New Improved Quench System with Closed-system Oil Cooler

Our <u>First</u> Quench System Employing Agitator and Baffles

After performing our heat-treat variables tests (Testing Knife Steel: Parts 1 and 2), we considered several areas for re-tests. The first area considered was the order of quenching—relative time in the furnace. The next area was the time variability of the quench. This had to do with manual agitation during the quench. By hand, this can be a fairly inconsistent approach as well as adding to the quench time.

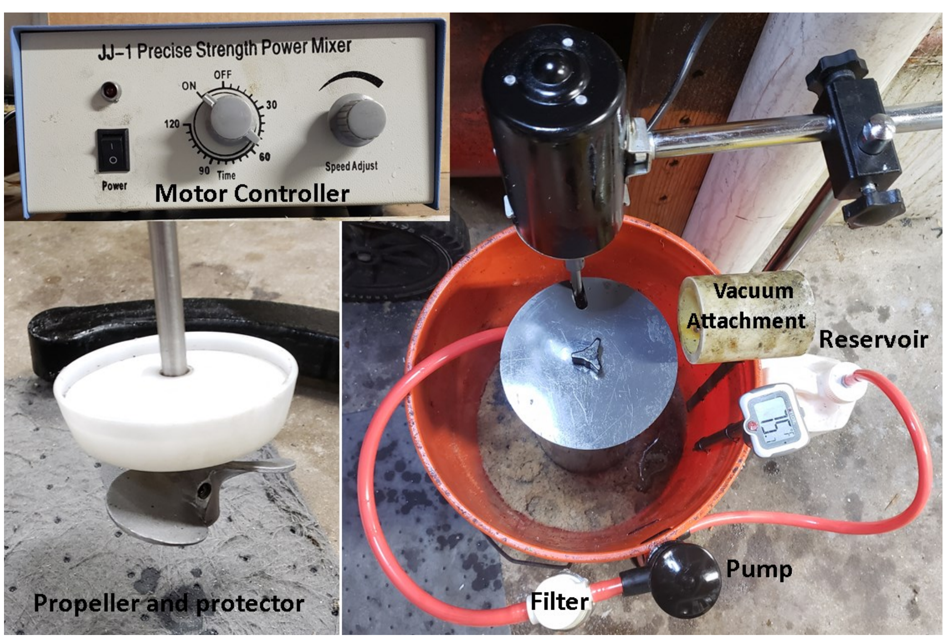
In order to address these issues, I decided to develop a more hands-free quench agitation system. Initially, we attached a paint mixer to a cordless drill. It worked great except for the awkward bit of juggling required to remove the knife from the furnace, plunge into quenchant while simultaneously starting the drill. I learned several things from this approach:

1. A mixer definitely dropped the knife temperature faster than manually moving it by hand.
2. Three hands, possibly four, would have been better for consistency of operation.
3. It created a hell of a vortex, sloshing hot oil (messy and a fire hazard) out of the quench tower.

So, I began researching self-standing quenchant systems. Since I already had a quench tower, I designed and built an overhead, motorized agitator. The agitator system below is based on a laboratory overhead agitator system (Amazon). I modified it by replacing the small impeller and shaft with a 3” propeller on a 5/16 shaft machined to 0.250” at the attachment point. It worked well, but it also created a huge vortex. I researched more and found that a vortex is not a good idea for a quenchant system. Who knew?

Shown below are details of the <u>original</u> improved quench system with baffles. Post-quench oil cooling was performed using a manual pump-out and replacement approach. After using for it for a while, I decided to make some improvements—still too messy. My main improvement was to add <u>closed-system</u> oil cooling, instead of the manual pump/replace system shown below. This approach would speed up the process of oil cooling for the next quench and allow for more consistent oil temperature.

Since the combination of overhead agitator and baffles worked well for quenching, the new recirculating system was all that was required to improve the process. But let’s look at the <u>baffles</u> before going forward.



Making The Agitator Baffles

After further research into quench oil agitation systems, I found that the vortex should be broken up in order to provide a bottom-to-top agitation, instead of a swirling motion, for more uniform quenching. So I went about fabricating a baffle system based on recommendations from George E. Totten's book, "Handbook of Quenchants and Quenching Technology".

Since we already had a quench tower, I decided to come up with a retrofit. According to Totten's book, baffle designs for cylindrical quench towers are typically based on a set of four equidistant baffles that are ~1/12 of the column diameter in width with a baffle stand-off from the column wall of ~1/36 of the column diameter. Since our quench tower internal diameter is 4.875", some quick calculations provided a baffle width of 0.41" (I went with 0.50", width of the steel) and baffle distance to column wall of 0.135" (I went with 0.125", the thickness of the steel). So, I just needed one piece of 0.50" x 0.125" x 36" soft steel (Home Depot). I then cut it into three 12" pieces.

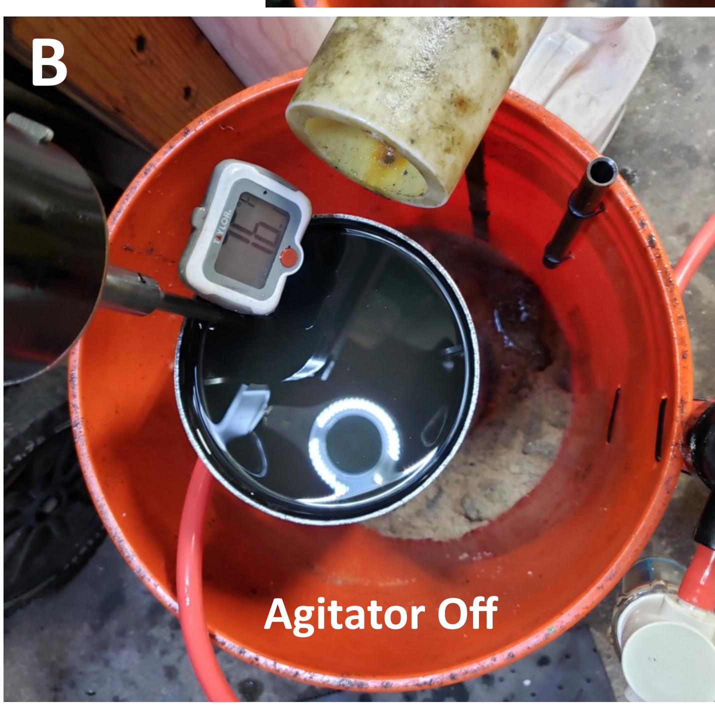
Because it was a retrofit, I made it an interference fit, so I wouldn't need to modify the quench tower. Below is the result of cutting, then heating and forming (support ends), and welding of the four baffles.

The Baffles in the Original Improved Quench System

Once completed , the baffles were placed in the quench tower. The bottom one was designed to fit snuggly while the top took more force to place in position. Picture **A** shows the baffles partially removed from the tower.

The baffle system is ~0.5” below the top and ~3.5” above the bottom. I wanted to make sure that there was adequate clearance for the bottom propeller.

When turned on, the baffles provided a nice bottom-to-top flow (Pictures **B** and **C**)—agitation with no vortex! The agitation shown is at room temperature. When I increased to 130° F (normal quench temp), the bottom-to-top agitation increased as well. I had to remove some oil to stop it from spill over. Worked really well!



Next Step: Adding a Closed-system Oil Cooler

After using the new system for a while, other improvements came to mind. So, shown below is our new improved quench system. Besides the agitator and baffle system described in our earlier version, we have added a closed-system oil cooler with two parallel ten foot sections of 1/2" aluminum tubing. Our oil cooling time after each quench is now ~ 50 seconds. I just hit the pump switch immediately after quenching, wipe down the knife and place it in the oven before shutting off the pump and grabbing the next knife for quenching.

New Improved System vs. Original Improved System: A Closer Look

While the original quench system with baffles worked well, I began to consider improvements every time I used it. The oil transfer process was improved, but still messy. Also, the vibration from the motor with the slightly out-of-balance propeller would cause the motor to shift over time. Constant re-adjustment was required to keep the propeller from hitting the sides of the quench tower.

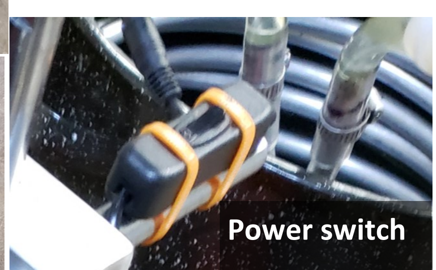
My first improvement was to replace the plastic motor support with an aluminum support using 5/16 x 18 bolts to tighten it in place. Having done a fair amount of research on quench systems, I decided to combine the vibration with the bottom-to-top agitation to improve quenching. So, I connected the vertical support to the quench tower with a bar of plastic to transfer the motor vibration to the quench tower while adding extra support.

All that was left to do was design a closed system for oil cooling that I could retrofit. The closed system required cooling coils in an ice-water bath, a pump motor and power switch. I originally had twenty feet of 1/2" aluminum tubing in a coil, but the back pressure from the coiled aluminum (fluid dynamics) was too much for the small pump motor—transfer was slow. To increase flow, I split the coils into two parallel ten foot sections. This doubled the flow rate and reduced the cooling time to less than a minute.

New improved quench system with baffles, using a closed system for oil cooling

Original improved quench system with baffles, using an open oil cooling process

Two parallel sections of 1/2" aluminum tubing



Power switch

Vibration transfer bar

Small DC pump

Solid aluminum support block

Summary

We are pleased with the performance of the new, improved quench system, but there is always room for improvement. Going forward, I am considering either a submersible pump placed in the bottom of the quench tower or a return tube shaped in a semi-circle (I saw this on a Bladeforums post—Great Idea!) that would provide a swirling action, similar to my current propeller system.   I could use a diverter valve to switch between the cooling system and a recirculating agitator system.

I am currently in the process of testing viability of each of these techniques. Maybe it will be better, maybe it will be a total bust. All I know is as an old retired engineer, I can't help tinkering.

I made a couple <u>mistakes</u> with the first closed system:

1. I originally used copper coils. After a very short period of time, I noticed the oil was no longer clear and had taken on a distinct green color. I researched this issue and found that copper, and its alloys, will contaminate mineral oil based quenchants. So I threw it out—oil and copper coil. I replaced it with aluminum tubing.

2. Next, I noticed extremely slow movement of oil through the coils with the small pump that I was using. More research yielded my ignorance of fluid dynamics. Having made a coil system for cooling wort when I made beer years ago, I expected a strong flow. Of course, back then I was using water from the hose—plenty of pressure.
   When I originally tested the small pump, it provided a strong flow rate, through a mostly straight section. Once coiled, the flow differential from outside to inside caused back-pressure that the small pump couldn't handle. In order to improve flow, I combined two parallel ten foot sections of maximum coil diameter. This provided significant flow improvement. I could have gotten a larger motor, but I first wanted to test this approach. It worked.