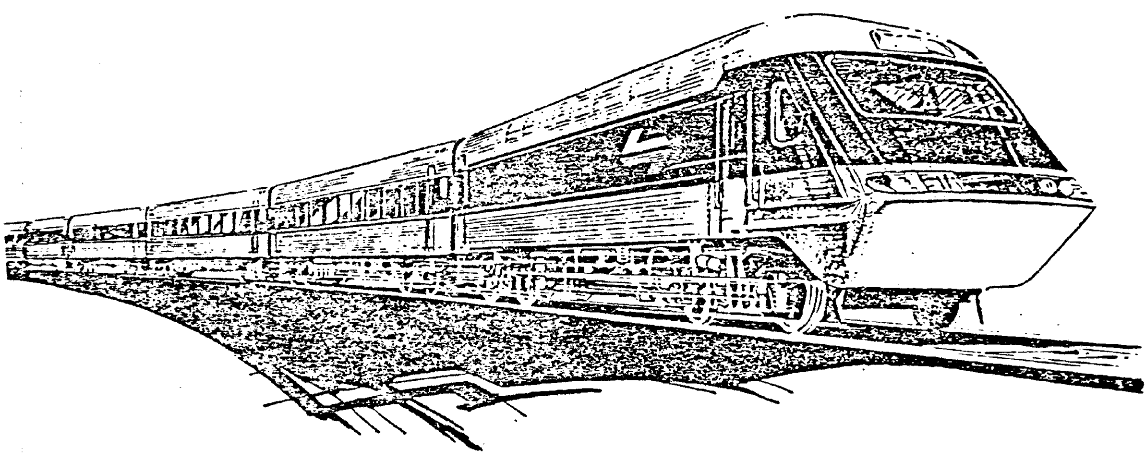
Npf 620.23 W733

TENTH INTERNATIONAL CONGRESS ON ACOUSTICS

INFRASOUND AND LOW FREQUENCY NOISE IN THE LOCOMOTIVE CAB

VENUE: UNIVERSITY OF NEW SOUTH WALES



B.J. WILLINGALE
SECRETARY
AUSTRALIAN FEDERATED UNION OF LOCOMOTIVE ENGINEMEN

SYDNEY JULY 1980.

1209

INFRASOUND AND LOW FREQUENCY NOISE IN THE LOCOMOTIVE CAB

INTRODUCTION

Locomotive enginemen have ever since the inception of the steam locomotive been subjected to noise exposure, covering a fairly extensive frequency range.

The type of noise experienced in the cab of the diesel-electric locomotive compared to the steam engine cab varies considerably being a fairly constant type noise exposure.

Many enginemen complain that both physical and mental fatigue, which sets in fairly early in a shift on a diesel-electric locomotive compared to a steam locomotive, is in some way contributed to by the cab environment of the diesel-electric locomotive and particularly in relation to noise exposure.

There are, of course, differences in the physical activity encountered in the diesel-electric locomotive cab compared to the steam locomotive and to the ride performance of both cabs and to vibration characteristics.

The noise exposure in the audible range is not so great in the case of the diesel-electric locomotive compared to the steam locomotive. However, it is of a more constant nature.

There are certain stress and tension factors which appear to be more present with the operation of the modern locomotive compared to the steam locomotive and it might well be argued that there are many contributing factors to this situation.

In July 1979, a new railway line was opened between Central and Bondi Junction in the Eastern Suburbs of Sydney. The line is partly underground and partly on viaduct. Only double deck type suburban electric trains operate on this line.

Prior to the opening of the line, there were quite a number of services operated on the line for training purposes.

Complaints were received from enginemen operating on this line relating to the experience of headaches, nausea and depression. The complaints came from enginemen who would normally show little interest in raising issues concerning their working conditions to the Union.

Complaints were also received, relating to severe air pressure changes that were experienced on entering the underground sections of the line.

Prior to the opening of the line, complaints relating to noise came from elsewhere and in particular, residents located near an overground section of the line. The Government employed a firm of Acoustic consultants to conduct research into the problems of noise in the operation of the line and the Public Transport Commission, itself conducted a number of tests in respect to audible noise levels on the line.

The Union also conducted a number of tests and it is proposed in this paper, to indicate some of these results.

BACKGROUND

For some considerable period of time now, the Union has shown an interest in literature dealing with infrasound and low-frequency noise exposure. This interest has been cultivated in the light of the alertness and attention that an engineman must pay to his duties in respect to decision making in the locomotive cab. While trains do not operate in this State to the speeds encountered in other countries, prompt response to signals and the situation concerning other hazards and operating conditions in the locomotive cab are nevertheless, very important ones to safety. Sydney suburban double deck trains carry up to 2,500 passengers and signals are spaced at very close intervals while long distance express trains speeds and express freight trains speeds are limited to 60 and 70 miles per hour an accurate and prompt response to operating procedures on these larger and faster trains, requires a clear mental state.

The subject of low frequency noise and infrasound has probably received the least attention compared to the mammoth amount of literature available in respect to noise exposure as related to hearing impairment problems.

The table of exposures and related frequency range and their relative effects appear to summarise what was known about the effects of infrasound at least in Western countries up till about 1975.

PHYSIOLOGICAL RESPONSE - DESCRIPTION

TABLE 1

		CPS	SPL
1.	Vertical Nystagmus	7 Hz	130 dB
2.	Vertigo, Nausea	7 Hz	140 dB
3.	30-40% increase in reaction time Tegarthy, euphoria, (running off road to drive into danger without being able to mentally reverse ones actions)	1-20 Hz	115-120 dB
4.	Affecting voice	50 Hz	

5.	Sitting and standing, difference in response.	15-20 Hz	
6.	Chest responce (structural) (subject to stature)	20-70 Hz	none higher than 107 dB
7.	Calf excitation	30-40 Hz	
8.	Affects balance	below 20 Hz	140 dB & above
9.	Chest wave vibrations, 'gagging' sensations, respiratory rythm changes	1-50 Hz	Man could tolerate up to 150dB at 1-100 Hz for short periods if ear plugs worn.
10.	Visual blurrings, choking, coughing and transient headaches	50-100 Hz	
11.	Irritation of internal organs	196 Hz	SPL not given
12.	Digestive trouble	16 Hz	SPL not given
13.	Visual blurring	7 Hz	SPL not given
14.	Swaying	2,6,7,10,15 Hz particularly at 7Hz	140 dB or higher
15.	Sensation of being thrown sharply off balance.	as above	146 dB
16.	Severe loss of balance, nausea (in cases of a person with a history of sensitivity to balance disturbances experiment had to be terminated due to extreme discomfort.)	2 Hz	105 dB
17.	As above	1 Hz	140 dB
18.	Second Test normal persons: swaying sensation, random horizontal eye movements particularly if simple arithmatic task given.	10 Hz	140 dB
19.	Third Test normal persons: nystagmic response (80% even with eyes closed)	as in No 14	130-146 dB
20	Uneasiness, wish to move without range.	8 Hz	
21.	Severe Physiological effects: oderate chest vibration, gazzing sensation, blurring of vision, ampletude modulation of speech, plus post-exposure fatigue for 24 hrs. after repeated testing.	2 - 100 Hz	
22.	Headaches	50Hz	150-155 dB
23.	Pain on swallowing, giddiness	66,73 Hz	as above
24.	Mild nausea, giddiness, flushing	100 Hz	as above
25.	Increased reaction time by 10% in ½ the subjects of a test group.	2-15 Hz	105 dB

	CPS	SPL
26 Increase in tracking error by 10% in visual experiment	2-15 Hz particularly below 10Hz	95 dB
27. Violent and sudden illness.	12 Hz	85-110 dB
28. Dizziness	10 Hz	115 dB for 5min.
	5 Hz	105 dB " 18 min.
	2 Hz	95 dB " 2 hrs.
29. Seasickness:	As much more moderate levels like found in a wide range of man-made environments, cars, high buildings and below the maximum safe levels for continuous exposure suggested at the Paris meeting: from 120 dB at 20 Hz up to 132 dB at 1 Hz.	
30. Arterial diseases: Hypertension, ulcers: etc.	The general morbidity entailing temproary loss of working capacity is 20-30% higher amongst persons working in noisy environments than in the general population,	
	Prolonged exposure to intense noise also reduces vigilance, slows down motor reactions, decreases muscular strength and diminishes resistance, resulting in a 5-20% drop in productivity and a falling off in work quality.	

Since then, there has been a general collating together of the known work, at least in a number of centres, by Dr. W. Tempest of Salford University and this publication appears to represent a revision of earlier work carried out at that University on the subject of exposure to infrasound.
In recent years, more information has become available on some of the work carried out on the subject in Eastern European countries.

Dr. H. G. Leventhall of Chelsea College, University of London, has carried out considerable work on the subject of low frequency sound and stemming from the work at that centre, it appears that there is a need to pay a great deal more attention to the effect of noise exposure to frequencies above the infrasonic range, to say a range of 100 Hz.

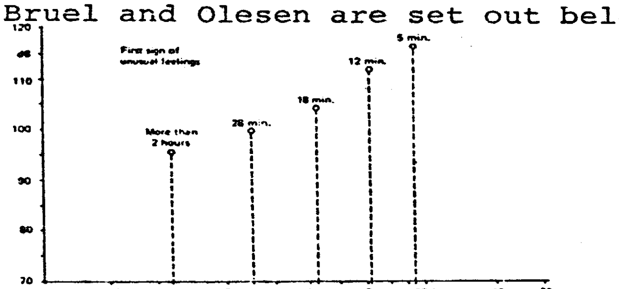
Bruel and Olesen report lower threshold levels than those that appear to be given in other literature. Their work dealt with sickness experienced in high rise buildings stemming from wind turbulence and experience with infrasound at the State Hospital, Copenhagen. Their report also deals with detection levels found within the flexible walls of a small office excited by a vibration exciter.

It was pointed out that although there were many psychological effects in these experiments which reduced the reliability of the results, the effects still appeared even for some of the persons involved who strongly believed that the whole thing was nonsense.

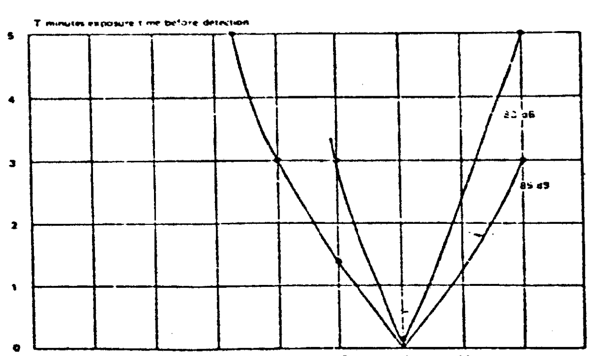
This had been the experience in other locations such as an aeroengine manufacturers plant where the head of the office did not believe in the complaints of his office staff but when installed in the office himself where complaints had been most severe in order to demonstrate that the whole thing was nonsense, he felt seasick after a relatively short time.

It was said that at 12 Hz there was instantaneous and violent ill-feeling experienced by several persons at a relatively low sound level of between 85 and 110 dB.

Graphs relating to exposure excitation time and threshold time relationship by Bruel and Olesen are set out below.



The sensory response of one person to infrasound excitation



The threshold/exposure time relationship around the most sen-

Andreeva-Galanina reporting in the Noise and Vibration Bulletin, January, 1971 drew attention to much greater sound pressure levels in the work place in the sub-sonic range and in the audio range.

It was pointed out that operators at railway compressor stations complained of fatigue, headache, insomnia and general malaise. The fundamental noise source arising from such compressors was the motor with peaks at 800 Hz and at 90 dB.

Andreeva-Galanina pointed out the sub-sonic vibrations due to industrial equipment may be capable of producing specific reactions in man after prolonged exposure further, there was no reason for attributing complaints from men operating at the compressor stations solely to the sub-sonic range.

Low frequency omissions in the infrasonic range and at high amptitudes effect various organs of the body including the liver, spleen and stomach and chest while higher frequencies cause pain in the mouth, throat, bladder and rectum further, fatigue is said to be one of the main psychological effects of sub-sonic vibrations, as a function of intensity and duration of exposure.

Welch, B. L., who like Tempest, brought together much of the work contributed to the Boston conference held in 1969 in his book, "The Physiological Effects of Noise" (Plenum Press, New York, London 1970) and dealt with this subject but more particularly in relation to audio frequencies and ultra frequencies

Nevertheless, he had this to say :

> The body is physiologically responsive to stimulation of the auditory nerve by sound even during sleep, under anaesthesia and, indeed, even after the cerebral hemispheres have been removed.
>
> Sound, either continuous or intermittent, activates subcortical neuronal systems to continually modify the pacing by the brain of cardiovascular, metabolic, endocrine, reproductive and neurological function. These activating neuronal systems are themselves restrained by inhibitory neuronal systems with which they interact, and tonic influences inherent in this interaction determine the level of many peripheral physiological functions.
>
> Bodily functions are different in different stimulus environments. In the truest sense, the individual and his environment are functionally inseparable. They are psychophysiologically linked.

> The weight of evidence available at this time is that the body does not "adapt" to long-term residence in different stimulus environments by maintaining, or returning to, pre-determined and characteristic "normal" levels of peripheral physiological function. Rather, it responds in a sensitive and continuous manner to its stimulus environment, and different basal levels of function are established and maintained according to the dictates of the prevailing Level of Environmental Stimulation.
>
> Pervasive and long-lasting changes are produced even by very short daily exposures to intense stressful stimulation.
>
> It is true that a reasonable amount of stimulation is necessary for normal development, and that in some instances the employment of sound in therapeutic treatment has been proposed. It is also true that habituation occurs with exposure to sound, and that this provides some degree of short-lasting protection against subsequent exposure.
>
> Chronic overstimulation, however, has pathological consequences, and a Level of Environmental Stimulation greater than the optimum is clearly harmful to health. It results in the so-called "diseases of adaptation". In considering the effects of long-term exposure to audible sound, and particularly to high levels of environmental noise, it is with the pathological processes of adaptation that we must be concerned.

The subject of course is not without controversy among different writers.

In the early 1950s work was carried out at the De La Warr laboratories at Oxford, England on the effects of exposure at various frequencies.

De La Warr spent most of life developing the treatment of disease by radionics but much of his earlier work related to not only the effects of noise at various frequencies but also the treatment of disease by noise.

His work did not receive the recognition it should have borne at that time.

There is little published material in respect to that area of De La Warr's work except to say that frequencies of 133, 264 and 255 Hz would bring about a dryness of the throat and that the heart muscle was affected by a combination of 105, 160 and 214 Hz. Frequencies of 98, 132 and 234 Hz affected the speech area of the brain.

Del De La Warr's ventures into ascoustics lead to a great deal of work being done in respect to the acceleration of growth in agriculture, an area where there is already a fair quantity

Lord Horder in the 1950s said that we were dying in great numbers from functional diseases such as coronary thrombosis, arterial-sclerosis and diabetes, and in all these maladies noise played a part.

FIELD MEASUREMENTS

The following measurements were required using a Bruel and Kjaer 2209 model sound level metre with a Bruel and Kjaer model 1621 filter set and model 2306 graphic pen recorder.

The microphone used is a 4165.

The model 2209 has a lower limiting frequency of 2 Hz. The microphone is accurate to 3 Hz with slight drop-off consideration needed to be given to the area between 2 and 3 Hz.

All readings represent a 23% octave band width.

Unless otherwise indicated on the graph the microphone was placed to the right side of the drivers face. The driver is situated on the left side of the cabin. In a number of readings the drivers window (on the left of the driver) is in the open position. With each reading or in the case of 2 graphs to a single page unless indicated differently on each graph, a key is given illustrating the position of doors and windows. Where neither particular type doors or windows are provided in the cab or are closed, a stroke is shown in a space provided and the letter (O) is shown to indicate where either a particular door or window is in the open position. All readings were taken clear of cuttings of any significance that is to say were taken in relatively open area unless otherwise indicated.

Most graphs have marked in on them wheather the locomotive was powering or coasting. Where the locomotive or train is coasting or iadling then this is usually shown by the word coast or idle particuly with a diesal loco and when under power the letters 'th' or '8th' or '8' throtle is shown. Electric type trains are an exception since there is no real problem with these wheather coasting or powering.

THE ELECTRIC LOCOMOTIVE (46 class)

The paper concentrates mostly on other type locomotives or trains but in passing some reference will be made to the electric locomotive.

The main noise source from the electric locomotive is the main generator and intermitant compressor noise as the compressor is required to replenish the air supply of the train and the locomotive. As with many other type trains, track noise masks machinery source noises once a certain track speed is reached. Sound pressure levels reaching 106-108 dB up to 38 Hz will be experienced at moderate speed with peaks exceeding 110 dB between 20 and 26 Hz.

Cab Noise Levels - Self Propelled Type Trains

The self propelled type train is a multiple unit type train powered by diesel units slung beneath the car chassis on passenger conveying power cars distributed throughout the length of the train. Such power cars operate remotely from the leading power car, similar to a suburban electric train or to use the terminology applying in a number of other countries, similar to "emu's".

Figures 1,2 and 3 represent those taken on a Budd type car, which has an air conditioned cabin. The first reading was taken while the train was stationary.

The reading below indicates SPL peaks at 4-5 Hz and 9-10 Hz of 112 dB and at 18-20 Hz of 110 dB. A cross wind was entering the driver's cab window on the driver's side.

Various other readings under coasting and idling conditions, at frequency ranges between 2.5 Hz and 8 Hz indicated sound pressure levels of between 96 and 114 dB in areas which were not susceptible to cross wind problems.

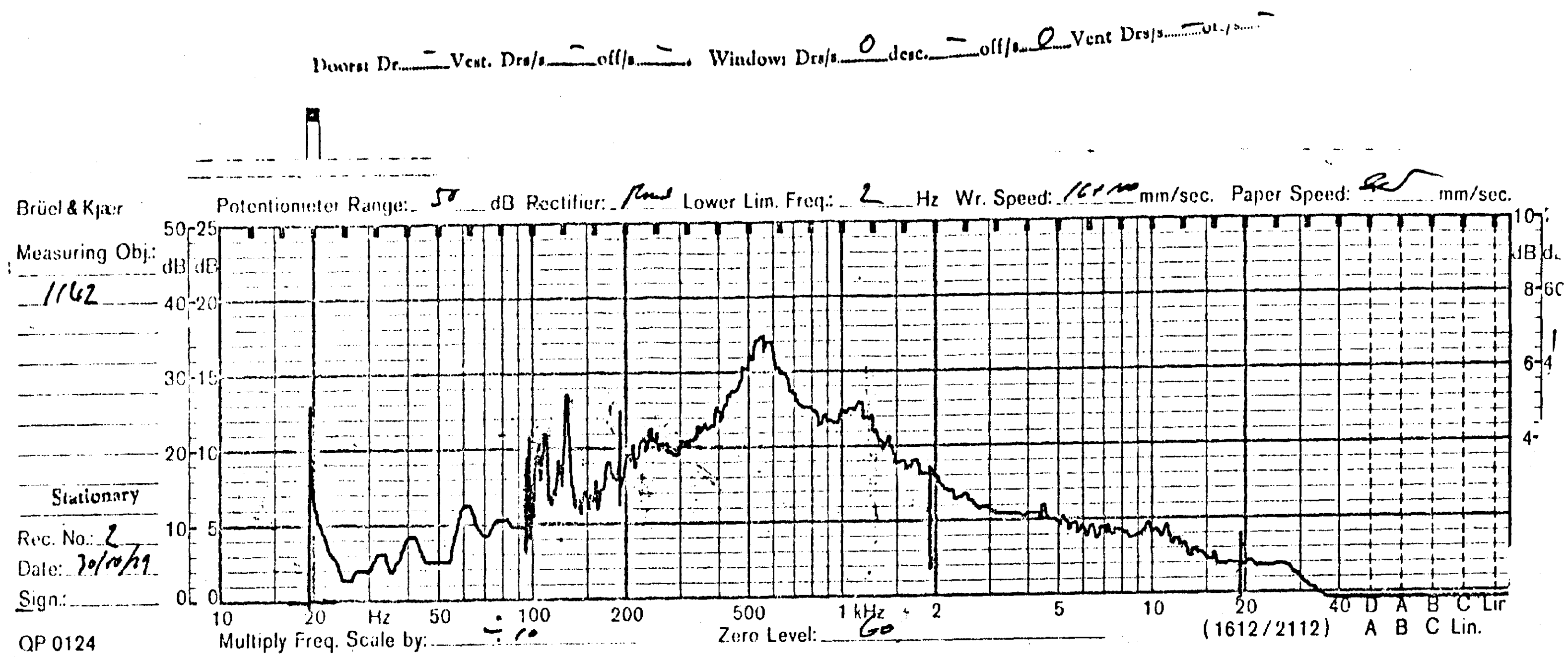


Figure 1

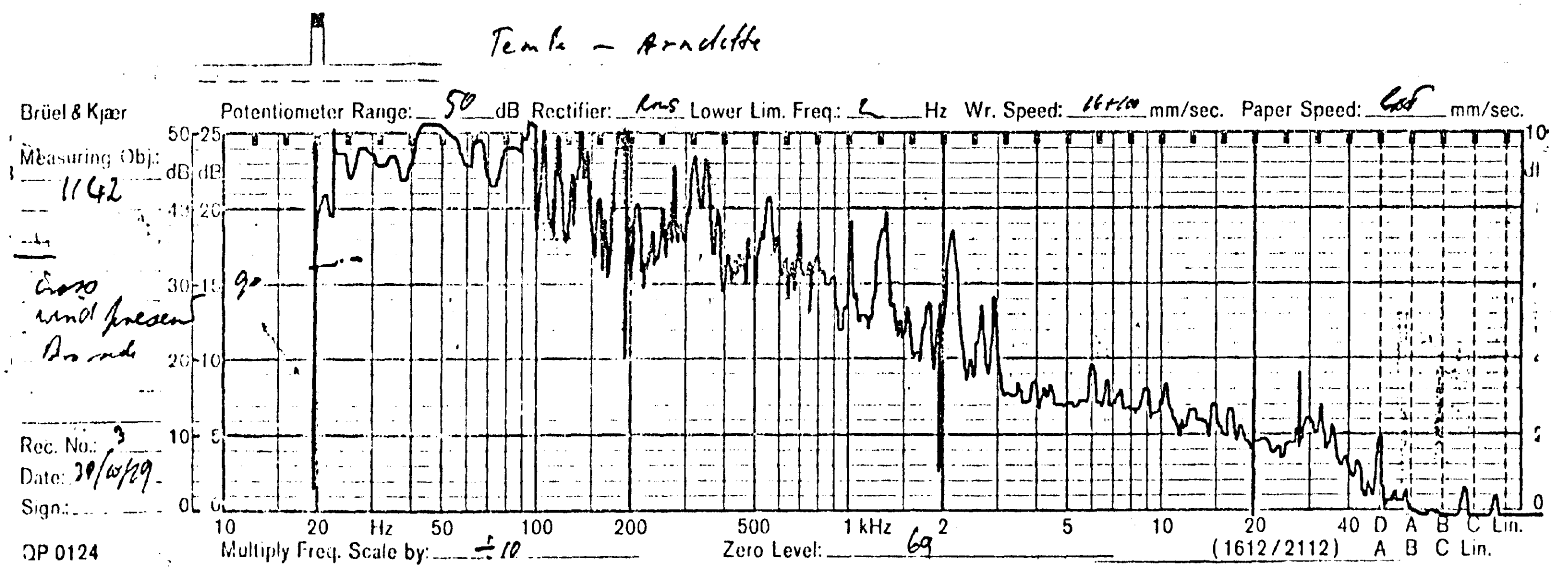


Figure 2

On yet another type self propelled type train of a different manufacture and style, with all windows and doors closed and travelling at speeds of 95 k.p.h. the sound pressure level reached 112 dB at 6 Hz. dB(A) readings taken at 70 and 75 k.p.h. indicated sound pressure levels of between 75 and 83 dB(A) whether coasting or powering. The readings taken in this drivers cabin is illustrated below viz. car 956.

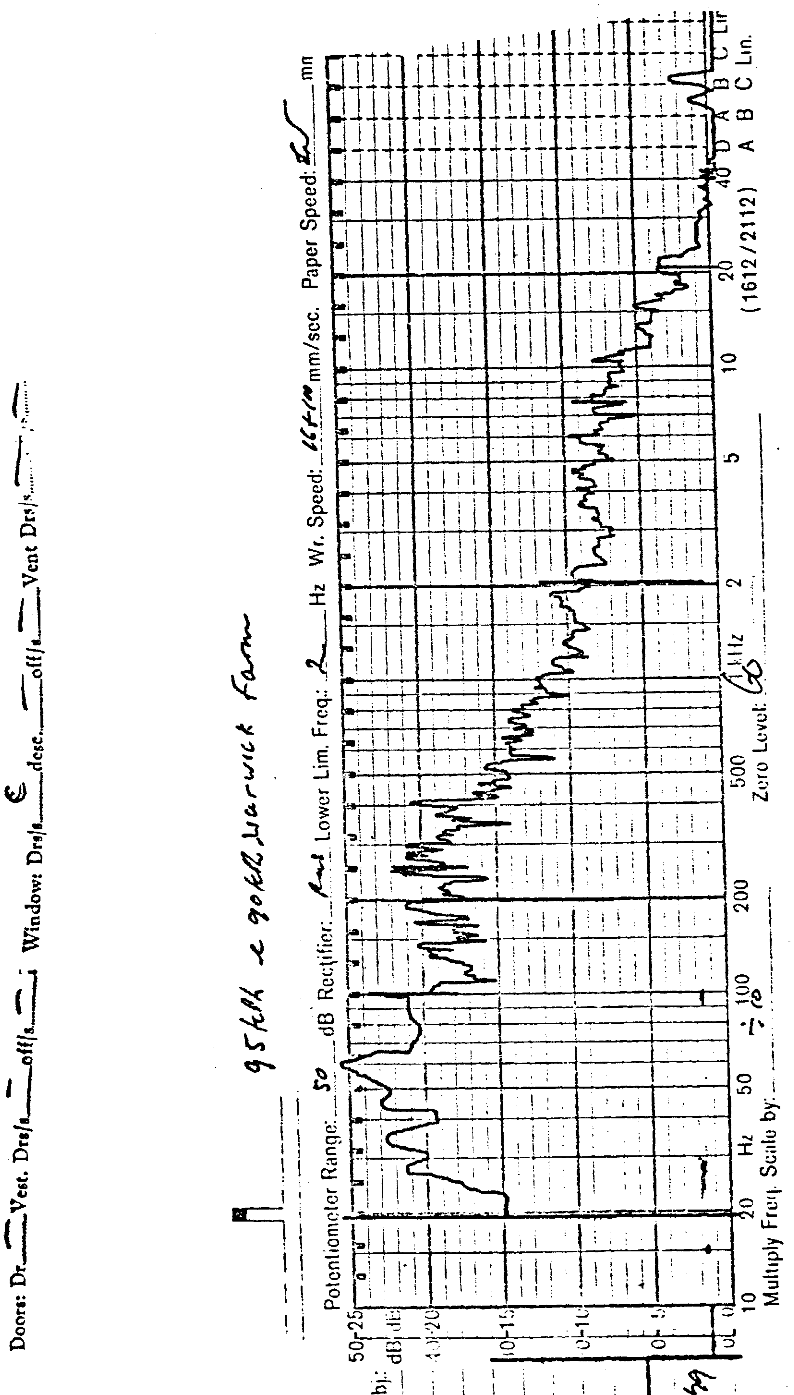


Figure 3

The Diesel-electric Locomotive - Cab Noise Levels

The following graphs illustrate a situation that is fairly typical of many locomotive cab readings, namely the rise in track noise level over diesel engine noise level at a certain train speed.

The locomotive involved here is a 45 Class locomotive No.4539, driven by a 16 cylinder 4 cycle diesel engine, providing power to a main generator for the electric axle slung traction motors. A 1,000 h.p. 48 class locomotive is coupled as a second locomotive. The load is 920 tonnes for 17 vehicles equal to 48 in length. Reading No. 1 represents the noise levels over the frequency range 2 hertz - 4,000 hertz, climbing at fairly low speed out of Darling Harbour towards Redfern. The reading has been taken in a cutting beyond the Darling Harbour tunnel exit. It will be noted that the two sound pressure peaks that are prominent are at 26 hertz and 82 hertz. A more general description of where the measurements were done would be more suitable.

Figure 5 shows the noise spectrum in the same train at 60 k.p.h. in open surroundings. The previous infrasonic area spectrum has risen to an extent where there are predominant peaks of 88 db between 2 hertz and 10 hertz and the predominant main peak of 26 hertz is shown again here at about 28 hertz.

The third reading of the same train, taken between Petersham and Summer Hill, is at a speed of 75 k.p.h. and on this occasion, the diesel power plant is idling, since the train is coasting downhill. The peak now is seen to be at about 4.2 hertz and the sound pressure level now is 108 decibels.

Noise levels in the infrasonic range are up to an area ranging between 96 decibals and 102 decibals setting aside for the moment the peak of 108 decibels.

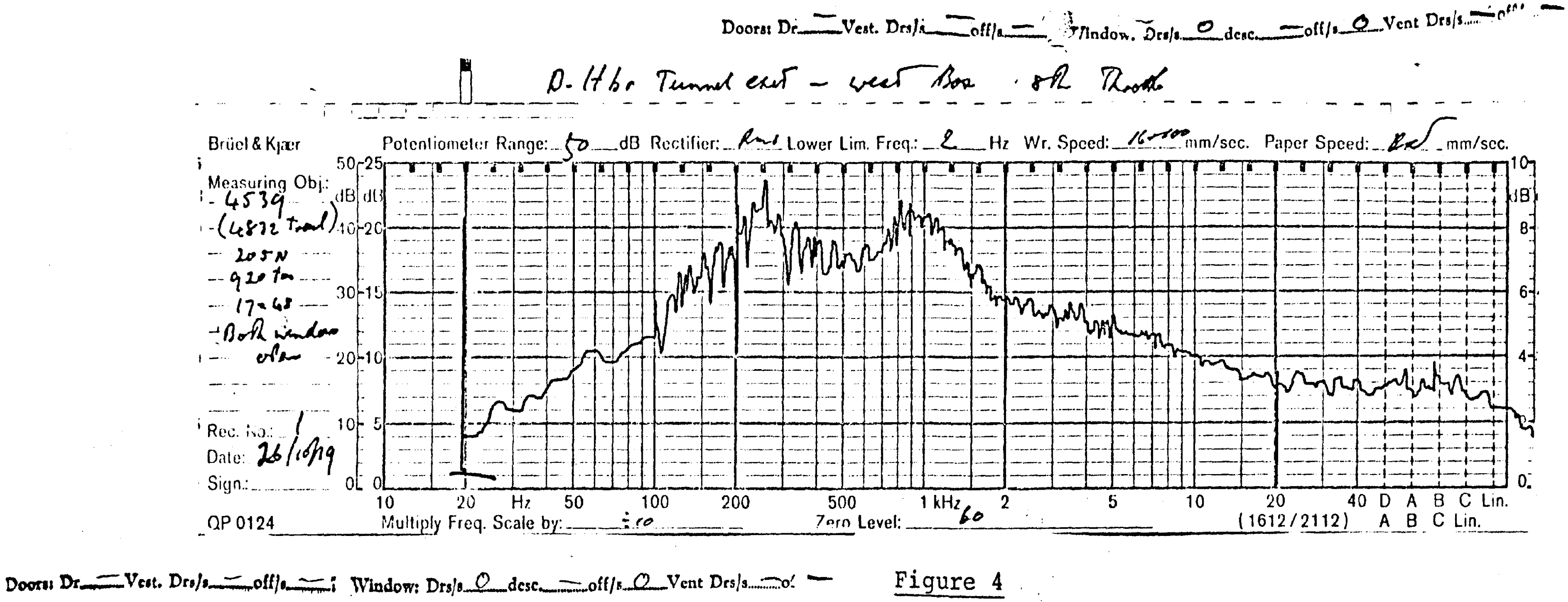


Figure 4

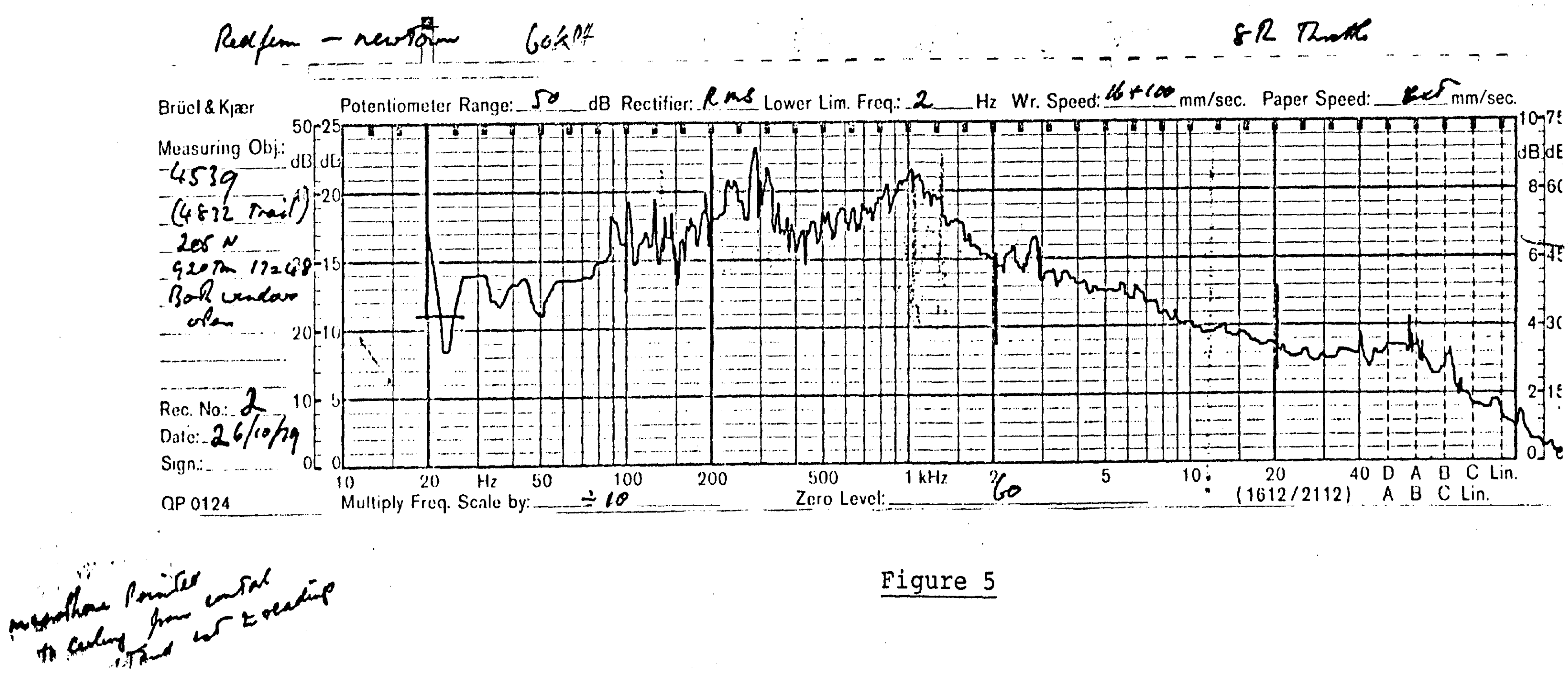
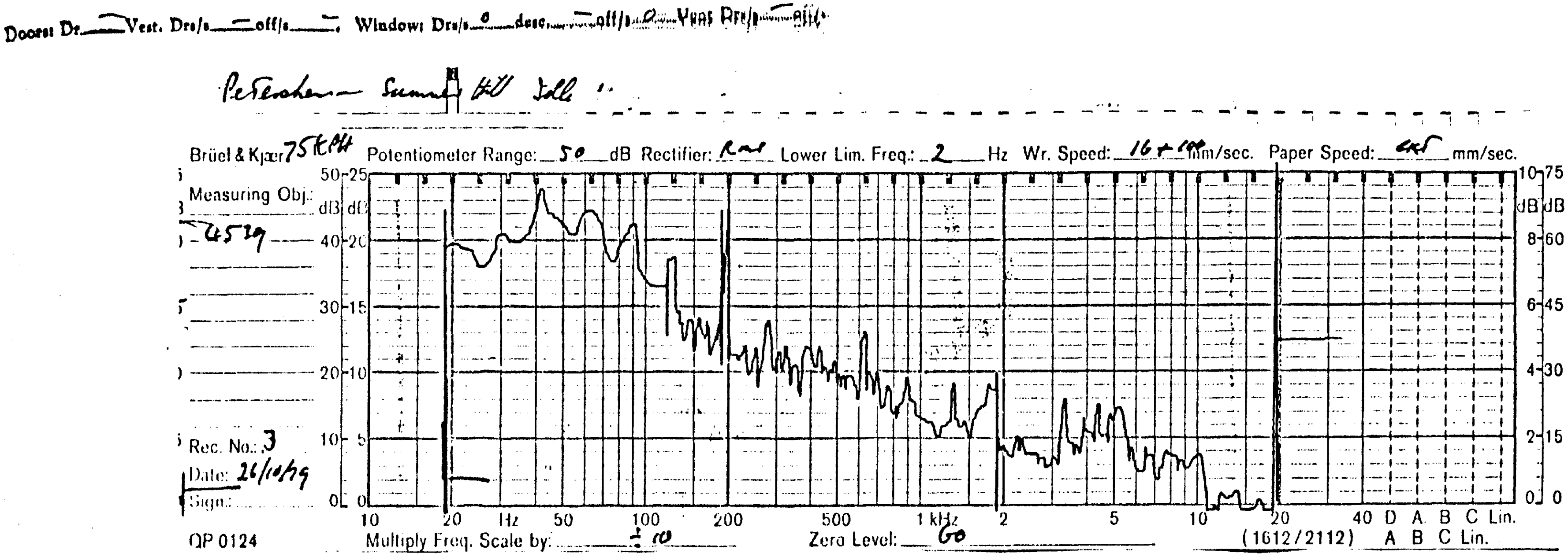


Figure 5



Doors: Dr. Vest. Drs/s off/s Windows Drs/s 0 desc off/s 0 Vans Drs/s
Brüel & Kjær
Potentiometer Range: 50 dB Rectifier:
Lower Lim. Freq.: 2 Hz
Wr. Speed: mm/sec.
Paper Speed: mm/sec.
Measuring Obj.:
Rec. No.: 3
Date: 26/10/79
Sign.:
QP 0124
Multiply Freq. Scale by:
Zero Level: 60
10 20 Hz 50 100 200 500 1 kHz 2 5 10 20 40
D A B C Lin.
(1612/2112) A B C Lin.
50 40 30 20 10 0
25 20 15 10 5 0
10 8 6 4 2 0
75 60 45 30 15 0
dB

Figure 6

Subsequently, some readings were taken at selected frequencies at one third octave band width. Of significance, are the following readings -

Figure 7 - 57 k.p.h. at full throttle and 3.1 Hz approximated 100 dB.

Figure_8 - at 2.5 Hz indicates varying speeds ranging from 30 k.p.h. with engine idle to 55 k.p.h. when the engine is then placed in full throttle, i.e., 8 Th where the sound pressure level then reaches 104 dB and continues to approximate this level, rising to 106 dB as the locomotives slow to 30 k.p.h. on the heavy grade beyond Cheltenham.

Both the driver and observers' side window was in the open position during all readings. A dB(A) reading taken at Concord West at 65 k.p.h. with the engine in full throttle indicates S.P.L. of approximately 89 dB(A) and with the diesel power unit returned to the idle position as the speed reaches 70 k.p.h., this level drops to approximately 83 dB(A).

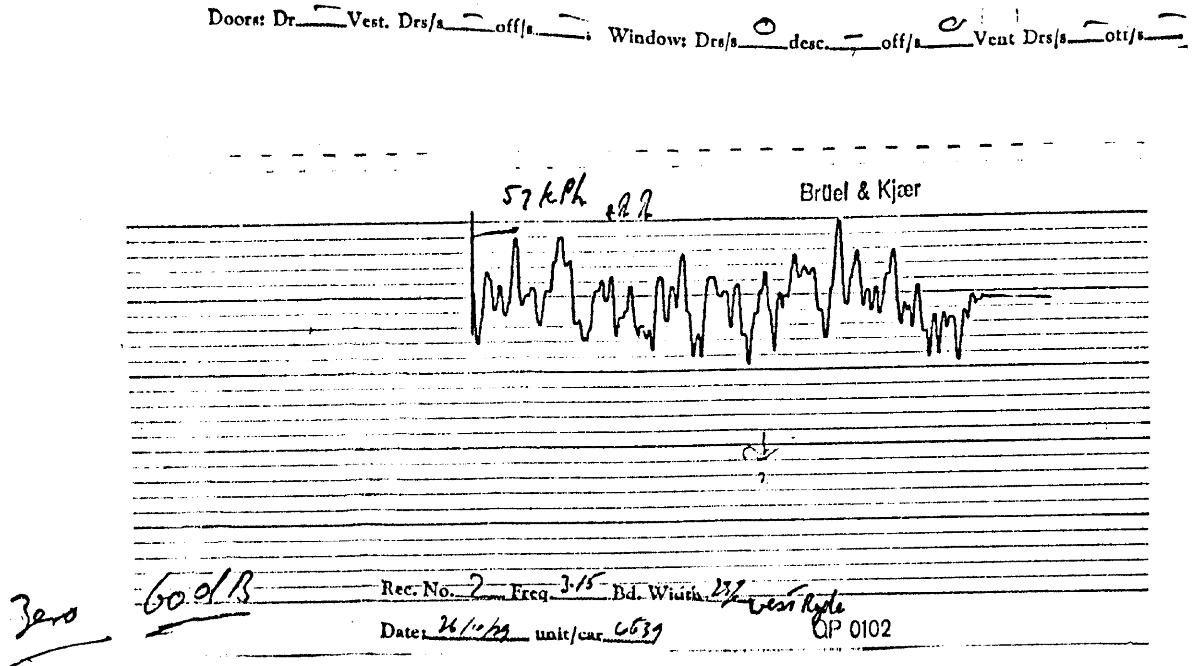


Figure 7

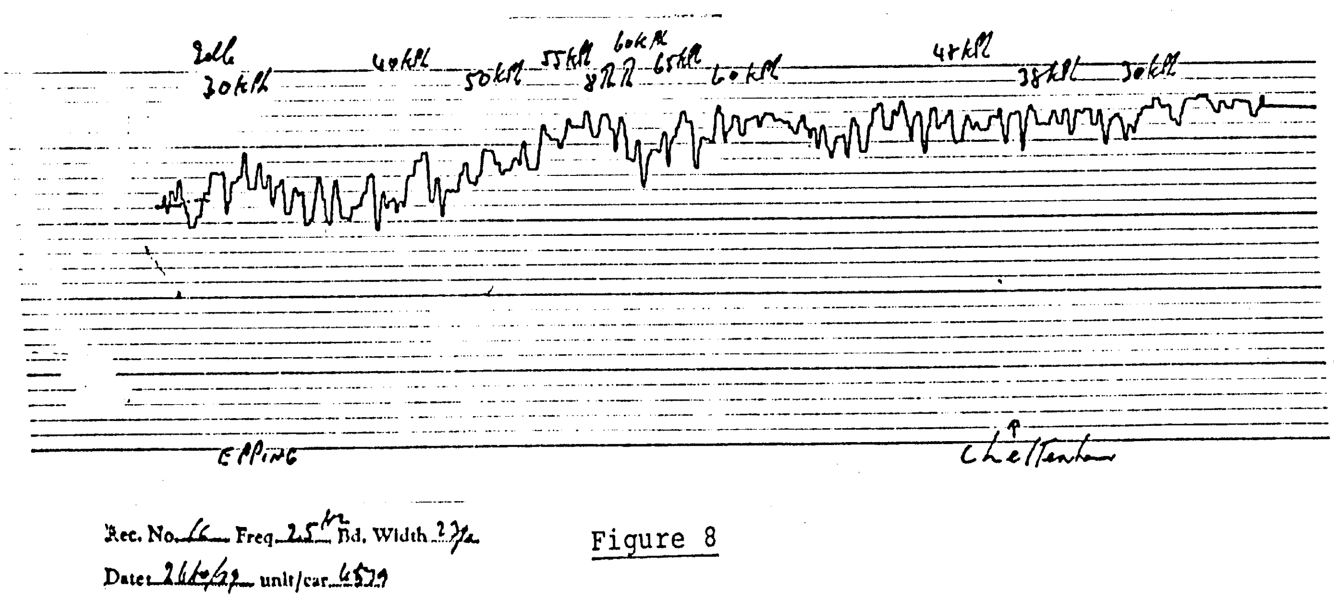


Figure 8

Locomotive 4445 (Diesel - Electric Locomotive)

This is also a 1600 h.p. Alco locomotive, this time working an express train. The dB(A) sound pressure level accellerating out of Sydney Station approximated 80 dB(A), rising to an approximate 86 dB(A) and 80 k.p.h.

At a speed of 100 k.p.h., 4445, 11.9.79, near Croydon, a reading of the frequency range of the sound pressure level in the cab revealed a peak of about 112 dB at 8-9 Hz and 100 dB and 5 and 6.5 Hz. A graph is shown below.

See Figure 9 overleaf.

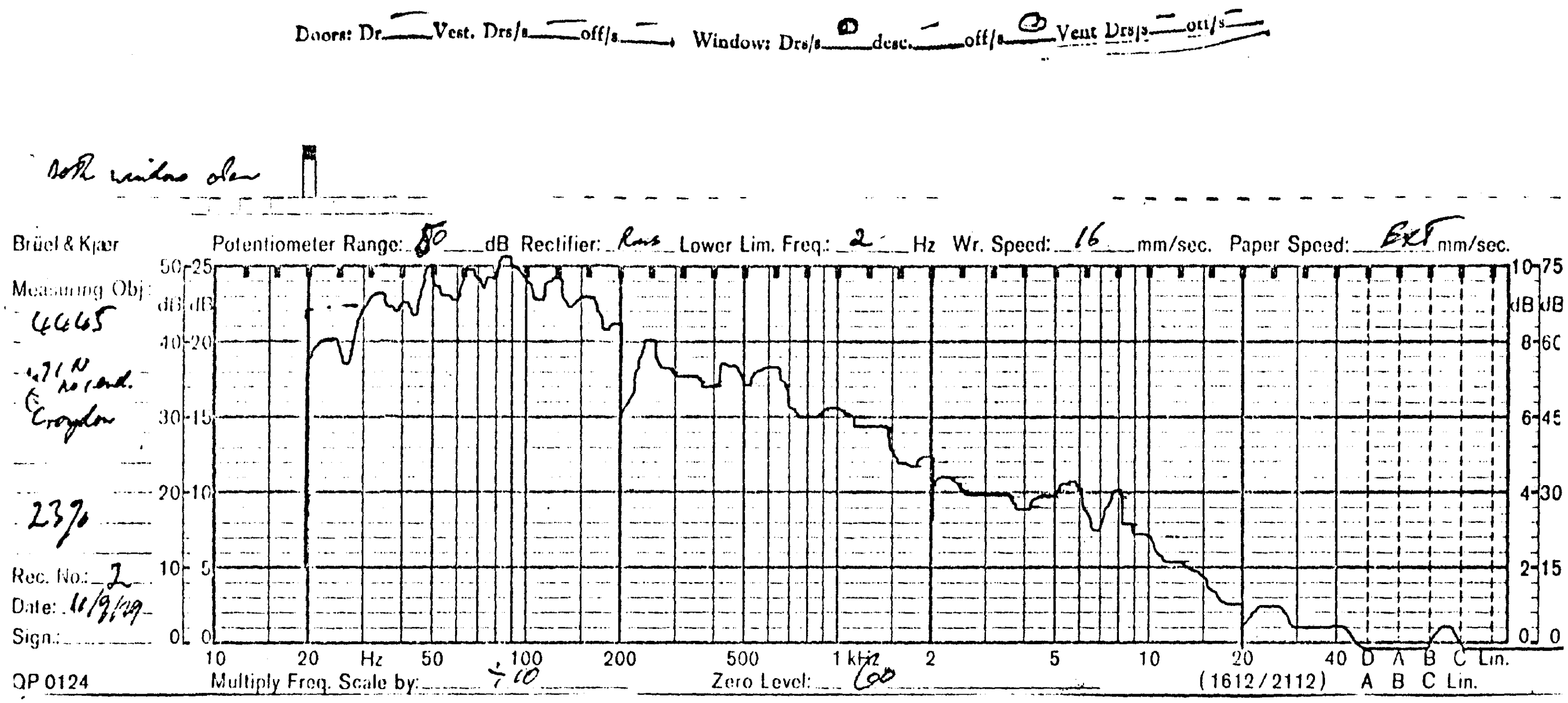

Doors: Dr. Vest. Drs/s off/s Window: Drs/s desc. off/s Vent Drs/s off/s
Brüel & Kjær
Measuring Obj:
Rec. No.:
Date:
Sign.:
QP 0124
Potentiometer Range: dB Rectifier: Lower Lim. Freq.: Hz Wr. Speed: mm/sec. Paper Speed: mm/sec.
50-25
dB dB
40-20
30-15
20-10
10-5
0 0
10-75
dB dB
8-60
6-45
4-30
2-15
0 0
10 20 Hz 50 100 200 500 1 kHz 2 5 10 20 40 D A B C Lin.
Multiply Freq. Scale by:
Zero Level:
(1612/2112)
A B C Lin.

Figure 9

Double Deck Electric Multiple Unit Inter-urban Train

The double deck inter-urban train is similar to a suburban double deck multiple unit electric train powered solely by axle slung traction motors and power cars marshalled periodically throughout the train.

In terms of audible sound levels, the cab of the double deck inter-urban train, is almost as environmentally satisfying as a city elevator.

The graphs indicated below show that there is a fairly high infrasonic and low frequency sound pressure level present. Car 8031 is used for the recordings.
Figure 10 indicates the reading with the train climbing steep grades 1 in 40(Hawkesbury River - Cowan Bank) clear of cuttings and at a speed of 60 k.p.h. Note that the zero level of this graph is 50 dB.

Figures 11 and 12 are further readings of the sound pressure levels climbing Hawkesbury River bank.

Figure 13 indicates sound pressure levels at 3.15 hertz and at a speed of 80 k.p.h. Zero line in the first section of the graph is set at 50 dB. It is later changed to 70 dB to accommodate the high infrasonic sound pressure levels. Figures 13, 14 and 15 (Rec. 8,9 and 11 appear on frequency spectrum graph paper) Cab and offside window was in the open position.

A dB(A) reading in the same cab, indicated a level approximating 78 dB(A) and ranging between 74 dB(A) and 82 dB(A).

Figure 14 shows the sound pressure level at 40 Hz. The train is departing Hornsby Station and accellerates to a speed of 100 k.p.h. Note that the zero line in this case is 70 dB. Riding speed commenced at 100 ml. per second but was changed to 16 ml. per second in order to avoid cramping the pen etchings.

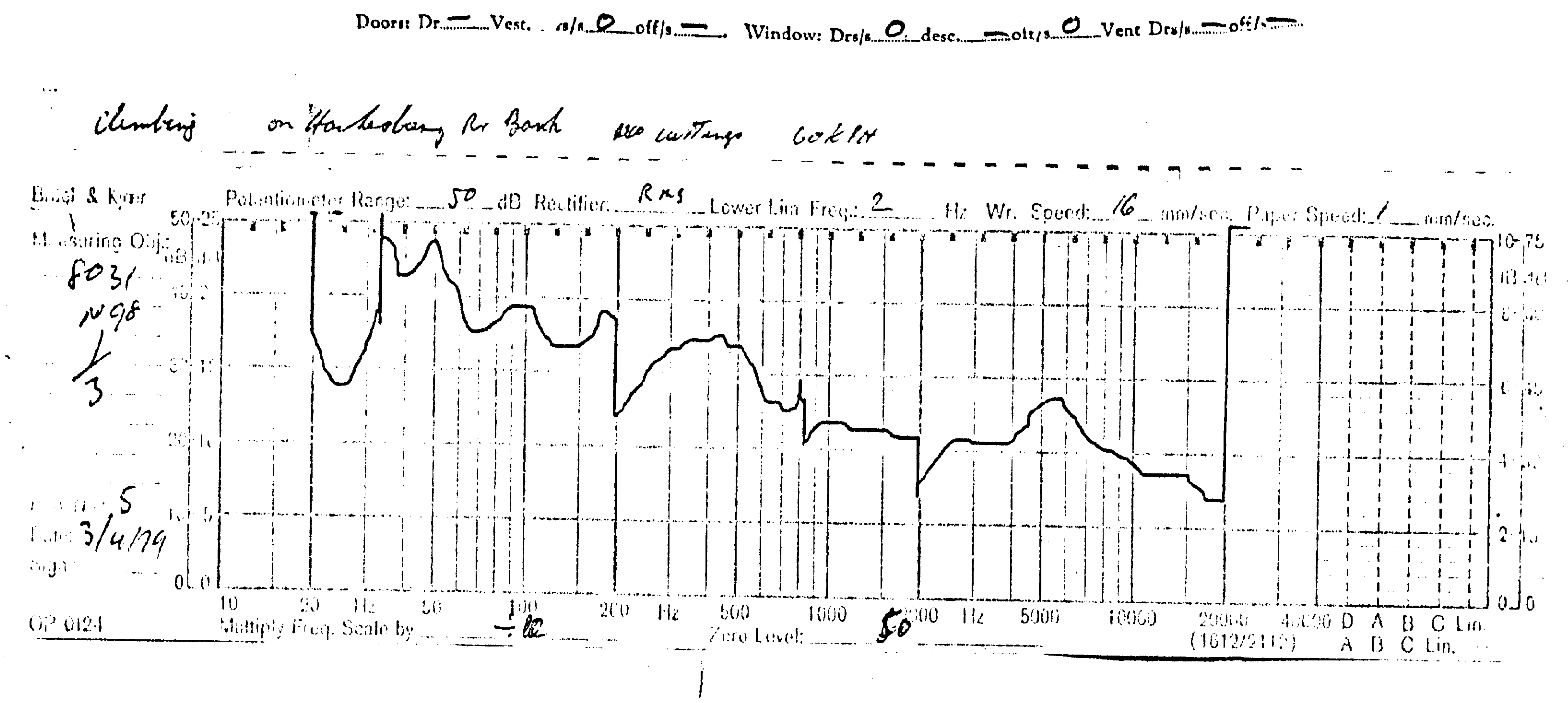

Doors: Dr. — Vest. o/s 0 off/s — Window: Drs/s 0 desc. — olt/s 0 Vent Drs/s — off/s —
Brüel & Kjær
Measuring Obj.:
Potentiometer Range: 50 dB Rectifier: RMS Lower Lim. Freq.: 2 Hz Wr. Speed: 16 mm/sec. Paper Speed: 1 mm/sec.
Multiply Freq. Scale by
Zero Level: 50
QP 0124
10 20 Hz 50 100 200 Hz 500 1000 5000 10000 20000 40000
A B C Lin.

Figure 10

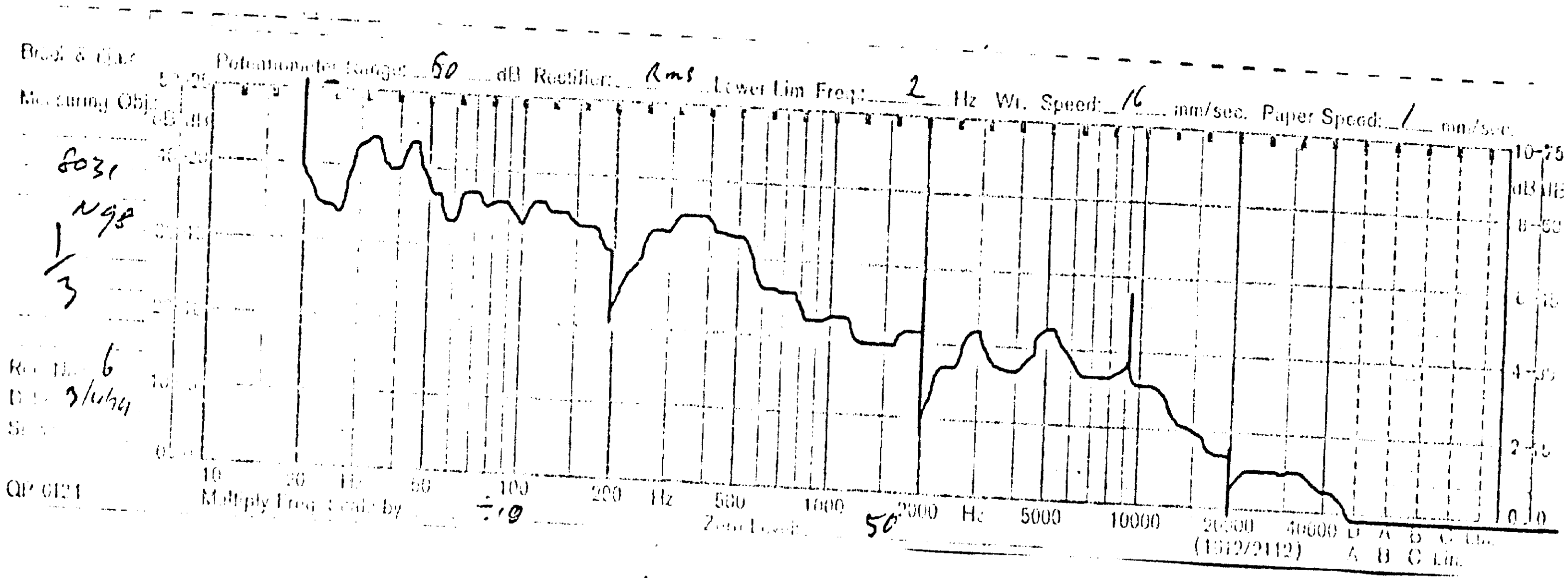


Figure 11

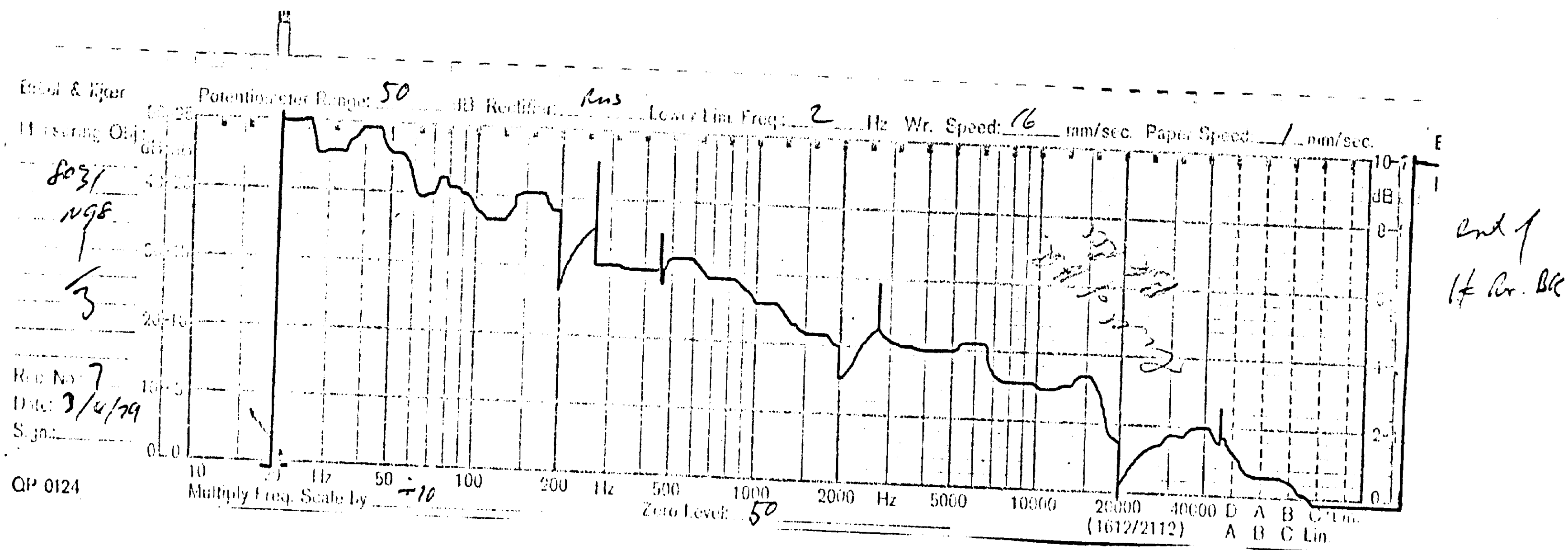


Figure 12

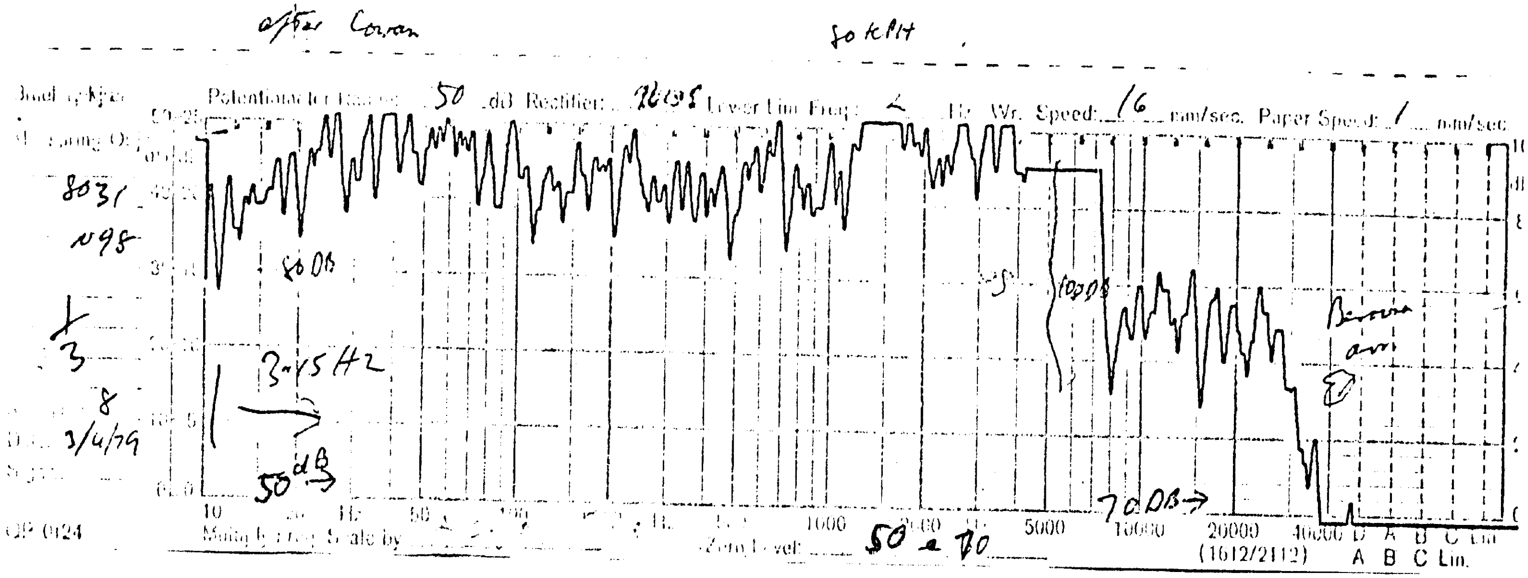


Figure 13

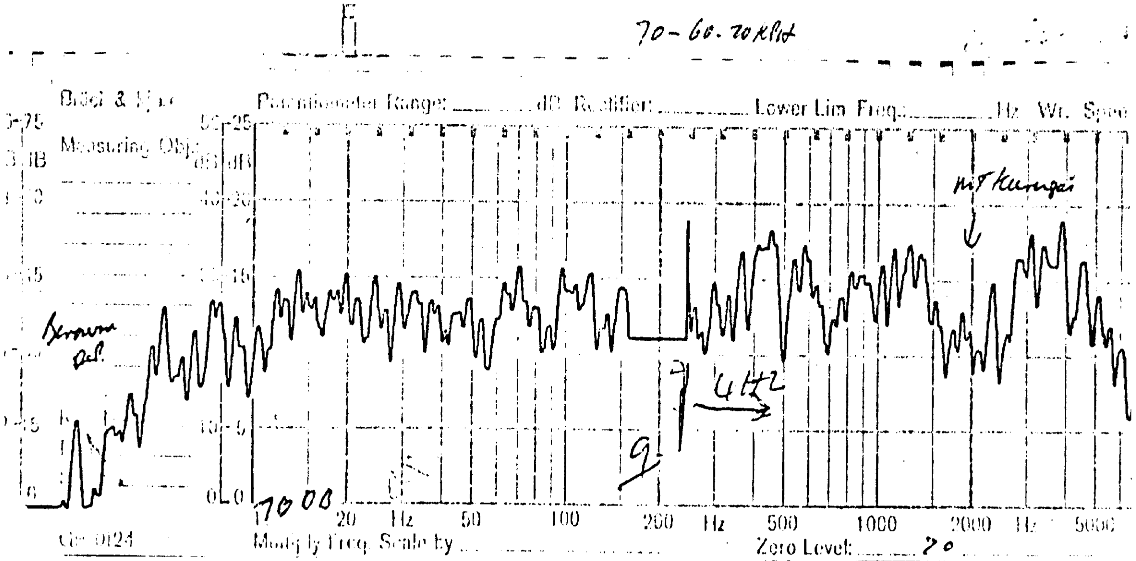


Figure 14

Cont'd

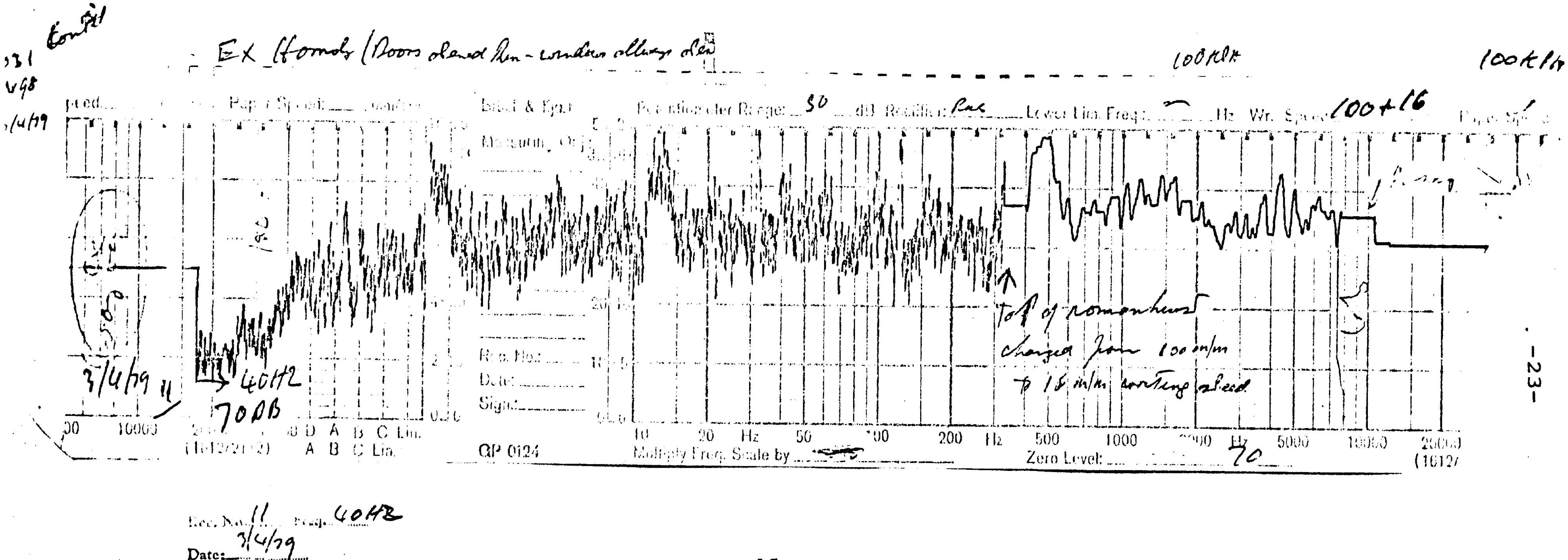

Ex (Homes (Doors closed Rm - windows always open)
Paper Speed
Potentiometer Range 50 dB
Rectifier
Lower Lim. Freq.
Hz
Wr. Speed 100+16
100KHz
Top of romonhues changed from 100 m/m to 16 m/m writing speed
3/4/79
40HZ
70DB
Rec. No.
Date
Sign.
QP 0124
Multiply Freq. Scale by
Zero Level
70
10
20
Hz
50
100
200
Hz
500
1000
5000
10000
20000
Rec. No. 11
Freq. 40HZ
Date: 3/4/79

Figure 15

The Eastern Suburbs Railway

As indicated earlier in this paper, there was some distinct problems with noise levels on this line actually prior to the line being open for public services. Only double deck cars operate on the Eastern Suburbs Railway.

dB(A) readings with windows and doors open reached sound pressure levels of 110 dB(A).

Peaks of 120 dB were experienced at 2.5 Hz, 3.15 Hz, 4 Hz, 10 Hz and 12.5 Hz and on one occasion, a peak of 124 dB was experienced at 12.5 Hz, all of these levels being reached in the underground section.

As with many other readings, the filter set was set at selected frequencies and continuous runs made from one station to the next at such frequencies in order to establish the various SPL changes from one point to another along the line.

Sound pressure levels on the viaduct sections of the line were much less, but still nevertheless, relatively high, being largely around the 100 to 112 dB in the infrasonic range as well as at frequencies measured up to 630 Hz, still on the viaduct area and in the tunnelled areas to 125 dB and certainly a number of peaks at 115 dB.

Air pressure changes as the train entered the tunnel section brought about severe middle ear disturbances to a large number of enginemen working this line.

There appears to be some easing of the sound pressure levels following the wearing in of rails both by grinding processes and by train operations themselves, now for a period of time, since the line was opened. Nevertheless, there is still a problem of relatively high infrasonic and low frequency noise exposure on this line and the number of shifts that a driver is required to work on the line, as a result, amounts to two round trips. The total journey, in one direction is 11 minutes and there is some turnaround time involved in changing ends to operate in the return direction.

Suburban Electric Trains - Overground System

There are both double deck and single deck type suburban electric services on this system. The double deck driver's cab opens out into a large guard's compartment, which may, if desired, also house the guard, on a particular trip. Some single deck cabs do likewise but most are represented merely by a partition across the width of the car leaving a narrow space some 3 feet wide across the breadth of the car front. In all cabs, there is a terminal gangway door, kept locked of course, when the driver occupies that car. The door is susceptible to air leaks, sometimes reaching an audible whistling level.

Recordings taken on old type stock of the above description with the driver's window closed indicate a sound pressure level of several peaks ranking between 104 and 106 dB at frequencies of 4 Hz, 6-7 Hz, and 15 Hz. There is no speedometer operating on old stock and it does not always work,where provided on new double deck stock, but the speed on the reading taken as a sample, would be approximating 75-80 k.p.h. (3185 REC. 4.24/4/79) Figure 16.

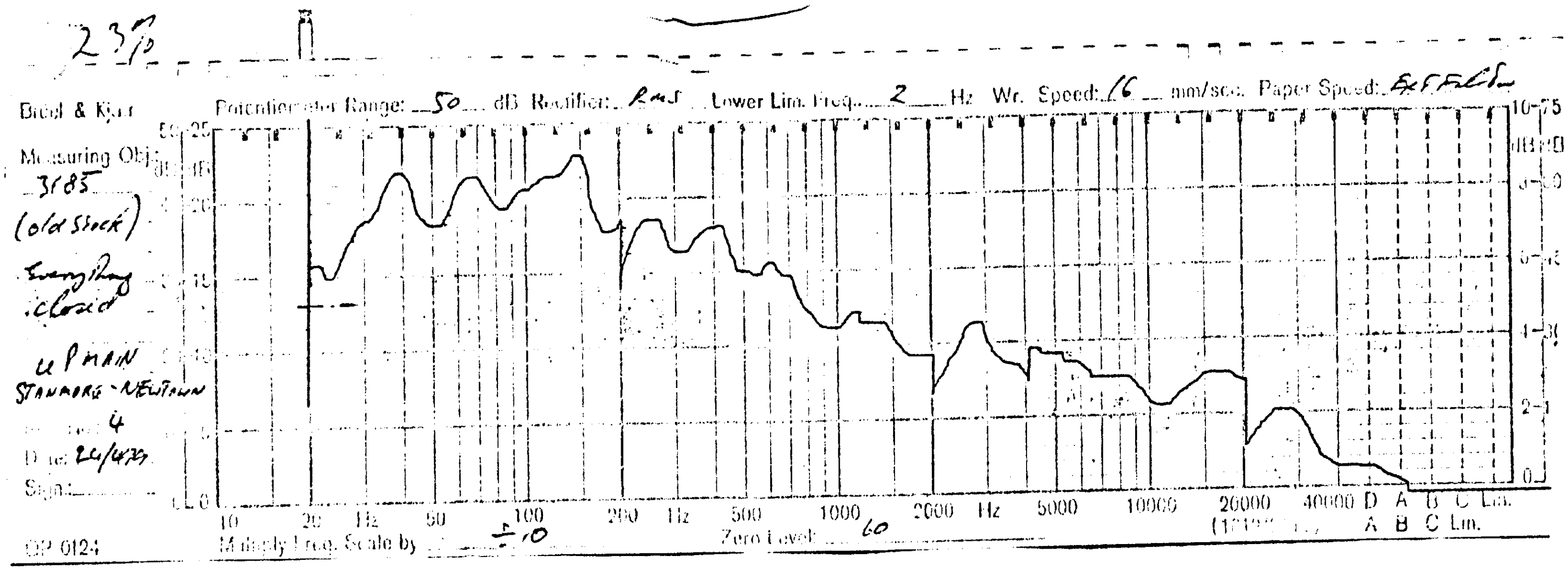
A dB(A) reading at a similar speed would be approximately 78 dB(A). Higher speeds may take this to 90 dB(A).

A window open situation would raise the dB(A) levels to between 80 and 90 dB(A) at similar speeds.

Similar dB(A) readings would be experienced with double deck rolling stock with guards' compartments vestibule entry doors open or with single deck stock in similar circumstances.

Various readings have been taken on various suburban stock of sound pressure levels at various frequencies with peaks being experienced in open country area of up to 108 dB at frequency ranges of between 6.3 Hz and 10 Hz.

Some much higher levels have been recorded, ranging to peaks of 122 dB at frequencies of between 2.5 and 12.5 Hz particularly when passing another train and with the driver's window closed but vestibule doors to platform open.



Doors: Dr.—Vest. Drs/s.—off/s.—; Window: Drs/s.—desc.—off/s.—Vent Drs/s.—

Figure 16

'A' Weighted Readings

The public transport commission conducted a number of dose meter tests on both overground and eastern suburbs trains which produced fairly high readings.

Our own tests using a Bruel and Kjaer graphic recorder coupled to a Bruel and Kjaer 2209 sound level meter revealed peak noise pressure level of up to 110 dB (A) with both windows and doors open. This is a situation which is normal during summer months for suburban train drivers.

Public Transport Commission dose tests of readings for the overground running of the Sydney suburban system taken during April 1979 are as follows:-

THE OVERGROUND SYSTEM

Results of Noise Dose Tests in Driver's Cabs

in 'Open' Running - April 1979

Trip	Openings	Leq.	Remarks
Strathfield - City Circle	Window Open	88	
Central - Bankstown - Blacktown.	Window Open	98	
Emu Plains - Hornsby	Window Open	88	
Hornsby - Central	Window Open	88	
Central - Sutherland - Central	Window Open	87	
Emu Plains - Redfern	Window Open	88	
Redfern - Emu Plains	Window Open	89	Wind noise
Clyde - Carlingford	Door Open	89	
Lverpool - Central	Door Open	89	
ntral - Liverpool	Door Open	89	
East Hills - Central	Door Open	90	
Homebush - Redfern via City Circle	Window Open	90	Whistling noise at door
Lidcombe - Campbelltown	Window Open	89	Several Detonators
ynyard - East Hills	Door Open	90	

EASTERN SUBURBS RAILWAY

INITIAL SPEED TEST.

" Initial testing was carried out on the Woollahra - Edgecliff Section to determine variations in levels with combinations of cab windows open and closed. These results are tabulated below (Table 1). Bruel and Kjaer Precision noise level meters were used."

Table 1

Noise Level Variation with speed, Driver's cab.

	Condition			
Speed km/h	All Windows Open	All Windows Closed	Driver's Window Open Only	Driver's Window Closed Only
80	99	89	99	94
70	98	88	97	93
60	96 95*	86	96	92
50	95	84	93	88

Note: All levels in dB(A). Level marked * is Goninan's Cab.

1. EASTERN SUBURBS RAILWAY:

Noise Dose Test

"Tests on 10.4.79 were carried out on a Comeng 2-Car set. For comparison a Goninan's power car was used on the second day's testing in a 4-car set.

In conjunction with Timetable information for various speeds, it was decided that further testing would be confined to maximum speeds of 60 and 70 Km/h to attempt to reduce driver noise dose.

Drivers were fitted with a Genrad noise dosimeter which was read after complete run (Central - Bondi Junction - Central). The other dosimeter was left in the cab (Comeng car) which trailed into Bondi Junction, to allow direct comparsion with a similar test carried out on the Goninan's car."

It is said that overground tests are applicable to double desk driving cabs. This being so it could be presumed that single deck driving cabins would assume peak sound pressure levels some five decibels higher then these based on our field measurement using a sound level meter.

Having a wide experience of both diesel and electric train cab operating conditions the writer estimates that the dose system are overstated but if correct then they are certainly a cause for concern.

These test runs would confuse a considerable amount of standing time at various stations along the route where the sound pressure levels would be insignificant. Thoughout a drivers shift he would have a certain amount of changeover time with other train runs.

The question of reconciling dose meter test resulting with sound meter test results aroused concern and so a Genrad noise dose meter was obtained of the same type and a series of tests commenced These tests have not been precisely the same as those of the Public Transport Commission. Never the less the dose levels appear to be higher then peaks experienced using the sound level meter.

A test was therefore run between Unanderra and Domnarton in the cab of a diesel locomotive. The track profile here is that of a constant heavy rising grade and so therefore we were able to control the noise emmission of the Diesal electric locomotive throughout the whole of the climb. The microphone of the dose level meter was attached beside the 4165 microphone of the 2209 sound level meter.

Both sets of equipment were switched on simultaneously at the beginning of the test and switched off the same time at the end of the test. The readings coincided fairly well.

Bruel writing in the Bruel and Kjaer Technical review (No 1 of 1976) raises the issue whether we measure inpulse noise correctly and developed the question of energy content of impulse type sound emissions. The issue raised was the need for dose meters with much faster response to impulse type noise exposure yet were thus so, then the disparaty in issue here would be greater.

Locomotive enginemen are exposed to a certain amount of impulse noise, perhaps to a lesser extent today then on a steam locomotive. The question of the dispute between dose meter levels and sound meter levels is not fully resolved.

This is a side issue to the problem of low frequency and infrasonic noise levels but some mention is made of the matter since the union experiences weekly a stream of compensation claims for hearing loss resulting from noise exposure in the locomotive cab. Claims of up to $7000 and $8000 thousand dollars are being met in some cases. Noise exposure is therefore of concern to locomotive enginemen.

<u>SUMMARY</u>

The unions special concern is in respect to low frequency noise for reasons already stated hence its interest in embarking into this area of research over the past few years.

Wheel to rail noise is obviously a predominant feature of cab noise levels to which locomotive enginemen are exposed. There is a great deal of literature published on this subject and there are certainly ways and means of reducing such noise levels.

Diesel engine noise, and emissions from other components of the locomotives such as traction motor whine, and other components which reach the locomotive cab can also be reduced by various conservation methods available today.

All of these sources produce an unacceptable high level of low frequency noise. The technology to deal with dampening of noise and vibration emissions from machinery has advanced dramatically over the last number of years, this was particularly borne out by many papers given at the I.L.O. noise symposium held in Dresden late last year.

Ultimately, the air conditioned locomotive cab will be the only total solution to reducing noise levels from external sources such as wheel/rail noise, at least to an acceptable level since the remedy and the technology for reducing such levels is by no means a simple one.

There is a need for a great deal more work to be done on respect to field measurement of infrasound and low frequency noise exposure and also as to the clinical effects of this area of the noise spectrum.