanding the flow dynamics in a well system requires a sophisticated mix of measurements and modelling. There are many variables to consider and, as in mathematics, unknowns must be solved to deliver a confident answer.

Building on established Chorus Acoustic Power Spectrum technology, ChorusX provides four new outputs that combine to help analysts resolve even the most complex flow scenarios downhole.

The new high-definition Acoustic Power Spectrum brings 3× the resolution, 4× the data density per station and enhanced visual clarity across a wider range of frequencies and sound amplitudes when compared with previous-generation technology. Flow activity is more clearly seen, flow characteristics more easily resolved, and low-energy flow sounds more readily captured and displayed thanks to ChorusX sensitivity improvements.

ChorusX also provides two new principal and complementary outputs: the Acoustic Phase Map and the Acoustic Radial Map. The phase map displays the results of advanced phase shift modelling, processing and measurements, indicating the depth of active flow zones and helping to identify whether flow is localised or distributed. When used with other outputs, such as temperature and the radial map, the phase map can help to identify and locate fractures and distinguish between matrix flow and localised fracture flow.

The radial map represents a substantial breakthrough in locating flow sources in the radial dimension, specifically indicating whether the flow source is ‘near’ or ‘far’ from the wellbore. Near sources relate to completion flows such as tubing leaks, ICD port flows and cemented annulus flow, whereas far sources represent reservoir, matrix or fracture flows. This powerful, radial distance identifying capability significantly improves diagnostic efficiency and the certainty of answers.

The fourth new answer product, the Sound Speed Log, is secondary to the other three in that it provides a qualitative indicator of fluid type in the wellbore to further clarify the dynamic fluid characteristics of the well system. Other measurement systems can provide more accurate fluid-type information, but the Sound Speed Log provides useful validation or an alternative in cases in where other measurements are compromised, for example, in horizontal wells.

## 3x More efficient

**Overall qualitative efficiency improvement**

ChorusX can help improve efficiency at all stages of the workflow, from surveying the well system through to implementing an action plan.

During the survey phase, ChorusX can deliver increased data density, reduced survey time or a combination of both. ChorusX stations can be 2 m apart, compared to the 1 m separation limit for single-sensor technology. Therefore, compared to single-sensor technology with stations an assumed 1 m apart, the ChorusX 8-sensor array spaced across 2 m can deliver four times the data at twice the survey speed. Multiple single-sensor tools can be combined to widen station intervals or improve survey efficiency but will not deliver the same resolution or answers as ChorusX.

During analysis, ChorusX delivers a range of clear, complementary answers that enable analysts to reach a more accurate interpretation more efficiently. A more robust and accurate picture of the well system enables better decisions and more effective and positive outcomes. This means that, when remediation plans are being implemented, there is a greater prospect of first-time success.