## *Building an Undershot Water Wheel*

I really miss the old days when we could leisurely peruse the scrap pile within our town 'recycling facility' and procure all the material necessary for any home project. These days however we must rely upon our ability to identify potential sources and secure those materials prior to them arriving at the collection point. I find doing this to be a bit more challenging since I must now be on the lookout at all times for the perfect item to fill a specific need. Perhaps you'll understand now why it took almost two years to identify and assemble the materials for this small project.

**Required material:**
1 large industrial wire spool*
12" – 15" Diameter PVC schedule 80 pipe*
3/8 inch Threaded Rod*
Fiberglass resin*
(2) 1½" Pillow block bearings (Northern Tool Item #1810 @ $13.99 ea)
1½" Cold rolled steel shaft*
14" automotive flex gear (or other gearing mechanism such as chain and sprockets)
Imagination
* *(optimal size is site dependent)*

In putting together this list, it has occurred to me that there are too many variables and alternatives available to the rest of the items I used so it would perhaps be best to let your creative juices flow as you consider what you'll use to build the sluiceway or power with this device. I'll merely relate the adventure as it unfolded…

One particular Spring thaw found me musing over the zillions of gallons of water flowing over our waterfall and how "… it would be nice to put that to work." The fall is merely four feet high so my mind sized out an appropriate overshot water wheel. On the way home from work that day, I stopped by a local electrical contractors shop to inquire about that large wire spool I had spied on his lot. To my surprise, he asked me to take as many as I'd like since he would have to dispose of them otherwise.



Several weeks later I found a source for the PVC pipe… a nearby town was replacing the storm drains and had various lengths of broken and short pieces they were eager to part with. I had decided to place as many vanes as was practical on the wheel and that appeared to be nine, but how would I space them evenly? I drew upon my high school geometry skills to sketch out the necessary chord length for the 40" diameter wheel and, after aligning and clamping the two disks as they would ultimately be joined (making note of and aligning the previous threaded rod penetrations and other holes) marked each point on the perimeter of the two wheels using a yard stick

and magic marker. My goal was to ascertain that the center holes and final rotational balance remained true. After separating the disks, I drew lines on the inside surfaces from each of the points to the center. Measuring the diameter of the PVC pipe, I fabricated a piece of metal strap with a small hole at each end which, when fastened to the edge of the surface plate on my router and a point on the wooden disks, would allow me to create a semicircular slot in the disks which would accommodate the end of each vane. I used a 3/8 inch router bit and made each slot ½" deep starting at the line marked on the disk perimeter and rotating around to the inside of the same line. Please note that before routing out the slots on the second disk, you should sketch out and mark



$$\emptyset = 360/N \text{ Where}$$
$$N = \text{number of vanes}$$

the direction of the proposed slots such that when the disks are assembled, the slots will correspond to one another.
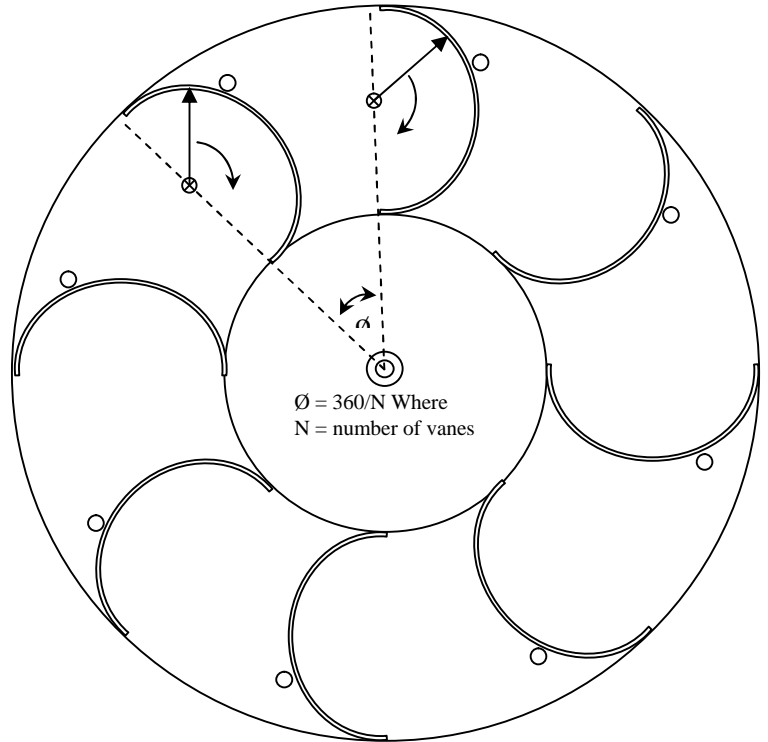
In order to overcome the challenges involved with cutting 1 foot diameter PVC pipe lengthwise with straight edges, I clamped a piece of wood strapping to the pipe at both ends (aligned as to be parallel) and made the initial cut with a skill saw. After determining and marking the proper cut location on the opposite edge, I once again clamped the strapping in such a location as to keep the blade on the marked line. That done, I cut each vane to the appropriate length using my miter saw such that the edges were square. A little bit of sandpaper and the vanes were ready.

The last thing to do before beginning assembly was to drill holes for the additional threaded rods that I felt were necessary since the disks would eventually tend to warp. Laying one disk down, I marked and drilled a 3/8 inch hole directly beneath the cup of each vane slot at a distance of 4 inches from the perimeter edge of the disk. Placing the two disks together as they would be mounted (slot to slot), I drilled through each hole again resulting in a corresponding set of 3/8 inch holes on the other disk.
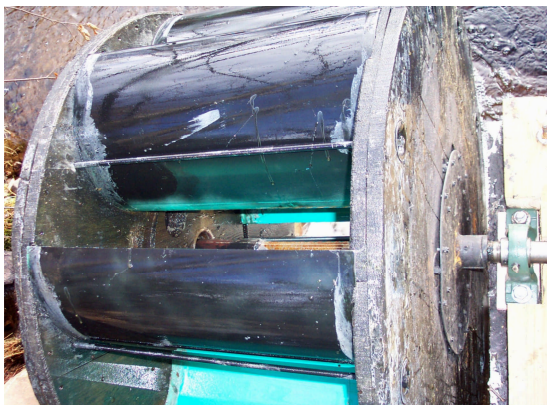


Undoubtedly the best part is putting all the pieces together and this is where I always find I've missed something but we'll get to that later. I inserted three or four lengths of threaded rod with retaining nuts into the inner holes on one disk and, with the disk flat on the ground, inserted the vanes, aligned the second disk and secured the rods but not too tightly. Having examined and

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assured myself of the proper seating of each vane in its corresponding slot, I inserted and tightened the remaining threaded rods. I found that I had to "persuade" proper seating with the judicious use of my sledge hammer, but I suspect that was due to moisture absorption resulting from the six months between routing the slots and assembling the wheel. Once the threaded rods where evenly torqued and the wheel appeared to rotate on a pipe without wobbling, I cut off the protruding rod ends (Notice the countersunk cup washers) and painted the surfaces flat black to appease my wife who by now had refused to let this "monstrosity" adorn 'her' waterfall and possibly be seen by the neighbors. While I nursed my wounded ego I decided to coat the "monstrosity" with fiberglass such that it would be more durable and retain its shape. Through negotiations with my wife, I was authorized to build another waterfall "somewhere out back" and resorted to more research. I decided upon an undershot water wheel configuration since I'd located a natural fall of two feet and wasn't particularly eager to reroute an entire stream. During the low flow week or two afforded me in September, I cut into the existing stream path such that I could place two concrete block pads at a distance of 26" from one another and using a ½" thick piece of plywood cut 26" wide, formed a 21" radius curved concrete form into which went rock, rebar and concrete. In fact, knowing how violent this little stream can become, I ended up placing forty feet of rebar and almost 3,000 pounds of concrete in such a fashion that the mount should not move from its designated location (Rebar driven 5' into the stream bed). I then landscaped the upstream shoreline to more narrowly confine flow to the wheel. It was my decision to allow water to bypass this structure if levels exceed the center height of the wheel since no one should underestimate the destructive forces behind rapidly flowing water. Judicious placement of a piece of 1" expanded steel assures my wheel will not fall victim to floating debris.



I inserted some "L" – shaped lengths of leftover threaded rod into the concrete before it set such that I could bolt down two lengths of pressure treated lumber onto which I could later locate and mount the gearbox and generator. If I was clever and had the pillow block bearings in hand at the time I would have also inserted threaded rod lengths in the appropriate locations to mount them, but as it was I ended up drilling holes and placing 5/8 inch threaded anchors later on. The clearance between the wheel and the formed sluiceway ended up being ¾" so one should be very careful if pre-placing threaded rod for the pillow blocks.

Getting the wheel mounted however took me until mid November since I still had to figure out how to secure the axle shaft to the wheel. The epiphany occurred while performing my annual autumn garage clearing ritual. There among the items scheduled to return to the future projects parts pool was the satellite dish assembly from which I

removed the positioning mechanism for my solar panel tracking mount project. The assembly consisted of two 14" steel disks bolted together with a 1" hole in the middle. I merely separated them and increased the hole size to accommodate a 6" length of 1½" plumbing pipe onto which I threaded a coupling and welded all together securely. The coupling added extra 'meat' to the pipe so I could drill, tap and insert a 3/8 inch set screw when securing the wheel onto the 1½" axle shaft. I bolted these assemblies onto the water
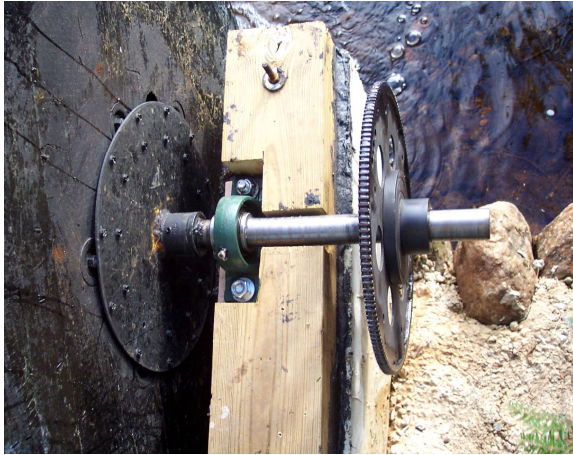


wheel after locating the center of rotation as best as I could with a tape measure. It is truly important that this be done accurately since any error will result in a multi-axis wobble and reduced clearance to the sluice.

Since, as some of you may have known the true interior diameter of 1½" pipe is 1 5/8 inch, I had to insert sleeves such that the axle would fit snug and run true… the chosen sleeve was a length of 1½" type L copper plumbing pipe which just happens to have the perfect dimension (1.503" ID & 1.625" OD).

Since I'd been gathering parts for this project for many months, I had located (and rescued) a 14" Chevrolet flex gear residing in the junk outside a service station knowing that I'd need quite a large gear ratio to reach adequate generator speed. The gear has a 12 pitch and mates perfectly with a Boston Gear #ND12B (Grainger #1L964 @ $13.09) spur gear which has a pitch diameter of 1" and therefore provides me a 14 to 1 gear ratio. I had a machinist friend turn a hub onto which I welded the flex gear (cost me a coffee) but when my son, the automotive instructor, saw it he thought it was a bored out vibration dampener welded to the gear so that may well be an option as could be the use of roller chain and bicycle gears. As it is, the 14 to 1 ratio is inadequate and must be multiplied
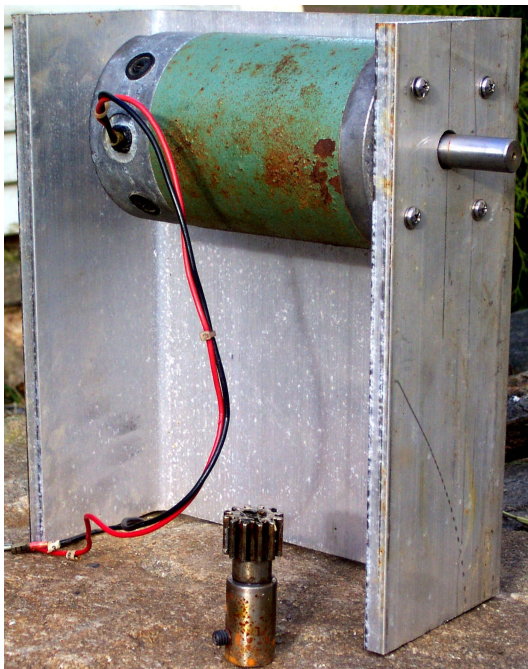


again by 3 to 1 in order to reach an appropriate speed of 1000 rpm for my particular generator. For this I'm using roller chain and sprockets (U.S. TSUBAKI 40B9F-5/8 and 40B28F-5/8) on a 5/8 inch axle to be installed in the chassis shown.

These gear ratios and necessary speeds will vary from one application to another since the diameter and width of the wheel as well as water flow determines how fast your wheel will rotate and the required generator speed will be dependant upon your generator. I'm using a surplused permanent magnet computer tape drive motor which, though not ideal, is very convenient. This specific motor should generate about 48 volts at 1260 rpm and

provide 12 amperes into a 12-volt battery load. Further information on the use of these motors is available at
[http://www.otherpower.com/otherpower_experiments_tapedrivemotors.html](http://www.otherpower.com/otherpower_experiments_tapedrivemotors.html).
The 40" wheel I assembled rotates at about 25.5 rpm at the nominal flow rate with a stall torque of 35 pounds measured on the perimeter, varying relative to flow. I've provided an Excel spreadsheet, which will be convenient for determining maximum power potential and construction measurements for those who are geometrically challenged.

My wife now frequently visits the water wheel and seems to be mesmerized by it… the other day, while working in the pasture, I caught her standing there talking to herself (or the dog) and I inquired as to whether she was speaking to me or not since I didn't hear her clearly. As she walked away she repeated herself… "Elegantly simple!"