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Arbeitsbericht NAB 16-09

Results of laboratory investigations in preparation of the dismantling of the FEBEX-e/FEBEX-DP in-situ test and on-site experiments during the dismantling

February 2016

García-Siñeriz J.L., Martínez V., Rey M. and Abós H.

AITEMIN

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Radioactive Waste

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KEYWORDS

FEBEX/FEBEX-DP, excavation techniques, bentonite, dismantling, unaltered samples

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1 Introduction

FEBEX (Full-scale Engineered Barrier Experiment in crystalline host rock) is a research and demonstration project that is being carried out by an international consortium. The aim of the project is to study the behaviour of near-field components in a repository for high-level radioactive waste in granite formations.

The project consists of two large-scale tests – "in situ" and "mock-up" –, a series of laboratory tests, and THM and THG modelling tasks. The full-scale heating test ("in situ" test) was performed at the Grimsel underground laboratory in Switzerland. A complete description of the project objectives and test program may be found in the Test Plan document and final report of the FEBEX project, (Fuentes-Cantillana & García-Siñeriz 1998) and (Fuentes-Cantillana et al. 2000).

The project started in 1994, and has been supported by the European Commission through consecutive contracts, identified as FEBEX I (contract No. FI4W-CT-95-0006) for the period January 1996 to June 1999, and FEBEX II (contract No. FIKW-CT-2000-00016), from September 2000 to December 2004. Afterwards, NF-PRO continued the work from January 2005 to December 2007. Finally, the current FEBEX-e consortium took the investigations from January 2008 until the final excavation.

The "in-situ" test was installed in 1996 in the Grimsel underground laboratory (Switzerland). The operational phase started in February 1997. Two electrical heaters, of the same size and of a similar weight as the reference canisters, were placed in the axis of a horizontal drift excavated in the Grimsel granodiorite.

Partial dismantling of the FEBEX "in situ" test took place during the summer of 2002, after 5 years of continuous heating (Bárcena, Fuentes-Cantillana & García-Siñeriz 2003). The operation included the demolition of the concrete plug, the removal of the section of the test corresponding to the first heater, and re-sealing the experiment with a new shotcrete plug.

The final dismantling of the "in-situ" experiment started at the beginning of 2015. The plan was to remove all the remaining parts of the "in situ" test, including the remaining canister (Bárcena & García-Siñeriz 2015). It also included a sampling campaign of the bentonite, rock, relevant interfaces, sensors, metallic components and tracers to allow the analysis of the barriers' condition after more than 18 years of heating and natural hydration, (Bárcena & García-Siñeriz 2015b) and (Rey, Bárcena & García-Siñeriz 2015).

2 Used terms and other relevant information

2.1 Terms

Terms most commonly used are listed hereafter to facilitate the comprehension of the text.

FDR Frequency Domain Reflectometry technique for volumetric water content measure

GBM Granulated Bentonite Mixture

GTS Grimsel Test Site

RH sensor Relative Humidity and temperature sensor

sXX Sampling section number XX

THM Thermo-Hydro-Mechanical

THG Thermo-Hydro-Geochemical

URL Underground Rock Laboratory

WC Water Content

2.2 Bentonite blocks used

The bentonite blocks used in the experiments were made of compacted raw material from the zone of Cabo de Gata (province of Almeria), Cortijo de Archidona site, and provided by the firm MINAS DE GADOR, S. A. This bentonite, so called FEBEX, is composed almost entirely of calcic-magnesic montmorillonite (Fuentes-Cantillana & García-Siñeriz 1998) and (Fuentes-Cantillana et al. 2000)

These blocks were manufactured for the FEBEX "in-situ" test, the dry one is a spare unit not installed that was preserved plastic-packed in the Aitemin facilities and the wet one was obtained from the dismantling of the EB experiment (García-Siñeriz et al 2015) that took place from October 2012 to February 2013, preserved plastic-packed too.

The dry density of the dry block was 1.69 to 1.70 g/cm^3 with a nominal water content (gravimetric) that ranges from 13.07 to 14.87 % (mean value of 14,4 %). Suction is in the range of 100 MPa (Villar 2006).

The dry density of the wet block ranged from 1.33 to 1.39 g/cm^3 with a water content between 34 and 37 % (gravimetric). In terms of degree of saturation of the blocks this is between 95 and 101 %. Suction is in the range of 1.25 to 2.2 MPa (García-Siñeriz et al 2015).

3 Objective

This document was initially intended to communicate the results obtained from laboratory experiments carried out by Aitemin to study and pre-test the most promising techniques/methods aiding the dismantling and sampling. A pre-report, containing just the status of the works and the main conclusion obtained, was delivered in February 2015. A more complete report was issued in March, before the start-up of the dismantling operation. Since the results obtained were not conclusive in some cases, it was decided to perform additional tests on-site during the dismantling operation to complete the work. This report presents all gathered results.

4 Scope

The planned activities were framed in the following topics:

- Study of the most promising tools for on-surface measurement of the bentonite water content
- Testing of the best steel/bentonite interface sampling methods
- Testing of optimised bentonite excavation techniques focused on the most humid parts
- Design of a sampling device to obtain unaltered samples of bentonite by the pushing method

5 Description of the different investigations and their obtained results

5.1 Study of the most promising tools for on-surface measurement of the bentonite water content

5.1.1 Rationale

The FEBEX buffer was made of highly compacted blocks and humidity was expected to range from almost saturation, close to the rock walls, to highly desiccated bentonite, close to the heater. Experience gained from the dismantling activities in both the first partial dismantling of FEBEX "in-situ" and recently in the EB experiment (Engineered Barriers experiment carried out in Mont Terri URL (Mayor et al. 2005 and Palacios et al. 2013), showed that the buffer sampling operation, even if done with all precautions and care, creates a certain degree of perturbation in the sampled material (desiccation, stress release, …) that jeopardises to an unknown extent the data to be obtained from analysis; in particular for water content and dry density.

For instance, the EB dismantling demonstrated that the water content loss in the GBM samples could range from 0.7 % to 1.5 % in 20 minutes, which is the average time required to process the samples for on-site analysis (Palacios et al. 2013) and (Villar 2013). The comparison between results obtained on-site and in the laboratory from a number of twin samples taken together from the same point at different locations throughout the barrier showed differences in average of up to 0.7 % in water content and up to 1.4 % for dry density. These differences are not relevant, but, fact is, they exist. Furthermore, bentonite blocks showed dimensional changes (expansion) during the dismantling phase, not only when the GBM was removed at each buffer section (Palacios et al. 2013), but also when block samples were measured again at Ciemat laboratory (Villar 2013).

5.1.2 Initial scope and succinct description of the techniques

The scope of this study considered the following list of techniques focused on water content determination at the buffer surface:

a) Suction/water activity measurement using thermo-hygrometers and psychrometers

These techniques, already used in the test for buffer monitoring, will provide punctual measurements by isolating a small volume of air in equilibrium with the dismantled buffer front; thermo-hygrometers are appropriate for less saturated areas while psychrometers are required in the most humid ones. The challenge was to determine how to insert the sensors on the buffer surface and to estimate the required stabilisation times.

b) Water content (volumetric) using FDR technique

This technique gives punctual measurements too but the electrodes of the measuring device need to be pushed into the buffer. Again the objective was to find the right way to emplace them on the buffer surface and to determine the required stabilisation times.

c) Water content measurement using micro-waves and specialised cameras (thermal, spectral and hyperspectral)

These techniques were considered as they have the potential to record the water distribution in the buffer front continuously. However, they would require some kind of automated procedure to measure large areas of the dismantled buffer front in a reasonable time period.

5.1.3 Laboratory investigations

5.1.3.1 Thermo-hygrometers and psychrometers

The equipment used for the test was:

- Two thermo-hygrometers-capacitive type-, based on Sensirion SHT75, which were manufactured by Aitemin for the tests (see technical description in Appendix A) and a portable reader for data download, custom made by Aitemin for this purpose (see technical description in Appendix B)
- Two psychrometers from Wescor Inc (see technical description in Appendix A) and a datalogger for registering the data, model Psypro from Wescor Inc and a portable readout unit HR33T from Wescor too (see technical description in Appendix B)

The tests were carried out at the laboratory on existing blocks from FEBEX and the EB dismantling (see characteristics in Section 2.2). Those blocks were made from the compaction of Serrata type bentonite. The dry one was a spare unit from the FEBEX installation and the wet one was a block retrieved during the dismantling of the EB experiment. The test layout can be seen in Fig. 1.

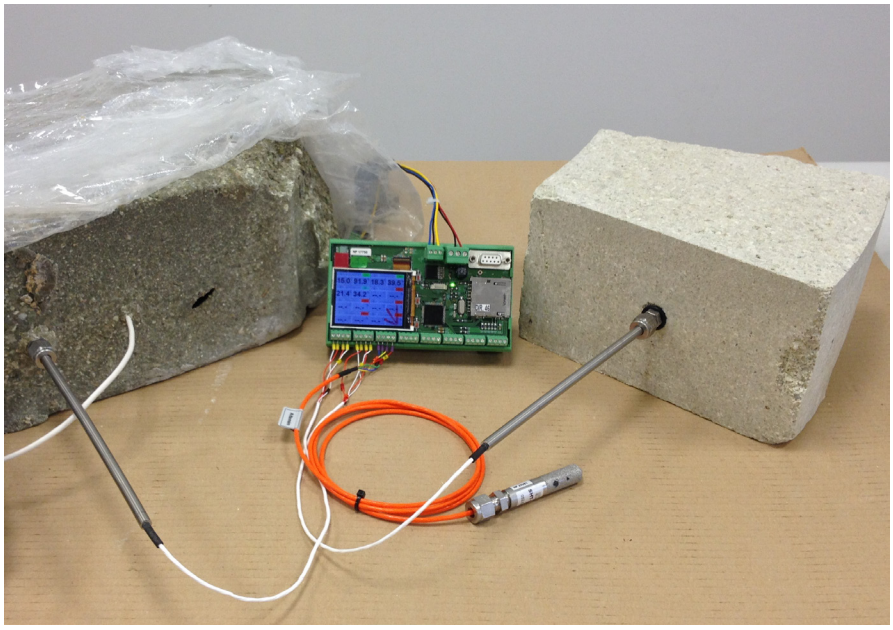

Fig. 1: EB wet block (left) and FEBEX dry block (right).

Thermo-hygrometers installed in both blocks (those with metallic tubing protecting the cable close to the blocks) and one psychrometer installed in the wet block. Thermo-hygrometers reading unit is in the centre.

Drillings (10 mm in diameter and 20 mm in length for the psychrometers and 14 mm in diameter and 80 mm in length for SHT75) were made in the blocks to insert the measuring probes and then sealed at the surface to create a kind of equilibration chamber within the block. As it can be seen in Fig. 2, a rubber ring (photo at the left) was used to properly isolate the sensor during the measurement in the dry block and the debris obtained from drilling the wet bentonite block was used as a kind of plaster for the wet block (photo at the right hand side).

Fig. 2: Detail of the sensors installation, left in the dry block and right in the wet one.

Fig. 3: Detail of the psychrometers´ readout units, Psypro on the left and HR33T on the right.

Obtained measurements for duration of at least 2 days, keeping the wet block isolated from the atmosphere, are illustrated in next figures.

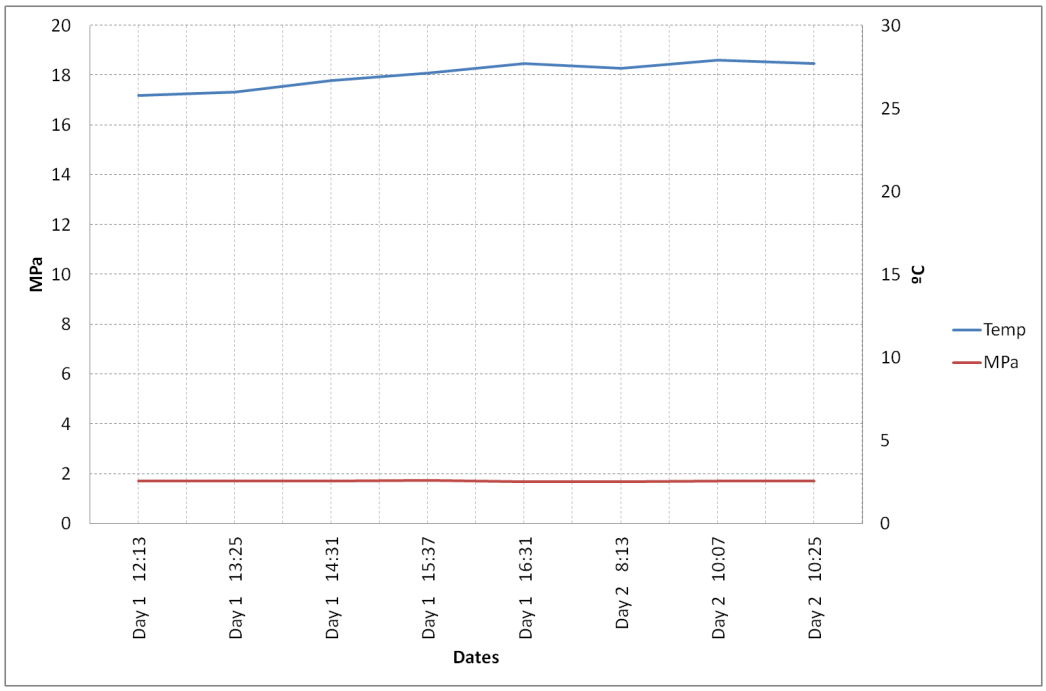

Fig. 4: Measurements over a period of about 1 day for the Psypro datalogger (Psychrometric method) in the wet block. Suction (MPa) in red colour and temperature (ºC) in blue.

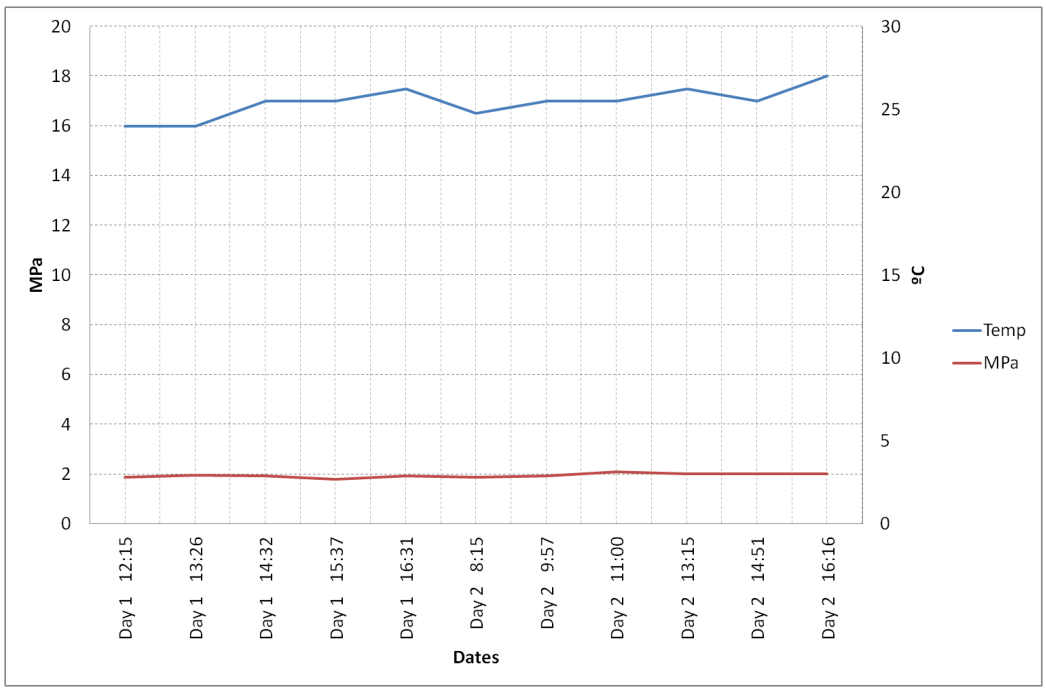

Fig. 5: Measurements over a period of about 1 day for the HR-33T reader (Psychrometric method) in the wet block. Suction (MPa) in red colour and temperature (ºC) in blue.

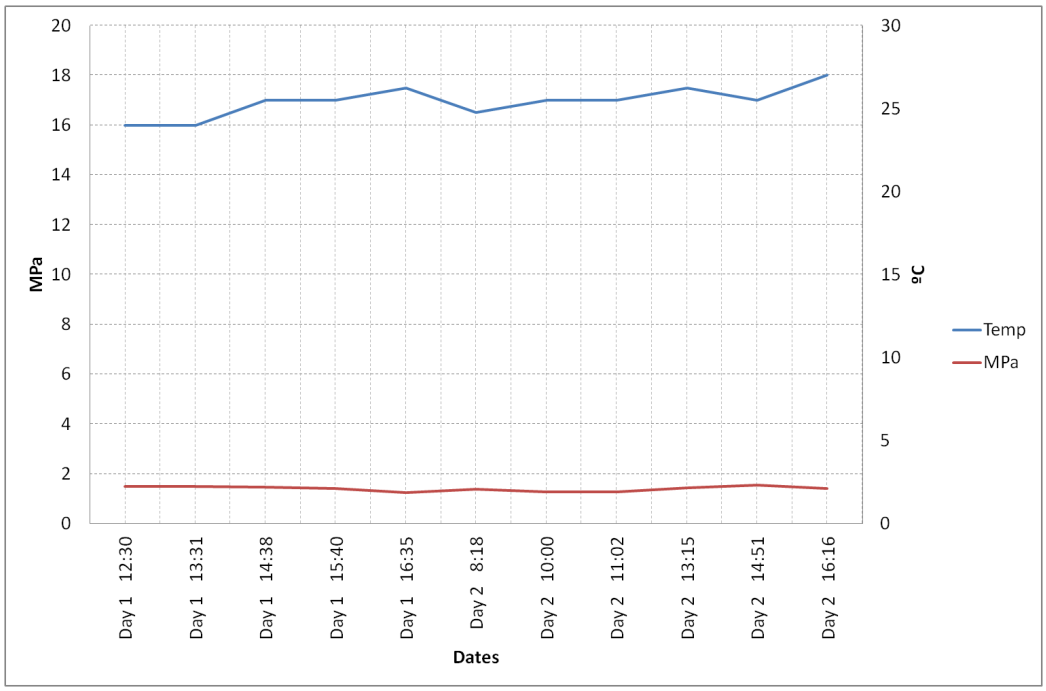

Fig. 6: Measurements over a period of about 1 day for the HR-33T reader (Dew point method) in the wet block. Suction (MPa) in red colour and temperature (ºC) in blue.

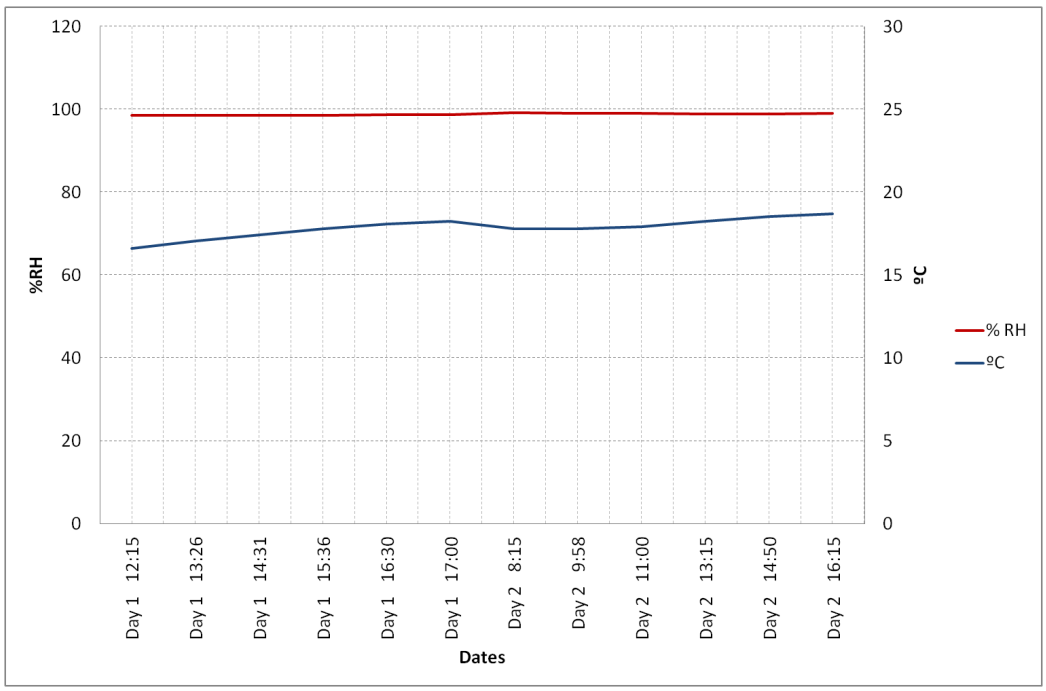

Fig. 7: Measurements for the HR sensor in the wet block. HR (%) in red colour and temperature (ºC) in blue.

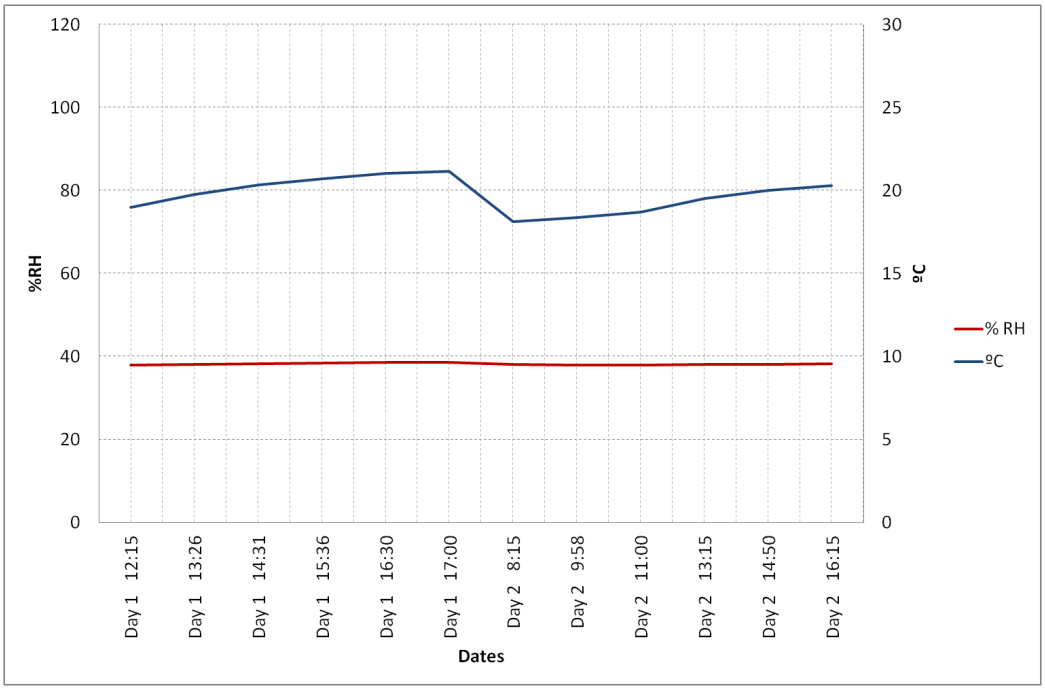

Fig. 8: Measurements for the HR sensor in the dry block. HR (%) in red colour and temperature (ºC) in blue.

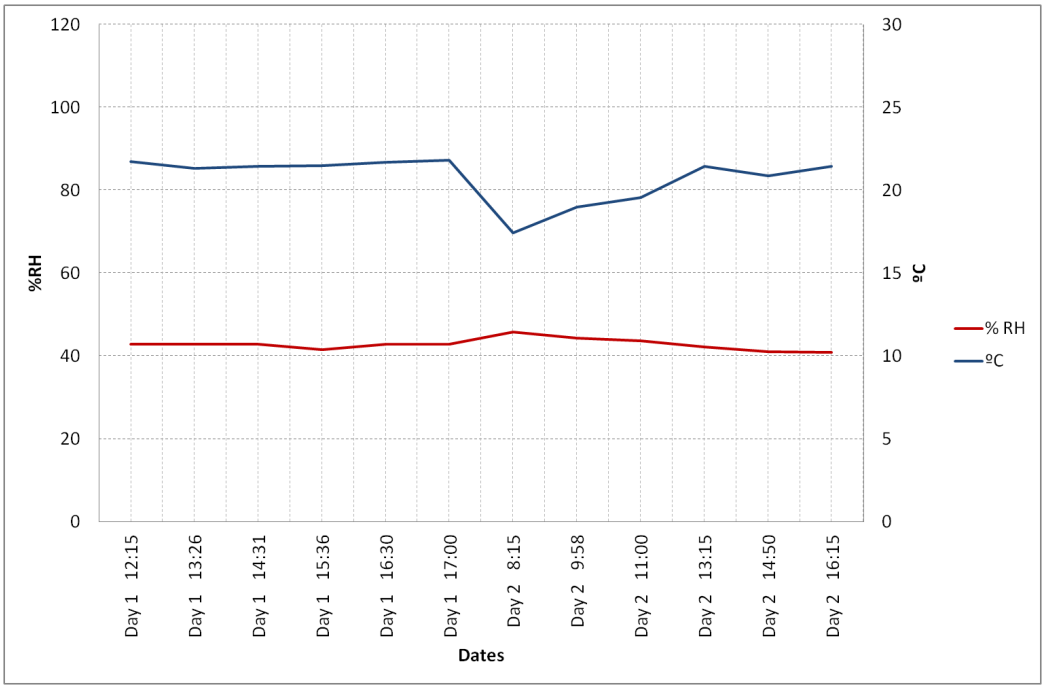

Fig. 9: Measurements for the HR sensor in the atmosphere of the test room. HR (%) in red colour and temperature (ºC) in blue.

As it can be observed from figures 4 to 6, both the Psypro and the HR-33T reader provide accurate measurements for the wet block (see Section 2.2), which is almost saturated and, therefore, the suction ranges from 2 to 3 MPa, depending on the measuring device and method. According to the measurements made during EB dismantling (Palacios et al. 2013 and Villar 2013) this corresponds with a water content value in the range of 36 – 34 % WC (gravimetric) that correlates well with the expected values.

Fig. 7 demonstrates that the HR sensor is capable of providing good measurements of the wet block too but as the accuracy at that range is lower, it would be almost impossible to track small changes in suction. However, this sensor is suitable for drier conditions, as can be seen in Fig. 8 when installed in the dry block or in Fig. 9 when measuring the ambient conditions. Since both the dry rock and the atmosphere of the test room have a similar temperature behaviour (Fig. 8 and Fig. 9), it is clear that the isolation method needs to be improved for the dry block. For example, using Silicone or better rubber O-rings, this could be more effective and should be reflected by a lower connection between inner and outer (ambient) temperatures.

Regarding the stabilisation time required to get accurate measurements, the results were better than the initially expected few hours; it took no more than 15 minutes in all cases.

Finally, another aspect to evaluate is the facility of each measuring device. Both the Psypro and HR-33T (only using dew-point method) are easy to use but the latter needs an additional data record, consequently the Psypro seems to be better suited for continuous measurements in harsh conditions.

5.1.3.2 FDRs

The equipment used for the test was:

- A FDR unit or ThetaProbe moisture sensor from Delta-T Devices Ltd, which was rented for the tests (see technical description in Appendix A)
- A datalogger for registering the data

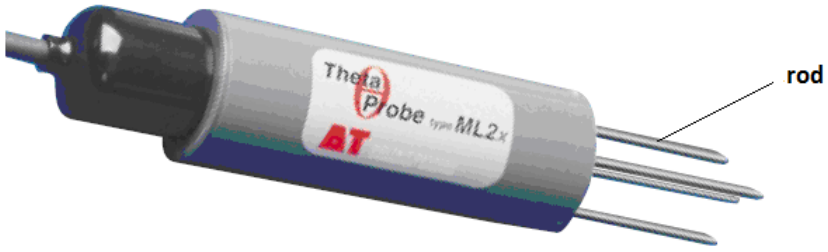

Fig. 10: Water content sensor.

The tests were carried out at the laboratory on existing blocks from FEBEX and the EB dismantling, see layout in Fig. 11.

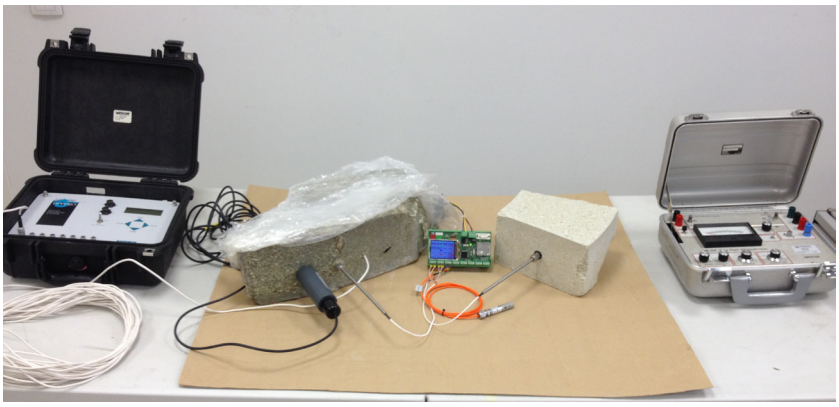

Fig. 11: Layout of the blocks with the sensors installed and the reading units around.

The insertion of the FDR was not feasible in the dry block just by pushing-in. The only way to place the measuring rods inside was to drill holes first, but then, a gap of air remained between the bentonite and the rods preventing a good measurement[1]. However, the insertion in the wet bentonite (Fig. 12) was easy by hand and therefore this was the only case studied.

Fig. 12: FDR inserted in the wet block (left hand side). Sensor SHT75 can be seen in the centre and a psychrometer at the right hand side.

Obtained measurements are illustrated by the examples given in Fig. 13 and Fig. 14. The jump in signal from one day to the next (Fig. 13Fig.), cannot be explained, and the FDR signal seems not to be as stable as the one provided by psychrometer. The corresponding volumetric water content is in the range of 27 – 28 % (no specific calibration was used). The observed daily decay (Fig. 14), which was observed systematically in similar tests with the same type of sensor, could be related to block desiccation, but as it does not match the results provided by the rest of sensors based on other techniques (psychrometer or Sensirion), this possibility was discarded.

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[1] The *ThetaProbe* is sensitive to the water content of the sample held within its array of 4 stainless steel rods, but this sensitivity is biased towards the central rod and falls off towards the outside of this cylindrical sampling volume. The presence of air pockets around the rods, particularly around the central rod, will reduce the value of moisture content measured.

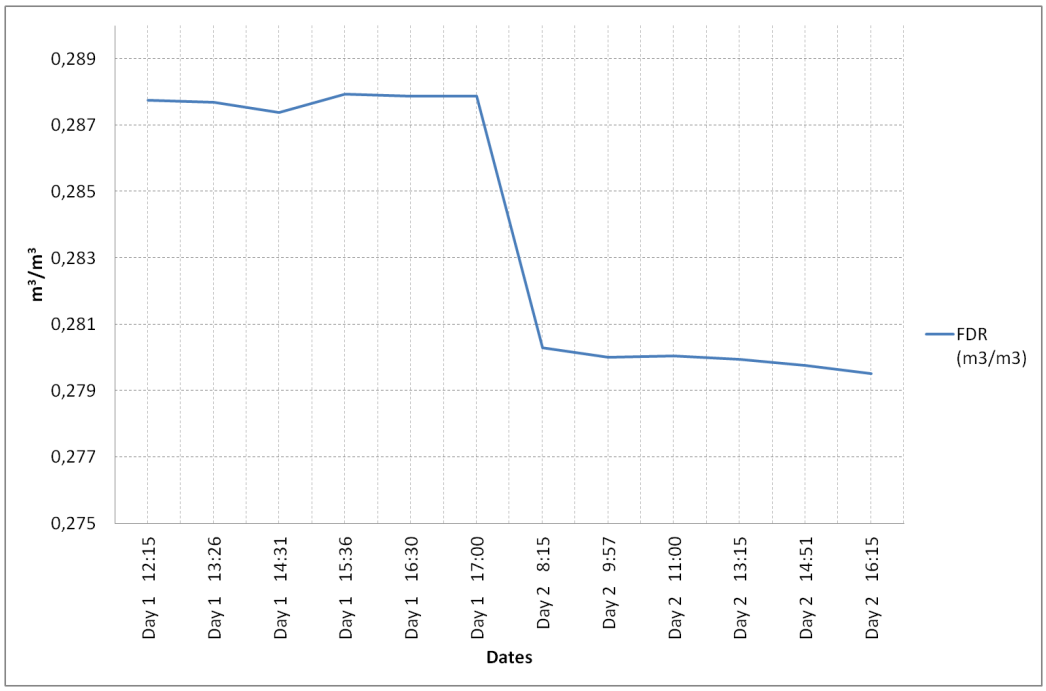

Fig. 13: Output of the FDR sensor inserted in the wet block, evolution registered during two consecutive days.

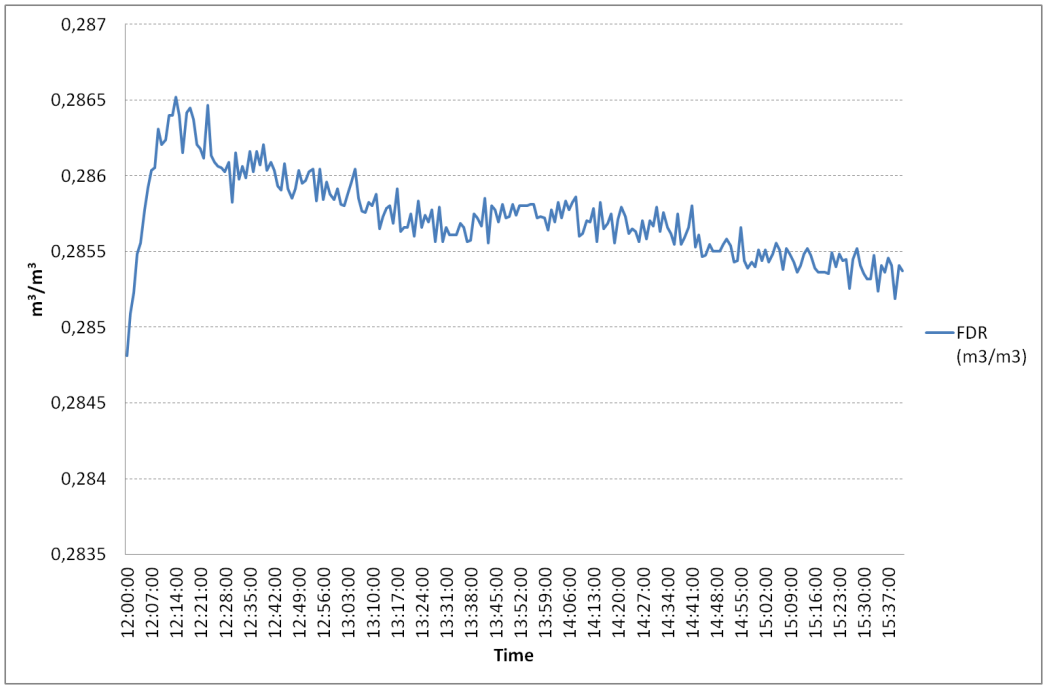

Fig. 14: Output of the FDR sensor inserted in the wet block showing the drift observed along one single day[2].

[2] Note that the two graphs (Fig. 13 and Fig. 14) were taken at different dates.

5.1.3.3 Micro-waves and specialised cameras

Micro-waves

After contacting a few Spanish suppliers of industrial type equipment to measure water content using microwaves in granular material or wood (Consergra S.L. representing TEWS Elektronik devices, and Trotec GmbH & Co KG) only one option was found. A portable measuring device (model 610) from Trotec intended for measuring humidity in construction materials. Technical data of this device is given in Appendix C.

According to the description provided by the manufacturer, this device is based on micro-waves and provides a non-destructive measurement of the moisture/water content contained in a volume up to 30 cm deep from the surface of the building component. However, measuring sensitivity decays with distance from surface, hence the mean value provided will be strongly affected by the material closer to the surface. The reading is relative in the sense that it gives a value between 0 and 200 that is proportional to the moisture but there is no calibration or correlation with a quantitative value.

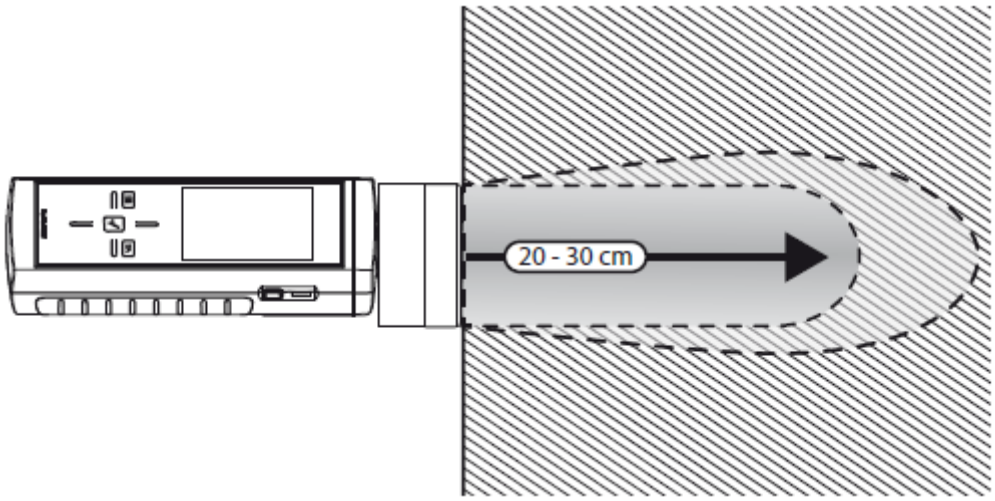

Fig. 15: Measuring with the portable microwaves device.

The device seems easy to use; just place the measuring head on the material surface, press the measuring button and wait for a few seconds to get the reading. It is light and rather cheap, around 625 €. However, it was not possible to get one before the release of the previous report to test if it could discriminate at least between the dry and wet blocks.

Specialised cameras

These techniques were tested at the laboratory using existing blocks from FEBEX and EB experiments dismantling operations. The devices (thermal and hyperspectral cameras) were provided by a local supplier that was contacted for this purpose. Unfortunately, no supplier for a spectral camera was found but as it is basically a hyperspectral one provided with a filter for getting a specific spectral band, the obtained results could be extrapolated.

The hyperspectral system was composed by: Headwall Photonics Hyperspec VNIR A-series (camera) + Hyperspec Starter Kit VNIR (running platform) + Hyperspec III (software) + lens Schneider Kreuznach with focal distance of 8 mm (F1,8). The market price of such system is around 58'000 € including data processing computer.

The thermal camera was: FLIR T650sc (with lens of 25 mm focal distance) and FLIR ResearchIR software. The market price of the camera with the software is around 30.000 € including data processing computer.

Technical data about both systems are provided in Appendix D.

Both dry and hydrated blocks were exposed to these cameras. Below are images of the devices and the investigations carried out (see Fig. 16 and Fig. 17).

On the left of Fig. 16 there is a wet brick taken form the dismantling of the EB experiment. On the right, one spare dry block from the ones used in the construction of the FEBEX experiment.

Fig. 16: EB wet block (left) and FEBEX dry block (right).

The use of the thermal camera is very simple, similar to a standard photographic one, and no special lighting is required. Fig. 17 shows the performance of the thermal camera when the two blocks are exposed. The wet areas are highlighted with brighter colours in the camera. In this scenario, a broken piece form the wet block was situated above the dry block (brighter images on top of the image in the thermal camera).

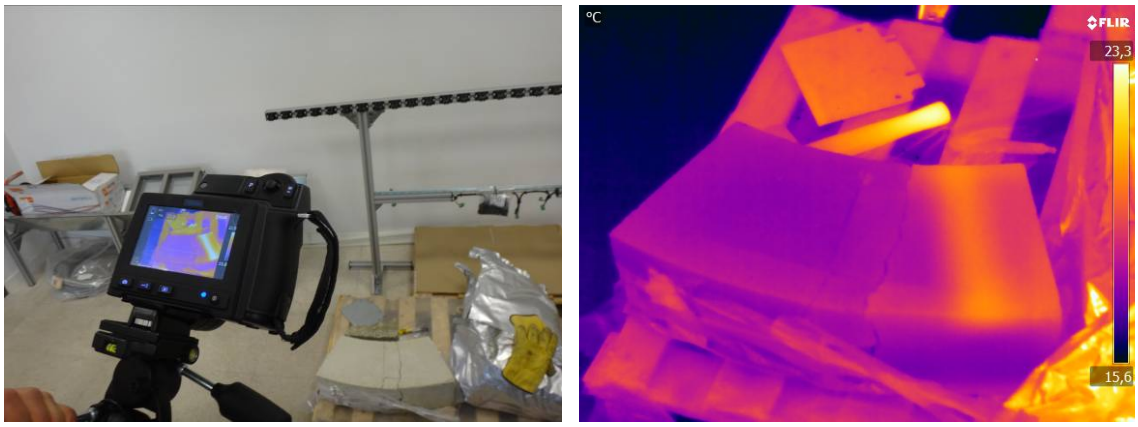

Fig. 17: Performance of the thermal camera (EB block on top of the image and FEBEX one below) on the left and image taken form the camera on the right.

Regarding the hyperspectral camera, it needs a special lighting system and a sweeping movement along the entire bentonite surface. In this case it was easier to move the bentonite blocks leaving the camera fixed. On the images below (see Fig. 18), the layout of the equipment that was necessary in order to carry the tests out is shown. The two images on the top show the equipment itself which consisted of (1) a stepping motor based on a moving platform where the sample is located, (2) a fixed hyperspectral camera focused on the platform and (3) an intense lighting system over the platform.

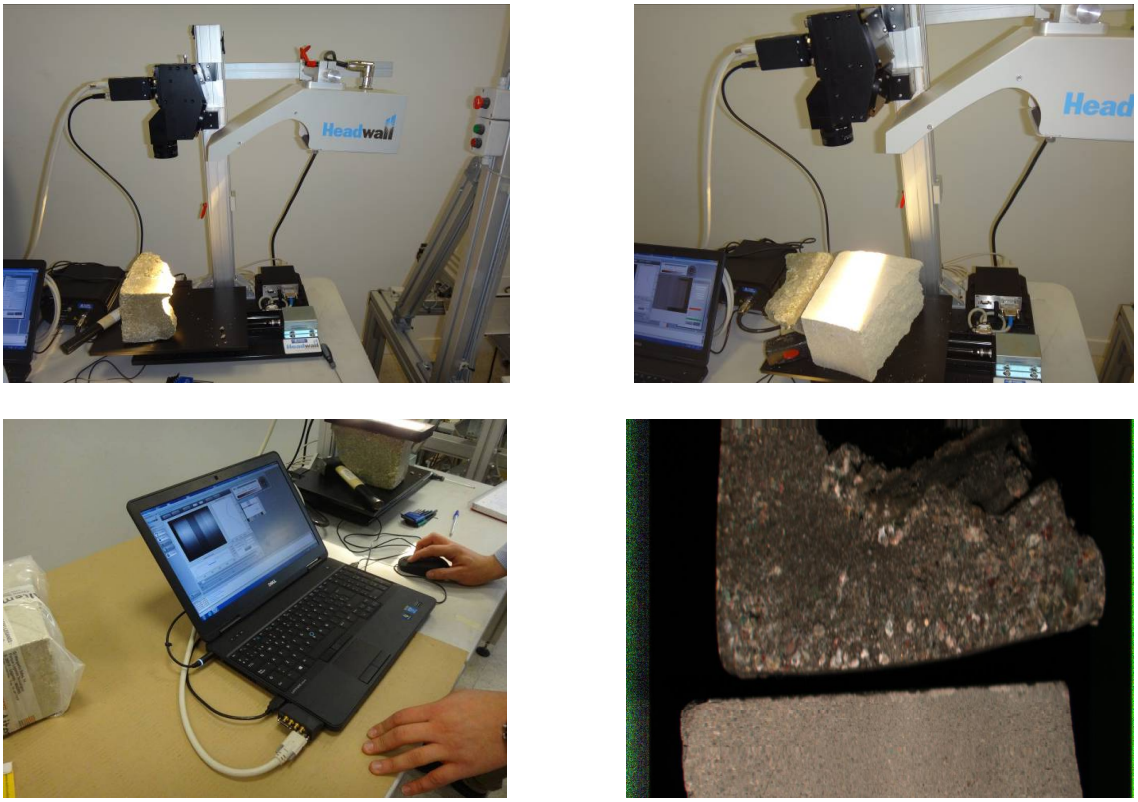

Fig. 18: Performance of the hyper spectral camera. Detail of the image taken with the camera on the bottom right (on top, the wet block and the dry one below).

After the sample was placed on the platform, it was moved, so the camera could cover the surface of the complete sample. The experimental process was longer than expected and the required powerful lighting heated the sample in such a way that the sample was altered rendering the results useless. The image right-below (Fig. 18) shows the result obtained with the camera.

5.1.4 Conclusions from the laboratory activities

The laboratory experimental investigations can be summarised by following conclusions:

- The use of Psychrometers, relative humidity sensors or FDRs will require making a chamber or guideholes at the buffer surface to measure or to insert the measuring pins (FDR). This could alter the bentonite status, requires good contact with the pins, takes time and it could be particularly difficult for dried bentonite in the case of FDR.
- In general, all techniques require a significant amount of time to obtain the measurements, including the preparation of the measurement chamber (from 15 minutes to one hour each). This is an obstacle for the planned dismantling operation: using them will require halting the operation which may change/alter the conditions of the buffer in contact with the atmosphere of the gallery.
- Psychrometers, relative humidity sensors or FDRs are able to provide punctual measurements. Consequently, taking into account the time required to emplace them at the surface and to obtain a measurement, they do not offer significant advantages when compared to the planned sampling and on-site analysis procedure. However, as they provide accurate measurements when stabilised with the buffer material, it would be valuable to evaluate if they could provide accurate information about the desiccation of the buffer front after finishing the planned sampling.
- Portable microwaves should be tested during the dismantling operation in order to ascertain if the in-situ relative measurements provided discriminate between the expected water content differences and can be correlated with the on-site determinations.
- Spectral cameras require good lighting on the bentonite which alters (heat) the surface of the samples too much and as the measurement basically reflects the surface status, the information gathered is not valid.
- Contrary to previous techniques, thermal cameras provide images very quickly and do not require specific lighting. The images apparently match well with different degrees of humidity in bentonite samples. As a consequence, there is a chance they will correlate with the planned on-site analysis, although in the lab there was no thermal effect due to the heating phase so the real performance is unknown.
- Although the tests were carried out using FEBEX blocks (Serrata type bentonite) there are no reasons to expect significantly different results from MX-80 bentonite blocks. However, as the granulometry of the Serrata bentonite is coarser than the MX-80, it might influence the results obtained using cameras and in particular the hyperspectral ones.

5.1.5 On-site investigations

Following the conclusions gathered from laboratory activities, the following activities were performed at GTS during the dismantling operation:

a) Testing of the psychrometer performance to follow the buffer desiccation

b) Testing a handheld microwave measuring device

c) Testing a Thermal camera

d) Testing a hyperspectral camera (done by University of Neuchatel)

The obtained results are described hereafter.

5.1.5.1 Psychrometers

The equipment used for the test was:

- Two-three psychrometers from Wescor Inc (see technical description in Appendix A)
- A datalogger for the psychrometers model Psypro (see technical description in Appendix B)

The tests were carried out at the front of the FEBEX "in-situ" test during the dismantling operation during the following dates: 19th, 20th, 21st, 22nd of May 2015 (Sampling Sections 37 & 38, bentonite layers from 71 to 66) and 12th, 15th, 16th, 17th of June 2015 (Sampling Section 43 and bentonite layers 57 to 53). Fig. 19 shows the recording device and the psychrometers installed at the buffer front.

Fig. 19: Recording of psychrometric measurements at buffer front (psychrometers are within the circles).

Obtained measures for duration of at least one night, keeping the wet block isolated from the atmosphere, are illustrated in next figures (Fig. 20 and Fig. 21).

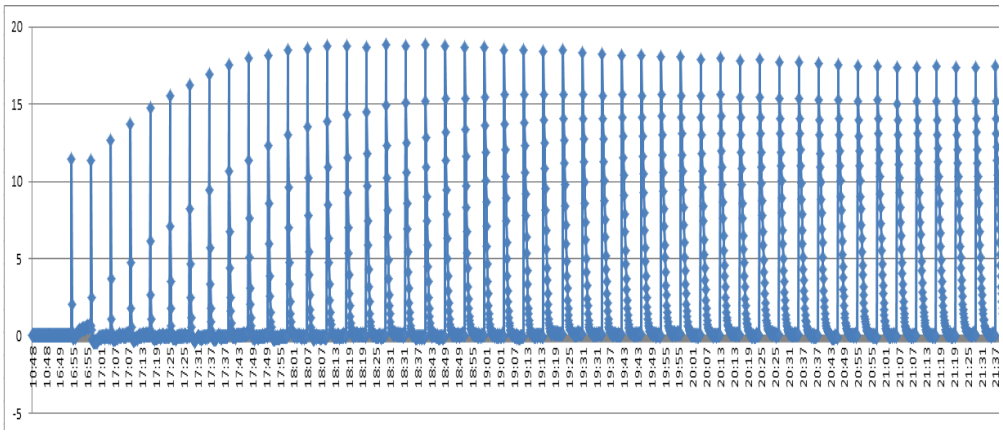

Fig. 20: Evolution of psychrometer response (mV) along the night of 20th of May[3].

[3] Readings were made using the psychrometric method and each peak corresponds with one measurement.

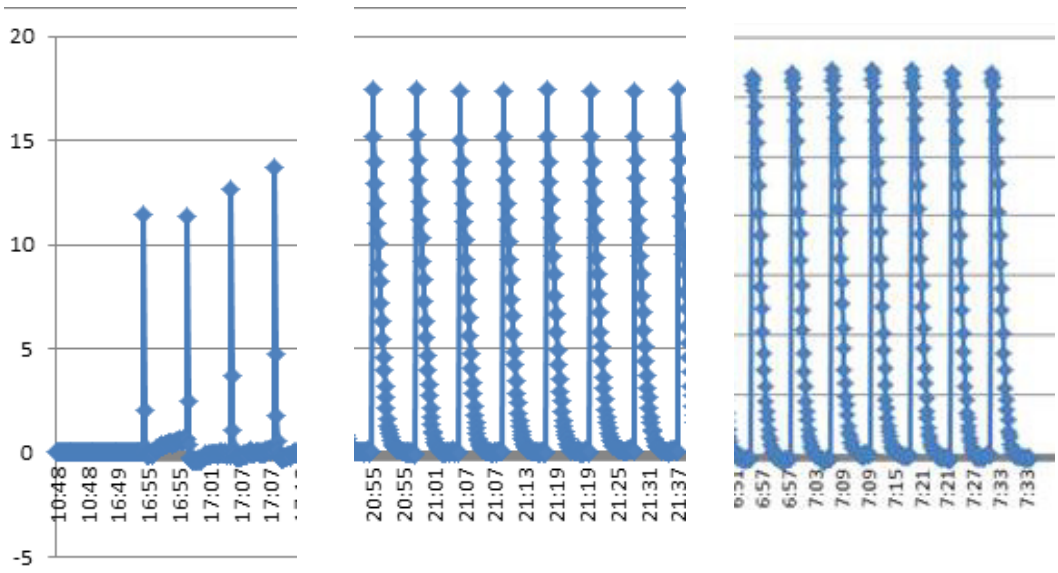

Fig. 21: Detail of the previous figure, comparing the psychrometer response (mV) after 4 and 14 hours.

According to the results (fast signal decay and plateau very close to 0 mV), it can be stated that the degree of saturation was very high (low suction) of 99.5 % or more. Besides, it can be seen that the response curve tends to reach higher values at the beginning and then widens with time (slower signal decay) which indicates the suction is increasing a bit slowly. This could be due to the desiccation of the front, the expansion of the bentonite front or both at the same time.

Finally, the psychrometers are being used by Ciemat for complementing the laboratory determinations that are being carried out with the bentonite samples obtained from the dismantling. Results gathered so far indicate they provide a good measurement of the water content after at least one hour of stabilisation time; when taking into consideration the density of the clay material, the values match well with the retention curve of the Serrata bentonite. However, the accuracy of the method is lower than the laboratory determination (weighing and drying in the oven). Concluding, this method could be a valid option to get a fast and preliminary overview of the water content distribution of the buffer front if the density changes are limited or the density distribution is known.

5.1.5.2 The Handheld microwave method

A portable measuring device from Trotec (model 610), intended for measuring humidity in building material was used. Technical data of this device is given in Appendix C.

The device was used as explained by the manufacturer: just placing the measuring head on the buffer surface, pressing the measuring button and wait for a few seconds to get the reading.

It was applied almost systematically in the sections intended for on-site analysis, (s39, s43, s45, s49, s52, s55, s56, s58 & s61) in order to cross-check the obtained values with the data obtained from the on-site determinations (Water contents and Saturation) in order to find a proper correlation if any. The initial measurement results were less good (s39 and s43) than those taken in the remaining sections, probably due to an initial inexperience with the device. The same is true of s61, but in this case the results may be worse due to the physical conditions of the bentonite front (lack of flatness).

In principle, there is a clear linear correlation between the measurements and the real water content (gravimetric) in the buffer, obtained from on-site and laboratory analysis (Aitemin and Ciemat respectively). The following examples (Fig. 22Fig.) show the results from samples of around 30 cm^3. There is also a linear correlation with saturation but less good. There are no clear differences or tendencies neither between cold or hot sections[4], nor between radiuses in the sections.

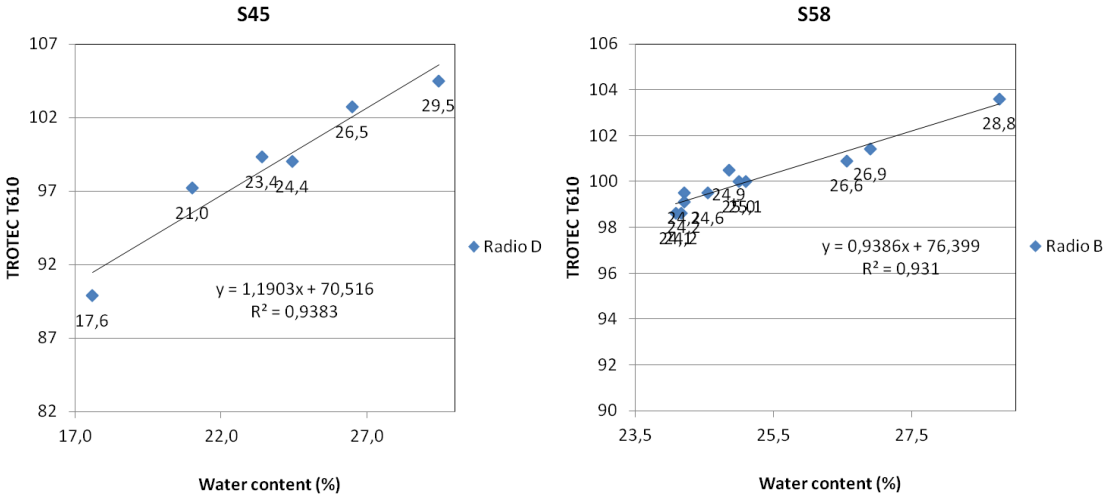

Fig. 22: Performance of the handheld microwaves device. Measurements (vertical axis) obtained from Sampling Sections 45 and 58 (hot and cold layers respectively) are correlated with gravimetric water contents obtained from on-site analysis.

[4] Hot sections are those close to the electrical heater while cold ones are located away from it.

Compiling the best results it is possible to extract a correlation as can be seen in the following graph (Fig. 23).

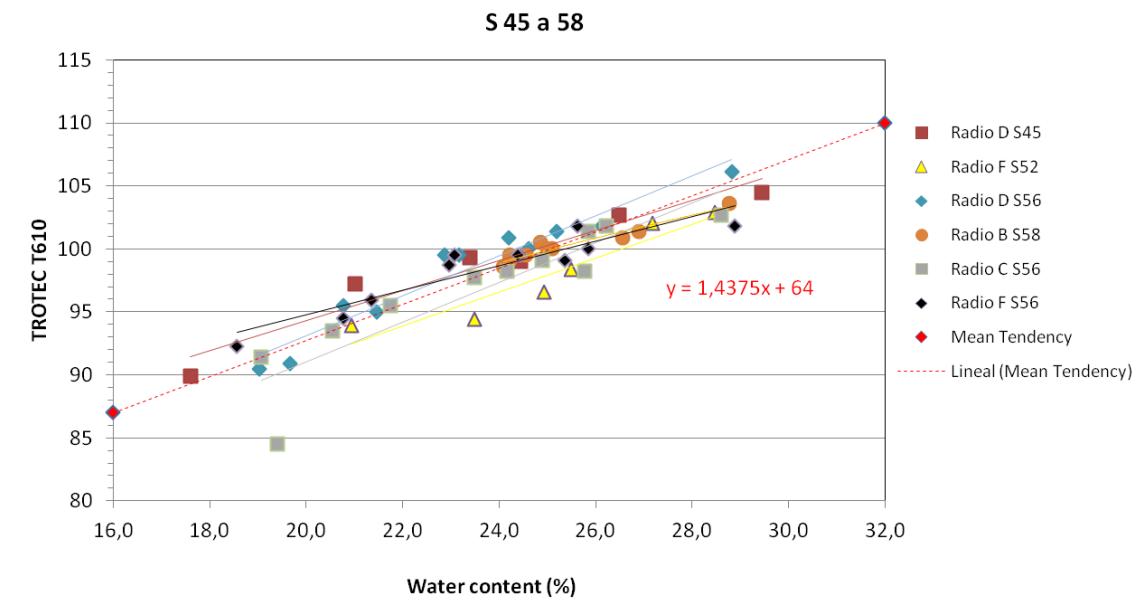

Fig. 23: Performance of the handheld microwaves device. Compilation of best values obtained from Sampling Sections 45 to 58.

According to the results, a potential equation to correlate the handheld measuring device with the real water content could be: WC (%) = (Measure-64)/1,4375. However, there are radiuses in all sections where the data were no so good (worse fitting in the linear equation). Reasons for that performance are unknown.

This device will be used by Ciemat to complement the laboratory determinations that are being carried out with the bentonite samples obtained from the dismantling. Results will help to ascertain if the obtained dispersion in some cases was due to defective warming time or a poor contact with the bentonite surface (this can be better controlled in laboratory conditions).

5.1.5.3 Thermal camera

A thermal camera FLIR E4 (see technical data in Appendix D), with Serial Number 63906965 and lens FOL7 (resolution 320 × 240), was rented from a local provider to carry out the desired on-site measurements. Several images were taken from the buffer front at layers 43, 45 and 49 (Sampling Section 46). Obtained results are given in the following images.

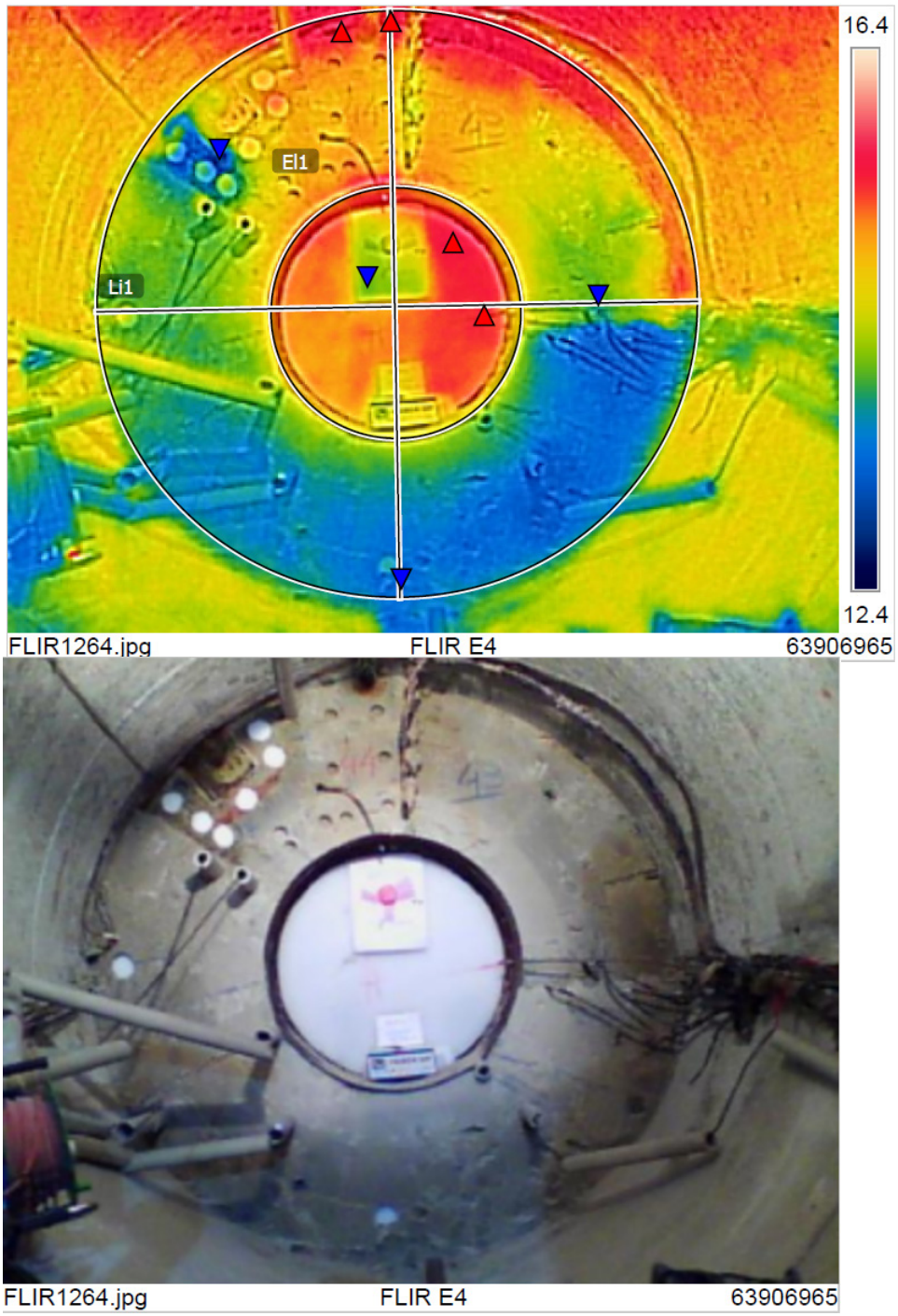

Fig. 24: Comparison of thermal image (colour vs temperature range in ºC at the right vertical axis) with normal photo taken for bentonite layer 43.

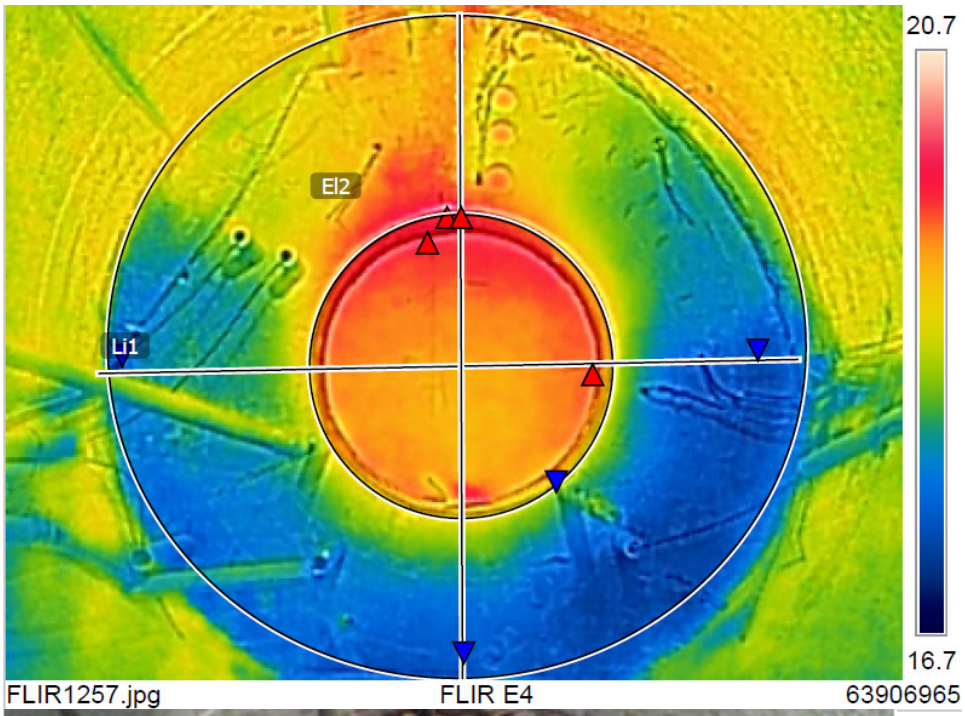

Fig. 25: Comparison of thermal image (colour vs temperature range in ºC at the right vertical axis) with normal photo taken for bentonite layer 45.

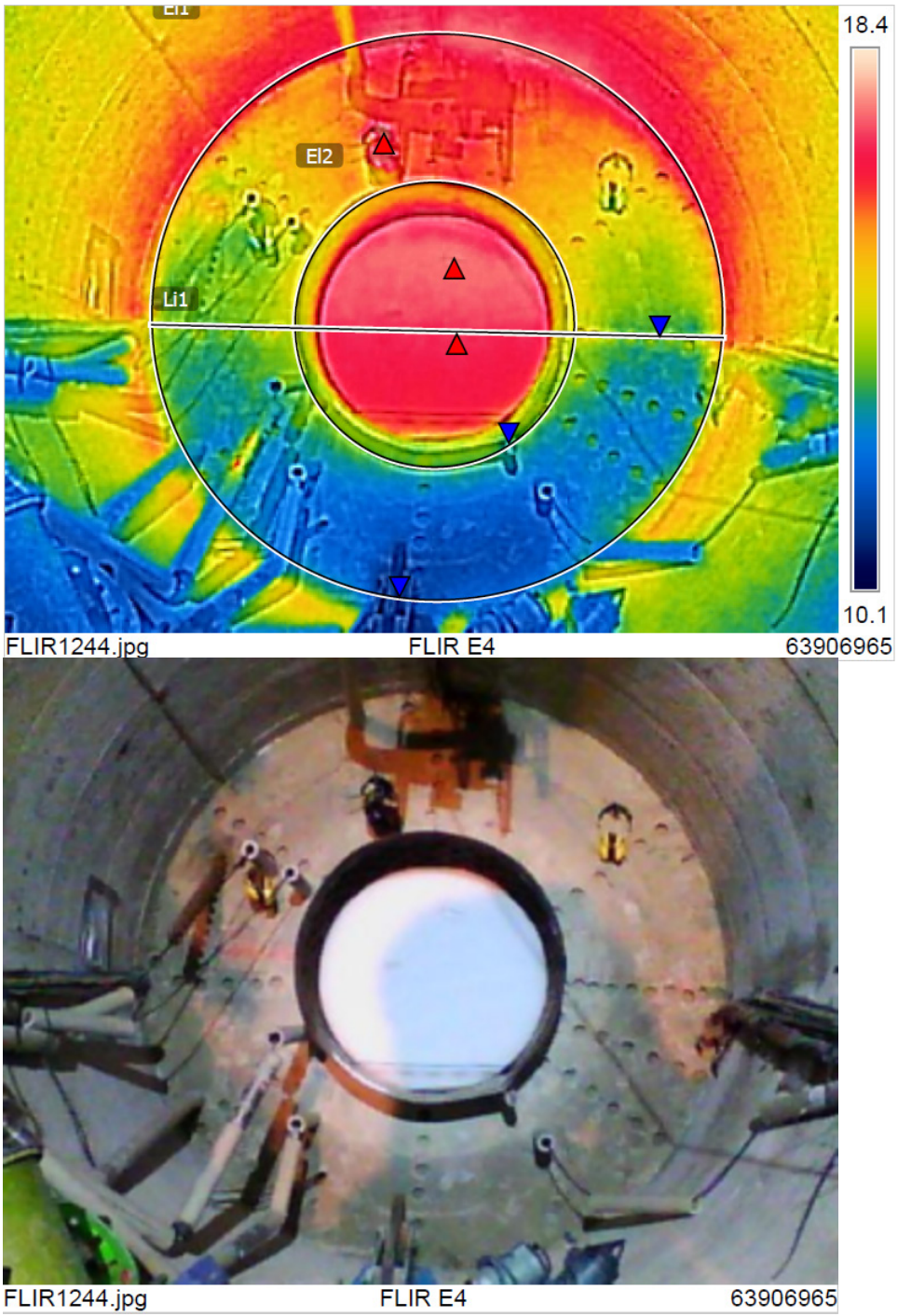

Fig. 26: Comparison of thermal image (colour vs temperature range in ºC at the right vertical axis) with normal photo taken for bentonite layer 49.

The comparison of the thermal gradient distribution matches the visual gradation of colour on the buffer surface, apparently darker/wetter in the lower part. However, when comparing the obtained thermal gradient with the results provided by the on-site analysis from samples taken in Sampling Section 45 (bentonite layer 49, see Fig. 27Fig.) it is evident that there is no good correlation, in particular with the water content distribution. Consequently, this method is not suitable for this type of application (obtaining a fast picture of the water content or degree of saturation of the excavated buffer front).

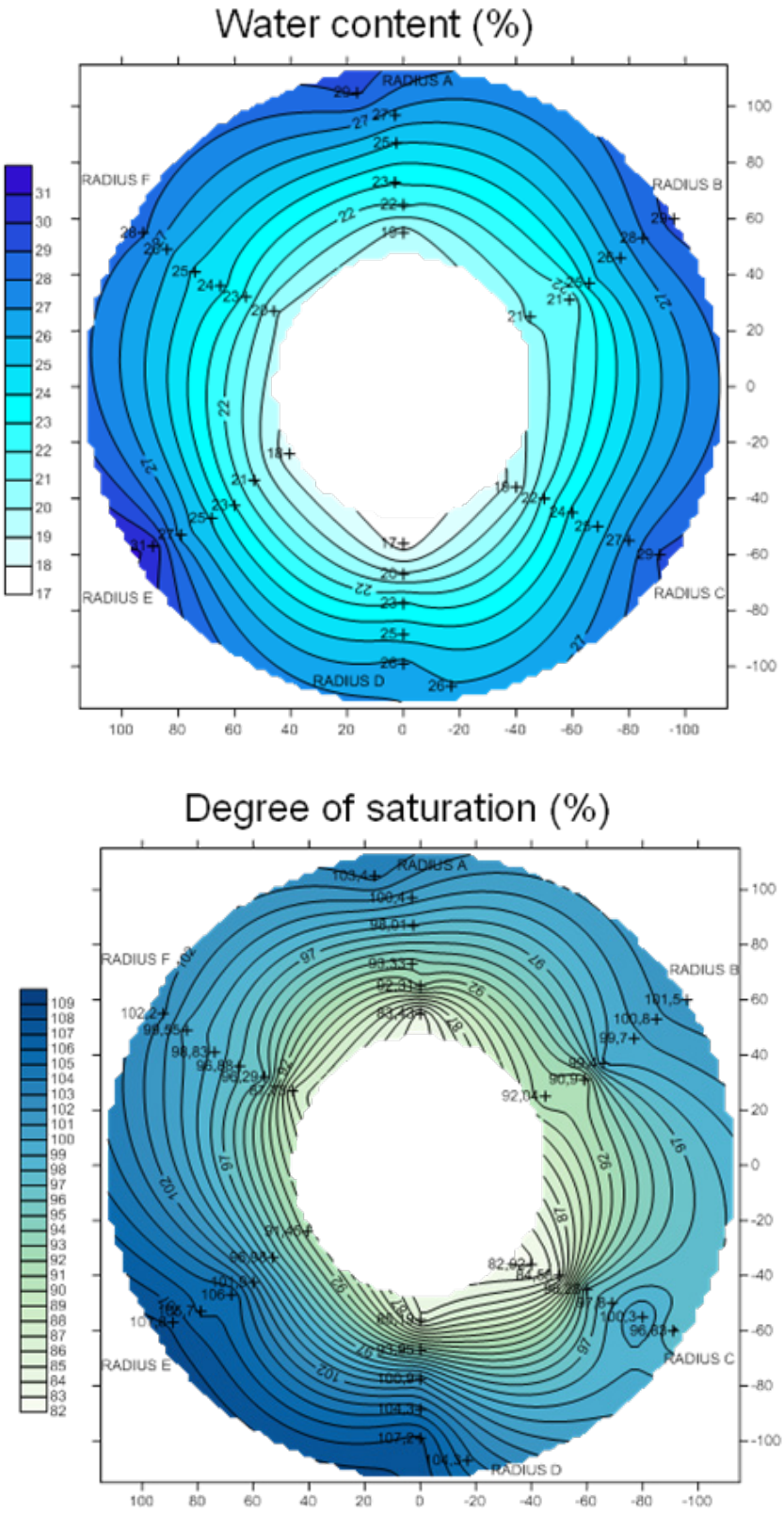

Fig. 27: Degree of saturation (below) and water content (upper) obtained from on-site determinations for bentonite layer 49 (prepared by M.V. Villar, Ciemat).

5.1.5.4 Hyperspectral camera

Despite the earlier conclusions from the laboratory tests (see section 0), it was decided by Nagra to perform additional tests at the site. On the 21st of July during the sampling of section 56 (bentonite layer 22, see Fig. 28) the University of Neuchatel conducted the experiments. The image (Fig. 29) was taken with wave length ranging from 900 to 2'400 nanometers allowing the determination of water content in the section.

Fig. 28: Buffer view before and during the camera recording (layer 22).

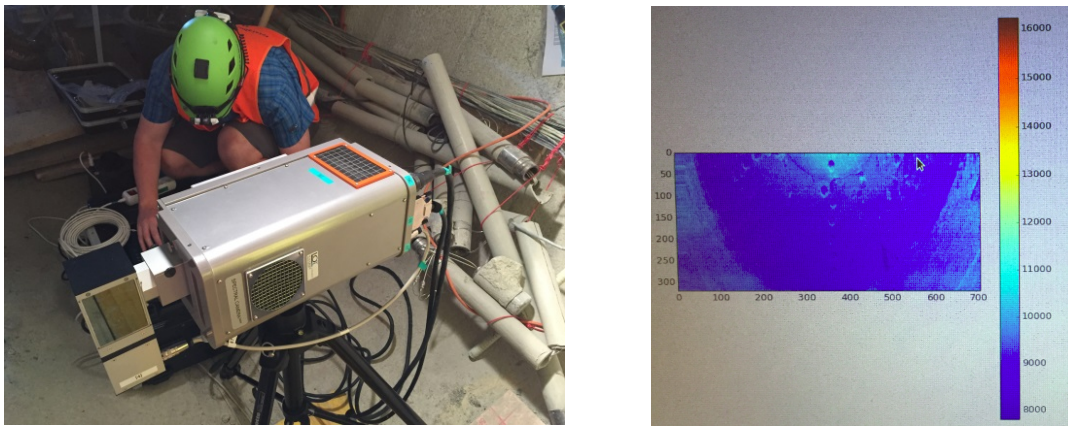

Fig. 29: Impression of the camera at work (left) and output provided (right).

Despite using strong illumination during the buffer face recording, the University of Neuchatel gathered promising results and a patent application is ongoing (Fasnacht et al. 2015).

5.1.6 Conclusions from on-site activities

The following can be concluded from the on-site investigations:

- Psychrometers were able to track the evolution of the buffer front and measurements match with the results provided by the on-site analysis (water contents). However, the measurement precision is not enough to entirely forego on-site water content determinations, unless only an approximate humidity distribution is required. The effect of the dry density cannot be taken into account, and as a consequence it is not possible to obtain a real saturation value from the psychrometer data.
- The microwave method showed that it has potential to provide buffer front water contents but the results were scattered in some cases. Additional work in the laboratory would be required to confirm this device as an option for obtaining a quick water content distribution of the buffer front. Again, the on-site analysis cannot be avoided even if this device is working well because the density distribution is not tracked and therefore neither is the saturation degree.
- Results gathered from the thermal camera do not match with the real water contents so this technique seems inappropriate here.
- Preliminary results obtained from hyperspectral camera seem promising but the real performance is still unknown (at the time of writing this report).

5.2 Testing the steel/bentonite interface sampling

5.2.1 Initial scope

The objective of the proposed testing was to assess the feasibility to obtain undisturbed samples from the steel/bentonite interface containing both materials and keeping their contact surfaces unaltered, which is still an open issue not addressed in these terms during the first dismantling.

Secondly, the objectives of the tests were: on the one hand, to demonstrate the feasibility of the techniques applied in-situ in terms of safety, cost and time consumption; on the other hand, to compare the performance of the techniques and evaluate the samples obtained to assess their validity.

5.2.2 Investigations carried out

The tests were carried out in a metal workshop in Toledo because it was easier and faster to move the metal piece there than to bring all the required equipment to our laboratories[5]. A piece of the dismantled liner from the first dismantling of the FEBEX was transported to the metal workshop Talleres Ferji S.L. located in Miguel Esteban (Toledo-Spain).

The sabre saw was excluded from this trial because after some preliminary tests in our workshop, using a metal band saw, it was clear it would be a very slow process given the hardness of the steel of the liner. However, it could be a very good option if the samples can be transported to a workshop near the GTS, and if there are no time constraints imposed by the

[5] It was initially planned to carry out these tests at the concrete gallery remaining from FEBEX at Toledo, but as the bentonite blocks were very deteriorated due to the atmospheric effects over time, it was concluded they were not representative of the expected conditions at the in-situ test and that working conditions could be very risky due to the potential collapse of the bentonite front and the liner installed inside. The bentonite and the liner were completely dismantled.

bentonite dismantling and the available space (narrow tunnel), because the quality of the cut is excellent and there are few thermal effects on the piece.

Different cutting techniques for separating bulk metallic pieces from the liner are tested. They are listed below from lower to higher cutting speed: radial saw, oxy-fuel and plasma cutting.

It was expected that with increasing cutting speed heat generation and consequently sample alteration would also increase, while the accuracy of the cutting would decrease. However, those powerful but less accurate techniques can be valuable in some cases (for instance when the cut is made from inside the liner) to obtain big samples in a short time, keeping in mind that the outer edges can be discarded so as to obtain an undisturbed sample for analysis.

The different tools are shown in the images below (Fig. 30 to 34).

Fig. 30 shows the performance of the radial saw cutting a piece of the liner. A few minutes are needed to obtain a sample of the liner, and the accuracy of the cut is good enough for the planned sampling purposes[6]. On the other hand, the high amount of sparks generated during the cut would pose safety issues for an operator working in a confined space. It would also increase the risk of a fire in the working place. The device used in this test was an ordinary electric radial saw for cutting metals.

Fig. 30: Performance and quality of the cut of the radial saw.

[6] It means that the desired shape for the simple could be obtained with dimensional deviations below 1 cm.

Fig. 31 shows the equipment needed to cut the liner using an oxy-fuel torch which consisted of a propane gas bottle and an O_2 gas bottle. The performance of this method is shown in Fig. 32. This method requires less time than the radial saw method, and the amount of generated sparks is also less. The accuracy of the cut is also good enough for our purposes (see Note 6). On the other hand, this method would be unsafe due to the toxic gases released during the oxy cut. However, this is not considered a real limiting factor, but it would still be dangerous in a confined working space in particular due to the presence of the gas bottles.

Fig. 31: Oxy-fuel equipment.

Fig. 32: Performance and quality of the cutting with the oxy-fuel torch.

Fig. 33 shows the equipment needed to cut the liner using a plasma torch which consisted of a torch supplied with a proper mouthpiece for the thickness of steel to be cut, and an air compressor. The performance of this method is shown in Fig. 34. The time needed to obtain a sample of the liner was more or less the same as the one spent with the oxy-fuel method, and the amount of generated sparks was the same. The accuracy of the cut was the best compared with the other two methods, although this method would oblige the operator to wear a specific mask and a filter mask while working with it. The device used for this test was a plasma cut equipment model GAR CUT 2500 and the technical information is given in Appendix E.

Fig. 33: Plasma cutting equipment.

Regarding the alteration of the sample, all techniques increased the temperature of the metal. No temperature measurements were taken but as an approximate criterion we measured the time needed to let the sample cool down and be able to touch it with bare hands. The longer the time needed (more than 15 minutes in some cases) the higher the risk of altering the bentonite located nearby, as the heat reaches a larger area (up to more than 10 cm away from the cut). The necessary time needed to let the piece cool down will delay the dismantling operation too.

Using the criteria described above, the plasma device has the lowest accumulated heat. In any case, if the alteration of the sample is an issue there are two options, either to cut an area larger than the surface of interest or to transport the piece to a workshop to cut it with a metal band saw.

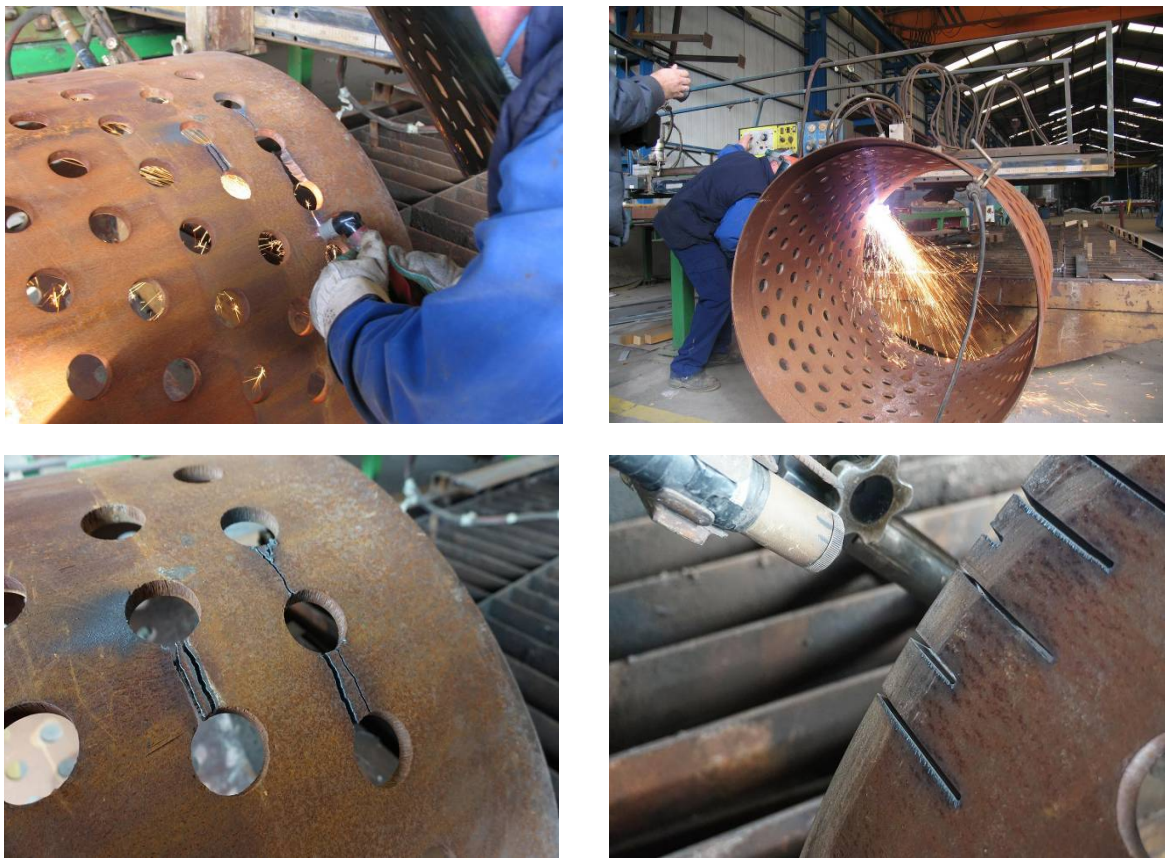

Fig. 34: Performance and quality of the cutting with the plasma torch.

5.2.3 Obtained results

The main conclusions so far are:

- The sabre saw is less powerful and therefore the cutting is very slow, making it not appropriate for use on-site because it could delay the dismantling too much.
- The radial saw is fast and precise enough but the high production of sparks makes it difficult and unsafe for the operator, in particular when working in a confined space (for instance inside the liner). However, this tool could be suitable for fast and simple cuttings such as bolts or little metal pieces.
- The Oxy-fuel method requires compressed gas bottles close to the cutting place implying an undesired risk when working inside the FEBEX drift; this technique was discarded due to safety reasons.
- Finally, the plasma cutting is the best option, fast and precise enough, if a large metal cutting is required in the drift.
- However, taking into account that the goal is to take samples of the metal/bentonite contact and that all techniques induce a lot of heat to the metal, except the sabre saw, they will most likely alter the conditions of the samples, unless the dimensions of the cut metal piece are quite large compared to the contact area of interest.

- Therefore, the suggestion is to avoid metal cutting inside the drift and try to preserve the bentonite sample in contact with the metal and then extract the metal piece to be cut in a workshop using a slow but low heat-generating cutting method. Nevertheless, if large metal cutting needs to be done, the use of portable plasma device will be the best option.

5.2.4 On-site application and obtained results

Several attempts were made in-situ to get unaltered samples of the metal/bentonite and bentonite/rock contact; the area of interest was preserved with a metallic or wooden case filled with epoxy resin. Then, the sample was drilled and cored but there was always a separation between both materials.

When needed, large metal cuts at the site were done using a plasma device model PLASMA CUT-700 (see characteristics in Appendix E). The cuttings were made both inside the drift and at the entry cavern of the FEBEX drift. No major difficulties were encountered and a margin of around 10 cm was left between the area to be preserved and the cut profile to minimise thermal effects. One example of cutting is given in Fig. 35.

Fig. 35: Cut made with the plasma device.

Consequently, this solution was appropriate providing reasonably good results in a short time with a minimal risk to the operator (using the required protections for the hands, body and mask).

5.3 Testing of optimised excavation techniques

5.3.1 Rationale

During the partial dismantling (Bárcena et al. 2003), carried out in 2002 after five years of natural hydration, it was observed that the outer bentonite ring in contact with the rock was saturated or close to saturation, depending on the zone. Removing these external blocks by breaking them with a hand percussion drill machine was a hard and time-consuming work, as they were plasticised. On the contrary, the central blocks, being drier, could be broken much more easily. Therefore, for each bentonite slice the central blocks were removed first (to obtain an opening or "window" to release the stresses) and then only one or two blocks in the outer ring had to be broken, so that the rest were released and could be extracted intact.

During the planned final dismantling, to be carried out after an additional thirteen years of saturation, the bentonite was expected to be much more humid, even in the central blocks, which could result in much harder demolition work when using the same technique.

5.3.2 Initial scope

Therefore, other excavation techniques should be tested as an alternative, focussing on the most humid parts. Tools considered were the following: sabre saw, chain saw, big diameter auger drilling, modified multipurpose hole saw and hollow stem auger. The test should serve to evaluate these techniques and to obtain unaltered bentonite samples (except the auger drilling).

5.3.3 Laboratory investigations

Again, this exercise was done in the laboratory using existing blocks from the installation of FEBEX "in-situ" test and the dismantling of the EB experiment (see Section 2.2). Different types of drilling crowns and percussion pikes or lances were tested using electrically and hydraulically operated drilling machines (light ones that could be handled by hand without additional support).

Two types of drilling crowns were tested: widia and diamond segments and each type was tested by changing the amount of segments from 2 to 4.

The drilling components used were (additional technical information is given in Appendix F):

- LP 18-30 E: Electric power pack, 30 lpm (8 gpm) from Atlas Copco
- LCD 500: Hydraulic core drill from Atlas Copco
- LH 11: Pick hammer from Atlas Copco
- Electric drilling motor DK-17 EL

Fig. 36 shows the auger drill bit used for the test (22 and 24 mm in outer diameter) as well as the result. The auger was used on wet bentonite with no problems in terms of penetration of the bentonite to create a hole, but this method does not break the bentonite and the dismantling would take very long. Moreover, the sample obtained would be debris, which is not suitable at all for the analyses scheduled in the different laboratories.

Fig. 36: Auger drill and debris resulted from the drilling of wet bentonite with the auger drill.

Fig. 37 shows the hydraulically operated percussion pike (see technical data in Appendix F) and how it would behave for dismantling the bentonite blocks. The hand tool was light enough to be operated by a technician. The blocks used with this method were wet blocks[7] taken from the dismantling of the EB experiment. The speed and accuracy of this method were very high but the fact that the blocks were not confined should be taken into account (it will be more difficult when confined). Nevertheless, lighter devices were used for the EB dismantling with good enough results so the impression is that more powerful tools will work much better but keeping in mind that a good balance between tool power and weight is required (around 5-6 kg is a suitable value for the machine weight). Another limitation is the accuracy of the excavation; the use of a more powerful and heavier machine will represent a higher risk for keeping sensors and cables intact. This machine is not used to obtain samples for analysis.

On the top left side of the Fig. 38 a crown with 4 diamond segments is shown and on the right, the hydraulically operated drill used to test the crown. The tool itself was light enough to be used by an operator, but once the crown was set, downward works needed too much effort from the technician. Regarding the performance, the time spent on every core was about 5 minutes and the sample taken was overheated (showing clear signs of desiccation and cracking), perhaps a lower speed would diminish the thermal effects but this method was discarded as a sampling method because other alternatives showed better results.

[7] There was a previous good experience with the performance of this device coming from the first partial dismantling, where the inner blocks were quite dry.

Fig. 37: Hydraulically operated percussion pike (top left) and performance on a wet brick (top right). Below, images of the devices used for the dismantling of the EB experiment.

The sample alteration effects were expected to be worse in confined conditions. Four different crowns were tested:

- 4 segments widia crown
- 2 segments widia crown
- 4 segments diamond crown
- 2 segments diamond crown

The drilling crown behaving best was the 2 diamond segmented crown; but even using this crown, the sample obtained was altered too much.

The multipurpose hole saw (Fig. 39), when tested, gave much better results, showing almost no alteration of the sample under unconfined conditions.

Fig. 38: 4 segment drilling crown (top left), hydraulically operated drill (top right) and performance on a wet brick (below)[8].

Fig. 39: Multipurpose hole saw.

[8] The tests were focused on wet blocks because the buffer is expected to be highly saturated after 18 years of maturation.

5.3.4 Obtained results

The main conclusions so far are:

- The auger type drilling bits worked fine (fast excavation and no significant heat release) but the bentonite cannot be obtained intact, only shavings or debris can be gathered and these are not appropriate for the planned laboratory analysis. The available hollow auger type drilling tools (see Appendix G) were too heavy to use with a manual drilling machine, and were not tested.
- Standard drilling crowns alter the bentonite too much due to the generated heat at the cutting surface (bentonite cooking), no matter the type or number of segments used. This will make it necessary to later discard the bentonite area close to the drilling surface and therefore the samples should be bigger in diameter, making the process more difficult. However, the so-called multipurpose hole saw (a type of drilling crown) gave the best results thanks to the lateral openings, which facilitate the material extraction and cooling.
- Pikes or lances are very effective to remove the bentonite using a hand operated electrical or hydraulic hammer. Although not specifically tested under confined conditions there are valuable and positive experiences from previous operations in the EB experiment. This is the solution selected for the bentonite dismantling operation.
- In principle, both the hydraulic operated drilling machine and hammer are more powerful and easier to manage than the electrical ones but they would require a hydraulic unit so these will be more expensive.
- If drilling crowns need to be used to get bentonite samples they will be the multipurpose hole saw type but enlarged (standard one are just 50 mm in length), see next section.

5.3.5 On-site application and obtained results

For the bentonite excavation two types of electrical operated hammers provided with pikes were used: HITACHI H41MB and BOSCH GSH 5 CE (see technical data in Appendix F). They provided good results showing an adequate balance between their weight and the excavation power. The pikes damaged cables and sensors in some cases, although this was mainly due to the lack of information about their exact position rather than an insufficient accuracy.

Regarding the use of hollow crowns, the initial design was improved by adding an outer cord or edge at the outer surface (see Fig. 40) facilitating the evacuation of debris during the cutting. Such a solution worked much better, in particular for deeper samples.

Fig. 40: Plain hollow crown (left) and the same one provided with the edges (right).

5.4 Design of a sampling device to get unaltered samples of bentonite

This section presents the best solutions to get unaltered bentonite samples.

5.4.1 Rationale

As observed during the first FEBEX dismantling in 2002 (Bárcena et al. 2003), not only the buffer excavation but the extraction of unaltered samples from the humid bentonite is a challenging task. The same was experienced during the EB dismantling while sampling for microbial analysis: in addition to the difficulties encountered both while hammering the sampling tubes into the bentonite (driven thin tube samplers) and pulling them out afterwards, analysis results from Canada and Switzerland showed clear differences: ranging from 0.4 % to 11 % in water content, with 4 % on average for water activity and ranging from 17 % to 36 % in dry density (Stroes-Gascoyne 2013).

5.4.2 Initial scope

Therefore, the goal in this case is to design an easy and fast sampling procedure that will obtain unaltered bentonite samples.

5.4.3 Investigations carried out

The different tools and methods tested are:

- Short (2 – 3 cm in length) cylindrical tubes pushed by hand with a hammer
- Long tubes pushed by a piston
- Long tubes pushed by a piston with a previous over-coring by a multipurpose hole saw crown

These tools were tested with confined wet blocks from the dismantling of the EB experiment as well as with dry ones from FEBEX.

Images of the performance of the different tools and methods are shown below (Fig. 41 – 43).

Fig. 41 shows the tubes used to obtain samples of bentonite to be analysed on site. This is a rather common method and the amount of bentonite that can be sampled with these tubes is adequate for the purpose. The tubes have a diameter of 6 cm, are 2.5 cm long and 1 mm thick. The samples were taken by pushing them with a manual hammer, into the dry bentonite as well as into the wet one. In both cases the method was simple and fast, and the sample was taken with no alterations.

The same pushing-in method was also tested to obtain longer samples (which are required for some partners as Ciemat, COMIC or MIND) and therefore using longer tubes, from 8 to 30 cm in length. In this case, the test was carried out with the help of a mechanical press to push the tube into a confined block. When dry blocks were used, the method worked with no problem, but with wet confined blocks, the tube was deformed (see Fig. 42Fig.) due to the pressure applied by the confined wet block.

Fig. 41: Short tubes (left) and sample of a dry block taken with these tubes by pushing with a hammer (right).

Fig. 42: Confined block (top left), press to push the long tubes in (top right) and result of the long tubes after being pushed into wet confined blocks.

Drilling a guide slot was required prior to sampling to reduce the push-in resistance and not damage the tube. The guide slot was made using an enlarged multipurpose hole saw crown so that when the tube was pushed in, there was almost no resistance and the sample could be taken, see Fig. 43. As the sample could be altered afterwards at the time of extraction from the tube, it is suggested to leave it inside and pack the tube with the bentonite to be sent to the laboratories.

Fig. 43: Extended multipurpose hole saw crown (top left), result of the over coring or guide slot done with the extended hole saw (top right), pushing the tube after the over-coring (below left) and sample inside the pushing tube after the over coring (below right).

5.4.4 Obtained results

The main conclusions so far are:

- Short tubes (2 – 3 cm in length) of 50 – 60 mm in diameter are easy to introduce in the dry or wet bentonite, using a piston or just a hammer provided with the right tool to well distribute the pressure in the tube walls.
- Larger tubes cannot be driven into the bentonite even using much force, due to the confinement and abrasion of the bentonite. The tubes were severely damaged.
- However, making a guide slot first with a multipurpose hole saw made the sampling tube installation possible because the outer material is displaced to the opening. The only problem is that the over-drill cannot be done by hand but has to be done using a support to avoid breaking the bentonite prematurely.
- The push-in tube method making a guide slot is the method suggested to get unaltered bentonite samples. However, a tool to handle the drilling tool and the pushing piston is required.

5.4.5 Device design

To facilitate the operation of pre-drilling the guide slot and then pushing the sampling tube in, a support for both the drilling machine and the pushing cylinder was conceived. However, such a device should be designed by taking into account the spatial constraints of the FEBEX drift and the presence of the liner, in particular if the heater cannot be extracted.

In principle the plan was that the liner pieces would be removed one by one, therefore, the proposed device could be located at some distance from the sampling front without interfering with the liner. Consequently, it consists on one metal ring attached to the rock walls, acting as a rail track, and a central beam, that rotates inside the ring. The central beam can be fixed at any desired angular position holding both the drilling machine and the pushing tube piston, which can be displaced and fixed at the desired position too along the beam (see Fig. 44).

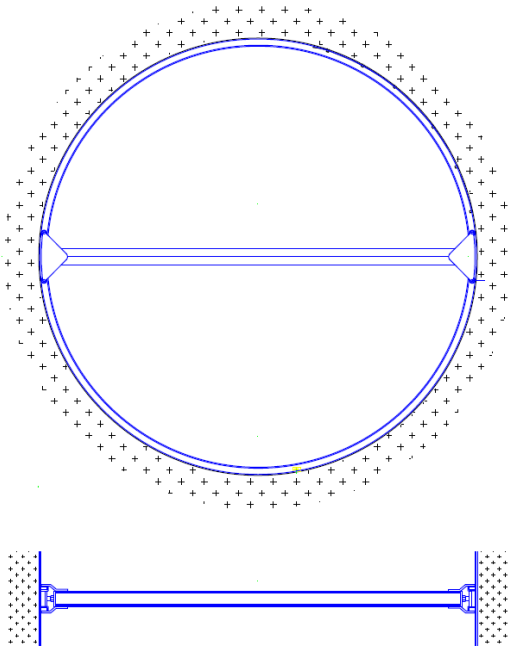

Fig. 44: Basic layout of the device proposed for supplementing the drilling and tube pushing.

If in the end, the heater cannot be extracted, the liner will be always "in the middle" so the three-piece device will require an additional arc-shaped footing to be attached to the liner in the centre. Thus, the central bar rotates in this case around the liner running on the two rings. There is an additional support to be installed within the liner just in the case this second design is applied for the standard case too (see Fig. 45).

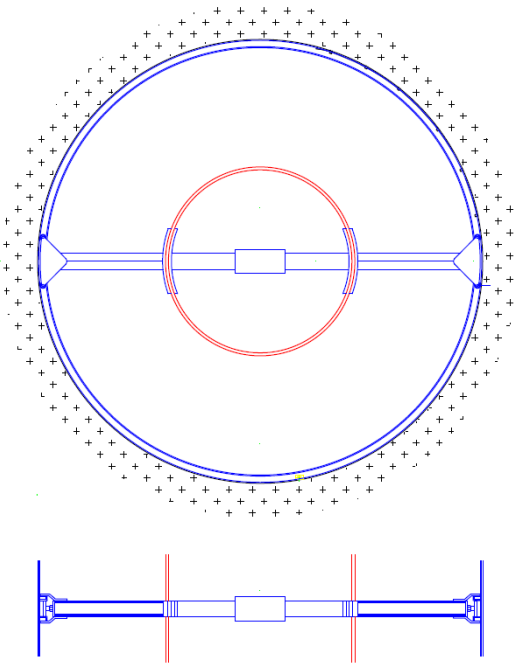

Fig. 45: Alternative layout of the device proposed for helping the drilling and tube pushing if the heater/liner cannot be extracted.

The previous estimation for the price of this device was around 4 k€.

5.4.6 Support built for the sampling

It was finally decided by Aitemin to proceed with the construction of the support in order to be able to take unaltered samples of bentonite. Both options were taken into account (without or with the liner on place) but at the end only the solution without the ring for the liner was used for practical reasons. Furthermore, the external ring to be attached to the rock walls was removed to simplify the device (see Fig. 46).

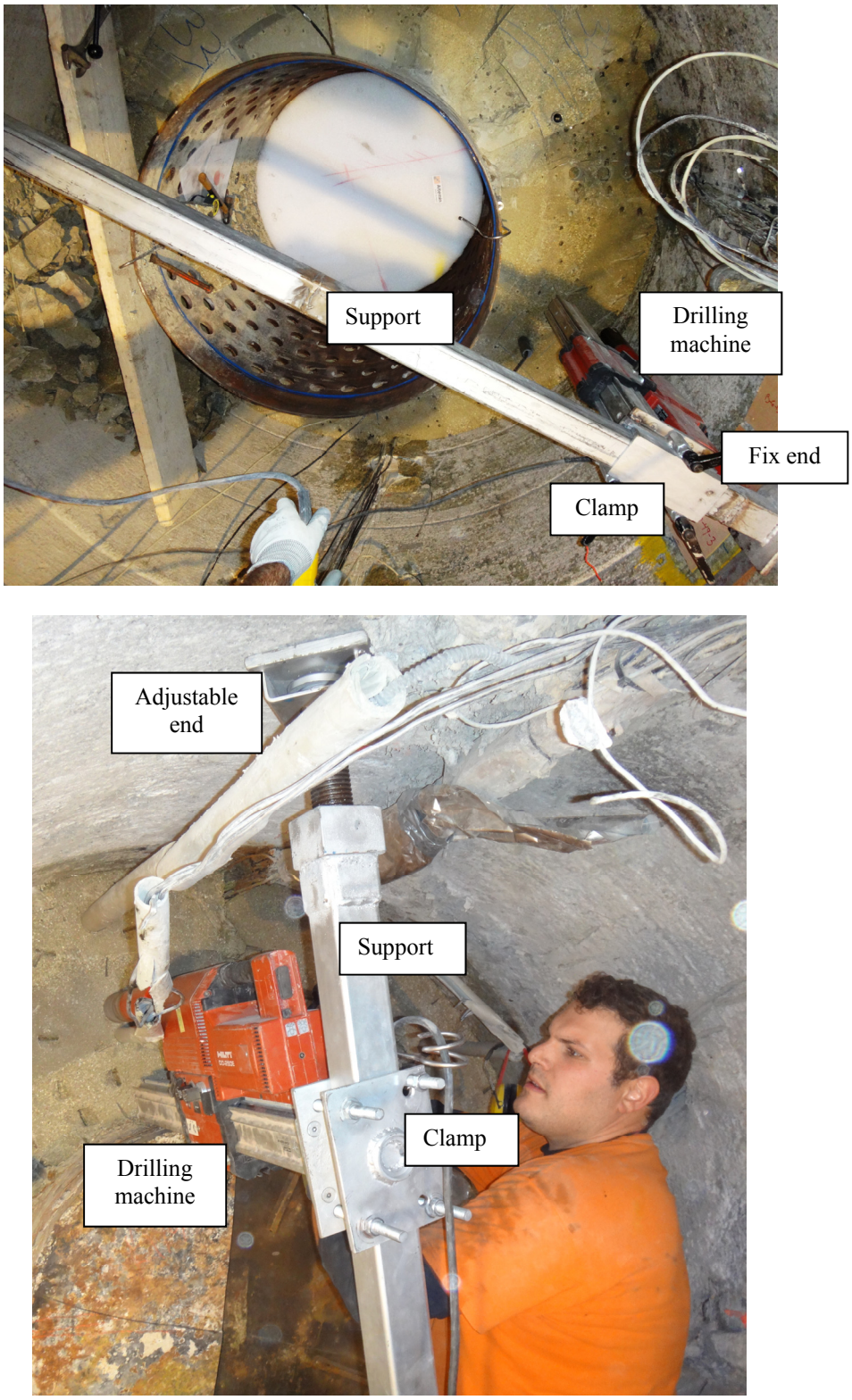

Fig. 46: Support built for the drilling machine.

5.4.7 On-site application and obtained results

The first support for the drilling machine, made of steel, needed to be modified after a few days because the clamp to attach the drilling machine was not easy to handle (no accurate positioning and slow tightening process). Then it worked as expected facilitating the positioning of the drilling machine without the need to make drillings in the rock walls, however, the weight of the device made it impossible to position it by one single operator. A similar development but made of aluminium, which is more expensive, could solve this inconvenience.

6 Final conclusions and recommendations

The main conclusions from all the investigations described in this report are:

1. There are techniques that could complement the on-site analysis to get a fast overview of the water content distribution of the bentonite buffer (less accurate than on-site analysis) such as psychrometers or RH sensors (depending on the degree of saturation) and probably the handheld microwaves unit or the hyperspectral camera. The use of psychrometers or RH sensors is also recommended to follow the evolution of the buffer during the periods of no activity (nights or weekends).
2. A portable plasma cutting device is an adequate tool to take metal samples inside the drift where necessary, providing a reasonable balance between the induced heat, ease of use, sampling speed and risks to the operator.
3. It was not possible to collect unaltered metal/bentonite or bentonite/rock contact samples, even when previously preserved with guide slots followed by over-coring. The contact was always broken during the drilling.
4. Enlarged multipurpose hole saw type drilling crowns worked fine but after modification with an external edge to facilitate the evacuation of debris (see Section 5.3.5)
5. Obtaining unaltered samples using the push-in technique worked properly but only after doing an over-core to release the confining stress. Then, depending on the sample diameter and length, it could be obtained by hand (with a hammer) or using a simple tool for emplacing the drilling machine, which was built for that purpose, to press the tube with its jack.
6. Hand-operated electrical or hydraulic hammers provided with pikes or lances worked well to remove the bentonite buffer when finding a correct balance between weight and power.

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Appendix A

Sensors technical specifications

Water content sensor-capacitive type

Under vapour equilibrium conditions, the water potential of a porous material is directly related to the vapour pressure of the air surrounding the porous medium, meaning that material water potential can be determined by measuring the relative humidity (RH) of a chamber inside a porous cup equilibrated with the surrounding solution.

The water content of the bentonite in the low range (0 – 95 % RH or 620 – 6.9 MPa of suction) can be measured with a capacitive type relative humidity sensor. Custom made sensors based on the commercial Sensirion SHT75 were used. They measure both relative humidity and temperature. The electronic circuit of the sensing element is located in a stainless steel body and protected from humidity by means of epoxy resin. The sensing element is mechanically protected with a steel filter. The sensor is very sturdy due to this special manufacturing. The signal is digital and the cable length is up to 100 m.

Fig. 47: SHT75 V3 relative humidity sensor (tubing protecting the cable not shown).

Main characteristics of SHT75 V3 relative humidity sensors are provided in Tab. 1.

Tab. 1: Characteristics of relative humidity sensors.

Model	Aitemin SHT75 V3
Measurement principle	Capacitive
Relative humidity range	0 % to 100 % R.H. (not condensing)
Temperature range	- 40 ºC to 124 ºC
Output	Digital 12 bit/14 bit
Resolution	0.03 % R.H. /0.01 ºC
Accuracy	± 1,8 % RH between 10 to 90 %/ ±0,3ºC
Dimensions	Diameter: 12 mm; Length: 87 mm
Head casing material	Stainless steel 316L with steel filter
Cable	RT47. Teflon jacketed. Screen threaded cable
Nº of wires	4 × 0.3 mm^2, Teflon insulated
Diameter of cable	3 mm
Cable protection (optional)	SS316L tubing ¼" OD

Water content sensor-psychrometric type

The water content of the bentonite in the high range (95-99.96 % RH or 6.9 MPa to 50 kPa of suction) can be measured by thermocouple psychrometers (Fig. 48Fig.)**.** In thermocouple psychrometry, the temperature depression of the sensing (wet) junction that is measured relative to the reference (dry) junction varies as a function of the relative humidity of air surrounding the sensing junction. A thermocouple is a double junction of two dissimilar metals. When the two junctions are subject to different temperatures, they generate a voltage difference (Seebeck effect). One junction of the thermocouple is suspended in a thin-walled porous ceramic or stainless screen cup in contact with the material, while another is embedded in an insulated plug to measure the ambient temperature at the same location.

Fig. 48: Thermocouple psychrometer.

Psychrometers have been designed for the measurement of equilibrium relative humidity, from which water potential can be determined. This measurement can be done by two different methods, the psychrometric (wet bulb) and the hygrometric (dew point) methods. The main characteristics are listed in Tab. 2.

Tab. 2: Characteristics of psychrometers.

Model	Wescor type PST-55
Temperature range	- 200/350 °C
Humidity range	95 % RH to 99.96 % RH
Suction range	50 to 6'900 kPa
Output signal	Two analogue outputs (µV). 0.47 µV/bar
Probe material	Stainless steel 316L with steel filter
Cable connection	Welded and epoxy sealed
Nº of wires	1 cable with 3 conductors, PVC insulation
Diameter of cable	3.8 mm
Dimensions	Diameter: 12 mm; Length: 87 mm
Cable protection (optional)	SS316L tubing ¼" OD

Water content-FDR type

The FDR type sensor (Frequency domain reflectometry) measures the volumetric water content (VWC).

Fig. 49: Thetaprobe ML2x.

Tab. 3: Characteristics of FDR sensor.

Model	Thetaprobe (Delta-T) ML2x
Range	All VWC
Accuracy	Better than 0.05 VWC (Delta –T)
Temperature range	0 °C to + 70 °C
Power	5 B B – 15 V DC, 19 – 23 mA (Delta-T)
Output	0 – 1 V DC (Thetaprobe)
Sensor dimensions	172 × 40 mm l × Ø (Thetaprobe)
Cable connection	6 pin IP68 M12 connector (15 mm diameter)
Case material*	PVC
Diameter of cable	3 mm
Protection	IP68 M12 connector (15 mm diameter)

The output signal of the sensor depends of the type of soil or material where the measure is taken. An example of ad-hoc calibration is given in Fig. 50Fig., made for the MPT project. This figure illustrates the loss of accuracy when air is present between the bentonite and the measuring rods (red diamonds).

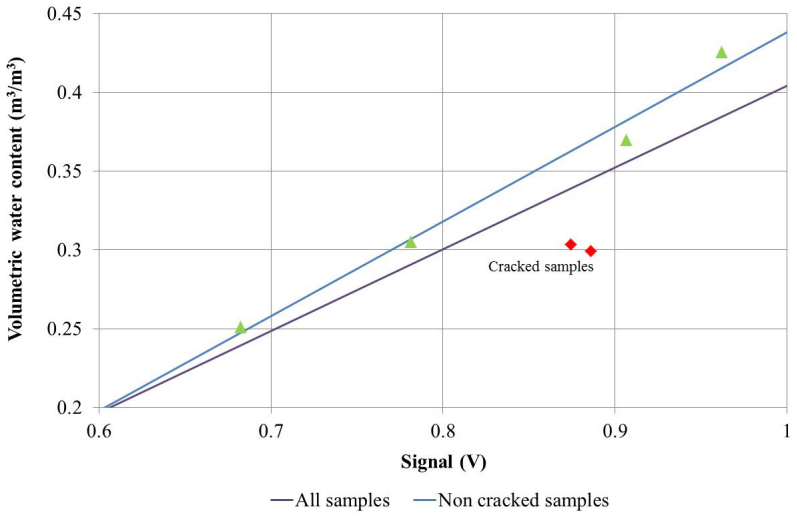

Fig. 50: FDR calibration. Points plotted as green triangles represent intact calibration samples and points plotted as red diamonds represent cracked samples.

Appendix B

Dataloggers and readers

Sensirion interface

Aitemin's SHT75 V3 relative humidity sensors are read using the SHC-V3 card (up to 8 channels) that allows up to 100 m cable length between the reading electronics and the sensor head. This low power consumption card allows both RS-485 and RS-232 serial communication and provides electrical isolation from the sensors' electronics. It incorporates leds to indicate the correct feeding and operation of the card.

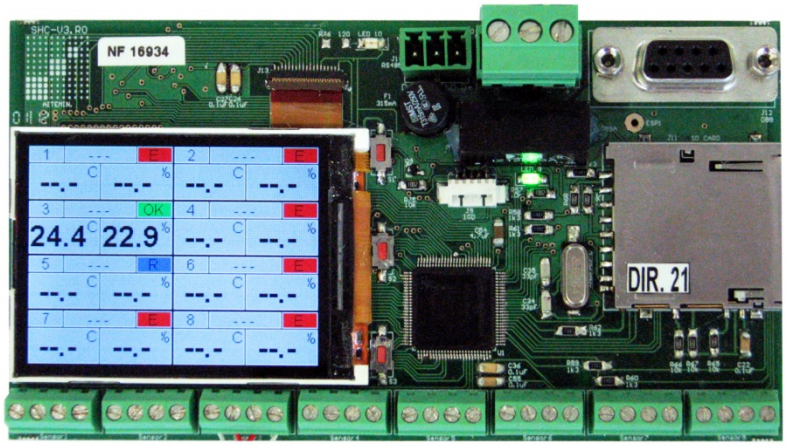

Fig. 51: SHC-V3 card.

Psychrometers datalogger

These sensors can be read by a dedicated data logging units, the Wescor Psypro datalogger. Each unit has 8 channels ready to read psychrometers.

Fig. 52: Psypro Datalogger.

Psychrometers manual reader

The psychrometers can be read using a manual reader, the Wescor's Dew Point Microvoltmeter, model HR-33T, which can determine water potential using both dew point and wet bulb methods. It contains sophisticated sensing and control circuitry that automatically maintains the temperature of the thermocouple junction at the dew point temperature when operating in the dew point mode. The HR-33T can be used in both a laboratory and a field environment.

Fig. 53: HR-33T reader.

Appendix C

Trotec 610

Aitemin

T610

EN

OPERATING MANUAL
MATERIAL MOISTURE
MEASURING DEVICE

TRT-BA-T610-TC-001-EN

TROTEC
AT WORK.

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Table of contents

Notes regarding the operating manual

Symbols

Danger!
Warns of a hazard which can lead to personal injury.

Caution!
Warns of a hazard which can lead to damage to property.

The current version of the operating manual can be found at: www.trotec.de

Legal notice

Warranty

The warranty is for 12 months. Damages caused by incorrect use by untrained people or start-up by unauthorised people are excluded from the warranty.
The device complies with the fundamental health and safety requirements of the applicable EU regulations and was tested at the factory for perfect functionality multiple times. However, if faults in the functionality occur and cannot be remedied with the measures in the chapter Errors and faults, please get in touch with your dealer or distributor. When making a warranty claim, supply the device number (see the rear of the device). The invoice acts as warranty certificate. When manufacturer's instructions or legal regulations have not been followed, or after unauthorised changes to the device are made, the manufacturer is not responsible for the resulting damages. Changes to the device or unauthorised replacement of individual parts can drastically impact the electrical safety of this product and leads to the forfeit of the warranty. Liability does not extend to damages to people or property caused by the device being used other than as described in the instructions in this operating manual. Subject to changes to technical design and model changes as part of constant development and product improvement without prior notice.
No liability is accepted for damages resulting from improper use. In such cases, entitlements to a warranty are then also forfeited.

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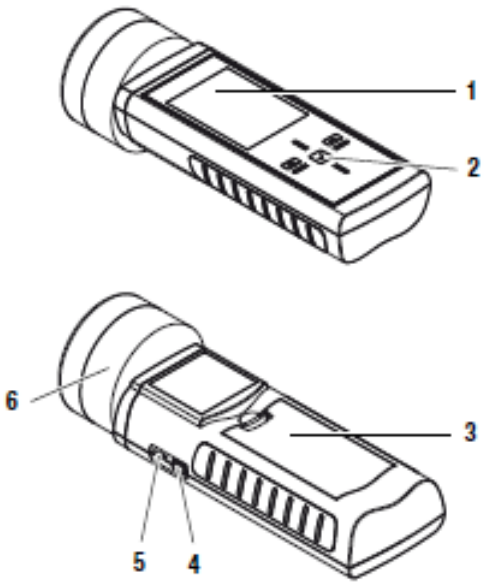
Information about the device

Description of the device

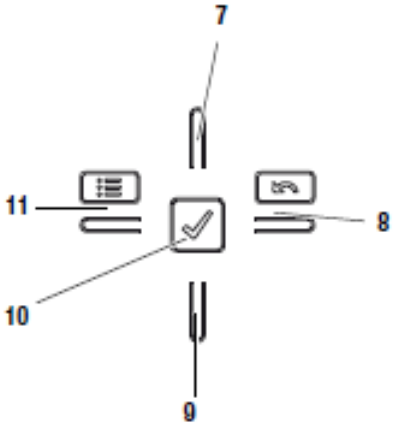
The material moisture measuring device T610 measures the moisture level of building material up to a depth of 30 cm by means of microwaves.
The measurement method belongs to the dielectric measurement methods.
A minimum, maximum and average function is available for the direct analysis of the measured data. Besides, the currently measured value can be recorded via the hold function.
The device can be operated via a capacitive touchscreen control panel.
When not in use, an automatic switch-off saves the battery.
You can connect the device to a computer by using the USB cable included in the scope of delivery. Then you can extract and analyse your measured results with the optional MultiMeasure Studio software.

Device depiction



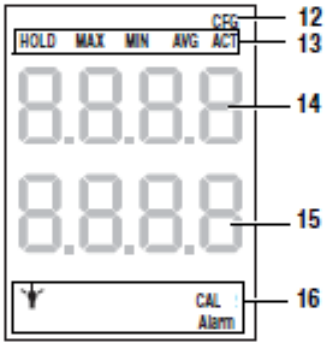
No.	Operating element
1	Display
2	Cross control
3	Battery compartment with battery cover
4	On/Off key
5	USB interface
6	Measuring head

Cross control



No.	Operating element
7	Up key
8	Right/back key
9	Down key
10	OK button
11	Left/menu key

Display



No.	Display element
12	Configuration mode display
13	Measuring mode
14	Measurement value display top
15	Measurement value display bottom
16	Configuration mode options

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Technical data

Parameter	Value
Model	T610
Dimensions (L x W x H)	191 x 63 x 35 mm
Weight incl. batteries	approx. 420 g
Measuring range	0 to 200 digits
Operating range	
Operating temperature	0 °C to +50 °C
Relative humidity	< 90 % or < 20 g/m³ (non-condensing)
Storage	
Relative humidity	< 95 % (non- condensing)
Ambient temperature	-20 °C to +60 °C
Energy	
Battery	4 x Alkaline LR6 AA, 1.5 V batteries comparable NiMH rechargeable batteries (> 2500 mAh)
Current consumption, active	approx. 110 mA
Current consumption, passive	approx. 40 µA
Battery life	at least 24 h

Scope of delivery

The scope of delivery includes:

- 1 x Material moisture measuring device T610
- 4 x Alkaline LR6 AA, 1.5 V batteries
- 1 x USB cable
- 1 x Display protection film
- 1 x Getting started guide
- 1 x Factory test certificate

Safety

Carefully read the operating manual before using the device and keep it within reach!

- Do not use the device in atmospheres containing oil, sulphur, chlorine or salt.
- Never use the device for measurements at live parts.
- Ensure that all connection cables are protected from damages (e.g. from kinks or crushing).
- Protect the device from permanent direct sunlight.
- Observe the storage and operating conditions (see chapter Technical data).

Intended use

Only use the material moisture measuring device T610 for the moisture measurement of building materials.
Here, read and observe the technical data.
To use the device for its intended use, only connect and use accessories and spare parts which have been approved by TROTEC®.

Improper use

Do not use the device in potentially explosive atmospheres, or for measurements in liquids. TROTEC® accepts no liability for damages resulting from improper use. In such a case, entitlements to a warranty are forfeited. Any unauthorised modifications, alterations or structural changes to the device are forbidden.

Personnel qualifications

People who use this device must:

- have read and understood the operating manual, especially the Safety chapter.

For maintenance or repair work which requires the housing to be opened, contact TROTEC® customer service. Devices which have been opened unlawfully are void of any warranty and warranty claims.

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Residual risks

Danger!
Do not leave the packaging lying around. Children may use it as a dangerous toy.

Danger!
The device is not a toy and does not belong in the hands of children.

Danger!
Dangers can occur at the device when it is used by untrained people in an unprofessional or improper way. Observe the personnel qualifications.

Caution!
To prevent damages to the device, do not expose it to extreme temperatures, extreme humidity or moisture.

Transport and storage

Transport

Use a suitable bag to transport the device safely.

Storage

When the device is not being used, observe the following storage conditions:

- dry,
- protected from dust and direct sunlight,
- with a plastic cover to protect it from invasive dust, if necessary.
- The storage temperature is the same as the range given in the chapter Technical data.
- When storing the device for a long time, remove the batteries.

Accessories

Optionally, the following accessories are available for transport and storage:

- TROTEC® Holster 3

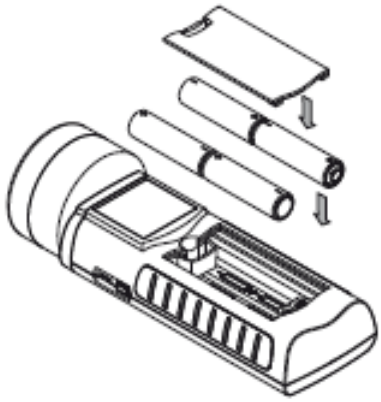
For further information please contact your TROTEC® customer service.

Operation

Inserting the batteries

- Insert the supplied batteries before first use.

Caution!
Make certain that the surface of the device is dry and the device is switched off.



1. Open the cover of the battery compartment (3).
2. Insert the batteries in the compartment as indicated in the figure.
3. Close the cover of the battery compartment (3).
   – The device can now be switched on.

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Switch-on and measurements

Notes:

Note that moving from a cold area to a warm area can lead to condensation forming on the device's circuit board. This physical and unavoidable effect can falsify the measurement. In this case, the display shows either no measured values or they are incorrect. Wait a few minutes until the device has become adjusted to the changed conditions before carrying out a measurement.

Please observe the information regarding the measurement principle.

The cross control is very sensitive. Therefore, avoid dirt on the control panel, because it could be misinterpreted by the device as keystroke.
Before use make sure that the touchscreen control panel is dirt-free.
If required clean the touchscreen control panel according to chapter Cleaning the device on page 10.

1. Hold the device pointing into clear space.
   – The device should point away from the body and not at or near material surfaces. When failing to observe the above instructions, the following calibration will be corrupt.
2. Press the On/Off key (4) until a beep is emitted.
3. The device performs a short self-test.
   – The device name and firmware version is shown on the display.
   – The battery charge is indicated on the display.
   – The device carries out an automatic calibration. During calibration the display indicates the lettering *CAL*. These flashing characters are accompanied by brief acoustic signals.
   – An extended acoustic signal indicates that the calibration has been completed.
   – The device is ready for operation.
4. Select the desired measuring mode.
5. Place the measuring head (6) vertically on the surface of the material to be measured. Hold the measuring head still during the entire measuring process.
   – The measured value will be displayed.

Carrying out a comparative measurement

1. Look for a preferably dry spot at the component.
2. Perform a measurement as previously described.
   – The thus determined measured value will be the reference value for *dry*.
3. Look for a preferably damp or wet spot at the component, if any.
4. Perform a measurement as previously described.
   – With regard to the present conditions, the thus determined measured value will be the reference value for *damp/wet*.
5. Carry out further measurements at the component.

Higher measured values usually signify a higher moisture content in the near-surface area of the material to be measured.

Carrying out a grid measurement

Particularly for larger areas, it is always recommended to perform measurements in form of a preferably close-meshed grid, for it is only this way that changes in the moisture content of the material can relatively confidently be detected and occasional outliers minimized.

1. Look for a preferably dry spot at the component.
2. Carry out at least five individual measurements within a radius of approx. 20 cm.
3. Calculate the average value of the individual measurement results.
   – The average will be the reference value.
4. Carry out further grid measurements at the component.
   – Higher measured values most likely signify the moisture penetration of the measured material.

Key lock

1. Briefly press the On/Off key (4) during operation.
   – The device emits a short beep.
   – The following message appears on the display: LoC on.
   – Key lock is activated.
2. Press the On/Off key (4) again.
   – The device emits a short beep.
   – The following message appears on the display: LoC off.
   – Key lock is no longer activated.

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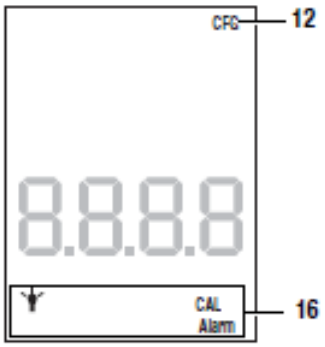
Configuration mode

1. Press the Left/menu key (11) for approx. 2 seconds.
   – The device emits a short beep.
   – The CFG symbol (12) is displayed in the upper right corner.
   – The available options for configuration mode (15) are displayed.
2. Use the cross control (2) to select the desired option.
3. Confirm the selection by pressing the OK button (10).
   – The selected symbol will be illuminated.



Configuration mode	Description
ALARM	Setting the threshold value for the alarm
Lamp	Adjusting the display illumination
CAL	Setting the offset value

Setting the alarm

Here you can determine the limit value for the alarm function. Upon exceeding this value, the device emits an acoustic signal and the indication ALARM (16) flashes. The alarm function draws on the current digit measured value. The limit value can be determined within a range of 0.1 to 200.

1. Select ALARM (16) whilst in configuration mode.
2. Press the OK button (10) to confirm.
   – The upper measurement value display (14) flashes.
3. Press the Up (7) or Down (9) key to activate or deactivate the alarm.
   – On or Off will be indicated in the upper measurement value display (14).
4. Press the Right/back key (8).
   – Depending on the selection, the alarm is either activated or deactivated.
   – The lower measurement value display (15) flashes.
5. Press the keys Left/menu (11) or Right/back (8) to select a digit.
   – The selected digit flashes.
6. Press the Up (7) or Down (9) key to change the value of the selected digit.
7. Repeat the steps 5. and 6. until the value is set as desired.
8. Press the OK button (10) for approx. 2 seconds.
   – The alarm is set.
   – The device switches to measuring mode.
   – With activated alarm function the indication ALARM (16) continues to be displayed.

Adjusting the display illumination

The display illumination can be adjusted within a range of 20 to 100 %. Another available setting is AL.on (always on). AL.on features a brightness of 100% and deactivates the automatic switch-off function.

1. Select the lamp (16) whilst in configuration mode.
2. Press the OK button (10) to confirm.
3. Select the desired value by use of the Up (7) or Down (9) key.
4. Press the OK button (10) for approx. 2 seconds.
   – The set value will be adopted.
   – The device switches to measuring mode.

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Setting the offset value

By use of CAL a single-point calibration can be carried out for the selected sensor indications. All sensors are already factory-calibrated and have a corresponding characteristic calibration curve. By stating a calibration value (offset) a global shift of the calibration curve, which has an effect on the entire measuring range, is performed for the single-point calibration! The offset value to be entered is that value by which the calibration curve will be shifted.

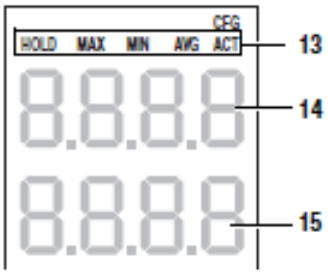
Example:
The displayed value is always 5 too high => change the offset value for this measurement channel to -5.
The offset value's default setting is 0.0.

Changing this value brings about an automatic reset of the measured values.

1. Select CAL (16) whilst in configuration mode.
2. Press the OK button (10).
3. Press the Up (7) or Down (9) key to activate or deactivate the offset.
   – *On* or *Off* will be indicated in the upper measurement value display (14).
4. Press the Right/back key (8).
   – Depending on the selection, the offset is either activated or deactivated.
   – The lower measurement value display (15) flashes.
5. Press the keys Left/menu (11) or Right/back (8) to select a digit.
   – The selected digit flashes.
6. Press the Up (7) or Down (9) key to change the value of the selected digit.
7. Repeat the steps 5. and 6. until the value is set as desired.
8. Press the OK button (10) for approx. 2 seconds.
   – The offset is set.
   – The device switches to measuring mode.
   – With set offset value the indication CAL (16) continues to be displayed.

Measuring mode

1. Press the keys Right/back (8) or Left/menu (11) until the desired measuring mode is displayed.
   – The selected measuring mode (13) will be indicated on the display (1).
   – The current measured value is displayed in the lower measurement value display (15).
   – The values of the measuring modes AVG, MIN, MAX and HOLD are displayed in the upper measurement value display (14).



The device comes with the following measuring modes:

Measuring mode	Description
ACT	Measured value in real time
AVG	Average value of measurements since switch-on
MIN	Minimum measured value
MAX	Maximum measured value
HOLD	Measured value will be held

Holding the measured value

1. Set the measuring mode to HOLD.
   – The current measured value will be held and displayed.
   – The device will hold this value until the measured values are set back or the device is switched off.

Resetting the measured values

1. Press the OK button (10) for approx. 2 seconds.
   – All previously stored measured values of the measuring modes AVG, MIN, MAX and HOLD will be set back.
   – All measured values are then determined anew based on the measurement proceeding in the background.

Measured value storage

Please note that measured values cannot be saved on the device itself. In order to save measured values, the device has to be connected to a PC via a USB cable using the MultiMeasure Studio software.

1. Briefly press the OK button (10).
   – The displayed measured value will be saved in the software.

Further information can be gathered from the help text of the MultiMeasure Studio software.

Aitemin

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USB interface

The device can be connected to a PC via the USB interface (5).
See chapter PC software on page 9.

Switch-off

1. Press and hold the On/Off key (4) for approx. 3 seconds until a beep is emitted.
   – The device will be switched off.

Measuring principle

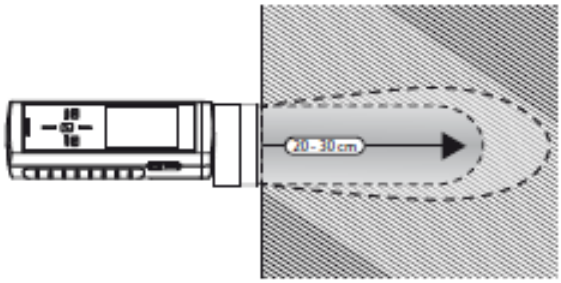
The measurement method applied here utilizing microwaves belongs to the dielectric moisture measurement methods.

- The measuring head generates an electromagnetic wave, which spreads throughout the material and is reflected.
- Not only the near-surface volume elements of the measured material contribute to the reflection of this wave, but also those located at a lower level. The weighting of the share in how the individual volume elements contribute drops with increasing depth. This means that underlying moisture zones have a proportionally lesser influence on the display value than near-surface moisture penetration.
- With increasing frequencies the influence of ohmic drops (ionic conductivities, e.g. salinization of the brickwork) declines distinctly. From roughly 1 GHz these drops are almost negligible as opposed to dielectric losses. The microwave method is thus almost independent of the salinity degree.

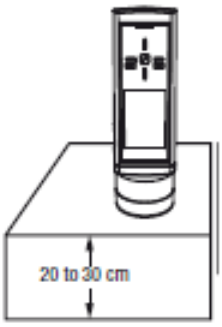
Dielectric moisture measurement methods are based on the dielectric properties of water.

- The water molecule aligns itself in a preferential direction within an externally applied field; it is polarizable. If an alternating electromagnetic field is applied, the molecules begin to rotate with the frequency of the field (orientational polarization). This effect is described macroscopically by the physical variable dielectric constant (DK).
- For water the dielectric effect is so pronounced, that the DK of water amounts to about 80. The DK of most solids, construction materials among them, is much smaller; it is in the range between 2 and 10, chiefly between 3 and 6. Hence measured is the difference between the DK of water and the DK of the building materials. Due to the great difference between these values, even small amounts of water can easily be detected.
- With increasing frequencies it is much harder for the water molecule to follow an externally applied alternating electromagnetic field owing to material-inherent bonding forces. In a way, there is friction within the material or in other words dielectric loss. These losses can be measured by means of specific microwave arrangements.

Notes regarding the measurement principle



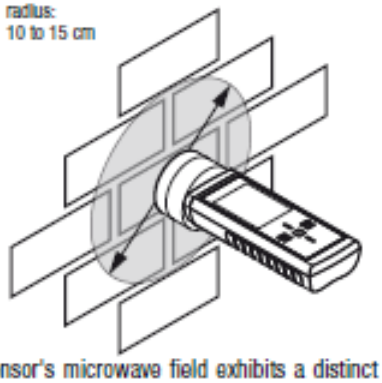
- The microwave sensor of the device at hand contains an antenna arrangement enabling non-destructive penetration depths of up to approx. 30 cm. It is suited to determine the moisture in the volume of the measured material.
- The measurement is effected according to a reflection principle, i.e. measured is the humidity-dependent share of the wave, which is reflected by the material to be measured.
- The maximum penetration depth is substantially reduced when the material to be measured or the component is soaked in the near-surface area.



- Depending on the material and moisture level the field advances 20 to 30 cm into the good to be measured. Therefore, the materials whose moisture is to be measured have to have at least this thickness.
- If the material to be measured is of lesser thickness, shares of the electromagnetic wave emitted by the sensor are reflected at the material's rear side, hence interfering with the moisture-dependent reflections at the measuring head antenna. Depending on the material and moisture level this effect can in part lead to substantial distortions of the measured value.

TROTEC

- In order to minimize measurement errors caused by varying material thicknesses or inhomogeneities, it is recommended to perform a preferably close-meshed grid measurement covering the entire area to be examined.



- The sensor's microwave field exhibits a distinct lateral expansion. A minimum distance to the side limits of the measured material must be observed, for otherwise the measured value might be falsified. In simplified terms the measuring volume can be seen as a cylinder with a radius of 10 to 15 cm. Therefore, the minimum distance for delimiting the material is stated as 10 cm.
- A moisture measurement with less distance to the side edge of the material can result in a distortion of the measured value.
- For a significant and exact measurement with the microwave sensor it must be ensured that the observed measuring volume is sufficiently dimensioned.
- The measured values are to be interpreted as relative values, for the microwave method only enables a differentiation between dry and wet building materials.
- The main area of use consists in comparative measurements at the same construction material or similar components. Depending on the display value, humid zones can be determined and narrowed down.
- Measuring according to the microwave method is further suited for the examination of water damage and for leak detection.
- If the test material contains metal (e.g. pipes, lines, reinforcements, plaster base), the measured value skyrockets. Thanks to the depth effect (penetration), the device is also suitable for localizing metal objects and detecting reinforcements.
- Owing to the correlation between the material's bulk density and the dielectric constant of building materials described above, there can be different display values with different material densities and multi-layered wall or floor constructions. Cluster measurements are recommended to avoid the misinterpretation of the measured values. For this, at least five individual depth measurements are carried out within a radius of 20 cm and from these individual results an average value is to be calculated. This value then constitutes the reference value for other cluster measuring spots.
- For a more precise analysis of homogenous materials (brickwork thicker than 30 cm) a cluster measurement is advisable. Generally, three measurements within a radius of 15 cm are a sufficient basis for evaluation.

PC software

Use the MultiMeasure Studio Standard PC software (free standard version) or MultiMeasure Studio Professional (paid professional version, dongle required) to carry out a detailed analysis and visualisation of your measured results. You can only use all configuration, visualisation and functional options of the device when using this PC software and a TROTEC® USB dongle (professional).

Installation requirements

Ensure that the following minimum requirements for installing the MultiMeasure Studio Standard or MultiMeasure Studio Professional PC software are fulfilled:

- Supported operating systems (32 or 64 bit version):
  - Windows XP from service pack 3
  - Windows Vista
  - Windows 7
  - Windows 8
- Software requirements:
  - Microsoft Excel (to display stored Excel files)
  - Microsoft .NET Framework 3.5 SP1 (is otherwise automatically installed during the software installation)
- Hardware requirements:
  - Processor speed: min. 1.0 GHz
  - USB connection
  - Internet connection
  - 512 MB RAM, minimum
  - 1 GB hard disk space, minimum
  - Optional: TROTEC® USB dongle (Professional) for using the professional version of the PC software

Aitemin

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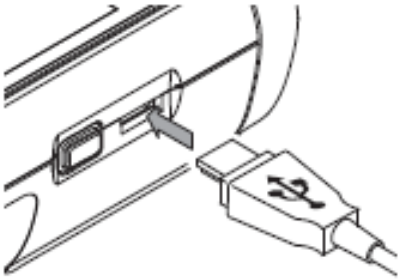
Installing the PC software

1. Download the current PC software from the Internet. To do so, visit the website www.trotec.de. First click on *Service*, followed by *Downloads* and then *Software*. Select the MultiMeasure Studio Standard software from the list. If you want to use the optionally available professional version of the PC software "MultiMeasure Studio Professional" (dongle), then get in touch with your TROTEC® customer service.
2. Double-click on the downloaded file to start the installation.
3. Follow the instructions of the installation wizard.

Starting the PC software

1. Connect the device to your PC via the USB connection cable provided in the scope of delivery.



Note:
Step 2 only needs to be performed, when using the Professional software functions.
If you only use the Standard software functions, please proceed to step 3.

2. In order to enable the Professional functions, connect the TROTEC® USB dongle to a free USB port on your PC.
   - The TROTEC® USB dongle (Professional) is automatically detected by the operating system.
   - If you only connect the TROTEC® USB dongle (Professional) to your PC after starting the PC software, click the *Parameters* menu item in the PC software. Afterwards, click the USB symbol (dongle check) to read the connected TROTEC® USB dongle (Professional).
3. Switch on the device (see chapter Switch-on and measurements on page 5).
4. Start the MultiMeasure Studio software.

Information regarding the use of the MultiMeasure Studio software is provided in the help text of the software.

Errors and faults

The accurate functionality of the device was tested during production a number of times. However, if functionality faults do occur, then check the device according to the following list.

The device does not switch on:

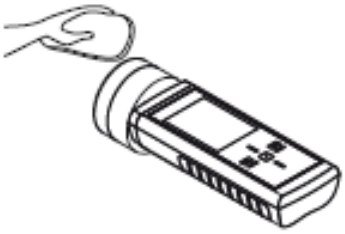
- Check the charging status of the batteries. Change the batteries when the message *Batt lo* is displayed upon switch-on.
- Check that the batteries are properly positioned. Check the polarity is correct.
- Never carry out an electrical check yourself; instead, contact your TROTEC® customer service.

Maintenance

⚠ **For maintenance or repair work which requires the housing to be opened, contact TROTEC® customer service. Devices which have been opened unlawfully are void of any warranty and warranty claims.**

Cleaning the device

1. Use a soft, lint-free cloth for cleaning.
2. Dampen the cloth with clean water. Do not use sprays, solvents, alcohol-based or abrasive cleaners to dampen the cloth.
3. Clear dirt from the housing, the connections and the colour display.



Battery change

Change the batteries when the message *Batt lo* is displayed upon switch-on or the device can no longer be switched on. See Inserting the batteries on page 4.

TROTEC

Disposal

In the European Union, electronic equipment must not be treated as domestic waste, but must be disposed of professionally in accordance with Directive 2002/96/EC of the European Parliament and Council of 27th January 2003 concerning old electrical and electronic equipment. After the end of its use, please dispose of this device in a manner appropriate to the relevant legal requirements.

In the European Union, batteries must not be treated as domestic waste, but must be disposed of professionally in accordance with Directive 2006/66/EC of the European Parliament and Council of 6th September 2006 concerning batteries and accumulators. Please dispose of batteries in a manner appropriate to the relevant legal requirements.

Declaration of conformity

in accordance with the EC Low Voltage Directive 2006/95/EC and the EC Directive 2004/108/EC about electromagnetic compatibility.
Herewith, we declare that the T610 material moisture measuring device was developed, constructed and produced in compliance with the named EC directives.

The CE marking is found on the rear of the device.

Manufacturer:
Trotec GmbH & Co. KG
Grebbener Straße 7
D-52525 Heinsberg
Phone: +49 2452 962-400
Fax: +49 2452 962-200
E-mail: info@trotec.de

Heinsberg, 31/03/2014

Managing Director: Detlef von der Lieck

Appendix D

Cameras

Headwall

Data Sheet

Hyperspec® VNIR

Hyperspectral Imaging Spectrometer

Hyperspec® VNIR imaging sensor for the 380nm to 1000 nm spectral range

Headwall's Hyperspec® VNIR family of integrated hyperspectral imaging sensors provides the foundation for utilizing hyperspectral imaging to achieve superior spectral sensing and chemical imaging results for mission-critical applications ranging from process monitoring to moving webs of product across conveyor lines to non-invasive medical imaging where precise color measurement is critical to the application.

The award-winning, Hyperspec® imaging spectrometer family is built on a totally reflective concentric, f/2.0 optical design and optimized for imaging in harsh environments. All Hyperspec® instruments are based on Headwall's patented aberration-corrected, imaging design which feature *original* high efficiency holographic diffraction gratings rather than replicates.

In order to minimize stray light and aberrations, transmissive optical components are not used within the imaging spectrometer. This platform is further enhanced by a telecentric optical input design which enables superior spectral and spatial imaging.

The Hyperspec® VNIR imaging spectrometer is available in two configurations - as a lens-based imager or as a multi-channel/multi-point spectrometer; each model providing different capabilities to support application requirements such as frame rates, dynamic range, region of interest binning, price, and more.

The Hyperspec® VNIR sensors are also available with the Hyperspec® Starter Kit, the Hyperspec® Reflectance/Fluorescence System, and in pan/tilt configurations for stationary deployment. Hyperspec VNIR N-Series provides 12-236 frames per second (FPS) and USB connectivity. The A-Series provides greater than 90 FPS and Cameralink connectivity. The E-Series provides between 100-400 FPS and Cameralink connectivity.

Applications:

- Machine vision
- Moving webs of product
- Color measurement
- Pulp & paper
- Textile production
- Food safety & quality
- LCD/display quality control
- Microscopy & health sciences
- Multi-channel/multi-point spectroscopy
- Process control of biomass/biofuels
- Remote sensing & analysis
- Military, defense & homeland security
- Waste recycling & sorting

Key Benefits:

- Superb imaging performance
- Exceptional spectral & spatial resolution
- Ideal for low light, low signal applications
- Accurate, consistent spectral measurement
- Compact with very wide field of view
- Extremely high signal-to-noise
- Low scatter or stray light
- Rugged design for durability & stability
- Cost effective deployment

Application-Specific Solutions For Critical Environments

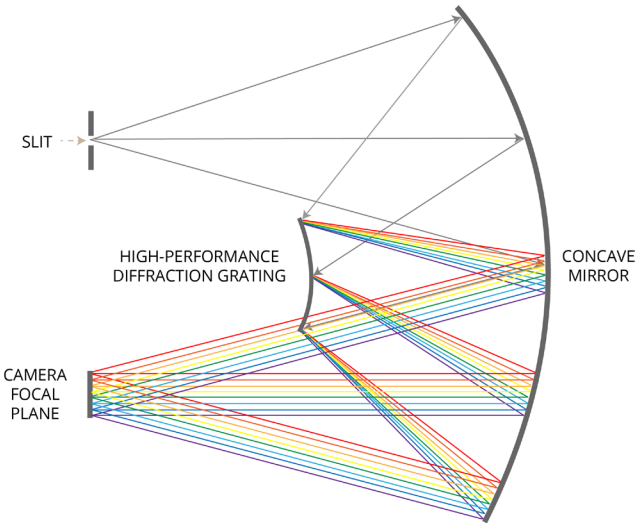
Hyperspec® VNIR Specifications

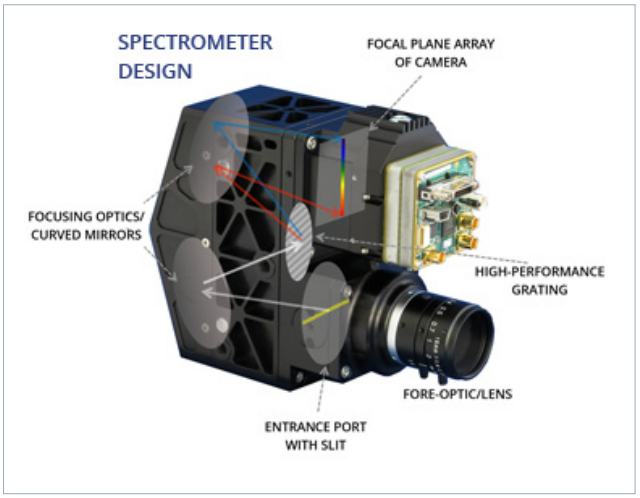
Hyperspec VNIR	A Series	N Series	E Series
Wavelength Range (nm)	400nm - 1000nm		
Aperture	F/2.0		
Dispersion per pixel	0.74 nm	0.80 nm	0.65 nm
Slit Width (Interchangeable) Optional - 16, 40, 60, 100	25 µm standard		
Slit Length	12 mm		
Spectral Resolution (25µ slit)	2-3 nm		
Spectral Bands	810	750	923
Spatial Bands	1000	1004	1600
Smile - Aberration-corrected	Yes		
Keystone - Aberration-corrected	Yes		
Stray Light	< 0.5%		

Image Acquisition	A Series	N Series	E Series
Detector	Silicon CCD		S-CMOS
Dynamic Range	60 dB	64 dB	88.6 dB
Frame Rates (fps)	> 90	12-236	100-400
Pixel Pitch (microns)	7.4	8.0	6.5
Read A/D	12 bit	14 bit	16 bit
Binning	Yes		
Region of Interest	Yes		
Camera Control Interface	base Cameralink	USB 2.0	full Cameralink

Environmental	A Series	N Series	E Series
Operational Temperature	0° C - 30° C	0° C - 30° C	10° C - 40° C
Storage Temperature	-20° C - 40° C	-25° C - 55° C	-10° C - 60° C
Relative Humidity (Non-Condensing)	< 70%	< 70%	10-80%
Weight	6.8 lbs/ 3.0 kg	7.5 lbs/ 3.4 kg	8 lbs/ 3.6 kg

All-Reflective Concentric Imager





Headwall covers the hyperspectral range!

- UV-VIS (250-825nm)
- VNIR (380-1000nm)
- Extended VNIR (550-1700nm)
- NIR (900-1700nm)
- SWIR (950-2500nm)
- MWIR (3,000-5,000nm)
- LWIR (8,000-12,000nm)

About Headwall Photonics: Headwall is the leading designer and manufacturer of imaging spectrometers and spectral instrumentation for industrial, commercial, and government markets. Headwall's high performance spectrometers, spectral engines, and holographic diffraction gratings have been selected by OEM and end-user customers around the world for use in critical application environments. As a pioneer in advanced, patented optics technology, Headwall enjoys a market-leading position through the design and manufacture of spectral instrumentation that is customized for application-specific performance.

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Headwall

Data Sheet

Hyperspec® Starter Kit

For VNIR/NIR/SWIR Imaging

Headwall's Starter Kits provide a simple and rapid means of collecting hyperspectral images that can be used for reflective spectroscopic analysis in the VNIR-SWIR spectral ranges. Gantry, linear stage, reflectance reference standard, and illumination represent the basic elements of the Starter Kit. Two versions of the Starter Kit are available, standard and large-format. The large-format Starter Kit features a wider translation stage with longer travel and can accomodate two sensors capable of working at different spectral ranges (one VNIR and one SWIR, for example). Headwall's fully reflective, patented spectrometer design eliminates image aberrations while offering high resolution with a wide field of view. This represents a major advantage where spectral and spatial imaging performance are critical success factors.

Standard UV-VIS

Large-format (VNIR/SWIR)

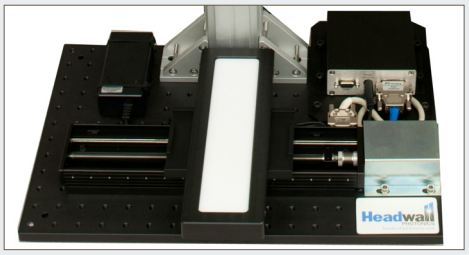
High Quantum-Efficiency (QE) detection electronics and 100% fill-factor mean high signal-to-noise characteristics for maximized sensitivity and dynamic range. Depending on the sensor chosen, a design-optimized objective lens provides excellent chromatic compensation and imaging results over the VNIR, NIR or SWIR spectral ranges. High intensity QTH Illumination provided on the VNIR/NIR/SWIR Starter Kit is optimized for wavelengths between 380-2500nm. Starter Kits designed for UV-VIS use a combination of QTH and pulsed Xenon illumination.

Headwall's Hyperspectral Data Processing Unit (HDPU) and Hyperspec III software are options that can be added to any Starter Kit. The HDPU contains a high-speed processor and high-capacity solid-state storage to deliver extremely fast capture, transfer and processing of the hyperspectral image data. Depending on the sensor, either USB 2.0 or CameraLink connectivity can be used; the HDPU contains ports for both. Hyperspec® III software allows the user to analyze the data more effectively and efficiently than any other comparable platform.

Application-Specific Solutions For Critical Environments

APPLICATION AREAS

- Fruit, seafood, grains, other foods
- Minerals
- Documents & artifacts
- Paintings



Moving stage with reflectance reference standard

elliptical light source

Key Benefits:

- Instantly scan sample materials & display hyperspectral results
- Determine spectral band differentiators
- Increased user productivity
- Cost-effective deployment
- Simple to set up, simple to use
- Flexibility to quickly modify configurations
- Quickly run multiple experiments
- Rapid development of spectral libraries

Key Features:

- Adjustable mounting stage and gantry
- Precision DC Servo linear stage and controller with 250mm travel distance (optional 300mm travel distance available)
- Lighting: Adjustable high-intensity QTH lamps or pulsed Xenon (depending on sensor and spectral range).

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Data Sheet

HYPERSPEC® III SOFTWARE

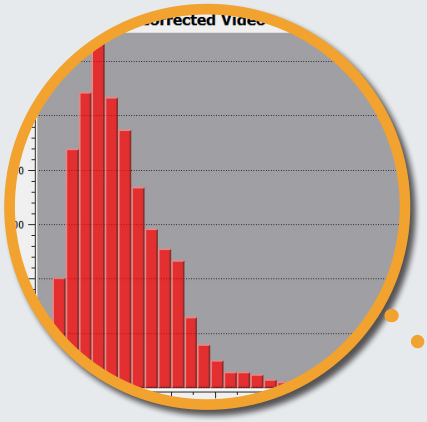
Headwall's Hyperspec® III software brings together a powerful set of hyperspectral acquisition and data manipulation tools in a single, easy-to-use environment for use across a wide range of applications.

Hyperspec III software is extremely versatile, using the industry-standard CameraLink and USB interfaces while supporting Windows 7, Windows 8, and Linux operating systems. It implements seamlessly into everything from advanced machine vision systems to airborne applications and interfaces with all of Headwall's hyperspectral sensors.

Across all operating situations, Hyperspec software provides high frame rates in excess of 400 fps and is multi-threaded for simultaneous processing and scalability. In a machine-vision application, for example, Hyperspec software integrates with downstream robotics via FTP and socket messaging.

For airborne applications, orthorectification is crucial when capturing hyperspectral data. Hyperspec software interfaces with GPS devices to make this possible and to allow for precise calibration and start/stop data capture (which can also be triggered using a time-based method). Also, multiple sensors can be simultaneously controlled by the software. Regardless of the application, Hyperspec III software manages all camera parameters and motion-control features such as pan-and-tilt as well as Headwall's Starter Kit with moving web.

Because Hyperspec III software and all connected sensors can be controlled remotely, full automation is possible. Airborne remote sensing applications can be fully automated with respect to control and operation of the sensor. Working in conjunction with Hyperspec III is Headwall's Hyperspec Data Processing Unit (HDPU), which is available in standard and lightweight airborne versions. Multiple display options exist within Hyperspec III software, including histogram and waterfall modes.

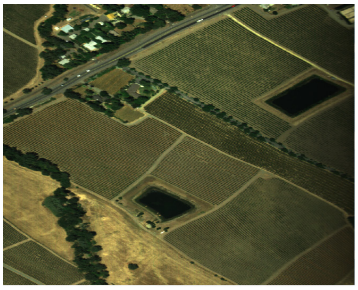


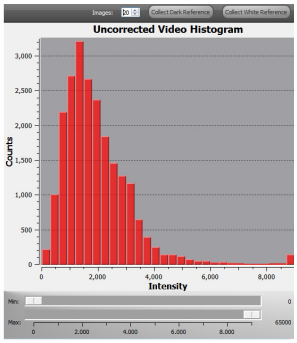
One software platform controls multiple sensors simultaneously!

Application-Specific Solutions For Critical Environments

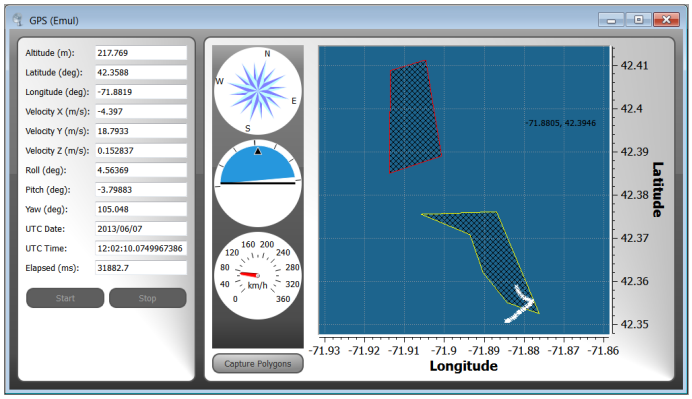
Hyperspec® III Software

Headwall's powerful Hyperspec III software is designed for laboratory, ground-based, and airborne applications. The software is pre-loaded onto Headwall's Hyperspec Data Processing Units (standard and compact versions). Depending on the application and use-case, various modules within the software package are available. For example, airborne applications will benefit from GPS and Polygon perimeter triggers, plus ortho-rectification capabilities during post-processing.

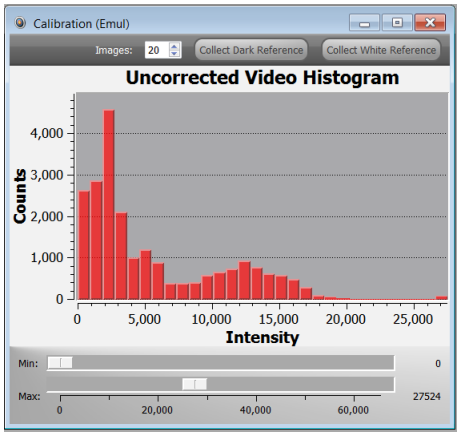




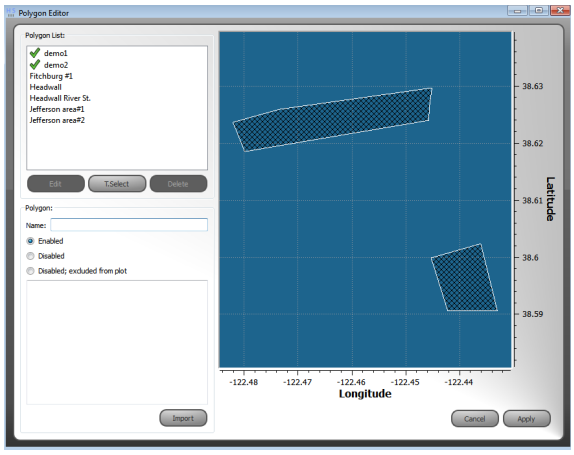
Waterfall Display Settings



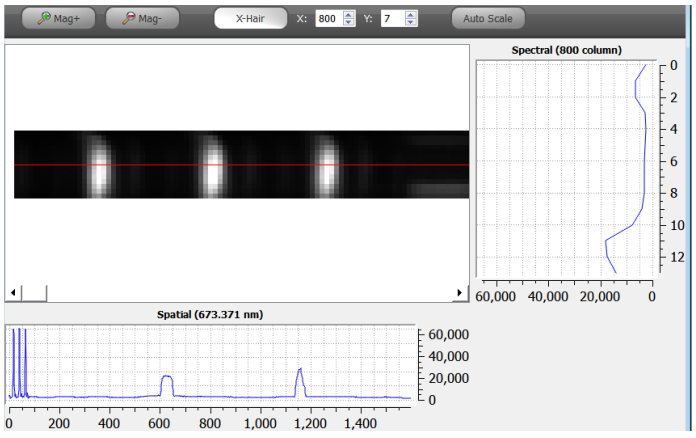
GPS



Histogram



Polygon Editor



Live View

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FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

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Language: en-US
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Formatted: 2015-03-21

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Customer support

http://support.flir.com

General description

The FLIR T650sc is designed for the expert requiring the highest performance and the latest technology available. The camera combines excellent ergonomics and feature-rich flexibility with superior image quality of 640 × 480 pixel infrared resolution. High accuracy and sensitivity together with radiometric recording and streaming options make the FLIR T650sc well suited for advanced research and development.

Benefits:

- Tailor made for research and development: The FLIR T650sc has high accuracy and high sensitivity to accurately measure the smallest temperature differences. With real-time radiometric recording by the camera, it is possible to capture fast events on an SD card for further analysis by the supplied analysis software.
- Flexible and feature rich: A wide variety of measuring and analysis functions makes the camera flexible and able to meet your every need. A programmable button provides easy access to favorite functions.
- Highest performance with the latest technology: The FLIR T650sc is equipped with the innovative Multi Spectral Dynamic Imaging (MSX) feature, which produces an image richer in detail than ever before. Continuous auto-focus makes the FLIR T650sc the first fully automatic infrared camera on the market.
- Extensive communication options: The Wi-Fi connectivity of the T650sc allows you to connect to smart phones or tablets for the wireless transfer of images or the remote control of the camera. The Bluetooth-based METERLiNK function transfers readings from external measurement instruments to the infrared image.
- Support for UltraMax: When enabling UltraMax in the camera, the resolution of images can be substantially enhanced when importing the images into FLIR Tools.

Imaging and optical data	
IR resolution	640 × 480 pixels
UltraMax	Yes
Thermal sensitivity/NETD	<20 mK @ +30°C (+86°F)
Field of view (FOV)	25° × 19°
Minimum focus distance	0.25 m (0.82 ft.)
Focal length	25 mm (0.97 in.)
Spatial resolution (IFOV)	0.68 mrad
Lens identification	Automatic
F-number	1.0
Image frequency	30 Hz
Focus	Continuous, one shot or manual
Digital zoom	1–8× continuous
Digital image enhancement	Adaptive digital noise reduction

FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

#55904-7823; r. /23380; en-US

Detector data	
Detector type	Focal plane array (FPA), uncooled microbolometer
Spectral range	7.5–14 µm
Detector pitch	17 µm

Image presentation	
Display	Built-in touch screen, 4.3 in. wide screen LCD, 800 × 480 pixels
Display type	Capacitive touch screen
Auto orientation	Automatic landscape or portrait
Viewfinder	Built-in 800 × 480 pixels
Automatic image adjustment	Continuous, histogram based
Manual image adjustment	Linear based; possible to adjust level/span/max./min.

Image presentation modes	
Infrared image	Full-color IR image
Visual image	Full color visual image
Thermal MSX	Thermal image with enhanced detail presentation
Picture in Picture	Resizable and movable IR area on visual image

Measurement	
Object temperature range	• –40°C to +150°C (–40°F to +302°F) • +100°C to +650°C (+212°F to +1202°F) • +300°C to +2000°C (+572°F to +3632°F)
Accuracy	• ±1°C (±1.8°F) or ±1% of reading for limited temperature range. • ±2°C (±3.6°F) or 2%, whichever is greater, at 25°C (77°F) nominal.

Measurement analysis	
Spotmeter	10
Area	5 areas (boxes or circles) with max./min./average
Profile	1 line profile with max/min temp
Automatic hot/cold detection	Auto hot or cold spotmeter markers within area and profile
Measurement presets	No measurements, Center spot, Hot spot, Cold spot, User preset 1, User preset 2
User presets	The user can select and combine measurements from any number of spots/boxes/circles/profiles/delta
Difference temperature	Delta temperature between measurement functions or reference temperature
Reference temperature	Manually set using difference temperature
Atmospheric transmission correction	Automatic, based on inputs for distance, atmospheric temperature and relative humidity
Optics transmission correction	Automatic, based on signals from internal sensors
Emissivity correction	Variable from 0.01 to 1.0 or selected from materials list
Emissivity table	Emissivity table of predefined materials

FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

#55904-7823; r. /23380; en-US

Measurement analysis	
Reflected apparent temperature correction	Automatic, based on input of reflected temperature
External optics/windows correction	Automatic, based on inputs of window transmission and temperature
Measurement corrections	Emissivity, reflected temperature, relative humidity, atmospheric temperature, object distance, external IR window compensation
Colors (palettes)	Iron, Rainbow, Rainbow HC, White hot, Black hot, Arctic, Lava

Alarm	
Color Alarm (isotherm)	Above/below/interval
Measurement function alarm	Audible/visual alarms (above/below) on any selected measurement function
Screening	Difference temperature alarm, audible

Set-up	
Set-up commands	Define user presets, Save options, Programmable button, Reset options, Set up camera, Wi-Fi, GPS & compass, Bluetooth, Language, Time & units, Camera information

Service functions	
Camera software update	Use PC software FLIR Tools

Storage of images	
Image storage	Standard JPEG, including digital photo and measurement data, on memory card
Storage media	Removable memory SD card
Image storage mode	• Simultaneous storage of thermal and digital photo in same JPEG file. • Optional to store digital photo as a separate JPEG file.
Time lapse	15 seconds to 24 hours
File formats	Standard JPEG, measurement data included
File formats, visual	Standard JPEG, automatically associated with corresponding thermal image

Image annotations (in still images)	
Voice	60 seconds (via Bluetooth) stored with the image
Text	Add table. Select between predefined templates or create your own in FLIR Tools
Image description	Add short note (stored in JPEG EXIF tag)
Sketch	Draw on thermal/digital photo or add predefined stamps
METERLiNK	Wireless connection (Bluetooth) to: FLIR meters with METERLiNK
Report generation	• Instant Report (*.pdf file) in camera • Separate PC software with extensive report generation

FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

#55904-7823; r. /23380; en-US

Geographic Information System	
GPS	Location data automatically added to every still image from built-in GPS
Compass	Camera direction automatically added to every still image

Video recording in camera	
Radiometric IR video recording	CSQ to memory card
Non-radiometric IR video recording	MPEG-4 to memory card
Visual video recording	MPEG-4 to memory card

Video streaming	
Radiometric IR video streaming	Full dynamic to PC using USB or to mobile devices using Wi-Fi.
Non-radiometric IR video streaming	• MPEG-4 using Wi-Fi • Uncompressed colorized video using USB
Visual video streaming	• MPEG-4 using Wi-Fi • Uncompressed colorized video using USB

Digital camera	
Built-in digital camera	5 Mpixels with LED light (photo as separate image)
Digital camera, FOV	Adapts to the IR lens
Video lamp	Built-in LED light

Laser pointer	
Laser	Activated by dedicated button
Laser alignment	Position is automatic displayed on the IR image
Laser classification	Class 2
Laser type	Semiconductor AlGaInP diode laser, 1 mW, 635 nm (red)

Data communication interfaces	
Interfaces	USB-mini, USB-A, Bluetooth, Wi-Fi, Digital Video Output
METERLiNK/Bluetooth	Communication with headset and external sensors
Wi-Fi	Peer to peer (ad hoc) or infrastructure (network)
SD Card	One card slot for removable SD memory cards

USB	
USB	• USB-A: Connect external USB device • USB Mini-B: Data transfer to and from PC / uncompressed colorized video
USB, standard	USB 2.0 high speed

Video output	
Video out	Digital video output (DVI)
Video, connector type	HDMI compatible

FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

#55904-7823; r. /23380; en-US

Radio	
Wi-Fi	• Standard: 802.11 b/g • Frequency range: 2412–2462 MHz • Max. output power: 15 dBm
METERLiNK/Bluetooth	Frequency range: 2402–2480 MHz
Antenna	Internal

Power system	
Battery type	Rechargeable Li ion battery
Battery operating time	> 2.5 hours at 25°C (+68°F) and typical use
Charging system	In camera (AC adapter or 12 V from a vehicle) or 2-bay charger
Charging time	2.5 h to 90 % capacity, charging status indicated by LED's
Charging temperature	0°C to +45°C (+32°F to +113°F)
External power operation	AC adapter 90–260 VAC, 50/60 Hz or 12 V from a vehicle (cable with standard plug, optional)

Environmental data	
Operating temperature range	–15°C to +50°C (+5°F to +122°F)
Storage temperature range	–40°C to +70°C (–40°F to +158°F)
Humidity (operating and storage)	IEC 60068-2-30/24 h 95% relative humidity +25° C to +40°C (+77°F to +104°F) / 2 cycles
EMC	• ETSI EN 301 489-1 (radio) • ETSI EN 301 489-17 • EN 61000-6-2 (Immunity) • EN 61000-6-3 (Emission) • FCC 47 CFR Part 15 Class B (Emission) • ICES-003
Radio spectrum	• ETSI EN 300 328 • FCC Part 15.247 • RSS-210
Encapsulation	IP 54 (IEC 60529)
Shock	25 g (IEC 60068-2-27)
Vibration	2 g (IEC 60068-2-6)
Safety	EN/UL/CSA/PSE 60950-1

Physical data	
Weight	1.3 kg (2.87 lb.)
Camera size, excl. lens (L × W × H)	143 × 195 × 95 mm (5.6 × 7.7 × 3.7 in.)
Tripod mounting	UNC ¼"-20
Housing material	Magnesium

FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

#55904-7823; r. /23380; en-US

Shipping information	
Packaging, type	Cardboard box
List of contents	• Infrared camera with lens • Battery (2 ea.) • Battery charger • Bluetooth headset • Calibration certificate • FLIR ResearchIR Max 4 • FLIR Tools download card • User documentation CD-ROM • Printed documentation • HDMI-DVI cable • HDMI-HDMI cable • Hard transport case • Large eyecap • Lens cap • Memory card • Neck strap • Power supply, incl. multi-plugs • Tripod adapter • USB cable, Std A to Mini-B
Packaging, weight	6.95 kg (15.3 lb.)
Packaging, size	495 × 192 × 370 mm (19.49 × 7.56 × 14.57 in.)
EAN-13	7332558007099
UPC-12	845188007430
Country of origin	Sweden

Supplies & accessories:

- T197914; IR lens, f=41.3 mm (15°) with case
- T197922; IR lens, f=24.6 mm (25°) with case
- T197915; IR lens, f=13.1 mm (45°) with case
- T198059; Close-up IR lens, 2.9× (50 µm) with case
- T198060; Close-up IR lens, 5.8× (100 µm) with case
- T198166; IR lens, f=88.9 mm (7°) with case and support for T6xx
- T198065; IR lens, f=6.5 mm (80°) with case
- T198066; Close-up IR lens, 1.5× (25 µm) with case
- T910814; Power supply, incl. multi plugs
- T198126; Battery charger, incl. power supply with multi plugs T6xx
- T198506; Li-Ion Battery pack 3.7V 29Wh
- T911230ACC; Memory card SDHC 4 GB
- 1910423; USB cable Std A <-> Mini-B
- T198509; Cigarette lighter adapter kit, 12 VDC, 1.2 m/3.9 ft.
- T910930ACC; HDMI type C to DVI cable 1.5 m
- T910891ACC; HDMI type C to HDMI type A cable 1.5 m
- T198625ACC; Hard transport case for T6xx series
- T198495; Pouch for FLIR T6xx and T4xx series
- T198497; Large eyecup
- T198498; Tripod Adapter
- T198499; Neck strap
- T197771ACC; Bluetooth Headset
- T911093; Tool belt
- 19250-100; IR Window 2 in
- 19251-100; IR Window 3 in.
- 19252-100; IR Window 4 in.
- 19250-200; SS IR Window 2 in.
- 19251-200; SS IR Window 3 in.
- 19252-200; SS IR Window 4 in.
- T198586; FLIR Reporter Professional (license only)
- T198584; FLIR Tools

FLIR T650sc 25° (incl. Wi-Fi)

P/N: 55904-7823

#55904-7823; r. /23380; en-US

- T198583; FLIR Tools+ (license only)
- DSW-10000; FLIR IR Camera Player
- APP-10002; FLIR Tools Mobile (Android Application)
- APP-10004; FLIR Tools (MacOS Application)
- T198697; FLIR ResearchIR Max + HSDR 4
- T199014; FLIR ResearchIR Max + HSDR 4
- T199044; FLIR ResearchIR Max + HSDR 4 Upgrade
- T198696; FLIR ResearchIR Max 4
- T199013; FLIR ResearchIR Max 4
- T199043; FLIR ResearchIR Max 4 Upgrade
- T198731; FLIR ResearchIR Standard 4
- T199012; FLIR ResearchIR Standard 4
- T199042; FLIR ResearchIR Standard 4 Upgrade

FLIR E4, E5, E6, E8 with MSX® Enhancement

- Display: 3” color LCD
- On-board 640 x 480 Digital Camera
- Easy-to-use, weighs only 1.2lbs
- 2% accuracy
- File format: Radiometric jpg
- Swappable Li-ion Battery with 4 hour life
- Spot Measurement mode
- Simultaneous storage of IR/Visual/MSX images
- Picture in Picture image (E6 and E8)
- Manual level and span thermal tuning (E6 and E8)
- Area Box Measurement mode (E5, E6 and E8)

Each includes power supply/charger with four plugs, rechargeable battery, FLIR Tools software, USB cable, and hard transport case. E8 also includes extra battery and external battery charger.

FLIR E4
- 4,800 pixels (80 x 60)

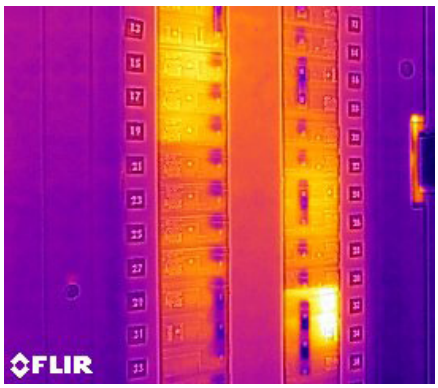
FLIR E5
- 10,800 pixels (120 x 90)

FLIR E6
- 19,200 pixels (160 x 120)

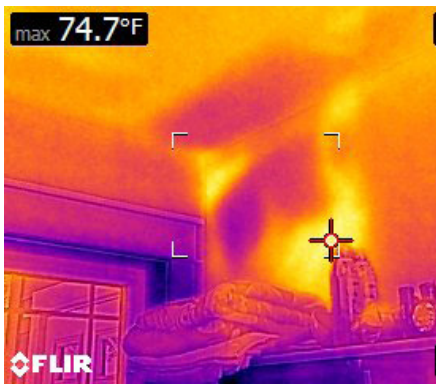
FLIR E8
- 76,800 pixels (320 x 240)

New Exclusive MSX Thermal Imaging Technology Made Affordable for Everyday Use

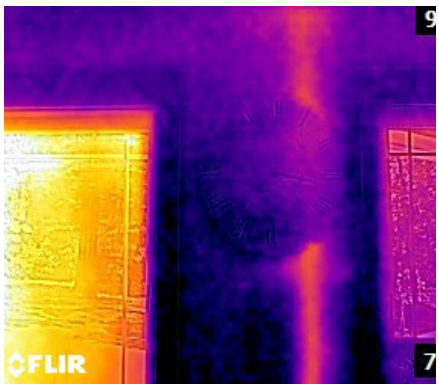
What is MSX?
Multi-Spectral Dynamic Imaging (MSX) for easier interpretation of an image - adds visible spectrum definition to IR images by detecting the edges of objects and including that detail in the thermal image. Text becomes clearly visible so that you can read a label or identifier within the IR image. This exclusive function provides extraordinary thermal detail that instantly highlights and orients problem locations and eliminates the need to refer back to a visual image for detail.



Breaker Panel
E8 with MSX



Missing Insulation – Summer Day
E6 with MSX



Warm Drain Pipe in Wall
E4 with MSX

Imaging Specifications

FEATURES	FLIR E4	FLIR E5	FLIR E6	FLIR E8
IR Pixel Resolution	4,800 (80 x 60)	10,800 (120 x 90)	19.200 (160 x 120)	76,800 (320 x 240)
Thermal Sensitivity	<0.15°C	<0.10°C	<0.06°C	<0.06°C
Temperature Range	-4 to 482°F (-20 to 250°C)			
Measurement modes	Centerspot	Centerspot, Area Box, Auto Hot/Cold detection	Centerspot, Area Box, Auto Hot/Cold detection	Centerspot, Area Box, Auto Hot/Cold detection
Frame Rate	9Hz			
Field of View	45° x 34°			
Focus	Focus free			
Auto Hot/Cold Detection	No	Auto min/max markers within area	Auto min/max markers within area	Auto min/max markers within area

Included in All Models

Additional Accessories Included with E8

Optional Accessories

Ordering Information

63901-0101 ..... FLIR E4 Compact Thermal Imaging Infrared Camera with MSX® Enhancement (80x60)
63901-0101-NIST..... FLIR E4 with Certificate Traceable to NIST

63905-0501..... FLIR E5 Compact Thermal Imaging Infrared Camera with MSX® Enhancement (120x90)
63905-0501-NIST ..... FLIR E5 with Certificate Traceable to NIST

63902-0202..... FLIR E6 Compact Thermal Imaging Infrared Camera with MSX® Enhancement (160x120)
63902-0202-NIST ..... FLIR E6 with Certificate Traceable to NIST

63903-0303..... FLIR E8 Compact Thermal Imaging Infrared Camera with MSX® Enhancement (320x240)
63903-0303-NIST..... FLIR E8 with Certificate Traceable to NIST

ACCESSORIES
T198529 ..... Pouch
T198530 ..... Replacement battery
T198531 ..... External battery charger
T198532..... Car Charger
T198534..... Power supply/charger with EU, UK, US and AU plugs
T198533..... USB cable
T198528..... Hard Transport Case

5-10-2 Protection

10-Year Detector Protection
5-Year Battery
2-Year Parts & Labor

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Av. Antonio Bardella
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www.flir.com
NASDAQ: FLIR

Appendix E

Plasma device

GAR CUT 2500
Gar Cut

Ref :45400000 1/2

Main function:
Compressed air blown electric plasma cutting.
Electronic cutting power adjustment. Cutting of all kinds of electricity conductor materials: Steel, stainless steel, aluminium, brass, etc.

Use:
Industrial use.

Electrical power supply:
3 Ph. - 230/400V - 50/60 Hz.

Main advantages:
- Up to 25 mm thick steel cut.
- 150 A torch. (6 m) Euroconnector. Safety protection.
- Electronic continuous adjustment (20 A ÷ 75 A).
- 75 A/60% - 55A/100%.
- Consumable wear reduction (reduction Ipiloto).

The plasma arc electronic control system reverts into a balanced and stable current wave format, which, compared with traditional equipment, provides the following advantages:
- Better cutting quality.
- Electricity consumption reduction.
- Greater lifecycle of consumables.
- Fumes and noise reduction.

TECHNICAL CHARACTERISTICS. GAR CUT 2500 Ref.: 454.00.000

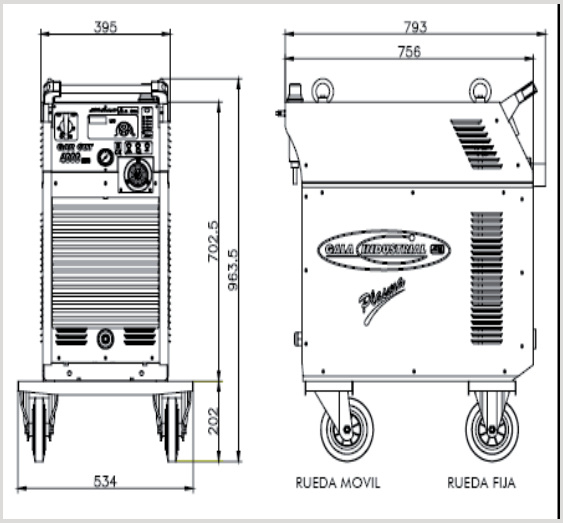
INPUT VOLTAGE U1 (50-60 Hz)	230/400 V
EFFECTIVE SUPPLY INTENSITY I1eff	40/ 23 A
TYPE OF INPUT GAS	AIR
WORKING PRESSURE	5.5 ÷ 6 Bar
RATED INPUT FLOW VOLUME	175÷210 l/min.
CUTTING INTENSITY	20 ÷ 75 A (60%)
RATED CUTTING INTENSITY (100%)	55 A
CUTTING THICKNESS RANGE (STEEL)	0.8÷25 mm.
THERMAL INSULATION	H (180º C)
VENTILATION	FORCED
MECHANICAL PROTECTION DEGREE	IP21
WEIGHT (WITHOUT WINDER)	135 kg.

APPLICATION STANDARD EN 60974

GAR CUT 2500
Gar Cut

Referencia:45400000 2/2

CIF A- 50 /045319 50.014 ZARAGOZA - SPAIN				**GAR CUT**	
TYP: GAR CUT 2500 REF:454.00.000					
3 ~		UNE-EN 60974-1: 00			
		20A /88V - 75A /140 V			
		X		60%	100%
S	U_0 250 V	I_2		75 A	55 A
		U_2		140 V	140 V
3 ~ 50/60 Hz	Cos phi = 0,65				
	U_1 230 V	I_{1max} =51 A		I_{1eff} =40 A	
	400 V	I_{1max} =30 A		I_{1eff} =23 A	
IP 21					



PLASMA CUT P-700 (400-440 V – 50/60 Hz)

CORTE POR PLASMA INVERTER

Ref. 46300000 FT46300000v2 13-08-2014 Pág. 1/1

CARACTERÍSTICAS GENERALES

Descripción:

Corte por plasma eléctrico soplado con aire comprimido. Corte de todo tipo de materiales conductores de la electricidad: Acero, acero inoxidable, aluminio, latón, étc. Sistema inverter de alta portabilidad.

Uso: Uso profesional,

	Acero	Aluminio
Máximo de calidad	20 mm	17 mm
Máximo	25 mm	20 mm
Máximo de separación	30 mm	25 mm

Alimentación eléctrica:

3.Ph 400V – 440 V ; 50/60 Hz. ±10 %

Dotación de serie:

- Fuente de Potencia.
- Antorcha manual P-100 / 6mt. Kit de consumibles de corte
- Manual de Instrucciones

Accesorios opcionales:

- Kit de consumibles de antorcha para función gubiado (descarne)
- Kit de consumibles de antorcha para función grating (corte de enrejados)
- Carro de transporte
- Antorcha recta P-100M

Ventajas principales:

- Antorcha P-100 de ignición automática SIN HF(alta frecuencia). Mayor fiabilidad de sistema electrónico. Sin perturbaciones CEM (perturbaciones electromagnéticas)
- Sistema de ignición"Back striking". Minima contaminación de consumibles. Máxima duración.
- Sistema inverter de bajo consumo eléctrico.
- Inverter de máxima potencia y velocidad de corte en equipo de gran portabilidad.
- Regulación electrónica de forma continua (20÷70A). Corte de acero hasta 30mm de espesor.
- 70 A/60 % - 55 A/100%. Equipo apto para instalaciones con pantógrafo
- Salida de control para sistemas automatizados.

CARACTERISTICAS TECNICAS	PLASMA CUT P-700 Ref. 46300000
Tensión alimentación (U1–3Ph 50/60 Hz)	400 V-440 V ± 10%
Intensidad primaria máxima Imáx	16/ 15 A
Intensidad primaria efectiva I1eff	12/ 11 A
Potencia absorbida máxima/efectiva (P1máx/P1eff)	11/8.3 KVA
Espesor de acero máximo de corte / de separación	25 mm / 30 mm
Margen de regulación de la corriente de corte I2	20 ÷ 70 A
Intensidad máxima de corte	70 A / 60% ; 55 A /100%
Compresor recomendado	4 CV – 480 l/min
Sistema semiautomático de filtro y descarga	SI
Modo de trabajo de reignición. (Corte de enrejados).	SI
Proceso de gubiado	SI
Protección sobrecalentamiento/Falta presión.	SI
Grado de protección mecánica	IP 21 S
Dimensiones (ANCHOXLARGOXALTO)	520x380X340 mm
Peso (Sin carro de transporte)	25 Kg
Según normas EN60974-1, , EN60974-7 y EN 60974-10	

Appendix F

Percussion drilling and tools

LP 18-30 E: Electric power pack, 30 lpm (8 gpm)

1807 0160 43

Create PDF sheet

Request information

Atlas Copco Construction Equipment
800 732 6762
Send an email

QUICK LINKS

Atlas Copco Print Shop
Atlas Copco Photo Archive

Product information

You can use the Atlas Copco power packs virtually anywhere: fitted with wheels and handles, they are easy to manoeuvre around building sites. They are easy to start, the noise level is low, and when they are not in use, the power packs are small enough to be stored on shelves. They are also lightweight enough that two people can lift one up and fit it in the back of a van.

Features & benefits

- Portable, compact and light weight
- High efficiency, low noise
- Low maintanance, long lifetime – moving parts move in a closed lubricated circuit
- Protective steel frame with foldable handles
- Lifting eye and cross lifting bar
- No exhaust or emission from the tools – power pack with engine can be placed away from tool
- Large return filter and replacement indicator
- Thermostatically-controlled oil cooler

Applications

- Power source for hydraulic tools

Technical data

Units: Metric Imperial

Technical Specifications	
Oil flow	7.4 - 8 gpm
Weight (incl oil)	287 lb
Length	32 inch
Width	24 inch
Height	27 inch
Max pressure	2494.65 psi
Hose included	NO
Sound power level guaranteed, Lw (2000/14/EC)*	101 dB(A)
Sound pressure level (ISO 11203)* Lp, r=1m	86 dB(A)
EHTMA class	D
Engine	
Power	11 kW
Voltage	3x400

LCD 500: Hydraulic core drill

1806 1014 38

Create PDF sheet

Request information

Atlas Copco Construction Equipment
800 732 6762
Send an email

QUICK LINKS

Atlas Copco Print Shop
Atlas Copco Photo Archive

Product information | Photos & Video

These powerful drills are ideal for jobs where there is no space for drill stands. Due to the non-kick back operation, you can still drill holes of up to 200 mm (8 in) in diameter free hand. Fully hydraulic, the tools can be used for wet diamond core drilling on the toughest jobs. The LCD core drill offers spark free operation – there are no electrical components – for safe operation inside buildings, in hazardous environments and even underwater.

Features & benefits

- High power to weight ratio
- Low vibrations
- Low kick-back
- Hydraulic torque control
- Fits in standard drill stands
- Closed hydraulic circuit
- Comes in carrying steel case as standard

Applications

- Safe handheld drilling in reinforced concrete and asphalt up to 200 mm diameter in confined spaces, for ventilation, heating, gas piping and other installations
- Works efficient also in underwater applications

Technical data

Units: Metric | Imperial

Technical Specifications	
Weight, incl. hoses	21 lb
Service weight, incl hoses and Ø 112 mm tool	29 lb
Length, without drill	16 inch
Oil flow	317 - 476 gpm
Working pressure	1160 - 2495 psi
Revolutions	600 - 900 rpm
Drill Diameter	1968 1/2 - 7952 23/32 inch
Hydraulic ports*	½" BSP
Vibration level 3 axes (ISO 28927-5), 20 lpm**	3.1 m/s²
Sound pressure level (ISO 11203)*	<70 dB(A)
EHTMA class	C/D

Product views

LH 11: Pick hammer

1801 1741 18

Create PDF sheet

Request information

Atlas Copco Construction Technique
+44 (0) 845 6010001
Send an email

QUICK LINKS

Atlas Copco Print Shop
Atlas Copco Photo Archive

Product information | Photos & Video

This D-handle hammer is ideal for horizontal work in brick, mortar and light concrete. It is one of the most powerful pick hammers on the market. With its detachable front handle, the LH 11 is a popular choice for renovation, demolition and structural alteration jobs.

Features & benefits

- Low noise levels
- Slim design
- High power to weight ratio

Applications

Breaking light concrete and brickwork

Technical data

Units: Metric | Imperial

Technical Specifications	
Shank Size (mm)	22x82,5
Shank Size (inch)	7/8x3 1/4
Weight, incl. hoses	15.5 kg
Length	650 mm
Oil flow	20 l/min
Working pressure	80 - 100 bar
Back Pressure, max	10 bar
Impact Rate	2300 blows/min
Vibration level 3 axes (ISO 28927-10)*	16.5 m/s²
Sound power level guaranteed, Lw (2000/14/EC)*	105 dB(A)
Sound pressure level (ISO 11203)* Lp, r=1m	92 dB(A)
EHTMA class	C

Product views

ELECTRIC DRILL MOTORS





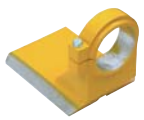
drill motor	Talpa 1800-162 only dry drilling	Talpa 1800-102-41 EL	C-BMH-152/3	DK-17 EL	C-BMS-200/3
drill-Ø from-to mm	30 - 162*	60 - 102 (162*)	20 - 152 (250*)	20 - 160 (200*)	35 - 200
rpm	920	580	530/1280/1780	540/1200/2520	385/920/1280
motor output kW	1,8	1,8	2,0	2,0	2,2
voltage V/Hz	230/50	230/50	230/50	230/50	230/50
connecting thread	M18x2,5	R½"+1¼" UNC	R½"+1¼" UNC	R½"+1¼" UNC	R½"+1¼" UNC
l/w/h mm	200/120/450	200/120/470	156/120/540	300/100/425	120/110/488
weight kg	4,6	4,6	6,8	6,3	7,3

* in abrasive material






drill motor	DK-32-EL C	C-BMS-300/3	BBM-33 L Extra	DK-52 water-cooled	SR-75 water-cooled	Beluga RX-SL high-frequency, water-cooled
drill-Ø from-to mm	50 - 350	30 - 300	45 - 450	101 - 500	150 - 900	100 - 1000
rpm	230/480/720	220/500/935	180/430/750	120/240/360	60/300	0 - 100/180/250/480
motor output kW	3,0	3,0	3,3	5,2	7,5	8,0
voltage V/Hz	230/50	230/50	230/50	400/50	400/50	400/50 (control box)
connecting thread	1¼" UNC	1¼" UNC	1¼" UNC	1¼" UNC	1¼" UNC	1¼" UNC
l/w/h mm	140/110/490	160/130/482	168/142/509	160/340/570	170/200/620	230/160/580
weight kg	11,9	12,2	13,2	22,5	19,5	4,8


motor mounting plate type B


motor mounting plate type C


motor mounting/distance plate type K (170 mm thick)

motor mounting plates and adaptor plates with selection chart		
plate	application with drill column	application with drill motor
mounting plate B	all CEDIMA drill columns except ROBO-351	Talpa 1800-162, Talpa 1800-102-41, C-BMH-152/3, DK-17, motors with adaptor collar Ø 60 mm
mounting plate C		C-BMS-200/3, C-BMS-300/3, DK-32-EL C, BBM-33 L Extra, DK-52
mounting plates J / N	P-6000	Typ J for SR-75, Typ N for Beluga RX-SL
adaptor plates M / P	P-6000	Typ M for SR-75, Typ P for Beluga RX-SL (only in connection with type K)
mounting/distance plate K	P-6000	DK-52, hydraulic drill spindle BSP-3

Demolition hammer with SDS-max GSH 5 CE Professional

Demolition hammer with SDS-max
GSH 5 CE Professional

Unbeatably powerful with up to 40% less vibration

Technical data	
Rated power input	1.150 W
Max. impact energy	8,3 J
Impact rate at rated speed	1.300 – 2.900 bpm
Weight	6,2 kg
Toolholder	SDS-max
Drilling range	
Functions	
Constant Electronic	✓
Electronic	✓
Part number	0 611 321 070

H41MB
Demolition Hammer

Features

- For SDS max bit shank
- Power input 930W
- Easy to change tool by single-step holder
- Variable lock mechanism to adjust tool at 12-step angle
- Functional and robust design

Specifications

Power Input	930W
Full Load Impact Rate	3,000/min.
Bit Shank	SDS max
Overall Length	430mm (17")
Weight	5.1kg (11.2lbs.)
Standard Accessories	Side Handle, Bull Point, Carrying Case

Note: Manufacturer reserves the right to change specifications of parts and accessories without notice. Specifications and standard accessories may vary from country to country.

Appendix G

Hollow augner tools

HOLLOW STEM AUGERS

Overview:

Hollow stem augers are commonly used in the geotechnical, environmental, and construction drilling markets. They work much like a temporary casing in that the centers of the augers are open, thus allowing work to commence inside the augers using soil sampling equipment, down the hole hammers and coring tools, or for installing wells, tie back rods or cables and more.

Drilling:

Hollow stem augers are commonly used with a plug assembly for the purpose of preventing soil from entering the inside (hollow stem) of the augers. The plug with pilot bit is held in place by a center drill rod and rod-to-cap adapter, bolted in the drive cap. This allows the pilot bit to turn in tandem with the auger. When the desired hole depth is achieved, the center rod, plug and pilot bit are removed, allowing sampling, coring or other work to commence inside the auger.

In water bearing sands, a flex plug can be used to prevent material from entering the hollow stem auger I.D., while continuing to allow for the sampling tube to pass through.

For applications not requiring sampling, a knock out plug can be inserted into the end of the cutterhead to eliminate the use of drill rods. When the desired hole depth is achieved, the plug may be knocked out of the bottom of the auger string to allow for well installation.

HOLLOW STEM AUGERS

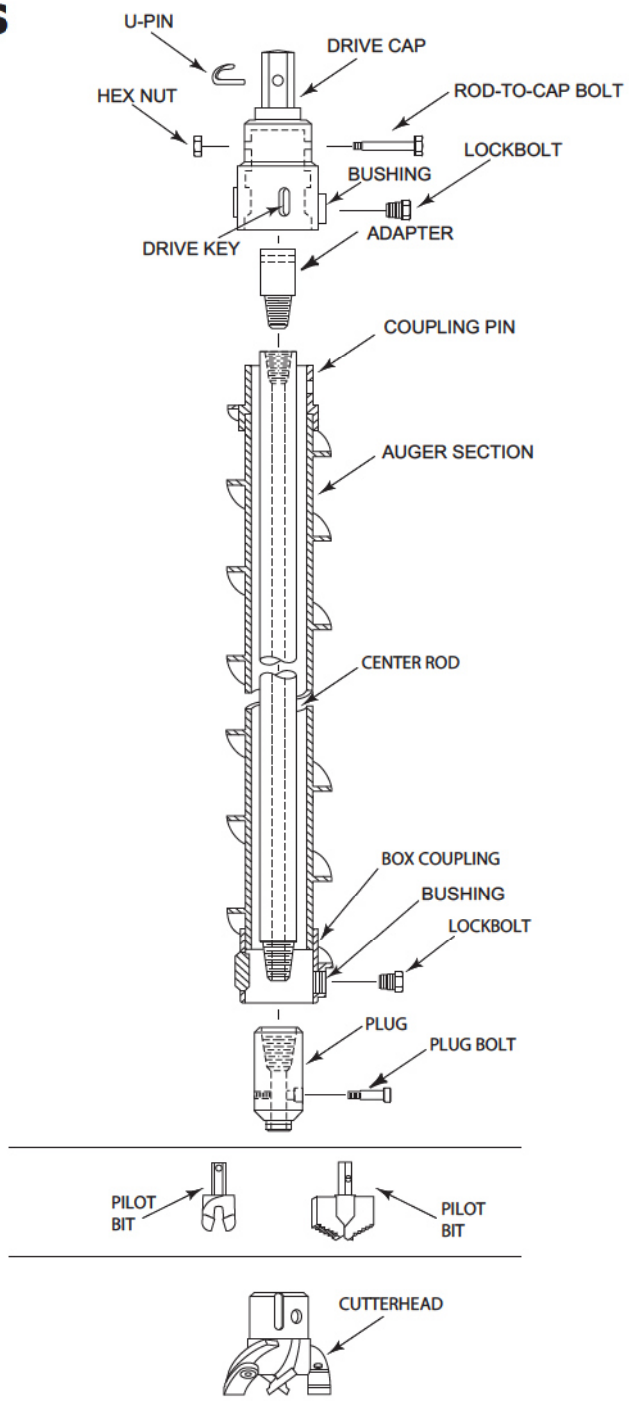
Hole Products offers standard and heavy duty hollow stem augers in five foot lengths (custom lengths available), sizes ranging from 2 1/4" through 10 1/4" (identified by the auger I.D.) and with a 2 key or 3 key drive system.

Diedrich and Acker octagonal style hollow stem augers are available upon request.

Standard duty augers are generally recommended for shallower drilling, (less than 70'), and for lower torque drill rigs.

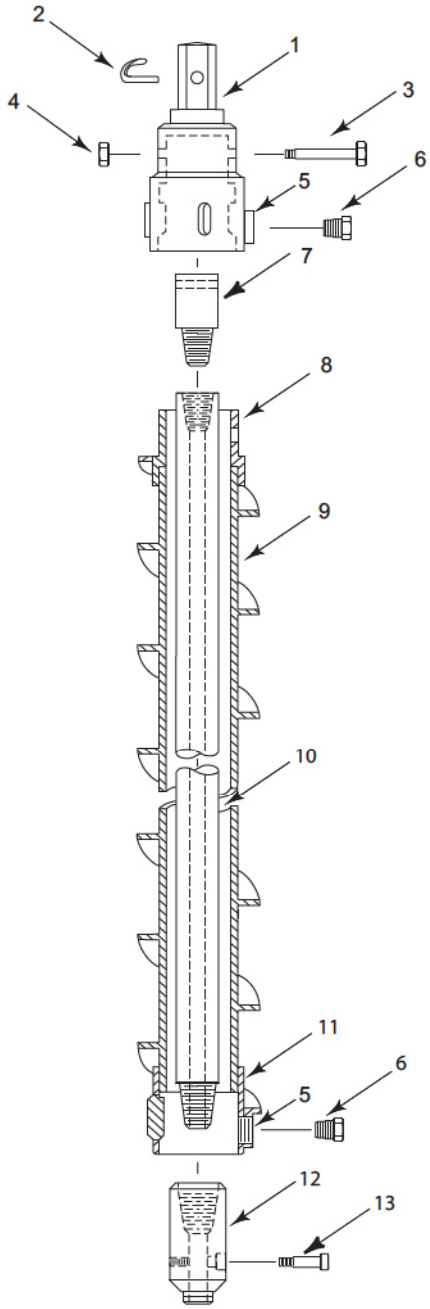
Heavy duty augers feature heavier tool joints and larger auger bolts and drive keys. HD augers are generally recommended for drilling in excess of 70', and for higher torque drill rigs.

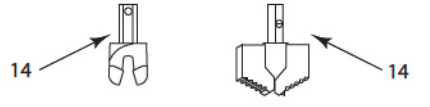
All augers are quality crafted from premium materials and include continuous hard faced flighting, to ensure performance and longevity in even the most demanding drilling conditions.

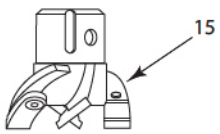


HOLLOW STEM AUGER SPECIFICATIONS							
AUGER I.D.		FLIGHT O.D.		CUTTERHEAD O.D.		WEIGHT	
INCHES	MM	INCHES	MM	INCHES	MM	LB	KG
2 1/4	57	5 5/8	143	6 1/2	165	52	23.0
3 1/4	83	6 1/2	165	7 1/4	184	69	31.3
4 1/4	108	7 5/8	194	8 1/2	216	90	40.8
6 1/4	159	9 5/8	244	11	279	105	47.6
6 5/8	168	10	254	11	279	105	47.6
8 1/4	210	12	305	13 3/4	349	144	65.3
10 1/4	260	14 1/4	362	15	381	256	116.1

HOLLOW STEM AUGERS
2 1/4" - 2 KEY







2 1/4" HOLLOW STEM AUGERS		
ITEM	PART # 2 KEY (SD)	DESCRIPTION
1	1350001	DRIVE CAP: 1 1/8" HEX
1	1350000	DRIVE CAP: 1 5/8" HEX
1	1350002	DRIVE CAP: 2" HEX
2	1301025	U-PIN 1 1/8" STANDARD*
2	1301000	U-PIN 1 5/8" STANDARD*
2	1301001	U-PIN 2" STANDARD*
3	1301050	ROD-TO-CAP BOLT
4	1301065	HEX NUT
5	1250051	BUSHING, W/ OUT FLANGE
5	1250052	BUSHING W/ FLANGE
6	1301005	AUGER BOLT
7	1250210	ADAPTER: AW ROD TO DRIVE CAP**
7	1250088	ADAPTER: AWJ ROD TO DRIVE CAP**
7	1250215	ADAPTER: NW ROD TO DRIVE CAP**
7	1250089	ADAPTER: NWJ ROD TO DRIVE CAP**
8	1250220	PIN COUPLING, HEAT-TREATED (REPAIR ONLY)
9	1450000	AUGER SECTION - 5'0 (1.5M)***
10	3050010	AW CENTER ROD - 5'0 (1.5M)
10	3050000	AWJ CENTER ROD - 5'0 (1.5M)
10	2150020	NW CENTER ROD - 5'0 (1.5M)
10	3050020	NWJ CENTER ROD - 5'0 (1.5M)
11	1250225	BOX COUPLING (REPAIR ONLY)
12	1250230	PLUG - 13/16" (29MM) HEX TO AW BOX
12	1250235	PLUG - 13/16" (29MM) HEX TO AWJ BOX
12	1250240	PLUG - 13/16" (29MM) HEX TO NW BOX
12	1250245	PLUG - 13/16" (29MM) HEX TO NWJ BOX
13	1250250	PLUG BOLT
14	1250255	PILOT BIT, 2-PRONG, 13/16" (29MM) HEX
15	---	CUTTERHEAD****

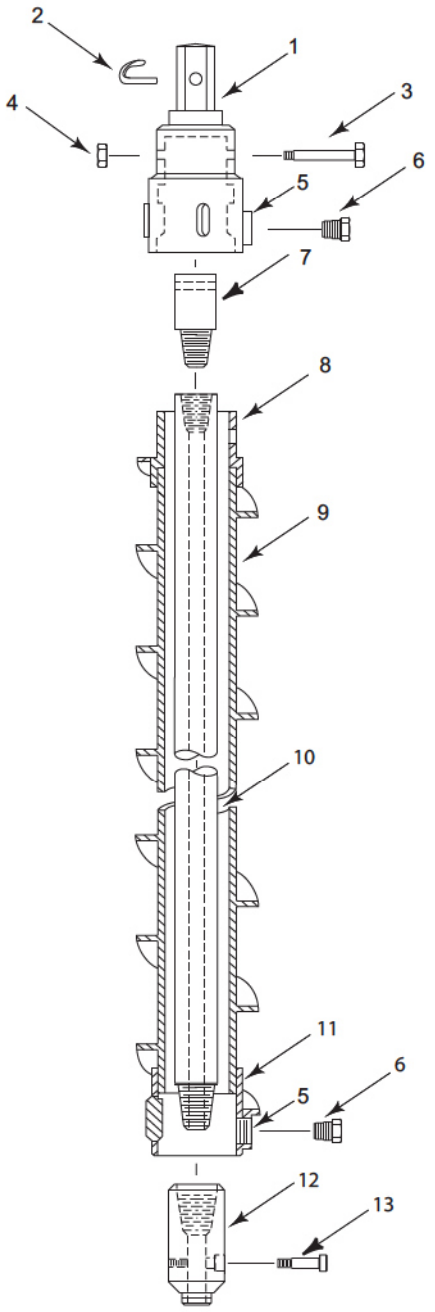
** Other u-pins available. See page 13.*

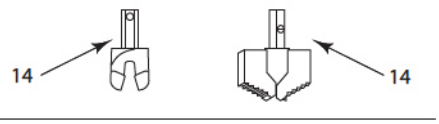
*** Other rod-to-cap adapters available upon request.*

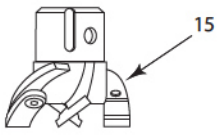
**** Additional lengths available.*

***** Refer to Cutterhead Section on page 14.*

HOLLOW STEM AUGERS
3 1/4" - 2 KEY AND 3 KEY







3 1/4" HOLLOW STEM AUGERS				
ITEM	PART #			DESCRIPTION
	2 KEY (SD)	2 KEY (HD)	3 KEY (SD)	
1	1350005	1350028	1350024	DRIVE CAP: 1 5/8" HEX
1	1350035	1350017	1350026	DRIVE CAP: 2" HEX
2	1301025	1301025	1301025	U-PIN 1 1/8" STANDARD*
2	1301000	1301000	1301000	U-PIN 1 5/8" STANDARD*
2	1301001	1301001	1301001	U-PIN 2" STANDARD*
3	1301055	1301055	1301055	ROD-TO-CAP BOLT
4	1301070	1301070	1301070	HEX NUT
5	1250051	1250130	1250305	REPAIR BUSHING W/OUT FLANGE
6	1301005	1301015	1301010	AUGER BOLT
7	1250210	1250210	1250210	ADAPTER: AW ROD TO DRIVE CAP**
7	1250088	1250088	1250088	ADAPTER: AWJ ROD TO DRIVE CAP**
7	1250215	1250215	1250215	ADAPTER: NW ROD TO DRIVE CAP**
7	1250089	1250089	1250089	ADAPTER: NWJ ROD TO DRIVE CAP**
8	1250135	1250260	1250265	PIN COUPLING, HEAT-TREATED (REPAIR ONLY)
9	1450005	1450006	1450015	AUGER SECTION - 5'0 (1.5M)***
10	3050010	3050010	3050010	AW CENTER ROD - 5'0 (1.5M)
10	3050000	3050000	3050000	AWJ CENTER ROD - 5'0 (1.5M)
10	2150020	2150020	2150020	NW CENTER ROD - 5'0 (1.5M)
10	3050020	3050020	3050020	NWJ CENTER ROD - 5'0 (1.5M)
11	1250270	1250275	1250280	BOX COUPLING (REPAIR ONLY)
12	1250285	1250285	1250285	PLUG - 1 1/8" (29MM) HEX TO AW BOX
12	1250290	1250290	1250290	PLUG - 1 1/8" (29MM) HEX TO AWJ BOX
12	1250295	1250295	1250295	PLUG - 1 1/8" (29MM) HEX TO NW BOX
12	1251008	1251008	1251008	PLUG - 1 1/8" (29MM) HEX TO NWJ BOX
13	1250300	1250300	1250300	PLUG BOLT
14	1251010	1251010	1251010	PILOT BIT, 2-PRONG, 1 1/8" (29MM) HEX
14	1250590	1250590	1250590	PILOT BIT, 3-WING, 1 1/8" (29MM) HEX
15	---	---	---	CUTTERHEADS****

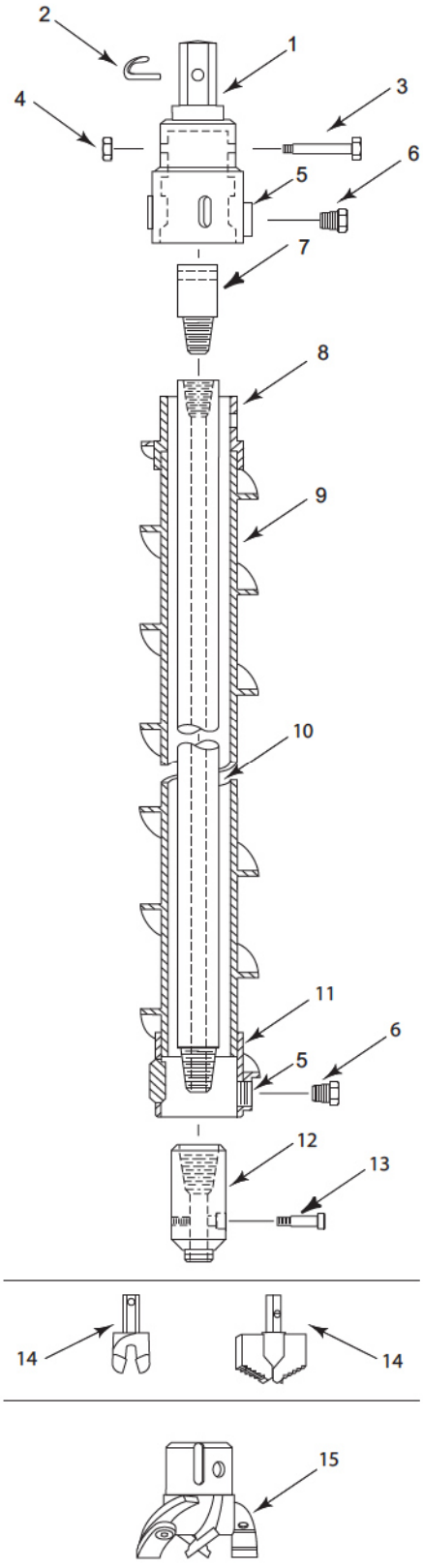
** Other u-pins available. See page 13.*

*** Other rod-to-cap adapters available upon request.*

**** Additional lengths available.*

***** Refer to Cutterhead Section on page 14.*

HOLLOW STEM AUGERS
4 1/4" - 2 KEY AND 3 KEY



4 1/4" HOLLOW STEM AUGERS				
ITEM	PART #			DESCRIPTION
	2 KEY (SD)	2 KEY (HD)	3 KEY (SD)	
1	1350015	1350022	1350021	DRIVE CAP: 1 5/8" HEX
1	1350003	1350016	1350040	DRIVE CAP: 2" HEX
2	1301025	1301025	1301025	U-PIN 1 1/8" STANDARD*
2	1301000	1301000	1301000	U-PIN 1 5/8" STANDARD*
2	1301001	1301001	1301001	U-PIN 2" STANDARD*
3	1301060	1301060	1301060	ROD-TO-CAP BOLT
4	1301075	1301075	1301075	HEX NUT
5	1250051	1250130	1350305	REPAIR BUSHING
6	1301005	1301015	1301010	AUGER BOLT
7	1250210	1250210	1250210	ADAPTER: AW ROD TO DRIVE CAP**
7	1250088	1250088	1250088	ADAPTER: AWJ ROD TO DRIVE CAP**
7	1250215	1250215	1250215	ADAPTER: NW ROD TO DRIVE CAP**
7	1250089	1250089	1250089	ADAPTER: NWJ ROD TO DRIVE CAP**
8	1251012	1250310	1250315	PIN COUPLING, HEAT-TREATED (REPAIR ONLY)
9	1450010	1450012	1450011	AUGER SECTION - 5'0 (1.5M)***
10	3050010	3050010	3050010	AW CENTER ROD - 5'0 (1.5M)
10	3050000	3050000	3050000	AWJ CENTER ROD - 5'0 (1.5M)
10	2150020	2150020	2150020	NW CENTER ROD - 5'0 (1.5M)
10	3050020	3050020	3050020	NWJ CENTER ROD - 5'0 (1.5M)
11	1251013	1250320	1250325	BOX COUPLING (REPAIR ONLY)
12	1250330	1250330	1250330	PLUG - 1 1/8" (29MM) HEX TO AW BOX
12	1250335	1250335	1250335	PLUG - 1 1/8" (29MM) HEX TO AWJ BOX
12	1250340	1250340	1250340	PLUG - 1 1/8" (29MM) HEX TO NW BOX
12	1251006	1251006	1251006	PLUG - 1 1/8" (29MM) HEX TO NWJ BOX
13	1250345	1250345	1250345	PLUG BOLT
14	1251007	1251007	1251007	PILOT BIT, 2-PRONG, 1 1/8" (29MM) HEX
14	1250595	1250595	1250595	PILOT BIT, 3-WING, 1 1/8" (29MM) HEX
15	---	---	---	CUTTERHEADS****

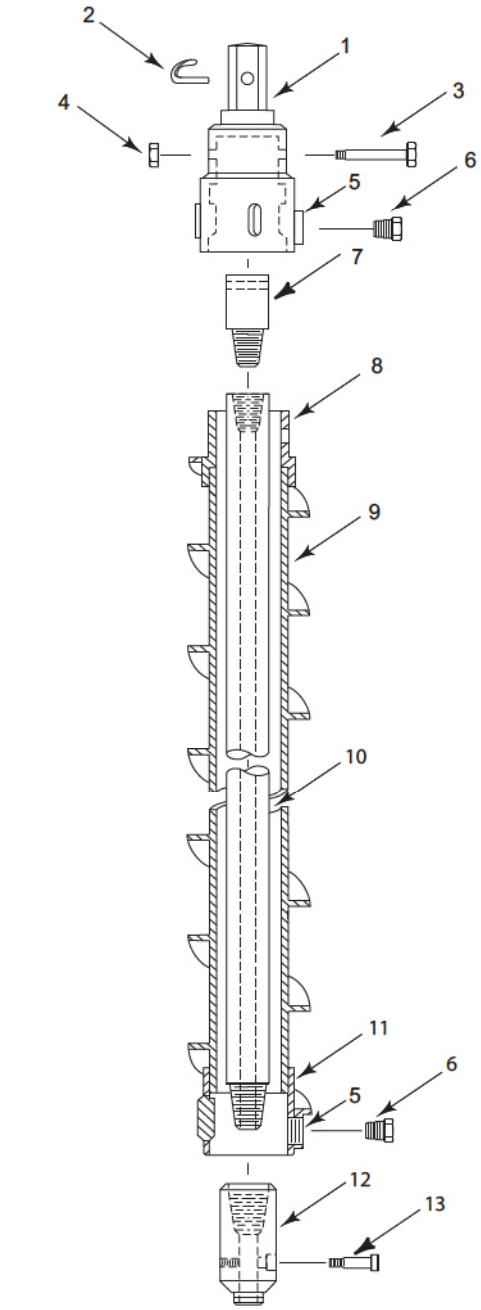
** Other u-pins available. See page 13.*

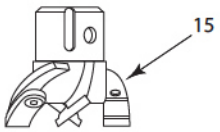
*** Other rod-to-cap adapters available upon request.*

**** Additional lengths available.*

***** Refer to Cutterhead Section on page 14.*

HOLLOW STEM AUGERS
6 1/4" - 2 KEY





6 1/4" HOLLOW STEM AUGERS			
ITEM	PART #		DESCRIPTION
	2 KEY (SD)	2 KEY (HD)	
1	1350018	1350045	DRIVE CAP: 1 5/8" HEX
1	1350030	1350033	DRIVE CAP: 2" HEX
2	1301025	1301025	U-PIN 1 1/8" STANDARD*
2	1301000	1301000	U-PIN 1 5/8" STANDARD*
2	1301001	1301001	U-PIN 2" STANDARD*
3	1301080	1301080	ROD-TO-CAP BOLT
4	1301090	1301090	HEX NUT
5	1250051	1250130	REPAIR BUSHING W/OUT FLANGE
6	1301005	1301015	AUGER BOLT
7	1250210	1250210	ADAPTER: AW ROD TO DRIVE CAP**
7	1250088	1250088	ADAPTER: AWJ ROD TO DRIVE CAP**
7	1250215	1250215	ADAPTER: NW ROD TO DRIVE CAP**
7	1250089	1250089	ADAPTER: NWJ ROD TO DRIVE CAP**
8	1250350	1250355	PIN COUPLING, HEAT-TREATED (REPAIR ONLY)
9	1450030	1450029	AUGER SECTION - 5'0. (1.5M)***
10	3050010	3050010	AW CENTER ROD - 5'0 (1.5M)
10	3050000	3050000	AWJ CENTER ROD - 5'0 (1.5M)
10	2150020	2150020	NW CENTER ROD - 5'0 (1.5M)
10	3050020	3050020	NWJ CENTER ROD - 5'0 (1.5M)
11	1250365	1250370	BOX COUPLING (REPAIR ONLY)
12	1250380	1250380	PLUG - 1 1/8" (29MM) HEX TO AW BOX
12	1250385	1250385	PLUG - 1 1/8" (29MM) HEX TO AWJ BOX
12	1250390	1250390	PLUG - 1 1/8" (29MM) HEX TO NW BOX
12	1250395	1250395	PLUG - 1 1/8" (29MM) HEX TO NWJ BOX
13	1250400	1250400	PLUG BOLT
14	1250405	1250405	PILOT BIT, 2-PRONG, 1 1/8" (29MM) HEX
14	1250580	1250580	PILOT BIT, 3-WING, 1 1/8" (29MM) HEX
15	---	---	CUTTERHEADS****

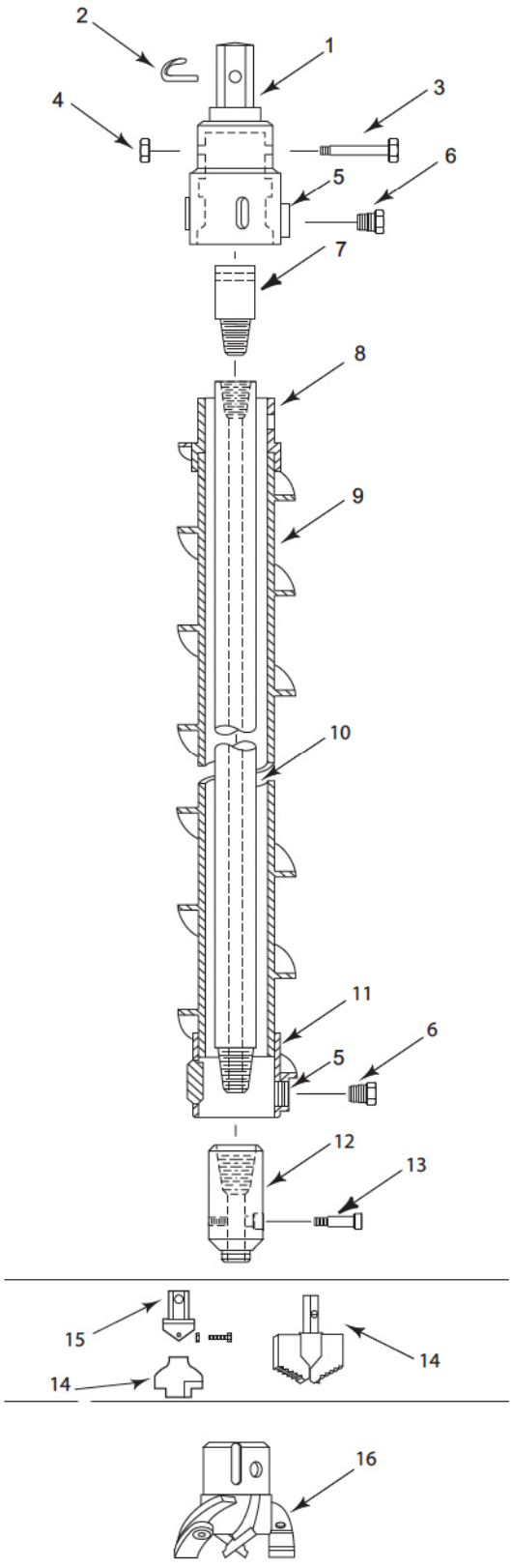
** Other u-pins available. See page 13.*

*** Other rod-to-cap adapters available upon request.*

**** Additional lengths available.*

***** Refer to Cutterhead Section on page 14.*

HOLLOW STEM AUGERS
6 5/8" - 3 KEY



6 5/8" HOLLOW STEM AUGERS		
ITEM	PART # 3 KEY (SD)	DESCRIPTION
1	1350023	DRIVE CAP: 1 5/8" HEX
1	1350050	DRIVE CAP: 2" HEX
2	1301025	U-PIN 1 1/8" STANDARD*
2	1301000	U-PIN 1 5/8" STANDARD*
2	1301001	U-PIN 2" STANDARD*
3	1301085	ROD-TO-CAP BOLT
4	1301095	HEX NUT
5	1250305	REPAIR BUSHING W/OUT FLANGE
6	1301010	AUGER BOLT
7	1250210	ADAPTER: AW ROD TO DRIVE CAP**
7	1250088	ADAPTER: AWJ ROD TO DRIVE CAP**
7	1250215	ADAPTER: NW ROD TO DRIVE CAP**
7	1250089	ADAPTER: NWJ ROD TO DRIVE CAP**
8	1250360	PIN COUPLING, HEAT-TREATED (REPAIR ONLY)
9	1450031	AUGER SECTION - 5'0. (1.5M)***
10	3050010	AW CENTER ROD - 5'0 (1.5M)
10	3050000	AWJ CENTER ROD - 5'0 (1.5M)
10	2150020	NW CENTER ROD - 5'0 (1.5M),
10	3050020	NWJ CENTER ROD - 5'0 (1.5M)
11	1250375	BOX COUPLING (REPAIR ONLY)
12	1250410	PLUG - 1 1/8" (29MM) HEX TO AW BOX
12	1250415	PLUG - 1 1/8" (29MM) HEX TO AWJ BOX
12	1250420	PLUG - 1 1/8" (29MM) HEX TO NW BOX
12	1250425	PLUG - 1 1/8" (29MM) HEX TO NWJ BOX
13	1250430	PLUG BOLT
14	1250435	PILOT BIT, 2-PRONG, 1 1/8" (29MM) HEX
14	1250585	PILOT BIT, 3-WING, 1 1/8" (29MM) HEX
15	1250440	PILOT BIT SHANK, 1 5/8" (41MM) HEX
16	---	CUTTERHEAD****

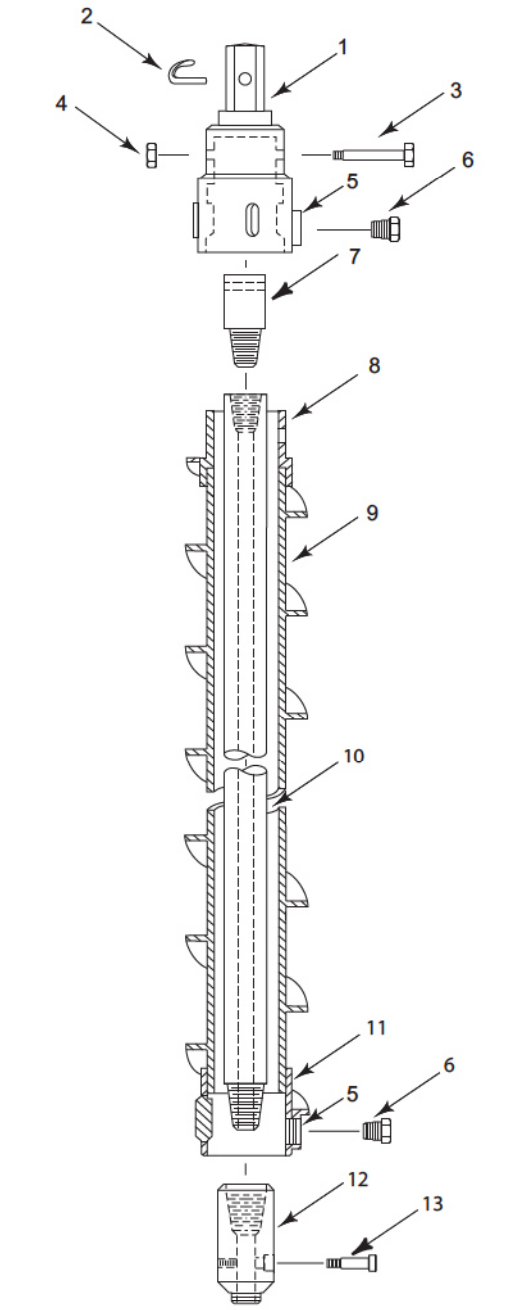
** Other u-pins available. See page 13.*

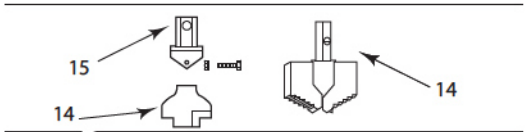
*** Other rod-to-cap adapters available upon request.*

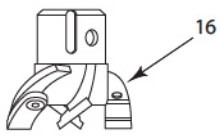
**** Additional lengths available.*

***** Refer to Cutterhead Section on page 14.*

HOLLOW STEM AUGERS
8 1/4" - 2 KEY AND 3 KEY







8 1/4" HOLLOW STEM AUGERS			
ITEM	PART #		DESCRIPTION
	2 KEY (HD)	3 KEY (SD)	
1	1350055	1350013	DRIVE CAP: 1 5/8" HEX
1	1350060	1350012	DRIVE CAP: 2" HEX
2	1301025	1301025	U-PIN 1 1/8" STANDARD*
2	1301000	1301000	U-PIN 1 5/8" STANDARD*
2	1301001	1301001	U-PIN 2" STANDARD*
3	1301100	1301100	ROD-TO-CAP BOLT
4	1301105	1301105	HEX NUT
5	1250130	1250305	REPAIR BUSHING W/OUT FLANGE
6	1301016	1301021	AUGER BOLT
7	1250210	1250210	ADAPTER: AW ROD TO DRIVE CAP**
7	1250088	1250088	ADAPTER: AWJ ROD TO DRIVE CAP**
7	1250215	1250215	ADAPTER: NW ROD TO DRIVE CAP**
7	1250089	1250089	ADAPTER: NWJ ROD TO DRIVE CAP**
8	1250450	1250455	PIN COUPLING, HEAT-TREATED (REPAIR ONLY)
9	1450040	1450026	AUGER SECTION - 5'0 (1.5M)***
10	3050010	3050010	AW CENTER ROD - 5'0 (1.5M)
10	3050000	3050000	AWJ CENTER ROD - 5'0 (1.5M)
10	2150020	2150020	NW CENTER ROD - 5'0 (1.5M)
10	3050020	3050020	NWJ CENTER ROD - 5'0 (1.5M)
11	1250465	1250470	BOX COUPLING (REPAIR ONLY)
12	1250475	1250475	PLUG - 1 1/8" (29MM) HEX TO AW BOX
12	1250480	1250480	PLUG - 1 1/8" (29MM) HEX TO AWJ BOX
12	1250485	1250485	PLUG - 1 1/8" (29MM) HEX TO NW BOX
12	1250490	1250490	PLUG - 1 1/8" (29MM) HEX TO NWJ BOX
13	1250495	1250495	PLUG BOLT
14	1250500	1250500	PILOT BIT, 2-PRONG, 1 1/8" (29MM) HEX
14	1250505	1250505	PILOT BIT, 3-WING, 1 1/8" (29MM) HEX
15	1251070	1251070	PILOT BIT SHANK, 1 5/8" (41MM) HEX
16	---	---	CUTTERHEADS****

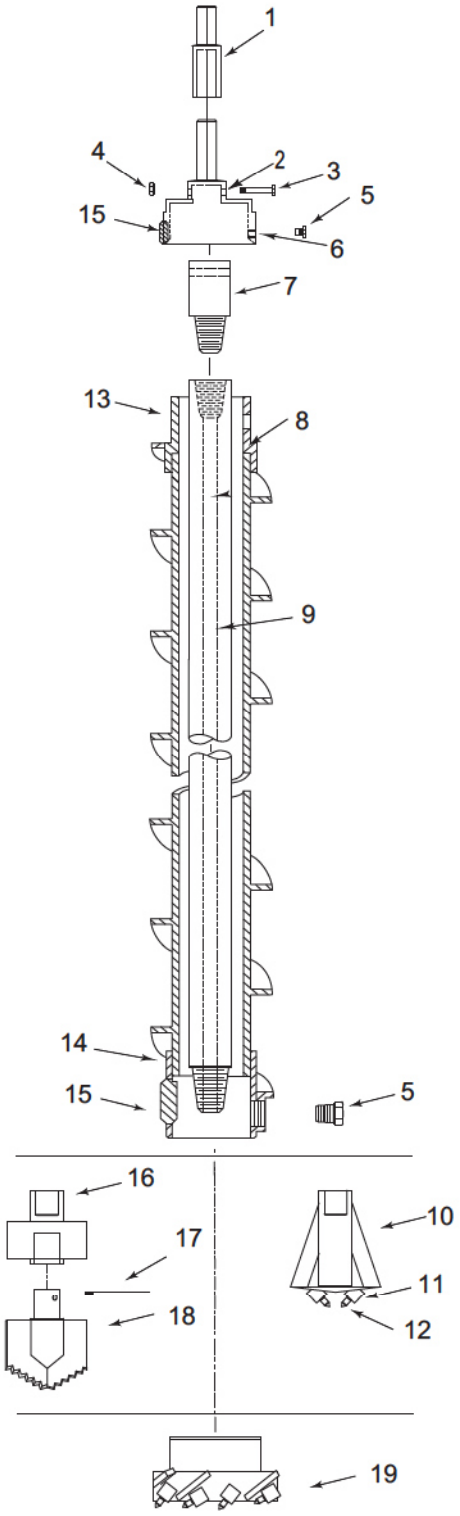
** Other u-pins available. See page 13.*

*** Other rod-to-cap adapters available upon request.*

**** Additional lengths available.*

***** Refer to Cutterhead Section on page 14.*

HOLLOW STEM AUGERS
10 1/4" - 3 KEY



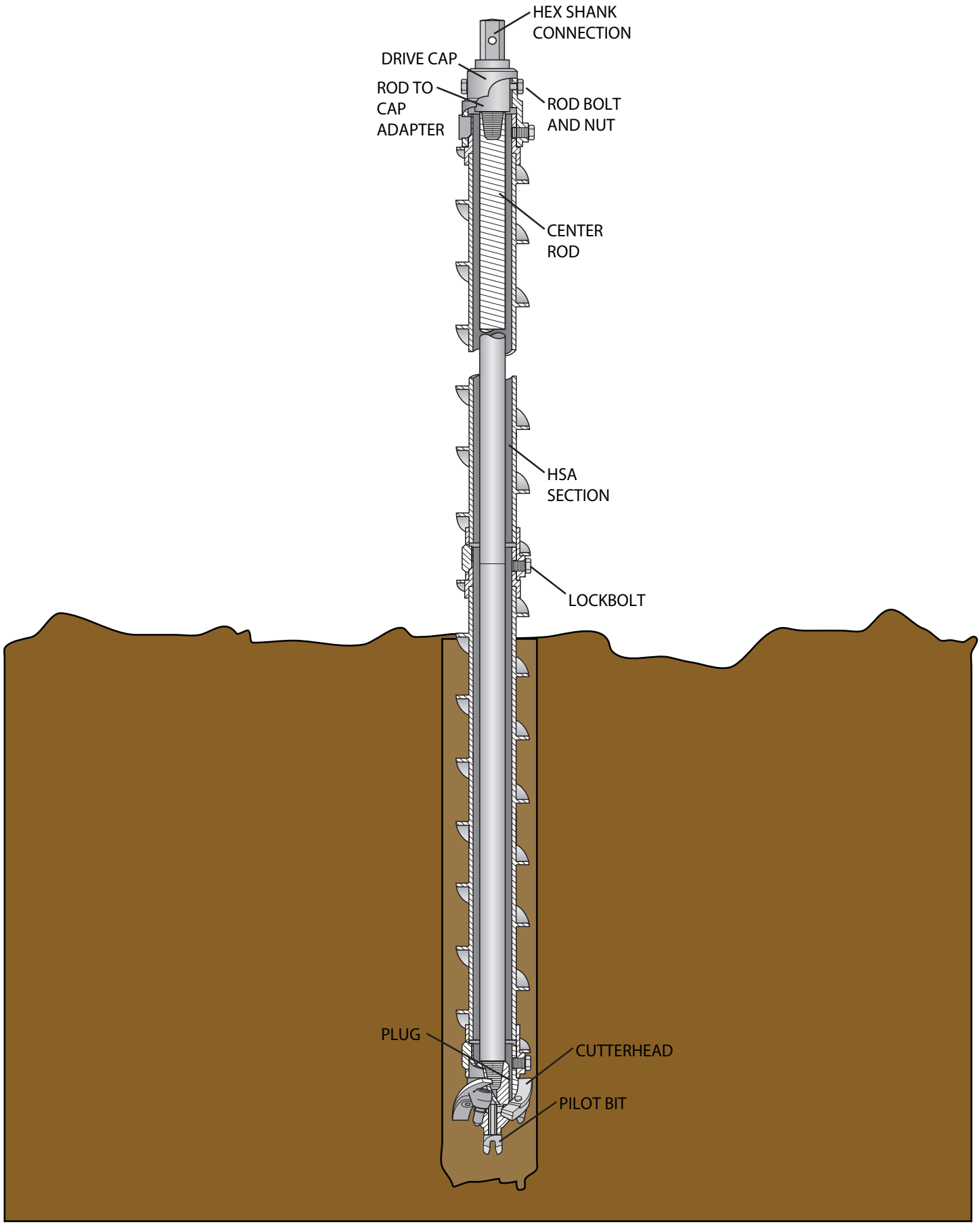
10 1/4" HOLLOW STEM AUGERS		
ITEM	PART # 3 KEY (SD)	DESCRIPTION
1	1250027	ADAPTER AUGER 1 5/8" HEX TO 2" HEX SOCKET
2	1350075	DRIVE CAP 2" HEX
3	1301120	ROD BOLT
4	1301125	ROD NUT
5	1301021	LOCKBOLT-(2 REQ.)
6	1250305	REPAIR BUSHING W/OUT FLANGE
7	1250215	ADAPTER - NW ROD TO DRIVE CAP*
7	1250089	ADAPTER - NWJ ROT TO DRIVE CAP*
8	1450034	AUGER SECTION 5'0" (1.5M)**
9	2150020	NW ROD CENTER ROD 5'0 (1.5M)
	3050020	NWJ ROD CENTER ROD 5'0 (1.5M)
10	1250520	PLUG-PILOT BIT COMBO W/TEN BULLET BITS AND BLOCKS NW ROD
	1250525	PLUG-PILOT BIT COMBO W/TEN BULLET BITS AND BLOCKS NWJ ROD
11	1501015	BIT BLOCK
12	1501010	BULLET BIT
13	1250540	REPAIR PIN
14	1250555	REPAIR BOX
15	1250510	REPAIR KEY
16	1250560	NW ROD BOX CENTER PLUG
	1250565	NWJ ROD BOX CENTER PLUG
17	1250570	PILOT BOLT
18	1250575	3 - WING PILOT BIT
19	---	CUTTERHEADS***

**Rod-to-cap adapter available upon request.*

***Additional lengths available.*

****Refer to Cutterhead Section on page 14.*

Hollow Stem Augers & Cutterheads



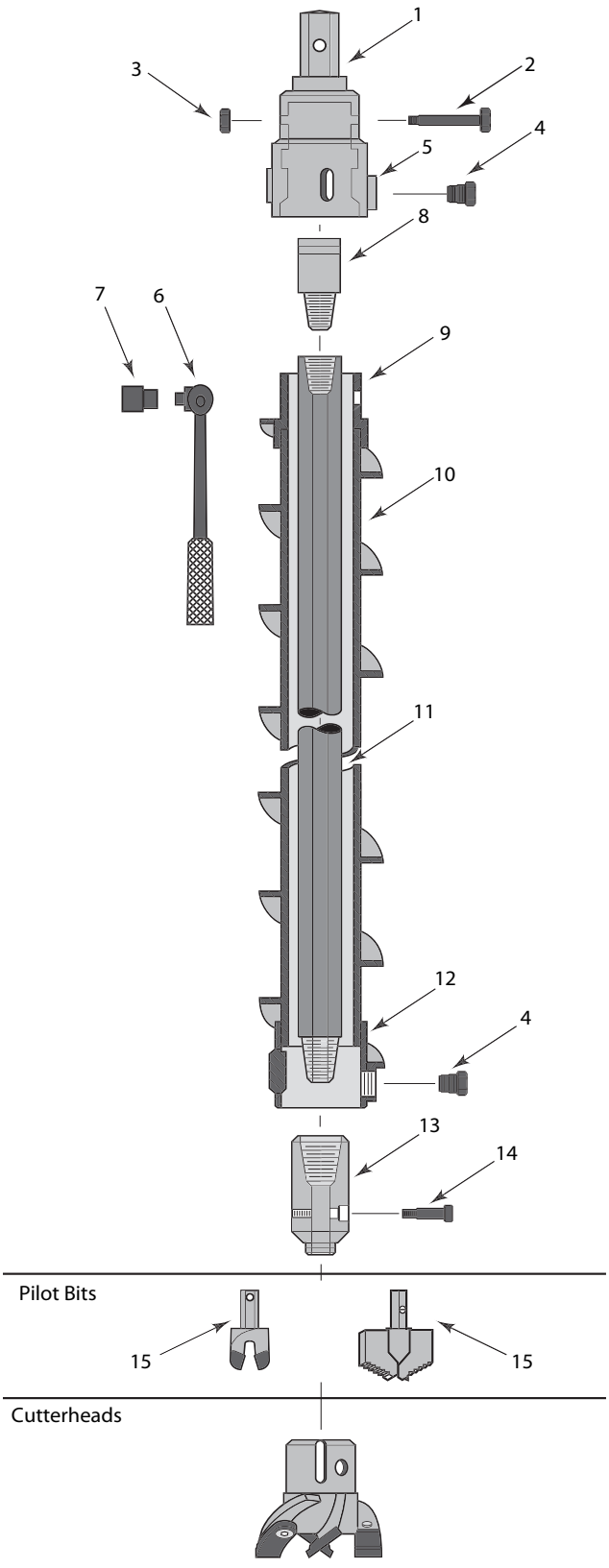
Hollow Stem Augers

3-1/4 (83mm) 3-KEY AUGER

Now with thicker flight and heat-treated pins for extended life. Predominately used for geotechnical applications such as split spoon sampling. Sizes are identified by hollow stem auger I.D. Meter length available.

6-1/2" (165mm) O.D

Component Parts

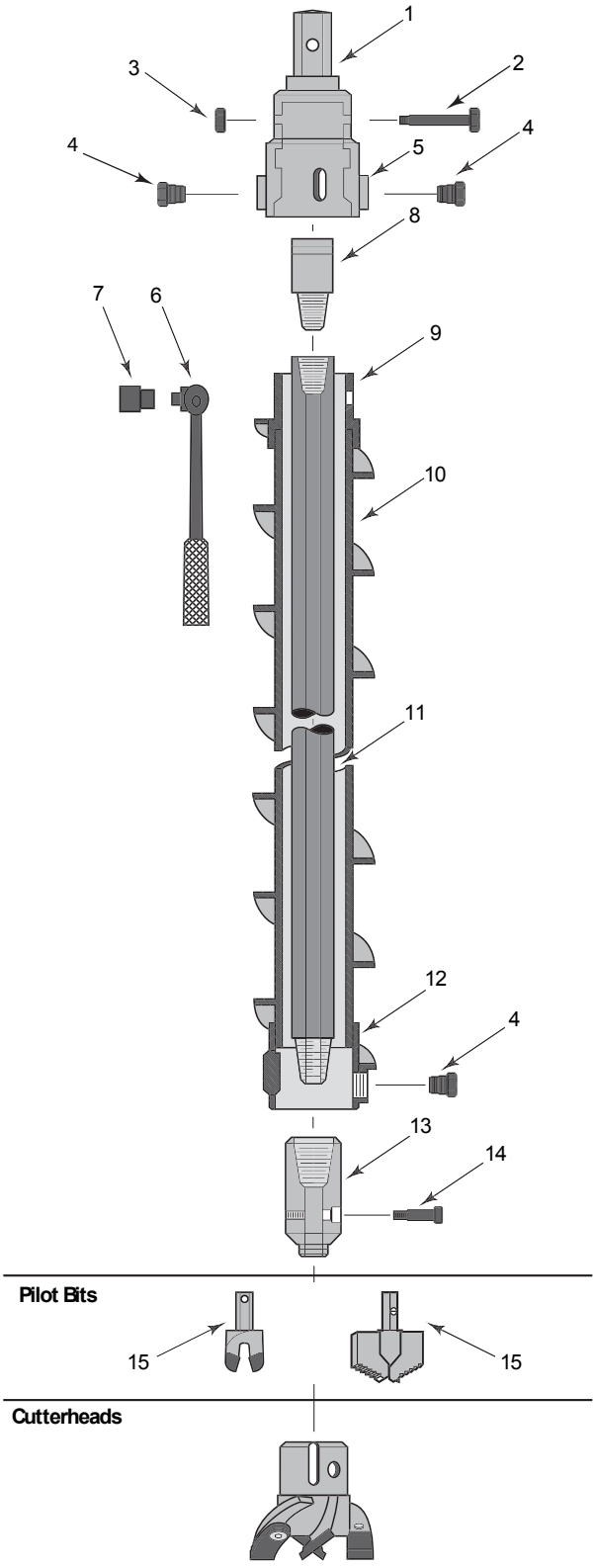


Ref	Description	Part No.	Lb/Kg
1	Drive Cap: 1-1/8. (29mm) Hex	150429	
1	Drive Cap: 1-5/8. (41mm) Hex	150292	17 (7.7)
1	Drive Cap: 2. (51mm) Hex	150322	22 (10)
2	Rod Bolt	3100-0184	
3	Hex Nut	3122-0012	
4	**Lockbolt - 1**	**217136-I**	
4	**Lockbolt - 1 Req'd (Hard Faced)**	**150307-I**	
5	Bushing, Field Replaceable	150308-I	
5	Bushing, Replaceable	150300-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod to Drive Cap	150310	5 (2.3)
8	Adapter: AWJ Rod to Drive Cap	150311	5 (2.3)
8	Adapter: NW Rod to Drive Cap	180049-03	11 (5)
8	Adapter: NWJ Rod to Drive Cap	180054-04	11 (5)
9	Coupling Pin, Heat-Treated (Repair Only)	150296	6 (2.7)
10	**Auger Section - 3'0. (.91mm)**	**150288-02**	**38 (17.2)**
10	Auger Section - 5'0. (1.5m)	150288	69 (31.3)
10	Auger Section - 5'0. (1.5m), Heavy Duty	150288-01	.85 (38.6)
11	Center Rod - 5'0. (1.5m), AW	001605	22 (10.0)
11	Center Rod - 5'0. (1.5m), AWJ	006276	15 (6.8)
11	Center Rod - 5'0. (1.5m), NW	001608	32 (14.5)
11	Center Rod - 5'0. (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	150295	6 (2.7)
13	Plug - 1-1/8. (29mm) Hex to AW Box	150312	12 (5.4)
13	Plug - 1-1/8. (29mm) Hex to AWJ Box	150379	12 (5.4)
13	Plug - 1-1/8. (29mm) Hex to NW Box	150306	11 (5)
13	Plug - 1-1/8. (29mm) Hex to NWJ Box	150377	11 (5)
14	Plug Bolt	3130-0098	
15	Pilot Bit, 2-Prong, 1-1/8. (29mm) Hex	200024	.2 (.9)
15	Pilot Bit, 3-Wing, 1-1/8. (29mm) Hex	150574-01	
	Repair Key	150576-I	
	Clean Out Tap (For Bushing)	150562	
	O-Ring	3538-0238	

4-1/4 (108mm) 3-KEY AUGER

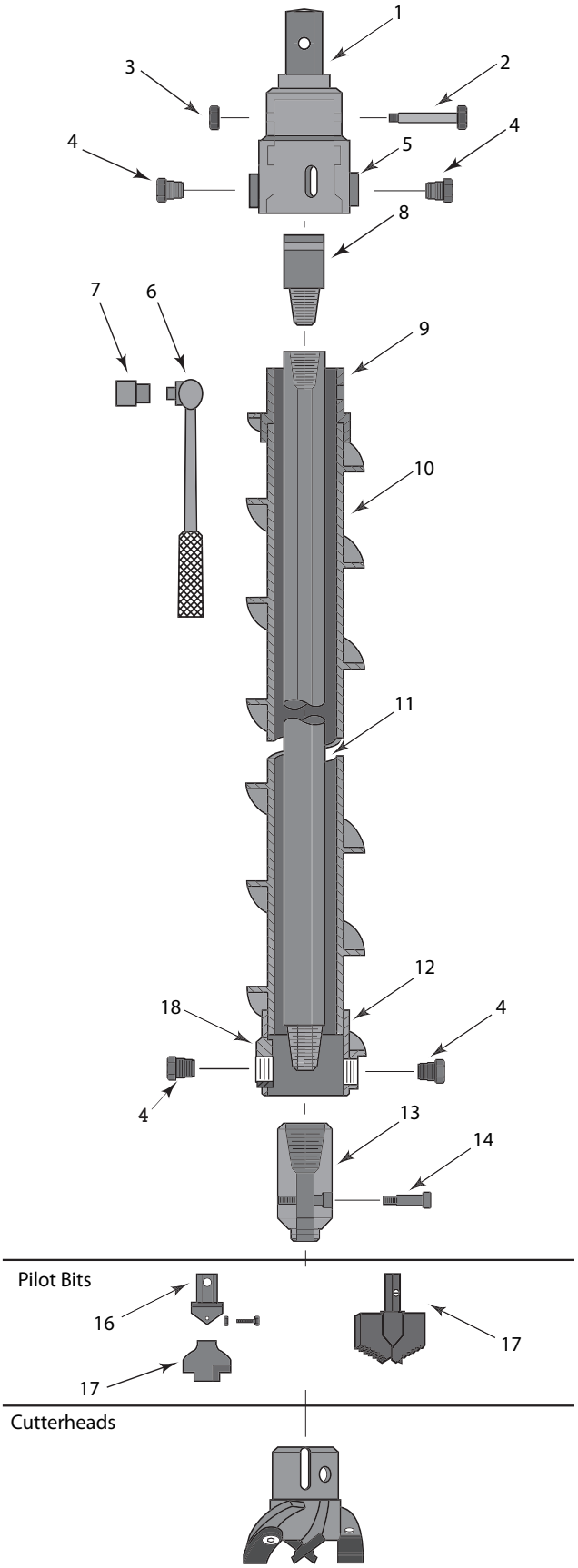
Now with thicker flight and heat-treated pins for extended life. Predominately used for geotechnical applications such as split spoon sampling. Sizes are identified by hollow stem auger I.D. Meter length available.

7-5/8" (194mm) O.D



Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1-5⁄8″ (41mm) Hex	150482	24 (10.9)
1	Drive Cap, 2″ (51mm) Hex	150490	28 (12.7)
2	Rod Bolt	3100-0279	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req'd**	**217136-I**	
4	**Lockbolt - 2 Req'd (Hard Faced)**	**150307-I**	
5	Repair Bushing	150477-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod to Drive Cap	150310	5 (2.3)
8	Adapter: AWJ Rod to Drive Cap	150311	5 (2.3)
8	Adapter: NW Rod to Drive Cap	180049-03	11 (5)
8	Adapter: NWJ Rod to Drive Cap	180054-04	5 (2.3)
9	Pin Coupling, Heat-treated (Repair Only)	150474	9 (4.1)
10	Auger Section: 3′0″ (.91mm).....	150473-02	45 (20.4)
10	**Auger Section: 5′0″ (1.5m),**	**150473**	**90 (40.8)**
10	Auger Section: 5′0″ (1.5m), Heavy Duty	150473-01	110 (49.9)
11	Center Rod: 5′0″ (1.5m), AW	001605	22 (10)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	150475	9 (4.1)
13	Plug: 1-1⁄8″ (29mm) Hex to AW Box	150492	19 (8.6)
13	Plug: 1-1⁄8″ (29mm) Hex to AWJ Box	150494	19 (8.6)
13	Plug: 1-1⁄8″ (29mm) Hex to NW Box	150488	18 (8.2)
13	Plug: 1-1⁄8″ (29mm) Hex to NWJ Box	150486	18 (8.2)
14	Plug Bolt	3130-0118	
15	Pilot Bit, 1-1⁄8″ (29mm) Hex, 2-Prong	004304	2 (.9)
15	Pilot Bit, 1-1⁄8″ (29mm) Hex, 3-Wing	150574-02	4 (1.8)
	Repair Key	150577-I	
	Clean Out Tap (for Lockbolt Hole)	150562	
	O-Ring	3538-0246	



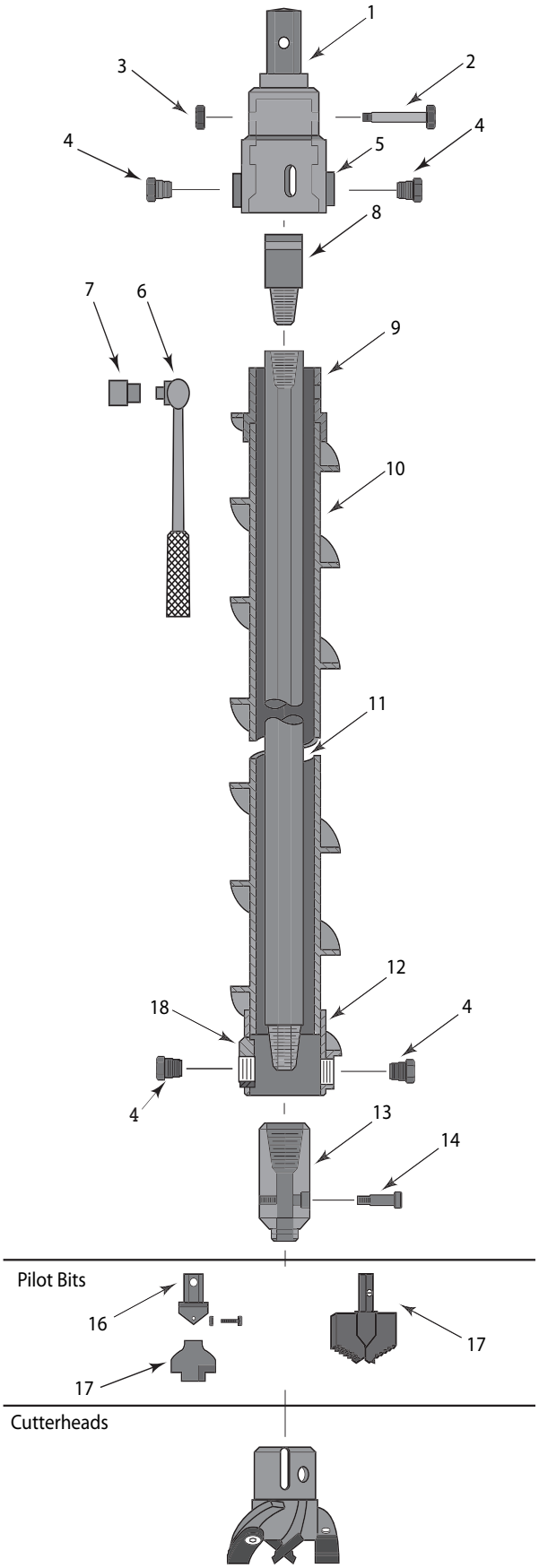
6-5/8 (168mm) 3-KEY AUGER

Thicker flight and heat-treated pins for extended life.
Sizes are identified by hollow stem auger I.D.
Meter length available.

10” (254mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1-5⁄8″ (41mm) Hex	150394	46 (20.9)
1	Drive Cap, 2″ (51mm) Hex	150401	49 (22.2)
2	Rod Bolt	3100-0280	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req’d**	**217136-I**	
4	**Lockbolt - 2 Req’d (Hard Faced)**	**150307-I**	
5	Repair Bushing	150477	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: NW Rod to Drive Cap	180049-03	11 (5)
8	Adapter: NWJ Rod to Drive Cap	180054-04	5 (2.3)
9	Pin Coupling, Heat-treated (Repair Only)	150388	15 (6.8)
10	**Auger Section: 5′0″ (1.5m),**	**150392**	**105 (47.6)**
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	150391	15 (6.8)
13	Plug: 1-5⁄8″ (41mm) Hex to NW Box	180036-15	50 (22.7)
13	Plug: 1-5⁄8″ (41mm) Hex to NWJ Box	180036-14	50 (22.7)
14	Plug Bolt	3130-0170	
16	Pilot Bit Shank, 1-5⁄8″ (41mm) Hex	LHX141L-I	3 (1.4)
17	Pilot Bit	004950	11 (5)
17	Pilot Bit, 1-5⁄8″ (41mm) Hex, 3-Wing	150574-03	
18	Repair Key	150578-I	
	Clean Out Tap (For Lockbolt Hole)	150562	
	O-Ring	3538-0262	



8-1/4” (210mm) 3-KEY AUGER

Thicker flight and heat-treated pins for extended life.
Sizes are identified by hollow stem auger I.D.
Meter length available.

12” (305mm) O.D

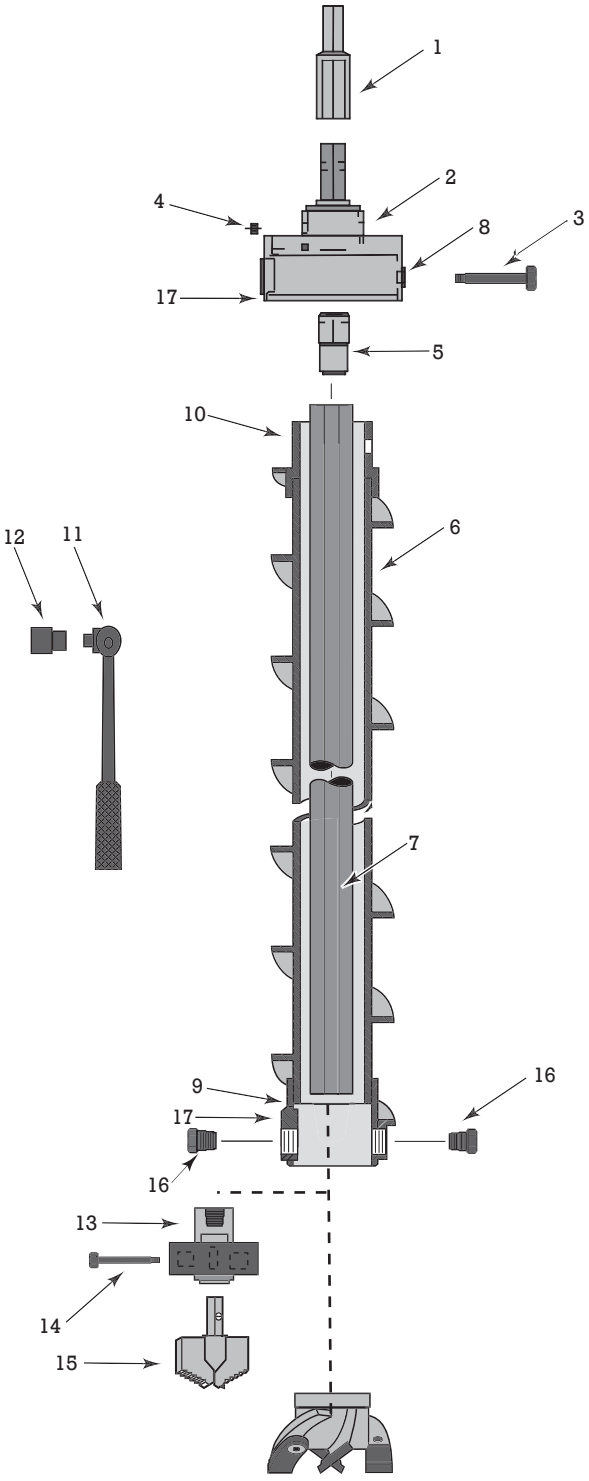
Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 2″ (51mm) Hex	150534	57 (25.9)
2	Rod Bolt	3100-0289	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req’d**	**217136-I**	
4	**Lockbolt - 2 Req’d (Hard Faced)**	**150307-I**	
5	Repair Bushing	150477-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: NW Rod to Drive Cap	180049-03	11 (5)
8	Adapter: NWJ Rod to Drive Cap	180054-04	5 (2.3)
9	Pin Coupling, Heat-treated (Repair Only)	150525	18 (8.2)
10	**Auger Section: 5′0″ (1.5m),**	**150531**	**144 (63.3)**
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	150529	18 (8.2)
13	Plug: 1-5⁄8″ (41mm) Hex to NW Box	180036-19	34 (15.4)
13	Plug: 1-5⁄8″ (41mm) Hex to NWJ Box	180036-20	34 (15.4)
14	Plug Bolt	3130-0191	
16	Pilot Bit Shank, 1-5⁄8″ (41mm) Hex	LHX141L-I	3 (1.4)
17	Pilot Bit	007188	8 (3.6)
17	Pilot Bit, 1-5⁄8″ (41mm) Hex, 3-Wing	150574-04	
18	Repair Key	150579-I	
	Clean Out Tap (For Lockbolt Hole)	150562	
	O-Ring	3538-0263	

10-1/4 (260mm) 3-KEY AUGER

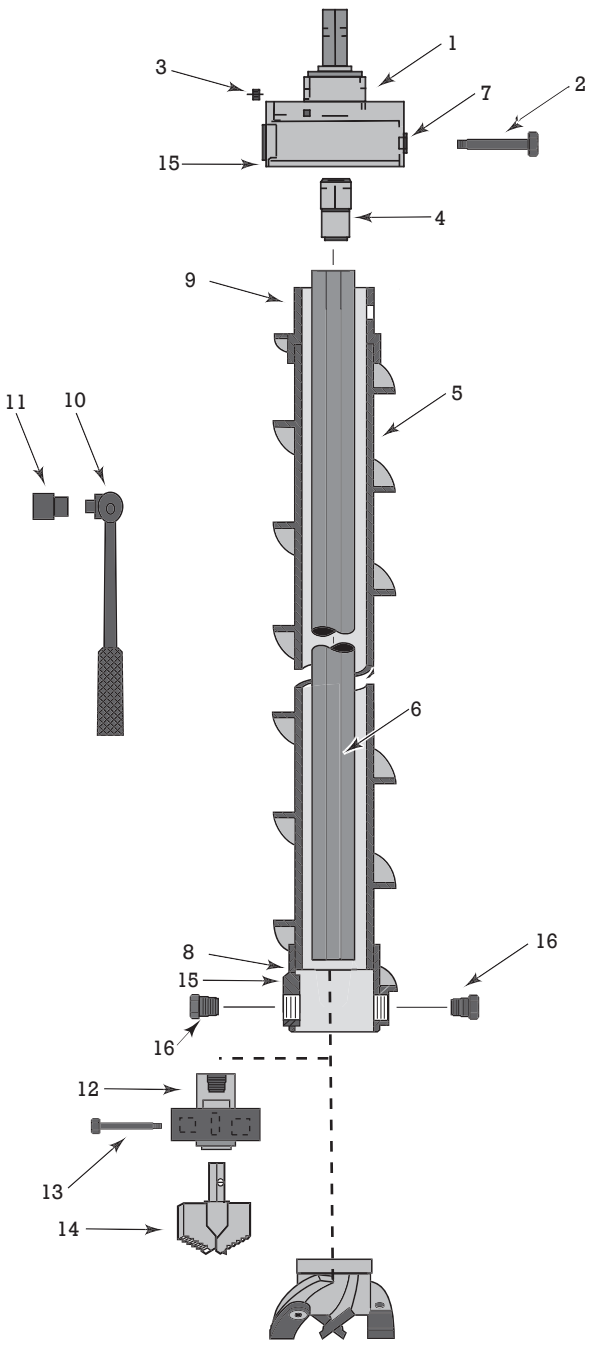
Thicker flight and heat-treated pins for extended life.
Sizes are identified by hollow stem auger I.D.
Meter length available.

14-1/4” (362mm) O.D



Component Parts

Ref	Description	Part No.	lb./kg.
1	Adapter, Auger, 1-5⁄8″ (41mm) Hex to 2” (51mm) Hex Socket	004643	11 (5.0)
2	Drive Cap, 2″ (51mm) Hex	150618	70 (31.8)
3	Rod Bolt	3100-0279	*
4	Hex Nut	3122-0012	*
5	Adapter: NW Rod to Drive Cap	180049-03	5 (2.3)
5	Adapter: NWJ Rod to Drive Cap	180054-04	5 (2.3)
6	**Auger Section: 5′0″ (1.5m),**	**150543-02**	**256 (116.1)**
7	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
7	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
8	Repair Bushing	150665	*
9	Repair Box	150610	35 (15.9)
10	Repair Pin	150611	28 (12.7)
11	Handle	3781-0010	*
12	Socket	3818-0020	*
13	NW Rod Box Center Plug	180036-27	93 (42.2)
13	NWJ Rod Box Center Plug	180036-25	92 (41.7)
14	Bolt	3130-0163	*
15	3-Wing Pilot Bit	150574-05	24 (10.9)
16	Lock Bolt - 2 Req’d	150666-I	*
16	Lock Bolt - 2 Req’d Hard Faced	150666-01-I	*
17	Repair Key	150614	*
	Plain Lock Bolt	150666-01	



12-1/4” (311mm) 3-KEY AUGER

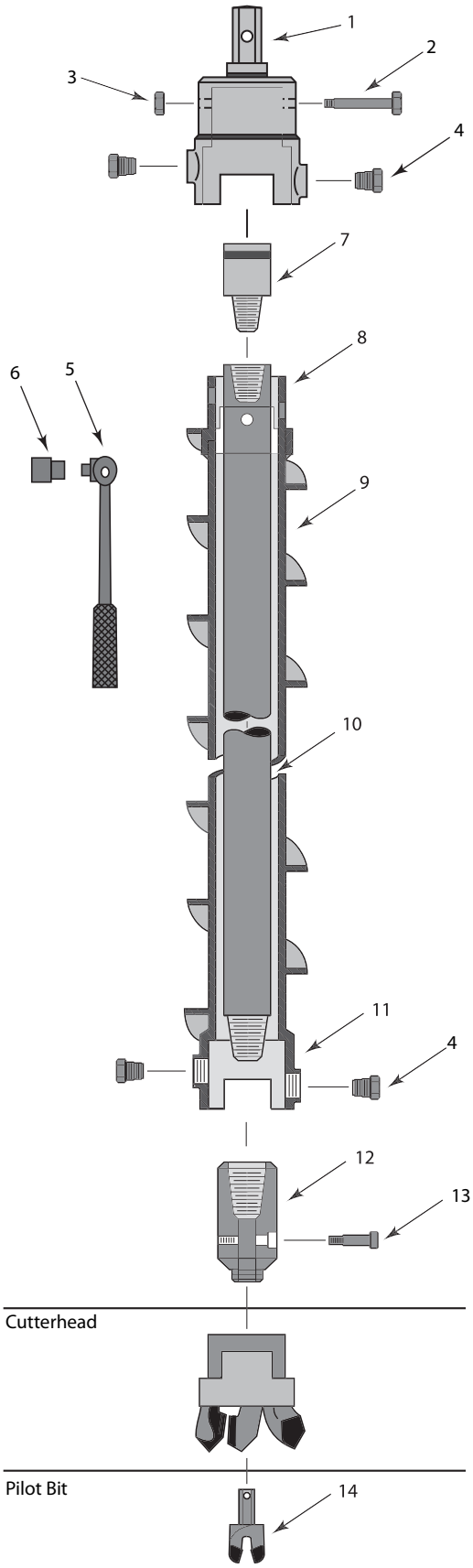
Thicker flight and heat-treated pins for extended life.
Sizes are identified by hollow stem auger I.D.
Meter length available.

17” (432mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 2″ (51mm) Hex	150643	70 (31.8)
2	Rod Bolt	3100-0242	*
3	Hex Nut	3122-0012	*
4	Adapter: NWJ Rod to Drive Cap	180054-04	5 (2.3)
5	**Auger Section: 5′0″ (1.5m),**	**150572-02**	**256 (116.1)**
6	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
7	Repair Bushing	150665-I	*
8	Repair Box	150639	35 (15.9)
9	Repair Pin	150640	28 (12.7)
10	Handle	3781-0010	*
11	Socket	3818-0020	*
12	NWJ Rod Box Center Plug	180036-25	92 (41.7)
13	Bolt	3130-0163	*
14	3-Wing Pilot Bit	150574-05	24 (10.9)
15	Repair Key	150642	*
16	**Lock Bolt - 2 Req’d**	**150666**	*
16	**Lock Bolt - 2 Req’d Hard Faced**	**150666-01-I**	*
	Hard Faced Lock Bolt	150666-01	

2-1/4” (57mm) LIGHT-FLIGHT AUGER

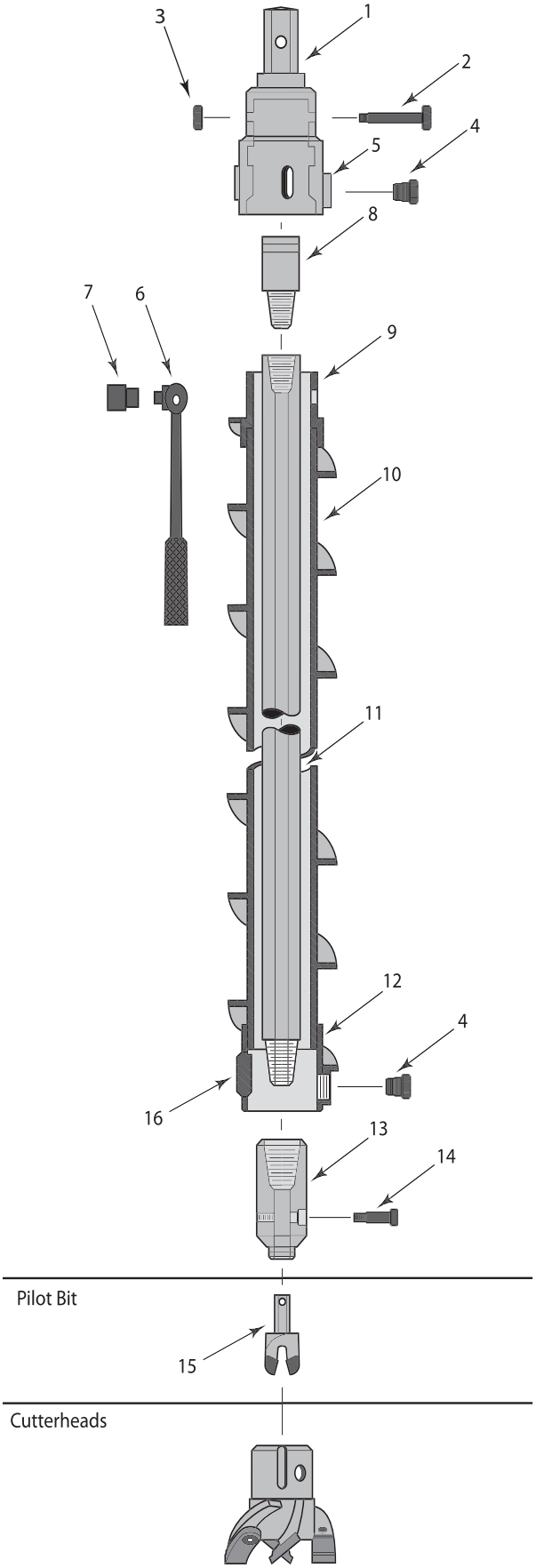


2-1⁄4″ (57mm) LIGHT-FLIGHT AUGER
LIGHT-FLITE augers are designed to fill the need for a lightweight, hollow stem auger for use with lightweight drilling rigs having a maximum torque output of not more than 3750 ft-lbs. For stronger machines, use standard duty 2-1⁄4″ I.D. 2-key HSA. LIGHT-FLIGHT’s 2-1⁄4″ (57mm) I.D. will allow standard penetration testing with 2″ (51mm) tools and equipment to a maximum of 22.5′ (6.8m). Sizes are identified by hollow stem auger I.D.

4-3/8” (111mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap 13⁄16″ (21mm) Hex	150404	6 (2.7)
1	Drive Cap 1-1⁄8″ (29mm) Hex	150399	6 (2.7)
2	Rod Bolt	3100-0128	
3	Hex Nut	3122-0012	
4	**Lock Bolt Without Hard Facing**	**217135**	
4	**Lock Bolt With Hard Facing**	**150383**	
5	Handle, 1⁄2″ (13mm) Sq Drive Flex x 1′6″ (457mm)	3781-0009	3 (1.4)
6	Socket, 15⁄16″ (24mm) Hex	3782-0013	
7	Adapter: EW Rod to Drive Cap	150402	1 (.5)
7	Adapter: AW Rod to Drive Cap	150310	2 (.9)
7	Adapter: AWJ Rod to Drive Cap	150311	2 (.9)
8	Pin Coupling (Repair Only)	150384	3 (1.4)
9	**Auger Section: 2′6″ (762mm)**	**150414**	**17 (7.7)**
10	Center Rod: 2′6″ (762mm), AWJ	150416	7 (3.2)
10	Center Rod: 2′6″ (762mm), EW	001753	7 (3.2)
11	Box Coupling (Repair Only)	150385	3 (1.4)
12	Plug: 13⁄16″ (21mm) Hex Socket to EW Box	180448-01	4 (1.8)
12	Plug: 13⁄16″ (21mm) Hex Socket to AW Box	180448-02	4 (1.8)
12	Plug: 13⁄16″ (21mm) Hex Socket to AWJ Box	180448-03	4 (1.8)
13	Pilot Bit	3130-0062	
14	Pilot Bit, 13/16″ (21mm) Hex	004981	1 (.5)
	Light Flight Cutterhead	150397	3 (1.4)



2-1/4” (57mm) 2-KEY STANDARD DUTY AUGER

Sizes are identified by hollow stem auger I.D.
Meter length available.

5-5/8” (143mm) O.D

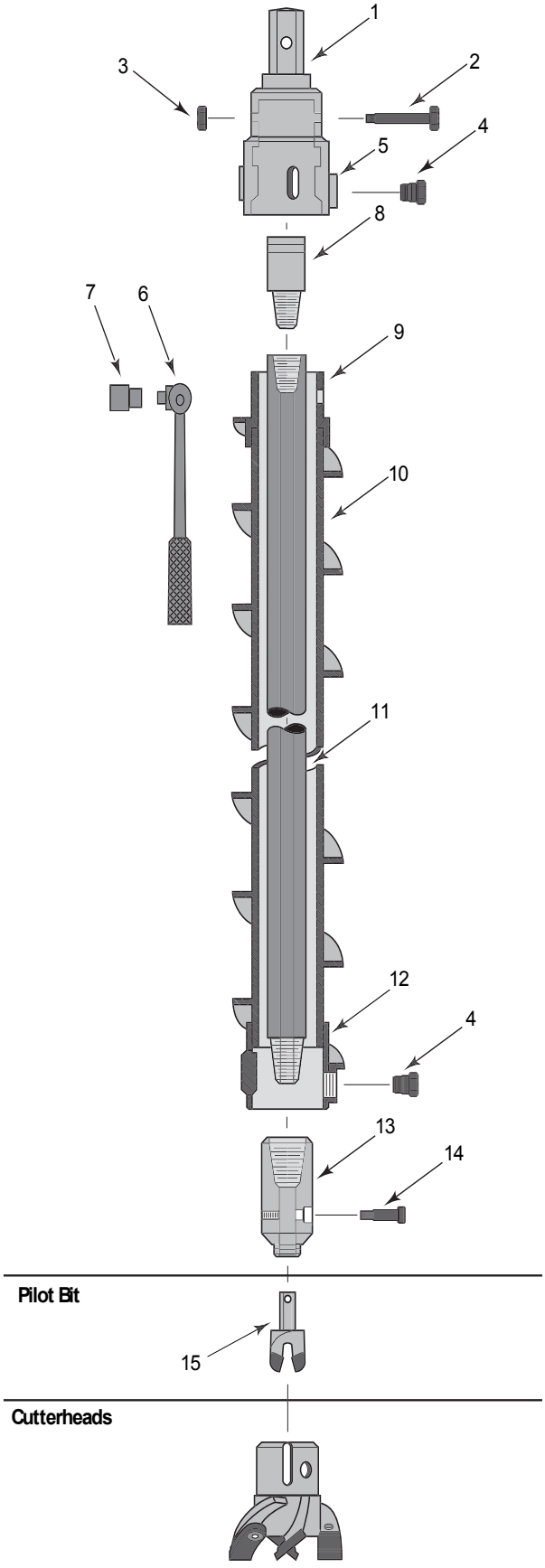
Component Parts

Ref	Description	Part No.
1	Drive Cap, 1-1⁄8″ (29mm) Hex	150717
1	Drive Cap, 1-5/8″ (41mm) Hex	21001
2	Rod to Cap Adapter Bolt	3100-0184
3	Rod to Cap Adapter Nut	3122-0012
4	**Lockbolt**	**21025-I**
4	**Lockbolt Hardfaced**	**21025HF-I**
5	Bushing	21068-I
6	Auger Wrench Handle	3781-0009
7	Auger Wrench Socket	3782-0016
8	Rod to Cap Adapter AW	21013
8	Rod to Cap Adapter AWJ	21014
9	Pin Coupling, Heat-treated (Repair Only)	21062
10	**Auger Section: 5′0″ (1.5m),**	**21007**
10	**Auger Section: 5′0″ (1.5m), Heavy Duty**	**21007HD**
11	Center Rod: 5′0″ (1.5m), AW	001605
11	Center Rod: 5′0″ (1.5m), AWJ	006276
12	Box Coupling (Repair Only)	21065
13	Center Plug AW Connection	180448-02
13	Center Plug AWJ Connection	180448-03
14	Center Plug Bolt/Pin	3130-0062
15	Pilot Bit	004981
16	Repair Key	21067
	O-Ring	21024
	Insert Clean Out Tap	21042
	Auger Hoisting Hook	21041

3-1/4” (83mm) 2-KEY STANDARD DUTY AUGER

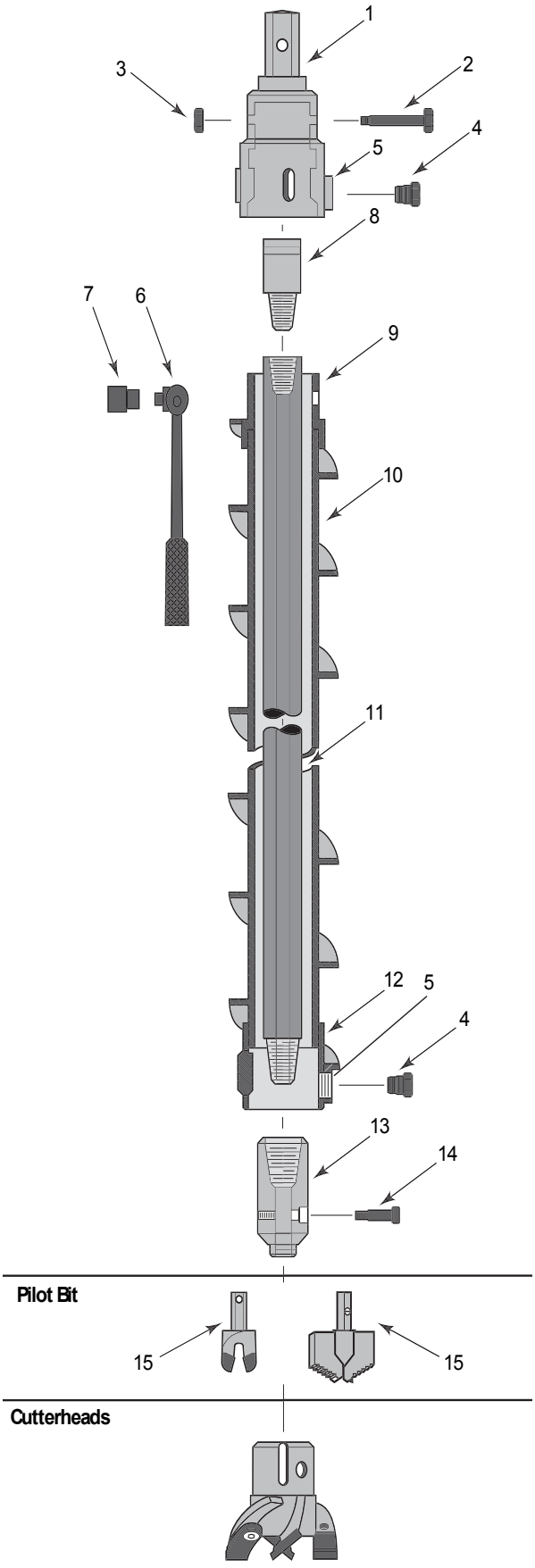
Sizes are identified by hollow stem auger I.D.
Also available in 2-key heavy-duty and 3-KEY.

6-1/2” (165mm) O.D



Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1-5/8″ (41mm) Hex	21263	17 (7.7)
1	Drive Cap, 2″ (51mm) Hex	150732	22 (10)
2	Drive Cap Bolt	3100-0184	
3	Drive Cap Nut	3122-0012	
4	**Lockbolt - 1 Req’d**	**21025-I**	
4	**Lockbolt - 1 Req’d (Hard Faced)**	**21025HF-I**	
5	Bushing	21068-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod to Drive Cap	21197	5 (2.3)
8	Adapter: AWJ Rod to Drive Cap	21198	5 (2.3)
8	Adapter: NW Rod to Drive Cap	21203	11 (5)
8	Adapter: NWJ Rod to Drive Cap	21204	11 (5)
9	Pin Coupling, Heat-treated (Repair Only)	21259	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**21191**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), AW	001605	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	21262	6 (2.7)
13	Plug - 1-1⁄8″ (29mm) Hex to AW Box	150312	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to AWJ Box	150379	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to NW Box	150306	11 (5)
13	Plug - 1-1⁄8″ (29mm) Hex to NWJ Box	150377	11 (5)
14	Plug Bolt	3130-0098	
15	Pilot Bit, 2-Prong, 1-1⁄8″ (29mm) Hex	200024	2 (.9)
15	Pilot Bit, 3-Wing, 1-1⁄8″ (29mm) Hex	150574-01	
	Repair Key	21067	
	Clean Out Tap (For Bushing)	21042	
	Auger Hoisting Hook	21041	
	O-Ring	21216	



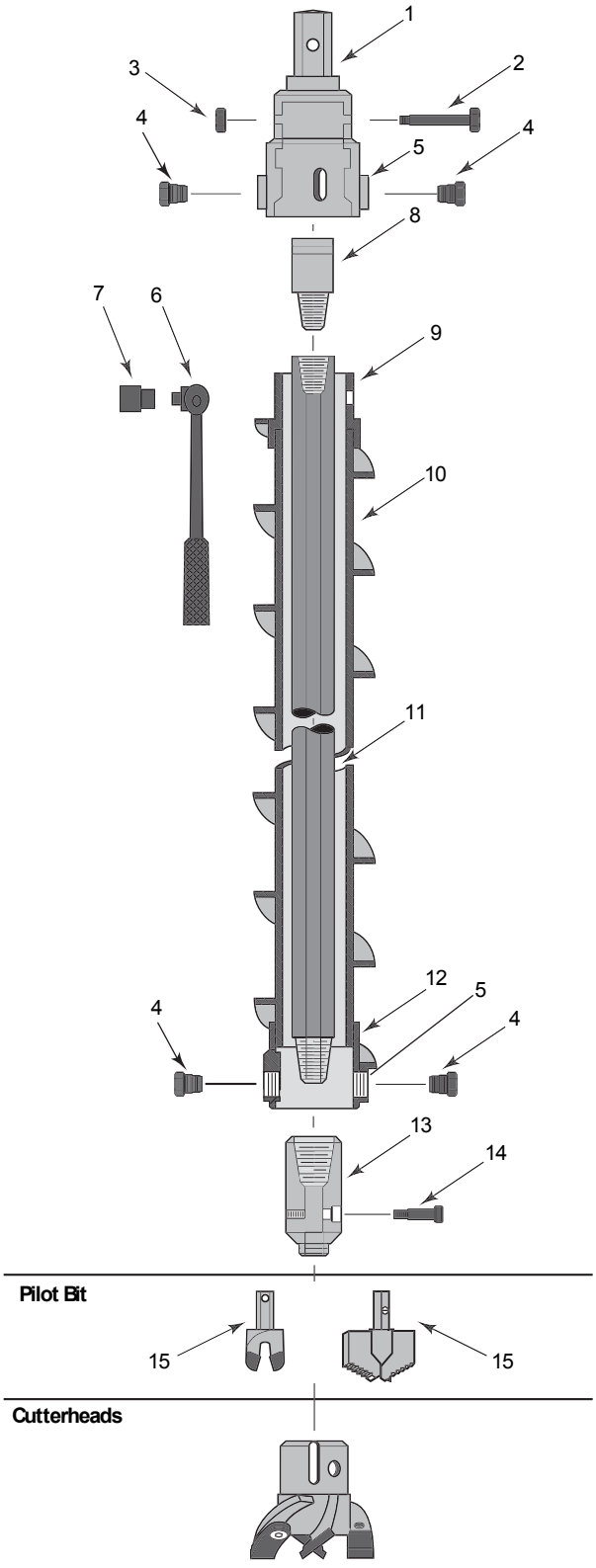
3-1/4” (83mm) 2-KEY HEAVY DUTY AUGER

Sizes are identified by hollow stem auger I.D.
Meter length available.

6-1/2” (165mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1 5/8″ (41mm) Hex	21900	
1	Drive Cap, 2″ (51mm) Hex	150646	22 (10)
2	Rod Bolt	3100-0184	
3	Hex Nut	3122-0012	
4	**Lockbolt - 1 Req’d**	**21913-I**	
4	**Hard Faced Lockbolt - 1 Req’d**	**21915HF-I**	
5	Bushing	21915-I	
6	Handle	3781-0010	
7	Socket	3782-0017	
8	Adapter: AW Rod to Drive Cap	21197	5 (2.3)
8	Adapter: AWJ Rod to Drive Cap	21198	5 (2.3)
8	Adapter: NW Rod to Drive Cap	21203	11 (5)
8	Adapter: NWJ Rod to Drive Cap	21204	11 (5)
9	Pin Coupling (Repair Only)	21929	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**21908**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), AW	001605	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	21928	6 (2.7)
13	Plug - 1-1⁄8″ (29mm) Hex to AW Box	150312	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to AWJ Box	150379	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to NW Box	150306	11 (5)
13	Plug - 1-1⁄8″ (29mm) Hex to NWJ Box	150377	11 (5)
14	Plug Bolt	3130-0098	
15	Pilot Bit, 2-Prong, 1-1⁄8″ (29mm) Hex	200024	2 (.9)
15	Pilot Bit, 3-Wing, 1-1⁄8″ (29mm) Hex	150574-01	
	Repair Key	21917	
	Clean Out Tap	21916	
	O-Ring	21912	
	Auger Hook	21041	



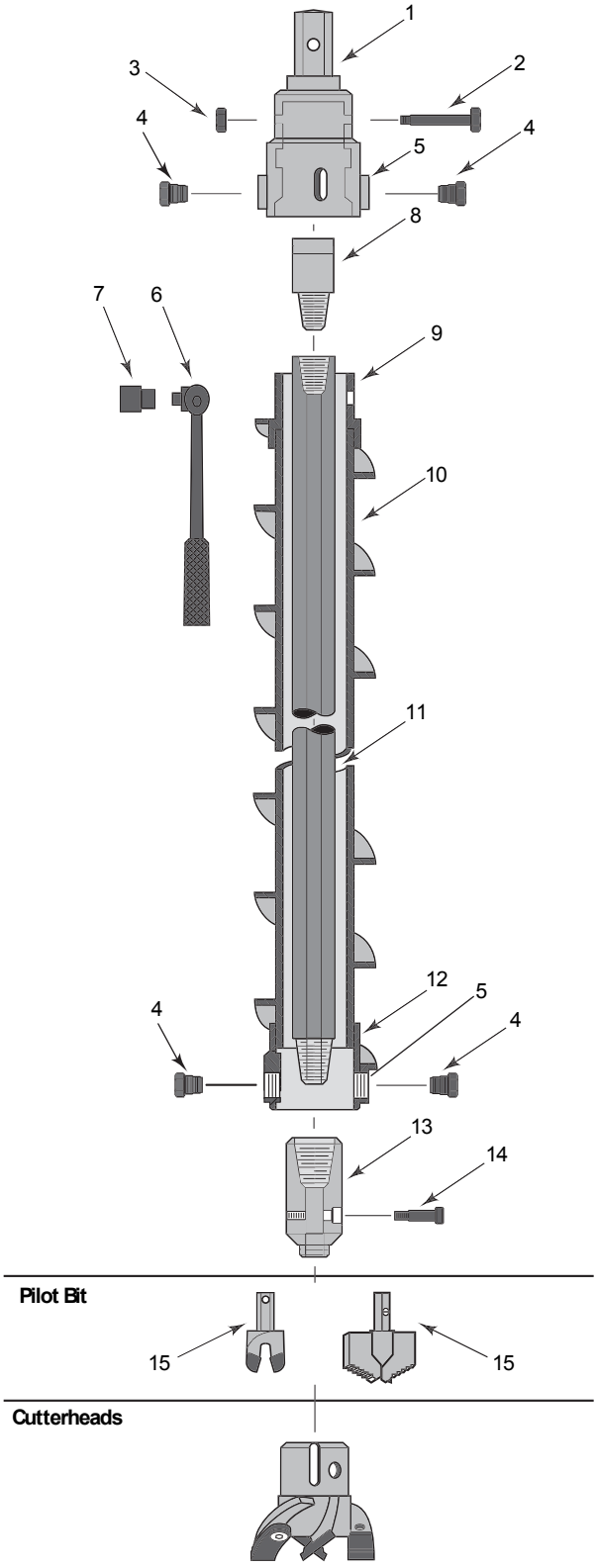
4-1/4” (108mm) 2-KEY STANDARD AUGER

Sizes are identified by hollow stem auger I.D.

8-1/4” (210mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1 5/8″ (41mm) Hex Shank	21469	
2	Rod Bolt	3100-0279	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req’d (Repair Only)**	**21025-I**	
4	**Hard Faced Lockbolt - 2 Req’d**	**21025HF-I**	
5	Repair Bushing	21068-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod Pin to Drive Cap	21418	5 (2.3)
8	Adapter: AWJ Rod Pin to Drive Cap	21482	5 (2.3)
8	Adapter: NW Rod Pin to Drive Cap	21487	11 (5)
8	Adapter: NWJ Rod Pin to Drive Cap	21488	11 (5)
9	Pin Coupling (Repair Only)	21543	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**21475**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), AW	001605	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	21546	9 (4.1)
13	Plug - 1-1⁄8″ (29mm) Hex to AW Box	150492	19 (8.6)
13	Plug - 1-1⁄8″ (29mm) Hex to AWJ Box	150494	19 (8.6)
13	Plug - 1-1⁄8″ (29mm) Hex to NW Box	150488	18 (8.2)
13	Plug - 1-1⁄8″ (29mm) Hex to NWJ Box	150486	18 (8.2)
14	Plug Bolt	3130-0118	
15	Pilot Bit, 2-Prong, 1-1⁄8″ (29mm) Hex	004304	2 (.9)
15	Pilot Bit, 3-Wing, 1-1⁄8″ (29mm) Hex	150574-02	4 (1.8)
	Repair Key	21067	
	Clean Out Tap	21042	
	Auger Seal / O-Ring	21988	
	Auger Hoisting Hook	21041	



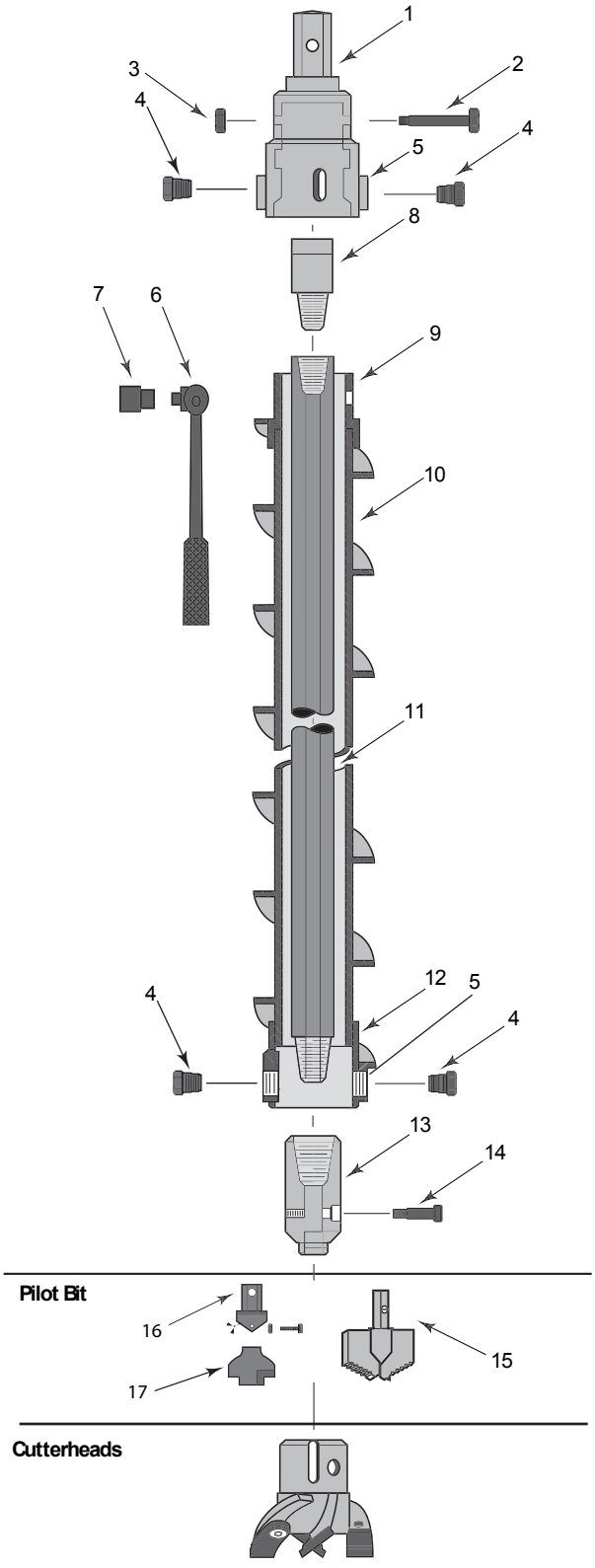
4-1/4” (108mm) 2-KEY HEAVY DUTY AUGER

Sizes are identified by hollow stem auger I.D.

8-1/4” (210mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1 5/8″ (41mm) Hex Shank	22047	
1	Drive Cap, 2″ (51mm) Hex Shank	22049	28 (12.7)
2	Rod Bolt	3100-0279	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req’d (Repair Only)**	**21913-I**	
4	**Hard Faced Lockbolt - 2 Req’d**	**21913HF-I**	
5	Repair Bushing	21915-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod Pin to Drive Cap	21481	5 (2.3)
8	Adapter: AWJ Rod Pin to Drive Cap	21482	5 (2.3)
8	Adapter: NW Rod Pin to Drive Cap	21487	11 (5)
8	Adapter: NWJ Rod Pin to Drive Cap	21488	11 (5)
9	Pin Coupling (Repair Only)	22071	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**22055**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), AW	001605	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	22070	9 (4.1)
13	Plug - 1-1⁄8″ (29mm) Hex to AW Box	150492	19 (8.6)
13	Plug - 1-1⁄8″ (29mm) Hex to AWJ Box	150494	19 (8.6)
13	Plug - 1-1⁄8″ (29mm) Hex to NW Box	150488	18 (8.2)
13	Plug - 1-1⁄8″ (29mm) Hex to NWJ Box	150486	18 (8.2)
14	Plug Bolt	3130-0118	
15	Pilot Bit, 2-Prong, 1-1⁄8″ (29mm) Hex	004304	2 (.9)
15	Pilot Bit, 3-Wing, 1-1⁄8″ (29mm) Hex	150574-02	4 (1.8)
	Repair Key	21917	
	Clean Out Tap	21916	
	Auger Seal / O-Ring	22059	
	Auger Hoisting Hook	21041	

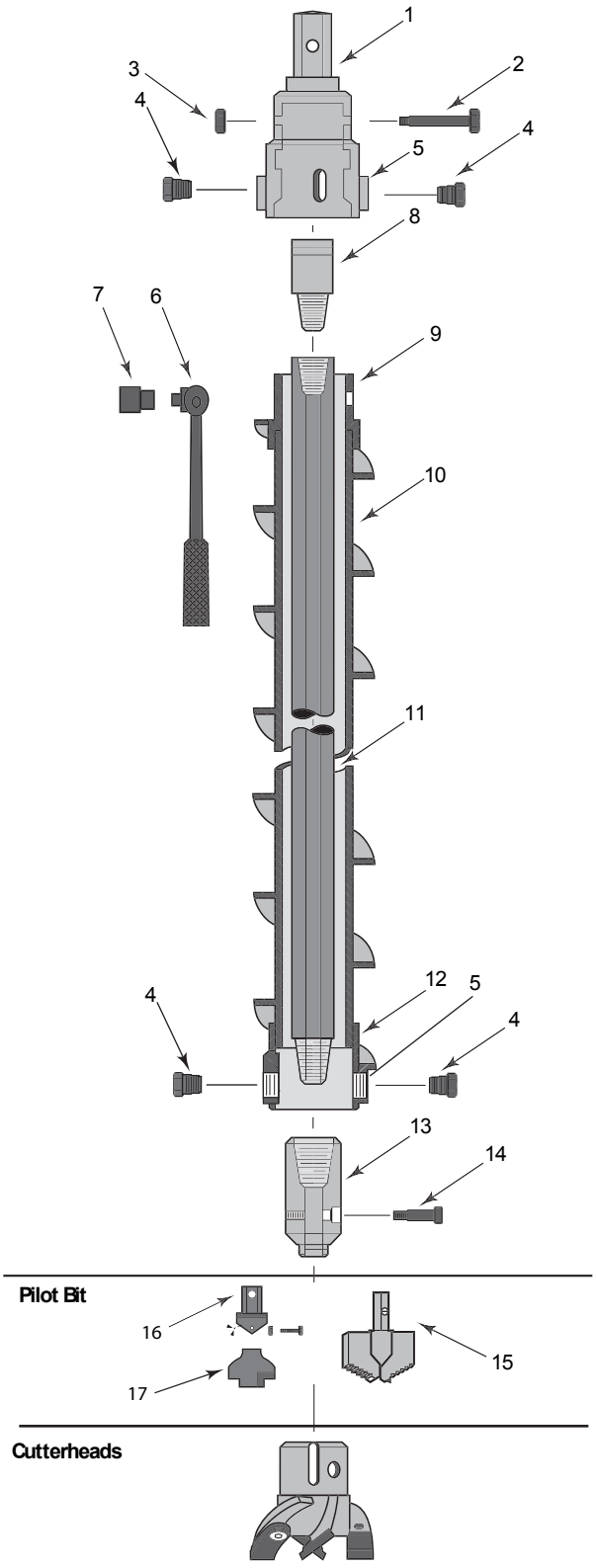


6-1/4” (83mm) 2-KEY Standard AUGER

Sizes are identified by hollow stem auger I.D.

10-1/4” (254mm) O.D

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1 5/8″ (41mm) Hex Shank	21674	
1	Drive Cap, 2″ (51mm) Hex Shank	21748	22 (10)
2	Rod Bolt	3100-0280	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req’d (Repair Only)**	**21025-I**	
4	**Hard Faced Lockbolt - 2 Req’d**	**21025HF-I**	
5	Bushing	21068-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod Pin to Drive Cap	NA	
8	Adapter: AWJ Rod Pin to Drive Cap	NA	
8	Adapter: NW Rod Pin to Drive Cap	21692	11 (5)
8	Adapter: NWJ Rod Pin to Drive Cap	21693	11 (5)
9	Pin Coupling (Repair Only)	21734	6 (2.7)
10	Auger Section: 5′0″ (1.5m),	21680	69 (31.3)
11	Center Rod: 5′0″ (1.5m), AW	NA	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	NA	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	21737	6 (2.7)
13	Plug - 1-5⁄8″ (29mm) Hex to NW Box	21701	11 (5)
13	Plug - 1-5⁄8″ (29mm) Hex to NWJ Box	21702	11 (5)
14	Plug Bolt	3130-0170	
15	5T Style Pilot Bit	19009-I	
15	Pilot Bit, 3-Wing, 1-5⁄8″ (29mm) Hex	19009-I	
16	Pilot Bit Lug	LHX141L-I	
17	Pilot Bit	TCH55171-I	
	Repair Key	21067	
	Clean Out Tap	21042	
	Auger Seal / O-Ring	21704	



6-1/4” (83mm) 2-KEY HEAVY DUTY AUGER

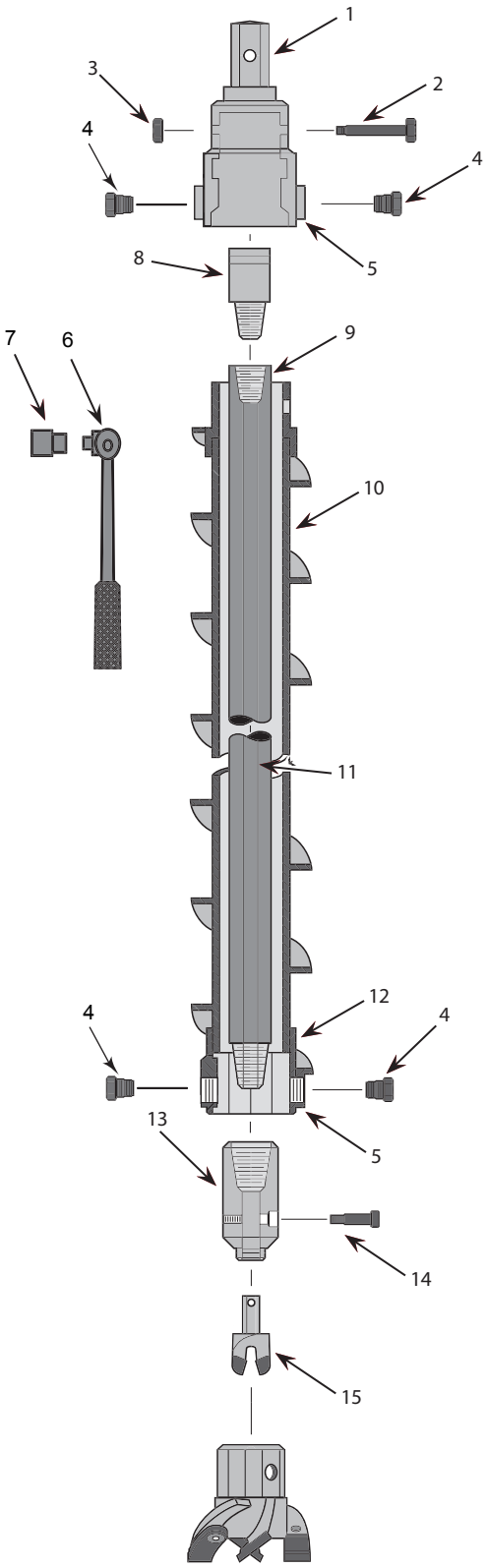
H.D. key size is 5⁄8″ (16mm)
Sizes are identified by hollow stem auger I.D.

10-1/4” (254mm) O.D

Component Parts

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1 5/8″ (41mm) Hex Shank	22189	
1	Drive Cap, 2″ (51mm) Hex Shank	22191	22 (10)
2	Rod Bolt	3100-0184	
3	Hex Nut	3122-0012	
4	**Lockbolt - 2 Req’d (Repair Only)**	**21913-I**	
4	**Hard Faced Lockbolt - 2 Req’d**	**21913HF-I**	
5	Bushing	21915-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod Pin to Drive Cap	NA	5 (2.3)
8	Adapter: AWJ Rod Pin to Drive Cap	NA	5 (2.3)
8	Adapter: NW Rod Pin to Drive Cap	001608	11 (5)
8	Adapter: NWJ Rod Pin to Drive Cap	006278	11 (5)
9	Pin Coupling (Repair Only)	22213	6 (2.7)
10	Auger Section: 5′0″ (1.5m),	150633	69 (31.3)
11	Center Rod: 5′0″ (1.5m), AW	NA	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	NA	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	21701	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	21702	35 (15.9)
12	Box Coupling (Repair Only)	22212	6 (2.7)
13	Plug - 1-5⁄8″ (29mm) Hex to NW Box	150306	11 (5)
13	Plug - 1-5⁄8″ (29mm) Hex to NWJ Box	150377	11 (5)
14	Plug Bolt	3130-0170	
15	5T Style Pilot Bit	19007	
15	Pilot Bit, 3-Wing, 1-5⁄8″ (29mm) Hex	19009-I	
16	Pilot Bit Lug	LHX141L-I	
17	Pilot Bit	TCH55171-I	
	Repair Key	21917	
	Clean Out Tap	21916	
	Auger Seal / O-Ring	22201	

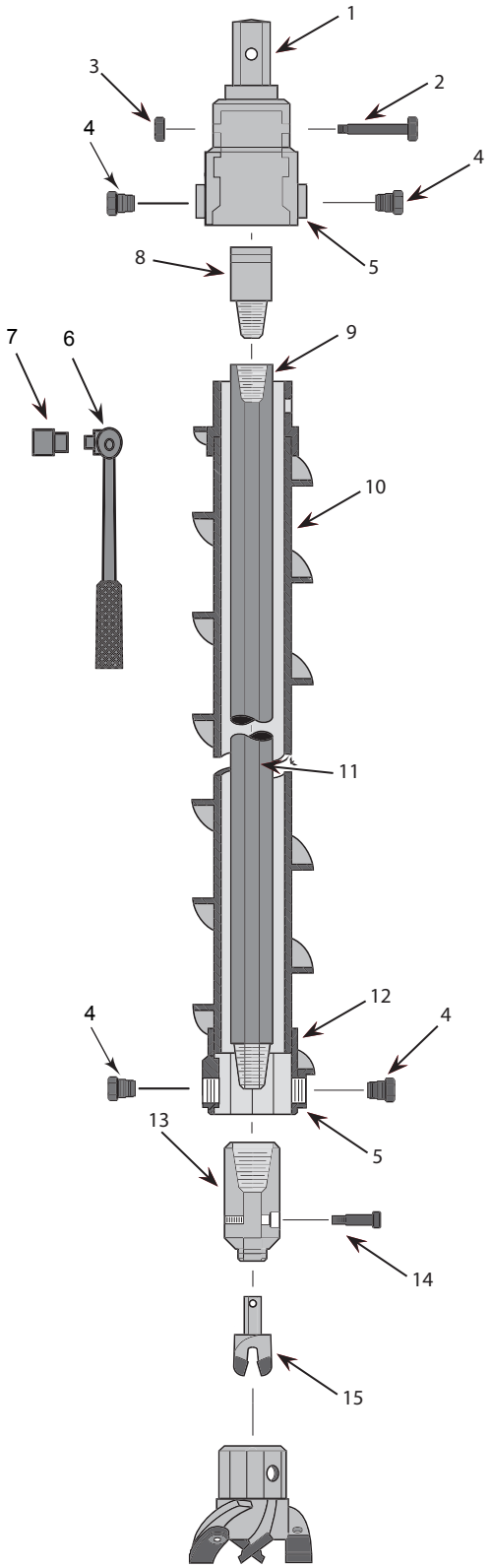
Octagonal 8-Sided Hollow Stem Augers



3-1/4” (83mm)
Octagonal Hollow Stem Auger
6-1/2” (165mm) O.D

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1-5/8″ (41mm) Hex	330695-0	17 (7.7)
1	Drive Cap, 2″ (51mm) Hex	330696-0	22 (10)
2	Drive Cap Bolt	3100-0184	
3	Drive Cap Nut	3122-0012	
4	**Lockbolt - 1 Req’d**	**21025-I**	
4	**Lockbolt - 1 Req’d (Hard Faced)**	**21025HF-I**	
5	Bushing	21068-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod to Drive Cap	21197	5 (2.3)
9	Pin Coupling, Heat-treated (Repair Only)	130520-0	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**330359-0**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), AW	001605	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	330591-0	6 (2.7)
13	Plug - 1-1⁄8″ (29mm) Hex to AW Box	21206	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to AWJ Box	150379	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to NW Box	150306	11 (5)
13	Plug - 1-1⁄8″ (29mm) Hex to NWJ Box	150377	11 (5)
14	Plug Bolt	3130-0098	
15	Pilot Bit, 2-Prong, 1-1⁄8″ (29mm) Hex	200024	2 (.9)
15	Pilot Bit Step Type	150574-01	
15	Pilot Bit w/replaceable teeth	19005-I	
	Clean Out Tap (For Bushing)	21042	
	Auger Hoisting Hook	21041	

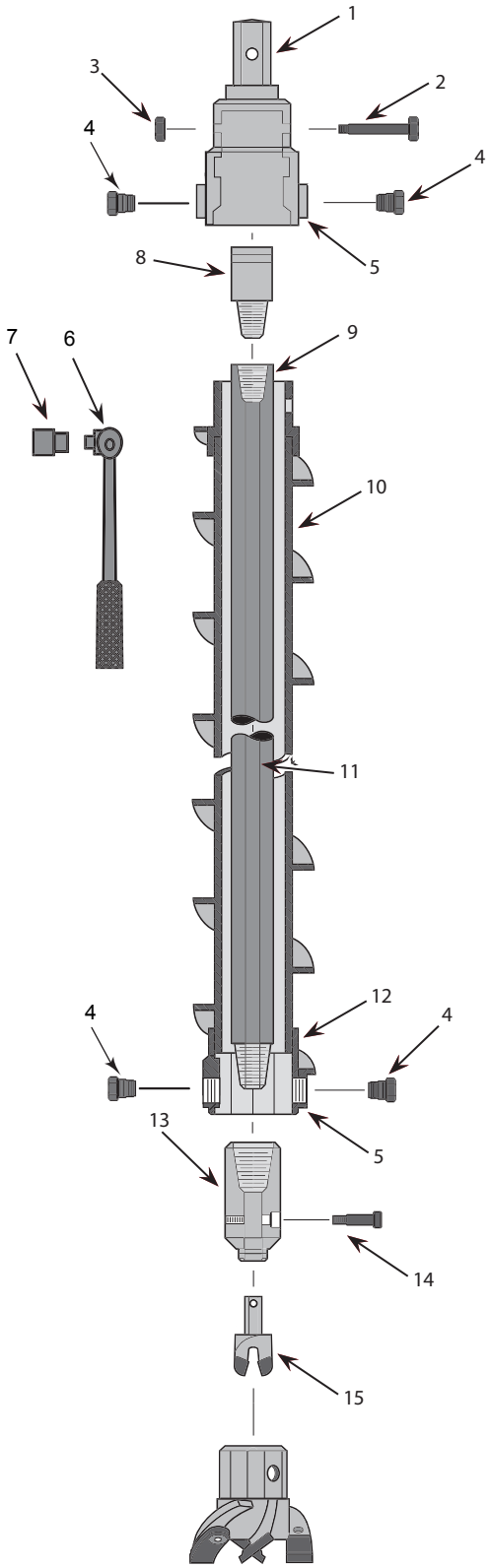
Octagonal 8-Sided Hollow Stem Augers



4-1/4” (108mm) Octagonal Hollow Stem Auger 7-5/8” (194mm) O.D

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1-5/8″ (41mm) Hex	330684	17 (7.7)
1	Drive Cap, 2″ (51mm) Hex	330685-0	22 (10)
2	Drive Cap Bolt	3100-0279	
3	Drive Cap Nut	3122-0012	
4	**Lockbolt - 2 Req’d**	**21025-I**	
4	**Lockbolt Hard Faced - 2 Req’d**	**21025HF-I**	
5	Bushing	21068-I	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: AW Rod to Drive Cap	21482	5 (2.3)
8	Adapter: AW Rod to Drive Cap	21487	
9	Pin Coupling, Heat-treated (Repair Only)	130606-0	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**330608-0**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), AW	001604	22 (10.0)
11	Center Rod: 5′0″ (1.5m), AWJ	006276	15 (6.8)
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	330670-0	6 (2.7)
13	Plug - 1-1⁄8″ (29mm) Hex to AW Box	150492	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to AWJ Box	150494	12 (5.4)
13	Plug - 1-1⁄8″ (29mm) Hex to NW Box	150488	11 (5)
13	Plug - 1-1⁄8″ (29mm) Hex to NWJ Box	150489	11 (5)
14	Plug Bolt	3100-279	
15	Pilot Bit, 2-Prong, 1-1⁄8″ (29mm) Hex	004304	2 (.9)
15	Pilot Bit	150574-02	
15	Pilot bit w/ replaceable Teeth	19003-I	
	Clean Out Tap (For Bushing)	21042	
	Auger Hoisting Hook	21041	

Octagonal 8-Sided Hollow Stem Augers



6-1/4” (159mm) Octagonal Hollow Stem Auger

10-1/4” (260mm) O.D

Ref	Description	Part No.	lb./kg.
1	Drive Cap, 1-5/8″ (41mm) Hex	330837-0	17 (7.7)
1	Drive Cap, 2″ (51mm) Hex	330691-0	22 (10)
2	Drive Cap Bolt	3100-0280	
3	Drive Cap Nut	3100-0280	
4	**Lockbolt - 2 Req’d**	**130660-0**	
5	Bushing	161273-0	
6	Handle	3781-0009	
7	Socket	3782-0016	
8	Adapter: NW Rod to Drive Cap	21692	5 (2.3)
9	Pin Coupling, Heat-treated (Repair Only)	130646-0	6 (2.7)
10	**Auger Section: 5′0″ (1.5m),**	**330647-0**	**69 (31.3)**
11	Center Rod: 5′0″ (1.5m), NW	001608	32 (14.5)
11	Center Rod: 5′0″ (1.5m), NWJ	006278	35 (15.9)
12	Box Coupling (Repair Only)	330645-0	6 (2.7)
15	Pilot Bit	004950	
15	Pilot Bit	150574-03	
15	Pilot bit w/ replaceable Teeth	190045-I	
15	Pilot Bit Shank	004591	
	Clean Out Tap (For Bushing)	21042	
	Auger Hoisting Hook	21041	