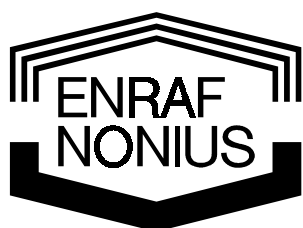


# Low and medium Frequency Electrotherapy

Therapy manual



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This book on 'Low- and Medium-Frequency electrotherapy' has been written with the aim of providing a fast and effective means of familiarizing the user with the therapeutic possibilities of Enraf-Nonius electrotherapy equipment. A major consideration has been that of achieving a balance between the technical background and the practical applications.

Chapter 1 explains the concepts of Constant current (CC) and Constant Voltage (CV), and relates them to the practical value of electrotherapy equipment as used in physiotherapy.

Chapter 2 discusses a number of theories explaining the mechanism underlying the pain reducing effect, and the consequences with respect to phase duration, frequencies and amplitude for various types of current.

Chapter 3 provides practical information on the use of various types of low- and medium-frequency current with the principal aims of reducing pain and restoring the balance of the sympathetic nervous system.

Diagnostic and therapeutic applications with reference to the neuromuscular system are dealt with in Chapters 4 to 6.

Chapter 4 is concerned with the application of intermittent direct current in muscle stimulation, and Chapter 5 deals with the use of alternating currents for muscle strengthening.

Muscle stretching by means of electric currents is described in chapter 6.

The specific applications of electrical currents in iontophoresis and wound healing are dealt with in Chapter 7 and Chapter 8 respectively. General indications and contra-indications are given in Chapter 9. Finally, chapter 10 provides examples of treatment which summarize the material in the preceding chapters.

As far as possible, this book uses the terminology\* agreed upon in the book "electrotherapeutic Terminology in Physical therapy", section on Clinical electrophysiology, American Physical Therapy Association, March 1990.

The authors hope that this book will be of value to the user, and will contribute to optimum use of the equipment.

R.V. den Adel

R.H.J. Luykx

\* See *Terminology and description of current types*

# 1 CONSTANT CURRENT (CC) VERSUS CONSTANT VOLTAGE (CV)

## 1.1 Introduction

In physiotherapy, both constant current (CC) and constant voltage (CV) electrotherapy equipment is now available. However, until recently, and particularly in Europe, virtually all the electrotherapy equipment in use worked on the CC principle. Before assessing the value of both characteristics in practice, we shall first consider the underlying principles.

The term 'current' (in the human body) refers to a flow of ions. Current (I) is expressed in milliampere (mA). The force required to make the ions flow is the potential (expressed in volt = V). The flow of ions between a pair of applied electrodes is hindered by the body tissues. The resistance met by the ion flow is expressed in ohm ( $= \Omega$ ). The current meets the greatest resistance in the skin, the subcutaneous fat tissue and bony structures<sup>(24,28)</sup>. The resistance of the skin is not always the same. It can be influenced by such factors as the thickness of the epidermis and subcutaneous fat tissue, moistness of the skin (transpiration), blood supply and metabolism.

The resistance of the skin can also be reduced artificially by:

- moistening the skin
- increasing the blood supply (in advance)
- allowing current to flow for a length of time.

## 1.2 Constant Current

There is a fixed relationship between potential (V), current (I) and resistance (I).

This is expressed by Ohm's law:  $V = I \cdot R$ .

As the resistance of the skin fluctuates during treatment, Ohm's law implies that the current can increase (strongly), resulting in an unpleasant sensation for the patient. With low-frequency direct current types, this undesirable increase in amplitude could cause damage of the skin.

Constant Current equipment avoids these effects, as the selected current amplitude is maintained at a constant value ( $I \cdot R \uparrow = V \uparrow$ ).

## 1.3 Constant voltage

The constant Current principle is a good choice for stationary techniques. However, it can lead to problems in dynamic application techniques, in which the effective area of the electrode is continually changing. The patient will experience this as an increase in amplitude, although, in fact, the amplitude does not increase. The increased sensation of current is due to an increase in the current density. This is not only unpleasant for the patient, but can also lead to an incorrect interpretation in electrodiagnostics. There can also be disconnection and connection reactions when the electrode is withdrawn and replaced.

These problems do not occur in equipment working on the Constant Voltage principle. In this case, if the effective electrode area is reduced, which is equivalent to an increase in the resistance, the amplitude will also be reduced ( $V : R \uparrow = I \downarrow$ ), so that the current density remains the same. The patient will experience no change in the sensation of current, and there will also be no disconnection or connection reactions, so that the patient experiences the current as safe and comfortable.

## 1.4 Constant Current and Constant Voltage in practice

The combination of both principles in one electrotherapy unit offers a wealth of possibilities for treatment. If the unit has two channels, stationary and dynamic techniques can be combined in one treatment session. In practice, this offers benefits in several areas of application:

- (bilateral) stationary treatment techniques;
- diagnosis and/or treatment with the same unit;
- combined stationary and dynamic treatment techniques (e.g. stationary treatment of a peripheral pain point combined with dynamic treatment for localizing trigger points at the segmental innervation level);
- the localization of motor trigger points;
- reduction of patients' fear of electric current.



## 2 PAIN CONTROL AND SELECTIVE STIMULATION

### 2.1 Introduction

Pain reduction can be achieved in many different ways. It is beyond the scope of this book to list all the means available. However, we shall discuss a number of the theories that have been advanced to explain the underlying mechanism of the pain reduction effect. With respect to electrotherapy, it will become clear that phase duration, frequency and amplitude play an important role.

### 2.2 Pain theories

Enraf-Nonius electrotherapy equipment offers a range of current types that relate to the present-day theories explaining the reduction of pain by electrostimulation. The following three theories are important.

#### 2.2.1 Gate control theory (Melzack and Wall)

This theory<sup>(7,21)</sup> is based on the assumption that stimulation of the thick myelinated nerve fibres will cause a neural inhibition at the spinal level. This inhibition will block the transport of pain stimuli to the brain via the thin non-myelinated nerve fibres.

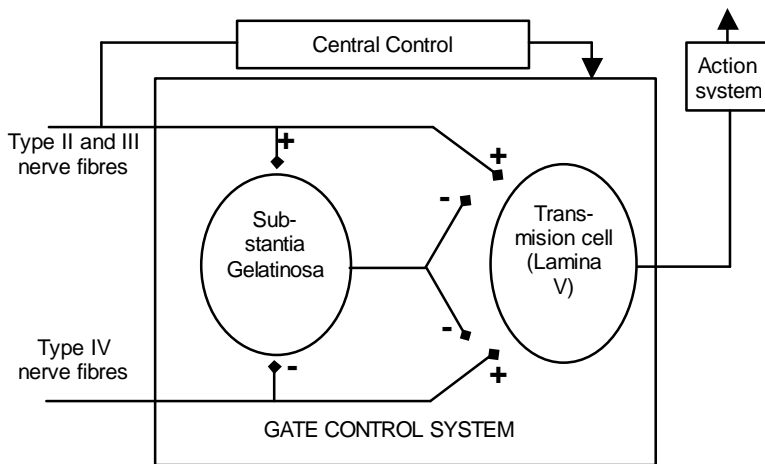


Fig. 1.  
Diagrammatic representation of the Gate-Control-Theory (Melzack and Wall).

In other words, selective stimulation of the type II and type III nerve fibres will create a feed-forward inhibition of the stimuli arising in the type IV nerve fibres. In this case, stimulation of the type IV nerve fibres is undesirable.

Although the existence of a central influence is now also considered (see paragraph 2.2.2), the Gate control theory is still regarded as one of the most important starting points in pain suppression<sup>(7)</sup>.

Category	Efferent	Afferent	Conductionspeed (m/s)	Diameter (µm)
Thick	A-α	I	70-120	12-22
	A-β	II	50-70	5-12
	A-γ	II	30-50	5-12
Thin	A-δ	III	<30	2-5
	B	-	3-14	1-3
	C	IV	<3	0.1-1.3

Table 1. an outline of nerve fibres.

### 2.2.2 Endorphin release theory (Sjölund and Eriksson)

This theory<sup>(27)</sup> is based on the assumption that, in chronic pain, there is either hypoactivity of the endorphin system, or an increased consumption of the endorphins released. The central nervous system can be stimulated to produce these endogenous opiates, resulting in pain suppression, by applying a 'Burst-TENS' current (also referred to as 'low-frequency, high-intensity TENS' or 'acupuncture-like TENS'). According to Sjölund and Eriksson, endorphins are only released at a burst frequency of 2-5 Hz, and 7 pulses per burst. The amplitude in Burst-TENS should be such that local muscle contractions occur, without discomfort (limit of tolerance).

Pain reduction in conventional TENS ('high-frequency, low-intensity TENS') is ascribed to local, spinal release of endogenous opiates (encephalins)<sup>(27,32,34)</sup>.

### 2.2.3 Postexcitation depression of the sympathetic nervous system (Sato and Schmidt)

This theory<sup>(26)</sup> states that a postexcitation depression of the sympathetic nervous system can be obtained by stimulating the type II and type III nerve fibres. In this case, excessive stimulation of the type IV nerve fibres must be avoided. In conditions involving overactivity of the sympathetic nervous system the emphasis should therefore be on stimulating the type II and type III fibres.

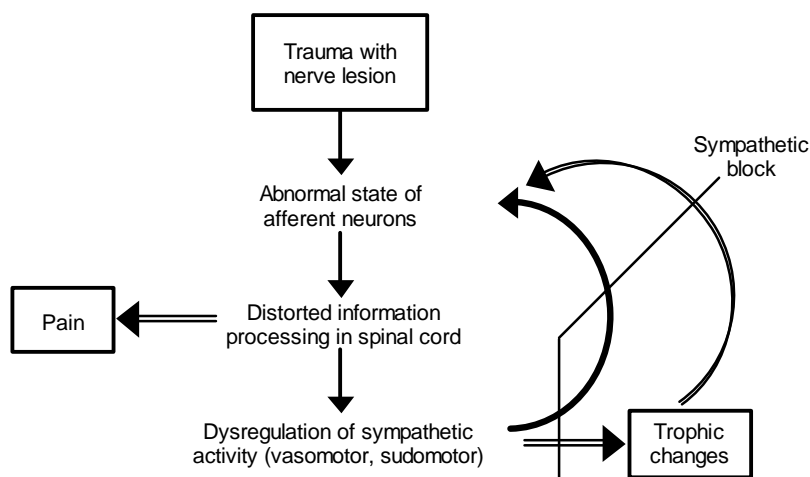


Fig. 2. Sympathetic reflex dystrophy.

## 2.3 Selective stimulation

From the foregoing it can be seen that there is a preference for stimulating the type II and type III nerve fibres. In addition, for muscle stimulation, selective stimulation of the type I ( $A\alpha$ ) motor neurons is preferred.

Investigators who have concerned themselves with selective stimulation of the peripheral nerves are Howson<sup>(8)</sup>, Lullies<sup>(18,19)</sup> and Wyss<sup>(18,35)</sup>.

### 2.3.1 Howson

Howson<sup>(7)</sup> states that it is best to use very short phase times for stimulation of the type II and type III nerve fibres, as well as for stimulation of the type I ( $A\alpha$ ) motor neurons (Fig. 3).

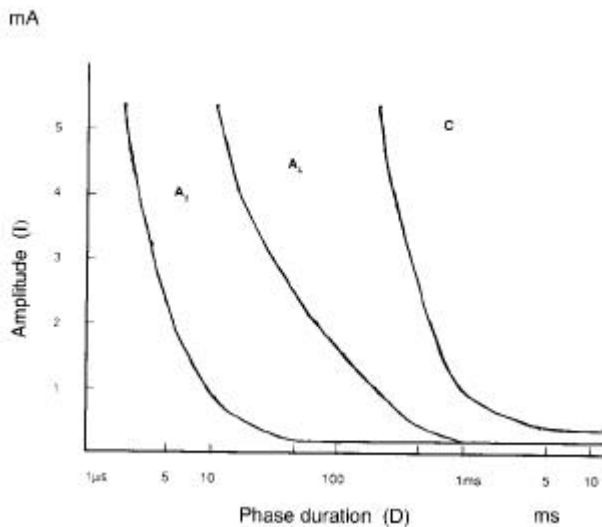


Fig. 3.  
The strength/duration curves of the different types of nerve fibre (Howson, 1978, from Li and Bak).

The strength/duration curves of the different types of nerve fibre show that with phase times shorter than 200  $\mu$ s it is possible to stimulate the sensory and/or motor nerves without stimulating the non-myelinated fibres (pain). In other words, with such short phase times it is possible to select a relatively high amplitude without stimulating the thin nerve fibres. There is thus a wide amplitude range. On the other hand, with longer phase times the different strength/duration curves lie so close together that a small increase in amplitude can result in stimulation of the thin nerve fibres. In this case, there is a narrow amplitude range.

### 2.3.2 Lullies

From investigations by Lullies<sup>(18,19)</sup> it is possible to draw certain conclusions regarding the conditions that an alternating current must meet for selective stimulation of the thick nerve fibres. These conditions are:

- a 'relatively' low current;
- a 'relatively' high frequency (above 3 Hz).

Although the frequency of the medium-frequency alternating currents in interferential therapy differs from the optimum frequency, these currents are still able to stimulate the thick nerve fibres.

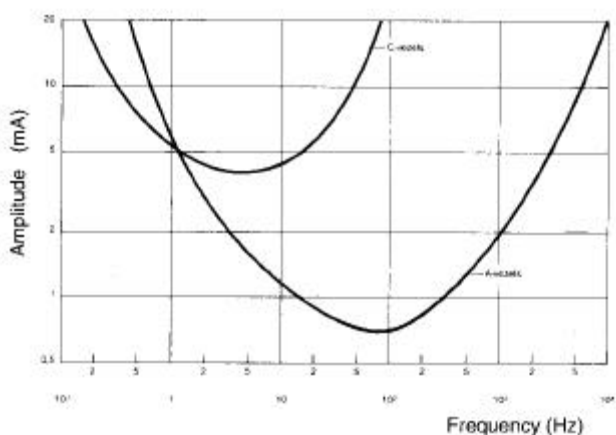


Fig. 4.  
The amplitude of a sinusoidal alternating current plotted against frequency for type I ( $Aa$ ) nerve fibres (myelinated motor neurons) and type IV (C) (non-myelinated autonomic) fibres of the sciatic nerve of a frog.

The Amplitude Modulation Frequency (AMF) has no effect on the selective stimulation of thick nerve fibres, but only determines the frequency with which the nerve fibres depolarize. Different AMF's produce different sensations in the patient, enabling the current to be adapted to the sensitivity of the affected tissues. The choice of AMF is therefore of therapeutic significance.

### 2.3.3 Wyss

Wyss<sup>(18,35)</sup> investigated the selectivity of using direct current pulses of different phase times for A and B fibres (Fig. 5). It appeared that A fibres were selectively stimulated by shorter pulses with lower amplitude than those required for selective stimulation of B fibres. Although no definitive physiological explanation has yet been given for the effects of the 2-5 current and the diodynamic current forms, it is striking that the phase duration of these currents corresponds closely with that reported by Wyss as being the optimum for the stimulation of thick nerve fibres, even though Wyss used exponential pulses. The phase duration of the (neo)faradic current forms appears to fit this model extremely well.

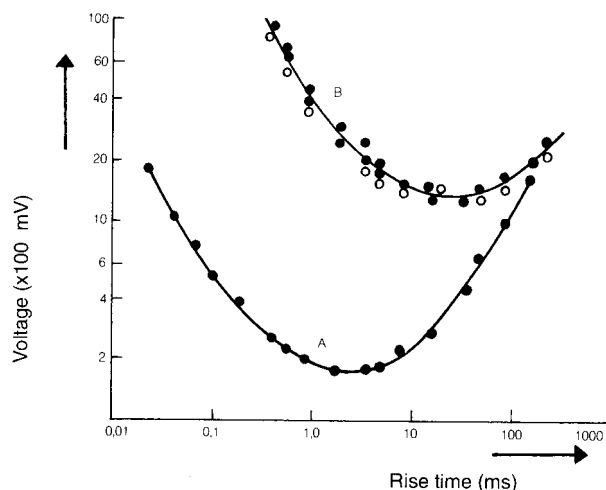


Fig. 5.

The dependence of the threshold voltage on different rise times (for A and B fibres) with progressively increasing pulses, according to Wyss.

### 2.4 Amplitude (stimulation level)

From the investigations mentioned above it is clear that, in addition to phase duration and frequency, the amplitude is also a determining factor in selective stimulation (Fig. 3, 4 and 5). In electrostimulation, reference is made to various stimulation levels, in order to indicate how high the amplitude should be in order to achieve truly selective stimulation. When the amplitude in a healthy subject is increased, the following reactions occur:

- the sensitivity threshold is reached;
- the motor threshold is reached;
- the pain threshold is reached; the patient experiences contractions and pain (Fig. 6).

This applies to all current types! It is therefore essential to check the patient's sensitivity before treatment.

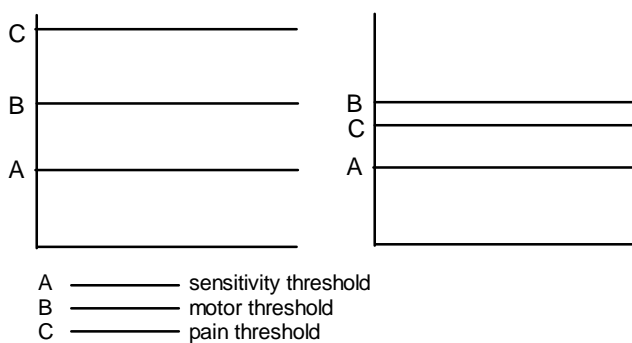


Fig. 6.

Coherence of stimulation level and amplitude.

The two classifications most commonly used to assess the correct amplitude are described below.

1. Classification bases on the sensation created in the patient:
  - a. submitis (amplitude at which the stimulus is just imperceptible);
  - b. mitis (amplitude at which the stimulus is just perceptible);
  - c. normalis (amplitude at which the stimulus is distinctly perceptible);
  - d. fortis (amplitude at which the stimulus is increased to the limit of tolerance).

A disadvantage of this classification is that it is, in fact, dependent on verbal information from the patient. In addition, it disregards any motor activity.

2. Classification according to both sensory and motor stimulation levels:
  - a. subsensory stimulation level;
  - b. sensory stimulation level;
  - c. motor stimulation level (clearly perceptible muscle contractions);
  - d. limit of tolerance (powerful, but not quite painful muscle contractions);
  - e. pain threshold.

In practice, this second classification is easier to use. However, it is still an open question as to whether a motor stimulation level is really below the limit of tolerance. In pathological cases, the sequence can change. Many factors play a role in this, such as the nature of the condition, the sensitivity of the patient, and the metabolism of the skin.

From this it will be clear that it is impossible to give exact figures with respect to the limits between the various stimulation levels. In the examples of treatment, we shall keep to Classification 2. If the aim of the treatment is to evoke a motor response, it will also be indicated whether the current amplitude may be increased to the limit of tolerance or to the pain threshold.

### 3 FROM THEORY TO PRACTICE

#### 3.1 Introduction

Enraf-Nonius electrotherapy equipment offers a range of current types capable of selectively stimulating the nervous system with the aim of reducing pain, restoring the autonomic balance or stimulating the musculature. This chapter describes the diadynamic current types, the 2-5 current and alternating currents (interferential and TENS currents). These various forms of low-and medium-frequency electrotherapy are dealt with in one chapter because, insofar as the aim is pain reduction or restoration of the autonomic balance, there are many similarities in the range of indications, the method of application and the electrophysiological effects.

#### 3.2 Diadynamic current types

##### 3.2.1 Description of current types

Bernard uses the term 'diadynamic current' to refer to a monophasic (MF – Monophasé Fixe) or double-phase (DF – Diphasé Fixe) rectified alternating current, with a frequency which is derived directly from the mains supply, resulting in sinusoidal pulses with a duration of 10 ms. This phase time of 10 ms will mainly depolarize thick fibres. Stimulation of thin fibres as well can only be obtained at higher current amplitudes (Fig. 5).

The diadynamic current types have won a significant position in the history of (European) physiotherapy. They are somewhat unfairly dismissed as outdated when compared with interferential currents or TENS. In fact, however, the diadynamic currents have quite specific effects when used for pain reduction or improvement of tissue metabolism.

Enraf-Nonius (low-frequency) electrotherapy equipment is based on the four classic diadynamic current types:

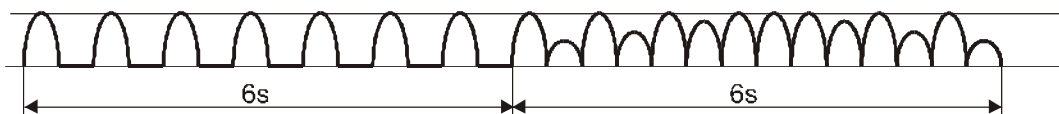
- MF (Monophasé Fixe), frequency 50 Hz
- DF (Diphasé Fixe), frequency 100 Hz
- CP (Courtes Périodes), rapid alternation between one second of MF current and one second of DF current
- LP (Longues Périodes), slow alternation between six seconds of MF current and a six-second DF phase. In the DF phase the intervals between the MF pulses are filled with additional pulses which gradually increase in amplitude to that of the MF pulses, resulting in a DF current, after which the amplitude of the additional pulses decreases again to zero and the MF current continues for a further six seconds. The whole duration of the DF phase, including increase and decrease (ramp up and ramp down), is six seconds.



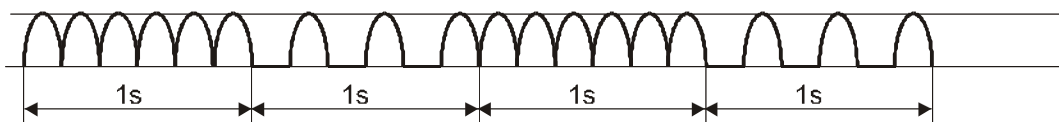
*DF double-phase rectified alternating current.*



*MF monophasic rectified alternating current.*



*LP Slow alternation between DF and MF.*



*CP rapid alternation between DF and MF.*

*Fig 7.  
Current types.*

The CP and LP dynamic current types are used to prevent accommodation. CP is more aggressive than LP, as the changes are quite abrupt (cf. the spectrum mode used in interferential therapy). Bernard also used the two current types to adapt the type of stimulation to the (actual) pathological condition.

### 3.2.2 Application of diadynamic current types

With all current types, the patient will fairly quickly experience a pricking sensation when the amplitude is increased. This is due to the effects of the phase duration. In addition, the galvanic effects often cause the current to be experienced as unpleasant, so that there is a tendency not to increase the amplitude further. However, if the amplitude is increased, the patient will feel the tickling (DF) or buzzing/vibrating (MF) sensation of the diadynamic current. This is certainly not unpleasant, and the pricking, burning sensation will no longer be dominant. Increasing the current amplitude during treatment in order to adapt the stimulus to changes in the pathological condition is not in accordance with Bernard's principle.

When these rectified currents are used, the possibility of damage of the skin should be taken into account. Due to its pulse form, diadynamic current has a relatively high DC amplitude, so that there is a significant chance of damage occurring. Damage is the result of electrochemical reactions under the anode and cathode, and changes in the pH value of the skin.

In order to keep the risk of damage to the minimum, treatment should be limited to ten minutes per application, and the amplitude should not be increased to the patient's pain threshold (Bernard advised a duration of max. 4 to 5 minutes). In addition, pads of viscose material should be used, with a minimum thickness of 1 cm<sup>2</sup>, in order to maintain a sufficient quantity of water at the site of application. A spray bottle can be used to add more water during treatment.

It is quite easy to cause contractions with the MF current type, from which it might be assumed that this current type is very suitable for use in muscle stimulation. However, the high galvanic component of the current makes this inadvisable, as muscle stimulation requires relatively high amplitudes.

Diadynamic current is particularly suitable for treating pain in small joints (e.g. finger joints and wrist joint). Segmental application of diadynamic current gives outstanding results in reflex dystrophy (Südeck's disease) and in superficial hyperalgesia. A familiar example of the latter is the effect of diadynamic current in the treatment of herpes zoster. Although there is still little known about the underlying mechanism, the results are astonishing.

## 3.3 2-5 Current (Träbert)

### 3.3.1 Description of the current type

Träbert uses the term '2-5 current' to refer to a direct current with a rectangular pulse having a phase duration of 2 ms and a phase interval of 5 ms. This current type is also referred to in the literature as 'Ultra-Reiz' current. The frequency of the current is approx. 143 Hz. As stated in paragraph 2.3., this current type is suitable for selective stimulation of thick fibres.

From the foregoing it is clear that the configuration of the current is very simple. Träbert himself offered no explanation for the choice of parameters. Nevertheless, many workers have adopted the therapy according to Träbert, and it is still applied with success. A remarkable effect is the freedom from pain which can already appear after the first treatment, and can last for several hours.

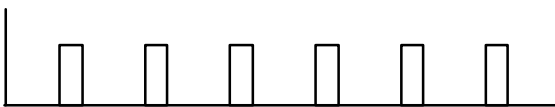
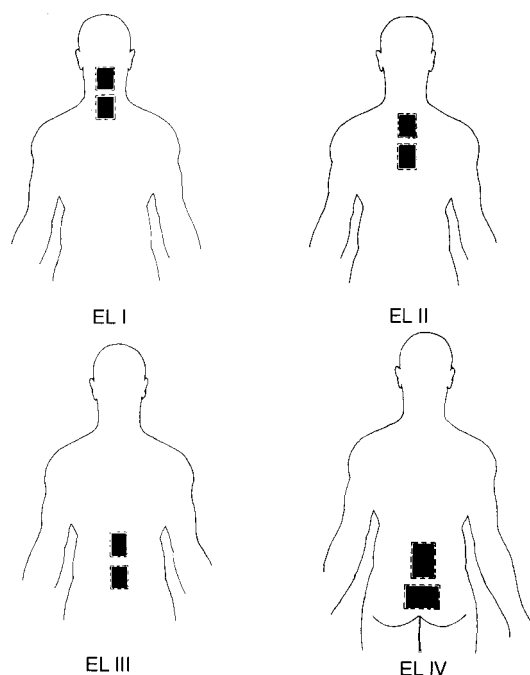


Fig. 8.  
2-5 Current (Träbert)

### 3.3.2. Application of 2-5 current

Träbert described four typical locations for the electrodes (EL = Electrode Localization), which correspond well with the segmental theory in electrotherapy (Fig. 9). The polarity depended on the target area. For example, EL I was used to treat both headaches and neck pain. In the treatment of headaches the negative electrode was positioned caudally with respect to the positive electrode, while in the treatment of neck pain radiating to the arm the negative electrode was positioned proximally with respect to the positive electrode. The electrode positioning is extremely well suited to segmental applications. For example, EL IV is particularly suitable for the treatment of intermittent claudication<sup>(29)</sup>. If the condition is bilateral, the negative electrode can be divided and positioned in the gluteal region.

Once the current amplitude has been set, accommodation will occur fairly quickly, due to the absence of frequency changes or interruptions. After a short period the patient will no longer feel the current as strongly as at the beginning. Träbert therefore recommended that the amplitude should be increased in steps, up to the limit of tolerance.



*Fig. 9.  
Position of electrodes (Träbert)*

The amplitude is increased at each step until muscle contractions occur. The muscle contractions must be palpable or just visible. The contractions may contribute to improved perfusion of the muscles (muscle pump mechanism). As soon as the contractions start to reduce, the current amplitude should be increased again. In practice, this means that the current amplitude is increased at intervals of one minute. The limit of tolerance is generally reached after 5 to 7 minutes, after which the current amplitude is no longer increased. In some cases, current amplitudes of 70-80 mA may be reached.

Although the direct value is relatively low, the increasing amplitude makes it necessary to use thick sponges (minimum thickness 1 cm) that are thoroughly wet. If required, water may be added during the treatment.

The electrodes must be fixed firmly in place. Due to the muscle contractions evoked, fixation with the aid of sandbags is not always sufficient.

In the literature, reference is made to a maximum treatment time of 15 minutes.



### 3.4 Medium-frequency currents

Although many different types of medium-frequency current may be used, the best known application is interferential therapy. This most frequently used form of medium-frequency current will therefore be considered in the following section. The specific application form known as 'Russian Stimulation' will be dealt with in Chapter 4.

#### 3.4.1 Description of the current forms

From the investigations of Lullies it is clear that the thick nerve fibres can be selectively stimulated using medium-frequency currents. However, in comparison with low-frequency current types, there is a difference in the way in which the nerve fibres are depolarized. Due to the higher frequency of the medium-frequency current, not every (alternating current) pulse will result in depolarization of the nerve fibre. Depolarization of the nerve fibre is the result of the summation principle (Gildemeister effect).

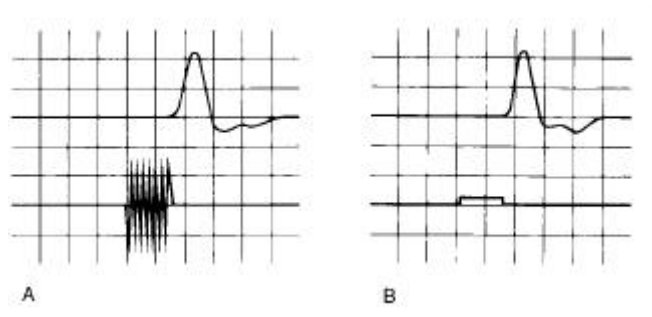


Fig. 10.  
An action potential arising as the result of a medium-frequency current (A) and a direct current pulse (B).

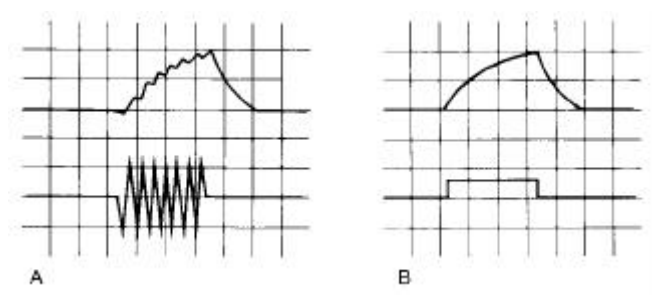


Fig 11.  
A. With a medium-frequency current an action potential only arises after a certain number of periods (summation principle).  
B. With a direct-current pulse of the same duration an action potential arises at a significantly lower amplitude.

According to Lullies, continued stimulation with a medium-frequency alternating current can result in a situation in which the nerve fibre ceases to react to the current (Wedensky inhibition) or the motor end plate becomes fatigued and may fail to transmit the stimulus.

To prevent this, it is necessary to interrupt the current after each depolarization. This can be achieved by rhythmically increasing and decreasing the amplitude (**amplitude modulation\***). The Amplitude Modulation Frequency (AMF) determines the frequency of the depolarization (Fig. 12).

The AMF corresponds to the frequencies used in low-frequency electrotherapy.

\* Equipment also exists nowadays in which amplitude modulation is replaced by pulse width modulation. The original idea (the necessity of interrupting the medium-frequency current after each polarization) remains the same. The only difference is that the interruption is now achieved in a different way. For the sake of clarity, we continue to use the term AMF.

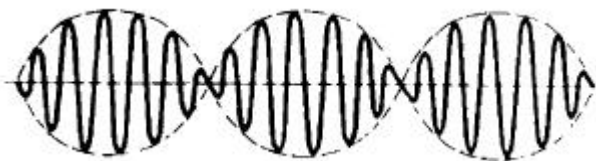


Fig. 12.  
Rhythmic interruption of the MF/current.

One method for obtaining amplitude modulation is **interferential therapy**.

*Definition: interferential therapy is the phenomenon that occurs when two or more oscillations simultaneously affect the same point or series of points in a medium.*

When interferential therapy is applied in electrotherapy, use is made of two medium-frequency alternating currents that interact with each other. One of these alternating currents has a fixed frequency of 4000 Hz, while the frequency of the other current can be adjusted between 4000 and 4250 Hz. The interference results from the superimposition of these two currents (Fig. 13').

At the point where the currents intersect, a new medium-frequency alternating current arises with a modulated amplitude. The AMF corresponds to the difference in frequency between the two currents.

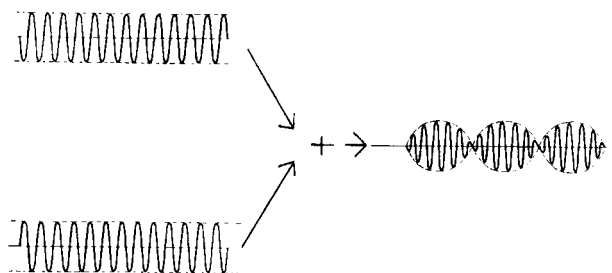


Fig. 13.  
Superimposition of two medium-frequency alternating currents with different frequencies.

In addition to the frequency, the amplitude modulation is also characterized by the **modulation dept (M)**. The modulation depth is expressed as a percentage, and can lie between 0 and 100%. It will be clear that a modulation dept of 100% is required to actually interrupt the current (Fig. 14).

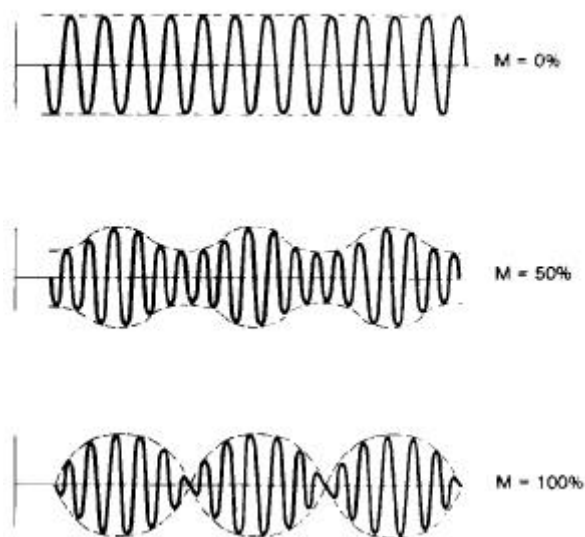


Fig. 14.  
Different depths of modulation (M) of a medium-frequency alternating current.

### 3.4.2 Application of interferential therapy

Application point for therapy may lie on the surface of the body, or in deeper-lying tissues.

Due to the higher frequency and the absence of galvanic effects, medium-frequency alternating current is suitable for treatment of deeper-lying tissues (muscles, tendons, burs or periosteum).

The selected application method will depend on the application points. The application methods are as follows:

- pain-point or trigger-point application,
- nerve application;
- (para) vertebral application;
- transregional application;
- muscular application (see Chapter 5).

The present range of Enraf-Nonius equipment offers five methods for interferential therapy:

1. two-pole (bipolar) method;
2. four-pole (tetrapolar) method (Classic Interferential without vector);
3. four-pole method with Dipole vector (manually adjustable);
4. four-pole method with Dipole vector (automatic);
5. four-pole method with Isoplanar vector

#### 3.4.2.1 The two-pole method

In this method two electrodes are used and superimposition of the two alternating currents takes place within the equipment. The current leaving the equipment is a fully modulated alternating current.

In the two-pole method the modulation depth is always 100% (Fig. 15).

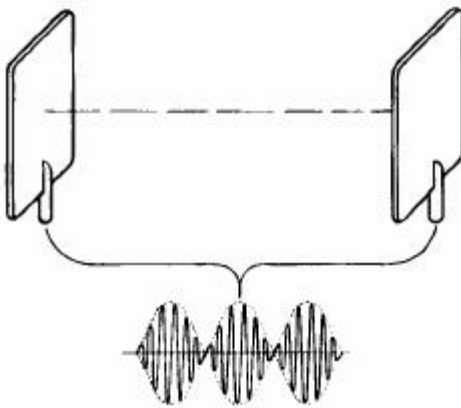


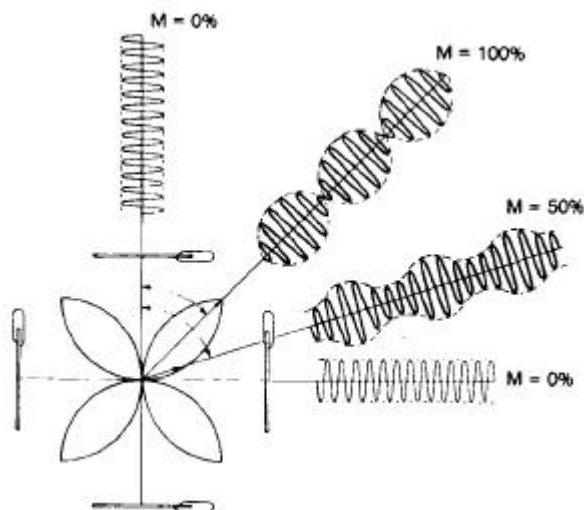
Fig. 15.  
*Bipolar interferential therapy*

#### 3.4.2.2 The four-pole method (Classic Interferential)

In this method four electrodes are used, and two unmodulated currents leave the equipment. Interference occurs where the two currents intersect within the tissue.

The modulation depth depends on the direction of the currents, and can vary from 0 to 100%. 100% modulation depth only occurs at the diagonals (and hence at the intersection) of the two currents.

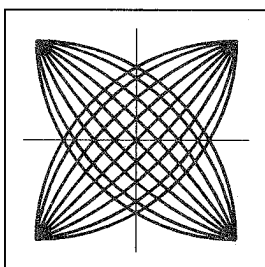
This is, of course, a theoretical situation, based on the assumption that the tissue is homogeneous. In the real situation, the tissue is heterogeneous, so that the intensity of the two channels has to be used to get the 100% modulation depth (Fig. 16). This can also be used to compensate for differences in sensation occurring under the electrode pairs.



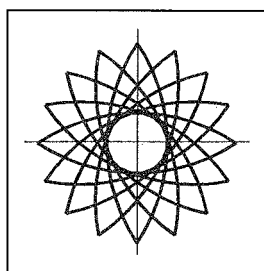
**Fig. 16.**  
In the four-pole method, the modulation depth is only 100% at the diagonals.

### Vector techniques

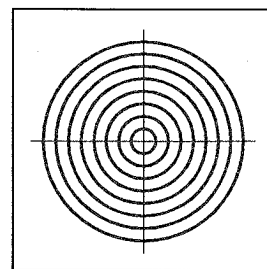
Additional to the classical Interferential, 3 different dynamic Vector techniques have been developed, which all aim to increase the treatment possibilities of 4-pole Interferential. The dynamic Vector techniques are used to increase the effective stimulated area. Each Vector technique distinguishes itself with a specific vector field (Fig. 17 - 19).



**Fig. 17**  
Vector field with Classical Interferential



**Fig. 18**  
Dipole vector field



**Fig 19**  
Isoplanar vector field

The Vector techniques are not only used to increase the treatment area. The Vector techniques can also be used to reduce the adaptation.

As already mentioned, the modulation depth is a criteria for the effectiveness of the electrical current and is expressed in a percentage. The stimulation is optimal when the modulation depth is 100%.

With the graphic drawing of the different vectors it is so that, when a cross is shown between the electrodes (as shown with Isoplanar vector, Fig. 23) there is an optimal stimulation in every direction. If a cross is shown, like with classical Interferential (see picture 20), it means that there is only effective stimulation in two directions. The electrode placement is in this case also very critical.

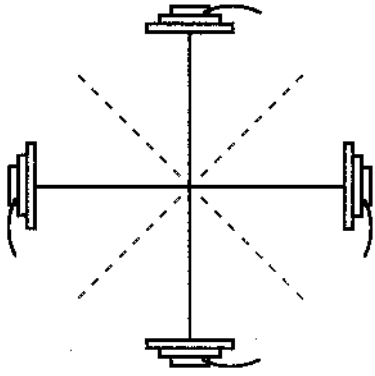


Fig. 20  
Classical Interferential (4-pole)

#### 3.4.2.3 The four-pole method with Dipole vector (manually adjustable)

The Manual adjustment of the dipole vector offers the opportunity to direct the stimulation exactly to a desired point in the area to be treated, without the need to change the electrode position. In this way you can for example find and treat pain points.

For an effective use of the vectors the current must be clearly perceptible by the patient.

If this is not possible, then it is easier to increase the intensity and see where muscle contractions appear. With this the correct spot is confirmed. The modulation depth with the dipole vector is 100%. The vector can be rotated 360° manually by means of a button on the unit.

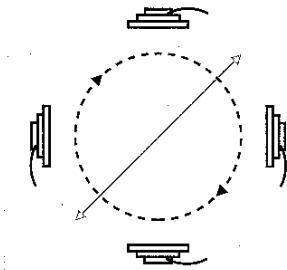


Fig. 21  
Dipole vector (manual adjustable)

#### 3.4.2.4 The four-pole method with Dipole vector (automatic)

This is the same as with the manual dipole vector, but with this vector the current will automatically and rhythmically flow through the whole treatment area and the stimulation point will rotate 360°.

Adaptation hardly occurs. The rotation speed of the vector is adjustable between 1 and 10 seconds per rotation. The rotation speed is defaulted at 3 rotations per second.

When the intensity of the current is increased until (or exceeding) the motor level, the muscle or muscle groups will alternately contract and relax. This will result in a venous drainage (Oedema resorption) and improved circulation. Additionally the automatic vector provides a significant decrease of the muscle tone. Thus offering an excellent technique for the treatment of areas where mechanical pressure (massage) must be avoided.

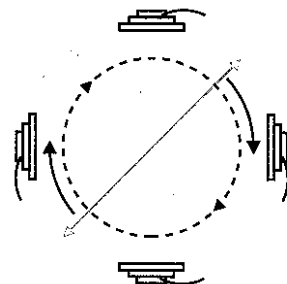


Fig. 22  
Dipole vector (automatic)

### 3.4.2.5 The four-pole method with Isoplanar vector

With the Isoplanar vector the total area between the 4 electrodes is optimally stimulated. The electrode positioning can be done simply and quickly. The modulation depth is everywhere 100%.

Isoplanar Interferential can be used for the treatment of problems which are located in a large area and which are very difficult to locate.

Isoplanar Interferential is also used as a mild pre-treatment. After this application the treatment is continued with a focus on a smaller, more local area.

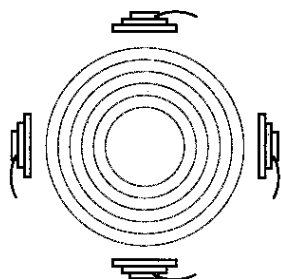


Fig. 23  
Isoplanar vector

### 3.4.3 Criteria for selecting the right parameters

It is not possible to lay down hard and fast guidelines with respect to the choice of **method**. However, there are certain important points that should be taken into account.

In the two-pole method the modulation depth is always 100%, while the modulation depth in the four-pole method is only 100% at the diagonals. As stated above, a modulation depth of 100% gives the optimum stimulation effect, and is therefore preferred for therapy.

In practice, two electrodes are simpler to position and fasten than four. Furthermore, it is also easier to find the correct localization with two electrodes.

The four-pole method has the advantages of less stress on the skin, combined with increased amplitude at the application point. However, the stress on the skin is already low with medium-frequency currents, due to the greater depth effect obtained with the higher frequency, and the absence of galvanic effects.

The dynamic vector techniques should be used when the region to be treated is relatively large. If localized treatment is required, the bi-pole method is preferable.

#### AMF

The **AMF** can be set as desired according to the type, stage, severity and location of the condition to be treated. The sensations experienced by the patient at the various AMF's have to be considered.

High frequencies are experienced as 'more comfortable', 'pleasanter' or 'lighter'.

A high AMF (80-200 Hz) is advised<sup>(5)</sup> for acute conditions, great pain and hypersensitivity. A high AMF is also preferable for initial treatment if the patient shows a fear of electricity. At low frequencies the sensation is 'rougher', 'deeper' or 'stronger'. Frequencies below 50 Hz can easily lead to (tetanic) contractions.

In less acute cases, i.e. less pain and lower sensibility conditions, and where muscle contractions are required, a low AMF is most suitable.

#### Choice of electrodes

In addition to the usual (flat) electrodes there is also a point electrode. This electrode is specifically intended for the detection and treatment of pain points. It is used in combination with a larger 'indifferent' electrode which is placed well away from the affected area. The point electrode cannot be used with the four-pole method.

#### Electrode positioning

The electrodes must be positioned in such a way that the patient experiences the stimulation in the affected area.

This should be checked during treatment, and the electrodes should be repositioned as necessary. This applies to both the two-pole and the four-pole method.

It is well known that, once a current has been set, the patient will feel the stimulus less clearly after a period of time, or even completely cease to feel it. This effect is referred to as accommodation, and is due to the fact that a fixed frequency the stimulated sensors will gradually transmit less information to the central nervous system.

Thus, if the stimulus remains unchanged, its effect will become less.

Accommodation must therefore be prevented.

There are three ways of preventing **accommodation**:

#### 1. Increasing the amplitude:

the possibility of strong tetanic contractions must be taken into account. These can be unpleasant for the patient.

## 2. Varying the frequency (the 'Frequency Modulation'):

Bernard was the first to use this method of preventing accommodation, in the form of the CP and LP currents. Here, there is a rhythmic alternation of 50 Hz and 100 Hz frequencies. The same principle is used in interferential therapy, in the form of 'Frequency Modulation' (Fig. 24).

The following parameters are of importance:

### a. The width of the Frequency Modulation

A 'broad' Frequency Modulation (i.e. a large frequency range) is better for preventing accommodation than a 'narrow' Frequency Modulation (i.e. a small frequency range); the large changes in frequency with a broad Frequency Modulation result in strongly varying sensations and/or contractions.

### b. The Frequency Modulation mode (Frequency Modulation variation or Frequency Modulation sweep)

Depending on the equipment used, there are various ways of indicating the ratio between the base AMF and the Frequency Modulation (in seconds). Examples are: 1/1, 1/5/1/5, 6/6 and 1/30/1/30 s.

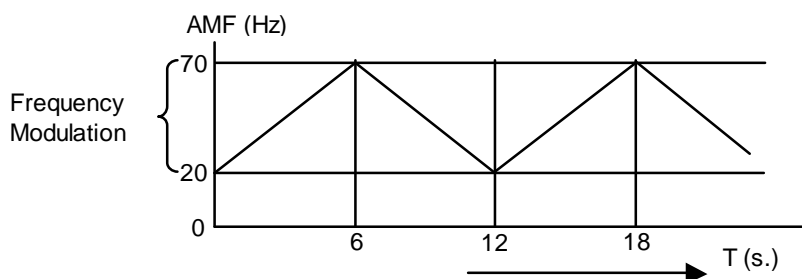


Fig. 24,

*Example of Frequency Modulation.*

If the AMF is set at 20 Hz and the Frequency Modulation at 50 Hz, the current will scan through all frequencies between 20 Hz and 70 Hz.

## 3. Setting a lower AMF.

The foregoing can be summarized in the following basic rules.

Taking accommodation into account, patients with acute conditions are treated with:

- a relatively low amplitude;
- a relatively high AMF;
- a relatively broad Frequency Modulation;
- a relatively gently changing Frequency Modulation program with a long duration (6/6 or 1/30/1/30 s).

Taking accommodation into account, patients with less acute conditions are treated with:

- a relatively high amplitude;
- a relatively low AMF;
- a relatively narrow Frequency Modulation;
- a relatively abrupt Frequency Modulation program with a short duration (1/1 s).

## 3.5 TENS

TENS (Transcutaneous Electrical Nerve Stimulation) is the application of electrodes to the skin with the aim of reducing pain by stimulating the thick afferent nerve fibres. In view of the fact that other current types such as diadynamic currents, 2-5 current and interferential currents also stimulate the nerves via the skin, the choice of the term TENS is somewhat unfortunate.

In TENS there is generally an alternating current, characterized by a variable phase duration and a variable phase interval which can be used to vary the frequency. The phase duration is generally very short, varying from 10 to 250  $\mu$ s. Thus, the TENS current types make it possible to stimulate the nerve fibres selectively (see paragraph 2.3.1). The best known types of TENS application are Conventional TENS (high-frequency, low-intensity TENS) with a frequency between 80 and 100 Hz, and low-frequency, high-intensity TENS ('acupuncture-like TENS') with a frequency of less than 10 Hz. More recently other frequencies and current types (Burst TENS) have been used, partly due to the influence of the publications of Sjölund and Eriksson<sup>(27)</sup>.

Enraf-Nonius supply several electrotherapy units that can be used to apply TENS current types (Fig. 25, 26 and 27). Lundeberg<sup>(20)</sup> has achieved excellent results with the use of an alternating square pulse in the treatment of wounds. This does not mean that the square pulse is unsuitable for other applications, but it does appear to have a specific application in wound healing. The application of TENS current types in wound healing is dealt with in more detail in Chapter 8.

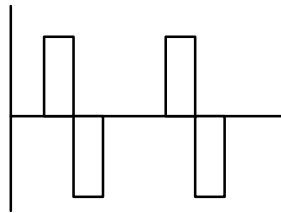


Fig. 25.  
Symmetrical biphasic rectangular waveform.

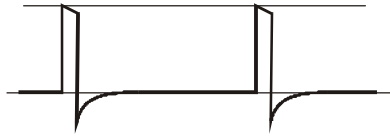


Fig. 26.  
Asymmetrical biphasic waveform.

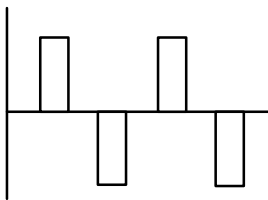


Fig. 27.  
Alternating rectangular waveform.

### 3.5.1 Burst frequency

The publications of Sjölund and Eriksson<sup>(27)</sup> have led to the use of a special frequency modulation in TENS therapy, known as 'Burst TENS' which is actually a modification of 'acupuncture-like' TENS. Burst TENS consists of a train or 'burst' of pulses of 2 Hz. Each burst lasts for 70 ms and, as the internal frequency of the bursts is 100 Hz, each burst contains 7 pulses. According to Sjölund and Eriksson, this results in the release of endorphins at the central level, which have a pain-reducing effect. They base this claim on the fact that the pain reduction is counteracted by naloxone, which is a morphine antagonist.

Naloxone does not counteract the pain reduction achieved by stimulation using conventional TENS. A precondition for the release of endorphins appears to be the use of a high amplitude. Consequently, this form of stimulation is rather aggressive. The burst frequency is therefore principally used for problems that are not acute. In addition to the frequency of 2 Hz mentioned above, the literature also mentions other frequencies, varying from 1 to 5 Hz.

In a burst application, a relatively high internal frequency current is preferable, not only because of the publications by Sjölund and Eriksson, but also because a low internal frequency brings the risk that no pulse falls within the burst. This can result in an irregular stimulation pattern.

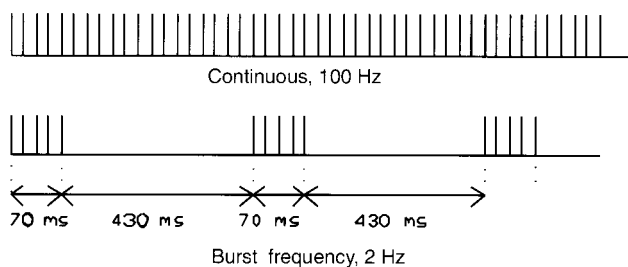


Fig. 28.  
Conventional and Burst TENS.



### 3.5.2 Application of TENS current types

The TENS current types are mainly used for pain suppression.

#### *a. High-Frequency, Low-Intensity TENS.*

High-Frequency, Low-Intensity TENS (Conventional TENS) is the most generally used of the TENS current types. The most effective frequency is between 50 and 100 Hz. A relatively short phase duration is selected ( $\leq 150 \mu\text{s}$ ), after which the amplitude is increased until a pleasant, light to medium paresthesia occurs in the region being stimulated. There should be no muscle contractions or fasciculations. If such contractions do occur, the current amplitude is too high.

Next, while the amplitude is kept constant, the phase duration is increased. If the paresthesia becomes deeper or is felt over a larger area, the greater phase duration is maintained.

However, if the stimulus only becomes stronger, without becoming deeper or more extensive, the phase width is returned to its original value. The apparent strength of the stimulus generally reduces after some five to ten minutes (accommodation). The amplitude should then be increased until the paresthesia returns.

The electrodes are generally positioned with one electrode over the peripheral nerves innervating the painful region, and one electrode placed distal to the region, in order to ensure optimum conduction through the region. Electrodes may also be positioned at the level of the segment where the peripheral nerves concerned arise from the spinal cord. There is no point in positioning electrodes on areas of the skin with reduced sensitivity.

Conventional TENS is often rapidly effective in the treatment of hyperaesthesia and causalgia resulting from peripheral nerve lesions, phantom pain, scar pain and post-operative pain. It can also give good results in the treatment of low back pain.

If the pain reduces after ten to twenty minutes of stimulation, the patient may be given a small TENS unit to use at home. This is certainly useful, as stimulation may have to be applied several times daily, often for an hour or more.

#### *b. Burst TENS.*

Burst TENS is applied if Conventional TENS proves ineffective, and is particularly suitable for the treatment of deeper lying painful regions (myofascial pain) and cases of chronic pain.

Burst TENS uses a relatively large phase duration (150-200  $\mu\text{s}$ ), a low burst frequency (1-5 Hz) and a high amplitude. Strong, visible contractions should occur in the muscles whose innervation corresponds with that of the painful region.

The pain-reducing effect generally does not appear for some twenty to thirty minutes, unlike the effect of Conventional TENS, which usually occurs fairly rapidly. However, the effect lasts for considerably longer than that of Conventional TENS after stimulation has ended. The pain-reducing effect of Burst TENS is due to the release of endorphins at both spinal and supraspinal level. When conventional TENS or Burst TENS does not produce sufficient results, Frequency Modulation can be used. Frequency Modulation can also be applied to prevent habituation. The electrodes are usually placed over the peripheral nerves innervating the affected muscles, or over the 'motor points' (often located 1/3 proximal from the muscle belly).

This type of stimulation does not generally last for longer than twenty to forty-five minutes, due to the likelihood of fatigue in the stimulated muscles and pain resulting from the continual muscle contractions.

If Conventional or Burst TENS give no or insufficient relief, Frequent Modulation can be used. Frequency Modulation can also prevent accommodation.

## 4 MUSCLE STIMULATION

### 4.1 Introduction

In physiotherapy, muscle contractions may be artificially induced for various objectives. The contractions can be induced with the aid of intermittent direct current, or with alternating current. A distinction should be made between objectives in the case of normally innervated muscles, and objectives where there is partial or complete denervation of the muscle fibres. This distinction is also of importance for the choice of current type(s).

The physiotherapeutic objectives may be:

- increasing muscle tone;
- improving circulation;
- muscle strengthening;
- restoration of feeling in the muscle (e.g. following surgery);
- relaxation of the musculature;
- investigating the response to electrical stimulation of motor neurons and muscle tissue;
- combatting atrophy and preventing fibrosis of muscle tissue;
- stretching musculature to increase the range of movement of a joint.

This chapter is concerned with the application of **intermittent direct currents**, and discusses both the diagnostic and the therapeutic possibilities of muscle stimulation.

Section 4.3 is concerned with single stimulation by means of rectangular and triangular pulses. The relationship between the two pulse types is shown in the strength/duration curve.

Section 4.4 discusses (neo)faradic current as a method for multiple stimulation by means of rectangular pulses.

**Alternating currents** (medium-frequency and TENS currents) are often applied with therapeutic objectives, and will be considered in Chapter 5.

### 4.2 Muscle stimulation with intermittent direct current

The term 'muscle stimulation' is used to refer to the production of a contraction in a muscle or muscle group by the application of an electrical stimulus. The objective is to assess the response to electrical stimulation of the peripheral motor neurons and the muscle tissue. Depending on the nature of the contraction that can be produced by means of direct current pulses, a distinction is made between single and multiple stimulation. In single stimulation, a single contraction is produced. Multiple stimulation leads to tetanic contraction. With respect to the pulse type, only rectangular and triangular pulses are of interest in muscle stimulation.

### 4.3 The strength/duration curve

#### 4.3.1 Diagnostics

The diagnostic objective of muscle stimulation is to obtain information on the sensitivity of the neuromuscular apparatus to electrical stimulation. This, in turn, gives an indication of the degree of denervation of the muscle tissue. In this investigation technique the relation between the current amplitude ( $I$ ) and phase (pulse) time of a rectangular and triangular pulse is expressed graphically in the strength/duration curve. Although some knowledge of the basic principles of electrophysiology is required, the strength/duration curve is not difficult to make.

It involves observing the current amplitude required at various phase times (ranging from 0.01 to 1000 ms) in order to produce a just perceptible (i.e. just visible or palpable) contraction of a muscle or muscle group. The values observed can be plotted as points on special logarithmic graph paper.

The curve is created by joining the plotted points (Fig. 29).

In the case of reduced or absent sensitivity to electrical stimulation, the strength/duration curve also gives an indication of the pulse form, phase time and amplitude of the electrical stimulus to be used in any therapy that may be applied.

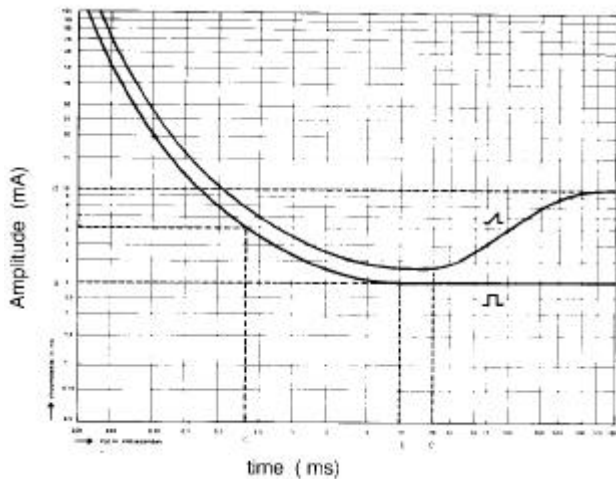


Fig. 29.  
Schematic representation of a rectangular and triangular pulse curve.

The investigation, which is carried out with both rectangular and triangular pulses, provides the following parameters:

#### a. the rectangular pulse curve:

##### *The rheobase:*

This is the amplitude that a rectangular pulse of 'infinite' duration must have in order to produce a just perceptible contraction. In practice, the phase duration is the maximum available (500 or 1000 ms, depending on the type of equipment). The phase interval should be at least twice the phase duration, in order to ensure a single contraction, and to avoid fatigue of the muscle fibres.

The value of the rheobase can vary from one muscle to another.

##### *The 'temps utile':*

This is the minimum time needed for a rectangular pulse to produce a just perceptible contraction at a current amplitude equal to the rheobase. For healthy muscle tissue, the temps utile is around 10  $\mu$ s.

##### *The chronaxy:*

The time needed for a rectangular pulse to produce a just perceptible contraction at a current amplitude equal to twice the rheobase. Normally, the chronaxy is between 0.1 and 1 ms.

#### b. the triangular pulse curve:

##### *The accommodation threshold:*

This is the current amplitude that a triangular pulse of 'infinite' duration must have in order to produce a just perceptible contraction. In practice, the phase duration is the maximum available (500 or 1000 ms, depending on the type of equipment).

##### *The optimum phase time*

The phase time required for a triangular pulse at a minimum current amplitude to produce a just perceptible contraction. For healthy tissue the optimum phase time is around 20 ms. Correct interpretation of the values found requires data from **both** the rectangular pulse curve **and** the triangular pulse curve. Neither set of data, on its own, is an adequate source of information.

However, the data from the longer phase times (from 50 ms\*) is often sufficient for interpretation of a strength/duration curve.

The triangular pulse curve is of particular interest, as it provides indications for the electrotherapy parameters.

To obtain a good insight into the (pathological) condition of the nerve tissue, it is often of practical value to determine the **Accommodation Quotient (AQ)**. Healthy nerve tissue has the ability to adapt to gradually increasing pulses.

This causes a gradual increase in the triangular pulse curve with respect to the rectangular pulse curve. The accommodation quotient is determined by dividing the accommodation threshold by the rheobase. For healthy nerve tissue, the value lies between 2 and 6. A lower value indicates degeneration of the nerve, while higher values may be a sign of neurogenic dystonia.

\*From:

*Niederfrequente Reizströme in der therapeutischen Praxis, O. Gillert.*

A lesion of the Aa motor neurons can lead to total or partial denervation of the associated muscles. In such cases, the appearance of the strength/duration curve is as follows:

#### 1. total denervation:

If the whole of the rectangular pulse curve is shifted upwards and to the right, total denervation of the muscle or muscle group has occurred (due to lesion or rupture of the nerve). The triangular pulse curve will show that the accommodation ability has been lost. If curves measured over a period of time show a shift downwards and to the left, this indicates reinnervation of the muscle. The clinical recovery may sometimes be observed as much as six to eight weeks later.

N.B. Degeneration of the nerve fibre cannot be prevented. Similarly, neither a rectangular nor a triangular pulse can accelerate the process of reinnervation.

#### 2. Partial denervation

A kink in the triangular pulse curve is an indication of partial denervation. The characteristic kink is visible at relatively long phase times, and only with the triangular pulse. The rectangular pulse curve cannot be determined for the affected motor units, as the just perceptible contraction will be caused by the healthy units.

### 4.3.2 Therapy

The therapeutic objectives of muscle stimulation include counteracting atrophy and preventing fibrosis of the muscle tissue. The optimum phase time for this purpose is determined using data from the strength/duration curve. The phase time to be used is found at the lowest point of the triangular pulse curve (Fig. 30). The triangular pulse is chosen in order to achieve selective contraction of the denervated muscle fibres. The phase interval should be sufficient to allow the muscle to recover after the contraction (at least twice the phase time). The amplitude is increased from the motor stimulation level up to the limit of tolerance.

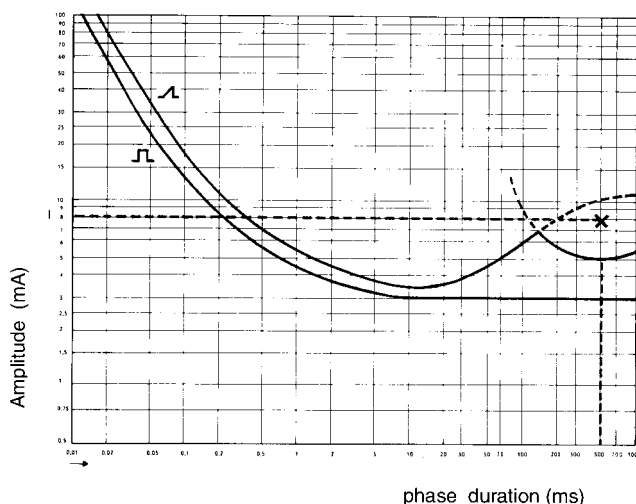


Fig. 30.  
*Derivation of the parameters for electrical stimulation in partial denervation.*

The maximum treatment time depends on the number of contractions required. The treatment is stopped if there are signs of fatigue in the muscle or muscle group. Electrical stimulation is only of value if there is a reasonable chance of re-innervation, as the ultimate objective of this type of treatment is optimization of the muscle tissues that will be required to function normally at a later stage.

### 4.4 Faradic current

#### 4.4.1 Description of the current type

As soon as the muscle or muscle group has a reasonable degree of innervation, multiple stimulation can be applied, supplemented by active (functional) exercise therapy.

In multiple muscle stimulation a series of rectangular or triangular pulses are used which result in tetanic (continuous) contraction. The series of direct-current pulses is therefore referred to as tetanizing or (neo) faradic current. The original faradic current, as described by Faraday himself, is a very irregular low-frequency alternating current. Due to the high degree of irregularity, this current type was very soon modified, resulting in the (neo) faradic current types. The (neo) faradic current in general use is a 'Reiz' current consisting of a train of rectangular pulses with a phase duration of 1 ms and a phase interval of 19 ms, resulting in a frequency of 50 Hz. (Neo) faradic currents consisting of triangular pulses have no practical application.

For practically all skeletal muscles, tetanic contraction requires a minimum frequency of 7 Hz. Lower frequencies result in separate contractions<sup>(2)</sup> (Fig. 31). The most comfortable tetanic contractions are obtained with frequencies between 40 and 80 Hz.

*N.B. In view of the frequency, faradic current is not only suitable for muscle stimulation but, with a lower amplitude (sensitivity threshold), also gives good results in pain suppression (see paragraph 2.3.3 Wyss).*

#### 4.4.2 Application of faradic current

It will be clear that muscle stimulation with faradic current the muscle must have a good general innervation. The current may be applied for both diagnostic and therapeutic objectives.

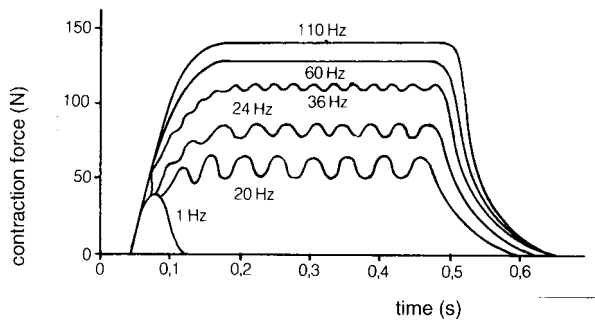


Fig. 31.  
*Production of an isometric tetanic contraction by increasing the stimulation frequency.*

Diagnostic objectives include:

- investigation of myasthenic reaction;
- investigation of myotonic reaction;
- localization of a neurapraxia block.

In therapy, faradic current is still frequently applied in the form of FES (Functional Electro-Stimulation). In this technique, the application of the electrical stimulus is combined with activity on the part of the patient. FES may be applied in the following cases:

- post-operative or post-traumatic inability to achieve voluntary contraction of certain muscles;
- early stages of re-innervation;
- atrophy following long-duration immobilization;
- paralysis/paresia (e.g. as a consequence of hemiplegia). In walking difficulties, stimulation can be applied via a peroneus stimulator.

## 5 MUSCLE STRENGTHENING WITH ALTERNATING CURRENTS

### 5.1 Introduction

This form of muscle stimulation can only be applied if the peripheral nervous system is intact. In physiotherapy, the objectives tend to be optimization of a nonpathological situation, rather than alleviation of a pathology. An exception is the prevention of atrophy, e.g. in immobilization.

The therapeutic objectives include:

- restoration of the sensation of muscle tension following surgery or trauma;
- increasing the muscle strength to improve the (active) stability of a joint;
- maintaining the condition of a muscle (prevention of atrophy).

Before giving an overview of the various types of alternating current that can be used, we shall first consider some kinesiological aspects.

### 5.2 Kinesiological aspects

In physiotherapy it has become usual to refer to tonic and/or phasic musculature. It would, in fact, be better to refer to tonic and/or phasic motor units. In general, the classification used is that proposed by Janda<sup>(8)</sup>. Janda's greatest contribution was to describe the clinical behaviour of the musculature.

However, Janda's classification is not accurate on all points. Posture (antigravity) muscles should be tonic, and tend towards shortening. According to Janda's classification, many typically postural muscles, such as the ascending and horizontal parts of the trapezius, belong to the phasic musculature. Furthermore, it has been found in practice that phasic musculature is also capable of shortening.

From other investigations<sup>(9, 14, 15)</sup> it appears that the distribution of fibre types in the muscles does not correspond to Janda's views, and that it can vary considerably from one individual to another. Johnson, in particular, showed in an autopsy study<sup>(9)</sup> carried out in six men within 24 hours of death that there are marked differences between the distribution of fibre types in the muscles of different individuals (Table 1).

With one exception, all muscles in the human body are composed of a mixture of fibre types. Thus, there appears to be a difference between the muscle fibre distribution in a particular muscle and its clinical behaviour as described by Janda.

In general it can be stated that, in a movement, the tonic motor units are the first to come into action. The phasic motor units only become active if additional strength is required<sup>(15)</sup>. In rapid movements, the phasic motor units may be activated earlier than the tonic motor units. According to Kluo and Clamann<sup>(15)</sup>, this phenomenon is most marked in synergistic muscles with different fibre distributions.

Electrical stimulation over a long period can lead to a change in the muscle fibre distribution<sup>(6)</sup>. The change appears to be mainly dependent on the frequency with which the motor neuron is depolarized by the electric current. This effect should be taken into account in lengthy treatments. The change in the muscle fibre distribution is reversible. In other words, the muscle fibre distribution will adapt the function if the muscle is used.

Tonic motor units	Phasic motor units
Red muscle fibres	White muscle fibres
Phylogenetically older	Phylogenetically younger
Better vascularization	Poorer vascularization
Innervation by Aa <sub>2</sub> neurons	Innervation by Aa <sub>1</sub> neurons
Tetanic frequency 20-30 Hz	Tetanic frequency 50-150 Hz
Slowly tiring	Rapidly tiring
Static	Dynamic

Table 2.  
Characteristics of tonic and phasic motor units<sup>(8)</sup>.

### Percentage type I (tonic) muscle fibres

M. gastrocnemius	46,9 – 56,9 %
M. gluteus maximus	41,2 – 71,5 %
M. iliopsoas	37,0 – 60,9 %
M. tibialis anterior	56,6 – 80,5 %
M. soleus	69,8 – 100,0 %
M. vastus medialis	53,5 – 79,8 %

The figure shows the average percentage of the fibre type to an accuracy of 95%.

Table 3.

*Distribution of fibre types in various muscles according to Johnson<sup>(9)</sup>.*

It can also be assumed that unmodulated alternating currents with frequencies above 3000 Hz will not affect the distribution of the muscle fibres. If modulated alternating currents are applied, a depolarization pattern can be imposed on the axons. At low frequencies, up to about 20 Hz, the muscle tends to become 'redder', while at higher frequencies, up to about 150 Hz, the muscle tends to become 'whiter'.

### 5.3 Application of alternating currents for muscle strengthening

As stated in chapter 2, both medium-frequency alternating currents and TENS current types are able to provide selective stimulation of the motor neurons (see graphs of Lullies and Howson).

#### 5.3.1 Medium-frequency alternating current

Muscle contractions can be produced with medium-frequency alternating current at any frequency between 1000 and 4000 Hz. However, the maximum depolarization frequency is dependent on the absolute refractory period. The length of this period is, in turn, dependent on the conduction velocity of the nerve fibre<sup>(2)</sup>. There appears to be a linear relationship between the conduction velocity and the absolute refractory period. For rapidly conducting fibres, such as the Aa<sub>1</sub> fibre, the absolute refractory period is approx. 0.2 ms. Consequently, the maximum depolarization frequency is around 2500 Hz (1000 ms : 0,4 ms = 2500). This frequency is used in the 'Russian Stimulation' muscle strengthening technique.

Depending on the desired effect, medium-frequency alternating currents can be divided into:

##### a. Modulated alternating current with a frequency of 2000-4000 Hz.

This current type is used where the objective is to change the distribution of muscle fibres (twitch speed). The AMF is used to affect the muscle fibre distribution.

A change in the distribution of muscle fibres can be achieved with **interferential current** and the use of the AMF. At a low AMF, up to about 20 Hz, the muscle becomes 'redder', while at a higher AMF, up to about 150 Hz, the muscle becomes 'whiter'. This method can be used to increase the explosive release of energy in high-jumpers, provided that is supplemented by functional exercises. The most comfortable tetanic contractions are obtained at an AMF between 40 and 80 Hz.

The treatment is applied in cycles of one minute. The minute is divided up as follows:

- during the first 10 seconds the amplitude is increased until a strong contraction occurs (from the motor stimulation level up to the limit of tolerance). The amplitude should preferably be set by the patient;
- the contraction is maintained for 20 seconds. If the tension in the muscle decreases during this period (accommodation), the current amplitude is increased;
- the stimulation is followed by a pause of at least 30 seconds.

The number of contractions per treatment is 15-20, so that the treatment lasts a corresponding number of minutes. The treatment frequency is from daily to at least three times per week.

##### b. Unmodulated (continuous) alternating current with a frequency of 2000-4000 Hz.

This current type is used where the objective is to strengthen the muscle without affecting the fibre distribution.

### 5.3.2 Russian stimulation

A variation on the latter current type is an intermittent alternating current with a carrier frequency of 2500 Hz. This current form is referred to as 'Russian Stimulation'.

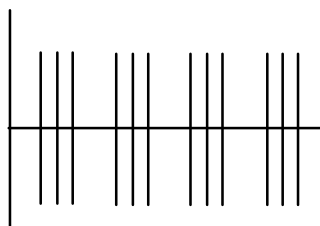


Fig. 32.  
Russian Stimulation

Kots<sup>(13)</sup>, a lecturer in sports medicine at the Moscow State Academy, was the first to use medium-frequency alternating currents for muscle strengthening in prosthesiology and in the training of Russian cosmonauts. In this technique the electrostimulation is applied both to individual muscles and to groups of muscles (either directly or via the nerve). In direct stimulation, a frequency of 2500 Hz was found to produce the greatest contraction, while the optimum frequency in indirect stimulation was 1000 Hz.

A specific feature of this type of muscle stimulation is that the alternating current is interrupted 50 times per second. This results in a pulse train, comparable to the 'burst' in TENS. The total duration of the pulse train is 20 ms, giving a phase duration/phase interval ratio of 1:1. Kots uses a train frequency (50 Hz) lying more or less in the middle of the frequency spectrum used to produce tetanic contraction (40-80 Hz). In addition to the 1:1 ratio, Kots also describes a phase duration/phase interval ratio of 1:5.

The amplitude should be increased until a powerful contraction is produced (from the motor stimulation level up to the limit of tolerance).

### 5.3.3 TENS current types

The phase times and frequencies used make TENS current types suitable for producing muscle contractions. The phase duration is usually 100-150  $\mu$ s. the frequency can be adjusted to according to the type of muscle tissue (phasic or tonic). A frequency of 50 Hz can be maintained in order to produce comfortable tetanic contractions.

The difference between the TENS currents used for muscle stimulation and those used for pain suppression lies not so much in the values of the phase time or frequency as in the amplitude used. For muscle stimulation the amplitude is increased until a powerful contraction is produced (from the motor stimulation level up to the limit of tolerance). The application method is broadly similar to that used for medium-frequency currents. The treatment is applied in cycles of one minute. During the first 10 seconds the amplitude is increased until a strong contraction occurs. The contraction is maintained for 20 seconds, followed by a pause of at least 30 seconds. If the strength of the following contraction indicates that the muscle has not fully recovered, the contraction time should be reduced and the pause increased. The number of contractions per treatment is 15-20, so that the treatment lasts a corresponding number of minutes. The treatment frequency is from daily to at least three times per week. The positioning of the electrodes is adapted to the size of the muscle. If the muscle is small, a small electrode is applied to the motor trigger point, while if the muscle is large a larger electrode is placed on the course of the muscle or elsewhere. In the case of larger muscles the electrodes should, in principle, be of the same size, and should be applied to the belly of the muscle in such a way that as much muscle tissue as possible lies between the electrodes.

*N.B. The motor trigger point can usually be found in the proximal third of the muscle. When searching for this point the equipment should, if possible, be switched to the Constant Voltage mode. This ensures that the amplitude is kept relatively low, so that no uncomfortably strong contractions occur when the trigger point is approached.*



## 6 MUSCLE STRETCHING

### 6.1 Introduction

No direct indications for the use of electric currents for stretching muscles are to be found in the literature. However, from fundamental studies of the architecture and behaviour of connective tissue, as well as from neurophysiology, it is possible to draw the conclusion that this method of muscle stretching offers several advantages over the other methods that have been used to date. Particularly if results have to be obtained in the very short term, i.e. if a muscle has to be lengthened quickly, muscle stretching with the aid of electric current appears to be an effective method<sup>(6)</sup>. For the sake of completeness, this technique is discussed below.

### 6.2 Choice of current type

In the use of electric current for muscle stretching, an alternating current type such as medium-frequency alternating current or TENS current is selected, with a mean direct current value of zero. The choice is based on the following considerations:

- the current is mild;
- the current does not erode the skin, avoiding an increase in nociceptor transmission after treatment;
- the current type permits current amplitudes greater than 140 mA. Low-frequency equipment does not permit current amplitudes in excess of 80 mA, while in this stretching technique current amplitudes higher than 100 mA are not unusual.

### 6.3 Amplitude

The current amplitude is determined subjectively, on the basis of the stretching sensation. As soon as the stretching sensation is felt, the amplitude is increased until the sensation disappears. The disappearance of the stretching sensation is due to such factors as the contraction caused by the electric current.

### 6.4 Treatment time

The treatment time is determined by the stretching effect. Treatment is stopped when the desired result has been achieved, or when the stretching sensation is no longer suppressed by the electric current.

### 6.5 Methods

After the electrodes have been applied on each side of the muscle belly, the current type is selected. In general, the mildest possible current type is chosen, for example interferential current with a carrier frequency of 4000 Hz and 100 Hz AMF.

The muscle is stretched until a supple, resilient feeling occurs. Next, the current amplitude is increased until a contraction is produced. The muscle is then lengthened by the action of the antagonist. Thus, no additional external force is applied, which could lead to rupture of the connective tissue. The lengthening process continues until the patient experiences a stretching sensation. The amplitude is then increased until the stretching sensation disappears. This procedure is repeated until the desired result has been achieved, or until the stretching sensation is no longer suppressed by the electric current. This indicates that the elasticity limit of the collagenous connective tissue has been reached.

### 6.6 Frequency of treatment

The frequency of treatment is mainly determined by the effect of the first treatment session. Various situations can be distinguished:

1. The muscle is stretched to the required length in one session. No subsequent shortening occurs.
2. The muscle is stretched to the required length in one session, but subsequently shortens again. If this occurs relatively rapidly, for example within a few hours., this may be a sign of functional muscle shortening. This is a relative contra-indication.
3. The muscle does not reach the desired length in one session. In this case, several treatment sessions are required, provided that no side effects occur. The frequency of treatment is determined by the patient. As soon as any symptoms of stiffness and/or muscle pain disappear, the following session can take place.

### 6.7 Indications

- Shortening of the muscles due to hypertonia;
- Shortening of the muscles due to stiffness of the connective tissue.

Examples include:

- Tendinitis with shortening of the connective tissue;
- Lateral epicondylitis;
- Tendinitis of the achilles tendon;
- Inguinal conditions with shortening of the connective tissue.

### 6.8 Relative contra-indications

- Muscle injuries, myotenositis, tendinitis;
- Acute joint conditions, arthritis, bursitis etc. with associated heat and loss of function;
- Tissue discontinuities such as fractures, muscle rupture and ligament rupture;
- Forms of spasticity;
- Functional muscle shortening.

## 7 IONTOPHORESIS

### 7.1 Introduction

Iontophoresis therapy is a very specific application of direct current. The therapy is, in fact, a form of medication using substances that can be introduced into the body as charged particles (ions) by a direct electric current. The medication is almost invariably in the form of an aqueous solution but, in a few cases, a gel may be used. An advantage of this form of therapy is that the medication can be introduced locally, without having to take account of the 'first pass' effect.

The therapy consists of applying the electrodes over the region to be treated, taking due notice of the polarity of both the medication and the electrode. Positive ions, which move towards the cathode, are referred to as cations.

Substances with a preponderance of cations should therefore be applied under the anode (+). Negative ions, which move towards the anode, are referred to as anions. Substances with a preponderance of anions should therefore be applied under the cathode (-)\*.

To date, iontophoresis is virtually exclusively applied using direct current (galvanic current).

When direct current is interrupted at a frequency of 8000 Hz, a new type of current is created: the medium-frequency direct current. At a phase interval of 5 µs and a phase duration of 125 µs, the duty cycle is 95%, resulting in a current which for most practical purposes is identical to a galvanic current. However, there is one major difference: the medium frequency of this current makes it 'patient friendly'<sup>(5, 18)</sup>. If patients are treated with both current types in succession (galvanic current and medium-frequency direct current) there is no observable difference in the effects. However, the patients report that the medium-frequency direct current is much more easily tolerated.

\* *The responsibility for deciding on the medication to be introduced lies with the physician. The physiotherapist has a reporting function, and should be aware of any side effects or interactions.*

### 7.2 Medication and safety

The effect of iontophoresis therapy depends on the medications to be introduced. Due to the wide diversity of available medication, the possible applications are very extensive.

When medication is applied it is essential that the therapist should be fully informed of the effects and possible side effects of the medication to be used before treatment begins. The indications and contra-indications for each substance should also be known. These are beyond the scope of this book.

However, with respect to the application of the current, there are some rules which should be taken into account:

- the active electrode (different electrode must have a relatively small area;
- the area of the indifferent electrode must always be greater than that of the active electrode. The indifferent electrode should preferably be positioned diametrically opposite the active electrode;
- the electrode surface must make good contact with the body surface, to prevent the occurrence of point effects;
- it is recommended that the maximum current density at the active electrode should not exceed 0.2 mA/cm<sup>2</sup>

The dosage of the medication to be introduced should also be taken into account. It is virtually impossible to determine the exact quantity of the medication introduced.

However, it is possible to calculate the maximum possible quantity by means of the following formula:

$$m = \frac{I \cdot t \cdot M}{n} \times \frac{1}{9,6 \cdot 10^4}$$

m = mass of substance introduced (kg)

I = current amplitude (A)

t = duration of current flow (s)

M = molar mass (kg/mol)

n = valency of substance introduced

$$\frac{1}{9,6 \cdot 10^4} = \text{a constant}$$

The quantity of medication actually introduced will be somewhat lower than this value. The reason for this is that there are always parasitic ions present on the skin which are also transported into the skin.

The formula given above is for uninterrupted direct current. The dosage with medium-frequency direct current can be somewhat higher, as the current is milder with less chance of skin erosion. Nevertheless, these guidelines should still be maintained, particularly where sedative medication is applied, as the resulting loss of sensitivity will eliminate the signalling function of pain. Similar considerations apply with substances that affect the total system (e.g. histamine).

### 7.3 Variations on a theme

Interruption of the direct current with a frequency of 8000 Hz offers more applicational possibilities than one would, in the first instance, expect.

In addition to iontophoresis, the medium-frequency direct current can be used for the treatment of neuralgia by transverse galvanization, as described by Kowarschik, as well as for such applications as the treatment of excessive perspiration in the hands and feet<sup>(25)</sup>, improvement of the peripheral circulation, wound healing and the treatment of hyperalgesic zones on the skin.

An explanation of the effects in these indications can be found in the influence on the sympathetic nervous system (see Chapter 10: Examples of Treatment).

## 8 WOUND HEALING

### 8.1 Introduction

When tissue is damaged, a sequence of complex physiological processes come into action, which should promote normal wound healing.

In some pathological conditions (e.g. varices, conditions affecting the peripheral arterial circulation, decubitus ulcers) the physiological wound healing process can be disrupted, resulting in ischaemic ulceration of the skin, followed by necrosis. This in turn can lead to gangrene, necessitating amputation.

Various techniques can be used to promote wound healing. From the literature, it is not yet clear which of these is the most effective. Furthermore, the underlying mechanisms of the effects of electrotherapy in accelerated wound healing are also not yet entirely understood. There is also some discussion of the effects of various current types. In the U.S.A., considerable use is made of 'microcurrent'. Although there is (as yet) no unequivocal scientific proof, this current type is said to produce good results. In addition, good results are apparently obtained with intermittent direct current, in the form of 'high voltage stimulation'.

All the claims that have been and are being made on this subject indicate that wound healing by electrostimulation has a great future, but that there is still a lack of unequivocal explanations.

With respect to direct current and TENS current types, a number of publications have appeared that are worth mentioning. Various workers describe a favourable effect of electrostimulation on wound healing<sup>(4, 10, 12, 20, 30, 31)</sup>. On the basis of these publications, some guidelines regarding the application of direct current and TENS current types are given in paragraph 8.3 below.

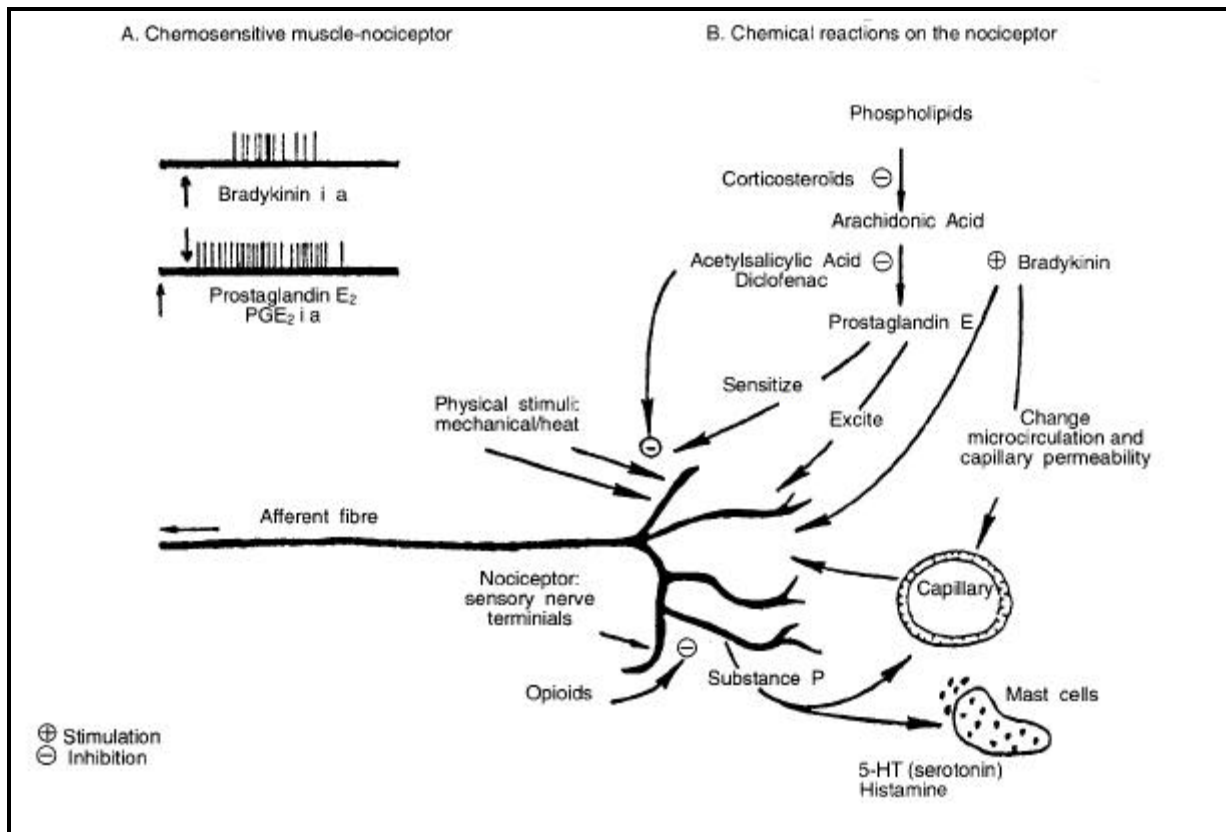


Fig. 33.  
The nociceptor and its (micro-) environment, Zimmermann<sup>(34)</sup>.

### 8.2 The mechanisms of wound healing

During a physiological wound healing process, various substances are released. As it is beyond the scope of this book to give a complete description of all the complex mechanisms involved in wound healing, we shall confine ourselves to giving a brief explanation of the working of one of these substances: 'Substance P' (SP). This is a neurotransmitter that plays an important role in the wound healing process.

Substance P has two principal effects<sup>(33)</sup>.

When tissue is damaged, SP stimulates the mast cells to produce histamine, causing vasodilation. The resulting hyperaemia causes an inflammatory reaction, and is the first stage in wound healing.

The second function of SP is to stimulate the production of specialized contractile fibroblasts known as myofibroblasts, resulting in contraction of the wound area. It can therefore be stated that SP has a tissue-restoring effect. In a disrupted wound healing process there is apparently no liberation of SP.

Electrostimulation affects the disrupted wound healing process in two ways:

1. Electrostimulation leads to antidromic stimulation of the sensory nerves, causing release of SP at the peripheral nerve endings<sup>(17)</sup> (Fig. 33).
2. The electric current influences the capillaries in the wound bed. Sprouting of these capillaries provides a good supply of nutrients, encouraging the laying-down of granulation tissue.

### 8.3 Wound healing in practice

Direct current and TENS current types appear to have a favourable effect on wound healing.

#### 8.3.1 Direct current

When direct current is applied, a low amplitude is set (0.1-1.0 mA/cm<sup>2</sup>).

Some remarks are required with respect to the polarity:

- skin naturally has a negative charge. If the skin is injured, the damaged area will have a positive charge with respect to the undamaged surroundings
- application of an anode in or on the wound encourages the laying-down of granulation tissue, but will also exacerbate any bacterial infection that may be present
- application of a cathode in or on the wound will retard the laying-down of granulation tissue, but also has a marked bactericidal effect<sup>(35)</sup>.

On the basis of the foregoing, the following guidelines can be followed<sup>(4,31)</sup>. During the first three days a negative electrode is applied on or near the skin lesion. Each treatment lasts for two hours, and is carried out two to six times per day. After three days, provided that no sepsis is present, a positive electrode is applied.

If the wound is deep, a sterile gauze soaked in distilled water or physiological saline solution should be placed in the wound, with the active electrode over it. The inactive electrode should be placed ca. 25 cm proximal to the lesion. When a continuous direct current is used, the amplitude is set between 0.2 and 0.8 mA.

For (objective) assessment of the results of treatment, it is advisable to:

- measure the area of the wound;
- measure or assess the depth of the wound;
- identify any micro-organisms present;
- describe any other aspects of the wound;
- photograph the wound (before the start of electrostimulation, and once a week thereafter);
- record the results after each treatment session.

#### 8.3.2 TENS current types

TENS current types can also be used to promote wound healing<sup>(12,20)</sup> (Fig. 33). Lundeborg<sup>(20)</sup> used an alternating rectangular pulse with a variable phase duration of 0.2-1.0 ms for the treatment of diabetic ulcer cruris, arterial and venous ulcers, and post-operative wounds (skin flap operation).

For initial treatment of diabetic, arterial and venous ulcers, a phase duration of 1.0 ms and a frequency of 50 Hz are selected. The amplitude should be sufficient to give a strong tingling sensation (sensory to motor stimulation level). If this is too painful for the patient, or if severe skin irritation occurs, the phase duration can be shortened down to 0.2 ms. As a symmetrical alternating current is used, the polarity is unimportant. The electrodes are applied as follows:

- a. If the sensitivity of the affected region is intact, one electrode is placed proximal to the lesion, and the other distal, as close as possible to the edges of the lesion.
- b. If the sensitivity in the region is impaired, both electrodes are placed proximal to the lesion in an area where the sensibility is still intact.

The duration of each treatment session 20-30 (60) minutes, and treatment is carried out twice daily with an interval of six hours.

For treatment of post-operative wounds such as ischaemic skin flaps, a phase duration of 0.4 ms and a frequency of 80 Hz are selected. The duration of each treatment session is two hours, and treatment is carried out twice daily.

According to Lundeborg's publications this results in rapid healing, speeding up the healing process by 110%<sup>(20)</sup>.

For treatment of decubitus ulcers, a phase duration of 1.0 ms is used, but with a low frequency of 2 Hz. The amplitude is set somewhat higher than in the previous instances: there should be clearly perceptible contractions in the region of the lesion (motor stimulation level). The duration of each treatment session is 20-30 minutes, and treatment is carried out twice daily with an interval of six hours.

## 9 INDICATIONS AND CONTRA-INDICATIONS

This chapter provides an overview of all possible indications and contra-indications for the current types described in this book. The information is arranged according to the physiotherapeutic objectives, such as 'restoration of muscle sensation' or 'improvement of local blood circulation by influencing the sympathetic nervous system', followed by the technical requirements for diagnostics or therapy.

The appropriate current types for each indication are shown as abbreviations. The following abbreviations are used:

DD	= diadynamic current
2-5	= 2-5 current (Ultra-Reiz or Träbert current)
D	= direct current (galvanic current)
DI	= direct current as used for iontophoresis (8000 Hz medium-frequency direct current)
ID	= intermittent direct current
FC	= faradic current
IF	= interferential current (4000 Hz medium-frequency current)
RS	= Russian Stimulation (2500 Hz medium-frequency alternating current)
TENS	= TENS current

### 9.1 Indications

#### 9.1.1 Diagnostics

Electropalpation for:

- locating pain points (D-DD-IF-TENS);
- locating trigger points (D-DD-IF-TENS);
- locating hyperaesthetic regions (D-DD-IF-TENS);
- locating motor trigger points (IF-TENS);
- plotting strength/duration curves (ID);
- multiple stimulation of partially denervated muscle tissue (ID-FC).

#### 9.1.2 Therapy

*A. Treatment of conditions where pain is predominant (DD-2-5-IF-TENS):*

- pain points;
- trigger points;
- hyperaesthetic regions.

Possible causes:

1. Disturbance of the autonomic balance, leading to impairment of circulation and organ functions;
2. Post-traumatic and post-operative conditions such as:
  - contusion;
  - distortion;
  - luxation;
  - rupture;
  - contracture resulting from immobilization.
3. Rheumatic conditions such as:
  - arthrosis, spondylosis;
  - peri-arthritis, bursitis, tendinitis etc.;
  - myalgia.

*B. Treatment of conditions where an autonomic imbalance is predominant (DD-2-5-IF-TENS):*

- peripheral circulation disorders;
- autonomic syndromes.

Including:

- shoulder-hand syndrome;
- Raynaud's disease;
- Buerger's disease;
- Südeck's dystrophy;
- neurological conditions;
- myalgia.



### C. Muscle strengthening (ID-FC-IF-RS-TENS):

The therapeutic objectives include:

- restoration of the sensation of muscle tension (post-operative or post-traumatic);
- revalidation – increasing the muscle strength in atrophy in order to improve the (active) stability of a joint;
- maintaining the condition of a muscle (prevention of atrophy) in immobilization or partial or complete denervation;
- muscle stimulation in paresis/paralysis (hemi-, quadri- or paraplegia) (ID-FC);
- stimulation of the internal and external sphincters in faecal and urinary incontinence (IF-TENS).

### D. Muscle stretching (IF-TENS):

- muscle shortening due to hypertonia;
- muscle shortening due to connective tissue stiffness.

### E. Iontophoresis (D-DI)

- scars;
- neuralgia;
- subcutaneous fibrosis (Dupuytren's contracture);
- tendinitis;
- wounds;
- fungal infections;
- injection site infiltrations;
- arthrosis.

### F. Wound healing (D-DI-TENS):

- poor healing of skin lesions due to peripheral circulation disorders;
- post-operative and post-traumatic wounds.

Notes:

1. For the majority of these indications it is possible to select either single- or two-channel treatment.

Two-channel treatment can be applied for:

- pain reduction;
  - segmental application;
  - bilateral conditions;
  - diagnosis and treatment of trigger points;
  - combined treatment – local pain suppression and treatment of the associated trigger points;
  - muscle stimulation.
2. Where several current types are shown, it can be assumed that a given indication can be treated with more than one type of current. In general, the current characteristics should be in accordance with the acuteness of the condition. 'Mild' current types such as interferential current and two-phase compensated alternating current are suitable for acute conditions, while Burst TENS or MF diadynamic current may be used for less acute or chronic conditions.

## 9.2 Contra-indications

### General contra-indications:

- pyrexia;
- tumours;
- tuberculosis;
- patient's unwillingness.

### Absolute contra-indication:

- loss of sensitivity in the region to be treated (due to warning function of pain).

### Relative contra-indications:

- skin defects and sensitivity disorders;
- localized inflammatory processes;
- thrombosis (due to the risk of embolism);
- pregnancy (lumbar or abdominal application);
- tendency to bleeding;
- pacemakers\*;
- metallic implants (if the patient experiences unpleasant sensations).

**Relative contra-indications or TENS current types:**

- carotid sinus region;
- eyes;
- heart conditions (anterior thorax);
- CVA (head).

*\* the presence of an 'on-demand' pacemaker is an absolute contra-indication for TENS current types.*

## 10 EXAMPLES OF TREATMENT

### 10.1 Introduction

The information in this chapter can be used in various ways. The simplest and most obvious way is simply to copy the examples, and 'project' them onto the patient. There is no objection to this, and it is even to be recommended for those who make little use of low- or medium-frequency electrotherapy. However, as every treatment situation is unique, it is impossible to include every imaginable situation in one book. The principal aim of this chapter is to use the examples of treatment to illustrate the field of application covered by this book.

### 10.2 Examples

#### 1. Arthrosis of the acromioclavicular joint

Objective	: pain reduction
Patient position	: supine or sitting
Electrode positions	: cathode on acromioclavicular joint anode between shoulder blades level T1 – T5
Current type	: 2-5 current (Träbert)
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: 10 – 15 minutes
Frequency of treatment	: twice weekly

#### Alternative

Current type	: TENS (biphasic asymmetrical puls)
Output characteristic	: CC
Frequency	: 100 Hz
Phase time	: 150 – 200 $\mu$ s
Burst	: 2 – 5 Hz
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: 10 – 15 minutes
Frequency of treatment	: twice weekly



#### 2. Chondromalacia of patellae

Objective	: pain reduction
Patient position	: semirecumbent
Electrode positions	: transverse
Current type	: diadynamic (DF – CP)
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: sensory level
Treatment time	: DF 4 min.; CP 6 min.
Frequency of treatment	: twice to three times weekly

#### Alternative

Current type	: TENS (biphasic asymmetrical puls)
Output characteristic	: CC
Frequency	: 50 - 80 Hz
Phase time	: 50 $\mu$ s
Burst	: 2 Hz
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: 15 minutes
Frequency of treatment	: twice weekly

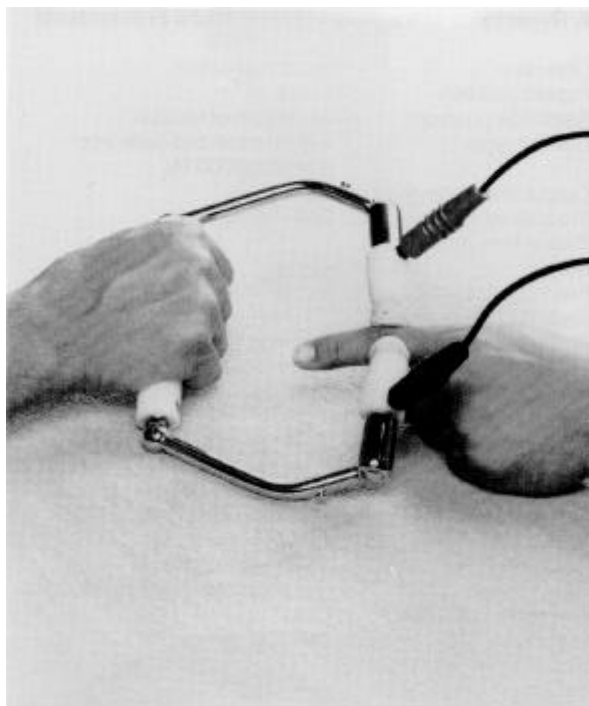


## 3. Rheumatoid arthritis of metacarpal joint

Objective	: pain reduction
Patient position	: sitting at couch
Electrode positions	: EL 1
Current type	: 2-5
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: sensory level
Treatment time	: 2 minutes per joint
Frequency of treatment	: three times weekly

### Alternative

Current type	: two-pole interferential, 4000 Hz
Output characteristic	: CC
Frequency	: AMF 100 Hz
Phase time	: -
Burst	: -
Frequency modulation	: 30-50 Hz
Sweep mode	: 1/30/1/30
Amplitude	: sensory level
Treatment time	: 3 minutes per joint
Frequency of treatment	: three times weekly



## 4. Cervicogenic headache

Objective	: pain
Patient position	: sitting at couch, forehead supported
Electrode positions	: EL 1
Current type	: 2-5 current (Träbert)
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: 10-15 minutes
Frequency of treatment	: twice weekly

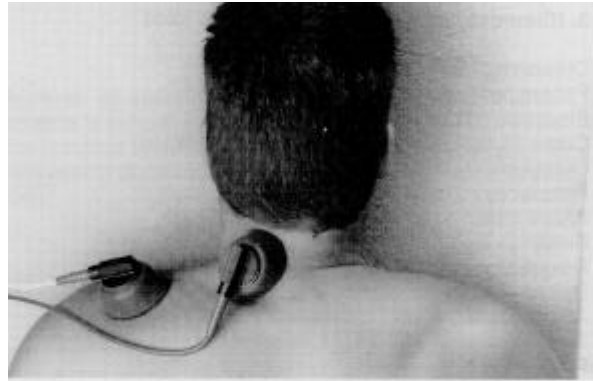
### Alternative

Current type	: two-pole interferential, 4000 Hz
Output characteristic	: CV (dynamic application)
Frequency	: AMF 50-100 Hz
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: sensory level
Treatment time	: treat each point until pain sensation disappears
Frequency of treatment	: twice weekly
Note	: point electrode is used for nociceptor localization along occipital border



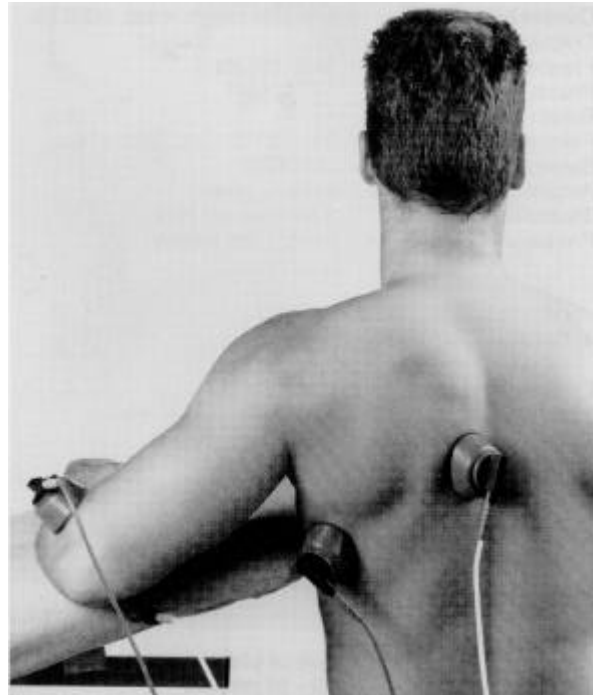
## 5. Hypertonia of trapezius muscle (pars descendens)

Objective	: tonus regulation
Patient position	: prone
Electrode positions	: on course of muscle
Current type	: two-channel two-pole interference, 4000 Hz
Output characteristic	: CC
Frequency	: AMF 50 Hz
Phase time	: -
Burst	: -
Frequency modulation	: 80 Hz
Sweep mode	: 1/1
Amplitude	: sensory – motor level
Treatment time	: 10 minutes
Frequency of treatment	: three times weekly



## 6. Lateral epicondylitis

Objective	: improving circulation
Patient position	: sitting
Electrode positions	: segmental and local
Current type	: two-pole interferential, 4000 Hz
Output characteristic	: CC
Frequency	: AMF 80 Hz
Phase time	: -
Burst	: -
Frequency modulation	: 100 Hz
Sweep mode	: 1/30/1/30
Amplitude	: sensory level
Treatment time	: 15 minutes
Frequency of treatment	: four times weekly

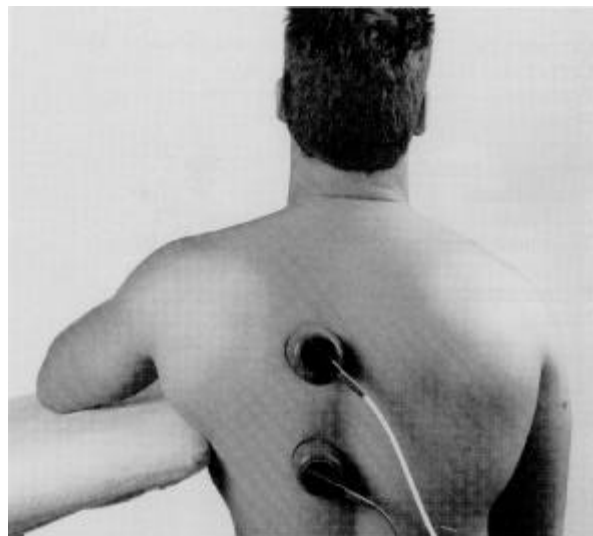


### Alternative

Current type	: TENS
Output characteristic	: CC
Frequency	: 100 Hz
Phase time	: 100 µs
Burst	: 5 Hz
Frequency modulation	: -
Sweep mode	: -
Amplitude	: motor level – limit of tolerance
Treatment time	: 10 minutes
Frequency of treatment	: three times weekly

## 7. Herpes zoster

Objective	: reduction of vesicle formation and prevention of post-herpetic neuralgia
Patient position	: sitting
Electrode positions	: within the dermatome, such that the vesicles fall within the electrode area
Current type	: diadynamic (CP, reverse polarity halfway through treatment session)
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: sensory level
Treatment time	: 10 minutes total
Frequency of treatment	: daily

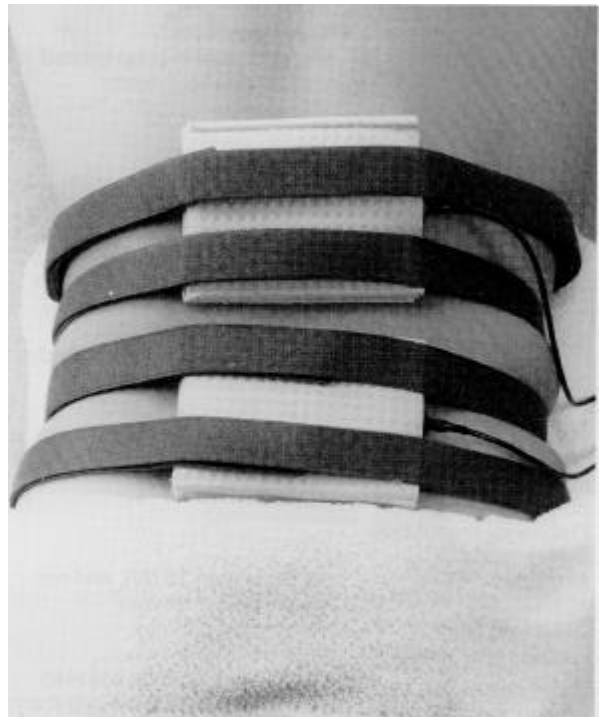


**8. Raynaud's disease**

Objective	: improvement of trophic state
Patient position	: sitting
Electrode positions	: segmental and local
Current type	: TENS (biphasic asymmetrical pulse)
Output characteristic	: CC
Frequency	: 10 Hz
Phase time	: 75 $\mu$ s
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: sensory – motor level
Treatment time	: 20 minutes
Frequency of treatment	: twice weekly

**9. Ischialgia**

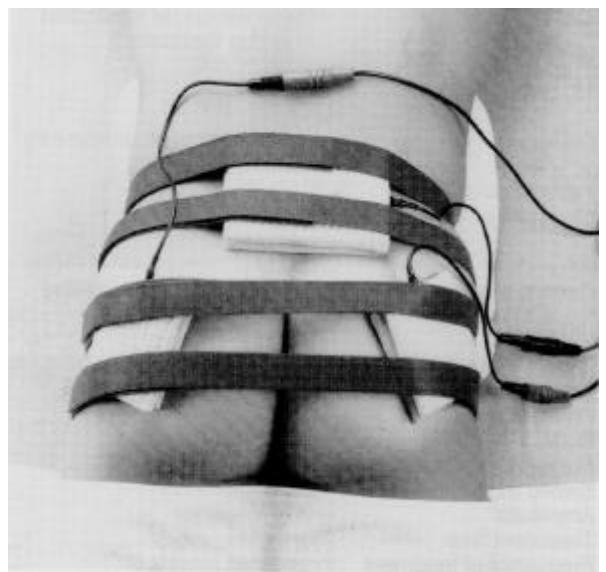
Objective	: pain reduction
Patient position	: prone
Electrode positions	: EL IV
Current type	: TENS (biphasic asymmetrical pulse)
Output characteristic	: CC
Frequency	: 100 Hz
Phase time	: 50 $\mu$ s
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: sensory level
Treatment time	: 20 minutes
Frequency of treatment	: three times weekly

**Alternative**

Current type	: four-pole interferential
Output characteristic	: CC
Frequency	: AMF 100 Hz
Phase time	: -
Burst	: -
Frequency modulation	: 100 Hz
Sweep mode	: 1/30/1/30
Amplitude	: sensory level
Treatment time	: 15 minutes
Frequency of treatment	: three times weekly

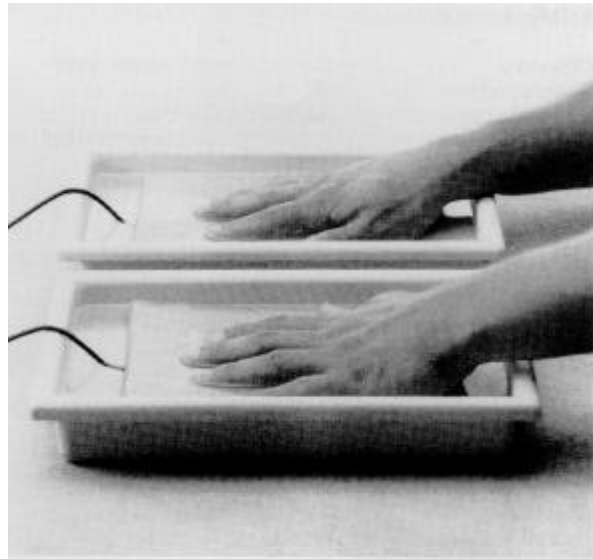
**10. Intermittent claudication**

Objective	: normalization of sympatheticus
Patient position	: prone
Electrode positions	: split cathode on skin segments L1-L2 anode segmental T10-L2
Current type	: 2-5 (Träbert)
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: 10-15 minutes
Frequency of treatment	: three times weekly



## 11. Hyperhydrosis palmoplantaris

Objective	:	normalization of sympathetic
Patient position	:	sitting, with feet/hands in two-cell bath
Electrode positions	:	electrodes are placed at the bottom of the bath compartments, sponges are placed on the electrodes, after which the feet/hands are placed on the sponges
Current type	:	medium-frequency direct current (reverse polarity halfway through)
Output characteristic	:	CC
Frequency	:	-
Phase time	:	-
Burst	:	-
Frequency modulation	:	-
Sweep mode	:	-
Amplitude	:	sensory level
Treatment time	:	16 minutes total
Frequency of treatment	:	three times weekly
Note	:	sponges must overlap treated area by a least 1.5 cm



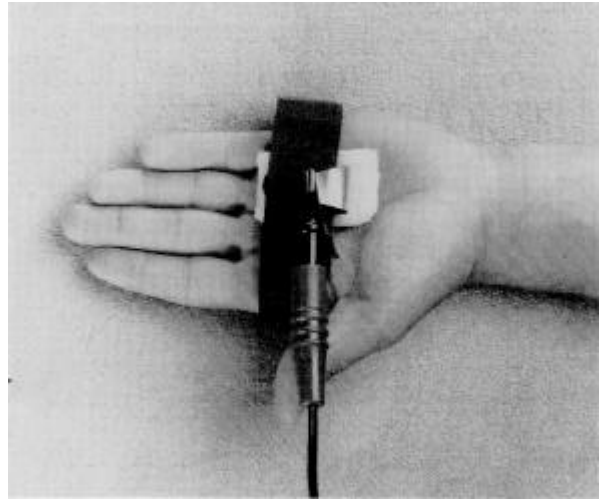
## 12. Lateral epicondylitis

Objective	:	introduction of histamin by iontophoresis
Patient position	:	sitting
Electrode positions	:	anode at the level of the origin of the extensor carpi radialis (longus or brevis) cathode (indifferent) elsewhere on body
Current type	:	medium-frequency direct current
Output characteristic	:	CC
Frequency	:	-
Phase time	:	-
Burst	:	-
Frequency modulation	:	-
Sweep mode	:	-
Amplitude	:	not more than 10 mA, and not more than 0.2 mA/cm <sup>2</sup>
Treatment time	:	maximum 5 minutes
Frequency of treatment	:	twice per week
Note	:	<ul style="list-style-type: none"> <li>do not use a sponge between the anode and the skin, but an absorbent gauze soaked in histamin solution (max. 0.1 %)</li> <li>the indifferent electrode should always be larger than the active electrode</li> </ul>

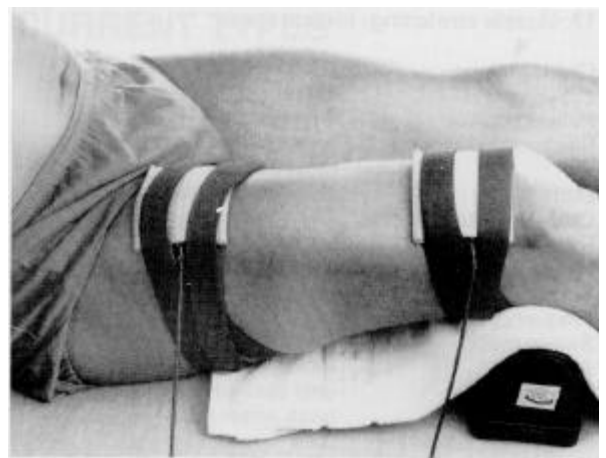


**13. Dupuytren's contracture**

Objective	: introduction of hyaluronidase by iontophoresis
Patient position	: sitting
Electrode positions	: anode on the contracture cathode (indifferent) elsewhere on body
Current type	: medium-frequency alternating current
Output characteristic	: CC
Frequency	: -
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: 20 minutes
Frequency of treatment	: three times weekly

**14. Muscle strengthening: quadriceps femoris**

Objective	: muscle strengthening
Patient position	: sitting on treatment couch
Electrode positions	: proximal and distal on musculature
Current type	: Russian Stimulation
Output characteristic	: CC
Frequency	: 50 Hz
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: limit of tolerance
Treatment time	: until fatigue occurs
Frequency of treatment	: daily
Note	: ratio between stimulation and pause is 1:2. Training program: 2/10/1/50

**15. Muscle strengthening: serratus anterior**

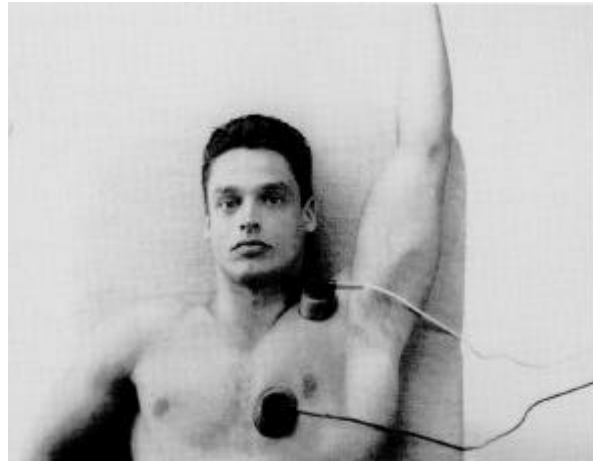
Objective	: muscle strengthening
Patient position	: sitting
Electrode positions	: proximal and distal on musculature
Current type	: TENS (biphasic symmetrical pulse)
Output characteristic	: CC
Frequency	: 50 Hz
Phase time	: 75 µs
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: motor level – limit of tolerance
Treatment time	: until fatigue occurs
Frequency of treatment	: daily
Note	: ratio between stimulation and pause is 1:4. Training program: 2/7/1/25





## 16. Muscle stretching: pectoralis major

Objective	: stretching of noncontractile structures
Patient position	: supine
Electrode positions	: proximal and distal on the musculature
Current type	: TENS (bi-phasic asymmetric pulse)
Output characteristic	: CC
Frequency	: 100 Hz
Phase time	: 100 $\mu$ s
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: motor level
Treatment time	: until desired lengthening has been achieved
Frequency of treatment	: daily



## 17. Muscle stretching: triceps surae

Objective	: stretching of noncontractile structures
Patient position	: supine
Electrode positions	: proximal and distal on the musculature
Current type	: Russian Stimulation
Output characteristic	: CC
Frequency	: 100 Hz
Phase time	: -
Burst	: -
Frequency modulation	: -
Sweep mode	: -
Amplitude	: motor level
Treatment time	: until desired lengthening has been achieved
Frequency of treatment	: daily
Note	: <ul style="list-style-type: none"> <li>• the ratio between stimulation and pause is 1:1.</li> <li>• no training program should be set</li> </ul>



## TERMINOLOGY AND DEFINITION OF CURRENT TYPES

In the book 'Electrotherapeutic Terminology in Physical Therapy' a start has been made on the standardization of electrotherapeutic terminology.

In this book the authors have tried, as far as possible, to apply the recommended standard terminology. For the sake of clarity, the new terms are given below, together with the terms previously used.

Amplitude	: Intensity, current strength
Phase duration/phase time	: Pulse duration/pulse time
Phase interval	: Pulse interval
Frequency modulation	: Spectrum variation or spectrum frequency
Direct current	: Galvanic current
Duty cycle	: Phase duration/cycle duration ratio in a pulse train

(Neo)faradic current

A variation of intermittent direct current with a phase duration of 1 ms and a phase interval of 19 ms

Medium-frequency direct current

Direct current with a duty cycle of 95% and a frequency of 8000 Hz.

Sweep mode:

Time in which the current type changes into frequency.

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