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Influence of motorcycle and operator characteristics on sound pressure level measured at the ear of the operator.

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INFLUENCE OF MOTORCYCLE AND OPERATOR CHARACTERISTICS ON SOUND PRESSURE LEVEL MEASURED AT THE EAR OF THE OPERATOR

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TO ELIZABETH,

IN MEMORY OF

KATHLEEN

ABSTRACT

In this investigation the sound level generated at the ear of a motorcycle operator is studied. The effects of variation of vehicle size and cycle of operation, subject size and posture, engine speed and head protection are examined. The sound level at the operator's ear is obtained by analyzing recordings made under specific test conditions. The recordings are obtained with an "Ear-Bug" unit, which incorporates a tiny microphone capable of fitting within the concha of the ear.

Tests were carried out in a semi-anechoic chamber where noise was produced by loudspeakers and subjects were seated on a test stand resembling a motorcycle. Here angle of incidence, helmet fit and variation of head gear were studied. These tests were supported by field measurements where a number of vehicles were used.

It is shown that subject size does not matter as much as posture, nor does vehicle size as much as the cycle of operation. Helmets do not attenuate noise from the rear as effectively as from the sides while visors do little to reduce the noise detected at the ear.

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NOMENCLATURE

ANSI	American National Standards Institute
AVG_1	First average of a set of results
AVG_2	Second average of a set using AVG_1
BFH	Best fit helmet
CC	Correlation coefficient
CH	Centre of head
CHABA	Commission on Hearing Bioacoustics and Biomechanics of America
DRC	Damage Risk Criterion
HO	Helmet only
HV	Helmet with visor
L_P	Sound Pressure Level
NH	No Helmet
NIPTS	Noise induced permanent threshold shift
NITTS	Noise induced temporary threshold shift
NYD	No visor; with helmet; down position
NYU	No visor; with helmet; upright position
OSHA	Occupational Safety and Health Act
RTA	Real time analyser
TTS_2	Temporary threshold shift 2 minutes after exposure
YYD	With visor; with helmet; down position
YYU	With visor; with helmet; upright position

Subscripts

A,B,C,D,E,F	Subjects
1,2,3,4,5,6	vehicles
S,M,L,XL	helmet sizes
α β γ	(NH-CH), (HO-NH), (HV-NH)
38N	Run no. 38 in north direction
38S	Run no. 38 in south direction

CHAPTER I

INTRODUCTION

A previous investigation made by Reif et.al. (18) which included discussions on motorcycle noise and crash helmet attenuation, has been extended by this study. These have been expanded herein to include such areas as (1) angle of incidence, (2) subject size, (3) noise frequency and energy content, (4) degree of head protection and (5) vehicle size and cycle of operation.

Motor vehicle noise has been measured in the past by such methods as "pass-by" testing where a vehicle is accelerated along a path some distance from a sound level meter in order to obtain the maximum sound level (e.g., SAE XJ 331 a (15)). In this study, however, the sound level was measured at the operator's ear by means of an ear bug unit wherein a miniature microphone was placed in the concha of the operator's ear. This then monitored the noise at the ear and fed the signal to a portable tape recorder fastened to the subject's chest. Sound level and frequency spectra of each test were obtained by laboratory analysis. This provided a simple, comprehensive and effective way of obtaining sound level at the ear for a large number to tests. For recordings made in the field which involved the use of motorcycles, the testing involved 4 subjects and 6 vehicles.

Thirty seven operating parameters were specified and these were used by each of the subjects on every vehicle. The operating parameters were designed to study the influence of subject size, vehicle size, engine operating cycle and head gear. The remaining areas were studied in the semi-anechoic chamber.

In the semi-anechoic chamber 6 subjects were involved. Here a test stand was used instead of motorcycles and noise was produced by loudspeakers located strategically around the test stand. Various types of noise could be generated in the speakers. Here influences such as helmet size, direction of noise, type of noise and head gear were examined.

In addition auxiliary testing was done in the field using motorcycles and a loudspeaker to produce the same type of noise used in the chamber. Vehicles were operated in both the stationary and moving modes at the same engine RPM. These tests were intended to provide additional data regarding the testing procedures.

The literature survey contains material which describes the hearing mechanism and its influence on the direction of sound. A discussion of Damage Risk Criterion (DRC) as proposed by the Committee on Hearing Bioacoustics and Biomechanics of the National Acadamy of Sciences-National Research Council (CHABA), is included to examine its current applicability. Recent work has suggested that TTS_2, the basis of the CHABA DRC, may not be an adequate measure of hearing damage. In addition, the method of applying the DRC is much too labourious for practical applications. As a result the literature also covers a simplified noise exposure evaluation technique which is based on the work done by CHABA in designing the DRC but proves to be much more practical.

Analysis of recordings was done with such instruments as a real time analyser with an octave converter and averaging unit to provide 1/3-octave displays of the frequency spectrum. A graphic level recorder was used to obtain the sound level. For the long duration highway recordings a Metrosonic Noise Analyser was used to obtain statistical data. Comparison of results included the deviation in sound level from measurements made at the centre of head location (CH) to those at the concha of the ear, as well as attenuation of sound level due to helmet and visor. Groups of recordings made in the field provided curves for which the slopes and zero-intercepts could be compared.

CHAPTER II

LITERATURE SURVEY

The damage to hearing is basically related to three parameters of noise which include sound level, frequency and duration. It is also important however to be aware of the mechanics involved as noise propagates from a source to an individual's ear and then on to the eardrum. Significant amplification of noise takes place as the pressure pulse impinges on the pinna flange and proceeds down the ear canal. An understanding of this is essential in the prediction of hearing damage.

2.1 Binaural Localization

The difference in sound level at each ear provides the basis for localization of high frequency sound. Low frequency sound is localized with the aid of phase differences. Quantitative evaluation of binaural localization involves sound diffraction.

A study was made by Weiner (27) concerning this mechanism. He studied the magnitude of sound pressures at the right and left ear drum of several observers. Each was exposed to a progressive sound wave as a function of frequency and angle of incidence. He points out that an increase of sound pressure at the eardrum over free field sound pressure is caused by a combined effect of diffraction by the head and resonance in the auditory canal. Pressure distribution in the auditory canal is essentially independent of orientation with respect to the source. In order to evaluate the obstacle effect, sound pressures were measured at the entrance to the auditory canal. These may then be taken as a measure of the diffraction ascribable primarily to the head and pinna.

Another study regarding the effect of azimuthal angle on response was done by Harris (8). He used a dummy head constructed of balsa wood with 3/8" coating of rubber to simulate the impedance of human flesh. At a selection of frequencies and azimuths, the head was rotated with continuous recording of the microphone output. These were located at the position of the eardrums. Removable pinnae were molded by the plaster of paris transfer technique. He observed that the head itself throws the more significant shadow and that acoustical properties depend on individual physiognomy. The pinna throws secondary shadows with large inter-eardrum intensity differences.

When directional fields vary in the vicinity of the head; one method of evaluating an individual's exposure to noise has been the use of a miniature microphone located within the ear (3). This is placed at the base of the concha and combines with a portable taperecorder to register the levels of exposure. In order to compare data obtained by this method with criteria for hearing conservation, a transfer function may be used to produce the equivalent diffuse field that would exist at the centre of the head in the absence of the subject.

2.2 Subject Influence

2.2.1 Ear Structure

Many questions have been asked regarding the manner in which humans detect sound. It is known that the sound field is transformed at the external ear as it gains directionality and undergoes high frequency modification. The head torso and pinna flange diffract sound while the concha and ear canal resonate it. Termination occurs at the eardrum. Thus the overall sensitivity of the hearing system is linked to the sound pressure transformation from the free field to the eardrum as a function of frequency, direction and distance. The acoustic impedance of the ear and the pressure distributions within the ear also play an important role.

The head produces a baffling effect in a field of low frequency sound propagation. The neck and torso also contribute to this effect. Under free field conditions the ear canal wall, the concha and the pinna flange as well as the surface of the head behave as boundaries to sound. This results in scattering, diffraction and resonance, which are identified with respect to the wavelength of sound and the dimensions of the above mentioned structures. Each structure contributes a different amount of acoustic pressure gain. Response measurements with the ear canal closed show that the concha alone contributes approximately 10 dB gain at 4 to 5 kHz (22). The pinna flange causes an increase in pressure gain at frequencies from 3 - 6 kHz when the source is in front of the ear. When the source is behind the ear there is a reduction in the gain. Shaw (22) suggests treating the helix, the antihelix and the lobule as a single structure since the results are not greatly affected by drastic changes in the shape and size of the pinna flange in model ears. He also found that the greatest overall acoustic pressure gain (transformation from free field to eardrum) for human subjects occurs at 45 degrees from the frontal plane, for frequencies from 2 - 5 kHz in the azimuthal plane. The ear canal and the concha compliment one another providing substantial acoustic pressure gain from 1.5 kHz to 7 kHz which implies that the concha is particularly important. Above 7 kHz response is largely determined by resonance frequencies and the angular properties of the concha transverse modes.

Another study by Flynn (6) compares the auditory threshold of cats with and without pinnae. He found that removal of the pinna resulted in significant loss of hearing particularly at high frequencies.

2.2.2 Hearing Loss

Noise affects people in a variety of ways. It is known that hearing loss and cochlear injury follow prolonged exposure to intense noise but such effects as noisiness and annoyance are not so quantifiable (18). The outer and middle ear are not as susceptible to damage as the inner ear (organ of corti). Excessive exposures to noise cause destruction of the hair cells and the auditory neurons. Such cells do not regenerate.

In any case, the degree of hearing loss must be determined with consideration made for presbycusis (increase in hearing threshold due to aging) and sociocusis (losses incurred due to day to day exposure and social interactions).

2.3 Mechanics of Noise Propagation

2.3.1 Steady State Noise

In 1963, a paper written by Karl D. Kryter (13) contained the opening sentence; "For the past 15 years or so there has been considerable speculation about so called damage risk criteria for exposure to sound". Kryter made reference to Ward, Glorig and Sklar when discussing work done on temporary fatigue from exposure to sound. Even at that time, attempts were being made to extrapolate relations found in temporary fatigue studies to specify DRC for prevention of permanent deafness. Furthermore, it was known that additional information was required to specify DRC for exposure to "steady-state noise". Steady state noise was characterized as containing complex sound (i.e., not made up of distinct pure tones) and having a steady over-all intensity within a few decibels for at least a minute. It was felt at that time that there was a relationship between noise induced temporary threshold shift (NITTS) and noise induced permanent threshold shift (NIPTS) of people exposed to a given noise over a period of many years. This was supported by investigations of NITTS which predicted reasonably well, the NIPTS that occurred in industrial workers. (NITTS is easily produced in subjects under laboratory conditions while NIPTS is measureable only after months or even years of exposure to a given noise environment).

In a paper written by Nixon and Glorig (16) three samples of industrial workers were studied who had been in industrial environments with steady-state noise having octave bands from 150 to 4800 Hz and levels of from 77 to 96 dB. Subsamples of these included times on the job of from less than one year to over 25 years. Only median hearing levels at 2000 and 4000 Hz were examined.

Having corrected for age, the NIPTS values were thus obtained. It was found that a maximum NIPTS value was produced at 4000 Hz and that it occurred within the first 10 years of exposure. These maximums were approximately equal to NITTS values predicted from the appropriate sound level of each sample. The amount of NIPTS at 4000 Hz showed little increase after about 10 years of exposure, although the NIPTS for lower frequencies continued to increase. In an attempt to regulate the amount of NIPTS, the Occupational Safety and Health Act (OSHA) established that a 5 dB increase be permissible with each factor of 2 reduction in exposure time based on NITTS experiments. More recent reports suggest that 3 dB per halving of exposure time is a better estimate.

2.3.2 Ear Canal Pressure

Since the human eardrum is not readily accessible to even a probe microphone it is usually necessary to measure acoustic pressure in the vicinity of the outer ear. This is acceptable because pressure amplitude within the ear canal is almost independent of the position of measurement below 1000 Hz. At higher frequencies measurements made at different positions can vary by 10 to 20 dB. Shaw (22) pointed out that the transfer functions showing average transformation of sound level from ear canal entrance to eardrum are essentially zero up to 500 Hz. Due to the difficulties encountered in placing and holding a microphone at an accurately defined position in the ear canal entrance, it is preferable to make pressure measurements at a point well removed from the ear canal entrance. Good correlation exists for most positions in the concha up to a frequency of 5 - 6 kHz.

2.3.3 Eardrum Impedance

Weiner and Ross (26) measured the variation of sound pressure along the auditory canal in both male and female subjects with a small flexible probe microphone. The subjects were placed in front of a loudspeaker in an anechoic chamber where various frequencies and orientations in the azimuthal plane were used. The sound pressure at the eardrum was found to be greater than the free field pressure thus verifying that the human ear is an effective amplifier.

Similar data resulted for both men and women.

2.3.3.1 Probe Tube Microphone

The sensitivity of a probe tube microphone decreases with frequency at about 6 dB per octave and the signal to noise ratio is 15 dB from 200 to 5000 Hz. It is 10 dB from 5000 to 8000 Hz. Free field correction is essentially zero for all angles of incidence. Calibration is independent of deformations of the flexible tube by bending. The pressure of a single probe tube in the auditory canal does not significantly distort the sound field at that point. Shaw (23) measured pressure levels generated at the entrance to the ear canal by progressive waves from a point source at one meter. Ten subjects and six angles of azimuth were used. The average ear canal versus free field pressure levels were in agreement with Weiner's data (26,27) over the common frequency range.

2.3.3.2 Outer Ear Measurement

It has been pointed out that for frequencies of less than 1000 Hz, the acoustical pressure at the ear canal entrance differs from that at the eardrum by only a fraction of a decibel. Hence at low frequencies, the pressure measurements in the external part of the ear are essentially equivalent to measurements at the eardrum. At higher frequencies the pressure is very dependent upon the position of the probe tube orifice.

Shaw (22) inferred that for each subject there is a constant ratio between pressure at the ear drum, and the mean pressure across the ear canal entrance, which is independent of the external sound field generating the pressure. Since the transverse dimensions of the ear canal are small compared to the wavelength, it is assumed that a plane wave is transmitted to the eardrum. Now we find that sound pressures within the ear differ from those measured near the head or in the absence of the subject and that arbitrarily positioning the microphone on or near the body gives little information on sound pressures near the eardrum. Thus it does not represent the levels causing hearing loss. A more realistic allowance is made for the presence of the subject in a noise field by recording sound pressures in the cavum of the concha and then reconstructing pressures at the eardrum, center of head position, or elsewhere by applying a frequency dependent pressure transformation (2). By retaining a record of the sound pressures as a function of time, all features of an exposure or temporal sequence, may be analyzed. Also the consequences of modifying exposures by wearing ear protectors may be predicted, which is not possible with dosimeters. Corrections for frequency response of the tape recorder and the microphone can be made by shaping the spectrum of the signal recorded on tape during playback.

2.3.4 Body Baffle

When a hearing aid is worn by a person it's overall frequency response is not the same as that measured when the aid is placed in a free sound field because the human body acts as a baffle (7). The degree to which the pressure at the microphone of the aid will differ from that in the free field will depend on; (a) frequency, (b) direction of the sound wave, (c) size and shape of the person, (d) position of the aid on the person, and (e) the clothing worn by the person. The effective response of the hearing aid is changed by approximately 10 dB when worn by a person facing a sound source under free field conditions.

2.3.5 Simplified Noise Measurement

The need for a simpler method of measuring noise was realized in order to facilitate effective preventive action in noise control because persons in a position to take action are not usually knowledgeable about acoustics. In addition to this existing methods of measuring noise were difficult to implement. (i.e,, CHABA method much too laborious for practical applications and just could not be used). Such a method was proposed by Botsford (1) and it was based on the CHABA method. Botsford consolidated the 10 graphs presented by CHABA, delineating permissible levels of exposure to various octave band sound pressure levels, into 3 graphs. He then substituted A-weighted sound levels for the octave band sound levels to obtain one graph describing acceptable all day exposure to manufacturing noises. This was done using data from a comprehensive survey of manufacturing noises. His final set of contours of equinoxious sound levels applies to both continuous and interrupted exposures. In comparing the two methods, Botsford permits the same total durations of noise for 80% of the manufacturing noises, slightly shorter exposures for 16% and slightly longer exposures for 4%. Thus it was deemed just as reliable as the octave band sound levels derived from the CHABA report in indicating hazard to hearing. Ward (25) examined Botsford's simplification of the CHABA DRC for intermittent exposure and felt that the DRC, for repeated long bursts, was in error. He did suggest however that it should be possible to derive a set of curves similar to Botsford's which would allow the risk to be assessed from only a knowledge of the temporal pattern and the dBA levels involved.

2.3.6 Damage Risk Criterion

A damage risk criterion (DRC) attempts to specify the maximum duration and spectra of sound which just meet the criterion, that will result in permanent hearing losses. In 1965, CHABA proposed a set of noise risk criteria for both continuous and intermittent exposures to steady (non-impulsive) noise (25). In the course of that study it was felt that more hearing protection was required in the lower frequency regions in order to preserve man's ability to communicate. Some of the difficulties involved in setting up a DRC can perhaps be explained by asking the following questions: for example, what are the effects of frequency on hearing damage? What constitutes "damage"? Perhaps the ability to clearly and distinctly perceive speech should be the ultimate criterion for evaluating noise induced hearing loss. The numerous regions of the frequency spectrum contribute in different ways to the perception of speech. Another important factor is duration. What auditory fatigue is caused by exposures of different durations? Work done has covered exposures from a few minutes up to 8 hours. One might further ask what effect bandwidth has on auditory fatigue. It was originally felt that the critical bandwidth was 1/10 octave but it is now thought to be 1/3 octave for much of the audible range (13).

The specifications of the current criterion covers most of these considerations. It is stated as follows: any exposure is excessive if it will cause ears with normal hearing to have a TTS of pure tone auditory accuity measured 2 minutes after exposure of as much as 10 dB in the frequency range up to 1000 Hz, 15 dB at 2000 Hz and 20 dB above 3000 Hz.

If a person has a NIPTS of this order he suffers about a 10% impairment in his ability to understand spoken sentences at normal speech signal which has no distortion and is in a relatively quiet environment. Such a person should however hear spoken sentences as well as a person with normal hearing if the environment is absolutely quiet. In order to specify maximum tolerable exposure, data was used from studies of NIPTS incurred by industrial workers as well as NITTS obtained in laboratories. The magnitude of NIPTS were corrected for presbycusis (increase in hearing threshold due to aging). Good data relating NIPTS to exposures of broadband steady-state noise incurred on a daily basis over a period of several years was obtained. Comparable data for shorter exposure to noise was not available and it was felt that these could be assessed on the basis of TTS. TTS can be defined as the difference in audibility measured before and after exposure to sounds. After a period away from intense sound, usually several hours, a person's level of audibility returns to normal. It is common practice to use the TTS measured 2 minutes after exposure (TTS_2) for this threshold shift. It was found that TTS was a consistent measure of the hazard associated with years of such exposure and that TTS_2 after one day's exposure was in fact a measure of what would produce NIPTS if repeated on a near daily basis for 10 years It was suggested that the NIPTS produced after many years of habitual exposure (i.e., 8 hours per day) in an industrial environment, was about equal to the NITTS at 1000 Hz produced in young, normal ears in one 8 hour exposure of the same noise. Variations in this comparison at different frequencies were higher or lower by 3 - 5 dB. In arriving at damage risk contours for short, intermittent and interrupted exposure to noise, the recovery of the ear between noise bursts must be taken into account. Otherwise estimations of hazardous noise could lead to greater noise control costs than are actually required.

2.3.7 Validity of TTS_2

Ward (25) has suggested that TTS_2 may be higher than predicted by the CHABA criterion and in addition some doubt exists regarding TTS_2 as a good indicator of NIPTS.

In his report he investigated the results presented by CHABA and also studied Botsford's proposal (1) for estimating damage risk by using A-weighted sound levels instead of octave bands. In exposing subjects to steady and intermittent noise which according to CHABA should produce certain specified TTS_2, he found several discrepancies. There was agreement for short uninterrupted exposures, and also intermittent exposures with short burst duration of 3 - 5 minutes, all with short recovery periods. However, for bursts of 10 minutes or more the limits were exceeded for TTS_2. This was attributed to an erroneous assumption about the course of recovery between bursts. Furthermore exposure to high frequency noise often produced a delayed recovery pattern. He specifically suggested that levels above 100 dB in the 1500 Hz range or higher, even with small noise duration to pause duration ratios, could be dangerous. Furthermore, the limiting values of TTS_{30} or even TTS_{100} should be used instead of TTS_2 because of the delay in recovery patterns.

The DRC proposed by CHABA were based on two assumptions: (1) that a certain degree of NIPTS could be tolerated if a lifetime exposure produced no more than 10 dB of NIPTS at frequencies up to 1000 Hz, 15 dB at 2000 Hz and 20 dB at frequencies of 3000 Hz and above, and (2) that the NIPTS would not exceed the TTS produced during a single day of exposure. In view of this, the CHABA DRC should indicate which noise patterns would produce 10 dB of TTS_2 at frequencies up to 1000 Hz, 15 dB at 2000 Hz and 20 dB at frequencies above 3000 Hz.

There was enough empirical data on TTS from single uninterrupted exposures to construct curves which indicate permissible duration for a single exposure to various levels of octave band noise. The resulting criterion indicated, for example that an 8 hour, exposure of 85 dB sound pressure level with octave band centered at 1000 Hz or above, was as damaging as 100 dB sound level from 50 to 100 Hz. This lesser noxiousness of low frequency noise was even more pronounced for shorter duration exposures. It is as desirable to have 15 minutes of exposure at 125 dB between 150 and 300 Hz.

Ward illustrated that the period of recovery is more complex than previously assumed: a worker exposed to 100 dB noise for 17 minutes produces a TTS_2 of 15 dB which requires 420 minutes for recovery. By leaving this environment for 30 minutes, he retains 7.5 dB of TTS.

At this point if he enters a 90 dB environment, his 7.5 dB residual is the equivalent of a TTS_2 that would have been produced in 13 minutes at 90 dB. Now if he remains for 17 minutes, his total exposure becomes 13 + 17 = 30 minutes. This produces a total TTS_2 of about 11 dB for which the general recovery would require about 200 minutes. The end result was a reduction of the recovery period from 7 hours to 3½ hours by a second exposure to noise. This clearly suggests that the process of recovery is not independent of the time it takes to produce TTS and that there must be a cumulative effect which produces a delay in recovery as the ear is repeatedly exposed.

In summary Ward concluded: (1) the CHABA DRC for continuous and intermittent noise with burst duration of less than 5 minutes does restrict the average TTS_2 after 8 hours exposure to 10 dB 1000 Hz or below, 15 dB at 2000 and 20 dB at 3000 Hz or above. (2) a TTS produced by noise with longer bursts will sometimes exceed these values. Therefore recovery from a given TTS_2 is not independent of how it was produced. (3) TTS_2 is not a valid risk indicator for intermittent exposure to 105 dB (1400 - 2000 Hz) noise which produces 15 dB of TTS_2 since full recovery may require 16 hours. Instead TTS_{30} or TTS_{100} should be used.

2.4 Helmet Attenuation Properties

When the United States Department of Agriculture (USDA) Forest Service, San Dimas, California expressed concern about damage to the hearing of forest service employees who used snowmobiles and motorcycles, an investigation was done by R. Harrison (10) to determine the amount of hearing protection provided by commercially available helmets under actual running conditions.

Sixteen helmets made by four different manufacturers were tested. These had fiberglass reinforced polyester shells with resilient and nonresilient inserts in the lining. Both flat shields and bubbles were used for eye protection. A 350 cc, 2-stroke motorcycle which produced 85 dBA at 50 feet was utilized. A ½ inch B & K microphone fitted with a probe tube was fastened near the rider's ear with a recording device on the rider's back. The A-weighted sound level and 1/3-octave frequency spectrum were obtained.

Harrison found that wind noise was important when no helmet was worn. Below 40 mph the engine noise predominated, while at 50 mph there was likely more wind noise interference. The extremity of variation for repeated runs was only 5 dBA. Typical run to run variation was only 2 dBA for all speeds. Rider to rider differences were negligible and tightness of fit made little difference in the noise received by the test rider. He concluded that motorcycle helmets do not function as hearing protectors.

He attributed this to a limited selection of helmet sizes and also to the fact that helmets were just not designed to be hearing protectors.

2.5 General Types of Motor Vehicle Noise

Most local noise sources contribute noise that is of relatively short duration compared to contributions made by motor vehicles. Lawn mowers and air conditioners only raise ambient levels locally. Intense sources such as trains and aircraft effect noise over a wider area but still only intermittently.

Motor vehicles account for steady ambient noise levels in urban areas and they can be treated statistically because of their large numbers. In a study by Olson (17) vehicles were characterized as follows: passenger cars, light, medium and heavy trucks, tractor trailers, buses, cement mixer trucks and motorcycles. The sound level of the average vehicle increases with speed and weight. The degree of increase was found to be as follows for speed changes from about 35 mph to about 65 mph: 8.5 dBA for passenger cars, 9.5 dBA for trucks and buses, 7 dBA for tractor trailers and 12 dBA for motorcycles. The octave band spectra of 4 motorcycles indicated dependance of level on parameters such as type and size of engine, muffler configuration and throttle setting.

2.5.1 Motorcycle Noise

Motorcycles are a completely different category on the basis of weight comparison since they have sound levels comparable to heavy trucks and tractor trailers (17). The engine is practically the sole source. Tire to road interaction results in relatively little noise. Throttle setting appears to be the most important parameter rather than engine speed or road speed. Full throttle operation results in maximum noise regardless of engine speed, road speed, or the gear in which the transmission is operating. Typical values range from under 80 to 95 dBA. Removing the baffle from the muffler results in higher noise output at frequencies below 250 Hz and little change at higher frequencies. The addition of a resonator to the end of the exhaust pipe, which was tuned to frequencies above 1000 Hz, resulted in attenuation of low frequency noise while frequencies from 500 to 1000 Hz were enhanced.

It is interesting to note that a larger 4 cycle engine was the quietest vehicle while a smaller single cylinder, 2-stroke engine produced a dramatic increase in level with increase in throttle at the fundamental firing frequency. Full throttle sound was similar for both loaded and unloaded (neutral) operation of engines.

2.5.2 Silencing Motorcycles

Attempts to improve silencing techniques have been successful. Roe (20) succeeded in reducing the noise output of a 750 cc Norton motorcycle from 98 dBA to 86 dBA under European test conditions without significant loss of power. He found that the principal sources of noise were exhaust, induction and mechanical noise. Induction noise was reduced 12 dBA by using a damped cavity side resonator. Exhaust hoise was reduced by 20 dBA with a new silencing principle.

When silencing motorcycles it is important to do so without significantly reducing the power to weight ratio. For exhaust noise, expansion box silencers have been tried where a computer predicts the performance. Intake noise has been virtually unsilenced in motorcycles until quite recently. The lack of space makes it even more difficult to achieve effective silencing in motorcycles. Considerations for this should be made in the design stages.

The European test calls for full throttle acceleration from 50 KPH in second gear for 20 meters. The microphone must be 7.5 meters from the runway and 1.2 meters above the ground. The current limit in Europe is 86 dBA while the West German limit is 84 dBA.

CHAPTER III

INSTRUMENTATION

3.1 The Ear Bug

The ear bug consists of a subminiature microphone, shielded cable, attenuator and recorder. The unit as a whole is carried by the subject while testing (see Figure F18) and is strapped to the chest with a special harness.

The microphone, a subminiature electret film microphone is manufactured by Knowles Electronics Inc. (model # 1785). It is 2.28 mm thick, 5.59 mm wide and 9.49 mm long. It has a flat frequency response from 3 Hz to 8000 Hz. The microphone is encased in an aluminum container and may be positioned within the concha of the ear with a wire clip which fits around the ear (see Figure F22). The cable is long enough to permit head movement with and without the helmet on as well as general body movement required in the operation of the vehicle. The attenuator provides impedance matching with the recording device. It consists basically of 2 resistors which are responsible for approximately locating the dynamic range of the ear bug system. The recorder is a Sony TC55 cassette tape recorder measuring 38 mm by 98 mm by 148 mm. It weighs 850 grams and the frequency response is flat from 90 Hz to 10,000 Hz. The recorder is modified to couple it with the attenuator and A-weighting of the input signal is provided.

Figures F5 and F6 show the frequency and dynamic characteristics of a typical device, respectively. The criterion used for the recording equipment was A-weighting as specified by ANSI Standard S1.4 - 1971, with tolerances allowed for a type II sound level meter. The ear bug was calibrated with a B & K 4230 sound level calibrator.

3.2 Data Acquisition Equipment

1. B & K 4145 one inch condenser microphone: used as a precision reference microphone both in the field and in the semi-anechoic chamber.

2. B & K 2619 preamplifier: provides a signal boost in the line feeding the measuring amplifier.

3. B & K 2607 measuring amplifier: provides accurate sound level measurement and also attenuates or amplified a signal while weighing it to A, B, C or D characteristics.

4. B & K 1022 beat frequency oscillator: provides pure tone signals from 20 to 10,000 Hz for frequency response studies of recording devices.

5. B & K 2307 graphic level recorder: provides recordings of sound pressure level with respect to time.

6. B & K 125 spectrum shaper: modifies a signal by providing individual frequency band attenuation.

7. B & K 1405 noise generator: provides pink noise

8. B & K 2706 power amplifier: amplifies pink noise and pure tone signals.

9. University sound (model C1C HF) speaker: generates pure tones for dynamic and frequency response testing.

10. Spectral Dynamics (SD 301c) real time analyzer with averager (SD 309) and octave converter (SD 305A): used for narrow band frequency analysis of a signal.

11. Hewlett Packard 7045A X-Y plotter: provides a plot of the results from the real time analyser.

12. Marshland (Princess 8) speaker: used for generation of pink noise and pure tones.

13. Metrosonics db-601 Sound Level Analyzer: for evaluation of recordings to provide Leq and statistical data.

3.3 Auxiliary Equipment

1. Motorcycles: selection was to include popular vehicles in use as well as provide a wide range of sizes:

a) Kawasaki (Kz 650, 1977); 4-stroke, 4-cylinder.

b) Kawasaki (Kz 400, 1977); 4-stroke, 2-cylinder.

c) Kawasaki (KH 400, 1977); 2-stroke, 3-cylinder.

d) Kawasaki (Kz 200, 1977); 4-stroke, 1-cylinder.

e) Honda (360cc, 1975); 4-stroke, 2-cylinder

f) Honda (175cc, 1975); 4-stroke, 1-cylinder, dirt bike.

2. Test Stand: a large Kawasaki frame was welded

to a suitable stand for use in the semi-anechoic chamber. It consisted of handlebars, gas tank and seat. A pivoting arm was attached to the frame to hold the reference microphone at the centre of the head position (CH) of each subject (see Figure F20).

3. Helmets: Ski-Doo T'N'T' snowmobile helmets were used.

4. Visors: the flat clear acrylic type which fastens to the hemet was used (Innov Model 500).

5. Semi-anechoic chamber: the dimensions were 4.9 meters wide by 4.9 meters high by 8.5 meters long. The walls and ceiling were lined with fiberglass wedges 56 cm high by 20 cm at the base and 61 cm long. The floor was smooth concrete. The cutoff frequency was 150 Hz (less than 1% reflection above 150 Hz) and the ambient sound level was 30 dB (see Figures F2, F3, and F19).

CHAPTER IV

PROCEDURE

4.1 The Semi-Anechoic Chamber

Four areas were investigated in the semi-anechoic chamber: (1) noise incidence angle, (2) noise type, (3) subject variation and (4) helmet size.

4.1.1 Noise Incidence Angle

To study the influence of angle of incidence, the equipment was arranged as shown in Figures F2 and F3. Noise was generated by loudspeakers instead of using actual vehicle noise. This was done to eliminate the irregularities associated with the real noise and for control over the level. Subjects were seated on a test stand during the testing. The type of noise could thus be varied as well as the direction from which it was generated. The speakers were located to provide a simulation of actual motorcycle noise since the noise was produced at the approximate location of the major sources. Front and rear tire noise were simulated by speakers on the floor, at the right of the stand, facing upward (no. 39 and no. 41, respectively). For exhaust noise a speaker was placed, again on the floor facing upward, but at the rear of the frame (no. 42). A fourth speaker was placed in the same manner on the left side for chain and transmission noise (no. 40). A fifth speaker was placed at eye level facing the subject to simulate wind noise (no. 38). The speakers on the floor were supported on foam to isolate vibrations.

Prior to testing, the location of the centre of each subject's head (CH) was determined.It was at this location that the reference microphone was placed for adjusting the noise as required. It also provided a reference point for noise measurement which could be compared to the at-ear noise level. The reference sound level was 75 dBA for all recordings. For the speakers on the floor the reference microphone was positioned with the diaphram at the CH position and facing vertically down (see Figures F19 and F20). For the speaker at eye level the reference microphone was located with the diaphram at the CH position and facing horizontally forward. The sound level was set from without the chamber with no one inside. When the level was properly adjusted the subject entered the chamber and proceeded. First a calibration signal was put on the tape and then the subject arranged the head and eye protection according to a set procedure (see section 4.1.4). In performing the test, each subject assumed a natural riding posture (see Figure F21). In order to resume the same riding position for all tests the subjects were to lock elbows while gripping the handles and sight through a V-notch below the frontal speaker to a target with personal markings, some distance beyond (see Figure F23). By this method subjects could position themselves to within one inch of the original CH location.

Recordings were made without interruption for all the arrangements of head and eye protection with one speaker and for one particular noise. Subjects marked the tape at suitable locations by calling "open" and "close" at the beginning and end of a recording respectively. The test portion of the recordings were about 15 seconds long. In all recordings and for all subjects the ear bug was worn with the microphone in the right ear.

4.1.2 Noise Generation Within the Chamber

Loudspeaker generated noise was used in the semi-anechoic chamber instead of real motorcycle noise because of the inconsistencies associated with the latter. The noise produced by motorcycles varies considerably with time because of uneven combustion and the inability to adequately fix the throttle. Loudspeaker noise was more convenient as well as more practical. There was no need to start the engine each time a test was done, the sound level could be adjusted to a desired level without anyone in the chamber and it eliminated many of the difficulties associated with vehicle operation. In selecting the type of noise to generate in the speakers, a study of motorcycle noise recorded at the operator's ear was done for several vehicles and at some of the speeds used in the field tests. By examination of the frequency spectrum of these noises, it was found that the predominant peaks for all the noises occured in 3 regions. The centre band frequency of each region was obtained and a pure tone was generated at each of these. In addition a broadband noise was required because of the nature of wind noise. Thus four noises were used, which included three pure tones of 160 Hz, 250 Hz and 500 Hz as well as pink noise. It was felt that although these could not be exact representations of the real noise, they would provide a more consistent means of studying the influence of a variety of parameters while containing some of the characteristics of the real noise.

The pure tones were generated by an oscillator and amplified prior to being fed to a loudspeaker. It was thus possible to produce the required sound level of 75 dBA at the CH location of the subject, as measured by the reference microphone. Pink noise was generated by feeding a signal from a pink noise generator. All sound generation and monitoring equipment was located outside the chamber in an adjoining room. A secondary microphone monitored the subject's voice. Here the signal was shaped to eliminate the noise generated while permitting enough of the subject's voice spectrum to be transmitted so that the subject's progress could be followed from the control room.

4.1.3 Subject Variation Within the Chamber

Six subjects were available for testing in the semi-anechoic chamber (see Figure F17). It was necessary to investigate the influence of body height and size on the sound level at the concha but there were also differences in ear shape and size as well as posture which might influence the sound reaching the eardrum. Four male subjects and two female subjects were selected to provide a wide range of sizes and body shapes. The physical characteristics appear in Table T11. A wire clip which held the microphone in place within the concha was shaped to suit each wearer's ear size and contour. This permitted relatively consistent placement of the microphone. Such placement required that the microphone diaphram be perpendicular to an axis through its centre which extended from between the tragus and anti-tragus of the ear, to the upper rear portion of the cavum of the concha. The CH positions for all the subjects with respect to the floor and frontal speaker, appear in Figure F4. The markings show that individual posture when seated caused the CH to change out of proportion with height although the overall trend is the same for both standing and seated positions. It can be seen in Figure F4 that the tallest subject (D) is highest above the ground and furthest from the front speaker while the shortest subject is lowest and closest, respectively. The markings of Figure F4 mirror those of Figure F23. In the plan view of Figure F4, however, the CH of all the subjects appears to be on the right side of the centre line running through speaker no. 38. This does not actually indicate that all subjects had a consistent lean to the right but that the test frame was slightly to the left of the centre-line. Also in the photograph of Figure F17, it appears that subject "A" is as tall as subject "C" which is not the case as can be verified from Table T11. In the photograph subject "A" is actually standing on a board covering an opening in the cement which accounts for a few inches.

4.1.4 Variation of Head and Eye Protection Within the Chamber

The helmets used in this study were similar to those used by Harrison (10). They were of fiberglass reinforced shells with resilient energy absorbing inserts in the lining. The eye protection was a flat shield. Four sizes of helmets were available, including small, medium, large and extra-large. Each subject had a helmet which was designated as his or her "best-fit-helmet" (BFH). This was determined by the subject and was based on comfort of fit (see Table T11 for details). All four helmet sizes were included in the set of tests done in the chamber so that the effects of both tight and loose fitting helmets could be examined. Rearrangement of the head protection was possible without disrupting the ear bug microphone significantly. The eye protection could be attached without removing the helmet but it was generally easier and quicker to do so. The testing consisted of one set of 9 different arrangements to be done by each subject, with each noise from each speaker. The 9 arrangements included recording first without a helmet (NH) then with a helmet only (HO) and finally with a helmet and visor (HV). One set of recordings could be made in less than 10 minutes. Only one set was performed at a time. The subjects rotated continually until all combinations had been done. Details of the arrangements and combinations appear in Table T1.

It should be noted that size progression from small to extra-large was not consistent. The sizes small, medium and large were used by subject A, B, C and D during field testing and had also been used prior to this. The lining in these was noticeably compressed while that of the extra-large was fuller because it was still new. As a result, the extra-large helmet fit almost as tightly as the medium helmet and the results reflect a discrepancy accordingly.

4.2 Field Testing

In addition to the testing done in the semi-anechoic chamber and, in fact, prior to it, testing was done on motorcycles in the field. Four subjects were involved in this part of the study. Six vehicles were used with the subjects performing a series of 37 test runs on each. The three head-eye protection arrangements were used including NH, HO and HV although NH was restricted to low speed runs. Two riding positions were examined. In addition some recordings were made on the highway for extended duration and some auxiliary recordings were made to study specific areas.

4.2.1 Vehicle Selection

The motorcycles ranged from 175 cc to 650 cc in displacement and included both 4-cycle and 2-cycle engines.

Four vehicles were new at the time of testing while 2 were used (2 years old). Five vehicles were road bikes and the sixth was a dirt bike. There was no fairing on the vehicles for drag reduction.

4.2.2 Field Operating Parameters

The testing was to provide the sound level produced at the operator's ear for the majority of operating conditions with variations in 3 areas including vehicle speed, engine RPM and the gear selected. In addition to these parameters the head-eye protection was varied and 2 positions were used. Each area was designated as a group of tests according to the controlling parameters. The first group was the vehicle speed or "KPH" set of recordings. Here 4 speeds were used: 35, 50, 65, and 80 KPH. Each speed was used for both upright and down positions (see Figure F24) first without visor on the helmet (HO) and then with the visor (HV) making this the largest group. These test runs are numbered 1 to 16 in Table T2. Since the control parameter was KPH, the engine RPM varied from vehicle to vehicle and could not be entered in the heading of Table T2. A separate table is included to provide KPH and RPM for all runs (see Table TB8). The gear selected for each test is indicated in the table heading. In the second group of tests the gear selected was the main concern and as a second control the RPM was set at 4000 RPM. Thus the KPH which varied from vehicle to vehicle, was not entered in the table heading. Here the tests included only the upright position but the two eye-protection conditions were used, i.e., with and without visor. All 5 forward gears were included. These runs number 17 to 26 and involve 5 runs in each of the 2 categories. The third group was the engine speed or "RPM" recordings, with magnitudes of 3000, 4000 and 5000 RPM, all in first gear. Again the vehicle speed or KPH varied from vehicle to vehicle and is not included in the table heading. The runs numbered 27 to 35 cover this group in 3 sections, one for each of the head-eye protection arrangements (NH, HO and HV). Only the upright position was used. Additional tests were made on the highway and at an auxiliary test site. These are described later. All of the test runs were performed twice. Once in one direction, then again in the opposite direction to average out external influences such as wind and grade.

The test site was an empty parking lot approximately 0.25 Km long with no reflecting surfaces within 10 meters of the runway on either side. The surface was smooth, relatively level pavement. Testing was reserved for days where a local wind measurement indicated less than 12 knots (see Table T2), with clear, dry weather. Ambient background noise was more than 10 dBA below the lowest levels encountered at the ear while testing. Subjects made the test runs individually to eliminate interference from each other since four vehicles were being tested simultaneously. The recordings were obtained as described for the semi-anechoic chamber. The duration of a single test was about 1 minute long, although only about 10 to 20 seconds of tape was at test speed. The recorder was started prior to testing and when test speed was attained the subject called out "open", waited 10 seconds and called "close", then decelerated and cleared the runway for the next subject testing. The test was then repeated in the opposite direction.

4.2.3 Highway Testing

Another part of the field testing was done on a 2-lane highway, running east-west, where the speed limit was 80 KPH and there was light-medium traffic. Runs were made with and without visor and are numbered 36 and 37, respectively (Table T2). The test was performed at 80 KPH in fifth gear for a duration of 27 minutes. Once again this was carried out in both directions. The subjects did this test in a group so that driving conditions and exposure to noise from local traffic would be similar for all four subjects on any given day. The group was, however, spread out enough to prevent interference from each other.

4.2.4 Auxiliary Testing

This was done to obtain a comparison of recordings made inside the semi-anechoic chamber with those made outside and in addition, to compare stationary testing versus moving tests on the vehicles.

The equipment from the semi-anechoic chamber was set up outside with a motorcycle in place of the test stand and a loudspeaker positioned on the ground at the location of the exhaust outlet (speaker no. 42). This was to study differences resulting from change in CH for the actual vehicle, additional baffling from the vehicle, and chamber influence.

An attempt was also made to eliminate some of the noise from actual vehicle operation and thus isolate the remaining ones. By operating the vehicle in neutral while raised on the stand the noises from tire to road interaction, chain and transmission movement as well as wind noise could be effectively eliminated. Here the engine speed was set at 3000, 3500, 4000, 4500 and 5000 RPM. Four arrangements were included: CH, NH, HO and HV (see Table TB3). Two subjects and two vehicles were used in this part of the testing. Climatic conditions were similar to those in section 4.2.2.

4.3 Method of Analysis

All the recordings made in the field and in the semi-anechoic chamber were analysed essentially in the same way. A graphic level recorder was used to obtain sound level variation with time. After setting the calibration signal on a suitable reference mark the sound level of each run could be determined with respect to it. These were tabulated for further analysis involving curvfitting by computer.

A frequency spectrum ($\frac{1}{3}$ - octave) was produced by real time analysis, where necessary. Tests were contained in relatively short sections of tape (10-20 seconds) but could be averaged with 32 ensembles most of the time. For the higher speed runs when the test section was sometimes too short, 16 ensembles were used. The range of the frequency spectrum was 5000 Hz. Details of equipment sensitivity settings appear in Appendix A. Highway recordings were analysed with a Metrosonics unit which provided values of Leq directly as well as L_1, L_{10}, L_{50} and L_{90}.

CHAPTER V

DISCUSSION OF RESULTS

5.1 Results from the Semi-Anechoic Chamber

5.1.1 Based on Sound Level

The results of the semi-anechoic chamber testing appear in Table T1. These are the sound levels of each recording made. In the column headings are 4 sub-headings for the noise used while the main headings designate subjects. Speakers are found in the main headings of each row with sub-headings for NH, HO and HV. Where the helmet is used, 4 sizes are included.

The sound levels appearing in Table no. T1 represent the sound level measured at the subject's ear under various conditions when noise generated via the speaker is set to a level of 75 dBA at the CH position for the specific subject.

By examining Table T1 it can be seen that the largest amplifications occur when no helmet is used (NH) with the average increase being about 7 dBA for the 250 Hz and 500 Hz pure tones and pink noise with sound from the frontal speakers 38 and 39. The 160 Hz pure tone undergoes less amplification. For the side and rear speakers less amplification takes place. Here the low frequency is seen to be attenuated rather than amplified. The amplification provided by the ear is seen to be reduced when the noise comes from behind even when no helmet is worn. This is a result of the forward facing construction of the pinna flange. Also for NH the 160 Hz pure tone is poorly received suggesting a lower limit to the frequency of sound which is effectively amplified by the ear. When a helmet is used the size does not appear to influence the results significantly, as far as the sound level goes, since there are no trends in going from small to extra-large. In fact the variation in sound level is only about 0.5 for each speaker and about 2 to 3 dBA between subjects. The use of a visor does not dramatically reduce sound level at the ear. Major differences occur when the noise direction is changed from front to rear and the frequency of the noise is altered. The 500 Hz pure tones receives the greatest amplification in most instances as does pink noise when no helmet is used. The attenuation of broadband noise is seen to be significant when a helmet is used but again the visor contributes little. In some cases the visor actually results in higher levels than with helmet only (HO). With helmet (HO) pink noise is attenuated by 7 to 13 dBA. The visor (HV) can reduce noise by an additional 5 dBA but it also results in amplification over HO conditions by as much as 7 dBA for pink noise.

The predominant nature of the 500 Hz pure tone could be attributed to resonance within the cavity between the head and inner surface of the helmet because it is lower when no helmet (NH) is used. Since it is still there for

(NH) it does however suggest that other mechanisms are also at play. It appears there is a gradual increase in amplification of the sound level with frequency in both cases of NH and HO with a noticeable decrease for broadband noise. The level resulting from broadband noise falls between the levels resulting from the 160 Hz and 250 Hz pure tones.

Subject size and characteristics do not reveal any specific trends in Table T1 since the results for subject E, who is the smallest, are within 2 to 4 dBA of those for D, the tallest person. The maximum variation is of this order with most differences being below 2 dBA.

In Figure F13 the difference between NH and HO can be seen based on the results in Table T1. HV is also plotted. Polar plots are included for each subject and in addition the results of NH for all subjects appear in F13L.

5.1.2 Frequency Spectrum ($\frac{1}{3}$ - octave)

The frequency of a noise affects the ability to penetrate the helmet and to be amplified by the ear.

5.1.2.1 Incidence Angle

A study by Shaw (22) showed the effect of frequency on angle of incidence. His results were based on pure tones of specific frequencies at different angles of azimuth. These were compared with the sound levels of corresponding centre band frequencies ($\frac{1}{3}$ - octave frequency spectrum) of pink noise at the available incidence angles used during this investigation. Shaw includes a synthesis of data obtained by numerous researchers for a wide range of incidence angles in the azimuthal plane with a probe microphone located at the ear canal entrance. He points out that there is a substantial measure of agreement among the various studies but also that there are numerous discrepancies greater than expected which are attributed to differences in experimental conditions. In this study the experimental conditions are very different, yet there is still reasonable agreement with Shaw. Firstly, four of the five sources have been dropped from the azimuthal plane to the floor. Secondly, distinct frequencies were not obtained by playing pure tones but by drawing from a frequency analysis of broadband noise. The comparison is made in Figure F9. At 300, 500 and 1000 Hz there is good agreement although relatively few data points were available. The results differ at the 1600 and 2500 Hz frequencies but more data might show better trends here. Also at the higher frequencies there could be a breakdown of reliability in the use of $\frac{1}{3}$ - octave centre-band frequencies. There may be some inter-band influence resulting from the use of broadband noise that would not exist if pure tones were used.

5.1.2.2 Transfer Function (α -group)

The study of transfer function and helmet attenuation includes comparisons of speakers, subjects and helmet size. Comparisons involving inside-outside, speaker-vehicle and stationary-moving data are also included in Appendix B.

In these and other figures involving the study of $\frac{1}{3}$ - octave analysis there are 3 categories. The first is called the α-group. This one involves the transfer function from CH to the concha and may be obtained by subtracting NH-CH values of sound level at corresponding centre-band frequencies for pink noise. The range of centre band frequencies extends from 125 Hz to 2500 Hz. Figures which fall into this category have been subscripted "α". If the sound level at the concha is larger than at the CH position the plot of an α-curve will go above the horizontal reference line. If it is less the curve will be below.

The second category involves the deviation in sound level solely at the concha under two conditions of headgear The group is designated the β-group and the values obtained from HO-NH. This yields the attenuation properties of the helmet without visor. Again the sound level at each centre-band frequency of pink noise is used ranging from 125 Hz to 2500 Hz.

The third category is the γ-group and involves NV-NH values which provide helmet attenuation with visor. These comparisons involve Figures F14 to F16 inclusive and FB1 to FB3 inclusive. Figures are subscripted according to category

Examination of Figure $F14_\alpha$ reveals that at low frequencies the transfer function is in the region of 1 to 5 dBA with significant crossing of curves for specific speakers. As the frequency increases some trends begin to appear. The most obvious is the path followed by speaker 40 since it dips below the CH line indicating attenuation rather than amplification for most centre-bands. This is reasonable in view of the shadow cast by the head. The other speakers do not display such unique characteristics. As expected the highest levels of amplification are attained for the frontal speaker no. 38. There is a slight hump in the curves at about 600 or 700 Hz indicating possible resonance at this point. Resonance resulting here would be a function of body baffle and ear structure since no helmet is involved.

In Figure $F15_{\alpha}$ subjects are compared. Here only one speaker is used (no. 41) and each subject has a best-fit-helmet (BFH). A similar pattern appears with little spread at low frequencies and increasing towards the high end. Again a hump appears at about 700 Hz. The response of subject B seems greatest while that of subject F follows along the bottom of the group of data points. This does not reveal dependence of transfer function upon subject size since the extremes in size do not correspond to the extremes of transfer function. In fact the largest and smallest subjects (D and E, respectively) both follow the same pattern which is at the low end of the group initially and at the high end towards the upper-most frequencies. Comparison of the female subjects yield little as the two are at opposite extremes of the groupings. A few dips below CH are noticed at the low frequencies. As a result no significant trends are indicated based on subjective parameters and the transfer function appears to be independent of subjective characteristics.

5.1.2.3 Helmet Attenuation (β-group)

Figure F14β shows that attenuation resulting from the helmet increases with frequency to a maximum of about 28 dBA at 2500 Hz for noise generated from speaker no. 39. Noise from both frontal speakers receives the greatest attenuation, since the noise level from the other sources is not as high to start with, having been attenuated by body baffling effects. It was not expected however that the noise produced by speaker 42 located at the rear-most extremity would receive the least amount of attenuation. At the higher frequencies even noise from speaker 41, which is immediately below the right ear, is subject to considerable attenuation. This leads to the conclusion that since the helmet does not fit tightly at the top of the neck which is necessary to allow for movement of the head, more penetration of noise results. On the other hand the helmet projections down over the ears are extensive enough to result in effective attenuation of noise generated from directly below as in the case of speaker 41. All this applies to high frequency noise, however, which is not of prime interest in view of the nature of motorcycle noise (predominantly low frequency). At the low frequency end of the spectrum the noise from all speakers is within 5 dBA of zero attenuation up to about 400 Hz and noise from speaker 41 receives less attenuation suggesting the more effective penetration of low frequency noise from below.

Figure F15β compares the attenuation for each subject. Again there is a relatively close cluster of data points with little attenuation at low frequency up to about 500 Hz, increasing to a maximum of about 33 dBA for subject D. Here attenuation is proportional to size, with the greatest amount for the largest subject and least amount for the smallest subject. Only speaker # 41 was used in this comparison, thus sound was from below. The results of recordings made by the female subjects show a tendency towards less attenuation with helmet in comparison to male subjects. This could be attributed to the same influence resulting from size, because both female subjects were in the medium to short range (see Figure F17). On the other hand if the back of a woman's head does have a certain unique curvature, then the lack of attenuation could be attributed to an even greater gap between helmet and neck permitting increased sound penetration from the rear.

In figure F15β it can be seen that there is some amplification of noise when helmet only (HO) is used instead of no helmet (NH). This is difficult to account for since resonance within the helmet cavity must be ruled out for low frequency noise (i.e., at 200 Hz the wavelength of sound is 1.72 meters which is much greater than the helmet dimensions).

The higher frequency components of the pink noise may account for this effect to some extent.

Also the two tallest subjects do not experience the same amplification of noise with HO. The formation of standing waves would account for this in that the ears of these taller individuals could be located at a quiet part of the wave pattern. This is feasible in view of the cutoff frequency of the semi-anechoic chamber (less than 1% reflection above 150 Hz), however one would not expect the low frequency reflections to produce standing waves of this magnitude.

In Figure 16 β the influence of helmet size is examined. The sound level at the concha is about the same for all sizes of helmet used to within about 5 dBA from low frequency to about 800 Hz. At this point a dramatic spread occurs with the small helmet producing the most attenuation and the large helmet the least. The extra-large helmet falls closer to the results of the small helmet because as mentioned previously, the newer material of the resilient inserts caused it to fit rather tightly. It suggests that size has little influence on low frequency noise and that at higher frequencies attenuation is as would be anticipated.

5.1.2.4 Helmet Attenuation with Visor (γ -group)

For this final group the visor was attached to the helmet to study HV-NH. The trends are similar to those of the β -group. Speaker to speaker comparisons yield no significant differences from that of the β -group. For subject comparison the same low frequency amplification is repeated but there is less attenuation at the high end with visor. This may suggest that the resonance effect is enhanced by the addition of a visor which could result from increasing the size of the cavity between head and helmet.

Comparing the size of helmets here, there is a hump in the curves at about 600 Hz and this appears to retard the spread from size to size, over the results of the helmet only group, until slightly higher frequencies. Data used in the curves comparing helmet size was drawn from tests made by subject A while exposed to noise from speaker no. 38. In conclusion the influence of helmet size for frontal noise appears to be minimal.

5.2 Results of Field Recordings

5.2.1 Description of Tables

The results of the field testing are compiled in Table T2. This includes the Leq obtained from the highway testing (runs no. 36 and 37) although the discussion pertaining to it is in Appendix B. Table T2 contains the data of all subjects and vehicles, as well as all the test parameters. The test parameters are numbered 1 to 37. The rows are divided into vehicles with subdivisions showing date of recording and wind velocity in knots. The table is divided into 8 pages with 2 per subject.

The results of Table T2 were processed by computer to obtain the slope, zero intercept and correlation coefficient of each group of runs. These are separated by the major divisions of the column headings. The computer results appear in Table T3 which is divided into 4 pages, one per subject. The notation used in Table T3 is described on Table T3A. The first 3 letters represent the run category, the letter-number combination following this are for subject and vehicle respectively and the final 3 letters indicate use made of visor, helmet and position respectively. Furthermore in Table T3 the calculation of slope was based on KPH as a common base so that conversion form RPM to KPH for each vehicle was required in the case of RPM and GEAR runs where RPM is designated in the table heading rather than KPH.

When the results of Table T3 were available the fitted curves were plotted along with the original data points for each group of runs. These appear in Table T4. This table is divided as was Table T2 since it contains the same information from a different point of view.

5.2.2 Interpretation of Data

From Table T4 certain trends can be easily spotted. The slope of the curves indicate the rate of increase in sound level as measured at the operator's ear, with the vehicle speed in KPH. The zero-intercept would reflect the level at which the vehicle starts out at the lower speeds.

A report is currently being prepared which examines the data of Table T4.

The increase in slope of RPM runs as compared to KPH runs indicate that engine noise varies more than a combination of wind, chain, tire and engine noise for the same increase in KPH when gear selection remains in first gear. The degree of increase can also be seen. The important information obtained is the degree of increase in sound level for RPM runs over KPH runs.

It suggests that comparing subject to subject curves yields very little since the changes are small. This perhaps reflects the repeatability of testing more effectively than influences of subject characteristics.

5.2.3 Description of Averaging Procedure (Field Data)

In order to compare the field data on a quantitative basis, groups of slope and zero-intercept were averaged to obtain the predominant trend according to subject, vehicle and operating conditions. The results appearing in Table T3 were used to obtain the first averages which were designated AVG_1 and the slopes of these appear in Table T5. These AVG_1 results were in turn averaged to yield the AVG_2 of slopes appearing in Table T6. The AVG_1 and AVG_2 of zero-intercepts appear in Tables T7 and T8 respectively. In Table T9 the AVG_1 of slope and zero-intercept for groups of runs in different riding positions have been recorded.

5.2.4 Results of Vehicle Comparison

Slopes and zero-intercepts were averaged to obtain AVG_2. This provided a single curve characterizing each vehicle or subject. Figure F10 displays the curves resulting for each vehicle. These agree with the expectations of the group. The smallest vehicle, a 4-stroke, single cylinder, 175 cc, dirt bike and a medium size 2-stroke, 3 cylinder, 400 cc vehicle were the noisiest of the lot. The rate of increase of noise is about equal for all vehicles. The early model medium size vehicle (#2) and the later model small vehicle (#3) are at the low end in noise output. The largest vehicle (#6) is in between the high and the low. The cycle of operation has the most obvious influence on noise level. The open construction of the dirt bike may also contribute to its higher noise levels by providing less baffling and having the source closer to the operator's ears while seated. The medium size motorcycle with the 4-cycle engine (#4) was the preferred vehicle and it appears to have a more noticeable reduction in the rate of increase although it starts out slightly above the three lowest vehicles. It is however at the higher vehicle speed that the vehicles are mostly operated thus a lower slope would be preferable. The largest vehicle was remarkably quiet despite being much more powerful. The 4 late model vehicles were dealer serviced to reduce the likelihood of differences in performance based on improper tuning. This was done at least twice during the

3-month period in which the majority of the testing was done. The early model vehicles (#1 and #2) were not serviced by the dealer. The results of Figure F10 are based on a plot of sound level versus vehicle speed. For the smaller vehicles the engine RPM required to attain the same vehicle speed was higher which may account for the position of the vehicle #1 curve. This is however, contradicted by the position of the vehicle #3 curve which is second from the bottom. This points to the fact that vehicle construction must play an important role in the containment of engine generated noise.

5.2.5 Results of Subject Comparison

In Figure F12 the curves produced by the AVG_2 of slopes and zero-intercepts show the relative positions of each subject's exposure produced by the motorcycles. Here there are no significant differences. The slopes are very close to each other. The zero-intercepts do not show consistent trends since reception by the tallest (D) falls between that of the two shortest subjects (A and B). At low speeds the medium height subject (C) detects higher levels on the average. This is a significant observation because it is a reflection of earlier findings. The riding position of subject C was distinctly different from that of the other subjects. This can be seen in Figure F25 which shows the riding positions assumed by each subject during highway testing. These positions were essentially the same during "upright" testing in the field. The spread of the knees for subject C is significantly greater than for the other subjects. This knee spread is reported to be subject C's natural riding position which may be attributed to his earlier experience of operating a small moped-type vehicle for a number of years. Others were asked to assume this position to see if it made any difference. No recordings were made of this test since it was not one of the control parameters originally outlined for study. As a result the increase in level cannot be reported on but it was agreed that there was a subject perception of a significant increase in the sound level produced at the ear when the knees were spread. Two reasons are suggested for the increase in sound level at the operator's ear when the knees are spread. Firstly, the spread knees form a sort of scoop which channels the air upward toward the face. Thus the increased turbulence at the face and around the head could account for some of the increase in sound level at the ear. Perhaps more importantly, however, is the second reason which proposes that with the knees spread, the engine noise is not baffled as well and thus contributes to higher levels at the ear. Since it was found that the influence of engine noise predominates over other sources, it is likely that this reasoning bears more weight.

It could be concluded from this that subject posture is more important than size and weight. More specifically, the noise received by an operator's ear may be enhanced if any exaggerated positions such as that of subject C is assumed.

5.2.6 Results of Position Comparison

Figure F12 shows plots of curves obtained from the data of Table T9, which contains the average of slopes and zero-intercepts for the groups of runs made in the field where upright versus down positions were used (see Figure F24).

The curves are in very close proximity to each other suggesting little influence from change of position. The no-visor, with-helmet, down-position (NYD), is comparable to the with-visor, with-helmet, down-position (YYD) for highest exposure levels. The effect of being in the down position puts the subject's ears closer to the engine although it may eliminate some of the noise resulting from wind. The result is in keeping with earlier observations that engine noise predominates as the noise source. It is perhaps a poor comparison because for the test speeds used where position was varied, the wind generated noise may have been less significant even in the upright position. The spread for the curves of Figure F12 is indeed small but the relative position of each is in order. Slightly more noise is perceived at the ear when in the down position than in the upright position.

CHAPTER VI

CONCLUSIONS

6.1 Semi-Anechoic Chamber

Frontally incident noise is effectively amplified by as much as 5 to 7 dBA from the centre of head to the concha under no-helmet conditions. Low frequency pure tones of 160 Hz are amplified to a lesser extent than pure tones of 250 or 500 Hz.

Helmet fit does not appear to significantly reduce the sound pressure measured at the ear but the sizes of commercially available helmets may not offer sufficient variation for the wide range of head shapes and sizes.

Visors do little to further reduce the sound level at the ear. In some cases the noise is reduced by 1 or 2 dB from the helmet-only condition but in many instances the levels are increased from helmet-only conditions suggesting that resonance may occur in the cavity formed within the helmet.

The influence of the helmet and visor with respect to the direction of incident sound is to attenuate noise from the sides more effectively than from the front or rear. The higher penetration of noise from the front and rear is attributed to a poorer fit between the head and helmet in these directions.

The size and characteristics of an individual have little influence on noise level at the ear of a motorcycle operator. A study of $\frac{1}{3}$ - octave frequency spectra shows that some difference may exist between the reception by subjects of engine generated noise depending on the distance of the individual's centre of head above the ground. There is significant difference in the attenuation of noise with a helmet, depending on the height of the operator.

The effect of having sources of noise at various angles of incidence in a plane slightly above floor level instead of having the sources at various angles in the azimuthal plane is relatively small for frequencies below 1000 Hz.

6.2 Field Recordings

Larger vehicles do not necessarily produce more noise at the operator's ear but the operating cycle of an engine has significant influence with 2-cycle engines producing the highest operator exposures.

A change in the vehicle operating position from the upright position where the torso is essentially vertical to the down position where the torso approaches the horizontal position and the face is shielded slightly from wind by the handle bars, does not result in significant difference in the noise level at the operator's ear. A change in the position of the operator's legs, however, from close to the gas tank to slightly away from the gas tank, results in a significant increase in exposure to the operator.

Operating a vehicle on the highway at higher speeds (i.e. 80 KPH) results in operator exposure which is independent of subject size and vehicle size because at this speed the predominant source is wind noise.

CHAPTER VII

RECOMMENDATIONS

In research where noise measurement is being made outside there is the ever present threat of discrepancy resulting because of wind noise which cannot be anticipated. An approach to this which would reduce the uncertainty associated with noise measurement under windy conditions would be to continuously monitor the wind velocity component of interest. Thus any increases in noise level coinciding with wind gusts could be eliminated or adjusted according to a previously obtained set of relations.

A study of the influence which clothing has on operator exposure may yield some interesting results by altering the baffle effect of the operator's body.

A closer investigation of the influence of operator position on sound level produced at the operator's ear should be made. More detail of the mechanism involved in going from the vertical position (upright) to the horizontal position (down) is required in order to understand why there is essentially no change in sound pressure. In addition to this the degree of increase in sound pressure when the legs are spread apart would be of interest.

Helmet fit should be examined using a wider range of sizes since head sizes vary to a greater extent than the sizes of commercially available helmets. It may be that individual tailoring is required for an effective seal at the back of the helmet.

More work is required to learn how to effectively isolate specific sources of motorcycle noise in order to determine the relative level of each.

An investigation should be made to determine the effects of the noise levels obtained herein, on the operator's hearing ability. Application of Botsford's method (1) could be made.

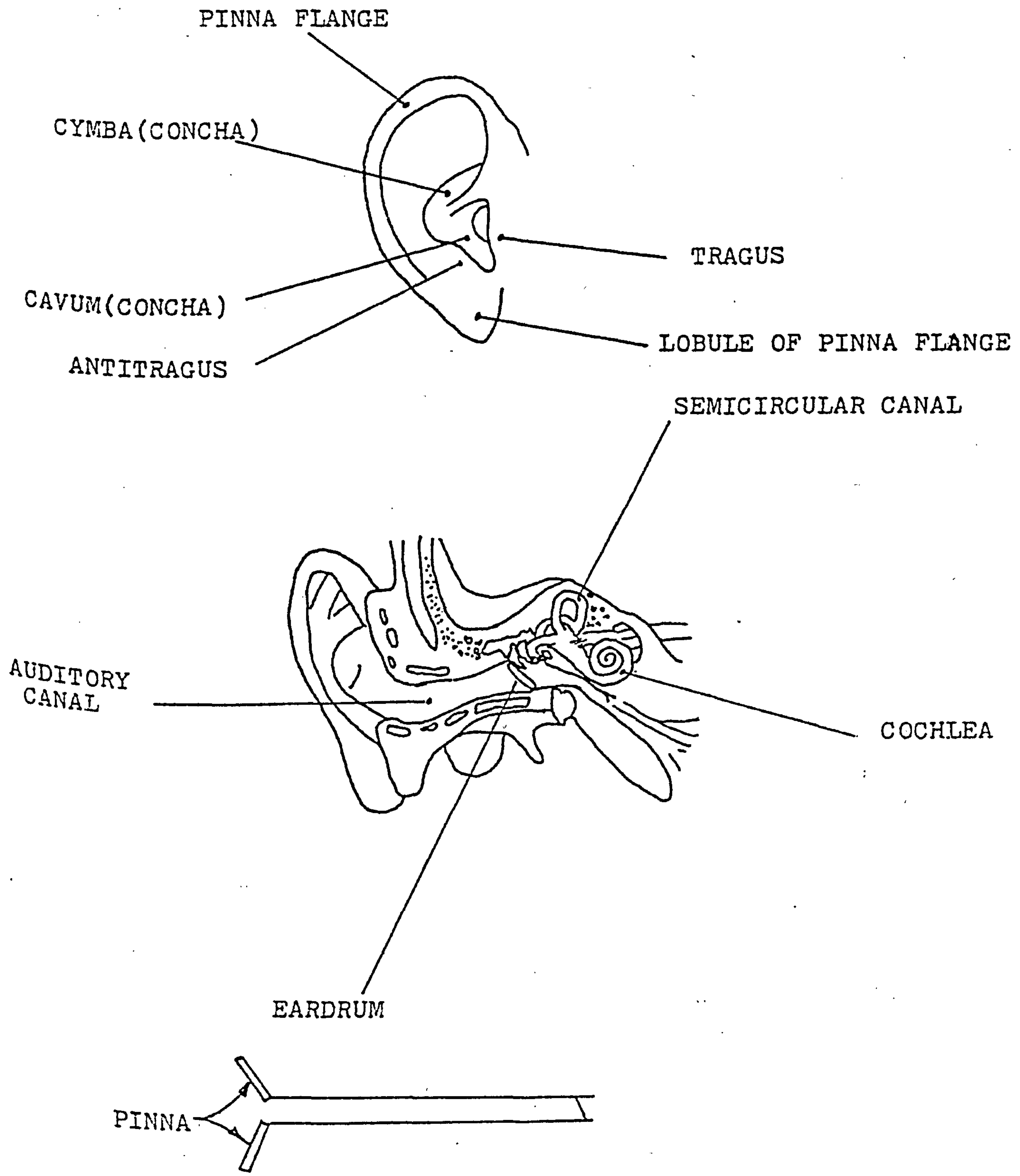


FIGURE F1- Schematic diagram of the human ear.

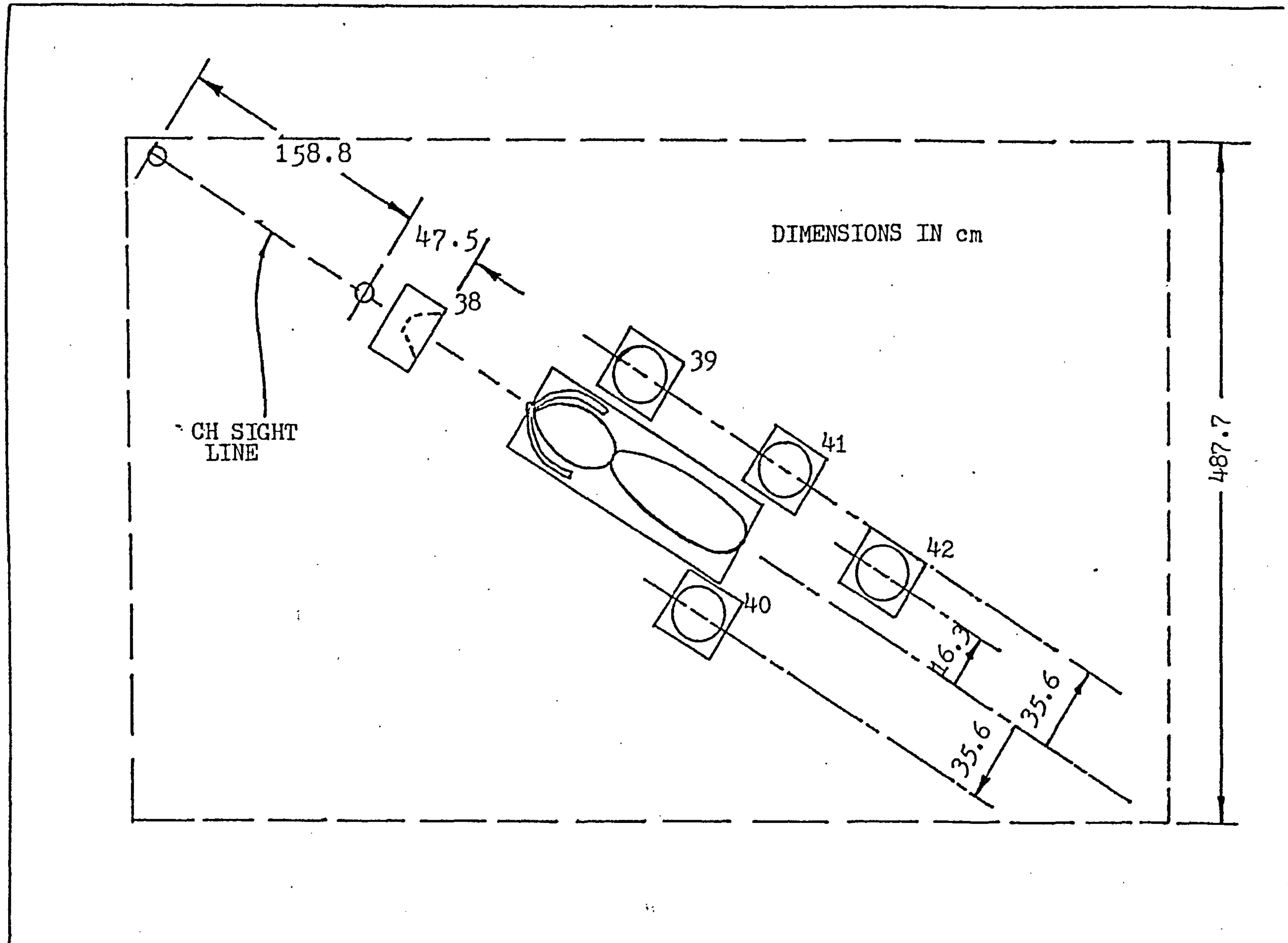


FIGURE F2- Schematic diagram of semi-anechoic chamber (plan view)

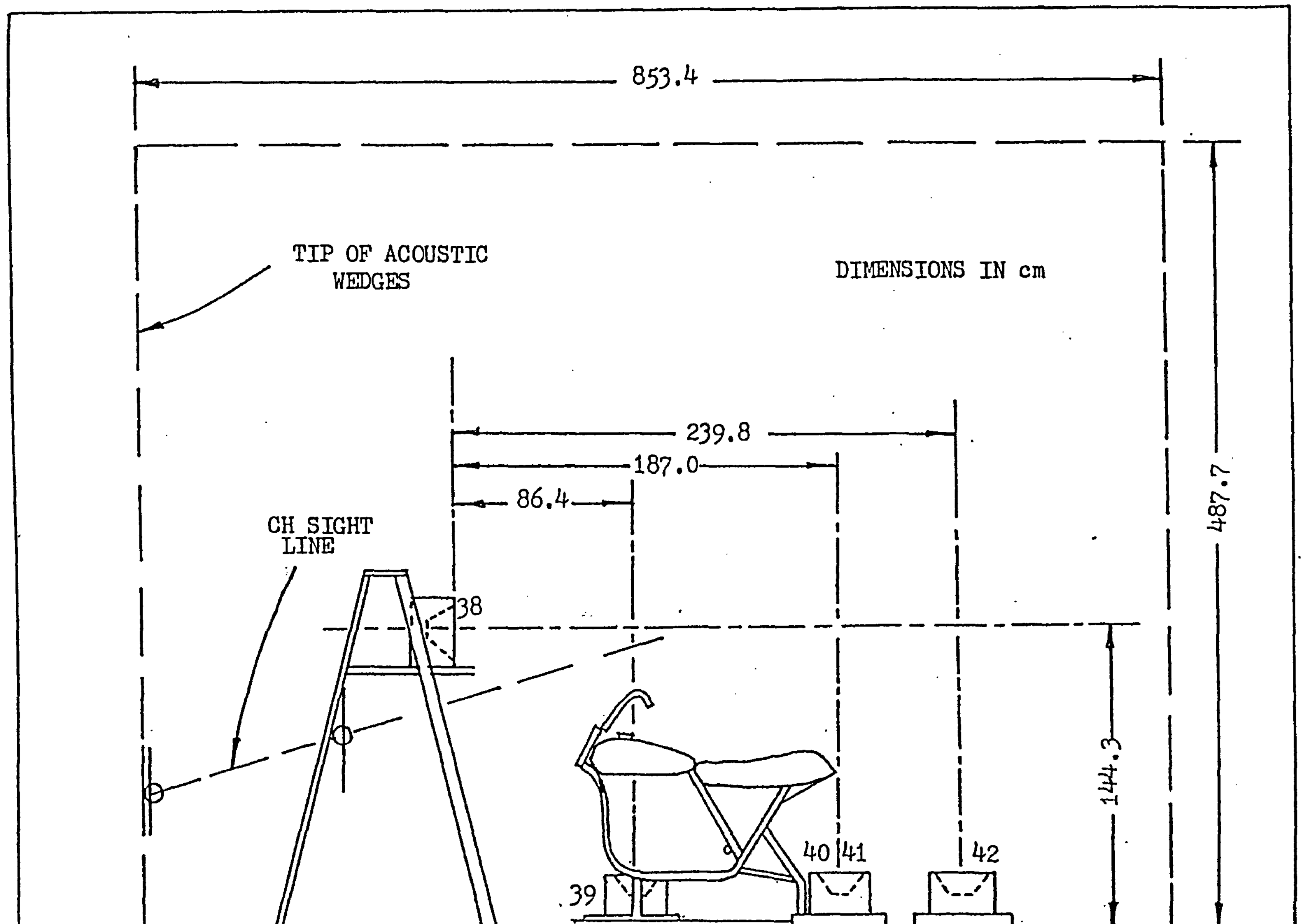


FIGURE F3- Schematic diagram of semi-anechoic chamber (side view)

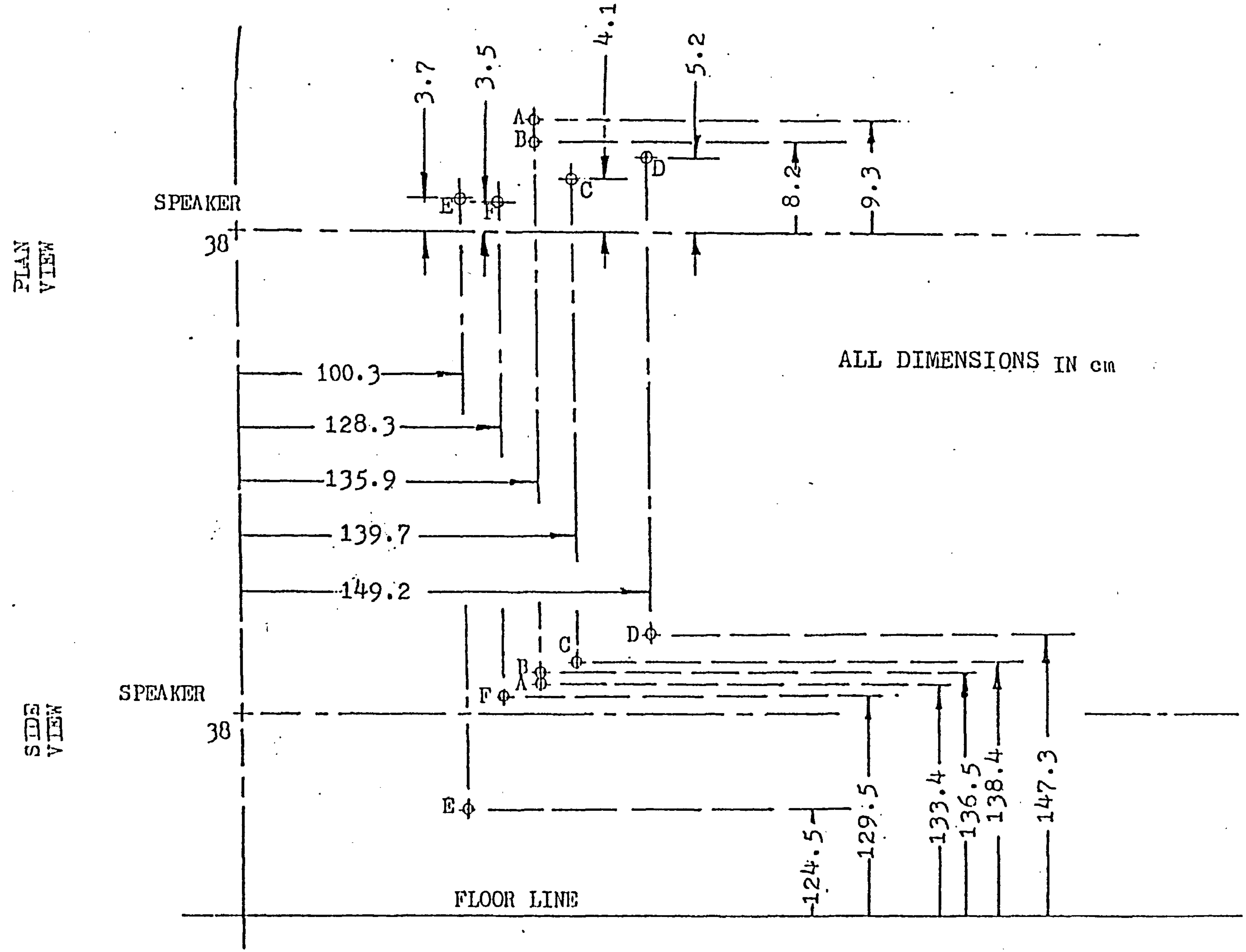


FIGURE F4 - RELATIVE CH POSITIONS FOR EACH SUBJECT

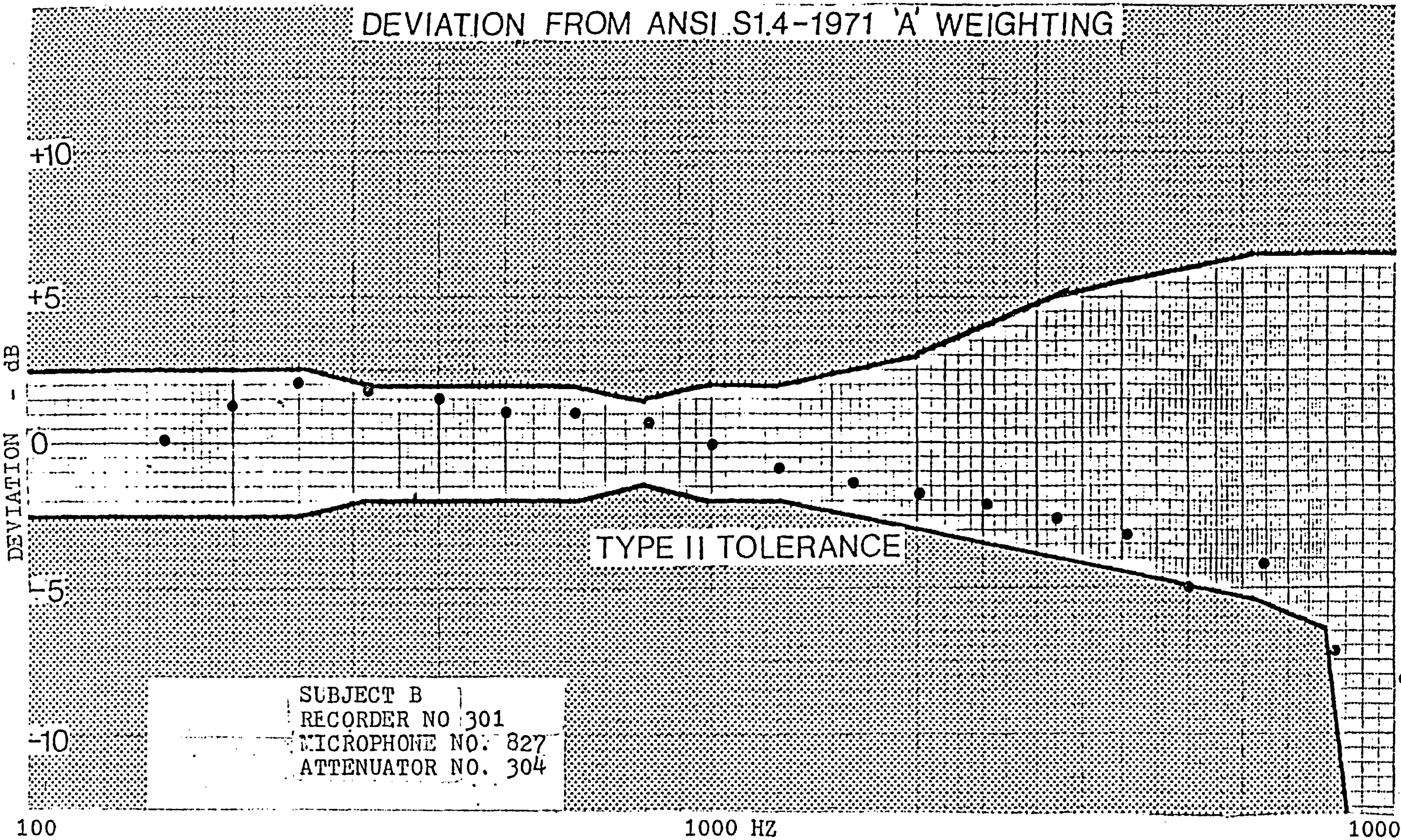


FIGURE F5- Typical frequency characteristics of an ear bug.

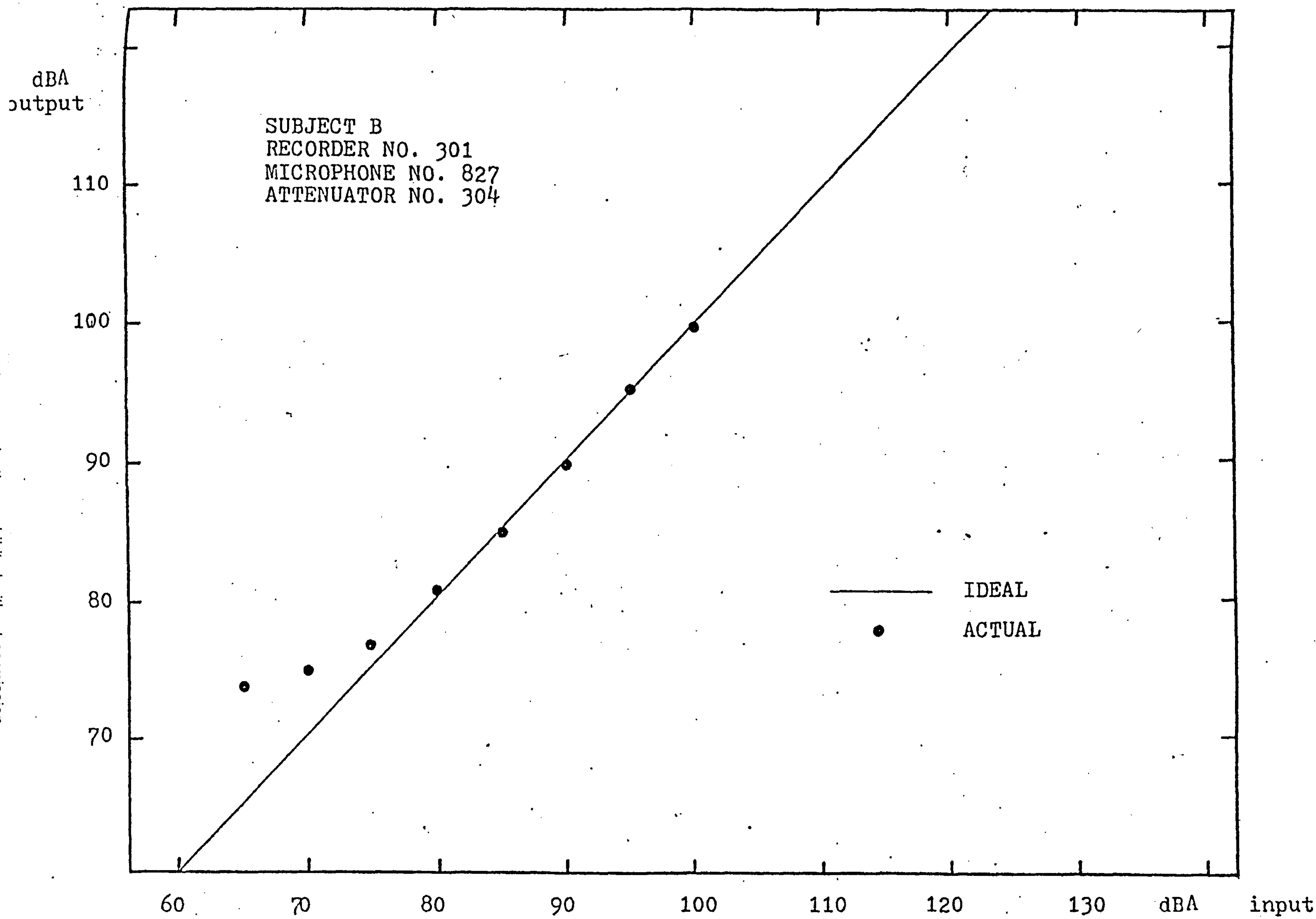


FIGURE F6- Typical dynamic characteristics of an ear bug.

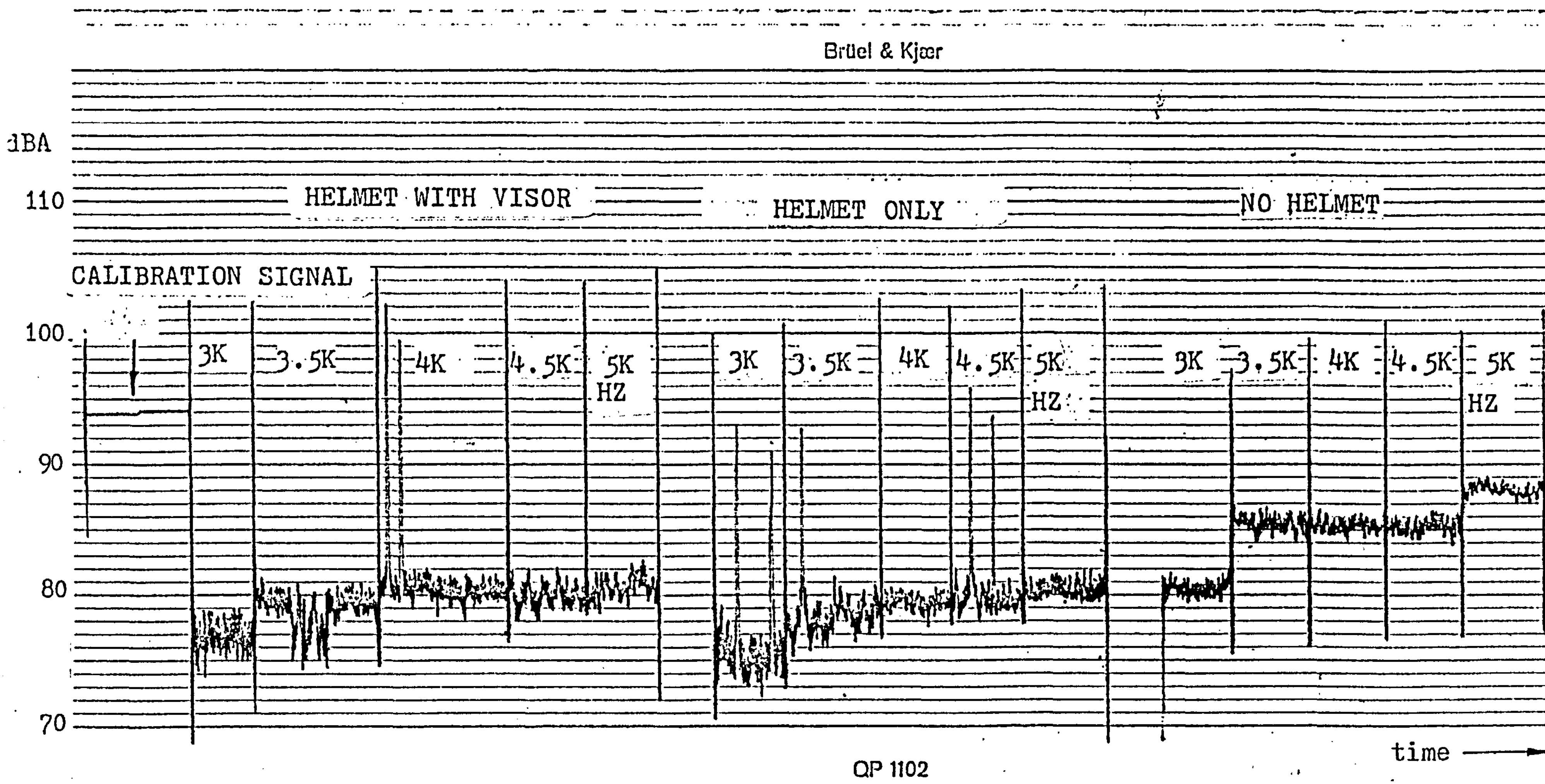


FIGURE F7- Typical Graphic Recording of Motorcycle Noise

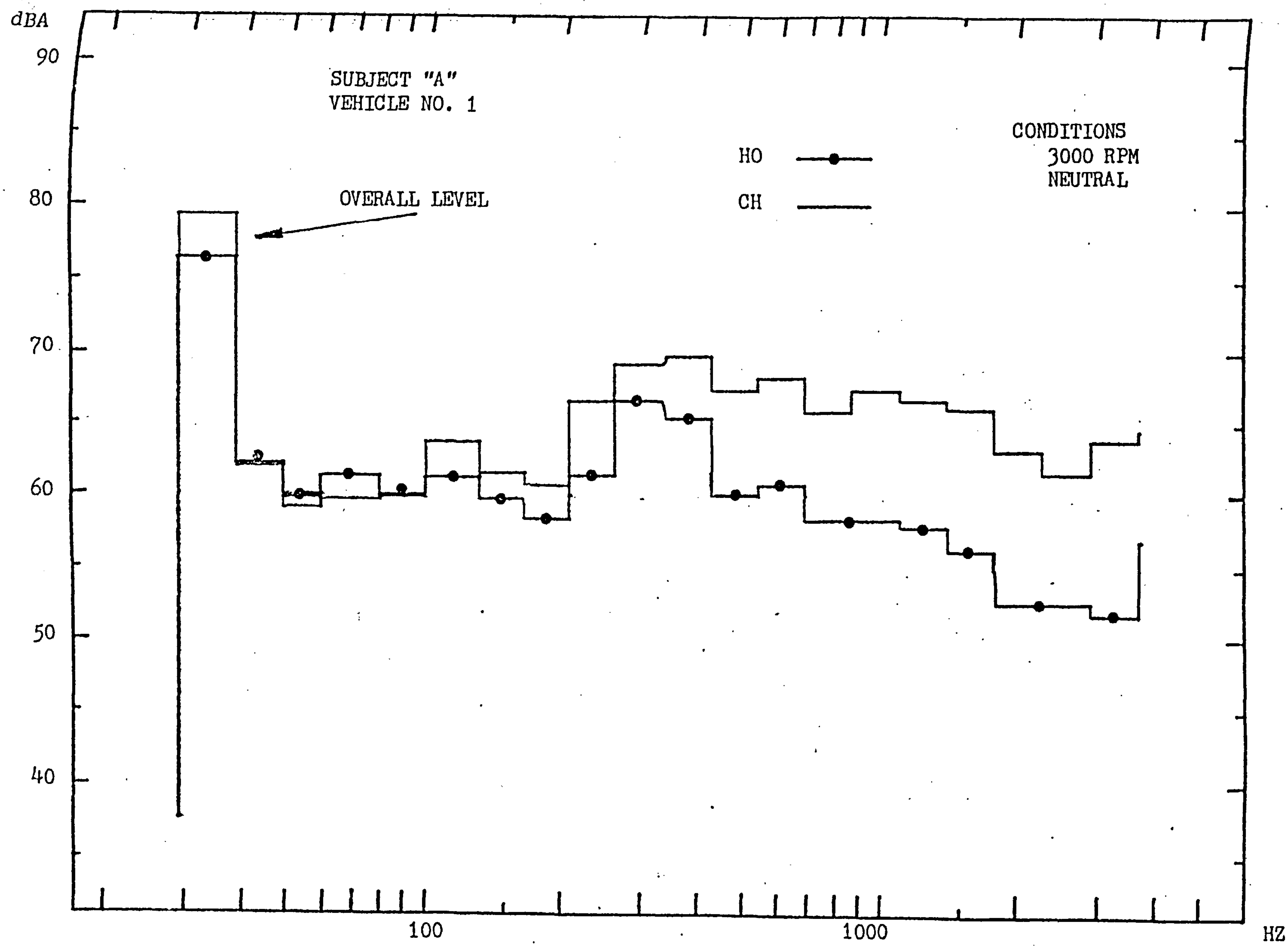


FIGURE F8- Typical 1/3- octave plot of motorcycle noise via real time analyzer.

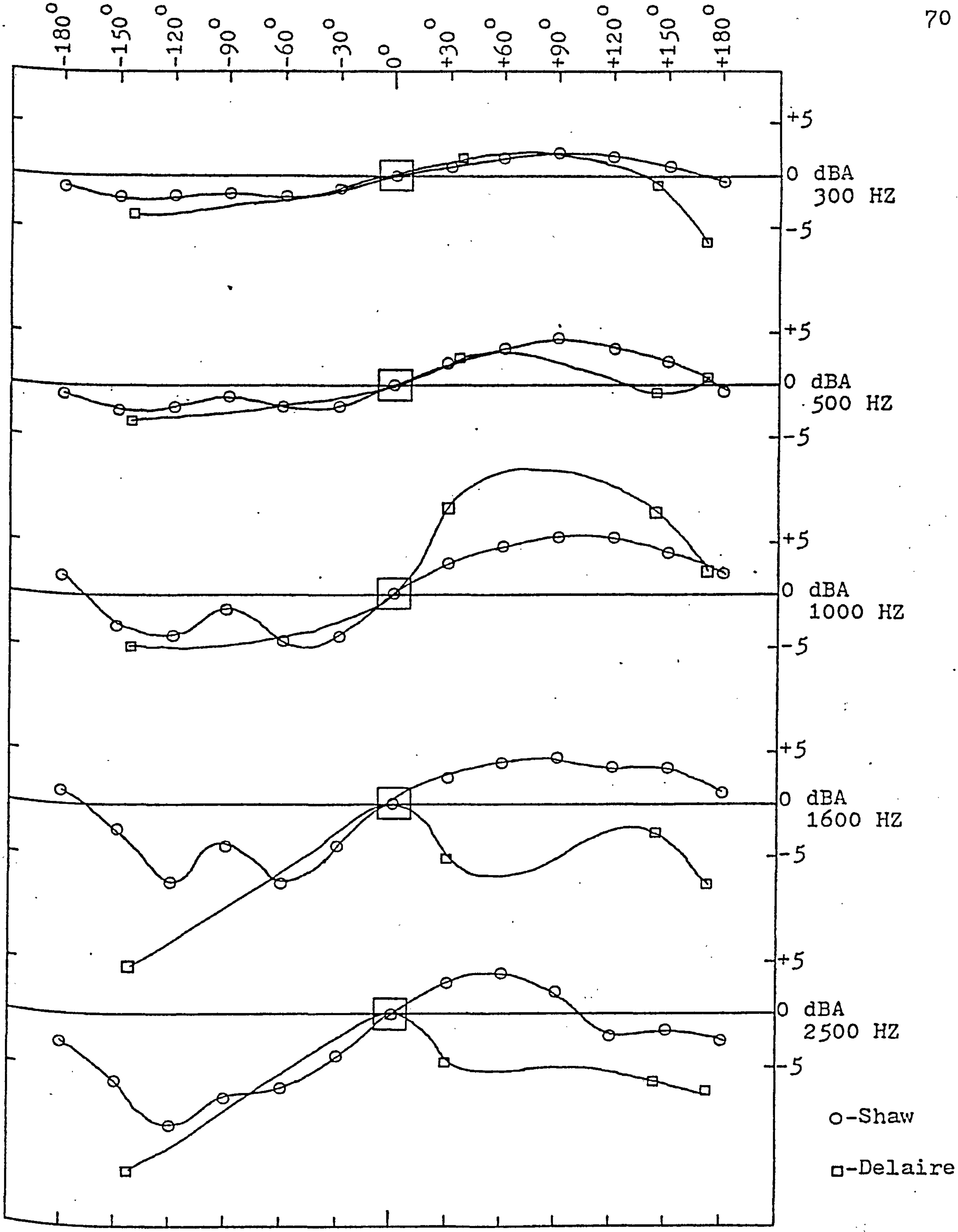


FIGURE F9 - Sound pressure versus angle of incidence at specific frequencies. (Shaw- azimuthal plane only;Delaire- floor plane + azimuthal plane).

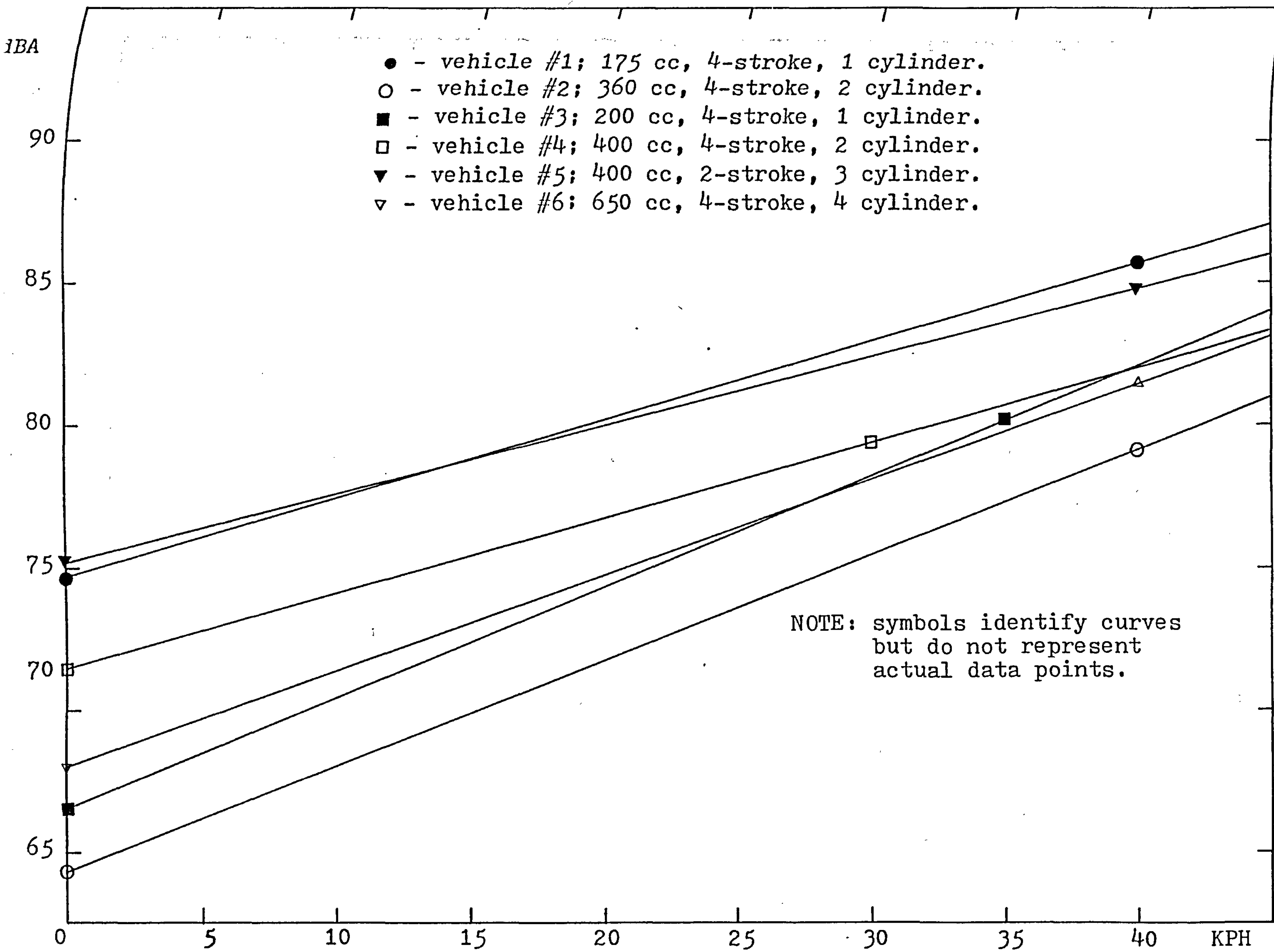


FIGURE F10- Vehicle comparison of AVG_2 for slope and zero-intercept.

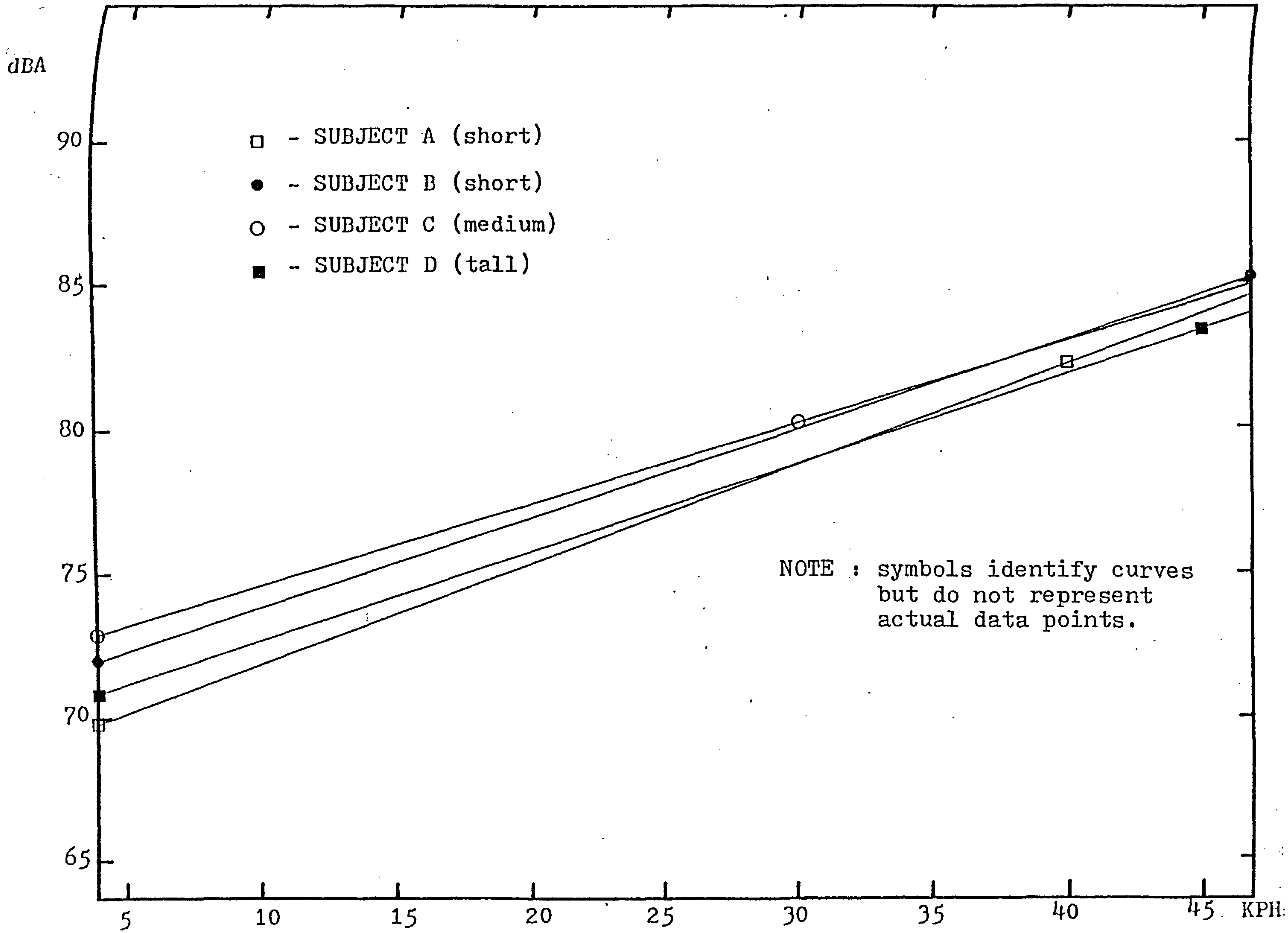


FIGURE F11- Subject comparison of AVG_2 for slope and zero-intercept.

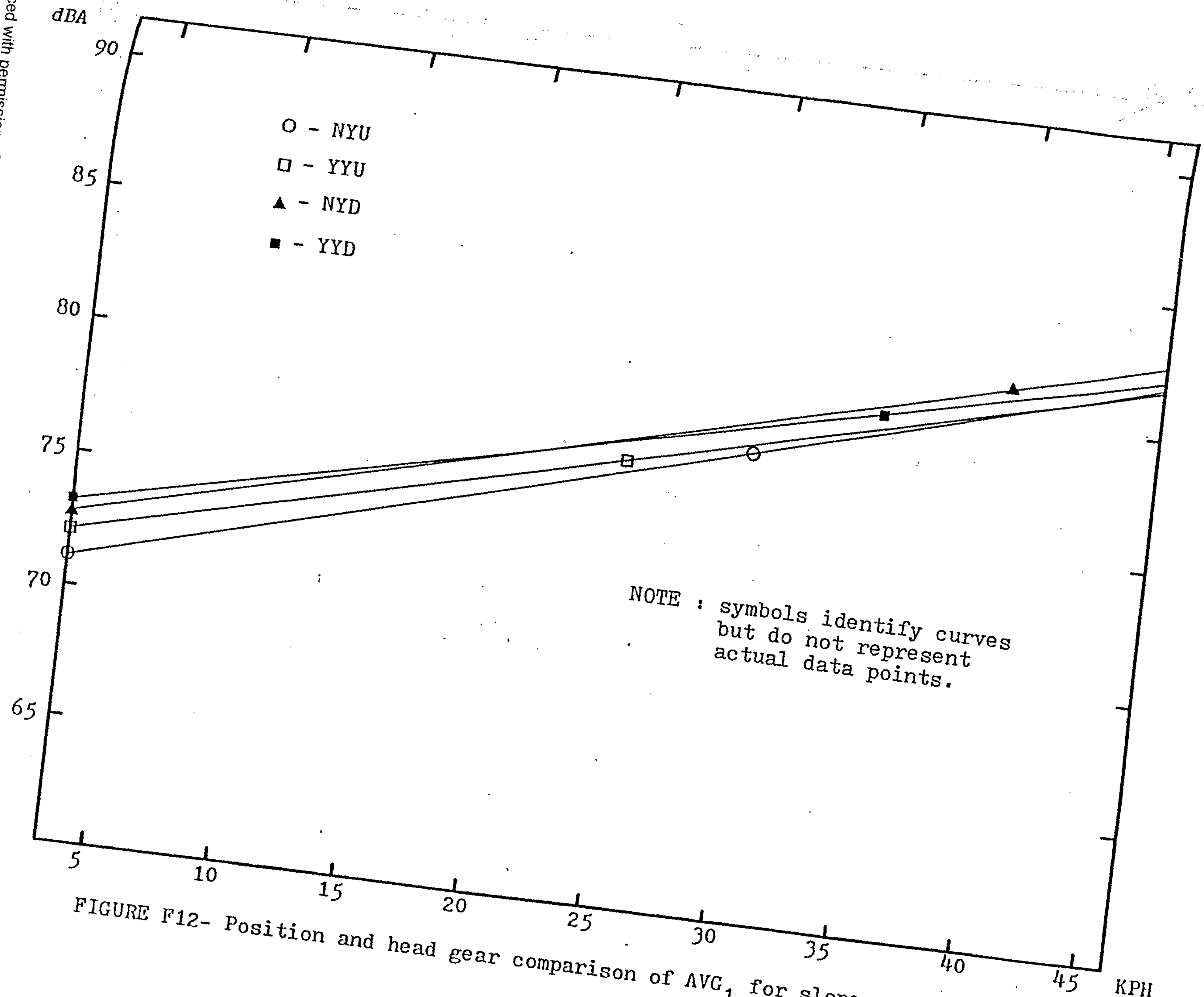


FIGURE F12- Position and head gear comparison of AVG_1 for slope and zero-intercept.

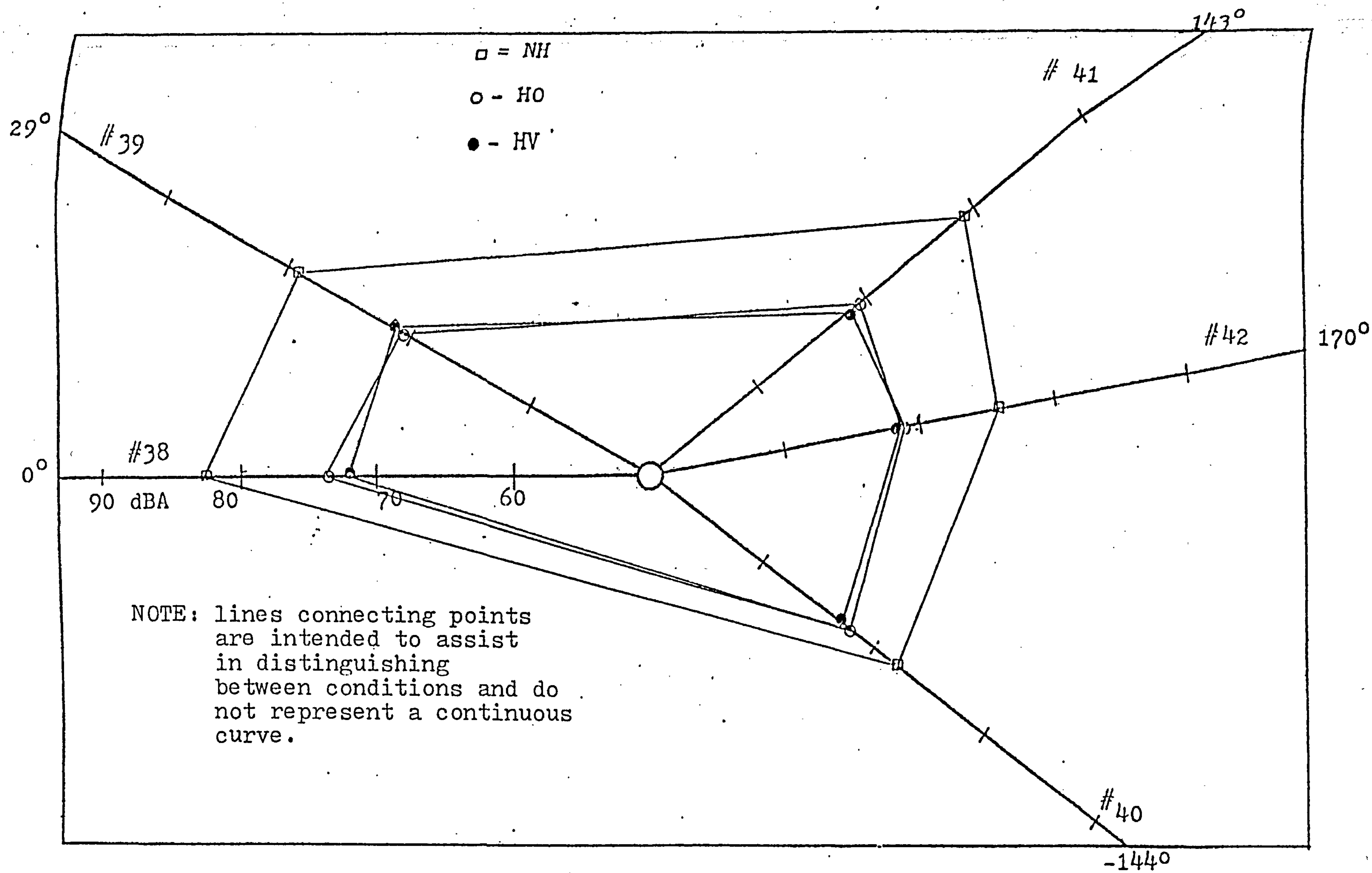


FIGURE F13A- Polar plot showing comparison of headgear arrangements.

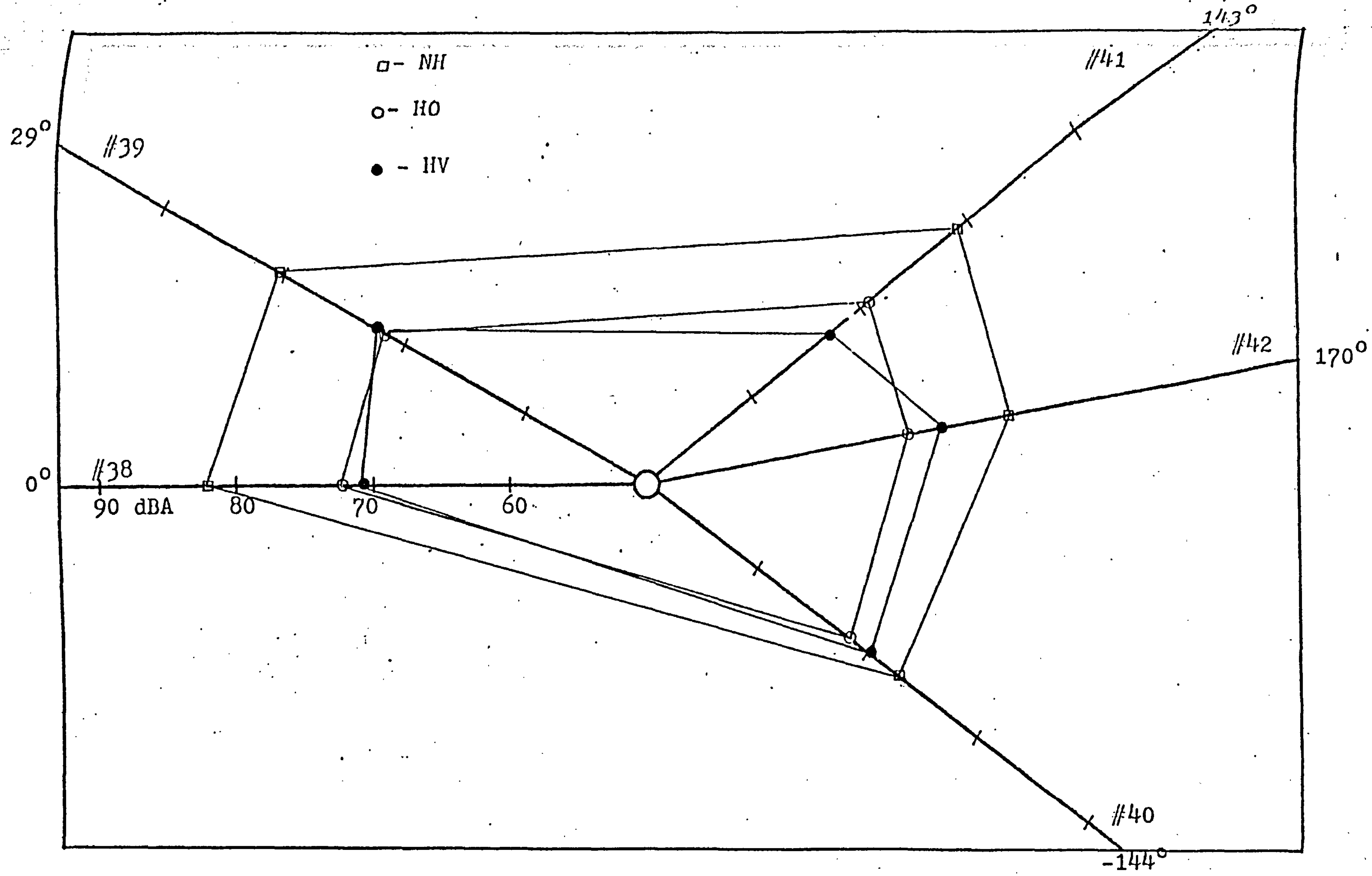


FIGURE F13B- Polar plot showing comparison of headgear arrangements.

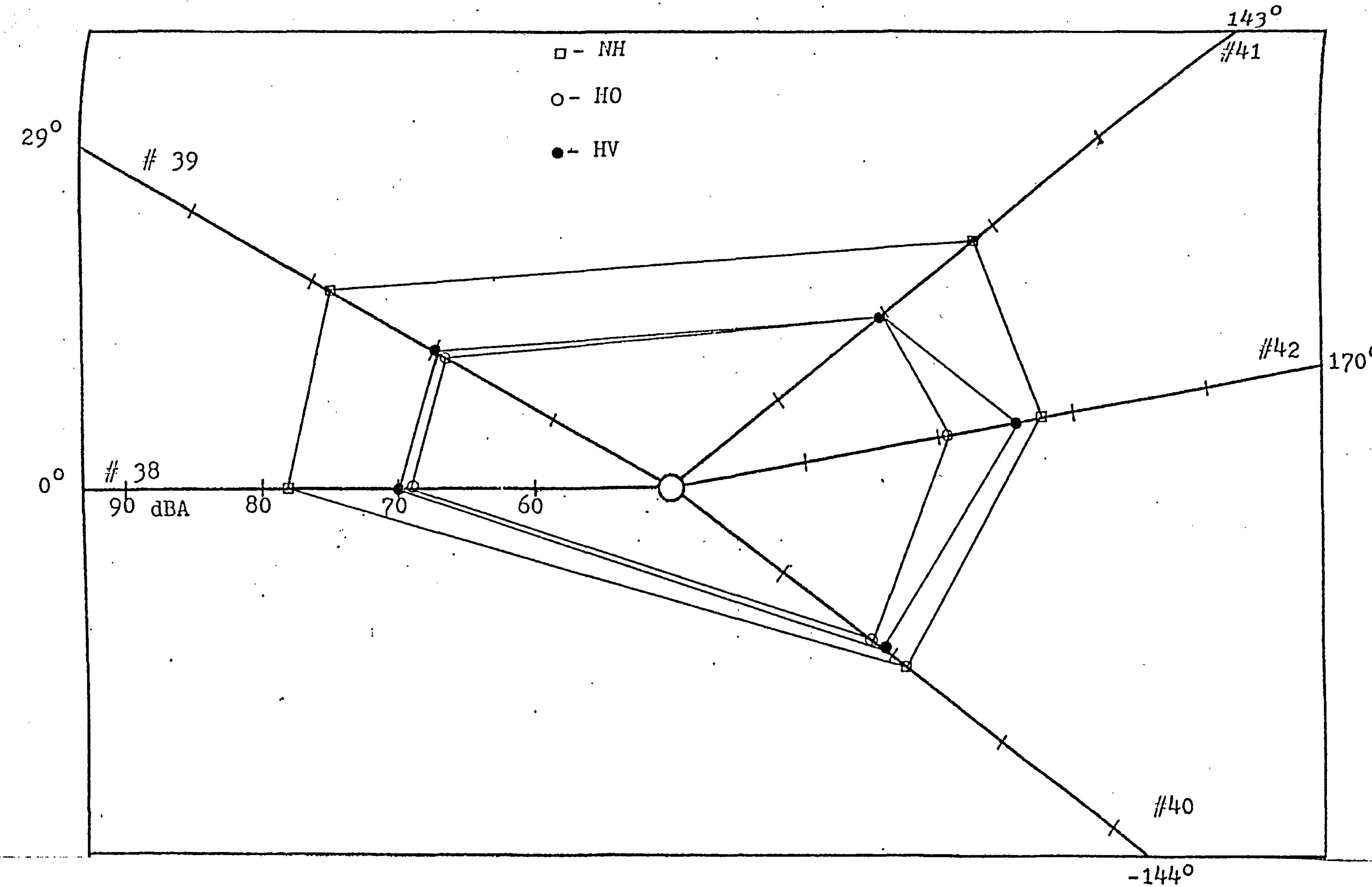


FIGURE F13C- Polar plot showing comparison of headgear arrangements.

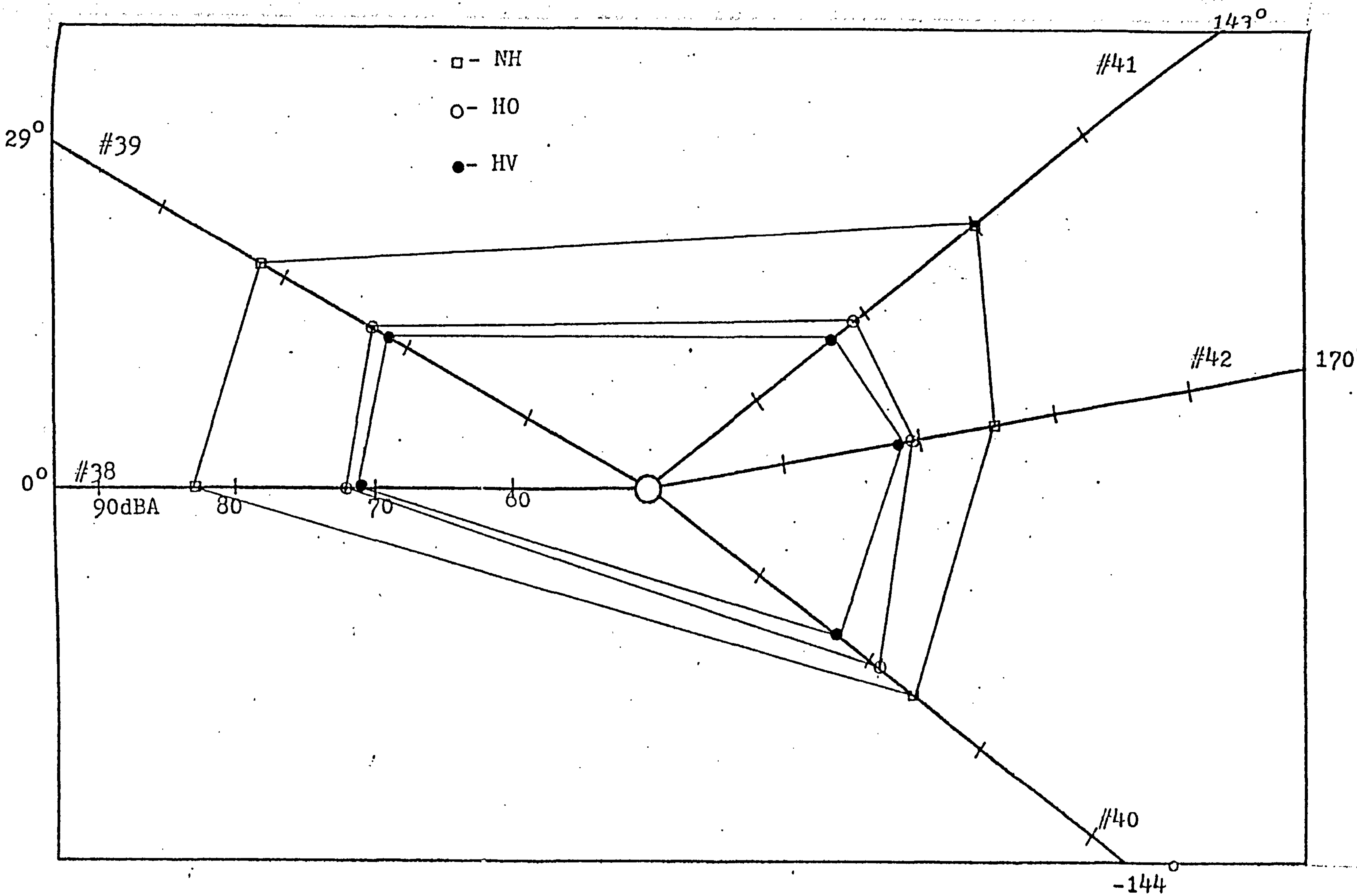


FIGURE F13D- Polar plot showing comparison of headgear arrangements.

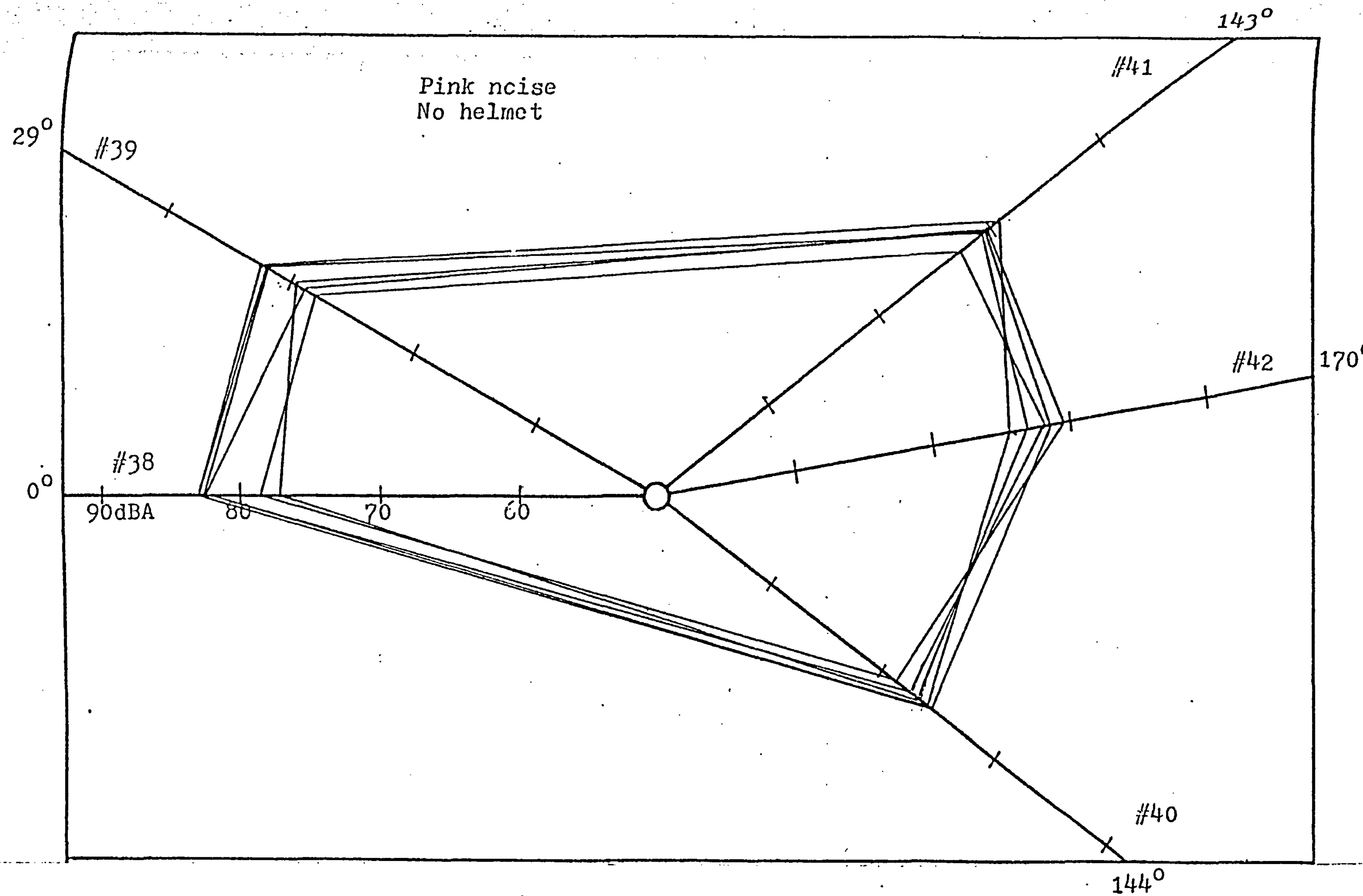


FIGURE F13L- Polar plot of subject comparison. Symbols not included due to difficulty in distinguishing between them.

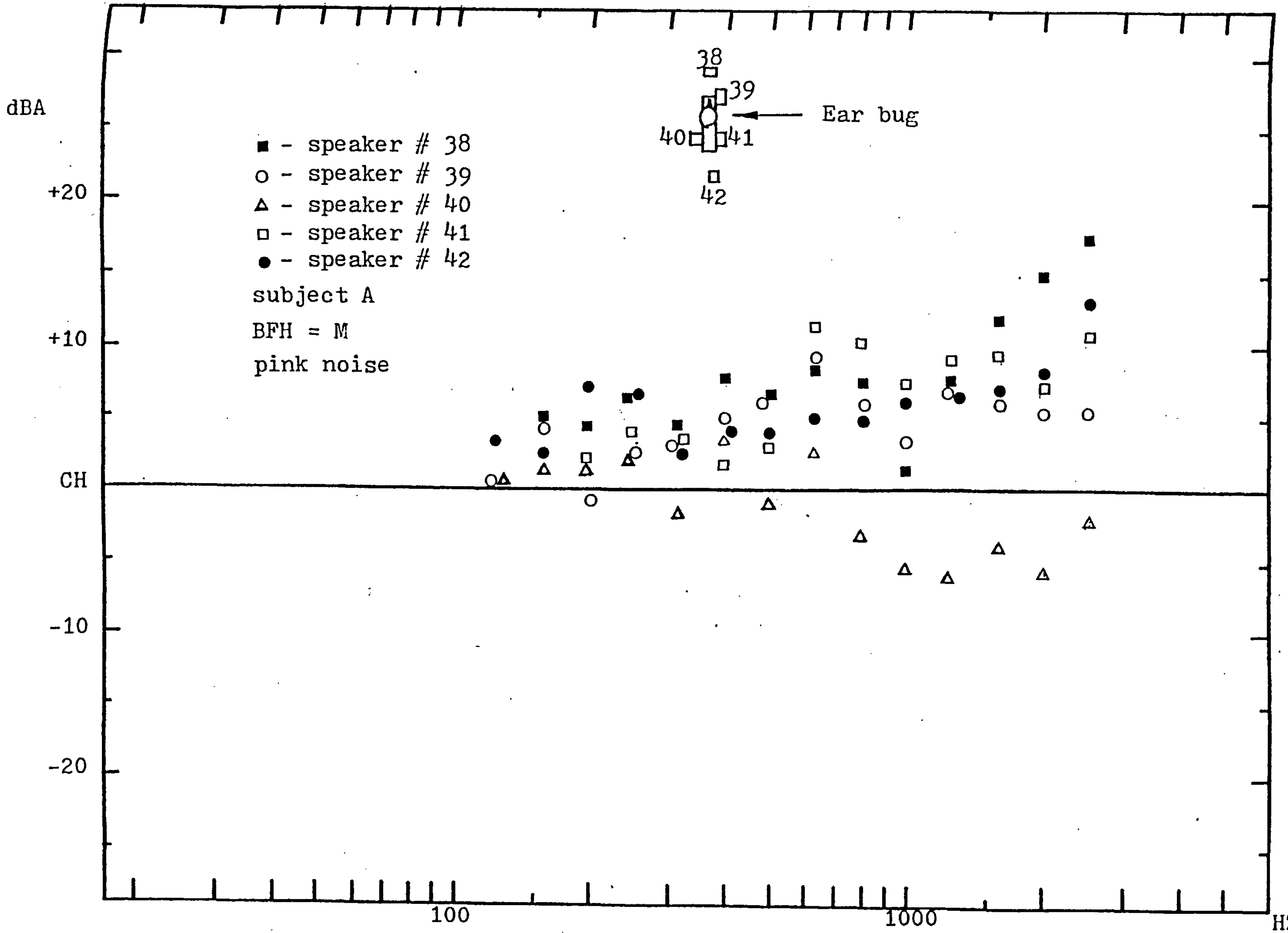


FIGURE F14α - 1/3 octave frequency spectrum of transfer function for all speakers.

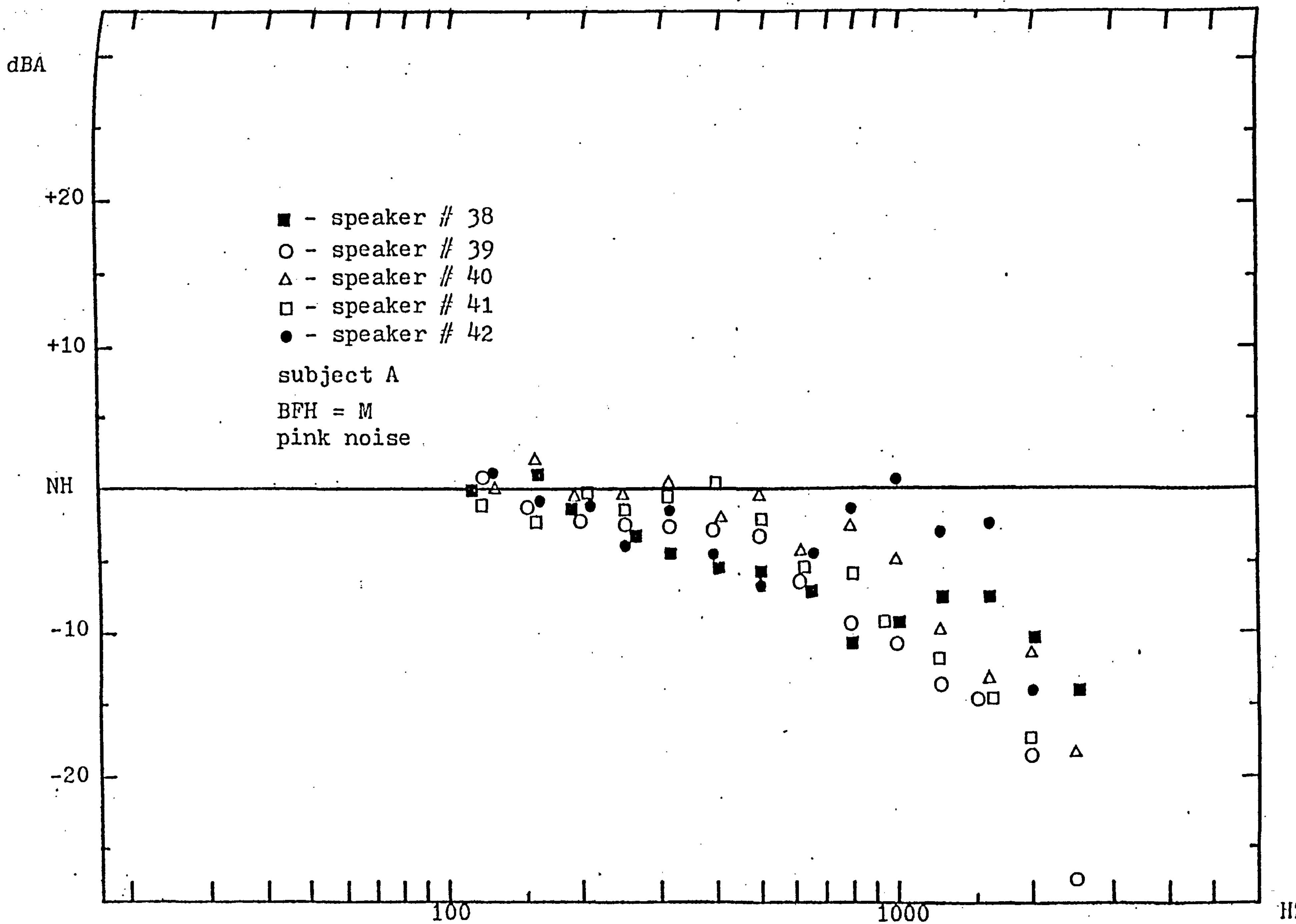


FIGURE F14/β- 1/3 octave frequency spectrum of helmet attenuation for all speakers.

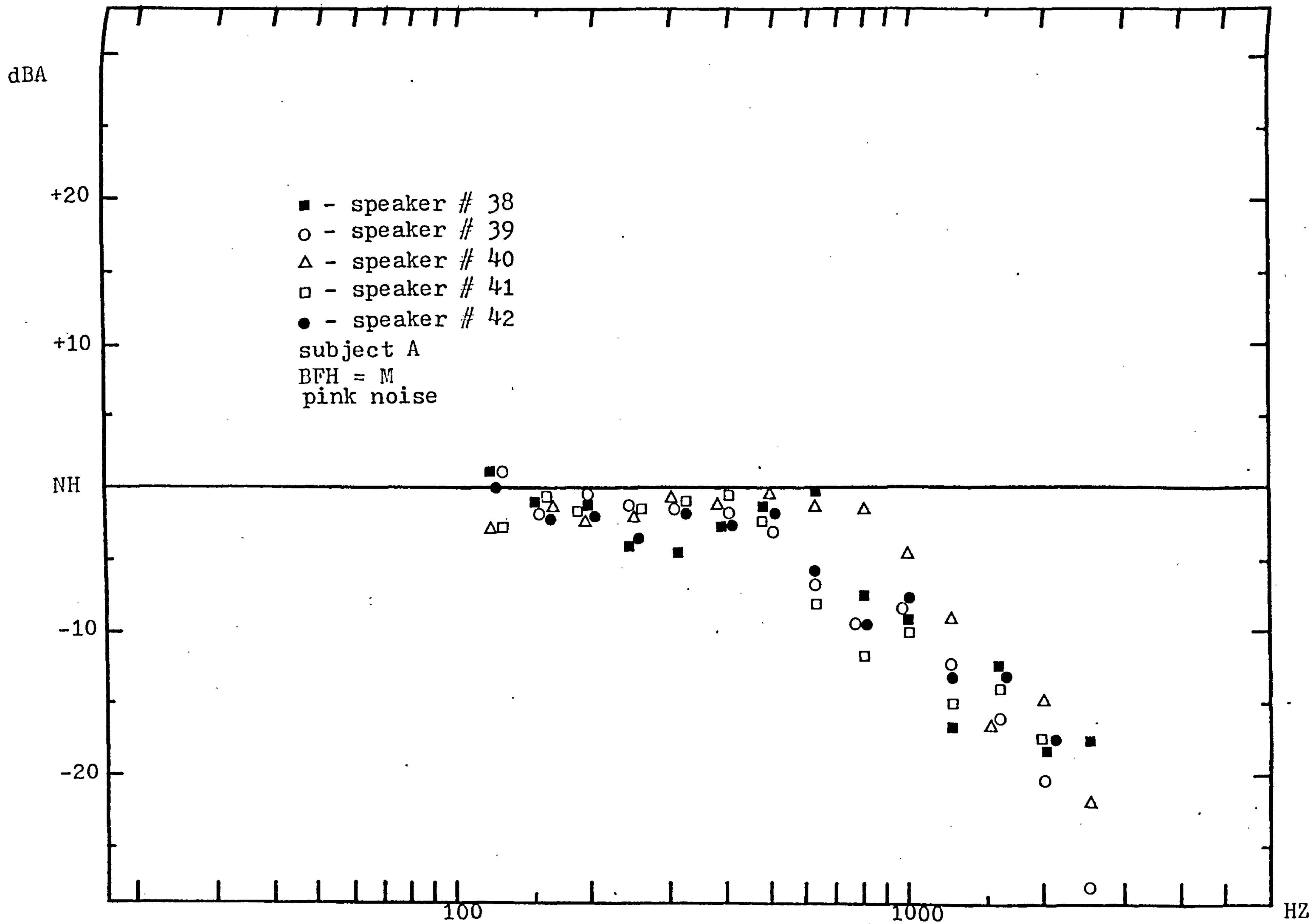


FIGURE F14γ -1/3 octave frequency spectrum of helmet + visor attenuation for all speakers.

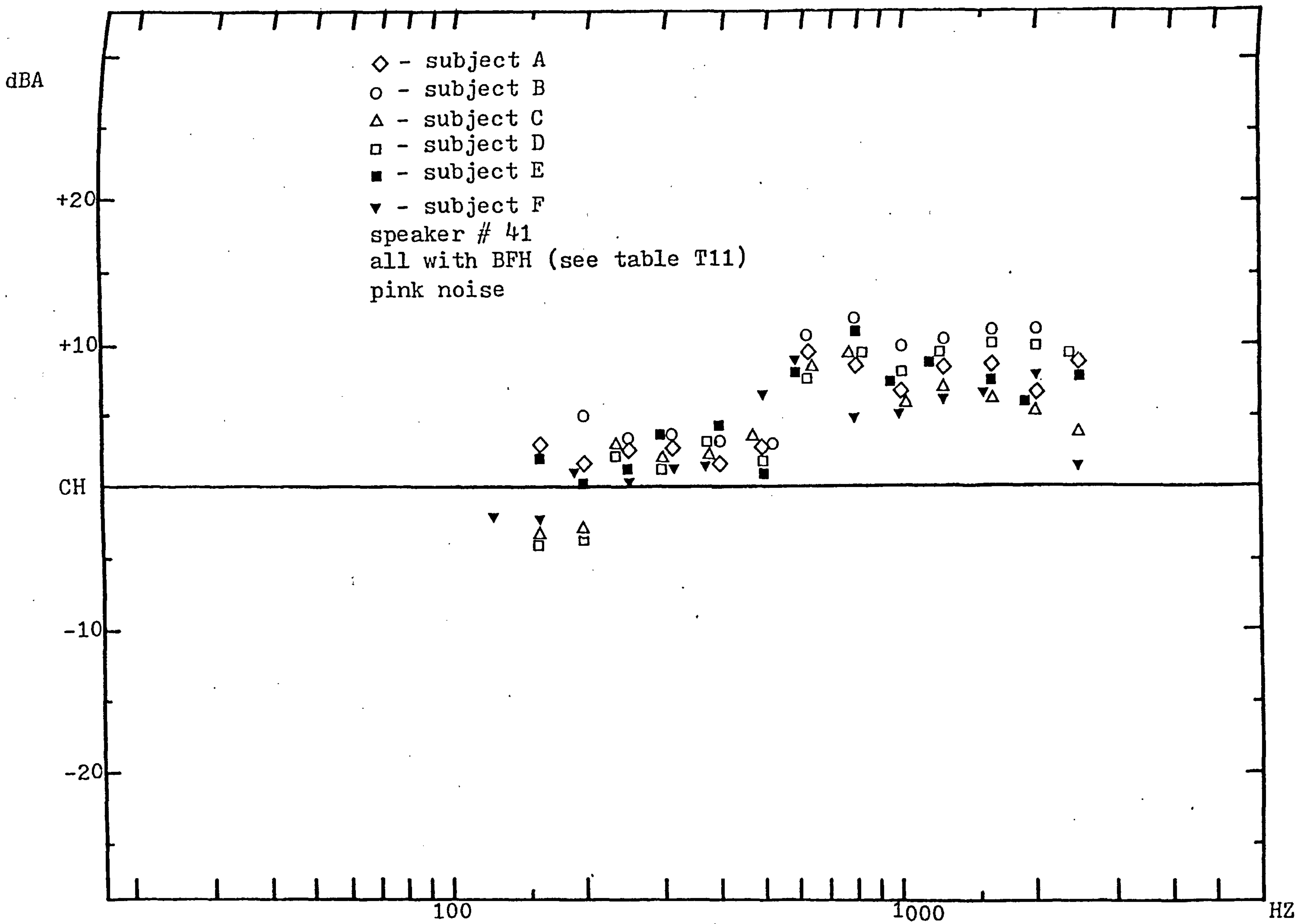


FIGURE F15α - 1/3 octave frequency spectrum of transfer function for all subjects.

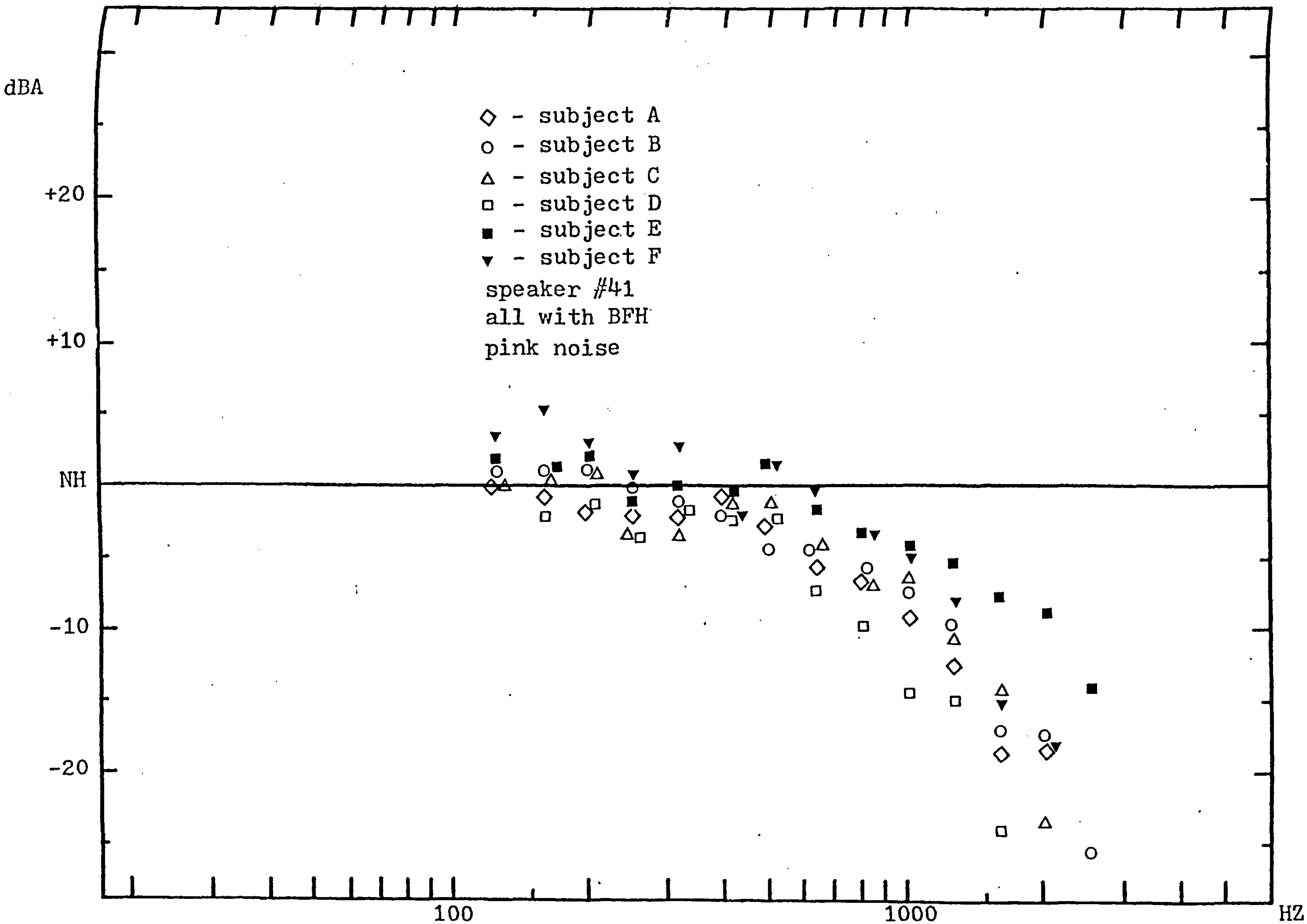


FIGURE F15β - 1/3 octave frequency spectrum of helmet attenuation for all subjects.

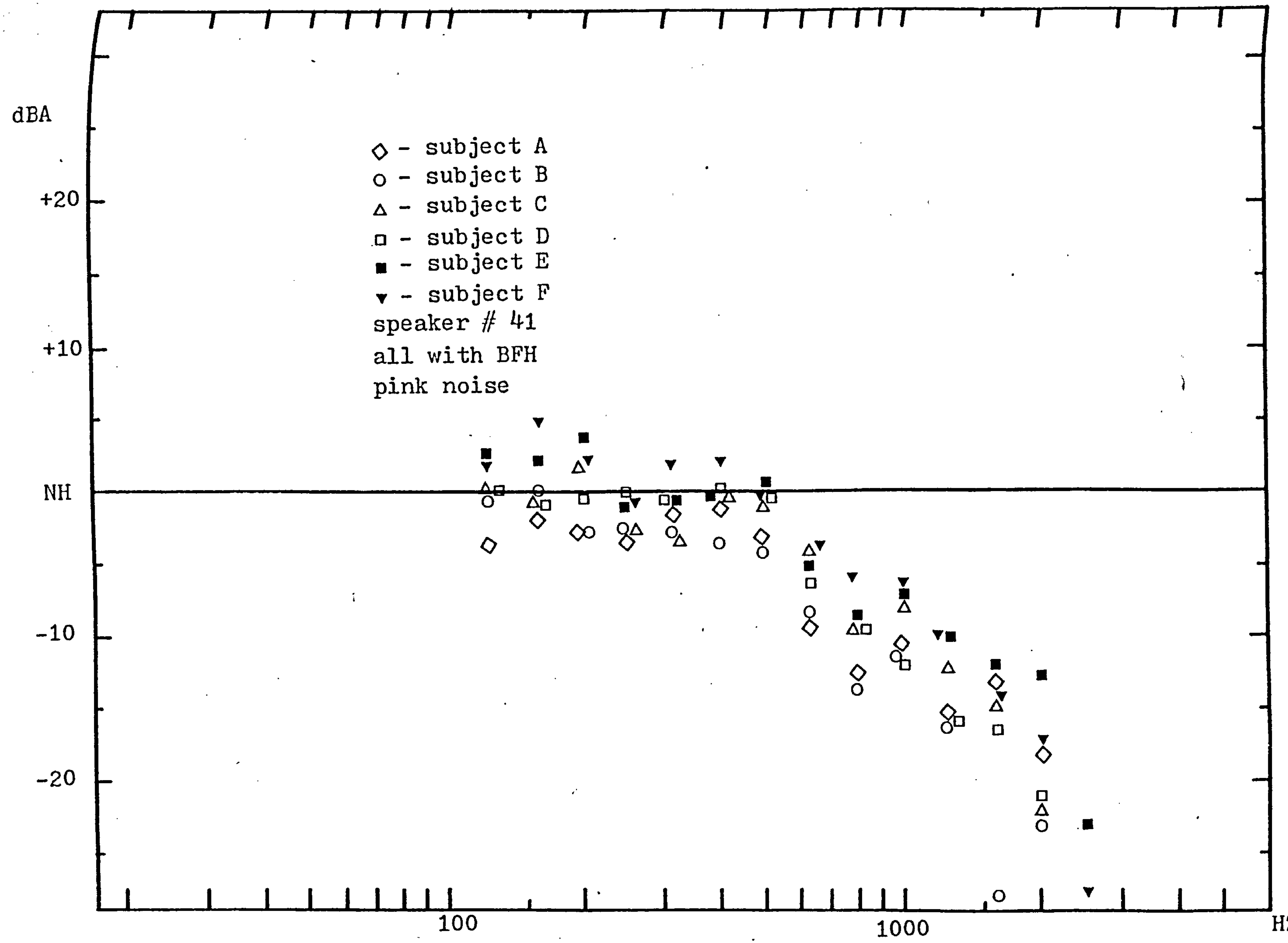


FIGURE F15γ - 1/3 octave frequency spectrum of helmet + visor attenuation for all subjects.

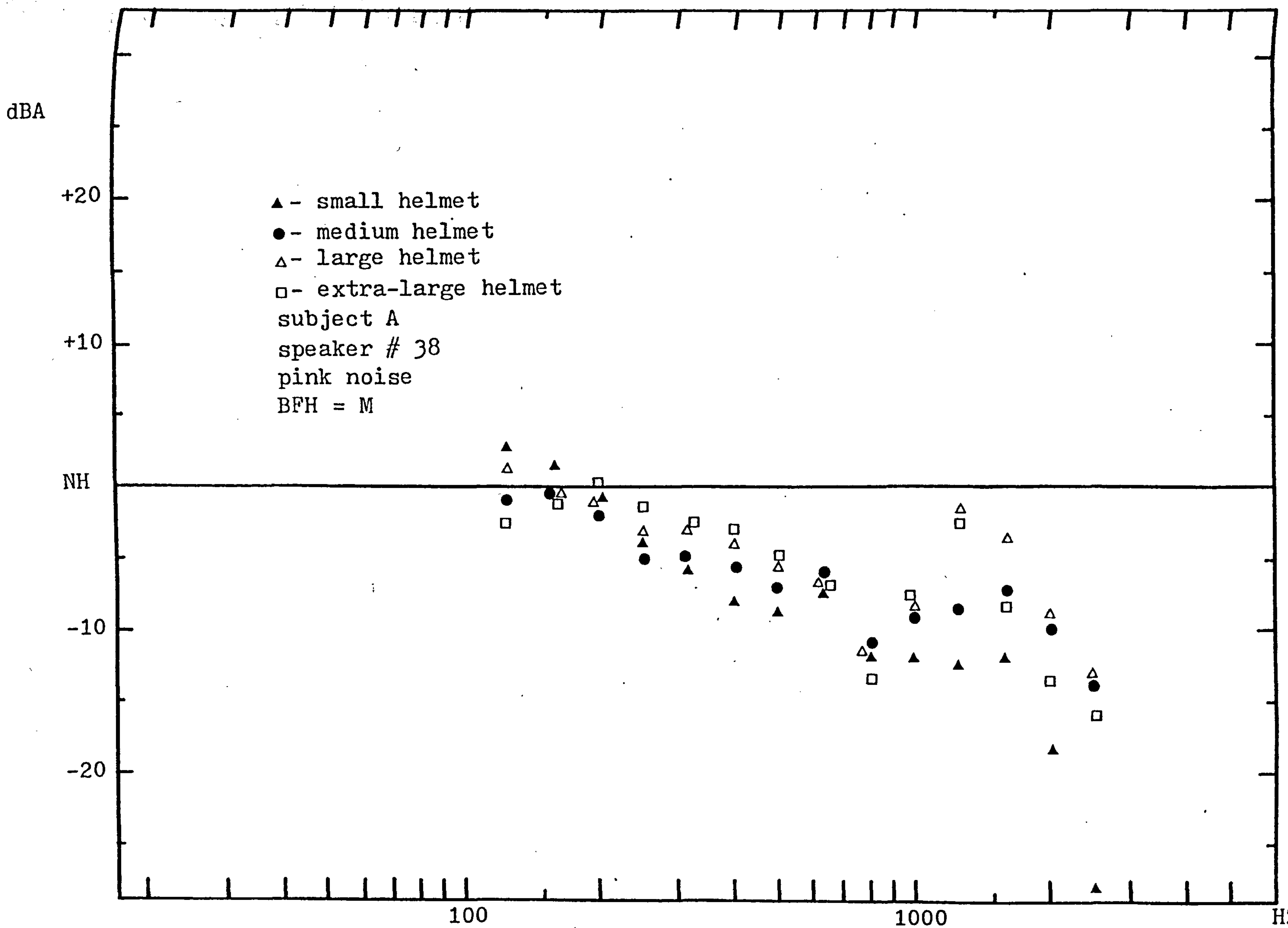


FIGURE F16β - 1/3 octave frequency spectrum of helmet attenuation for all helmet sizes.

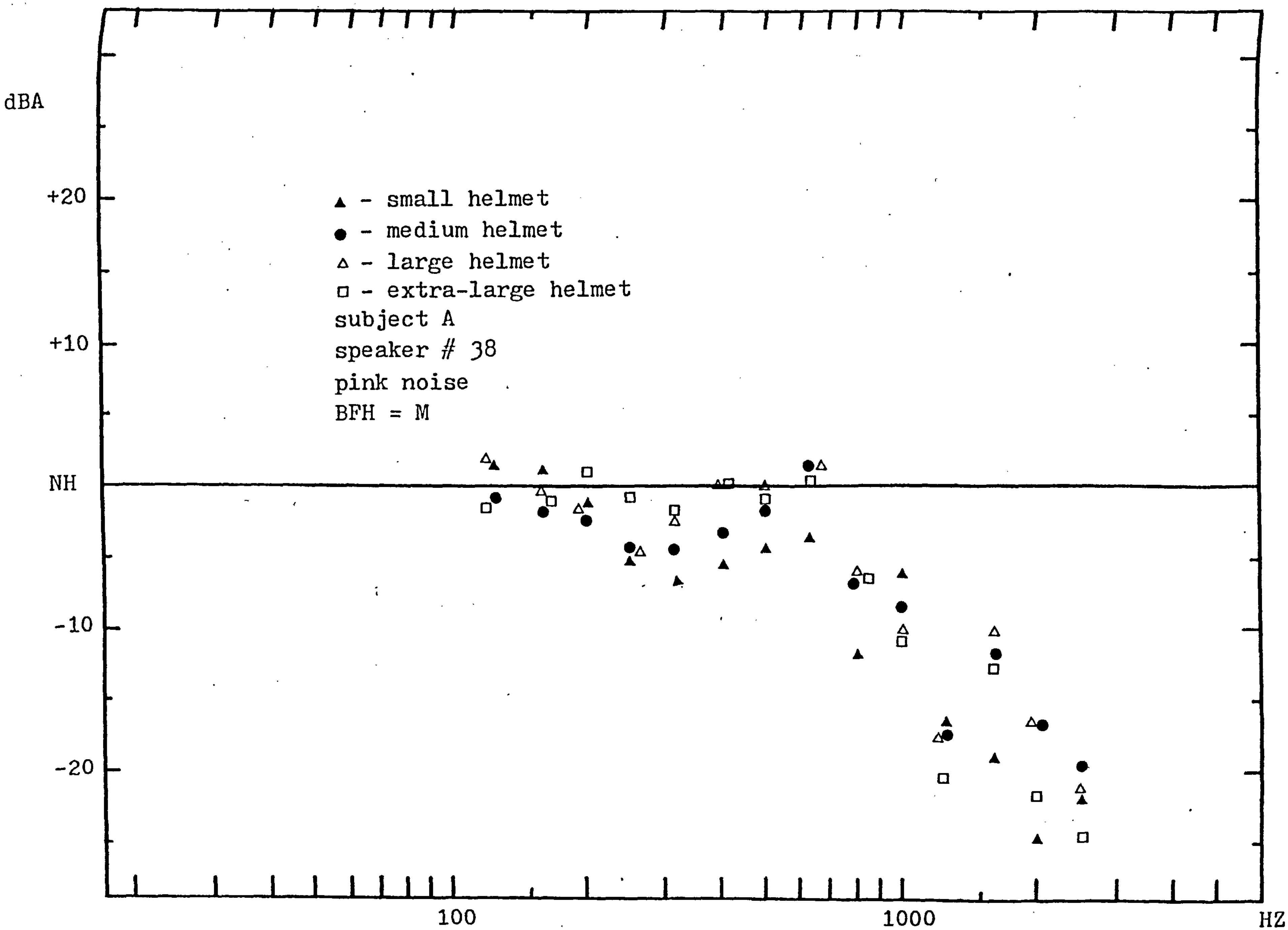
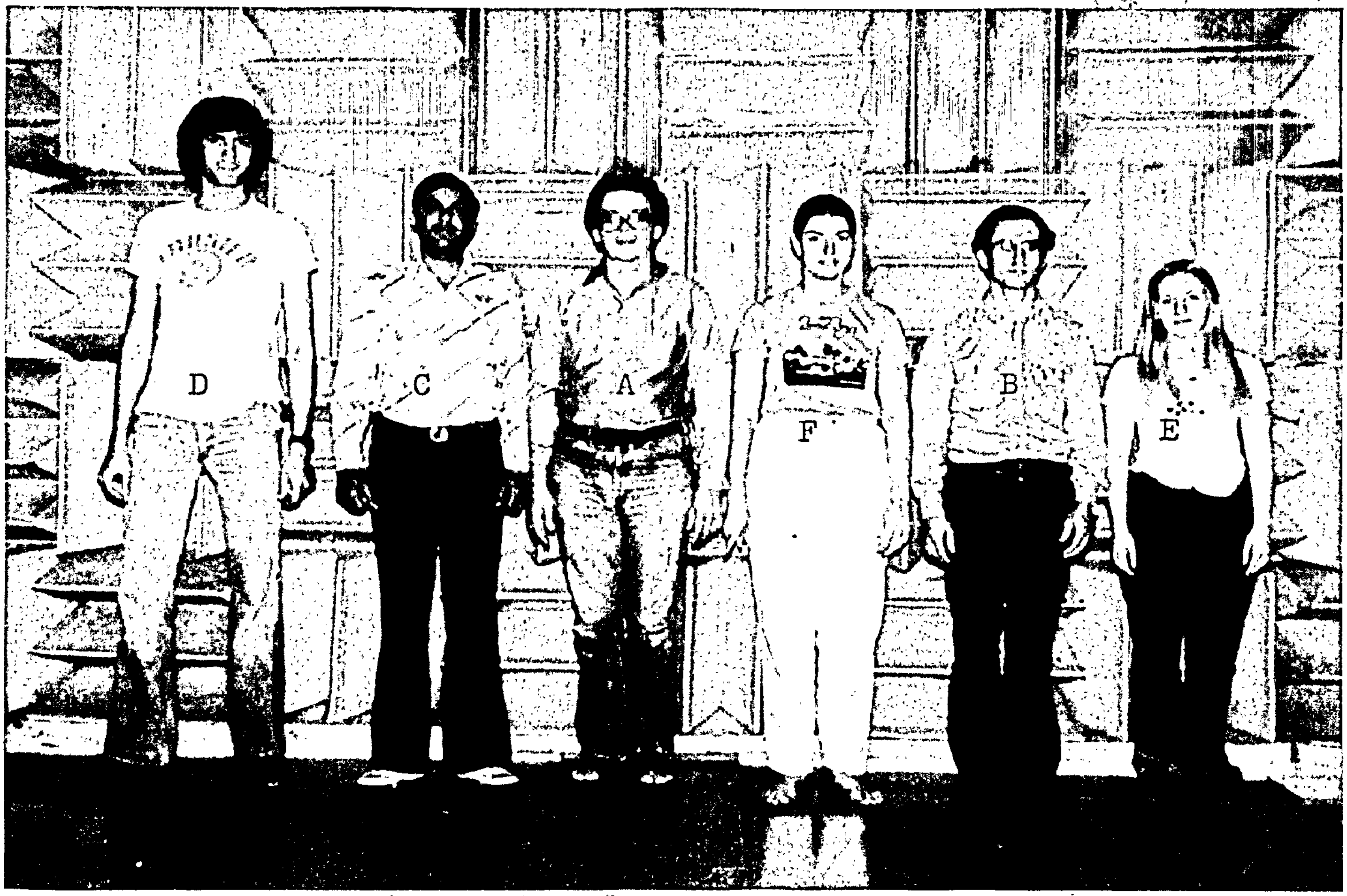
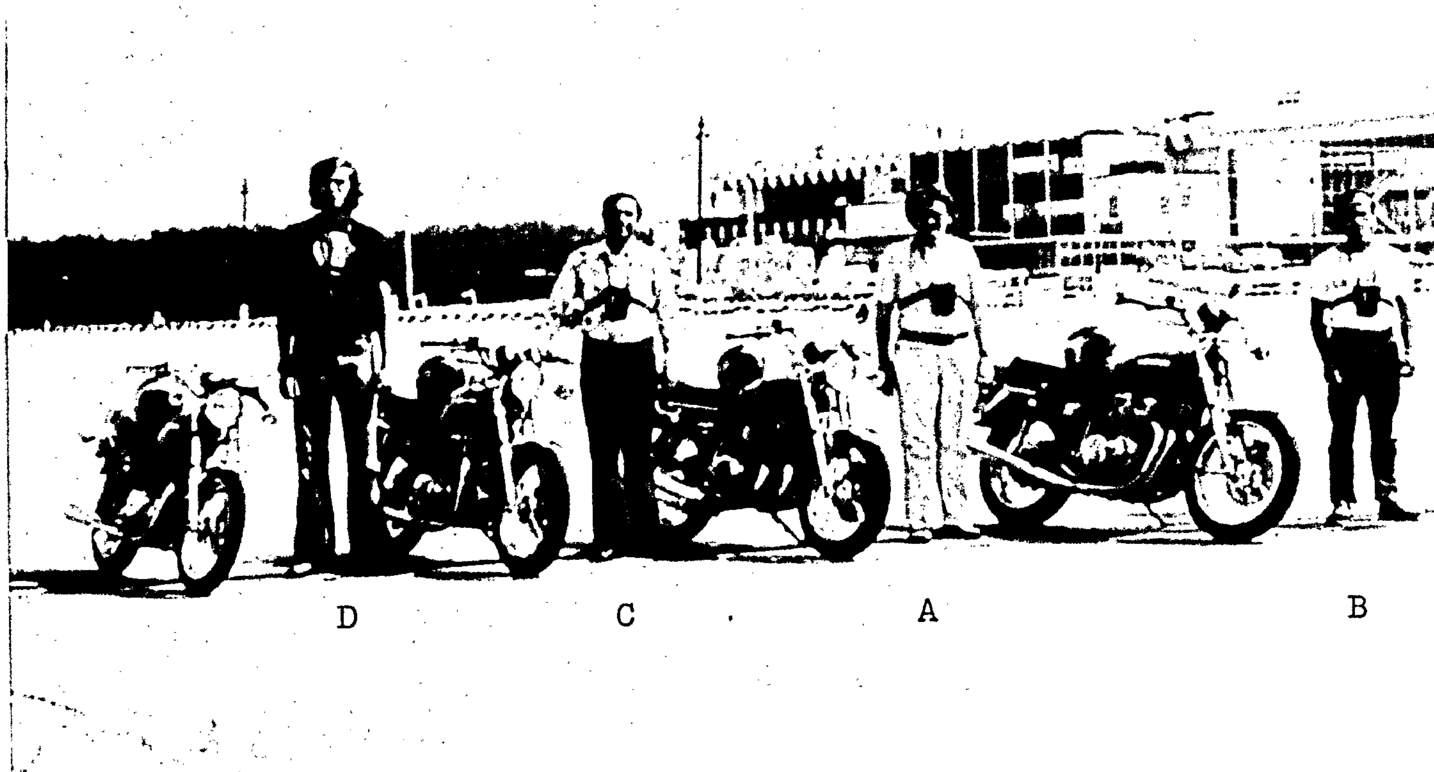


FIGURE F16γ - 1/3 octave frequency spectrum of helmet + visor attenuation for all helmet sizes.



Inside semi-anechoic chamber



Outside

FIGURE F17 - Subjects.

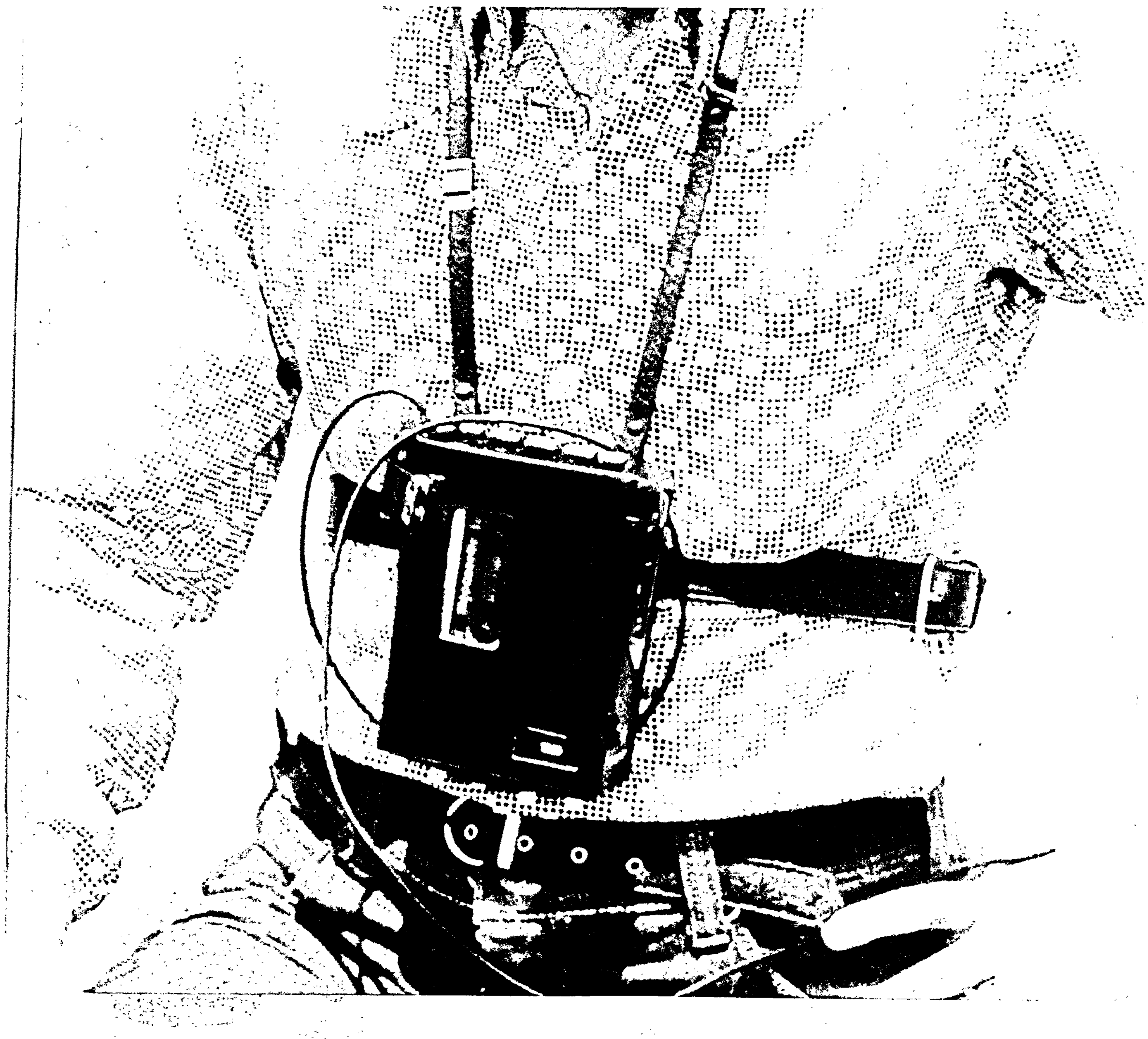


FIGURE F18 - Chest harness for ear bug recorder.

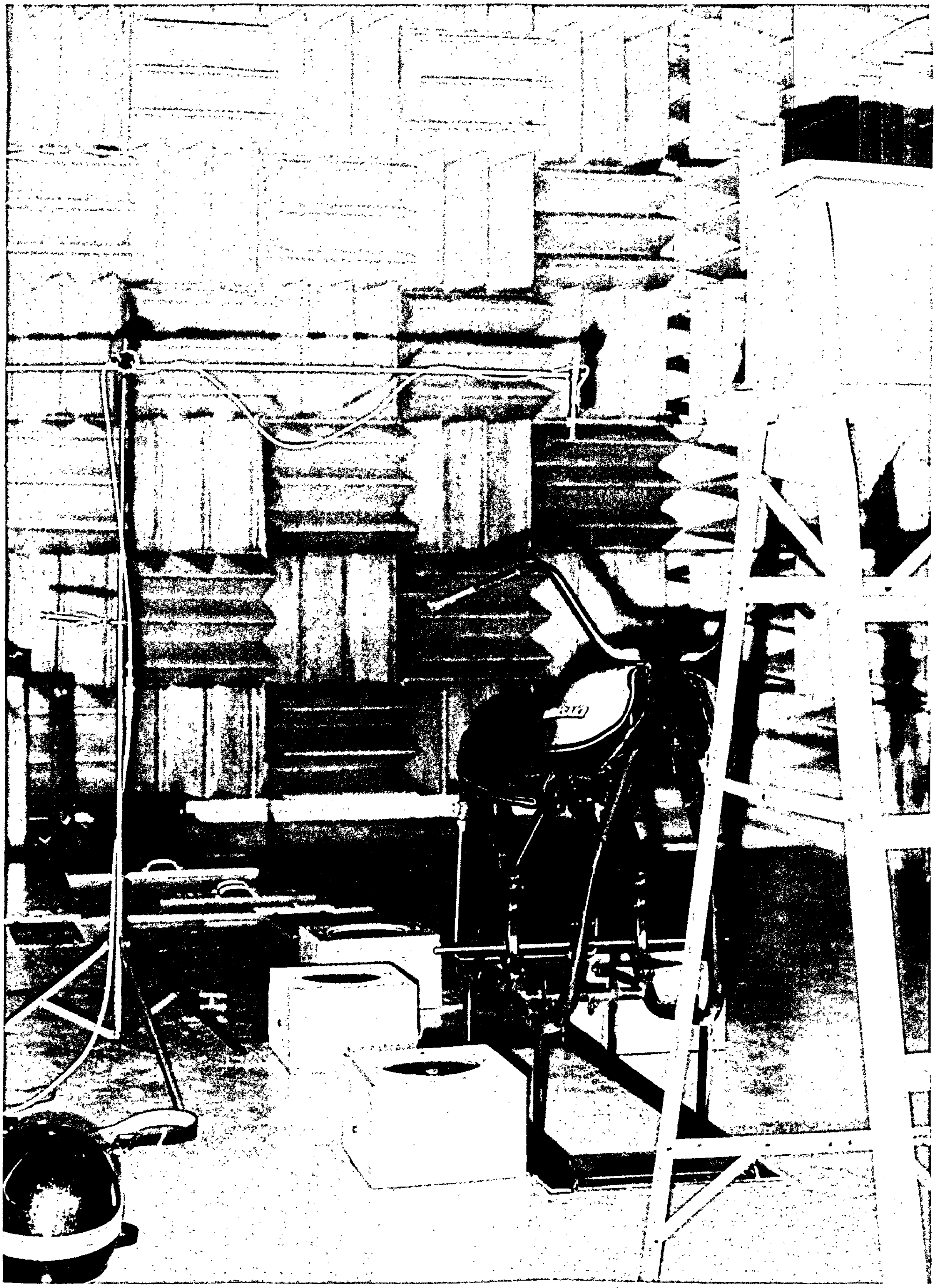
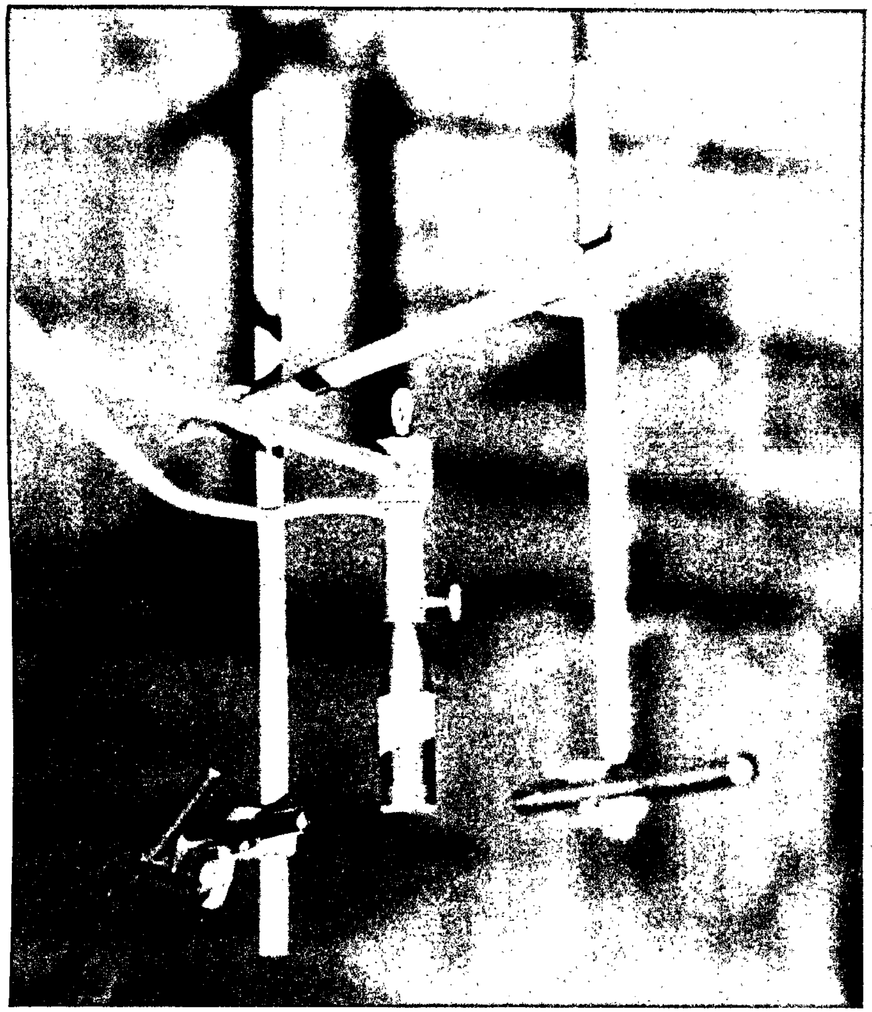
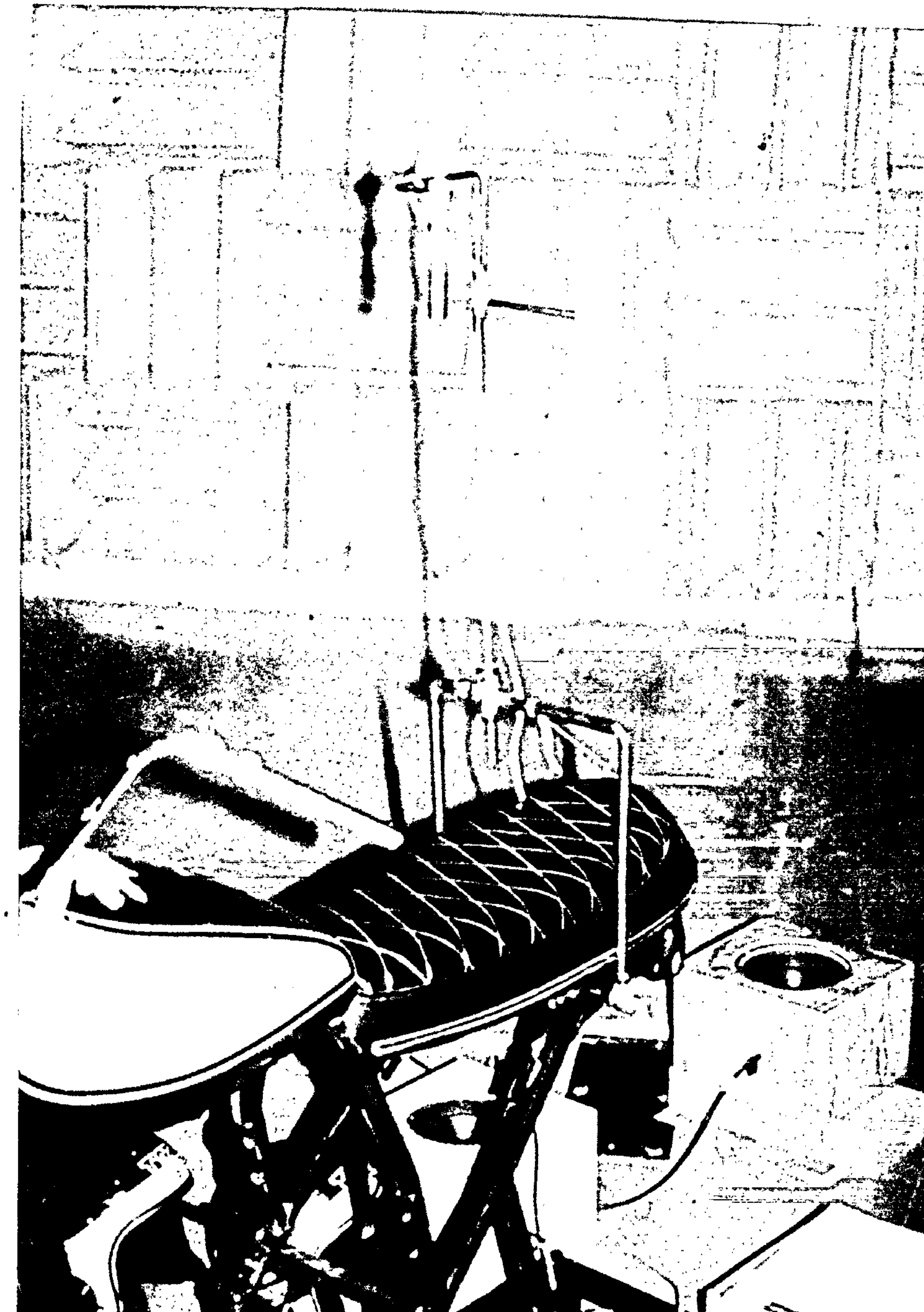


FIGURE F19 - Photograph of semi-anechoic chamber test facility.



Initial location of CH position



Automatic reposition device

Figure F20 - CH locating devices (S.A.Chamber).

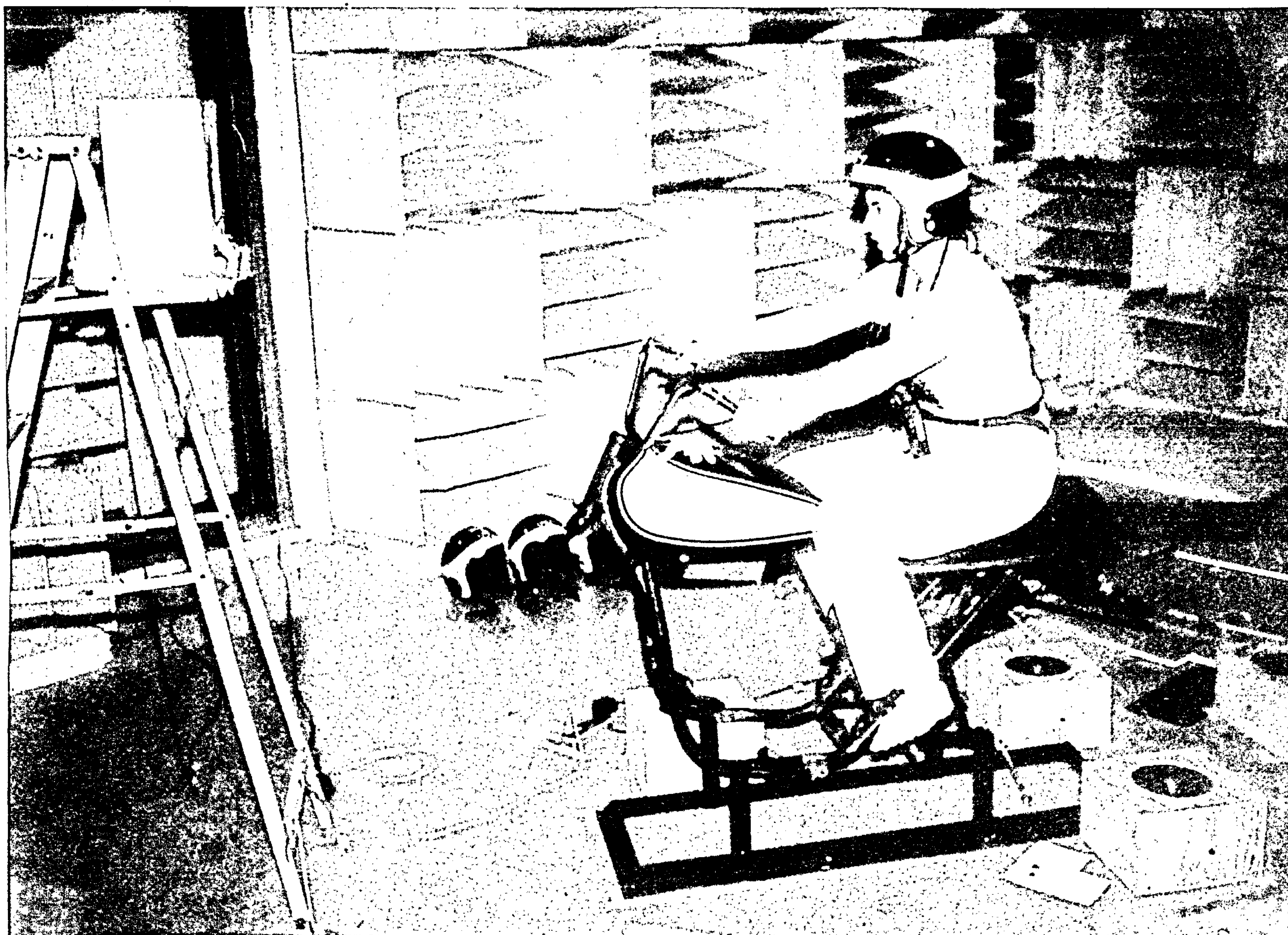


FIGURE F21 - Position assumed while recording during S.A.Chamber testing.

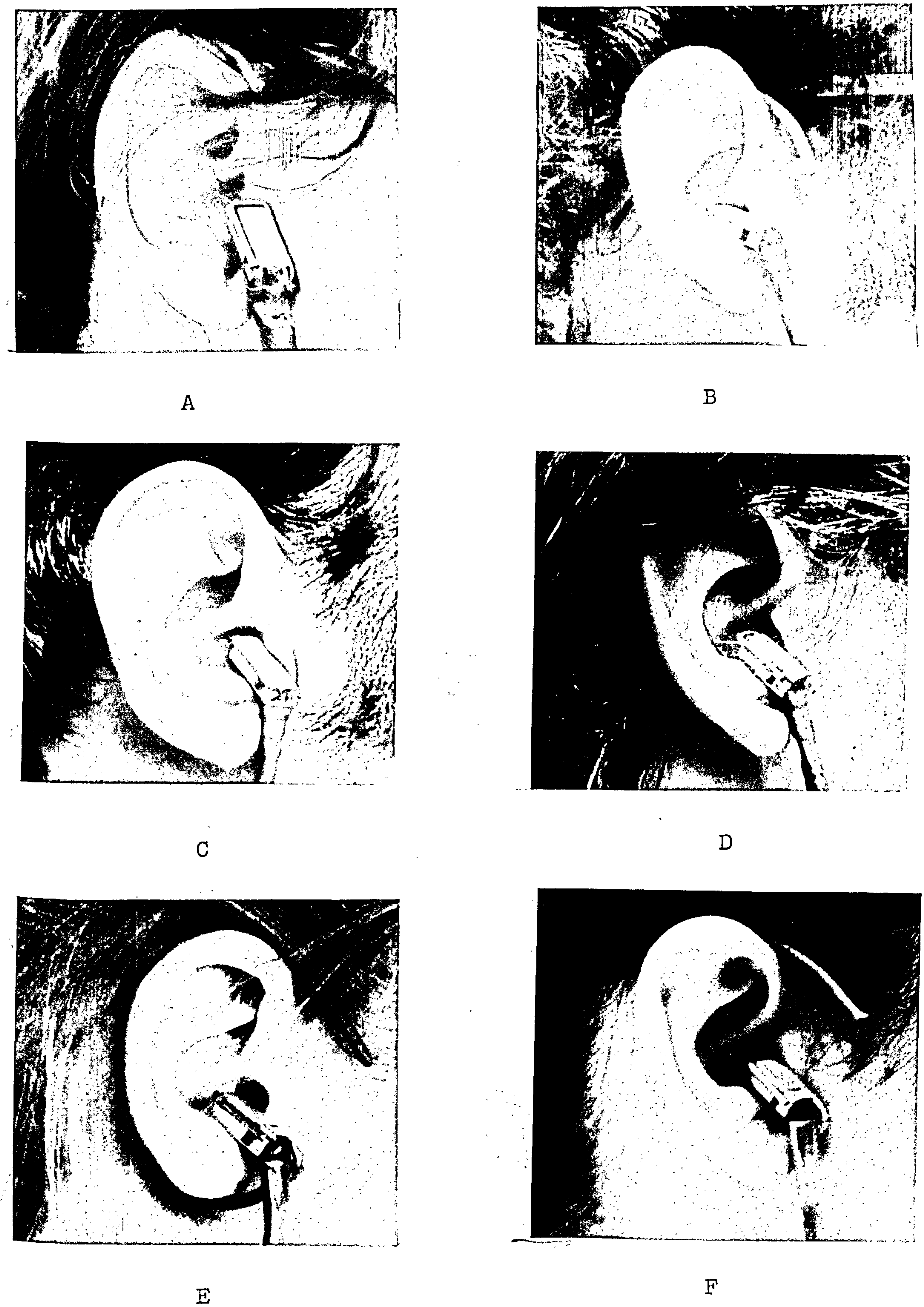


FIGURE F22 - Photographs of subject ears with ear bug mounted.

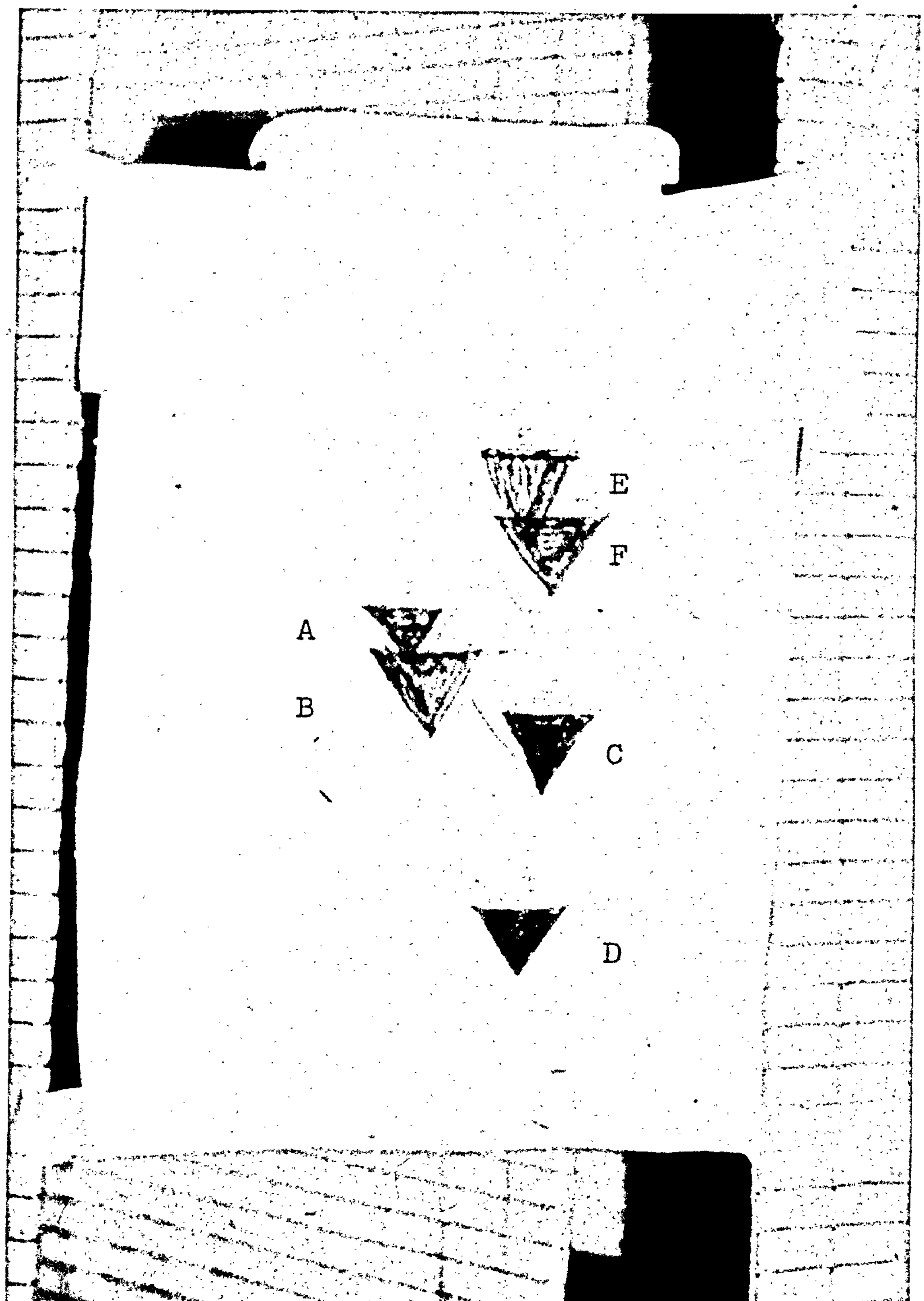
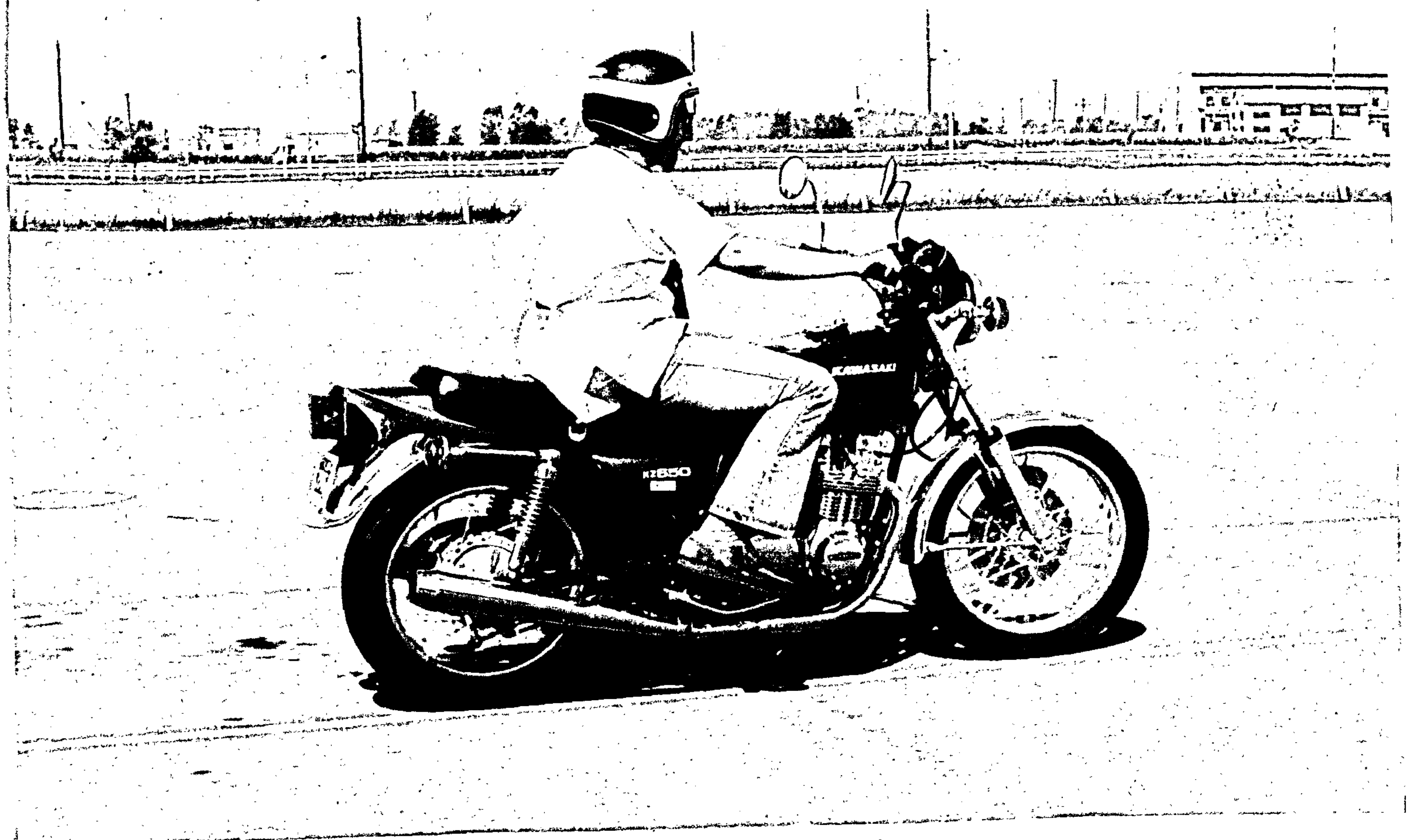
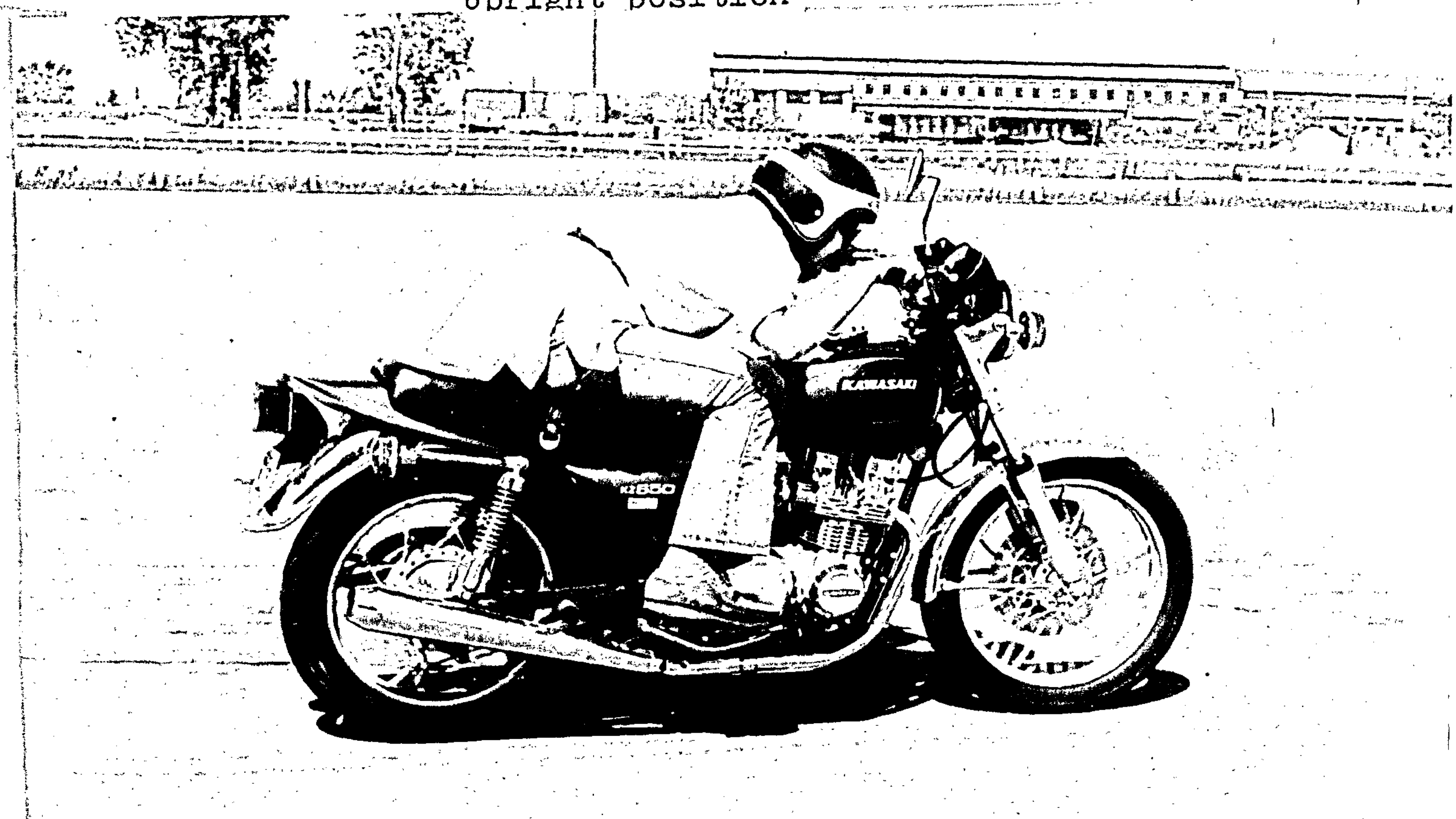


FIGURE F23 - Individual markings on distant target for visual location of CH position.



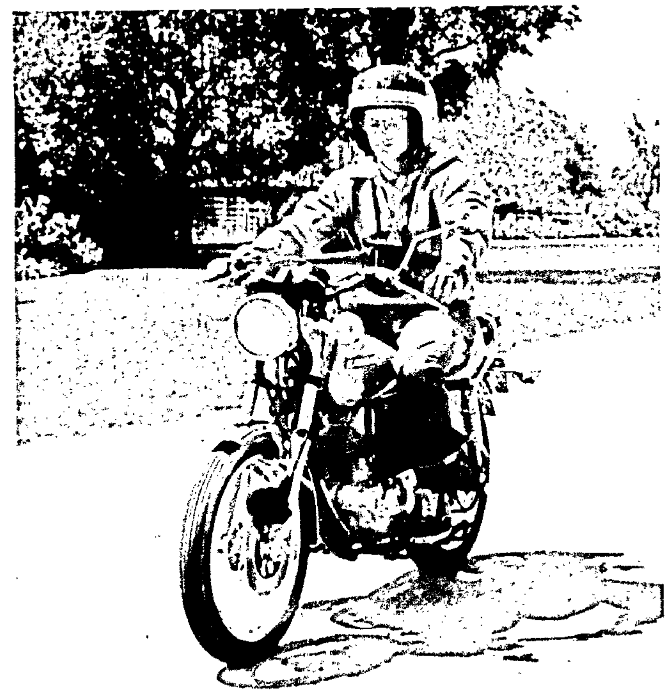
Upright position



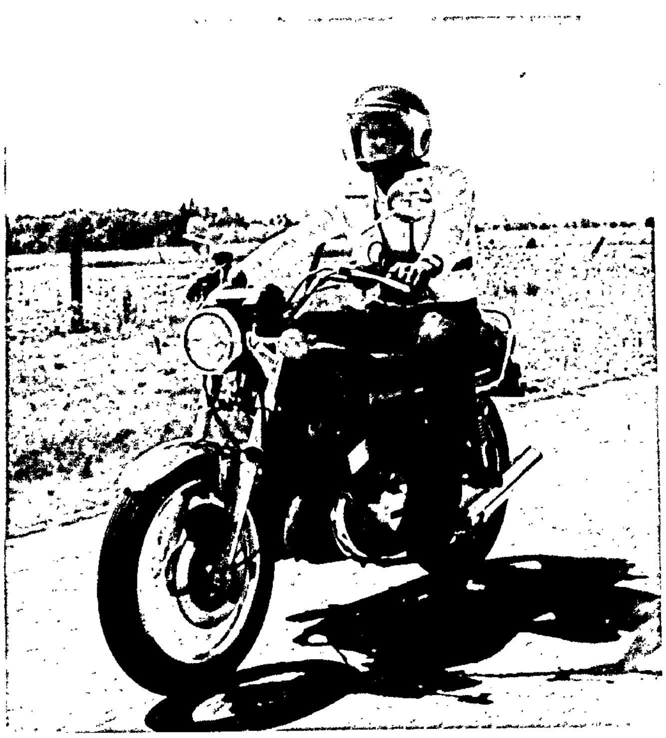
Down position

FIGURE F24 - Two field operating positions.

A



B



C

D

FIGURE F25 - Individual riding posture during highway testing.

Position	Helmet	Visor	A 160 Hz	A 250 Hz	A 500 Hz	A Pink	B 160 Hz	B 250 Hz	B 500 Hz	B Pink	C 160 Hz	C 250 Hz	C 500 Hz	C Pink
	NO HELMET		82.6	84.0	85.0	82.5	78.2	81.0	83.5	82.5	78.0	80.8	83.0	78.5
SPEAKER NO. 38	SMALL	NO VISOR	79.2	79.8	78.2	69.0	79.0	79.8	79.2	72.5	78.0	77.3	74.0	67.5
	MEDIUM		81.2	79.9	79.5	73.5	79.0	80.2	82.8	75.8	77.8	77.0	78.2	69.5
	LARGE		80.1	80.0	80.8	75.2	79.2	79.5	82.0	76.8	78.3	77.2	78.3	70.0
	X-LARGE		83.3	81.0	81.0	73.5	79.2	81.3	84.5	77.5	78.0	79.0	76.5	69.5
FRONT EYE LEVEL	SMALL	WITH VISOR	80.8	80.0	79.8	69.3	79.5	80.5	84.0	71.8	78.8	78.3	78.0	68.5
	MEDIUM		81.2	79.5	84.2	72.0	79.8	81.2	87.0	74.0	77.6	79.5	83.0	70.5
	LARGE		81.1	80.4	85.0	73.5	79.5	81.0	87.0	74.5	78.5	80.0	81.4	71.5
	X-LARGE		83.2	81.8	84.2	72.5	79.5	82.0	88.0	75.0	78.2	80.2	77.0	70.5
	NO HELMET		75.8	83.5	83.0	79.0	75.5	82.3	82.8	81.5	75.0	80.0	82.5	78.5
SPEAKER NO. 39	SMALL	NO VISOR	76.2	78.5	73.2	68.0	76.3	80.5	79.0	72.5	76.0	75.5	74.5	67.0
	MEDIUM		75.6	79.5	77.0	70.5	75.3	80.3	82.7	74.5	76.0	74.5	79.0	70.0
	LARGE		75.4	79.2	78.8	72.0	76.3	79.7	82.0	74.5	76.2	74.5	78.0	71.0
	X-LARGE		76.2	80.0	79.8	72.0	76.7	81.3	84.3	75.5	75.8	76.5	77.2	70.0
RIGHT FRONT WHEEL	SMALL	WITH VISOR	76.0	78.8	76.8	68.6	76.5	81.3	81.3	72.5	76.0	77.2	76.5	67.5
	MEDIUM		74.5	80.8	80.0	71.0	76.5	80.7	84.7	75.5	76.2	76.0	80.8	70.5
	LARGE		75.5	80.2	80.0	71.5	77.0	80.3	86.3	75.0	76.8	75.0	80.0	70.0
	X-LARGE		76.0	82.2	82.0	72.0	76.7	82.7	87.5	75.7	76.0	77.5	77.8	69.5
	NO HELMET		74.0	80.0	74.0	72.5	75.0	75.2	76.0	73.0	73.5	79.5	74.5	71.3
SPEAKER NO. 40	SMALL	NO VISOR	75.0	76.3	69.0	64.5	76.2	75.0	74.0	68.0	76.0	77.6	73.2	69.2
	MEDIUM		74.2	77.5	71.8	67.5	75.2	74.0	75.8	69.2	76.0	77.8	75.4	68.0
	LARGE		74.8	77.2	73.4	69.0	76.5	73.9	77.0	69.0	76.0	79.4	76.5	68.5
	X-LARGE		75.0	79.2	76.0	68.3	76.2	76.0	78.5	71.0	75.5	78.3	75.5	68.0
LEFT REAR CHAIN	SMALL	WITH VISOR	75.2	77.6	70.8	65.2	77.4	76.0	77.8	70.0	76.0	76.8	75.5	68.5
	MEDIUM		74.8	78.0	74.0	67.8	77.0	74.8	78.8	71.0	76.8	77.2	76.8	69.5
	LARGE		75.2	77.0	76.4	69.0	77.5	74.8	79.3	71.2	77.0	79.2	77.8	70.2
	X-LARGE		75.8	78.2	77.3	69.6	76.8	76.2	81.2		76.2	78.3	78.0	69.5
	NO HELMET		74.0	75.8	78.4	79.2	73.8	76.8	79.0	79.2	73.8	77.3	80.0	78.0
SPEAKER NO. 41	SMALL	NO VISOR	74.0	73.4	73.0	66.9	74.8	74.4	75.2	70.5	75.3	73.8	76.7	68.0
	MEDIUM		73.8	73.8	75.8	69.5	74.8	73.6	77.3	70.8	75.6	74.0	78.8	69.5
	LARGE		74.4	73.2	76.6	70.5	74.8	74.2	78.5	71.5	75.6	73.6	80.0	71.2
	X-LARGE		74.2	75.8	81.8	71.5	74.2	75.2	81.8	72.0	75.4	73.6	80.7	72.1
RIGHT REAR WHEEL	SMALL	WITH VISOR	74.8	71.8	74.4	65.0	76.1	76.2	75.2	67.0	75.9	74.0	76.7	68.0
	MEDIUM		74.1	73.2	77.2	68.8	75.2	75.2	77.8	70.0	77.0	74.0	78.8	69.5
	LARGE		74.5	73.4	78.4	69.5	76.0	76.3	78.2	70.5	77.0	75.6	80.0	71.0
	X-LARGE		74.8	75.8	80.8	73.0	75.1	76.3	79.2	71.5	76.4	75.6	80.7	71.2
	NO HELMET		72.5	77.0	76.6	76.0	73.6	76.0	78.0	77.0	73.4	75.8	78.4	77.8
SPEAKER No. 42	SMALL	NO VISOR	73.5	73.2	70.0	65.6	75.0	76.0	76.5	69.5	73.4	74.2	74.2	70.2
	MEDIUM		72.9	74.0	74.0	69.0	74.2	75.2	77.0	72.5	74.4	73.2	76.8	70.8
	LARGE		73.6	72.6	73.5	70.5	75.2	74.5	78.8	73.5	74.4	73.6	[illegible]	71.8
	X-LARGE		72.8	74.5	78.5	71.5	74.6	77.0	77.8	73.5	74.1	72.5	77.4	73.2
REAR EXHAUST	SMALL	WITH VISOR	73.2	72.2	71.6	66.5	76.0	78.0	77.0	72.0	75.4	71.0	73.8	74.2
	MEDIUM		73.2	76.0	74.3	69.0	75.8	75.6	78.8	71.0	75.2	74.7	77.1	76.0
	LARGE		73.5	73.0	74.0	69.0	76.0	76.2	79.0	71.5	75.4	73.2	77.2	77.7
	X-LARGE		73.6	75.6	76.0	70.0	75.5	76.0	80.0	72.0	74.4	73.2	78.0	73.0

TABLE T1A,B,C - Sound level data from semi-anechoic chamber recordings.

			Subject D				Subject E				Subject F			
			160 Hz	250 Hz	500 Hz	Pink	160 Hz	250 Hz	500 Hz	Pink	160 Hz	250 Hz	500 Hz	Pink
SPEAKER NO. 38	NO HELMET		78.2	80.3	80.9	83.0	77.6	81.0	84.6	77.5	77.8	81.0	82.0	81.0
	SMALL	NO VISOR	79.0	78.0	74.0	67.0	80.0	82.5	86.2	74.5	78.2	80.0	77.0	67.5
	MEDIUM		77.0	78.5	76.0	71.0	80.0	83.0	87.3	74.0	78.0	77.8	79.2	69.8
	LARGE		78.0	77.9	75.0	71.0	80.3	83.0	87.2	75.0	78.0	79.2	79.0	71.2
	X-LARGE		78.2	79.0	76.0	70.5	80.0	83.5	87.0		77.5	79.5	79.8	70.5
FRONT EYE LEVEL	SMALL	WITH VISOR	78.2	79.0	77.5	69.5	80.0	83.5	89.0		78.5	78.5	82.0	68.5
	MEDIUM		77.8	79.0	80.0	70.0	80.3	84.5	88.0		78.8	89.0	85.0	72.0
	LARGE		78.0	79.0	80.2	71.8	80.6	84.5	89.0		79.0	79.8	85.0	72.0
	X-LARGE		78.0	80.0	79.8	71.5	80.3	85.7	88.5		78.2	80.2	82.2	70.0
SPEAKER NO. 39	NO HELMET		75.5	81.0	84.8	82.0	75.0	79.8	80.5	79.5	74.5	80.7	79.0	
	SMALL	NO VISOR	75.8	78.8	78.5	68.7	77.0	81.0	81.5	76.0	74.5	79.3	80.3	
	MEDIUM		74.8	78.5	81.8	71.5	77.0	81.5	81.0	75.0	74.3	78.0	81.3	
	LARGE		75.5	77.8	81.0	71.5	76.8	82.5	80.5	76.0	74.8	77.5	80.3	
	X-LARGE		76.2	78.3	82.2	71.5		82.5	79.0	75.0	75.0	79.0	81.5	
RIGHT FRONT WHEEL	SMALL	WITH VISOR	75.9	76.8	80.2	70.0	77.2	81.0	81.5	75.2	74.5	79.0	83.0	
	MEDIUM		75.2	78.8	85.0	72.0	77.8	81.0	82.2	75.0	74.7	78.8	81.8	
	LARGE		75.8	77.6	84.2	73.0	77.8	79.5	83.8	75.0	74.0	76.3	82.2	
	X-LARGE		77.8	78.9	85.0	72.0	72.6	82.2	81.5	75.2	74.8	76.3	82.3	
SPEAKER NO. 40	NO HELMET		75.0	80.0	76.8	74.0	74.5	78.8	78.0	74.2	74.0	77.5	75.0	71.0
	SMALL	NO VISOR	75.4	78.0	70.8	66.0	76.5	80.2	81.8	73.0	75.2	77.0	74.8	66.6
	MEDIUM		75.7	77.8	74.0	66.8	76.8	80.3	80.5	72.5	75.0	76.0	75.2	66.5
	LARGE		75.8	78.0	73.8	67.0	76.9	80.8	79.9	72.3	75.2	76.8	75.8	68.0
	X-LARGE		76.3	79.2	76.2	69.0	76.4	80.0	79.8	73.0	74.8	76.6	76.8	68.6
LEFT REAR CHAIN	SMALL	WITH VISOR	76.0	79.2	73.3	68.0	77.3	80.8	82.0	74.0	75.8	76.6	77.5	69.0
	MEDIUM		76.2	79.0	76.3	69.3	77.8	81.5	83.8	73.6	76.8	77.3	79.2	69.0
	LARGE		76.2	78.2	77.6	70.6	78.0	80.2	81.0	73.5	77.8	76.2	79.0	70.0
	X-LARGE		77.0	80.0	78.2	71.2	77.2	82.2	81.3	74.2	76.8	78.0	78.8	70.5
SPEAKER NO. 41	NO HELMET		74.0	77.5	79.0	80.8	74.0	75.5	78.5	79.0	73.6	76.5	79.2	80.4
	SMALL	NO VISOR	74.2	73.9	74.0	66.0	76.0	74.0	76.8	74.2	74.3	74.5	78.6	73.1
	MEDIUM		72.8	74.0	74.6	67.5	75.8	75.2	79.0	72.0	74.2	72.8	79.8	72.6
	LARGE		73.0	72.8	77.3	67.5	75.7	77.0	78.5	75.0	74.6	74.8	81.6	73.4
	X-LARGE		75.2	75.2	79.0	69.5	75.3	77.5	78.5	75.5	74.2	75.4	83.3	73.1
RIGHT REAR WHEEL	SMALL	WITH VISOR	74.5	74.0	72.3	66.0	76.5	77.3	71.8	71.5	74.2	73.8	76.8	71.6
	MEDIUM		73.2	73.5	75.2	67.0	76.3	77.0	78.0	71.0	74.1	75.7	81.8	72.4
	LARGE		74.6	74.0	77.5	69.5	76.5	79.0	80.0	72.8	74.5	76.6	81.5	74.6
	X-LARGE		75.6	75.2	79.0	69.5	76.3	78.3	78.3	72.2	74.7	78.1	81.1	73.4
SPEAKER No. 42	NO HELMET		73.7	76.3	78.0	75.9	74.2	77.0	78.9	78.6	73.8	76.2	79.5	79.5
	SMALL	NO VISOR	73.7	74.5	71.7	65.5	75.0	77.2	77.0	73.0	74.1	74.8	78.2	72.4
	MEDIUM		73.3	74.5	74.3	69.0	75.2	77.6	76.5	73.0	74.6	75.8	78.2	72.4
	LARGE		74.0	75.0	75.5	69.0	75.5	76.2	77.0	73.5	74.8	73.8	80.4	75.1
	X-LARGE		74.7	75.1	71.7	71.3	75.6	74.0	77.2	73.5	75.2	74.4	79.8	74.6
REAR EXHAUST	SMALL	WITH VISOR	73.7	75.8	73.0	68.0	76.2	77.6	75.8	71.8	74.6	75.8	77.5	71.4
	MEDIUM		74.0	76.4	76.7	69.1	76.2	76.2	76.5	69.0	75.1	76.1	79.5	72.6
	LARGE		74.3	76.4	76.5	69.8	76.4	76.5	75.2	70.9	75.2	75.6	81.3	73.6
	X-LARGE		75.4	77.0	77.5	70.0	76.0	77.8	75.6	71.0	75.6	75.2	79.6	75.5

TABLE T1D,E,F - Sound level data from semi-anechoic chamber recordings.

SUBJECT A HEIGHT 1.69 m WEIGHT 84.00 K.		KPH															
			NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN			
		RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		KPH	35	50	65	80	35	50	65	80	35	50	65	80	35	50	65	80
	WIND	GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
DATE	KNOTS	RPM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78-05-31 78-05-20 78-05-18	2-3 3-5 0-2	VEH. #1 175cc 1 CYL. 4 STRK.	82.0	85.5	90.5	95.0	82.0	84.0	88.5	91.0	85.5	86.0	91.5	95.5	82.5	84.0	86.0	90.0
78-06-01 78-05-24 78-05-20	1-2 1-3 3-5	VEH. #2 360cc 2 CYL. 4 strk.	74.0 71.0	79.5 77.0	84.5 81.0	87.0 82.0	75.0 74.0	79.5 80.5	83.0 84.0	86.5 88.0	81.5 74.0	86.5 80.5	86.0 85.0	89.0 88.0	75.5 77.5	79.5 81.0	83.0 84.0	87.5 90.0
77-09-05 77-09-02 77-08-25 77-08-23 77-08-15 77-07-27 77-07-22 77-07-26	1-2 5-8 4-8 4-8 0-3 4-6 7-11 5-8	VEH. #3 200cc 1 CYL. 4 STRK.	77.0	81.0	89.0 89.0	87.0 88.5	78.0 76.0	81.0 80.0	85.0 84.0	89.0	79.0 77.5	85.0	85.0 88.5	91.0	77.5	82.5 83.0	86.0	91.5
78-06-07 77-09-05 77-09-02 77-08-26 77-08-25 77-08-23 77-08-08 77-08-04 77-07-22	3-6 1-2 5-8 2-3 4-8 4-8 3-5 1-4 7-11	VEH. #4 400cc 2 CYL. 4 STRK.	78.5 79.0	83.5 89.5 83.5 80.0	82.0 90.0 90.0 87.0	92.0 89.0	79.0 80.0	81.0 83.0	75.0 85.5 85.5 85.0	88.5 91.0	80.0 79.0	83.0 88.0 87.0 82.5	86.0 92.0 91.5 88.0	93.5 95.5	81.0 81.5	82.5 82.0	85.0 87.0 85.0	89.0 87.0 92.0
77-09-05 77-09-02 77-08-25 77-08-18 77-08-16 77-07-27 77-07-25	1-2 5-8 4-8 1-2 0-2 4-6 8-10	VEH. #5 400cc 3 CYL. 2 STRK.	81.0	83.0	87.0		80.5	84.5 84.0 86.0	86.0	91.0	80.0	85.5	89.0		77.0 81.0	88.0	87.0	92.0
78-05-29 77-09-07 77-09-02 77-08-25 77-08-19 77-07-26	7-9 1-2 5-8 4-8 3-4 5-8	VEH. #6 650cc 4 CYL. 4 STRK.	73.0 77.0	76.0 83.0 83.5 79.0	83.0 84.0	90.0	76.0 78.0	79.0 78.0	83.5 84.0	87.0	83.0 77.0	76.0 84.0 83.5 80.0	83.0 88.5	89.5 92.0	75.0 77.0	78.0 82.0 82.0 81.0	80.0 85.0	85.0

TABLE T2A - Sound level data from field recordings.

NOTE: see table TB10 for correlation between KPH and RPM.

SUBJECT A HEIGTH 1.69 m WEIGHT 84.00 K			GEARS										RPM									HWY	
			NO VISOR					WITH VISOR					NO HELMET			NO VISOR			WITH VISOR			NV.	WV.
		RUN	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
		KPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WIND	GEAR	1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
DATE	KNOTS	RPM	4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-
78-05-31 78-05-20 78-05-18	2-3 3-5 0-2	VEH. #1 175cc 1 CYL. 4 STRK.	76.5	77.0	78.5	82.0	83.0	78.0	79.0	80.0	81.0	84.0	76.5	81.5	85.0	73.5	76.5	78.5	74.0	77.5	79.5	95.0	93.0
78-06-01 78-05-24 78-05-20	1-2 1-3 3-5	VEH. #2 360cc 2 CYL. 4 strk.	74.5 75.5	77.0 78.5	80.0 83.0	82.5 88.0	84.5 89.5	74.5 75.5	76.5 77.0	78.5 80.5	81.0 83.5	86.0 87.0	75.0 78.0	80.5 90.0	84.0 97.0	70.5 71.0	75.0 74.5	76.5 78.5	71.0 72.0	74.5 75.5	77.5 79.0	92.0	89.0
77-09-05 77-09-02 77-08-25 77-08-23 77-08-15 77-07-27 77-07-22 77-07-26	1-2 5-8 4-8 4-8 0-3 4-6 7-11 5-8	VEH. #3 200cc 1 CYL. 4 STRK.	74.5	75.5	78.0	82.0	84.0	75.0	75.5	78.5	80.5	83.0	76.0 75.5 76.0 75.0	78.0 78.0 79.0	83.0 83.0 84.5	72.0 71.0 72.5	75.0 73.0 75.0	78.0 76.0 78.0	73.0 72.0 75.0	76.0 74.0 73.0	78.5 77.0 79.0	94.0	93.0
78-06-07 77-09-05 77-09-02 77-08-26 77-08-25 77-08-23 77-08-08 77-08-04 77-07-22	3-6 1-2 5-8 2-3 4-8 4-8 3-5 1-4 7-11	VEH. #4 400cc 2 CYL. 4 STRK.	76.5 78.0	77.5 81.0	80.5 84.5	85.0 87.0 89.5	88.5 87.0	76.0 79.0	77.5 80.5	79.5 83.5	81.0 85.0	84.5 86.0	75.0	79.5 82.0	86.0 85.0	73.0	77.0	78.5	74.0	75.0	77.0	94.0 91.0	88.0
77-09-05 77-09-02 77-08-25 77-08-18 77-08-16 77-07-27 77-07-25	1-2 5-8 4-8 1-2 0-2 4-6 8-10	VEH. #5 400cc 3 CYL. 2 STRK.	80.0	83.0	87.0 86.5 87.5	89.0	91.5 92.0	81.5	85.0	88.0 88.0 87.5	90.5	96.5 96.0	78.5	88.0 82.0	88.0 86.0	77.5 75.0	76.5	79.5	78.5	80.5	82.5	94.0	93.0
78-05-29 77-09-07 77-09-02 77-08-25 77-08-19 77-07-26	7-9 1-2 5-8 4-8 3-4 5-8	VEH. #6 650cc 4 CYL. 4 STRK.	76.0 79.0 78.5	77.0 85.0 83.5	81.0 87.0 86.5	87.0 91.0 91.0	89.0 93.5 93.5	76.5 80.0 79.0	78.0 81.0 80.5	80.0 87.0 86.5	83.5 90.0 89.0	85.0 91.0 90.5	75.0 82.0	80.0 84.0 83.5 84.0	85.0 92.0 93.0 90.0	73.0 75.0 75.0 77.0	75.5 78.0 78.0 79.0	79.5 85.5	73.0 77.5	76.0 80.5	79.0 86.5	96.0	91.0

TABLE T2A - Sound level data from field recordings.

SUBJECT B			KPH															
			NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN			
HEIGHT 1.69 m		RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WEIGHT 65.9 Kg		KPH	35	50	65	80	35	50	65	80	35	50	65	50	35	50	65	80
DATE	WIND KNOTS	GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
		RPM	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	--
78-05-24	1-3	VEH #1 175cc 1 CYL 4 ST	82.0	84.0	89.5	95.0	84.0	86.5	90.5	93.0	85.0	89.5	93.0	97.5	85.5	87.0	90.5	94.5
78-05-20	3-5																	
78-05-18	0-2																	
78-05-31	2-3	VEH #2 360cc 2 CYL 4 ST	73.5	76.5	83.5	88.5	75.0	79.5	84.5	89.5	75.0	81.0	86.0	89.0	76.0	83.0	85.0	89.0
78-05-18	0-2																	
78-04-29	5-7																	
77-08-26	2-3	VEH #3 200cc 1 CYL 4 ST																
77-08-25	4-8									90.0		82.0						
77-08-23	4-8			83.0		90.5						81.0						
77-08-08	3-5																	
77-08-04	1-4																	
77-07-26	5-8																	
77-07-21	7-9									90.0				88.0				91.0
77-0718	0-2		79.0	83.0	87.0		79.0	84.0	87.0		81.0	86.0	89.0		82.0	83.0	87.0	
78-06-01	1-2	VEH #4 400cc 2 CYL 4 ST			89.5	94.0	81.0	82.5	85.5	90.0	81.5	85.5	89.5	94.5	83.0	84.5	88.5	91.5
78-05-29	7-9		79.5	81.5	89.5	91.5	80.0	82.0	86.0	89.0	81.0	83.0	90.5	91.0	83.0	82.0	85.0	88.0
77-08-23	4-8					90.0			86.0	90.0				90.0				89.5
77-08-19	3-4																	
77-08-02	4-5					93.0			80.0	91.0				92.0			88.0	
77-07-26	5-8																	
77-07-21	7-9					91.0				89.0				91.0				89.5
77-07-14	5-6		88.0	90.5	97.0	97.5	81.0	85.0	88.0		81.0	86.0	88.0	92.0	75.0	82.0	83.0	
77-08-25	4-8	VEH #5 400cc 3 CYL 2 ST		85.5														
77-08-23	4-8					90.0				89.5				90.5				90.0
77-08-15	0-3																	
77-08-02	4-5			84.0														
77-07-28	0																	
77-07-22	7-11																	
77-07-21	7-9					93.5				91.0				94.0				92.0
77-07-20	5-6		85.5	89.0	91.0		88.0	89.0	91.0		85.0	89.0	93.0		85.0	90.0	93.5	
78-06-07	3-6	VEH #6 650cc 4 CYL 4 ST	77.0	84.0	79.0	94.0	76.5	80.5	86.0	90.5	77.0	81.0	85.5	90.0	78.0	82.0	83.5	86.0
77-08-25	4-8			81.0	86.0													
77-08-18	1-2																	
77-08-16	0-2																	
77-08-02	4-5			85.0	89.0		76.0								76.0	83.5		
77-07-28	0					94.5				95.0				95.0				91.0
77-07-25	8-10																	
77-07-22	7-11																	
77-07-15	5-6		78.0	82.0	90.0		74.0	77.0	81.0		80.0	83.0	88.0		74.0	78.0	81.0	

TABLE T2B - Sound level data from field recordings.

SUBJECT B HEIGHT 1.69 m WEIGHT 65.9 Kg DATE	WIND KNOTS	RUN / KPH / GEAR / RPM	GEARS NO VISOR 17	18	19	20	21	GEARS VISOR 22	23	24	25	26	RPM NO HELMET 27	28	29	RPM VISOR NO 30	31	32	RPM VISOR 33	34	35	HWY NV 36	HWY V 37
KPH			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GEAR			1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
RPM			4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-
78-05-24 78-05-20 78-05-18	1-3 3-5 0-2	VEH #1 175cc 1 CYL 4 ST	78.5	79.5	81.0	82.5	86.0	79.5	80.0	80.5	82.0	85.0	78.0	81.5	85.0	75.0	78.0	80.0	76.5	79.5	81.0	95.0	95.0
78-05-31 78-05-18 78-04-29	2-3 0-2 5-7	VEH #2 360cc 2 CYL 4 ST	76.5	78.0	79.5	87.5	91.5	77.5	79.0	81.0	83.0	86.0	75.0	79.0	82.5	72.0	75.5	77.0	72.0	75.5	77.0	84.0	92.0
77-08-26 77-08-25 77-08-23 77-08-08 77-08-04 77-07-26 77-07-21 77-0718	2-3 4-8 4-8 3-5 1-4 5-8 7-9 0-2	VEH #3 200cc 1 CYL 4 ST	72.0 72.0	74.0 74.0	78.0 77.0	80.0 78.0	83.0 82.0	73.0	75.5 74.0	78.0	79.5 81.5	83.5 81.0	75.5	76.0 74.0 79.5	81.5 77.0 83.0	72.5	75.0	77.0	73.0	76.0	79.5	90.0	89.0 93.0
78-06-01 78-05-29 77-08-23 77-08-19 77-08-02 77-07-26 77-07-21 77-07-14	1-2 7-9 4-8 3-4 4-5 5-8 7-9 5-6	VEH #4 400cc 2 CYL 4 ST	79.5 80.0 77.5	81.0 80.5 78.0	84.5 81.0 81.0	87.5 83.0 85.0 83.0	91.5 86.0 88.5 91.0 87.0	80.0 80.5 78.0	81.0 81.5 79.0	83.0 82.0 82.0	85.0 83.5 85.0 83.5	87.5 86.0 85.0 89.0 87.5	78.0 78.5 77.0 79.0	81.0 82.0 83.0	84.5 85.0 87.0	76.5 77.0 76.0	78.0 79.5 79.5	80.5 81.5 81.0	77.5 78.0 77.0	80.0 80.5 81.5	82.0 83.0 83.5	93.0	90.0
77-08-25 77-08-23 77-08-15 77-08-02 77-07-28 77-07-22 77-07-21 77-07-20	4-8 4-8 0-3 4-5 0 7-11 7-9 5-6	VEH #5 400cc 3 CYL 2 ST	82.0	83.5	87.0	90.0	90.5 94.0	81.5	83.5	86.0	88.5	90.5 94.0	82.0	82.0 86.0	91.0	80.0	79.0 82.0	80.0 84.8	82.5	80.0 84.5	81.0 86.0	94.0	90.0
78-06-07 77-08-25 77-08-18 77-08-16 77-08-02 77-07-28 77-07-25 77-07-22 77-07-15	3-6 4-8 1-2 0-2 4-5 0 8-10 7-11 5-6	VEH #6 650cc 4 CYL 4 ST	78.5 80.5	81.0 83.0	88.5 87.5	93.5 93.0	96.0 95.5	79.5 80.0	82.0 83.0	86.0 81.5 87.5	90.0 90.0 89.5	92.0 95.5	78.5 82.0 80.0 75.5	83.0 84.5 85.0 77.0	86.5 91.0 90.0 82.0	75.5 74.0 74.0 76.5	78.0 78.5	83.5 84.5	76.5 76.0 77.0	80.0 80.0 78.5	84.5 86.0	95.0	91.0

TABLE T2B - Sound level data from field recordings.

SUBJECT C			KPH															
			NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN			
HEIGHT 1.85 m		RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WEIGHT 75.0 kg		KPH	35	50	65	80	35	50	65	80	35	50	65	80	35	50	65	80
	WIND	GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
DATE	KNOTS	RUN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78-06-20 78-06-10 78-05-29	2-5 3-5 7-9	VEH #1 175cc 1 CYL 4 ST	84.0	85.5	38.5	92.0	88.0	89.5	91.0	91.5	83.5	88.0	88.5	90.0	87.0	87.5	88.5	90.0
78-06-16 78-06-09	5-8 3-5	VEH #2 360cc 2 CYL 4 ST	73.5 79.0	80.0 84.5	85.0 86.5	88.0 87.5	77.0 78.0	77.5 84.0	83.5 86.5	85.5 88.5	78.5 79.5	82.5 82.5	84.5 86.0	87.0 88.0	78.5 83.5	78.5 85.0	79.6 86.0	79.0 88.0
77-09-07 77-09-02 77-08-25 77-08-19 77-08-02 77-07-27 77-07-21 77-07-20	1-2 5-8 4-8 3-4 4-5 4-6 7-9 5-6	VEH #3 200cc 1 CYL 4 ST	77.5 77.5 78.0 78.0	80.5 81.0 84.0 82.0	87.0 86.0	87.5	77.5 77.0 77.0 76.0	82.0 82.0	85.0 85.0	89.5	76.5 79.0	81.5 88.0	86.0 84.0	90.0	77.5 82.0	81.0 88.0	84.0 90.0	86.5 87.0 86.5
77-09-07 77-09-02 77-08-25 77-08-16 77-07-28 77-07-25 77-07-21 77-07-18	1-2 5-8 4-8 0-2 0 8-10 7-9 0-2	VEH #4 400cc 2 CYL 4 ST	80.0	80.5	85.0	89.0	79.0	85.0 80.5	33.5	93.0	82.0 79.0	80.0	88.0 85.0	83.5	79.0	83.0	86.0	89.0
77-09-07 77-09-02 77-08-08 77-07-28 77-07-25 77-07-22	1-2 5-8 3-5 0 8-10 7-11	VEH #5 400cc 3 CYL 2 ST	82.0	85.0	87.0	95.0	81.5 83.0	84.0	88.0	96.0	82.5	85.0	88.0	93.0	82.0	85.0	88.0	93.5
77-09-07 77-09-02 77-08-25 77-08-02 77-07-28 77-07-26 77-07-20 77-07-14	1-2 5-8 4-8 4-5 0 5-8 5-6 5-6	VEH #6 650cc 4 CYL 4 ST	78.5 79.5	87.5	91.5	97.0 94.0	79.0 76.5	85.5 84.0	88.0	93.5 89.0	77.0	84.0 85.0	86.0 85.0	95.0 92.0	83.0 80.0	78.0 84.0	90.5	90.5

TABLE T2C - Sound level data from field recordings.

SUBJECT C			GEARS										RPM									HWY	
HEIGHT 1.85 m			NO VISOR					VISOR					NO HELMET			NO VISOR			VISOR			NV	V
WEIGHT 75.0 Kg		RUN	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
		KPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WIND	GEAR	1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
DATE	KNOTS	RPM	4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-
78-06-20 78-06-10 78-05-29	2-5 3-5 7-9	VEH #1 175cc 1 CYL 4 ST	78.5	79.5	80.0	81.0	81.5	82.0	83.5	81.5	83.5	85.0				75.5	76.5	80.0	78.5	81.0	82.5	91.0	87.0
78-06-16 78-06-09	5-8 3-5	VEH #2 360cc 2 CYL 4 ST	75.5	77.5	80.0	83.5	85.0	67.0 78.0	67.0 88.0	71.0 82.5	75.5 85.0	79.5 86.5				70.5	75.5	78.0	68.0 74.0	74.0 77.5	77.5 79.5		
77-09-07 77-09-02 77-08-25 77-08-19 77-08-02 77-07-27 77-07-21 77-07-20	1-2 5-8 4-8 3-4 4-5 4-6 7-9 5-6	VEH #3 200cc 1 CYL 4 ST	72.5 73.5 73.0 74.0	75.5	76.0 78.0	81.0	84.0 83.5	76.0 74.5	75.0	76.0	79.0	84.0 82.0	75.0	78.0 79.5	83.5	72.0	74.0	78.0	72.5	75.5 75.0	78.0	92.0	90.0
77-09-07 77-09-02 77-08-25 77-08-16 77-07-28 77-07-25 77-07-21 77-07-18	1-2 5-8 4-8 0-2 0 8-10 7-9 0-2	VEH #4 400cc 2 CYL 4 ST	76.5	78.0	83.0 83.5 84.0 81.0	85.0	88.5	78.0	80.0	83.5	86.0	88.0	78.0 80.0	81.0 82.0	83.0 86.0	76.5 76.0	78.5 78.0	80.5 81.5	78.0	80.5	82.5	91.0	86.0
77-09-07 77-09-02 77-08-08 77-07-28 77-07-25 77-07-22	1-2 5-8 3-5 0 8-10 7-11	VEH #5 400cc 3 CYL 2 ST	82.0	83.5	88.0	91.0	88.5	83.5	86.0	89.0 88.0	90.0	89.0	82.0	86.0	89.0	79.5	82.0	82.5 84.0	81.0	83.5	86.0	91.0	91.0 89.0
77-09-07 77-09-02 77-08-25 77-08-02 77-07-28 77-07-26 77-07-20 77-07-14	1-2 5-8 4-8 4-5 0 5-8 5-6 5-6	VEH #6 650cc 4 CYL 4 ST	80.0	83.5	87.0	89.5	90.5	80.5	82.5	86.5 85.5	87.0 88.0 88.5	88.0	82.0 82.5 78.0 80.5	83.5 84.0 85.5 83.0	88.0 89.5 88.5	77.5	82.0	85.0	78.5	83.0	85.0	89.0	88.0

TABLE T2C - Sound level data from field recordings.

SUBJECT D			KPH															
			NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN			
HEIGHT 2.03 m		RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WEIGHT 81.8 Kg		KPH	35	50	65	80	35	50	65	80	35	50	65	80	35	50	65	80
	WIND	GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
DATE	KNOTS	RPM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78-06-21	3-5	VEH #1 175cc 1 CYL 4 ST																
78-06-16	5-7		82.5	83.0	87.5	90.0	84.5	85.5	88.5	90.0	84.5	85.5	91.5	93.5	84.5	87.0	88.5	93.0
78-06-13	0-2																	
78-06-09	2-4		80.0	82.0	85.0	90.5	84.0	82.5	87.0	91.0	83.5	86.5	88.5	95.0	80.0	85.0	87.5	93.0
78-06-08	1-2		82.0	85.5	87.5	92.5					84.0							
78-06-21	3-5	VEH #2 360cc 2 CYL 4 ST	71.5	75.0	80.5	82.0	74.5	76.5	80.0	86.0	75.5	76.5	80.0	83.0	75.0	76.5	83.0	85.5
78-06-19	0-2																	
77-08-25	4-8	VEH #3 200cc 1 CYL 4 ST	78.0	79.5	84.0		77.0	79.5	82.5		76.5	79.5	84.0		77.0	80.5		88.0
77-08-23	4-8					87.0				88.0				89.0				90.0
77-08-18	1-2																	
77-08-16	0-2																	
77-07-25	8-10																	
77-07-22	7-11																	
77-07-20	5-6		79.5	82.0	86.0		71.0	74.0	76.5		81.0	84.0	87.5		71.0	74.0	77.0	
77-07-18	0-2		78.0	79.0	82.5						79.0	81.5	83.0					
77-08-25	4-8	VEH #4 400cc 2 CYL 4 ST								89.0								
77-08-23	4-8					89.0				87.0				88.5				88.5
77-08-15	0-3																	
77-08-02	4-5			75.5											72.0	75.0	79.0	
77-07-21	7-9					87.5				91.5				86.0				86.0
77-07-20	5-6																	
77-07-15	5-6		79.0	82.0	83.0		79.0	82.0	81.0		77.5	82.0	84.0		83.0	83.0	86.0	
77-08-25	4-8	VEH #5 400cc 3 CYL 2 ST			85.5												88.0	89.0
77-08-23	4-8				84.0	87.5				86.0				87.0			82.5	90.0
77-08-19	3-4																	
77-07-28	0																	
77-07-26	5-8																	
77-07-21	7-9																	
77-07-14	5-6		83.0	84.0			83.0	86.0	89.0	90.0	82.0	83.0	86.0	91.0	80.0	82.0	83.0	
77-08-26	2-3	VEH #6 650cc 4 CYL 4 ST																
77-08-25	4-8		75.0										84.0	87.5		80.0	84.0	87.5
77-08-04	1-4																	
77-08-01	5-7																	
77-07-28	0-0					88.5				89.5				89.5				90.0
77-07-26	5-8																	
77-07-21	7-9																	
77-07-18	0-2		78.0	82.5	87.5		79.5	83.0	86.5		78.0	82.0	85.5		80.5	83.0	87.0	

TABLE T2D - Sound level data from field recordings.

SUBJECT D			GEARS										RPM									HWY	
			NO VISOR					VISOR					NO HELMET			NO VISOR			VISOR			NV	V
HEIGHT 2.03 m		RUN	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
WEIGHT 81.8 Kg		KPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WIND	GEAR	1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
DATE	KNOTS	RPM	4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-
78-06-21 78-06-16 78-06-13 78-06-09 78-06-08	3-5 5-7 0-2 2-4 1-2	VEH #1 175cc 1 CYL 4 ST	77.0 77.5	78.5 76.5	79.0 76.5	79.0 78.0	81.0 81.5	77.0	78.5	79.5	80.0	84.0	77.5	82.5	85.5	74.5 74.0	76.0 75.5	80.0 78.5	75.5	79.0	80.5	91.0	92.0
78-06-21 78-06-19	3-5 0-2	VEH #2 360cc 2 CYL 4 ST	73.5	74.0	75.0	76.5	78.5	74.5	75.5	76.5	79.0	80.0	74.0	78.0	82.0	70.5	74.5	78.0	71.5	75.0	78.5	92.0	91.0
77-08-25 77-08-23 77-08-18 77-08-16 77-07-25 77-07-22 77-07-20 77-07-18	4-8 4-8 1-2 0-2 8-10 7-11 5-6 0-2	VEH #3 200cc 1 CYL 4 ST	74.0	73.5	75.0	82.0	84.0	71.5	75.0	74.0	80.0	88.5	73.0 73.5	75.0	81.5	70.0	74.0	79.0	71.0	74.0	79.0	88.0	91.0
77-08-25 77-08-23 77-08-15 77-08-02 77-07-21 77-07-20 77-07-15	4-8 4-8 0-3 4-5 7-9 5-6 5-6	VEH #4 400cc 2 CYL 4 ST	71.0 81.5	72.5 82.5	74.0 84.5	79.0 87.5	72.0 83.0	74.0 79.5	81.0	76.0 81.0	77.0 82.5	84.0 80.0 83.0	75.0	80.0 77.0	83.5 80.0	73.0	75.0	76.5	73.5	76.0	78.0	89.0	88.0
77-08-25 77-08-23 77-08-19 77-07-28 77-07-26 77-07-21 77-07-14	4-8 4-8 3-4 0 5-8 7-9 5-6	VEH #5 400cc 3 CYL 2 ST	81.5	83.5	86.0	88.0	89.5 90.5	83.0	85.5	87.5	89.0	90.5 91.0 91.0	81.5	84.5	88.5	79.0	81.5	83.0	80.5	82.5	84.5	91.0	91.0
77-08-26 77-08-25 77-08-04 77-08-01 77-07-28 77-07-26 77-07-21 77-07-18	2-3 4-8 1-4 5-7 0-0 5-8 7-9 0-2	VEH #6 650cc 4 CYL 4 ST	79.5	81.0	84.0	84.0 90.5	87.5	81.0	80.0 85.0	87.0	89.0	90.0	79.0	80.0	85.5	75.5	78.5	81.0 84.5	77.5	82.5	85.5	89.0 90.0	89.0

TABLE T2D - Sound level data from field recordings.

Nomenclature: KPH, GRS & RPM - run designation per tables T2 and T4.
A1, A2, etc. - subject and vehicle.
NYU, YYU, NYD, etc. - head gear and position.
eg., NYU - no visor, with helmet, upright position.

CARD NUMBER	SLOPE	Y-INT.	CORR.
KPHA1NYU	0.2933	71.3833	0.9977
KPHA2NYU	0.2700	63.9750	0.9090
KPHA3NYU	0.2512	69.5487	0.8711
KPHA4NYU	0.2515	70.8712	0.7841
KPHA5NYU	0.2000	73.6667	0.9819
KPHA6NYU	0.3098	64.4215	0.8748
KPHA1YYU	0.2100	74.3000	0.9893
KPHA2YYU	0.2783	65.3083	0.9869
KPHA3YYU	0.2628	67.5896	0.9856
KPHA4YYU	0.1981	71.6635	0.6732
KPHA5YYU	0.2154	73.5247	0.9658
KPHA6YYU	0.2375	66.8749	0.8606
KPHA1NYD	0.2367	76.0167	0.9613
KPHA2NYD	0.2283	70.6833	0.8295
KPHA3NYD	0.2758	69.1667	0.9541
KPHA4NYD	0.3365	67.9291	0.9015
KPHA5NYD	0.3000	69.8333	0.9919
KPHA6NYD	0.2558	69.3269	0.7912
KPHA1YYD	0.1633	76.2333	0.9732
KPHA2YYD	0.2667	66.9167	0.9745
KPHA3YYD	0.2782	67.6859	0.9256
KPHA4YYD	0.1879	73.8333	0.9097
KPHA5YYD	0.2745	70.4510	0.9011
KPHA6YYD	0.1931	70.2548	0.8204
GRSA1NYU	0.2180	71.9874	0.9614
GRSA2NYU	0.3107	65.8271	0.9212
GRSA3NYU	0.2647	68.0006	0.9772
GRSA4NYU	0.2567	71.3511	0.9167
GRSA5NYU	0.2170	74.1490	0.9935
GRSA6NYU	0.2667	69.4988	0.9002
GRSA1YYU	0.1706	74.5993	0.9624
GRSA2YYU	0.2791	66.0989	0.9652
GRSA3YYU	0.2178	69.6154	0.9777
GRSA4YYU	0.1689	73.6482	0.8587
GRSA5YYU	0.2687	73.1362	0.9716
GRSA6YYU	0.2036	71.4694	0.8450
RPMA1NNU	0.7252	68.4538	0.9932
RPMA2NNU	1.2297	48.5030	0.7669
RPMA3NNU	0.7768	62.8753	0.9723
RPMA4NNU	0.7398	64.9286	0.9749
RPMA5NNU	0.5346	69.7441	0.7848
RPMA6NNU	0.7433	59.8749	0.8469
RPMA1NYU	0.4265	68.7877	0.9916
RPMA2NYU	0.5927	57.1844	0.9719
RPMA3NYU	0.5500	62.9500	0.9341
RPMA4NYU	0.3929	67.9167	0.9672
RPMA5NYU	0.2092	72.0252	0.7671
RPMA6NYU	0.4487	63.9107	0.8184
RPMA1YYU	0.4689	68.8881	0.9854
RPMA2YYU	0.5922	57.7834	0.9774
RPMA3YYU	0.4833	65.1278	0.8325
RPMA4YYU	0.2143	70.8333	0.9818
RPMA5YYU	0.2758	73.2845	0.9808
RPMA6YYU	0.4688	63.7500	0.7306

NOTE: Slopes calculated on the basis of dBA versus KPH.

TABLE T3A - regression and correlation data for field runs.

CARD NUMBER	SLOPE	Y-INT.	CORR.
KPHB1NYU	0.2967	70.5667	0.9819
KPHB2NYU	0.3467	60.5667	0.9898
KPHB3NYU	0.2564	70.1410	0.9995
KPHB4NYU	0.2466	73.8768	0.7431
KPHB5NYU	0.1648	78.7036	0.8100
KPHB6NYU	0.3409	65.3560	0.8607
KPHB1YYU	0.2067	76.6166	0.9953
KPHB2YYU	0.3233	63.5333	0.9997
KPHB3YYU	0.2353	71.4118	0.9924
KPHB4YYU	0.2000	73.1250	0.8732
KPHB5YYU	0.0510	86.5392	0.7547
KPHB6YYU	0.3667	61.6667	0.9347
KPHB1NYD	0.2767	75.2166	0.9996
KPHB2NYD	0.3133	64.7333	0.9897
KPHB3NYD	0.1875	74.1875	0.9025
KPHB4NYD	0.2363	73.1176	0.9575
KPHB5NYD	0.1549	80.6960	0.8501
KPHB6NYD	0.3117	67.0167	0.9479
KPHB1YYD	0.2033	77.6833	0.9825
KPHB2YYD	0.2733	67.5333	0.9732
KPHB3YYD	0.2067	73.8665	0.9730
KPHB4YYD	0.2087	72.7296	0.8335
KPHB5YYD	0.1186	82.7451	0.7229
KPHB6YYD	0.2567	67.3071	0.8341
GRSB1NYU	0.2190	74.0547	0.9584
GRSB2NYU	0.3870	63.3279	0.9498
GRSB3NYU	0.2701	65.9805	0.9777
GRSB4NYU	0.2177	73.1643	0.8734
GRSB5NYU	0.1987	75.9109	0.9572
GRSB6NYU	0.3232	68.6290	0.9849
GRSB1YYU	0.1583	76.0181	0.9263
GRSB2YYU	0.2059	71.0483	0.9877
GRSB3YYU	0.2590	67.0822	0.9558
GRSB4YYU	0.1662	75.2817	0.9180
GRSB5YYU	0.2004	75.3108	0.9515
GRSB6YYU	0.2611	70.5640	0.9426
RPMB1NNU	0.5981	71.1521	0.9999
RPMB2NNU	0.6581	59.7921	0.9996
RPMB3NNU	0.5417	66.2080	0.6376
RPMB4NNU	0.5279	70.7825	0.9612
RPMB5NNU	0.6253	68.8889	0.8681
RPMB6NNU	0.5234	66.1667	0.7418
RPMB1NYU	0.4265	70.2874	0.9916
RPMB2NYU	0.4396	62.1154	0.9765
RPMB3NYU	0.4500	65.3833	0.9979
RPMB4NYU	0.3214	72.0833	0.9594
RPMB5NYU	0.1479	76.9166	0.4510
RPMB6NYU	0.5483	61.6136	0.9668
RPMB1YYU	0.3834	72.3666	0.9791
RPMB2YYU	0.4396	62.1154	0.9765
RPMB3YYU	0.6500	62.5167	0.9990
RPMB4YYU	0.3810	72.3333	0.9631
RPMB5YYU	0.0847	80.4610	0.2096
RPMB6YYU	0.5337	63.2692	0.9647

TABLE T3B - Regression and correlation data for field runs.

CARD NUMBER	SLOPE	Y-INT.	CORR.
KPHC1NYU	0.1800	77.1500	0.9859
KPHC2NYU	0.2533	68.4333	0.8982
KPHC3NYU	0.2467	69.3939	0.9547
KPHC4NYU	0.2100	71.5500	0.9613
KPHC5NYU	0.2733	71.5333	0.9519
KPHC6NYU	0.3614	67.2193	0.9778
KPHC1YYU	0.0800	85.4000	0.9798
KPHC2YYU	0.2183	70.0083	0.8762
KPHC3YYU	0.2767	67.3889	0.9919
KPHC4YYU	0.2833	68.3333	0.8873
KPHC5YYU	0.2843	71.4313	0.9536
KPHC6YYU	0.2902	68.6960	0.9436
KPHC1NYD	0.1333	79.8333	0.9225
KPHC2NYD	0.1883	72.7333	0.9822
KPHC3NYD	0.2660	67.9871	0.9681
KPHC4NYD	0.0789	78.7764	0.4162
KPHC5NYD	0.2300	73.9000	0.9862
KPHC6NYD	0.3282	66.3589	0.9408
KPHC1YYD	0.0667	84.4166	0.9759
KPHC2YYD	0.0567	78.9916	0.2655
KPHC3YYD	0.1454	76.0000	0.6782
KPHC4YYD	0.2200	71.6000	0.9973
KPHC5YYD	0.2500	72.7500	0.9869
KPHC6YYD	0.2358	71.9553	0.7903
GRSC1NYU	0.0915	76.9904	0.9948
GRSC2NYU	0.2463	68.0322	0.9943
GRSC3NYU	0.2663	67.3153	0.9705
GRSC4NYU	0.2690	70.2320	0.9602
GRSC5NYU	0.1536	78.0275	0.8898
GRSC6NYU	0.2000	74.3229	0.9813
GRSC1YYU	0.0622	81.0855	0.6195
GRSC2YYU	0.2343	66.3323	0.4575
GRSC3YYU	0.1996	69.9876	0.8866
GRSC4YYU	0.2259	72.9359	0.9959
GRSC5YYU	0.1145	81.1529	0.9167
GRSC6YYU	0.1579	75.9857	0.9449
RPMC3NNU	0.8500	61.1500	0.9815
RPMC4NNU	0.3929	73.4167	0.9001
RPMC5NNU	0.4818	73.0599	0.9948
RPMC6NNU	0.4901	68.7630	0.9239
RPMC1NYU	0.3864	70.6491	0.9566
RPMC2NYU	0.6591	55.5958	0.9839
RPMC3NYU	0.6000	62.0667	0.9819
RPMC4NYU	0.3393	71.3750	0.9799
RPMC5NYU	0.2491	75.0240	0.9274
RPMC6NYU	0.4688	66.5000	0.9934
RPMC1YYU	0.3411	74.7657	0.9375
RPMC2YYU	0.6539	56.0188	0.8210
RPMC3YYU	0.5500	63.7000	0.9959
RPMC4YYU	0.3214	73.5833	0.9979
RPMC5YYU	0.3447	74.4806	0.9998
RPMC6YYU	0.4063	69.1667	0.9762

TABLE T3C -- Regression and correlation data for field runs.

CARD NUMBER	SLOPE	Y-INT.	CORR.
KPHD1NYU	0.2111	73.5278	0.9346
KPHD2NYU	0.2467	63.0667	0.9802
KPHD3NYU	0.1937	71.2813	0.9155
KPHD4NYU	0.2394	68.3030	0.8567
KPHD5NYU	0.0910	79.4295	0.8877
KPHD6NYU	0.2863	67.1274	0.9556
KPHD1YYU	0.1500	78.0000	0.8903
KPHD2YYU	0.2533	64.6833	0.9731
KPHD3YYU	0.2718	63.6025	0.8064
KPHD4YYU	0.2292	70.0208	0.8759
KPHD5YYU	0.1059	80.2352	0.7463
KPHD6YYU	0.2233	71.7833	0.9993
KPHD1NYD	0.2269	75.5787	0.9665
KPHD2NYD	0.1733	68.7833	0.9792
KPHD3NYD	0.2153	71.0903	0.8692
KPHD4NYD	0.2069	70.7745	0.9692
KPHD5NYD	0.1647	75.5882	0.9039
KPHD6NYD	0.2285	70.1382	0.9791
KPHD1YYD	0.2283	74.1833	0.9393
KPHD2YYD	0.2533	65.4333	0.9715
KPHD3YYD	0.3162	61.8014	0.8558
KPHD4YYD	0.2183	69.0083	0.6789
KPHD5YYD	0.2132	71.5277	0.8627
KPHD6YYD	0.1445	75.1187	0.8612
GRSD1NYU	0.1097	74.7195	0.7725
GRSD2NYU	0.1222	69.4156	0.9659
GRSD3NYU	0.2929	65.7485	0.9017
GRSD4NYU	0.0760	75.3309	0.2199
GRSD5NYU	0.1589	76.9670	0.9921
GRSD6NYU	0.1711	73.9394	0.8387
GRSD1YYU	0.1893	73.3625	0.9413
GRSD2YYU	0.1426	69.9967	0.9832
GRSD3YYU	0.3931	61.7633	0.8841
GRSD4YYU	0.1021	74.8704	0.5672
GRSD5YYU	0.1423	79.2499	0.9980
GRSD6YYU	0.1863	74.7735	0.9021
RPMD1NNU	0.6821	70.0324	0.9875
RPMD2NNU	0.7016	57.6996	0.9999
RPMD3NNU	0.8000	59.8667	0.9406
RPMD4NNU	0.4796	68.3570	0.8647
RPMD5NNU	0.4834	72.1848	0.9981
RPMD6NNU	0.4063	68.5000	0.9286
RPMD1NYU	0.4287	69.0000	0.9530
RPMD2NYU	0.6581	55.2921	0.9996
RPMD3NYU	0.9000	55.4333	0.9979
RPMD4NYU	0.2500	69.5833	0.9965
RPMD5NYU	0.2750	73.9716	0.9867
RPMD6NYU	0.5795	61.0455	0.9864
RPMD1YYU	0.4253	70.9663	0.9709
RPMD2YYU	0.6140	57.2352	1.0000
RPMD3YYU	0.8000	57.8667	0.9897
RPMD4YYU	0.3214	69.0833	0.9979
RPMD5YYU	0.2758	75.2845	0.9998
RPMD6YYU	0.5000	65.8333	0.9397

TABLE T3D - Regression and correlation data for field runs.

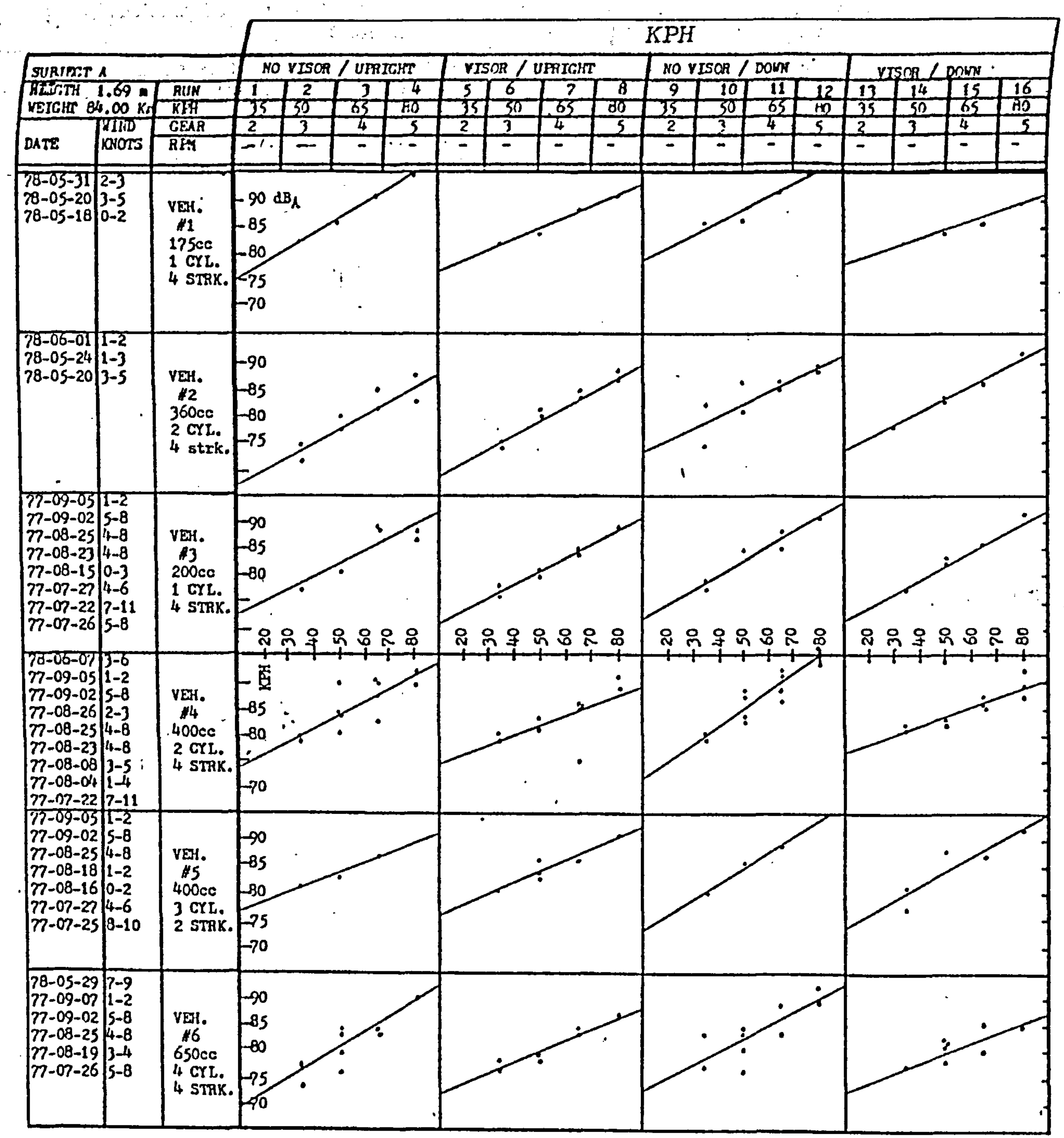


TABLE T4A - Sound level data from field recordings + fitted curves.

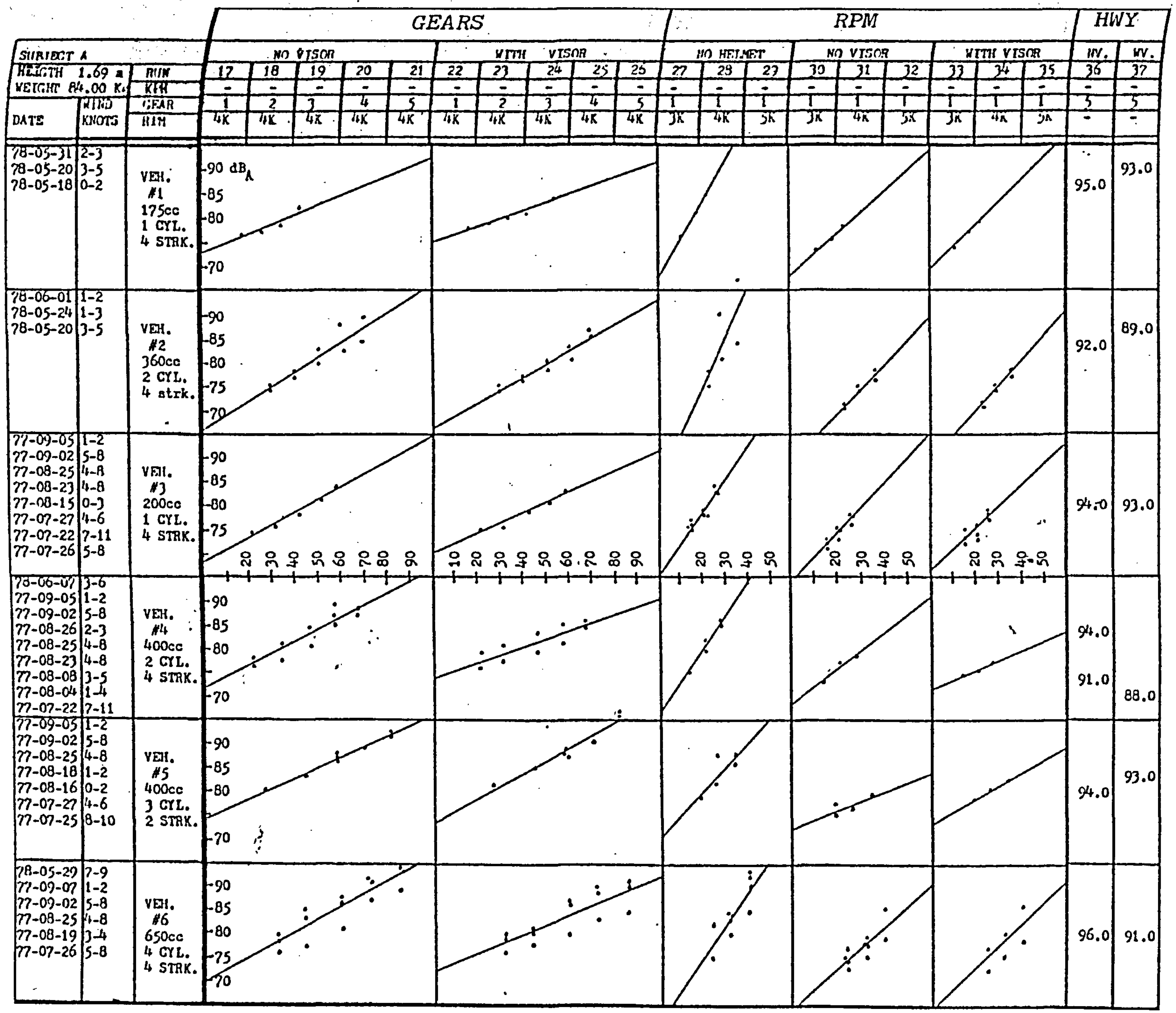


TABLE T4A - Sound level data from field recordings + fitted curves.

SUBJECT B			NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN			
HEIGHT 1.69 m		RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WEIGHT 65.9 Kg		KPH	35	50	65	80	35	50	65	80	35	50	65	80	35	50	65	80
DATE	WIND KNOTS	GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
		RPM	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	--

KPH

DATE	WIND KNOTS	VEHICLE
78-05-24 78-05-20 78-05-18	1-3 3-5 0-2	VEH #1 175cc 1 CYL 4 ST
78-05-31 78-05-18 78-04-29	2-3 0-2 5-7	VEH #2 360cc 2 CYL 4 ST
77-08-26 77-08-25 77-08-23 77-08-08 77-08-04 77-07-26 77-07-21 77-0718	2-3 4-8 4-8 3-5 1-4 5-8 7-9 0-2	VEH #3 200cc 1 CYL 4 ST
78-06-01 78-05-29 77-08-23 77-08-19 77-08-02 77-07-26 77-07-21 77-07-14	1-2 7-9 4-8 3-4 4-5 5-8 7-9 5-6	VEH #4 400cc 2 CYL 4 ST
77-08-25 77-08-23 77-08-15 77-08-02 77-07-28 77-07-22 77-07-21 77-07-20	4-8 4-8 0-3 4-5 0 7-11 7-9 5-6	VEH #5 400cc 3 CYL 2 ST
78-06-07 77-08-25 77-08-18 77-08-16 77-08-02 77-07-28 77-07-25 77-07-22 77-07-15	3-6 4-8 1-2 0-2 4-5 0 8-10 7-11 5-6	VEH #6 650cc 4 CYL 4 ST

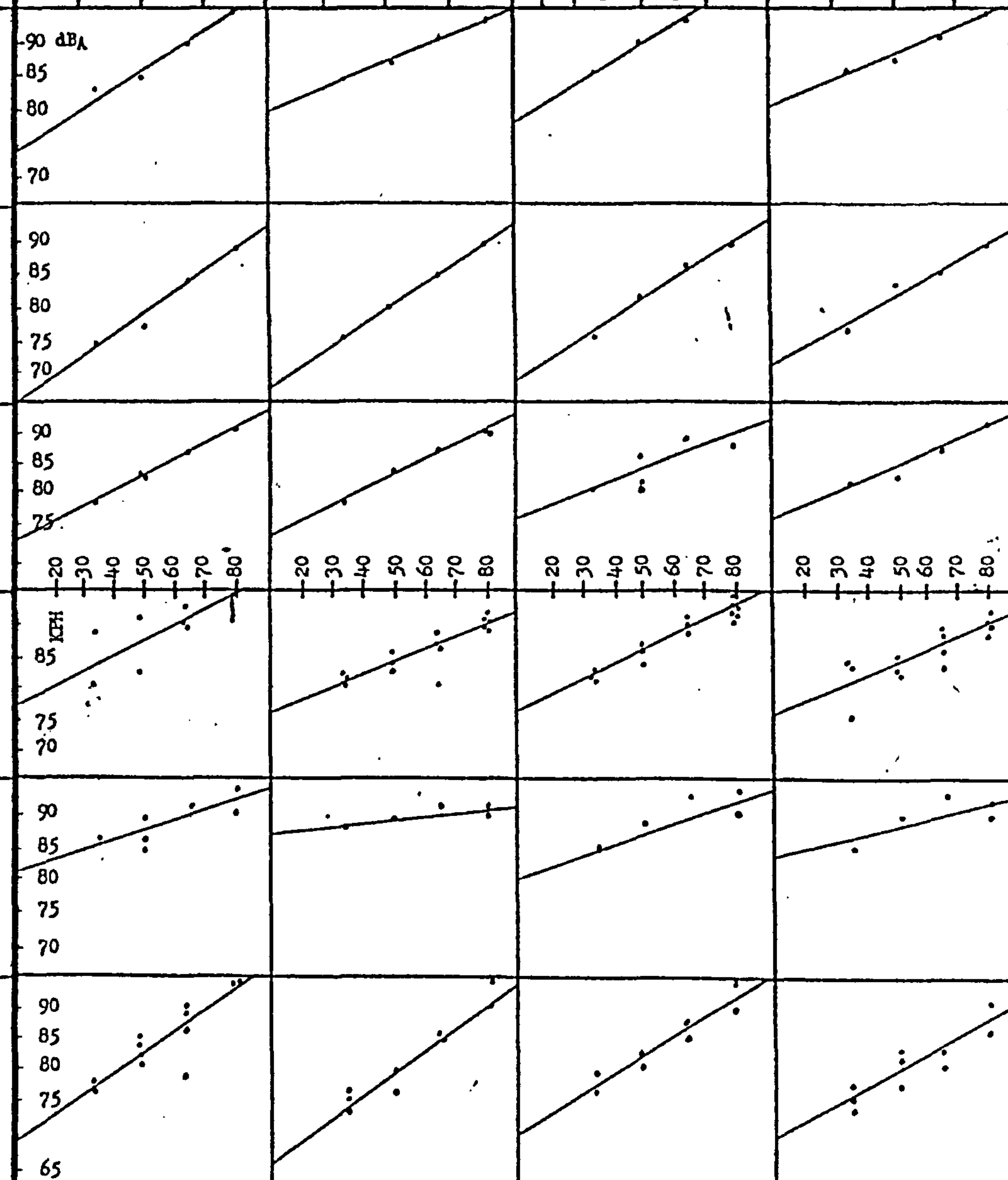


TABLE T4B - Sound level data from field recordings + fitted curves.

SUBJECT B			GEARS										RPM									HWY	
			NO VISOR					VISOR					NO HELMET			VISOR NO			VISOR			NV	V
HEIGHT 1.69 m		RUN	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
WEIGHT 65.9 Kg		KPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DATE	WIND KNOTS	GEAR	1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
		RPM	4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-

DATE	WIND KNOTS	VEHICLE	HWY NV	HWY V
78-05-24 78-05-20 78-05-18	1-3 3-5 0-2	VEH #1 175cc 1 CYL 4 ST	95.0	95.0
78-05-31 78-05-18 78-04-29	2-3 0-2 5-7	VEH #2 360cc 2 CYL 4 ST	84.0	92.0
77-08-26 77-08-25 77-08-23 77-08-08 77-08-04 77-07-26 77-07-21 77-0718	2-3 4-8 4-8 3-5 1-4 5-8 7-9 0-2	VEH #3 200cc 1 CYL 4 ST	90.0	89.0 93.0
78-06-01 78-05-29 77-08-23 77-08-19 77-08-02 77-07-26 77-07-21 77-07-14	1-2 7-9 4-8 3-4 4-5 5-8 7-9 5-6	VEH #4 400cc 2 CYL 4 ST	93.0	90.0
77-08-25 77-08-23 77-08-15 77-08-02 77-07-28 77-07-22 77-07-21 77-07-20	4-8 4-8 0-3 4-5 0 7-11 7-9 5-6	VEH #5 400cc 3 CYL 2 ST	94.0	90.0
78-06-07 77-08-25 77-08-18 77-08-16 77-08-02 77-07-28 77-07-25 77-07-22 77-07-15	3-6 4-8 1-2 0-2 4-5 0 8-10 7-11 5-6	VEH #6 650cc 4 CYL 4 ST	95.0	91.0

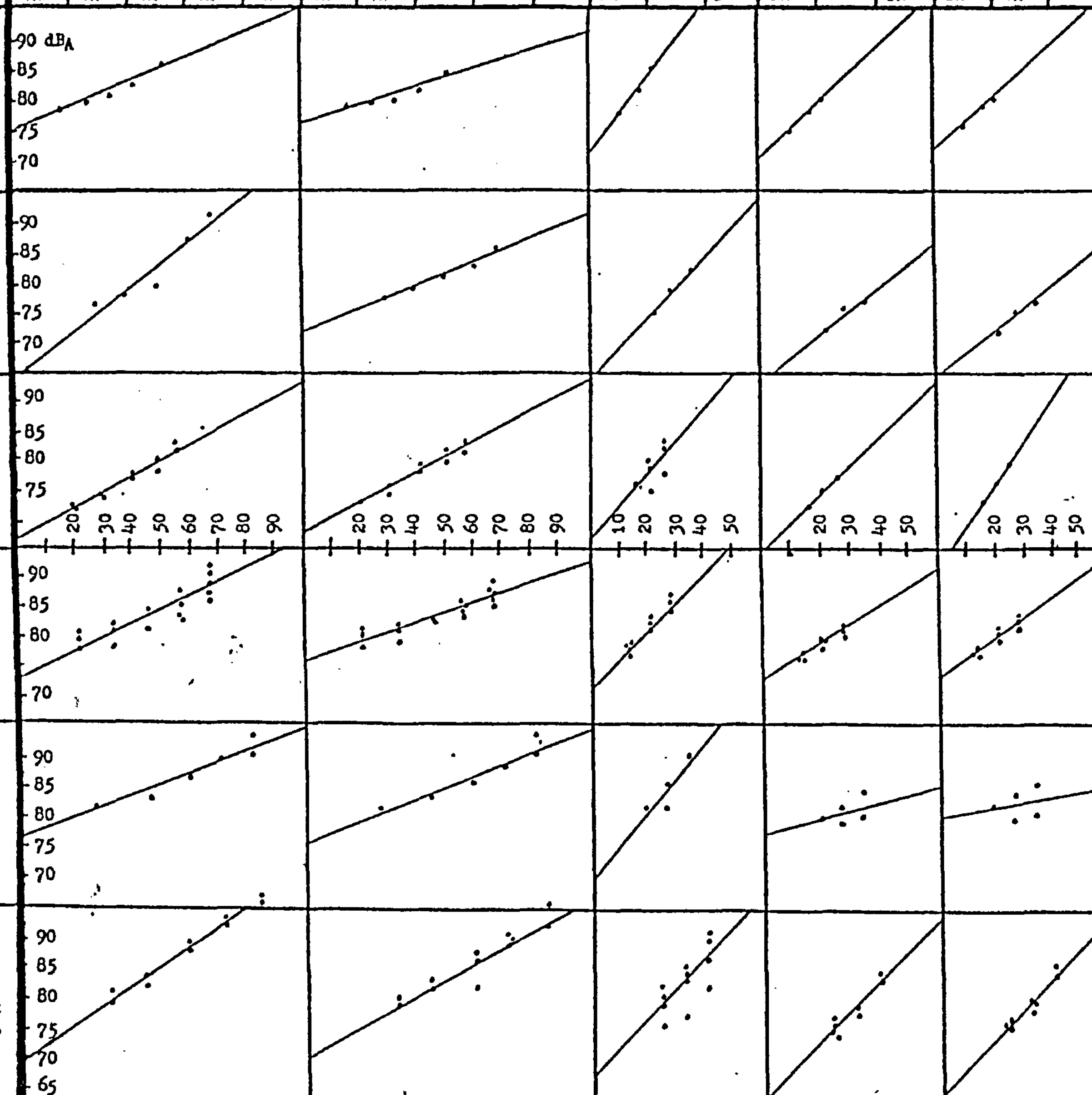


TABLE T4B - Sound level data from field recordings + fitted curves.

SUBJECT C		KPH															
			NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN		
HEIGHT	1.85 m	RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WEIGHT	75.0 Kg	KPH	35	50	65	80	35	50	65	80	35	50	65	80	35	50	65	80
		GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
DATE	WIND KNOTS	RPM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DATE	WIND KNOTS	VEHICLE
78-06-20 78-06-10 78-05-29	2-5 3-5 7-9	VEH #1 175cc 1 CYL 4 ST
78-06-16 78-06-09	5-8 3-5	VEH #2 360cc 2 CYL 4 ST
77-09-07 77-09-02 77-08-25 77-08-19 77-08-02 77-07-27 77-07-21 77-07-20	1-2 5-8 4-8 3-4 4-5 4-6 7-9 5-6	VEH #3 200cc 1 CYL 4 ST
77-09-07 77-09-02 77-08-25 77-08-16 77-07-28 77-07-25 77-07-21 77-07-18	1-2 5-8 4-8 0-2 0 8-10 7-9 0-2	VEH #4 400cc 2 CYL 4 ST
77-09-07 77-09-02 77-08-08 77-07-28 77-07-25 77-07-22	1-2 5-8 3-5 0 8-10 7-11	VEH #5 400cc 3 CYL 2 ST
77-09-07 77-09-02 77-08-25 77-08-02 77-07-28 77-07-26 77-07-20 77-07-14	1-2 5-8 4-8 4-5 0 5-8 5-6 5-6	VEH #6 650cc 4 CYL 4 ST

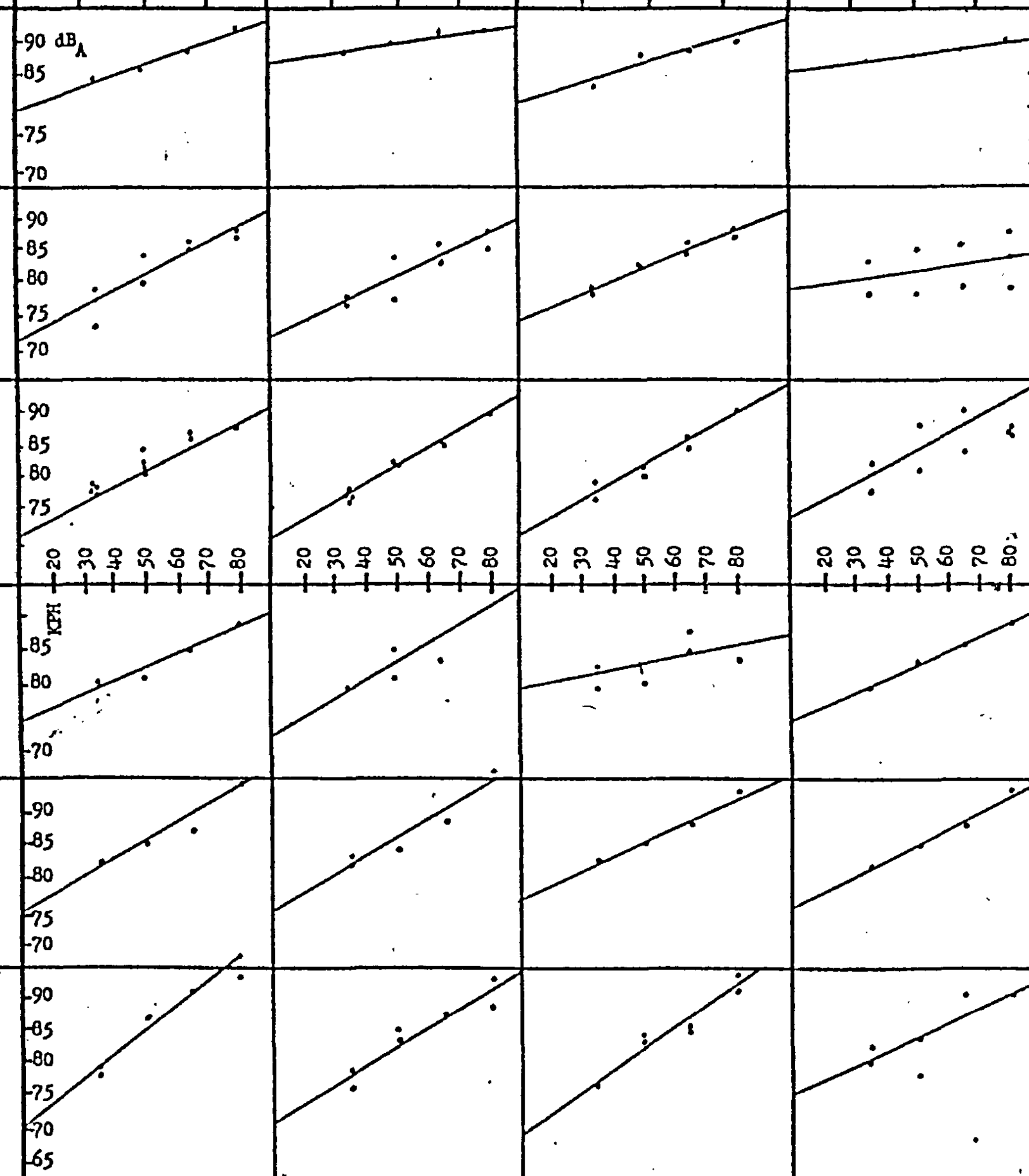


TABLE T4C - Sound level data from field recordings + fitted curves.

SUBJECT C		RUN	GEARS: NO VISOR					GEARS: VISOR					RPM: NO HELMET			RPM: NO VISOR			RPM: VISOR			HWY: NV	HWY: V
HEIGHT 1.85 m		RUN	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
WEIGHT 75.0 Kg		KMH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WIND	GEAR	1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
DATE	KNOTS	RPM	4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-

DATE	WIND KNOTS	VEHICLE	HWY NV	HWY V
78-06-20 78-06-10 78-05-29	2-5 3-5 7-9	VEH #1 175cc 1 CYL 4 ST	91.0	87.0
78-06-16 78-06-09	5-8 3-5	VEH #2 360cc 2 CYL 4 ST		
77-09-07 77-09-02 77-08-25 77-08-19 77-08-02 77-07-27 77-07-21 77-07-20	1-2 5-8 4-8 3-4 4-5 4-6 7-9 5-6	VEH #3 200cc 1 CYL 4 ST	92.0	90.0
77-09-07 77-09-02 77-08-25 77-08-16 77-07-28 77-07-25 77-07-21 77-07-18	1-2 5-8 4-8 0-2 0 8-10 7-9 0-2	VEH #4 400cc 2 CYL 4 ST	91.0	86.0
77-09-07 77-09-02 77-08-08 77-07-28 77-07-25 77-07-22	1-2 5-8 3-5 0 8-10 7-11	VEH #5 400cc 3 CYL 2 ST	91.0	91.0 89.0
77-09-07 77-09-02 77-08-25 77-08-02 77-07-28 77-07-26 77-07-20 77-07-14	1-2 5-8 4-8 4-5 0 5-8 5-6 5-6	VEH #6 650cc 4 CYL 4 ST	89.0	88.0

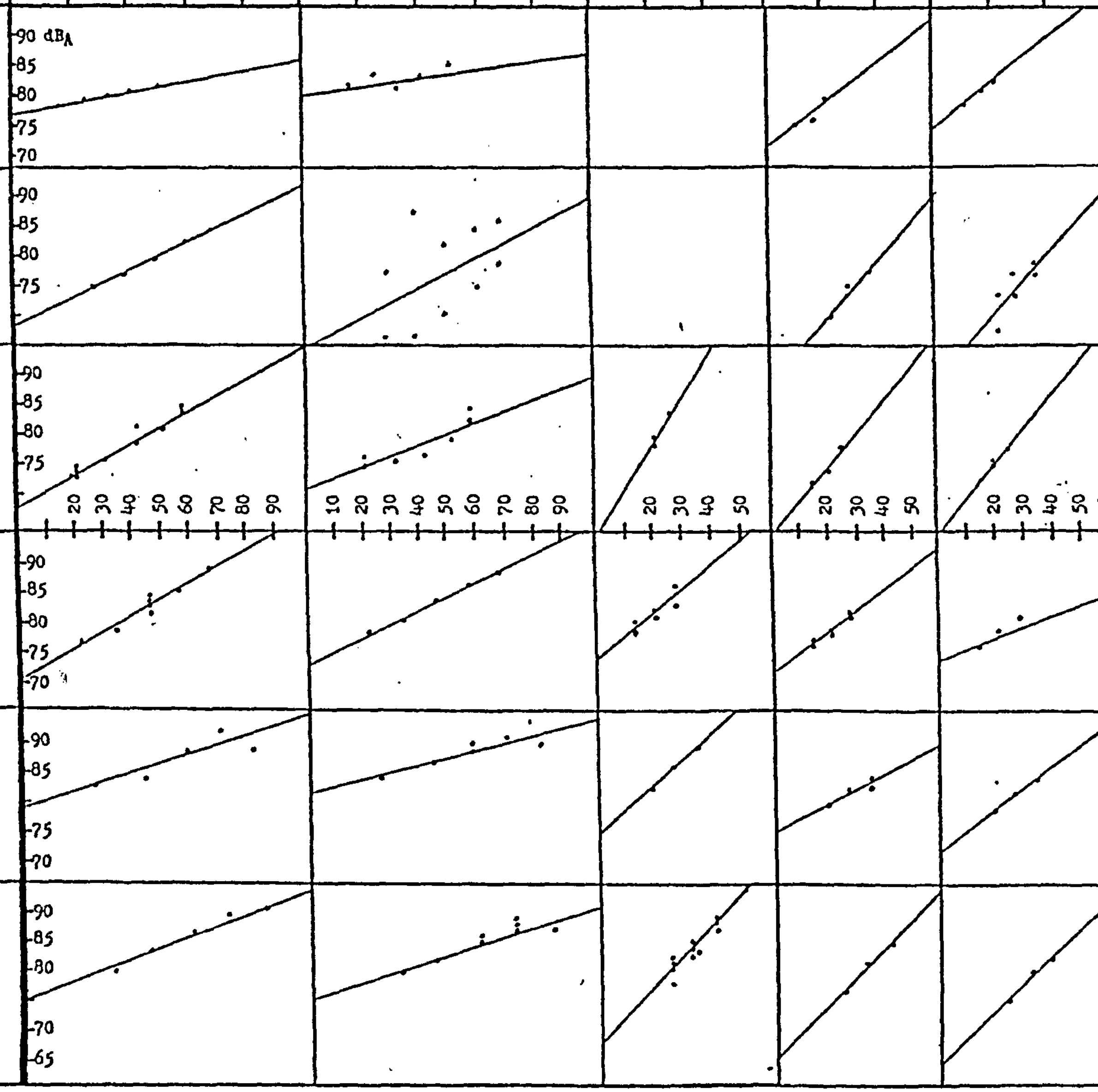


TABLE T4C - Sound level data from field recordings + fitted curves.

SUBJECT D		KPH															
		NO VISOR / UPRIGHT				VISOR / UPRIGHT				NO VISOR / DOWN				VISOR / DOWN			
HEIGHT 2.03 m	RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WEIGHT 81.8 Kg	KPH	35	50	65	80	35	50	65	80	35	50	65	80	35	50	65	80
	GEAR	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
	RPM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DATE	WIND KNOTS	VEHICLE
78-06-21 78-06-16 78-06-13 78-06-09 78-06-08	3-5 5-7 0-2 2-4 1-2	VEH #1 175cc 1 CYL 4 ST
78-06-21 78-06-19	3-5 0-2	VEH #2 360cc 2 CYL 4 ST
77-08-25 77-08-23 77-08-18 77-08-16 77-07-25 77-07-22 77-07-20 77-07-18	4-8 4-8 1-2 0-2 8-10 7-11 5-6 0-2	VEH #3 200cc 1 CYL 4 ST
77-08-25 77-08-23 77-08-15 77-08-02 77-07-21 77-07-20 77-07-15	4-8 4-8 0-3 4-5 7-9 5-6 5-6	VEH #4 400cc 2 CYL 4 ST
77-08-25 77-08-23 77-08-19 77-07-28 77-07-26 77-07-21 77-07-14	4-8 4-8 3-4 0 5-8 7-9 5-6	VEH #5 400cc 3 CYL 2 ST
77-08-26 77-08-25 77-08-04 77-08-01 77-07-28 77-07-26 77-07-21 77-07-18	2-3 4-8 1-4 5-7 0-0 5-8 7-9 0-2	VEH #6 650cc 4 CYL 4 ST

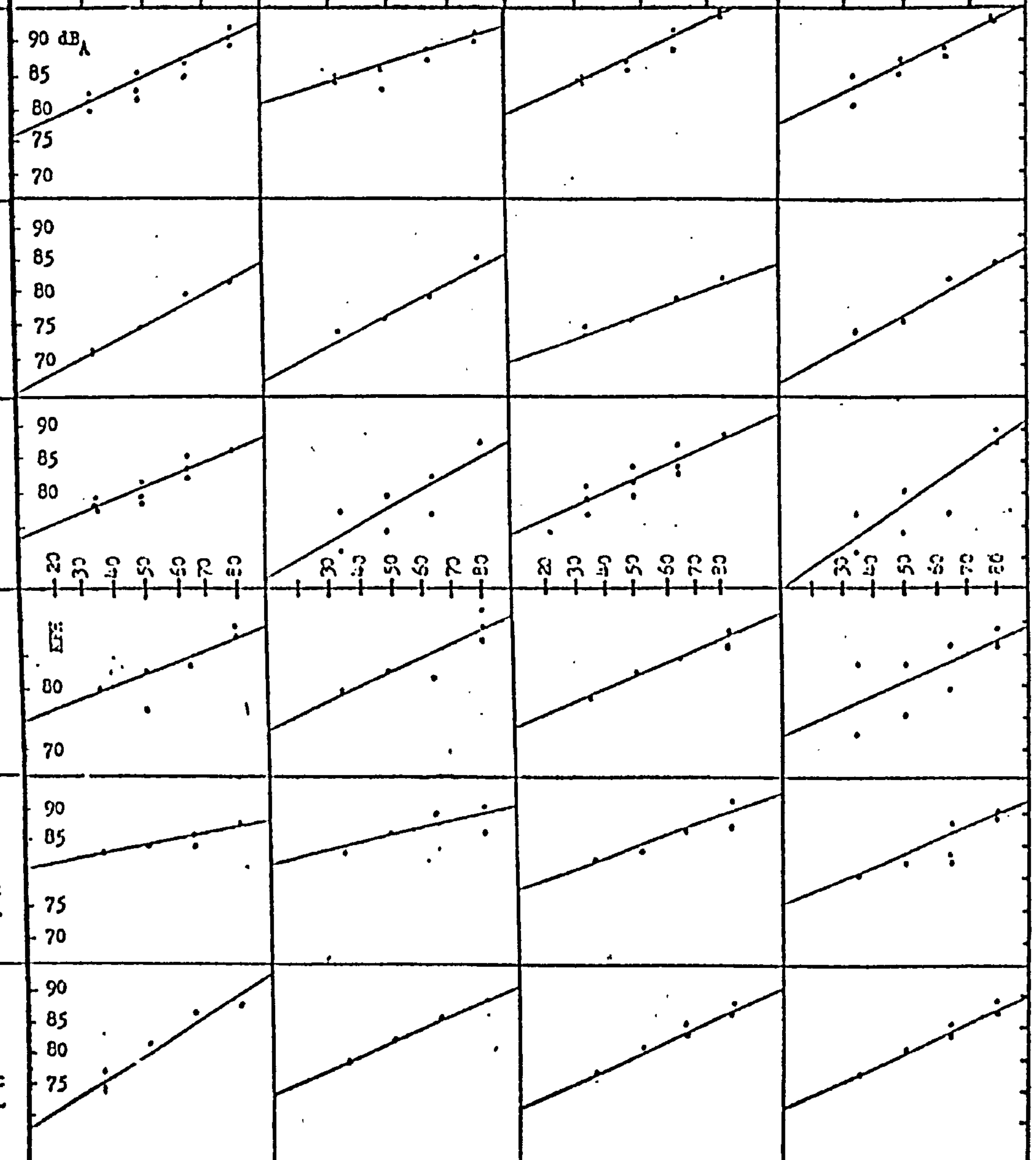
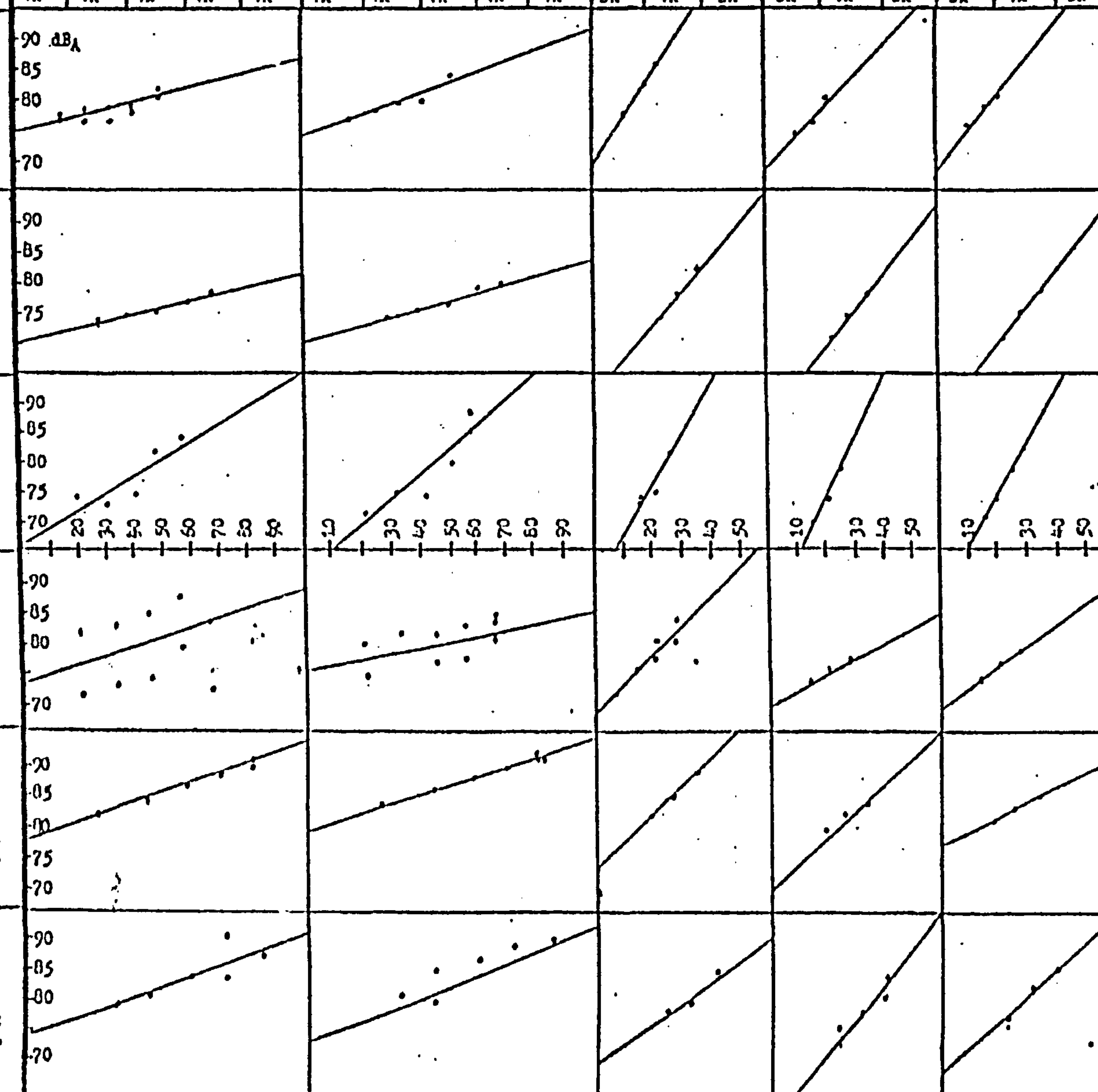


TABLE T4D - Sound level data from field recordings + fitted curves.

SUBJECT D			GEARS										RPM									HWY	
			NO VISOR					VISOR					NO HELMET			NO VISOR			VISOR			NV	V
HEIGHT 2.03 m		RUN	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
WEIGHT 81.8 Kg		KPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WIND	GEAR	1	2	3	4	5	1	2	3	4	5	1	1	1	1	1	1	1	1	1	5	5
DATE	KNOTS	RPM	4K	4K	4K	4K	4K	4K	4K	4K	4K	4K	3K	4K	5K	3K	4K	5K	3K	4K	5K	-	-



DATE	WIND KNOTS	VEHICLE	HWY NV	HWY V
78-06-21 78-06-16 78-06-13 78-06-09 78-06-08	3-5 5-7 0-2 2-4 1-2	VEH #1 175cc 1 CYL 4 ST	91.0	92.0
78-06-21 78-06-19	3-5 0-2	VEH #2 360cc 2 CYL 4 ST	92.0	91.0
77-08-25 77-08-23 77-08-18 77-08-16 77-07-25 77-07-22 77-07-20 77-07-18	4-8 4-8 1-2 0-2 8-10 7-11 5-6 0-2	VEH #3 200cc 1 CYL 4 ST	88.0	91.0
77-08-25 77-08-23 77-08-15 77-08-02 77-07-21 77-07-20 77-07-15	4-8 4-8 0-3 4-5 7-9 5-6 5-6	VEH #4 400cc 2 CYL 4 ST	89.0	88.0
77-08-25 77-08-23 77-08-19 77-07-28 77-07-26 77-07-21 77-07-14	4-8 4-8 3-4 0 5-8 7-9 5-6	VEH #5 400cc 3 CYL 2 ST	91.0	91.0
77-08-26 77-08-25 77-08-04 77-08-01 77-07-28 77-07-26 77-07-21 77-07-18	2-3 4-8 1-4 5-7 0-0 5-8 7-9 0-2	VEH #6 650cc 4 CYL 4 ST	89.0 90.0	89.0

TABLE T4D - Sound level data from field recordings + fitted curves.

	SUBJECTS			
VEHICLE	A	B	C	D
1	0.3236	0.3076	0.1677	0.2947
2	0.4497	0.3763	0.3144	0.3517
3	0.3734	0.3396	0.3779	0.4648
4	0.3052	0.2784	0.2601	0.2340
5	0.2772	0.1941	0.2646	0.2122
6	0.3481	0.3851	0.3265	0.3029

TABLE T5 - AVG_1 of slopes for field data.

VEHICLE	AVG_2	SUBJECT	AVG_2
1	0.2734	A	0.3462
2	0.3730	B	0.3135
3	0.3889	C	0.2852
4	0.2694	D	0.3101
5	0.2370		
6	0.3407		

TABLE T6 - AVG_2 of slopes for field data.

	SUBJECTS			
VEHICLE	A	B	C	D
1	72.295	73.774	78.786	73.930
2	62.476	63.863	67.025	63.512
3	66.951	68.531	67.221	63.162
4	70.331	72.944	72.423	70.592
5	72.202	78.464	74.596	76.049
6	66.598	65.743	69.885	69.807

TABLE T7 - AVG_1 of zero-intercepts for field data.

VEHICLE	AVG_2	SUBJECT	AVG_2
1	74.696	A	68.475
2	64.219	B	70.553
3	66.466	C	71.656
4	71.372	D	69.509
5	75.327		
6	68.008		

TABLE T8 - AVG_2 of zero-intercepts for field data.

		KPH							
		NYU		YYU		NYD		YYD	
SUB.	VEH.	SLOPE	Y-INT.	SLOPE	Y-INT.	SLOPE	Y-INT.	SLOPE	Y-INT.
A	1	.2933	71.4	.2100	74.3	.2367	76.0	.1633	76.2
A	2	.2700	64.0	.2783	65.3	.2283	70.7	.2667	66.9
A	3	.2512	69.6	.2628	67.6	.2758	69.2	.2782	67.7
A	4	.2515	70.9	.1981	71.7	.3365	67.9	.1879	73.8
A	5	.2000	73.7	.2154	73.5	.3000	69.8	.2745	70.5
A	6	.3098	64.4	.2375	66.9	.2558	69.3	.1931	70.3
B	1	.2967	70.6	.2067	76.6	.2767	75.2	.2033	77.7
B	2	.3467	60.6	.3233	63.5	.3133	64.7	.2733	67.5
B	3	.2564	70.1	.2353	71.4	.1875	74.2	.2067	73.9
B	4	.2466	73.9	.2000	74.1	.2363	73.1	.2087	72.7
B	5	.1648	78.7	.0510	86.5	.1549	80.7	.1186	82.8
B	6	.3409	65.4	.3667	61.7	.3117	67.0	.2567	67.3
C	1	.1800	77.2	.0800	85.4	.1333	79.8	.0667	84.4
C	2	.2533	68.4	.2183	70.0	.1883	72.8	.0567	79.0
C	3	.2467	69.4	.2767	67.4	.2660	68.0	.1454	76.0
C	4	.2100	71.6	.2833	68.3	.0789	78.8	.2200	71.6
C	5	.2733	71.5	.2843	71.4	.2300	73.9	.2500	72.8
C	6	.3614	67.2	.2902	68.7	.3282	66.4	.2358	72.0
D	1	.2111	79.5	.1500	78.0	.2269	75.6	.2283	74.2
D	2	.2467	63.1	.2533	64.7	.1733	68.8	.2533	65.4
D	3	.1937	71.3	.2718	63.6	.2153	71.1	.3162	61.8
D	4	.2394	68.3	.2292	70.0	.2069	70.8	.2183	69.0
D	5	.0910	79.4	.1059	80.2	.1647	75.6	.2132	71.5
D	6	.2863	67.1	.2233	71.8	.2285	70.1	.1445	75.1
AVG_1		.2509	70.3	.2271	71.4	.2314	72.1	.2075	72.5

TABLE T9 - AVG_1 of slopes and zero-intercepts for KPH field runs only.

SPEAKER NO.			40					38	39					41		42		
AZIMUTHAL ANGLE	-180	-150	-144	-120	-90	-60	-30	0	29	30	60	90	120	143	150	170	180	FREQUENCY (HZ)
SHAW	-1.0	-2.0		-2.0	-1.6	-2.0	-1.3	0		1.0	1.8	2.2	1.8		0.8		-0.5	300
DELAIRE			-3.6					0	1.1					-0.8		-6.4		
SHAW	-1.0	-2.5		-2.2	-1.2	-2.2	-2.1	0		2.2	3.5	4.5	3.5		2.2		-0.5	500
DELAIRE			-3.4					0	2.5					-0.7		0.6		
SHAW	1.8	-3.0		-4.0	-1.5	-4.5	-4.0	0		3.0	4.8	5.5	5.5		4.0		2.0	1000
DELAIRE			-5.0					0	8.3					7.8		2.4		
SHAW	1.2	-2.5		-7.5	-3.5	-7.5	-3.5	0		2.5	4.0	4.5	4.0		3.5		1.0	1600
DELAIRE			-15.6					0	-5.5					-2.6		-7.8		
SHAW	-2.5	-6.5		-10.5	-8.0	-7.0	-4.0	0		3.0	4.0	2.0	-2.0		-1.5		-2.5	2500
DELAIRE			-15.2					0	-4.7					-6.8		-7.4		

TABLE T10 - Deviation of sound level from zero incidence at specific frequencies. (see figure F9)

SUBJECT	HEIGHT	WEIGHT	BFH	SEX
A	1.69m	84.0kg	M	M
B	1.69m	65.9kg	S	M
C	1.85m	75.0kg	M	M
D	2.03m	81.8kg	L	M
E	1.62m	N/A	S	F
F	1.71m	N/A	S	F

TABLE T11 - Some physical characteristics of subjects involved in the testing.

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APPENDIX A

A.1 Sensitivity of Analyzing Equipment

A.1.1 Real Time Analyser

- frequency range: 5000 Hz
- no. of ensembles: 16 to 64
- averaging mode: linear
- bandwidth: $\frac{1}{3}$ - octave

A.1.2 Graphic Level Recorder

- Potentiometer range: 50 dB
- response: RMS
- lower limiting frequency: 20 Hz
- writing speed: 100 mm/sec
- paper speed: 0.1 cm/sec

A.1.3 Metrosonics dB-601 Sound Level Analyzer

- Detector constant: fast
- Sampling rate: 16/second
- Input: 100dB Display Mode: 1) L_n with n=1,10,50 and 90
  2) Leq

A.1.4 B & K 2607 Amplifier

- Gain Control: calibrate
- Scale: SA 0056

A.1.4 B & K 2607 Amplifier Cont'd..

- Input attenuator to suit scale
- Output attenuator: to suit scale
- Meter Function: RMS
- Filter: A-weighting

APPENDIX B

AUXILIARY TESTING

B.1 Highway Testing

The procedure for highway testing was described in the main body of this report. The equivalent noise level was obtained (Leq) for each test and the results appear in Table T2. Table TB2 contains the AVG_1 and AVG_2 of the sound levels obtained. There is only 2 to 4 dBA difference between maximum and minimum values. This suggests that the predominant source for highway speeds must be wind noise because the variation in engine noise is much greater. Subject influence is also insignificant although this has been the trend all along. The addition of a visor tends to do little to further reduce noise levels but there seems to be some indication of this. Generally, levels were reduced by 1 to 5 dBA when a visor was used but a few increases were found.

B.2 Inside versus Outside

The test facility of the semi-anechoic chamber was duplicated outside, in part, to examine the influence of the test stand, test chamber and any unforseen influences. This test was performed by subject B only with the speaker located at the exhaust, approximately where speaker no. 42

was positioned with respect to the test stand. In this case vehicle #4 was used. Anticipated influences were additional baffling due to vehicle construction and a change in the subject's CH position. The test was performed on a paved surface with no obstructions within 10 meters, except 2 light posts. There was essentially no wind.

The same α , β and γ comparisons appear in Figure FB1 for this test. The α-curve inside follows the α-curve outside quite closely but it is about 6 dBA higher. The similar shape of the curves suggest that there is no change in the frequency content of the two noise recordings. The difference in sound level could be attributed to incomplete sound absorption within the chamber.

Examination of the β-curves show that helmet attenuation is not changed by going outside. The γ-curves show slight inconsistencies between each other but in a general sense they confirm that addition of a visor makes little difference.

B.3 Speaker versus Vehicle

Figure FB2 shows the results of section B.2 combined with an equivalent plot of noise produced by vehicle no. 1, at 4000 RPM, in the neutral mode. The α-curves show that the pink noise of the chamber testing was compatible with the noise produced by vehicle no. 1. The transfer functions are similar. This also applies for the helmet and visor attenuation curves (β and γ).

B.4 Stationary versus Moving

Since the CH recordings cannot be made while in the moving mode, only β and γ curves can be compared here. The similarity of results in both cases seems to negate the possibility of isolating predominant sources by measuring levels in these two modes of operation (test facility: Figure FB6). The results of averaging slopes and zero-intercepts of the stationary recordings appear in Table TB3. AVG_1 AVG_2 are included in Table TB4 for the slopes of data in the stationary mode. Equivalent data was obtained for the moving mode (Table TB5). Tables TB6 and TB7 contain the data for zero-intercepts. This data yielded the curves of Figures FB4 and FB5.

From Figure FB4 it can be seen that the noise level is consistently higher in the stationary mode at equal RPM values. This is supported by Figure FB5 where vehicle AVG_2 values are compared. The results were not anticipated since additional noise from wind, tire and chain should have contributed to higher levels while in the moving mode. This suggests that stationary testing is more complex than was anticipated and other means of isolating specific sources would have to be found in order to determine the level of each.

B.5 Performance Curves

The interpretation of the results of Table T2 became complicated by the fact that for each test only the control parameter could be specified since the complimentary parameter would vary from vehicle to vehicle. Hence a separate table is included showing both RPM and KPH for each vehicle under each test condition (Table TB10). The performance curves have been plotted from this data in Figure FB7 which consists of a page for each vehicle. These agree with performance curves provided by the manufacturers.

B.6 Signal Shaping to Meet Standards

During the course of the investigation the recorder frequency characteristics did not remain constant. Continual monitoring of these characteristics proved very time consuming and, as a result, a test was made to determine the extent of influence that the changes would have on the sound levels obtained.

Figure FB8 shows the unshaped frequency characteristics of the worst case detected. Spectrum shaping was provided to the extent shown. This produced the results of Table TB1, where several recordings made with other recorders are played through the defective device with and without shaping. The results are favourable in that the dBA levels are higher by about 2.5 dBA on the average. This is comparable to the run to run deviation. It does not reflect the recording capabilities of the device but these should not be significantly different. It should be pointed out however that the unshaped condition of Figure FB8 did not exist throughout the recording session. All recording devices were found to conform to type II tolerances at the start.

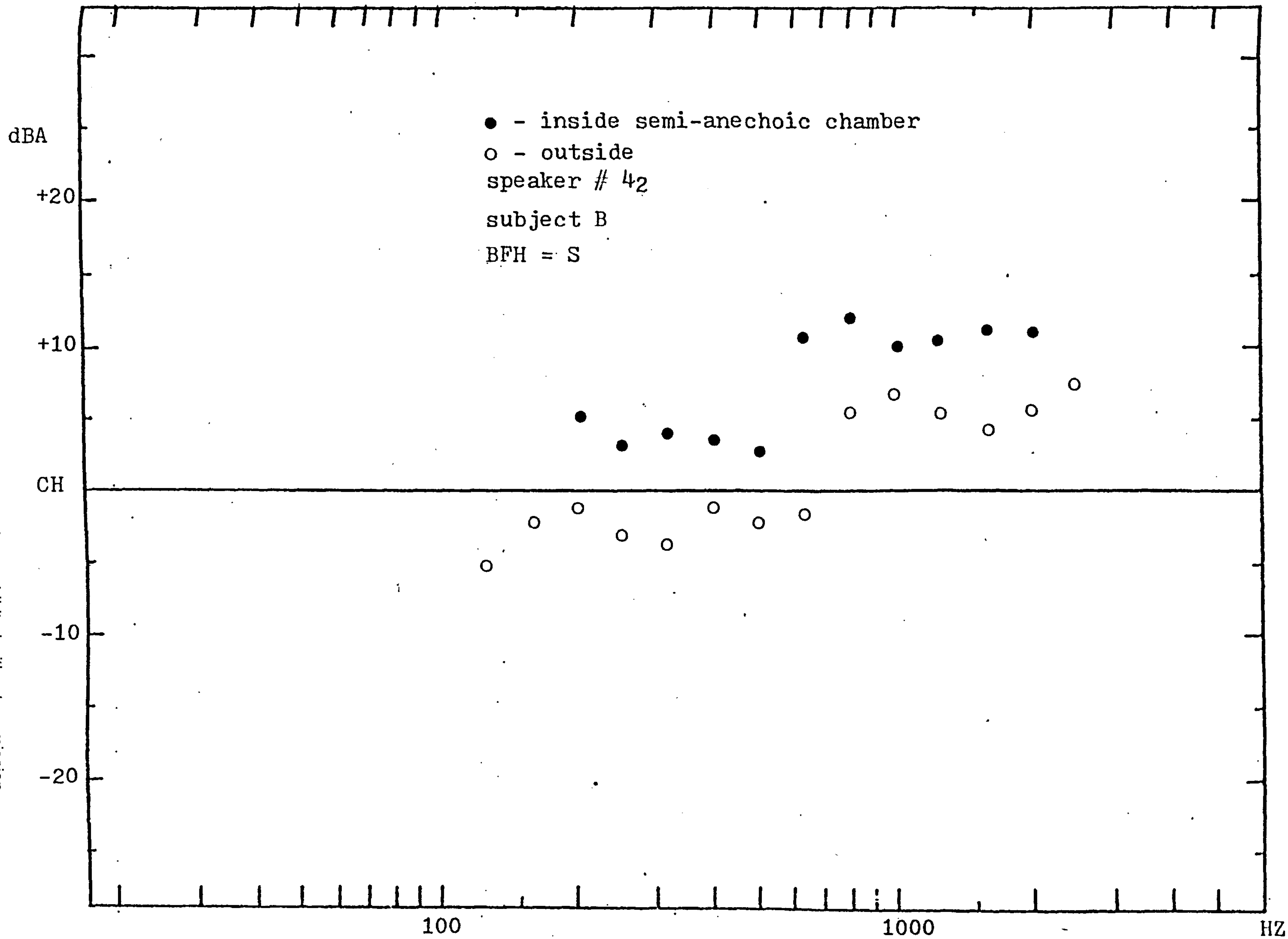


FIGURE FB1α - 1/3 octave frequency spectrum of transfer function for recordings made inside and outside.

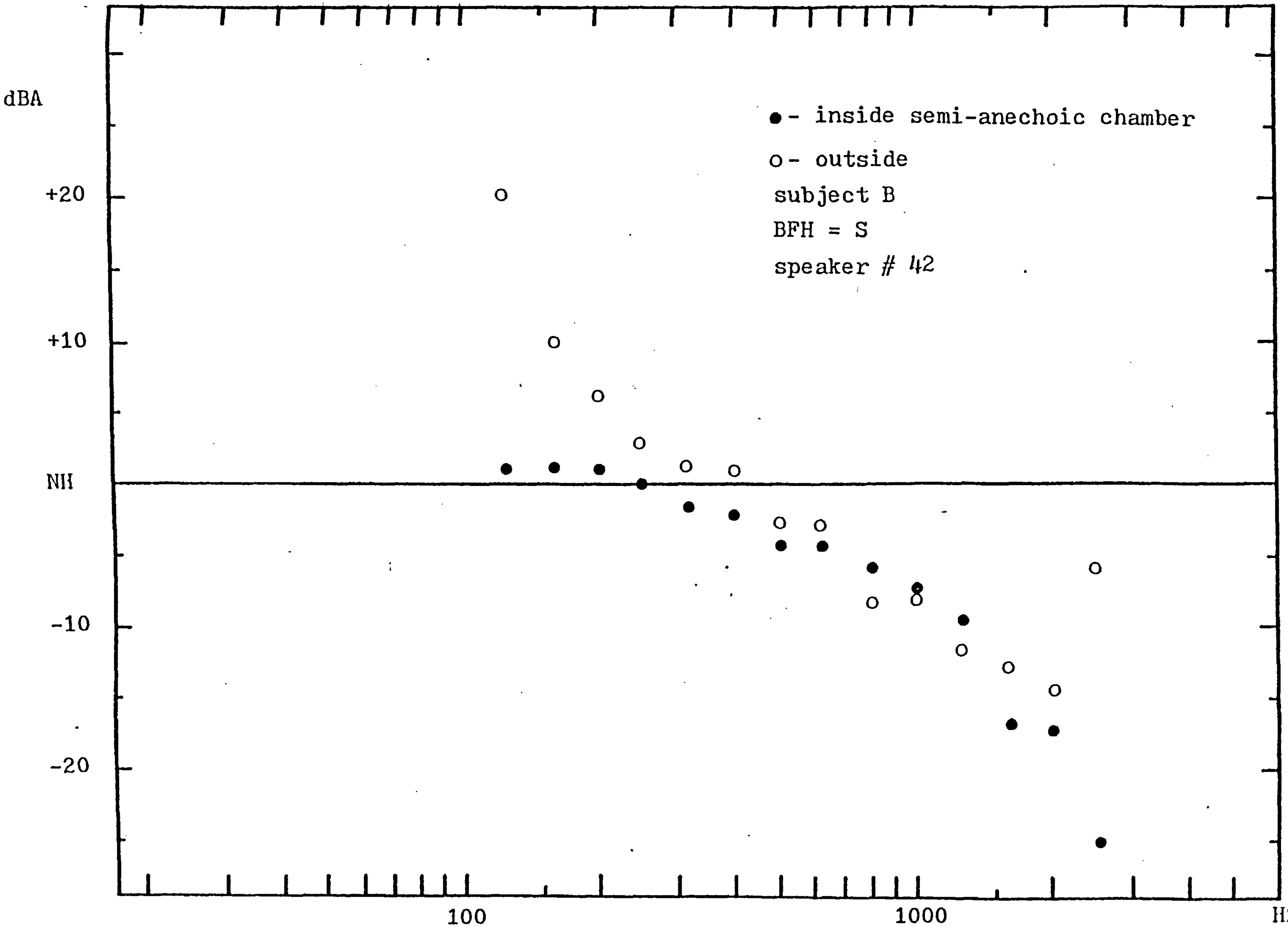


FIGURE FB1β - 1/3 octave frequency spectrum of helmet attenuation for inside-outside comparison.

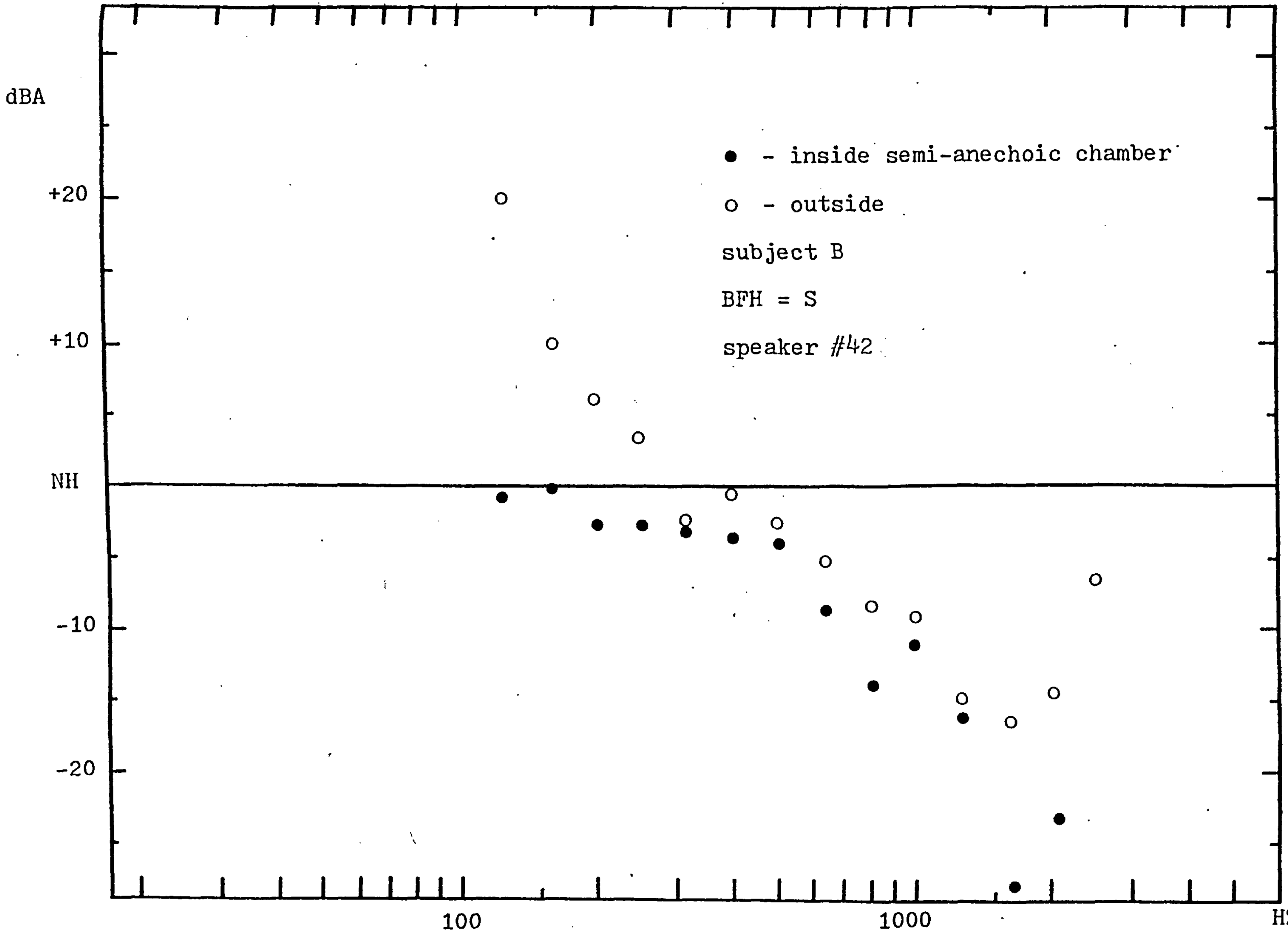


FIGURE FB1γ - 1/3 octave frequency spectrum of helmet + visor attenuation for inside-outside comparison.

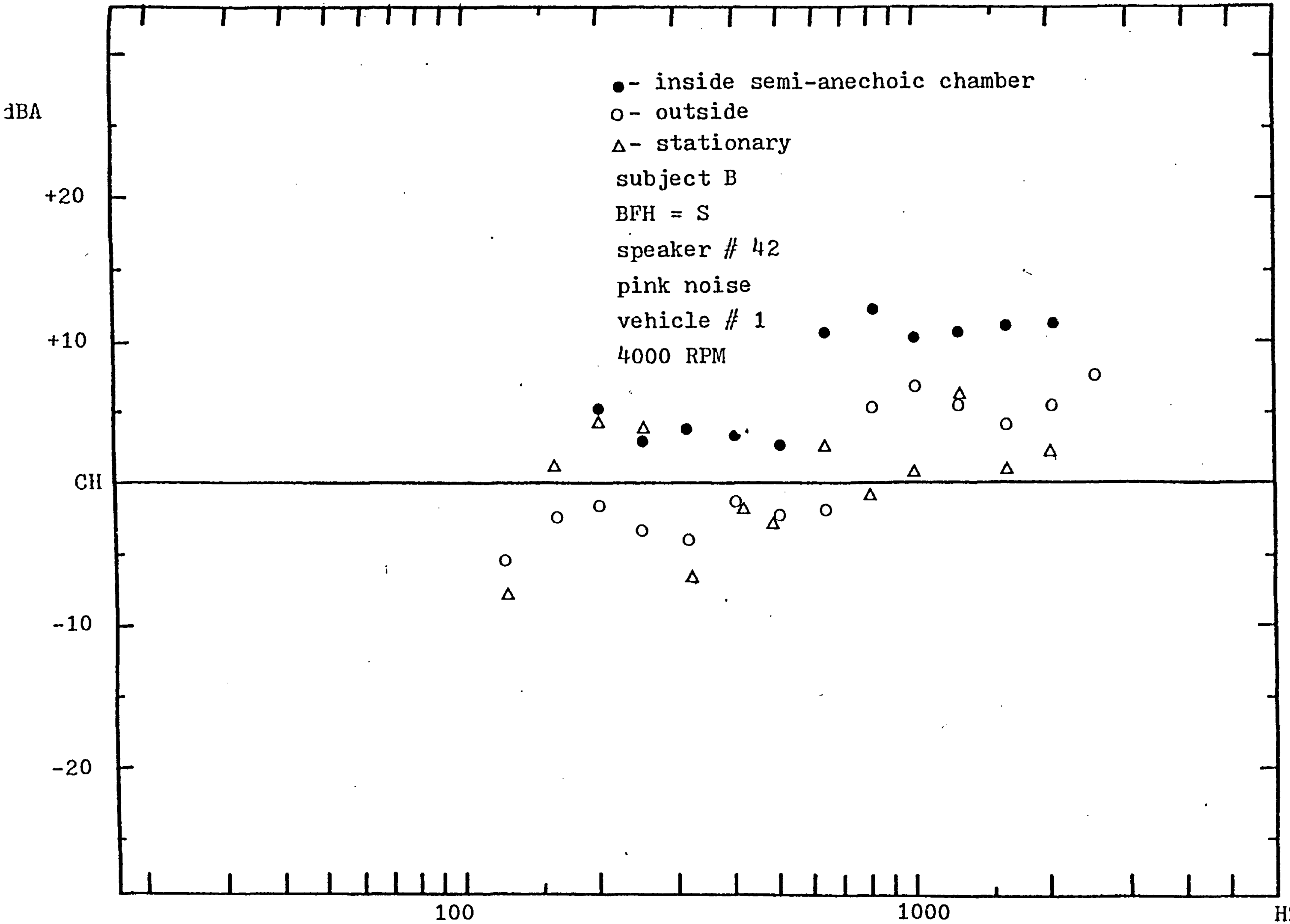


FIGURE FB2∝ - 1/3 octave frequency spectrum of transfer function for inside-outside-stationary comparison.

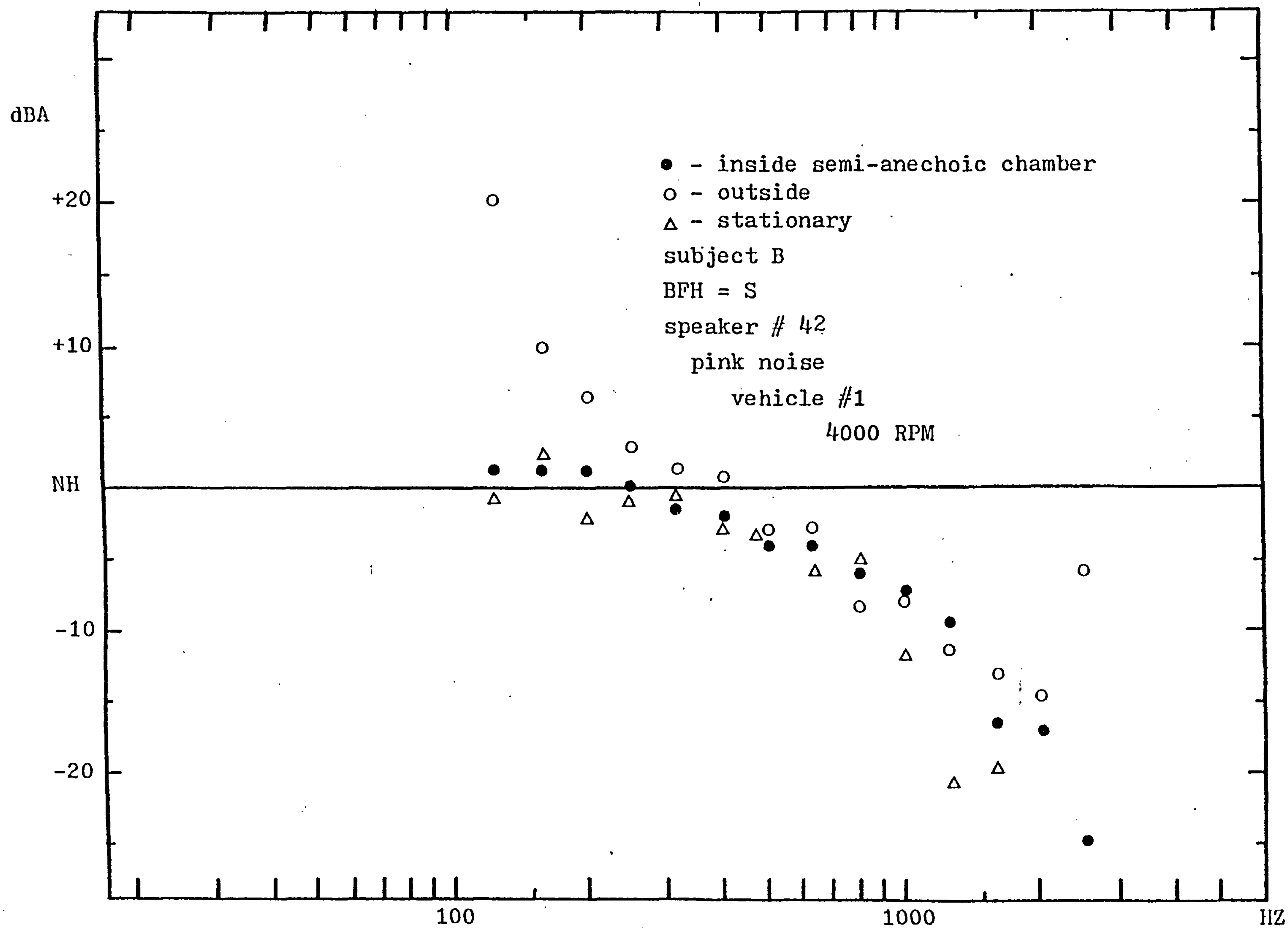


FIGURE FB2β - 1/3 octave frequency spectrum of helmet attenuation for inside-outside-stationary comparison.

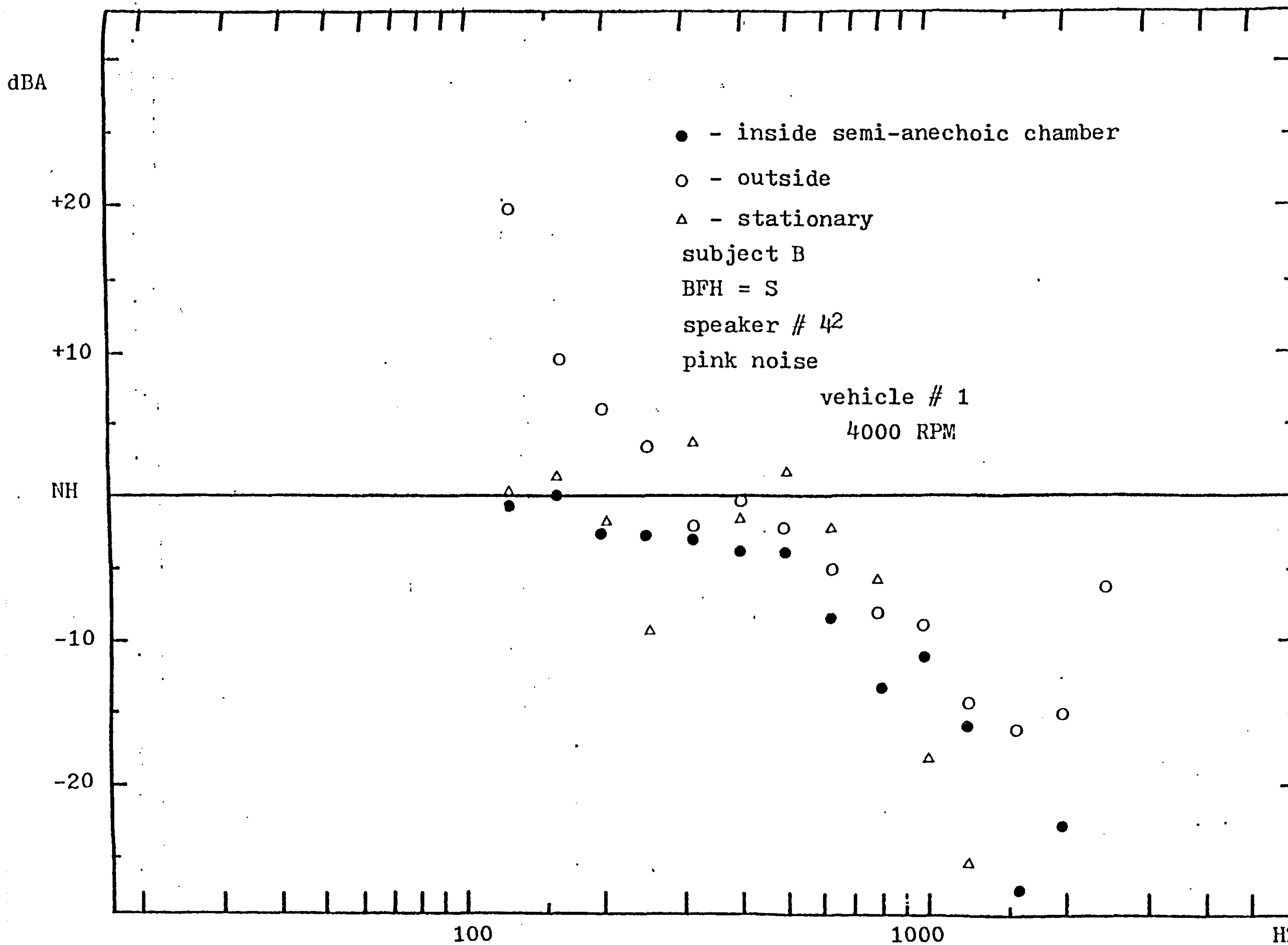


FIGURE FB2γ - 1/3 octave frequency spectrum of helmet + visor attenuation for inside-outside-stationary comparison.

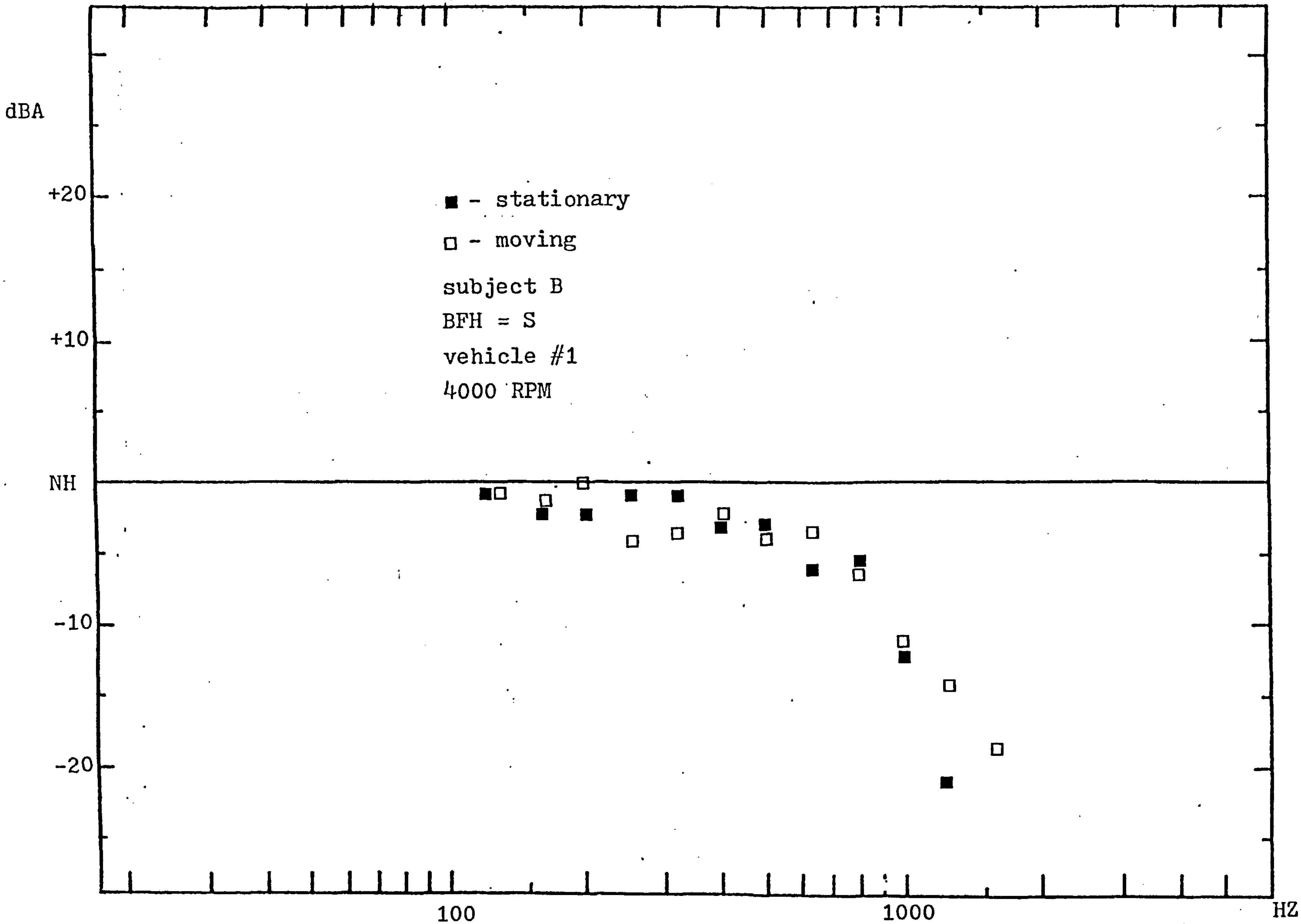


FIGURE FB38 - 1/3 octave frequency spectrum of helmet attenuation for moving versus stationary test.

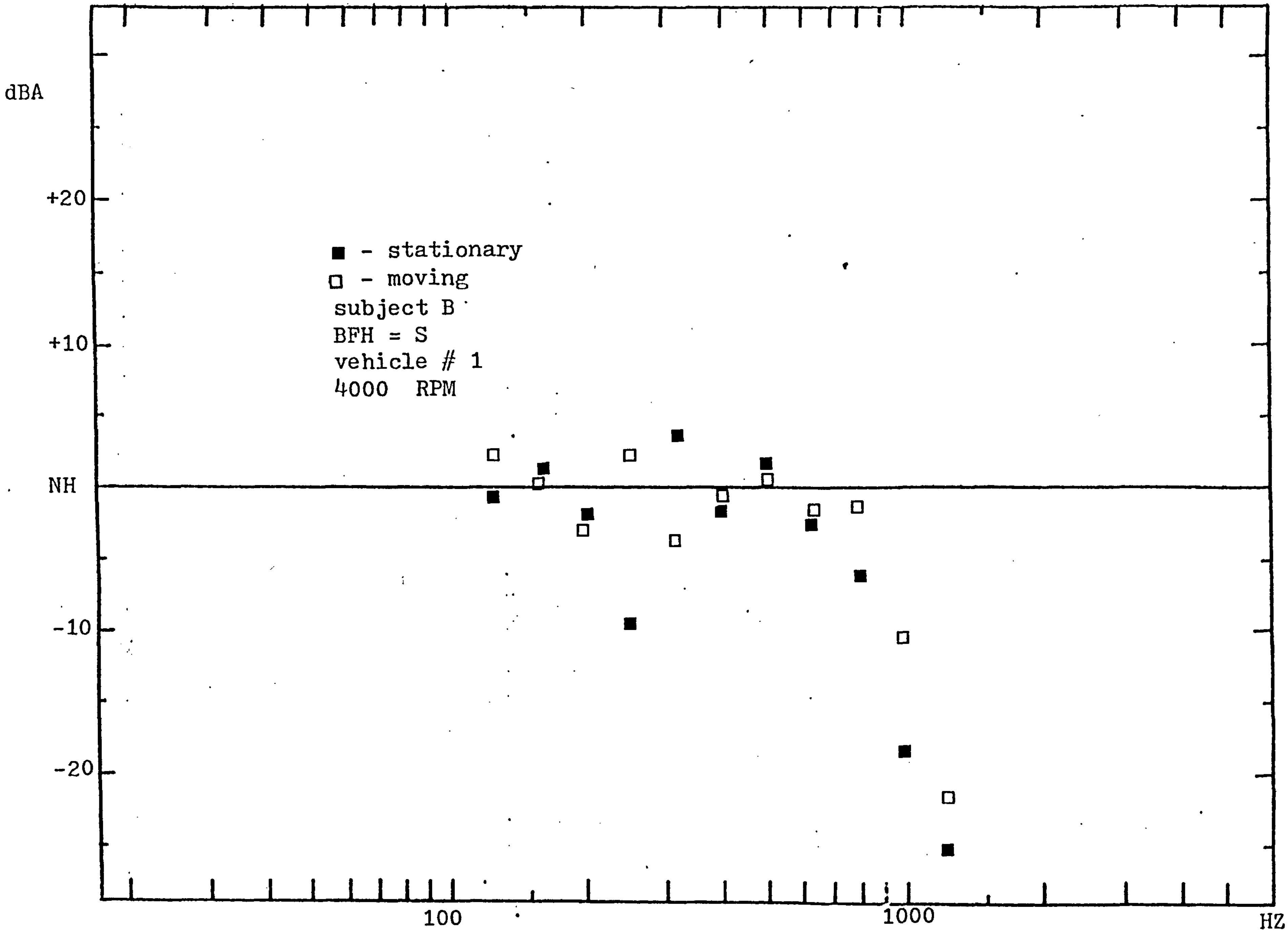


FIGURE FB3γ - 1/3 octave frequency spectrum of helmet + visor attenuation for moving versus stationary test.

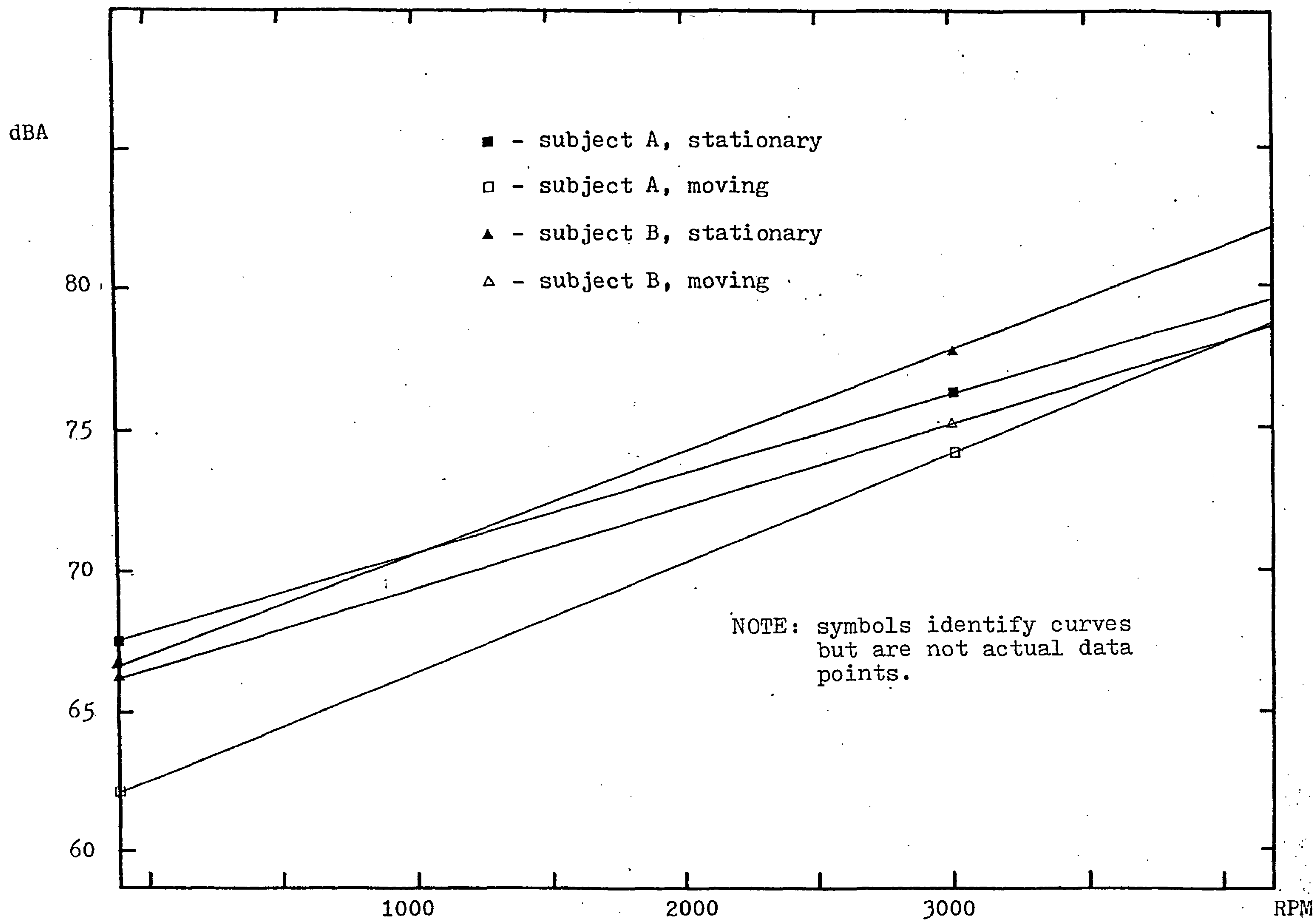


FIGURE FB4 - Plot of AVG_2 of auxiliary recording results for stationary versus moving test (subject comparison).

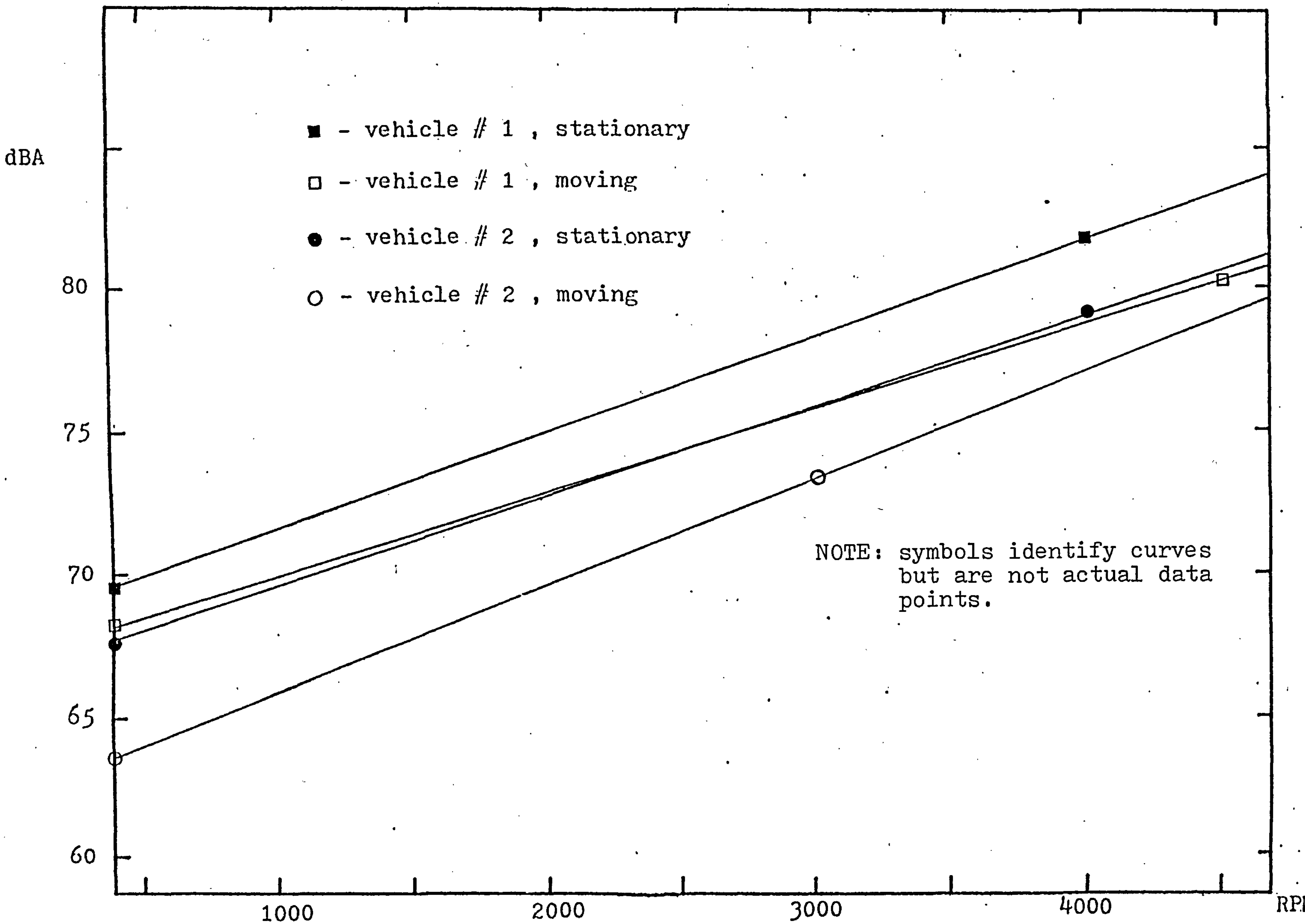
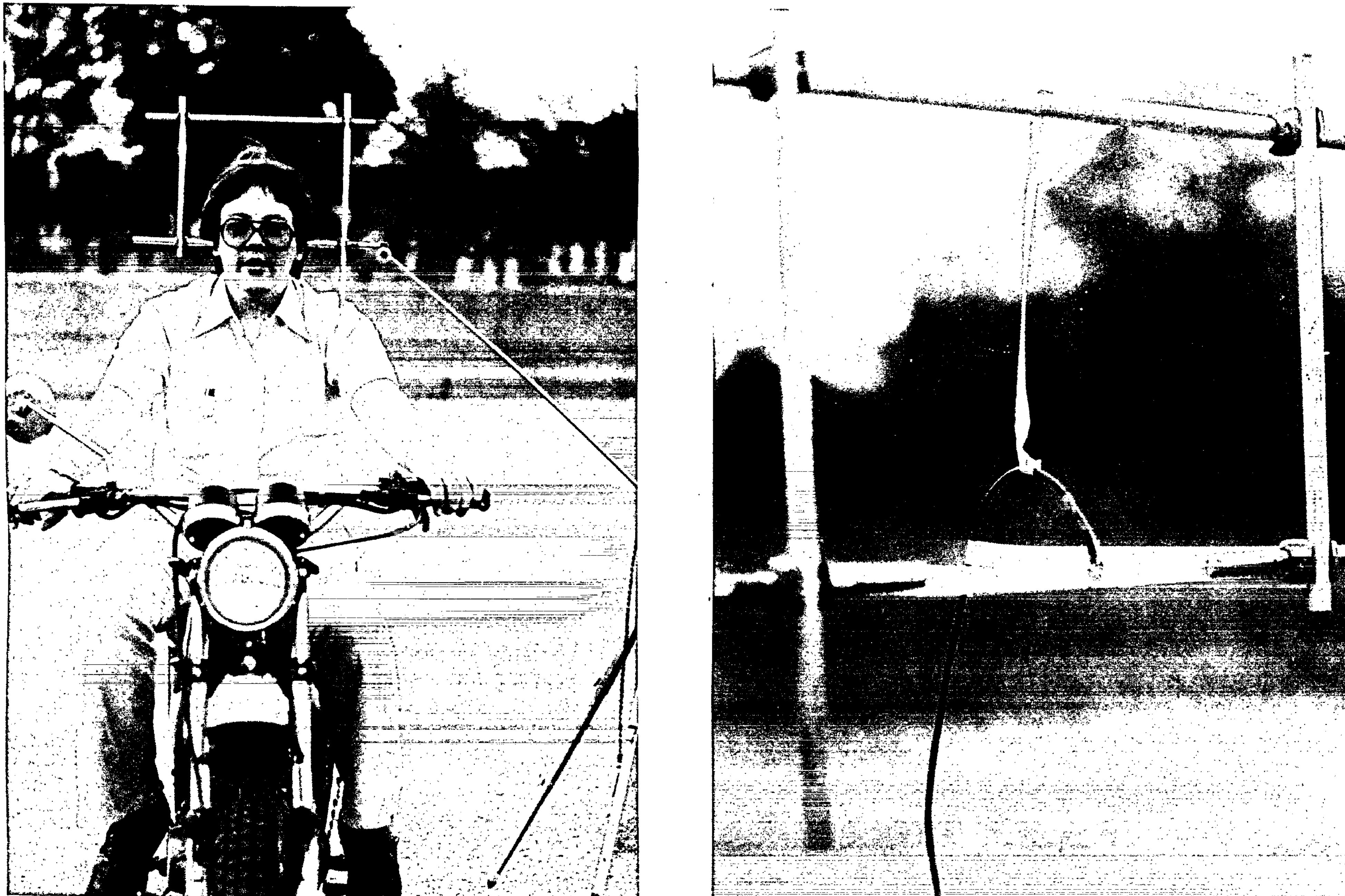


FIGURE FB5 - Plot of AVG_2 of auxiliary recording results for stationary versus moving test (vehicle comparison).



Locating the CH position of subject A   Recording at the CH position

FIGURE FB6 - Test facility for stationary field recordings.

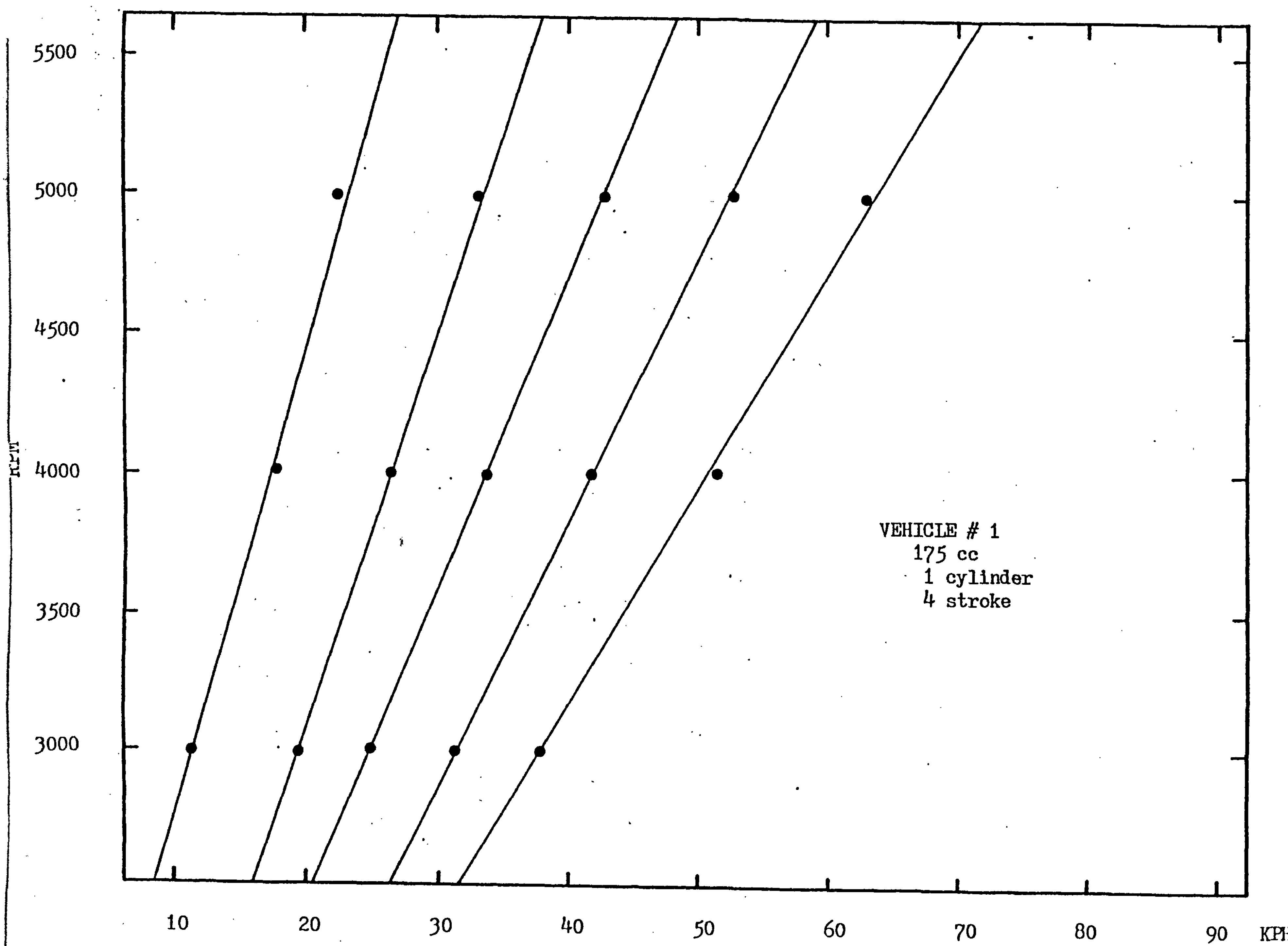


FIGURE FB7(i)-VEHICLE PERFORMANCE CURVES

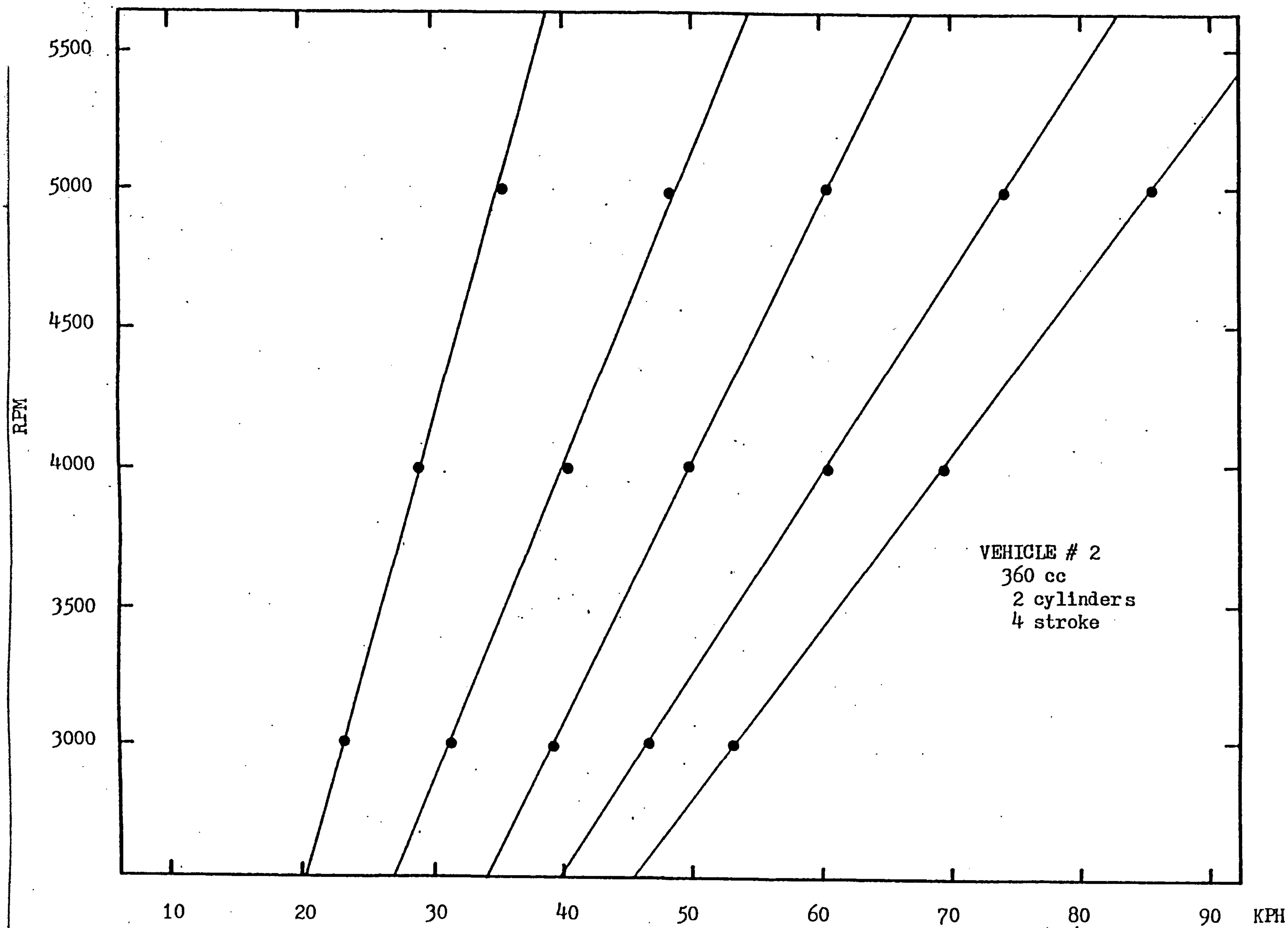


FIGURE FB7(ii)- VEHICLE PERFORMANCE CURVES

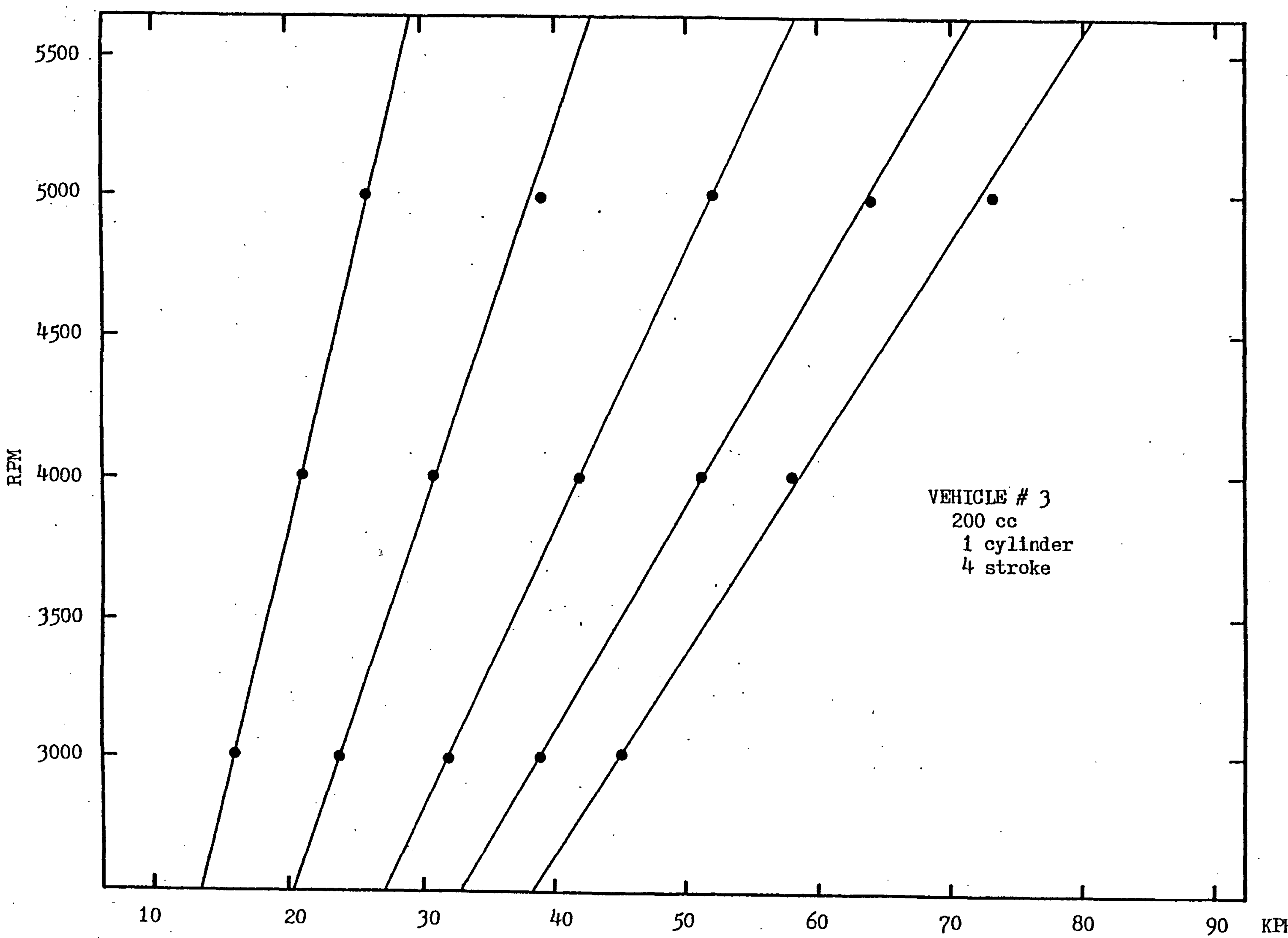


FIGURE FB7(iii)- VEHICLE PERFORMANCE CURVES

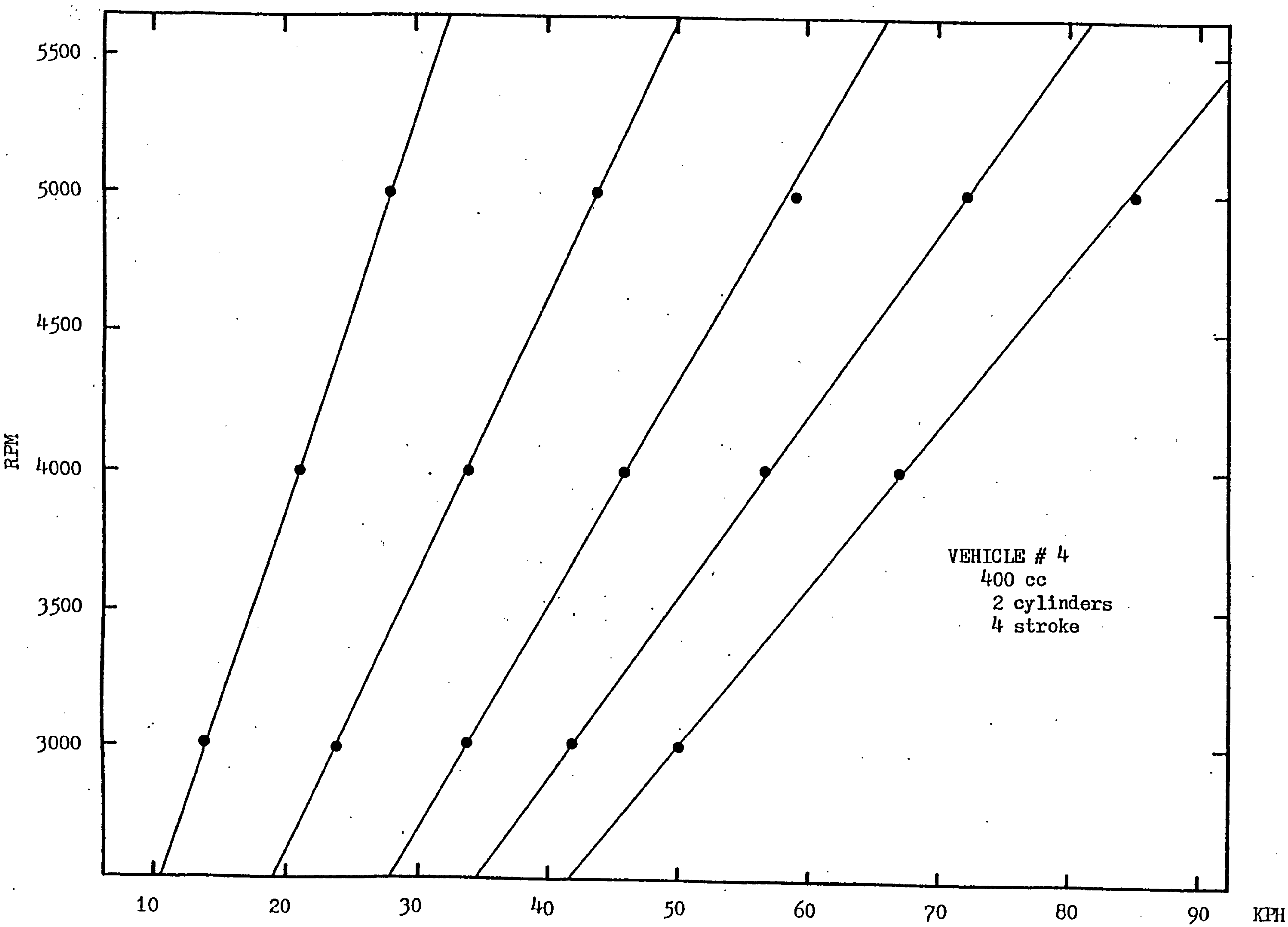


FIGURE FB7(iv)- VEHICLE PERFORMANCE CURVES

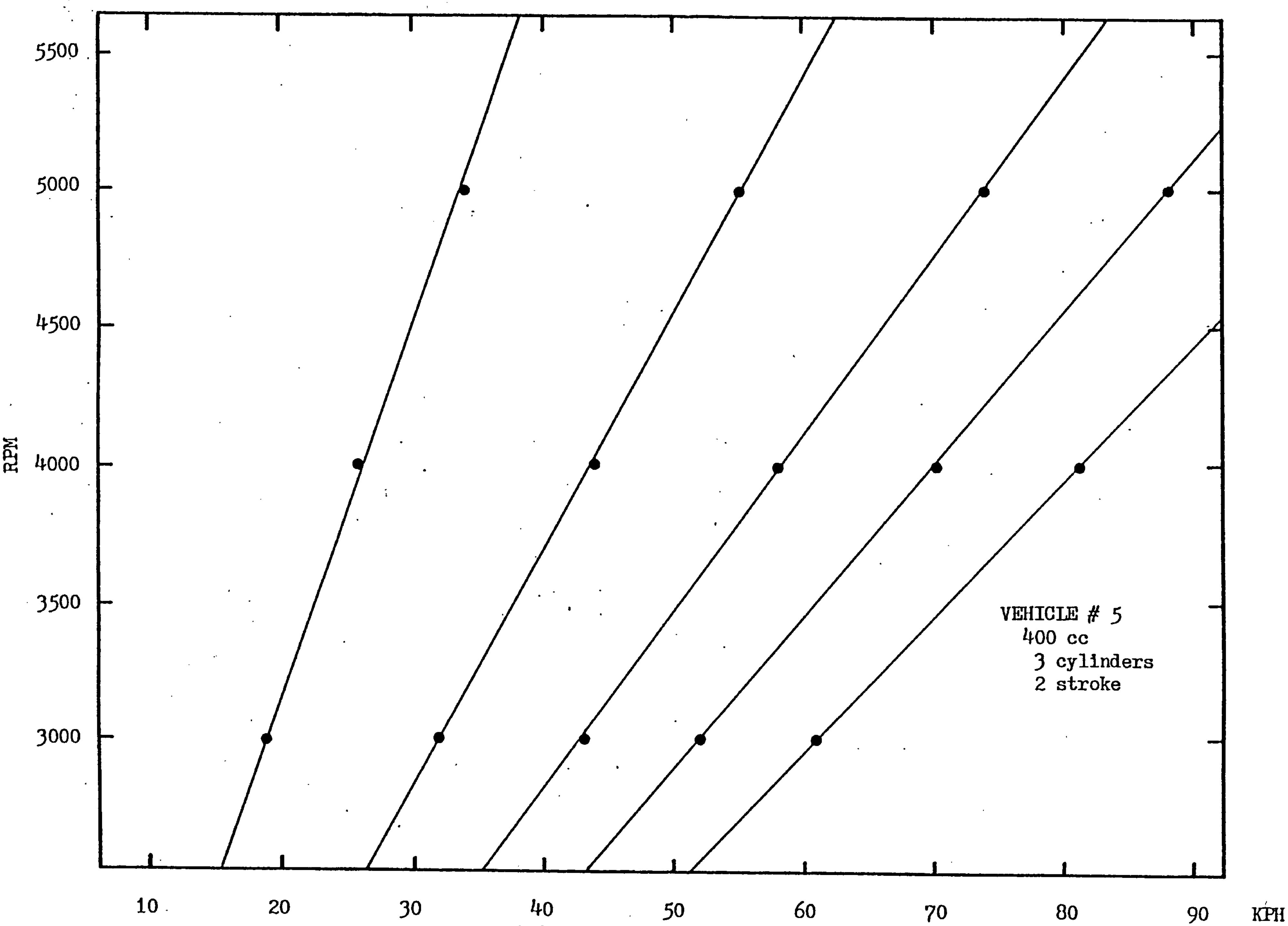


FIGURE FB7(v) - VEHICLE PERFORMANCE CURVES

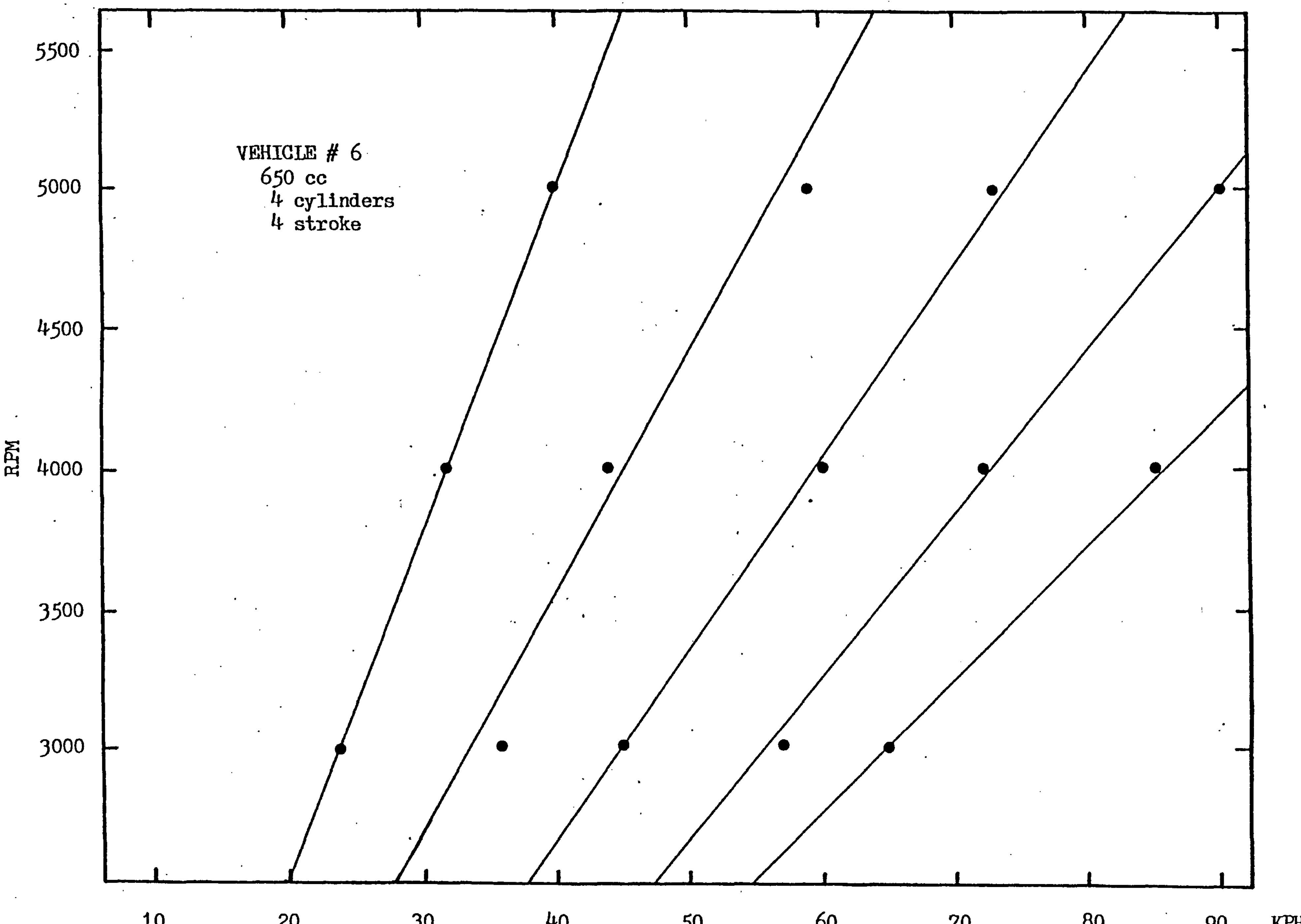


FIGURE FB7(vi) - VEHICLE PERFORMANCE CURVES

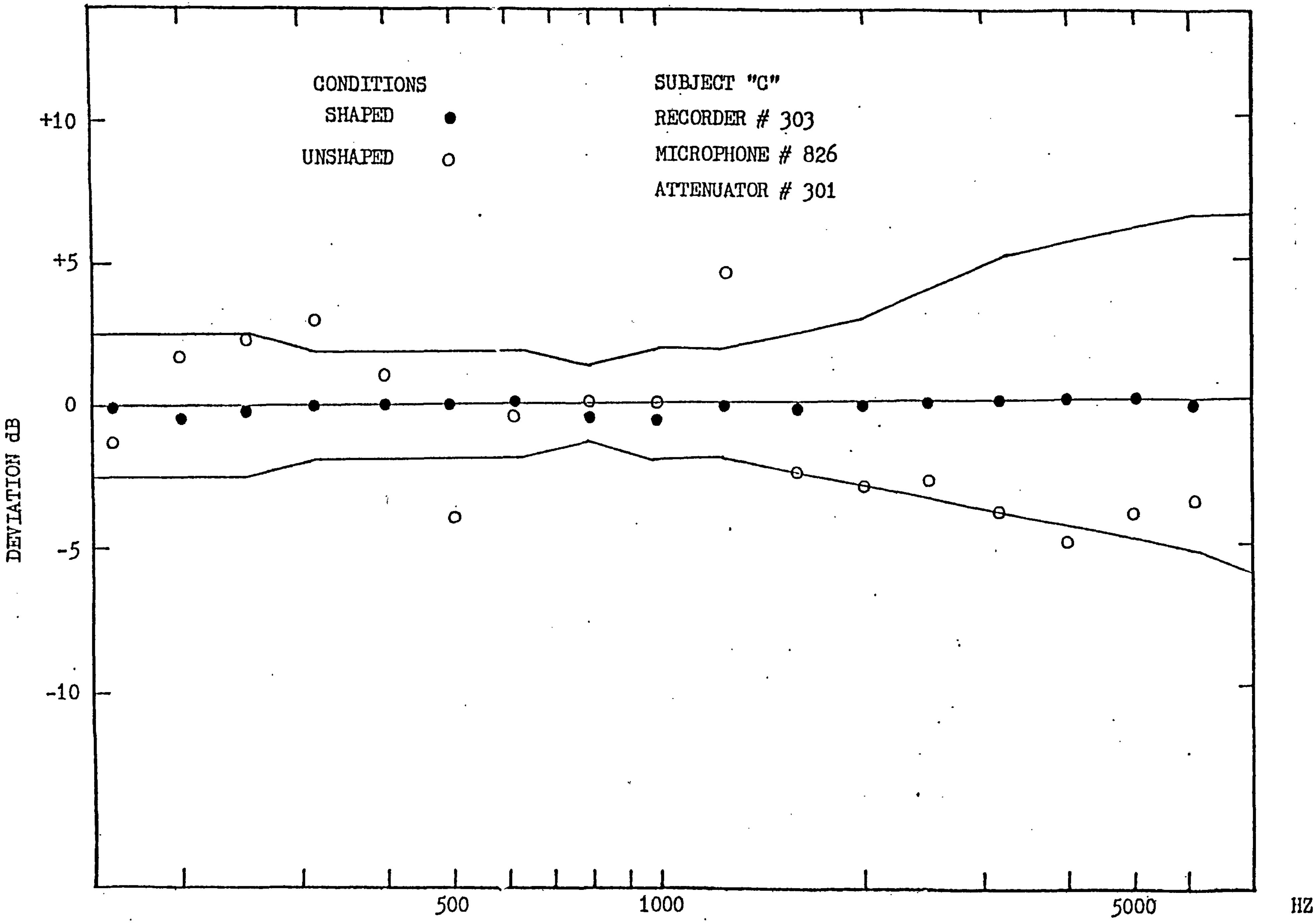


FIGURE FB8 - Narrow band frequency spectrum of shaped and unshaped frequency characteristics for a particular ear bug unit.

SUBJECT " C "
RECORDER # 303
MICROPHONE # 826
ATTENUATOR # 301

RECORDING NUMBER & DIRECTION	SIGNAL WITHOUT SHAPING (dB A)	SIGNAL WITH SHAPING (dBA)	DIFFERENCE (dBA)
27N	83.0	84.5	1.5
27S	81.5	83.5	2.0
28N	85.5	88.0	2.5
28S	85.5	88.0	2.5
29N	89.5	93.0	3.5
29S	88.5	92.5	4.5
30N	81.5	83.5	2.0
30S	79.0	81.0	2.0

TABLE TB1 - Sound level comparison of recordings with and without shaping.

VEHICLE	SUBJECT	L_{eq} HO	L_{eq} HV
1	A	95.0	93.0
1	B	95.0	95.0
1	C	91.0	92.0
1	D	91.0	92.0
2	A	92.0	89.0
2	B	84.0	92.0
2	C	--	--
2	D	92.0	91.0
3	A	94.0	93.0
3	B	90.0	89.0/93.0
3	C	92.0	90.0
3	D	88.0	91.0
4	A	94.0/91.0	89.0
4	B	93.0	90.0
4	C	91.0	86.0
4	D	89.0	88.0
5	A	94.0	93.0
5	B	94.0	90.0
5	C	91.0	91.0/89.0
5	D	91.0	91.0
6	A	96.0	91.0
6	B	95.0	91.0
6	C	89.0	88.0
6	D	89.0/90.0	89.0

TABLE TB2 - Equivalent sound pressure for highway testing. Summarized from table T2.

SUBJECT	VEHICLE	WIND (KNOTS)	STATIONARY RECORDINGS (NEUTRAL) CENTER OF HEAD (RPM/1000)					WITH VISOR (RPM/1000)					NO VISOR (RPM/1000)					NO HELMET (RPM/1000)					SYMBOL
			3.0	3.5	4.0	4.5	5.0	3.0	3.5	4.0	4.5	5.0	3.0	3.5	4.0	4.5	5.0	3.0	3.5	4.0	4.5	5.0	
A	1	2-4	80.5	85.5	85.5	86.0	88.5	76.5	79.5	80.5	80.0	81.0	75.5	77.5	79.5	79.5	80.5	77.5	81.0	84.5	85.0	86.0	▼
A	2	2-4	79.5	80.5	82.5	85.5	85.0	74.5	76.0	76.5	78.5	79.5	72.5	74.5	75.5	77.5	78.0	77.5	79.5	81.5	83.0	84.5	▼
B	1	2-4	80.5	85.0	85.5	87.5	88.0	77.5	80.5	83.0	84.0	84.5	77.0	80.0	82.5	83.5	85.0	80.5	82.5	85.5	87.0	88.5	◻
B	2	2-4	79.0	81.0	82.0	88.0	85.0	76.5	77.5	78.5	80.0	83.5	75.5	77.0	77.5	79.5	80.0	77.5	79.5	82.5	85.0	86.0	■
A	4	0-1						74.0	76.5	79.0	79.0	81.0	73.0	75.0	77.5	78.0	79.5	75.5	76.5	79.5	79.5	81.5	⊙

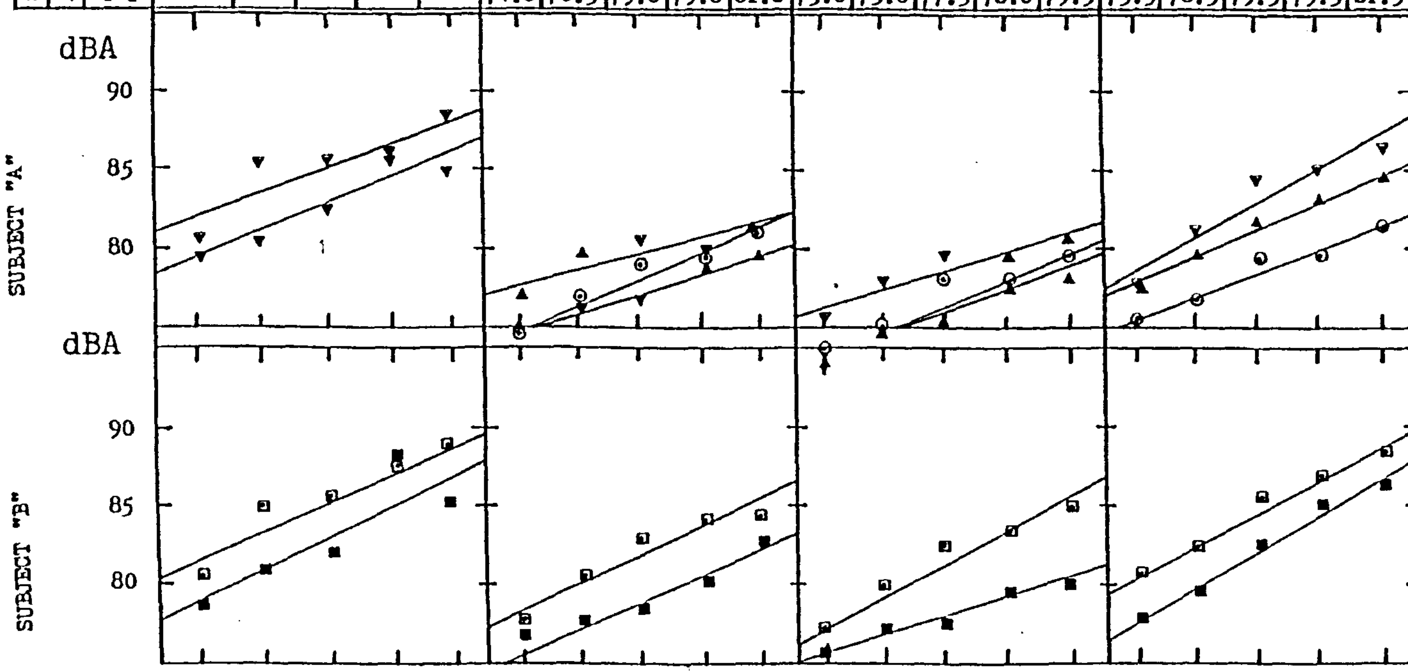


TABLE TB3 - Sound level data from auxiliary stationary testing.

STATIONARY				
VEHICLE	SUBJECT	NH(UP)	HO(UP)	HV(UP)
1	A	0.0042	0.0024	0.0019
1	B	0.0041	0.0039	0.0035
2	A	0.0035	0.0028	0.0025
2	B	0.0045	0.0023	0.0033
	VEHICLE	AVG.$_1$	AVG.$_1$	AVG.$_1$
	1	0.0042	0.0032	0.0027
	2	0.0040	0.0026	0.0029
	SUBJECT	AVG.$_1$	AVG.$_1$	AVG.$_1$
	A	0.0039	0.0026	0.0022
	B	0.0043	0.0031	0.0034

VEHICLE	AVG.$_2$
1	0.0034
2	0.0032
SUBJECT	AVG.$_2$
A	0.0029
B	0.0036

TABLE TB4 - AVG$_1$ and AVG$_2$ of slopes for stationary data (slopes based on dBA versus RPM . See table TB3)

MOVING				
VEHICLE	SUBJECT	NH(UP)	HO(UP)	HV(UP)
1	A	0.0043	0.0025	0.0028
1	B	0.0035	0.0025	0.0023
2	A	0.0070	0.0034	0.0034
2	B	0.0038	0.0025	0.0025
	VEHICLE	AVG.$_1$	AVG.$_1$	AVG.$_1$
	1	0.0039	0.0025	0.0026
	2	0.0054	0.0030	0.0030
	SUBJECT	AVG.$_1$	AVG.$_1$	AVG.$_1$
	A	0.0057	0.0030	0.0031
	B	0.0037	0.0025	0.0024

VEHICLE	AVG.$_2$
1	0.0030
2	0.0038
SUBJECT	AVG.$_2$
A	0.0039
B	0.0029

TABLE TB5 - AVG$_1$ and AVG$_2$ of slopes for moving data equivalent to the data of table TB4.

STATIONARY

VEHICLE	SUBJECT	NH(UP)	HO(UP)	HV(UP)
1	A	66.0	68.9	71.9
1	B	68.4	66.0	67.9
2	A	67.2	64.4	67.0
2	B	64.1	68.7	66.0
	VEHICLE	$AVG._1$	$AVG._1$	$AVG._1$
	1	67.2	67.5	69.9
	2	65.7	66.6	66.5
	SUBJECT	$AVG._1$	$AVG._1$	$AVG._1$
	A	66.6	66.7	69.5
	B	66.3	67.4	67.0

VEHICLE	$AVG._2$
1	68.2
2	66.3
SUBJECT	$AVG._2$
A	67.6
B	66.9

TABLE TB6 - AVG_1 and AVG_2 of zero-intercepts for stationary data.

MOVING

VEHICLE	SUBJECT	NH(UP)	HO(UP)	HV(UP)
1	A	64.0	66.2	66.0
1	B	67.5	67.7	70.0
2	A	56.1	60.8	61.4
2	B	63.8	64.8	64.8
	VEHICLE	$AVG._1$	$AVG._1$	$AVG._1$
	1	65.8	67.0	68.0
	2	60.0	62.8	63.1
	SUBJECT	$AVG._1$	$AVG._1$	AVG.
	A	60.1	63.5	63.7
	B	65.7	66.3	67.4

VEHICLE	$AVG._2$
1	66.9
2	62.0
SUBJECT	$AVG._2$
A	62.4
B	66.5

TABLE TB7 - AVG_1 and AVG_2 of zero-intercepts for moving data.

RUN NUMBER	VEH. NO. 1 KPH	VEH. NO. 1 RPM	VEH. NO. 1 GR	VEH. NO. 2 KPH	VEH. NO. 2 RPM	VEH. NO. 2 GR	VEH. NO. 3 KPH	VEH. NO. 3 RPM	VEH. NO. 3 GR	VEH. NO. 4 KPH	VEH. NO. 4 RPM	VEH. NO. 4 GR	VEH. NO. 5 KPH	VEH. NO. 5 RPM	VEH. NO. 5 GR	VEH. NO. 6 KPH	VEH. NO. 6 RPM	VEH. NO. 6 GR
1 5 9 13	35.0	5200	2	35.0	3425	2	35.0	4550	2	35.0	4100	2	35.0	3250	2	35.0	3125	2
2 6 10 14	50.0	5825	3	50.0	4000	3	50.0	4800	3	50.0	4300	3	50.0	3460	3	50.0	3350	3
3 7 11 15	65.0	6200	4	65.0	4350	4	65.0	5100	4	65.0	4525	4	65.0	3740	4	65.0	3550	4
4 8 12 16	80.0	6300	5	80.0	4675	5	80.0	5575	5	80.0	4750	5	80.0	3940	5	80.0	3725	5
17 22	17.2	4000	1	29.0	4000	1	21.0	4000	1	21.0	4000	1	26.0	4000	1	32.0	4000	1
18 23	26.5	4000	2	40.0	4000	2	31.0	4000	2	34.0	4000	2	44.0	4000	2	45.0	4000	2
19 24	33.8	4000	3	50.0	4000	3	42.0	4000	3	46.0	4000	3	58.0	4000	3	59.5	4000	3
20 25	42.0	4000	4	60.5	4000	4	51.5	4000	4	57.0	4000	4	70.0	4000	4	72.5	4000	4
21 26	50.5	4000	5	69.5	4000	5	58.5	4000	5	67.0	4000	5	81.0	4000	5	86.0	4000	5
27 30 33	11.5	3000	1	23.2	3000	1	16.0	3000	1	14.0	3000	1	19.0	3000	1	24.0	3000	1
28 31 34	17.2	4000	1	29.0	4000	1	21.0	4000	1	21.0	4000	1	25.0	4000	1	32.0	4000	1
29 32 35	23.2	5000	1	34.6	5000	1	26.0	5000	1	28.0	5000	1	33.5	5000	1	40.0	5000	1
36 37	80.0	6300	5	80.0	4675	5	80.0	5575	5	80.0	4750	5	80.0	3940	5	80.0	3725	5

TABLE TB8 - Vehicle performance data for specific test runs.

VITA AUCTORIS

1950	Born in Sudbury, Ontario, Canada on October 31st.
1969	Completed Secondary School at Sheridan Technical College, Sudbury, Ontario, Canada in June.
1973	Received Certificate from ASME for presentation at Regional Student Conference, Gannon College, Erie, Pennsylvania, U.S.A. in March.
1973	Received Bachelor of Applied Science Degree in Mechanical Engineering from University of Windsor, Windsor, Ontario, Canada in May.
1974 to 1977	Employed by Otis Elevator Co. Ltd. in Montreal and Ottawa, Ontario.
1980	Accepted into Ph.D. programme at the University of Windsor, Ontario, Canada.
1980	Currently a candidate for Degree of Master of Applied Science in Mechanical Engineering at the University of Windsor, Windsor, Ontario, Canada.