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Degree-ing Cams

Degreeing cams is an expression used to mean measuring certain characteristics of the cam movements (cam specs).
The act of degreeing cams doesn't change anything but gives you an understanding of what the cams are doing and when.

Why Degree Your Cams?

It is not a requirement to degree your cams.
And franky, it is usually deemed un-neccessary for a street engine.
Especially given the amount of set-up time for the instruments only to find nothing more about the cams than are published in the manufacturer's specs.

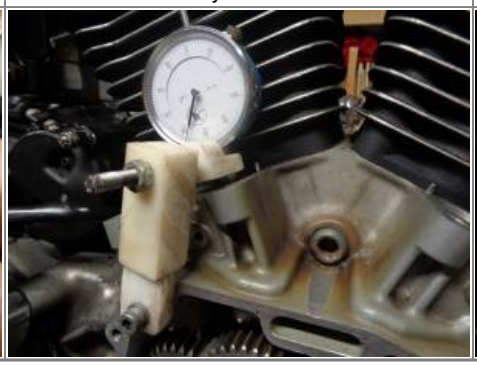
But, checking the cam specs isn't the only advantage to performing this procedure.

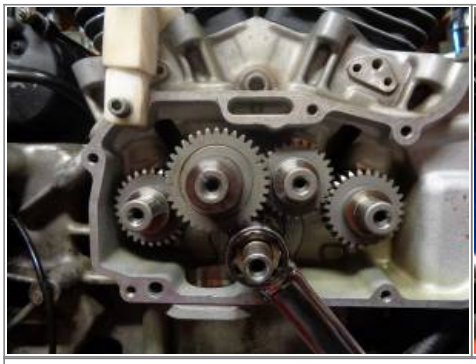
- You can degree the cams to check;
  - Max cam lobe lift.
  - Duration of the cam lobe lift.
    (this is required if you're planning on changing your valve opening and closing times).
  - Wear loss of the cam lobes.
  - Opening and closing of the valves in crankshaft degrees.
- You can also degree the cams to eliminate errors in;
  - General manufacturing of the cams.
  - Proper cam installation.
    A compression test will also immediately point out a cam timing problem. [1)]
    See also Performing a cylinder compression test in the REF section of the Sportsterpedia.

Setting up the Equipment

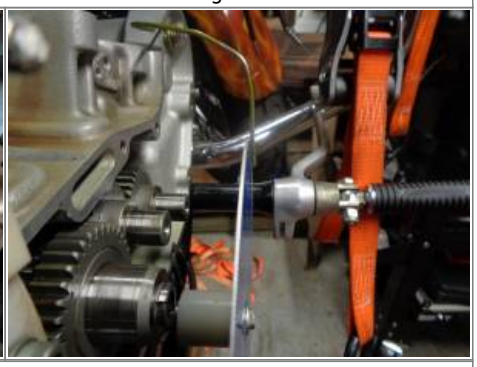
[2)]

- You'll need to Find True TDC of the Piston for precise measurements.
  - See also Finding True TDC Using a Piston Stop and a Degree Wheel
- Or, for spot checking cam installation, a dial caliper placed in the spark plug hole and a degree wheel will do to find TDC.
  - See also Finding True TDC Using a Dial Indicator and a Degree Wheel
  - By using only a dial indicator on top of the piston, the point where the indicator falls off it's high point will be different.
    (depending on which direction you rotate the engine to find the high point). [3)]
  - There will be a few degrees of interpretation before the piston rolls back down.
  - However, a cam gear off by a tooth will show much more of a degree change than the caliper dwell at TDC.
- See also Confirming Which TDC You're On Using the Timing Rotor Cup in the Sportsterpedia for pics showing the different cam gear positions at TDC (compression) and TDC (exhaust) strokes for each cylinder.

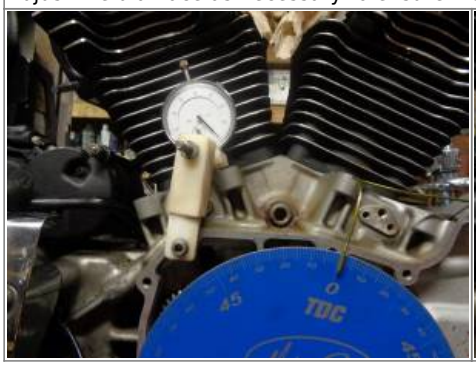
Oil the lifter bodies to ensure smooth up and down movement.	Install a dial indicator over the top of the lifter being tested. It doesn't have to be zero'd yet, but lower it enough so the probe will still touch the lifter the when it is all the way down.	Install a piston stop or dial indicator in the spark plug hole for locating TDC (front head for cams 3-4 & rear head for cams 1-2). See the links above for finding TDC.
		
Once you've found piston TDC, remove the piston stop or dial indicator from the spark plug hole. Install a degree wheel on either the crankshaft or pinion shaft (without moving the piston location).		



Install a pointer on the engine (a cut up close hanger works well).
It should come over the wheel and point directly at the center and parallel with the hash marks without touching the wheel.

You may have to adjust both the pointer and the wheel for alignment. Be sure the piston is still at TDC before making final adjustments.
With the wheel zero'd at TDC, spin the engine over and watch for movement of the lifter being tested.
When the cam is on the base circle, the dial indicator shouldn't move.
Move the indicator face to zero and rotate the engine several degrees to insure the lifter is settled in that position.
Adjust the dial face as necessary to ensure it stays on zero when it should.



Note:

1. It is advisable to rotate the engine over several TDCs and ensure the dial indicator returns to zero after rising and falling.
   Stop at certain degrees along the way, note the readings on the indicator and repeat.
2. If the indicator fails to stop on the same the spot repeatedly, your test results will vary.
   Reposition the indicator, zero the face and repeat note 1 above.
3. When you have confirmed accurate placement of the indicator, the equipment is now set up for testing.

Equipment Specifics

Dial Indicator for Measuring the Cam Lobe Lift

A dial indicator is set on top of the lifter body to measure the lift on each cam lobe,
As well as the start and end times of the lobe lifts (corresponds to opening and closing of valves).
Placing the indicator directly on the cam lobe is best, but most indicator probes aren't that long.
So, most will use the lifter as a spacer to allow the use of a standard indicator.

For the purpose of measuring the lifter position while it's on the cam's base circle, it's not critical that you're precisely at TDC.
Anywhere between where the intake valve closes (on the way up the compression stroke) and where the exhaust valve opens (on the way down the power stroke) will work.
Compression TDC is about halfway between those two events, so it's a nice safe place (to measure when the lifter is all the way down and the valves will be closed). [4)]

When you are confident that the cam lobe is at it's lowest point, re-set the dial face to 'zero'.

Dial caliper mounted over lifter bore [5)]

Piston Stop Tool

Commercial Piston Stop Installed [6)]

Degree Wheel

Degree wheel mounted on primary side [7)]

Degree wheel mounted to the pinion shaft [8)]

Cam Spec Definitions and Measuring

TDC Compression (compression stroke)

At TDC on the compression stroke, both valves are closed.
The piston is passing through top dead center with both cam lobes sitting on their base circle.

TDC Overlap (exhaust stroke)

At TDC on the exhaust stroke, both valves are at an overlap (both open at the same time).
The piston is passing through top dead center, finishing it's exhaust stroke and beginning it's intake stroke. [9)]

Timing Specs

The timing figures are referenced to each (intake and exhaust) cam.
The intake timing tells you the open and close points relative to the intake stroke.
The exhaust timing tells you the open and close points relative to the exhaust stroke.

For example, the Andrews N4 opens the intake valve at 30° and closes it at 46°.
That means it opens at 30° before the intake stroke begins (or 30° before the intake stroke's top dead center point)
It also closes the valve at 46° after the intake stroke ends (or 46° degrees after bottom dead center).
Each stroke is 180° long.
The duration can be calculated from the published timing figures.

Cam Lobe Lift

The actual cam lift is any amount of lift greater (taller) than the base circle.
This corresponds to how far the valves are open.
This can also be viewed as the beginning or ending of the lobe ramp.
As cam specs go, total cam lift is not measured.
It is rather measured from and to a certain height.
It is also subjective to measure.

The total lobe lift is not as important as the lift at TDC (exhaust stroke).
That's where the concern is for valves to slap the piston or each other.
This event also has more to do with the lobe ramp (sides) than total lobe lift.

However, a natural assumption can be that if the total lift has degraded, the ramps are also suspect.
You can measure the total cam lobe lift with a dial indicator on an installed lifter.
This doesn't require a degree wheel but if you're already set up to degree the cams,
You might as well check total cam lobe lift so you won't wish you had later.

Check all four cams and compare the results.

You can also measure cam lobe lift with the cams removed by using a caliper. [10)]
The base circle is the smallest dimension of a cam lobe.
If you measure the largest dimension of the lobe and subtract the smallest dimension you get the lobe lift.

Multiply that by the rocker ratio and you get the valve lift.

Duration

The true duration is the length of cam lift (at any height) from the start of the lift to the end of the lift.
The value for the duration of lift is expressed in rotational crankshaft degrees.

However, different cam manufacturers may have their own starting and ending points for measuring duration.
So, measuring true duration doesn't help you to check or match their advertised specs.
You have to know the lift spec for the duration advertised to match their specs.
The value for the advertised duration is the length in crankshaft degrees that the cam lobe is at or above the specified lift figure.

- The advertised duration for Andrews N4 cams is 256° at .053“ lift. [11)]

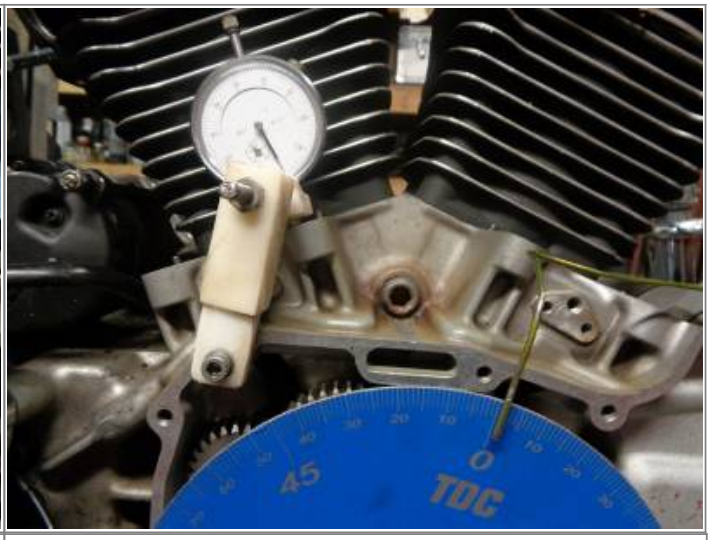
Example using Andrews N-4 specs.					
Intake Stroke			**Exhaust Stroke**		
Valve opening, Cam lift is .053”	Intake Stroke Length	Valve Closing, Cam lift is .053“	Valve opening, Cam lift is .053”	Exhaust Stroke Length	Valve Closing, Cam lift is .053“
30° before TDC Exhaust or (BTDC)	180°	46° after BDC or (ABDC)	52°	180°	24°
Calculated Intake Cam Duration: 30+180+46 = 256°			Calculated Exhaust Cam Duration: 52+180+24 = 256°		

- To measure advertised duration:
  1. Rotate the crankshaft and ensure the dial indicator reads '0' with the cam lobe on it's base circle.
  2. Then rotate the crankshaft forward until the cam rises to a height of .053”
     Note the degree at the pointer on the degree wheel.
  3. Continue rotating the crankshaft forward while the cam lobe rises and then lowers back to .053“ on the way down.
     Note this degree at the pointer on the degree wheel.
  4. Calculate the length, in degrees, between the two numbers to get the duration advertised.

Example using Andrews N4s on the rear intake cam:

1. Cam on the base circle, degree wheel zero'd at TDC [12)]

2. With rotated cam lobe height at .053”,
Degree wheel shows:
30° before TDC (BTDC) on exhaust stroke [13)]



3. Continued rotation up / back down to .053“ cam lobe height.
Degree wheel shows:
46° after bottom dead center (ABDC) [14)]

4. Calculate advertised duration:
30° BTDC + 180° (TDC to BDC) + 46° ABCD = 256° [15)]

This can also be done to measure true duration by tossing out the .053” height.
Simply note the start degree before the initial lift and the end degree after the last fall of the indicator.
Then calculate the distance in between as in the example above.

TDC Lift

TDC lift values are taken at TDC Overlap (TDC on exhaust stroke).
This tells how much both valves are open as the piston passes through top dead center during the overlap period. [16)]

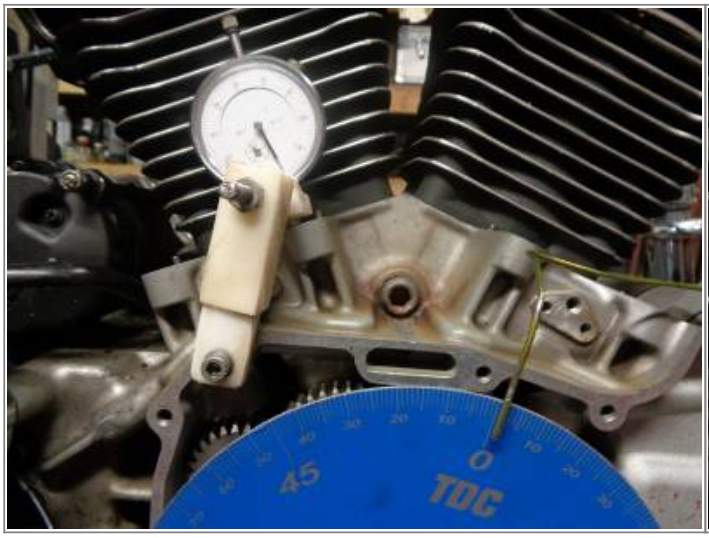
TDC Valve Lift is calculated by multiplying the cam lobe lift, at TDC exhaust, by the rocker arm ratio.

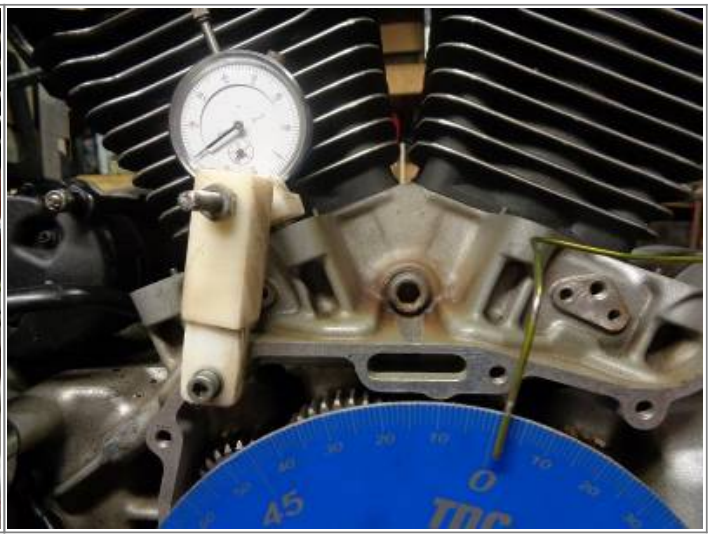
Valve to piston clearance has nothing to do with maximum lift (which occurs with the piston well down the bore).
The valve lift as the piston passes through TDC on the overlap stroke is the concern with clearance problems from both 'piston to valve' and 'valve to valve'.

The TDC lift value counted against the 'piston to valve clearance' value tells if the two will smack into each other during operation.
High TDC lift figures can also cause issues with valve to valve clearance.

Example using Andrews N4s on the rear intake cam:

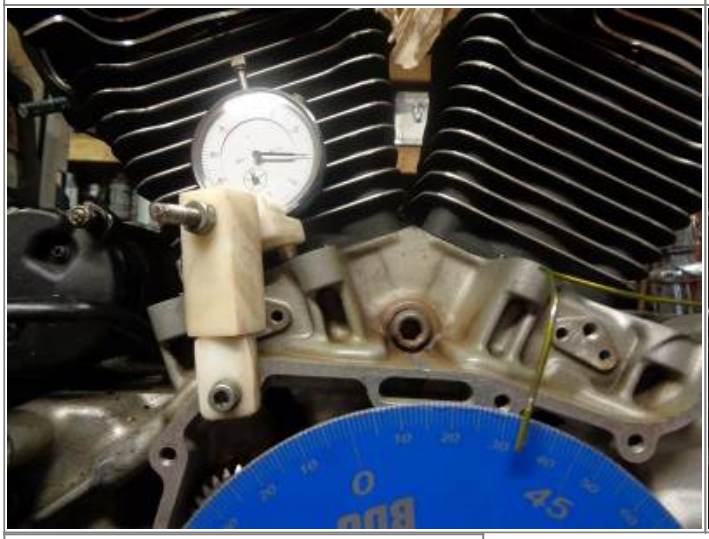
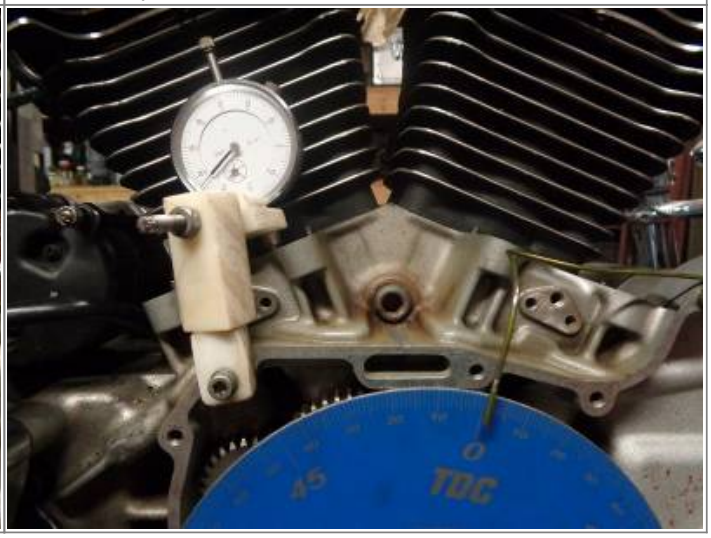
1. Cam on the base circle, dial indicator set at '0'. Degree wheel zero'd at TDC (compression) [17)]	2. Rotate the crankshaft forward until the pointer is at TDC on exhaust stroke. Note the measurement on the dial indicator: In this case it is .130“ [18)]





- This test repeated revealed 2° difference at the following TDC stop point.
- The dial indicator was repositioned and repeated results were different but consistent.

With the dial indicator repositioned:

1. Cam on the base circle, dial indicator set at '0'. Degree wheel still set properly. [19]	2. Rotate the crankshaft forward until the pointer is at TDC on exhaust stroke. Note the measurement on the dial indicator: Now at a repeatable result of .137” [20]
	

3. Calculate TDC Lift:
.137 * 1.633 = .223721“ (or .224”)
.137 * 1.625 = .2226“ (or .227”)

Wear Loss of the Cam Lobes

#2 Cam Gear Location

The outside gear on the #2 cam is pressed on from the factory.
There is always a concern to check this gear for movement of the press fit connection.

One visual on 91 and up Andrews cam gears is to look at the keyway for the timing cup.
The timing mark for the pinion gear should be between two gear teeth on the cam.
The pinion gear tooth with the timing mark should mate between the two adjacent teeth on the cam. (on either side of the cam gear mark)
For #2 cams with the timing cup notch;
The centerline of the notch points to the right adjacent tooth from the pinion timing mark.
(the centerline of the timing notch is 4.5° clockwise from the center timing mark on the #2 cam. [21] as in the pic below):

#2 Cam, Outside Gear Location (91 and Up Models) [22]

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1)
aswracing of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-engine-conversions/97704-so-i-put-my-bike-back-together-got-a-dyno-tune-not-happy/page3?highlight=degree#post2030753
2)
photo by povertyflats of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-bottom-end/130556-fitting-buell-xb-cams-551-e-grind-to-xl/page2?s=03729fd1877416d73eb9535bdf896822#post4051327
3)
rivethog of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-era-specific-and-model-specific/ironhead-sportster-motorcycle-talk-1957-1985/138903-ccing-my-combustion-chambers?t=1507847
4)

http://www.hammerperf.com/ttspotcheckcamtiming.shtml
[5], [6], [7]

photo by Jorgen of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-motor-engine/sportster-motorcycle-bottom-end/92792-cam-choices/page4?t=761410&highlight=degreeing+cams&page=4
[8], [13], [14], [15], [17], [19], [22]

photo by Hippysmack
[9]

http://www.nrhsperformance.com/tech_camshafts.shtml
[10]

rocketmangb of the XLFORUM
https://www.xlforum.net/forum/vendors/hammer-performance/160789-gaterman-lifters-now-available-from-hammer-performance?s=73d24db8f0756ef41c6215fd92ad0055#post3437771
[11]

Andrews Products, Inc. “Sportster Evolution Engine Cam Gear Installation Instructions” PDF dated 10/06
http://www.andrewsproducts.com/motorcycle-parts/instruction-sheets
[12], [18], [20]

photos by Hippysmack
[16]

http://www.hammerperf.com/xlvalvetrain.shtml#andrewscams
[21]

Andrews Products Inc. (XL-91-2timing.pdf) “Sportster #2 drive gear installation” sheet
http://www.andrewsproducts.com/motorcycle-parts/instruction-sheets