The Link Trainer Slip Stream Simulator

Linktrainer.net

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The link trainer utilizes oil filled resistance dash pots or dampers to simulate the control resistance that is normally experienced in the movement of an aircraft's controls. These devices are known as "slip stream simulators" and they provide a sense of control feedback, albeit fixed, that is intended to replicate the forces imparted by slipstream airflow over the control surfaces. Three such devices are utilized in the Link C3 for movements related to rudder, elevator, and aileron. The figure shown below is an excerpt from a Link Trainer maintenance manual that illustrates the major features of a slip stream simulator.

The Problems of age

These devices are filled with oil that over the years can solidify and greatly increase the force required to move the flight controls. In some cases the force required to overcome the slip stream simulators can begin to place undue stress on the links and couplings that are connected to them, sometimes to the point of failure. The units found on my link trainer were very stiff. After removal of the filler hole-plug it was obvious that the once liquid oil had solidified to a consistency of rubber.

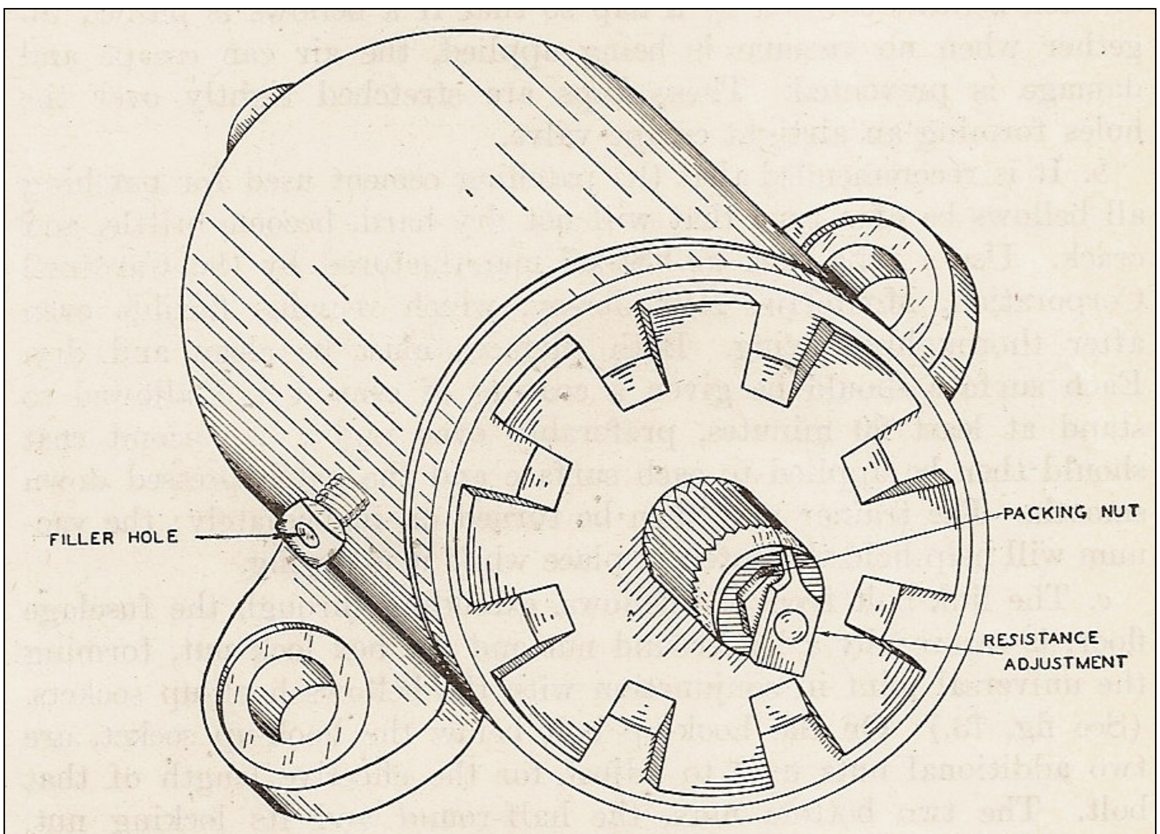


FIGURE 72.—Slip-stream simulator (hydraulic).

Figure 1 Illustration from a Link Trainer Manual

17. Slip-stream simulator.—*a.* These units are designed to stiffen, or load, the elevator, aileron, and rudder control.

b. The body of the unit contains vanes on the large shaft which operate in fluid-filled compartments. The fluid flows from one side of each vane to the other side through a controllable valve which can be adjusted to furnish the desired resistance, or stiffness, of elevator or rudder control. Protruding from the unit is a large shaft to which a lever arm is clamped. The adjustment is located in the end of this shaft in the form of a rectangular "head" or "nut" with an ear on one side bent over to form a pointer. (See fig. 72.) The hex nut, between the adjustment and lever arm, holds in place a packing to prevent leakage around the valve shaft.

c. These units should be checked for any lost motion in the link rods to the controls, for the degree of stiffness, and for leakage. The stiffness is controlled by means of the resistance adjustment shown in figure 72. This figure also shows the packing nut. If this nut is too tight, it will cause excessive friction and a slight jerkiness at the start of movements. It is seldom necessary to refill the unit. If fluid is required, it should be filled to the bottom of the filler hole. Use only No. 500 shock absorber oil.

Figure 2 Excerpt from a Link manual describing the Slip-stream simulator

What's inside?

The Link manual provides information that is helpful for maintaining and adjusting a functional slip stream simulator, but not much insight regarding the details of construction or how they should be repaired or overhauled. After being unable to locate any information regarding the internal construction of these units, a quick search on the web of older patents revealed much useful information. Patent 2,358,988 shown in Figure 3 below, reveal features that are a very close resemblance to the device used in the Link C3. Many other patents related to this type of device may also be found. Most were assigned to the Houdaille-Hershey Corporation of Detroit Michigan. The reader is invited to review the patent sited which is readily available for viewing at www.google.com/patents by merely typing in the patent number in the search field.

These devices are known as rotary dampers or hydraulic shock absorbers of a rotary type. Further research revealed that the Houdaille shock absorber was built in various types were used in the suspension of automobiles built in the 1920's through the 1940's. One of the first patents filed by Maurice Houdaille for a rotary damper dates back to 1909 (US patent 933076). Modern versions are still produced today for various applications. While no definitive markings could be found on these rotary dampers it appears that they were manufactured by Houdaillel Hershey of Detroit Michigan.

Since these rotary shock absorbers were used in many early automobiles there are a number of companies that will rebuild them, Figure 5 displays an excerpt from one company that will rebuild the Houdaille shock absorber for $145. Additionally, a web search for "Houdaille shock absorber" will return many results including a number of articles written about them and. The following is a listing of the more notable.

http://www.oldcarmanualproject.com/manuals/Ford/Haudaille/index.html

This site has jpegs of an overhaul manual for the Houdaille shock showing the various special tools used for disassembly.

http://www.geocities.com/MotorCity/Garage/1205/hhist.html

This site provides information about the Houdaille shock and tips on how to rebuild them.

http://www.streetrodderweb.com/tech/0907sr_the_technology_behind_shocks/photo_11.html

This site has a variety of photographs of the Houdaille type shock that has become popular with the hot-rod crowd, especially the chrome plated version.

The patent and web information revealed that it could be disassembled by removing the large threaded end. The threaded end plate (item 19 in Figure 3) has symmetrical indentations that were intended for use with specialized tooling to open or close the unit.

How it works

The design of these devices consists of two opposing chambers which is revealed in Figure 3 as items17/18 and 17'/18'. A common movable vane (item 16 in Figure 3) divides each chamber. Each of the four chambers shown, 17, 18, 17', 18', are filled with oil. The oil is allowed to move from the chambers that are being compressed into the chambers being expanded as the vane moves. The flow of the oil is restricted by a valve that is adjustable through the pointers shown as item 47 in Figure 3. This adjustment is what is referred to as the resistance adjustment in the Link manuals. A small reservoir of oil is maintained within the unit and small check valves, item 21 in Figure 3, allow oil to enter a chamber when it is under a negative pressure.

The rotary dampers documented in this paper were very similar to the type of construction shown in Figure 3 but none of the patents found were an exact representation of the damper found in the model C3 documented here.

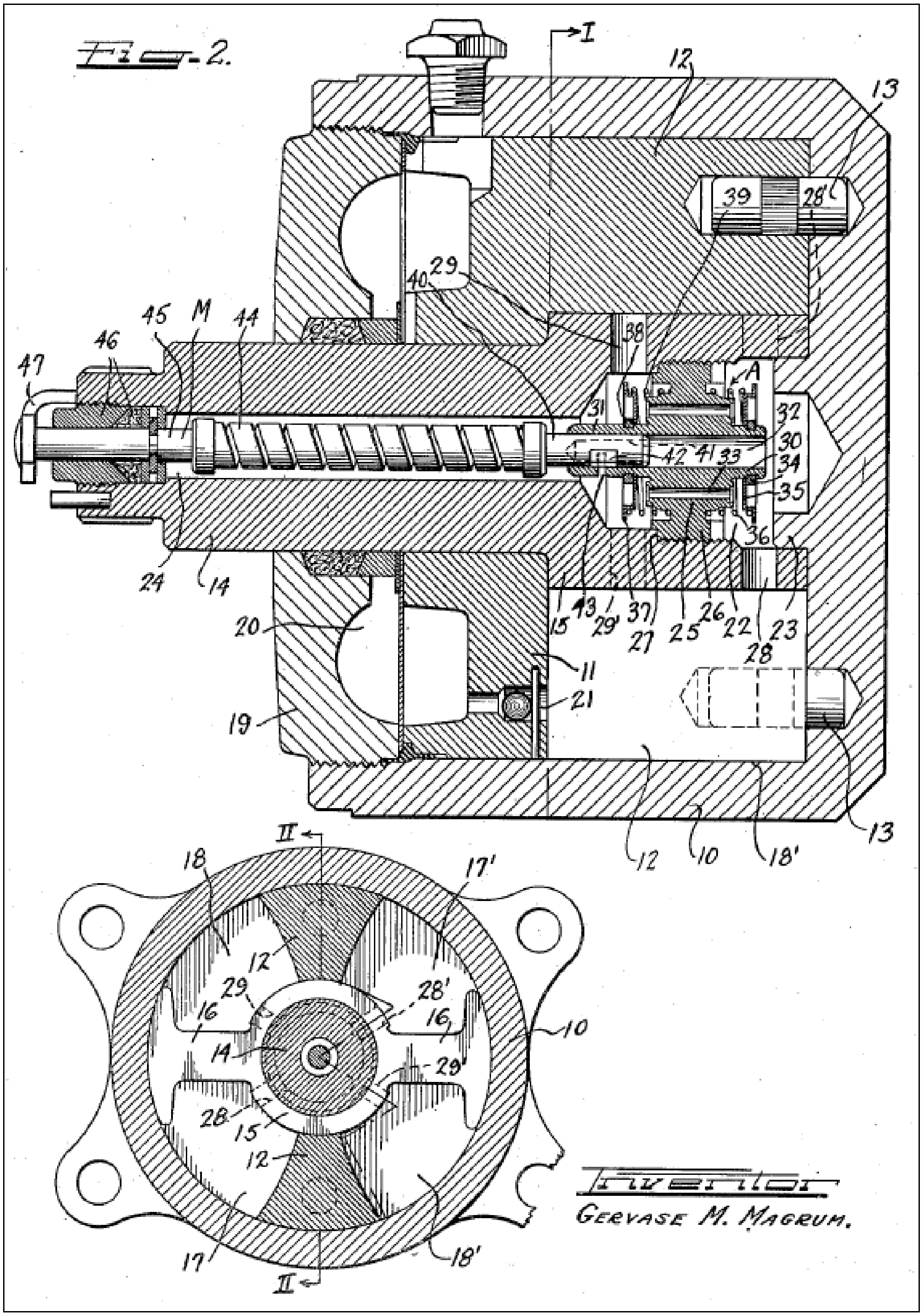
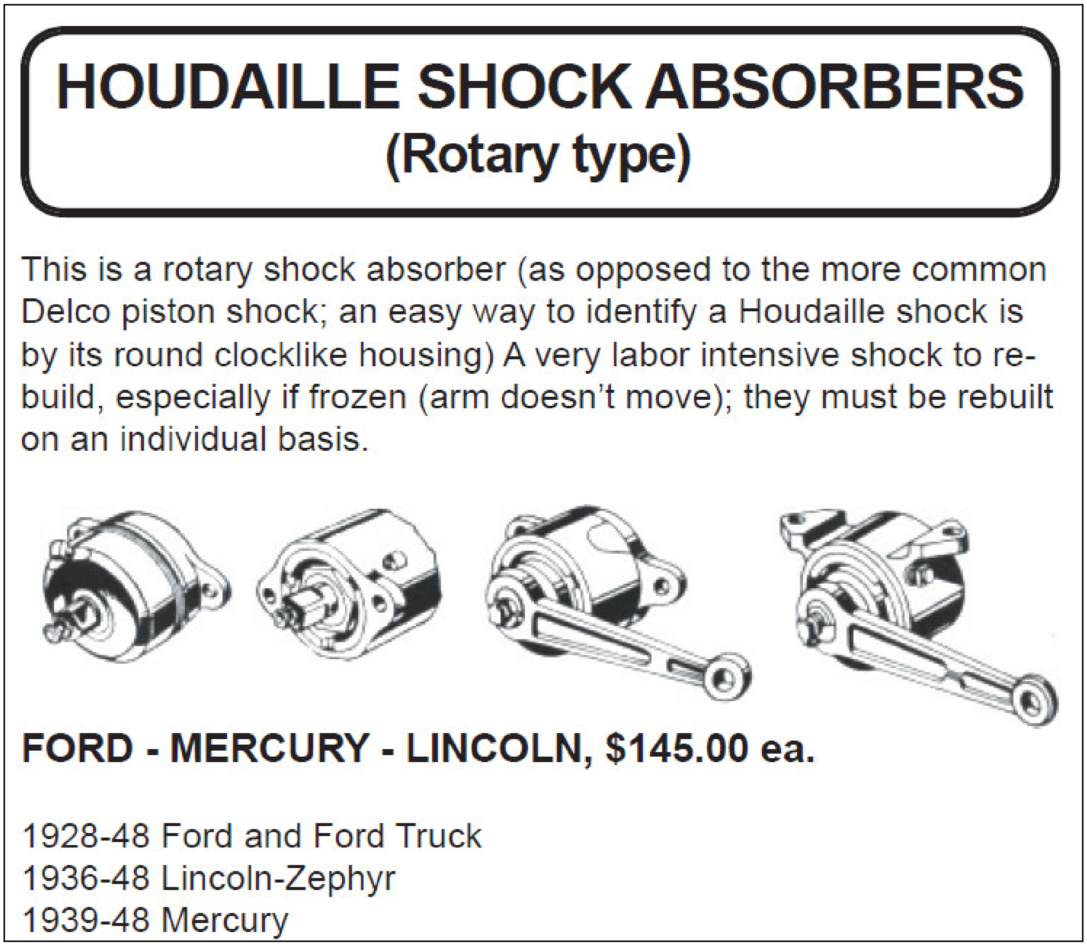


Figure 3 Cross section views from patent 2,358,988



HOUDAILLE SHOCK ABSORBERS
(Rotary type)

This is a rotary shock absorber (as opposed to the more common Delco piston shock; an easy way to identify a Houdaille shock is by its round clocklike housing) A very labor intensive shock to re-build, especially if frozen (arm doesn't move); they must be rebuilt on an individual basis.

FORD - MERCURY - LINCOLN, $145.00 ea.

1928-48 Ford and Ford Truck
1936-48 Lincoln-Zephyr
1939-48 Mercury

Figure 4 Except from the Apple Hydraulics catalog - a company that specializes in antique automobile shock absorbers, the price shown is the cost of rebuilding a Houdaille shock absorber – note the version on the far right bears a strong resemblance to the type used in the Link C3 : www.applehydraulics.com

Determining if there is a problem

Each damper has a mechanical lever attached to the spline shaft that is connected to the respective control. An adjustment device, previously discussed, is located at the center of the shaft and may be turned through a range of 180 degrees to adjust the resistance to motion. If the resistance to motion is difficult for all settings of the adjustment, or the shaft will not move, then the oil within the unit has probably become too viscous or possibly solidified.

The Disassembly process

Figure 5 displays a photograph of one of the rotary dampers. The more challenging aspect of disassembly is the removal of the large threaded end that seals the housing. The large diameter threads can be difficult to loosen. The following is one suggested means of disassembly.

Figure 5 Photo of a "slip stream simulator" or rotary damper

As with any rebuilding process taking notes and or photographs can aid in reassembling the unit. The various components should also be laid out in the order removed.

Disassembly

The first step involves the removal of the oil fill plug which is a straight forward process. If very little of no oil can be drained after the removal of this plug this is an indication that the oil has begun to solidify.

The next step is to remove the adjustment pointer and packing (note that this could be done prior to removing of the housing cap). This is accomplished by backing out the “nut” between the pointer and the spline shaft. This captures and retains the entire valve assembly and removal will allow the entire valve to be extracted. Figure 12 displays this valve after being removed and the securing clip detached. Note the packing and fiber washer. If the packing washers are in good shape they may be reused. In the case of the rebuild pictured it was decided to replace the packing with off the shelf O-rings available from a local hardware store.

Next is to remove the large threaded housing cap that holds the assembly together. This can be difficult and in my case required heating of the housing cap threads followed by impact with a modified cold chisel and hammer.

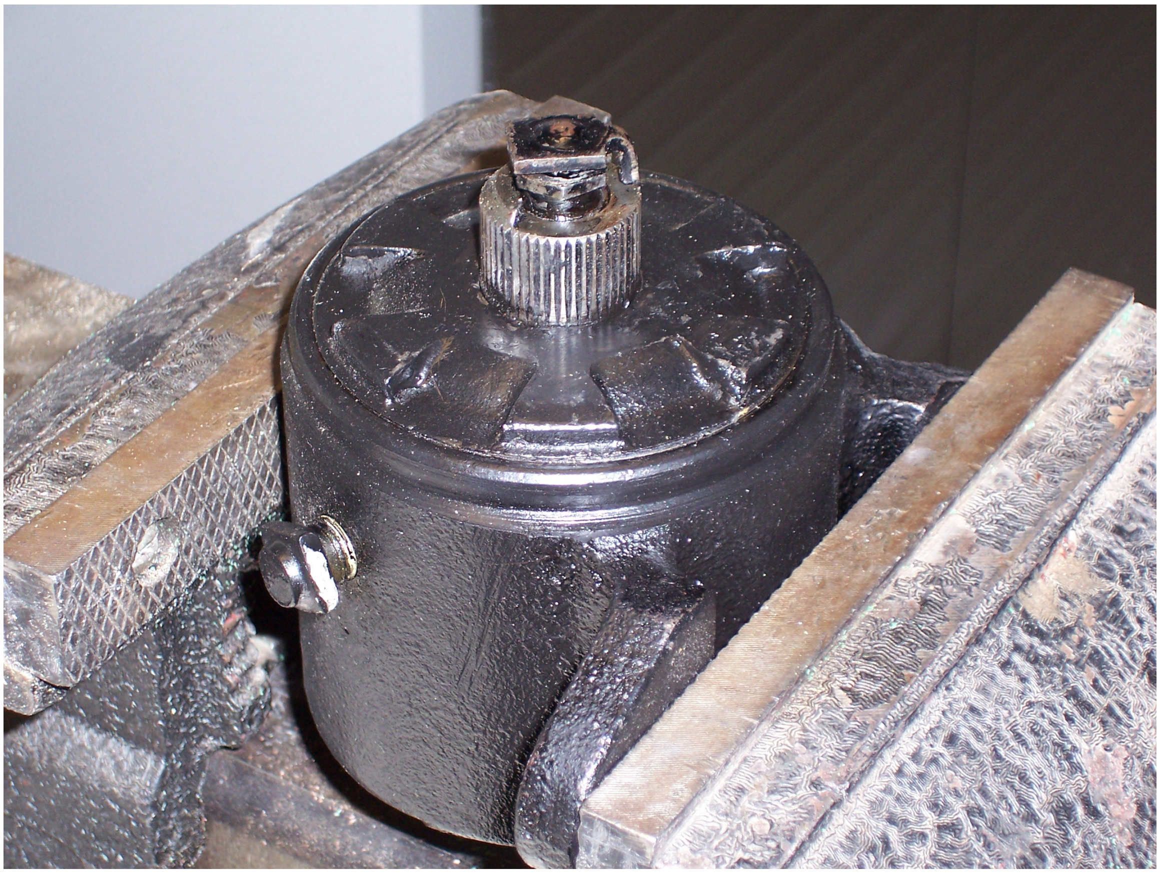


Figure 6 Mounting the damper in a bench vise (adjustment pointer still in place but should be removed prior to removing the end-cap

The damper was first mounted into a large bench vise as shown in Figure 6. A cold chisel as shown in Figure 7 was modified by grinding down the end to make it flat so that it mated nicely with the serrations of the housing cap. Next an acetylene torch was then used to heat the circumference of the threads. The part is fairly massive and requires a good heat source which could probably also be provided by a MAP gas type torch.

Caution: Some sources have reported that the old working fluid can become unstable to a point of being explosive. Before applying heat be sure that the fill plug is removed and you are working in an area clear of readily combustible materials. Keep a fire extinguisher handy at all times.

While the damper is still hot the cold chisel and large ball peen hammer are used to break the housing cap threads free. The threads are right handed and the chisel blows should be distributed to all of the serrations of the end cap so as to distribute the stress. Some chipping of the material may occur so be sure to wear safety glasses during this operation.

Figure 7: Cold Chisel modified by grinding the end flat.

A custom tool, shown in Figure 8, designed to engage the housing cap was made by brazing some ½ X 3/16 steel strips onto a large metal washer was fabricated and is shown in Figure 8. The vertical metal pieces were spaced and aligned so as to engage the detents in the housing cap. This tool was used with a pry-bar as shown in Figure 9 to aid in unscrewing the housing cap once it was broken loose.

Once the housing cap is loosened carefully unscrew it. Figure 9 shows how the custom tool is used to aid in unscrewing the end-cap. **Error! Reference source not found.** displays what may be found if the oil has solidified. The compression spring and retaining washer should be removed, cleaned and set aside for use during reassembly.

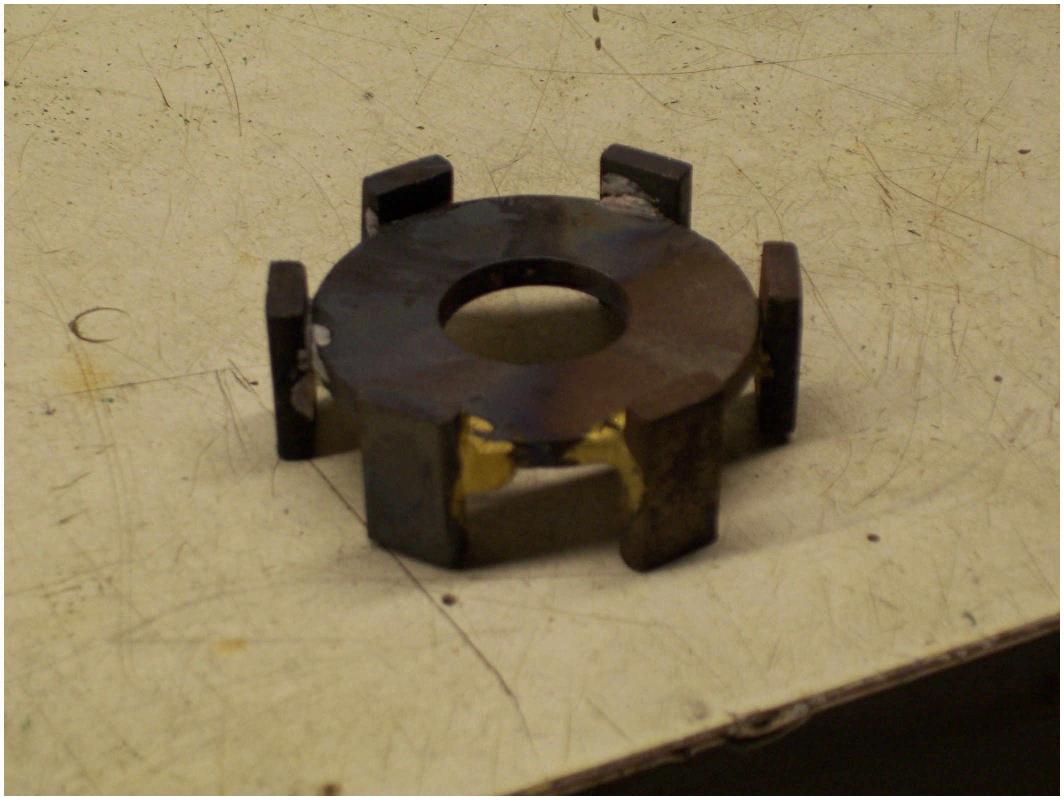


Figure 8 A custom tool used to assist in unscrewing the end-cap

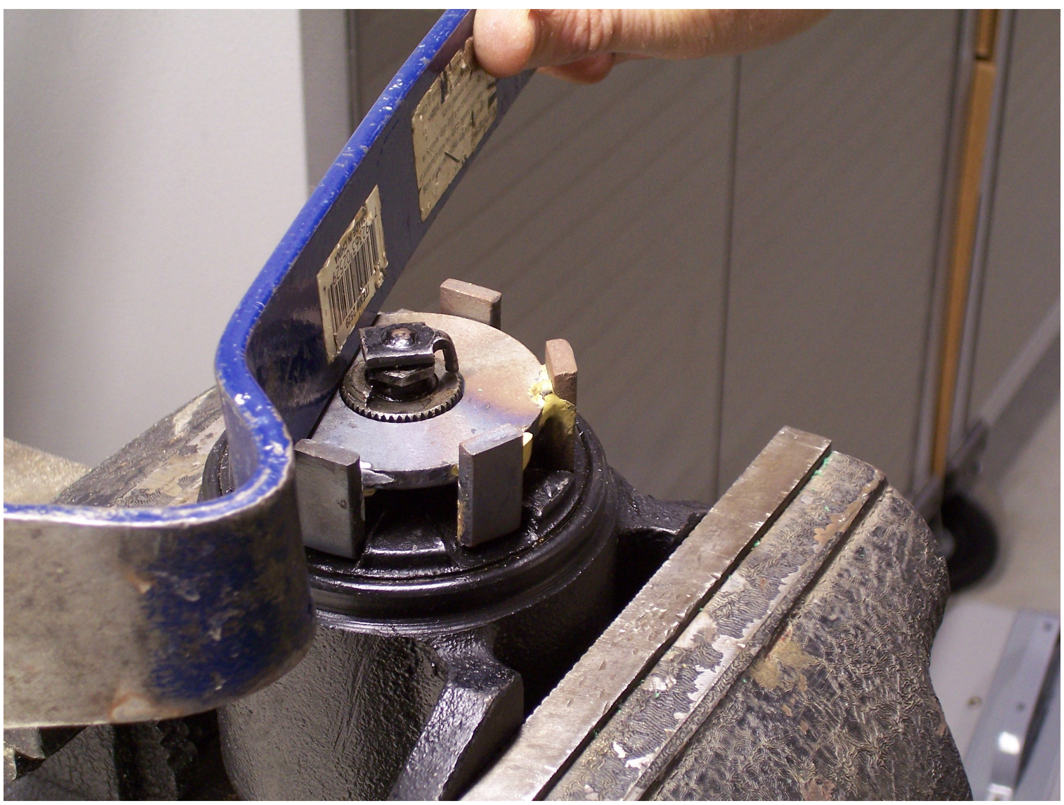


Figure 9 Using the custom tool to aid in the removal of the end-cap

Cleaning out the damper

At this point it is necessary to remove all of the old oil still present in the damper. In some cases (depending upon condition) it may be necessary to disassemble the damper to the point where the vanes are removed. Since this particular damper was in good condition it was possible to clean the unit through the use of solvents and avoid further disassembly.

The two points of entry are the valve port down the center of the shaft and two check valve ports located near the base of the damper and shown in Figure 13. The cleaning process involves circulating solvent through the damper to clean out the interior and the check valves. A container that is resistant to oil and solvents should be used to capture the sludge as it is extracted during the cleaning process. Start by pooling some “liquid wrench” or solvent of your choice into the reservoir cavity and injecting some down the center of the shaft, then attach the arm to the spline and cycle the valve back and forth so that the solvent is circulated. It may be necessary to hold a finger over the hole in the shaft as some of the solvent may try to exit as the valve is cycled. Periodically drain the solvent and sludge into the aforementioned container and repeat the process. It may be necessary to insert a small diameter blunt object (such as a drift punch) into the check valves to help free them up. Continue this process until the unit no longer produces sludge. Remove as much of the solvent as possible and wipe down the damper.

Figure 10 Figure after the housing cap is removed showing the solidified oil with a viscosity similar to that of hot rubber

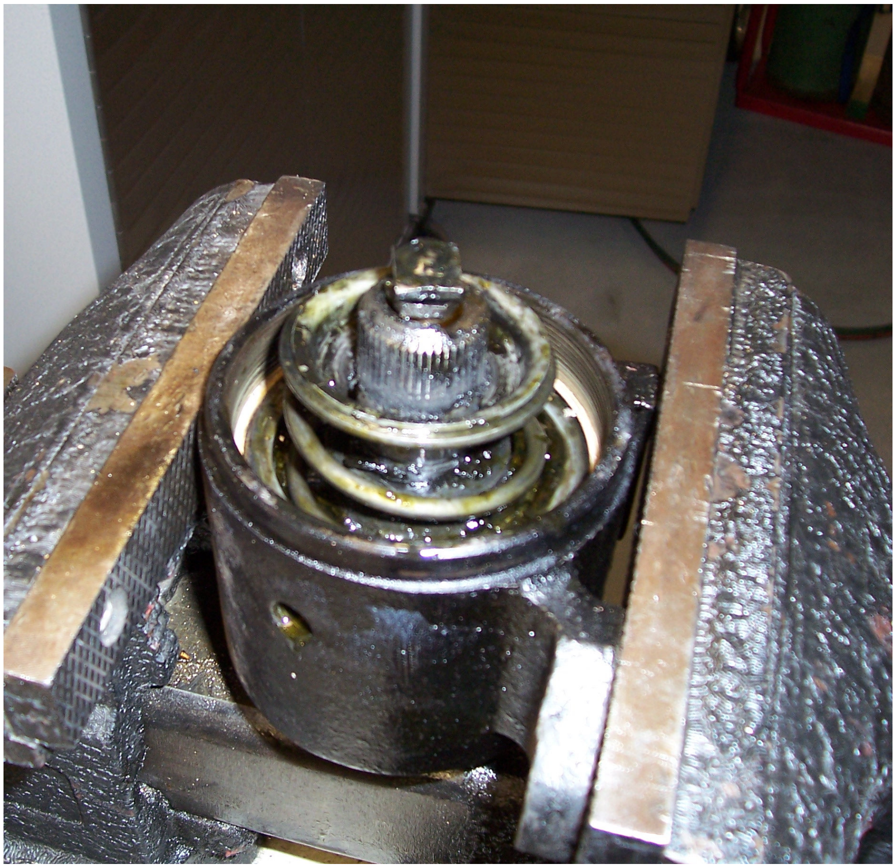


Figure 11 Showing the compression spring

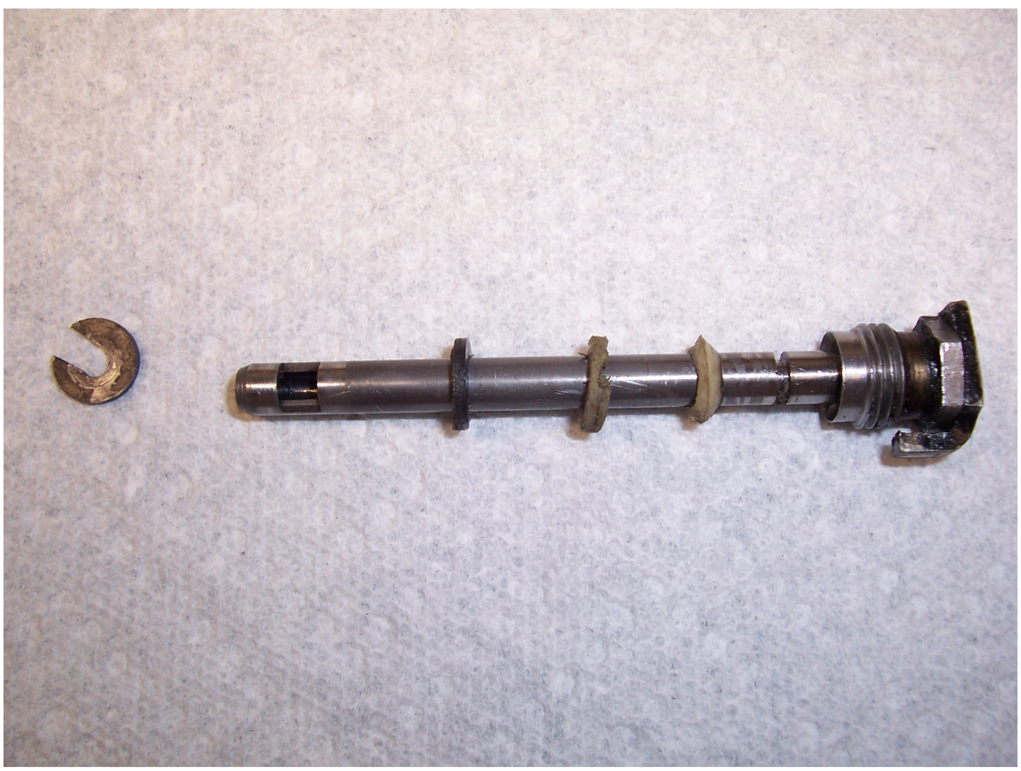


Figure 12 flow adjustment valve showing packing, securing clip and passage

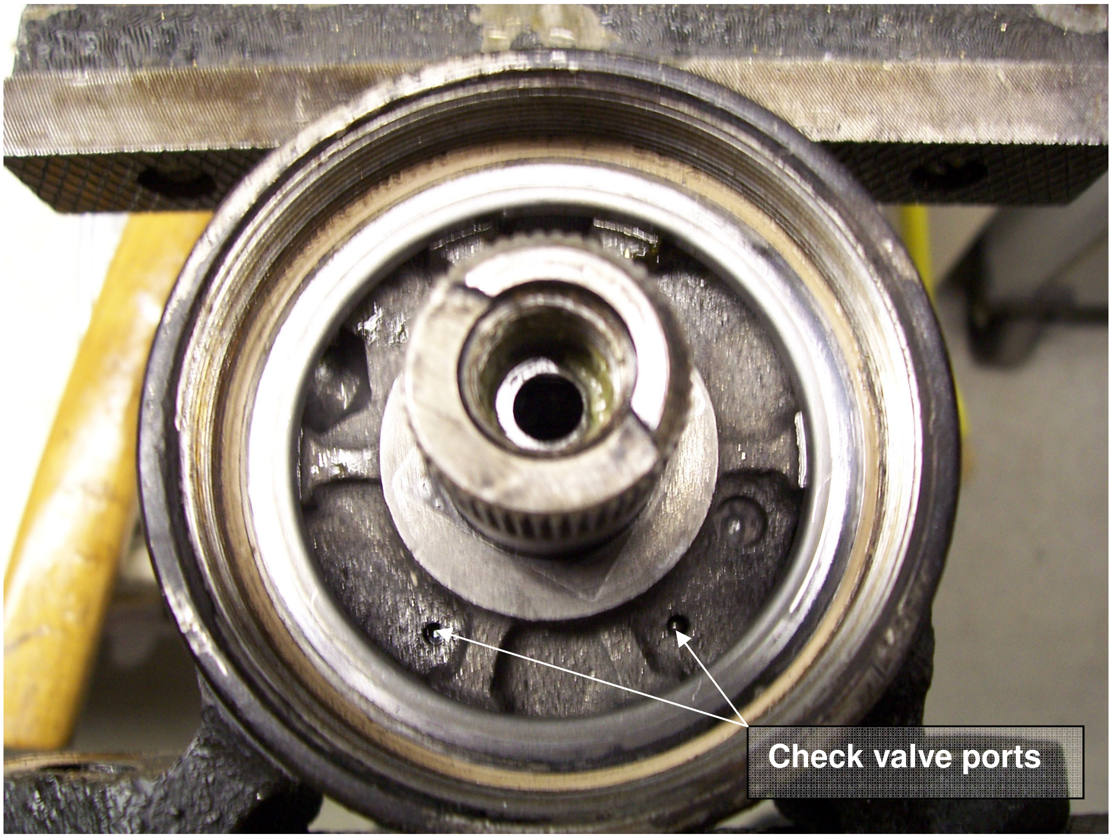


Figure 13 View showing check valve ports and adjustment valve port.

Reassembly

After all the removed components are cleaned and the vane cavities cleared of old oil the unit is reassembled by reinstalling the removed components in the reverse order they were removed although the center. It is necessary to apply pressure on the en-cap in order to compress the spring and engage the threads. The custom tool may be used to screw on the end-cap but it may be necessary to use the cold chisel and hammer to tighten the end-cap. Again, use eye protection as needed.

The flow adjustment valve should be reassembled and the new O-ring and packing reinstalled and retained by the securing clip. Lubricate the O-ring with oil prior to installation. Oil may now be added to the reservoir through the fill plug. Synthetic 5-30W multi-viscosity motor oil was used in lieu of the originally specified “500 shock absorber” oil noted in the original Link maintenance manual. Set the flow adjustment valve for minimum resistance and place the slip stream simulator on a flat surface (as normally mounted) such that the internal check valves will be exposed to the oil in the reservoir. Temporarily slide the arm onto the spline and oscillate the shaft to pull oil into the vane chambers – add oil until the fill port overflows.

Resistance adjustment

The flow valve may be rotated to set the resistance to motion – a lower resistance will place less strain on the linkages. It is suggested that the minimum resistance setting be used until after reinstallation into the trainer. If a higher simulated control loading is desired the flow control value may be adjusted as needed.