9 Noise Logging

Noise logging is applicable whenever fluid flow, either in the borehole or in the casing formation annulus, produces a detectable noise. Detection is by means of a microphone suspended in the well. Experience teaches that analysis of noise is a refined technique for deducing the source of the noise. Student life in the low-rent district is enough to turn even the untrained ear into a veritable Sherlock Holmes, distinguishing the characteristic sounds of flushing toilets from draining bath tubs. The human ear and brain perform this function well by making an amplitude-frequency analysis of the total audible spectrum. Tools for well-flow analysis have to perform a similar function in order to earn their keep. Only by this kind of frequency analysis can the hiss of gas be distinguished from the gurgle of liquids.

Tools Available

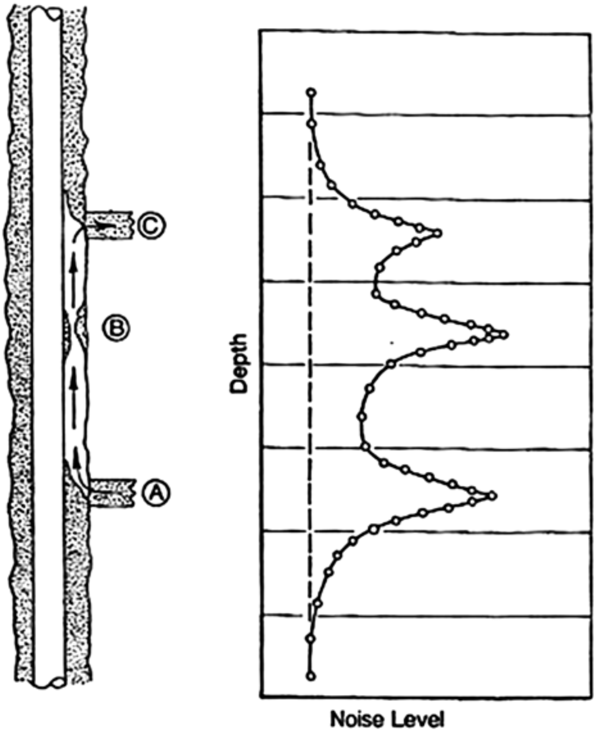
Many service companies offer noise logging service, under a number of trade names such as:

- Sonan Log
- Audio Log
- Borehole Audio Tracer Survey (BATS)
- Noise Log
- Borehole Sound Survey

In general, measurements are made at preselected stations in the well. At each station, the amplitude of the noise in a number of frequency bands is determined and plotted on the log. Subsequently, these individual station readings may be joined together by straight lines to give the appearance of a continuous log. Figure 9.1 illustrates such a log. The total noise amplitude is generated by flow from formation A via the casing/formation annulus to formation C. Note the increase in noise at restriction B.

R.M. Bateman, *Cased-Hole Log Analysis and Reservoir Performance Monitoring*,
DOI 10.1007/978-1-4939-2068-6_9

Fig. 9.1 Noise log



Operating Principle

Through controlled experiments it is possible to derive noise amplitude-frequency spectra that are characteristic of fluid flow regimes. For example, Fig. 9.2 shows the spectrum for 70 BWPD expanding across a 90 psi differential into a channel behind the pipe. Note that the majority of the noise energy is concentrated in the frequency range from 800 to 2,000 Hz.

By contrast, Fig. 9.3 shows the spectrum for sound emanating from 3.8 Mcf/D of gas expanding across a pressure differential of 10 psi into a gas-filled channel behind the pipe. Note the two peaks at 800 and 1,800 Hz.

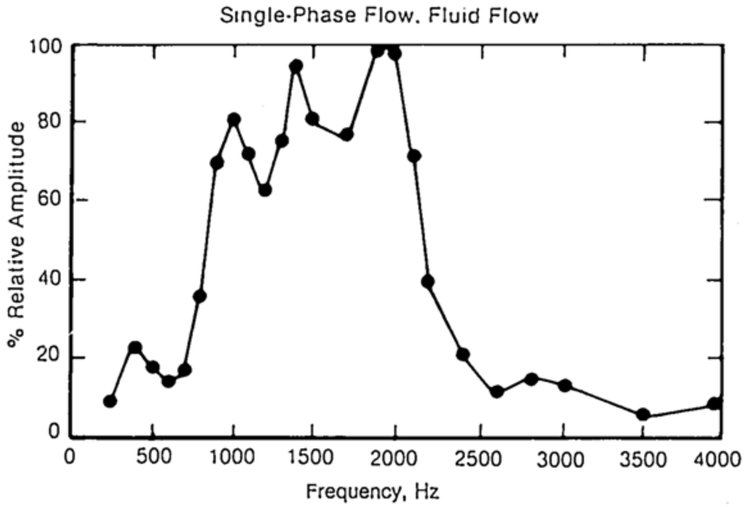


Fig. 9.2 Noise generated from a 70 BWPD flow into a channel behind pipe. Courtesy Baker Hughes

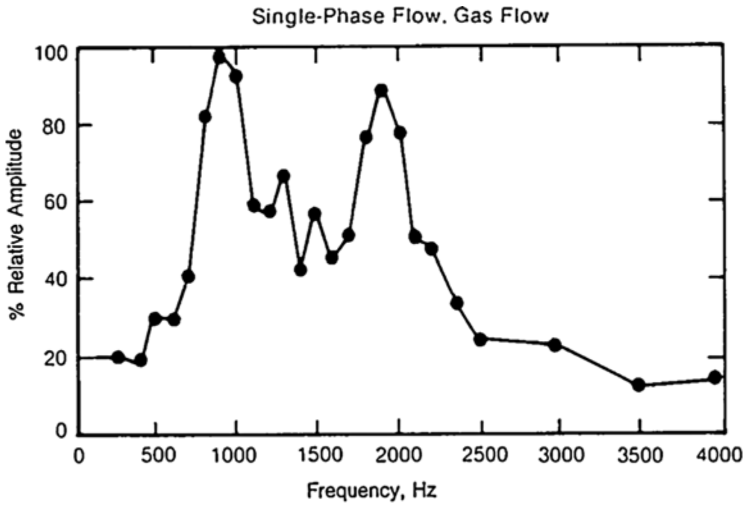


Fig. 9.3 Noise spectrum for single-phase gas flow. Courtesy Baker Hughes

Figure 9.4 shows a very different spectrum, obtained when 0.3 Mcf/D of gas expands into a water-filled channel. Here the peak noise is at less than 500 Hz.

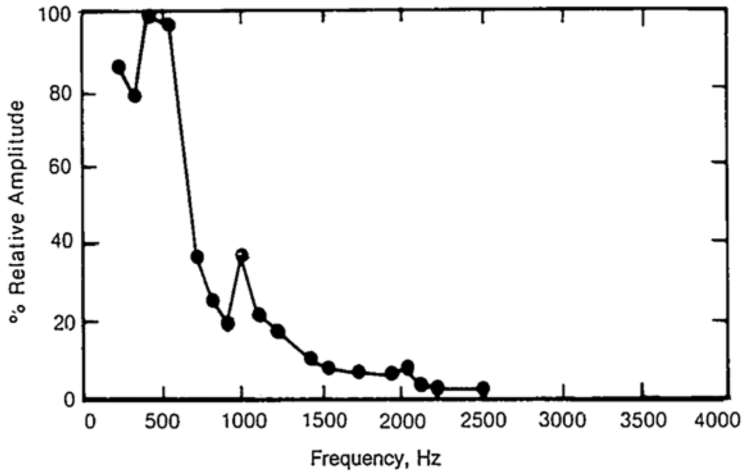


Fig. 9.4 Noise spectrum for two-phase flow (gas/water). Courtesy Baker Hughes

In order to distinguish these spectra from one another, the total signal is filtered through band-pass filters that allow the frequencies ≥200+, ≥600+, ≥1,000+, and ≥2,000+ Hz to pass. The choice of limits on these bands varies somewhat between different service companies. Since the 200-Hz filter allows all frequencies above 200 Hz to pass, this filter normally gives the highest amplitude. The 2,000-Hz filter, which only allows frequencies above 2,000 Hz to pass, normally gives the lowest amplitude. Figure 9.5 illustrates the band-pass filter response.

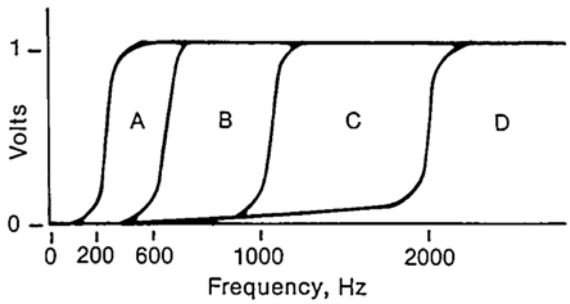


Fig. 9.5 Filter response in noise logging. Courtesy Baker Atlas

Interpretation

The interpretation of noise logs is an empirical art governed by common sense and a body of experimental data. In general, the noise level in the low-frequency bands correlates fairly well with a normalized gas flow rate, the normalization factor depending on the pressure drop. Figure 9.6 shows such a correlation.

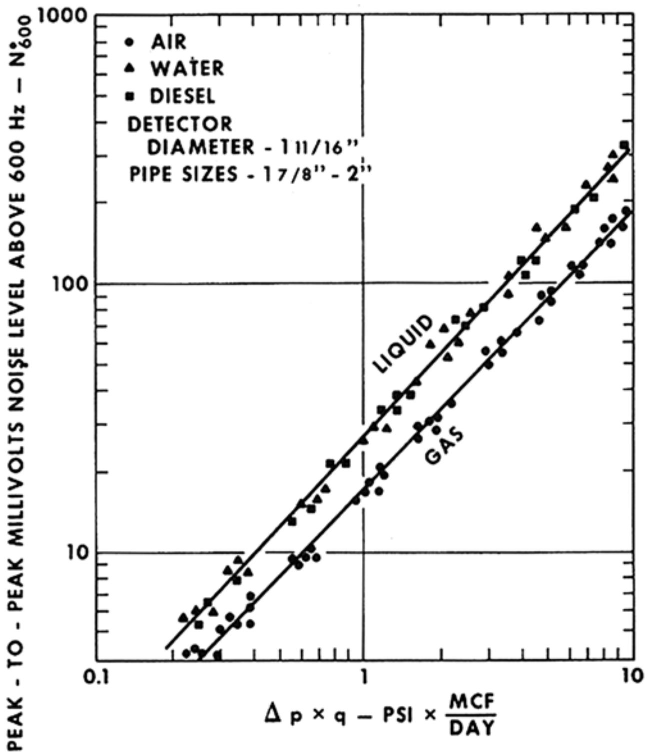


Fig. 9.6 Noise (N_{600}) vs. normalized flow rate for liquid and gas flow

In general experimental calibration of noise levels to flow rate shows that the related variables are:

- Fluid density
- Flow rate
- Pressure gradient
- Tool OD and Casing (or tubing) ID

For example the log shown in Fig. 9.7 records the noise level above the 600 Hz filter. The cube of the flow rate may be related to the recorded noise and inversely proportional to the density of the fluid flowing.

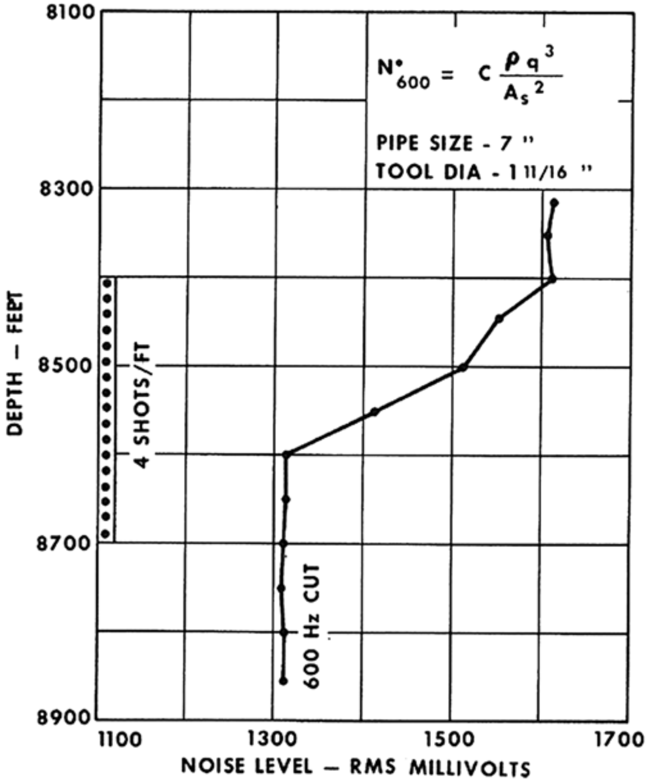


Fig. 9.7 Noise log over a gas producing interval

Sounds carry great distances in cased wells. Any surface noise should be eliminated before attempting a noise survey. Pump jacks, motors, etc., can generate noise unrelated to fluid flow in the well and confuse interpretation of noise logs. Two general rules apply:

1. Changes in noise level indicate a change in volumetric flow rate.
2. Changes in the relative noise levels in different frequency bands indicate changes in the phase make-up of the fluid mixture.

Noise and Temperature Combinations

Often a judicious combination of a noise log with a temperature survey can provide a superior analysis than could be obtained from either one singly. It is now possible to make accurate heat transfer models of the formations traversed by a well based on thermal conductivity and specific heat data and/or assumptions. When coupled with spectral noise analysis and/or flowmeter profiles obtained in the borehole a much more accurate and precise picture can be drawn of the flow of fluids into, out of, and around the cased well. Figure 9.8 illustrates a combination of noise and temperature logging where the challenge was to quantify the relative production from two perforated zones. Temperature logs were run both during production and after shut-in and warm-back was permitted. During the dynamic flow period a noise spectrum was also recorded as shown in the right-hand track. The color coded images show the noise amplitude (dB) by the colored band (red is loud, blue is quieter) across the track and the noise frequency distribution via position from the left edge of the track (100 Hz on the left, 30 kHz on the right).

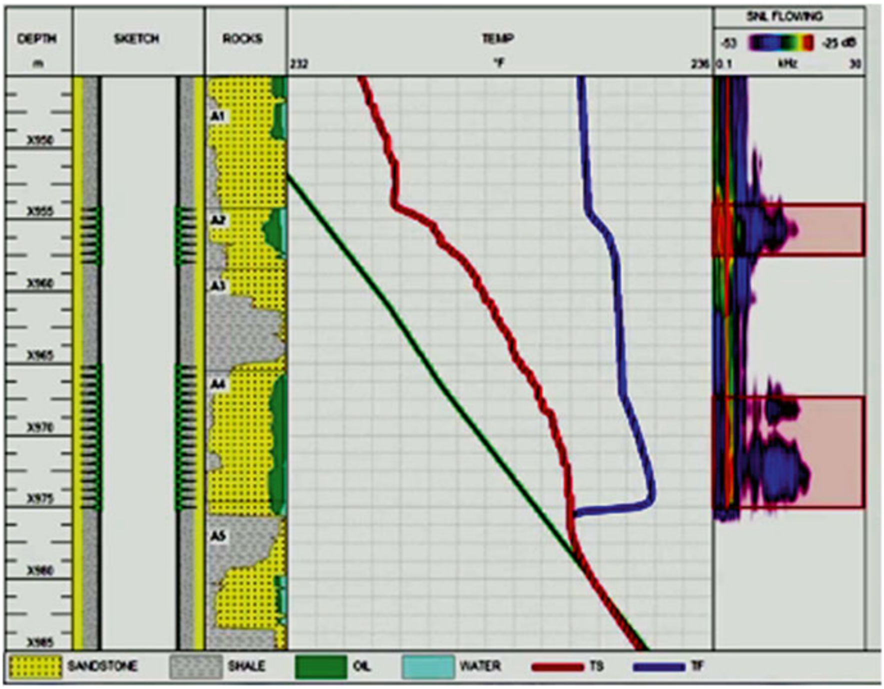


Fig. 9.8 Combination noise and temperature logs. Courtesy TGT

The green temperature line shows the geothermal gradient. The blue trace shows the flowing condition temperature distribution and the red trace the distribution after extended shut-in. Multiple computer modeling iterations can match expected profiles to the observed ones by varying the relative flow rates from the two producing intervals.

Noise and Flowmeter Combinations

Noise spectral analysis can also provide useful complementary data when analyzing flowmeter logs. An example is given in Fig. 9.9 where a fluid entry point in the well, as seen by the flowmeter alone, fails to detect that in fact flow from the formation is more extensive and that there is cross-flow behind pipe before it reaches the entry point in to the wellbore. The wellbore-noise, reservoir-matrix-noise, and the flow-through-perforation-noise can be nicely discriminated by the color coded frequency/amplitude track on the right-hand side of the figure. A possible explanation for such flow behavior could be plugged perforations. In such a case re-perforating the interval could well result in increased flow rate.

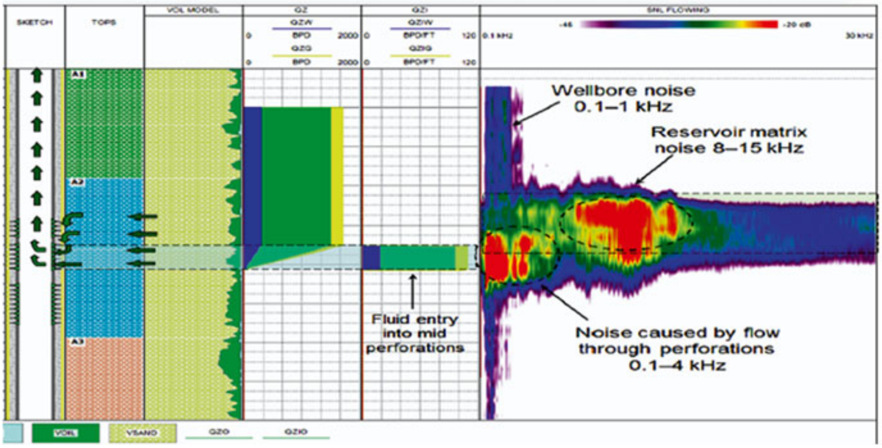


Fig. 9.9 Cross-flow detected by spinner and noise log. Courtesy TGT

Fiber Optic Sensors

The use of fiber optics to continuously measure temperature and sound energy along the entire completion string is covered in Chap. 14. Commonly referred to as *Distributed Audio System* (DAS) and *Distributed Temperature System* (DTS) these high tech permanent gauges open up an entirely new way of production monitoring.

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