

Governor Linkage for Butterfly Throttle Valves

Application Note 50516

Governor Linkage for Butterfly Throttle Valves



WARNING

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.

The engine, turbine, or other type of prime mover should be equipped with an overspeed (overttemperature, or overpressure, where applicable) shutdown device(s), that operates totally independently of the prime mover control device(s) to protect against runaway or damage to the engine, turbine, or other type of prime mover with possible personal injury or loss of life should the mechanical-hydraulic governor(s) or electric control(s), the actuator(s), fuel control(s), the driving mechanism(s), the linkage(s), or the controlled device(s) fail.

Application of hydraulic and electric governors to gas and gasoline engines with butterfly throttle valves has been complicated by problems of response and system stability. This publication is directed towards throttle linkage for engines driving alternators or other constant speed applications. These same ideas apply to engines in variable speed service.

Governor output position versus engine developed torque affects system stability.

The amount of governor stabilizing function (compensation setting or buffer spring scale) to obtain stability with a given installation depends on the rate at which the engine begins accelerating from its steady-state speed when an unbalance in developed torque and load occurs. The acceleration rate of an engine is a function of developed torque and polar moment of inertia of the engine and is usually determined when developed torque is 100% and load torque is zero. Since the inertia remains constant on a given engine, the acceleration is directly proportional to the torque unbalance. The engine-developed torque at steady-state speeds, when neglecting the change in engine efficiency at different loads, is proportional to the rate of fuel flow to the engine. With linear linkage between the governor and a linear fuel metering device, or linear throttle, the developed torque is proportional to governor output position.

Graphs in Figures 2 through 10 illustrate a particular point and, while typical for all engines with butterfly throttles, do not represent any particular installation. The butterfly throttle used in the graphs has a total travel of 75°. When this butterfly throttle is installed and adjusted to the engine, the engine idles at 80% speed with the throttle 5° open and runs at 100% speed no load with the throttle open 7°. The maximum 75° opening of the throttle produces 100% developed torque at rated speed. This 100% developed torque is the maximum the engine can develop and is not necessarily the engine rating.

Figure 1 illustrates the linear relation between governor output and developed torque which it is possible to obtain on a diesel engine installation with linear linkage. With this linear relationship the expression $\Delta T/\Delta\theta = C$ holds for all positions of the governor output, and this characteristic results in an ideal installation [ΔT = the change in the percentage of torque, and $\Delta\theta$ = the change in governor terminal shaft position in degrees].

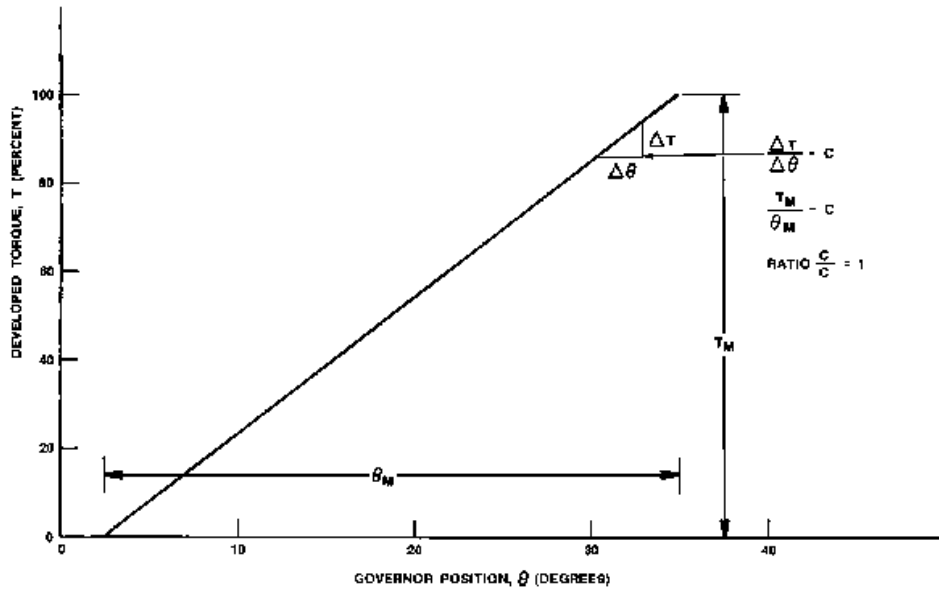


Figure 1. Governor Position vs. Developed Torque of a Diesel Engine

Figure 2 shows a typical throttle-torque engine curve obtained from data taken on a butterfly-throttle-controlled gas engine at rated speed.

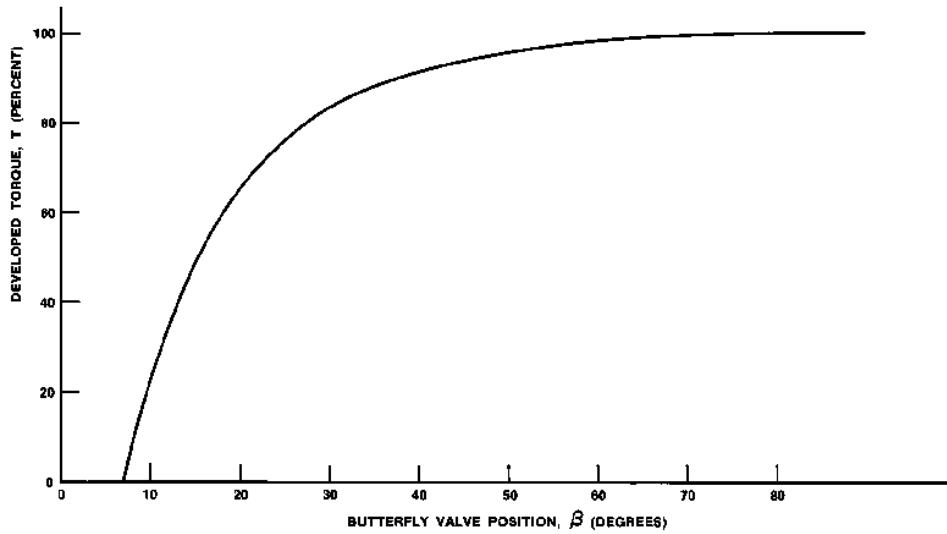


Figure 2. Butterfly Valve Torque Curve at Rated Engine Speed

Figure 3 shows the relationship between governor and butterfly when the linkage is linear. When this butterfly is connected to the governor through this linear linkage, the governor position with respect to developed torque is shown in Figure 4.

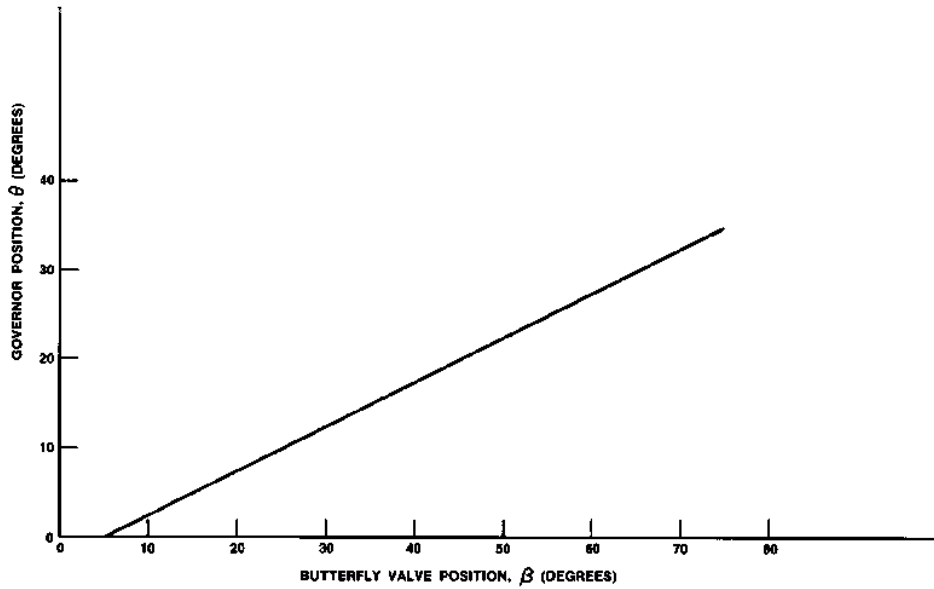


Figure 3. Governor to Butterfly Valve Linear Linkage

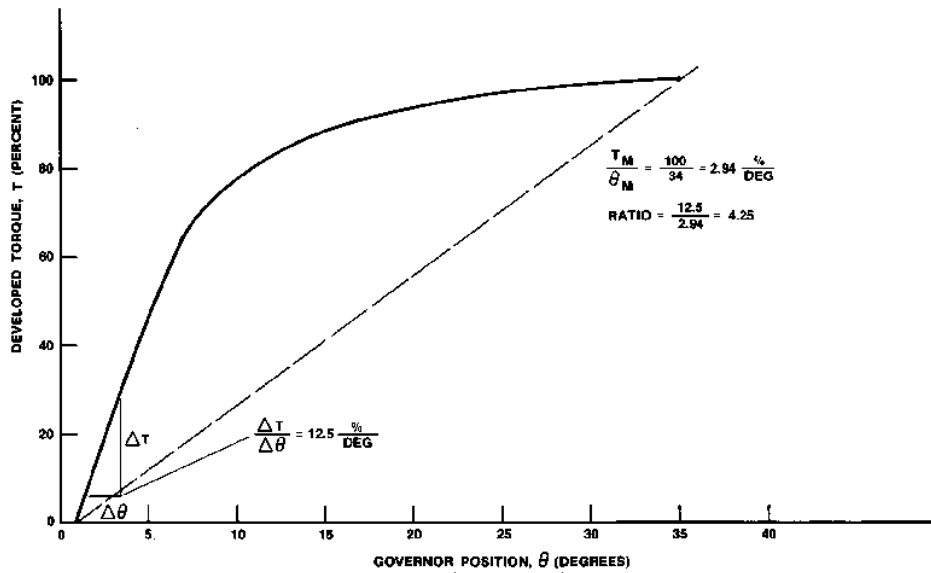


Figure 4. Developed Torque vs. Governor Position from Figures 2 and 3

With this linkage arrangement, the butterfly starts from 5° open and rotates 70 to its 75° position which is maximum opening as the governor travels from 0 to 35°. Near the wide open position of the butterfly, the incremental value of $\Delta T/\Delta\theta$ is 0, while at the no-load end, the value of $\Delta T/\Delta\theta$ is 12.5% change in torque per degree of governor travel. Note that the engine runs at rated speed no load at 1° of governor travel.

When this 12.5% of torque change per degree is projected through the 34° of remaining governor travel, it results in a 425% change in torque for total governor travel. From Figure 4, the governor travels 34° to open the butterfly throttle to maximum position, resulting in the engine developing 100% torque. This is an average engine torque change of 2.94% per degree. To obtain stability over the engine load range, the governor must contain components which will stabilize an engine which has 12.5% torque change per degree of governor travel. This requires use of higher scale buffer springs in the PSG, EGB, and PG governors; high compensation settings on the UG governors; and high values of droop on SG governors. The high stabilizing forces required for no-load stability results in excessive speed deviation and recovery times when a large step load change is made.

A speed control system with this type of engine torque-governor relationship is difficult to control satisfactorily, but it can be improved by the use of non-linear linkage between governor and butterfly throttle. This results in a more desirable developed torque vs. governor output relationship.

Figure 5, with a sketch of the linkage, illustrates the relationship between governor output shaft and butterfly positions obtained with simple linkage of maximum non-linearity. The important things about this linkage when in the non-load position are:

1. The lever which is attached to the governor, and the connecting link, are in line with the governor output shaft and the point of attachment of the connecting link to the butterfly lever.
2. The butterfly lever is at 90° with the connecting link.

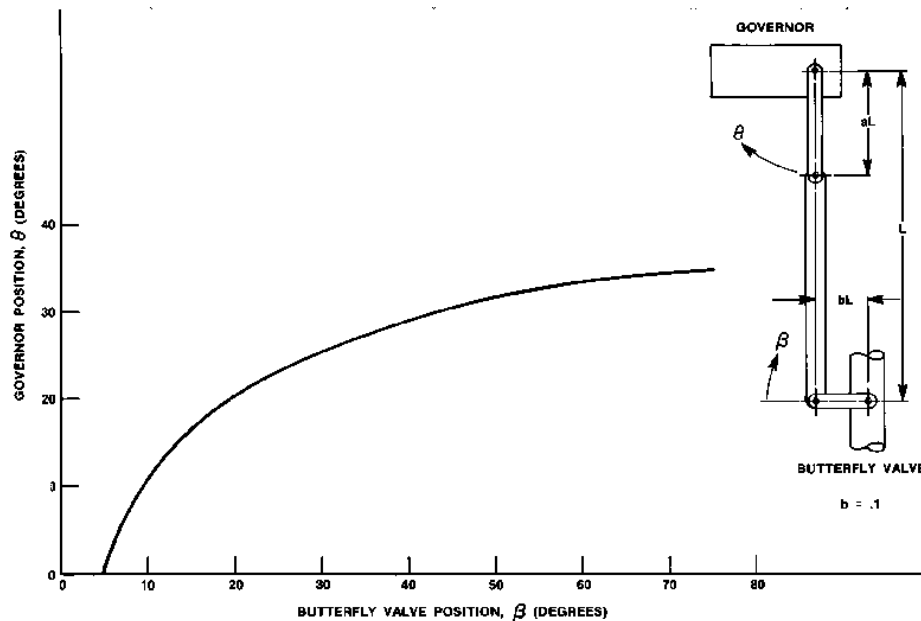


Figure 5. Governor Position vs. Butterfly Valve Position

In order to judge what is accomplished with the non-linear linkage, the ratio of the maximum torque change per degree of governor travel should be compared to the average torque change per degree for the "0" to 100% torque range.

Example:

Refer to Figure 1. For this ideal linear relation between torque and governor position,

- $\Delta T/\Delta\theta = C$ and
- $T_{\max}/\theta_{\max} = C$,
- hence the ratio C/C is 1:1.

Also refer to Figure 4 at the minimum fuel position,

- $\Delta T/\Delta\theta = 12.5$ and
- $T_{\max}/\theta_{\max} = 2.94$,
- hence the ratio $12.5/2.94 = 4.25$.

The closer this ratio is to unity, the more desirable the linkage.

Figure 6 is obtained by combining Figures 5 and 2, which yields engine torque vs. governor position.

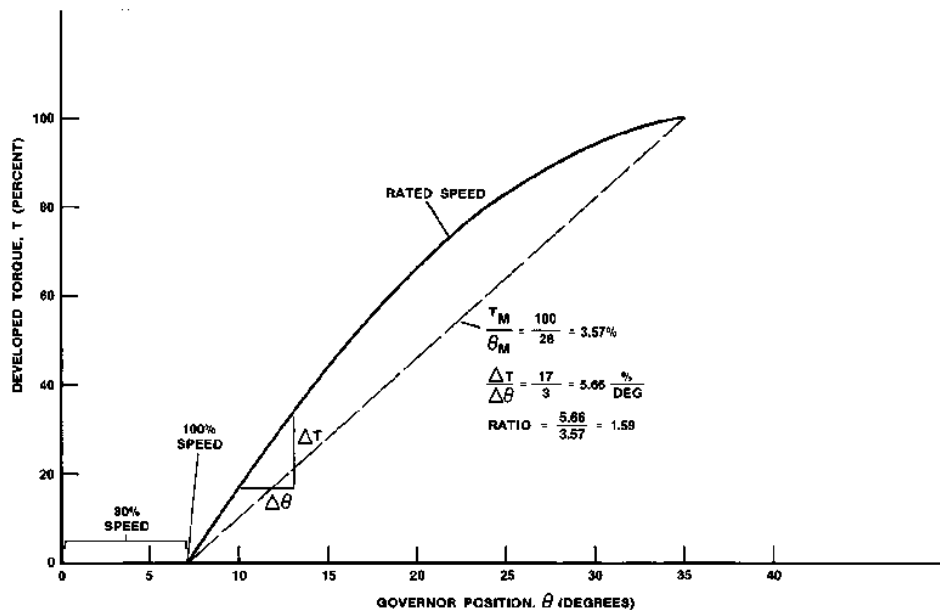


Figure 6. Developed Torque vs. Governor Position from Figures 2 and 5.

$\Delta T/\Delta\theta$ is 5.66% torque change per degree of governor travel at the no-load end, and 0.5% per degree at 100% torque. The average change per degree for the entire travel of the governor is 3.57%. Therefore, when comparing the maximum torque change per degree with the average torque change per degree, the non-linear linkage results in a ratio of 1.59 to 1. This type of linkage results in great improvement over linear linkage in the developed torque vs. governor position relationship (compare Figures 4 and 6).

Figures 7 and 8, with sketches of linkages, are included to illustrate how rapidly the desirable characteristics of maximum non-linear linkage are lost if the linkage is not properly designed or properly adjusted. Ratios of 2.17:1 and 3.33:1 result.

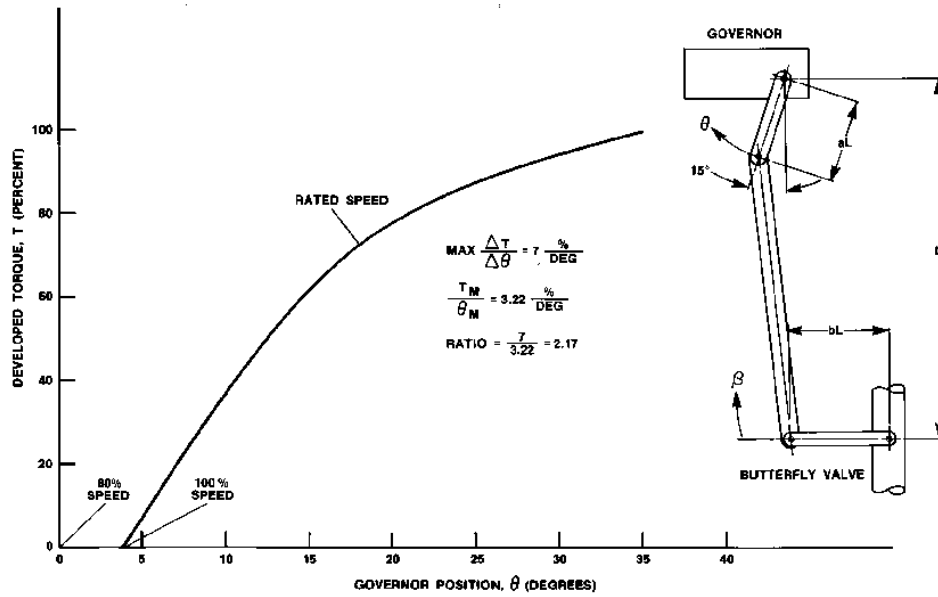


Figure 7. Developed Torque vs. Governor Position

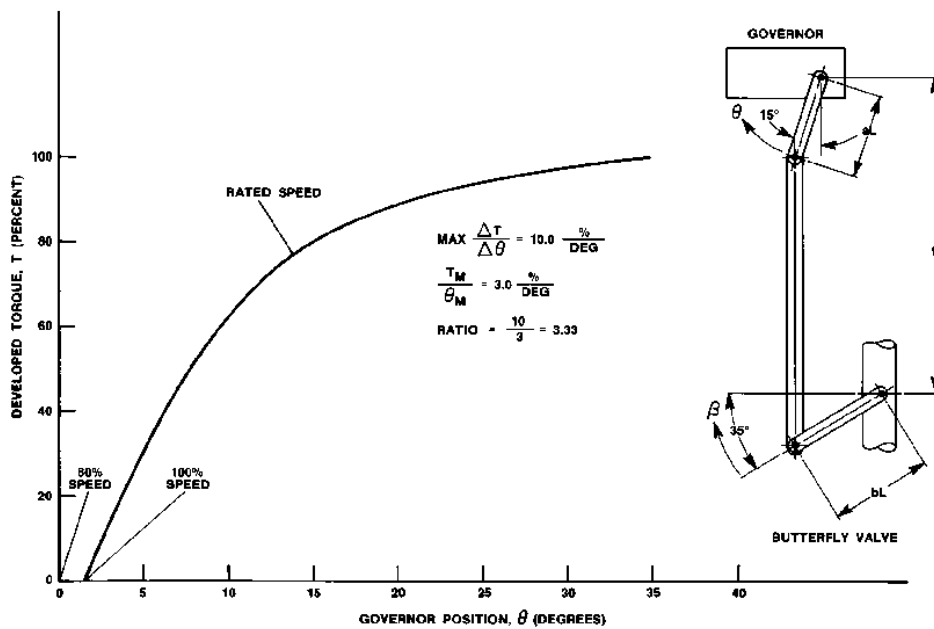


Figure 8. Developed Torque vs. Governor Position

Figure 9 is a sketch of a linkage which includes an intermediate shaft. At the no-load position with this linkage, the lever on the governor shaft and the transmitting lever on the lay shaft are on the line between the output shaft and the point of link attachment to the driven levers. However, with this linkage, the driven levers are not at 90° with the links at the minimum position, but move equally about its 90° position.

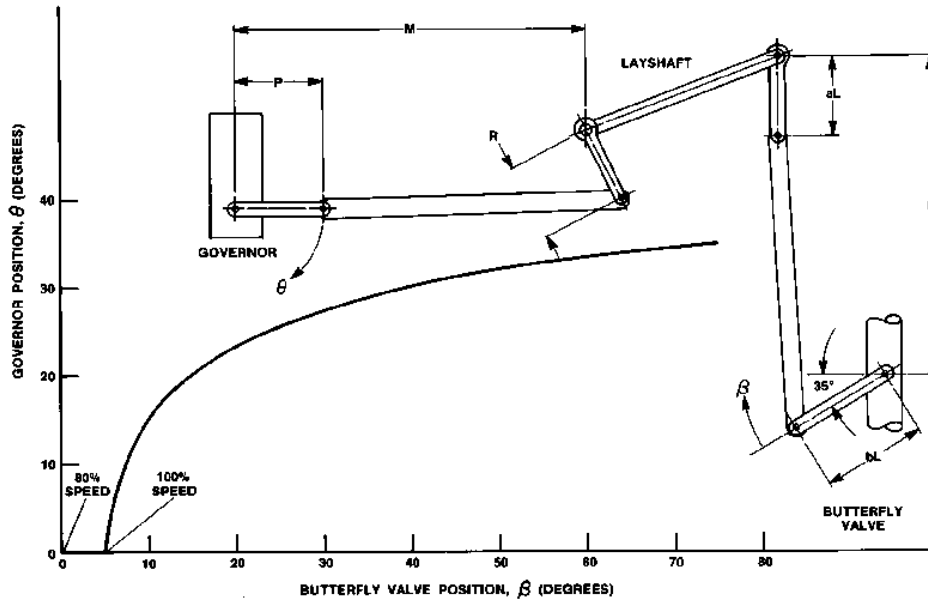


Figure 9. Governor Position vs. Butterfly Valve Position with Intermediate Lay Shaft

Another linkage system which would be satisfactory when an intermediate shaft is used, would be to use maximum non-linear linkage on only one of the driving levers and linear linkage on the remaining one.

Figure 10 is obtained by combining Figures 9 and 2. Note that at minimum torque position, $\Delta T/\Delta\theta = T_{max}/\theta_{max}$. This is an improvement over the simple linkage shown in Figure 6.

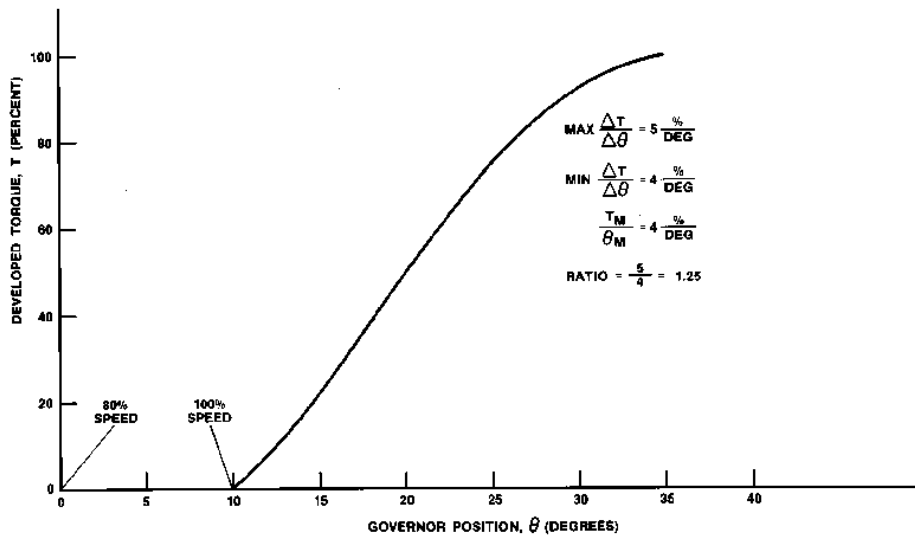


Figure 10. Developed Torque vs. Governor Position

Adjustment of Linkage

The linkage should be set up so that at minimum position of the governor the butterfly is open enough to run the engine at about 80% of rated speed. The governor lever should be of the proper length to use all of the available governor travel when the butterfly is completely open.

There are many variations and combinations of linkage design which would be satisfactory when an intermediate shaft is used. It is even possible to obtain so much non-linearity between governor and throttle butterfly that a great deal of the available governor travel would be used in advancing the butterfly from 80% speed no load to 100% speed no load. This seriously limits the governor travel between no load and 100% load.



NOTE

The 60% of governor travel from 0 load to 100% load which is usually recommended does not apply to gas or gasoline engines equipped with butterfly throttles.

There are four ways to construct suitable simple non-linear linkage. Schematic drawings of each of the four ways with their mathematical equations are shown in Figures 11, 12, 13, and 14.

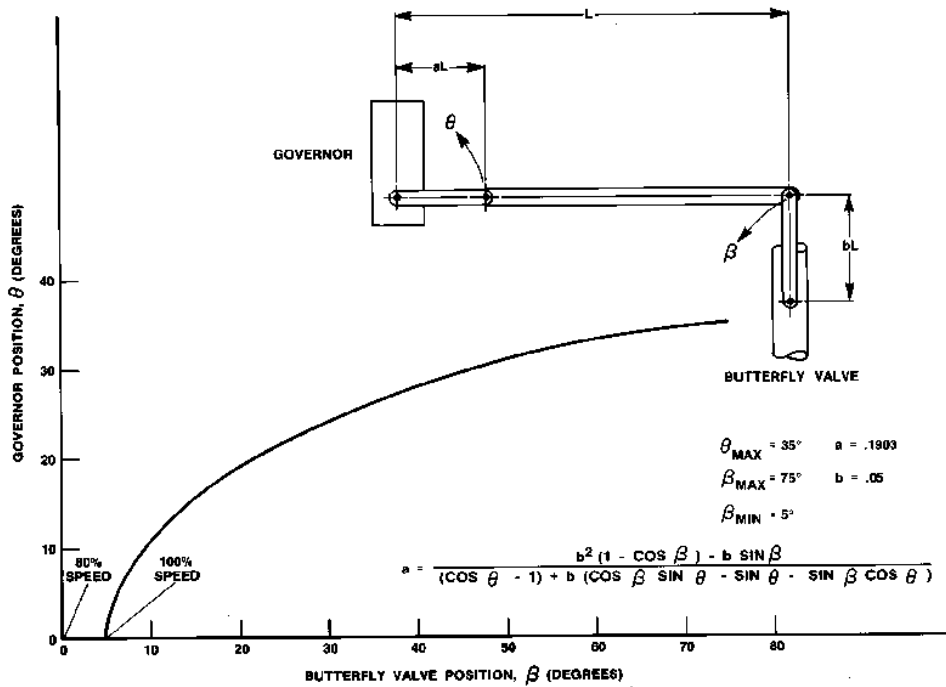


Figure 11. Governor Position vs. Butterfly Valve Position

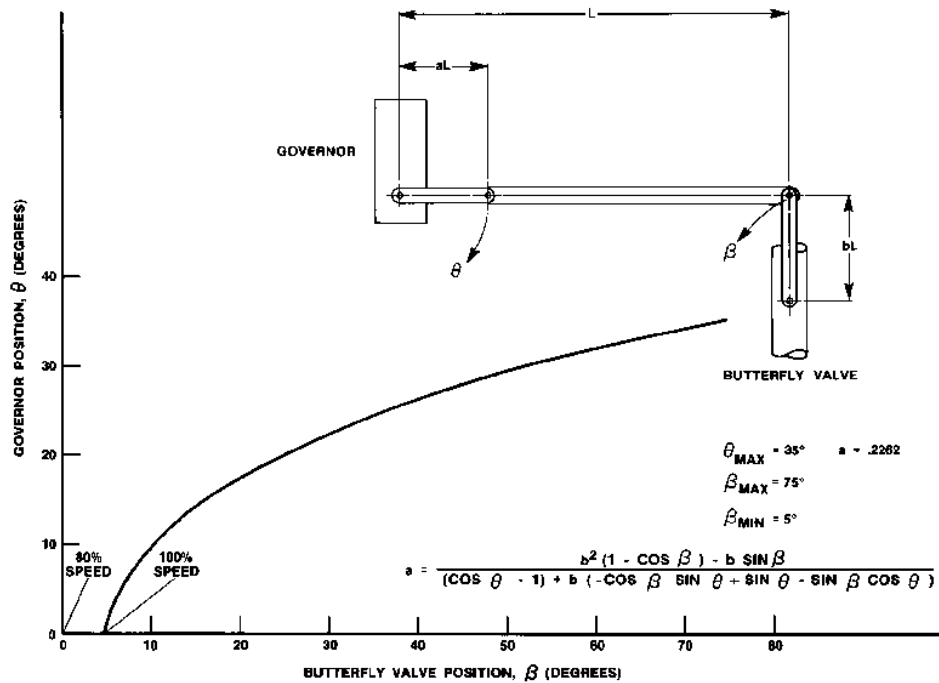


Figure 12. Governor Position vs. Butterfly Valve Position

These equations can be used to determine the length of the lever (aL) on the governor output shaft. To use the equations, the following parameters must be known:

1. Distance between butterfly shaft and governor output shaft (L).
2. Maximum rotation of butterfly shaft in degrees (β_{max}).
3. Maximum rotation of governor output shaft in degrees (θ_{max}).
4. Select a butterfly lever length (bL).
 - L is the distance between terminal shaft and butterfly shaft.
 - aL is the length of the governor lever.
 - bL is the length of the butterfly lever.
 - θ is the angular travel of the governor terminal shaft.
 - β is the angular travel of the butterfly shaft.

These equations are easy to use to determine “a” when all the other parameters are known. However, plotting a graph of θ versus β is best done by computer, as was done for the graphs of Figures 11, 12, 13, and 14.

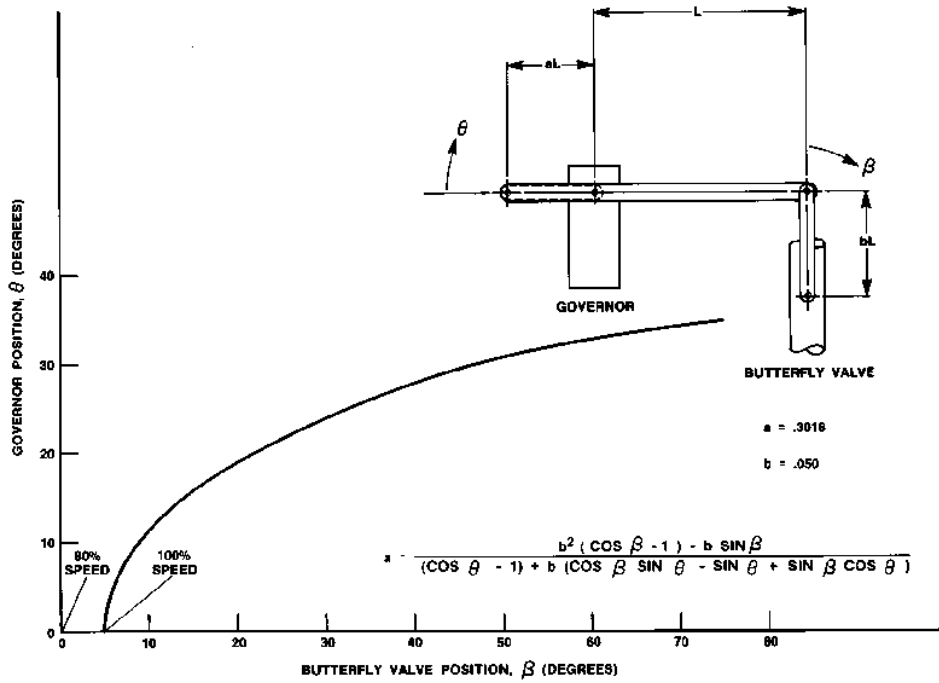


Figure 13. Governor Position vs. Butterfly Valve Position

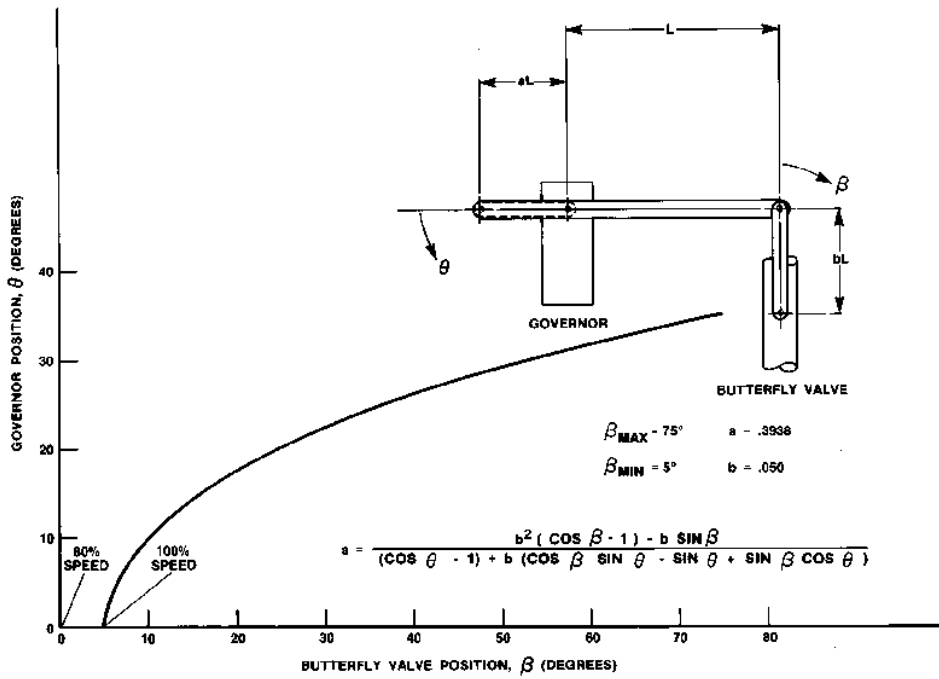


Figure 14. Governor Position vs. Butterfly Valve Position

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please include the manual number from the front cover of this publication.



PO Box 1519, Fort Collins CO 80522-1519, USA
1000 East Drake Road, Fort Collins CO 80525, USA
Phone +1 (970) 482-5811 • Fax +1 (970) 498-3058

Email and Website—www.woodward.com

**Woodward has company-owned plants, subsidiaries, and branches,
as well as authorized distributors and other authorized service and sales facilities throughout the world.**

Complete address / phone / fax / email information for all locations is available on our website.