Texas Instruments
TURI Case Studies
2003

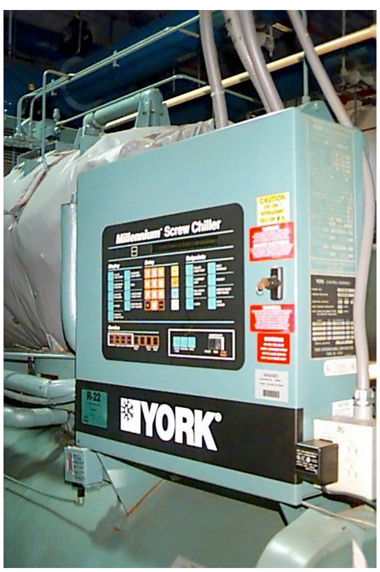
# CHILLED WATER/THERMAL ICE STORAGE

## Project Description

Figure 1: Building 11 Ice Storage System

Two office, manufacturing complexes, Buildings 11 and 12 at the Texas Instruments' (TI) Attleboro, Massachusetts facility require chilled water 24 hours per day, 365 days per year. The chilled water serves the heating, ventilation and air conditioning (HVAC) and process loads of these operation. Historically, chilled water production accounted for a significant portion (~15%) of the total electrical demand of TI's Attleboro facility during peak electricity demand periods – when electricity is more expensive. This had significant negative financial implications for TI.

Figure 2: Chiller Panel




As part of its energy management program, TI installed two chilled water/thermal ice storage systems between 1994 and 1996 to make ice at night, during off peak electricity demand periods, and melt it to serve HVAC and process loads in the buildings during the peak demand periods of the day. The chilled water/thermal ice storage systems consist of ice storage (see Figures 1 and 3), electric drive chillers (see Figure 2), cooling towers with variable frequency drives (VFDs), and water/coolant re-circulating pumps with VFDs (see Figure 4). An additional plate and frame heat exchanger is used to provide "free" cooling using the cooling towers during cold weather without the requirement to run a chiller (see Free Cooling case study).

Prior to the construction of the central chilled water/thermal ice storage systems, cooling loads for Building 11 were served by an aging air-cooled refrigeration (DX and chilled water) system while a centrifugal chiller served Building 12. Both systems benefited from the technical and financial assistance from Massachusetts Electric Company (MECo) as provided under its Design 2000 energy efficiency rebate program.

Figure 3: Building 12 Ice Storage System

## Energy and Cost Savings

The new central chilled water/thermal ice storage systems include high efficiency equipment and shifts electricity load by producing ice during lower cost off-peak hours. As a result, these projects shifted 1.1 MW of peak demand to of-peak periods helping to level the facility load factor. TI estimates that the annual savings from these projects is approximately $460,000.

## Environmental Benefits

It is estimated that indirect emission reductions occur (at electric generating facilities feeding into the regional New England Power Pool - NEPOOL) when load (MW) shifts from less efficient peaking electric generating units and is shifted to more efficient base load electric generating units as a direct result of these peak demand reduction projects. Estimated annual emission reductions are provided below.[1]

**Chilled Water/Thermal Ice Storage**

| | |
|---|---|
| **Total Capital Costs** | **$ 3.3 million** |
| **MECo Rebates** | **$ 1.2 million** |
| **Net Cost to TI** | **$ 2.1 million** |
| **Demand Savings** | **1.1 MW** |
| **Cost Savings** | **$460,000/year** |
| **Emissions Avoided** | |
| **NOx** | **~0.5 tons/year** |
| **$SO_2$** | **~1.4 tons/year** |
| **$CO_2$** | **~96.4 tons/year** |
| **Mercury** | **~0.0005 lbs/year** |

Figure 4: Variable Frequency Drives

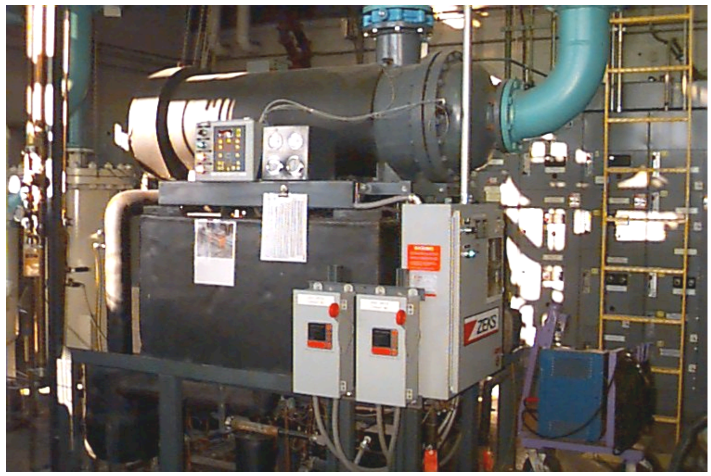
[1] It is estimated that this peak demand reduction project shifts 1.1 MW of demand and the corresponding emissions associated with the production of that electricity by more efficient base load units. Estimated emission reductions are based on published fossil emission rates feeding into the New England Power Pool (NEPOOL).

# COMPRESSED AIR SYSTEM MANAGEMENT

## Project Description

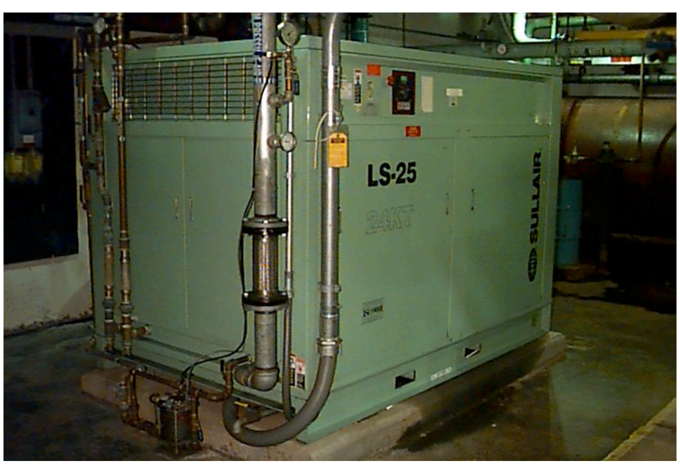
Many industries use compressed air systems as power sources for tools and equipment. In fact, compressed air is so widely used throughout industry it is often considered the "fourth or fifth utility" at many facilities. Texas Instruments (TI) utilizes compressed air at its Attleboro, Massachusetts facility for manufacturing related processes such as pneumatic tools and automation equipment in addition to other miscellaneous uses. Compressed air systems at TI consist of a supply side, which includes compressors and air treatment (air drying), and a demand side, which includes distribution, regulation, storage systems as well as end-use equipment.

**Figure 1: Air Dryer**




As part of its compressed air management system, TI commissioned a comprehensive compressed air system audit in 1996. The audit included an examination of both the air supply side and demand side and the interaction between the two. All components of the compressed air system were inspected individually and problem areas were identified. TI found that losses due to system leaks accounted for 22% of the entire demand on the system, which equaled an additional $165,000 in annual electricity use alone not including demand charges. The audit also identified several poor system design elements, system misuse, as well as insfficientl system dynamics issues. TI used the audit as a tool to identify opportunities to improve energy efficiency and productivity of its compressed air system.

Figure 2: High Efficiency Enclosed Compressor




TI implemented the following measures to reduce the $1 million annual electricity cost associated with the operation of its compressed air system by approximately 29%. First, TI implemented an aggressive leak control program. Next, TI removed 10-15% of unnecessary compressed air use from its facilities through an internal demand side management program. Third, TI improved its compressed air equipment by replacing its oversized and inefficient 200 horsepower (hp) air compressor with two 100 hp high efficiency air compressors and also rebuilt several compressor drive motors for higher operating efficiency. TI also initiated a rebuild of the primary base load steam turbine driven high-speed compressor located in the steam powerhouse. Based on their system approach, TI replaced their desiccant air dryers with refrigerated dryers, installed a central control system to sequence the compressor on and off as needed, installed control valves to regulate the pressure across the entire site +/- 2 psi. Finally, TI installed a central information and computer management system to allow system automation.

Figure 3: Primary Regulator Valves

## Energy, Emissions and Cost Savings[1]

Delivering compressed air to a manufacturing facility is an expensive operation. As noted above, TI historically spent approximately $1 million dollars annually on the associated electric costs. According to the Department of Energy (DOE), compressed air systems account for $1.5 billion per year of U.S. energy costs.[2] Electricity costs are by far the largest expense of owning an operating a compressed air system. High-pressure air is more expensive to produce and deliver than low-pressure air. For a system operating at around 100 psig, a rule of thumb is that every 2-psi in operating pressure requires an additional 1% in operating energy costs. Optimization of compressed air systems can provide energy-efficiency improvements of 20%-50%. The combined improvements to the air compressor system have resulted in annual electricity cost savings of $289,000.

**Compressed Air System Management**

| | | |
|---|---|---|
| **Total Capital Costs** | **$ 650,000** | |
| **MECo Rebates** | **$ 200,000** | |
| **Net Cost to TI** | **$ 450,000** | |
| **Electricity Savings** | **3,313 MWhs/year** | |
| **Cost Savings** | **$289,000/year** | |
| **Emissions Avoided** | | |
| **NOx** | **3.1** | **tons/year** |
| **$SO_2$** | **10.3** | **tons/year** |
| **$CO_2$** | **2,465** | **tons/year** |
| **Mercury** | **0.013** | **lbs/year** |

[1] Estimated emission reductions are based on published fossil emission rates feeding into the New England Power Pool (NEPOOL).
[2] Department of Energy, Office of Industrial Technologies, Best Practices http://www.oit.doe.gov/bestpractices/compressed_air/

# FREE COOLING

## Project Description

The Texas Instruments (TI) facility in Attleboro, Massachusetts uses "free" cooling techniques to substantially reduce energy costs. Typical vapor compression cycle refrigeration systems are rated buy their coefficient of performance (COP) which is the ratio of cooling energy provided divided by the amount of energy used to run the refrigeration plant with typical values between 4 and 5. The 1300-ton cooling load in TI's buildings 11 and 12 represents about 4.57 MW of cooling load, which is effectively provided with about 1.1 MW of electrical consumption for a COP of 4.16. However there are periods of the year where (in the case of TI) cooling towers can be utilized to provide nearly free cooling (COP >50) - where the only energy consumption is from the use of re-circulating pumps and cooling tower fans.

Figure 1: Cooling Tower VFD Panel


The TI chilled water/thermal ice storage system is by-passed during seasonal periods where ambient temperatures are generally above freezing 32F and below 55F wet bulb temperature. The secondary cooling source (i.e. cooling tower) acts as the primary cooling source under these conditions. A plate and frame heat exchanger within the building is then used to provide heat transfer from the cooling tower loop to the internal cooling loop. This system effectively provides nearly free cooling using the cooling towers during cold weather without the requirement to run a chiller. The chiller is essentially shut off during this period, thereby saving energy and also allowing scheduled preventative maintenance to take place. The chiller can be shut down from 1 to as many as 4 months a year (from late Fall until early spring) the payback of the plate heat exchanger system varies based on its use in the system from six months and two years.

## Project Energy and Cost Savings

Free cooling saves a projected $121,000 in energy costs annually. From 1990 – 2001, free cooling has saved TI an estimated $284,000.

## Project Environmental Benefits

Utilization of free cooling techniques at the TI facility avoid approximately 0.7 tons per year of NOx, 2.4 tons per year of SO2, 586 tons per year of CO2 and an estimated 0.003 lbs of Mercury emissions from avoided electric generation.

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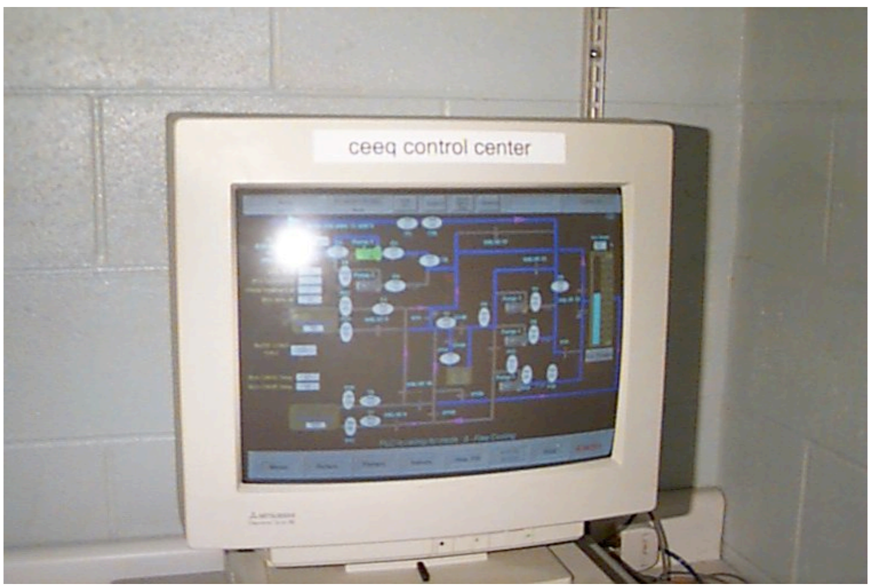


**Free Cooling Project**

| | |
|---|---|
| **Total Capital Costs** | **$** |
| **MECo Rebates** | **$** |
| **Net Cost to TI** | **$** |
| **Demand Savings** | **MW** |
| **Cost Savings** | **$year** |
| **Emissions Avoided** | |
| **NOx** | **~ tons/year** |
| **$SO_2$** | **~ tons/year** |
| **$CO_2$** | **~ tons/year** |
| **Mercury** | **~ lbs/year** |

# FURNACE ATMOSPHERE CONVERSION PROJECT

## Project Description

In 1998, the Texas Instrument (TI) Attleboro, Massachusetts facility completed a furnace atmosphere conversion project. The site annealing furnaces utilize a mix of $N_2/H_2$ as a reducing atmosphere. Prior to the conversion, the $N_2/H_2$ gas was supplied by breaking anhydrous ammonia contained in on-site storage tanks into nitrogen and hydrogen. The Attleboro site had average annual deliveries of ammonia of over 2,000,000 lbs. A site Pollution Prevention team investigated the possibility of supplying the required furnace atmospheres by combining gaseous hydrogen and nitrogen stored on-site rather than dissociating the anhydrous ammonia. A liquid hydrogen tank was subsequently permitted for the Attleboro.

Figure 1: Anhydrous Ammonia Tanks

## Energy and Cost Savings

This project resulted in an annual energy cost savings of $100,000 through the elimination of the ammonia gas dissociation system. The ammonia was dissociated by electrically heating it to 1,800 F. In addition to the energy cost savings, the project also resulted in an annual chemical cost savings of $20,000, annual product yield improvements of $20,000 and avoided compliance costs (based on estimates derived from TI's 112r – Risk Management analysis) of about $125,000 (one time avoidance).

## Environmental Benefits

The primary environmental benefit of this program was the consumption reduction of over 2,000,000 lbs of anhydrous ammonia use as well as minor amounts of fugitive ammonia emissions from the storage tanks systems. Once dissociated the only potential process emissions are nitrogen and hydrogen. Also, because the anhydrous ammonia system had been large enough to trigger Clean Air Act, Risk Management Planning (112r) thresholds, the furnace atmosphere conversion project allowed the site to avoid these potentially onerous regulatory requirements (projected as a 1999 Cost Avoidance).From a Safety perspective, TI's insurer has indicated that the new $N_2/H_2$ supply system is "magnitudes safer" than the anhydrous ammonia system it replaces.

**Furnace Atmosphere Conversion Project**

| | |
|---|---|
| **Total Capital Costs** | **$** |
| **Energy Cost Savings** | **$100,000/year** |
| **Chemical Cost Savings** | **$20,000/year** |
| **Avoided Compliance Costs** | **$125,000** |
| Anhydrous ammonia **Consumption avoided** | **2 million lbs** |

# HIGH VACUUM VAPOR DEGREASERS

### Project Description

High Vacuum Vapor Degreasing (HVVD) is a cleaning technology in which solvent cleaning is performed within a vacuum chamber. By not allowing solvent and air to mix, HVVD technology does not suffer from the problems associated with conventional open top vapor degreasers. For example, HVVD cleaners do not require the extensive cooling coils contained within conventional degreaser to remove solvent from air and are therefore more energy efficient. Additionally, because the cleaning occurs in a closed vacuum system, the only losses of solvent are the small puffs that occur when the chamber is opened and minor quantities in still bottoms. These units are extremely efficient users of solvent and require up to 90% less input solvent. The major drawback to this technology is the high, up-front capital expense.

HVVD technology allows for continuation of the use of solvent in M&C Core Processes for which a suitable non-solvent technique has been not developed. Because of the availability of this technology, the M&C businesses were not adversely impacted by Clean Air Act restrictions on solvent cleaners. Solvent use has been greatly reduced over previous year’s usage related to the replaced conventional vapor degreasers.

### Energy and Cost Savings

As a result of this project, energy costs are reduced by $12,000 annually. In addition, chemical cost savings total $61,500 annually, waste disposal cost savings total $8,000 annually, avoided compliance costs total $16,000 and estimated avoided permitting costs total $14,000.

### Environmental Benefits

The primary environmental benefit of this program is the reduction of solvent use and emissions. HVVD technology is not subject to the Subpart T NESHAP requirements for Halogenated Solvent Cleaners; thus, reducing the annual compliance costs per degreaser (estimated to be approximately $8K greater per unit over what is currently being allocated). Additionally, Since HVVD technology uses solvent in such small quantities; these units can be permitted in Massachusetts under the small cleaner (i.e., monthly solvent consumption of less than 100 gallons per month) exemption.

| High Vacuum Vapor Degreasers | |
|---|---|
| **Total Capital Costs** | **$** |
| **Energy Cost Savings** | **$12,000/year** |
| **Chemical Cost Savings** | **$61,500/year** |
| **Avoided Compliance Costs** | **$16,000** |
| Avoided Solvent Use | |

# CHILLED WATER/THERMAL ICE STORAGE

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Figure 1: Building 11 Ice Storage System

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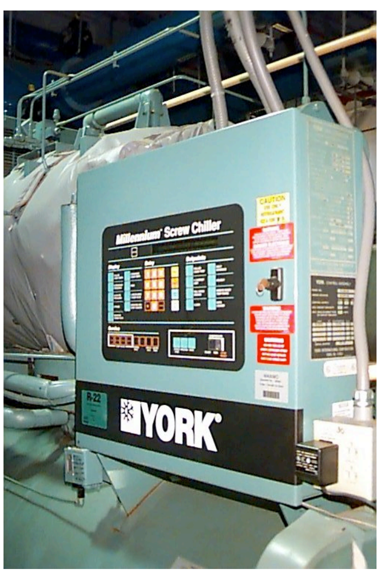


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Figure 4: Variable Frequency Drives

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TEXAS INSTRUMENTS

**TURI Energy Efficiency Case Study**

# COMPRESSED AIR SYSTEM MANAGEMENT

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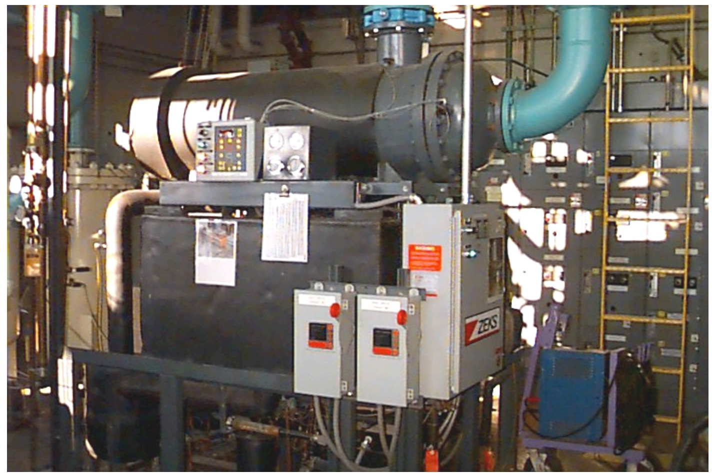


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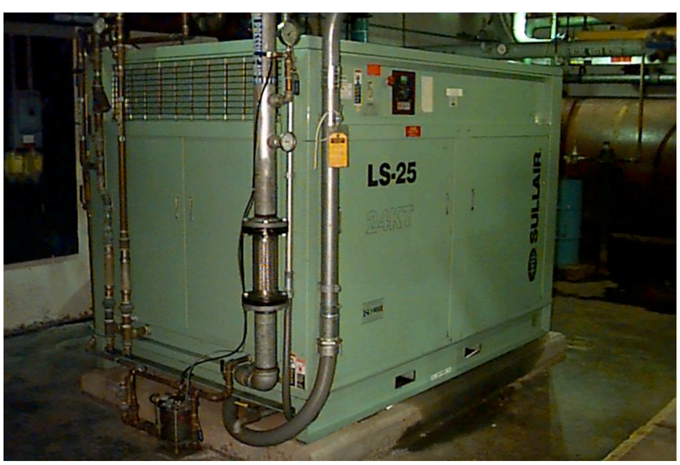


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**Compressed Air System Management**

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Figure 1: Cooling Tower VFD Panel


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## Project Environmental Benefits

Utilization of free cooling techniques at the TI facility avoid approximately 0.7 tons per year of NOx, 2.4 tons per year of SO2, 586 tons per year of CO2 and an estimated 0.003 lbs of Mercury emissions from avoided electric generation.

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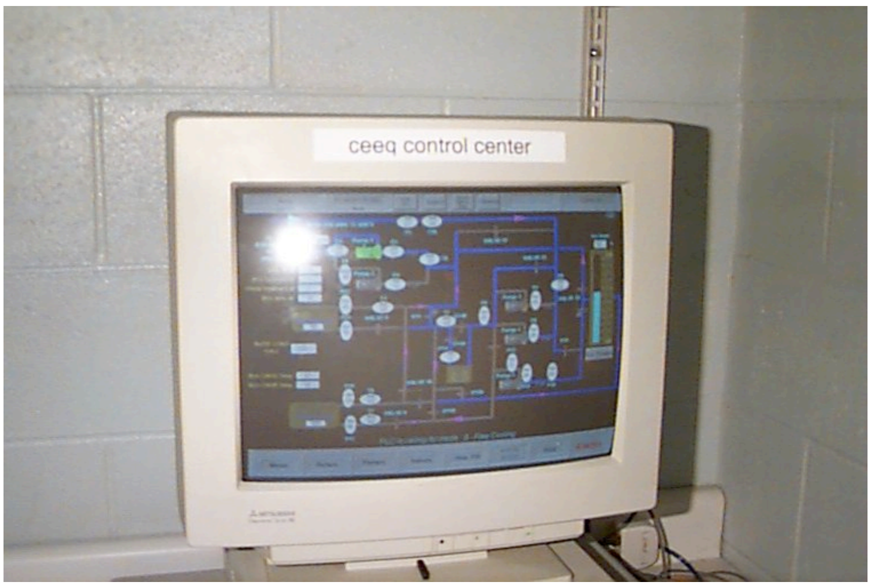


**Free Cooling Project**

| | |
|---|---|
| **Total Capital Costs** | **$** |
| **MECo Rebates** | **$** |
| **Net Cost to TI** | **$** |
| **Demand Savings** | **MW** |
| **Cost Savings** | **$year** |
| **Emissions Avoided** | |
| **NOx** | **~ tons/year** |
| **$SO_2$** | **~ tons/year** |
| **$CO_2$** | **~ tons/year** |
| **Mercury** | **~ lbs/year** |

# HIGH EFFICIENCY MOTORS/ ADJUSTABLE SPEED DRIVES

## Project Description

Drive-power systems are one of the largest electricity consuming elements in industrial processes. In addition to the electric motor, a drive- system can consists of a number of other electrical components, such as pumps, fans, compressors, piping and ducting, motor drive machine tools. Texas Instruments (TI) has implemented what is referred to as a "systems approach" to its use of drive-power systems as a means to reduce its power consumption and high electricity costs.

**Figure 1: High Efficiency Compressor Motor**

**Figure 2: High Efficiency Drive Motors**


A systems approach seeks to increase the efficiency of electric motor systems by shifting the focus from individual components and functions to total system performance. When applying a systems-approach to the design process, the entire system can be optimized. The steps involved in accomplishing a system optimization involve characterizing the process load; minimizing distribution losses; matching the driven equipment to load requirements; controlling the process load in the most optimal manner, considering all cycles of the process load; and properly matching motor and drive to each other, as well as the load.

TI has significantly improved the energy efficiency of its drive systems by reducing the energy losses in the system and by improving the efficiency of the motors. TI further improved the energy efficiency of motors by applying variable frequency drives (VFD) for their electric drive motor systems, replacing motors with high-efficiency motors and optimizing the size of the motor drives. Adjustable speed drives offer the single largest opportunity for energy savings in drive-power systems.[4]

## Energy and Cost Savings

Industrial motor systems represent the largest, single, electrical end use in the American economy—25% of the Nation's electricity consumption and 64% of the electricity consumed in the U.S. industrial sector. High efficiency motors and variable frequency drive systems reduce energy demand, lower emissions, and assist TI to maintain its competitiveness.

## Environmental Benefits

Indirect emission reductions occur (at electric generating facilities feeding into the regional New England Power Pool - NEPOOL) as a result of reduced electricity consumption benefits derived from these projects. Variable speed drives and starters (soft starters) result in reduced kWh consumption and to a lesser extent demand kW reductions resulting from lower demand from several drive motors under simultaneous operation. The environmental benefits here are estimated primarily from reduced energy consumption. Annual emission reductions are estimated in the table below.[5]

**High Efficiency Motors and Variable Frequency Drives**

| | | |
|---|---|---|
| **Total Capital Costs** | **$** | |
| **MECo Rebates** | **$** | |
| **Net Cost to TI** | **$** | |
| **Electricity Savings** | **5,888 MWhs/year** | |
| **Cost Savings** | **$471,000/year** | |
| **Emissions Avoided** | | |
| **NOx** | **5.6** | **tons/year** |
| **$SO_2$** | **18.2** | **tons/year** |
| **$CO_2$** | **4,381** | **tons/year** |
| **Mercury** | **0.023** | **lbs/year** |

**Figure 3: Variable Frequency Drives**

[4] S. Nadel, M. Shepard, S. Greenberg, G. Katz and A.T. de Almeida, *Energy-Efficient Motor Systems: a Handbook on Technology, Program and Policy Opportunities* (Washington, D.C.: American Council for an Energy-Efficient Economy, 1992).

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Industrial motor systems represent the largest, single, electrical end use in the American economy—25% of the Nation's electricity consumption and 64% of the electricity consumed in the U.S. industrial sector. High efficiency motors and variable frequency drive systems reduce energy demand, lower emissions, and assist TI to maintain its competitiveness.

## Environmental Benefits

Indirect emission reductions occur (at electric generating facilities feeding into the regional New England Power Pool - NEPOOL) as a result of reduced electricity consumption benefits derived from these projects. Variable speed drives and starters (soft starters) result in reduced kWh consumption and to a lesser extent demand kW reductions resulting from lower demand from several drive motors under simultaneous operation. The environmental benefits here are estimated primarily from reduced energy consumption. Annual emission reductions are estimated in the table below.[2]

**High Efficiency Motors and Variable Frequency Drives**

| | | |
|---|---|---|
| **Total Capital Costs** | **$** | |
| **MECo Rebates** | **$** | |
| **Net Cost to TI** | **$** | |
| **Electricity Savings** | **5,888 MWhs/year** | |
| **Cost Savings** | **$471,000/year** | |
| **Emissions Avoided** | | |
| **NOx** | **5.6** | **tons/year** |
| **$SO_2$** | **18.2** | **tons/year** |
| **$CO_2$** | **4,381** | **tons/year** |
| **Mercury** | **0.023** | **lbs/year** |

**Figure 3: Variable Frequency Drives**

[1] S. Nadel, M. Shepard, S. Greenberg, G. Katz and A.T. de Almeida, *Energy-Efficient Motor Systems: a Handbook on Technology, Program and Policy Opportunities* (Washington, D.C.: American Council for an Energy-Efficient Economy, 1992).

[2] Estimated emission reductions are based on published fossil emission rates feeding into the New England Power Pool (NEPOOL).

# HIGH VACUUM VAPOR DEGREASERS

### Project Description

High Vacuum Vapor Degreasing (HVVD) is a cleaning technology in which solvent cleaning is performed within a vacuum chamber. By not allowing solvent and air to mix, HVVD technology does not suffer from the problems associated with conventional open top vapor degreasers. For example, HVVD cleaners do not require the extensive cooling coils contained within conventional degreaser to remove solvent from air and are therefore more energy efficient. Additionally, because the cleaning occurs in a closed vacuum system, the only losses of solvent are the small puffs that occur when the chamber is opened and minor quantities in still bottoms. These units are extremely efficient users of solvent and require up to 90% less input solvent. The major drawback to this technology is the high, up-front capital expense.

HVVD technology allows for continuation of the use of solvent in M&C Core Processes for which a suitable non-solvent technique has been not developed. Because of the availability of this technology, the M&C businesses were not adversely impacted by Clean Air Act restrictions on solvent cleaners. Solvent use has been greatly reduced over previous year's usage related to the replaced conventional vapor degreasers.

### Energy and Cost Savings

As a result of this project, energy costs are reduced by $12,000 annually.  In addition, chemical cost savings total $61,500 annually, waste disposal cost savings total $8,000 annually, avoided compliance costs total $16,000 and estimated avoided permitting costs total  $14,000.

### Environmental Benefits

The primary environmental benefit of this program is the reduction of solvent use and emissions.  HVVD technology is not subject to the Subpart T NESHAP requirements for Halogenated Solvent Cleaners; thus, reducing the annual compliance costs per degreaser (estimated to be approximately $8K greater per unit over what is currently being allocated). Additionally, Since HVVD technology uses solvent in such small quantities; these units can be permitted in Massachusetts under the small cleaner (i.e., monthly solvent consumption of less than 100 gallons per month) exemption.

| High Vacuum Vapor Degreasers | |
|---|---|
| **Total Capital Costs** | **$** |
| **Energy Cost Savings** | **$12,000/year** |
| **Chemical Cost Savings** | **$61,500/year** |
| **Avoided Compliance Costs** | **$16,000** |
| Avoided Solvent Use | |