Recommended Parameters for Modeling Steam Air Compressor Governors

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Introduction

In ORTS, the air compressor governor—which automatically starts and stops the compressor—is very simple in operation. The compressor turns on when the main reservoir pressure falls below the value specified in the **AirBrakesCompressorRestartPressure** parameter, and shuts off when the main reservoir pressure reaches the value specified in the **AirBrakesMainMaxAirPressure** parameter. This is very simple and works for many locomotives, mainly diesel and electric locomotives.

However, my research has revealed that in the case of steam engines, the compressor governors are more elaborate, and some can even change the cut-in and cut-out pressures depending on the braking system status. Here is an analysis of several steam air compressor governor types and how they may be modeled in ORTS. I will only be sticking to the governors made by the Westinghouse Air Brake Company, as they are the most common in the US, but other makes of governors (such as New York) can be theoretically modeled in much the same fashion.

Analysis of Westinghouse Steam Compressor Governors

The "Type S" Single Top Governor

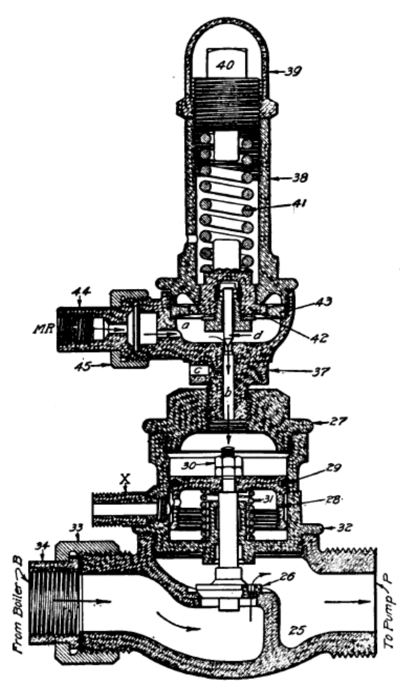

Fig. 13. Westinghouse Type "S" Single-Top Steam Compressor Governor Closed

Fig. 1: Westinghouse type S Single-Top Compressor Governor. Steam valve is in closed position.

The earliest governor Westinghouse introduced was the Type S. It was very simple in operation, using the main reservoir pressure to control the flow of steam to the compressor. During this time, the governor was set to"cut out" at 90 PSI, although the actual pressure used was dependent on the railroad's standard practice.

Theoretically, this type of governor is modeled in much the same manner as what we currently have with the **AirBrakesCompressorRestartPressure** and **AirBrakesMainMaxAirPressure** parameters. However, there is a feature not currently modeled in ORTS that would add realism to the governor model.

The first is in the use of steam after the compressor has "cut out." Contrary to ORTS' current logic logic, the governor does not shut off the flow of steam to the compressor completely when it "cuts out" the compressor. Instead, the steam valve disk has a small orifice (number 26 in Fig. 1) drilled through it that, when the governor piston forces the valve disk to the "down" position against its seat, allows a small trickle of steam to flow to the compressor to keep it moving extremely slowly, or "idling". There are many reasons for doing this: 1) It ensures lubrication is still flowing into the compressor steam cylinders, 2) It prevents condensation from forming in the cylinders, 3) It prevents the compressor pistons form seizing up during cold weather, and 4) It allows the compressor to compensate for any leakage at the main reservoir or elsewhere within the air system. However, it doesn't run the compressor fast enough to exceed the maximum main reservoir pressure.

Currently in ORTS, the compressor uses 100% steam when "cut in" and 0% (or 0 lb/hr) when "cut out." To facilitate the aforementioned "idle" movement after the cut-out pressure is reached, the steam usage between the point where the compressor "cuts out" and when it's "cut in" again must be greater than 0 lb/hr. In most compressor governors, the main valve disk has an outer diameter of about 1 inch, while the orifice used to have the compressor "idle" is around 1/16" or 1/32". So the formula for determining the steam usage after the compressor has "cut out" will be:

Idle Steam Usage = Full Steam Usage * (1/16)

For example, if the compressor uses 1725 lb/hr at full speed, the steam usage at idle speed would be :

1725 lb/hr Full Steam Usage * (1/16) = 107.8125 lb/hr at Idle

Incidentally, the nature of the diaphragm and spring pressure sensors seems to dictate that, instead of there being a 5- or 10-pound difference between the cut-in and cut-out pressure, the difference is in the neighborhood of 1 pound or less.

The “Type SD” Dual Top or Duplex Governor

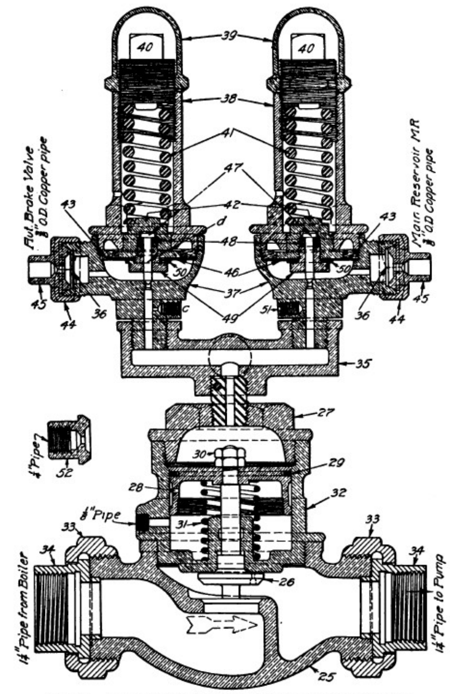

Fig. 15. Westinghouse Type "SD" Duplex Steam Compressor Governor Shown in Section

Fig. 2: Westinghouse Type SD Duplex Governor. Left top senses EQ reservoir/brake-pipe pressure when the train brake valve is in the "Running" position, right top senses main reservoir pressure at all times.

The type SD governor (Fig. 2) is similar in operation to the type S, except for the addition of a second “top” (spring/diaphragm valve assembly), and the two tops are connected to the same actuating cylinder by means of a Siamese or “Tee” fitting. The first governor top, known as the “high pressure” top, is connected to the main reservoir in much the same manner as previously described for the type S. The second governor top, known as the “low pressure” top, is connected to a port in the automatic (train) brake valve between the feed valve and the brake pipe. This arrangement allows the compressor to anticipate the demands upon the main reservoir by having an excess pressure stored to assist in releasing the brakes and charging the brake pipe on longer trains.

The pressures the tops are set to vary from railroad to railroad, but they are usually 90 PSI for the low-pressure top and 120 PSI for the high-pressure top. When the train brake valve is in the “Running” position, air from the brake pipe feed valve is sent to the low-pressure top, and therefore, when running over the road, the main reservoir pressure is held at 90 PSI. However, once the train brake valve is moved from the “Running” position to any other position, the supply of air from the feed valve to the low-pressure top is cut off, allowing the high-pressure top to take over, and increase the main reservoir pressure to 120 PSI.

It should be noted that ORTS' definition of “Running” is drastically different than Westinghouse's definition. Westinghouse defines the “Running” as the brakes being released, with the brake pipe held at the pressure determined by the feed valve. This state is analogous to what ORTS calls “Release”. ORTS thinks of “Running” as being a synonym for “LAP.”

To simulate this duplex method of control, new variables need to be added to the ***.eng** file on locomotives so equipped. Instead of using one **AirBrakesMainMaxAirPressure** parameter and one **AirBrakesCompressorRestartPressure** parameter, there needs to be two of each. These would be called **AirBrakesMainMaxHighAirPressure**, **AirBrakesMainMaxLowAirPressure**, **AirBrakesHighCompressorRestartPressure**, and **AirBrakesLowCompressorRestartPressure**, respectively. So, in terms of operation, the logic would be:

IF TrainBrakeNotch = Release, THEN:

AirBrakesCompressorRestartPressure = AirBrakesLowCompressorRestartPressure
AirBrakesMainMaxAirPressure = AirBrakesMainMaxLowAirPressure

ELSE:

AirBrakesCompressorRestartPressure = AirBrakesHighCompressorRestartPressure
AirBrakesMainMaxAirPressure = AirBrakesMainMaxHighAirPressure

So, therefore, if the **AirBrakesMainMaxHighAirPressure** is set to a value of 120 PSI, and **AirBrakesMainMaxLowAirPressure** is set to 90 PSI, the compressor will stop if the main reservoir pressure is 90 PSI with the Train Brake handle in the Release position, and at 120 PSI at all other times. Aside from this difference in operation, the governor operates exactly the same as previously described for the type S, including allowing the compressor to run at an “idle” speed when the maximum main reservoir pressure is reached.

The "Type SF" Duplex Governor

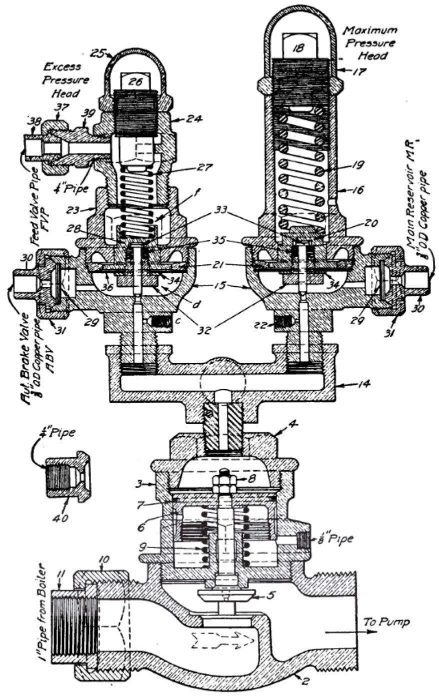

Fig. 16. Westinghouse Type "SF" Duplex Steam Compressor Governor Shown in Section

Fig. 3: The Westinghouse type SF Duplex Governor. The upper pipe on the left governor top is directly connected to the feed valve.

In the type SF governor (Fig. 3), the "Low-pressure" top from the type SD governor is now known as the "excess-pressure" top. This top has two pipe connections. The first, lower connection, is connected to the train brake valve between the feed valve and brake pipe in much the same manner as the low-pressure top on the type SD. The second, upper connection is connected directly to the feed-valve output pipe so that it is constantly charged with feed-valve pressure at all times. The goal was to maintain a fixed "excess" of main reservoir pressure over the brake pipe pressure with the train brake valve in the "running" position.

The high-pressure head was usually set to 120 PSI as before, and the excess-pressure head was usually set to 20 PSI. This means that with a maximum brake pipe pressure of 70 PSI, the exce3ss-pressure head would cut out the compressor at a main-reservoir pressure of 90 PSI.

Adding the variable **AirBrakesMainExcessAirPressure** may be added to simulate this type of governor. The logic for the governor would thus be:

IF TrainBrakeNotch = Release, THEN:

AirBrakesMainMaxAirPressure = (TrainBrakesControllerMaxSystemPressure +AirBrakesMainExcessAirPressure)

ELSE:

AirBrakesMainMaxAirPressure = AirBrakesMainMaxAirPressure

The “Type AD” Governor and “Type ADA” “Super Governor”

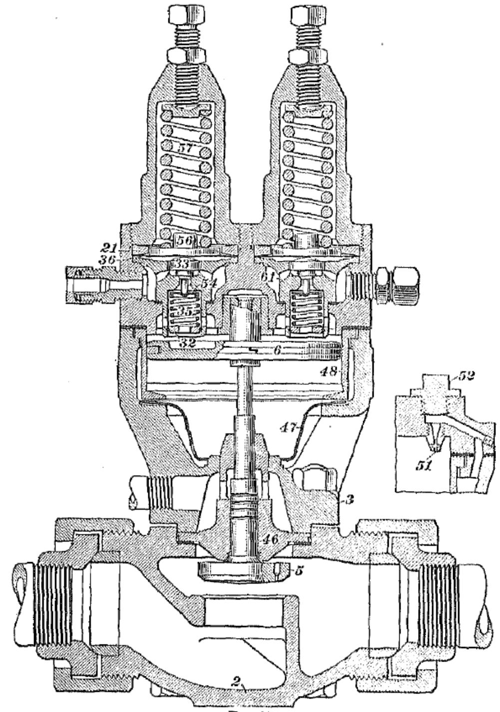

Fig. 34

Fig. 4: The Westinghouse type AD "Super Governor" was utilized on most latter-day US steam locomotives.

The type AD governor (Fig. 4) and the later type ADA, used with both the 6ET and 8ET equipment, and all brake equipment introduced thereafter, was introduced in the 1930s and resulted from the increased use of superheated instead of saturated steam to drive the locomotive air compressors. These changes necessitated the use of better materials to withstand the intense heat of the superheated steam.

The type AD governor is used with steam pressures of up to 275 PSI, while the type ADA can handle up to 500 PSI.

By this time, the maximum main reservoir pressure was semi-standardized at 130-140 PSI. The AD governors worked on a similar principle to the SD—the low-pressure top being used whenever the brake handle is in either “Release” (ORTS equivalent: Overcharge), “Running” (ORTS equivalent: “Release”) and either “Holding” (6ET, ORTS Equivalent: “Hold Engine”) or “First Service” (8ET, ORTS Equivalent: “Minimal Reduction” or “Slow Service.”). The high-pressure top is used when the brake handle is in either Lap, Service or Emergency.

The AD governor's operation is essentially analogous to that of the type SD. The logic would thus be:

IF TrainBrakeNotch = Release, OR
TrainBrakeNotch = Overcharge, OR
TrainBrakeNotch = Minimal Reduction, OR
TrainBrakeNotch = Hold Engine, OR
TrainBrakeNotch = Slow Service, THEN:

AirBrakesCompressorRestartPressure = AirBrakesLowCompressorRestartPressure

AirBrakesMainMaxAirPressure = AirBrakesMainMaxLowAirPressure

ELSE:

AirBrakesCompressorRestartPressure = AirBrakesHighCompressorRestartPressure
AirBrakesMainMaxAirPressure = AirBrakesMainMaxHighAirPressure

Westinghouse Automatic Compressor Steam Throttle Valve

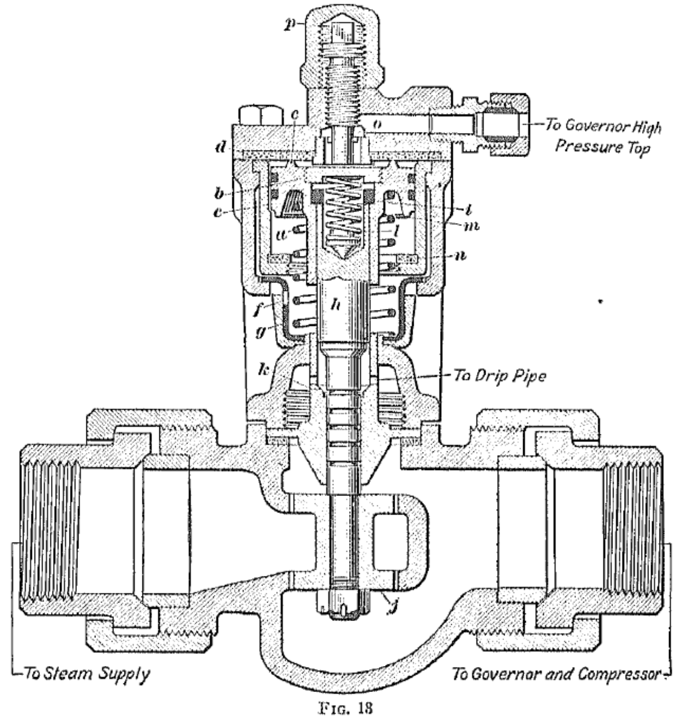

Fig. 5: The Westinghouse Automatic Compressor Steam Throttle was used in the 8ET and later systems to prevent the compressor from racing and wearing itself out when the main reservoir pressure is too low.

The Westinghouse Automatic Steam Throttle Valve (Fig. 5) was introduced with the 8ET and used on all brake systems thereafter until the end of steam in the US. It is placed in the steam supply line to the compressors just before the governor. When the main compressor steam throttle valve, located at the cab turret or further downstream, is wide open, the throttle valve allows a full flow of steam as long as the main reservoir pressure is high enough to provide a “cushion” for the compressor air pistons. However, in the event of a low-air condition that prevents this from happening (usually less than 40 PSI), such as when first starting the compressor during the firing-up process, the throttle valve reduces the flow of steam even if the main compressor throttle valve is fully open, eliminating any liability for damage to the compressor cylinder heads or pistons caused by racing when there is insufficient main reservoir pressure to cushion the compressor air pistons.

While it is highly unlikely that ORTS would allow the main reservoir pressure to fall to such a low level, this is something to keep in mind if there is any interest in modelling it.

The Type AF Governor

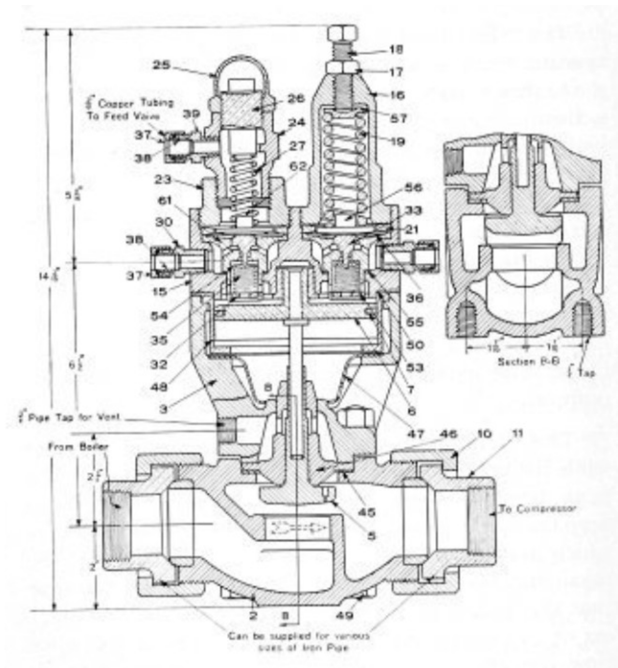

Fig. 4. Sectional View of Type "AF" Compressor Governor

Fig. 6: The type AF governor is the modernized, superheated equivalent of the type SF (see Fig. 3).

The type AF, was introduced alongside the AD and is similar in that it can handle the higher pressures and temperatures associated with superheated steam, but functionally it is equivalent to the type SF, with its fixed-excess-pressure functionality. The logic for this governor would be:

IF TrainBrakeNotch = Release, OR
TrainBrakeNotch = Overcharge, OR
TrainBrakeNotch = Minimal Reduction, OR
TrainBrakeNotch = Hold Engine, OR
TrainBrakeNotch = Slow Service, THEN:

AirBrakesMainMaxAirPressure = (TrainBrakesControllerMaxSystemPressure +AirBrakesMainExcessAirPressure)

ELSE:

AirBrakesMainMaxAirPressure = AirBrakesMainMaxAirPressure

Further Reading

Harding, JW, *ICS Textbook No. 515D: No. 6 and No. 8 ET Brake Equipment*
Scranton, PA, International Textbook Company, 1942.

ICS Staff, *ICS Textbook No. 514B: Compressors and Brake Equipment*
Scranton, PA, International Textbook Company, 1935.

Ludy, Llewellyn V, *Air Brakes: An Up-to-Date Treatise on the Westinghouse Air Brake as Designed for Passenger and Freight Service And for Electric Cars, With Rules For Care and Operation.*
Chicago, American Technical Society, 1918.

Instruction Pamphlet No. 5032-1: No. 8 ET Locomotive Brake Equipment
Pittsburgh, Westinghouse Air Brake Co, 1938.