Noise logging

Noise logging is an inexpensive way to investigate whether there is channeling in injection or production wells.

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Noise logging tool

The noise-logging tool "listens" passively to downhole noise, for example, from gas bubbling up through liquid in the wellbore. Behind pipe, a channeling flow often passes through cramped spaces and constrictions. These "tight spots" cause high velocities, sudden pressure reductions, and significant flow turbulence. The noise tool listens to the noise associated with the turbulence.

The tool includes piezoelectric crystals (transducers) which convert the oscillating pressure of wellbore sound to a corresponding oscillating voltage. At the surface, the oscillating voltage is applied to a speaker, permitting the logging operator to hear the downhole sound. The oscillating voltage also is applied to each of four high pass filters. A high pass filter is unresponsive to frequency components of the oscillating voltage that are below the filter's "cutoff" frequency, while it generates an oscillating output signal whose amplitude represents the content of the oscillating voltage of frequencies in excess of the cutoff. The cutoff frequencies most often used are 200, 600, 1,000, and 2,000 Hz.

Measurement procedures

For quality measurements, the operator stops the tool at a selected depth and waits for extraneous noise, such as the noise generated by tool and logging-cable movement, to subside. Hurrying contaminates the measurements with extraneous noise. Then, a recording system averages and records the amplitude of each filter's oscillating output signal. Subsequently, the tool is moved to a new measurement depth; after waiting for the extraneous noise to subside, the operator initiates the averaging and recording of the amplitudes at the new depth. Thus, four values are recorded for each measurement depth. These are plotted in millivolts across the chart at a measurement depth. The amplitude of the 200-Hz filter output is the greatest; as the cutoff frequency increases, the amplitude correspondingly decreases, with the amplitude of the 2,000-Hz filter output being the least. To form a log, the plotted 200-Hz amplitudes are joined by line segments between successive measurement depths, as are the amplitudes for 600, 1000, and 2,000 Hz.

Because a filter's output signal is oscillatory, it consists of positive excursions from neutral alternating with negative excursions. There are two ways of measuring the amplitude of the output. One measures the amplitude from the peak of a positive excursion to the trough of the following negative excursion. The resulting amplitude is known as "peak to peak," and the recording is characterized as "standard gain" or "standard sensitivity." The other amplitude measurement is from the peak of a positive excursion to neutral, with the amplitude being characterized as "peak" and the recording sensitivity as "one-half standard gain." Other measures are sometimes used.

A single-station measurement typically lasts 3 to 4 minutes. Relocating the tool usually requires 1 minute. Thus, the logging rate is approximately 15 stations per hour. A 4-hour logging run accommodates 60 measurements. Thirty of these are used for a coarse-measurement grid, with successive measurements separated by one-thirtieth of the total survey interval. The remaining 30 measurements are used for detailing areas of interest, such as a noise peak identified by the coarse grid, a gas/liquid interface in the wellbore, a plug, or a packer. For detailing, the separation between successive measurements can be as little as 1 to 3 ft.

Fig. 1 shows the "dead-well" response recorded at one-half standard gain in a shut-in injection well. As expected, the 200-Hz amplitude is greatest, and the amplitudes progressively decrease as the frequency increases. Notice that the trace for one frequency never crosses the trace for another frequency. If such crossings occur, the log is faulty. If a dead-well response does not appear at all, the log is suspect. The figure is illustrative, and the amplitudes of the dead-well response in other wells may vary from those shown.

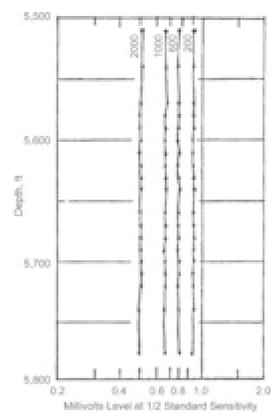

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Fig. 1 – Shut-in injection well.

The cutoff frequencies were carefully determined from laboratory measurements. The 200-Hz cutoff rejects most logging-truck vibrations transmitted through the logging cable, while it is low enough to identify gas bubbling up through liquid. The 1,000-Hz cutoff permits identification of single-phase flow, the strongest frequencies of which occur at 1,000 Hz or higher. The determination of whether behind-pipe flow is single-phase or gas-through-liquid is facilitated by the 600- and 2,000-Hz cutoffs.

One service company uses software processing that implements four different *high*-cutoff frequencies with the same *low*-frequency cutoff of 100 Hz in all four instances. Thus, the computed amplitudes pertain to the frequency "bands" between 100 Hz and each of the high-cutoff frequencies. One difficulty is that the lower-frequency components of the sound, whatever their origin, have amplitudes more variable with time than those of the higher frequencies. Also, extraneous noise sources tend to be more intense at the lower frequencies. The result is that each of the bandpass amplitudes can be contaminated by the variable amplitudes and the extraneous sources.

Noise can travel appreciable distances to the noise tool, both vertically and horizontally. The user must be sure that all extraneous noise from surface operations (with the exception of logging-truck vibrations) and flow in nearby wells is eliminated, so that the only noise recorded is that associated with the suspected well problem.

Fig. 2 pertains to a 20-B/D water flow behind pipe into a depleted gas zone. Only one noise peak occurs, corresponding to a single "tight spot" between the water sand and the gas sand. Almost 30 measurement stations were used. Farthest away from the peak, the spacing between measurements was greatest. Closer to the peak, the spacing was reduced. The measurements were densest in the locality of the peak for best detailing of the peak itself. The single-phase nature of the behind-pipe flow is evident from the "bunching" of the 200-, 600-, and 1,000-Hz traces at the peak. Gas-through-liquid flow would separate the 200- and 600-Hz traces, in addition to the separation of the 1,000- and 2,000-Hz traces.

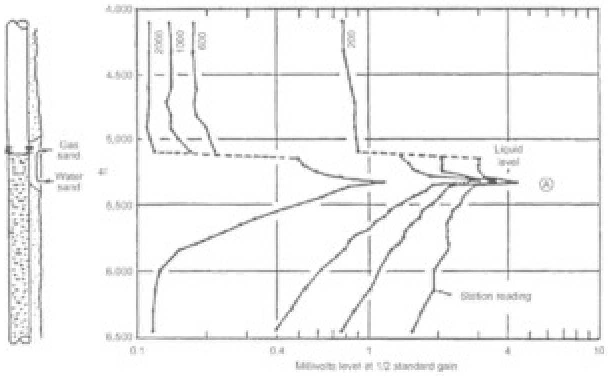

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Fig. 2 – Noise log format with a 20-B/D water flow behind pipe into a gas zone depleted by 250 psi.

Because there is no noise peak at the water or gas sand, the entry and exit of flow to and from the channel occur in absence of a tight spot at either sand. With the known 250-psi pressure drop between the sands confined to a single constriction, it is possible to estimate the flow rate of the channeling water from the pressure drop and the level of the 1,000-Hz trace at the peak (twice the level shown on the log, which was recorded at half-standard gain), yielding the 20-B/D rate. The rate equations are discussed in the appendix. If there were multiple tight spots, the estimate could still be made based upon total pressure drop and upon the sum of all the peak 1,000-Hz noise levels.

Above the gas/water interface in the wellbore, all four traces in **Fig. 2** decline rapidly to dead-well response because of two attenuating factors. First, much of the sound reflects downward at the interface itself. Second, the tool sensor is constructed for coupling to liquid rather than to gas. In the water below the interface, only the 2,000-Hz trace, which attenuates the most rapidly with distance, reaches dead-well level. Because the water transmits sound at much less attenuation with distance than the gas, the 2,000-Hz trace requires almost 700 ft to reach the dead-well level in the water. In the gas, the dead-well level is reached in considerably less distance. In the water, the other traces show typical noise behavior; the attenuation with distance is least for the 200-Hz trace and increases with increasing frequency. In a production or injection well, it is not unusual to find a gas/liquid interface.

Noteworthy papers in OnePetro

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Stein, N., Kelly, J., Baldwin, W.F. et al. 1972. Sand Production Determined from Noise Measurements. *J Pet Technol* **24**

(7): 803-806. SPE-3498-PA. http://dx.doi.org/10.2118/3498-PA (http://dx.doi.org/10.2118/3498-PA)

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