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A COMPUTER CONTROLLED SYSTEM FOR ASSESSING AND CLASSIFYING NOISE INDUCED HEARING LOSS.

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1. INTRODUCTION.

Screening audiometry is the audiometric procedure used to assess the levels at which an individual can hear single frequency stimuli (1). Original screening audiometry was a laborious and manual process which was highly inefficient when used as part of mass screening programs and so the automatic audiometer was developed to increase efficiency. The result of automatic audiometry is still an audiogram and requires the occupational health practitioner to spend much time analysing the resultant data and forces subjective judgements to be made as to whether hearing damage has occurred and whether a valid measurement has been made.

The 1980's can be said to be the era when the computer made its presence felt throughout British industry and with the advent of corporate occupational health systems then the automatic audiometer's role is long due for revision. A new audiometric device, the computer controlled audiometer will be described and its benefits for the audiometric practitioner will be highlighted.

2. INDUSTRIAL AUDIOMETRY : THEORETICAL BASIS AND ITS USES.

Hearing ability varies with frequency, and so most hearing tests are performed against a background of a controlled output and frequency spectrum. The output level varies with reference to an internationally defined reference zero (2) - 0 dBHL, which was derived from a test of a large group of young adults without hearing problems. IEC 645 defines minimum test frequencies for screening audiometers, though most industrial audiometers exceed these requirements to support analysis such as categorisation.

Industrial testing assesses the individual's response to pure tone frequencies, whereas in clinical situations tones may be superimposed to create masking of signals or signals applied via bone conductors to access the mastoid region of the ear. These latter procedures are intended to diagnose the nature and extent of a hearing defect, which is in stark contrast with industrial audiometry's purpose of highlighting problem cases - in essence a sieving process.

However, industrial screening audiometry differs from many other audiometric procedures in that

It is routine : tests are periodic.
The subjects are adults.
It may have financial and legal consequences.
It may have management implications.
It is intended to highlight a problem rather than diagnose the cause of difficulties.
It is repetitive, tests are repeated to look for deterioration.

THE COMPUTER CONTROLLED AUDIOMETER.

The principal aim of industrial audiometry is to detect the onset of noise induced hearing loss. This manifests itself as a "dip" in the hearing threshold at typically starting at 4 kHz (3).

Routine benefits of audiometry can be considered as providing an essential worker health check as the considerate caring employer will wish to minimise workplace related damage to his staff's health. Cynics may argue that recent interest in audiometry is more related to the insurance companies wish to mitigate their losses as the costs of hearing loss claims rise.

Irrespective of which view is taken then the use of routine industrial screening undoubtably has a part in a comprehensive hearing conservation program (4). Such audiograms may reveal whether personal protection equipment has been used correctly begging the question as to whether the problem arises from ignorance about how to correctly use such protection or deliberate negligence in not using protection provided or lastly, they could indicate the need for such protection to be used. Additionally, industrial audiograms may show whether the individual is unusually sensitive to noise, and may highlight the possibility of out of hours activities, such as shooting, contributing to his noise dose. Finally, industrial audiograms may be thought of a "stop-loss" precaution, whereby all new starters and those leaving employment are given pre and post-employment audiograms. This obviously establishes datum lines for future litigation and may spot undetected hearing defects unrelated to industrial noise.

3. THE COMPUTER CONTROLLED AUDIOMETER : DESIGN AND APPLICATIONS.

Whilst the development of audiometry has been outlined, a stimulus for the latest designs has been the growth in corporate worker health programs and databases allied to ever more powerful data processing techniques.

3.1 The Concept of The Computer Controlled Audiometer.

The computer controlled audiometer seeks to advance the practice of industrial screening audiometry by replicating the ease of use of automatic audiometers but enhancing their power by the application of powerful data processing techniques to remove the analytical burden and minimise doubt.

The basic requirement of any audiometer is to generate a test signal at a range of frequencies and output levels in a set of headphones. The patient then responds by using a response switch to indicate that they have been able to hear the tone or otherwise - using a manual audiometer the level is increased or decreased appropriately by the tester who also notes the level to result in an audiogram.

The automatic audiometer mechanises this process by adjusting levels in response to the signal from a patient response switch and compiling a real time plot of the audiogram. However, such a procedure still requires the resultant plot to be analysed to determine whether the test data is acceptable and to what degree hearing damage has occurred. Since such processes are essentially mathematical then implementation on a microcomputer is a logical extension in the evolution of industrial screening audiometers.

The computer controlled audiometer consists of a computer controllable audiometer, which

duplicates the functions of the conventional automatic audiometer with readouts of the level and frequency on its panel. This is linked via an RS 232 serial interface to any MS-DOS computer. The computer houses the analytical software and the audiometric records, and stores each reversal of the audiometer in the individual patient's record. This computer can then use an associated printer to provide a hard copy of the audiometric test and analysis data.

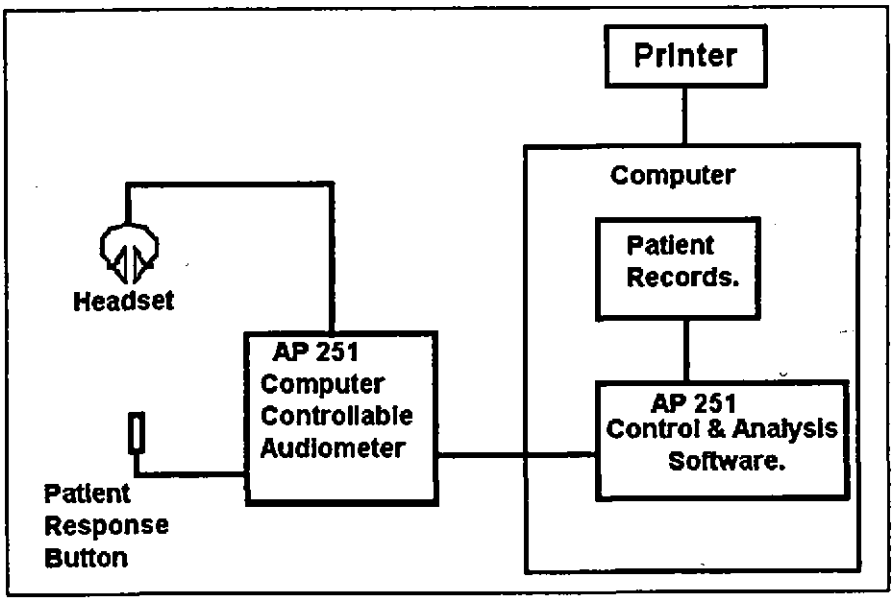

Figure 1 : Block Diagram Of Alfred Peters AP 251 Computer Controlled Audiometric System.

3.2 The Operational Benefits to the User.

For any new instrument to be useful, it must provide valued real benefits for the user and either provide a better method of deriving results or provide increased operational flexibility.

The principle benefits of a computer controlled audiometer are :

Totally automated testing.
Storage of test data for analysis.
Alternative representation of test data.
Analysis of audiograms to determine extent of potential hearing damage.
Determine validity of test data.
Ability to look back at previous tests to determine extent of deterioration.

THE COMPUTER CONTROLLED AUDIOMETER.

The computer controlled audiometer replicates the mechanised testing implemented on automatic devices, and whereas the automatic unit produces a real time plot then the computer controlled audiometer shows the data on a computer screen. The occupational health practitioner can view the test but there is virtually no possibility of the tested individual viewing the test's progress and resulting in fallacious data.

Additionally, an automatic audiometer produces the patient's audiogram by printing out data during the test and to reproduce these results, the audiogram must be photocopied. The computer controlled audiometer on the other hand stores the basic test data and is able to reproduce the test data on demand in one of three formats - disk storage, screen display, or hard copy on a printer.

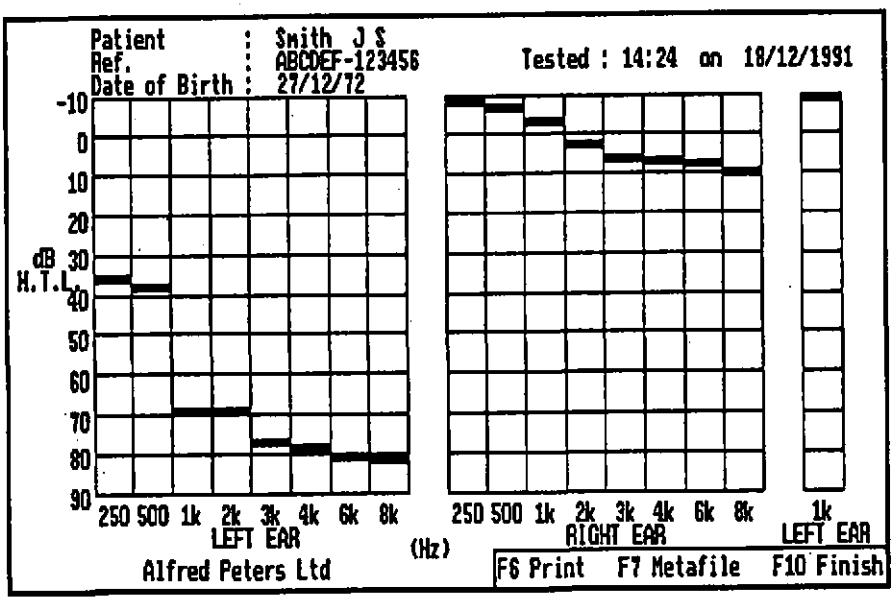

Figure 2 : Simplified Audiogram Showing Average Levels Only.

The simplest form of an audiometric test result is a simple plot showing the average hearing levels at each frequency. However, such data is normally shown in a different format when referring the subject for further investigation by clinical audiometricians (5). Since the data is digitally stored then re-presenting the test results is easily produced as shown overleaf :

3.3 The Analytical Benefits.

A computer controlled audiometer gathers the patient's audiometric test records and stores the

THE COMPUTER CONTROLLED AUDIOMETER.

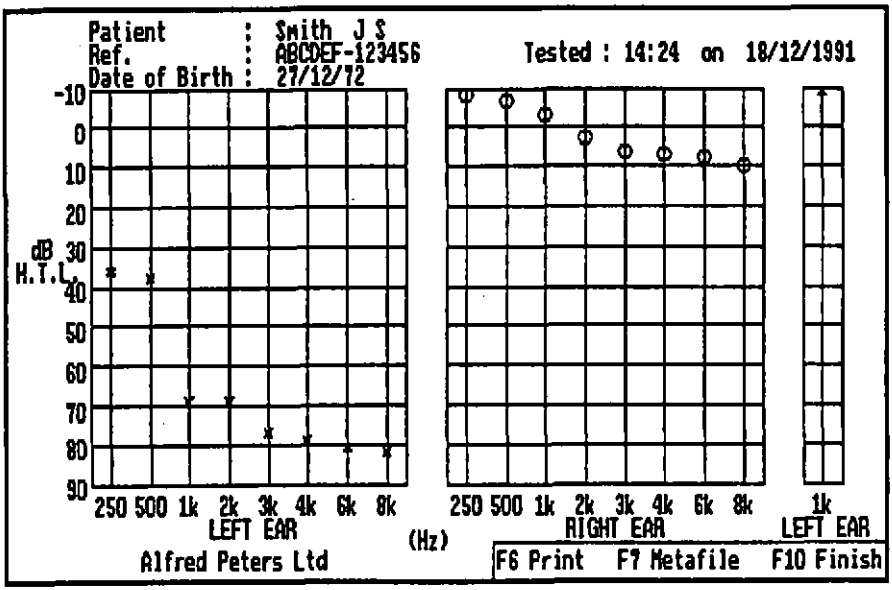

Figure 3 : The Same Audiometric Data Plotted In Accordance With The B.S.A.'s Guidelines.

base data on the computer's hard disk so alternative analyses can be performed on the data or alternatively, data can be represented in the differing forms shown above.

However, the power of a computer system lies in its data analysis capabilities, and so the audiometric data is analysed to provide two desired outputs: firstly, the audiogram can be categorised for hearing loss; and secondly, the test data can be analysed to assess whether a reliable hearing test has been conducted.

3.3.1. Categorisation.

Once an audiogram has been obtained, the industrial audiometric practitioner wants to know whether subject does indeed have a hearing defect, most likely resulting from noise induced hearing damage. The computer controlled system has a significant advantage when compared to automatic systems in its ability to recall a base population for comparison and categorisation purposes.

The base population currently used is that suggested in the Health and Safety Executive's suggested guidelines (6) and using this data base then the individual audiogram is assessed on the basis of the summed middle and high frequency hearing levels when compared to the reference

levels. If the tested individual's results show adverse result then warning or referral messages are automatically generated.

Age in Years.	Warning Level Middle Frequencies.	Referral Level Middle Frequencies.	Warning Level High Frequencies.	Referral Level High Frequencies.
20-24	45	60	45	75
25-29	45	66	45	87
30-34	45	72	45	99
35-39	48	78	54	111
40-44	51	84	60	123
45-49	54	90	66	135
50-54	57	90	75	144
55-59	60	90	87	144
60-64	65	90	100	144
65 +	70	90	115	144

Table 1 : HSE 's Suggested Categorisation levels of Industrial Hearing Loss.

At the same time the individual's hearing test records are compared with their previous test data to assess whether there has been significant deterioration, again in accordance with HSE's guidelines and problems are highlighted. Finally, the hearing levels between the left and right ears are compared and hence significant variations as may be caused by single ear problems are highlighted.

At this point it should be stated that much discussion is presently taking place following Robinson's (7) recent publication of an alternative reference population which accounts for sexual bias and could possibly be more meaningful in negating the extent of presbycusis in industrial audiometry.

3.3.2. Reliability.

The British Society of Audiology's code of practice (8) suggests an audiometric test may be deemed of an unreliable nature if:

(A) The test has less than six reversals (3 complete cycles).
(B) The peaks deviate by more than 10 Db among themselves.
(C) The valleys deviate by more than 10 dB among themselves.

As the audiometer is designed to perform all tests using eight reversals for each frequency then the

THE COMPUTER CONTROLLED AUDIOMETER.

first possible cause of unreliability is eliminated.

Each audiogram is easily analysed by the computer to assess whether either the peaks or troughs of any one frequency deviate by more than 10dB and should such an occurrence be found then it is highlighted.

A similar check is made to see if the repeated 1kHz left ear test deviates from the original by more than 5dB indicating inconsistent data possibly as a result of the patient misunderstanding the tester's instructions.

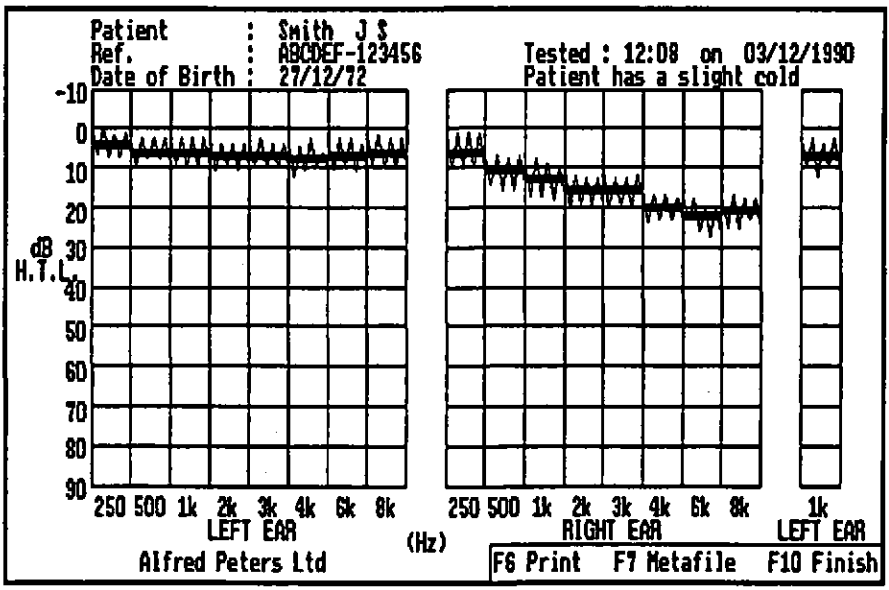

Figure 4 : Detailed Audiogram Showing Each Reversal During a Test.

4. FUTURE DEVELOPMENTS.

Since the system is essentially computer based, then its future developments may take five forms -

New modules geared to known problems such as vibration white finger.

Customised modules for research or investigative use.

Upgraded modules to reflect changing international standards or categorisation.

Alternative computer operating systems such as WINDOWS to increase such a system's implementation possibilities.

Clinical and diagnostic variants of the audiometer with compatible data files for ease of follow on investigations.

5. CONCLUSION.

A computer controlled audiometric testing system has been developed in the United Kingdom which the writers feel has advanced the science of industrial audiometry. This new system, the Alfred Peters AP 251 Computer Controlled Audiometer provides increased ease of use, less subjective and more objective hearing tests, and lastly incorporates enhanced presentation possibilities.

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