Reverse-Engineering a Naturally-Aspirated Lunenburg Foundry Carburetor

by

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ABSTRACT

The Lunenburg Foundry, based out of Nova Scotia, is a well-known manufacturer for early 20th century marine engines made famous by its Atlantic Marine Engine. This engine revolutionized the fishing industry along the Atlantic coast of Canada by creating a sort of “iron sail” for fisherman and sailors. The goal of this thesis is to reverse-engineer a naturally-aspirated Lunenburg Foundry carburetor from the Atlantic engine. The actual carburetor at MIT is one of few in existence, and has no accompanying patterns or drawings. The carburetor was disassembled and each part carefully measured by hand. A CAD assembly was developed of the entire carburetor to serve as an engineering database for future manufacturing and study.

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1 Introduction

The Lunenburg Foundry in Nova Scotia, Canada has been durably and reliably casting parts since 1891 and is still going strong today. By the 1900’s they became pioneers in the development of marine internal combustion engines. They designed and built one of the first make and break engines, a one-lunger called the Atlantic Engine. This engine was an integral part of revolutionizing boating and greatly impacted the fishing industry. All along the northeastern coast of North America, fishing vessels could commonly be found with these marine engines. The marine engine was considered a sort of “iron sail” for fisherman and sailors as travel time for fishing trips was drastically reduced, increasing catch volume and efficiency.

While the Lunenburg Foundry is still known for distributing the most engines of any other foundry in Canada, a lot of the expertise about casting one-lunger engines has faded. This thesis aims to reverse-engineer an important part of the Atlantic engine, the naturally-aspirated carburetor, in order to create a modern engineering database for those to use in the future and to keep the memory of the Atlantic engine alive.

The actual carburetor at MIT is one of few in existence, and has no accompanying patterns or drawings. The carburetor was disassembled, measured by hand, and then each part was individually modeled in SolidWorks to create a final assembly. The goal of having a CAD assembly of the carburetor is to use as a foundation for patterns and core molds so that the carburetor could be recast in the future.

1.1 The Atlantic Engine

The carburetor being modeled was originally used for the Atlantic Engine, a single-cylinder two stroke engine. This engine is a make and break engine, meaning that its ignition system is driven by a spark that is triggered in an induction circuit with every revolution of the crankshaft [1]. The ignition lights an air-fuel mixture sucked in from the carburetor when the piston is at the top, and it is driven down delivering power to the crankshaft which is attached to a heavy flywheel. When the piston drives down, the air-fuel mixture is compressed and released through an exhaust port. The flywheel then pushes the piston back up, sucking in more air-fuel mixture into the combustion chamber, and the cycle repeats. An example of a similar one-lunger engine can be seen in Figure 1.
Note the liberal proportioning, and simplicity assuring durability of all parts, their accessibility and ease of adjustment. Fewer working parts are required than in any other engine of the same general type. The design and workmanship is of the very highest order, placing the "Acadia" in a class distinctively its own.

Figure 1: Acadia one-lunger engine ad [2]

1.2 Carburetor in the Atlantic Engine

The role of the carburetor is to mix together air and fuel that is then sucked into the combustion chamber of the engine, the rate of which is controlled by the throttle. Initially, carburetors were imported from overseas and added to the rest of the engine that was cast in Nova Scotia. As the world entered wartime in the 1910s, it became increasingly difficult to import carburetors, so the Lunenburg Foundry began manufacturing their own fuel-efficient carburetor.
The model of this carburetor was based off of the Schebler Model D. Although the Model D was only made by Schebler through the 1930s, the Lunenburg foundry continued making them afterwards for their own engines [3]. While this model of carburetor was not the most robust for multiple engine purposes, it served well for marine engines used on small-boats. The butterfly-shaped shutter used in the throttle made it very easy to have two main speeds. When the shutter is mostly closed the speed is very slow, ideal for docking and fishing. When it is wide open it can move the boat close to its hull speed. With the amount of fishing boats relying on this type of engine in the early 1900s, this carburetor met simple demands and was very popular. The fact that Lunenburg Foundry started manufacturing their own also made it easy for engine owners to get replacement parts. Despite being limited to a very specific field and industry, the Model D was considered a remarkable development for marine combustion engines.

For the purposes of this thesis reference was made to a copy of an Atlantic Marine Engine instruction book from the Lunenburg Foundry. The manual makes reference to the Model D
Schebler Carburetor and parts. The section view in Figure 3 was especially useful in estimating internal geometries of the physical carburetor.

Figure 3: Model “D” Schebler carburetor parts

2 Carburetor Disassembly

In order to create an appropriate CAD assembly of the carburetor, it was first necessary to disassemble it. The carburetor was taken apart based on sub-assemblies, such as the throttle, air valve, cork float, and bowl casting. After each sub-assembly was separated from the full carburetor assembly, they were then disassembled and organized. Photos and notes from the main sub-assemblies are detailed in the proceeding sub-sections.
2.1 Throttle

The throttle assembly could not be easily disassembled because the parts were welded together. In the front view, there are 4 small bumps that are likely plug welds. Although it was unable to be taken apart, it is interpreted from Figure 3 that the assembly consists of four main parts: the throttle front with lead screw, the throttle back, the throttle lever, and the butterfly shutter.
Figure 5: Throttle assembly front view

Figure 6: Throttle assembly top view
2.2 Air Valve

The air valve attaches to the top of the lid and consists of the following parts: the air valve casting, the air valve adjusting screw, the adjusting screw lock nut, and the air valve disk insert with spring. The air valve disk itself is made of cork and is riveted onto the insert, which is placed inside the spring and sits in the spherical cavity of the air valve. This is all held in place by the adjusting screw and lock nut.
Figure 8: Air valve assembly (a) top view (b) front view (c) side view (d) bottom view

Figure 9: Internal view of spring and disk insert in air valve casting
2.3 Bowl Casting and Cork Float

The bowl casting has several parts attached to it. The largest is the lid that attaches the air valve. There is also a cork gasket that is necessary to secure the connection between the lid and the air channel in the bowl casting. Inside the bowl but separate from the air channel is the cork
float assembly, which serves to keep fuel from overflowing out of the carburetor. It is attached to the side of the bowl casting through the float valve. The float valve also contains an elbow piece and top cap.

Figure 12: Lid casting (a) top view (b) bottom view (c) side view

Figure 13: Cork gasket
Figure 14: Bowl casting internal view

Figure 15: Cork float disassembly
Also attached to the bottom of the bowl casting is the fuel nozzle, needle valve, and needle valve connection. The nozzle contains threads and is easily removable. This is done on purpose.
so that engine owners could replace and change the size of the nozzle if desired. The bottom of the casting also has a thread for a stopper.

**Figure 18:** Needle and connection

**Figure 19:** Bowl casting with nozzle and nozzle connection removed
3 CAD Design Process

Since this thesis was done without associated engineering drawings and with the intention to not damage the original carburetor, many of the internal geometries were estimated and designed in CAD with reference to the section view of a Schebler Model D carburetor shown in Figure 3. Casting constraints were also taken into account to estimate the shape and location of internal features. This was true especially for the throttle assembly as the front and back pieces were welded together.

Because there were no engineering drawings with the carburetor, all dimensions were measured and estimated from the physical parts. In some situations numbers were estimated
while taking into account casting effects. For example, on smaller features it is possible that shrinkage could have occurred so the measurements used in the CAD model were based on what may have been the original desired dimension (i.e. something that was just over 0.24" was most likely to be a quarter inch).

There are also many post-machined surfaces, and in any instance where it was possible the machined dimension was used, as casting can change intended shape. Adjustments were also made to insure proper alignment of features. The most common case of this can be seen by comparing machined surfaces to the original cast surface. It is not uncommon in the parts to find instances where machined lips and bosses are not concentric with the casting. In this case the CAD measurement used was of the machined part and then it was made concentric with the intended cast shape. An example of this can be seen in the bottom view of the lid in Figure 12(b). On the physical part it is obvious that the through holes on either side of the intake hole are not centered, and that the lip of the air channel opening does not have a consistent thickness. When modeled in CAD it was assumed that the through holes were centered and the intake circles were concentric. Also, any threads were modeled as smooth surfaces in SolidWorks based off of the approximate inner diameter for internal threads or outer diameter for external threads.

For odd shapes such as the throttle front and back, an image was overlaid in a SolidWorks sketch to judge the correctness of the shape (see Figure 22). Due to perspective shifts in the images, this is not a precise way to create sketches. However, this is a good method to do a check on general shape. For the throttle, multiple radii were measured to create circles, which were then connected with wide arcs. After measuring by hand and creating the sketch in SolidWorks, an actual image was added to do a check by eye.
3.1 Bowl Casting

The bowl casting was the first part to be modeled as it is the most complex. The main order of operations was to start with generic shapes made from revolved extrusions, then add planes to create sketches and extrusions of external shapes (such as the throttle face and the float valve). For this part, all of the external dimensions could easily be measured with calipers. However, for the internal chambers, shape had to be estimated using the sketch from Figure 3. The most difficult feature to estimate was the angle of the slot that holds the nozzle and needle. To create this feature, a new plane was created at an estimated angle of 30 degrees from the centerline.
3.2 Lid

For the lid, as mentioned earlier, many of the through holes and circular features were corrected to be concentric in the CAD model, even though it was off on the physical part. The holes in the lid (and many other parts of the carburetor) were post-machined, so it is not strange that features would not be concentric as the post-machining was done to exact dimensions ensuring a successful assembly with other parts.
One feature worth mentioning is the small air hole in the top right of the top face. The shape of the mound protruding from the lid looks as if it could have been made directly in the sand when the flask was being packed. This was likely done to provide greater thickness for the small hole into the part. It was added in the CAD for this thesis, but if a future casting were to be done it may not be necessary to machine this feature into the part pattern.

![Figure 24: Lid CAD model (a) top view (b) bottom view (c) front view (d) isometric view](image)

3.3 **Throttle Assembly**

The throttle assembly was created as four separate parts in CAD, however the physical assembly was not taken apart as it was welded together, likely with weld plugs. The approximate locations of the plugs were added as through holes in the throttle front piece.
As the throttle could not be disassembled, the internal features were estimated again using small images of the parts in Figure 3. The throttle back had to have had some sort of pocket to hold the butterfly shutter, which was a rounded cutout from sheet metal. The shutter would have rotated around the base of the lever, which also could have been welded to the shutter in order to stabilize it.

Aside from the internal shutter and pocket, the rest of the dimensions were measured by hand with calipers, and then sketched in SolidWorks. The overall shape was estimated by sketching multiple circles placed a distance from the center of the threaded opening, and then connected using wide arcs, as seen in Figure 25.

Figure 25: Sketch of throttle shape
3.4 Air Valve Assembly

The air valve assembly consisted of a cork disk insert held in place by a spring, which was kept in line with an adjusting screw and lock nut. The internal cavity thickness could not be measured by hand and was estimated to be about 0.1”, as this was consistent with other parts in the carburetor.

Figure 26: Throttle CAD assembly (a) assembled view (b) exploded view
3.5 Cork Float Assembly

The final subassembly modeled was the cork float assembly, which sits in the fuel chamber to ensure that the carburetor does not over flow. It consists of a u-shaped cork float connected to a rod that rotates about the pin that connects on either side of the float valve. The end of the rod
sat on top of a machined pin that sat inside the float valve. All of this was held in place by a small hex screw.

Figure 28: Cork float CAD assembly (a) side view (b) bottom view (c) isometric view (d) exploded view

3.6 Full Carburetor Assembly

Finally, all of the subassemblies as well as other various parts connected to the bowl casting were mated together as an assembly in SolidWorks. The other parts include the nozzle, needle, and corresponding attachment as well as the cap and elbow pieces for the float valve. A final rendering was done in cast bronze, which is the material of the carburetor (exact bronze alloy is unknown).
Figure 29: Render of full carburetor assembly
Summary and Next Steps

This thesis began with the disassembly of an actual Lunenburg Foundry Atlantic Engine carburetor at MIT, which was then carefully measured by hand and constructed in SolidWorks. The CAD assembly of the carburetor can now serve as an engineering database for the part. This will allow future engineers and engine enthusiasts to reference a part from one of the most revolutionary engineering feats that greatly impacted fishing and marine vehicles in the early 20th century.

If one wanted to recast the carburetor, this CAD assembly will help make it possible. The next step would be to make CAD patterns and core boxes for the cast parts. This would be done by de-featuring items such as through holes, bosses, and anything that would be post-machined.
Then appropriate draft should be added. Next, CAM software would be used to write tool-paths for machining the patterns and core boxes. The patterns could then be machined into an appropriate pattern material. The Lunenburg Foundry used to craft patterns out of wood, however depending on the number of uses needed from the patterns something such as REN Shape (a high density urethane foam commonly used in model making) could be used. Careful consideration should also be taken for assembly of the patterns and core boxes to allow for easy removal from casting sand. For example, a core box could be cut into multiple pieces and then clamped together, decreasing the amount of sheer force the core would feel when being removed from the mold. Examples of patterns made from REN shape can be seen in the figures below. These patterns are from an exhaust cylinder on an 1897 Herreshoff steam engine, which was built for a senior project in the Pappalardo Apprenticeship program at MIT.

Figure 31: Casting pattern for a Herreshoff engine exhaust cylinder machined out of REN Shape. The pattern is cut in half for the cope and drag parts of the flask.
Figure 32: Core pattern for the Herreshoff exhaust cylinder. This pattern is clamped and cut to minimize shear force when releasing the sand core from the core box. Cores are typically made from a bonded resin sand, and are later inserted into the packed flask.

Figure 33: Example of a packed flask. This is the cope for the exhaust cylinder without the core mold inserted.

After casting is complete using a flask and green sand, then the parts could be post-machined down to correct dimension that is in the CAD model created in this thesis. Some parts may not
be cast but machined directly from bronze stock, including the nozzle, butterfly shutter, air valve
insert, and various other pins and screws (note that the main screws that hold together the air
valve and the throttle to the bowl casting were not modeled in the assembly).

This thesis provides a solid starting point for those in the future to remake the carburetor
using the steps just described. Similar models could be created of other parts of the Atlantic
Engine, which could again be manufactured to keep the memory of the Lunenburg Foundry’s
revolutionary engine alive as well as to pass on the knowledge of traditional foundry practice.
5 References


