APPENDIX A
Examples of Completed Engineered Worksheets
June 2025

RETROFIT COMPRESSED AIR ENGINEERED WORKSHEET

A company has a compressed air system consisting of five (5) compressors operating from 9:00 a.m. to 9:00 p.m. Mondays to Fridays and from 9:00 a.m. to 6:00 p.m. on Saturdays. The facility is closed on Sundays and certain holidays. The existing compressor and motor information are as follows:

OPERATING INFORMATION

Using the 24 hour 7 day table below, enter "1" if the equipment is scheduled to operate and "0" if the equipment is not scheduled to operate. Times during operation will illuminate purple. These numbers are used in energy calculations therefore if the time falls within the hour (i.e. 7:30) use your best estimate to choose the appropriate time.

If the system operates on a different schedule during the summer (June through August) then it may be required to complete a separate calculation outside of this worksheet.

Hour of Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0:00-0:59 am	0	0	0	0	0	0	0
1:00-1:59 am	0	0	0	0	0	0	0
2:00-2:59 am	0	0	0	0	0	0	0
3:00-3:59 am	0	0	0	0	0	0	0
4:00-4:59 am	0	0	0	0	0	0	0
5:00-5:59 am	0	0	0	0	0	0	0
6:00-6:59 am	0	0	0	0	0	0	0
7:00-7:59 am	0	0	0	0	0	0	0
8:00-8:59 am	0	0	0	0	0	0	0
9:00-9:59 am	0	1	1	1	1	1	1
10:00-10:59 am	0	1	1	1	1	1	1
11:00-11:59 am	0	1	1	1	1	1	1
12:00-12:59 pm	0	1	1	1	1	1	1
1:00-1:59 pm	0	1	1	1	1	1	1
2:00-2:59 pm	0	1	1	1	1	1	1
3:00-3:59 pm	0	1	1	1	1	1	1
4:00-4:59 pm	0	1	1	1	1	1	1
5:00-5:59 pm	0	1	1	1	1	1	1
6:00-6:59 pm	0	1	1	1	1	1	0
7:00-7:59 pm	0	1	1	1	1	1	0
8:00-8:59 pm	0	1	1	1	1	1	0
9:00-9:59 pm	0	0	0	0	0	0	0
10:00-10:59 pm	0	0	0	0	0	0	0
11:00-11:59 pm	0	0	0	0	0	0	0

Statutory Holidays and Other Shutdown Times

Adjust the number of weekdays (Monday-Friday) by month that the equipment is not operating due to statutory, civic or other holidays, lieu days or scheduled shutdowns. The numbers pre-populated in the table represent the default statutory, civic or other holidays, per the table on the right.

January	1
February	1
March	0
April	2
May	1
June	0
July	1
August	1
September	1
October	1
November	0
December	2
TOTAL:	11

Ontario Statutory, Civic or Other Holidays	
New Years Day	January 1
Family Day	3rd Monday in February
Good Friday	Friday before Easter Sunday
Easter Monday	Monday after Easter Sunday
Victoria Day	Monday before May 25
Canada Day	July 1
Civic Holiday	1st Monday in August
Labour Day	1st Monday in September
Thanksgiving Day	2nd Monday in October
Christmas Day	December 25
Boxing Day	December 26

69	This is the typical weekly number of operating hours for the equipment based on the schedule above (excluding holidays)
3468	This is the annual number of operating hours for the equipment based typical weekly and holiday schedule entered

Existing Compressed Air System

	A.C.#1	A.C.#2		
Compressor Designated Name	Main Unit	Paint Line		
Manufacturer (CAGI Box 1)	Please select	Please select		
Model (CAGI Box 2)	R110I-A110	R551-A110		
Rated Capacity at Full Load Operating Pressure (CAGI Box 3)	751	361	1,112	acfm (Total)
Full Load Operating Pressure (CAGI Box 4)	100	100	100.0	psig (Average)
Maximum Full Flow Operating Pressure (CAGI Box 5)	110	110	110.0	psig (Average)
Drive Motor Nominal Rating (CAGI Box 6)	150	75	225	HP (Total)
Total Package Input Power at Zero Flow (CAGI Box 10)	36.8	20.0	56.8	kW (Total)
Total Package Input Power at Rated Capacity and Full Load Operating Pressure (CAGI Box 11)	129.9	65.8	97.9	kW (Average)
Typical Percent of Full Load Operating Point (F.L.) *	**90.0%**	**70.0%**	80.0%	Percent Full Load
Typical Operating Pressure for this Compressor *	**108.0**	**107.0**	107.5	psig (Average)
Operating Flow	675.9	252.7	928.6	cfm
			179.3	kW
			542,190	kWh
			$ 59,641	dollars

Proposed Energy Efficiency Measures:

The company is implementing the four measures included in the Compressed Air Engineered Worksheet, namely:

Measure 1 – Reduce Air Leaks

Measure 2 - Reduce Operating Pressure

Measure 3 - Use Efficient Air Dryers

Measure 4 – Use Zero Loss Air Drains

Calculation of Energy Savings (kWh) for each Measure:

Measure 1 – Reduce Air Leakage

Information needed: Target for Maximum Allowable Air Leaks and Non-Productive Air Use = 15.0 %

Dimensions of Air receiver tanks

	Receiver Tank Diameter (feet)	Receiver Tank Height (feet)	No. of Similar Receivers (#)
Air Receiver(s) - Type 1	1.0	5.0	3
Air Receiver(s) - Type 2	2.5	8.0	1

Dimensions of Distribution Pipes

	Outside Pipe Diameter (inches)	Pipe Length (feet)
Largest Diameter Distribution Pipe (Diameter and Length)	4.0	600
Second Largest Diameter Distribution Pipe (Diameter and Length)	2.5	300

Pressure Decay Test Results

Test Number	Initial Pressure (psig)	Final Pressure (psig)	Time for Decay (Seconds)
1	105.0	70.0	125
2	106.0	68.0	120
3	102.5	60.0	105
4	106.4	70.0	130
5	104.5	71.0	115
Average	**104.9**	**67.8**	**119**

Volume of Air Receiver Tanks

Example for AC #1:

$$\text{Tank Volume (ft}^3) = \frac{\text{Outside Cylinder Diameter} \times 3.14\ \text{ft}^2}{4} \times \text{Cylinder Height (ft)} \times \text{Quantity on Site}$$

$$= \frac{1.00^2 \times 3.14}{4} \times 5.00 \times 3.00$$

$$= 11.78\ \text{ft}^3$$

Repeating the same calculation for AC #2 will yield a volume of 39.25 ft^3.

Volume of Largest Distribution Pipes

Example for AC #1:

$$\text{Pipe Volume (ft}^3) = \frac{\text{Outside Pipe Diameter}^2 \text{ (inch}^2) \times 3.14}{4 \times 144} \times \text{Pipe Length (ft)}$$

$$= \frac{4.00^2 \times 3.14}{4 \times 144} \times 600$$

$$= 52.33 \text{ ft}^3$$

Repeating the same calculation for second distribution pipe will yield a volume of 10.22 ft^3.

Total Volume of Air Receiver Tanks and Largest Distribution Pipes

$$\text{Total Volume of Piping and Receivers (ft}^3) = \text{AC \#1 Tank (ft}^3) + \text{AC \#2 Tank (ft}^3) + \text{AC \#1 Pipe (ft}^3) + \text{AC \#2 Pipe (ft}^3)$$

$$= 11.78 + 39.25 + 52.33 + 10.22$$

$$= 113.58 \text{ ft}^3$$

Estimated Leakage and Non-Productive Air Losses (at 100% Compressor Flow Output)

$$\text{Estimated Leakage at 100\% Compressor Flow Output (cfm)} = 1.25 \times \text{Total Volume of Piping and Receivers (ft}^3) \times \frac{\text{Starting Pressure (psig)} - \text{Ending Pressure (psig)}}{\text{Decay Time (min)} \times 14.7 \text{ psig}} \times 60 \text{ sec/min}$$

$$= 1.25 \times 113.58 \times (104.9 - 67.8) / (119 \times 14.7) \times 60$$

$$= 181 \text{ cfm}$$

Operating Flow

Example for AC #1:

$$\text{Operating Flow (cfm)} = \text{Rated Capacity at Full Load Operating Pressure (acfm)} \times \text{Typical Percent of Full Load Operating Point (\%)}$$

$$= 751 \times 90\%$$

$$= 675.9 \text{ cfm}$$

Repeating the same calculation for AC #2 will yield an operating flow of 675.9 cfm.

Estimated Air Leaks and Non-Productive Air Losses as Percentage of Normal Compressor Flow

$$\text{Estimated Air Leaks as Percentage of Normal Compressor Flow (\%)} = \frac{\text{Estimated Leakage at 100\% Compressor Flow Output (cfm)}}{\text{Total Operating Flow (cfm)}} \times 100$$

= (181) / (675.9 + 252.7) x 100

= 19.4 %

Slope of Compressor Performance Line

Example with AC #1

$$\text{Slope} = \frac{\text{Total Package Input Power at Rated Capacity (kW)} - \text{Total Package Input Power at Zero Flow (kW)}}{\text{Rated Capacity at Full Load Operating Pressure (acfm)}}$$

= (129.9 - 76.8) / 751

= 0.1240

Expected Power at Operating Flow and Design Pressure

Example with AC #1

Expected Power = Total Package Input Power at Zero Flow (kW) + Slope x Operating Flow (kW)

= 36.8 + 0.1240 x 675.9

= 120.59 kW

Expected Power at Operating Flow and Actual Operating Pressure

Example for AC #1:

$$\text{Power Demand at Typical Operating Level (kW)} = \left[1 - \left[\text{Full Load Operating Pressure (acfm)} - \text{Typical Operating Pressure for Compressor (psig)} \right] \times 0.05 \right] \times \text{Power Demand at Operating Flow (kW)}$$

= [1 - (100.0 - 108.0) x 0.05] x 120.59

= 125.41 kW

Estimated annual kWh consumption per Air Compressor

Example for AC #1:

Energy Consumption of Compressor at Operating Level (kWh) = Power Demand at Typical Operating Level (kW) x Annual Operating Hours (hrs)

= 125.41 x 3,486

= 434,934 kWh

Estimated total annual kWh consumption

$$\text{Annual Energy Consumption for Air Compressors at Typical Operating Level (kWh)} = \text{AC\#1 Energy Consumption of Compressor at Operating Level (kWh)} + \text{AC\#2 Energy Consumption of Compressor at Operating Level (kWh)}$$

$$= 434{,}934 + 186{,}863$$

$$= 621{,}797 \text{ kWh}$$

$$\text{Annual Energy Savings (kWh)} = \left[\text{Estimated Air Leaks (\%)} - \text{Target Allowable Leaks (\%)} \right] \times \text{Annual Energy Consumption for Air Compressors at Typical Operating Level (kWh)}$$

$$= (19.4\% - 10.0\%) \times 621{,}797$$

$$= 58{,}729 \text{ kWh}$$

A maintenance program is in place to ensure leaks are maintained. Hence, the annual energy savings by repairing air leaks is discounted by 50%. Annual energy savings therefore is 29,364 kWh.

Estimated Annual Demand Savings from Reducing Air Leaks

$$\text{Annual Demand Savings (kW)} = \frac{\text{Annual Energy Savings (kWh)}}{\text{Annual Operating Hours (hours)}}$$

$$= \frac{58{,}729}{3{,}468}$$

$$= 16.9 \text{ kW}$$

A maintenance program is in place to ensure leaks are maintained. Hence, the annual demands savings by repairing air leaks is discounted by 50%. Annual demands savings therefore is 8.47 kW.

Measure 2 – Reduce Discharge Pressure

Information needed: Baseline calculations (see Measure 1 calculations)
Target for Average Air Discharge Pressure = 98 psig

Annual kWh Savings

$$\text{Annual kWh Savings} = \left[\text{Average normal operating discharge pressure (psig)} - \text{Target pressure (psig)} \right] \times \frac{\text{Annual Energy Consumption of Compressors (kWh)} - \text{Annual Energy Savings from Reduced Leaks (kWh)}}{2 \text{ psig} \times 100}$$

$$\text{Annual kWh Savings} = \left[107.5 - 98.0 \right] \times \frac{621{,}797 - 58{,}729}{2 \text{ psig} \times 100}$$

$$\text{Annual kWh Savings} = 26{,}746 \text{ kWh}$$

Annual kW Savings

$$\text{Annual kW Savings (kW)} = \frac{\text{Annual Energy Savings (kWh)}}{\text{Annual Operating Hours (hours)}}$$

$$= \frac{26{,}746}{3{,}486}$$

$$= 7.7 \text{ kW}$$

Similar to Measure 1, if the facility has a maintenance program that ensures that a reduced set point is maintained, the Annual Energy Savings is discounted by 50%. Otherwise, it is discounted by 25%. In this example the annual kW and kWh savings are discounted by 50%, resulting in savings of 3.9 kW and 13,373 kWh.

Measure 3 – Use Appropriate Dryer

Information needed: Type of dryer currently employed = refrigerant or desiccant dryers
Amount of flow allocated to each Dryer = 500 cfm and 200 cfm
Tested flows for each of the dryer at 100% and 10% output
Each Dryer's Total Input Power

Base Case Dryer 1 Power (Refrigerant Example)

$$\text{Base Case Dryer 1 Power (kW)} = \text{Dryer Input Power at 10\% Flow of Existing Dryer (kW)} + \left[\text{Amount of Flow Allocated to Dryer \#1 (cfm)} - \text{Tested 10\% Flow (CAGI Box 6 for Refrigerant Dryers) (cfm)} \right] \times \frac{\text{Dryer Input Power at 100\% Flow of Existing Dryer (kW)} - \text{Dryer Input Power at 10\% Flow of Existing Dryer (kW)}}{\text{Tested Existing Flow at 100\% (cfm)} - \text{Tested Existing Flow at 10\% (cfm)}}$$

$$= 7.2 + \left[500 - 131 \right] \times \frac{7.4 - 7.2}{981 - 131}$$

$$= 7.29 \text{ kW}$$

A similar calculation is applied to generate a value for the power consumed by the Proposed Case Dryers. Repeating the calculation for Proposed Case Dryer 1 and 2 would yield the values 3.0 kW and 2.1 kW respectively.

Base Case Dryer 2 Power (Desiccant Example)

$$\text{Base Case Dryer 2 Power (kW)} = \frac{\text{Amount of Flow Allocated to Dryer \#2 (cfm)}}{100} \times 2.5\ \text{(kW/cfm)}$$

$$= 200 / 100 \times 2.5$$

$$= 5\ \text{kW}$$

Base Case Total Dryer Power

$$\text{Base Case Total Dryer Power (kW)} = \text{Base Case Dryer 1 Power (kW)} + \text{Base Case Dryer 2 Power (kW)}$$

$$= 7.29 + 5.00$$

$$= 12.29\ \text{kW}$$

Repeating a similar calculation for the Proposed Case Total Dryer Power (kW) yields 5.10 kW.

Annual kW Demand Savings

$$\text{Annual kW Demand Savings (kW)} = \text{Base Case Total Dryer Power (kW)} - \text{Proposed Case Dryer (kW)}$$

$$= 12.29 - 5.10$$

$$= 7.2\ \text{kW}$$

Base Case Dryer Energy Consumption (kWh)

$$\text{Base Case Dryer Energy Consumption (kWh)} = \text{Base Case Total Dryer Demand (kW)} \times \text{Annual Operating Hours (hours)}$$

$$= 12.29 \times 3{,}468$$

$$= 42{,}622\ \text{kWh}$$

Repeating a similar calculation for the Proposed Case Dryer Energy Consumption (kWh) yields 17,687 kWh.

Annual kWh Energy Savings

$$\text{Annual kWh Energy Savings (kWh)} = \text{Base Case Dryer (kWh)} - \text{Proposed Case Dryer (kWh)}$$

$$= 42{,}622 - 17{,}687$$

$$= 24{,}935 \text{ kWh}$$

Measure 4 – Zero Loss Drain

Information needed: Compressed Air System Operating Hours per Year = 4551
Blended Cost of Power = $0.11/kWh
Seeking Incentive for this quantity of Zero Loss Drains = 3
Average drain blowdown time between cycles = 15 seconds
Average time between blowdown cycles = 2 min

Assumed loss of 85 CFM when the drain is operating with 100 psig on the system at $0.25/1000 CF of compressed air = 0.02125

$$\text{Annual Energy Savings (kWh)} = \text{Average drain blowdown time between cycles (s)} \times \frac{\text{Compressed Air System Operating Hours per Year (hr)}}{\text{Average time between blowdown cycle (min)}} \times 0.02125 \times \frac{\text{Seeking Incentive for this quantity of Zero Loss Drains}}{\text{Blended Cost of Power (\$/kWh)}}$$

$$= 15 \times 3{,}486 / 2 \times 0.02125 \text{ X } 3 / 0.11$$

$$= 15{,}074 \text{ kWh}$$

Annual kW Savings

$$\text{Annual kW Savings (kW)} = \frac{\text{Annual Energy Savings (kWh)}}{\text{Compressed Air System Operating Hours per Year (hr)}}$$

$$= \frac{15{,}074}{3{,}468}$$

$$= 4.3 \text{ kW}$$

Total Annual Energy Savings

$$\text{Total Annual Energy Savings (kWh)} = \text{Annual Energy Savings from Measure 1 (kWh)} + \text{Annual Energy Savings from Measure 2 (kWh)} + \text{Annual Energy Savings from Measure 3 (kWh)} + \text{Annual Energy Savings from Measure 4 (kWh)}$$

$$= 29{,}364 + 13{,}373 + 24{,}935 + 15{,}1074$$

$$= 82{,}746 \text{ kWh}$$

A similar calculation is applied to Total Annual Demand Savings, which yields a value of 23.9 kW. This is the maximum summer peak demand. An Average Summer Peak Demand of 23.04 kW calculated using a ratio of energy savings during peak period and annual energy savings is used for incentive calculations.

Calculation of Total Project Costs ($):

Total Project Costs ($) are calculated from the summation of the total eligible project costs of each measure shown in the individual measures tab.

Total Project Costs ($)	=	Total Eligible Project Cost for Measure 1 ($)	+	Total Eligible Project Cost for Measure 2 ($)	+	Total Eligible Project Cost for Measure 3 ($)	+	Total Eligible Project Cost for Measure 4 ($)
	=	1,547	+	1,593	+	27,000	+	1,825
	=	$ 31,965						

Calculation of Incentives ($):

In calculating the Participant Incentives, $1,800/kW and $0.20 incentive rates are used for compressed air measures.

Calculated kW Participant Incentive ($1,800/kW of Demand Savings):

Participant Incentive	=	23 kW	x	$ 1,800/kW
	=	$ 41,400		

Calculated kWh Participant Incentive ($0.20/kW of Energy Savings)

Participant Incentive	=	82,746 kWh	x	$ 0.20/kWh
	=	$ 16,549		

Participant Incentive based on kW savings ($41,400) is greater than the Participant Incentive based on kWh savings ($16,549). Therefore, $41,400 is selected.

A cap is placed on the Participant Incentives as 50% of the total eligible project costs. 50% of the total eligible project costs in this scenario is $15,982.50. Therefore the Participant Incentives is capped at $15,982.50

RETROFIT VARIABLE SPEED DRIVE (VSD) COMPRESSED AIR WORKSHEET

A facility is installing a new VSD air compressor to replace the existing fixed speed air compressor with intended compressor discharge pressure of 100 psig. The CAGI data sheets for the existing and new compressors are shown below. The operating hours of the air compressor is from 7 AM to 10 PM on weekday and 1 PM to 6 PM on weekends with 11 days of holidays annually.

Existing Fixed Speed Air Compressor is Kaeser Model # DSD 150, the efficiency performance of the compressor is captured on a CAGI data sheet available from the manufacturer.

Proposed VSD Air Compressor is Kaeser Model # SFC 90S, the efficiency performance of the compressor is captured on a CAGI data sheet available from the manufacturer and shown below.

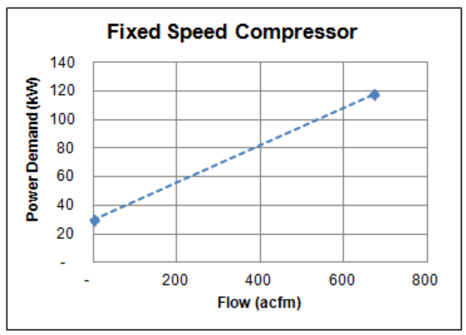
On the Design and Assumption Tab, enter the intended compressor operating Discharge Pressure in psig.

TYPICAL OPERATING PRESSURE	
100	Intended Compressor Operating Discharge Pressure (psig)

Using the fixed speed air compressor CAGI Data Sheet shown below, enter information in Box # 1, 2, 3, 4, 10 & 11. Once all information is entered, a graph is generated on the side showing power and flow relationship of (y = mx + b) y = 0.131x + 29.7

FIXED SPEED COMPRESSOR (CAGI DATA SHEET INPUTS)

CAGI Data Sheet Field #	Description	Value	Units
1	Manufacturer	Kaeser	
2	Model	DSD 150	
3	Rated Capacity at Full Load Operating Pressure:	671	acfm
4	Full Load Operating Pressure	115	psig
10	Total Package Input Power at Zero Flow	29.7	kW
11	Total Package Input Power at Rated Capacity and Full Load Operating Pressure	117.5	kW



5.7 Full Load Flow:Power ratio seems OK (4-6 acfm/kW)

Rated Pressure of Fixed Speed Compressor seems OK for Operating Pressure Requirements.

KAESER COMPRESSORS

COMPRESSOR DATA SHEET

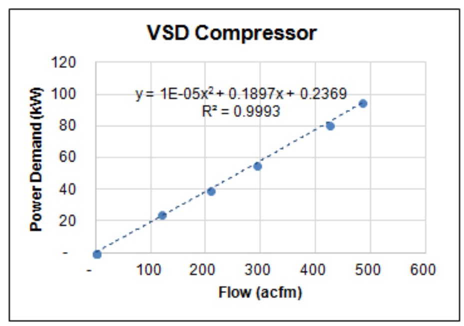
Rotary Compressor: Fixed Speed

MODEL DATA - FOR COMPRESSED AIR			
1	Manufacturer: Kaeser Compressors, Inc.		
2	Model Number: DSD 150 - 125 psig / 460V/3ph/60Hz	Date:	12/3/2012
	☐ Air-cooled ☒ Water-cooled	Type:	Screw
	☒ Oil-injected ☐ Oil-free	# of Stages:	1
3*	Rated Capacity at Full Load Operating Pressure [a, e]	671	acfm [a,e]
4	Full Load Operating Pressure [b]	115	psig [b]
5	Maximum Full Flow Operating Pressure [c]	125	psig [c]
6	Drive Motor Nominal Rating	150	hp
7	Drive Motor Nominal Efficiency	95.8	percent
8	Fan Motor Nominal Rating (if applicable)	0.4	hp
9	Fan Motor Nominal Efficiency	75	percent
10*	Total Package Input Power at Zero Flow [e]	29.7	kW [e]
11	Total Package Input Power at Rated Capacity and Full Load Operating Pressure [d]	117.5	kW [d]
12*	Specific Package Input Power at Rated Capacity and Full Load Operating Pressure [e]	17.5	kW/100 cfm [e]

Using the VSD Compressor CAGI Data Sheet, enter information shown in Box # 1, 2, 3, 4, 10 & 11. Once all information is entered, a 2nd degree polynomial equation is generated ($y = ax^2 + bx + c$) $y = 1.01E\text{-}05x^2 + 0.1897x + 0.2369$ and graphically shown on the side.

VSD COMPRESSOR (CAGI DATA SHEET INPUTS)			
CAGI Data Sheet Field #	Description	Data Input	
1	Manufacturer	Kaeser	
2	Model Number	SFC 90S	
3	Rated Operating Pressure (psig)	125	
8	Input Power and Capacity	Input Power (kW)	Capacity (acfm)
	Point 1 (Max)	95.5	484.0
	Point 2	81.4	424.0
	Point 3	55.6	293.0
	Point 4	40.0	207.0
	Point 5	24.7	118.0
	Point 6	0.0	0.0
	Point 7	0.0	0.0
	Point 8	0.0	0.0
9	Total Package Input Power at Zero Flow	0.0	

Rated Pressure | Enter the cost of the VSD compressor, including | s OK for Operating Pressure Requirements.



KAESER COMPRESSORS

COMPRESSOR DATA SHEET
Rotary Compressor: Variable Frequency Drive

MODEL DATA - FOR COMPRESSED AIR				
1	Manufacturer: **Kaeser Compressors, Inc.**			
2	Model Number: **SFC 90S - 125 psig / 460V/3ph/60Hz**		Date:	**12/3/2012**
	[X] Air-cooled [ ] Water-cooled		Type:	**Screw**
	[X] Oil-injected [ ] Oil-free		# of Stages:	**1**
3	Rated Operating Pressure		**125**	psig[b]
4	Drive Motor Nominal Rating		**100**	hp
5	Drive Motor Nominal Efficiency		**94.1**	percent
6	Fan Motor Nominal Rating (if applicable)		**2**	hp
7	Fan Motor Nominal Efficiency		**84**	percent
8*	Input Power (kW)		Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]
	95.5	Max	**484**	**19.74**
	81.4		**424**	**19.20**
	55.6		**293**	**18.97**
	40.0		**207**	**19.36**
	24.7	Min	**118**	**20.86**
9*	Total Package Input Power at Zero Flow[c, d]		**0.0**	kW

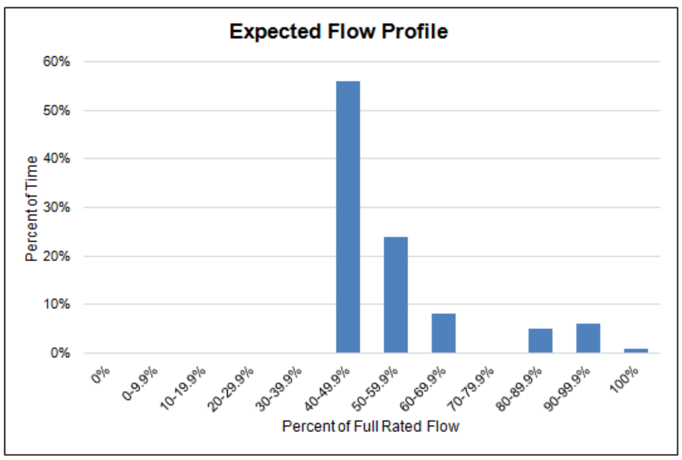
Enter a typical operationg profile that sums up to 100%. For example as shown below, 56% of the time, the air compressor operates between 40 to 49.9% of maximum flow.

TYPICAL OPERATING PROFILE

484 Design Basis Maximum Flow (acfm)

Bin Midpoint Flow (acfm)	Rated Flow Bin Profile (based on Smaller Compressor)	Percent of Time in This Flow Range
0	0%	0%
24	0-9.9%	0%
73	10-19.9%	0%
121	20-29.9%	0%
169	30-39.9%	0%
218	40-49.9%	56%
266	50-59.9%	24%
315	60-69.9%	8%
363	70-79.9%	0%
411	80-89.9%	5%
460	90-99.9%	6%
484	100%	1%
	Total	100%

OK, Total =100%



It is MANDATORY to provide a short note describing or explaining how the flow profile was determined. If this field is left blank, the energy savings will automatically default to 0.

SHORT EXPLANATION

Provide short explanation regarding method used for flow profile estimate. Note this calculator does not accept VSD Compressor flows less than 40% of fully rated capacity.

Flow pattern based on data logging results for April 10-17 by XYZ Testing company...

Calculation of Energy and demand savings:

Refer to the following tables for the computation of the energy and demand savings:

For example at 40 to 49.9% Flow Bin Profile, demand for fixed power is y = 0.131x + 29.7 = 0.131 (218) + 29.7 = 58.26 x 56% = 32.59 kW

Demand for Variable speed power is $y = 1.01E\text{-}05x^2 + 0.1897x + 0.2369 = 1.01E\text{-}05\,(218)^2 + 0.1897x + 0.2369$ = 42.03 x 56% = 23.59 kW

Rated Flow Bin Profile	% Time	Expected Flow	Fixed Power	VSD Power		
0%	0%	0	0.00	0.00		
0-9.9%	0%	24	0.00	0.00		
10-19.9%	0%	73	0.00	0.00		
20-29.9%	0%	121	0.00	0.00		
30-39.9%	0%	169	0.00	0.00		
40-49.9%	56%	218	32.59	23.54		
50-59.9%	24%	266	15.49	12.35		
60-69.9%	8%	315	5.67	4.87		
70-79.9%	0%	363	0.00	0.00		
80-89.9%	5%	411	4.18	4.00		
90-99.9%	6%	460	5.39	5.38		
100%	1%	484	0.93	0.94		
			64.25	**51.07**		
			0.925	0.875		
			59.43	**44.69**	**14.74**	
					Demand Savings	
			4260	4260	No. of Hours	
			253,166	**190,373**	**62,793**	
					Energy Savings	

The sum of demand is adjusted by the pressure difference between rated pressure and actual operating pressure expressed in psig as per following table.

Pressure Adjustment for Fixed Speed Compressor	
Conventional Rated Pressure (psig)	115
Actual Operating Pressure (psig)	100
Pressure Difference x 0.5%	0.075
Adjustment	0.925
Pressure Adjustment for Variable Speed Compressor	
Conventional Rated Pressure (psig)	125
Actual Operating Pressure (psig)	100
Pressure Difference x 0.5%	0.125
Adjustment	0.875

VSD Air Compressor Engineered Worksheet

OPERATING INFORMATION

Using the 24 hour 7 day table below, enter "1" if the equipment is scheduled to operate and "0" if the equipment is not scheduled to operate. Times during operation will illuminate purple. These numbers are used in energy calculations therefore if the time falls within the hour (i.e. 7:30) use your best estimate to choose the appropriate time.

If the system operates on a different schedule during the summer (June through September) then it may be required to complete a separate calculation outside of this worksheet.

Hour of Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0:00-0:59 am	0	0	0	0	0	0	0
1:00-1:59 am	0	0	0	0	0	0	0
2:00-2:59 am	0	0	0	0	0	0	0
3:00-3:59 am	0	0	0	0	0	0	0
4:00-4:59 am	0	0	0	0	0	0	0
5:00-5:59 am	0	0	0	0	0	0	0
6:00-6:59 am	0	0	0	0	0	0	0
7:00-7:59 am	0	1	1	1	1	1	0
8:00-8:59 am	0	1	1	1	1	1	0
9:00-9:59 am	0	1	1	1	1	1	0
10:00-10:59 am	0	1	1	1	1	1	0
11:00-11:59 am	0	1	1	1	1	1	0
12:00-12:59 pm	0	1	1	1	1	1	0
1:00-1:59 pm	1	1	1	1	1	1	1
2:00-2:59 pm	1	1	1	1	1	1	1
3:00-3:59 pm	1	1	1	1	1	1	1
4:00-4:59 pm	1	1	1	1	1	1	1
5:00-5:59 pm	1	1	1	1	1	1	1
6:00-6:59 pm	0	1	1	1	1	1	0
7:00-7:59 pm	0	1	1	1	1	1	0
8:00-8:59 pm	0	1	1	1	1	1	0
9:00-9:59 pm	0	1	1	1	1	1	0
10:00-10:59 pm	0	0	0	0	0	0	0
11:00-11:59 pm	0	0	0	0	0	0	0

Statutory Holidays and Other Shutdown Times

Adjust the number of weekdays (Monday-Friday) by month that the equipment is not operating due to statutory, civic or other holidays, lieu days or scheduled shutdowns. The numbers pre-populated in the table represent the default statutory, civic or other holidays, per the table on the right.

January	1
February	1
March	0
April	2
May	1
June	0
July	1
August	1
September	1
October	1
November	0
December	2
TOTAL:	11

Ontario Holidays	
New Years Day	January 1
Family Day	3rd Monday in February
Good Friday	Friday before Easter Sunday
Easter Monday	Monday after Easter Sunday
Victoria Day	Monday before May 25
Canada Day	July 1
Civic Holiday	1st Monday in August
Labour Day	1st Monday in September
Thanksgiving Day	2nd Monday in October
Christmas Day	December 25
Boxing Day	December 26

85	This is the typical weekly number of operating hours for the equipment based on the schedule above (excluding holidays)
4270	This is the annual number of operating hours for the equipment based typical weekly and holiday schedule entered

SHORT EXPLANATION
Provide short explanation regarding method used for flow profile estimate. Note this calculator does not accept VSD Compressor flows less than 40% of fully rated capacity.
placeholder

VSD and Fixed Speed Compressors are within 10% Capacity

COMMENTS & NOTES FOR TECHNICAL REVIEWER TO BE AWARE OF
placeholder

ECONOMIC VALUES		
Value	**Units**	**Description**
$ 0.25	$/kWh	Blended Cost of Power based on Actual Billing Data
	$	Show Non Electrical Annual Savings as Positive (Show Costs as a Negative Number)

PROJECT COST BREAKDOWN FOR FIXED SPEED AND VSD COMPRESSOR	
Costs which are eligible to be included in determining applicable Participant Incentives must be directly related to the procurement and implementation of the Eligible Measures and are limited to the following list. Please enter the Eligible Costs below as applicable.	
$ 44,500	Actual costs of the VSD Compressor purchased and installed
$ 32,550	Actual costs of an equivalent Fixed Speed Compressor purchased and installed
	Actual costs to dispose or decommission the replaced equipment
	Actual costs of inspection of the Project as may be required pursuant to Laws and Regulations
$ 11,950	Incremental Cost of VSD Compressor vs. Fixed Speed Compressor if Project is Implemented
$ 44,500	**TOTAL ELIGIBLE COSTS FOR THE PROJECT**

ANNUAL SAVINGS AND ECONOMICS		
Value	**Units**	**Description**
253,760	kWh	Estimated Fixed Speed Compressor Annual Energy Consumption
190,820	kWh	Estimated VSD Compressor Annual Energy Consumption if Project is Implemented
62,941	kWh	**Estimated Annual Energy Savings (Permanent and Non-Permanent) if Project is Implemented**
59.4	kW	Estimated Fixed Speed Compressor Peak Demand while Operating
44.7	kW	Estimated VSD Compressor Peak Demand while Operating if Project is Implemented
14.7	kW	Estimated Demand Reduction (while operating) if Project is Implemented
25%	%	% Energy Savings
$ 15,735	$	Annual Electrical Savings if Project is Implemented ($)
$ 15,735	$	**Annual Total Savings if VSD Project is Implemented**
$ 44,500	$	Total Project Cost for VSD Compressor ($)
$ 11,950	$	**Incremental Capital Cost for Improvements if Project is Implemented ($)**
2.8	Years	Simple Payback for Incremental Cost Before Incentive (years)
$ 22,250	$	**Potential Incentive Amount ($)**
1.4	Years	**Simple Payback for Incremental Cost After Incentive (years)**

VSD Option is Better than Fixed Speed Option

PROJECT ENGINEERING ESTIMATES

This section highlights the demand and energy consumption for the Base Case and Energy Efficient Case. From this data, the savings associated with implementing the energy efficient option are calculated.

	Base Case Measure	Energy Efficient Case	Savings Summary	
Maximum Summer Peak Period Demand (kW)	59.4	44.7	14.7	(Occurs During Summer On-Peak Period)
Average Summer Peak Demand (kW)	57.4	43.1	14.3	(Summer On-Peak Energy/On-Peak Hours)
Average to Maximum Ratio (%)	97%	96%	97%	
Maximum Winter Peak Period Demand (kW)	59.4	44.7	14.7	(Occurs During Winter On-Peak Period)
Average Winter Peak Demand (kW)	56.7	42.6	14.1	(Winter On-Peak Energy/On-Peak Hours)
Average to Maximum Ratio (%)	95%	95%	95%	
Annual Electricity Consumption (kWh)	253,760	190,820	62,941	

* Highlighted items to be entered into Custom track online

PROJECT ECONOMICS

Based on cost information entered by the user along with calculated Participant Incentive amounts, the project economics are summarized. If the motor option is selected, the Participant Incentive is based on the Prescriptive Motor Eligible Measures Worksheet. In this scenario, the Demand Savings and Energy Savings are backed out of the calculated Participant Incentive and the prescriptive amount is entered.

Assumed Blended Electricity Rate ($/kWh):	$ 0.250
Estimated Annual Energy Savings ($/year):	$ 15,735
Other Savings (Cost) ($/year):	$ -
Estimated Total Annual Savings ($/year):	$ 15,735
Demand Savings[1] (kW) for the purpose of calculating the Participant Incentive	**14.3**
Energy Savings[2] (kWh) for the purpose of calculating the Participant Incentive	**62,941**
Total Eligible Costs for the Project($):	$ 44,500
Calculated kW Participant Incentive ($1800/kW of Demand Savings)	$ 25,740
Calculated kWh Participant Incentive ($0.20/kWh of Energy Savings)	$ 12,588
Estimated Participant Incentive Amount[3,4]:	**$ 25,740**
Simple Payback (without Participant Incentive)	2.8
Simple Payback (with Participant Incentive)	1.4

***NOTE** : These values must match online with Save on Energy RETROFIT Program Application under the Site and Project Details of the Custom Approach - Demand (kW) and Energy (kWh) Savings*

QC & DIAGNOSTICS

This section displays some checks related to the average to maximum threshold.

Average to Maximum Threshold Level (%)	50%
Actual Average to Maximum Threshold Level (%)	97%
Average to Maximum Ratio exceeds Average to Maximum Threshold Level[4]:	YES

Calculation of Total Project Costs ($):

It is assumed that the total project costs amount to $ 44,500.00

Calculation of Incentives ($):

Calculated kW Participant Incentive ($1,800/kW of Demand Savings):

Participant Incentive	=	14.3 kW	x	$1,800/kW
	=	$ 25,740		

Calculated kWh Participant Incentive ($0.20/kW of Energy Savings)

Participant Incentive	=	62,941 kWh	x	$ 0.20/kWh
	=	$ 12,588		

A cap is placed on the Participant Incentives as 50% of the total eligible project costs. 50% of the total eligible project costs in this scenario is $25,740. Therefore the Participant Incentives is at $17,640.

RETROFIT VARIABLE SPEED DRIVE (VSD) ON FANS ENGINEERED WORKSHEET

A company has decided to install a VSD on its 50,000 cfm fan. The fan's operating hours are from 6:00 a.m. to 10:00 p.m. Mondays to Fridays and from 7:00 a.m. to 7:00 p.m. on Saturdays. The facility is closed on Sundays and holidays.

Ontario Statutory Holidays	
New Years Day	January 1
Family Day	3rd Monday in February
Good Friday	Friday before Easter Sunday
Easter Monday	Monday after Easter Sunday
Victoria Day	Monday before May 25
Canada Day	July 1
Civic Holiday	1st Monday in August
Labour Day	1st Monday in September
Thanksgiving Day	2nd Monday in October
Christmas Day	December 25
Boxing Day	December 26

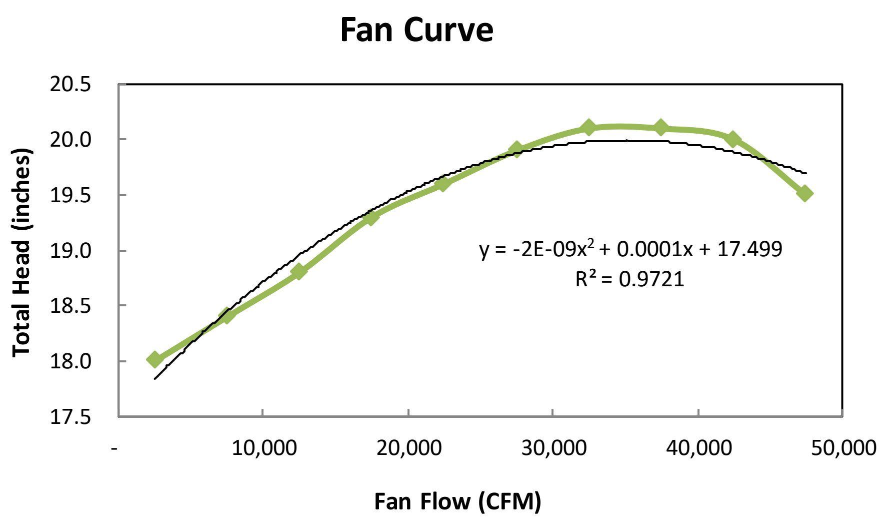
The existing fan and motor information are as follows:

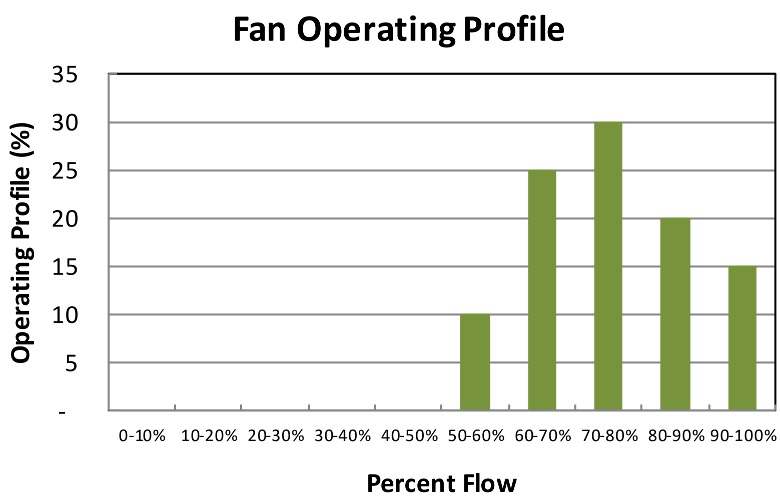
FAN AND MOTOR INFORMATION		
	Units	**Description**
890	rpm	Motor Rated Speed
200	BHP	Motor Rated Power
68	°F	Gas Temperature
0.075	lb/ft3	Density of Gas (use 0.075 lb/ft3 for air at 68F)
19.5	"WG	Design Head (at X)
0.0	"WG	Static Head
ABC-123	n/a	Motor Make and Model
XYZ-999	n/a	Fan Make and Model
10	years	Approximate age of Motor
10	years	Approximate age of Fan

The design head and fan efficiency for different percent flow as read from the performance curve of the fan, as well as the operating profile are entered on the following table:

%Flow	Design Head ("WG)	Corresponding Fan Efficiency (%)	Operating Profile (%)
0-10%	18.0	20	
10-20%	18.4	20	
20-30%	18.8	20	
30-40%	19.3	20	
40-50%	19.6	30	
50-60%	19.9	40	10
60-70%	20.1	50	25
70-80%	20.1	60	30
80-90%	20.0	70	20
90-100%	19.5	80	15
Design	**19.5**	**87**	**100**

The fan curve and the operating profile as generated by the Engineered Worksheet are shown on the next page.





FAN AND MOTOR EFFICIENCY		
	Units	Description
93.0	%	Motor Full Load Efficiency
86.7	%	Fan Efficiency at Damper Fully Open
0.96	fraction	Motor Efficiency Correction Factor for Lower Loads
0.95	fraction	VSD Efficiency Factor (When Operating > 40% Load)
0.82	fraction	Motor Efficiency Correction Factor for VSD Operation
0.96	fraction	Belt/Coupling Efficiency Factor

Calculation of Energy Savings (kWh):

For each % flow in the conventional fan system, the fan horsepower (FHP) is calculated using the following equation:

$$\text{Fan Horsepower } (FHP_b) = \frac{Q_b \times P \times \rho}{\eta_{fan} \times 6356}$$

For 50-60% flow, consider Q_b = 50,000 cfm x 0.55 = 27,500 cfm; P = 19.9"WG; ρ = 0.075 lbs/ft^3; and η_{fan} = 0.40

$$\text{Fan Horsepower } (FHP_b) = \frac{27{,}500 \times 19.9 \times 1.0}{0.40 \times 6356}$$

$$= 215.25 \text{ hp}$$

The conventional fan system energy consumption (kWh) for each bin is calculated using the following equation:

$$\text{Conventional Annual Energy Consumption } (kWh_b) = \frac{FHP_b \times 0.746 \times H}{(\eta_{motor} \times \eta_{belt/coupling}) / 100}$$

The annual operating hours is located under the *System Schedule* tab. For the above equation, H represents the operating hours for each % flow. For 50-60%, H = 5,296 hours x 0.10 = 529.6 hours.

$$\text{Conventional Annual Energy Consumption } (kWh_b) = \frac{215.25 \times 0.746 \times 529.6}{(0.93 \times 0.96 \times 0.96) / 100}$$

$$= 99{,}221 \text{ kWh}$$

Conventional Annual Energy Consumption (kWh_b) for each Flow

%Flow	Flow (cfm)	Design Head ("WG)	Fan Efficiency (%)	Operating Profile (%)	Hours	Fan HP	kWh
0-10%	2,500	18.0	20			35.40	
10-20%	7,500	18.4	20			108.56	
20-30%	12,500	18.8	20			184.86	
30-40%	17,500	19.3	20			265.69	
40-50%	22,500	19.6	30			231.28	
50-60%	27,500	19.9	40	10	530	215.25	99,221
60-70%	32,500	20.1	50	25	1,324	205.55	236,879
70-80%	37,500	20.1	60	30	1,589	197.65	265,040
80-90%	42,500	20.0	70	20	1,059	191.05	170,791
90-100%	47,500	19.5	80	15	794	182.16	122,136
Design		**19.5**	**87**	**100**		**Total:**	**894,066**

The total annual energy consumption for the base case sums up all the energy consumption in the 10 bins. For this particular example, total annual energy consumption is 894,066 kWh.

Likewise, for the Variable Speed Drive on Fans option, the annual energy consumption in kWh is calculated the same way as the Conventional Fan System except that there is an additional definition for total head and efficiencies.

$$P = P_s + (P_d - P_s) (Q / Q_d)^2$$

For the 50-60% flow, static head P_s = 0; design head for P_d = 19.5 in H_2O; Q = 27,500 cfm; Q_d = 50,000 cfm

$$P = 0 + (19.5 - 0) (27{,}500 / 50{,}000)^2$$

$$P = 5.90 \text{ in } H_2O$$

Calculate the fan horsepower for the VSD option:

$$\text{Fan Horsepower (FHP}_r\text{)} = \frac{Q_r \times P \times \rho}{\eta_{fan} \times 6356}$$

For 50-60% flow, consider Q_r = 50,000 cfm x 0.55 = 27,500 cfm; P = 5.9"WG; ρ = 0.075 lbs/ft^3; and η_{fan} = 0.867

$$\text{Fan Horsepower (FHP}_r\text{)} = \frac{27{,}500 \times 5.9 \times 1.0}{0.867 \times 6356}$$

$$= 29.44 \text{ hp}$$

The energy consumption (kWh) for each bin for the VSD option is calculated using the following equation:

$$\text{VSD Option Annual Energy Consumption (kWh}_r\text{)} = \frac{FHP_r \times 0.746 \times H}{\eta_{motor} \times \eta_{VSD} \times \eta_{belt/coupling}}$$

$$= \frac{29.44 \times 0.746 \times 529.6}{(0.93 \times 0.82) \times 0.95 \times 0.96}$$

$$= 16{,}722 \text{ kWh}$$

The total annual energy consumption for the VSD option sums up all the energy consumption in the 10 bins. For this particular example, total annual energy consumption is 410,422 kWh. See table on the next page.

Getting the difference between the conventional and the VSD option, annual savings is calculated to be 465,637 kWh.

VSD Option Annual Energy Consumption (kWh$_b$) for each Flow

%Flow	Flow (cfm)	System Head	Operating Profile (%)	Hours	Fan HP	kWh	Savings
0-10%	2,500	0.05			0.02		
10-20%	7,500	0.44			0.60		
20-30%	12,500	1.22			2.76		
30-40%	17,500	2.39			7.59		
40-50%	22,500	3.95			16.12		
50-60%	27,500	5.90	10	530	29.44	16,722	82,499
60-70%	32,500	8.24	25	1,324	48.59	69,004	167,875
70-80%	37,500	10.97	30	1,589	74.64	127,204	137,835
80-90%	42,500	14.09	20	1,059	108.66	123,448	47,343
90-100%	47,500	17.60	15	794	151.70	129,258	(7,123)
Design			**100**		**Total:**	**465,637**	**428,429**

Calculation of Demand Savings (kW):

The maximum summer and winter peak period demand (kW) savings are calculated by dividing the annual energy savings (kWh) by the total annual hours of operation.

$$\text{Demand Savings (kW)} = \frac{\text{Annual Energy Savings (kWh)}}{\text{Annual Operating Hours (hrs)}}$$

= 428,429 kWh /5,296 hrs

= 80.9 kW

Average Summer Peak Period Demand Savings (kW) = Total Peak Demand (Base) - Total Peak Demand (Retrofit)

Average Peak Period Demand Savings (kW) = 168.8 kW – 87.9 kW

Average Peak Period Demand Savings (kW) = 80.9 kW

Calculation of Total Project Costs ($):

It is assumed that the total project costs amount to $ 141,500.00 broken down as follows:

Variable speed drive cost	$ 125,000.00
Labour to install VSD	$ 16,500.00
Total:	$ 141,500.00

Calculation of Incentives ($):

Calculated kW Participant Incentive ($1,800/kW of Demand Savings):

Participant Incentive = 80.9 kW x $1,800/kW

= $ 145,620

Calculated kWh Participant Incentive ($0.20/kWh of Energy Savings)

Participant Incentive = 428,429 kWh x $ 0.20/kWh

= $ 85,686

A cap of 50% of the total eligible project costs is placed on the participant incentive. 50% of the total eligible project cost in this scenario is $70,750. The selected participant incentive of $145,620 exceeds this cap, so it is capped at $70,750.

RETROFIT VARIABLE SPEED DRIVE (VSD) ON PUMP ENGINEERED WORKSHEET

A company has decided to install a VSD on its 1,100 gpm pump. The fan's operating hours are from 10:00 a.m. to 8:00 p.m. Mondays to Fridays and from 10:00 a.m. to 5:00 p.m. on Saturdays. The facility is closed on Sundays and holidays.

Ontario Statutory Holidays	
New Years Day	January 1
Family Day	3rd Monday in February
Good Friday	Friday before Easter Sunday
Easter Monday	Monday after Easter Sunday
Victoria Day	Monday before May 25
Canada Day	July 1
Civic Holiday	1st Monday in August
Labour Day	1st Monday in September
Thanksgiving Day	2nd Monday in October
Christmas Day	December 25
Boxing Day	December 26

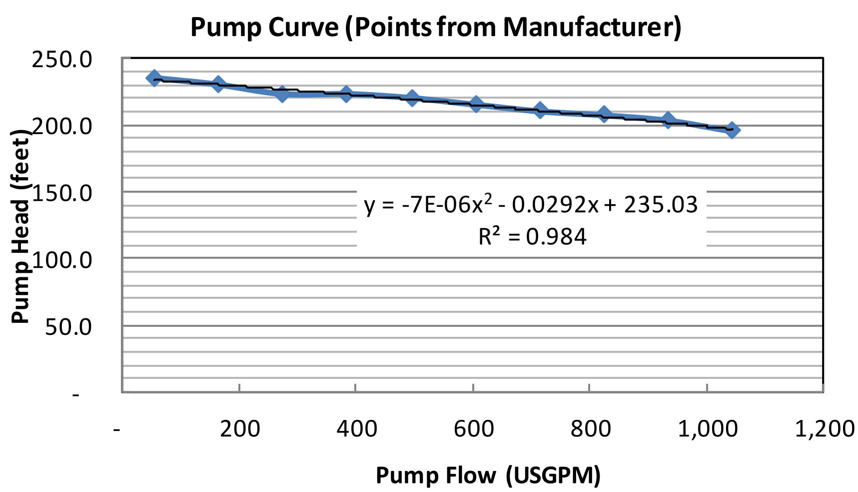
The existing pump and motor information are as follows:

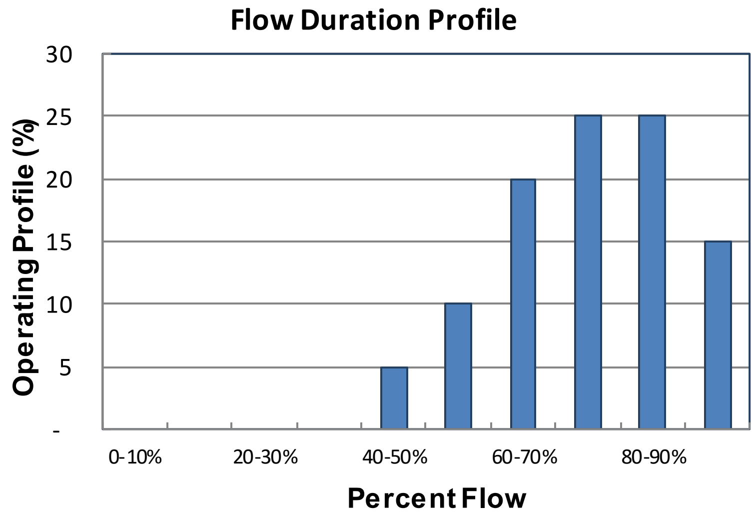
FAN AND MOTOR INFORMATION		
	Units	**Description**
1750	rpm	Motor Rated Speed
75	BHP	Motor Rated Power
65	°F	Fluid Temperature
1.00	S.G.	Specific Gravity of Fluid (Water =1.00)
190.0	ft	Design Head (at X)
20.0	ft	Static Head
ABC-123	n/a	Motor Make & Model
XYZ-999	n/a	Pump Make and Model
5	years	Approximate age of Motor
3	years	Approximate Age of Pump

The pump head and pump efficiency for different percent flow as read from the performance curve of the pump, as well as the operating profile are entered on the following table:

%Flow	Pump Head (ft)	Corresponding Pump Efficiency (%)	Operating Profile (%)
0-10%	235.0	20.0	
10-20%	230.0	20.0	
20-30%	223.0	35.0	
30-40%	223.0	50.0	
40-50%	220.0	60.0	5.0
50-60%	215.0	70.0	10.0
60-70%	210.0	72.0	20.0
70-80%	207.0	74.0	25.0
80-90%	203.0	76.0	25.0
90-100%	195.0	78.0	15.0
Design	**190**	**80**	**100**

The pump curve and the operating profile as generated by the Engineered Worksheet are shown on the next page.





PUMP AND MOTOR EFFICIENCY		
	Units	Description
95.4	%	Motor Full Load Efficiency
80.0	%	Pump Efficiency (at X)
0.95	fraction	Motor Efficiency Correction Factor for Lower Loads
0.95	fraction	VSD Efficiency Factor (When Operating > 40% Load)
0.82	fraction	Motor Efficiency Correction Factor for VSD Operation

Calculation of Energy Savings (kWh):

For each % flow in the conventional pump system, the pump horsepower (PHP) is calculated using the following equation:

$$\text{Pump Horsepower } (PHP_b) = \frac{Q_b \times P \times \gamma}{\eta_{pump} \times 3958}$$

For 50-60% flow, consider Q_b = 1,100 gpm x 0.55 = 605 gpm; P = 215 ft; γ = 1.0; and η_{pump} = 0.70

$$\text{Pump Horsepower } (PHP_b) = \frac{605 \times 215 \times 1.0}{0.70 \times 3958}$$

$$= 46.95 \text{ hp}$$

The conventional pump system energy consumption (kWh) for each bin is calculated using the following equation:

$$\text{Conventional Annual Energy Consumption } (kWh_b) = \frac{PHP_b \times 0.746 \times H}{(\eta_{motor})}$$

The annual operating hours is located under the *System Schedule* tab. For the above equation, H represents the operating hours for each % flow. For 50-60%, H = 3,228 hours x 0.10 = 322.8 hours.

$$\text{Conventional Annual Energy Consumption } (kWh_b) = \frac{46.95 \times 0.746 \times 322.8}{(0.954 \times 0.95)}$$

$$= 12{,}474.8 \text{ kWh}$$

Conventional Annual Energy Consumption (kWh_b) for each Flow

%Flow	Flow (GPM)	Design Head (ft)	Pump Efficiency (%)	Operating Profile (%)	Hours	Pump HP	kWh
0-10%	55	235.0	20.0			16.33	-
10-20%	165	230.0	20.0			47.94	-
20-30%	275	223.0	35.0			44.27	-
30-40%	385	223.0	50.0			43.38	-
40-50%	495	220.0	60.0	5.0	161	45.86	6,431
50-60%	605	215.0	70.0	10.0	323	46.95	12,474
60-70%	715	210.0	72.0	20.0	646	52.69	27,999
70-80%	825	207.0	74.0	25.0	807	58.31	37,166
80-90%	935	203.0	76.0	25.0	807	63.10	40,220
90-100%	1,045	195.0	78.0	15.0	484	66.01	25,244
Design		**190**	**80**	**100**		**Total:**	**149,535**

The total annual energy consumption for the base case sums up all the energy consumption in the 10 bins. For this particular example, total annual energy consumption is 163,432 kWh.

Likewise, for the Variable Speed Drive on Pump option, the annual energy consumption in kWh is calculated the same way as the Conventional Pump System except that there is an additional definition for total head and efficiencies.

$$P = P_s + (P_d - P_s)\,(Q / Q_d)^2$$

For the 50-60% flow, static head P_s = 20 ft; design head for P_d = 190 ft; Q = 605 gpm; Q_d = 1100 gpm

$$P = 20 + (190 - 20)\,(605 / 1100)^2$$

$$P = 71.43 \text{ ft}$$

Calculate the fan horsepower for the VSD option:

$$\text{Pump Horsepower } (PHP_r) = \frac{Q_r \times P \times \gamma}{\eta_{pump} \times 3958}$$

For 50-60% flow, consider Q_r = 1,100 gpm x 0.55 = 605 gpm; P = 71.43 ft; γ = 1.0; and η_{pump} = 0.80

$$\text{Pump Horsepower } (PHP_r) = \frac{605 \times 71.43 \times 1.0}{0.8 \times 3958}$$

$$= 13.65 \text{ hp}$$

The energy consumption (kWh) for each bin for the VSD option is calculated using the following equation:

$$\text{VSD Option Annual Energy Consumption } (kWh_r) = \frac{PHP_r \times 0.746 \times H}{\eta_{motor} \times \eta_{VSD}}$$

$$= \frac{13.65 \times 0.746 \times 3{,}228}{(0.954 \times 0.82) \times 0.95}$$

$$= 4{,}422 \text{ kWh}$$

The total annual energy consumption for the VSD option sums up all the energy consumption in the 10 bins. For this particular example, total annual energy consumption is 105,626 kWh. See table on the next page.

Getting the difference between the conventional and the VSD option, annual savings is calculated to be 43,090 kWh.

VSD Option Annual Energy Consumption (kWh_b) for each Flow

%Flow	Flow (gpm)	System Head	Operating Profile (%)	Hours	Pump HP	kWh	Savings
0-10%	55	20.43			0.35	-	-
10-20%	165	23.83			1.24	-	-
20-30%	275	30.63			2.66	-	-
30-40%	385	40.83			4.96	-	-
40-50%	495	54.43	5.0	161	8.51	1,378	5,052
50-60%	605	71.43	10.0	323	13.65	4,422	8,052
60-70%	715	91.83	20.0	646	20.73	13,437	14,562
70-80%	825	115.63	25.0	807	30.13	24,404	12,762
80-90%	935	142.83	25.0	807	42.17	34,165	6,056
90-100%	1,045	173.43	15.0	484	57.24	27,819	(2,575)
Design			**100**		**Total:**	**105,626**	**43,090**

Calculation of Demand Savings (kW):

The maximum summer and winter peak period demand (kW) savings are calculated by dividing the annual energy savings (kWh) by the total annual hours of operation.

$$\text{Demand Savings (kW)} = \frac{\text{Annual Energy Savings (kWh)}}{\text{Annual Operating Hours (hrs)}}$$

$$= 43{,}090 / 3{,}228 \text{ hrs}$$

$$= 13.6 \text{ kW}$$

Average Summer Peak Period Demand Savings (kW) = Total Peak Demand (Base) - Total Peak Demand (Retrofit)

Average Peak Period Demand Savings (kW) = 46.3 kW – 32.7 kW

Average Peak Period Demand Savings (kW) = 13.6 kW

Calculation of Total Project Costs ($):

It is assumed that the total project costs amount to $ 30,800.00 broken down as follows:

Variable speed drive cost	$ 23,200.00
Labour to install VSD	$ 7,600.00
Total:	$ 30,800.00

Calculation of Incentives ($):

Calculated kW Participant Incentive ($1,800/kW of Demand Savings):

Participant Incentive = 13.6 kW x $1,800/kW

= $ 19,800

Calculated kWh Participant Incentive ($0.20/kWh of Energy Savings)

Participant Incentive = 43,090 kWh x $ 0.20/kWh

= $ 8,782

A cap of 50% of the total eligible project costs is placed on the participant incentive. 50% of the total eligible project cost in this scenario is $15,400. The selected participant incentive of $19,800 exceeds this cap, so it is capped at $15,400.

RETROFIT UNITARY AIR-CONDITIONING (A/C) ENGINEERED WORKSHEET

A community centre in Ottawa is installing an energy efficient rooftop unit to retrofit its existing unit serving 400 m^2 of space. The facility operates from 10:00 am to 9:00 p.m. Monday to Friday and from 10:00 a.m. to 5:00 p.m. on Saturday, Sunday and holidays.

Existing Unitary A/C System (Quantity of 2):

- Capacity – 72,000 Btu/h
- EER – 8.9

Proposed Unitary A/C System (Quantity of 2):

- Capacity – 72,000 Btu/h
- EER – 12.0

Calculation of Demand Savings (kW):

The energy performance of the Unitary A/C is determined by calculating the energy consumption of both the existing (base case) and retrofit (design case) units for each hour that the equipment operates during the year. First, peak (rated) power (in watts) is calculated by dividing the capacity (Btu/hr) by the energy efficiency ratio (EER). This is then converted to kilowatts.

$$\text{Rated } kW_b = \frac{\text{Capacity (Btu/h)}}{\text{EER (Btu/Wh)} \times 1000}$$

$$= 72{,}000 / (8.9 \times 1000)$$

$$= 8.09 \text{ kW}$$

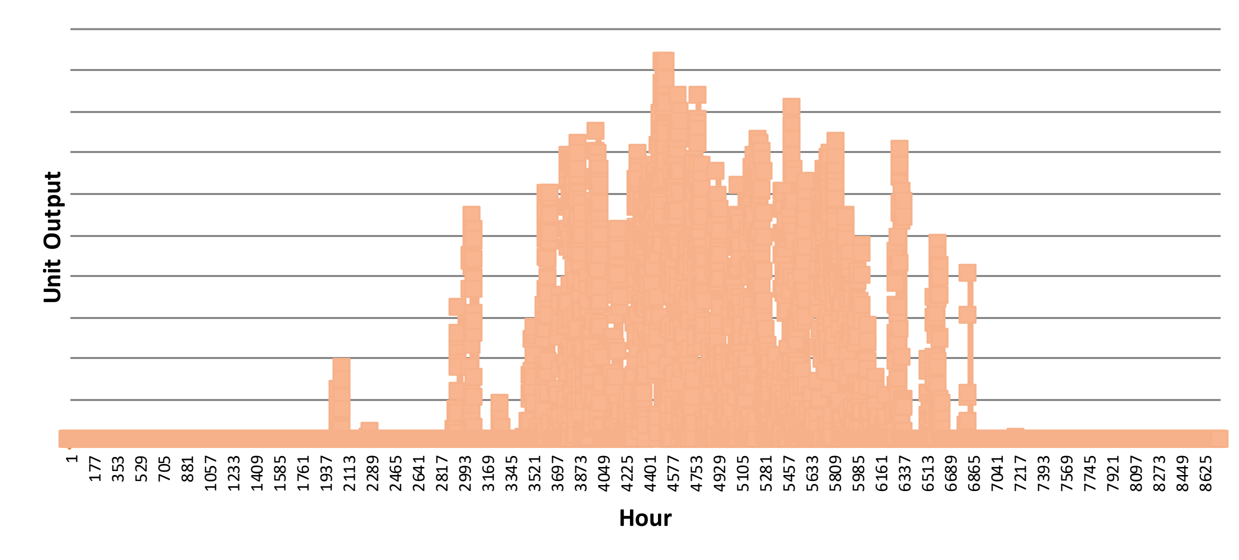
$$\text{Rated } kW_r = \frac{\text{Capacity (Btu/h)}}{\text{EER (Btu/Wh)} \times 1000}$$

$$= 72{,}000 / (12.0 \times 1000)$$

$$= 6.0 \text{ kW}$$

Power consumption at part load is calculated via a methodology published by NRCan for use in a building modeling software called EE4. This methodology is based on percentage unit output, wet bulb and dry bulb temperatures and yields the % of peak power consumed at part load. This calculation is performed for each hour of the year that operation is scheduled.

For this example, a community centre is selected and will assume a part load for the whole 8760 hours represented by the graph below. For calculation purposes, we will show how power consumption at part load is estimated using NRCan's methodology. We will assume a weekday in July from 11:00 a.m. to 5:00 p.m.



Data Input Requirements

Time	% Unit Output	Dry Bulb Temperature	Wet Bulb Temperature
11:00 am – 12:00 pm	0.01250	73.22	59.62
12:00 pm – 1:00 pm	0.03075	73.76	58.90
1:00 pm – 2:00 pm	0.04600	75.20	58.96
2:00 pm – 3:00 pm	0.13325	74.84	57.98
3:00 pm – 4:00 pm	0.05625	75.74	58.99
4:00 pm – 5:00 pm	0.13950	75.74	57.73

For each hour, the base consumption and retrofit consumptions will be calculated using NRCan's methodology.

Cooling Capacity Adjustment Curve

$$CAP\_FT = 0.8740302 + (-0.0011416 \times t_{wb}) + (0.0001711 \times t_{wb}^2) + (-0.0029570 \times t_{odb}) + (0.0000102 \times t_{odb}^2) + (-0.0000592 \times t_{wb} \times t_{odb})$$

Adjustment to Rated Efficiency due to Environmental Variables

$$EIR\_FT = -1.0639310 + (0.0306584 \times t_{wb}) + (-0.0001269 \times t_{wb}^2) + (0.0154213 \times t_{odb}) + (0.0000497 \times t_{odb}^2) + (-0.0002096 \times t_{wb} \times t_{odb})$$

Part Load Ratio

$$PLR = \frac{Q_{operating}}{Q_{available}\,(t_{wb}, t_{odb})}$$

$Q_{operating}$ = % Unit Output x Capacity

$Q_{available}$ (t_{wb}, t_{odb}) = CAP_FT x Q_{rated}

Adjustment to Rated Efficiency due to Changes in Coil Load

EIR_FPLR = 0.2012301 + (-0.0312175 x PLR) + (1.9504979 x PLR^2) + (-1.1205105 x PLR^3)

Calculated Values

Time	CAP_FT	EIR_FT	PLR_b	PLR_r	EIR_FPLR_b	EIR_FPLR_r
11:00 am – 12:00 pm	0.9939	0.7935	0.0126	0.0126	0.2011	0.2011
12:00 pm – 1:00 pm	0.9806	0.7989	0.0314	0.0314	0.2021	0.2021
1:00 pm – 2:00 pm	0.9743	0.8140	0.0472	0.0472	0.2040	0.2040
2:00 pm – 3:00 pm	0.9620	0.8100	0.1385	0.1385	0.2314	0.2314
3:00 pm – 4:00 pm	0.9721	0.8197	0.0579	0.0579	0.2057	0.2057
4:00 pm – 5:00 pm	0.9541	0.8197	0.1462	0.1462	0.2349	0.2349

To compute for the base and retrofit demand (kW) for each hour, we use

$Demand\ (kW)_b$ = Rated kW_b x CAP_FT x EIR_FT x EIR_FPLR_b

$Demand\ (kW)_r$ = Rated kW_r x CAP_FT x EIR_FT x EIR_FPLR_r

Time	Base Case kW	Efficiency Case kW	Savings
11:00 am – 12:00 pm	1.2833	0.9518	0.3315
12:00 pm – 1:00 pm	1.2810	0.9501	0.3309
1:00 pm – 2:00 pm	1.3088	0.9707	0.3381
2:00 pm – 3:00 pm	1.4584	1.0817	0.3768
3:00 pm – 4:00 pm	1.3262	0.9836	0.3426
4:00 pm – 5:00 pm	1.4859	1.1020	0.3839

Demand (kW) savings is automatically obtained by the engineered worksheet by getting the difference of the maximum kW occurring during the summer peak window (11:00 a.m. to 5:00 pm), Mondays to Fridays from June 01 to September 30 for both the base and retrofit case.

Max Demand $(kW)_b$ = Existing AC Unit Type 1 x Quantity Type 1 + Existing AC Unit Type 2 x Quantity Type 2 + Existing AC Unit Type 3 x Quantity Type 3

= 6.7026 kW x 2 + 0 kW x 0 + 0 kW x 0

= 13.4 kW

Max Demand $(kW)_r$ = Retrofit AC Unit Type 1 x Quantity Type 1 + Retrofit AC Unit Type 2 x Quantity Type 2 + Retrofit AC Unit Type 3 x Quantity Type 3

= 4.9710 kW x 2 + 0 kW x 0 + 0 kW x 0
= 9.9 kW

For this particular example, base case maximum demand is 13.4 kW while the retrofit case maximum demand is 9.9 kW. Getting their difference, the demand (kW) savings is 3.5 kW (13.4 kW – 9.9 kW).

Calculation of Energy Savings (kWh):

The base case and retrofit case energy consumption (kWh) are obtained by summing up all the demand (kW) for each hour for the whole 8760 hours. Base case energy consumption is 6,051 kWh while the retrofit case energy consumption is 4,488 kWh. Energy savings, therefore, is 1,563 kWh (6,051 kWh - 4,488 kWh)

Calculation of Total Project Costs ($):

It is assumed that the total project costs amount to $ 12,000.00 broken down as follows:

Unitary AC cost	$ 10,000.00
Labour to install new Unitary AC	$ 2,000.00
Total:	$ 12,000.00

Calculation of Incentives ($):

Calculated kW Participant Incentive ($1,800/kW of Demand Savings):

Participant Incentive = 3.5 kW x $1,800/kW
= $ 6,300

Calculated kWh Participant Incentive ($0.20/kWh of Energy Savings)

Participant Incentive = 1,563 kWh x $ 0.20/kWh
= $ 312.6

Maximum Allowable Participant Incentive (50% of Total Eligible Costs for the Project)

Participant Incentive = $ 12,000.00 x 50%
= $ 6,000.00

The Participant Incentive is the greater value between the calculated incentive based on kW and kWh savings, subject to a maximum 50% of total eligible costs for the project. Therefore, the total incentive for this project is $6,000.