Differential Hoist notes

Alexander Rose 10/07/97

Concept: Daniel Hillis

To take advantage of a slight radius difference between two gears (1 & 2) with a weight suspension device as a means to power a clock.

Drawings: Alexander Rose (The Long Now Foundation)

Machining: Chris Rand (Rand Machine Works)

Assembly & Testing: Alexander Rose & Chris Rand

Materials:

Shafts: Rand Machine Works
- .5" drill rod

Sprockets: Martin Sprockets #25 @ .25" pitch (Bearing Engineering)
- 6 x 18 tooth (t)
- 2 x 30t
- 1 x 54t
- 1 x 60t
- 2 x 70t
- 2 x 72t

Chain: Martin #25 (Bearing Engineering)
- 1 x 10' length

Needle Bearings: BA (Bearing Engineering)
- 16 x BA-87 (.5" I.D., .6875" O.D., .4375 W)

Brass: Metal Service Center
- 1 plate brass 260 @ .75" x 5" x 13"

Aluminum: Metal Service Center
- 1 plate 60-61 T6 @ .25" x 20.5" x 34.75"

Hardware: Rand Machine Works & Bearing Engineering
- 8 x 1/4-20 x 1.5" flat heads (weights)
- 2 x 1/4-20 x 1" SHCS (weight brackets)
- 4 x 10-24 x 1" SHCS (linking gear ass'y)
- 8 x .5" snap rings
- 2 x 1/2-20 nuts (adjustable shaft)

Thoughts while designing:

I decided to build a chain & sprocket version of this concept as I felt it would be the most economical both in time and resources. It also lends itself to a certain amount of interchangability. I ordered most the parts from Bearing Engineering here in S.F.. I over ordered in terms of sprockets so that I would be able to try different combinations. I went with wide needle bearings knowing that they are not the lowest friction choice, but I wanted to use only a single bearing per sprocket, and this seemed to be the most stable way. I designed the weight suspension sprocket assemblies (9,10 & 11,12) so that they could be hung on the chain without any disassembly. (this did make them not perfectly balanced so I designed in a slot on the bracket to allow it to be adjusted so that the weight will hang straight.) I also designed in a slot in the main plate that allows the adjustment of a chain tensioner between the linking gears (3 & 4) by the way of two nuts) I chose the size and thickness of the weights fairly arbitrarily, mostly based on aesthetics, material availability, and space requirements. I chose to move the linking assembly to be in front of the main gears (1 & 2) to put the weight load as close to the plate as possible. This was limited however by the 1.5" thickness of the weights. During building Chris Rand brought up the idea that since the main gears were linked in a 1:1 ratio that it would hang up and not be able to take advantage of the tooth difference. This made some sense so we made a set of linking gears that were identical to the main gears to make for an exact ratio difference.

Machining:

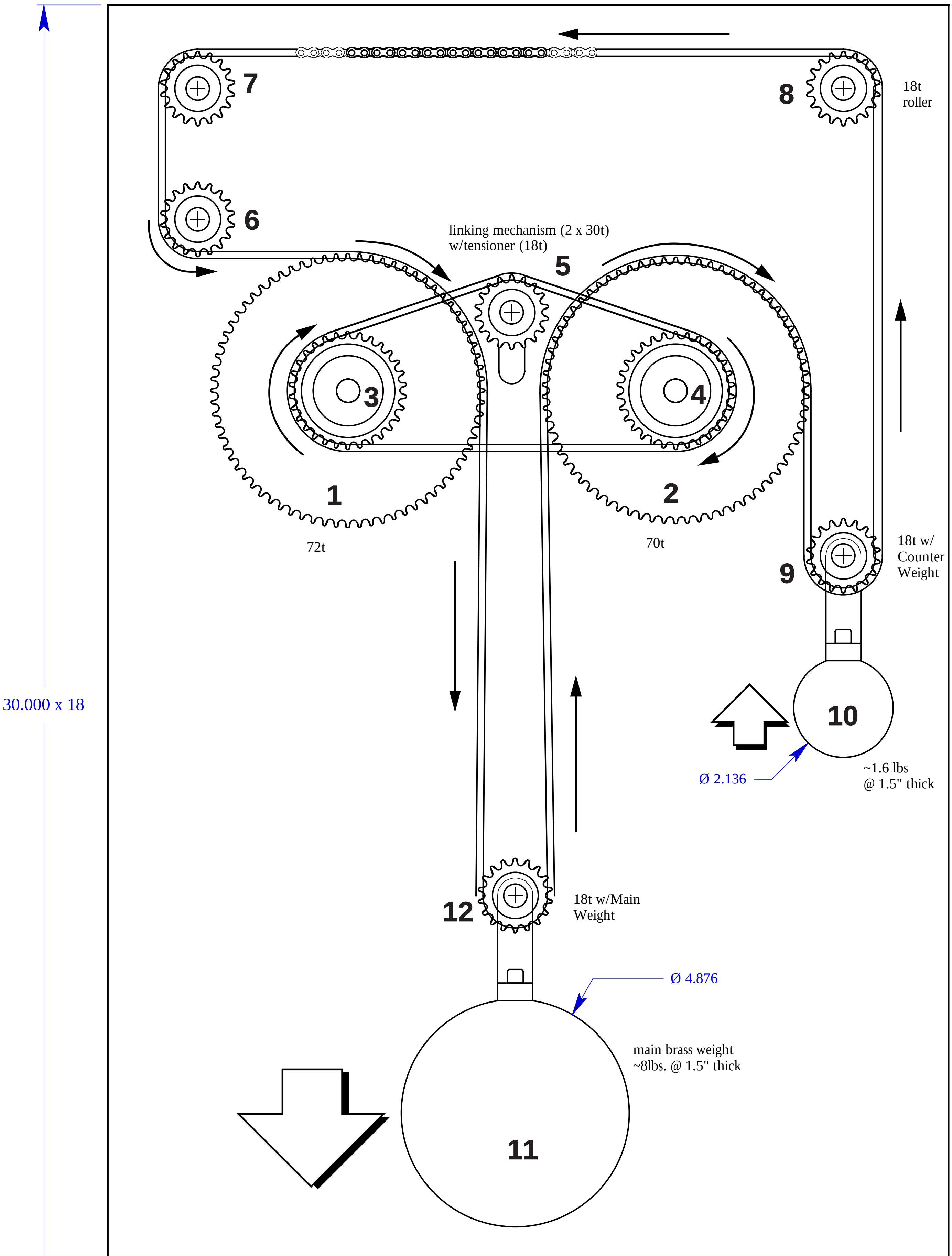
This was done by Chris Rand, but I noticed some things worth remembering. That these type of bearings are not like ball bearings with inner and outer races. They do not achieve their spec'd I.D. UNTIL PRESS FIT. Even then some were still large as far as I.D. goes. We ended up press fitting them into .687 counter bores. Another little problem was encountered while assembling the main gear / linking gear assemblies. When the two were bolted together they would tend to wobble on their axis. I can only assume that this means that the surfaces we were bolting to were not perpendicular to the shaft hole. Therefore the first thing I would do if preparing them again would be to make a cent expanding chub to turn them with and taking passes on ALL reference surfaces before chucking it up to counter bore for the bearings.

Assembly & Testing:

We put it together with 72t and 70t main gears and identical linking gears. It did nothing. When we pulled the chain the weights did not move up or down. So we took off the linking chain and played around with it. We realized, by the rates the gears were moving, that we were doing something right, but without the linking chain the mainweight (11) would simply drop to the ground. So we hooked up the linking mechanism again, this time with the originally planned 1:1 ratio (with 30t sprockets). It still did not move. But when I pulled on the chain I noticed that the weights did move ever so slightly. I tried pushing down on the mainweight and removing the counterweight but it still would not move. At this point we realized that the principal was working but we had way too much friction. So we put on a 54t in place of the 70t and...IT WORKED. It took about 1 minute to complete its 14 inch journey.

Retrospect:

So the principle works great but in order for us to truly use an extremely close main gear differential we would have to engineer away a ton of friction. If we were to use this we would probably use metal tape instead of chain to remove the majority of the moving parts. Additionally we would want to look closely at the linking mechanism and counterwieght system to maybe reduce the number of moving parts there as well. In this model a lot could be removed by: Removing the upper left sprocket (7) it is unneeded, & degreasing the chain and bearings. I would also increase the size of sprocket 6 to give the chain a little more wrap around sprocket 1. (sometimes it slips) I would also replace the bearings with unsealed, un-greased, grade 8 roller bearings. I also think that by making delrin sliders instead of sprockets for 5,6,7,8,9, & 12 that there would be less rotational weight to overcome which I think is a bigger consideration than the friction on these sprockets in this model.



"N/N+1" Differential Hoist Drive.Assy		
1:3	10/07/97	v.2.5
#25-.25"pitch chain and sprockets		
for roller chain study		

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