COMMUNITY RESPONSE TO AIRCRAFT NOISE IN RELATION TO BACKGROUND NOISE LEVELS

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ABSTRACT

This paper examines the effect of variations in background noise levels on community reactions to aircraft noise using questionnaire and sound level data collected at a stratified random sample of residential sites in the vicinity of Toronto International Airport. The effects of variations in background noise (24 hour L_{eq}) on individual and aggregate responses to aircraft noise are examined. The response variables considered include annoyance, activity interference and complaints. The results of various statistical analyses show that the effect of background level is generally not significant. The direction of the weak effects on individual responses varies by level of aircraft noise exposure and type of response. These findings are compared with those from previous studies.

There are compelling reasons to believe that community response to intrusive noise such as that from aircraft is *not* independent of background noise levels. It seems intuitively reasonable to suppose that the impact, however defined, of the intrusive noise will show a relative decrease as background levels increase. If such a relationship exists, measures of noise impact which fail to account for background noise conditions are suspect. On these grounds the adequacy of NNI and NEF as measures of aircraft noise exposure and by extension of noise impact can be questioned. Neither index incorporates information pertaining to the background noise levels against which the aircraft noise is experienced.

Johnston and Haasz (1978, p.1) argue that the need for explicit recognition of the effect of background noise levels has increased due to reduction in the noise generated by aircraft resulting from technological advances over the past decade. The consequences of this reduction is that aircraft noise is less likely totally to dominate the noise environment even in areas quite close to airports. Clearly, with increasing distance from an airport, the degree to which aircraft noise is dominant declines and the potential influence of background noise increases. Whereas the interaction between intrusive and background noise levels can be estimated quite easily in purely physical terms, the problem is more complex where the concern is to estimate the effects of the interaction in terms of changes in the impact of the intrusive noise on the community.

In this context, this paper examines the effect of background noise levels on community response to aircraft noise in the vicinity of Toronto International Airport. The analysis is based on questionnaire data and sound level measurements collected at 56 residential sites randomly selected within 4 NEF zones. The effect of background noise level on individual and aggregate response to aircraft noise are considered. The paper begins with a synthesis of the findings of previous studies. A description of the data follows. The analysis is then outlined and the results are discussed. Finally, a brief summary is presented.

PREVIOUS FINDINGS

The two studies most closely related to the present one are those of Powell and Rice (1975) and Johnston and Haasz (1978). Both studies explicitly examined the effects of background noise level on judged annoyance of aircraft noise. They differ from this study in that both were conducted in a laboratory setting. The extent to which the findings of laboratory research can be generalized to real world conditions remains an open question.

Powell and Rice found that average annoyance due to individual flyover events decreased with increasing background level when the background level was held continuous over a laboratory session. For variable background conditions, however, no such trend was observed. Based on regression analysis, the equivalent reduction in aircraft noise level by moving from lowest (mean = 32.3 dB(A)) to highest (mean = 46.4 dB(A)) continuous background noise levels was 4.9 dB. With reference to earlier studies, Powell and Rice find this reduction in close agreement with that reported by Pearsons (1966) and contrary to the larger equivalent reduction reported by Nagel *et al.* (1967). Analysis of the effects of background noise level on annoyance scores averaged over the various flyover events yielded inconclusive results. Contrary to the findings for the individual flyovers a small but non-significant increase in average annoyance was observed with increased background level. In conclusion, Powell and Rice recognize the need for field study data to complement and supplement laboratory research. Field study data are not only potentially more realistic but also permit analysis of the effects of background noise level on long-term exposure to aircraft noise.

In the Johnston and Haasz study, each of 35 jurors made an annoyance judgement for each of six flyover events, under four differing conditions of background traffic noise and three differing signal durations. Regression analysis revealed that background noise had a significant effect on annoyance scores for the two shorter signals (22 and 44 seconds). The effect of background noise for the longest signal (88 seconds) was not significant. Consistent with Powell and Rice's findings, the direction of the significant effects was such that increasing background levels was associated with reduced annoyance scores. Johnston and Haasz estimate that under conditions where the background traffic noise is of substantially longer duration than the flyover events and where the mean background level is equal to the peak indoor aircraft level, the equivalent reduction in aircraft noise is in the range of 5-6 dBA.

The results of these two studies are in general consistent, showing that background noise level has a significant influence on the judged annoyance of *single* flyover events as experienced within the laboratory situation. In the real world situation we are generally more interested in the effects of background noise level on subjective response to aircraft noise over a prolonged period of exposure. It is uncertain to what extent the findings of these laboratory studies can be generalized to that situation. The finding reported in the Powell and Rice study that background noise had a non-significant effect on annoyance averaged over a set of flyover events is possibly the one most relevant to real world conditions.

The effect of background noise on reaction to aircraft noise has been examined in at least two field surveys (Bottom, 1971; Grandjean *et al.*, 1976). Using McKennell's Guttman scale, Bottom obtained annoyance scores from 35 residents at each of 9 sites combining three different NNI levels (60, 45 and 25) and three levels of traffic flow (over 32,000 vehicles/day, 19,000 vehicles/day and access traffic only). Plotting the relationship between mean annoyance against NNI for each level of traffic flow separately, showed that, for any given NNI, annoyance was greater the lower the traffic flow. A two-way analysis of variance revealed both factors - NNI and traffic flow - as having a statistically significant effect on annoyance scores. When general noise dissatisfaction was used as the dependent variable within a second analysis of variance, the effect of NNI was significant as was the interaction between NNI and traffic flow. Traffic flow itself was not found to have a significant effect. Bottom concludes that NNI is not the best predictor of either aircraft noise annoyance or total noise dissatisfaction and he supports the use of Robinson's L_{NP} index (Robinson, 1971) gives its applicability to conditions involving a mix of noise sources.

As part of a major survey of the effects of aircraft noise around three airports in Switzerland, Grandjean *et al.* collected traffic noise measurements around the Basle airport. Using questionnaire data collected from 944 residents, they report a marked decrease in complaints about aircraft or aircraft noise with increased traffic noise. Although no statistical analysis is reported, they conclude that "the surrounding noise is relevant to the disturbing effect of aircraft noise" (p.87). Unfortunately no mention is made of the effect of traffic noise levels on responses to aircraft noise other than complaints.

The results of neither of these two field studies are conclusive. In Bottom's study the data set is quite limited; in the Swiss study the data set is larger but few results relating to the effects of background noise are reported and no statistical analysis was performed. Considered together the findings from these different studies provide some support for the intuitive expectation that background noise levels significantly influence subjective response to aircraft noise. However, the extent and perhaps even the existence of this influence under real world conditions remains uncertain.

DATA DESCRIPTION

The data used in this analysis were collected at 56 residential sites selected by means of a stratified random sample of block faces around Toronto International Airport. The sites are located in one of three NEF zones (30-35, 25-30, <25) and represent a range of background noise levels due primarily to road traffic (24 hour L_{eq} ranges from 49 to 72 dBA). At each site 12 to 15 household interviews were completed using a structured questionnaire. The questionnaire was introduced as a neighbourhood attitude survey and began with general questions about the neighbourhood leading on to more specific questions about the sounds noticed in the neighbourhood and the impacts of each sound reported as disturbing. The impact measures included annoyance, activity interference, health effects and complaints. A total of 673 interviews was completed. 88 percent of the respondents mentioned hearing aircraft and 74 percent were to some degree disturbed by aircraft noise.

24 hour sound level measurements were taken at each site. A record was kept of the sound levels (L_{eq}) for each flyover event. These were accumulated for each hour and subtracted from the overall L_{eq} for that hour to provide a measure of the background L_{eq}. For this analysis the background hourly L_{eq}s were accumulated to give a 24 hour L_{eq}.

For analysis purposes the questionnaire data can be used in both a disaggregate and aggregate form. In the former case, the data comprise each subject's responses to a specific noise source, in this case aircraft. In the latter case, the data are aggregated for each of the 56 sites and expressed in terms of the percentage of subjects at a site reporting a particular response.

ANALYSIS

Statistical analysis of the effects of background noise levels on responses to aircraft noise was performed using both the disaggregate and aggregate data.

Disaggregate Analysis

The disaggregate analysis involved comparing the responses of residents exposed to the same level of aircraft noise but different levels of background noise. This was achieved by grouping respondents by NEF (30-35, 25-30, <25) and performing separate tests for each of the three groups. Twelve different response variables were examined comprising various measures of aircraft noise annoyance, activity interference, health effects and complaint action. Annoyance ratings examined were an overall rating on a 9 point bipolar scale (ranging from *extremely agreeable* to *extremely disturbing*) and ratings on an 11 point unipolar scale (0 = not all disturbing to 10 = unbearably disturbed) for different combinations of location (inside or outside) and time of day (day, evening or night). Also examined were mentions of speech interference, volunteered and any sleep interruption, increased tension, and complaints. The relationship between the bipolar rating and background level was tested using non-parametric correlation (Kendall's Tau). Tests of relationships involving the unipolar ratings were based on Pearson's correlation (r). The relationships between the remaining responses and background level were examined by a difference of means test (student's t statistic).

The test results (Table 1) show that only 8 of the 36 relationships examined were statistically significant. Two of these were in the NEF <25 groups, 5 in NEF 25-30, and 1 in NEF 30-35. Six of the significant relationships involve the annoyance scales. Reporting of speech interference and complaint action was significantly related to background level in the lowest NEF category.

Examination of the direction of the relationships reveals some inconsistency. For the NEF <25 group, the relationships are such that the reporting of speech interference and complaints is associated with lower background noise levels. In the case of speech interference, this finding can probably be explained by the fact that only at lower background noise levels would the relatively low aircraft noise (NEF <25) be sufficiently intrusive to impair communication. In contrast, the significant relationships in the higher NEF categories are in the opposite direction; aircraft noise was rated as more disturbing the higher the background noise level. This finding is contrary to previous studies. Closer examination of the data revealed that the significant relationships for the NEF 25-30 group could be attributed to the annoyance ratings at the site with the highest background level. When this site was removed none of the relationships were significant. The overall conclusion drawn from the disaggregate analysis is that background level does not have a consistent or clearly significant effect on individual level response to aircraft noise.

Aggregate Analysis

Regression analyses were performed to examine the effect of background level on aggregate response to aircraft noise. Three aggregate response variables are considered: percent highly disturbed, percent reporting speech interference and percent having complained. These three variables reasonably represent the types of response variable included in the analysis and are variables commonly employed in previous studies of community response to noise. Percent highly disturbed was defined as the percentage of respondents who rated aircraft noise either "considerably" or "extremely disturbing" on a 9 point bipolar scale ranging from "extremely agreeable" to "extremely disturbing". Percent reporting speech interference was based on the percentage reporting interference in one or more of the following speech related activities: conversing indoors, conversing outdoors, watching television, speaking on the telephone. Percent having complained represents the percentage having contacted one or more of several agencies (e.g. the noise source, the police, some level of government) to complain about aircraft noise. These aggregate variables were calculated for each of the 56 sites.

The regression analysis was conducted in two ways. First, the 56 sites were divided into two groups based on background level. Separate regressions were performed for each group and the slope and intercept parameters were compared. Second, the 56 sites were treated as a single set and multiple regression equations were calculated with the aircraft and background noise levels as the two independent variables.

The two groups of sites for the first approach comprised those (16 sites) at which the background level exceeded 60 dBA (24 hour L_{eq}) and those (26 sites) where the background level was less than 57 dBA (24 hour L_{eq}). Sites with background levels between 57 and 60 dBA (24 hour L_{eq}) were excluded. The purpose of this grouping was to separate sites with relatively high and low background levels.

For each site group three equations (Table 2) were calculated by regressing the three aggregate response variables against aircraft noise level (24 hour L_{eq}). The equations for the same response variable were compared by first testing for differences in the slope coefficients according to the following formula:

$$t = \frac{b_1 - b_2}{s(\hat{y})_p \left(\frac{1}{\sum_i (x_{i1} - \bar{x}_1)^2} + \frac{1}{\sum (x_{i2} - \bar{x}_2)^2} \right)^{\frac{1}{2}}}$$

with $(N_1 - 2) + (N_2 - 2)$ degrees of freedom,

where b_1 = the slope of the regression line for the first subgroup

$\sum_i (x_{i1} - \bar{x})^2$ = the sum of squared deviations about the mean of the independent variable in the first sub-group,

$s(\hat{y})_p = [s^2(\hat{y})_{pooled}]^{\frac{1}{2}}$,

$$s^2(\hat{y})_{pooled} = \frac{(N_1-2)s^2(\hat{y}_1) + (N_2-2)s^2(\hat{y}_2)}{(N_1-2) + (N_2-2)}$$

$s^2(\hat{y}_1)$ = variance of the estimate of the dependent variable for the first subgroup, and

N_1 = the number of observations in the first subgroup,

N_2 = the number of observations in the second subgroup.

None of the t statistics are significant at the .05 level. We conclude therefore that the slopes of the paired regression lines are not significantly different.

Under the assumption of no significant difference in slopes, a pooled estimate of the slope was calculated and a test for differences in intercepts was performed. This involved calculating a regression equation for each response variable including a dummy independent variable to represent the background level (0 = background <57 dBA; 1 = background >60 dBA). The dummy variable did not make a significant contribution to any of the three equations (Table 2) leading to the conclusion that the intercepts are not significantly different. In other words, there is no significant difference in the aggregate response to the same level of aircraft noise between sites with high and low background levels.

The second approach to the regression analysis treated the background level as a continuous variable. Two steps are again involved to test: first, whether the background level significantly affects the rate of change in response to aircraft noise (i.e. is there an interaction effect?); and second, whether the level of response is significantly affected by the background level (i.e. is there an independent effect?). The first test involved calculating regression equations containing three terms entered in the following order: the aircraft noise level (24 hour L_{eq}); the cross product of the aircraft and background levels; and the background level (24 hour L_{eq}). In none of the three equations was the explained variation (R^2) attributable to the cross product term significant (Table 3). This shows that the background level does not affect the rate of change in response to aircraft noise. A second set of equations was calculated (Table 3) excluding the cross product term. The contribution of the background level in these equations was not significant leading to the conclusion that the level of response to aircraft noise is not affected by the background noise. In the equations for percent highly annoyed and percent reporting speech interference, the regression coefficients for aircraft L_{eq} are significant. This is not the case for percent complaining underlining the difficulty of predicting of complaint action.

The results of both approaches to the regression analysis are consistent. Background level does not significantly effect either the rate of change in response to aircraft noise or the level of response. These findings reinforce the conclusions of the disaggregate analysis. From these data therefore there is a strong basis for concluding that background levels do not significantly effect either individual or aggregate responses to aircraft noise.

DISCUSSION

It is now appropriate to compare these findings with those of the previous studies described earlier. Firstly, compared with the laboratory studies of Powell and Rice (1975) and Johnston and Haasz (1978), this analysis has not shown background levels to have as significant an effect on reactions to aircraft noise. But the comparison is hardly a fair one given that the significant effects of background levels observed in both laboratory studies were on reactions to individual flyover events and not long-term exposure to aircraft noise which was the focus of this analysis.

As noted earlier, in so far as these laboratory studies provide any indication of the effects of background noise levels on longer term exposure, they suggest that the effect is weaker than for individual flyover events and quite possibly non-significant. The present findings are clearly in general consistent with this suggestion.

Comparison with Bottom's study (Bottom, 1971) is complicated by the fact that he used different metrics from those used in this analysis to measure both aircraft and background noise levels. In addition, the background conditions represented in his data are limited to only three levels of traffic flow. Allowing for these differences, it seems likely that the present findings are not consistent with Bottom's results. The significant effect of background levels that he reports is not confirmed by our data. Comparison with Grandjean's results (Grandjean *et al.*, 1976) is also difficult because his findings are limited to the effects of background levels on aircraft noise complaints and further because no statistical analysis is reported. Again, allowing for these difficulties, it appears that our results for percent complaints show neither as strong nor as uniform an effect of background levels as those reported by Grandjean.

Considered overall the results of this analysis do not support the research hypotheses implicit in the introductory section of the paper. The null hypothesis that reactions to aircraft noise are independent of background levels cannot be rejected with the normally required level of confidence. It follows from this that measures of noise exposure such as NEF and NNI are not insufficient on the grounds that they fail to account for background levels. As predictors of noise impact they may of course be insufficient on other grounds and the relatively weak relationships observed in these data between NEF and the response variables certainly suggest this.

Allowing for the weak effects of background level overall, the research hypothesis concerning the direction of the effect also lacks support. The expectation that for a given exposure level, the impact of aircraft noise will decrease as background levels increase does not hold for all levels of exposure. To the extent that conclusions can be drawn from the weak relationships observed using the disaggregate data, the effect of background level on aircraft noise response changes, such that where the intrusive level is relatively low (NEF <25) higher background levels do as expected lead to a reduced impact, but where the intrusive level is higher (NEF 30-35) higher background levels are associated with increased impact.

SUMMARY

This paper has examined the effects of background noise levels on community response to aircraft noise. Previous detailed investigation of this topic has been based primarily on analysing subjective reactions to individual flyover events under laboratory conditions. The extent to which the findings of these studies apply to community responses to aircraft noise over an extended time period under real world conditions is uncertain. The questionnaire and sound level data used in this analysis were collected at 56 sites within four NEF zones around Toronto International Airport. Statistical analysis of individual and aggregate responses to aircraft noise leads to two main conclusions. First, the effect of background level is generally not significant. Second, the direction of the effect on individual responses is not consistent. High background levels tend to reduce the speech interference and complaint responses, but to accentuate annoyance.

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continued ---►

Table 1

Significant Effects of Background Noise Level

on Individual Responses to Aircraft Noise

Variable	NEF <25	NEF 25-30	NEF 30-35
Bipolar	-	tau=.1167*	tau=.1102*
Unipolar ratings			
indoors, day	-	r=.1489*	-
outdoors, day	-	r=.1763**	-
indoors, evening	-	-	-
outdoors, evening	-	r=.1857**	-
night	-	-	-
overall	-	r=.1877**	-
Activity interference			
speech	t=2.47*	-	-
sleep (vol)	-	-	-
sleep (any)	-	-	-
Nervousness	-	-	-
Complaints	t=2.08*	-	-

- not significant at .05 level

* significant at .05 level

** significant at .01 level

Table 2

Effects of Background Noise (Dichotomized Variable) on Aggregate Response to Aircraft Noise

Response variable	R^2	Std. Error
Test for differences in slope coefficients:		
% highly annoyed		
low background: $\%HA = -76.5 + 1.838\ AC\ L_{eq_{24}}$	.236	13.179
high background: $\%HA = -190.2 + 3.845\ AC\ L_{eq_{24}}$	.367	20.766
difference in slope coeffs. = -2.007; t = -1.48; df = 38; prob. = 0.15		
% speech interference		
low background: $\%SI = -142.3 + 3.330\ AC\ L_{eq_{24}}$	.377	17.066
high background: $\%SI = -238.1 + 4.810\ AC\ L_{eq_{24}}$	.491	20.159
difference in slope coeffs. = -1.48; t = -0.98; df = 38; prob. > 0.3		
% complaints		
low background: $\%C = -14.8 + 0.484\ AC\ L_{eq_{24}}$	.013	16.926
high background: $\%C = -122.4 + 2.091\ AC\ L_{eq_{24}}$	.249	14.963
difference in slope coeffs. = -1.607; t = -1.20; df = 38; prob. > 0.2		
Test for differences in intercepts:		
% highly annoyed		
$\%HA = -123.4 + 2.609^{***}\ AC\ L_{eq_{24}} + 6.68^{NS}\ BACK$	.284	16.637
% speech interference		
$\%SI = -176.9 + 3.898^{***}\ AC\ L_{eq_{24}} - 7.05^{NS}\ BACK$	.458	18.256
% complaints		
$\%C = -52.4 + 1.101^{NS}\ AC\ L_{eq_{24}} - 1.17^{NS}\ BACK$	.073	16.320

*** significant at .001 level

NS not significant at .05 level

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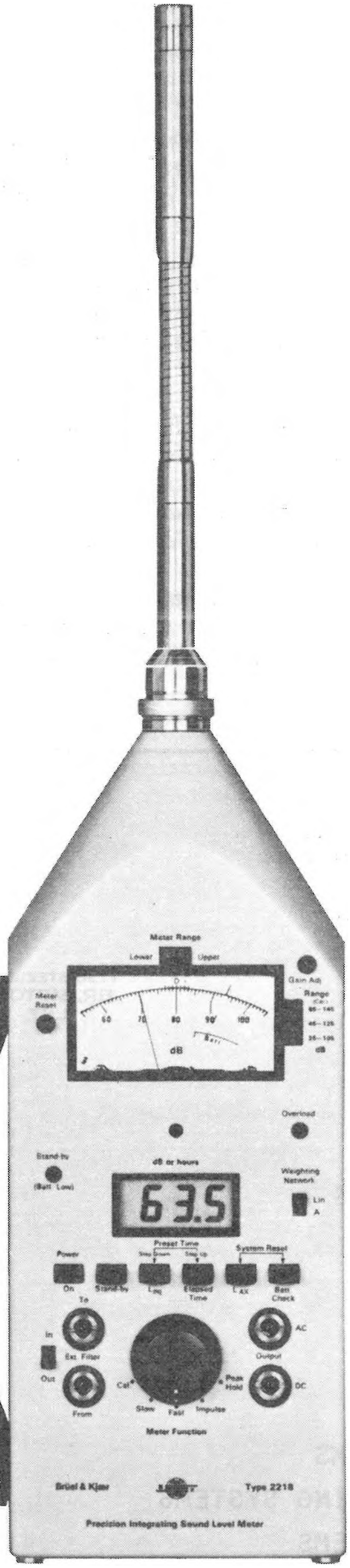

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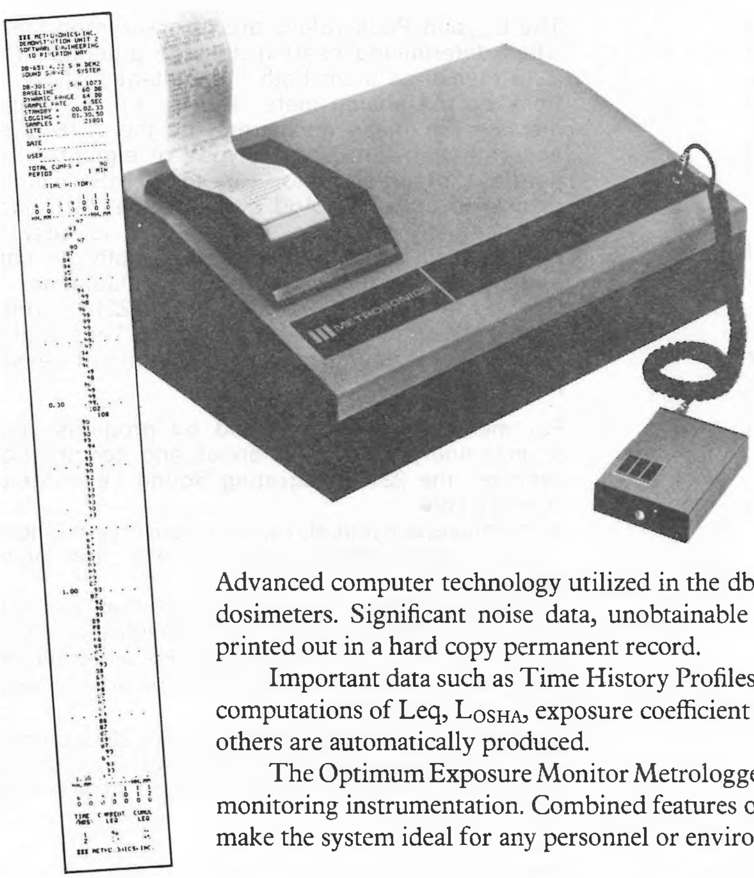

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The Optimum Exposure Monitor Metrologger/Metroreader system is a significant advance in noise monitoring instrumentation. Combined features of size, computer performance and automatic printout make the system ideal for any personnel or environmental noise measurement program.

With Convenient Immediate Visual Readout

db-306 METROLOGGER

Real Time Exposure Computations In Palm of Hand

Combining a patented digital sound level meter with a programmable microcomputer, the 306 produces fast and accurate answers to complex measurements. A four digit LED display permits direct readout of sound level, L_{max}, L_{eq}, and test duration (hours, minutes and seconds).

A major advantage is the capability for interchanging PROMs which adapt the db-306 in accordance with different ISO, OSHA and US Air Force (proposed DOD) noise exposure criteria. The db-306 can measure over the bounded dBA range specified in the various occupational noise exposure standards or it can measure over the full range of noise amplitude for evaluating community noise and for rating noise emission of cyclical machinery.

Represented in Canada by Leq MEASUREMENTS LTD.

The Now Generation of Noise Analyzers

METROSONICS INC.

P.O. BOX 23075 ▪ ROCHESTER, N.Y. 14692 ▪ 716-334-7300

Table 3

Effects of Background Noise (Continuous Variable) on Aggregate Response to Aircraft Noise

Interaction effect:

Response Variable	Incremental explained variation (R^2) due to independent variables: AC L_{eq}	Cross Product	Background L_{eq}
% highly annoyed	.1075*	.0271^{NS}	.0359^{NS}
% speech interference	.3708***	.0050^{NS}	.0335^{NS}
% complaints	.0373^{NS}	.0001^{NS}	.0583^{NS}

Independent effect:

Response Variable	R^2	Std. Error
% highly annoyed $\%HA = -100.6 + 1.733^{**}\ AC\ L_{eq_{24}} + .564^{NS}\ BACK\ L_{eq_{24}}$	.131	19.2
% speech interference $\%SI = -121.0 + 3.271^{***}\ AC\ L_{eq_{24}} - .330^{NS}\ BACK\ L_{eq_{24}}$	.378	18.1
% complaints $\%C = -33.9 + 0.853^{NS}\ AC\ L_{eq_{24}} - .028^{NS}\ BACK\ L_{eq_{24}}$	.037	18.4

NS not significant at .05 level

* significant at .05 level

** significant at .01 level

*** significant at .001 level

Rotor Dynamics
Noise and Vibration Control

ONTARIO HYDRO'S DESIGN AND DEVELOPMENT DIVISION offers a Toronto-based position for a professional engineer interested in analytical work in the following areas, to provide techical expertise to groups within the Power Equipment and Energy Studies, Stations Project, and other design departments. Candidates with expertise in the first area only will be considered:

- Critical Speed and vibration analyses of bearing/rotor systems using digital computer techniques, including design requirements for vibration monitoring systems.

- Noise control measures for new or proposed rotating equipment.

- Seismic qualification of specific items of power cycle equipment to meet nuclear safety requirements.

The successful candidate requires a Bachelor's degree or higher with emphasis on applied mechanics/vibration theory, (courses in applied acoustics would be considered an asset), and up to ten years experience in rotor dynamics/vibration analysis and noise control of large rotating equipment.

Qualified candidates are invited to forward resumes detailing qualifications, work experience and salary expectations, quoting File No. CAAJ-567 in letter and on envelope to:

Staffing Officer, Ontario Hydro
700 University Avenue,
Toronto, Ontario
M5G 1X6

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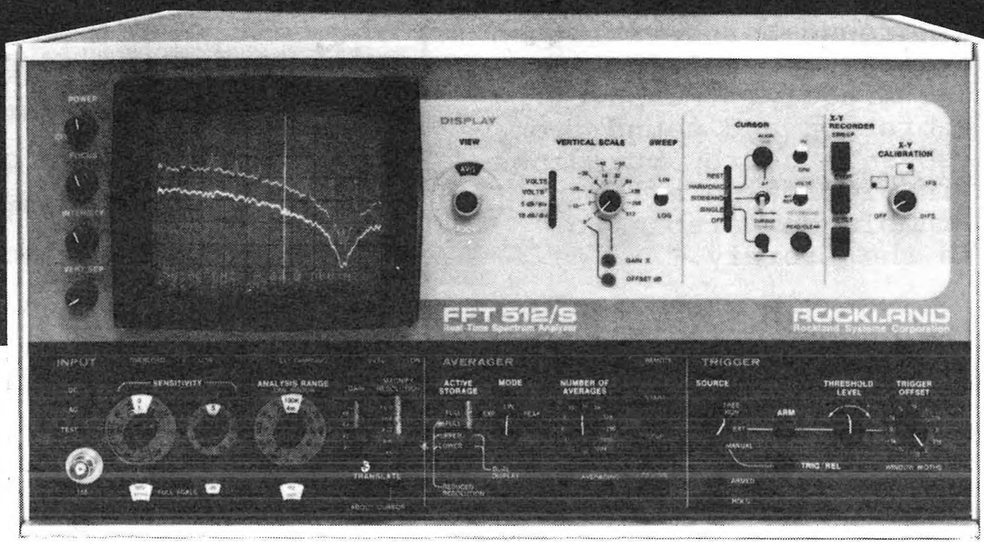

Real-Time Spectrum Analyzer: 0–100KHz

THE ALL. Rockland's Model FFT 512/S is the most versatile design in its class... and the most advanced. By specifying one of the dozens of mainframe-plus-option combinations, you get all these performance-optimizing features: *all-digital range translation* ("frequency zoom") for *51,200 lines* of resolution; *digital interfaces* for computers or calculators; *1/3-octave and full-octave bandwidths; narrowband (tunable) power readout; and ultra-low-frequency analysis* (2, 5, 10 Hz ranges).

And *before* you add options, you get standard mainframe features that others provide as options (if at all): *the most advanced readout system* in the field... everything can be measured, displayed and recorded, in absolute or engineering units.

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THE LESS. Believe it or not, you'll pay *less* for our mainframe plus several options than others charge for a bare-bones box.

THE WHY. Simply this: we use an inherently superior circuit architecture. Most features cost us far less to implement — so we charge less.

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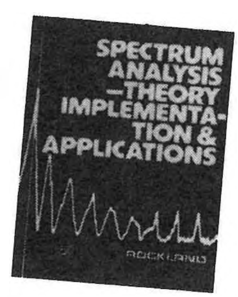

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