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Natural Gas Compressor Station Noise Abatement Systems

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ABSTRACT

In recent years urban residential growth has created a serious encroachment problem to all industrial complexes including natural gas compressor stations. Union Gas Ltd. has recently been involved in the design of an acoustically treated compressor station. Noise emanating from a station into the environment outside the property perimeter is caused by mechanical equipment in operation and gas flowing through piping and valves. Noise generated from a turbine station varies in power level and frequency. The noises, varying from the high frequency startling type to the low frequency throbbing type, create a number of problems for surrounding residential homes. This paper describes the Parkway Compressor Station located near Toronto, Ontario, Canada at which various items of mechanical equipment were identified and acoustically treated with satisfactory results.

INTRODUCTION

Union Gas Ltd. is a unique company which has expertise in a variety of gas handling areas. Union transports, distributes and stores natural gas in Southwestern Ontario. Union's existing system includes the following facilities: distribution network (570,000 customers); transportation system (3000 km of transmission lines); production systems and gas storage facilities (4 billion cubic meters).

To transport the annual volumes of approximately 6.9 billion cubic meters (m^3) Union operates compressor stations which total over 160,000 kilowatts (kw). Ninety percent (90%) of this power is generated by gas turbines.

Compressor stations are generally located in remote agricultural areas along the pipeline systems, Union's eastern end being on the fringes of Toronto, Ontario, is where the rapid residential development has taken place. Union's most easterly compressor facility (5700 kW reciprocating units) originally located in a rural setting, became surrounded by residential homes within a two year time frame. As a result of this development, Union Gas implemented a noise abatement program in 1986. The difficult part of the program was to try and identify the predominant noise sources in a station that was built within the standards of 1957. The noise sources were identified to be the engine exhaust, air intakes, air exchange oil coolers and piping vibrations. An earth berm 6 meters high was built around the plant to help reduce the transmission of low frequency noise levels. The engine exhaust and intakes were attenuated with silencers, new slower fan blades were installed on the coolers, pulsation bottles were added to the piping system and the piping was installed below ground where practical. The overall noise was reduced from approximately 63 dB(A) to 47 dB(A) at a point 100 meters from the Compressor Station. See Table 1 and Figure 1.

Table 1

COMPRESSOR STATION NOISE LEVELS
(NEAR TRAFALGAR COMPRESSOR STATION)

DATE	ABATEMENT & MEASURES	SOUND LEVEL IN dBA AT LOCATION NUMBER (1)									
		I	II	III	IV	V	VI	VII	VIII	IX	X
1977	ORIGINAL	64	63	63	62	63	62	66	66	63	60
1980	ENGINE EXHAUST SILENCERS ADDED	60	59	57	56	57	56	62	59	55	58
1984	PERIMETER BARRIERS BUILT	56	55	53	53	53	53	53	53	52	48
1986	ENGINE INTAKE SILENCERS ADDED	54	53	48#	50	51	48	52#	52#	45#	46
1988	WATER COOLERS MODIFIED	48	49	49#	47	•	44	49#	48#	•	•
1977-1988	NOISE REDUCTION	16	14	14#	15	•	18	17#	18#	•	•

\# THESE VALUES INCLUDE THE EFFECTS OF REINFORCING REFLECTIONS FROM NEARBY BUILDINGS.

• IT WAS NOT POSSIBLE TO MAKE NOISE MEASUREMENTS AT THESE LOCATIONS BECAUSE OF INTERFERENCE FROM LOCAL (AMBIENT) NOISE SOURCES.

(1) REFER TO FIGURE 1 FOR LOCATION NUMBERS

The problem was cured with very expensive retrofit measures. The local authorities and residents were satisfied with our results.

In 1987, a new turbine compressor station was approved for Union's eastern end. As opposed to the retrofit previously

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described, the new station was designed from the beginning with acoustically treated components. Public meetings were held to show Union's concerns about noise as a potential problem for local residents in the future.

The difficulty of the project was to determine a reasonable and acceptable noise level to all parties concerned. It was decided to design to a modified NR-35 noise reduction curve at 100 meters. This criteria represents a relatively quiet sound level of approximately 43 dB(A) at 100 meters or 35 dB(A) at the area where a future residential development could take place 250 meters to the east of the station site.

This paper briefly describes the various noises produced at a compressor station and the silencing methods used to reduce the noise levels.

GENERAL

Noise emanating from compressor stations into the environment outside the station perimeter is caused by mechanical equipment in operation and by gas flowing through and from the piping systems. The noise generated within buildings can be attenuated by designing the building walls and roof to provide sound absorption and transmission reduction. Noise produced within the piping system can be attenuated by increasing pipe wall thickness, burying the pipe, or by wrapping the piping components in acoustical insulation.

NOISE MEASUREMENT LOCATIONS (TRAFALGAR COMPRESSOR STATION)

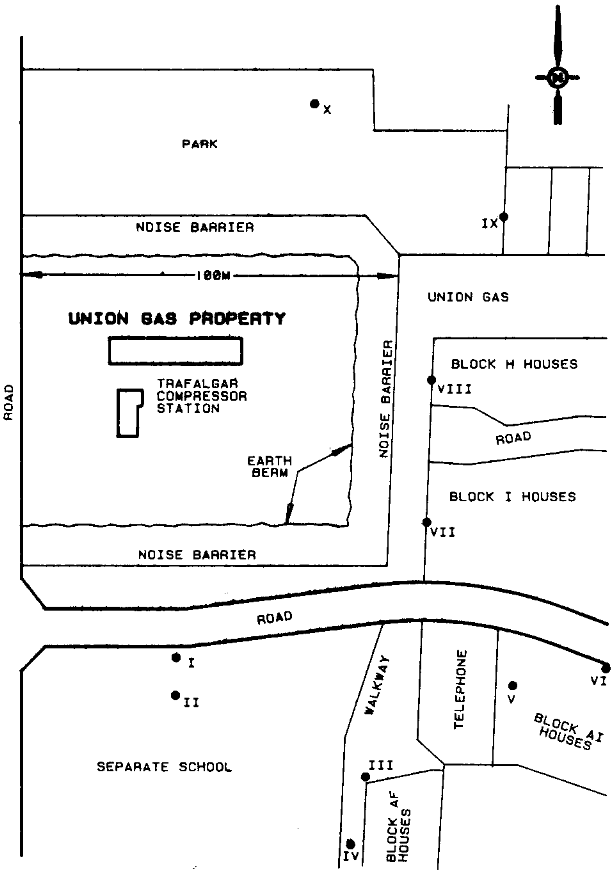

Figure 1

TYPES OF NOISE

Compressor stations generate two primary types of noise, continuous noise and impulsive noise. Continuous noise occurs when all facilities, in operation, generate noise of varying intensity. Sources include the gas turbine inlet and exhaust, oil coolers, gas generator casing, gas generator and power turbine lube oil consoles, compressor casing, miscellaneous vent fans, aftercooler fans, and the piping system. Also included in this type of noise is the auxiliary power unit when it is in operation. Impulsive noise is generated by high intensity release of sound energy over short durations of time. Impulsive noise in a compressor station is typically created by the emergency evacuation of piping components through blowdown systems or by gas exhausting from valve operators. These high intensity sound energy releases can cause a startling effect and in some cases, hearing damage. Therefore, these sources require careful consideration when designing a station.

ATTENUATION

The magnitude of sound pressure waves will be reduced by both natural and controlled methods. Natural attenuation results from the reduction in noise level with distance and some absorption by atmosphere and surrounding. Controlled methods will be used on an individual basis to attenuate the noise at its source. Following is a discussion of these effects. Distance attenuation may result from a variety of causes. Sound energy from a point source radiates spherically in all directions. Therefore, the measured intensity of the sound at any point is calculated by dividing the total radiated energy by the surface area of the sphere. If no energy absorption occurs the total sound energy remains constant. However, the surface area of the sphere continues to increase with the square of the distance from the energy source. The net result is a decrease in sound intensity. Distance attenuation will be applied as follows. For every doubling of distance the sound level will be reduced by 6 dB. Air attenuation is caused by losses arising from rotational and vibrational relaxation of the molecules in the air. The amount of absorption varies with air temperature and humidity. Greatest sound absorption (ex. at 8 kHz absorption is equal to 18 dB/100 meters) occurs for the higher frequencies when the relative humidity is low and the temperature is above 15 degrees centigrade. The amount of attenuation caused by ground absorption is dependent upon the type of ground covering. The effect of ground absorption by hard packed and gravelled areas within the station boundary is minimal and will not result in additional attenuation as would grass, shrubbery or bush.

BASIS OF MEASUREMENT

The intensity of the sound being transmitted through the surrounding medium is defined as the energy that flows through a unit area in a unit time. This sound intensity causes a pressure wave which we perceive as noise. Sound pressure waves are referenced to a sound pressure level of 2E-5 N/m^2 established as the threshold of hearing at a sound frequency of 1000 Hz. A decibel (dB) is the unit of measure and is a dimensionless ratio based on the logarithms of the ratio of the sound level to some reference point commonly referred to as zero dB. In order to represent the entire spectrum of sound, the dB levels of individual noise sources are taken at each of the center band frequencies and then combined on an energy basis.

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DIRECTIVITY

Point sources of noise in free space radiate noise spherically in all directions. However, sources of noise on a hard surface (such as the ground) are unable to radiate noise in all directions and are assumed to have sound energy radiate in a hemisphere with twice the sound intensity. Reflection of a sound wave upon itself causes some increase in the propagating sound intensity. This feature of sound allows the design of station components located next to the compressor building to use distance attenuation to reduce sound levels, by redirecting sound away from sensitive receptors to points further away in other directions. Horizontal air cooled heat exchangers tend to project sound in an upward direction.

SOUND SPECTRUM

The audible frequency range is usually represented by a series of ten octave bands, the first covering 22 Hz through 44 Hz. Each successive band covers twice the width of its predecessor. Therefore, the 10th octave band covers 11,360 Hz through 22,702 Hz. The center band frequency of band 1 is 31.5 Hz and doubles in value for each successive band until it reaches 16 kHz. The human ear is relatively insensitive to noise at very low frequencies and therefore the first octave band is usually not considered unless the noise levels in this band are much higher than in other bands. However, low frequency noise, although not audible, may be a nuisance by causing standing waves in dwellings as far as 1 km from the source. The low frequency noise manifests itself in the form of structural vibration, which in turn causes residents to complain. For this reason, the low frequency aspect of the sound spectrum should be carefully controlled.

WEIGHTING SCALES

The apparent loudness (effect on the human ear) attributed to sound varies with sound pressure and frequency. For example, high-frequency sound at a low sound pressure level seems as loud as low-frequency sound at higher sound pressure levels. To account for this insensitivity in the human ear a weighting may be applied to the measured sound level in decibels. Three types of weighting may be applied depending on the type of correction required, "A", "B" and "C" weighting scales. The most commonly applied scale is "A" weighting which is used to calculate dBA. To determine dBA, measurements of the dB at each of the center band frequencies must be taken and then the "A" weighting correction applied or a meter with 'A' weighting network may be used.

DESIGN CRITERIA

Individual station noise sources were identified and combined to predict the overall noise level during continuous operation. The objective was a noise level for a fully built-up station that would not result in noise complaints from the proposed subdivision directly across the road to the east or from existing neighbours. The station property consists of parallelogram shaped parcel of land approximately 250 meters wide by 350 meters deep. The distance from the centerline of the gas turbine to the property line closest to a proposed subdivisions is approximately 250 meters. The area surrounding the compressor building is surfaced with gravel. There is 100 meters of existing bush present between the site of the compressor building and the proposed subdivision. The property is level but the prevailing wind blows from the compressor building toward the future development. The objective of the design was to develop a station which generated an overall noise level equivalent to a modified NR-35 curve at a distance of 100 meters from any source of noise during continuous operation. The modification is applied to the 16 and 31.5 Hz bands to reduce low frequency rumble, typical of that generated by the power turbine. This design criteria is illustrated in Figure 2 for a modified NR-35 curve. Impulsive noise sources such as unit vent or station blowdown lines were silenced to prevent a startle effect on passersby and to preclude hearing damage to anyone close to the vent discharge during its operation. The noise criteria chosen was 85 dB(A) at the nearest property line. In order to ascertain the ambient noise levels, site readings were taken on October 5, 1987 and March 3, 1988. During the October 5th survey the ambient temperature was 20°C under moderate wind conditions. The lowest background level measured was 46 dB(A). Conditions during the March 3rd survey were 0°C temperature with no wind. The background levels varied between 34 and 36 dB(A). Complete details of these surveys are presented in Table 2. The noise measurements for the existing ambient noise levels were taken with a Bruel & Kjaer (B&K) model 2215 Precision Octave Band Analyzer (S/N 788614) with a B&K model 4165 free field microphone (S/N 816483) and fitted with a four inch wind screen. The sound level meter was end-to-end calibrated with a B&K model 4230 Acoustic Calibrator (S/N 782537) before and after the measurement period. The sound level meter system met the requirements of the American National Standards Institute (ANSI) for Type 1 precision instruments. The noise measurements compiled after the plant was completed and operating were taken with a B&K model 2209 Impulse Precision Sound Level Meter, B&K model 1613 Octave Filter Set, B&K model 1616, 1/3 Octave Filter Set, B&K model 4230 Sound Level Calibrator and a B&K model 2226 Integrating Impulse Sound Level Meter. Residual or background "A" weighted sound level measurements were made at all locations and residual octave band sound pressure level measurements were taken at selected locations. An "A" weighted sound level is an overall value taking into account the non linear frequency response of the human ear. The octave band sound pressure levels are the levels in nine individual frequency bands from 31 Hz to 8 KHz which extend over the audible frequency range. The residual levels were measured during lulls in the intrusive noise from vehicle traffic and aircraft flyovers.

Table 2

COMMUNITY NOISE MEASUREMENT *

dBA	OCTAVE BAND CENTER FREQUENCIES IN Hz								
	31	63	125	250	500	1K	2K	4K	8K
36	56	48	42	36	34	26	18	15	14

* READINGS TAKEN 100 METERS FROM COMPRESSOR STATION OPERATING AT 5700 KW LOAD.

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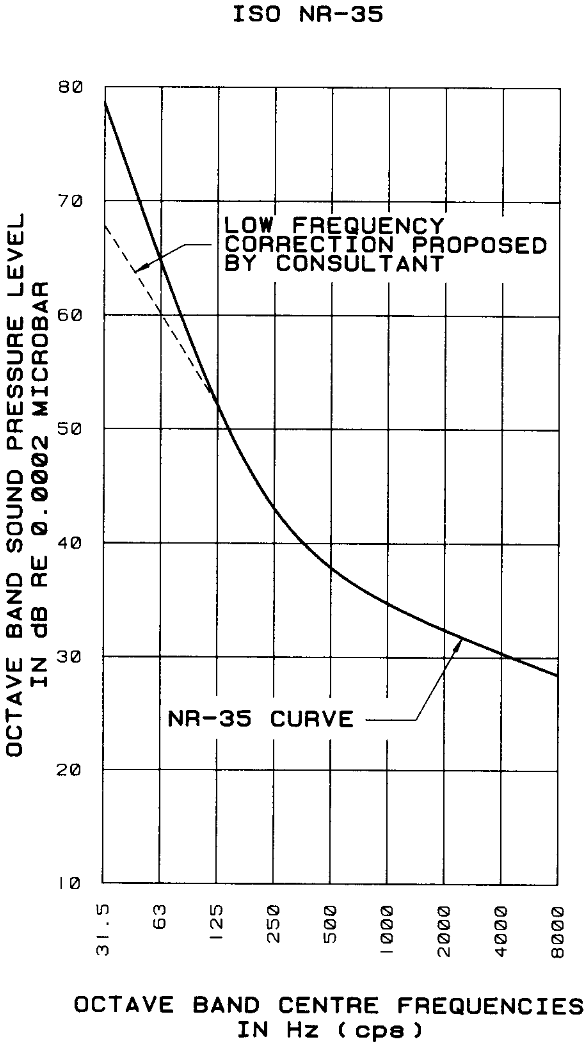

Figure 2

EQUIPMENT SPECIFICATIONS

Gas Turbine/Compressor Package The combination of the air intake, exhaust and acoustic enclosure noise levels including ventilation openings was specified at modified NR-35 level at 100 meters. The dB level on the low frequency octave band levels was reduced below the standard NR-35 requirement to effectively cut off any power turbine rumble in the subaudible range.

In order to meet these requirements the specific components of the package had to be addressed separately.

Air Intake Air intake to the turbo compressor set creates noise. However, inlet structures are usually directed downwards which results in some sound absorption by the ground surface and shielding by the compressor building. See Figure 3.

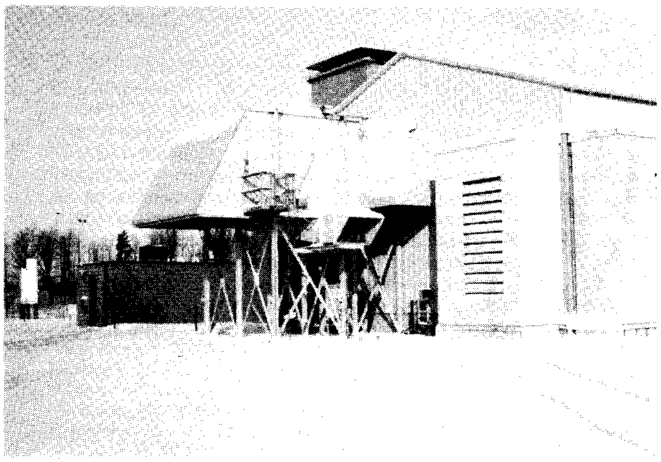

Figure 3

The air filtration system for this package is a self-cleaning filter. This system provides clean inlet air to the gas generator with the benefit of noise attenuation by the filter media in addition to those provided by the inlet silencer.

The inlet silencer and inlet plenum provide noise attenuation characteristics through the flow path design and the sound-deadening materials used in their construction.

Acoustic Enclosure An acoustic enclosure was provided for the gas generator and power turbine assembly. Noise attenuation was achieved by the use of sound absorbing materials in the construction of the enclosure and by ensuring tight seals.

This enclosure requires a separate ventilation system in order to alleviate the high temperatures that can be developed within the enclosed space. The inlet and exhaust of this ventilation system is also constructed of sound deadening materials.

Exhaust System Exhaust stacks project noise upwards. However, this type of noise is less focused because the metal walls of the exhaust project sound cylindrical in a horizontal direction. Still the net reduction in overall exhaust noise levels with 90 degree directivity can be as much as 15 dB at the higher frequencies. See Figure 4.

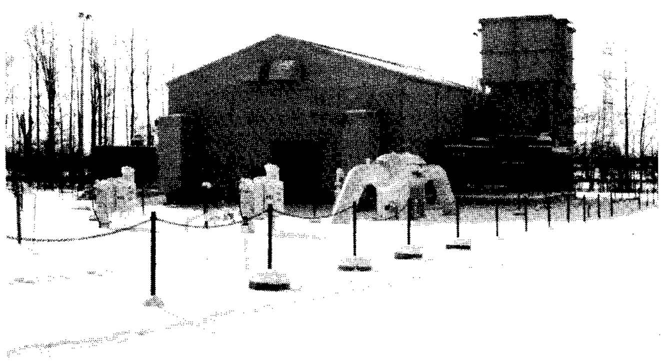

Figure 4

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The exhaust was designed and manufactured by silencing specialists. It employs two primary features in order to obtain the desired sound levels.

a. Diffuser

The primary diffuser is located at the circular flex joint located within the compressor building. This diffuser is a 13 mm thick plate with holes 25.4 mm in diameter drilled through it. This plate creates an additional exhaust loss which has to be carefully calculated since the plate has a 50% effective area with the holes.

b. Effective Length

The length of the exhaust silencer was increased in order to provide more sound attenuation in the exhaust system. The desired length of the silencer was 33 m. However, in order to maintain a relatively low profile station, it was not desirable to construct an exhaust stack 33 m in height. Therefore, two - 180° bends were used and the overall height of the silencer was kept to less than 14 m. The total weight of the exhaust stack was 68,000 kg.

Ventilation Systems All ventilation air entering the building is taken in through inlet silencers. This included the compressor building inlets and auxiliary building inlets. Openings for air exhausted from the compressor building are also silenced. These inlet and exhaust silencers were designed by a specialized acoustical manufacturer. See Figure 5.

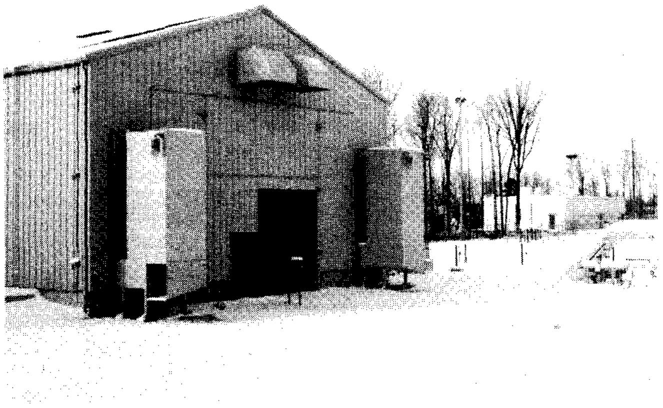

Figure 5

Lube Oil Cooler The lube oil cooler is mounted in one corner of the compressor building and provides a direct unobstructed path for sound emanating from the compressor package to escape to the surrounding area. In order to attenuate this noise emission, the lube oil cooler was fitted with inlet and exhaust silencers. See Figure 6.

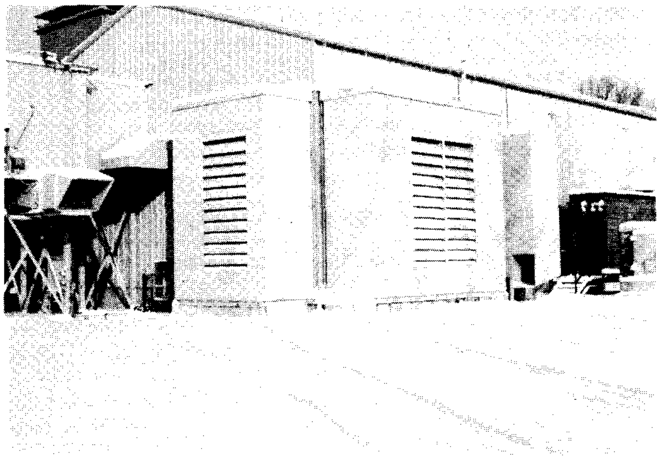

Figure 6

Gas Coolers The coolers are equipped with two speed fans. This enables the operation to take advantage of low ambient temperatures whenever possible through the selection of the low speed fan thereby minimizing noise levels. The fan blading has a good aerodynamic profile which also assists in meeting the noise criteria. See Figure 7.

Blowdown Silencers The unit and station piping is blown down during Emergency Shut Down (ESD) scenarios or during maintenance and expansion of the facilities. Due to the ESD requirement of the blowdown, the noise levels produced by the blowdown valve would be approximately 160 dB(A) at 1 m from the exhaust point. This sound level was attenuated by blowdown silencers to provide a level no more than 85 dBA at 120 m radius. A total of 4 silencers are installed at the station. See Figure 7.

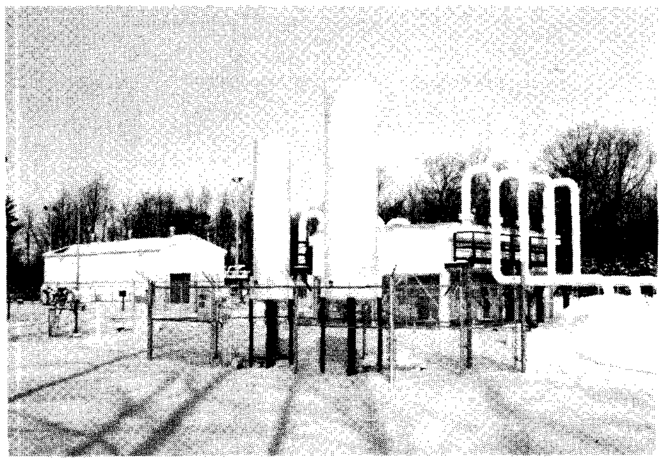

Figure 7

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Auxiliary Power Unit When emergency power is required at the station, a reciprocating engine driven generator is used. This generator set is housed in the Auxiliary building. The generator set was specified at 103 dB(A) at a distance of 1 m. The externally mounted equipment which includes a hospital grade exhaust silencer and a jacket water radiator was designed for 41 dB(A) at a distance of 100 m.

Unit Valves and Piping Union Gas' station design philosophy utilizes flange by flange unit valves typically installed above grade. In order to attenuate the noise associated with the operation of unit valves, modifications to the standard design were required.

The unit piping is installed below grade with the unit valves housed in below grade concrete valve chambers. The valve operators which protrude above the chambers were covered by acoustic enclosures.

High Pressure Piping Three critical areas of high pressure piping were identified as being sources of detrimental sound levels. These were the piping immediately upstream and downstream of the compressor suction and discharge nozzles; the piping immediately upstream and downstream of the recycle and surge control valves; and the piping on the control valve runs in the gauge building. In order to reduce the impact of these sources on the overall station noise levels, the piping was wrapped with acoustical insulation. See Figures 8 and 9.

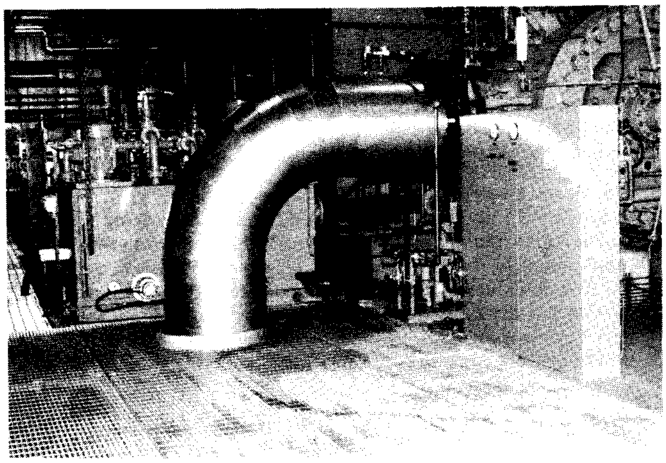

Figure 8

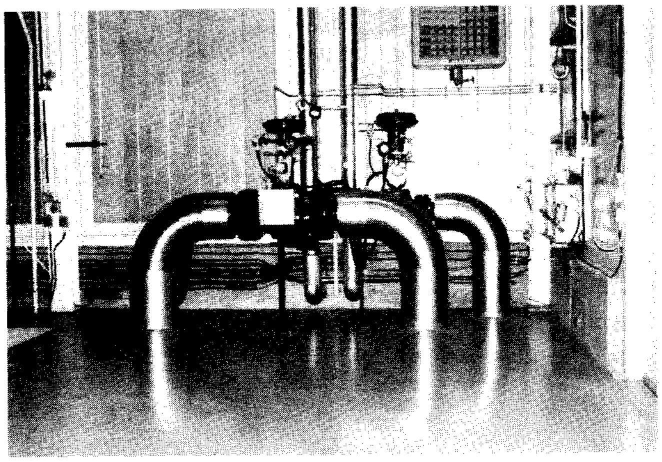

Figure 9

BUILDING CONSTRUCTION

In addition to the acoustical treatments provided for the equipment and piping systems, the methods and materials used in the design and construction of the buildings also provided significant noise attenuation.

Compressor Building The compressor building is made up of the roof and wall panels and composed of 10 layers of material in order to achieve the desired sound attenuation. The total thickness of these panels is approximately 200 mm. See Figure 4 and Table 3.

Table 3

ALLOWABLE 100 M OCTAVE BAND SOUND PRESSURE LEVELS FROM ENTIRE BUILDING, EXCLUDING GAS GENERATOR INTAKE AND EXHAUST

	OCTAVE BAND CENTRE FREQUENCY, HZ								
	31	63	125	250	500	1K	2K	4K	8K
LINE 1 INTERIOR DESIGN LEVEL	92	98	99	98	102	98	90	85	78
LINE 2 GUARANTEED 100 M. LEVEL	62	55	47	39	33	29	26	24	22

COMPRESSOR BUILDING
TYPICAL ROOF AND WALL PANEL CROSS SECTION

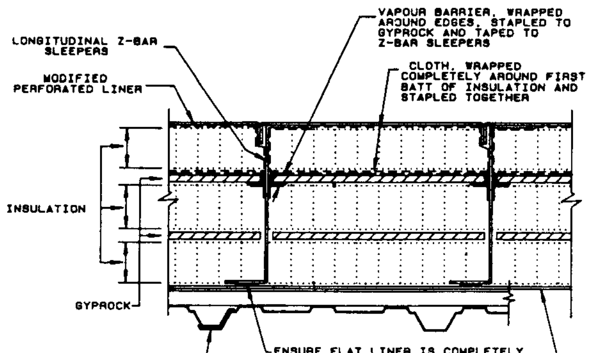

Figure 4

Gauge Building The control valve piping runs in the gauge building are acoustically insulated. However, this insulation alone would not meet the design noise criteria. Therefore, the building which houses this piping was constructed of hollow masonry block filled with acoustical insulation material. See Figure 10.

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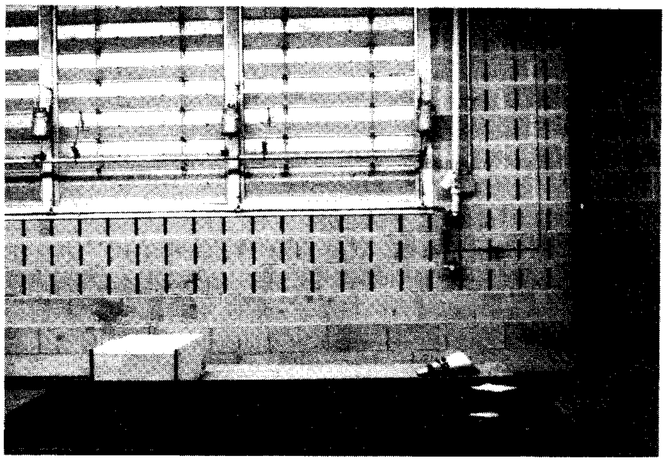

Figure 10

Table 4

COMPRESSOR STATION NOISE LEVELS
(NEAR PARKWAY COMPRESSOR STATION)

TEST	STATION (1) LOCATION NO.S	OCTAVE BAND LEVELS IN dB								LEQ IN dBA
		31.5	63	125	250	500	1k	2k	4k	
I	P1	58	48	44	40	33	36	38	32	42
	P2	54	50	44	36	32	33	32	25	39
	P3	52	46	41	37	35	39	32	18	40
	P6									41
	P7	61	53	46	41	42	52	47	40	54
II	P1	56	51	45	41	36	37	39	33	42
	P2	52	57	47	39	34	35	32	25	42
	P3	51	52	45	39	36	35	30	19	41

(1) REFER TO FIGURE 11 FOR LOCATION NUMBERS.

Auxiliary Building - A.P.U. Room As noted earlier, the auxiliary power unit was specified to produce a sound level of 103 dB(A) at a distance of 1 m. In order to ensure that the A.P.U. did not adversely affect the overall station noise level, the room in which it is housed was constructed of block walls of the same design as the gauge building.

RESULTS

In order to verify that all the noise attenuation features employed in the design and construction of the station were successful in achieving the required noise levels, a complete set of readings were taken when the plant was in an operating mode.

The locations of these measurements are shown in Figure 11 and the results summarized in Table 4.

SUMMARY

During the summer of 1989, a public meeting was held during which the station was vented to the atmosphere. People inside the service building could hardly hear the gas being vented. The effects of Union's noise abatement systems at the station were substantial to the point at which the station cannot be heard from the closest road. A great deal of difficulty was encountered in trying to get to the proper conditions, for a meaningful test. The weather conditions, plant operating conditions and traffic (including aircraft) conditions had to be at the proper levels to establish noise readings from the equipment and not the ambient. Numerous attempts were made resulting in the ambient noise levels being considerably higher than the station. On 89/12/28 a successful noise survey was completed as previously described in Table 4 and Figure 11.

NOISE MEASUREMENT LOCATIONS
(PARKWAY COMPRESSOR STATION)

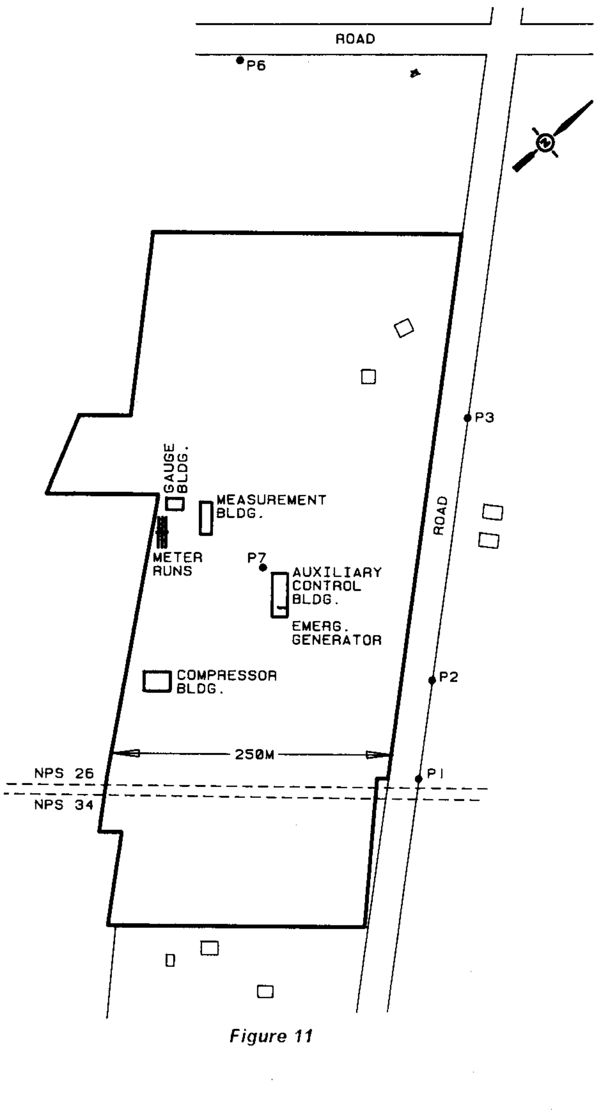

Figure 11

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The results of Union's efforts are captured best by the comments made by one of our station operators. "When I'm in the master control room, the only noticeable indication that the plant is running are the heat waves coming out of the exhaust stack."

ACKNOWLEDGEMENTS

The author wishes to thank the station engineering department at Union Gas Ltd. for their assistance in compiling this paper. The author also wishes to thank Stone and Webster and SPL Control for their successful acoustical designs of the Compressor Station.

REFERENCES

Burgess Industries, Silencing Handbook.

Keeler, J.S., 1988, Review of the Noise Abatement Programme at the Trafalgar Compressor Station from 1974 to 1988. Page 4 and 5.

Stone and Webster Canada Ltd., 1988, Design Basis Memorandum, Greenbelt Compressor Station Project.

Stone and Webster Canada Ltd., 1988, Union Gas Greenbelt Compressor Station Noise Analysis, Greenbelt Compressor Station Project.

S.P.L. Control Inc., 1988, Greenbelt Acoustical Designs, Greenbelt Compressor Station Project.

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