



EXECUTIVE SUMMARY

FINAL REPORTS ART-21CR/612-20090-01 AND ARTI-21CR/612-20090-02 ASHRAE PROJECT 1292-RP: COMPARISON OF TOTAL ENERGY CONSUMPTION OF SERIES VERSUS PARALLEL FAN POWERED VAV TERMINAL UNITS

During the first phase of this project the performance of the series and parallel fan powered terminal units were tested at the Energy Systems Laboratory. From the data that were collected, models were developed that characterized the performance of the terminal units over their full operating range. This phase of the project built upon the work of the first phase.

The objective of the second phase was to develop system models of single duct, multi-zoned VAV systems based on series and parallel fan terminal units and to use the model to compare the performance of the systems. It was a project requirement that the system model be verified using controlled laboratory experiments before the model was used to compare the systems based on the two terminal unit types.

During the first stage of the second phase a laboratory test stand was built that supported a three zone single duct VAV system. The test stand was able to handle 8 inch and 12 inch (203 and 305 mm) series and parallel terminal units in groups of three.

While the test stand was being built, separate three zone models were developed for series and parallel based systems. The three zone models were used to develop the operating set points for the three zone test stand. The test points included specifications for upstream static pressure, downstream static pressure, inlet flow damper position, and SCR motor control settings for both series and parallel systems using 8 inch and 12 inch (203 and 305 mm) terminal units.

Using the test points determined with the three zone models, a test matrix was developed that provided for testing all 12 terminal units tested during Phase 1 as part of a system. A total of 144 tests were conducted and the data were used to verify the system models for the series and the parallel systems. The verification process consisted of using the measured data in combination

with the system models to predict the supply temperatures. The predicted supply temperatures were compared to the measured supply temperatures from the test data. The measured supply temperatures for both series and parallel systems were within the uncertainty of the predicted temperatures for almost all of the measured values. The results from the verification process were used to improve the system model and were implemented in the five zone model.

After the laboratory verification of the model was complete, a five zone model was developed that supported both the series and parallel fan powered terminal units. Both the series and the parallel five zone models were built into a single Excel workbook that had separate worksheets for each of the zones, the system, and the hourly profiles for the cooling and heating loads for each zone. The loads from the model were based on normalized load profiles that were scaled to the cooling capacities of the terminal units. The normalized load profiles were developed using hourly sensible and latent loads from DOE 2 simulations of a simple, single story, five zone structure at five geographic locations in the United States. The structure that was modeled was intended to be “typical” of commercial office space in the United States. The five zone system models were used to estimate the operation of the series and the parallel systems for one year at Houston, Phoenix, Chicago, New York, and San Francisco.

The parallel fan power terminal unit consistently used less energy than the series fan power terminal unit when leakage was not considered. The measurements taken during Phase 1 indicated that leakage was a factor and that all parallel terminal units leaked as much as 30% or more. The leakage of the parallel units varied as a function of operating conditions and terminal unit design. There were not enough terminal units tested in Phase 1 to determine a leakage curve that could be used in the model. Phase 1 results did indicate that an average leakage rate of between 10% and 20% would be reasonable.

For all 12 hour operating cases, the series system used more energy to handle the same space loads as the parallel system by 17% or more when leakage was not considered. For the 24 hour operating schedule the series system used 9% more energy than the parallel system. When leakage was included with the 12 hour operating schedule the results changed significantly. At 10% leakage rate the series unit used about 3% to 4% more energy than the parallel system. At 20% leakage rate the series system used an average of 5.5% less energy than the parallel based system which was a complete reversal from the no leakage case.

The model indicated a strong relationship between the leakage rate and the energy use of the parallel based system. The model indicated that the energy consumption of the system was more sensitive to the parallel system leakage rate than any other variable except the operating schedule. The leakage rates of the parallel terminal units needs to be studied in greater detail particularly since the Phase 1 measurements indicate that ALL of the parallel terminal units have serious leakage problems.

A number of operating conditions were analyzed using the five zone model and included 12 hour operating schedules, 24 hour operating schedules, minimum static pressure for the primary fan of 1.0 in.wg. (units), 15% return air heat gain to model roof loads, series terminal units that used no power, and primary fans that used no power and average leakage rates of 10% and 20%.