Accurately Measuring the Volume of the Model T Head Combustion Chamber

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This document outlines a process to determine the volume of a Model T head and how to calculate the amount to remove to achieve a desired final volume. Following this procedure the volume of the combustion chambers can be measured to an accuracy of 2.2 cc (with a 66% level of confidence).

You will need the following equipment:

- A scale accurate to 0.1 grams
- A 10 cc syringe with 0.2 cc graduations
- Sheet of 20 ga sheet metal of area to cover the combustion area
- 100 cc (or so) container for water
- Distilled water
- Silly putty
- 3 – 5/16 (of 3/8”) NC carriage bolts 3” long along with washers and nuts
- Bubble level accurate to about 5 minutes of arc (detect 0.005” in 3.4”)
- Plexiglas to cover the combustion chamber, with a 3/8” hole
- Grease

Following is the procedure in a discussion format. Below is the same procedure outlined step by step.

The first step is to measure the volume of each head chamber. Using the silly putty, plug a spark plug hole to be flush with the inside of the chamber. Using the grease, put a thin layer around the edge of the combustion chamber. Suspend the head in three locations (two at one end and the middle at the other end) using the carriage bolts, nuts and washers. Carefully level the head using the bubble level. Position the scale and ensure that it is also level. (Note: a scale off level by 5 degrees will result in a weight error of 0.4% corresponding to a final volume error of 1 cc.) Zero the scale, weigh the empty water container and record the weight. Now carefully fill the container with distilled water for a net weight of about 90 grams. Record the new weight, pour the water into the cylinder and then reweigh the empty container. The empty container should be within 0.1 grams of the first empty container measurement. Repeat the process twice with another 90 grams of water each time. At this point you should have the combustion chamber nearly full with about 270 grams of water. To calculate the actual volume note that water at room temperature and at sea level has a density of 0.9975 grams per cubic centimeter. Therefore, if you measured 270.0 grams, the correct volume would be 270.7 cc.

Next step is to lay the Plexiglas over the thin layer of grease on the head. Typical high heads have a volume of about 290 cc so if you have added 270 cc of distilled water you have about 20 cc left to fill. Fill the syringe with 10 cc of distilled water, being careful to remove any bubbles. Gently fill the head through the Plexiglas hole until you see the water come into full contact with the bottom of the Plexiglas. It may take more than one full syringe. Determine the extra water needed to within 0.2 cc. The total volume will be the calculated volume (using the density of 0.9975 grams/cc) plus the total measured syringe volume.

The Plexiglas must be **flat** to insure an accurate measurement. It needs to be within about 0.002 flat over the area that it covers the combustion chamber. You can correct for this by repeating the above measurements and flipping the Plexiglas over. Then average the two measurements to get the correct volume. A 0.008 inch dip in the Plexiglas will result in an error of about 1-2 cc in volume so making the measurement twice with the Plexiglas flipped can be important. A thin layer of grease on the head will position the Plexiglas as much as

0.004 in **above** the plane of the head. This can result in an overestimation of the true volume by 1.2 cc. This can be eliminated by firmly clamping the Plexiglas on the head (see uncertainty analysis below).

If you want to reduce the volume of the chamber you will need to measure the area of the combustion chamber where it meets the head gasket. First cut the 20 sheet metal into an accurate rectangle or square which is larger than the combustion chamber. Measure the area of the sheet metal and then measure its mass carefully. Divide the mass by the area and you will now know the areal density of the sheet metal. Next carefully cut out the metal to the same area of the combustion chamber. When finished trimming, remeasure the cutout mass. Divide the cutout mass by the grams per unit area which will result in the area of the combustion chamber in the plane of the head gasket. Now that you know the area you can easily calculate the thickness to remove by dividing the volume you want to remove by the measured area. This will be the amount to remove by milling the head.

Temperature	Water density
10 C (50 F)	0.9997 gm/cc
20 C (68 F)	0.9982
30 C (86 F)	0.9956

Step by Step Procedure to Measure Combustion Chamber Volume of 270 cc

1. Plug the spark plug hole with the putty flush to the combustion chamber.
2. Apply a thin layer of grease around the edge of the combustion chamber.
3. Using the carriage bolts, nuts and washers, suspend the head and, using bubble level, level the head
4. Level the scale
5. Zero the scale
6. Place the empty container on the scale and record it’s mass (M_C)
7. Using distilled water, fill the container to obtain a reading of about 90 grams plus the container weight and record its mass (M_{T1})
8. Carefully pour the water into the combustion chamber (make sure that the putty plug is not leaking).
9. Place the empty container on the scale and ensure that the empty mass is equal to M_C (if not you will have to correct for the lost water)
10. Record the empty mass (M_C)
11. Using distilled water, fill the container to obtain a reading of about 90 grams plus the container mass and record its mass (M_{T2})
12. Carefully pour the water into the combustion chamber.
13. Place the empty container on the scale and ensure that the empty mass is equal to M_C (if not you will have to correct for the lost water)
14. Record the empty mass (M_C)
15. Calculate the volume of water in the chamber: $V1 = \frac{M_{T1}+M_{T2}-2M_C}{0.9975}$
16. Calculate V = 265 – V_1
17. Multiply V by 0.9975 to get the mass of water you will need to add to obtain 265 cc of water (W_{add})
18. Add M_C to M_{add}, this is the indicated mass of distilled water to add to the empty container to obtain a water volume of 265 cc
19. Pour the water into the combustion chamber.
20. Place the Plexiglas over the combustion chamber
21. Fill the syringe to 10 cc, eliminating bubbles
22. Add water through the Plexiglas hole until the water is fully contacting the bottom of the Plexiglas. Record the added volume,, V_S

23. The total combustion chamber volume is 265 cc + V_S
24. Repeat all the above with the Plexiglas flipped over if you are not sure that the Plexiglas is flat. In this case, average the two volume readings to obtain the final volume.

Estimate of Measurement Uncertainty

Each of the three mass measurements have an estimated uncertainty of 0.1 grams, combined they have an uncertainty of 0.17 grams. 0.17 grams of mass error corresponds to a volume error of about 0.17 cc. We assume that the accuracy of the syringe is mostly due to reading the meniscus which is about 0.2 cc. Repeated measurements under the same conditions result in volume measurements that vary about 1.0 cc. This repeatability is mostly due to the difficulty of ascertaining the precise point at which the water fully contacts the lower surface of the Plexiglas. Assuming the putty is only within 1 mm of the combustion chamber results in an uncertainty of about 0.13 cc. Finally, the grease layer on the head surface, can raise the plexiglass as much as 0.004 inch, this would result in an overestimation of volume of 1.2 cc. Combining all these uncertainties as follows:

Uncertainty due to measurement error in water mass:	0.17 cc (random)
Uncertainty due to the syringe	0.20 cc (random)
Repeatability	1.0 cc (random)
Putty not level with chamber	0.13 cc (random)
Uncertainty due to plexiglass not in contact	1.2 cc (systematic)

Total estimated uncertainty = 1.0 cc plus the 1.2 cc due to plexiglass contact. The 1.2 cc contribution could be eliminated by firmly clamping the plexiglass to the head surface. Ignoring this contribution will result in an overestimation of the true volume by as much as 1.2 cc.

Conclusion: The final measured volume can have an uncertainty of up to 2.2 cc.

This uncertainty corresponds to approximately one standard deviation, in other words, there is a 66% probability that the true volume measurement is within 2.2 cc. For example, if the measured result is 270 cc there is a 66% probability that the true value can be as large as 272.2 cc and also a 66% probability that the true value is as small as 267.8 cc. These probabilities should be taken into account when making judgements of the pass/fail for a questionable combustion chamber.

Note that this analysis assumes that the Plexiglas is perfectly flat, if not one should repeat the volume measurement with the Plexiglas flipped and average the results.)

Note: We have ignored the following contributions to uncertainties: density of water w/ altitude, evaporation of water during the measurement, bubbles in the syringe, putty absorbing some water– these should all be small.