Designing and Building a Machine for Energy Conservation (and Convincing a Customer it is Worth it)

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In cooperation with

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The Cost of Air

- Compressed air provides the energy needed to do work, it is the power behind the muscles – cylinders, rotary actuators, etc. on a machine.
- What does it cost?
  - As compressed air is derived from the power fed to electric motors, the cost to produce compressed air is the utility rate plus the delivery charge plus the cost of maintaining the compressors and the delivery system to each machine.
  - Also add in the cost of leaks in the delivery system.
  - And leaks on each machine
  - And inefficient pneumatic designs on the machines
  - And…..
- Data in this report is based on 3.5:1 CFM/bhp ratio, $0.10kW/hr electric cost, 8,760 hr/yr operation and 90% average motor efficiency.

Energy Optimized Design

- This presentation is focused on those costs associated with machine design; over pressurization and leaks on a machine as well as other improvements to reduce energy usage.
- In collaboration with SMC Corporation of America, a study was performed on existing designs for a case packer and what the cost savings are for an optimized design. Data was also collected for brand new machines and nearly identical machines that had been operating in the field to analyze the effects of leaks and improperly adjusted pressure and flow devices.

Existing design

- Design practices for pneumatic systems on equipment is based on traditional methods.
  - Size the lines based on machine cycles, length of lines, etc. and then add a ‘fudge factor’ to avoid any issues. “I know that if I use 3/8” line there will be enough…”.
  - Assume any leaks that may occur on the system will be corrected by maintenance in a timely fashion.
  - Size the air cylinders with a factor of safety to ensure enough force is available for the task.
- Yes, the system will work but it will use more air and cost more to operate.

Improved Design

- Apply engineering techniques to ensure:
  - Line diameter and length is sized correctly for the task
  - Flow rates are optimized and are controlled
  - Cylinders bore and stroke are sized for the application
  - Pressure is controlled overall and at point of use
  - A leak detection system is added to ensure leaks are addressed in a timely fashion
  - A simple slow start pressure valve is added on the main to shut air down to machine during down times

Line Size and Length

- Line size or diameter
  - Increased diameter enables greater flow but it consumes more air, it is volume that does no work when pressurized.
- Line Length
  - Longer lines have increased pressure drop (loss) and again add volume that must be pressurized.
- Solution: Analyze flow and pressure required for each device. Distribute valve manifolds on machine for optimal air usage by keeping line size and length minimized. Utilize vendor sizing programs as aid to select right size components.

Line Size and Length

- Over sizing or over extending tubing adds volume that needs to be filled each time the cylinder actuates. What is the cost of excessive sized tubing?

Right Sizing Line Diameter – Example 4cylinder Simple machine		
	3/8" line	1/4" Line
Operating Pressure	50	50
Bore (inch)	3	3
Stroke (inch)	3.41	3.41
# of cylinders	4	4
Line Length (inch)	96	96
Tubing I.D. (inch)	0.25	0.16
# of elbow fittings	2	2
Rate: Cycle Time (sec)	1.5	1.5
CFM Required	24	19.86
Annual Cost of Operation	$ 4,979	$ 4,120
ANNUAL SAVINGS		**$ 859**

For the case packer, the savings is a reduction in flow of 4.14CFM or 17.3%.

Flow Setting

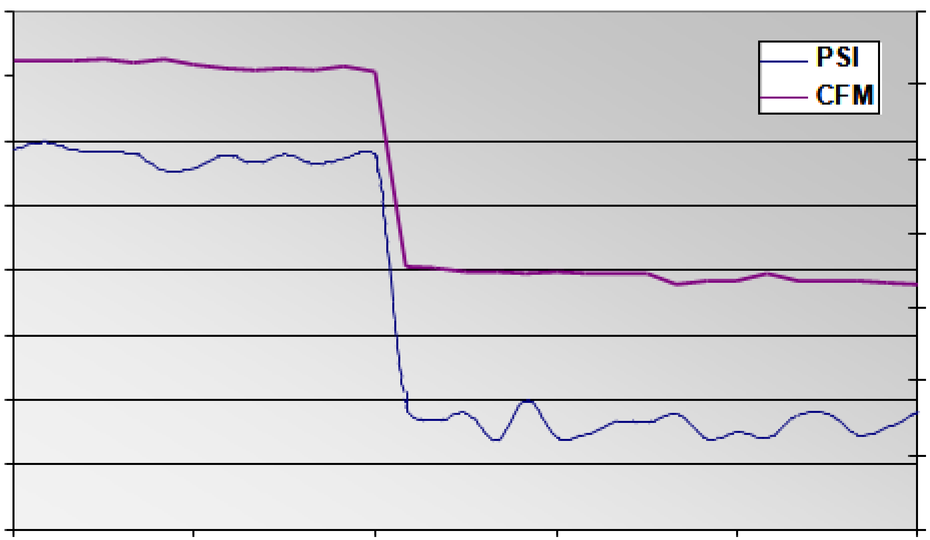
- In general, increased flow will result in increased motion speeds.
- But in a machine it does not make sense to increase the speed of mechanisms if they then must wait for something else to happen.
  - Results in increased wear and tear and will contribute to leak potential, jams and defective product.
- Solution: Set flow to optimal and use tamper resistant flow controls or fixed orifices to control mechanism speed.
  - A mechanism running faster than required may not generate greater machine throughput, but instead, it will likely decrease.

Pressure Control

- Over pressurization is a large contributor to cost
  - Higher stress on mechanisms resulting in increased wear and tear and increased potential to develop leaks.
  - Higher pressure requires more cost to produce.
- Solution: Regulate pressure (use locking type), use easy to see gauges, shut machine down on BOTH under and over pressure.
  - Overall Machine - If the machine is designed for 60psi, why run it at 90psi?
  - Point regulation – If the return stroke is not doing work, run the return at a lower pressure.

Pressure Control

- As shown in the chart below, flow and pressure function in a very linear fashion. As the supply pressure is decreased, we see that flow decreases proportionally.

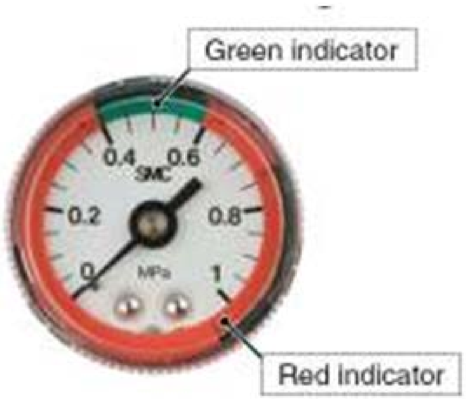


Statistics 100 PSI			
	Average	Minimum	Maximum
PSI	98.82	97.78	100.00
CFM	71.40	70.96	71.78

Statistics 80 PSI			
	Average	Minimum	Maximum
PSI	78.24	76.89	80.00
CFM	57.10	56.59	57.75

A general rule of thumb that for every 2 PSI of pressure a machine is reduced, 1% of the required brake horsepower (BHP) is conserved. In this case, the annual savings is $520. ***TURNING UP THE PRESSURE NEVER HELPS THE PROCESS, IT ONLY COSTS YOU MONEY.*** Also if only a few machines in your plant require higher operating pressure, consider running at a lower pressure and use boosters on those machines.

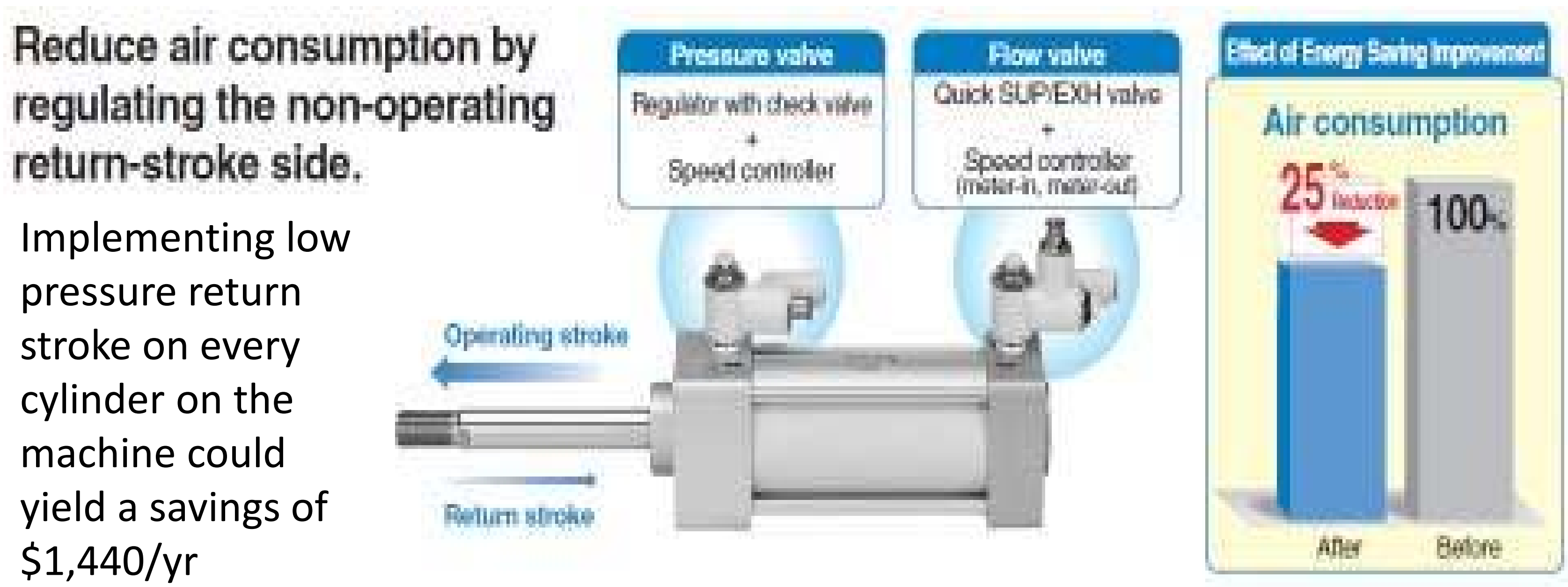
Pressure Control



- Courtesy of SMC

Pressure Control

- Limit pressure on return or non-working stroke of actuator.



Implementing low pressure return stroke on every cylinder on the machine could yield a savings of $1,440/yr

A typical savings of up to 25% per machine can be achieved. Image courtesy of SMC. SMC model ASR.

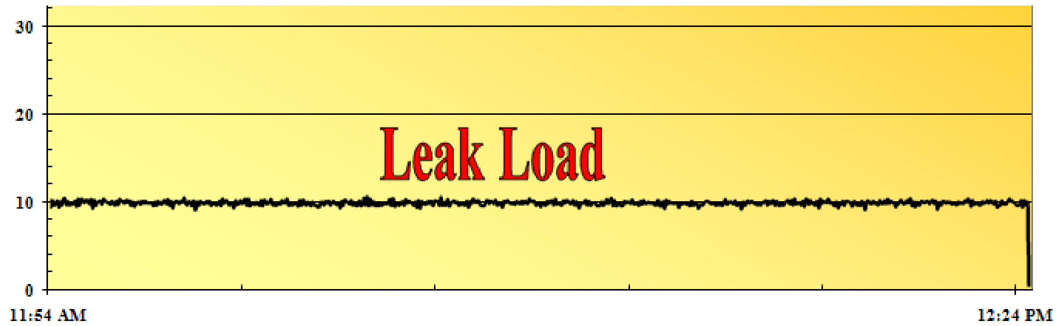
Leaks

PSSSSSSSSSSSSSS

- A large cost
  - It is truly money 'up in the air', like running your furnace with all the doors and windows open.
- Solution: Detect leaks and alert maintenance
  - Add a leak detection system. It monitors usage at idle times.
  - More sophisticated leak detection systems can help maintenance determine where the leak is, even to the exact point where the leak is.

Leaks PSSSSSSSSSSSSS

- Measured results for a machine with leaks

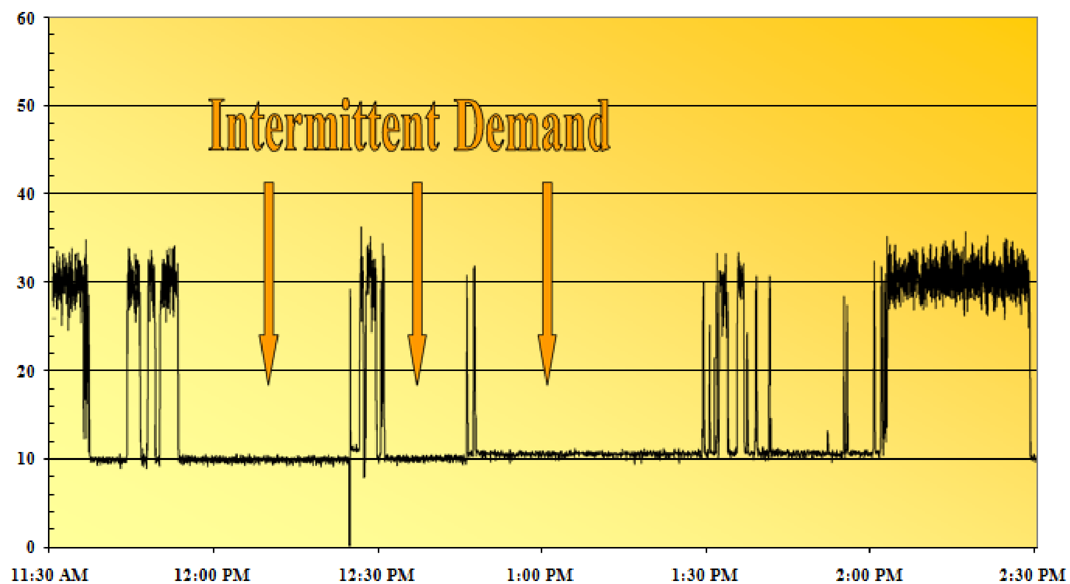


This is an example of the leak load on a case packer that had been in operation. Several leaks were found on the machine – worn cylinders, broken fittings, etc. The static flow seen on the chart is indicative of leaks and wasted air. While 10 CFM may not seem like much, it is over 35% of this case packers average flow which is normally 27. 9 CFM.

10 CFM or $2,074 annually per machine – that over 1/3 of the normal cost to operate the machine.

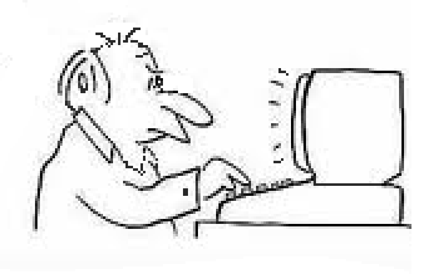
Intermittent Demand

- Intermittent demand is an issue in every facility and is one of the top ten wasteful uses of compressed air. If equipment is not in operation, then supplying compressed air is often not required. Even a very small hole blowing off a work piece can cost thousands of dollars per year in energy. Shutting off compressed air when equipment is not in operation will also isolate any potential air leaks. Also consider using high efficiency nozzles for blow offs, drying, or cooling applications.



Is it worth it?

- It does take extra engineering effort (cost) to do such a detailed design to optimize for conservation of energy.



- Also, there can be more components on the system, increasing material costs.
- Let's look at a real world example
  - Case Packer 1 using 'standard' design methods.
  - Case packer 2 - identical to case packer 1 but with an optimized design.

Results

- Based on the measured results of 2 new machines at our facility and 2 used machines in production for about 2 years, SMC made several recommendations to reduce energy usage.
  - Add flow meter on main air line and continuously monitor flow to look for leaks during machine idle times. Optional system can be added with additional logic to pinpoint leaks at the source.
  - Add dual set point switch to warn for both under AND over pressure conditions.
  - Use red/green indicator gauges at key regulation points so pressure set points are easily verified.
  - Add soft start valve in main line to shut off air at infeed during idle times.
  - Add point regulators to reduce pressure of return strokes for each actuator.
  - Use tamper resistant flow control valves.
  - Size tubing, cylinders and valves for that circuits' requirements.

Results

- Implementing SMC recommendations does add cost to the machine
  - Machine price adder: $ 7,900
- Estimated annual cost savings: $5,700
- Payback: 16 months - $57,000 savings over ten years
- One plant has 10 machines
- ***<u>$570,000</u>*** plant savings / 10 yrs

Conclusion

- Yes it is worth it!
- For machine builders, adding an enhanced energy saving option can become a differentiator to win a sale.
- For the customer, the added cost has a relatively short payback and provides improved sustainability and savings that payback year after year of operation.