



# **User's Guide**

## **Overburden Rock Core Cell (DBCH)**

Version 1.10

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**Daedalus Innovations LLC**

Aston, Pennsylvania

United States



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## **WARNINGS / INFORMATION**



This device has been thoroughly tested to provide safe and continuous operation to the identified pressure and temperature rating. Exceeding this point can be dangerous to the user and equipment. Pressure delivery devices should have proper regulatory capability and proper safety precautions should be exercised.



Optimal safety and protection of the device can be achieved by using a suitable burst disc in-line with the pressure delivery lines to prevent accidental over pressurization of the cell. The recommended rating for this disc is no more than 20% over the rated pressure.



During operation the cell should be allowed to equilibrate to the experimental operation temperature before the unit is pressurized. Thermal gradients across the housing wall may cause unexpected failure of the cell.



User safety can be enhanced by placing a shield around any exposed portion of the unit, including the metal plugs in the unlikely chance of a cell failure. The most likely failure mode is the end of the vessel to shear which could lead to exposure to high velocity fragments or hot internal fluids.



The cell should not be pressurized outside of the instrument without proper shielding to protect the user. The DCH PROTECTIVE BOX provides the appropriate protection for such operations.



The extreme operational pressure and temperature conditions of this overburden cell demand that users be thoroughly familiar with this manual and handling of the cell. It is highly encouraged that expert users be established that can then supervise general users of the equipment.



If the main zirconia housing is dropped on the floor or if there is chipping of the housing the cell must be returned for recertification. Failure to note these instances and take corrective action could result in equipment damage, severe injury or even death.



A usage log documenting the maximum pressure and temperature and duration of exposure should be maintained. This log should also document any issues with the setup or any other items of interest that could be used for later troubleshooting.

## **ITEMS TYPICALLY INCLUDED WITH THE OVERBURDEN CELL KIT**

The actual items may vary depending on the configuration of the cell shipped. Some items may not be present and others added for certain setups. The actual part list is shipped with the overburden cell.

<b>Quantity</b>	<b>Description</b>	<b>Source</b>
1	Zirconia housing with threaded ends	Daedalus
2	Matched bronze end plugs	Daedalus
2	Bronze piston plugs	Daedalus
1	Overburden cell assembly cradle	Daedalus
100	End plug seals; CHPS	Daedalus
100	Core mount seals; MSCS	Daedalus
50	PTFE piston seals; PSCH-1/2" NUT	Daedalus
10 ft	FEP heat shrink sleeving	Daedalus
4	Piston tube sections; 1/4" OD x 12" length	High Pressure Equipment
2	Coupler, LM4 to LM4, 1/4" tubing	High Pressure Equipment
2	Adapter, LM4 to AF1, 1/4" to 1/16" reducer	High Pressure Equipment
8	Style AM1 glands for 1/16" tubing	High Pressure Equipment
8	Style AM1 compression collars for 1/16" tubing	High Pressure Equipment
8	Style LM4 glands for 1/4" tubing	High Pressure Equipment
8	Style LM4 compression collars for 1/4" tubing	High Pressure Equipment
8	Style HM4 glands for 1/4" tubing	High Pressure Equipment
8	Style HM4 threaded collars for 1/4" tubing	High Pressure Equipment
10 ft	1/16" high pressure tubing, 0.03" ID; 316 stainless steel; 15,000 psi	High Pressure Equipment
1	Mounted left hand rethreading die for piston tube sections	
1	Bottle, Rapid-Tap fluid for rethreading applications	
1	Interchangeable head click-type torque wrench	
1	5/8" torque wrench head	
1	1/2" torque wrench head	
1	2" open end wrench	
1	1-3/4" open end wrench	
1	1-1/4" open end wrench	
1	3/4" open end wrench	
1	5/8" open end wrench	
1	1/2" open end wrench	
1	5/16" x 1/4" combination wrench	
2	Precision hooks for seal removal	
1	3/16" hex wrench	
1	1/2"-20 rethreading tap	
1	Tap wrench	
1	1/2"-20 rethreading die; 1-1/16" between flats	

## ***ITEMS TO BE SUPPLIED BY THE END-USER***

Some additional tools may be required to complete the setup or maintenance of the instrument.

**Metal tubing cutter:** A 1/16" and 1/8" metal tubing cutter and deburring tool will be necessary to cut sections of tubing for making connections between the rock core cell and external pressure delivery devices.

**Stainless steel anti-seize compound:** Stainless steel is relatively soft. Depending on the applied torque it is possible to generate a condition where the parts seize. This is especially true for adapters to pipe fittings. The application of an anti-seize compound will extend the life of the components. A light grade machine oil may be used as a substitute, but is not as effective as a proper anti-seize compound.

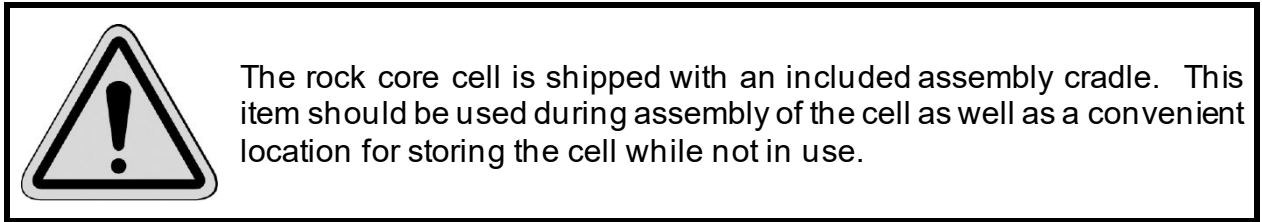
**Adjustable open-end wrench:** Wrenches that are included with the kit have specific functions and should be used where indicated in the manual. However, some sizes may not be available. Rethreading dies do not include die stock tools so an adjustable wrench would be used in that instance.

**Heat source for shrinking FEP sleeve:** The FEP-Sleeve component must be heated to shrink against the core and core mount seals. This is most uniformly done using an oven at 130°C. A heat gun or radiant heat wand can also be used to shrink the tubing, but care must be exercised to avoid unbalanced heating in one area as this may tear the sleeve.

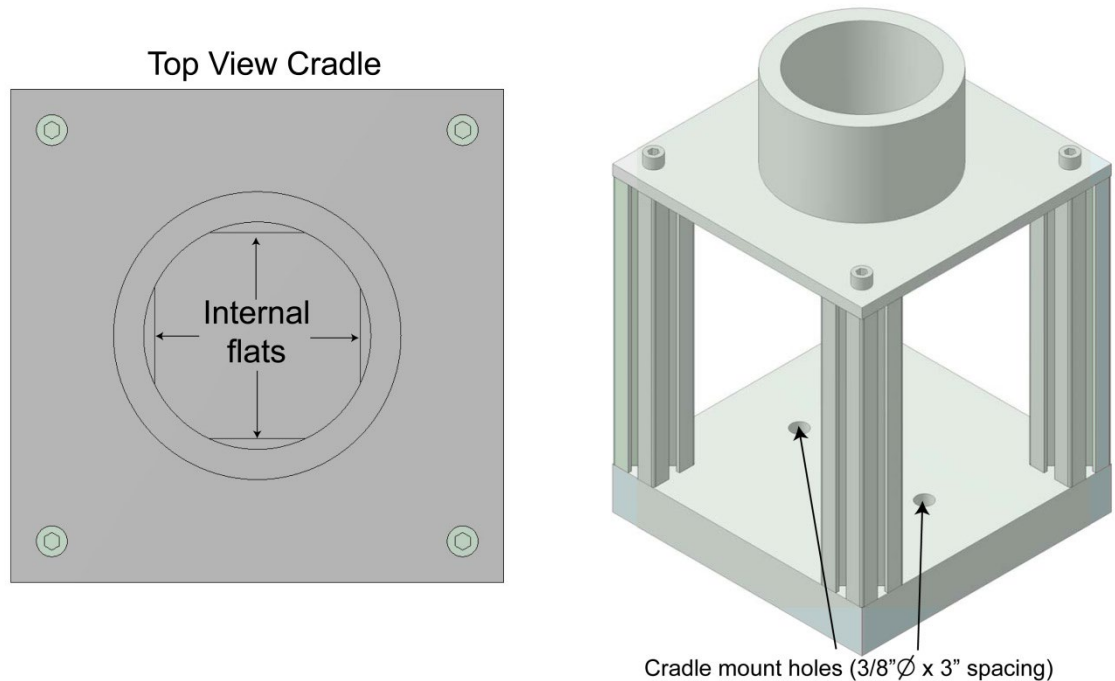
- **NOTE:** The sleeve can be preshrunk to varying degrees using lower temperatures. For example, shrinking the tubing around a 1.5" mandrel for 2-3 hours at 70°C will shrink the tube to the size of the mandrel, but still be easy to remove. This can then be forced past the seals on the core mounts and may be sufficient to provide initial sealing force until confining pressure is applied. This approach may be important is the core sample cannot be heated.



## UNIT ASSEMBLY CONSIDERATIONS:



The assembly cradle provides a stable platform with which the rock core cell can be assembled. The top view in Figure 1 shows that inside the stabilizing retaining cylinder there are four flat surfaces which match to the flats on the zirconia housing. The cell should be placed in the cradle and matched to those surfaces.



**Figure 1:** Cradle Details

During assembly of the cell torque may be applied at various steps. The cradle is meant to help brace the cell during these actions. To further stabilize the cradle as an assembly platform, it can be mounted directly to a bench using the predrilled holes in the base. These holes are  $3/8''$  in diameter with the spacing between holes of 3". The top (or base) of the cradle can be removed using the included  $3/16''$  hex wrench.

## CONNECTION DETAILS

Fittings and adapters have been included for making connections to the rock core cell. These can be either with compression fittings for 1/16" or 1/8" tubing, or threaded collars for 1/4" tubing. For compression fittings a sleeve is used to hold the tube while under pressure and must be assembled with sufficient torque to provide proper holding power. The tubing must also be properly prepared for optimal sealing performance. Technical information for each fitting can be obtained from the High Pressure Equipment Company website ([www.highpressure.com](http://www.highpressure.com)).

For the 1/16" tubing, the high pressure 15-AM1 glands and 15-2A1 collars are used. For the 1/8" tubing, the high pressure 15-AM2 glands and 15-2A2 collars are used.



Never assemble and compress new connections directly to the bronze caps. Instead use an equivalent adapter to first assemble the fitting and then connect the now assembled end to the plugs. Doing otherwise may damage the plugs.

These steps should be followed when making a high pressure connection:

- i) Cut and deburr the end of the tube section.
- ii) Assemble the gland then sleeve onto the tube end.
- iii) Insert the end of the tube into one of the stainless steels fittings until it bottoms. **DO NOT MAKE CONNECTIONS DIRECTLY TO THE BRONZE CAPS. USE A STAINLESS STEEL FITTING FROM HIGH PRESSURE EQUIPMENT COMPANY FOR THE INITIAL ASSEMBLY.**
- iv) For the AM1/AF1 style fitting tighten the gland to 55 in·lbs. A “bottoming out” or “dead stop” should be felt when the connection is properly assembled. For the AM2/AF2 style fitting and initial application of 120 in-lb. will compress the sleeve part way. A second step requires application of torque to 300 in-lbs. to fully compress the sleeve. After seating the sleeve for assembly, any reconnection can be made using less torque (~160-190 in-lbs.).

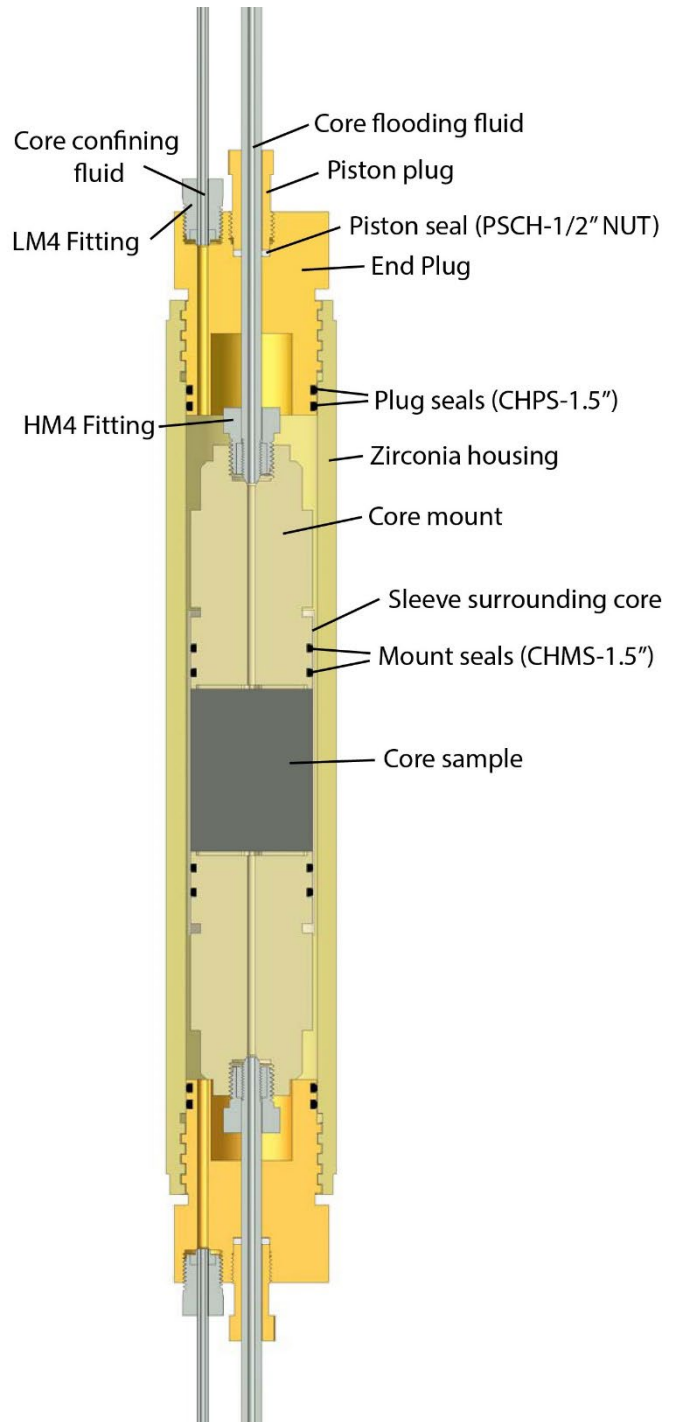
The AM2 style fittings are difficult to assemble and without use of anti-seize compound could damage the associated adapter that is being used for the assembly purposes. Should damage occur a 1/2"-20 tap and die can be used to reprofile the threads. Always use tapping fluid for these operations.

## ***THEORY OF OPERATION***

The assembled overburden cell is shown in Figure 2 with the individual components labeled. The patent pending housing is manufactured from an advanced ceramic zirconia. This material provides very high strength and has innate flexibility that allows threads to be used as a mechanism of retraining the end plugs against internal pressure.

The core sample is placed between two mounts that are connected externally through the end plugs using standard high pressure fittings. To fully isolate the core from the confining fluid a sleeve is placed around the core and is sealed in place by dual core mount seals (MSCS-1.5" or MSCS-1.0") at either end. These initially compress by directed heating of the sleeve, and are further compressed by the confining fluid so that internal pressure in the core can be nearly equal to the confining pressure.

The high pressure tubing from the core mounts provides a path for fluid to be directed to and through the core. These tubing sections are sealed into the end plugs using a PTFE piston seal (PSCH-1/2" NUT) compressed into place using the piston plugs. The seal is dynamic such that as the core is compressed it can move axially as is necessary. Correspondingly, confining pressure applied to the core mounts translates into axial force on the core.



**Figure 2:** Assembled cell with parts labeled

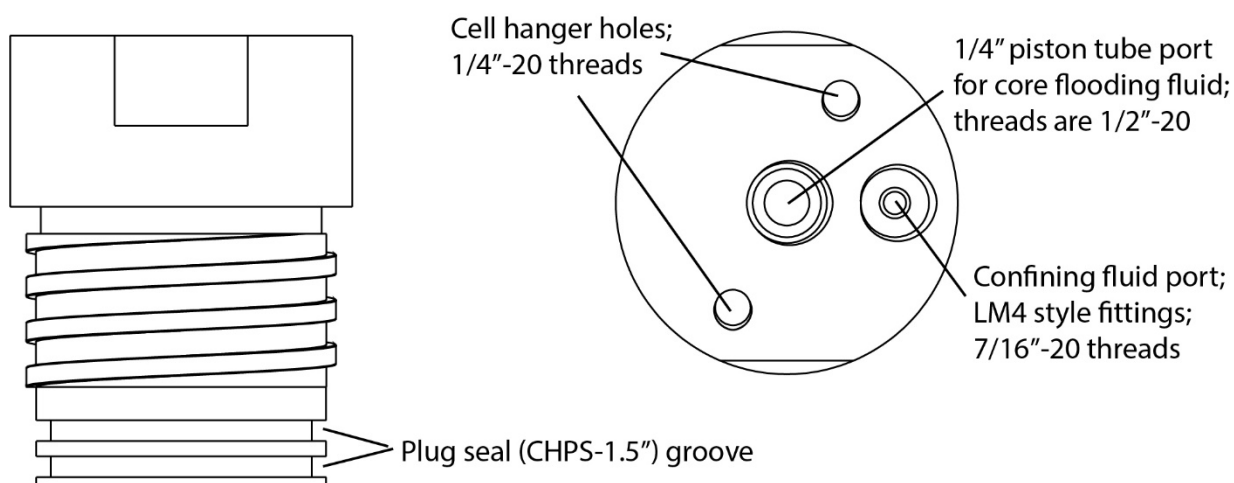
The confining fluid is directed into the internal space surrounding the core assembly through high pressure connections in the end plugs. Fluid can flow into the interior, then around the isolated core, and out the bottom plug thus providing hydrostatic pressure to the core in both the axial and radial directions.

The end plugs themselves thread into the zirconia housing. These are sealed against the internal pressure using dual plug seals (CHPS-1.5" or CHPS-1.0"). These seals are compressed into position by the simple action of threading the plugs into the housing. It does not require significant force to set these seals and it may be possible to perform by hand. In a sense the plugs are floating in the housing to accommodate movement as the cell is pressurized.

## **DESCRIPTION OF CELL COMPONENTS**

### **Core Holder End Plugs:**

Figure 3 shows a draft image of the end plug. On the top face of the plug are two ports plus two additional threaded holes. The center port is for the core flooding fluid. Through this port passes a 1/4" high pressure tube section which is sealed into the plug using a PTFE seal and piston plug. The peripheral port is the confining fluid port to which directly connects a LM4 high pressure fitting for 1/4" tubing for 1.5" diameter core holders. The fitting style for the 1.0" core holders is also for 1/4" tubing but uses a modified LM4 gland. (See *Special Assembly Notes For 1" Core Holders*). The remaining two threaded holes are for hangers that might be employed by the user to hold the cell while in the NMR instrument. These are 1/4"-20 threads with a depth of 0.625". See Appendix D for additional details on dual port end plugs.



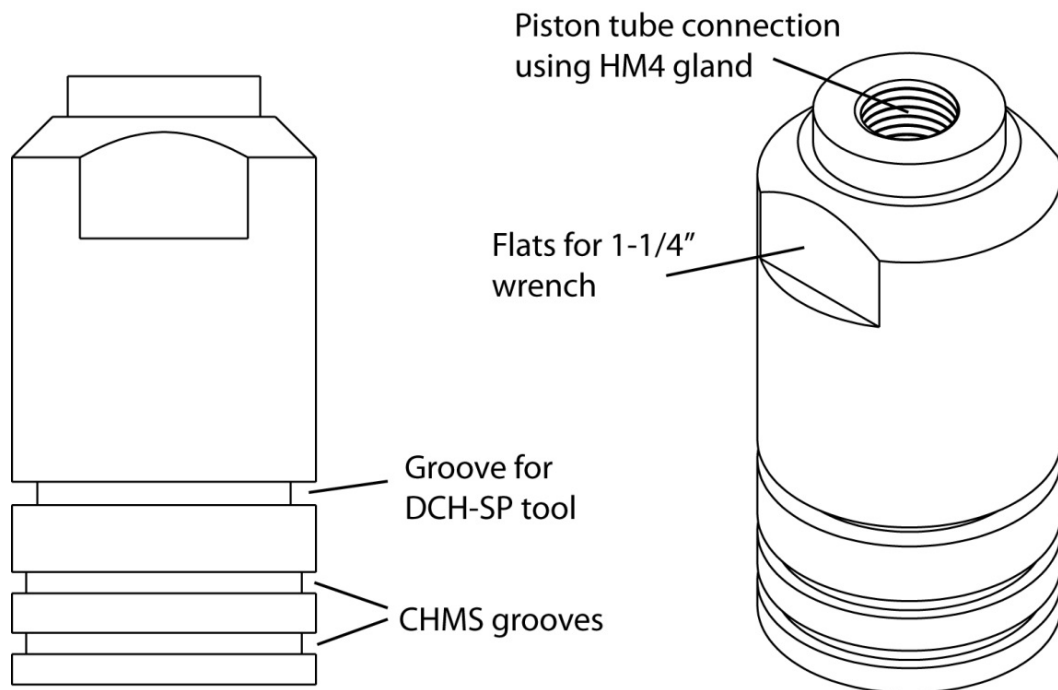
**Figure 3:** Cell end plugs for 1.5" core holders with notations



If possible the connection to the confining fluid port should remain connected during disassembly. Repeated disassembly may eventually damage the sealing surfaces.

### Sample Core Mounts:

The PEEK sample core mounts in Figure 4 are the components between which the rock core sample is mounted. The configuration of the mounts may be different than that shown in the figure, but each mount has the same functional features. At the face, not shown in the image, is a star pattern fluid dispersion face. This is meant to deliver fluid to the core sample in a more uniform fashion. Above the bottom face are two grooves that accept MSCS seals. When the FEP tubing is shrunk around the core and mounts these seals are engaged to provide sealing force against penetration of the confining fluid. Thus the core sample is isolated from the confining fluid.



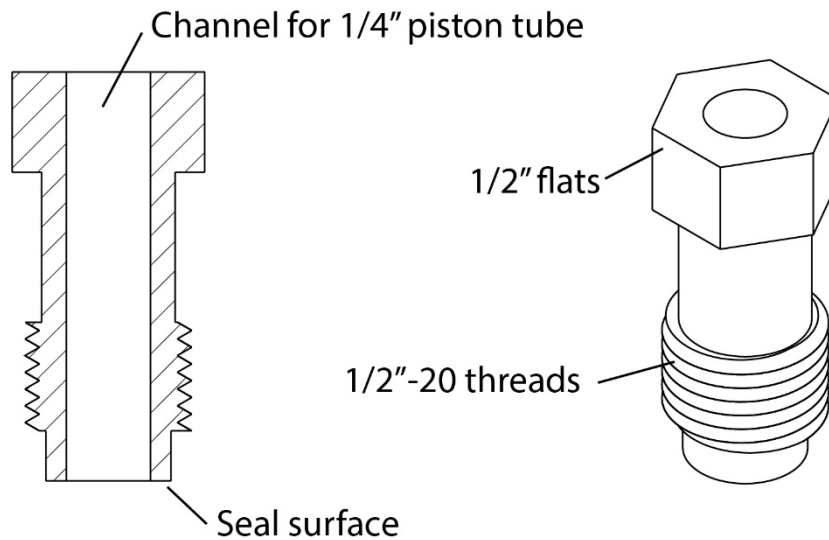
**Figure 4:** Sample core mounts for 1.5" core holders

For the 1.5" core holder mounts a third groove on the mount provides a slot where the DCH-SP tool is placed during building of the core assembly. The FEP tubing rests on

this tool to maintain optimal placement as the tubing is shrunk into position. This is not present in the 1.0" core holder mounts.

At the top of each mount is a port for connecting the piston tubes. This fitting style is HF4 for accepting the HM4 gland. The thread style is 9/16"-18. The fitting is tightened into the mount using only moderate force. The pressure provided by the confining fluid assists in completing the seal between the metal fitting and PEEK body. Flats on the core mount body for the 1.5" core holders is a 1-1/4" wrench which helps hold the mount when making these connections. The flat are 1" for the 1.0" core holders. The hand tools for making these connections are provided with the cell.

**Piston Plugs:**



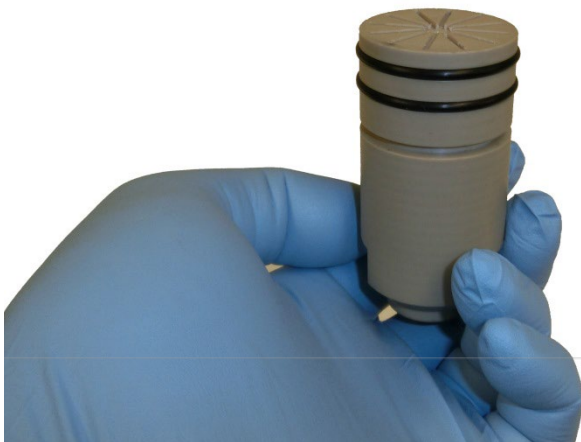
**Figure 5:** Piston plug with notations

The piston plug is used to set the PTFE seal against the high pressure piston tubes. It performs this action by crushing the seal into a recess in the end plug and tightly against the tube. The plug has 1/2" flats for assembly purposes. The threads on the plug itself are 1/2"-20 threads.

## INTERNAL CORE SAMPLE ASSEMBLY

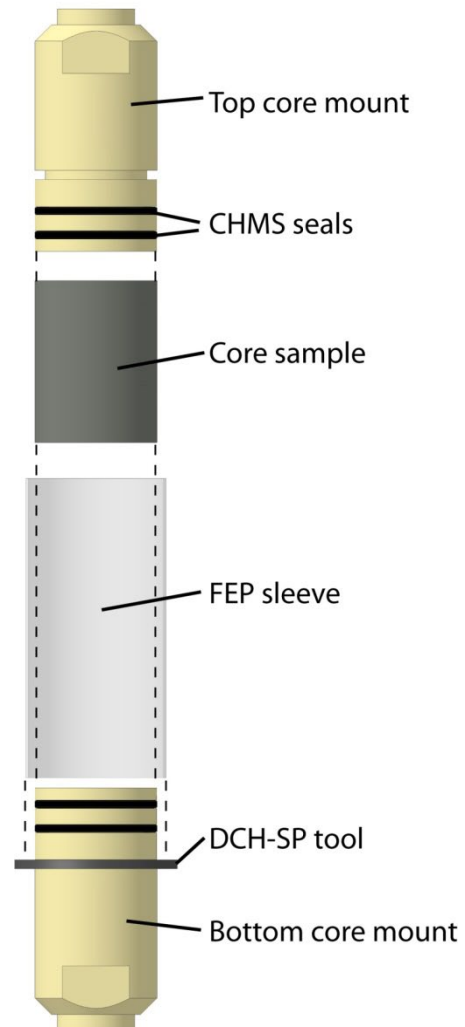
The core sample assembly forms an internal chamber for the rock sample that fully isolates the sample from the confining fluid. The core assembly can compress and stretch as needed upon the application of confining pressure. The assembly also allows for direct connection of an external pressure source to the core for static or flow measurements. Fluid dispersion channels on the mounts deliver fluid to the sample in a more uniform manner.

An exploded view of the core assembly is shown in Figure 6. The first step in the process is to place two MSCS seals on each core mount as shown in Figure 7. **It is important that seals be stretched into position rather than rolled into position.** Rolling the seal will cause the seal to twist in the groove and degrade the ability of the seal to resist pressure. These seals are single use so will need to be replaced with each sample.



**Figure 7:** Place seals on core mounts

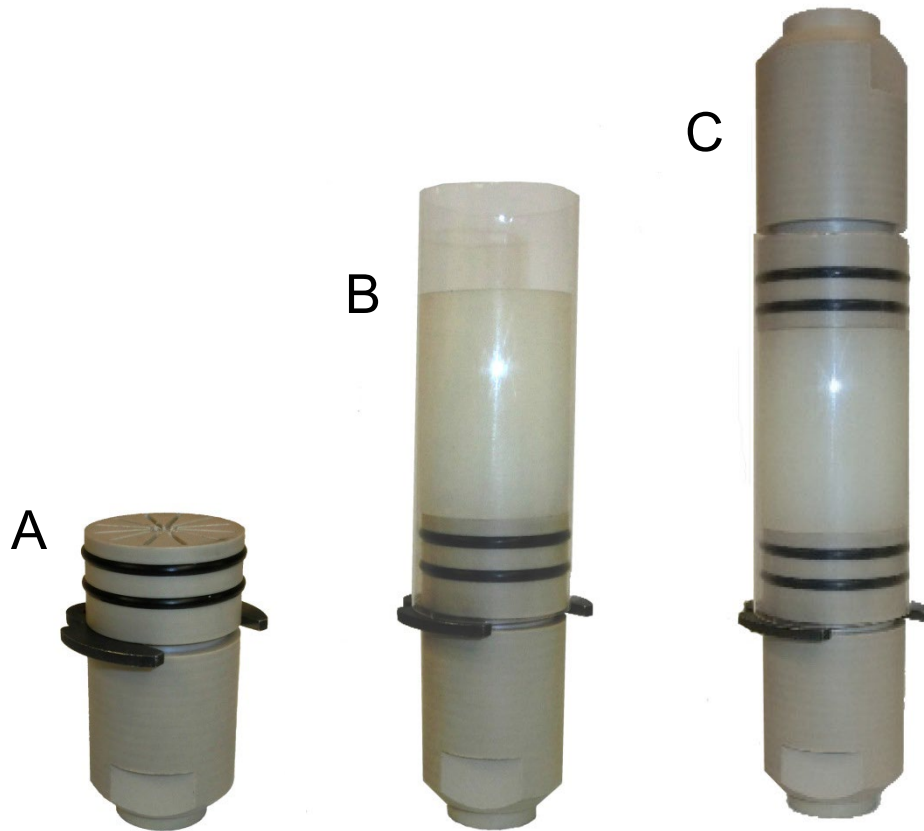
the core with the bottom resting on the DCH-SP tool (Figure 8B). **The FEP sleeve for the 1.0" core holder mounts rests on the larger diameter section of the mount**



**Figure 6:** Core assembly diagram

The next steps are illustrated in Figure 8. For the 1.5" core holders the DCH-SP tool is placed into the third groove on what will become the bottom mount. With the mount placed on the bench (Figure 8A), the core sample can be positioned on the bottom mount. Next a suitable length of FEP sleeve can be placed around

so the DCH-SP tool is not required. Finally the top mount can be placed on the core (Figure 8C). The FEP sleeve should overlap with the topmost seal on the top mount by at least 0.1”.



**Figure 8:** Steps to build the core assembly

To set the seals in the top and bottom core mounts sufficiently to resist pressure, heat must be applied to shrink the FEP tubing. This can be done by place the entire assembly in an oven at 130°C or using a heat gun to uniformly shrink the tubing. Radiant heat-shrink wands can also be used. When placed in an oven it takes about 10 minutes to shrink the tubing. The sleeve can also be preshrunk at lower temperatures. . For example, shrinking the tubing around a 1.5” mandrel for 2-3 hours at 70°C will shrink the tubing to the size of the mandrel, but still be easy to remove. This can then be forced past the seals on the core mounts and may be sufficient to provide initial sealing force until confining pressure is applied. Generally, no additional heating would be necessary. This may be important if the core cannot be exposed to high temperatures.



After removing the assembly from the oven and before it cools, the DCH-SP tool should be removed, and the assembly rolled on the bench to help axially align all the components.

At both ends of the core assembly are HF4 style ports. These lead directly to the fluid dispersion faces on the core mount. Once the assembly has cooled the 1/4" OD piston tubes can be connected to these ports using the HM4 glands and collars. The first step of the process is to place a gland on the tube, followed by a collar. The collars are left-hand threaded. The collar does not need to be fully threaded onto the tube. Instead thread only until the first two threads are exposed (see Figure 9). A gland and collar should only be placed on one side of each piston tube.

The piston tubes are the delivery channels for the fluid sent to the core. In addition to that role the high pressure tubing serves to help axially align the core sample and provide a rigid anchor within the housing itself.



**Figure 9:** HM4 gland assembly

The piston tubes can be of any length required to make the connections to external pressure sources so long as the 1/4" OD is maintained. This requirement is due to the PTFE piston seal to be set later in the assembly process.

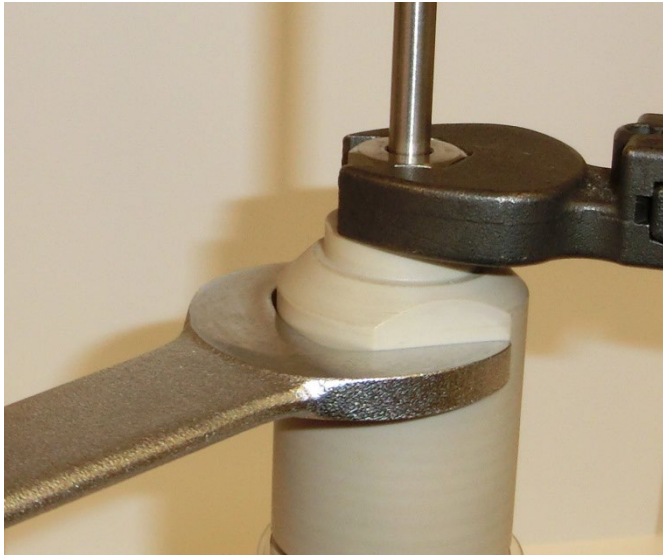
Connect the piston tubes to both ends of the core assembly unit. **Use a 1-1/4" open end wrench for 1.5" mounts and 1" open end wrench for 1.0" mounts to hold the mount and a torque wrench equipped with a 5/8" open end wrench head to torque the gland to 50 in-lbs.** The process is shown in Figure 10.



Use only 50 in-lbs to tighten the piston tube glands to the core mounts. Do not over tighten as this may strip the PEEK threads or cause other damage and ruin the core mount. To maximize the life of the mounts do not remove this tubing from the mount between samples.

The core mounts are made of PEEK plastic whereas the piston tubes and glands are stainless steel. Over time the stainless steel will wear the PEEK threads to the point of failure. This failure point can be delayed by keeping the piston tubes connected to the core mounts between samples. However, this may not be practical for all

applications. It may also be possible to refurbish the threads using a 9/16"-18 tap. This can extend the life of the mount. It should be expected though that at some point the mounts will wear out. The wear time is highly user and condition dependent, but it is expected that the mounts should be replaced after 20 uses.



Multiple core samples can be premounted in assemblies for rapid sample change-out.

With the piston tubes now connected to the core assembly the overburden cell can now be assembled for use.

**Figure 10:** Attach piston tubes to core mounts

## ***ASSEMBLY OF THE OVERBURDEN CELL***

Briefly, with the housing placed in the cradle, the assembly proceeds as follows:

**Step 1:** Insert the bottom end plug into the housing and then flip the housing over in the cradle.

**Step 2:** Place the core assembly into the housing by feeding the bottom piston tube through the bottom end plug.

**Step 3:** Insert the top end plug into the housing.

**Step 4:** Place the PSCH on the piston tube and set this seal using the piston plug. Flip the housing in the cradle once again.

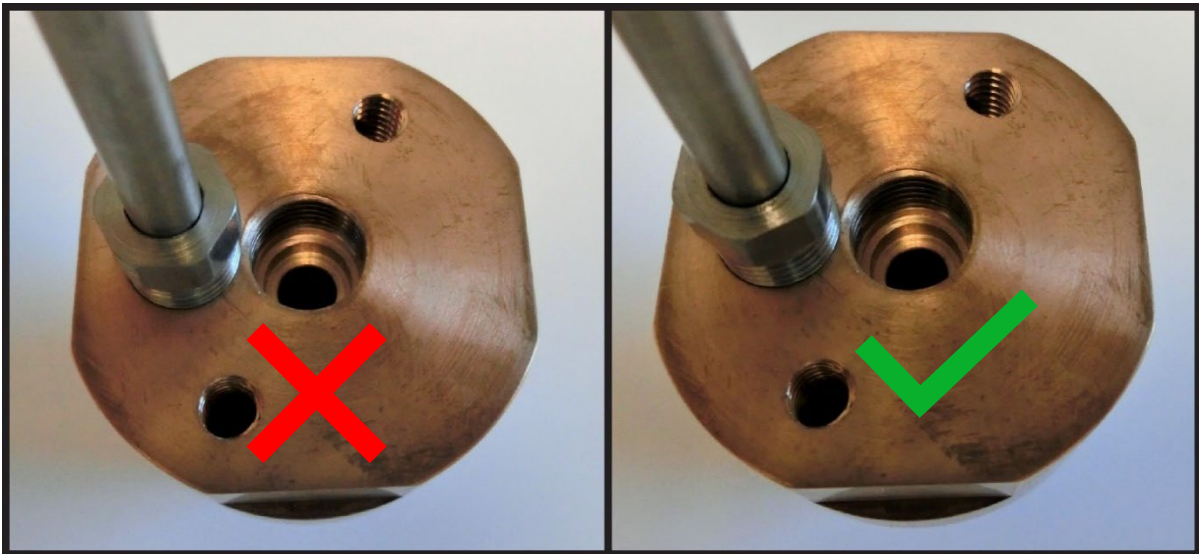
**Step 5:** Secure the bottom piston tube in the housing using a PSCH seal and piston plug.

**Step 6:** Add any necessary adapters and hangers.

The instructions details the assembly for standard single port end plugs. Dual port end plugs generally follow the same assembly process but may have additional considerations. See Appendix D for more details.

### Special Assembly Notes For 1" Core Holders:

For the 1" core holders the spacing between the confining port and central port is quite small. It is not possible to attach the confining port line after the piston nut has been installed because there is not sufficient space to rotate the included modified LM4 – 7/16" gland even though the footprint has been reduced in size. It is also true that in certain states the modified LM4 gland may impede the connection of the piston nut. An example is shown in the figure below where an apex of the gland hex pattern is pointed toward the flooding port. To allow the piston nut to fit with the LM4 gland attached the flat edge must be facing the flooding port.



**Figure 11:** Proper confining port setup for 1" core holders

The left box of Figure 11 shows the apex of the hex pattern flats pointed towards the flooding port. The piston nut cannot be connected to the plug in this orientation. The right box shows the flat surface towards the flooding port. This is the required position to allow connection of the piston nut, provided the confining port tubing is already in place.

One solution for assembling the connections is to first thread the confining port gland into the plug, but not fully tighten it to allow the flat edge to be properly positioned. The piston nut can then be assembled as typical followed by a final tightening of the LM4 gland. This method may require the confining port line to also be loosened during the disassembly process.

If desired the confining port line can be connected more permanently by trying to tighten the gland such that the final position is with the flat to the flooding port. This

requires adjustment of the collar piece to change the thread engagement position of the gland. A general guideline is to adjust the collar until the gland hand threads into the port with the apex pointing toward the flooding port when hand-tight. The tightening process will rotate the gland more to bring the flat into alignment. This arrangement is perhaps better such that the line need not be disconnected with each use since doing so decreases the sealing effectiveness of the connection.



**LEGACY UNITS:** The initial building of AM2 gland and collars should not be done using the confining port. Due to the high levels of torque required for this process it would likely damage the end plugs. Instead use another fitting or adapter to initially assemble the tube ends.

**LEGACY UNITS:** The AM2 style fittings used with the 1.5" core holders require significant torque to properly compress the collar around the tubing. To avoid damage to the end plugs do not perform initial assembly operation using the confining fluid port. Instead use another stainless steel component that can accept the AM2 glad for this purpose such as the kit component HiP 15-21AF2. Always use an anti-seize compound for stainless steel when completing this operation.




To minimize damage to the end plugs, the tubing or adapter connected to the end plug should be removed only sparingly. Frequent swaps of any high pressure connection will eventually degrade the sealing performance.

The connection to the confining port should not be disconnected very often. Repeated assembly and disassembly of any high-pressure fittings will eventually degrade the sealing performance. Instead, short lengths of tubing should be connected to the end plug then coupled to longer lengths of tubing for general operation. The couplers (HiP 15-21AF2 or HiP 20-21LF4) have been provided with the kit for this purpose. Typically a short 6-12" length of tubing is all that is required to provide sufficient distance from the end plug to have access to make the additional connections to the confining port.

Before the full cell assembly takes place the CHPS seals should be placed in the grooves on the end plugs as shown in Figure 12. The adapter or tubing section should also be connected to the end plug using 190 in-lbs. of torque. Once these minor steps are complete the cell can be fully assembled.



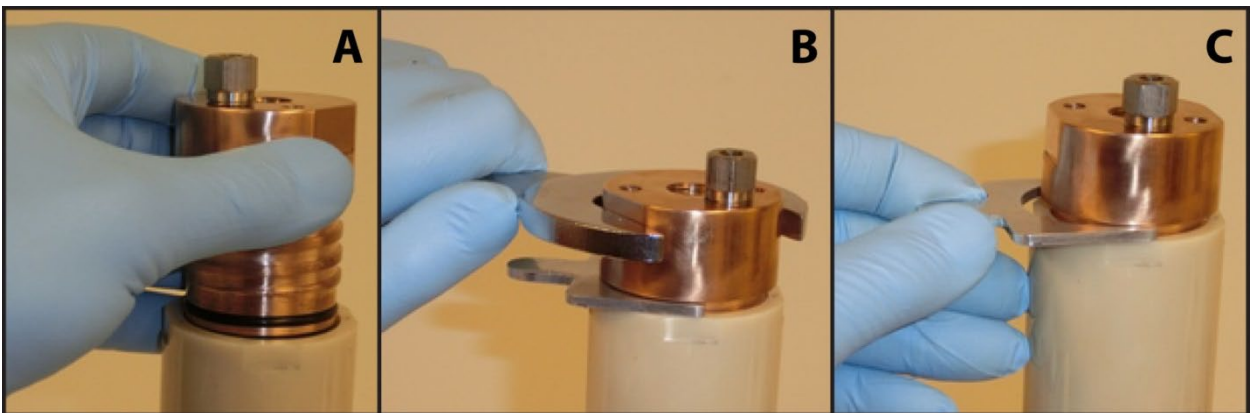
 Always stretch the seals into position. Do not roll the seal or pressure performance will be reduced.

Place two CHPS seals on each end plug in preparation for assembling the overburden cells. **To prevent twisting of the seal in the groove, stretch the seal into position; do not roll.**

**Figure 12:** End plug with seals

A detailed explanation of the assembly steps will be provided.

**Step 1: Insert the bottom end plug into the housing and then flip the housing over in the cradle.**



**Figure 13:** Assembly of bottom plug to the housing

The housing at this point should be placed in the cradle with the flats on the housing matched to the internal cradle flats. This will help keep the housing from rotating as other steps are performed.



For the first use of the cell the end plugs can be placed in either the top or bottom position. Once the orientation of the cell has been established, the same end plug should be used in the same housing end for subsequent assemblies.

With the dual CHPS seals in the proper grooves on the end plug thread the end plug into the housing (Figure 13A). The seals protrude more than the inner diameter of the threads so a small amount of force will be needed to work the plug end past the first threads. Then continue to thread the plug into the housing by hand. There will be mild resistance to this action.

At some point the resistance will markedly increase when the first seal encounters the narrowing point in the housing. It is the compression of the seal due to this narrowing that provides the required sealing force. It may no longer be possible to turn the plug by hand so use the 1-3/4" open end wrench on the flats of the end plug to continue the step. If necessary, the largest open end wrench supplied with the kit can be used to hold the housing itself.



If resistance to threading the end plug becomes significant it is a sign the seal is binding as it is forced into the narrow bore section. Simply back the plug out a 1/8-1/4 turn and resume threading the plug into the housing.

Continue to slowly thread the end plug into the housing. If it seems to bind reverse the action about a 1/4 turn, then resume threading. This phenomenon will be encountered for the second seal as well.

Place the DCH-EPS tool in the groove below the plug flange (Figure 13B) before the plug bottoms-out against the housing. This tool is meant to provide a consistent spacing for the end plugs during assembly. Providing a gap between the housing and end plug allows the entire assembly to flex during high pressure and temperature

applications. It is, however, important that a consistent position of the plug in the housing be maintained.

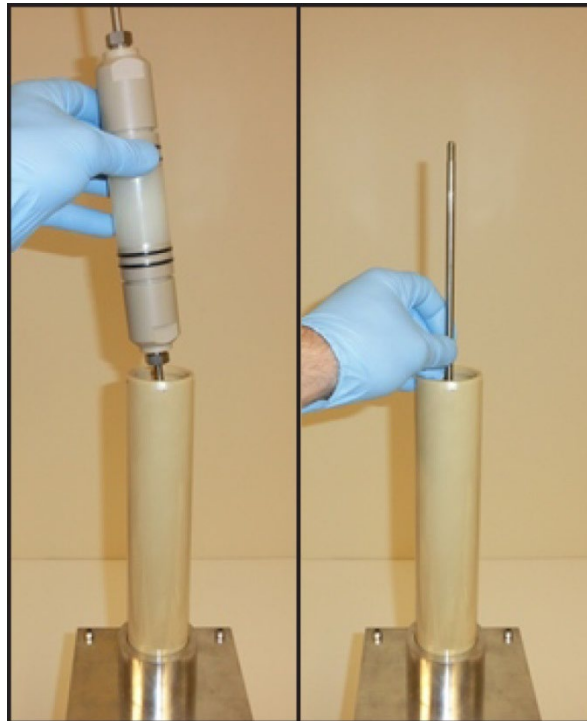
With the DCH-EPS tool in place continue to tighten the end plug until it just contacts the DCH-EPS tool. It should not be so tight that the tool cannot be removed. If it is too tight against the tool the plug should be backed out a quarter to half turn with the wrench and rethreaded into the housing until the contact condition is met and the DCH-EPS tool can be removed. The final action before removing the tool should always be a clockwise turn where the threads are engaging.



The final direction of action when assembling the end plug in the housing should be one of thread engagement or a clockwise motion.

This is not an exact positioning technique, but it assures the proper number of threads is engaged in the housing to provide the necessary strength to resist the internal pressure.

Upon completion of this step, flip the housing in the cradle.



**Figure 14:** Insert the core assembly with the bottom piston tube-end first

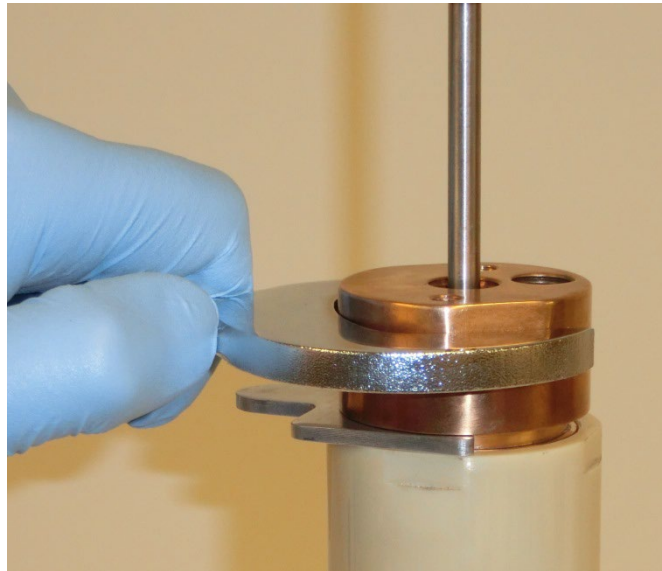


**Step 2: Place the core assembly into the housing by feeding the bottom piston tube through the bottom end plug.**

With the bottom plug now positioned at the bottom, feed the core assembly unit into the housing and through the bottom plug (Figure 14). If the core assembly has an orientation due to differing length piston tubes, be sure the bottom goes in first.

**Step 3: Insert the top end plug into the housing.**

Using the same procedure from Step 1, insert to the top plug into the housing. After properly positioning the end plug leave the DCH-EPS tool in position (Figure 15).



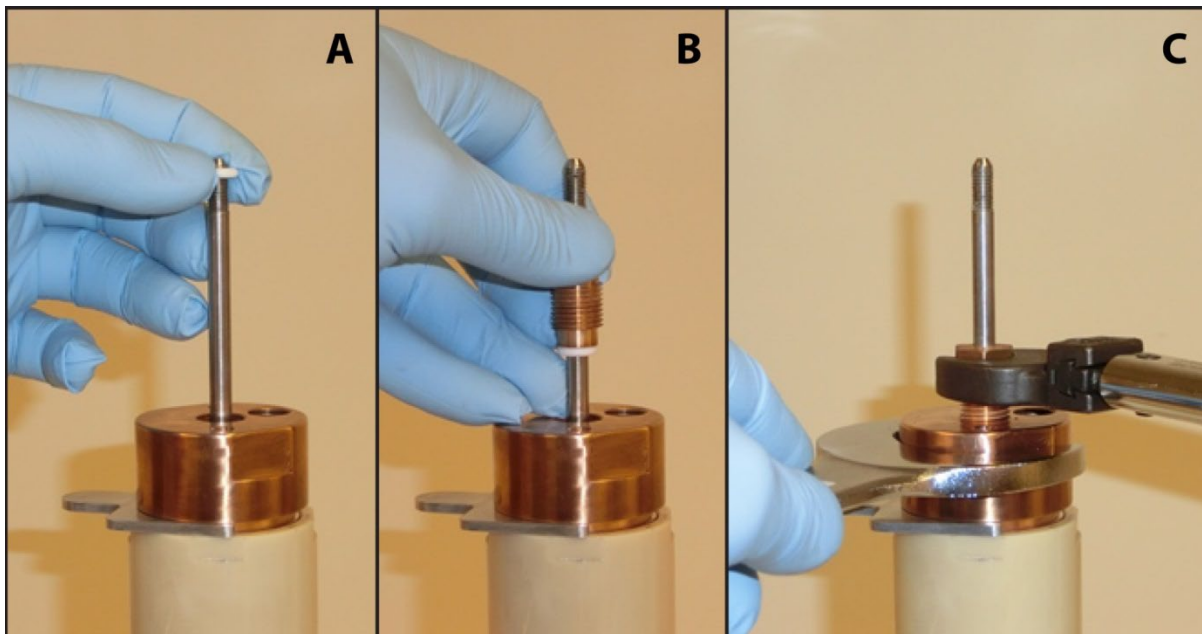
**Figure 15:** Insert top plug in housing

**Step 4: Place the PSCH on the piston tube and set this seal using the piston plug. Flip the housing in the cradle once again.**

At this point the core assembly is free to move inside the housing with nothing restraining the piston tubes. The core holder and core mounts are fabricated so that, depending on the length of the core sample, there may be a small amount of space available for the core assembly to move. This allows for slightly larger, as well as smaller, core lengths to be accommodated without changing the mounts. It also allows for axial core stretching during operation.



This condition means that the core itself may not be at the exact center of the housing. This may require later positioning of the housing to place the sample in the sweet spot of the NMR instrument. With the core assembly resting on the bottom plug the top PSCH and piston plug should be attached (see Figure 16).



**Figure 16:** Process for connecting the piston plug

Take one PSCH seal and place it on the piston tube (Figure 16A). To push the seal past the threads may require a bit of force. This process can be facilitated by using the piston plug as the ram to push it down the tube (Figure 16B).

**Tighten the piston plug into the cell end plug using a 1-3/4" open end wrench on the end plug and an adjustable torque wrench with a 1/2" open end head to a torque setting of 190 in-lbs.** This will press the PSCH seal against the tube and generate a dynamic seal against the internal pressure.

The DCH-EPS tool should be checked again to assure it can be removed. If not, then make the appropriate adjustments. The core assembly is not tethered on the other side so this operation is still possible. Once the setup has been confirmed, remove the DCH-EPS tool and flip the cell in the cradle once again.

**Step 5: Secure the bottom piston tube in the housing using a PSCH seal and piston plug.**

Place the DCH-EPS tool back in the groove and confirm the position of the bottom end plug and adjust if necessary. Then follow the same procedure from Step 4 and connect the other piston plug (Figure 16). At this point the core assembly is now fixed in place in the housing. It is still free to move as necessary during operation of the cell, but requires significant force to do so.

**Step 6: Add any necessary adapters and hangers.**

The overburden cell is now assembled so the next step is to add any necessary accessories to the cell. The piston tubes should be terminated with an additional LM4 or HM4 gland and collar and then terminated with, for example, the HiP 15-21AF1LF4 or HiP 15-21AF1LF4 adapter to convert from 1/4" tubing to 1/16" tubing.

If the confining fluid tubing or adapter is not connected it can be done now. This port uses LM4 glands and collar. This tubing section can be terminated with the HiP 20-21LF4 coupler to extend the connection to the confining port fluid delivery device. Note: Earlier version holders used 1/8" tubing and AM2 glands and collars to make a direct connection to the end plugs.

The overburden cell may need to be suspended inside the NMR instrument. On both the top and bottom plugs are holes that can be used to mount hangers. These holes have 1/4"-20 threads to a depth around 0.625". To avoid collisions with existing hardware it is recommended that the maximum diameter for the part be 0.572" which would be equivalent to a 1/2" hex nut.

The cell can now be inserted into the NMR instrument or with suitable shielding pressure tested outside of the instrument.



The cell should not be pressurized outside of the instrument without proper shielding to protect the user. The DCH PROTECTIVE BOX provides the appropriate protection for such operations.

***DCH PROTECTIVE BOX USAGE***

The protective box attachment provides the ability to pressurize the overburden cell on the bench. This might be performed for initial pressure tests to assure the setup is

sound prior to inserting the cell into the magnet. It might also be done for core aging experiments where the overburden cell is to be maintained under pressure for extended periods of time.

The protective box mounts on top of the assembly cradle as shown in Figure 17. The dual panels of clear polycarbonate plastic provide protection while allowing visual inspection of the overburden cell. The dual aluminum plates at the top have a hole of sufficient size to pass the pressure lines through, but still provide protection in the axial direction. The hangers cannot be attached while the protective box is in place.

To secure the protective box to the cradle, four mount arms are provided. The cradle is shipped with two T-nuts in the framing channels on opposing sides. The protective box has two T-nuts in the channels on all sides to allow it to be secured in any position. It is to these T-nuts that the mounts are attached.

Using a 3/16" hex wrench first loosely connect each mount to the T-nut at the bottom of the assembly cradle with a 1/2" socket head screw. Then slide each mount upward until the top hole aligns with the T-nut on the protective box and secure the mount to the box. Repeat this process for all four mounts. The screws in



**Figure 17:** Protective box on cradle



**Figure 18:** Protective box arm screw tightening scheme

the top position should be tightened fully whereas the screws in the bottom position should be snug or just hand tight (see Figure 18). This configuration will, in the unlikely event of a failure, allow the mass of the protective box to be used as a mechanism to initially absorb and reduce axial forces.

## ***OPERATION OF THE CELL***

The objective of this section is to highlight several operational considerations for the overburden cell.

- Do not pressurize the overburden cell outside the NMR instrument without proper shielding of the unit. Though this unit has been thoroughly tested prior to shipping there should always be a degree of caution applied as this is a high pressure device.
- When the unit is in operation in the NMR instrument it is advisable to place shielding above, and if necessary, below the NMR instrument to protect the user from unexpected failure in fixtures or the housing itself.
- The unit should not be pressurized to the maximum rated pressure while undergoing a significant temperature shift. The housing is ceramic so large thermal gradients across the wall of the housing could create a failure condition. It is better to allow the unit to equilibrate at temperature at no more than 30% maximum rating then increase the pressure to experimental conditions.
- The confining pressure should always be 300 psi (plus margin of uncertainty of the pressure measurements) above that of the core pressure. A smaller differential could lead to loss of containment.
- Place safety burst discs in-line with the pressure delivery systems. Ideally this should be fairly close to the confining fluid inlet port. The overburden cell has been tested to a point over the rated pressure for an extended period. This is to assure pressure spikes caused by inadequate regulation or thermal spikes will not fracture the housing. The safety disc should be rated at 20% over the maximum operational pressure. It must be noted that safety discs do wear out so any outlet from the safety disc housing should be connected to a receptacle capable of receiving the operational fluids.
- Fluids in motion will display a pressure drop across the system. The magnitude of this differential is dependent on the viscosity and tubing diameter, but could be quite large. It is recommended a pressure gauge or sensor be placed close to the inlet port for the confining fluid to get a more accurate reading of the pressure of the fluid into the overburden cell. A gauge near the outlet will provide a good measure of the pressure differential across the cell.

- The temperature of the rock sample can be measured at the faces of the core sample using thermocouples. The 1/4" piston tubing used for the core injection fluid has an inner diameter of 0.083". Thermocouples with 1/16" outer diameters can be inserted in these tubing sections and secured with a high pressure fitting. An example setup with part list is shown in Figure 19. Appendix B has additional information.



**Figure 19:** Thermocouple setup for sample temperature monitoring

Example part list:

- HiP P/N 15-21AF1LM4-T (adapter for 1/16" thermocouples)
- HiP P/N 20-23LF4 (high pressure Tee for HM4 fittings)
- HiP P/N 15-21AF1LM4 (standard reducer from 1/4" to 1/16" tubing)
- Omega P/N TJ36-CPIN-116-U-18-XX (18" T-type thermocouple) or TJ36-ICIN-116-U-18-XX (18" J-type thermocouple)
- Omega P/N TC-08 (8-channel USB thermocouple data acquisition module)

Replicate for the bottom of the cell.

## ***DISASSEMBLY OF THE OVERBURDEN CELL***

The process for disassembling the cell is less ordered than the assembly process, but can be broken down into a few key focus points.

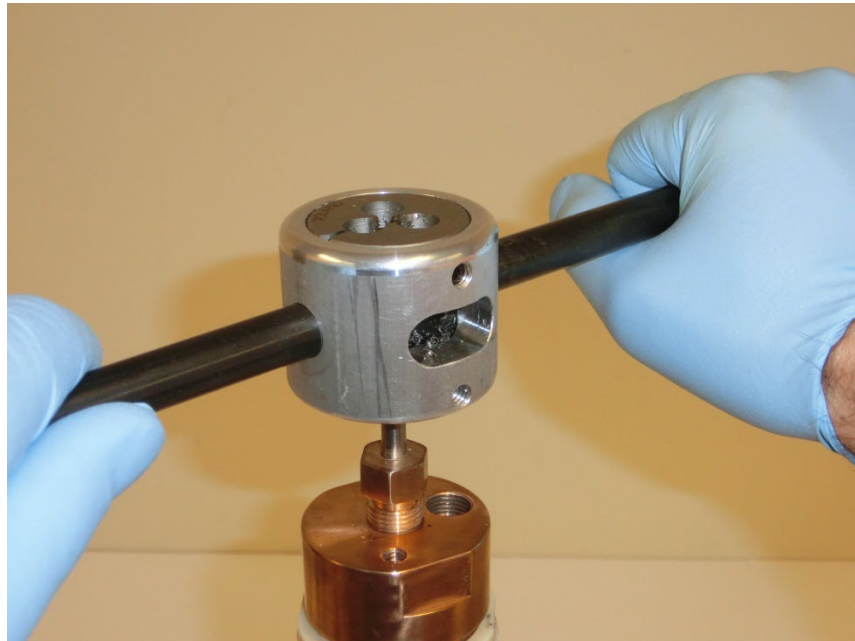
### **Point 1: Piston plugs and reconditioning piston tube ends**

Before the end plugs can be removed, the piston plugs must first be removed. However, before that is done it is recommended that the protruding end of the piston tube be reconditioned with the provided left-handed rethreading tool. The reason for performing this operation is that the stainless steel threads at the tip of these tubes will deform over time. If the threads are not reconditioned it will at some point be impossible to remove the gland and collar. This of itself is not a major problem since the tube could be removed by disconnecting it from the internal core assembly.

Figure 20 shows the rethreading tool being used to recondition the threads. Use a drop of the Rapid-Tap fluid on the tube threads then feed the end of the tube through the guide hole at the bottom of the tool. Proceed to turn the tool in a left handed fashion (counter clockwise motion) for half a turn followed by a brief reverse turn to break the chips loose.

Continue in this step-wise fashion (forward, then reverse) until the tube is rethreaded. This process should be done with the piston plug still in place to restrain the piston tube from turning during the process.

After reconditioning the piston tube threads the piston plug can be removed. The end plug can also be removed.



**Figure 20:** Rethreading piston tubes during disassembly (tool may vary from the picture)

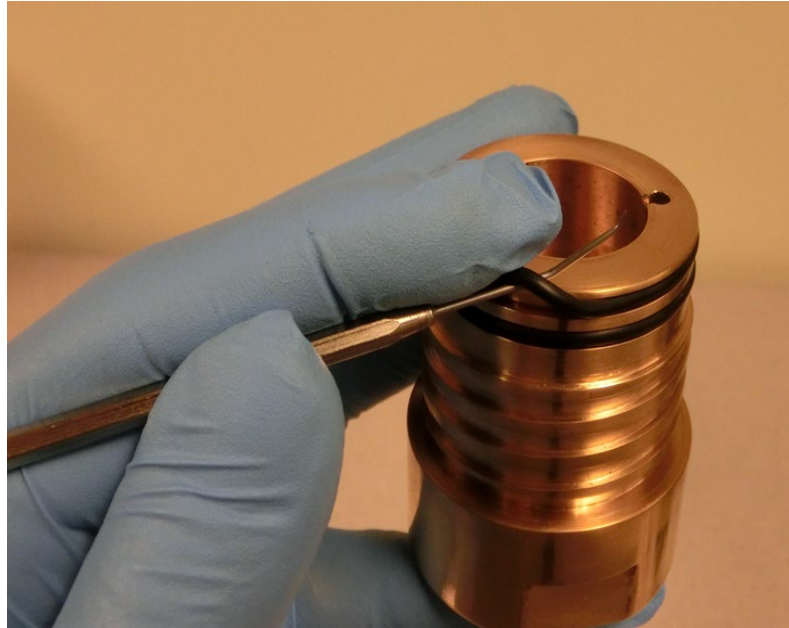


## Point 2: Removing seals from plugs and mounts

The seals used in the overburden cell are single-use only. These should be replaced after each use. Several hooks have been provided as part of the kit to help remove the seals from the grooves and recesses.

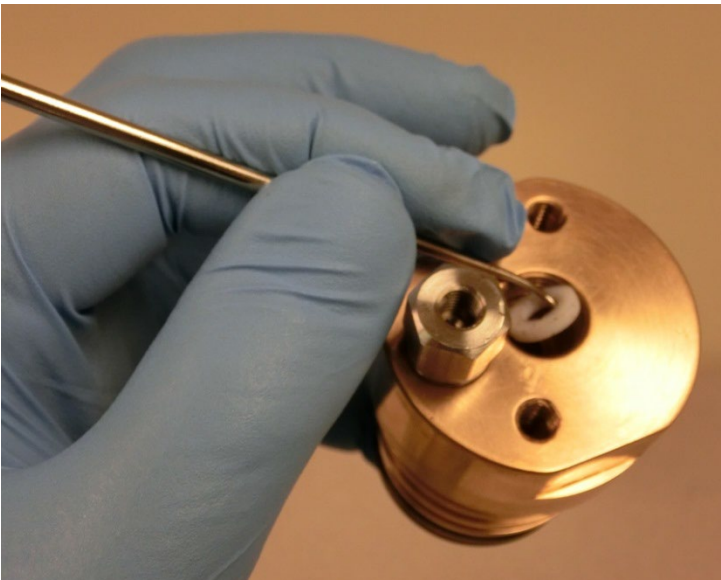
To remove CHPS seals from the end plugs and the MSCS seals from the core mounts the precision hook should be used. Slide the hook tip along one side of the seal, then force the tip under, and bring the tip out the other side (Figure 21). By lifting on the hook at this point the seal can be grabbed and removed.

It is important to keep the hook tip from scratching or scoring the plugs or mounts. This could degrade the performance of the components.



**Figure 21:** Use precision hook pry out plug and mount seals

The PTFE seal should also be removed from the recess in the top of the end plug.



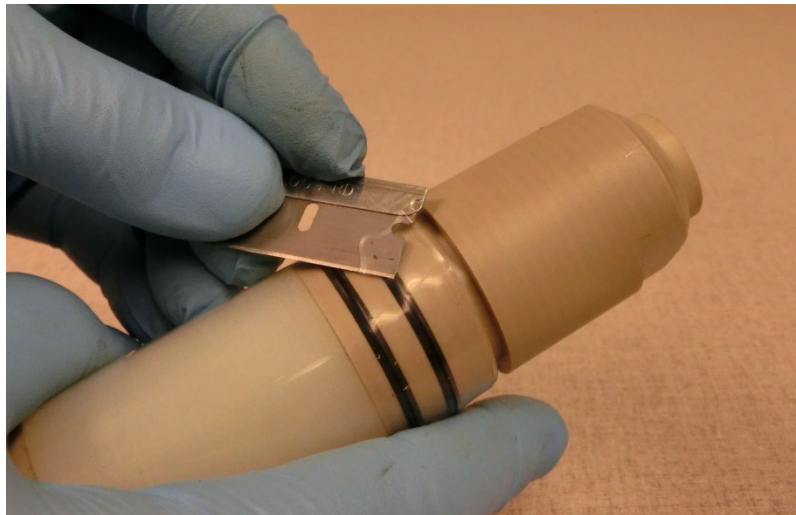
**Figure 22:** Remove PSCH seal using curved hook

There is a general use hook that it meant to be used for this purpose. It has been noted that it may not have a fine enough tip to perform this function. Instead the five-piece hook set has a similar hook that can be used instead. Again, every effort should be made to not score the walls of the recessed area or scrape the hook tip along the threads.

### **Point 3: Removing the FEP heat shrink sleeve**

Before the MSCS seals can be removed the FEP sleeve needs to be cut away from around the core. Using a razor blade or other sharp tool place the leading edge of the blade under the sleeve and cut with the blade at a tangent to the mount circumference (Figure 23). Do not drag the blade along the surface of the core mount as this will scratch or nick the mount.

Once an initial cut has been made the sleeve can be peeled away from the core assembly.



**Figure 23:** Removing FEP sleeve from the core assembly

### **Point 4: Restraining housing to remove end plugs**

It may be necessary to restrain the housing during removal of the end plugs. The cradle can be used for this purpose. A better method is to use the largest open end wrench supplied with the kit on the flats of the housing nearest the end plug. Though the force to remove the end plug is never expected to be large it is prudent to minimize potential rotational stress in the center of the cell.



## **OVERBURDEN CELL USAGE LOG**

It is recommended that a log book be kept of the operational conditions to which the cell was subjected. Service alerts regarding the operational life-time of the cell or cell components may be issued in the future. An accurate accounting of the operational life of the cell may be important in determining whether the cell falls within the classification of said alerts. It is also good practice to make note of any irregularities in the setup or damage to components. Something that may seem trivial at the time could lead to later failure of a component, and an accurate record will assist in identifying the problem.



The extreme operational pressure and temperature conditions of this overburden cell demand that users be thoroughly familiar with this manual and handling of the cell. It is highly encouraged that expert users be established that can then supervise general users of the equipment.

An example log book might take the following form:

<b>Date</b>	<b>User</b>	<b>Pressure</b>	<b>Temperature</b>	<b>Duration</b>	<b>Notes</b>

Generally only the maximum pressure and temperature for a given experimental setup need to be recorded. If the cell is tested for integrity outside the magnet prior to insertion, those short bursts do not need to be recorded independently since it is assumed that is done as part of the general operation. If there is a problem with the setup however, that should be recorded along with the corrective action taken to assist in future troubleshooting.

However, if there are instances where multiple pressure or temperature steps are taken for a given setup, and those steps are for significant periods of time, then those events should be recorded separately. This will better allow the duty-cycle of the cell to be quantified.



If the main zirconia housing is dropped on the floor or if there is chipping of the housing the cell must be returned for recertification. Failure to note these instances and take corrective action could result in equipment damage, severe injury or even death.

The notes section should be used extensively to record potential issues or damage that may occur during general use. As users gain experience from using the cell it will become more clear which items alter the performance so specificity will develop. General examples of items to record:

- End plug thread damage
- Thread damage of inlet ports
- Seal damage upon assembly or disassembly
- Scoring of the sealing surfaces
- Failures to hold pressure or temperature
- Routine maintenance activities

This is not an exhaustive list; rather it is provided as a guide for developing strategy for employing a log book effectively.

## ***ADDITIONAL MAINTENANCE CONSIDERATIONS***

Two maintenance points have been previously identified in the text. Those are:

- Reconditioning the threads on the piston tubes after each use
- Reconditioning the threads on the top port of the core mount to extend component life

Other maintenance issues follow along the same path.

### **Piston Nut / AM2 Fittings / 1/2"-20 Tap and Die**

The 1/2"-20 tap and die can be used on the piston plug to recondition the threads if that becomes necessary. However, extreme caution should be used to avoid running the bottom of the tap against the leading edge of the recess. This can create a burr on this section of the end plug that will greatly impact the operation. Should this happen the burr can be removed by sanding. Always use the Rapid-Tap fluid for any of these operations.

The use of the AM2 fittings requires that significant torque be applied during the initial assembly of the gland and collar. It has been noted that the initial assembly of these fittings should not be done using the core holder end plugs. In doing so it may damage the threads slightly to the point where they will need to be reconditioned as well. The kit includes both a 1/2"-20 tap for internal threads and a 1/2"-20 die for external threads for this purpose. The Rapid-Tap fluid should be used at all times for rethreading purposes.

**7/16"-20 Tap**

A 7/16"-20 tap can be used for reconditioning the confining port threads should that be necessary. Always use the Rapid-Tap fluid for any of these operations.

**TORQUE SPECIFICATIONS**

End plug in housing	None – use DCH-EPS tool for placement
PEEK core mount (HM4)	50 in-lbs.
Confining fluid port (LM4)	190 in-lbs.
Piston plug	190 in-lbs.

Torque requirements for the preparation of fittings from High Pressure Equipment Company ([www.highpressure.com](http://www.highpressure.com)) to stainless steel components.

AF1	55 in-lbs.
AF2	120 in-lbs.; initial compression 300 in-lbs.; final seating
LM4	240 in-lbs.*
HF4	300 in-lbs.**

\*LM4 style fittings are designed for pressure up to 20,000 psi. When making connections to the bronze end plug we suggest a slightly lower torque setting to minimize damage.

\*\*HF4 style fittings are designed for pressure up to 60,000 psi which is well beyond the requirements here. It has been noted that it can be very difficult to apply the stated torque to fittings involving the overburden cell. Therefore, a more modest torque target of 150-200 in-lbs. may be used. Experience with the assembly will help guide the user towards the proper torque required.

For AF1 and AF2 fittings there should be bottoming-out or dead-stop when the connection is properly assembled. **These torque settings are for the preparation only and do not apply when making connections to the overburden cell.**

## ***FURTHER INFORMATION***

This document may be updated periodically to reflect questions from users. Please check back at [www.daedalusinnovations.com](http://www.daedalusinnovations.com) in the support section for more recent versions of this document.

Technical support can also be obtained by emailing questions to [support@daedalusinnovations.com](mailto:support@daedalusinnovations.com), or contacting Daedalus directly at 610-358-4728.

Other correspondence can be directed to:

Daedalus Innovations, LLC  
200 Racoosin Drive, Suite 106  
Aston, PA 19014

## **APPENDIX A: USING WRENCHES ON HIGH PRESSURE COMPONENTS**

Initial mating of the connections should be able to be achieved by hand. Occasionally the connections may not be lined up and the strain on the connection may make hand tightening difficult. This is especially true for connections made at the top and the bottom of the cell. Instead of forcing the connection with wrenches, small movements of the connections should be made to help engage the threads. Stainless to stainless connections are particularly prone to seizing under high torque so wherever permissible anti-seize compound for stainless steel should be used on the threads. For connections common to the overburden cell the AM2 style fittings are most prone to this. If the compound has worn off and applying more does not help lubricate the threads, the connections may need to be re-tapped.

### **Using Wrenches**

Always ensure that the flats of the wrench are fully engaged on the connector. Failure to do so could result in slippage and damage the flats of the connector. This is shown in Figure 24.

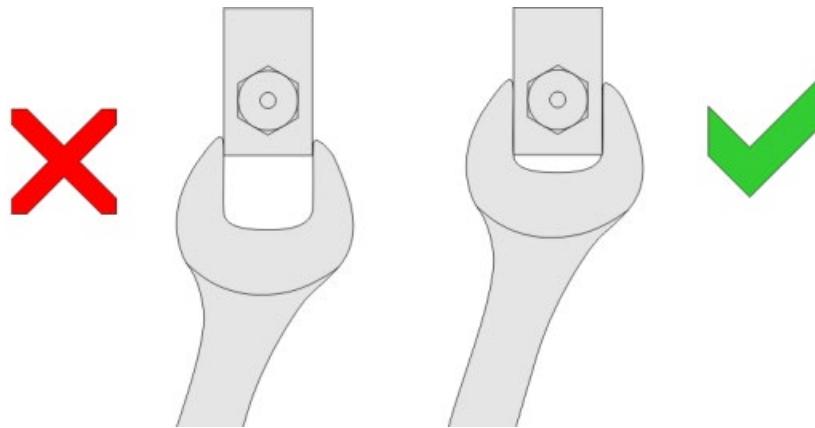


Figure 24: Proper engagement of wrenches

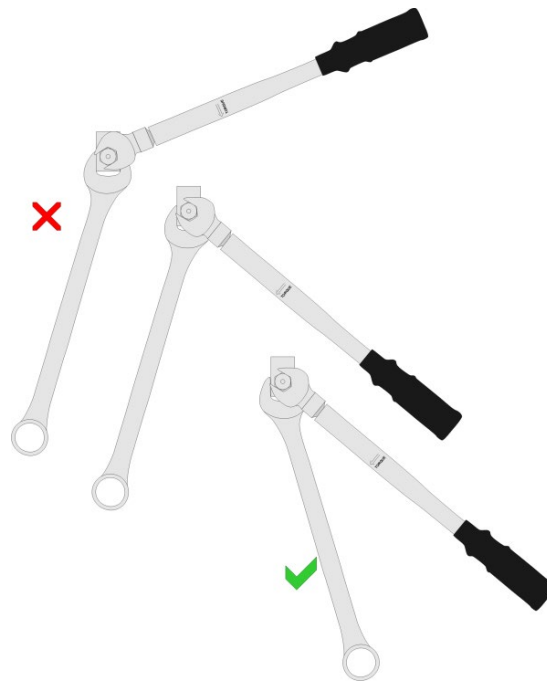
### **Using Torque Wrenches**

A torque wrench is designed to yield slightly when the desired torque is applied. The desired torque is chosen by rotating the handle until the torque value (in-lbs.), is just visible above the handle indicator. The torque must always be applied in the direction of the arrow shown on one side of the torque wrench. Once the desired torque is reached the head will yield slightly and an audible click will be heard. When this

happens no further torque should be applied. The torque wrench is supplied with an instruction manual for proper setting and use of the wrench.

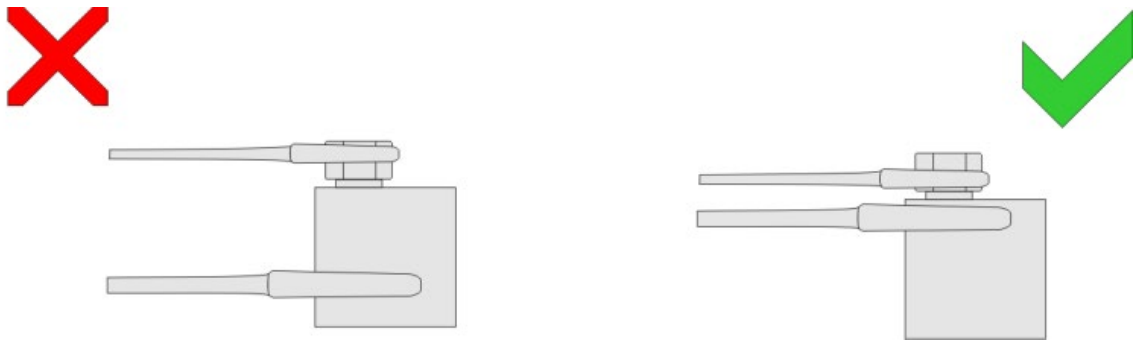
### Tightening Fittings

When applying a large torque with two wrenches it is essential that the torque is always applied in a squeezing motion. When using a fixed wrench and a torque wrench to tighten the fittings it is significantly easier to control the motion and apply the desired torque if the angle between the two tools is kept as small as possible. The fixed wrenches supplied with the overburden cell have the opening at an angle of  $15^\circ$  from the main lever arm. Turning a wrench upside down will change the angle of the main lever arm by  $30^\circ$ , when the wrench is engaged on the same flats. When tightening the high pressure fittings the orientation of the fixed wrench should be chosen in conjunction with the flats on the connector to ensure that the angle is kept to a minimum. Figure 25 shows three options for arranging a torque wrench and a fixed wrench for a connector, and how the positioning can be altered to bring minimize the angle between the lever arms of the wrenches.



**Figure 25:** Positioning the fixed and torque wrenches for tightening

When using pairs of wrenches it is important to, as much as possible, have them in the same plane (Figure 26). This makes the torque much easier to control.



**Figure 26:** Keep wrenches close when tightening

### **Loosening Fittings**

When loosening the fittings the fixed wrenches should be used. The same principles as tightening fittings apply, always use a squeezing motion, always engage the flats fully, try to keep the wrenches in the same plane, and try to minimize the angle between the two wrenches. Since the fittings will give significantly as soon as the initial seal is broken it is very important to have excellent control over the torque. The best way to do this is to try and arrange the two wrenches so that the lever arms can be spanned with both hands and squeezed to loosen. This gives the best way of sensing the torque and being able to release it quickly.

## APPENDIX B: SAMPLE TEMPERATURE MONITORING

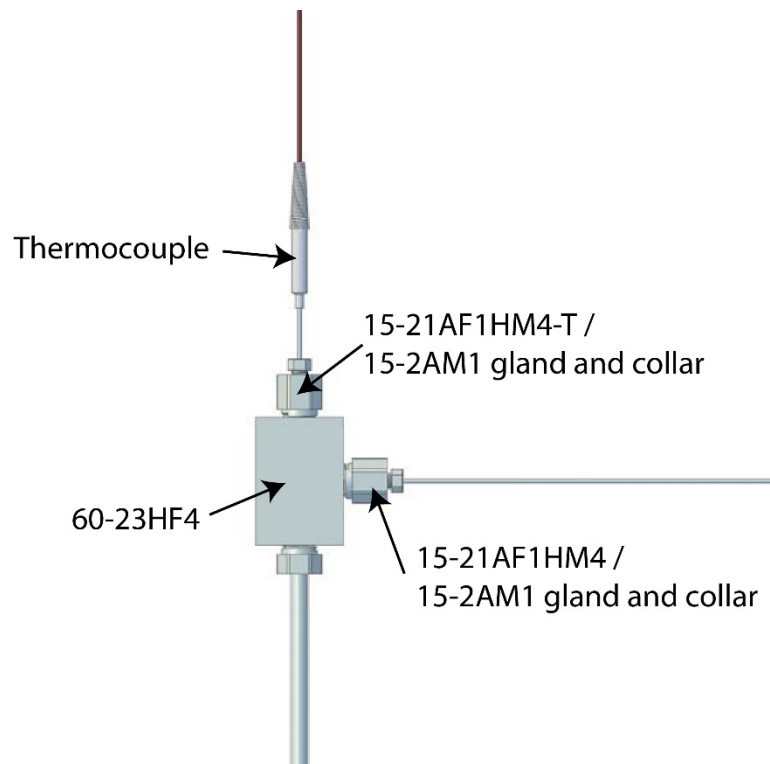
The temperature of the core sample can be measured at the faces using thermocouples. The 1/4" piston tubing used for the core injection fluid has an inner diameter of 0.083" which provides sufficient space to insert small diameter thermocouples, but maintain sufficient volume for injection fluid. Long length thermocouples with 1/16" outer diameters can be inserted inside these tube sections and secured with a high pressure fitting.

The part list for making this connection is as follows:

- HiP P/N 15-21AF1HM4-T (adapter for 1/16" thermocouples)
- HiP P/N 60-23HF4 (high pressure Tee for HM4 fittings)
- HiP P/N 15-21AF1HM4 (standard reducer from 1/4" to 1/16" tubing)
- Omega P/N TJ36-CPIN-116-U-18-XX (18" T-type thermocouple) or TJ36-ICIN-116-U-18-XX (18" J-type thermocouple)
- Omega P/N TC-08 (8-channel USB thermocouple data acquisition module)

If space constraints are an issue use style LM4 instead of HM4 which have smaller footprints. Swap LM4/LF4 into the part numbers listed.

The assembly is shown below in Figure 27.



**Figure 27:** Thermocouple mounting diagram

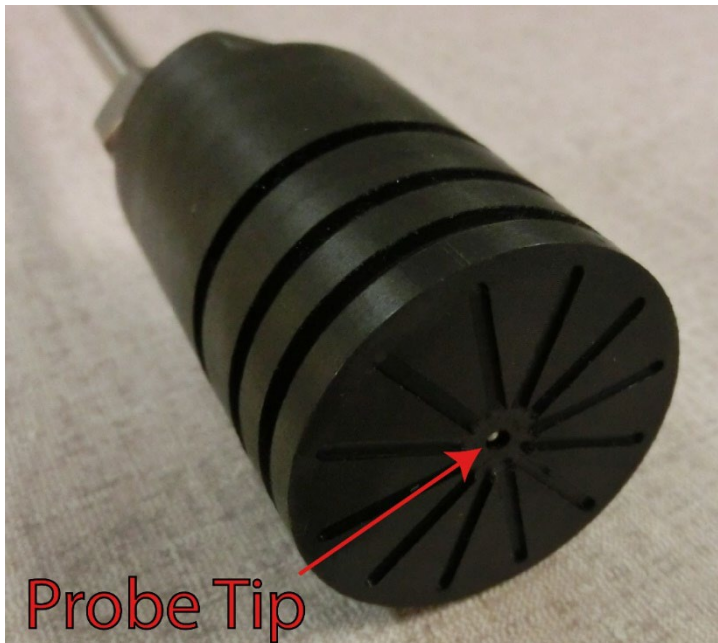


This assembly connects directly to the piston tubes passing through the overburden cell end caps. The fluid passing to the core would enter through the side port of the thermocouple assembly. This assembly can be duplicated for the opposite side of the cell for monitoring the top and bottom of the sample.

The thermocouple is secured in the 15-21AF1HM4-T adapter using a standard 15-2AM1 gland and collar. The AM1 fitting is a compression fitting which will bite into the thermocouple to form the pressure seal. This means that once the gland is fitted to the thermocouple it cannot be removed. Thus the positioning is specific to a certain core mount and piston tube length. Generally for the standard components supplied with the overburden cell this should not cause problems when switching between samples. However, if the piston tube or core mount size is altered it will require specific thermocouple/gland setups to match the combined length.

### First Time Positioning of the Thermocouple

To properly position the thermocouple the piston tube should be connected to the core mount and tightened to specification. The 60-23HF4 Tee should be connected to the piston tube and the 60-21AF1HM4-T adapter tightened to the Tee as shown in Figure 27. Then with a new 15-2AM1 gland and collar placed on the thermocouple, it should be passed through the 60-21AF1HM4-T adapter until the probe tip is near the end of



**Figure 28:** Thermocouple probe placement

the core mount. The tip should be slightly recessed from the face (see Figure 28). The AM1 gland can then be tightened to the 60-21AF1HM4-T adapter. Be sure to monitor the probe tip placement as the gland is tightened as it can move slightly during the initial phases of tightening. The gland/collar can still be moved during this phase if alignment problems occur. Once placement is confirmed tighten the AM1 gland to the same specification used for 1/16" tubing connections.

The thermocouples should be connected to the Daedalus circulation system to provide feedback for maintenance of the sample temperature. The thermocouples can also be connected to the Omega P/N TC-08 which provides USB connection to a PC for output monitoring. It is important to note that the thermocouples specified are immersion thermocouples and may not read accurately if the core injection fluid is not present. Therefore, it is important when monitoring both faces of the core that fluid be delivered to both ends even when flow of fluid through the core is not intended.

The thermocouple assembly shown in Figure 27 can be treated as a unit. When disassembling the overburden cell simply loosen the HM4 fitting on the bottom of the 60-23HM4 Tee to free it from the piston tube. The thermocouple can then be carefully retracted from the piston tube and the assembly set aside for the next use.

## APPENDIX C: SPECIAL CONFINING PORT ADAPTERS

These connection instructions are for older core holders and may not apply to newer models.

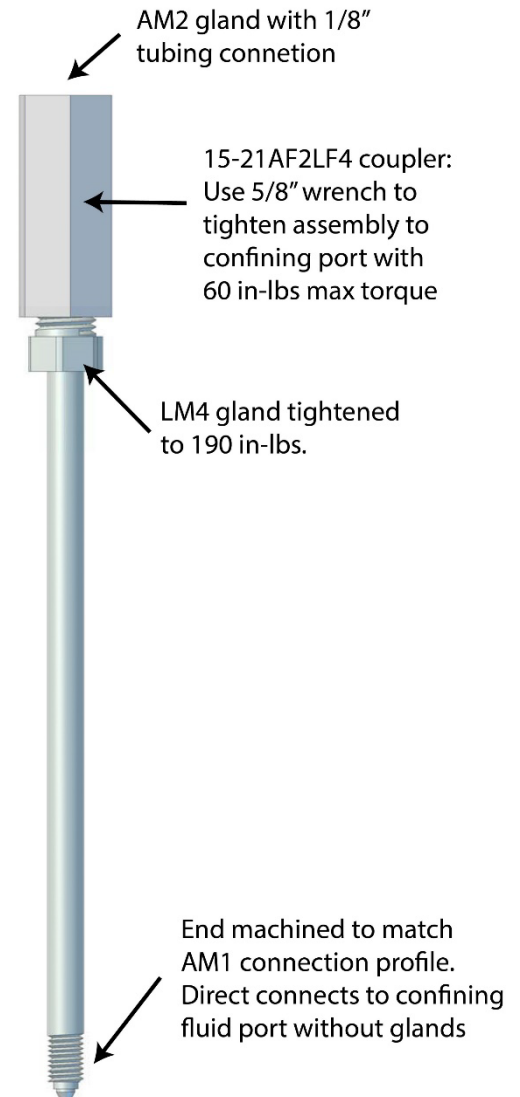
The smaller end-plug dimensions for the 1" diameter core holders do not permit large bore tubing to be connected directly to the confining port plug. As configured, the fitting port is AF1-style (HiP) for 1/16" tubing. The largest bore tubing is only 0.03" inner diameter, but the through hole in the end-plug is 0.0625" diameter. This constriction can create a sizeable, but still manageable pressure drop across the top and bottom of the overburden cell. Depending on the circulation system used it may also inhibit stable temperature regulation of the core.

To overcome this limitation an adapter can be used (Figure 29). This direct connect adapter is made from 1/4" tubing with a 0.083" inner diameter. One end is machined to accept any of the HiP fittings for 1/4" tubing; that being left-hand threaded 1/4"-28 threads with 60° chamfer. The other end is machined to match the dimensions of an assembled AM1 gland and collar. This permits the tubing itself to be threaded directly into the confining port plug without additional glands or collars.

The opposing standard end can be terminated as needed. The assembled adapters as shipped are terminated with a coupler that accepts LM4 fittings on one end and AM2 fittings on the other. This permits the standard 1/8" tubing, with 0.06" inner diameter to be connected to the confining port. Other couplers could also be connected as required.

Tighten the LM4 gland to the coupler with 190 in-lbs torque.

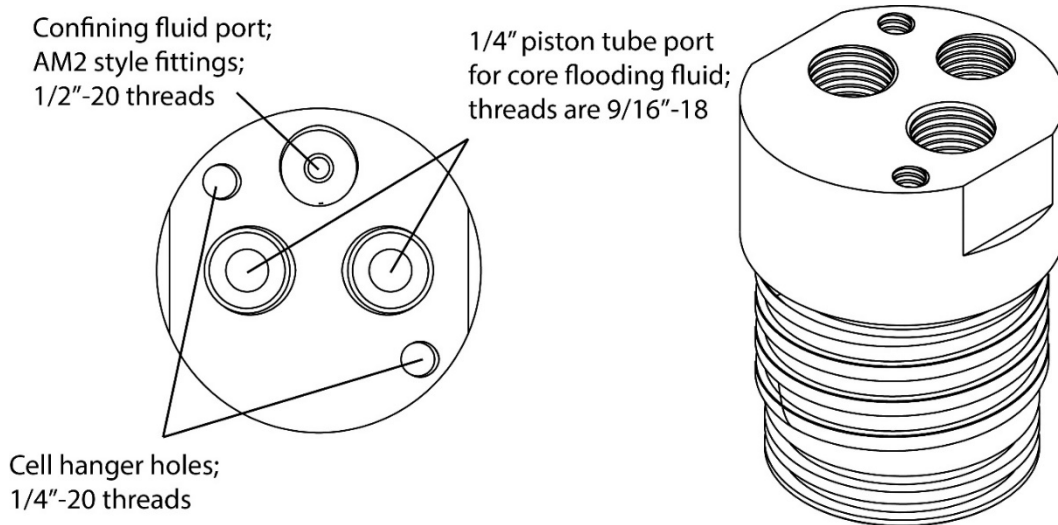
Connect the assembled adapter to the confining port by using a 5/8" wrench on the coupler. **Tighten to 60 in-lbs torque.** Excess torque could damage the end-plug.



**Figure 29:** Confining port direct connect adapter

## APPENDIX D: DUAL PORT END PLUG ASSEMBLY CONSIDERATIONS

The dual port end plug is available for the 1.5" diameter core holders. This allows for two fluids to be injected through the end plug to a dual port core mount where the fluid impinge with each other at the face of the core sample. The end plug is shown in Figure 30. The description of the end plug in the section *DESCRIPTION OF CELL COMPONENTS* covers the details of the plug in more detail. The main distinction of the dual port plug is it has offset ports for the passage of two 1/4" piston tube sections secured with the piston nuts in the usual fashion. The piston tubes then connect to the core mounts in the same manner as for the single port setup. Core mounts are available for the 1.5" and 1" core diameters.



**Figure 30:** Dual port end plug for 1.5" core holders

Referring to the diagram in Figure 2 the single port configuration allows the piston tube to be axially aligned with the housing and the associated end plug. In this configuration the rotation of the end plugs is decoupled from the core sample assembly. It only becomes coupled when fixed in position with the piston nuts. The dual port configuration with offset ports necessarily couples the rotation of the adjacent mount with that of the end plug (see Figure 31). If the opposite end is already fixed in place this rotation will cause the adjacent mount to rotate about its axis. This is not really a problem, but a slight shift in the procedure of assembly eliminates any issues that could arise from the rotation.

Recall from the assembly procedure that the bottom plug is to be installed first. The idea for doing that is the core sample assembly can then be inserted and forced to the

bottom of the cell to assure a consistent positioning of the core within the overburden cell. In this case, the dual port plug should be installed first regardless of whether it will be in the top or bottom position. Further, the core assembly should be fed through the dual port plug prior to inserting into the cell. Generally, there is sufficient tension in the piston tubes to hold the core assembly in position in the plug even when inverted. Thus the procedure is as follows with reference to the *ASSEMBLY OF THE OVERBURDEN CELL* section for routine details of plug placement and piston nut assembly.

**Step 1:** Feed the piston tubes for the dual port side through the end plug.

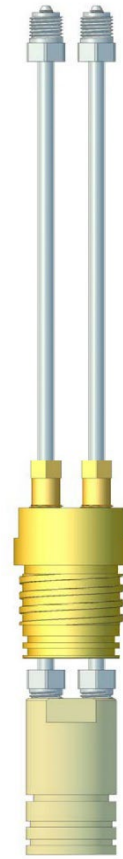
**Step 2:** Thread the dual port plug into the housing, but do not secure the piston tubes with the piston nuts at this time. Invert the cell in the cradle.

**Step 3:** Thread the single port plug into the housing.

**Step 4:** If the dual port plug is to be at the bottom of the cell the core sample assembly should be pushed to the bottom and the single tube secured with the piston nut. If the dual port plug is to be at the top the cell should be inverted in the cradle again, and the core assembly pushed to the bottom. Both piston tubes should be secured with piston nuts.

**Step 5:** Invert the cell once again and secure the piston tube(s) as usual.

The core sample temperature can still be monitored with the dual port plug by inserting a thermocouple down one of the two available piston tubes. The combined length of the piston tube and core mount is different than for the single port configuration. Therefore a dedicated thermocouple assembly (see Appendix B for details) will be required if switching between dual and single port configurations. The other tube can be terminated with a 15-21AF1HF4 coupler or something similar to allow connection to flow pumps.



**Figure 31:** Dual assembly

## Using Two Dual Port End Plugs

The cell can be closed at both ends with dual port plugs. This configuration is the most difficult to assemble since now both core mounts of the assembly are linked to the end plug rotation. The first end plug can be assembled as described previously in this section. Assembling the second requires an additional strategy to assure a proper setup.

The core assembly is tied to both end plugs such that rotation of the second end plug will rotate one of the core mounts about its axis. Alternatively, the threading of one end plug might translate into motion that unthreads the opposite end plug. It is inevitable that the force to thread one end plug will be greater than the force to unthread the other. In other words one sits tighter in the housing than the other. This can be an advantage since once it is known which plug sits tighter it can be assembled first and the extra resistance provided by the tighter fit will prevent rotation when the second plug is threaded into the housing. This is not always true since there is also resistance from the compressed seals of the core mounts, but generally it requires less force to spin the mounts around their axis than it does to unthread the end plug.

**Strategy Point 1: Determine which end plug has the tightest fit and note that for future assemblies. Thread this end plug into the housing first being sure to use the DCH-EPS to assure proper positioning of the threaded plug.**

The first end plug should be connected the cell, but do not secure with the piston nuts. The cell can then be placed back in the cradle with the open end at the top.

The next step is to pass the second end plug over the piston tubes. The end plug requires slightly less than four complete rotations to thread into the housing. However, the CHPS seals protrude a bit and these should be forced past the threads without rotating the end plug. This can be difficult, but every effort should be made to accomplish this without rotating the end plug.

As the end plug is threaded into the housing there may be a tendency for the core sample assembly to pull apart. To prevent this a downward force on the piston tubes should be applied regularly to force the mounts back into position. To make this less hard on the hands the HM4 collar can be



**Figure 32:** Inverted HM4 glands

threaded onto the piston plugs and the HM4 gland inverted on top to provide a larger flat surface upon which to push down on the piston plugs (see Figure 32).

**Strategy Point 2: While threading the second end plug into the housing, regularly push down on the piston tubes to help maintain the integrity of the internal core sample assembly.**

With the CHPS seal pushed past the threads and making sure to regularly apply a downward force on the piston tubes slowly thread the second plug into the housing. As the threading is performed note whether plug at the other end is unthreading. A 1-3/4" wrench can be used to restrict motion on this plug as the second plug is threaded. Iteratively thread and check until the second plug is in position by using the DCH-EPS tool. It may be necessary to take the cell out of the cradle and lay it on the bench for this process. That will allow easier manipulation of both plugs as the second plug is threaded into the housing. **Be certain that both plugs are at the proper spacing from the housing using the DCH-EPS tool.**

Once both plugs have been set to the proper position it will now be necessary to add the PSCH seal and piston nuts to secure the core sample assembly in the housing. This can be done in the usual fashion. The only consideration is the position of the core sample assembly. As in all cases it should be pushed to the bottom to provide consistent depth positioning for placement in the NMR instrument.

**Strategy Point 3: Once the plugs are in position, the core sample assembly is still free to move. Push on the piston tubes to move the assembly towards the bottom plug before securing with the piston nuts.**

At this point the hangers, thermocouple assemblies, and any other connections can be made in the usual fashion.