We Claim:

1. A method for operation of a transcritical refrigerant vapor compression system for supplying conditioned air to a temperature controlled space comprising operating the refrigerant vapor compression system in at least one transition mode when staging up or staging down between a higher capacity mode and a lower capacity mode.

2. The method as recited in claim 1 wherein operation in the transition mode comprises:

monitoring a first parameter and a second parameter; and

staging out of the transition mode in response to a determination that at least one of a first condition related to said first parameter and a second condition related to said second parameter has been established or has been established for a particular period of time.

3. The method as recited in claim 1 wherein operation in the transition mode comprises:

monitoring a temperature control differential, TSETPT – TCRTL, between a control temperature set point, TSETPT, and a sensed control temperature, TCRTL; and

establishing a trend in a change of the temperature control differential over an elapsed time.

4. The method as recited in claim 3 wherein establishing a trend in a change of the temperature control differential over an elapsed time comprises calculating an average derivative of the temperature control differential over the elapsed time.

5. The method as recited in claim 4 further comprising:

entering a stage down transition mode for staging down from operation in a high capacity mode to operation in one of a first low capacity mode and a second lower capacity mode;

determining whether the average derivative of the temperature control differential has been positive for an elapsed time greater than a preset first period of time; and

if the average derivative of the temperature control differential has been positive for an elapsed time greater than the preset first period of time, staging down to the second lower capacity mode and bypassing the first low capacity mode.

6. The method as recited in claim 5 further comprising:

if the average derivative of the temperature control differential has not been positive for an elapsed time greater than the preset first period of time, determining whether the temperature control differential is currently less than zero; and

if the temperature control differential is currently less than zero, staging down to the first low capacity mode.

7. The method as recited in claim 6 further comprising:

if the temperature control differential is not currently less than zero, determining whether the temperature control differential has been greater than zero for a preset second period of time; and

if the temperature control differential has been greater than zero for the second preset period of time, staging down to the second lower capacity mode and bypassing the first low capacity mode.

8. The method as recited in claim 7 further comprising:

if the temperature control differential has not been greater than zero for the second preset period of time, continuing operation in the high capacity mode.

9. The method as recited in claim 4 further comprising:

entering a stage up transition mode for staging up from operation in a low capacity mode to operation in one of a first high capacity mode and a second higher capacity mode;

determining whether the average derivative of the temperature control differential has been negative for an elapsed time greater than a preset third period of time; and

if the average derivative of the temperature control differential has been negative for an elapsed time greater than the preset third period of time, staging up to the second higher capacity mode and bypassing the first high capacity mode.

10. The method as recited in claim 9 further comprising:

if the average derivative of the temperature control differential has not been negative for an elapsed time greater than the preset third period of time, determining whether the temperature control differential is currently greater than zero; and

if the temperature control differential is currently greater than zero, staging up to the first high capacity mode.

11. The method as recited in claim 10 further comprising:

if the temperature control differential is not currently greater than zero, determining whether the temperature control differential has been less than zero for a preset fourth period of time; and

if the temperature control differential has been less than zero for the fourth preset period of time, staging up to the second higher capacity mode and bypassing the first high capacity mode.

12. The method as recited in claim 11 further comprising:

if the temperature control differential has not been less than zero for the fourth preset period of time, continuing operation in the low capacity mode.

13. A refrigerant vapor compression system comprising:

a compression device for compressing a refrigerant vapor from a suction pressure to a discharge pressure, a refrigerant heat rejection heat exchanger and a refrigerant heat absorption heat exchanger arranged in serial refrigerant flow relationship in a transcritical cycle closed-loop primary refrigerant circuit, the refrigerant heat rejection heat exchanger functioning as a refrigerant gas cooler and the refrigerant heat absorption heat exchanger functioning as a refrigerant evaporator; and

a controller operatively associated with the refrigerant vapor compression system, the controller configured to control operation of the refrigerant vapor compression system in a transition mode when staging up or staging down between a higher capacity mode and a lower capacity mode, the controller further configured to monitor a temperature control differential, TSETPT – TCRTL, between a control temperature set point, TSETPT, and a sensed control temperature, TCRTL, during operation in the transition mode; and to calculate an average derivative of the temperature control differential over an elapsed time during operation in the transition mode.

14. The refrigerant vapor compression system as recited in claim 13, wherein the controller is further configured to:

enter a stage down transition mode when staging down from operation in a high capacity mode to operation in one of a first low capacity mode and a second lower capacity mode;

determine whether the average derivative of the temperature control differential has been positive for an elapsed time greater than a preset first period of time; and

if the average derivative of the temperature control differential has been positive for an elapsed time greater than the preset first period of time, stage down to the second lower capacity mode bypassing the first low capacity mode.

15. The refrigerant vapor compression system as recited in claim 14, wherein the controller is further configured to:

if the average derivative of the temperature control differential has not been positive for an elapsed time greater than the preset first period of time, determine whether the temperature control differential is currently less than zero; and

if the temperature control differential is currently less than zero, stage down to the first low capacity mode.

16. The refrigerant vapor compression system as recited in claim 15, wherein the controller is further configured to:

if the temperature control differential is not currently less than zero, determine whether the temperature control differential has been greater than zero for a preset second period of time; and

if the temperature control differential has been greater than zero for the second preset period of time, stage down to the second lower capacity mode bypassing the first low capacity mode.

17. The refrigerant vapor compression system as recited in claim 13, wherein the controller is further configured to:

enter a stage up transition mode for staging up from operation in a low capacity mode to operation in one of a first high capacity mode and a second higher capacity mode;

determine whether the average derivative of the temperature control differential has been negative for an elapsed time greater than a preset third period of time; and

if the average derivative of the temperature control differential has been negative for an elapsed time greater than the preset third period of time, stage up to the second higher capacity mode bypassing the first high capacity mode.

18. The refrigerant vapor compression system as recited in claim 17, wherein the controller is further configured to:

if the average derivative of the temperature control differential has not been negative for an elapsed time greater than the preset third period of time, determine whether the temperature control differential is currently greater than zero; and

if the temperature control differential is currently greater than zero, stage up to the first high capacity mode.

19. The refrigerant vapor compression system as recited in claim 18, wherein the controller is further configured to:

if the temperature control differential is not currently greater than zero, determine whether the temperature control differential has been less than zero for a preset fourth period of time; and

if the temperature control differential has been less than zero for the fourth preset period of time, stage up to the second higher capacity mode bypassing the first high capacity mode.

20. A method for controlling low capacity operation of a transcritical refrigerant vapor compression system for supplying conditioned air to a temperature controlled space, the refrigerant vapor compression system having a primary refrigerant flow circuit including a compression device driven by a variable speed motor driven by a variable speed drive, a refrigerant gas cooler, a high pressure expansion device, a flash tank, an evaporator expansion device, and an evaporator disposed in serial refrigerant flow arrangement in the primary refrigerant flow circuit and a compressor unload circuit including an unload valve selectively positionable to open or close the compressor unload circuit, the method comprising:

opening the unload valve to allow refrigerant to pass from the compressor through the compressor unload circuit to a suction pressure portion of the primary refrigerant flow circuit;

opening the high pressure expansion valve to a full open position;

operating the compressor drive motor at a frequency to drive the compressor at a low/minimum speed; and

controlling operation of at least one of an air moving device associated with the gas cooler or a heating device associated with the evaporator for heating a flow of air drawn from the temperature controlled space .

21. The method as recited in claim 20 wherein operation of at least one of an air moving device associated with the gas cooler or a heating device associated with the evaporator for heating a flow of air drawn from the temperature controlled space is controlled in such a way as to preserve the temperature control sensitivity of the variable speed drive driving the variable speed motor driving the compression device.

22. The method as recited in claim 20 wherein controlling operation of the air moving device associated with the gas cooler comprises cycling the gas cooler air moving device through a plurality of on/off duty cycles wherein in each duty cycle the gas cooler air moving device is on for a first time period and off for a second time period.

23. The method as recited in claim 22 wherein the first time period is increased and the second time period is increased when advancing from a duty cycle to a next duty cycle when cycling the air moving device through a plurality of on/off duty cycles.

24. The method as recited in claim 20 wherein controlling operation of the air moving device associated with the gas cooler comprises selectively varying the speed of the air moving device.

25. The method as recited in claim 20 wherein controlling operation of a heating device associated with the evaporator comprises selectively cycling the heating device associated with the evaporator through a plurality of on/off duty cycles for repeatedly heating the air flow for a first time period and not heating the air flow for a second time period.

26. The method as recited in claim 20 wherein controlling operation of a heating device associated with the evaporator comprises selectively varying the amount of electric current supplied to an electric heater associated with the evaporator.

27. A method for operation of a transcritical refrigerant vapor compression system for supplying conditioned air to a temperature controlled space comprising:

operating the refrigerant vapor compression system in one of an economized mode, a non-economized mode, and an unloaded mode; and

operating the refrigerant vapor compression system in a transition stage when staging down of staging up between any two operating modes of said economized mode, said non-economized mode, and said unloaded mode.

28. The method as recited in claim 27 wherein said transition stage comprises a first transition down stage for staging down from operation of the refrigerant vapor compression system in the economized mode to operation in one of either the non-economized mode or the unloaded mode.

29. The method as recited in claim 28 wherein said transition stage comprises a second transition down stage for staging down from operation of the refrigerant vapor compression system in the non-economized mode to operation in the unloaded mode.

30. The method as recited in claim 27 wherein said transition stage comprises a first transition up stage for staging up from operation of the refrigerant vapor compression system in the unloaded mode to operation in the non-economized mode.

31. The method as recited in claim 30 wherein said transition stage comprises a second transition up stage for staging up operation of the refrigerant vapor compression system in the non-economized mode to operation in the economized mode.

We claim:

1. A method for operation of a transcritical refrigerant vapor compression system for supplying conditioned air to a temperature controlled space comprising operating the refrigerant vapor compression system in at least one transition mode when staging up or staging down between a higher capacity mode and a lower capacity mode, wherein the higher capacity mode and the lower capacity mode includes at least one of an economized mode, a standard non-economized mode, and an unloaded mode; and

operating the refrigerant vapor compression system in the transition mode to avoid overshoot and undershoot of a temperature band bounding a control temperature set point when staging down or staging up between any two operating modes of said economized mode, said standard non-economized mode, and said unloaded mode.

2. The method as recited in claim 1 wherein operation in the transition mode comprises: monitoring a first parameter and a second parameter; and staging out of the transition mode in response to a determination that at least one of a first condition related to said first parameter and a second condition related to said second parameter has been established or has been established for a particular period of time.

3. The method as recited in claim 1 wherein operation in the transition mode comprises: monitoring a temperature control differential, TSETPT-TCRTL, between a control temperature set point, TSETPT, and a sensed control temperature, TCRTL; and establishing a trend in a change of the temperature control differential over an elapsed time.

4. The method as recited in claim 3 wherein establishing a trend in a change of the temperature control differential over an elapsed time comprises calculating an average derivative of the temperature control differential over the elapsed time.

5. The method as recited in claim 4 further comprising: entering a stage down transition mode for staging down from operation in a high capacity mode to operation in one of a first low capacity mode and a second lower capacity mode; determining whether the average derivative of the temperature control differential has been positive for an elapsed time greater than a preset

first period of time; and if the average derivative of the temperature control differential has been positive for an elapsed time greater than the preset first period of time, staging down to the second lower capacity mode and bypassing the first low capacity mode.

6. The method as recited in claim 5 further comprising: if the average derivative of the temperature control differential has not been positive for an elapsed time greater than the preset first period of time, determining whether the temperature control differential is currently less than zero; and if the temperature control differential is currently less than zero, staging down to the first low capacity mode.

7. The method as recited in claim 6 further comprising: if the temperature control differential is not currently less than zero, determining whether the temperature control differential has been greater than zero for a preset second period of time; and if the temperature control differential has been greater than zero for the second preset period of time, staging down to the second lower capacity mode and bypassing the first low capacity mode.

8. The method as recited in claim 7 further comprising: if the temperature control differential has not been greater than zero for the second preset period of time, continuing operation in the high capacity mode.

9. The method as recited in claim 4 further comprising: entering a stage up transition mode for staging up from operation in a low capacity mode to operation in one of a first high capacity mode and a second higher capacity mode; determining whether the average derivative of the temperature control differential has been negative for an elapsed time greater than a preset third period of time; and if the average derivative of the temperature control differential has been negative for an elapsed time greater than the preset third period of time, staging up to the second higher capacity mode and bypassing the first high capacity mode.

10. The method as recited in claim 9 further comprising: if the average derivative of the temperature control differential has not been negative for an elapsed time greater than the preset third period of time, determining whether the temperature control differential is currently greater

than zero; and if the temperature control differential is currently greater than zero, staging up to the first high capacity mode.

11. The method as recited in claim 10 further comprising: if the temperature control differential is not currently greater than zero, determining whether the temperature control differential has been less than zero for a preset fourth period of time; and if the temperature control differential has been less than zero for the fourth preset period of time, staging up to the second higher capacity mode and bypassing the first high capacity mode.

12. The method as recited in claim 11 further comprising: if the temperature control differential has not been less than zero for the fourth preset period of time, continuing operation in the low capacity mode.

13. A refrigerant vapor compression system comprising: a compression device for compressing a refrigerant vapor from a suction pressure to a discharge pressure, a refrigerant heat rejection heat exchanger and a refrigerant heat absorption heat exchanger arranged in serial refrigerant flow relationship in a transcritical cycle closed-loop primary refrigerant circuit, the refrigerant heat rejection heat exchanger functioning as a refrigerant gas cooler and the refrigerant heat absorption heat exchanger functioning as a refrigerant evaporator; and

a controller operatively associated with the refrigerant vapor compression system, the controller configured to control operation of the refrigerant vapor compression system in a transition mode when staging up or staging down between a higher capacity mode and a lower capacity mode, the controller further configured to monitor a temperature control differential, TSETPT-TCRTL, between a control temperature set point, TSETPT, and a sensed control temperature, TCRTL, during operation in the transition mode; and to calculate an average derivative of the temperature control differential over an elapsed time during operation in the transition mode

wherein the higher capacity mode and the lower capacity mode includes at least one of an economized mode, a standard non-economized mode, and an unloaded mode; and

the controller operating the refrigerant vapor compression system in the transition mode to avoid overshoot and undershoot of a temperature band bounding a control temperature set point when staging down or staging up between any two operating modes of said economized mode, said standard non-economized mode, and said unloaded mode.

14. The refrigerant vapor compression system as recited in claim 13, wherein the controller is further configured to: enter a stage down transition mode when staging down from operation in a high capacity mode to operation in one of a first low capacity mode and a second lower capacity mode; determine whether the average derivative of the temperature control differential has been positive for an elapsed time greater than a preset first period of time; and if the average derivative of the temperature control differential has been positive for an elapsed time greater than the preset first period of time, stage down to the second lower capacity mode bypassing the first low capacity mode.

15. The refrigerant vapor compression system as recited in claim 14, wherein the controller is further configured to: if the average derivative of the temperature control differential has not been positive for an elapsed time greater than the preset first period of time, determine whether the temperature control differential is currently less than zero; and if the temperature control differential is currently less than zero, stage down to the first low capacity mode.

16. The refrigerant vapor compression system as recited in claim 15, wherein the controller is further configured to: if the temperature control differential is not currently less than zero, determine whether the temperature control differential has been greater than zero for a preset second period of time; and if the temperature control differential has been greater than zero for the second preset period of time, stage down to the second lower capacity mode bypassing the first low capacity mode.

17. The refrigerant vapor compression system as recited in claim 13, wherein the controller is further configured to: enter a stage up transition mode for staging up from operation in a low capacity mode to operation in one of a first high capacity mode and a second higher capacity mode; determine whether the average derivative of the temperature control differential has been

negative for an elapsed time greater than a preset third period of time; and if the average derivative of the temperature control differential has been negative for an elapsed time greater than the preset third period of time, stage up to the second higher capacity mode bypassing the first high capacity mode.

18. The refrigerant vapor compression system as recited in claim 17, wherein the controller is further configured to: if the average derivative of the temperature control differential has not been negative for an elapsed time greater than the preset third period of time, determine whether the temperature control differential is currently greater than zero; and if the temperature control differential is currently greater than zero, stage up to the first high capacity mode.

19. The refrigerant vapor compression system as recited in claim 18, wherein the controller is further configured to: if the temperature control differential is not currently greater than zero, determine whether the temperature control differential has been less than zero for a preset fourth period of time; and if the temperature control differential has been less than zero for the fourth preset period of time, stage up to the second higher capacity mode bypassing the first high capacity mode.

20. The method of claim 1 wherein operation of the transcritical refrigerant vapor compression system includes controlling low capacity operation of the transcritical refrigerant vapor compression system for supplying conditioned air to a temperature controlled space, the refrigerant vapor compression system having a primary refrigerant flow circuit including a compression device driven by a variable speed motor driven by a variable speed drive, a refrigerant gas cooler, a high pressure expansion device, a flash tank, an evaporator expansion device, and an evaporator disposed in serial refrigerant flow arrangement in the primary refrigerant flow circuit and a compressor unload circuit including an unload valve selectively positionable to open or close the compressor unload circuit, the method comprising:

opening the unload valve to allow refrigerant to pass from the compressor through the compressor unload circuit to a suction pressure portion of the primary refrigerant flow circuit;

opening the high pressure expansion valve to a full open position;

operating the compressor drive motor at a frequency to drive the compressor at a low/minimum speed; and

controlling operation of at least one of an air moving device associated with the gas cooler or a heating device associated with the evaporator for heating a flow of air drawn from the temperature controlled space.

21. The method as recited in claim 20 wherein operation of at least one of an air moving device associated with the gas cooler or a heating device associated with the evaporator for heating a flow of air drawn from the temperature controlled space is controlled in such a way as to preserve the temperature control sensitivity of the variable speed drive driving the variable speed motor driving the compression device.

22. The method as recited in claim 20 wherein controlling operation of the air moving device associated with the gas cooler comprises cycling the gas cooler air moving device through a plurality of on/off duty cycles wherein in each duty cycle the gas cooler air moving device is on for a first time period and off for a second time period.

23. The method as recited in claim 22 wherein the first time period is increased and the second time period is increased when advancing from a duty cycle to a next duty cycle when cycling the air moving device through a plurality of on/off duty cycles.

24. The method as recited in claim 20 wherein controlling operation of the air moving device associated with the gas cooler comprises selectively varying the speed of the air moving device.

25. The method as recited in claim 20 wherein controlling operation of a heating device associated with the evaporator comprises selectively cycling the heating device associated with the evaporator through a plurality of on/off duty cycles for repeatedly heating the air flow for a first time period and not heating the air flow for a second time period.

26. The method as recited in claim 20 wherein controlling operation of a heating device associated with the evaporator comprises selectively varying the amount of electric current

supplied to an electric heater associated with the evaporator.

27. A method for operation of a transcritical refrigerant vapor compression system for supplying conditioned air to a temperature controlled space comprising: operating the refrigerant vapor compression system in one of an economized mode, a standard non-economized mode, and an unloaded mode; and operating the refrigerant vapor compression system in a transition stage when staging down or staging up between any two operating modes of said economized mode, said standard non-economized mode, and said unloaded mode; and

operating the refrigerant vapor compression system in the transition stage to avoid overshoot and undershoot of a temperature band bounding a control temperature set point when staging down or staging up between any two operating modes of said economized mode, said standard non-economized mode, and said unloaded mode.

28. The method as recited in claim 27 wherein said transition stage comprises a first transition down stage for staging down from operation of the refrigerant vapor compression system in the economized mode to operation in one of either the standard non-economized mode or the unloaded mode.

29. The method as recited in claim 28 wherein said transition stage comprises a second transition down stage for staging down from operation of the refrigerant vapor compression system in the standard non-economized mode to operation in the unloaded mode.

30. The method as recited in claim 27 wherein said transition stage comprises a first transition up stage for staging up from operation of the refrigerant vapor compression system in the unloaded mode to operation in the standard non-economized mode.

31. The method as recited in claim 30 wherein said transition stage comprises a second transition up stage for staging up operation of the refrigerant vapor compression system in the standard non-economized mode to operation in the economized mode.