Energy Efficient Building Equipment and Envelope Technologies

Final Report

December 2003

Submitted to:
U.S. Department of Energy
National energy Technology Laboratory
Pittsburgh, Pennsylvania
Award No. DE-FC26-00NT40990

By:
Rocky Research
1598 Foothill Drive
Boulder City, Nevada 89005

January 5th 2004

Summary 3
Task 2.1 .....Testing and design of the Bulb Charge, spring force, orifice size, valve seat and valve cavity..... 4
Efforts on the Lennox Pulsed TXV 4
Task 2.2 TXV Performance Tests 9
Task 3. Industry Participation 12
Task 4. Reliability Testing 13
Efforts on the Refrigeration Pulsed TXV..... 14
Conclusion..... 20

Summary

Summary of Objectives

Objectives of this project under this cooperative agreement are to evaluate the energy efficiency and performance enhancements of a pulsed thermal expansion valve (TXV), its cost and reliability. This device could replace the currently used devices, a capillary tube and modulating TXVs, in household and commercial refrigeration and air conditioners. Determination of the economics and first cost of such devices, once performance enhancements have been defined, shall be performed and reported. This work shall be accomplished with the support of commercial partners in the HVAC&R industries. The reliability of the pulsed TXV shall also be determined, which is an important factor for its commercial success.

Summary of work performed

Work performed last month was focused on refining the existing TXV design for primarily HVAC applications and refrigeration applications. Different components of the TXV were investigated for optimum performance using numerical techniques, then drawings for these components were made using AutoCAD.

Also a potential manufacturer of the pulsed TXV was contacted. Micro Instruments of Rochester New York has been contacted regarding production, design for manufacturing and cost of mass production.

A TXV test stand has been designed and built. The test stand can be used to map the performance of individual pulsed TXV's and its components. The first test with the pulsed TXV was done for the residential air conditioner pulsed TXV.

A refrigerator from Viking Range Corp. was instrumented and tested.

Work details are presented in the following pages.

Task 2.1 Testing and design of the Bulb Charge, spring force, orifice size, valve seat and valve cavity.

Efforts on the Lennox Pulsed TXV

Bulb charge: Bulb charge is selected to give the desired superheat and superheat response versus evaporator temperature. It is usually desirable that superheat be set at normal operating temperature, and that a charge be selected that gives higher superheat at higher evaporator temperatures. This response helps avoid flooding during compressor startup

Final Report

December 2003

Submitted to:
U.S. Department of Energy
National energy Technology Laboratory
Pittsburgh, Pennsylvania
Award No. DE-FC26-00NT40990

By:
Rocky Research
1598 Foothill Drive
Boulder City, Nevada 89005

January 5th 2004

Summary 3
Task 2.1 ....Testing and design of the Bulb Charge, spring force, orifice size, valve seat and valve cavity..... 4
Efforts on the Lennox Pulsed TXV 4
Task 2.2 TXV Performance Tests 9
Task 3. Industry Participation 12
Task 4. Reliability Testing 13
Efforts on the Refrigeration Pulsed TXV..... 14
Conclusion..... 20

Summary

Summary of Objectives

Objectives of this project under this cooperative agreement are to evaluate the energy efficiency and performance enhancements of a pulsed thermal expansion valve (TXV), its cost and reliability. This device could replace the currently used devices, a capillary tube and modulating TXVs, in household and commercial refrigeration and air conditioners. Determination of the economics and first cost of such devices, once performance enhancements have been defined, shall be performed and reported. This work shall be accomplished with the support of commercial partners in the HVAC&R industries. The reliability of the pulsed TXV shall also be determined, which is an important factor for its commercial success.

Summary of work performed

Work performed last month was focused on refining the existing TXV design for primarily HVAC applications and refrigeration applications. Different components of the TXV were investigated for optimum performance using numerical techniques, then drawings for these components were made using AutoCAD.

Also a potential manufacturer of the pulsed TXV was contacted. Micro Instruments of Rochester New York has been contacted regarding production, design for manufacturing and cost of mass production.

A TXV test stand has been designed and built. The test stand can be used to map the performance of individual pulsed TXV's and its components. The first test with the pulsed TXV was done for the residential air conditioner pulsed TXV.

A refrigerator from Viking Range Corp. was instrumented and tested.

Work details are presented in the following pages:

Task 2.1 Testing and design of the Bulb Charge, spring force, orifice size, valve seat and valve cavity.

Efforts on the Lennox Pulsed TXV

Bulb charge: Bulb charge is selected to give the desired superheat and superheat response versus evaporator temperature. It is usually desirable that superheat be set at normal operating temperature, and that a charge be selected that gives higher superheat at higher evaporator temperatures. This response helps avoid flooding during compressor startup when capacity is higher and the bulb is warmer.

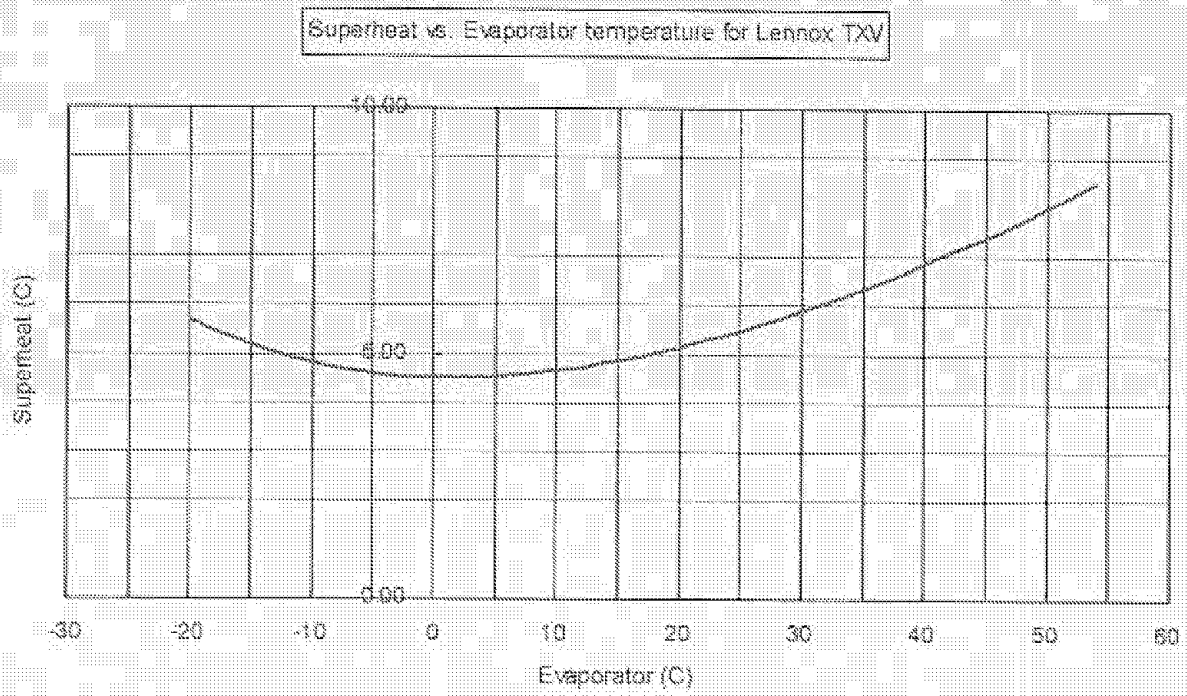


Figure 1 Superheat vs. Evaporator temperature

Spring Force: Increasing spring force results in increased superheat, but the magnitude of the effect is less at high evaporator pressure/temperature. Proper superheat and response must be obtained by proper selection of spring force and bulb charge. The spring force chosen is in the range of 15 to 30lbs. The effect of different spring forces is

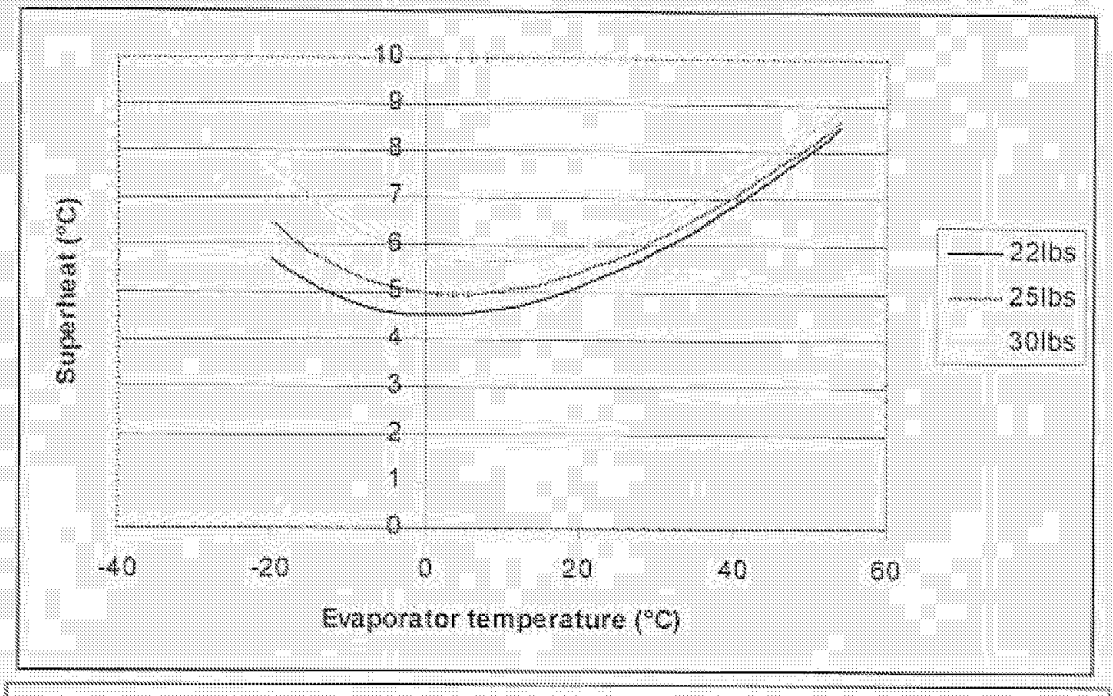


Figure 2. Effect of spring force on superheat

shown in Figure 2. The current design will be such that the spring force can be adjusted on the fly without any need of TXV removal.

Orifice size: The size of the outlet orifice is selected to be more restrictive than the inlet seat to ensure that the valve re-closes quickly, but must be small enough to allow refrigerant flow at the design rate with only one or two psi pressure drop. The calculations is for a range of 0 to 20% vapor quality are shown in Figure 3 for the Lennox unit. Currently the outlet orifice chosen is 0.180".

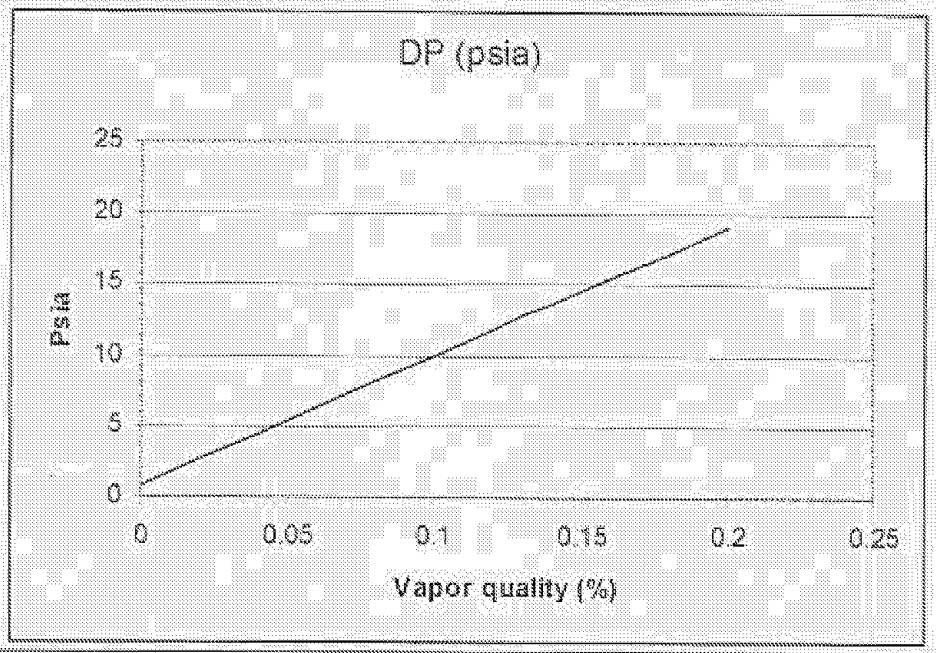


Figure 3. Pressure drop for a 0.18 outlet orifice

Valve Cavity

Design of the valve cavity will determine the frequency of the opening/closing of the valve. For the Lennox TXV the flow rate is about 40 cm^3/sec. The volume of the cavity is designed to be 2.6 cm^3 resulting in frequency of less than 20 Hz. As shown in Figure 4 the natural frequency of the mass-spring system is dependent on spring force and the operation will never reach the natural frequencies.

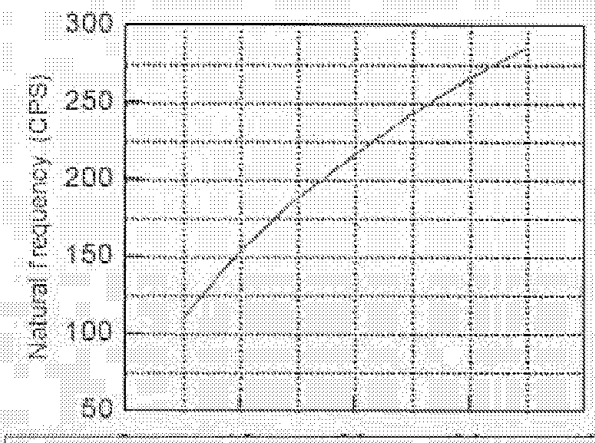


Figure 4. Natural frequency of the TXV vs. spring force

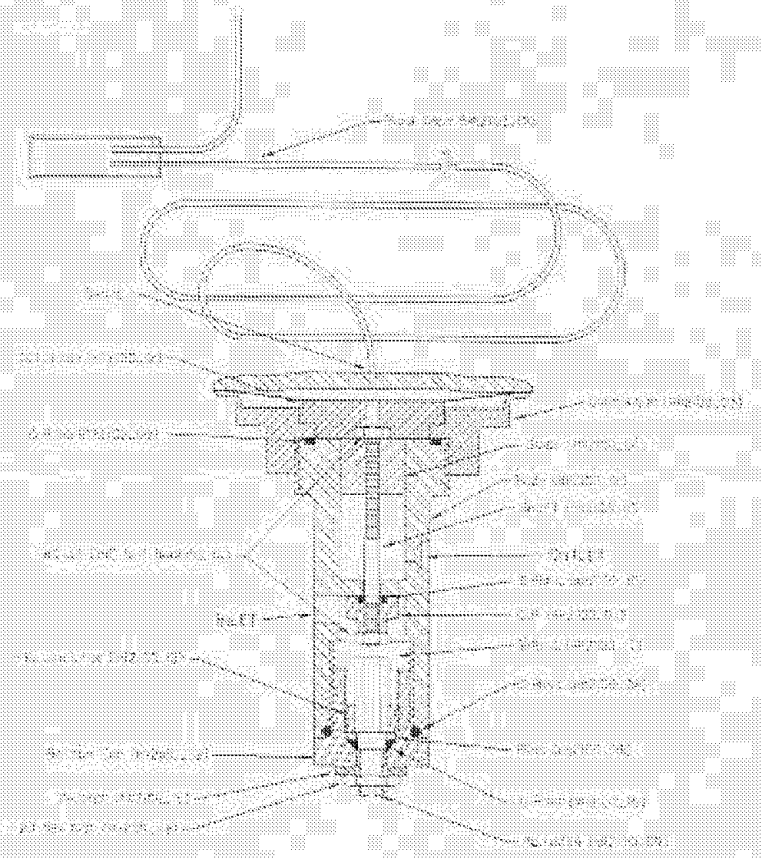


Figure 5. CAD drawing of the Lennox TXV

Show in Figure 5 the AutoCAD drawing of the Lennox TXV is shown. All of the components are shown. The complete sets of drawings were also sent to Micro Instruments for fabrication, review and comments. The first TXV was fabricated and sent to us for further testing.

TXV Test Stand

The TXV was tested for performance and functionality at several temperatures. Figure 6 shows the results as superheat vs. refrigerant mass flow.

TXV was tested in two ways:

1. TXV bulb was set in a constant temperature bath and the pressure on the outlet side of TXV was varied. Flow is measured with inlet and outlet pressures and logged.
2. Inlet and outlet pressures are kept constant and bulb temperature is varied by ramping the bath temperature up and down. Flow, pressures and temperature is logged as before.

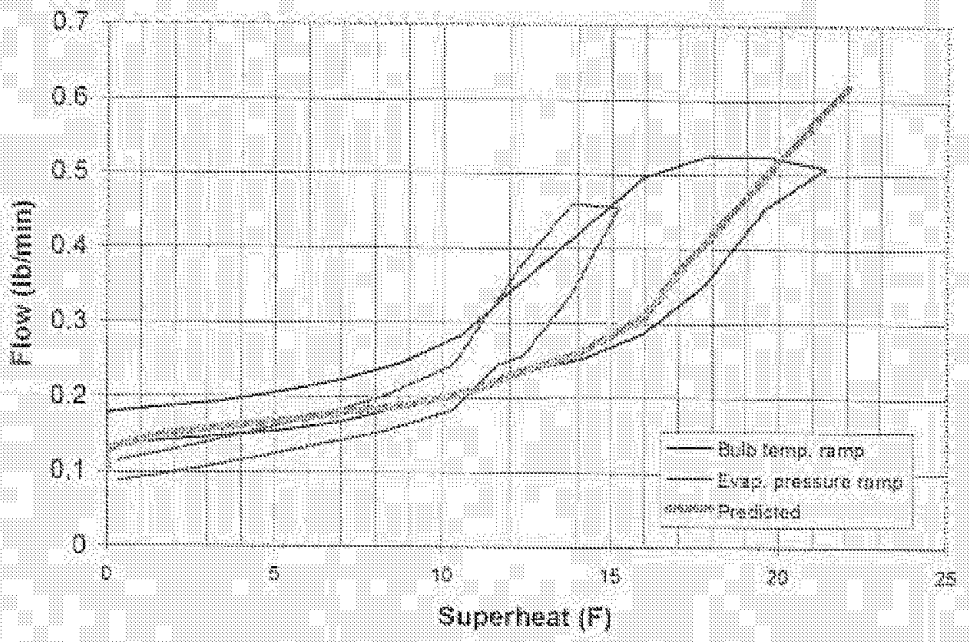


Figure 6. Results of the TXV test stand, superheat vs. flow

The difference between the two sets of graphs is due to hysteresis and response delay of the bulb. The agreement between predicted and measured is also shown; the difference could be due to the bulb charge variations.

Task 2.2 TXV Performance Tests

The goals of this task were:

- Modify existing test setups to test the pulsed TXV alone.
  - Complete mapping of TXV performance
    - Superheat vs. evaporator/condenser temperatures
    - Refrigerant flow vs. evaporator/condenser temperatures
- Testing with a Refrigeration/HVAC system
  - System baseline performance without the pulsed TXV, with the
  - Evaluate system performance with the pulsed TXV

The test room is divided to two sections, Indoor and outdoor rooms. Two constant bath temperatures are installed with air handlers to simulate loads. Instrumentation of the split Lennox heat pump includes a wattmeter to measure energy efficiency. The data acquisition program measures and logs data to a PC. The first set of baseline tests are done at 90°F outdoor temperature. Test results are shown in Figure 7. Shown are power measurements and both outdoor and indoor temperatures. As it is seen the power required is very sensitive to the outdoor temperature. The room temperature variations of a few degrees increase the power by more than 100 Watts. The indoor temperature was kept constant in order to have the compressor run continuously during the test.

Further tests planned at 90°F outdoor will continue to establish the current modulating TXV performance. A flow meter and several thermocouples was added to the Hydronic loop to better measure the capacity.

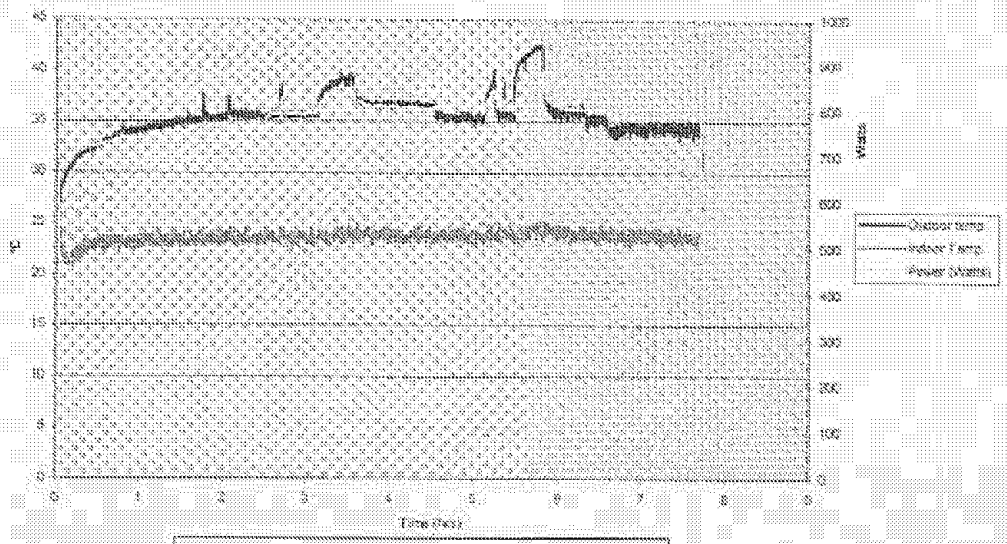


Figure 7. Lennox Heat pump test data

Testing the Lennox HVAC unit was completed according to the test points shown in table 1 with its results.

Test #	Evaporator Temperature (°F)	Condenser Temp (°F)	Capacity	Average Cooling (Watts)	Average Electrical Input (Watts)	Special conditions
1	42-48	92-95	Full	5107	3188	None
2	42-48	92-95	Full	5098	3026	Startup from 95°F ambient
3	42-48	82-85	Full	5440	2802	None
4	42-48	82-85	Full			Start-up from 85°F ambient
4	42-48	92-95	80%	4380	2342	Part-load
5	42-48	92-95	60%	3584	1876	Part-load
6	42-48	92-95	Full	5439	3050	80% of full refrigerant mass
7	42-48	92-95	75%			75% of full airflow through evaporator coil

Figure 8 shows the test results over a period of about 6 hours. Shown are both electrical input and cooling power measured directly in Watts. Also both indoor and outdoor temperatures are shown.

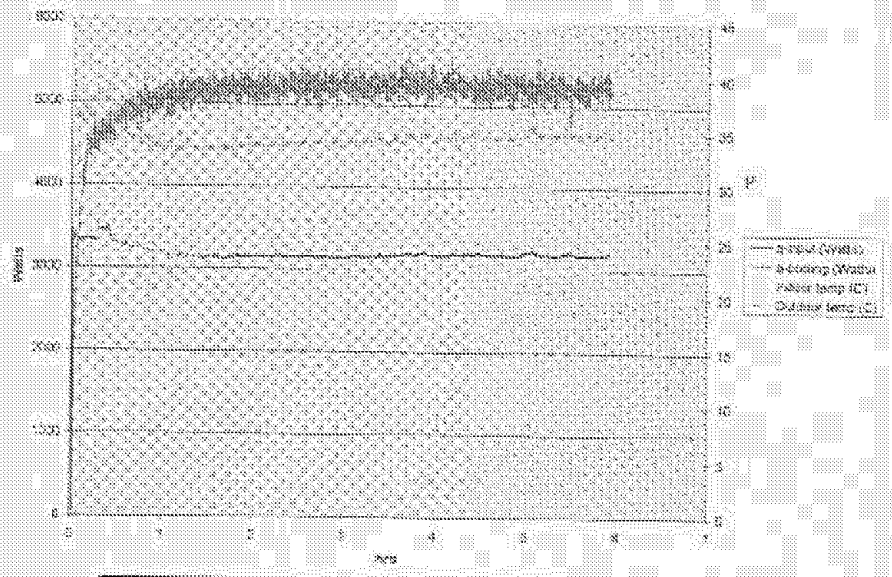


Figure 8. Base condition no. 1 test results

Figure 9 shows the test results for test point 7. Shown are both electrical input and cooling power measured directly in Watts and both indoor

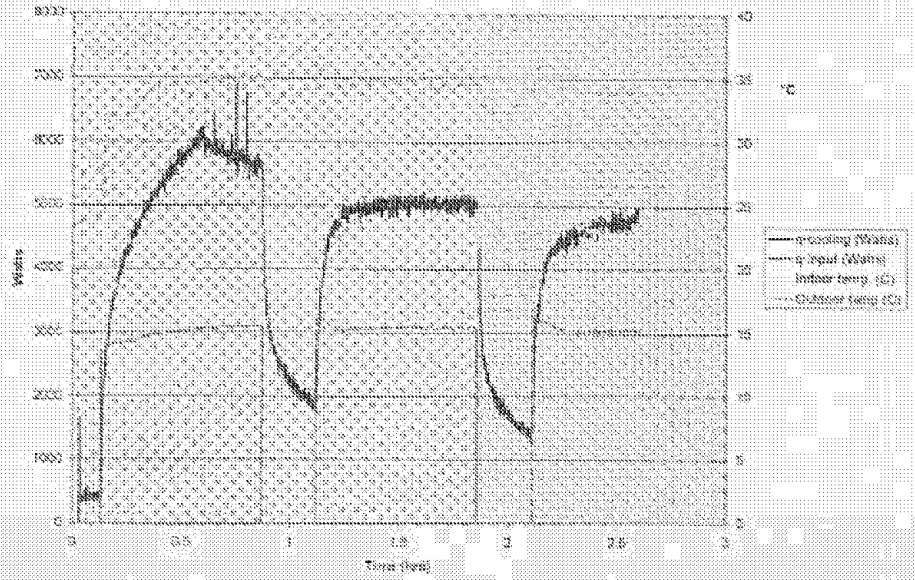
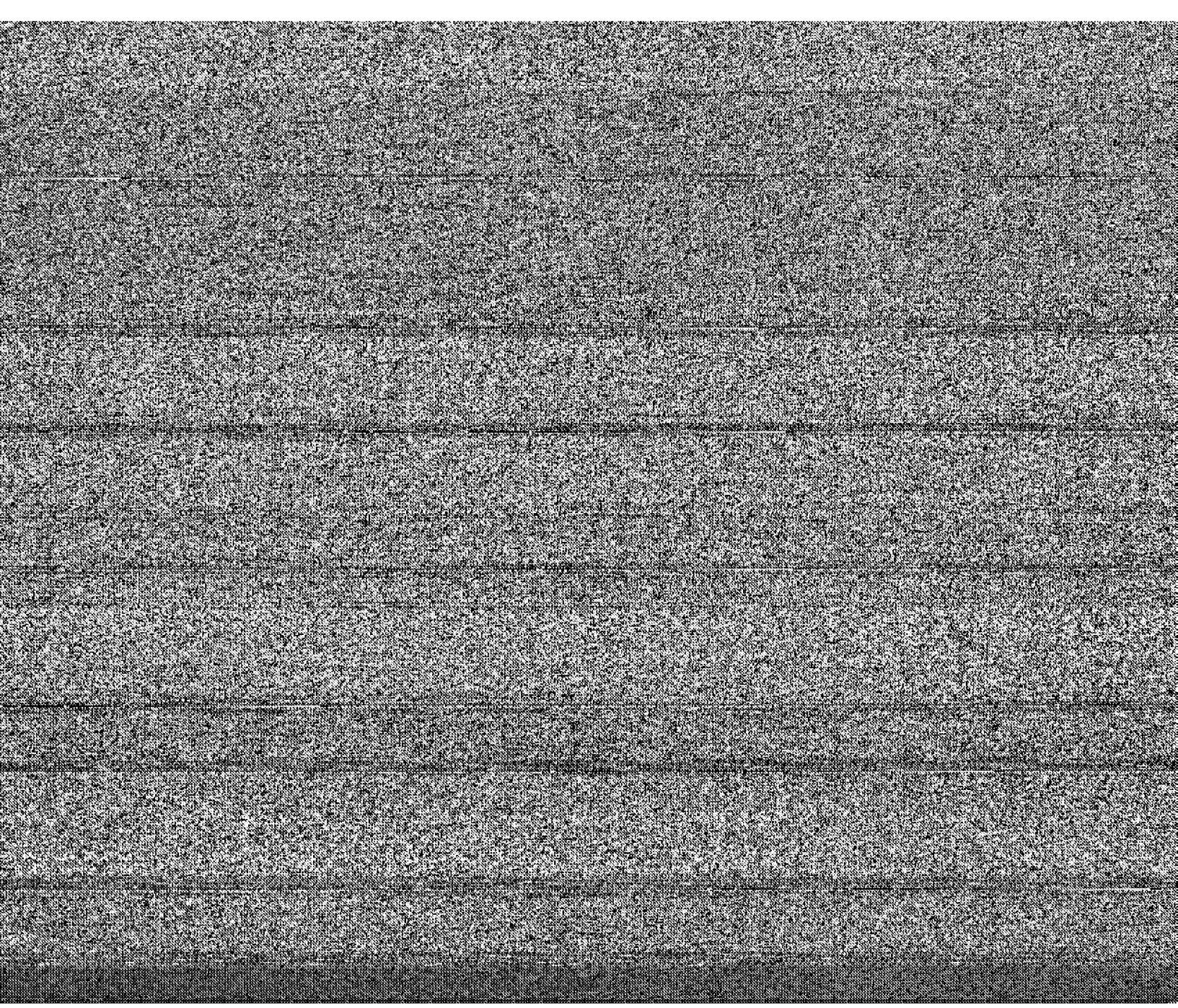


Figure 9. Test results at test point 7



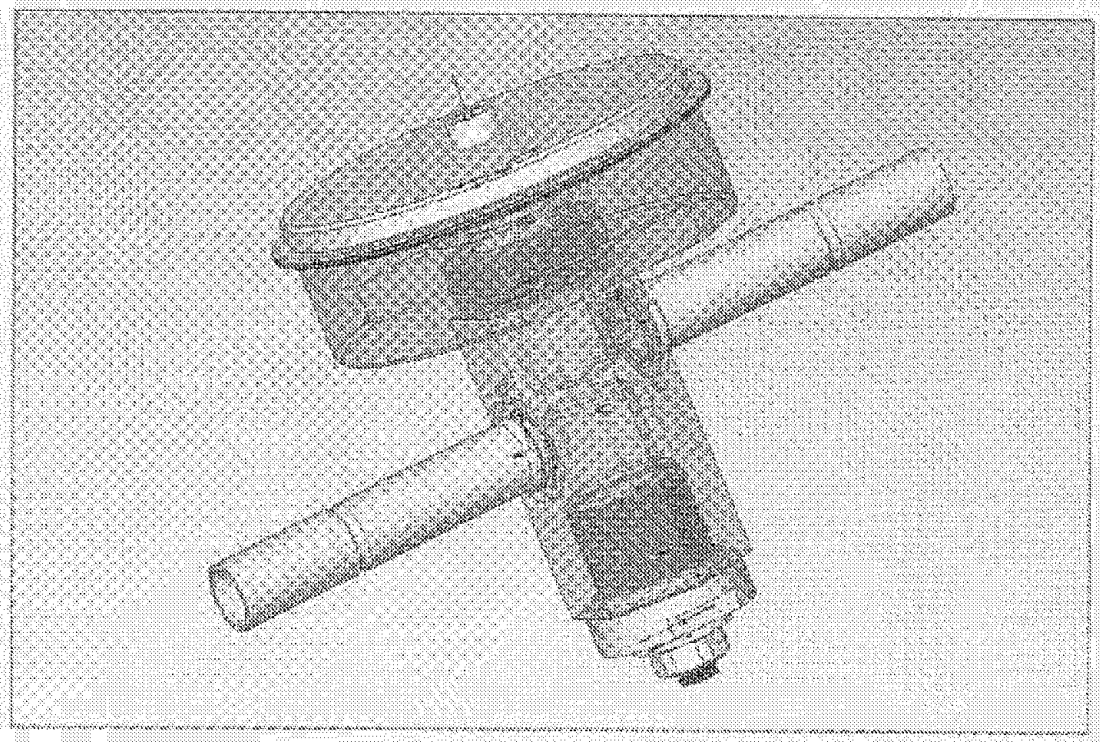


Figure 9. Pre-Commercial Pulsed TXV

Task 4. Reliability Testing

The critical component in a TXV is the diaphragm and needs to be life-tested for reliability. It has to be noted that this reliability test has no effect on the pulsed TXV performance and is only a matter of life and endurance. Since the pulsing TXV design is different from traditional TXV in that the pulsing design puts a higher stress on the diaphragm than modulating TXV, it is important to test the diaphragm for reliability.

A pre-production Brass TXV used for long-term reliability testing on a Viking refrigerator has been working since July 2001 24 hrs/7days a week automatically. No problems have been observed. Number of cycles logged in this unit has passed 32,000,000 cycles at the time of this report.

GAX Heat pump

Testing of alpha and Beta units were done using a slightly different TXV with non copper based metal alloys. All TXV's used in these chillers/heat pumps are of pulsed TXV kind. So far results are very encouraging and it seems that refrigerant control to the evaporator is well within the design parameters. It has to be noted that all other conventional TXV's used could not match the performance of the pulsed TXV's wit this system.

Efforts on the Refrigeration Pulsed TXV

The following is a summary of the test results on the two High-end bottom-mount freezer refrigerators tested at Rocky Research during 2001. One of the units is used for life cycle testing of the pulsed TXV (V-1) while the other (V-2) is used to measure the effect of different components including the pulsed TXV on the overall efficiency.

The V-2 unit was first instrumented and tested without any modifications[1]. The energy used was slightly larger than 800 kW-hr/year. Upon installing the pulsed TXV the energy usage was about 690 kW-hr/yr, savings of almost 15%. Figures 10 and 11 show the results. Figure 12 shows the side-by-side comparison, where the electrical power usage for the pulsed TXV is about 150 Watts as compared to 172 Watts for the capillary system. A cool-down comparison is shown in Figure 13 where the Pulsed TXV system can reach the freezer temperature 40 minutes sooner than the original capillary system.

The adjustable pulsed TXV sketch is shown in Figure 14. The variable speed compressor made by Embraco™ was tested with the pulsed TXV. The improvement was measured at 5% bringing the total energy consumption down to 590kW-hr/yr.

All energy consumption data shown above and below are measured results at Rocky Research facilities. Hot room facility limitations and test operation at limited temperature conditions commonly result in higher absolute energy consumption values than obtained under the official 10CFR430.A1 testing rules for energy efficiency qualification. Therefore, the improvements made need to be evaluated on a relative scale.

The V-1 has been used to life cycle test diaphragms made by Weiss instruments. The The Weiss Instrument diaphragm assembly has been tested for more than 1-year or 120,000,000 cycles. No problems have been observed in either performance or pulldown.

Table 1. Viking-2 test summary

Description	Average energy usage
As is, A watt meter and ambient TC is used	> 800 kW-hr/yr
Replaced capillary with the pulsed TXV and instrumented the unit	690 kW-hr/yr
New evaporator and condenser	615 kW-hr/yr
The Embraco VCC	590 kW-hr/yr

[1] All test conditions are at warm-warm settings and 90°F ambient temperatures in this report.

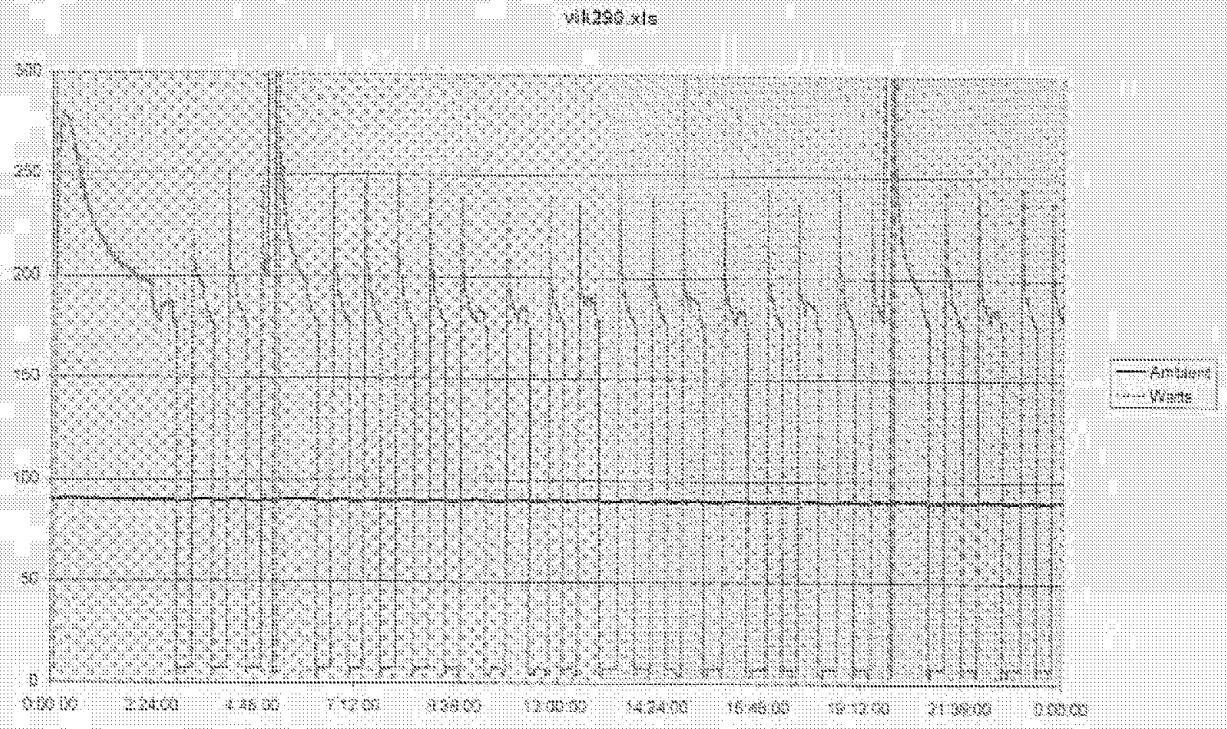


Figure 10. Viking-2 with Capillary

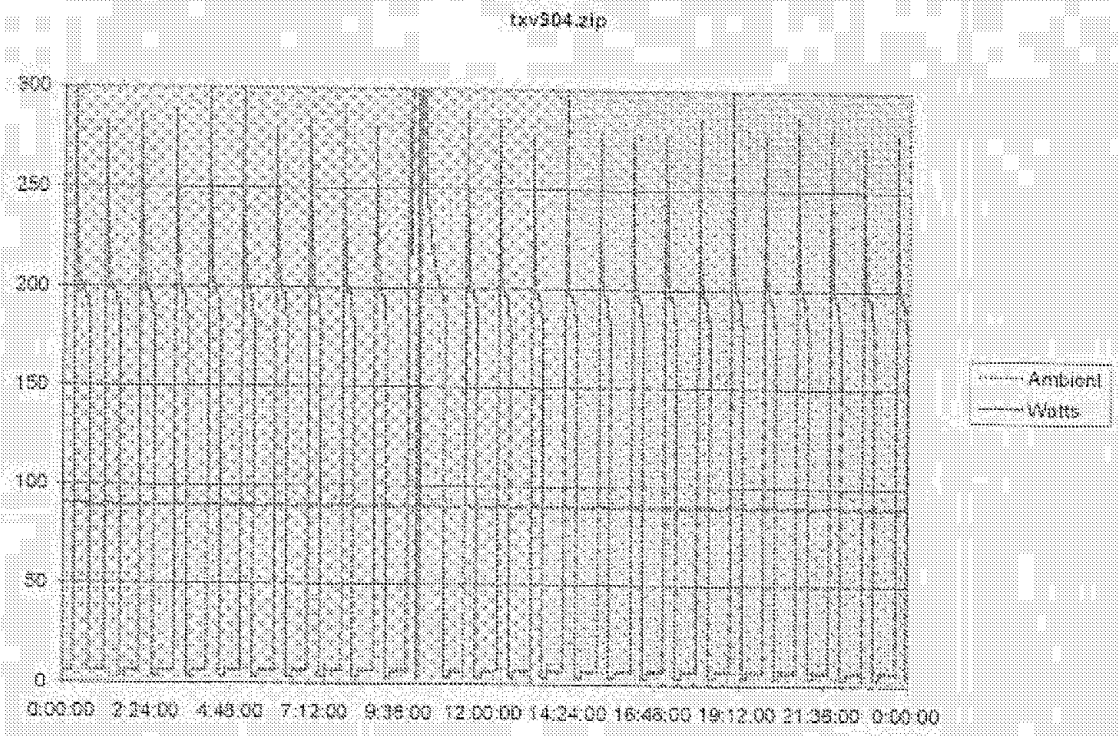


Figure 11. Viking-2 with the Pulsed TXV

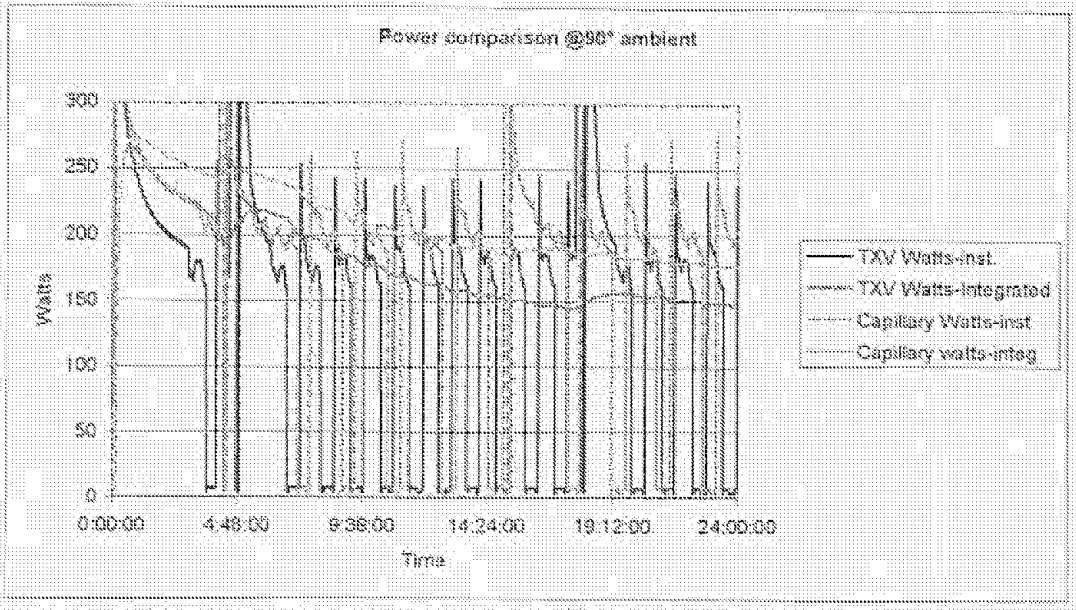


Figure 12. Power comparison between capillary system and the pulsed TXV

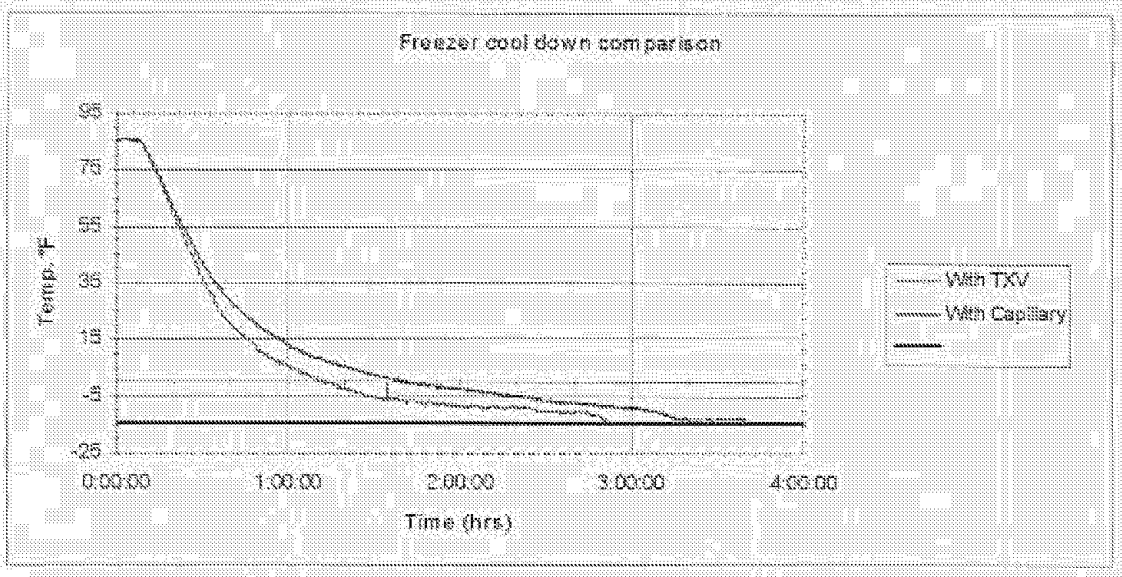


Figure 13. Cool-down comparison

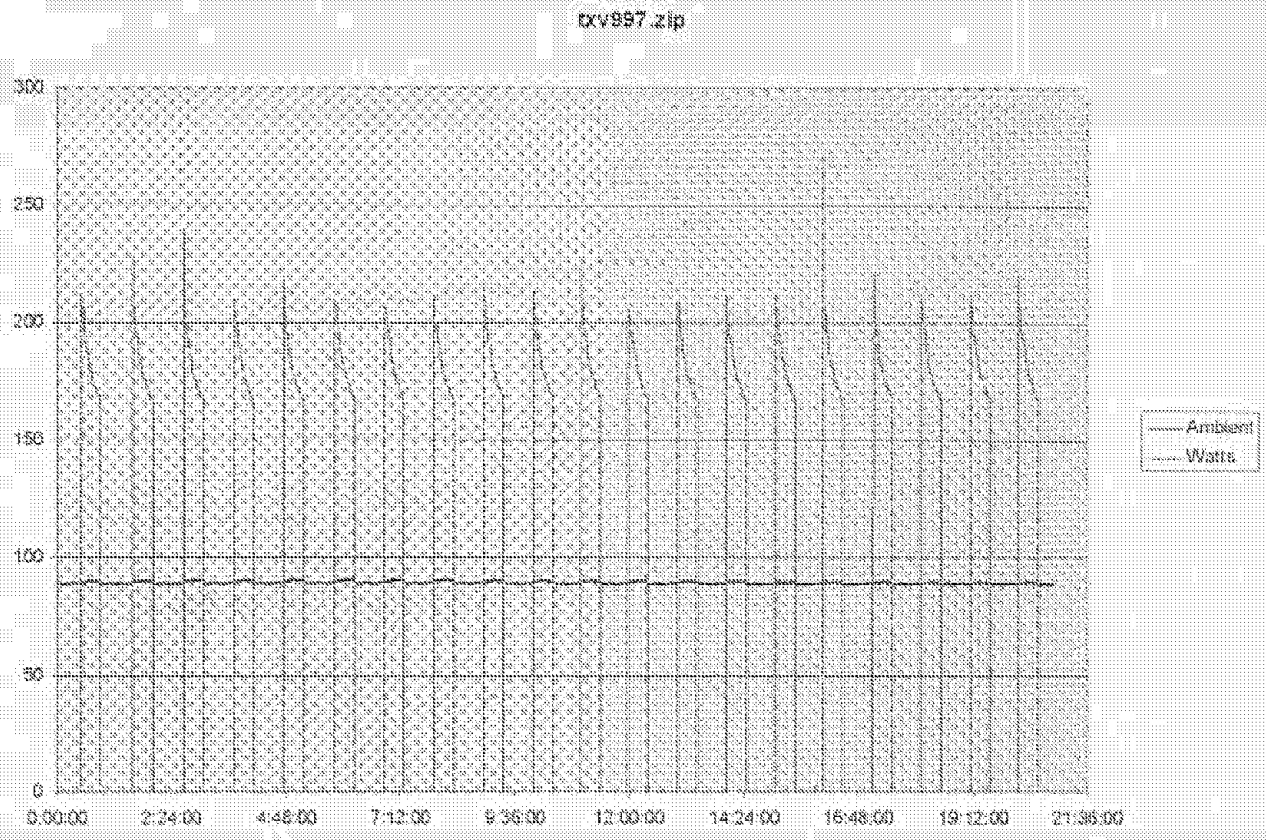


Figure 14. Test results with the Embraco VCC

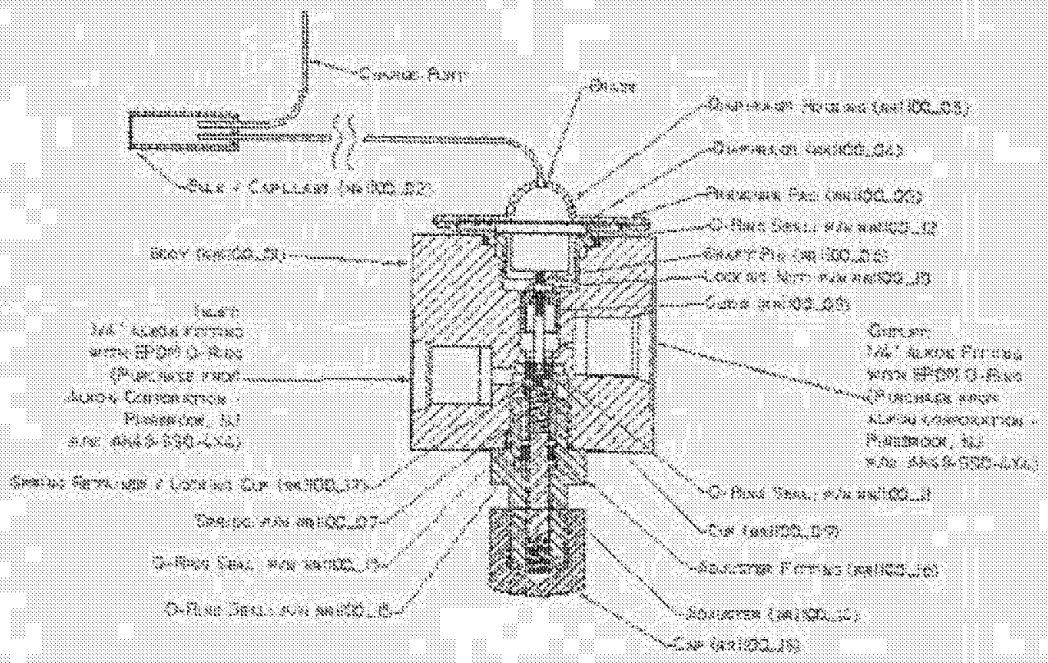


Figure 15. The adjustable pulsed TXV

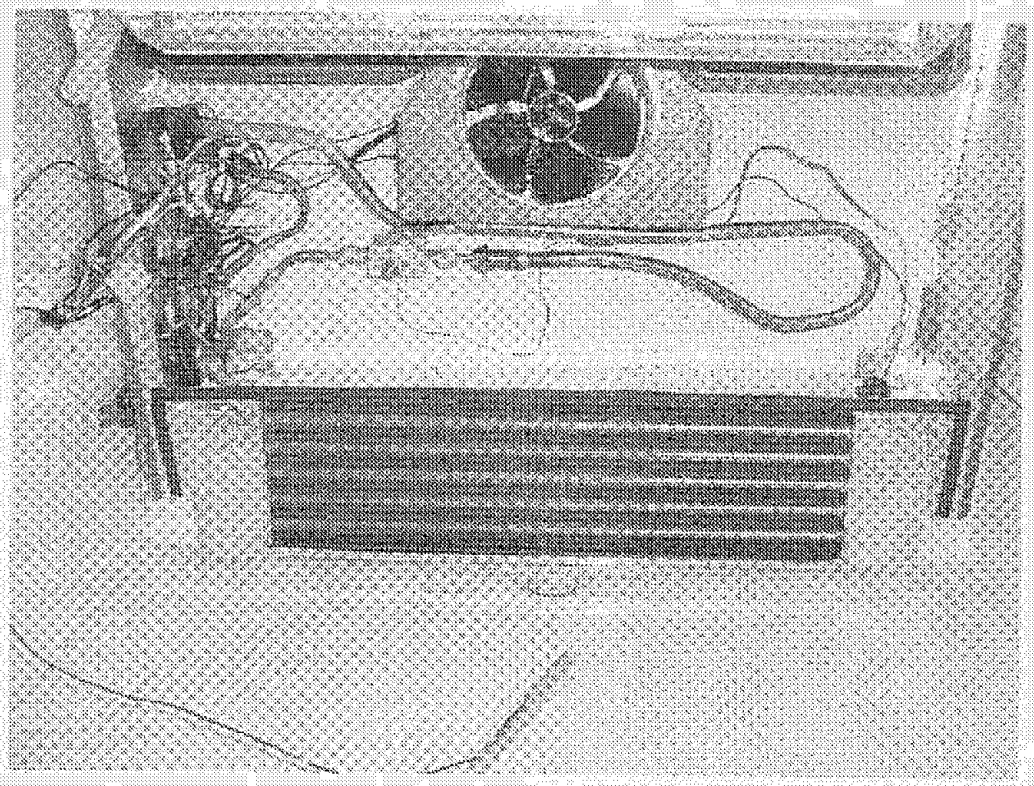


Figure 16. Freezer compartment with a the pulsed TXV

Conclusion

All Objectives of this cooperative agreement namely evaluation of the energy efficiency and performance enhancements of a pulsed thermal expansion valve (TXV), its cost and reliability were met. It was shown that the pulsed TXV performance improvements over traditional modulating TXV in both performance and cool-down. The improvements were more obvious with household refrigerators where a capillary is used and due to small system size modular TXV's are not a viable option.

This device could replace the currently used devices, a capillary tube and modulating TXVs, in household and commercial refrigeration and air conditioners. Determination of the economics and first cost of such devices were performed and reported. This work was accomplished with the support of commercial partners in the HVAC&R industries. The reliability of the pulsed TXV shall was established using a household refrigerator as a test vehicle, which is an important factor for its commercial success.