Integrated Electric Make-Up Air Systems MAU Series Engineering Design and Application Guide

Performance, Controls, and Design Guidance

Prepared for Consulting Engineers, Architects, Contractors, Facility Owners, and End Users

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Executive Summary

Mechanical exhaust and outdoor air ventilation are key elements of indoor air quality in commercial and industrial buildings. Exhaust systems remove heat, moisture, odors, and airborne contaminants, while properly designed make up air systems replace exhausted air with controlled outdoor air to help prevent negative pressure and uncontrolled infiltration.

The King Electric MAU Series supports ventilation and indoor air quality by delivering predictable, filtered, and tempered outdoor air while maintaining occupant comfort and stable building operation.

This white paper outlines the engineering principles, system architecture, and application design considerations of the King Electric MAU Series and provides guidance for specifying and integrating the system into commercial and industrial ventilation projects.

Unlike traditional gas fired make up air systems that require fuel piping, combustion venting, and extensive safety coordination, the MAU Series uses fully modulating electric resistance heat with integrated control architecture to simplify installation while providing precise discharge air temperature control.

The MAU Series combines airflow delivery, modulating electric heat, filtration, and coordinated controls in a compact packaged system for commercial and industrial ventilation applications.

This paper examines ventilation challenges, airflow and heating design, indoor air quality considerations, and integrated controls to support reliable make up air system design and application.

Ventilation Challenges in Commercial and Industrial Facilities

Commercial and industrial buildings use mechanical exhaust systems to remove heat, moisture, odors, and airborne contaminants. Common applications include kitchen hoods, laboratory exhaust, restroom exhaust, and industrial process ventilation.

These systems often remove large volumes of conditioned air. If this air is not replaced with controlled outdoor air, the building can develop sustained negative pressure.

Negative Pressure Can Cause Several Issues

- Infiltration of unconditioned outdoor air through doors and openings
- Back drafting of combustion appliances
- Reduced occupant comfort from drafts and temperature swings
- Increased heating energy use
- Unstable building pressure relationships
- Control instability in building automation systems

To maintain proper building pressure and ventilation performance, exhausted air must be replaced with controlled outdoor air.

An Effective Make-Up Air System Should Provide:

- Predictable airflow
- Controlled heating of cold outdoor air
- Controlled outdoor air for ventilation and indoor air quality
- Reliable coordination with exhaust systems
- Stable discharge air temperature control
- Compatibility with building automation systems
- Simplified installation and commissioning

The MAU Series integrates these functions into a compact, electrically heated make up air system designed for commercial and industrial applications.

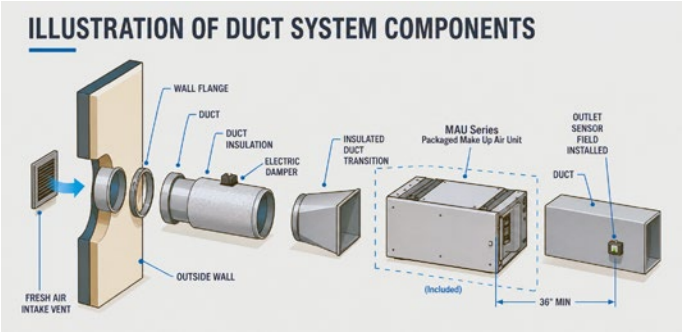
Supporting Indoor Air Quality Through Controlled Outdoor Air

A properly designed make up air system can support indoor air quality by replacing exhausted air with filtered outdoor air and helping dilute indoor airborne contaminants.

The MAU Series also helps maintain intended building pressure and makes outdoor air practical during cold weather by tempering it before delivery.

System Overview

The MAU Series is a packaged, plenum rated make up air solution designed for concealed ceiling installation in commercial and industrial buildings.



Performance Range

- Airflow 700 to 1770 CFM at 0.2 inch static pressure
- Heating Capacity 3.8 kW to 34.5 kW electric resistance heat
- Voltage Options 208V, 240V, 480V / Single and Three Phase
- Motor Options ECM motors available in 1/3, 1/2, and 3/4 horsepower
- Installation Horizontal or vertical mounting

- Cabinet Construction 20 Gauge Pre-Painted steel with corrosion resistant finish
- Air Filtration Factory installed Filter housing for 16 x 20 filter / 1 inch standard, compatible with 2-inch filter

The plenum rated cabinet allows installation above ceilings or in concealed mechanical spaces without requiring a dedicated mechanical room.

Design Responsibility and Application Limitations

This white paper supports preliminary design and product selection. Final airflow, heating capacity, duct design, controls, electrical requirements, and code compliance must be verified by the project's design professional based on project-specific conditions and applicable codes.

Fully Modulating Electric Resistance Heat

At the core of the MAU Series is a fully modulating electric resistance heating system controlled through solid state relay and SCR power modulation.

Unlike staged electric heat systems that energize elements in Stepped increments, the MAU uses proportional 0 to 10V control to continuously vary element wattage output.

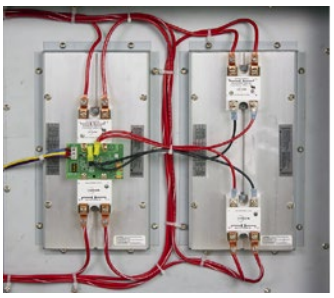
// Heating Control Architecture

- Thermostat provides 0 to 10VDC analog output
- Signal drives SCR power controller
- SCR modulates electric element output proportionally
- Solid state relays eliminate mechanical contactor failure from high cycling rates

// This Design Delivers:

- Precise discharge air temperature control
- Reduced temperature set point overshoot
- Stable temperature rise
- Reduced electrical stress
- Extended component life

The thermostat can be relocated and used as a wall mounted room thermostat when required by design intent.



Specification Advantages for Basis of Design

The MAU Series provides:

- Integrated relay logic control platform
- Factory wired 14-point terminal strip
- Fully modulating 0 to 10V electric heat control
- ECM motor with field torque adjustability
- Exhaust fan interlock capability
- Motorized damper control
- Environmental lockout functionality
- Fan only override mode
- BMS dry contact enabled compatibility
- Plenum rated concealed installation
- Broad voltage flexibility
- Made in the USA
- Five speed ECM airflow control architecture with field configurable operating points
- Three Year Limited Warranty

By integrating airflow delivery, proportional heating, and complete low voltage control architecture within a single cabinet, the MAU Series reduces field coordination, simplifies commissioning, and improves long term reliability.

Do not configure airflow settings that produce a temperature rise greater than 90°F across the heating section.
When multiple speed commands are present simultaneously, the ECM motor automatically operates at the highest selected airflow setting.
Additional motor taps may be connected in the field to support staged ventilation or cascaded exhaust fan applications.
The factory configuration utilizes one primary heating airflow setting and one secondary fan only airflow setting.
The MAU Series incorporates an ECM motor platform with five selectable speed taps that may be commanded using 24VAC control signals.

Airflow Engineering and ECM Torque Adjustability

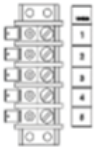
Effective make up air design requires coordination between airflow, external static pressure and required temperature rise.

The MAU Series incorporates an ECM motor platform with five selectable torque settings.

During commissioning:

1. External static pressure is measured.
2. Motor torque is adjusted to meet calculated airflow.
3. Heating output modulates to achieve required temperature rise.

Only one torque setting may be selected for heating mode and one for fan only mode, preventing electrical back feed conditions.



Motor Tap#	1/3 HP Torque	1/2 HP Torque	3/4 HP Torque	Wire Color
1	6.8 in-lb.	15.0 in-lb.	26.0 in-lb	RED
2	9.4 in-lb.	19.0 in-lb.	30.0 in-lb	ORANGE
3	12.0 in-lb.	22.5 in-lb.	35.0 in-lb	BLACK
4	17.0 in-lb.	26.0 in-lb.	40.5 in-lb	ORANGE/BLACK
5	20.0 in-lb.	30.0 in-lb.	45.0 in-lb	BROWN/BLACK

Comprehensive airflow tables provide CFM, static pressure, and temperature rise data to support accurate load modeling. (See Instructional Manual)

Engineering Note

The ECM motor provides selectable torque settings to adjust airflow for actual duct-system static pressure. Select one setting for each operating mode or heating stage. Stage 1 and Stage 2 may be set independently. Verify final airflow during commissioning.

Integrated Low Voltage Relay Logic Control Architecture

The MAU Series incorporates a factory wired 24VAC relay logic control system with a 14-point terminal strip for direct integration of auxiliary devices and automation systems.

This architecture allows direct integration with building automation systems and auxiliary equipment without requiring external control panels or programming.

No programming is required. Control functions are logically enabled through terminal wiring.

Engineering Note

Make up air systems are commonly interlocked with exhaust fans to ensure that outdoor air is supplied whenever exhaust airflow is operating. This prevents sustained negative building pressure.

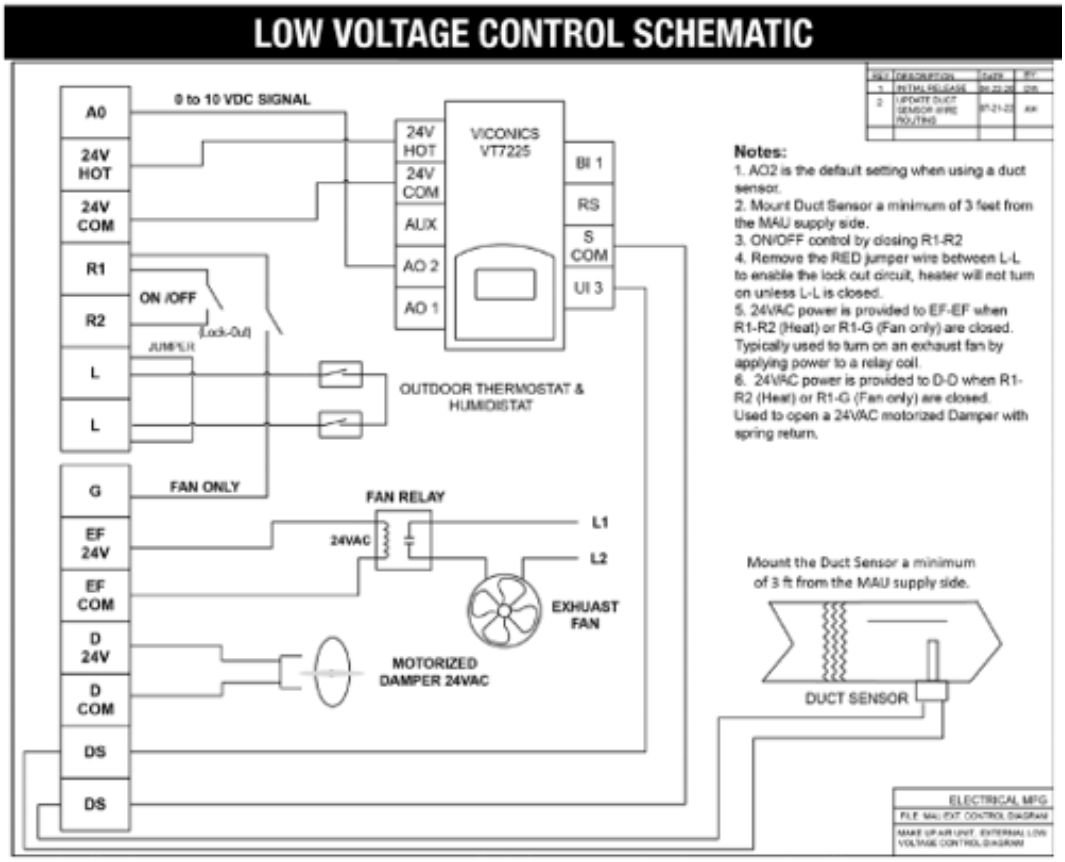
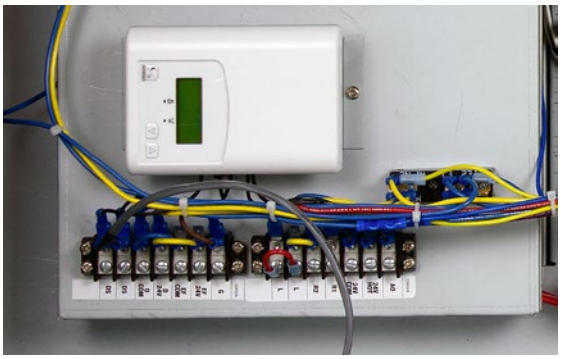


Diagram 1

ON OFF Enable Control



Terminals R1 and R2 provide dry contact enable.

Closing R1 to R2 Activates:

- ECM fan
- Electric heating modulation circuit

This Input May Be Controlled By:

- Building management system
- Current transformer monitoring exhaust fan
- Timer
- Manual switch

Proportional Heat Modulation

Terminal A0 provides the 0 to 10VDC signal from the thermostat to the SCR power controller.

The Thermostat May Control:

- Supply air temperature via duct sensor
- Room temperature if relocated

Engineering Note

When used as a room thermostat, the internal duct sensor can be removed and wiring extended per installation guidance. (See Diagram 1)

Duct Sensor Control

DS terminals accept a Type 2 NTC 10K thermistor duct sensor. The duct sensor provides discharge temperature feedback to the thermostat, enabling stable supply air control.
Without the duct sensor connected, heat will not energize during startup procedure. (See Diagram 1)

Fan Only Mode

Closing G to R1 activates fan only operation.

In this mode:

- Heating contactor does not close
- Electric heat remains disabled
- Damper and exhaust control circuits remain active

Engineering Note

Fan only operation allows ventilation without electric heating during moderate outdoor conditions and can reduce overall energy consumption.

Lockout Circuit

Terminals L and L provide lockout functionality.

Removing the Factory Jumper Enables Connection to:

- Outdoor thermostat
- Humidistat
- Occupancy sensor
- CO2 sensor
- BMS interlock

This prevents MAU activation under defined environmental conditions. (See Diagram 1)

Damper and Exhaust Fan Control

Damper Circuit
Terminals D and D provide switched 24VAC for spring return motorized damper.

Exhaust Circuit
Terminals EF and EF provide switched 24VAC for exhaust fan relay.

Maximum combined load of damper and exhaust circuits is 40VA. (See Diagram 1)
These circuits are energized in both heating mode and fan only mode.

Control Power Architecture

The MAU Incorporates:

- Dedicated 24VAC control 40 Va. power transformer
- Separate control transformer for auxiliary devices
- Electrically held high temperature limit
- Internal relay logic platform
- SCR modulation control

The ECM motor is line powered but switched via 24VAC control logic, ensuring safe and coordinated operation.

Electrical and Safety Architecture

Line voltage connections terminate at a two or three pole contactor marked L1, L2, L3 and Ground. (See Diagram 2)

System Protections Include:

- Electrically held high temperature limit
- Series element high temperature limits
- Grounding per NEC
- Field installed disconnect option

The high temperature limit resets by opening R1 R2 or cycling power.

Installation Flexibility

The MAU Series Supports:

- Horizontal mounting
- Vertical mounting with inlet facing downward
- Ceiling mounted concealed installations

Minimum clearances must be maintained for service access. Ducting must utilize rigid metal duct and insulated inlet duct in cold climates.

Outdoor Intake Hood Must Be:

- Minimum 18 inches above grade
- Minimum 6 feet from contaminant sources

Applications and Design Guidance

The MAU introduces controlled outdoor air to offset mechanical exhaust systems and maintain neutral or slightly positive building pressure in commercial/ industrial facilities.

These systems are commonly applied where sustained exhaust airflow would otherwise create negative pressure conditions that impact equipment performance, occupant comfort, and building safety. The following sections describe common application types and recommended system configuration practices when specifying the MAU Series.

Engineering Application Summary Table

Exhaust Air Application	Range of Airflow	Control method	Sensor Control Point
Commercial kitchen exhaust	800 to 3000 CFM	Exhaust Fan	Discharge of make-up air
Restroom and building exhaust	251 to 1500 CFM	BMS, Timer or Occupancy Sensor	Discharge of make-up air
Industrial and manufacturing exhaust	700 to 1700 CFM	Equipment or Exhaust Fan	Space Control or discharge of make-up air
Warehouse ventilation	700 to 1700 CFM	Timer or BMS	Space control, Temperature or Humidity
Laboratory exhaust support	400 to 2000 CFM	Exhaust fan, Timer, Humidity or Occupancy	Discharge of make-up air

Engineering Note

Applications exceeding the capacity of a single MAU may require multiple units or an alternate system selection.

Commercial Kitchen Exhaust Replacement

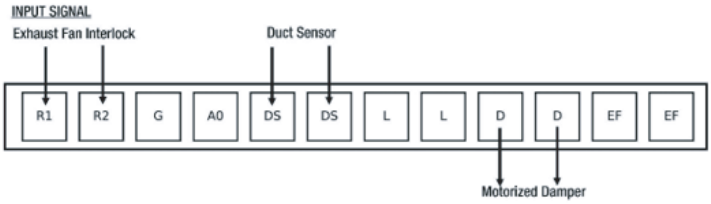
Commercial kitchens use Type I and Type II exhaust hoods that remove heat, grease vapors, and combustion byproducts.

Without a dedicated make up air source, kitchen exhaust can create severe negative building pressure which may cause back drafting of combustion appliances, reduced hood capture efficiency, and uncontrolled infiltration.

The MAU is commonly interlocked with the kitchen exhaust fan so make up air delivery tracks hood operation.

Recommended Configuration:

1. Enable signal: Exhaust fan interlock wired to terminals R1 and R2.
2. Motorized damper: Connected to D and D terminals.
3. Thermostat modulation: Connected to A0 terminal.
4. Duct temperature sensor: Connected to DS terminals.
5. Airflow is commissioned by adjusting ECM motor torque settings after measuring external static pressure.



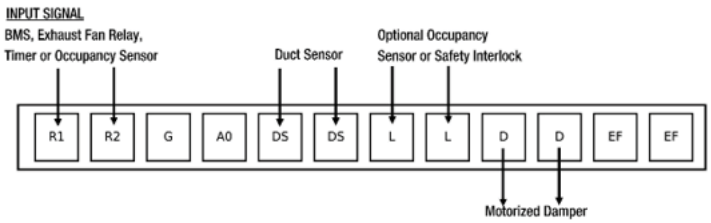
General Building Exhaust Replacement

Continuous exhaust from restrooms and support spaces can create sustained negative pressure within the building envelope.

The MAU restores neutral pressure by supplying tempered outdoor air equal to or slightly exceeding total exhaust airflow.

Recommended Configuration:

1. Enable signal provided by building automation system, timer, occupancy sensor or exhaust fan relay connected to R1 and R2 terminals.
2. Thermostat modulation connected to A0 terminal.
3. Duct temperature sensor connected to DS terminals.
4. Motorized intake damper connected to D and D terminals.
5. Optional environmental lockout devices connected to L and L terminals.



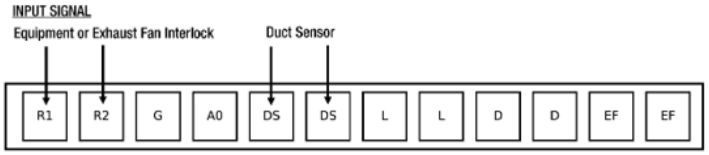
Industrial and Manufacturing Exhaust Systems

Manufacturing facilities frequently utilize localized exhaust for welding, process heat removal, paint booths, dust collection, and equipment ventilation.

These systems remove conditioned air during operation and must be balanced with make up air to maintain building pressure stability.

Recommended Configuration:

1. Enable signal from equipment interlock or exhaust fan auxiliary contact wired to R1 and R2.
2. Thermostat proportional control connected to A0 terminal.
3. Duct sensor connected to DS terminals.
4. Airflow adjusted during commissioning by selecting appropriate ECM torque setting based on measured static pressure



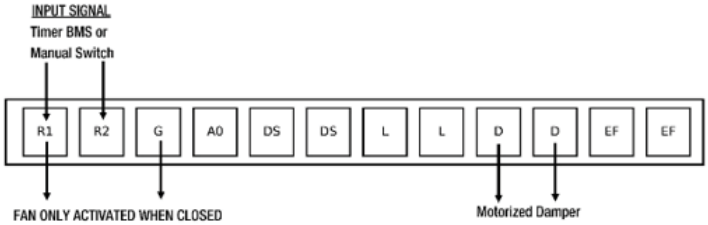
Warehouse and Large Volume Building Ventilation

Warehouses and distribution centers often require make up air to reduce infiltration caused by loading dock operation and frequent door cycling.

Fan only ventilation may be desirable during moderate outdoor temperatures. Fan only mode is enabled by closing G to R1.

Recommended Configuration:

1. Enable signal from timer, BMS, or manual switch connected to R1 and R2.
2. Fan only mode activated by closing G to R1.
3. Heating modulation controlled through thermostat connected to A0.
4. Motorized intake damper connected to D and D terminals.



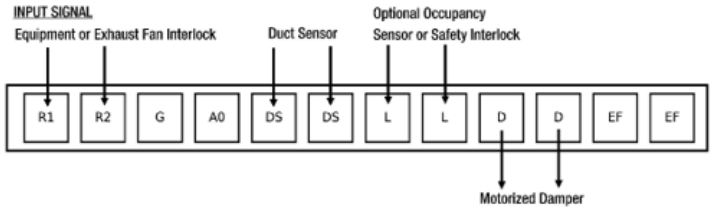
Laboratory and Controlled Ventilation Spaces

Laboratories frequently utilize fume hoods and exhaust systems that remove conditioned air continuously to maintain safe working environments.

Reliable make up air delivery is required to maintain hood containment performance and building pressure balance.

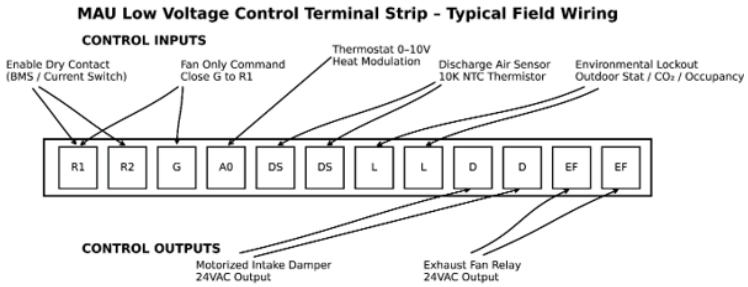
Recommended Configuration:

1. Exhaust fan interlock connected to R1 and R2 terminals.
2. Thermostat proportional heat modulation connected to A0 terminal.
3. Duct temperature sensor connected to DS terminals.
4. Environmental lockout devices such as occupancy sensors or safety interlocks connected to L and L terminals.



Appendix A.
MAU Terminal Strip Control Wiring Schematic

The schematic below summarizes typical field wiring connections at the MAU terminal strip for common control functions.



Appendix B.
Design Engineering Guidance Airflow Sizing Guidance

Make up air airflow is typically selected to offset the connected exhaust airflow. For many projects the design target is near neutral building pressure, with a slight positive bias where dust or infiltration control is desired.

For kitchen hoods and laboratory exhaust, the MAU is commonly interlocked to the exhaust fan and selected to provide a defined fraction of exhaust airflow as required by the overall ventilation and pressure design strategy.

Engineering Note

Make up air airflow is typically selected to offset between eighty and one hundred percent of the connected exhaust airflow depending on the desired building pressure strategy. Slightly positive building pressure is commonly maintained to reduce infiltration through doors and building envelope openings.

Temperature Rise and Heating Capacity

Electric heating capacity should be selected to achieve the required supply air temperature rise at the design airflow. Temperature rise is defined as the difference between the desired discharge air temperature and the outdoor design temperature.

Heating capacity can be estimated using the following relationship:
kW ≈ CFM × temperature rise × 0.000316

This equation can be rearranged to estimate expected temperature rise for a given airflow and installed heating capacity.
During commissioning, verify that airflow meets the design CFM. Once airflow is confirmed, verify stable discharge air temperature control with the duct sensor connected at DS and the thermostat modulation signal connected at terminal A0.

Engineering Note

Heating capacity must be sufficient to temper outdoor air to an acceptable discharge air temperature under winter design conditions. Temperature rise is calculated as the difference between outdoor air temperature and the desired supply air temperature.

// MAU Selection Example:

Design: 1,200 CFM, 20°F outdoor air, 55°F discharge air, 0.2 in. w.c.

Temperature rise: 55°F − 20°F = 35°F
Required heat: 1,200 × 35 × 0.000316 = 13.3 kW

Select the next available capacity, then confirm voltage, phase, airflow at design static pressure, ECM setting, controls, and a temperature rise below 90°F.

External Static Pressure and Duct Design

The MAU Series airflow performance depends on external static pressure from intake duct, filters, fittings, and supply duct distribution. Duct design should minimize pressure loss using smooth transitions, limited elbows, and appropriately sized ductwork.

For cold climates, insulate the outdoor air intake duct to reduce condensation risk and heat loss. Provide service access for filter replacement and ensure that the intake hood location avoids contaminant sources.

After installation, measure external static pressure and set the ECM motor torque setting to achieve the design airflow. Confirm that the selected torque settings for heating mode and fan only mode are configured per the product setup requirements.

Intake Hood and Damper Considerations

Outdoor intake hoods should be located and sized to prevent water entrainment and to maintain acceptable inlet velocity. Provide a spring return damper controlled by the D and D output so the intake closes when the unit is disabled.

Sequence of Operation

MAU Series Plenum Rated Make Up Air Unit

This sequence describes standard factory operation of the MAU Series when installed per manufacturer instructions.

Power Up Condition

Upon Application of Line Voltage:

1. Line voltage is present at the main contactor (L1, L2, L3 as applicable).
2. The 24VAC control 40 Va. power transformer energizes the low voltage control circuit.
3. The unit remains in standby until an enable signal is received at terminals R1 and R2.

No fan or heating operation occurs until R1 and R2 are closed and the lockout circuit is satisfied.

Enable Signal

When a Dry Contact Closes Between Terminals R1 and R2:

1. The internal control relay energizes.
2. The ECM fan motor is enabled.
3. The heating modulation circuit becomes active.
4. Damper and exhaust fan control circuits are energized.

The Enable Signal May Originate From:

- Building management system
- Current transformer sensing exhaust fan operation
- Time clock
- Manual switch

Lockout Circuit Verification

Prior to full operation, the lockout circuit between terminals L and L must be closed.

If the factory jumper has been removed and an external device is connected, the MAU will not operate unless the lockout circuit is closed.

The Lockout Circuit May Be Controlled By:

- Outdoor thermostat
- Humidistat
- Occupancy sensor
- CO2 sensor
- BMS safety interlock

If the Lockout Circuit is Open:

- Fan and heating operation are inhibited
- Auxiliary circuits are not energized

Fan Operation

When R1 and R2 are Closed and Lockout Conditions are Satisfied:

1. 24VAC control signal enables the ECM motor.
2. The motor operates at the torque setting selected for heating mode.
3. Airflow is delivered per configured CFM and external static pressure. The ECM motor is powered from line voltage but switched via the 24VAC control circuit.

Heating Operation

Heating Operation Requires:

- R1 and R2 closed
- Lockout circuit closed
- Duct sensor connected
- Thermostat setpoint above measured temperature

Upon Application of Line Voltage:

1. The thermostat generates a proportional 0 to 10VDC signal at terminal A0.
2. The 0 to 10V signal drives the SCR cycle rate control circuit.
3. The SCR modulates electric resistance element output proportionally.
4. The solid-state relay regulates wattage to maintain discharge air temperature.

Heating output continuously adjusts to maintain setpoint regardless of outdoor air temperature.

The main power contactor closes only during heating mode.

Duct Sensor Control

The discharge air temperature is controlled using a Type 2 NTC 10K thermistor duct sensor connected at DS terminals.

If the Duct Sensor is Not Connected:

- Heating will not energize.
- The thermostat will not signal to produce heat output.

When Configured as a Room Thermostat System:

- The internal duct sensor may be remote.
- Thermostat may be relocated farther downstream or in the room.
- Wiring is extended per terminal instructions.

Damper Operation

When the circuit is enabled in either heating mode or fan only mode:

1. The internal control relay energizes the auxiliary control transformer.
2. 24VAC is supplied to terminals D and D.
3. The motorized spring return damper opens.

When the Circuit is Disabled:

- 24VAC is removed.
- The damper returns to closed position via spring return.

Exhaust Fan Interlock

When the circuit is enabled:

1. 24VAC is supplied to terminals EF and EF.
2. The exhaust fan relay energizes.
3. Exhaust fan operates concurrently with make-up air delivery.

Maximum combined auxiliary load of damper and exhaust circuits shall not exceed 40VA.

Fan Only Mode

When G is closed to R1:

1. ECM fan is energized.
2. Heating circuit is bypassed.
3. Main heating contactor does not close.
4. Damper and exhaust circuits remain energized.

This mode provides ventilation without electric heat.

Fan only mode uses a separate motor torque setting from heating mode to prevent back feed conditions.

High Temperature Limit Protection

The MAU includes:

- Electrically held primary high temperature limit
- Series element high temperature limits

If a high limit trips:

1. Heating output is disabled.
2. The unit must be reset by opening R1 and R2 or cycling power.
3. If limits continue to trip, system must be inspected for airflow restriction or malfunction.

The unit must not operate with bypassed safety devices.

Shutdown

When R1 and R2 Open:

1. Heating modulation signal drops to 0V.
2. Main contactor opens.
3. Fan stops.
4. 24VAC is removed from damper and exhaust terminals.
5. Damper returns to closed position.

Conclusion

The King Electric MAU Series is not simply a heated fan assembly. It is a fully integrated electric make up air control platform engineered to meet the ventilation, airflow, temperature control, and automation integration requirements of modern large residential, commercial and industrial buildings.

With proportional 0 to 10V heat modulation, factory integrated relay logic, exhaust interlock capability, damper control, and environmental lockout functionality, the MAU Series provides engineers and architects with a specification ready basis of design solution that delivers predictable performance and simplified installation.

Supplemental ECM Multi Speed Engineering Guidance

The ECM motor platform incorporated within the MAU Series supports up to five discrete airflow operating points through independent 24VAC speed tap control.

Factory configured airflow settings are selected to coordinate heating capacity, airflow delivery, temperature rise, and external static pressure performance.

Additional motor speed taps may be connected in the field when multiple airflow operating modes are required.
Applications include multiple exhaust fan staging, occupancy based ventilation control, freeze protection airflow increase, and reduced airflow fan only operation.

When multiple speed inputs are energized simultaneously, the ECM motor automatically operates at the highest active airflow setting.

Do not configure airflow settings that produce a temperature rise greater than 90°F.

// Applicable Codes and Standards

Consult the current adopted editions of the following, as applicable:

ASHRAE 62.1 – Ventilation and indoor air quality

ASHRAE Standard 241 – Control of Infectious Aerosols, where applicable to the project ventilation

International Mechanical Code – Ventilation, exhaust, make-up air, and air-intake requirements

International Energy Conservation Code and ASHRAE 90.1 – Energy-efficiency requirements

NFPA 96 – Commercial kitchen ventilation and fire protection

ANSI/ASSP Z9.5 and NFPA 45 – Laboratory ventilation and safety

Applicable state and local building, mechanical, energy, fire, and health codes

Equipment listings, manufacturer instructions, and authority-having-jurisdiction requirements

About the Author

Dean Wilson is Chief Executive Officer and Chief Technology Officer of King Electrical Manufacturing. As CTO, he leads the company's product and manufacturing technology strategy, including the implementation of automation and modernization initiatives that have expanded King's flexible, lean manufacturing capabilities. Dean has directed major product and control-system advancements across the KFUH and CKL product lines and led the development of King's Make-Up Air and PlatinumX product families. His leadership and technical vision continue to strengthen King's position as an innovative and trusted manufacturer in the electric heating industry. King Electrical