3 - AR No. 6 - Separate Compressed Air Grids

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Recommendation

Separate production plant and die shop compressed air grids, and reduce compressed air pressure in the production plant to 95 psig. This will reduce the production plant's compressor load, and associated annual air compressor energy consumption by 6.7%, also generating a 6.9% reduction in electrical demand.

Annual Savings Summary

Source	*Quantity*	*Units*	*Cost Savings*
Electrical Consumption	44,767	kWh (site)	$2,079
Electrical Demand	63	kW Months / yr	$376
Total	**153**	**MMBtu**	**$2,456**

Implementation Cost Summary

Description	*Cost*	*Payback (yrs)*
Before Incentives	$10,125	4.1
After Incentives	$5,063	2.1

Facility Background

The facility operates two 100 HP air compressors 24 hours a day, 7 days a week. One of the compressors works by modulating the load using a variable frequency drive (VFD), while the other unit operates on load-unload controls. The system generates compressed air at 112 psig to supply the die shop requirements; however, the rest of the production plant requires air at 95 psig.

Actual die shop equipment air consumption information was not available. The table below presents the maximum air demand found in the equipment manuals.

Die Shop Equipment Max Air Consumption

Equipment ID	*Max Air Consumption [acfm]*
HVC 140/30000/42000rpm	
STEP TEC	
6000.320A.82.00.en	16.3
HVC 170/36000	
6006.146.F.82.00.en	15.3
6006.146.D.82.00.en	15.3
HVC 140/54000	
6040.009.B.82.00.en	18.4
HPC 170/24000	
6041.005.A.82.02.en	18.4
HPC 170/28000	
6054.001.A.82.00.en	20.4
In-Line HSK 120000 rpm	
5005.004.81.01.en	9.2
Total	113.3

Technology Background

Compressing air is inefficient, with as much as 90% of compressor energy dissipated as heat. Maintaining a high system pressure increases the work the compressors must perform for a given volume of compressed air. This high system pressure can also increase the air demand of unregulated end uses such as leaks, blow-off wands, and some production applications. With higher than necessary pressure, the system consumes more air and the compressors use more energy with little added benefit. Reducing system pressure will reduce compressor full-load power by approximately half of one percent for every one psi pressure reduction. A local receiver near high use applications is sometimes needed to reduce air pressure, as the pressure maintained in the receiver does not have to account for considerable friction due to distribution.

Proposal

Separate compressed air grids by installing a new 40 HP compressor in the die shop. Reduce the current pressure set point for the air compressors in the production plant to 95 psig, and maintain compressed air production at 112 psig in the die shop. This will reduce the compressor load, and lower associated annual energy consumption by 44,767 kWh and demand by 63.3 kW-month. This will result in associated savings of $2,456 per year, with an implementation cost of $10,125 and a simple payback of 4.1 years before incentives.

Calculation Methodology

The motor analysis tool (MAT) was used to determine the average power draw for each compressor motor. The MAT uses both nameplate information and live power measurements to calculate energy consumption, load, shaft power output, and efficiency. MAT information was used with the compressed air baseline analysis tool (CABAT) to calculate compressor performance using motor readings collected with the data logger. CABAT information was then used to determine the savings associated with reducing compressor air pressure. Analysts assumed that 0.5% of total energy is saved per psig reduced.

Analysts estimated a linear relationship between airflow and energy use to determine the incremental cost of producing 1 acfm of compressed air at 95 and 112 psig. These values were then used to estimate the total cost of supplying air at 95 psig for the production plant and 112 psig for the die shop.

Notes

When lowering plant air pressure, reduce air pressure incrementally to ensure production is not affected.

Information about airflow requirements for the die shop were not available. Analysts estimated the maximum air requirements using equipment manuals and estimated that under normal operative condition the die shop will require a sustained 75% if its maximum air consumption. This value was subtracted from the current air consumption calculated using the CABAT to estimate current air demand of the production plant. Actual air requirements could easily be lower, increasing savings available for this recommendation.

To separate the production plant compressed air system from the die shop there are two alternatives. The first option assumed in this recommendation is to install a separate air compressor; which allows a greater autonomy to the production plant and the die shop, at a higher initial cost. The second option is installing a compressed air booster, which can be pneumatic or electric. Pneumatic boosters operate using compressed air from the main system to produce a higher pressure flow; the rate of air required from the system to high pressure air ranges between 1.5 to 2, inducing a higher demand of compressed air on the main system. Electric boosters mechanically compress air from the main system, inducing an increase in demand from it, in addition to its electrical consumption. Both boosters are adequate in operations requiring lower air flows at much higher pressures than the main system.

References

[1] *Reduce the Pressure of Compressed Air to the Minimum Required*. IAC. IAC Missouri, 22 Jun. 2009. Web. 25 Apr. 2016.

[2] *Energy Saving in Compressed Air Systems*. Kaeser. Kaeser Compressors, 10 May. 2010. Web. 25 Apr. 2016.

3 - AR No. 6 - Analysis

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General Information

Utility Data

Incremental Electricity Cost	(IC_E)	*$0.04645*	/kWh	**(Rf. 1)**
Incremental Demand Cost	(IC_D)	*$5.94*	kW	**(Rf. 1)**

Compressor Operation Data

Compressed Air Production	(Q_C)	*390.5*	acfm	**(Rf. 2)**
Max. Die Shop Air Flow	(Q_{CD})	*113.3*	acfm	**(Rf. 3)**
High Pressure Air Use Factor	(UF)	*75%*		**(N. 1)**
Pressure Required - Die Shop	(P_D)	*112*	psig	**(N. 2, Rf. 4)**
Pressure Required - Plant	(P_P)	*95*	psig	**(N. 2, Rf. 4)**

Energy Analysis

Current Energy Conditions

Energy Consumption (112 psig)	(E_{C112})	*673,167*	kWh/yr	**(Rf. 2)**
Compressor Demand	(D_{C112})	*922.1*	kW-mo/yr	**(Rf. 2)**
Pressure Ratio	(PR_C)	***1.85***		**(Eq. 1)**

Proposed Conditions

Energy Reduction Per PSIG	(n_{psig})	*0.5%*	/psig	**(N. 3, Rf. 6)**
Energy Consumption (95 psig)	(E_{C95})	***615,948***	kWh/yr	**(N. 4, Eq. 2)**
Pressure Ratio	(PR_P)	***1.78***		**(Eq. 1)**
Demand Consumption (95 psig)	(D_{C95})	***841.2***	kW-mo	**(Eq. 3)**
Incremental Compressed Air Energy Equivalent (112 psi)	(E_{QH})	***1,724***	kWh/acfm·yr	**(N. 4, Eq. 4)**
Incremental Compressed Air Demand Equivalent (112 psi)	(D_{QH})	***2.36***	kW-mo/acfm	**(N. 4, Eq. 5)**
Incremental Compressed Air Energy Equivalent (95 psi)	(E_{QL})	***1,577***	kWh/acfm·yr	**(N. 4, Eq. 4)**
Incremental Compressed Air Demand Equivalent (95 psi)	(D_{QL})	***2.15***	kW-mo/acfm	**(N. 4, Eq. 5)**

Notes

N. 1) Information regarding the actual air flow requirements for the die shop was unavailable. Analysts assumed that all the equipment will not operate at maximum capacity at the same time, and at most they will require a sustained 75% of their maximum air demand. Actual air requirements could easily be lower, increasing savings available for this recommendation.

N. 2) Analysts were informed that 95 psig is the minimum pressure required to operate production machinery. However, a constant pressure of 112 is maintained to satisfy die shop air requirements.

N. 3) Energy saved for pressure reduction is a general rule of thumb. Actual savings may vary.

Equations

Eq. 1) Pressure Ratio ($PR_{[C,P]}$) **(Rf. 5)**

$$\left(\frac{P_i + 14.7\,psi}{14.7\,psi}\right)^{0.286}$$

Eq. 2) Energy Consumption (E_{C95})

$$E_{C112}\times\left(1-(P_D-P_P)\times n_{psig}\right)$$

Eq. 3) Demand Consumption (D_{C95}) **(Rf. 6)**

$$D_{C112}\times\left(1-\left(\frac{PR_C-PR_P}{PR_C-1}\right)\right)$$

Eq. 4) Average Compressed Air Energy Equivalent ($E_{Q[H,L]}$)

$$\frac{E_{C112,C95}}{Q_C}$$

Eq. 5) Average Compressed Air Demand Equivalent ($D_{Q[H,L]}$)

$$\frac{D_{C112,C95}}{Q_C}$$

References

Rf. 1) Incremental electricity and incremental demand costs developed in the Utility Analysis section of this report.

Rf. 2) Developed in the compressed air baseline analysis tool (CABAT) located in the Site Data section of this report.

Rf. 3) Information obtained from the equipment manuals during site visit.

Rf. 4) Information provided by facility personnel during site visit.

Rf. 5) "Reduce the Pressure of Compressed Air to the Minimum Required". *IAC*. IAC Missouri, 22 Jun. 2009. Web. 25 Apr. 2016. [1]

Rf. 6) "Energy Saving in Compressed Air Systems". Kaeser. Kaeser Compressors, 10 May. 2010. Web. 25 Apr. 2016. [2]

Proposed Conditions

Energy Use Die Shop	(E_{PD})	*146,500*	kWh/yr	**(Eq. 6)**
Demand Consumption Die Shop	(D_{PD})	*201*	kW-mo/yr	**(Eq. 7)**
Energy Use Plant	(E_{PP})	*481,900*	kWh/yr	**(Eq. 8)**
Demand Consumption Plant	(D_{PP})	*658*	kW-mo/yr	**(Eq. 9)**
Global Energy Consumption	(E_P)	*628,400*	kWh/yr	**(Eq. 10)**
Global Demand Consumption	(D_C)	*859*	kW-mo/yr	**(Eq. 11)**

Savings

Energy Savings	(E_S)	*44,766.7*	kWh/yr	**(Eq. 12)**
Demand Savings	(D_S)	*63.3*	kW-mo/yr	**(Eq. 13)**

Implementation

Material Costs

Compressor Cost	(C_M)	*$8,500*	/unit	**(N. 5, Rf. 7)**

Labor Costs

Installation	(C_L)	*$1,625*		**(Rf. 8)**

Economic Results

Energy Cost Savings	(S_E)	*$2,079*	/yr	**(Eq. 14)**
Demand Cost Savings	(S_D)	*$376*	/yr	**(Eq. 15)**
Annual Cost Savings	(S)	*$2,456*	/yr	**(Eq. 16)**
Implementation Cost	(C_I)	*$10,125*		**(Eq. 17)**
Simple Payback	(t_{PB})	*4.1*	years	**(Eq. 18)**

Notes

N. 4) Analysts calculated the operation cost producing the same volume of air (Q_C) at 95 psi. This value was used to estimate the incremental compressed air energy and demand required to produce 1 acfm of compressed air at 95 psig. Analysts assumed that the cost of producing 1 acfm of compressed air at 112 psig will be the same for a similar system.

N. 5) Analysts considered a 40 HP Rotary Screw Air Compressor to supply 165 CFM of air at 125 psi maximum.

Equations

Eq. 6) Energy Use Die Shop (E_{PD})

$$Q_{CD} \times UF \times E_{QH}$$

Eq. 7) Demand Consumption Die Shop (D_{PD})

$$Q_{CD} \times UF \times D_{QH}$$

Eq. 8) Energy Use Plant (E_{PP})

$$(Q_C - Q_{CD} \times UF) \times E_{QL}$$

Eq. 9) Demand Consumption Plant (D_{PP})

$$(Q_C - Q_{CD} \times UF) \times D_{QL}$$

Eq. 10) Global Energy Consumption (E_P)

$$E_{PD} + E_{PP}$$

Eq. 11) Global Demand Consumption (D_C)

$$D_{PD} + D_{PP}$$

Eq. 12) Energy Savings (E_S)

$$E_{C112} - E_{PP}$$

Eq. 13) Demand Savings (D_S)

$$D_{C112} - D_C$$

Eq. 14) Energy Cost Savings (S_E)

$$E_S \times IC_E$$

Eq. 15) Demand Cost Savings (S_D)

$$D_S \times IC_D$$

Eq. 16) Annual Cost Savings (S)

$$S_E + S_D$$

Eq. 17) Implementation Cost (C_I)

$$C_M + C_L$$

Eq. 18) Simple Payback (t_{PB})

$$\frac{C_I}{S}$$

References

Rf. 7) Information obtained from www.compressorworld.com

Rf. 8) Information obtained from RS Means 2016, Mechanical Cost Data. Motor-Control Centers, p. 432.

3 - AR No. 6 - Incentive Analysis

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Incentive Data

Annual Energy Savings	(E_s)	***44,767***	kWh	**(Rf. 1)**
Annual Demand Savings	(E_s)	***63***	kW-mo	**(Rf. 1)**
Annual Cost Savings	(S)	***$2,456***	/yr	**(Rf. 1)**
Implementation Cost	(C_I)	***$10,125***		**(Rf. 1)**
Simple Payback	(t_{PB})	***4.1***	years	**(Rf. 1)**

Incentive Analysis Summary

Description	*Incentive*	*After Incentive*	*Payback*	*Notes*
			(yrs)	
Clark Public Utilities	***$5,063***	***$5,063***	***2.1***	*Custom-Industrial Retrofit Projects*

Clark Public Utilities (CPU)

All commercial and industrial customers of Clark Public Utilities are eligible to receive incentives for custom projects. Incentives are based on verified electrical savings and the utility may assist with energy studies as well as measurement and verification of savings. Eligible projects include replacement or installation of new energy efficiency equipment or technologies that are above current code. Some examples include upgrades to compressed air, refrigeration or general process systems.

For eligible projects approved and coordinated by Clark Public Utilities, incentives for industrial retrofit projects are $0.25 per kWh up to 50% of cost.

References

Rf. 1) Developed in this recommendation on the previous pages.

3 - AR No. 6 - Financial Analysis

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Recommendation Data

Economic Results

Annual Cost Savings	(S)	*$2,456*	/yr	**(Rf. 1)**
Implementation Cost	(C_I)	*$10,125*		**(Rf. 1)**
Incentives Total	(I)	*$5,063*		**(N. 1, Rf. 1)**
Cost Basis	(C_B)	*$5,063*		**(Eq. 1)**
Simple Payback	(t_{PB})	*4.1*	years	**(Rf. 1)**
Simple Payback after Incentives	(t_{PBI})	*2.1*	years	**(Rf. 1)**

Capital Information

Terminal Dep. Yr. (Recovery Period)	(t_T)	*7*	years	**(N. 2, Rf. 2)**
Class Life	(t_L)	*12*	years	**(N. 2, Rf. 2)**
Estimated WACC^{ADJ}	(r)	*6.29%*		**(Rf. 3, N. 3)**
Estimated Corporate Tax Rate	(T_C)	*35%*		**(Rf. 4)**

Economic Analysis

No Depreciation Schedule

Initial After Tax Cash Flow (t = 0)	($CF_{N,0}$)	*-$3,291*		**(Eq. 2)**
After Tax Cash Flow (t = 1, 2,…t_L)	($CF_{N,t}$)	*$1,596*		**(Eq. 3)**
Net Present Value	(NPV_N)	*$9,881*		**(Eq. 4)**
Annual Internal Rate of Return	(IRR_N)	*48.1%*		**(N. 4, Eq. 5)**

Straight-Line Depreciation Schedule

Depreciation	(DEP)	*$723*		**(Eq. 6)**
After Tax Benefit	(CF_{TB})	*$253*		**(Eq. 7)**
Initial After Tax Cash Flow (t = 0)	($CF_{S,0}$)	*-$5,063*		**(Rf. 5)**
After Tax Cash Flow (t = 1, 2,…t_T)	($CF_{S,t}$)	*$1,849*	/yr	**(Eq. 8)**
After Tax Cash Flow (t = t_{T+1}...tL)	($CF_{S,t}$)	*$1,596*	/yr	**(Eq. 9)**
Net Present Value	(NPV_S)	*$9,507*		**(Eq. 4)**
Annual Internal Rate of Return	(IRR_S)	*35.1%*		**(N. 4, Eq. 5)**

Notes

N. 1) Incentives presented in this analysis do not account for timing of receipt.

N. 2) The General Depreciation Schedule is used. Recovery Period and Class Life may differ if analysts found a better known estimate. The Salvage Value of any equipment is assumed to be zero as it is out of the scope of this analysis and provides a further conservative estimate.

N. 3) WACC^{ADJ} is Weighted Average Cost of Capital Adjusted for Taxes. Cost of Capital is different for every business, and accurately estimating it for this facility is beyond the scope of this analysis. An industry average of WACC^{ADJ} is used **(Rf. 3)**, and is considered a conservative estimate. Analysts may adjust the WACC^{ADJ} if a more accurate estimate is identified in **(Rf. 3)** or it is given.

N. 4) An IRR greater than the WACC^{ADJ} (r) is an attractive investment option.

Equations

Eq. 1) Cost Basis (C_B)

$$C_I - I$$

Eq. 2) Initial A.T. Cash Flow (t = 0) ($CF_{N,0}$)

$$(-C_B)\times(1-T_C)$$

Eq. 3) A.T. Cash Flow (t =1, 2,...t_T) ($CF_{N,t}$)

$$S\times(1-T_C)$$

Eq. 4) Net Present Value ($NPV_{[N,S]}$)

$$CF_{[i],0}+\sum_{t=1}^{t_L}\frac{CF_{[i],t}}{(1+r)^t}$$

Eq. 5) Internal Rate of Return ($IRR_{[N,S]}$)

$$NPV=0=$$

$$CF_{[i],0}+\sum_{t=1}^{t_L}\frac{CF_{[i],t}}{(1+IRR)^t}$$

Eq. 6) Depreciation (DEP)

$$C_B/t_T$$

Eq. 7) After Tax Benefit (CF_{TB})

$$DEP\times T_C$$

Eq. 8) A.T. Cash Flow (t =1, 2,...t_T) ($CF_{S,t}$)

$$C_B\times(1-T_C)+CF_{TB}$$

Eq. 9) A.T. Cash Flow (t =t_{T+1},...t_L) ($CF_{S,t}$)

$$C_B\times(1-T_C)$$

References

Rf. 1) Developed in this recommendation on the previous pages.

Rf. 2) Recovery Period and Class Life are referenced from IRS publication 946, Table B-2, based on the best-fit industry sector. https://www.irs.gov/pub/irs-pdf/p946.pdf.

Rf. 3) Cost of Capital is based on New York University's Stern School of Business' *Cost of Capital by Sector* , data from January 2016. Industries not related to the IAC were omitted, and an average was calculated. http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/wacc.htm

Rf. 4) Based on Tax Rate Schedule from: www.irs.gov/pub/irs-pdf/i1120.pdf

Rf. 5) Initial A.T. Cash Flow is the negative of the above Implementation Cost.