f 816

ACOUSTICS AND NOISE CONTROL IN CANADA

THE CANADIAN ACOUSTICAL ASSOCIATION

L'ACOUSTIQUE ET LA LUTTE ANTIBRUIT AU CANADA

L'ASSOCIATION CANADIENNE DE L'ACOUSTIQUE

Avril 1978
Vol.6, N°2

April 1978
Vol.6, No.2

ACOUSTICS AND NOISE CONTROL IN CANADA

L'ACOUSTIQUE ET LA LUTTE ANTIBRUIT AU CANADA

CONTRIBUTIONS

Articles in English or French are welcome. They should be addressed to a regional correspondent or to a member of the editorial board.

SUBSCRIPTIONS

Acoustics and Noise Control in Canada is distributed free. To have your name put on the mailing list, please contact the Noise Control Division, Environmental Protection Service, Department of the Environment, Ottawa, Ontario K1A 0C8. Postal codes must be provided for all addresses in Canada.

This newsletter is published by the Canadian Acoustical Association. Printing and distribution are provided by the Department of the Environment. The contents of the newsletter and any opinions expressed are the responsibility of the authors and do not necessarily represent the views of the Canadian Acoustical Association or the Canadian Government, its departments or agencies.

(continued on inside back cover)

o o o o o o o o o

CONTRIBUTION

Vous êtes invités à faire parvenir des articles en anglais ou en français. Prière de les adresser à un correspondant régional ou à un membre de la rédaction.

SOUSCRIPTION

L'acoustique et la lutte antibruit au Canada est distribué gratuitement. Veuillez communiquer avec la Division de la lutte antibruit, Service de la protection de l'environnement, Ministère de l'Environnement, Ottawa (Ontario), K1A 0C8, pour faire inscrire votre nom sur la liste d'envoi. Il est nécessaire que tous les résidants du Canada indiquent leur code postal.

Ce bulletin d'information est publié par l'Association canadienne de l'acoustique. Le Ministère de l'Environnement s'occupe de l'impression et de la distribution. Le contenu du bulletin ainsi que les avis exprimés ne représentent pas nécessairement l'opinion de l'Association canadienne de l'acoustique ou du gouvernement du Canada et des ministères et organismes fédéraux; ce sont les auteurs qui en assument la responsabilité.

(suite au recto de la couverture inférieure)

Contents/Table Des Matieres

Notice Board

CAA Annual Meeting and Symposium

The Annual Meeting and Symposium of the Canadian Acoustical Association will be held in Halifax on November 2 and 3, 1978. Details of this meeting and a call for papers will be sent to the members directly.

Preceeding the meeting and symposium will be a seminar "Introduction to Acoustics" on November 1. This seminar will cover some basic acoustics and a review of recent standards.

For those planning to travel by air to Halifax the rates can be reduced if you

(a) Obtain charter class air fare rates by reserving before September 15, 1978, and staying a week, or

(b) By writing to the secretary (Cameron Sherry) requesting information on how you can obtain a 20% discount on your fare from Montreal to Halifax. This is particularly advantageous to anyone living within 150 kilometers of Montreal.

Directors Award

The Directors of the CAA have agreed to offer an award to a young Canadian (35 years or under) who has a paper published in "Acoustics and Noise Control in Canada". The award will be a plaque or medal known as the Directors Award and will be presented at the Annual Meeting of the CAA. If a paper has multiple authorship, the first mentioned name will be considered as the primary author and this person will be the one considered.

Papers to be considered will be compiled by the editor and one other person. These will be voted on by all directors by a mail ballot. It is hoped that the first award can be made for papers submitted in 1978 and presented at the Annual Meeting in 1979.

Ultrasonics International 79

A first call for papers is made for this conference to be held in Graz Austria on May 15-18, 1979. The conference is to cover all aspects and applications of ultrasound in science and industry. The emphasis will be on the most recent developments in this field and especially on practical applications.

Authors offering papers for presentation should send abstracts of 150-250 words with one illustration to

Dr. Z. Novak
Conference Organizer
Ultrasonics International 79
IPC House 32 High Street Guildford
Surrey GU1 3EW U.K.

General enquiries should be sent to the Conference Organizer, however enquiries regarding the exhibition, which is traditionally held parallel with the conference, should be sent to Mr. John Gregory, Exhibition Manager, at the same address.

Second Congress of the Federation of Acoustical Societies of Europe

The Second Congress of the Federation of Acoustical Societies of Europe (FASE)(listed below) will be held in Warsaw on the 18-22 of September. Details of this program can be obtained by writing Cameron Sherry for a booklet containing all the information.

INTERNATIONAL COMMISSION ON ACOUSTICS
(ICA) - Information Service

c/o Acoustical Commission of the Czecho-
slovak Academy of Sciences
Plzenska 66, 15124 Prague 5

Circular ICA/ICS 228/77

Prague, 10 October 1977

A C O U S T I C A L   E V E N T S   1 9 7 8

1978

Australia May 29-30, 1978, Adelaide

"Machinery Vibration and Noise"

Institute of Engineers, 11 National Circuit,
Barton, A.C.T., 2600

Brazil October 1978, Rio de Janeiro

"5th Jornadas de Acustica"

Prof. G.L. Fuchs, Universidad Nacional de
Cordoba, Ciudad Universitaria, Est.-32
Cordoba, Rep. Argentine

Czechoslovakia October 3-6, 1978, High Tatra

"17th Acoustical Conference on Electro-
acoustics and Measuring Technique"

organized by the Acoustical Commission
of the Czechoslovak Academy of Science

Secretariat: House of Technology
Skultétyho, 881 30 Bratislava

Denmark August 16-18, 1978, Odense

"Scandinavian Acoustical Meeting 1978"

Main theme: Life and sound

Organiser: Dansk Akustisk Selskab
Lundtoftevej 100, 2800 Lyngby

Federal Republic of Germany

a) März 14-16 1978 in Bochum

"DAGA '78" - 6.Tagung - alle Gebieten der Akustik

Kurzfassung des Vortrages muss bis spät. zum 30.November 1977 dem Herrn Prof.Dr. J.Blauert, Ruhr-Universität, Universitätsstr.150, Gebäude IC/1 D-4630 Bochum vorliegen.

Anmeldungen: Herr Schier
VDE Zentrale Tagungen
Stressemannallee 21
D-6000 Frankfurt/Main

b) May 16-19, 1978, Freiburg

"International Conference on Biological Effects of Noise"

Details from: G. Jansen, International Commission on Biological Effect of Noise,
P.O. Box 358, Norman, Oklahoma 73069, USA

c) October 2-5, 1978, Hannover

"VDE-Kongress '78"

Details from: VDE-Zentralstelle Tagungen
Stresemannallee 21
D-6000 Frankfurt/M. 70

d) October 12-13, 1978, Karlsruhe

"VDI-Schwingungstagung '78"

Details from: VDI-Gesellschaft Konstruktion und Entwicklung, Fachbereich Schwingungstechnik
Graf-Recke-Str.84, D-4000 Düsseldorf

France

a) May 31 - June 2, 1978, Lannion

"GALF Annual Meeting - Speech Communication"

Details from: C.N.E.T.
route de Trégastel
22301 Lannion

b) July 3-6, 1978, Paris

8th Symposium on Nonlinear Acoustics"

Details from: A.Zarembowitch, Laboratoire de Recherches Physiques
Tour 22, Université Pierre et M.Curie
4, Place Jussieu, 75230 Paris Cedex 05

Hungary

April 11-13, 1978, Györ

"IV.Kolloquium" - Tage des Maschinenbaulichen Umweltschutzes

Sektionen: Lärm - u.Schwingungsschutz
Schutz gegen Wasserverschmutzung
Schutz gegen Luftverschmutzung

Informationen: Wissenschaftlicher Verein
fur Maschninenbau
1372 Budapest, Postfach 451

Italy

a) October 1978

"Annual Congress of AIA" (Italian Association of Acoustics)

Details from: Italian Association of Acoustics, Secretary
Via Cassia 1216
00189 Roma

b) 1978
"Annual Congress of Italian Society of Audiology"

Details to be announced: Italian Association
of Acoustics, Secretary
Via Cassia 1216
00189 Roma

Poland

a) September 14-16, 1978, Poznan

"Symposium of Acoustics"

Details from: Polish Acoustical Society
ul.Matejki 48/49
60 769 Poznan

b) September 18-22, 1978, Warsaw

"FASE 78 - Second Congress of the Federation of
Acoustical Societies of Europe"

Main Topics: Acoustic waves and structure of matter,
Ultrasonic methods of location and
recognition, Objective and subjective
evaluation of sound in a limited space

Papers to be offered not later than 10 December 1977

Secretariat: FASE 78 Organizing Committee
IPPT-PAN
ul.Swietokrzyska 21
00-049 Warsaw

United Kingdom

a) April 5-7, 1978, Cambridge

"Institute of Acoustics Spring Conference and Exhibition"

Details from: Prof. J.E.Ffowcs-Williams
Engineering Department
Trumpington Street
Cambridge

b) August 1978, London

"Third International Conference on Methods in Dialectology"

Contact: Prof. H.R. Wilson
Dept. of English, University of
Western Ontario, London
Ontario, N6A 3K7, Canada

U.S.A.

a) May 16-19, 1978, Providence, Rhode Island

"Meeting of the Acoustical Society of America"

Chairman: Dr. Stanley L. Ehrlich
Raytheon Co., Submarine Signal Division
P.O. Box 360, Portsmouth
Rhode Island, 02871

b) May 8-10, 1978, Jack Tar Hotel

"INTERNOISE 78" (Sponsored by INCE)

The emphasis will be on practical solutions to important noise control problems

Abstracts are due on 24 October 1977;
3 copies to Daniel R. Flynn, Technical Program Chairman
National Bureau of Standards
Washington, D.C. 26234

Details from: INTER-NOISE 78
P.O. Box 3469
Arlington Branch
Poughkeepsie, NY 12603

c) November 27- December 1, 1978, Honolulu, Hawaii

"Meeting of the Acoustical Society of America"

- jointly with AS of Japan

Chairman: Dr. John C. Burgess
University of Hawaii, Dept. of Mechanical Engineering
2540 Dole St., Honolulu
Hawaii 96822

THE ENERGY COSTS OF SOME NOISE ABATEMENT PROCEDURES

R.K. Leong, Civil Aeronautics
Transport Canada, Place de Ville,
Ottawa, Ontario K1A 0N8

1. INTRODUCTION

The growth of commercial jet transport since 1957 has been accompanied by a growing concern with the increased noise levels in communities adjacent to airports. To alleviate this impact, noise abatement procedures for aircraft operations were implemented. Amongst these procedures are: the use of preferential runway systems to avoid overflying densely populated areas, power reduction after takeoff, reduced thrust takeoff, steeper glide slopes during approach and delayed flap landing. However, the recent "energy crisis" and subsequent sharp rise in aviation fuel prices have created a need to determine how much these noise abatement procedures are costing us. In an attempt to obtain some energy costs of these procedures, a theoretical study was conducted. For this paper, fuel consumption and noise reduction benefits of some noise abatement departures are presented.

2. NOISE ABATEMENT DEPARTURES

The departure noise problem occurs as the aircraft passes over or near noise sensitive areas after departing the immediate vicinity of the runway. This problem is dominated by the engine noise and the climb performance of the airplane. A reduction of engine power at some point of the departure is recognized as a means of reducing noise at the ground level. TABLE I lists the two types of noise abatement departures that utilize thrust reduction. Departure Type A (ATA Procedure) in use by several airlines, establishes the 1,000 ft. height as the point for flap retraction. Upon clean-up, thrust is reduced and the airplane then climbs at zero flap speed to 3,000 ft. Unlike the ATA Procedure, Type B departure tends to keep the airplane high before flap retraction or thrust reduction or both is applied. It usually establishes thrust reduction when the airplane is still in a "dirty" configuration.

Figure 1 illustrates the ATA Departure (Type A) profile of a B747. It requires the airplane to climb out using takeoff thrust to 1,000 ft. at V2 + 10 knots. At this point, the airplane continues climbing and at the same time retracts flaps at the appropriate minimum speeds. After clean-up, it reduces thrust and climbs at zero flap speed, VZF (in this case V2 + 80 kts.) to 3,000 ft. At this altitude or higher, the aircraft accelerates expeditiously from VZF to 250 kts., maintaining an approximate rate of climb of 500 - 1,000 ft/min. Type B, shown in Figure 2, requires the aircraft to climb using takeoff thrust to 1,500 ft. at a constant V2 + 10 kts. and takeoff flap. Climb thrust is then set and straight climb out is performed with flaps retracted at the scheduled speeds. The aircraft then accelerates to 250 kts. and climbs to 10,000 ft. In order to determine the energy costs of these noise abatement departures, a takeoff procedure that does not contain noise abatement is used as a reference. The departure profile is shown on Figure 3. It requires the aircraft to climb straight ahead at V2 + 10 kts. to the height selected for flap retraction. In this study, the FAA minimum height requirement of 400 ft. is used. The aircraft then accelerates and retracts flaps at the appropriate minimum speeds. Upon clean-up climb thrust is set and the aircraft then accelerates to 250 kts.

3. FUEL CONSUMPTION ANALYSIS

The fuel consumption analysis of a departure is done in steps related to specific segments defined by changes in airplane configuration, engine thrust or speed. Figure 4 shows the segments used in the fuel consumption analysis of the B747 ATA (Type A) departure. The first segment begins where the airplane has attained a height of 35 feet to the flap retraction height of 1,000 ft. AGL. The second segment starts at this altitude and ends at the point where the next flap retraction speed is reached (here V2 + 20 kts.). The third segment begins from here and ends at the height where V2 + 40 kts. is reached and so on until clean-up. The next segment, then, is the climb at VZF to 3,000 ft. AGL and the last segment is the acceleration from clean-up speed to 250 kts.

The outline of the procedure used in calculating the fuel consumed in each segment is given in Figure 5. The data required for each segment are: aircraft takeoff weight, aircraft speeds at the start and end of segment, flap setting, thrust setting, airport temperature, initial and final or estimated final aircraft altitudes and rate of climb (if available). From here, drag, delta, mach number, sonic speed, dT/dH and TAT are computed. With these aerodynamics quantities, the thrust per engine is then calculated. If the aircraft speed is maintained constant throughout the segment, then the acceleration, rate of climb, climb gradient, traversed time and distance are calculated. If the aircraft is accelerating as well as climbing, then its traversed time and distance, its acceleration and final altitude are computed. Finally, the fuel consumed is computed from the fuel flow rate for the thrust setting and the traversed time.

4. DISCUSSION OF RESULTS

Figure 6 shows the effect of the three types of departure on the noise level under the flight path. The aircraft is a B747-100 at a takeoff weight of 513,000 lbs. and powered by four JT8D-3A engines. As can be seen, the two thrust reduction departures are about 2 - 5 EPNdB quieter then the non-noise abatement (reference) procedure for most distances under the flight path. The ATA procedure (Type A), however, has an additional 1-2EPNdB reduction. This is due to two factors:
(1) the reduction in thrust upon clean-up, and (2) the higher altitude attained due to the higher speeds associated with a clean configuration. Table II gives the results of the computation. It is evident that the two noise abatement departures consumed more fuel; about 993.1 lbs. more fuel for the Type B and 201.9 lbs. more for the ATA procedure. Based on the fuel price of 8¢ per lb., their respective extra costs are $79.45 and $16.16. It would appear that for the B747-100, the Type A (ATA procedure) departure offers the best compromise between noise and fuel consumed.

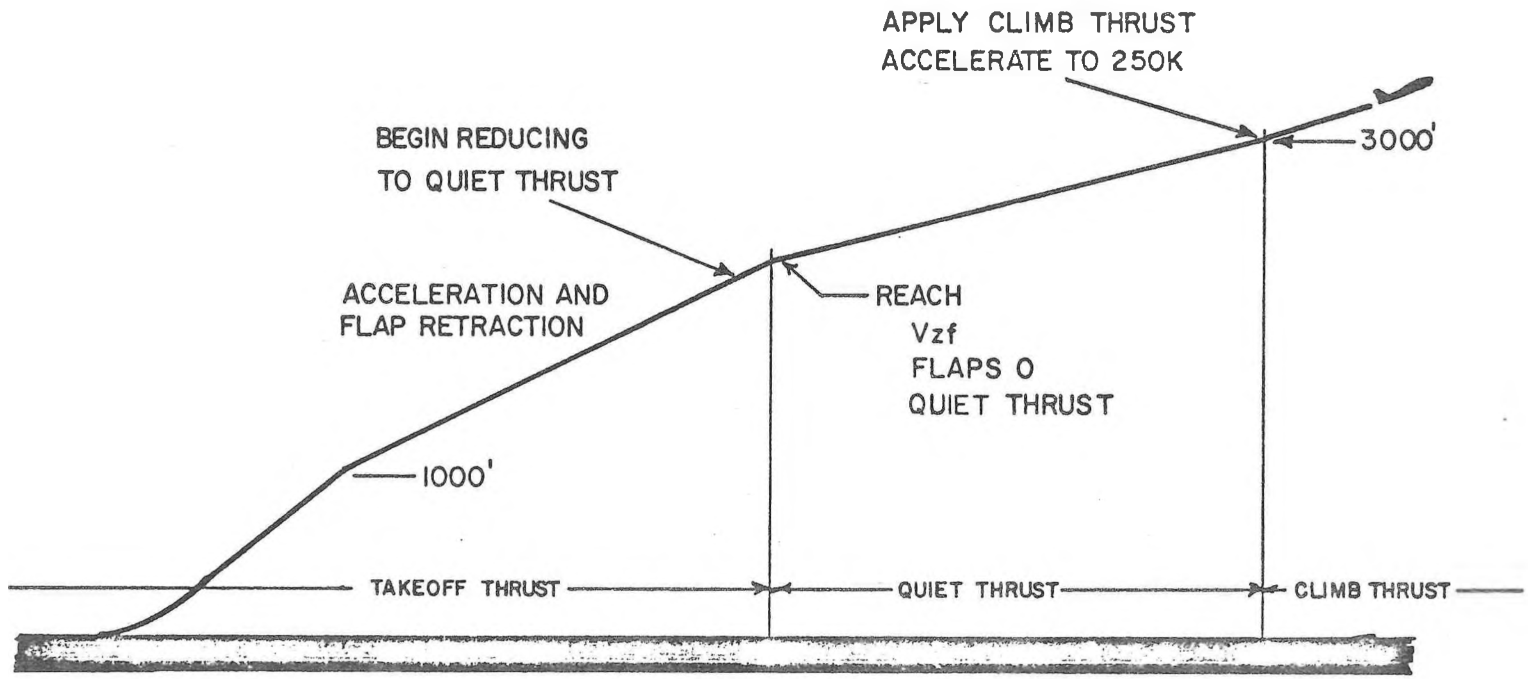
Figure 7 shows the noise levels under the flight path of the three departures. The aircraft is a L-1011 at a takeoff weight of 425,000 lbs. and powered by three RB.211-22B engines. Again it can be seen that the two noise abatement departures are substantially quieter (2 - 5 EPNdB) than the reference procedure. The ATA procedure also shows a slight noise advantage over the normal takeoff procedure (Type B). The energy costs of these departures are shown in Table III.

Figure 8 shows the noise levels under the flight path of a B727-200. The aircraft is at a takeoff weight of 191,000 lbs. and powered by three JT8D engines. At the takeoff phase of the departure, the noise due to the Type A (ATA) procedure is 1 - 2EPNdB higher than that of the Type B. This is mainly due to the lower altitude of the aircraft during flap retraction. However, after clean-up the aircraft maintains a much higher altitude; subsequently, its noise level under the flight path is much lower than that due to the other two departures. Figure 9 shows similar noise benefits from the two noise abatement departures for the DC-9-30 airplane. The ATA (Type A) departure, however, is not significantly quieter than the normal (or Type B) departure.

The energy costs of using noise abatement departures for both the B727-200 and the DC-9-30 are given in TABLE IV. It would appear that there is little extra fuel consumed by the DC-9-30 airplane even when noise abatement techniques are carried out during departure. For the case of the B727-200 the cost penalties are slightly higher. The short flap retraction schedules and light takeoff weights may be the reasons behind the smaller cost penalties associated with noise abatement departures.

The effect of takeoff weight on fuel consumption for the two noise abatement departures is illustrated from the results in Table V. For the Type A (ATA) departure, as the takeoff weight gets larger, the fuel penalty decreases. This may be due to the similarities in the flight characteristics of the two departures at large takeoff weight. The Type B departure, on the other hand, has the reverse trend. This may be due to the extra power required by the airplane to maintain the necessary heights and climb gradients of the profile.

Note: The above paper reflects the views of the author and should not be thought to reflect those of Transport Canada.



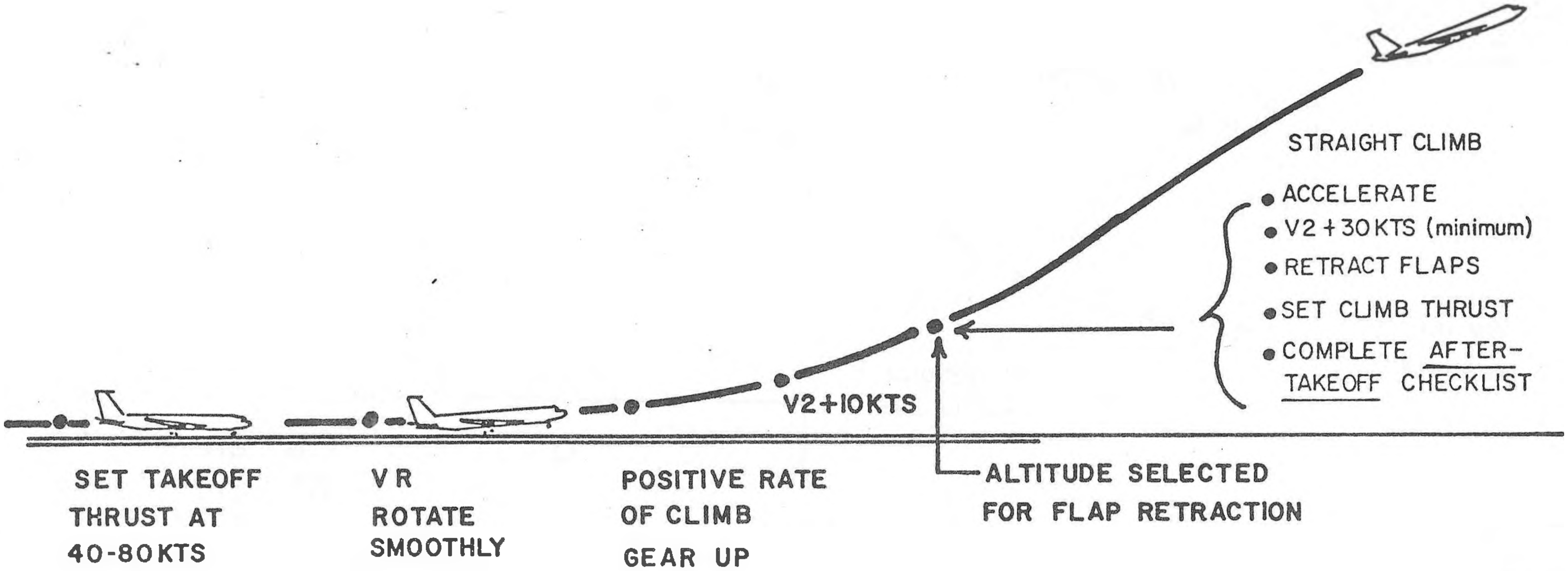
THRUST CUTBACK PROCEDURE

FIG.1

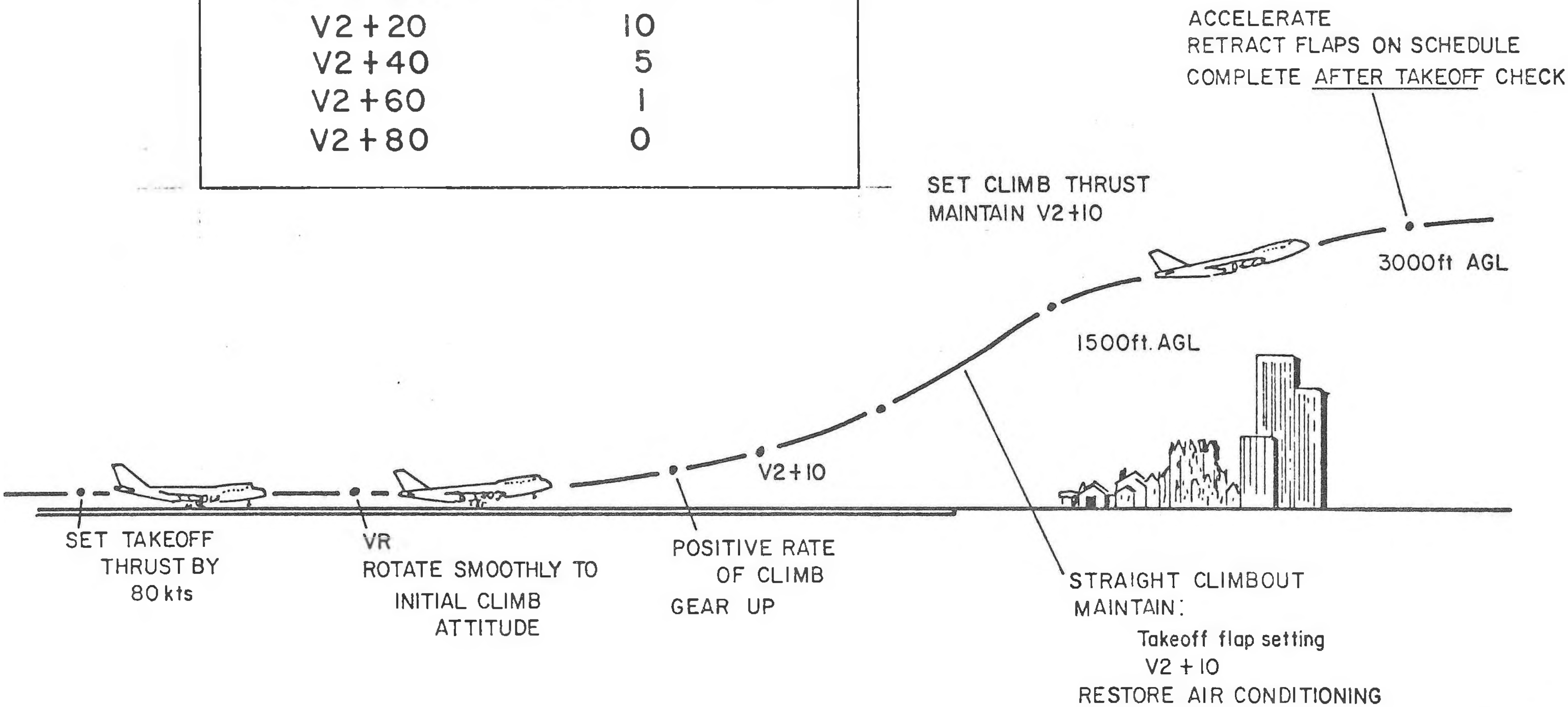
STANDARD TAKEOFF AND CLIMB

(NON-NOISE ABATEMENT)

FIG. 3



TAKEOFF FLAP RETRACTION SCHEDULE	
AT SPEED	SELECT FLAPS
V2 + 20	10
V2 + 40	5
V2 + 60	1
V2 + 80	0



STANDARD TAKEOFF AND CLIMB

FIG. 2

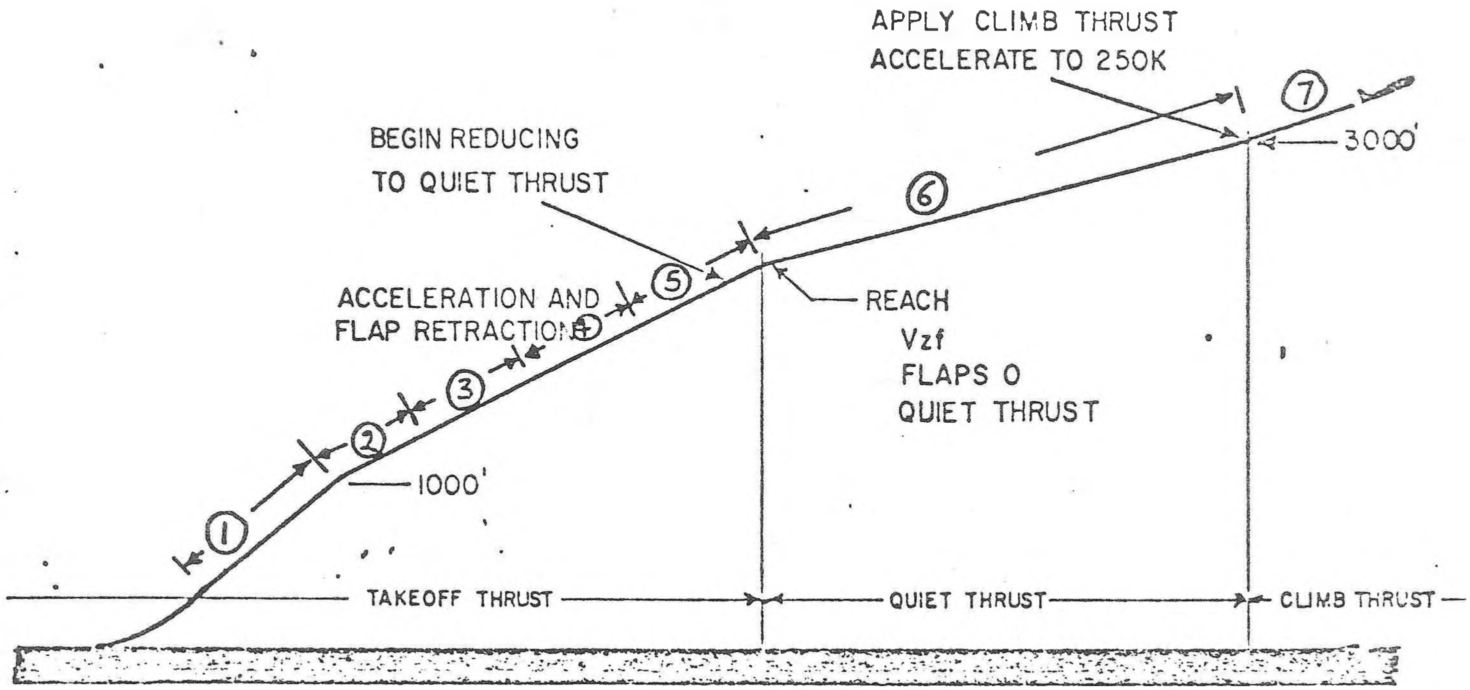


FIGURE 4: PROFILE TYPE A (ATA) DEPARTURE

SEGMENT	1	2	3	4	5	6	7	8
ALTITUDE	35' TO 1,000'	1,000' TO FLAP 10°	FLAP 10° TO FLAP 5°	FLAP 5° TO FLAP 1°	FLAP 1° TO FLAP 0°	FLAP 0° TO 3,000'	3,000' TO 10,000'	
VELOCITY (KTS.)	V2+10	V2+10 TO V2+20	V2+20 TO V2+40	V2+40 TO V2+60	V2+60 TO V2+80	V2+80	V2+80 TO 250 KTS.	
THRUST	T.O	T.O	T.O	T.O	T.O	REDUCED THRUST	CLIMB THRUST	

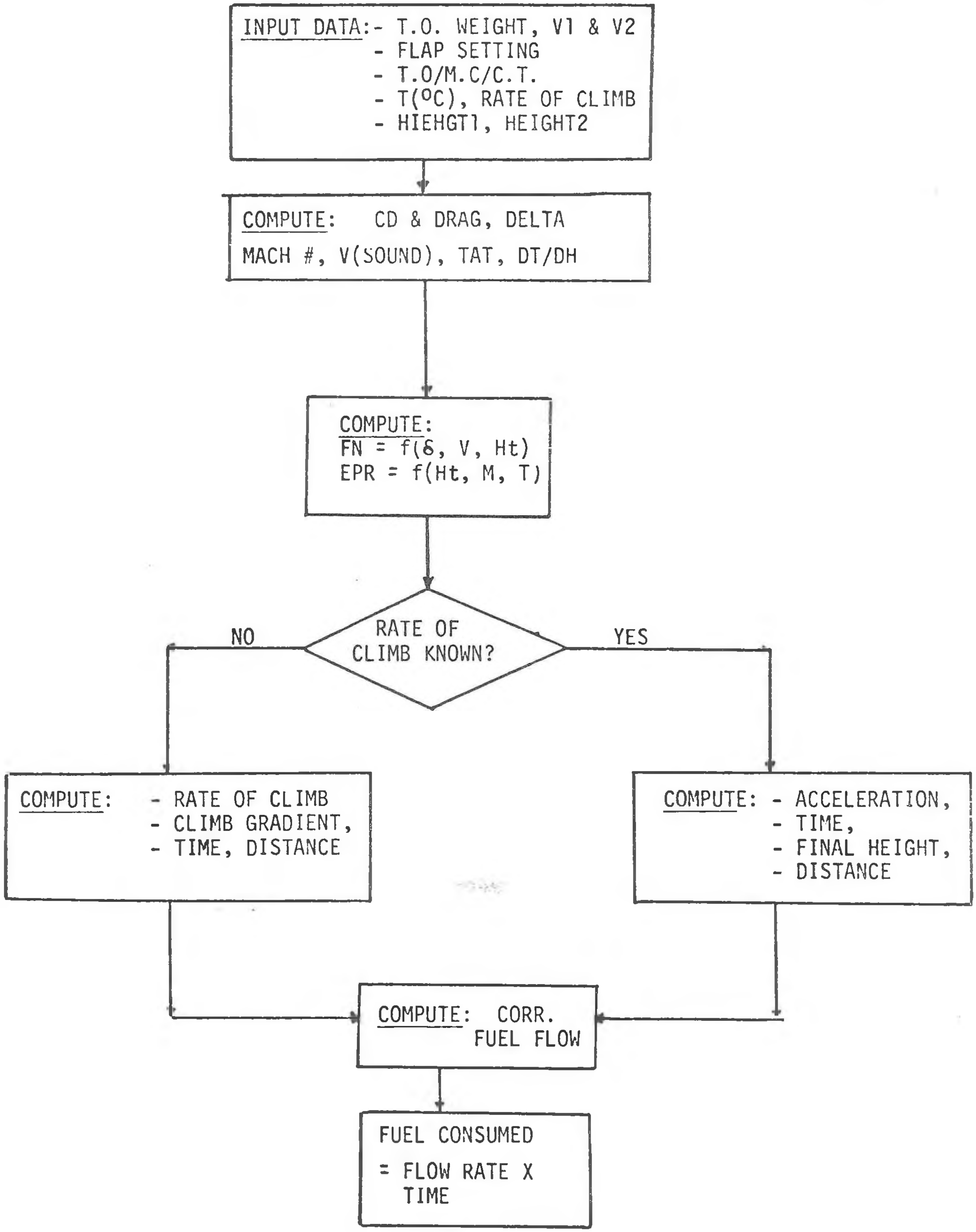

INPUT DATA:- T.O. WEIGHT, V1 & V2
- FLAP SETTING
- T.O/M.C/C.T.
- T(°C), RATE OF CLIMB
- HIEHGT1, HEIGHT2
COMPUTE: CD & DRAG, DELTA
MACH #, V(SOUND), TAT, DT/DH
COMPUTE:
FN = f(δ, V, Ht)
EPR = f(Ht, M, T)
RATE OF CLIMB KNOWN?
NO
YES
COMPUTE: - RATE OF CLIMB
- CLIMB GRADIENT,
- TIME, DISTANCE
COMPUTE: - ACCELERATION,
- TIME,
- FINAL HEIGHT,
- DISTANCE
COMPUTE: CORR. FUEL FLOW
FUEL CONSUMED
= FLOW RATE X TIME

FIGURE 5

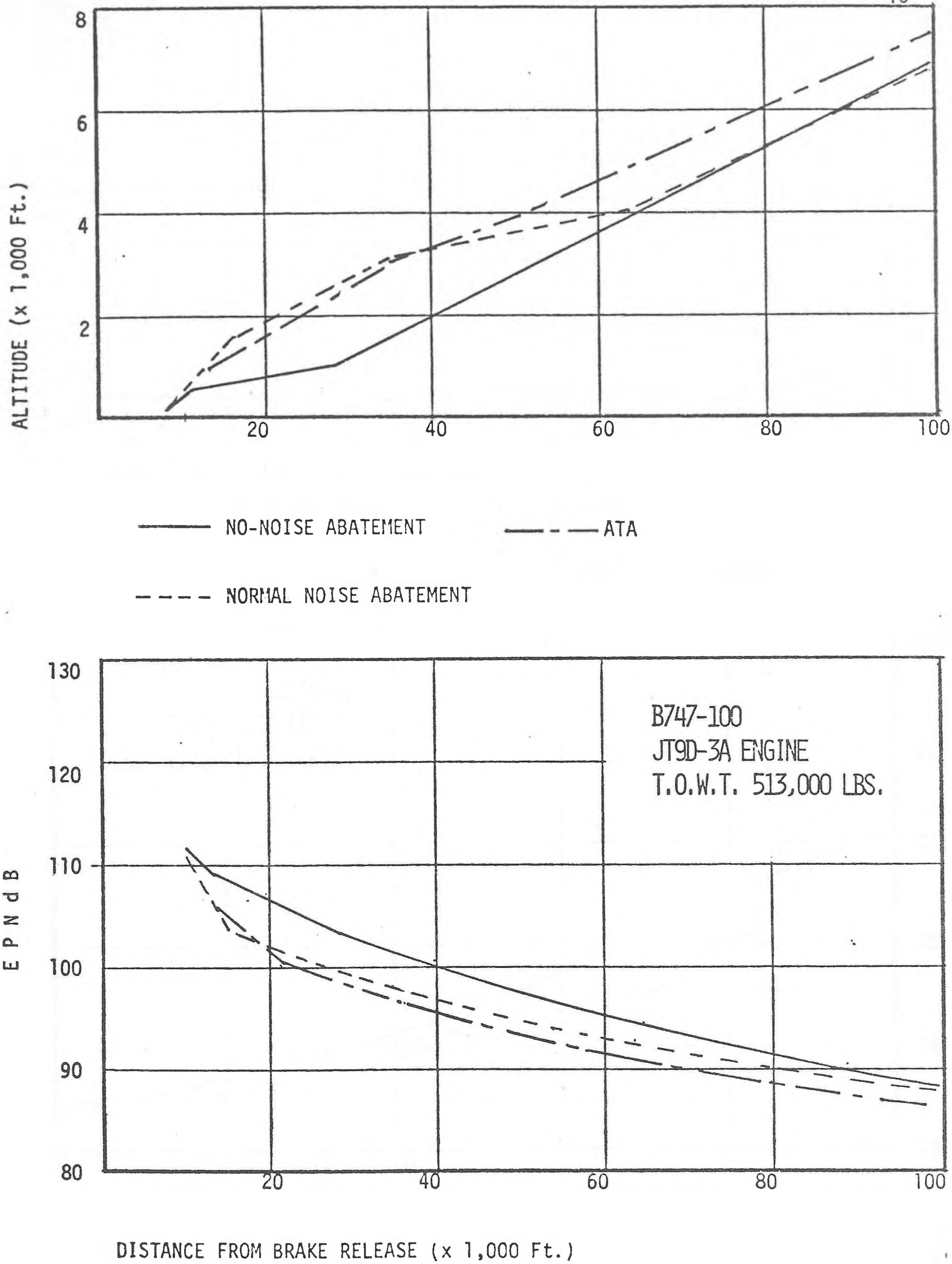
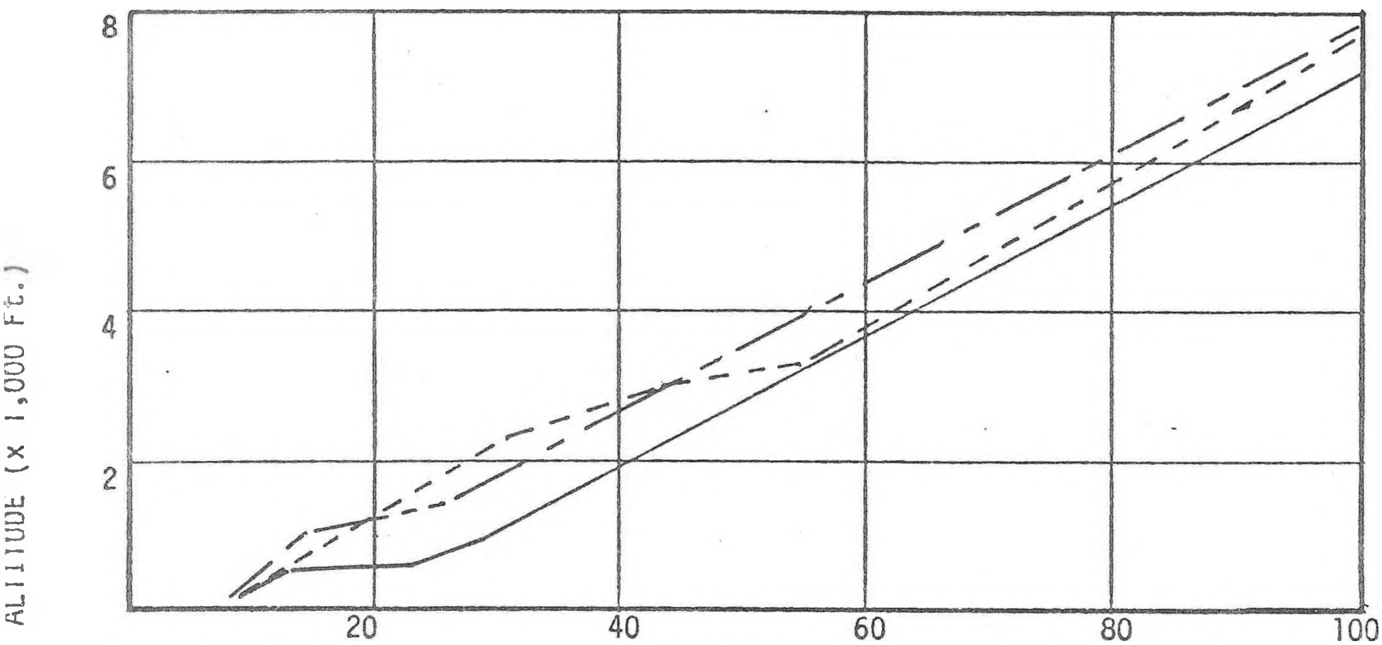
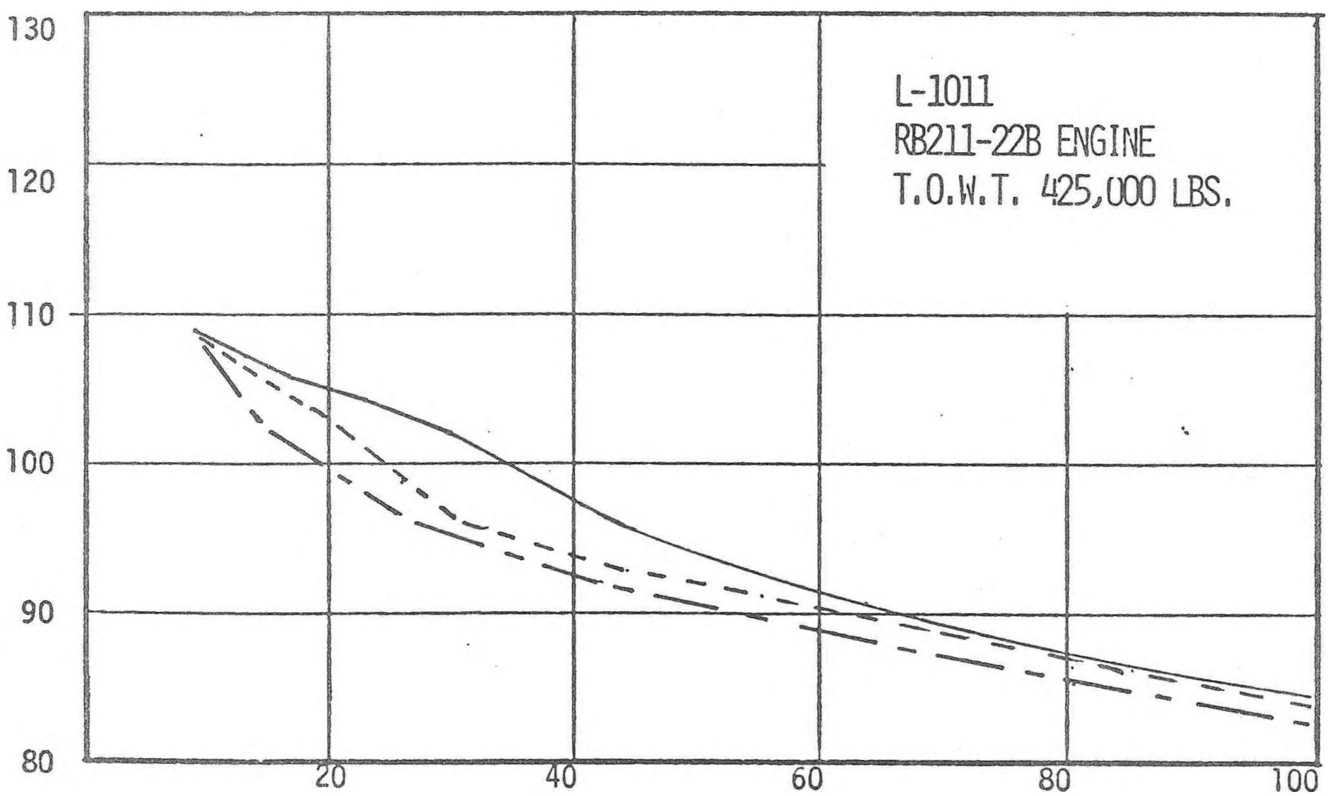

8
6
4
2
ALTITUDE (x 1,000 Ft.)
20
40
60
80
100
NO-NOISE ABATEMENT
ATA
NORMAL NOISE ABATEMENT
130
120
110
100
90
80
E P N d B
B747-100
JT9D-3A ENGINE
T.O.W.T. 513,000 LBS.
20
40
60
80
100
DISTANCE FROM BRAKE RELEASE (x 1,000 Ft.)

FIGURE 6



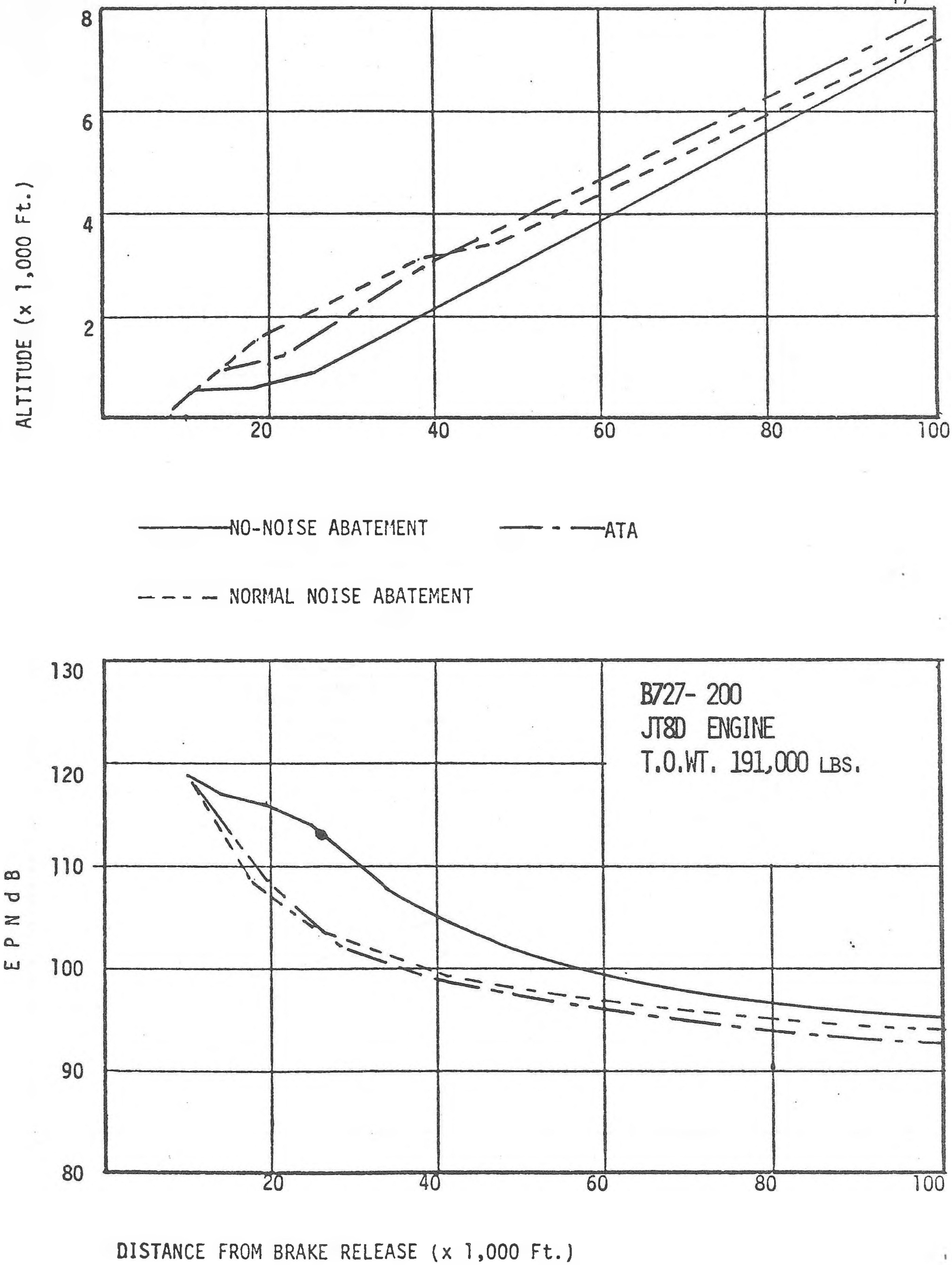
NO-NOISE ABATEMENT — ATA

NORMAL NOISE ABATEMENT



DISTANCE FROM BRAKE RELEASE (x 1,000 Ft.)

FIGURE 7



ALTITUDE (x 1,000 Ft.)
8
6
4
2
20
40
60
80
100
NO-NOISE ABATEMENT
ATA
NORMAL NOISE ABATEMENT
E P N d B
130
120
110
100
90
80
B727- 200
JT8D ENGINE
T.O.WT. 191,000 LBS.
DISTANCE FROM BRAKE RELEASE (x 1,000 Ft.)

FIGURE 8

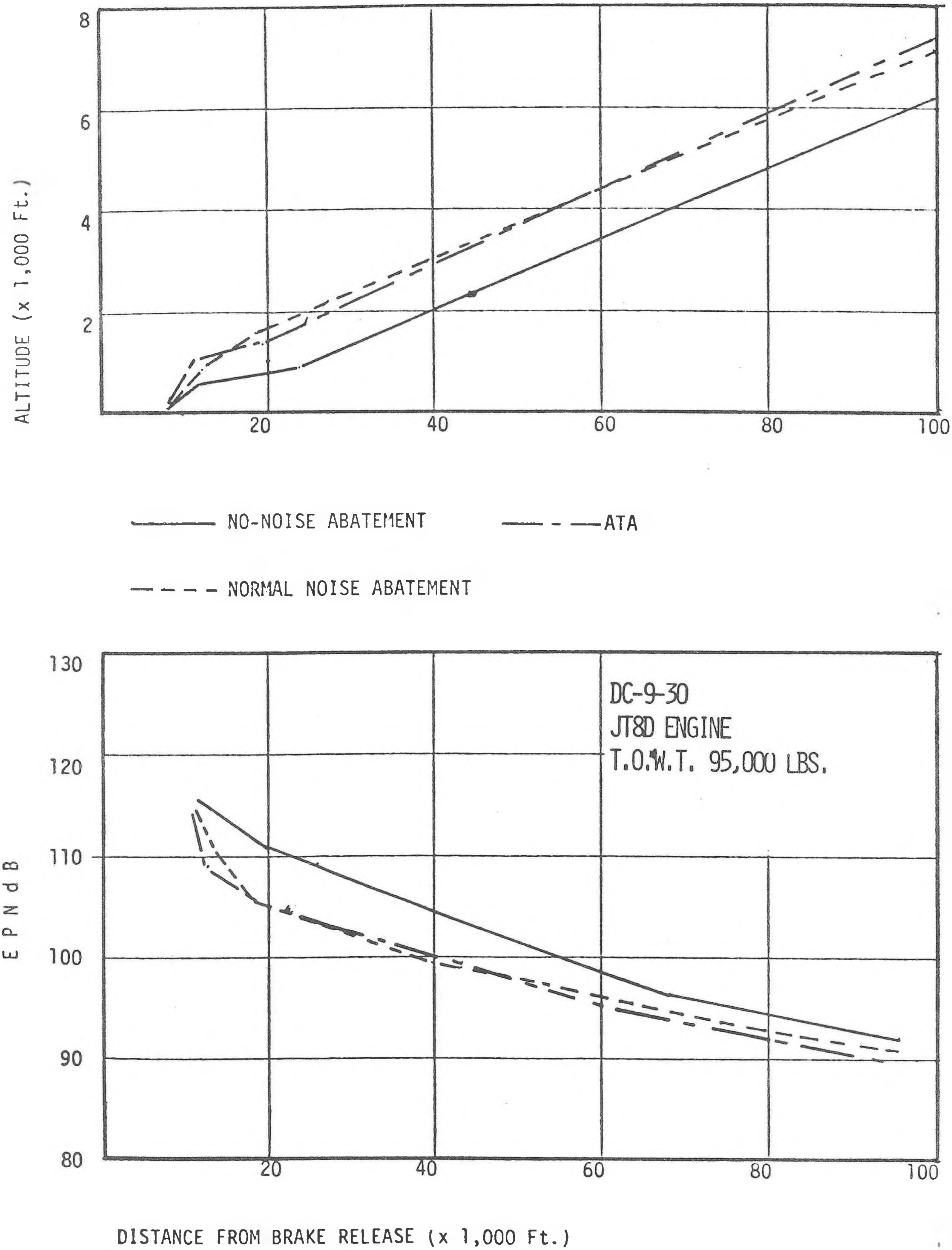

ALTITUDE (x 1,000 Ft.)
8
6
4
2
20
40
60
80
100
NO-NOISE ABATEMENT
ATA
NORMAL NOISE ABATEMENT
E P N d B
130
120
110
100
90
80
DC-9-30
JT8D ENGINE
T.O.W.T. 95,000 LBS.
20
40
60
80
100
DISTANCE FROM BRAKE RELEASE (x 1,000 Ft.)

FIGURE 9

TABLE 1

DEPARTURE TYPE	FEATURES
TYPE A (ATA PROCEDURE)	- TAKE-OFF THRUST - AT 1,000 FEET, RETRACT FLAPS - REDUCE THRUST, CLIMB AT VZF TO 3,000 FEET - ACCELERATE FROM VZF TO 250 KNOTS AND MAINTAIN APPROPRIATE RATE OF CLIMB
TYPE B (NORMAL NOISE ABATEMENT PROCEDURE)	- TAKE-OFF THRUST TO 1,500 FEET ALTITUDE - REDUCE THRUST TO CLIMB SETTING AND RETRACT FLAPS - ACCELERATE FROM VZF TO 250 KNOTS AND MAINTAIN APPROPRIATE RATE OF CLIMB

TABLE II

DEPARTURE TYPE	FUEL CONSUMED LBS.	COSTS $0.08/LB.
REFERENCE	3747.8	$299.82
TYPE A (ATA PROCEDURE)	3949.7	$315.98 (+ $16.16)
TYPE B (NORMAL NOISE ABATEMENT)	4740.9	$379.27 (+ $79.45)

TABLE III

DEPARTURE TYPE	FUEL CONSUMED LBS.	COSTS $0.08/LB.
REFERENCE	3110.6	$248.85
TYPE A (ATA PROCEDURE)	3382.1	$270.57 (+ $21.72)
TYPE B (NORMAL NOISE ABATEMENT)	3601.7	$288.14 (+ $39.29)

TABLE IV

AIRCRAFT	DEPARTURE	FUEL PENALTY (LBS.)	COST PENALTY $0.08/LB.
B727-200	TYPE A (ATA PROCEDURE)	+ 188.2	+ $15.06
	TYPE B (NORMAL NOISE ABATEMENT)	+ 389.9	+ $31.19
DC-9-30	TYPE A (ATA PROCEDURE)	+ 86.9	+ $ 6.95
	TYPE B (NORMAL NOISE ABATEMENT)	+ 112.7	+ $ 9.02

TABLE V

B747 Takeoff Weight (lb.)	Type A (ATA) Departure		Type B Departure	
	Fuel Penalty (lbs.)	Cost Penalty ($0.08/lb.)	Fuel Penalty (lbs.)	Cost Penalty ($0.08/lb.)
513,000	+ 201.9	$ 16.15	+ 993.1	$ 79.45
650,000	+ 181.3	$ 14.50	+ 1690.5	$ 135.24
700,000	+ 134.7	$ 10.78	+ 2501.3	$ 200.10

Impulsive Noise Measurements with a Conventional Sound Level Meter

A. Behar, Research Engineer
Acoustics Office, Systems Research and Development Branch
Ministry of Transportation and Communications, Ontario

J.M. Riganti, Engineer
División Acústica
Instituto National de Tecnologia Industrial
Buenos Aires, Argentina

1. INTRODUCTION

A continuous noise can be defined by its sound pressure level and its frequency content. If the energy of the noise is also of interest, then the duration must also be taken into account.

The situation is not the same when an impulsive noise has to be evaluated because, besides the characteristics listed above, the peak value and shape of the waveform, as well as its duration, are of interest.

In most industrial environments, high reverberation times cause the shape of the decay of an impulse to be approximately exponential. This fact at first sight offers an attractive possibility for inexpensively deriving the signal time constant, ζ *, as well as the peak level, when using an SLM set first to the "fast" and then to the "slow" response. As can be seen in Figure 1, if we have

$$a_{125} = Ae^{-125/\zeta}$$

and

$$a_{1000} = Ae^{-1000/\zeta}$$

then

$$\zeta = 875/\ln (a_{125}/a_{1000})$$

and

$$A = a_{125}(a_{125}/a_{1000})^{0.143}$$

where A is the peak value, and a_{125} and a_{1000} are the SLM readings for the "fast" and "slow" settings, respectively.

---

* ζ is defined as the interval between the time at which the signal reaches its peak value, and the time at which it drops 8.7 dB below this value.

The object of the present study was to find out if it is possible to find the impulse signal's time constant and its peak level by using an inexpensive SLM,such as one built to IEC 123 specification accuracy, and measuring the "fast" and "slow" response readings.

2. EXPERIMENT

A GR 1564 Sound Level Analyzer and GR 1556 B Impact Noise Analyzer were used, their "slow", "fast" and "peak" characteristics having been previously measured according to the method listed in the IEC 123 Recommendation, and also by using an oscilloscope.

The test signals used in the experiment were:

(a) Electrical pulses whose envelope had a rise time of less than 1 ms and decay times of different durations, the modulated signal being a sinusoid of 1 kHz,

(b) The same pulses as for (a), but using modulated pink noise,

(c) Impulsive noises generated by striking two wooden planks against one other. These noises were produced within enclosures of different acoustical characteristics, and picked-up by the SLM under test placed at different distances from the noise source, thus varying the characteristics of the noise at the microphone position.

A modulator was specially designed to be capable of shaping the test signals (a) and (b) in the following way: the envelope always had the same rise time of the order of 0.1 ms, decaying exponentially thereafter. The corresponding time constant could be varied in steps in order to obtain good repeatability. The signal thus obtained was introduced to the SLM under test, as well as to the oscilloscope, the latter being used as a monitoring instrument. An Impact Noise Analyzer (INA) was used to measure the peak levels of the signals as well as their decay times, which were also monitored on an oscilloscope.

Figure 2 shows photographs of the electrical signals (a) and (b). In Figure 2(a) the impulse has a 1 kHz sine content. Figure 2(b) shows the same envelope with pink noise. It can be seen that the second envelope is less regular than the first because of the probabilistic nature of the pink noise.

Figure 3 shows the waveforms corresponding to a real-life impulse obtained within a semi-reverberant acoustical enclosure. It can be easily seen that both the rise and the decay of the signal are quite irregular, due mostly to the changing predominance of the direct and reflected sound waves.

In all cases the following variables were recorded:

(a) "slow" and "fast" readings on the SLM under test, and

(b) "peak" and "time constant" on the INA.

3. RESULTS AND CONCLUSIONS

In order to normalize the results, the difference in reported sound pressure level found between the "peak" and "slow" (P-S) responses, as well as between the "fast" and "slow" (F-S), were evaluated as a function of the time constant. Figure 4 shows a graph of the results obtained by using the electrical 1 kHz signals for the P-S difference together with the calculated regression line. The same procedure was used throughout the experiment, and the correlation coefficients were obtained.

As can be seen from Table 1 where those coefficients are shown, the correlation is quite acceptable in the case of the electrical pulses.

The best results are found using sinusoidal signals. In this case the correlation is almost the same for the "peak" - "slow" and for the "fast" - "slow" values.

For pink noise the results are also good. However, due to its probabilistic nature, the energy contained within each impulse is not the same. Since the integration time of the "slow" response is 8 times longer than that of the "fast" response, the probability of each burst having the same amount of energy is higher for the former. Then since the "peak" level is always the same, and the "slow" is nearly constant while the "fast" is not, the correlation of the difference "P-S" with ζ is better than that for "F-S".

The correlation coefficients corresponding to "real life" noises are not acceptable due to their low values. This result is explained mainly by the fact that the decay of pulses is not exponential, as shown in Figure 3.

Consequently, we are able to conclude that it is impossible to measure accurately the acoustical characteristics of a given impulsive noise by using an SLM which meets the IEC 123 Recommendation. The correlation coefficients are too low to calculate either the peak level or the decay time with acceptable accuracy, except in the rare case of sinusoidal or pink noise pulses having proven exponential decays.

In this study we did not take into account the difficulty of reading the "fast" value due to the ballistic characteristics of the display, because this can be overcome by the use of digital indication devices.

BIBLIOGRAPHY

1. IEC 123 (1961) Recommendations for Sound Level Meters.

TABLE 1. Correlation Coefficients (see text)

		r	
TEST SIGNAL	n	P-S	F-S
Sinusoidal	32	.97	.96
Pink Noise	50	.94	.9
Real-Life Noise	37	.61	.55

n = number of measurements
r = correlation coefficients
P-S = SPL difference recorded between "peak" and "slow" meter response settings
F-S = SPL difference recorded between "fast" and "slow" meter response settings.

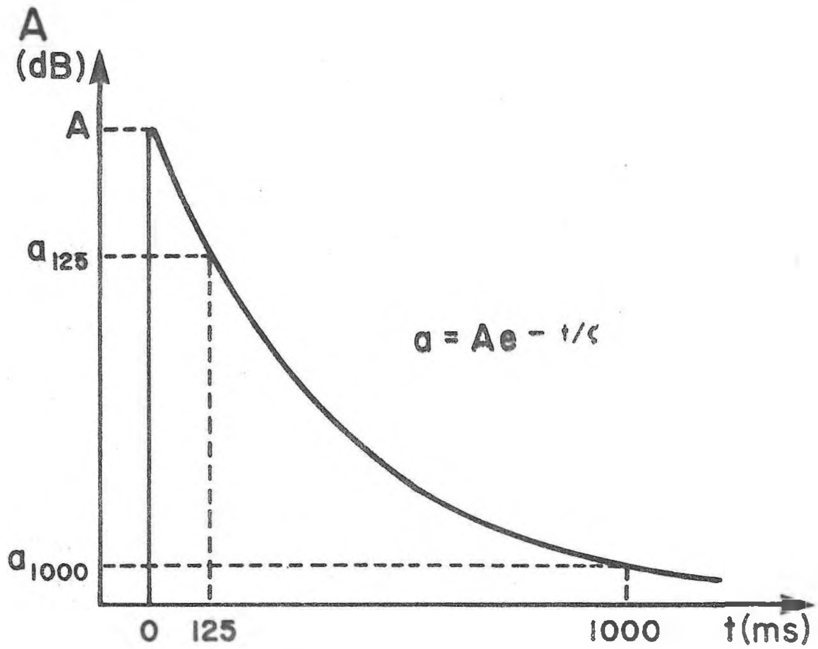
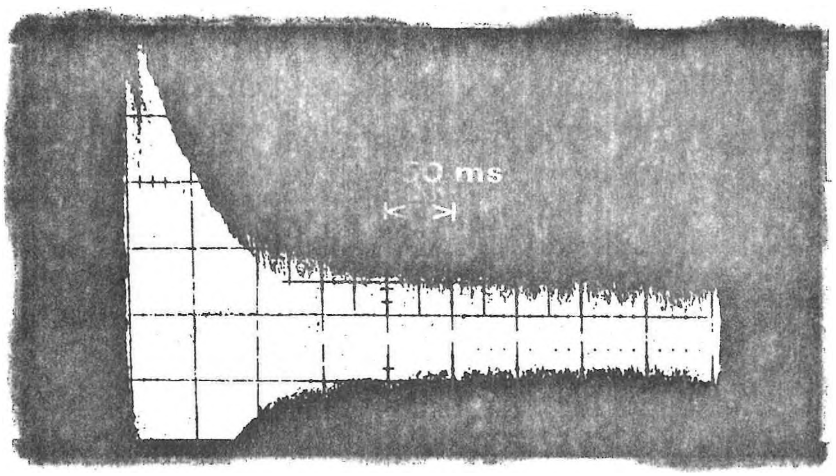
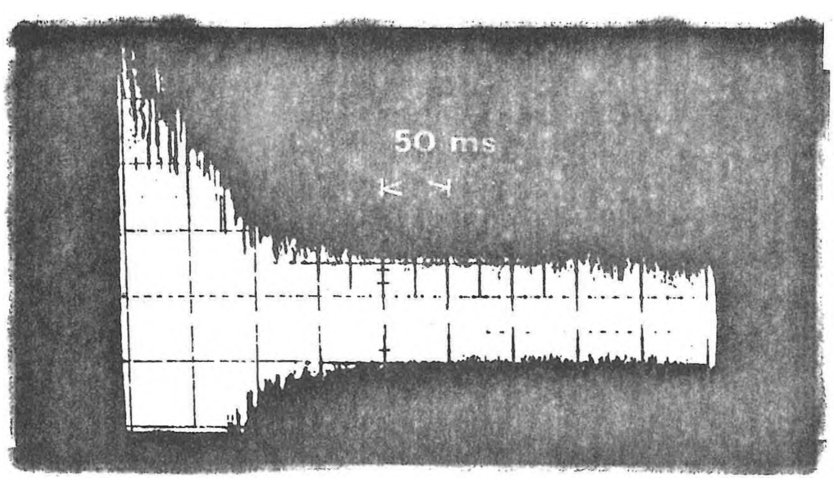


FIGURE 1. Characteristics of an Exponentially Decaying Signal



2(a)
White Noise



2(b)
Pink Noise

FIGURE 2. Oscillographs of the Electrical Test Signals

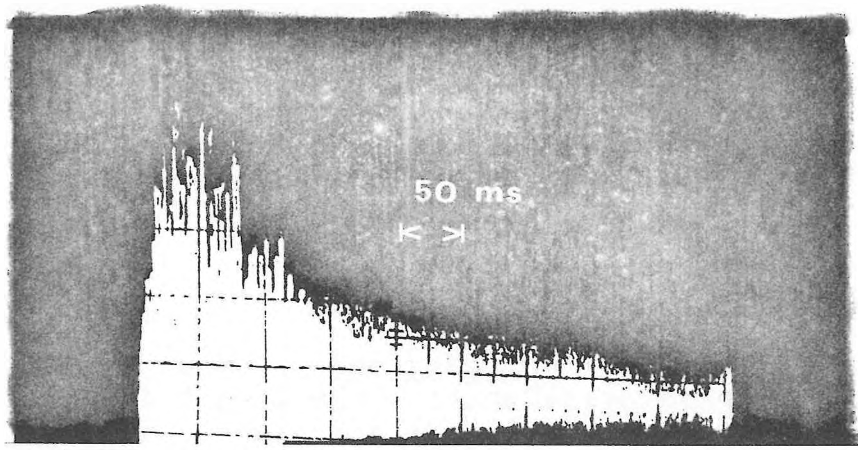


FIGURE 3. Oscillograph of a Real-Life Signal Recorded in a Semi-Reverberant Enclosure

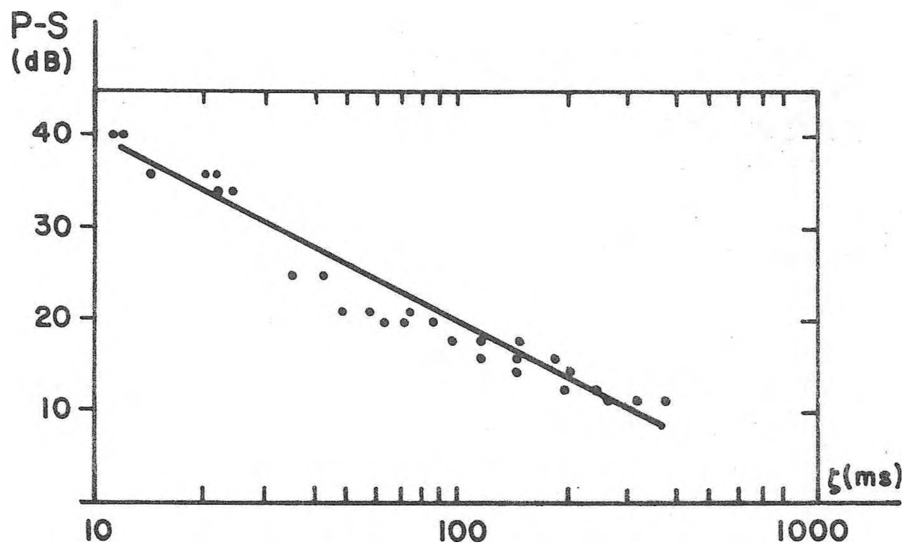


FIGURE 4. SPL Difference Recorded Between "Peak" and "Slow" Meter Response Settings (P-S) as a Function of the Time Constant (ζ) for Modulated 1 kHz Sine Tone

P-S = SPL Difference
ζ = Time Constant

Properties of Railway Wheels

L. Strasberg, N. Perfect, G.L. Elliott
Systems Research and Development Branch
Research and Development Division
Ontario Ministry of Transportation and Communications

INTRODUCTION

The urban railway is ideally suited for high density corridors or for those areas where urban growth is considered desirable. However, urban railways are limited in their application by high capital requirements and by train noise which can disturb tne community served by the system (1).

Previous investigations into the nature of railway noise (2) have shown that wheel/rail noise is dominant, at least insofar as electric trains are concerned. It has been shown that sound radiated by the wheel is a significant part of the total noise. Many different types of railway wheels have been tested on transit systems with varying degrees of success. However, little has been published which would enable an operator to compare the different wheels on the basis of their fundamental mechanical properties. The purpose of this paper is to present some laboratory data on four common railway wheels.

BEHAVIOUR OF EXISTING WHEELS

Wheels which are presently manufactured can be grouped into two categories - solid and resilient. In Table 1, the standard wheel is representative of the former group since it is made entirely of steel.

The resilient wheels use an elastomeric element to separate the wheel tread from its hub. The elastomer reduces the unsprung mass of the wheel/rail system and adds damping to the wheel. This damping reduces the squeal noise which can occur on short radius curves in the track. On the other hand, field experience indicates that resilient wheels do not appreciably reduce the rolling noise which occurs on straight track.

For this study, four properties of the wheels were sought: frequencies; mode shapes; modal damping ratios; and the degree of coupling between in-plane and out-of-plane wheel vibrations. This so-called "radial/axial" coupling has been postulated as an important mechanism in the generation of rolling noise (3).

The vibratory properties of the wheels were determined by mounting the wheel on the apparatus shown in Figure 2, and striking the wheel with a hammer. The resulting vibration was detected by an accelerometer and decomposed by a real-time analyser into the fundamental frequencies. Damping ratios were found by passing the signal through a narrow band filter and measuring the decay rate. The radial/axial coupling was determined primarily by static loading. Further evident was obtained by the detection of the same frequency using accelerometers with axial and radial orientations.

Typical vibration patterns for the wheels are shown in Figures 3 through 6. In each case, P represents the direction and location of the impact and A represents the direction and location of the accelerometer. It is important to note that the scales are different in each figure and that no attempt was made to control the magnitude of the impact. Complete results for the wheels are available in (4) and (5).

The laboratory data was compared to trackside audio recordings taken at a curve on the Toronto Transit Commission subway system. (Refer to Figure 7.) It was apparent that there is strong correspondence between the noise spectrum and the wheel frequencies at 5.24, 11 and 17 kH_z.

The damping ratios for the wheels showed considerable scatter (Table 2). The standard wheel was, for all practical purposes, undamped while the Acoustaflex wheel produced the highest damping ratios. For all wheels except the Acoustaflex, only one sample was available for testing. Four Acoustaflex wheels were tested and these showed considerable variance in damping ratios. It is not known if such variance is typical of resilient wheels or if this behaviour is restricted to the sample tested.

To study radial/axial coupling in more detail, a Bochum wheel and a standard wheel were analysed using a static finite element model. In addition these wheels were subjected to radial and axial loads to determine stress and deflection behaviour. The slope of the web causes a load eccentricity which enhances radial/axial coupling. It was apparent from the model that the position of the load alters this eccentricity and modifies the coupling. Since the railway vehicle is free to oscillate across the rail head, the position of the actual load on the wheel is varied. This effect is one source of variability in the vibration behaviour of wheels (Figure 9).

The effect of load eccentricity can be reduced by various means. Two such methods are shown in Figure 10 and their deflections are compared to a standard wheel. It is apparent that a straight web reduces the deflections of the wheel and that they can be made very small by the use of an "A" frame.

RESULTS FROM TWO PROTOTYPE WHEELS

The investigation into existing practice showed that several design components of railway wheels could be improved. These included:

(a) damping ratios;
(b) radial/axial coupling;
(c) unsprung mass.

Two prototype wheels were designed to demonstrate these improvements (Figure 1). Several new features distinguished them from most existing wheels:

(a) a thin rim to reduce the unsprung mass and attempt to increase the wheel/rail contact area;

(b) a straight web (wheel A) or an "A" frame construction (wheel B) to reduce radial/axial coupling;

(c) aluminum centers to reduce the total wheel mass;

(d) more flexible elastomers to improve the damping ratios; and

(e) bolted construction for easier assembly.

In experiments, the prototype wheels were found to produce high damping ratios (Table 3). It is apparent that, by reducing the wheel rim mass and the elastomer stiffness, the damping ratio will increase for all modes which have a rim displacement component. Since these modes have already been identified as contributors to squeal noise then obviously an improvement is effected. In addition, the use of bolted construction increases the amount of damping available because of frictional effects.

The introduction of the elastomeric blocks near the center of wheel B improved the damping ratios marginally. These blocks reduced both the axial and radial stiffness of wheel B significantly when compared with wheel A. The radial stiffness of wheel A was 320,000 lb./in. (56 041 600 N/M) compared with 80,000 lb./in. (14 011 200 N/M) for wheel B. The axial stiffness measured at the rim of wheel A was 30,000 lb./in. (5 254 200 N/M) compared with only 2,000 lb./in. (350 260 N/M) for wheel B.

CONCLUSIONS

The damping ratios of established railway wheels are low; generally below one percent. Of the wheels tested, the Bochum and Acoustaflex wheels produced the highest damping ratios. The damping ratios of resilient wheels can be improved by judicious selection of mass and stiffness properties. Two prototype wheels were tested to demonstrate this principle.

REFERENCES

(1) May, D.N., "Criteria and Limits for Wayside Noise from Trains", Journal of Sound and Vibration, 46(4), 1976, Academic Press Inc., London, England, pp. 537-550.

(2) Remington, P.J. et al, "Wheel/Rail Noise and Vibration", Report No. UMTA-MA-06-0025-75-10, U.S. Department of Transportation, Urban Mass Transportation Administration, Office of Research and Development, Rail Technology Division, Washington, D.C., 20590, 1975.

(3) Lotz, Robert, "Wheel Rail Noise: A Progress Report", Inter-Noise 74, Washington, D.C., September 30 - October 2, 1974.

(4) Perfect, N., "Vibration Testing of Damped and Undamped Steel Wheels", Report No. 76-TIL-4, Research and Development Division, Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1976.

(5) Perfect, N., "Vibration Testing of Acoustaflex Wheels", Report No. 76-TIL-25, Research and Development Division, Ministry of Transportation and Communications, Downsview, Ontario, Canada, 1976.

Table 1

Four Railway Wheels

WHEEL	MANUFACTURER
Bochum	Bochumer Verein A.G. West Germany
S.A.B.	Svenska Aktiebolaget Bromsregulator Sweden
Acoustaflex	Standard Steel Company U.S.A.
Standard	Canadian Steel Wheel Division Hawker Siddeley Canada Ltd.

Table 2

Frequencies and Damping Ratios of Railway Wheels

COMPONENT	FREQUENCY kHz	DAMPING RATIO			
STANDARD WHEEL	0.62	0.00032			
	1.58	0.00014			
	2.75	0.000073			
	3.99	0.000042			
	5.28	0.000041			
	6.25	0.000041			
BOCHUM WHEEL	0.434	0.0051			
	1.24	0.0031			
	2.20	0.0083			
	4.60	0.0048			
S.A.B. WHEEL	0.433	0.0024			
	1.19	0.0011			
	2.10	0.00083			
	3.07	0.00081			
	4.09	0.00051			
	5.16	0.00039			
ACOUSTAFLEX WHEEL	0.46	0.0062	0.0027	0.0113	0.0044
	1.35	0.0048	0.0168	0.0082	0.0075
	2.45	0.003	0.005	0.0033	0.0029
	3.67	-	0.0043	-	-
	4.96	-	0.0041	-	-

Table 3
Damping Ratios of Two Prototype Wheels

COMPONENT	FREQUENCY	DAMPING RATIO
WHEEL A	330 Hz	0.008
	988 Hz	0.017
	1.83 Hz	0.026
	2.33	0.024
	2.83	0.025
	3.61	0.027
	4.54	0.027
	4.98	0.028
	5.44	0.027
	7.32	0.017
WHEEL B	360 Hz	0.032
	1.00 kHz	0.012
	1.84	0.017
	2.36	0.040
	2.84	0.034
	3.60	0.032
	4.56	0.022
	5.52	0.021
	6.44	0.016
	7.20	0.009

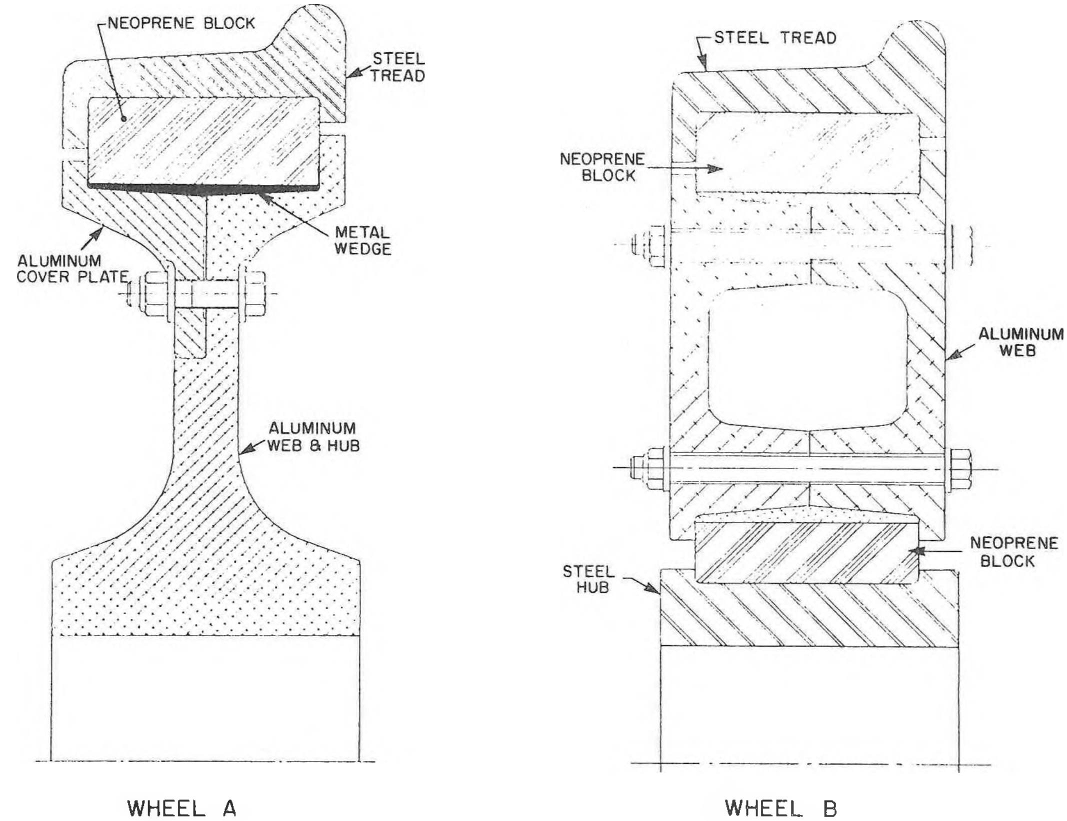


Figure 1, Cross-Section of Each Prototype Wheel

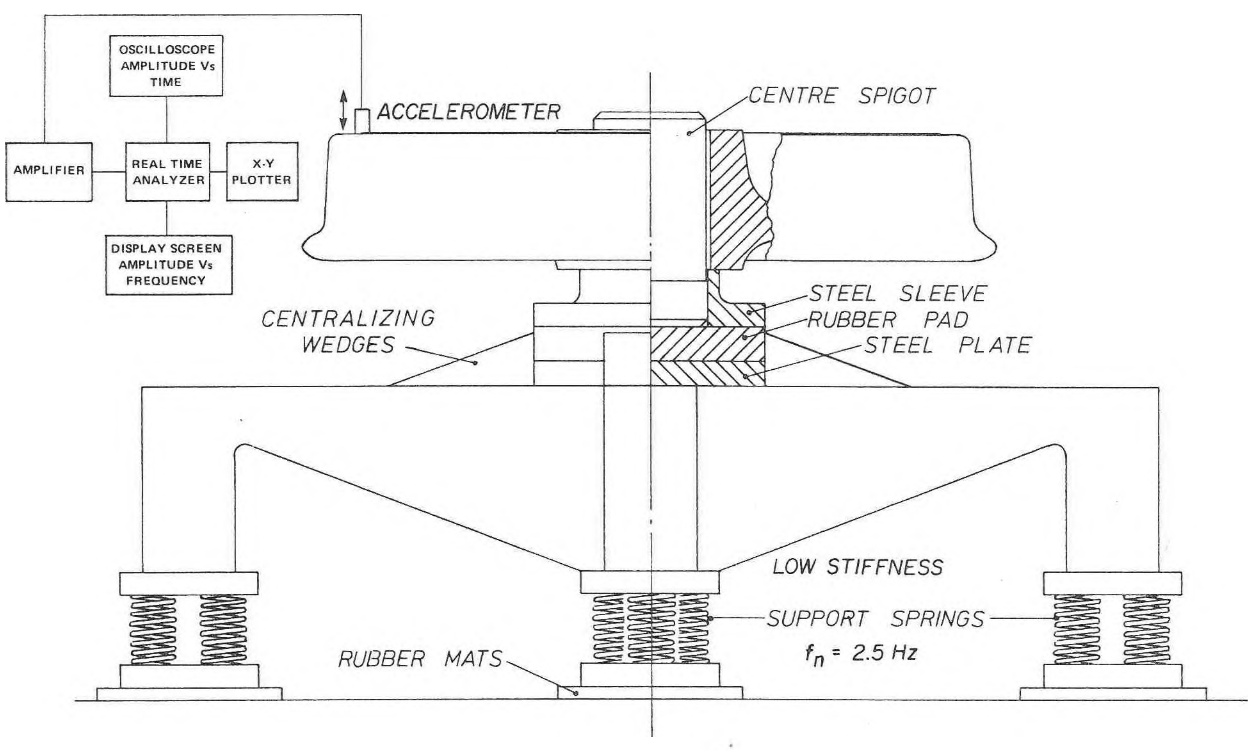


Figure 2, Test Set-Up Used to Find Natural Frequencies of Wheels

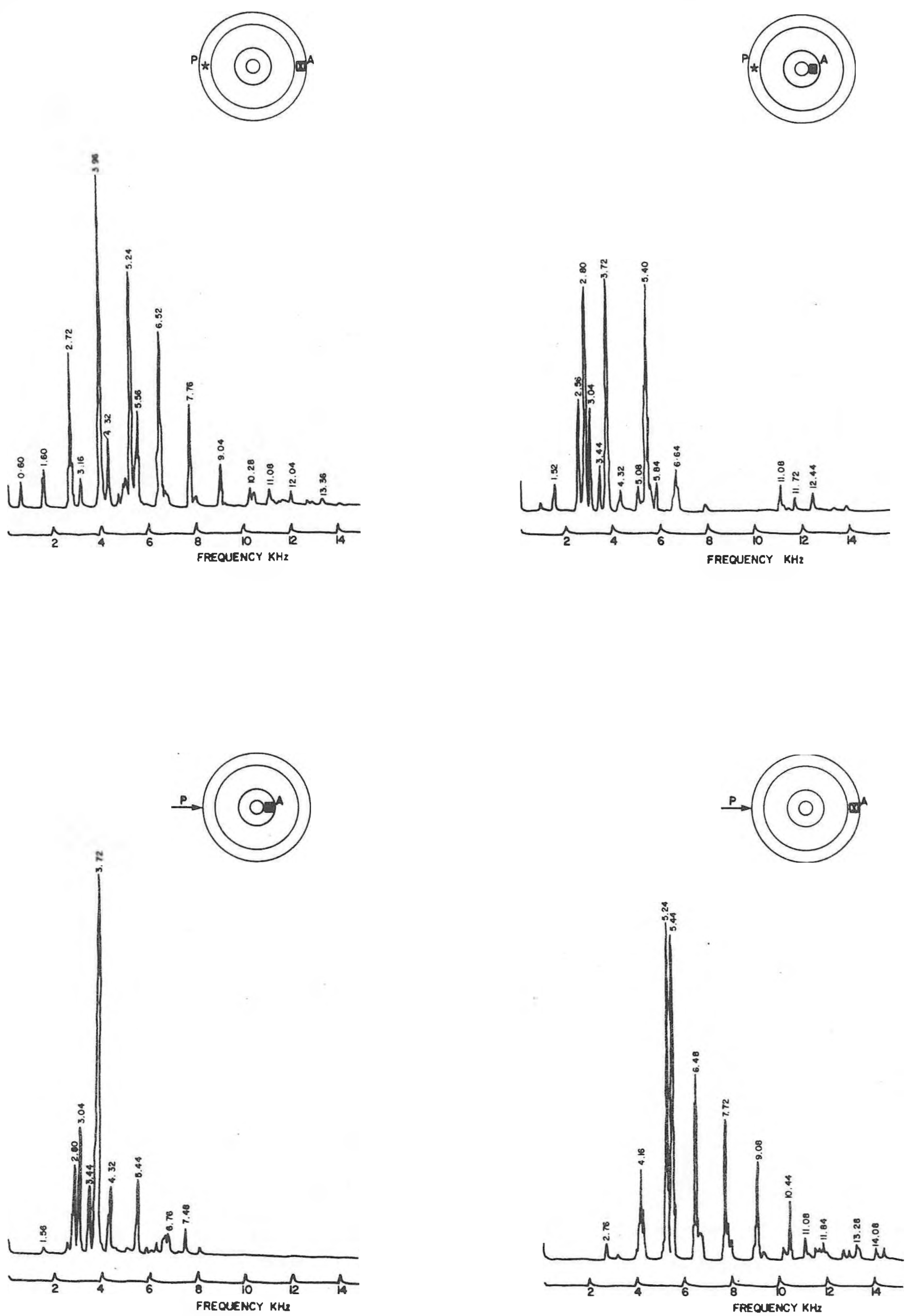


Figure 3, Natural Frequencies of a Standard Wheel

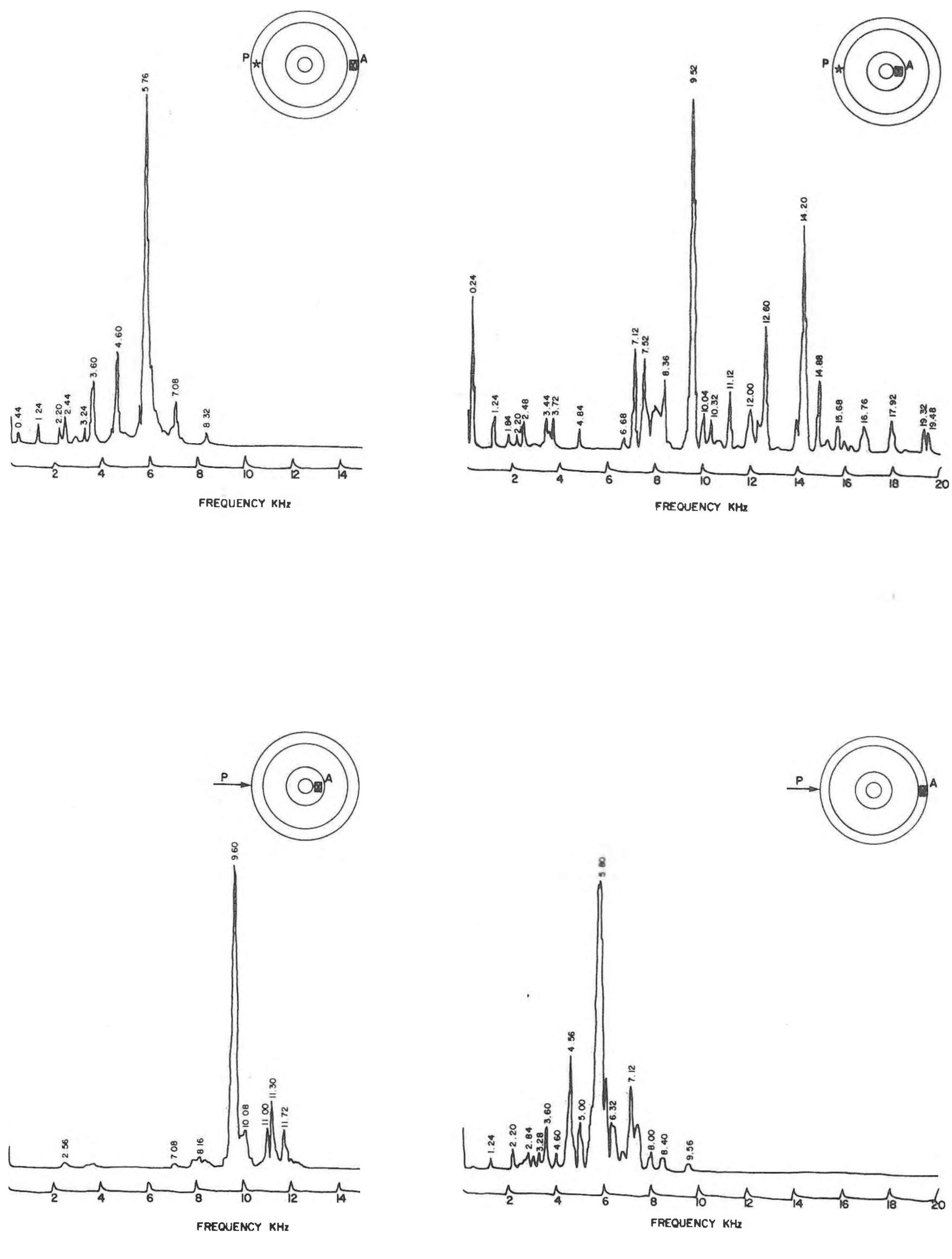


Figure 4, Natural Frequencies of a Bochum Wheel

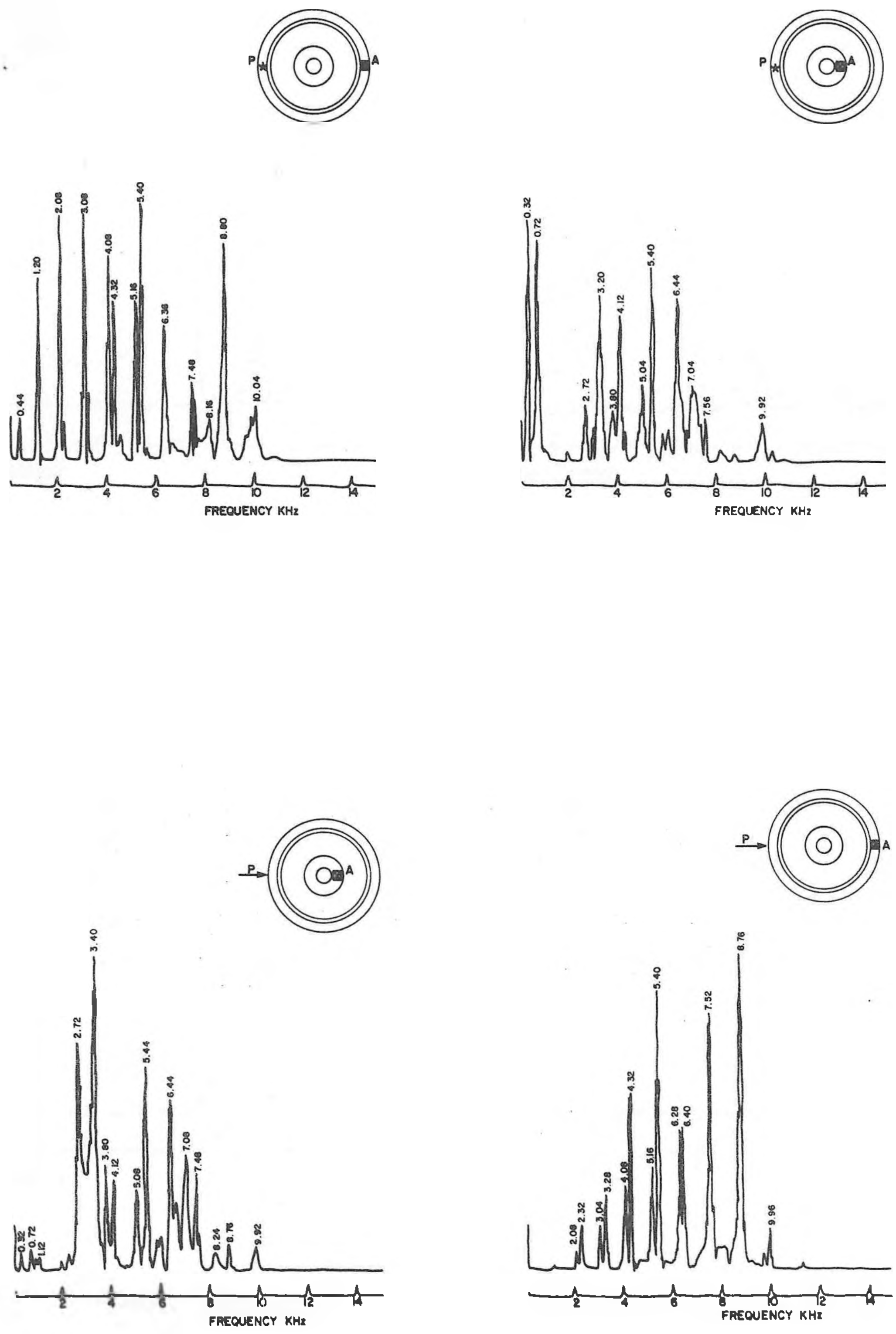


Figure 5, Natural Frequencies of an S.A.B. Wheel

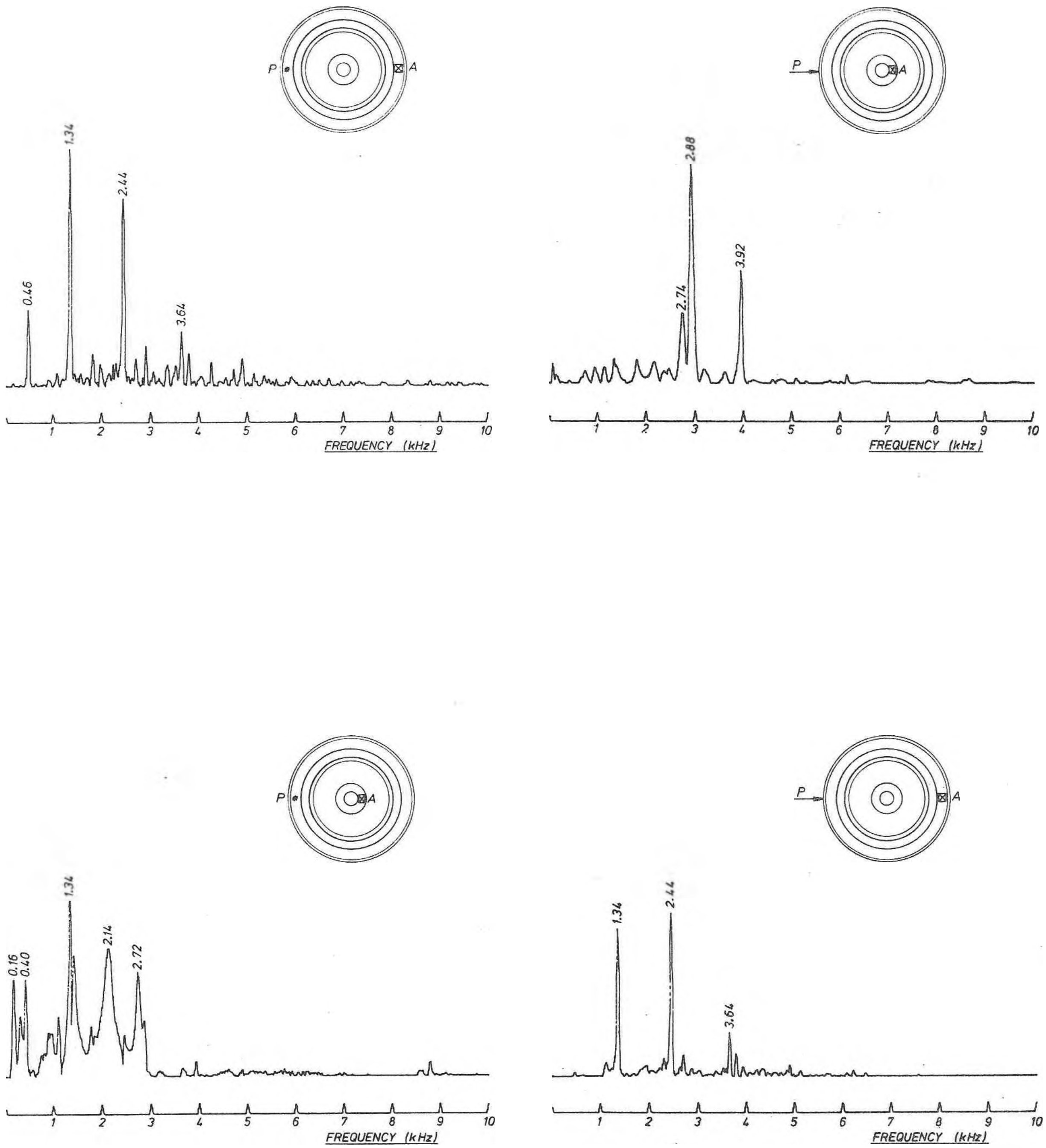


Figure 6, Natural Frequencies of an Acoustaflex Wheel

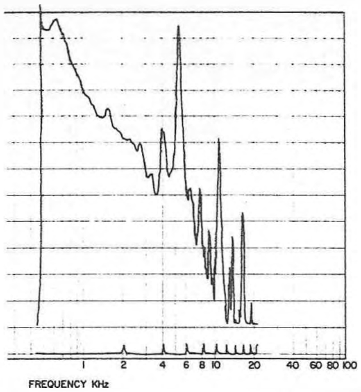


Figure 7a, TTC Train Noise Spectra from Trackside Recording on Curved Track

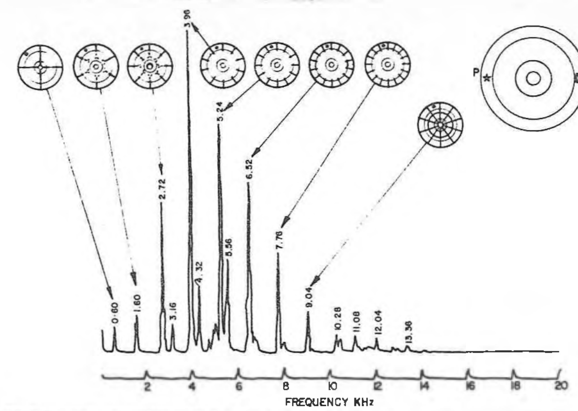


Figure 7b, Modal Patterns of Standard Wheel

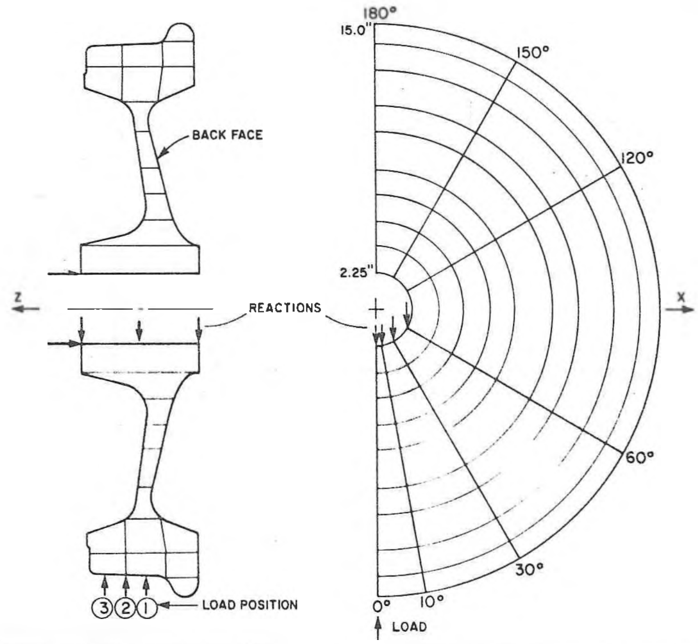
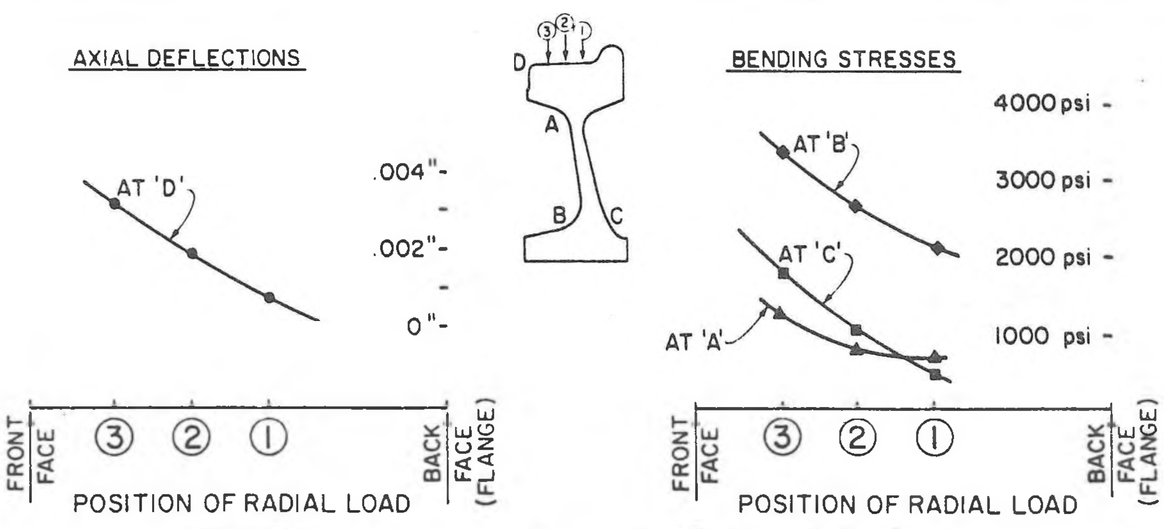


Figure 8, Finite Element Model Used for Analysis



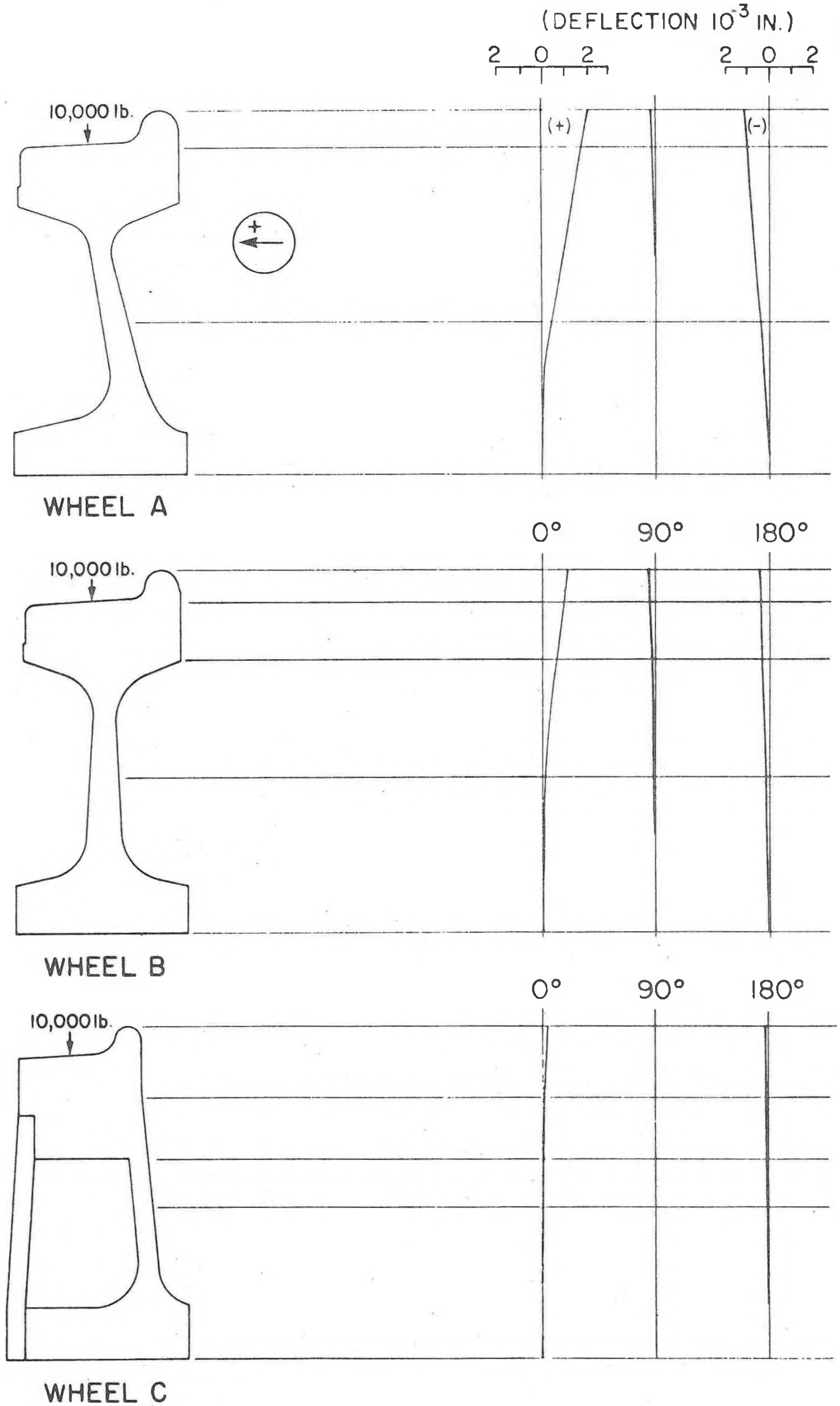


Figure 10, Axial Deflections on Back Face of Three Wheels Due to 10,000 lb. Radial Load at Position 2 of Figure 9