Liquefaction Test in the Brutus Tank
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Liquefaction Test
in the Brutus Tank

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CONTENTS:

1. INTRODUCTION

In order to verify the capability of finite element models with the constitutive model MONOT (Molenkamp, 1980) to predict both the initiation of liquefaction of a slope of loose sand and the initial flow pattern a series of liquefaction tests in the BRUTUS-tank at Delft Geotechnics has been proposed (Molenkamp, 1982).
It was intended to prepare numerical predictions before performing the actual tests. For these predictions to be realistic the boundary conditions and the soil parameters in the experiment should be known before hand. Besides the experimental set-up should be adapted in such a way that liquefaction could be induced in a controlled way. Therefore a series of calibration tests were performed and required improvements of the experimental set-up were defined (Greeuw, Molenkamp, 1986).

Although the numerical predictions were not available yet the experiments were started in September 1986. During the preparation of the sand bed several experimental problems were met. All problems involved the preparation of the profile of the slope. The test was performed successfully.

During the elaboration of the measured data it was found that the plotting software had to be adapted in order to plot all measured data at the same time scale.

In this report the test is described and the measured data are presented in such a way that a comparison with numerical predictions is possible.

2. EXPERIMENTAL SET-UP

The BRUTUS-tank has the following internal sizes:

- height : 1 meter
- width : 1 meter
- length : 2 meters

The side walls of the box are made of glass with a thickness of 4 cm.

At a level of 3 cm above the bottom of this box a fluidisation system is installed, which consists of 20 parallel p.v.c. tubes with a diameter of 5.0 cm (see figure 1). These 20 tubes are interconnected by a similar tube supplying them with the water for fluidisation. In the 20 fluidisation tubes sets of three holes with 1 mm diameter have been drilled at distances of 10 cm, through which the fluidisation water can enter the tank. In figure 1 also the planned geometry of the slope is indicated.
In the Brutus-tank an uniform horizontal bed of loose sand can be prepared under water by applying fluidisation and subsequent sedimentation. Then the slope can be made under water by sucking consecutive thin layers of sand (see figure 2). This is done by moving a suction head with a spoiler (see figure 3a) across the sand surface. To prepare a flat surface the suction head is mounted on two interconnected carts on top of the tank. One cart allows the longitudinal motion; the other the transverse motion. The level of the suction head with respect to the carts can be varied continuously. The suction is supplied by an ejector (venturi)(see figures 3b and 3c), which is water operated. To prevent severe vibrations in the tank and subsequent densification the ejector with hoses is hung freely on a rope above the carts.

To apply fluidisation, water is pumped from a reservoir (via the by-pass, see figure 2) to the tubes for fluidisation. The tubes can be saturated before fluidisation is started. For later testing the water from the reservoir can be pumped via a valve (Samson AG, type 241-1) and a flow meter (flowmetering instruments LTD, type: D 357-001/002) in the fluidisation system; in this way the flow of water to the bottom of the BRUTUS-tank can be controlled. Also the differential pressure across the holes at the end of the fluidisation tubes can be measured by means of a differential pressure gauge; it measures the difference in fluid pressure at the same level in the tubes and in the sand. To prevent mechanical damage to the fluidisation tubes a metal grid is positioned on top of the tubes.

Several sensors have been installed, namely:

- 4 pore pressure gauges at the bottom of the tank (= PPGB)
- 9 pore pressure gauges in the slope (= PPGS)
- 3 gap sensors near the toe of the slope (= GS)

The locations of these sensors are indicated in figures 4a and 4b.

The pore pressure gauges in the slope have been connected to nylon wires, which have been stretched between the metal grid near the bottom and a support near the top of the tank. During the test these wires have been detached from the upper support and have been supported by small floats to facilitate retrieval of the sensors (see figure 5).

The gapsensors have been connected to very stiff bars, supported at the top of the tank. The reflectors consisted of a piece of perspex with dimensions:

- length : 160 mm
- width : 35 mm
- thickness : 3 mm

and a piece of copper glued to it with dimensions:

- length : 85 mm
- width : 35 mm

thickness : 0.5 mm

These reflectors were stuck vertically about 90 mm into the soil.

The above mentioned equipment for the preparation of the profile of the slope has been developed during a process of solutions of consecutive experimental problems.

In the first trial the suction pressure in the suction head was produced by the hydraulic head of the water in the BRUTUS-tank. The suction head was moved by hand. This produced a very irregular suction and often a complete blockage of the suction pipe occured.
In the following trial the suction was produced by an ejector (venturi). This ejector produced better suction without any blockage. However, the motion by hand of the suction head appeared to be too irregular to obtain the required profile. Several times the sand bed liquefied while using this method. To obtain a controlled horizontal motion of the suction head on top of the tank a guiding system was mounted. This system consisted of two carts on top of each other. The lower cart could move in longitudal direction of the tank; its width was equal to that of the tank. The upper cart could move in the transverse direction of the tank. The suction head was connected to this upper cart; in this way it could be moved by hand in a horizontal plane at any level in the tank. It was thought to be possible to suck off horizontal layers with a constant thickness. However, several refinements of the mounting of the suction pipe appeared necessary to obtain sufficient flexibility to remove a thin layer of sand across the required area. Near the sides of the tank the sand bed became irregular; besides both the slope and the surface of the horizontal sand layer could not be made flat and once an irregularity induced a spontaneous liquefaction of the slope during the suction process.

As a possible remedy the suction head was adapted with spoilers to allow suction from the front of the suction head only. After these adaptations the required profile could be made. However, it was found that during the preparation of the slope significant densification had occured; this densification was believed to be caused mainly by the vibrations, which were induced by the ejector (venturi) which was mounted on the upper cart on top of the tank. Despite the high density a first liquefuction test was performed, but because the sand was too dense no liquefaction occured.

To prevent the densification during the preparation for the next proper liquefaction test on loose sand the ejector was hung freely above the carts; in this way no vibrations were propagated to the tank and a sufficiently loose sand bed was obtained.

3. PREPARATION OF SLOPE

After installing the 4 porepressure gauges at the bottom and the 9 porepressure gauges for the slope on the nylon wires the tank was partly filled with water. Then the sand was placed hydraulically, to prevent any damage to the pore pressure gauges, which are relatively sensitive (maximum ranges of 175 and 350 mbar). The total dry weight of the sand was approximately 2600 kg.
Then the fluidisation could be started. The water entered from the reservoir via the "by-pass". The flow of water was controlled in such a way that the surface of the fluidized sand reached to only 1 cm below the overlet of the tank; the required flow was 50 - 60 L/min.

To ensure a complete fluidisation of the sand bed a steel stirring plate was moved through the sand on top of the metal grid at the bottom of the tank. This fluidisation was maintained until the outcoming water was clear; this took about 4 hours.
After stopping the flow of water the sand settled during one hour. Then the surface reached a level of about 750 mm above the top of the metal grid.
Next again fluidization was induced. During this phase both the differential pressure and the pore pressures at the bottom of the tank were measured. The results are shown in figure 6. It should be noticed that in the plot the time bases of the different signals have been shifted.
The differential pressure increases within about 3 minutes to about 43 mbar. The pore pressures at the bottom (channels 11, 13 and 14) increase within about 1.4 minutes to an average maximum value of about 69 mbar; ($\approx 6900 \frac{N}{m^2}$); in fact also an overshoot of about 5% occurs.

The pore pressure at channel 12 indicates only 54 mbar, ($\approx 5400 \frac{N}{m^2}$) thus only 78% of the other sensors.

The expected increase in pore pressure Δu at the bottom of the tank during fluidisation is calculated by:

$$\Delta u = (1 - n)(\gamma_s - \gamma_w)\ h \qquad (1)$$

in which (see Greeuw, Molenkamp, 1986)

$n \approx 0.465$: assumed porosity
$\gamma_s \approx 26500 \frac{N}{m^3}$: unit weight of mineral
$\gamma_w \approx 10000 \frac{N}{m^3}$: unit weight of water

For an estimated thickness of the fluidized bed above the metal grid of h = 0.75 m the increase in pore pressure near the bottom reads:

$$\Delta u = 5754 \frac{N}{m^2}$$

and for an estimated thickness of all the sand above the bottom

$$h = 0.75 + 0.105 = 0.855 \text{ m}$$

it becomes

$$\Delta u \approx 6559 \frac{N}{m^2}$$

Comparing the measured and expected pore pressures it can be concluded that near the gauges of channels 11, 13 and 14 all the sand has been liquefied while near the gauge of channel 12 a layer with the thickness Δh may not have been fluidized, while:

$$\Delta h \approx 0.855 * \frac{(69 - 54)}{69} \approx 0.19 \text{ m}$$

In this case the stirring might have helped to improve the homogeniety of the liquefied mixture.

After stopping the fluidisation again and allowing settlement during 1 hour the sand reached the same top level of 0.75 m above the top of the metal grid. Then the sand was densified by giving impacts to the side of the tank. As a result the surface settled to a level of about 0.678 m above the top of the metal grid. Then a series of input flows were applied. The results are shown in figures 7A and 7B. In table 1 the measured average excess pore pressures Δu, the differential pressure Δp (channel 15) and the flow q (channel 16) have been collected.
The properties of the fluidisation system can be expressed in the form of a relation between the flow q and the differential pore pressure across the holes of the fluidisation tubes.
The measured flow q and differential pressures Δp of table I are shown in figure 8. The measured data have been fitted by the following expression:

$$q = C \, \Delta p^{\alpha} \tag{2}$$

in which Δp in kPa and q in L/min.
The fit of figure 8 is obtained by using the following parameters.

$C \approx 17.092$ L/min
$\alpha \approx 0.719$

In figure 9 the flow q is shown versus the excess pore pressure Δu at the bottom. The linear fit gives

$$\frac{q}{\Delta u} \approx 3.28 \left(\frac{L}{\min *KPa}\right)$$

From this the permeability k can be estimated by

$$k = \frac{ql\gamma_w}{A^*\Delta u} = \frac{3.28\left(\frac{L}{\min.KPa}\right) . 0.678 \ (m) \ 10}{2 \ (m^2)} \left(\frac{KPa}{m}\right) = 11.1 \left(\frac{L}{m^2.\min}\right)$$

$$= 11.1 * \frac{10^{-3}}{60} \left(\frac{m}{sec}\right) \approx 1.85 \ 10^{-5} \left[\frac{m}{sec}\right]$$

in which A is the area of the plan of the tank.

Next a new sand bed was prepared by applying fluidisation and subsequent sedimentation during one hour. To get some insight into the speed by which a pore pressure wave propagates through the sand the pressure in the fluidisation tubes was increased in one step as fast as possible. The responses of the pore pressures at the bottom (PPGB 12) and half way the height (PPGS 8) were measured by means of an oscilloscope. The resulting photo is shown in figure 10. From this picture it is seen that at the bottom the pore pressure increases stepwise in about 1.0 sec. The pore pressure halfway the height shows a very similar response with hardly any delay in time; the shapes of both responses are practically equal; consequently the velocity of propagation is higher than can be measured by means of the current instrumentation. This result suggests a reasonable degree of saturation of the sand (see also Greeuw, Molenkamp 1986).

Next again fluidisation was applied. After stopping the fluidisation and resting during 1 hour the sand reached again the same top level of 0.75 m above the top of the metal grid.
Then the sand was densified by applying a slight tap at each corner of the tank. The tap was given by hand with a wooden block with sizes of 500 * 150 * 50 mm. The stroke of the wooden block before impact was about 30 cm. In figure 11 some measured pore pressures are shown for two taps; one at the side of the toe of the slope, the other at the side of the top of the slope. The maximum excess pressures Δu have been collected in table 2, together with the estimated excess pressure to cause complete liquefaction.
From these results it is learnt that after each tap only complete liquefaction occurs near the side were the tap has been given (for location of gauges, see figures 4 a and 4 b). From figure 11 it is also learnt that the excess pressures dissipate in about 30 sec.

The taps caused a settlement of the surface of approximately 15 mm; thus the average level after densification was about 735 mm above the top of the metal grid.
Then the sand was left for another 24 hours; during this period no further settlement occured. Then the density of the sand was measured by means of a perspex cylinder with wings (see figure 12). This cylinder had been submerged in the liquefied sand during fluidisation and fixed at a stable position near the end of the tank at the side of the toe of the slope by means of 2 steel rods connected to the top of the tank. After settlement of the sand this cylinder was sticking out of the sand about 40 - 50 mm. Then a thin flat layer (about 30 - 40 mm) of sand was sucked off by means of a suction pipe with a diameter of about 20 mm. The suction pressure was supplied by the hydraulic head of the water in the Brutus tank. Then the suction pipe was adjusted in such a way that again a flat layer with a thickness of exactly 100 mm could be sucked; this sand was collected, dried and weighted. In this way both the in-situ volume and weight were known and the in-sity density could be calculated; a porosity of n = 0.453 was obtained.

Then the slope was prepared. As described in chapter 2 this aspect was found to be unexpectedly difficult. Many problems had to be overcome before a suitable slope could be made. Here, only the final procedure is described.
First the shape of the slope was indicated by sticking tape on both glass side walls.
Then for each horizontal layer to be sucked off a small groove was dug by means of a small spade near the end of the tank, in which the suction head could be lowered. Next the thin layer of sand (about 2 cm) was sucked off across the required area. The operator had to move the upper cart by hand while standing up and looking at the suction head through the water surface, which gives a distorted view.
To improve his observation also a video camera and screen were installed; the camera was positioned near the glass wall. In this way it was found to be possible to guide the suction head carefully past the nylon wires supporting the PPGS's and to obtained a flat horizontal surface.
The slope was formed by sucking successive horizontal layers with different lengths; these lengths were extended so far that a flat natural slope occured with a steepless of about 30.9°, which is very similar to the planned steepness.
Finally the gapsensors were installed. The reflectors of the gapsensors were stuck in the sand very gently and the gapsensors were mounted on the rigid bars and positioned near the reflectors. In addition 3 horizontal rows of small plastic nobs were put on top of the sand to improve the later visual observations of the motion of the surface. A photo of this situation is shown in figure 13.

It is seen that the water is very clear. During previous stages sometimes the water had become very cloudy by growing algae. Several methods were tried to improve the clearness of the water; e.g. by adding poison and chloride and reducing the amount of light. The best method was found to be a refreshing of the water above the slope.

4. MEASURING SYSTEM

The measuring system is only described superficialy. It is indicated schematically in figure 14.
Each sensor is indicated by a typename, namely: PPGS - (Pore pressure gauge of slope), PPGB - (pore pressure gauge of bottom), DIFFPR - (differential pressure across holes in fluidisation tubes), FLOW - (flow meter), GS - (gap sensors). If required also a sequence number is given (see figures 4A, 4B and 14).
Each sensor is connected to an amplifier via a channel; each channel has a sequence number as indicated in figure 14. Because a series of pore pressure gauges were already in fault before the test was started, they are not shown in figure 14; a total of 16 channels were sufficient. The signals produced by the amplifiers are electric analog. From those 16 channels 12 have been connected to 2 penrecorders with each 6 channels. Besides all 16 channels have been connected to a datalogger (HP 3497A) with for each channel an integration time of about 30 µsec and a sample interval of about 550 µsec. The digital data can be printed and plotted. For the plots per channel the actual sampling times have been determined. Because all channels are sampled, one after the other, within each sample interval of 550 µsec for each channel the actual sample time differs from those of the others. On average the time interval between successive channels was found to be about 35 µsec.

The valve of the fluidisation system has been controlled by means of a PID-controller (proportional integral differential controller; VDO Mess- und Regeltechnik GMBH, type 24/81-14). The input signal has been generated by a function generator; the coupling has been obtained by means of the signal from the pore pressure gauge PPGB1 (see figures 4A, 4B and 14). The PID-controller produced the input signal for the I/P (current/pressure) converter, which produces an air pressure to control the valve of the fluidisation system.

5. CALIBRATIONS

First the flowmeter has been calibrated. In this calibration an output signal in Volts has been used. The calibration has been performed in the range: $0 \geqq q \geqq 50$ L/min.

The measured data are shown in figure 15.
In the range $0 < q < 50$ L/min a reasonable linear fit is obtained with:

$$q = F * V \qquad (3)$$

in which:

$$F \approx 237 \left(\frac{L}{min} * \frac{1}{Volt}\right)$$

The data of the calibrations of all sensors have been collected in tables 3 to 19.

For each type of sensor the following maximum absolute errors were found:

- pore pressure gauges in slope (PPGS8) : 0.21 kPa
- pore pressure gagues at bottom (PPGB1): 0.038 kPa
- gap sensors (GS1) : 0.040 mm
- differential pressure gauge : 0.021 kPa

Next the regulation of the PID-control of the valve of the fluidisation system is discussed. This regulation has been performed after performing the first fluidisation and subsequent sedimentation as discussed in chapter 3. Some typical data of this regulation are shown in figures 16, 17 and 18. The aim of the regulation is to obtain an instantaneous response of the flow when changing the input signal instantaneously by means of the function generator. However, in reality always some delay and overshoot will occur and besides oscillations may be induced. Therefore a kind of optimum adjustment must be chosen. The method to find this optimum is described by e.g. Cool, Schijff, Viersma (1979, in Dutch).

The controlling process is illustrated in figure 19. The input signal R(s) represents the required values of the flow, as generated by a function generator as a function of the frequency s.
The output signal C(s) is the actual input flow in the tank; in fact in the current tests the resulting excess porepressure at the bottom of the tank are considered.
The frequency response function H(s) of the fluidisation system causes delays of the output signal C(s) compared to the input signal R(s).

The controller with frequency response G(s) must be adjusted in such a way that the delay in the output C(s) becomes minimum. The properties of the controller are usually approximated by the function:

$$G(s) = K_p \left(1 + \frac{1}{\tau_i s} + \tau_d s\right) \qquad (4)$$

in which:

K_p - amplification factor
τ_i - time constant of integration
τ_d - time constant of differentiation

The magnitudes of these parameters have to be chosen. To this end the constants τ_i and τ_d of the controller are put at zero and the amplification factor K_p is increased stepwise untill oscillation occurs.
The current value at oscillation of the amplification factor K_{posc} and the resulting period T_{osc} of oscillation are noted.
Then the optimum values of all constants K_p, τ_i and τ_d can be estimated using the rules by Ziegler and Nichols as indicated in table 20. Depending of the values of K_p, τ_i and τ_d different types of control can be applied.

In the test first proportional type of control (P) has been applied with K_p = 6 (see figure 16). Oscillation occured.
Then a value of K_p = 4 has been applied. Still oscillation occured.
Next also values of K_p = 2.5 and K_p = 1.6 have been used.
In both cases oscillations occured only in the rising part of the response. The period of oscillation was about T_{osc} = 30 sec.
Application of the control rule of table 20 gives:

Type of action	K_p	τ_i sec	τ_d sec
P	2	0	0
PI	1.8	25.5	0
PID	2.4	15	3.75

When trying the PI-type of action with K_p = 1.6 and τ_i = 30 sec too much damping has been measured. Reduction of τ_i to τ_i = 0.3 sec resulted in too much overshoot (see figure 17).
Finally only proportional type of control has been chosen with K_p = 1 (see figure 18). In this case the flow could increase from zero to 31.5 L/min within 1.5 sec (see figure 18). An acceptable overshoot of only 4% occured.

6. VISUAL OBSERVATIONS DURING THE TEST

As shown in photo 1 (figure 10) at time 11 hours - 6 minutes - 53.2 sec. (11-6-53.2) at this stage the slope is stable. At about 11-6-54 the pump of the hydraulic system is switched on; this can be heart from the sound track of the video recording.
At 11-6-55 no visual changes have occured yet (see figure 20, photo 2).
At 11-6-57.2 the slope has deformed, causing horizontal displacements of all reflectors of about 1 to 2 cm (see figure 21, photo 3). At this stage the lower gap sensors (GS) has raised by about 1 to 2 cm, the middle GS has settled by about 1 cm and the higher GS has settled by about 3 cm. The lower part of the slope is bulging while the higher part is settling.
At 11-6-59.4 significant flow has occured (see photo 4, figure 21) while at 11-7-1.6 (see figure 22 photo 5) the surface changes towards a horizontal surface.
Consecutive photo's at 11-7-3.7 (figure 22 photo 6) 11-7-6 (figure 23 photo 7) and 11-7-8 (figure 23, photo 8) show that the surface becomes practically horizontal; thus the sand behaves like a thick fluid.

7. EXPERIMENTAL DATA

The measured data during the first 15 sec. of the test as digitized by means of the datalogger have been plotted as a function of time in figures 24 up to 31. Because the time interval of 0.55 sec between consecutive samples of each measured quantity is relatively large compared to the step-response time of about 1.0 sec. (see figure 10) of the system the above mentioned plots will be rather rough approximations of the actual measured data. Therefore also the measured analog data as plotted by means of the penrecorders have been added in figures 32 and 33. In those figures the curves have been shifted as a function of time due to the mechanical properties of the penrecorders. In these figures also the measured data during the switching off of the flow are shown.

As shown in figure 24 the flow q has been increased from zero to a value of q ≈ 8.6 L/min within a rising time of about 2.5 sec. According to figure 24 the flow started to increase at a time of about 1.125 sec. of the time scale. From the data of the penrecorders (see figure 32, channel 16) it was understood that first during about 0.3 sec the flow increased relatively slowly at a rate of about 2 L/min/sec. Then it increased faster at a rate of about 7 L/min/sec during about 0.8 sec. Finally the rate decreased to zero during about 1.5 sec when the flow reached the maximum value of q ≈ 8.6 L/min.
The measured data of the excess porepressure at the bottom (PPGB's, channels 11, 12, 13 and 14) are shown in figure 25. The data of channels 12, 13 and 14 are very similar. They increase almost linearly within about 3.75 sec to a value of about Δu = 4.5 KPa.
The data of channel 11 are similar to the above mentioned data during about 2.7 sec when reaching an excess porepressure of about 3.25 KPa but then for channel 11 a much slower response is measured; the value of Δu = 4.5 KPa is only reached at about 9.4 sec after the start of the flow. The same conclusions can be drawn on the basis of figure 32 in which analog data of channels 11 and 12 are shown.

The measured data of the excess pore pressure in the slope (PPGS) are shown in figures 26, 27 and 28. In figure 26 the data of channels 1, 3 and 4 in a cross-section of the slope (see figure 4b) have been collected; for channels 1 and 4 also the analog data according to figure 33 have been indicated. It is found that for these channels the porepressure increase is very similar untill about 1.35 sec after the start of the flow. After that channel 4 shows an increasing porepressure while channel 1 shows a sharp decrease and even tension during about 0.9 sec. Channel 3 shows an intermediate behaviour. In the next phase, thus after about 2.25 sec after the start of the flow, the excess porepressures increase further to reach a maximum of about 3 to 4 KPa at about 10 sec after the start of flow.
In figure 27 the measured excess porepressures of channels 2 and 5 are shown together with the data of the differential pressure (channel 15). Also the analog data of channels 5 and 15 are indicated on the

basis of the data in figures 32 and 33. It is found that the response of channel 2 is very similar to that of channel 1 as shown in figure 26, but unexpectedly the data of channel 5 are not similar to those of channel 4; namely channel 5 only starts to increase after about 2.1 sec after the start of the flow.
In figure 28 the excess porepressure at channels 4, 5 and 6 in the slope parallel to the toe of the slope are shown. Also the analog data of channel 6 according to figure 33 are indicated. It is found that the data of channels 4 and 6 are similar thus channel 5 remains the exception.

The digitized data of the gapsensors (GS) have been plotted in figure 29. Besides also the analog data of channels 7 and 9 according to figure 32 are drawn. It is found that the sensors of channels 7 and 9 become large (10 mm) after about 1.7 sec after the start of the flow, while for channel 8 this occurs about 2.2 sec after this start.
Besides it is learnt that channel 8 becomes again measurable after about 8.1 sec.
From the visual observations it is learnt that the latter phenomenon is caused by the reflector of channel 9 which approaches the sensor of channel 8.
Comparision of the visual observations as described in chapter 6 with the current measured data indicate that zero time of the measurements coincides roughly with about 11 hours 6 minutes and 54 seconds of the visual observations.
To facilitate comparisons all digitized measured data as shown in figures 24 up to 29 have been collected in figure 30.

In figure 31 again all digitized measured data are shown during a period of 100 sec. During this period the liquefaction induced flow occurs completely and even the porepressures dissipate.

8. FINAL STATE AFTER LIQUEFACTION

To obtain some insight into the internal deformation of the sand, at the end of the test after switching off the flow also the final state has been determined. The mean height of sand at that stage was about 50.5 cm above the top of the metal grid.
The positions of the floats supporting the nylon wires by which the pore pressure gauges in the slope had been placed were measured again. These values have been collected in table 21 together with the data as measured before the test was performed.

After switching off the flow the penrecorders showed that for the pore pressure gauges in the slope pore pressures remained. In figure 28 the recorded data with the flow are shown. Only the initial part of the test and the part with the switching off of the flow are shown (channel 16). In figure 29 the recorded data of PPGS 1, 4, 5 and 6 during this period are given. The remaining pressures after switching off have been collected in table 22. The related vertical displacements have also been collected in table 21. Assuming that the nylon wires between the top of the metal grid and the pore pressure gauges remain stretched at constant length the horizontal displacement can be estimated when the settlement of the gauges are known. These calculated horizontal displacements also have been collected in table 21.
To visualize these results in figure 30 the estimated new positions of the wires are sketched roughly. From these results it can be understood that all gauges have moved to the left, especially the upper layer has moved significantly.

After draining the sand from the tank the final density of the sand was measured again by means of a metal ring of approximately 30 cm diameter which was pushed approximately 15 cm in the sand. The measured porosity read: n = 0.439.

9. SUMMARY

By fluidation and subrequest sedimentation in the Brutustank an uniform sand bed has been prepared. By sucking off thin layers of sand underwater an uniform underwater slope has been made. This slope has been loaded in a controlled way by water flowing from the fluidisation tubes at the bottom of the sand bed; in this way liquefaction has been induced.
The measured data of displacement and porepressure allow the verification of the capabilities of the MONOT model to predict liquefaction.

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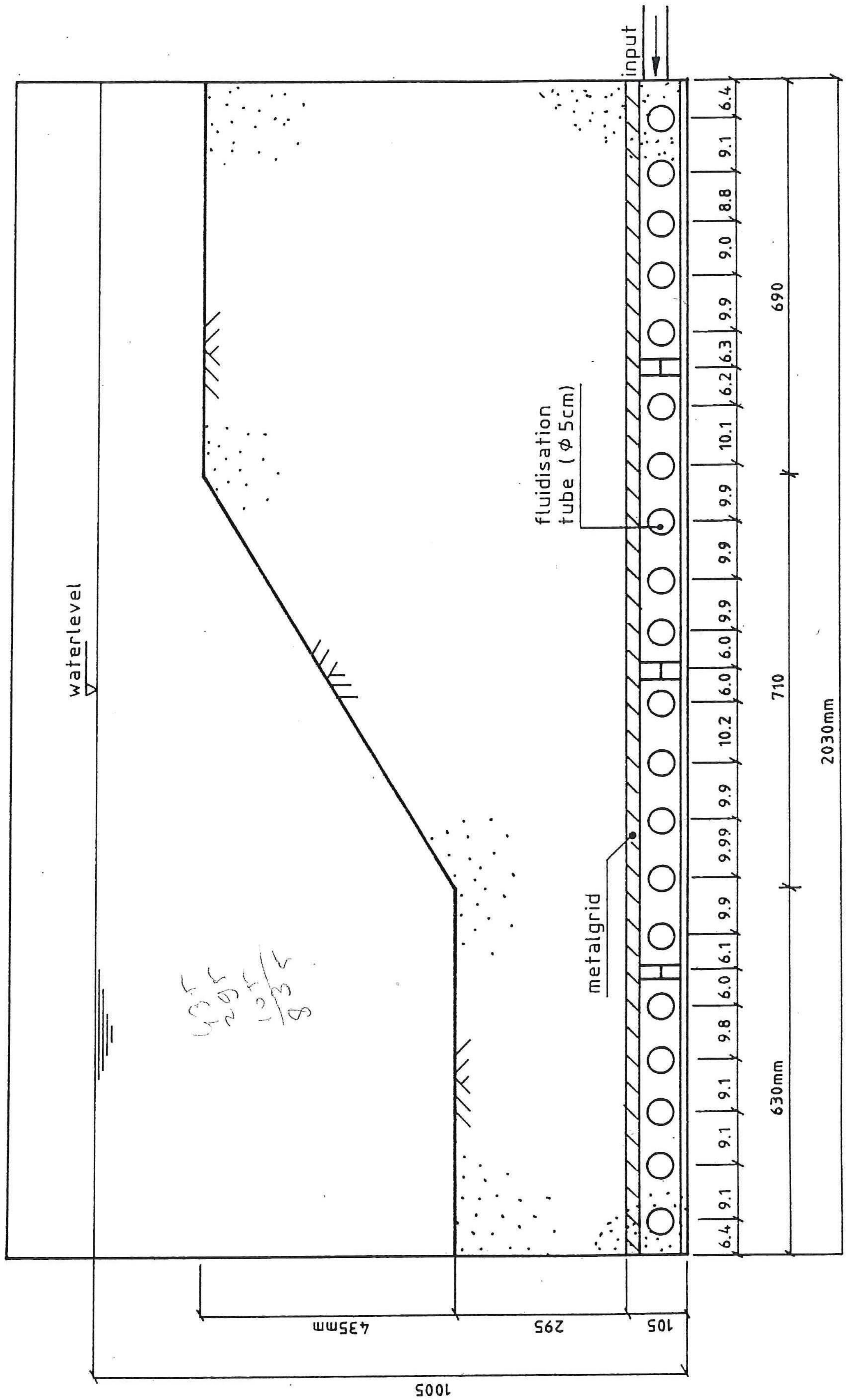

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CROSS-SECTION OF BRUTUSTANK
WITH FLUIDISATION TUBES

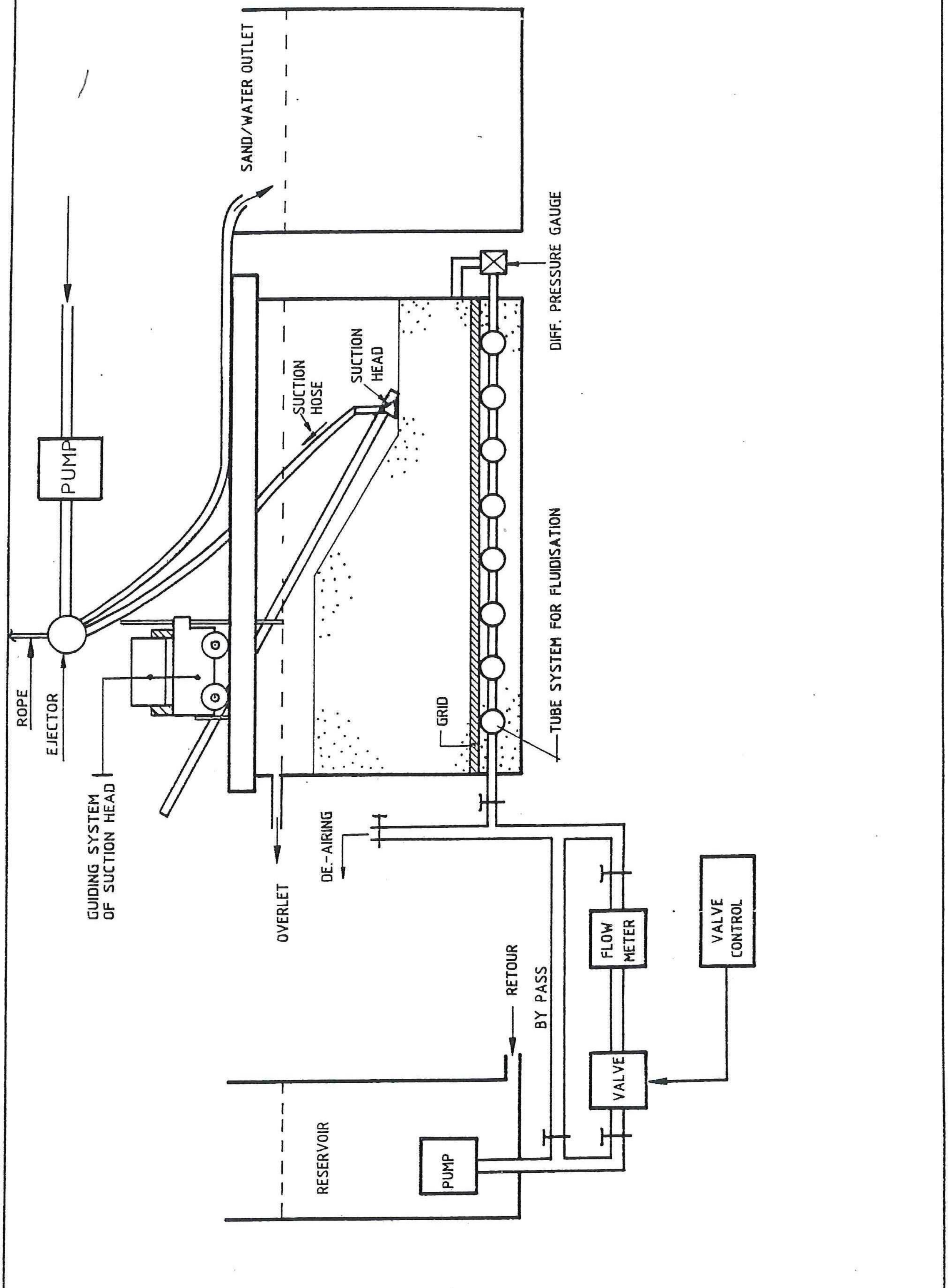
CO-287130
BO-690504

gez.

FIG. 1

form.
A4

LIQUEFACTION TEST BRUTUSTANK



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d d.
87 - 02 - 19
get.
EB

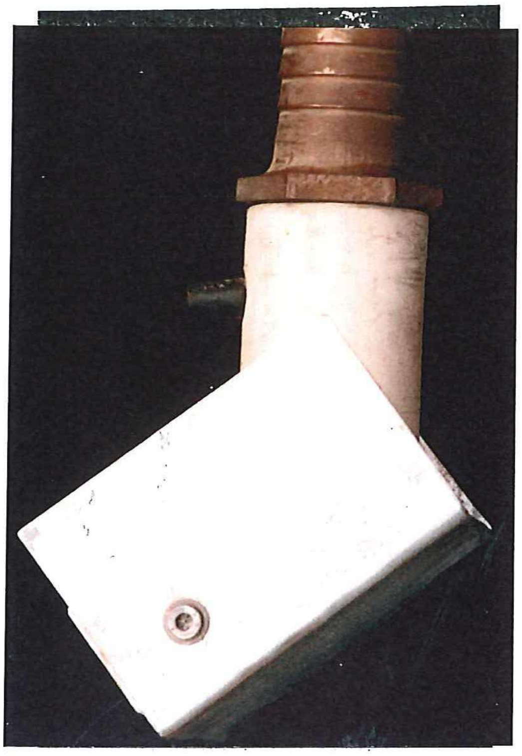
VIEW OF THE MECHANICAL PARTS

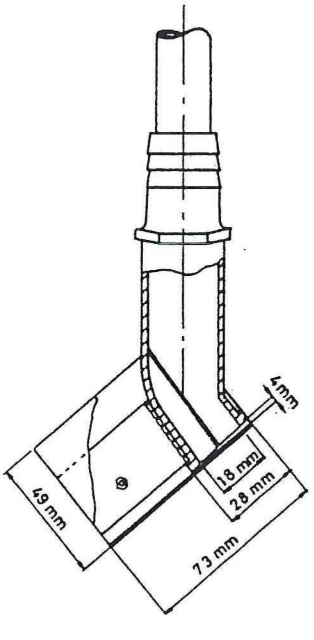
CO - 287130
BO - 690504
gez.

form
A4

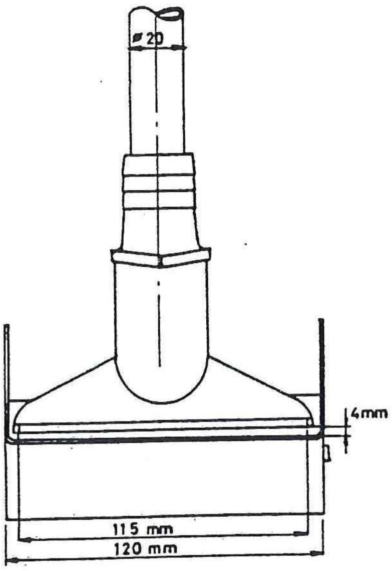
LIQUEFACTIONTEST BRUTUS TANK

FIG. 2





CROSS-SECTION



FRONT VIEW

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LIQUEFACTIONTEST BRUTUSTANK

CO-287130
BO-690504

DETAILS OF SUCTION HEAD

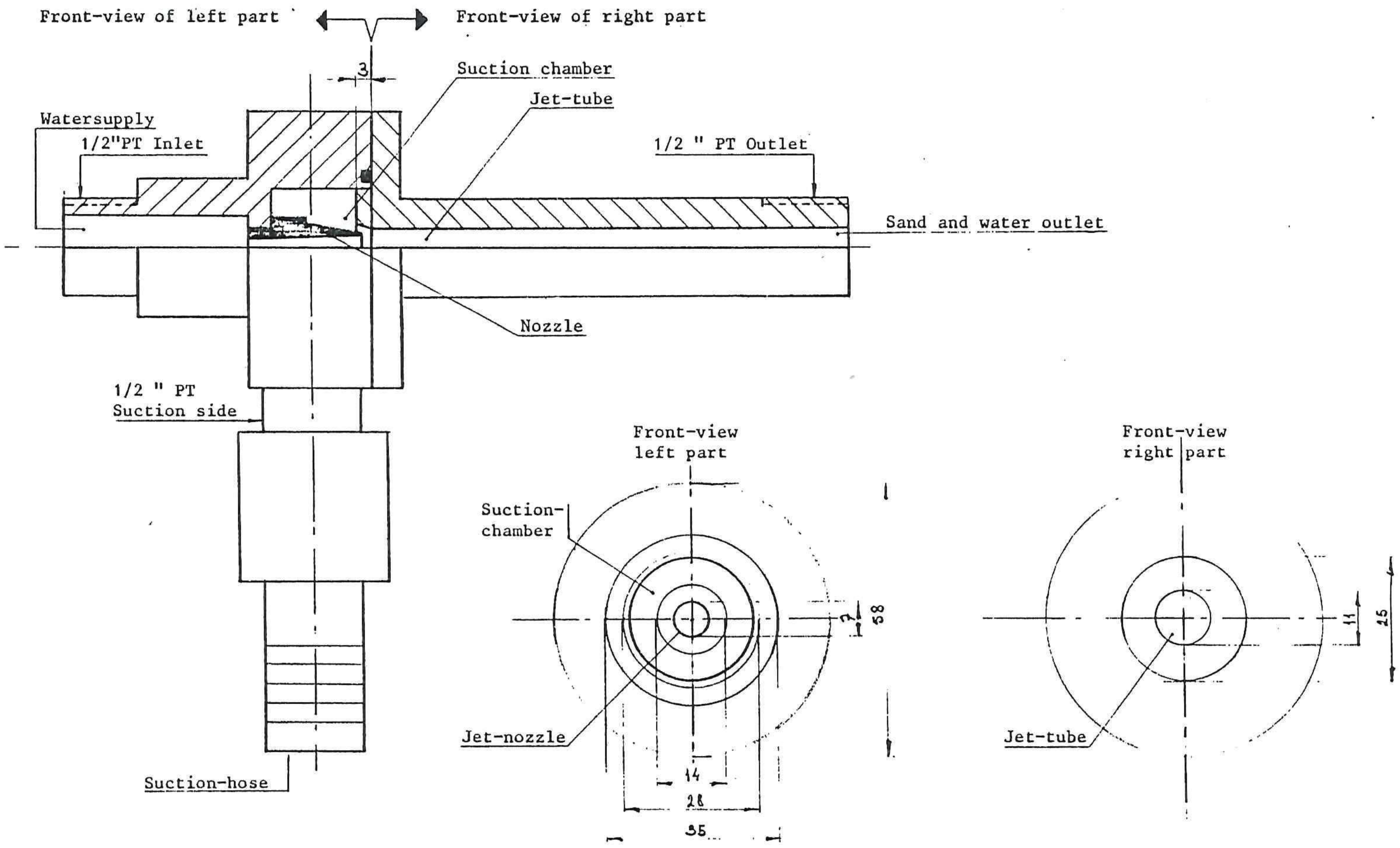
FIG. 3A

form
A4

COMBINED CROSS-SECTION AND VIEW

Fabr. : ELLEHAMMER - DENMARK

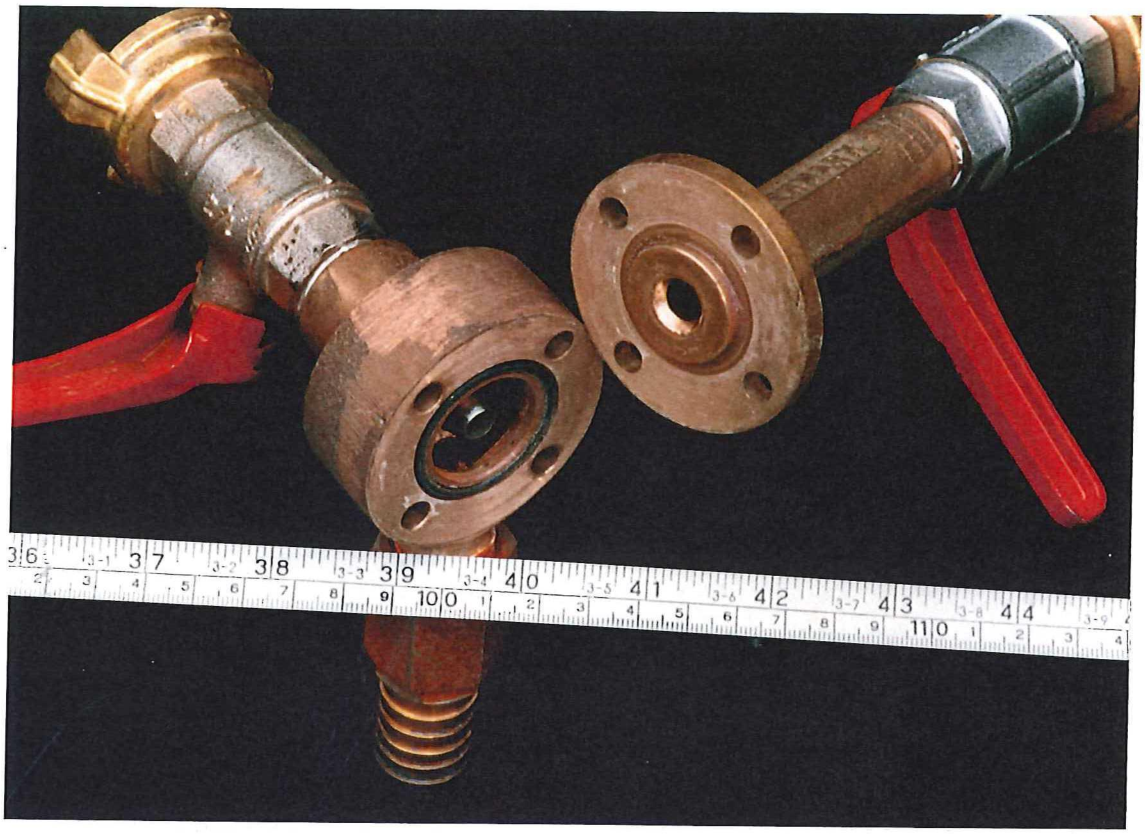
Distr.: KUYL EN ROTTINGHUIS - UTRECHT



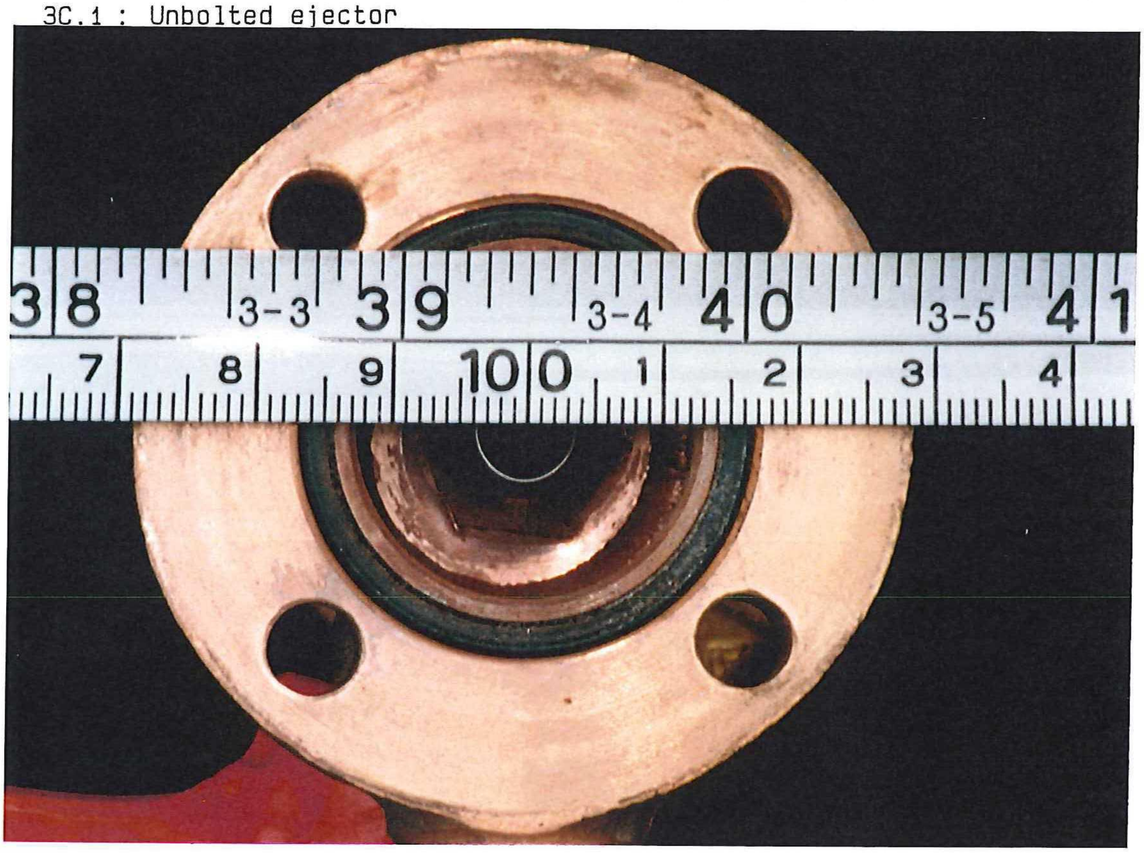
DELFT GEOTECHNICS

LIQUEFACTIONTEST BRUTUSTANK
Jetpump - ejector

Dt: 87-02-19
CO - 287130
Figure : 3 b



3C.1 : Unbolted ejector



3C.2 : Front of left part ejector

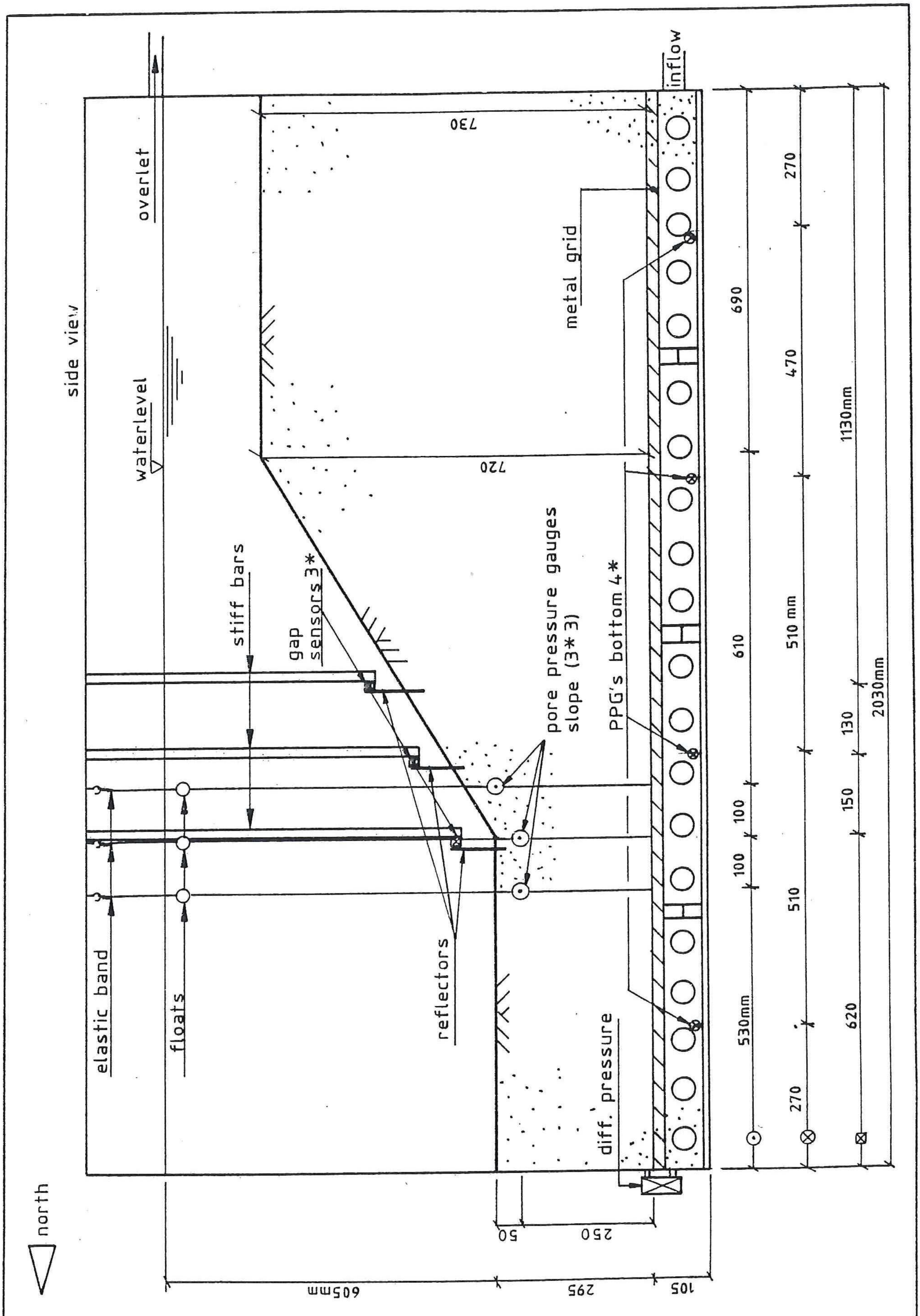
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Jetpump - ejector

CO - 287130

Figure : 3 c



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R.

LOCATION OF GAUGES BEFORE THE TEST-SIDE VIEW

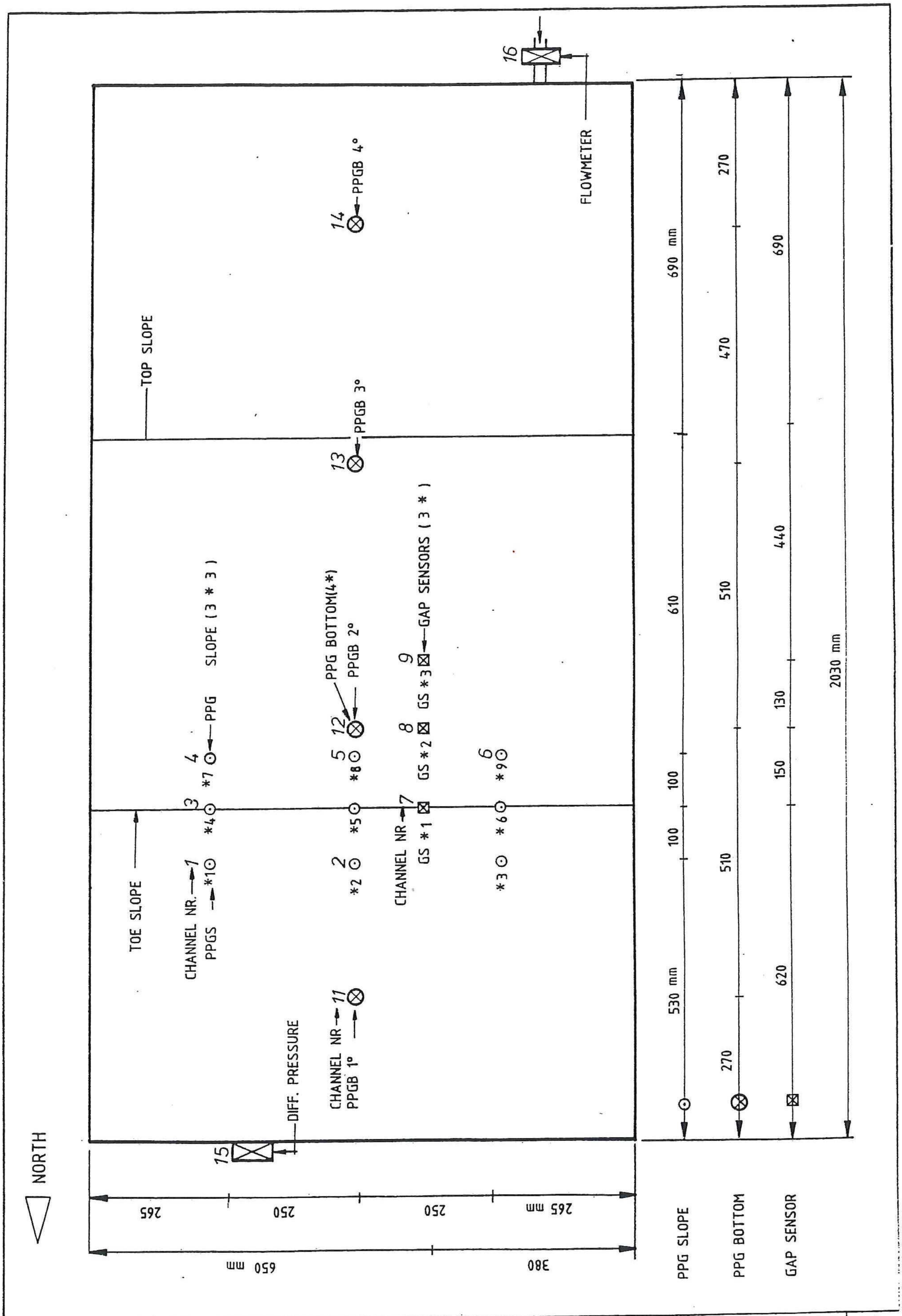
CO-287130
BO-690504

gez.

form.
A4

FIG. 4A

LIQUEFACTIONTEST BRUTUSTANK



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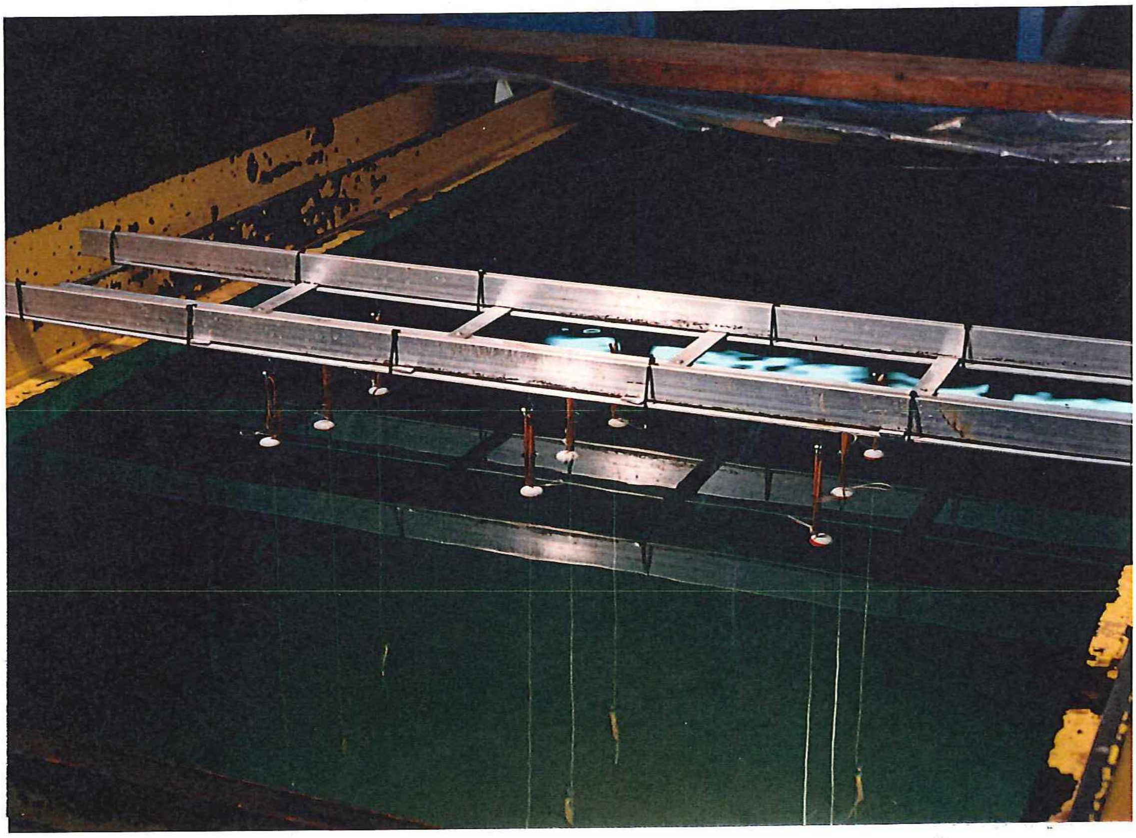
LOCATION OF THE GAUGES BEFORE THE TEST - TOPVIEW

LIQUEFACTIONTEST BRUTUS TANK

d d.
87 - 02 - 19
get
EB
CO - 287130
BO - 690504
gez
FIG. 4B
form
A4

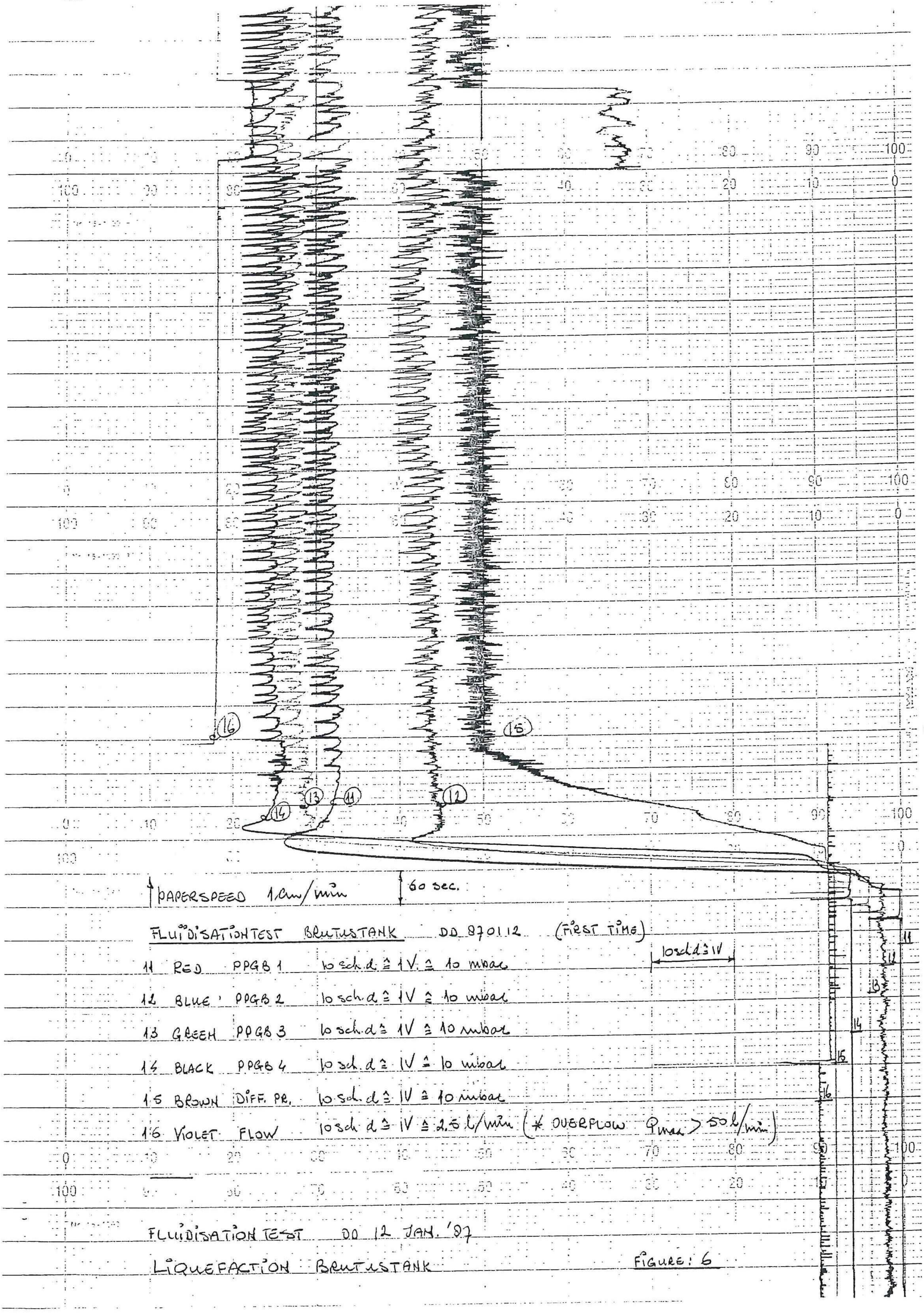
5A : Total view of porepressure gauges in slope



5B : View of upper support and porepressure gauges in slope

DELFT GEOTECHNICS	Dt: 87-02-19
LIQUEFACTIONTEST BRUTUSTANK View of porepressure gauges in slope	CO - 287130 Figure : 5

E1 - Sec



↑PAPERSPEED 1cm/min

60 sec.

FLUIDISATIONTEST BRUTUSTANK DD 870112 (FIRST TIME)

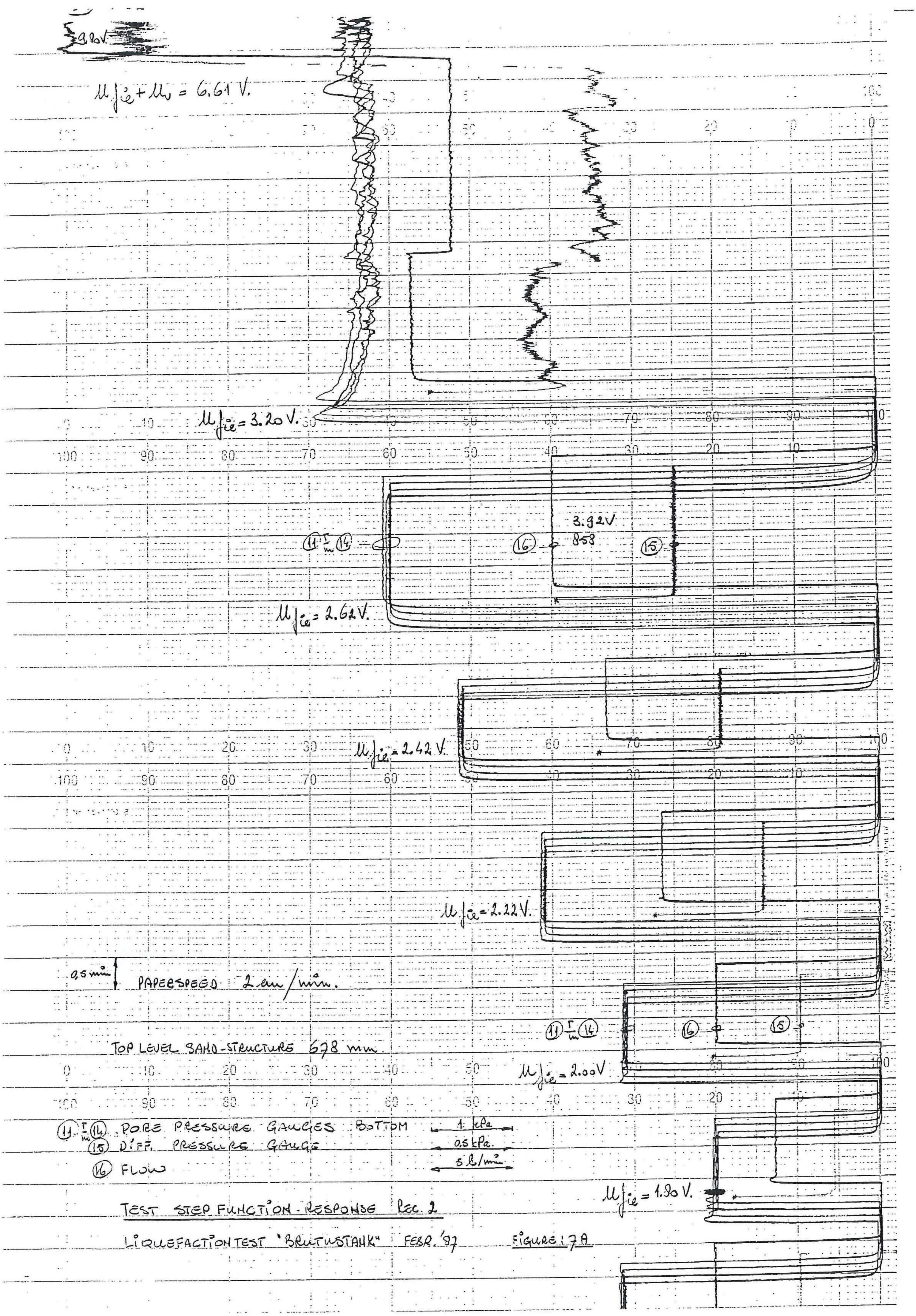
10 sch.d ≙ 1V

11 RED PPGB 1 10 sch.d ≙ 1V ≙ 10 mbar
12 BLUE PPGB 2 10 sch.d ≙ 1V ≙ 10 mbar
13 GREEN PPGB 3 10 sch.d ≙ 1V ≙ 10 mbar
14 BLACK PPGB 4 10 sch.d ≙ 1V ≙ 10 mbar
15 BROWN DIFF. PR. 10 sch.d ≙ 1V ≙ 10 mbar
16 VIOLET FLOW 10 sch.d ≙ 1V ≙ 2.5 l/min (* OVERFLOW Qmax > 50 l/min)

FLUIDISATION TEST DD 12 JAN. '87

LIQUEFACTION BRUTUSTANK

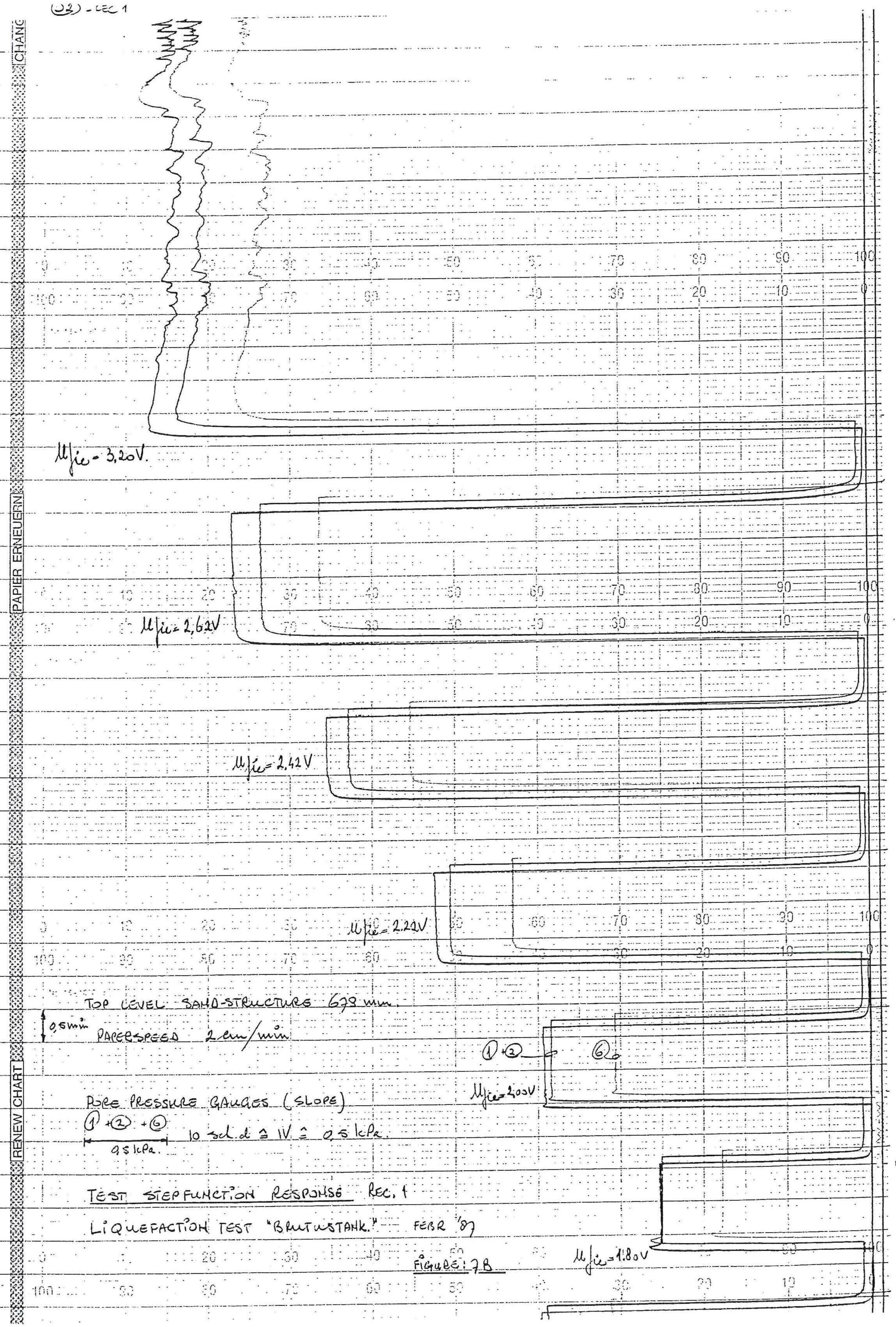
FIGURE: 6



TEST STEP FUNCTION-RESPONSE Rec. 2

LIQUEFACTIONTEST 'BRUTUSTANK" FEBR. '87 FIGURE 17A

(U2) - REC 1



TOP LEVEL SAND-STRUCTURE 678 mm.

PAPERSPEED 2 cm/min

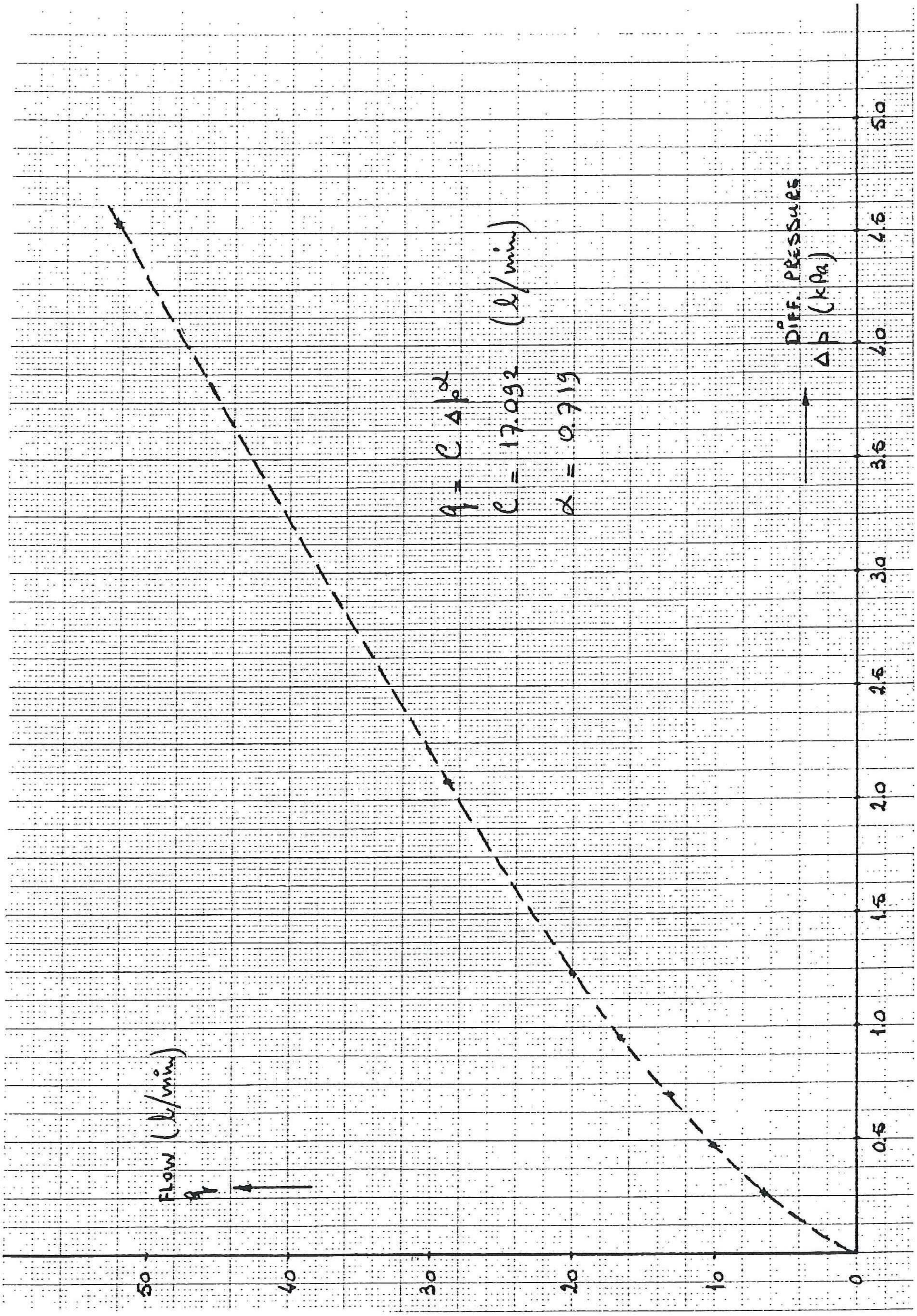
PORE PRESSURE GAUGES (SLOPE)

① + ② + ⑥ 10 sch. d ≙ 1V ≙ 0,5 kPa.

TEST STEPFUNCTION RESPONSE REC. 1

LIQUEFACTION TEST "BRUTUSTANK." FEBR '87

FIGURE: 7B



DELFT GEOTECHNICS

Dt: 87-02-19

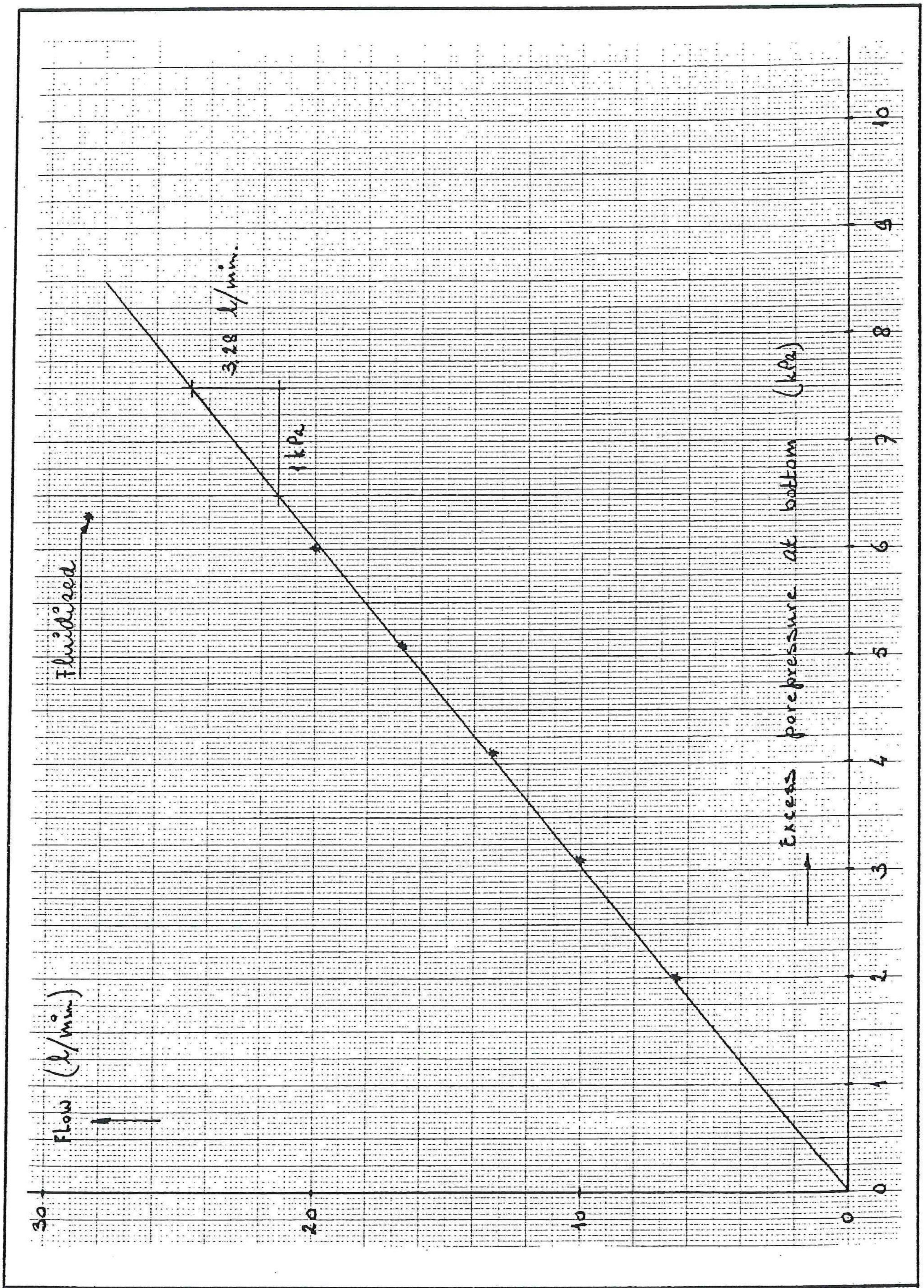
LIQUEFACTIONTEST BRUTUSTANK

CO - 287130

Flow versus diff. pressure

Chann./Scans : 15-16

Figure:8



DELFT GEOTECHNICS

Dt: 87-02-19

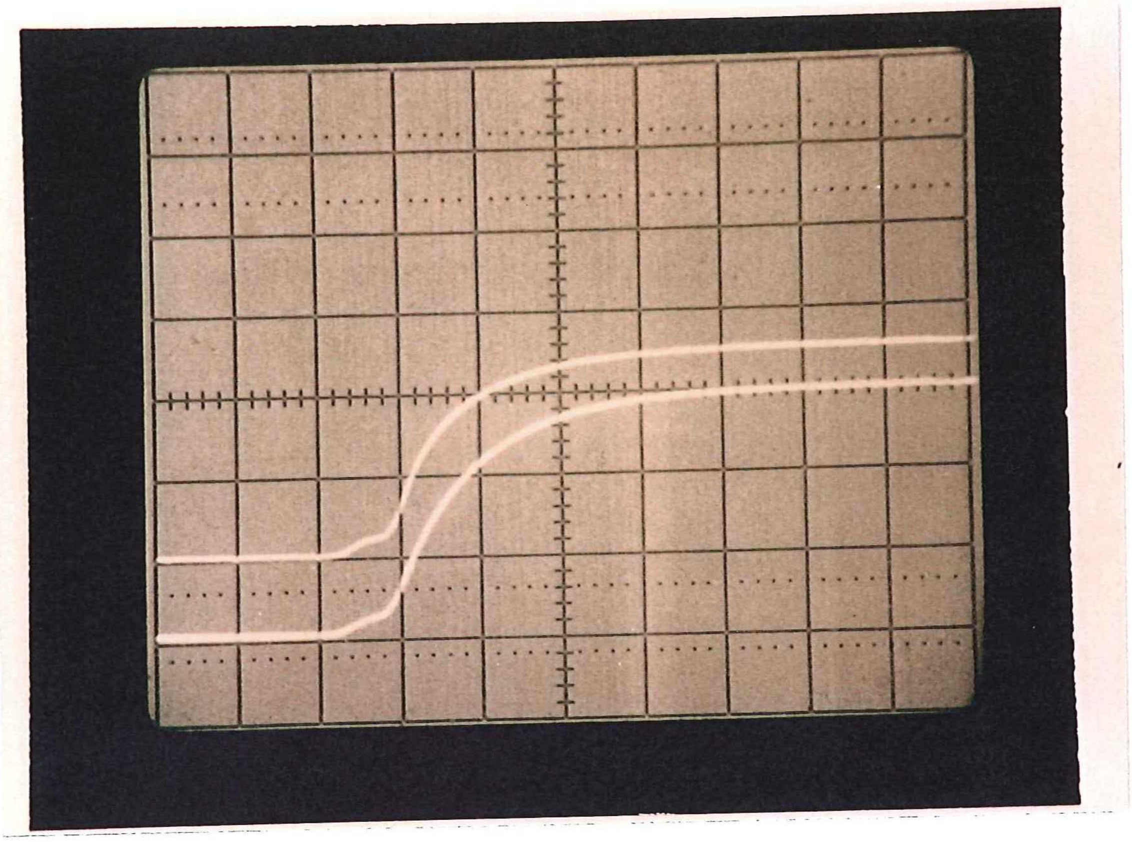
LIQUEFACTIONTEST BRUTUSTANK

Flow versus excess porepressure at bottom

Chann./Scans : 11-12-13-14

CO - 287130

Figure : 9

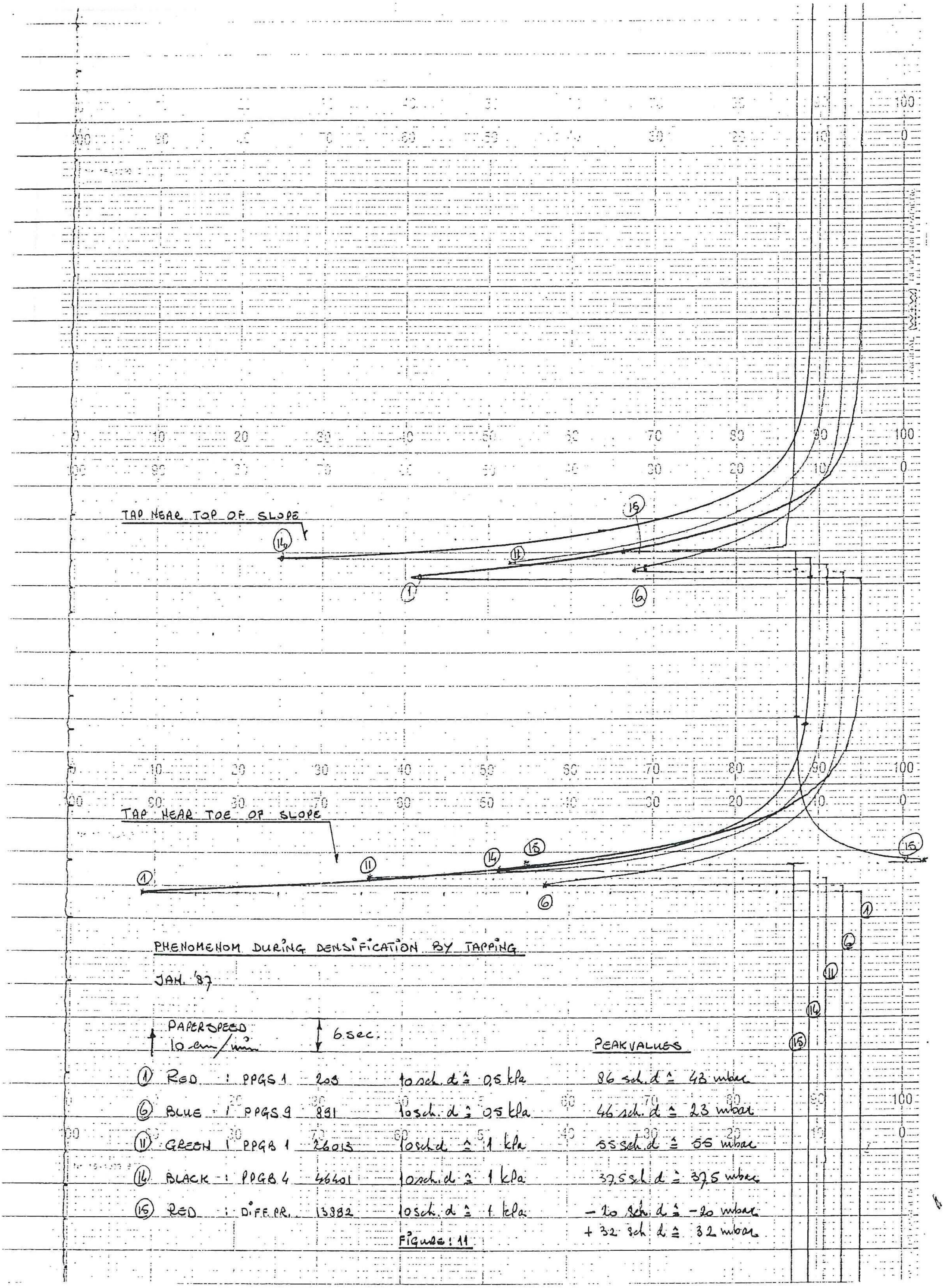


Definition of the response of the pore pressure gauges
(one on the bottom of the tank and one in the slope)
as result of a pressure-shock in the fluidisation-system.

↑ Y 1	pore pressure gauge on bottem tank	1 kPa / div.
↑ Y 2	pore pressure gauge in slope	0.5 kPa / div.
→ X	time	0.5 sec / div.

DELFT GEOTECHNICS
Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Response of the porepressure gauges
CO - 287130
Figure : 10



PHENOMENOM DURING DENSIFICATION BY TAPPING

JAN. '87

PAPERSPEED 10 cm/min

6 sec.

PEAKVALUES

① RED : PPGS 1 203 10 sch. d ≙ 0,5 kPa 86 sch. d ≙ 43 mbar

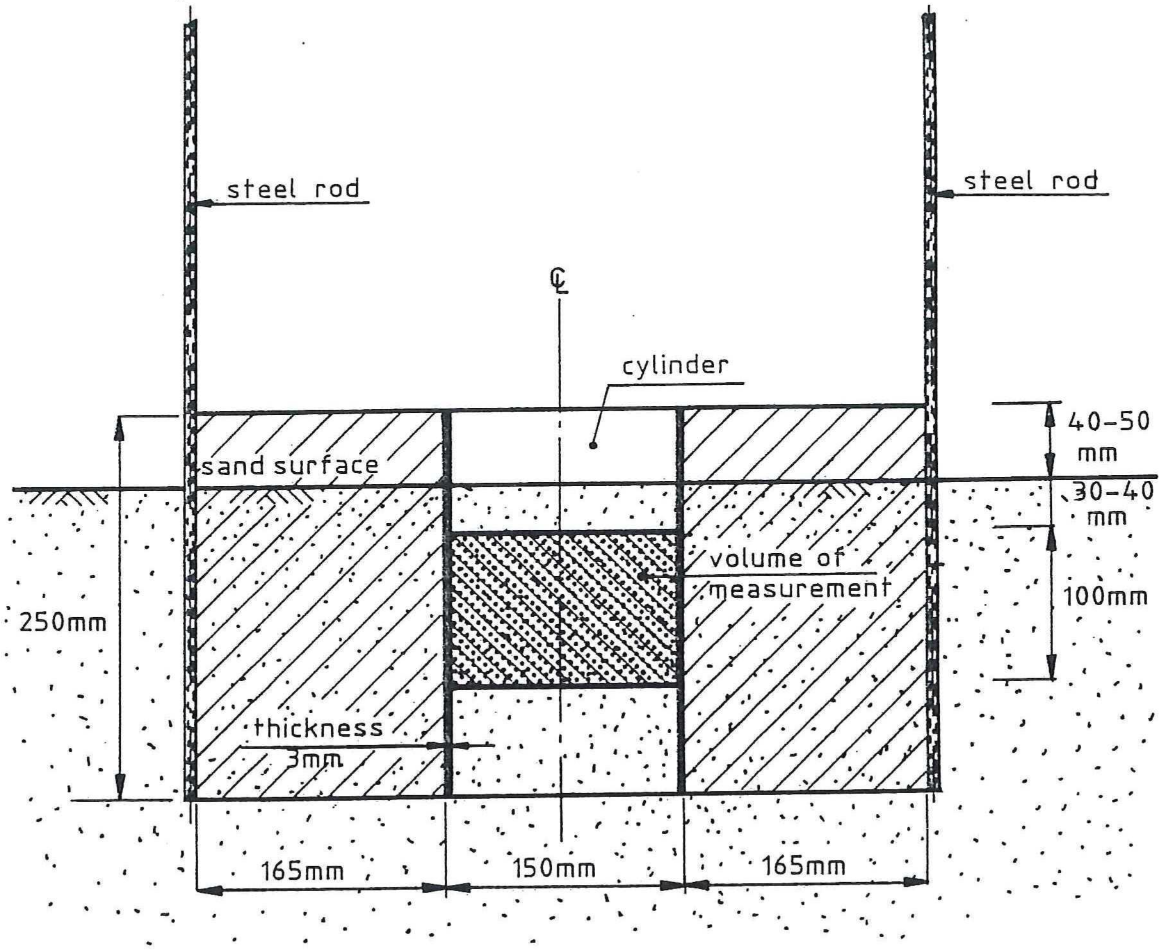
⑥ BLUE : PPGS 9 891 10 sch. d ≙ 0,5 kPa 46 sch. d ≙ 23 mbar

⑪ GREEN : PPGB 1 26013 10 sch. d ≙ 1 kPa 55 sch. d ≙ 55 mbar

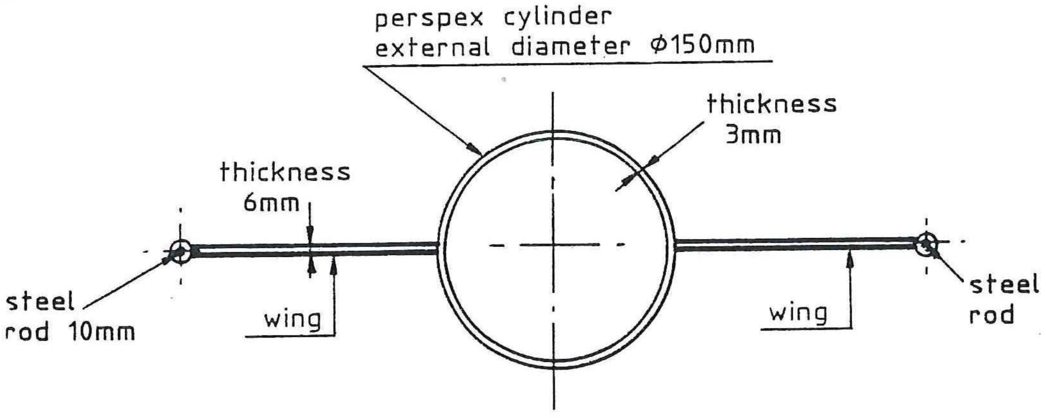
⑭ BLACK : PPGB 4 46401 10 sch. d ≙ 1 kPa 37,5 sch. d ≙ 37,5 mbar

⑮ RED : DIFF. PR. 13882 10 sch. d ≙ 1 kPa − 20 sch. d ≙ −20 mbar
+ 32 sch. d ≙ 32 mbar

FIGURE: 11



SIDE VIEW



TOP VIEW

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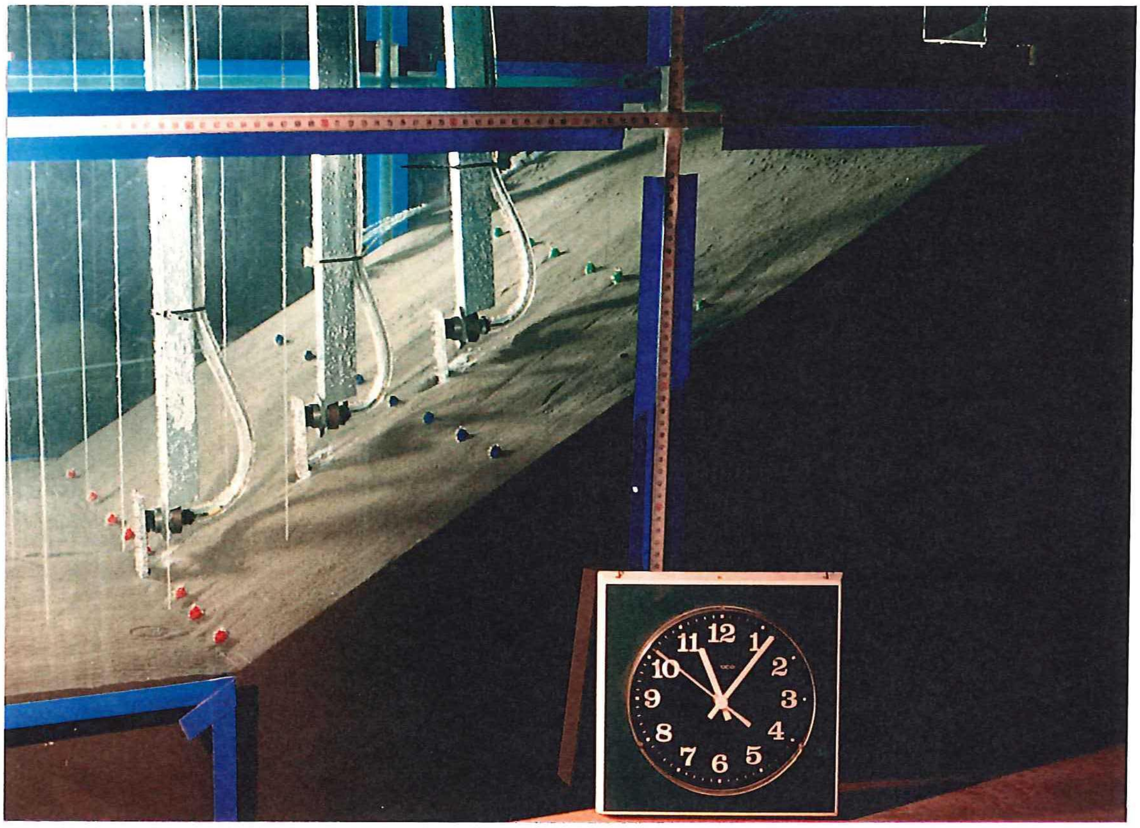
CYLINDER FOR MEASURING IN-SITU DENSITY OF SAND

LIQUEFACTIONTEST BRUTUSBAK

FIG. 12

form. A4



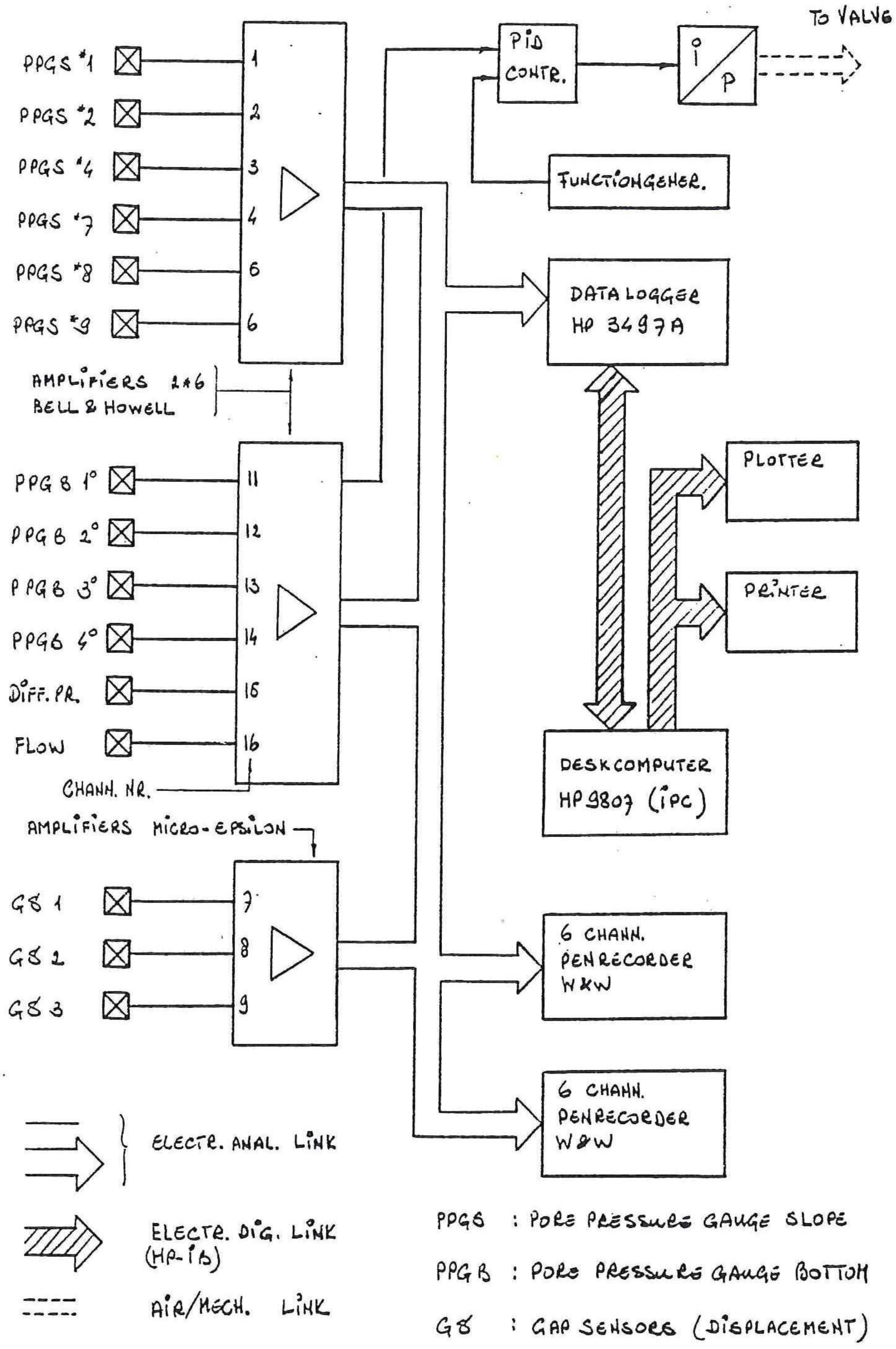
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Slope before the test

CO - 287130

Figure : 13



PPGS : PORE PRESSURE GAUGE SLOPE
PPG B : PORE PRESSURE GAUGE BOTTOM
GS : GAP SENSORS (DISPLACEMENT)

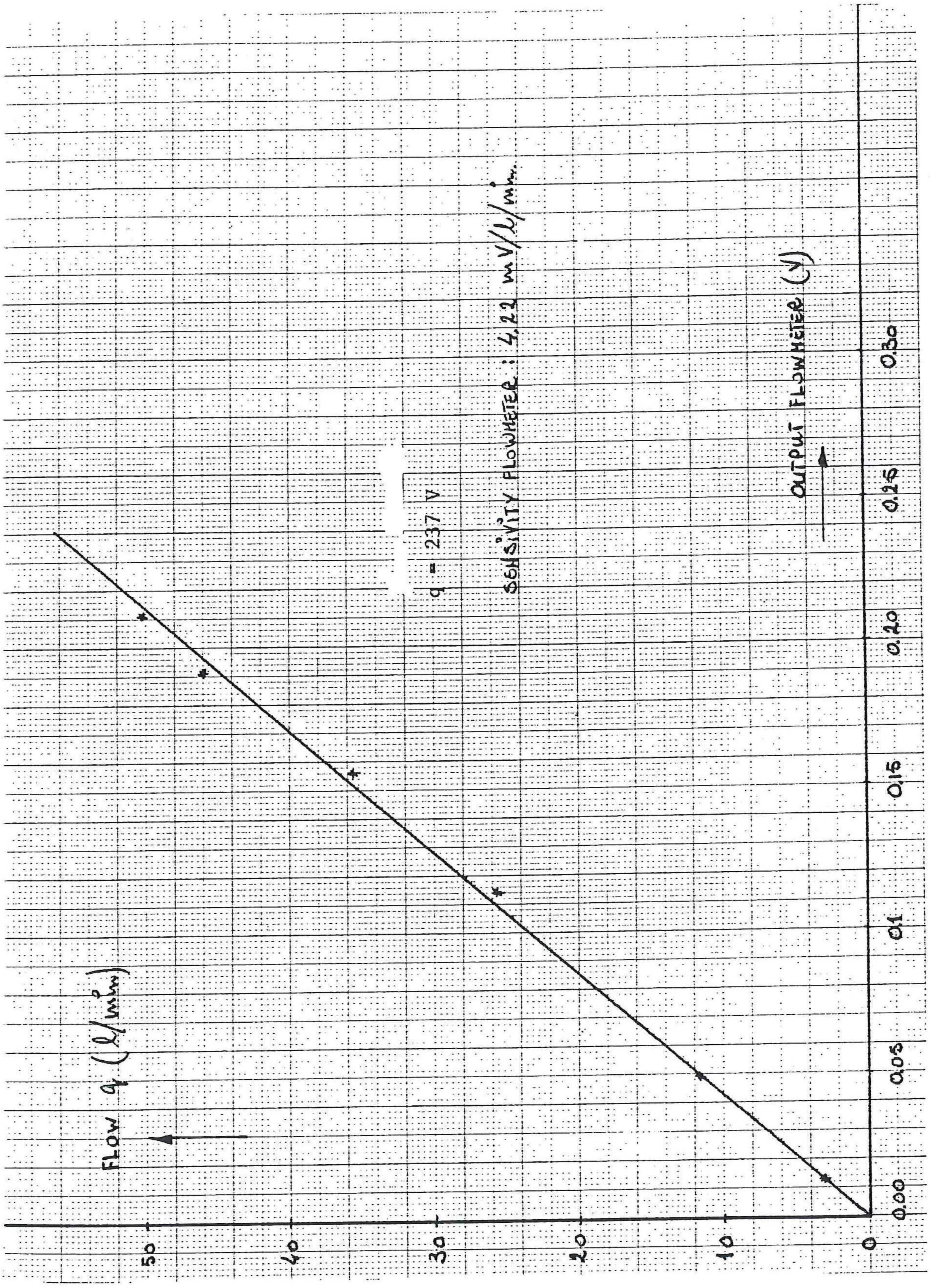
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Schematic electronic part

CO - 287130

Figure : 14



DELFT GEOTECHNICS

LIQUEFACTIONTEST BRUTUSTANK
Flow (l/min) versus output flowmeter (V)
Chann./Scans : 16

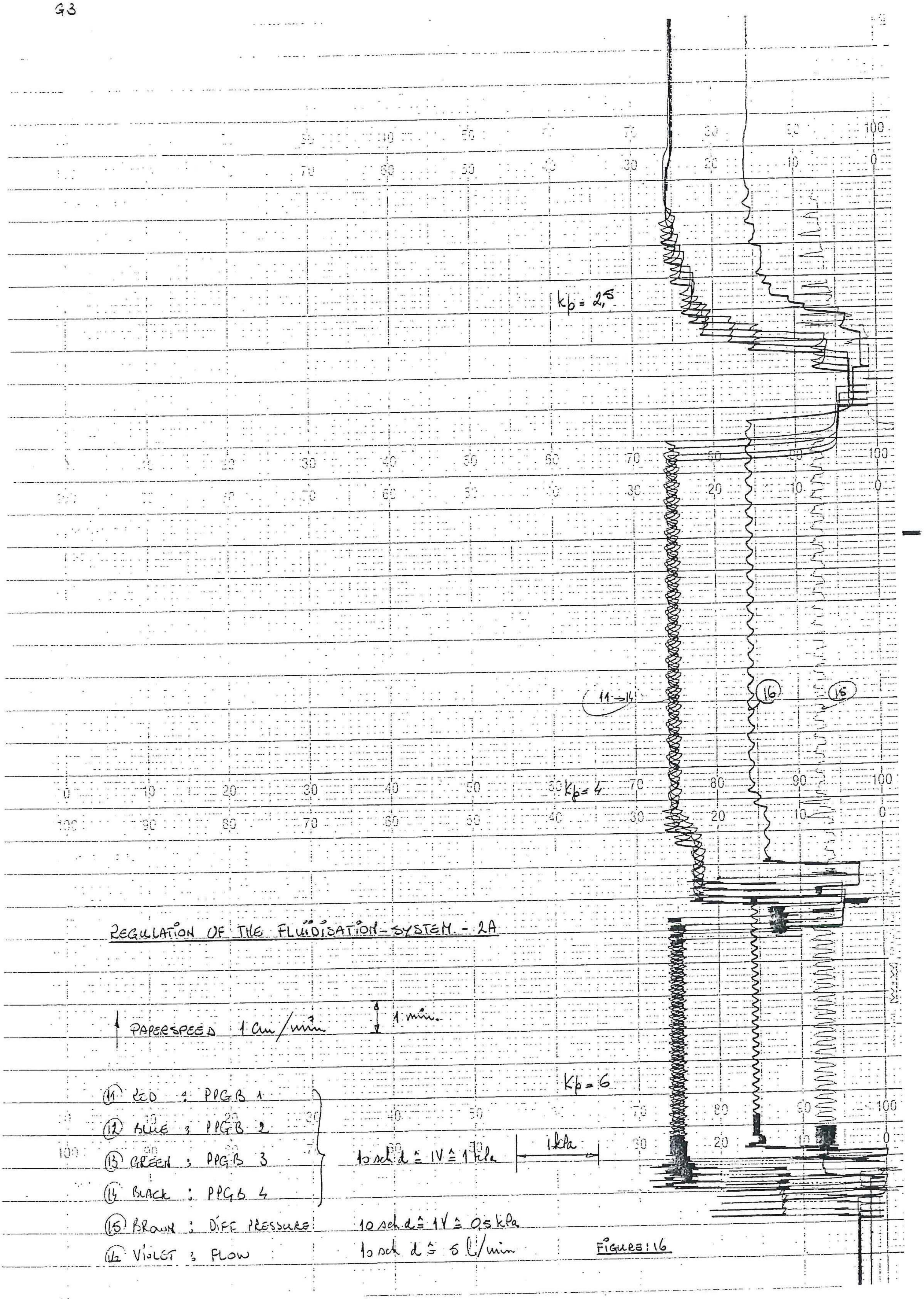
Dt: 87-02-19

CO - 287130

Figure : 15

NJ

G3



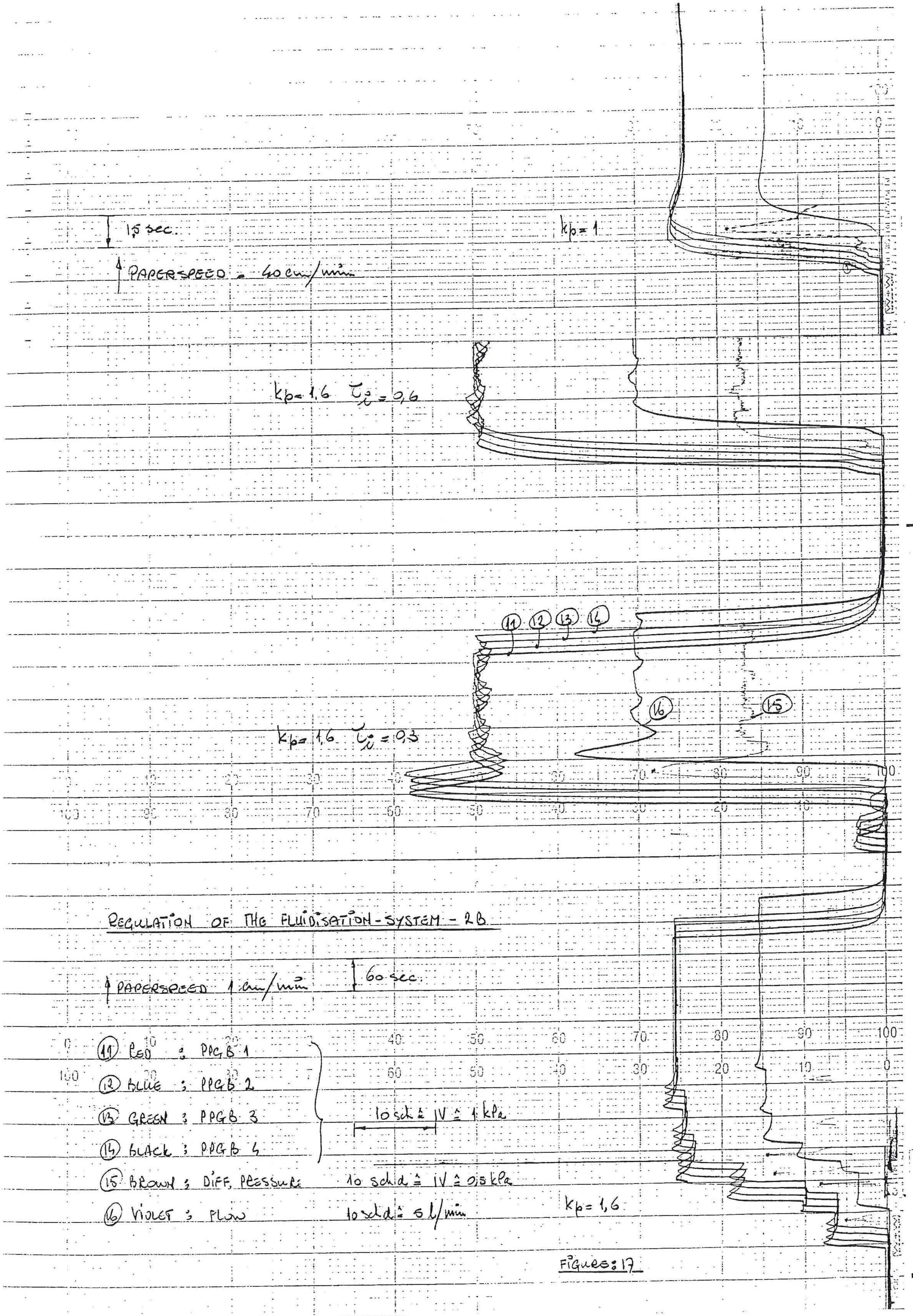
REGULATION OF THE FLUIDISATION-SYSTEM - 2A

PAPERSPEED 1 cm/min

⑪ RED : PPGB 1
⑫ BLUE : PPGB 2
⑬ GREEN : PPGB 3
⑭ BLACK : PPGB 4
10 sch d ≙ 1V ≙ 1 kPa

⑮ BROWN : DIFF PRESSURE 10 sch d ≙ 1V ≙ 0,5 kPa
⑯ VIOLET : FLOW 10 sch d ≙ 5 l/min

FIGURE: 16

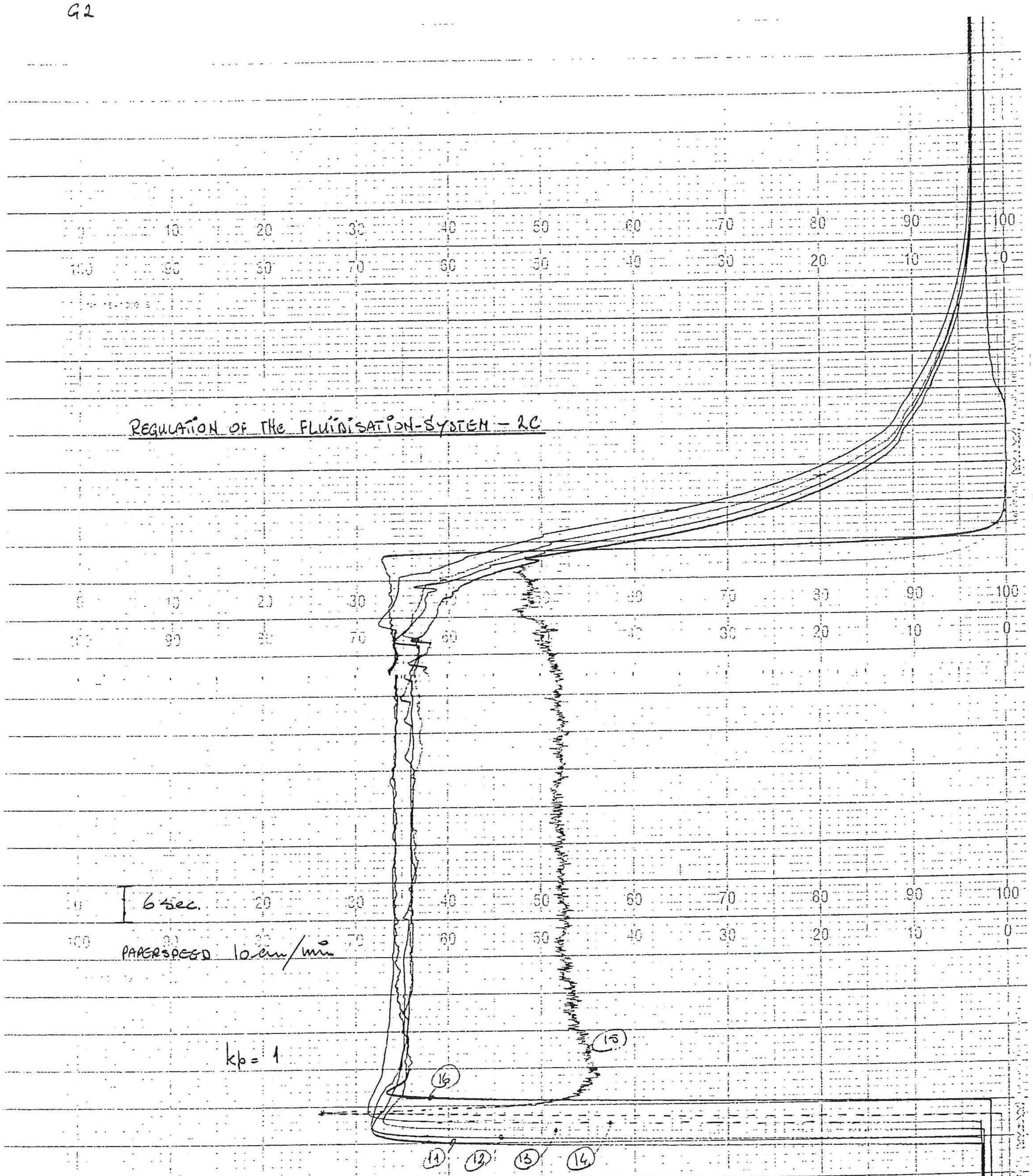


REGULATION OF THE FLUIDISATION-SYSTEM - 2B

FIGURES: 17

G2

REGULATION OF THE FLUIDISATION-SYSTEM – 2C



6 sec.

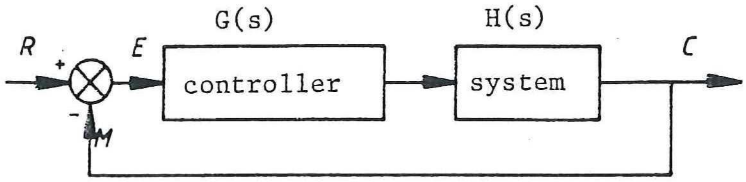
PAPERSPEED 10 cm/min

kp = 1

⑪ RED : PPG BOTTOM 1
⑫ BLUE : PPG BOTTOM 2
⑬ GREEN : PPG B 3
⑭ BLACK : PPG B 4
10 sch. d ≙ 1V ≙ 1 kPa
⑮ BROWN : DIFF. PRESSURE   10 sch.d ≙ 1V ≙ 0,5 kPa
⑯ VIOLET : FLOW   10 sch. d ≙ 1V ≙ 5 l/min
RECORDER 2

FIGURE: 18

G1



R : Set-value / desired value

C : Controlled value

M : Measured value

E : Error signal / offset

G(s) : Frequency-response function of controller

H(s) : Frequency-response function of system

DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK

CO - 287130

Principle of controlling process

Figure : 19

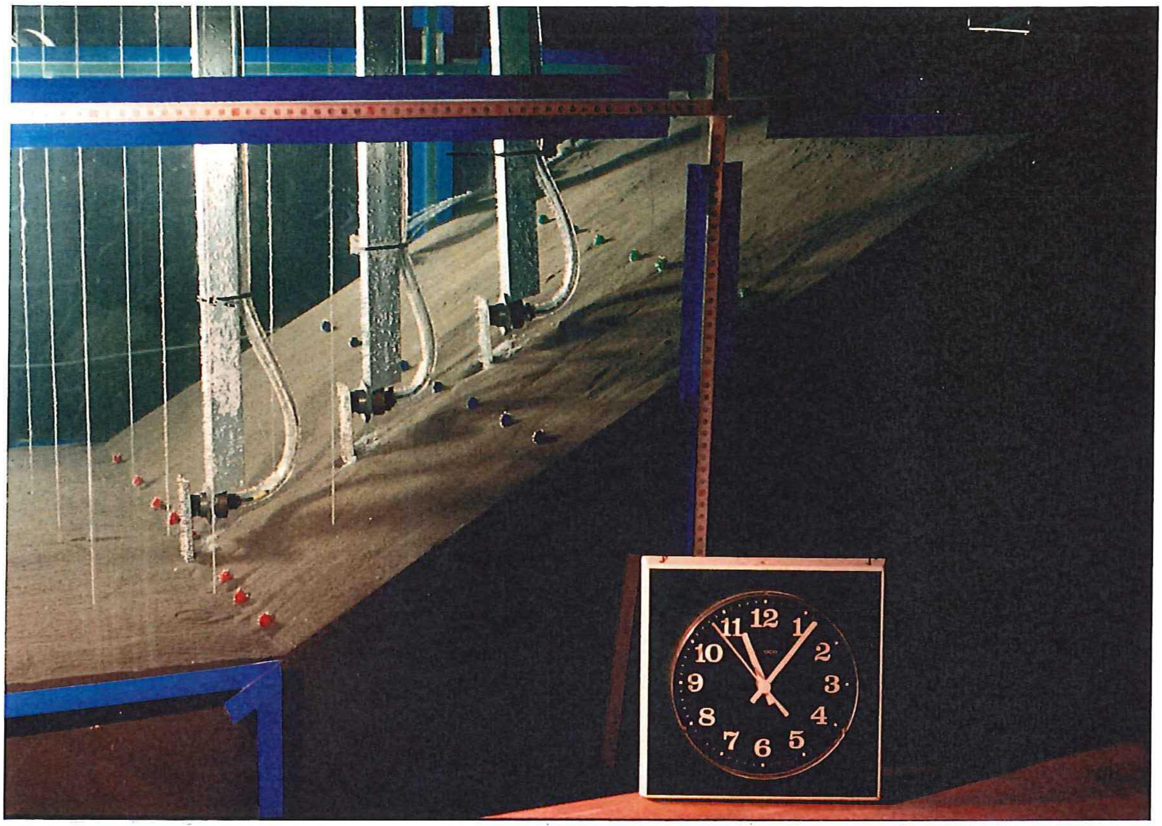


Photo 1

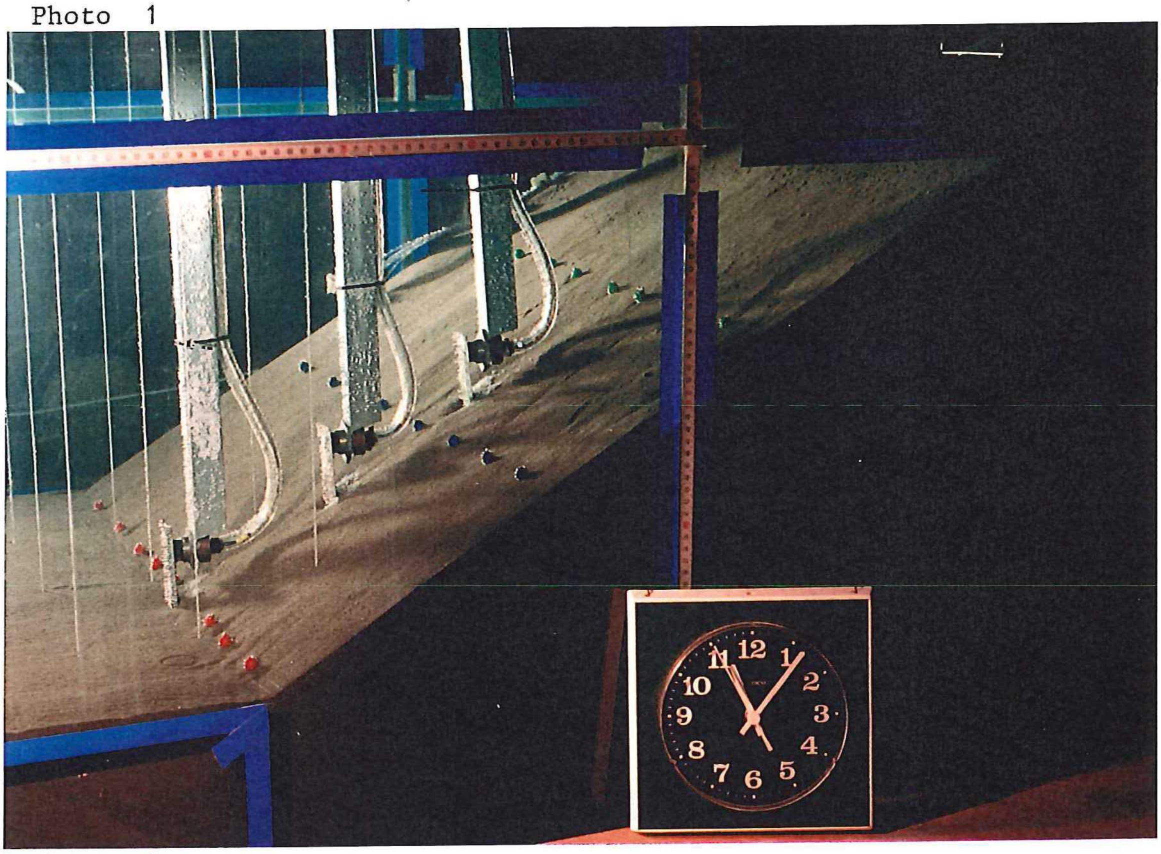


Photo 2

DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK

Liquefaction of the slope

CO - 287130

Figure : 20

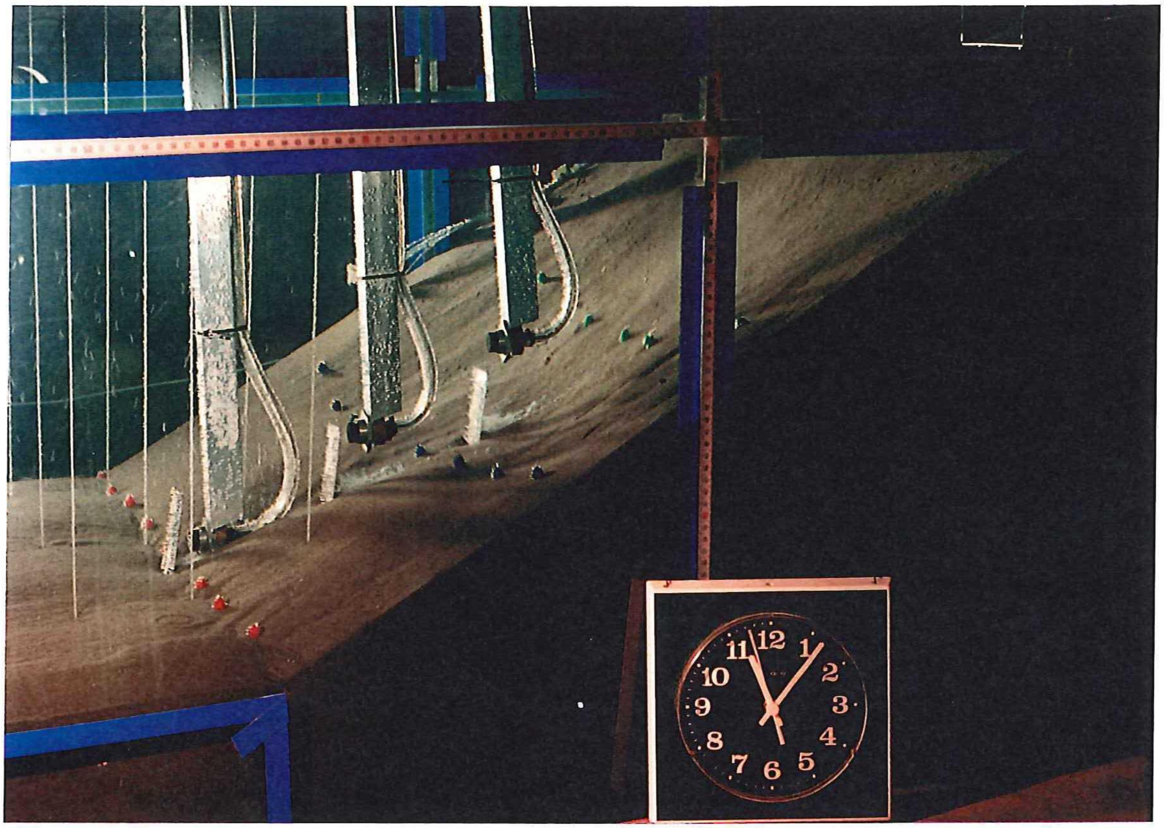


Photo 3

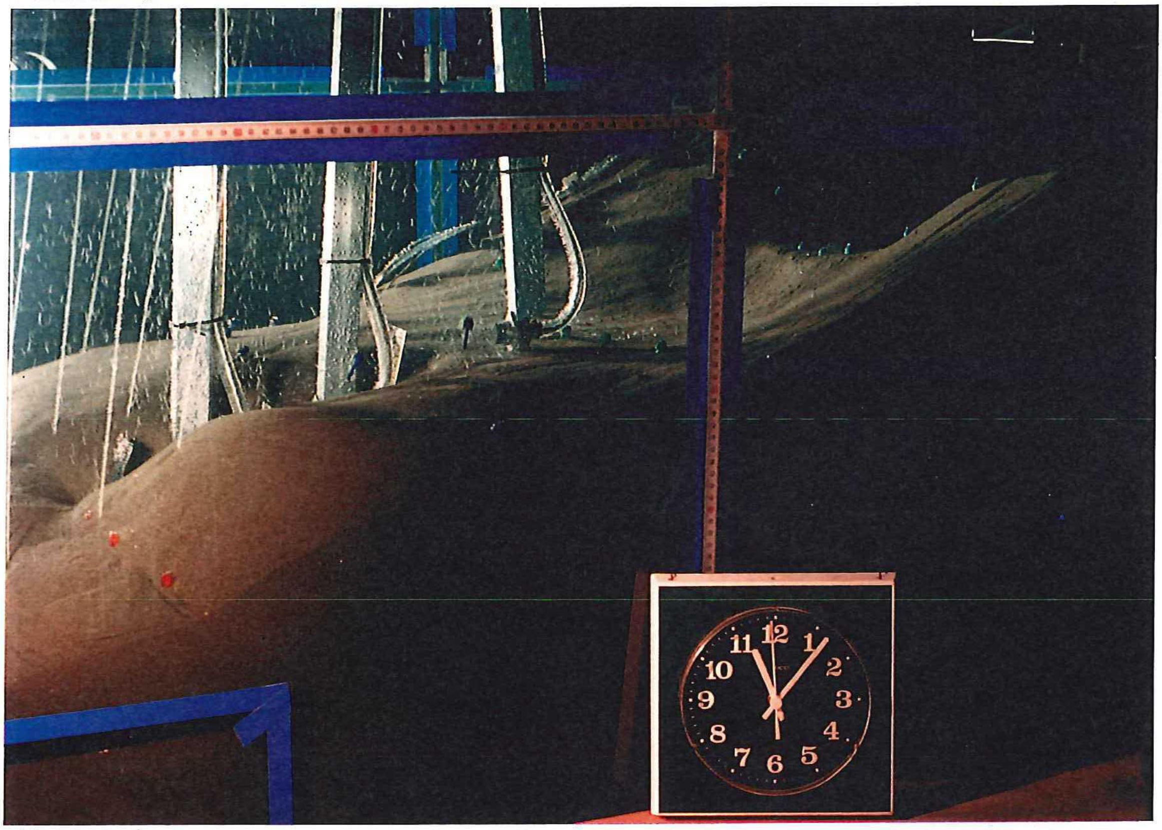


Photo 4

DELFT GEOTECHNICS	Dt: 87-02-19	
LIQUEFACTIONTEST BRUTUSTANK Liquefaction of the slope	CO - 287130	DW3/
	Figure : 21	

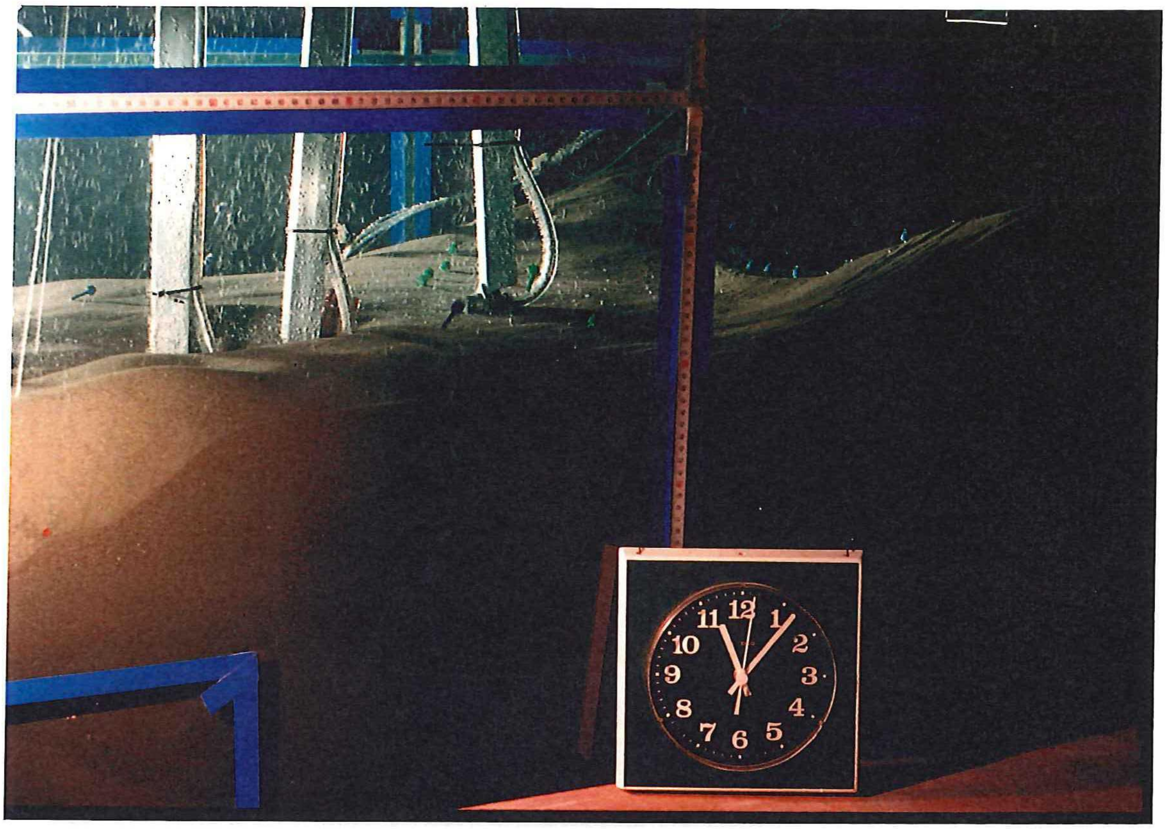


Photo 5

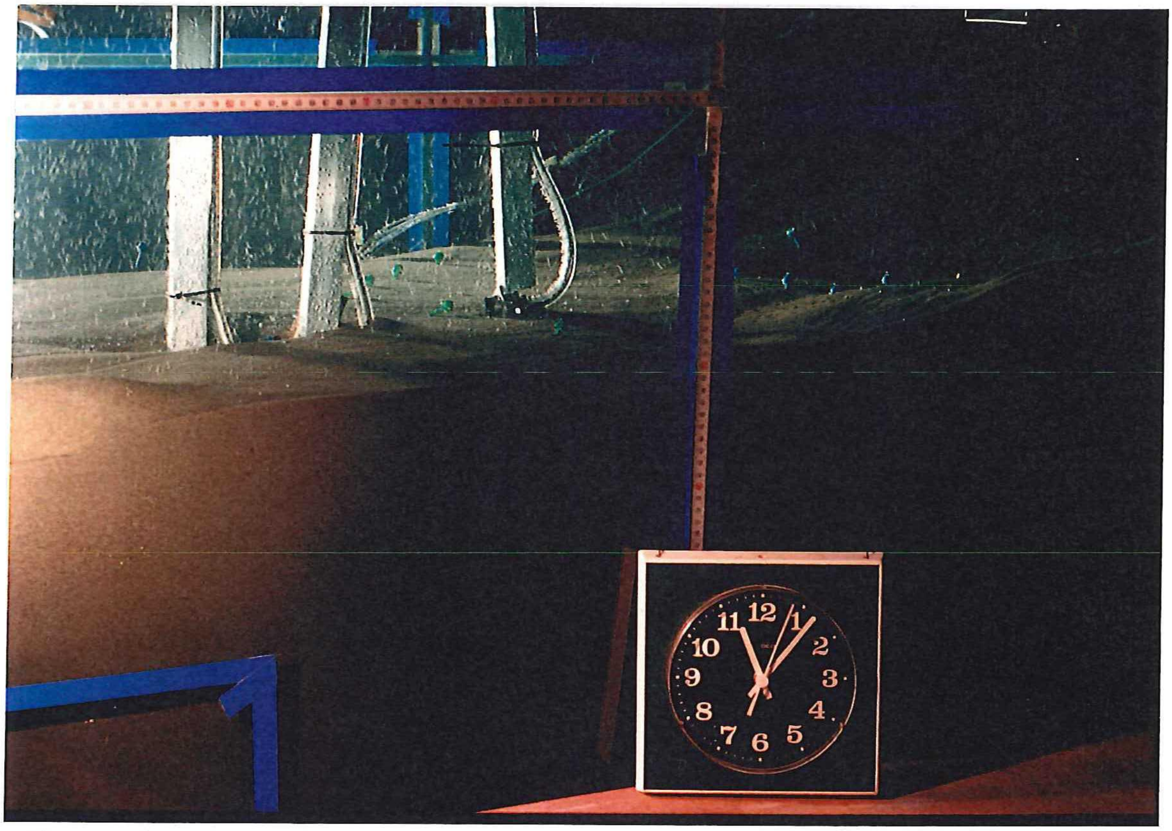


Photo 6

DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK

Liquefaction of the slope

CO - 287130

Figure : 22

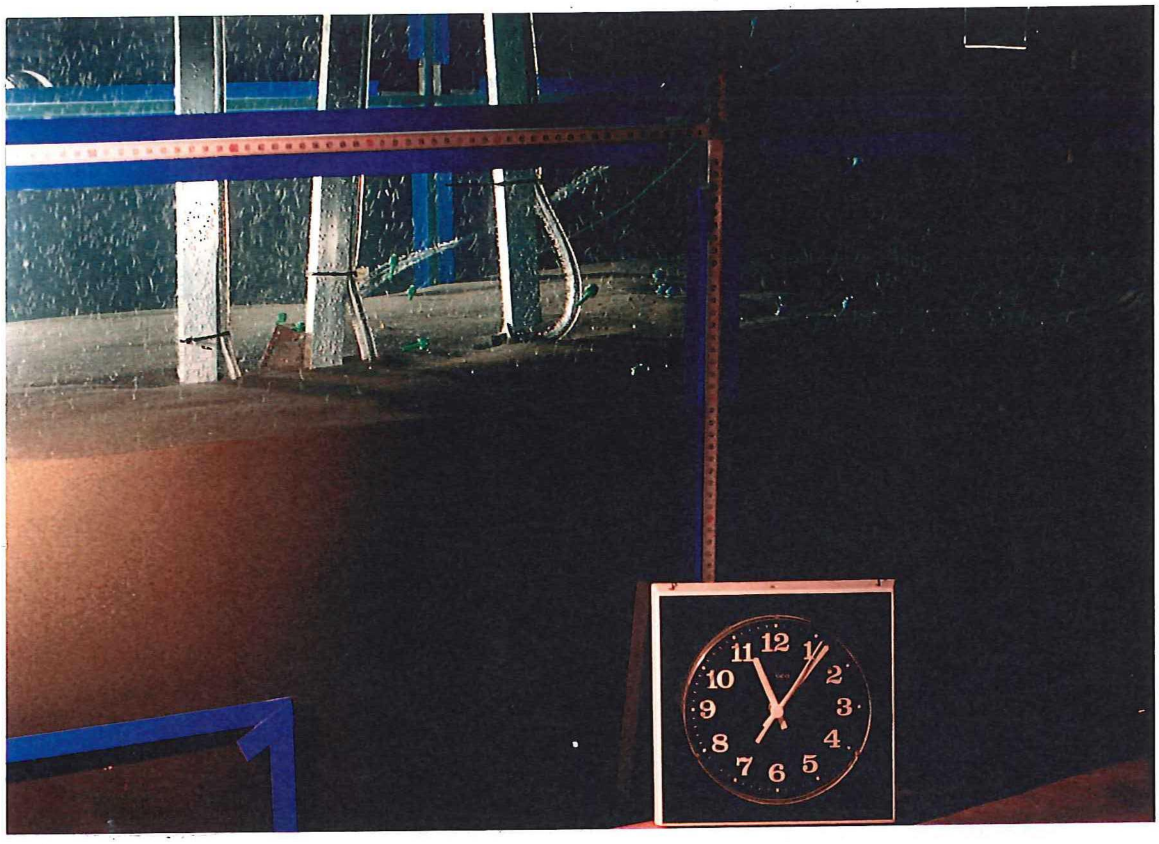


Photo 7

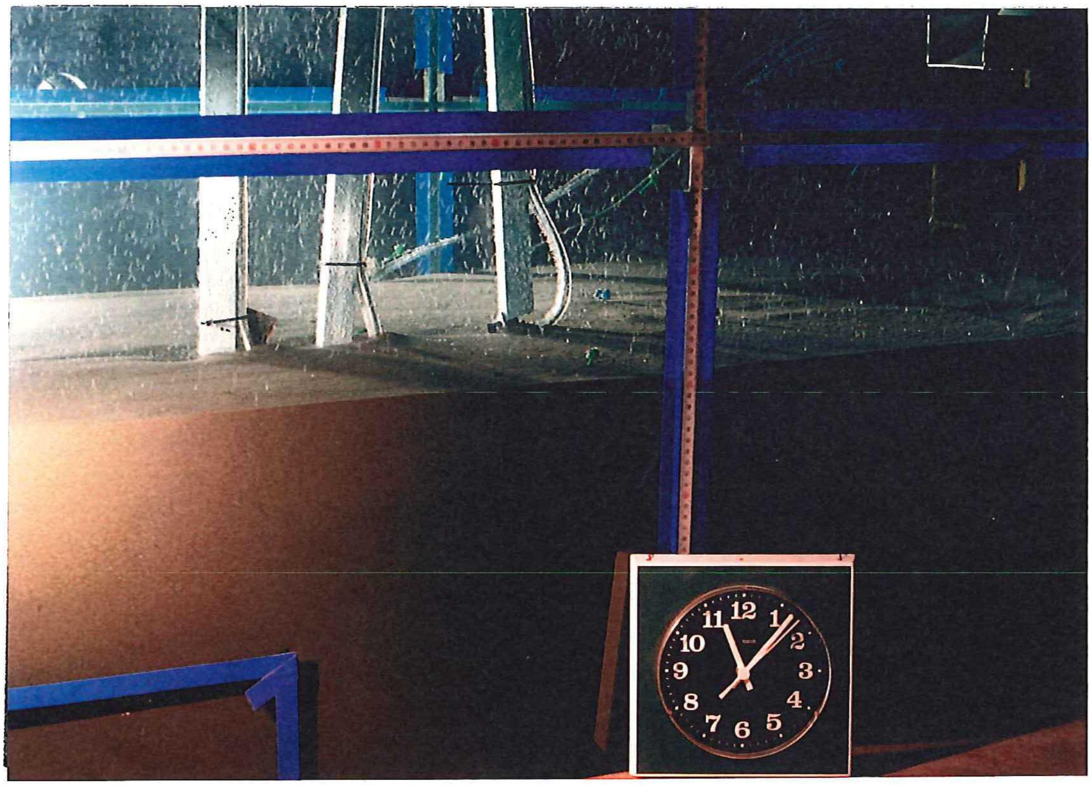


Photo 8

DELFT GEOTECHNICS

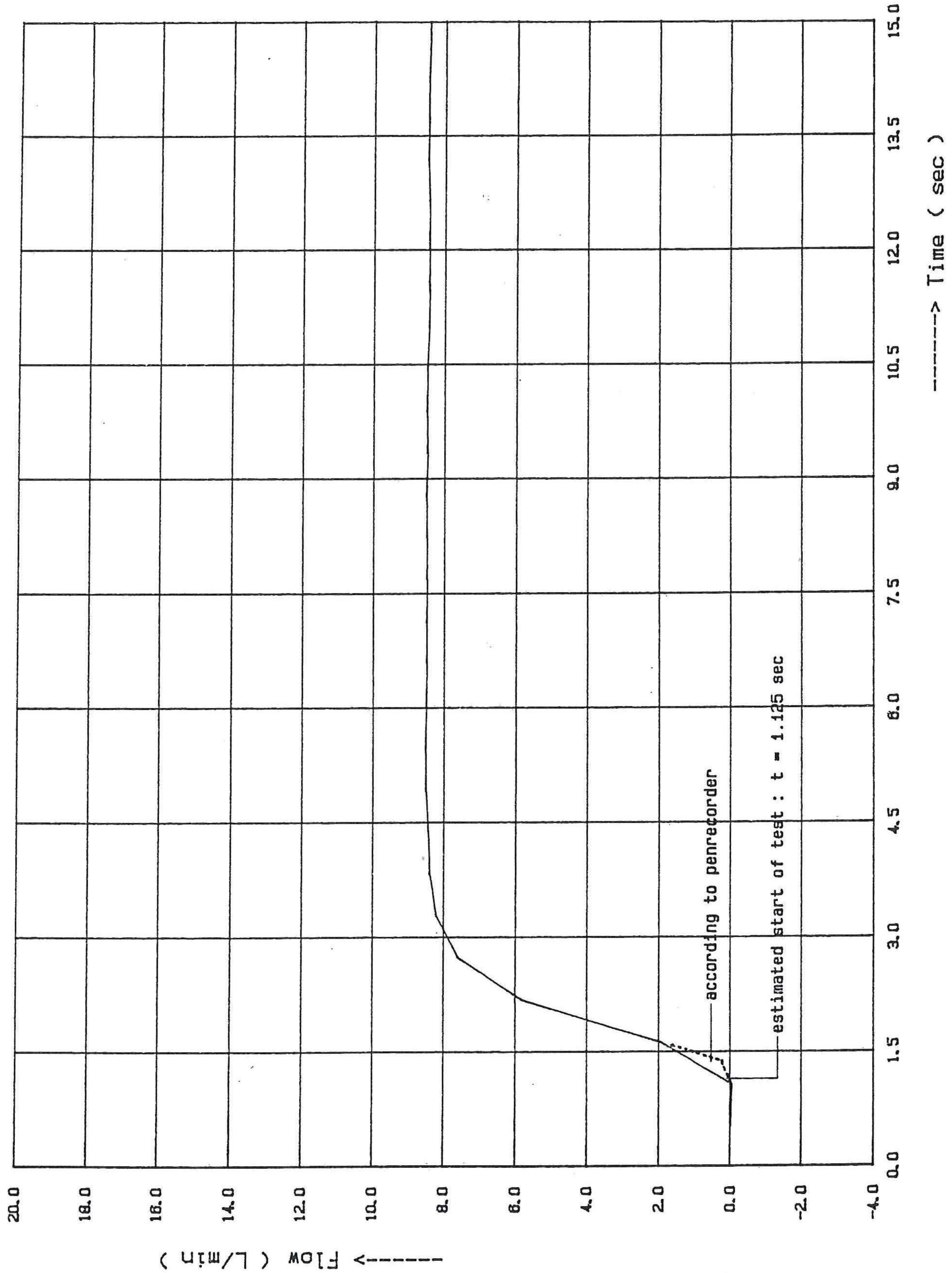
Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK

Liquefaction of the slope

CO - 287130

Figure : 23



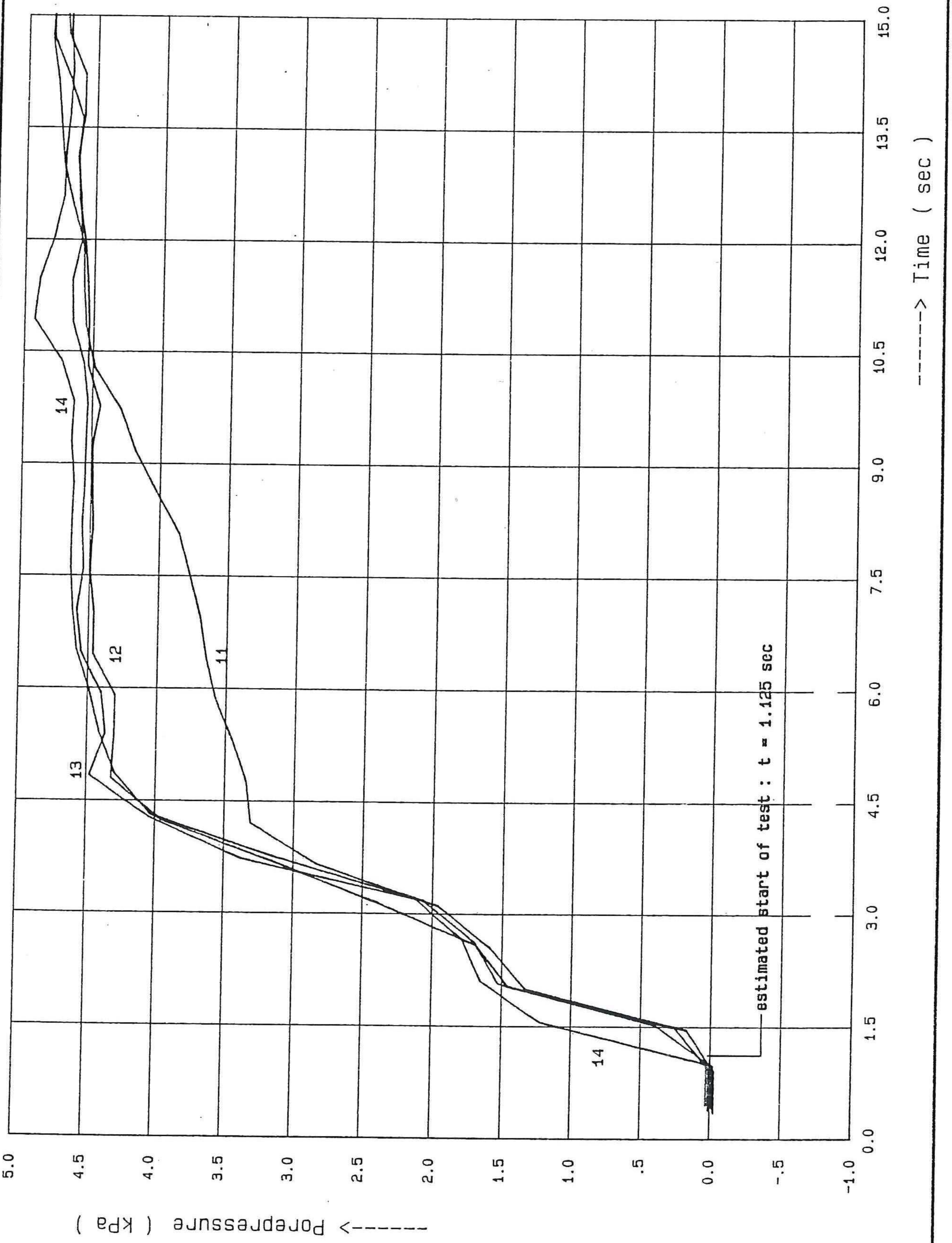
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Flow = func. (t)
Chann. /Scans : 16 / #95 - #122

CO - 287130

Figure : 24



DELFT GEOTECHNICS

Dt: 87-02-19

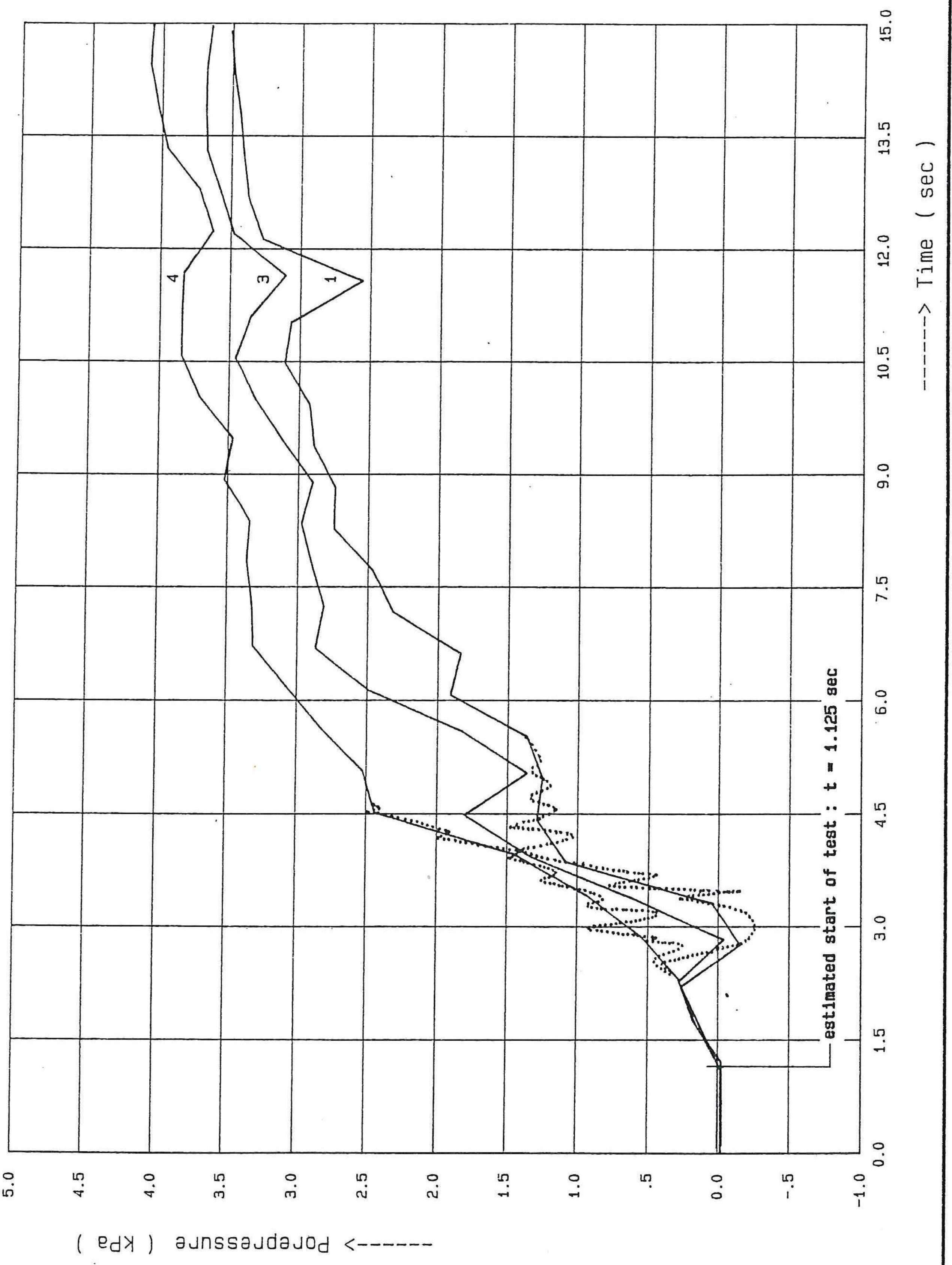
LIQUEFACTIONTEST BRUTUSTANK

Porepressure (bottom) = func. (t)

Chann./Scans : 11-12-13-14 / #95-#122

CO - 287130

Figure : 25



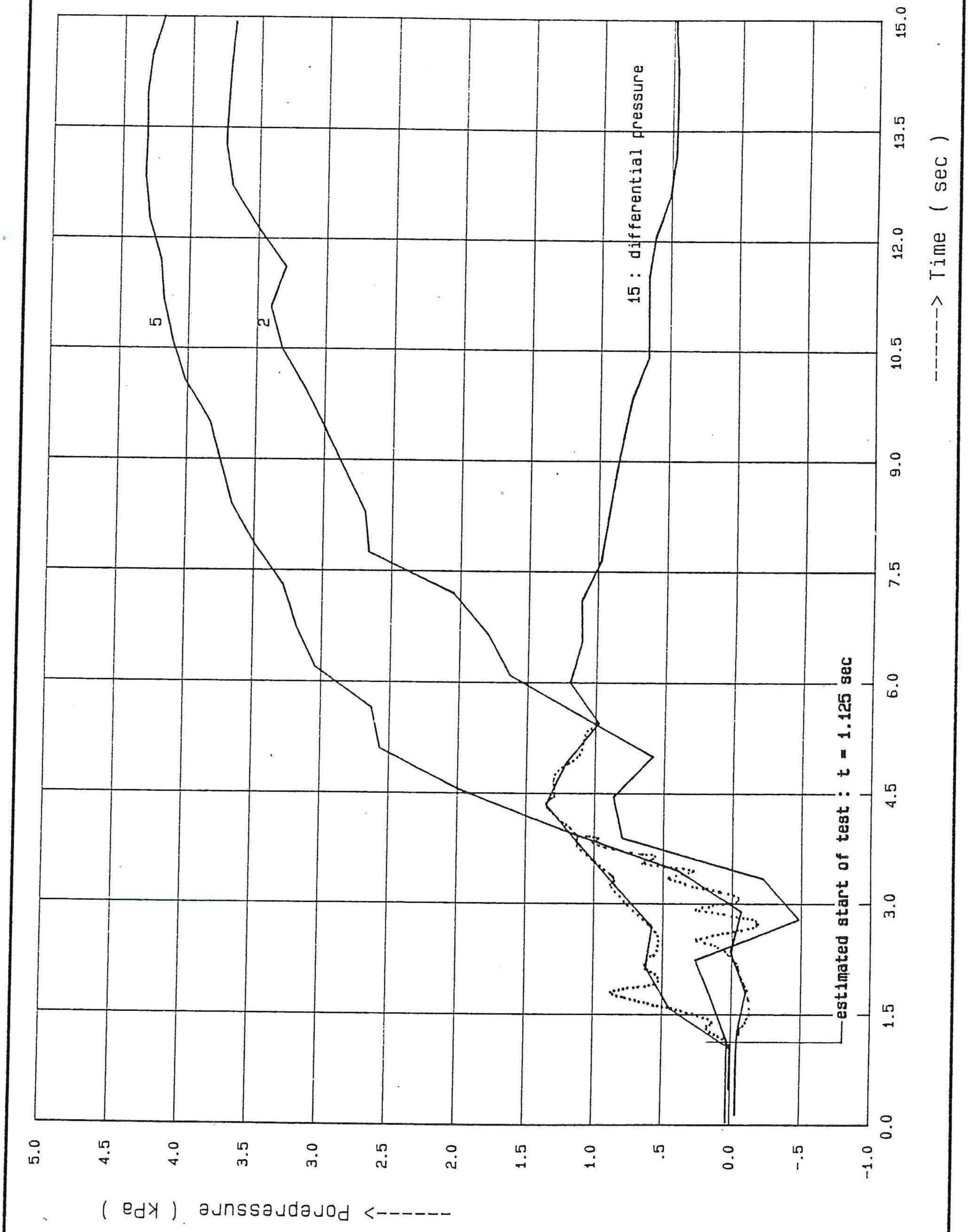
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Porepressure (slope) = func. (t)
Chann./Scans : 1-3-4 / #95 - #122

CO - 287130

Figure : 26



DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Porepressure (slope) = func. (t)
Chann./Scans : 2-5-15 / #95 - #122

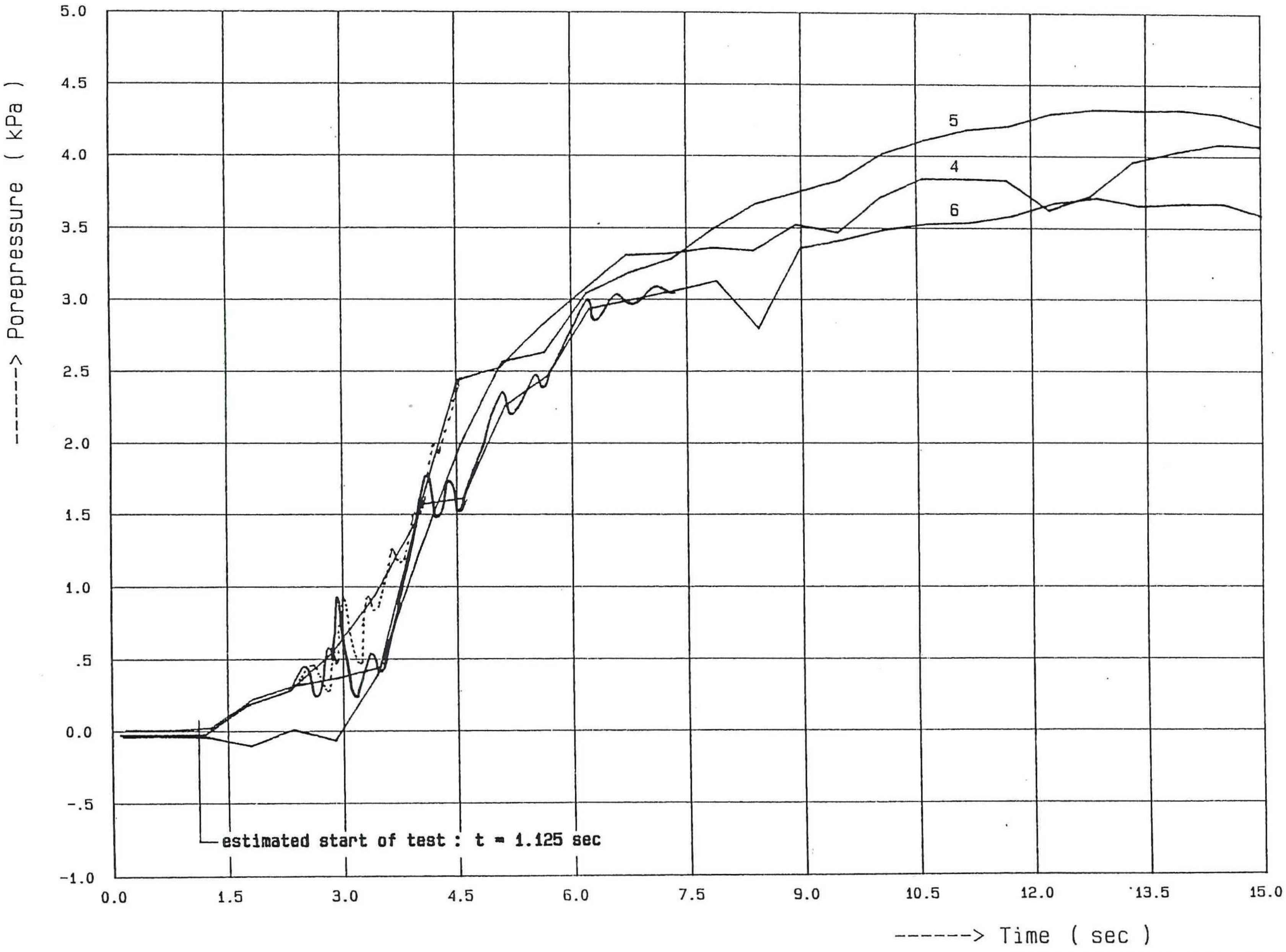
CO - 287130

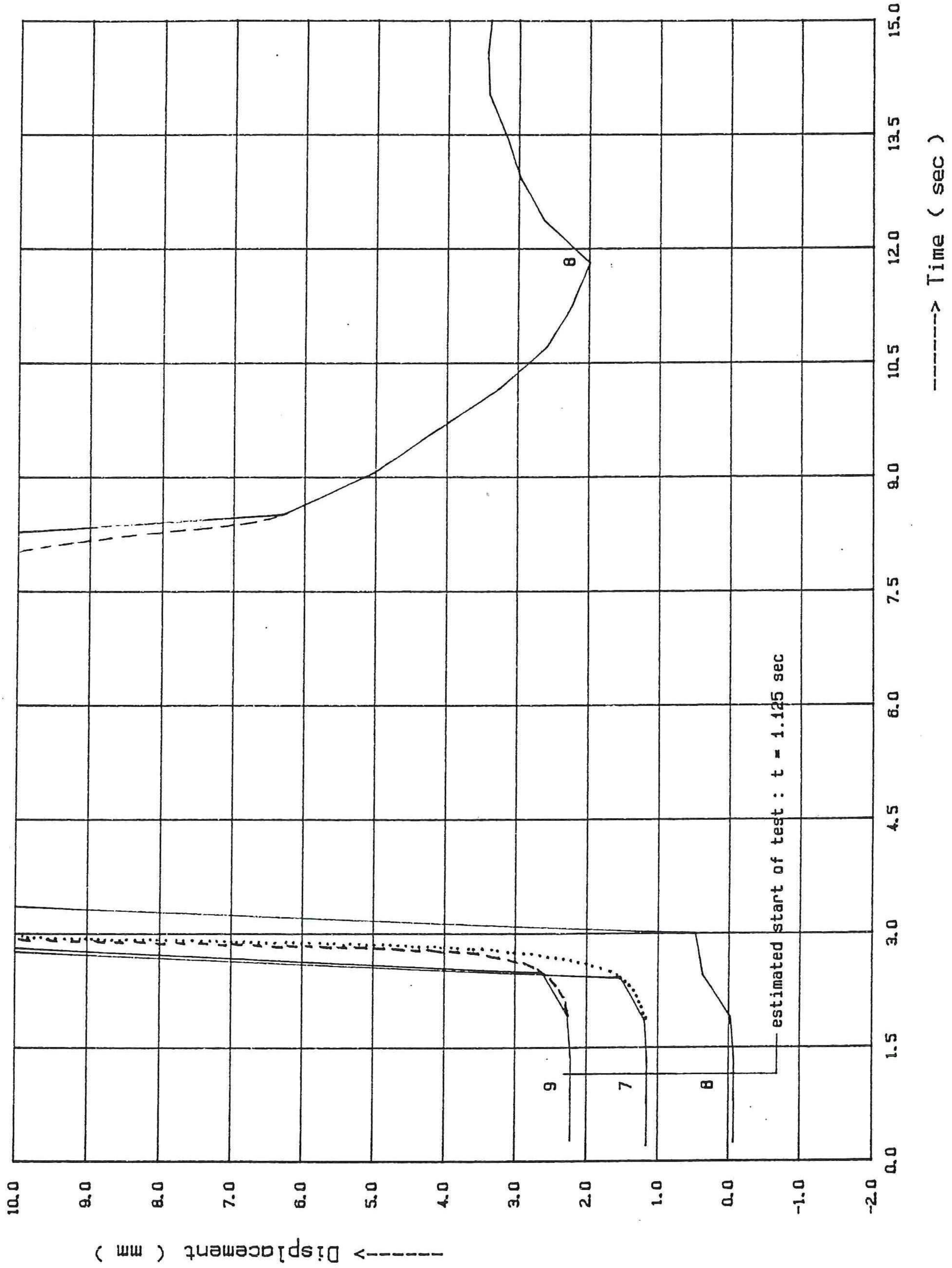
Figure : 27

DELFT GEOTECHNICS

LIQUEFACTIONTEST BRUTUSTANK
Porepressure (slope) = func. (t)
Chann./Scans : 4-5-6 / #95 - #122

Dt: 87-02-19
CO - 287130
Figure : 28





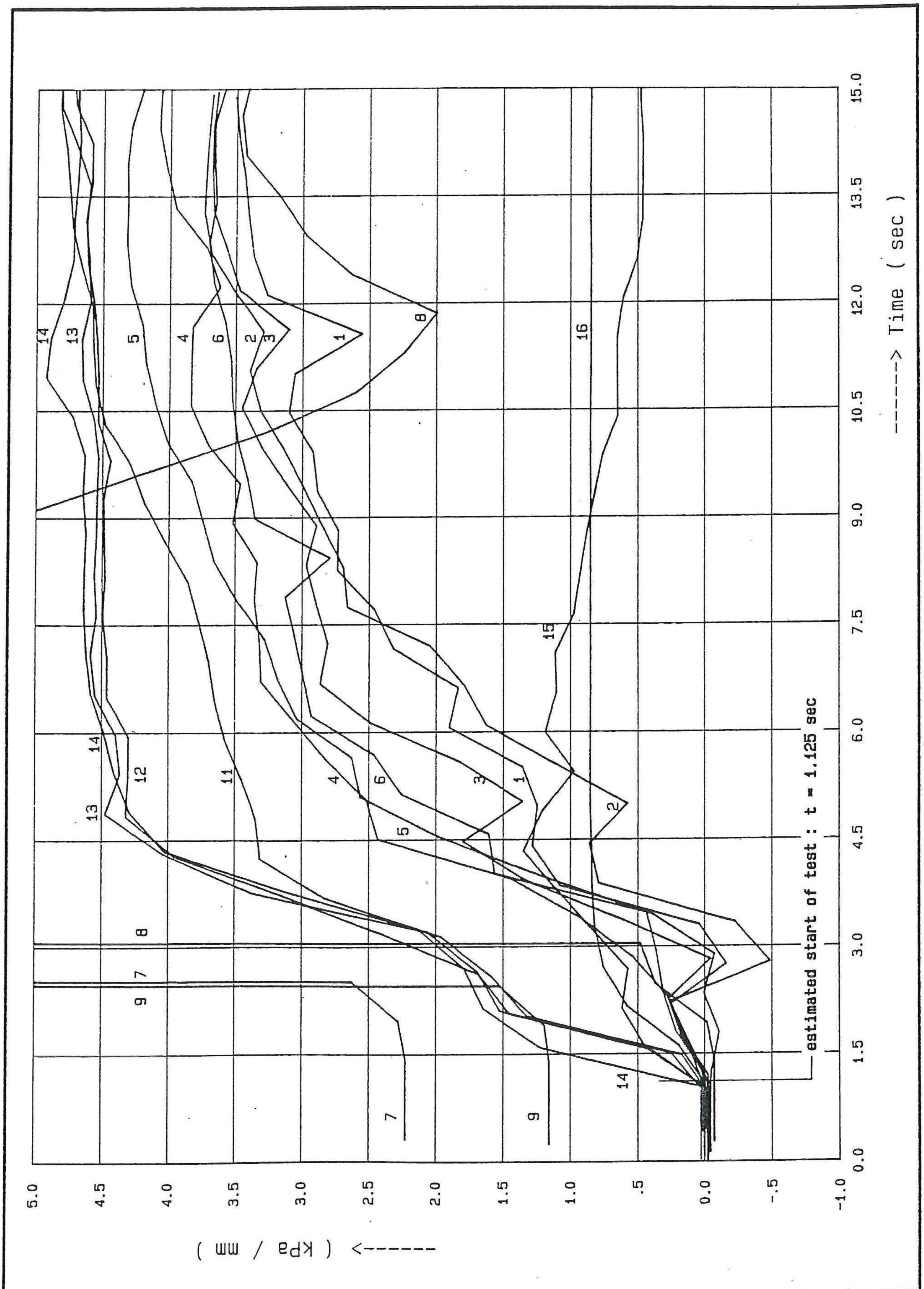
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
Displacement = func. (t)
Chann./Scans : 7-8-9 / #95-#122

CO - 287130

Figure : 29



DELFT GEOTECHNICS

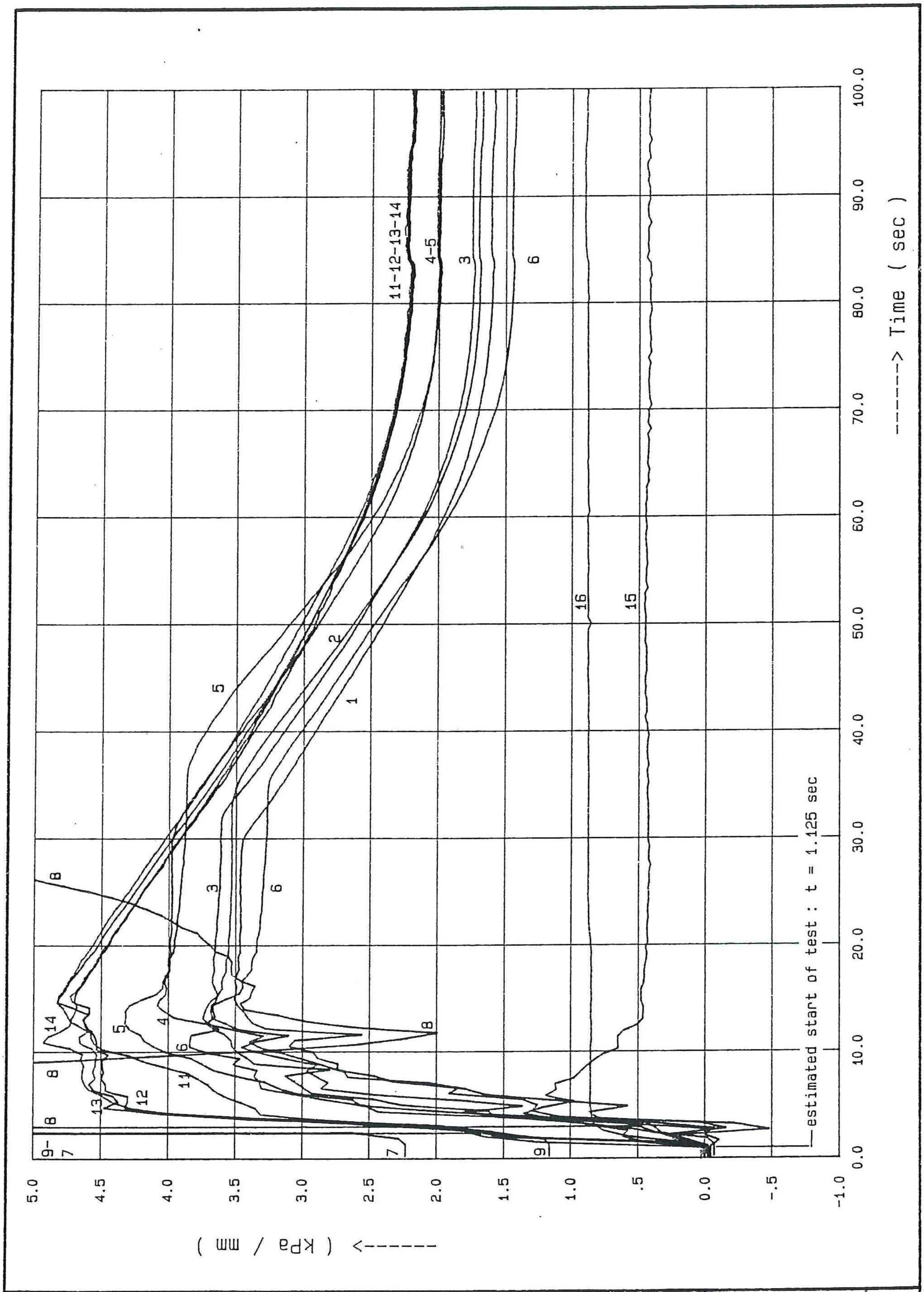
Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
PPGS-PPGB-DIFF-GS-FLOW = func. (t)
Chann./Scans : 1 to 9 - 11 to 16 / #95 - #122

CO - 287130

7-10/

Figure 30



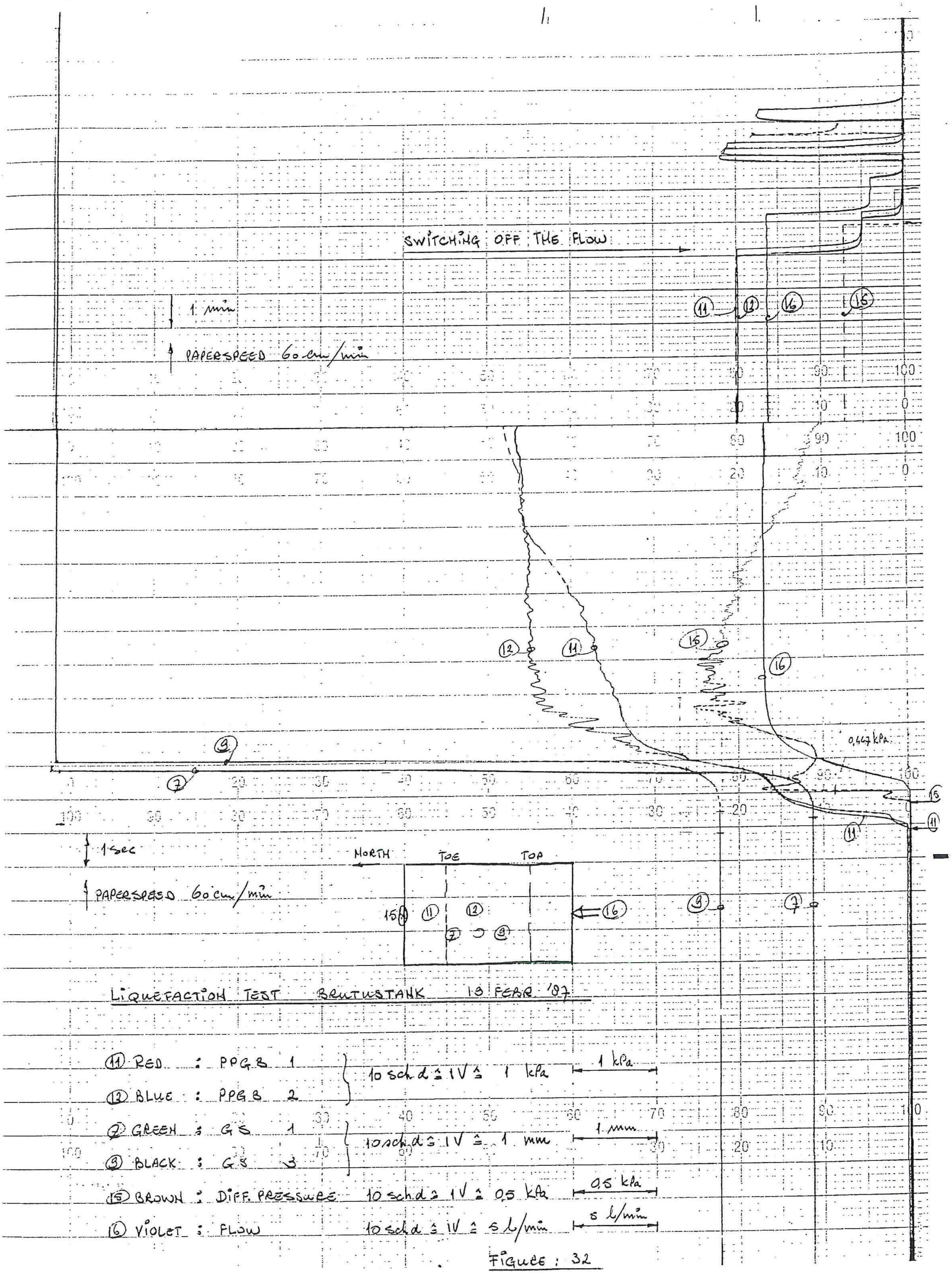
DELFT GEOTECHNICS

Dt: 87-02-19

LIQUEFACTIONTEST BRUTUSTANK
PPGS-PPGB-DIFF-GS-FLOW = func. (t)
Chann./Scans : 1 to 9 - 11 to 16 / #95 - #276

CO - 287130

Figure : 31



LIQUEFACTION TEST BRUTUSTANK 19 FEBR '87

⑪ RED : PPG B 1 } 10 sch.d ≙ 1V ≙ 1 kPa

⑫ BLUE : PPG B 2

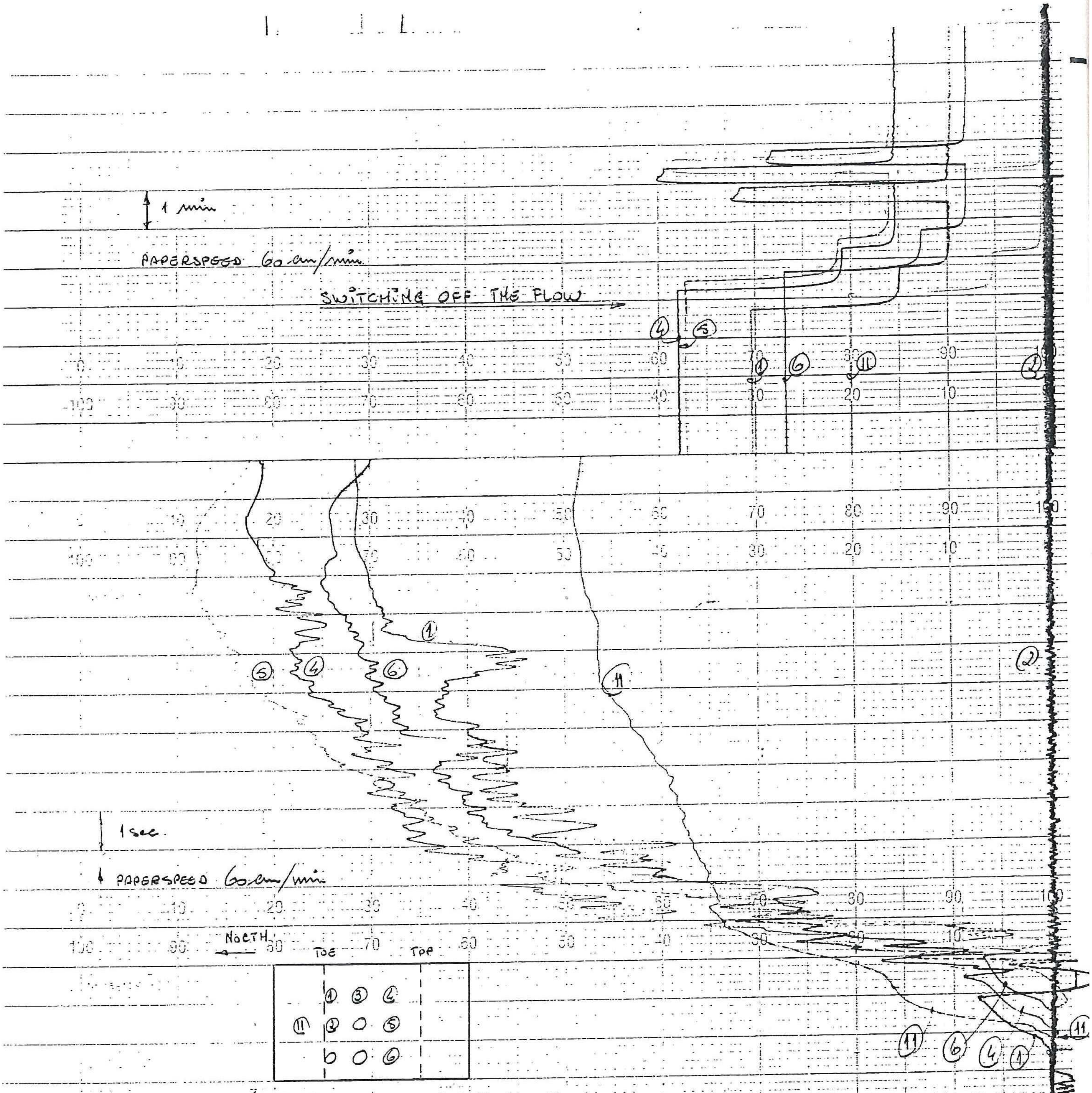
⑦ GREEN : G S 1 } 10 sch.d ≙ 1V ≙ 1 mm

⑨ BLACK : G S 3

⑮ BROWN : DIFF. PRESSURE 10 sch.d ≙ 1V ≙ 0,5 kPa

⑯ VIOLET : FLOW 10 sch.d ≙ 1V ≙ 5 l/min

FIGURE : 32



LIQUEFACTIONTEST BRUTUSTANK DD: 870219

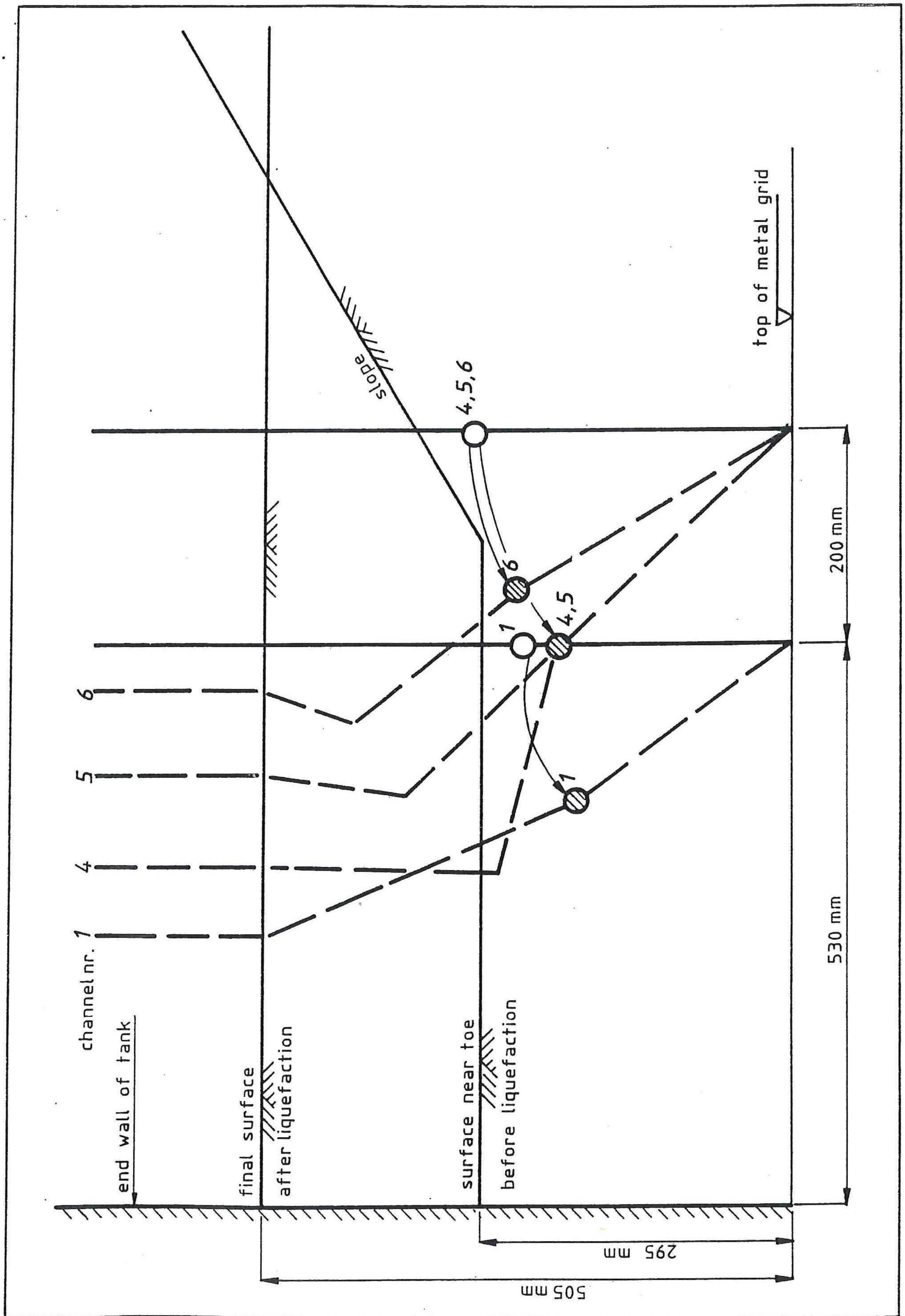
① RED : PPGS 1
* ② BLUE : PPGS 2 } 10 schd ≙ 1V ≙ 0,5 kPa ⟵ 0,5 kPa ⟶

⑪ GREEN : PPG B 1 10 schd ≙ 1V ≙ 1 kPa ⟵ 1 kPa ⟶

④ BLACK : PPGS 4
⑤ BROWN : PPGS 5 } 10 schd ≙ 1V ≙ 0,5 kPa ⟵ 0,5 kPa. ⟶
⑥ VIOLET : PPGS 6

* CH. ② RECORDER DEFECT

FIGURE : 33



GRONDMECHANICA
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LIQUEFACTIONTEST BRUTUSTANK

CO-287130
BO-690504

ESTIMATED POSITION OF PORE PRESSURE GAUGES
BEFORE AND AFTER TEST

FIG. 34

form.
A4

excess pore pressure

flow channel 16 L/min	diff. pressure channel 15 kPa	bottom channels 11, 12, 13, 14 kPa	PPGS 1 channel 1 kPa	PPGS 2 channel 2 kPa	PPGS 9 channel 6
6.4	0.26	2.0	1.25	1.20	
10.0	0.47	3.1	1.95	1.85	zero value not on paper
13.3	0.69	4.1	2.60	2.50	
16.7	0.95	5.1	3.30	3.10	
20.0	1.24	6.0	3.85	3.60	
28.5	2.1	6.3	4.25	4.00	fluidisation

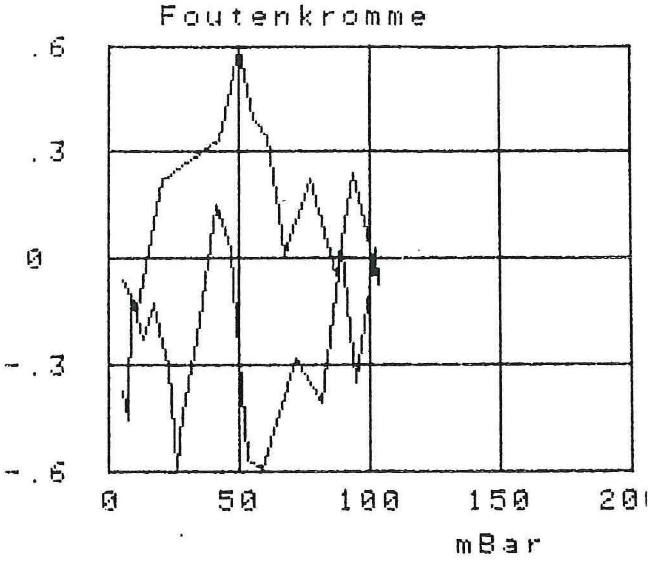
Table 1. Measured excess pore pressures for a series of applied flows.

Gauge	Channel	Excess pore pressure kPa		
		Tap near toe	tap near top	required for complete liquifaction
PPGS 1	1	4.35	2.70	3.835
PPGS 9	6	1.80	1.25	3.452
PPGB 1	11	5.50	3.80	6.559
PPGB 4	14	3.70	6.40	6.559

Table 2. Maximum excess pore pressure after tapping and the required excess pore pressure for liquifaction

Best of Straight Line

PPGS 1 - KAN. 1



879017 VERWEKINGSPR."BRUTUS" 871030 RvO
DRUCK MPW Snr 209

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 100.00000 mBar

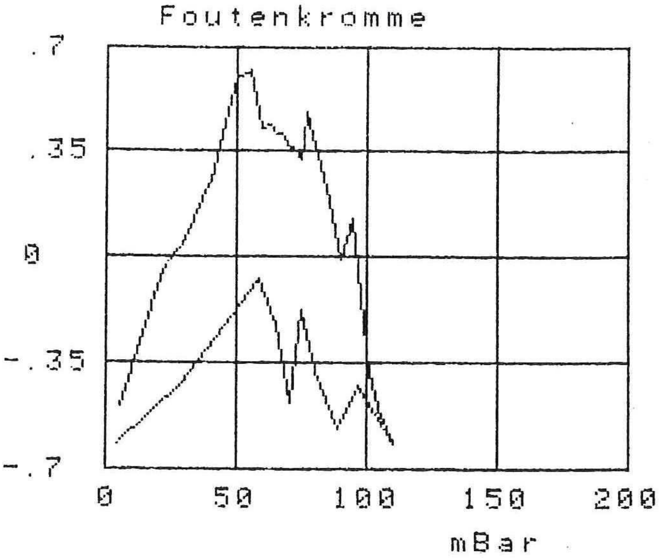
NULPUNTSINSTELLING : -24.57947 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 3.12616 mVolt/V / 100.00000 mBar
RECIPROKE GEVOELIGHEID : 31.98811 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .59814 mBar
MAXIMALE FOUT : .59814 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	4.7200	-23.1230	4.7200	4.6590	-.0610	-.0610	-1.2927
2	10.3600	-21.3870	10.3600	10.2121	-.1479	-.1479	-1.4274
3	20.8200	-18.0020	20.8200	21.0401	.2201	.2201	1.0571
4	42.1000	-11.3140	42.1000	42.4337	.3337	.3337	.7927
5	50.4500	-8.6210	50.4500	51.0481	.5981	.5981	1.1856
6	55.4800	-7.1130	55.4800	55.8719	.3919	.3919	.7065
7	61.1800	-5.3460	61.1800	61.5242	.3442	.3442	.5627
8	68.0100	-3.3160	68.0100	68.0178	.0078	.0078	.0115
9	77.8100	-.1850	77.8100	78.0333	.2233	.2233	.2870
10	87.1700	2.6560	87.1700	87.1211	-.0489	-.0489	-.0561
11	94.3700	4.9960	94.3700	94.6063	.2363	.2363	.2504
12	103.6800	7.8110	103.6800	103.6110	-.0690	-.0690	-.0666
13	102.8300	7.5760	102.8300	102.8593	.0293	.0293	.0285
14	95.5500	5.1820	95.5500	95.2013	-.3487	-.3487	-.3649
15	89.4100	3.3800	89.4100	89.4371	.0271	.0271	.0303
16	81.8500	.8820	81.8500	81.4464	-.4036	-.4036	-.4930
17	71.7600	-2.2360	71.7600	71.4725	-.2875	-.2875	-.4006
18	58.8500	-6.3690	58.8500	58.2519	-.5981	-.5981	-1.0164
19	53.7500	-7.9540	53.7500	53.1817	-.5683	-.5683	-1.0572
20	47.1900	-9.8200	47.1900	47.2128	.0228	.0228	.0482
21	40.7600	-11.7920	40.7600	40.9047	.1447	.1447	.3550
22	33.5700	-14.1570	33.5700	33.3395	-.2305	-.2305	-.6866
23	28.3600	-15.8520	28.3600	27.9175	-.4425	-.4425	-1.5602
24	25.4800	-16.8010	25.4800	24.8819	-.5981	-.5981	-2.3475
25	22.0600	-17.7800	22.0600	21.7502	-.3098	-.3098	-1.4042
26	17.2700	-19.2210	17.2700	17.1407	-.1293	-.1293	-.7484
27	12.6900	-20.6830	12.6900	12.4641	-.2259	-.2259	-1.7803
28	8.4200	-21.9810	8.4200	8.3120	-.1080	-.1080	-1.2824
29	7.6100	-22.3430	7.6100	7.1541	-.4559	-.4559	-5.9914
30	4.7300	-23.2180	4.7300	4.3551	-.3749	-.3749	-7.9261

TABLE: 3

Best of Straight Line

PPGS 2 - KAN. 2



879017 VERWEKINGSPR."BRUTUS" 871030 RvO
DRUCK MPW Snr 525

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 100.00000 mBar

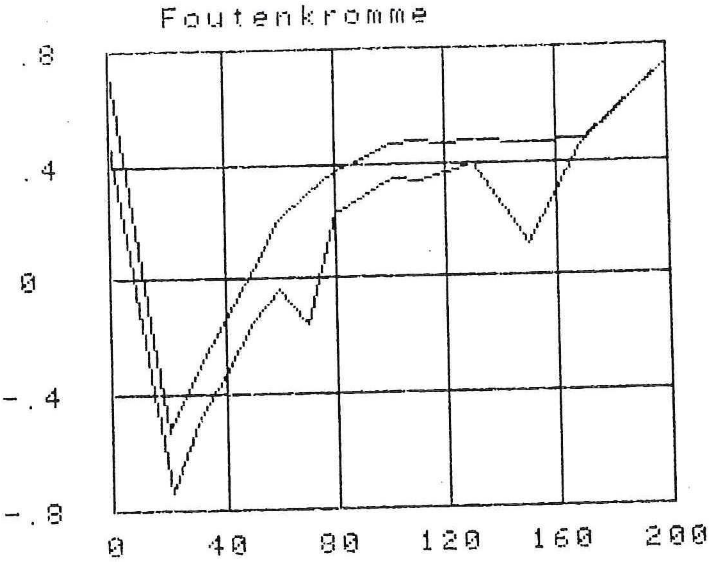
NULPUNTSINSTELLING : 27.40499 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 3.24141 mVolt/V / 100.00000 mBar
RECIPROKE GEVOELIGHEID : 30.85081 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .61703 mBar
MAXIMALE FOUT : .61703 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	4.4300	28.6810	4.4300	3.9366	-.4934	-.4934	-11.1378
2	21.4800	34.3520	21.4800	21.4321	-.0479	-.0479	-.2230
3	30.1800	37.2050	30.1800	30.2338	.0538	.0538	.1784
4	40.3000	40.5510	40.3000	40.5565	.2565	.2565	.6365
5	50.2900	43.8970	50.2900	50.8792	.5892	.5892	1.1716
6	55.2600	45.5170	55.2600	55.8770	.6170	.6170	1.1166
7	60.2600	47.0770	60.2600	60.6898	.4298	.4298	.7132
8	62.6400	47.8530	62.6400	63.0838	.4438	.4438	.7085
9	65.3200	48.7100	65.3200	65.7277	.4077	.4077	.6241
10	67.7400	49.4950	67.7400	68.1495	.4095	.4095	.6045
11	70.5100	50.3760	70.5100	70.8674	.3574	.3574	.5069
12	72.2700	50.9490	72.2700	72.6352	.3652	.3652	.5053
13	75.1100	51.8560	75.1100	75.4334	.3234	.3234	.4305
14	77.4900	52.6780	77.4900	77.9693	.4793	.4793	.6185
15	80.2900	53.5510	80.2900	80.6626	.3726	.3726	.4640
16	85.3900	55.1580	85.3900	85.6203	.2303	.2303	.2697
17	90.1900	56.6360	90.1900	90.1800	-.0100	-.0100	-.0110
18	95.0100	58.2430	95.0100	95.1378	.1278	.1278	.1345
19	101.4500	60.1620	101.4500	101.0580	-.3920	-.3920	-.3864
20	105.0500	61.2930	105.0500	104.5473	-.5027	-.5027	-.4786
21	110.2300	62.9350	110.2300	109.6130	-.6170	-.6170	-.5598
22	97.6700	58.9260	97.6700	97.2449	-.4251	-.4251	-.4353
23	89.9100	56.3620	89.9100	89.3347	-.5753	-.5753	-.6398
24	80.4000	53.3420	80.4000	80.0178	-.3822	-.3822	-.4754
25	75.0100	51.6600	75.0100	74.8287	-.1813	-.1813	-.2417
26	70.3300	50.0440	70.3300	69.8432	-.4868	-.4868	-.6922
27	65.0300	48.4100	65.0300	64.8022	-.2278	-.2278	-.3504
28	59.3000	46.6030	59.3000	59.2274	-.0726	-.0726	-.1224
29	29.5400	36.8450	29.5400	29.1232	-.4168	-.4168	-1.4110
30	4.0600	28.5210	4.0600	3.4430	-.6170	-.6170	-15.1975

TABLE : 4

Best of Straight Line

PAGE 3 - KAN. —



KPL 5737 ZETTINGSULOEI "BRUTUS-BAK" 870128 RvO
DRUCK PDCR 81 MPW Snr889

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mVolt
MEETGROOTHEID GEYKTE OPNEMER : mV/V
GEVOELIGHEID REF. OPNEMER : 1
GEIJKTE BEREIK (MAX-MIN) : 200.00000 mBar

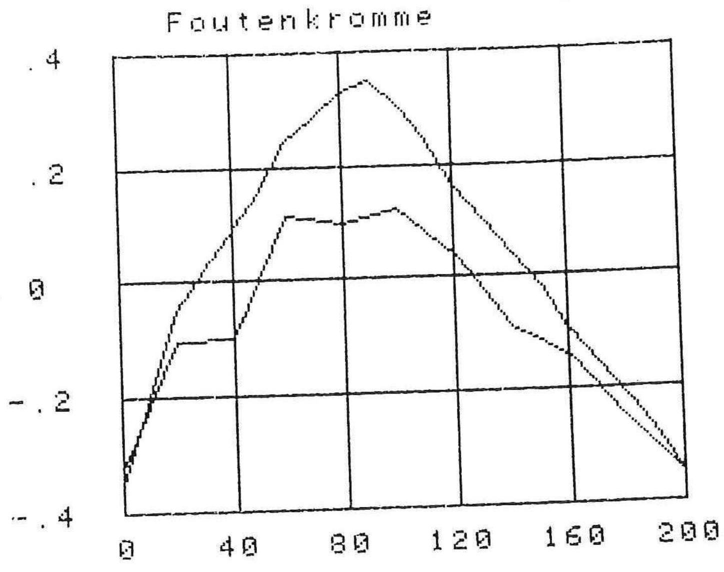
NULPUNTSINSTELLING : -8.07500 mV/V
GEVOELIGHEID GEIJKTE OPNEMER : 3.68034 mV/V / 200.00000 mBar
RECIPROKE GEVOELIGHEID : 54.34285 mBar /mV/V
MAXIMALE ABSOLUTE FOUT : 1.48549 mBar
MAXIMALE FOUT : .74274 % BEREIK

MEETNR.	REF.MEETW. mVolt	YKMEETW. mV/V	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	.0300	-7.9780	.0300	1.5155	1.4855	.7427	4951.6306
2	20.0000	-4.7710	20.0000	18.9432	-1.0568	-.5284	-5.2838
3	30.5200	-2.7570	30.5200	29.8879	-.6321	-.3161	-2.0711
4	40.0500	-.9370	40.0500	39.7783	-.2717	-.1359	-.6784
5	50.2700	1.0070	50.2700	50.3425	.0725	.0363	.1443
6	60.0600	2.8700	60.0600	60.4666	.4066	.2033	.6770
7	69.8800	4.7120	69.8800	70.4766	.5966	.2983	.8537
8	80.0500	6.6120	80.0500	80.8017	.7517	.3759	.9390
9	90.4100	8.5330	90.4100	91.2410	.8310	.4155	.9191
10	100.2900	10.3700	100.2900	101.2238	.9338	.4669	.9311
11	110.0200	12.1650	110.0200	110.9783	.9583	.4791	.8710
12	120.0900	14.0140	120.0900	121.0263	.9363	.4681	.7797
13	130.0000	15.8410	130.0000	130.9547	.9547	.4774	.7344
14	150.3300	19.5790	150.3300	151.2681	.9381	.4690	.6240
15	170.1500	23.2290	170.1500	171.1032	.9532	.4766	.5602
16	199.4900	28.7260	199.4900	200.9755	1.4855	.7427	.7446
17	168.9000	22.9920	168.9000	169.8153	.9153	.4576	.5419
18	149.7600	19.3430	149.7600	149.9856	.2256	.1128	.1506
19	130.0900	15.8260	130.0900	130.8732	.7832	.3916	.6021
20	110.8200	12.2600	110.8200	111.4946	.6746	.3373	.6087
21	100.2400	10.3160	100.2400	100.9303	.6903	.3452	.6886
22	90.2500	8.4570	90.2500	90.8280	.5780	.2890	.6404
23	80.2100	6.5870	80.2100	80.6659	.4559	.2279	.5683
24	70.4100	4.6440	70.4100	70.1070	-.3030	-.1515	-.4303
25	60.1900	2.8050	60.1900	60.1134	-.0766	-.0383	-.1273
26	50.2900	.9440	50.2900	50.0002	-.2898	-.1449	-.5763
27	40.1000	-.9970	40.1000	39.4522	-.6478	-.3239	-1.6154
28	30.9000	-2.7480	30.9000	29.9368	-.9632	-.4816	-3.1172
29	20.8200	-4.6990	20.8200	19.3345	-1.4855	-.7427	-7.1349
30	.0200	-8.0750	.0200	.9884	.9684	.4842	4841.8176

TABLE : 5

Best of Straight Line

PPGS 4 - KAN. 3



KPL 5737 ZETTINGSVLOEI "BRUTUS-BAK" 870128 RvO
DRUCK PDCR 81 MPW Snr 896

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mVolt
MEETGROOTHEID GEYKTE OPNEMER : mV/V
GEVOELIGHEID REF. OPNEMER : 1
GEIJKTE BEREIK (MAX-MIN) : 200.00000 mBar

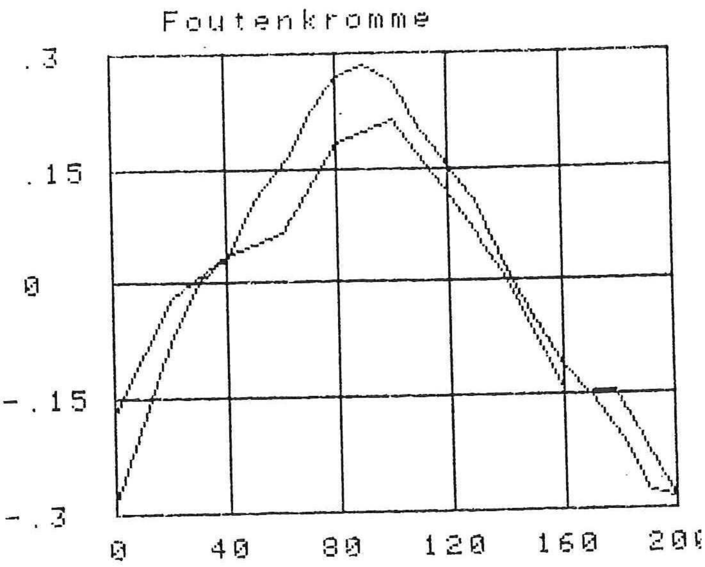
NULPUNTSINSTELLING : .07900 mV/V
GEVOELIGHEID GEIJKTE OPNEMER : 3.71925 mV/V / 200.00000 mBar
RECIPROKE GEVOELIGHEID : 53.77430 mBar /mV/V
MAXIMALE ABSOLUTE FOUT : .69650 mBar
MAXIMALE FOUT : .34825 % BEREIK

MEETNR.	REF.MEETW. mVolt	YKMEETW. mV/V	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	0.0000	.0790	0.0000	-.6965	-.6965	-.3483	
2	20.2500	3.9560	20.2500	20.1518	-.0982	-.0491	-.4850
3	30.0000	5.7950	30.0000	30.0409	.0409	.0204	.1363
4	41.6600	7.9920	41.6600	41.8551	.1951	.0975	.4683
5	50.1400	9.5900	50.1400	50.4482	.3082	.1541	.6147
6	59.9800	11.4540	59.9800	60.4718	.4918	.2459	.8199
7	70.0500	13.3410	70.0500	70.6190	.5690	.2845	.8122
8	80.0600	15.2190	80.0600	80.7178	.6578	.3289	.8216
9	90.1900	17.1100	90.1900	90.8865	.6965	.3483	.7723
10	101.2400	19.1460	101.2400	101.8349	.5949	.2975	.5877
11	110.2500	20.8040	110.2500	110.7507	.5007	.2504	.4542
12	120.0400	22.5930	120.0400	120.3709	.3309	.1655	.2757
13	130.0300	24.4270	130.0300	130.2332	.2032	.1016	.1562
14	140.1800	26.2930	140.1800	140.2674	.0874	.0437	.0624
15	150.2700	28.1470	150.2700	150.2372	-.0328	-.0164	-.0218
16	160.1400	29.9530	160.1400	159.9488	-.1912	-.0956	-.1194
17	170.2500	31.8110	170.2500	169.9401	-.3099	-.1550	-.1820
18	180.8600	33.7610	180.8600	180.4261	-.4339	-.2170	-.2399
19	189.8900	35.4170	189.8900	189.3311	-.5589	-.2794	-.2943
20	199.7500	37.2250	199.7500	199.0535	-.6965	-.3482	-.3487
21	179.3800	33.4740	179.3800	178.8828	-.4972	-.2486	-.2772
22	160.3800	29.9800	160.3800	160.0940	-.2860	-.1430	-.1783
23	140.3100	26.2690	140.3100	140.1384	-.1716	-.0858	-.1223
24	120.5400	22.6380	120.5400	120.6129	.0729	.0365	.0605
25	100.0800	18.8660	100.0800	100.3293	.2493	.1246	.2491
26	80.4400	15.2030	80.4400	80.6317	.1917	.0959	.2384
27	60.2400	11.4520	60.2400	60.4610	.2210	.1105	.3669
28	40.5900	7.7200	40.5900	40.3924	-.1976	-.0988	-.4867
29	20.1300	3.9140	20.1300	19.9259	-.2041	-.1020	-1.0137
30	.0700	.1000	.0700	-.5836	-.6536	-.3268	-933.6806

TABLE: 6

Best of Straight Line

PPGS 5 - KAN. —



KPL 5737 ZETTINGSVLOEI "BRUTUS-BAK" 870128 RvO
DRUCK POCR 81 MPW Snr 911

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mVolt
MEETGROOTHEID GEYKTE OPNEMER : mV/V
GEVOELIGHEID REF. OPNEMER : 1
GEIJKTE BEREIK (MAX-MIN) : 200.00000 mBar

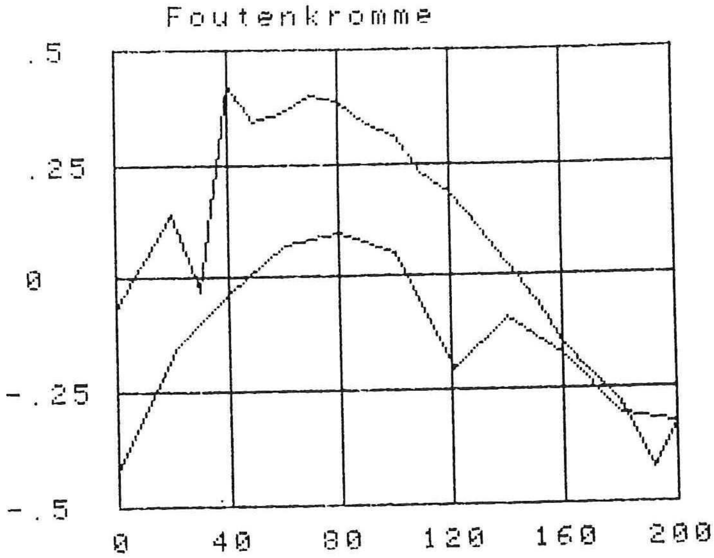
NULPUNTSINSTELLING : 18.79400 mV/V
GEVOELIGHEID GEIJKTE OPNEMER : 2.68959 mV/V / 200.00000 mBar
RECIPROKE GEVOELIGHEID : 74.36069 mBar /mV/V
MAXIMALE ABSOLUTE FOUT : .56977 mBar
MAXIMALE FOUT : .28489 % BEREIK

MEETNR.	REF.MEETW. mVolt	YKMEETW. mV/V	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	.0800	18.7690	.0800	-.4898	-.5698	-.2849	-712.2137
2	20.2500	21.5370	20.2500	20.0933	-.1567	-.0784	-.7740
3	30.1200	22.8860	30.1200	30.1245	.0045	.0023	.0150
4	41.4200	24.4150	41.4200	41.4943	.0743	.0371	.1793
5	50.2600	25.6230	50.2600	50.4770	.2170	.1085	.4319
6	62.4300	27.2740	62.4300	62.7540	.3240	.1620	.5190
7	70.2400	28.3390	70.2400	70.6734	.4334	.2167	.6170
8	80.7700	29.7690	80.7700	81.3070	.5370	.2685	.6648
9	90.0100	31.0160	90.0100	90.5798	.5698	.2849	.6330
10	100.1600	32.3750	100.1600	100.6854	.5254	.2627	.5245
11	110.8600	33.7960	110.8600	111.2520	.3920	.1960	.3536
12	120.0600	35.0220	120.0600	120.3687	.3087	.1543	.2571
13	130.1700	36.3670	130.1700	130.3702	.2002	.1001	.1538
14	140.4300	37.7230	140.4300	140.4535	.0235	.0117	.0167
15	150.7000	39.0860	150.7000	150.5889	-.1111	-.0556	-.0738
16	160.2300	40.3530	160.2300	160.0104	-.2196	-.1098	-.1371
17	170.0400	41.6610	170.0400	169.7367	-.3033	-.1516	-.1784
18	180.2800	43.0240	180.2800	179.8721	-.4079	-.2040	-.2263
19	190.4700	44.3750	190.4700	189.9182	-.5518	-.2759	-.2897
20	199.8500	45.6340	199.8500	199.2802	-.5698	-.2849	-.2851
21	177.9500	42.7260	177.9500	177.6561	-.2939	-.1469	-.1651
22	161.1500	40.4660	161.1500	160.8506	-.2994	-.1497	-.1858
23	140.8000	37.7700	140.8000	140.8030	.0030	.0015	.0021
24	120.5900	35.0820	120.5900	120.8148	.2248	.1124	.1864
25	100.7100	32.4360	100.7100	101.1390	.4290	.2145	.4260
26	80.1000	29.6560	80.1000	80.4667	.3667	.1834	.4578
27	60.7900	27.0280	60.7900	60.9247	.1347	.0674	.2216
28	40.4400	24.2830	40.4400	40.5127	.0727	.0364	.1798
29	20.6300	21.6050	20.6300	20.5989	-.0311	-.0155	-.1506
30	.0300	18.7940	.0300	-.3039	-.3339	-.1669	-1112.8973

TABLE: 7

Best of Straight Line

PPGS 6 - KAN. —



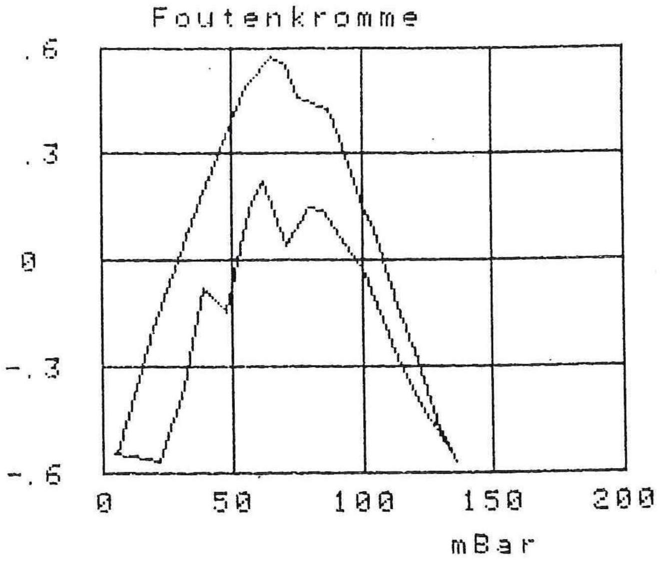
KPL 5737 ZETTINGSVLOEI "BRUTUS-BAK" 870128 RvO
DRUCK POCR 81 MPW Snr 943

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mVolt
MEETGROOTHEID GEYKTE OPNEMER : mV/V
GEVOELIGHEID REF. OPNEMER : 1
GEIJKTE BEREIK (MAX-MIN) : 200.00000 mBar

NULPUNTSINSTELLING : -2.45400 mV/V
GEVOELIGHEID GEIJKTE OPNEMER : 2.96859 mV/V / 200.00000 mBar
RECIPROKE GEVOELIGHEID : 67.37213 mBar /mV/V
MAXIMALE ABSOLUTE FOUT : .84743 mBar
MAXIMALE FOUT : .42372 % BEREIK

MEETNR.	REF.MEETW. mVolt	YKMEETW. mV/V	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	-.0100	-2.3400	-.0100	-.1394	-.1294	-.0647	1293.9083
2	20.1300	.7110	20.1300	20.4158	.2858	.1429	1.4200
3	30.1800	2.1520	30.1800	30.1242	-.0558	-.0279	-.1850
4	40.7300	3.8520	40.7300	41.5774	.8474	.4237	2.0806
5	50.1000	5.2190	50.1000	50.7872	.6872	.3436	1.3717
6	59.9600	6.6880	59.9600	60.6842	.7242	.3621	1.2078
7	69.9900	8.1880	69.9900	70.7900	.8000	.4000	1.1430
8	80.6200	9.7620	80.6200	81.3944	.7744	.3872	.9605
9	89.9900	11.1380	89.9900	90.6648	.6748	.3374	.7498
10	100.1800	12.6420	100.1800	100.7975	.6175	.3088	.6164
11	110.2000	14.1060	110.2000	110.6608	.4608	.2304	.4182
12	120.0900	15.5600	120.0900	120.4567	.3667	.1834	.3054
13	130.1400	17.0290	130.1400	130.3537	.2137	.1068	.1642
14	140.0700	18.4800	140.0700	140.1294	.0594	.0297	.0424
15	150.4100	19.9900	150.4100	150.3026	-.1074	-.0537	-.0714
16	159.9300	21.3760	159.9300	159.6404	-.2896	-.1448	-.1811
17	170.1900	22.8770	170.1900	169.7529	-.4371	-.2185	-.2568
18	180.3000	24.3600	180.3000	179.7442	-.5558	-.2779	-.3083
19	190.9400	25.8960	190.9400	190.0926	-.8474	-.4237	-.4438
20	199.9900	27.2680	199.9900	199.3360	-.6540	-.3270	-.3270
21	180.2600	24.3460	180.2600	179.6499	-.6101	-.3051	-.3385
22	160.1000	21.3920	160.1000	159.7482	-.3518	-.1759	-.2198
23	140.5300	18.5120	140.5300	140.3450	-.1850	-.0925	-.1317
24	120.7900	15.5490	120.7900	120.3826	-.4074	-.2037	-.3373
25	100.7400	12.6500	100.7400	100.8514	.1114	.0557	.1106
26	90.3700	9.6380	80.3700	80.5590	.1890	.0945	.2351
27	60.8200	6.7300	60.8200	60.9671	.1471	.0736	.2419
28	40.7300	3.7240	40.7800	40.7151	-.0649	-.0325	-.1592
29	20.7200	.7110	20.7200	20.4158	-.3042	-.1521	-1.4679
30	-.0500	-2.4540	-.0600	-.9074	-.8474	-.4237	1412.3886

TABLE : 8



Best of Straight Line

PPGS 7 - KAN. 4.

879017 VERWEKINGSPR."BRUTUS" 871030 RvO
DRUCK MPU Snr 891

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 100.00000 mBar

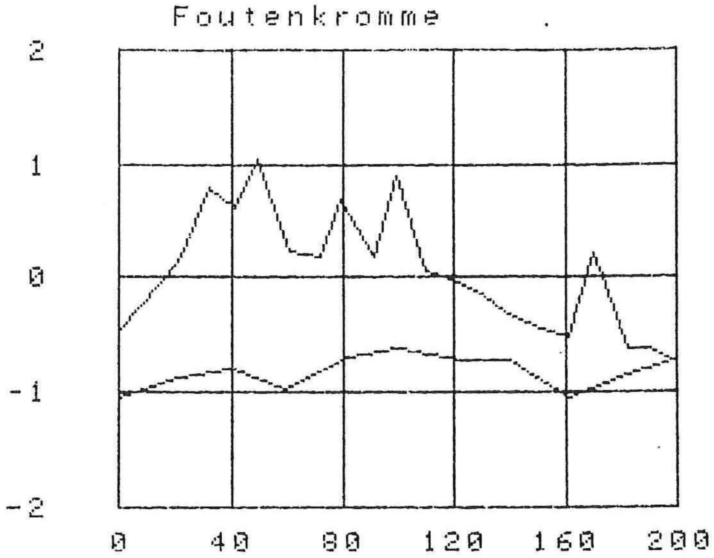
NULPUNTSINSTELLING : -3.11345 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 1.77786 mVolt / 100.00000 mBar
RECIPROKE GEVOELIGHEID : 56.24755 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .56900 mBar
MAXIMALE FOUT : .56900 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	4.4700	-2.4160	4.4700	3.9230	-.5470	-.5470	-12.2376
2	20.4500	.4920	20.4500	20.2798	-.1702	-.1702	-.8325
3	40.3700	4.1020	40.3700	40.5851	.2151	.2151	.5329
4	55.2400	6.7950	55.2400	55.7326	.4926	.4926	.8917
5	65.8000	8.6860	65.8000	66.3690	.5690	.5690	.8647
6	70.9600	9.6000	70.9600	71.5100	.5500	.5500	.7751
7	75.0300	10.3070	75.0300	75.4867	.4567	.4567	.6087
8	87.5900	12.5340	87.5900	88.0131	.4231	.4231	.4830
9	91.9900	13.3020	91.9900	92.3329	.3429	.3429	.3727
10	99.6700	14.6370	99.6700	99.8419	.1719	.1719	.1725
11	104.9300	15.5560	104.9300	105.0111	.0811	.0811	.0773
12	110.0500	16.4430	110.0500	110.0002	-.0498	-.0498	-.0452
13	114.5900	17.2320	114.5900	114.4382	-.1518	-.1518	-.1325
14	119.8700	18.1520	119.8700	119.6129	-.2571	-.2571	-.2145
15	129.2600	19.7820	129.2600	128.7813	-.4787	-.4787	-.3704
16	135.5600	20.8860	135.5600	134.9910	-.5690	-.5690	-.4197
17	126.0700	19.2190	126.0700	125.6145	-.4555	-.4555	-.3613
18	115.5000	17.3650	115.5000	115.1862	-.3138	-.3138	-.2716
19	100.6400	14.7740	100.6400	100.6125	-.0275	-.0275	-.0273
20	93.6600	13.5460	93.6600	93.7053	.0453	.0453	.0484
21	85.1200	12.0440	85.1200	85.2569	.1369	.1369	.1609
22	80.1400	11.1600	80.1400	80.2846	.1446	.1446	.1805
23	70.4500	9.4190	70.4500	70.4919	.0419	.0419	.0595
24	62.3000	8.0020	62.3000	62.5217	.2217	.2217	.3558
25	56.5900	6.9720	56.5900	56.7282	.1382	.1382	.2442
26	48.3100	5.4490	48.3100	48.1617	-.1483	-.1483	-.3070
27	39.0500	3.8140	39.0500	38.9652	-.0848	-.0848	-.2172
28	31.2000	2.3690	31.2000	30.8374	-.3626	-.3626	-1.1621
29	21.2200	.5580	21.2200	20.6510	-.5690	-.5690	-2.6814
30	4.2300	-2.4580	4.2300	3.6867	-.5433	-.5433	-12.8431

TABLE : 9

Best of Straight Line

PPGS 8 - KAN. 5



KPL 5737 ZETTINGSVLOEI "BRUTUS-BAK" 870128 RvD
DRUCK PDCR 81 MPU Snr 946

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mVolt
MEETGROOTHEID GEYKTE OPNEMER : mV/V
GEVOELIGHEID REF. OPNEMER : 1
GEIJKTE BEREIK (MAX-MIN) : 200.00000 mBar

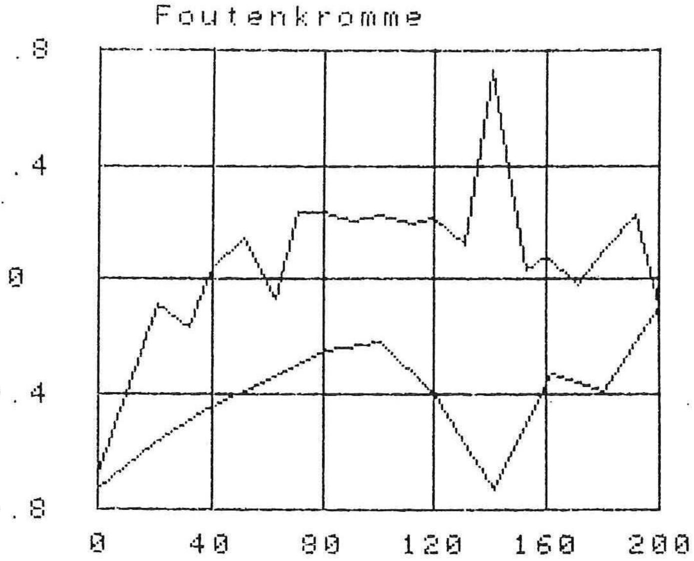
NULPUNTSINSTELLING : -5.30900 mV/V
GEVOELIGHEID GEIJKTE OPNEMER : 3.33147 mV/V / 200.00000 mBar
RECIPROKE GEVOELIGHEID : 60.03352 mBar /mV/V
MAXIMALE ABSOLUTE FOUT : 2.09215 mBar
MAXIMALE FOUT : 1.04607 % BEREIK

MEETNR.	REF.MEETW. mVolt	YKMEETW. mV/V	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	-.0600	-5.3090	-.0600	-.9955	-.9355	-.4678	1559.2108
2	21.5700	-1.5040	21.5700	21.8472	.2772	.1386	1.2852
3	32.3200	.5020	32.3200	33.8900	1.5700	.7850	4.8575
4	41.1300	1.9100	41.1300	42.3427	1.2127	.6063	2.9484
5	50.0600	3.5440	50.0600	52.1521	2.0921	1.0461	4.1793
6	61.0800	5.1120	61.0800	61.5654	.4854	.2427	.7947
7	71.8400	6.8870	71.8400	72.2214	.3814	.1907	.5308
8	79.7200	8.3630	79.7200	81.0823	1.3623	.6812	1.7089
9	90.9800	10.0700	90.9800	91.3300	.3500	.1750	.3847
10	99.9200	11.7950	99.9200	101.6858	1.7658	.8829	1.7672
11	110.0700	13.2140	110.0700	110.2046	.1346	.0673	.1223
12	121.6200	15.1020	121.6200	121.5389	-.0811	-.0406	-.0667
13	130.9900	16.6200	130.9900	130.6520	-.3380	-.1690	-.2580
14	141.2100	18.2670	141.2100	140.5395	-.6705	-.3352	-.4748
15	152.0300	20.0350	152.0300	151.1534	-.8766	-.4383	-.5766
16	160.6700	21.4480	160.6700	159.6362	-1.0338	-.5169	-.6435
17	169.9600	23.2350	169.9600	170.3642	.4042	.2021	.2378
18	181.7400	24.9240	181.7400	180.5038	-1.2362	-.6181	-.6802
19	190.1500	26.3230	190.1500	188.9025	-1.2475	-.6237	-.6561
20	199.0200	27.7730	199.0200	197.6074	-1.4126	-.7063	-.7098
21	178.6800	24.3310	178.6800	176.9438	-1.7362	-.8681	-.9717
22	161.1700	21.3550	161.1700	159.0779	-2.0921	-1.0461	-1.2981
23	140.5800	18.0330	140.5800	139.1347	-1.4453	-.7226	-1.0281
24	121.9100	14.9100	121.8100	120.3863	-1.4237	-.7119	-1.1688
25	100.2400	11.3520	100.2400	99.0263	-1.2137	-.6068	-1.2108
26	80.9700	8.1100	80.9700	79.5635	-1.4065	-.7033	-1.7371
27	60.3700	4.5940	60.3700	58.4557	-1.9143	-.9572	-3.1710
28	40.4200	1.3250	40.4200	38.8307	-1.5893	-.7946	-3.9319
29	21.3400	-1.8780	21.3400	19.6020	-1.7380	-.8690	-8.1444
30	-.0200	-5.4950	-.0200	-2.1121	-2.0921	-1.0461	10460.7498

TABLE : 1b

Best of Straight Line

PPGS 9 - KAN. 6



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KPL 5737   ZETTINGSVLOEI "BRUTUS-BAK"   870128        RvO
DRUCK                      PDCR 81 MPV    Snr 947


PROBLEEMGROOTHEID                  :  mBar
MEETGROOTHEID REF. OPNEMER         :  mVolt
MEETGROOTHEID GEYKTE OPNEMER       :  mV/V
GEVOELIGHEID REF. OPNEMER          :  1
GEIJKTE BEREIK (MAX-MIN)           :      200.00000  mBar


NULPUNTSINSTELLING                 :       -1.80600  mV/V
GEVOELIGHEID GEIJKTE OPNEMER       :        3.22315  mV/V      /   200.00000  mBar
RECIPROKE GEVOELIGHEID             :       62.05114  mBar       /mV/V
MAXIMALE ABSOLUTE FOUT             :        1.46379  mBar
MAXIMALE FOUT                      :         .73190  % BEREIK

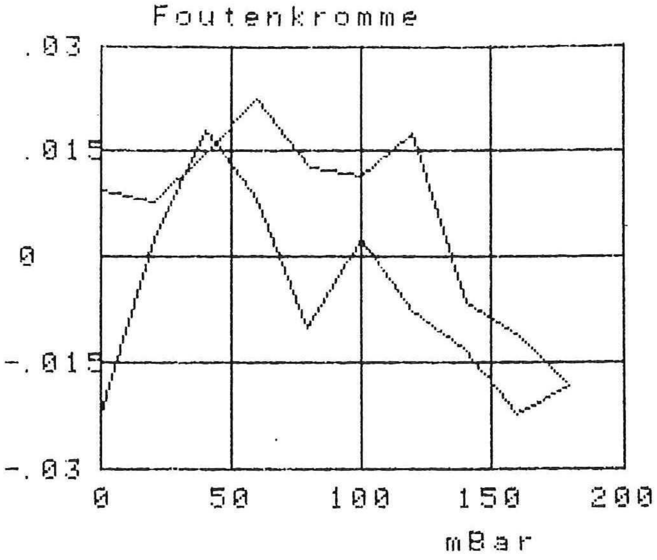

MEETNR.          REF.MEETW.    YKMEETW.  REF.PROBL.W     YKPROBL.W      ABS.FOUT        FOUT     REL.FOUT
                      mVolt        mV/V         mBar          mBar          mBar    % BEREIK            %


   1                 0.0000     -1.8060       0.0000       -1.3531       -1.3531      -.6766
   2                20.8600      1.7470      20.8600       20.6937        -.1663      -.0832        -.7974
   3                32.3800      3.5780      32.3800       32.0552        -.3248      -.1624       -1.0030
   4                40.6000      4.9710      40.6000       40.6989         .0989       .0495         .2437
   5                51.2400      6.7150      51.2400       51.5207         .2807       .1403         .5477
   6                62.4500      8.4540      62.4500       62.3114        -.1386      -.0693        -.2220
   7                70.7000      9.8830      70.7000       71.1785         .4785       .2392         .6768
   8                79.9900     11.3800      79.9900       80.4675         .4775       .2388         .5970
   9                90.9500     13.1370      90.9500       91.3699         .4199       .2100         .4617
  10               101.1600     14.7890     101.1600      101.6208         .4608       .2304         .4555
  11               112.1200     16.5430     112.1200      112.5045         .3845       .1923         .3430
  12               120.2500     17.8600     120.2500      120.6767         .4267       .2133         .3548
  13               131.4500     19.6360     131.4500      131.6969         .2469       .1235         .1879
  14               140.0000     21.2100     140.0000      141.4638        1.4638       .7319        1.0456
  15               152.1600     22.9460     152.1600      152.2359         .0759       .0379         .0499
  16               160.1700     24.2520     160.1700      160.3398         .1698       .0849         .1060
  17               171.3900     26.0280     171.3900      171.3600        -.0300      -.0150        -.0175
  18               181.3200     27.6690     181.3200      181.5426         .2226       .1113         .1228
  19               190.9300     29.2560     190.9300      191.3901         .4601       .2301         .2410
  20               199.7500     30.5730     199.7500      199.5623        -.1877      -.0939        -.0940
  21               180.0200     27.2990     180.0200      179.2467        -.7733      -.3866        -.4295
  22               161.8100     24.3850     161.8100      161.1650        -.6450      -.3225        -.3986
  23               141.7300     21.0170     141.7300      140.2662       -1.4638      -.7319       -1.0328
  24               121.5300     17.8650     121.5300      120.7077        -.8223      -.4112        -.6766
  25               100.6100     14.5570     100.6100      100.1812        -.4288      -.2144        -.4262
  26                80.6800     11.3340      80.6800       80.1821        -.4979      -.2490        -.6171
  27                60.7300      8.0860      60.7300       60.0279        -.7021      -.3511       -1.1561
  28                40.4400      4.7870      40.4400       39.5572        -.8828      -.4414       -2.1830
  29                20.3700      1.5110      20.3700       19.2292       -1.1408      -.5704       -5.6002
  30                  .0300     -1.8190        .0300       -1.4338       -1.4638      -.7319    -4879.2765
```

TABLE : 11

Best of Straight Line

PPGB 1 - KAN. 11



5732 .BRUTUS MLK 850114 RVO
DRUCK POCR 10/0 Snr 26013 A

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 150.00000 mBar

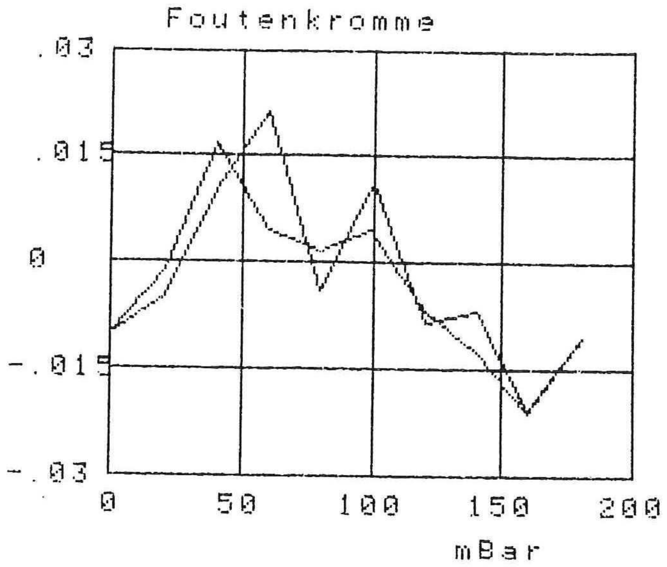
NULPUNTSINSTELLING : -.02008 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 2.18294 mVolt/V / 150.00000 mBar
RECIPROKE GEVOELIGHEID : 68.71458 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .03380 mBar
MAXIMALE FOUT : .02254 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	0.0000	-.0250	0.0000	-.0338	-.0338	-.0225	
2	20.0200	2.8940	20.0200	20.0240	.0040	.0027	.0199
3	39.6700	5.7570	39.6700	39.6970	.0270	.0180	.0680
4	59.9900	8.7120	59.9900	60.0021	.0121	.0081	.0202
5	80.0200	11.6230	80.0200	80.0049	-.0151	-.0100	-.0188
6	100.3200	14.5800	100.3200	100.3238	.0038	.0026	.0038
7	120.5100	17.5160	120.5100	120.4984	-.0116	-.0077	-.0096
8	140.0400	20.3570	140.0400	140.0203	-.0197	-.0132	-.0141
9	160.0500	23.2670	160.0500	160.0162	-.0338	-.0225	-.0211
10	180.0600	26.1800	180.0600	180.0328	-.0272	-.0182	-.0151
11	160.4800	23.3320	160.4800	160.4628	-.0172	-.0114	-.0107
12	140.7100	20.4560	140.7100	140.7005	-.0095	-.0063	-.0067
13	120.1700	17.4720	120.1700	120.1961	.0261	.0174	.0217
14	100.0800	14.5470	100.0800	100.0971	.0171	.0114	.0171
15	80.2400	11.6600	80.2400	80.2592	.0192	.0128	.0239
16	60.3600	8.7690	60.3600	60.3938	.0338	.0225	.0560
17	40.3000	5.8480	40.3000	40.3223	.0223	.0149	.0553
18	20.8300	3.0130	20.8300	20.8417	.0117	.0078	.0561
19	0.0000	-.0180	0.0000	.0143	.0143	.0095	

TABLE : 12

Best of Straight Line

PPG6 2 - KAN. 12



5732 BRUTUS MLK 850114 RVO
DRUCK PDCR 10/0 Snr 26014 A

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 150.00000 mBar

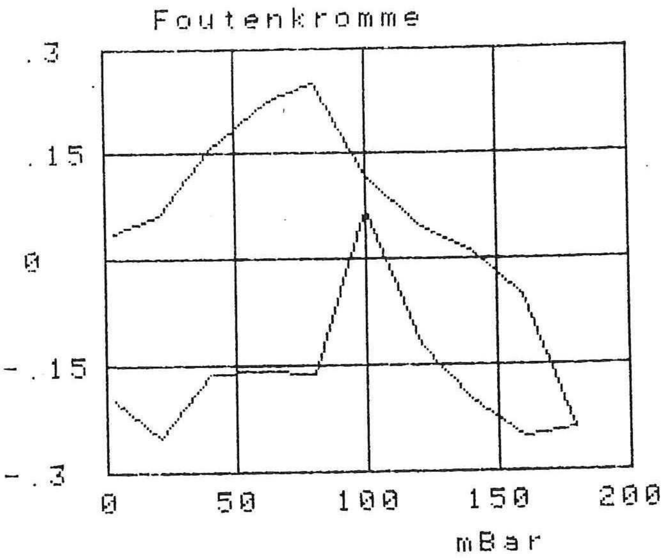
NULPUNTSINSTELLING : -.47081 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 2.18896 mVolt / √ / 150.00000 mBar
RECIPROKE GEVOELIGHEID : 68.52566 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .03185 mBar
MAXIMALE FOUT : .02123 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	0.0000	-.4730	0.0000	-.0150	-.0150	-.0100	
2	20.3100	2.4920	20.3100	20.3029	-.0071	-.0048	-.0351
3	40.2900	5.4110	40.2900	40.3055	.0155	.0103	.0385
4	60.2900	8.3320	60.2900	60.3218	.0318	.0212	.0528
5	80.0700	11.2130	80.0700	80.0641	-.0059	-.0039	-.0074
6	100.2900	14.1670	100.2900	100.3066	.0166	.0110	.0165
7	120.0000	17.0390	120.0000	119.9871	-.0129	-.0086	-.0107
8	140.2400	19.9930	140.2400	140.2296	-.0104	-.0069	-.0074
9	160.1400	22.8940	160.1400	160.1089	-.0311	-.0207	-.0194
10	180.3400	25.8440	180.3400	180.3240	-.0160	-.0107	-.0089
11	159.9900	22.8720	159.9900	159.9582	-.0318	-.0212	-.0199
12	140.1800	19.9830	140.1800	140.1611	-.0189	-.0126	-.0135
13	120.5800	17.1240	120.5800	120.5696	-.0104	-.0069	-.0086
14	99.9300	14.1130	99.9300	99.9365	.0065	.0044	.0065
15	80.1300	11.2230	80.1300	80.1326	.0026	.0017	.0033
16	59.8900	8.2700	59.8900	59.8970	.0070	.0047	.0117
17	40.1500	5.3920	40.1500	40.1753	.0253	.0169	.0630
18	20.5100	2.5220	20.5100	20.5084	-.0016	-.0010	-.0076
19	0.0000	-.4730	0.0000	-.0150	-.0150	-.0100	
20	0.0000	-.4750	0.0000	-.0287	-.0287	-.0191	
21	.0100	-.4730	.0100	-.0150	-.0250	-.0167	-249.9601
22	0.0000	-.4740	0.0000	-.0218	-.0218	-.0146	
23	.0100	-.4740	.0100	-.0218	-.0318	-.0212	-318.4858
24	0.0000	-.4710	0.0000	-.0013	-.0013	-.0009	
25	0.0000	-.4730	0.0000	-.0150	-.0150	-.0100	
26	0.0000	-.4710	0.0000	-.0013	-.0013	-.0009	
27	0.0000	-.4720	0.0000	-.0081	-.0081	-.0054	
28	0.0000	-.4740	0.0000	-.0218	-.0218	-.0146	
29	0.0000	-.4740	0.0000	-.0218	-.0218	-.0146	

TABLE : 13

Best of Straight Line

PPGB 3 - KAN. 13



879017 VERWEKINGSPR."BRUTUS" 87.10.30 RVO
DRUCK POCR 100 Snr 24105 C

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 150.00000 mBar

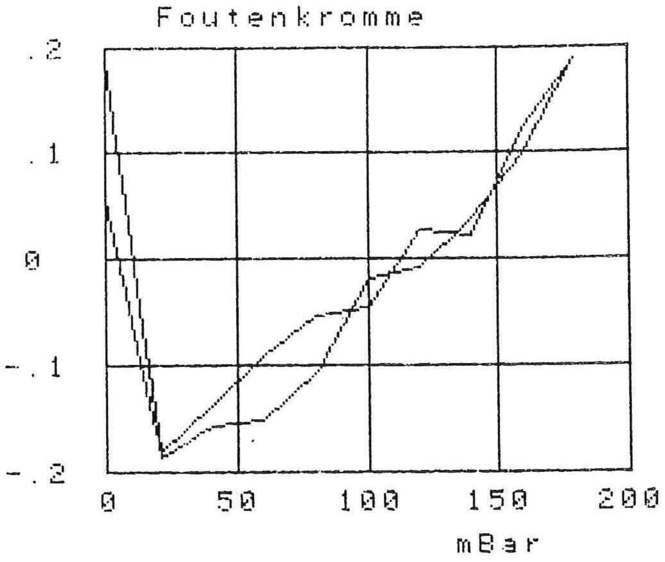
NULPUNTSINSTELLING : -.99069 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 2.15133 mVolt/√ / 150.00000 mBar
RECIPROKE GEVOELIGHEID : 69.72445 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .37610 mBar
MAXIMALE FOUT : .25073 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	2.9500	-.5600	2.9500	3.0030	.0530	.0353	1.7955
2	20.1400	1.9110	20.1400	20.2319	.0919	.0613	.4562
3	39.8700	4.7610	39.8700	40.1033	.2333	.1556	.5853
4	62.7300	8.0550	62.7300	63.0706	.3406	.2271	.5429
5	80.5300	10.6130	80.5300	80.9061	.3761	.2507	.4670
6	100.0700	13.3870	100.0700	100.2477	.1777	.1184	.1775
7	120.6400	16.3220	120.6400	120.7118	.0718	.0479	.0595
8	140.1900	19.1180	140.1900	140.2067	.0167	.0112	.0119
9	159.8300	21.9210	159.8300	159.7505	-.0795	-.0530	-.0497
10	180.1000	24.7880	180.1000	179.7405	-.3595	-.2397	-.1996
11	160.2800	21.9430	160.2800	159.9039	-.3761	-.2507	-.2346
12	140.2900	19.0870	140.2900	139.9906	-.2994	-.1996	-.2134
13	120.9100	16.3240	120.9100	120.7257	-.1843	-.1228	-.1524
14	100.8400	13.4870	100.8400	100.9449	.1049	.0699	.1040
15	80.8900	10.5760	80.8900	80.6481	-.2419	-.1613	-.2990
16	60.2300	7.6130	60.2300	59.9888	-.2412	-.1608	-.4005
17	40.1300	4.7300	40.1300	39.8872	-.2428	-.1619	-.6050
18	20.3500	1.8740	20.3500	19.9739	-.3761	-.2507	-1.8482
19	3.3000	-.5600	3.3000	3.0030	-.2970	-.1980	-9.0010

TABLE : 14

Best of Straight Line

PPGB 4 - KAN. 14.



5732 BRUIUS MLK 850115 RUO
DRUCK PDCR 10/0 Snr 46401 A

PROBLEEMGROOTHEID : mBar
MEETGROOTHEID REF. OPNEMER : mBar
MEETGROOTHEID GEYKTE OPNEMER : mVolt
GEVOELIGHEID REF. OPNEMER : 1 mBar / mBar
GEIJKTE BEREIK (MAX-MIN) : 150.00000 mBar

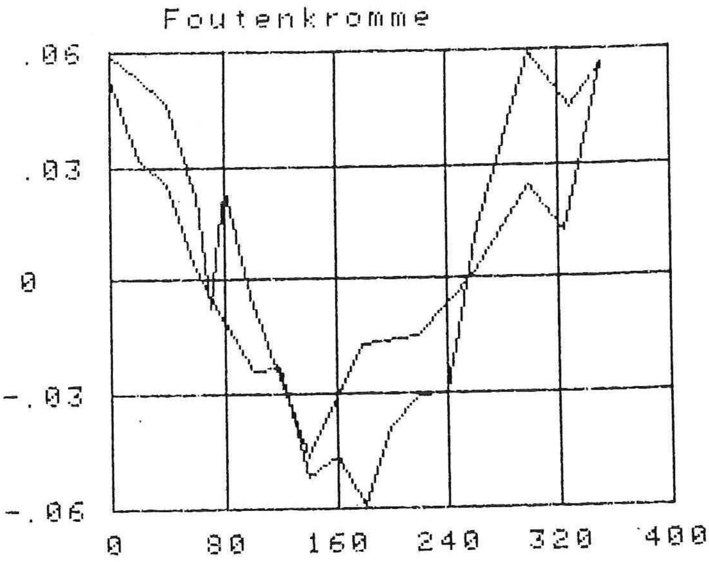
NULPUNTSINSTELLING : -1.02933 mVolt
GEVOELIGHEID GEIJKTE OPNEMER : 1.12267 mVolt/V / 150.00000 mBar
RECIPROKE GEVOELIGHEID : 133.61011 mBar /mVolt
MAXIMALE ABSOLUTE FOUT : .28163 mBar
MAXIMALE FOUT : .18775 % BEREIK

MEETNR.	REF.MEETW. mBar	YKMEETW. mVolt	REF.PROBL.W mBar	YKPROBL.W mBar	ABS.FOUT mBar	FOUT % BEREIK	REL.FOUT %
1	-.0100	-1.0090	-.0100	.2716	.2816	.1878	
2	20.0000	.4470	20.0000	19.7253	-.2747	-.1832	-1.3737
3	40.2800	1.9700	40.2800	40.0741	-.2059	-.1373	-.5112
4	60.3200	3.4750	60.3200	60.1824	-.1376	-.0917	-.2281
5	80.1200	4.9610	80.1200	80.0369	-.0831	-.0554	-.1038
6	100.1200	6.4590	100.1200	100.0517	-.0683	-.0456	-.0683
7	120.0500	7.9590	120.0500	120.0932	.0432	.0288	.0360
8	140.0100	9.4520	140.0100	140.0412	.0312	.0208	.0223
9	160.1000	10.9670	160.1000	160.2831	.1831	.1221	.1144
10	179.9900	12.4630	179.9900	180.2712	.2812	.1874	.1562
11	160.0300	10.9590	160.0300	160.1762	.1462	.0975	.0914
12	139.9300	9.4480	139.9300	139.9877	.0577	.0385	.0413
13	120.1600	7.9630	120.1600	120.1466	-.0134	-.0089	-.0111
14	100.2400	6.4710	100.2400	100.2120	-.0280	-.0187	-.0279
15	80.2900	4.9680	80.2900	80.1304	-.1596	-.1064	-.1988
16	60.0100	3.4450	60.0100	59.7816	-.2284	-.1523	-.3807
17	40.0300	1.9490	40.0300	39.7935	-.2365	-.1577	-.5908
18	19.9000	.4390	19.9000	19.6184	-.2816	-.1878	-1.4152
19	0.0000	-1.0230	0.0000	.0846	.0846	.0564	

TABLE: 15

Best of Straight Line

DIFF. PRESSURE - KAN. 15



5737 BRUTUS-BAK 861215 RvO
DRUCK PDCR 120WL/35 Snr 135892

PROBLEEMGROOTHEID : mBAR
MEETGROOTHEID REF. OPNEMER : mV
MEETGROOTHEID GEYKTE OPNEMER : mV
GEVOELIGHEID REF. OPNEMER : 1
GEIJKTE BEREIK (MAX-MIN) : 350.00000 mBAR

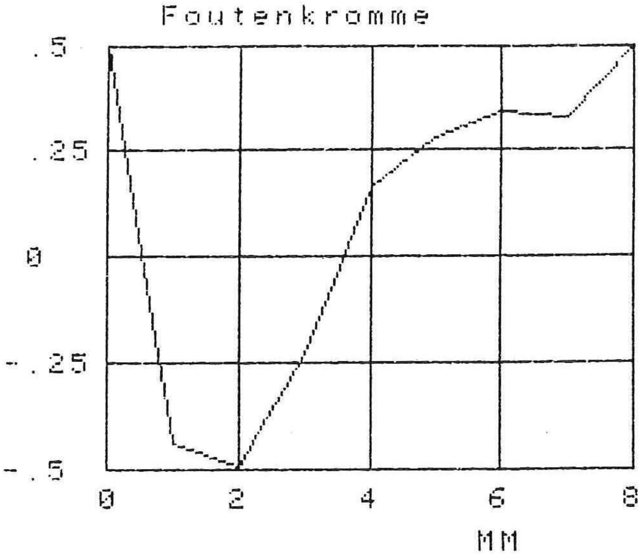
NULPUNTSINSTELLING : -.79250 mV
GEVOELIGHEID GEIJKTE OPNEMER : 4.98715 mV / V / 350.00000 mBAR
RECIPROKE GEVOELIGHEID : 70.18036 mBAR /mV
MAXIMALE ABSOLUTE FOUT : .20773 mBAR
MAXIMALE FOUT : .05935 % BEREIK

MEETNR.	REF.MEETW. mV	YKMEETW. mV	REF.PROBL.W mBAR	YKPROBL.W mBAR	ABS.FOUT mBAR	FOUT % BEREIK	REL.FOUT %
1	0.0000	-.7940	0.0000	.1867	.1867	.0533	
2	20.4000	2.1020	20.4000	20.5109	.1109	.0317	.5437
3	40.1000	4.9060	40.1000	40.1895	.0895	.0256	.2232
4	60.0000	7.7300	60.0000	60.0084	.0084	.0024	.0140
5	80.0000	10.5730	80.0000	79.9607	-.0393	-.0112	-.0491
6	100.6000	13.5020	100.6000	100.5165	-.0835	-.0238	-.0830
7	120.5000	16.3380	120.5000	120.4197	-.0803	-.0229	-.0667
8	139.9000	19.0880	139.9000	139.7193	-.1807	-.0516	-.1292
9	160.1000	21.9690	160.1000	159.9382	-.1618	-.0462	-.1010
10	180.0000	24.7980	180.0000	179.7923	-.2077	-.0594	-.1154
11	200.0000	27.6580	200.0000	199.8639	-.1361	-.0389	-.0681
12	220.0000	30.5120	220.0000	219.8933	-.1067	-.0305	-.0485
13	240.0000	33.3620	240.0000	239.8947	-.1053	-.0301	-.0439
14	259.9000	36.2180	259.9000	259.9382	.0382	.0109	.0147
15	300.0000	41.9560	300.0000	300.2077	.2077	.0594	.0692
16	328.2000	45.9670	328.2000	328.3571	.1571	.0449	.0479
17	350.1000	49.0930	350.1000	350.2955	.1955	.0558	.0558
18	323.4000	45.2670	323.4000	323.4445	.0445	.0127	.0137
19	299.4000	41.8530	299.4000	299.4849	.0849	.0243	.0283
20	260.9000	36.3560	260.9000	260.9067	.0067	.0019	.0026
21	220.1000	30.5340	220.1000	220.0477	-.0523	-.0149	-.0238
22	179.1000	24.6910	179.1000	179.0413	-.0587	-.0168	-.0328
23	140.0000	19.1050	140.0000	139.8386	-.1614	-.0461	-.1153
24	100.3000	13.4690	100.3000	100.2849	-.0151	-.0043	-.0150
25	80.1000	10.6050	80.1000	80.1853	.0853	.0244	.1065
26	70.3000	9.1930	70.3000	70.2758	-.0242	-.0069	-.0344
27	60.0000	7.7400	60.0000	60.0786	.0786	.0225	.1310
28	40.0000	4.9020	40.0000	40.1614	.1614	.0461	.4035
29	20.1000	2.0700	20.1000	20.2863	.1863	.0532	.9270
30	0.0000	-.7910	0.0000	.2077	.2077	.0594	

TABLE : 16

Best of Straight Line

GAP SENSOR 1 - KAN. 7



19-12-86 M.VISSER

GD U8 1048

PROBLEEMGROOTHEID : MM
MEETGROOTHEID REF. OPNEMER : MM
MEETGROOTHEID GEYKTE OPNEMER : MM/V
GEVOELIGHEID REF. OPNEMER : 1 MM / MM
GEIJKTE BEREIK (MAX-MIN) : 8.00000 MM

NULPUNTSINSTELLING : -.95000 MM/V
GEVOELIGHEID GEIJKTE OPNEMER : 7.88002 MM/V / 8.00000 MM
RECIPROKE GEVOELIGHEID : 1.01523 MM /MM/V
MAXIMALE ABSOLUTE FOUT : .03960 MM
MAXIMALE FOUT : .49495 % BEREIK

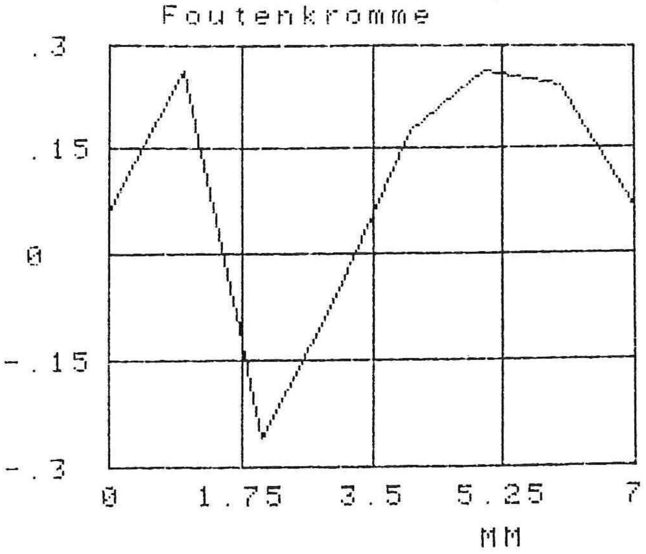
MEETNR.	REF.MEETW. MM	YKMEETW. MM/V	REF.PROBL.W MM	YKPROBL.W MM	ABS.FOUT MM	FOUT % BEREIK	REL.FOUT %
1	0.0000	-.9110	0.0000	.0396	.0396	.4949	
2	1.0000	0.0000	1.0000	.9645	-.0355	-.4442	-3.5533
3	2.0000	.9810	2.0000	1.9604	-.0396	-.4949	-1.9798
4	3.0000	1.9870	3.0000	2.9817	-.0183	-.2285	-.6093
5	4.0000	3.0030	4.0000	4.0132	.0132	.1649	.3298
6	5.0000	3.9970	5.0000	5.0223	.0223	.2791	.4465
7	6.0000	4.9870	6.0000	6.0274	.0274	.3425	.4567
8	7.0000	5.9710	7.0000	7.0264	.0264	.3298	.3769
9	8.0000	6.9690	8.0000	8.0396	.0396	.4948	.4948

Min 302
Max 353
[illegible] 548

TABLE : 17

Best of Straight Line

GAP SENSOR 2 - KAN. 8



19-12-86 M.VISSER

GD U8 1175

PROBLEEMGROOTHEID : MM
MEETGROOTHEID REF. OPNEMER : MM
MEETGROOTHEID GEYKTE OPNEMER : VOLT
GEVOELIGHEID REF. OPNEMER : 1 MM / MM
GEIJKTE BEREIK (MAX-MIN) : 7.00000 MM

NULPUNTSINSTELLING : -.99737 VOLT
GEVOELIGHEID GEIJKTE OPNEMER : 6.97375 VOLT / 7.00000 MM
RECIPROKE GEVOELIGHEID : 1.00376 MM /VOLT
MAXIMALE ABSOLUTE FOUT : .01819 MM
MAXIMALE FOUT : .25991 % BEREIK

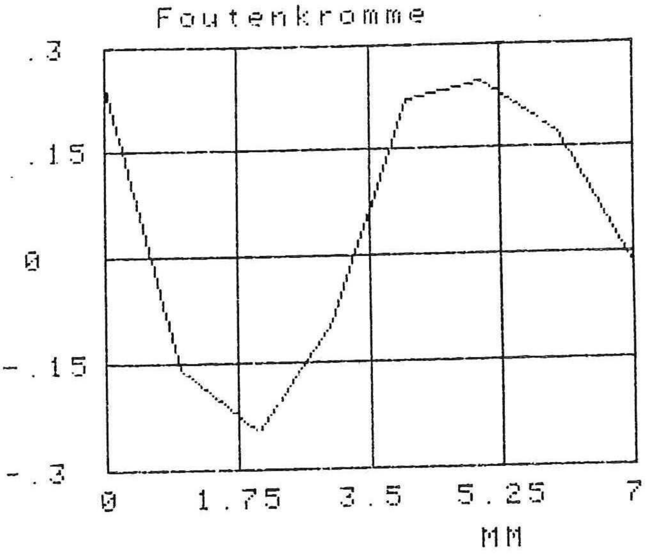
MEETNR.	REF.MEETW. MM	YKMEETW. VOLT	REF.PROBL.W MM	YKPROBL.W MM	ABS.FOUT MM	FOUT % BEREIK	REL.FOUT %
1	0.0000	-.9930	0.0000	.0044	.0044	.0627	
2	1.0000	.0170	1.0000	1.0182	.0182	.2599	1.8193
3	2.0000	.9770	2.0000	1.9818	-.0182	-.2599	-.9097
4	3.0000	1.9870	3.0000	2.9956	-.0044	-.0627	-.1464
5	4.0000	3.0000	4.0000	4.0124	.0124	.1775	.3105
6	5.0000	4.0020	5.0000	5.0182	.0182	.2599	.3639
7	6.0000	4.9970	6.0000	6.0169	.0169	.2420	.2823
8	7.0000	5.9810	7.0000	7.0046	.0046	.0663	.0663

lin : 426
fin : 381
(20.0 : 553

TABLE : 18

```
Best of Straight Line
```

GAP SENSOR 3 - KAN 3



```
                                  19-12-86     M.VISSER
GO                     U8         1176


PROBLEEMGROOTHEID                  :  MM
MEETGROOTHEID REF. OPNEMER         :  MM
MEETGROOTHEID GEYKTE OPNEMER       :  VOLT
GEVOELIGHEID REF. OPNEMER          :  1  MM / MM
GEIJKTE BEREIK (MAX-MIN)           :       7.00000  MM


NULPUNTSINSTELLING                 :       -.99220  VOLT
GEVOELIGHEID GEIJKTE OPNEMER       :       6.95940  VOLT      /     7.00000  MM
RECIPROKE GEVOELIGHEID             :       1.00583  MM        /VOLT
MAXIMALE ABSOLUTE FOUT             :        .01730  MM
MAXIMALE FOUT                      :        .24715  % BEREIK


MEETNR.         REF.MEETW.    YKMEETW.  REF.PROBL.W    YKPROBL.W    ABS.FOUT      FOUT    REL.FOUT
                        MM        VOLT           MM           MM          MM  % BEREIK           %


  1                 0.0000     -.9750       0.0000        .0173       .0173     .2472
  2                 1.0000     -.0090       1.0000        .9889      -.0111    -.1581     -1.1064
  3                 2.0000      .9790       2.0000       1.9827      -.0173    -.2472      -.8650
  4                 3.0000     1.9840       3.0000       2.9936      -.0064    -.0920      -.2146
  5                 4.0000     3.0000       4.0000       4.0155       .0155     .2213       .3872
  6                 5.0000     3.9960       5.0000       5.0173       .0173     .2471       .3460
  7                 6.0000     4.9850       6.0000       6.0121       .0121     .1724       .2011
  8                 7.0000     5.9660       7.0000       6.9988      -.0012    -.0173      -.0173
```

lin : 382,5
gain : 382
zero : 552,5

TABLE : 13

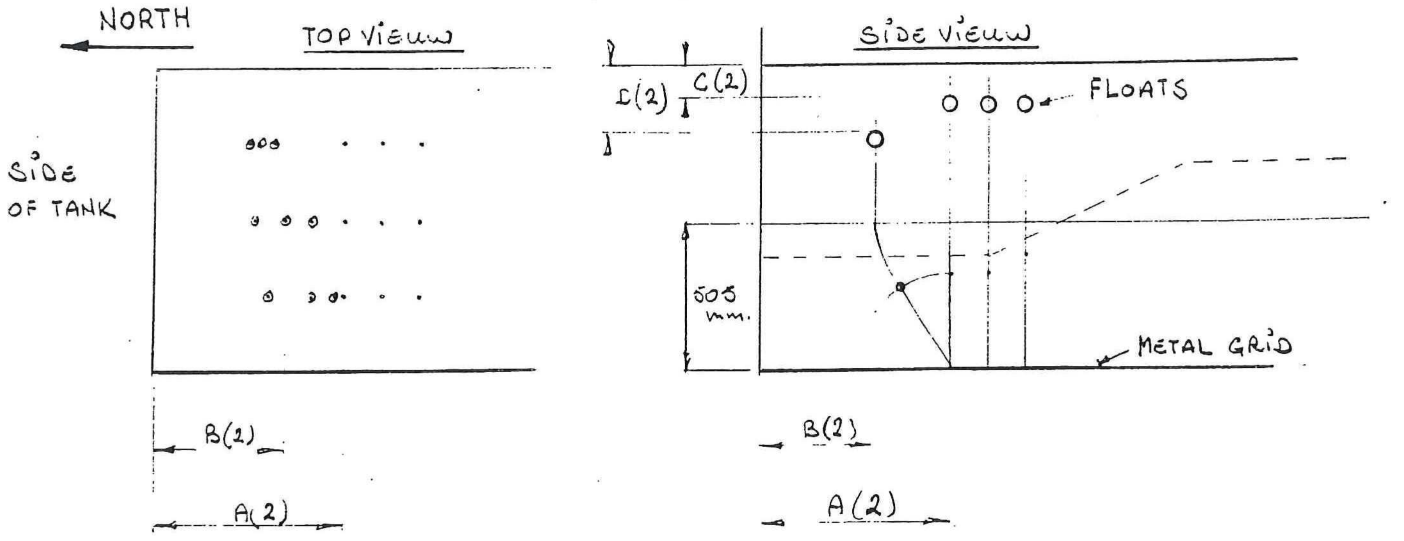
Type of control	K_p	τ_i	τ_d
Proportional (P)	0.5 K_{posc}	0	0
Proportional-integral (PI)	0.45 K_{posc}	0.85 t_{osc}	0
Proportional-integral-differential (PID)	0.6 K_{posc}	0.5 t_{osc}	0.125 t_{osc}

Table 20. Control rules by Ziegler and Nichols after (Cool, Schijff, Viersma, 1979)

PLACE OF THE PORE-PRESSURE GAUGES
BEFORE AND AFTER THE TEST
[illegible]

GRONDMECHANICA DELFT

87 02 19



A	HORIZONTAL	DISTANCE	BEFORE	THE TEST
B	HORIZONTAL	DISTANCE	AFTER	THE TEST
C	VERTICAL	DISTANCE	BEFORE	THE TEST
D	VERTICAL	DISTANCE	AFTER	THE TEST

GAUGE	CHANN.	A (mm)	B (mm)	C (mm)	D (mm)	A - B (mm)	D - C (mm)	SETTLEMENT PPGS (mm)	HORZ. DISPL. PYTHAGORAS
1	1	530	255	90	165	275	75	50	150
2	2	530	285	60	145	245	85		
3		530	300	70	157	230	87		
4	3	630	280	60	265	350	205	77	201
5		630	340	70	182	290	112	80	204
6		630	420	70	132	210	62	40	150
7	4	730	325	70	294	405	224		
8	5	730	410	70	207	320	137		
9	6	730	490	60	150	240	90		

TABLE : 21

Channel	Pore pressure KPa	Settlement in mm
1	0.50	50
4	0.775	77.5
5	0.80	80
6	0.40	40

Table 22

Recorded pressures and related settlement after switching off the flow at the end of the test