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Contempo HVAC Upgrade

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INTRODUCTION

Temperature control for the radio antennas is important for data quality. Until the radio signals are digitized, temperature changes in equipment and signal lines can shift the phase and so distort the data. Since digitization at the VLBA takes place in Room 104 of the Station Control Building, better building temperature control seems indicated. As well, the hydrogen maser, an atomic clock/oscillator critical to time stability of the data, is also located in Room 104. Good temperature control is necessary for the maser environment for best frequency stability. Application of Staefa Smart II/DDC controllers in controlling temperature at the VLA and VLBA vertex rooms has been very successful, so Steve Troy and Jim Ruff recommended that the same controller be used for Room 104 temperature stability. The pre-DDC on/off Contempo controls cause wide swings in the room and rack temperatures.

HOW IT WORKS

Proportional controls on the HVAC for the VLA and VLBA vertex rooms now provide accurate temperature control for all but 1 of the 38 antennas. The Contempo control project is more complicated than the vertex room controls, however. Humidity control is not required in the vertex rooms, but the Contempo HVAC controls humidity by either humidifying or dehumidifying (except at Saint Croix where the humidifier is disabled). Humidity control in Room 103 of the VLBA station building is important because head wear on the magnetic tape data recorders located in 103 is proportional to humidity. At $7000+ each for recorder heads, humidity must be kept as low as practical. Also, the Contempo controls the temperature in two rooms, 103 and 104, instead of just one. Since the DDC can control more than one channel, a single DDC module converts the Contempo humidifying, heating, and cooling from on/off to proportional control.

The Contempo has 2 to 3 times the necessary capacity for the heat and cooling loads in Rooms 103 and 104. In fact, that is one of the problems with the pre-DDC controlled Contempo. When the cooling comes on, a blast of cold air cools everything down, but then the rooms heat up several degrees before the next cooling cycle. Furthermore, increasing air flow into Room 103 with the on/off Contempo reduces air flow to Room 104 and causes Room 104 to heat up. The DDC, on the other hand, commands the Contempo to keep the control point located beneath the maser cabinet in Room 104 at 20 C. If air flow into Room 103 is increased, the Contempo will be commanded to lower the output temperature as necessary to force the control point to 20 C. Where adjustments of thermostats and airflow are required to respond to changed heat loads with the on/off Contempo, no adjustment is necessary with the DDC. The DDC parameters may be changed by connecting a computer to the DDC communication port (see the DDC manual), but changing the set point from 20 C to some other temperature will just shift a temperature problem to some other area. The solution for temperature control with the DDC-controlled Contempo is to increase air flow to hot spots and decrease air flow to cool spots.

The DDC controllers use what is called a proportional-integral-differential (PID) servo control. With PID, only the minimum amount of heating and cooling is used to maintain a set point instead of an on-off control. The PID controller responds proportionally (or linearly) to a temperature change, but can also respond to the total change over time and to the rate of change, hence the term integral-differential. With PID, not only is the control more accurate, the energy savings are impressive. It took awhile to match the vertex room PID parameters with real life winter and summer conditions, but now the DDC controllers have worked for several years at the vertex rooms without change and the energy savings at the VLA are well known.

The DDC provides PID control through pulse width modulation. A pulse output every 10 seconds from the DDC provides "on" control. The width of the pulse determines how long the "on-cycle" will be. For heating, the on-cycle turns on the heating coils; for cooling, the on-cycle controls a solenoid which permits the refrigerant to flow.

CURRENT STATUS AND PROBLEMS

Steve installed the controllers at Pie Town, Fort Davis, and Kitt Peak in 1997, and has been adjusting operation to match real world conditions. The first problem encountered was the comfort levels in Rooms 103 and 104. The DDC controller servos to the control point, a temperature transducer in the floor plenum and under the maser in Room 104, and maintains that point at 20 C very accurately; but temperatures in the racks and in the rooms controlled by the Contempo, Rooms 103 and 104, may vary as a function of air flow. Initially, there was not enough air flow in Rooms 103 and 104 to keep them cool. Increasing the Contempo blower speed, enlarging the ducting into Room 104, and the addition of perforated floor panels has corrected the cooling problem except at Kitt Peak. Room 103 and 104 temperatures at Pie Town and Fort Davis now stay pretty stable at 23 C.

At Kitt Peak, the temperature of the sensor on the side of the C rack between the maser and the rack makes an infrequent 3 C shift. This "maser environment sensor" is called the "maser sensor". Plots of the problem show the shift occurs when the dehumidifier cycles. Since air flow from the Contempo drops in half during the dehumidification cycle, the air flow from plenum to the maser sensor also drops. With less airflow, the sensor will register a higher temperature because of radiant heat from the surrounding equipment racks. Figure 1, a plot of VLBA Kitt Peak monitoring points prepared by Bob Broilo using routinely available software, shows the shift of temperature with relative humidity (RH). In Figure 1, the maser sensor, depicted by the yellow line, falls 3 C when the RH, depicted by the green line, falls below the RH set point. When RH rises above the set point, the maser sensor rises 3 C. The temperature shift problem has been reduced by adding a perforated floor panel and can be reduced further with the installation of additional floor panels. It may be necessary at some point to move wall board in the plenum between Rooms 103 and 104 at Kitt Peak to improve air flow into Room 104. The important point is that temperature control can be servoed to one and only one control point; all other temperatures must be controlled by controlling air flow.

Another problem with the modification resulted from interaction between the emergency power generator, the UPS (uninterruptable power supply), and DDC controller. When switching the 6 KW heating load on or off while on emergency power, the station power generator cannot react to the load variations quickly enough to prevent the UPS from going on line. The UPS will stay on line for 20 seconds if no further power perturbations are detected. Since the 10 second DDC pulse rate is less than the 20 second "on-cycle" of the UPS, the UPS stays on line until the batteries go dead, about 20 minutes. To correct the problem, the heat is now disabled during emergency power at the modified sites.

Then another problem occurred during emergency power operation. At one of the 3 modified VLBA sites in December, the dehumidifier came on during emergency power operation. Without the addition of heat, Rooms 103 and 104 cooled down to 59 F and the compressor frosted up. Rather than complicate the DDC control further, the plan is now just to switch over to the back-up Contempo automatically during emergency power operation using the power transfer switch. The back-up is not DDC controlled. In fact, it may be possible to schedule Contempo maintenance in conjunction with generator tests to minimize temperature perturbations.

Some confusion has occurred on power-up of the DDC-controlled Contempo unit after emergency operation or other shutdown. The DDC has to start somewhere, so it is programmed to begin with the heat cycle to establish control. If the rooms are already warm, the 10 second "on" pulses for the heater may be very short and so little or no heat is actually added, but the Contempo annunciator will show that the heater is on, causing consternation to a hot and sweaty Site Tech. After a few minutes, the DDC will update to the correct cycle. Problems of this nature should lessen as Site Techs become more familiar with and develop confidence in the Contempo "smart" operation.

When the dry winter weather arrived and the humidifiers began to turn on, the additional heat from the humidifier caused the RH reading to fluctuate. The DDC attempted to maintain a tight RH set point of 18% and the humidifier/dehumidifier cycled back and forth causing the plenum temperature under the maser to fluctuate. Steve has corrected the problem at Pie Town and Kitt Peak by reprogramming the DDC control for a "dead band." The Fort Davis site DDC parameters were changed recently, but it is too soon to report results. Now no humidification or dehumidification takes place from 12% RH to 24% RH. At 12% RH, the humidification receives a 10% demand. Contempo humidification then increases proportionally as the RH decreases until it is on 100% at 9% RH. Proportional humidification is accomplished by pulsing the humidification heating coils.

Likewise, dehumidification increases proportionally from 24% RH to 27% RH. Proportional dehumidification is accomplished by staging the cooling coils at 0, 2/5, and full; and by pulsing the re-heat heating coils used with the dehumidifier. Integral/differential control for humidity was disabled to slow down response. The temperature control should now be seamless between dead band and the humidification cycle. Since the air flow drops in half on the dehumidification cycle as explained earlier, some temperatures may rise during this cycle. The effect can be minimized by improving air flow to critical areas.

At this writing, a possible problem with the equipment rack temperature control has emerged. Before the radio signal (data) is digitized, it is transmitted between modules in the C and D racks on coaxial cables that use

PTFE (polytetrafluoroethylene). PTFE phase modulates (distorts) the transmitted signal over the temperature range 10 C to as high as 27 C, so the rack temperatures should be kept out of this range, or at least at the top end of it, if at all possible. The plenum temperature with the new DDC-controlled system is 20 C and in the unstable PTFE range, but the temperature rises as it passes up through the racks. We plan measurements to see if the rack temperature rise is sufficient to keep the PTFE stable. Fortunately, PTFE is not used outside the racks or under the floor. The control point temperature cannot be raised without sacrificing room comfort.

A problem as yet not encountered, but certainly possible, is poor calibration of the 20 C control sensor. Loss of calibration would cause wrong temperatures everywhere.

There may be some additional tweaking of DDC parameters required to meet changing circumstances, but very soon the design will be considered complete, and further changes in the DDC parameters or elsewhere in the design will require a change order.

RESULTS TO DATE

The hydrogen maser engineer, Leon Abeyta, reports improvement of peak-to-peak temperature control of the maser environment at the Kitt Peak, Pie Town, and Fort Davis VLBA sites from 2 - 3 C to < 0.5 C. Where the maser frequency output was degraded because of the wide temperature swings, the stability of the maser frequency output at the modified sites is now improved by a factor of 2, reports Larry Beno, Electronics Division Deputy Head. The plan now is to install the controllers for the remaining VLBA Contempo HVAC units during regularly scheduled maintenance visits.