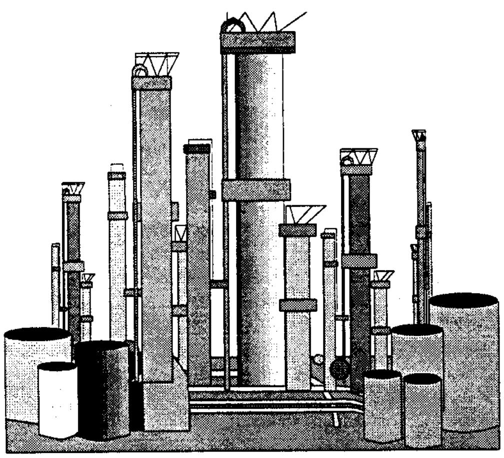
San Diego Gas & Electric
Marketing Programs & Planning
8306 Century Park Court
San Diego, California 92123

1995 Industrial Energy Efficiency Incentives Program

First Year Load Impact Evaluation

February 1997



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Study ID No. 962

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Section 1

Section 1
Executive Summary

This is an evaluation of the 1995 Program Year (PY95) first year load impacts for SDG&E's industrial customers, who are a subset of the nonresidential customers that participated in SDG&E's 1995 Commercial/ Industrial/Agricultural (C/I/A) Energy Efficiency Incentives (EEI) Programs. The C/I/A EEI Programs help customers reduce energy costs and increase energy efficiency at their facilities. There are three major end uses covered by this report: (1) lighting, (2) motors, and (3) industrial process.

The lighting study employed a load impact regression model. The results show that the realization rate for the gross load impacts was 119.8%. The net-to-gross ratio of 89.0% was taken from the commercial lighting results from SDG&E's 1995 Commercial Energy Efficiency Incentives Program First Year Load Impact Evaluation Study, February 1997, Study ID No. 959.

The industrial process and motors end use evaluations completed by Xenergy entail on-site verifications of the *ex ante* engineering assumptions. The gross energy impact realizations rates for industrial process and motors were both 101 %. The net-to-gross ratios were 85% for industrial process and 29 % for motors.

The IEEI Program study results shown in the designated unit of measurement for each end use are as follows:

Table 1
Study Results for the IEEI Programs

End Use	Industrial Participants	Energy Savings[1] (kWh)	Realization Rate	Demand Savings[1] (kW)	Realization Rate	Net-to-Gross Ratio
Indoor Lighting	56	0.31	77.5%	0.16	41.0%	89 %
Motors	38	105.40	101.0%	0.20	110.0%	29%
Process	12	846,260	101.0%	97.39	61.0%	85%

1 Lighting DUOM: load impacts per square foot per 1000 hours of operation
Process DUOM: load impacts per project
Motors DUOM: load impacts per hp

Organization of Report

The report is organized into several sections.

Section 2: Study Overview: This section presents the program description, a discussion of the participant database and data collection.

Section 3: Indoor Lighting Study: This section discusses the regression models and results obtained for the first year load impact study for lighting.

Section 4: Industrial Process & Motors Study by XENERGY: This section contains the first year load impact study for industrial processes conducted by XENERGY

Appendices: This section contains all the appendices referenced throughout the report, and the M&E Protocols Reporting Requirements Tables 6 and 7 for the various end uses.

Section 2

Section 2
Study Overview

Program Description

San Diego Gas & Electric offers the C/I/A EEI Programs to help customers reduce energy costs and increase energy efficiency at their facilities. The C/I/A EEI Programs, supported through audit programs, energy services representatives, and account executives, provide cost-effective DSM energy savings when existing customers have retrofit opportunities. SDG&E has three main market delivery mechanisms for providing incentives for retrofit or replace-on-burnout applications: (1) Commercial/Industrial (C/I) Incentives Program, (2) Power to Save Program, and (3) Commercial Rebates Programs. Through this marketing strategy, SDG&E is provided the flexibility needed to encourage the adoption of energy efficient measures that would not otherwise be installed by customers due to economic market barriers.

C/I Incentives. This program typically targets large customers where SDG&E's account executives are involved in assisting customers with major retrofit applications. This program offers incentives to customers for the installation of standard mechanical and complex custom energy efficient measures. Energy efficient measures that have been identified as cost-effective when applied to specific building types are categorized as standard measures. Incentives are also available for measures on a customized basis, providing the project meets the program cost-effectiveness tests. Energy savings are determined and reviewed by SDG&E's engineering staff. Additionally, for further verification, an outside consulting engineering firm performs semi-annual reviews of the completed job files.

Power to Save. This marketing strategy offers incentives to customers for the installation of energy efficient lighting and mechanical technologies. This full service strategy focuses on standard and custom lighting applications, as well as less complex standard and custom mechanical applications for all sizes of commercial and industrial customers, but tends to accommodate medium/small commercial/industrial customers.

Customer participation begins with an energy audit and recommendations for energy efficient equipment based on audit results. Customers are encouraged to participate in this program by installing cost-effective energy efficient measures and receiving incentives for those measures.

Commercial Rebates. These rebates are delivered through retailers/wholesalers who give the commercial/industrial/agricultural customer an instant incentive at the point of purchase. This program offers rebates to these customers for the following measures: (1) high efficiency refrigerators, (2) compact fluorescent lamps, (3) other energy efficient lighting technologies, (4) energy efficient motors, and (5) HVAC measures.

Sampling & Data Collection for the Lighting End Use

This section describes only the lighting end use of SDG&E's Industrial EEI Program.

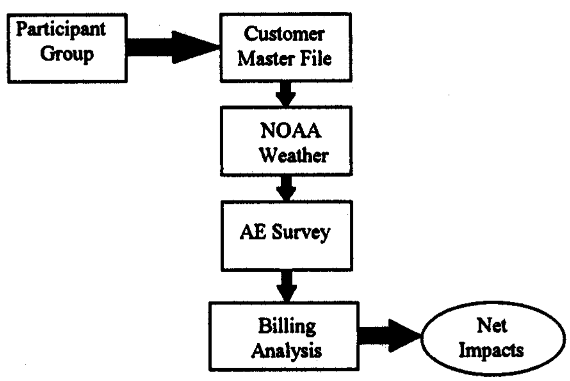
Data Collection

Data for the impact analysis were obtained from the following major sources:

- Customer name, address, lighting square footage, lighting hours of operation, and installation date from the program tracking database;
- Consumption history from the Customer Master File;
- Information on other changes for all assigned customers in the participant group were obtained from a survey conducted on the account executives; and
- Hourly weather data for three climate zones from NOAA files.

The following diagram describes the flow of data into the final new impact results:

Data Flow Diagram



Participant Database

A total of 56 industrial customers were identified who installed only indoor lighting measures in the 1995 commercial/industrial database for the lighting load impact study.

Account Executive Survey

SDG&E conducted an internal survey of all account executives who had responsibility for customers that installed DSM measures in program year 1995. The survey was used to identify any impacts on consumption due to any changes (DSM or non-DSM) with respect to the company that may impact the way the company used energy from January 1993 through September 1995, which covers the study period. A copy of the survey instrument is in Appendix B

A total of 1777 surveys for both commercial and industrial customers were sent out to all SDG&E Marketing account executives with a cover letter explaining the survey. Approximately 9 percent (5 out of 56 participants) of the industrial lighting participants were reported to have some type of change to the company (hiring, layoffs, elimination of shifts, addition of shifts, or other) or changes to equipment (HVAC, lighting, process, refrigeration, or other). This information was incorporated in the analysis for lighting.

Billing and Weather Data

Hourly weather data were estimated from daily highs and lows from NOAA data files and converted to heating and cooling degreehours (with a base of 65 degrees Fahrenheit). These were matched to consumption data from the Customer Master File by billing cycle and climate zone for each household.

Long-term averages for cooling degree hours and cooling degree days are used for weather-normalization purposes in the regression models. These are the average cooling degree hours and cooling degree days covering a period of 14 years dating back to 1983.

For each customer in the participant group, consumption data and weather data gathered for use in the analysis covered the period beginning January 1993 through October 1995. Each customer's consumption and weather data were further reduced to meet the Protocols data requirement of twelve months pre-installation and nine months post-installation data. Customers that did not meet this data requirement were removed from the analysis. The following table illustrates data attrition for the participant group.

Table 2
Study Group Pre-Regression Attrition

Status	Participants
Starting Study Group	56
Billing Data Available	55
Sufficient Pre/Post Data	50

Industrial Lighting Net-to-Gross Ratio

The M&E Protocols do not require a comparison group to determine the net-to-gross ratio for the load impacts of industrial end uses. SDG&E has derived a net-to-gross ratio in its 1995 Commercial Energy Efficiency Incentives Program First Year Load Impact Evaluation Study, February 1997, Study ID No. 959. This was the net-to-gross ratio that was applied to derive the net-to-gross ratio for the industrial lighting load impacts. SDG&E chose to use the net-to-gross ratio developed for the commercial lighting end use because of the small number of industrial participants and the similarity of the application of the lighting measures between the commercial participants and the industrial participants.

Section 3

Section 3
Indoor Lighting Study
The General Model

The Individual Elements of the General Model

For customer i and month t, the general regression model is,

Equation 1 (The General Structure of the Regression Equation)

$$kWh_{it} = X_{it} + W_{it} + S_{it} + e_{it}$$

The dependent variable kWh_{it} is the monthly energy consumption for customer i, normalized for the length of the billing cycle.

A trend term and a zero-one indicator variable (for other reported changes in monthly consumption) are included in the model, as well as an additional component based on the indicator variable d_{it}^{x}:

Equation 2 (The Non-Weather/Non-DSM Portion of the Regression Equation)

$$X_{it} = \beta_{0i} + \beta_{1i}(t) + \Delta\beta_{0i}\left(d_{it}^{x}\right)$$

Before estimating the model, customers (both participants and nonparticipants) were surveyed for <u>any</u> significant changes in their level of energy consumption. The indicator variable d_{it}^{x} can be appropriately defined at the customer level. This variable takes on the value 0 when there is no reported non-DSM change at the customer site. It is 1 starting from the date of a reported change. This data was gathered through the account executive survey of participants. As for the comparison group, the data was obtained both from the on-site audits and from the account executive survey. The coefficient $\Delta\beta_{0i}$ can then be estimated, allowing us to adjust the regression for changes in expected consumption unrelated to the DSM installation under consideration.

Cooling-degreehours and cooling-hours make up the weather-sensitive portion of the model:

Equation 3 (The Weather Portion of the Regression Equation)

$$W_{it} = \beta_{2i}\left(cdh_{it}\right) + \beta_{3i}\left(ch_{it}\right)$$

The cooling-degreehour variable is the sum of the cooling degrees for the corresponding normalized billing month. The cooling-hours variable is the estimated number of hours for which cooling has occurred, so that the term $\beta_{3i}(ch_{it})$ represents the interaction between the lighting and space cooling end uses.

For customer i, DSM contract j is associated with the weather-normalized *ex ante* estimate of monthly energy savings F_{ij}. The statistical estimate for monthly savings S_{ijt} is,

Equation 4 (The DSM Portion of the Model)

$$S_{it} = \sum_{j} S_{ijt}$$

$$S_{ijt} = \left(\gamma_{1ij} + \gamma_{2ij}cdh_{it} + \gamma_{3ij}ch_{it}\right)d_{ijt}F_{ij}$$

The term, $\left(\gamma_{1ij} + \gamma_{2ij}cdh_{it} + \gamma_{3ij}ch_{it}\right)$ is the estimated realization rate for contract j, generated in the regression by the indicator variable d_{ijt} depending on the date of DSM installation.

The Lighting Regression Model

For the lighting model, the cooling-degreehour variable is suppressed, so that $\gamma_{2ij} = 0$. We assume that the realization rate is constant across contracts (within customers):

$$\gamma_{1ij} = \gamma_{1i}$$

$$\gamma_{3ij}\left(\overline{ch}_i\right) = \gamma_{3i}\left(\overline{ch}_i\right)$$

given the long-term average value $\overline{ch}_i$. After a significant rearrangement of terms,

$$S_{it} = \left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}\left(\sum_j d_{ijt}F_{ij}\right) + \left\{\gamma_{3i}\left(\overline{ch}_i\right)\right\}\left(\frac{ch_{it}}{\overline{ch}_i} - 1\right)\left(\sum_j d_{ijt}F_{ij}\right)$$

A final transformation of the DSM portion of the model will allow us to maintain consistency between the participant regression results and the nonparticipant regression results. We define the scaled *ex ante* estimate F^*_{ij},

$$F^*_{ij} = \frac{F_{ij}}{k_i}, \quad k_i = \max_t \sum_j d_{ijt}F_{ij}$$

$$S_{it} = \left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}k_i\left(\sum_j d_{ijt}F^*_{ij}\right) + \left\{\gamma_{3i}\left(\overline{ch}_i\right)k_i\right\}\left(\frac{ch_{it}}{\overline{ch}_i} - 1\right)\left(\sum_j d_{ijt}F^*_{ij}\right)$$

When a single customer has only a single contract, it follows that $F^*_{ij} = 1$, and the model degenerates into a fairly simple model based on a straightforward zero-one indicator variable. However, the real importance of this last transformation stems from the fact that the regression coefficient $\left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}k_i$ is in units of monthly kWh. This allows for consistency when we move on to the nonparticipant model where there are no *ex ante* estimates of savings.

Final Regression Components with Transformed Variables

Further linear transformations of the regressors in the model gives,

Equation 5 (The Transformed Non-Weather/Non-DSM Portion of the Lighting Regression Equation)

$$X_{it} = \beta^*_{0i} + \beta_{1i}(t - t^*) + \Delta\beta_{0i}\left(d^x_{it}\right)$$

Equation 6 (The Transformed Weather Portion of the Lighting Regression Equation)

$$W_{it} = \beta_{2i}\left(\frac{cdh_{it}}{\overline{cdh}_i} - 1\right) + \beta_{3i}\left(\frac{ch_{it}}{\overline{ch}_i} - 1\right)$$

Equation 7 (The Transformed DSM Portion of the Lighting Regression Model)

$$S_{it} = \left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}k_i\left(\sum_j d_{ijt}F_{ij}^*\right) + \left\{\gamma_{3i}\left(\overline{ch}_i\right)k_i\right\}\left(\frac{ch_{it}}{\overline{ch}_i} - 1\right)\left(\sum_j d_{ijt}F_{ij}^*\right)$$

where β_{0i}^* is the new intercept determined by the various transformations. Clearly, β_{0i}^* can be interpreted as the weather-normalized value for monthly kWh consumption, prior to the DSM installation, evaluated along the trend at month t^* (taken to be December, 1995).

Derivation of the Designated Unit of Measurement (DUOM) from the Lighting Gross-Impact Regression Model

The key regression result will be the single regression coefficient $\left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}k_i$, generated by the regressor $\sum_j d_{ijt}F_{ij}^*$. This coefficient represents the monthly kWh load impact. As a result, the load impact, per square foot, per thousand hours of operation is,

Equation 8 (The Designated Unit of Measurement for Lighting Participants)

$$DUOM^{part} = \frac{(12 \text{ months}) \times (1{,}000 \text{ hours}) \sum_{i \in part} \left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}k_i}{\left(\overline{hours}^{part}\right) \sum_{i \in part} sqft_i}$$

The sample-wide realization rate for the *ex ante* energy estimates can also be calculated:

$$\rho = -\frac{\sum_{i \in part} \left\{\gamma_{1i} + \gamma_{3i}\left(\overline{ch}_i\right)\right\}k_i}{\sum_{i \in part} k_i}$$

Estimation

Data

After screening for required pre-installation data (12 months) and required post-installation data (9 months), 50 participating customers were subjected to regression analysis. The sample was further reduced, based on four other criteria. First, those customers who also had contact with the company's PY95 Nonresidential New Construction (NRNC) Program were eliminated. Second, some customers who had lighting retrofits were also associated with other aggregate retrofit contracts for which the energy savings estimates could not be disaggregated. Third, a portion of the sample did not satisfy a root-mean-squared-error (RMSE) criterion, explained in the next section. Lastly, customers whose *ex ante* savings estimate was less than 1% of the estimated normalized average monthly consumption were eliminated (1% savings criterion).

Table 3
Determination of Regression Participant Sample

Customer involved in 1995 NRNC program	Customer involved in individual and aggregate contract	Satisfies RMSE criterion	*Ex ante* savings greater than 1% of normalized energy consumption	Industrial Sector
no	no	yes	yes	34
no	no	yes	no	9
no	no	no	yes	3
no	no	no	no	1
no	yes	yes	yes	0
no	yes	no	yes	0
yes	no	yes	yes	1
yes	no	yes	no	2
yes	no	no	yes	0
yes	yes	yes	yes	0
yes	yes	no	yes	0
Grand Total				50

Estimation Methods

The model specified in Equation 1, and Equation 5-Equation 7 was estimated at the customer level for participants. The exact month for the retrofit installation was weighted out of the regression.

Once the regressions were completed, an additional filter, the RMSE criterion, was applied. This stems from the fact that within the broad and complicated setting of commercial and industrial energy consumption, a fairly simple tool like regression analysis will not perform with uniform success; a fraction of the regressions simply will not "work" (the specified model will not be a reasonable approximation to reality). As a result, a reasonable and systematic criterion must be put in place for which there is a high probability of omitting unreasonable regression results. Along these lines, a ratio was calculated for each customer by dividing the root-mean-squared error for the regression by the intercept β^*_{0i}. This ratio is very likely to be large when a regression simply fails, since inadequacies in the specification of the model for a particular customer will result in excessively large estimated regression errors. Within the analysis, regressions were omitted where this ratio was greater than 15%.

Lighting Load Impact Results

Lighting Energy Load Impact Estimates

Table 4 summarizes estimated lighting energy load impacts based on the participant model.

Table 4
Lighting Results

Savings greater than 1%	Parameter	No sqft data	Have sqft data	Grand Total
Industrial Participants				
No	Total Estimated Impact (kWh per month)	5,418	-16,240	-10,822
	Variance of Estimate	173,113,388	156,491,937	329,605,325
	Total Database *Ex Ante* Estimate (kWh per month)	1,683	701	2,384
	Average Annual Hours	8,372	8,760	8,458
	Total Lighted Square Footage	0	35,000	35,000
	Sample Size	7	2	9
Yes	Total Estimated Impact (kWh per month)	30,252	-119,481	-89,229
	Variance of Estimate	183,894,292	1,130,665,402	1,314,559,694
	Total Database *Ex Ante* Estimate (kWh per month)	3,660	110,574	114,233
	Average Annual Hours	7,278	4,149	4,425
	Total Lighted Square Footage	0	1,102,161	1,102,161
	Sample Size	3	31	34
	Load Impact (kWh per square foot, per 1,000 hours)		-.3135	
	Realization Rate Based on Sample *Ex Ante* Estimates	-827%	108%	78%
	Commercial Net-to-Gross[1]		**89.0%**	

Lighting Demand Load Impact Estimates

The lighting gross demand estimate was derived using the gross energy estimate from the regression analysis adjusted by the system coincident peak load factor. This system coincident peak load factor is the weighted load factor from each commercial building type. The weights were determined using the *ex ante* gross energy savings by building type reported in the PY95 program database. The load factor from each industrial building type was obtained from SDG&E's 1994 Market Segment End Use Report (September 1995). The peak load factor is the ratio of the average demand (or the total annual energy savings divided by 8760 hours) and the

1 Obtained from the 1995 Commercial Energy Efficiency Incentives Program, First Year Load Impact Evaluation, February 1997, Study ID No. 959

system coincident peak demand. The following table provides the necessary information to calculate the peak load factor:

Table 5
Lighting Load Factors

Building Type	*Ex Ante* Energy Savings	Load Factor	Weight	Weighted Load Factor
1 Shift Operation	264,439	0.86	0.201	0.173
2-Shift Operation	1,048,522	0.98	0.799	0.783
Total	1,312,961		1.000	0.956

The estimated gross demand savings is estimated by Equation 9:

Equation 9 (Estimated Participant Demand Savings)

$$\text{Est. Total Demand Savings} = \frac{(119{,}481\ \text{kWh}) * 12}{8760\ \text{hours} * 0.956} = 171.21\ \text{kW}$$

$$\text{Demand Savings (DUOM)} = \frac{1000 * 171.21\ \text{kW}}{1{,}102{,}161\ \text{sq. ft}} = 0.155\ \text{kW}$$

with a realization rate of 38.6% (0.155 kW divided by the *ex ante* demand savings of 0.40 kW).

Section 4

Section 4

Industrial Process and Motors
by
XENERGY, Inc.

1995 INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM

Process and Motor End Uses

FIRST YEAR LOAD IMPACT EVALUATION

FINAL REPORT

Prepared for

San Diego Gas & Electric
San Diego, California

Prepared by

XENERGY Inc.
San Diego, California

February 1997

1 INTRODUCTION

1.1 INTRODUCTION

San Diego Gas & Electric (SDG&E) commissioned XENERGY Inc. to evaluate the first year load impacts of measures installed under its *1995 Industrial Energy Efficiency Incentives* (*IEEI*) *Program*. These measures were installed to provide resource value by improving the energy efficiency of the facilities that participated in the *IEEI Program*.

The overall objectives of SDG&E's *1995 Industrial Energy Efficiency Incentives Program First Year Impact Evaluation* were to:

- evaluate the gross and net load impacts of the measures installed at these facilities; and
- verify the physical installation of the measures identified in the program tracking system.

These objectives were accomplished using the following methodology:

- verifying the physical installation of the measures identified in the program tracking system (electronic and hard copy);
- gathering data through direct measurement, observation, and interviews with site personnel; and
- performing engineering analysis of energy impacts based on the data.

1.2 REPORT ORGANIZATION

The remainder of this report is organized as follows:

Section 2	Results
Section 3	Study methodology
Section 4	Site specific analyses for Process Measures
Section 5	Analysis for Motor Measures
Appendix A	Industrial Motors Detailed Worksheets

2 RESULTS

This section presents the results of the *First Year Impact Evaluation* of *SDG&E's 1995 Industrial Energy Efficiency Incentives Program* for industrial measures installed during Program Year 1995 (PY95).

2.1 OVERVIEW

A total of 24 participants, as identified by a unique 5-digit ID number., had 28 measures installed under SDG&E's Industrial Energy Efficiency Incentives Program during PY95. In addition, 90 industrial motor measures were installed. This section provides a summary of the site specific engineering analyses conducted for each measure. The site specific analyses for process measures are described in Section 4. The analysis for motor measures is described in Section 5.

2.2 PROCESS MEASURES: *EX POST* LOAD IMPACT ESTIMATES

This section presents the estimation of gross impacts of the *Impact Evaluation of Industrial Process Measures.* Site specific engineering models and analysis were used to estimate the load impacts for the 28 industrial process measures installed under SDG&E's 1995 Industrial Energy Efficiency Incentives Program.

The gross impacts for electricity and natural gas were estimated *ex post*, where appropriate. The *ex post* gross impacts were compared to *ex ante* impact estimates through realization rates for each site. Realization rates were calculated for each measure as defined in Table 6 of the *M&E Protocols*, where it is defined as "the load impacts estimated by the Evaluation, divided by the load impacts filed in a utility's first year earnings claim." Equation 2-1 shows the formula used for calculating the realization rate.

(Eq. 2-1)

$$R = \frac{P}{A}$$

where,

R = Realization rate for the measure,

P = Ex post impact estimate for the measure, and

A = Ex ante impact estimate for the measure.

2.2.1 Overview - Process Measures

Table 2-1 provides a description of each of the measures evaluated and a summary of what sites were visited on site. A total of 10 million kWh and almost 38,000 therms were saved as a result of the 1995 IEEI Program.

Table 2-1
Industrial Process Measure Descriptions and Share of Impacts Evaluated On Site

ID No.	Measure Description	On-Site Visit Conducted?	Gross Ex Ante kWh Saved	Gross Ex Ante kW Reduced	Gross Ex Ante Therms Saved	kWh of Sites Visited	kWh of Sites Not Visited	kW of Sites Visited	kW of Sites Not Visited	Therms of Sites Visited	Therms of Sites Not Visited
7259	Air Compressor Replacement	Yes	54,542	13.45	-	54,542	0	13.45	-	-	-
13671	Upgrade Air Compressors	Yes	4,049,409	1,102.78	-	4,049,409	0	1,102.78	-	-	-
13792A/B	Covers on Melting Pots & Upgrade Process Furnace	Yes	-	-	19,290	-	-	-	-	19,290	0
13893	Conversion of Cleaning Process	Yes	518,300	109.45	-	518,300	0	109.45	-	-	-
13968	Solid State Frequency Converter	Yes	78,840	0.00	-	78,840	0	0.00	-	-	-
13976A	Downsize Process Vacuum System	Yes	246,500	29.00	-	246,500	0	29.00	-	-	-
13976B	Downsize Deionized Water System	Yes	363,779	43.00	-	363,779	0	43.00	-	-	-
13976C	Modify Nitrogen Vaporizer	Yes	70,456	8.00	-	70,456	0	8.00	-	-	-
13983	Air Compressor Replacement	Yes	108,712	4.50	-	108,712	0	4.50	-	-	-
14082	Downsize Air Compressor	Yes	112,700	25.00	-	112,700	0	25.00	-	-	-
14092	Downsize Air Compressor	Yes	63,750	20.00	-	63,750	0	20.00	-	-	-
14093	Downsize Air Compressor	Yes	71,400	35.00	-	71,400	0	35.00	-	-	-
14115	Replace Compressed Air Piping	Yes	307,941	49.70	-	307,941	0	49.70	-	-	-
14116	Air Compressor Replacement	Yes	74,601	17.80	-	74,601	0	17.80	0	-	-
14127	Replacement For Hydraulic Drives	No	227,510	54.70	-	0	227,510	0.00	54.7	-	-
14139	Air Compressor Replacement	Yes	123,920	20.00	-	123,920	0	20.00	-	-	-
14144	Cycling Compressed Air Dryer	Yes	9,851	0.00	-	9,851	0	0.00	-	-	-
14148A	Cycling Compressed Air Dryer	Yes	21,807	2.50	-	21,807	0	2.50	-	-	-
14148B	Intermediate Controller on Compressed Air System	Yes	68,062	7.80	-	68,062	0	7.80	-	-	-
14152	Steam and Condensate Pipe Insulation	Yes	0	0.00	13,119	-	-	-	-	13,119	0
14188	Variable Volume Hydraulic Drives	No	359,920	42.80	-	0	359,920	0.00	42.8	-	-
14270	Amplifier Sequencer	Yes	71,353	0.00	-	71,353	0	0.00	0	-	-
14352	Variable Speed Drive on an Air Compressor	No	249,433	26.11	-	0	249,433	0.00	26.11	-	-
17144	Boiler Replacement	Yes	0	0.00	5,415	-	-	-	-	5,415	-
17476	Crossover Piping	Yes	700,424	79.96	-	700,424	0	79.96	0	-	-
17504	Compressed Air System Loss Abatement	Yes	1,602,356	174.00	-	1,602,356	0	174.00	0	-	-
18012	Variable Speed Drives on Injection Molders	Yes	471,744	63.00	-	471,744	0	63.00	0	-	-
Total			**10,027,310**	**1,928.55**	**37,824**	**9,190,447**	**836,863**	**1,804.94**	**123.61**	**37,824**	**0**
			Share evaluated on site			92%	8%	94%	6%	100%	0%

The table shows that over 90 percent of the load impacts were subjected through *ex post* on-site evaluations, with the remainder evaluated through an *ex post* analysis without on-site visits.

As would be expected, a variety of measure types were installed. These ranged from straightforward insulation of high temperature piping to frequency converters for electronic test equipment.

2.2.2 Load Impact Estimates: Process Measures

The gross impact analysis was conducted using site specific engineering models. The analysis used inputs that were verified by XENERGY's project engineer through observation, measurement, monitoring, site interviews, or other records provided during the evaluation. The analysis for each site may be found in Section 4.

Table 2-2 provides a summary of the gross impact analysis. The *ex ante* impact estimates were obtained from the program tracking database and the *ex post* estimates were developed through the engineering analysis of this study.

As shown in Table 2-2, the realization rates for the program were 1.01, 0.61, and 1.41 for kWh, kW, and therms, respectively.

Table 2-2
1995 Industrial Energy Efficiency Incentives Program
First Year Load Impact Evaluation
Summary

		Gross *Ex Ante* Load Impacts			Gross *Ex Post* Load Impacts			Gross Realization Rates			Net *Ex Post* Load Impacts			
ID No.	Measure Description	kWh Saved	kW Reduced	Therms Saved	kWh Saved	kW Reduced	Therms Saved	kWh Saved	kW Reduced	Therms Saved	Net-To-Gross	kWh Saved	kW Reduced	Therms Saved
7259	Air Compressor Replacement	54,542	13.45	-	28,903	0.00	-	0.53	0.00	-	0.00	0	0.00	-
13671	Upgrade Air Compressors	4,049,409	1,102.78	-	4,435,776	513.40	-	1.10	0.47	-	1.00	4,435,776	513.40	-
13792A/B	Covers on Melting Pots & Upgrade Process Furnace	-	-	19,290	-	-	17,044	-	-	0.88	1.00	-	-	17,044
13893	Conversion of Cleaning Process	518,300	109.45	-	454,523	74.10	-	0.88	0.68	-	0.75	340,892	55.58	-
13968	Solid State Frequency Converter	78,840	0.00	-	81,468	0.00	-	1.03	0.00	-	1.00	81,468	0.00	-
13976A	Downsize Process Vacuum System	246,500	29.00	-	240,378	28.20	-	0.98	0.97	-	0.75	180,284	21.15	-
13976B	Downsize Deionized Water System	363,779	43.00	-	364,565	42.89	-	1.00	1.00	-	0.75	273,424	32.17	-
13976C	Modify Nitrogen Vaporizer	70,456	8.00	-	77,350	9.10	-	1.10	1.14	-	0.75	58,013	6.83	-
13983	Air Compressor Replacement	108,712	4.50	-	162,350	16.70	-	1.49	3.71	-	1.00	162,350	16.70	-
14082	Downsize Air Compressor	112,700	25.00	-	307,343	25.10	-	2.73	1.00	-	0.00	0	-	-
14092	Downsize Air Compressor	63,750	20.00	-	78,831	23.80	-	1.24	1.19	-	1.00	78,831	23.80	-
14093	Downsize Air Compressor	71,400	35.00	-	189,879	39.50	-	2.66	1.13	-	0.40	75,952	15.80	-
14115	Replace Compressed Air Piping	307,941	49.70	-	322,425	47.00	-	1.05	0.95	-	1.00	322,425	47.00	-
14116	Air Compressor Replacement	74,601	17.80	-	107,297	39.40	-	1.44	2.21	-	1.00	107,297	39.40	-
14127	Replacement For Hydraulic Drives	227,510	54.70	-	221,385	54.70	-	0.97	1.00	-	1.00	221,385	54.70	-
14139	Air Compressor Replacement	123,920	20.00	-	50,563	21.80	-	0.41	1.09	-	1.00	50,563	21.80	-
14144	Cycling Compressed Air Dryer	9,851	0.00	-	13,591	0.00	-	1.38	-	-	1.00	13,591	0.00	-
14148A	Cycling Compressed Air Dryer	21,807	2.50	-	32,340	0.00	-	1.48	0.00	-	1.00	32,340	0.00	-
14148B	Intermediate Controller on Compressed Air System	68,062	7.80	-	30,899	0.00	-	0.45	0.00	-	1.00	30,899	0.00	-
14152	Steam and Condensate Pipe Insulation	-	-	13,119	-	-	29,916	-	-	2.28	0.50	-	-	14,958
14188	Variable Volume Hydraulic Drives	359,920	42.80	-	518,284	43.90	-	1.44	1.03	-	0.40	207,314	17.56	-
14270	Amplifier Sequencer	71,353	0.00	-	71,352	0.00	-	1.00	-	-	0.00	0	0.00	-
14352	Variable Speed Drive on an Air Compressor	249,433	26.11	-	398,259	0.00	-	1.60	0.00	-	0.00	0	0.00	-
17144	Boiler Replacement	-	-	5,415	-	-	6,489	-	-	1.20	0.00	-	-	0
17476	Crossover Piping	700,424	79.96	-	368,908	42.10	0	0.53	0.53	-	1.00	368,908	42.10	-
17504	Compressed Air System Loss Abatement	1,602,356	174.00	-	958,203	110.14	-	0.60	0.63	-	1.00	958,203	110.14	-
18012	Variable Speed Drives on Injection Molders	471,744	63.00	-	640,244	36.80	-	1.36	0.58	-	1.00	640,244	36.80	-
TOTAL		**10,027,310**	**1,928.55**	**37,824**	**10,155,116**	**1,168.63**	**53,449**	**1.01**	**0.61**	**1.41**		**8,640,157**	**1,054.92**	**32,002**
PROGRAM NET-TO-GROSS RATIO												**0.85**	**0.90**	**0.60**

2.2.3 Net-To-Gross: Process Measures

The net-to-gross ratio for each measure was estimated using the process described in Section 3.2.5. The rules described in Table 3-1 were applied to each measure for estimating the net-to-gross ratios for each measure. Information gathered through interviews with site staff and project documentation were compiled to estimate the net-to-gross.

Table 2-3 provides a summary of the net-to-gross ratio estimation. The payback values were those estimated during the project implementation phase.

The net load impacts for the measures and for the program are shown in Table 2-2. The program level net-to-gross ratios are 0.85, 0.90, and 0.60 for kWh, kW, and therms, respectively.

Table 2-3
Net-To-Gross Estimates

ID No.	Measure Description	Ex Ante Payback (w/o inc.)	Ex Ante Payback (w/ inc.)	Payback Threshold	Measure Adoption Information	Ex Ante Net-To-Gross	Level of SDG&E Involvement	Did Incentive Influence the Decision?	Payback w/o Incentive	Ex Post Net-To-Gross
7259	Air Compressor Replacement	1.78	1.32	No answer	Price quotes received 12/93. Other quotes received 3/94. Engineering analysis reviewed 5/95.	0.75	Low	No	1.78	0.00
13671	Upgrade Air Compressors	1.71	1.14	2.00	SDG&E commissioned a study by Plant Air Technology. Compressor replacement was a recommendation of the study. The program was a major factor in the decision to change compressors.	0.75	High	-	-	1.00
13792A/B	Covers on Melting Pots & Upgrade Process Furnace	3.47	2.87	2.00	The rebate was a strong psychological factor in undertaking the measure, even though the financial impact of the rebate was not that great. Long lead time between contract sign date and installation.	1.00	Medium	Yes	3.47	1.00
13893	Conversion of Cleaning Process	1.40	0.73	2.00	The rebate was a strong psychological factor in implementing the recommendation. Initial engineering done 4/11/94. Couldn't ID the genesis of the project.	0.75	Medium	Yes	1.40	0.75
13968	Solid State Frequency Converter	3.37	2.35	No answer	Engineering proposal as a result of an energy survey 6/94 recommending the measure.	0.75	High	-	-	1.00
13976A	Downsize Process Vacuum System	1.04	0.90	2.00	Engineering analysis 7/12/94. Rebates may have moved the project up in priority.	0.75	Medium	Yes	1.04	0.75
13976B	Downsize Deionized Water System	0.80	0.61	2.00	Engineering analysis 7/12/94. Rebates may have moved the project up in priority.	0.75	Medium	Yes	0.80	0.75
13976C	Modify Nitrogen Vaporizer	0.54	0.39	2.00	Engineering analysis 7/12/94. Rebates may have moved the project up in priority.	0.75	Medium	Yes	0.54	0.75
13983	Air Compressor Replacement	0.99	0.60	2.00	SDG&E conducted a review of a vendor proposal recommending the measure on 8/94. The rebate and assistance provided by SDG&E were strong factors in the decision to implement the measure.	0.75	Low	No		1.00
14082	Downsize Air Compressor	1.05	0.83	No answer	Vendor proposal 12/30/94. Invoices 2/95 indicating work completed. Engineering study 2/17/95.	0.75	Low	No	1.05	0.00
14092	Downsize Air Compressor	2.11	1.59	2.00	Rebate was a strong psychological factor in implementation of the measure. Since the existing compressors were operational, there was no other strong motivation to replace the compressors.	1.00	Medium	Yes	2.11	1.00
14093	Downsize Air Compressor	1.86	1.36	No answer	Vendor generated engineering analysis 3/16/95. Contract 6/23/95.	0.75	Low	Yes	1.86	0.40
14115	Replace Compressed Air Piping	2.79	1.72	2.00	SDG&E conducted an engineering study. This measure was a part of the recommendation.	1.00	High	-	-	1.00

(Continued)

Table 2-3 (continued)
Net-To-Gross Estimates

ID No.	Measure Description	Ex Ante Payback (w/o inc.)	Ex Ante Payback (w/ inc.)	Payback Threshold	Measure Adoption Information	Ex Ante Net-T0-Gross	Level of SDG&E Involvement	Did Incentive Influence the Decision?	Payback w/o Incentive	Ex Post Net-To-Gross
14116	Air Compressor Replacement	3.57	3.00	No answer	SDG&E conducted an engineering study that recommended downsizing, although genesis of project concept is unclear.	0.75	Medium	Yes	3.57	1.00
14127	Replacement For Hydraulic Drives	2.06	1.78	No answer	SDG&E engineering study conducted 1/19/95 with recommendations for the measure.	1.00	High	-	-	1.00
14139	Air Compressor Replacement	3.38	2.55	2.00	SDG&E conducted an engineering study. This measure was a part of the recommendations. Pricing 5/4/95 gathered by SDG&E engineer from vendor. The rebate moved the payback closer to the firm's 2 year threshold.	1.00	High	-	-	1.00
14144	Cycling Compressed Air Dryer	1.05	0.44	2.00	SDG&E conducted an engineering study. This measure was a part of the recommendations.	0.75	High	-	-	1.00
14148A	Cycling Compressed Air Dryer	0.96	0.61	No answer	SDG&E conducted a compressed system audit Fall 1994 with recommendations.	0.75	High	-	-	1.00
14148B	Intermediate Controller on Compressed Air System	3.13	2.46	No answer	SDG&E conducted a compressed system audit Fall 1994 with recommendations.	0.75	High	-	-	1.00
14152	Steam and Condensate Pipe Insulation	1.04	0.85	2.00	Engineering study 5/4/95 but couldn't determine genesis of the project. Contract 5/22/95. Installed 10/6/95. SDG&E assisted in the preparation of the rebate application.	0.75	Medium	No	0.75	0.50
14188	Variable Volume Hydraulic Drives	0.25	0.16	No answer	Engineering study 5/6/95.	0.40	Medium	No	0.25	0.40
14270	Amplifier Sequencer	1.00	0.83	No answer	Engineering study 7/13-25/95, although genesis of the project could not be determined. Project completed 12/7/95.	0.75	Medium			0.00
14352	Variable Speed Drive on an Air Compressor	2.13	1.52	No answer	Engineering study, 8/1/95, although genesis of the project could not be determined.	1.00	Medium			0.00
17144	Boiler Replacement	1.83	1.31	2.00	The rebate and assistance provided by SDG&E were not strong factors in the decision to implement the	0.75	Low	No	1.83	0.00
17476	Crossover Piping	1.16	1.04	2.00	SDG&E performed a study of the yard's salt water distribution system. Installation of the crossover piping modification was a recommendation of the study.	0.75	High	-	-	1.00
17504	Compressed Air System Loss Abatement	0.37	0.06	2.00	SDG&E commissioned a study by Plant Air Technology. Compressed air loss abatement was a recommendation of the study. The program was a significant factor in implementing the measures.	0.40	High	-	-	1.00
18012	Variable Speed Drives on Injection Molders	2.13	1.65	2.00	Vendor proposal to SDG&E 10/9/95, indicating SDG&E assisted in the implementation process. The rebate reduced the payback to less than two years which allowed it to meet the firm's investment criteria.	1.00	High	-	-	1.00

2.3 Motor Measures: *Ex Post* Load Impact Estimates

This section presents a summary of the results of the *ex post* evaluation of the load impacts of motors installed under SDG&E's 1995 *IEEI* Program. As shown in Table 2-4 over 71 percent of the *ex ante* kW and kWh impacts were surveyed in accordance with the 70% of the kW, kWh and therm savings for the motors end-use required by Table C-5 of the *M&E Protocols*.

Table 2-4
Industrial Motors Survey Distribution

	Program Participants	Surveyed	Percent Surveyed
No. Motors	81	48	59%
No. Horsepower	2,138.00	1606.50	75%
kW Reduced	38.66	28.53	74%
kWh Saved	221,110	167,148	76%

Table 2-5 shows that the *ex post* load impact realization rates for kW and kWh.

Table 2-5
Industrial Motors Load Impact Realization Rate Summary

For Motors Surveyed	Ex Ante	Ex Post	Realization Rate
kWh Saved	167,148	169,323	1.01
kW Reduced	28.53	31.33	1.10

Table 2-6 shows the *ex post* program load impacts for industrial motors.

Table 2-6
Industrial Motors Program Load Impact Summary

	kWh	kW
Ex ante estimate	221,110	38.66
Realization rate	1.01	1.10
Gross ex post impacts	223,987	42.45
Net-to-gross ratio	0.29	0.28
Net program impacts	64,537	11.68

3 METHODOLOGY

This section describes the methodology used to conduct SDG&E's *1995 Industrial Energy Efficiency Incentives Program First Year Load Impact Evaluation.*

3.1 OVERVIEW

The approach used to conduct the *Evaluation* utilized end-use **engineering models** with verified input assumptions. Measurements of equipment performance and monitoring of equipment operations were performed to refine the inputs into the engineering models developed for each measure. The methodology used for this study is consistent with Table C-5 of *the M&E Protocols*. The approach used for estimating *ex post* load impacts for industrial process measures is described in Section 3.2, while the approach used for estimating the *ex post* load impacts for motor measures is described in Section 3.3.

3.2 *EX POST* LOAD IMPACT ESTIMATION APPROACH FOR INDUSTRIAL PROCESS MEASURES

This section describes the approach and tasks used to conduct the site-specific impact studies for the IEEI Program.

3.2.1 Task 1: Gather Available Site Data

Site data were gathered and compiled from available sources. Typically, these sources included hard copies of customer applications, SDG&E work papers, design reports, invoices, and pre- and post-field surveys. A site profile was developed from which an evaluation plan was designed.

3.2.2 Task 2: Develop Site Evaluation Plan

The initial evaluation plan for each site was developed by XENERGY and submitted to SDG&E for review. An example of the *general* work flow is displayed as Figure 3-1. All industrial process sites were targeted for on-site visits. Thus, a census was attempted, however, site visits for several measures could not be arranged. For these sites an *ex post* analysis was performed using existing data that were augmented with data from secondary sources.

Evaluation Approach and Methodologies

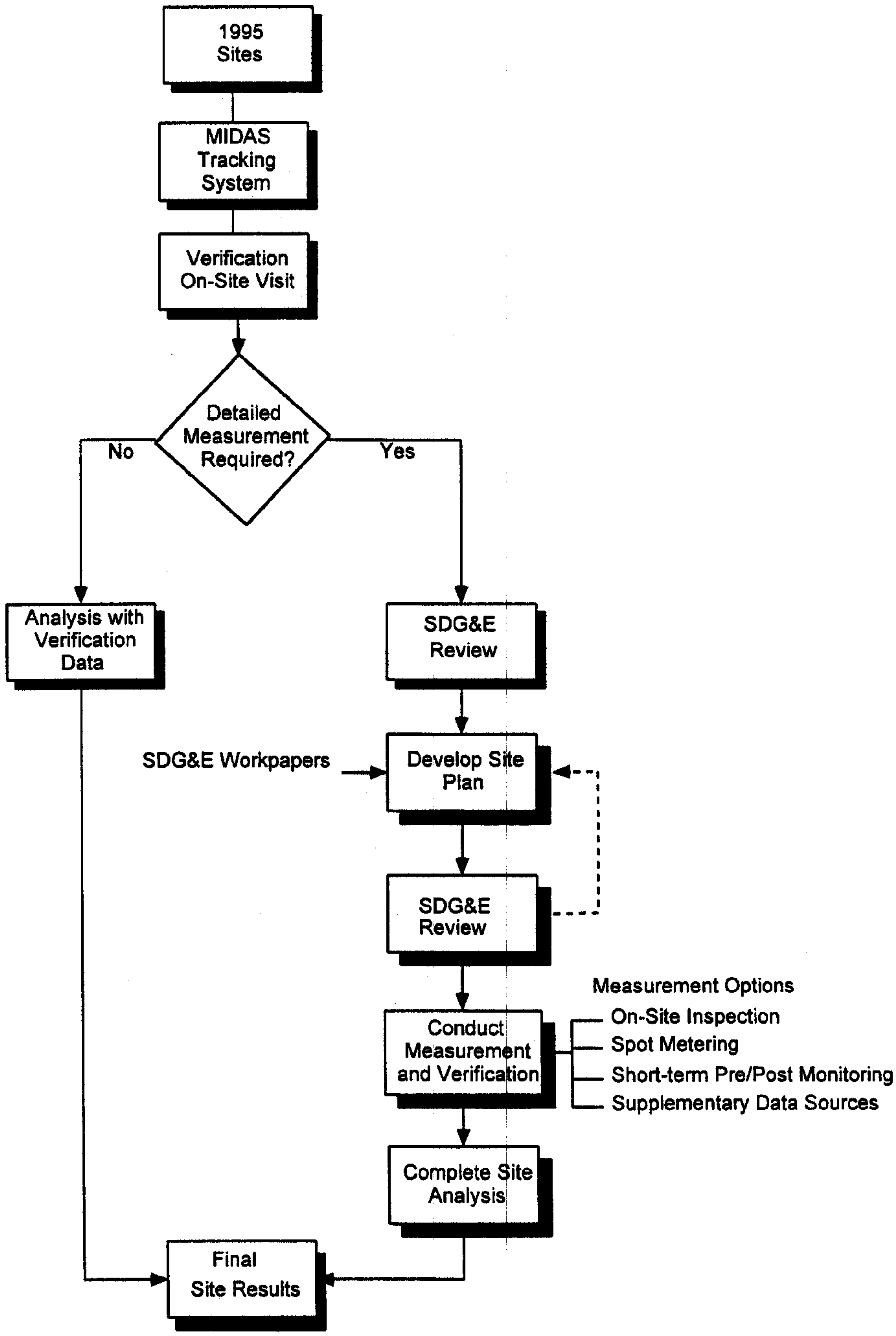
The measurement approach must take into account the various types of technologies, processes, and operations schedules found in the industrial sector.

To meet the impact measurement needs of this project, appropriate combinations of the following tools were used:

- engineering models and analysis;
- equipment data collection tools and methods;
- on-site surveys; and
- short-term metering and spot measurements.

On-site surveys were conducted to verify the installation of the measures, and to verify or improve the engineering assumptions that were used to estimate *ex ante* load impacts. Previously collected data were used to help reduce the scope of the on-site data collection effort where feasible. Project documentation provided by SDG&E was the primary source for engineering calculations of *ex ante* energy impact estimates in most cases.

Figure 3-1
General Study Work Flow



3.2.3 Task 3: Conduct Site-Specific Analysis of IEEI Program Projects

Site-specific analyses were completed for all participants of *SDG&E's 1995 Industrial Energy Efficiency Incentives Program* that installed measures classified as industrial process.

Sub-Task 3a: Develop Project-Specific Evaluation Plan

Individual evaluation plans were developed for each IEEI Program participant and summarized in spreadsheet form. Each site plan was developed individually using the appropriate methodology as discussed in Section 3.2.2.

Sub-Task 3b: Determine Gross Site-Specific Impacts

The next subtask was to estimate the gross impacts for each site.

Data Collection

On-site data collection activities were conducted from October 1996 through January 1997 for those sites evaluated through the on-site approach. Measure installations were verified, measurements were taken to support load impact estimation, and other on-site data were collected via interview with site personnel and inspection of operating records.

For those sites not evaluated on site, data from the project files were reviewed and augmented as appropriate with data from credible secondary sources.

Gross impacts were calculated on an individual project basis.

Estimating The Load Impacts For Process Measures

The gross load impacts of Industrial process measures were estimated *ex post* using engineering based models. Most sites were visited *ex post* to verify key engineering assumptions used in the *ex ante* analysis. For those sites where site visits were not conducted a review of the *ex ante* analysis was conducted and *ex post* load impacts estimated using augmented input data or alternate algorithms. In general, the engineering approach used to estimate the *ex ante* impacts was the basis for the *ex post* analysis.

3.2.4 Task 4: Estimate Total Gross Impacts

Gross impacts were estimated for the PY95 industrial DSM measures. This includes total gross kW, kWh and therm impacts, as appropriate. Realization rates were calculated for each type of measure as defined in Table 6 of the *M&E Protocols*, where it is defined as "the load impacts estimated by the Evaluation, divided by the load impacts filed in a utility's first year earnings claim."

Integrate Site-Specific Gross Impacts

After the individual impacts from each project were estimated, the results were aggregated to estimate total program gross impacts.

3.2.5 Task 5: Determine Total Net Impacts

Net impacts were addressed through an assessment of the net-to-gross ratio. An interview was conducted with each site contact as part of the on-site post-installation field visit. Assessment of net-to-gross was done through self-reported responses to questions about the factors that affected the customer's decision to implement the measure recommendation, as well as supporting documentation found in project files.

A net-to-gross ratio was estimated for each measure installed based on information gathered during the site visit and from the project files. The decision rules for estimating the net-to-gross are shown in Table 3-1. Among the underlying principles on which these rules were based is a basic consumer behavior model comprised of four steps:

1. awareness of a problem or need;
2. information gathering for solutions;
3. evaluation and (more information gathering if necessary); and
4. the purchase.

Through the IEEI Program, SDG&E has several opportunities to intervene and facilitate this consumer process. SDG&E can proactively identify energy efficiency opportunities and quantify their potential impacts and costs. The customer can be made aware of energy efficiency measures and provided information on associated costs and benefits. Incentives may be provided to reduce the cost barriers to implementation. The customer will go through an evaluation phase, where additional information may be gathered, perhaps a different equipment configuration. Finally, a decision will be made whether to implement the measure or not.

Figure 3-2 shows a decision tree that reflects the rules described in Table 3-1 for assigning the net-to-gross ratio on a site-specific basis.

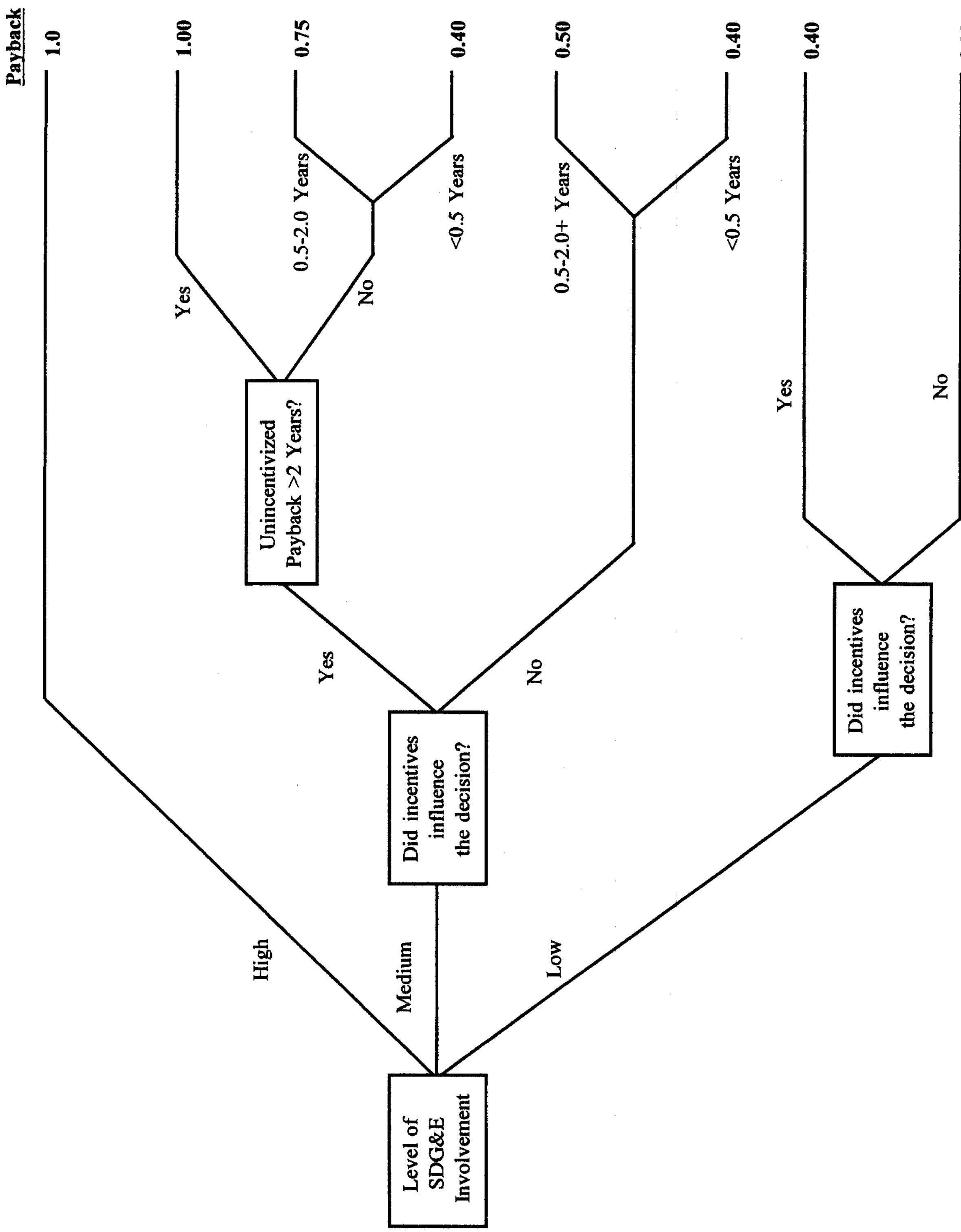
Table 3-1
Decision Rules For Estimating Net-To-Gross Ratio

Level of SDG&E Involvement	Description	Net-To-Gross Ratio
High: Clear evidence that: (1) SDG&E performed or commissioned a site-specific engineering study in advance of the conceptual development of the project was found; or (2) the unincentivized paybacks were outside the firm's payback investment threshold and the incentive allowed the firm to invest in the measure.	The IEEI Program was primarily responsible for the development of the energy efficiency concept and/or ultimate development of the measure through a combination of technical and financial assistance.	1.00
Medium: SDG&E prepared analysis that provided cost-justification through engineering analysis and the incentives in advance of the installation of the measure. The originator of the project concept was not clear. SDG&E did however, provide clear assistance in the evaluation and implementation phases of the process.	The IEEI Program was instrumental in providing information to the customer. The project concept, however, may have been originated by a non-program source, e.g., a vendor. In these cases, project cost barriers may have been reduced through incentives offered through the program.	**If incentive influenced the decision:** If payback w/o incentive >2.0 years: 1.00 If payback w/o incentive is 0.5-2.0 years: 0.75 If payback w/o incentive <0.5 years: 0.40 **If incentive did not influence the decision:** If payback w/o incentive >0.5 years: 0.50 If payback w/o incentive <0.5 years: 0.40
Low: Little evidence of technical support and/or engineering analysis that affected the final decision making, e.g., the origination of the measure concept.	The IEEI Program appeared to have little involvement and little influence on the decision to implement. Unincentivized paybacks were not sufficiently long enough to affect the purchase decision.	**If incentive influenced the decision**: 0.40 **If incentive did not influence the decision**: 0.00

By evaluating information gathered from customer personnel and the project files the net-to-gross ratios were assigned for each site. The site specific net-to-gross ratios were combined with the gross savings estimate per site to estimate the net impacts on site-specific basis. The net impacts were then aggregated to the program level.

The net-to-gross ratio for the program was estimated by dividing the *ex post* net load impacts by the *ex post* gross load impacts. Thus, the program net-to-gross is weighted by the individual measure load impacts.

Figure 3-2
Net-To-Gross Decision Tree



3.3 *Ex Post* Load Impact Estimation Approach For Industrial Motor Measures

This section provides an overview of the *ex ante* and *ex post* methodologies and general equations for estimating the load impacts of the industrial motor measures.

3.3.1 Sampling

The sample was drawn from program participants in accordance with Table C-5 of the *M&E Protocols*. Projects representing at least 70 percent of the total *ex ante* impacts for the motor end use element were selected for the study.

3.3.2 Ex Ante Load Impact Estimation Methodology

Each of the motor measures was installed as part of SDG&E's Energy Efficient Motor Rebate Program. Under this program, the nonresidential market in San Diego was targeted. Open Drip-Proof (ODP) and Totally Enclosed Fan-Cooled (TEFC) motors from 1 to 200 HP were included in the program. These motors were single-speed energy efficient motors. A method documented by EPRI[1] was used to estimate *ex ante* impacts for single-speed motors. Equations 3-1 and 3-2 were used to estimate *ex ante* load impacts, using standard assumptions regarding the operations of the motors. Among these assumptions were 4,000 hours of operation annually and rated load factor for base and energy efficient motors of 0.75.

(Eq. 3-1)

$$\Delta kWh = (units)(0.746)\left[\frac{(hp_{base})(RLF_{base})}{\eta_{base}} - \frac{(hp_{ee})(RLF_{ee})}{\eta_{ee}}\right](FLH),$$

where:

ΔkWh = *gross annual energy savings,*

$units$ = *number of motors installed under the program,*

η_{base} = *efficiency of base motor,*

η_{ee} = *efficiency of high-efficiency motor,*

hp_{base} = *horsepower of base motor (hp),*

hp_{ee} = *horsepower of high-efficiency motor (hp),*

RLF_{base} = *rated load factor for the base motor,*

RLF_{ee} = *rated load factor for the high-efficiency motor,*

FLH = *full-load hours, and*

0.746 = *conversion factor (kW / hp).*

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[1] Electric Power Research Institute, Engineering Methods for Estimating the Impacts of Demand-Side Management Programs, Volume 2: Fundamental Equations for Residential and Commercial End Uses, pp. 3-84 to 3-85.

Ex ante demand impacts were estimated using Equation 3-2.

$$\Delta kW = (units)(0.746)\left[\frac{(hp_{base})(RLF_{base})}{\eta_{base}} - \frac{(hp_{ee})(RLF_{ee})}{\eta_{ee}}\right](DF)(CF), \quad \text{(Eq. 3-2)}$$

where:

ΔkW = *gross coincident demand savings,*

$units$ = *number of motors installed under the program,*

η_{base} = *efficiency of base motor,*

η_{ee} = *efficiency of high-efficiency motor,*

hp_{base} = *horsepower of base motor (hp),*

hp_{ee} = *horsepower of high-efficiency motor (hp),*

RLF_{base} = *rated load factor for the base motor,*

RLF_{ee} = *rated load factor for the high-efficiency motor,*

FLH = *full-load hours,*

DF = *demand diversity factor,*

CF = *coincidence factor, and*

0.746 = *conversion factor (kW / hp).*

3.3.3 Ex Post Gross Load Impact Estimation Methodology

Site-specific engineering analysis with verified data on operating characteristics was the basis for *ex post* load impact estimates. Verification of the operating conditions of the motors was performed through on-site inspections and/or telephone interviews. Operations logs and spot measurements were taken to determine pump loads and operating hours. Interviews with site personnel were conducted to confirm the site information.

The *ex post* estimation methodology used Equations 3-3 and 3-4 to estimate the load impacts of each of the motor measures.

$$kW\_Savings = (Qty)(Capacity)(\%\,Load)\left(\frac{1}{Eff_{baseline@\,load}} - \frac{1}{Eff_{retrofit@\,load}}\right), \quad \text{(Eq. 3-3)}$$

where:

Qty = *Quantity of retrofit motors,*

$Capacity$ = *Rated Output Horsepower in kW converted from Horsepower (1 kW = 0.7457 HP),*

$$\%\,Load = \left(\frac{\text{Output Horsepower at Actual Load Conditions}}{\text{Rated Output Horsepower}}\right),$$

$Eff_{baseline@\,load}$ = *Rated Baseline Motor Efficiency at Actual Load Conditions, and*

$Eff_{retrofit@\,load}$ = *Rated Retrofit Motor Efficiency at Actual Load Conditions.*

(Eq. 3-4)

$$kWh\_Savings = (kW\_Savings)(Ann\_Op\_Hours),$$

where:

$$kW\_Savings = \text{calculated in Equation 5 - 3, and}$$

$$Ann\_Op\_Hours = \text{Hours estimated from onsite visit.}$$

Estimating Base Case For Motor Measures

For those sites where the new motor was a *retrofit of a working motor*, the description of the old motor from the Energy Efficient Motor Program Customer Enrollment Form ("Enrollment Form") was used as the base case. However, (1) for those motors where the new motor was *replacing a burned out unit*, (2) for those sites where a *new facility or application* was indicated on the "Enrollment Form," or (3) for those measures where the old motor information was not provided on the "Enrollment Form," a base case motor representing an "average" motor that would typically be purchased over the counter was developed using the following procedures.

Baseline (standard) motor efficiency data was obtained from the MotorMaster+ database (Washington State Energy Office, 1996). This database contains cost and efficiency data on more than 10,000 NEMA Design B motors. Baseline motor data was chosen by searching the database for motors with efficiencies less than the NEMA 12-6B standard and selecting the motor with the median efficiency at 100% load. Efficiency and Power Factor curve data were available for load conditions from 25% to 100% in quartile increments.

Load Impact Estimation

The gross load impacts for the motor were estimated by taking the difference of energy use for the baseline and energy efficient motors.

Realization rates were calculated for the Program as defined in Table 6 of the *M&E Protocols*, where it is defined as "the load impacts estimated by the Evaluation, divided by the load impacts filed in a utility's first year earnings claim."

The realization rate was applied to the *ex ante* total kWh saved and kW reduced to estimate the Program gross load impacts.

3.3.4 Net-To-Gross Ratio

The net-to-gross ratio was estimated for motors based on customer reported responses during the survey. The responses were categorized into two categories: (1) always buy energy efficient motors; and (2) the program/rebate made a difference. A net-to-gross ratio was assigned to each surveyed motor. A net-to-gross ratio of zero was assigned to the first category and a net-to-gross of 1.0 was assigned to the latter, as shown in Table 3-2.

Table 3-2
Net-To-Gross Categories
Industrial Energy Efficient Motors

Category	Net-To-Gross Ratio
Always buy energy efficient motors	0.00
Program/rebate made a difference	1.00
No response	N/A

The assigned net-to-gross ratios were applied to the gross *ex post* energy and demand impacts to estimate the net impacts for the motors studied. The Program net-to-gross ratio for industrial motors was estimated by dividing total net impacts by total gross impacts for the studied motors. The Program net load impacts were estimated by applying the Program net-to-gross to the total Program *ex post* gross load impacts.

4 PROCESS MEASURES

4.1 INTRODUCTION

This section provides the site specific analyses for the industrial process measures installed under SDG&E's 1995 Industrial Energy Efficiency Incentives Program.

4.2 ID NO. 7259 - AIR COMPRESSOR REPLACEMENT

4.2.1 Facility Information

This is a manufacturing facility in San Diego, CA which operates 24 hours per day, 6 days per week, 52 weeks per year, with 8 holidays (7,296 hours per year).

The plant's compressed air requirements were provided by a single 50 horsepower compressor which was oversized compared to the demand for compressed air. The compressor had poor part load efficiency. By replacing the existing 50 horsepower air compressor with a unit that has a relatively high part load efficiency and that is sized (30 horsepower) so that it operates at a high percentage of full load most of the time, the energy requirement was reduced. The savings will occur because the system uses a smaller motor and, since it operates at a high percentage of full load, its efficiency will be optimized.

4.2.2 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates were based on a worksheet that is used to estimate the demand of the baseline and retrofit equipment. Demand reductions are then estimated and multiplied by the operating hours to calculate the energy savings.

The baseline and retrofit demand are:

$$\begin{aligned} kW_{Baseline} &= (480\ V)(65\ A)(0.001)(0.65)(phase) \\ &= 35.12\ kW \end{aligned}$$

$$\begin{aligned} kW_{Retrofit} &= (480\ V)(40\ A)(0.001)(0.65)(phase) \\ &= 21.68\ kW \end{aligned}$$

The *ex ante* demand reduced and energy savings are:

$$kW\ reduced_{ex\ ante} = kW_{Baseline} - kW_{Retrofit}$$
$$= 35.12\ -\ 21.68$$
$$= 13.45\ kW$$

$$kWh_{ex\ ante} = (kW\ reduced_{ex\ ante})(Operating\ hours)$$
$$= (13.45)(4{,}056\ hours / year)$$
$$= 54{,}542\ kWh / year$$

4.2.3 Ex Post Load Impact Estimation

The site was visited on November 15, 1996, and the equipment was inspected. It was found that the old compressor had been left installed and, according to plant personnel, it is operated approximately half of the time. It was not in operation during the site visit or during the time when logger data was being taken.

Spot measurements were taken on the new compressor operating in loaded and unloaded modes. Quantities measured were: demand, kVA, power factor, and kVAR. A current logger was installed on the new compressor and allowed to gather data for approximately 96 hours. These data were used with manufacturer's performance data to generate *ex post* values for peak demand and annual energy consumption.

The baseline for comparison is the plant operating with the 50 horsepower compressor.

The plant and its compressed air system operate 7,296 hours per year.

Table 4-1 shows the assumptions used in estimating the *ex post* load impacts.

Table 4-1
Assumptions for *Ex Post* Load Impacts

Parameter	Value
Existing compressor kW	90% of full load over range of output from 60% to 100%
Motor load	80% when compressor is at full load.
Compressor operations	Compressor operate between 60% t 100% of full capacity 50% of the time.
kW when compressor is unloaded	50% of full load kW

The baseline energy use is:

$$\text{Peak kW} = \frac{(50\text{ hp})(0.746\text{ kW / hp})}{0.80\text{ efficiency rating}}$$

$$= 29.84\text{ kW:}$$

The compressor operates fully loaded 50% of the time and unloaded the other 50%. The average demand is:

$$kW\ loaded = (29.84)(0.90)$$
$$= 26.86\ kW$$

$$kW\ unloaded = (29.84)(0.50)$$
$$= 14.92\ kW$$

$$kW\ average = \frac{26.86 + 14.92}{2}$$

$$= 20.89\ kW$$

The annual energy consumption is:

$$kWh_{Baseline} = (20.89)(7{,}296)$$
$$= 152{,}413\ kWh / year$$

Ex post measurements show:

$$Peak\ kW_{Retrofit} = 25.46\ kW$$
$$Average\ kW_{Retrofit} = 16.94\ kW$$

The annual energy consumption for the retrofit system is:

$$kWh_{Retrofit} = (Average\ kW_{Retrofit})(Operating\ hours)$$
$$= (16.94\ kW)(7{,}296\ hours / year)$$
$$= 123{,}594\ kWh / year$$

Since the 50 hp compressor is still in operation, there will be no reduction in peak demand. Thus, the demand impact is:

$$kW\ reduced_{ex\ post} = 0\ kW$$

The *ex post* energy impacts attributable to the measure are:

$$
\begin{aligned}
kWh\ saved_{ex\ post} &= kWh_{Baseline} - kWh_{Retrofit} \\
&= 152{,}413 - 123{,}594 \\
&= 28{,}819\ kWh/year
\end{aligned}
$$

Table 4-2 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-2
kW and kWh Impacts by Time-Of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	3.95	3.95	1.00	2,931	0.10
Summer Semi-peak	3.95		1.00	3,768	0.13
Summer Off-peak	2.74		0.69	5,414	0.19
Winter On-peak	3.95	3.95	1.00	1,742	0.06
Winter Semi-peak	3.95		1.00	7,548	0.26
Winter Off-peak	2.74		0.69	7,497	0.26
			Totals	28,900	1.00

4.2.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-3 summarizes the *ex ante* and *ex post* load impact estimates. Comparison of the *ex ante* and *ex post* peak demand values shows a realization rate of 0. This is because the *ex ante* analysis assumed that the 50 hp compressor was to be removed when the 30 hp unit was installed. In fact, both units are installed and are operated on a rotating basis according to plant personnel. The
ex ante analysis was brief and its assumptions were not defined. Because of this, the *ex ante* estimates could not be reproduced.

Table 4-3
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	13.45	54,542	N/A
Ex post estimated gross impacts	0	28,903	N/A
Difference	-13.45	25,639	N/A
Realization rate	0	0.53	N/A

4.2.5 Persistence of the Measure

The 15 year measure life is reasonable and consistent with other similar measures.

4.3 ID No. 13671 - Upgrade Air Compressors

4.3.1 Facility Information

This is a ship building and repair facility in San Diego, CA which operates 24 hours per day, 360 days per year (8,640 hours per year). The yard uses large quantities of compressed air for various purposes throughout the facility. The plant was served by six compressors with a total of 2,400 horsepower.

An *ex ante* survey of the existing compressors showed that one 800 hp compressor was only operated as a last resort backup and ran less than 100 hours per year. Measurements were taken on the remaining compressors (1,600 hp) and it was found that they typically produced 2.17 cfm/hp or a total of 3,472 cfm.

The five smaller compressors were replaced with two high efficiency units which produce 3,400 cfm at 4.86 cfm/hp and the 800 hp compressor was left in place as a backup.

Since the capacities of the two configurations are the same, it is assumed that the duty cycles will be the same. The new units will consume less than half the power used by the existing units.

4.3.2 Ex Ante Load Impact Estimation

Table 4-4 show the compressor load assumptions used for the *ex ante* load impact estimates.

Table 4-4
***Ex Ante* Compressor Load Assumptions**

Parameter	Horsepower
Baseline compressor capacity	2,400
Retrofit compressor capacity	700
Compressor capacity reduced	1,400

The *ex ante* kW reduced is:

$$\text{kW reduced}_{\text{ex ante}} = \frac{\text{(Compressor hp reduced)(o.746 kW / hp)(Load factor)}}{\text{Efficiency Rating}}$$

$$= \frac{\text{(1,700 hp)(0.746 kW / hp)(0.8)}}{\text{0.92 Efficiency Rating}}$$

$$= 1{,}102.78 \text{ kW}$$

The *ex ante* energy saved is:

$$\begin{aligned} kWh\ saved_{ex\ ante} &= (kW\ reduced_{ex\ ante})(Operating\ hours) \\ &= (1{,}102.78)(3{,}672) \\ &= 4{,}049{,}408\ kWh \end{aligned}$$

4.3.3 Ex Post Load Impact Estimation

Ex ante measurements were used to calculate the peak demand and annual energy consumption for the compressed air plant before retrofit. *Ex post* spot measurements were taken of power consumption, voltage, current, power factor, and total harmonic distortion. Current loggers were connected to both of the new air compressors and allowed to gather data for two representative days. These measurements were used to calculate peak demand and annual energy consumption after retrofit.

The baseline for comparison is the yard operating 24 hours per day, 360 days per year (8,640 hours per year) with the baseline compressor inventory shown in Table 4-5.

Table 4-5
Baseline Compressor Inventory

Compressor	Count	Horsepower (Each)	Horsepower (Total)	kW (Total)
Sullivan	1	400	400	259.5
Joy	4	300	1,200	778.4
Clark	1	800	800	519.0

Since the Clark compressor is used only as a backup, it will not be counted. Also, since the compressors operate near full load all the time, the peak demand will be equal to the average demand.

Baseline demand and energy consumption are:

$$kW_{Baseline} = 1{,}037.9\ kW$$

$$\begin{aligned} kWh_{Baseline} &= (kW_{Baseline})(Operating\ hours) \\ &= (1{,}037.9\ kW)(8{,}640\ hours\ /\ year) \\ &= 8{,}967{,}546\ kWh \end{aligned}$$

Table 4-6 shows the inventory of retrofit compressors.

Table 4-6
Retrofit Compressor Inventory

Compressor	Count	Horsepower (Each)	Horsepower (Total)	kW (Total)
Leroi	2	350	700	524.5
Clark	1	800	800	519.0

Since the Clark compressor is used only as a backup, it is not included in the load estimation.

Ex post measurements indicate that:

$$kW_{Retrofit} = 524.5\ kW$$

$$\begin{aligned} kWh_{Retrofit} &= (kW_{Retrofit})(Operating\ hours) \\ &= (524.5\ kW)(8{,}640\ hours\ /\ year) \\ &= 4{,}531{,}680\ kWh \end{aligned}$$

The *ex post* load impact estimates are:

$$\begin{aligned} kW\ reduced_{ex\ post} &= Peak\ kW_{Baseline} - Peak\ kW_{Retrofit} \\ &= 1{,}037.9 - 524.5 \\ &= 513.4\ kW \end{aligned}$$

$$\begin{aligned} kWh\ saved_{ex\ post} &= kWh_{Baseline} - kWh_{Retrofit} \\ &= 8{,}967{,}456 - 4{,}531{,}680 \\ &= 4{,}435{,}776\ kWh \end{aligned}$$

Table 4-7 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-7
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	513.4	451.8	1.00	380,943	0.09
Summer Semi-peak	513.4		1.00	489,784	0.11
Summer Off-peak	513.4		1.00	1,014,478	0.23
Winter On-peak	513.4	451.8	1.00	226,409	0.05
Winter Semi-peak	513.4		1.00	981,107	0.22
Winter Off-peak	489.0		0.95	1,337,904	0.30
			Totals	4,430,625	1.00

4.3.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-8 summarizes the *ex ante* and *ex post* load impact estimates. A comparison of the *ex ante* and *ex post* estimates shows a realization rate of 0.47 for demand reduction and 1.10 for annual energy savings. The primary reasons for the differences are:

- The old Clark air compressor (800 hp) was assumed in the *ex ante* analysis to operate 80% of full load before the retrofit and to be removed in the retrofit. In fact, this machine was held as a backup and barely run before the retrofit. It was not removed in the retrofit and is still kept as a backup. This resulted in a lower *ex post* demand reduction estimate.
- The *ex ante* analysis is based on calculated values of power demand for the compressors, this requires some assumptions as to efficiencies and load factors while the *ex post* analysis is based on values measured on site.

Table 4-8
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	1,102.8	4,049,408	N/A
Ex post estimated gross impacts	513.4	4,435,776	N/A
Difference	589.4	-386,368	N/A
Realization rate	0.47	1.10	N/A

4.3.5 Persistence of the Measure

The 7 year life assigned to the compressors is appropriate and conservative.

4.4 ID No. 13792A - Covers On Melting Pots

4.4.1 Facility Information

This is a production facility in El Cajon, CA which produces precision stamped and forged metal parts, mainly for the aerospace industry. The forms over which sheet metal parts are formed are cast in-house from lead and Kirksite which are melted in two gas fired melting pots.

The two melting pots operate uncovered throughout their cycle, resulting in substantial heat loss. The installation of insulated covers on the two melting pots reduced heat loss. Energy savings are achieved through lower gas consumption required to make up heat loss from the melting pots.

4.4.2 Ex Ante Load Impact Estimation

Table 4-9 shows the assumptions used to estimate the basecase therm usage for the *ex ante* load impact estimation.

Table 4-9
***Ex Ante* Load Impact Assumptions**

Parameter	Value
Melting pot temperature	900° F
Surface area of Kirksite pot	26.7 square feet
Surface area of lead pot	13.6 square feet
Ambient temperature of plant	70° F
Burner efficiency	80%
Operating hours	3,250 hours per year

The following equation for calculating heat loss was taken from *Marks' Mechanical Engineers Handbook.*

$$\text{Heat Loss} = A(h_c + h_r)\Delta T,$$

where,

A = surface area of pots,

h_c = convective heat transfer coefficient,

h_r = radiation heat transfer coefficient, and

ΔT = difference between surface and ambient temperatures.

Interpolating from Table 11 in *Marks' Mechanical Engineers Handbook,* the base case energy use for the two melting pots is:

$$\Delta T = 900 - 80$$
$$= 820°\, F \text{ (a horizontal surface will transfer heat upward).}$$

$$(h_c + h_r) = 7.79\ Btu / hour \text{ - } s.f.\text{-}°\, F.$$
Thus,
$$Heat\ Loss = (26.7 + 13.6\ s.f.)x(7.79\ Btu / hour \text{ - } s.f.\text{-}°\, F)x(830°\, F),$$
$$= 260{,}568\ Btu / hour.$$

Interpolating from Table 11 in *Marks' Mechanical Engineers Handbook,* the retrofit energy use for the two melting pots is:

$$\Delta T = 900 - 80$$
$$= 820°\, F \text{ (a horizontal surface will transfer heat upward).}$$

$$(h_c + h_r) = 7.79\ Btu / hour \text{ - } square\ foot\text{-}°\, F.$$
Thus,
$$Heat\ Loss = (26.7 + 13.6) s.f.x(7.79\ Btu / hour \text{ - } s.f.\text{-}°\, F)x(830°\, F),$$
$$= 260{,}568\ Btu / hour.$$

4.4.3 Ex Post Load Impact Estimation

Ex post measurements indicate that the outer surface of the insulated lid has a temperature of 160°F.

The heat loss equation from Marks' was used to estimate therm savings.

Base case energy use used the same conditions as the *ex ante* estimate except that the ambient temperature was 80°F.

$$Heat\ Loss_{BaseCase} = (26.7 + 13.6\ s.f.)x(8.48\ Btu / hour \text{ - } s.f.\text{-}°\, F)x(820°\, F),$$
$$= 280{,}230\ Btu / hour,$$
$$= (280{,}230\ Btu / hour)x(3{,}250\ hours / year)x(100{,}000\ Btu / therm),$$
$$= 9{,}107\ therms / year.$$

The energy use for the retrofit was calculated using the following equations:

$$\Delta T = 160 - 80$$
$$= 80° F \textit{ (a horizontal surface will transfer heat upward).}$$

$$(h_c + h_t) = 2.21\ Btu / hour - s.f.-° F.$$

Thus,

$$Heat\ Loss_{Retrofit} = (26.7 + 13.6\ s.f.)x(2.21\ Btu / hour - s.f.-° F)x(80° F),$$
$$= 7,125\ Btu / hour,$$
$$= 7,125\ Btu / hour\ x\ 3,250\ hour / year / 100,000\ Btu / therm,$$
$$= 231.6\ therms / year.$$

The annual energy savings attributed to the installation of insulated covers for the two melting pots is:

$$Annual\ energy\ savings_{ex\ post} = \frac{\text{Heat Loss}_{\text{Base Case}} - Heat\ Loss_{\text{Retrofit}}}{Burner\ Efficiency}$$

$$= \frac{9{,}107 - 232}{0.80 \text{ Burner efficiency rating}}$$

$$= 11{,}094\ therms / year.$$

There are no electric load impacts associated with this measure.

4.4.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-10 summarizes the *ex ante* and *ex post* load impact estimates. The *ex post* estimate is slightly higher, with a realization rate of 1.08.

Table 4-10
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	N/A	N/A	10,321
Ex post estimated gross impacts	N/A	N/A	11,094
Difference	N/A	N/A	773
Realization Rate	N/A	N/A	1.08

4.4.5 *Persistence of the Measure*

ASHRAE *HVAC Handbook, 1987, Table 5 Equipment Service Life* indicates a life for insulation of process equipment of 20 years, thus, the 15 year *ex ante* value is conservative and appropriate.

4.5 ID No. 13792B - Upgrade Process Furnace

4.5.1 *Facility Information*

This is a production facility in El Cajon, CA which produces stamped and forged metal parts, mainly for the aerospace industry. Some of the manufactured parts must be heat treated as part of the production process. The plant has a natural gas fired heat treatment furnace which, according to *ex ante* measurements, operates 3,250 hours per year.

According to *ex ante* measurements, the outside shell of the heat treating furnace operates at 225°F which causes significant energy losses to the environment. The 12 burners in the furnace are of a type which uses a minimum of 100% excess combustion air.

The baseline conditions for the furnace are shown in Table 4-11 for comparison is the furnace operating with a shell temperature of 225°F, using the *ex ante* burners.

Table 4-11
Baseline Operating Conditions

Parameter	Value
Shell temperature	225°F
Area of sides	203 ft^2
Area of top	51 ft^2
Operating hours	3,250 hours/year
Shop temperature	80°F

To improve the energy efficiency of the furnaces the following measures were implemented:

- improving the insulation in the walls of the heat treating furnace will reduce heat losses to the environment; and
- replacement of the furnace burners with units that use less excess air to increase burner efficiency and reduce natural gas consumption.

Energy savings are generated through:

- burning less gas to replace heat lost through the walls of the furnace; and
- from the improvement of burner efficiency allowing the furnace to perform its work while burning less gas.

4.5.2 Ex Ante Load Impact Estimation

The *ex ante* energy impacts from the furnace insulation were calculated as follows:

$$\text{Burner efficiency} = 65\% \text{ for a 50 year old unit}$$

$$\begin{aligned} Q_{w/o insulation} &= (h_c + h_r)_{top}(Area)(\Delta T) + (h_c + h_r)_{side}(Area)(\Delta T) \\ &= (2.68)(51\ \text{s.f.})(155^\circ\ \text{F}) + (2.43)(203\ \text{s.f.})(155^\circ\ \text{F}) \\ &= 97{,}645\ \text{Btu / hour} \end{aligned}$$

$$\begin{aligned} Q_{w/ insulation} &= (h_c + h_r)_{top}(Area)(\Delta T) + (h_c + h_r)_{side}(Area)(\Delta T) \\ &= (2.00)(51\ \text{s.f.})(50^\circ\ \text{F}) + (1.82)(203\ \text{s.f.})(50^\circ\ \text{F}) \\ &= 23{,}573\ \text{Btu / hour} \end{aligned}$$

$$\text{therms saved} = \frac{(Q_{\text{w/o insulation}} - Q_{w/ insulation})\ hour}{\text{Burner efficiency}}$$

$$\text{therms saved (insulation)}_{\text{ex ante}} = \frac{(97645 - 23{,}573\ Btu / hour)(3{,}250\ \text{hours})}{0.65\ \text{Burner efficiency}}$$

$$= 3{,}704\ \text{therms / year}$$

The *ex ante* energy impacts from the burner retrofits were calculated using the assumptions shown in Table 4-12.

Table 4-12
***Ex Ante* Furnace Burner Retrofit Assumptions**

Parameter	Value
Sealed burner flow rate	135,000 Btu/hour
No. of burners	12
Diversity factor	50%
Fuel saving percentage	20%

The *ex ante* energy savings from the retrofit of 12 furnace burners were calculated as follows:

$$\text{therms saved}(burner\ retrofits)_{ex\ ante} = \frac{(Flow\ rate)(\#\ burners)(Operating\ hours)(Diversity\ factor)(\%Fuel\ savings)}{100{,}000\ Btu\ /\ therm}$$

$$= \frac{(135{,}000\ Btu\ /\ hour)(12)(3{,}250 hours\ /\ year)(0.2)}{100{,}000\ Btu\ /\ therm}$$

$$= 5{,}265\ therms\ /\ year$$

Total savings are calculated as follows:

$$\begin{aligned} therms\ saved\ (total)_{ex\ ante} &= therms\ saved\ (furnace\ insulation)_{ex\ ante} \\ &\quad + therms\ saved\ (burner\ retrofit)_{ex\ ante} \\ &= 3{,}704 + 5{,}265 \\ &= 8{,}969\ therms\ /\ year \end{aligned}$$

4.5.3 Ex Post Load Impact Estimation

The following equation for estimating heat loss was taken from *Mark's Mechanical Engineers Handbook*:

$$Heat\ Loss = A(h_c + h_r)\Delta T,$$

where,

A = *transfer area,*

h_c = *convective heat transfer coefficient,*

h_r = *radiation heat transfer coefficient, and*

ΔT = *difference between surface and ambient temperatures.*

Using values from Table 11 in *Mark's Mechanical Engineers Handbook*:

For the top surface at 225° F:

$$(h_c + h_r) = 2.62\ Btu\ /\ hour - ft^2 - {}^\circ F$$

For the walls at 225° F:

$$(h_c + h_r) = 2.37\ Btu\ /\ hour - ft^2 - {}^\circ F$$

Heat losses are calculated as:

$$Heat\ Loss_{Top\ Surface} = 51\,ft^2 x 2.62\ Btu/hour\text{-}ft^2\text{-}{}^\circ F\ x\ (225-80)^\circ F,$$
$$= 19{,}755\ Btu/hour.$$

$$Heat\ Loss_{Sides} = 203\,ft^2 x 2.37\ Btu/hour\text{-}ft^2\text{-}{}^\circ F\ x\ (225-80)^\circ F,$$
$$= 69{,}761\ Btu/hour.$$

$$Heat\ Loss_{Total} = Heat\ Loss_{Top\ Surface} + Heat\ Loss_{Sides},$$
$$= 19{,}755 + 69{,}761,$$
$$= 89{,}516\ Btu/hour.$$

Table 4-13 shows the manufacturer's specifications on the flow rates for the baseline burners at high and low fire.

Table 4-13
Flow Rates of Baseline Burners

Parameter	Value
Flow rate-high fire	135,000 Btu/hour/burner
Flow rate-low fire	13,500 Btu/hour/burner
Burner efficiency	33%

To provide 89,516 Btu/hour, the burners must operate at low fire 55% of the time. The volume of natural gas required to supply this heat is:

$$\text{Fuel Required}_{\text{Baseline}} = \frac{(13{,}500\ Btu/hour)(12\ burners)(0.55\ \text{Duty Cycle})(3{,}250\ \text{hour/year})}{0.33\ \text{Burner Efficiency} \times 100{,}000\ \text{Btu/therm}}$$

$$= 8{,}775\ \text{therms/year}$$

Ex post measurements indicate the furnace shell temperature was 150°F.

Using Table 11 from *Mark's Mechanical Engineers Handbook*:

For the top surface at 150° F:

$$(h_c + h_r) = 2.14\ \text{Btu/hour-}\ ft^2\text{-}{}^\circ F$$

For the walls at 150° F:

$$(h_c + h_r) = 1.94\ \text{Btu/hour-}\ ft^2\text{-}{}^\circ F$$

Heat losses are calculated as:

$$\text{Heat Loss}_{\text{Top Surface}} = 51\ \text{ft}^2 x 2.14\ \text{Btu / hour - ft}^2 -^\circ F \text{ x } (150 - 80)^\circ \text{F}.$$
$$= 7{,}640\ \text{Btu / hour.}$$

$$\text{Heat Loss}_{\text{Sides}} = 203\ \text{ft}^2 x 1.94\ \text{Btu / hour - ft}^2 -^\circ F \text{ x } (150 - 80)^\circ \text{F},$$
$$= 27{,}567\ \text{Btu / hour.}$$

$$\text{Heat Loss}_{\text{Total}} = \text{Heat Loss}_{\text{Top Surface}} + \text{Heat Loss}_{\text{Sides}},$$
$$= 7{,}640 + 27{,}567,$$
$$= 35{,}207\ Btu\ /\ hour.$$

Ex post measurements show that the burner efficiency is 64% at high fire and 41.3%
To provide 35,207 Btu/hour, the burners must operate at low fire 22% of the time. Tl
require a gas input of:

$$Fuel\ Required_{Baseline} = \frac{(13{,}500\ Btu\ /\ hour x 12\ burners)(0.22\ Duty\ cycle)(3{,}250\ hour}{0.41\ Burner\ efficiency \times 100{,}000\ Btu\ /\ therm}$$

$$= 2{,}825\ therms\ /\ year$$

The total *ex post* energy savings from the installation of the furnace insulation and th
is:

$$Total\ Energy\ Savings_{ex\ post} = Fuel\ Required_{Baseline} - Fuel\ Required_{Retrofit}$$
$$= 8{,}775 - 2{,}825\ therms\ /\ year$$
$$= 5{,}950\ therms\ /\ year$$

4.5.4 Comparison of Ex Ante and Ex Post Impact Estimates

As shown in Table 4-14, a comparison of the *ex ante* and *ex post* savings estimates sl
realization rate of 0.66. A major source of the difference is that the *ex ante* analysis t
insulation upgrade and the burner retrofit as separate measures, this ignores the intera
measures and overstates the potential savings. The *ex ante* analysis assumed a burne
of 65% while measurements show it to be 33%.

Table 4-14
Demand and Energy Impacts

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	N/A	N/A	8,969
Ex post estimated gross impacts	N/A	N/A	5,950
Difference	N/A	N/A	3,019
Realization rate	N/A	N/A	0.66

4.5.5 Persistence of the Measure

ASHRAE *HVAC Handbook 1987, Table 5 Equipment Service Life* states a life of 20 years for insulation of process equipment and 21 years for burner retrofits, thus, the 15 year life assigned is conservative and appropriate.

4.6 ID No. 13893 - Conversion of Cleaning Process

4.6.1 Facility Information

This is a production facility in Oceanside, CA which manufactures precision electronic connectors for the defense and aerospace industries. The plant operates 16 hours per day, 355 days per year (5,680 hour per year). The newly machined parts must be cleaned thoroughly before they are plated. This cleaning is done by using two solvent vapor degreasers.

The solvent vapor degreasers are electrically heated, using a total of 114 kW continuous power to maintain the required vapor density in the tanks.

By changing the process from two solvent vapor degreasing tanks to an aqueous/soap degreasing system consisting of five tanks, the heating energy use can be reduced substantially. The savings are achieved because the solvent vapor degreasers require continuous heating to maintain the vapor blanket in the cleaning tank, while the aqueous/soap degreaser requires only enough heat to maintain the water based solutions in the five tanks at 150°F.

4.6.2 Ex Ante Load Impact Estimation

Operating hours for the facility is 5,680 hours per year.

Baseline consumption comes from solution tanks in two areas, the machine shop and plating shop. The total demand for the tanks in these areas is:

$$\begin{aligned} kW_{Baseline} &= (78\ kW) + (36\ kW) \\ &= 114\ kW \end{aligned}$$

The energy consumption is:

$$
\begin{aligned}
kWh_{Baseline} &= (kW_{Baseline})(Operating\ hours) \\
&= (114\ kW)(5{,}680\ hours\ /\ year) \\
&= 647{,}520\ kWh\ /\ year
\end{aligned}
$$

Heat is required to maintain the tanks at 150°F. The heat loss for the tanks is:

$$\text{Heat required for each tank} = 15{,}520\ \text{Btu / hour}$$

$$= \frac{15{,}520\ \text{Btu / hour}}{3{,}413\ \text{Btu / kWh}}$$

$$= 4.55\ \text{kW}$$

$$
\begin{aligned}
kWh\ per\ tank &= (4.55\ kW)(5{,}680\ hours\ /\ year) \\
&= 25{,}844\ kWh\ /\ year\ /\ tank
\end{aligned}
$$

$$
\begin{aligned}
kWh\ five\ tanks &= (5\ tanks)(25{,}844\ kWh\ /\ year\ /\ tank) \\
&= 129{,}220\ kWh\ /\ year
\end{aligned}
$$

The *ex ante* load impacts attributable to the measure are:

$$
\begin{aligned}
kW\ reduced_{Baseline} &= kW_{Baseline} - kW_{Baseline} \\
&= 114 - 4.55 \\
&= 109.45\ kW
\end{aligned}
$$

$$
\begin{aligned}
kWh\ saved_{Baseline} &= kWh_{Baseline} - kWh_{Retrofit}) \\
&= 647{,}520 - 129{,}220 \\
&= 518{,}300\ kWh\ /\ year
\end{aligned}
$$

4.6.3 Ex Post Load Impact Estimation

Between the time of this retrofit and the *ex post* site visit, the system had been further modified to increase its production rate and to use natural gas as a heat source, rather than electricity. Because of this, information was taken from the project file to estimate the *ex post* load impacts of the measure.

The baseline for comparison is the plant operating on its normal schedule with the electrically heated solvent vapor degreasers. According to *ex ante* measurements the solvent vapor degreasers use 114 kW continuously, so the annual energy consumption is:

$$kW_{Baseline} = 114\ kW$$

$$\begin{aligned} kWh_{Baseline} &= (kW_{Baseline})(Operating\ hours) \\ &= (114)(5{,}680\ hours/year) \\ &= 647{,}520\ kWh/year \end{aligned}$$

From information in the project file:

$$Heat\ loss\ from\ liquid\ surface = 1{,}040\ Btu/hour\text{ - }sf$$
$$Heat\ loss\ from\ sides\ and\ bottom = 180\ Btu/hour\text{ - }sf$$

Each tank is 4-ft L x 2-ft W x 3-ft H, therefore, heat loss is:

$$\begin{aligned} \text{Total heat loss} &= [(4x2)(1{,}040)] + [[(2x3x4) + (2x2x3) + (2x4)](180)] \\ &= 16.240\ \text{Btu/hour} \end{aligned}$$

$$= \frac{16.240\ \text{Btu/hour}}{3{,}413\ \text{Btu/kWh}}$$

$$= 4.76\ \text{kW}$$

It is possible that all five tanks could be in heating mode at the same time, so the peak demand would be:

$$\begin{aligned} kW_{tanks} &= (5\ tanks)(4.76\ kW/tank) \\ &= 23.8\ kW \end{aligned}$$

It is conservative to assume that this is also the average demand.

The annual energy consumption for heating is:

$$\begin{aligned} \text{kWh}_{\text{tanks}} &= (\text{kW}_{\text{tanks}})(5{,}680\ \text{hours/year}) \\ &= 135{,}135\ \text{kWh/year} \end{aligned}$$

In addition to the above, the project file lists a collection of pumps, motors and controls which are part of the aqueous/soap degreaser system. This group requires:

$$\begin{aligned} Peak\ kW_{parasitic} &= 16.10\ kW \\ Average\ kW_{parasitic} &= 10.19\ kW \\ Annual\ kWh_{parasitic} &= 57{,}865\ kWh \end{aligned}$$

The total peak demand and energy consumption for the retrofit is:

$$\begin{aligned} \mathrm{kW}_{\mathrm{ex\ post}} &= \mathrm{kW}_{\mathrm{tanks}} + \mathrm{Peak\ kW}_{\mathrm{Parasitic}} \\ &= (23.8\ \mathrm{kW}) + (16.10\ \mathrm{kW}) \\ &= 39.9\ \mathrm{kW} \end{aligned}$$

$$\begin{aligned} \mathrm{kWh}_{\mathrm{ex\ post}} &= \mathrm{kWh}_{\mathrm{tanks}} + \mathrm{kWh}_{\mathrm{Parasitic}} \\ &= (135{,}135) + (57{,}865) \\ &= 193{,}000 \end{aligned}$$

The *ex ante* load impacts are:

$$\begin{aligned} kW\ reduced_{ex\ post} &= kW_{ex\ ante} - kW_{ex\ post} \\ &= 114 - 39.9 \\ &= 74.1\ kW \end{aligned}$$

$$\begin{aligned} kWh\ saved_{ex\ post} &= kWh_{ex\ ante} + kWh_{ex\ post} \\ &= 647{,}520 - 193{,}000 \\ &= 454{,}520\ kWh\ /\ year \end{aligned}$$

Table 4-15 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-15
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	80.01	80.01	1.00	59,367	0.13
Summer Semi-peak	80.01		1.00	76,330	0.17
Summer Off-peak	27.14		0.34	53,629	0.12
Winter On-peak	80.10	80.10	1.00	35,324	0.08
Winter Semi-peak	73.94		0.92	141,299	0.31
Winter Off-peak	32.38		0.40	88,592	0.19
			Totals	454,541	1.00

4.6.4 Comparison of Ex Ante and Ex Post Impact Estimates

As shown in Table 4-16, a realization rate for demand reduction of 0.68 and annual energy savings of 0.88 was calculated. There are multiple reasons for the differences, the principal ones are: (1) there is an arithmetic error in the *ex ante* calculation of the surface area of the tank which understates the area, and, therefore, the heat loss from the tank by 10%; and (2) there is a group of auxiliary equipment listed in the project file as part of the aqueous/soap degreaser system whose demand and energy consumption is not included in the *ex ante* analysis.

Table 4-16
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	109.45	518.300	N/A
Ex post estimated gross impacts	74.1	454.523	N/A
Difference	35.4	63,777	N/A
Realization rate	0.68	0.88	N/A

4.6.5 Persistence of the Measure

No published data on the measure expected service life could be found, but the 15 year life assigned appears reasonable and appropriate.

4.7 ID No. 13968 - Solid State Frequency Converter

4.7.1 Facility Information

This facility, located in San Diego, CA produces and tests electronic equipment. The plant requires a supply of 400 Hz electricity for use in its testing work. It currently uses a continuously running motor-generator set to provide the necessary power. The testing facilities operate 24 hours per day, 365 days per year (8,760 hours per year). The power supply is fully-loaded approximately 40% of the time and idle 60%.

The motor-generator set uses 25% of full load power (17 kW) when it is running idle. This represents 89,350 kWh of energy wasted annually.

The savings are generated by the lower energy consumption of the solid state converter in no load condition which occurs 60% of the time. There will be no demand savings from this measure.

According to its manufacturer, a solid state frequency converter which would serve the testing load has a power draw of 1.5 kW at idle. This would reduce the energy wasted to 7,880 kWh per year.

4.7.2 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates used the assumptions shown in Table 4-17, resulting in *ex ante* load impact estimates of 78,840 kWh per year in a simplified engineering analysis. No demand benefits were claimed.

Table 4-17
***Ex Ante* Load Impact Assumptions**

Parameter	Value
Base case motor-generator load	68 kW
Base case motor-generator load at idle	17 kW (25% of full load)
Retrofit motor-generator load at idle	2 kW
System operates loaded	40% of year
System operates idle	60% of year

The *ex ante* energy use for the baseline configuration was:

$$kWh_{Baseline} = (0.60\ idle\ time)(17\ kW@\ idle)(8{,}760\ hours\ /\ year)$$
$$= 89{,}352\ kWh$$

The *ex ante* energy use for the retrofit configuration was:

$$kWh_{Retrofit} = (0.60\ idle\ time)(2\ kW@idle)(8,760\ hours/year)$$
$$= 10,512\ kWh$$

The *ex ante* energy savings for the measure was:

$$kWh_{Saved} = kWh_{Baseline} - kWh_{Retrofit}$$
$$= 89,352 - 10512$$
$$= 78,840\ kWh/year$$

4.7.3 Ex Post Load Impact Estimation

Interviews with facility staff indicate that the solid state frequency converter draws 1.5 kW in idle mode which is consistent with the manufacturer's specification. The assumptions used in the *ex post* load impact estimation are shown in Table 4-18.

Table -4-18
***Ex Post* Load Impact Assumptions**

Parameter	Value
Base case motor-generator load	68 kW
Base case motor-generator load at idle	17 kW (25% of full load)
Retrofit motor-generator load at idle	1.5 kW
System operates loaded	40% of year
System operates idle	60% of year

The energy impacts for the solid state frequency converter are shown in the following equations.

$$kWh_i = (8,760\ hours/year) * (\%Idle) * (kW_i),$$
$$where,$$
$$i = base\ case\ or\ retrofit,$$
$$\%Idle = 0.60,$$
$$kW_i = 17\ kW,\ when\ i = base\ case,\ and$$
$$kW_i = 1.5,\ when\ i = retrofit.$$

$$kWh\ saved_{ex\ post} = kWh_{base\ case} - kWh_{retrofit}$$
$$= 89,352 - 7,884$$
$$= 81,468\ kWh$$

$$kW\ reduced_{ex\ post} = 0\ kW$$

The *ex post* kWh savings were estimated at 81,468 kWh. There are no *ex post* demand impacts estimated.

Table 4-19 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-19
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	9.3	0	1.00	6,901	0.08
Summer Semi-peak	9.3		1.00	8,872	0.11
Summer Off-peak	9.3		1.00	18,377	0.23
Winter On-peak	9.3	0	1.00	4,101	0.05
Winter Semi-peak	9.3		1.00	17,772	0.22
Winter Off-peak	9.3		1.00	25,445	0.31
			Totals	81,468	1

4.7.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-20 summarizes the *ex ante* and *ex post* load impact estimates. The only appreciable difference between the *ex ante* and *ex post* impact estimates is that the *ex ante* estimate assumed the idle load for the solid state frequency converter to be 2.0 kW rather that the 1.5 kW used in the *ex post* estimate. This resulted in a slightly higher *ex post* estimate.

Table 4-20
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	0	78,840	N/A
Ex post evaluation gross impacts	0	81,468	N/A
Difference	0	-2,628	N/A
Realization Rate	N/A	1.03	N/A

4.7.5 Persistence of the Measure

No published estimate for the life of the solid state frequency converter could be found, however, the 15 year life assigned is reasonable and appropriate.

4.8 ID No. 13976A - Downsize Process Vacuum System

4.8.1 Facility Information

This is a manufacturing facility in San Diego, CA which operates 8,500 hours per year. The plant uses low pressure vacuum (28 inches-hg) for various production processes. The vacuum is furnished by a 50 horsepower vacuum pump which operates at 100% load continuously, regardless of demand for vacuum.

The plant's manufacturing volume and, consequently, its demand for low pressure vacuum has decreased substantially, so the unused branches of the vacuum system were closed off. After this modification, the remaining system demand could be met by a 15 horsepower pump.

Replacing the 50 horsepower pump with a 15 horsepower unit will reduce demand and save energy. The savings will be achieved because the plant will be operating a much smaller motor to provide its requirements for low pressure vacuum.

4.8.2 Ex Ante Load Impact Estimation

The *ex ante* demand impact for the measure is:

$$kW_{Baseline} = \frac{(50 \text{ horsepower})(0.746 \text{ kW / horsepower})}{0.90 \text{ efficiency rating}}$$

$$= 41.4 \text{ kW}$$

$$kW_{Retrofit} = \frac{(15 \text{ horsepower})(0.746 \text{ kW / horsepower})}{0.90 \text{ efficiency rating}}$$

$$= 12.4 \text{ kW}$$

$$\begin{aligned} kW \text{ reduced}_{ex\ ante} &= kW_{Baseline} - kW_{Retrofit} \\ &= 41.4 - 12.4 \\ &= 29.0\ kW \end{aligned}$$

The *ex ante* energy impact for the measure is:

$$\begin{aligned} kWh\ saved_{ex\ ante} &= (kW\ reduced_{ex\ ante})(Operating\ hours) \\ &= (29.0)(8{,}500) \\ &= 246{,}500\ kWh\,/\,year \end{aligned}$$

4.8.3 Ex Post Load Impact Estimation

A site visit was made to verify that the changes had, in fact, been made. The wiring of the equipment is of a sealed, moisture proof type so measurements could not be taken. Motor nameplate data were taken.

Based on information provided in the Rebate Application Package and the MotorMaster Database, demand and annual energy consumption were calculated for the *ex ante* and the *ex post* configurations from which savings were derived.

The *ex post* energy use for the 50 horsepower baseline motor was:

$$\begin{aligned} kW_{Baseline} &= \frac{(50\ horsepower)(0.746\ kW/horsepower)}{0.90\ efficiency\ rating} \\ &= 41.4\ kW \end{aligned}$$

$$\begin{aligned} kWh_{Baseline} &= (kW_{Baeline})(Operating\ hours) \\ &= (41.4)(8{,}500) \\ &= 352{,}277\ kWh/year \end{aligned}$$

The *ex post* energy use for the 15 horsepower retrofit motor was:

$$\begin{aligned} kW_{Retrofit} &= \frac{(15\ horsepower)(0.746\ kW/horsepower)}{0.85\ efficiency\ rating} \\ &= 13.2\ kW \end{aligned}$$

$$\begin{aligned} kWh_{Retrofit} &= (kW_{Retrofit})(Operating\ hours) \\ &= (13.2)(8{,}500) \\ &= 111{,}900\ kWh/year \end{aligned}$$

The *ex post* load impacts for the measure was:

$$\begin{aligned} kWh\ saved_{ex\ post} &= kWh_{Baseline} - kWh_{Retrofit} \\ &= 352{,}277 - 111{,}900 \\ &= 240{,}378\ kWh/year \end{aligned}$$

$$\begin{aligned} kW\ reduced_{ex\ post} &= kW_{Baseline} - kW_{Retrofit} \\ &= 41.4 - 13.2 \\ &= 28.2\ kW \end{aligned}$$

Table 4-21 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-21
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	28.2	28.2	1.00	20,924	0.09
Summer Semi-peak	28.2		1.00	26,903	0.11
Summer Off-peak	28.2		1.00	55,723	0.23
Winter On-peak	28.2	28.2	1.00	12,436	0.05
Winter Semi-peak	28.2		1.00	53,890	0.22
Winter Off-peak	25.6		0.91	70,042	0.29
			Totals	239,918	0.99

4.8.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-22 shows a summary of the demand and energy impacts of the measure. A comparison of *ex ante* and *ex post* estimates of load impacts show realization rates for demand reduction and energy savings of 0.97 and 0.98, respectively. The differences are mainly due to the assumption in the *ex ante* estimate of a motor efficiency for the 15 horsepower motor of 90% while the MotorMaster Database shows the efficiency of for the specific motor in question is 85%.

Table 4-22
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	29.0	246,500	N/A
Ex post estimated gross impacts	28.2	240,378	N/A
Difference	0.8	6,122	N/A
Realization rate	0.97	0.98	N/A

4.8.5 Persistence of the Measure

The 15 year life assigned is consistent with the ASHRAE Journal article, *Service Lives*, in the December 1988 edition.

4.9 ID No. 13976B - Downsize Deionized Water System

4.9.1 Facility Information

This is a manufacturing facility in San Diego, CA which operates 8,500 hours per year. The plant uses deionized water for various production processes. The deionized water is provided by a system that sterilizes water with ultraviolet radiation and passes it through a deionizing system. The deionized water is distributed by a separate pump through the distribution system. The ultraviolet sterilizer consists of numerous modules, each of which draw 0.75 kW continuously when the plant is in operation. The pumping of water to pass it through the deionizer system is performed by a set of 40 horsepower pumps which operate at 75% load when the plant is in operation. Distribution of the deionized water is provided by a 30 horsepower pump which operates at 75% load.

The plant's manufacturing volume and, consequently, its demand for deionized water has decreased, so the production and distribution system for it could be downsized. The system is configured so that the power draw by the sterilizers, circulation pumps, and distribution pump are constant regardless of demand for deionized water.

By reconfiguring the deionized water system, seven ultraviolet sterilizer units were eliminated, the circulation pumping capacity was reduced so that one 40 horsepower pump can be removed, and the distribution pumping requirements were reduced from 30 horsepower to 7.5 horsepower. The 7.5 horsepower pump still operates at 75% of capacity.

4.9.2 Ex Ante Load Impact Estimation

The total load impacts for the reconfigured deionized water system are: 42.8 kW and 363,779 kWh for demand and energy impacts, respectively. These figures were estimated using accepted engineering algorithms for estimating energy use for motors.

4.9.3 Ex Post Load Impact Estimation

A site visit was made to verify that the changes had, in fact, been made. The wiring of the equipment is of a sealed, moisture proof type so electrical measurements could not be performed.

The baseline condition for comparison is the plant with current demand for deionized water, operating with a multi-unit sterilizer, a multi-unit circulation pump system and a 30 horsepower distribution pump. All pumps operate at 75% load 8,500 hours per year.

Reconfiguration of the system allowed removal of one 40 horsepower circulation pump which had run full time at 75% capacity and seven ultraviolet sterilizer units. Additionally, a 30 horsepower distribution pump which operated full time at 75% load was replaced with a 7.5 horsepower pump operating under 75% load. The *ex post* load impacts were estimated for each component of the reconfigured system.

Circulating Pump

One 40 horsepower pump was removed from service. From the MotorMaster Database, motor efficiency for the 40 horsepower motor is 0.92

$$\text{kW reduced}_{\text{Circulating pump}} = \frac{(40 \text{ hp})(0.746 \text{ kW / hp})(0.75 \text{ loading})}{0.92 \text{ efficiency rating}}$$

$$= 24.3 \text{ kW}$$

Sterilizer

Seven sterilizer units were removed from service.

$$kW\ reduced_{Sterilizers} = (7\ units)(0.75\ kW / unit)$$
$$= 5.25\ kW$$

Distribution Pump

A distribution pump could be downsized from 30 horsepower to 7.5 horsepower. From the MotorMaster Database, the motor efficiency for the 30 horsepower motor is 0.92 and 0.85 for the 7.5 horsepower motor.

$$kW_{Baseline} = \frac{(30\ hp)(0.746\ hp / kW)(0.75\ loading)}{(0.92\ efficiency\ rating)}$$

$$= 18.25\ kW$$

$$kW_{Retrofit} = \frac{(7.5\ hp)(0.746\ hp / kW)(0.75\ loading)}{(0.85\ efficiency\ rating)}$$

$$= 4.94\ kW$$

$$kW\ reduced_{distribution\ pump} = kW_{Baseline} - kW_{Retrofit}$$
$$= 18.25 - 4.94$$
$$= 13.31\ kW$$

Total *Ex Post* Load Impacts

$$kW\ reduced_{ex\ post} = kW\ reduced_{circulating pump} + kW\ reduced_{sterilizer} + kW\ reduced_{distribution pump}$$
$$= 24.33 + 5.25 + 13.31$$
$$= 42.89\ kW$$

$$kWh\ saved_{ex post} = (kW\ reduced_{ex\ post})(Operating\ hours)$$
$$= (42.89\ kW)(8{,}500\ hours / year)$$
$$= 364{,}565\ kWh / year$$

Table 4-23 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-23
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	42.89	42.89	1.00	31,824	0.09
Summer Semi-peak	42.89		1.00	40,917	0.11
Summer Off-peak	42.89		1.00	84,751	0.23
Winter On-peak	42.89	42.89	1.00	18,914	0.05
Winter Semi-peak	42.89		1.00	81,963	0.22
Winter Off-peak	38.81		0.90	106,184	0.29
			Totals	364,553	1

4.9.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-24 provides a summary of the demand and energy impacts for the measure. The *ex ante* and *ex post* load impacts for the reconfiguration of the deionized water system were virtually identical. The small differences are primarily due to the assumption in the *ex ante* analysis of motor efficiency for all the motors of 90% while the MotorMaster Database shows different efficiencies for the respective motors.

Table 4-24
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	43	363,779	N/A
Ex post estimated gross impacts	42.89	364,565	N/A
Difference	0	786	N/A
Realization rate	1.00	1.00	N/A

4.9.5 Persistence of the Measure

The 15 year life assigned is consistent with the ASHRAE Journal article, *Service Lives*, in the December 1988 edition.

4.10 ID No. 13976C - Modify Nitrogen Vaporizer

4.10.1 Facility Information

This is a manufacturing facility in San Diego, CA which operates 8,500 hours per year. The plant uses substantial quantities of gaseous itrogen for its operations. The nitrogen is delivered and stored in liquid form and is vaporized as needed. The plant uses a forced draft vaporizer which uses two five horsepower fans to move ambient air over the vaporizer coils to provide heat.

The plant's manufacturing volume and, consequently, its demand for nitrogen has decreased substantially, so the vaporizer system can be downsized. The system is configured so that the power draw by the fan is constant regardless of the demand for nitrogen.

By reconfiguring the vaporizer, the vaporizer can be made to deliver adequate gaseous nitrogen with natural convection and the fans can be removed. The savings will be achieved because the plant no longer operates the two five horsepower fans.

4.10.2 Ex Ante Load Impact Estimation

The *ex ante* demand impact were calculated as:

$$kW\ reduced_{ex\ ante} = \frac{(5\ hp)(0.746\ hp\ /\ kW)}{(0.90\ efficiency\ rating)}(2\ motors)$$
$$= 8.3\ kW$$

The *ex ante* energy impact from the removal of the two fans is:

$$\begin{aligned} kWh\ saved_{ex\ ante} &= (kW\ reduced_{ex\ ante})(Operating\ hours) \\ &= (8.3\ kW)(8{,}500\ hours/year) \\ &= 70{,}456\ kWh/year \end{aligned}$$

4.10.3 Ex Post Load Impact Estimation

Reconfiguration of the system allowed removal of two five horsepower fans that operated continuously at full load. From the MotorMaster Database, the motor efficiency for the five horsepower fan motors is 82%.

The *ex post* demand impacts from the removal of the two fans is:

$$kW\ reduced_{ex\ post} = \frac{(5\ hp)(0.746\ hp/kW)}{(0.82\ efficiency\ rating)}(2\ motors)$$

$$= 9.10\ kW$$

The *ex post* energy impacts from the removal of the two fans is:

$$\begin{aligned} kWh\ saved_{ex\ post} &= (kW\ reduced_{ex\ post})(Operating\ hours) \\ &= (9.10\ kW)(8{,}500\ hours/year) \\ &= 77{,}350\ kWh/year \end{aligned}$$

Table 4-25 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-25
kW and kWh Impacts by Time-Of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	9.10	9.1	1.00	6,752	0.09
Summer Semi-peak	9.10		1.00	8,681	0.11
Summer Off-peak	9.10		1.00	17,982	0.23
Winter On-peak	9.10	9.1	1.00	4,013	0.05
Winter Semi-peak	9.10		1.00	17,390	0.22
Winter Off-peak	8.24		0.91	22,545	0.29
			Totals	77,363	1

4.10.4 Comparison of Ex Ante and Ex Post Impact Estimates

As shown in Table 4-26, a comparison of the *ex post* impact calculations to the *ex ante* estimates shows a realiztion rate for demand saving of 1.14, and for annual energy savings of 1.10. The differences are primarily due to the *ex ante* assumption of motor efficiency to be 90% while the *ex post* estimates used a motor efficiency taken from the MotorMaster Database of 82% for the specific motors removed.

Table 4-26
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	8.0	70,456	N/A
Ex post estimated gross impacts	9.1	77,350	N/A
Difference	1.1	6,894	N/A
Realization rate	1.14	1.10	N/A

4.10.5 Persistence of the Measure

The 15 year life assigned is consistent with the ASHRAE Journal article, *Service Lives*, in the December 1988 edition.

4.11 ID No. 13983 - Air Compressor Replacement

4.11.1 Facility Information

This is a manufacturing facility in Carlsbad, CA which operates 24 hours per day Monday through Friday and 16 hours per day on Saturday and Sunday. It is closed for 8 holidays per year. The total operating hours are 7,736 hours per year. During periods when the production facility is closed, the compressed air system continues to run at a minimum load. The plant's compressed air requirements are furnished by two 100 horsepower compressors which are configured so that each furnishes half of the requirement and the two compressors operate independently. The two compressors installed have poor part load efficiencies, and the configuration forces them both to operate at part load most of the time.

Replacing one of the compressors with a unit that has a higher part load efficiency reduced energy consumption. Energy is saved under part load conditions because of the higher operating efficiency of the new unit. Part load conditions prevail most of the time in this system.

4.11.2 Ex Ante Load Impact Estimation

An engineering analysis using spreadsheet calculations was used to estimate the *ex ante* load impacts for this measure. The analysis estimated the impacts for the two 100 horsepower compressors. However, only one compressor was installed. These calculations were divided in half to represent the *ex ante* load impact estimates for the one installed compressor.

The *ex ante* demand reduction was 4.5 kW. The *ex ante* energy savings was 108,712 kWh.

4.11.3 Ex Post Load Impact Estimation

The site was visited on December 11, 1996, and the new equipment was inspected. Spot measurement of power, kVA, power factor, voltage, and current were taken from the new compressor. A current logger was installed on the new compressor and allowed to gather data for eight days. These data were used with manufacturer's performance data to calculate *ex post* annual energy consumption and peak demand.

The baseline for comparison is the plant operating with all of its compressed air demand furnished by two compressors with the characteristics of the pre-retrofit compressors, each providing one half of the requirement and operating independently of the other machine.

Ex ante measurements were used to generate a load profile for the compressor. This profile was converted to demand levels using manufacturer's performance data. The *ex ante* analysis indicates that the peak demand is 89.5 kW. The baseline hourly load profile is in Table 4-27 under the columns titled "kW Pre-Retrofit."

Table 4-27
Hourly Load Profiles

	Summer						Winter					
	Weekdays			Weekends & Holidays			Weekdays			Weekends & Holidays		
Hour	kW Pre-Retrofit	kW Post-Retrofit	kW/kWh Saved	kW Pre-Retrofit	kW Post-Retrofit	kW/kWh Saved	kW Pre-Retrofit	kW Post-Retrofit	kW/kWh Saved	kW Pre-Retrofit	kW Post-Retrofit	kW/kWh Saved
1	76.40	64.80	11.60	76.40	58.50	17.90	76.40	64.80	11.60	76.40	58.50	17.90
2	75.60	64.80	10.80	75.60	58.50	17.10	75.60	64.80	10.80	75.60	58.50	17.10
3	75.20	64.80	10.40	75.20	58.50	16.70	75.20	64.80	10.40	75.20	58.50	16.70
4	74.80	64.80	10.00	74.80	58.50	16.30	74.80	64.80	10.00	74.80	58.50	16.30
5	74.80	64.80	10.00	74.80	58.50	16.30	74.80	64.80	10.00	74.80	58.50	16.30
6	75.20	64.80	10.40	75.20	58.50	16.70	75.20	64.80	10.40	75.20	58.50	16.70
7	76.00	64.80	11.20	76.00	58.50	17.50	76.00	64.80	11.20	76.00	58.50	17.50
8	76.80	64.80	12.00	76.80	58.50	18.30	76.80	64.80	12.00	76.80	58.50	18.30
9	78.70	64.80	13.90	78.70	58.50	20.20	78.70	64.80	13.90	78.70	58.50	20.20
10	81.70	64.80	16.90	81.70	58.50	23.20	81.70	64.80	16.90	81.70	58.50	23.20
11	84.50	64.80	19.70	84.50	58.50	26.00	84.50	64.80	19.70	84.50	58.50	26.00
12	86.70	64.80	21.90	86.70	58.50	28.20	86.70	64.80	21.90	86.70	58.50	28.20
13	88.20	64.80	23.40	88.20	58.50	29.70	88.20	64.80	23.40	88.20	58.50	29.70
14	89.10	64.80	24.30	89.10	58.50	30.60	89.10	64.80	24.30	89.10	58.50	30.60
15	89.50	64.80	24.70	89.50	58.50	31.00	89.50	64.80	24.70	89.50	58.50	31.00
16	89.50	64.80	24.70	89.50	58.50	31.00	89.50	64.80	24.70	89.50	58.50	31.00
17	89.30	64.80	24.50	89.30	58.50	30.80	89.30	64.80	24.50	89.30	58.50	30.80
18	88.20	64.80	23.40	88.20	58.50	29.70	88.20	64.80	23.40	88.20	58.50	29.70
19	86.70	64.80	21.90	86.70	58.50	28.20	86.70	64.80	21.90	86.70	58.50	28.20
20	84.50	64.80	19.70	84.50	58.50	26.00	84.50	64.80	19.70	84.50	58.50	26.00
21	81.40	64.80	16.60	81.40	58.50	22.90	81.40	64.80	16.60	81.40	58.50	22.90
22	78.00	64.80	13.20	78.00	58.50	19.50	78.00	64.80	13.20	78.00	58.50	19.50
23	76.40	64.80	11.60	76.40	58.50	17.90	76.40	64.80	11.60	76.40	58.50	17.90
24	76.40	64.80	11.60	76.40	58.50	17.90	76.40	64.80	11.60	76.40	58.50	17.90

Ex post measurements taken on-site show that the new compressor has an average demand of 64.8 kW and a peak demand of 72.8kW from Monday through Friday. On Saturdays, Sundays, and holidays, the average demand is 58.5 kW with a peak demand of 69.0 kW. These data are shown in Table 4-27 under the column "kW Post-Retrofit."

The demand reduced attributed to the measure is:

$$\text{kW reduced}_{\text{ex post}} = 89.5 - 72.8$$
$$= 16.7 \text{ kW}$$

Table 4-28 shows the energy savings by season and time period, as well as the total annual *ex post* energy savings of 162,350 kWh per year.

Table 4-28
***Ex Post* Energy Impacts**

SUMMER	Weekdays (106 Days)			Weekends & Holidays (47 Days)		
	# Hours	Per Day	kWh	# Hours	Per Day	kWh
Max On-peak kW	7	24.70			N/A	
Max Semi-peak kW	9	23.40			N/A	
Max Off-peak kW	8	13.20		24	31.0	
Average On-peak kW:	7	23.31			N/A	
Average Semi-peak kW:	9	16.22			N/A	
Average Off-peak kW:	8	11.15		24	22.9	
Summer kW Coincident w/ System Peak		24.50				
Summer On-peak kWh	7	163	17,299		N/A	
Summer Semi-peak kWh	9	146	15,476		N/A	
Summer Off-peak kWh	8	89	9,455	24	550	25,831
Total Summer kWh			**42,230**			**25,831**
WINTER	**Weekdays (147 Days)**			**Weekends & Holidays (65 Days)**		
	# Hours	**Per Day**	**kWh**	**# Hours**	**Per Day**	**kWh**
Max On-peak kW	3	23.40			N/A	
Max Semi-peak kW	13	24.70			N/A	
Max Off-peak kW	8	11.60		24	31.0	
Average On-peak kW:	3	21.67			N/A	
Average Semi-peak kW:	13	19.00			N/A	
Average Off-peak kW:	8	10.80		24	22.9	
Winter kW Coincident w/ System Peak		23.40			N/A	
Winter On-peak kWh	3	65	9,555		N/A	
Winter Semi-Pk kWh	13	247	36,309		N/A	
Winter Off-peak kWh	8	86	12,701	24	549.6	35,724
Total Winter kWh			**58,565**			**35,724**
TOTAL kWh/year						**162,350**

4.11.4 Comparison of Ex Ante and Ex Post Impact Estimates

As shown in Table 4-29, a comparison of the *ex ante* and *ex post* estimates of peak demand reduction gives a realization rate of 3.1. This is largely due to the use of average demand in place of peak demand in the *ex ante* analysis. Annual energy savings show a realization rate of 1.49. This is partly due to the use of the same average demand values for all days of the year in the *ex ante* estimates, while the *ex post* measurements indicate that the average demand is less on weekends and holidays. The average demand values measured *ex post* are also lower than those assumed in the *ex ante* analysis.

Table 4-29
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	4.5	108,712	N/A
Ex post estimated gross impacts	16.7	162,350	N/A
Difference	-12.2	-53,638	N/A
Realization rate	3.71	1.49	N/A

4.11.5 Persistence of the Measure

The expected service life for this measure of 20 years seems to be somewhat higher than for similar measures.

4.12 ID No. 14082 - Downsize Air Compressor

4.12.1 Facility Information

This is a manufacturing facility in El Cajon, CA which produces precision metal parts, mostly for the aerospace industry. Compressed air is used throughout the plant for a variety of purposes. The plant operates Monday through Friday 7 a.m. until 11 p.m. and Saturday 6 a.m. until 2 p.m. There is equipment in the plant that requires a constant supply of compressed air 24 hours per day, 7 days per week, 365 days per year. The compressed air is currently supplied by a 50 horsepower screw type compressor with output modulation to match demand..

Due to changes in operations which have decreased the demand for compressed air, the existing 50 hp screw type compressor is oversized and operates typically at less than 60% of full load. This type of compressor has a poor part load efficiency, it draws 90% of full load power when its load is 60% or less of full load.

A 15 hp reciprocating unit with on-off control will have a power demand which is roughly proportional to the load. In addition, a load which represents 60% of the capacity of the 50 hp compressor is full load for the new unit, so it will operate at maximum efficiency. The savings are achieved because a smaller motor is being operated and because the compressor is operating in its most efficient range.

4.12.2 Ex Ante Load Impact Estimation

The demand reduction for the measure was estimated using an engineering analysis. When the compressor operates at 60% load it still requires 90% of full power. This is reflected in the engineering analysis as the *load factor adjustment* of 0.9.

$$kW \text{ reduced}_{ex\ ante} = kW_{Baseline} - kW_{Retrofit}$$

$$kW_{Baseline} = \frac{(50 \text{ horsepower})(0.746 \text{ kW / horsepower})}{0.90 \text{ efficiency rating}} (\textit{Load} \text{ factor adjustment})$$
$$= (41.4)\ (0.9)$$
$$= 37.3 \text{ kW}$$

$$kW_{Retrofit} = \frac{(15 \text{ horsepower})(0.746 \text{ kW / horsepower})}{0.91 \text{ efficiency rating}}$$
$$= 12.3 \text{ kW}$$

$$kW \text{ reduced}_{ex\ ante} = 37.3 - 12.3$$
$$= 25.0\ kW$$

A spreadsheet analysis using the facility operating schedule and (kW reduced_{exante}) to calculate the energy savings of 112,700 kWh.

4.12.3 Ex Post Load Impact Estimation

The site was visited and the installation inspected. Spot measurements of voltage, current, power, kVA, power factor, and total harmonic distortion were taken. A current logger was installed on the compressor and allowed to collect data for 48 hours. These data were used to calculate *ex post* power demand and energy.

The baseline for comparison is the plant operating with the 50 hp screw type compressor loaded at 60% of full capacity for 4,656 hour per year and at a low load, estimated at 15% of full load the balance of the year.

According to manufacturer's performance information, at 60% of full load or less, the 50 hp screw type compressor draws 90% of full load power. The *ex ante* impact analysis shows that the power demand for this machine at 60% of full load or less is:

$$kW_{Baseline} = 37.3\ kW$$

The baseline energy consumption is:

$$kWh_{Baseline} = (kWh_{Baseline})(Operating\ hours)$$
$$= (37.3)(8,760)$$
$$= 326,748\ kWh$$

Ex post measurements indicate that the peak demand of the 15 hp compressor is 12.2 kW. The average demand is 3.5 kW during normal plant operating hours (4,464 hours per year). During the plant's off hours (4,296 "off hours" per year) the peak demand will still be 12.2 kW, while the average demand will be 0.88 kW.

The retrofit energy consumption is:

$$\begin{aligned} kWh_{Retrofit} &= (Average\ kW\ normal\ hours_{Retrofit})(\#\ Normal\ hours) \\ &\quad + (Average\ kW\ Off\ hours)(\#\ Off\ hours) \\ &= (3.5)(4{,}464) + (0.88)(4{,}296) \\ &= 19{,}405\ kWh \end{aligned}$$

The *ex post* demand reduction is:

$$\begin{aligned} kW_{ex\ post} &= Peak\ kW_{Baseline} - Peak\ kW_{Retrofit} \\ &= 37.3 - 12.2 \\ &= 25.1\ kW \end{aligned}$$

The *ex post* energy savings is:

$$\begin{aligned} kWh_{ex\ post} &= kWh_{Baseline} - kWh_{Retrofit} \\ &= 3326{,}748 - 19{,}405 \\ &= 307{,}343\ kWh \end{aligned}$$

Table 4-30 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-30
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	33.8	33.8	1.00	25,080	0.08
Summer Semi-peak	34.4		1.02	32,818	0.11
Summer Off-peak	36.1		1.07	71,334	0.23
Winter On-peak	33.8	36.2	1.01	14,906	0.05
Winter Semi-peak	34.0		1.01	64,974	0.21
Winter Off-peak	36.2		1.07	99,043	0.32

4.12.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-31 summarizes the *ex ante* and *ex post* load impact estimates. Comparison of the *ex ante* and *ex post* values for demand reduction shows a 1.00 realization rate. The energy savings are understated in the *ex ante* analysis such that the realization rate is 2.73. The difference is due to differences in operating hours. Both analyses start with the operating schedule provided by the plant, Monday - Friday, 7 a.m. through 11 p.m. and Saturday 6 a.m. through 2 p.m. The *ex ante* analysis counts this as 4,576 hours per year while it is really 4,464 hours per year. In addition, *ex post* interviews with plant personnel indicate that the system operates at a capacity of 25% of full load for the existing compressor when the plant is not in operation. The *ex ante* analysis assumed that the compressor was turned off outside normal plant operating hours.

Table 4-31
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	25	112,700	N/A
Ex post estimated gross impacts	25.1	307,343	N/A
Difference	0	194,343	N/A
Realization rate	1.00	2.73	N/A

4.12.5 Persistence of the Measure

The assigned 20 year life of the measure is reasonable for a normally operated unit, however, with the extended hours of operation, the 20 year life may be optimistic.

4.13 ID No. 14092 - Downsize Air Compressor

4.13.1 Facility Information

This is a metal fabrication company which produces precision forged parts for the aerospace industry. The plant operates 7 a.m. to 3:30 p.m. Monday through Friday with nine holidays per year (a total of 2,140 hours per year). The plant is provided compressed air by two compressors, a 125 hp rotary screw type machine and a 50 hp unit.

Ex ante measurements show that the plant requires an average of 400 cfm 25% of the time and 163 cfm 75% of the time. The 125 hp compressor has a capacity of 540 cfm and the 50 hp compressor has a capacity of 200 cfm. The 125 hp compressor operates at 74% load 25% of the time and 30% load 75% of the time and it performs inefficiently at these low load conditions

By replacing the 125 hp compressor with one rated at 50 hp, the 400 cfm load is served by using both 50 hp compressors at 100% load, and when the load decreases to 163 cfm, one compressor can meet the demand at 82% load.

The savings are achieved because smaller motors are operated and the compressors are operating in their most efficient operating range.

4.13.2 Ex Ante Load Impact Estimation

The *ex ante* load impacts were estimated using an engineering based analysis. A spreadsheet was used to calculate the demand impacts of:

$$kW\text{ reduced}_{ex\ ante} = kW_{Baseline} - kW_{Retrofit}$$

$$\begin{aligned} kW\text{ reduced}_{ex\ ante} &= 102 - 82 \\ &= 20\ kW \end{aligned}$$

The *ex ante* energy savings estimate was based on an average hourly savings estimate that considered the load following pattern of the secondary compressor. The primary compressor would run 100% of the time, while the secondary unit would operate 25% of the time.

The daily kWh usage for the baseline unit was calculated as:

$$\begin{aligned} kWh\text{ daily}_{Baseline} &= (8\text{ hours})(0.75\text{ loading factor})(75\text{ kW of primary compressor}) \\ &\quad + (8\text{ hours})(0.25\text{ loading factor})(102\text{ kW of secondary compressor}) \\ &= 654\text{ kWh / day} \end{aligned}$$

The daily kWh usage for the retrofit unit was calculated as:

$$\begin{aligned} kWh\ daily_{Retrofit} &= (8\ hours)(1.00\ loading\ factor)(40\ kW\ of\ primary\ compressor) \\ &\quad + (8\ hours)(0.25\ loading\ factor)(42\ kW\ of\ secondary\ compressor) \\ &= 404\ kWh / day \end{aligned}$$

The average daily savings and average hourly savings were calculated as:

$$\begin{aligned} Average\ daily\ kWh_{Savings} &= kWh\ daily_{Baseline} - kWh\ daily_{Retrofit} \\ &= 654 - 404 \\ &= 250\ kWh / day \end{aligned}$$

$$\begin{aligned} Average\ daily\ kWh_{Savings} &= \frac{Average\ daily\ kWh_{Savings}}{8\ hours} \\ &= \frac{250}{8} \\ &= 31.25\ kWh \end{aligned}$$

These values were used with facility operating schedule information in a spreadsheet to calculate the *ex ante* energy savings of 63,750 kWh.

4.13.3 Ex Post Load Impact Estimation

Spot measurements were taken on both compressors which included power, power factor, voltage, current, and total harmonic distortion. Current loggers were installed on the compressors and allowed to gather data for 4 days. The data were used to calculate power and energy input to the compressors which were in turn compared to the baseline.

Ex post monitoring data show that the plant is currently operating from 5:30 a.m. to midnight Monday through Friday, and the loggers recorded no occasions where the demand for air exceeded the capacity of one compressor. Interviews with plant personnel indicate that the plant operates two shifts 10% of the time and the operation of two forging machines, which requires the use of the second compressor, occurs about 15% of the time. This represents a significant change in operation from that used in the *ex ante* analysis.

Considering the operating conditions the facility operations schedule shown in Table 4-32.

Table 4-32
Ex Post Facility Operations Schedule

Schedule Duration	Operating Schedule
10% of the days	18.5 hours per day 2 hours @ 400 cfm load compressed air load 16.5 hours @ 163 cfm compressed air load
90% of days	8 hours per day 1 hour @ 400 cfm of compresses air load 7 hours @ 163 cfm compressed air load

This schedule was translated to the share of total work hours the compressed air facility would operate to meet the demand for compressed air shown in Table 4-33.

Table 4-33
Share of Total Work Hours

Percent of Work Days	No. Days	No. Hours At High Compressed Air Demand	No. Hours At Low Compressed Air Demand
10%	25.3	50.6	417.45
90%	227.7	227.7	1593.9
	Total	278.3	2011.35

The operating characteristics from the project file shown in Table 4-3 were used to develop the baseline condition.

Table 4-34
***Ex Post* Baseline Condition Equipment Assumptions**

Equipment	Load/Output	Value
125 hp compressor	400 cfm	102 kW
	175 cfm	75 kW

The baseline energy and demand values were calculated as:

$$\begin{aligned} kWh_{Baseline} &= (kW_{High\ load})(Hours\ at\ high\ load) + (kW_{Low\ load})(Hours\ at\ low\ load) \\ &= (102\ kW)(278.3\ hours/year) + (75\ kW)(2011.4\ hours/year) \\ &= 179{,}238\ kWh \end{aligned}$$

$$\begin{aligned} kW_{Baseline} &= kW_{High\ load} \\ &= 102\ kW \end{aligned}$$

Ex post measurements show that the average current draw for the new compressor is 58.4 amps at 460 Volt, 3∅ with a power factor of 0.84. The demand for the new compressor is, therefore, 39.1 kW. When the demand for compressed air is increased by operation of the second forging machine, the air demand will require the use of two compressors. The kW for the two compressors is 78.2 kW. Applying the same duty cycle as the baseline, the retrofit energy and demand is:

$$\begin{aligned} kWh_{Retrofit} &= (kW_{High\ load})(Hours\ at\ high\ load) + (kW_{Low\ load})(Hours\ at\ low\ load) \\ &= (78.2\ kW)(278.3\ hours/year) + (39.1\ kW)(2011.4\ hours/year) \\ &= 100{,}407\ kWh \end{aligned}$$

$$\begin{aligned} kW_{Retrofit} &= kW_{High\ load} \\ &= 78.2\ kW \end{aligned}$$

The *ex post* load impacts are:

$$\begin{aligned} kWh\ saved_{ex\ post} &= kWh_{Baseline} - kWh_{Retrofit} \\ &= 179{,}238 - 100{,}407 \\ &= 78{,}831\ kWh \end{aligned}$$

$$\begin{aligned} kW\ reduced_{ex\ post} &= kW_{Baseline} - kW_{Retrofit} \\ &= 102 - 78.2 \\ &= 23.8\ kW \end{aligned}$$

Table 4-35 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-35
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	34.2	36	1.00	25,376	0.32
Summer Semi-peak	8.0		0.23	7,632	0.10
Summer Off-peak	0		0.00	0	0.00
Winter On-peak	12.0	36	1.00	5,292	0.07
Winter Semi-peak	21.2		0.62	40,513	0.51
Winter Off-peak	0		0.00	0	0.00
			Totals	78,813	1.00

4.13.4 Comparison of Ex Ante and Ex Post Impact Estimates

As shown in Table 4-36 the *ex ante* estimates understate the load impacts such that the realization rate for demand reduction is 1.19 and for energy savings is 1.24. The differences in demand reduction were primarily due to manner in which the *ex ante* demand reduction was estimated through an average hourly energy use approach and that a conservative value was selected for the demand reduction. The difference in the energy savings is primarily due to the increased operations for the facility.

Table 4-36
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated gross impacts	20	63,750	N/A
Ex post estimated gross impacts	23.8	78,831	N/A
Difference	3.8	15,081	N/A
Realization rate	1.19	1.24	N/A

4.13.5 Persistence of the Measure

The 15 year life estimated for the new air compressor is reasonable and consistent with other, similar compressors.

4.14 ID No. 14093 - Downsize Air Compressor

4.14.1 Facility Information

This is a metal fabrication company which produces precision forged parts for the aerospace industry. The plant operates 7 a.m. to 3:30 p.m. Monday through Friday with nine holidays per year for a total of 2,140 hours per year. The plant is provided compressed air by a 125 horsepower rotary screw type compressor.

Ex ante measurements showed that the plant required an average of 175 cfm and a peak which is not much higher. The 125 horsepower compressor had a capacity of 540 cfm. The 125 horse-power compressor operates at 32% of full load. The compressor performed inefficiently at this low load condition.

By replacing the 125 horsepower compressor with a 50 horsepower unit, the 175 cfm load can be served by operating the compressor at 88% of full load.

The savings are achieved because smaller motors are used to meet the demand and are operating the compressor in its most efficient operating range.

4.14.2 Ex Ante Load Impact Estimation

A spreadsheet analysis was used to estimate the *ex ante* kW impacts of the measure. These results were:

$$
\begin{aligned}
kW_{Baseline} &= 75\ kW \\
kW_{Retrofit} &= 40\ kW \\
kW\ reduced_{ex\ ante} &= kW_{Baseline} - kW_{Retrofit} \\
&= 75 - 40 \\
&= 35\ kW
\end{aligned}
$$

The *ex ante* energy savings were calculated through a spreadsheet analysis. These results were:

$$\begin{aligned} kWh_{Baseline} &= (8\ hours)(75\ kW) \\ &= 600\ kWh / day \end{aligned}$$

$$\begin{aligned} kWh_{Retrofit} &= (8\ hours)(40\ kW) \\ &= 320\ kWh / day \end{aligned}$$

$$\begin{aligned} Average\ daily\ kWh_{Savings} &= kWh_{Baseline} - kWh_{Retrofit} \\ &= 600 - 320 \\ &= 280\ kWh / day \end{aligned}$$

$$\begin{aligned} Average\ hourly\ kW_{Savings} &= \frac{Average\ daily\ kWh_{Savings}}{8\ hours} \\ &= \frac{280\ kWh / day}{8\ hours} \\ &= 35\ kW \end{aligned}$$

The average hourly $kW_{savings}$ was used with facility operating schedule information in an engineering based spreadsheet analysis to estimate *ex ante* energy savings of 71,400 kWh.

4.14.3 Ex Post Load Impact Estimation

Spot measurements were taken on the compressor which included power, power factor, voltage, current, and total harmonic distortion. A current logger was installed on the compressor and allowed to gather data for several days. The data were used to calculate power and energy input to the compressors which were in turn compared to the baseline.

Ex post measurements indicate that the plant is currently operating from 5 a.m. to 12 Midnight Monday through Friday. The baseline for comparison is the plant before compressor retrofit operating 19 hours per day. Allowing for nine holidays per year, this is 4,807 hours per year.

In addition to information gathered at the site visit, data was taken from the Rebate Application packet furnished by SDG&E and from interviews of plant personnel.

Baseline

The 125 hp compressor operating at 32% of full load draws a current of 113 amps at 460 Volts 3∅ with a power factor of 0.80. This translates to $kW_{Baseline}$ = 72.0 kW.

$$kWh_{Baseline} = (kW_{Baseline})(Operating\ hours)$$
$$= (72)(4,807)$$
$$= 346,104\ kWh$$

Ex post measurements indicate that the new compressor draws an average of 44.6 amps at 484 Volts, 3∅ with a power factor of 0.87. This translates to $kW_{Retrofit}$ = 32.5 kW.

$$kWh_{Retrofit} = (kW_{Retrofit})(Operating\ hours)$$
$$= (32.5)(4,807)$$
$$156,228\ kWh$$

The *ex post* load impacts for the measure are:

$$kW\ reduced_{ex\ post} = kW_{Baseline} - kW_{Retrofit}$$
$$= 72.0 - 32.5$$
$$= 39.5\ kW$$

$$kWh\ saved_{ex\ post} = kWh_{Baseline} - kWh_{Retrofit}$$
$$= 346,104 - 156,228$$
$$= 189,876\ kWh$$

Table 4-37 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-37
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	39.5	39.5	1.00	29,309	0.15
Summer Semi-peak	39.5		1.00	37,683	0.20
Summer Off-peak	6.36		0.16	12,567	0.07
Winter On-peak	39.5	39.5	1.00	17,420	0.09
Winter Semi-peak	39.5		1.00	75,485	0.40
Winter Off-peak	6.37		0.16	17,428	0.09
			Totals	189,892	1

4.14.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-38 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* demand reduction estimate was somewhat lower than the *ex post* value in that it was taken from an average value. The difference in energy savings is primarily due to the increased operating hours used in the *ex post* estimation.

Table 4-38
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	35.0	71,400	N/A
Ex post estimated gross impacts	39.5	189,876	N/A
Difference	4.5	118,476	N/A
Realization rate	1.13	2.66	N/A

4.14.5 Persistence of the Measure

A published value for the estimated life of the new air compressor could not be found, however the 15 year life assigned is consistent with other similar equipment and is appropriate.

4.15 ID No. 14115 - Replace Compressed Air Piping

4.15.1 Facility Information

This manufacturing facility located in El Cajon, CA, produces metal parts and cutlery. Compressed air is used throughout the plant for many purposes. The plant's compressed air distribution piping was made of PVC Schedule 40 pipe and has many leaks. A leakage rate of 270 cfm was determined through measurements. This rate is present at all times the plant is in operation, which is nominally 24 hours per day, 5 days per week, 52 weeks per year.

Replacing the PVC compressed air distribution piping with copper pipe and implementing a program of leak elimination throughout the plant reduced the demand for compressed air.

4.15.2 Ex Ante Load Impact Estimation

The demand of the system is defined solely by the motor driving the compressor. The demand for the motor was:

$$kW_{ex\ ante} = \frac{(60\text{ horsepower})(0.746\text{ kW / horsepower})}{0.90\text{ efficiency rating}}$$

$$= 49.7\text{ kW}$$

A spreadsheet was used to calculate energy savings by combining the facility operating schedule with the $kW_{ex\ ante}$. The *ex ante* energy savings estimate was 307,941 kWh.

4.15.3 Ex Post Load Impact Estimation

The reduction in leakage lowered the compressor peak electrical demand by 47 kW and consequently lowered the annual energy consumption for the plant.

The site was visited on November 12, 1996. An interview was conducted with the Facilities Manager of the plant. The new installations were inspected. The project file included information regarding the *ex ante* leakage levels and the amount of energy expended to make up the lost air. Current loggers were installed on each air compressor and allowed to run for five days including a weekend when the plant was not operating.

Compressed air consumption during periods when the plant was closed was monitored as an indication of leakage. Plant personnel indicated that this was a reasonable assumption. Leakage in the retrofit configuration was compared to the baseline and the load impacts calculated.

The baseline condition is the plant with its existing compressed air system and the PVC distribution piping. The baseline also excludes the effect of the leak elimination program.

Ex ante measurements indicate that leakage from the baseline system amounts to 270 cfm continuously when the plant is in operation. Applying the performance data on air compressors in place from the project files, this would require:

$$hp_{Baseline} = (0.21\ hp / cfm)(270\ cfm)$$
$$= 56.7\ hp$$

This would require a nominal kW input of:

$$kW_{Baseline} = \frac{(56.7\ hp)(0.746\ kW/hp)}{0.90\ efficiency\ rating}$$

$$= 47.0\ kW$$

The baseline energy consumption is:

$$\begin{aligned} kWh_{Baseline} &= (kW_{Baseline})(Operating\ hours) \\ &= (47.0)(6{,}860) \\ &= 322{,}406\ kWh \end{aligned}$$

The *ex post* monitoring and measurements indicate that compressor operation during times when end uses are shut off is negligible, therefore, the leakage is negligible. Thus, the retrofit demand is:

$$kW_{Retrofit} = 0.0\ kW$$

The retrofit energy consumption is:

$$kWh_{Retrofit} = 0\ kWh$$

The *ex post* load impact estimates are:

$$\begin{aligned} kW\ reduced_{ex\ post} &= kW_{Baseline} - kW_{Retrofit} \\ &= 47.0 - 0 \\ &= 47.0\ kW \end{aligned}$$

$$\begin{aligned} kWh\ saved_{ex\ post} &= kWh_{Baseline} - kWh_{Retrofit} \\ &= 322{,}406 - 0 \\ &= 322{,}406\ kWh \end{aligned}$$

Table 4-39 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-39
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	47.0	47	1	34,874	0.11
Summer Semi-peak	47.0			44,838	0.14
Summer Off-peak	28.0			55,400	0.17
Winter On-peak	47.0	47	1	20,727	0.06
Winter Semi-peak	47.0			89,817	0.28
Winter Off-peak	28.0			76,769	0.24
			Totals	322,425	1

4.15.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-40 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* estimation yielded slightly higher motor horsepower required to compensate for leakage. The plant operating hours were taken as 6,240 hours per year (24 hours per day, 5 days per week, 52 weeks per year) in the *ex ante* estimation. Interviews with plant personnel indicated that the plant operated 24 hours on Saturdays about half the time which makes 6,860 operating hours per year resulting in higher *ex post* energy savings.

Table 4-40
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	49.7	307,941	N/A
Ex post estimated gross impacts	47.0	322,425	N/A
Difference	2.7	-14,484	N/A
Realization rate	0.95	1.05	N/A

4.15.5 Persistence of the Measure

No published estimate for the life of either the piping modifications or the leak elimination measures could be found. The 20 year life used is probably satisfactory for the piping part of the work, but the leak elimination measures will not last as long.

4.16 ID No. 14116 - Air Compressor Replacement

4.16.1 Facility Information

This is an envelope manufacturing plant in Santee, CA which operates Monday through Friday 6:30 a.m. to 11:00 p.m. (4,175 hour per year). The plant's compressed air requirements are furnished by five compressors (four 20 horsepower and one 40 horsepower) for a total capacity of 300 cfm at 100 psi according to *ex ante* measurements.

According to *ex ante* measurements, the 20 horsepower compressors run loaded 55% of the time and unloaded 45% of the time. In unloaded mode, the 20 hp compressors draw 19% of full load power requirement.

Replacing all of the existing compressors with two 75 horsepower units configured so that only one operates at a time and the other is available as a backup will lower energy consumption and peak demand. Savings will be achieved by reducing total compressor horsepower. Additionally, the new compressors operate at a load which will allow them to be more efficient.

4.16.2 Ex Ante Load Impact Estimation

Five compressors (four 20 hp and one 40 hp) were operated to meet a plant load for compressed air of 300 cfm. One 75 hp compressor was installed to replace the five existing compressors.

The *ex ante* load impact estimation started with the estimation of the compressed air requirement for the plant. The compressed air load for each of the compressors was estimated. The total baseline plant load was:

$$\begin{aligned} \textit{Base plant load for compressed air} &= \sum_{1}^{5} \textit{cfm for compressors 1 through 5} \\ &= 40.7 + 40.7 + 39.3 + 33.4 + 145 \\ &= 299\ \textit{cfm} \end{aligned}$$

The power requirements for each compressor was then calculated and summed for the total plant power requirement.

$$\begin{aligned} \textit{kW air compressors}_{\textit{Baseline}} &= \sum_{1}^{5} \textit{kW for compressors 1 through 5} \\ &= 11.2 + 10.7 + 8.7 + 10.7 + 33.1 \\ &= 74.4\ \textit{kW} \end{aligned}$$

The retrofit power requirements were estimated with the compressor operating loaded 94% of the time and unloaded 6% of the time.

$$\text{kW air compressor}_{\text{Retrofit}} = \frac{[(0.94*75)+(0.06*0.19*75)](0.746)}{0.941 \text{ efficiency rating}}$$
$$= 56.6 \text{ kW}$$

The *ex ante* kW reduced is:

$$kW\ reduced_{ex\ ante} = 74.4 - 56.6\ kW$$
$$= 17.8\ kW$$

The kW reduced$_{ex\ ante}$ was input into a spreadsheet that calculated the total kWh saved.

$$kWh\ saved_{ex\ ante} = 74{,}601\ kWh$$

4.16.3 Ex Post Load Impact Estimation

The site was visited on December 10, 1996, and the installation was inspected. Spot measurements were taken on the new compressor which included voltage, amperage, power, kVA, power factor, and kVAR. A current logger was installed on the new compressor and allowed to gather data for eight days. The data were used with manufacturer's performance data to evaluate peak demand and annual power consumption.

Table 4-41 shows baseline power requirements for the five compressors.

Table 4-41
Baseline Compressor Power Requirements

Compressor	HP	Peak Demand (kW)	Avg Demand (kW)
1	20	17.66	11.2
2	20	16.86	10.7
3	20	16.95	8.7
4	20	15.99	10.7
5	40	33.91	33.1
Totals		101.37	74.40

Since it is reasonable to assume that all the compressors will not operate at the same time most of the time, the total average demand should be adjusted by a diversity factor. A diversity factor of 0.8 was assumed. The average total demand is:

$$\begin{aligned}\text{Average total kW}_{\text{Baseline}} &= (74.4)(0.8)\\ &= 59.5\text{ kW}\end{aligned}$$

Similarly, it can be assumed that there will be times when all the compressors operate fully loaded simultaneously so the peak demand will be:

$$\text{Peak kW}_{\text{Baseline}} = 101.37$$

The annual energy consumption is:

$$\begin{aligned}\text{kWh}_{\text{Baseline}} &= (\text{Average total kW}_{\text{Baseline}})(\text{Operating hours})\\ &= (59.5\text{ kW})(4{,}175\text{ hours / year})\\ &= 248{,}412\text{ kWh / year}\end{aligned}$$

Ex post measurements taken at the site indicate that the new compressor has average and peak demands of:

$$\begin{aligned}\text{kW average}_{\text{Retrofit}} &= 33.80\text{ kW}\\ \text{kW peak}_{\text{Retrofit}} &= 62.0\text{ kW}\end{aligned}$$

The annual energy consumption is:

$$\begin{aligned}\text{kWh}_{\text{Retrofit}} &= (\text{kW average}_{\text{Retrofit}})(\text{Operating hours})\\ &= (33.8\text{ kW})(4{,}175\text{ hours / year})\\ &= 141{,}115\text{ kWh / year}\end{aligned}$$

The *ex post* load impact estimates attributed to the measure are:

$$\begin{aligned}\text{kW reduced}_{\text{ex post}} &= \text{Peak kW}_{\text{Baseline}} - \text{Peak kW}_{\text{Retrofit}}\\ &= 101.37 - 62.0\\ &= 39.37\text{ kW}\end{aligned}$$

$$\begin{aligned}\text{kWh saved}_{\text{ex post}} &= \text{kWh}_{\text{Baseline}} - \text{kWh}_{\text{Retrofit}}\\ &= 248{,}412 - 141{,}115\\ &= 107{,}297\text{ kWh / year}\end{aligned}$$

Table 4-42 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-42
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	25.70	25.70	1.00	19,069	0.18
Summer Semi-peak	24.27		0.94	23,154	0.22
Summer Off-peak	1.38		0.05	2,727	0.03
Winter On-peak	25.70	25.70	1.00	11,334	0.11
Winter Semi-peak	25.7		1.00	49,113	0.46
Winter Off-peak	0.69		0.03	1,888	0.02
			Totals	107,285	1.02

4.16.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-43 summarizes the *ex ante* and *ex post* load impact estimates. Comparison of the *ex ante* and *ex post* values for peak demand show a realization rate of 2.21. This is due partly to the fact that the *ex ante* analysis used average demand values instead of peak demand and no allowance was made for diversity in the operating patterns of the machines. The realization rate for annual energy savings is 1.44. This can be attributed to the fact that *ex post* measurements show that the new compressor operates at a lower average demand than was anticipated in the *ex ante* analysis.

Table 4-43
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	17.8	74,601	N/A
Ex post estimated gross impacts	39.4	107,297	N/A
Difference	-21.6	-32,696	N/A
Realization rate	2.21	1.44	N/A

4.16.5 Persistence of the Measure

The 15 years assigned is consistent with other similar measures.

4.17 ID No. 14127 - Replacement of Hydraulic Drives

A site visit was not conducted on this site. An engineering audit of the project file was conducted.

4.17.1 Facility Information

This is a bottling plant in San Diego, CA that operates 16 hours per day, 5 days per week, 52 weeks per year less 8 holidays per year for a total of 4,032 hours per year. The plant is equipped with a central hydraulic system that consists of six 50 horsepower hydraulic pumps, four of which are in operation at any given time. The hydraulic system serves all of Production Line #3 and the filler on Production Line #2. Production Line #3 operates 16 hour per day, 5 days per week, 52 weeks per year less 7 holidays, for a total of 4,048 hours per year. The production lines operate at constant speed continuously and represent a constant load for the hydraulic system whenever the plant is operating.

The hydraulic conveyor drives have significant energy losses due to pump and hydraulic motor inefficiencies. The drives on Production Line #3 were converted from hydraulic to direct electric motor drive to avoid the losses inherent to hydraulic drive systems. The savings are achieved because the direct electric motor drives operate at higher efficiencies than the hydraulic drives.

4.17.2 Ex Ante Load Impact Estimation

The demand for the hydraulic system was:

$$
\begin{aligned}
kW_{Baseline} &= \sum \frac{(Amps)(Volts)(\Phi)(Power\ factor)}{1{,}000} \\
&= \frac{(50)(480)(\sqrt{3})(.86)}{1{,}000} \\
&\quad + \frac{(10)(480)(\sqrt{3})(.55)}{1{,}000} \\
&\quad + \frac{(30)(480)(\sqrt{3})(.83)}{1{,}000} \\
&\quad + \frac{(27)(480)(\sqrt{3})(.81)}{1{,}000} \\
&= 79.06\ kW
\end{aligned}
$$

Baseline annual energy use is:

$$
\begin{aligned}
kWh_{Baseline} &= (kW_{Baseline})(Operating\ hours) \\
&= (79.06\ kW)(4{,}160\ hours/year) \\
&= 328{,}890\ kWh/year
\end{aligned}
$$

Retrofit demand is:

$$
\begin{aligned}
kW_{Retrofit} &= \sum (Motor\ kW) \\
&= \sum \frac{(hp)(0.746\ kW/hp)}{motor\ eff.} \\
&= \Bigg(\left[\frac{(5)(0.746)}{0.831}\right] \\
&\quad + \left[\frac{(3)(0.746)}{0.798}\right] \\
&\quad + \left[\frac{(2)(0.746)}{0.815}\right](3\ motors) \\
&\quad + \left[\frac{(1.5)(0.746)}{0.785}\right](2\ motors) \\
&\quad + \left[\frac{(1)(0.746)}{0.77}\right](4\ motors) \\
&\quad + \left[\frac{(0.75)(0.746)}{0.77}\right](3\ motors) \\
&\quad + \left[\frac{(10)(0.746)}{0.85}\right]\Bigg)(0.8\ load\ factor) \\
&= 24.37\ kW
\end{aligned}
$$

The annual energy use of the retrofit system is:

$$
\begin{aligned}
kWh_{Retrofit} &= (kW_{Retrofit})(Operating\ hours) \\
&= (24.37\ kW)(4,160\ hours/year) \\
&= 101,379\ kWh/year
\end{aligned}
$$

The *ex ante* load impacts are:

$$
\begin{aligned}
kW\ reduced_{ex\ ante} &= kW_{Baseline} - kW_{Retrofit} \\
&= 79.06 - 24.37 \\
&= 54.69\ kW
\end{aligned}
$$

$$
\begin{aligned}
kWh\ saved_{ex\ ante} &= kWh_{Baseline} - kWh_{Retrofit} \\
&= 328,890 - 101,379 \\
&= 227,511\ kWh/year
\end{aligned}
$$

4.17.3 Ex Post Load Impact Estimation

Ex ante measurements indicate that the hydraulic system draws an average of 79.06 kW continuously for 4,048 hours per year. Since the demand is constant, the peak demand will be equal to the average demand, or 79.06 kW.

$$kW_{Baseline} = 79.06\ kW$$

The annual energy consumption would be:

$$\begin{aligned} kWh_{Baseline} &= (kW_{Baseline})(Operating\ hours) \\ &= (79.06\ kW)(4{,}048\ hours/year) \\ &= 320{,}035\ kWh/year \end{aligned}$$

The motors shown in Table 4-44 were installed to replace the hydraulic drive system.

Table 4-44
Motors Installed To Replace Hydraulic System

Purpose	Count	HP	Efficiency	kW
DePalletizer	1	2	0.815	1.46
Rinser	1	1	0.770	0.78
Rinser	1	3	0.798	2.24
Filler (Line #3)	1	5	0.831	3.59
Packager	2	2	0.815	2.93
Conveyor	3	0.75	0.770	1.74
Conveyor	3	1	0.770	2.33
Conveyor	2	1.50	0.785	2.28
Filler (Line #2)	1	10	0.850	7.02
			Total	24.37

Assuming 80% full load operation, peak demand and average demand will be equal.

$$kW_{Retrofit} = 24.37\ kW$$

The annual energy consumption for the retrofit system is:

$$\begin{aligned} kWh_{Retrofit} &= (kW_{Retrofit})(Operating\ hours) \\ &= (24.37\ kW)(4{,}048\ hours/year) \\ &= 98{,}650\ kWh/year \end{aligned}$$

The *ex post* load impacts attributable to the measure are:

$$\text{kW reduced}_{\text{ex post}} = \text{kW}_{\text{Baseline}} - \text{kW}_{\text{Retrofit}}$$
$$= 79.06 - 24.37$$
$$= 54.69 \text{ kW}$$

$$\text{kWh saved}_{\text{ex post}} = \text{kWh}_{\text{Baseline}} - \text{kWh}_{\text{Retrofit}}$$
$$= 320{,}035 - 98{,}650$$
$$= 221{,}385 \text{ kWh / year}$$

Table 4-45 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-45
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	54.7	54.7	1.00	40,587	0.18
Summer Semi-peak	54.7		1.00	52,184	0.24
Summer Off-peak	0		0.00	0	0.00
Winter On-peak	54.7	54.7	1.02	24,123	0.11
Winter Semi-peak	50.5		0.92	96,506	0.44
Winter Off-peak	2.94		0.05	8,044	0.04
			Totals	221,444	1.01

4.17.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-46 summarizes the *ex ante* and *ex post* load impact estimates. An *ex post* site visit was not conducted on this site. A detailed review of the *ex ante* analysis shows that it was complete and thorough. The difference between *ex ante* and *ex post* energy savings is attributable to a slight difference in the operating hours used.

Table 4-46
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	54.7	227,510	N/A
Ex post estimated gross impacts	54.7	221,385	N/A
Difference	0	6,125	N/A
Realization rate	1.00	0.97	N/A

4.17.5 Persistence of the Measure

ASHRAE Journal December 1988, Table 1 *Service Lives* lists service life for measures of this type at 15 years, so the 20 year life assigned seems optimistic.

4.18 ID No. 14139 - Air Compressor Replacement

4.18.1 Facility Information

This manufacturing facility located in El Cajon, CA produces metal parts and cutlery and uses compressed air throughout the plant for many purposes. The compressed air plant consists of two 100 hp air compressors, each with a capacity of 500 cfm at 100 psi. The plant operates 24 hours per day Monday through Friday and some Saturdays, 52 weeks per year. According to the Rebate Application, Monday through Friday the plant requires an average of 180 cfm during the first shift and 680 cfm during the second and third shifts. When the plant operates on Saturday, the demand for compressed air is 180 cfm all day.

After a program of leak reduction, the peak compressed air load was reduced from 950 cfm to 680 cfm. The demand required that one of the compressors operate at 100% of capacity and the other operate at 180 cfm. The existing compressors were inefficient at part load; the lower the load, the lower the efficiency.

Replacing one of the existing compressors with a new machine that has a favorable part load operating characteristic allows the existing compressor to operate at full load to optimize its efficiency and the new machine handles the part load demands. Operating the one compressor at full load allows it to work at maximum efficiency and the new compressor can produce air at part load conditions with a minimum loss of efficiency.

4.18.2 Ex Ante Load Impact Estimation

The *ex ante* demand impact estimate was based on the reduced horsepower required to meet the demand for compressed air. The retrofit compressor requires 25 fewer horsepower than the baseline unit to meet the facility's compressed air need. The kW associated with the reduced horsepower is:

$$\text{kW reduced}_{\text{sx ante}} = \frac{(25\text{ horsepower})(0.746\text{ kW / horsepower})}{0.945\text{ efficiency rating}}$$

$$= 20\text{ kW}$$

The *ex ante* energy impacts were calculated through a spreadsheet that incorporated the facility's operating schedule and the $kW\ reduced_{ex\ ante}$. The *ex ante* energy savings from the measure was 123,920 kWh.

4.18.3 Ex Post Load Impact Estimation

The site was visited on November, 12 1996. An interview was conducted with the Facilities Manager of the plant. The new installations were inspected. *Ex post* spot power measurements were taken on both compressors. These measurements included power factor and total harmonic distortion, as well as voltage, current, and power. Current loggers were installed on both compressors and allowed to collect data. The project files included information regarding the performance characteristics of the existing and proposed compressors, as well as the compressed air demand pattern of the plant. This information, along with the measurements taken were used to calculate the demand and energy impacts of the measure.

Baseline Operations

First Shift and Saturday: According to the load profile in the project file, the average compressed air demand was 180 cfm. From the performance data furnished for the existing air compressors, this demand required one compressor operating at 76 hp or 59.9 kW.

Second and Third Shift: The load profile shows that the average demand for compressed air was 680 cfm. This required one compressor operating at full load (500 cfm, 100 hp or 78.9 kW) and the other operating at an average load of 180 cfm, 76 hp or 59.9 kW for a total of 176 hp or 138.8 kW

Retrofit Operations

First Shift: Measurements on the new compressor show that it draws an average of 73.3 kW or 92.9 hp which would be consistent with a compressed air demand of 435 cfm.

Second and Third Shift: Current logger data for the two compressors indicate that the old compressor draws 77.1 kW or 97.7 hp and the new one draws 39.9 kW or 50.6 hp. This gives total draw of 117.0 kW or 148.3 hp.

Saturday: Current logger data shows that the old compressor is typically shut down and the new compressor draws an average of 73.9 kW or 93.6 hp when the plant is operating.

These data were combined with operating data to estimate the load impacts as shown in Table 4-47. Table 4-48 shows the seasonal and total annual energy savings for the measure.

Table 4-47
Ex Post Hourly Load Impacts By Season

	SUMMER						WINTER					
	Weekday			Weekends & Holidays			Weekdays			Weekends & Holidays		
Hour of Day	kW Pre-retrofit	kW Post-retrofit	kW/kWh Saved	kW Pre-retrofit	kW Post-retrofit	kW/kWh Saved	kW Pre-retrofit	kW Post-retrofit	kW/kWh Saved	kW Pre-retrofit	kW Post-retrofit	kW/kWh Saved
1	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
2	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
3	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
4	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
5	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
6	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
7	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
8	59.90	73.30	-13.40	17.40	21.50	-4.10	59.90	73.30	-13.40	17.40	21.50	-4.10
9	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
10	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
11	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
12	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
13	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
14	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
15	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
16	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
17	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
18	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
19	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
20	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
21	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
22	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
23	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10
24	138.80	117.00	21.80	17.40	21.50	-4.10	138.80	117.00	21.80	17.40	21.50	-4.10

Table 4-48
Ex Post Load Impacts By Season

	Weekdays			Weekends		
SUMMER	***hours***	***Per Day***	***106 days***	***hours***	***Per Day***	***47 days***
Max On-peak kW	7.00	21.80			N/A	
Max Semi-peak kW	9.00	21.80			N/A	
Max Off peak kW	8.00	21.80		24.00	-4.10	
Average On-peak kW:	7.00	21.80			N/A	
Average Semi-peak kW:	9.00	10.07			N/A	
Average Off peak kW:	8.00	-0.20		24.00	-4.10	
Summer kW Coincident w/ System peak		21.80				
Overall Summer Off peak Avg.			-2.43			
Summer On-peak kWh	7.00	152.60	16,175.6 0		N/A	
Summer Semi-peak kWh	9.00	90.60	9,603.60		N/A	
Summer Off peak kWh	8.00	-1.60	-169.60	24.00	-98.40	-4,624.80
Total Seasonal kWh	**24.00**	**241.60**	**25,609.6 0**	**24.00**	**-98.40**	**-4,624.80**
WINTER	***hours***	***Per Day***	***147 days***	***hours***	***Per Day***	***65 days***
Max On-peak kW	3.00	21.80			N/A	
Max Semi-peak kW	13.00	-21.80			N/A	
Max Off-peak kW	8.00	21.80		24.00	-4.10	
Average On-peak kW:	3.00	21.80			N/A	
Average Semi-peak kW:	13.00	15.93			N/A	
Average Off-peak kW:	8.00	-4.60		24.00	-4.10	
Winter kW Coincident w/ System peak		21.80			N/A	
Overall Winter Off peak Avg.			-4.31			
Winter On-peak kWh	3.00	65.40	9,613.80		N/A	
Winter Semi-peak kWh	13.00	213.00	31,311.0 0		N/A	
Winter Off-peak kWh	8.00	-36.80	- 5,409.60	24.00	-94.30	-6,129.50
Total Seasonal kWh	**24.00**	**241.60**	**35,515.2 0**	**24.00**	**-94.30**	**-6,129.50**
Total Annual kWh Saved	**50,371 kWh /Year**					

Table 4-49 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-49
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	21.8	21.8	1	16,176	0.32
Summer Semi-peak	10.07		0.46	9,604	0.19
Summer Off-peak	(0.20)		-0.01	(4,602)	-0.09
Winter On-peak	21.8	21.8	1	9,614	0.19
Winter Semi-peak	15.9		0.73	26,137	0.52
Winter Off-peak	-3.77		-0.17	(6,365)	-0.13
			Totals	50,564	1

4.18.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-50 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* analysis was derived from a daily load profile which was furnished by the customer. *Ex post* measurements indicate that the first shift compressed air demand is understated in the daily load profile by a factor of 2. The customer says that they know of no reason for such a large increase in first shift compressed air demand since the original analysis was done. The realization rate for demand is 1.09, and for energy consumption it is 0.41 due largely to the discrepancy in the first shift compressed air demand.

Table 4-50
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	20	123,920	N/A
Ex post estimated gross impacts	21.8	50,563	N/A
Difference	-1.8	73,357	N/A
Realization rate	1.09	0.41	N/A

4.18.5 Persistence of the Measure

The 15 year life estimated for the new air compressor is reasonable and consistent with other, similar compressors.

4.19 ID No. 14144 - Cycling Compressed Air Dryer

4.19.1 Facility Information

This manufacturing facility located in El Cajon, CA produces metal parts and cutlery. Compressed air is used throughout the plant for many purposes. The plant operates 24 hours per day, 5 days per week, 52 weeks per year, with operation on the sixth day about half of the weeks for 6,860 hours per year.

The plant was equipped with a constant running refrigerated compressed air dryer with a 3 hp compressor which operates whenever an air compressor was running.

The air dryer was sized to process the full output capacity of the compressor plant. When the compressors were operating at less than capacity, or when the moisture content of the air was lower than nominal, the dryer had excess capacity. This excess capacity was dissipated through a hot gas bypass valve so the refrigeration compressor always operated at full load.

Replacement of the existing compressed air dryer with one of a cycling design reduced refrigeration compressor run time and saved energy.

The cycling air dryer contains a thermal mass which is cooled by the refrigeration compressor. When the moisture load declines, the compressor cools the mass to a preset temperature and shuts off. The mass then cools the air to condense moisture until it is warmed up to the high temperature set point when the compressor starts again. The energy savings is achieved when the compressor is turned off.

4.19.2 Ex Ante Load Impact Estimation

There is demand reduction attributed to this measure. The *ex ante* energy impacts were calculated by:

$$\text{Utilization factor for air dryer} = \frac{180}{520}$$

$$= 0.36$$

$$\text{Refrigeration compressor kW} = \frac{(3\text{ horsepower})(0.746\text{ kW / hp})}{0.90\text{ motor efficiency}}$$

$$= 2.49\text{ kW}$$

$$\text{Average power savings}_{ex\ ante} = (1 - \text{utilization factor})(\text{ref. compressor kW})$$

$$= (1 - 0.36)(2.49)$$

$$= 1.59\text{ kW}$$

A spreadsheet analysis using the facility operating schedule and Average Power Savings$_{ex\ ante}$ to calculate the energy savings of 9,851 kWh.

4.19.3 Ex Post Load Impact Estimation

Spot power measurements were taken for the air dryer including power factor and total harmonic distortion. Additionally, a current logger was connected to the dryer and allowed to run for five days which included a weekend when the plant was closed. The spot readings established nominal current, power, and power factor values for the system. Total harmonic distortion was measured to assure the validity of the other readings taken. Current logger data were analyzed to give current draw and duty cycle of the refrigeration compressor.

The baseline condition is the plant with a constant running air dryer sized for the maximum capacity of the compressed air plant.

The manufacturer's literature indicates that the constant running and the cycling air dryers have the same size refrigeration compressor. This is logical since either system would have to serve the maximum capacity of the compressor.

Data from the spot power measurements indicate that the power factor for the dryer is 0.88. Monitored data showed that the compressor draws 3.3 amps and has a duty cycle of 15%. The compressor power for either dryer is:

$$kW_{compressor} = (3.3\ \text{amps})(460\ \text{volts})(0.88\ \text{powerfactor})\left(\sqrt{3}\right)$$
$$= 2.31\ kW$$

Annual energy consumption for the continuous running dryer is:

$$kWh_{\text{continuous running dryer}} = (2.31\ kW)(6{,}860\ \text{hours / year})$$
$$= 15{,}872\ kWh$$

Annual energy consumption for the cycling dryer, is:

$$kWh_{\text{cycling dryer}} = (2.31\ kW)(6{,}860\ \text{hours / year})(0.15\ \text{duty cycle})$$
$$= 2{,}381\ kWh$$

The *ex post* load impacts from this measure are:

$$kWh\ saved_{\text{ex post}} = kWh_{\text{continuous running dryer}} - kWh_{\text{cycling dryer}}$$
$$= 15{,}872 - 2{,}381$$
$$= 13{,}491\ kWh$$

There are no demand reductions associated with this measure.

Table 4-51 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-51
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	1.96	1.96	1.00	1,454	0.11
Summer Semi-peak	1.96		1.00	1,870	0.14
Summer Off-peak	1.17		1.00	2,312	0.17
Winter On-peak	1.96	1.96	1.00	864	0.06
Winter Semi-peak	1.96		1.00	3,746	0.28
Winter Off-peak	1.17		0.60	3,201	0.24
			Totals	13,447	1.00

4.19.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-52 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* analysis assumed a duty cycle for the dryer compressor of 36%. Power consumption was calculated on the assumption of full load condition and a motor efficiency of 90% which gives a power requirement of 2.49 kW. Actual measurements show that the power consumption is 2.31 kW and the duty cycle is 15.1%. The result of these differences is a realization rate for energy savings of 1.37.

Table 4-52
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	0	9,851	N/A
Ex post estimated gross impacts	0	13,591	N/A
Difference	N/A	3,640	N/A
Realization rate	N/A	1.37	N/A

4.19.5 Persistence of the Measure

No published estimate for the life of the cycling air dryer could be found, however the 15 year life used is reasonable and consistent for this type of equipment.

4.20 ID No. 14148A - Cycling Compressed Air Dryer

4.20.1 Facility Information

This is a manufacturing plant in San Diego, CA which manufactures computer-related hardware. The plant operates normally 24 hours per day, for 354 days per year. In addition, it operates on holiday schedule 24 hours per day, 6 days per year and is shut down completely for maintenance 5 days per year. According to *ex ante* measurements, the plant's compressed air system produces an average of 500 cfm in normal operation and 400 cfm on holiday schedule.

A new air dryer was installed at the facility. The practical choices for the new dryer were either a continuous running dryer or a cycling one. The continuous running unit has a compressor sized for the maximum moisture load on the system, and when the load is less than maximum, the excess refrigeration capacity is dissipated through a hot gas bypass valve. The compressor operates at full load all the time.

The cycling type dryer contains a thermal mass which is cooled down by the refrigeration system. When the load is near maximum, this dryer operates the same as a non-cycling one. As the load decreases, the excess refrigeration capacity is used to lower the temperature of the thermal mass until it reaches it lower limit temperature when the refrigeration system turns off. Air is cooled by the thermal mass until it reaches its high limit temperature is reached and the refrigeration system starts again.

While both types of dryers use the same size refrigeration compressor (6 hp), savings are achieved in the cycling type dryer by turning the refrigeration system off for part of the time when the load is less than maximum.

4.20.2 Ex Ante Load Impact Estimation

An engineering analysis was performed to estimate the *ex ante* load impacts of the cycling dryer. The analysis considered a number of factors in formulating the load impact estimates, including the facility operating schedule, demand for compressed air, and utilization of the compressed air facility. The *ex ante* load impacts for kW and kWh are 2.5 kW reduced and 21,808 kWh saved, respectively.

4.20.3 Ex Post Load Impact Estimation

The duty cycle of the refrigeration compressor in the cycling type dryer was measured *ex post* by a current logger. Energy consumption of the cycling dryer was compared to the baseline unit.

The baseline for comparison is a 6 hp noncycling type dryer operating as described earlier (8,496 normal hours, 144 holiday hours).

The demand and energy consumption of the constant running dryer are:

$$kW_{Baseline} = \frac{(6\text{ hp})(0.746\text{ kW / hp})}{0.91\text{ efficiency rating}}$$

$$= 4.92\text{ kW}$$

$$kWh_{Baseline} = (kW_{Baseline})(8{,}640\text{ hours / year})$$
$$= 42{,}497\text{ kWh}$$

Since the refrigeration compressor uses the same motor in both the baseline and retrofit cases, the demand of both units will be equal. *Ex post* measurements show that the refrigeration compressor operates an average of 0.239 of the time, so the annual energy consumption of the retrofit case is be:

$$kW_{Retrofit} = kW_{Baseline}$$
$$= 4.92 \text{ kW}$$

$$kWh_{Retrofit} = (kW_{Retrofit})(8{,}640 \text{ hours / year})(\text{Duty cycle})$$
$$= (4.92)(8{,}640)(0.239)$$
$$= 10{,}157 \text{ kWh}$$

The *ex post* load impacts for the measure are:

$$\text{kW reduced}_{ex\ post} = kW_{Baseline} - kW_{Retrofit}$$
$$= 0 \text{ kW}$$

$$\text{kWh saved}_{ex\ post} = kWh_{Baseline} - kWh_{Retrofit}$$
$$= 42{,}497 - 10{,}157$$
$$= 32{,}340 \text{ kWh}$$

Table 4-53 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-53
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	3.74	3.74	1.00	2,775	0.09
Summer Semi-peak	3.74		1.00	3,568	0.11
Summer Off-peak	3.74		1.00	7,390	0.23
Winter On-peak	3.74	3.74	1.00	1,201	0.04
Winter Semi-peak	3.74		1.00	7,147	0.22
Winter Off-peak	3.74		1.00	10,233	0.32
			Totals	32,314	1.01

4.20.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-54 summarizes the *ex ante* and *ex post* load impact estimates.

Table 4-54
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	2.5	21,808	N/A
Ex post estimated gross impacts	0.0	32,340	N/A
Difference	-2.5	-10,532	N/A
Realization rate	N/A	1.48	N/A

4.20.5 Persistence of the Measure

There are no published values for the expected life of the cycling line dryer, however, the value of 15 years assigned is consistent with similar types of equipment.

4.21 ID No. 14148B - Intermediate Controller on Compressed Air System

4.21.1 Facility Information

This is a manufacturing plant in San Diego, CA that produces computer accessory hardware. The plant uses compressed air for various purposes and has a compressed air plant which consists of two compressors: a 200 horsepower screw type compressor with a capacity of 1,100 cfm at 115 psig; and a 250 horsepower unit with a capacity of 1,380 cfm at the same conditions. The smaller compressor is operated as the base load machine most of the time. The plant uses air even when there is no production, so the compressed air system operates 24 hours per day, 365 days per year for a total of 8,760 hours per year.

The plant air system operates at 115 psig from the receiver to the point of use where it is regulated down to the pressure required by the user. *Ex ante* measurements indicate that the system has 200 cfm of leakage at this line pressure.

Installation of an intermediate controller, or demand expander, allows the plant to operate with air at 98 psig ±1 psi. The reduced downstream pressure reduces the amount of loss from leaks in the system.

The savings are achieved by reducing compressor run times due to lower demand for air by the amount of leak reduction.

4.21.2 Ex Ante Load Impact Estimation

The *ex ante* load impacts were estimated using an engineering analysis. A number of factors were considered in the analysis, including demand for compressed air, leaks in the compressed air system, system operations, and equipment operating characteristics. The *ex ante* energy savings and demand reductions were entered into the tracking system as 68,062 kWh and 7.8 kW, respectively. There was, however, an error in data entry, where the values should have been 34,031 kWh and 3.9 kW. These values were on another line in the *ex ante* analysis workpapers. The reason for the two set of numbers was because two scenarios were run, one with the intermediate controller and another with compressed air line additions and modifications. *Ex post* interviews conducted with facility staff indicated that the line additions and modifications did not take place.

4.21.3 Ex Post Load Impact Estimation

The air demand of the plant was broken down into three categories: normal, peak demand, and nonproduction. The compressor run time was evaluated for each loading condition before and after leak reduction. These results were used to calculate peak demand and annual energy consumption *ex post* and *ex ante*.

The baseline for comparison is the compressed air plant delivering 115 psig air to the plant distribution system.

The compressor control is designed so that the compressor operates fully loaded or unloaded, there is no modulation. *Ex ante* measurements indicate that fully loaded, the compressor draws 240 kW and unloaded it draws 46 kW.

Table 4-55 shows information taken from the plant control system by plant personnel.

Table 4-55
Plant Control System Information

Parameter	Value	Hours/Year
Normal Load	700 cfm	6,655
Peak Load	850 cfm	1,913
Nonproduction Load	200 cfm	192
Receiver pressure	114-120 psig	-
Receiver volume	174 cu. ft.	-

From the *Compressed Air and Gas Handbook Fifth Edition*, "CFM vs Pressure for Various Orifices" it was determined that a reduction in downstream pressure from 115 psig to 100 psig will reduce flow to leaks by 11%. In order to be conservative, we will use a10% reduction in leakage. In this case, with 200 cfm of leakage, the reduction in leakage will be 20 cfm.

From the *Compressed Air and Gas Handbook Fifth Edition*, the following equation which gives the time for the pressure in the receiver to rise or fall over a range given the supply and demand of the system:

$$T = \frac{V(p_1 - p_2)}{(C - S)p_0},$$

where:

$T =$ time for receiver pressure to change from p_1 to p_2 (minutes)

$V =$ Volume of Receiver (ft^3)

$p_0 =$ Atmospheric pressure (psig)

$p_1 =$ Pressure at beginning of cycle (psig)

$p_2 =$ Pressure at end of cycle (psig)

$C =$ Air demand (ft^3 / min)

$S =$ Air supply (ft^3 / min)

This equation was used to estimate the percent of cycle that is loaded or unloaded.

Baseline

Before installation of the intermediate controller, the system must provide the plant demand, including leakage. The system will operate as shown in Table 4-56.

Table 4-56
Baseline Energy Use

	Supply (cfm)	Demand (cfm)	Run Time per Cycle (Sec)	% of Cycle	Average kW	kWh per Year
Normal Load (6,655 hr/yr)					169.45	1,127,720
Compressor Loaded	1,100	700	10.7	63.6		
Compressor Unloaded	0	700	6.1	36.4		
Peak Load (1,913 hr/yr)					195.91	374,774
Compressor Loaded	1,100	850	17.0	77.3		
Compressor Unloaded	0	850	5.0	22.7		
Nonproduction Load (192 hr/yr)					81.27	15,604
Compressor Loaded	1,100	200	4.7	18.2		
Compressor Unloaded	0	200	21.3	81.8		
Total Annual Energy Consumption						1,518,098

Retrofit

After the installation of the intermediate controller, the system must provide the plant demand with reduced leakage so the demand will be reduced by 20 cfm. The system will operate as shown in Table 4-57.

Table 4-57
Retrofit Energy Use

	Supply (cfm)	Demand (cfm)	Run Time per Cycle (Sec)	% of Cycle	Average kW	kWh per Year
Normal Load (6,655 hr/yr)					165.93	1,104,246
Compressor Loaded	1,100	680	10.1	61.8		
Compressor Unloaded	0	680	6.3	38.2		
Peak Load (1,913 hr/yr)					192.38	368,026
Compressor Loaded	1,100	830	15.8	75.7		
Compressor Unloaded	0	830	5.1	24.5		
Nonproduction Load (192 hr/yr)					77.75	14,927
Compressor Loaded	1,100	180	4.6	16.4		
Compressor Unloaded	0	180	23.7	83.6		
					Total Annual Energy Consumption	1,487,199

Load Impacts

There will be no demand reductions attributable to the measure.

$$\begin{aligned} \text{kWh saved}_{\text{ex post}} &= \text{kWh}_{\text{Baseline}} - \text{kWh}_{\text{Retrofit}} \\ &= 1{,}518{,}098 - 1{,}487{,}199 \\ &= 30{,}899 \text{ kWh} \end{aligned}$$

Table 4-58 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-58
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	3.52	3.52	1.00	2,612	0.08
Summer Semi-peak	3.52		1.00	3,358	0.11
Summer Off-peak	3.52		1.00	6,956	0.23
Winter On-peak	3.52	3.52	1.00	1,552	0.05
Winter Semi-peak	3.52		1.00	6,727	0.22
Winter Off-peak	3.52		1.00	9,631	0.31
			Totals	30,836	1.00

4.21.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-59 summarizes the *ex ante* and *ex post* load impact estimates. Since the compressor in the system did not change in the retrofit, and there are times when the compressor must operate at capacity, thus, the peak demand for the system did not change. The *ex ante* analysis worksheets indicate a reduction of 3.9 kW which represented the demand reduction associated with only the intermediate controller. It appears a clerical error in data entry took place where 7.8 kW was entered into the tracking system, which represented demand reductions under a scenario where line additions and modifications would take place.

When examining the *ex ante* worksheets for energy impact estimates the incorrect value was entered into the program tracking system. While the value entered was 68,061 kWh, it should have been 34,031 kWh. This is the major reason for the discrepancy between the *ex ante* and *ex post* estimates.

Table 4-59
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	7.8	68,062	N/A
Ex post estimated gross impacts	0.0	30,899	N/A
Difference	7.8	37,163	N/A
Realization rate	N/A	0.45	N/A

4.21.5 Persistence of the Measure

No published values for service life of an intermediate controller unit could be found, however, the life of 15 years assigned seems consistent with similar types of equipment and appropriate.

4.22 ID No. 14152 - Steam and Condensate Pipe Insulation

4.22.1 Facility Information

This manufacturing facility located in San Diego, CA produces garments, mainly men's fashions. Low pressure steam is used throughout the plant for pressing, etc. The steam runs to the work stations via exposed 3/4" black iron pipes and condensate is returned to the boiler through similar piping. There are about 1,500 feet each of steam and condensate pipe, all of it is uninsulated. The plant operates an average of 10 hours per day, 5 days per week, 46 weeks per year or 2,300 hours per year.

Insulating the steam and condensate piping reduced heat loss to the space. The savings come from lower load on the plant's steam boiler which allows lower gas consumption. Since the plant is not air conditioned, there is no energy savings from that area but there is an increase in occupant comfort.

4.22.2 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates used the assumptions shown in Table 4-60.

Table 4-60
***Ex Ante* Load Impact Assumption**

Parameter	Value
Length of uninsulated steam pipe	1,500 feet
Length of uninsulated condensate pipe	1,500 feet
Saturated steam @ 100 psig	338°F
Condensate return temperature	200°F
Operating hours	10 hours per day 5 days per week 46 weeks per year 2,300 hours per year

The heat loss was calculated through the uninsulated steam pipe as:

$$q = \frac{t_i - t_o}{\frac{1}{h_i A_i} + \frac{\ln(\frac{r_2}{r_1})}{2\pi k_1 L} + \frac{1}{h_o A_o}},$$

where,

q = heat loss,

t_i = 338° F (temp. on inside of pipe 100 psig saturated steam),

t_0 = 70° F (temp. on outside of pipe),

k_1 = 25 (source: Marks' Mechanical Engineers Handbook, for pipe),

$A_i = 2\pi r_i L$,

r_1 = radius to inside of pipe,

r_2 = radius to outside of pipe, and

L = length of pipe.

$\frac{q}{L}$ (uninsulated steam pipe) = 237 Btuh / foot

The heat loss was calculated through the insulated steam pipe as:

$$q = \frac{t_i - t_o}{\frac{1}{h_i A_i} + \frac{\ln(\frac{r_2}{r_1})}{2\pi k_1 L} + \frac{\ln(\frac{r_3}{r_2})}{2\pi k_2 L} + \frac{1}{h_o A_o}},$$

where,

q = heat loss,

t_i = 338° F (temp. on inside of pipe 100 psig saturated steam),

t_0 = 70° F (temp. on outside of pipe),

k_1 = 25 (source: Marks' Mechanical Engineers Handbook, for pipe),

$A_i = 2\pi r_i L$,

r_1 = radius to inside of pipe,

r_2 = radius to outside of pipe,

r_3 = radius to outside of insulation, and

L = length of pipe.

$\frac{q}{L}$ (insulated steam pipe) = 32.2 Btuh / foot

Similarly, the heat loss through the uninsulated and insulated condensate pipes were calculated.

$$\frac{q}{L}\text{(uninsulated condensate pipe)} = 115 \text{ Btuh / foot}$$

$$\frac{q}{L}\text{(insulated condensate pipe)} = 15.6 \text{ Btuh / foot}$$

The energy saved was calculated as:

$$\text{Therms saved}_{total} = \text{Therms saved}_{steam} + \text{Therms saved}_{condensate},$$

where,

$$\text{Therms saved}_{steam} = \frac{(237 - 32.2 \text{ Btuh / foot})(1{,}500 \text{ feet})(2{,}300 \text{ hour / year})}{(0.8 \text{ boiler efficiency})(100{,}000 \text{ Btu / therm})}$$
$$= 8{,}832 \text{ therms / year.}$$

$$\text{Therms saved}_{condensate} = \frac{(115 - 15.6 \text{ Btuh / foot})(1{,}500 \text{ feet})(2{,}300 \text{ hours / year})}{(0.8 \text{ boiler efficiency})(100{,}000 \text{ Btu / therm})}$$
$$= 4{,}287 \text{ therms / year}$$

$$\text{Therms saved}_{total} = 8{,}832 + 4{,}287$$
$$= 13{,}119 \text{ therms / year}$$

4.22.3 Ex Post Load Impact Estimation

An on-site visit was conducted on November 14, 1996. The facilities manager for the plant was interviewed and the installation of insulation on the steam and condensate piping was inspected. The gas meter only serves this boiler, so it is, in effect, an end use meter. Gas consumption data were collected for one year before and one year after the date of the retrofit, August 1, 1995, and these data was analyzed for savings.

The base line is the facility with the steam and condensate lines having no insulation.

From the gas billing data, the gas consumption for the boiler in the year prior to the retrofit was 191,572 therms and for the year after retrofit it was 161,656 therms. The saving is 29,916 therms per year. Since plant personnel assure us that there has been no change in production between the two periods, this reduction can all be attributed to the new insulation.

There are no electricity load impacts associated with this measure.

4.22.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-61 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* analysis was performed on the basis of standard engineering calculations for heat loss from the steam and condensate pipes. The formulae used in this approach are sensitive to variation of system parameters such as, heat transfer coefficients, operating hours, ambient temperature, etc. The calculation understates the savings such that the realization rate for this project is 2.28.

Table 4-61
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	N/A	N/A	13,119
Ex post estimated gross impacts	N/A	N/A	29,916
Difference	N/A	N/A	16,797
Realization rate	N/A	N/A	2.28

4.22.5 Persistence of the Measure

At the time of inspection, the insulation was all in place and functioning. The *ASHRAE HVAC Handbook*, 1987 "Equipment Service Life" lists a service life of 20 years for this material. Thus, the 15 year useful life assigned to the measure is appropriate, although somewhat conservative.

4.23 ID No. 14188 - Variable Volume Hydraulic Drives

4.23.1 Facility Information

This is a manufacturing facility in San Diego, CA that operates 24 hours per day, 7 days per week, 50 weeks per year (8,400 hours per year). The two manufacturing production line conveyors are driven by constant volume hydraulic pumps with standard efficiency motors. The conveyors move the line for about 5 seconds and idle for 10 seconds, the cycle is then repeated.

The constant pressure hydraulic pumps are configured so that the pump motor operates at full load continuously. The excess hydraulic oil was bypassed through a pressure relief valve back to the reservoir. The motors driving the pumps were standard efficiency units.

The hydraulic pumps were changed to variable volume units which allow the pump output to be matched to demand, reducing the waste due to bypassing of hydraulic oil. The pump motors were replaced with energy efficient units.

The variable volume hydraulic units allow the pump output, and consequently, its power demand to be matched to the system demand for oil. The energy efficient motors will use less energy for the same work than standard efficiency units.

4.23.2 Ex Ante Load Impact Estimation

The *ex ante* load impact estimates used the following series of algorithms to estimate the *ex ante* load impacts.

$$\begin{aligned}\text{Power}_{\text{Constant volume}} &= \frac{(\text{Q gal / min})(\text{P psi})}{1{,}714} \\ &= \frac{(35\text{ gal / min})(2{,}000\text{ psi})}{1{,}714} \\ &= 40.8\text{ bhp}\end{aligned}$$

$$\text{Power}_{\text{Variable volume}} = \frac{(\text{Q gal / min})(\text{P psi})}{1{,}714} + \text{CH}_\text{p}$$

$$\text{CH}_\text{p} = 7\text{ hp (from mfr's spec sheet)}$$

Demand savings were shown as a diversified average.

$$\text{Demand}_{\text{Idle}} = \left[\frac{(\text{Q gal / min})(\text{P psi})}{1{,}714} + \text{CH}_\text{p}\right]\left[\frac{0.746\text{ kw / hp}}{(\text{eff})(\text{part load eff.}_{@7\text{ hp}})}\right]$$

$$= \left[\frac{(0.5\text{ gal / min})(2{,}000\text{ psi})}{1{,}714} + 7\text{ hp}\right]\left[\frac{0.746\text{ kw / hp}}{(0.941)(0.79)}\right]$$

$$= 7.6\text{ kW}$$

$$\text{Demand}_{\text{Full}} = \left[\frac{(\text{Q gal / min})(\text{P psi})}{1{,}714} + \text{CH}_\text{p}\right]\left[\frac{0.746\text{ kw / hp}}{(\text{eff})(\text{part load eff.})}\right]$$

$$= \left[\frac{(35\text{ gal / min})(1{,}000\text{ psi})}{1{,}714} + 7\text{ hp}\right]\left[\frac{0.746\text{ kw / hp}}{(0.941)(1.0)}\right]$$

$$= 21.7\text{ kW}$$

Assume the operations of the pump is 33% of the time at full load and 67% of the time at idle. The *ex ante* demand impacts are:

$$
\begin{aligned}
kW_{\text{Variable volume}} &= (1/3)(\text{Demand}_{\text{Full}}) + (2/3)(\text{Demand}_{\text{Idle}}) \\
&= (1/3)(21.7) + (2/3)(7.6) \\
&= 12.3 \text{ kW}
\end{aligned}
$$

$$
\begin{aligned}
kW_{\text{Constant volume}} &= \frac{(40.8 \text{ hp})(0.746 \text{ kW / hp})}{0.903 \text{ eff.}} \\
&= 33.7 \text{ kW}
\end{aligned}
$$

$$
\begin{aligned}
\text{kW reduced}_{\text{ex ante}} &= (kW_{\text{Constant volume}} - kW_{\text{Variable volume}})(\#\ \text{pumps}) \\
&= (33.7 - 12.3)(2) \\
&= 42.8 \text{ kw}
\end{aligned}
$$

The *ex ante* energy savings for the measure was calculated as:

$$
\begin{aligned}
kWh_{\text{Constant volume}} &= (kW_{\text{Constant volume}})(\text{Operating Hours}) \\
&= (33.7 \text{ kW})(8{,}400 \text{ hours / year}) \\
&= (283{,}080 \text{ kWh}
\end{aligned}
$$

$$
\begin{aligned}
kWh_{\text{Variablet volume}} &= (kW_{\text{Variable volume}})(\text{Operating Hours}) \\
&= (12.3 \text{ kW})(8{,}400 \text{ hours / year}) \\
&= 103{,}320 \text{ kWh}
\end{aligned}
$$

$$
\begin{aligned}
\text{kWh saved}_{\text{ex ante}} &= (kWh_{\text{Constant volume}} - kWh_{\text{Variablet volume}})(\#\ \text{pumps}) \\
&= (283{,}080 - 103{,}320)(2) \\
&= (179{,}760 \text{ kWh / year / pump})(2) \\
&= 359{,}920 \text{ kWh}
\end{aligned}
$$

4.23.3 Ex Post Load Impact Estimation

A site visit to the plant was not permitted by facility management due to major activity in facilities and production, so the *ex ante* analysis using data included in the Rebate Application Package was reviewed. This information was used to calculate demand reduction and energy savings which were.

The baseline for comparison is the plant before retrofitting with constant volume hydraulic pumps and standard efficiency pump motors, operating 8,400 hours per year. Each constant volume hydraulic pump supplies 35 gpm of oil at 2,000 psi. The standard efficiency motor has an efficiency of 90.3%.

The baseline energy use and demand were calculated as:

$$\text{Output horsepower} = \frac{(\text{Q gpm})(\text{P psi})}{1{,}714}$$
$$= \frac{(35\text{ gpm})(2{,}000\text{ psi})}{1{,}714}$$
$$= 40.84\text{ bhp}$$

$$\text{Pump horsepower} = \frac{\text{Output Horsepower}}{\text{Pump Efficiency}}$$
$$= \frac{40.84}{0.82}$$
$$= 50\text{ hp}$$

$$kW_{Baseline} = \left[\frac{(\text{Pump horsepower})(0.746\text{ kW / hp})}{\text{Pump Efficiency}}\right](\#\text{ motors})$$

$$= \left[\frac{(50\text{ hp})(0.746\text{ kW / hp})}{0.903}\right](2\text{ motors})$$

$$= 82.62\text{ kW}$$

$$kWh_{Baseline} = (kW_{Baseline})(\text{Operating hours})$$
$$= (82.62\text{ kW})(8{,}400\text{ hours})$$
$$= 694{,}008\text{ kWh}$$

The retrofit energy efficient motor has an efficiency of 94.1%. From manufacturer's performance data, the general equation for calculating the pump horsepower required by a variable volume hydraulic unit is:

$$\text{Pump horsepower} = \frac{(\text{Q gpm})(\text{P psi})}{1{,}714} + C_{hp},$$

where,

$$C_{hp} = \text{compensation factor}(@1000\text{ psi } C_{hp} = 4\text{ hp, } @2000\text{ psi } C_{hp} = 7\text{ hp})$$

When the conveyor is stopped, the hydraulic unit operates at 2,000 psi with a volume of 0.5 gpm. When it is in motion, the output is 1,000 psi with a volume of 35 gpm. The conveyor is idle 2/3 of the time and in motion 1/3 of the time.

The load per motor when the conveyor is at idle for the retrofit is:

$$\text{Pump horsepower} = \left[\frac{2{,}000 \times 0.5}{1714}\right] + 7$$
$$= 7.58 \text{ hp}$$

$$\text{kW}_{\text{Idle}} = \left[\frac{(\text{Pump horsepower})(0.746 \text{ kW / hp})}{\text{Eff}}\right](\#\ \text{motors})$$
$$= \left[\frac{(7.58)(0.746 \text{ kW / hp})}{0.941}\right](2 \text{ motors})$$
$$= 12.02 \text{ kW}$$

The load per motor when the conveyor is in motion for the retrofit is:

$$\text{Pump horsepower} = \left[\frac{1{,}000 \times 35}{1715}\right] + 4$$
$$= 24.41 \text{ hp}$$

$$\text{kW}_{\text{Motion}} = \left[\frac{(\text{Pump horsepower})(0.746 \text{ kW / hp})}{\text{Eff}}\right](\#\ \text{motors})$$
$$= \left[\frac{(24.41)(0.746)}{0.941}\right](2 \text{ motors})$$
$$= 38.70 \text{ kW}$$

$$\text{kW}_{\text{Retrofit}} = (1/3)(38.7 \text{ kW}) + (2/3)(12.02)$$
$$= 20.9 \text{ kW}$$

$$\text{kWh}_{\text{Retrofit}} = (\text{kW}_{\text{Retrofit}})(\text{Operating hours})$$
$$= (20.9 \text{ kW})(8{,}400 \text{ hours})$$
$$= 175{,}672 \text{ kWh}$$

The *ex post* load impacts for the measure were:

$$\textit{kW reduced}_{\textit{ex post}} = \textit{kW}_{\textit{Baseline}} - \textit{kW}_{\textit{Retrofit}}$$
$$= \textit{82.62 - 38.7}$$
$$= \textit{43.92 kW}$$

$$\textit{kWh saved}_{\textit{ex post}} = \textit{kWh}_{\textit{Baseline}} - \textit{kWh}_{\textit{Retrofit}}$$
$$= 694{,}008 - 175{,}672$$
$$= \textit{518,336 kWh}$$

Table 4-62 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-62
kW Reduction and kWh Savings by Time-Of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	63.00	70.6	1.00	46,746	0.09
Summer Semi-peak	61.70		0.98	58,862	0.11
Summer Off-peak	61.23		0.97	120,990	0.23
Winter On-peak	70.60	70.6	1.00	31,135	0.06
Winter Semi-peak	51.50		0.82	98,417	0.19
Winter Off-peak	59.55		0.95	162,929	0.31
			Totals	518,284	0.99

4.23.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-63 summarizes the *ex ante* and *ex post* load impact estimates.

Comparison of the *ex ante* and *ex post* load impact estimates shows a realization rate for demand reduction of 1.03 and for energy savings of 1.44. The differences came from differences of interpretation of manufacturer's data provided.

Table 4-63
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	42.8	359,920	N/A
Ex post estimated gross impacts	43.9	518,284	N/A
Difference	1.1	158,354	N/A
Realization rate	1.03	1.44	N/A

4.23.5 Persistence of the Measure

ASHRAE Journal December 1988, *Service Lives* lists service life for energy efficient motors as 15 years. No published service life for variable volume hydraulic pumps in process applications could be found, however, the 15 year life assigned to the measure is reasonable.

4.24 ID No. 14270 - Amplifier Sequencer

4.24.1 Facility Information

This facility, located in San Diego, CA produces and tests electronic equipment. The plant performs high power vibration testing on electronic components. The testing facilities operate 24 hours per day, 90 days per year (2,160 hours per year). During this time, the testing vibrator is in operation approximately 10 minutes of each hour and idle 50 minutes.

Ex ante measurements showed that the vibrator had an idle mode power consumption of 39.7 kW, which represents wasted energy.

By installing an amplifier sequencer the vibrator coil is turned off when it is not in actual operation, thus, the energy wasted during idle periods can be saved. The savings are generated by the lower energy consumption of the solid state converter in no load condition which occurs 60% of the time. There are no demand savings from this measure.

4.24.2 Ex Ante Load Impact Estimation

A test was conducted to monitor the power requirements of the amplifier under load and no-load conditions. Under baseline operations, the amplifier would not be turned off. The results of the test show the typical demand under no-load conditions would be 39.7 kW. This is the kW reduced when the amplifier sequencer is operating. There would, however, be no demand reduction benefits as a result of the measure.

The *ex ante* energy saved is:

$$\begin{aligned} \text{kWh saved}_{\text{ex ante}} &= (39.7\text{ kW reduced})(20\text{ hours / day})(90\text{ days / year}) \\ &\quad -(108\text{ kWh in additional energy consumed by the measure}) \\ &= 71{,}460 - 108 \\ &= 71{,}352\text{ kWh / year} \end{aligned}$$

4.24.3 Ex Post Load Impact Estimation

The site was visited on December 4, 1996. Interviews were conducted with plant personnel. The new installations were inspected. The testing system was not in use at the time of the site visit, and it was not expected to be used in the immediate future.

The program file included information regarding the performance characteristics of the vibrator and the sequencer, as well as the results of the *ex ante* measurements. This information, along with the measurements taken *ex post*, were used to calculate the *ex post* demand and energy impacts.

The baseline condition is the vibration test facility operating without the amplifier sequencer, in which case, the vibrator coil draws power continuously as long as the facility is active.

The existing vibration tester drew 39.7 kW in the idle mode. The baseline energy use was calculated as:

$$kW(\text{existing vibration tester}) = 39.7\ kW$$

$$\begin{aligned}\text{Hours the tester is in idle mode} &= (24\ \text{hours / day})(90\ \text{day / year})(50\ \text{min / hour})(1 / 60\ \text{hour / min}) \\ &= 1{,}800\ \text{hours / year}\end{aligned}$$

$$\begin{aligned}kWh_{Baseline} &= (39.7\ kW)(1{,}800\ \text{hours}) \\ &= 71{,}460\ kWh\end{aligned}$$

The retrofit vibration tester drew 0.06 kW in the idle mode. The *ex post* retrofit energy use was calculated as:

$$kW(\text{retrofit vibration tester}) = 0.06\ kW$$

$$\begin{aligned}\text{Hours the tester is in idle mode} &= (24\ \text{hours / day})(90\ \text{day / year})(50\ \text{min / hour})(1 / 60\ \text{hour / min}) \\ &= 1{,}800\ \text{hours / year}\end{aligned}$$

$$\begin{aligned}kWh_{Baseline} &= (0.06\ kW)(1{,}800\ \text{hours}) \\ &= 108\ kWh\end{aligned}$$

The *ex post* load impacts due to the retrofit were:

$$\begin{aligned}\text{kWh}_{\text{Baseline}} &= \text{kWh}_{\text{Baseline}} - \text{kWh}_{\text{Retrofit}} \\ &= 71{,}460 - 108 \\ &= 71{,}352\ \text{kWh}\end{aligned}$$

Table 4-64 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-64
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	8.15	8.15	1.00	6,047	0.08
Summer Semi-peak	8.15		1.00	7,775	0.11
Summer Off-peak	8.15		1.00	16,104	0.23
Winter On-peak	8.15	8.15	1.00	3,594	0.05
Winter Semi-peak	8.15		1.00	15,575	0.22
Winter Off-peak	8.15		1.00	22,298	0.31
			Totals	71,393	1.00

4.24.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-65 summarizes the *ex ante* and *ex post* load impact estimates. The amplifier sequencer is function as expected.

Table 4-65
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	0	71,352	N/A
Ex post estimated gross impacts	0	71,352	N/A
Difference	N/A	0	N/A
Realization rate	N/A	1.00	N/A

4.24.5 Persistence of the Measure

No published estimate for the life of the amplifier sequencer could be located, but, given the type of equipment, the 15 year life assigned is reasonable and appropriate.

4.25 ID No. 14352 - Variable Speed Drive on an Air Compressor

4.25.1 Facility Information

This is a bottling plant in San Diego, CA. The plant operates 24 hours per day, 7 days per week, 52 weeks per year (8,760 hours per year). Compressed air for the plant is provided by two 150 horsepower compressors with different operating characteristics. The plant's operating schedule is shown in Table 4-66.

Table 4-66
Plant Operating Schedule

Shift	Time Period	Lines Operating	% Capacity of One Compressor
First Shift	6 a.m.-2 p.m.	3 Lines	60%
Second Shift	2 p.m.-10 p.m.	2 Lines	40%
Third Shift	10 p.m.-6 a.m.	1 Line	20%

Ex ante measurements indicate that the compressors are each operates 50% of the time and that only one compressor operates at any given time.

One of the existing compressors uses an inlet throttling valve and the other uses a turn valve for capacity control. Both of these methods of control result in poor part load efficiency for the machines.

Replacement of the turn valve and the inlet throttling valve in the two compressors with a variable speed drive controlling the system will increase the part load efficiency of both compressors. Since the compressors operate at part load most of the hours of the year, an increase in the part load efficiency of the units will reduce the peak demand and the annual energy consumption.

4.25.2 Ex Ante Load Impact Estimation

Operations of the turn valve compressor were obtained by monitoring a 100 hp turn valve compressor. The inlet valve compressor data were obtained by locking the turn valve 100% open. No data exists for air flows below 41.6%. The units will modulate the air flows below this point, but the kW will remain constant. These data are shown in Table 4-67.

Table 4-67
Compressor Input kW

	Total Power In kW		
%Flow	Inlet Valve	Turn Valve	VSD
41.6%	73.53	64.78	42.43
55.7%	77.67	65.36	53.51
66.3%	79.73	68.39	63.64
60.0%	78.51	66.59	57.62

Table 4-68 shows the energy savings of a 100 horsepower compressor unit.

Table 4-68
kWh Savings For a 100 Horsepower Compressor

				kW Reduced		Operating Hours		kWh Savings/Year		
8 Hour Shifts	# Lines	Air Flow Required	Air Flow Supplied	Inlet Valve Unit	Turn Valve Unit	Inlet Valve Unit	Turn Valve Unit	Inlet Valve Unit	Turn Valve Unit	Total
6 am-2 pm	3	60%	60.0%	20.89	8.97	1,456	1,464	30,410	13,132	43,542
2 pm-10 pm	2	40%	41.6%	31.10	22.35	1,456	1,464	45,282	32,720	78,002
10 pm-6 am	1	20%	41.6%	31.10	22.35	1,456	1,464	45,282	32,720	78,002
								120,974	78,573	199,546

The savings shown in Table 4-68 are from a 100 hp compressor. The savings for a 125 hp unit was obtained through a proportioning of the savings as:

$$
\begin{aligned}
kWh_{ex\ ante} &= \frac{(kWh\ savings\ from\ 100\ hp\ unit)}{100\ hp}(125\ hp) \\
&= \frac{199{,}546\ kWh}{100\ hp}(125\ hp) \\
&= 249{,}433\ kWh
\end{aligned}
$$

The *ex ante* demand reduction is estimated as:

$$
\begin{aligned}
kW\ for\ 100\ hp\ unit &= kW_{Inlet\ valve\ @60\%\ Flow} - kW_{VSD\ @60\%\ Flow} \\
&= 78.51 - 57.62 \\
&= 20.89\ kW
\end{aligned}
$$

$$
\begin{aligned}
kW_{ex\ ante} &= (kW\ for\ 100\ hp\ unit)\left(\tfrac{125\ hp}{100\ hp}\right) \\
&= 26.11\ kW
\end{aligned}
$$

4.25.3 Ex Post Load Impact Estimation

A site visit was not performed at the site due to scheduling and production conflicts. An analysis was performed using the compressor performance characteristics and load profile provided in the project file to calculate the demand and energy consumption on an hourly basis *ex ante* and *ex post*.

The baseline for comparison is the plant operating on the load profile generated from *ex ante* measurements with either the inlet valve and turn valve compressor operating such that each machine operates 50% of the time.

Compressor performance data were taken from a presentation to SDG&E entitled, *Screw Compressors and AF Drives: Applications and Opportunities,* by Eaton Corporation, February 1994. Values shown in this presentation represent test data taken from a 100 hp compressor and was extrapolated to the larger compressors which exist at the plant.

The data shown in Table 4-69 indicates that for the inlet valve and turn valve controls, reduction of the compressor load below 41.6% of full load does not reduce the power demand. This is not true of the VSD control. Power demand will decrease with compressor load as low as 20% of full load.

Table 4-69
Total Power Demand (kW)

%Load	Control Method		
(Flow)	Inlet Valve	Turn Valve	VSD
60%	117.75	99.89	86.43
40%	110.30	97.17	61.38
20%	110.30	97.17	32.09
Interpolated from presentation in project file, adjusted for 150 hp compressor.			

Ex ante measurements show that the inlet valve and the turn valve controlled compressors each operate, on average, 4,380 hours per year divided equally between 60%, 40% and 20% of full load. It is reasonable to believe that at some time, each compressor will operate at full load which means that the peak demand will be:

$$Peak\ kW_{Baseline} = 135.87\ kW$$

The annual energy consumption will be:

$$\begin{aligned} kWh_{Baseline} &= (1{,}460\ hours)(117.75\ kW + 110.30\ kW + 110.30\ kW) \\ &\quad + (1{,}460\ hours)(99.89\ kW + 97.17\ kW + 97.17\ kW) \\ &= 923{,}567\ kWh \end{aligned}$$

In the retrofit configuration, the VSD control operates 8,760 hours per year on average divided evenly between 60%, 40%, and 20% of full load. It is reasonable to believe that at some time, each compressor will operate at full load which means that the peak demand will be:

$$Peak\ kW_{Retrofit} = 135.87\ kW$$

The annual retrofit energy consumption will be:

$$\begin{aligned} kWh_{Retrofit} &= (2{,}920\ hours)(86.43\ kW + 61.38\ kW + 32.09\ kW) \\ &= 525{,}308\ kWh \end{aligned}$$

The *ex post* load impacts from this measure are:

$$kW\ reduced_{ex\ post} = Peak\ kW_{Baseline} - Peak\ kW_{Retrofit}$$
$$= 135.87 - 135.87$$
$$= 0\ kW$$

$$kWh\ saved_{ex\ post} = kWh_{Baseline} - kWh_{Retrofit}$$
$$= 923{,}567 - 525{,}308$$
$$= 398{,}259\ kWh$$

Table 4-70 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-70
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	33.80	42.4	1.00	25,080	0.06
Summer Semi-peak	31.27		0.93	29,832	0.07
Summer Off-peak	56.70		1.68	112,039	0.28
Winter On-peak	42.36	42.4	1.00	18,681	0.05
Winter Semi-peak	33.86		1.00	64,706	0.16
Winter Off-peak	54.07		1.60	147,936	0.37
			Totals	398,274	0.99

4.25.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-71 summarizes the *ex ante* and *ex post* load impact estimates. While the compressors operate, on average, on the profile set forth earlier, it is reasonable to believe that at some time during the day, the compressor in operation will reach 100% load. This is true *ex ante* and *ex post*. For this reason, there will be no demand reduction. Since the *ex ante* analysis predicts a reduction, the realization rate for demand is 0. A comparison of the annual energy savings estimates from the *ex ante* and *ex post* analyses show a realization rate of 1.60. Understatement of the savings in the *ex ante* analysis is due partly to an error by which the size of the compressors was taken as 125 hp when they are actually 150 hp. Further understatement comes from the assumption that the energy demand of the VSD would not decrease with load below 40% of full load. In fact, the demand of the VSD will decrease more or less linearly with load down to 20% of full load.

Table 4-71
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	26.11	249,433	N/A
Ex post estimated gross impacts	0	398,259	N/A
Difference	26.11	-148,826	N/A
Realization rate	0	1.60	N/A

4.25.5 Persistence of the Measure

The ASHRAE Journal, December 1988 lists a Service Life for Process Adjustable Speed Drives of 16 years. This indicates that the 15 years assigned is appropriate.

4.26 ID No. 17144 - Boiler Replacement

4.26.1 Facility Information

This is a manufacturing facility in San Diego, CA. The plant processes use steam and hot water 24 hours per day, 365 days per year (8,760 hours per year). The plant was equipped with a gas-fired steam boiler and a steam hot water.

A steam boiler with stack heat recovery will have a higher system efficiency than a new boiler and hot water generator separately. Savings will be achieved because the higher efficiency of the boiler with heat recovery and the elimination of losses in the steam hot water generator will mean less gas is required to do the work.

4.26.2 Ex Ante Load Impact Estimation

An engineering analysis was used to estimate the *ex ante* load impacts of the measure.
Table 4-72 shows the assumptions used in estimating the *ex ante* load impacts for the measure.

Table 4-72
***Ex Ante* Load Impact Assumptions**

Equipment	Parameter		Value
Baseline boiler w/o economizer	Size		100 horsepower
	High fire:	Efficiency	80%
		Input	4,184,000 Btuh
		Output	3,347,500 Btuh
	Low fire:	Efficiency	81%
		Input	2,066,000 Btuh
		Output	1,673,750 Btuh
		Load served	50%
	Load factor		70%
	Operating hours		24 hours/day 365 days/year 8,760 hours/year
	Standby factor		10% runtime in standby mode.
Retrofit boiler w/ economizer	Size		100 horsepower
	High fire	Efficiency	84%
		Input	3,985,100 Btuh
		Output	3,347,500 Btuh
	Low fire	Efficiency	85%
		Input	1,969,000 Btuh
		Output	1,673,750 Btuh
	Operating hours		24 hours/day 365 days/year 8,760 hours/year
	Standby factor		10% runtime in standby mode.

The demand for steam/hot water was estimated.

$$\begin{aligned} \textit{Demand for steam / hot water} &= (\textit{Boiler output}_{\textit{Low fire}})(24 \textit{ hours / day})(\textit{Load factor}) \\ &= (1{,}427{,}400 \textit{ Btuh})(24 \textit{ hours / day})(0.70) \\ &= 23{,}973{,}600 \textit{ Btu / day} \end{aligned}$$

Thus, the boiler need to provide 23,973,600 Btu per day to meet the demand for steam and hot water. To meet this demand the baseline boiler would run:

$$Hours\ /\ day = \frac{Demand\ for\ steam\ /\ hot\ water}{Boiler\ low\ output_{Baseline}}$$

$$= \frac{(23,973,600\ Btu\ /\ day)}{1,673,750\ Btuh}$$

$$= 14.32\ hours\ /\ day$$

The 14.32 hours/day equates to a load factor of 0.597.

Ex ante energy use through the baseline boiler was estimated at:

$$Therms\ (full\ load)_{Baseline} = (20.66\ therms\ /\ hour)(24\ hours\ /\ day)(365\ days\ /\ year)(0.597)$$
$$= 108,046\ therms\ /\ year$$

$$Therms\ (standby)_{Baseline} = (20.66\ therms\ /\ hour)(24\ hours\ /\ day)(365\ days\ /\ year)(0.403)(0.10)$$
$$= 7,294\ therms\ /\ year$$

$$Therms\ (total)_{Baseline} = Therms\ (full\ load)_{Baseline} + Therms\ (standby)_{Baseline}$$
$$= 108,046 + 7,294$$
$$= 115,340\ therms\ /\ year$$

The *ex ante* energy use through the retrofit boiler was calculated as:

$$Therms\ (full\ load)_{Retrofit} = (19.69\ therms\ /\ hour)(24\ hours\ /\ day)(365\ days\ /\ year)(0.597)$$
$$= 102,973\ therms\ /\ year$$

$$Therms\ (standby)_{Retrofit} = (19.96\ therms\ /\ hour)(24\ hours\ /\ day)(365\ days\ /\ year)(0.403)(0.10)$$
$$= 6,951\ therms\ /\ year$$

$$Therms\ (total)_{Retrofit} = Therms\ (full\ load)_{Retrofit} + Therms\ (standby)_{Retrofit}$$
$$= 102,973 + 6,951$$
$$= 109,924\ therms\ /\ year$$

The *ex ante* energy savings for the measure was calculated as:

$$\begin{aligned} Therms\ saved_{ex\ ante} &= Therms\ (total)_{Baseline} + Therms\ (total)_{Retrofit} \\ &= 115{,}340 - 109{,}924 \\ &= 5{,}415\ therms / year \end{aligned}$$

No electricity load impacts were estimated for this measure.

4.26.3 Ex Post Load Impact Estimation

The baseline condition for comparison is a 100 hp Clayton boiler and a steam hot water generator providing the same amounts of steam and hot water as the then-installed Miura boiler and with heat exchanger to generate hot water. The Miura boiler and heat exchanger had to be replaced, thus the Clayton unit is used as the baseline.

Ex ante measurements indicate that the baseline system was producing steam and hot water at an average output of 999,180 Btu/hour. According to manufacturer's performance data, the Clayton boiler without economizer has a rated input of 4,184,000 Btu/hour at high fire with an operating efficiency of 80% and 2,066,000 Btu/hr and 81% at low fire. The corresponding rated outputs are 3,347,200 Btu/hour at high fire and 1,673,460 Btu/hour at low fire. For calculation purposes, we will use an average capacity of 2,510,330 Btu/hour.

To match the capacity of existing boilers, the Clayton boiler will operate at a duty cycle of:

$$Duty\ cycle_{Baseline} = \frac{999{,}180\ Btu/hour}{2{,}510{,}330\ Btu/hour}$$

$$= 39.8\%$$

The daily output will be:

$$Daily\ output = \frac{(0.398)(24\ hours/day)(2{,}510{,}330\ Btu/hour)}{100{,}000\ Btu/therm}$$

$$= 239.8\ therms/day$$

During the time when the boiler is not operating (60.2%), it will be in standby mode which means it will fire at low fire 10% of the time. The output will be:

$$Standby\ output = \frac{(1-0.398)(24\ hours/day)(0.10)(1{,}673{,}460\ Btu/hour)}{100{,}000\ Btu/therm}$$

$$= 24.2\ therms/day$$

Total daily output is:

$$\begin{aligned} \textit{Total daily output} &= \textit{Daily output} + \textit{Standby output} \\ &= 239.8 + 24.2 \\ &= 264.0 \textit{ therms / day} \end{aligned}$$

Taking an average efficiency for the Clayton boiler without heat recovery of 80.5%, the gas input will be:

$$\text{Daily gas consumption}_{\text{Baseline}} = \frac{264.0 \text{ therms / day}}{0.805 \text{ efficiency rating}}$$

$$= 328.0 \text{ therms / day}$$

$$\begin{aligned} \text{Annual gas consumption}_{\text{Baseline}} &= (328.0 \text{ therms / day})(365 \text{ days / year}) \\ &= 119{,}720 \text{ therms / year} \end{aligned}$$

The *ex post* stack gas analysis shows that the efficiency of the Clayton boiler with an economizer is 84.9% at high fire and 85.2% at low fire, an average of 85.1%. The firing rates are the same in both cases, so the annual energy consumption for the retrofit case will be:

$$\text{Daily gas consumption}_{\text{Retrofit}} = \frac{264.0 \text{ therms / day}}{0.851 \text{ efficiency rating}}$$

$$= 310.2 \text{ therms / day}$$

$$\begin{aligned} \text{Annual gas consumption}_{\text{Retrofit}} &= (310.2 \text{ therms / day})(365 \text{ days / year}) \\ &= 113{,}231 \text{ therms / year} \end{aligned}$$

The *ex post* energy savings is:

$$\begin{aligned} \textit{Energy savings}_{\textit{ex post}} &= \textit{Annual gas consumption}_{\textit{Baseline}} - \textit{Annual gas consumption}_{\textit{Retrofit}} \\ &= 119{,}720 - 113{,}231 \\ &= 6{,}489 \textit{ therms / year} \end{aligned}$$

There are no electric load impacts associated with this measure.

Table 4-73 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

4.26.4 Comparison of Ex Ante and Ex Post Impact Estimate

Table 4-73 summarizes the *ex ante* and *ex post* load impact estimates. The major reason for the difference between the *ex ante* and *ex post* load impact estimate was due to method of calculation of duty cycle in the *ex ante* analysis where it was assumed the boiler never operates at high fire. This overstates the duty cycle and understates the savings. Another factor is that the *ex ante* analysis uses the manufacturer's efficiency ratings of 84% at high fire and 85% at low fire for the retrofit boiler, while the *ex post* analysis uses measured efficiency values of 84.9% high fire and 85.2% at low fire. This would also result in understatement of the savings.

Table 4-73
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	N/A	N/A	5,415
Ex post estimated gross impacts	N/A	N/A	6,489
Difference	N/A	N/A	1,074
Realization rate	N/A	N/A	1.20

4.26.5 Persistence of the Measure

The typical expected service life for a heat exchanger is 10 years for this measure, while the typical service life for a boiler is 15 years. On this basis, the 15 year life assigned to the entire system is somewhat on the optimistic side.

4.27 ID No. 17476 - Crossover Piping

4.27.1 Facility Information

This is a ship repair facility in San Diego, CA which operates 7 days a week, 24 hours per day, 365 days a year (8,760 hours per year). The yard has a system which provides pressurized (120-150 psi) salt water for fire protection and other uses. The system consists of two piping loops, each served by a 200 horsepower pump which delivers 1,000 gallons per minute at 150 psi. When the demand for salt water is low, the excess pump capacity is bypassed back to San Diego Bay through pressure relief valves.

By installing crossover piping between the two loops, both loops can be served by one pump during periods of low demand, reducing pump horsepower. When the demand increases, both pumps can be operated. Savings are achieved by better matching pumping capacity to demand and eliminating the bypassing of pressurized salt water back to the Bay. This can be measured in terms of lower pump horsepower.

4.27.2 Ex Ante Load Impact Estimation

Through the installation of crossover piping, one 200 hp pump was to removed from service. An existing 200 hp pump would have been used to meet its load, as well as the load of the pump that was removed. To meet the additional loads, the load on the existing pump increased from 140 bhp to 180 bhp. The load of the pump that was to be removed was 140 bhp.

The *ex ante* demand reduction was:

$$\text{kW reduced}_{\text{ex ante}} = \frac{(\text{bhp removed - bhp added})(0.746\ \text{kW / bhp})}{0.933\ \text{efficiency rating}}$$

$$= 79.96\ \text{kW}$$

The system operates 8,760 hours per year. The *ex ante* energy saved is:

$$\begin{aligned}\text{kWh saved}_{\text{ex ante}} &= (\text{kW reduced}_{\text{ex ante}})(\text{operating hours}) \\ &= (79.96\ \text{kW})(8{,}760\ \text{hours / year}) \\ &= 700{,}424\ \text{kWh}\end{aligned}$$

4.27.3 Ex Post Load Impact Estimation

The system had been modified substantially between the time of the retrofit and the site visit. Thus, it was not possible to take *ex post* measurements on the equipment that would accurately represent the pre-retrofit condition. An analysis was done using the pump performance characteristics furnished by the customer. These were used to calculate demand savings which were, in turn, used to calculate energy savings based on schedule information.

The baseline condition is the plant as it existed before the retrofit with two 200 horsepower pumps operating 8,760 hours per year, each serving one piping loop. Excess capacity is bypassed back to the Bay.

From pump performance curves the assumptions in Table 4-74 were identified.

Table 4-74
***Ex Post* Load Impact Assumption**

Parameter	Value
At 1,000 gpm	Pressure=152 psi Brake hp=125 bhp
From motor performance data: between 100 to 200 hp	Motor efficiency=93%

The power demand will be:

$$kW_{Baseline} = \frac{(125\ bhp)(0.746\ kW/bhp)}{0.93\ efficiency\ rating} * (2\ pumps)$$

$$= (100.25\ kW/pump)(2\ pumps)$$
$$= 200.5\ kW$$

Energy consumption for the baseline is:

$$kWh_{Baseline} = (200.5\ kW/pump)(8{,}760\ hours/year)$$
$$= 1{,}756{,}709\ kWh/year$$

After the retrofit, the customer indicated that the yard was able operate on one pump 75% of the time and required two pumps 25% of the time. From the pump performance curves, when one pump is providing 2,000 gpm, the pressure will fall off to 122 psi, and the bhp requirement will be 180 bhp.

The kW demand for the retrofit is:

$$kW_{Retrofit} = (0.75)(kW_{one\ pump}) + (0.25)(kW_{two\ pumps})$$

$$= (0.75)\frac{(180\ bhp)(0.746\ kW/bhp)}{0.93\ efficiency\ rating.} + (0.25)(200.25)$$

$$= 158.4\ kW$$

The annual energy consumption is the sum of the energy use for the one pump and two pump configurations:

$$\begin{aligned} kWh_{\text{One pump}} &= (8{,}760 \text{ hours / year})(0.75)(144.39 \text{ kW}) \\ &= 948{,}623 \text{ kWh / year} \end{aligned}$$

$$\begin{aligned} kWh_{\text{Two pumps}} &= (8{,}760 \text{ hours / year})(0.25)(200.6 \text{ kW}) \\ &= 439{,}178 \text{ kWh / year} \end{aligned}$$

$$\begin{aligned} \text{kWh total}_{\text{Retrofit}} &= kWh_{\text{One pump}} + kWh_{\text{Two pumps}} \\ &= 948{,}623 + 439{,}178 \\ &= 1{,}387{,}801 \text{ kWh / year} \end{aligned}$$

The *ex post* energy savings is:

$$\begin{aligned} kWh\ saved_{ex\ post} &= kWh_{Baseline} - kWh\ total_{Retrofit} \\ &= 1{,}756{,}709 - 1{,}387{,}801 \\ &= 368{,}908\ kWh / year \end{aligned}$$

The *ex post* demand reduction is:

$$\begin{aligned} kW\ reduced_{ex\ post} &= kW_{Baseline} - kW_{Retrofit} \\ &= 200.5 - 158.4 \\ &= 42.1\ kW \end{aligned}$$

4.27.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-75 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* analysis was based on the assumption that the crossover piping would allow the yard to operate with one pump all year. Yard personnel indicate that it is necessary to operate a second pump to meet demand about 25% of the time resulting in lower *ex post* load impact estimates than the exante estimates.

Table 4-75
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	79.96	700,424	N/A
Ex post estimated gross impacts	42.10	368,908	N/A
Difference	37.86	331,516	N/A
Realization rate	0.47	0.53	N/A

4.27.5 Persistence of the Measure

The 20 year life assigned is appropriate based on industry literature.

4.28 ID No. 17504 - Compressed Air System Loss Abatement

4.28.1 Facility Information

This is a facility that manufactures and tests gas turbine power units for non-aircraft uses. The plant is located in San Diego, CA and operates 8,760 hours per year. The plant uses large amounts of compressed air throughout the facility for various purposes. The compressed air plant consists of seven (7) air compressors with a total of 2,850 horsepower that are cycled on and off as needed to meet demand.

An *ex ante* study of the compressed air system commissioned by SDG&E indicated that there were two principal sources of air loss from the system. System air leakage was measured at 685 cfm and loss due to inefficient moisture trap operation accounted for 56 cfm. It was determined that the system leakage could be reduced to 250 cfm and the loss through the moisture traps could be eliminated entirely.

An aggressive program of leak abatement was undertaken in which over 1,000 air leaks of various sizes were identified and repaired. Additionally, the system moisture traps were changed to a type which operated with less loss of air. The savings are achieved by reducing the air demand on the system which reduces compressor loading and run time.

4.28.2 Ex Ante Load Impact Estimation

An engineering analysis was performed to estimate the *ex ante* load impact estimates for this facility. The *ex ante* demand and energy impacts were 174 kW and 1,602,355 kWh, respectively.

4.28.3 Ex Post Load Impact Estimation

A site visit was made and a sample of the system modifications were verified visually. Spot measurements of power, power factor, voltage, current, and total harmonic distortion were taken for one of the compressors. A current logger was installed on this compressor and allowed to gather data over Christmas Day when the plant was closed and no equipment was operating to determine whether the system was leaking. It was arranged with the plant personnel to disable all the air compressors except the one being monitored on Christmas Day.

The key research assumption is that any compressor operation in the system during the holiday schedule would be due to leakage or moisture trap losses and the make-up pressure must be furnished by the single compressor.

With all equipment shut down over Christmas Day, it was determined through monitored data that the average compressor demand was 116.4 kW. These data, however, cannot be directly converted into the load impacts of the compressed air system improvements. Rather, they were an indicator that the compressed air system had leaks.

A review of the project file showed that the pre-retrofit analysis actually recommended measures which would reduce compressed air leakage from 685 cfm to 250 cfm. This key assumption was used to estimate the demand reduced due to the measures:

$$kW\ reduced_{ex\ post} = \frac{(dCFM)(Cp)(p)(dT)}{Ec}$$

where,

$dCFM$ = *air loss reduction, SCFM*

Cp = *Specific heat of air at constant pressure, 0.24 Btu/#-F*

p = *air density at site, 0.0736 #/cf*

dT = *temperature differential across compressor (559° F - 70° F)*

Ec = *compressor mechanical efficiency (60%)*

Thus, the *ex post* kW reduced was:

$$kW\ reduced_{ex\ post} = \frac{(435)(0.24)(0.0736)(489)}{(0.6*2545)}$$

$$= 110.14\ kW$$

The *ex post* energy saved was:

$$kWh\ saved_{ex\ post} = (kW\ reduced_{ex\ post})(operating\ hours)$$

$$= (110.14\ kW)(8,700)$$

$$958,203\ kWh$$

4.28.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-76 summarizes the *ex ante* and *ex post* load impact estimates. The low realization rates for demand and energy are the result of taking the wrong level of reduction in air loss in the *ex ante* estimate. An *ex ante* analysis of the compressed air system showed an average air loss of 741 cfm. It also showed that this could be reduced to 250 cfm. The *ex ante* load impact analysis assumed that the air loss would be reduced to zero cfm, resulting in overstatement of the load impacts of the measure.

Table 4-76
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	174.0	1,602,355	N/A
Ex post estimated gross impacts	110.1	958,203	N/A
Difference	63.9	644,152	N/A
Realization rate	0..63	0.60	N/A

4.28.5 Persistence of the Measure

The benefits from replacement of the moisture traps will last for the 5 year life assigned. The savings from the leak abatement program will last as long as the program is continued, but if the program is discontinued, i.e., leaks are not regularly repaired, the savings will diminish. This component of the savings will likely have reduced persistence.

4.29 ID No. 18012 - Variable Speed Drives On Injection Molders

4.29.1 Facility Information

This is a manufacturing facility in National City , CA which produces plastic parts. The plant operates 24 hours per day, 6 days per week, 52 weeks per year for a total of 7,488 hours per year. The plant is equipped with nine injection molding machines which produce the parts.

The injection molding machines are electro-hydraulic devices. In normal operation, the hydraulic pump operates at full load continuously with excess oil being bypassed back to the reservoir. This represents a waste of energy that could be reduced.

By retrofitting the pump drive with a variable speed drive (VSD) that adjusts pump output so little or no oil is bypassed, the waste of energy can eliminated.

Six of the nine molders were fitted with VSD's. The principal savings are from reduced energy consumption by the pump motors. Analysis of utility bills shows that the peak demand was also reduced by an average of 36.8 kW over the first year of operation after the retrofit. *Ex post* measurements have shown that the molders that were retrofitted with VSD units have lower cycle times by 5 seconds per cycle. This means that each machine can produce 16% more parts, about 750 parts per day with a value of $875.

4.29.2 Ex Ante Load Impact Estimation

The *ex ante* load impacts of this measure were estimated through an engineering analysis of the motor loads associated with the six injection molding machines affected by the measure. Motor load tests were conducted to gather data for the *ex ante* load impact estimates.

The *ex ante* load impact estimates were 63 kW and 471,744 kWh.

4.29.3 Ex Post Load Impact Estimation

Ex ante data on the performance and energy consumption of the molders was included in Rebate Application Package. This information was used to establish a baseline. Post-retrofit data were gathered from study data provided by SDG&E for similar machines. The peak demand was taken from utility bills for the year before and the year after the retrofit.

The baseline for this measure is the plant operating with no variable speed drives on its molding machines. Table 4-77 shows the energy use for the baseline injection molders.

Table 4-77
Baseline Injection Molder Energy Use

#	Machine Type	Tons	HP	kWh/hr Before	kWh/hr After	Saving kWh/hr	Saving kWh/yr
1	Kawaguchi	265	50	25	12	13	97,344
2	Kawaguchi	365	50	28	12	16	119,808
3	Kawaguchi	220	40	21.5	9.5	12	89,856
4	Toshiba	310	50	24.5	12	12.5	93,600
5	Van Dorn	230	40	22	14	8	59,904
6	Vistar	500	40/50	49	25	24	179,712
	Totals			170	84.5	85.5	640,224

Table 4-78 shows the *ex post* load impacts by time-of-use period. This table typically incorporates average kW values, thus the coincident impacts may not match the *ex post* kW reduced shown above.

Table 4-78
kW and kWh Impacts by Time-of-Use Period

Costing Period	Average kW Reduced	kW Reduced Coincident with System Peak Period	kW Adjustment Factor	kWh Savings	kWh Adjustment Factor
Summer On-peak	85.5	85.5	1.00	63,441	0.10
Summer Semi-peak	85.5		1.00	81,567	0.13
Summer Off-peak	62.4		0.73	123,302	0.19
Winter On-peak	85.5	85.5	1.00	37,706	0.06
Winter Semi-peak	85.5		1.00	163,391	0.26
Winter Off-peak	62.4		0.73	170,726	0.27
			Totals	640,133	1.01

4.29.4 Comparison of Ex Ante and Ex Post Impact Estimates

Table 4-79 summarizes the *ex ante* and *ex post* load impact estimates. The *ex ante* estimates of demand and energy savings were taken from vendor's literature and seem to be somewhat conservative. *Ex post* energy savings were derived from a study done by Efficient Industrial Control Systems on the effect of VSD's on energy use of injection molders. In the *ex ante* analysis, the vendor used a technique in which the energy consumption is measured over a period of time (30 minutes or more) and this energy (kWh) was divided by the time period to get a value for kWh per hour. This technique is not appropriate for calculating changes in peak demand. The realization rate for demand reduction is 0.58 and for energy savings is 1.36. No adjustment was made in the *ex ante* analysis for the increased production of the machines after retrofit, so none was made in the *ex post* analysis to allow direct comparison of the two estimates.

Table 4-79
Demand and Energy Impact Summary

	Demand (kW/Year)	Energy (kWh/Year)	Gas (Therms/Year)
Ex ante estimated impacts	63.0	471,744	N/A
Ex post estimated gross impacts	36.8	640,244	N/A
Difference	26.2	168,500	N/A
Realization rate	0.58	1.36	N/A

4.29.5 Persistence of the Measure

In the December 1988 edition of the *ASHRAE Journal*, Table 1 in the article, *Service Lives*, lists a service life of 16 years for Process Adjustable Speed Drives. This is somewhat longer than the 10 years used by the utility. Thus, the 10 year life estimated for the project is an appropriate and conservative figure.

5 MOTOR MEASURES

The methodology for estimating the *ex post* load impacts of industrial motors installed under SDG&E's 1995 Industrial Energy Efficiency Incentives Program is discussed in Section 3.3. This section presents the results of the evaluation.

5.1 GROSS LOAD IMPACTS - MOTORS

A survey, both on-site and telephone, was conducted to verify operating hours and to gain an understanding of the motor load characteristics. Table 5-1 shows that the study sample disposition was in compliance with the requirements of Table C-5 of the *M&E Protocols* that at least 70 percent of the total kW and kWh for the end use element must be subjected to the *ex post* evaluation of load impacts.

Table 5-1
Study Sample

	Participants	Surveyed	Percent Surveyed
No. Motors	81	48	59%
No. Horsepower	2,138.00	1606.5	75%
kW Reduced	38.66	28.53	74%
kWh Saved	221,110	167,148	76%

A summary of the gross load impacts of motor measures installed under the IEEI Program are shown in Table 5-2. Appendix A presents a detailed worksheet of motors included in the study.

Table 5-2
Summary of Gross IEEI Motor Load Impacts
Survey Participants

	Ex Ante	*Ex Post*	Realization Rate
kWh Saved	167,148	169,323	1.01
kW Reduced	28.53	31.33	1.10

Appendix A contains detailed worksheets used to estimate the motor load impacts.

5.2 NET-TO-GROSS - MOTORS

The net-to-gross ratio was estimated for surveyed motors based on customer reported responses during the survey. The responses were categorized into two broad categories: (1) always buy energy efficient motors; and (2) SDG&E's program/rebate made a difference. A net-to-gross ratio of zero was assigned to the first category and a net-to-gross of 1.0 was assigned to the latter, as shown in Table 5-3.

Table 5-3
Net-To-Gross Categories
Industrial Energy Efficient Motors

Category	Net-To-Gross Ratio
Always buy energy efficient motors	0.00
SDG&E's program/rebate made a difference	1.00
No response	N/A
Total	

By applying the net-to-gross ratios assigned per Table 5-3 to the gross energy and demand impacts, the net impacts were estimated. The Program net-to-gross ratio for industrial motors was estimated by dividing net impacts by gross impacts, as shown in Table 5-4.

Table 5-4
Net-To-Gross Ratio for Industrial Motors

Values for respondents of net-to-gross interview	kW	kWh
Ex post gross	25.71	132,025
Ex post net	7.07	38,041
Net-to-gross	0.28	0.29

5.3 PROGRAM LOAD IMPACTS FROM MOTOR MEASURES

The Program *ex post* load impacts attributable to industrial motor measures was calculated by applying the realization rate estimated in Section 5.1 and the net-to-gross ratios estimated in Section 5.2 to the *ex ante* gross load impacts for the program participants. These results are shown in Table 5-5.

Table 5-5
Industrial Motors Program Load Impacts

	kWh	kW
Ex ante estimate	221,110	38.66
Realization rate	1.01	1.10
Gross ex post impacts	223,987	42.45
Net-to-gross ratio	0.29	0.28
Net program impacts	64,537	11.68

Appendix C

Table 6
Results Used to Support PY95 Second Earnings Claim

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY95 SECOND EARNINGS CLAIM FOR THE INDUSTRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, FEBRUARY 1997, STUDY ID NO. 962

Designated Unit of Measurement: LOAD IMPACTS PER SQUARE FOOT PER 1,000 HOURS OF OPERATION
END USE: INDOOR LIGHTING ONLY

				5. A. 90% CONFIDENCE LEVEL				5. B. 80% CONFIDENCE LEVEL			
				LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND
1. Average Participant Group and Average Comaprison Group		PART GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP
A. Pre-install usage:	Pre-install kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pre-install kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW/ designated unit of measurement	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh/ designated unit of measurement	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B. Impact year usage:	Impact Yr kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kW/designated unit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh/designated unit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. Average Net and Gross End Use Load Impacts		AVG GROSS	AVG NET	AVG GROSS	AVG GROSS	AVG NET	AVG NET	AVG GROSS	AVG GROSS	AVG NET	AVG NET
	A. i. Load Impacts - kW	5.52	4.92	2.97	8.08	2.64	7.19	3.53	7.52	3.14	6.69
	A. ii. Load Impacts - kWh	46251	41163	24,839	67,662	22,107	60,220	29,564	62,938	26,312	56,014
	B. i. Load Impacts/designated unit - kW	0.155	0.138	0.083	0.227	0.066	0.155	0.099	0.211	0.099	0.155
	B. ii. Load Impacts/designated unit - kWh	0.31	0.28	0.30	0.33	0.30	0.32	0.30	0.32	0.31	0.32
	C. i. a. % change in usage - Part Grp - kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. b. % change in usage - Part Grp - kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. a. % change in usage - Comp Grp - kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. b. % change in usage - Comp Grp - kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D. Realization Rate:	D.A. i. Load Impacts - kW, realization rate	56.3%	60.3%	55.9%	56.7%	29.0%	91.7%	56.0%	56.6%	35.9%	84.8%
	D.A. ii. Load Impacts - kWh, realization rate	118.4%	125.5%	63.6%	173.2%	-4.9%	125.6%	75.7%	161.1%	9.5%	111.2%
	D.B. i. Load Impacts/designated unit - kW, real rate	39.7%	42.6%	21.3%	58.2%	23.1%	62.2%	25.4%	37.5%	27.4%	57.8%
	D.B. ii. Load Impacts/designated unit - kWh, real rate	78.4%	83.0%	75.4%	81.4%	80.3%	85.7%	76.0%	80.7%	80.9%	85.1%
3. Net-to-Gross Ratios		RATIO		RATIO	RATIO			RATIO	RATIO		
	A. i. Average Load Impacts - kW	89.0%		N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	89.0%		N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	89.0%		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	89.0%		N/A	N/A			N/A	N/A		
	C. i. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kW	N/A		N/A	N/A			N/A	N/A		
	C. ii. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kWh	N/A		N/A	N/A			N/A	N/A		
4. Designated Unit Intermediate Data		PART GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP
	A. Pre-install average value	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. Post-install average value SQUARE FOOTAGE	35,554	N/A	20,287	50,820	N/A	N/A	23,656	47,451	N/A	N/A
	B. Post-install average value HOURS OF OPERATION	4,149	N/A	3,649	4,649	N/A	N/A	3,759	4,539	N/A	N/A
6. Measure Count Data		NUMBER									
	A. Number of measures installed by participants in Part Group	***									
	B. Number of measures installed by all program participants in the 12 months of the program year	***									
	C. Number of measures installed by Comp Group	N/A									
7. Market Segment Data		SIC	PERCENT	SIC	PERCENT	SIC	PERCENT	SIC	PERCENT	SIC	PERCENT
	Distribution by 3 digit SIC - Industrial	152	1.0%	271	0.8%	306	3.8%	361	2.3%	382	2.5%
		154	4.3%	273	1.0%	308	1.8%	366	4.6%	384	5.1%
		171	13.7%	274	0.5%	341	5.1%	367	7.9%	394	3.1%
		173	0.3%	275	0.8%	344	1.5%	369	0.3%	399	3.3%
		179	1.8%	277	2.5%	349	3.8%	372	6.4%		
		251	0.5%	279	0.3%	357	8.7%	373	0.8%		
		267	0.3%	282	1.3%	359	2.0%	381	8.1%		

NOTE: The net-to-gross ratio applied here was derived in the 1995 CEEI Program Load Impact Evaluation (Study Id No. 959)
*** Due to the volume of information, Measure Count Data is presented on the following pages.

SECTOR=IND STUDY=LIGHTING

OBS	NEW_DESC	NEW_QTY	CUST_CST
1	CF-13Q Hardwire Fxtr	3	$75
2	Delamp (2 ft)	55	$-91
3	Delamp (4 ft)	542	$339
4	Electronic Bal (8ft)	169	$1,234
5	Exit Sign Kit (LED)	962	$-928
6	Exit Sign 14W CF	12	$-428
7	Hybrid Bal (4ft/21a)	628	$2,079
8	Install Occupancy sensors in restrooms	4	$96
9	Install Occupancy Sensors	23	$552
10	Motion Sensors	1	$130
11	Occupancy sensor	43	$1,032
12	Occupancy Sensors	6	$78
13	Opt Refl(2ft/1dlamp)	65	$164
14	Opt Refl(4ft/1dlamp)	2,510	$2,425
15	Opt Refl(4ft/2dlamp)	1,370	$1,294
16	Opt Refl(8ft/1dlamp)	46	$708
17	T-8 El Bal (4ft/21a)	6,808	$1,889
18	T-8 El Bal (4ft/31a)	1,869	$5,733
19	T-8 El Bal (4ft/41a)	847	$1,095
20	1CFQ13H	57	$496
21	1CF18H	2	$94
22	1FO25/1B3-EL	2	$58
23	1FO96/.5B8-T8	2	$24
24	1XLED2	10	$223
25	13W CF lamp	213	$947
26	17T8 Bal (2ft)	110	$431
27	17T8 Lamp (2ft)	263	$175
28	18W CF lamp	6	$78
29	2CFQ13H	90	$2,808
30	2CFQ18H	23	$718
31	2CF9H	2	$82
32	2FO32/1B4T8-2L	12	$172
33	2FO32/1B4T8-2L/1R8-D1	171	$1,772
34	2FO32/1B4T8-2L/2R4-DO	1	$39
35	2FO96/1B8-T8	4	$50
36	2F72/1B6-EL	2	$117
37	31T8 U-Bal (2ft)	225	$1,210
38	31T8 U-Lamp (2ft)	438	$1,149
39	32 Watt lamp	12,515	$546
40	4FO32/1B4T8-4L	234	$941
41	4FO32/1B4T8-4L/1R8-DO	245	$2,360
42	4FO32/1B4T8-4L/2R4-D2	108	$4,770
43	6FO32/2B4T8-3L/2R4-DO	97	$4,023
44	7W CF lamp	48	$624

SAN DIEGO GAS & ELECTRIC
M&E PROTOCOLS TABLE 6 - RESULTS USED TO SUPPORT PY95 SECOND EARNINGS CLAIM FOR INDUSRIAL ENERGY EFFICIENCY INCENTIVES PROGRAM
FIRST YEAR LOAD IMPACT EVALUATION, FEBRUARY 1997, STUDY ID NO. 962

Designated Unit of Measurement: LOAD IMPACTS PER HORSEPOWER
End Use: Industrial Motors

				5. A. 90% CONFIDENCE LEVEL				5. B. 80% CONFIDENCE LEVEL			
				LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND
1. Average Participant Group and Average Comparison Group		PART GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP
A. Pre-install usage:	Pre-install kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pre-install kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kW/ designated unit of measurement	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Base kWh/ designated unit of measurement	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B. Impact year usage:	Impact Yr kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kW/designated unit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Impact Yr kWh/designated unit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. Average Net and Gross End Use Load Impacts		AVG GROSS	AVG NET	AVG GROSS	AVG GROSS	AVG NET	AVG NET	AVG GROSS	AVG GROSS	AVG NET	AVG NET
	A. i. Load Impacts - kW	0.653	0.180	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. ii. Load Impacts - kWh	3,527.558	1,016.396	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A. iii. Load Impacts - therm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. i. Load Impacts/designated unit - kW	0.020	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. ii. Load Impacts/designated unit - kWh	5,404.500	32.442	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. iii. Load Impacts/designated unit - therm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. a. % change in usage - Part Grp - kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. i. b. % change in usage - Part Grp - kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. a. % change in usage - Comp Grp - kW	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C. ii. b. % change in usage - Comp Grp - kWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D. Realization Rate:	D.A. i. Load Impacts - kW, realization rate	1.098	0.314	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. ii. Load Impacts - kWh, realization rate	1.013	0.311	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.A. iii. Load Impacts - therm, realization rate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. i. Load Impacts/designated unit - kW, real rate	1.098	0.425	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. ii. Load Impacts/designated unit - kWh, real rate	0.922	0.374	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	D.B. iii. Load Impacts/designated unit - therm, real rate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3. Net-to-Gross Ratios		RATIO		RATIO	RATIO			RATIO	RATIO		
	A. i. Average Load Impacts - kW	0.275		N/A	N/A			N/A	N/A		
	A. ii. Average Load Impacts - kWh	0.288		N/A	N/A			N/A	N/A		
	A. iii. Average Load Impacts - therm	N/A		N/A	N/A			N/A	N/A		
	B. i. Avg Load Impacts/designated unit of measurement - kW	0.425		N/A	N/A			N/A	N/A		
	B. ii. Avg Load Impacts/designated unit of measurement - kWh	0.374		N/A	N/A			N/A	N/A		
	B. iii. Avg Load Impacts/designated unit of measurement - therm	N/A		N/A	N/A			N/A	N/A		
	C. i. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kW	N/A		N/A	N/A			N/A	N/A		
	C. ii. Avg Load Impacts based on % chg in usage in Impact year relative to Base usage in Impact year - kWh	N/A		N/A	N/A			N/A	N/A		
4. Designated Unit Intermediate Data		PART GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP	PART GRP	PART GRP	COMP GRP	COMP GRP
	A. Pre-install average value	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B. Post-install average value	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6. Measure Count Data		NUMBER									
	A. Number of measures installed by participants in Part Group	48									
	B. Number of measures installed by all program participants in the 12 months of the program year	81									
	C. Number of measures installed by Comp Group	N/A									

Designated Unit of Measurement: LOAD IMPACTS PER HORSEPOWER
End Use: Industrial Motors

7. Market Segment Data		SIC	PERCENT
	Distribution by 3 digit SIC - Commercial/Industrial	144	9.70
		154	1.20
		201	1.20
		204	1.20
		205	2.40
		251	1.20
		265	1.20
		267	1.20
		281	1.20
		285	1.20
		308	2.40
		327	10.90
		336	2.40
		341	3.60
		344	1.20
		347	1.20
		351	4.80
		353	3.60
		357	2.40
		358	3.60
		359	3.60
		365	23.00
		367	4.80
		372	6.00
		394	2.40
		399	1.20
		509	1.20

Appendix D

Appendix D

Table 7
Data Quality and Processing Documentation

Table 7

Data Quality and Processing Documentation for Indoor Lighting

A. Overview Information

1. **Study Title and Study ID:** 1995 Industrial Energy Efficiency Incentives (IEEI) Program: First Year Load Impact Evaluation, February 1997, MPAP-95-P98-962-R708, Study ID No. 962.

2. **Program, Program Year, and Program Description:** San Diego Gas & Electric offers the PY95 Commercial/Industrial/Agricultural (C/I/A) Energy Efficiency Incentives (EEI) Program to help customers reduce energy costs and increase energy efficiency at their facilities. The C/I/A EEI Program, supported through audit programs, energy services representatives, and account executives, provide cost-effective DSM energy savings when existing customers have retrofit opportunities. SDG&E has three main market delivery mechanisms for providing incentives for retrofit or replace-on-burnout applications: (1) Commercial/Industrial (C/I) Incentives Program, (2) Power to Save Program, and (3) Commercial Rebates Program. Through this marketing strategy, SDG&E is provided the flexibility needed to encourage the adoption of energy efficient measures that would not otherwise be installed by customers due to economic market barriers.

3. **End Uses and/or Measures Covered:** The end use covered by this report is indoor lighting.

4. **Methods and Models Used:** The main statistical model used is ordinary least squares regression analysis, applied at the customer level for participants. See the modeling section of the report for a complete discussion on the models used.

5. **Participant and Comparison Group Definition:** For the load impact analysis of the lighting end use, a participant was defined as a customer or a group of customers with a common contract for DSM measures who completed installation by December 31, 1995. There was no comparison group used in this study.

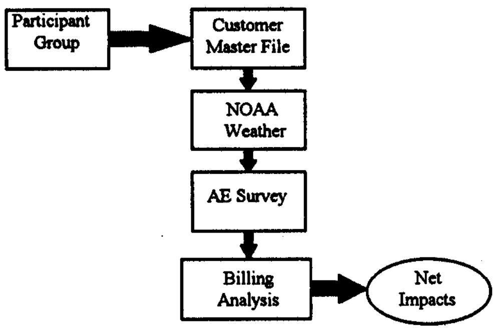
6. **Analysis Sample Size:**

	Participants
Study Group	50
No. of Measures Installed	30,843
Average No. of Billing Months	27.9

B. Database Management

1. **Data Flow Chart:** The following diagram illustrates the relationship of the data elements used in the analysis:

Data Flow Diagram



2. **Data Sources:** Data for the impact analysis were obtained from the following major sources:
   a. Customer name, address, affected square footage, lighting hours of operation, and installation date from the program tracking database;
   b. Consumption history from the Customer Master File;
   c. Information on other changes for all assigned customers in the participant group were obtained from a survey conducted on the account executives;
   d. Hourly weather data from NOAA files for the SDG&E climate zones: Maritime, Coastal and Transitional climate zones.

3. **Data Attrition:** An attempt was made to use all participants in the regression analysis.

Status	Participants
Starting Study Group	56
Billing Data Available	55
Sufficient Pre/Post Data	50
Customers Involved Only In The Retrofit Program	35
Customers With No Overlapping Contracts	34

4. **Data Quality Checks:** The data sets used in the regression analysis were merged in SAS by the appropriate key variables. Counts of data before and after data merges were verified to ensure accurate merging. Surveys, billing data and other relevant information were merged by Premise ID number. Weather data were merged by billing cycle and climate zone.

5. **Data Collection:** All data collected was used.

C. Sampling

1. **Sampling Procedures and Protocols:** An attempt to use all program participants with the end use of interest was made.

2. **Survey Information:** A total of 1777 surveys for both commercial and industrial customers were sent out to all SDG&E Marketing account executives with a cover letter explaining the survey. Approximately 9 percent (5 out of 56 participants) of the industrial lighting participants were reported to have some type of change to the company (hiring, layoffs, elimination of shifts, addition of shifts, or other) or changes to equipment (HVAC, lighting, process, refrigeration, or other). This information was incorporated in the analysis for lighting.

3. **Statistical Descriptions:**

Lighting Energy Load Impacts

Savings greater than 1%	Parameter	No sqft data	Have sqft Data	Grand Total
Industrial Participants				
NO	Total Estimated Impact (kWh per month)	5,418	-16,240	-10,822
	Variance of Estimate	173,113,388	156,491,937	329,605,325
	Total Database *Ex Ante* Estimate (kWh per month)	1,683	701	2,384
	Average Annual Hours	8,372	8,760	8,458
	Total Lighted Square Footage	0	35,000	35,000
	Sample Size	7	2	9
YES	Total Estimated Impact (kWh per month)	30,252	-119,481	-89,229
	Variance of Estimate	183,894,292	1,130,665,402	1,314,559,694
	Total Database *Ex Ante* Estimate (kWh per month)	3,660	110,574	114,233
	Average Annual Hours	7,278	4,149	4,425
	Total Lighted Square Footage	0	1,102,161	1,102,161
	Sample Size	3	31	34
	Load Impact (kWh per square foot, per 1,000 hours)		-.3135	
	Realization Rate Based On Sample *Ex Ante* Estimates	-827%	108%	78%
	Commercial Net-to-Gross[1]		**89.0%**	

[1] Obtained from the 1995 Commercial Energy Efficiency Incentives Program, First Year Load Impact Evaluation, February 1997 (Study ID No. 959).

D. Data Screening and Analysis

1. **Treatment for Outliers and Missing Data:** Outliers were determined using the RMSE criterion and the 1% Savings criterion (see page 3-5).

   Customers with missing square footage were discarded in the calculation of the final load impacts but were subjected to the regression analysis. Customers with missing billing information were deleted from the analysis if the missing data caused the participant to fail the billing data requirement.

2. A trend variable was included to account for any changes that occurred outside the DSM activity but could potentially affect the load impact estimate. See the discussion on the Non-Weather/Non-DSM Portion of the Regression Equation on page 3-1.

3. See above item B.3. on Data Attrition.

4. **Regression Statistics:** See item C.3.

5. **Specification:**
   a. Individual regressions were estimated for each customer in the participant group. This accounts for customer heterogeneity.
   b. Weather and trends were accounted for in each customer regression analysis. See the General Model Section on pages 3-1 and 3-2.
   c. No explicit accounting for self-selection bias was used in the model although SDG&E completed an alternative net-to-gross study that accounts for self-selection.
   d. SDG&E does not believe that any regressors of any consequence have been omitted from the analysis.
   e. This is discussed on page 3-4 for the lighting end use.

6. **Errors in Measuring Variables:** This was not addressed.

7. **Autocorrelation:** This was not accounted for in the model specification. It is SDG&E's opinion that when autocorrelation is not corrected, the analysis does not produce a biased estimate but may cause the estimator to be inefficient.

8. **Heteroskedacity:** With ordinary least squares regression analysis when applied at the customer level, the variance of the regression disturbance terms can vary at the customer level, and the estimator will still be efficient.

9. **Collinearity:** PROC REG in SAS will generate errors indicating severe collinearity problems caused by collinearity in the model. No errors were noted in the SAS output.

10. **Influential Data Points:** Influential data points were determined based on the RMSE criterion and the 1% Savings criterion described on page 3-5.

11. **Missing Data:** Participants that did not meet the billing data requirements were eliminated from the analysis. Although some sample points did not have square footage, they remained part of the regression analysis. Their savings estimates, however, were not used in the calculation of the DUOM.

12. **Precision:** Standard errors are reported in the results tables provided above.

E. Data Interpretation and Application:

1. **Calculation of Net Impacts:** Method C was used to determine net impacts.

2. The M&E Protocols do not require a comparison group to determine the net-to-gross ratio for the load impacts of industrial end uses. SDG&E has derived a net-to-gross ratio in its 1995 Commercial Energy Efficiency Incentives Program First Year Load Impact Evaluation, February 1997, Study ID No. 959. This was the net-to-gross ratio that was applied to derive the net-to-gross ratio for the industrial lighting load impacts. SDG&E chose to use the net-to-gross ratio developed for the commercial lighting end use because of the small number of industrial participants and the similarity of the application of the lighting measures between the commercial participants and the industrial participants.

M&E PROTOCOLS TABLE 7
DATA QUALITY AND PROCESSING DOCUMENTATION
For 1995 Industrial Energy Efficiency Incentives Program
First Year Load Impact Evaluation
February 1997
Study ID No. 962

A. OVERVIEW INFORMATION

1. **Study Title and Study ID:** 1995 Industrial Energy Efficiency Incentives Program: First Year Load Impact Evaluation, Process and Motor Measures, February 1997, Study ID No. 962.

2. **Program, Program Year(s), and Program Description (design):** 1995 Industrial Energy Efficiency Incentives Program for the 1995 program year. The Program is designed to help industrial customers control energy costs by providing incentives for the installation of energy efficient equipment at their facilities.

3. **End Uses and/or Measures Covered:** Industrial process and motor measures..

4. **Methods and models used:** Site-specific simplified engineering with verified inputs.

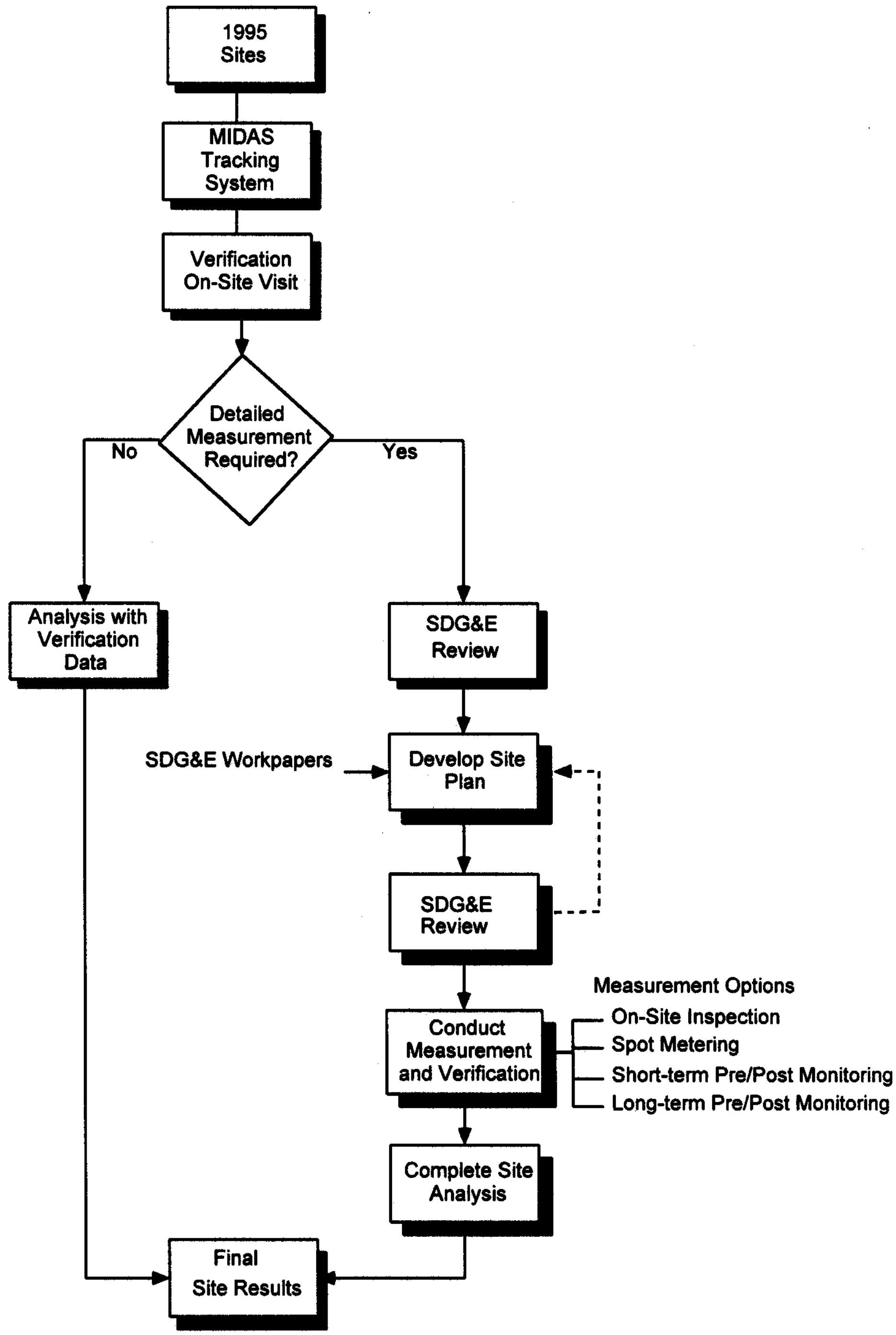
5. **Participant and comparison group definition:** For the load impact analysis, the participants in the 1995 Industrial Energy Efficiency Incentives Program are defined as having at least one of the aforementioned measures installed. A comparison group was not required for this evaluation.

6. **Analysis sample size:**

Electric Participant Sample for 1995 Industrial Energy Efficiency Incentives Program			Gas Participant Sample for 1995 Industrial Energy Efficiency Incentives Program		
Measure Type	**No. of Participants**	**No. of Measures**	**Measure Type**	**No. of Participants**	**No. of Measures**
Process	21	24	**Process**	3	4
Motor	34	48	**Motor**	0	0
Total	55	72	**Total**	4	4

B. DATABASE MANAGEMENT

1. Flow Charts:



2. **Data sources:** the data came from the following sources:

- Customer name, address, appliance saturation, installed measures, and participation date from the program tracking database.
- Electric and gas consumption history, where applicable, from the Customer Master File.
- Site-specific data gathered on-site through measurements and monitoring..
- *Ex ante* engineering assumptions and analyses from program project files.
- *Ex post* on-site survey data.

3. **Data Attrition:**

   a. **Participant Sample - Load Impact Analysis**

   No attrition.

   b. **Nonparticipant Sample - Load Impact Analysis**

   Not applicable.

4. **Data Quality Checks**

   Not applicable for this evaluation.

5. **All data collected** for this analysis were utilized.

C. SAMPLING

1. **Sampling procedures and protocols:** A census of process measure participants was conducted. Sampling of the motor measure participants was taken to assure 70% of the total program energy and demand levels were attained per the M&E Protocols.

2. **Survey information:** On-site inspections were conducted that included a review of operations logs, interviews of on-site staff, and measurements of the measures in operation.

3. **Statistical Descriptions:** Not applicable.

D. DATA SCREENING AND ANALYSIS

1. **Outliers:** Not applicable.

   Missing data points: Not applicable.

   Weather adjustments: Not applicable.

2. **"Background" variables:** Not applicable.

3. **Screening procedures:** Not applicable.

4. **Regression statistics:** Not applicable.

5. **Specification:**

   a. Not applicable.

   b. Not applicable.

   c. Not applicable.

   d. Not applicable.

   e. Not applicable.

6. **Error in measuring variables:** On-site observation of measure installation and on-site measurements were taken to mitigate possible errors from project files.

7. **Autocorrelation:** Not applicable.

8. **Heteroskedasticity:** Not applicable.

9. **Collinearity:** Not applicable.

10. **Influential data points:** Not applicable.

11. **Missing Data:** Not applicable.

12. **Precision:** Not applicable. Standard errors and other statistically based measures of precision are not applicable to the site-specific engineering analyses employed in this analysis.

E. <u>DATA INTERPRETATION AND APPLICATION</u>

1. **Calculation of net impacts:** Not applicable.

2. **Processes, choices made and rationale for E.1:** Not applicable.