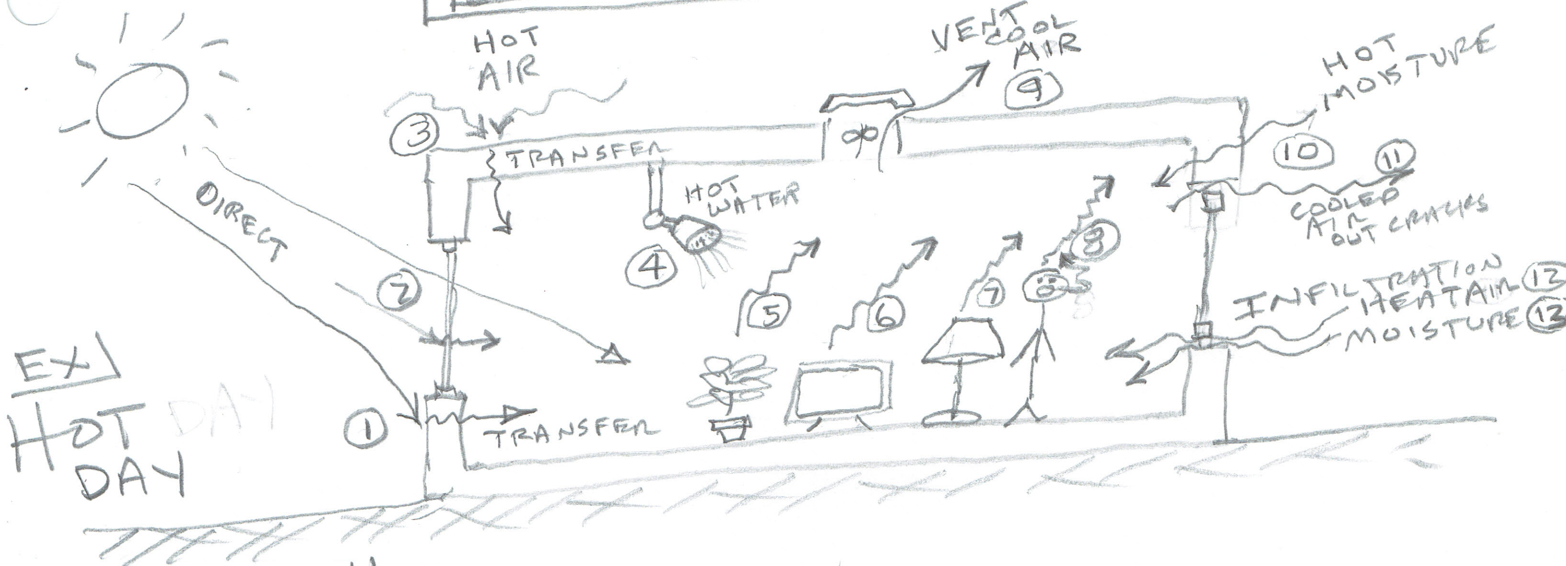
# CH 15 THERMAL ENVELOPE

## HEAT GAIN



⇓

① AND ③ ABOVE

HEAT GAIN THROUGH WALLS AND ROOFS

$$\boxed{H.G._{\text{WALLS + ROOFS}}} = \left(\text{AREA OF WALLS OR ROOF}\right) \times \left(\frac{1}{R_{\text{ESISTANCE OF WALL, ROOF}}}\right) \times \left(\overset{\text{DESIGN EQUIVALENT TEMPERATURE DIFFERENCE}}{DETD}\right)$$

WHERE: $DETD = f\left(\Delta T,\ \text{MASS}_{\text{OF BUILDING}},\ \underline{\text{ALBEDO}}\right)$

ALBEDO → REFLECTANCE OF BOTH VISABLE AND INFRARED EM RADIATION

| | | |
|---|---|---|
| WALLS | WHITE PAINT | 50-90 |
| | COLOREDPAINTS | 10-40 |
| ROOFS | HIGHLY REFLECTIVE ROOF | 60-70 |
| | ~BLACK ROOF | 5-20 |
| | MAX | 100 |
| | MIN (FULL ABSORBTION) | 0 |

RESEARCH EXAMPLE SHOWED:

HG↓ AND AIRCONDITIONING LOAD ↓20% IF AVE ALBEDO OF WALLS + ROOF CHANGED FROM 30 TO 90

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$$\boxed{\underset{\text{THROUGH WINDOWS}}{\overset{\text{EAT AIN}}{H.G.}}} = \left(\text{AREA OF WINDOWS}\right) \times \left(\overset{\text{OLAR EAT AIN ACTOR}}{SHGF}\right) \times \left(\overset{\text{OLAR EAT AIN OEFF}}{SHGC}\right)$$

$$= f\left(\text{LATITUDE}, \text{WINDOW ORIENTATION TO SUN}, \text{SEASON}, \text{TIME OF DAY}\right)$$

$$= f\left(Q_{\text{SHADING}} = f\left(\text{GLAZING TYPES}, \text{TREES}, \text{SHADING STRATEGIES}, \text{ETC}\right)\right)$$

→ SEE CH9 "PASSIVE COOLING"

EX) DOUBLE-GLAZED 4FT X 5FT WINDOW, 80% GLASS ON WALL FACING SOUTH IN BUILDING LOCATED AT 40° NORTH LATITUDE. TIME IS 11:00 AM ON MARCH 21

→ USING TABLES FROM REFERENCE BOOKS (COURSE TEXT, ASHRAE "FUNDAMENTALS", AIA STANDARDS)

FIND:

$$SHGF = 197 \frac{BTU/HR}{FT^2}$$

$$SHGC = 0.73$$

TABLE 9.21 (P251)

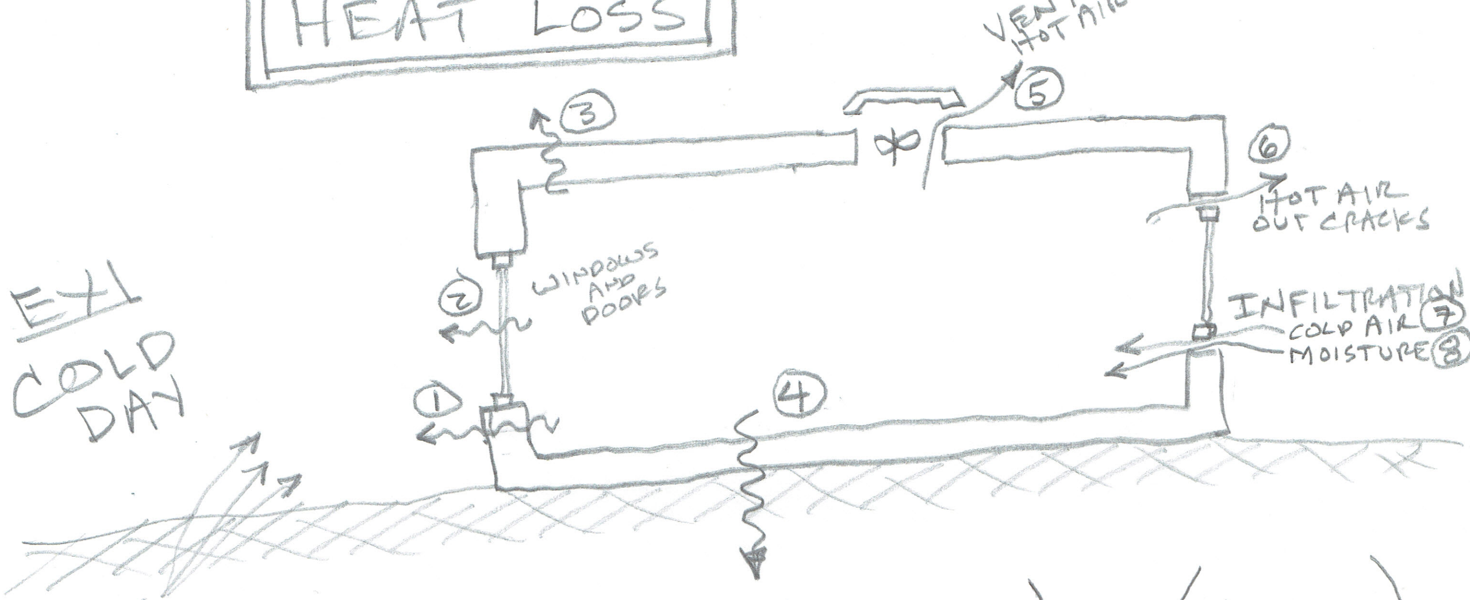
$$\text{GLASS AREA} = (4\,FT \times 5\,FT) \times 0.80 = 16\,FT^2$$

$$\underset{\text{THROUGH WINDOW}}{H.G.} = (16\,FT^2) \times \left(197 \frac{BTU/HR}{FT^2}\right) \times (0.73)$$

$$= \boxed{2301\ BTU/HR}$$

# HEAT LOSS

EX1 COLD DAY



①,②,③ ABOVE

HEAT LOSS

$$\boxed{\begin{array}{c}\text{H.L.}\\ \text{THROUGH WALLS, WINDOWS, DOORS, ROOFS}\end{array}} = \left(\text{AREA}\ {\scriptstyle\text{OF WALLS, WINDOWS, DOORS, ROOFS}}\right) \times \left(\frac{1}{R_{T}^{\text{ESISTANCE OF}}\ {\scriptstyle\text{WALLS, WINDOWS, DOORS, ROOF}}}\right) \times \left(\Delta T_{\text{EMP}}\right)$$

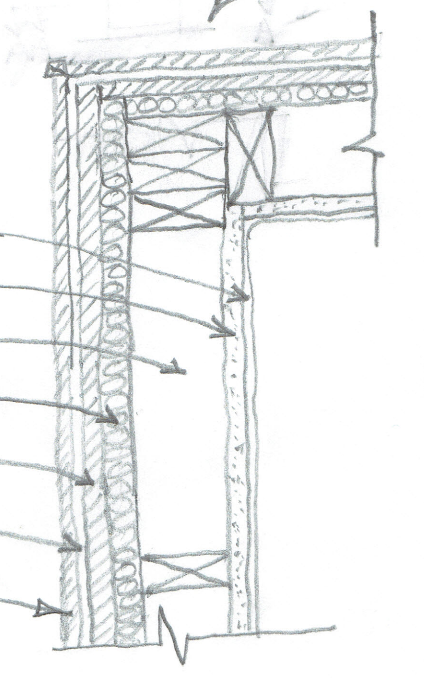
$$\rightarrow R_{Total} = \Sigma \text{ ALL R's FOR ALL MATERIALS IN A SECTION}$$

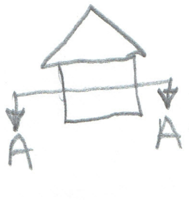
EX1 WALL SECTION A-A

EX1 4mil "poly"

| R | |
|---|---|
| 0.7 | INDOOR VAPOR BARRIER (PLASTIC) |
| 0.45 | ½" GYPSUMBOARD ("DRYWALL", "SHEETROCK") |
| 1.0 | 3½" AIRSPACE (NO INSULATION!) |
| 2.5 | ½" RIGID-BOARD INSULATION (POLYSTERENE) |
| 0.6 | ½" PLYWOOD SIDING |
| 0.2 | OUTDOOR AIR FILM ("TYVEC") INFILTRATION BARRIER |
| 0.5 | WOOD SIDING |

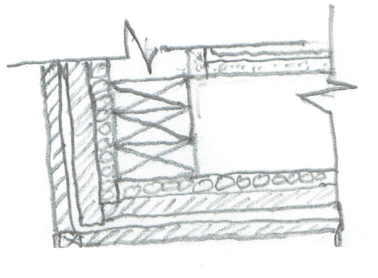
$R_T = 5.95$





SECTION A-A:

A BUILDING "DETAIL"



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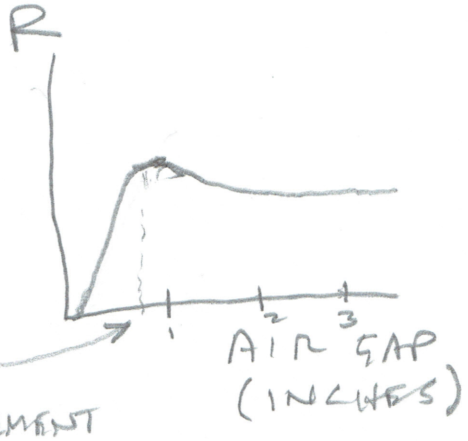
WE CAN GREATLY IMPROOVE THIS $R_T$ FROM 5.95 BY FILLING 3½" AIR GAP. (EVEN THOUGH AIR IN INSULATION IS OFTEN A CRITICAL COMPONANT OF IT'S THERMAL RESISTANCE)



AFTER 3/4" NO IMPROOVEMENT IN R VALUE AS

INULATION WE COULD USE:

| R PER INCH | INSULATION TYPE |
|---|---|
| ~1.5 | STRAW (MAYBE USE IN AFRICA) |
| ~ 2.5 | BLOWN-IN FIBERGLASS OR WOOL |
| ~ 3.5 | FIBERGLASS BATTS (IN ROLLS → STAPLE IT) |
| ~4.5 | EXPANDING FOAM (POLYSTYRENE) |

SO WE COULD IMPROOVE OUR $R_T$ FROM 5.95 BY (1.5 * 3.5" = 5.25) TO (4.5 * 3.5" = 15.75)

IF WE WANT MORE, MAKE THICKER WALLS

→ IN SOME PLACES IN U.S., BUILDING CODES NOW REQUIRE $R_T$ FOR EXTERIOR WALLS TO BE SO HIGH THAT EVERYONE IS SWITCHING FROM "2×4" STUDS (1½"×3½" ACTUAL) TO "2×6" STUDS (1½"×5½" ACTUAL)

SO WITH THIS 5½" AIR GAP, WE COULD IMPROOVE OUR $R_T = 5.95$ BY (1.5×5.5" = 8.25) TO (4.5 * 5.5" = 24.75)

FROM TABLE 15.6A (P471)

RECOMMENDED MIN $R_T$

| | ROOF | WALLS | BASEMENT OR SLAB |
|---|---|---|---|
| SOUTHEAST, PA. | 50 | 20 | 2.6 |
| PHOENIX, AZ. | 50 | 20 | 1.7 |
| MIAMI, FL. | 40 | 14 | 1.7 |

ACTUALLY, MANY IN PA CHOOSE HIGHER SINCE DIFFICULT TO GET RT=20 WITH 2X4 STUDS, SO IF NEED 2X6, USE SPACE WISELY

GOTO: http://ENERGYCODE.PNL.GOV/ENERGY/CODEREQS

## RADIANT BARRIER

→ CAN ADD TO $R_T$ BY 3 TO 11
→ METAL FOIL (TYPICALLY ALUMINUM)

| ~ $R_T$ IMPROOVEMENT | |
|---|---|
| 3 | WALL |
| 2 | CEILING IN WINTER (KEEP IN HEAT) |
| 11 | " " SUMMER (" OUT ") |

## GLASS ("GLAZING")

| $R_T$ | |
|---|---|
| 1 | SINGLE GLASS |
| 2 | GLASS BLOCK (AVERAGED THICKNESS) |
| 2.5 | DOUBLE-PANE |
| 3 | " " WITH LOW E COATING |
| 3 | TRIPLE " |
| 4 | " " " " " " |
| 4 | QUADRUPLE " |
| 6 | " " " " " " |

## TRANSLUCENT PANELS (10 TO 50% LIGHT TRANSMITTAN

$R_T$ = 7 TO 20

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# DRAPES

### Governing Equations and Required Input:

$$\text{Heat flux} = \frac{\text{heat loss rate}}{\text{area}} = \frac{q}{A} = U\Delta T = \frac{\Delta T}{R}$$

Where U is the thermal conductance which is the inverse of the more widely known thermal resistance or R-value. The R-value is calculated as $R = l/k$ where $l$ is the thickness of the material and k is the thermal conductivity.

The thermal resistances for the window with and without drapes are:

Without drape: $R_{total} = R_{airfilm} + R_{window} + R_{airfilm}$

With drapes: $R_{total} = R_{airfilm} + R_{drapes} + R_{gap} + R_{window} + R_{airfilm}$

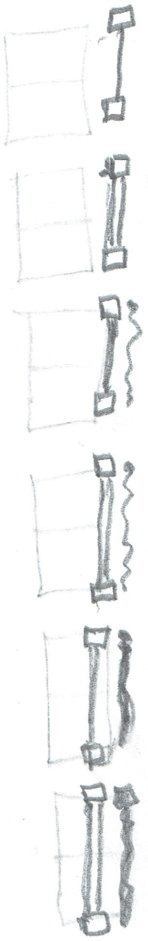
Assumed values from ASHRAE Fundamentals (2001):

- Thickness of glass = *1/8 inch*
- Curtain-window spacing = *3.5 inch*
- Conductivity of glass = *0.81 BTU/(hr ft °F)*
- Conductivity of drapes = *0.035 BTU/(hr ft °F)*
- Thickness of drapes = *1/16 inch*
- Thickness of insulated drapes = *½ inch*

| **Air Space/Gap** | **R-value (hr ft² °F/BTU)** |
|---|---|
| Inside vertical air film, $R_{airfilm}$ | *0.68* |
| Uninsulated drapes, $R_{drapes}$ | *0.15* |
| Insulated drapes, $R_{drapes}$ | *1.2* |
| 3.5 inch vertical air gap, $R_{gap}$ | *1.1* |
| Single glazed window (wood or vinyl frame), $R_{window}$ | *1.2* |
| Double glazed window (wood or vinyl frame), $R_{window}$ | *2.0* |
| Outside vertical air film, $R_{airfilm}$ | *0.25* |

**Final Answer:**

Using the analysis described above:



| Window/ Drapes | Governing Equation | Overal R-value (hr ft² °F/BTU) |
|---|---|---|
| Single-paned window<br>No drapes | $R_{total} = R_{airfilm} + R_{window} + R_{airfilm}$<br>NOT DOUBLE GLAZED | $R_{total} = 0.68 + 1.2 + 0.25 = 2.13$ |
| Double-paned window<br>No drapes | $R_{total} = R_{airfilm} + R_{window} + R_{airfilm}$ | $R_{total} = 0.68 + 2 + 0.25 = 2.93$ |
| Single-paned window<br>Regular drapes | $R_{total} = R_{airfilm} + R_{drapes} + R_{gap} + R_{window} + R_{airfilm}$ | $R_{total} = 0.68 + 0.15 + 1.1 + 1.2 + 0.25 = 3.38$ |
| Double-paned window<br>Regular drapes | $R_{total} = R_{airfilm} + R_{drapes} + R_{gap} + R_{window} + R_{airfilm}$ | $R_{total} = 0.68 + 0.15 + 1.1 + 2 + 0.25 = 4.18$ |
| Single-paned window<br>Insulated drapes | $R_{total} = R_{airfilm} + R_{drapes} + R_{gap} + R_{window} + R_{airfilm}$ | $R_{total} = 0.68 + 1.2 + 1.1 + 1.2 + 0.25 = 4.43$ |
| Double-paned window<br>Insulated drapes | $R_{total} = R_{airfilm} + R_{drapes} + R_{gap} + R_{window} + R_{airfilm}$ | $R_{total} = 0.68 + 1.2 + 1.1 + 2 + 0.25 = 5.23$ |

For single glazed windows, adding drapes reduces heat loss by 37%. Adding the same drapes to double glazed windows reduces heat loss by 30%. Adding insulated drapes to a single glazed window reduces heat loss by 56% (48% for double glazed windows).

So, for single and double glazed windows, both claims are approximately true. The reduction in heat loss is smaller for double glazed windows than it is for single glazed windows.

MAKE THIS SO: PUT DRAPES CLOSE TO WALL → MAY EVEN TUCK BEHIND RADIATOR (IF NOT FIRE HAZARD) OR FURNITURE

**However, This Answer Made Some Important Assumptions:**

1. The air in the gap between the drapes is perfectly still. This is a bad approximation. Cool air trapped between the drape and the wall would fall to the floor. Warm air would enter the space from above the window, cool down, and fall. This process would create a convective loop that would serve to mix the air in the room better and also cause more heat to be lost to the outside. This mixing can actually cause greater heat loss than if there were no drapes.

STOP CONVECTION CURRENT!

2. HUMIDITY CONTROLLED TO PREVENT DEW POINT CONDENSATION ON WINDOWS
→ DRAPES ALSO COME WITH VAPOR BARRIERS

JT Wunderlich PhD

# VENETIAN BLINDS

- SIMULAR INSULATING EFFECTS AS DRAPES (UNINSULATED)
  - TRAP AIR GAP
  - ALSO CAN REFLECT HEAT WITH SPECIAL COATINGS
  - MAY BE EASIER TO SEAL EDGES TO PREVENT CONVECTION CURRENTS
- CAN WORK WELL WHEN COMBINED WITH THERMAL DRAPES

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# INFILTRATION BARRIERS

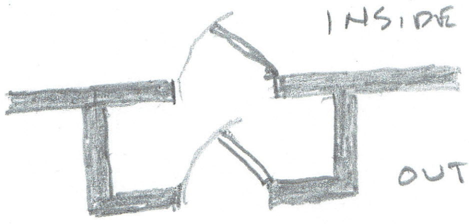
→ STOP AIR FLOW IN AND OUT OF BUILDING:

① WEATHER-STRIPPING IN CRACKS:
- Ⓐ DOORS
- Ⓑ WINDOWS
- Ⓒ FOUNDATION SILL PLATE
  (INTEFACE BETWEEN FOUNDATION WALL AND FLOOR STRUCTURE FOR FIRST FLOOR)

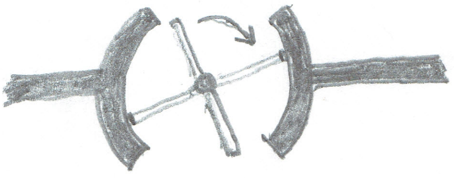
② AIR-BARRIER ("BUILDING-WRAP")
- → EX: "TYVEC"
- → WOOVEN FABRIC

② AIR LOCKS

Ⓐ VESTIBULE



Ⓑ REVOLVING DOOR



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# MOISTURE CONTROL

- → TO CONTROL ADVERSE THERMODYNAMICS
- → " " BUILDING DAMAGE
  - → MOLD
  - → WOOD ROT

→ CONTROL MOISTURE TRANSPORT:

① FLUID FLOW (IN BULK)

IN BULK
- → BUILDING WRAP
- → ROOFING
- → GUTTERS & SPOUTS
- → FLASHING AT JOINTS
- → CAULKING " "

CAPILARY
- → "WEEP-HOLES" FROM CAVITIES (BEHIND BRICK FAÇADES, ETC.)

② VAPOR

- → VIA VENTED AIR
  - → MANAGE AIR EXCHANGES CAREFULLY
- → THROUGH WALLS & ROOF
  - Ⓐ USE VAPOR BARRIER
    - → UNDER DRYWALL
    - → PLASTIC

EX) 4 mil. "POLY"

1000TH OF AN INCH

☆ BUT → BE CAREFUL NOT TO TRAP $H_2O$

SOME VAPOR BARRIERS HAVE CHANNELS TO DRAIN WATER

Ⓑ PROPER CONTROL OF INDOOR HUMIDITY [illegible]

TO PREVENT [illegible]

[illegible]

Ⓒ USE HYGRIC BUFFER

- → BRICK FACADES
- → WOOD SIDING
- → THEY STORE MOISTURE, SO LESS TO ENTER BUILDING

Ⓓ CONSIDER NON-POROUS INSULATION

- → RIGID BOARDS
- → EXPANDING FOAM

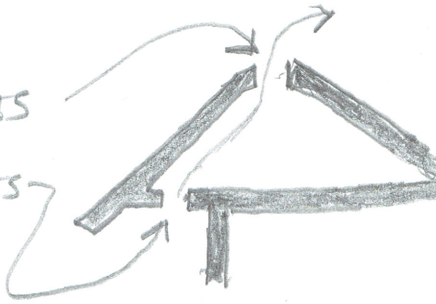
Ⓔ USE ACTIVE + PASSIVE WAYS FOR BUILDING TO DRY ITSELF

Ⓕ GOOD DRAINAGE OFF AND AROUND BUILDING

JT Wunderlich PhD

## Ⓖ VENTING

- → VENT BASEMENTS
- → VENT ATTICS
  - → RIDGE VENTS
  - → SOFFIT VENTS



- → VENT BATHROOMS
- → VENT DRYERS

## Ⓗ CONTROL AIR INFILTRATION

- → SEE LAST SECTION