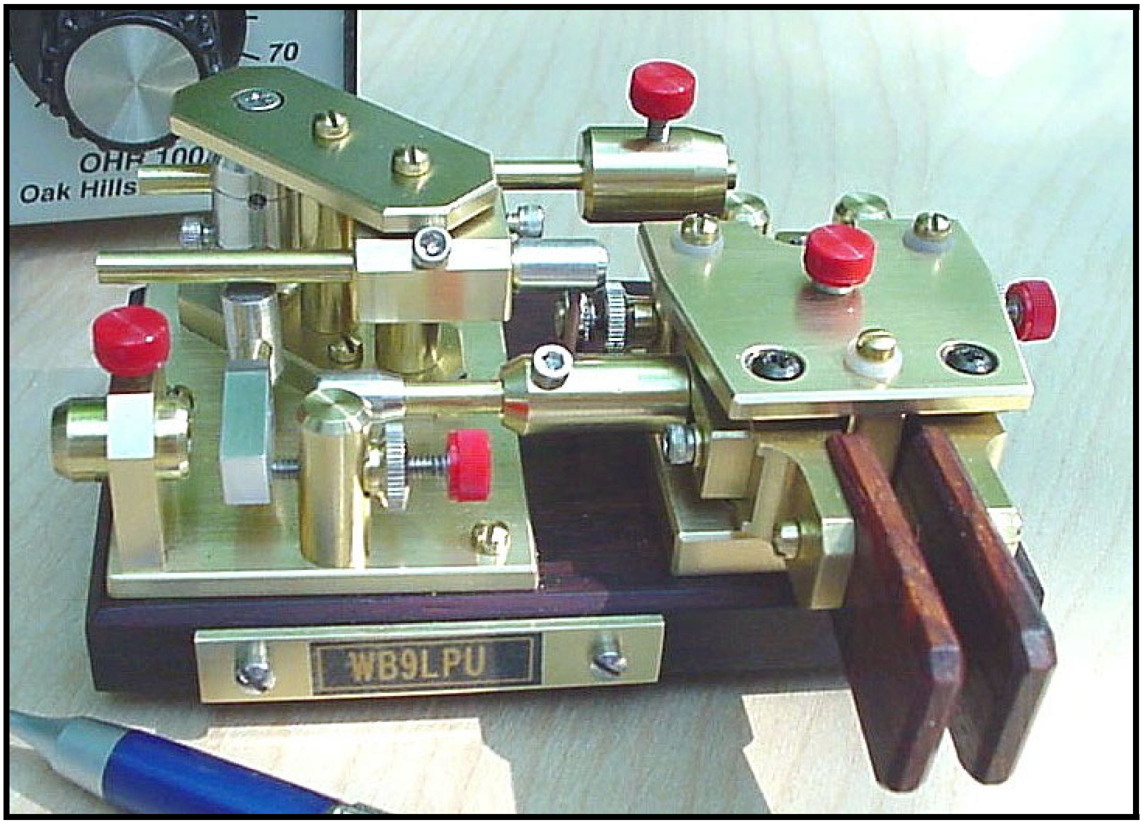
The Millennium Bug Project

by

Richard Meiss, WB9LPU



How it started

Having tried my hand at making straight keys and paddles, I wanted to see if I could make a successful bug. I especially wanted to test out an idea for a magnetic pendulum that had come to me while I was working with a magnetically tensioned straight key. I spent about eight months mentally designing and building a new kind of bug before I put anything down on paper (or wood and metal). These were some of the design goals. The bug should

- Be functionally equivalent to a standard mechanical bug (Vibroplex, etc.).
- Use only permanent magents (no springs or electromagnets) to set the speed of the "dit" pendulum.

Richard Meiss, WB9LPU
Speedway, IN
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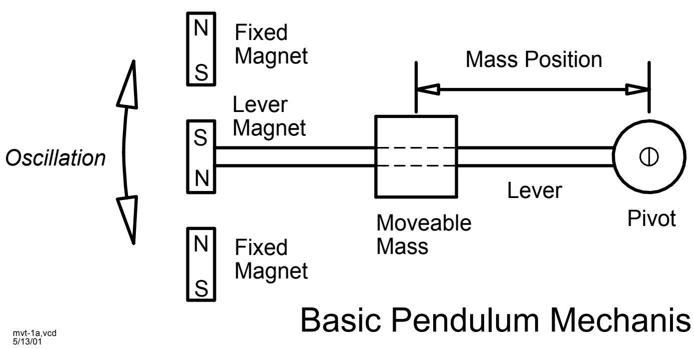
- Use a non-contact system to pick up the movement of the pendulum.
- Use no power supply or external circuitry.
- Keep its settings without frequent adjustment.
- Require only one adjustment to change speed over its whole range.
- Be as small as possible, in keeping with other QRP gear.
- Look as good as a commercial bug, if possible.

I think I have been able to come close to meeting these goals with my current design, although my efforts are continuing.

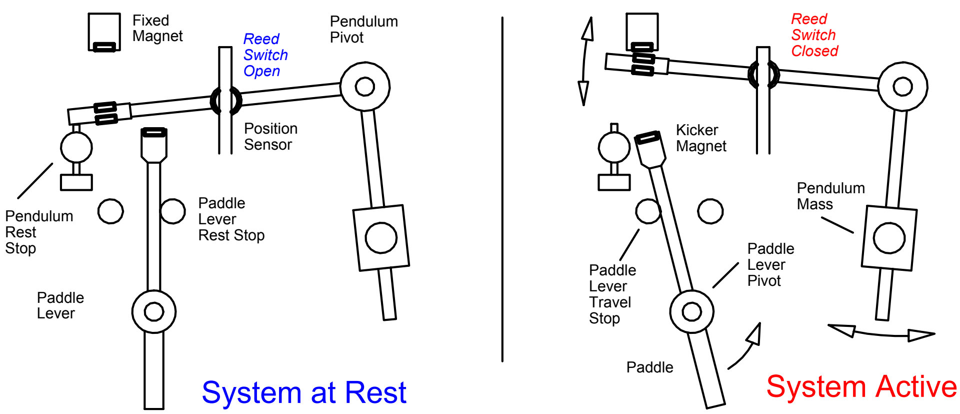
Designing the Bug

The heart of the design is the permanent magnet pendulum system. In its simplest form, it consists of two stationary magnets mounted on a mass-loaded lever as shown below



Basic Pendulum Mechanism

The magnet on the lever is repelled equally by the fixed magnets and stays in the center position if left alone. If it is suddenly displaced and let go, it will oscillate back and forth at a rate set by the strength of the magnets, the size of the mass, and its position on the lever. Friction in the pivot bearing will eventually reduce the lever movement, but the period will stay the same over a wide range of displacements. To make the pendulum practical for a bug, the magnets must be small, light, and strong . (I used Radio Shack 64-1895 rare earth magnets.) There must also be a way to set the pendulum in motion and stop it quickly and prevent it from bouncing after it has been stopped.. The resulting mechanism is shown below.



Basic Pendulum Mechanism in Operation

In practice, the lever is "folded" 90 degrees for compactness, and the mass is on this extension. Another permanent magnet mounted on the lever closes the contacts of a sealed magnetic reed switch each time the lever passes under it.

At rest, the fixed magnet pushes the pendulum lever toward the "kicker" magnet on the paddle lever. The magnet mounted on the pendulum repels the paddle lever, pushing it to one side (the rest position for the paddle). Because of this, no return spring is needed on the paddle lever. Two stops maintain the extent of the paddle lever travel, and a third stop sets the rest position of the pendulum lever.

When the paddle lever is pushed into the active position, the "kicker" magnet repels the pendulum lever toward the fixed magnet. As long as the paddle lever is held in the active position, the pendulum will oscillate and produce a string of "dits". The duty cycle (spacing between "dits") is set by changing the reed switch position. Letting the paddle lever go back to its rest position stops the oscillation, and magnetic repulsion holds the paddle lever in the rest position. Pendulum lever damping (as it comes to rest) is provided by a felt pad on the end of the lever, and the residual bounces are generally too small to trip the reed switch.

Richard Meiss, WB9LPU
Speedway, IN
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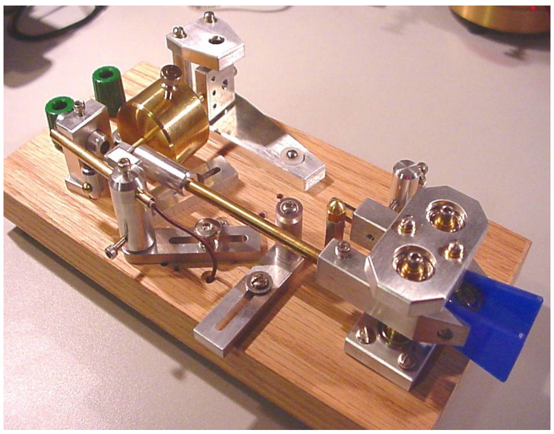
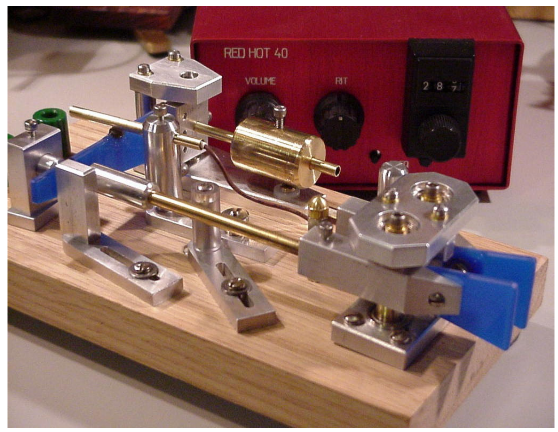
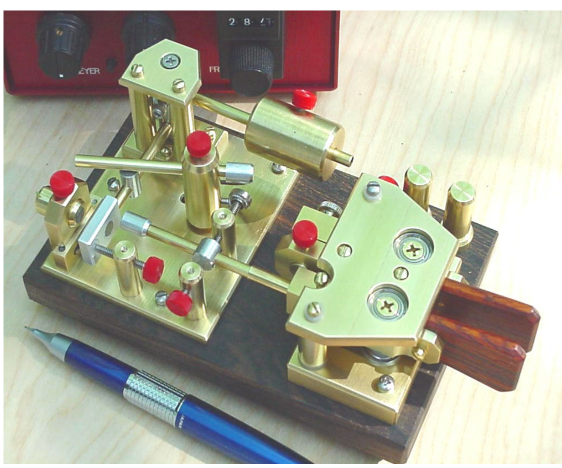
Building and Testing the Bugs

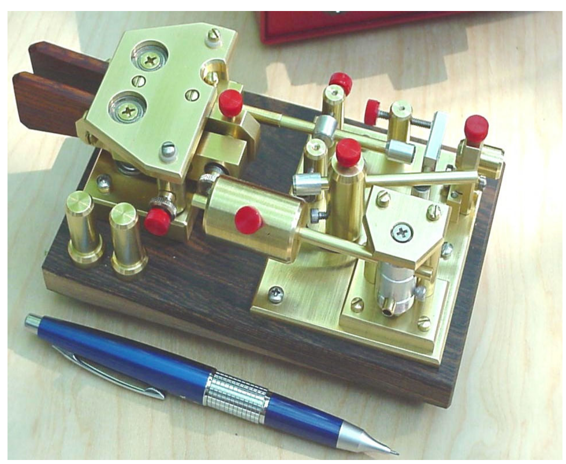
The first step was to build a "test bed" as shown below. It was made so that various configurations could be tried out and a wide range of adjustments could be made. I tried out several arrangements, varying the locations of the reed switch pick-up, the sliding weight, the paddle stops, etc. Then, since I had never used a bug, I took some time out to practice and put it on the air. People I QSOed with were able to copy my questionable fist, so I figured I was on the right track.





The next step was to make a finished instrument, using what was learned from the test bug. This is Parkwood Bug #1, shown here.





It uses a folded pendulum configuration for compactness, with the position pick-up between the pivot and the pendulum magents and with the speed-control weight on the other side of the pivot. The pivot uses upper and lower ball bearings for low friction. For mechanical simplicity, I used a two-paddle design, with the "dah" paddle having its own tension and spacing adjustments. The paddles, which also run in ball bearings, were

Richard Meiss, WB9LPU
Speedway, IN
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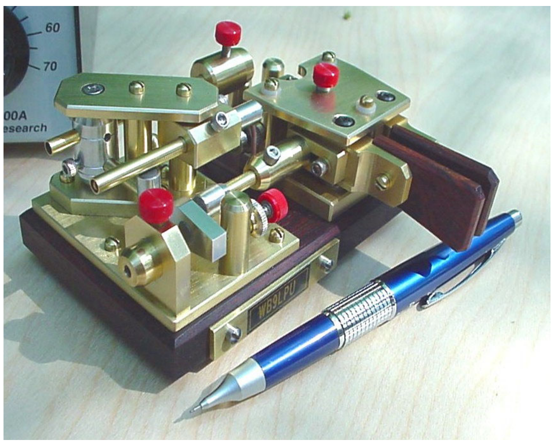
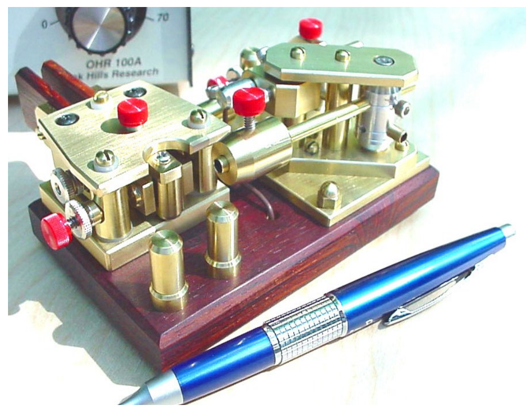
positioned conventionally at one end of the instrument. Most of the parts are machined from brass; fittings are stainless steel or aluminum (used where light weight was desired). The pendulum lever rods were made of brass tubing for light weight and strength. The base was of bocate wood and the paddles were made from cocobolo wood. All brass parts (except for the pendulum parts, where sliding had to be allowed) were finished with clear lacquer.

Bug #1 worked well, but it was rather large. Parkwood Bug #2 was an attempt to make a QRP-sized bug, which is shown here.





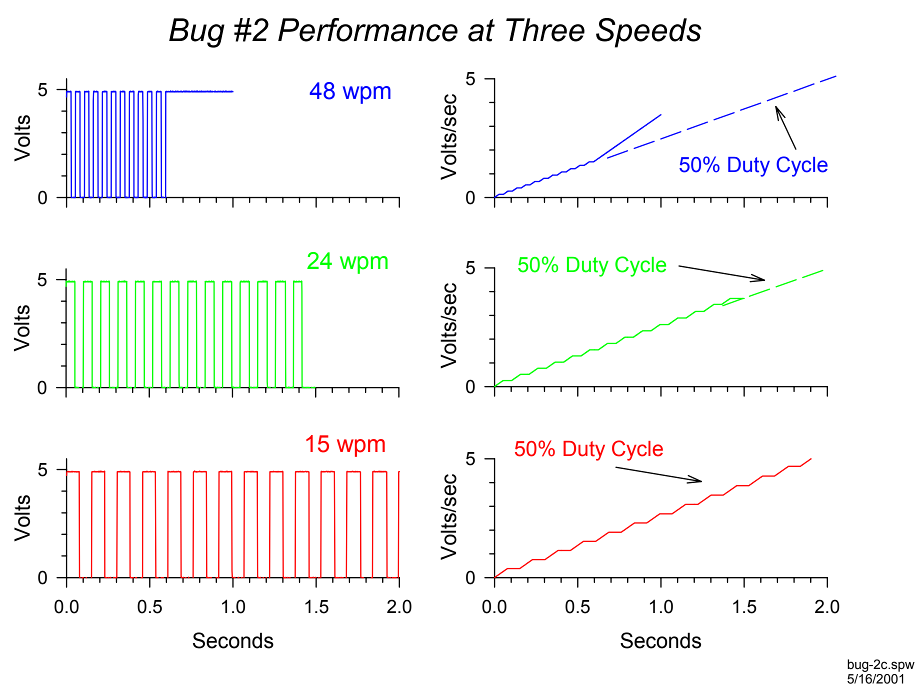
Again I chose a two-lever design. For compactness both the pendulum and paddle-lever paths were folded. The travel stops for both the "dit" and "dah" were built into the lever-bearing assembly (which was modified from my paddle design--why re-invent the wheel?). This bug is lighter in operation than Bug #1, but it is still heavy enough to stay put during operation. With the present weight, it can be adjusted from 15 wpm to about 48 wpm.

Performance Tests

Besides using them on the air, I decided to evaluate their performance more objectively. Of the most concern was how constant the duty cycle remained over a string of "dits". Having access to an elderly digital oscilloscope, I was able to make some careful measurements. I used the bug under test to key a +5 volt source and display the result, a train of pulses ("dits"), on the scope. I selected three speeds corresponding to (1), no weight on the pendulum; (2), the weight at midpoint on the lever; and (3), the weight at the very end of the lever. Using the formula,

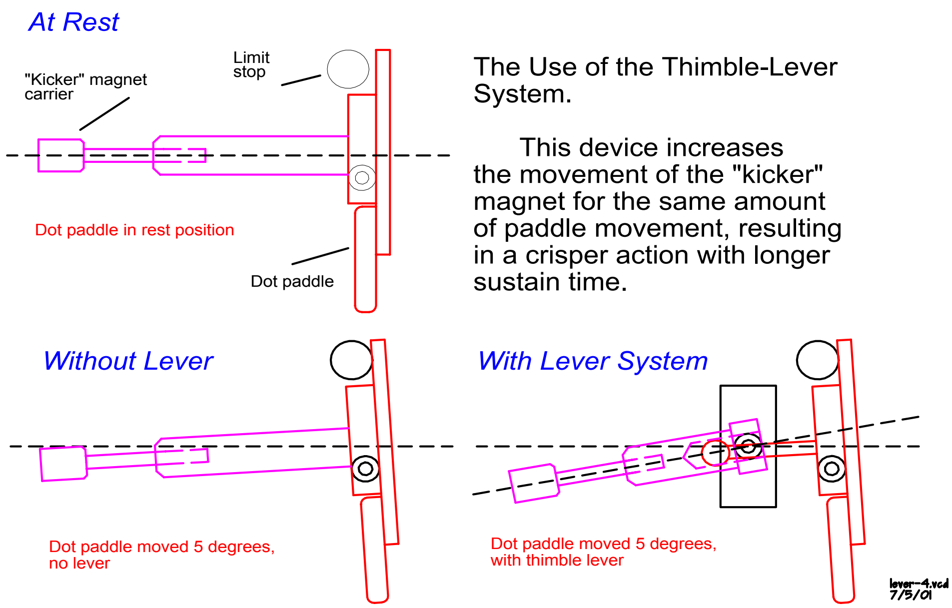
Speed in words per minute = (dits per second) x 2.4

I determined these settings to yield 48, 25, and 15 wpm, respectively. (The source of the formula was QRP-L, where my inquiry set off a week-long thread - thanks for all the replies, folks.) Using the scope software, I integrated each pulse train. This will produce a "stairstep" function having a constant slope of 2.5 volts/sec^2 if the duty cycle is constant at 50%. The graph below, using data from Bug #2, shows that this was the case. This approach is a fancy version of the "ohmmeter test" long used to set up mechanical bugs. The test also showed the contact closures to be very clean.

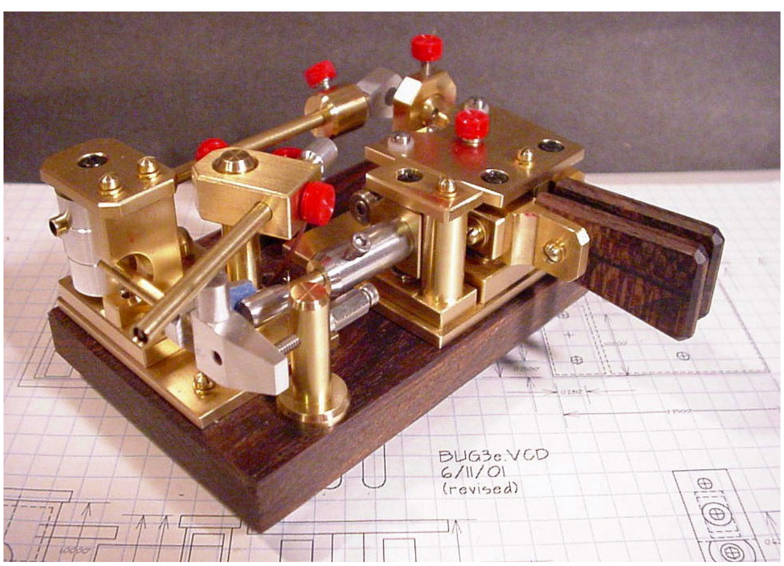


Improving the Bug

While both of these bugs worked well, some improvements were needed. An improved damping mechanism was added to reduce errors from sloppy keying, by trapping the lever before it could bounce. This modification was made to Bug #2 (damper not illustrated). A more serious problem had to do with the amount of dot-paddle movement required to produce an adequate deflection of the "kicker" magnet. This was not a problem with Bug #1, given its larger size. However, in the miniaturized Bug #2, this movement was fairly large (compared with a conventional bug) and resulted in a different feel. What was needed was an amplifying lever system, but one without backlash that would still preserve the smooth feel of the Bug #2 action. For this reason, the thimble-lever system, illustrated below, was devised:



This system, which used a nylon or brass ball running in a polished cylinder that was pivoted on its own bearings, was incorporated into Parkwood Bug #3. It resulted in a bug that could easily sustain a string of 30 or more dots, even with a small paddle deflection. Bug #3 also tested the movement of the fixed magnet to the end of the speed-weight lever; this allowed longer lever arms within the small footprint. Bug #3 is shown below:



Front View of Parkwood Bug #3. The thimble-lever system is to the left of the dot paddle.

Richard Meiss, WB9LPU
Speedway, IN
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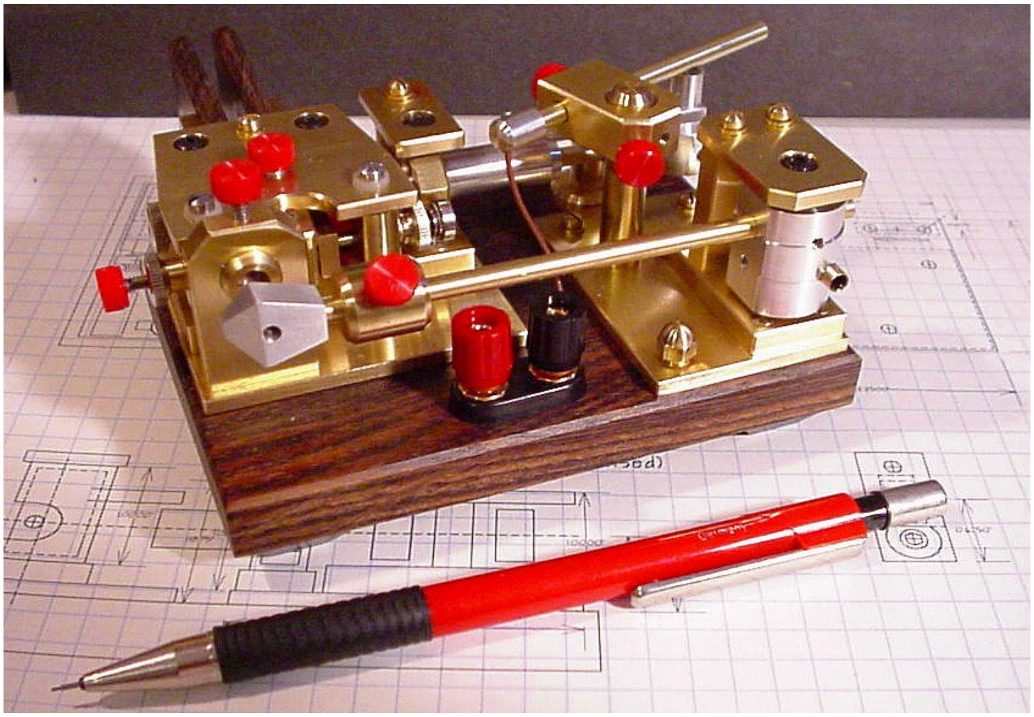

Rear View of Bug #3. Note the fixed magnet at the left.

With the small weight provided, the speed range is from 15 to 23 wpm at the current magnet spacings, etc. The range can be increased by suitable adjustment and the use of a larger sliding weight.

Further Plans

Currently under development is a more compact version of the thimble-lever system, which will be used in a compact version of Bug #1. Plans are also underway for a bug that makes both dots and dashes automatically, while using only a single weight for speed adjustment.

Richard Meiss, WB9LPU
Speedway, IN
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