STEADY-STATE ANALYSIS OF SINGLE-SPEED RESIDENTIAL SPLIT SYSTEMS WITH ZONING BYPASS

C. Heflin
Associate Member ASHRAE

F.J. Keller, P.E.
Member ASHRAE

ABSTRACT

The primary purpose of air-side zoned systems is comfort enhancement and energy savings. This study analyzes the effect of a simulated zoned system with an air bypass on a single-speed, residential, split-system air conditioner and heat pump. The system was tested at steady-state conditions to determine the impact of the bypass on performance (i.e., capacity, power, and EER) and reliability indicators (i.e., compressor suction superheat and discharge superheat). The experimental study was followed by a computer simulation used to predict system measures.

Capacity and EER drop significantly with increasing air bypass for both the air conditioner and heat pump. The capacity and the EER of the air conditioner decreased 47% and 46%, respectively, with an increase in bypass from 0% to 79% for DOE A test conditions. For the air conditioner with a fixed-orifice expansion device, the compressor suction superheat temperature was near 0°F (0°C) for bypass amounts greater than 20%. For the air conditioner with a thermal expansion device (TXV), the compressor suction superheat was greater than 14.5°F (8.1°C) for all bypass amounts. The near 0°F (0°C) superheat condition could present a compressor reliability problem.

Although the zoned heat pump system did not present a severe compressor reliability concern because of the presence of an accumulator (in cooling and heating) and a TXV (in cooling), the indoor leaving air temperature (LAT) increased from 91.0°F (32.8°C) to 125.5°F (51.9°C) for an increase in bypass of 0% to 79% for typical heating conditions. The higher LAT could present a comfort problem for occupants and/or a reliability problem for air-side equipment. In addition, power consumption rose 29% in the heating mode for the same set of conditions. This indicates greater energy use for steady-state zoning at higher bypass amounts in the heating mode.

INTRODUCTION

Higher appliance efficiencies are being driven by the National Appliance Energy Conservation Act, which established a minimum SEER of 10 Btu/W·h for all air conditioners and heat pumps built on or after January 1, 1992. Moreover, in an attempt to reduce peak loads, utility companies are offering rebates for more efficient residential systems.

The primary feature of a zoned system is its ability to provide conditioned air when and where it is needed, while reducing energy consumption by setting back/up the thermostats in unoccupied zones. The basic air-side zoned system consists of (1) single or multiple heating/cooling unit(s), (2) multiple thermostats, (3) multiple adjustable duct dampers, (4) means for separating zones (i.e., doors and walls), and (5) control algorithms. By constantly monitoring the room temperatures and using the setpoints in each zone, the control algorithm determines damper positions necessary to satisfy each zone's load. When all zones reach their setpoints, the heating/cooling equipment is deactivated.

An air bypass duct or a dump zone can be used to prevent excessive total external static pressure created by closing dampers with single-speed equipment. A bypass duct uses a modulating damper to recirculate a portion of the indoor unit discharge air back to the air handler inlet. A dump zone uses a modulating damper to direct excess air to an unoccupied space, i.e., a storage area or basement.

Zoned systems are common in commercial applications such as office buildings. Commercial zoning systems can utilize standard working hour schedules and setback/setup temperatures to reduce energy consumption while also using modulating dampers to improve comfort levels.

In an attempt to improve the efficiency and comfort of residential unitary systems, several manufacturers are selling similar air-side zoning systems to home contractors. Because the indoor section of residential equipment is more commonly a single-speed unit, a dump zone or bypass duct is necessary. Similarly, the outdoor section of a residential air conditioner and heat pump is usually a single-speed, single-stage unit. Since the bypass duct and dump zone vary the system airflow rates, they also indirectly control the cooling/heating capacity delivered to each zone. (This differs from commercial applications, which typically use two-speed and/or multiple-stage equipment to achieve capacity modulation.)

During steady-state operation of a system with a direct bypass duct, excess conditioned air returning to the inlet of the indoor unit will decrease/increase the net inlet temperature in the cooling/heating mode. This not only affects the capacity and efficiency of the unit, but it can also impact

Chris Heflin is a senior engineer and **Fred J. Keller** is director of split system development at United Technologies Carrier, Indianapolis, IN.