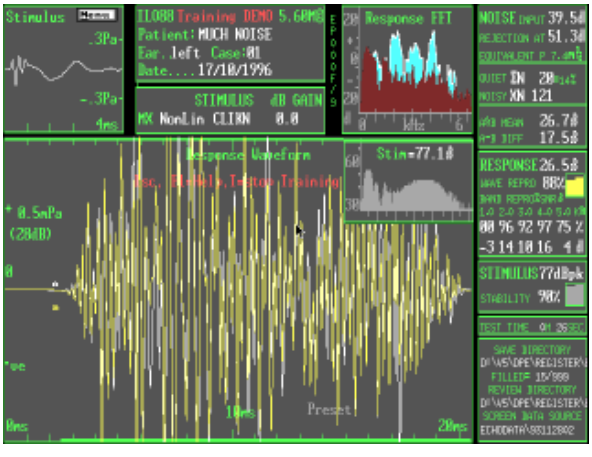
ILO OAE Instrument User Manual



TEOAE Measurements

- ILO88 & 88*i* Systems
- ILO88 & 288 Echoport

TE & DPOAE Measurements

- ILO88DP & 88DP*i* Systems
- ILO292 DP Echoport
- ILO92 System

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PART ONE

Introduction and Installation

Introduction : Otoacoustic Emissions

The basics

Otoacoustic emissions are sounds which can be recorded in the ear canals of functionally normal ears. They are the result of compressions and rarefactions of the air in the ear canal due to movements of the ear drum. Of course the ear drum vibrates as we speak and breathe and as our hearts beat. All of these movements result in sound which can be detected in the ear canal. Otoacoustic emissions are special because they result from ear drum vibration driven by the inner ear. Prior to 1977 no one suspected that ear drum vibration BY the cochlea was a part of the normal hearing process. We now know however that in order to achieve its exquisite sensitivity to sound the cochlea must actively manage the sound energy it receives and direct the individual frequency components to the appropriate sensory cells which lie along the Organ of Corti.

The flow of sound energy through the cochlea happens relatively slowly. The so called travelling wave takes a few milliseconds to travel the three centimetre or so length of the human cochlea. In this time, the external sound has travelled a further metre or more. Von Bekesy was the first to describe the cochlear travelling wave but he also noticed that it tended to die away before reaching its peak of vibration. More recent measurements in healthy live ears have shown that the travelling wave can build up as it travels to exceed the vibration entering the cochlea at the oval window by hundreds of times. This rapid build up in travelling wave energy is only found in healthy cochleas where the outer hair cells are in perfect condition. Any insult to the cochlea or disease tends to rapidly depress the travelling wave size. This leads to a decrease in sensitivity and elevation of hearing threshold.

It appears that the cochlea cannot completely contain all the energy from the enhanced travelling wave. A fraction of this wave scatters back to act upon the middle ear rather than the sensory cells. Although this is wasted energy from the point of view of cochlear function, it is extremely valuable in audiology because it gives us a way of detecting the presence of a strong travelling wave. As the scattered back travelling wave impinges on the oval window it moves the middle ear and consequently the ear drum. The oscillations of the ear drum move the air in the ear canal. This on its own would generate very little sound because the air can move freely in and out of the ear canal. When the ear canal is closed by the otoacoustic emission probe a substantial sound pressure is developed as the small trapped volume of air is periodically compressed and rarefied by the ear drum motion. Otoacoustic emission sound levels recorded in this way can sometimes exceed 30dBspl - an audible level!

Otoacoustic emission sounds have very particular characteristics which derive from their origin in the cochlear travelling wave. Firstly, as these vibrations derive from the original sound stimulus they are synchronised to it and contain the same frequencies as the stimulus. Secondly, as they originate from the slowly travelling wave deep within the cochlea they emerge with a delay or latency usually of several milliseconds. Finally, as the internal strengthening of the travelling wave is due to the action of the sensory cells within the Organ of Corti they exhibit the typical biological characteristic of non-linearity and saturation. This results in two important characteristics of acoustic emissions. The output strength of acoustic emissions is found to saturate with increasing levels of stimulation. For example with a stimulus level of 10dBspl the acoustic emissions level could be 5dBspl. If we now raise the stimulus level to 40dBspl we might find that the otoacoustic emission level had risen only to 15dBspl, a rise of only one third of the decibel input increase. This distortion of the relation between output and stimulus also occurs rapidly with each wave of the stimulus. The consequence of this is a distortion of the individual oscillations occurring in the cochlea and this generates inter-modulation distortions (similar to 'beats'). The emerging otoacoustic emissions therefore contain frequency components not presented to the ear but generated internally by a distortion process.

These characteristics of otoacoustic emissions help us to measure them efficiently and discriminate between otoacoustic emission sounds and other sounds of environmental and physiological origin.

What can we learn from OAEs?

Because otoacoustic emissions are a natural by-product of a strong cochlear travelling wave, their appearance in the ear canal helps us to confirm normal function of a large part of the peripheral auditory system.

Because we know otoacoustic emissions are presented to the ear canal through ear drum motion they confirm normal mobility of the entire middle ossicular chain. In contrast to tympanometry, the mobility of the oval window and the stapes is as important to the final result as mobility of ear drum; but OAEs are not a *measure* of middle ear function. They are a measure of the level of activity inside the cochlea related to the strengthening of the travelling wave. The presence of otoacoustic emissions therefore confirms that the general anatomical and physiological environment of the inner ear is able to function normally. This includes the Basilar Membrane, the structure of the Organ of Corti and the health of the outer hair cell system. The latter requires the endolymph to have been properly conditioned by the action of the Stria Vascularis. It is universally observed that otoacoustic emissions are depressed whenever the status of these systems is degraded. However, no way has

so far been found for differentiating between types of cochlear dysfunction or pathologies using otoacoustic emissions. The presence of otoacoustic emissions must therefore be seen as evidence for the functional integrity of the entire middle ear and cochlear system up to and including the outer hair cells.

A most important feature of otoacoustic emissions is their synchronisation to the stimulus. The OAE signal is highly frequency specific to the stimulating sound, in contrast to evoked responses of neural origin. This frequency specificity permits the use of powerful signal extraction and processing techniques which lie at the heart of otoacoustic emission instrumentation. It means for example that we can extract the multiple responses of the cochlea at a wide range of frequencies simultaneously by frequency analysis. We are not restricted to having to use pure tone or toneburst stimuli. We may use complex stimuli such as clicks and multiple tones to stimulate the ear and still extract the individual frequency components of the cochlea's response.

Otoacoustic emissions can therefore provide highly frequency specific information about the cochlear response. Laboratory studies have shown that the otoacoustic emission response of the ear to a particular frequency is largely generated in a place specific region of the cochlea. Clinical studies have shown that otoacoustic emissions fail to emerge at frequencies for which there is substantial hearing loss. Using otoacoustic emissions we can therefore map out the good and bad regions of cochlear function. This can be achieved with the presentation of either a complex broad band stimulus or a serially presented set of tonal stimuli. The good frequency specificity of otoacoustic emissions does not translate perfectly into a cochlear place specificity. The creation of the back scattered wave is a complex process. Furthermore, when we present even a pure tone to the cochlea the internal travelling wave stimulates a broad region of the cochlea - perhaps as large as 30% of the entire sensory cell population. It is incorrect therefore to consider that the use of precisely defined pure tones targets a precisely defined place or group of cells in the cochlea. Nevertheless it has been shown that there is a useful 'place specificity' of otoacoustic emissions which allows for a general correlation between frequency regions of otoacoustic emission activity and frequency regions of normal audiometric threshold, but *not* between the OAE levels and hearing threshold.

Although we cannot reconstruct the audiogram by using otoacoustic emissions, we can detect quite small changes in cochlear status. An individual's otoacoustic emission response is highly individual and very specific to the intensity and spectrum of the stimulus sound. If the latter two are kept constant then changes in the acoustic emission with time are a sure indicator of changes in the physiological status of the peripheral auditory system. This property has been used as a sensitive indicator of changes caused by noise or therapy on a patient's ear. However, it must be remembered that a change in otoacoustic emission is as likely to be caused by a change in middle ear status as by a change in cochlear status.

What can I NOT do with OAEs?

The presence of otoacoustic emissions cannot be used to infer functional normality of any part of the auditory system beyond the outer hair cells. The inner hair cells play no part in the generation of OAEs so far as we know. As the inner hair cells are the primary sensory cells of the inner ear, they largely determine hearing threshold through their synapses with the auditory nerve. While a strong cochlear travelling wave is a necessary ingredient for normal sensitive hearing, it is not sufficient in itself to guarantee that any hearing function occurs. A defective inner hair cell population or auditory nerve will result in a greatly elevated threshold even with strong otoacoustic emissions.

It is an accident of biology that the vast majority of sensory hearing impairments are located in the cochlea and negatively affect the function of the outer hair cell mechanism. Otoacoustic emissions therefore are successful in detecting the vast majority of sensory hearing impairment. They cannot, however, be used to predict the audiometric threshold of a patient. While the presence of otoacoustic emissions confirms normal function of middle and inner ears so far as sound vibration is concerned, their absence cannot be used to locate the nature of any disorder in the system. OAEs cannot be used to detect retro-cochlear disorder in normal clinical use. An ear with OAEs may also have a retro-cochlear lesion. An ear with a retro-cochlear lesion may or not have normal otoacoustic emissions. OAEs are therefore a valuable addition to the diagnostic process and not a replacement of previously trusted methods.

TEOAEs and DPOAEs - what's the difference?

The technical jargon sometimes gets in the way of the simple fact that the healthy inner ear produces OAEs and an ear with sensory hearing loss generally does not.

Of course, the middle ear has to be working efficiently if we are to see OAEs at all, so that OAE testing is really a test of the functional integrity of the whole peripheral auditory system, including the middle ear.

To test the ear with OAEs we must first give it a sound and it's here that the technical jargon begins! If we give it a brief transient sound, we can make use of the natural delay of all waves in the cochlea to pick out the cochlea's own sound from the stimulus delivered. This is an echo-sounding technique where we send a brief pulse of sound in and collect the delayed emission or echo from the ear. This turns out to be a technically simple task and is very sensitive to cochlea problems because we measure the response in the quiet period between each transient sound.

Alternatively, we can deliver a continuous sound to the ear and try to measure its continuous response. We can't use the natural delay of the ear as easily and so it is quite difficult to separate the continuous acoustic emission response from the continuous driving sound. It's quite easy to recover at least a part of the OAE by providing two continuous sounds at different frequencies. The saturating acoustic response of the cochlea (non-linearity) means that the emission is a distorted copy of the sounds presented. The distortion part can be separated by signal analysis and has been shown to behave very similarly to the whole emission when it comes to hearing loss. This by-product of the inner ear, or 'distortion product' otoacoustic emission, requires a higher complexity of equipment to extract but has potentially the same clinical value as transiently evoked emissions, so far as we know. There are differences, however, in practical terms.

Firstly, it's possible to deliver much more stimulus power with continuous tones than with brief clicks. This means that continuous tones can more easily be used to squeeze an OAE out of a less than perfect ear. This may seem like a disadvantage clinically but in fact many older adult ears have reduced OAEs above 3K and DPOAE analysis can be used to confirm that substantial useful function still remains. The lower sensitivity and higher specificity of DPOAE testing at levels of 60dBspl and above therefore complement the high sensitivity and lower specificity of the TEOAE method. When testing young ears, TEOAEs offer the ideal characteristics, whereas for testing older ears, TEOAE measurements should be followed by DPOAEs if the TEOAE response is deficient. TEOAEs are also more successful at recording low frequency responses below 1kHz owing to technical considerations. Balancing this, the DPOAE signal extraction method is superior to the TEOAE method above 4-5kHz and is therefore essential when screening for hearing loss above the speech range.

In summary, DPOAEs and TEOAEs are not different responses, but different technologies for response measurement. They each have their advantages and disadvantages with TEOAEs alone adequate for newborn screening work and a combination of TE and DPOAE more suited to clinical investigation with older age groups.

OAEs in service

Otodynamics OAE instrumentation

Otoacoustic emissions (OAEs) have become an important part of clinical audiology and paediatric hearing assessment. Around the world, hundreds of thousands of newborns are tested each year using Transient Evoked OAEs (TEOAEs) and Distortion Product OAEs (DPOAEs) and they are finding an increasing number of applications in diagnostic audiology and hearing research.

OAEs are the only objective indicator of cochlear status at the level of the Organ of Corti which is sensitive to small departures from normality. Depending on the level of stimulation and type of technique used, OAEs can detect hearing losses of between 20 and 30dB. Not only are OAEs highly sensitive to peripheral hearing loss, they offer the added bonus of frequency specific information. The TEOAE recording method has proved to be the most sensitive OAE technique and provides frequency specific information from 500Hz up to 5,000Hz. DPOAEs have slightly lower sensitivity but higher specificity and complement TEOAEs in the clinical investigatory environment.

OAEs were discovered in a Department of University College London, known as the 'ILO', in 1977. ILO otoacoustic emission equipment is available through Otodynamics Ltd., UK.

Otodynamics continues to lead the field in both technology and product quality. The 1997 range of OAE products includes fully integrated DP and TEOAE measurement systems in both battery portable and desktop formats. There are also a number of TEOAE-only systems which meet the needs of rapidly growing newborn hearing screening programmes both economically and effectively.

This manual

This manual contains important information on setting up and using your Otodynamics OAE instrument. It also contains important information about the background to OAEs and their interpretation and use, both for screening and as part of the audiometric test battery. (See Hardware Installation Manual).

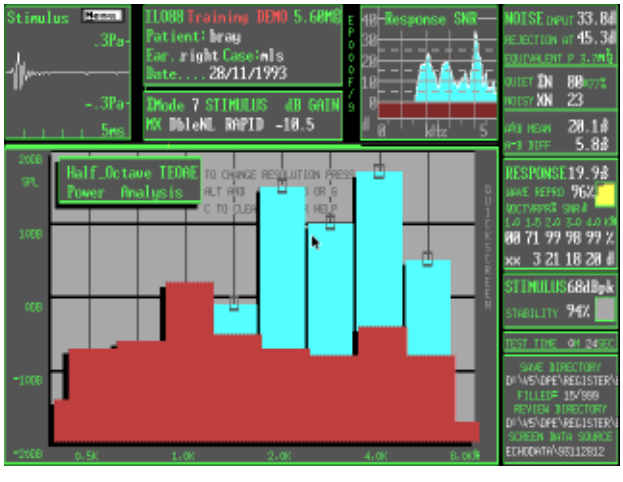
It is not the aim of this manual to provide a comprehensive guide to the clinical uses of otoacoustic emissions. The reader is referred to the growing body of literature on this topic. The primary aim of this manual is to ensure that the reader is able to conduct an OAE recording session and correctly identify the presence of otoacoustic emissions.

To make good OAE recordings some knowledge about the equipment and the behaviour of sound in the ear canal is essential. Like any physiological response measurement system, otoacoustic emission instruments can give misleading and sometime erroneous results if incorrectly used. Signals which superficially resemble real physiological signals but actually originate from non-physiological processes are called artefacts. Otodynamics instrumentation and software include a number of safeguards and protections against artefactual responses. Users should familiarise themselves with the characteristics of otoacoustic emissions, the characteristics of known artefacts and with the artefact detection and rejection facilities offered in the software.

Product overview

The first commercially available OAE system provided TEOAE measurement facilities only and was known as the ILO88. Today's TEOAE instruments are based on the ILO88 but there have been a number of important changes in the hardware which interfaces to the PC. This has been in response to developments in the construction and design of personal computers and has resulted in increased speed and also reduced dimensions. Otodynamics has re-engineered the ILO88 interface card, both to fit into today's smaller desktop computers and also to interface through the parallel and serial ports of today's laptop computers. Rapid development has also occurred in the software and memory capacity of personal computers. The ILO88 programme data has been revised to take full advantage of these changes but has remained compatible throughout. The Version5 ILO software described in this manual is capable of running all previous Otodynamics ILO88 hardware to its maximum capacity.

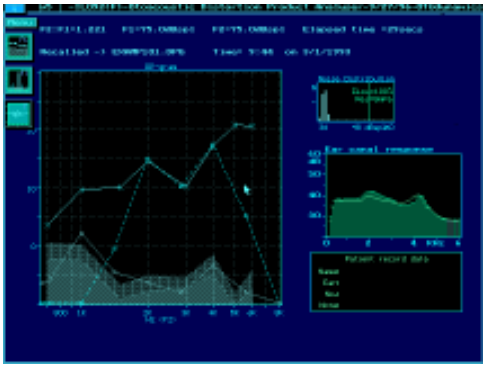
The products ILO88, ILO88*i* and ILO88 Echoport all reproduce the original ILO88 functions with the improved convenience and capacity of modern PCs. They provide TEOAE-only facilities and owners of these products should disregard sections of this manual dealing with DPOAEs.



The products ILO88DP, ILO88DP*i* and ILO292 DP Echoport also provide the

full TEOAE facilities of the ILO88 but in addition combine measurements of DPOAEs. The ILO88*i* unit may be upgraded to the ILO88DP*i* unit at any time.

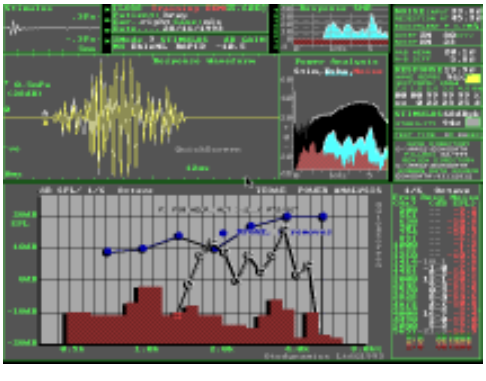
The ILO88DP series and the ILO292 DP Echoport instruments provide a unique combination of TE and DPOAE measurements which we believe will provide the user with the most comprehensive view possible of cochlear mechanical status available today.



Functional description

The ILO88 Otodynamics Analyser performs an auditory screening function by objectively testing for normal function of the combined middle ear and cochlea. The transducer assembly of the ILO88 is similar to that used for middle ear measurement in that it contains a loudspeaker for stimulus presentation to the ear and a microphone for measurement of the sound energy within the ear canal following stimulus presentation. A band pass filter is used to capture the appropriate frequency range for the test 500-6000Hz. However, by selecting and measuring only those signals *delayed by more than 2.5ms* after stimulation, the ILO88 is primarily sensitive only to sounds which have passed through the middle ear, into the cochlea and then returned. Non-linear signal processing can remove residual acoustic signals from the stimulator, ear canal and middle ear. The ILO88 therefore primarily tests cochlear status.

Although good middle ear status is essential for the passage of sounds to and from the cochlea, the ILO88 does not measure middle ear function and is not a tympanometer. The ILO88 performs the same function as an automated screening audiometer in so far as the system software identifies cochlear function based on a measured response to the given sound pressure level and stimulus frequency.



The delayed acoustic response of the cochlea measured by the ILO88 is commonly known as an otoacoustic emission.

Operational description

a) The ILO88 acoustic probe, fitted with a disposable plastic tip, is inserted into the patient's ear.

b) A standard click stimulus is applied and the resultant sound in the ear canal is displayed as a waveform and spectrum so that the operator can adjust the fit of the probe and ensure proper stimulation for performing the test.

c) Following the fit check, the test is begun. The preset stimulus is repeatedly applied and the delayed sound field in the ear canal captured, digitised and accumulated in the computer memory to enhance the detection of the small cochlear echo signals against the background noise.

d) On termination of the test the accumulated response is displayed as a waveform on the computer screen and also as a frequency spectrum for inspection by the operator. The responses are automatically tested for signal validity by methods of *non-linearity and reproducibility. The operator inspects the display for evidence of otoacoustic emissions at the frequencies of sounds delivered to the ear and for confirmation of valid test condition (e.g. acceptable levels of noise).

   (*Explanation of signal processing - Biological signals are intrinsically non-linear or saturating. Non-biological acoustic and mechanical responses are not. Also true responses to the stimulus are reproducible whereas noise signals are not. Hence the ILO88 software can identify true otoacoustic emissions and measure noise contamination.)

Interpretation of ILO88 results

The lack of a visible otoacoustic response in the waveform panel and the frequency response panel of the ILO88 display can be caused by blockage of the probe, blockage of the ear canal, excessive overlaid noise, middle ear dysfunction, or cochlear dysfunction. Lack of a response in the case of a properly functioning probe, properly fitted in a clear ear canal and with low background noise, indicates the need for audiological investigation of the ear to establish the cause of the dysfunction. A frequency analysis is provided of both the validated response and the noise energy present. This is useful in visualising otoacoustic responses in limited frequency bands. The activity level of the cochlea and the level of background noise is shown as blue and red respectively, permitting identification of the response at individual frequencies. An OAE at one frequency should not be taken as evidence of normal cochlear function at any other frequency. It is possible for low frequency background noise to make the whole OAE waveform unreadable but still allow the OAE response spectrum to show a strong indication of a cochlear response at higher frequencies. To summarise - the operator should examine both the waveform and spectrum for evidence of cochlear

responses across frequency. They should examine response reproducibility to confirm that response is true. They should observe the measured level of noise contamination before deciding if an OAE is absent (indicating further audiological investigation is necessary) or is simply obscured by noise (indicating that a re-test is required).

Detectable otoacoustic emissions on the ILO88 provide objective evidence of function of the cochlear mechanism and by implication also of the middle ear. Otoacoustic emissions are not normally present if hearing loss exceeds 20-30dB at the stimulated frequency. The absolute decibel level of OAEs is not in itself interpretable as it can be affected by probe fitting and insignificant middle ear factors. There is no particular waveform of OAEs which is right or normal. What matters is the frequency content of the waveform. This can be estimated by eye but is best measured by spectral analysis.

Indications for use

The transient otoacoustic emission test conducted by the ILO88 is useful when objective confirmation of cochlear function is required, as would be the case with the screening of infants (including newborns) and with other patients unable to co-operate with a hearing test, such as the mentally impaired or unconscious patient. It is also of use when it is necessary to know if a hearing impairment established by other means (e.g. by BSER or subjective audiometry) involves or is accompanied by impairment of cochlear function. Evidence of intact cochlear function in the presence of retrocochlear hearing loss can influence the management of patients undergoing diagnostic investigation, of candidates for surgery, and infants identified as needing amplification. The ILO88 is not useful in cases of middle ear pathology and failure to show an OAE can indicate cochlear OR middle ear dysfunction. The ILO88 is not useful in determining the level of impairment and is therefore best regarded as a frequency specific screener.

ILO V5 software overview

ILO V5 OAE software is a Windows 95 and MS-DOS compatible program with the capability of operating all previous types of ILO equipment to maximum capacity. Please see the section entitled Version5 Software Installation for details of how to install the program and also how to configure it to work correctly with your existing ILO system, if you have one.

V5 OAE facilities - a brief review

ILO V5 software provides advanced TEOAE recording facilities and, on suitable ILO equipment, fully integrated DPOAE recording. There is enhanced memory capacity so that up to 1,000 data recordings can be quickly reviewed and analysed with the software. TEOAE recording modes include the classic ILO88 mode, the QUICKSCREEN mode, which is being used to great effect in newborn screening programs, and a spontaneous OAE search facility which can be useful in distinguishing between noise artefacts and unusually high level OAEs obtained from some very active and healthy ears. One new feature of the software is the pre-programmed test termination facility, which allows the test sequence to be programmed to continually monitor all measurement and response parameters and automatically terminate the recording either if there are indications of technical inadequacy or indications of strong otoacoustic emission presence. This facility is automatically active on start up and uses information read from a 'stop logic' file. Two pre-programmed Stop files are provided, 'Manual' and 'Quick'. You may edit the **Quick Stop** protocol in order to gain familiarity with its behaviour. The protocol can be edited either from the second 'options' screen of the opening selection box screen, or from inside the ILO88 TEOAE program by selecting **STOP LOGIC** from the Settings menu. The STOP LOGIC file can be pre-selected from the STOP LOGIC box on the opening screen.

While exploring Version5 software, you may find it useful to press F1 for available help on the topic in question. While displaying the Stop protocol termination edit menu, F1 will provide a description of the usage of this facility.

Use of the automatic Stop system can aid in training and supervision in universal screening programs by setting limits to the duration and stimulus at levels during tests. More powerfully, by setting acceptable OAE levels for the specific program, tests will be terminated when adequate information is obtained, usually saving valuable time per baby by preventing unnecessarily long recordings. With care, the user may set the STOP LOGIC to indicate when the test result has satisfied the local screening criteria or if the infant needs to be tested further.

When a TEOAE recording has been automatically terminated, a message will briefly appear on the screen, giving the reason for test termination, e.g. 'good signal-to-noise ratio', or 'too much noise'. This message is saved with the data and is available for further inspection. It also briefly appears when the recording is retrieved from the data store.

Another useful new facility in Version5 in screening programs is the score logging system. Each time a recording is made, an entry is made in a log file by the name of 'Tested.log' and the contents of this file can be reviewed after a recording session by accessing the Score on the main opening box screen. When this mode is activated, a list is displayed containing one example from each case number or patient name. A case may be selected by pressing Enter and when this is done, the tests made on that patient's case appear in summary form. The best recording for one of the two ears is selected and the full data display is shown, along with a scoring tool bar. The data is evaluated by the doctor or audiologist as representing a pass, refer or a technical fail requiring a re-test, by pressing keys 1, 2 or 3, followed by Enter. At this point, a confirmatory identity number must be entered and then this score is saved in a file by the name of SCORE.LOG. The scored ear is then removed from the list. When the other ear of the patient has been the scored, the case is removed from the list. This proceeds until all cases from the tested list have been scored and transferred to the scored list.

The scores saved in the SCORE.LOG file (stored in the ILO-V5\ECHOPROG directory) may be printed as a short report using any word processor. The scored files can be transferred to a separate directory for archiving. This process is controlled using the back-up button on the main opening screen. This process of scoring was developed by Otodynamics originally for the HI•SCREEN program developed by the National Center for Hearing Assessment and Management. The facilities just described, however, do not themselves constitute the HI•SCREEN function. For further information on HI•SCREEN and linking the ILO system with the HI•SCREEN database, please contact the National Center for Hearing Assessment and Management in Utah, USA.

Making a TEOAE recording is simple with the ILO. Activating the **TEOAE** box on the opening screen will lead to the ILO88 display screen. (If you do not have active ILO hardware, you will be requested to confirm that the software operates in training mode. In this case, answer Yes, with **Y**, and you will be invited to load a sample recording).

Collect Preset Mode: This mode is set to the original ILO88 20ms sweep mode, but can be modified to refer to any of the other modes by pressing Control Return on that selection.

Original ILO88 Test: Performs a click-evoked, non-linear TEOAE measurement on a 20ms time sweep and is ideal for research investigations and for capturing the lowest frequency of OAEs.

QuickScreen: Uses a shorter timescale and a stimulus with medium frequency emphasis to obtain the fastest possible screening operation. The alternatives, accessed by K or W on this line, provide respectively a form of QuickScreen which saves the usually discarded linear component of the OAE and a modified low frequency boosted stimulus.

Tone Pip Stimulus: Provides a tone pip at the frequency requested and performs a tone burst OAE. The parameters of the tone pip may be modified with the third level ILO menu access by pressing **3** for the main screen.

SOAE Activity Check: Performs the search for spontaneous or lingering OAE activity, which is often a component of TEOAE activity and can be confused with noise artefacts.

Probe Cavity Test: Used to confirm the frequency response of probes in frequent use.

Linear Click: Provides a uniform click stimulus for accessing the whole OAE without non-linear processing (see detailed user instructions).

Non-Linear Click: Duplicates the standard ILO88 function.

Various facilities are available to view and analyse the recordings. Briefly, these are accessed by pressing F3 - this provides a frequency analysis with cursor. F5 provides a time analysis with the cursor. **H** provides a half-octave analysis of the response, cancelled by **W** to restore the waveform. **R** splits the screen, showing both the waveform and frequency analysis. Frequency analysis may be converted to one octave, one-third, one-fourth, one-fifth, one-sixth, by pressing the keys 1, 2, 3, 4, 5, 6 immediately after pressing **H**, or by pressing Alt 1, 2, 3 etc. at any time.

DPOAE facilities

On appropriate equipment, DPOAEs can be recorded. Press **D** from the Transient OAEs screen, or select the **DPOAE** box from the opening screen. The method of recording DPOAEs is described further on in this manual. Briefly, DPOAEs consist of acoustic emissions in response to two-tonal stimuli. These can have more intensity than the TEOAE click and therefore can evoke responses from weaker ears, but nevertheless give a useful identification of hearing impairment at peripheral level. DPOAEs are particularly useful in adult clinical investigations and where higher frequency information is required.

DPOAE grams may be superimposed on the patient's TEOAE grams. On terminating a DP measurement, pressing **T** will return to the TEOAE measurement if previously made. In general, DPOAE and TEOAE levels are similar and recordings take similar time, depending on the noise conditions. The ratio of DP and TEOAEs has not yet been explored.

Sample OAE data

A number of pre-recorded samples are included with this software. This can be accessed from the TEOAE screen by pressing F7 and from the DPOAE screen by pressing F3. Explore the variety of OAE responses which can be obtained and practice the manipulation of data by using the ILO facilities.

Real-time monitoring of TEOAEs

It is sometimes useful to quickly monitor acoustic conditions in the ear canal prior to making a test. From the main opening selection screen, select the **Viewer** box. This option requires working ILO hardware to be present. The ear is given a standard ILO88 click stimulus and if strong OAEs are present, they will be seen in real-time on the upper window. They can be copied for reference down to the lower window by pressing **S** and reproducibility can therefore be confirmed. While this is interesting for training or demonstration purposes and can detect strong emissions, it lacks the security systems necessary for diagnosis of hearing impairment and should never be used for screening and clinical purposes.

Version5 software installation

The installation software comprises four disks or one CD. It may be installed under DOS or Windows 95. We do not recommend installation under Windows 3.1 as this version of Windows has not proved a totally reliable means of operating the ILO high performance data acquisition hardware.

Installation under DOS

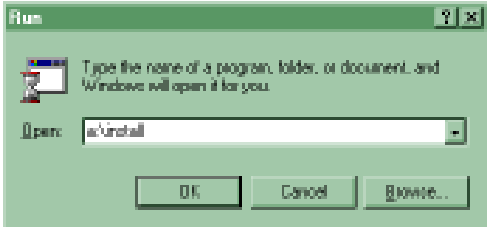
1. Insert V5 installation diskette 1 into the A drive of your computer.

2. To start the installation process, from the C prompt, type **a:\install** and press Enter. Then follow steps 3-7 below.

Installation under Windows 95

1. Click on the **Start** button and select **Run**.

2. If you are installing from **diskette**, insert disk 1 in the A drive, type **a:\install** in the window and press Enter, or click on **OK**.



   If you are installing from **CD**, place the CD in your CD-ROM drive and click on the **Browse** button. Select your CD-ROM drive, followed by **Install**.

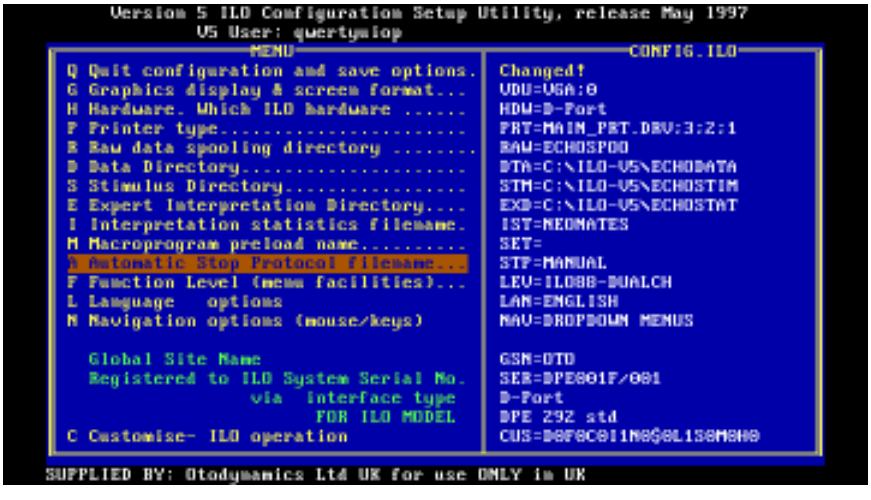
3. You will see an information screen describing the software version. When you have read this and if you agree to the conditions, press Enter. Otherwise, press ESC.

4. You will be able to select the disk drive on which the ILO software will be installed. The sub-directory is automatically named. To continue the installation, press Enter.

5. A number of files will now be copied to your hard disk which will take a couple of minutes. If you are installing from diskette, insert disks 2, 3, 4 etc. when requested and press Enter.

6. Installation is now completed.

   In the case of a **fully registered installation**, when you start the program for the first time, it will ask you to insert the Registration Disk provided with the software. This will fully register the system. The Configuration program will then be automatically run. You will probably be informed that automatic configuration is necessary. Accept this option by pressing the Enter key. Automatic configuration reads your registration file and sets the system configuration to look for and recognise your particular ILO system. It also enters the global site name which has been issued to you into the system. Configuration is also used to select the display screen and printer you will be using. After automatic configuration is complete, you will see the screen below.



In the case of an **provisionally registered installation** of the program, when you start the program for the first time you will be given the following options:

1. To load your registration file from a disk in drive A:
2. To enter your new registration details manually
3. To restore the previous registration stored in register.ilo
4. To continue using software and register later
5. To Exit the program now

When new registration details have been entered or loaded, the **ILOCFG** screen will then be presented, as shown above. If registration details are not loaded, an option to load will be presented each time the ILOV5 program is run.

After registration and automatic configuration, the **ILOCFG** configuration program can be recalled from within the ILOV5 program or externally by calling **ILOCFG** from within the ILO-V5 directory. The operation of ILOV5 can be customised using this program.

6.1 Select **G** to identify the graphics display; select option 3 for standard VGA graphics displays. If your system normally runs in SVGA mode, you may select option 5. If problems arise with this option on your machine, revert to option 3. The remaining options are included for compatibility with older software and will not normally be required. Option 1 (CGA) provides monochrome, low resolution graphics suitable for very old PCs.

6.2 When you have made your selection, you will be offered choices of screen colors. We recommend that you accept the standard option (0) and explore the other options at your leisure once you have become familiar with the ILO software.

Please note that the graphics choice becomes effective on starting the ILO program.

6.3 The line **H** identifies the Otodynamics hardware you will be using. If the software has already been registered to you, then this will have been pre-selected. Please check the entry.

A list of hardware is shown below:

1-Card Identifies the ILO88 XP, ILO92

2-Card Identifies the original ILO88 system, comprising two full-length expansion cards with desktop amplifier unit

E-Port Identifies the ILO88 and ILO288 parallel port interfaced products (Echoports)

CODECi Identifies the internally mounted ILO systems - ILO88*i*, DP*i,* TE*i* and 88DP*i*

1-88DP Identifies the ILO88 DP clinical desktop ILO system employing one full-length expansion card

D-Port Identifies the ILO292 DP Echoport battery portable TEOAE and DPOAE system

1DPT96 Identifies the ILO96 research OAE system with DPT desktop amplifier

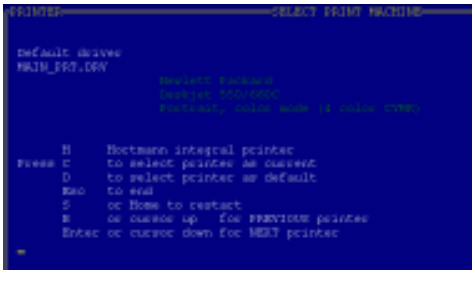
NoCard This option will not search for ILO hardware but will allow data to be examined and simulated recordings made for training purposes. This is useful if running the ILO software on a second computer for analysis purposes.

Other information about your registration is shown. The Global Site Name is incorporated in all data files and identifies your testing site. The serial number should be as marked on your ILO hardware. If your system is not working and the registration details do not match your installation, please consult your dealer.

6.4 Check the printer type shown:

e.g. P printer PRT=MAIN_PRT.DRV;0;0;0

To ensure that the ILO is configured for your printer, select the **P** Printer Type option. You will see the Select Print Machine screen. The properties of the current printer driver will be shown.



To change the printer, use the up/down cursors to find your printer or a related printer. Press **D** to select this printer. Select Standard print content (**0**). You will then be offered the Printer Port selection; enter **0** if you are using the standard printer port. The program will return to the opening screen.

6.5 Check the level of function. eg:

Level of Function (menu facilities) .. LEV=ILO88-DUALCH

For ILO88 systems for use in the USA and for general screening purposes, this should be set to Option 6 ILO88+SCREEN. For clinical and research systems, including DPOAEs, it should be set to LEV=ILO88-DUALCH.

ILO88 and ILO288 Echoport systems will not provide DPOAE functions, even if selected.

6.6 To exit, press **Q** followed by Enter.

6.7 The installation is now complete. You may return to ILOCFG at any time to make changes to the installation.

7. There are a number of other options available on this screen which you do not need to change until you begin to use the system. You can run the program ILOCFG at any time from within the ILOV5 program. The options available are listed below.

7.1 **R Raw data spooling directory**. This identifies the directory where raw data from a test may be saved. If left blank, raw data will be saved on ECHOSPOO, with the file extension .MEG. See Customise for how to enable raw data recording.

7.2 **D Data Directory**. This sets the directory where standard ILO data files are stored. If left blank, the directory ECHODATA is used.

7.3 **S Stimulus Directory**. This determines the directory from which custom stimuli are read. If blank, the directory ECHOSTIM is used. It is not usually necessary to make an entry here.

7.4 **E Expert Interpretation Directory**. This defines the directory where normative data profile are stored. If blank, the directory ECHOSTAT is used. Refer to Use of the ILO Statistical Analyser.

7.5 **I Interpretation statistics filename**. Enter the name of the statistical database file created by ILOSTATS for use with the OEG function of the analysis menu.

7.6 **M Macroprogram preload name**. Enter the name of the macro program library file to be automatically loaded with the ILOV5. Files beginning with the letters AUTO will automatically result in program 1 being run (included for compatibility with earlier versions).

7.7 **A Automatic Stop Protocol filename**. Enter the name of the protocol file you wish to use to control the test. The file may be created and edited within the ILOV5 program. A control is enabled using the Customise T option and if no name is entered, the file MANUAL is used.

7.8 **F Function Level (menu facilities)**. Controls the menu complexity and options available. Not every level can be used with all installations.

7.9 **L Language options**. Selects the language used on the main menus.

7.10 **N Navigation options (mouse/keys)**. We strongly recommend drop down menu option, which requires a mouse. The original 'keystroke' operation mode of the ILO88 can be selected for compatibility with earlier versions. The mouse can be used to navigate around the ILO program. The recommended mode is DROPDOWN MENUS. The current mode is indicated on the N Navigation Options line. Selecting this option will allow the choice of the original ILO88 hot key system (0), hot key control with the choice of mouse operation (1) and mouse operation with dropdown menus (2). The ILO software recognises the computer mouse, if one is installed on your PC. Its use in controlling the ILO292 functions is optional. The software may be completely controlled using keystrokes. These are identified in the User Manual and also by operating Help keys on important screens. The DPOAE section of the program accepts both keystroke and mouse operation, by default. The TEOAE section of the program offers two modes of operation, vis a vis the classic keystroke operated ILO88 mode or the V5 dropdown menu mouse operated mode. To change modes on the TEOAE program, you need to call **ILOCFG** from the DOS prompt.

7.11 **C** This allows various switches to be set for customised options of the ILO. Not all the options are available to all installations. On selecting **C**, the customising menu in seen. Options of general use are as follows:

A Turns on or off the ILO beep sounds.

H Enables measurements up to 8kHz on certain systems only. The function must be additionally enabled in the set-up options of the DP program.

I Performs a more rapid start-up by by-passing the opening screens, if the software has been recently accessed.

L Activates the interface with compatible databases such as Hi•Screen. In addition, it is necessary to select ILO+DATABASE. Access to HiScreen requires registration with NCHAM.

M Allows or inhibits mouse operation.

N Enables additional low frequency rejection during recording. This is useful when screening in noisy conditions.

O Automatically opens the ILO spool file which allows raw data from a test to be saved. This option requires substantial memory - only use it if advanced statistical processing is required.

P This controls the probe usage tracking system, which records the workload of each probe for warranty and service purposes. Currently, DP Echoport and TE, 88*i* and 88DP*i* systems are capable of automatic probe identification.

X Works in conjunction with P and sets the time between reminders to test the probe condition.

R This controls the automatic display of processed data during the test.

S Allows the original ILO file naming protocol to be used if required. The new protocol identifies the site in the name so that every test record is globally unique.

T Enables automatic test termination according to the conditions set out in the protocol file. The specific file should be named at the main ILO CFG screen, see A, Automatic Stop Protocol filename. The default protocol file MANUAL is used if no selection is made.

PART TWO

TEOAE User Manual

TEOAE functions of the ILO Version 5 software

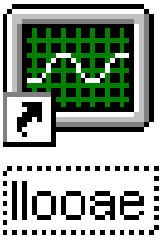
Running the ILO program

To run the program in DOS:

- Change directory by typing: **cd\ilo-v5** or the alternative you have selected during installation.
- Type **ILOV5** to start the program.

To run the program from Windows 95:

- Double-click on the ILOOAE icon.

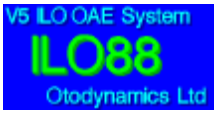


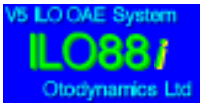
Windows will automatically open an MS-DOS application area which will close automatically when the program is terminated. Windows cut-and-paste utilities will not be available. You will be able to switch windows between the ILO and other programs, but we strongly recommend you do not do this while the ILO is actually collecting data as your computer may not have sufficient speed to service both applications.

An alternative way to run the ILO program from Windows 95 is to open an MS-DOS application area by selecting the MS-DOS prompt option from the Program list after pressing Start. Once in the MS-DOS area, proceed as for running under DOS.

If the program fails to recognise the requested hardware, a message will be issued (see Appendix 3: Error Messages).

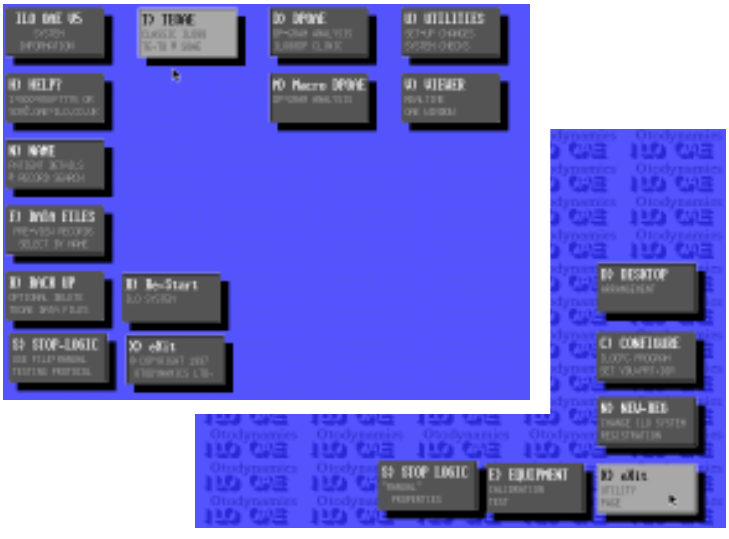
You will now be presented with your opening screen. The center panel will indicate the ILO hardware you have installed, as shown below:





If no hardware is recognised, the screen will default to the basic ILO88 format. This is quite normal if you are running the software on a second PC. If the software fails to recognise the hardware that you have installed, check that your hardware is correctly identified in the ILOCFG program.

Press Enter and you will be presented with the Options screen; selecting **Utilities** will show a second screen containing various set-up options.



The options screen provides the following selections:

System Information: Shows which products your release of the software can operate. It also shows the registered serial number and the unique three-letter site identification code allocated to your installation.

Help: Provides the Otodynamics telephone number applicable to your area.

Name: Allows entry of the patient's details before selecting TEOAEs or DPOAEs programs. After entering the patient's name, the current data directory may be searched for previous matching records.

Data Files: Provides a list and summary of TEOAE files. If a file is selected, it is temporarily loaded and displayed. The display is cleared by pressing the Enter key.

Back Up: Transfers files from the current TEOAE directory into the Back Up directory. The option to clear the current directory is given after copying.

Stop Logic: Selects the automatic test termination protocol for the TEOAE test. Please see **Menu** section for details.

TEOAE: Enters the ILO88 TEOAE program for data recording.

DPOAE: Enters the ILO DP program for recording.

Viewer: A utility for observing OAEs in real-time as a preview to full measurement. The Viewer detects only strong OAEs.

Utilities: This opens the second page of options.

Equipment:	This runs the system test program.
Configure:	Runs the ILOCFG program for customised options.
New-Reg:	Reads a registration file from a floppy disk in drive A. This may be required as part of an upgrade.
Stop Logic:	Provides a means of designing a test protocol file.
Exit:	Returns to the main opening screen.

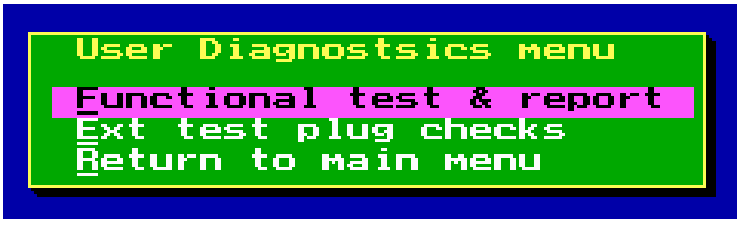
Restart: Restarts the Version5 program so that option changes can become effective.

Exit: Terminates Version5.

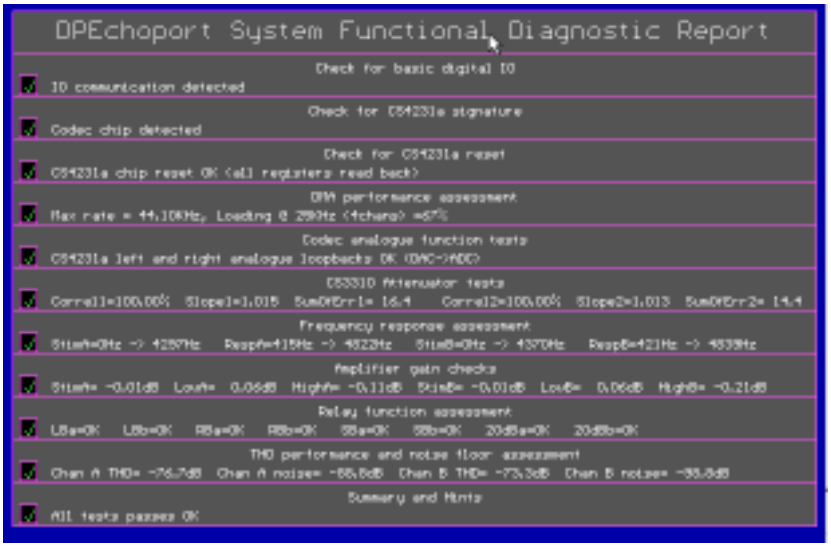
Running the test program

We strongly recommend that the ILO test program is run immediately following installation, to check that the hardware is correctly installed and calibrated.

1. From the opening Options screen, select the **Utilities** box.
2. Double-click on the **Equipment** box, or press **E** on the highlighted **Equipment** box.
3. You will see the opening screen of the hardware specific test program matching the hardware that you have installed. Follow the instructions.
4. Select the **Menu** button and then **User Diagnostics**, followed by **Functional test & report**.



The test is automatically performed on your hardware and the following report screen is shown:



This may take several minutes. Each function of the equipment is listed and ticked if correct. If a cross is seen in any box, please obtain advice from your Otodynamics distributor. You may be asked to examine an error log file or run additional tests.

On termination of the test program, you may have to restart the ILO program.

*NB: The test program for the two-card ILO88 must be run from the DOS prompt using the call **ILOTEST**.*

Opening up an OAE recording session

From the Options screen, select the **TEOAE** box. This will open up the ILO88 TEOAE screen. Enter the patient name, ear and case note identifier and then press Enter. The ILO will perform the acoustic probe fit test called Checkfit. A 'click' sound should be heard from the OAE probe and the top left panel of the ILO screen should register this click and other sounds made by the patient. To continue with the standard test, press Enter.

The DPOAE program can be accessed from the Options screen or from the TEOAE program by pressing **D** from the main display screen.

Mouse operation

The ILO software recognises the computer mouse, if one is installed on your PC. Its use in controlling the ILO292 functions is optional. The software may be completely controlled using keystrokes. These are identified in the User Manual and also by operating Help keys on important screens. The TEOAE section of the program offers two modes of operation, vis a vis the classic keystroke operated ILO88 mode or the V5 drop-down menu mouse operated mode. The mode of operation can be selected using the ILOCFG program - option **Navigate**. You may select **Option 0**, Original ILO88 Hot Key Menus, **Option 1**, Hot Key Menus or Mouse option, or **Option 2**, Mouse & Drop down menus. With Option 1, activate the mouse mode within the TEOAE program by clicking on the **Menu** button with the mouse. To revert to the keystroke mode, select **Toolbar off** from the **Options** menu.

Preparing for a TEOAE recording

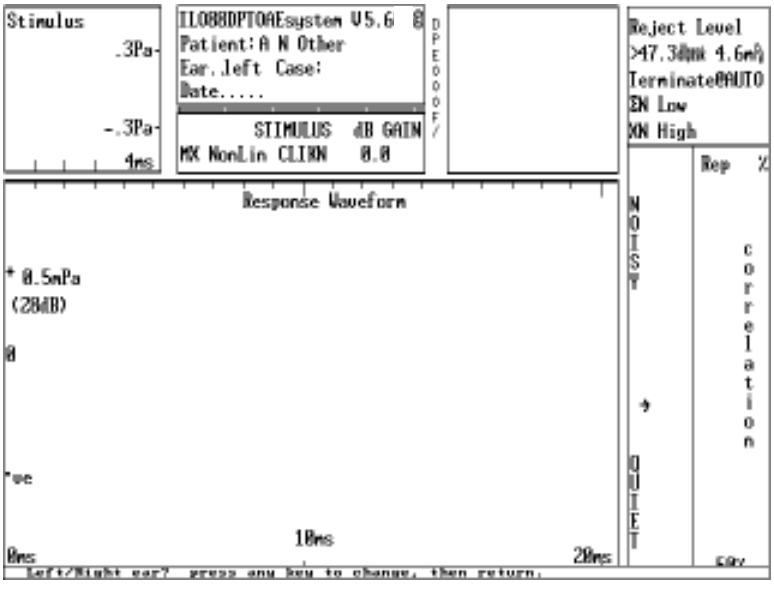
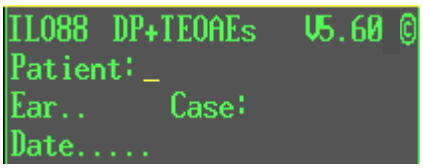


Fig 1

Figure 1 shows the opening screen of the ILO88 TEOAE system. Instructions are shown at the bottom of the screen. The cursor is set to receive the patient's name (maximum of 17 characters), followed by the Enter key. The left or right ear can be selected. Pressing any key will change the ear from left to right, or vice versa. Press the Enter key when the selection is correct. A hospital ID number or other information can be entered into the Case field. Entering a Case field is optional. If no patient name is entered, the test can proceed but a patient name will be asked for when the data is saved to disk. The date is automatically entered on completion of the Patient Name panel (fig 2) and is saved along with the TEOAE recording. It is important that the computer date is correctly set before using the ILO88.



Start subsequent test by selecting an option from the Test menu (right).

Fig 2

The Checkfit panel appears on completion of the Patient Name panel and is shown in fig 3. This stage of the test is to assist with the correct fitting of the probe in the ear and the setting of stimulus levels.

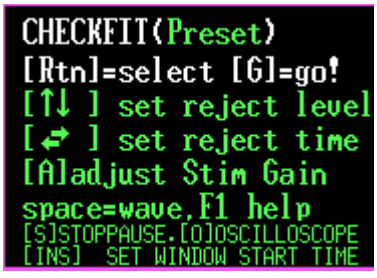


Fig 3

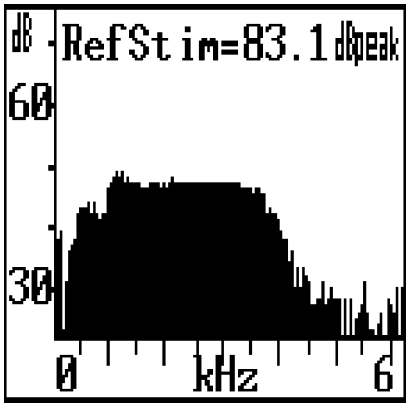


Fig 4

The Stimulus panel is active and shows the stimulus waveform being monitored in the ear canal. The panel gives real-time feedback so that the effect of adjustments to the probe can be immediately seen. If a click stimulus is being applied (this is the default stimulus) then the stimulus waveform should be as short as possible and normally less than 1ms in duration. Occasionally, the characteristics of an ear canal will distort the stimulus waveform - this is discussed further in the Advanced Testing Techniques section. This section also discusses the use of the Stimulus Spectrum panel (fig 4).

The Stimulus Confirmation Panel (fig 5) is seen below the Patient Name Panel. The purpose of this panel is to confirm the stimulus conditions. The default setting is for a non-linear stimulus of Name CLIKN for the standard (preset) TEOAE and DbleNL RAPID for the Quickscreen option to be presented with 0dB gain.

Fig 5

Fitting the OAE probe

A well fitted probe fulfils the following conditions:

(a) It seals the ear canal in order to convert the small movements of the eardrum into a pressure fluctuation which can be detected by the probe microphone.

(b) It excludes external noise from interfering with the recording.

(c) It provides a suitable acoustic environment in which the probe loudspeaker can generate the correct stimulus.

To achieve this, the probe must be fitted with a removable soft tip. The size of this tip must be selected after visually inspecting the patient's ear canal size. See the section entitled Otodynamics Probes and Accessories : Identification for a review of probe types and tips available. Probe tips should be discarded after use.

If the tip is too small, it may allow noise to enter the ear canal or distort the stimulus content. If the tip is too large, the probe will not penetrate sufficiently into the ear canal. This may result in a small response and instability of the probe during the recording. It may also not be possible to exclude sufficient noise if the tip is too large.

The tip should be fully fitted onto the probe. In the case of single round-hole tips, ensure that it is pushed on fully so that its surface is level with the sound tubes. Tips which extend beyond the sound tubes can introduce oscillations of the stimulus waveform.

When the probe is inserted into the ear, the end of the probe must not become pressed against the ear canal wall as this will impede the delivery of the stimulus and/or the recording of the OAE. This situation is usually obvious from the waveform in the stimulus panel.

The adult or child patient should be still, quiet and sitting comfortably. Ideally, the probe is pushed into the ear firmly so that it does not need to be held to stay in place. It is usually helpful to extend the pinna slightly. If this cannot be achieved, it is acceptable for the patient to held the probe, once fitted. The probe should not be fitted by the patient. By supporting the cable around the subject's shoulders, noise and any drag on the probe will be minimised.

To make TEOAE measurements on infants, the infant should be lying quietly. In the case of newborns, the ear canal can close as the probe is inserted. To avoid this, gently pull on the pinna towards the back of the head. Inspect the ear canal to see that it is open and, if so, insert the probe firmly. At insertion, it is helpful to position the probe so that the cable is directed towards the front. After insertion, and while still holding the pinna, rotate the probe so that the cable is directed 45 deg towards the top of the head. At this point, release the pinna.

The ears of newborns are frequently wet or contain debris. If a good stimulus and recording are not achieved on first insertion, remove the tip, together with any material it contains, and replace the probe after fitting a new tip.

Monitoring the probe fit quality

With the ILO88 in the Checkfit mode, the Stimulus panel displays the sound pressure being delivered to the ear canal. It is easy to detect common fitting problems using this display.

Fig 6 shows an oscillatory stimulus waveform. This is not ideal for TEOAE recording. In an adult ear it can be caused by bad fitting or by an atypical ear canal shape. In the latter case, the stimulus waveform has to be accepted but refitting should always be tried. Fig 7 shows a good adult probe fitting.

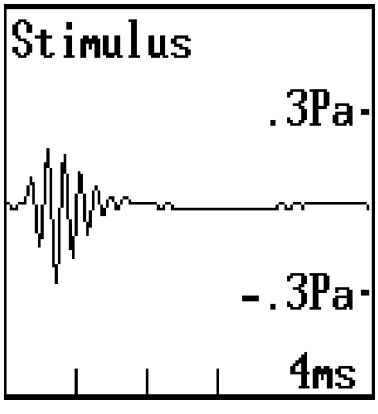


Fig 6

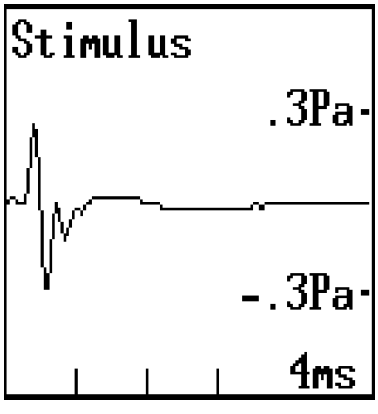


Fig 7

In the case of newborns, some oscillation is always found. Fig 8 shows an acceptable degree of oscillation in a newborn.

Fig 9 shows the effect of the probe coming too close to the ear canal wall or other obstruction. The characteristic of this condition is a slow, rounded, low frequency wave following the initial sharp peaks. The probe should be refitted if this is seen.

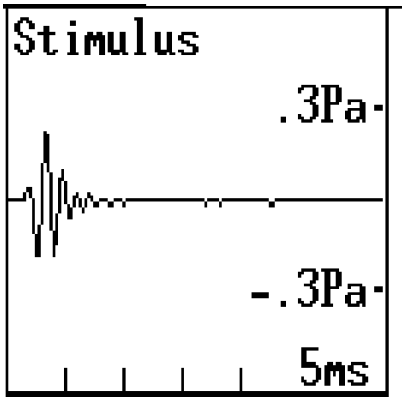


Fig 8

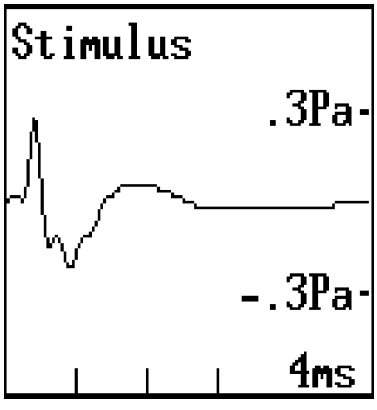


Fig 9

Fig 10 shows the effect of excessive noise on the stimulus waveform. This may be caused by a loose probe fit, allowing external noise to enter the ear canal, or by noises made by the patient. Patient noises are typically breathing, swallowing or teeth grinding. Some ILO instruments, e.g. the ILO292, include an audio monitor for tracing the origin of excessive noise.

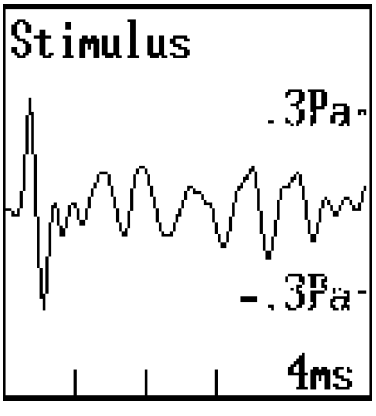


Fig 10

Monitoring the noise level

The ILO88 continuously monitors the level of noise being received by the microphone. Excessive noise can be seen on the Stimulus Waveform panel. Even small amounts of noise can degrade the quality of OAE recordings.

Incoming noise is analysed on the Noise Control panel on the right-hand side of the screen (fig11). The lower section contains a dynamically updated indicator bar which registers the instantaneous level of noise. If the bar reaches the upper part of the panel (marked NOISY) then conditions are unsuitable for making recordings. Provided the bar is not permanently at the top of the panel, it may be possible to record strong OAEs, given sufficient recording time. However, we recommend that the source of noise is traced and reduced.

Useful recordings can be made with the noise bar in the lower two-thirds of the panel. As the bar is updated, a record is left of the noise levels that have been encountered, in the form of a histogram. This allows the operator to assess the proportion of time when the patient/room is quiet.

The arrow indicates the maximum level of noise which is accepted for recording. This is adjustable by the operator. The arrow can be moved up and down using the cursor keys. The Reject Level is indicated in the upper panel in both the dBspl and sound pressure (milliPascals). If placed opposite to the maximum of the noise histogram, then approximately 50% of the sweeps will be accepted and 50% rejected. This is a suitable setting for medium levels of noise, i.e. 45-52dBspl pe (coloured light green through orange). For lower levels of noise, the reject arrow can be set to include two-thirds or more of the sweeps. This region is coloured dark green. If recordings are made in noisy conditions (red colour), the reject arrow should be set so as to accept only the small percentage of quiet sweeps.

As the test proceeds, the number of accepted (low noise) sweeps is shown as N low and the number of rejected sweeps as XN high.

When the probe fit and reject level are set, the Checkfit process may be terminated by pressing the Enter key. Additional facilities are available during the Checkfit process.

Fig 11

Additional features of Checkfit

The Checkfit panel indicates additional facilities of use for optimising recording conditions. These functions are called out on the Checkfit panel.

S
Pressing the **S** key will immediately stop the delivery of stimulus to the ear and freeze the Checkfit display. This is useful for example when a mistake has been made in the fitting of the probe and the operator must attend to the patient. With newborns who are becoming restless the brief cessation of the stimulus click may be helpful. Any key pressed after **S** will cause a resumption of the stimulus and the Checkfit process.

Space Bar
On pressing the space bar, an extended view of the sound waveform in the ear canal is obtained in the Response Waveform panel. This can be useful in identifying the nature and source of noises which are interrupting the Checkfit process.

O
Pressing the **O** key provides an extended display of the ear canal sound waveform. This serves as an oscilloscope and is useful for tracking down sources of interfering noise. The oscilloscope function is often useful at installation time where it can be used to identify interference of electrical origin from either the power supply or radio interference. Please consult your dealer if regular patterns of noise appear on this display even with the probe fully blocked by the finger. (The oscilloscope display is terminated by pressing the **O** key a second time).

A
Pressing the **A** key will display the Auto Adjust Stimulus panel. This panel is used to normalise the stimulus peak level in the ear canal to the recommended level for Transient OAE measurement (0.3 Pascals). The precise stimulus level is not critical for TEOAE measurements. This function should be used with caution since it is incorrect to adjust the stimulus to compensate for a bad probe fit. First optimise the probe fit using the default stimulus level and only after this is achieved press the **A** key on the Auto Adjust Stimulus panel. The stimulus gain will then be automatically increased or decreased to fine tune the stimulus level to the recommended value. The ILO88 adult probe is designed to give an acceptable stimulus in the average adult ear with the default stimulus gain settings. Similarly, the neonate probes are designed to give the correct stimulus level in the average newborn ear. When using these probes with adults or newborns respectively, it is not normally necessary to adjust the stimulus level. With infant or child ears the Adjust function is useful since these patients have intermediate sized ear canals.

Activation of the Auto Adjust key (**A**) leads to a termination of the Checkfit process and the presentation of the Test Select Menu (see below).

G
Pressing the **G** (GO) key allows the default ILO88 TEOAE test to proceed immediately.

Enter
Pressing the Enter key calls up the Test Option Select menu from which different stimulus patterns may be selected. The Checkfit process is always conducted with the standard click stimulus as the wide frequency band nature of this stimulus allows all aspects of ear canal and probe fitting characteristics to be displayed.

Cursors
The function of the UP/DOWN cursor keys has already been discussed. These are used to manually adjust the level at which noisy sweeps are rejected in the signal averaging process. The LEFT/RIGHT cursor keys have a specialised use in that they change the window over which noise reject assessment is made. Normally this should be as wide as possible and is preset to begin at 3.8ms from the stimulus. This setting usually succeeds in excluding any stimulus artefacts which may be of substantial level. In the case of other stimuli being used (e.g. Toneburst) or of an ear canal which cannot be optimally fitted and suffers from a recognisable stimulus artefact invasion into the response period then the LEFT/RIGHT cursor keys may be used to exclude this initial corrupted period from the noise response analysis. The new setting of the Reject Time Window can be made permanent for the session by pressing the INSERT key after adjustment. Please see the advanced usage section for further information.

Esc (Escape)
Pressing the ESCAPE key during the Checkfit process immediately terminates the Checkfit.

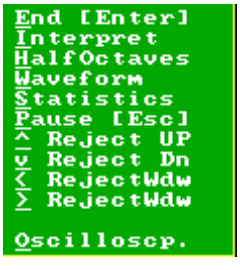
F1
Pressing the **F1** key calls up Help information on the Checkfit process.

Managing a TEOAE recording

To start a test, pull down the Test menu, select TE fullmenu for the full selection of TEOAE tests, or choose QUICK TEOAE, TonePip TEs or Spontaneous options. The Checkfit will commence, as described in the previous section.

After the Checkfit process, the Tests selection menu appears if you took the full TE fullmenu option. Otherwise, the preselected test will commence automatically.

The pre-set TEOAE recording mode is the original ILO88 mode which uses click stimuli arranged in a pattern to detect non-linear OAEs. Recording of TEOAEs commences immediately on termination of the Checkfit process with the 'G' (GO) key. If the Enter key is used to terminate the Checkfit process then a Test Option Selection menu is presented. Pressing the Enter key will select the pre-set TEOAE mode and the test will commence immediately. For information on the alternative stimulation modes please see Advanced Usage of the ILO88.



When the TEOAE test begins the Collecting Data menu is shown. The second line shows the selected option (default is 'pre-set'). The operator is provided with various facilities to assist in the optimisation of the TEOAE recording. These are as follows.

End [Enter]

The Enter key terminates the collection process. A single press will result in termination when the number of quiet sweeps collected reaches the next multiple of 10. This is recommended for normal termination. In the case that there is excessive noise and termination is not occurring due to rejects, then a second press of the Enter key will result in immediate termination of the collecting process.

Interpret

Pressing the **I** key interprets the data collected so far as a complete recording and displays this information graphically. This is useful in deciding whether the test should be manually terminated at any time.

Half Octaves

The **H** key function also interprets the data collected so far but differs from the **I** key function in that a half octave frequency analysis is displayed. This can be useful in detecting significant OAE responses in restricted frequency bands. This is normally useful when recording in less than optimal noisy conditions. The **I** key can be used after the **H** key to change the display back to the more common waveform display.

Waveform

The **W** key restores the normal waveform display monitoring.

Statistics

This displays a statistical analysis of the evidence for OAEs in frequency bands. Refer to the **Analysis** menu, **Statistics**.

Pause [Esc]

Pressing the Escape key pauses the data recording and provides options to go back to Checkfit (press **C**) or in advanced usage of the machine to compare the current fitting of the probe with the previous fitting (the **R** key). For information on the advanced use of the 'Retry Probe Fit Comparison' screen please see Advanced User Information. Briefly this function allows the probe fit to be monitored with great accuracy so that it may be returned to a previous position or the effect of different positions may be examined, for example during the training process.

Cursors

The UP and DOWN cursors change the Noise Reject level as described above. This is frequently used during a test to accommodate the range of noise presented by the subject.

The LEFT/RIGHT cursors change the window over which noise assessment is made. It is not normally necessary to adjust this.

Oscilloscope

The **O** key provides a real-time oscilloscope display of the current waveform in the ear canal. This can be useful in identifying the source and nature of interfering noise as described above. When using the live input display during the collecting process the UP and DOWN cursor keys can be used to change the viewing scale so that the nature of both very large and very small sound waveforms can be examined. Recording continues during the oscilloscope display. The display may be terminated by pressing the **O** key a second time. The oscilloscope function is not normally part of routine recording. It is useful when setting up the system, when training new operators and when investigating interfering noise. No clinically significant observations can be made from using the oscilloscope display.

Space bar

Pressing the space bar of the keyboard will briefly display the current waveform held in the signal accumulating memory. This waveform naturally grows as the test progresses and can be useful to provide an early indication of excessive noise or good response.

In addition to the monitoring of normal noise levels in the right hand noise panel the ILO88 detects the occurrence of excessive noise and flashes a warning (OVERLOADING check fitting and stimulus waveform) across the screen and sounds an audible warning of overload. (The occurrence of excessive noise can easily be due to the patient making a noise e.g. speaking or crying). Recording does not continue during excessive noise. This facility also acts as a warning if stimulation greater than 94dB is inadvertently applied to the ear. In the event of repeated overload conditions the test will automatically stop and the stimulus will be disconnected from the probe. This acts as a safety device.

The stimulus is continually monitored during the recording. The ILO88 performs brief Checkfit tests at intervals and refreshes the Stimulus Waveform display. This is useful to detect probe slippage. If the probe fit changes substantially, the filled circle in the stimulus panel changes to a hatched circle. If the change becomes major, an X is seen in place of the circle. Colour changes are also visible on a colour VDU.

After termination of the collection process the data is immediately analysed and displayed graphically on the screen.

Assessment of response during recording

Using the options above from the Collecting Data menu, the response can be assessed during the recording. Whenever the Interpret key is pressed all the panels are updated. This process happens automatically if the Refresh Rate is set to be greater than zero (Settings menu) or if Automatic Termination is set using the Stop Logic Protocol.

An additional panel is introduced onto the display at this time if the Band Set option is checked. The panel shows a measure of the statistical validity of the data in each frequency band based on the reproducibility of the data collected so far. This offers a reliable method for assessing the quality of the recording and the presence or otherwise of emissions which exceed the current level of background noise.

Alternative TEOAE stimuli

The ILO88 default stimulus is a click which has a broad frequency spectrum useful for evoking responses from the cochlea between 500 and 6,000kHz. The default sound delivered by the adult probe in the average ear results in a 0.3 Pascal peak stimulus (84dBspl pe). The stimulus is repeated at intervals of 20ms which allows enough time for acoustic emission for OAE responses to be returned from the furthest part of the cochlea (the apex). Such a long time interval is not necessary if response frequencies below 1kHz are not required. In newborn screening applications it is not normally useful to collect information below 1kHz (a) because the probe fit and the acoustic characteristics of the newborn ear canal result in an attenuation of these frequencies and (b) because the typical noise present during newborn screening is of low frequency and generally masks the appearance of OAEs below 1 kHz. If it is appropriate to miss the very lowest frequency OAE response then the stimulus rate may usefully be increased. This is provided for in the Quickscreen stimulus option.

The Quickscreen TEOAE stimulus utilises a repetition rate of 80Hz (12.5ms between stimuli). The increase in rate over the standard stimulus provides increased speed of data recovery. Furthermore, there is increase in data quality at high frequencies which normally emerge from the ear within the first 10ms. This is due to the removal of noise without signal which occurs at the end of the standard OAE sweep. (The same enhancement can be obtained by retrospectively windowing the first 10ms of the response as described in Advanced User Information. The advantage of the increased rate cannot be restored after the recording is finished). In addition to the increased stimulus rate, the Quickscreen stimulus has a slight redistribution of total stimulus energy to give a small boost (3-4dB) in the 2-3kHz region and a corresponding decrease in the energy provided at frequencies below 1kHz which are not useful at this stimulus rate. The Quickscreen stimulus was designed to achieve optimum results in newborn screening and was validated in trials at the Rhode Island Hearing Assessment Project at Women & Infants Hospital, Providence. Although designed for newborn screening, the test may be applied to adults' ears and can often succeed in identifying significant activity above 4kHz when this is not visible with the default mode due to noise.

One advantage of the TEOAE recording method using clicks is that all accessible parts of the cochlear response are tested simultaneously. Frequency analysis of the OAE after the recording allows responses at individual frequencies to be identified. However, it is sometimes necessary to restrict the stimulus band width and this is achieved by replacing the click stimulus with a short Toneburst. Obviously in the case of a

toneburst stimulus responses can only be recorded within the band frequencies provided by the stimulus. However there are two advantages in making this change:

(a) The TEOAE test can be conducted at a specific band of frequencies to match data available from electrical evoked responses on the same patient. The ILO provides facilities for tailoring the Toneburst stimulus to match that available on ABR diagnostic instrumentation.

(b) If no response is obtained in a significant frequency range using the click stimulation method then Toneburst stimulation at the frequency of missing OAEs can be used to confirm their absence. Delivery of a Toneburst stimulus at the same peak level as the click stimulus (0.3 ta) maximally stimulates the relevant region of the cochlea providing the maximum chance of observing any OAE response present.

The Toneburst stimulus option is available on terminating the Checkfit process. On selecting the Toneburst option the centre frequency of the Toneburst must be entered and the test proceeds normally. The final result displays the limited region of stimulation and the Toneburst stimulus waveform so the interpreter is in do doubt that Toneburst stimulus has been used. If it is required to match the Toneburst profile with that of other equipment used in diagnostic evoked response measurements, this is available at the stimulus wave menu item. It is not normally necessary to change the Toneburst stimulus wave envelope and this should be undertaken only by persons familiar with the significance of stimulus signal characteristics. The ILO88 contains controls which inhibit the use of stimuli which may lead to misleading or artefactual results.

The Test Stimulus selection panel provides the opportunity to select both linear and non-linear click stimuli. Non-linear stimulation presents a balanced set of stimuli of both positive and negative polarity which automatically cancels proportional acoustical responses such as are obtained from the middle ear system in the early portion of the sweep. The use of non-linear stimulation provides a robust TEOAE test which rarely contains stimulus artefact signals. A disadvantage of this method is that a proportion of the genuine TEOAE is also rejected, resulting in a reduction in signal-to -noise quality and a corresponding decrease in test specificity. The experienced user may select linear stimulation to obtain a higher signal quality and greater specificity. Considerable caution is needed however, since the operator must now visually recognise the appearance of any stimulus artefact in the earlier part of trace. This is quite characteristic and consists of an oscillatory signal dying away rapidly in the first 3-6ms of sweep. OAEs present will extend beyond this interval and across the screen. Examination of the linearly derived TEOAE can be useful in confirming otherwise uncertain evidence of OAEs by experienced users. The method is considered to be safe when used with stimulus levels around 10dB below the default level. The data should be disregarded when the Checkfit stimulus waveform exhibits a long oscillatory form.

Response validation

The ILO88 incorporates a number of features to ensure that your artefacts are excluded from the recorded data. These features include the noise reject system, the low frequency cut filter, the data window, which excludes stimulus oscillations from the response and the non-linear detection system.

The ILO non-linear detection system relies upon a special stimulus pattern consisting of three positive-going clicks, followed by one negative-going click of three times the intensity. The response to each of the four clicks is added into memory. As a result, any response component which is accurately proportional to the size of a click stimulus becomes cancelled. This includes most of the stimulus signal and the response of the middle ear system, which are thereby eliminated from the recording. A proportion of the OAE response is also eliminated. This sacrifice of signal quality is considered worthwhile, particularly when recording from adult ear canals, which can create oscillatory stimulus responses which otherwise might be confused with an OAE. The experienced user may select the linear stimulus option to record the whole OAE signal, but must exercise caution not to accept responses of low latency which may be caused by extended oscillation of the stimulus in the ear canal. This is particularly important when the Checkfit process shows an unsatisfactory probe fitting or when higher stimulation levels are used.

A number of other possibilities exist for artefactual signals to be present in the final response, although this is rare. If a very low number of sweeps are used, it is possible for background noise to pose as an OAE. This is due to the variable statistics of short noise samples. For this reason, sweep numbers less than 60 are not recommended. If data can only be recorded in shorter sections, these should be compared to ensure that the suspected OAE signal is reproduced on all recordings.

Background noise may have tonal characteristics which prove more difficult to eliminate by signal averaging. It is possible for the tonal noise to be partially synchronised by chance to the ILO instrument. When this occurs, a regular oscillation can be added to the OAE response and a corresponding peak can appear in the OAE spectrum. If accidental synchronisation occurs, the tonal interference noise can appear as a validated blue peak. Characteristically, it will appear red on the subsequent recordings. We recommend the following procedures to guard against this form of artefact.

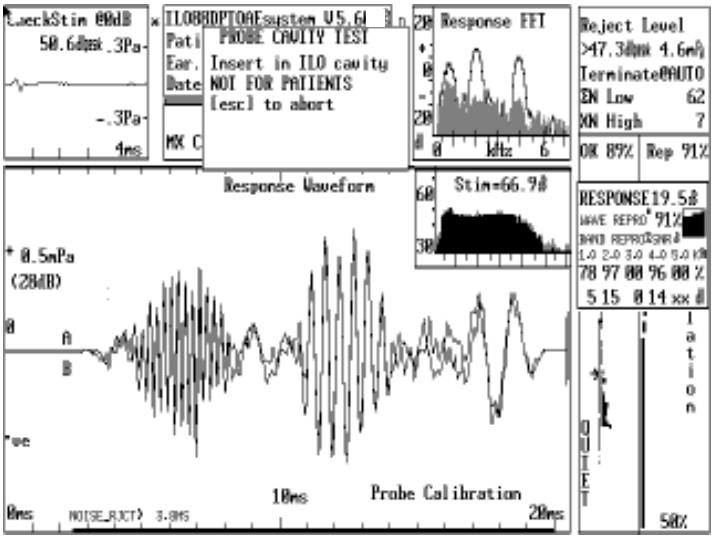
Firstly, the noise present in the test room should be regularly analysed. This can be achieved by making an OAE recording with the probe open to the room. If the noise level prevents this recording, then it is too high and must be reduced by acoustic treatment. When a test is possible, the oscilloscope option during the Checkfit process should be used to examine the waveform of the room noise. Periodic patterns generally indicate electrical interference, which needs to be eliminated by proper grounding of the instrumentation. The acoustic noise in the room will also be seen. Acoustic noise may be distinguished from electrical noise by blocking the probe firmly with the

finger. This should eliminate all acoustic noise. When the full TEOAE test is completed with the open probe, the presence of high peaks in the noise spectrum will become evident. Acoustic treatment is necessary to eliminate these.

Occasionally, infant ears can contain their own continuous tonal background interference. These are known as spontaneous otoacoustic emissions. They can exceed the size of stimulated OAEs. They are visible as sharp peaks on the OAE response spectrum and as a uniform oscillation right across the Response Waveform panel. Spontaneous OAEs can therefore appear to be acoustic interference. To distinguish between SOAEs and acoustic interference, the SOAE Check option should be selected. This repeats the TEOAE measurement with a reduced click stimulus and registers only OAEs which are sustained for long periods after stimulation (the click rate is reduced by a factor of four and data is recorded from 20 to 80ms post stimulus time). Since spontaneous OAEs are readily synchronised with this stimulus and external interference is not, true spontaneous OAEs can be recognised by the instrument and be distinguished from noise. The normal waveform response panel is filled with a noise analysis panel showing the spectrums of true noise and true SOAEs respectively. The latter are coloured blue. TEOAE data can be accepted if SOAEs are confirmed as the cause of the unusual waveform and spectrum.

System checks

A special test program is provided for thorough checking of all parts of the electronic system used for OAE recording. Use of this is described in the installation section. It is, however, useful to be able to check the proper operation of the system when in use and this is provided by the Probe Check option. The Probe Check option, which is available after completing a Checkfit process, is intended for use with the test cavity provided with the ILO system. The probe is inserted in the test cavity and its correct fitment is monitored during the Checkfit process. When the Probe Check option is selected, a synthesised OAE signal is delivered to the cavity via the probe loudspeaker and collected by the probe microphone. If all is correct, a recognisably artificial OAE response is obtained, consisting of three Tonebursts distributed across the screen. This test is used to check every Otodynamics probe before despatch and a printout of the response is provided with each probe. If the test OAE is not obtained, the system must be considered as defective. If the pattern obtained is markedly different from that delivered with the probe, then a deterioration of the probe response must be suspected. In the case of suspected system failure, the Otodynamics test program should be run on the instrument. In the case of suspected probe deterioration, the probe should be visually examined and cleaned to remove debris and re-tested. The probe must be disconnected from the system before cleaning or servicing; see the instructions supplied with system and probe.



Instrument calibration

The operator of ILO equipment should be familiar with the instrumentation test program. Details of this are shown in the installation booklet for your hardware.

There is a Probe Test option on the ILO menus, which allows the current probe to be evaluated, assuming that the instrumentation is working normally.

There follow instructions for performing a calibration of the ILO system.

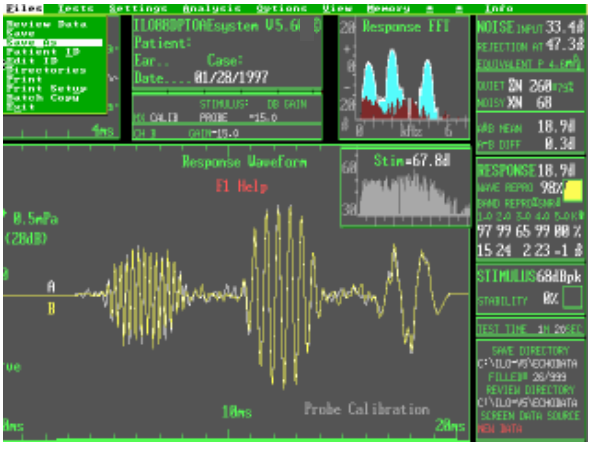
The test program should first be run and, if completed satisfactorily, this confirms that the internal circuit is working correctly. This test automatically confirms that the correct amplification is present in each section of the system.

The test program does not perform tests on the OAE probe. This is performed using the ILO88 OAE measurement program.

Probe condition

The probe to be tested is fitted into the probe socket and the TEOAE program started. The probe is fitted into the 1cc acoustic calibration cavity. A Checkfit can be performed at this stage as if beginning a patient measurement. On closing the Checkfit process, select the **Probe test** option from the **Collection** menu. Confirm the type of probe being tested and continue with the test. The probe test injects an artificial OAE which is recorded on the screen as a series of three oscillatory tone bursts at 700,

2,000 and 4,000 Hz respectively. A typical probe response is shown below:



A copy of the probe test performed at the time of manufacture accompanies every probe. We recommend that you perform and print a probe test on your equipment on first receiving the probe and retain this for later comparison. Substantial changes (>3dB) on any tone burst may indicate contamination of the sound tubes, deterioration of the probe transducers or incorrect fitting into the test cavity. If, on cleaning the probe and properly fitting it into the cavity, substantial deterioration of performance is seen, the probe should be replaced. Contamination typically reduces the higher frequencies first, loose coupling to the test cavity can reduce the low frequency response and may artificially enhance the middle frequency response.

While the above test is useful, it is unable to distinguish between changes in the performance of the microphone and the loudspeaker. An independent external calibration should be performed at least annually when your ILO292 DP Echoport is serviced, or at any time.

Two methods are provided for externally validated calibration of the ILO sensitivity - a quick check and a detailed check. In both cases, the DP Echoport itself is used as a sound analyser and known sounds are presented to the instrument via the acoustic probe.

In the quick method, the probe should be placed in a known sound field of 84dBspl ($0.1N/m^2$) at 1kHz. Such a field may be obtained from a hearing aid test system or, alternatively, with the use of a freefield audiometer. In the latter case, a sound level meter is needed to set the sound field to 84dBspl. This should be set with the OAE probe already in position next to the sound level meter microphone. Care should be taken that no movement of personnel in the room occurs during the subsequent measurement.

With the external sound field applied, and with the software performing the Checkfit process, the stimulus window should show a sine wave peaking at +/- 0.33Pa. This level is marked by check marks on the side of the stimulus window box. Production tolerance allows for a +/- 2dB variation in probe performance which equates to a +/- 20% deviation from the calibration marks. If absolute calibration of OAE levels are required, a small correction can be computed from the actual level shown in the stimulus window. It should be noted that the microphone sensitivity may change with frequency and it may be required to repeat this test at higher frequencies.

For a thorough analysis of the ILO acoustic sensitivity through any probe, the detailed calibration options should be selected. With this option, the ILO screen shows a spectrum analyser display which records all sounds presented to the probe. The provision of an external sinusoidal tone will result in a peak appearing at the appropriate frequency on the ILO screen. The nominal intensity of the sound according to the present calibration will appear above the peak detected. On pressing the space bar, the user is able to enter the true sound pressure level as indicated by their own acoustic instrumentation. On pressing Enter, this value is saved in a file against the identity of that particular probe. A series of frequencies can then be applied and the calibration entered and this data will then be recorded for later use. It is recommended that at least one point of calibration is made for every third of an octave of frequency, or a greater number of points if possible. The dead file can be accessed whenever that particular probe is re-inserted into the instrument and absolute calibration of the acoustic measurements made by applying a correction.

NB: This detailed procedure is effective only when used with a probe which has integral electronic ID. The accuracy of this process is limited to the accuracy of the acoustic measurement of the sound field supplied to the probe. The use of the ILO system for clinical screening purposes is not critically dependent upon the absolute calibration of the instrument. This is a screening device used to detect rather than to measure cochlear activity. For research purposes, the above procedure may be important. For general screening use, the quick test will be sufficient to ensure that correct screening results are obtained from the ILO system.

Back up

When the ILO TEOAE system is making recordings, it keeps a list of new recordings in a separate file, called ‘TESTED.TXT’. Also, when data is manually scored, it keeps a list of scored data in the file ‘SCORED.TXT’. The Back Up option allows data which has been scored, or data which is being newly taken, to be copied onto the Back Up directory, which the user may select. After backing-up the data, the user is given options to clear the list of new or scored data. The user is also given an option to delete the original copies of data, once they have been backed up.

How to read the ILO response screen

Screen contents

Fig 12 shows the result from a typical healthy adult ear. Fig 13 shows a typical result from a healthy newborn ear. Both recordings were made with the default ILO88 settings.

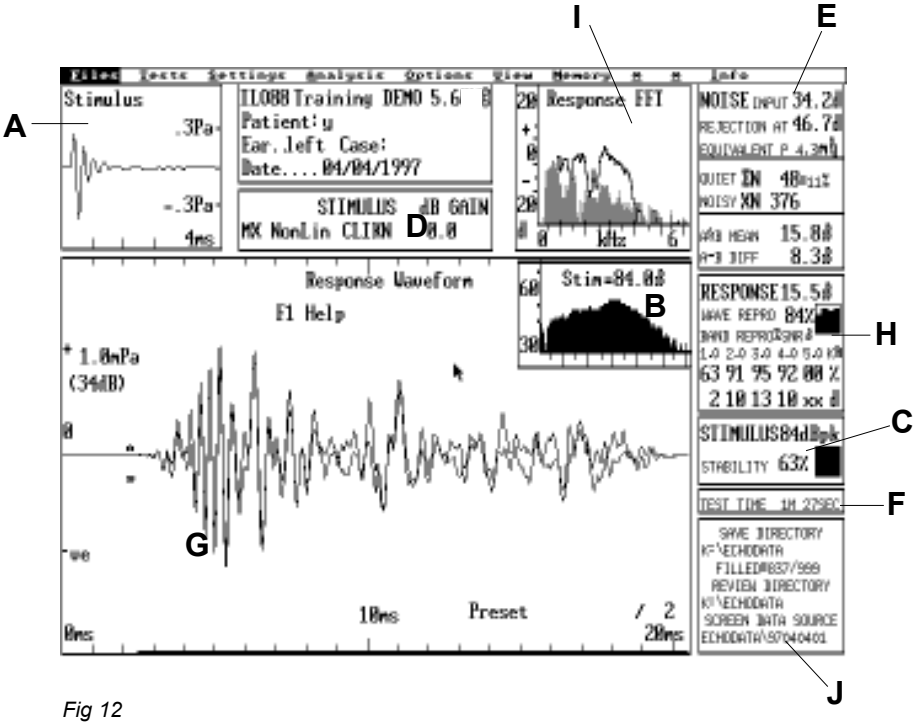


Fig 12

Healthy adult ear

The Stimulus panel (A) shows a short, biphasic click stimulus of duration 1ms. The Stimulus Spectrum (B) shows a smooth distribution across frequency (the decrease towards 6kHz is a result of eardrum reflection - see advanced usage section). The stimulus has a peak level of 84dBspl, shown on Stimulus Analysis panel C, which also provides a figure for the stability of the stimulus peak level during the recording. The inset graph in the Stimulus Analysis panel shows the stability of the probe fit during the test. A large-scale graph is available on pressing **P** or on selecting the Analysis menu item **Progress**. The figure given here of 63% indicates that the peak stimulus changed by 37% during the test, probably because the probe slipped towards the end of the test. This could be examined by using the Progress Analysis in the Analysis menu. A useful result may still be obtained with probe movement, provided the recording is stopped immediately (see stimulus stability indicator in the recording section). Panel D confirms that the stimulus was non-linear and of type CLIKN. No adjustment to the default gain had been made and this remains at 0.0dB.

The upper right-hand Noise Analysis panel (E) displays the conditions during the test. The NOISE INPUT was 34.2dBspl and this refers to the mean level of noise in the ear canal responsible for the residual contamination by noise in the final stimulus. The residual contamination in the OAE response is shown by the entry A-B DIFF 8.3dBspl, which is the noise level present after the averaging process. Sweeps with noise greater than the selected reject level were rejected from the averaging process. The rejection level was set at 46.7dBspl (4.3mPa) for this recording. In this recording, 376 noisy sweeps were rejected (NOISY XN 376) and only 48 sweeps were accepted. The total recording (F), (TEST TIME) took 1 minute 27 seconds. Clearly, the subject was noisy during this recording, but the ILO program was effective in rejecting the noisy samples and the result was a clear indication of OAE activity from 2 to 4kHz. The response at 1kHz was partially obscured by noise, but nevertheless was present.

The Response Waveform panel (G) shows the OAE waveform over a 20ms period. Note that the earlier waves, 3-9ms, are more closely spaced (of higher frequency) than the later waves, around 15ms. This is quite typical but not seen in every case. The intensity of the response is shown in the Response Analysis panel (H) and is 15.5dB-spl. This contrasts with the noise contamination figure of 8.3dBspl (see above). The overall signal-to-noise ratio of this measurement is therefore 15.5 - 8.2 = 7.3dB.

It is important to note that the absolute response level (15.5dB) relates to the energy of the OAE, whereas the signal-to-noise ratio (7.3dB) relates to the quality of the final measurement. The latter quantity can be improved by a longer recording, or lower noise levels, whereas the former quantity is set by the characteristics of the ear.

Noise contamination in the final result causes a reduction in reproducibility. This is automatically tested in the ILO88. During the recording, two independent collections are made using alternate pairs of stimuli. The Response Waveform panel (G) actually

contains two superimposed OAE waveforms. The differences are very small in this example, but can be seen around 15ms. The reproducibility is derived from the correlation between the two overlaid waveforms and this is indicated in the Response Analysis panel (H) by WAVE REPRO 84%. A perfect recording would have a reproducibility of 100%. A 50% reproducibility would indicate that one half of the visible signal consists of noise contamination. There is no fixed criteria for rejecting a response solely on the reproducibility figure. However, a high value is always advantageous. An experienced operator can use the analysis facilities of the ILO to confirm OAE responses which have an overall reproducibility of less than 50% - refer to the advanced user guide. The inset graph in the Response Analysis panel shows the increase in reproducibility during the test. Normally, this grows consistently throughout the test. A large-scale graph is available on pressing **P** or on selecting the **Analysis** menu item **Progress**.

A more useful measure of the quality of a recording is obtained after the response is broken down into its component frequencies. Panel I shows the Response Frequency Analysis, from 0 to 6.3kHz. The hatched region shows the frequency components of the residual noise. This appears red in the colour display. The unshaded area represents the valid response, which should exceed the noise contamination. The shape of this detailed frequency analysis is often quite irregular, sharp peaks and notches being very common. To assist in the interpretation of this information, a numerical summary is provided in the Response Analysis panel (H). The reproducibility is shown as a percentage, five equal frequency bands centred on 1,2,3,4,5kHz respectively. Below this is shown the related signal-to-noise ratio in each band. A signal-to-noise ratio of =/>+3dB or a reproducibility >65% is normally significant in any frequency band. It is recommended that a significant OAE response in at least two bands is obtained before considering the ear to have passed a test. The Response Waveform panel (D) contains the text Preset, indicating that the test conducted was the default test for the ILO88. The most common choice for newborn screening is QuickScreen; this would appear in the response panel. If the test is conducted under an automatic stop protocol, the reason for test termination isalso shown in the response panel, e.g. !"GoodSNR". This would indicate that the recording was automatically terminated according to the protocol selected by the operator and refer to the presence of the required number of frequency bands having a signal-to-noise ratio considered to be passable. The frequency band analysis is supplemented by other functions, discussed later, which are the Half-Octave Analysis and the Spectrum Cursor.

The final panel on this display, J, shows information about the filing of this data and of the capacity for additional recordings to be saved. The panel also shows the current directories for saving data and for recalling data for review. These may differ.

Healthy newborn ear

Fig 13 shows results obtained from a healthy newborn ear recording in typical office conditions.

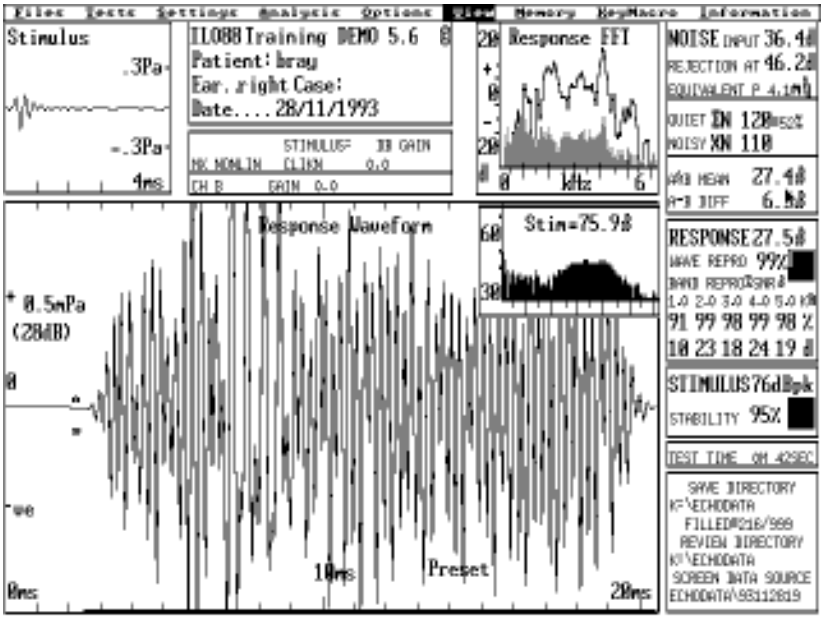


Fig 13

There are a number of differences between this result and the result of the adult test. The Stimulus Waveform panel shows that the stimullus is more oscillatory and its magnitude, 76dB, falls significantly below the 84dB peak target of the ILO88. This is acceptable if a strong emission is obtained, as in this case. The Stimulus Confirmation panel confirms that no readjustment has been made to normalise the stimulus. Even so, the response obtained is very large (27.5dBspl). This high level of OAE is common in healthy newborn ears which are dry and clean. In addition to the differences in stimulation and response, the Noise Analysis panel indicates differences in the recording conditions. The noise input was 36.4dB and the noise reject was set higher, at 46.2dB. 110 noisy sweeps were rejected, i.e. approximately half of the total. As a result, the newborn test took longer - 42 seconds. Despite this, a very high wave reproducibility was obtained (99%). This can be attributed to the high strength of the OAE. High reproducibility is shown in each of the five frequency bands. The stimulus stability was good at 95%, but not as high as obtained from the adult.

Fig 14 shows a recording from the same newborn using the Quickscreen stimulus. The overall result is very similar. The stimulus is greater by 3dB as a result of the redistribution of stimulus energy in the middle frequencies. The noise contamination is 3dB less. The response intensity is 5dB less, but this is the result of a normalisation process which takes into account the uncollected response between 12.5 and 20ms. It is clear that the peak OAE intensity is almost identical in both recordings and the frequency spectrum is also very similar. The significant difference between the two recordings is the reduction in time with the Quickscreen stimulus (26 compared to 42 seconds) for a similar quality of recording. The advantages of Quickscreen become more significant when recording weaker responses (see below).

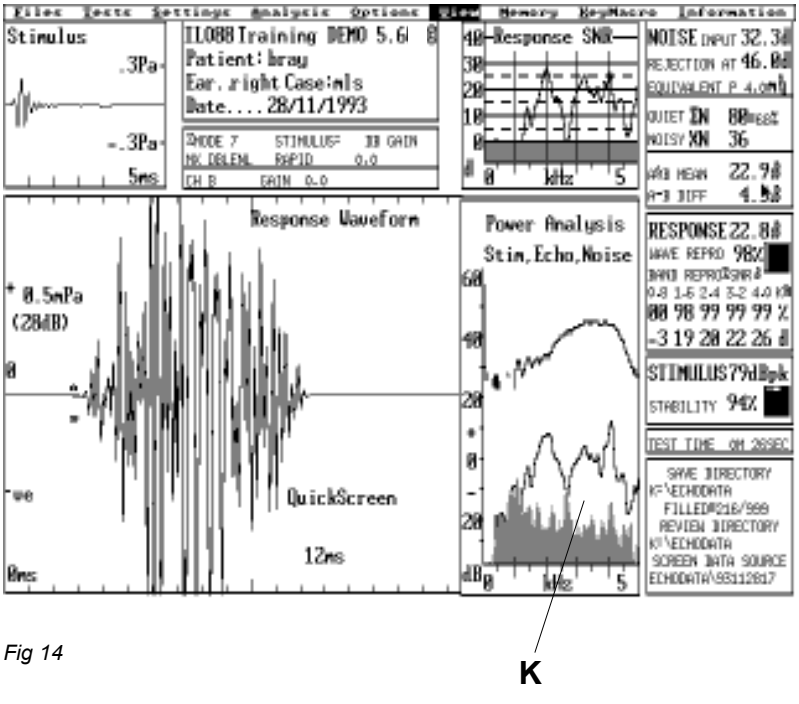


Fig 14

As will be seen, the Quickscreen display includes an additional panel (K). This composite graph shows the stimulus, reproducible response and noise contamination frequency spectra and their relative magnitudes. This replaces panels I and B of the standard display. In place of I, the Quickscreen display panel L shows the response signal-to-noise ratio as a function of frequency. Note also that the centre frequencies of the bands used in the Response Analysis panel differ from the standard response values. This is a consequence of the more rapid stimulus rate. Improved frequency band analysis is provided by the Half-Octave Analysis function.

Interpreting weaker OAE responses

Fig 15 shows a response from a mature adult ear. The OAE response intensity is smaller than the first adult ear shown and the noise contamination is higher. The waveform reproducibility is 74% overall but the frequency band analysis shows that OAEs are present in four bands at or above the 3dB signal-to-noise level between 1 and 4kHz. This can be considered to be a satisfactory pass since the number of sweeps taken (237) is adequate and the overall noise level is low. Higher signal-to-noise levels are often demanded when screen neonates under noisy conditions. Higher values would also be necessary to pass an ear with fewer sweeps comprising the result.

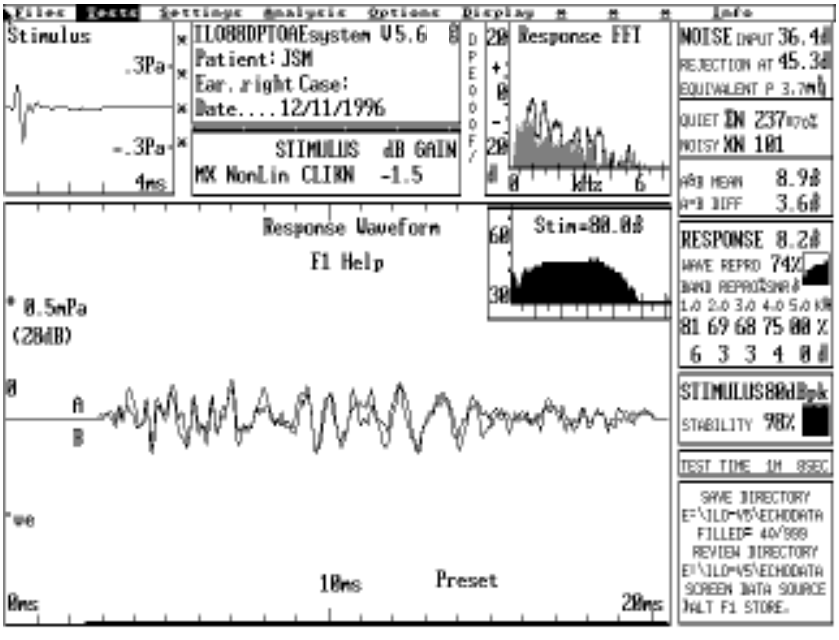


Fig 15

Fig 16 shows the result of a recording in an adult ear with very small OAEs. The hearing is within normal limits. Examination of the Stimulus and Noise Analysis panels show that the recording has been correctly made. The noise contamination of 0.8dB-spl is satisfactory, as is the total number of sweeps recorded, 260. However, the total response intensity is less than the noise level of 0.8dBspl and therefore is not indicated. The reproducibility of the response is only 38%, which is unsatisfactory.

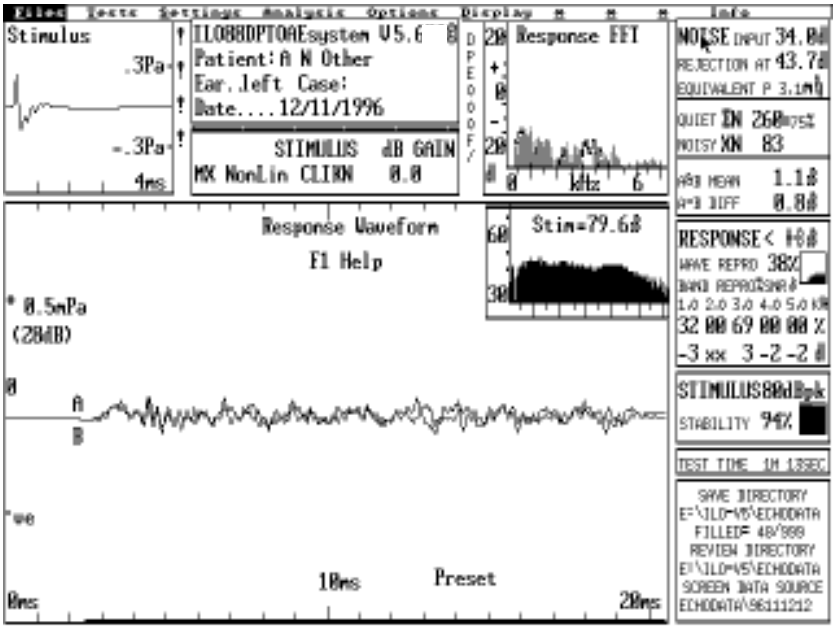


Fig 16

Careful examination of the response waveform shows a possible response in the 4-6ms period. This is also visible in the Response Frequency Analysis panel at 3-4kHz. The 3kHz band in the Response Analysis panel indicates a 69% reproducibility and a +3dB signal-to-noise level. The limited response at 3kHz must be regarded as significant from a physiological point of view but inadequate from a clinical viewpoint because evidence of cochlear function is present only over a very restricted range of frequencies.

It is sometimes necessary to further validate such marginal responses. This may be achieved by repeating the standard measurement. Alternatively, the Quickscreen option may be used to enhance the signal-to-noise.

Fig 17 shows the same ear, examined using the Quickscreen option. The marginal OAE is now clearly recorded with a level of -1.8dBspl. The reproducibility is 73% overall and achieves a reproducibility in excess of 65% in the 1.5, 2.2, 3.0 and 3.7kHz bands. This test provides confirmation of cochlear function across the whole middle frequency band. The small intensity of the OAE puts this response below average. The clinical significance of this would depend on the purpose of the measurement. For mature adult ears, this type of result normally indicates a subclinical decrease in cochlear activity, as would occur in early presbyacusis or noise induced hearing loss. This example illustrates the value of the Quickscreen option in clarifying cochlear status in marginal cases.

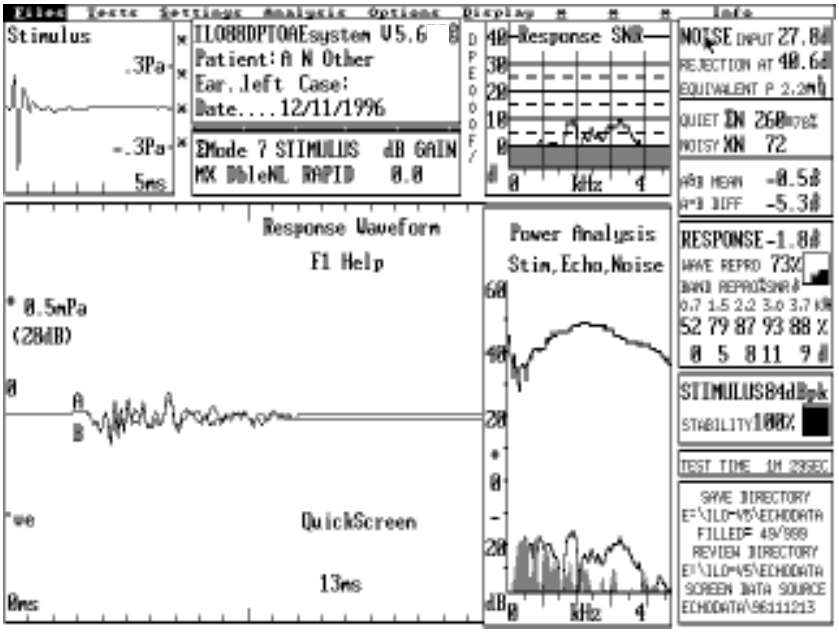


Fig 17

Fig 18 shows standard results from an adult ear with an average hearing loss of 20dB. The OAE is not visible. Application of the Quickscreen option, Fig 19, shows a marginal OAE at around 4kHz. This ear fails the OAE test.

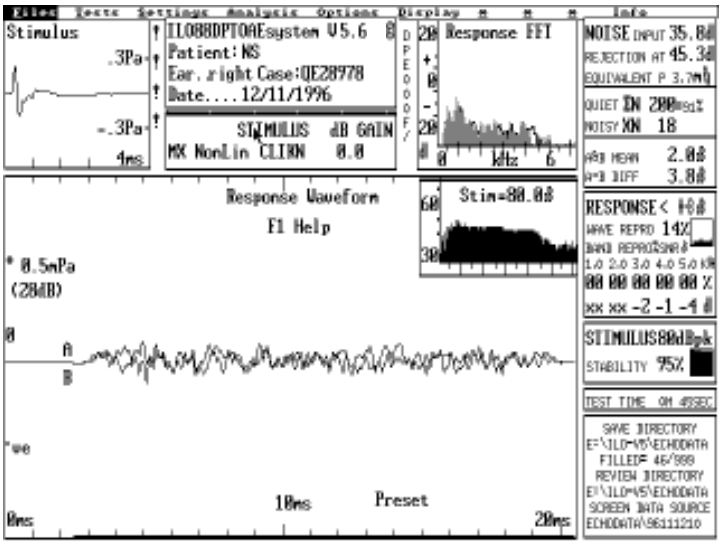

Stimulus
.3Pa
-.3Pa
4ms
ILO88DPTOAEsystem V5.6
Patient: NS
Ear, right Case:QE28978
Date....12/11/1996
STIMULUS dB GAIN
MX NonLin CLICK 0.0
Response FFT
kHz
Response Waveform
F1 Help
Stim=80.0dB
* 0.5mPa
(28dB)
10ms
Preset
20ms
NOISE INPUT 35.8dB
REJECTION AT 45.3dB
EQUIVALENT P 3.7mPa
QUIET IN 200mst
NOISY XN 18
ABD MEAN 2.0dB
A-B DIFF 3.8dB
RESPONSE < 1kHz
WAVE REPRO 14%
BAND REPRO%SNR
1.0 2.0 3.0 4.0 5.0 kHz
00 00 00 00 00 %
XX XX -2 -1 -4 dB
STIMULUS80dBpk
STABILITY 95%
TEST TIME 0M 49SEC
SAVE DIRECTORY
E:\ILO-V5\ECHODATA
FILLED= 46/500
REVIEW DIRECTORY
E:\ILO-V5\ECHODATA
SCREEN DATA SOURCE
ECHODATA\96111210

Fig 18

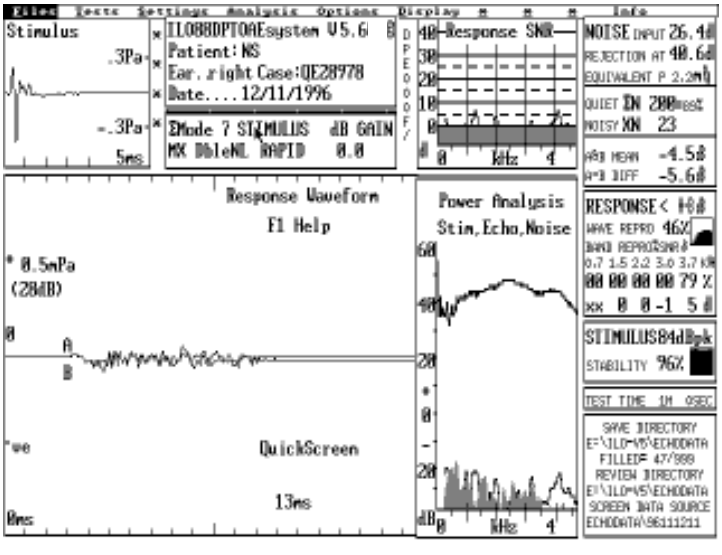

Stimulus
.3Pa
-.3Pa
5ms
ILO88DPTOAEsystem V5.6
Patient: NS
Ear, right Case:QE28978
Date....12/11/1996
EMode 7 STIMULUS dB GAIN
MX DbleNL RAPID 0.0
Response SNR
kHz
Response Waveform
F1 Help
Power Analysis
Stim,Echo,Noise
* 0.5mPa
(28dB)
QuickScreen
13ms
NOISE INPUT 26.4dB
REJECTION AT 40.6dB
EQUIVALENT P 2.2mPa
QUIET IN 200mst
NOISY XN 23
ABD MEAN -4.5dB
A-B DIFF -5.6dB
RESPONSE < 1kHz
WAVE REPRO 96%
BAND REPRO%SNR
0.7 1.5 2.2 3.0 3.7 kHz
00 00 00 00 79 %
XX 0 0 -1 5 dB
STIMULUS84dBpk
STABILITY 96%
TEST TIME 1M 0SEC
SAVE DIRECTORY
E:\ILO-V5\ECHODATA
FILLED= 47/500
REVIEW DIRECTORY
E:\ILO-V5\ECHODATA
SCREEN DATA SOURCE
ECHODATA\96111211

Fig 19

Finally, Fig 20 shows a recording made using the Quickscreen option with the probe inserted in the test cavity provided by Otodynamics. No OAE is visible, as would be expected. Recordings should be routinely made in the test cavity to confirm that the equipment is operating normally and does not produce artefactual responses. This example contains a small artefactual response confined to frequencies below 500Hz. It is caused by the retention of unusual amounts of low frequency by the hard-walled nature and the firm rubber seal of the test cavity. This small low frequency artefact can be tolerated because OAE signals below 500Hz are not recorded by the ILO88. Also, low frequency artefacts appear at the early part of the trace and low frequency OAEs, if present, appear towards the end of the trace.

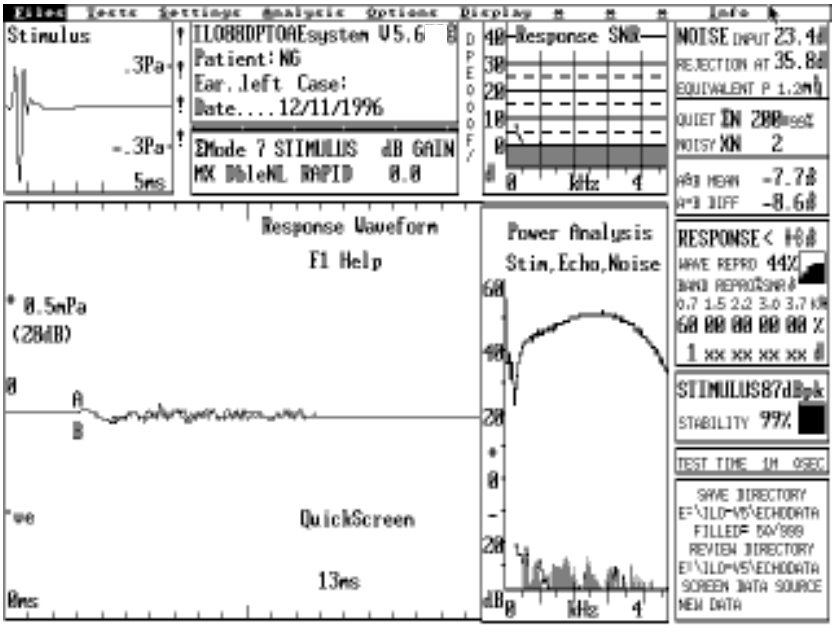


Fig 20

Data analysis utilities

Use of the octave based OAE analyser

At any time when OAE data is displayed on the screen, an octave based analysis can be obtained by pressing **H** or the **Half-Octave** item on the Analysis menu. This will produce a display similar to that shown in Fig 21. The initial display shows the OAE and noise level divided into half-octave frequency bands matching the frequencies used in audiometry. Narrower bands and higher resolution can be obtained by pressing the keys **3** through **6** after the display appears, to give one-third, one-quarter, one-fifth and one-sixth octave displays respectively. A one-octave analysis is also available.

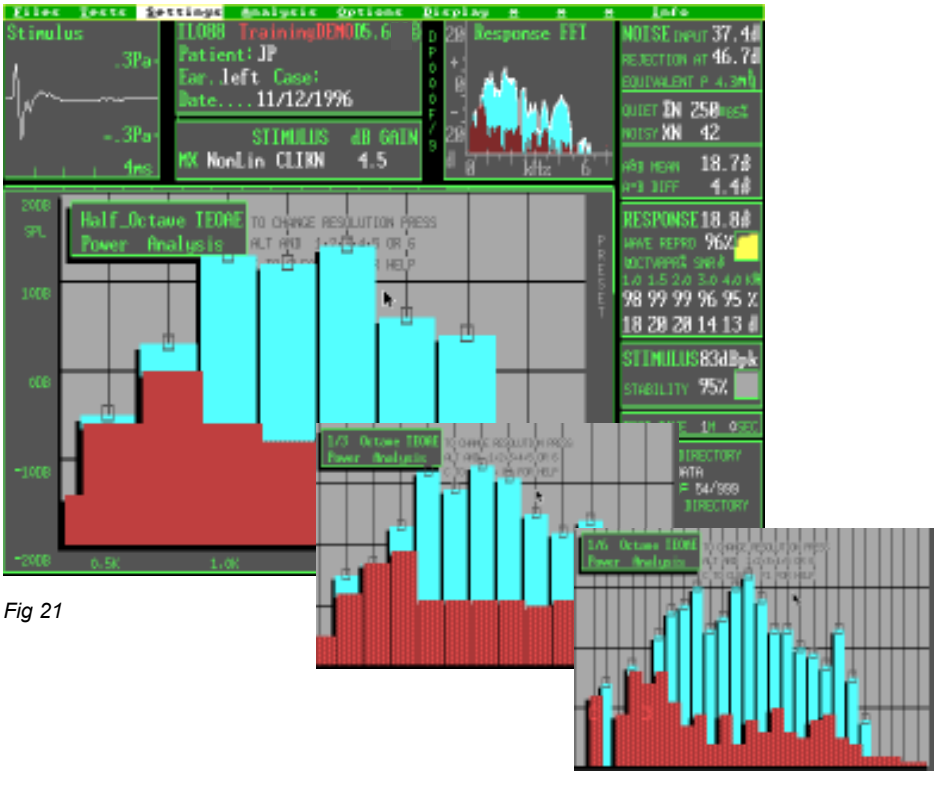


Fig 21

From this display, a reliable assessment of cochlear status can be made. The analysis groups together all response components and noise contamination in the stated frequency band and displays these simultaneously so that both the response amplitude and the signal quality (SNR) can be assessed. This display supersedes the information provided in the Response Analysis panel.

Use of the spectrum and waveform cursors

Detailed examination of the TEOAE spectrum

If it is required to see the detailed spectrum content of a TEOAE, an enlargement of panel I can be obtained by selecting **Spectrum** from the **Analysis** menu, or pressing the hot key **F3** (Fig 22).

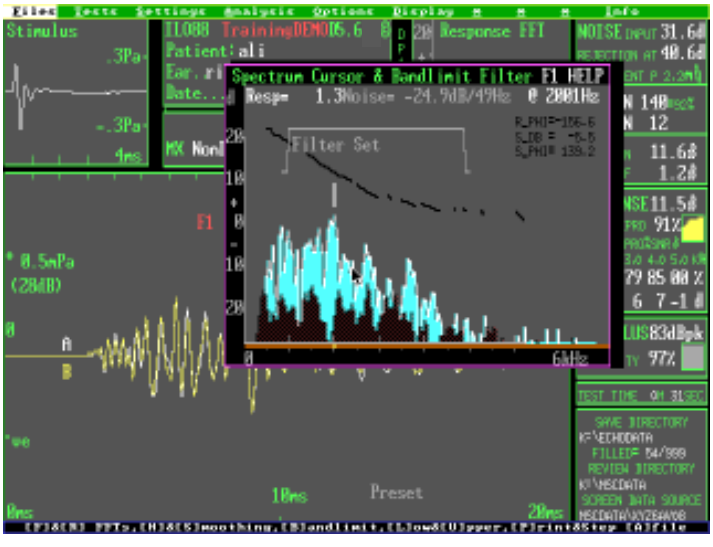


Fig 22

The left and right cursor keys allow the level of response and noise to be measured at any frequency. The PageUp and PageDown keys provide course movement of the cursor. The Home and End keys move the cursor to the maximum and minimum frequency. The spectrum is usually quite irregular. There is no clinical significance to the detail seen. Changes in detail may, however, relate to changes in cochlear status.

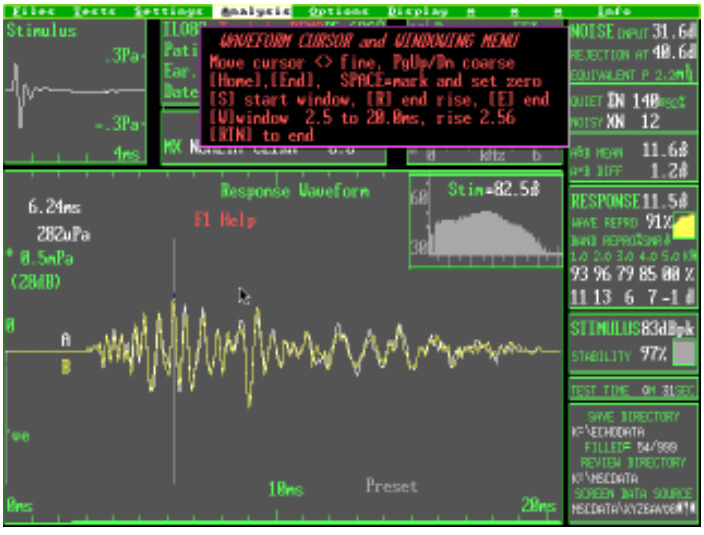
A band of frequencies may be selected for further examination. Set the cursor to the lower frequency of the band required and press **L**. Position the cursor at the highest frequency required and press **U**. Pressing **B** at this point will band-limit the OAE response. The regular Response Waveform panel (G) will then display only that part of the OAE between the frequencies specified. In this way it is possible to examine an OAE response in frequency band sections. This is useful when substantial frequency regions have been obscured by noise but other regions have escaped noise contamination. A band-limit operation can be reversed by pressing the hot key **F10**, or by reloading the data from file. (The band defined in this way has a secondary use in specifying the frequency limits of noise generated in the stimulus wave research function, which is not described in this manual.)

Two alternative spectrum display formats are available. With the large spectrum already displayed, pressing **F** will display a smoothed spectrum and key **H** will display a blocked histogram. These are useful only if it is required to document the OAE response at individual frequencies. The **F** and **H** options assist in averaging the response and reduce the quantity of data generated. The default format is restored by pressing **R**. To assist with the documentation, individual frequency points can be printed by pressing **P** and at the same time pressing the left or right cursor key. At each cursor key press, a line is sent to the printer indicating frequency, response and noise level intensities. (Some printers will not print less than a full page without a manual page feed instruction). Alternatively, the information can be sent to the file ILOFFT.TXT. To do this, the key **A** is pressed. The frequency is incremented by one place each time the key is pressed and a line is appended to the text file in simple ASCII format. Pressing **F1** provides essential help on the above topics.

OAE waveform documentation

If it is required to document details of the OAE waveform, a cursor key can be obtained by pressing the hot key F5 or selecting the **Waveform** option on the Analysis menu. The left and right cursors control the cursor bar, allowing the sound pressure of the OAE waveform to be read at intervals of 40 microseconds with the standard stimulus and 50 microseconds with the Quickscreen stimulus. The individual peaks and troughs of the OAE sound wave have no clinical significance. Changes in these peaks may relate to changes in cochlear status but may also be influenced by changes in middle ear status and probe fit. The PageUp and PageDown keys provide course movement of the cursor. The Home and End keys move the cursor to the start and end of the waveform response.

A limited time window may be extracted for further analysis. This is achieved by positioning the cursor at the start of the time window required and pressing **S**. The cursor is then moved to the upper window (the numeric readout shows the time interval from the marked start point). Pressing the **E** key marks the end of the required time window. Pressing **W** will result in the windowing of the OAE by the time period se-

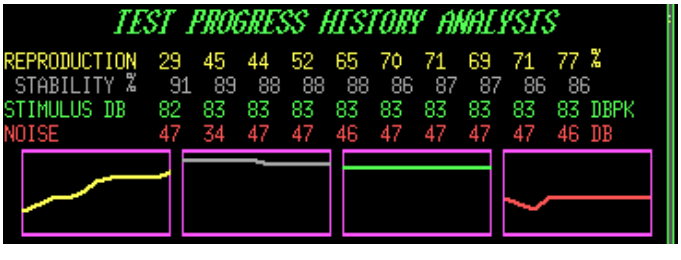


lected. The default rise and fall time is 2.5ms and is of cosine form. This may be changed by marking the end of the rise required and pressing **R**.

When an OAE response has had a window applied, it is immediately reprocessed so that the ILO response screen measures the intensity of response within that time window. This is useful to separate out and measure OAE responses confined to short durations, which would otherwise be obscured by the general noise background. Pressing the **F10** hot key will restore the waveform to its un-windowed form.

Test progress

The inset graphs in panels H and C show the history of the reproducibility and the stimulus stability during the recording. An enlargement of this may be obtained by pressing **P**, or alternatively by selecting the **Progress** option from the Analysis menu. The numerical data gives values of waveform reproducibility, stability percentage, peak



stimulus dB and noise level at ten time intervals equally spaced throughout the test. These are shown graphically from left to right. The example shows a steady rise in waveform reproducibility due to averaging and a small drop in stimulus stability half-way through the test.

Test Progress History Analysis is useful in assessing the technical quality of a recording. For example, if the probe has become dislodged during the test and the final stimulus stability is zero, it may still be possible to determine at what point in the test the probe became dislodged and whether to accept or discard the results of the test. The History Analysis panel can be cleared by pressing **C**.

Test protocol and ILO Stop Logic

Facilities are available for the operator to control the point at which the recording is terminated. The recording may be terminated at any time by pressing the Enter key and the default protocol is for the recording to automatically terminate after 260 low noise sweeps. The operator may set additional conditions for the test to terminate, including conditions based on unsatisfactory stimulus and noise values and satisfactory OAE response values. The purpose of this facility is to reduce time wastage, either by extended recordings in unsatisfactory conditions, or by unnecessarily long recordings when the OAE response has been very quickly resolved. The facility is also useful as a support in the training process. The operator can set limits on the duration, stimulus levels and other parameters of the recording session.

The Stop Logic protocol may be selected from the opening Version5 block selection screen, or by selecting the **Terminator** option in the **Analysis** menu inside the program. Protocols are contained in files ending with the extension .STP. From within the program, select the **Stop Logic** option from the **Settings** menu. A list of the current automatic termination parameters will be seen.

The name of the protocol file from which these parameters are drawn is shown. Each parameter is identified by a single number or letter, shown on the left-hand side of the panel. On pressing this key, the specific parameter may then be altered by use of the cursor. The number is accepted by pressing the Enter key. After editing the protocol list, the list may be resaved by pressing **S**. Protocol files should be write-protected to avoid tampering. An edited

parameter list cannot be resaved if it has been write-protected. It can be saved under a new protocol name and this file may be optionally write-protected. Otodynamics supplies only an example protocol file, which sets broad safety limits on the recording process. Operators are recommended to work with the ILO system and to consult with other users before introducing their own protocols. An explanation of the protocol parameters is given below.

0 ASSESS EVERY : Determines how often the software examines the data for compliance with the protocol parameters. The default is 260 blocks where each block is comprised of a pair of non-linear stimulus sets and corresponds to one count of the low noise sweep counter in the Noise panel. Reducing this figure will increase the speed of reaction to conditions requiring test termination, but will slow down data recording due to the time taken to redraw the screen. Any parameter can be effectively deactivated by setting its value to be outside of the normal range, e.g. setting the 'MUCHDATA' parameter to 9999 will probably result in the test terminating on some other condition. By setting the 'LOWSTABILITY' parameter to 0, the test will not terminate solely because of the loss of stimulus, but may nevertheless terminate because of the excessive noise reaching a displaced probe.

1 LONGTIME : Defines the maximum time for which a test will be allowed to run.

2 MANYREJECTS : Causes the test to terminate unconditionally when this number of sweeps have been rejected. This may indicate excessive noise.

3 MUCHDATA : Causes the test to terminate unconditionally when this number of sweeps have been accepted for averaging. This would indicate that no previously defined good or bad condition had been reached throughout the test. The default value is 260.

4 HIGHSTIMULUS : If the peak stimulus level exceeds this value continuously for more than approximately three sweeps, the test is terminated unconditionally to protect the patient from excessive stimulation. This condition can also be the result of excessive noise from the patient.

5 LOWSTIMULUS : If the peak stimulus level falls below this level, the test is terminated unconditionally. This may indicate that the probe has become dislodged.

6 LOWSTABILITY : If stimulus stability reaches this low level, the test will be unconditionally terminated. This could indicate that the probe has become dislodged.

7 MUCHNOISE : If the noise indicator bar reaches this level on a number of consecutive occasions, the test is terminated. This action can be disabled by setting the value well above the normal range of noise levels.

8 DEADNOISE : If this low level of noise is reached, the test is terminated as it is assumed that this must be due to the failure or disconnection of the probe or its having

become blocked. A suitable value for this parameter may be obtained by observing the noise level with the probe disconnected, e.g. 10 micro Pascals.

NB: The above conditions represent absolute limits outside of which the recording cannot proceed.

The following parameters relate to quality factors from which the operator may build a set of conditions for the test to terminate because a satisfactory result has been achieved.

9 GOODRESPDB : When the response reaches this decibel level, the test will terminate provided conditions B and C have been met. This is useful in terminating the recording early in the case of an exceptionally strong OAE response.

A - GOODREPRO : When the quality of accumulated incoming data has reached this level of reproducibility, the test will be terminated, provided condition B is met. This is useful in terminating the recording early in the case of an exceptionally strong OAE response or a response recorded in exceptionally quiet conditions.

B - MINIMUMDATA : This number of accepted quiet sweeps is necessary before any automatic termination of the test based on OAE response quality or strength. This protects the statistical validity of the test and should not be set very low. We consider that 60 blocks is a suitable minimum.

C - MINIMUMREPRO : This degree of reproducibility is necessary before any automatic termination of the test based on OAE strength. It is not necessary to set this value to a reproducibility level which, in itself, guarantees validity. If set to zero, it allows the other quality parameters to become active, in particular the half-octave band based measures. Minimum repro should be activated only when the frequency band measures are not to be used.

D - MIN N GOODSNR : This parameter refers to the OAE signal-to-noise ratio evaluated in half-octave bands. It defines the minimum number of bands which must contain a valid OAE before the test is automatically terminated. The test will be terminated only after conditions C and B are met.

E - MIN SIGNIFSNR : This parameter defines the signal-to-noise ratio which an OAE in a half-octave band must have in order to be considered significant. This is a separate indicator to the level set in G, which defines the acceptable level for a pass. Parameter E is used to count the number of marginal half-octave bands. The default is 3dB.

F - FIXED TERMINATION : Switches off the automatic stopping logic and reverts to fixed sweep number termination.

G - GOODSNR DB : These values define for each half-octave band the signal-to-noise level judged by the operator to indicate a valid OAE in that band. On pressing G, the figure for each half-octave band is highlighted in turn. As each value is adjusted and the Enter key pressed, the next value will be highlighted, etc., until all of the values have been edited. It is useful to control the acceptable signal-to-noise level in each band as experience shows that much higher values for signal-to-noise can be obtained for mid-to-high frequency bands than for low frequency bands. This, however, depends on the local noise environment.

Q - QUALITY : Similar to G, but the decision is based on the value of the reproducibility in each band, rather than the signal-to-noise level.

N - NOISEFLOOR : Defines the level of noise in each half-octave band at which it would be considered that any OAE in the normal range would have already become visible. These values serve to set a limit on extended recording. When this limit is reached and the recording has not already been stopped by other conditions, it may be assumed that no OAE has been found. The five parameters are individually set as for G.

P - PROBABILITY : This is active only when advanced statistical interpretation is in use. It defines the minimum probability of an emission being present in a band.

H - NOISE HI dB : Defines the level of noise present in each half-octave band at which normal levels of OAE would be obscured. No decision is possible under these circumstances, so the test is considered invalid, if no OAE is present. If an exceptionally high OAE is nevertheless seen, this evidence can be accepted.

R - RETRIES : If this value is set at other than zero, the software will make an early assessment of the data after a number of sweeps shown following the @ character. The software examines the data for some evidence of a significant emerging OAE response in the half-octave band analysis. The level of significance is set by the dB value following the X NSNR figure. If no evidence is found, the operator will be offered the opportunity to restart the test after examining the probe. If evidence of an OAE is found, the test will continue automatically. The most common cause for the ILO failing to detect an OAE in healthy newborns is debris or incorrect probe fitment. The operator will be recommended to inspect and refit the probe after changing the tip, if necessary. R defines the number of retries that will be offered before continuing with the full test. To change the time at which the early assessment is made, the @ key is pressed and the number adjusted. To change the level of significance, press X.

J - MAX REJECTLVL : This limits the freedom of the operator to raise the noise artefact reject arrow level. This prevents recordings being made under levels of noise judged to be too high for quality recordings. The experienced operator may wish this restriction to be removed. This can be achieved by setting the parameter to be greater than the normal range of the noise reject level.

NB: Pressing the F1 key at the Stop Logic parameter protocol list will provide essential help information.

When a recording is terminated according to the Stop Logic protocol, the condition which initiated the termination is printed on the screen under the OAE waveform. This information is also stored when the file is saved and is recalled on review.

Alt+R : When recorded data is being displayed, pressing the keys Alt+R will result in the current data being re-evaluated according to the protocol. The Stop conditions it fulfils will be listed on the screen. This is a useful way of evaluating recordings made prior to the implementation of a protocol or of evaluating a new protocol against a set of previously reviewed data.

Use of the ILO Statistical Analyser

The ILO Statistical Analyser is called by selecting **ILOSTATS** from the **Analysis** menu. This hands control to the ILOSTATS program, which is designed to perform retrospective analysis on the entire contents of the current TEOAE data directory. The purpose of this analysis is to provide the manager of a screening programme with the average values for each of the measurement parameters shown on the ILO data screen across a large number of patients. Currently, the maximum number is 1,000. The program also determines the 5th and 95th percentile values of each measurement parameter. For example, it can provide the mean OAE intensity obtained from a group of patients and indicate the OAE intensity levels which separate the 5% lowest levels from the normal population range.

This data can be useful for quality control purposes. Regular analysis of patients' data can be used to detect changing noise levels in the test environment and changes in protocol by the test operatives. It can also be useful to set local criteria for passing and failing individual ears belonging to a identified sub-group, e.g. infants between six months and one year, newborns, etc. It has been used to compare the OAE intensity and test duration in each of the first three days from birth. It is typically found that the mean OAE intensity on the first day is lower than on subsequent days.

On entering the ILOSTATS program, the following process is carried out.

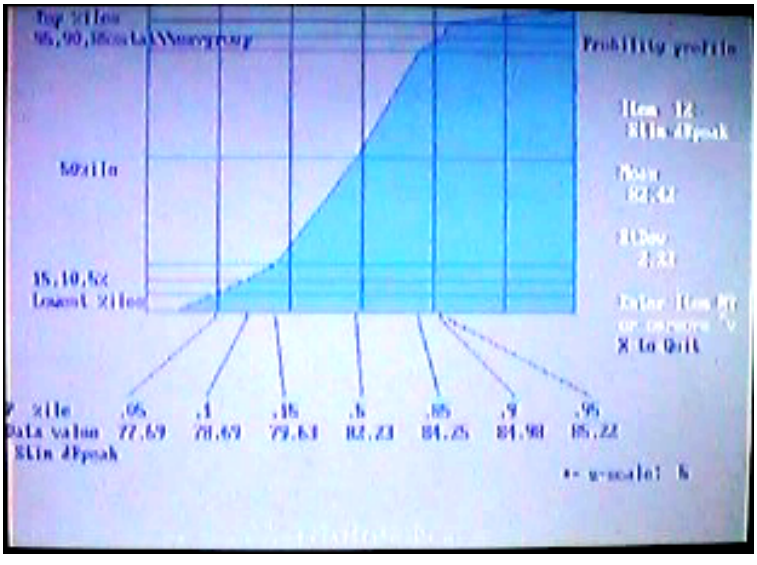
(a) The individual data records are automatically read in, in summary form, from the data directory.

(b) The means of every recorded parameter are calculated and displayed.

(c) The distribution of values around each mean is analysed to identify the 5th and 95th percentile points. The program also identifies the 10%, 15%, 85% and 90%ile values.

Options are then available to display the distribution of any measurement parameter graphically (Stat Scan P%); to display a scattergram relating to selected parameters, e.g. reproducibility against time of test (Scattergram); process data may be saved in binary form for future recall (Stat BSave); or in word processor readable form (Stat ASave).

This utility is provided to assist with the management of test programmes and the development of local protocols and criteria. Use of the program has no influence on the measurement of TEOAEs by the ILO and operates independently on stored data.



Graphical display of stimulus level

ILO88 menus

Version5 software introduces for the first time with ILO88 software a fully mouse-operable menu system. This section describes the mouse-operable menu system, which is the default whenever the mouse option is checked in the ILOCFG configuration program. The menu system can be changed by hiding the toolbar under the Options menu.

The ILO88 TEOAE toolbar

When the mouse control option is active, the ILO88 Toolbar is seen at the top of the screen. Drop-down menus can be selected by mouse or keyboard. There are nine main menu titles. Each one is highlighted as the mouse passes over and a menu drops down. The menu is cleared by the Escape key; the highlighted menu title can be changed using the left and right cursors. The down cursor will cause the menu to drop. The menu can also be called by pressing the underscored key in the menu title, e.g. **F** for File menu.

When a menu is showing, the highlighted item can be changed by pointing the mouse at another item, or by the use of the up/down cursors. When highlighted, an item can be selected by pressing the Enter key, or the key corresponding to the underscored character of the item name, or by clicking the mouse. The left/right cursor keys cause the left or right menu to replace the one currently showing.

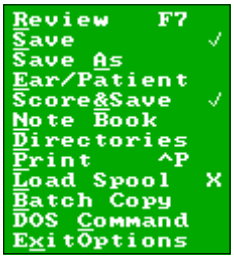
Some items cannot be activated and this is indicated by lighter text. This occurs when related essential selections have not been made or when it is not appropriate to use the item. If an option is not installed or appropriate for your system, all associated items will be shown in lighter text.

Some items are used to turn on and off the function. When the function is already operative, a tick (check) is shown at the end of the line. Selecting an item already checked will cause the option to be turned off. Also, when data is available for saving, the Save item is checked. The check clears once the data has been saved.

Some items have a hot keystroke indicated at the end of the name. You may use this hot key to activate the function, even where the menu is not showing.

The toolbar can appear without any highlights. In this case, select a main menu title as detailed above. The selection of some items causes a secondary menu to appear. This is operated in the same way.

Files menu



This menu contains general utilities concerned with filing and retrieving test information. It also includes the exit route.

#TL0101

Files > Review

This shows the list of patient data files stored on the current data directory, together with the graphical summary of the OAE recorded. **Review** may also be called by pressing the **F7** key.

A particular file is selected with the cursor keys or mouse and loaded into the main screen by pressing the Enter key. The panel is headed by the name of the directory being reviewed.

The graphical summary panel shows, from the top down: stimulus waveform; OAE power spectrum analysis (not for SOAE); response waveform or SOAE spectrum; the name, type of test and main parameters. The frame of the summary panel is coloured blue for a left ear and red for a right ear.

If the test was subject to an **automatic stop** procedure, the reason for termination is shown as a numerical code (see Appendix : ILO Codes). If the test has previously been scored within the ILO, its file name extension will reflect the score. The score is shown in the graphical summary stimulus panel as P!, Q!, R!, I!, representing PASS, QUERY PASS, REFER and INVALID test respectively. The list entry colour also

indicates whether the test has been scored (Pass - green; Refer - blue; Invalid Test - red).

If Escape is pressed, a keystroke menu will appear giving the opportunity to select a new directory or to pre-select a group of files of the same patient or test session if available. Press key **N** to enter a new directory, key **S** to select on patient's name. Type the whole or the first part of a name to select a patient group. Once selected, these files will appear in the review panel. If Escape is pressed, the keystroke menu will show the option to cancel the selection, **X**. It will also give the option to save the selected group names as a file. This filed list may later be used to batch process the group of files. (See Batch Copy, *#TL0110*).

To change the review format, key **C** to list patient case notes, **P** to list patient's name and **F** to list file name only.

#TL0102

Files > Save

Saves newly collected or modified data to the current data directory. The file name is automatically selected. Once a recording has been saved, it cannot be re-saved. The **Save** menu item is checked when new data has not yet been saved.

#TL0103

Files > Save As

Saves As allows data to be saved on the current data directory using a name provided by the operator. The normal extension for ILO data is .DTA and this should be used to ensure that the data can be recognised and read by the ILO Review command.

#TL0104

Files > Ear/Patient

This item activates a secondary menu concerned with identifying the patient and ear to be tested and also with searching for the patient's files.

#TL2501

Ear/Patient > Patient ID

Allows the patient's identification to be entered prior to testing. It automatically applies to the next test recording. The **Patient ID** consists of the patient name (up to 17 characters), the Ear and the Case Note or Hospital Number (up to 10 characters). This data will eventually be saved with the test recording.

#TL2502

Ear/Patient > Edit ID

Allows previously entered patient data to be changed.

#TL2503

Ear/Patient > Mistaken Ear

Allows for the correction of data files where the wrong ear was entered. Select 'Correct the ear?' to change the ear. You will then be able to re-save the data, over-writing the original file if required.

#TL2504

Ear/Patient > Name Search

This searches the current directory for other files containing the same patient name. The name of the last tested or last recalled file is automatically adopted but can be changed or edited. It is possible to search using only the beginning of a name. When the search is complete, Review is called, listing all the matching files found in the directory. The Review panel header clearly states that a file selection is in operation. The group of files selected may be retained or cleared. The highlighted file may be loaded. After loading, you will be asked to confirm the file selection. If the file selection is retained, then subsequent calls to review will show only the selected files. This may be cleared at any time using Escape then **X** from the Review panel.

#TL2505

Ear/Patient > Case Search

This performs a review of patient data files in the current directory. Grouping is according to the Case Note portion of the Patient ID. If no Case Note was entered, then the Patient Name is substituted for the Case Note, preceded by a colon.

Only the first file of each case group is listed. In the Case Select summary panel to the right, the Case and Patient Name are repeated, together with the total number of files found matching that identity. The cursor can be used to examine the number of files in each case. When a case is selected by highlighting and pressing Enter, or clicking with the mouse, all of the files belonging to that case are displayed in the Review panel, together with a graphical summary. Data may be selected as in Review.

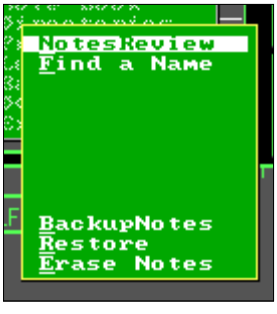
#TL0105

Files > Score & Save

Operates as the Save option, but precedes the Save function by showing the scoring bar on the top of the screen. After inspecting the data, select PASS, REFER or INVALID from the scoring bar. The selected item will be highlighted. A questionable Pass may be marked by pressing the **Q** key. Confirm the score by pressing the Enter key. You will be required to enter your personal ID as a scorer. On pressing the Enter key the data is saved using the ILO automatic file naming system. Scoring affects the extension of the file name. Pass results in .DTP, Refer as .DPR and Invalid as .DTI. A queried Pass has the extension .DTQ. An entry is made in the Note Book as the data is saved.

#TL0106

Files > Note Book



Note Book provides an easy means of making notes for later editing. It calls the Microsoft Edit program. The default filename is NOTEBOOK.TXT, but this may be changed. The default location is the directory from which ILO-V5 is called. A full range of basic editing functions is available. The file created is in DOS Text format, which may be imported into all word processing programs.

Each time a test result is saved, an entry is automatically added to the Note Book file NOTEBOOK.TXT. An example follows.

```
FILE:       97061102.dta
DATED:      11/06/1997        TIME:  8:17: 3
SUBJECT:    G BROWN           EAR:   left
CASENOTE:   HP190659
TEST TYPE:  QuickScreen
PROTOCOL:   NEWBORN           STOP AT:  GoodSNR
SCORE:      PASS
```

This entry is added at the end of the previous text and additional notes can be made as required. **Ctrl+End** will immediately take you to the end of the Note Book text. The score is entered automatically only if the Save & Score option is selected.

If you are operating an Otodynamics Echoport, then caution should be exercised when directly printing from the Note Book since your printer port may already be committed to your ILO hardware.

#TL2701

Notebook > Notes Review

This displays the current contents of the Note Book.

#TL2702

Note Book > Find a Name

Displays the notes associated with the patient name entered.

#TL2710

Note Book > Backup Notes

Copies the current Note Book onto a backup file, NOTEBOOK.BAK.

#TL2711

Note Book > Restore

Replaces a current Note Book with the file NOTEBOOK.BAK. The current Note Book is backed up.

#TL2712

Note Book > Erase Notes

Clears the current Note Book. A backup is made.

#TL0107

Files > Directories

Directories activates a secondary menu, as shown, providing review facilities for all directories and a means of changing the special ILO88 directories.

#TL1601

Directories > Explore DIRS

This initially shows only sub-directories within the primary ILO-V5 directory. Once a directory is selected (stage two), all files in the directory are shown.

The special ILO88 directories, e.g. ECHODATA, are coloured yellow and identified (other directories are coloured green). The default special directories names are:

ECHOPROG : ILO Program directory
ECHODATA : patient file directory
ECHOSTAT : all ILO statistical database files and automatic stop procedure files

ECHOIMAG : for screen images as PCX files
ECHOBACK : used to back-up patient files after scoring and/or deletion
ECHOSPOO : data spooling files of unprocessed patient data
ECHOSTIM : contains the special calibration stimuli and any custom stimuli designed by the user.

In stage two, all files within the selected directory are listed, file name and data filing are shown. If the file is an ILO datafile, its graphical summary will automatically be displayed and the file may be loaded in the normal way. Other recognised files are ILO spool files (.MEG), image files (.PCX) and ILO stop protocol files (.STP). Both MEG and STP files are accompanied by brief contents summaries. PCX files can be loaded for viewing directly from Explore.

In Explore, buttons appear above the review window allowing the drive or the file extension listed to be changed. Selection can be made by clicking the mouse or by keying the highlighted letter. Within the Explore review panel the route directory can be selected.

Changing Special Directory Names

The following menu items allow different directories to be nominated to receive ILO data files, image files etc. Each item below consists of a keystroke menu; select **D** to change the directory name; directory listings can also be obtained using keys **A** to view existing directories at the ILO-V5 level and **F** to show appropriate ILO files within the current special directory listed. If a new directory name is requested which does not already exist, you will be given the option to create a new directory.

#TL1602

Directories > Data TE DIR

The recorded data directory. The default is ECHODATA.

#TL1603

Directories > Stimulus DIR

The Stimulus Library, where custom stimuli are stored, including the probe test calibration stimulus. The default is ECHOSTIM.

#TL1604

Directories > Stats DIR

Interpretative statistics directory, where normative information can be stored and retrieved for comparison with individual records. The default is ECHOSTAT.

#TL1605

Directories > Images DIR

Screen image directory, where PCX images of particular displays can be stored and retrieved using the key sequence **Ctrl+U** and **Ctrl+V** respectively. The default is ECHOIMAG.

#TL1606

Directories > Spooling DIR

Data spooling directory, where raw data collected during a test may be saved for later reprocessing. **Ctrl+Y** will open up the data spooling facility, **Ctrl+X** initiates a recording and **Ctrl+Z** reloads raw data. The default is ECHOSPOO.

#TL1607

Directories > Config DIR

Contains the ILO88 configuration file, CONFIG.ILO. The default is ECHOPROG.

#TL1608

Directories > File of DIR

Creates a list of the names of data files held in the current data directory to a file of the user's choice.

#TL1609

Directories > Make Default

Makes the current choices for data, stimulus and stats directories default on next entering the ILO program.

#TL1611

Directories > Open New DIR

This creates a new directory on the current disc using the DOS instruction 'MKDIR'. The full pathway may be entered, e.g. see: MYDATA:TUESDAY, in which case the directory will be created exactly as written. Alternatively, a single directory name may be entered, e.g. TUESDAY, in which case this directory will be created at a level parallel to the other directories used by the ILO. For example, if the ILO is currently installed in the directory C:\ILO-V5, then the directory created will be C:\ILO-V5\TUESDAY. The directory created will appear on the Explore list when next accessed. Creating a new directory does not change the allocation of directories to specific ILO data functions.

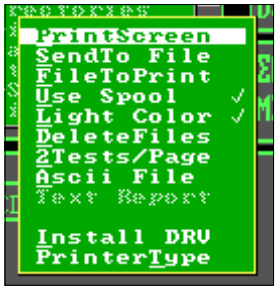
#TL1612

Directories > New Data DIR

This provides a convenient way to select a new directory on which to record and review OAE data. It replaces the directory ECHODATA or the current data directory if different. The review panel displays current directories in the ILO-V5 directory. Special ILO directories are coloured yellow; other directories are coloured green. You may select any directory for the current data directory except those already allocated to other specific ILO functions, e.g. ECHOSPOO. On selection, the directory automatically becomes the directory for saving and reviewing data. Selection of a new data directory by this method does not change the default directory, which will be adopted next time the program is run.

#TL0108

Files > Print



Print activates a secondary menu providing print and print control options. The screen may be printed at any time by pressing **Ctrl+P**.

#TL2001

Print > Print Screen

Sends the current display (with menu removed) to the selected printer. This function is also duplicated by **Ctrl+P**, which may be operated at any time without invoking the menu.

#TL2002

Print > Send To File

As Print Screen, but does not transmit the image to the printer immediately. The image is stored for future use as a file. The file is stored in the sub-directory PRTSTORE located in the ECHOPROG directory. The file is specific to the printer type already selected and carries the short-form name of that printer. The file extension is incremental from 000 each time a file is created.

#TL2003

Print > File To Print

Allows previously filed screen prints to be transmitted to the selected printer. Only files named appropriately for the selected printer can be transmitted. On selecting **File to Print**, a list of files awaiting printing is shown, together with the date of the files' creation. These files are automatically deleted after printing.

#TL2004

Print > Use Spool

When checked, print output is temporarily stored to a disc file and printed after completion. This is useful when two tests per page are being printed. It also increases overall efficiency. It is normally checked.

#TL2005

Print > Light Color

This removes the grey background from color prints, saving ink and aiding legibility.

#TL2006

Print > Delete Files

Allows a screen print sent to file and no longer required to be deleted. Print files are automatically deleted after printing. A maximum of 100 print files are allowed for each printer.

#TL2007

Print > 2Tests/Page

Holds the first print in memory until a second print operation is made. This is useful for printing left and right ears on the same page.

#TL2008

Print > ASCII File

Provided only for compatibility with earlier versions. It provides an elaborate numerical listing of some ILO88 parameters in character format with quotes and commas used for delineation. This is compatible with some databases and spreadsheets. There are options for including waveform and FFT information in the file. It is not recommended that this is used as a routine data logging facility.

#TL2009

Print > Text Report

This item is reserved for a future OAE test report facility.

#TL2011

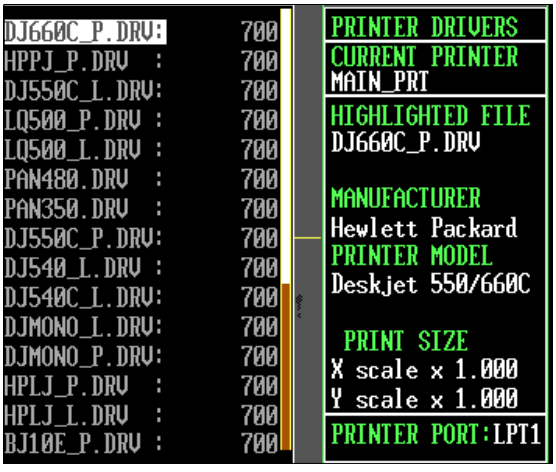
Print > Install DRV

This allows additional printer drivers to be installed from floppy disk. Supplementary drivers will be issued from time to time by Otodynamics as new printers are marketed or will be supplied to customers to meet individual needs. Insert the printer driver disk into drive A and press Enter. If no drivers are present on the disk, a File Not Found error will be shown. Existing drivers will be over-written by the new drivers of the same name.

#TL2012

Print > Printer Type

Lists all available printer drivers. The main review panel shows the driver name. The highlighted name can be selected with the mouse or the Enter key. On the left is a summary of the driver which is highlighted, including the manufacturer, model name and printing scale. Also shown in the summary panel is the name of the current printer and the current printer port, e.g. LPT1. The printer port can be changed by pressing **P**. The information line at the base of the screen gives additional information regarding the highlighted driver.



On selecting a driver, a message is displayed. Pressing the Enter key confirms the use of this printer for the remainder of the session. Pressing **M** copies the printer driver to the default file, MAIN_PRT. On next starting up the ILO program, the printer selection will revert to that previously entered in the ILOCFG configuration program. The entry in this program needs to be changed for a permanent change in printer type.

#TL0109

Files > Load Spool

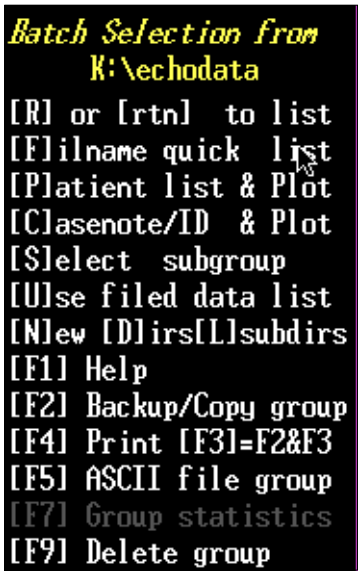
This item is not normally active. Activation requires a research version of the software and also that data spooling is set on in the **Settings** menu (see below).

Load Spool allows a raw data file (MEG file) to be loaded and a previously recorded test sequence to be replayed. A listing of available spool files appears in the review panel. Selection is by mouse or Enter key. On loading, an indication of the length of the recording is given, together with the name of the subject and ear. The loading of a spool file has no influence on the normal operation of the ILO88. (See **Replay Spool**, *#TL0207*).

#TL0110

Files > Batch Copy

Provides utilities for the manipulation of groups of data files. Individual or groups of data files can be selected, as in Review. Press Enter for the review panel, select a file by highlighting and pressing Enter or clicking the mouse. The selected file name will appear on the selected batch list. Press Enter to select another file for the batch list. They may then be directed to a back-up disk (**F2**) or to the printer (**F4**) or to a list file (**F5**). **F3** combines the functions of **F2** and **F4**. The group may be deleted using **F9** - a warning is given. If no file selections are made, then all of the files in the current directory are processed by **F2**, **F4**, **F5** and **F9**.



#TL0111

Files > DOS Command

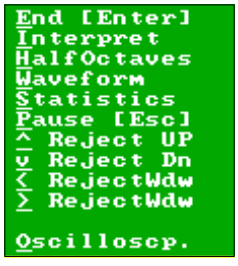
Temporarily exits to DOS for command line instructions. Type **EXIT** to return to the ILO.

#TL0112

Files > Exit Options

Immediately terminates the ILO88 program if all current data has been saved. If not, an invitation to save current data is given. The program exits to the opening block selection screen, from which TEOAE or DPOAE recording can be selected, together with other utilities.

Tests menu



The test menu (above left) provides a selection of testing options and access to testing utilities. Once a test is commissioned, the right-hand panel will be seen. This gives options to full control of the test. The mouse is not operative on the right-hand panel. Keystrokes must be used during testing itself. Please refer to **Managing a TEOAE Recording** for further information.

#TL0201

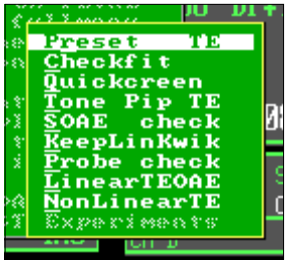
Tests > QUICK TEOAE

Performs the QuickScreen TEOAE test. It automatically installs the Low Cut Filter, which assists in artefact rejection. No further selections are available after the Checkfit stage.

#TL0202

Tests > TE fullmenu

Provides for the full choice of TEOAE test options. All tests begin with the Checkfit function and this is followed by the **Test Option** secondary menu.



#TL1101

TE Select > Preset TE

This performs the default original TEOAE test using an 80 microseconds non-linear click stimulus and 20.48 milliseconds sweep time. This default test can only be changed in research installations.

#TL1102

TE Select > Checkfit

This performs the standard ILO88 fit adjustment test using the default click stimulus. During the Checkfit process a keystroke menu is shown, allowing the artefact reject level to be set using the up/down cursors and the stimulus level to be normalised using the automatic gain adjustment (key **A**). Other useful functions include the key **O**, providing a real-time oscilloscope monitor of the ear canal sounds and key **S**, which will cause stimulation to temporarily pause. Press Enter or **G** to go on with the testing.

#TL1103

TE Select > QuickScreen

This initiates the **QuickScreen** test protocol as in Quick TEOAE on the main Tests menu, but *without* the automatic application of the Low Cut Filter.

#TL1104

TE Select > Tone Pip TE

This is identical to **Tone Pip TE** on the main tests menu.

#TL1105

TE Select > SOAE Check

This is identical to the Spontaneous option on the main Tests menu.

#TL1106

TE Select > KeepLinKwik

This option provides a QuickScreen test in a form which keeps both the linear and non-linear components of the response.

#TL1107

TE Select > Probe Check

This option performs a special test which reveals errors in the probe calibration, usually indicating contamination (see **Calibration** section).

#TL1108

TE Select > Linear TEOAE

Performs a measurement on the original 20.48 format using quick stimuli of uniform height. This method has the advantage of lower noise levels and greater sensitivity to OAEs than the standard non-linear default test (preset). It has the disadvantage of greater susceptibility to artefacts of ear canal ringing origin. It is not recommended that this option is used routinely and it is essential that it is never used with high stimulation levels. Ear canal acoustic artefacts occur at the commencement of the response trace and are usually easily recognised. They can be removed from the response using the waveform editor (**F5**) or the **Analysis** menu.

#TL1109

TE Select > NonLinear TEOAE

Performs the standard default ILO88 test, identical to the preset option above. It is provided here to ensure the default test remains available when the preset option has been changed in research installations.

#TL1110

TE Select > Experiments

Initiates a third-level menu providing tests of special interest to auditory research laboratories. This menu can also carry custom functions. These options are not available on standard software but only on research software. They are detailed in the **Research Supplement**.

#TL0203

Tests > TonePip TEs

After the Checkfit process, a keystroke menu is provided which allows for the frequency of the stimulus tone pip to be selected. The parameters of the tone pip (amplitude, length, plateau, multiplex) are also noted but cannot be changed from this menu. (See **Settings > Stimulation > Waveform > Tone Burst**).

#TL0204

Tests > Spontaneous

Spontaneous performs a synchronised spontaneous OAE activity test. A special data collection procedure operates. A click stimulus is applied at one quarter the normal rate. Data is captured during the periods that no stimuli are given. Synchronisation of the SOAE by the trigger stimulus ensures temporal synchronisation. This allows synchronous averaging to be employed to extract very small spontaneous emissions. An advantage of the protocol is that it discriminates against tonal noise in the environment. A disadvantage is that is records ‘quasi-spontaneous emissions’ which may be present only for short periods after stimulation.

#TL0206

Tests > Continue F8

If selected immediately following a test, the test is recommenced. This option will be checked (✔) if continuation is possible. This is useful if a recording was abandoned due to patient noise and then can be continued.

#TL0207

Tests > Replay Spool

This function relates to reprocessing raw data saved during the previous test or loaded from disk. Before the facility can be used, it is necessary to open the data spool using the **Settings** menu.

#TL2901

Replay Spool > Re-run Test

Re-presents the raw data stream from the probe for reprocessing. Applies only when raw data has been previously spooled to memory and saved. See **Settings** option, **Data Spool** and also **Load Spool**.

The following options are only available when advanced statistical processing is enabled. This facility is not available on all installations.

#TL2902

Replay Spool > View Sweeps

#TL2903

Reconstruct

#TL2904

Super Reject

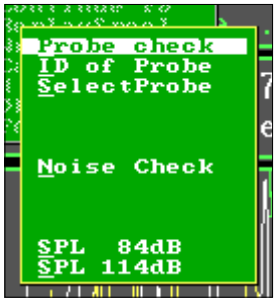
#TL0208

Tests > Write Spool

Operates only when the Data Spool option has been activated. When selected, the entry is checked and raw data from subsequent tests is kept in memory. This process may slightly decrease the efficiency of recording on slower computers. When writing to spool is occurring during the test, this is indicated in the Patient ID panel. To cancel the Write to Spool option, select **Write Spool** a second time.

#TL0209

Tests > Calibration



Calibration provides facilities for the confirmation and calibration of the ILO system by the user. We recommend the complete ILO system is checked at least once per week or if the user is doubtful as to the condition of the probe. The most thorough test of the whole system is achieved using the Probe Calibration test. If this test shows substantially differing readings from previous tests with this probe, a complete Equipment Test should be undertaken to eliminate possible electronic errors. If the system is to be used to record data for research purposes or for comparison with data from other centres, or with data collected on other probes, then the acoustic calibrations should be undertaken. Acoustic calibrations require access to external calibration equipment not supplied by Otodynamics but available in most audiometric equipment service departments. There are a number of calibration options:

#TL2801

Calibration > Probe Check

This performs a special test on the probe placed into the Otodynamics cavity (not an ear). The test records a synthesised OAE consisting of three response tone bursts which can be compared with the recording made on your probe at the factory. This is described elsewhere (the **Collecting Options** menu, **Probe Calibration**).

#TL2802

Calibration > ID of Probe

This displays the current identification associated with the current probe. In DP Echoport, TE*i*, 88*i*, 88DP*i* systems the electronic ID of the probe is read automatically. Not all probes include an electronic ID. In these cases and also in the cases of other ILO systems, a zero ID is entered, but the user may name the probe. The ILO automatically keeps a log of probe usage for each probe ID and/or name and this is useful for service and warranty purposes. See **Information > Probe Check** for further details. The ILO will automatically remind the user to check the probe after a set number of uses. In systems where the probe ID cannot be automatically read, the user must enter or select the probe name when the probe is changed if the usage log is to remain correct.

#TL2803

Calibration > Select Probe

This displays a list of probe IDs and names, previously entered and saved. On selecting a probe, all usage is logged under that probe's identity (see above). If no probe files are shown, or if a new probe is to be introduced, press ESC to skip the selection and then enter the name/ID of the probe to be used. A new probe entry is saved only after a test is completed. The ILO can be set to request a probe selection at start-up (see ILOCFG program Customisation). With hardware capable of reading the electronic probe ID, this is not necessary. We recommend automatic start-up probe selection in all other cases.

#TL2807

Calibration > Noise Check

This performs a modified 'Checkfit' procedure in which the live signal from the probe is displayed on the screen so that the level and type of noise background can be seen. This test is only useful if all the ports of the probe are firmly blocked (with a finger) so that no external acoustic noise enters the probe. This will also ensure that no stimulus sounds enter the microphone. The level of noise is represented by the size of waveform fluctuations across the screen. To obtain a measure of these, observe the noise histogram on the right-hand panel and adjust the artefact reject arrow using the cursor keys so that it lies at the maximum of the distribution. Then read the peak level of the noise recorded by the microphone at the top right (Reject dB). With the probe removed, the instrumental noise will typically register around 24dB spl (23.7 shown). With a probe fitted and fully blocked, the mean noise may typically be 30dB spl (29.7 shown) with peaks up to 36dB spl.

The test is particularly useful in identifying electrical/radio interference. This can be caused by improper grounding of the PC or by very strong local radio interference sources. Power line interference typically results in spikes which move across the screen, radio interference takes the form of fluctuating oscillations.

#TL2811

Calibration > SPL 84dB

This performs a modified Checkfit procedure in which the live signal from the probe is shown on the screen and the sound pressure and peak frequency registered by the ILO is indicated by a display panel. Apply a free-field externally calibrated sound field of 84dB spl at 1kHz and observe the level registered by the ILO. Standard adult and DP probes should show a figure of 84dB +4/-3dB. The small serviceable neonate and general purpose probes have a higher sensitivity and will show up to 90dB on the display. A correction of 6dB should be applied to data obtained with these probes if true spl figures are required. The response of the probe at other frequencies may vary (see **Calibration > Probe Check** above).

#TL2812

Calibration > SPL 114dB

This is as for SPL 84dB but is designed for use with an acoustic calibrator delivering 114dB spl to which the probe is directly coupled. To perform this test, an Otodynamics calibration kit is essential, which includes a 30dB probe signal attenuator and acoustic coupler.

Calibration: Additional Information. The systems of the ILO can be confirmed by running the Equipment Test program. A probe should not be inserted during this test. With the Otodynamics two-card, ILO92, ILO88 Echoport and ILO288 Echoport, a calibration plug must be inserted replacing the probe. With the ILO292 and internal systems such as 88*i*, DP*i* and 88DP*i*, the probe should be removed but no calibration plug should be inserted as this connection is made internally. A special test plug is available for checking DP functions of appropriate ILO systems. For this, a DP cross coupler plug is needed for insertion when requested by the program. The Equipment Test functions are discussed in more detail in the Installation section of this manual.

The ILO system can be regarded as a sophisticated sound level meter and analyser. To check the calibration of this function, it is necessary to supply a known sound to the acoustic probe in free field or within a calibration instrument. Using this option, the sound levels as read by the ILO system are displayed. This data may be used to apply fine corrections to the measurements made by the ILO and to detect malfunctioning equipment against previously supplied readings.

OAE probes differ slightly from each other due to manufacturing tolerances. Also, for compatibility purposes, Otodynamics ILO probes have the same general response characteristics as probes supplied with the original ILO machines from 1988. It will be possible to correct for the frequency response of the new ILO probes, which include an electronic ID. Users having suitable equipment can be supplied with this information on a disk file. However, there is no clinical benefit from applying such corrections since judgements on the ILO are based on signal-to-noise and relative measurements rather than absolute sound pressure measurements. However, this correction may be necessary for research purposes. The user should note that older instruments (ILO88, ILO92 and Echoport 88 and 288) are not able to detect the electronic identity of the probe and therefore it is possible to load the wrong correction file for the probe being used. The ILO292, the ILO88*i*, DP*i* and 88DP*i* all have the capacity to read the probe ID if an ID labelled probe is in use. In this case, the instrument will give a warning message if the probe being used has an identity conflicting with the probe correction data currently loaded. Older probes and most probes supplied in 1997 did not include the electronic identity facility. Please contact Otodynamics if you need to use the probe correction facility.

#TL0210

Tests > H Database

This option needs to be enabled in the ILOCFG program by setting the custom option L to 1 and the level of use to be ILO+DATABASE. The option also requires that a screening management program such as HiScreen or the Otodynamics screening manager is installed.

On selection, control is transferred to the data management program where patient lists can be entered and screening tests initiated.

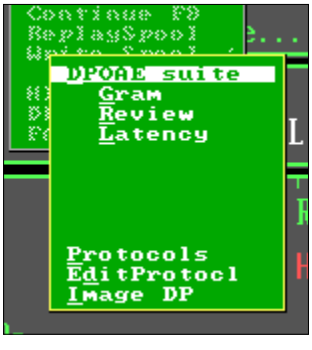
The ILO is licenced to work directly with the National Center for Hearing Assessment & Management's Hi•Screen program. If registered with NCHAM, selection this option will call the Hi•Screen program. With this program, patients' demographic information can be entered and screening workloads managed. Individual TEOAE QuickScreen tests can be initiated and responses scored and filed. Please contact NCHAM for further information.

NB: Even when Hi•Screen is installed in your system, it is necessary to indicate its use in the configuration of the ILO using the ILOCFG program.

#TL0211

Tests > DPOAEs

When DPOAEs are installed on your system, this option activates the **DPOAE** secondary menu, which provides access to a range of functions previously part of the ILO92 program. DPOAEs may also be selected by pressing the key **D**.



#TL1001

DPOAEs > DPOAE Suite

Transfers to the DPOAE screen if available on your installation. To access the DP menus on this screen, press **M** or click on the **Menu** box. A DPOAE measurement sequence may be initiated immediately by pressing **F6**. Please see **Part Three : DPOAE User Manual**. The DPOAE mode can be exited to the TEOAE mode by pressing **T**. Only shows on DP capable systems.

#TL1002

DPOAEs > Gram

Automatically proceeds to the DP-Gram measurement function of the DPOAE module.

#TL1003

DPOAEs > Review

Lists the DPOAE patient files.

#TL1004

DPOAEs > Latency

Automatically proceeds to the DP Latency check function of the DPOAE module.

#TL1010

DPOAEs > Protocols

Lists the DPOAE macro programs that have been created by the user, in addition to those used to provide the fast DPOAE option below. Select a protocol by highlighting and pressing Enter or clicking with the mouse. A message will appear to confirm that the macro program has been activated. On next selecting DPOAE Suite from this menu or by pressing **D**, the selected program will automatically be loaded and run. The selected macro program is automatically deactivated once used and must be reselected. The ILO88 keystroke macro programming facility can be used to automate this process.

#TL1011

DPOAEs > Edit Protocol

Calls the ILO DPOAE macro editor. This provides standard facilities for editing and saving protocol files. Under the Help option, a library of macro commands is to be found.

#TL1012

DPOAEs > Image DP

When checked, it causes the DPOAE display screen to be captured as a PCX file at the point of transfer between the DPOAE program and the TEOAE program.

#TL0212

Tests > Fast DPgram

Transfers immediately to the DPOAE program and performs a half-octave DP-Gram under the control of a macro program V5KWIKDP.MAC. This achieves efficient data collection by repeating only those points where the signal-to-noise remains inadequate. The test continues until every point has 10dB clearance above the 95% confidence noise level. The test may be terminated manually at any time. The specifications may be copied to other file names and edited to form a macro program suiting the user's needs.

Settings menu

#TL0301

Settings > Stimulation

Activates a secondary menu allowing for changes in the stimulation level and format.

#TL1801 & #TL1802

Stimulation > Gain Stim A

Stimulation > Dual Gain AB

These options allow the stimulus gain to be changed. Options are available to change only the primary gain A or gains A and B on certain hardware options. These relate to the output levels. Within the adjustment panel there are two entries. CHECK FIT REFerence gain controls the level used during the Checkfit process. The TEST GAIN operates during the main recording process. These should normally be set identically. The TEST GAIN is copied to the CHECK FIT gain when the **R** key is pressed. It is not normally necessary to change the stimulus gain for screening purposes unless OAE recordings at reduced stimulus levels are required. A further option waveform is provided. Stimulus Maths allows small changes to the stimulus size for fine adjustments. The form of the stimulus waveform presented during the preset mode can also be altered. *(#TL1801)*

#TL1805

Stimulation > Auto Adjust

When checked, it enables an automatic adjustment of stimulus level when A is pressed during the Checkfit. The level is set using the Target Level option.

#TL1806

Stimulation > Target Level

Sets the peak stimulus level used for Auto Adjust. The default setting is 300 milliPascals. It can be changed using the cursor keys. Ensure good probe fit before using Auto Adjust. The maximum probe output is limited and the target level may not always be met.

#TL1809

Stimulation > Waveform

Activates a third-level menu available only on research level systems. The menu allows for changes in the waveform of the preset stimulus and for the saving and retrieval of custom stimuli. Custom stimuli should not be used for clinical purposes. They are provided for research purposes only. Users are referred to the **Research Supplement**.

#TL0302

Settings > Stop Logic

Calls up the automatic test termination secondary menu. It provides facilities for specifying the conditions under which a test recording will automatically terminate.

#TL1901

Stop Logic > Auto Stop

This enables the automatic stop facility which uses information read from the preselected stop protocol file (the default file is MANUAL). When operating, the automatic stop facility will terminate the test when predetermined conditions are met.

#TL1902

Stop Logic > Fixed Stop

Disables automatic termination and sets the number of low noise sweeps as the only terminator of the test sequence, other than manual interruption.

#TL1903

Stop Logic > Load Protocol

Lists the automatic stop protocol files created by the user and supplied by Otodynamics. The files have the extension STP and appear in the standard review panel. A file summary is shown on the right; this indicates the currently operative

file and gives details of the highlighted file, including the author, source and date. STP files can be set as editable or read-only at the time of creation. Their status is also indicated in the summary panel.

For further discussion and illustration, see **Test protocol and ILO Stop Logic** in **Data Analysis Utilities**.

#TL1904

Stop Logic > Edit Protocol

Calls the automatic termination keystroke menu which allows the adjustment of approximately 50 parameters which can define the limits of a test. These are described elsewhere. When activated, the Stop Logic main menu option is checked and subsequent tests will terminate automatically when stop conditions are met. Automatic stopping can be disabled by selecting either the Fixed N option below or by pressing the **F** key in the automatic termination keystroke menu.

Stop parameters can be individually altered using the index code provided and the up/down cursors. Edited protocols can be saved and loaded using the **S** and **L** keys. Protocols can be write-protected and have provision for notes to be added.

#TL0303

Settings > Data Window

Displays the current setting of the measurement window applied to standard OAE recordings. Key **W** re-windows current data. We recommend that the newer **F5** function be used instead. Key **D** superimposes the already applied window onto the response waveform for information. Key **S** can be used to alter the window automatically applied to recorded data. This would only be necessary if it was decided to permanently use an alternative stimulus to the standard click stimuli provided.

#TL0304

Settings > Data Filter

Displays the settings of the band width limit previously set in the **F3** cursor spectrum panel. Key **F** reapplies this filter to the data. Key **S** allows this manual filter setting to be changed, but we recommend this is performed from the **F3** cursor spectrum panel. Key **S** also allows the automatic filter applied to input data to be changed. The default is 732Hz to 7324Hz. The automatic filter is applied to all recorded data and assists in the removal of unwanted low and high frequencies which might otherwise obscure valid OAEs. We do not recommend that these settings be changed.

#TL0305

Settings > Low Cut Filter

This can be permanently set on at start using the customised option N in the ILOCFG program. It activates a high pass filter operation on incoming data which is useful in reducing the interference caused by noise. It operates to provide additional attenuation below 1000Hz. On selection, a panel indicates that the Low Cut Filter is to be switched on or off. When switched on, a rectangle appears in the Response Waveform panel during recording and on recall. The noise levels indicated during recording will be reduced by the removal of low frequencies.

#TL0306

Settings > Refresh Rate

Sets the interval between automatic reanalysis and screen updates during recording.

#TL0307

Settings > ILO CONFIG

Allows limited access to the basic default settings through the ILOCFG program. ILOCFG can also be accessed from the opening Options utility screen.

#TL0308

Settings > Environment

Where installed, this option allows for the current settings on all menus to be stored and retrieved.

#TL0309

Settings > Data Spool

Accesses a secondary menu allowing data spooling to be turned on and off. When on, all probe signals are saved prior to analysis and can be replayed - see above. Data may be saved to disk and reloaded; note that a typical test will consume approx. 0.5MB of disk space. Data spooling, if left on, will quickly fill your hard drive. Data spooling files may be deleted from this menu.

#TL1701

Data Spool > Create Spool

Reserves the memory required to store raw data for an entire test. Computers with restricted memory will not accommodate long tests. Only activate the spool if spooling is required. When activated, the Create Spool option is checked. The **Data Spool** item of the **Settings** menu and the **Load Spool** item of the **Files** menu are also checked.

#TL1702

Data Spool > Include Stim

When checked, the spooling system stores the stimulus waveform in the initial portion of the response waveform. This is the default setting. It may be changed by selecting the highlighted **Include Stim** item.

#TL1703

Data Spool > Save Spool

This saves the raw data retained during a test recording to a disk file. The default directory for spool files is ECHOSPOO and the normal extension is MEG.

#TL1704

Data Spool > Load Spool

This loads a spool file from the current spool directory. The data is held in memory and does not influence the normal running of a test. (See also **Load Spool** in the **Files** menu). Spooled data can be replayed through the ILO using the **Replay Spool** option of the **Tests** menu.

#TL1705

Data Spool > Data Status

Displays the current index pointer to data held in the spool memory. With no data loaded, N=O and Index=32721. N indicates approximately the number of sweeps stored. Each count equals 63 x 512 point waveforms.

#TL1706

Data Spool > Auto Saving

When checked, this option ensures that a raw data spool file is saved automatically when the results of a test are saved in the normal way. This avoids the necessity of using the Save Spool option and ensures that the name of the spool file is identical to the name of the standard ILO data file.

#TL1707

Data Spool > Erase Spool

Shows a list of spool files. On selecting a file, the option to Erase or Retain is given. Because spool files typically occupy a Megabyte of disc space, it is recommended that spool files are deleted when no longer required to prevent your disc from becoming full.

#TL1708

Data Spool > Part Spool

Allows for the start and end of a spool replay operation to be defined so as to avoid portions of the recording which are of little value.

#TL17012

Data Spool > Spool DIR

Allows for the directory for spooled data to be changed. This option is identical to that provided for in the **Directories** item of the **Files** menu.

#TL0310

Settings > Processes

This calls a secondary menu, indicating the setting of various internal functions and options of the ILO system. These options cannot be changed except in the research version of the program. The options control the timing, windowing and averaging functions of the ILO. These should not be changed for clinical uses of the instrument. See **Research Supplement** for further information.

#TL0311

Settings > Q Summary

Enables a display panel shown during testing which lists the response reproducibility in each frequency band. Large characters are used to aid visibility. When used in conjunction with the automatic stop facility, bands which have attained the minimum required value are highlighted.

#TL0312

Settings > Band Set

Activates a secondary menu which controls the default frequency band analysis of OAE data. This analysis is used to provide the band reproducibility and band signal-to-noise figures in the right-hand display screen panel. For compatibility with previous versions, the option Linear is checked by default. We recommend that the Half Octave option is checked. The band setting for the Half Octave main screen graphical analysis (see **Analysis > Band Levels**) is Half Octave by default. This can be changed by checking the desired Octave interval in the above menu.

Analysis menu

The Analysis menu provides a range of utilities and processes found to be useful when examining TEOAE data. The menu items are only accessible when data has been loaded or recorded and is displayed on the screen.

#TL0401

Analysis > Spectrum

#TL2401

Spectrum > Spectrum F3

Initiates a detailed response spectrum display with cursor. The display shows the intensity of response and noise against frequency. For an illustration and detailed documentation see **Data Analysis Utilities**, **Detailed Examination of the TEOAE Spectrum**). The left/right and Home/End cursor keys move the spectrum cursor and Page Up and Page Down provide course movements. Clicking the mouse will also move the cursor to that position. The response and noise intensities are shown at the top of the panel, together with the frequency. Keys **F**, **R** and **S** provide alternative degrees of smoothing.

A rectangular bridge marks the band width selected for optional band limiting (filtering). The start and end of the filter set band width may be altered by double clicking with the mouse, or positioning the cursor and pressing **L** for the lower limit and **U** for the upper limit. The key **B** will activate the filtering. The filtering can be removed if **F10** is pressed immediately after closing the spectrum panel. The primary use of filtering is to cut out low frequency noise below 1kHz. Narrow band widths should be used with great caution.

Research installations have access to the phase of the TEOAE. Press **G** to display the pattern of phase change (only shown if response is greater than noise). Shown in black on grey are the phases of the response (RPHI), the stimulus (S5) and the intensity of the stimulus (STB) at the cursor position.

The cursor values can be printed or saved to file. Pressing the key **P** causes the data at the current cursor position to be sent to the printer and the cursor position advanced one frequency point (Echoport users should ensure their unit is not connected). No page feed is included so the form advance button of your printer may need to be manually operated. The key **A** will result in the opening of a file ILOFFT.TXT. The option to enter a marker message is given. New data is appended to old data. Once opened, data is written to the file for each cursor position. Move the cursor over the frequency region required to be documented. The ILOFFT.TXT file is automatically terminated when the spectrum panel is closed.

The spectrum panel can be called without a menu present by pressing the **F3** key. It can be closed by pressing the Escape key or **F3** a second time, or by clicking the mouse outside the panel.

#TL2402

Spectrum > Frequency Time

Displays the OAE as a spectrogram, showing clearly the frequencies present at different times. Spontaneous and near-spontaneous OAEs show as horizontal lines on this display. A 'classic' adult TEOAE has a descending frequency content with time, seen as a sweep from top left to bottom right on the frequency time display. The display is useful in visualising the degree of internal reverberation in the inner ear and for confirming if spontaneous OAEs have contributed to the TEOAE waveform. No clinical implications are implied by this display.

#TL0402

Analysis > Waveform

#TL3001

Waveform > Waveform F5

This introduces a moveable cursor onto the main response panel. The sound pressure in microPascals is shown at the position of the cursor together with the time of the cursor in microseconds. The cursor movement can be controlled with the left/right, Home and End keys and Page Up and Page Down provide course movements.

Relative time measurements can be made by pressing the spacebar to mark a position of the cursor. The time measurement will then show zero. Movement of the cursor will ensure the relative time between the new and old positions.

The Waveform Cursor and Windowing keystroke menu is shown above the response panel. A data window may be created and applied. Key **S** sets the start of the window to the cursor position. Key **R** marks the end of the rise of the window

following the start and key **E** marks the end of the window following a fall, as defined by **R**. Default settings are shown and key **W** applies the window to the data. The windowing can be removed if **F10** is pressed immediately after closing the Waveform Cursor window.

The waveform cursor function may be called without a menu present by pressing the **F5** key. The function can be ended without changing the data by pressing the Enter key or by clicking outside the keystroke panel.

For illustration and further discussion, see **OAE waveform** in **Data Analysis Utilities**.

#TL3002

Waveform > Profile F6

Underlays the waveform display with its power profile. This is the correlated (possibly response) power. Noisy traces will have a lower energy profile than clean traces. In a clean response, the profile will follow the envelope of the waveform, passing 30% below the peaks and thus representing the sound pressure level, not peak level. This requires that the two waveforms, A and B, are in phase. (The two waveforms are multiplied together, smoothed over 5 points and square rooted. The RMS sound pressure is shown.) Pure noise will in general have a profile much lower than the waveform. There may be power peaks by change coincidence, but these will generally not be at the peaks of the waveform.

The display is useful to visualise the times when energy is arriving and in understanding why a large (noisy) trace is not valid as an OAE.

#TL3003

Waveform > Gating shF6

Displays the envelope of the gating window used in processing the current data (white) together with the mean waveform (A+B)/2.

It is important to remember that the accuracy of the frequency analysis applied to the waveform requires the beginning and end of the recorded waveform to be faded out. This means that frequency components only present at the start (e.g. the highest frequencies) may be lost.

Re-windowing may be useful. Note that previously gated-out data in saved data is not usually recoverable.

#TL3004

Waveform > Reveal AB F2

The two independently collected TEOAEs, A and B, are normally superimposed on the Response Display. This option separates the two waveforms so that areas of difference and similarity can be examined visually.

#TL3005

Waveform > A-B wave F4

The two independently collected TEOAEs, A and B, are normally superimposed on the Response Display. This option displays the differences between waveforms A and B. Differences are quantified in the 'noise' (red) component of the OAE FFT spectrum. The difference display is useful only in showing where in the waveform difference occurred.

#TL3006

Waveform > Delay Shift

This function is intended only for use when two different files are being compared. **Delay Shift** allows a correction to be applied for any time difference between two recordings. This might occur as a result of different probe insertion depths, or seal qualities. The left and right cursor keys introduce a relative time shift between traces A and B. This is relevant when comparing traces recorded on different occasions from the same ear. Ear canal fit changes can be corrected for, but only in limited frequency ranges. Time shift should be adjusted so as to maximise reproducibility in that band. This is displayed as a conversion of red spectrum data to blue spectrum data in the Response FFT. We recommend you gain experience by introducing a delay into a single recalled measurement first for comparison.

The delay introduced between A and B response traces is shown in the top of the Response panel in milliseconds. The function is ended by pressing the Escape or Enter keys. The final delay is shown.

#TL3007

Waveform > Zero Delay

Cancels any delay introduced with the previous option.

#TL0403

Analysis > Progress

Progress displays the history of important parameters during the course of recording, for technical test evaluation purposes. Use this display to decide on the reasons for a test failure. The panel shows graphs of reproducibility, stimulus stability, stimulus level and noise level at intervals during the testing. Reproducibility should grow steadily during a good test; stability should remain high and stimulus dB should be steady. Noise level may show fluctuations with a noisy patient. Good test results with poor stimulus indicated at the end of the test may be accepted if the progress chart shows stimulus decline to be limited to the very end of the test.

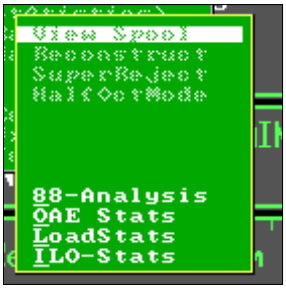
The **Progress** panel may be called without any menus present by pressing the **P** key. The panel can be closed by pressing **P** a second time, or by pressing the key **C** (clear).

For illustration and further discussion, see **Test progress** in **Data Analysis Utilities**.

#TL0404

Analysis > Statistics

Initiates a secondary menu, providing a range of statistical tools with which to analyse the data. These are of two types. The first group utilises raw data saved during a recording and reprocesses the data using advanced procedures. This is shown shaded if not in use. The second group does not require advanced statistical processing. It compares the currently displayed response data with normative data held on file to produce an assessment of the response. For further details, see **Use of the ILO Statistical Analyser**.



#TL2201

Statistics > View Spool

When the raw data spool contains data, this option displays data from each sweep and its spectrum, one by one, making a movie of the data sequence. This is useful in identifying good and bad sections of the recording for reprocessing. With strong TEOAEs, each sweep can contain a recognisable OAE.

#TL2202

Statistics > Reconstruct

Reprocesses the raw data from the spool (if loaded). Reject level can be preset. A probability assessment is made for each band.

#TL2203

Statistics > Super Reject

Reprocesses the raw data from the spool (if loaded). Rejection is on a band by band basis - making maximum use of available data. A probability assessment is made for each band.

#TL2204

Statistics > Half Octave Mode

For use only with spool reprocessing. When checked, the probability assessment in Reconstruct and Super Reject is in Half Octave bands, otherwise it is in 12 harmonic bands (800Hz for Quickscreen data).

#TL2209

Statistics > 88-Analysis

Provides the popular Version2 ILO88 program, ‘Analysis’, which can load a number of TEOAE files and display them in various forms.

#TL2210

Statistics > OAE Stats

Provides the simple Version4 ILO88 'OtoEmissionGram', which gives a rough assessment of validity in band reproducibility. If an ILO normative stats file is loaded, the percentile rating of the OAE is shown relative to the population stats.

#TL2211

Statistics > Load Stats

Loads normative data as produced by ILOSTATS, for use by OAE stats.

#TL2212

Statistics > ILO Stats

Provides a link to the ILOSTAT utility which can process up to 1,000 ILO88 data files and generate statistical summaries.

#TL0405

Analysis > Band Levels

Band Levels switches to dual screen if not already set. It provides an analysis of the OAE signal in half-octave bands (default). Resolution can be changed during the display by pressing **1** through **8** for one octave through to one-eighth octave bandwidths. If the screen is in the normal display mode, the analysis is shown as a histogram against the background noise. If the display screen is rearranged to dual mode (keystroke **R**), the analysis is shown as a linear graph with numerical values to the right. The default analysis resolution for the session can be changed using the Settings menu Bandset option.

In the standard display form, the analysis panel can be called without menus present by pressing the key **H**. The panel can be closed by pressing **H** a second time, or **C** to clear, or **W** for waveform display. The display is also cleared when a new recording takes place, but may be requested during a recording with the **H** key.

In the dual screen mode, the band analysis panel is retained during subsequent recordings and is refreshed along with the rest of the screen. Dual screen mode is cancelled by pressing the **R** key. The resolution of the display is as set in **Settings > Band Set**.

#TL0406

Analysis > Half Octave

This displays a half octave analysis of the response, independently of the current band setting. The display takes the form of a histogram. Resolution can be changed using keys 1 through 8.

#TL0409

Analysis > Compare Merge

Comparison allows the selection of a second data file to overlay the resident file. The review panel is displayed and the file loaded in the usual way. The two files must be of identical response types, e.g. both QuickScreen, in order for the comparison to be meaningful. The newly loaded file appears on the display screen together with the previously loaded file. In particular, the response waveforms of the two files are overlaid and can be compared. The contents of the two files are correlated. A correlation (e.g. reproducibility greater than zero) indicates a degree of identity between the two recordings. This can occur over the whole frequency range or over limited parts only. In the Response FFT display, the differences between the responses are shown in red and the co-related response components are shown in blue. Unlike the display of a single file, the red spectrum portions do *not* necessarily indicate noise, but a combination of the noise present and the differences between the responses. Responses differing in amplitude but not waveform will exhibit substantial 'noise' due to the differences between them on subtraction. Responses of identical waveform but shifted in time relative to each other will also show a high 'noise' level. This may indicate probe fitting differences. Time delays can be corrected using the Delay Shift function above.

#TL0410

Analysis > View & Score

This enters the ILO Score Mode. The scoring toolbar is displayed at the top of the screen. The test is rated as either PASS, REFER or INVALID. The selected rating is highlighted and confirmed with the Enter key. A request for the scorer's ID appears (signature) and when entered, the files for the other ear of the patient appear in the Review panel. It is possible to mark a pass as doubtful before signing off the file by pressing the **Q** key. The file can be rescored before signature by pressing the Escape key. It is possible to perform other analyses on the data while in the score mode by selecting the View Data button, or pressing the **V** key. The normal analysis menu is then accessible. To return to the score mode, select the Score Mode button with the mouse. Score mode may be terminated by selecting the Quit Score button, or pressing the **Q** key. This retains the scores on the scoring data file but abandons the function which renames the data files (see below). It is not possible to quit between left and right ear scoring.

The rating will be marked onto the extension of the file name (e.g. before scoring .DTA, pass is .DTP, refer is .DTR, invalid is .DTI and doubtful pass is .DTQ). Scored files are copied to a file list by the name of SCORED.LST to be found in the ECHOPROG directory. This list can be used by the Back Up utility in the main ILO-V5 option box screen after exiting from the ILO test program.

#TL0411

Analysis > Terminator

Re-examines the current data against the current Stop Logic protocol and indicates the primary condition which would have led to termination of the test recorded under that protocol. This process can be used to apply a standard pass criteria to previously recorded data.

Options menu

#TL0501

Options > Desktop Set

Provides for rearrangement of the display screen, saving and loading customised arrangements. To customise the arrangement of your desktop, select **Arrange Desk** either from the secondary menu or from the **Options** menu. The user may modify the desktop using the mouse. The toolbar is automatically removed. The individual display panels may be moved and changed in size as desired. The desktop may then be saved (**S**) or loaded (**L**) or made the default for future sessions (**M**). To move a panel, hold down the left mouse button on the centre of the panel. To change the size of the panel, hold down the right mouse button on the edge of the panel.

If the arrangement of the display has been changed using the Arrange option, it may be restored by pressing the **Z** key. The **Z** key does not change the overall size of the desktop.

#TL0503

Options > Hide Tool Bar

Removes the toolbar and restores the Escape menu system of the original ILO88, described elsewhere. The mouse becomes active to rearrange the desktop. Key **Z** will restore the default desktop format. Pressing **Z** whilst holding the left mouse button will enlarge a panel to full screen. The toolbar may be restored by pressing **Alt+F**.

#TL0504

Options > Sound Prompt

Turns on and off the ILO audible prompts. When on, the option is checked (✔).

#TL0505

Options > Training

If connected, the ILO hardware is disabled and test recording is conducted using synthesized signals. This option is used only for training and should not be employed during clinical recordings. All recordings made with this option are identified as training recordings.

#TL0506

Options > Old ILO 88

Removes the toolbar and restores the Escape menu system of the original ILO88, described elsewhere. The mouse becomes active to rearrange the desktop. Key **Z** will restore the default desktop format. Pressing **Z** whilst holding the left mouse button will enlarge a panel to full screen. The toolbar may be restored by pressing **Alt+F**.

View menu

#TL0601

View > Clear Screen C

Refreshes the display screen and removes temporary panels. The **Clear Screen** function can be called without menus by pressing the **C** key. The **Z** key performs a more powerful reset of the display.

#TL0602

View > Normal View N

Restores the standard ILO88 waveform display format.

#TL0603

View > Dual View R

Provides a split screen. The upper screen contains the standard OAE response panels. The lower screen contains a half (or alternative) octave frequency analysis of the TEOAE. If the DPOAE software is visited, the DPOAE response recorded will be superimposed on the TEOAE half-octave analysis in the lower panel. If the key **Y** is pressed, the current display is copied to the lower half and held so that other data may be recalled and compared with the stored data on screen.

The **Dual Screen** can be accessed without menus visible by pressing the **R** key (rearrange). Pressing the **R** key a second time restores the single screen mode.

#TL0604

View > Copy Down Y

Copy Down utilises the dual screen format, which is automatically set if not already activated. The active display is copied to the lower half of the screen; work may then proceed on the upper half and the results may be compared to the original data below.

The Copy Down function may be accessed without menu showing. Press the **Y** key to copy the active display to the lower half of the screen.

#TL0605

View > Quad View Q

Redraws the current screen in reduced format four times. Work can be conducted on any one of the four panels. The active panel can be selected by clicking with the mouse on the panel. On normal VGA, the resolution available does not allow for perfect representation of the data. The feature is of use for comparison of recordings. The **Quad View** can be terminated by selecting the menu option a second time, or by performing a Display Reset (key **Z**).

#TL0606

View > Scale Wave

Magnifies or reduces the displayed image for inspection purposes. A permanent expansion or reduction may be applied by pressing the * key.

#TL0607

View > Reveal AB F2

Separates the two overlaid traces recorded alternately during the test so underlying similarities or differences can be seen more clearly. Duplicates the action of the **F2** key.

#TL0608

View > Expand Response

Stretches the timescale by four times to allow detailed aspects of the waveform to be examined. To move the observation window left and right, use left and right cursors.

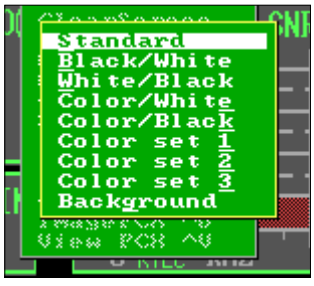
TL0609

View > Longer Stim

Displays the full waveform of stimulus waveforms which exceed the length of the standard stimulus window. This might arise if you use a customised tone burst stimulus of a low frequency. The option is only available if you accepted the option to modify the recording window which is presented at the time of stimulus construction. Custom stimuli are constructed using the **Stimulus** sub-menu **Waveform** option in research capable installations. Extended tone burst stimuli can also be selected in regular installations from the **Test** menu **Tone Burst** option. Selection of a low frequency tone burst stimulus automatically reduces the time window available for response recording.

#TL0610

View > Colours



Selects the palette used for screen display. The user may select black on white, or white on black, which are more suitable for some printing and photographic operations. Various colour palettes are supplied which may be preferred with specific colour printers.

The Background option switches the grey background of the ILO screen to black. Second selection restores the grey. This can be useful with some printers. Colour selections are not cleared by either the **Z** or **C** screen clear functions.

To restore normal ILO screen colours, select **View > Colours > Standard**.

#TL0611

View > Image Save

Saves an image of the current screen on a file. This function can be accessed at any time without the menu by pressing **Ctrl+U**.

#TL0612

View > View PCX

Allows a saved image to be recalled and displayed on the screen.

Memory menu

The ILO has five test response memories. One is the active response memory holding the data displayed on the screen. There are four other reserve response memories which can be recalled to the screen. When a new recording is made, it is placed both on the screen and in the first of the four other memories. Previously stored responses are shifted along in the memory. The memory can therefore hold the last four standard recordings. Spontaneous emission recordings occupy the whole of the memory available.

The memory menu helps to manage the ILO memory.

#TL0701

Memory > Get Memory

This displays the contents of the four reserve memories in the quad display format. Top left is Memory 1, with Memories 2, 3 and 4 displayed clockwise. A reserve memory can be selected and displayed on the screen by keying in its number, **1**-**4**, or clicking on it with the mouse. Selection can be abandoned by pressing Escape, when the previous display will be redrawn.

#TL0702

Memory > Arrange Memory

This displays graphical summaries of the four reserve memories in sequence across the screen. Any Memory 3-4 can be brought forward to position 1 by keying in its number. Memory 4 is lost each time a new recording is made. A secondary use of this display is to observe the time course of response during an SOAE recording which spans four memory regions.

#TL0703

Memory > Series Memory

This displays the four reserve memories in a special ILO format which allows for the detailed response waveforms to be compared. The Response FFT for each waveform is also displayed across the top of the screen. The stimulus waveform for each memory can be substituted for the Response FFT and vice versa by clicking in the upper part of the display. Press Escape to clear the display.

#TL0704

Memory > Combine Memory

This displays the four reserve memories in quad display format, as in Get Memory above. It is then possible to enter a numerical formula, e.g. 1+2-4, to specify a combination of responses to be displayed and transferred to the active memory for analysis. One application is to subtract two repeat recordings in order to define the differences; another is to add together repeat recordings in order to obtain an improved average. Note that the arithmetic is applied literally. The result of 1+2 will not be the average of responses 1 and 2, but the sum. It will therefore be necessary to use the **Scale Wave** function of the **View** menu to produce a true average, by dividing by 2.

#TL0705

Memory > Put in Memory

This enables the active screen to be stored in memory position 1, displacing existing memories by one position.

#TL0706

Memory > Extract Raw

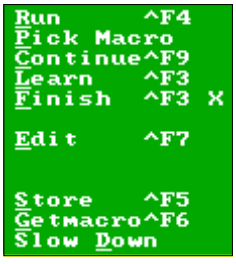
This displays the un-windowed version of the current active memory, where available. It is normally only available for freshly recorded data (not recalled data).

#TL0712

Memory > Save Spool

This saves the raw data retained during a test recording to a disk file. The default directory for spool files is ECHOSPOO and the normal extension is MEG.

Key Macro menu



This menu allows for automatic operation of menu sequences, according to pre-recorded macro programs. This is helpful in setting up user preferences and in accomplishing a series of measurements automatically.

A single macro program can hold approximately 30 instructions comprising up to 100 characters. Macro programs can call each other. They are saved in groups of ten, identified by number, 1 through 10. Each macro can also be named.

#TL0801

Key Macro > Run

This initiates the macro program. If a program has been previously picked using the Pick option, it will commence running immediately. If not, the desired program number must first be selected. Any key will interrupt the program. The Program Pause keystroke menu is displayed. The Enter key will continue the program; key **B** breaks the program at that point (the program may then be continued by selecting the Continue item in the Key Macro menu). Keys **L** and **R** set the left and right ear respectively in the Patient ID panel and key **N** allows the entry of a new patient name. Run can also be activated using **Ctrl+F4**.

#TL0802

Key Macro > Pick

Pick lists the available programs by number and name. The highlighted program is selected by clicking with the mouse or pressing Enter. This program will be automatically selected when the Run command is given. When a macro program has been picked, its number is shown opposite the Run command.

#TL0803

Key Macro > Continue

Continues an interrupted keystroke program.

#TL0804

Key Macro > Learn

This sets the ILO into Learn mode. Every keystroke is recorded into the selected macro program memory. The mouse is ***not*** operational during learning. All menus may be operated using the cursor keys, underscored keys and the Enter key. All other operations of the ILO remain the same. As recording progresses, the macro index number 1 through 99, is shown top right. To terminate the program, press **Ctrl+F3**. This corresponds to the Finish menu item below. When programming a test recording, it is not necessary to perform an actual test. **Ctrl+F8** will request a test without it being actually initiated at that time. The program may call anothother program previously prepared. Press **Ctrl+F4**. The option to run the second macro at that time, or not, will be given.

#TL0805

Key Macro > Finish

This terminates the learning mode. It is preferable to terminate the learning mode using the **Ctrl+F3** key operation to avoid learning the steps to highlight the Finish item.

#TL0807

Key Macro > Edit

The macro number is first selected. The macro program listing menu is displayed. **L** lists the actual keystrokes pressed. Key **I** allows for the insertion of a new command; key **D** deletes a command and key **E** ends the listing function. **List** function can also be accessed by **Ctrl+F7**.

#TL0810

Key Macro > Store

This saves the current set of ten macros to a named disk file. This function can also be accessed by **Ctrl+F5**.

#TL0811

Key Macro > Get

This gets a set of macros from a named disk file.

#TL0812

Key Macro > Slow Speed

Macros normally run faster than keystrokes can be entered manually and it is difficult to see what they are doing. If the slow speed option is checked (✔), the macro operation is slowed down so that it may be reviewed. The slow speed option remains active until **Slow Speed** is checked for the second time.

Information menu

#TL0901

Information > Version

Shows the software version, together with the number and compilation date of the specific release. This should be quoted when reporting problems with the program.

#TL0902

Information > Licensed to

Gives the serial number and registered location or ownership of the ILO system to which the software belongs.

#TL0903

Information > Probe Check

This displays the currently registered probe identification and the number of tests performed under that probe ID. The number of tests which will trigger the calibration reminder is also shown. A keystroke option **S** is provided.

On pressing **S**, the option of making a service disk is given. The history of a current probe is written to a floppy disk (provided by the user) and should be sent with the probe in the case of a warranty claim or service request.

#TL0904

Information > F Keys

This displays a summary of the keystroke shortcuts to some ILO functions. These are identical to those in Version3 and 4 ILO software. Press Escape and then **F1** to clear.

#TL0905

Information > Hot Keys

This displays the functions of various keystroke shortcuts to some ILO functions when operating the ILO in the original mode (without mouse operated menus). The functions are identical to those in Version3 and 4 ILO software. They are included for compatibility with earlier versions but Otodynamics reserves the right to withdraw hot key functions in future versions.

#TL0909

Information > Menu Display

This shows a gallery of all available mouse operated menus with their corresponding reference numbers and names. There are two pages; the second page is accessed by the Enter key. It is possible to save the screens in PCX format by pressing **Ctrl+U**.

#TL0910

Information > Write Menus

Allows the text of every menu to be copied to a file.

#TL0911

Information > Read Menus

Allows the entire text of the menu system to be replaced for the purpose of language translation. Please contact Otodynamics with requests for alternative menu languages. Otodynamics cannot guarantee to meet every request.

#TL0912

Information > Service Code

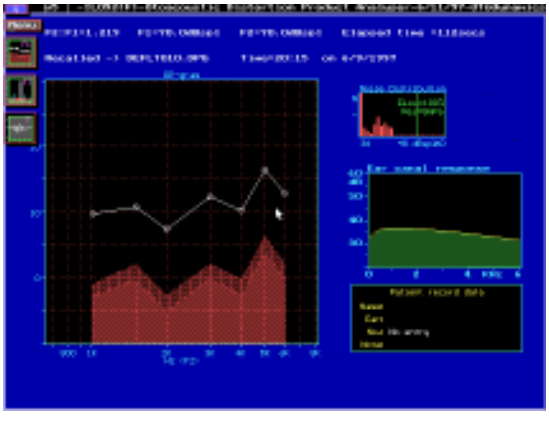
Allows Otodynamics service engineers to obtain technical information about your system. You may be asked to access this function if you report a fault by telephone and enter specific service codes.

PART THREE

DPOAE User Manual

DPOAE functions of ILO V5 software

What are DPOAEs?



DPOAEs are part of the normal process of otoacoustic emission by the cochlea. They are the part that does not totally reflect the stimulus presented to the cochlea - hence the name Distortion Product. No biological system responds precisely to the exact form of the stimulus and this is true of the ear. A distorted response is also called a non-linear response. The ILO88 typically records the non-linear part of the otoacoustic emission response to a click stimulus, because this helps identify the biological nature of the response and eliminate artefacts.

DPOAEs are the non-linear part of the otoacoustic emission to a pair of tones. A pair of tones is used instead of a click stimulus as this makes it technically easy to extract the distortion OAE.

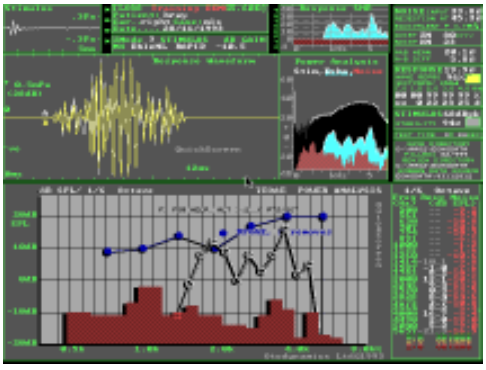
The figure above shows a DP-Gram which represents the level of distorting otoacoustic emission activity at a series of frequencies.

Are DPOAEs the same as click OAEs?

Essentially yes, but the technology is different and each technology has its own practical advantages and disadvantages.

Click or transient evoked non-linear OAEs (TEOAE) are most sensitive to cochlear loss because the recording is made during the silence between the clicks. Unfortunately, high frequency TEOAEs emerge very quickly and are lost in the stimulus portion of the recording.

The DPOAE method does not depend on the time delay of OAE for its detection, so the technique is effective up to higher frequencies. The method is valuable in clinical screening. Higher levels of stimulation are needed to keep recording times short, because each frequency band has to be measured separately. This means that the DPOAE method is a little less sensitive to slight cochlear disorder leading to only 10-20dB hearing loss.



The combination of TEOAE followed by DPOAE provides a comprehensive view of cochlear status not afforded by either technique on its own viz. high sensitivity, speed and high frequency effectiveness.

DPOAEs also have a delay like TEOAEs and this can be tested to ensure it's greater than 2.5ms - as in the TEOAE method.

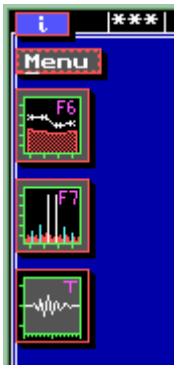
The figure above shows a TEOAE recording and DPOAE recording compared on the same screen.

Starting DPOAEs from the TEOAE screen

DPOAE recordings can be initiated from the Tests menu of the ILO88 program. Please see the **Tests** menu for details. Alternatively, DPOAEs can be called from the opening Options screen by clicking on the DPOAE button. Immediate transfer from DPs back to TEOAEs can be achieved with the **T** key and from TEOAEs to DPs with the **D** key.

Overview of the DPOAE menus

On starting up the ILO88DP Distortion Product program, either from the opening selection box screen or transferring from the ILO88 screen, you will see five icons on the top left of the screen.



From top to bottom, these are:

i
Information button

Menu
This activates the tool bar from which many other menus are accessible. The tool bar can be activated with the mouse or by pressing **M** on the keyboard.

DP-Gram (F6)
The icon provides a shortcut to the measurement of DPOAEs as a function of frequency. It can be activated with the mouse or by pressing the function key F6.

DP Spectrum (F7)
This provides a shortcut to the measurement of Distortion Product generation at a specific stimulus frequency. It may be activated by the mouse or by pressing the function key F7.

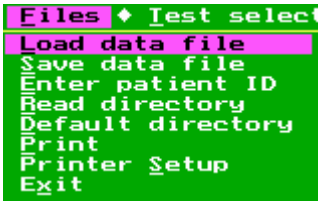
Transient OAE (T)
This provides a shortcut to the ILO88 TEOAE functions. This may be activated with the mouse or by pressing the key **T**.

NB: Icons present on the ILO88DP screen are activated by a single press of the mouse button.

The ILO88 DPOAE toolbar

On pressing the menu icon, or the key **M**, the tool bar will appear, as shown above. To access any of these menus, either press the highlighted letter on the keyboard or click once on the topic with the mouse.

Files menu



Files > Load data file

This function allows stored recordings to be retrieved and analysed. On selecting this option, a list of file types is displayed, together with the number of files of that type stored on the current directory. The file types on the ILO88DP are DP-Gram and DP-Spectrum. Selecting the file type provides a directory listing of the files, together with a graphical summary of the data contained. Selection of the file name results in the file being loaded and displayed on the screen.

To abort any selection, press the Esc key to return to the main tool bar.

Files > Save date file

This function provides for the saving to disk of recorded data. It is mandatory for the patient's name and ID to be entered before saving. The file name is constructed from the patient's name, together with a serial number.

Files > Enter patient ID

This allows the patient's name and hospital ID to be entered prior to recording or saving the DPOAE data.

Files > Read directory

This provides an immediate display of all the files held on the current data directory. There is provision for sorting and selecting sections of this file list.

Files > Default directory

This allows for the data directory to be renamed in order to access other data stores. The directory entered here is automatically reinstated when the program is next called.

Files > Print

Print will provide a graphical print of the displayed data on the pre-selected printer.

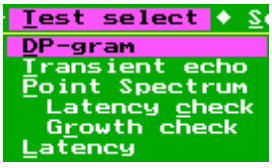
Files > Printer Setup

This allows for your printer to be identified for future print operations.

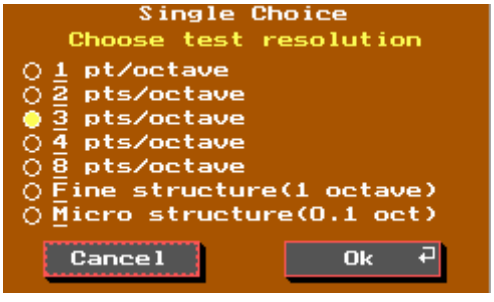
Files > Exit

This terminates the DPOAE program and returns the user to the main software selection box screen.

Test select



Test Select > DP-Gram

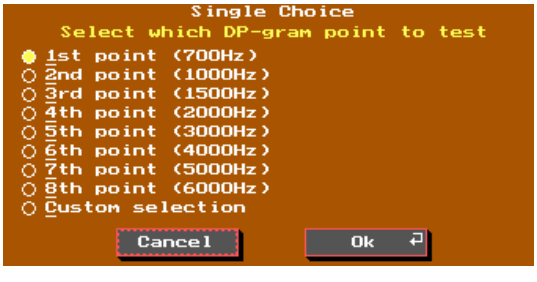


This is the main measurement function of the ILO88DP DPOAE system. The stimulus frequency pair (f_1&f_2) are automatically swept across the frequency range 1,000-6,000Hz and the resolution (interval between steps) may be pre-selected to be from one octave to one-eighth of an octave. There is also the possibility to zoom in to limited frequency ranges to provide a more detailed view of the DPOAE response. The default protocol is for cyclic repetition of all measurements with averaging of results. Please see the detailed instructions on DP-Gram operation later in this manual.

Test Select > Transient echo

Activation of this menu item will transfer directly to the ILO88 program. The data recorded on the DPOAE section of the program is retained and can be returned to at any time by pressing the key **D** from the ILO88 program. In this way, DP and TEOAE responses can be quickly compared.

Test Select > Point Spectrum



When **Point Spectrum** is activated, the stimulus tones are preselected and there is no automatic sweep. Instead, the DPOAE recorded is displayed, together with other signal and noise components whilst averaging continues. Please see more detailed instructions following.

Test Select > Latency check

When this item is checked, the ILO88DP will automatically perform a latency check on the DP being measured and will alert the user to unusually low latency by changing the colour and the point format of the data at that frequency. Otoacoustic emissions have a characteristic latency. OAEs of latencies smaller than 2.5ms would not have registered on the ILO88 Transient system and therefore should be confirmed as not being due to an artefact. Please see additional instructions in the detailed DP-Gram user section below.

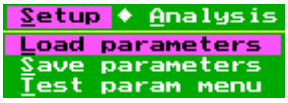
Test Select > Growth check

When this item is checked, the ILO DP system automatically performs a DP measurement at two levels of stimulation 10dB apart (optionally 6dB). DPOAE responses normally grow steadily between stimulus levels, typically at around 1dB increase for 1dB increase in stimulation. If the ILO DP detects a gradient steeper than 2dB/dB, the user is alerted by changing colour and point format on the data at that specific frequency. Since rapid growth can be an indication of artefactual distortion generation, the user is recommended to confirm this data point. Steep DPOAE gradients can occasionally arise from natural causes within the cochlea, such as phase cancellation. Such events happen only at very specific frequencies and levels and are of no clinical significance. However, it is recommended that the presence of true DPOAEs is confirmed at adjacent frequencies.

Test Select > Latency

When this item is checked, the ILO DP system automatically performs a latency measurement on the DPOAE by measuring its phase for two slightly different frequencies a few tens of Hz apart. The DPOAE response normally takes from 2 to 10ms to emerge and this is revealed by the gradient of phase between the two frequency products. If the latency is smaller than 2ms or smaller than the normal range for the frequency being observed, this must cast doubt on the physiological origin of the DPOAE. DPOAEs observed at high levels are more likely to suffer contamination from probe distortions than those collected at low levels.

Setup menu



Setup > Load parameters

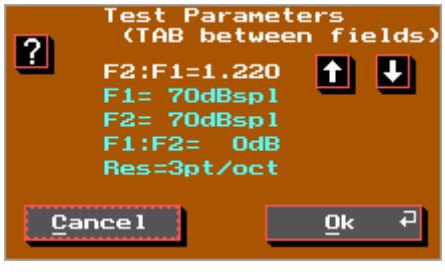
This provides for the loading of a file from disk which contains specific settings of the stimulus conditions to be used for the DP measurement, e.g. the ratio of frequencies and amplitudes.

Setup > Save parameters

This allows the current stimulus parameters to be saved to a disk file. The disk file can either have a name of the user's choice, or be identified as a start-up file. In the latter case, when the system is next used, the parameter file will automatically be loaded. Please see below for the content of the parameter file.

Setup > Test param menu

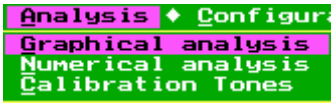
This item allows for the adjustment of the intensities and frequency ratios of the stimulus tones. This is achieved by the cursors and the tab key (or the mouse) to identify the item to be changed. Please see the detailed section on DPOAE measurements with the ILO88DP for further information on the choice of parameters.



Setup > Adopt loaded file params

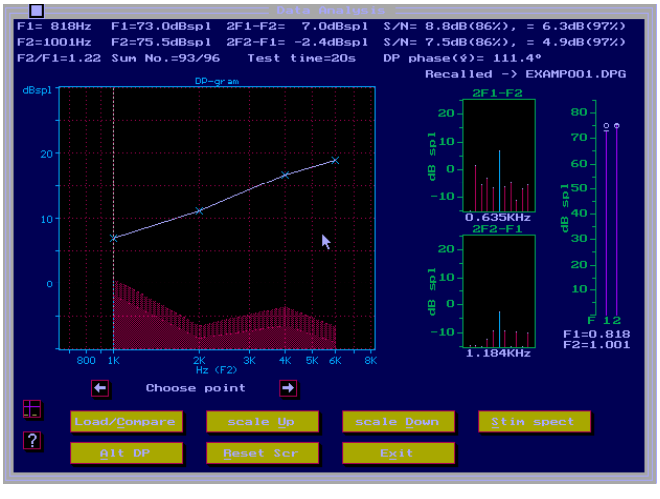
This option only appears once a data file has been loaded. **Adopt loaded file params** transfers the parameters which were used on the displayed DPOAE measurements to become the current test parameters for the next test. This is useful when the previous recording of the patient has been recalled and it is desired to repeat the measurement using the same parameters. In this case, the parameters from the recalled data are adopted.

Analysis menu



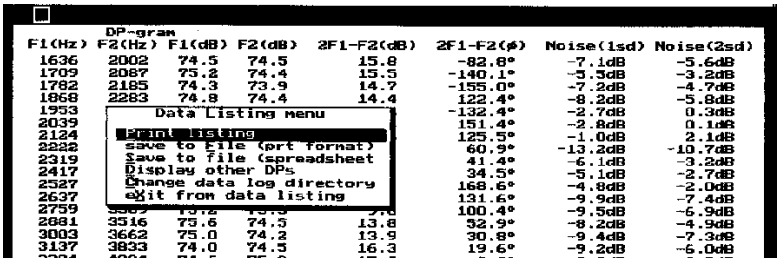
The analysis menu provides a means of observing the DPOAE data more closely.

Analysis > Graphical analysis



This item displays the current DPOAE data and allows for its inspection. In particular, a specific point may be highlighted and the conditions pertaining to the measurement at that point are displayed, e.g. length of time used to record the point, noise level and actual stimulus conditions for that point.

Analysis > Numerical analysis



This option displays the data collected in numerical form on the screen. This numerical data can be printed or, alternatively, transferred to database format for later analysis.

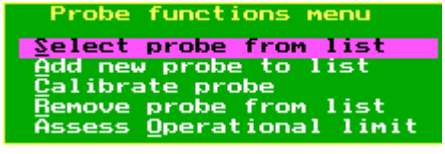
Analysis > Calibration Tones

Calibration Tones provides for the setting of two frequencies to be applied continuously to the probe so that they may be measured by external calibration equipment. The frequencies are adjusted after pressing **T** for F1 and **O** for F2. Either tone may be turned on or off. On pressing the Enter key a real-time display of sounds detected by the microphone is shown. The level of each tone may be set using the up/down cursor keys for F1 and the + and - keys for F2. The internally derived measure of sound level should be compared with that from the external measuring equipment.

Configuration menu

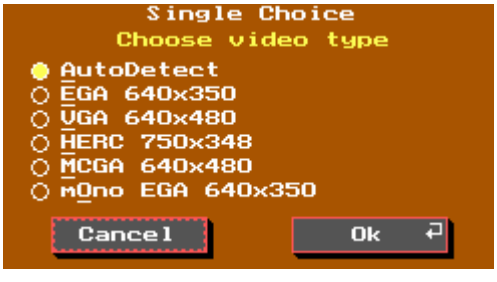
Configuration > Probe menu

This allows for the calibration of OAE probes, the saving of this calibration data and its recall. Probe calibration data is used to compensate for differences between probes and sound level measurements during the test.



Configuration > VDU type

This allows for the selection of the screen resolution in use.

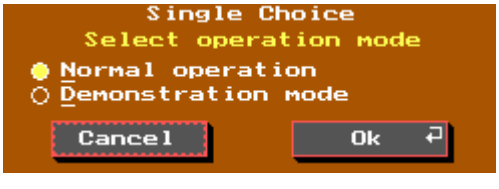


Configuration > Screen Colours

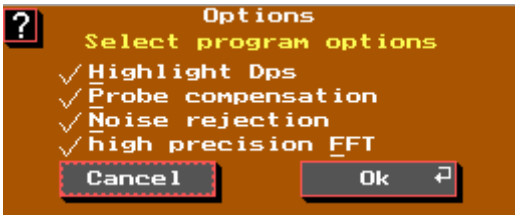
Screen Colours provide the options of halftone, black and white or full colour graphic displays.

Configuration > Demonstration mode

This option allows the software to be run without hardware present. This is useful for reviewing data on another PC. Once this item is checked and the program closed, the program will reopen in the demonstration mode and therefore will not access the hardware or make recordings.



Configuration > Program operation



This provides options relating to the display of data and its collection. These are:

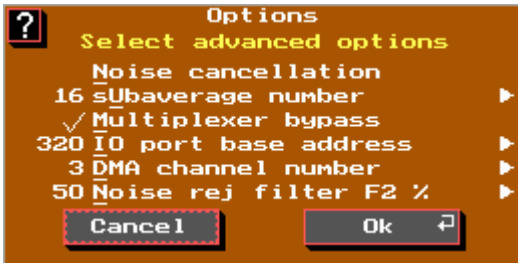
(a) The graphical highlighting of DPOAE frequencies for easy identification.

(b) Implementation of probe response compensation, according to a loaded calibration file.

(c) Implementation of noise rejection based on its level.

(d) Use of high precision frequency analysis (FFT), maximising precision and signal-to-noise for the fastest PCs only.

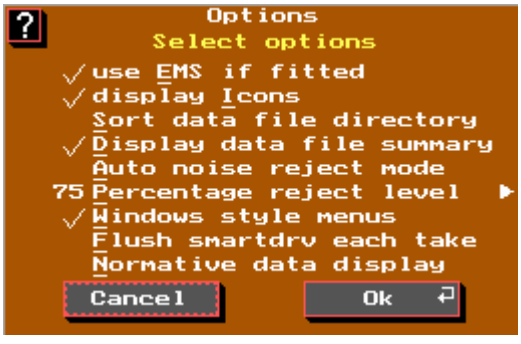
Configuration > Advanced operation



These options are applicable to research uses of the ILO DP system and are fully documented in the **DP Research Software Guide**.

Configuration > Environment/Preferences

This provides a range of options relating to the PC and the user interface of the program. These options include:



(a) The use of EMS computer memory, if available, to enhance speed.

(b) The use of icons to display shortcuts to functions.

(c) Full or limited menu options to remove setup functions from the user's screen.

(d) Sort Data File Directory determines the order of files displayed on directory functions.

(e) Display Data File Summary activates the graphical summary during directory review.

(f) Auto Noise Reject Mode provides an automatic limit to the amount of noise tolerated before recording.

(g) Percentage Reject Level provides the base line for the automatic noise reject level.

(h) Windows Style Menus determines the order of the tool bar as it appears on the screen.

(i) Flush Smart Drive Each Take complements the disk caching utility of your computer by ensuring that data will not be lost when the program is closed or the computer is switched off.

(j) Normative Data Display - when checked, the program looks for a user supplied file containing the limits of normal DP levels appropriate to the local protocol adopted.

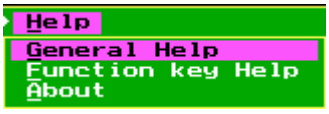
Configuration > Load configuration

This loads from disk previously saved environment/preferences selection.

Configuration > Save configuration

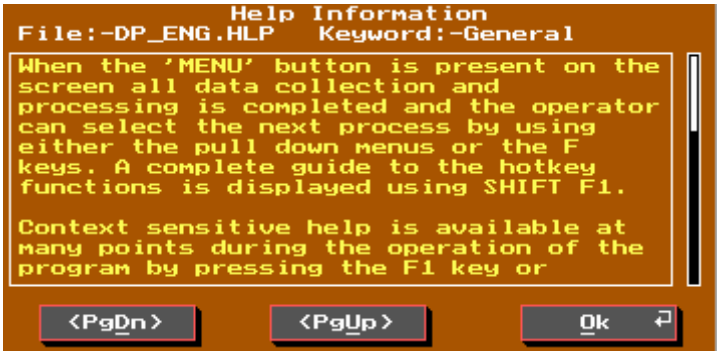
This saves to disk the current environment/preferences options selected.

Help menu



Help > General Help

This function provides a simplified online manual to guide users through the use of the controls of the program.



Help > Function key Help

This provides a summary of the shortcuts to important functions via function keys.

Help > About

This identifies the version and origin of the program currently being used, followed by user support contact information.

Making and interpreting DPOAE measurements

Indications for use

Both TEOAEs and DPOAEs are useful as screening tests for cochlear function in infants, children and adults. They are particularly useful when the patient is unable to respond.

DPOAEs are particularly useful with older patients, as the method can tolerate sub-clinical depression of cochlear activity. DPOAEs are also of use to test the higher frequency region of the cochlea.

The absence of DPOAEs may indicate sensory or middle ear pathology. This should be investigated with tympanometry. The presence of DPOAEs with hearing loss does not prove a retro-cochlear function but is consistent with this. Electro-physiological confirmation of auditory function should be undertaken in cases where there is risk of neurological involvement, e.g. following serious jaundice in newborns. In general, infants with known risk factors for hearing impairment should receive both OAE and ABR tests.

The most common application of OAEs is in the routine screening of newborns to confirm normal peripheral auditory function.

OAEs have proved useful in establishing the site of lesion. For example, they have been used to detect cochlear dysfunction associated with eighth nerve tumours and to detect cochlear dysfunction accompanying meningitis. They have also proved useful in detecting cases of hearing loss in children, when it is of purely retro-cochlear origin. In these cases, the provision of acoustic amplification often needs to be re-examined.

Presence of true DPOAE activity means some degree of normal cochlear function is present at that frequency. Missing DPOAE over at least one-third octave indicates further investigation is needed. Middle ear as well as cochlear pathology can block DPOAEs.

No precise relation to threshold of hearing has been determined. The dB level of DPOAE is not clinically significant. The ILO88 with DPs is still a screening instrument.

Calibration

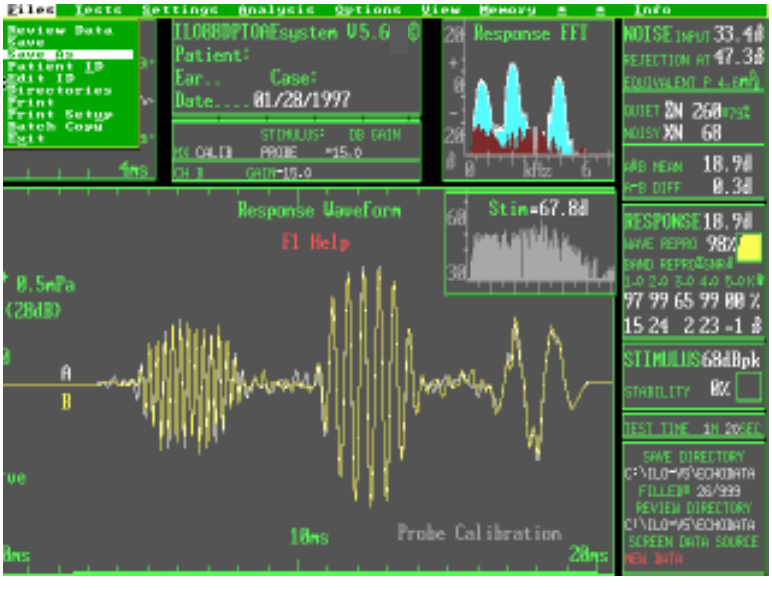
The test program should first be run and, if completed satisfactorily, this confirms that the internal circuit is working correctly. This test automatically confirms that the correct amplification is present in each section of the system.

The test program does not perform tests on the OAE probe. This is performed using the ILO88 OAE measurement program.

Probe condition

The probe to be tested is fitted into the probe socket and the TEOAE program started. The probe is fitted into the 1cc acoustic calibration cavity. A Checkfit can be performed at this stage as if beginning a patient measurement. On closing the Checkfit process, select the **Probe test** option from the **Collection** menu. Confirm the type of probe being tested and continue with the test. The probe test injects an artificial OAE which is recorded on the screen as a series of three oscillatory tone bursts at 700, 2,000 and 4,000 Hz respectively.

A typical probe response is shown below.



A copy of the probe test performed at the time of manufacture accompanies every probe. We recommend that you perform and print a probe test on your equipment on first receiving the probe and retain this for later comparison. Substantial changes (>3dB) on any tone burst may indicate contamination of the sound tubes, deterioration of the probe transducers or incorrect fitting into the test cavity. If, on cleaning the probe and properly fitting it into the cavity, substantial deterioration of performance is seen, the probe should be replaced. Contamination typically reduces the higher frequencies first, loose coupling to the test cavity can reduce the low frequency response and may artificially enhance the middle frequency response.

While the above test is useful, it is unable to distinguish between changes in the performance of the microphone and the loudspeaker. An independent external calibration should be performed at least annually when your ILO292 DP Echoport is serviced, or at any time.

Two methods are provided for externally validated calibration of the ILO sensitivity - a quick check and a detailed check. In both cases, the DP Echoport itself is used as a sound analyser and known sounds are presented to the instrument via the acoustic probe.

In the quick method, the probe should be placed in a known sound field of 84dBspl ($0.1N/m^2$) at 1kHz. Such a field may be obtained from a hearing aid test system or, alternatively, with the use of a freefield audiometer. In the latter case, a sound level meter is needed to set the sound field to 84dBspl. This should be set with the OAE probe already in position next to the sound level meter microphone. Care should be taken that no movement of personnel in the room occurs during the subsequent measurement.

With the external sound field applied, and with the software performing the Checkfit process, the stimulus window should show a sine wave peaking at +/- 0.33Pa. This level is marked by check marks on the side of the stimulus window box. Production tolerance allows for a +/- 2dB variation in probe performance which equates to a +/- 20% deviation from the calibration marks. If absolute calibration of OAE levels are required, a small correction can be computed from the actual level shown in the stimulus window. It should be noted that the microphone sensitivity may change with frequency and it may be required to repeat this test at higher frequencies.

For a thorough analysis of the ILO acoustic sensitivity through any probe, the detailed calibration options should be selected. With this option, the ILO screen shows a spectrum analyser display which records all sounds presented to the probe. The provision of an external sinusoidal tone will result in a peak appearing at the appropriate frequency on the ILO screen. The nominal intensity of the sound according to the present calibration will appear above the peak detected. On pressing the space bar, the user is able to enter the true sound pressure level as indicated by their own acoustic instrumentation. On pressing Enter, this value is saved in a file against the

identity of that particular probe. A series of frequencies can then be applied and the calibration entered and this data will then be recorded for later use. It is recommended that at least one point of calibration is made for every third of an octave of frequency, or a greater number of points if possible. The dead file can be accessed whenever that particular probe is re-inserted into the instrument and absolute calibration of the acoustic measurements made by applying a correction.

NB: This detailed procedure is effective only when used with a probe which has integral electronic ID. The accuracy of this process is limited to the accuracy of the acoustic measurement of the sound field supplied to the probe. The use of the ILO system for clinical screening purposes is not critically dependent upon the absolute calibration of the instrument. This is a screening device used to detect rather than to measure cochlear activity. For research purposes, the above procedure may be important. For general screening use, the quick test will be sufficient to ensure that correct screening results are obtained from the ILO system.

Mouse operation

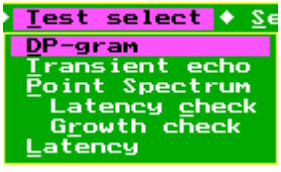
The ILO software recognises the computer mouse, if one is installed on your PC. Its use in controlling the ILO292 functions is optional. The software may be completely controlled using keystrokes. These are identified in the User Manual and also by operating Help keys on important screens. The TEOAE section of the program offers two modes of operation, vis a vis the classic keystroke operated ILO88 mode or the V5 drop-down menu mouse operated mode. To activate the mouse mode within the TEOAE program, click on the **Menu** button with the mouse; to revert to the keystroke mode, select **Toolbar off** from the **Options** menu.

Before the mouse can be recognised by the ILO program, you need to set the mouse active using the ILOCFG program - refer to your ILO Version5 Software Installation instructions, Configuration, paragraph 7.

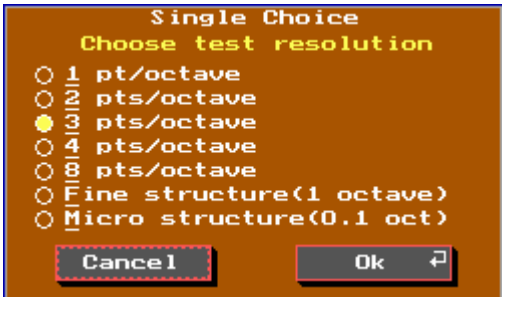
Preparation

Superficially examine the patient's ear and select a tip size which is appropriate. Fit this to the DPOAE probe and gently insert it into the ear. Check that the probe is comfortable and that it completely fills the ear canal so that noise may not enter.

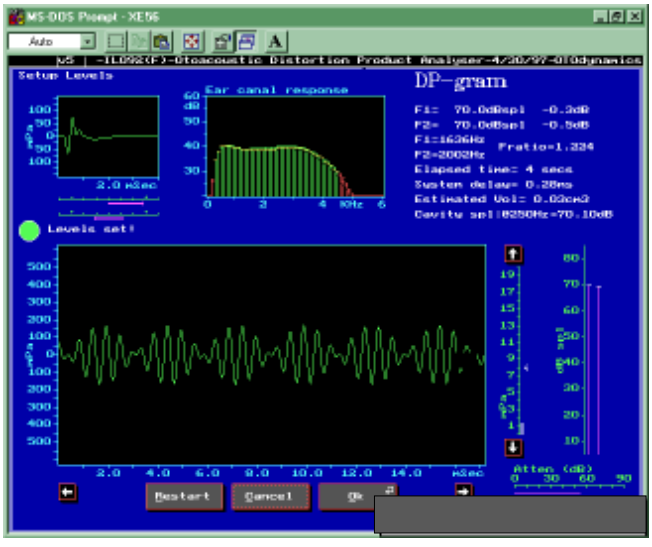
Select the **DP-Gram** option from the **Test** menu. Choose the test resolution. Remember that higher resolutions (e.g. 8 points per octave) will take longer to complete. We recommend that 3 points per octave be adopted for a routine first examination, unless time is at a premium, where lower resolutions may be selected. Where the DP audiogram appears to contain wide differences between adjacent points, higher resolution may be useful in resolving this.



After selection of the test resolution, the set-up levels screen is shown. There are a number of windows. The top left window provides the checkfit function of the ILO88. It uses a click stimulus in order to detect anomalies in probe fitting. The ear canal response panel shows the frequency spectrum of the click stimulus. This also helps to reveal anomalies in probe fit. Since DPOAE measurement requires two stimuli via two transducers, it is important that the responses obtained from the two transducers are similar. The ear canal response panel superimposes the response from the two transducers. If these separate (green and yellow traces), then it may not be possible for the machine to maintain optimum stimulation during the test. The test may nevertheless be attempted. If the probe fit produces strong peaks and valleys in the stimulus spectrum it may not be possible for the software to maintain the desired stimulus level. These regions are indicated by red on the ear canal response panel.

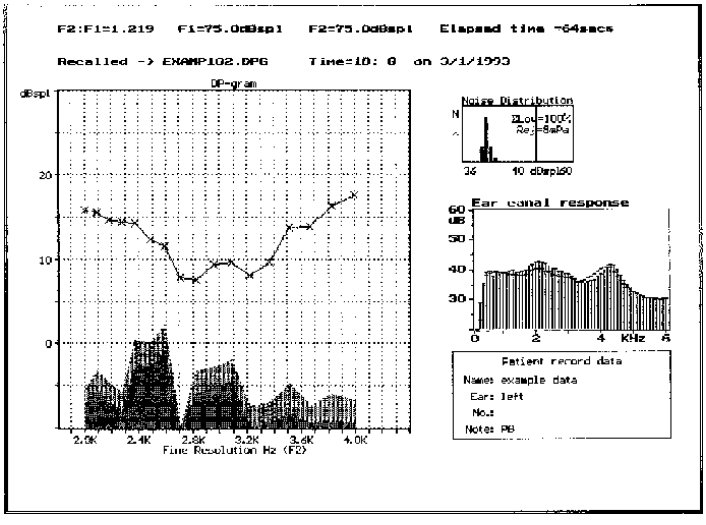


When the click stimulus Checkfit routine has been completed and the probe fit is the best that can be achieved, pressing the Enter key will result in the DP tones being presented to the ear. These will be automatically adjusted to the pre-set level and their waveform will be displayed on the large central panel. At this point, the user may monitor the level of background noise and pre-set the artefact reject arrow with the cursor keys. In the event of the machine being unable to set the stimulus levels correctly, this will prevent progress to the test proper.

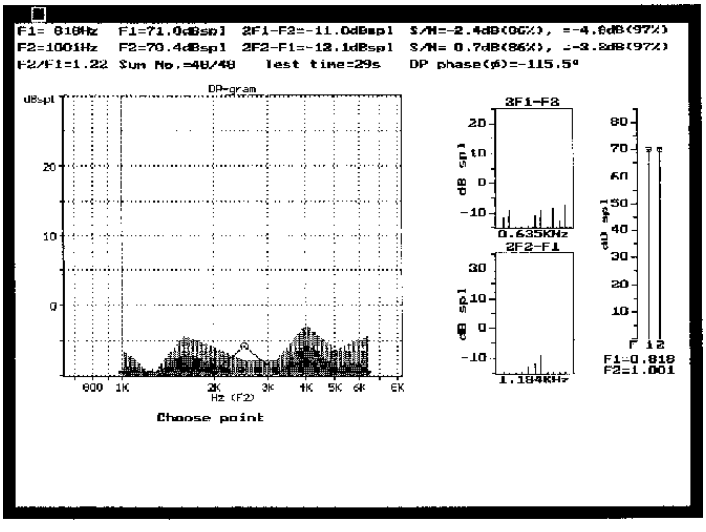


When the probe fit and the stimulus levels are correctly set, the Enter key or the **OK** button will take the test on to the main section.

The DP-Gram measurement consists of a series of DPOAE measurements at $2f_1$-f_2 with the stimulus frequency swept between 1K and 6K Hz at steps defined by the requested resolution. The frequency sweep is repeated indefinitely and data is averaged. As more data is collected, the noise contamination (shown red), will recede and drop in value, revealing the DPOAE data (white circles) standing above the noise level. The noise display is shaded in two sections. Solid shading encompasses all levels within one standard deviation of the background noise. Data points reaching the limits of this area have a 16% chance of being due to statistical factors and the test should be continued until a higher level of confidence is achieved. The lighter shading red area indicates the limits of the 95% confidence region and is based on two standard deviations from the background noise. The test should be continued, if possible, to obtain a DPOAE point above the 95% limit.



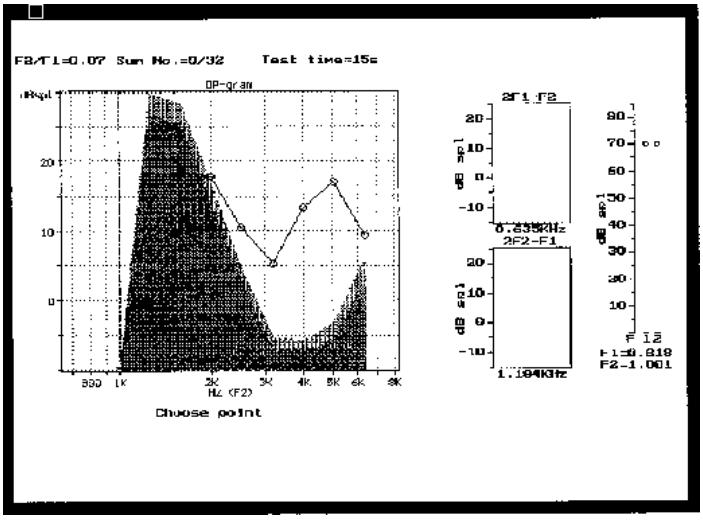
Normal DPOAEs



Absent DPOAEs

It is usual for one or two points to suffer more contamination by noise than other points. If this is the case, time wasted on well resolved points can be avoided by pressing the left or right cursor and entering the manual frequency progression mode. Using the cursors, the test frequency can then be switched to the frequencies most needing additional time, until the whole DP audiogram is completed.

While the test is in progress, two small panels on the right show the DP as currently observed, together with a region of frequencies illustrating the current noise levels in the data. Also shown is the current level of noise and the stimulus levels maintained in the ear canal for both f_1 and f_2.



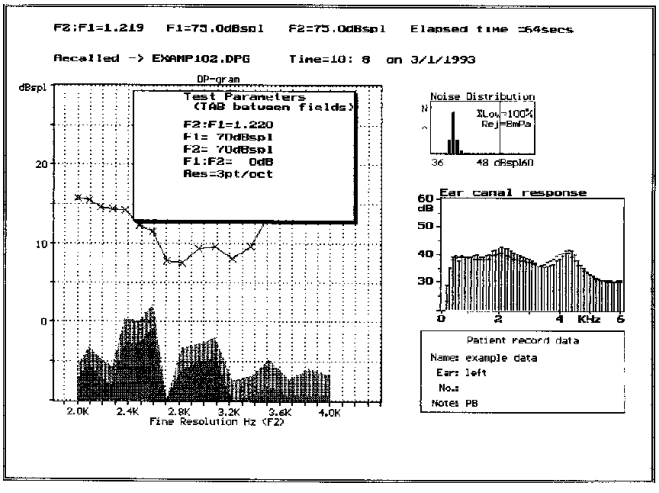
At any time during the test, the probe fit may be checked by pressing the **Probe Checkfit** button with the mouse, or the **C** key. This performs an immediate click stimulus check and allows probe movement to be detected. If movement is detected and the test is almost complete, then it should be terminated and saved. If the test has not progressed sufficiently, it is recommended that it is aborted and the Checkfit is repeated. This is possible by pressing the **Go To Checkfit** button.

The actual level of DPOAE from a healthy ear can vary widely. One important factor determining this is the coupling between the probe and the cochlea via the ear canal and middle ear. This factor has little relevance on the hearing of the individual and therefore no absolute interpretation of the DPOAE level can be made. However, it is

normal for healthy ears to have strong DPOAEs of 10dBspl and more. Young ears and infants may have levels in excess of 20dBspl. It is common for ears of older patients to have smaller DPOAEs and this should be taken into account. Levels of DPOAE below 0dBspl may be considered low, but nevertheless provide objective evidence of cochlear function.

The limiting noise of the instrumentation combined with the 95% confidence limit recommended, means that DPOAEs less than -10dB cannot be considered valid. It is, nevertheless, possible to record DPOAEs below this level.

Choice of stimulus parameters



The relationship between stimuli and the response is complex with DPOAEs. Full characterisation of the cochlea's response would require measurement at multiple levels, multiple frequencies and multiple frequency ratios. Time prohibits full investigation. As a result of this, there are a number of differing opinions as to the optimum choice for a single DPOAE measurement. These issues are addressed in the scientific literature. There is, however, general agreement that DPOAEs are most easily detected if the ratio of primary stimulus frequencies is between 1.2:1 and 1.3:1. The relative levels of the intensities has a significant effect upon the DPOAE response. It is generally agreed that the level of f_1 may be equal to or greater than the level of f_2 to advantage. No advantage has been noted by lowering the level of f_1 below that of f_2.

The default setting on the ILO88DP is for f_1 and f_2 to have equal amplitudes of 70dBspl. The default frequency ratio is 1.2:2. These settings can easily be modified. It is generally agreed that if lower levels of stimulation are used, then the level at f_1 should be maintained at least 6dB above that of f_2 for optimum performance. f_1:f_2 intensity differences as great as 15dB have been used by some workers.

It is strongly recommended that you adopt a stimulus protocol which is well supported in the scientific literature. We also recommend that you perform DPOAE measurements on patients with known audiograms and normal ears, in order to familiarise yourself with the variety of responses that can be obtained. Please bear in mind that the clinical value of the DP-Gram rests in the objective evidence it provides of cochlear function in response to the stimulation tones. It is generally agreed that the frequency of f_2 largely defines the region of the cochlea being tested but that this is in no way a single point within the cochlea and may spread over 20% of the cochlea length.

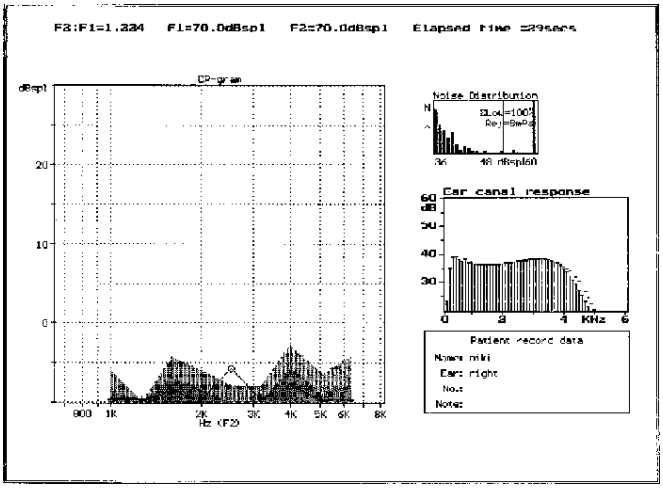
Validating a DPOAE measurement

Since distortions can be introduced within the instrumentation or the probe, it is essential to control for the possibility of artefactual distortions being interpreted as evidence of cochlear function. We recommend attention to the following points:

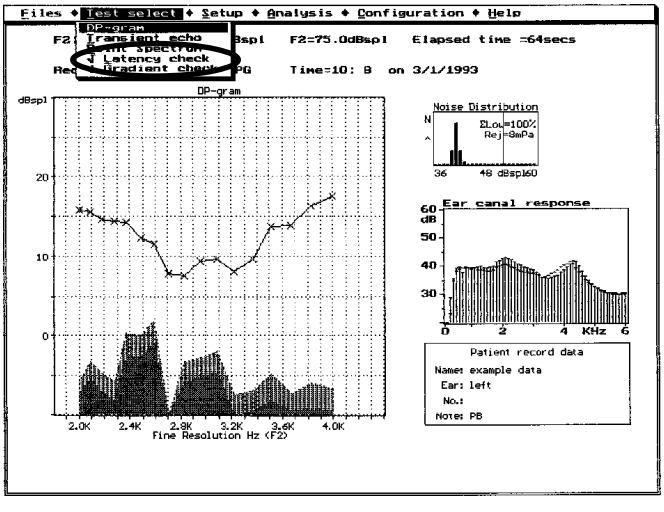
1. Regularly perform a DP-Gram in the supplied test cavity, using the stimulus conditions adopted, to ensure that no visible DP is recorded. Ephemeral DP data points can appear in the early stages of recording due to statistical factors. These should never exceed -5dBspl and should disappear on continuous monitoring. In the event that DP signals are observed within the cavity, the OAE probe should first be suspected and exchanged if possible. Because of the nature of distortion, deterioration of a probe will first become apparent at the higher levels of stimulation. A probe which does not produce any artefactual distortion in a cavity run at 70dBspl can be relied upon not to produce artefactual distortion at lower levels.

2. Because individual ears present unique acoustic environments for the acoustic probe, the cavity test (‘1’ above) cannot be wholly relied upon. In the case that the probe passes the cavity test but nevertheless there is a limited region of frequencies in which the patient apparently produces DPOAEs which are absent over extended regions, it is necessary to confirm that the apparent DPOAE is of cochlear origin. This is particularly important when the system is used near to the maximum recommended stimulus levels.

   This check can be achieved by observing the latency of arrival of a distortion product relative to the stimuli. In all cases of local distortion in the instrumentation

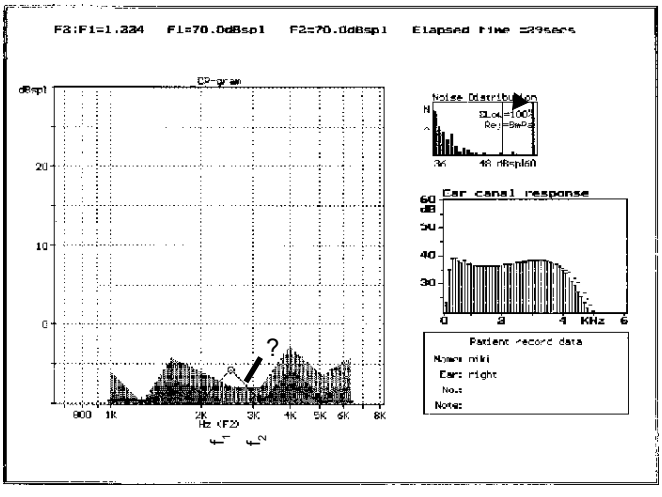


or the probe, the latency of arrival would be close to zero. In the case of physiological DPOAEs which emanate from the cochlea, there would be a latency of at least 2.5ms. This latency is the basis of the ILO88 Transient OAE test and therefore incorporated within the ILO88DP test. To activate the latency check, the item is ticked in the test menu. The DP-Gram is then re-run with the latency checking in progress.



The **latency check** is achieved by slightly altering the frequencies on alternate measurements and recording the phase change observed. If the measured latency is less than 2.5ms, the offending point is highlighted and coloured red. A data point put in doubt in this way should be confirmed, preferably by using stimuli of slightly differing frequency. Failure to obtain a latency checked DPOAE point should result in the DP-Gram being regarded with suspicion. Further audiological investigation should then be undertaken to test the ear.

DPOAE validity may also be checked by measurement of the gradient with respect to input level. Artefactual DPOAEs due to overload of the probe or instrumentation system are characterised by a very rapid growth of DPOAE with input level.



To activate the **gradient check**, this item is ticked on the test menu. The DP-Gram is then re-run and the gradient check is automatically implemented. This is achieved by changing the level of stimulation between alternate measurements by 6 or 10dB. If a gradient greater than 2 is detected, the offending point is highlighted and coloured red. In this case, the user is recommended to attempt to reconfirm the point by using a slightly different frequency condition. If the point cannot be confirmed, then the DPOAE data must be considered suspect and audiological investigation undertaken to asses the ear.

In the case that a latency check has shown a point to be invalid, then the probe calibration should be immediately repeated to ensure that the probe is not defective. In the case of a gradient check failure, the probe and system should also be checked, but this is less urgent since gradient check failure can occasionally result from normal interference effects within the cochlea. As these are confined to specific frequency

combinations, it is likely that the gradient failure will occur only on single points and be eliminated by a minor change in frequency.

It cannot be over-emphasised that when a DP-Gram is used for screening, every care must be taken to ensure that DP points remain valid. Low levels of DP confined to limited frequencies should be confirmed before this is taken as evidence of general cochlear health. Conversely, the absence of a small region of response in an otherwise strong DP-Gram should not be taken as an indication of a defect or dip in the audiogram at that frequency. Complex interference effects can cause distortions of the DP-Gram in limited regions.

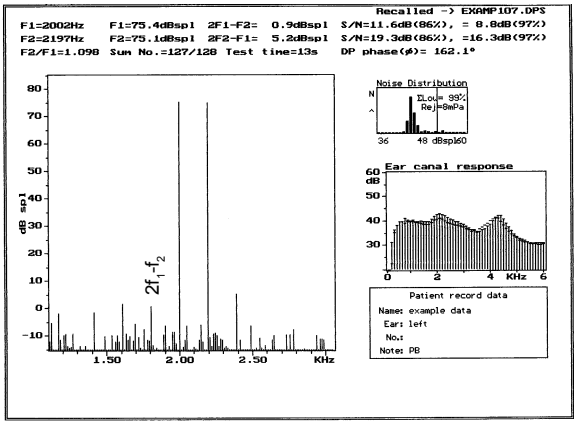
Finally, it should be noted that a DP-Gram does not measure the entire function of the cochlea since it does not test the transduction of the signal into the auditory nerve. DPOAEs can confirm cochlear function at the sensory level but cannot confirm hearing. It follows also that the level of DPOAE is not well correlated to the auditory threshold of the individual.

Use of the DP Spectrum

The DP Spectrum display provides a full analysis of the response of the ear canal to a pair of fixed stimulus tones. The DPOAE $2f_1$-f_2 can usually be clearly seen in this display and the characteristics of the noise contamination can also be assessed.

In this display, the additional Distortion Products which are naturally present, e.g. $2f_20f_1$, $3f_1$-f_2, are highlighted in blue to distinguish them from noise components, which are coloured red.

The DP Spectrum is useful to extract evidence of DPOAEs in noisy conditions or when the DPOAE is small or doubtful. Use of a fixed frequency pair maximises collection efficiency. In the DP-Gram only a proportion of the time available is spent looking at each point. We recommend that a DP-Gram is always performed first and that no conclusion is made about the condition of an ear based on a single DP Spectrum measurement.



Use of the patient noise monitoring headphone

The ILO292 DP Echoport provides for the audio monitoring of noise received by the OAE probe microphone while placed in the patient's ear. For this, a standard Walkman headphone (supplied) is fitted to the rear jack socket on the DP Echoport. The headphone is live to the microphone signal only during the Checkfit stage of operation of the ILO88 DP software. When not in use, the headphone plug should be removed from the DP Echoport. If the headphones are left in close proximity to the OAE probe, the possibility of audio feedback exists. This will take the form of a whistle. No damage will be caused by this feedback and it will cease immediately the probe is placed in the patient's ear. We do, however, advise that the monitoring headphone is used only when necessary to diagnose the cause of noisy recording. The jack sockets should not be connected to any external device other than the headphones supplied.

Often, OAE recordings are impossible or are degraded by the presence of noise. It is not always evident from the OAE monitoring screen what is the cause of the noise. For example, the ingress of background noise from air conditioning may appear on the ILO screen as indistinguishable from the sound of breathing or swallowing by the baby or patient. In fact, the remedy for the noise differs markedly in the two cases and they can readily be distinguished by listening to the offending sound through the earphone. Many other sources of noise have been reported, including electrical detection of radio broadcasts and otherwise inaudible vocalisations by the patient! In any event, the solution to the noise problem will be more evident once the sound is listened to.

PART FOUR

Appendices

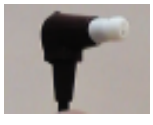
APPENDIX 1
Otodynamics Probes & Accessories - Identification

Transient probes

All Transient probes are available in both 5-pin and 8-pin versions.

SNS: Newborn (blue)
serviceable

SGS: General Purpose (red)
serviceable



BS: Adult
standard

Service accessories

- **TPC** transient probe replacement coupler tubes for SNS & SGS
- **BNS** replacement body and lid for newborn serviceable probe
- **BGS** replacement body and lid for general purpose serviceable probe

Distortion Product/Transient probes

All DP probes are 8-pin variety and require an adaptor for 5-pin usage which is supplied free on request.

HP: Newborn
standard DP

CD: Child
standard DP

BP: Adult
standard DP

Probe tips

Twin-tube Transient OAE tips (T)

T3E Twin-holed elliptical tip, fits 3mm ear canal, elliptical shaped end. (Formerly known as ‘small’). Designed for small and premature newborns.

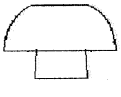
T4.5C Twin-holed conical tip, fits 4 to 5mm ear canal. (Formerly known as ’medium’). Suitable for small newborns.

T5.5B Twin-holed blob shaped tip, fits 5.5mm ear canal. (Formerly known as ’large’). Suitable for most newborns.

T6.5B Twin-holed blob shaped tip, fits 6.5mm ear canal. Suitable for large newborns and first year infants.

T8M Twin-holed mushroom shaped tip, fits 8 to 8.5mm ear canal. (Formerly known as ‘extra-large’). Designed for infants and small adults.

T9M Twin-holed mushroom shaped tip, fits 9 to 10 mm ear canal. Designed for most adults.



T11M* Twin-holed mushroom shaped tip, fits larger ear canal.

Cloverleaf DPOAE tips (C)

C4.5C Cloverleaf-holed conical tip, fits 4 to 5mm ear canal. (Formerly known as 'medium'). Suitable for newborns.

C5.5B Cloverleaf-holed blob shaped tip, fits 5.5mm ear canal. (Formerly known as 'large'). Suitable for newborns.

C8M Cloverleaf mushroom shaped tip, fits 8 to 8.5mm ear canal. (Formerly known as 'extra-large'). Designed for infants and small adults.

Round-tube TE/DPOAE tips (R)

R4.5C* Round-holed conical tip, fits 4 to 5mm ear canal. Replacement for C4.5C. Suitable for newborns.

R5.5B* Round-holed blob shaped tip, fits 5.5mm ear canal. Replacement for C5.5b. Suitable for newborns.

R9.5F Round-holed foam shaped tip, fits 9.5 to 10.5mm ear canal. Suitable for adults. For use with adult single and adult dual channel probes.

NB: ** Not yet available.*
The sound intensity provided by the neonatal probe is limited by a 20dB attenuator.

All the Otodynamics Ltd. probe tips are disposable and should be discarded after use. DO NOT sterilize probe tips as this may result in retention of the solution within the tip, which may damage your probe.

APPENDIX 2
Probes - Cleaning

The following is the suggested method of cleaning the Otodynamics ILO neonatal probes. It should be noted that the probe is a precision assembly and as such care should be taken throughout in its handling and cleaning.

Cable

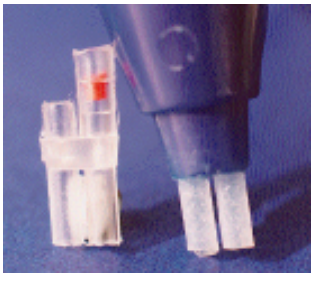
Cables may be cleaned with antiseptic fluid or wipes.

Probe casing

We recommend that the probe casing is cleaned using antiseptic wipes and dried with a tissue immediately afterwards. Avoid liquids entering the sound tubes.

Coupler assembly

Each coupler assembly has at least two sound tubes. These are protected from ingress of foreign materials by the disposable probe tip. At the end of each tube a loudspeaker or microphone is found. Cleaning solution must not penetrate the tubes.



Serviceable probes

Serviceable probes have the sound tubes combined into a single coupler assembly, so that they can easily be replaced. This enables users to fit new couplers at intervals as a preventive measure and to deal with contaminated tubes. Apart from the new servicing procedure, the usage of these probes is exactly the same as for the non-serviceable equivalents and should always be as per the OAE system user documentation. The probe is supplied with five spare coupler assemblies, a spare body and lid, and a range of tips.

This guide gives instructions on disassembling and reassembling serviceable probes. They can be identified by the serial number on the cable sleeve near the plug, which begins with the letter '**S**'. Newborn probes use a lower drive level to compensate for the smaller ear canal and it is important to use the correct probe type for a particular subject. Probes are therefore also colour coded according to their usage:

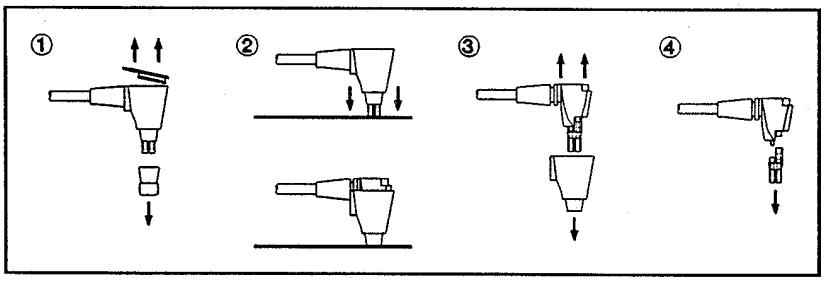
- **Newborn** serviceable probes are **blue**, with a serial number beginning '**SN**'.
- **General purpose** serviceable probes are **red**, with a serial number beginning '**SG**'.

Because serviceable probes have body and lid mouldings which must be removed from the probe for servicing, it is essential that probes are reassembled without mixing bodies and lids of one type with inner transducer assemblies of a different type. For this reason the body, lid and inner transducer assembly of each probe is made the same colour, so that users can be certain of component identity by ensuring matching colours. The OAE system display also indicates the sound level achieved in the ear canal, which should always be monitored during testing to ensure it is correct. An excessively high sound level is positively indicated by a warning message flashed onto the screen, providing an additional safeguard.

This guide also gives instructions on an occlusion test which must be carried out by the user after servicing, in conjunction with a probe cavity test, in order to confirm correct probe function.

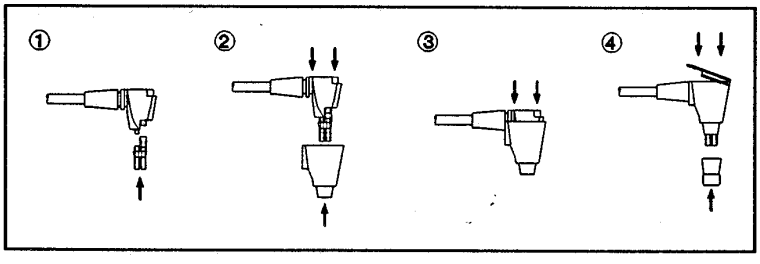
Disassembling the probe

First, unplug the probe from the system. Remove the tip by pulling off as shown in **Fig. 1**, then remove the lid by lifting the tab on the cable edge of the lid, also shown in **Fig. 1**, and remove the inner transducer assembly by pushing the coupler tubes down onto a hard surface, as shown in **Fig. 2**, then pulling out the inner transducer assembly by gripping it as shown in **Fig. 3**. Never remove it by pulling on the cable. Finally, pull the coupler assembly away from the inner transducer assembly as shown in **Fig. 4**. If the coupler assembly stays inside the body section of the outer shell, remove it with tweezers.



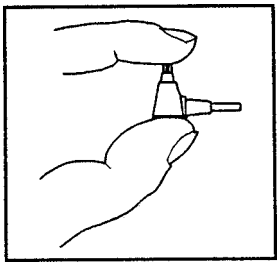
Reassembling the probe

Fit the coupler assembly to the inner transducer assembly as shown in **Fig. 1**, ensuring that the coupler has a red/orange component in the longer tube; this is important for correct sound level. Fit the body section of the outer shell as shown in **Figs. 2 and 3**, followed by the lid section of the outer shell, as shown in **Fig. 4**. Be sure to engage the edge of the lid opposite the tab first, with the tab aligned with the cable, and then click the lid into place using firm finger pressure only. After testing as described in the section below, fit the tip as shown in **Fig. 4**.



Testing after servicing

After reassembling the probe it is essential to carry out an occlusion test and a probe cavity test to confirm correct probe function. The occlusion test must be carried out without a tip fitted to the probe. Set the OAE system to checkfit and press a finger firmly over the end of the coupler assembly, closing both sound tubes. There should be no visible stimulus waveform or FFT. If either is visible then this indicates sound leakage inside the probe, caused by incorrect assembly, in which case the probe



assembly must be corrected and confirmed by re-test. If all is well carry out a probe cavity test before use, following the instructions in your system user documentation.

When to service

As with all probes it is important to:

- fit a new tip for each test
- visually check for unobstructed sound tubes when fitting the tip
- observe screen feedback during checkfit and testing to detect signs of contamination, e.g. low stimulus and/or response levels
- carry out regular probe cavity tests.

If contamination is visible at the open ends of the sound tubes it is permissible to remove it with a fine wire, following standard practice for audiological probes; at any sign of contamination which cannot be dealt with in that way, **fit a new coupler**. In order to minimise downtime, we recommend fitting a new coupler at regular intervals as a preventive measure. The interval between changes will depend on the intensity of your testing program and the experience of the operators. For experienced operators once every one or two hundred tests may be appropriate; if you are less experienced then once every fifty tests might be a suitable starting point. If you need more couplers please contact your dealer.

Remember the coupler is designed as a low cost disposable part - **if in doubt replace it! Do not attempt to clean the coupler as this may damage the acoustic filter**.

Remember!

DO

- *Use disinfectant wipes to clean probe shell*
- *Discard all tips after use*
- *Carefully remove wax using fine wire hook if ingress has occurred*
- *Check calibration regularly*
- *Change the sound tubes of serviceable probes regularly, or if they become contaminated*

DO NOT

- *Bend the cable near probe tip*
- *Allow wax to be pushed up tubes*
- *Use any liquid to clean the probe shell - liquid must not be allowed to enter the probe tube*

APPENDIX 3
Error Messages

2	File not found
3	Path not found
4	Too many open files
5	File access denied
6	Invalid file handle
12	Invalid file access code
15	Invalid drive number
16	Cannot remove current directory
17	Cannot rename across drives
18	No more files
100	Disk read error
101	Disk write error
102	File not assigned
103	File not open
104	File not open for input
105	File not open for output
106	Invalid numeric format
150	Disk is write-protected
151	Bad drive request struct length
152	Drive not ready
154	CRC error in data
156	Disk seek error
157	Unknown media type
158	Sector Not Found
159	Printer out of paper
160	Device write fault
161	Device read fault
162	Hardware failure

APPENDIX 4
ILO Codes

[0]	=	Not Autostopped
[1	=	LongTime
[2]	=	ManyRejects
[3]	=	MuchData
[4]	=	HighStimulus
[5]	=	LowStimulus
[6]	=	LowStability
[7]	=	MuchNoise
[8]	=	DeadNoise
[9]	=	GoodRespdB
[10]	=	GoodRepro
[11]	=	ReachedNois; {will add SNR score", in tops}
[12]	=	GoodSNR
[13]	=	GoodQuality
[14]	=	Reserved
[15]	=	OperatorEnded