

Soil Trace Gas Trapping Sub-Chamber Housing Application Note

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Abstract:

Crucial to the operation of any trace gas trapping device is the proper function of a sub-chamber which must accurately trap specific volumes of gas for sampling. This application note provides a procedure for creating a sub-chamber housing design.

Keywords:

Dead Volume, PVC

Introduction:

A sub-chamber housing in a soil trace gas trapping device is responsible for trapping specific volumes of ambient air to be later circulated throughout a trapping system. For approximately 90% of a sub-chamber's life, it will be open and therefore exposed to the ambient environment. During this time, it is critical that the sub-chamber have no dead volumes which would ruin the integrity of each sample. The other 10% of the sub-chamber's life is spent closed during which time circulation of the sub-chamber's contents through a trapping system occurs. During this period, the sub-chamber's ability to seal and not react with the sample is of paramount concern.

Objective:

The purpose of this note is to describe the basic considerations undertaken when designing a sub-chamber housing for use in a soil trace gas trapping device.

Design Procedure:

1. Choosing a sub-chamber shape

The basic shape of the sub-chamber housing is chosen based on physical constraints and customer input. One must know the volume of the flux chamber where the sub-chamber housing is located in order to choose an overall sub-chamber shape. Additionally, knowing of any other packaging issues such as the sub-chamber housing's clearance with respect to an outer door or rainfall simulator down pipe is important. Another key input is the volume of each

sample required by the customer. Incorporating sample volumes required by the customer early into the design of a sub-chamber housing can mean the success of a design.

To begin the example used to aid in understanding for this application note, if one knows the flux chamber which holds the device is a cylinder 270mm wide and 150mm in height the volume of this cylinder may be calculated using equation 1 below.

$$V_{CYLINDER} = H * \pi R^2 = (150mm) * \pi (270mm/2)^2 = 8588329mm^3 \approx 8588mL \quad (1)$$

This volume may be compared with the customer given sample volumes to see in general if the sub-chamber housing will fit inside the flux chamber. For example, if it is known that the two sub-chambers must be 150mL and 20mL respectively. Adding these two values makes an overall estimated volume of 170mL. Clearly this value is less than that calculated using equation 1 so the design process may continue.

Since the actual shape of the sub-chamber housing is not chosen yet, it will be necessary to rewrite several basic shape volume calculations, so that they may be used to ascertain specific dimensions. Now using equations 2, 3, and 4 below and choosing some basic height and length dimensions which must be less than 150mm and 270mm respectively, a basic sub-chamber housing shape may be chosen. In order to account for the thickness of walls to make the sub-chamber as well as proper ventilation, a 55mm buffer must be allotted above and below the sub-chamber housing. This reduces the maximum height to 40mm in this example. Note that these shapes are not the only possible. Using other volume calculations may render different shapes just as feasible.

Rectangular Solid: $V_{RECTANGULAR} = L * W * H \quad (2)$

Criteria:	V = 170mL	Chosen Value:	H = 40mm
	L < 270mm		W = 20mm
	H < 40mm	Calculated Value:	L = 212.5mm

$$L = \frac{V_{RECTANGULAR}}{W * H} = \frac{(170000mm^3)}{(20mm) * (40mm)} = 212.5mm$$

Cylindrical Solid: $V_{CYLINDRICAL} = H * \pi R^2 \quad (3)$

Criteria:	V = 170mL	Chosen Value:	H = 200mm
	H < 270mm	Calculated Value:	R = 16.5mm

$$R = \sqrt{\frac{V_{CYLINDRICAL}}{\pi * H}} = \sqrt{\frac{(170000mm^3)}{\pi * (200mm)}} = 16.5mm$$

Hexagonal Solid:
$$V_{HEXAGONAL} = H * \frac{3\sqrt{3}}{2} t^2 \quad (4)$$

Criteria: V = 170mL Chosen Value: H = 200mm
 H < 270mm Calculated Value: t = 18.1mm

$$t_{EDGELENGTH} = \sqrt{\frac{V_{HEXAGONAL} * 2}{H * 3\sqrt{3}}} = \sqrt{\frac{(170000mm^3) * 2}{(200mm) * 3\sqrt{3}}} = 18.1mm$$

Having made, in this example, three separate sub-chamber volume calculations it is clear all are feasible within the constraints of the flux chamber from a physical standpoint. The next step is to consider what type of door opening mechanism is most desirable. Choosing a door opening mechanism will dictate the shape of the sub-chamber. For this example, a sliding door design was chosen. To accommodate this design choice, a rectangular cross section sub-chamber housing was adopted. This decision will be explained later in the text.

2. Choosing a door opening mechanism

Picking a feasible door opening mechanism for a sub-chamber is important for proper chamber seal during gas circulation and to avoid the presence of a dead volume. When choosing a door opening mechanism, five questions must be asked:

1. What kind of door am I using?

Choosing an actual door type can be a long process. Door choices can be broken into three main categories which are a hinged door, slide door, and other. Hinged doors can be an attractive option for any sub-chamber design. They are fairly simple to manufacture and hinges themselves are usually readily available at various shops. Sliding Doors are also an attractive option, but they do require more design in regards to rails and sealing mechanisms. The other doors category was included to stress the importance that other options are available for a sub-chamber. One such door mechanism could be a cylinder which rotates inside another. In this design, each cylinder has holes which line up with each other during the equilibrate cycle. This door type may be viewed in figure 1.



Figure 1. Other door type where one cylinder rotates inside another

2. Can this door be prototyped easily to seal effectively?

Whether or not the door type chosen may be easily prototyped to seal effectively is really the major concern of the whole sub-chamber design. The rotating cylinder design of sub-chamber was not used in this example because it is far too hard to build as a prototype and have seal effectively.

The hinged door design was eliminated as a choice for one reason. Knowing that the sub-chamber housing will in essence be separated by a wall, the door would have to seal along its edge *and* down the middle to seal one sample from the other. It was decided that this would be far too complicated to execute in the limited amount of time the team had for this example.

For the example followed in this text, a sliding door design was chosen. This design type allows for relatively easy manufacturability, reliability, and sealing. This is possible because of the physical operation of the door. Analogous to the end of section three, to aid these features of manufacturability, reliability, and sealing, a rectangular cross section sub-chamber housing was chosen. For this specific design shown in figure 2, a pocket sliding door was chosen because it actually allows for two different opportunities to seal on either side of the door. In addition, having force applied on the door from both sides by the compression of a rubber seal puts even wear on the rails of the door.

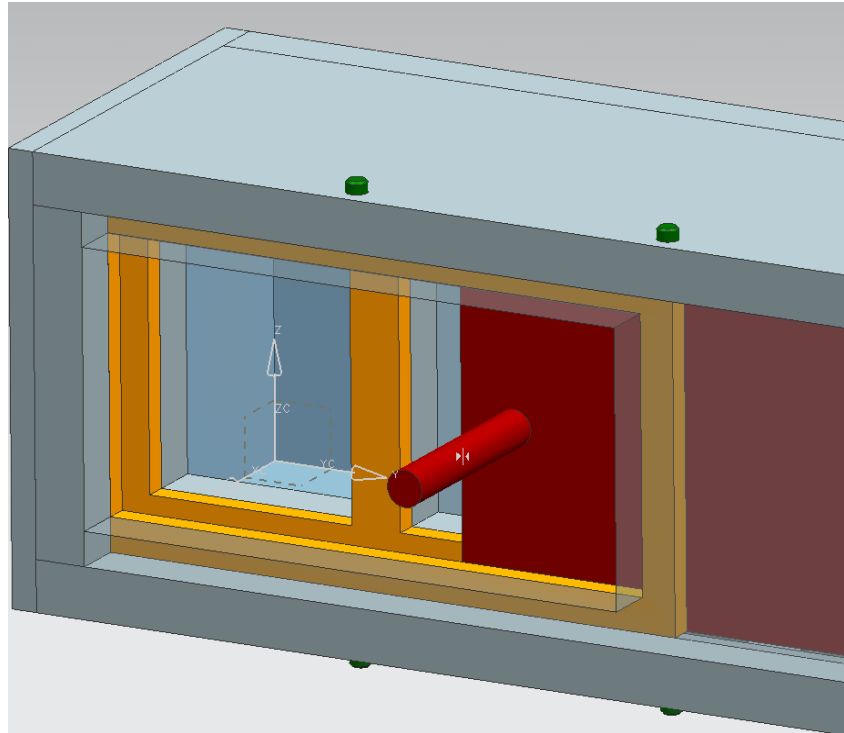


Figure 2. Rectangular sub-chamber housing shown with a sliding pocket door. These design choices allow for simple manufacturability, reliability, and sealing.

3. Will this door create a dead volume in the sub-chamber?

Whether or not a dead volume is present in the sub-chamber is of major concern. Were a dead volume to be present, a proper equilibrate cycle with the ambient environment would not be possible. At this point it is necessary to consider the location of the door on your sub-chamber housing and its size. If too small and placed so that there is a bias present in regards to circulation, a dead volume could be present.

4. If absolutely necessary, should I have a second door?

As a result of the fact that a major difference in volume size of samples is present in this example design, a dead volume is a concern. In essence, because the difference in sample volumes is so great, the dividing wall between the two chambers is biased to one side of the sub-chamber housing. For this reason, adding a second door on the end of the sub-chamber housing is a necessity. If possible, this door should be operated by the same door type as chosen through your process of elimination. However, as in the case of this example, due to geometry, clearance was of major concern with the second door, and so a hinged door was added to the existing design. This design addition may be viewed in figure 3.

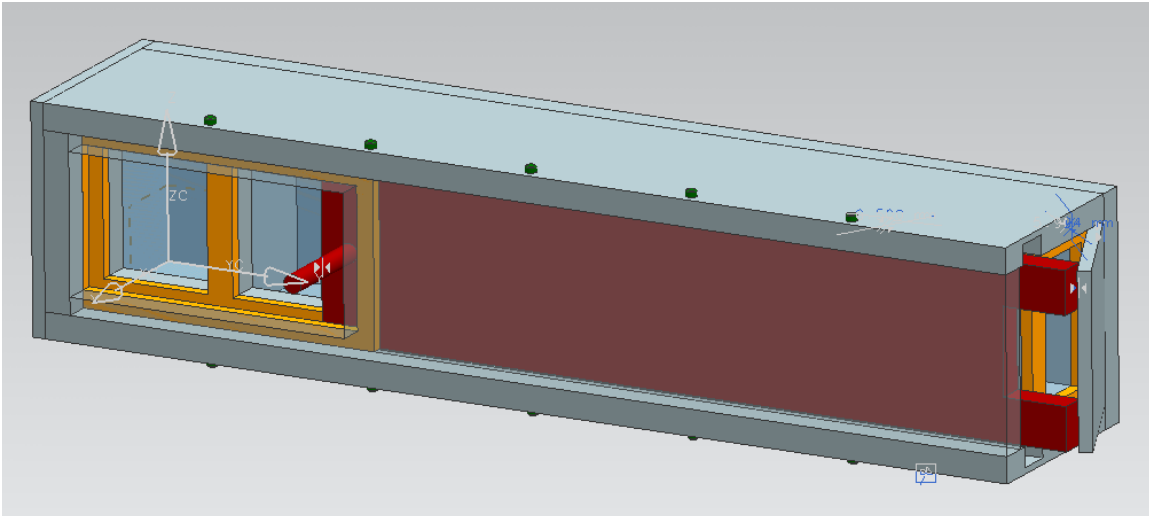


Figure 3. Sub-chamber housing with a second hinged door added to promote circulation during the equilibrate cycle and to eliminate a dead volume

5. How do I automate the door mechanism?

Choosing a method by which to automate the door mechanism can be a pretty simple process, depending on how thoroughly the last four steps were carried out. If using a hinged door, applying a servo or motor to turn the door is always an option. This same device could be applied to this examples sliding door design using a four bar linkage. To keep things simple however, a linear actuator was used to move the sliding pocket door (shown in figure 4 in red), and this door in turn rotates the hinged door shown on the very right of figure 4.

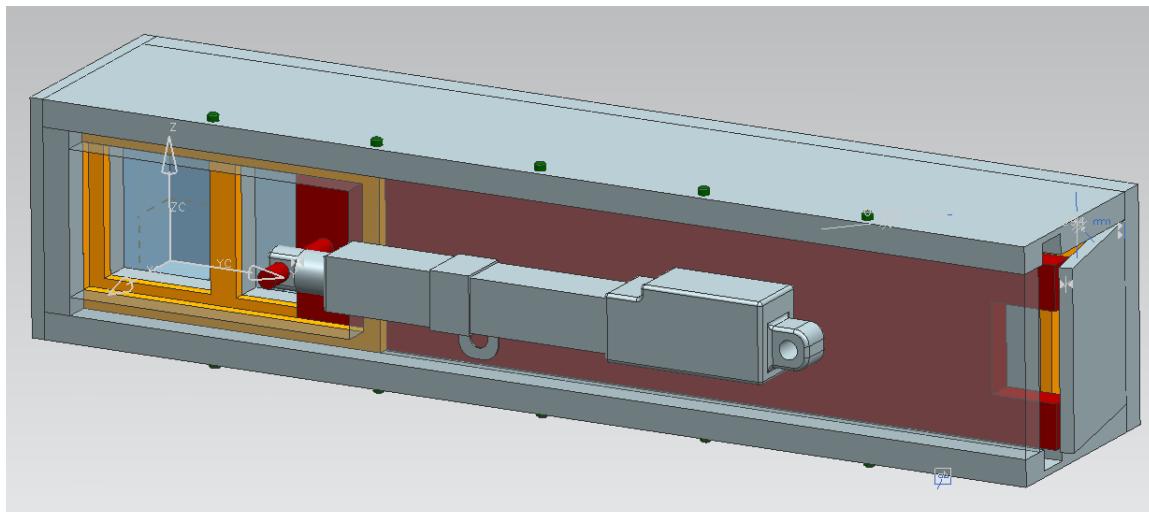


Figure 4. Sub-chamber housing with the linear actuator mounted to the sliding door and device itself

This choice allows for two things. First, using a linear actuator eliminates having to design a linkage system to be used with a servo. Second, using a linear actuator with this design saves having to use two separate actuators. The specific linear actuator used in the example may be viewed in figure 5 and 6. Make sure when choosing a linear actuator similar to the one pictured that the length of the actuator when fully extended is considered for packaging issues. Now that a basic design has been achieved, materials may be chosen.



Figure 5. The linear actuator used in the example covered in the text

3. Choosing materials

Material choice is an important process of sub-chamber housing design reliant on customer input, cost, manufacturability, and material interaction. Customer need is of course the most important component. For this example the customer asked in particular for the sub-chamber housing to be constructed out of PVC. In addition, the customer asked for the rubber sealing components to be chemically inert so as not to affect the integrity of the experiment. In this case, much of the material selection was done for the designer. These items are of reasonably low cost and are easy to use for prototype building. Knowing that material interaction is a major concern where the doors seal, they were chosen to be Aluminum. This is because, Aluminum is relatively light, easy to mill, does not corrode, and will not wear when rubbed with a rubber material.

4. Modeling the sub-chamber

Modeling the sub-chamber is the last step of design before constructing a prototype and testing. It is important to model the sub-chamber housing, usually using a CAD program or less often by classic drafting methods, so that packaging concerns and part interaction may be visualized. Usually when modeling a sub-chamber housing you will run into problems with your design and have to alter details to make it work properly.

6. Minor testing

Following the creation of a prototype for the sub-chamber housing, it is a good idea to test it. Minor testing includes filling each chamber with water to check the seals of the sub-chamber. Also, it is a good idea to attach whatever actuator you've chosen to the sub-chamber and to actually run it and see how it

operates. If you have any problems with either of these tests, it may be necessary to change your design or prototype manufacturing process.

Result:

Once the prototype build was completed the example covered in this text proved to be an effective design for a sub-chamber housing to be used in a trace gas sampling device. Testing was conducted on the sub-chamber housing and an effective seal was created with both doors. The hope is that this guide may be utilized to not only recreate the success of this team, but also to further improve upon sub-chamber design.

References:

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2. Firgelli Technologies, http://www.firgelli.com/pdf/L12_datasheet.pdf