RETRO-TEK BALANCING AMPLIFIER

INSTRUCTIONS

The RetroTek Model 135 is a sensitive dynamic balancing amplifier based upon the Gisholt method of balancing. It may be used on a soft balancing machine for one or two plane balancing a single rotor or for production balancing of a batch of rotors. A single rotor or the first of a production run is temporarily balanced. The amplifier is then setup to permanently balance the initial or all succeeding identical rotors. The panel meter indicates the amount of unbalance in the left or right correction plane. The strobe flash indicates the angle at which the correction is to be applied. The amplifier may be set to indicate either the heavy side for the removal of weight or the light side for the addition of weight and the meter may be calibrated to directly indicate the amount of correction.

These instructions assume that you know some of the basics of dynamic balancing. There are two sources of detailed information on the Gisholt method: The Gisholt Balancing School and Dynamic Balancing School. Paper copies of each should accompany this operator's manual. If you found this manual online, Dynamic Balancing School is on this website.

AMPLIFIER

The output of the pickups in the bearing planes are fed into the amplifier via phono jacks on the left and right side. The signals for each plane go to a set of three switches. From the outside edge of the front panel to the right or left they are labeled I/O, A/B, A/B. These switches are used to set the amplifier to read either the heavy or the light side of the rotor. They are also used to setup the amplifier for different types of rotors.[1]

Above the switches are two potentiometers for each correction (balancing) plane. The potentiometers nearest the meter labeled PLANE are used to cancel the cross-effect from the other end of the rotor. The potentiometers labeled CALIBRATION are used to set the meter to read the amount of correction directly in some unit.[2]

At the bottom of the front panel are the POWER switch and pilot light. To the right of the power switch is the ANGLE SHIFT potentiometer which is used to set the strobe light flash to Top Dead Center (TDC) or some other location.

To the right of the Angle Shift control are the FILTER tuning potentiometer and its counting dial. The filter sets the amplifier to its maximum sensitivity for the operating speed (RPM) of the rotor. It also filters out most of the electrical noise which could affect the output of the amplifier. It may also be used to change the phase angle of the strobe flash if necessary. RetroTek BA105 amplifier circuit boards do not have a phase shift circuit although they may installed into cases with a phase shift potentiometer in the front panel. In this case use the filter to make the final setting of the strobe flash.[3]

The meter has two ranges on its dial: 0 – 10 and 0 – 50. Note that no units are specified on the dial. These are just numbers which are used to make the setup adjustments to the amplifier. Units such as gram-inches will be attached to those numbers during the calibration of the amplifier. This is the last step in the setup procedure.

Most balancing is performed using these two ranges. They are selected on the remote control switch box. The switches labeled 0 – 50 set the amplifier to read on the 0 – 50 scale which has the widest range. Balancing begins with this range. As the amount of unbalance is decreased to a reading of 10 on the 0 – 50 scale, the 0 – 10 switch on the remote control box may be used to read the more sensitive 0 – 10 scale.[4]

The switch to the left of the power switch controls the amplification of the input signal. Most balancing is done with the switch in the X10 position. If the rotor cannot be brought within the

[1] See Gisholt's publication "The Gisholt Balancing School" for more information.
[2] There are no fixed units for unbalance. They are chosen by the design engineer or by the operator if not specified by the engineer. The units may be any combination of Imperial or Metric units of weight multiplied by the radius of the correction plane. This amplifier does not use unbalance displacement units such as mils.
[3] The BA 105 printed circuit board is obsolete and should be replaced with BA106.
[4] There is a trim potentiometer on the amplifier printed circuit board which adjusts the two scales to read a value of 10 on either scale. This provides accurate continuity of readings as the amount of unbalance passes through the value of 10.

desired balance tolerance the X1 position may be selected. This amplifies the input signal by a factor of 10. This is useful when a rotor must be operated at low speeds which result in a low input signal or light weight rotors that operate at high speeds with sensitive balancing tolerances. [5]

The four scales of unbalance available on this amplifier are:

	Remote Control 0 – 10	Remote Control 0 – 50
Panel Switch X10	0 - 10	0 - 50
Panel Switch X1	0 – 1	0 - 5

Table 1

ROTOR SETUP

Place rotor between supports with the belt running over a major diameter of the rotor. More surface area of belt contact is better. The balance amplifier requires a very constant speed. Any slippage will change the phase angle reading.

Adjust the idler pulleys so that the run of the belt from the rotor to the idler sheaves is vertical and parallel. This adjustment assures that the carriage is centered in its supports. A correct length belt will allow the idler pulley arm to be about horizontal. The belt tension should be just enough to drive the rotor without slipping.

The rotor must operate at a speed that is within the range of the RetroTek amplifier.[6] When possible run the rotor slow rather than fast. Increasing the speed increases the sensitivity but with an increase in potential safety hazard. Moving parts such as motor starting switches or baskets with silicon wafers may “settle” into a more fixed position with centrifugal force. Running these rotors at a higher RPM may assist settling.

It is best practice to have the top of the rotor turning away from the machine operator – that is, the rotor turns clockwise when viewed from the right end. This is a safety precaution. If a rotor comes out of its bearings it will tend to move away from the operator.

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[5] The labeling of this switch appears to be reversed. This is not a major problem and the operator will easily adjust to this. This may be corrected by inverting the switch in the panel and lengthening the connected wires.

[6] The initial intended operating range of the RetroTek amplifiers is not known. The center frequency of the filter in the unmodified circuit board tested by the author is 27 Hz which equals 1620 RPM. Assuming that the filter can operate over a range of X10, that would imply a range of 360 to 3600 RPM. Some boards have been modified by changing the tuning capacitors for a different center frequency. This was done so that the center frequency of the amplifier was near the typical operating RPM of a particular balancing machine.

Mark the rotor with some convenient number of equal angular divisions. The numbered divisions should increase in the direction of rotation. The number of divisions should allow the operator to see at least three numbers at one time. The numbers may be in the correction planes but may be placed in a more convenient and easily readable location.

The strobe flash will illuminate a number which will allow you to identify either the heavy or light area of the rotor. When the amplifier is properly adjusted the strobe will “strike” once per revolution of the rotor – that is, only one number will be illuminated. However, as the amount of unbalance decreases to the minimum detectable amount, the flash will occur at different numbers.

PHASE ANGLE

Balancing a rotor requires two pieces of information. The first is the amount of the correction. This is relatively easy to acquire. The output of the pickups and the meter reading are proportional to the amount of unbalance. The meter reading will decrease as the rotor balance is improved, that is, as the amount of unbalance decreases.

The second piece of information that is required to balance a rotor is where to put the correction. This is harder to acquire. The strobe flash will illuminate one number on the divisions marked on the rotor. The number of divisions and the accuracy of their placement will vary.

The placement of a correction should be at the correct phase angle within small limits. The inherent problem of balancing under these conditions is that the operator can see that the flash strikes at, for example, #5 on an 8 division scale but the numbers on this scale span 45°. Where does the correction go?

The second problem is that there are phase shifts throughout the system. There is no fixed or positive correlation between the location of the unbalance, either the light or heavy spot, and the strobe flash. It is influenced by the RPM of the rotor, the setting of the filter and the phase shift potentiometers (as noted above the phase shift potentiometer may not be functional in some circuit boards). The strobe flash may be at a completely different spot.

Phase angle is set with an empirical balancing procedure and remains set for that amplifier with that balancing machine. If the amplifier has been exchanged or for some reason the phase shift potentiometer setting has been changed, the phase angle must be reset.

The third problem is that the amplifier may be set to read either the heavy or light spot. This must be set for each type of rotor. Different rotor configurations will require different settings of the switches on the front panel.

THE GISHOLT METHOD

There are two major steps in the Gisholt balancing method. First, the rotor is balanced by an empirical method – cut and try. This process also adjusts the amplifier to indicate either the heavy or light spot. Then the rotor is unbalanced by a known amount in a single location and the amplifier is adjusted to null the cross-effect and to calibrate the meter to read in unbalance units.

TRIAL WEIGHTS

Trial weights are temporarily attached to the rotor to make a measurement. This may be done with any suitable method including bolting, clamping or tack welding. Modeling clay works well for many rotors. The best clay is Crayola brand. Press the clay onto the rotor firmly and seal all around the edges with your finger. The mounting surface must be clean, dry and oil-free.

It is not important where the trial weights are placed on the rotor – closest to the bearing supports on the ends are the best. The farther from each other and at a greater radius, the less weight is needed to balance the rotor. It is not necessary to place the trial weights in the final correction planes.

AMPLIFIER SETUP

Set all potentiometers in the top row of the amplifier CCW to zero, all switches in the second row to "up" position. On the bottom row set the sensitivity switch to X10. The Phase Shift potentiometer is not changed at this time.

The first setup runs will:

1. Determine the meter range which results in a reading between 1 (on the upper meter scale) and full scale.
2. Tune the filter to the frequency of the signal from the pickups
3. Find which correction plane, left or right, has the highest amplitude reading

Start the balancing machine. As the motor starts, the rotor and its carriage will begin to vibrate within the supports. On smaller balancing machines which do not have a carriage lock it is good practice to restrain the carriages with a finger before stepping on the foot pedal. This will dampen the vibration induced by starting the rotor. At this time you will begin to get an idea of how much unbalance is in the rotor.

4. Press <u>LEFT 0-50</u> button on the remote control then the <u>RIGHT 0-50 button</u>. Use the plane, left or right, which provides the highest reading for the remainder of the setup steps.

5. If the meter reading is less than 1(on the upper meter scale), press the 0 – 10 button. If the reading remains lower than 1 change the sensitivity switch from X10 to X1. A temporary weight may also be added to the rotor to increase the signal. This will make it easier to perform the next steps in the setup procedure.
6. Set the filter frequency by adjusting the potentiometer for maximum meter reading. The phase angle will change while tuning the amplifier filter.
7. If the meter reading rises above full scale on the 0 – 50 meter scale, temporarily turn the CALIBRATION potentiometer for that plane down to read mid-scale or above on the meter. Set the meter to read 40 rather than 50 – that is, less than full scale, so that finding the light or heavy side (the next step) can be performed.
8. Read and record the amplitude meter reading and phase angle for each plane.[7]

If this is the first time that the amplifier has been run the phase shift will be adjusted using the procedure given in Setting the Phase Shift Potentiometer below. If the phase shift has been previously adjusted with this procedure it is usually not necessary to adjust it for a different rotor and the operator can skip this section and proceed to Amplifier Setup II.

SETTING THE PHASE SHIFT POTENTIOMENTER

If this is a new installation of the amplifier on the balancing machine the phase shift potentiometer must be adjusted so that the strobe illuminates either the heavy or light spot.

1. Run the unbalanced rotor and record the unbalance and phase angle of the strobe flash at the end with the greatest amount of unbalance.
2. Place a temporary weight in the center of the division indicated by the strobe flash. Run the rotor, the amount and phase angle will change. Record (or remember) the new amount and location.
3. Move the trial weight toward the initial flash angle by some angle and run the rotor. If the amount decreased the weight was moved toward the light side. If the amount increased the weight was moved toward the heavy side.
4. Move the trial weight away from the initial flash and read the amount. If the amount decreased the weight was moved toward the light side. If the amount increased the weight was moved toward the heavy side. The direction of the light or heavy side is now known.
5. Succeeding runs will move the trial weight toward either the heavy or light spot. If the rotor is poorly balanced it is best to move toward the light spot. If the rotor is well balanced move toward the heavy spot. Record (or remember) the readings as the weight is moved.
6. At some location of the trial weight the change in the readings will reverse. If the weight is moving toward the heavy spot the readings will increase to a maximum then begin to

[7] Experienced operators will remember the readings and not have to record them on paper.

decrease. If the weight is moving toward the light spot the reading will decrease to a minimum and then increase.

7. Fine tune the location of the trial weight to the maximum or minimum reading.
8. The strobe flash will probably not be at the location of the trial weight. Turn the phase shift potentiometer knob to indicate the trial weight. If the trial weight cannot be indicated, flip both of the A/B switches for that correction plane to their other position and continue tuning the strobe flash. It is not necessary to check the other end of the rotor at this time. This step sets the amplifier to read the heavy side.

This procedure is used after the initial installation of the amplifier to a balancing machine and whenever there is a doubt about the accuracy of the phase shift adjustment. It is usually not necessary to perform this check when changing to a different rotor.

AMPLIFIER SETUP II

Amplifier Setup II is used in day to day operation of the balancing machine.

1. Add a small trial weight to the rotor at the end which has the highest reading and at the angular location shown by the strobe flash.
2. If the amplitude reading goes down the amplifier is reading the light side.
3. If the amplitude reading goes up the amplifier is reading the heavy side.
4. If the amplitude change is small, try a larger trial weight.
5. If the phase angle shifts 180° the amplifier is reading the light side and the trial weight is too large.
6. To change the reading from heavy to light or vice versa, flip both A/B switches for that end to their down position. The number shown by the strobe will change 180 degrees.
7. Remove the weight from the high reading end and install on the other end and set the amplifier to read the light side of this end. The switches may not be in the same positions for both ends of the rotor.
8. Set the A/B switches for each end to read the light side and remove the trial weights.

BALANCING THE FIRST ROTOR

The rotor is next balanced using temporary weights. These weights may be placed in any convenient plane on the rotor.

1. Add a trial weight to the end of rotor that has the greatest unbalance amount at the indicated location. The amount will change and phase angle may or may not change. If there is little change in the amount, try a larger weight. If the phase angle changes by 180°, decrease the weight.
2. Run the rotor and check the amount of unbalance at both ends.
3. Add a small amount of weight to the end with the greatest amount reading. The amount should decrease. If it increases, the trial weight is too large and the amplifier is reading

the heavy spot. Reduce the trial weight and, if necessary, check that the amplifier is reading the light spot.

4. Because there will be some error in reading the phase angle of the light spot and in the placement of the temporary correction weights, it may help to move the weights slightly in one direction or the other and see which way decreases the amount of unbalance. Continue correcting the unbalance at the end with the greatest unbalance.
5. As the amount of unbalance decreases and the meter reading goes below 1 on the meter scale use a lower amplification factor in this order:
    a. If the calibration potentiometer has been turned clockwise to decrease the meter reading (Step # 4(e) above) return it CCW to its zero reading first.
    b. Change from the 0 – 50 scale to the 0 – 10 scale.
    c. Use the X1 switch setting if necessary.
6. At very low amplitudes the phase angle indication may become indistinct[8] and the meter will show a minimum reading. Rotor is now balanced as far as possible.

NULLING THE CROSS EFFECT

The temporary balancing was done by applying the correction weights in a convenient plane which may not be the permanent balancing plane. The next process, nulling the cross effect and calibrating the amplifier, must be done with the weights in each correction plane. Leave the temporary balancing weights in place while nulling the cross-effect and calibrating the amplifier meter.

1. Right Null
    a. Place a measured weight in the left correction plane. Adjust the weight to get a midscale meter reading with the strobe flash at this weight.
    b. This additional weight at the left end will change the reading for the right end from zero[9] to some amount. Adjust the right PLANE potentiometer so that the meter once again reads zero. This cancels the cross-effect from the left plane to the right plane.
    c. If turning the right PLANE potentiometer down increases the amplitude reading, change one of the Right A/B switches to the "other" position. Use the switch closest to the center of the front panel first, then the switch in the middle.
    d. Either one of the two switches will allow the meter reading to go down. Do not flip both switches when nulling the cross-effect. After the meter reading has been reduced to its minimum, further rotation of the PLANE potentiometer will result in an increased meter reading. Reverse the rotation of the potentiometer to set the meter to its minimum reading.
2. Left Null

[8] When the rotor is well balanced the signal from the pickups will be small and the amplifier phase angle circuit may trigger at different phase angles. This is probably due to electrical noise in the signal.
[9] Near zero, there being no such thing as perfect balance.

a. Remove the measured weight from the left correction plane and place on the right correction plane.
b. Null the cross-effect for the left correction plane by adjusting the Left PLANE potentiometer using the procedure above.

The rotor is now nulled so that cross-effect from an unbalance in either end is eliminated from the amplitude reading of the other end. The meter will now read the unbalance in either plane directly. The meter is next calibrated to a known weight at a known radius; that is, a known unbalance, in each correction plane.

CALIBRATION

The maximum allowable residual unbalance specified for the rotor is typically used for calibration of the amplifier. This will be in units of unbalance, the product of the unbalance weight and the radius of the correction plane.

1. Measure the diameter of the correction plane and divide by 2 to obtain the radius.
2. Divide the maximum allowable residual unbalance by the radius to obtain the maximum unbalance weight.
3. Multiply that weight by 10 to obtain the calibration weight.
4. Accurately weigh a calibration weight and place on the rotor at a random spot on a correction plane.
5. Run the rotor and calibrate the meter to read 10 using the 0 – 10 scale.
6. The meter reading is now calibrated to read unbalance at the correction plane multiplied by 10. The maximum allowable residual unbalance is at a reading of 1. Any reading below 1 is within the required tolerance.
7. Check the phase angle. The strobe flash should illuminate the calibration weight at either the top dead center or at the operator selected location. Fine tune the phase angle as necessary.
8. Repeat steps e through h for the other end of the rotor.
9. Example: a rotor recently in the shop had a maximum residual unbalance of 13 gm-mm per plane. The diameter of the correction plane was 56.5 mm. The calibration weight then is 13 gm-mm/56.5mm X 10 = 2.3 gm. If the meter reads 7.4 the correction weight is 7.4 divided by 10 = .74 gm.

The amplifier is now set to perform the permanent balancing corrections. Remove all trial weights and run the unbalanced rotor. Divide the meter reading by 10 to get the necessary weight change and make the correction at the phase angle indicated by the strobe flash, either adding or subtracting that weight.

Make haste slowly, particularly as the amount of unbalance decreases. A small correction at a small phase angle error can cause a surprisingly large change in indicated amount and phase angle. If the amount of unbalance does not appear to be changing properly then stop making permanent corrections and continue with temporary weights until you understand what is happening.

AFTERWARD

The RetroTek Model 135 dynamic balancing amplifier is a 1970's solid state upgrade of the original vacuum tube amplifier designed and built by Westinghouse Electric Company to implement the cross-effect null and calibration method of Gisholt Machine Company. The Model 135 may be used with any (non-computerized) balancing method which does not require a once per revolution signal from a photoelectric pickup reading a mark on the rotor. Some methods that may be useful are given in Machinery Vibration: Balancing, Victor Wouk, ISBN 0-07-071938-1. This work has an large amount of related information and should be in your library.

The RetroTek amplifier is well designed and built, durable, and easy to repair. A set of reverse engineered schematics for most of the boards is included with this manual. The primary difference between the various generations of amplifier printed circuit from BA105 to BA 106 Rev. 1 and BA 106 Rev. 2 is in the filter circuit and in the operational amplifier integrated circuits (IC's) used.

The components of the amplifier are easily identified and at the time of writing this manual (2016) are still in production. The only unknown components are germanium diodes which are probably AA134s. Any similar diode may be used. The Plane and Separation potentiometers are Allen-Bradley mil-spec devices and should be replaced with equivalent.

So far as is known the xenon strobe lamps are no longer available. One replacement has been identified, a flash lamp assembly FY-505 by Perkin-Elmer, but this line has been sold to another vendor. The power supply transformer is no longer available but as it will probably have to be changed to suit a new flash lamp this may not be a problem.

The only known weaknesses are the front panel switches and the three relays. These are electro-mechanical devices with a limited lifespan. The DPDT switches on the front panel are standard power devices and are readily available. The relays on the printed circuit board have special contacts. Specify and purchase only the same model number to obtain gold plated signal level contacts. At this time they are still available.

The graduated dials on the PLANE and CALIBRATION potentiometers may be replaced with ten turn counting dials like the one on the filter. This upgrade may be useful when work on the balancing machine is repeat batches of different rotors. This makes it easier to setup the amplifier for each batch. The settings of each potentiometer are recorded for each type of rotor and are simply dialed in at the beginning. One well balanced rotor of each type is retained in the balance shop to check the settings. A quick check with a known weight in each plane will verify the null and calibration for that plane. The rotors may now be balanced with this simplified setup procedure.

This publication is also an operator's manual for West Coast Balancing amplifiers which have similar front panel layouts.