A method of leak detection, based on high-temperature resistant microphones, was originally developed in JNC to detect leakages with flow rates from 1m$^3$/h to 500m$^3$/h. The development performed in Fugen and reported here focuses on detection of a small leakage at an early stage by the same microphone method. Specifically, for the inlet feeder pipes the leak rate of 0.2gpm (0.046m$^3$/h) has been chosen as the target detection capability. Evaluation of detection sensitivity and leak localization accuracy was conducted based on various analysis methods in order to check the capability of the method to satisfy this requirement. The possibility of detecting and locating a small leakage has been demonstrated through the research. The probabilistic detection algorithm and multi-channel location-based detection are proposed in order to improve both the detection sensitivity and the localization accuracy.
\[ PWL(f_i) = 10 \log \left( \frac{a_i D^4 F(P, T)}{10^{12}} \right) + Q \approx 0.274 \left( \frac{\pi D^2}{4} \right) \]

- \( i \) – number of frequency band
- \( a_i \) – empirical coefficients
- \( D \) – equivalent diameter of leak hole
- \( F(P, T) \) – function of thermo-hydraulic parameters of coolant

\[ PWL_{i_1}(f_i) = SPL_{i_1}(f_i) + nL_e - 10 \log \left( \frac{e^{2 \beta_{i_1}}}{4\pi m^2} \right) + 2\sigma \]

- \( i \) – number of frequency band
- \( m \) – number of microphone
- \( r_{m} \) – distance between a sound source and \( m \)th microphone

**Diagram**

A: Sound attenuation & detection range - 0.2gpm, 16kHz

B: Comparative analysis

1/3 Octave Spectrum of BGN and emitted PWL

- BGN: Fugen, LNPP

Sound levels at various frequencies and distances.
\[
\delta_{jk} = \frac{1}{M} \sum_{m=1}^{M} \left( SPL_{j,m} - 10\log \frac{e^{-2\rho_{jk} - 0.5}}{4\pi r^2} \right) - \text{PWL}_{jk}
\]

\[
\text{PWL}_{jk} = \frac{1}{M} \sum_{m=1}^{M} \left( SPL_{j,m} - 10\log \frac{e^{-2\rho_{jk} - 0.5}}{4\pi r^2} \right)
\]

\[
\begin{array}{c}
\text{BGN, 20kHz} \\
\delta_{\text{ref}} = 5.1\text{dB} \\
\text{PWL}_{\text{eval}} = 77.6\text{dB}
\end{array}
\]
The figure shows the relationship between signal strength and delay time in a communication system. The correlation coefficient between the signal and the baseband is calculated as follows:

$$\rho_{AB}(\tau) = \frac{\rho_{SNR} \cdot \frac{\text{SNR}_a \cdot \text{SNR}_b}{\text{SNR}_a + \text{SNR}_b}}{\sqrt{\text{SNR}_a \cdot \text{SNR}_b + \text{SNR}_a + \text{SNR}_b + 1}}$$

- \(\rho_{SNR}\) is the correlation level in the absence of BGN.
- \(\rho_{BGN}\) is the BGN correlation level.
- \(\text{SNR}_a\) and \(\text{SNR}_b\) are the signal-to-noise ratios in channel A/B.

The figure illustrates three scenarios:

1. A: Max=0.57, Delay=4.5ms (4.5ms)
2. B: Max=0.12, Delay=4.3ms (4ms)
3. C: Max=0.12, Delay=4.3ms (4ms)

The diagrams show the correlation between the signal and the baseband for different delay times and signal strengths.
Cross-correlation factor inside the boxes (DistB = 0.8–1m)

The diagram shows the cross-correlation factors inside the boxes for different distances. The correlation values are plotted against the distance, with each frequency range represented by a specific symbol.

The detectable zone (correlation level: 0.06–0.13) is highlighted, and the SNR range of SNR_{AB} = 3dB is also indicated. The BGN zone (correlation level of BGN: 0.03–0.05) is also shown.

Mathematical expression:

\[ \Psi = \frac{1}{N} \sum_{n=1}^{N} \tau_n - \tau(m_{ik}, p_{ik}) \Rightarrow \Psi \approx \frac{\Psi_{dr} - \Psi_{\min}}{\Psi_{dr}} \]

- \( \Psi_{dr} \) – coordinates of current spatial point denoted as \( ijk \)
- \( m_{ik} = [x_i, y_i, z_i] \) – coordinates of \( n^{th} \) microphone pair (microphones A and B)
- \( N \) – total number of microphone pair

The diagram also includes a chart showing the correlation values for different frequency ranges. The frequencies range from 2.5-7.5Hz, 7.5-12.5Hz, 12.5-17.5Hz, 17.5-22.5Hz, and 22.5-25Hz.
The figure shows the results of signal processing with different signal-to-noise ratios (SNR) and delay compensation.

1. **A**:
   - Signal + BGN (BGN: Background Noise)
   - Delay-compensated CCF (Cross Correlation Function)
   - A: 5.5m, SNR=3dB
   - B: 6.8m, SNR=14dB

2. **B**:
   - Multi-CCF, 4ch
   - Signal + BGN

3. **C**:
   - Multi-CCF, 3ch
   - Signal + BGN

The graphs illustrate the effectiveness of delay compensation in improving the correlation between signals.

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1) The correlation between the signal and background noise is enhanced with delay compensation.
2) Multi-CCF for 4 channels shows better suppression of background noise.
3) The 3-channel Multi-CCF also provides effective noise reduction.
4) The delay compensation technique significantly improves the signal-to-noise ratio.
5) The results indicate the potential for improving signal processing in real-world applications.
6) Further research is needed to optimize the parameters for various environmental conditions.