SEATTLE CITY LIGHT's INDUSTRIAL RETROFIT DEMONSTRATION PROJECT USES QUASI-EXPERIMENTAL RESEARCH DESIGN AND METERING TO MEASURE SAVINGS

Tim M. Newcomb
Seattle City Light

INTRODUCTION

A primary objective of Seattle City Light's Industrial Retrofit Demonstration Project (IRD) is to measure the effect of efficient retrofits on plant electrical load. The Utility provides financial incentives to participating firms and undertakes the metering and analysis needed to measure the impact of new equipment on electricity use. The project manager works with industrial auditors from the Utility who suggest retrofit projects, evaluate probable conservation potential, review research analyses and inspect the installations. Retrofit projects to date include a more efficient refrigeration system, ceramic furnace insulation, electrical monitoring and analysis of a refrigeration system, vestibule loading doors in a cold storage plant, interior high pressure sodium lighting, efficient motors, and power factor improvement. The impact analyses typically require more than half of all the time spent on a project and make use of mainframe statistical packages with interactive graphics, database libraries, and macro programming software to save time and manage large databases.

DEFINING RETROFITS, LOAD TIME PERIODS, AND VARIABLES IMPACTING LOADS

Each impact analysis of an industrial retrofit project starts with the same basic model in mind:

> The targetted electricity end-use load in plant X is a function of production level, the presence or absence of an efficient retrofit, and exogenous variables such as temperature or air infiltration levels which affect that end-use.

Each industrial plant is treated as a unique case, because of the variety of retrofit types and the great differences among these plants in both production methods and retrofit characteristics.

The definition of a conservation measure is dependent on the timing of measures installed in a plant. If several types of equipment which affect the same end use are installed at the same time, then for purposes of research these become one measure. The municipal aquarium is considering the installation of efficient motors and efficient pumps in an aquarium. Since the motors which drive the pumps must be sized to fit the pumps and vice versa, these two components are installed at the same time and constitute one conservation measure for research purposes, rather than two measures.

If several conservation measures are to be installed in one site, then agreements should be made to install the measures sequentially with a hiatus in between so that each measure is clearly defined in time and new baselines can be calculated after each step. This is especially true where measures affect the same electricity load. A cold storage plant is undertaking three separate measures to conserve electricity: replacing the refrigeration system, replacing indoor mercury vapor lighting with high pressure sodium lighting, and installing vestibule loading doors to cut down on the infiltration of warm air during loading. Each of these measures directly impacts refrigeration load, and therefore, we stipulated that the measures be installed separately with brief periods in between installations so we could collect data on the impacts one at a time.

Once satisfactory definitions of measures have been reached, the locations of electrical circuits which completely contain the electric load powering the old and the new equipment for each measure must be determined. Recording meters which measure demand and energy (KW), and if necessary power factor (KVAR) are connected to record hourly data for periods of several months before and after the retrofit occurs. This process of leaving recording meters in place can be simplified where a motor is being replaced with a more efficient model. In this case, a current transformer can be used to measure the voltage, amperage and if necessary power factor under different load conditions during one or two visits to the plant.

In the case of the cold storage plant the end-use of greatest interest is the refrigeration load. Since the old refrigeration system is comprised of seven separate reciprocating compressors, and the feeder lines to these machines are not attached to one common line, seven separate hourly recorders would have to be installed to measure the pre-retrofit load directly. This is too expensive, but it is possible to record current and voltage leading to all the other loads with three recorders. In this way, total plant load, lighting load and "other loads" can be measured, and at the same time the refrigeration load can be measured simply by subtracting lighting and "other loads" from the total, all at a more reasonable cost.

The definition of production shifts is likely to be out of the control of the researcher. Fortunately, most of the plants we have worked with have their own computerized production systems which record volume of product. These volumes are totalled by each shift, or by day, or by each separate use of the dominant piece of equipment such as a furnace. The problem is to aggregate the hourly electric load data from the recording meters so that it matches the time periods for the production data. For an eight hour shift in the bottling plant, the production data in ounces of soft drink must be matched with the correct eight hours of electric load to arrive at the kilowatt-hours per ounce of drink produced.

Therefore, the smallest unit of analysis is one shift of eight hours, and not one hour of load data. This in turn means that a longer period of time will have to be studied to demonstrate conservation impacts because fewer time units are available for analysis.

The definition of the "other" exogenous variables which will affect the electric load in question can cause serious problems for two reasons. First it is not necessarily obvious which factors in addition to the retrofit and production rate will affect electric load. In the second place, it may not be possible to get a real measure for the variable which is believed to have an influence. For example, a major source of refrigeration load at the cold storage plant is infiltration of warm air during loading and unloading of stored materials. Mechanical counters were installed on the loading doors so that the daily variation in door openings could be recorded. Regression analyses of refrigeration load against daily outdoor temperatures and door opening frequencies yield a multiple R^2 of about 0.40 and openings are a significant factor in the refrigeration load curves during working hours.

RESEARCH DESIGNS TO MEASURE CONSERVATION IMPACTS

An example of a research design which is made possible by special equipment is the installation of capacitors to correct low power factor at a bottling plant. The plant uses six reciprocating compressors to cool water before bottling. The capacitors were installed at the motors and equipped with manual switches. Since the switch position did not interfere with the operation of the compressors, it was possible to alternately turn the capacitors on and off over a period of one month. Water temperature and production levels did not vary greatly during this test period. This is referred to as an equivalent times samples design by Campbell and Stanley (1963).

Figure 1 shows the power factor, energy load and volume of product at the bottling plant and illustrates both the types of data collected in IRD research and the equivalent time samples approach to measuring impact. The periods during which the capacitors were switched on are clearly associated with higher power factor at the plant. A regression analysis of power factor using shift production, presence of capacitors, and water temperatures as independent variables showed the capacitor increased power factor 5.5 percent with a T-test value of 10.1.

Energy management systems in industry could be evaluated effectively by installing the monitoring side of the equipment and obtaining accurate readings of electricity loads and system parameters before the new controls are used. By this means a very accurate description of the state of the system can be documented for subsequent comparison with loads and conditions once new controls are used. If the energy management system includes ways of storing and archiving data on system parameters and electricity loads, this can be a valuable source of data for comparing the pre-retrofit and post-retrofit periods.

The heat treating plant where new ceramic fiber installation will be installed presents a very difficult savings evaluation problem because up to six separate loads are treated each day, and each load can differ according to the weight of material and the temperature of the furnace. Several furnaces are to be retrofitted, but these represent a minority of the plant's equipment. As a result it would be difficult to estimate the impact of the insulation by examining the total load of the plant before and after the retrofits. There are many complex variables which affect the electric load of any individual heat treatment load, so specifying all possible combinations of variables is impossible. Nevertheless, it would be helpful to estimate the impact of the new insulation for a variety of conditions under which these furnaces operate.

The method we selected has two parts. First we analyzed logs describing the temperature and duration of loads from two different years to determine the distribution of loads by type. Then we devised a schedule which includes the common temperature ranges. We will request that the plant follow this schedule before insulation is installed in one typical furnace. After the insulation is installed and working properly, we will have the plant use the same schedule again. Since this only involves one furnace, it will be easy to record the KW for that one furnace at five-minute intervals over the test periods using a recording meter. The results can be analyzed in detail to determine the savings from the new insulation for each common type of heat treatment for the typical furnace, and then extrapolated to the annual energy load using the frequency distribution of heat types. Eventual data for one year post retrofit may provide corroboration of these detailed calculations. Our experience, however, is that over the course of one year, conditions are likely to change in industrial plants.

SHIFT 1 : VOLUME, POWER FACTOR & KWH LOAD

FEBRUARY 5 TO APRIL 30,1988

Source File : C.T.PLOTS JUNE 7,1988

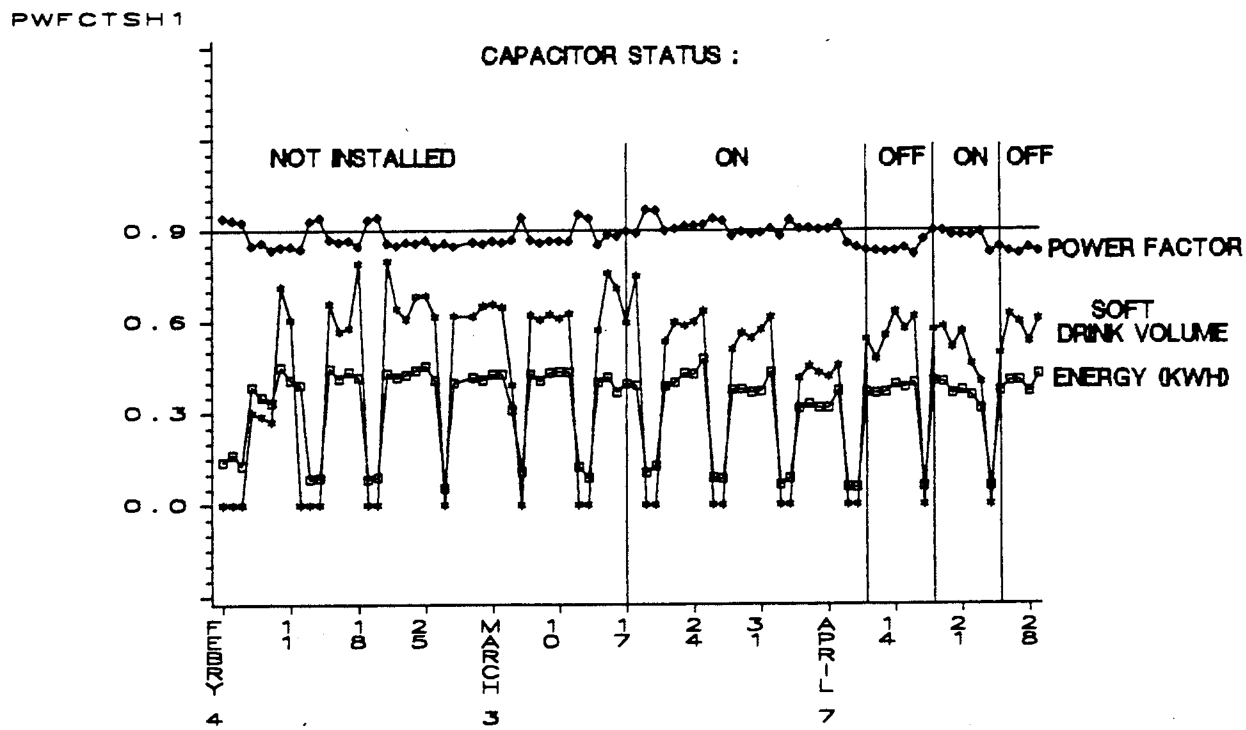

Figure 1. Soft drink volume, power factor and energy load for first shift.

D. T. Campbell and J. C. Stanley, Experimental and Quasi-Experimental Designs for Research, Chicago; Rand McNally, 1963.