Documentation system for Continuous Compaction Control

CDS-012-J

CDS-012-051E/0010
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1. Introduction

1.1. Background

Over the last couple of years the conditions for compaction and control of unbound material have dramatically changed. For not long ago, compaction was considered to be of least importance in any construction processes, but today, with increasing demand on quality and the worsening world economic situation, the need for better compaction has increased tremendously. A detailed financial study of the total cost of a road, shows clearly that the life time of the expensive asphalt layer is strongly dependent on the grounds bearing capacity, i.e. compaction results.

The traditional spot check methods used today to control compaction results give neither the necessary general information of a construction site nor the necessary detailed information on every compacted square meter. Modern electronics has however made it possible to take measurements while compaction is in progress and to process, analyse and present large amount of data. The electronic roller integrated compaction meter and the roller-mounted system for documentation of the whole compaction process has drastically changed the technology of compaction.

The authorities in a number of European countries have noticed today’s requirements and possibilities. They have therefore issued new specifications and/or revised the existing rules and specifications in accordance with the prevailing conditions. As from 1994, Continuous compaction control (CCC) is included in the Swedish, Finish, German and Austrian specifications.
1.2. Contents

This manual is meant to give the reader a comprehensive view as well as detailed information about continuous compaction control, CCC, and to answer questions concerning the CCC's practical application.

In chapter 2, *Soil and rock fill compaction*, the reader is given an overview on the equipment and procedures involved in compaction control and compaction of soil and blast stones. Chapter 3, *Continuous compaction control, CCC*, describes CCC in practice.

Chapter 4, *CDS - system components*, and Chapter 5, *Installation*, describes the parts of the system and how to install the system.

Chapter 6, *Operation instructions*, contains user instructions and chapter 7, *Menus*, contains detailed information about the system's software.

Chapter 8, *CCC-report*, examines the contents in the One Page Documentation hard copy.

Chapter 9, *Fault localisation*, gives solutions to common problems. It also contains a schematic description of how to locate defects causing malfunction of the system and how to repair the defects.

Chapter 10, *Printer*, explains how to connect a printer to the system.

Data stored in the documentation system can be transferred to a PC for further analysis and processing. Software programs for processing and transmission of CDS data are described in chapter 11, *Data processing software*.

In chapter 12, *Replacing the EPROM*, is a description of how to change the EPROM in CDS.

The system's specifications are listed in chapter 13, *Technical specifications*, and chapter 14, *Spare parts*, contains a list of the system's accessories.

Chapter 15, *References*, contains a list of books and publications where more information about CCC can be found.

At the end of this manual is an *Alphabetic index* over some key words found here and there in this manual.
2. Soil and rock fill compaction

This chapter describes briefly the tools and procedures used in compaction and compaction control of soil and rock fill. There is certainly not enough space here to fully describe all the preconditions and methods used, therefore for further information refer to other technical literature on the subject (see chapter 15, Literature).

2.1. Compaction tools

The aim of compacting unbound layers of soil and rock fill is to increase the ground's ability to bear a given static load, e.g. a building or a dynamic load, e.g. traffic on a road. Compaction ought to be done effectively in order to achieve a uniformly compacted surface in the shortest possible time without over- or under compacted regions. Irregular compaction will most likely cause settlement differences that eventually can damage the construction (building, road, runway and etc.).

Figure 1. From left to right: A.) a static roller, B.) a vibrating roller and C.) an oscillating roller.
Compaction of soil or rock fill layers during the construction of roads, railways, runways, ponds and waste dump is normally done by one or more suitable rollers. There are three different types of rollers today:

A. Static rollers
B. Vibrating rollers
C. Oscillating rollers

Figure 1 shows the three types of rollers.

Each roller type can have a number of different designs e.g. single-roll, tandem, drawn or self propelled. A roller can be specified by its static parameters (drum diameter, drum length, line load, weight, etc.) and by its dynamic parameters (vibration amplitude, vibration frequency, roller speed, the roll direction in relation to the eccentric’s direction of rotation etc.). The static rollers (see figure 1) use only their weight to compact. Therefore they cannot be used for CCC and they will not be discussed here.

**Vibrating rollers**

Vibrating rollers have one or two vibrating drums (see figure 1). Vibration is caused by an eccentric weight rotating inside the drum. The eccentric weight rotates with a frequency from 20 - 40 Hz (Hz = Hertz = revolutions per second) and causes the drum to vibrate with an amplitude of 0.5 - 2.0 mm.

Most vibrating rollers have two amplitudes (low and high) and each of these have a corresponding frequency (normally low amplitude is combined with high frequency).

There are cases when a combination of the roller's weight, a particular frequency, a particular amplitude and the condition of the compacted layer, cause the vibrating roller to fall into "double jump or rocking mode". The roller functions in a very strange way when it falls into double jump or rocking mode. The noise level increases considerably and the roller shakes violently. This is a very undesirable state in compaction because:

1. This affects negatively the compaction results, e.g. the material can loosen up and be crushed.
2. The violent shaking can limit the rollers lifetime.
3. The environment suffers from the violent vibrations.
4. The roller driver's working environment become unbearable.
5. CMV- values are affected.

If the roller falls into a rocking mode or double jump at high amplitude it is advisable to change to the low amplitude. If this happens at the low amplitude, then cease compaction with the current roller. In order to continue working at the same location another roller must be used.

**Oscillating rollers**

Oscillating rollers (see figure 1) operate under new, patented compaction principles. An oscillating roller has two synchronously rotating eccentric shafts. The shafts’ rotation causes a very fast alternating movement of the drum back and forth, instead of the up and down movement of the vibrating drum (vertical impact into the ground). The oscillating drum never lifts from the ground instead compaction is achieved through a combination of the roller's weight (like a static roller) and the horizontal shearing force ("rubbing in" the ground).
Generally, oscillating rollers have the same amplitudes and frequencies as their corresponding vibrating rollers. The amplitude for the oscillating rollers is also given in mm but here it is meant to be the tangential amplitude of oscillation (in contrast to the vertical amplitude of vibration for the vibrating rollers).

Oscillating rollers have many advantages over the static and vibrating rollers:

- Oscillating rollers compact through the force of their weight and through the shear force in contrast to static rollers that compact only through the force of their weight.

- Oscillating rollers do not lift from the ground i.e. they do not hit the ground. Therefore, with oscillating rollers, compaction is smoother and much more uniform than with vibrating rollers that hit the ground.

- Oscillating rollers have a narrower depth effect than the vibrating rollers. This is of an advantage in compaction of thin layers but a disadvantage in compaction of layers as thick as 40 -50 cm.

It is important to note that for all the three types of rollers, high efficiency is achieved if compaction is done at an appropriate roller speed and for the vibrating and oscillating rollers, with optimum frequency and amplitude. In order to obtain uniform compaction it is very important that the area to be compacted is divided into parallel strips and these should be compacted with some degree of overlapping.

### 2.2. Spot check methods of compaction control

The material to be compacted, e.g. soil, gravel or rock fill, can be of highly varying properties (e.g. grain shape, grain distribution, grain size distribution and water content) that compaction and control of the work done becomes much more difficult.

The possibility and ease to compact and control compaction can also depend on the thickness of the layer to be compacted, its compaction state (not compacted, badly/well compacted irregularly/uniformly compacted) and the state of the ground or underlying layers (soft, hard).

Traditionally, compaction is controlled by means of different spot check methods aimed at determining the materials density or the E-modulus of the layers in different spots. The most common methods used are density measurement, plate load testing and falling weight deflectometer.
2.2.1. Density measurement

There are different methods to determine the density of a given material "in-situ, i.e. on site, and the most common ones are with a water balloon test and with a radiometric probe, see figure 2 and figure 3 respectively.

To determine the density of a material with a water balloon test, you need to dig a hole of about 1-2 litres in the material, determine the volume of the hole using a water filled rubber bladder, then weigh the material that you dug out, dry the material and weigh it again. The weight of the dried material divided by the volume of the hole gives you the density of the dry sample in g/cm$^3$.

The measurement of density with a radiometric probe is based on the ability of the compacted material to damp or attenuate gamma radiation. There are two types of radiation measuring instruments

- Reflecting radiation meter (backscatter)
- Transmitting radiation meter

The backscatter has both the radiation source and detector on its lower side well as the transmitting radiation meter has its radiation source on the tip of a probe that is placed down about 30 cm into the material, see figure 3. The detector is placed on the meter's lower side or on the tip of another probe (the double probe meter) that is also placed down parallel to the probe with the radiation source.

Figure 2. Measurement of density with the "water balloon".

Figure 3. Measurement of density with a radiometric probe.

The depth effect of a backscatter is about 7 cm in normal soil and rock fill layers and it is 20 cm maximum for a transmitting radiation meter with one probe.

Another test, the modified proctor compaction test, is normally also made. In this case a large volume of material from the same spot where the water balloon or the radiometric probe test was made is examined in a laboratory whereby the optimum water content in the material and the material's maximum density are determined. The ratio of the density in-situ to the maximum density from the
Proctor test (standard or modified) is what is known as "Relative density, Rd" and it is given in percentage.

The density in-situ and the Rd give a measure of the compaction state only at those spots where the samples were taken. The determination of density with the water balloon method takes about 45 minutes excluding the time for weighing and drying the sample and the radiometric probe test takes about 5 - 15 minutes. A Proctor compaction test with five samples, weighing, drying and etc. takes about 4 hours.

The Technische Universität München made a detailed study of the results from tests made with different instruments and found that the results from different density measurements of the most common unbound material widely differ. This can be mainly due to local variations in the material but can also be due to external factors like the instrument used, the operator of the instrument, weather etc.

2.2.2. Bearing capacity measurement

Plate load testing

In principle, the plate load test includes twice loading and unloading a stiff plate of about 30 cm in diameter in a specified way, see figure 4.

From a load/deformation curve, see figure 5, the material's E-modulus under the first loading (Ev$_1$) and under the second loading (Ev$_2$) can be determined. The ratio Ev$_2$/Ev$_1$ must not be greater than a given value, that might differ from country to country.

![Figure 4. Plate load testing with one-dial-instrument.](image-url)
The original plate load test instrument has three deformation gauges (three meters) that are visually read. A modern version (figure 4) of the instrument has only one meter and the load cycles are registered by a potable computer which means in principle that the results cannot be manipulated.

The composition of the material under the plate affects the results of the plate load testing i.e. if the plate rests on one or more big stones or if the material under the plate is composed of a correction of fine grained material then the test results are more likely to be wrong. To prevent this, the composition of the material up to 50 cm under the plate ought to be controlled after every test.

**Figure 5.** *Load/deformation curve.*

If this control reveals an accumulation of big stones and fine-grained material then the test ought to be repeated in another spot.

In some countries, e.g. German, it is required that the loose upper layer be removed so that the plate rests on a representative surface. It takes about 30 minutes to take a plate load test with a modern instrument (having one meter). The potable computer then immediately calculates the E-modulus. With the original test instrument there will be extra time required to analyse the results manually.

**Falling weight deflectometer**

The falling weight deflectometer (FWDM) was originally developed for the control of bound layers (pavement) but the method has also been used (for research purposes) for control of unbound layers.

In this method, a load with a given weight is released to fall on a plate with a given weight and diameter. The load's retardation and the ground deformation in and around the target are registered by geophones or by accelerometers when the load hits the plate (figure 6).

The ground's E-modulus is then calculated from the measured deformations. An FWDM test with fully automatic instruments takes about 2 minutes.

It should be however noted that the FWDM test compacts the unbound material every time it hits the ground, and that today there is no given standard for compaction control of unbound layers using falling weight deflectometer.

**Figure 6.** *Falling weight deflectometer.*
2.3. Continuous Compaction Control, CCC

Continuous compaction control was developed in order to improve compaction and to increase the efficiency of compaction and compaction control.

CCC has the following advantages over the conventional methods used today to control compaction:

- **Compaction meter values are reproducible**

  Reproducibility is very good, an example of that is shown in figure 7, where three successive passes on the same strip are plotted. One can see clearly that every pass resembles the previous/subsequent pass (tops and valleys are always around the same place).

![Figure 7. An example of CCC's good reproducibility.](image)

- **Simultaneous measurement and compaction**

  The conventional control methods slows down compaction a great deal, this is partly because no work (compaction) is permitted in the vicinity of measurement points and partly because the evaluation of measurements can take hours or even days and the work cannot be continued before the results are ready. With CCC measurements are collected as compaction continues (simultaneously). The roller driver can directly read the measurement results from the system’s LCD-display and both the contractor and the client can at anytime obtain a copy of the CCC-report.

- **Registered measured data is not manipulable**

  Most of the spot check methods produce results that can be affected by external factors like human errors, the apparatus itself, weather and the like. These results can also be manipulated intentionally or unintentionally and there is no possibility to verify the validity of these results later. With CCC data is saved in its original form without any possibility intentionally or otherwise to change or alter it.
• **Continuous**
  With CCC every compacted square meter is measured, the results are stored and can be presented anytime.

• **Overview**
  An easy to understand grey tone presentation of the results gives the driver, the contractor and the customer an overview, in every strip, of the current state of the compacted area.

• **CDS-system can be mounted on all dynamic rollers.**
  With the exception of static rollers, CDS-system can be mounted on any dynamic roller (vibrating and oscillating).

• **Cost**
  Vägverket (Swedish national road administration) compared the cost of compaction control with CDS-system to that without the CDS-system in a "VÄG 94" project and found that the CDS-system completely pays for itself after being used on an area 13 m wide and 10 km long. Time and improved quality costs are not included in this calculation. The figures from Austria confirms "Vägverket's calculations.

More about *Continuous Compaction Control* in chapter 3
3. Continuous Compaction Control, CCC

Continuous compaction control, CCC, is a new, easy, effective and cheap method of controlling, testing and documenting the whole compaction process. This method was developed in Sweden and first used on a large scale in Germany by Prüfamt für Grundbau, Technische Universität München. It was used in the construction of the BMW-factory in Regensburg, a marshalling yard in Munich, Munich’s new airport MUC II etc.

CCC system is designed first and foremost to control the compaction of layers with unbound material such as rock fill, crushed material, gravel, sand and mixed soil with a small amount of fine grained material. New specifications in which CCC is included have been released in a number of countries. These specifications concern especially unbound roadbase, sub-base and capping layer.

CCC is finding more and more application in Sweden and many other countries mainly because it is the only effective way today to achieve uniform compaction. Non uniform compaction or the remnants of soft sections, soon or later lead to differences in settlement that eventually damage the constructed object (highway, runway, railway, building etc.).

At the time of this publication, Continuous Compaction Control of asphalt does not exist, but research is in progress. In some countries, e.g. Austria, CCC is being used to guaranty that the unbound ground to be laid with asphalt is homogeneous and evenly compacted immediately before the asphalt is laid. The reason for this is mainly because the Compaction State of the ground determines the asphalt’s lifetime and consequently the cost for repair and maintenance.

3.1. Necessary equipment

CCC requires that the compaction tool (roller) is equipped with a compaction meter (Compactometer or Oscillometer) and a documentation system, CDS-012. Also required is an IBM-compatible computer (PC) with MS-DOS version 3.3 or higher and the necessary software for saving, analysing and presentation of compaction data. Geodynamik has developed software programs CdsView, CdsCom and CdsMap for data processing, data evaluation and etc. These programs are discussed in detail in chapter 11, *Software for data processing*. 
Figure 8 shows how a CCC system can be used.

The roller in figure 8 is equipped with a documentation system, CDS-012, and a roller integrated compaction meter. Compaction data is collected and stored in the CDS during compaction. At the end of compaction, the CDS can be connected to a PC and the collected data is transferred to the PC for permanent storage or for further processing with CdsView, CdsCom or CdsMap software. The CDS can also be connected to a printer to obtain a hard copy of the CCC-report.

3.2. Compaction meter values CMV and OMV

A roller integrated compaction meter continuously registers the ground's compaction state and presents it in form of a "Compaction-Meter-Value", CMV for vibrating rollers or "Ocillo-Meter-Value)", OMV for oscillating rollers. This value is registered, stored and presented by the documentation system, CDS-012.

The compaction meter value is a relative dimensionless unit that measures the compaction state of a material and its absolute value varies with the material's rigidity. Continuous compaction control that is based on a compaction meter is meant first and mainly to control compaction of layers of unbound materials like rock fill, crash material, gravel, sand and mixed soil with a little percentage of fine grained material.
When compacting mixed soil with a large amount of fine-grained material (fines, clay and etc.), the water and binder content affect the compaction meter values CMV and OMV. The consequence of this can be that the CMV/OMV values correspond to the water content other than the compaction state or E-modulus.

In order to compare the compaction meter values from different spots or from different regions of an area, especially in the final documentation, it is very important that the roller and project parameters are kept constant throughout the compaction process (Roller parameters: compaction direction, roll speed, vibration/oscillation amplitude, vibration/oscillation frequency. Project parameters: layer type, layer thickness, material).

Proper documentation also requires that the roller and project data entered into the CDS-system is correct. It is better that this is done before compaction begins and in an office where it is easy to obtain the necessary data. If a particular CDS-system is to be used on only one roller, then the roller data, weight, amplitude and etc. are entered only once and they are never changed. This data is normally available in the roller's instruction manual.

Even the roller's amplitude, frequency and speed can be obtained from the roller's instructions manual and there are usually many different alternatives. Therefore, when entering data into the CDS-system, select this data in accordance with the specifications of the project in question or, if a calibration has been made, use the data used in the calibration.

The current project data (project name, layer type, layer number and etc.) should, if possible, be entered into the CDS-system before hand in an office. The data for an area (start line, direction, strip length and etc.) should be entered when the CDS-system is already installed on the roller and before compaction of that particular area begins.

### 3.3. Compaction and documentation

An area comprising up to 10 parallel strips normally undergoes 4 passes of compaction first. The CDS-system's LCD-display, displays immediately and continuously the compaction results achieved so far in a graphic form. On this LCD-display, the current compaction state of every square meter is presented in an easy to understand grey tone graphics. Therefore, by just watching the LCD's graphic presentation, you get immediate and continuous information about the current compaction state.

After the fourth pass, the CDS-system can calculate the so called "compaction gradient". This gradient provides the roller operator with concrete information as to where further compaction is required and the number of extra passes required to achieve the specified compaction results. The roller symbol in the CDS-system's LCD, indicating the current position of the roller, helps the roller operator to locate regions where extra compaction is required.

The concentration of extra compaction to those parts where extra compaction is both necessary and useful makes it possible to achieve even compaction results over the whole area in the shortest possible time and to avoid the unnecessary, and often destructive, overcompaction. Overcompaction is the continuation of compaction of areas where the specified rigidity/bearing capacity have been already achieved. Overcompaction can easily cause a roller to fall into rocking mode or double jump whereby the roller shakes violently and the already satisfactorily compacted layers are negatively affected.
through loosening, crushing of material and the pressing down of the compacted layer into the subgrade. The next chapter discusses double jump and rocking mode in detail.

In some countries, there is a difference between a "production roller" and a "test roller". Both are equipped with a CDS-system, but the production roller is used throughout the whole compaction work well as the control roller, which is often specially calibrated, is only used for documentation of the compaction results. Sometimes many different production rollers of varying size/fabrication are used on the same area and the final compaction is documented and carried out by a special test roller.

3.4. Double jump and rocking mode

Double jump and rocking mode are phenomena that happen when compacting relatively stiff ground. This can happen rather unexpectedly and it takes a long time to come out of this phenomenon. The roller operator immediately notices this condition because the roller violently shakes and the noise becomes unbearable.

Double jump/rocking mode occurs when the relation between the compacted ground's condition and the roller's dynamic properties (frame weight, vibration amplitude, vibration frequency) exceeds a given limit. This limit varies from roller to roller. Double jump and rocking mode occur only when working with vibrating rollers (never with oscillating rollers). Some types of rollers, like tandem rollers and tractor rollers with heavy frames, rarely fall into double jump/rocking mode condition well as some other types easily fall into this state.

During double jump, the drum's eccentrics course the whole drum to be in the air a whole period with no contact to the ground every other period. Rocking mode is when only one side of the drum is in the air at a time.

In both conditions, double jump and rocking mode, compaction is practically carried out at half the set frequency and double the set amplitude. This is against the compaction's rule of the thumb that says that compaction ought to be began at a high amplitude and at a low frequency and be ended at a high frequency and at a low amplitude. Double jump and rocking mode must therefore be avoided. During double jump, the roller re-loosens the already compacted layer, crushes the material and the vibrations are spread to the surrounding environment. In addition, both the roller and the roller operator are badly affected by the violent vibrations and worst of all, the roller operator is forced to work in extremely noisy conditions created as a result of the double jump/rocking mode. Normally the easiest way to come out of double jump/rocking mode is to switch from high to low vibration amplitude but if double jump/rocking mode occurs even at low amplitude then compaction with the current roller ought to be stopped.

Due to the abrupt fall of the vibration frequency during double jump/rocking mode, the CMV values are affected and actually are reduced to about half the normal value. This means that during double jump, the CMV values of an area well compacted will read as if it is undercompacted. In some countries therefore, it is required that the CMV values registered during double jump/rocking mode be marked so that inspectors or the customer can differentiate the true low CMV-values from the false values due to double jump/rocking mode.

In many countries, among them Sweden and Austria, it is not required to register or indicate the occurrence of double jump and rocking mode because it is basically assumed that no compaction and particularly no documentation ought to be made in case double jump or rocking mode occurs
Geodynamik has developed a special compaction meter, ALFA-022R which indicates whether the roller is stable, about to fall into double jump/rocking mode or is already in that condition. A processor in ALFA-022R calculates the so called RMV value (Resonance-Meter-Value) in every measurement interval and these values are grouped together in groups of five. If any one value in a group exceeds the specified limit then the whole section corresponding to the group is marked with a line in the working screen, the results screen and the CCC-report. The compaction meter, ALFA-022R can also be equipped with an RMV dial instrument (RMV-meter).

3.5. Continuous Compaction Control, CCC

At the end of the compaction work (the last pass should be carried out at low amplitude), a documentation report of both the compaction process and the compaction results can be obtained. This report is known as the "CCC-report" and can be obtained in two different ways:

**PC - printer hard copy**

![Figure 9. Printing from a PC.](image)

Normally the CDS is dismounted from the roller and carried to the office where it is connected to a computer and the compaction data is transferred from The CDS to the computer. You can then with the help of CdsCom or CdsView PC-programs print a copy of the CCC - report using a printer connected to your computer (see figure 9).

CDS can also be connected to a portable computer and a copy of the CCC - report can be obtained just in the same way as above.

**Direct CDS - printer hard copy**

The CDS can be taken to the office where it is connected to a printer (figure 10) and using the CDS Print menu a copy of the CCC- report can be printed.
If necessary CDS can be connected to a potable printer inside the roller and like above, using the CDS menu PRINT, obtain a copy of the CCC - report.

Printers that are compatible with CDS are discussed in chapter 10, Printer.

The CCC-report (see chapter 8, CCC-report, for more information) contains:

- A graphic presentation of the compaction results in four grey tones (white, light grey, dark grey, and black)
- Average compaction meter values for every strip/area
- A grey tone scale that shows the "accept value" and the limits used in the graphic presentation
- Project- and material data
- Roller data (specifications)
- Date

It is important to note that the CCC report is a document that is impossible to manipulate because compaction data cannot be altered or changed after it has been recorded and registered. Even when the grey tone scale is changed, the original data will remain unaltered in the CDS memory.

The CCC report has many advantages to a contractor and customer.

Advantages to a contractor:

- **Self control**
  At the end of compaction, the contractor can immediately receive an easy to understand overview document, at the basis of which he can decide whether to terminate the work or, depending on the results, take appropriate measures (recompaction with another type of compactor, stabilisation, change material, etc.).

- **Saves time**
Since there is no need to wait for the conventional spot tests, a lot of time will be saved (no compaction is allowed where conventional control is taking place and it can take days before the results are ready).

- **Reliability**
  The fear that the customer might demand that further measures be taken before starting on the next layer is eliminated.

Advantages to the customer:

- **Reliability**
  The customer is always certain that the specified compaction results have been achieved, since the CCC - report gives a complete view of the compaction result.

- **Quality**
  All irregularities in the compaction routine that does not conform to the specifications are recorded and documented (number of passes, roller parameters etc.).

- **Self control and extra measures directed on weak spots**
  It is easy for the customer to choose spots for eventual supplementary spot control and sections where extra measures ought to be taken.

- **Reconstruction possibility**
  In case damage is observed later on the built object, it is easy with the help of CCC- report to reconstruct the cause of the damage.

For sometime now, a new form of contract is being signed in Sweden and a number of other countries, the so-called "Functionsentreprenad". In this type of contract, the contractor guarantees that for a given period of time, e.g. 10 years, the construction will always satisfy the given conditions e.g. smoothness. In such cases, the CCC is of great importance because the whole compaction process from the surface layer to basecourse is documented. Any weak spots can then be identified and effectively dealt with to minimise compaction variation that might otherwise result into settlement difference that in turn can damage the construction. The ability to control and document every stratum increases the quality of the construction (e.g. a highway) and decreases the risk for damage within the guaranty period. This means that the usually high insurance premium for the "Functionsentreprenad" contracts is greatly reduced if CCC is applied.

### 3.6. Calibration of the compaction meter values

Compaction meter values are relative values, therefore it is required at least under a transition period that CMV/OMV-values be calibrated against one of the conventional control methods, density measurement/relative density or plate load testing.

CMV calibration procedures vary from country to country. In principle, the spots where the calibration data is to be collected should be selected in such a way that the ground's properties (mainly bearing capacity and material composition) in the selected spots are representative of the whole area to be documented. If these properties vary a great deal within the area to be compacted then select many more different calibration spots.
During calibration, a layer representative of the area to be documented in both material and thickness is compacted at suitable frequency and speed (according to the roller's instruction manual) and at low amplitude. It is better to divide the calibration area into 3 strips with 20 cm overlapping. Density should be measured either by taking samples or by the plate load testing in at least three points every other pass, see figure 11.

Figure 11. Calibration.

Compaction for the purpose of calibration should be ended when no considerable rise in the compaction results can be noticed or when double jump for the first time occurs (compaction should not continue when double jump occurs).

The measured density, compaction grade (standard or modified Proctor) or E-modulus (Ev$_1$ or Ev$_2$) in a spot is plotted against the registered compaction meter value in the same spot. This can be done manually or automatically using software like the CdsView. We strongly recommend the CdsView for the following reasons:

- The values are entered in a form of a table that is compatible with the data registered by the CDS
- The program automatically gets the CMV-values for every test point from the data files
- The results are plotted and presented in a calibration diagram, (figure 12), that is displayed on the screen and a copy of which can be printed using a printer or a plotter.
- By regression analysis, a straight line through the points is computed and drawn.
- The regression coefficient is calculated.
- An extra straight line corresponding to the regression line multiplied by a certain factor can be drawn and used to determine the accept level when the unavoidable statistical variations have to be taken into consideration.
The calibration results in CdsView are stored in special calibration files. New calibrations can be added or wrongly entered data can be changed afterwards. The calibration data can also be stored in a dBase- or Lotus-123-format for further processing using other programs.

3.7. Accept level and allowed deviations

A CCC-report gives an overview of the whole compacted area and makes it possible to make a reliable judgement of the compaction results. It is of course equally important that the uniformly compacted area also meet the required bearing capacity, a requirement that is today given as E-modulus or indirectly as the least degree of compaction.

Out of the calibration diagram mentioned above, a compaction meter value corresponding to the required density, degree of compaction or E-modulus is obtained. This "accept level", CMV or OMV is entered in the CDS-system as the accept level in the Limits menu.

No soil or rock fill is so homogeneous that one can demand that everywhere the compaction level be equal to the accept level. It is therefore appropriate to give an 'allowed deviation', i.e. a band of CMV or OMV values above and below the accept level. This band is conveniently given by setting: limit 1 to accept level minus allowed deviation downwards and limit 3 to accept level plus allowed deviation upwards. If the limits are set in that way, the allowed deviations will be shown on the LCD-screen and in the CCC-report as light grey and dark grey. The white will then represent undercompaction and the black will represent overcompaction.

If no calibration has been made then the accept level and the allowed deviation can be obtained either from a "material catalogue" containing a table of materials, layer thickness, roller sizes and CMV/OMV values (e.g. practised in Austria), or from norm/specifications or whenever applicable from the tender contract.
3.8. Supervisory control

For different reasons, in Sweden and some other countries, supervisory control is sometimes carried out at random by plate loading or density measurement. In Sweden, for example, for every control area (4500 m² to 6000 m²) a region of at least 10 m² with the lowest compaction meter values undergoes supervisory control in at least two spots. If the control results are above the specified minimum $E_v^2$ (or % modified Proctor) value then the whole control area is approved otherwise further measures ought to be taken (additional compaction with a different roller, stabilisation, change of material etc.).

3.9. Standards and specifications

CCC is included in the following standards and specifications:

**Sweden**

- Vägverkets Byggnadstekniska Allmänna beskrivningar för väg 1992 (VÄG 94), Kapitel 5 "Obundna överbyggnadslager"
- Vägverkets metodbeskrivning (VVMB 603:1993) "Yttäckande packningskontroll"

**Finland**

- The Finish national road administration specifies the use a compaction meter

**Germany**

- Deutsche Bundesbahn: "Einsatz der flächendeckenden dynamischen Verdichtungskontrolle (FDVK) zur Prüfung von Erdbauwerken bei der DB", Teil 1, Anwendung bei nichtbindigen und schwachbindigen Böden, July 1990
- ZTVE StB 94, "Zusätzliche Technische Vertragsbedingungen und Richtlinien für Erdarbeiten im Straßenbau"
- Technische Prüfvorschrift für Boden- und Fels, TP BF - StB Teil E 2 "Prüfung der Verdichtung mit flächendeckenden dynamischen Verfahren", 1994

**Austria**

- ÖNORM S 2074 Teil 2, Nov. 1990, Geotechnik im Deponiebau, Erdarbeiten
4. System components

4.1. CDS-012-J

The compaction documentation system, CDS-012-J, contains the following:

- Display unit
- I-sensor
- Start/Stop button
- Mounting plate
- AC/DC-converter for power supply to the display unit from the mains
- cables (used to connect the Compactometer and a printer to the display unit)
- Manual

The CDS-012-J system was designed to be fitted to the Geodynamik’s compaction meters, the Compactometer ALFA-022R and the Oscillometer POM-060, but it can also be fitted to other compaction meters of different makes. Figure 13 shows a documentation system connected to a compaction meter.

*Figure 13. A documentation system connected to a compaction meter.*
The main component of the CDS-012-J system is the display unit. This unit was specially designed to function even in rough conditions like those in a roller at work. On the upper side of the display unit is an LCD display and thirteen keys, see figure 14. The display unit is sometimes simply called CDS.

A microprocessor inside the display unit controls the collection of data and the presentation of the results. The system's software is permanently stored in the memory inside the unit. The software functions include:

- Registration of the project, roller and material data
- Continuous registration of data while rolling
- Display of results, roller position, etc.
- Printing of the registered data and results
- Transfer of data to/from an IBM-compatible computer

**Figure 14. Display unit and panel.**

The display unit panel is shown below:

1. Power switch
2. LCD contrast control
3. Compaction meter terminal, (also used to connect a printer and a PC)
4. Contact to connect either a printer or a PC (9-way DSUB-contact)
5. Standard contact (2-way contact) to connect AC/DC converter or Start/Stop button
6. Start/stop button contact, (also used to connect an AC-DC converter for power supply from the mains.)
At the bottom of the display unit is a threaded hole used to fasten the display unit to a mounting plate. After compaction, the display unit can easily be detached from the plate and connected to a printer to obtain a hard copy of a CCC-report (more on CCC-report in chapter 8, *CCC-report*).

The display unit can also be connected to a computer to transfer the registered data to a PC file. To do this you need a software program *CdsCom* or *CdsView*. Data transferred to a file can be processed further with the help of CdsView and CdsMap programs. These programs are discussed in details in chapter 11, *Data processing software*.

### 4.2. Compaction meter

**Principle of operation**

Generally, a compaction meter comprise of a sensor, a processor unit, cables and meters, see figure 15.

![Figure 15. Components of a compaction meter.](image)

The sensor should be connected to a part of the roller that vibrates together with the drum. The sensor contains an accelerometer, usually a piezoelectric accelerometer, and electronics for amplification and filtration of the accelerometer signal. During compaction the sensor vibrates together with the drum and continuously reads the drum's vibrations that are then transformed into an electric signal. The signal is amplified and filtered, to remove mechanical and electrical noise, and then lead through a cable (the same cable supplies power to the sensor from the processor) to the processor where the signal is analysed and CMV (compaction meter value) is calculated.

The documentation system, CDS-012-J, is designed to be fitted to Geodynamik's Compactometer (vibrating rollers) and Oscillometer (oscillating rollers).
Compactometer ALFA-022R

The Compactometer is the first ever roller integrated compaction meter. It is patented and can be fitted on all types of vibrating rollers. Today, there are thousands of them out on rollers of different fabrications.

The Compactometer comprises of:

- A-sensor
- Processor
- CMV meter
- Frequency meter
- Cables

A-sensor detects the drum's vertical vibrations and transforms them into electric signals. The signals are amplified, filtered and then sent to the processor via a cable. In the processor, the signals are analysed and the CMV (Compaction Meter Value) is calculated. This CMV signal is then sent to the CMV-meter and to the CDS. CMV is a measure of how much the vibration signal differs from a pure sinusoidal signal. If the ground is soft the signal will be nearly sinusoidal and CMV will be nearly zero. If on the other hand the ground is stiff the signal will be distorted and far from sinusoidal and the CMV will be high. The CMV typically varies from 0 to 120 depending on the stiffness of the ground.

The reason why the vibration signal differs from a sinusoidal signal is because the drum hits the ground. If the ground is hard the impact will be very short in duration and very powerful and consequently the distortion of the signal from the A-sensor will be very large.

This method of measuring compaction can be considered to be a continuous loading test of the ground while the drum rolls on - a load test for every impact into the ground. In principle you get about 25 - 40 load tests per second. In order to level out the CMV variations from impact to impact, the processor builds up a moving average that is valid a given period of time. The overall effect will be that the CMV values that the processor sends at a given time is the average of the load test results for the last half second. see figure 16.

The ALFA-022R has electronics for the detection of double jump or rocking mode. The degree of double jump or rocking mode is measured continuously and presented in a form of a signal called RMV (Resonance Meter Value) that can be read from a meter (optional) or registered in the same way as CMV-values.

Figure 16. Presentation of CMV-values.
The CDS uses the RMV signal to mark, if required, regions in the working screen, in the result screen and in the CCC-report where RMV exceeds a given limit.

**Oscillometer POM-060**

An Oscillometer is a patented roller integrated compaction meter for oscillating rollers. It can be mounted on all types of oscillating rollers of all fabrications.

The Oscillometer comprises of:

- A-sensor
- Processor
- I-sensor
- OMV-meter
- Roll speed meter
- Oscillation frequency meter
- Cables

The operation of the Oscillometer is based on the indirect measurement of the reaction force in the horizontal direction brought about as a result of the drum's contact with the ground. This reaction force accelerates the whole roller horizontally. An A-sensor registers this horizontal acceleration and transforms it into an electrical signal. This signal is then filtered, amplified and sent to a processor unit via a cable.

In the processor, the signal is analysed and the OMV (Oscillo-Meter-Value) is computed and sent to an OMV-meter or to a CDS-system. The analysis includes the computation of the maximum reaction force into the ground during the oscillation of the drum. This reaction force increases with increasing rigidity of the ground in a specific way provided all the other factors affecting the whole system are kept constant.

The friction between the ground and the oscillating drum is not big enough to keep the drum and the ground in contact during the whole oscillation instead, there is always certain gliding between the drum and the ground. The processor in POM takes this into consideration and uses only that part of the signal where the gliding between the ground and the drum does not occur. The POM values correspond to the reaction force that would have existed if the friction were big enough to prevent gliding between the drum and the ground.

This method of measurement can be considered as equivalent to a continuous dynamic loading test of the ground while the drum rolls. The Compactometer analyses loading tests with vertically directed loads well as the Oscillometer uses horizontally directed oscillating loads.

In principle you get even here 25 - 40 load tests per second. In order to level out the variations between cycles, the processor builds up a moving average. The overall effect will be that the CMV values that the processor sends at a given time is the average of the load test results for the last half second.
5. Installation

5.1. I-sensor

The I-sensor is a proximity transducer that produces an electric pulse whenever a metallic object passes by. The metallic object can be a gear tooth, a wheel bolt or a hollowed metallic disc. The I-sensors are available in three diameters: M8, M12 and M18. Our standard sensor has a M18 diameter and a 5 m long cable.

The I-sensor can be mounted radially or axially, see figure 17.

Figure 17. Alternative ways to install an I-sensor, radially or axially.
Important sizes for a proper installation of an I-sensor are listed in Table 1.

**Table 1. Critical measurements in I-sensor installation.**

<table>
<thead>
<tr>
<th>I-sensor type</th>
<th>d (mm)</th>
<th>s (mm)</th>
<th>h1, w1, w2 (mm)</th>
<th>h2 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M8</td>
<td>8</td>
<td>0.1 - 1.2</td>
<td>&gt; 5</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>M12</td>
<td>12</td>
<td>0.1 - 1.6</td>
<td>&gt; 8</td>
<td>&gt; 5</td>
</tr>
<tr>
<td>M18</td>
<td>18</td>
<td>0.1 - 4.0</td>
<td>&gt; 16</td>
<td>&gt; 8</td>
</tr>
</tbody>
</table>

The installation of an I-sensor to a roller is dependent on the type of the roller in question. For the instructions of how to install the I-sensor contact the roller manufacturer or their agents in your country.

**Pulses/m**

One of the parameters required in the system is the number of pulses per roll length (pulses/meter). The value of this parameter can be calculated from the number of gear teeth, gears and the tyre diameter. The minimum number of pulses should be 2/m and the maximum number should be 500/m and this number should preferably be a multiple of 2. This is particularly important if the number of pulses is less than 10 per meter.

In case you do not know this parameter and you are unable to calculate it then follow the instruction below step by step to determine the number of pulses per roll meter:

1. Mark out and measure the length of an even and plain strip. The strip length should be a multiple of the section interval (usually 20m) and occupies nearly the whole CDS strip length.
2. Enter a guessed number of pulses per meter in the CDS.
3. Drive the roller over the measured strip while registering with the CDS.
4. Read from the CDS the registered length that has been covered.
5. Change the number of pulses in the CDS to: (length read from CDS / measured length) * old number of pulses.
6. Repeat 3 and 4 to control the results.

Repeat 3-6 if necessary until the CDS registered length is equal to the measured length.

**Note:** Select "New area" in press to start menu every time you change this parameter.
5.2. **CDS display unit**

To install a display unit into a roller, you fasten a mounting plate inside the roller cabin and screw the display unit to the mounting plate. The display unit should be placed in such a way that the LCD display is fully visible and all the keys can easily be reached, see figure 18.

*Figure 18.* Display unit installed inside a roller.
6. Operation instructions

6.1. Organisation of a documentation area

Correct documentation of the compaction process requires that the project, material and roller parameters are correct and correctly entered into the CDS. It is also very important that the positions of the areas to be documented given in CDS corresponds to the actual positions i.e. start line, stop line and the position of each and every strip must be well specified.

The best procedure is to first mark the start and stop lines with ranging poles placed outside the area to be compacted but along the lines. Measure the total width of the area to be compacted and documented, divide this width by the width of the roller’s drum to get the number of strips. Then divide the width of the area to be compacted by the number of strips obtained above to obtain the strip width. The difference between the drum's width and strip width is what is known as “overlapping”.

As an example, assume that the start line is at 14/600 (km/m) and the stop line at 14/720 (km/m). Take the total width of the area to be compacted to be 18.0m and the drum width to be 210 cm. The number of strips will then be 9, each 200 cm wide and the overlapping will be 10 cm wide.

When compacting large areas it might be necessary to give a reference distance, i.e. a perpendicular distance from a reference line to the area to be compacted. This reference distance is measured in meters to the left or to the right of the reference line, see chapter 7.1.10 Registration.
6.2. Starting the system

Make sure that the AC-DC converter is set at 12 volts DC output then plug in the converter to 220V AC mains. Connect the converter cable to the display unit's stop/start contact.

Turn the display unit's power switch to on, The LCD display will now show the Main menu, see figure 19.

![Main menu](image)

**Figur 19. Main menu.**

The black squares against each menu item correspond to a key on the same row. To select a menu, press the key opposite to the menu. Below some menu items in the Main menu window are important constants that are stored in memory. They are shown to give you a quick and simple survey of these constants.
6.3. Registration

Below is a recommended procedure to operate the CDS-012-J and make registrations.

1. Enter roller and project data in the CDS, see chapter 7.1.4 Roller data and chapter 7.1.2 Project data respectively.
2. Fasten the CDS inside the roller cabin.
3. Start the roller and switch on the CDS. The Main menu, will be displayed see figure 19.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig20.png}
\caption{Working screen for a new area.}
\end{figure}
4. Press **PRESS TO START** key, a new window and a new menu with items **RETURN TO MENU, NEW AREA, CONT. LAST AREA** and **CONT. ANY AREA** will appear. Choosing **RETURN TO MENU** takes you back to the **main menu** and any of the others displays a new screen, the working screen (figure 20), *see chapter 7.1.10 Registration*.

5. Place the roller a few meters behind the start line at the first strip and turn on the vibration. Adjust the vibration frequency while observing the frequency indicator in the working screen.

6. Press the RE-key or the Start/Stop button. The RE symbol changes to SS and the roller symbol \( \square \) appears at the start line. The System is now ready to start registering and if SS-key or Start/Stop button is pressed, recording and storage of data in memory will begin.

7. Drive the roller and adjust the roll speed while observing the speed indicator in the working screen. Press the SS-key or the Start/Stop button when the drum axis passes the start line. As an indication that recording and registration are taking place, the SS-symbol changes to a blinking RE-symbol and the symbols GR, EX, \( \leftarrow \) and \( \rightarrow \) disappear. During compaction, the following can be observed in the working screen:
   - the roller symbol moves along the strip
   - the frequency and speed indicators show continually variations in frequency and speed from the specified values.
   - a grey tone graphic presentation of CMV/OMV values after the roller symbol.
   - strips where the frequency, speed and double jump are outside the given limits, are marked with a line for each.

   The blinking of the RE-symbol indicates that data is continuously being collected and stored in the display unit's memory.

8. When the drum's axis passes the stop line at the end of the current strip, press the blinking RE-key or the Start/Stop button. The following takes place:
   - The roller symbol disappears.
   - The arrow indicating the roll direction (direction arrow) moves and/or change direction depending on the program selected. The arrow indicates the strip to be compacted next and the direction of compaction.
   - The mean CMV for the compacted strip is edited in the information block above the grey tone graphic field.
   - In the upper right corner the average CMV for the whole area is edited.

---

1Note that the direction arrow (fig. 20) at the beginning of a new registration points at the first strip (the first strip on the left - except if in the **Project data** menu, "Change strip" was chosen to be to the, in which case the direction arrow will point at the first strip on the right).

2Note that these deviations can only be indicated if in the **Settings menu** "Show F-D-V-A" was selected. In addition, double jump can only be measured and shown if the CDS is connected to a compaction meter of type ALFA-020R.
9. Drive the roller to the strip indicated to by the arrow on the display unit screen or move the arrow with the arrow key to the strip you want. It is important that the roller rolls on the same strip and in the same direction as indicated by the arrow and the roller symbol.

10. repeat 5 - 9.

11. After at least four passes in a strip, a gradient screen can be obtained by pressing the GR- key, see chapter 7.3 Gradient.

12. Recompact the regions where, according to the gradient screen, extra compaction is required. Do not register anything.

13. Compact and record the compaction results of the whole area.

14. Print out a CCC-report.
7. Menus

This chapter describes in details the CDS-020-J system's operating procedures and menus. We suggest therefore that you read this chapter carefully in order to exploit to the fullest the functions of the system.

7.1. Main menu

The main menu together with some of the parameters at the moment stored in memory are displayed when power is turned on, see figure 21 below.

![Main menu screen](image)

*Figure 21. Main menu screen.*
7.1.1. Settings

The Settings menu is selected from the main menu screen by pressing the key shown in figure 22 (i.e. the second key from above).

Figure 22. The hidden Settings menu.

The Settings menu is hidden to protect important installation parameters from being accidentally changed. This menu should be used only when changing permanent installation parameters e.g. language, company name and etc., see figure 23.
• **LANGUAGE:** The CDS can be installed in one of the following languages:

1. Swedish (S)
2. German (D)
3. English (E)

• **SHOW F-D-V-A:** Select Y(es) to show or indicate the occurrence of the following:

Regions compacted at speeds and frequencies beyond the allowed limits are marked with lines in the graphic presentation of the compaction results (i.e. in the working screen, results screen and in the CCC-report).

Regions where the magnitude of double jump during compaction was higher than the allowed level are marked with a line in the graphic presentation.

The amplitude used during the last pass (low or high) is indicated with a sine-symbol in every strip provided that the roller’s amplitude selector is connected to a compaction meter.

Select No not to show or indicate any of the above. The selection made here cannot be changed for a particular area the moment registration begins on that area.

• **D-LIMIT:** Double jump is indicated if its magnitude is above this limit (10%, 15%, 20% or 25% limit can be selected). The cause of double jump and the way it affects CMV values differ from roller to roller. This limit is selected with regard to calibration, "Material catalogue" or the customer’s recommendation. The D-limit does not affect the double jump values registered it only affects the indication of double jump. This selection cannot be changed for a particular area the moment registration begins on that area.

• **AUTO STOP:** If automatic stop is selected (Yes) then the maximum strip length in every strip will be set to the first compacted length in the area. All subsequent Registrations in every strip will be automatically stopped at the set strip length. If the area to be compacted is not rectangular, select No before compaction begins. You will then have to select the length of every strip individually by stopping the registrations manually with the START/STOP button or the (SS)- key. Auto stop has no effect in program 2 (see Project data menu) because the strip length in program 2 is set automatically irrespective of the Auto stop selection.

• **CROSS HATCHING:** If the number of strips to be compacted (this number is selected in Project data menu) is less than ten, you can select here Yes, to hatch the strips that are not to be used or No, not to. Both the number of strips and Cross-hatching can be changed at any time even after starting the registration.

• **REF DIST =** Reference distance: If you intend to use a reference line to the area to be compacted, select Yes. The actual reference distance is selected in Press to start menu (New area).

• **LASER PRINTER:** There are two printer routines in CDS, one for laser printers (HP PCL) and the other for matrix printers e.g. IBM proprinter. Select Yes for laser printer or No for matrix printer.

Figure 23. Settings menu screen.
• **ASCII**: Select *Yes* to send characters to the printer in ASCII (ISO) character codes or select *No* to send the characters in IBM-PC code. If the printed characters are wrong change your selection here or/and the printer installations.

• **LINE FEED**: You can select CR (Carriage Return), LF (Line Feed) or CR+LF (Carriage Return and Line Feed). Your selection here determines the code to send to the printer after every new line. Select another alternative or/and change your printer installation if the line feed is wrong!

• **COMPANY NAME**: With not more than 20 characters enter your company's name here otherwise the company name printed on CCC-report will be GEODYNAMIK AB.

Table 2 summarises the items and alternatives found under the Settings menu.

<table>
<thead>
<tr>
<th></th>
<th>Alternatives</th>
<th>can be changed after registration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language</td>
<td>Swedish, German, English</td>
<td>Yes</td>
</tr>
<tr>
<td>Show F-D-V-A</td>
<td>Yes or No</td>
<td>No</td>
</tr>
<tr>
<td>D-limit</td>
<td>10%, 15%, 20% or 25%</td>
<td>No</td>
</tr>
<tr>
<td>Auto stop</td>
<td>Yes or No</td>
<td>No</td>
</tr>
<tr>
<td>Cross hatch.</td>
<td>Yes or No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ref dist.</td>
<td>Yes or No</td>
<td>No</td>
</tr>
<tr>
<td>Laser printer</td>
<td>Yes or No</td>
<td>Yes</td>
</tr>
<tr>
<td>ASCII</td>
<td>Yes or No</td>
<td>Yes</td>
</tr>
<tr>
<td>Line feed</td>
<td>CR, LF or CR+LF</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Table 2. Alternative selections in Settings menu.*
Changing alternatives

Change to another alternative by pressing the **CHANGE**-key. Every time you press this key a different available alternative appears. When the alternative you want is displayed confirm it by pressing the **CONFIRM**-key.

Press the **ERASE**-key to erase the present text (part or all the text can be erased) then enter the new text by pressing the keys corresponding to the desired characters. The characters opposite the 10 upper keys can be shifted by pressing the **SHIFT**-key.

The characters are displayed in this order:

1. A - J
2. K - T
3. In Swedish: U - Ö and Ü
   In German:  U - Z and Å, Ä, Ö, Ü.
   In English:   U - Z and Ç É Ö Ñ
4. 0 - 9
5. + - . \ : ; < = >

Press the **CONFIRM**-key to accept the text entered.

After confirming all the entries above two new keys appear at the bottom of the screen like in figure 24 below.

![Figure 24. Controlling entered data.](image)

The program asks you if the entered data is correct. Press the **YES**-key, to store the entered data or press the **NO**-key and make changes.

After pressing the **YES**-key above, a new menu screen appears, see figure 25.
This menu allows you to change the naming of the layer types. To change the text, press the ERASE-key to erase the present text (part or all the text can be erased) and then enter the new text by typing the desired characters. The characters can be shifted by pressing the SHIFT-key. Confirm the entered text by pressing the CONFIRM-key.

![Layer types menu screen](image1)

*Figure 25. Layer types menu screen.*

After confirming all the entries above two new keys appears at the bottom of the screen like in figure 26 below:

![Confirming the entered data](image2)

*Figure 26. Confirming the entered data.*

The program asks you if the entered data is correct. Press the YES-key, to store the entered data and go back to the Main menu or press the NO-key and make changes.
7.1.2. Project data

Use this menu to change the project name and its data (i.e. number of strips, section interval, strip width, program and amplitude), see figure 27.

- **PROJECT NAME**: Name of project, in the example DEMO.
- **NO. OF STRIPS**: Number of parallel strips: These can be from 1 to 10, in the example above 9 strips are chosen. If the number entered is less than 1 the number of strips will be set to 1 and if the number entered is bigger than 10, the number registered will be set to 10.
- **SECT INTERV** = Section interval (in the example above 20 m): This is the distance between the horizontal lines shown in the working screen, in the results screen and in the CCC-report (see figure 28).

![Figure 27. Project name menu.](image)

In figure 28 the section interval is 20 m, i.e. the distance between the horizontal lines is 20 m. The minimum possible section interval is 10 m and the maximum possible is 250 m. If you enter any figure less than 10 the interval will be set to 10 m and if you select a figure greater than 250, the interval will be set to 250 m.

![Figure 28. Section interval.](image)

- **STRIP WIDTH**: The strip width (in fig. 27 equal to 200 cm) is the difference between the drum's width (e.g. 210 cm) and overlapping (e.g. 10 cm), see chapter 6.1, *Organisation of a documentation area*. The possible minimum strip width is 50 cm and the maximum is 305 cm. If you enter a figure less than 50, the strip width will be set to 50 and if you enter a figure greater than 305, it will be set to 305 cm.
• **STRIP CHANGE**: With strip change, you can choose to compact an area from left to right (→) or from right to left (←), (in the example →). Compaction from right to left should to be used only in special cases.

• **PROGRAM**: Organisation of compaction (in example 1). There are two ways in which compaction can be organised, i.e. program 1 and program 2, see figure 29.

Program 1 is the most common way to organise compaction. In this case the roller is driven forward vibrating and then backwards statically in the same strip. No registrations are made in the backward direction. The driver changes strip behind the start line and compacts the next strip with a vibrating roller in the forward direction and then backward statically without registering, and so on. Alternatively, the roller can be driven backwards vibrating without registering. When compacting an area with unequal strip lengths, e.g. areas that are not rectangular, program 1 must be used.

![Program 1 and Program 2 Diagram](image)

**Figure 29. Organisation of compaction according to programs 1 and 2.**

In program 2, you drive the roller in a strip forward vibrating and when you pass the stop line you turn around the roller and drive in the next strip vibrating and so on. Alternatively, you can change strips without turning around the roller and thereby compacting every other strip with the roller rolling backward. Program 2 can only be used for rectangular areas because all strips must be equal in length. It is automatically set equal to the first compacted length.

• **AMPLITUDE**: You can choose between high and low amplitude (in the example low). Enter the actual amplitude in mm for the two alternatives low and high in the Roller data menu.
Table 3 lists the maximum number of characters you can enter in a given field and the units of measurements of each parameter.

<table>
<thead>
<tr>
<th></th>
<th>No. of characters</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Number of strips</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Section interval</td>
<td>3</td>
<td>m</td>
</tr>
<tr>
<td>Strip width</td>
<td>3</td>
<td>cm</td>
</tr>
</tbody>
</table>

Table 3. No. of characters/field and parameter units in Project data menu.

Table 4 lists the available alternatives in project data menu: strip change, program and amplitude.

<table>
<thead>
<tr>
<th></th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip change</td>
<td>← or →</td>
</tr>
<tr>
<td>Program</td>
<td>1 or 2</td>
</tr>
<tr>
<td>Amplitude</td>
<td>High or low</td>
</tr>
</tbody>
</table>

Table 4. Possible alternatives in Project data menu.

Changing and altering text in project data menu

To change the project name, number of strips, section interval and strip width, press the ERASE-key to erase the present text (part or all the text can be erased) and then enter the new text by typing the keys corresponding to the desired characters. The characters can be shifted by pressing the SHIFT-key. After typing the text confirm by pressing the CONFIRM-key.

Change between the different strip change, program and amplitude alternatives by pressing the CHANGE-key. Every time you press this key a different available alternative appears. When the alternative you want is displayed confirm it by pressing the CONFIRM-key.

After confirming all the entries above two new keys appears at the bottom of the screen like in figure 30 below:

Figure 30. Control of the entered data.

The program asks you if the entered data is correct. Press the YES-key, to store the entered data and go back to the Main menu or press the NO-key and make changes.
7.1.3. Clock

This menu is only used if the time or date shown is not correct or when changing to summer/winter time, see figure 31.

To enter the date, type the year, the month and lastly the day (YYMMDD) and for the time enter first the hours then the minutes (HHMM). This is a 24 hour clock, for example 2.30 p.m. is displayed as 1430.

To change the date press the ERASE-key, you can erase part or the entire test shown. Enter the new date with the numeric keys shown. Confirm the new date by pressing the CONFIRM-key.

The time is set in the same way as the date above that is first erase the time shown then enter the new time and finally press the CONFIRM-key.

Once the date and time are set they will be correct for many months. A battery that can last at least 5 years drives the clock.

Figure 31. Clock menu.
7.1.4. Roller data

Use the roller data menu to enter roller specifications that are essential for CCC, see figure 32. These specifications can be obtained from the roller handbook, official standards catalogue or from calibrations. Pay attention to the parameters' measurement units (kg, kN/m, etc.).

- **TYPE**: Roller's designation, in the example TEST.
- **WEIGHT**: Roller's total weight in kg, in the example 8000 kg.
- **LINE LOAD**: Roller's line load in kN/m (1.02 times the value in kg/cm), in the example 24 kN/m.
- **WIDTH**: Drum's width in cm, in the example 210 cm.
- **DIAMETER**: Drum's diameter in cm, in the example 130 cm.
- **PULSES/M**: Number of pulses from the I-sensor per roll length in meters. Given with two decimals, in the example 1.83. Note: The number of pulses must always be set to 2.00 pulses/m if the CDS is connected to a POM-processor.

*Figure 32. Roller data menu.*

- **FREQUENCY**: Specified vibration frequency in Hz and percentage of allowed variation, in the example 28 Hz and 2% respectively. In the Settings menu you can choose to indicate or not to indicate the regions where the frequency is outside the set limits. Not allowed frequency deviation is indicated by a line in the working screen, in the result screen and in the CCC-report in every strip and section it occurs.

- **SPEED**: Specified rolling speed in km/h and percentage of allowed speed variation, in the example 3 km/h and 10% respectively. In the Settings menu you can choose to indicate or not to indicate regions where the speed is beyond the set limits. Not allowed speed deviation is indicated by a line in the working screen, in the result screen and in the CCC-report in every strip and section it occurs.

- **AMPLITUDE**: Current amplitude in mm. Two values corresponding to LOW and HIGH can be entered, in the example 0.8 mm and 1.6 mm.
Table 5 lists the maximum number of characters you can enter in a given field and the units of measurements of each parameter.

<table>
<thead>
<tr>
<th>Number of</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>char/field</td>
<td></td>
</tr>
<tr>
<td>Type weight</td>
<td>8</td>
</tr>
<tr>
<td>Line load</td>
<td>5</td>
</tr>
<tr>
<td>Width</td>
<td>2</td>
</tr>
<tr>
<td>Diameter</td>
<td>3</td>
</tr>
<tr>
<td>Pulses/m</td>
<td>3</td>
</tr>
<tr>
<td>Frequency</td>
<td>5</td>
</tr>
<tr>
<td>speed</td>
<td>2</td>
</tr>
<tr>
<td>Amplitude</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5. Number of characters/field and units in the Roller data menu.

Changing "roller data" entries

To change the text, press the ERASE-key to erase the present text (part or all the text can be erased) and then enter the new text by typing the desired characters. The characters can be shifted by pressing the SHIFT-key. After entering the text confirm by pressing the CONFIRM-key.

Finally, after confirming the last entry (amplitude) two new keys appears as in figure 33.

Figure 33. Controlling the entered data.

The program asks you if the entered data is correct. Press the YES-key, to store the entered data and go back to the Main menu or press the NO-key and make changes.
7.1.5. Strip length

Under this menu, you enter the maximum strip length to be displayed by the display unit. The whole of this length need not be used in every strip. You can make shorter registrations in some or all the strips.

The maximum strip length is dependent on the roller data (drum diameter and the number of pulses from the I-sensor). The maximum number of CMV values that can be registered in a strip is 120 irrespective of pass or strip. Therefore, the choice of this length (strip length) is going to affect the length of the interval between measurements and consequently also the resolution. A long strip length results in long measurement interval and low resolution while a short strip length results in a short measurement interval and high resolution.

The available maximum strip length alternatives are a multiple of 60 m, see table 6.

![Figure 34. Strip length menu screen.](image)

<table>
<thead>
<tr>
<th>Strip length (m)</th>
<th>Measurement interval (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>0.5</td>
</tr>
<tr>
<td>120</td>
<td>1.0</td>
</tr>
<tr>
<td>180</td>
<td>1.5</td>
</tr>
<tr>
<td>240</td>
<td>2.0</td>
</tr>
<tr>
<td>300</td>
<td>2.5</td>
</tr>
<tr>
<td>360</td>
<td>3.0</td>
</tr>
<tr>
<td>420</td>
<td>3.5</td>
</tr>
<tr>
<td>480</td>
<td>4.0</td>
</tr>
<tr>
<td>540</td>
<td>4.5</td>
</tr>
<tr>
<td>600</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Table 6. Strip length as a multiple of 60 m and the corresponding measurement interval.

Note: If the number of pulses/m is not a multiple of 2 then the strip lengths cannot be set to an exact multiple of 60 but instead you get strip lengths that slightly differ from those listed in table 6.

Figure 34 shows Strip length menu screen.

You increase or decrease the strip length by pressing the **INCREASE**-key or the **DECREASE**-key respectively. Accept the displayed value by pressing the **CONFIRM**-key.
7.1.6. Limits

The limits for the grey tone in the working screen, gradient and results screens are selected in the Limits menu. The limits are given in CMV (Compaction Meter Value) units or OMV (Oscillo-Meter_Value) units. Figure 35 shows the Limits menu screen.

- **LIMIT 1, 2 and 3.** These limits are given in CMV/OMV units and are used to set the grey tone scale of the graphic presentation of the compaction results.

  The grey tone scale is graduated from 0 to 120 and is set according to the following:

  White: CMV/OMV-values between 0 and limit 1

  Light grey: Values between limit 1 and limit 2

  Dark grey: Values between limit 2 and limit 3

  Black: Values greater than limit 3

- **ACCEPT:** This is the compaction level given in CMV/OMV units that is supposed to be achieved in the final results. This level is indicated with a black mark on the upper side of the grey tone scale in the working screen and the CCC-report.

**Figure 35.** Limits menu screen and the grey tone scale.

- **PRE-COMPACTION:** This is a real or fictitious number of passes that depicts the pre-compaction degree of an area. This value is used in the gradient function to calculate the number of extra passes required to reach the accept level.

In some countries the "minimum value" concept is used i.e. a minimum compaction value is given and it is required that the final compaction results should not contain values below the "minimum value". From a practical point of view this method is almost impossible and economically extremely expensive.

CDS’s grey tone scale is meant to make the documentation of realistic and easy. This scale is based on the accept level and the allowed deviation i.e. a band of CMV or OMV values around (above and below) the accept level. This band of CMV/OMV values is set by giving the limits according to the following:

LIMIT 1 = accept level minus the minimum allowed deviation.

LIMIT 2 = accept level.

LIMIT 3 = accept level plus the maximum allowed deviation.
If the limits are set in this way then regions with compaction results within the allowed limits will be graphically displayed as light grey and dark grey in the CCC-report, working and results screens. The white will represent undercompacted regions and the black will represent overcompacted regions.

Accept level and allowed deviation can be obtained from a calibration or from a "material catalogue" with tables of possible material, thickness of layers, rollers and CMV/OMV values (e.g. in Austria). These values can also be obtained from official standards and specifications.

To change the limits, accept level and pre-compaction, press the ERASE-key to erase the present values (part or all the text can be erased) and then enter the new values by pressing the keys corresponding to the desired figures. After entering the new value confirm by pressing the CONFIRM-key.

After confirming all the entered data, the screen will appear like in figure 36.

The program asks you if the entered data is correct. Press the YES-key, to store the entered data and go back to the Main menu or press the NO-key and make changes.

Figure 36. Confirm the entered data.
7.1.7. Display

With this menu you can view the compaction results in the Results screen, you can view detailed information about the registered area in the Diagram screen and you can view a list of all the registered areas, see figure 37. The list (figure 37) can contain a maximum of 32 areas (the maximum number of areas possible to register in CDS) and every row contains identification data for that area.

<table>
<thead>
<tr>
<th>No</th>
<th>Sect</th>
<th>Area</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>015/400-</td>
<td>S2a</td>
<td>1105</td>
<td>1535</td>
</tr>
<tr>
<td>2</td>
<td>014/400-</td>
<td>S2a</td>
<td>1104</td>
<td>0012</td>
</tr>
<tr>
<td>3</td>
<td>014/729+</td>
<td>S2a</td>
<td>1106</td>
<td>1044</td>
</tr>
<tr>
<td>4</td>
<td>014/400+</td>
<td>S2a</td>
<td>1106</td>
<td>1516</td>
</tr>
<tr>
<td>5</td>
<td>014/400+</td>
<td>S2a</td>
<td>1106</td>
<td>1532</td>
</tr>
<tr>
<td>6</td>
<td>014/400+</td>
<td>S2a</td>
<td>1115</td>
<td>0387</td>
</tr>
<tr>
<td>7</td>
<td>014/400+</td>
<td>S2a</td>
<td>1117</td>
<td>0934</td>
</tr>
<tr>
<td>8</td>
<td>014/384+</td>
<td>S2a</td>
<td>1117</td>
<td>1234</td>
</tr>
<tr>
<td>9</td>
<td>014/384+</td>
<td>S2a</td>
<td>1117</td>
<td>1537</td>
</tr>
<tr>
<td>10</td>
<td>014/240-</td>
<td>S2a</td>
<td>1119</td>
<td>0805</td>
</tr>
<tr>
<td>11</td>
<td>014/120-</td>
<td>S2a</td>
<td>1119</td>
<td>1047</td>
</tr>
<tr>
<td>12</td>
<td>014/000-</td>
<td>S2a</td>
<td>1119</td>
<td>1404</td>
</tr>
<tr>
<td>13</td>
<td>015/000-</td>
<td>S2a</td>
<td>1119</td>
<td>1544</td>
</tr>
</tbody>
</table>

Figure 37. A list of the registered areas.

To select an area, move the highlight up or down to the desired area with the help of the arrow keys (figure 37).

The EX-key invokes the Main menu and the DI-key invokes the result screen that shows the compaction results of the chosen area, see figure 38.
Results screen

The DI-key in the Display menu invokes the result screen (figure 38).

Press the DI-key (Diagram) to view the results in a diagram form or press the GR-key (Gradient) to view the gradient screen. Pressing the EX-key invokes the Main menu screen and pressing any other key invokes the Display menu screen.

**Figure 38. Results screen.**

Diagram

Detailed compaction state of a strip can be studied with the help of the Diagram function, see figure 39.

**Figure 39. Diagram.**
PASS = Any of the registered passes in the chosen strip.

STRIP: Any of the registered strips (from 1 to 10).

In the diagram, the x-axis represents the CMV/OMV-values (from 0 to 120, i.e. 30 between the vertical lines.) and the y-axis represents the measured length. You get a clear picture of how the CMV/OMV-values change from pass to pass in a strip by comparing the diagrams of different passes in a strip. You can, for instance, identify old ditches and trenches that cross the compacted area by comparing at the same pass, diagrams of different strips.

This diagram can be used for a detailed study of every strip and to select suitable sports for supervisory control.

You select a particular strip and a particular pass by pressing the two uppermost keys. If you have a printer directly connected to the display unit, you can get a hard copy of the diagram by simply pressing the PR-key. The EX-key takes you back to the result screen.

With the PC-program CdsView, you can perform detailed analysis of the strips, passes and a lot more, see chapter 11, *Data processing software*.

**Gradient**

The gradient function helps the roller driver to compact effectively because this function, besides the grey tone scale, shows with a figure/character information the compaction results in relation to the accept value (figure 40). More on this in chapter 7.3, *Gradient*.

Pressing the DI-key (Diagram) invokes the diagram screen and pressing the EX-key invokes the Main menu screen. Pressing any other key takes you back to the Display menu.

*Figure 40. Gradient screen.*
7.1.8. Print

Use the Print menu to print one or more CCC-report hard copies of the registered areas. A list of all the registered areas will be displayed, see figure 41. The areas are numbered from 1 to 32. Every row contains data that identifies a particular area.

![Print menu screen]

Figure 41. Print menu screen

Move the cursor up and down the list with the arrow keys (the arrow in the first column of the list indicates the position of the cursor) and select areas to print by pressing the SE-key. Selected areas are highlighted. If you want to drop a selection, move the cursor with the arrow key to the selected area you want to drop and then press SE-key. The area will no longer be highlighted indicating that it is no longer among the selected areas.

Press the AL-key to select all the areas present.

Press the PR-key to print the selected areas.
7.1.9. Data transmission

The "Data transmission" function is used to transfer data from the display unit to a PC for permanent storage, to empty the display unit's memory and to transfer data earlier stored in a PC back to the display unit, see figure 42.

To transfer data from the unit to a PC, press **TO PC**-key and to transfer data from a PC to the unit, press **FROM PC**-key. To go back to the Main menu press **RETURN TO MENU**-key.

Figure 42. *Data transmission menu.*

Transferring data from the display unit to a PC

Data is transferred from the display unit to a PC for two reasons, to permanently store the data and to empty the display unit's memory. The unit's memory has the capacity to store between 30 000 m² (if the strip width is 1.5 m and the interval between measurement is 0.5 m) and 400 000 m² (if the strip width is 2.0 m and the measurement interval is 5.0 m) or maximum 32 areas. Data transfer ought to be done from time to time at equal intervals to avoid loosing data.
TO PC-key invokes a list of areas that are currently stored in the display unit's memory, see figure 43.

Figure 43. TO PC menu screen.

Move the cursor up and down the list with the arrow keys (the arrow in the first column of the list indicates the position of the cursor) and select areas to transfer by pressing the SE-key. Selected areas are highlighted. If you want to drop a selection, move the cursor with the arrow key to the selected area you want to drop and then press SE-key. The area will no longer be highlighted indicating that it is no longer among the selected areas.

Press the AL-key to select all the areas present.

Normally you select all the areas with the AL-key then you drop those areas that for some reason you do not want to save.

Run the PC program that facilitates the PC to receive data from the display unit then when this PC-program is ready to receive data press the ST-key (=store).
During data transmission the screen will look like figure 44a.

\[ \text{Figure 44 a and b. Screen information during data transfer: unit to PC.} \]

Under the text \textbf{TRANSMITTING DATA!} is a figure. This figure is the registration number of the area that is currently being transferred. At the end of transmission you are asked: \textbf{ERASE MEMORY?}. Press the \textbf{NO}-key not to erase the memory. You are then taken back to Data transmission menu screen (figure 42). If you press the \textbf{YES}-key, a new screen appears, see figure 44b.

If now you press the \textbf{YES}-key the whole memory will be erased and if you press the \textbf{NO}-key the memory will not be erased. In both cases you are taken back to Data transmission menu screen (figure 42).
Transferring data from a PC to the display unit

If there is data in the display unit’s memory, that data will be written over by the data from the PC. Before data is transferred from the PC, you are warned that data in the unit will be erased (figure 45a).

Figure 45 a and b. Warnings before data transmission from the PC to the unit.

YES-key invokes a new screen (figure 45b), and the NO-key invokes the Data transmission menu screen without erasing the memory.
If in the new Screen (figure 45b) you press the **Yes**-key the unit will wait for the data from the PC and a message shown in figure 46 will be displayed. You can now begin the transfer. If on the other hand you press the **NO**-key, the memory will not be erased and you will be taken back to the Data transmission menu screen.

---

**Figure 46. Start transmission from the PC to the CDS.**
7.1.10. Registration

To begin the registration press the **PRESS TO START**-key in the *Main menu* and a new screen, the *Registration menu* screen, appears (figure 47), in chapter 6.3. you will find the recommended proceeding to make a registration.

If you intend to register a new area press the **NEW AREA**-key, if you are to continue the registration of the last area press the **CONT. LAST AREA**-key and if you wish to continue the registration of any other area press the **CONT. ANY AREA**-key. The last two alternatives are available only if there is data in the CDS's memory. Press the **RETURN TO MENU**-key to return to the *Main menu*.

![Registration menu screen.](image)

**New area**

Pressing the **NEW AREA**-key invokes a *New area menu screen*, see figure 48.

On entering this menu, the data listed is exactly identical to the last registered area's data and this data can now be confirmed or changed.

- **SECTION**: start section (km/m), (in figure 48: 014/600).
- **DIRECTION**: Roll direction in relation to the direction of increasing length.

  + = positive direction i.e. rolling in the direction of increasing length,

  - = negative direction i.e. rolling in the direction of decreasing length (see figure 49, in figure 48 +).
Figure 48. New area menu screen.

![Area Menu Screen](image)

**Positive (+) direction**

<table>
<thead>
<tr>
<th>Strip No.</th>
<th>000/000</th>
<th>000/100</th>
<th>000/200</th>
<th>000/300</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Negative (-) direction**

<table>
<thead>
<tr>
<th>Strip No.</th>
<th>000/000</th>
<th>000/100</th>
<th>000/200</th>
<th>000/300</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 49. Roller's directions: positive (+), negative (-).

- **AREA PART**: If the area to be compacted is very large, it can be divided into three parallel regions or area parts A, B and C, each with 10 strips and with identical layer types, layer numbers and start lines, see figure 50 (in figure 48 the area part is A).

![Area Parts](image)

Area part A | Area part B | Area part C

Stop line

Start line

Figure 50. Area parts.

- **LAYER TYPE**: R, S, C and G stand for Roadbase, Sub-base, Capping layer and Subgrade respectively. Other symbols can be used if the names of the standard layer types have been changed in the Settings menu, see chapter 7.1.1.

- **LAYER NO.**: The layers are numbered from 0 to 5 (0=lowermost layer) to facilitate the registration of a number of layers, one above the other, of the same layer type (in fig. 48 the layer no. is 2). If you enter a number greater than 5, the layer no. will be set to 5.

- **REF DIST** = reference distance. This is the distance from the reference line to the left edge of the CDS-screen i.e. left edge of strip 1, see figure 51. This is valid even if the first strip is not registered. This distance is measured to the right or left of the reference line in meters (in fig. 48 this is given as: Right 12.3 m). The reference distance can be from 0 to 6000 m. If you enter a number greater than 6000 the distance will be set to 6000 m.

Note: the item **REF DIST** appears only if it was selected in the Settings menu (chapter 7.1.1).
Figure 51. Reference distance, an area to the left and an area to the right of the reference line.

By left and right is meant the side of the reference line facing the direction of increasing distance on which the left edge of strip 1 lies, see figure 51. Note that it is assumed that all the strips are parallel to the reference line.

Changing the "new area" parameters

To change the section, layer no. and ref dist, press the ERASE-key (part or all text can be erased). Enter the new values using the 10 uppermost keys then confirm the entries by pressing the CONFIRM-key.

Direction, area part and layer type can be changed by pressing the CHANGE-key whereby the available alternatives are shown. Confirm an alternative by pressing the CONFIRM-key. When all the entries have been confirmed, two new keys appears, see figure 52.

Figure 52. Controlling entered data.

The program asks you if the entered data is correct. Press the YES-key, to store the entered data or press the NO-key and make changes. The working screen will now appear if there is enough memory to register one complete strip (see figure 53) otherwise a warning text "MEMORY FULL SAVE → PC!"
will appear. In such a case data should be transferred to a PC to free more memory, see chapter 7.1.9 Data transmission. More about the working screen in chapter 7.2, working screen.

Continue last area

```
Figure 53. Working screen for a new area.
```

Pressing the CONT. LAST AREA-key invokes the working screen of the last registered area provided there is enough memory otherwise you get a warning: "MEMORY FULL SAVE. → PC!"). In that case data should be transferred to a PC to free more memory, see chapter 7.1.9 Data transmission.
Continue any area

If you press the **CONT. ANY AREA**-key, a list of the registered areas will be displayed, see figure 54.

![Figure 54. A list of the registered areas.](image)

Move the cursor to the desired area with the help of the arrow keys. Press the **SE**-key to invoke the working screen of the selected area if there is enough memory otherwise you get a warning: "MEMORY FULL SAVE → PC!". Data should then be transferred to a PC to free more memory, see chapter 7.1.9 Data transmission. If the **EX**-key is pressed you get back the Registering menu screen.
7.2. Working screen

Figure 55. Working screens before and during registration.

Figure 55 shows a working screen before registration (left) and a working screen during registration (right). During registration the RE-key blinks and the roller symbol moves along the strip being registered.

1. Average compaction meter values

The average compaction meter values (CMV or OMV) for the last and first three passes in every strip are displayed at the top of the working screen, see figure 56.

Figure 56. Average compaction meter values.

The average values for the first up to the fourth pass are displayed with dark text on a bright background. If more than four passes have been recorded in a strip then the average CMV value of the latest pass is displayed on the first row with light text on a dark background and the number of passes done in the strip is displayed below the average value field.

The average compaction meter values for the whole compacted area are shown on the left for each of the passes 1, 2, 3 and the final pass.
2. Grey tone scale

This is the black and white graphic graduation scale of the CMV values displayed above the graphics field in the working screen, see figure 57.

This scale has 12 graduations ranging from 0 to 120 CMV i.e. 10 units between marks. The black mark on the upper side of the scale marks the acceptable CMV level (accept value).

If the limits and accept level were set correctly as recommended in chapter 7.1.6 Limits, then the scale is graduated according to the following:

- white: soft area- Insufficient compaction (CMV/OMV between 0 and limit 1)
- light grey: acceptable compaction (values between limit 1 and limit 2)
- dark grey: acceptable compaction (values between limit 2 and limit 3)
- black: excessive compaction (values over limit 3)

3. Graphic field

The biggest part of the working screen is take up by the graphic field. Here, the current compaction state, i.e. the last compaction results in each strip, of an area is displayed. The position of the roller is indicated by the roller symbol).

4. Information block

The information block, figure 58, is displayed at the bottom of the screen.

The block displays, from left to right:

- The area's registration number, (same as in Display menu screen)
- The start section (km/m) where the start line is positioned (Corresponding to the lower border of the graphic field)
- The roller's direction in relation to the direction of increasing length(+ = in the increasing length direction, - = in the opposite direction)
- Layer type (R=Roadbase, S=Sub-base, C=Capping layer, G=subGrade or your own alternatives, see Settings menu)
- Layer number (0-5)
- Area part (A-C)
- Changing strips (→ from left to right, ← from right to left)
5. Memory indicator

The memory indicator is above the information block and it indicates the amount of memory used up so far, see figure 59.

**Figure 59. Memory indicator.**

The filled part gives the percentage of the memory used (0 to 100%). In figure 59, the memory is almost full. Instructions how to empty the CDS's memory can be found in chapter 7.1.9 *Data transmission*.

The CDS memory has the capacity to store an amount of data equivalent to between 30 000 m² (if the strip width is 1,5 m and the measurement interval is 0,5 m) and 400 000 m² (strip width= 2,0 m and measurement interval = 5,0 m) or maximum 32 different areas.

6. Speed and frequency indicators

To the right of the graphic field are two indicators. The one marked with a "V" is the speed indicator and the other marked with an "F" is the frequency indicator.

This indicator shows the deviation in speed from the specified value. In this case the specified value is 3 km/h (the value entered in roller data menu). The black in the scale indicates the amount of deviation. If the roller speed is exactly the same as the specified speed, the black pillar will be very thin and in the middle of the scale around the specified value (3 km/h in the figure).

This indicator shows the deviation of the frequency from the specified value. In the example, the specified value is 28 Hz (the value entered in roller data menu). The black in the scale indicates the amount of deviation. If the roller's frequency is exactly the same as the specified frequency, the black pillar will be very thin and in the middle of the scale around the specified value (28 Hz in the figure).

7. Keys:

- **GR** = Gradient function (see chapter 7.3)
- **EX** = Exit (to the Main menu)
- ← = Change strips from right to left
- → = Change strips form left to right
- **RE** = Register
- **SS** = Start/stop
Indication of forbidden deviations

Forbidden deviations (frequency, double jump\(^3\), speed) and amplitude are indicated only if "SHOW F-D-V-A" was selected in Settings menu.

Higher up in every strip the symbol (\(\sim\)) indicates that the last pass in the strip was carried out at a low amplitude and the symbol (\(\nearrow\)) indicates a high amplitude. These symbols are shown only if the roller's amplitude selector is connected to the compaction meter. If there is no connection between the amplitude selector and the compaction meter the symbol for high amplitude (\(\nearrow\)) will always be shown even when the amplitude is low.

Generally the final documentation pass should be done at low amplitude. If in this case the amplitude selector is connected to the compaction meter and the symbol for high amplitude (\(\nearrow\)) is shown then this pass should not be accepted as the final documentation pass.

If "Show F-D-V-A" was selected in Settings menu, then frequency, speed or double jump deviations are collected for every measurement interval, the values are then grouped in groups of 5. If there is a value in a group that is beyond the allowed limits then the whole group will be marked with a vertical line in the strip. Depending on the background, the lines are either black or white.

- A line on the left: Not allowed deviation of frequency from the specified value, see figure 60.

![Figure 60. Not allowed frequency deviation.](image)

In figure 60, the roller vibrations were switched on late therefore the frequency had not come up to the right level before the start line. The program indicates then that the frequency was beyond the allowed limits. As long as the frequency is unstable no CMV values can be obtained from the compaction meter and that can be clearly seen from figure 60.

\(^3\) Double jump can only be measured and shown if the CDS is connected to a compaction meter of the type ALFA-022R.
• A line in the middle: High double jump, see figure 61.

• A line on the right: The speed is beyond the allowed limits, see figure 61.

![Figure 61. High double jump and the speed beyond the allowed limits.](image)

Irregular areas

In case of an irregular area the work screen can look like in figure 62.

![Figure 62. The Working screen of an irregular area during (left) and after (right) registration.](image)

The figure on the left shows the working screen during registration when the RE-key blinks and the roller symbol moves along the strip. The right figure shows the working screen before registration starts.

To register irregular areas you must choose program 1 (in Project data menu) and drop the auto stop alternative (in settings menu). The strip length will then be chosen individually in every strip by terminating the registration manually with the help of the RE-key or the Start/Stop button.
7.3. Gradient

The gradient function helps to achieve effective compaction. The gradient function can be applied after at least four passes in a strip. Apart from the grey tone the graphic field will now contain number/character signs indicating where the accept values have been achieved, where and how many more passes are required to achieve acceptable values as well as places where it is meaningless or even destructive with further compaction. This information is available for every area of at least 8 measurement intervals, see figure 63.

The numbers 2, 4 and 6 gives the number of extra passes required and the X means that 8 or more extra passes are required which practically means that the region marked with an X cannot be compacted with the current roller. Areas with compaction values over the accept level, i.e. approved compaction results are marked with black rectangles.

Regions where CMV values decrease with increasing number of passes are marked with one or two minus signs. One minus sign means that the CMV/OMV values are decreasing for every new pass and if in addition the last value is lower than the accept level then the region will be marked with two minus signs.

The gradient diagram is based on pre-compaction values (if available) and values from the first to the fourth pass only (even if more than four passes have been registered).

Figure 63. Gradient screen.
8. **CCC-report**

Compaction results from a registered area can be summarised and printed on a single page, ready for filing. The printed copy shows a graphic presentation of the compaction results and data that is important for a complete documentation of the compacted area. This document known as CCC-report is shown in figure 64.

![CCC-report graphic](image)

**Figure 64. CCC-report.**

---

### PROJECT: DEMO

### ROLLER DATA
- **Model:** TEST
- **Weight:** 8000 kg
- **Width:** 210/200 cm
- **Amplitude:** 0.8/1.6 mm

### CALIBRATION VALUES
- **Layer:** 2 A Sub-base
  - **f:** 28 Hz
  - **v:** 3.0 km/h
  - **A:** Low

### STRIP MARKINGS for
- **f-deviation:** > 2% (27.4 - 28.6)
- **Double jump:** > 10%
- **v-deviation:** > 10% (2.7 - 3.3)

### RESULTS - LAST PASS
- **Max. striplength:** 120.0 m
- **Compacted area:** 2159 m²
- **One value:** 2.2 m²

### COMPACTION METER VALUES

<table>
<thead>
<tr>
<th>Number</th>
<th>Mean</th>
<th>SD</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>990</td>
<td>62.1</td>
<td>16.5</td>
<td>27%</td>
</tr>
</tbody>
</table>

- **< 40:** 225 m² (10%)
- **Limit:** 30 40 80
- **Area:** 83 225 1882 m²
- **4:** 10 87 %

### FREQUENCY/SPEED
- **Min:** 27.1 28.0 28.5 Hz
- **Max:** 2.7 3.0 3.2 km/h

### REF DIST:
- **12.3 m right**

**JUDGEMENT:**
1. Name

Figure 65. Company name and date.

The first field at the top of the page contains company name and date see figure 65.

2. Average compaction meter values

The average compaction meter values (CMV or OMV) in the strips are displayed in the second field, see figure 66.

Figure 66. Average compaction meter values.

The average values in the first four passes are displayed in dark text on a bright background. If more than four passes have been recorded in a strip, the average CMV value in the last pass is displayed on the first row in light text on a dark background and the number of passes made in the strip is displayed below the average values.

The average compaction meter values for the whole compacted area are shown on the left for each of the passes 1, 2, 3 and the final pass.

3. Grey tone scale

This is the black and white graphic graduation scale showing the limits used in the graphic presentation, see figure 67.

Figure 67. Grey tone scale.

This scale is graduated from 0 to 120 with 10 units between graduation marks. The black mark at the upper side of the scale indicates the accept level.

4. Graphic presentation

The current compaction state of an area, i.e. the last compaction results in each strip, is presented in a black and white graphic form. If "show F-D-V-A" was selected in the Settings menu, then the regions where the frequency, speed and double jump were higher or below the allowed limits are marked with vertical lines. These lines can be either white or black depending on the background colour.

- A line on the left represents not allowed frequency deviation.
- A line in the middle represents not allowed Double jump.
- A line on the right represents not allowed speed deviation.
5. Information block

The information block contains the identification data of the area displayed, see figure 68.

**Figure 68. Information block.**

First row:
- Project name

Second row, from left to right:
- The area's registration number, (same as in Display menu screen)
- The start section (km/m) where the start line is positioned (corresponding to the lower border of the graphic field)
- The roller's direction relative to the direction of increasing length (+ = in the increasing length direction, - = in the opposite direction)
- Compaction date
- Compaction time

6. Important data is printed on the right side of the graphic field:

**PROJECT:** The project name that was entered in Project data menu.

**ROLLER DATA:** Roller specifications that were entered in Roller data menu and Project data menu.
- Model: Roller designation
- Weight: Roller's total weight
- Width: The drum width and the strip width respectively
- Amplitude: Low and high amplitude respectively

**CALIBRATION VALUES:** The data shown here is the data entered in Project data and Roller data menus.
- Layer: The layer registration number, the area part and the layer type respectively
- f: Specified vibration frequency
- v: Specified rolling speed
- A: Specified vibration amplitude (high/low)

If "SHOW F-D-V-A" was selected in Settings menu, then the frequency, speed and double jump deviations are collected in every measurement interval, the values are then grouped in groups of 5. If any value in a group is outside the allowed limits then the whole group will be marked with a vertical line. Depending on the background, the lines are either black or white.

**STRIP MARKINGS:** This information is shown only if "SHOW F-D-V-A" was selected in the Settings menu. The frequency, speed and double jump are collected in every measurement interval, the values are then grouped in 5’s. If in a group there is a value that is out of the allowed limits then the whole section represented by the group will be marked with a vertical line. The lines are either black or white depending on the background colour.
The values appearing here are the values entered in Settings and Roller data menus.

- **f-deviation**: The allowed deviation expressed as a percentage of the specified frequency and the limits within which the frequency is allowed to vary (Regions compacted at frequencies outside these limits will be marked).
- **Double jump**: The limit above which double jump is not allowed
- **v-deviation**: The allowed deviation expressed as a percentage of the specified speed and the limits within which the speed is allowed to vary (Any region compacted at a speed out of these limits will be marked).

**RESULTS - LAST PASS**: A summary of the compaction results for the whole compacted area. Only the results from the last pass in every strip are listed here.

- **Max. striplength**: The longest compacted length in a strip in the last pass
- **Compacted area**: Total number of square meters compacted in the last pass
- **One value**: measurement interval, i.e. number of square meters per reading

**COMPACtion METER VALUES**: 

- **Number**: Number of compaction meter values
- **Mean**: Mean compaction meter value for the whole compacted area
- **SD**: Standard deviation
- **CV**: Coefficient of variation (CV=SD/Mean)
- **< Accept level**: Total size of the area with CMV values less than the accept level given in square meters and as a percentage of the total compacted area
- **Limit**: Limits 1, 2, and 3
- **Area**: Total size of the area with CMV values below limit 1, limit 2 and limit 3 given in square meters and as a percentage of the total compacted area

**FREQUENCY/SPEED**

- **f**: The lowest, mean and highest frequency measured in the last pass
- **v**: The lowest, mean and highest speed measured in the last pass

**REF DIST** = reference distance. Perpendicular distance from the reference line to the compacted area. This value is printed only if in the Settings menu it was selected to show the reference distance.

**JUDGEMENT**: There is space here for some official commentary e.g. approving or disapproving the results, further compaction, change material and etc
9. Fault localisation

9.1. Operation

In order to localise faults in an instrument or system, it is important to know the functions of the different parts of the system/instrument and their input and output signals. We therefore begin this chapter by looking at the functions of different parts of the CDS-system. Figure 69 shows the pin assignment, connections and parts of the CDS-system fitted to a compaction meter (type: ALFA-022R).

![CDS-system parts and signals](image-url)

**Figure 69.** CDS-system parts, pin assignments and signals.
Processor unit, ALFA-022R

Inside the processor unit of the Compactometer, ALFA-022R, is a processor that processes the signal from the A-sensor. It computes the CMV (Compaction Meter-value), the RMV (Resonance Meter Value) and the frequency, transforms these values into electric signals and sends these signals to their respective meters and to the CDS (if available). The processor unit also supplies power, high/low amplitude signal and the I-sensor signal to the CDS. It serves therefore in addition as a "junction box" for the CDS.

Processor unit, POM-060

The processor unit of the Oscillometer, POM-060, contains a microprocessor that analyses the signal from the A-sensor and computes the frequency and OMV (Oscillo-Meter-Value). From the I-sensor the processor unit receives a signal, which is used to determine the roller's speed. The OMV, frequency and speed signals are sent to the respective meters as well as to the CDS. The unit supplies power and I-sensor pulses to the CDS. One pulse corresponds to half a meter. This means that if the CDS is connected to a compaction meter of type POM-060, the number of pulses must always be set to 2.00 pulses/m in the Roller data menu.

Like the Compactometer, the Oscillometer directly interfaces the CDS-system, note however that the pin assignment and the signal level for connectors 4 and 5 differ from those of the Compactometer, ALFA-022R, see figure 70.

![Figure 70. Pin assignment and signal levels for connectors 4 and 5 of an Oscillometer.](image)

A-sensor

The A-sensor is a piezoelectric accelerometer that generates an analogue signal proportional to its acceleration. The A-sensor supply voltage is 12V DC (11 - 15V DC) and its output signal has a DC-component of 6V (i.e. half the supply voltage). 0.1V AC output corresponds to an acceleration of 1g.

**Warning:** The A-sensor must not be dropped on a hard surface and any welding close to the sensor must be avoided. In both cases the sensor can be destroyed and cannot be repaired.
Meter-instruments

A compaction meter of type ALFA-022R has two meters, the CMV and the frequency dials. ALFA-022R can be equipped with an extra meter, the RMV (Resonance-Meter-Value) meter. POM-060 compaction meter has three meters, OMV, frequency and speed meters, see table 7.

<table>
<thead>
<tr>
<th>Compaction meter</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALFA-022R</td>
<td>CMV, frequency, RMV (optional)</td>
</tr>
<tr>
<td>POM-060</td>
<td>OMV, frequency, speed</td>
</tr>
</tbody>
</table>

All the meters are dial type with a moving coil, where full scale corresponds to 4V DC (RMV-meter: 2.5V). The two connectors up on the backside of the meters are for power supply to the background light, see figure 71.

![Figure 71. Dial type.](image)

CDS-012-J

Input signals are received in the CDS via the analogue and the digital ports and are stored in the CDS memory in a digital form. The registered data is then if required presented on the LCD-screen in a graphic form and can be printed out if there is a printer serially connected to the CDS. The data can also be transferred to a computer for further processing.

The CDS supply voltage is 12V DC (min. 11V and max. 15V DC). The supply current is about 0.5A.

Data to the analogue ports:

<table>
<thead>
<tr>
<th>Port</th>
<th>Value</th>
<th>Units</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMV</td>
<td>0-120</td>
<td>CMV</td>
<td>0-4 V DC</td>
</tr>
<tr>
<td>RMV</td>
<td>0-25</td>
<td>RMV</td>
<td>0-2.5 V DC</td>
</tr>
<tr>
<td>Frequency</td>
<td>0-60</td>
<td>Hz</td>
<td>0-4 V DC</td>
</tr>
</tbody>
</table>

Data to the digital port:

<table>
<thead>
<tr>
<th>Port</th>
<th>Threshold voltage</th>
<th>Min/Max. voltage</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-sensor</td>
<td>2V</td>
<td>0V/15V</td>
<td>High: open or &lt;0,8V Low: &gt;3,8V</td>
</tr>
<tr>
<td>High/Low</td>
<td>2V(TTL)</td>
<td>0V/15V</td>
<td></td>
</tr>
</tbody>
</table>

The CDS has an RS 232 serial interface with the following features:

- Baud rates: 9600
- Data length: 8
- Stop bits: 1
- Parity: None
- Protocol: XON/XOFF

At rest the output signal is a square wave from -9V to +9V.
AC/DC Converter

The AC/DC-converter (figure 72) is used to provide power to the CDS from a 220V AC, 50 Hz mains. The converter has an output voltage of 17 - 19 V (no load) and 12V DC (with a load). The maximum current is 600 mA.

![AC/DC-Converter](image1)

Figure 72. AC/DC-Converter.

I-sensor

This is an inductive proximity switch that detects metallic objects in its vicinity without contact. The I-sensor signal switches between 12V (supply, metal present) and 0V (ground, no metal).

9.2. Test Equipment

Geodynamik has developed a number of test equipment that easily and quickly assist to localise faults. This equipment will be presented in this chapter.

A-tester

The A-tester (figure 73) simulates the A-sensor. With the help of this tester we can determine whether or not the problem originates from the A-sensor.

![A-tester](image2)

Figure 73. A-tester.

Remove the A-sensor cable from the processor and replace it with the A-tester, see figure 74.
The A-tester generates a signal corresponding to an A-sensor signal of 100 CMV (can be between 95 - 105) and 30 Hz (can be 27 -33 Hz). If with the A-tester the CMV-meter reads 100 CMV and the Frequency meter reads 30 Hz then the defect is in the A-sensor.

**I-tester**

The I-tester (figure 75) simulates the I-sensor. The I-tester tests the functioning of the I-sensor and the measurement of length and speed.

1. Remove the I-sensor cable from the processor unit
2. Replace it with an I-tester, see figure 74
3. Connect a CDS display unit to the processor unit
4. Enter 20,00 pulses/m and 3 km/h speed in the Roller data menu
5. If the speed indicator indicates 3 km/h then the problem is in the I-sensor.
D-tester

The D-tester (figure 76) tests the meters as well as the ALFA-022R power supply.

![Figure 76. D-tester.](image)

The D-tester should be connected to the 7-pole power/instrument connector, see figure 74. The D-tester delivers 1.5V, corresponding to 50 CMV (allowed variation: 45 - 55), to the CMV-meter and 1.5V, corresponding to 25 Hz (allowed variation: 22 - 28 Hz), to the Frequency-meter. If the CMV-meter indicates 50 and the frequency-meter indicates 25 then the meters and cables are OK.

If you press the button on the D-tester, the D-tester delivers to the meters through a resistance a voltage equal to the supply voltage. At 24 volts power supply the meter pointer swings to the end of the scale and at 12V it goes halfway. In this way the supply voltage can be tested.

C-tester

C-tester (figure 77) can simulate processor unit ALFA-022R or POM-060 including all the system sensors. With the help of C-tester the function of the CDS can be tested.

![Figure 77. C-tester.](image)

The C-tester should be connected to the CDS-cable's 7-pole connector, see figure 74. The CDS can then be powered in one of the following alternatives:

1. AC/DC-converter
2. 12V DC-source connected to the C-tester (+12V to the narrow contact, 0V to the wide contact).
3. Through a special cable connected between a cigarette lighter socket and the CDS's start/stop contact.

The C-tester simulates an ALFA-022R or a POM-060 system (processor unit and sensors).

Select the Roller data menu of the CDS, enter pulses/m: 20,00, frequency: 30 Hz, Speed 3 km/h. If the CDS shows CMV=100 (95-105), f=30 Hz (27-33) and v= 3 km/h (2.8-3.2) then the problem is in the processor or/and the sensors.
4-way test cable

One end of the 4-way test cable should be connected to the processor's I- or A-sensor contact and the other end to the I- or A-sensor cable. This cable (figure 78) is used to measure the I- or A-sensor signals with a multimeter or an oscilloscope.

Figure 78. 4-way test cable.

A bit of the insulation on each conductor is removed to enable the measurement of the signals, figure 78. Table 8 lists the pin assignment of the 4-way test cable.

<table>
<thead>
<tr>
<th>Pin</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>- (0V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Brown</td>
<td>Red</td>
<td>Orange</td>
<td>Black</td>
</tr>
</tbody>
</table>

Table 8. 4-way test cable pins.

7-way test cable

One end of the 7-way test cable (figure 79) should be connected to the processor's CDS- or power/instrument contact and the other end to the CDS- or power/instrument cable. This cable is used when measuring the signals between the CDS and ALFA and when checking the supply voltage and the voltage to the meters.

Figure 79. 7-way test cable.

A bit of the insulation on each conductor is removed to enable the measurement of the signals. Table 9 lists the pin assignment of the 7-way test cable.

<table>
<thead>
<tr>
<th>Pin</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>- (0V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Brown</td>
<td>Red</td>
<td>Orange</td>
<td>Yellow</td>
<td>Green</td>
<td>Blue</td>
<td>Black</td>
</tr>
</tbody>
</table>

Table 9. 7-way test cable pins.
9.3. Troubleshooting CDS-012-J

Use the table below to diagnose and solve some of the problems that might occur in the CDS. If the problem is non of those listed below then find out what part of the system is not working properly with the help of the fault localisation flowchart.

<table>
<thead>
<tr>
<th>Problem Description</th>
<th>Possible Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>The LCD-display remains blank when the unit is turned on:</td>
<td>• No power from the roller</td>
</tr>
<tr>
<td></td>
<td>• The contrast screw is in min. position</td>
</tr>
<tr>
<td></td>
<td>• The fuse is out</td>
</tr>
<tr>
<td></td>
<td>• Low power supply</td>
</tr>
<tr>
<td>The LCD-display is black when the unit is turned on:</td>
<td>• The contrast screw is max. position*</td>
</tr>
<tr>
<td></td>
<td>• Low power supply</td>
</tr>
<tr>
<td>The roller symbol does not move or the speed shown is wrong:</td>
<td>• Wrong number of Pulses/m entered in CDS menu Roller data**</td>
</tr>
<tr>
<td></td>
<td>• I-sensor is not connected</td>
</tr>
<tr>
<td></td>
<td>• The distance between the metal object and the I-sensor is too big</td>
</tr>
<tr>
<td></td>
<td>• Defective I-sensor (test with I-tester)</td>
</tr>
<tr>
<td>The Strip length shown does not correspond to the real strip length:</td>
<td>• Wrong number of Pulses/m entered in CDS menu Roller data**</td>
</tr>
<tr>
<td></td>
<td>• The distance between the metal object and the I-sensor is too big</td>
</tr>
<tr>
<td></td>
<td>• Defective I-sensor (test with I-tester)</td>
</tr>
<tr>
<td>Wrong or no frequency shown:</td>
<td>• The frequency entered in the CDS is not the roller's frequency. (compare with a frequency meter)</td>
</tr>
<tr>
<td></td>
<td>• Loose contact or CDS-cable damaged</td>
</tr>
<tr>
<td></td>
<td>• A-sensor or A-sensor cable damaged (test with an A-tester)</td>
</tr>
<tr>
<td></td>
<td>• The Processor unit is damaged (Test with an A-tester)</td>
</tr>
</tbody>
</table>

* If the screen remains black irrespective of what ever contrast you set, then set the contrast to minimum, switch on power and set the contrast to your liking. If the problem still persist then contact you dealer.
<table>
<thead>
<tr>
<th>The clock and contents in the memory changes every time the CDS is switched off for a while:</th>
<th>• The Backup battery is down, contact your dealer.</th>
</tr>
</thead>
</table>
| The LCD displays wrong or strange characters and symbols** | • Not enough power  
• The Processor unit is damaged |
| Warning PC test "Transmission error" | • Check the printer cable (Disconnect pin 20 of the 25 pole DSUB connector)  
• Defective Serial interface (test with another PC) |

*** CDS memory error. Transfer the data in the CDS to a PC and erase the CDS memory (see Data transmission menu above).
Testing the ALFA-Processor

1. Switch off engine.

2. Disconnect everything from the processor. Connect 7-way test cable between the processor's Power/instr. contact and Power/instr. cable's connector. Switch on engine. Measure voltage between the test cable's black (-) and brown (+) wires.

3. 11 - 15 V?
   - Yes
   - No: Disconnect the test cable from the processor and measure again.

4. Connect A-tester to the processor.

5. Indicate:
   - CMV-meter: 95 - 105
   - f-meter: 27 - 33 Hz

6. Yes
   - No: Power failure from the roller. Fix it

7. Connect I-sensor to the processor.

8. Indicate:
   - CMV-meter: 95 - 105
   - f-meter: 27 - 33 Hz

9. Yes
   - No: Examine the I-sensor
     - Indicate:
       - I-sensor: 95 - 105
       - f: 27 - 33 Hz

10. Yes
    - No: Repair it
    - Yes: The Processor unit is OK!

11. Connect CDS-kable to the processor.

12. Indicate:
    - CMV: 95 - 105
    - f: 27 - 33 Hz

13. Yes
    - No: Examine the CDS
      - Indicate:
        - CDS: 95 - 105
        - f: 27 - 33 Hz

14. Yes
    - No: Repair it
    - Yes: The Processor is out of order. Consult your dealers
Testing the ALFA-022R meter instruments

1. Switch off engine
2. Remove power/instr. cable from the processor
3. Is the D-tester battery OK?
   - no
     - Replace battery
   - yes
     - Connect D-tester to the processor's power/instr. contact
4. Does the CMV-meter read 40 - 50?
   - no
     - Connect the 7-way test cable instead of D-tester, measure the resistance between:
       - R1: black cable - neg. terminal (-)
       - R2: yellow cable - pos. terminal (+)
     - R1, R2 ≤ 0.5 ohm
       - yes
         - CMV-meter defective, repair/replace
       - no
         - Power/instr.-cable
   - yes
     - f-meter available?
       - yes
         - Does the f-meter read 20 - 25?
           - no
             - f-meter defective, repair/replace
           - yes
             - RMV-meter available?
               - yes
                 - Does the RMV-meter read 12 - 16?
                   - no
                     - RMV-meter defective, repair/replace
                   - yes
                     - The meter is OK!
               - no
                 - Connect the 7-way test cable instead of D-tester, measure the resistance between:
                   - R1: black cable - neg. terminal (-)
                   - R2: orange cable - pos. terminal (+)
                 - R1, R2 ≤ 0.5 ohm
                   - yes
                     - f-meter defective, repair/replace
                   - no
                     - Check connections/replace Power/instr.-cable
               - Check connections/replace Power/instr.-cable
             - no
               - RMV-meter available?
                 - yes
                   - Does the RMV-meter read 12 - 16?
                     - no
                       - RMV-meter defective, repair/replace
                     - yes
                       - The meter is OK!
                 - no
                   - Connect the 7-way test cable instead of D-tester, measure the resistance between:
                     - R1: black cable - neg. terminal (-)
                     - R2: red cable - pos. terminal (+)
                   - R1, R2 ≤ 0.5 ohm
                     - yes
                       - The meter is OK!
                   - no
                     - Check connections/replace Power/instr.-cable
Testing the ALFA-Processor

1. Disconnect everything from the processor. Connect a 7-way test cable between the processor's Power/instr. contact and Power/instr. cable's connector. Switch on engine. Measure the voltage between the test cable's black (-) and brown (+) wires.

2. Connect A-tester to the processor.
   - Connect the test cable from the processor and measure again.
   - Measure voltage between the test cable's black (-) and brown (+) wires.
   - Power failure from the roller. Fix it.

3. Connect I-sensor to the processor.
   - Connect the I-sensor to the processor. The meters indicate:
     - CMV-meter: 95 - 105
     - Frequency meter: 27 - 33 Hz
   - Are the meters and I-sensor OK?
   - Repair it.

4. Connect CDS-kable to the processor.
   - Connect the CDS-kable to the processor. The meters indicate:
     - CMV: 95 - 105
     - Frequency: 27 - 33 Hz
   - Examine the CDS.
   - CDS OK?
   - Repair it.

5. The Processor unit is OK!
Testing the ALFA-022R meter instruments

Switch off engine

Remove power/instr. cable from the processor

Is the D-tester battery OK?

Connect D-tester to the processor's power/instr. contact

does the CMV-meter read 40 - 50 ?

no

f-meter available?

yes

does the f-meter read 20 - 25 ?

no

RMV-meter available?

yes

does the RMV-meter read 12 - 16 ?

no

The meter is OK!

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

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no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no

no
Testing the ALFA-022R meters and supply voltage

1. **Switch off the engine.**

2. **Disconnect power/instr. cable from the processor.**
   - **Is the D-tester battery OK?**
     - **Yes**
       - **Connect the D-tester to the power/instr. contact.**
       - **Indicates:**
         - CMV-meter 40 - 50 ?
         - Yes
   
   - **No**
     - **Have you an f-meter?**
     - **Yes**
       - **Indicates f-meter 20 - 25 ?**
       - **Yes**
         - **Have you RMV-meter?**
         - **Yes**
           - **Indicates:**
             - RMV-meter 13 - 17 ?
             - **Yes**
               - **Switch on engine, press D-tester’s red button.**
               - **Indicates:**
                 - CMV-meter: 55 - 75 ?
                 - f-meter: 27 - 38 ?
                 - **No**
                   - **Wrong supply voltage, correct it.**
                 - **Yes**
                   - **Instrument and power supply OK!**
         
     - **No**
       - **Indicates:**
         - CMV-meter: 55 - 75 ?
         - f-meter: 27 - 38 ?
         - **No**
           - **Wrong supply voltage, correct it.**
         - **Yes**
           - **Instrument and power supply OK!**

3. **Replace the battery.**

4. **Connect 7-way test cable instead of D-tester. Measure resistance between: 7-way test cable and CMV-meter.**
   - R1: black cable - neg. terminal(-)
   - R2: yellow cable - pos. terminal (+)
   - **R1,R2 ≤ 0.5ohm ?**
     - **Yes**
       - **Inspect connections/change power cable.**
     - **No**
       - **Faulty CMV-meter, examine/change it.**

5. **Connect 7-way test cable instead of D-tester. Measure resistance between: 7-way test cable and f-meter.**
   - R1: black cable - neg. terminal(-)
   - R2: Orange cable - pos. terminal (+)
   - **R1,R2 ≤ 0.5ohm ?**
     - **Yes**
       - **Inspect connections/change power cable.**
     - **No**
       - **Defective f-meter, examine/change it.**

6. **Connect 7-way test cable instead of D-tester. Measure resistance between: 7-way test cable and RMV-meter.**
   - R1: black cable - neg. terminal(-)
   - R2: red cable - pos. terminal (+)
   - **R1,R2 ≤ 0.5ohm ?**
     - **Yes**
       - **RMV-meter defective, examine/change it.**
     - **No**
       - **Inspect connections/change power cable.**

7. **Switch on engine, press D-tester’s red button.**

---

*Kontrollera anslutningar/byt power/instr.-kabel.*

*Wrong supply voltage, correct it.*
Testing the A-sensor

1. Disconnect CDS-cable, I-sensor and A-sensor from the processor.
2. Connect a 4-way test cable to the processor's A-sensor input. Switch on the engine. Measure the voltage between the test cable's black (-) and brown (+) wires.
   - If the voltage is between 10 - 15 V, proceed to Step 3.
   - If not, go to Step 1.
3. Connect the A-sensor to the other end of the 4-way test cable. Then measure the voltage (V1) between the black (-) and brown (+) wires of the test cable.
   - If V1 is between 10 - 15 V, proceed to Step 4.
   - If not, consult your dealer.
4. Measure the voltage (V2) between the black (-) and orange (+) wires of the test cable.
   - If V2/V1 is between 0.4 - 0.6, proceed to Step 5.
   - If not, consult your dealer.
5. Place the roller on a soft ground, switch on the vibrations. Measure the AC voltage between the black (-) and orange (+) wires of the test cable.
   - If AC is between 0.2 - 0.6 V and decreases when vibrations are switched off, proceed to Step 6.
   - If not, consult your dealer.
6. A-sensor is OK!

Note: AC-voltage is proportional to the roller's amplitude. The given interval is valid for the most common rollers. Measure and compare with FAM.
Testing I-sensor-008, -012, -018

1. Switch off engine
2. Disconnect CDS-cable, A-sensor and I-sensor from the processor
3. Connect a 4-way test cable to the processor's I-sensor-contact. Switch on engine and power, measure the DC-voltage between the test cable's black (-) and brown (+) wires.
4. Is 10 - 15 V?
   - Yes: The I-sensor is OK!
   - No: Connect the I-sensor to the other end of the test cable, measure the DC voltage between the test cable's black (-) and brown (+) wires.
5. Is 9 - 15 V?
   - Yes: The I-sensor is OK!
   - No: Measure with a voltmeter the voltage between the black (-) and orange (+) wires of the test cable when a metal is held in front of the sensor, V1, and when it is taken away V2.
6. Is V1 < 0.8 V and V2 > 8 V?
   - Yes: The I-sensor is out of order. Consult your dealer.
   - No: Check the processor and its supply voltage.

I1 - I2

The I-sensor is out of order. Consult your dealer.
Testing the CDS-012-J

1. Switch off engine and CDS
2. Disconnect the CDS-cable from ALFA/POM-processor and with this cable connect a C-tester to the CDS
3. Connect the CDS to one of the following +12V supply:
   - AC/DC converter
   - Cigarette cable
   - C-tester pins (+12V small pin, 0V wider pin)
4. Switch on 12V first then CDS
5. Is the CDS text readable?
   - Yes
   - No, turn the contrast to min., switch the CDS off and then on, increase the contrast until you are able to read the text
6. Are the pulses/m set to 20.0 p/m?
   - Yes
   - No
7. Select ROLLER DATA menu enter:
   - Pulses/m: 20.0 p/m
   - Frequency: 30 Hz
   - Speed: 3.0 km/h
8. Select: PRESS TO START and then NEW AREA menus
9. Does the v-indicator show 2.8 - 3.2 km/h?
   - Yes
   - No
10. Does f-indicator show 28.2 - 31.8 Hz?
    - Yes
    - No
11. Start registering
12. Does the roller symbol move?
    - Yes
    - No
13. Stop registering
14. Does the CDS read CMV: 9.6 - 10.4?
    - Yes
    - No
15. Registration with the CDS is OK!

A1 - A5

A1
- replace the CDS-cable and test again.
A2
- are the result the same, i.e. faulty?
A3
- does the v-indicator show 2.8 - 3.2 km/h?
A4
- does the roller symbol move?
A5
- does the CDS read CMV: 9.6 - 10.4?

CDS service required contact your dealer
There are two ways to print out the CCC-report from a CDS:

1. Transfer the data from the CDS to a PC with the help of either the CdsCom or the CdsView software then print out the report using the printer connected to the PC, see figure 80.

2. Connect a printer directly to the CDS and select Print from the main menu, see figure 81.

*Figure 80. Printing via a PC.*

*Figure 81. A printer connected to the CDS.*
Only printers with a serial interface (RS 232) can be connected to the CDS and the printer installations should be as follows:

- Baud rate: 9600
- Data length: 8 bits
- Stop bits: 1
- Parity: none
- Protocol: XON/XOFF

Graphic matrix printers and laser printers that have or can emulate HP-PCL can be used to make hard copies from the CDS. The printing is in portrait (standing) orientation. The copy fits even on an 11 inch page.

Suitable printers are Epson type of printers with 9-wire print head, IBM printers and printers that can emulate IBM mode. 24-wire printers must be adjusted to emulate the IBM 9-wire printers (72 dots/in.). Some 24-wire printers (e.g. Epson LQ) cannot emulate a 9-wire printer with 72 dots/in resolution. If you use this type of printer, the pages will be longer than A4.

A Laser printer can be used, provided it has a serial interface and it is HP-compatible (HP-PCL).

Some ink beam printers (e.g. HP DeskJet) can also be used provided they use HP-PCL and have a serial interface.
11. Data processing software

Geodynamik has developed four programs, CdsCom, CdsView, CdsComXL and CdsMap used to process the collected data. The functions of these three programs are summarised below in table 10.

<table>
<thead>
<tr>
<th>Function</th>
<th>CdsView</th>
<th>CdsCom</th>
<th>CdsComXL</th>
<th>CdsMap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transfer to and from the CDS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Edit data file</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calibration</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Database function</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overview: Diagram, Zoom, Strip diagram</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Print CCC-report</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Print Overview</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDS-area printed to scale</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Supports laser printers</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Supports matrix printers</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Supports pen plotter</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free to choose printer commands</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Generates colour/black and white bitmap-files</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Exports calibration data to dBase and Lotus files</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help function</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Excel-functions for diagrams, calibration, sorting of data etc</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Table 10.* A general survey of CdsCom, CdsView, CdsComXL and CdsMap.
11.1 CdsView

CdsView is a program for storing, handling and processing data collected by the CDS.

Included in the program are functions for transmitting data between a CDS and a computer and for storing data in the computer or on diskettes.

![CdsView main menu](image)

**Figure 82.** CdsView main menu.

With the help CdsView, an overview diagram can be obtained as well as a detailed analysis of the stored CMV/OMV data.

The overview diagram, figure 83, shows the sections and strips that were registered. The data files resulting from all the recordings made by one or more CDS are processed to give an overview on the PC-screen of a selected layer type for the whole length of the project.

![Overview diagram](image)

**Figure 83.** Overview diagram.

The width of the screen picture initially shows the entire length of the project – many kilometres in many cases. Areas containing CMV values below a set limit value are marked with red colour. This view is
used to demarcate the areas having insufficient compaction or unsuitable soil material. For a more
detailed picture of smaller areas a zoom function can be applied, figure 84.

**Figure 84. Zoom function.**

An even more detailed presentation can be made as a diagram along one roller strip, figure 85. The
diagram shows in detail the recorded values and can quickly be changed between the different roller
passes. Two different filter functions can be applied to reduce too rapid variations of the result.

This screen also shows basic statistical data for the investigated stretch:

- **Average value**
- **Maximum value**
- **Minimum value**
- **Standard deviation**

**Figure 85. Strip diagram.**
CdsView is also used to manually enter and store data from the conventional test methods made in places that were documented by the CDS. The program can generate a calibration diagram and plot the results from the conventional tests against the compaction meter values obtained in the same area and spots, see figure 86.

The calibration diagram can be printed or stored in a Lotus or dBase data format for further processing using other software.

**Figure 86.** Calibration diagram.
11.2 CdsCom

CdsCom is a PC-program used to transfer data from a CDS to a PC, from a PC to a CDS and to print CCC-reports.

![CdsCom Interface]

*Figure 87. CdsCom: Transmitting data from a CDS.*

CdsCom is both keyboard- and mouse-controlled and contains functions to:
- transfer data from a CDS to a PC
- transfer data from a PC to a CDS
- type on the screen or print a list of all the files available and a list of contents of a file
- edit files
- print CCC-reports, either directly from a stored file or relayed from a CDS, on a laser or matrix printer

The program contains a help function where you can get answers to some common questions concerning the program and the CCC-report.
11.3 CdsComXL

Present your CDS-data in the Windows Excel environment with the help of CdsComXL.

CdsComXL offers you a flexible handling of CDS-data. You have the possibility to determine your own way of presenting the results to the customer, the client or to the quality controlling manager.

The program is an Excel add-in and is available in two versions
- A 16-bits version for users of Excel 5 for Windows 3.1
- A 32-bits version for users of Excel for Windows 95/98/2000/NT.

CdsComXL creates a new menu in Excel that handles CDS-data in a flexible way. You can transfer data from the CDS, create tables of saved files and CDS-data. You can make use of all the functions in Excel to create diagrams and present the results in your own way.

Summarize and present the results in illustrative 2D- and 3D-diagrams.

Create your own calibration diagrams with optional format.

Plot CMV-values chosen from particularly interesting parts of a compaction project. You can also create diagrams of the whole length of the object.

Figure 88. Examples of CdsComXL use.
11.4 CdsMap

CdsMap is a PC program designed to generate a scaled plan drawing, mapping a number of CDS-areas. The program can also create bitmap files (*.bmp files) in colour or in black and white. These bitmap pictures can then be used in reports written in e.g. MS Word or MS Excel.

All the input data needed by the program is read from a command file. CdsMap's command file is a pure text file and is created using a text editor or a spreadsheet program.

The following data is entered in a header section at the beginning of the command file:
1. Heading to be printed at the top of the drawing.
2. X/Y- co-ordinates for the lower left corner of the drawing.
4. Portrait or landscape format for the printout.
5. Resolution to be used in the printer.
6. Scale.

The header section is followed by a list of recorded CDS-areas to be mapped.

Normally the program gets the size and position of the areas from the stored CDS-files. If some of these data are missing in the CDS-files, the missing data can be entered in the command file.

Figure 89 shows a CdsMap plot of a waste disposal project in Winkl.

Figure 89. Example of CdsMap plot.
12. Replacing the EPROM

Note! This ought to be done only by a qualified technician.

Before replacing the EPROM
- Save the data in the CDS.
- Disconnect CDS from the power supply.
- Turn over the CDS and unscrew the 12 screws around the base. Use a screw driver no. 1. Do not unscrew the two upper screws on the front panel.
- Remove the bottom cover.

Dealing with CMOS/IC
- Warning for static electricity!
- Make sure, the EPROM, CDS and you are not charged.

Removing the old EPROM
- Use an extractor.
- In case you do not have an EPROM extractor, use a small screw driver. Push the EPROM slowly from below alternately on both ends of the EPROM. Be very careful not to damage the circuit board or any other component.

Putting in a new EPROM
- Make sure the EPROM is facing the right direction. The end with a half circle cut must face towards the left, see figure 89.

*Figure 90. Replacing an EPROM.*
• Direct the pins on one side of the IC into their sockets but do not push down the IC.

• Hold the EPROM firmly at both ends and slowly push it on one side so that all the pins on the other side enter the sockets.

• Check to make sure that all the EPROM pins are directed into the sockets then push carefully the whole IC down in place!

Testing the new program

• If the previous program was of an earlier version then a message will appear warning that the memory will be erased.

• Press the second key from above to enter the Settings menu. Select the settings you want, e.g. type of printer, language, company and etc.

• Check all the menus and make sure that the program is running properly.
13. Technical specifications

Size (display unit): 305x200x40 mm

Weight (display unit): 2900 g

Operating temperature: -5 to +55°C

Supply voltage: 12 V (11-15 V)

Supply current: 500 mA

Screen: LCD, 222x98 mm (640x200 pixels)

Memory: 400 000 m² or maximum 32 areas

Internal clock: Powered by built-in batteries when the CDS is switched off. The batteries have a lifetime of at least 5 years.

Connections: The connectors on the CDS's front panel are as shown below:

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CMV/OMV</td>
<td>1</td>
<td>+12V</td>
</tr>
<tr>
<td>2</td>
<td>+12V</td>
<td>2</td>
<td>Start/Stop</td>
</tr>
<tr>
<td>3</td>
<td>Proximity sensor</td>
<td>3</td>
<td>0 V</td>
</tr>
<tr>
<td>4</td>
<td>High/low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Frequency (analogue)</td>
<td>6</td>
<td>RMV</td>
</tr>
<tr>
<td>7</td>
<td>RXD</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Signal ground</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>TXD</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0 V (ground)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>n.c.</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>
## 14. Spare parts

### ALFA-022R

<table>
<thead>
<tr>
<th>Item</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>ALFA-022R-001</td>
</tr>
<tr>
<td>Cable</td>
<td>ALFA-020-006</td>
</tr>
<tr>
<td>CMV-dial</td>
<td>ALFA-020-003</td>
</tr>
<tr>
<td>Frequency-dial</td>
<td>ALFA-020-004</td>
</tr>
<tr>
<td>RMV-dial</td>
<td>ALFA-020-005</td>
</tr>
<tr>
<td>A-sensor</td>
<td>A-SENSOR-001</td>
</tr>
<tr>
<td>A-tester</td>
<td>ALFA-020-020</td>
</tr>
<tr>
<td>D-tester</td>
<td>ALFA-020-021</td>
</tr>
<tr>
<td>4-core test cable</td>
<td>ALFA-020-022</td>
</tr>
<tr>
<td>7-core test cable</td>
<td>ALFA-020-023</td>
</tr>
<tr>
<td>Manual</td>
<td>ALFA-022R-051E</td>
</tr>
</tbody>
</table>

### CDS-012-J

<table>
<thead>
<tr>
<th>Item</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display unit</td>
<td>CDS-012-006</td>
</tr>
<tr>
<td>Mounting plate</td>
<td>CDS-012-002</td>
</tr>
<tr>
<td>CDS cable</td>
<td>CDS-012-003</td>
</tr>
<tr>
<td>AC/DC converter</td>
<td>CDS-012-008</td>
</tr>
<tr>
<td>Start/Stop button</td>
<td>CDS-012-005</td>
</tr>
<tr>
<td>I-sensor M8&quot;1</td>
<td>I-SENSOR-008</td>
</tr>
<tr>
<td>I-sensor M12&quot;1</td>
<td>I-SENSOR-012</td>
</tr>
<tr>
<td>I-sensor M18&quot;1</td>
<td>I-SENSOR-018</td>
</tr>
<tr>
<td>I-tester</td>
<td>CDS-012-020</td>
</tr>
<tr>
<td>C-tester</td>
<td>CDS-012-021</td>
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<td>Printer/serial cable</td>
<td>CDS-012-035</td>
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<td>PC gender changer</td>
<td>CDS-012-036</td>
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<td>PC adapter 25-9 pin</td>
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<td>CDS-012-051E</td>
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<td>EPROM</td>
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<tr>
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