Everybody dealing with early historical recordings remembers the unnatural, somewhat dull sound of such documents, whether on disc or cylinder.

This is due to the fact that in the recording chain there are two essential parts which change the incoming sound dramatically. These parts are the recording horn and the recorder itself.

The whole system acts completely passively in the electrical sense, which means there is no active amplification. Such a system, however, emphasises certain frequencies, so that the frequency response is non-linear; there is thus also distortion.

The recording horn has a low frequency cut-off, which depends on the diameter of the opening mouth and offers resonances like a pipe open on both ends, decaying in amplitude with rising frequency. Very high sound pressure levels excite additional resonances along the horn causing unpleasant distortion. But the recording horn is the essential tool for capturing the sound.

The recorder converts the sound pressure into displacement by means of a membrane to which the cutting chisel is attached. The membrane is a very thin circular plate of appropriate material (mica, glass, wood etc.). That plate has a limited frequency response and offers resonances too. All together create the typical sound of early recordings with frequency content not exceeding the telephone range. All Georgian wax cylinders have been recorded using just that technology.

Is there a possibility to correct those radical changes in frequency response?

Not really – but you can make the recording more listenable by gaining information about the alterations in sound caused during the actual recording. If you listen carefully to such an early recording, you will observe a certain sound being present in the background noise even without the wanted signal. That certain sound keeps information about the frequency response of the recording chain without the wanted signal. The reason for that lies in recording technique itself. The recording chisel which has to cut the groove acts against the blank wax of the wax cylinder. The wax surface being cut is not of unlimited softness and infinite grain size. It gives very small and short stimuli to the cutting chisel stimulating the recording chain, thus recording and preserving information about the response of the whole recording system in the absence of the wanted signal.

Tests have shown that the performance during actual recording delivers qualitatively similar results but differs in level at certain frequencies.

In order to correct this unwanted change in frequency response there is the widely used method of filtering the sound signal by means of the reverse response in order to get it flat. The method is not totally objective and therefore scientifically objectionable,

but it delivers valuable results for transcription purposes.

The analysis of the background noise without wanted signals can also be useful in order to search for cylinder recordings made with the same equipment and the same settings. Since the frequency response of the recording chain is the same, the background noise shows the same frequency spectrum. It delivers information for the easier enhancement of related recordings, because they ask for the same filter setup.

The restoration of historical recordings on cylinder or disc requires useful soft- and hardware which makes enhancement easy and does not introduce additional artefacts. There is a lot of software available, but during tests it has turned out that packages which work very effectively and do not produce unwanted artefacts are expensive. Concerning hardware tools there are nice stand alone units manufactured by CEDAR.

With restoration it is an accepted rule to remove heavy disturbances first, thus proceeding from the rough tools to the fine tools. The first step will always be editing, step two removing the clicks, afterwards the crackle and at last reducing the noise. Concerning the very last step one must be careful and take into account the psychoacoustics of the human ear. It is of paramount importance not to filter too closely to the signal, because one may change the onset of musical instruments, and the sound will get unnatural.

All the different steps of enhancement can be applied on the one and only item chosen. The basic restoration work has been carried out on an audio workstation equipped with Wavelab and special restoration plug-ins (declicker, decrackler etc.). Additional equipment was involved for making FFT analyses and applying the corresponding filtering.

At first the clicks were removed. During the restoration work it turned out that clicks shorter than 3 ms can be removed manually or automatically without any visible and audible accompaniment. Problems arise for clicks or scratches exceeding that limit.

After declicking parts of the content being masked by the clicks will be audible for the first time.

The second step will be decrackling. “Crackle” is the common term for the background noise pattern created by pressing shellac records. Its noise pattern is dependent on the graininess of the slate being used.

A similar effect occurs when cutting wax. If the wax is very smooth, the background noise will be pleasant; if the wax is more of a grainy kind, the background noise pattern will be similar to that of shellac records pressed of grainy slate.

As far as the scientific approach of restoration is concerned, most of the work has been done now. What remains is careful band pass filtering without affecting the content.

But if we want to make the recording more understandable, we have to go one step further.

At first we analyse the background noise without the wanted signal by making an FFT. The spectrum is not flat at all. It shows several distinct resonances in the lower frequency range and also some resonances in the midrange. It ends with a sharp cut-

off at about 3.5 kHz. Two frequency ranges can easily be distinguished: the lower range referring to the performance of the horn, and the upper range referring to the recording box. If we apply an equalisation to the noise in order to get it flat, we have gained at the same time an equalisation for the recorded sound which makes the content more understandable. It will work well for fairly high signal levels. In sections with exceeding sound pressure levels the recording horn generated additional resonances leading to big distortions in such parts of the recording. Such resonances cannot be removed totally, but they may be attenuated to a certain degree. To gain the proper information a supplementary FFT has to be made from this very part of the signal. This FFT has to be matched with the FFT made from the background noise in order to find the fundamental frequencies for additional selective filtering. Applying that filter the most annoying resonances can be attenuated and thus the sound gains clarity.

It has to be pointed out that this method lacks objectivity in a strictly scientific sense; however, it represents a valuable way to make certain spoken content understandable.