ZENSOL AUTOMATION INC.

COMPUTERIZED TEST EQUIPMENT

ZENSOL

CIRCUIT BREAKER PERFORMANCE ANALYZER

CBA-32P
Micro CBA

MANUAL 8W E
Kit-ZLB User's Guide

Version 4 **November 6th 2004**

1 Overview of the kit 3
1.1 What is in the kit? 3
1.2 What is the usefulness of this kit? 3
1.3 What are the advantages ? 4

2 How to use the kit 5
2.1 How do I connect the TLH to the CBA? 5
2.2 How do I attach the TLH to the circuit breaker? 5
2.2.1 Setup on an Alstom SF6 circuit breaker (GL212-15M 145kV) 6
2.2.2 Setup on a candle-type SF6 circuit breaker. 8
2.2.3 Setup on an oil breaker. 14
2.2.4 Setup on ABB circuit breaker. 17
2.2.5 Setup on 6-contact SF6 breaker. 18
2.2.6 Setup on air-blast breaker. 19
2.2.7 Setup on SF6 circuit breaker. 20

3 Analyzing and using the results 22
3.1 Configuring CBA Win software for a linear kit 22
Analog input configuration: 22
3.2 Acquisition and display of results. 23
3.2.1 General precautions 24
3.2.2 Example curves 27

4 Theory 29
Linear displacement transducer theory 29
4.1.1 Description 29
Circuit Breaker Theory 30
4.1.2 Description 30
4.1.3 Power section 31
4.1.4 Control section 33
4.2 Transducer operating principle 36
4.3 The displacement curve 36
4.4.1 Description 36
4.4.2 Operation on Open 37
4.4.2.1 Zone A : Start of motion 37
4.4.2.2 Zone B : Contact separation 38
4.4.2.3 Zone C : Deceleration 38
4.4.3 Operation on closing 38
4.4.3.1 Zone A : Start of motion 38
4.4.3.2 Zone B : Contact closing 38
4.4.3.3 Zone C : Deceleration 40
4.4.4 Velocity Curve 40
4.4.5 Acceleration Curve 40

5 Appendix 1 : Calibration procedure for a TLH transducer 41
Preparation phase : 41
Testing phase : 42
Calculation phase : 43

6 Appendix 2: Connecting a NC3FX (ZENSOL female) connector to a TLH 45

1 Overview of the kit

1.1 What is in the kit?

The Kit-ZLB linear displacement kit consists of:

- An upper mechanical base.
- A lower mechanical base.
- A rod-to-transducer coupling.
- A cable for connecting to the CBA-32P.
- Two clamps.
- A hard carrying case for the entire kit.
- A user's manual.
- Associated screws and hardware.

Note: the displacement transducer is not a part of the kit.
It is sold separately because there are many choices of TLH transducers available.

1.2 What is the usefulness of this kit?

The kit :

You will find in this kit all the essential instruments required to perform your displacement measurements.
Its base adapts to any type of circuit breaker and the clamps will allow you to precisely install your measurement apparatus.
To help you with installation, schematics are provided with the kit.
The kit is supplied with a hard carrying case ensuring maximum protection for the equipment.

The TLH :

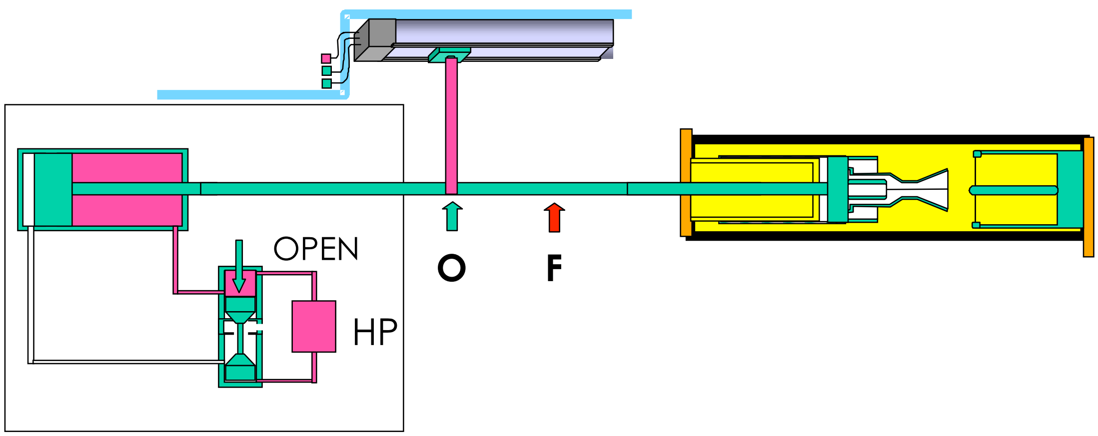
The TLH is a resistive transducer designed to directly and precisely measure displacement or distance in control, measurement and regulation applications.
The rodless design allows the read/write arm to be driven from the side, in the lengthwise direction of the unit, thus avoiding problems with the "*pumping*" effect normally associated with conventional transducers, with travel distances up to 600mm.

The base and clamps:

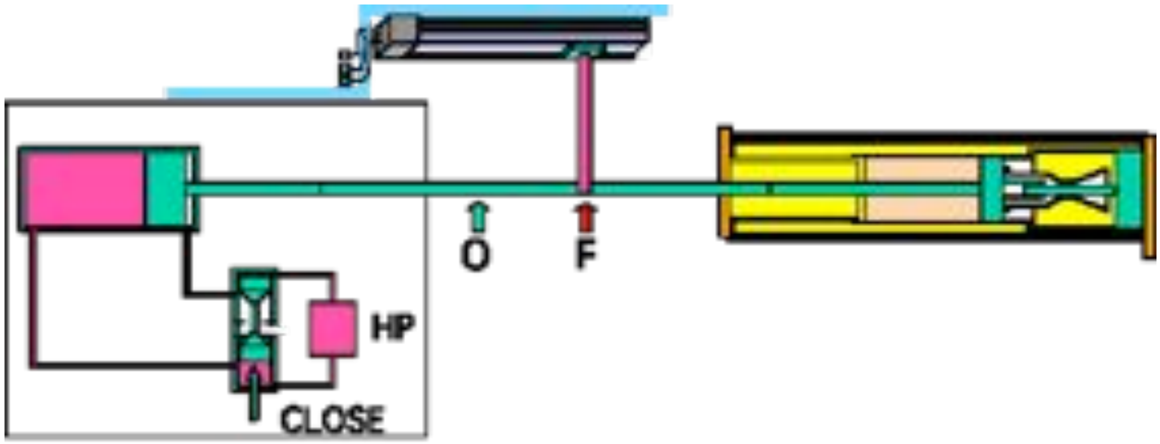
The ajustable base and clamps will allow you to precisely install your measurement apparatus on any type of circuit breaker.

1.3 What are the advantages ?

The goal is to exactly reproduce the motion of the moving contact in the chamber of the circuit breaker, which is normally not accessible because the mechanism is inside an enclosed space. While the end motion of this moving contact is always linear, it is not always the case with the initial motion generated by the control mechanism..
The control mechanism's initial motion may be rotary, and transformed by a series of levers and connecting rods into the actual linear displacement.
When the linear motion of the contact is indirectly accessible, as in the case of a connecting rod, for example, a linear transducer can exactly record this motion when it is properly attached to the aforementioned rod.. In figure 2.3a is an example of linear motion recorded with a linear transducer (in the case where the linear motion is accessible).



Linear transducer installed in OPEN position



Linear transducer installed in CLOSED position

2 How to use the kit

2.1 How do I connect the TLH to the CBA?

Attach the linear displacement transducer to the breaker control rod.
Connect the displacement transducer's cable to one of the 0-10 volts analog inputs on the CBA-32P.
*For a photo see page 20 in Manual 1W – Operator's Manual.

2.2 How do I attach the TLH to the circuit breaker?

Here are a few photos that show various ways that the displacement transducer can be installed on a circuit breaker.

2.2.1 Setup on an Alstom SF6 circuit breaker (GL212-15M 145kV)
Location: Montréal

In this location, displacement measurements are effected with a rotary transducer that can be positioned with a «drill mandrel ».

Here, there are two ways to measure displacement:
- Either by using a rotary transducer with its own base (see examples on following pages)
- Or by using a linear transducer and its own base (see examples on following pages)

There are two places on this breaker where displacement measurements are possible. One can use a rotary displacement kit. Here we are interested in using a linear transducer.

Setup with a linear transducer

2.2.2 Setup on a candle-type SF6 circuit breaker.

Location: Peru

Lower part of the linear displacement mechanism on a candle-type circuit breaker.

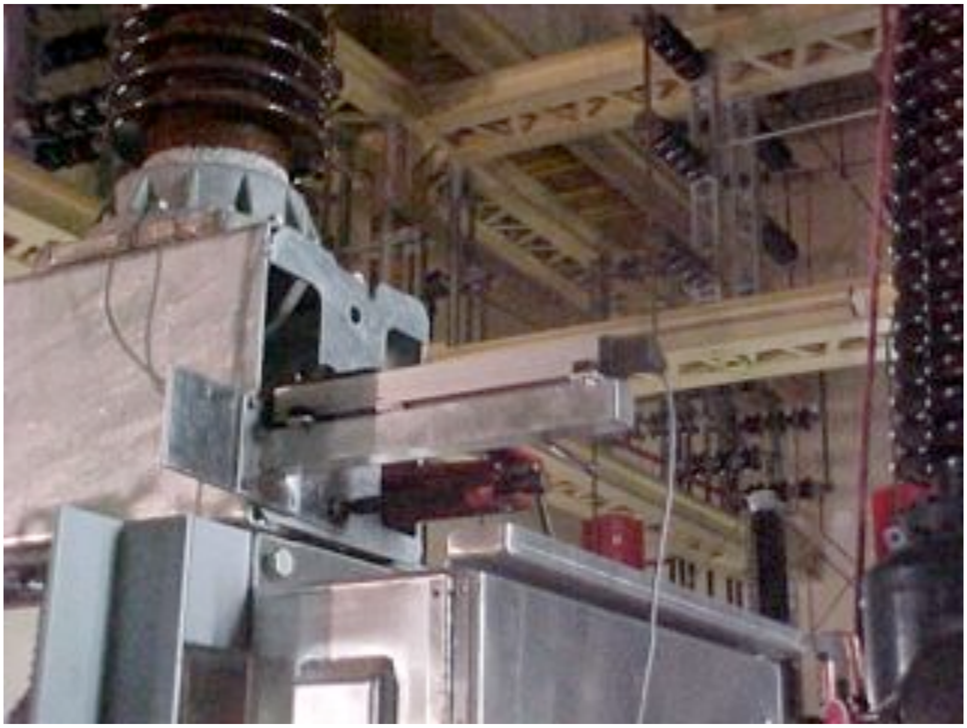
Upper part of mechanism in closed position.

Upper part of mechanism in open position.

In this photo, one can see the challenge presented to us. One must attach the breaker control rod to the linear displacement transducer, despite the fact that the available space is about three centimeters (one and a quarter inches).

To solve this problem, encountered in a remote location, one of the workers proposed using a simple curved steel rod.

Steel rod attaching the base and the linear transducer to the mechanism.



2.2.3 Setup on an oil breaker.
Location : Québec

Linear transducer and base attached to the breaker.

Linear transducer and base.

Upper part of linear transducer.

If at all possible the rod and the linear transducer must be placed parallel to each other.

2.2.4 Setup on ABB circuit breaker.

Location : British Columbia

Linear transducer adapted to ABB breaker.

Adaptor supplied by ABB.

If the output rod of the breaker has a rotary motion of less than 180 degrees, and if there is enough room, it is possible to use the linear transducer with the adaptor to measure displacement.

2.2.5 Setup on 6-contact SF6 breaker.

Location: Mexico

SF6 breakers.

Linear transducer mounted on 6-contact SF6 breaker.

2.2.6 Setup on air-blast breaker.

Location: Texas

Linear displacement mechanism mounted on a small air breaker.

2.2.7 Setup on SF6 circuit breaker.

Location: Alabama

SF6 breakers.

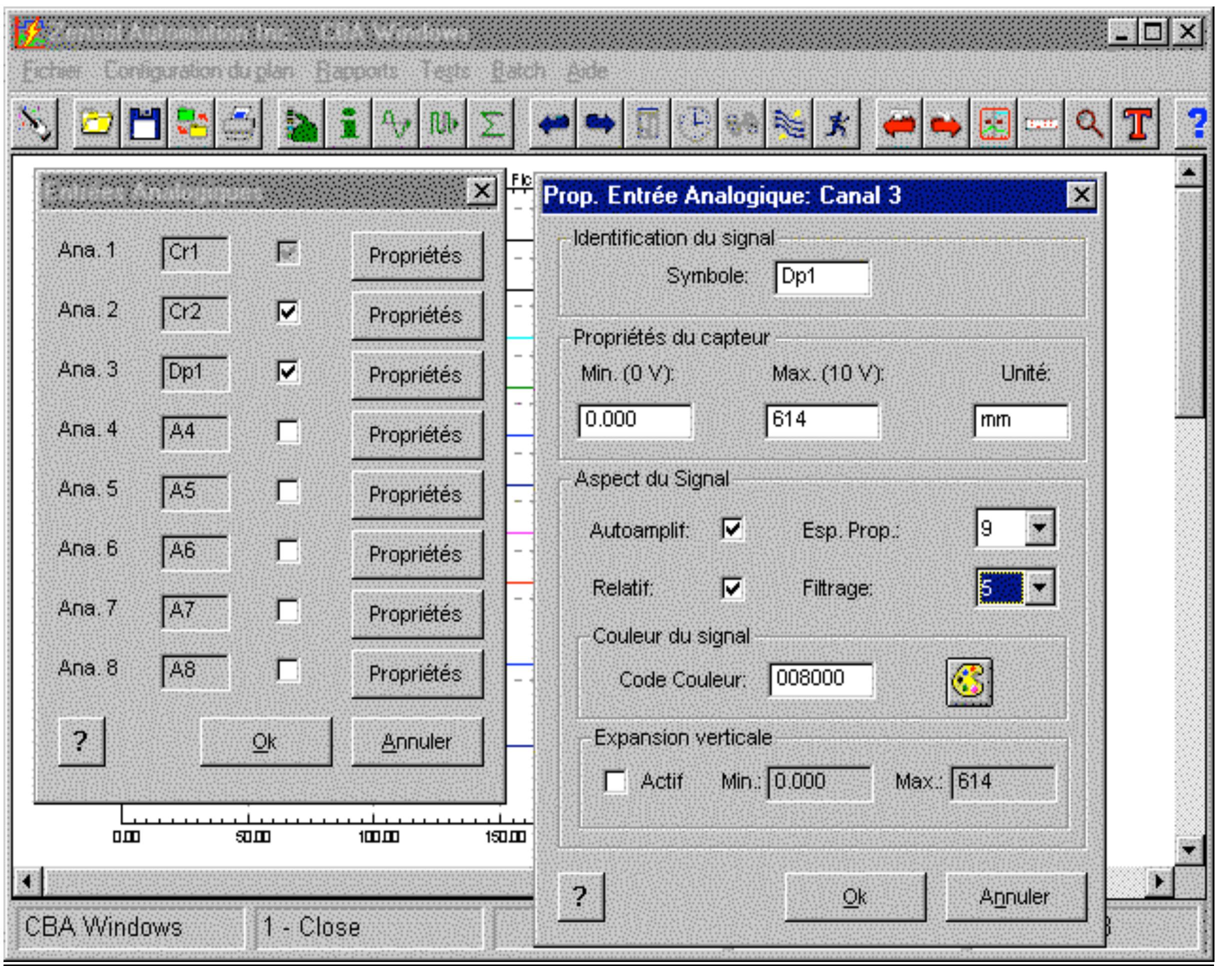
Example of base mounting.

3 Analyzing and using the results

3.1 Configuring CBA Win software for a linear kit

Analog input configuration:

These screens allow the enabling or disabling of the analog inputs, as well as setting the specifications of each analog input.



To activate an analog input, click the corresponding checkbox. To change the properties of a channel, click on the associated Properties button.

The function of each analog input is as follows:

- Channel 1: Current sensor (close).
- Channel 2: Current sensor (open).
- Channels 3-8: General 0-10 VDC analog inputs, or displacement transducers

Note 1: To see the analog channels on a graphic page, add their channel numbers to that page in the Graphics Report Designer.

Note 2: The checkbox for analog input #1 is gray and not accessible. This channel must absolutely be active for all tests.

3.2 Acquisition and display of results.

The acquisition and display of results is effected by the ZENSOL CBA-32P and its analog channels. (see Fig. 2.4a)
Each analog channel has three wires numbered (1), (2), and (3) on its connector.
Between (1) and (3) is a 10 volt signal generated during the test. The signal returned from the displacement tranducer is collected between wires (2) and (3) and transmitted to the CBA Win analysis software, which traces the displacement curve over time on the computer screen. In (Fig. 2.4b) is an example of a graphic page displayed by CBA Win as seen on a computer screen.

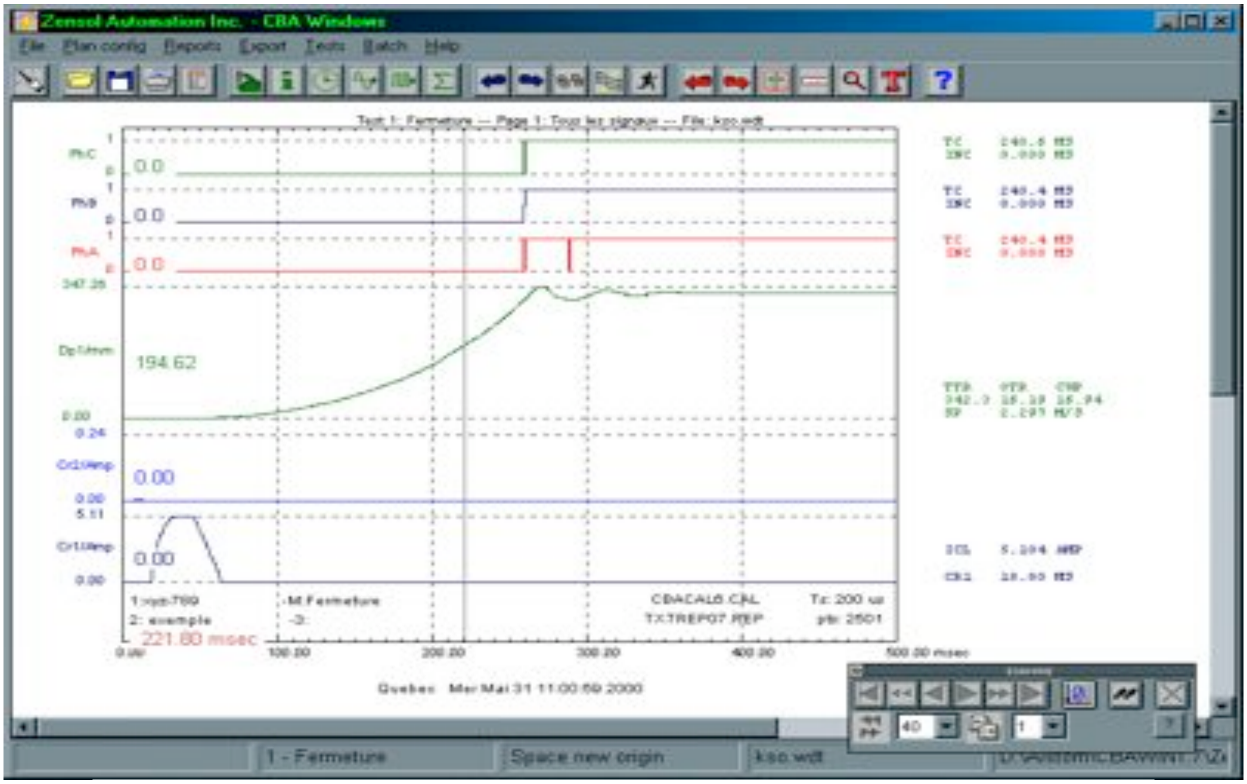


Fig 2.4b CBA Win graphic page as seen on a computer screen

3.2.1 General precautions

When installing and connecting the transducer, certain precautions are to be observed:

3.2.1.1 Inverted curves

In general, displacement curves are shown with the "CLOSED" position higher than the "OPEN" position. To maintain this rule, wires 2 and 3 must not be reversed on the transducer, otherwise the curve will be displayed upside-down (see figs. 2.5.6a and b)

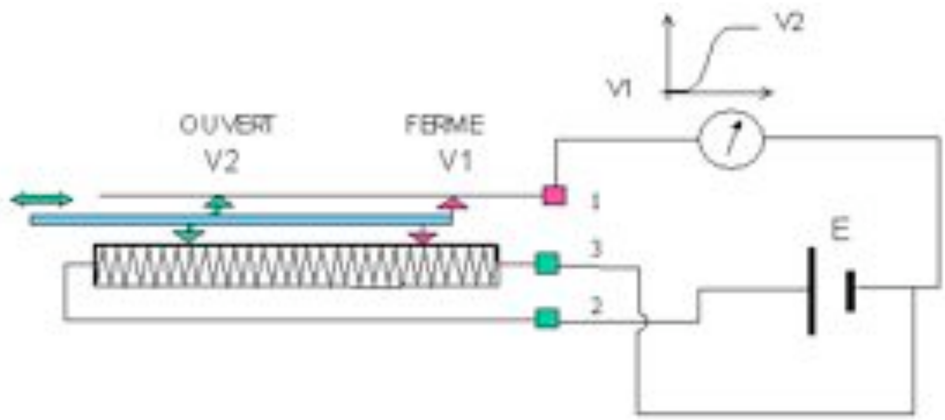
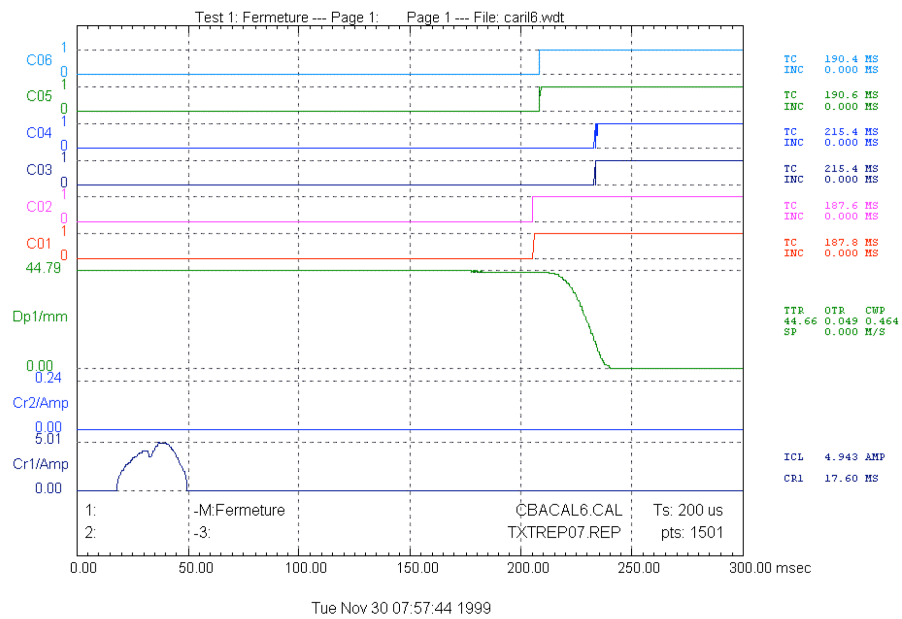


Fig. 2.5.6 a: Example of inverted connection on displacement transducer



3.2.1.2 Transducer capacity

When installing the transducer, one must ensure that the measured motion does not exceed the capacity of the transducer or it will be damaged, and the displayed curve will not show the true motion of the breaker. Figure 2.5.6.2 illustrates a case where the transducer has reached the end of its travel range, or "bottoms out" before the breaker has finished its motion in an open operation. The abrupt angle at the bottom of the curve is evidence for this condition.

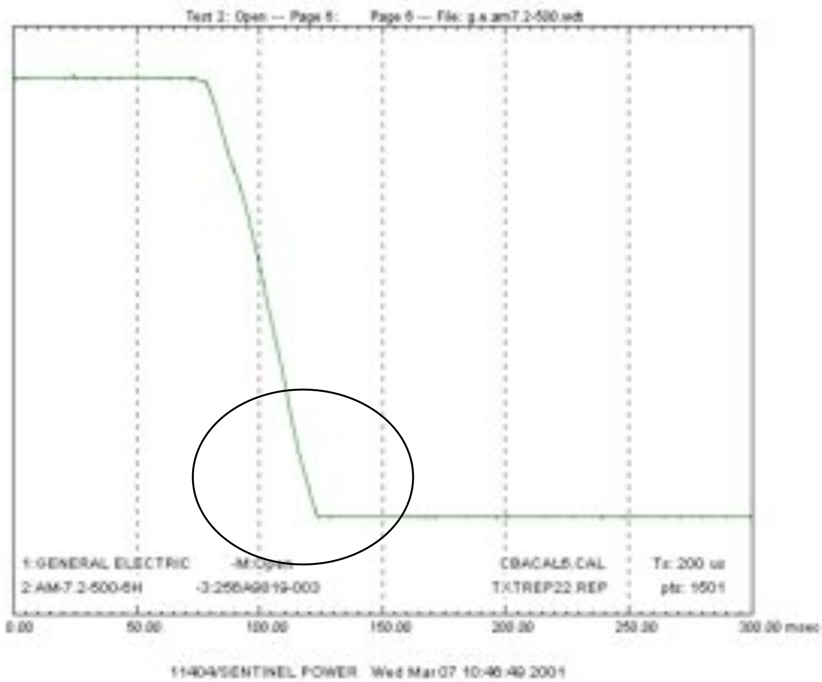
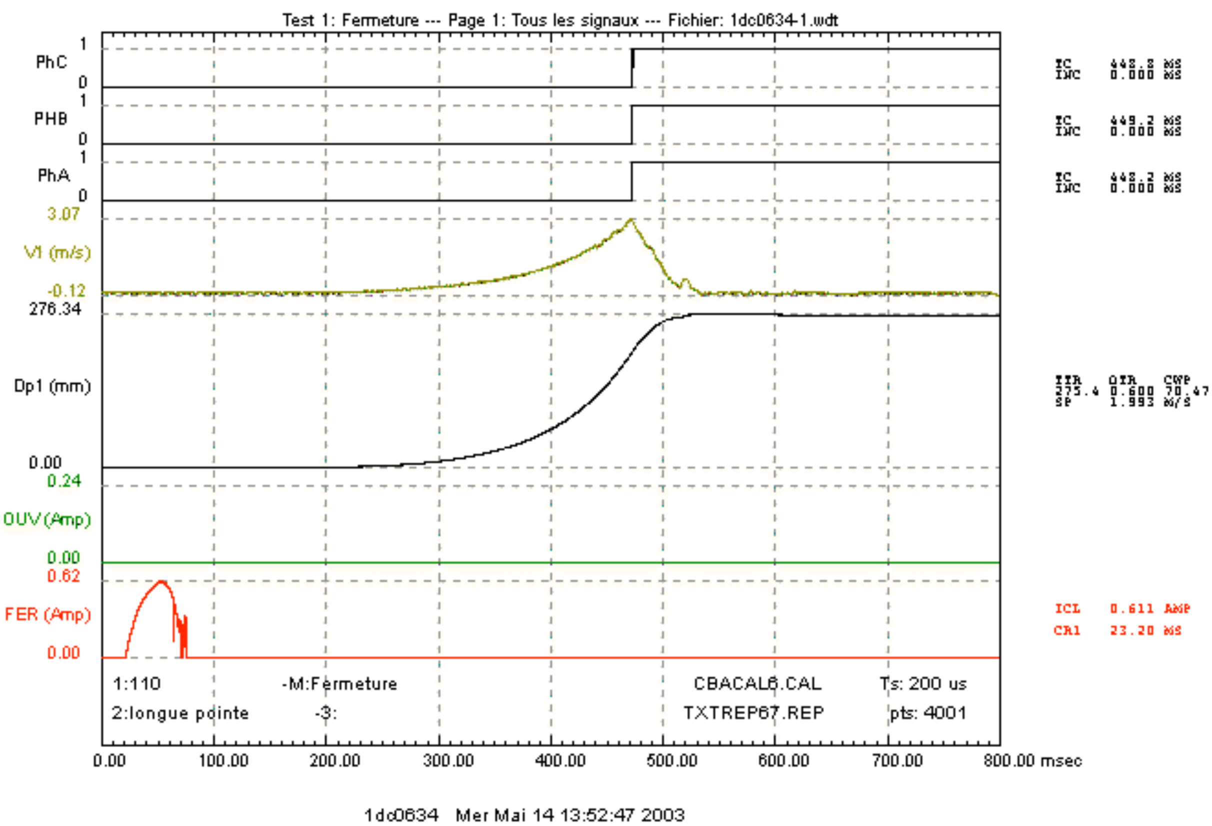


Fig. 2.5.6.2 Example of displacement curve beyond the transducer's capacity

3.2.2 Example curves

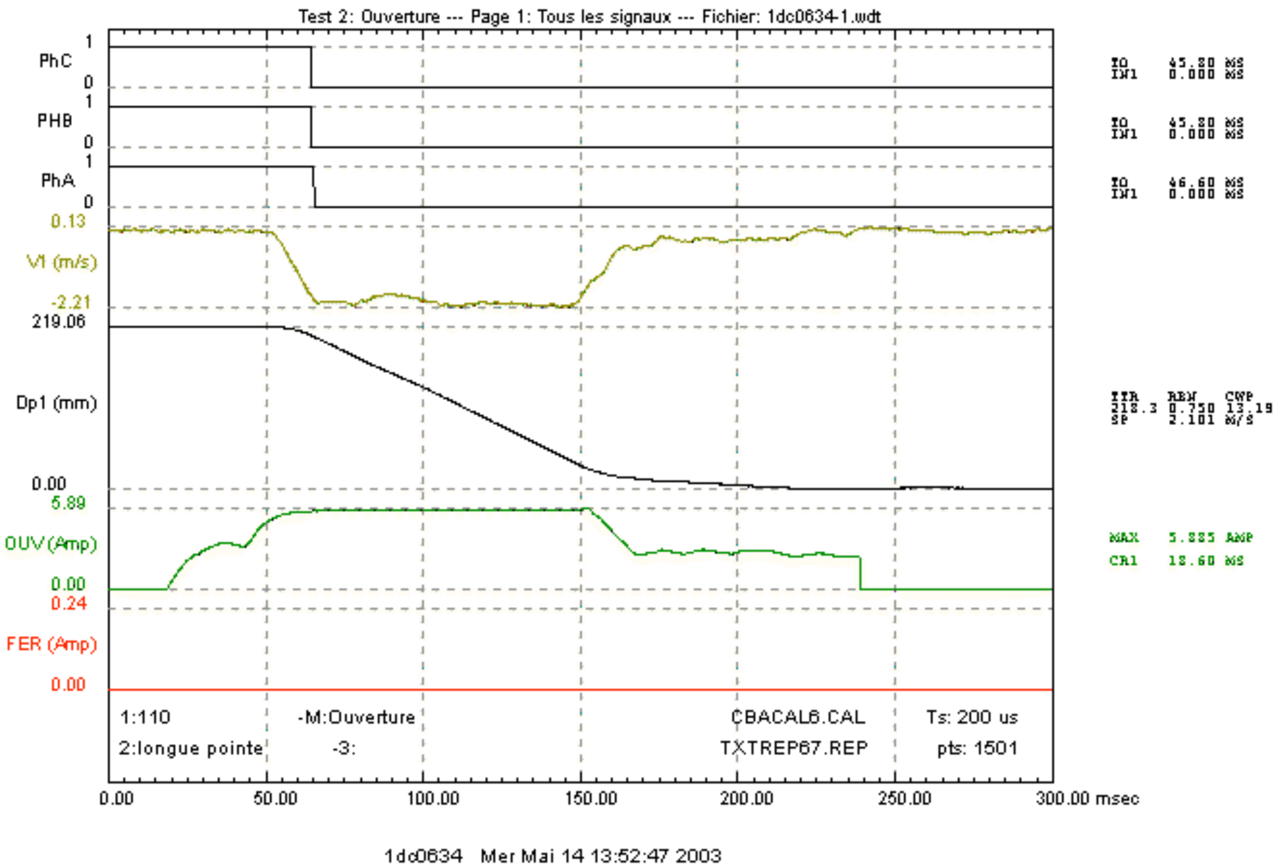
In order to help you validate your tests, here are a series of typical curves. Recorded curves resembling the examples indicate a successful installation.

Close test :

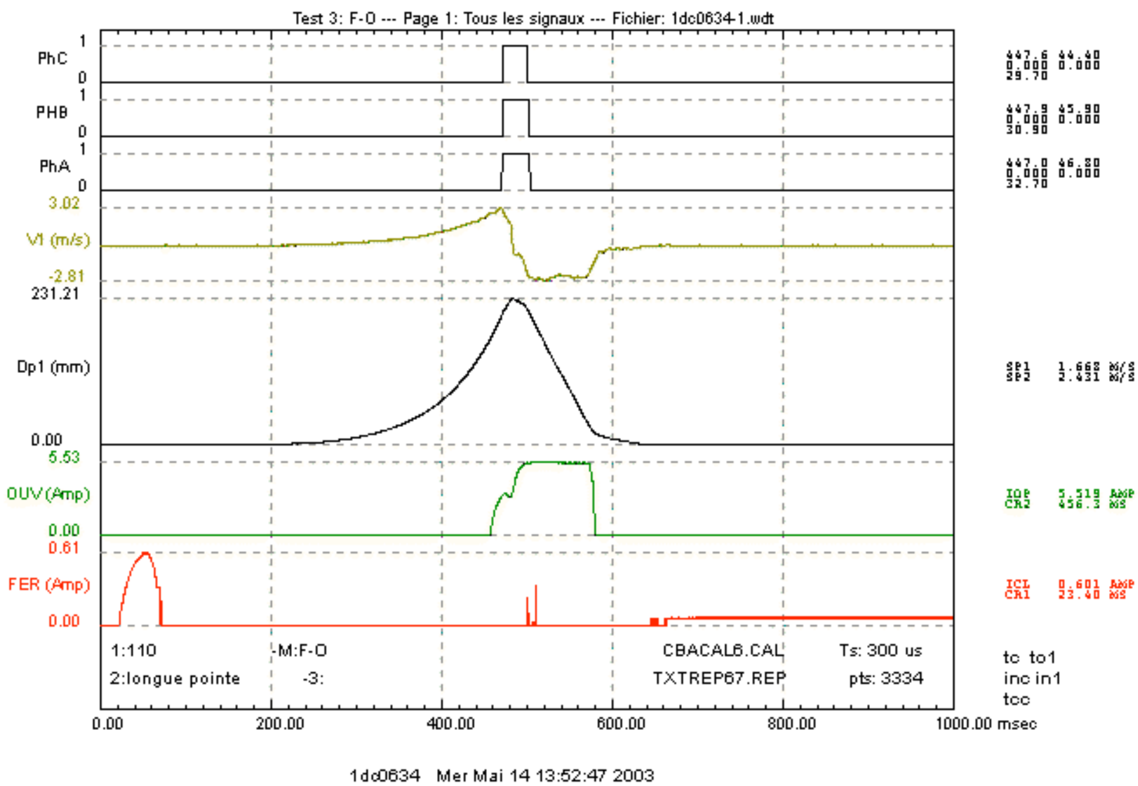


:

Open test:


Test 2: Ouverture --- Page 1: Tous les signaux --- Fichier: 1dc0634-1.wdt
PhC
1
0
PHB
1
0
PhA
1
0
0.13
V1 (m/s)
-2.21
219.06
Dp1 (mm)
0.00
5.89
OUV (Amp)
0.00
0.24
FER (Amp)
0.00
TO 45.80 MS
IN1 0.000 MS
TO 45.80 MS
IN1 0.000 MS
TO 46.60 MS
IN1 0.000 MS
TTR RBW CWP
218.3 0.750 13.19
SP 2.101 M/S
MAX 5.885 AMP
CR1 18.60 MS
1:110
2:longue pointe
-M:Ouverture
-3:
CBACAL6.CAL
TXTREP67.REP
Ts: 200 us
pts: 1501
0.00
50.00
100.00
150.00
200.00
250.00
300.00 msec
1dc0634 Mer Mai 14 13:52:47 2003

Close-Open Test:



4 Theory

Linear displacement transducer theory

4.1.1 Description

The displacement transducer, in its simplest form, consists of a fixed component and a mobile one. The moving part is attached to the moving contact of the breaker under test and moves with it, while the fixed or stationary component becomes the reference point.
Many types of transducers are available on the market. They differ by the method used to identify the relative value versus the reference value.. For example :

- Magnetic transducers
- Optical transducers
- Resistive transducers
- etc.

The resistive transducer is the most widely used. This type of transducer consists of a resistor and mobile cursor moving along the resistor.
One type of resistive transducer is the linear displacement transducer, schematically represented here:

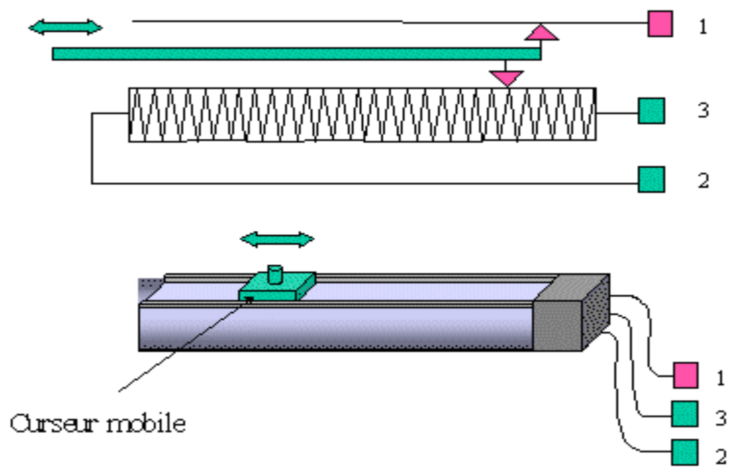


Fig 2.11a Linear transducer

Circuit Breaker Theory

4.1.2 Description

A high-voltage circuit breaker consists of two main parts:

1. Electric power section (active part)
2. Control section

The first has the task of making or breaking the current in the high-voltage circuit where the breaker is installed. The second has the task of generating the required energy to effect these operations.

The connection between the control and active sections is usually made by means of an insulated rod, shown in red in Fig. 2.21.

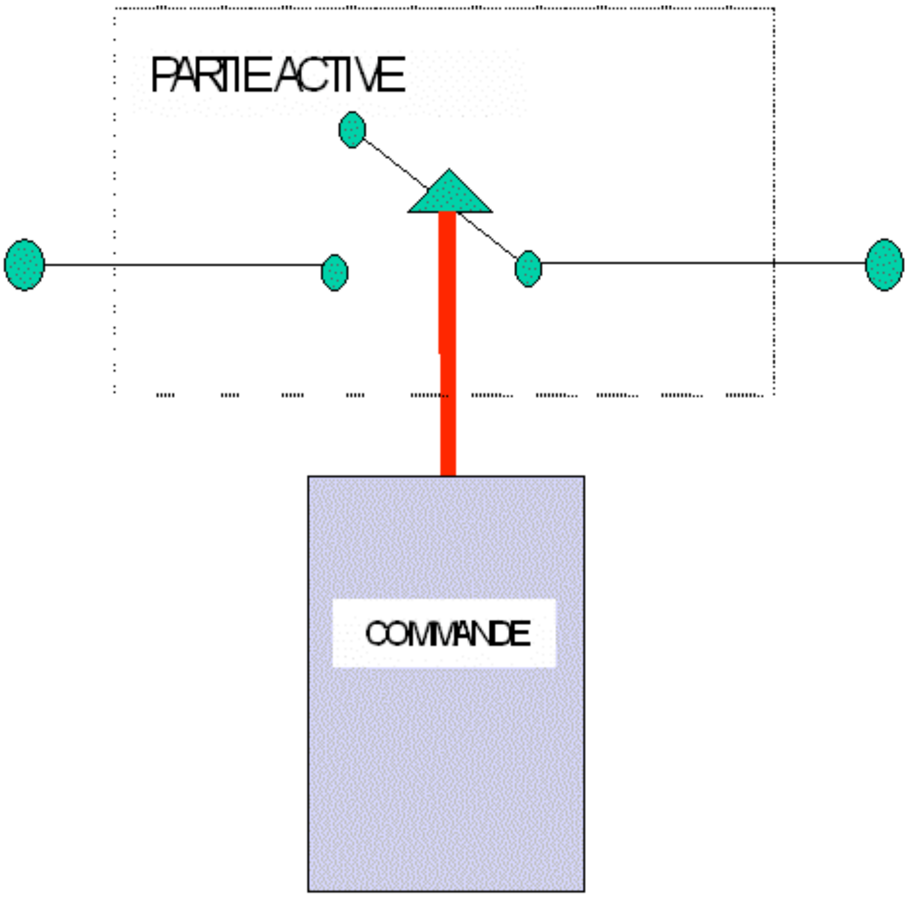


Fig 2.21 Circuit breaker principle

4.1.3 Power section

This part is usually composed of three equal phases. Each phase has a fixed contact assembly and a moving contact assembly. When the two contact assemblies touch, it is said that the breaker is "CLOSED" and current passes through the power section.
To interrupt the current flowing through the power circuit, the moving contact assembly is physically moved away from the fixed contact assembly and stopped at a sufficient distance to ensure electrical isolation.

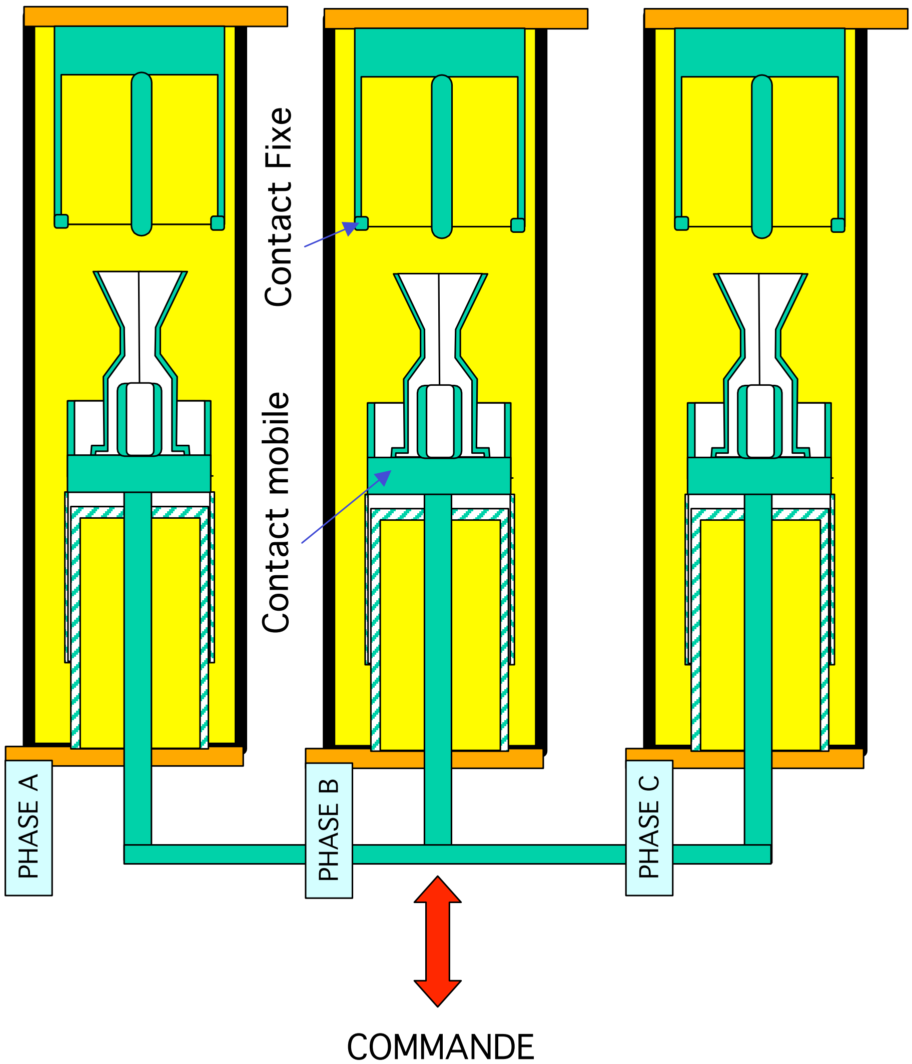


Fig. 2.22 A circuit breaker's power section

4.1.4 Control section

This section creates the necessary energy to perform the mechanical work required by both open and close operations.

Three types of controls are widely used in high-voltage circuit breakers :

- Pneumatic control
- Hydraulic control
- Mechanical spring control

4.1.4.1 Pneumatic control

This is usually found in compressed air breakers. This type of circuit breaker uses compressed air as a dielectric medium and has piston-type moving contacts.

A series of valves, activated at precise moments, injects compressed air on one side of the piston, which displaces it through the action of the pressure difference between opposite sides of the piston. The motion of the moving contact is not usually accessible in this type of circuit breaker, which makes it nearly impossible to use conventional transducers.

4.1.4.2 Hydraulic control

This type of control has an energy storage device, or accumulator, as nitrogen under presure or as springs compressed by hydraulic oil and a pump. The breaker's moving contact is connected to the piston of a powerful hydraulic ram though an insulating connecting rod.

A set of hydraulic valves allows the pressure previously accumulated to be placed on one side or the other of the ram's piston, which moves the moving contact in the desired direction.

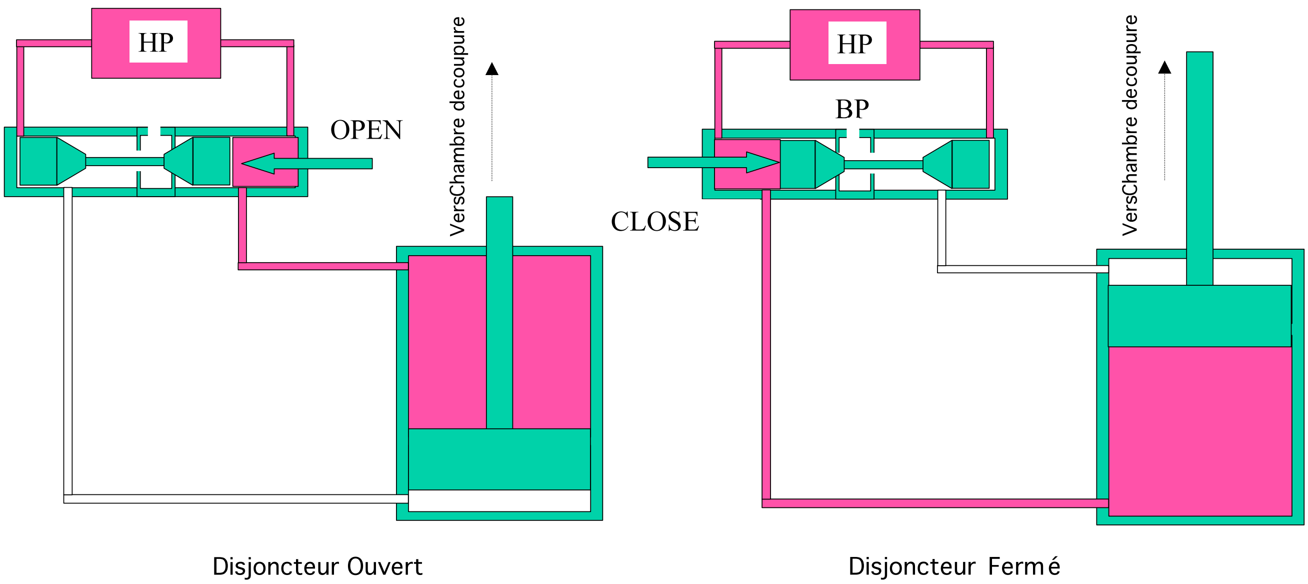


Fig 2.2.32 Hydraulic control in open (left) and closed (right) positions

4.1.4.3 Mechanical spring control

This type of control is much sought after because of its proven reliability and low periodic maintenance frequency.

It usually consists of a compressed spring that accumulates energy required for the close operation, and another spring containing energy for the open operation.
The Close spring (E) is manually compressed with a lever, or electrically with a motor. A set of locking levers holds the energy accumulated in the Close spring.

This energy is released by the release of the Close spring, and provokes the displacement of the mobile contact toward the fixed contact, through the connecting rods, while loading the Open spring, which is held by its own locking levers to store energy for the next Open operation.

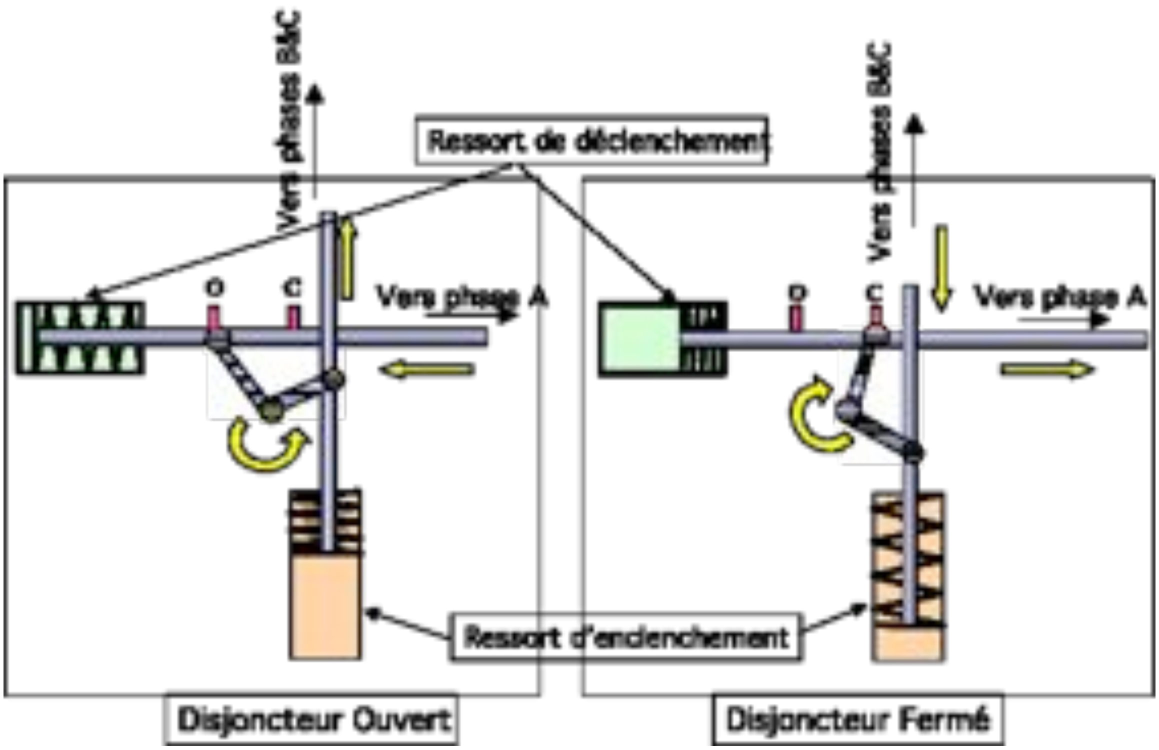


Fig. 2.2.33 Mechanical spring control in open (left) and closed (right) positions

4.2 Transducer operating principle

The transducer is solidly attached to the breaker support, and the moving cursor is solidly attached to the moving contact's control rod.
A fixed voltage source (E) is connected to points (1) and (3). When the breaker is in the CLOSED position, the voltage measured at points (2) and (3) of the transducer is (V1); as the moving contact moves toward the OPEN position, the measured voltage (Vt) between (2) and (3) decreases with time down to (V2), which is less than (V1), at the end of the contact's travel.

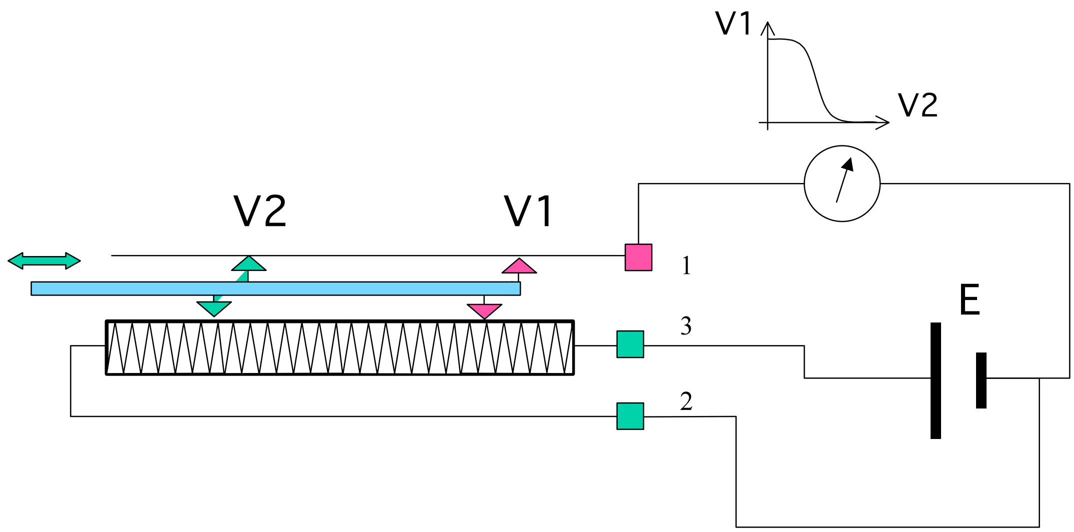


Fig. 2.12 How a displacement transducer works

4.3 The displacement curve

4.4.1 Description

During a circuit breaker timing test, the operating time from the start of the command in the command coil, up to the change of the state of the main contact, is recorded by the timing instrument, for example the ZENSOL CBA-32P.
These readings give valuable information on the state of the breaker and more often than not precisely shows the presence or absence of anomalies and malfunctions. But even this valuable information doesn't reveal all the breaker's secrets. Important information still remains hidden from view.
Where possible, a point-by-point recording of the movement of the internal parts of the breaker, over the entire travel range, allows tracing what is called a DISPLACEMENT CURVE.

While the timing curve of the main contact only shows when movement begins and when the contact changes state, the information revealed by the displacement curve is interesting because it shows is the entire motion from beginning to end.

4.4.2 Operation on Open

An example of a displacement curve for an Open operation is shown in **Fig. 1.2** superimposed on a main contact timing curve (in red).

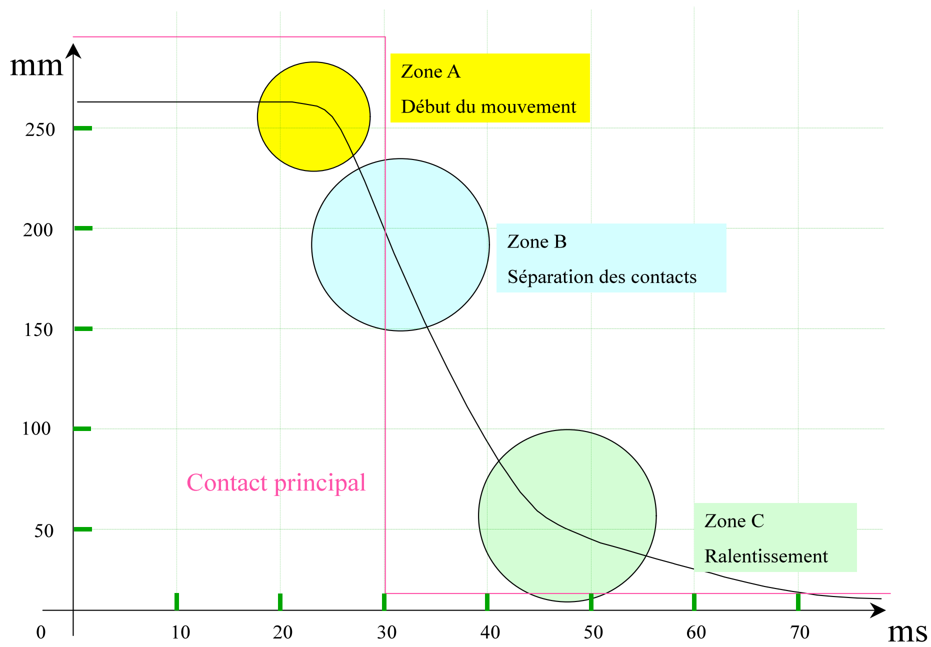


Fig 1.2 Displacement curve for Open operation

Even if the general appearance of the curve is to be checked first, three zones (circled in Fig.1.2) merit particular attention:

1. Zone A : start of motion
2. Zone B : time of contact separation.
3. Zone C : from the start of deceleration until the final rest point.

4.4.2.1 Zone A : Start of motion

This is where the motion begins. It is extremely important to know if the motion has started at the correct point. For example, a delay relative to the reference specification means there is an electrical problem, if the coil is not energized in time, or a mechanical one somewhere between the control mechanism where the motion is initiated and the moving contact of the breaker.

4.4.2.2 Zone B : Contact separation

This is where the main contacts separate. At this moment the arc is formed and the breaker begins the arc extinguishing process. Separation speed is an important factor and of prime importance to succeed in breaking the circuit.
The calculation method for the average speed in this zone is determined by the designer of the breaker. Only the designer can determine the calculation method and the reference value.

4.4.2.3 Zone C : Deceleration

This is where the motion slows down until the moving contacts have completely stopped.
The energy released in the interruption process is as great or greater than the current being interrupted. Once the current has been interrupted and the arc is extinguished, this energy is quite large.
Effective means of damping are implemented to absorb this excess energy, thus reducing the risk of damage to the breaker's internal components. Examination of this zone shows if the damping or absorption is optimal, meaning that the motion is stopped gently.
Insufficient damping, or underdamping, allows the the moving parts to undergo shocks at the end of the travel, which causes severe damage.
A sudden damping, where the kinetic energy developed by the moving parts is absorbed over a very short time, causes damage similar to underdamping, This phenomenon is called overdamping.

4.4.3 Operation on closing

An example of a displacement curve for a Close operation is shown in Fig.1.3, superimposed on a timing curve for the main contact (in red).
Even if the general appearance of the curve is to be checked first, three zones (circled in Fig.1.2) merit particular attention:

1. Zone A : start of motion
2. Zone B : time of contact separation.
3. Zone C : from the start of deceleration until the final rest point

4.4.3.1 Zone A : Start of motion

As in the case of the opening displacement curve, this is where motion starts, and it is extremely important to know if the motion started at the correct point.

4.4.3.2 Zone B : Contact closing

This is where the main contacts come into contact. In this zone, also called the pre-arc zone, as the contacts come closer to each other, the dielectric, as a function of the separation distance, becomes insufficient and a pre-arc current forms within an arc, the duration of which is a function of the speed of the contacts.
Thus, contact velocity is an important factor in limiting premature wear of the contacts.

As in the case of the open operation, the method for calculating the average speed in this zone is also determined by the designer of the apparatus. Only the designer may determine this calculation and establish the reference specification.

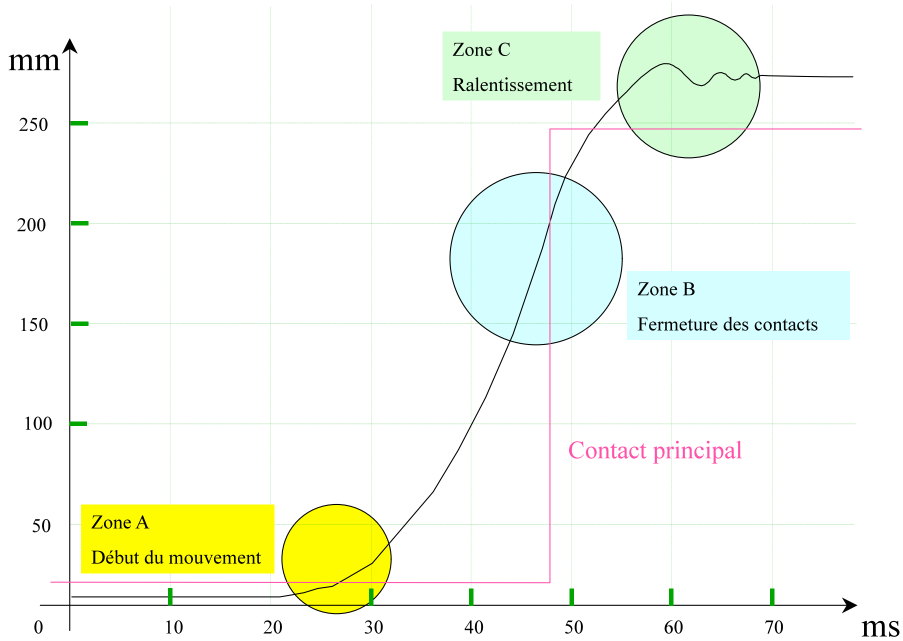


Fig 1.3 Displacement curve for Close operation

4.4.3.3 Zone C : Deceleration

This is where the motion slows down to a complete stop of the breaker's moving contacts.
The energy involved in the closing process is less than that developed in the breaking process, but it is nonetheless quite considerable.
Excess energy is translated into overtravel which, if it exceeds tolerances, may cause severe damage to the device.

4.4.4 Velocity Curve

A velocity curve is calculated by the derivative of the displacement curve, using the CBA Win analysis software, for example. The velocity curve gives the speed as a function of time, which gains new information on the dynamic behavior of the circuit breaker.

4.4.5 Acceleration Curve

In the same manner, an acceleration curve can be traced, as the derivative of the velocity curve, again using the CBA Win analysis software, which gives us even more useful data.

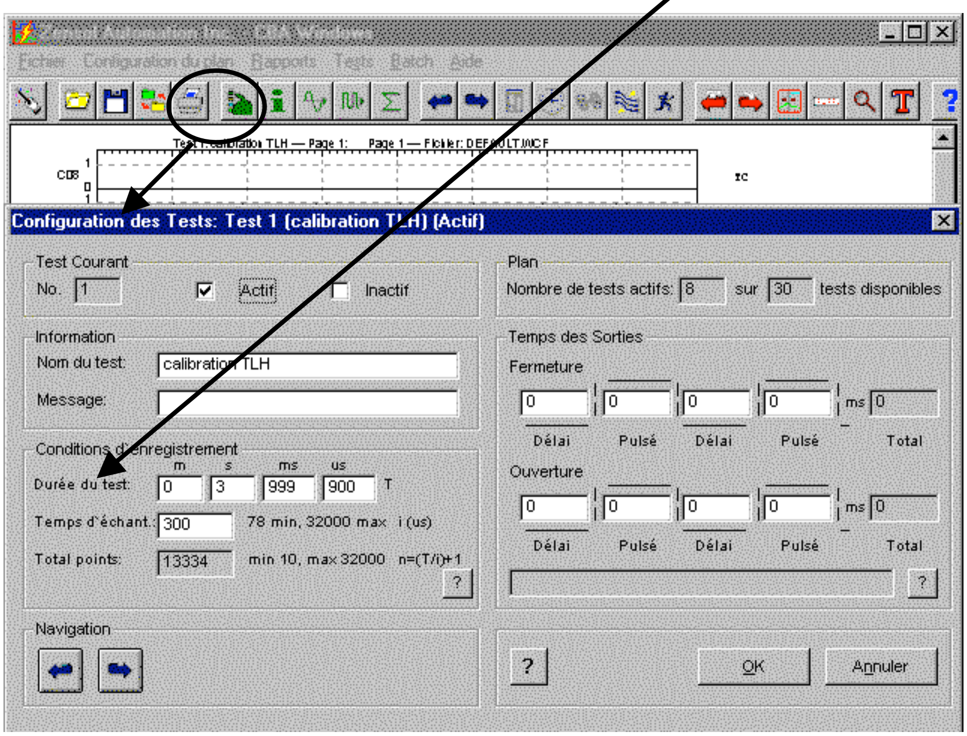
5 Appendix 1 : Calibration procedure for a TLH transducer

Goal :
Calibrating a TLH transducer, before first use or for maintenance purposes.

Materials required :
The TLH to calibrate, 1 CBA-32P connected to a computer, an appropriate standard ruler and 2 C-Clamps.

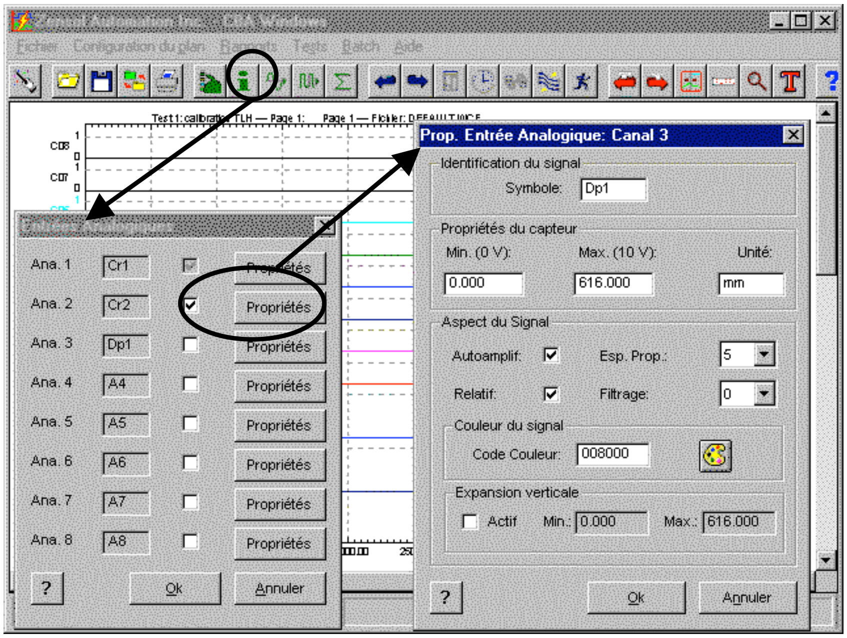
Preparation phase :

- Connect the TLH on one of the analog inputs (except 1 and 2) of the CBA-32P.
- Turn on the CBA-32P.
- Position the standard ruler on the TLH (it is not recommended to place it at the sides) using the two C-Clamps. This ruler will limit the displacement of the cursor to a well-defined range.
- Position the cursor at one end if the ruler.
- In CBA Win, set the duration of the test in the **Test Configuration** screen, as shown below. We will use a test duration of **4 seconds**.



One must now set the parameters for the analog input on which the TLH is connected. Locate the analog channel number on the CBA-32P where the TLH transducer is connected.

In CBA Win, click on **Analog inputs**, then on the **Properties** button associated with the appropriate analog channel, as shown below:



- In the **Transducer properties**, put 0 (zero) in the Min.(0V) box and in the Max. (10 V) box :

If there is a calibration sticker on your transducer, enter the value printed on it. Otherwise, use the default values:

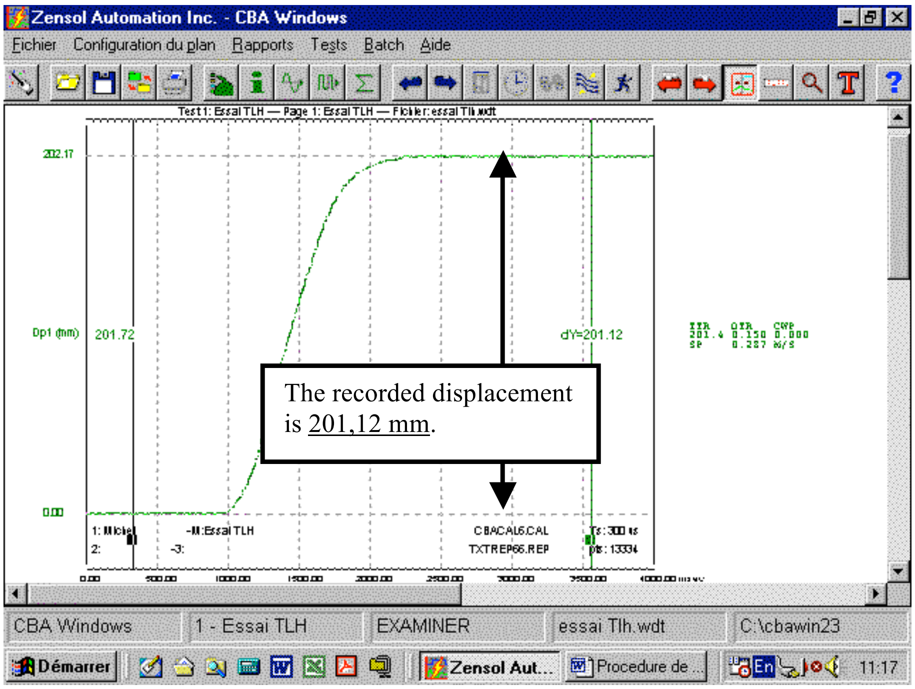
<u>Default values:</u>

TLH 100 : 108 mm
TLH 225 : 234 mm
TLH 300 : 310 mm
TLH 360 : 372 mm
TLH 450 : 463 mm
TLH 600 : 616 mm

Testing phase :

- The testing phase is organized as follows:
  - Trigger the test.
  - Wait about one second.
  - Move the cursor to the other end of the ruler quickly enough so that about one second remains until the end of the test.
  - Wait for the results to display.
  - End of test.

Click on the **Examine** button in the button bar. A vertical bar will appear. Using the mouse, move the bar to the left-hand level section. Press the Space Bar and move the second bar to the right-hand level section. The screen should appear approximately as shown below. The dY measurement, on the right, indicates the measured displacement.



Two cases are possible :

- It is a maintenance procedure :
  - If the recorded displacement is equal to that indicated on the ruler, your TLH is well calibrated.
  - Otherwise, proceed to the calculation step below.
- This is the first time the TLH is calibrated. The procedure is as follows:
  - If the recorded displacement is equal to that indicated on the ruler, your TLH is well calibrated and the value entered for Max. (10V) will be the value to be shown on your TLH.
  - Otherwise, you must apply the following calculation rule :

Calculation phase :

Note : to illustrate the calculation rule, we will use our example of : Max (10 V) = 616 mm and dY=201,72.

Assume : error = 200 – *201,72* → *Measured length in CBA Win*

↓

Length of the standard ruler

⇔ So error = -1,72

Error for :	**200 mm**	is :	**-1,72 mm**
And so for :	**616 mm**	it is :	**x**

We obtain : $x = \frac{616 * (-1,72)}{200}$ = **-5,30 mm**

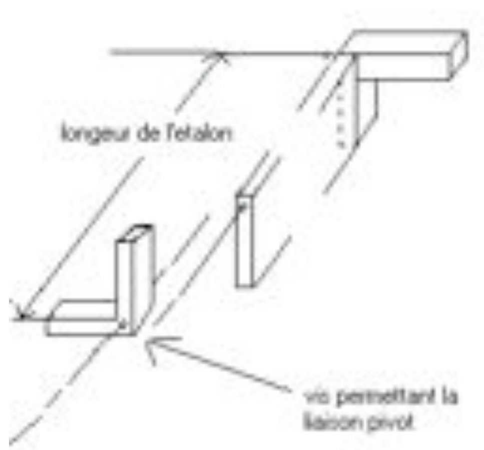
You must now enter, for Max.(10 V): 616 **- 5,30** = 610,7 mm.

- Redo the test using the new Max. (10 V) setting, and if the measured value differs from the length of the standard ruler, you must repeat the preceding steps until the values are equal.

Note : Standard ruler lengths for each transducer are:

For a :	TLH 100: 30 mm	TLH 225: 70 mm
	TLH 300: 100 mm	TLH 360: 120 mm
	TLH 450: 150 mm	TLH 600: 200 mm

Here is a sketch of the standard ruler :

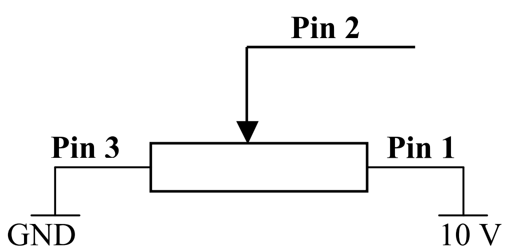


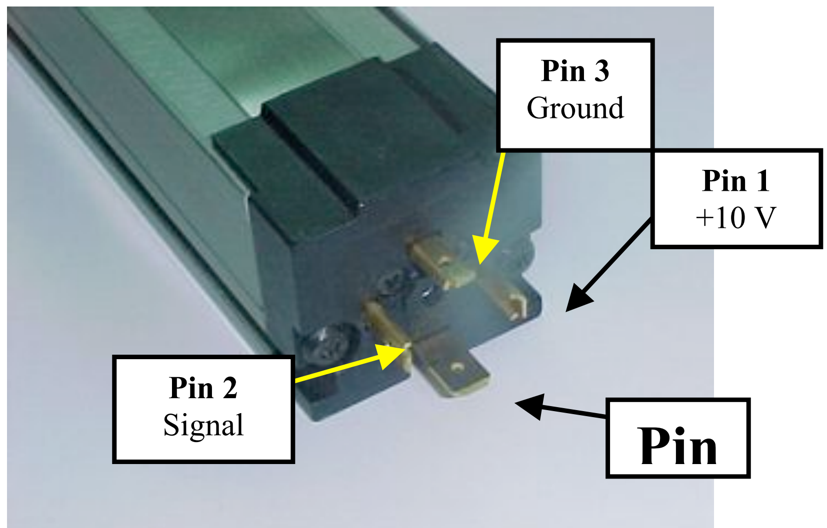
6 Appendix 2: Connecting a NC3FX (ZENSOL female) connector to a TLH

Note: it is very important, during this process, to recognize the difference between the pin numbers on the TLH XXX and the pin numbers on the NC3FX (ZENSOL female) connector. For clarity, **pin numbers on the TLH XXX will be in bold**, *and and the pin numbers of the NC3FX (ZENSOL female) connector will be underlined.*

First, here is how the TLH looks without any connection. In the photo below, you can see the different connection pins on TLH.

Schematic of TLH





Note that **Pin 4** is a screen connection and must not be connected as a "protective conductor" according to DIN EN 61010 T1.

Pins TLH XXX	*Pins NC3FX (ZENSOL female) connector*
Pin 1	Pin 3
Pin 2	Pin 1
Pin 3	Pin 2