

Acoustics Instrumentation used for preventing Neck-Shoulder Pain during Work

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*Photographs courtesy
of Richard Tiefenbacher*

One of the most common causes of reduced working ability or sickness absence in industry is excessive load on the musculo-skeletal system. The problems are often localized in the neck-shoulder-arm area and are strongly correlated with unsuitable muscle load.

To reduce the risk of such work-related problems, a method for routine examination of muscle activities has been developed and tested within the department of occupational health at the Swedish company ASEA AB, Västerås. The method is based on electromyography (EMG), and is primarily intended to ease the ergonomic evaluation of, and the choice between, alternative working methods.

The present method differs from the previous methods in that it immediately produces useful results, can be used on the spot, and does not require costly and time-consuming consequent laboratory analysis.

Background

A very common reason for muscle pain is tension in the musculature. It is characteristic that the pain in most cases is not caused by maximum load conditions. Instead there is a closer relationship between the pain and working situations in which the exerted muscular force is fairly low, but continuous or frequently repeated.

It is believed that submaximal work load of this nature may cause lasting damage, or at least prolonged and serious symptoms for the employee. This

implies that great consideration should be given to working postures, working movements and work patterns.

Technical planners as a rule know very little about these physiological factors. Medical arguments are usually seen as being hypothetical and abstract, completely incompatible with the quantitative approach used by engineers.

The present method has thus been developed in order to fill this gap by giving immediate results on local muscle load, for a higher degree of "objective" decision making in production method planning.

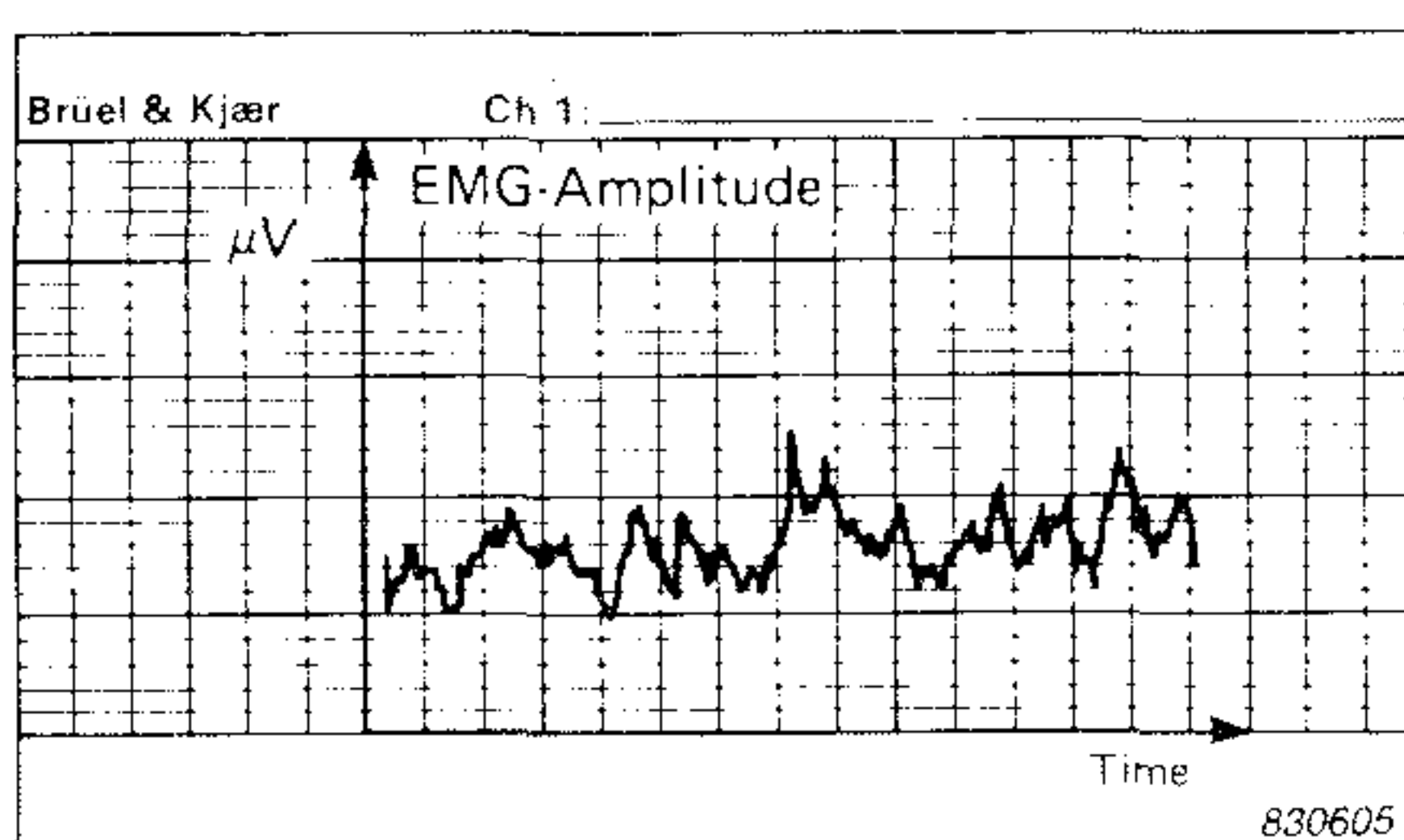


Fig. 2. Surface electrodes (*m. Trapezius*) and electromyogram (integrated)

The aim, however, has not been to evaluate the total content of information available from the myoelectric signals, but simply to give a quick and reliable method for *minimizing* practical working loads by comparing different working situations. (As objectively as possible.)

Electromyography and Muscle Load

The electromyogram, as measured with surface electrodes, reflects the activity of muscles under the skin surface. An increase in exerted muscle force leads to an increase in the myoelectric signal amplitude.

Knowing the true nature of this relationship, it is possible to convert any measured amplitude value into a force value, and thus get a good idea of the muscle load. (The myoelectric signal amplitude may increase even during periods with constant muscle load. This reflects muscle fatigue, but has not been proved to disturb the practical applicability of the method.)

It should be noted that in this method no normalization of the myoelectric results is done. The procedure to determine the amplitude/force relationship and the maximal voluntary contraction force (MVC) is considered too complicated and unreliable, especially when carried out under shop floor conditions. The method is therefore limited to comparative measurements on alternative working methods, working postures, working move-

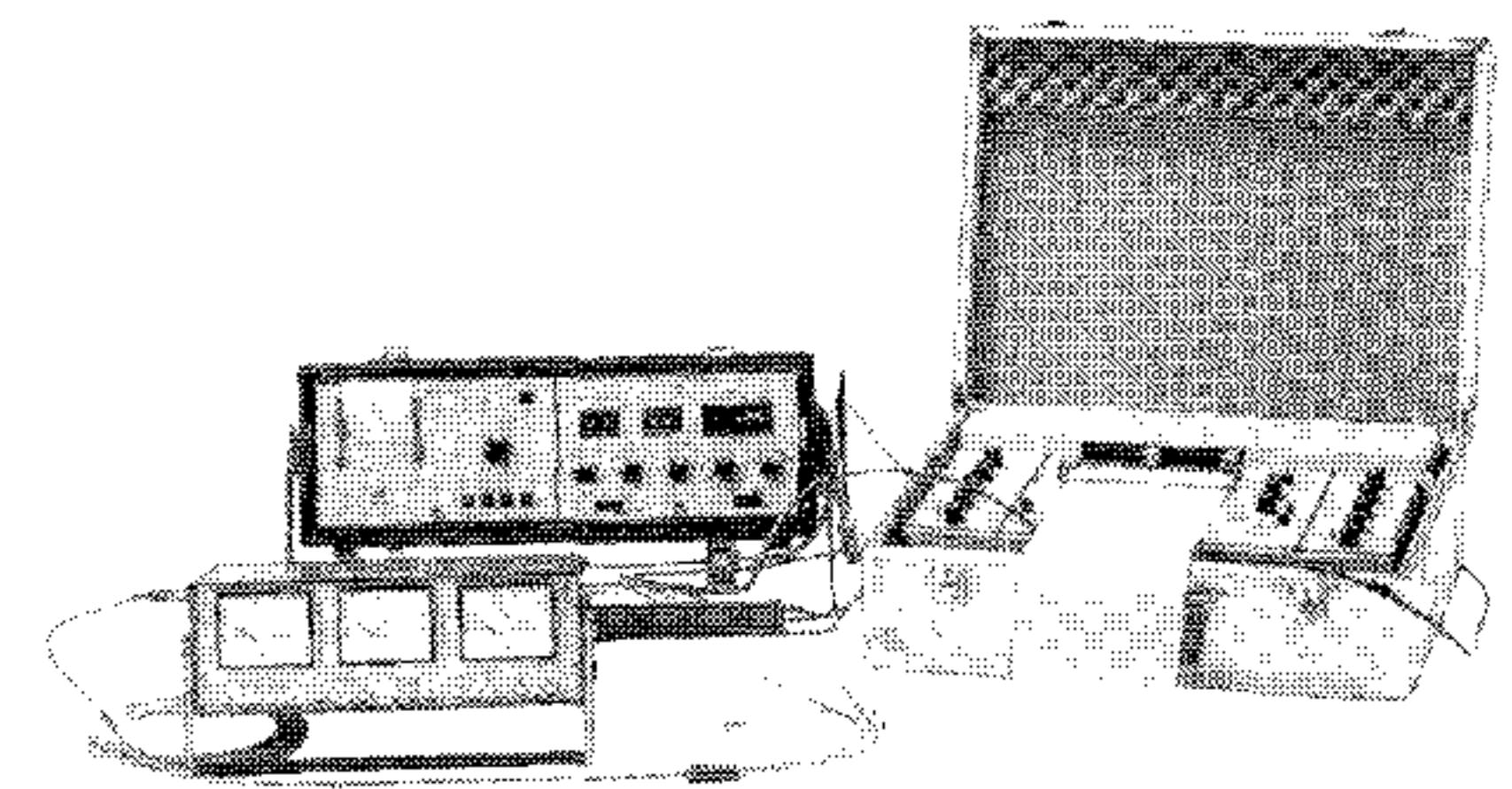


Fig. 3. Equipment set-up. From left: Electromyograph, B&K Alphanumeric Printer Type 2312 and Statistical Noise Level Analyzer Type 4426 in carrying case, B&K Two Channel Level Recorder Type 2309 in carrying case

ments etc. during the same examination.

Equipment Set-up

The following measurement apparatus has been employed:

1. Preamplifier and Electromyograph.
2. B&K Statistical Analyzer Type 4426 for storage and statistical processing of data.
3. B&K Alphanumeric Printer Type 2312 for print-out of statistical tables.
4. B&K 2-Channel Level Recorder Type 2309 for graphic recording of both instantaneous values and statistically processed data.

The electromyograph had built-in safety isolation amplifiers. A very high rejection of unwanted signals (common mode rejection ratio of 110 dB)

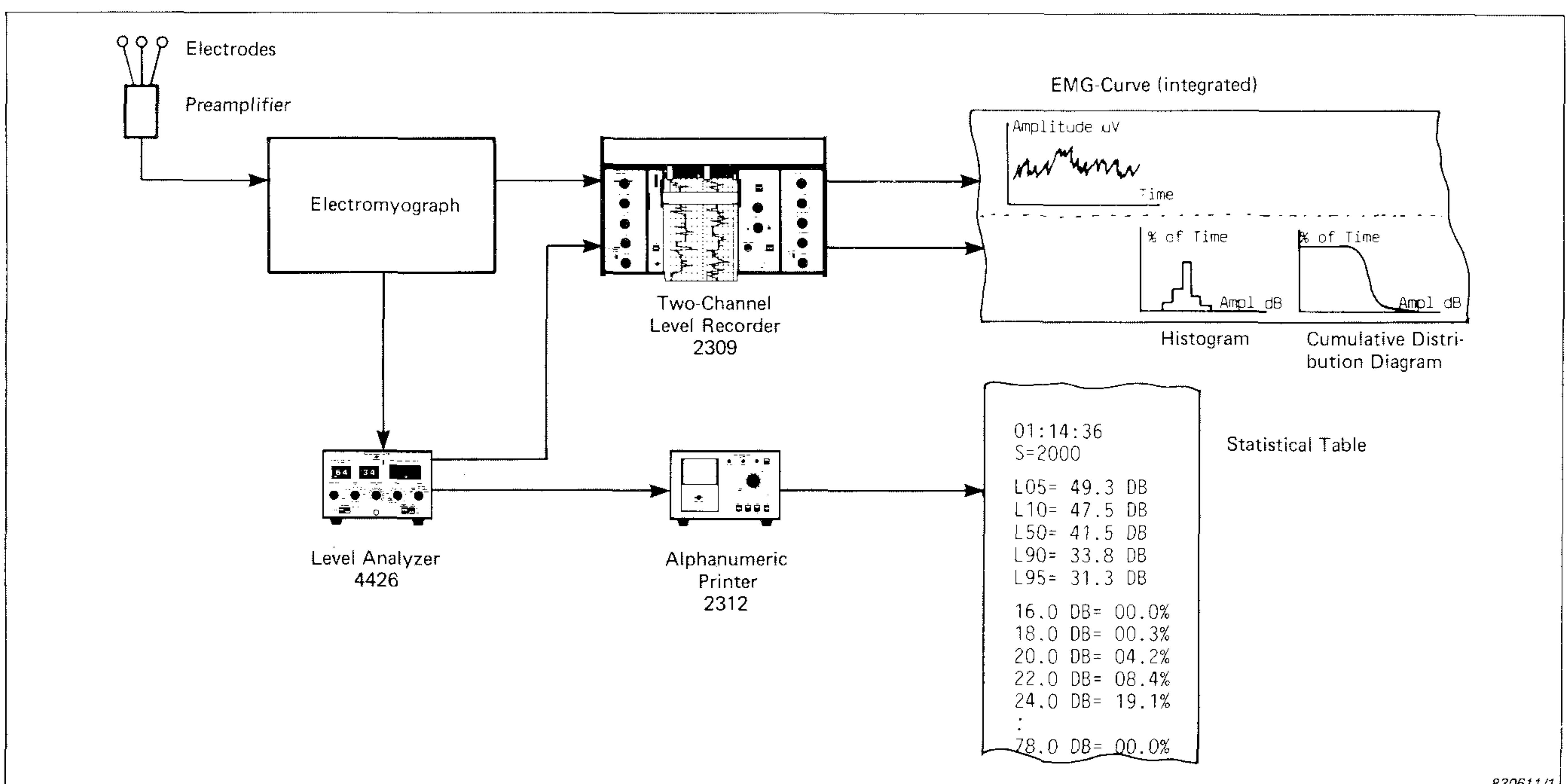


Fig. 4. Measurement system for analysis of EMG signals

was necessary in order to suppress noise. An integration time of 100 ms proved suitable for all practical measurements.

The main statistical values from the Type 4426 used for print-out were the number of samples taken, average level L_{50} , various other levels L_N , (e.g. L_{10} or L_{90}), and level distribution (percentage of samples) in intervals of 2 dB. Furthermore, statistical diagrams for probability and cumulative distribution were calculated.

For ease of documentation the internal clock of Type 4426 was used for print-out. Fig.5 shows one example of such a print-out from the Type 4426 using the Type 2312.

All equipment used was battery operated to provide portability and minimize possible electrical hazards.

00:11:32
S:01000
L0002=061.00B
L0010=059.00B
L0050=055.30B
L0090=050.00B
L0095=047.30B
L0098=042.80B
0016.00B=000.0%
0018.00B=000.0%
0020.00B=001.0%
0048.00B=004.3%
0050.00B=005.3%
0052.00B=015.8%
0054.00B=025.0%
0076.00B=000.0%
0078.00B=000.0%

Fig. 5. Statistical table

Diagrams

The EMG curves give a direct graphical representation of the amplitude of the EMG signals as a function of time. This has the advantage that, duration and place in time of different load levels, especially peak loads and periods when muscle restitution can take place, can be read. This information is useful in evaluating the influence of specific single movements or movement sequences. The EMG curves also give a direct monitoring of the quality of the signals, and may indicate sources of noise. These curves

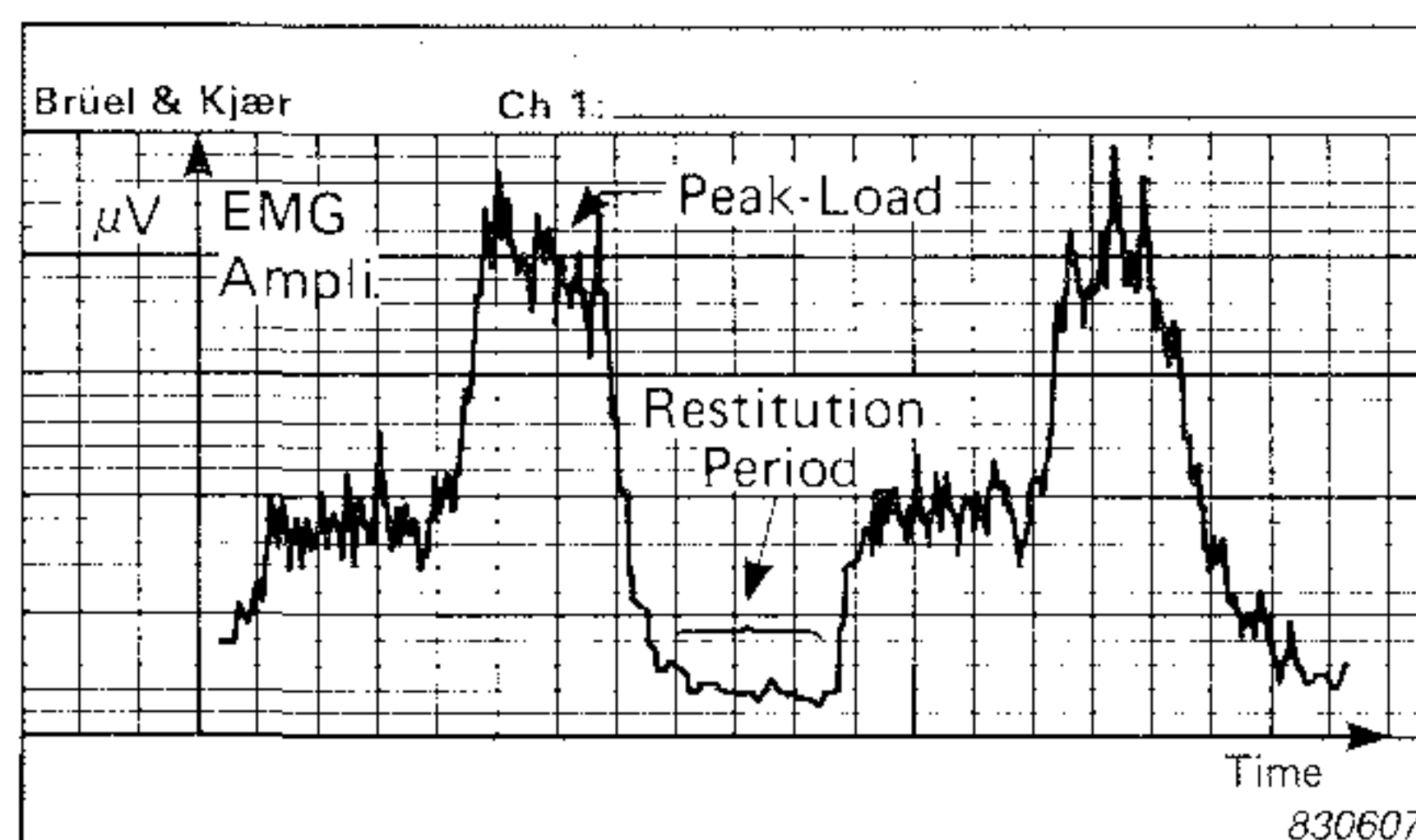


Fig. 6. EMG curve

should thus be recorded, although their interpretation is difficult.

To enable evaluation of the quality and quantity of muscle load during a whole EMG study, it is for practical reasons necessary to carry out a statistical analysis of the myoelectric signal amplitudes, recorded during the study.

In the method described here, analyses of this kind are very rapidly done by an on-line "computer" (Type 4426). The results are graphically presented in a way that makes it easy to compare data collected from different studies.

This is important, as the primary aim of this method is to clearly point out differences in character and degree of EMG activity/muscle load between different working situations.

The amplitude distribution of the EMG signals is shown as a histogram, and also as a cumulative distribution diagram.

The histogram shows the distribution of amplitude in intervals, and thus gives easily-read information on the percentage of time at each given level of muscle load.

Each amplitude interval is 2 dB wide. This implies that a difference of three intervals indicates a difference of a factor two in amplitude. The resulting total load is indicated by the position of the "centre of gravity" for the diagram on the X-axis. The histogram even gives the possibility of making a rough estimation as to the character of the load.

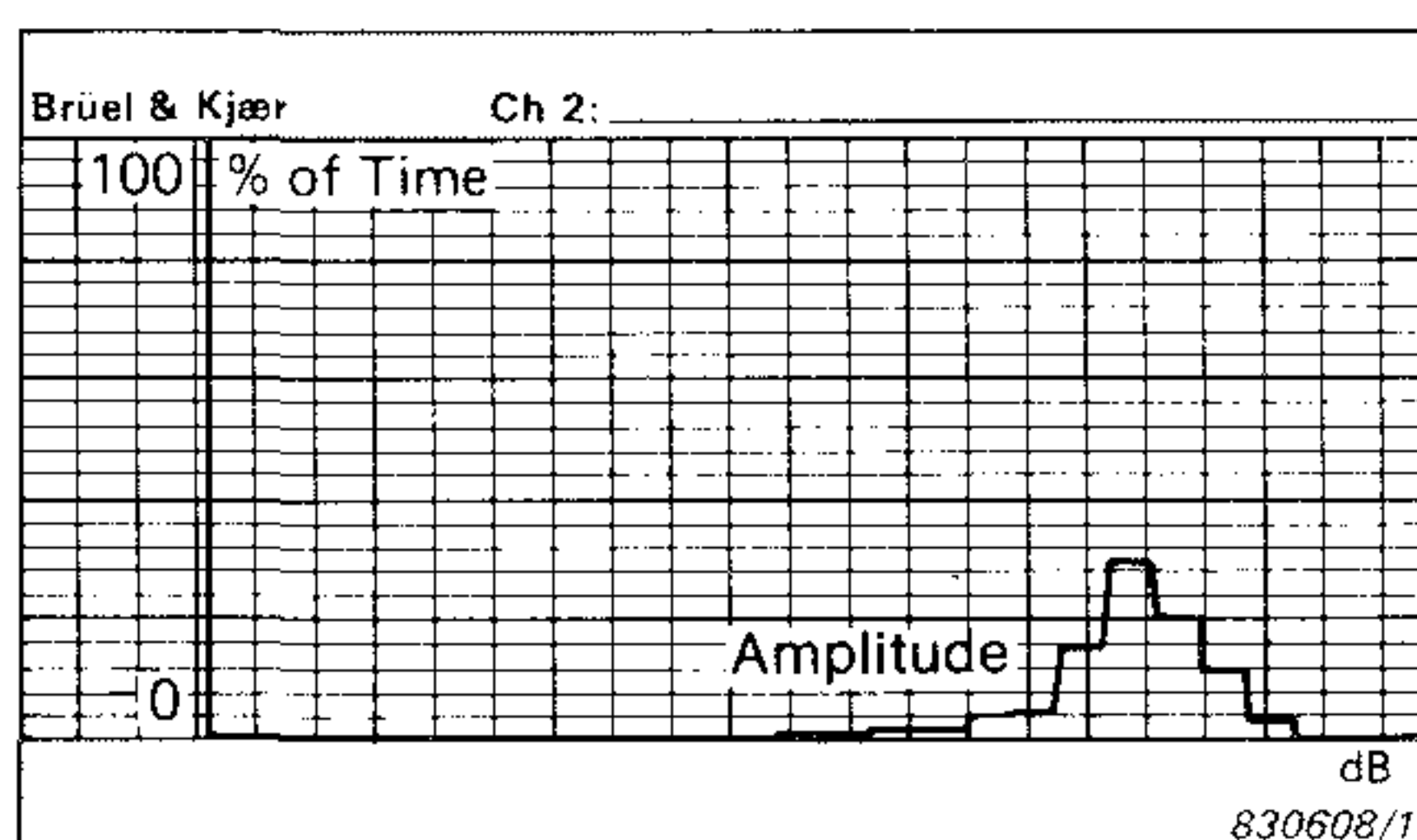


Fig. 7. Histogram

The cumulative distribution diagram shows in a very straight-forward manner how large a percentage of time any given load has been exceeded. The appearance of the curve, i.e. the inclination, gives information on the character of the load (the smoothness of the distribution of the load).

The area under the cumulative distribution diagram gives information in an easily understood manner on the total relative muscle load of the working sequence. The cumulative distribution curves are clearly superior to the histograms in this respect, and are very valuable in trend studies.

It should be noted that even the X-axis has a dB- or logarithmic scale to cover a large dynamic range on a diagram of reasonable physical size.

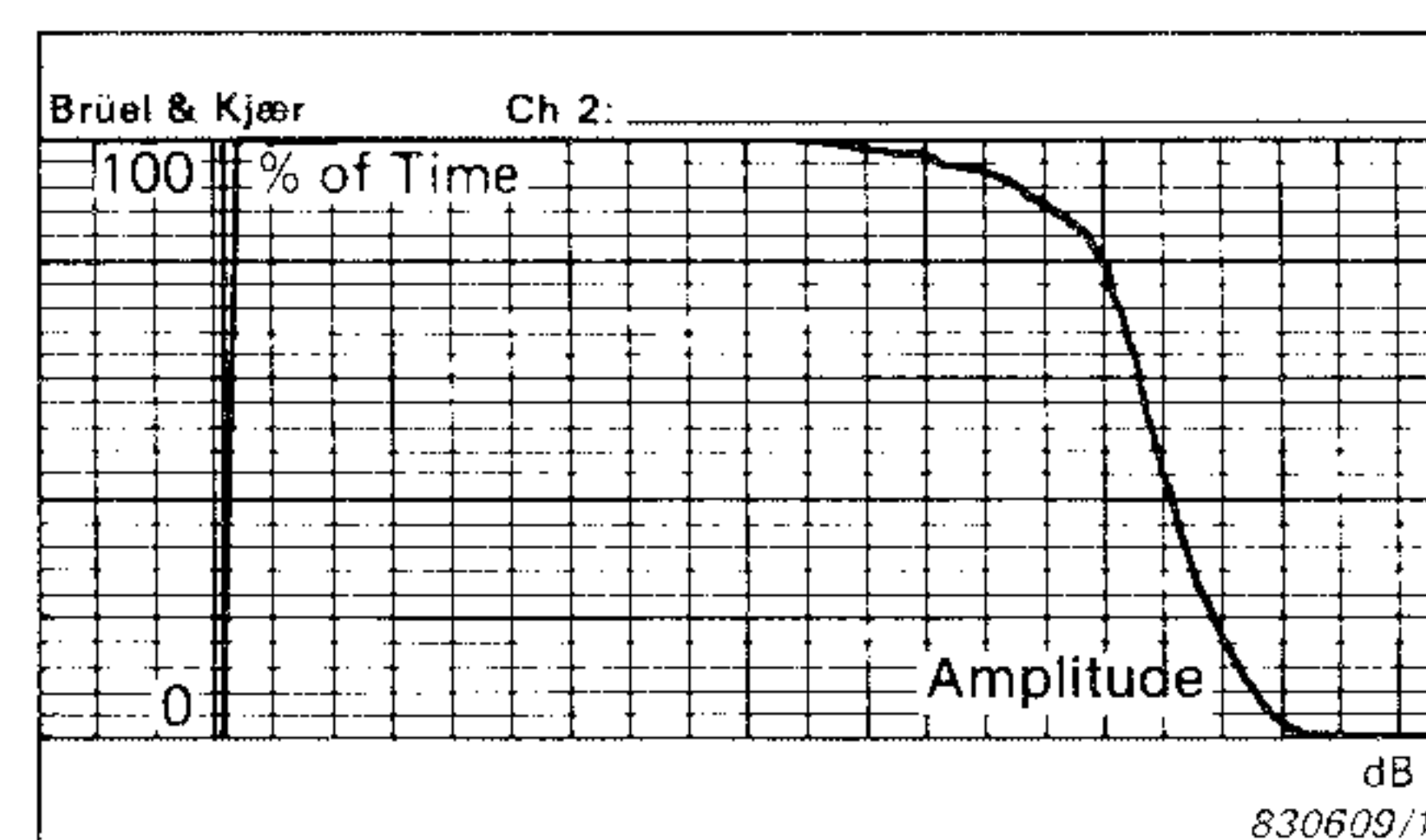


Fig. 8. Cumulative distribution diagram

Measurements and Results

As a result of the great impact of neck-shoulder problems, EMG studies were concentrated on the Trapezius muscle. This muscle is particularly easy to study using surface electrodes, and the load of the muscle is also considered to reflect relatively well the muscle load on the shoulder as a whole.

As telemetry transmitters were not available, all studies were performed with employees in restricted working environments. The work tasks were all of a short and well defined nature.

During the test period, eight persons in seven different work situations were studied. A total of 70 well documented measurements were performed. It was verified that *direct* documentation of EMG signals and their statistical distribution was possible with the equipment, and that a *direct comparison* between different measurements could easily be made due to the graphical representation (especially of the statistical distribution) of the measurement signals.

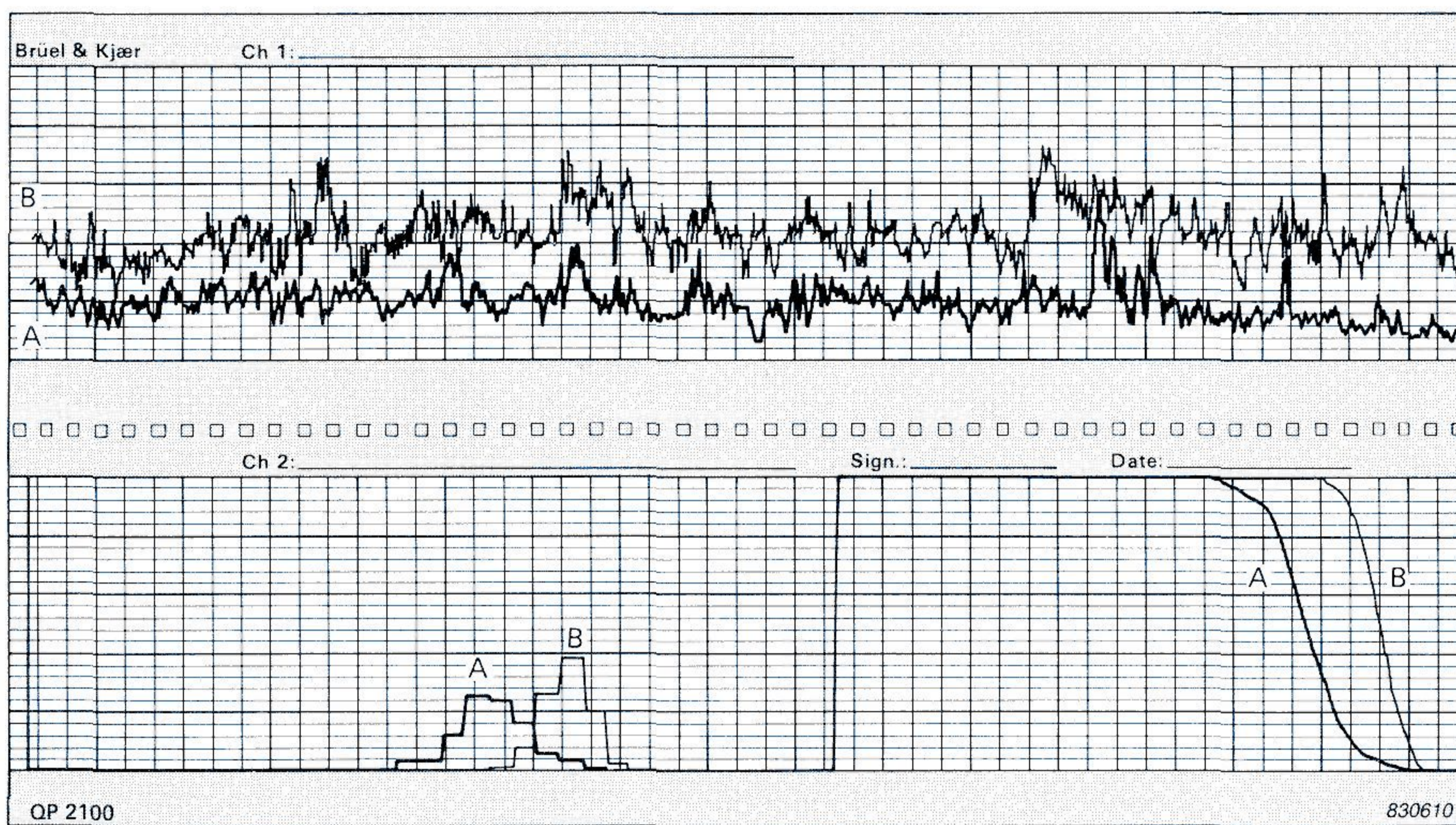


Fig. 9. Small parts assembly. Top left: Pneumatic assembly device (method A). Top right: Manually (method B). Bottom: Results from an EMG study

Conclusion

The most important of aspect of the statistical EMG-amplitude method described here, is that *changes* in the working situation can be readily detected, as is illustrated in Fig.9. This

implies that it is fully possible to make a more objective analysis and evaluation of alternative working methods using comparative EMG studies.

The studies performed have confirmed that:

1. EMG amplitude studies of this kind form a very valuable aid for objective analysis and evaluation for industrial engineering as well as medical decisions.
2. Very good differentiation can be achieved between working loads in different working situations.
3. The method fulfills the requirements for an immediate presentation of results, simplified analysis, in-field use and simple operation.

It is, however, very important to note that, as no normalization of the myoelectric results is done, intra-individual and inter-individual differences play a big role with this comparative EMG method. Influence of factors related to the individual, such as tissue resistance, stress, fatigue etc., must be kept similar, for studies to be compared. This means that measurements should be performed closely spaced in time and on the same individual. Electrodes should be left untouched between all measurements. The method is now routinely used by the department of occupational health at ASEA AB in Västerås.

Literature

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