CONTROLLING CONTROL VALVE NOISE: A CASE STUDY

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1.0 INTRODUCTION

Transfer stations along long pipe line systems of gas utilities are used for isolating individual pipe lines for routine maintenance work and to supply local distribution networks. Control valves, located in short pipes, are operated in a throttled condition to empty and refill individual lengths of pipe lines. The noise level generated by the conventional valves, headers and associated piping during operations can be as high as 140 dBA. A case study, involving the design of control valves for a proposed transfer facility is presented in this paper. Applicable noise guideline procedures and feasible noise control measures are highlighted. The cost estimates of the noise control measures are also discussed.

2.0 NOISE CRITERIA

Transfer facilities are usually located in remote areas, considered rural and the applicable criteria are listed in the Ontario Ministry of the Environment and Energy (MOEE) publication NPC-132, "Guidelines for Noise Control in Rural Areas" [1]. In rural areas, within 30 m of a dwelling or a camping area, in any hour, the equivalent sound level (L_{EQ}) of a stationary source should not exceed the ninetieth percentile sound level (L_{90}) of the natural environment, by more than 10 dB. Further, L_{90} of the stationary source should not exceed the L_{90} of the natural environment, by more than 5 dB. The minimum MOEE noise limit is L_{EQ} and/or L_{90} of 40 dBA. The Energy Resources Conservation Board (ERCB) of Alberta have issued a Noise Control Directive for controlling noise from installations such as transfer facilities [2]. The directive is straight forward to apply and the limit is evaluated from a base night time sound level, L_{EQ}, in dBA. Unlike the Ontario limits, adjustment factors for day time operations and ambient environment can be applied.

For a typical valve site in rural areas, the MOEE limit is 40 dBA at the nearest receptor even if the blowdown or pipe equalization operations take place during the day-time hours and the operations take place for only a day. However, the ERCB limit at the nearest receptor is 70 dBA (40, base level + 10 dBA for day time operations + 5 dBA for absence of strong tonal components + 15 dBA for periodic one day only activity). It is seen that the Ontario limit is very restrictive and ERCB limits provide additional compensations. It is important to note that the Ontario limit of 40 dBA has been established with little consideration for the type activity undertaken at a typical transfer station. The Ontario Energy Board has reviewed MOEE guidelines and has indicated that the utility is to exercise a best effort to reduce noise from transfer stations. Using 55 dBA at a hypothetical receptor located at a distance of 100 m from the station, the applicable limit would be 70 dBA along the property line of the station.

3.0 NOISE LEVELS OF A VALVE SITE

The lay out of a typical transfer station is shown in Figure 1. The station consists of a pair of headers that are connected to different main pipe lines. The headers are used to purge gas from isolated sections of a main pipe line and for pressure equalization of an empty pipe line after the required maintenance is completed. The time required for the purging operations and for refilling usually varies between 8 to 24 hours.

The two headers in the existing station are connected to four main pipe lines. A small line connects the two headers and the blow-down pipe. Three small valves, plug type, control the purging and equalizations process. The valves numbers are shown in Figure 1.

The purging and equalization operations could only be simulated, since the four lines were in peak demand during the measurement period. The venting operation was simulated by: valve 1-closed; valve 3 (silencer valve) - open; and valve 2 was throttled. The pipe equalization was simulated by: (a) valve 1-open; valve 3-closed; and valve 2 was throttled and (b) valve 2-open; valve 3-closed; and valve 1 was throttled. The header (#2) used for the simulation had a residual low flow at a pressure of 200 psi due to a leaky main valve that connects the header to one of the main pipes. The header therefore could not be purged completely. The gas flow is always from valve 1 to valve 2 for pipe equalization operation. The exact location of the throttling valve could not be determined and it was between 1/4 open to 1/2 open.

The noise levels were measured (Locations are shown in Figure 1) at location A for purging; at location B for valve 1 throttling; and at location C for valve 2 throttling. The results are reported in Figure 2. The noise level from the venting operation through valve 2 for a line pressure of 350 psi was measured near the silencer. The overall sound pressure levels (SPL) were 101 dB and 88 dBA. The silencer performance increase with frequency and is shown in Figure 2. The valve throttling noise levels during pipe equalization process are also shown in Figure 2. The line pressures were approximately 800 psi before the valve and 200 psi after the valve due to the residual flow in the header. The overall SPL increased from 112 dBA to 124 dBA for the two valves. A general increase of the spectrum by about 10-15 dB was evident between the two conditions at all frequencies. The peak frequency range was from 1000 Hz to 4000 Hz for valve 1 throttling, whereas, the peak frequency range was from 400 Hz to 4000 Hz for valve 2 throttling. The level at 400 Hz increased from 85 to 105 dB and the level at 4000 Hz increased from 100 to 110 dB.

4.0 NOISE PREDICTIONS

Shock, shock-turbulence interaction, turbulence mixing and flow separation phenomena are common for the high pressure ratios and the resulting choked flow commonly encountered in control valves. This confined jet turbulent mixing process takes place after the valve-throttling element within a length anywhere from 4 to 10 diameters downstream of the valve and is the main cause of the aerodynamically generated sound field in the pipe. Details of valve noise generation process are reported in references 3 thru` 6.

The simplified prediction model from Reference 6 is applied in our study. In addition, the empirical procedure based on the ISA Standard [5], developed by Fishers Control Company is also used in the predictions. The models assume inline valves operating into a long downstream pipe without any sudden area changes. Most of the required inputs can be obtained from handbooks. However, two main inputs, valve flow coefficient C_v and valve pressure recovery coefficient F_l, are usually obtained from valve manufacturers and are only approximate empirical values. The following is assumed in the prediction model: upstream and downstream pressure are 800 and 200 psi; the valve were 1/2 open; and the valve pipes are very long with no sudden area changes. The predicted noise levels at a distance of 1 m from the valve are 127 and 128 dBA by the two procedures. It is seen that the two methods predict levels within one dB of each other.

The predicted levels must be further adjusted to reflect the actual operating conditions. It was pointed earlier that the exact valve position could not be determined exactly and hence the coefficients C_v and F_l are only approximate. The uncertainty factor is around 6 dB. The valve 2 was 1 m away from its junction with the header and hence additional dipole type sources were created by the turbulence/mixing region interacting with the sudden area change. The ring frequencies of the large header are excited which is reflected in the increase of the frequency range (from 400 Hz to 4000 Hz) for valve 2 throttling. If one used approximate adjustment factors for the above, the predicted noise level at 1 m from the valve for Valve 2 throttling is 126 dBA (127 - 6 dB factor for C_v + 5 dB due to sudden area change). On the other hand, the source region for valve 1 throttling was more than 20 feet away from its junction with the header and further, most of the connecting pipe from valve 1 and the empty header (#2) is buried under ground. A portion of the noise source region is therefore shielded. The predicted noise level at 1 m from the valve for Valve 1 throttling is 111 dBA (127 - 6 dB factor for C_v - 10 dB due to lagging effect by the ground). The predicted results are within 3 dB of the measured results. The simplified model can be used to predict potential noise impact from proposed transfer station with reasonable accuracy.

The lay out of a proposed transfer station is very similar to the existing station shown in Figure 1. Design details of pipe sizes, header-pipe connection details and valve selections were to be finalised depending on the noise assessment. The noise criteria for the proposed site was 70 dBA at the property line of the station. The simple Fisher Controls prediction model was used to predict the noise levels from two different valves. Valves of one manufacturer (B) was consistently producing 6 dB more noise than the other manufacturer (A). Valves of Manufacturer A was used for further analysis. It must be remembered that two valves (#1 and 2 of Figure 1) are needed for the throttling operations as well as for controlling pipe line flows in both directions.

The base noise level is evaluated with the assumption that the throttling valves are located sufficiently (minimum of 15 to 20 pipe diameters) away from the connecting headers. The property line was approximately 25 metres away from the nearest valve-header junction and a conservative 20 dB distance attenuation was assumed in the evaluations. The design pipe pressure is 900 psi and the valve is kept 1/2 open during throttling. The base noise level from a regular plug valve (large line) is 122 dBA. The noise level reduces by 4 dB to 118 dBA if the size of the valve (and the connecting line) is reduced by 2" (small line). However the flow rate is reduced by 30%, i.e., the time taken to fill the empty main line increases considerably. Similarly, if the valve is throttled by keeping the valve 1/4 open, the noise level reduces by 7 dB, but the flow rate is reduced by more than 50%. Even though the noise level is reduced at the property line with the above modifications, the level would last for a longer period. The evaluations show that the property line noise levels exceed the criteria by about 40 dB for the worst case condition. Feasible and practical noise control conditions are described in the next section.

5.0 NOISE CONTROL MEASURES AND COST

The proposed operating configuration requires 40 dB of noise reduction. Five possible measures can be used to reduce the valve noise. They are outlined below. (Cost of Regular Valves is CD$12,500).

A) Replace the valves with 'Quiet Venturi' type; (CD$8,000)
B) Bury the valves and as much as the connecting pipes;
C) Install a silencer in the connecting line with the condition that flow is from the throttling valve to the farther header (silencer insertion loss is 25 dB); (CD$30,000)
D) Lag the header and the entire exposed connecting line (lagging insertion loss is 20 dB);(CD$80,000)
E) Replace the valves with "smart" valves.(CD$150,000 for two)

Smart valves provide substantial noise benefit by applying the "tortuous path approach." The flow expands through a series stacked discs and thereby reducing the noise generation. The cost associated with the control measures as well as expected noise reduction of the measures are outlined in Table 1.

6.0 CONCLUSIONS

The noise emission from control valves were measured and compared with applicable prediction models. The suitable prediction models were used to estimate the noise output of control valves at a proposed transfer station. Various control options were evaluated and appropriate control recommendations were presented to satisfy a noise control limit of 70 dBA at the property line.

REFERENCES

1. "Model Municipal Noise Control By-Law, Final Report." Ministry of the Environment and Energy of Ontario, 1978.

2. "Noise Control Directive," Interim Directive ID 92-2, Energy Resources Conservation Board of Alberta, April, 1992.

3. J.G. Seebold, "Control Valve Noise," Noise Control Engineering Journal, Vol. 24(1), pp. 6-12, 1985.

4. G. Reethof and W.C. Ward, "A Theoretically based Valve Noise Prediction Method for Compressible Fluids," Journal of Vibration, Acoustics, Stress and Reliability in Design, Vol. 108, pp. 329-338, 1986.

5. Instrument Society of America, "Control valve Aerodynamic Valve Noise Prediction," ANSI/ISA Standard S75.17, 1989.

6. L.L. Beranek and I.L. Ver, "Noise and Vibration Control Engineering, Principles and Applications," J. Wiley and Sons, Toronto, 1982.

Table 1. Noise Control Potential and Associated Costs
(Noise Levels in dBA at 20 m from the valves)

Noise Control Combination	Noise Level (Large Line)	Noise Level (Small Line)
Regular Valves (2)	122	118
Item A (2)	115	113
Item B	117	113
Item C	97	93
Item D	102	98
Items A + B	110	108
Items A + C	90	88
Items A + D	95	93
Items A + C + D	70	68
Item E (2)	70	70

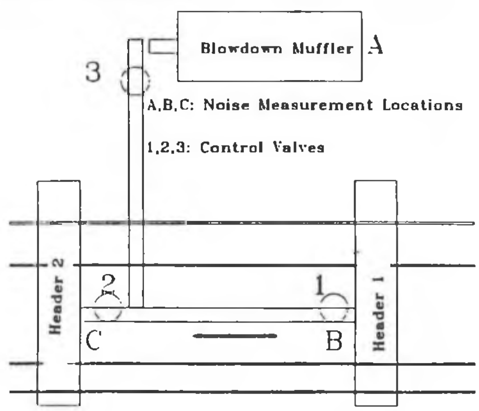

Figure 1. Lay Out of a Transfer Station

Figure 2. Control Valve Noise Levels