

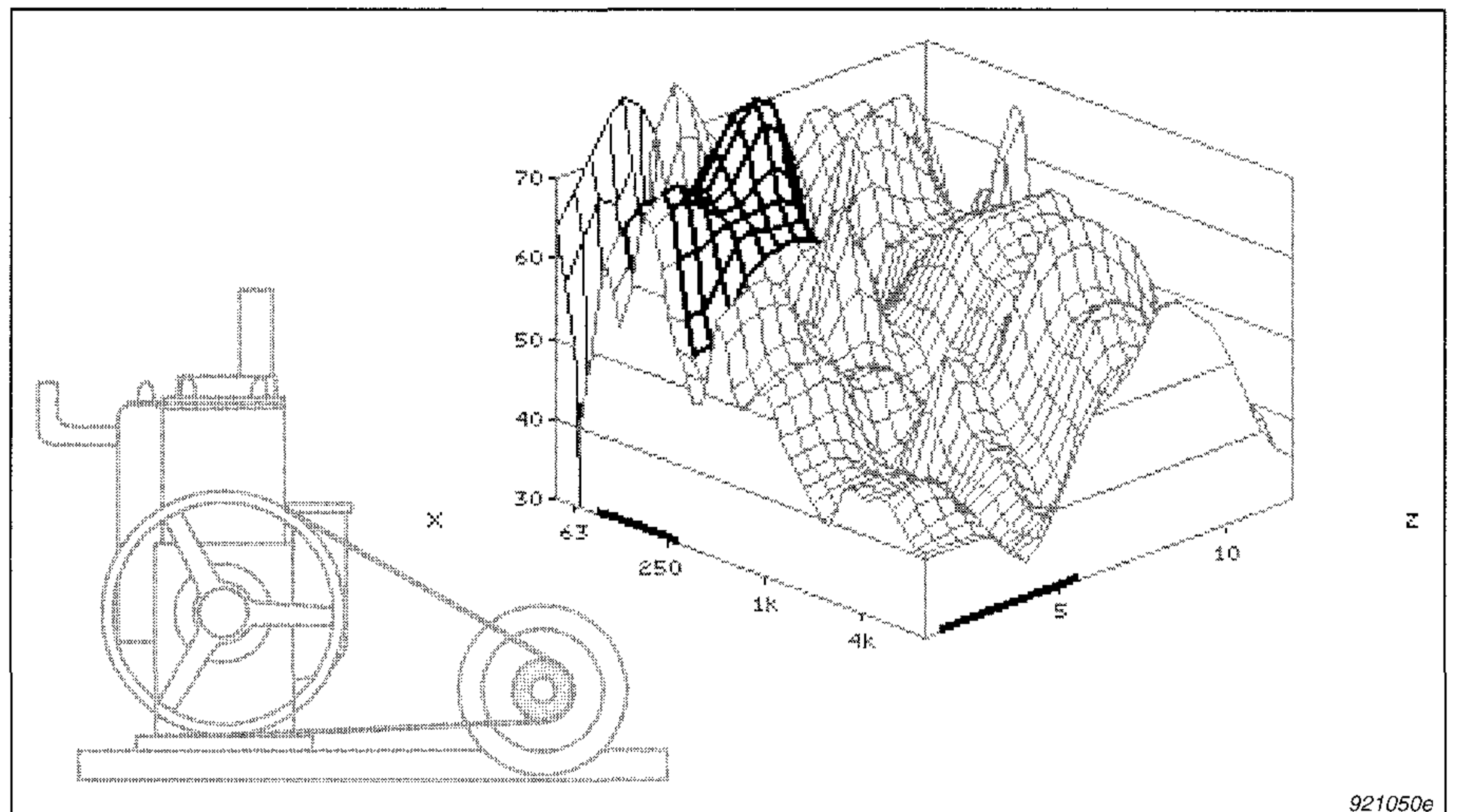
Application Note

Noise control survey on a pump using the gated technique

by K. B. Ginn

What is the gated technique?

When making noise control surveys on rotating machinery, one is often interested in parts of the rotational cycle and the noise events which occur during that part. By taking a trigger signal from a rotating part to initiate a measurement, the filters of the analyser start to respond and their outputs are detected at a specified number of "windows" or "gates" per revolution (Fig.1).



Introduction

The gated technique has been used successfully on machinery such as pumps, mixers and cement ovens. In the automotive industry in particular the gating technique has been used to test internal combustion engines, gear trains, etc. The technique can also be used for repetitive signals where frequency analysis as a function of time is required.

What are the benefits of the gated technique?

Gated measurements enable an event (noise, vibration etc.) related to a rotating part of a machine to be studied as a function of the angle of rotation. The quantity measured could be sound pressure, sound intensity, vibration level etc. In this application note, for example, gated intensity measurements enabled the relative sound power

radiated from a simple pump to be partitioned between the air intake and the air expulsion phases. From the source ranking of the noise generating processes in order of importance, modifications to the pump were proposed, implemented and rapidly evaluated by a further measurement.

What are the limitations of the gated technique?

As in all aspects of frequency analysis, consideration of the Bandwidth x Time product is of the utmost importance. For high rotational speeds, and for many windows, the effective averaging time will be very short for one rotation because the effective averaging time is equal to the window length. The BT product can be increased by performing the measurement over a large number of revolutions, thus im-

proving the statistical uncertainty in the measured amplitude.

Filter response time

Filters have a finite response time which is approximately equal to the reciprocal of the bandwidth. The output of the filter may or may not occur during the same measurement window in which the event occurred. For low frequencies the response of the filter will usually lag behind and will occur in some later window. The lower the frequency, the greater this lag will be. In other words, one must be careful in the interpretation of landscape plots of frequency, amplitude and window number as some of the events at lower frequencies may appear later than they actually are.

Nomogram for gated measurements

The parameters which have most influence on the validity of the results are:

1. Bandwidth of analysis
2. Frequency range
3. Averaging time
4. Number of windows
5. Speed of rotation of the machine.

The relationship between the first three parameters is well known. Some analysers have a "Warning Line" on the screen which indicates the frequency bands where the required BT product is not fulfilled, based on the assumption that the signal is wide band noise.

The relationship between the number of windows, speed of rotation of the machine and frequency range depends on the type of filter used in the analysis and whether one or two channels (i.e. detectors) of the analyser are used. A nomogram with these relationships for the third octave filters used in this investigation is given as an appendix. Similar nomograms exist for other filter types available in the analyser.

Measurements on a pump

The simple, single cylinder pump under test was driven by an electric motor connected to the pump's fly wheel by a belt. There were two main stages of the operating cycle, each with a distinctive noise associated with it. For the first half cycle of rotation of the fly wheel, the pump sucked in air through a metal flap valve which produced a rattling noise at high frequencies. For the second half of the cycle, the pump expelled air through an output valve producing a good deal of rumble. The instrumentation used was a Brüel & Kjær Dual Channel Real Time Frequency Analyser 2133 with a BZ7021 mapping programme. A photoelectric probe type MM0024 was used and aimed at a piece of reflective tape on the fly wheel (Fig.2). Twelve windows were defined. An intensity probe was used at 0.5m from the pump and pointing towards the input and outlet valves. The total measurement time was less than 30 seconds. An adjustment of the

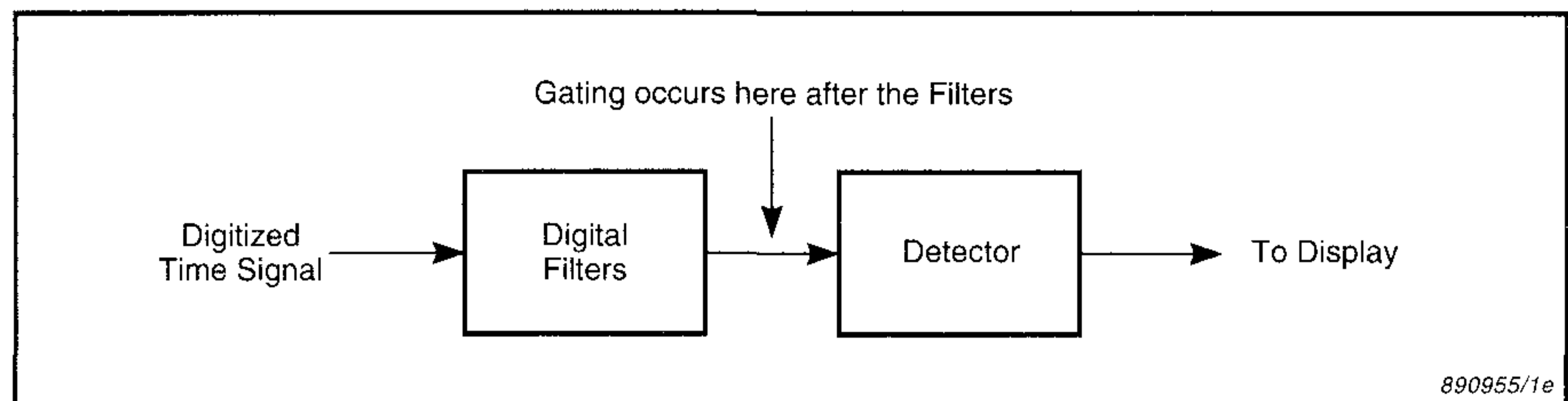


Fig. 1 Schematic diagram of the gated technique as implemented in Real-time Analysis 2123/2133

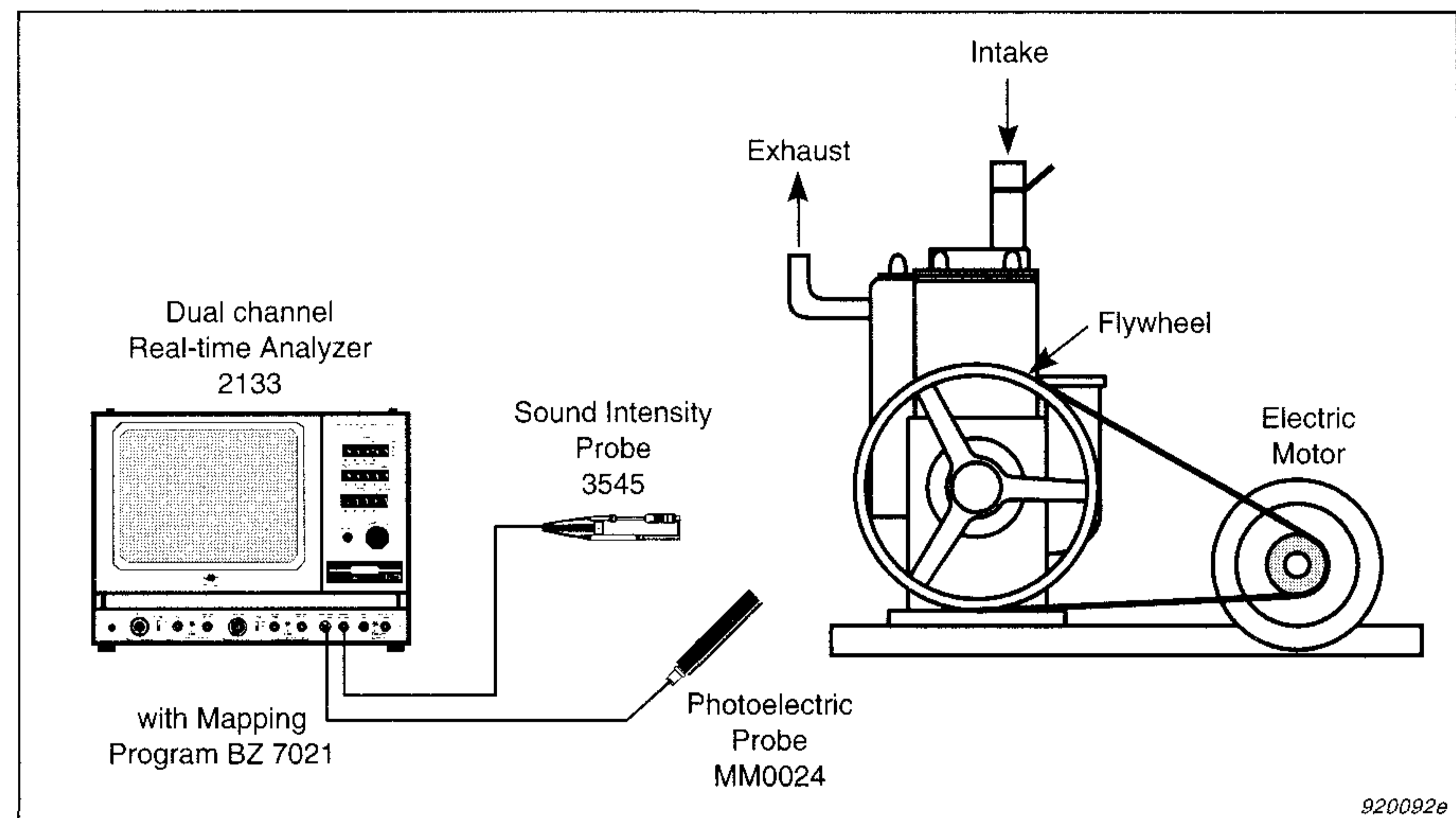


Fig. 2 Instrumentation used for the gated measurement technique on a pump

trigger point enabled the resulting landscape and contour plots (Figs.3 & 4) of the sequential multispectra to clearly show the two events; inhalation and exhalation.

A certain number of modifications were proposed for reducing the overall noise level: muffler over the exhaust, muffler over the intake, partially closed intake valve, anti-vibrational mounts and a complete enclosure of the pump with and without the other modifications. Only the results of placing a muffler on the intake valve are shown here.

A muffler consisting of a rubber tube was placed over the intake valve and the measurement performed again. A considerable reduction of the noise due to the inhalation (Fig.5) was obtained although it is worth noting that the noise during the exhalation stage was

slightly increased (Fig.6 & 7). The total sound power of the pump is increased after modification although the total A-weighted sound power is decreased (Table 1). The investigation of this modification took about 5 minutes.

Conclusion

The gated measurement technique in combination with intensity measurements has been demonstrated to be an effective way of ranking noise generating processes originating from a pump. Modifications were implemented and evaluated objectively by means of the measured sound power values and also visually by using the sequential mapping feature of the analyser. The total noise control survey involving all the modifications mentioned took less than 30 minutes.

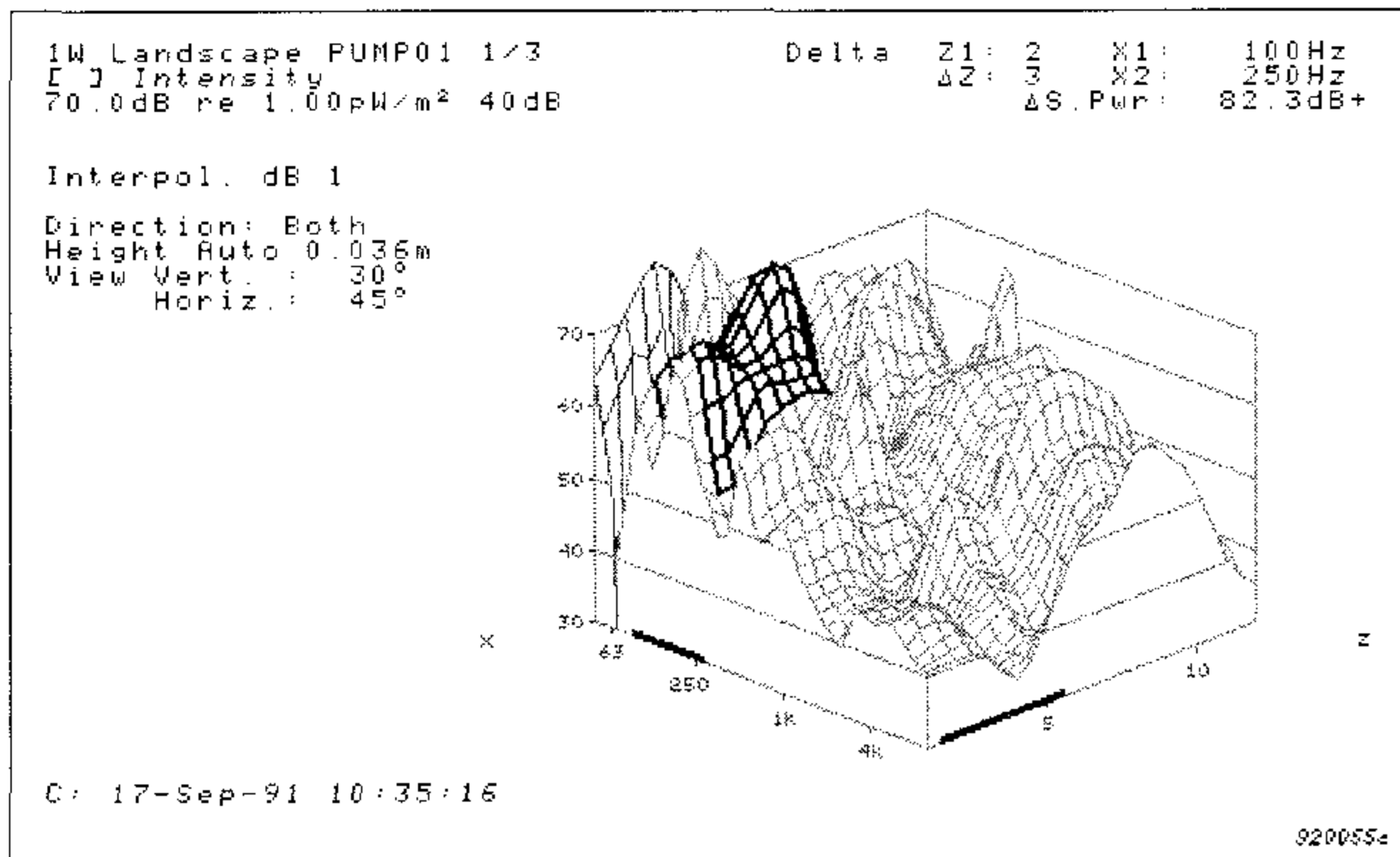


Fig. 3 A landscape plot of the original pump. The region highlighted by the delta cursor is the low frequency noise due to the exhalation.

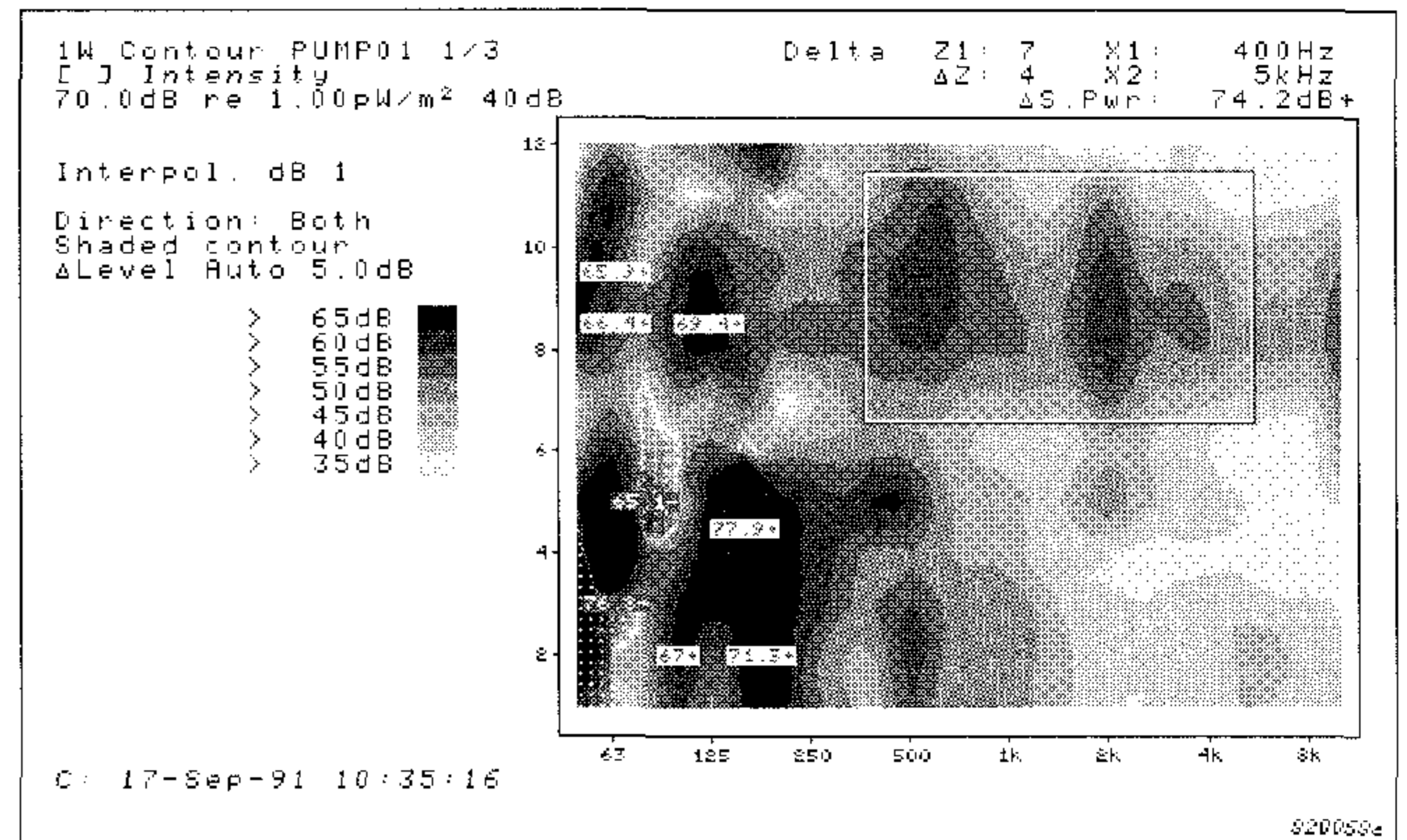


Fig. 4 The same as Fig.3 but the data is represented as a contour plot. The region indicated by the delta cursor is the high frequency noise due to the inhalation.

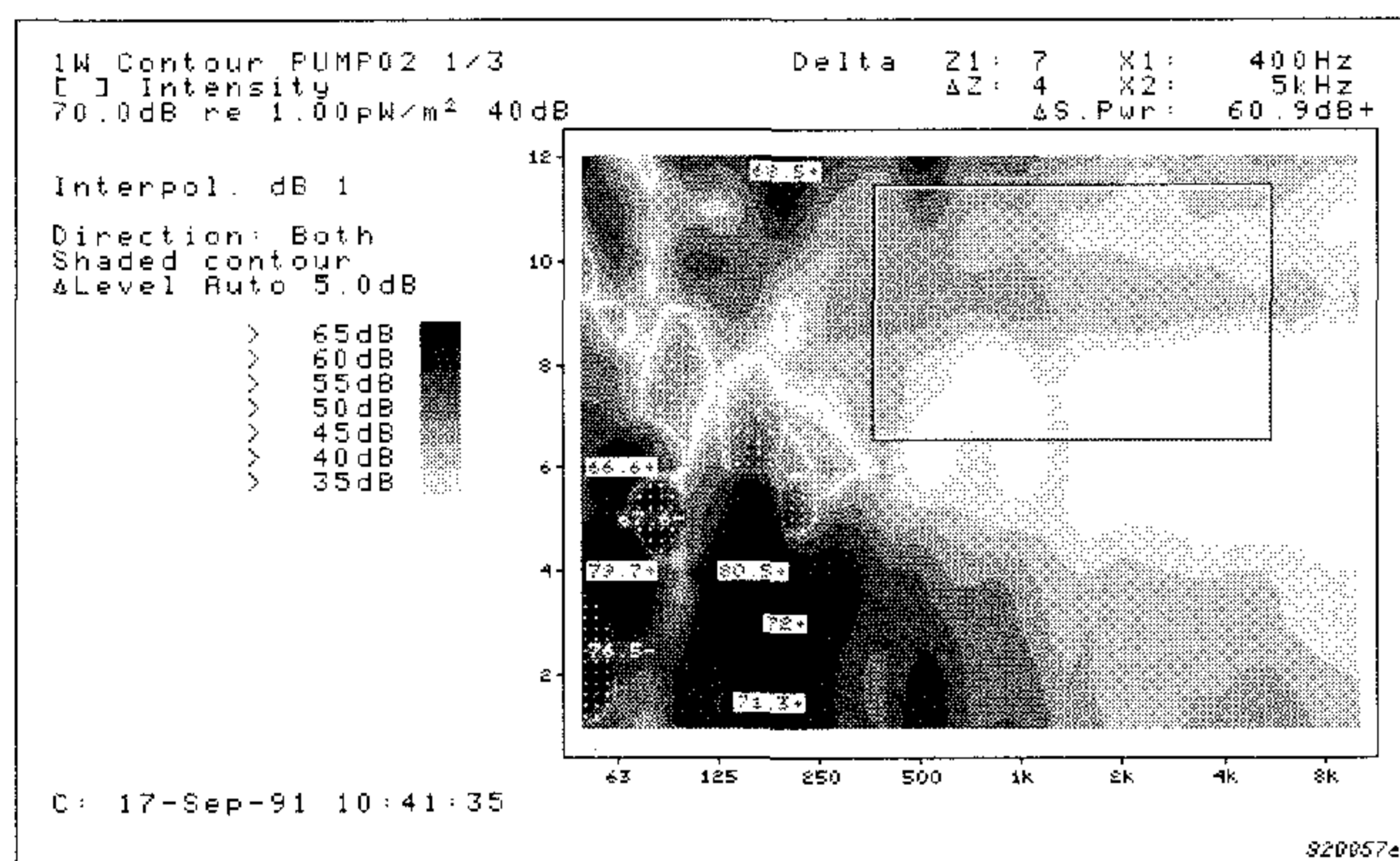


Fig. 5 A contour plot of the modified pump showing that the effect of the muffler was to substantially reduce the noise due to inhalation.

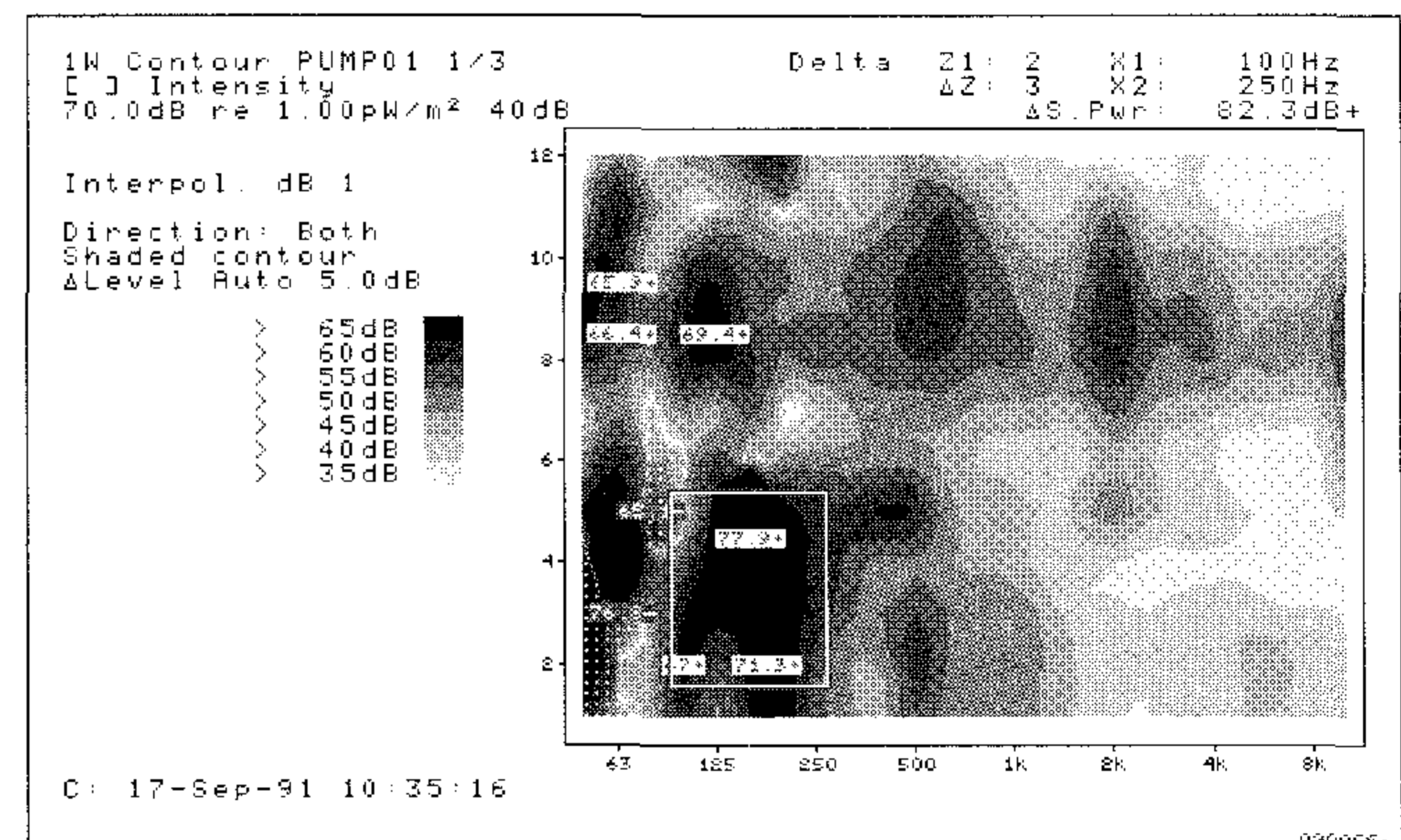


Fig. 6 A contour plot of the original pump. The region highlighted by the delta cursor is the low frequency noise due to the exhalation.

	Inhalation	Exhalation	Overall	
Original pump	74.2 dB	82.3 dB	84.4 dB	76.7 dBA
Modified pump	60.9 dB	83.9 dB	85.7 dB	74.0 dBA

Table 1 Sound power of the two noise generating processes of the pump, before and after modification

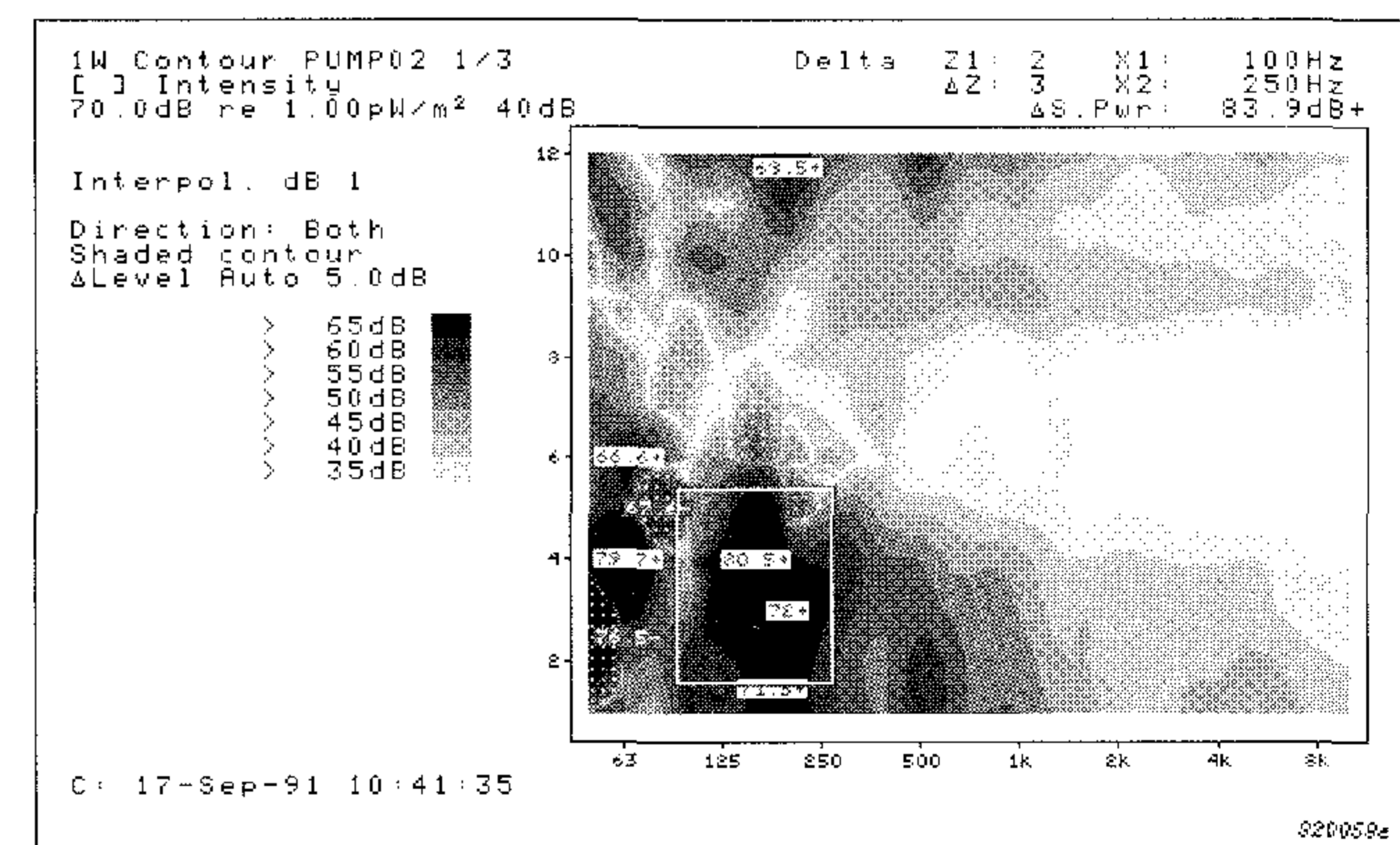


Fig. 7 A contour plot of the modified pump. The region highlighted by the delta cursor is the low frequency noise due to the exhalation.

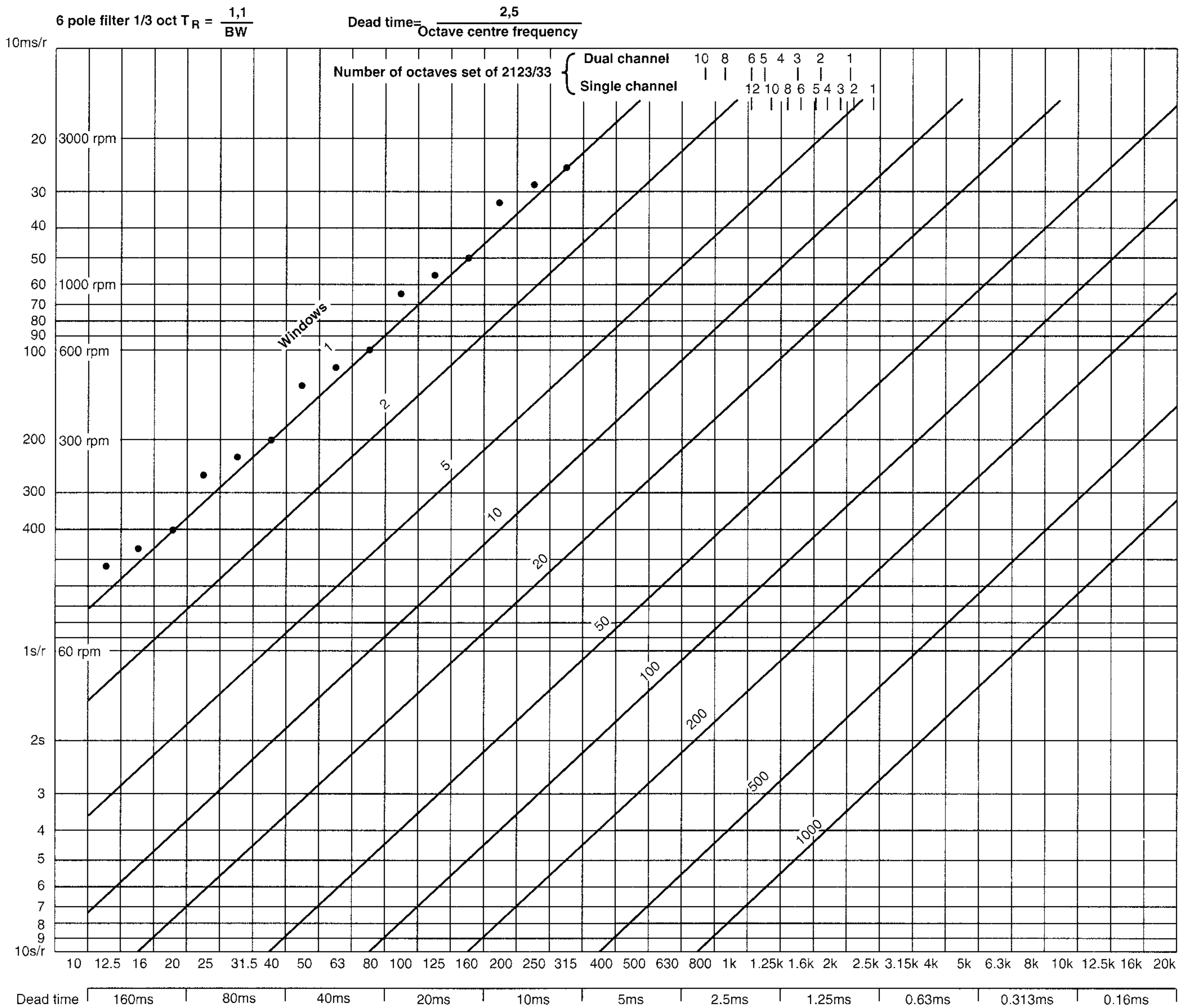


Fig.A1. Nomogram showing the relationship between speed of rotation, frequency for 6 pole 1/3 octave filter

Appendix

Nomograms for gated measurement technique using third-octave filters

As an example on the use of the nomogram consider the pump measurement just described. Two quantities were measured (sound intensity and mean spectrum) in third octave bands over a frequency range of 50Hz to 10 kHz (8 octaves). The rotational speed was 60rpm.

On the nomogram (Fig.A1), draw a horizontal line to mark the rotational

speed of 60rpm. Next, draw an oblique line to represent the 12 windows. The speed line and the window line intersect at 100Hz which is the lower limiting frequency for which events are correctly positioned in the measurement windows. At lower frequencies the response time of the filters is no longer negligible compared to the window length.

A vertical line drawn downwards from the "dual channel 8 octaves" mark at the top of the nomogram, intersects

the 12 window line at 600rpm. This is the upper speed limit for which the spectra can be gathered without exceeding the calculation capacity of the analyser (known as overrun). The pump was rotating at 60 rpm which means the measurements are slow enough to be registered correctly, without overrun occurring.

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