

**Northern Development, LLC/Harbec Plastics, Inc. Combined Heat and Power
Project**

Final Report for Task 5

**THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**
Albany, NY

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Agreement No.: 6846

May 2004

EXECUTIVE SUMMARY

The purpose of Task 5 entitled **Design, install and commission refurbished heat recovery units** is to improve the operation and efficiency of the five Unifin heat exchangers that had been supplied by Capstone . A single Unifin heat exchanger is placed between four Capstone microturbines. There are twenty Capstone microturbines, thus, five Unifins are required to transfer the heat from the exhaust gas of the microturbines to hot water. The hot water is then sent to air handlers to provide heat to the Harbec manufacturing area, to a thermal loop to provide radiant heat to a warehouse or to an absorber to provide chilled water for air conditioning. Unfortunately, the material, design and assembly of the Unifins were of extremely poor quality resulting in extremely poor heat transfer, hence poor efficiencies. Thus, the decision was made to rebuild the five Unifins replacing practically all of the components. Prior to the rebuild, the Unifins would receive 500° F exhaust gas from the microturbines and discharge 320°F exhaust gas to the stacks leading to the roof. The heat removed from the exhaust gas heated 170°F inlet water to 180°F outlet water. After Harbec rebuilt the Unifins, each heat exchanger received 500°F exhaust gas and discharged approximately 210°F exhaust gas to the stacks in the roof. The 170°F inlet water was heated to 200°F. The delta between the temperature of the exhaust gasses going to the stacks and the outlet water going to the chiller or air handlers is only 6°F versus 140°F Δ between gas temperature and water temperature prior to the rebuild. This is a 95% improvement in heat removal efficiency.

BACKGROUND

Northern Development, LLC is a real estate holding company that owns a 48,752 sq. ft. commercial and industrial building that it leases to Harbec Plastics, Inc. Harbec is primarily a plastic injection molder that produces highly engineered custom plastic parts as well as engineering models and the molds used for mass production. The facility consists of a 14,521 sq. ft. warehouse, a 2,479 sq. ft. power plant, 20,634 sq. ft. of manufacturing space and 11,118 sq. ft. of office and non-production space. Harbec employs approximately 100 employees. Harbec is a Service Class 3 electric power customer of Rochester Gas & Electric. In the past twelve months, Harbec purchased 112,251 kWh from RG&E at a cost of \$30,139.96. Gasmark supplies the natural gas. Harbec purchased 396,236 therms for a total cost of \$212,051.39 including transportation and taxes.

PROJECT DESCRIPTION

Each Unifin heat exchanger receives the heated exhaust gasses from four 30 kW Capstones. Prior to this rebuild project each of the Unifins suffered from the following issues:

1. Exhaust gas leaking from the housing joints;
2. By-pass damper valves sticking or broken;
3. Lack of damper modulation preventing accurate water temperature control;
4. High exhaust back-pressure and minimal heat transfer, due to poor water coil design;

5. Pump failures due to incorrect impeller material and incorrectly located check valves;
6. Excessive heat loss, due to lack of adequate insulation;
7. Water leaking from poorly made heater coils.

The rebuild project began with the removal of one Unifin heat exchanger from its connection to four Capstone microturbines (See Photo #1 below). The four Capstones were disabled for the period of time required to rebuild the Unifin. After the unit was unhooked from the water, exhaust and electrical services it was pulled out of location and completely disassembled. The Unifin cabinet consisting of sheet metal was discarded as it only got in the way of routine service. The failing insulation was removed and discarded (See Photos #2&3).

The damper assembly (upper housing) (Photo #5) was unbolted and lifted off with an overhead hoist. This assembly underwent several changes that started with complete disassembly and sand-blasting. The damper blade pivot bearings were removed, due to complete failure, and replaced with a new component of different design. The damper blade fixation to the damper shaft, which had failed on four of the five units, was modified with “clamp blocks” which were welded to cutouts in the damper blade (Photos 6 & 7). The original was simply “through bolted” to the shaft. The bolts fatigued and broke, allowing the shaft to turn free of the damper blade. The result was loss of damper control. The damper usually failed in the closed or by-pass position. This situation resulted in no heat transfer to the water.

The shaft to which the blade was attached was carbon steel and had rust on it (Photos # 8 & 9). This caused excessive wear on the poorly supported bearings at each end. The bearing consisted of a sintered metal bushing supported by a 1/8” thick plate (Photo #10). The thin plate only held the fragile bushing in one thin plane causing the bushing to crack and fall apart. The new components consist of a hard-chrome plated shaft, supported by Garlock DU series bushings, pressed into a 3/4” thick steel plate (fully supported bushings) (Photo #11).

The force of the actuator that moves the shaft is high enough to cause the over-hung shaft to deflect, therefore causing unnecessary bushing wear. An out-board bearing assembly was added to put the actuator in double-shear (eliminating the deflection) (Photo #12). The actuator (motor driven Acme screw with feedback) was reversed with minor modification. The pivot pinholes that mount both ends were bored and filled with Garlock DU bushings and new pins. This reduced the noise from the linkage assembly and increased the accuracy of adjustment.

A new damper crank arm (Photo #12 & 13) was designed and fitted with a bushing and this assembly connects to the actuator. The length of the arm was calculated to allow 100% damper movement, fully open, fully closed, without stalling the actuator. This motion is completed within the limits of the switches that limit actuator travel. The old system would cause the actuator to stall or bind before stopping.

The water coil (Photo #14 & 15) was replaced by a new one (Photos 16 & 17) that consists of flat copper plates with hydroformed stainless steel tubes and headers. Fifty percent more tube was used to increase heat transfer. The flat copper plates allow much less exhaust gas pressure drop and heat transfer than the original spiral-fin tube unit (Photo #18). The height dimension of the new coil was about six inches higher; therefore,

the frame assembly that supports the heat exchanger was shortened to maintain the unit's original height (Photo #19). This allowed the turbine exhaust pipes to fit without modification.

The assembly of the damper unit to the coil unit and lower return duct housing was originally accomplished with bolted flanges. The problem was that the bolt spacing was too large, and this allowed for large gaps to form between the surfaces. (Photos 20 & 21) This was the source of major exhaust gas leakage. The cure for this included drilling a new hole between every existing hole and doubling the count per flange. A gasket made of woven ceramic fiber was added between the flanges to allow for imperfect surfaces (Photo #22). The bolts now include a stainless bellville washer (Photo # 22), which creates a constant tension on the bolt. This imparts a constant compression on the gasket, reducing the effects of thermal cycling and leakage.

The original pump impeller material was plastic and failed repeatedly. This caused the unit to overheat and damage the coil. A check valve was located on the inlet of the pump, causing possible cavitation damage to the pump. A new pump was selected with a bronze impeller and an 1800-rpm high-efficiency motor (Photo #23)). The check valve was repositioned in the piping layout on the output of the pump, eliminating the reduced pressure at the pump inlet. All metal components were painted with a high heat primer (Photo #24) and topcoat after sand blasting (Photo #25).

The completed assembly was insulated with 4" of mineral wool board type insulation. (Photo #26). The original was 1 1/2" thick fiberglass. This material failed due to the high operating temperatures.

To facilitate servicing the completed unit, steel casters were added. (Photo # 27).

The above described rebuild process was repeated with the other four heat exchangers.

The damper assembly in each heat exchanger is now controlled by one PLC. (Photo # 28) This PLC controls all five heat exchangers. A third thermocouple was added to each unit. This thermocouple measures the departing exhaust gas temperature. Monitoring the temperature of the departing exhaust gas permits the comparison of the exiting water temperature with the departing exhaust gas temperature. Since the rebuilding of the five heat exchangers, the temperature of the exiting water is often as close as 5° F to the temperature of the exhaust gas temperatures. This is a very significant improvement over the previous 40°F differential as described in the Executive Summary above.

The main purpose of the PLC is to eliminate the damper slamming open and closed. Eliminating these actions achieved control of the water temperature set point. The damper modulates, the motion is very smooth and controlled, drastically improving the life of the components involved. (Photo #29)

Snap disc temperature switches were added to the coil output pipe to monitor temperature extremes. If this occurs, the switch will open and turn off the microturbines allowing them to cool down. This is a safety system designed to prevent major problems.

The end result is 100% satisfactory. The redesigned heat exchangers now provide a constant supply of 200°F water. The control of the water temperature is very stable and without issue. The damper actuators are not seeing any large loads and should last much longer. The pumps are running at high water temperatures with no problems. Heat losses to the room are minimal. Harbec now has a very efficient heat recovery system.

Task 5 was completed in April 2004.

NOTICE

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