When you need more than just Ventilation!

Carnes Energy Recovery

Carnes, a leader in providing HVAC solutions, recognized over 40 years ago that energy conservation and equipment efficiency via Energy Recovery is key to providing acceptable indoor air quality through outside air ventilation. A pioneer of Energy Recovery Wheels, no other manufacturer can boast a record of over 43 years of continuously providing Energy Recovery solutions to the commercial work place. Over more than 4 decades, Carnes Research and Development teams have developed a unique process with a **permanently bonded polymer desiccant** with a time tested delivery system that continues to perform. No media or desiccant used in Energy Recovery today has the track record of results and performance that Carnes has.

BENEFITS OF ENERGY RECOVERY WHEEL TECHNOLOGY:

- Immediate and daily dollar Savings: Reduce cost to condition outside air up to 80% by recovering **sensible** and **latent** exhaust air energy.
- Reduce Investment by downsizing required Cooling Capacity.
- Enthalpy Recovery increases cooling recovery up to 300% with latent recovery.
- Cost effectively aids in meeting ASHRAE 62 ventilation guidelines.
- Complies with ASHRAE 90.1 energy guidelines requiring energy recovery.
- Carnes Energy-C-Lect Performance Software makes choosing the optimal solution time and cost effective.

Request your FREE ENERGY-C-LECT ™ Performance Software

Today!

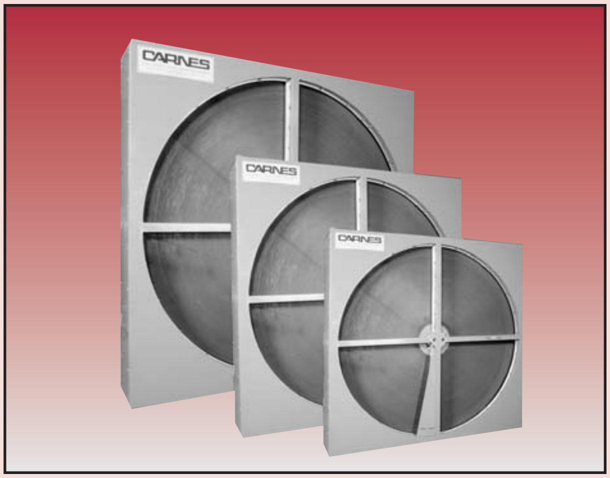
Carnes Energy Recovery Wheels (350 to 41,500 CFM)

Carnes Energy Recovery Wheels feature a water selective permanently bonded desiccant coating on self-cleaning corrugated aluminum media wound into a welded, structurally rigid rotor for long reliable performance and life. The welded and painted heavy gauge steel cassette supports the rotor, bearings, drive motor, and effective brush seals. Standard wheel purges adjust for maximum effectiveness and minimum purge flow, and are available in 4 duct arrangements.

Media shows ASTM E84 Tested Flame Spread and Smoke Index of 0.

AVAILABLE OPTIONS INCLUDE:

- ETL/CSA Listing for quick Building Code approvals.
- Sensible Only Media for dry energy only transfer applications.
- Corrosion Protected Media for salt air and chemical environments.
- Segmented Rotors and Cassettes for specification matching and constrained space installations.
- Replacement Rotors/Media for Carnes, ENRECO, Wing, and others..
- Variable Speed Controls with Defrost.
- Temperature or Enthalpy Economizer Controls.
- Stand-Alone or BMS/DDC Control Options.
- Rotation Detector for rotor operation assurance.
- Insulated Frames to prevent condensation.
- Dual Belts, Spare Belts, Urethane or Flex Link Belts.
- Optional 5 Year Wheel Warranty.



PRODUCT OVERVIEW

Carnes enthalpy (sensible and latent) energy recovery wheel is designed to economically recover sensible heat and latent moisture from a conditioned exhaust air stream. The wheel may be incorporated into a packaged air handling unit or designed into a building duct system. The total recovery wheel is the only recovery technology that passively corrects humidity levels (latent energy) and temperature (sensible energy) while preconditioning outside makeup air. The benefits to the building owner include reduced cooling equipment requirements, reduced heating equipment requirements and reduced operating costs. Under many operating environments, both reduced first cost investment and reduced operating costs may be achieved.

Related sensible recovery only allows for the recovery of sensible energy only where the transfer of humidity between exhaust and supply air streams is not needed (for example, heating only applications). Design and construction features are identical except that the wheel rotor media is not coated with desiccant.

Carnes manufactures nine free standing wheel sizes for capacities from 350 to 41,500 CFM. Wheels and rotors for retrofit and OEM applications are available. Carnes Energy Recovery product line includes energy recovery ventilators for capacities from 300 CFM and built up air handler systems to 11,000 CFM utilizing Carnes energy recovery wheels.

APPLICATION BENEFITS

Carnes Energy Recovery Wheels help designers economically meet ASHRAE Standard 62 guidelines for minimum fresh air ventilation of 15 to 20 CFM per person. ASHRAE Standard 62 guidelines require dramatically increased outside air ventilation to avoid indoor air quality problems from indoor air contaminants. Adherence to ASHRAE Standard 62 is generally considered the best possible defense against liabilities related to design ventilation rates. Increased outside air intake necessarily demands increased cooling capacity or preconditioning of outside air. In many cases, a realistic design credit for energy recovery will result in lower first costs due to reduced cooling equipment requirements. In most middle latitude climates with moderate to high summer humidity levels, payback periods range from immediate to one year. Use of the energy recovery wheel complies with ASHRAE 90.1 guidelines. Please contact the factory for assistance with annual operating savings estimates.

CONSTRUCTION DETAILS

The heart of Carnes energy recovery wheels is an aluminum media that is corrugated to form a high efficiency transfer media. In the case of the sensible and latent, the aluminum media is coated with a proprietary permanently bonded acrylic desiccant. An optional acrylic coating is recommended for coastal or salt laden environments. Epoxy edge coating is also available for additional corrosion protection.

Optional segmented construction is available such that the rotor may be disassembled into multiple sections. This option is primarily intended for retrofit or restricted access installation applications.

The rotor is centered on a welded steel hub with self-aligning sealed bearings equipped with grease fittings.

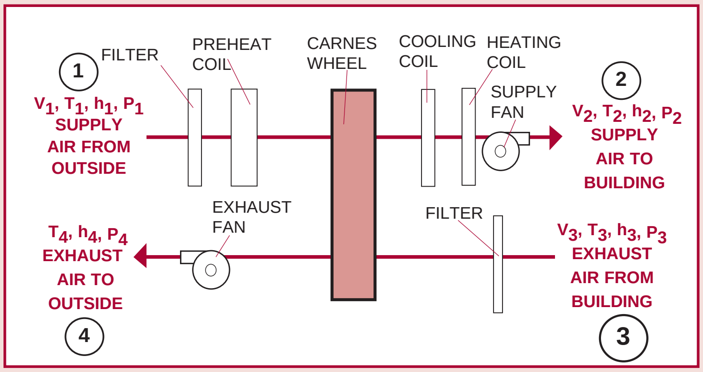
The rotor is supported in a heavy gauge steel frame. Nylon wiping seals are provided at the periphery of the rotor and along the divider between supply and exhaust air streams to minimize leakage. A field adjustable purge section is provided to limit carry over of any exhaust contaminant's to less than 0.04%.

The rotor is perimeter belt driven by a fractional horsepower, permanently lubricated, totally enclosed, integrated inline reduction drive.

DESIGN CONSIDERATIONS

• FAN CONFIGURATION

Supply and exhaust air streams must flow in opposite directions through the wheel. To provide optimum performance from the energy recovery wheel, both supply and exhaust fans should be located in a draw-through configuration to provide a uniform velocity profile across the thermal transfer media. Use of a blow-through supply fan will minimize cross contamination, but can reduce thermal performance, and could damage wheel media due to high air velocities. If used, care should be taken to locate the supply fan as far upstream as possible so as not to hinder thermal performance.



TYPICAL SYSTEM FLOW SCHEMATIC

CAUTION: A blow-through exhaust fan used with a draw-through supply fan will cause reverse purge operation and maximize exhaust carry over.

• DUCT CONFIGURATION

The Carnes Wheel is intended for vertical installation serving horizontal air streams. Vertical orientation minimizes rotor deflection and encourages long bearing life and proper sealing. (Consult the factory for installation requirements to serve horizontal installations with vertical air streams.) Height restrictions can be accommodated using multiple smaller wheels mounted side by side with horizontal purge. Refer to Chart 10 for optional purge orientations. Access should be provided to both upstream and downstream sides of the wheel for routine inspection and maintenance. In addition, side access should be provided for rotor removal as well as motor and drive service. Optional motor location is available for design flexibility.

• FILTRATION

Locate supply and exhaust air streams in a counter-flow arrangement to take advantage of the self-cleaning feature of the Carnes Wheel, and interlock the wheel with blowers to prevent dust accumulation. Both supply and exhaust filters are required upstream of the Carnes wheel. For most HVAC applications, only low efficiency roughing filters are required to maintain performance.

Filters with 30% efficiency (ASHRAE 52 Mass Arrestance Test) are suitable for normal conditions. Provide downstream protection from filter blow out.

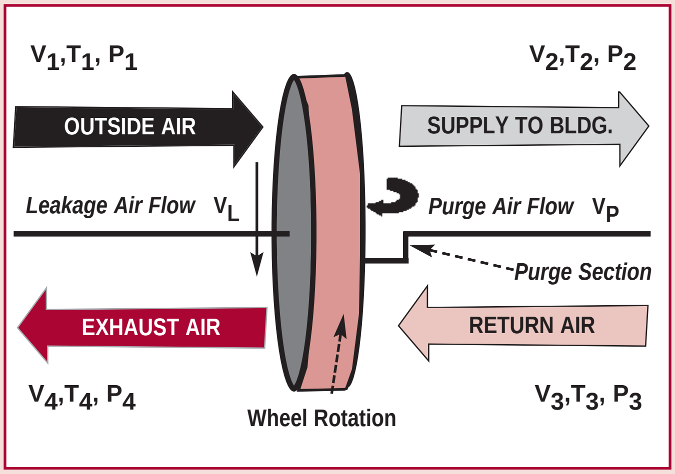
• FROST FORMATION POTENTIAL

Frost formation is a function of the outside air temperature (T_1), and the building return air humidity. In most comfort-to-comfort applications frost formation will not occur, but the potential should be evaluated using Carnes Energy-C-Lect software. Frost formation will occur at higher temperatures with sensible only media.

• PURGE OPERATION

Carnes wheels are provided with a standard adjustable purge section designed to limit trapped exhaust air from being carried over in the thermal transfer media to the supply airstream.

Using a purge section, a small stream of supply air is diverted, sent back through the wheel media on the exhaust side of the wheel, and exhausted to the outside. By maintaining a positive pressure difference between the supply and exhaust ducts, exhaust carryover (cross contamination) can be minimized.



PURGE DETAIL

Normally fans should be located downstream of the wheel for draw-through air flow to insure max-

DESIGN CONSIDERATIONS

PURGE OPERATION *(Continued)*

imum energy transfer. The purge section is designed to operate in this arrangement if there is a lower pressure on the downstream exhaust side (P_4) than on the downstream supply side (P_2).

In order to compensate for the outside air being exhausted through the purge (V_P), the exhaust fan capacity should be increased depending on the pressure differential between the downstream exhaust side (P_4) of the wheel and downstream supply side (P_2) as shown in the system flow schematic above. For rough estimating assume 10% extra exhaust airflow (V_4) with draw-through draw-through fans, and 20% extra exhaust airflow (V_4) with blow-through supply fan, draw-through exhaust fan.

Leakage around seals can also be determined depending on the pressure differential between the downstream exhaust side (P_4) of the wheel and the upstream supply side (P_1). The draw-through exhaust fan must be increased in capacity to accommodate this leakage.

Chart 1: ***Purge Volume (V_P)***

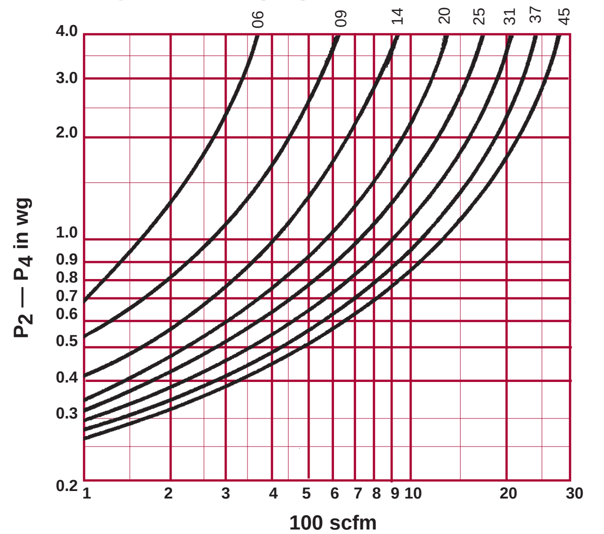
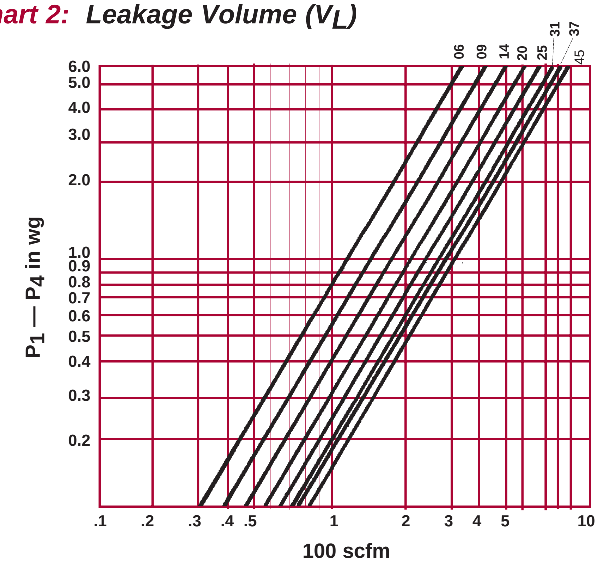


Chart 2: ***Leakage Volume (V_L)***



The actual exhaust fan capacity required (V_4) is determined by adding the purge value (V_P) and leakage volume (V_L) to the return air volume (V_3).

For example, if the return air volume (V_3) of the Model WWCD-31 is 20,000 cfm, and the difference between the downstream supply pressure (P_2) and the downstream exhaust pressure (P_4) is 1.0 in wg. from Chart 1, the purge volume (V_P) is 950 cfm. The difference between the upstream supply pressure (P_1) and downstream exhaust pressure (P_4) is 1.5 in. wg. From Chart 2 the leakage volume (V_L) is 330 cfm. The exhaust fan should be sized for:

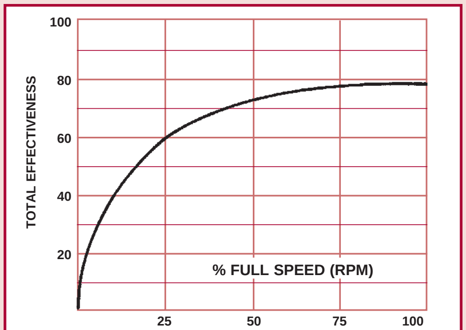
$$V_4 = V_{Purge} + V_{Leakage} + V3$$

$$V_4 = 900 + 330 + 20{,}000 = 21{,}230 \text{ cfm}$$

• SUPPLY AIR TEMPERATURE CONTROL

The Carnes wheel is available with several temperature control options depending on the supply air discharge requirements (T_2) of the application. Since energy transfer is a function of rotational speed, controls can be provided to vary supply air temperature. Chart 3 illustrates the relationship between effectiveness and RPM.

Chart 3: ***Wheel Effectiveness vs. RPM.***



Constant Speed Drive

Designed room neutral condition applications in which an energy loss is present in the space, require constant speed drive for maximum energy transfer. Since the Carnes Wheel recovers

DESIGN CONSIDERATIONS

***SUPPLY AIR TEMPERATURE CONTROL** (Continued)*

approximately 75% of the difference between outside air temperature (T_1) and return air temperature (T_3), supplemental heating or cooling is needed to maintain space conditions.

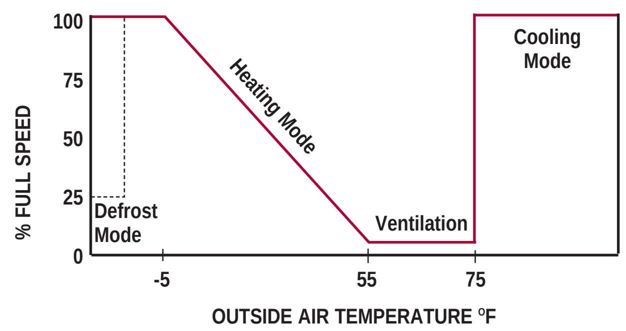
Temperature Controlled Economizer
Adjustable temperature actuated thermostats operate wheel for heating and cooling, and stop wheel for "free cooling" economizer mode. Most appropriate for low humidity climates.

Enthalpy Controlled Economizer
Adjustable enthalpy actuated thermostats operate wheel for heating and cooling, and stop wheel for economizer mode. Ideal for use in high humidity climates where latent recovery is the major contributor to total energy savings. An override switch for winter operation is required.

Variable Speed Drive
HVAC applications in which heat gain is present in the space, require a variable speed drive to prevent over-heating. A constant speed energy recovery wheel will produce a rising supply air discharge temperature (T_2) as the outside air temperature (T_1) increases. This supply air discharge temperature may exceed the maximum required to maintain space conditions in moderate weather. The variable speed drive controls supply discharge temperature with an AC motor through a variable frequency controller, proportional discharge sensor and heating/cooling changeover controller. The discharge sensor should be mounted on the downstream supply side (T_2) of the wheel in an accurate average temperature location. Set point is the desired winter mode supply air discharge temperature required to maintain space conditions. On a change in discharge temperature, the variable frequency controller will modulate the energy recovery wheel RPM and energy transfer effectiveness to maintain a constant discharge temperature.

The heating/cooling changeover control sensors should be mounted in outside airstream (T_1) and in building return airstream (T_3). When outside air temperature (T_1) is lower than building return air temperature (T_3), the recovery wheel operates in a heating mode, varying wheel speed to maintain desired average (T_2) wheel discharge temperature. When outside air temperature (T_1) exceeds building return air temperature (T_3), recovery wheel operates in a cooling mode, with wheel rotating at full speed to achieve maximum energy transfer effectiveness.

***Chart 4** — Variable Speed Drive*



Assume that an equal flow application is returning 75°F air (T_3) from the space, a nominally selected Carnes wheel is used and a maximum winter mode discharge temperature of 55°F (T_2) is required. Chart 4 illustrates the change in wheel RPM and thermal performance required to maintain a constant discharge temperature. For typical comfort-to-comfort winter design conditions above -5°F (T_1), the Carnes wheel can eliminate the need for supplemental heating. Variable speed drive is also available with an external speed signal for BMS/DDC Control.

Variable Speed Drive with Frost Control
A differential pressure switch and outside air thermostat are added to the variable speed control scheme to reduce wheel rotational speed upon sensing:

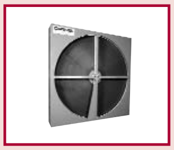
1. An increase in wheel pressure drop.
2. Freezing outside air temperature.

This speed reduction increases the media residence time in the exhaust airstream, which allows the frost build-up to thaw and return the wheel to normal service.

• ROTATION DETECTOR

In addition to temperature controls, a rotation detector is available to signal rotation failure. The rotation detector includes a factory mounted infrared sensing device. Remote mounted warning light or alarm to be supplied by others.

SELECTION PROCEDURE



Carnes provides equipment selection and performance calculation software for the energy recovery wheel (Energy-C-Lect). This powerful tool is the simplest and fastest way to perform energy recovery performance, unit selection, and submittals. The latest Energy-C-Lect may be requested from the Carnes website. The following manual selection guidelines are provided primarily so that you may understand the underlying assumptions and calculations behind the selection software. Use Energy-C-Lect for actual selections.

• THERMAL TRANSFER MEDIA

Two types of thermal transfer media are available depending on the application. Carnes sensible and latent total recovery media is constructed of aluminum, coated with a non-migrating, water selective, permanently bonded desiccant which permits both sensible and latent energy transfer with minimal cross contamination. The sensible only media is also constructed of aluminum for applications requiring sensible only energy transfer. Both media types are available with an acrylic coating and epoxy edge coating for salt air corrosion resistance. Sensible and latent recovery media is recommended for most HVAC comfort-to-comfort applications.

• WHEEL SELECTION — SENSIBLE & LATENT RECOVERY

Selection of Carnes Energy Recovery Wheel:

1. Determine design conditions.
2. Select wheel size.
3. Determine wheel performance.
4. Calculate discharge air conditions.
5. Calculate energy recovery.
6. Determine purge arrangement.
7. Select controls and options.

• DESIGN CONDITIONS

Based on the design conditions of the supply air from outside (V_1, T_1) and the return air from the building (V_3, T_3), refer to the enthalpy table, Chart 11, to determine entering supply enthalpy (h_1) and entering return enthalpy (h_3). Design condition notation is shown in the system flow schematic found on Page D-3.

• WHEEL SIZE

For some applications, as many as four different wheel sizes may be utilized. The ultimate selection is based on performance, size and economic considerations. A midpoint selection can be made using the following formula to determine the nominal wheel face area.

$$\text{Nominal Wheel Area, Sq. Ft.} = \frac{\text{SUPPLY or EXHAUST Volume, cfm}}{650 \text{ fpm}}$$

Refer to Chart 5 and select the wheel size which approximates the required face area. For example, a Model WWCD-31 would be selected for an application requiring 20,000 cfm supply (V_1), latent recovery. Complete unit nomenclature can be found on Page D-10.

$$\text{NOMINAL WHEEL AREA} = \frac{20{,}000 \text{ cfm}}{650 \text{ fpm}} = 30.8 \text{ Sq. Ft.}$$

The final wheel size selected will typically be based on the financial payback resulting from the reduction in required outside air conditioning capacity, and the incremental annual energy savings versus the incrementally larger installed cost of the larger wheel. Larger wheels will provide higher energy recovery effectiveness with lower

Chart 5: Wheel Face Area (A_F) Sq. Ft. (Sq. Decimeters)

SIZE	03	06	09	14	20	25	31	37	45
FACE AREA PER SIDE	3.5 (.38)	5.8 (.62)	9.3 (1.00)	14.3 (1.54)	20.2 (2.17)	26.0 (2.80)	32.2 (3.47)	38.3 (4.12)	46.1 (4.96)

pressure drop at a higher initial cost and larger dimensional envelope. Higher effectiveness will increase the annual energy savings and may allow selection of reduced cooling equipment capacity. Lower wheel pressure drop will reduce required fan motors BHP, and may allow selection of a smaller fan motor size.

• WHEEL PERFORMANCE

a) Equal Flow

Based on the wheel face velocity (v), the thermal effectiveness (E) and pressure drop (ΔP) can be determined from the performance data shown in Chart 6. Calculate the face velocity for both supply and exhaust air streams using the actual face area shown in Chart 5. Assuming an equal flow of 20,000 cfm supply (V_2) and 20,000 cfm return (V_3), a Model WWCD-31 would have a face velocity of 621 fpm.

$$v = \frac{V}{A_F}$$

$$v = \frac{20{,}000 \text{ cfm}}{32.2 \text{ Sq. Ft.}} = 621 \text{ fpm}$$

Equal Flow Performance
Carnes Sensible and Latent Wheel

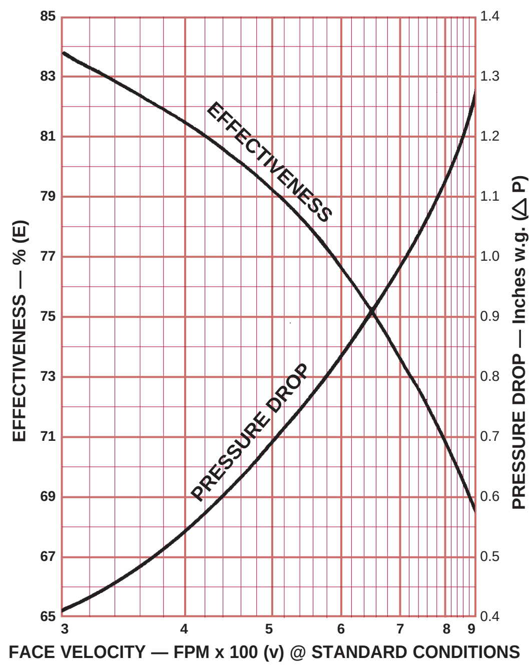


Chart 6

Enter the equal flow performance shown in Chart 6 for the sensible and latent wheel at the actual face velocity. Find an effectiveness of 75.8% and a pressure drop of .87 in. wg. across the supply and exhaust sides.

b) Unequal Flow

If the supply volume and return volumes are unequal, it is necessary to correct the difference in mass flow using the flow ratio (K). Assuming a supply volume (V_2) of 15,000 cfm and an return volume (V_3) of 20,000 cfm, K is calculated to be 1.33.

$$K = \frac{V \text{ max.}}{V \text{ min.}}$$

$$K = \frac{20{,}000 \text{ cfm}}{15{,}000 \text{ cfm}} = 1.33$$

Determine the supply and return face velocities using the same formula shown in the equal flow example. A Model WWCD-31 would have a supply and exhaust face velocity of 466 fpm and 621 fpm respectively.

$$v \text{ Supply} = \frac{15{,}000 \text{ cfm}}{32.2 \text{ Sq. Ft.}} = 466 \text{ fpm}$$

$$v \text{ Return} = \frac{20{,}000 \text{ cfm}}{32.2 \text{ Sq. Ft.}} = 621 \text{ fpm}$$

Enter the unequal flow performance Chart 7 at the supply side face velocity and appropriate K factor. The Model WWCD-31 would have an effectiveness of 90.5%. Refer to Chart 6 and read 0.65 in w.g. for the supply side pressure drop and 0.87 in w.g. for the return.

NOTE:

_1._ _Catalog performance data is based on independent tests conducted in accordance with ASHRAE Standard 84 method of testing Air-to-Air Heat Exchangers. Test conditions are in accordance with ARI Standard 1060._

SELECTION PROCEDURE

Unequal Flow Performance
Carnes Sensible and Latent Wheel

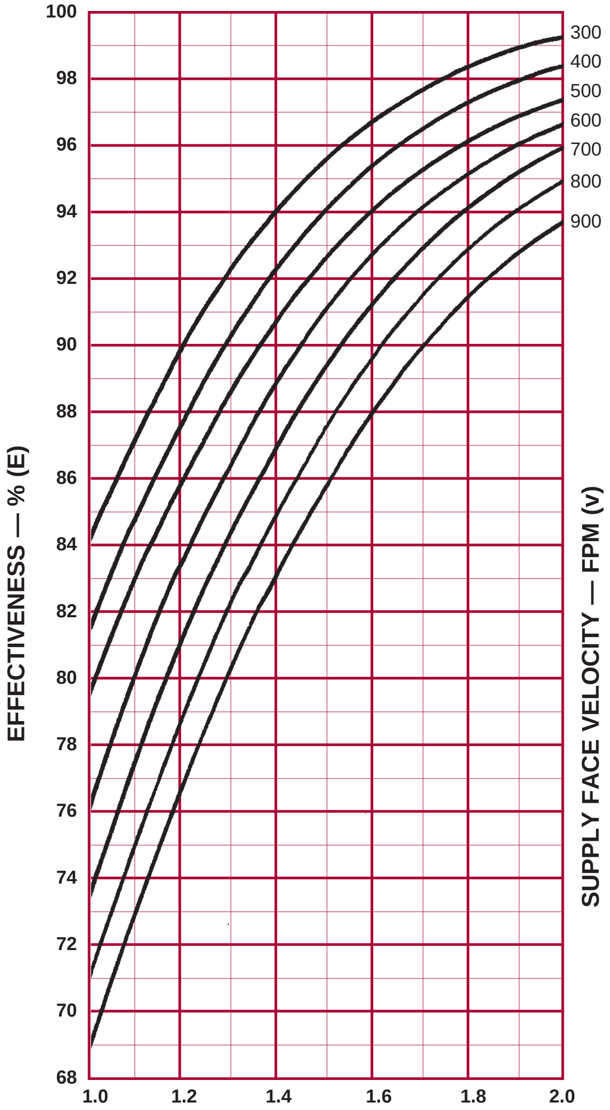


Chart 7

• DISCHARGE AIR CONDITIONS

Based on the design conditions entering the wheel (T_1, h_1, T_3, h_3) and the wheel effectiveness (E), the supply air conditions (T_2, h_2) are calculated using the following formulas:

$$T_{2DB} = T_1 + (E)\frac{V\ min.}{V_1}(T_3 - T_1)$$

$$h_2 = h_1 + (E)\frac{V\ min.}{V_1}(h_3 - h_1)$$

Continuing the unequal flow example, if the outside air temperature (T_1) is 90°F dry bulb, 74°F wet bulb and building return air temperature (T_3) is 70°F dry bulb, 59°F wet bulb, the supply air temperature (T_2) from a Carnes Model WWCD-31 would be:

$$T_{2DB} = 90^oF + (.905)\left[\frac{15{,}000}{15{,}000}\right](70^oF - 90^oF)$$

$$= 71.9^oF_{DB}$$

The enthalpy of the leaving supply air to the building (h_2) can be calculated:

$$h_2 = 37.66 + (.905)\left[\frac{15{,}000}{15{,}000}\right](25.78 - 37.66)$$

$$= 26.90\ BTU/lb.$$

• ENERGY RECOVERY CALCULATION

Concluding with the unequal flow example, the energy recovered and returned to the building is calculated as follows:

a) Sensible Energy

$$Q_S = 1.08\ (V_1)\ (T_{2DB} - T_{1DB})$$

= 1.08 (15,000) (71.9°F — 90°F) = —293 MBH

b) Total Energy (Sensible plus latent)

$$Q_T = 4.5\ (V_1)\ (h_2 - h_1)$$

= 4.5 (15,000) (26.90 BTU/lb. — 37.66 BTU/lb.)

= —726 MBH

CARNES®

• WHEEL SELECTION — SENSIBLE ONLY RECOVERY

For applications requiring sensible only energy transfer, the same procedure is utilized. Since latent recovery is not required, calculations involving enthalpy (h_1, h_2, h_3) and total energy (QT) are not considered. Delivered air conditions (T_2) and sensible recovery (Qs) are determined in the same manner as the sensible and latent. Refer to Chart 8 and 9 for sensible only media performance data.

Equal Flow Performance
Carnes Sensible Only Wheel

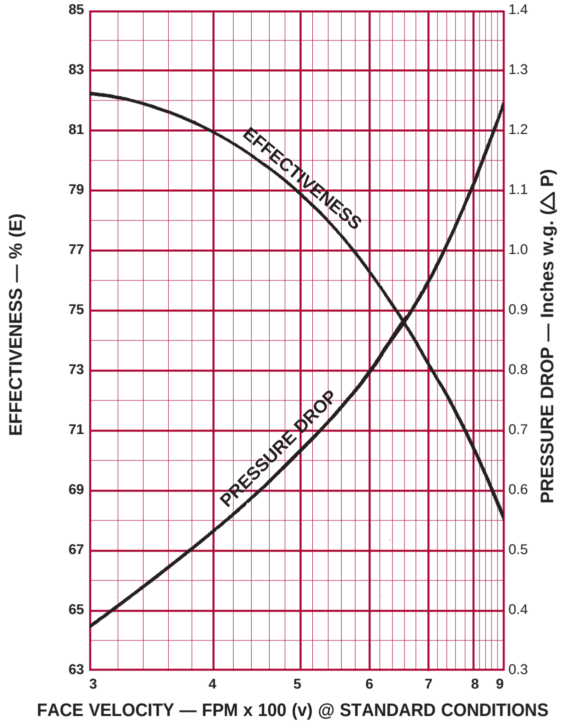


Chart 8

Unequal Flow Performance
Carnes Sensible Only Wheel

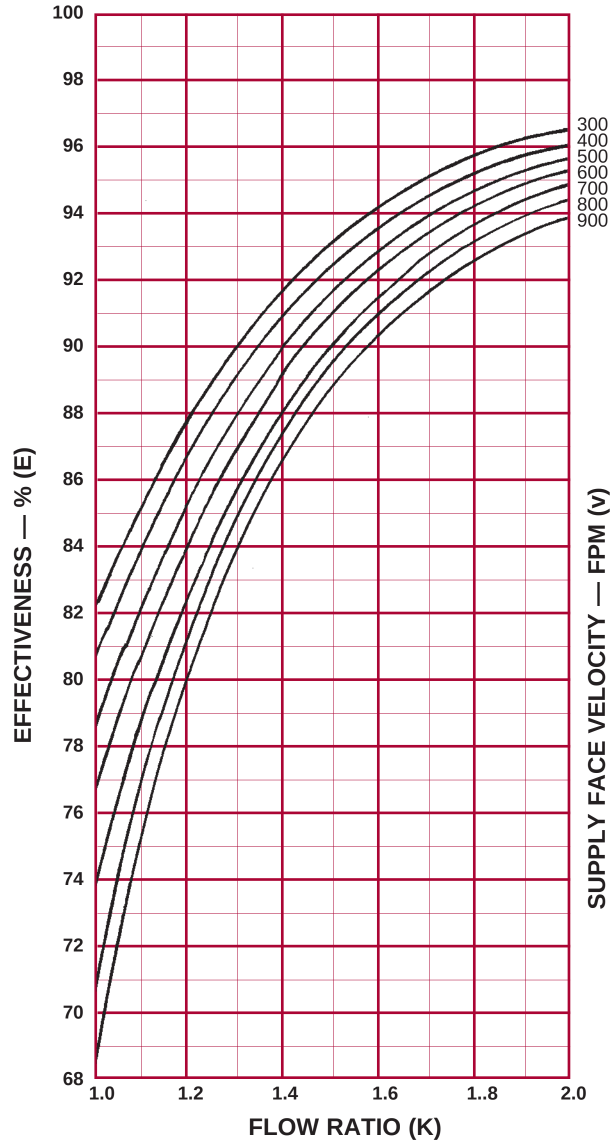


Chart 9

ENTHALPY TABLE

***Chart 11:** Enthalpy at Saturation, BTU Per Pound Of Dry Air*

Wet Bulb Temp-F	Tenths of a Degree									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
35	13.01	13.05	13.10	13.14	13.18	13.23	13.27	13.31	13.35	13.40
36	13.44	13.48	13.53	13.57	13.61	13.66	13.70	13.75	13.79	13.83
37	13.87	13.91	13.96	14.00	14.05	14.09	14.14	14.19	14.23	14.27
38	14.32	14.37	14.41	14.46	14.50	14.55	14.59	14.64	14.68	14.73
39	14.77	14.82	14.86	14.91	14.95	15.00	15.05	15.09	15.14	15.18
40	15.23	15.28	15.32	15.37	15.42	15.46	15.51	15.56	15.60	15.65
41	15.70	15.75	15.80	15.84	15.89	15.94	15.99	16.03	16.08	16.13
42	16.17	16.22	16.27	16.32	16.36	16.41	16.46	16.51	16.56	16.61
43	16.66	16.71	16.76	16.81	16.86	16.91	16.96	17.00	17.05	17.10
44	17.15	17.20	17.25	17.30	17.35	17.40	17.45	17.50	17.55	17.60
45	17.65	17.70	17.75	17.80	17.85	17.91	17.96	18.01	18.06	18.11
46	18.16	18.21	18.26	18.32	18.37	18.42	18.47	18.52	18.58	18.63
47	18.68	18.73	18.79	18.84	18.89	18.95	19.00	19.05	19.10	19.16
48	19.21	19.26	19.32	19.37	19.43	19.48	19.53	19.59	19.64	19.70
49	19.75	19.81	19.86	19.92	19.97	20.03	20.08	20.14	20.19	20.25
50	20.30	20.36	20.41	20.47	20.52	20.58	20.64	20.69	20.75	20.80
51	20.86	20.92	20.97	21.03	21.09	21.15	21.20	21.26	21.32	21.38
52	21.44	21.50	21.56	21.62	21.67	21.73	21.79	21.85	21.91	21.97
53	22.02	22.08	22.14	22.20	22.26	22.32	22.38	22.44	22.50	22.56
54	22.62	22.68	22.74	22.80	22.86	22.92	22.98	23.04	23.10	23.16
55	23.22	23.28	23.34	23.41	23.47	23.53	23.59	23.65	23.72	23.78
56	23.84	23.90	23.97	24.03	24.10	24.16	24.22	24.29	24.35	24.42
57	24.48	24.54	24.61	24.67	24.74	24.80	24.86	24.93	24.99	25.06
58	25.12	25.19	25.25	25.32	25.38	25.45	25.52	25.58	25.65	25.71
59	25.78	25.85	25.92	25.98	26.05	26.12	26.19	26.26	26.32	26.39
60	26.46	26.53	26.60	26.67	26.74	26.81	26.87	26.94	27.01	27.08
61	27.15	27.22	27.29	27.36	27.43	27.50	27.57	27.64	27.71	27.78
62	27.85	27.92	27.99	28.07	28.14	28.21	28.28	28.35	28.43	28.50
63	28.57	28.64	28.72	28.79	28.87	28.94	29.01	29.09	29.16	29.24
64	29.31	29.39	29.46	29.54	29.61	29.69	29.76	29.84	29.91	29.99
65	30.06	30.14	30.21	30.29	30.37	30.45	30.52	30.60	30.68	30.75
66	30.83	30.91	30.99	31.07	31.15	31.23	31.30	31.38	31.46	31.54
67	31.62	31.70	31.78	31.86	31.94	32.02	32.10	32.18	32.26	32.34
68	32.42	32.50	32.59	32.67	32.75	32.84	32.92	33.00	33.08	33.17
69	33.25	33.33	33.42	33.50	33.59	33.67	33.75	33.84	33.92	34.01
70	34.09	34.18	34.26	34.35	34.43	34.52	34.61	34.69	34.78	34.86
71	34.95	35.04	35.13	35.21	35.30	35.39	35.48	35.57	35.65	35.74
72	35.83	35.92	36.01	36.10	36.19	36.29	36.38	36.47	35.56	36.65
73	36.74	36.83	36.92	37.02	37.11	37.20	37.29	37.38	37.48	37.57
74	37.66	37.76	37.85	37.95	38.04	38.14	38.23	38.33	38.42	38.52
75	38.61	38.71	38.80	38.90	38.99	39.09	39.19	39.28	39.38	39.47
76	39.57	39.67	39.77	39.87	39.97	40.07	40.17	40.27	40.37	40.47
77	40.57	40.67	40.77	40.87	40.97	41.08	41.18	41.28	41.38	41.48
78	41.58	41.68	41.79	41.89	42.00	42.10	42.20	42.31	42.41	42.52
79	42.62	42.73	42.83	42.94	43.05	43.16	43.26	43.37	43.48	43.58
80	43.69	43.80	43.91	44.02	44.13	44.24	44.34	44.45	44.56	44.67
81	44.78	44.89	45.00	45.12	45.23	45.34	45.45	45.56	45.68	45.79
82	45.90	46.01	46.13	46.24	46.36	46.47	46.58	46.70	46.81	46.93
83	47.04	47.16	47.28	47.39	47.51	47.63	47.75	47.87	47.98	48.10
84	48.22	48.34	48.46	48.58	48.70	48.83	48.95	49.07	49.19	49.31
85	49.43	49.55	49.68	49.80	49.92	50.05	50.17	50.29	50.41	50.54

**Interpolated to tenths of degrees from ASHRAE Guide & Data Book.
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