Electrophoresis Power Supply EPS 3500 XL

User Manual

19-3500-06
Edition AB

Amersham Biosciences

Important user information

Reading this entire manual is necessary for full understanding and safe use of this product.

The exclamation mark within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance instructions in the literature accompanying the instrument.

The lightning symbol within an equilateral triangle is intended to alert the user to the risk of exposure to high voltages.

Should you have any comments on this manual, we will be pleased to receive them at:

Amersham Biosciences AB
S-75182 Uppsala
Sweden

Amersham Biosciences reserves the right to make changes in the specifications without prior notice.

Warranty and Liability

Amersham Biosciences AB guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions supplied by Amersham Biosciences AB.

Amersham Biosciences AB shall in no event be liable for incidental or consequential damages, including without limitation, lost profits, loss of income, loss of business opportunities, loss of use and other related exposures, however caused, arising from the faulty and incorrect use of the product.

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1. Introduction

The Amersham Biosciences Electrophoresis Power Supply EPS 3500 XL is a high quality, high precision and safe power supply for electrophoresis applications that require advanced programming and high voltage.

EPS 3500 XL is primarily designed for techniques using programming in several phases and/or voltage gradients:

- 2-D (Two dimensional) electrophoresis using Immobiline®
- IEF (Isoelectric focusing)

EPS 3500 XL is also suitable for:

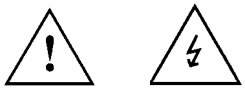
- DNA sequencing
- SDS-PAGE (Polyacrylamide Gel Electrophoresis)
- Native PAGE
- Agarose electrophoresis
- Electroblotting
- DNA pulsed field electrophoresis

Nine programs each with up to nine phases can be saved. Limiting values for voltage, current and power as well as voltage gradients can be programmed for precise control of the electrophoresis. The EPS 3500 XL automatically switches over the controlling parameter according to programmed limits and gradients and conductivity variations in the system.

Two electrophoresis units can be connected to the EPS 3500 XL and run with the same programmed method at one time.

2. Safety information

2.1 Safety precautions



Extreme caution should be exercised in the operation of this instrument as it can develop sufficient voltage and current to produce a lethal shock.

To avoid any risk of injury, the instrument should only be operated by properly trained personell and always in accordance with the instructions provided.

Read this entire manual before using this power supply.

1. This instrument is designed for indoor use only.
2. The instrument must always be used with the protective earth lead of the power cord correctly grounded to earth at the mains outlet.
3. To permit sufficient cooling, ensure that the vents in the rear and sides of the instrument are not covered.
4. Do not operate the instrument in extreme humidity (above 95%). Avoid condensation by letting the unit equilibrate to ambient temperature when taking the power supply from a colder to a warmer environment.
5. Keep the instrument dry and clean. Wipe regularly with a soft damp cloth. Let the power supply dry completely before use. If wetted, unplug the power supply until the instrument is dry.
6. Use only undamaged electrical wire and equipment approved for the voltages you will use. High voltage wires must meet the requirements of the IEC 1010-2-031:1993 electrical standard.

   Any electrophoresis equipment connected to the power supply should meet the requirements of the IEC 1010-1:1993.
7. Note that the output is connected to the chassis / reference earth.

2.2 In-built safety features

The EPS 3500 XL is designed in accordance with the IEC 1010 (EN 60 1010-1) electrical safety standard. The power supply also has several built-in safety functions:

1. Functional earth leakage.

Should the power supply be connected to an electrophoresis unit that has a leakage path to earth, the EPS 3500 XL will detect this fault and the high voltage is turned off.

2. Start current check.

To ensure that an electrophoresis unit is connected correctly, the power supply checks that the resistance is not higher than a specified limit at a low safety voltage (<40 V). If this resistance is too high, the voltage is turned off. Too high a resistance can also be caused by using buffers with extremely low conductivity. The high voltage is also turned off in this case. This function can be disabled to perform certain applications (see 5.5 Optional programming).

3. Sudden load change detection.

This function prevents accidents under running conditions due to a break in the electrical circuit such as a bad connection to the electrophoresis unit. The high voltage is turned off in such an event.

Error messages are also shown on the display.

3. Unpacking and installation

Unpacking

Check the contents against the packing list supplied. Inspect for any damage that may have occurred during transit. Report any damage immediately to your local Amersham Biosciences representative and to the transport company concerned.

Mains connection

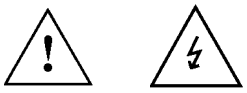
Select the appropriate voltage range, 100-120 or 220-240 V, see Fig. 2.

Warning! If the power supply is connected to 220-240 V with the range set to 100-120 V, the instrument can be severely damaged.

Select the appropriate mains cable and connect one end to the mains socket on the EPS 3500 XL power supply, see Fig. 2, and the other end to an AC grounded outlet. Switch on the power. Each time the instrument is turned on a self diagnostic test is done. If an error is detected during the test a message will appear on the display and an alarm will sound.

Connection of the electrophoresis unit(s)

Connect the leads from the electrophoresis unit (red to red, and black or blue to blue), see Fig. 1. The red lead is the positive and black or blue is the negative.



Warning! Use only undamaged electrical wire and equipment approved for the voltage you will use.

Two electrophoresis units can be run simultaneously with the same program. Please remember to double the limiting current and power if two electrophoresis units are run at the same time. The voltage will be the same regardless of the number of units.

Local regulation for Great Britain

WARNING IMPORTANT

This appliance must be earthed.

The wires in the mains lead are coloured in accordance with the following code:

Green and yellow	Earth
Blue	Neutral
Brown	Live

If the plug provided is unsuitable for your socket outlets, the plug must be cut off and suitable plug fitted. The cut-off plug should be disposed of and must not be inserted into any 13 amp socket as this can result in electric shock. The plug or adapter of the distribution panel should be provided with 13 amps fuse. As the colours of the wires in the mains lead of this appliance may not correspond with coloured markings identifying the terminals in your plug, proceed as follows: The green and yellow wire must be connected to the terminal in the plug which is marked with the letter E or by the earth symbol ⏚ , or coloured green, or green and yellow. The blue wire must be connected to the terminal which is marked with the letter N or coloured black. The brown wire must be connected to the terminal which is marked with the letter L or coloured red.

NOTE

After replacing or changing a fuse, the fuse cover in the plug must be replaced with a fuse cover which corresponds to the colour of the insert in the base of the plug or the word that is embossed on the base of the plug, and the appliance must not be used without a fuse cover.

Only 13 Amps fuse approved to B.S 1362 A.S.T.A. should be used.

4. Technical description

4.1 Front panel

The front panel consists of an alphanumeric display, a keyboard with 9 membrane keys, a light emitting diode (LED) that lights when voltage is applied (HV on) and connectors for two electrophoresis units.

4.1.1 Display

A 32 digit alphanumeric display guides you through the programming, shows current parameter values during the electrophoresis and final parameter values afterwards. It also asks questions and shows error messages. The display has an upper and lower row.

Fig. 1 shows the display in the start position when power is switched on. The mode (in this case SET) is shown in the upper row on the left. The program number, the chosen way of controlling (step or gradient) and the phase number are shown in the center of the upper row. The program number shown is that of the previously entered program. The blinking figure, in this case “1”, indicates that it can be changed by using the ⇧ ⇩ keys. The default way of controlling the power supply is by step programming (⌠). The upper right shows the programmed breakpoint for the actual phase. In this case it is 0:00h. The lower left, middle and right positions show voltage, current and power respectively, which all are zero for an unused program.

4.1.2 Keyboard

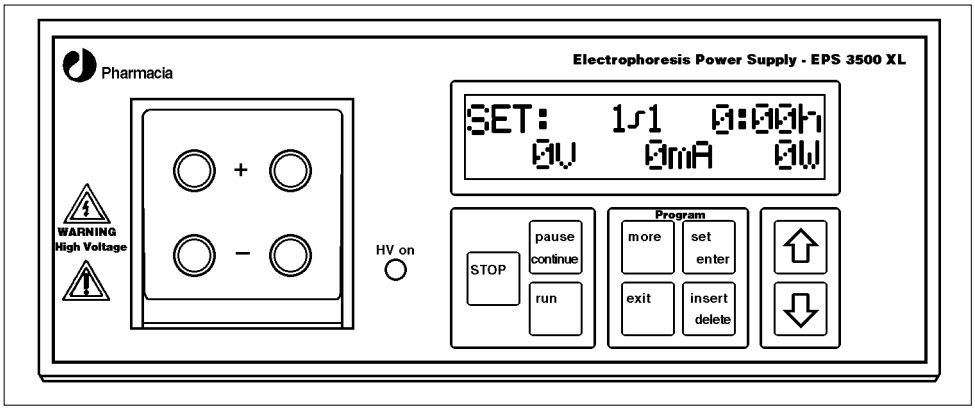


Fig. 1. The front panel of the EPS 3500 XL.

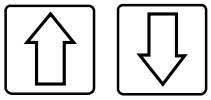
Set/enter

set
enter

Enters a value or choice, confirms this if valid, and moves programming to the next field. Valid values are voltage 35-3 500 V, current 1-150 mA, power 1-100 W, time 0:01-500 h, volthours 1-500 000 Vh, milliampere-hours 1-25 000 mAh.

In the RUN mode, pressing [set enter] shows the programmed parameters for the actual run. In addition, [set enter] allows you to make changes in the program during a run after first pressing [pause continue].

After a run, when in END mode, pressing [set enter] puts the instrument into SET, its programming mode.



Change up/Change down

Changes the parameter, value or other choice in the field which is blinking. Numerical values are changed in an accelerating manner when a key is held down. Clicking a key changes the value in preset increments. Parameters or units (e.g. Vh) and choices (e.g. YES / NO) are changed with one key push. The keys can also be used to switch between time and volthours in RUN, PAUSE and END. The values scroll i.e. they automatically change from maximum to minimum value or vice versa.

Run

Pressing [run] starts the run and puts the program into RUN mode. The current values for voltage, current and power are shown on the display. The elapsed time, volthours or milliamperehours are also displayed. Switch between these last three parameters with [⇧] [⇩].

Pause

Puts the instrument in PAUSE mode and switches off the voltage. The display shows the status of the run at the time the key was pressed.

[pause continue] only operates in RUN mode. Time, integrated voltage and integrated current are retained.

In the PAUSE mode, [set enter] can be used to make changes in the program.

Return to RUN mode by pressing [pause continue] or by pressing [run].

Stop

Stops the run and puts the instrument in END mode. The voltage is switched off and the end parameters are displayed. Switch between time, integrated voltage and integrated current by pressing [⇧] [⇩].

A run cannot be continued after pressing [STOP].

Press [run] to run the same method again or press [set enter] to choose another program, program a new method or make changes in an existing method.

Insert
delete

Insert/delete

Press Insert delete to insert or delete a phase in a program. This function is activated in SET mode. Note that a program must be completed by answering YES to the question “Last Phase?” in SET mode or by pressing exit before you can use Insert delete.

more

More

Places program in MORE mode. Gives access to some special functions. These include:

COPY: Copying a program.
CLEAR: Clearing a program
SETUP: Disabling the start current check.

MORE mode cannot be activated in RUN or PAUSE mode.

Leave MORE by pressing exit.

exit

Exit

Stops the execution of an operation, such as the entry of a value. Only values / units that have already been confirmed by set enter are retained when exit is pressed. Note that if a phase contains zeros when pressing exit, that phase will be deleted.

Returns the instrument to the mode that was left or to the start position in SET.

4.1.3. Output sockets

There are two sets of output sockets to allow two electrophoresis units to be connected and run at the same time, see Fig. 1. The voltage output is 0-3500 V. The negative output socket gives between 0 and -1750 V and the positive gives between 0 and +1750 V.

4.2 Rear panel

The rear panel is shown in Fig. 2. On the rear panel there is:

1. A mains switch. Press in **I** to switch on the power to the power supply. Press **O** to switch off the power.
2. A socket for the mains cable.
3. A switch for voltage range. The left position corresponds to 100-120 V and the right to 220-240 V.
4. Fan vents.

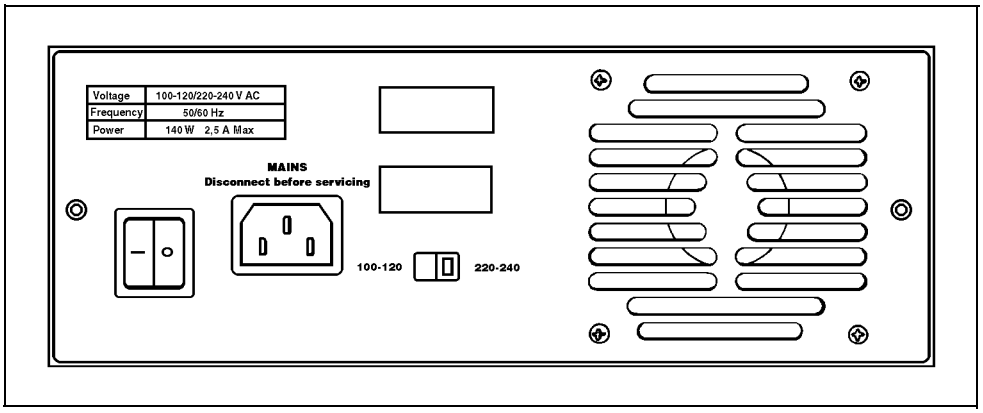


Fig. 2. The rear panel of the EPS 3500 XL.

5. Operation

5.1 Overview

The main user operations of the EPS 3500 XL are:

1. Programming a method.
2. Editing a method.
3. Running a method.

Programming, editing and running are discussed in more detail in the following three sections.

Blinking characters are shown as **bold** characters.

5.2 Programming a method

Figure 3 summarizes this operation.

Start position

When the power supply is switched on, the display shows the start position in SET mode. The previous program set is shown and that program number is blinking.
If the power supply is switched on for the first time or if the program has been cleared, see section 5.5, the default way of controlling is step (⌐),the breakpoint parameter is time (h), the alarm is off and the values are all zero.

SET:	**1**⌐1	0:00h
0V	0mA	0W

Choosing a program

Up to nine programs, each with up to nine phases, can be entered. Press [set enter] to confirm the program shown by the number on the display or use [⇧] [⇩] keys to choose another. Confirm with [set enter].

Choosing step or gradient programming

Press [set enter] to confirm step(⌐) or use [⇧] [⇩] keys to choose gradient (⟋).Confirm with [set enter]

Note that your choice of gradient or step programming applies for all phases within the program and you will only be asked to choose one of them when programming the first phase.

Choosing step ⌐ means that **voltage**, **current and power limiting values** are programmed. The electrophoresis will be controlled by one of these limiting values, which means that it is run at either constant voltage, current or power. The EPS 3500 XL automatically switches over the controlling parameter according to programmed limits and conductivity variations in the system. Thus the controlling parameter can switch within a phase.

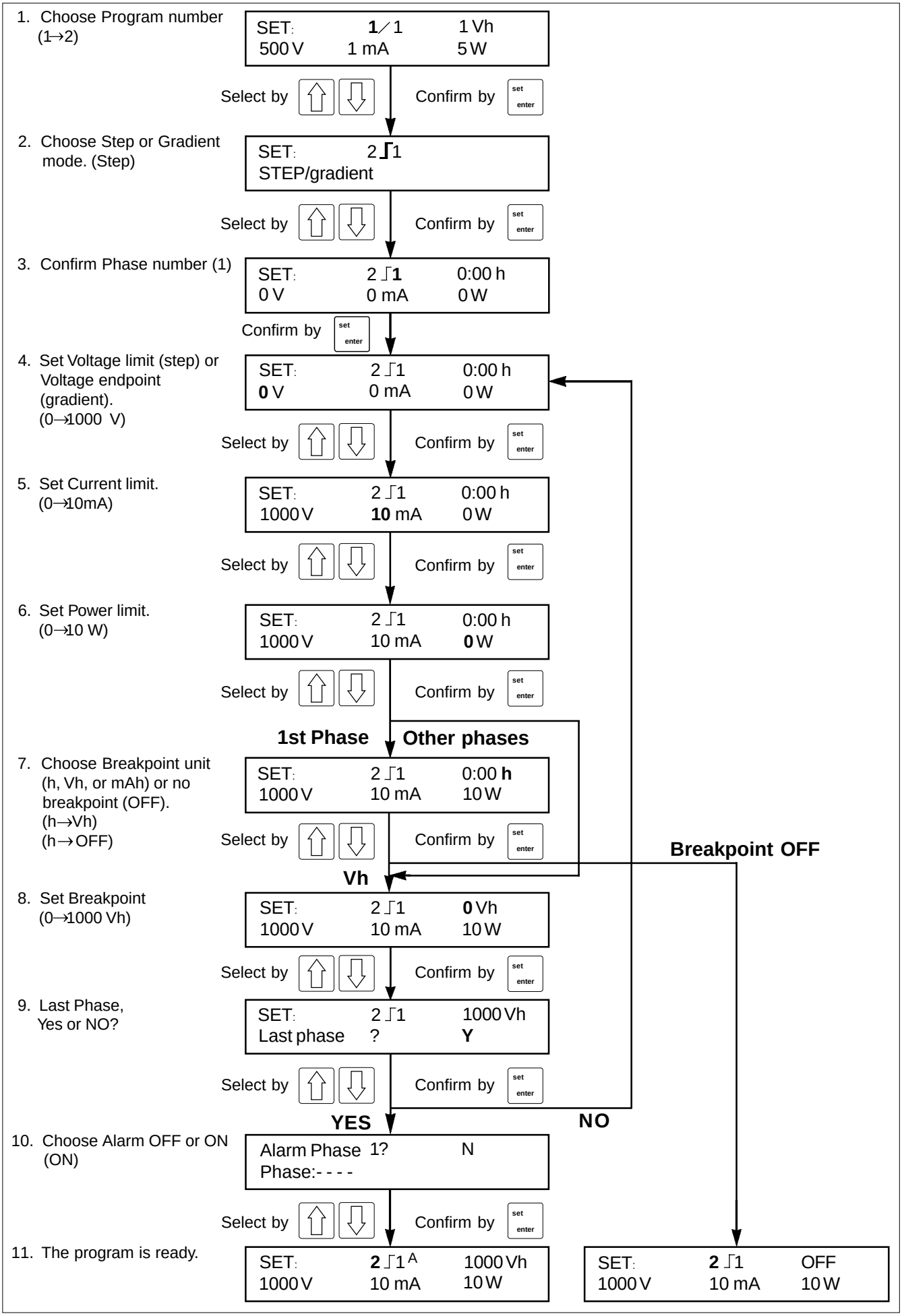


Fig. 3. Step-by-step summary of programming.

Table 1 and Fig. 4 illustrate a step program. The programming and running of this application are shown as Figs. 3 and 7.

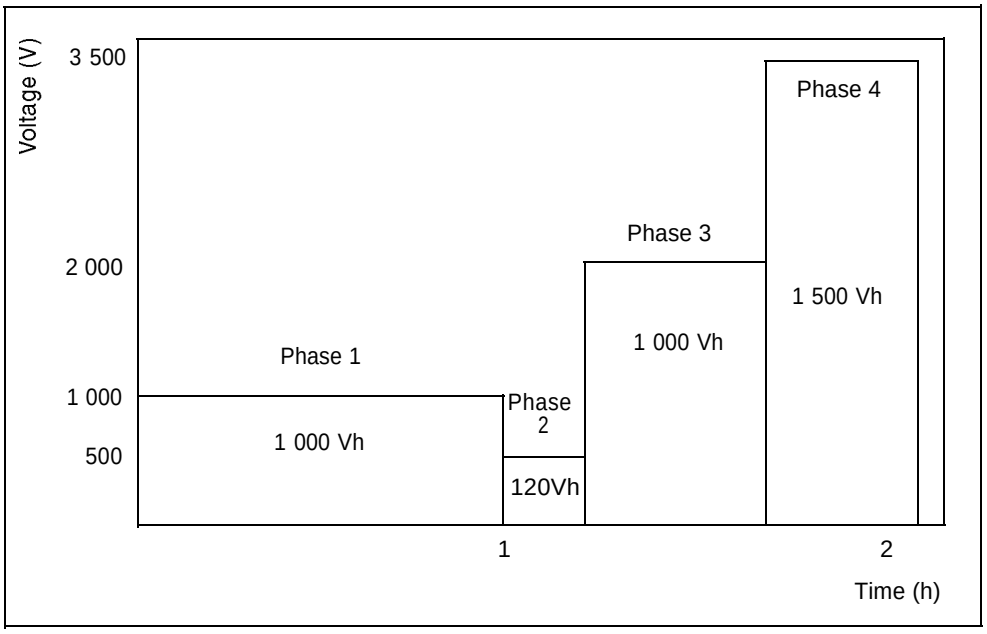


Fig. 4. Programming the voltage limiting profile in STEP mode. The parameters shown are the same as those listed in Table 1.

Table 1. The parameters of a step program.

Phase number	Voltage (V)	Current (mA)	Power (w)	Volthours (Vh)
1	1 000	10	10	1 000
2	500	10	5	120
3	2 000	20	15	1 000
4	3 500	30	25	1 500

Choosing gradient (⁄), means that a **voltage endpoint** for the actual phase is programmed together with **current and power limiting values.** A linear voltage gradient is made with zero (for the first phase) or the programmed endpoint of the phase before (for the next phases) as starting point and the programmed endpoint as endpoint. The electrophoresis will be controlled by this voltage gradient provided the limiting current or power is not attained. The EPS 3500 XL thus automatically switches over the controlling parameter according to the programmed limits and conductivity variations in the system.

To illustrate voltage gradient programming, the programming for the IEF part of a 2-D electrophoresis with Immobiline DryStrip® is shown in Table 2 and Fig. 5. Note that the first phase is a very steep gradient to reach the 500 V start level (0 – 500 V, within 1 Vh). The next phase is actually a step since the endpoint for phase 2 is 500 V which is the same as the endpoint for phase 1. Phase 3 is the “real” gradient, the voltage is changed from 500 to 3 500 V in 5 hours. The last phase is a step again, the endpoint voltage is the same as for the phase before and the voltage will remain on 3 500 V for 9.5 hours.

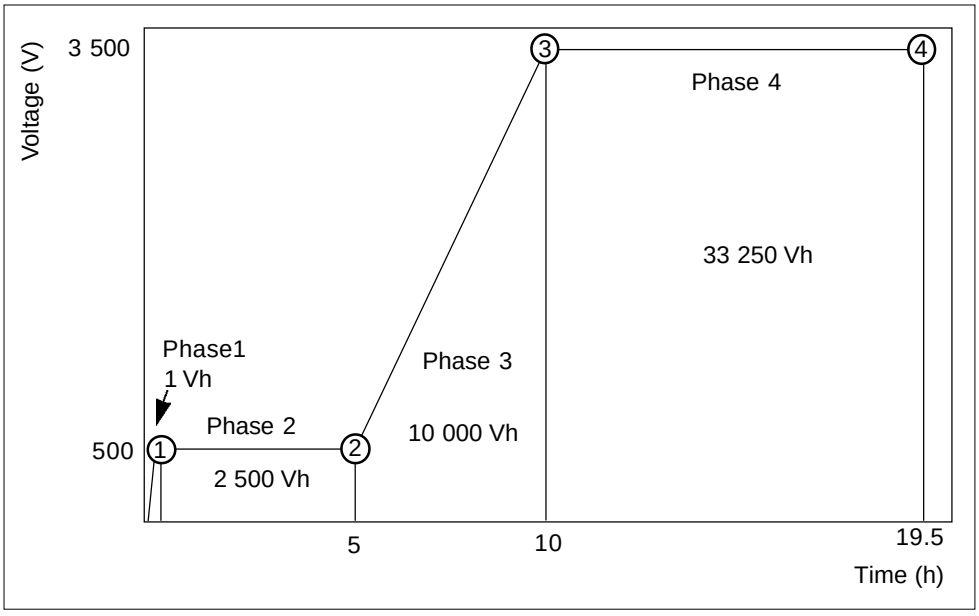


Fig. 5. Programming the voltage limiting profile in GRADIENT mode. The parameters shown are the same as those listed in Table 2.

Table 2. The parameters of a gradient program.

Phase number	Voltage (V)	Current (mA)	Power (W)	Time (h)	Volthours (Vh)
1	500	1	5	0:01 *	1 *
2	500	1	5	5	2 500
3	3 500	1	5	5	10 000
4	3 500	1	5	9.5	33 250

* The ramping from 0 to 500 V should be done as quickly as possible. The smallest possible time that can be set is 1 minute and the smallest possible Vh that can be set is 1 Vh. Vh was chosen for this program as breakpoint unit.

Choose phase number

Choose phase number with ⇧ ⇩ and confirm with set enter .
For a new program the default phase number is 1. If the first phase has been programmed and the question “Last phase ?” is answered by NO, the default number is 2 and so on.

Setting voltage, current and power

The display will now flash for the set voltage limit (step mode) or voltage endpoint (gradient mode).Using the ⇧ ⇩ keys, select the voltage limit or voltage endpoint desired for the run.Confirm with set enter .

Repeat the same procedure for limiting current and limiting power. Programmable values for voltage are 35-3 500; current, 1-150 mA; power, 1-100 W.

Setting breakpoint

Choose between automatic or manual break. For automatic break, choose breakpoint unit in either hours (h), volthours (Vh) or milliamperehours (mAh).

Select the correct unit or, for manual break, choose “OFF” with ⇧ ⇩.
Confirm with [set enter].
Note that the breakpoint unit is valid for all phases within the program and you will only get this question when programming the first phase, see “Other phases” bypass in Fig. 3.

If h, Vh or mAh is chosen, the display will flash for the break value for the actual phase. Set the value with ⇧ ⇩ and confirm with [set enter].
Programmable values for time are 0:01-500 h, volthours, 1-500 000 Vh, milliamperehours, 1-25 000 mAh.

If OFF is chosen, you have to break the electrophoresis manually by pressing [STOP] and only one phase can be entered. The program will go back to the start position and the program number will flash.

Last Phase?

After programming the breakpoint you are asked if this is the last phase or not. Select YES or NO with ⇧ ⇩ and confirm with [set enter].
If YES is selected, no more phases will be added and the alarm question will be shown, see below.
If NO is selected, the next phase number for the program will be shown on the display together with zero values for all parameters. Program the next phase according to “Setting voltage, current and power” above and Fig. 3 point 4. Up to nine phases can be programmed.

Choosing alarm

The alarm can be set separately for each phase. The following question is shown:
Alarm Phase 1? Select YES or NO with ⇧ ⇩ and confirm with ⇩.
If YES is selected in a 4 phase program this will be indicated by changing from - - - - to 1 - - - after “Phase:” on the lower row in the display. Then you will be asked about an alarm for the next phase. After answering YES or NO for the last phase, the start position in the SET mode will be shown. If alarm is selected for a phase a small “A” appears on the right of the phase number, i.e. $2\lceil 2^{A}$.

Back to start position

The program is now back to the start position in the SET mode with the program number flashing. It is possible to go back to this position at any stage during programming in SET mode by pressing [exit] or [STOP]. Note that the program is automatically saved with all choices that have been confirmed by [set enter] when [exit] or [STOP] is pressed. If a phase containing invalid values (zeros) is left, **this phase will be deleted.**

Disabling the start current check

See Section 5.5 if you want to use this feature.

5.3 Editing a program

Changing a parameter value

To change a parameter value, move to the start position in SET mode by pressing [exit] or [set enter] and choose program number as described on p. 10.

If the programming mode (step or gradient) is changed it will be changed for all the phases within the program.

Select phase number by [⇧] [⇩] and move in the program with [set enter] to the value to be changed. Change with [⇧] [⇩] and confirm with [set enter]. Press [exit].

Inserting and deleting a phase

Inserting and deleting a phase is described schematically in Fig. 6.

Note that you must first enter a phase before it can be inserted or deleted:

1. If needed, change program number by entering the start position in SET mode with [set enter] or [exit], changing the number with [⇧] [⇩] and confirming by [set enter].
2. Bypass the mode question with [set enter].
3. Change to the desired phase number by [⇧] [⇩] and confirm with [set enter].

Choose to delete the phase shown on the display or insert a new phase with this phase number by pressing [⇧] [⇩] and confirm with [set enter].

If DELETE is chosen, the selected phase will be deleted and the program will move back to the position with the phase number blinking. Note that by deleting a phase, the numbers of the following phases will decrease by 1.

If INSERT is chosen, the program will enter the same position and the new phase can be programmed as a new phase (see section 5.2 and Fig. 3, points 4–8). After entering the breakpoint, the question “Last Phase?” will be bypassed and the starting point for the next phase will be entered. Note that by inserting a new phase the number for the old phase with that number and the numbers for the following phases will increase by 1.

Adding a phase after the last phase is done by entering the last phase as above, moving to the question “Last Phase?” and answering NO. The program will jump to the start position for programming a phase with the phase number blinking. Proceed with programming as described for a new program.

It is not possible to insert or delete a phase for a running program.

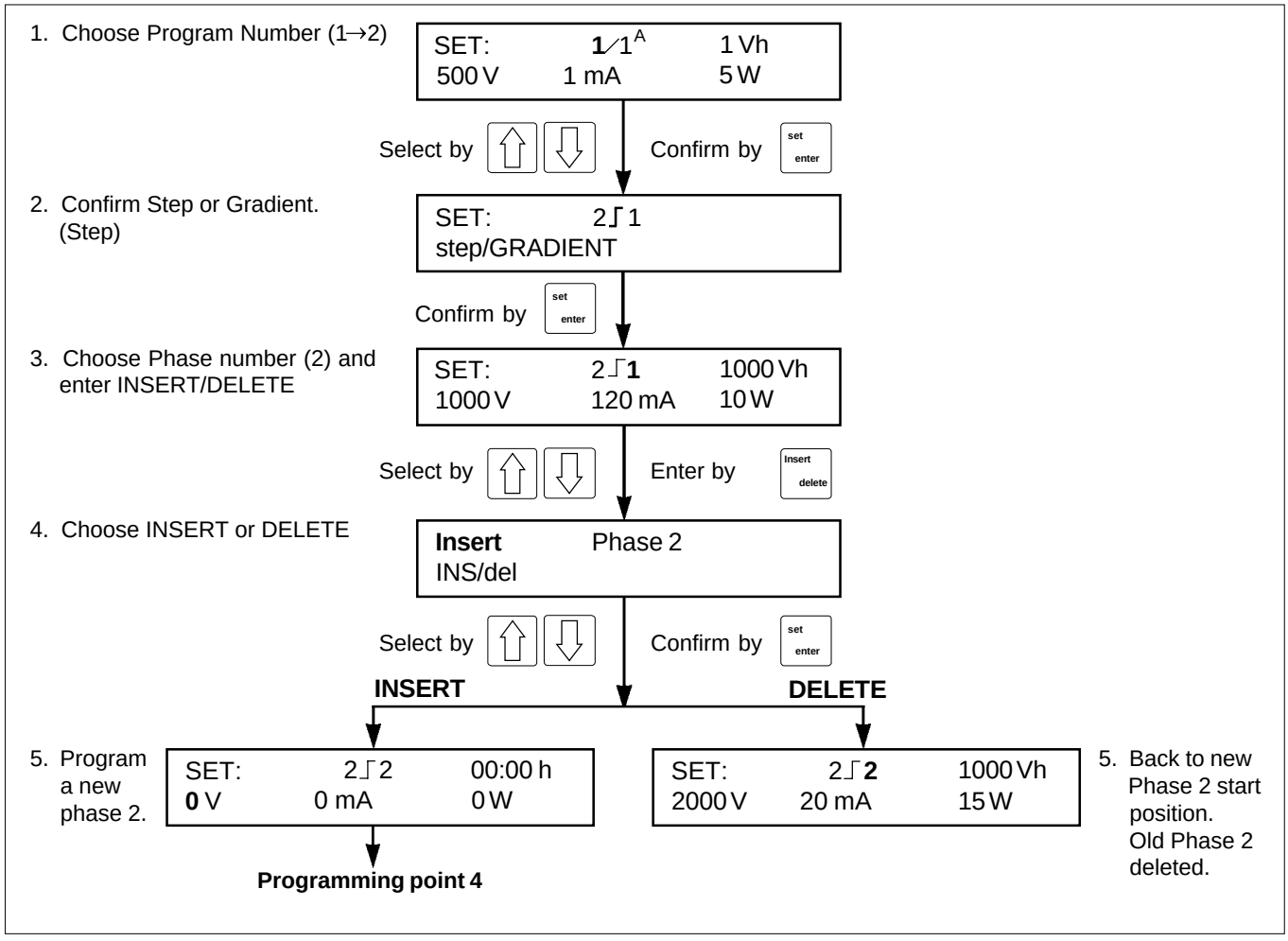


Fig. 6. Inserting and deleting a phase in a program.

Editing a running program

See section 5.4

Copying and clearing a program

See section 5.5.

5.4 Running a program

Connect the leads from the electrophoresis unit (red to red, and black or blue to blue). Red is positive and black or blue negative. UP to two electrophoresis units can run at the same voltage at one time. Please remember to double the maximum current and power conditions if two units are to be run. Voltage will be the same regardless of the number of units. The current should also be doubled if two gels are run on the same unit.

Running a program is described schematically in Fig. 7.

Choosing a program

Press set enter and select the program you wish to run by pressing ⇧ ⇩ until the value is correct. (Omit this step if you have just programmed or edited a method as described in sections 5.2 and 5.3.)

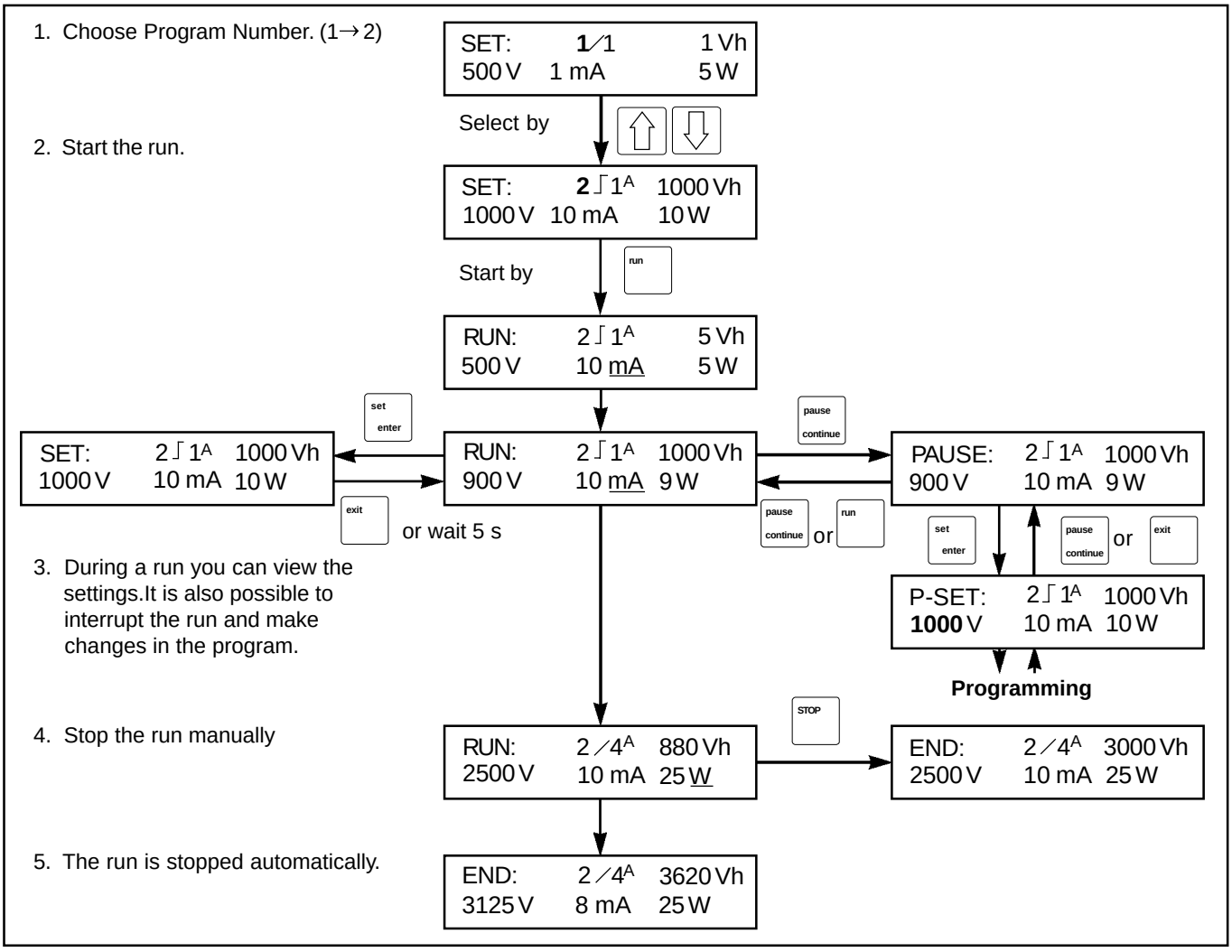


Fig. 7. Running, viewing and pausing a program.

Running

Press run to start the electrophoresis. Information about the status of the start current check will be displayed for a few seconds. The display will then show current values for voltage, current and power and one of elapsed time, volthours or milliamperehours. You can switch between showing the elapsed time, volthours or milliamperehours by ⇧ ⇩ .

The parameter controlling the electrophoresis is underlined.

A light emitting diode shows when voltage is applied (HV on).

If no current is displayed or if “HALT: Low start current” is shown, please check the electrical connections to the electrophoresis equipment.

Pausing

You can interrupt the electrophoresis for sample loading and/or changing the program by pressing pause continue . Voltage will no longer be supplied, the

"HV on" LED goes off, and you may safely load your samples.

The display shows the status of the run when [pause continue] was pressed.

Switch between time, integrated voltage and integrated current for the phase running when [pause continue] was pressed with [⇧] [⇩] .

When sample loading is complete, press either [pause continue] again or [run] to continue the run from where it was interrupted.

Editing a running program when in PAUSE

When in the PAUSE mode you can also press [set enter] to make changes in the program. This mode is called the P-SET mode. When the P-SET mode is entered you can make changes as described in the editing section (5.3, Changing a parameter value). It is not possible to insert or delete a phase for a running program. The P-SET mode is the same as the SET mode apart from restrictions in setting the breakpoint. Naturally, it is not possible to enter a time, integrated voltage or current that is already passed.

Press [exit] or [pause continue] to go back from P-SET to PAUSE. Press [run] or [pause continue] to proceed with the electrophoresis.

View programmed values

It is also possible to view the programmed values during a run by pressing [set enter]. Note that no values can be changed here. Only one phase is shown at one time. Switch to another phase by using [⇧] [⇩]. The display returns automatically to show RUN values after 5s. Alternatively use [exit] or [run] .

Stopping the run and viewing end parameter values

When the programmed time, volthours or milliamperehours for the last phase is attained, the program will enter the END mode. It is also possible to break the run manually by pressing [STOP] .

In both cases, the voltage, current and power will go to zero as indicated by the "HV on" LED switching off. The end parameter values are displayed.

Switch between total elapsed time, integrated voltage or integrated current for all phases in the program by [⇧] [⇩] .

An alarm will sound at the end of each phase if selected in the program. You can stop the alarm after the last phase by pressing [STOP] .

A run cannot be continued after pressing [STOP] .

Disconnect the leads and proceed with post-electrophoretic techniques.

Since diffusion will begin as soon as voltage is turned off, you should remove the gel and begin staining, blotting or autoradiography immediately.

5.5 Optional programming

Some special functions are placed in MORE. These are:

COPY: Copying a program.

CLEAR: Clearing a program.

SETUP: Disabling the current check.

The MORE mode is described in Fig. 8.

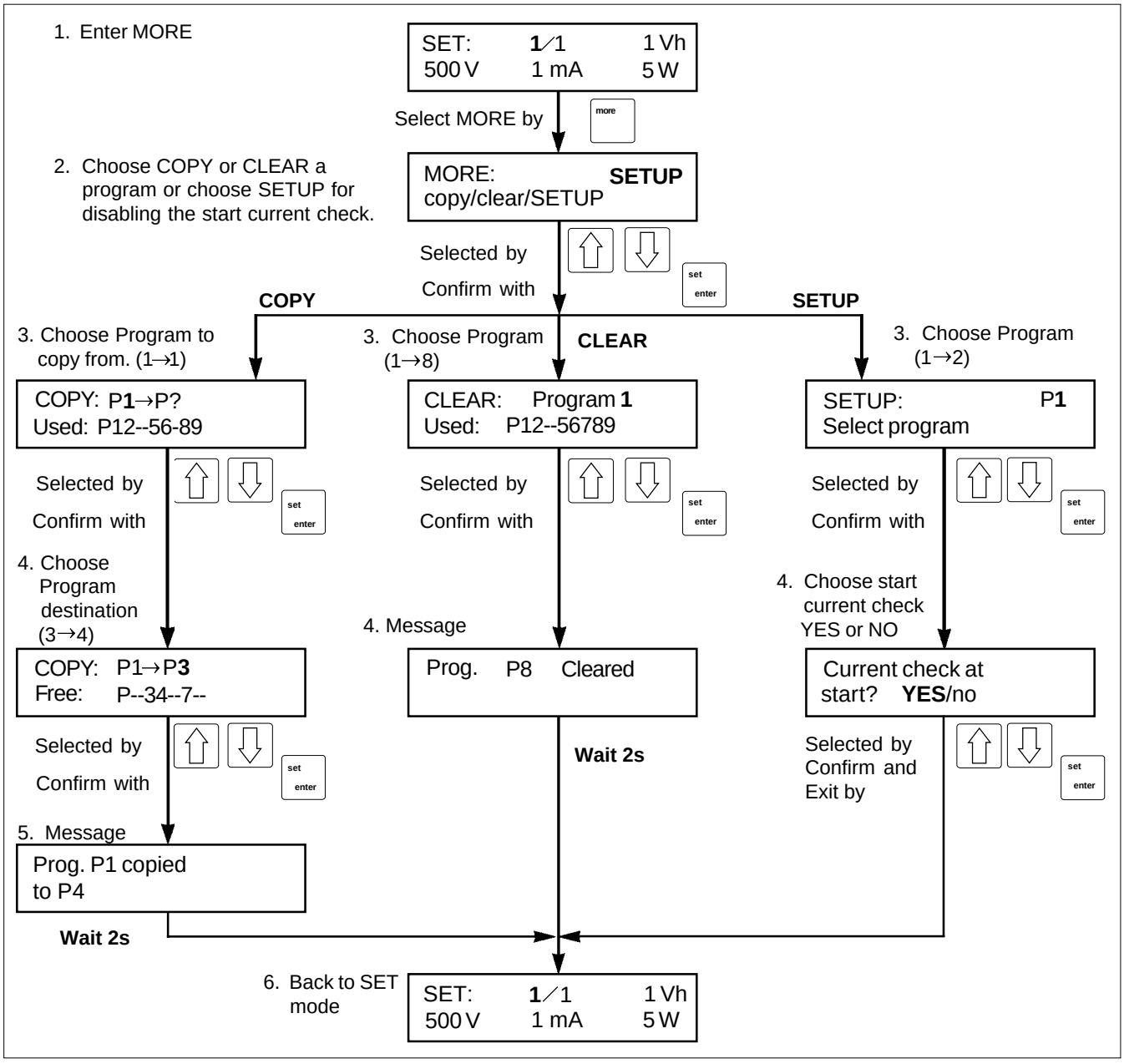


Fig. 8. Optional programming in MORE mode

Copying a program

Enter the MORE mode by pressing [more] . Choose between COPY, CLEAR and SETUP with [⇧] [⇩] and confirm with [set enter].

After choosing COPY you are asked which program should be copied.

Programs that can be copied are shown in the lower row on the display.

Select with [⇧] [⇩] and confirm with [set enter] .

Select to which program number the program should be copied. Empty (available) programs are shown in the lower row. Select with [⇧] [⇩] and confirm with [set enter].

If an already programmed method is chosen, a warning is shown: “Program 7 not empty: Copy?”. If you answer YES, the program with this number is replaced by the one you have copied.

A message confirming that your instruction has been carried out is shown for a few seconds.

The program returns automatically to the start position in SET mode.

Deleting a program

Enter the MORE mode by pressing [more] . Choose between COPY, CLEAR and SETUP with [⇧] [⇩] and confirm with [set enter] .

After choosing CLEAR you are asked which program should be cleared.

Programs that can be cleared are shown in the lower row on the display.

Select with [⇧] [⇩] and confirm with [set enter].

A message confirming that your instruction has been carried out is shown for a few seconds.

The program returns automatically to the start position in SET mode.

Disabling the start current check

You can disable the start current check that otherwise detects that the resistance is not higher than a specified limit. Disabling this check is important when performing certain applications such as the first step in 2-D electrophoresis using Immobiline DryStrip. This disabling function is set in the MORE mode instead of the SET mode in order not to confuse users who do not need this feature, and for safety reasons.

Enter the MORE mode by pressing [more] . Choose between COPY, CLEAR and SETUP with [⇧] [⇩] and confirm with [set enter].

After choosing SETUP, the program asks you for the program number and if you want to keep the start current check.

Choose program number and change between “YES” and “NO” by [⇧] [⇩] and confirm with [set enter] . Choosing “NO” for start

current check means that the function is disabled and high voltage can be applied despite a very high resistance. Leave the MORE mode by

set enter or exit .

Warning! By disabling the start current check, the power supply can deliver high voltage even if it is not connected to electrophoresis equipment.

Note that a message showing whether the start current check is ON or OFF is shown for a few seconds every time run is pressed.

5.6 Choosing run parameters

EPS 3500 XL is an automatic cross-over power supply that allows the user to set limits for voltage, current and power. It is also possible to program linear voltage gradients. During electrophoresis, only one of the parameters is limiting at a time. The limiting parameter determines, together with the conductivity in the electrophoresis system, the values for the other two parameters. Voltage, current, power and conductivity are related by the following equations:

$U = I / L$ (1)

$P = U \times I$ (2)

Where U = Voltage, I = Current, P = Power and L = Conductivity
Equation (1) is more familiar if the conductivity is replaced by the reciprocal resistance (R):

$U = R \times I$ (Ohm's law)

The electric field E, measured in V/cm, is the driving force behind electrophoresis.

$E = U / d$

where E = Electrical field strength, U = Voltage, d = distance

The electrical field strength is achieved by applying a voltage. The higher the voltage, the faster the electrophoresis. Fast electrophoresis is beneficial since it counteracts diffusion.

The disadvantage of increasing the voltage too much is that most of the generated electrical energy, the product of power and time, is transformed to heat. Therefore cooling of electrophoresis equipment is recommended. Cooling will also reduce "smiling" effects which are caused by mobility differentials across an electrophoresis gel resulting from poor heat transfer. Since the cooling efficiency cannot be increased indefinitely, the power should be limited when programming the power supply.

The parameter that should be chosen as the constant and thus control the electrophoresis depends on the type of electrophoresis. In the case of homogeneous buffers throughout the system (same electrode and gel buffer), the conductivity is constant during the electrophoresis. If the conductivity is constant, the voltage will be proportional to the current and the power to the square of the current, according to (1) and (2). This means that the result of the electrophoresis will be the same, regardless of which parameter

is chosen as the constant. For historical and practical reasons, voltage is most commonly used for regulation. Submarine gel electrophoresis of DNA/RNA and pulsed field electrophoresis are usually run at constant voltage. SDS-PAGE using continuous buffer systems is run at constant voltage or current.

For discontinuous buffer systems, the resistance will increase as the electrophoresis proceeds due to a decrease in conductivity. Running at constant voltage will result in decreasing current and power. Constant voltage will thus be “safe” in the respect that the power will not increase and produce more and more heat. On the other hand, the separation will slow down and impair resolution due to an increased time available for diffusion. Running at constant power would give a faster electrophoresis and controlled power, while running at constant current would, at the first sight, seem to be problematic because of increasing voltage and power.

During discontinuous electrophoresis, however, the voltage is not distributed evenly across the gel. These gels have a region with low ionic strength that causes a high electrical field strength. This region increases as the electrophoresis proceeds. This means that the main part of the voltage is spread over a greater and greater distance and a higher and higher power is tolerated. This is the reason why constant current is chosen for such applications. It is, however, recommended to also limit the power as a precaution against overheating the gel. The power supply will probably switch over to limiting power at the end of the run due to increased voltage.

The crossing-over between different parameters controlling the electrophoresis can be illustrated by IEF (isoelectric focusing) using carrier ampholytes. A graphical representation of the changes in power, voltage and current that may occur during a typical IEF run is given in Fig. 9. Since the pK values of the carrier ampholytes and the proteins are temperature dependent, IEF must be carried out at a constant temperature. Therefore cooling of electrophoresis equipment and controlling by power is recommended. The main part of the IEF is thus controlled by power (phase II). The conductivity is gradually decreasing because the carrier ampholytes and sample will loose their net charge during the build up of the pH gradient. Thus the current will decrease and the voltage increase at constant power. During the early stage of the formation of the pH gradient it is important to limit the current. Otherwise the gradient will be irregularly shaped (phase I). The conductivity is not constant along the gel so it is important to also limit the voltage. This means running at constant voltage for the last phase (phase III) to prevent local overheating.

For detailed information about parameter values, always follow the gel supplier’s recommendations.

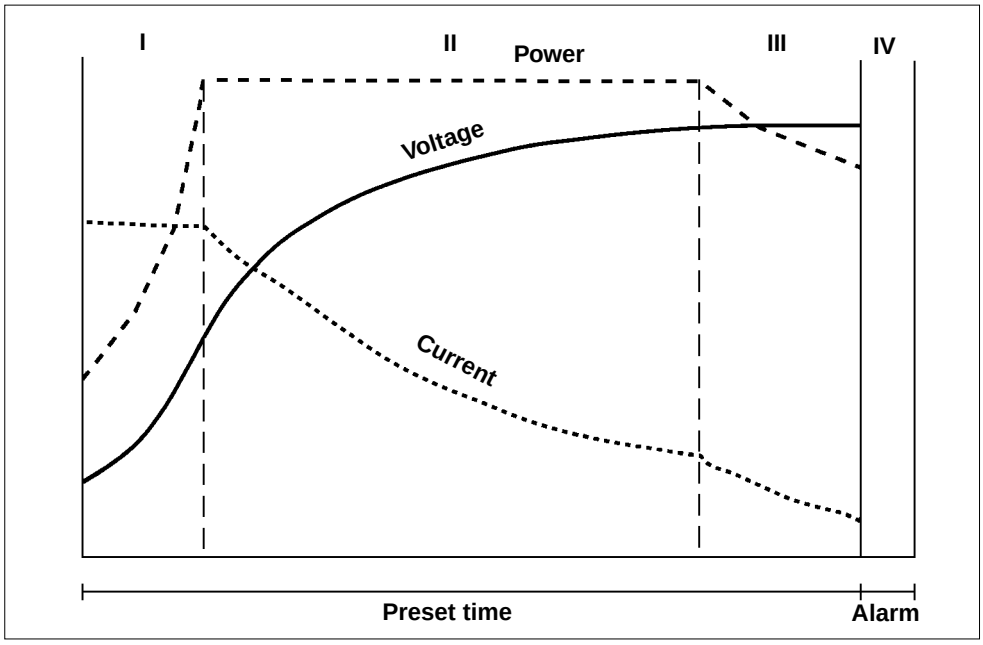


Fig. 9. Changes in power, voltage and current during an IEF run.

5.7 Short instructions

This section summarizes the main programming points covered earlier in this chapter. Use it as a check list once you are familiar with the detailed programming, editing and running instructions. Refer also to the separate schematic operating guide included with the power supply. We recommend you keep this schematic guide close by the instrument.

1. Turn mains power ON. The display should have the program number flashing.
2. Press [set enter] for the actual program number, or use [⇧] [⇩] to select the program number desired. Press [set enter].
3. The display now asks if you wish to perform a step or gradient program. Select ⌠ with [set enter], or ⁄ with [⇧] [⇩] followed by [set enter].
4. The display will blink for phase 1. Press [set enter] to confirm.
5. For each of the parameters Voltage, Current and Power, press [⇧] [⇩] until the value desired is reached. If gradient mode has been selected, the voltage endpoint for the phase should be chosen. Confirm by pressing [set enter] after each parameter, and the display will automatically move to the next parameter.
6. Choose between manual break or automatic break. For automatic break, choose breakpoint unit in either time (h), volthours (Vh) or milli-amperehours (mAh). Select the correct unit or, for manual break, choose "OFF" with [⇧] [⇩]. Confirm with [set enter].
7. If hours, volthours or milliamperehours were chosen, set the value to be used for the breakpoint with [⇧] [⇩] and [set enter].

8. If you only want one phase, press [set enter] for YES to confirm that this is the last phase. If more phases are required, select NO with [⇧] [⇩] and confirm with [set enter]. To add more phases, repeat steps 5–8, until the desired number of phases have been programmed. Up to 9 phases can be programmed.
9. After all phases have been programmed, you will be asked if you wish for alarms to sound after the different phases. Press [set enter] for NO or change to YES and then press [set enter].
10. When programming is completed, connect your electrophoresis unit to the outputs, and press [run].

6. Maintenance

Check regularly that the fan is working properly. Wipe the instrument regularly with a damp cloth. Let the instrument dry completely before use. Otherwise no user maintenance is necessary. All servicing should be entrusted to qualified personnel only. Please contact your local Amersham Biosciences representative for more service information.

7. Trouble shooting

If an error that can be corrected by the user occurs, either during a run or when switching on the power supply, the program enters the HALT mode and the output is switched off. Four different types of errors can cause HALT. The following list shows the error message on the display, the cause and the remedy.

Error message	Cause	Remedy
HALT: Low start current!	The current is less than the lower limit. This can be due to incorrect connection of the electrophoresis equipment or due to use of buffers with extremely low conductivity.	1. Check connections and/or buffers. 2. Press [more], switch off the start current check in the MORE mode. IMPORTANT! Read Section 5.5 first. 
HALT: Ground leakage current	The current to ground leakage in the electrophoresis unit is too high.	Check the electrophoresis unit.
HALT: Mains Voltage too low!	The mains voltage is too low, see Specifications.	Check voltage selector. Check mains voltage.
HALT: Mains fail Program stopped	Mains power failure for more than 7 s.	Press [pause continue] to continue running a program or [STOP] to interrupt the run.

If a serious error occurs, the program enters the FAIL mode. The output is switched off and an error message is shown in the display.

FAIL:Code No: xxx
Call service

Please read the error code number and contact your Amersham Biosciences representative.

8. Technical specifications

Programming	9 programs each with up to 9 phases
Regulation	Maximum voltage, current and power with automatic crossover at preset limits
Output range	Voltage: 0-3 500 V DC, Current: 0-150 mA Power: 0-100 W
Programming range	Voltage: 35-3 500 V DC Current: 1-150 mA Power: 1-100 W Time: 00:01-500 h Volthour: 1-500 000 Vh Amperehour: 1-25 000 mAh
Output resolution	Voltage: 1 V Current: 1 µA, 0-149 µA 10 µA, 0.15-1.49 mA 100 µA, 1.5-14.9 mA 1 mA, 15-150 mA Power: 1W
Programming resolution	Voltage: 5 V Current: 1 mA Power: 1 W Time: 1 min, 00:01-99:59, 1h, 100-500 h Volthour: 1 Vh, 1-9999 Vh, 100 Vh, 10.0-99.9 kVh 1 kVh, 100-500 kVh Amperehour: 1 mAh, 1-999 mAh 10 mAh, 1.00-9.99 Ah 100 mAh, 10.0-25.0 Ah
Accuracy	Voltage: 1%, ± 5 V Current: 1%, ± 1 mA Power: 2%, ± 1 W Timer: 0.1% ± 1 min, 00:01-99:59 h 0.1%, ± 10 min, 100-500 h
Line regulation	< 0.2%
Load regulation	< 1% at load change 10-90% of maximum load
Ripple	< 1 % at 3 500 V
Short term stability	< 0.2% /10 h after warm up
Long term stability	< 1% /year
Start current check	Resistance not greater than 5 MΩ at 40 V (Current less than 8 µA). Can be disabled

Sudden load change check	
Ground leakage check	Leakage not greater than 500 µA
Output protection	Fully protected against any overload conditions
Recovery after power failure	Duration < 8 s, The program continues automatically Duration ≥ 8 s, The program continues after manual restart
Ambient operating temperature	4-40 °C
Ambient operating humidity	0-95%
Ambient operating pressure	106-84 kPa (corresponds to 0-2 000 m)
Mains requirements	100-120V/220-240V; 50/60 Hz
Power consumption	Max 140 W
Dimensions (WxDxH)	250 x 385 x 95 mm
Weight	4.7 kg

9. Ordering information

Designation	Code No.
Electrophoresis Power Supply - EPS 3500 XL	19-3500-01

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