USING KPI'S FOR PEAK EFFICIENCY

By Ron Marshall for the Compressed Air Challenge®

For many industrial sites the only indicator of compressed air performance is the big old pressure gauge right outside the maintenance manager's office. Over the years someone may have penciled a red line on the gauge, and if the pressure falls below the line the manager will start shouting. This is an example of the saying "What gets measured, gets managed", definitely the plant pressure in a facility is a very important indicator of adequate compressed air system operation, but is it the only parameter that needs to be monitored? This article explores some important compressed air KPI's and provides some examples of how they can be collected and used.

What are KPI's

Key Performance Indicators are widely used in business and finance to track important aspects of the performance of something. They can be defined as "A set of quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their strategic and operational goals. KPIs vary between companies and industries, depending on their priorities or performance criteria." (Source Investopedia.com). As business processes get leaner and input costs get higher it has become more and more important to keep track of how important parts of your business are performing.

A compressed air system is no different than any other cost center in an organization, its performance has an impact on production quality, plant efficiency, operating costs and ultimately profitability. Proper attention to the key aspects of the compressed air system can go a long way in solving production problems and reducing waste. Recent advances in the quality, availability and affordability of data collection equipment has made the monitoring of key compressed air performance indicators (KPI's) even more possible now than ever before.

How KPI's can be used

The collection and analysis of key performance indicators is important to ensuring efficient and effective performance of a system. Some uses of KPI's with regard to energy and system performance:

- Determining system efficiency and setting a baseline before improvement projects are started
- Helping justify improvement projects and providing data to receive utility incentives
- Proving the results of improvement projects
- Ensuring the savings gained from projects are maintained
- Monitoring the levels of waste and triggering corrective actions
- Detecting impending operational and equipment performance problems

Compressed Air KPI's

With regard to the performance of compressed air powered compressed air equipment the most important indicator is definitely system pressure. But other aspects of the system are important as well. Knowing the cost of producing the air is important too, especially with rising electricity rates. This means the power consumption of compressors and associated equipment is an important factor. So too is a measurement of the compressed air flow produced by the air production equipment.

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Once power input and output flow are measured system specific power can be calculated which is an indicator of how efficiently your equipment produces air for a given energy unit input. And also important, the compressed air must be produced to an adequate level of quality with regard to contaminants and water content (dewpoint) in order to keep air powered machines operating without problems and to keep product from becoming contaminated.

There are other less common performance indicators that are important to keep up on, like ambient and compressed air discharge temperature, compressed air leakage and in some cases the compressed air cost per unit production.

Pressure

The red line drawn on the gauge at the manager's office was one example of the use of pressure monitoring to trigger action. But low plant pressure is not the only pressure related indicator important to system performance. Since screw compressor power consumption increases ½ % with each psi in discharge pressure, and unregulated compressed air flows increase by almost 1% for every psi, the manager should also be concerned about having average pressure levels that are too high. And, although it seems like he is always at his desk, he may not be attentive enough to know or around during the times where the system goes unstable due to control problems and causes production shutdowns.

Pressure differential measurements across filters and air dryers is also an important indicator of system efficiency and is a maintenance related condition.

If the plant has a pressure/flow controller the plant pressure may not be a true indicator of the pressure at which the compressed air is actually being produced. For these reasons it is important to monitor discharge pressure, pressure after the cleanup equipment and one or more points within the plant.

Power

Compressed air production equipment power consumption is the least commonly measured parameter in a compressed air system. With the exception of flow and power, the local instrumentation on typical air compressors provides all other important parameters. The actual power

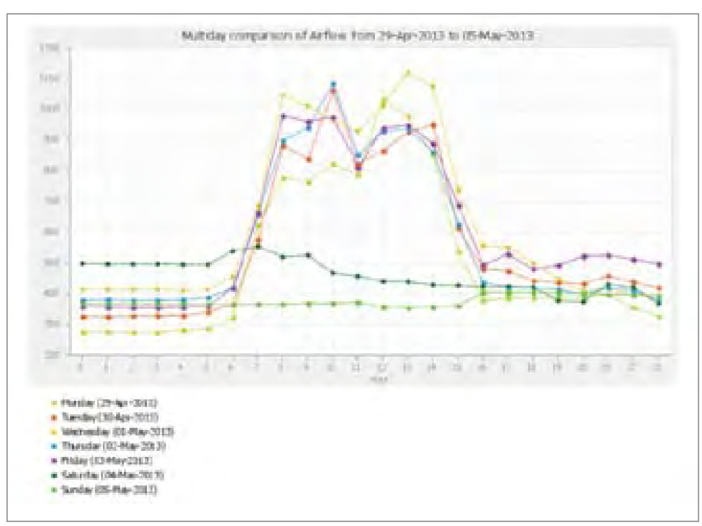

Chart A — Attention to flows during non production times can help track waste. (Source Air Power Analytics)

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consumption of a compressor is often a complete surprise to the system operator. For example a recent measurement revealed a set of 55 kW rated air-cooled screw compressors at an industrial site were consuming 70 kW each at full load and rated pressure. Still another 75 kW compressor was consuming 92 kW under the same conditions, and was consuming far more power than rated in the unloaded condition. This information was very useful to the customer as they previously assumed that the units would be consuming no more than nameplate rating like other similar electrical equipment.

Installation of power measurement meters on each air compressor and dryer can be used to calculate the electrical operating cost of the system and to detect system problems. These readings can be used in conjunction with flow measurement to keep track of system efficiency in terms of specific power.

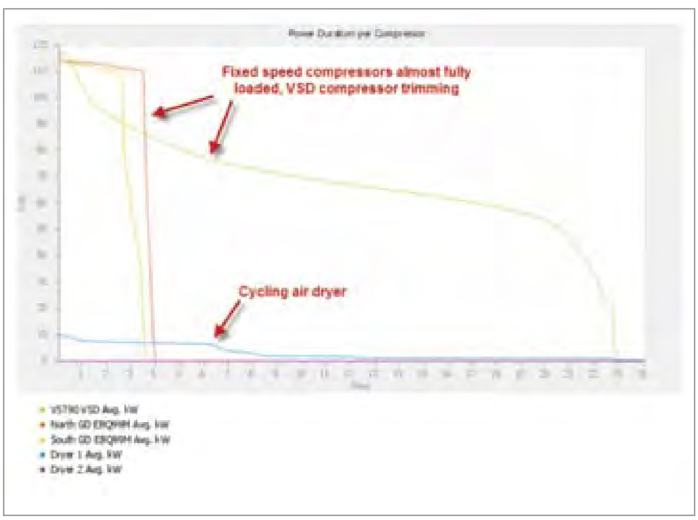

Chart 2 — Power duration (power sorted highest to lowest) shows compressors and dryers operating efficiently. (Source Air Power Analytics)

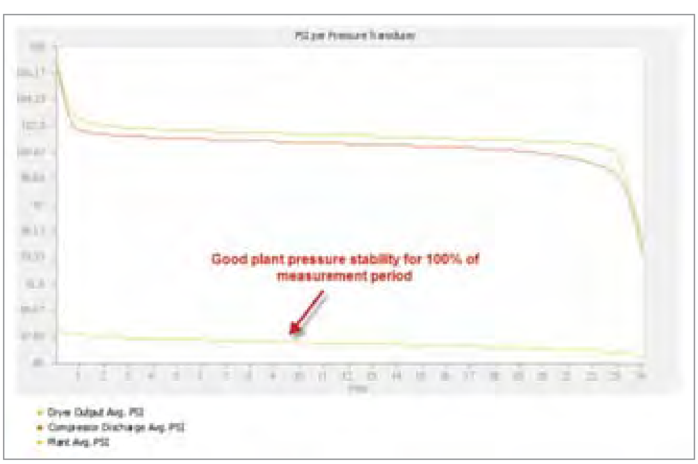

Chart 3 — Pressure readings sorted highest to lowest shows good pressure stability. (Source Air Power Analytics)

The use of energy meters that record energy (kWh) is also desirable as the readouts of these meters can be useful even if a system does not log kW or if the logging system fails at some points.

Flow

The measurement and logging of compressed air flow is very important to ensuring a compressed air system is performing efficiently. It is often very difficult to accurately estimate the amount of compressed air a particular compressor is producing, especially units that modulate, blow off or have complex variable capacity controls. In the past the measurement of flow was an inaccurate and very expensive exercise. But recent changes to flow measurement technology has made thermal mass flow measurement very affordable and very easy to install for any organization, even for small systems.

Flow measurement can track other items besides compressor output. The performance of air dryers that consume purge air or nitrogen systems that consume compressed air and output a smaller amount of nitrogen can be tracked using strategically located flow meters.

While the total accumulated air volume is important, the instantaneous flows tracked over time can reveal some system problems that can cause system performance deficiencies. For example, in a shift oriented plant with minimal weekend production the air flow at midnight on a Saturday might be a good indicator of system waste due to leakage and abandoned production machinery left to consume air when the machine is turned off.

Dewpoint

Tracking the dewpoint of compressed air is a good way of ensuring the air drying equipment is operating normally and that the quality of the compressed air is at required levels. Tracking dew point over time can reveal transient problems related to higher than desired dryer inlet temperatures or the impending failure of the dryer onboard dryer control system.

Specific Power

In the past few years most compressor manufacturers in North America have been publishing CAGI data sheets relating to the efficiency of rotary screw compressors. These data sheets are very helpful in determining what an air compressor system should be consuming if it is operating efficiently. For example, a large air-cooled rotary screw compressor might be rated at a specific power of 18 kW per 100 cfm of air output. Measurement instruments might detect a system using a number of these compressors as having an average power consumption of 435 kW while producing an average of 1500 cfm of compressed air. Doing the math on this reveals a specific power of 29 kW per 100 cfm which compared to the rated specific power might suggest some issues with compressor control, and some good potential for energy savings.

Leakage

But a specific power is not always completely relevant if the appropriateness of the compressed air usage is not known. A super efficient system could be producing low cost compressed air for a facility that is wasting 50% or more of the output due to system leaks. Often compressed air reading can be taken to determine flows at specific times of the week. If it is known that the flow at that particular time is only compressed air waste then this can be tracked and trigger points set. Once a threshold is exceeded leak repair efforts can be initiated by maintenance.

Temperature

Often air quality problems due to water condensation are not the result of the failure of the dryer but due to excessive compressor room temperatures leading to higher than desired discharge temperatures. Monitoring ambient temperatures and compressed air temperatures is desired if this is a continual problem for a system.

Annual Carbon Emissions

Knowing the energy consumption of the system and the characteristics of your power provider can allow you to calculate and track your equivalent annual carbon emissions and your savings if improvements are made. This may be an important parameter for your corporate energy management personnel to track.

DAILY AVERAGE CFM CONSUMPTION BASED ON 7 DAY TOTAL								
% OF MAX. CFM	HOURS	AVERAGE CFM	AVERAGE KW	SPECIFIC POWER	DAILY KWH	DAILY COST	ANNUAL KWH	ANNUAL COST
70	0.1	1,286.37	219.81	17.09	21.98	$1.19	7,693	$415
65	0.2	1,183.84	212.95	17.99	42.59	$2.30	14,907	$805
60	0.5	1,109.92	204.09	18.39	102.05	$5.51	35,716	$1,929
55	1.0	1,021.13	188.80	18.49	188.80	$10.19	66,079	$3,568
50	1.3	930.60	178.42	19.17	231.95	$12.53	81,183	$4,384
45	1.3	843.07	168.96	20.04	219.65	$11.86	76,877	$4,151
40	0.9	750.75	155.83	20.76	140.24	$7.57	49,085	$2,651
35	0.8	648.55	121.19	18.69	96.95	$5.24	33,933	$1,832
30	2.0	551.67	93.26	16.91	186.53	$10.07	65,285	$3,525
25	5.7	460.06	77.72	16.89	443.00	$23.92	155,051	$8,373
20	7.4	373.21	70.87	18.99	524.41	$28.32	183,543	$9,911
15	2.5	296.93	68.89	23.20	172.22	$9.30	60,277	$3,255
10	0.3	198.66	70.70	35.59	21.21	$1.15	7,423	$401
Totals	**24**	**530.54**	**99.66**	**18.78**	**2,391.58**	**$129.15**	**837,051**	**$45,201**
Annual carbon cost for 7-day period: 695 tons of CO^2. Leak load: 369 cfm								

Chart 4 — Table showing key performance indicators of a weekly sample of data. (Source Air Power Analytics)

Cost per production output

Often there are production related KPI's being tracked in a plant. It is sometimes useful to see how compressed air costs track seasonal and/or production level variations. These numbers can be compared between similar factories in companies with multiple production facilities. Often some outliers are detected where one factory is consuming considerably more compressed air costs that other similar plants, or in some cases considerably less. This can drive innovation across the corporation if one or more efficiency changes can be replicated across all production facilities.

Example System

Manitoba Hydro has implemented some permanent compressed air efficiency monitoring installations in a number of large facilities that have received significant utility incentives to support efficiency projects in the last 10 years. This was done to ensure the

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SAMPLE PERIOD COMPARISON FOR SUPPLY NEW COMP PACKAGE BASED ON 7-DAY TOTAL									
SAMPLE PERIOD	START DATE	AVERAGE CFM	DAILY KWH	DAILY COST	ANNUAL KWH	ANNUAL COST	SPECIFIC POWER	LEAK LOAD (CFM)	ANNUAL CO_2 EMISSIONS
Aug 30-Sep 5, 2012	08/30/2012	638	3,163.04	$170.83	1,107,065	$59,782	20.65	451.5	833,575 kg
Sep 4-10, 2012	09/04/2012	714	3,636.24	$196.36	1,272,685	$68,725	21.16	552.0	958,280 kg
Sep 11-17, 2012	09/11/2012	662	3,381.41	$182.60	1,183,492	$63,909	21.19	448.5	891,121 kg
Sep 17-23, 2012	09/17/2012	639	3,453.89	$186.53	1,208,862	$65,279	22.53	412.5	910,224 kg
Sep 25-Oct 1, 2012	09/25/2012	795	3,714.23	$200.56	1,299,979	$70,199	19.41	502.5	978,831 kg
Mar 04-10, 2013	03/04/2013	506	2,406.47	$129.95	842,264	$45,482	19.82	326.9	634,190 kg
Mar 11-17, 2013	03/11/2013	519	2,496.87	$134.82	873,903	$47,191	19.99	372.6	658,014 kg
Mar 18-24, 2013	03/18/2013	503	2,434.42	$131.47	852,047	$46,011	20.16	338.2	641,557 kg
Mar 25-31, 2013	03/25/2013	458	2,122.76	$114.63	742,966	$40,120	19.33	285.7	559,423 kg
Apr 01-07, 2013	04/01/2013	527	2,355.77	$127.19	824,520	$44,524	18.61	327.1	620,830 kg
Apr 08-14, 2013	04/08/2013	546	2,507.74	$135.41	877,707	$47,396	19.14	388.0	660,878 kg
Apr 15-21, 2013	04/15/2013	518	2,308.09	$124.64	807,833	$43,623	18.58	314.4	608,265 kg
Apr 26-May 02, 2013	04/26/2013	499	2,609.83	$140.94	913,441	$49,326	21.80	316.4	687,784 kg
Apr 29-May 05, 2013	04/29/2013	531	2,391.58	$129.15	837,051	$45,201	18.78	368.6	630,266 kg
May 06-12, 2013	05/06/2013	549	2,473.53	$133.57	865,736	$46,750	18.78	366.8	651,864 kg

Chart 5 — Comparison chart showing key performance indicators for selected weeks showing efficiency and leakage improvement. (Source Air Power Analytics)

ongoing sustainability of the project savings, especially where compressor control systems or leakage management was part of the efficiency measures.

One example system is from a transportation products manufacturer who upgraded their system from a system of four load/unload screw compressors to a system using two fixed speed compressors and one VSD controlled compressor. Power monitors were placed on each compressor and two air dryers. Pressure monitors were installed to measure compressor discharge, air dryer output and the output of the pressure/flow controller. A flow monitor measures total plant flow.

Data is collected by a dedicated measurement system uploading the data to a cloud database. Weekly reports are then generated that show the KPI's of the system in an understandable format available without further processing.

Chart A is an example of the air flow comparisons on a weekly basis. The subsequent charts and tables show efficiency related parameters that can be used to determine if the system is operating normally and how it compares week on week.

Energy Management Systems Certification

Those plants wanting to meet the ISO 50001 Energy Management Systems certification may require some sort of monitoring of their compressed air system if it is a significant energy user. Permanent systems can be used for both baselining and verification of projects. Temporary system installed by qualified compressed air system auditors following the ANSI EA-4 Compressed Air Assessment standard may also provide adequate indication of a system's KPI's.

KPI's without installing instruments

If budgets are tight and you can't afford instrumentation or qualified experts, in some cases, measurement and calculation of key performance indicators can be done manually using the available instrumentation. Compressor outputs can be estimated using loaded and unload hours if the hours are logged by personnel on a regular basis.

Using compressor ratings the approximate power and flow can be calculated, and an approximate specific power. Additional manual measurements can be made using a stopwatch during off production hours to assess leakage levels. As long as the personnel know at what level action needs to be initiated this can serve as an excellent tracking system.

Also, some compressor control systems have internal calculation algorithms that can calculate KPI's and generate reports to track the health of your system.

In general keeping track of the key compressed air system performance indicators is a good way of making sure you are aware of how well your system is operating. Have a look at your parameters and assess if it is worthwhile to initiate improvement measures to reduce your operating costs and improve system parameters. BP

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