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The ~~Two~~ Minute Solutionizer

Storage part 2 – Storage and Compressor Efficiency

The last Two-Minute Solutionizer addressed the subject of sizing the receiver to protect the customer's productivity, following a failure of the base compressor. We will now address the impact of storage and compressor efficiency.

For years the way manufacturers have illustrated compressed air efficiency at part loads has been a point of contention. As different control modes have been developed and introduced the debate as raged. What has consistently been missing is the effect of system storage on compressor efficiency. Armed with this Solutionizer you will be able to explain to air users the effect that storage has on capacity controlled air compressors.

Figure 1 is the most often published graph. We have always said that on-line / off-line control is more efficient compared to modulation when you have a suitably sized air receiver. A variable speed driven compressor is even more efficient as the power is directly proportional to the capacity. What has not been made clear is the definition of a suitably sized air receiver.

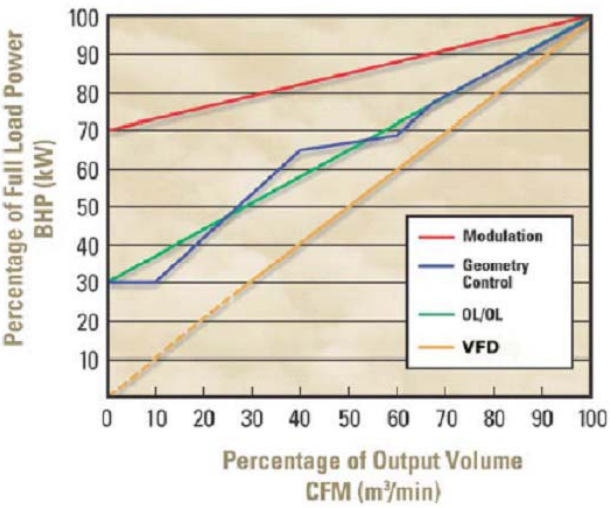


Figure 1: η with $\kappa = 10$

To understand how best to select the most appropriate sized air receiver we must understand the effect of k. The graph shown in figure 2 to shows how a different k value will effect the compressors efficiency.

K = 1 = 124 litres of storage per 1 m^3 of compressed air
K = 5 = 620 litres of storage per 1 m^3 of compressed air
K = 10 = 1240 litres of storage per 1 m^3 of compressed air

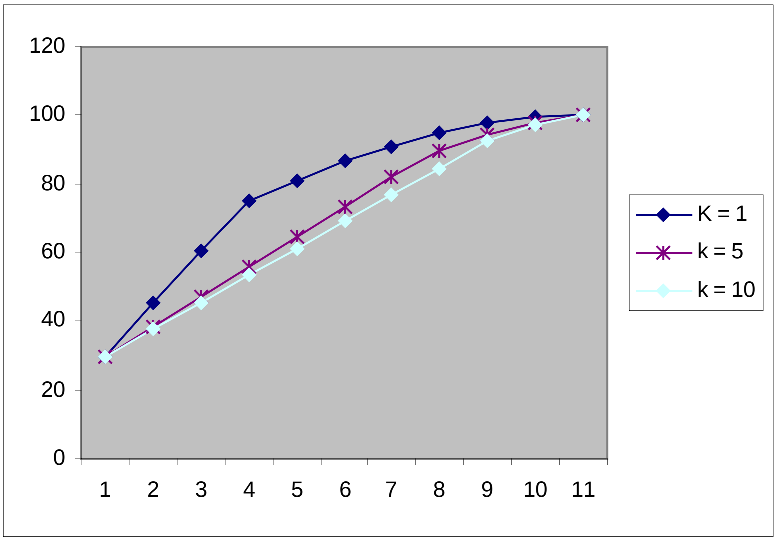


Figure 2 - Varying k and the effect on compressor efficiency

You will notice that the on-line / off-line curve shown in figure 1 is based on a k value of 10. When examining a compressed air system k equals 124 litres of storage per 1 m^3 of compressed air. When k is equal to 10 the storage is 1240 litres per 1 m^3 of compressed air. At the point where k = 10, effects of storage on compressor efficiency becomes negligible. As different k values are tested with control modes other than on-line / off-line the curves do not change. This is explained by the static position of the inlet control valve. As plant demand changes with a compressor control mode such as modulation the capacity control valve for the compressor changes incrementally, and therefore the effect of a varying k is small.

If the installation has a storage capacity of 2000 litres and the compressor volume is 12.7 m^3/min the k value would be 1.27.

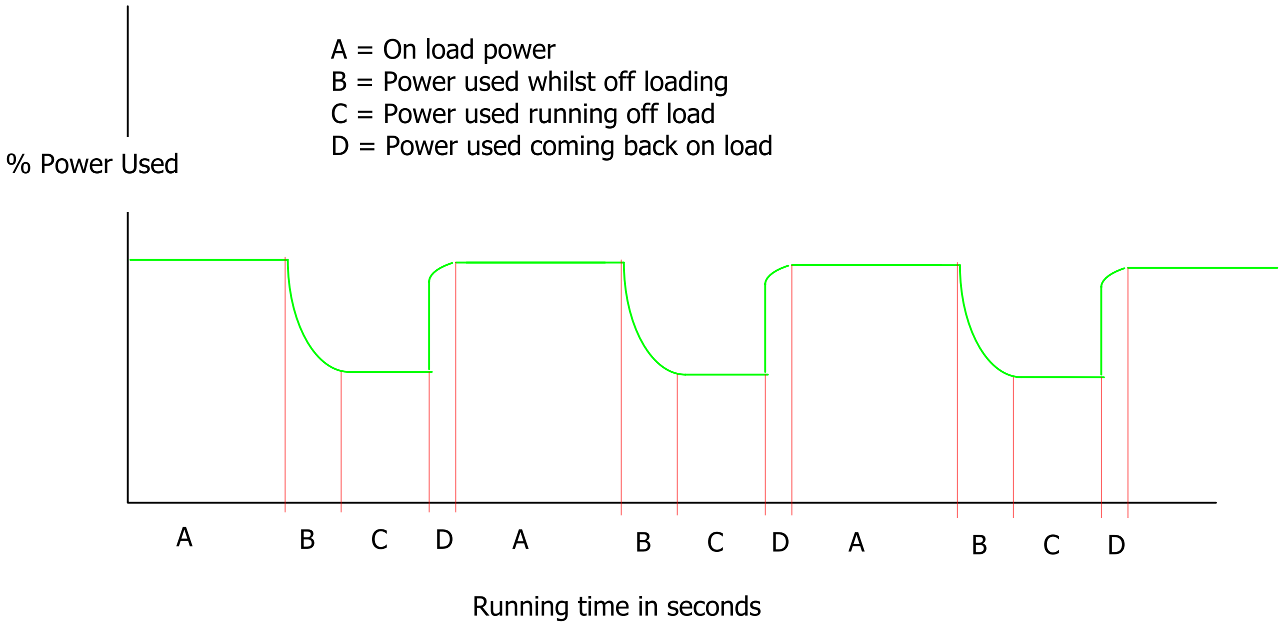
2000 litres / 12.7 m^3/min / 124 litres = k 1.27

The results are dramatically different when looking at a varying k with a compressor operating in on-line / off-line control. As k moves towards 1 the compressor efficiency degrades rapidly. The industry standard for the past 20 years as related to rotary screw compressors has been to install compressed air systems with a k = 1 believing that efficiency is not affected. What new research shows is that k = 10 will yield the efficiency results that are desired.

What causes the fall off in efficiency is the rapid movement of the capacity control valve where k approaches one. As k approaches one the duty cycle of the compressor moves away from 100% fully utilised, the capacity control valve is forced to open and close as the plant air changes. This in effect is the duty cycle of the compressor. So what happens when a compressor cycles?

When the compressor reaches its off load pressure set point the inlet valve closes, load solenoid de-energises and the blow-down solenoid is energised. The compressor then blows down to an unloaded sump pressure which is just under 2-barg. This blow-down is regulated through a fixed orifice. At the point at which the compressor is fully unloaded is where the compressor manufacturer will declare the off load power. The unloaded power varies from machine to machine and manufacturer to manufacturer but is normally stated at around 25-30% of full load power. It is not unusual for a compressor to take 15 seconds to reach its declared off load power. Some manufacturers that use large separator tanks and unload into the inlet of the airend using small orifices, take much longer to unload. Therefore if you measure the power during unloading this can be as much as if it was fully loaded. In reality a compressor that cycles frequently will never reach its unloaded power as it takes several seconds to off-load.

The below illustration represents the power consumed by the compressor, shown by the green line at various stages of the loading cycle.



Each time the capacity control valve is then forced to open by the duty cycle of the compressor, the compressor experiences an in-rush of current to achieve the increased torque requirements of the compressor motor. With $\kappa = 1$ and a duty cycle less than 100%, the in-rush effect of the capacity control valves rapid cycling causes the compressor efficiency η to degrade.

Figure 3 below illustrates the end effect of allowing $\kappa = 1$. Comparing the on-line / off-line control methodology to other traditional control modes, illustrates the loss of efficiency of installing compressed air system storage at traditional levels. Either more storage must be added, or compressors with alternate control methodology must be installed to achieve peak efficiency at full load.

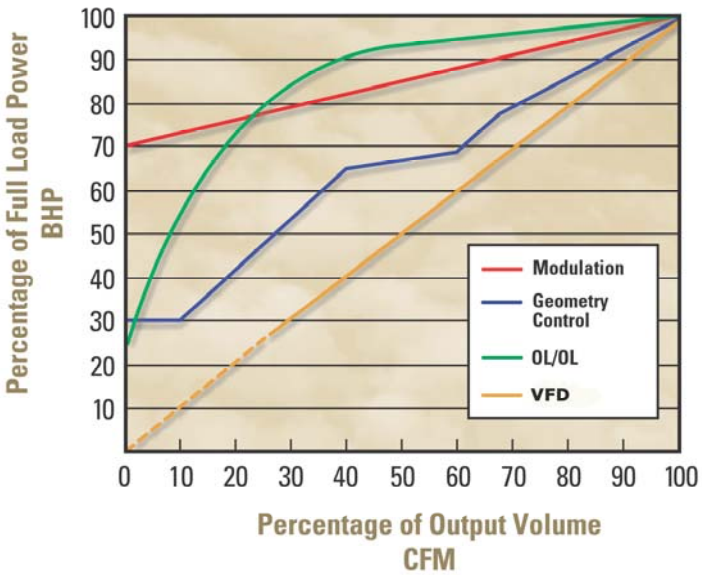


Figure 2: η with $\kappa = 1$

To help you determine the effect of k in your compressed air systems use the table shown in figure 4. This is based on a 9-second blow down and a 0.5 barg load and unload differential. Decreasing or increasing the differential will affect the power drawn.

Figure 4 - Based upon 9 seconds to reach off-load condition

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
K value											
1	30	45.22	60.44	75.09	81.16	86.55	91.15	94.9	97.68	99.42	100
2	30	41.11	52.22	63.33	74.44	82.88	87.94	92.47	96.25	98.94	100
3	30	39.74	49.48	59.22	68.96	78.7	86.31	91.07	95.3	98.57	100
4	30	39.05	48.11	57.16	66.22	75.27	84.33	90.17	94.62	98.26	100
5	30	38.64	47.29	55.93	64.58	73.22	81.86	89.54	94.11	98	100
6	30	38.37	46.74	55.11	63.48	71.85	80.22	88.59	93.72	97.79	100
7	30	38.17	46.35	54.52	62.7	70.87	79.05	87.22	93.41	97.61	100
8	30	38.03	46.05	54.08	62.11	70.14	78.16	86.19	93.15	97.45	100
9	30	37.91	45.83	53.74	61.65	69.57	77.48	85.39	92.94	97.31	100
10	30	37.82	45.64	53.47	61.29	69.11	76.93	84.75	92.58	97.19	100

For example, using a small receiver where k=1 the compressor would consume 75.09 % of full load power whilst operating at 30% load. (70% unloaded)

For more information on this subject please contact your Pit Crew Support.

What this show's up more than ever is the saving potential with Nirvana as the trim compressor and that a fixed speed compressor only operates efficiently at 100%.

Do you realise Mr Customer that we can save you a considerable amount of energy by increasing the amount of your compressed air storage. By metering your air to the lowest possible demand side pressure using an Intelliflow we can reduce your artificial demand and leaks, which will make considerable energy savings. Talking low energy solutions with minimal capital investment will increase yours and your customer's profits as well as improving your customer's reliability and their productivity.

As a Solutionizer you can offer your customer a double whammy, avoiding loss in productivity in the event of a base compressor failure and energy savings.

<u>Glossary</u>
Demand side – outside the compressor room into the plant.