STANDARD AIRGUN TESTING

Helston Forensics
FORENSIC BALLISTIC LABORATORIES

The gun trade have considered for a long time now, if it was possible to prepare a standard airgun test, it would be helpful to manufacturers of airguns, and those that have to test them when asked to report on an airguns power.

Pressure from certain sectors of the manufacturing industry of both projectiles and air guns has been never ending, for instance some pre charged air gun makers want a medium weight pellet only to be used (out of the question as the gun may perform better with a heavy weight pellet). Some spring air gun makers want the same so that light weight pellets are discounted.

There have been many suggestions for test procedures, including:

1. Moulding wax pellets in the bore before firing, to determine velocity.
2. Using the volume of air produced on firing to determine power.
3. The most unbelievable was to fire a pellet at a 1 pound block of steel to see how far it would move!

Anyway, the most logical that we can come up with is the one enclosed.

This is the procedure Helston Forensics now use for testing, and refer to, to validate our findings. It is fair to all concerned and more important it can be used to prepare similar results from Cornwall to Scotland!

Things to consider

1. Definition of muzzle velocity.
2. Pellet drag coefficients, their effect deceleration.
3. Humidity.
4. Acceleration due to gravity.
5. Correction for altitude.
6. Down range velocity reduction.
7. Correction for latitude.
8. Acceleration due to muzzle blast.
9. The effects of the position of the sun and moon
10. Equipment error.
11. Inaccuracies of energy formula.

DOWN RANGE DRAG COEFFICIENTS

Take an energy calculation from a test firing of .22 that gives a reading of say 12.2ft lbs, look to the drag coefficients chart for the nearest which is 12.277 The down range deceleration over 12 inches will be in the region of 1/3 of the difference between 12.277 and 12.091 (0.062 ft/lbs).

This figure will alter slightly if the shape of the pellet changes, deceleration will usually be increased if the pellet is flat nosed, also the weight of the pellet will have an effect, note that the down range chart is calculated for a 14.5gr sphere (.22).

ALL EFFECTS WITH THE EXCEPTION OF MUZZLE BLAST DOES NOT INCREASE THE SPEED OF THE PELLET, THEREFORE ANY CORRECTION TO THE CRONO READING SHOULD BE AN INCREASE IN FT/LBS!

MUZZLE BLAST

The effect of the pressure on the projectile (if it is still accelerating under pressure when the pellet is at the muzzle) is to push the projectile on when it is free of the muzzle.

As the pellet just leaves the muzzle it comes into a space of forward moving air pushed ahead of it, therefore for a short period it does not feel the effect of the drag it will encounter further down range.

The pellet is also pushed by the blast of air from behind, the vacuum effect caused by the air expelled in front of the pellet, coupled with the extra push from behind when the pellet becomes free of drag from the walls of the bore of the gun allow the blast to accelerate the pellet. This effect is very small but worthy of note. The peak velocity is usually about 3 inches from the actual muzzle.

The law asks for energy “at the muzzle”. Fortunately calculations show that the difference between energy at the muzzle and those at a distance away from the muzzle where measuring becomes practical are very small (in the 6 to 12 ft lb range and above).

After making corrections that are practical to improve the accuracy of a reading, you must be aware of other factors that have an appreciable effect on the pellet down range measurement, they include humidity and pellet drag.

AMBIENT AIR DENSITY

Air temperature, pressure, and humidity variations make up the ambient air density. Humidity has a counter intuitive impact. Since water vapour has a density of 0.8 grams per litre, while dry air averages about 1.225 grams per litre, higher humidity actually decreases the air density, and therefore decreases the drag.

HUMIDITY

Any test conducted in a natural environment is valid, damp air or dry. It is worthy of note that if the air was extremely damp or dry it would make a difference in effect. The effect is so small it is less than you would expect to note from the difference between one shot and the next. The facts prevail, if the airgun produces a reading "over the limit" in damp air (as encountered in the UK atmosphere), then the airgun is capable of exceeding the legal limit.

The molecular weight of air that is dry is heavier than air that is humid. If the air is damp the pellet velocity will be greater as there is less drag, also, the air density will change as you rise above sea level. All these factors have an effect on the projection back to the muzzle from the point of measurement but are discounted as the difference between the velocity at the point of measurement comparative to the actual velocity at the muzzle will be negligible.

Equipment Error

The "standard test" calls for a maximum equipment error not to exceed 0.5%.

The compound error of a 0.5% error in the weight of a pellet and a similar error in the device used to record the speed can result in the following:

Fig 1.
Calculations (Energy in foot pounds)

1] Example: Standard Calculation

$$\frac{14.5 \text{ Pellet} \times (500\text{FPS})^2}{(32.2+32.2) \times 7000} = \frac{3625000}{450800} = 8.04125998225$$

2] With 0.5% error applied to pellet

$$\frac{14.5725 \text{ Pellet} \times (500\text{FPS})^2}{(32.2+32.2) \times 7000} = \frac{3643125}{450800} = 8.08146628216$$

3] With 0.5% error applied to the speed

$$\frac{14.5 \text{ Pellet} \times (502.5\text{FPS})^2}{(32.2+32.2) \times 7000} = \frac{3661340.6}{450800} = 8.12187355811$$

4] With 0.5% applied to both

$$\frac{14.5725 \text{ Pellet} \times (502.5\text{FPS})^2}{(32.2+32.2) \times 7000} = \frac{3679647.3}{450800} = 8.16248291925$$

In this example the difference between the standard calculation and with 0.5% applied to both weight and speed is 0.121222937 foot pounds of energy.

As you will see it is possible with speed and weight errors on 14.5 pellet at 500 FPS to have an equipment error that will change the reading by 0.12ft lbs! It is also possible for one error to cancel the other out, so don't make an allowance just for equipment error, but be aware of its potential.

LATITUDE AND ALTITUDE

For gravity a fixed value is used in the conversion to muzzle energy, a conversion for your particular altitude is not required as the speed measured is a FACT as is the weight of the projectile.

The same applies to a conversion in the calculation from speed to energy for latitude and any change this will give to acceleration due to gravity.

The important point to be aware of is that latitude and altitude will have an effect on the projection back to the muzzle from the point of measurement, this effect is very small indeed.

ACCELERATION DUE TO GRAVITY

The weight of a grain depends upon the altitude, the standard value for gravitational acceleration is 9.80665m/s (32.174048556) per second per second (at sea level).

This calculation uses a theoretical standard for acceleration due to gravity as the gravitational attraction is not consistent and varies due to a number of variables including height above sea level, where on earth's surface the measurement is taken and the gravitational forces from the sun and moon etc., for calculations related to dynamics it is usual to give the acceleration due to gravity in three significant figures therefore we recommend 32.2 is used for all dynamic calculations.

PELLET WEIGHT DURING TESTING

It must be taken into consideration that the weight of pellet used in the calculation of muzzle velocity is the weight of the pellet measured before the test. The weight of the pellet as it passes through the chronograph is technically unknown. Friction in the bore or miss-alignment (especially on airguns with tap loading systems) may mean that the pellet may shed some of its mass by the time it leaves the muzzle. During testing this consequence is unlikely to have a measurable effect on the result and could be argued that is accounted for if a 5% error is applied, however, to ensure that this argument is not used in court, you may wish to consider weighing the pellets again after completion of the test as part of your S.O.P.

THE WAY FORWARD

1] To obtain a standard conforming to BS6002, using grams to express the mass of the pellet, and give the results of energy in joules.

2] To express the results of the test by its standard deviation, giving a percentage of confidence to confirm the airguns legal status.

Note: In law the charge is for possessing an air weapon capable of exceeding the permitted limit, normally when tests are conducted the airgun is not in the possession of the accused, therefore the result of the test presume that they would be the results if the air weapon was tested when in the possession of the accused …. can you be absolutely certain? or should you be pointing out this is an assumption!

Other assumptions often quoted are velocities and energies of pellets where deaths have occurred, these figures should be expressed with the declaration that this is an assumption made after testing the air weapon for power, whilst not unreasonable the velocity of the 'death pellet' is actually unknown.

KINETIC ENERGY IN FOOT/ POUNDS (Ft/ Lbs) ($KE = 0.5 \times MV^2$)

FORMULA: $\frac{\text{½ WEIGHT (grains) X VELOCITY}^2}{\text{GRAVITY X 7000}} = \frac{0.5W \times V^2}{G \times 7000} = \frac{W \times V^2}{G+G \times 7000}$

E = Kinetic energy (Ft/Lbs)
W = Weight of body in lbs
V = Velocity (feet per second)
G = Acceleration due to gravity

Note: 7000 grains = 1lb

EXAMPLE: $E = \frac{\text{WEIGHT (grains) x VELOCITY (feet per second)}^2}{\text{GRAVITY + GRAVITY x 7000}}$

$E = \frac{14.5 \times (500)^2}{(32.2 + 32.2) \times 7000}$

$E = \frac{3625000}{450800}$

E = 8.04 ft lbs

7000 grains = 1 Pound Avoirdupois
453.59237 grams = 1 Pound Avoirdupois
To convert grams into grains multiply by 15.4323607345
To convert grains into grams multiply by 0.0648
To convert F.P.S. into M.P.S. multiply by 0.3048
To convert M.P.H. into F.P.S. multiply by 1.466667
To convert joules to foot pounds (KE) multiply by 0.73756214927727
To convert foot pounds to joules (KE) multiply by 1.3558179483314004

KINETIC ENERGY IN JOULES ($KE = 0.5 \times MV^2$)

FORMULA: $E = \frac{\text{½ MASS (grams) x VELOCITY}^2}{D} = \frac{0.5\ M \times V^2}{D} = \frac{M \times V^2}{D+D}$

E = Kinetic energy (Joules)
M = Mass (grams)
V = Velocity (meters per second)
D = Denominator weight

Note: The denominator weight when using grams for the projectile weight is 1kg expressed in grams (1,000)

EXAMPLE: $E = \frac{\text{MASS (grams) x VELOCITY (metres per second)}^2}{\text{WEIGHT + WEIGHT}}$

$E = \frac{0.9396 \times 152.4^2}{1000 + 1000}$

$E = \frac{0.9396 \times 23225.76}{2000}$

$E = \frac{21822924096}{2000}$

= 10.91 joules

7000 grains = 1 Pound Avoirdupois
453.59237 grams = 1 Pound Avoirdupois
To convert grams into grains multiply by 15.4323607345
To convert grains into grams multiply by 0.0648
To convert F.P.S. into M.P.S. multiply by 0.3048
To convert M.P.H. into F.P.S. multiply by 1.466667
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STANDARD AIR GUN TEST
(For the purpose of establishing muzzle energy)

1] Test fire 3 sets of 5 shots as follows:

a) 5 shots with lightweight lead air gun pellet
b) 5 shots with medium weight lead air gun pellet
c) 5 shots with heavyweight lead air gun pellet

This test is to establish if a formal test is required.
Note: In the case of .20, .25, etc, where light, medium and heavy weight pellets are not always available in a waisted profile use other shape commercially available pellets.

2] If the test shows that the air gun on any of the shots produces a muzzle energy that exceeds the maximum allowed by the Firearms Act 1968 as amended for non-specially dangerous airguns a formal test using the pellet weight giving the highest reading shall be conducted.

3] Weigh 10 pellets individually before the test fire (for simplicity in presenting results it is preferred that all pellets weigh the same), fire each pellet recording the velocity.

4] If one or more of the test shots exceed the maximum energy (currently six foot pounds for air pistol and twelve foot pounds for air weapons other than air pistols), the result will be positive.

5] Note: If the airgun is subject to the possibility of having been used illegally and is seized with pellets, test fire with pellet found and the airgun as seized. Then conduct the standard airgun test for classification (note this is optional and subject to your S.O.P.)

6] Note: If carrying out the test in paragraph 5 on pre-charged airguns or those powered by CO^2 canisters, test the airgun as found / supplied to you before recharging to the manufacturers recommended pressures or the fitting of a new CO^2 canister.

7] For multiple stoke pneumatic guns perform the test in paragraph 1 at the manufacturers recommended maximum pumps. Having ascertained the most efficient pellet weight, perform a formal test with that pellet by increasing pumps until it

produces energy over the legal limit or until you have pumped the gun up to twice the manufacturer's recommendations.

8] For pre-charged guns fill to the manufacturers recommended fill pressure and perform the screening shots in paragraph 1 of the airgun test. Having ascertained the most efficient pellet weight, re-fill to the manufacturers recommended fill pressure and perform a formal test firing, firing until peak velocity is achieved.

9] To test airsoft guns test with 3 different BB weights, (weights approx: light 0.12 medium 0.2 - 0.25 heavy 0.4 - 0.5 grains). If over, perform a formal test with the BB that gives the highest result. Note: Semi-automatic airsoft guns must not produce more than 2.5 Joules (KE), fully automatic airsoft guns must not produce over 1.3 Joules (KE).

10] Testing of .177 BB guns. Current commercially available BB's include steel BB's, plated steel and Lead BB's with full copper jackets. The weight and nominal diameter of the available BB's can have significant variation and will have an effect on performance. For testing perform a screening with a light and heavy weight BB, (weights approx: light 5.25 grains for steel and heavy 7.4 grains for lead). If over, perform a formal test with the BB that gives the highest reading.

<u>Pellet type (to apply unless the pellet type found with the airgun differs)</u>

Lead Airgun pellet type must conform to the description of waisted pellet examples below.

BB pellet type (steel)

BB pellet type (lead)

Soft air pellet type (plastic)

11] Pellet diameter (mm)

	Maximum	Minimum
The diameter for .177	4.52	4.49
The diameter for .20	5.10	5.04
The diameter for .22	5.52	5.49
The diameter for .25	6.35	6.32

12] Weight category (shown to give an indication of typical examples)

Pellet weight in grains	.177	.20	.22	.25
Light	7.0-7.5	9.0-9.5	11.9-14.0	13.8-16.5
Medium	8.2-9.3	11.7-14.9	14.2-18.0	17.0-22.5
Heavy	10.0-12.0	16.5-17.0	18.2-25.0	24.0-27.0

13] Equipment

a] The equipment used to conduct the test must be of sufficient quality and be accompanied by a valid and current calibration certificate, the certificate must be traceable to a national standard or issued by the design authority (manufacturer).

b] Maximum equipment error must not exceed 0.5%, (95% confidence).

c] The equipment must be tested and calibrated in accordance with manufacturers recommendations.

d] All tests must be completed with muzzle of the air gun between 12 and 15 inches from the first point of measurement and in the horizontal plane.

e] Scales must be capable of weighing to an accuracy of one tenth of a grain.

f] The scales must be checked with a reference weight of a weight within the range of the pellets to be used for the test, i.e. for .22 a weight between 11.9 and 25 grains. Therefore 2 weights will be sufficient to test the scales for pellets ranging from .177 to .25 calibre, i.e. 10 grains and 15 grains. The weights must be accompanied by a valid calibration certificate, this certificate must be traceable to a national standard.

14] Notes

i] Pellet quality and consistency can be determined by a visual check.

ii] It is known that an airgun can give different results if the temperature when tested is high or low, it is important to record the temperature when testing. If the temperature is within the standard climatic range as found in the United Kingdom, the result will be valid, however, extremes should be avoided, as they can affect the airgun as well as the flight of the projectile. Therefore it is recommended that the temperature range is within 5° to 30° Celsius.

iii] Normally observed humidity will not affect the speed of the pellet over the distance of 12 to 15 inches from the muzzle of the airgun enough to affect results appreciably, however an adjustment for the effect of gravity, humidity and other factors must be considered when considering a discount to muzzle energy results.

iv] Test pellets should be selected from commercially available pellets.

v] The pellets used for the recorded power test should be carefully examined for visual defects. Each pellet must be weighed before firing and its weight recorded.

vi] The airgun upon receipt shall have no more than 15 test shots fired before a formal recorded test. Unless testing with pellets seized/supplied with the airgun is required, the number of pellets fired of each type will be subject to the forensic strategy decided upon. A formal test will not normally be necessary if a screening test firing 5 pellets for low weight, 5 of medium and 5 of heavy weight show the airgun to be under maximum power permitted.

vii] The purpose of a standard airgun test is to determine the muzzle energy of the airgun, the above procedures are designed to give a fair and honest appraisal of power using commonly available pellets.

Viii] Having considered and applied all known variables that can be calculated consider rounding this up to a 5% discount to all muzzle energy results to discount any possibility of equipment error, variables due to calculation values and the effects of drag, altitude, latitude and humidity and other external factors.

Viiii] The definition for the muzzle velocity using this test:
The average velocity for a decelerating projectile where the measurement has been taken from a point between 12 to 15 inches (304.8mm to 381mm) from the muzzle of the air weapon, with no calculation made back to the muzzle for retardation due to free air.

"Legislation should be given the interpretation most favourable to the defendant" (R.V.Law (Nathan).

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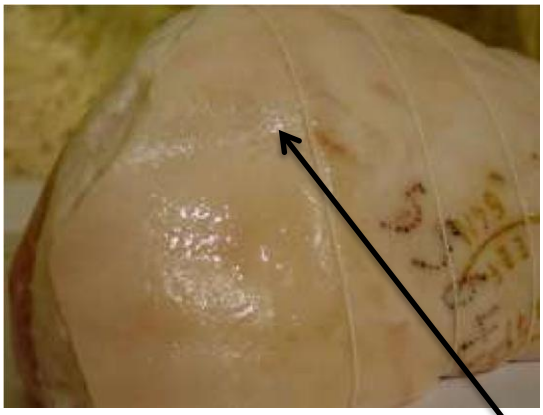
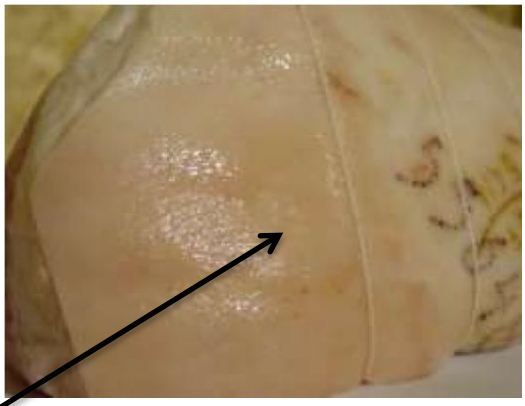
TESTS ON PORK

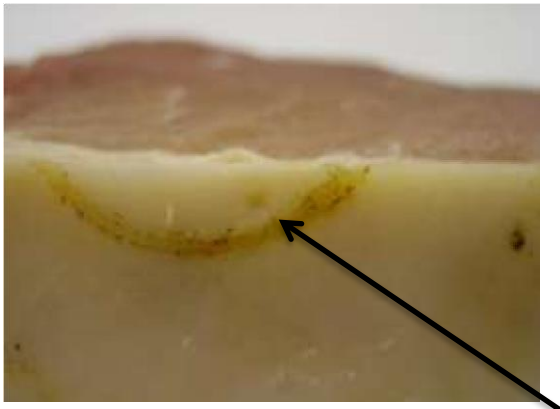


.177BB (steel)
Impact velocity: 243 FPS (165 MPH)
Impact energy: 0.95 joules
Pellet weight: 5.3 grains
Result: No penetration

Impact

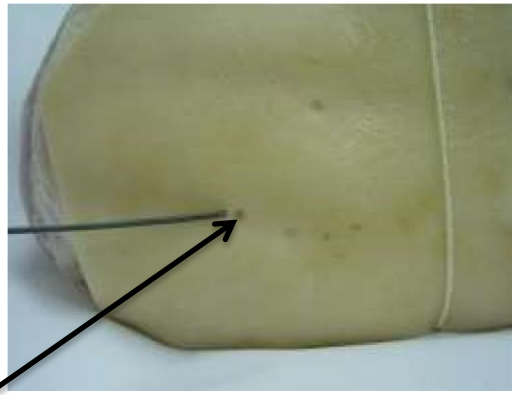


6mm BB (plastic)
Impact velocity: 657 FPS (448 MPH)
Impact energy: 2.43 joules
Pellet weight: 1.8 grains
Result: No penetration



.177BB (steel)
Impact velocity: 274 FPS (186 MPH)
Impact energy: 1.20 joules
Pellet weight: 5.3 grains
Result: Skin breakage (no penetration)

Impact



.177BB (steel)
Impact velocity: 274 FPS (186 MPH)
Impact energy: 1.20 joules
Pellet weight: 5.3 grains
Result: Skin breakage (no penetration)

.177BB (steel)
Impact velocity: 413 FPS (281 MPH)
Impact energy: 2.72 joules
Pellet weight: 5.3 grains
Result: Penetration to 3mm

6mm BB (plastic)
Impact velocity: 1066 FPS (726 MPH)
Impact energy: 6.17 joules
Pellet weight: 1.8 grains
Result: Penetration to 9mm

.177BB (steel)
Impact velocity: 719 FPS (490 MPH)
Impact energy: 8.25 joules
Pellet weight: 5.3 grains
Result: Penetration to 70mm

6mm BB (plastic)
Impact velocity: 1232 FPS (840 MPH)
Impact energy: 8.22 joules
Pellet weight: 1.8 grains
Result: Penetration to 18mm

Notes:

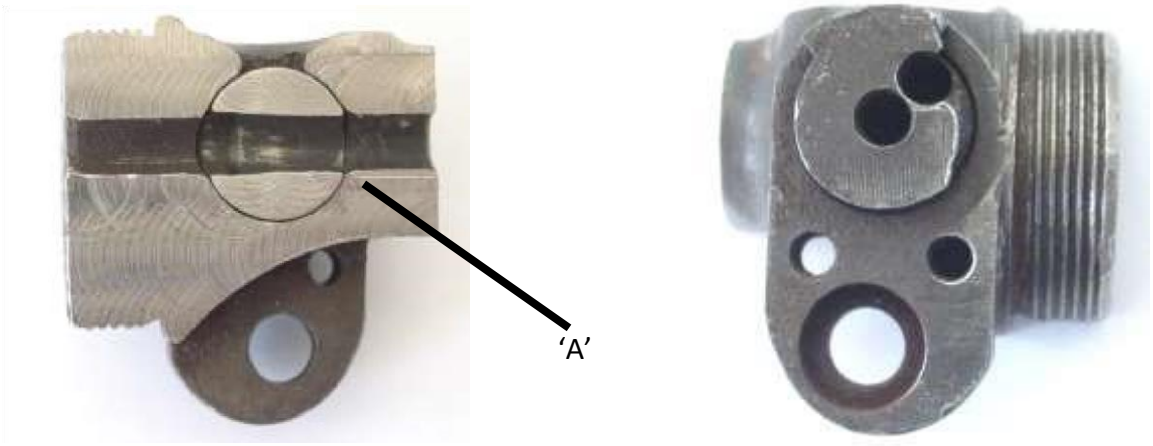
1. 177 steel BB penetrates deeper than 6mm plastic BB, due to surface area of projectile/energy density.

2. With a muzzle velocity of 1232 feet per second (840 MPH) for the 6mm plastic BB, note the projectile has fragmented.

3. 1232 feet per second was achieved by firing the 6mm plastic BB in a high power air rifle.

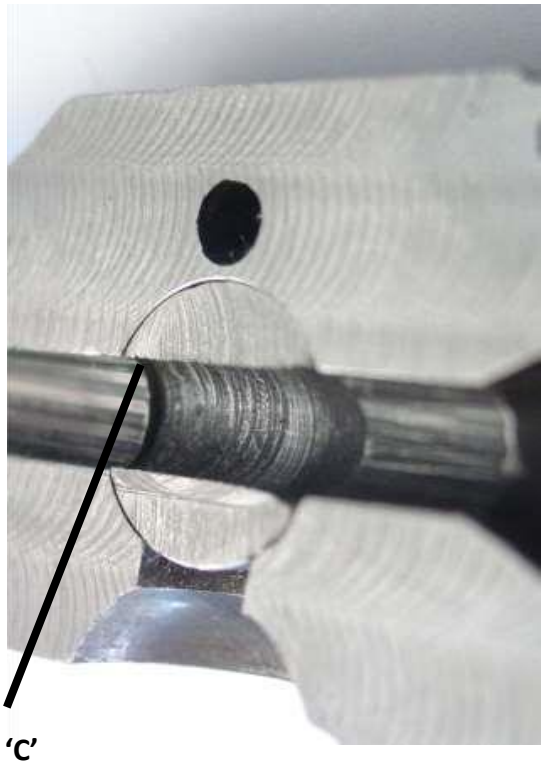
THREE TYPICAL 'TAP LEVER AIR RIFLES (.22)

LINCOLN JEFFERY Note: Barrel with chamfer / lead to guide pellet into bore 'A'.



RELUM TORNADO Note: Barrel with chamfer/lead to guide pellet into bore 'A'.

BSA AIRSPORTER



Notes:

1. Rifling both sides of tap 'A'.
2. Barrel with no chamfer/lead to guide pellet into bore 'B'.
3. Tap does not align with bore 'C'.
4. Tap with no shim (shim would make the fault worse) 'D'.
5. Where the tap does not align with barrel, expect a 'shave' of pellet head and skirt.
6. Weigh pellet after firing to ensure the pellet passing through chrono is complete and has not been 'shaved' by the non-alignment.