Compressed Air as Energy Savings, Leak Survey and Recognizing Right Fittings to Show Cost Benefits

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***Abstract*—Energy savings being one of the most focused topics in every industry. Some leaks that are not obvious or visible has to be detected through technology with tedious work process. This study mainly focuses one of the specialty chemical production unit compressed air leaks through a continuously improving instruments and methods. These studies summarize conclusively that the best "overall" value a company can receive from tube fittings is by investing in higher quality, not by getting the lowest price. Add to this the fact that there are other fluid streams, besides compressed air, that are consumed at production facilities. These fluid streams (such as natural gas, nitrogen, or steam), due to their higher prices compared to compressed air, carry a significantly higher cost savings opportunity, and can more easily help justify standardizing on the highest quality tube fittings.**

***Index Terms*—Energy efficiency and intensity, smart manufacturing, process systems engineering, energy savings.**

I. Introduction

An Energy Survey in terms of air leaks in the entire unit was conducted at the mid-scale specialty chemical company. Not only are these leaks insidious in nature (24 hours a day, every day of the year), but substantially add to operating costs, promote fugitive emissions and adversely affect the environment. Six different types of fitting brands were recognized in this survey. For confidentiality purposes and to avoid any conflicting marketing intentions, the brand with top two users and results were named "Company A" and Company B" in this article. Results were presented along with recommendations in terms of potential cost savings and number of leaks generated throughout the unit. Commissioning of the survey & result analysis was done along with operations and management alike. SNOOP Liquid Leak Detector was used to locate leaks. The survey concentrated mostly ISBL (Inside Battery Limits) side of the unit. When leaks were discovered, they were identified by tube fitting size, number of ports tested, number of ports leaking, tube fitting brand and if they were tightened sufficiently. If the fittings were not repairable they were then tagged for future maintenance.

There were a total of 1306 tube fitting ports tested of which 126 leaks were identified. These leaks represented 9.6% of the total fittings tested. There were 6 brands of tube fittings identified during the survey. The Company B brand represented the largest number of fittings found in the currently running unit.

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857 Company B fittings were checked with 114 leaks for an average leak rate of 3.3%

336 Company A fittings were checked with 5 leaks for an average leak rate of 1.4%

81 Hamlet were checked with 2 leaks for an average leak rate of 2.4%

14 Hoke fittings was checked with 4 leaks for a leak rate of 28.5%

8 DK Lok fittings were checked with 1 leak for an average leak rate of 12.5%

4 SSP fittings were checked with 0 leaks for an average leak rate of 0%

Visual Leak Examples (in Fig. 1 and Fig. 2).

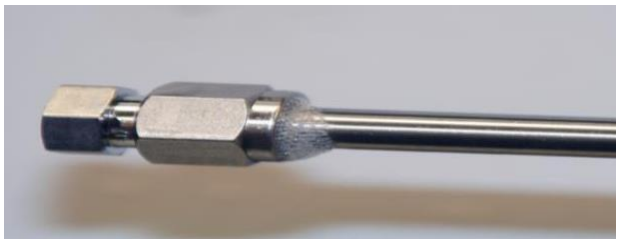

Fig. 1. Small leak checked with snoop® liquid leak detector.

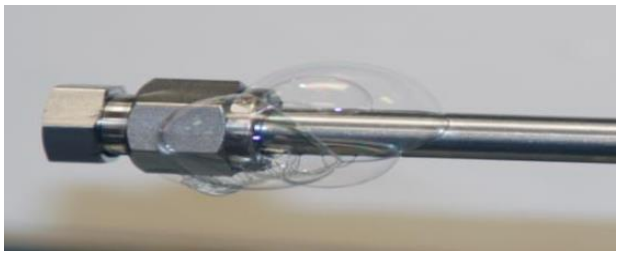

Fig. 2. Large leak checked with snoop® liquid leak detector.

Air leak loss and higher than normally required system air pressure lead to artificial demand. Now let's look at some formulas that will help us understand this concept a little better [1].

Values for pressures above 15 psig can be calculated by the following approximate formula by S.A. Moss [2].

$M = 0.5303 \times (A \times C \times P1) / \sqrt{T1}$

M = leak rate in lbs per second
A = area of leak in square inches
C = coefficient of flow
P1 = upstream total pressure in psia
T1 = upstream temperature in degrees Rankin (70 + 460 = 530)

Mass flows (M) are converted to volume flows (cu ft/min) by using a density factor of 14.7 psia, 70 ℉, 0% RH which is 0.07494 lbs/cu ft. Here is an example using a 1/8-inch air leak:

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A = πd2/4 = 3.14 x (0.125)2 / 4 = 0.0123 in2
C = coefficient of flow = 1
P1 = 100 psig = 114.7 psia
T1 = (70 + 460 = 530) square root of 530 = 23.0217

M = 0.5303 x (A x C x P1) / √T1
M = 0.5303 x (0.0123 x 1 x 114.7) / 23.0217
M = 0.0326 lb/sec Air at 70 ℉ and 14.7 psia weighs 0.07494 lb/cu ft (0.0326 lb/sec x 60 sec/min)/0.07494 lb/cu ft = 26.1 cu ft/min

II. Survey

Survey program has been reviewed and monitored through operations team and reviewed through Engineering due to concern for safety and performance. Leak survey conducted using SNOOP® or other appropriate, leak detectors. Certain conditions are met before the leak survey:

Area of plant selected where gas (not liquid) service is common - air - natural gas -hydrogen - helium, etc; so SNOOP can be used [3].

All fittings in a given area, regardless of brand, plus all small valve tube ends and packing must be tested, so that comparative results can be demonstrated.

Operations to identify fittings of other manufacturers visually, so that the results can be validated.

A group of 1086 different process installations are reported through this study.

TABLE I. Results of Comparison of Leak survey Through Different Companies Tube Fittings

Brand	Fittings Surveyed	Leaks	Percentage
Company A	333,162	5,000	1.50%
Interchange/Intermix	2,461	511	20.76%
Company B A-Lok	22,515	3,492	15.51%
Company B CPI	5,725	817	14.27%
Bi-Lok	1,037	147	14.18%
Gyrolok	10,117	697	6.89%

This data is not offered as test results that are scientifically valid or statistically significant.

Many variables are considered when comparing a product, i.e. price, performance, quality, availability, service, over-all cost effectiveness, etc.

These results correlate well with a study performed by Dr. Arthur Sterling of the Chemical Engineering Department at Louisiana State University in 1999 [4]. Dr. Sterling surveyed eleven industrial plants in the Louisiana area and determined that leaks were present in many areas of the plant. The average instrument air leak was 494 milliliters per minute. Using a cost of $0.40 per 1000 cubic feet of instrument air, the average fitting leak costs $0.31 per month.

While the 1.50% leak rate for Company A fittings seems high, it must be remembered that many Company A fittings are not installed according to standard practice or instructions. Poor installation practices, poor tubing, improper tubing or fitting selection - all these contribute to leak rates.

The purpose of the SNOOP leak survey is to check fitting performance as it currently exists in the plant. Corrective action can be implemented afterwards.

III. Results and Discussion

Tube fitting design differences (Tube Fitting Torque):

One of the leading reasons for tube fittings leakage is due to the amount of torque required to make-up different manufacturer's tube fittings. Studies conducted on the amount of torque required to make-up a tube fitting have shown that lower torque leads to two benefits [5]: 1) lower potential of failure due to installation error and, 2) less potential for galling, or seal failure. installation errors can occur when fittings are made-up by feel. With higher torque, fittings are more likely to be under-tightened and thus have a higher potential to leak. With lower torque required for assembly, there is less of a chance that the sealing surfaces will gall during fitting make-up, minimizing the potential for leaks. Fig. 3 shows the potential damages that can occur with false torque in the fittings.

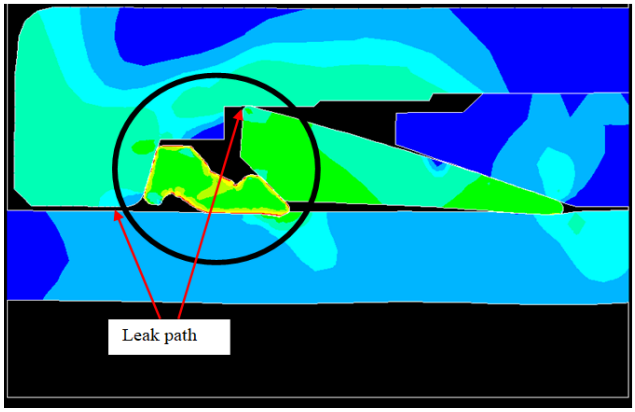

Fig. 3. Installation error: Leaking due to high torque.

A. Compressed AIR cost

Compressed air is one of the most expensive utilities that is necessary in production facilities to manufacture a final product [6], [7]. It is also the most common utility to be overlooked, as compressed air is considered by many plant personnel to be free or with no cost. The philosophy that compressed air is free makes it one of the most costly, wasted utilities that exist in facilities today. The good news is that compressed air system solutions are quite simple to establish.

Compressed air is probably the most expensive form of energy available in a plant. Using air efficiently is very important because, as a transfer of energy, it is basically inefficient. The typical overall efficiency is around 10%. For this reason, it is to any compressed air user's benefit to continually monitor, audit, and manage the basic efficiency of this highly expensive utility.

Power cost is very identifiable and any extra savings (or expenses) move directly to the bottom line. In today's real world, management wants to review the resultant savings on recovery for expenses such as efficient equipment, better piping, training and awareness programs, etc. If the identifiable power cost savings can offset these costs in the required time frame, the decision becomes easy.

There are many ways to define the cost of compressed air:

- Initial Price
- Depreciation
- Maintenance Cost
- Replacement Cost

What needs to be kept in mind is that the power cost-of-operation of a compressor can "equal or exceed" the initial cost of the unit, EVERY YEAR. Add to this the annual maintenance costs, which can be an additional 10% or more of the initial cost of the system.

Overall system efficiency is the key to maximum cost savings. Too often users are only concerned with initial cost and accept the low bid on a compressed air system, ignoring system efficiency. The same is true with tube fittings. Many compressed air system users neglect this area, thinking they are saving money, but end up spending much more in energy and maintenance costs. Too many decisions regarding compressed air systems are made on a first-cost basis. To achieve optimum compressed air economies, compressed air system users should select equipment and components based on life-cycle economics.

B. Compressed Air Leaks

Air system leaks are a continuing source of lost power and should always be minimized. Leaks can be a significant source of wasted energy in an industrial compressed air system, sometimes wasting 20-30% of a compressor's output. Typical plant that has not been well maintained will likely have a leak rate equal to 20% of total compressed air production capacity. Therefore, 20% of all compressed air that is produced leaks to atmosphere, provides no production benefits, and costs energy dollars. On the other hand, proactive leak detection and repair can reduce leaks to less than 10% of compressor output.

In addition to be a source of wasted energy, leaks can also contribute to other operating losses [8], [9]. Leaks cause a drop-in pressure, which can make air tools function less efficiently, adversely affecting production. In addition, by forcing the equipment to cycle more frequently, leaks shorten the life of almost all system equipment (including the compressor package itself). Increased running time can also lead to additional maintenance requirements and increased unscheduled downtime. Finally, leaks can lead to adding unnecessary compressor capacity.

There are many variables that add up to a high efficiency compressed air system. While leakage can come from any part of the system, one of the most common problem areas is with tube fittings. Tube fittings are one of the leading components related to air loss. A number of small leaks equivalent to that of a ¼" orifice can cost you $6,600 in power cost annually [10]-[12].

TABLE II. CORRELATION BETWEEN COST AND SIZE OF LEAK

Leak Diameter	Flow Rate *cfm*	Power Loss *hp*	Energy Lost *kWh/yr*	Energy Cost Savings *per year*	Peak Demand Savings *kW-mo/yr*	Peak Cost Savings *per year*	Total Cost Savings *per year*
1/64	0.4	0.1	591	$21	0.9	$12	$33
1/32	1.5	0.3	1,770	$62	2.7	$36	$98
3/64	3.4	0.7	4,136	$146	6.3	$83	$229
1/16	6.1	1.3	7,681	$271	11.6	$153	$424
3/32	13.8	3	17,725	$624	26.9	$355	$979
1/8	24.5	5.3	31,314	$1,103	47.4	$625	$1,728
3/16	55.0	11.9	70,309	$2,476	106.5	$1,405	$3,881
1/4	97.9	21.2	125,256	$4,412	189.8	$2,503	$6,915

As the Table II shows, the cost of compressed air leaks increases exponentially as the size of the leak increases. This can be seen even more clearly in the graph shown in figure 4. As part of a continuing program to find and repair compressed air leaks, the table II or graph in the figure 4 can be referenced to estimate the cost of any air leaks that might be found.

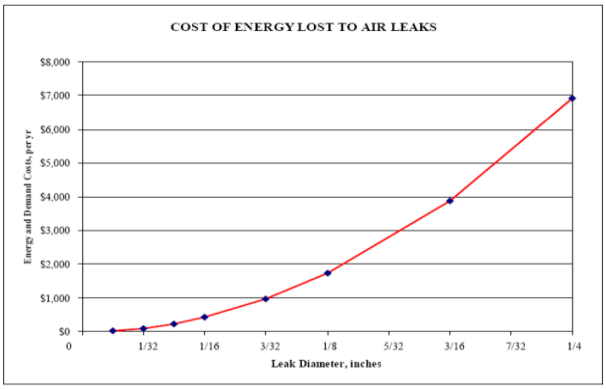

Fig. 4. Compressed air leak size versus cost (per year).

Performance vs. Price

9900 pieces Max level inventory for mid-scale specialty chemical company. Doubled to count as 2 end connections per piece = 19800

Difference in leak rate:

13.3% Company B– 1.4% Company A = 11.9% (Performance Difference)

11.9%/100*19,800= 2356 more leaking end connections

2356 x $100.00 annually per leak = $235,600 loss energy per year. (This is only calculating the number of connections in inventory maximum.

$235,600 Performance Cost Savings if using Company A Tube Fittings

The Financial Savings of Using Company A

1. Price
   a. Company A-$85,133.95
   b. Company B CPI -$42,566.97@50% off Company A
   c. Price difference is $42,566.97
2. Performance
   a. 11.9% lower leak rate and enhanced design saving $235,600-$42,566.97=
   b. Lower torque that leads to better performance

The savings to mid-scale specialty chemical company is $193,033.03

Total Savings $193,033.03 & 2356 less leaks

IV. COMMENTS

Fittings that were leaking during the survey were marked with ribbon. Able to calculate a 1.4% leak rate, this includes fittings that were not pulled up properly and improper tubing and fitting selection.

Fittings that were not pulled up to 1 ¼ turns were tested with a gap inspection gage to verify that they were under tighten.

V. RECOMMENDATIONS AND CONCLUSION

The survey shows that company benefits by using a reliable tube fitting with high standards in maintenance and construction projects. The data shows a much greater leak rate using other products. These leaks do not stop at the end

of the shift! Leaks cost money around the clock, day after day [13].

Do not overlook the cost savings opportunities by using tubing in place of pipe.

Improvise training courses to improve operations working knowledge of tube fittings. There are many reasons why a fitting will leak but can't avoid a problem if we do not know it exists! The training program illustrates the problems that can occur during installation and gives the employee the knowhow for proper installation and performance.

Set up continuing leak inspections by maintenance personnel. Air leakage and correction is one of the most significant items in managing compressed air usage and is one of the most inexpensive to accomplish. A good leak prevention program will include the following components: identification (including tagging), tracking, repair, verification, and employee involvement. A record should be kept of these findings and of the results. The leak can be measured as to estimate flow and a measurable "cost value" assigned to it. Consider setting up a program where production people (particularly operators and supervisors) are positively motivated to identify and repair leaks. Walk the line and listen. Audible leaks can account for more than 10 times the cost of an inaudible leak on a tube fitting [14], [15].

VI. Summary

Many studies summarize conclusively that the best "overall" value a company can receive from tube fittings is by investing in higher quality, not by getting the lowest price [16], [17]. Add to this the fact that there are other fluid streams, besides compressed air, that are consumed at production facilities. These fluid streams (such as natural gas, nitrogen, or steam), due to their higher prices compared to compressed air, carry a significantly higher cost savings opportunity, and can more easily help justify standardizing on the highest quality tube fittings.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Rahul Patil conducted the field study and wrote the paper. Rahul Patil and Kevin Rickert constructed the Results and Discussion, and section and analysis of the experimental results. Both Rahul and Kevin were involved with planning and supervising the overall work involved in the field study.

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