How to calculate a trial weight amount and location, both manually and using the AMS 2140 balancing program calculator.

The point in calculating a trial weight for a balancing procedure is to change the rotating element's response from the as-found imbalanced condition (Reference Run) to another condition of imbalance. The goal is to affix a trial weight that changes the vibration response vector by either 30% lower or higher amplitude (Mils) or by 30 degrees or more of phase change (known as the 30/30 rule). This can be a bit tricky, as the desired outcome is to add enough weight to achieve the 30/30 change in response without adding so much weight as to damage the machine. Technicians can and do develop rules of thumb that assist in the determination of amount and placement of trial weights, and some even 'guess' (which really are educated estimates, not guesses) based on personal history and familiarity of a specific machine. But how does one properly estimate a trial weight if no prior history exists?

The first step is to gather some information about the machine: What is the operational speed of the machine? What does the rotor weigh? What is the resonance frequency of the machine in relationship to the operational speed? Where will sensors be placed (measurement plane)? Where the weights be mounted (trial and weight correction radius (radii) and plane(s))? How will Phase be measured? Will this be a single or dual plane balance? After gathering the machine's descriptive data, a manual calculation of the force exerted by the additional weight should be carried out to check for excessive force. This data is summarized in the table below:

Balancing Parameter	Variable Name	Typical Value
Operational Speed	N (RPM or Cycles/Sec. (Hz).	3600 (60); 1800 (30); 1200 (20); 3000 (50). VFD equipment will vary from these values.
Rotor Weight or Mass	Wt. (Lbs., Oz. or Grams); M = (Wt./gravitational constant (32.4 Feet/S^2 or 386 inches/S^2).	If using rotor Wt., add 10% to the weight of the rotor to be balanced to account for system dynamics. (force of imbalance vs. gravity).
Resonance Frequency	F_{res} (Hz.) Used to determine the estimate of System Lag (L).	45 or 135 degrees, depending upon if the running speed is above or below resonance.
Trial Wt. Radius from shaft center	L = TW_{Radius} (in.) Usually in inches from the center of the shaft.	Varies, typical values are a few inches to over 60 inches.
Phase (degrees)	Φ (degrees).	0 to 360 as measured from the tach mark to the high spot against rotation.
Sensor to Tach Angle (degrees)	Θ (degrees).	Measure the angle from tach to sensor against rotation (use 0 degrees if the tach and sensor are mounted in the same location, typical values are 0, 90, 180 and 270).
Amplitude Units Correction	C (degrees).	Correction for the type of units used. Note: For Emerson analyzers, the corrections are: Accel to Disp = 0; Accel to Vel = 90; Accel to Accel = 180.*
System Lag	L (degrees).	See resonance frequency above.
Amplification Factor	AF (unitless).	Typical value is 3.
As found 1XRPM amplitude value (Mils or inches)	Reference run amplitude value, Mils (convert to inches where 1 Mil = 0.001 inches).	4 Mils = 0.004 inches.
Rotation View	CW or CCW	Clock-wise or Counter Clock Wise from the point of view of the analyst.

**These values are for using a physical accelerometer and converting to the units used for display. These settings may seem counter-intuitive to the astute user, as normally there is a 180 degree correction using an accelerometer and displaying in Mils of displacement to account for the phase shift in the math from the conversion. However, the unit is already correcting for the math phase shift, so these are the correct settings.*

$$\text{Heavy Spot Location} = \Theta + \Phi + C - L$$

$$\text{Trial Weight Location} = \text{Heavy Spot Location} - \text{or} + 180 \text{ degrees}$$

Notice that when a 'guess' is made, the trial weight is either placed in the hemisphere containing the light spot or the trial weight is placed in the hemisphere containing the heavy spot. Either way, the resultant imbalance vector is changed enough to cause a 30-degree or 30% change in amplitude. This is why the act of 'guessing' sometimes will work, but that method is not a best practice.

For an illustrative example, if the sensor and tach are in the same location, then **Θ = 0**. And if the display units are set to mils and one is using an accelerometer to acquire the reference and trial runs, then **C = 0**. This simplifies the equation to just subtracting the System Lag (**L**) reading from the phase (**Φ**) reading. Should the user happen to set up the balancing job in this manner, and then just Ignore the System Lag component, the phase reading will be the only component left. To see this, let us assume that the phase reading is 120 degrees. Therefore, we know that the heavy spot is preceding the high spot by 120 degrees. Assuming the tach and the sensor are both mounted at Top Dead Center (TDC) of the shaft, and rotation is CCW, then the actual location of the heavy spot is at 120 degrees as counted against rotation, or at 120 degrees clockwise (about 4 O'clock) from TDC. Because we want to place the trial weight opposite the heavy spot, we add or subtract 180 from 120 and get 300 degrees (or -60 degrees, so we would count with rotation since the -60 value is negative, but either way we wind up at the same spot of 300 degrees as counted against rotation from TDC, or about 10 O'clock. Note that this is close to the same spot as the light spot of the complete calculation above, which is: Trial Wt. Location = 120 (phase reading) – 45 (system lag, below resonance) + 180; or 75 + 180 = 255 degrees. This means that putting a trial weight at either 255 or 300 degrees will likely reduce the 1XRPM vibration because we have arrived in the correct hemisphere on the rotor at nearly the same location quite by accident.

Calculating the correct location for mounting a trial weight is best not left up to chance. Understanding the machine's response and operational speed relative to the machine's resonance frequency is critical to deriving the 'correct' location to mount the trial weight. Use the full calculation above if possible.

Now to the calculation of the appropriate Trial Weight amount. There are two commonly used equations to calculate the amount of weight to add to the shaft. First, there is the equation using an estimated amplification factor:

Trial Weight (oz.) = (Reference Run Amplitude (inches) X Rotor Weight (Ounces))
/((Amplification Factor) X Trial Weight radius location))

Note that this equation does not use the speed of the rotor to calculate the needed trial weight, and this equation also estimates the actual imbalance in the rotor. For this equation, the user needs to convert given numbers, such as Mils to Inches (4 Mils = 0.004 inches); and rotor weight is often given in pounds, so multiplying by 16 (oz/lb.) will give the correct weight in ounces. Note that the Amplification Factor is unitless and is just an estimation, so the 'guess' of 3 used here is a source of error! However, the goal again is simply to change the system response, so this estimated value of 3 will work in a majority of cases. Use a higher number (4 or 5) if you are closer to resonance, but beware – balancing near a resonance frequency is difficult, if not impossible, due to the rapidly-changing phase readings. Once the trial weight response is acquired, then the actual influence coefficient and system lag numbers are known, so these are used to calculate the correction weight amount and location (or weights at discrete locations).

Another way to calculate the Trial weight amount is to use this equation, which uses the RPM of the machine:

Trial Weight (oz.- inches) **= (56,320 X Rotor Weight (lbs.))/(RPM)^2**

Note that this trial weight calculation only requires the rotor weight and RPM. However, the result is in ounce – inches, so the actual weight to be added must be divided by the radius in inches. Note that the equation result is NOT ounces/inch, but oz. – inches!

So, how are these two equations related? Well, the common factors are the rotor weight (oz.) and the trial weight radius (inches). Other than those, the first equation needs to have the Reference run amplitude and the amplification factor, while the second equation divides through by the square of the speed, which is related to the force in lbs. being generated. The force generated is amplified by the value from the system response curve, which we estimated as 3.

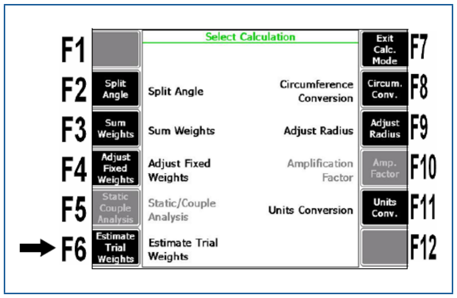
Here is a calculation using a rotor weight of 1200 lbs at 1800 RPM with a weight radius of 60 inches:

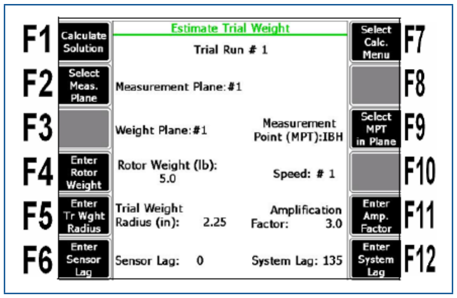
$$TW = (56{,}320 * 1200)/(18002 * 60) = 0.348 \text{ ounces}$$

From the first equation, the TW = ((.003 * 19,200)/(3 * 60)) = 0.32 ounces.

Using 4 mils (0.004 inches) instead of three mils (0.003 inches) gives 0.43 ounces to use for the trial weight.

From the Balancing Downloadable Program (DLP) calculator in the AMS 2140, several options are available, including the option to estimate trial weights. The information needed to estimate the trial weight is the same as in the above manual calculations: Rotor Weight (lbs.); Trial Weight Radius (inches); Amplification Factor Estimate (3); and System Lag (enter 45 if operating speed is below resonant frequency, or 135 if RPM is above resonant frequency. The sensor lag field below is NOT the angle between the sensor and tach, but is an electronic sensor lag hold-over from slower electronic system front ends. Note that the program has already acquired the reference run data, so the instrument already has the initial vibration displacement amplitude and phase (high spot) information. Finally, the angle between the sensor and the tach is set by the user in the system setup.





Trial Run # 1

Measurement Plane: #1

Weight Plane: #1

Measurement Point (MPT): IBH

Rotor Weight (lb): 5.0

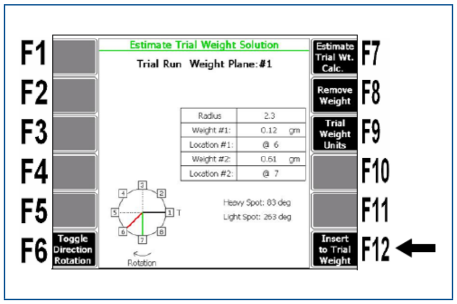
Speed: # 1

Trial Weight Radius (in): 2.25

Amplification Factor: 3.0

Sensor Lag: 0

System Lag: 135

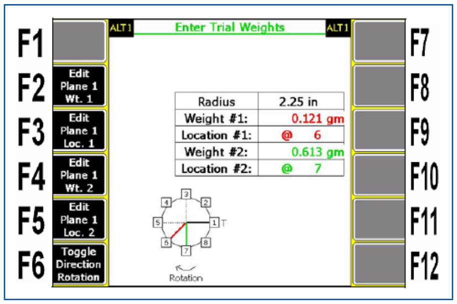


Trial Run Weight Plane: #1

Radius	2.3
Weight #1:	0.12 gm
Location #1:	@ 6
Weight #2:	0.61 gm
Location #2:	@ 7

Heavy Spot: 83 deg

Light Spot: 263 deg



Radius	2.25 in
Weight #1:	0.121 gm
Location #1:	@ 6
Weight #2:	0.613 gm
Location #2:	@ 7

Once the trial weight has been calculated, the F12 ‘Insert to Trial Weight’ key can be pressed to input the trial weight into the calculations. Should you discover that the weight is not available, you can manually enter the actual trial weight used and the location at which the trial weight is placed, indicated by the red colored fields above. Best practice is to attach at the amount and location suggested, but minor adjustments can be made if needed.

Finally, one should carry out the equation to determine the additional force added to the system, which is give by:

$$F_{ub}\ (lbs.) = 0.002841 \text{ X } \omega^2\ (cps) \text{ X } Wt._{Trial}\ (lbs.) \text{ X } Radius_{WT}\ (inches) \qquad \text{where:}$$

$\mathbf{F_{ub}}$ is the Force of the added unbalance from the trial weight (assumes a perfectly balanced rotor).

$\boldsymbol{\omega^2}$ is the radian cyclic speed, which is $(2 \pi N)^2$ where N = the actual turning speed in Hertz (cps).

$\mathbf{Wt._{Trial}}$ is the weight of the trial weight added to the rotor. Here we are assuming a perfectly balanced rotor and calculating only the added unbalance of the trial weight.

$\mathbf{Radius_{WT}}$ is the rotorline center to the trial weight mounting radius.

The table below gives an example of adding a 6 gram (1 gram = 0.00220462 lbs.) trial weight thumbscrew at a radius of 1.75 inches running at 3500 RPM (3500/60 = 58.33 Hz).

F_{ub} (lbs.)	Constant	ω^2 (cps)	Wt.$_{Trial}$ (lbs.) converted from grams	Radius$_{WT}$ (inches)	Result
	0.002841	$(2 X \pi X 58.33)^2$	0.01322772	1.75	9.35 lbs.

In other words, the addition of a 6 gram weight at a speed of 3500 RPM and a radius of only 1.75 inches results in an additional centripetal force of about 9 lbs.! This is the additional force that the rotor's internal structure and bearings must absorb and not break. To calculate the total imbalance force exerted on the machine, a vector resolution must be calculated from the initial reference run vector and the trial weight run vector. Correction weights can then be calculated and located to bring the rotor into a balanced operating condition.

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