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Environmental Technology Verification Report

Evaluation of the KCH Services, Inc. Automatic Covered Tank System for Energy Conservation

Prepared by

Concurrent Technologies Corporation

Under a Cooperative Agreement with

U.S. Environmental Protection Agency

ETV ETV ETV

NOTICE

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Evaluation of the KCH Services, Inc. Automatic Covered Tank System for Energy Conservation

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FOREWORD

The Environmental Technology Verification (ETV) Program has been established by the U.S. Environmental Protection Agency (EPA) to evaluate the performance characteristics of innovative environmental technologies for any media and to report this objective information to the states, local governments, buyers, and users of environmental technology. EPA's Office of Research and Development (ORD) has established a pilot program to evaluate alternative operating parameters and to determine the overall feasibility of a technology verification program. ETV began in October 1995 and will be evaluated through September 2000. EPA is preparing a report to Congress containing results of the pilot program and recommendations for its future operation.

EPA's ETV Program, through the National Risk Management Research Laboratory (NRMRL), has partnered with *CTC* under the Environmental Technology Verification Program for Metal Finishing Pollution Prevention (P2) Technologies (ETV-MF) Program. The ETV-MF Program, in association with EPA's Metal Finishing Strategic Goals Program, was initiated to identify promising and innovative metal finishing pollution prevention technologies through EPA-supported performance verifications. The following report describes the verification of the performance of the KCH Services, Inc. Automatic Covered Tank System for Energy Conservation (ACTSEC).

ACRONYMS & ABREVIATIONS

°C	Degrees Celsius
°F	Degrees Fahrenheit
$/ft^2	Dollars per Square Feet
ACTSEC	Automatic Covered Tank System for Energy Recovery
ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
AMCA	Air Movement and Control Association
amp	Ampere
bhp	Brake Horsepower
BTU	British Thermal Unit
CFM	Cubic Feet per Minute
CS	Cost Savings
CTC	Concurrent Technologies Corporation
EPA	U.S. Environmental Protection Agency
ES	Energy Savings
ETV	Environmental Technology Verification
ETV-MF	Environmental Technology Verification Program for Metal Finishing P2 Technologies
ETV-MF QMP	ETV-MF Quality Management Plan
fs	Full Scale
ft	Feet
ft^2	Square Feet
ft^3	Cubic Feet
g	Gram
gal	Gallon
hp	Horsepower
hr	Hour
HV	Heating & Ventilation
JTA	Job Training Analysis
kw	Kilowatt
kWh	Kilowatt-hour
L	Liter
lb	Pound
mg	Milligram
mg/L	Milligrams per Liter
min	Minute
mL	Milliliter
NRMRL	National Risk Management Research Laboratory
O&M	Operation and Maintenance
ORD	Office of Research and Development
OSHA	Occupational Safety & Health Administration
PARCCS	Precision, Accuracy, Representativeness, Comparability, Completeness, Sensitivity
P2	Pollution Prevention

ACRONYMS & ABREVIATIONS (continued)

PLC	Programmable Logic Controller
QA	Quality Assurance
QC	Quality Control
QMP	Quality Management Plan
TCS	Total Cost Savings
TSA	Technical Systems Audit
wg	Water Gauge

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This is to acknowledge Valerie Whitman and Marvin South of *CTC* for their help in preparing this document. *CTC* also acknowledges the support of all those who helped plan and implement the verification activities and prepare this report, specifically Joe Candio and Jon Voigt of CAMP. A special thanks to George Moore, Ph.D., EPA ETV Center Manager, and Lauren Drees, EPA Quality Assurance Manager. *CTC* also expresses sincere gratitude to KCH Services, Inc., the manufacturer of the KCH Automated Covered Tank System for Energy Conservation, for their participation in and support of this program, and their ongoing commitment to improve metal finishing operations. In particular, *CTC* thanks Ken Hankinson, Rick Hall, and the KCH staff for their assistance. *CTC* also thanks Mr. Tommy Steward of Goodrich Aerospace Landing Gear Division, of Tullahoma, Tennessee, for the use of the facilities and resources, and extensive contributions of Mr. David Allen throughout the verification test project.

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

U.S. Environmental Protection Agency

Concurrent Technologies Corporation

ETV VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**ENERGY CONSERVATION**		
APPLICATION:	**TANK LID COVERS**		
TECHNOLOGY NAME:	**The Automated Covered Tank System for Energy Conservation**		
COMPANY:	**KCH Services, Inc.**		
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The United States Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved, cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, and stakeholder groups consisting of buyers, vendor organizations, states, and others, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are credible.

The ETV Metal Finishing Pollution Prevention (P2) Technologies (ETV-MF) Program, as part of the ETV Pollution Prevention, Recycling and Waste Treatment Center, is operated by Concurrent Technologies Corporation, in cooperation with EPA's National Risk Management Research Laboratory. The ETV-MF Program has successfully evaluated the performance of several innovative Metal Finishing P2 Technologies. This verification statement provides a summary of the test results for the KCH Services, Inc. Automated Covered Tank System for Energy Conservation (ACTSEC).

VERIFICATION TEST DESCRIPTION

The KCH ACTSEC technology was tested, in an idle mode, at Goodrich Aerospace Landing Gear Division in Tullahoma, Tennessee. The system of lids on each tank is designed to reduce the overall ventilation required to meet the American Conference of Governmental Industrial Hygienists (ACGIH) guidelines for pollutant exposure in the workplace. This correlates to a reduction in the size of the scrubber, scrubber pump motor, and induced draft fan, lower energy costs, and ultimately less pollution from power plants generating the energy. The verification test evaluated the ability of the KCH ACTSEC to reduce the ventilation and heater power load as compared to a baseline system design without the lids.

For the technology verification, key measurements were taken during seven tests noted below.

- The first test evaluated the technology based on heater power consumption with lids open.
- The second test evaluated the technology based on heater power consumption with lids closed.
- The third test evaluated the technology based on scrubber pump motor power consumption.
- The fourth test evaluated the technology based on power consumption of the lid motors.
- The fifth test evaluated the technology based on power consumption of the induced draft fan.
- The sixth test evaluated the technology based on ventilation specified in the original design.
- The seventh test evaluated the technology based on static pressure specified in the original design.

TECHNOLOGY DESCRIPTION

The KCH ACTSEC technology is a system designed to provide an efficient removal of air contaminants from the workplace at a reasonable cost and at a level that minimizes the overall power consumption and exhaust volume to the air pollution control device. This installation is set up as one semi-automated process control system. The process is wash and etch of titanium parts. The lids and exhaust are automated. All vented tanks are fitted with covers that open and close as the hoist moves over the tank to load or unload parts for washing or etching. The line is exhausted via its own exhaust system, comprised of a scrubber and fan.

Each vented tank has two lateral exhaust hoods, each with its own volume damper. The volume dampers are interlocked with tank covers and open and close at the same time. This allows for an increase in airflow through the hoods as required when the covers are in the open position.

The exhaust system has a bleed-in air control damper, located between the line hoods and the scrubber, that opens and closes as required to compensate for the fluctuation in static pressure due to the opening and closing of tank covers and hood dampers. This maintains a constant volume and static pressure through the scrubber and fan.

The system provides a constant volume with a slight negative airflow in the room. Makeup air is brought in from the outside, tempered, and distributed throughout the room.

VERIFICATION OF PERFORMANCE

The KCH ACTSEC technology was tested to verify if the statements made by the vendor as to the energy savings from decreased power requirements were accurate. Energy was consumed by the scrubber pump motor, induced draft fan, lid actuator motors, and the immersion heaters. These are all components of the KCH ACTSEC technology. The scrubber pump motor operates continuously along with the induced draft fan motor due to ACGIH ventilation requirements. The lid motors are operated when it is necessary to enter or exit a tank, and the immersion heaters operate automatically to maintain a set temperature in the baths. The induced draft fan was tested for power consumption, and the induced draft system was tested for flow and static pressure.

The measured data from the verification test compared to equipment nameplate data is illustrated in **Table i**. The nameplate data for the amperage for the various motors is a full load value. The data for the amperage is lower in most cases. The only exception is the scrubber pump motor, which may indicate a need for maintenance. Nearly all amperage data is within 75 percent completeness (percentage of valid measurements compared to total number of measurements). Only the completeness for the lid motor data is outside the specified 75 percent when compared to the nominal value. However, CAMP verified that the motors for the lids were rated for a 500-lb load but are only driving a 350-lb load. This decreased load results in lower power consumption than nameplate data for the motors. At 70 percent of nominal, based on partial loading of the motors, the data is within 75 percent completeness. One heated tank was tested. The wash tank was operating at a temperature sufficient, even with insulation, to cause the immersion heaters to cycle on and off in just over one hour. The remaining hot rinse and etch tanks were operating at a temperature very near ambient. A long heater cycle time for these tanks prohibited testing. The measured flow rate of 18,150 CFM is a reduction of 31,970 CFM from the baseline design flow rate of 50,120 CFM for a tank system without lids.

ELECTRICAL

ITEM	Nameplate Volts	Nameplate Amps	Actual Volts	Actual Amps	Energy Consumed kWh./Year
Immersion Heaters – Lids Open	480	86.7	486	79.0	1,076,429
Immersion Heaters – Lids Closed	480	86.7	489	80.1	1,010,393 *
Lid Motors (911 Tank)	110-120	4.6	119	3.3	3 *
Scrubber Pump Motor	480	2.1	484	2.6	21,671
Induced Draft Fan Motor	480	34.9	486	30.8	306,044

*** Figure considers annual part throughput.**

VENTILATION

ITEM	Nameplate Data	Value
Flow Rate	17,612 CFM (KCH Design)	18,150 CFM
Static Pressure	5.5• wg	6.08• wg

Table i. Summary of Key Analytical Data

Operation and Maintenance Labor. Operation and maintenance (O&M) labor requirements for the KCH ACTSEC technology were not monitored during testing. However, O&M information obtained from the facility indicated yearly O&M costs were $8,547.

Cost Analysis. Cost analysis of the KCH ACTSEC technology was performed using current operating conditions. The reduction in the size of the scrubber and the induced draft fan due to the lower ventilation requirements with the lids in use results in a lower cost for equipment and power requirements. The reduction in the size of the induced draft fan is significant. The facility anticipates a saving of $65,884 annually, which is comprised of energy and O&M cost savings. Additionally, the initial capital expenditure is significantly reduced due to component size reduction. A capital cost saving of $61,283 is anticipated.

SUMMARY

The test results show that the KCH ACTSEC technology, when placed on a tank system with ventilation and heating requirements, results in a smaller load demand for power and a reduced need for ventilation to meet ACGIH standards. Consequently, a smaller scrubber, scrubber pump motor, and induced draft fan are needed when the KCH ACTSEC technology is used. This translates into not only a reduced power demand, but also a lower equipment cost. The cost of the power consumed by the lid motors is small compared to the overall savings when the lids are used. Furthermore, the reduction in energy used by a facility using the KCH ACTSEC technology results in a corresponding reduction in atmospheric pollutant emissions from any fossil fuel power plant supplying the energy.

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TABLE OF CONTENTS

Table of Contents (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

The KCH ACTSEC technology is designed to provide lids that are capable of opening and closing over metal finishing process baths for the expressed purpose of controlling the emissions from the tanks and reducing the heat loss from those tanks that are heated. By means of these lids, the overall need for ventilation is reduced significantly, the size of the scrubber is reduced accordingly, and the power necessary to maintain a set temperature in each of the heated tanks is reduced.

The verification test evaluated the ability of the KCH ACTSEC technology to reduce the power and ventilation requirements. The technology was tested by *CTC* under the U.S. Environmental Protection Agency (EPA) Environmental Technology Verification Program for Metal Finishing Pollution Prevention (P2) Technologies (ETV-MF). The purpose of this report is to present the results of the verification test.

The KCH ACTSEC technology was tested to evaluate and characterize its operation, through measurement of various process parameters. Testing was conducted at Goodrich Aerospace, Landing Gear Division, in Tullahoma, Tennessee (see **Figure 1**). Goodrich Aerospace, Landing Gear Division, is a major manufacturer of aircraft landing gear for the military and commercial markets.

Figure 1. KCH ACTSEC Technology at Goodrich

2.0 TECHNOLOGY DESCRIPTION

2.1 Theory of Operation

The KCH ACTSEC technology is a system designed to provide efficient ventilation control and minimize heat loss at a reasonable cost. The result is reduced overall power consumption and exhaust volume to the air pollution control device. This installation is set up as one semi-automated process control system. The process is to wash and etch titanium parts. The lids and exhaust are automated. All vented tanks are fitted with covers that open and close (see **Figure 2**) as the hoist moves over the tank to load or unload parts for washing or etching. The line is exhausted via its own exhaust system, comprised of a scrubber and blower.

Closed Lids Open Lid

Figure 2. Vented Tanks with Covers

Each vented tank (see **Figure 2**) has two lateral exhaust hoods, each with its own volume damper. The volume dampers are interlocked with the tank covers and open and close at the same time. This allows for an increase in airflow through the hoods as required when the covers are in the open position.

The exhaust system has one bleed-in air control damper, located between the line hoods and the scrubber, that opens and closes as required to compensate for the fluctuation in static pressure due to the opening and closing of the tank covers and hood dampers. This maintains a constant volume and static pressure through the scrubber and fan.

The system provides a constant volume with a slight negative airflow in the room. Makeup air is brought in from the outside, tempered, and distributed in the room along the length of the line.

2.2 Equipment and Flow Diagram

One automated metal wash and acid etch line in a layout that spans approximately fifty feet was installed at Goodrich Aerospace, Landing Gear Division, during the course of 2000. The line consists of process tanks with a ventilation system. The process system is intended to meet EPA Method 9 Visible Emissions, Tennessee Air Pollution Control Board Permit, and Occupational Safety and Health Administration (OSHA) requirements. Each process tank is 14 feet long by 4 feet wide by 8 feet deep. OSHA requirements for ventilation are derived from the American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual [Ref. 1]. Conventional ventilation would require a total exhaust flow rate of 50,120 cubic feet per minute (CFM). With the addition of the lids and semi-automated control to coordinate the opening and closing operation, the ventilation requirements drop down to 17,612 CFM. This reduces the air volume of the exhaust system and its equipment. The external ductwork for the system's exhaust is shown in **Figure 3**.

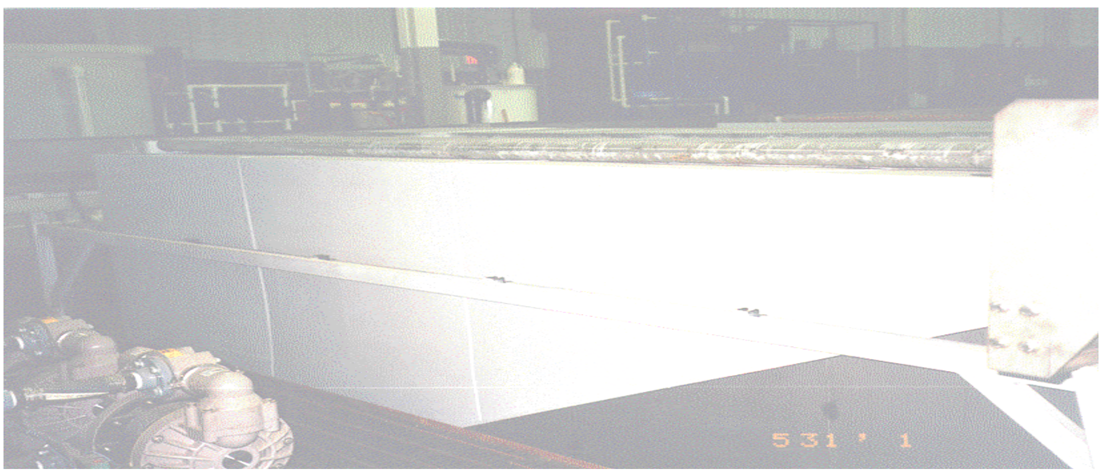

Figure 3. Ductwork for Exhaust System

The scrubber was designed to remove pollutants so that the facility maintains compliance with its Construction Air Permit that was issued by the State of Tennessee, Department of Environment and Conservation, Division of Air Pollution, Permit Number 953204P. The exhaust system and its equipment are sized smaller for this system than for a similar system without the benefit of the lids. This is due to the fact that the air volume is lower. Scrubber differential pressure can be manually monitored at the scrubber transitions via a magnahelic pressure gauge.

The line is serviced by a semi-automated hoist system. A programmable logic controller (PLC) controls the lid opening and closing. The hoist movement is under the control of the operator. In normal operation, the PLC activates the opening/closing of cover and dampers. As the lids open, the bleed-in air damper closes and the hood dampers open. The operator can manually open or close the cover with a push button switch, if need arises. The KCH ACTSEC technology is fed and controlled from the electrical control cabinet shown in **Figure 4**.

Figure 4. KCH ACTSEC Electrical Control Cabinet

Volume dampers located in each hood are operated via a pneumatic actuator and adjusted in the closed position to provide minimal airflow through the hoods when the tank covers are closed. The bleed-in air control damper is controlled via a pneumatic actuator that will change the position of the damper to open or closed as required. This is accomplished with the PLC.

The tanks are maintained at a constant temperature. Additionally, the tanks are maintained without stratification due to an air sparger system laid out on the bottom of each tank. This helps to lower the heating costs of the tanks in conjunction with the lid usage. The lids also minimize the chemical exposure to employees working in the general vicinity.

KCH claims that this installation has been designed to accommodate one lid opening at a time for entry and exit of the processing parts while maintaining sufficient ventilation for Goodrich's Titanium Etch Process.

KCH has completed calculations to determine the necessary airflow on the tanks when the lids are both open and closed. KCH used engineering calculations to determine the appropriate airflow to properly control the emission of various pollutants so they will not be detrimental to the employees or the environment. That basic design is illustrated by **Figure 5**.

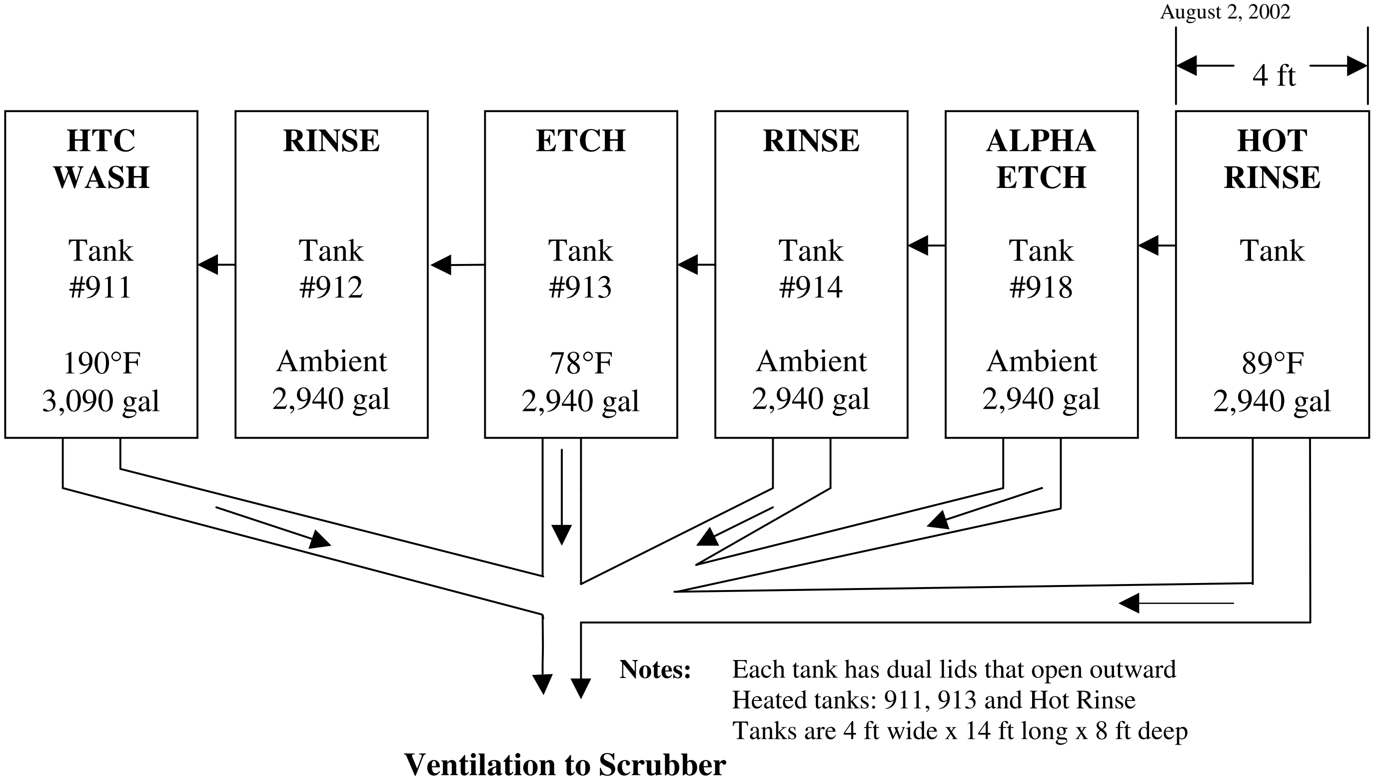

Figure 5. Diagram of Vented Tanks

Tank #	Contents	Volume
913	Nitric Acid Hydrofluoric Acid Water	40 gal 4 gal 2896 gal
914	Deionized Water	Tank Fill
918	Nitric Acid Hydrofluoric Acid Water	10 gal 3 gal 2927 gal

Table 1. Tank Volume & Contents

2.3 Ventilation Design Concept

All covered tanks are normally closed except when parts are being lowered into or being lifted from the tank. The exhaust of the covered tanks will, therefore, need only to be sufficient to prevent fumes from escaping around the perimeter of the tank. In practice, this level of exhaust is only 10-25 percent of the total CFM normally required to exhaust an uncovered or conventional open process tank. This range is based on previous experience and is calculated by evaluating the actual gaps in square feet along a tank perimeter versus open tank ventilation requirements.

When the tank covers open, the exhaust volume is increased to full industrial ventilation flow rate by the automatic opening of the exhaust damper(s) located on the outlet of the exhaust hood(s).

The velocity of the air traveling through the fume control device (horizontal scrubber) must remain constant in order to ensure proper operation and control. Therefore, a secondary device, an automatic relief damper, is used to maintain a constant flow rate through the control device. The relief damper is installed upstream of the control device and downstream of the tankline exhaust manifold. The relief damper serves to maintain constant velocity by introducing bleed-in air when all tanks are closed.

The total exhaust system sizing is based upon the assumption that all covers are in the closed position except one tank, the worst-case tank. In this case, the worst-case tank is Tank 913, with a hazard rating of A-1. The reasoning for this assumption is that, since the covers are automatically interlocked to the hood damper(s), and since the tested system has only one hoist, only one cover will be open at any one time.

If the tank line were to be serviced by two hoists, then two covers could be open at any one time, and the system would be sized accordingly. Therefore, the system size is dependent upon the number of hoists on the tankline, assuming that the worst-case tanks could be open simultaneously, with work being lifted or lowered into the tanks.

The system for Goodrich Aerospace, Landing Gear Division, is sized at approximately 10 percent of the full open top flow plus the worst-case exhaust volume of one tank. The exhaust for four of the five tanks is sized at 10 percent of the full tank exhaust rate, while the worst-case tank requires 100 percent or 14,000 CFM. The system total is 17,612 CFM; compared against the open top exhaust flow rate of 50,120 CFM, a savings of 32,508 CFM is realized, which represents approximately 65 percent energy savings (see **Table 2**).

Tank	Hazard Rating*	Area Sq. Ft.	CFM/ Sq. Ft.	Open Cover CFM	KCH System Design CFM
913	A-1	56	250	14,000	14,000
911	C-1	56	175	9,800	980
914	D-1	56	130	7,280	728
918	A-1	56	250	14,000	1,400
H.R.	D-2	56	90	5,040	504
		Total	**CFM**	50,120	17,612

* Rating taken from ACGIH, Industrial Ventilation, Pages 10-96 to 10-98, Table 10.70.1, 10.70.2 & 10.70.3, 24th Ed, 2001. [REF. 1]

Table 2. Goodrich Titanium Wash and Etch Line Ventilation

2.4 Test Site Installation

The KCH ACTSEC technology is installed at Goodrich Aerospace, Landing Gear Division, in Tullahoma, Tennessee. The KCH system was installed to accompany the new wash and acid-etch line at Goodrich. The facility has been utilizing the KCH ACTSEC technology since startup of this line at the end of 2000. Due to the new process configuration, there is no process data available for the technology prior to installation.

3.0 METHODS AND PROCEDURES

3.1 Test Objectives

The overall goal of the verification test was to evaluate the ability of the KCH ACTSEC technology to reduce the energy consumption for the bath heaters, ventilation fan, and scrubber pump motor. This technology was evaluated under actual production conditions, and the operation of the unit was characterized through the measurement of various process control factors.

Table 3 describes project objectives and how they relate to the test measurements for evaluation of the KCH ACTSEC technology. This report contains the results of the test.

Test	Test Objectives	Test Measurement	Modification
Test #1 Power Consumption simulating no KCH system i.e. no lids	Determine energy consumption of immersion heaters for each of the three heated tanks	Amperage draw of heaters Voltage of heaters Temperature of bath	Test was conducted for three hrs instead of one and only on 911 tank (one test only)
Test #2 Power Consumption normal operations i.e. lids closed	Determine energy consumption of immersion heaters for each of the three heated tanks	Amperage draw of heaters Voltage of heaters Temperature of bath	Test was conducted for three hrs instead of one and only on 911 tank (one test only)
Test #3 Typical Power Consumption	Determine energy consumption of scrubber pump motor	Amperage draw of motors Voltage of motor	One test run due to number of data points collected
Test #4 Typical Power Consumption	Determine energy consumption of lid motors	Amperage draw of motors Voltage of motors	None
Test #5 Typical Power Consumption	Determine energy consumption of induced draft fan	Amperage draw of fan Voltage of fan	One test run due to number of data points collected
Test #6 Ductwork Airflow	Determine volumetric airflow rate compared to reported by KCH	Air velocity in fpm converted to volumetric airflow rate in CFM	None
Test #7 Ductwork Static Pressure	Determine static pressure compared to reported by KCH	Water gauge for static pressure inside exhaust ductwork	None

Table 3. Test Objectives and Related Test Measurements

Under normal system operation at Goodrich Aerospace, Landing Gear Division; test measurements were used to:

- Prepare an energy balance for all power consuming units of significance:

    1. Evaluate Tank 911 with lids open and lids closed. This was done only for Tank 911 due to altered field conditions described in the test plan modification.
    2. Evaluate the power consumption of the induced draft fan, lid motors, and scrubber water pump motor.

- Compare the actual ventilation parameters to KCH's design criteria:

    1. Evaluate the flow rate CFM of the induced draft fan.
    2. Evaluate the static pressure rating between the scrubber and induced draft fan.

- Determine the cost savings.
- Quantify environmental benefit by determining the energy savings and the subsequent pollution prevention due to reduced power required from power supplier.

3.2 Test Procedure

3.2.1 System Set-Up

The acid etch system baths were operating at the facility's specifications in that the ventilation was operating normally, the air spargers were on continuously, the bath heaters were operating automatically, though not at the temperature reported by the host test site, and the lid motors were functioning as specified. There was no special set-up required for this test.

3.2.2 Testing

The KCH ACTSEC technology was tested in accordance with the verification test plan [Ref. 2]. Deviations to the verification test plan were documented using a Test Plan Modification Request. Testing was planned for ventilation and power consumption of the lid motors, fan motor, scrubber pump motor, and bath heaters.

During the ***first test***, the KCH ACTSEC technology was tested for power consumption on the "Hot Rinse" tank using the Reliable Power Meter 1600 Series Power Recorder. The tank heaters on the Hot Rinse tank did not cycle on during the one-hr test, as the temperature of the bath was 89°F rather than the 150°F originally specified by KCH. The ambient temperature of 74°F did not vary enough from the bath temperature to cause a cooling effect that would result in a need for heating to maintain the bath temperature. The Hot Rinse tank testing was stopped due to this lack of heater cycle during the test and no data was collected. Additionally, tank 913 was not tested as the set point for the immersion heater was set at 78°F, as opposed to the original set point of 110°F. The facility was able to meet production quality requirements at a lower bath set temperature, using process optimization to minimize energy use.

Tank 911 was observed as the immersion heaters cycled. The heaters were found to cycle from on to off to on in little more than one hour. Thus, to test two cycles of the heater, it was necessary to test longer than one hour (hr). The Reliable Power Meter is capable of recording power consumption only according to the following time intervals: 15 minutes, 30 minutes, one hr, three hrs, six hrs, 12 hrs, 24 hrs, 48 hrs, five days, one week, one month, and one year. Thus, it was decided that the three-hr time interval would provide the best data collection for this test. During the three-hr test, two complete cycles of the immersion heaters took place. This test of one of the immersion heaters (72 kW) took place with the lids open. Tank 911 has three sets of heaters: two 72 kW and one 36 kW. The test was started immediately after the heaters cycled off. The collected data was downloaded to a personal computer at the conclusion of the test.

During the ***second test***, the KCH ACTSEC technology's power consumption was tested on one of Tank 911's immersion heaters (72 kW) with the lids closed. The test was conducted for three hrs. This test also started immediately after the immersion heaters cycled off. The power monitor leads that were put in place for the first test of the 911 tank (with the lids open) were not changed for the second test to ensure that the same circuit was monitored for both tests. The collected data was downloaded to a personal computer at the conclusion of the test.

During the ***third test***, the KCH ACTSEC technology's power consumption was tested on the scrubber pump motor. This pump motor runs continuously to maintain the scrubber at its nominal efficiency while the ventilation system is operating. This test was conducted for one hr, and the collected data was downloaded to a personal computer.

During the ***fourth test***, the KCH ACTSEC technology's lid motor for the lids on Tank 911 were checked for power consumption as the lids opened and closed. Four cycles of the lids were monitored. The opening and closing of the lids was activated manually. When the test was completed after 15 minutes, the collected data was downloaded to a personal computer.

During the ***fifth test,*** the KCH ACTSEC technology's induced draft fan was monitored for one hr. This fan runs continuously to maintain an acceptable hygiene balance in the room where the wash and etch system is located. When the test was complete, the collected data was downloaded to a personal computer.

During the ***sixth test***, the KCH ACTSEC's ventilation system was monitored for airflow using an Alnor MicroManometer with a 36-inch Pitot tube, according to the ACGIH Industrial Ventilation Manual [Ref. 1]

During the *seventh* test, the KCH ACTSEC's static pressure was measured using a MicroManometer per ACGIH procedure. Measurements were recorded in units of water gauge (wg). Two holes were drilled at uniform distances around the duct for insertion of the probe. This was done to obtain an average and to detect any discrepancy in value. The data was recorded and compared with the reported static pressure as stated by KCH.

3.2.3 Field Modifications

Several test plan modifications were necessary due to unannounced changes at Goodrich Aerospace, Landing Gear Division. These included changes in the set temperatures of each tank to be tested (911, 913, and Hot Rinse), the quantity of data points taken by the Reliable Power Meter, and interpretation of data.

3.2.3.1 Test Plan Modification #1

Tank 913 and the Hot Rinse tank were not at documented temperature. The operating temperature was very close to ambient. Tank 911 was higher than was initially indicated. Therefore, only Tank 911 was tested. Tank 913 and the Hot Rinse tank were not tested, as minimal heat loss was anticipated. Tank 911's heaters were set up as two 72 kW and one 36 kW heaters. One of the 72 kW heaters was tested, and the total energy consumed by the three heaters in Tank 911 was determined by calculation.

3.2.3.2 Test Plan Modification #2

The Reliable Power Meter was set up to take 3,600 data readings per test interval. The scrubber pump motor and the induced draft fan motor operate continuously. The accuracy of the readings was acceptable as explained earlier in this report, and in essence 3,600 measurements of the power consumed were taken during each test period. Therefore, this series of points served as duplicate measurements.

3.2.3.3 Test Plan Modification #3

Tank 911 was found to have its heaters cycling on at just over one-hr intervals. Therefore, the test was modified to run for three hrs (to accommodate the Reliable Power Meter) instead of one hr. The test was run at this time interval with the lids both open and closed. This resulted in the heaters cycling at just over two times.

3.2.3.4 Test Plan Modification #4

The test plan called for all field data to be recorded in the logbook. Because the data recorded by the Reliable Power Meter consisted of 3,600 data points for each test, the information for power had to be interpreted from the data. The data was taken by the meter and downloaded to a personal computer for further analysis.

3.3 Quality Assurance/Quality Control (QA/QC)

3.3.1 Data Entry

A Project Team member recorded field sampling events and process measurements in a field notebook. Some data was recorded in a pre-designed form as prescribed in the test plan. Data from power measurements were downloaded to a personal computer. Due to the nature of the power data recorded, it was not possible to record the data on the pre-designed form.

3.3.2 Sample Collection and Handling

All data was taken from the Reliable Power Meter and the Alnor MicroManometer. No samples were taken for laboratory analysis. Additionally, no measurement beyond the ventilation and the power consumption was conducted.

3.3.3 Calculation of Data Quality Indicators

Data reduction, validation, and reporting were conducted according to the verification test plan [Ref. 2] and the ETV-MF Quality Management Plan (QMP) [Ref. 3]. Calculations of data quality indicators are discussed in this section.

3.3.3.1 Precision

In instrument measurements, precision refers to the smallest change in the quantity being measured that the instrument will detect. Precision is ensured by making the proper choice of instruments to make measurements and by proper maintenance and calibration. The Reliable Power Meter and the Alnor MicroManometer were certified as calibrated for verification testing. Each measurement of the power consumption, for tests one to five, involved 3,600 data points taken during the given time frame. Precision was ensured by performing a traverse in two directions across the duct at 90° and then averaging the data, per ACGIH Industrial Ventilation guidelines.

3.3.3.2 Accuracy

Accuracy is a measure of the agreement between an experimental determination and the true value of the parameter being measured. For the Reliable Power Meter and Alnor MicroManometer, proper maintenance and calibration of the equipment per the user manual's ensured accuracy.

3.3.3.3 Completeness

Completeness is defined as the percentage of measurements judged to be valid compared to the total number of measurements made for a specific property under study. A valid measurement is a measurement made by a properly operating instrument on a properly operating piece of equipment. As a rule, if the instrument reading is within 25 percent of the equipment nominal value, the measurement is valid. Completeness is calculated using the following formula:

$$\text{Completeness} = \frac{\text{Valid Measurements}}{\text{Total Measurements}} \times 100\%$$

QA objectives will be satisfied if the percent completeness is 75 percent or greater. Completeness results are found in **Appendix A**.

3.3.3.4 Comparability

Comparability is another qualitative measure designed to express the confidence with which one data set may be compared to another. Measurement techniques and analytical method affect comparability. Comparability is limited by the Precision, Accuracy, Representativeness, Comparability, Completeness, and Sensitivity (PARCCS) parameters because data sets can be compared with confidence only when precision and accuracy are known. Comparability was achieved in this verification by the use of consistent methods during measurement and analysis.

3.3.3.5 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of a particular parameter. For the purposes of this demonstration, representativeness will be determined by testing identical points. During the tests for power consumption, the Reliable Power Meter checks 3,600 data points for each test. Representativeness for the ventilation flow rate was ensured by performing a traverse in two directions across the duct at 90° and then averaging the data, per ACGIH Industrial Ventilation guidelines.

4.0 VERIFICATION DATA

4.1 Process Measurements

Electric immersion heaters heat the tank baths. A PLC at the electric control panel controls these heaters. Each heater is set for a specific temperature, which is maintained by applying current to the heaters when the bath temperature drops below a certain temperature. The bath is then heated until it reaches the set point temperature. These heater controls are calibrated every three months by the facility. The heaters were last calibrated on September 21, 2001, for each tank. Tank 911 was calibrated to maintain a temperature of 190°F, Tank 913 at 78°F, and the Hot Rinse tank at 89°F. The ambient temperature was 74°F. This was determined by a tank of water located in the room that had been standing for several weeks without a change in volume or external temperature variation, according to the operator of the Titanium Etch System.

4.2 Measurement Results

A complete summary of analytical data is presented in **Table 4.**

ELECTRICAL

Item	Nameplate Volts	Nameplate Amps	Actual Volts	Actual Amps	Energy Consumed kWh/year
Immersion Heaters - Lids Open (Tank 911)	480	86.7	486	79.0	1,076,429
Immersion Heaters - Lids Closed (Tank 911)	480	86.7	489	80.1	1,010,393 *
Lid Motors (Tank 911)	110-120	4.6	119	3.3	3 *
Scrubber Pump Motor	480	2.1	484	2.6	21,671
Induced Draft Fan Motor	480	34.9	486	30.8	306,044

* Figure considers annual part throughput. See Table 5 through Table 8.
Total energy consumed by the process/year = 1,010,393 + 3 + 21,671 + 306,044 = 1,338,111 kWh/year.

VENTILATION

Item	Nameplate Data	Actual Value
Flow Rate	17,612 CFM	18,150 CFM
Static Pressure	5.5" wg	6.08" wg

Table 4. Summary of Measurements/Calculations

Recorded power data was downloaded from the Reliable Power Meter to a personal computer, then analyzed and reported. The data for the ventilation system was recorded in the field notes and field data collection sheet, then analyzed and reported.

The raw electrical field data was initially not of a form that was usable in the report. The trapezoid method was utilized with Microsoft Excel to convert the raw data to a usable form. First a wattage value was calculated for each data point by multiplying together the measured voltage, current, the absolute value of the power factor, and 1.732 (a constant used to convert phase voltage to line voltage). This results in 3,600 wattage values. Next each adjacent wattage data point is added and divided by two to get an average value (example: (a+b)/2, (b+c)/2, (c+d)/2….n). Each average is then multiplied by three, which represents three seconds, or the time interval between each data point reading. All of these values are summed together to obtain the total area under the wattage curve.

Since the integration process used seconds for the time interval, a graph is produced with a time base in seconds. The test took 3,600 data points over a three-hr period, with three seconds in between, each reading giving 10,800 seconds for the test. To convert the time base into three hrs, the total area obtained was divided by 3,600 (3,600 is the number of seconds in one hr) to obtain a wattage value within the three-hr period. The wattage value for the three-hr period was then divided by three to find an average wattage during one hr. Finally all three phase averages (A, B, C) were added together to find the total average for a one-hr period.

For the ID Fan and Scrubber tests a time base of one second was used. The total power calculated was divided by 3,600 to change the time base into hrs. This new value was not divided by three because, the test lasted one hr, not three hrs.

For the Lids Motor test a time base of 0.25 seconds was used to represent a 15-minute period. The total power calculated was divided by 900 and multiplied by 4 (900 equals the number of seconds in 15 minutes) to change the time base into hrs.

The methodology described above is used to find the total true AC power draw during the test (see **Appendix B**). Average power factors were used within the above calculations. Additionally, the power value for the 911 tank is only for the 72 kW heater. The tank has two 72 kW heaters and a 36 kW heater. In order to calculate the true power consumed by all heaters in the 911 tank, the test value must be multiplied by a factor of 2.5. The heater manufacturer verified this factor. The energy consumption for the heaters is based on the power data collected during a three-hr test.

The energy consumption for the lid motors was based on single-phase power data collected during a 15-minute test.

4.2.1 Power Requirements

4.2.1.1 Power Requirements of Immersion Heaters in Tank 911

When the covers to Tank 911 were left open, as the tank would be set up with no lids, the power drawn by the immersion heaters was recorded for three hrs. This tank was also monitored with the lids closed, to see how much power the immersion heaters would draw.

Table 5 shown below lists the results of the three-hr test in watt-hrs (wh) in the second column, while the third column represents the energy consumption for one hr of operation. The fourth column illustrates normalized open-lid and closed-lid tank heater energy consumption for one year, assuming one year of operation is based on 8,760 service hrs.

Lid Configuration	Power for Three Hrs Wh	Energy Consumption for One Hr kWh	Normalized Energy Consumption for One Year kWh
Open (Tank 911)	147,451	122.88	1,076,429
Closed (Tank 911)	138,410	115.34	1,010,393 *

* Figure considers annual part throughput.

Table 5. Immersion Heater Power

The sequence of calculations shown below supports **Table 5** and is based on field measurement and the trapezoid method described in the previous section.

$$\frac{122.88\text{kWh}}{\text{hr}} \Bigg| \frac{8{,}760\text{ hr}}{\text{year}} = \frac{1{,}076{,}429\text{ kWh}}{\text{year}} \qquad \text{(open-lid)}$$

$$\frac{115.34\text{kWh}}{\text{hr}} \Bigg| \frac{8{,}760\text{ hr}}{\text{year}} = \frac{1{,}010{,}378\text{ kWh}}{\text{year}} \qquad \text{(closed-lid)}$$

It is then necessary to normalize annual closed-lid energy consumption, by subtracting lid-closed energy consumption during the period of lid actuation, and adding lid-open energy consumption during the same period of lid actuation.

The period of lid actuation is based on 116[1] parts produced annually. The closed-lid configuration for the tank 911 heater is based on one year of operation.

The closed-lid and open-lid energy consumption relation during lid actuation cycle time is as follows:

(closed-lid)

$$\frac{116\text{ parts}}{\text{year}} \Bigg| \frac{1\text{ lid cycle}}{\text{part}} \Bigg| \frac{1\text{ minute}}{\text{lid cycle}} \Bigg| \frac{1\text{ hr}}{60\text{ minutes}} \Bigg| \frac{115.34\text{ kWh}}{\text{hr}} = \frac{222.99\text{ kWh}}{\text{year}}$$

(open-lid)

$$\frac{116\text{ parts}}{\text{year}} \Bigg| \frac{1\text{ lid cycle}}{\text{part}} \Bigg| \frac{1\text{ minute}}{\text{lid cycle}} \Bigg| \frac{1\text{ hr}}{60\text{ minutes}} \Bigg| \frac{122.88\text{ kWh}}{\text{hr}} = \frac{237.57\text{ kWh}}{\text{year}}$$

The calculation shown below illustrates that a brief actuation period exhibits a minimal impact to energy consumption.

[1] This production information was obtained from the host test site.

$$\frac{1{,}010{,}378\ \text{kWh}}{\text{year}} - \frac{222.99\text{kWh}}{\text{year}} + \frac{237.57\text{kWh}}{\text{year}} = \frac{1{,}010{,}393\ \text{kWh}}{\text{year}}$$

4.2.1.2 Power Requirements of Scrubber Pump Motor

The scrubber pump motor operates continuously to maintain the scrubber at nominal efficiency while the ventilation system is operating. **Table 6** illustrates the energy consumption exhibited by the scrubber pump motor.

Energy Consumption for One Hr Wh	Energy Consumption for One Hr kWh	Normalized Energy Consumption for One Year kWh
2,473.84	2.47	21,671

Table 6. Scrubber Pump Motor Power

4.2.1.3 Power Requirements of Lid Motors

The lids draw power as they open and close. The analysis shown below illustrates how the lid motor power draw impacts the energy consumption during one year of production.

$$\frac{116\ \text{parts}}{\text{year}} \left| \frac{5\ \text{lid cycles}}{\text{part}} \right| \frac{1\ \text{minute}}{\text{lid cycle}} \left| \frac{1\ \text{hr}}{60\ \text{minutes}} \right| \frac{0.33\ \text{kWh}}{\text{hr}} = \frac{3\ \text{kWh}}{\text{year}}$$

Table 7 records the important lid motor information.

Energy Consumption for One Hr Wh	Energy Consumption for One Hr kWh	Normalized Energy Consumption for One Year kWh
329.95	0.33	3*

* Figure considers annual part throughput.

Table 7. Lid Motor Power

4.2.1.4 Power Requirements of Induced Draft Fan Motor

The induced draft fan draws power as this fan operates continuously with no speed change. The results of the power analysis are shown in **Table 8**.

Energy Consumption for One Hr Wh	Energy Consumption for One Hr kWh	Normalized Energy Consumption for One Year kWh
34,936.48	34.94	306,044

Table 8. Induced Draft Fan Motor Power

4.2.2 Ventilation Requirements

The ventilation system was measured for flow and static pressure.

The static pressure was measured at a point between the scrubber and the induced draft fan. Each reading in **Table 9** was identical at 6.08 inches water gauge (wg).

Run	In. wg
1	6.08
2	6.08
Avg.	6.08

Table 9. Static Pressure Data

The flow data is presented in **Table 10**.

Probe Insertion Point	No. 1 Ft/Min	No. 2 Ft/Min	No. 3 Ft/Min	No. 4 Ft/Min	No. 5 Ft/Min	MID Ft/Min	No. 6 Ft/Min	No. 7 Ft/Min	No. 8 Ft/Min	No. 9 Ft/Min	No. 10 Ft/Min	Avg. Ft/Min
0°	2420	3483	3130	3822	3804	3636	3458	3327	3117	3030	2541	3213
90°	2935	3242	3264	3242	3543	3625	3858	3439	3635	3267	2450	3288
Avg.												3250

Table 10. Ventilation Flow Data

Ventilation system data was measured using an Alnor 550 MicroManometer with a 36-inch Pitot tube probe. The flow data was measured at a site 17 ft. 8 ½ inches off of the floor, along two different planes, 90° of each other. The probe was inserted into each drilled hole, and held level to the flow with the probe opening receiving the airflow. Eleven points were traversed along each measured plane of the 32-inch diameter duct, according to test plan procedure. The middle reading was discarded for the calculations, per ACGIH guideline. The ten other readings were added together and divided by ten to obtain an average. This method of averaging was followed for the numbers associated with each measured plane.

4.2.2.1 Flow Rate

To determine the volumetric flow rate, multiply linear flow rate by the cross sectional area of the duct.

$$\frac{3250\ \text{ft}}{\text{min}} \cdot \frac{256\ \text{in}^2}{} \cdot \frac{1\ \text{ft}^2}{144\ \text{in}^2} = 18{,}150\ \text{CFM}$$

The difference in the verification testing reading and KCH's engineering calculations for the ventilation flow is calculated below.

18,150 CFM (Test Results)		
-17,612 CFM (KCH Calculation)		
538 CFM		

$$\frac{538\ \text{CFM}}{17{,}612\ \text{CFM}} \times 100\% = 3\ \text{percent}$$

Based on field measurement, the fan exceeds the vendor design criteria of 17,612 CFM by 3 percent.

4.2.2.2 Static Pressure

The static pressure data was taken at a point between the scrubber and the induced draft fan. The data was collected using the MicroManometer with one leg of the Pitot tube probe open to the ambient air. The Pitot tube probe was inserted so that the probe opening received the flow and was maintained level while taking the reading.

The static pressure read 6.08 inches wg. KCH uses 5.5 inches wg as a basis for their design.

The difference in the verification testing reading and KCH's design value for the ventilation static pressure is calculated below.

6.08 wg
-5.50 wg
0.58 wg

$$\frac{0.58\ \text{wg}}{5.50\ \text{wg}} \times 100\% = 10.5\ \text{percent}$$

Based on field measurement taken, the fan is within 10.5 percent of the vendor design value of 5.5 wg.

4.3 Nameplate Data

Nameplate data was obtained as shown in **Table 11**.

Item	Volts	Amps
Induced Draft Fan Motor	480	34.9
Scrubber Pump Motor	480	2.1
Lid Motors	110 - 120	4.6
Immersion Heaters in Tank 911 (72 kW)	480	86.7
Immersion Heaters in Tank 911 (36 kW)	480	43.35

Note: Nameplate data for amperage is full load amperage

Table 11. Nameplate Data

4.4 Other Data

Other data collected during the course of the verification test is summarized in **Table 12**.

Description	Value
Cost of electricity	$.044/kWh
Average unit surface area of part	321.5 ft^2
Average number of parts processed	116/year

Table 12. Other Data

5.0 EVALUATION OF RESULTS

5.1 Energy and Cost Savings

The energy and cost savings are evaluated by considering several system energy and cost components. The components include a reduction in size of pump and fan motor, reduction in air volume, and reduction in bath heating requirements. Additionally, O&M costs consider scrubber chemicals, materials (packing, filters, etc.), and labor. Costs are annualized and a capital savings as well as total savings due to energy reductions are presented later in this verification report and in **Appendix C**.

a) Ventilation Fan Horsepower

Evaluation of the horsepower required for ventilation of a process line with the KCH ACTSEC technology as compared to a process line without the KCH ACTSEC technology is shown below.

Fan Horsepower Calculation:

With the static pressure assumed to be 5.5• wg and tested as 6.08• wg (which is within 10.5 percent of the 5.5• value), Air Movement and Control Association (AMCA)-certified KCH data tables [Ref. 4] are used to estimate the brake horsepower (bhp) required for each operating condition using KCH size 60 and size 33 NH fans respectively. All sizes were provided by KCH and verified by CAMP.

Standard Design bhp:

50,120 CFM = 62 hp (all six tank covers open)
Ventilation fan motor is not available in 62 hp. The next size up is a 75-hp motor. The 75 hp is used as the baseline for the calculations.

KCH Design:

17,612 CFM = 26 hp (one tank cover open, five closed)
Ventilation fan motor is not available in 26 hp. The next size up, 30 hp, is used in the calculations for the system verified.

Since the ventilation readings taken (18,150 CFM) were within three percent of the KCH design and the static pressure is within 10.5 percent of the KCH design value, the 30-hp system meets or exceeds the original design criteria.

The design yields a reduction of 45 hp for the fan, based on the 75-hp motor and 30-hp motor.

To estimate the amount of energy saved, it is necessary to estimate the amount of time the fan runs. The fan is kept running 24 hrs a day/7 days per week.

The amount of energy savings (ES) for the fan is calculated by using the equation ES = power x time.

Annual Energy Savings Calculation for Fan:

$$ES_{fan} = \frac{45\ \text{hp}}{} \left| \frac{0.746\ \text{kW}}{\text{hp}} \right| \frac{24\ \text{hr}}{\text{day}} \left| \frac{365\ \text{days}}{\text{year}} \right. = 294{,}073\ \text{kWh/year}$$

Annual Cost Savings Calculation for Fan:

The amount of annual cost savings (CS) for the fan is calculated by using the equation $CS_{fan} = ES_{fan}$ x electricity cost.

$$CS_{fan} = \frac{294{,}073\ \text{kWh}}{\text{year}} \left| \frac{\$0.044}{\text{kWh}} \right. = \$12{,}939/\text{year}$$

Therefore, the estimated energy savings associated with use of the smaller fan is 294,073 kWh/year and the estimated cost savings is $12,939/year.

b) Reduction in Scrubber Size

As the scrubber decreases in size, due to lower ventilation throughput, the amount of water recirculated over the scrubber packing surface decreases as well. A 50,000 CFM scrubber would require a 10-hp pump motor; a reduction of 5-hp is anticipated based on a reduced ventilation throughput anticipated when using the KCH ACTSEC technology. Due to a decrease in air volume as shown earlier in the report, a smaller scrubber and motor can be specified to meet particular site requirements depending on the given application.

Due to the fact that the ventilation stream contains both nitric and hydrofluoric acid, air pollution control is required according to the facilities permit to construct issued by the Tennessee Air Pollution Control Board (TACB). The host test facility indicated via air permit application that a water scrubber was to be used to comply with air pollution control requirements.

The scrubber is sized to meet a ventilation demand of the KCH ACTSEC technology with lids, which is 17,612 CFM. The sizing is based on packing type and volume needed to adequately scrub out the acids. In turn, the scrubber pump motor is sized according to the scrubber packing surface area and volume. CAMP verified that the water flow rate required to scrub the acids was 108 gpm. This water flow rate can be achieved with a 5-hp motor used to drive the scrubber pump.

If traditional processing is installed containing no lids, the ventilation flow rate is increased to just over 50,000 CFM. To handle a larger volume of air and consequentially more acid, a larger scrubber is required to accommodate more packing and a higher water flow rate. CAMP also verified that water flow rate of 300 gpm is required to adequately remove acids from the air. At a flow of 300 gpm, a 10-hp motor is required for the pump to maintain this flow rate.

In each case, motor hp is identified using the manufacturer's pump curves at the specified flow rate in gpm. CAMP has also verified the water flow rate based on the manufacturer's literature on scrubber size, packing type, and packing volume.

The energy savings due to pump size can be calculated in the same manner as the energy savings for the fan motor shown above. The same rationale holds true for calculation of the cost savings anticipated for the pump. The equations used and assumptions made are taken from "Energy Conservation & Process Control Utilizing Covered Tanks" by Kenneth C. Hankinson [Ref. 5].

The design yields a reduction of 5-hp for the scrubber motor. To estimate the amount of energy saved, it is necessary to estimate the amount of time the scrubber motor runs. The motor runs 24 hrs a day/7 days per week. The equation used for the fan energy savings (ES = power x time) can also be used for the scrubber.

Annual Energy Savings Calculation for Scrubber Pump Motor:

$$ES_{scrubber} = \frac{5\ \text{hp}}{} \left| \frac{0.746\ \text{kW}}{\text{hp}} \right| \frac{24\ \text{hr}}{\text{day}} \left| \frac{365\ \text{days}}{\text{year}} \right. = 32{,}675\ \text{kWh/year}$$

Annual Cost Savings Calculation for Scrubber Pump Motor:

The amount of annual CS for the scrubber pump motor is calculated by using the equation $CS_{fan} = ES_{fan}$ x electricity cost.

$$CS_{scrubber} = \frac{32{,}675\ \text{kWh}}{\text{year}} \left| \frac{\$0.044}{\text{kWh}} \right. = \$1{,}438/\text{year}$$

The estimated energy savings associated with the use of a smaller scrubber pump motor is 32,675 kWh/year and the estimated cost savings is $1,438/year.

c) Heating and Ventilation (HV) Cost Savings

The facility is climate-controlled to maintain uniform process conditions and uniform working conditions for employees. This requires that any air drawn in for makeup air must be tempered during the year.

One way to estimate annual cost data for tempering of air is shown on pages 7-18 & 7-19 of the ACGIH Industrial Ventilation Manual [Ref. 1] and is based on the degree day method. The formula is given as follows:

$$CS_{HV} = \frac{0.154\ (Q)\ (dg)\ (T)\ (c)}{q}$$

where:

CS_{HV}	=	Annual Cost Savings	\$/year
Q	=	Airflow Rate	18,150 CFM
dg	=	Annual Degree Days	3,895 days
T	=	Operating Time	168 hr/wk
c	=	Cost of Fuel, \$/unit	$\$0.00978/ft^3$
q	=	Available Heat/Unit of Fuel	$1{,}000\ BTU/ft^3$

For a process system with the lid-closing capability that the KCH ACTSEC technology provides, the cost for tempering air would be:

$$CS_{HV} = \frac{0.154\ (18{,}150)\ (3{,}895)\ (168)\ (\$0.00978)}{1{,}000\ \text{BTU/ ft}^3} = \$17{,}888/\text{year}$$

For a process system without the lid closing capability that the KCH ACTSEC technology provides, the cost for tempering air would be:

$$CS_{HV} = \frac{0.154\ (50{,}120)\ (3{,}895)\ (168)\ (\$0.00978)}{1{,}000\ BTU/\ ft^3} = \$49{,}395/year$$

The yearly cost savings associated with tempering of the air of the KCH ACTSEC technology is $49,395 - $17,888 = $31,507.

Annual Energy Savings ES_{temper} can be calculated, using a unit cost to produce one kWh of electricity:

$$ES_{temper} = \frac{\$31{,}507}{\$0.044/kWh}$$

The ES_{temper} is 716,068 kWh.

d) Bath Heating Calculations

Electric immersion heaters are provided in three of the tanks to maintain a temperature above ambient. As the bath cools down, the PLC signals the immersion heaters to energize until the temperature set point is reached in the bath. The Reliable Power Meter can measure the power consumed while the heater is energized.

Due to unannounced changes to the process temperatures of all the heated tanks, only tank 911 shows a significant cost saving. The 913 and the Hot Rinse tank are set at 78°F and 89°F respectively. This is not different enough from the ambient temperature of 74°F to cause a significant saving in these two tanks.

For tank 911, the normalized energy consumption for open-lid and closed-lid configuration is given in Table 5 as 1,076,429 kWh/year and 1,010,393 kWh/year. The annual energy and cost savings is calculated as follows.

Annual Energy Savings Calculation for Bath Heating:

1,076,429 kWh/year - 1,010,393 kWh/year = 66,036 kWh/year

The normalized annual energy consumption for open-lid and closed-lid configuration can be divided by 8760 hrs/year to provide a normalized hourly consumption of 122.88 kWh and 115.34 kWh (P_1 and P_2), respectively.

Annual Cost Savings Calculation for Bath Heating:

The formula is given as follows:

$$C_t = ((P_1 - P_2) \times (C_e)) \times (8{,}760)$$

where:

C_t	=	Annual cost savings for bath heating
P_1	=	Power consumed with lids open (122.88 kWh)
P_2	=	Power consumed with lids closed (115.34 kWh)
C_e	=	Cost for electricity in $ per kWh ($0.044/kWh)
8,760	=	Hrs/year conversion factor

Sample Bath Heating Cost Savings Calculation:

$$Ct = 7.54\ \text{kWh} \times \frac{\$0.044}{\text{kWh}} \times \frac{8{,}760\ \text{hr}}{\text{year}} = \$2{,}906/\text{year}$$

The estimated energy and cost savings when heating the 911 tank is 66,036 kWh/year and $2,906/year, respectively.

e) Operating and Maintenance Labor Analysis

O&M labor cost for the KCH ACTSEC technology from November 2000 to February 2001 was $2,849[2]. Based on continuous operation of the system throughout the full year, the extrapolated annual cost is $8,547[3].

Total O&M Cost is $8,547 annually for the KCH ACTSEC Technology.

The same process system without the KCH ACTSEC technology would have an O&M cost of approximately three times as much for the labor and water treatment materials, according to documentation from Goodrich that was verified by the CAMP. The estimate is based on a comparison of the amount of water flow for the existing 5-hp motor (108 gpm) to the anticipated flow rate of 300 gpm for a 10-hp motor.

Since the flow rate is approximately three times that of the 5-hp motor, the test facility estimates that the O&M will be three times as much. Three times the 5 hp O&M cost of $8,547 estimated by the host test site is $25,641[4], which includes chemicals and labor for the scrubber water. No downtime is anticipated with the O&M activity. The saving on total O&M cost is shown below.

$25,641 - $8,547 = $17,094

The O&M Cost Saving ($C_{O\&M}$) is $17,094 annually. This figure includes chemicals and labor but excludes power.

[2] This information was obtained from the host test site.
[3] This information was obtained from the host test site.
[4] This methodology was verified by CAMP.

f) Total Cost Savings (TCS) Annually

The TCS represents total annual savings associated with energy savings due to the reduction in size of pump and fan motor, reduction in the volume of air, and reduced tempering requirements.

The TCS is calculated by summing the annualized individual cost elements including O&M costs and dividing by the total production capacity, operating 24 hrs per day, seven days per week year round. The TCS is expressed in dollars per square foot processed ($\$/ft^2$).

Capital costs will be considered, with the understanding that they will vary depending on each KCH ACTSEC technology application.

The following equation is used to calculate the TCS:

$$TCS = (CS_{fan} + CS_{scrubber} + CS_{HV} + C_t + C_{O\&M}) / P_n$$

where:

CS_{fan} = Cost savings associated with fan ($)
$CS_{scrubber}$ = Cost savings associated with scrubber pump ($)
CS_{HV} = Cost savings due to ventilation ($)
C_t = Cost savings for bath heating ($)
$C_{O\&M}$ = Cost savings due to O&M activities ($)
P_n = Production capacity per year (ft^2)

The sum of the individual cost saving components per year is:

$12,939/year	CS_{fan}
$1,438/year	$CS_{scrubber}$
$31,507/year	CS_{HV}
$2,906/year	C_t
+ $17,094/year	$C_{O\&M}$
$65,884/year	

Annual Cost Savings = $65,884 annually with the KCH ACTSEC technology.

The facility processes approximately 116[5] parts each year. The average square footage of the parts is 312.5[6]. The value for P_n is shown below.

$$\frac{116 \text{ parts}}{\text{year}} \times \frac{312.5 \text{ ft}^2}{\text{part}} = \frac{36{,}250 \text{ ft}^2}{\text{year}}$$

[5] This information was obtained from the host test site.
[6] This information was obtained from the host test site.

TCS = ($12,939 + $1,438 + $31,507 + $2,906 + $17,094) / 36,250 ft^2

TCS is $1.82/$ft^2$ of Landing Gear Assembly.

Capital costs are considered, with the understanding that they will vary depending on each KCH ACTSEC application. The total capital cost of the KCH ACTSEC technology in 2001 was $125,989[7], which includes equipment and installation. For a similar system without the lids, which would require a larger scrubber, water treatment capacity, and induced draft fan, the cost would be $187,272[8]. Therefore, an initial Capital Cost Saving of $61,283 is associated with the installation of the KCH ACTSEC technology at the host test site.

Item	Energy Cost Savings ($/year)
Induced Draft Fan Motor	12,939
Scrubber Pump Motor	1,438
Tempering of Air	31,507
Immersion Heaters	2,906
Total	48,790

Table 13. Cost Savings for Power

5.2 Ventilation Flow Rate

The ventilation is provided to maintain ACGIH requirements for protection of the workers. The lids allow a significant reduction in the ventilation. The vendor, KCH, claimed that the ventilation would be reduced from 50,120 CFM to 17,612 CFM. Upon testing the ventilation system, field measurements yielded the actual ventilation flow rate to be 18,150 CFM. This is a difference of three percent from the KCH design flow rate. The static pressure was checked at a point between the scrubber and induced draft fan and found to be 6.08" wg as compared to the 5.5" wg specified by KCH. This is within 10.5 percent of the KCH design value.

This verifies that ventilation flow rate and static pressure with lids in place exceeds the original design criteria. A previous industrial hygiene survey [Ref. 6] indicted that the level of ventilation provided by the ventilation system for the etch baths was adequate to properly protect the workers according to OSHA and ACGIH requirements.

5.3 Energy Use

The results of the tests on the system components requiring power, including the lid motors, induced draft fan motor, immersion heaters, and scrubber pump motor, provided data that shows there is a reduction in the energy requirements for a system with lids in comparison to a system without lids.

[7] This information was obtained from the vendor.
[8] This information was verified by CAMP.

A summary of component energy savings is shown in **Table 14**.

Item	Energy Savings (kWh/year)
Induced Draft Fan Motor	294,073
Scrubber Pump Motor	32,675
Tempering of Air	716,068
Immersion Heaters	66,036
Total Energy Savings	1,108,852

Table 14. Energy Savings

The reduction in energy amounts to 1,108,852 kWh/year.

5.4 Environmental Benefit/Credit

Electric power is distributed by traditional means. For each kW of power generated at a power plant, pollutants are emitted at a given level (see **Table 15**). Any qualified decrease in power derived from this technology multiplied by a pollutant emission estimate from a power generation plant will provide a ballpark figure for the amount of atmospheric pollutant avoided. Consequently, a reduction in energy consumption can result in a decrease in pollution generated by a power generation utility.

The following simple relationship illustrates pollutant emissions avoided:

$$\text{Pollutant saved} = \text{kWh saved} \times \frac{\text{amount of pollutant}}{\text{kWh}}$$

Fuel	Net Generation (Thousands of Megawatts)	SOx (Thousands of short tons)	NOx (Thousands of short tons)	CO_2 (Thousands of short tons)
Coal	1,652,914	11,248	6,508	1,752,527
Gas	307,306	1	533	161,969
Petroleum	60,844	321	92	50,878

Table 15. Fossil Fuel Electric Power Generation Estimated Emissions 1995 [Ref. 7]

5.5 Project Responsibilities/Audits

Verification testing activities and sample analysis were performed according to the Verification Test Plan [Ref. 2] and Quality Management Plan [Ref. 3].

There was one audit conducted during the verification test of this technology. The audit was an internal *CTC* Technical Systems Audit (TSA), conducted by Mr. Clinton Twilley, *CTC* QA Manager, on November 28, 2001. Mr. Twilley identified two minor findings and one observation (opportunities for improvement). Actions for implementing these opportunities for improvement are being incorporated into future test projects.

6.0 REFERENCES

Verification Test Plan [Ref. 2] and Quality Management Plan [Ref. 3] are available by accessing the EPA ETV website at: www.epa.gov/etv.

1. American Conference of Government Industrial Hygienists, *Industrial Ventilation, A Manual of Recommended Practices, 24th Edition, 2001.*

2. Concurrent Technologies Corporation, "*Environmental Technology Verification Program for Metal Finishing Pollution Prevention Technologies Verification Test Plan, Evaluation of KCH Automated Covered Tank System for Energy Conservation,*" November 7, 2001.

3. Concurrent Technologies Corporation, "*Environmental Technology Verification Program Metal Finishing Technologies Quality Management Plan,*" Revision 1, March 26, 2001.

4. KCH Services, Inc. "Corrosion Resistant Fans," per AMCA Certified Ratings Program by Kenneth C. Hankinson.

5. *"Energy Conservation and Process Control Utilizing Covered Tanks,*" by Kenneth C. Hankinson, Tom Brady, and Alan Chmiglewski, October 1997.

6. Liberty Mutual Industrial Hygiene Evaluation Conducted March 29, 2001, by Mr. Michael A. Shepige, CIG, CSP, Senior Industrial Hygienist.

7. Electric Power Annual 1995, Volume 2, Energy Information Administration, Department of Energy, Washington, DC., December 1996.

7.0 DISTRIBUTION

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APPENDIX A

Completeness Calculations

Completeness Calculations

$$\text{Completeness} = \frac{\text{Valid Measurements}}{\text{Total Measurements}} \times 100\%$$

Sample: The immersion heater nameplate value is 86.7 Amps for one 72 kW heater. For the closed lids configuration the number of valid phase A, phase B, and phase C measurements have been summed and divided by the number of total phase A, phase B, and phase C measurements.

For the immersion heater closed lid configuration, **reference value = 86.7 Amps:**

$$\text{Completeness} = \frac{\text{Valid Measurements (3-phase)}}{\text{Total Measurements (3-phase)}} = \frac{1409}{1409} \times 100 = 100 \text{ percent}$$

For the immersion heater open lid configuration, **reference value = 86.7 Amps:**

$$\text{Completeness} = \frac{\text{Valid Measurements (3-phase)}}{\text{Total Measurements (3-phase)}} = \frac{1526}{1530} \times 100 = 99.7 \text{ percent}$$

For the induced draft fan, **reference value = 34.9 Amps:**

$$\text{Completeness} = \frac{\text{Valid Measurements (3-phase)}}{\text{Total Measurements (3-phase)}} = \frac{3589}{3589} \times 100 = 100 \text{ percent}$$

For the scrubber pump motor, **reference value = 2.1 Amps:**

$$\text{Completeness} = \frac{\text{Valid Measurements (3-phase)}}{\text{Total Measurements (3-phase)}} = \frac{3304}{3589} \times 100 = 92.1 \text{ percent}$$

For the lid motors, **reference value [9] = 3.9 Amps:**

$$\text{Completeness} = \frac{\text{Valid Measurements (1-phase)}}{\text{Total Measurements (1-phase)}} = \frac{482}{485} \times 100 = 99.4 \text{ percent}$$

[9] Note that the lid motors are designed to run at partial capacity, to raise and lower 350 lb lids. Since, the motors are rated for 500 lb, the reference value has been adjusted to 70% of the recorded 4.6 Amps nominal value.

APPENDIX B

Power Measurement Data Summary

AMPERAGE AND VOLTAGE MEASURMENT				
Immersion Heaters	**Low**	**High**	**Average [1]**	**Standard Deviation [1]**
Open Phase A Amps	0.00	81.85	79.11	2.74
Open Phase B Amps	1.47	81.49	78.37	2.67
Open Phase C Amps	2.38	84.42	80.43	2.70
Closed Phase A Amps	0.18	82.95	79.91	3.05
Closed Phase B Amps	0.92	82.59	79.07	2.96
Closed Phase C Amps	2.38	85.52	81.14	3.00
Open Phase A Volts	4.88	284.32	279.12	9.35
Open Phase B Volts	4.88	282.73	278.68	9.32
Open Phase C Volts	4.88	290.55	282.64	9.46
Closed Phase A Volts	4.88	287.25	281.24	10.38
Closed Phase B Volts	4.88	286.27	280.50	10.31
Closed Phase C Volts	4.76	294.82	284.85	10.47
Induced Draft Fan Motor	**Low**	**High**	**Average**	**Standard Deviation**
Phase A Amps	30.95	34.61	32.56	0.10
Phase B Amps	29.12	32.96	30.80	0.12
Phase C Amps	27.47	30.95	28.96	0.17
Phase A Volts	280.41	283.83	282.62	0.52
Phase B Volts	277.85	281.02	279.96	0.52
Phase C Volts	276.14	279.80	278.45	0.72
Scrubber Pump Motor	**Low**	**High**	**Average**	**Standard Deviation**
Phase A Amps	0.00	18.31	2.01	0.10
Phase B Amps	1.65	19.78	2.58	0.07
Phase C Amps	2.56	19.59	3.29	0.05
Phase A Volts	0.98	282.24	278.08	16.06
Phase B Volts	0.98	283.71	278.36	16.08
Phase C Volts	0.98	289.45	281.57	16.26
Lid Motor	**Low**	**High**	**Average [1]**	**Standard Deviation [1]**
Amps	0.00	7.14	3.30	1.48
Volts	118.42	119.64	118.71	0.11
Scrubber Pump Motor Data Summary	**Average PF**	**Average Power Total Run**	**Average Power While Energized**	**Standard Deviation**
Scrubber Pump Motor Phase A Wattage	0.89	970.29	970.29	50.65
Scrubber Pump Motor Phase B Wattage	0.63	1243.14	1243.14	48.58
Scrubber Pump Motor Phase C Wattage	0.52	1606.17	1606.17	48.74
Immersion Heater Data Summary	**Average PF [1]**	**Average Power Total Run**	**Average Power While Energized**	**Standard Deviation [1]**
Immersion Heaters Phase A Wattage Open	1.00	16260.91	38299.99	1679.41
Immersion Heaters Phase B Wattage Open	1.00	16111.36	37900.76	1685.58
Immersion Heaters Phase C Wattage Open	1.00	16778.04	39435.57	1727.43
Immersion Heaters Phase A Wattage Closed	1.00	15308.72	39571.61	1943.27
Immersion Heaters Phase B Wattage Closed	1.00	15105.83	39003.49	1907.94
Immersion Heaters Phase C Wattage Closed	1.00	15722.10	40611.02	1972.73
Lid Motor Data Summary	**Average PF [1]**	**Average Power Total Run**	**Average Power While Energized**	**Standard Deviation [1]**
Lid Motors Wattage	0.95	92.37	347.67	48.25
Induced Draft Fan Data Summary	**Average PF**	**Average Power Total Run**	**Average Power While Energized**	**Standard Deviation**
Induced Draft Fan A Wattage	0.76	15935.80	15935.80	51.72
Induced Draft Fan B Wattage	0.82	14937.85	14937.85	65.32

Induced Draft Fan C Wattage		0.76	13968.48	13968.48	73.93
TRUE POWER USAGE					
Immersion Heaters Testing over Three Hr Period	**Three Hr Power Sum Watt Seconds**	**Three Hr Power Sum Wh**	**One Hr Power Sum Wh**	**All Tank 911 Heaters [2] One Hr (A + B + C) X 2.5 Total Power Wh**	**All Tank 911 Heaters [2] One Hr Total Power kWh**
Phase A Open	175,617,879.78	48,782.74	16,260.91		
Phase B Open	174,002,665.78	48,334.07	16,111.36		
Phase C Open	181,202,849.36	50,334.12	16,778.04		
Total Power Watts				**122,875.78**	
Total Power Kilo-Watts					**122.88**
Phase A Closed	165,334,191.13	45,926.16	15,308.72		
Phase B Closed	163,142,970.66	45,317.49	15,105.83		
Phase C Closed	169,798,629.51	47,166.29	15,722.10		
Total Power Watts				**115,341.63**	
Total Power Kilo-Watts					**115.34**
Induced Draft Fan Motor Testing over One Hr Period	**One Hr Power Sum Watt Seconds**	**One Hr Power Sum Wh**	**One Hr Power Sum Wh**	**One Hr Total Power (A + B + C) Wh**	**One Hr Total Power kWh**
Phase A	43,698,082.38	12,138.36	12,138.36		
Phase B	43,848,904.90	12,180.25	12,180.25		
Phase C	38,224,364.94	10,617.88	10,617.88		
Total Power Watts				**34,936.49**	
Total Power Kilo-Watts					**34.94**
Scrubber Pump Motor Testing over One Hr Period	**One Hr Power Sum Watt Seconds**	**One Hr Power Sum Wh**	**One Hr Power Sum Wh**	**One Hr Total Power (A + B + C) Wh**	**One Hr Total Power kWh**
Phase A	3,091,099.30	858.64	858.64		
Phase B	2,827,776.59	785.49	785.49		
Phase C	2,986,942.50	829.71	829.71		
Total Power Watts				**2,473.84**	
Total Power Kilo-Watts					**2.47**
Lid Motor Testing over Fifteen Minute Period	**Fifteen Minutes Power Sum Watt Seconds**	**Fifteen Minutes Power Sum Wh**	**One Hr Power Sum Wh**	**One Hr Total Power Wh**	**One Hr Total Power kWh**
Phase A	**74,250.52**	**82.50**	**330.00**		
Total Power Watts				**330.00**	
Total Power Kilo-Watts					**0.33**

[1] The referenced figure is caluclated based only on data collected when the equipment was energized.
[2] To calculate the true power consumed by all heaters in the 911 tank, the test value must be multiplied by a manufacturers factor of 2.5.

APPENDIX C

Cost Savings Calculation

Cost Savings Calculation

The system cost without the KCH ACTSEC	$187,272 [10]
The system cost with the KCH ACTSEC	- $125,989 [11]
	$ 61,283

Capital Savings = $ 61,283 for process system with ACTSEC compared to no ACTSEC

Annual Energy Cost Saving = $48,790
O&M Cost Saving = $17,094

Annual Energy Cost Savings + O&M Cost Savings = Total Annual Savings.

$48,790 + $17,094 = $65,884 Total annual savings

[10] This information was verified by CAMP.
[11] This information was obtained by the vendor.