THE CALAID: AUSTRALIA'S OWN HEARING AID

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The Calaid hearing aid was introduced in 1948/9 to provide assistance to hearing impaired children, war veterans and (from 1968) eligible pensioners. Designed and manufactured by the Commonwealth Acoustic Laboratories (CAL), later the National Acoustic Laboratories (NAL), the aid was redesigned a number of times until it was phased out in 1992/3.

During the more than 40 years of its production, over one million Calaids were produced. Designed on the basis of in-house and internationally published research, the aids were a vital part of one of the world's most significant Audiological services, and provided results which were at least equivalent to those obtained with the best of the world's commercially designed and manufactured products.

At the completion of World War II, Australian health authorities were confronted with two new and quite disparate groups of hearing impaired people.

One group consisted of the thousands of ex-service persons returning to civilian life with war caused hearing damage. This group generally exhibited the mild to moderate loss of sensitivity to higher frequency sounds resulting from exposure to excessive loud noise.

The second group comprised young children, born with hearing impairment after an Australia wide epidemic of rubella during the early years of the War. Investigations of these children, initially by Gregg (1941), led to the first realisation that in-utero conditions could have effects on the child. The known children were typically severely to profoundly hearing impaired, with little or no speech. They were born to parents who had normal speech and language, and wanted their children to grow up in an oral, auditory world.

Apart from placement in a manual language school for deaf children, no model existed anywhere in the world for management of the problems presented by the 2 groups. Accordingly, the National Health and Medical Research Council was asked for advice, and a branch of the Council, the Acoustic Research Laboratory issued a Report recommending the establishment of a dedicated facility to research and provide service. This led to the formation of the Commonwealth Acoustic Laboratories, soon known as CAL. According to the Acoustic Laboratories Act, given Royal Assent in June, 1948, the Laboratories were "...for scientific investigation including that in respect of hearing aids and their application to the needs of individuals, and in respect of problems with noise as it affects individuals."

The title and status of the Laboratories has changed over time. Originally the Commonwealth Acoustic Laboratories (CAL), the name was changed to National Acoustic Laboratories (NAL) in 1974. In 1993, the term NAL was restricted to the research arm of the new Australian Hearing Services (AHS), which took responsibility for service delivery, and, in turn, became Australian Hearing (AH) in 1997.

Initially service by the Laboratories was provided using hearing aids imported from the U.S.A. These were found to be highly expensive, particularly for repair parts, which, because the users were young children, were frequently required. Further, there was a scarcity of U.S. dollars to pay for imports. Consequently, the decision was taken that hearing aids would be designed and manufactured in Australia, by the CAL. Thus was the Commonwealth Acoustic Laboratory Aid, the Calaid, born.

One of the first projects of the Laboratories was the development of an extremely accurate and reliable system for acoustic measurement. This involved standardisation of the measurement of sound pressure level derived from the reciprocity calibration of Western Electric 640 AA microphones. Before the availability of test chambers for measuring the acoustic performance of hearing aids, CAL's measurement system involved applying essentially constant sound pressure signals, over the frequency range of interest, through the small cavity formed by covering the hearing aid microphone with a MX/41AR cushion and Permaflux PDR3 earphone. The output of the hearing aid earphone was measured in a NBS 2cc coupler, which simulated its use in the ear. This system, the rigorous standardisation of which was a characteristic of the Laboratories history, became the basis of design and quality control of the Calaid, at a time when few other countries in the world could boast such refinements.

The first Calaid designed and manufactured by the Laboratories was first used in 1948/9. As with all hearing aids of the time, this was a body level type with a button earphone attached by a cord. The aid was based on 3 valves, and used a piezoelectric microphone and electro magnetic earphone. The aid came in 3 power ranges, with power determined by the battery voltage of 45, 33 or 22.5 volts. No record of the maximum power, or peak clipping levels, is available, although the 3 levels are presumed to have approximated 115, 120 and 125 dB SPL average level as measured in a 2cc coupler or artificial ear. The frequency response of the aid was dictated by the characteristics of the microphone and earphone, but 3 tone controls, including a high frequency control, were included.

The introduction of the transistor in the mid 1950s gave the opportunity for a much smaller and more convenient aid with a more efficient amplifier. Further, the transistor aid could be used with a 1.5 volt penlight battery, allowing great savings in size and battery costs. Initial production of a transistor aid, the Calaid T, began in 1955/6.

The Calaid T was also a body level aid, housed in a stainless steel, screw together case. The aid was based on 3 transistors, and included an induction coil for telephone and induction loop use. It was produced in four power configurations. This aid had numerous advantages over its predecessor. Worn high on the body, in shirt pocket or clipped to an undergarment strap, the Calaid T was smaller, more convenient to use, more economical, more reliable and easier and less costly to repair. During its life, the aid underwent 2 subsequent redesigns, although it retained the same case. Altogether, the Calaid T satisfied all the Laboratories' requirements for hearing aids for almost 10 years, then, after the introduction of an ear level aid, met all the requirements for body aids for a further 10 years.

The Calaids Valve and T both had the disadvantages of all body worn aids. Body baffle accentuated low frequency and decreased high frequency amplification. Body shadow further decreased high frequency input of signals from the sides or behind the listener (Byrne, 1972). Broad band masking resulted from the sounds of clothes rub on the aid case. Further, in common with most aids manufactured before the mid 1960s, the electro acoustic performance of the aid was significantly influenced by the findings of the Harvard Report (Davis et al, 1947). Among a number of recommendations, this Report indicated that one frequency response, a 6 dB per octave upward slope from 300 to 4000 Hz, would be suitable for most, if not all, hearing aid wearers. The Report also recommended that the maximum power of the aid should be as high as the wearer could tolerate "without undue discomfort". This was aimed at providing "head room" between the amplified peak levels of hearing aid processed signals and the level at which peak clipping occurred. Compression limiting was not recommended because of the loss of approximately 6 dB from the maximum output.

The effect of these problems and design influences was that the lowest maximum power of any hearing aid was approximately 115dB. This, coupled with the gently upward sloping frequency response, meant hearing aids in general were only suitable for the relatively small proportion of persons with moderate to severe degrees of hearing loss, affecting all frequencies equally. The aids were most successful with persons with conductive (middle ear) impairments, in which there is normally a wide dynamic range between hearing threshold and loudness discomfort. Aids were usually too noisy for the majority of people with hearing impairment, who have sensorineural (inner ear) impairments, usually mild or moderate in degree, typically being worst for high frequencies, and almost inevitably exhibiting recruitment. That is, the difference between hearing threshold and loudness discomfort is small, and audition is characterised by intensity distortions and loss of frequency discrimination, which lead to loss of speech discrimination, particularly in adverse signal to noise ratios.

The state of the hearing aid art changed during the 1960s. Research demonstrating that hearing aid microphones should be located on the head, led to the development of smaller microphones and earphones, capable of inclusion in small aids worn on the head. The availability of integrated circuits and smaller batteries also made on the head aids more feasible. Such aids were expected to avoid the problems of body baffle, body shadow and clothes rub, and provide additional benefits such as signal enhancement from head diffraction and microphone placements. These advantages were expected to provide improved speech recognition and listening comfort by providing a wider frequency response, enhancement of high frequency output and reduced masking.

Two basic designs of an on the head aid were attempted around the world. One design consisted of an aid worn behind the ear, the other an aid worn wholly within the ear.

Initial attempts to make a behind the ear aid encountered a number of problems, particularly with mechanical and acoustic feedback. These problems were accentuated because the designers continued the search for "head room" to avoid harmonic distortion from peak clipping. Attempts to overcome feedback led to variable placements of the aid microphone, including backward facing from the centre of the aid case, and, finally, downward facing from the bottom of the case. These attempted solutions had the effect of reducing the potential benefit of the on the head aid, making it more sensitive to sounds originating behind the listener than to those from the front, and imposing further undesirable shadows.

In the face of these problems, the CAL elected to produce an aid worn wholly within the ear. This allowed the microphone to be forward facing, and be located within, or at the edge of, the pinna. This was aimed at taking as much advantage as possible of head diffraction and pinna effects, as well as to fit in with the usual listening tactic of the hearing aid wearer, which is to look at the person to whom they are speaking. The aid featured a one stage impression/earmould, in which a dynamic earphone was buried and sealed as far from the magnetic microphone as possible. The amplifier was based on a 3 transistor integrated circuit, and the aid was powered by a size 13 battery. The aid also included a user operated attenuator switch rather than a conventional volume control. First used in 1964/5, this was the Calaid E.

The Calaid E was in production, and was the most commonly fitted aid in the Laboratories' service for 10 years, being used in 75% of all fittings. During this 10 years there were 2 redesigns to take advantage of the rapid improvements in the components becoming available. In addition, a version was produced in which the earphone was located on the opposite side of the head to the microphone and amplifier. This allowed the head to act as a baffle, reducing acoustic feedback. It also allowed reduction or removal of head shadow, so that sounds detected on one side of the head were heard in the contralateral ear.

The Calaid E, because of its smaller earphone, was less powerful than the preceding body aids, and was hence more adaptable for use with milder hearing losses. Further, despite the attempt to keep them as far apart as the earmould would permit, the proximity of the earphone and microphone increased the risk of both acoustic and mechanical feedback, dictating that the range of available gain was restricted. These two limitations on output meant the aid was much more suitable than body aids for the mild to moderately hearing impaired. As a consequence, the number of people who could be helped by hearing aids was dramatically increased.

The availability of the low power/low gain Calaid E was a critical factor in the Federal Government's 1967 decision to provide free hearing aids to all pensioners and their dependents. This decision was to be implemented by an expansion of CAL. It would have been extremely difficult, if not impossible, to implement such a decision using only a body level hearing aid. As it turned out, the range of performance options provided by the Calaid E and Calaid T was such that they were able to fully satisfy the requirements of the Government's hearing aid schemes until the mid 1970s.

The next step in the history of the Calaid came about as a result of a number of research and other findings. The late 1960s and early 1970s was a period of great interest in the real ear as opposed to sound field and 2cc coupler performance of hearing aids. Flowing from the open mould technique of the Contralateral Routing of Signals ("CROS") aid (Harford and Barry, 1965), earmould vents and tubing modifications (such as diameter changes, horn effects and attenuators) were introduced as methods of controlling the real ear response of aids. Much of the work involved in the investigation of these response controls was performed within the Laboratories (e.g. McCrae, 1981; 1982). Interest in real ear response led to development of methods for measuring real ear performance, particularly real ear gain. Aided and unaided soundfield thresholds, and aided and unaided acoustic reflex thresholds (Tonisson, 1975) were used as measures of real ear gain. Finally, in the 1980s, ear canal probe tubes became the method of choice for real ear measurement.

The ability to control, and predict, real ear aided responses and to measure the outcomes, were important aspects in the development of a standardised hearing aid gain/frequency response selection procedure. A number of these were developed throughout the world, with the most influential and widely used being that known as the NAL procedure (Byrne & Tonisson 1976, revised Byrne & Dillon 1986). This procedure, based upon audiometric pure tone thresholds, led to development of a required performance specification for hearing aids, finally superseding the 1948 Harvard Report.

While these audiological developments were taking place, new hearing aid microphones were being developed. The Ceramic microphone was quickly followed by the Electret. Among other advantages, these microphones were virtually vibration free, which allowed them to be mounted close to the earphone without producing feedback. This permitted behind the ear aids to be produced with top mounted microphones and with much higher gains and power than before, extending the range of hearing losses which could benefit from on the head listening.

The opportunities presented by the audiological research and the improved microphones led the Laboratories to produce a range of new aids. In particular, the movement was away from the Calaid E to behind the ear aids, to give more versatility in performance (particularly venting and tubing modifications), and to extend the range of hearing losses which could be fitted with on the head devices.

The first of CAL's behind the ear aids was the Calaid H, first issued in 1974. This aid, using a top facing microphone, was made in three power ranges and was suitable for hearing levels up to approximately 85 dB (re audiometric zero). It included a choice of two microphones, one offering a steeper low frequency roll off than the other, as well as a user operated low tone cut. The aid could be used with a full range of acoustic modifications. This aid quickly took over from the Calaid E as well as taking a significant proportion of the body aid usage.

To supplement the Calaid H, and provide a higher powered aid, particularly for profoundly hearing impaired children, the Laboratories, in 1976, purchased by tender a number of commercially manufactured high powered behind the ear aids, called the Calaid RE. This purchase in turn was supplemented by an aid of the Laboratories own design in the same commercial case, which was to be known as the Calaid P. The success of these aids led to further purchase of very high powered behind the ear aids for use particularly with very deaf children.

While the behind the ear aids had by now taken over most of the fitting load, there was still a requirement for approximately 10% of body level aids, for people unable to manipulate the behind the ear type. and for the very profoundly deaf, for whom the maximum power of the behind the ear aid was still not sufficient. After more than 20 hears of service the Calaid T range was replaced by a new lightweight body aid known as Calaid G. This aid, again in four power ranges, included the most powerful of Calaids, the Calaid G12G.

In 1978, the Australian Bureau of Statistics issued a report outlining details of hearing aid possession and use in Australia (1978; Upfold and Wilson, 1980). Among other findings, this Report indicated that, regardless of whether the aid was privately purchased or was a CAL/NAL provided Calaid, 22.1% of persons with a hearing aid used it less than once a week, or never used it.

These findings, together with further audiological research results, led to a number of changes in NAL's approach, including a decision to develop behind the ear aids further. A new aid type, the Calaid V, was introduced featuring a forward facing microphone, and three potentiometers for adjustment of maximum gain, maximum power output, and low frequency roll off. The Calaid V was introduced in the early 1980s and remained the most frequently used aid in NAL's service for the next 10 years. Designed for use with hearing losses ranging from mild to profound, the aid was produced in three power ranges, each of which was adjustable downward by potentiometer. One effect of this was that it was possible to fit aids for milder impairments than before (Upfold, 1988). In turn, this created a need for an aid which employed output compression limiting, rather than peak clipping, to minimise harmonic distortion and further reduce the maximum power output. The Calaid V was soon changed to output compression limiting, which became the standard fitting mode throughout the Laboratories for all but the most severely and profoundly deaf, who required the additional power available with peak clipping.

During the later 1980s, the commercial advertising of all-in-the ear styles of hearing aids led to a demand by consumers for the suggested cosmetic advantages and possible potential acoustic advantages of this aid type. NAL conducted an extensive study of the comparative advantages of behind the ear versus in the ear aids (May, Upfold & Battaglia, 1990; Upfold, May & Battaglia 1990) which concluded there was justification for an in the ear aid, largely because some elderly people found it easier to manipulate. Accordingly, the NAL developed two versions of an in the ear aid, known as Calaid J. These aids were employed for about two years until the Calaid range ceased production with the commencement of a joint venture between NAL and a well established hearing aid manufacturer.

Throughout its history the Calaid was designed by CAL/NAL, its components were individually specified and purchased by CAL/NAL and assembly was performed by several Australian companies under periodic contracts.

The question which must be asked is how successful was this concept of a range of hearing aids designed and manufactured by one Government organisation to satisfy its own requirements for hearing aids to fit to a market consisting of the very young and the elderly? Absolute answers are impossible, but some conclusions may be drawn from available sources. Firstly, there is the number of aids produced. From an initial 200 aids a year the number grew from 2,285 a year in 1966 to 14,679 in 1970 to 36,876 in 1980, to 86,600 in 1992. Secondly, the ABS 1978 survey allowed comparison of client usage of Calaids and client usage of privately purchased aids commercially produced by most of the world's major manufacturers. This comparison showed there was no difference in use rates (measured in hours per day) by the two groups. This was found even though the Government group was much older than the private group, and even though the private group included only those who actually purchased an aid after trying it (Upfold & Wilson, 1982). Thirdly, battery use figures by Calaid users indicated an increase in mean hours of use from 6.4 hours a day to 9.6 hours a day between 1978 and 1981, an increase ascribed to improved audiological fitting techniques with the Calaids (Upfold & Wilson 1982). These aid use figures indicate that Calaids were being used as much as most aids produced throughout the world (Stevens, 1977). Fourthly, surveys of persons obtaining a Calaid as a replacement aid in 1976 and 1981 showed that the majority of persons previously using a private commercial aid felt their new Calaid was better than their old aid (Upfold & Wilson 1982). Similarly, studies of client satisfaction was Calaids invariably showed satisfaction levels to be high (Dillon et al 1991a, 1991b).

In the period of its production, from 1947 to 1993, well over a million Calaids were produced and fitted to a population of the very young and the elderly throughout the nation. Supported by an active and internationally acclaimed research programme, the Calaid was a significant part of Australia's health and acoustic history.

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