

HVAC Ducts Buried within Ceiling Insulation in a Vented Attic (Buried Ducts)

For Low-Rise Residential Buildings

A buried duct system is a practical and cost-effective alternative to installing ducts inside conditioned space or constructing unvented (semi-conditioned) attics for housing the HVAC system. If constructed in accordance with the recently-approved provisions of the 2018 International Residential Code (IRC), buried ducts provide an effective and energy-efficient air distribution system that ensures comfort and savings for the homeowner.

Buried Ducts. Heating and cooling ducts installed in a vented attic and located within ceiling insulation (Figure 1).

This TechSpec provides an overview of key attributes and implementation details for transitioning from a traditional duct design to a buried duct system. The focus is on using conventional materials and practices that do not rely on spray foam. The described system uses fiberglass insulation (loose fill and/or batts) and any code-compliant air sealing solutions.

Note that before the 2018 edition, the IRC did not prohibit installation of buried ducts but also did not provide any requirements for ensuring adequate performance and demonstrating compliance. The practice of installing ceiling insulation over ducts or adjacent to ducts has been and is currently in use by builders around the country. Until the 2018 IRC is adopted by your jurisdiction, code compliance for buried ducts can be achieved in accordance with the IRC provisions for alternative materials, design and methods of construction and equipment under section R104.11 of the 2015 IRC.

The new code provisions address critical **performance aspects of buried ducts** regarding energy loss and condensation potential:

- A minimum ceiling insulation value at buried ducts is specified to minimize the effect of displaced ceiling insulation; and
- Minimum duct insulation values are specified to avoid condensation at the outer jacket of the duct insulation during the cooling season.

Further, under the **performance compliance path**, the 2018 IRC offers two new distinct advantages for energy models of homes with buried ducts:

- An effective duct insulation value of R-25 can be claimed for “deeply buried ducts,” if certain criteria are met; or
- Buried ducts can be considered inside conditioned space, if certain criteria are met (including a reduced duct leakage limit).

Figure 1. Buried Ducts: Insulated HVAC Ducts Buried within Fiberglass Ceiling Insulation.



Benefits of Buried Ducts. For slab-on-grade houses and two-story houses with open floor plans, installing ducts inside conditioned space can be a challenge – ducts within floors, chases, or dropped ceilings can have considerable cost implications for builders, whereas bulkheads concealing ductwork may not be acceptable to buyers. Building unvented attics for housing HVAC systems is a viable alternative, but it has high first cost and involves special installation procedures. Installing ducts conventionally above the attic insulation is a more straightforward approach, yet it comes with a significant energy penalty. A buried duct system strikes the balance between ease of installation and reduced heating/cooling loads and may allow for lower capacity, lower cost HVAC equipment.

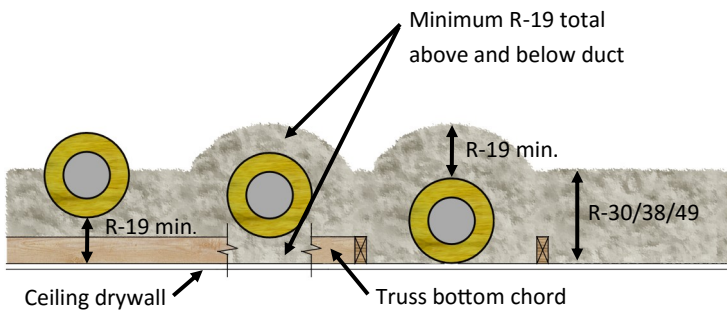


Figure 2. Example partially buried duct (left), buried duct across the truss bottom truss chord (middle), and buried duct on the ceiling (right).

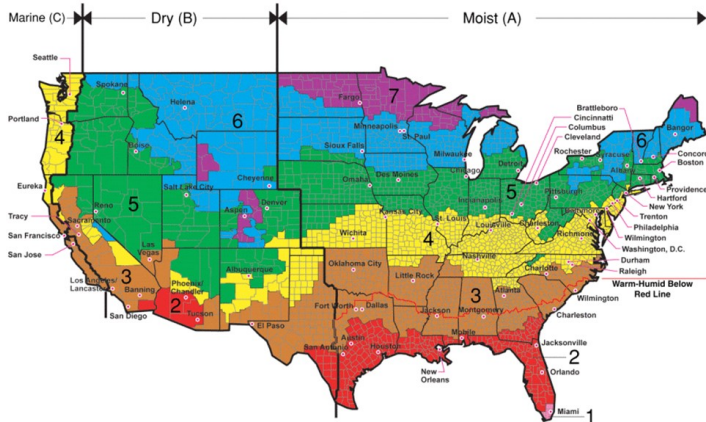


Figure 3. Climate Zone Map. Source: DOE. [2015 map shown – some climate zones were modified for 2018]

Buried Ducts – General Criteria for 2018 IRC Compliance

In recognition of energy performance improvements compared to ducts installed above ceiling insulation, the 2018 IRC explicitly allows ducts (supply and/or return) to be fully or partially surrounded by ceiling insulation. As a basic construction requirement, the code does not specify a minimum amount of insulation above the duct as long as the sum of the insulation value above and below the duct is at least R-19 total, excluding the duct R-value (Figure 2). There is also no minimum level of duct embedment into the insulation. See Table 2 for minimum ceiling insulation requirements for specific configurations and climates and see applicable section below for specific provisions for deeply buried ducts and ducts in conditioned space.

As with all ducts installed in the attic, the buried ducts must have a minimum wall insulation of R-8 underneath a vapor impermeable exterior jacket. In **Climates Zones 1A, 2A, and 3A** (Figure 3), the minimum duct wall insulation for all **supply ducts** that are completely covered with ceiling insulation is increased to R-13 to minimize condensation potential. See Table 1 for common duct insulation types and example methods to achieve R-13 duct insulation for warm-humid climates. The supply ducts that are only partially surrounded by ceiling insulation (i.e., partially buried such that the top of the duct jacket is visible) must comply only with the typical R-8 requirement. The **return ducts** are not subject to the R-13 requirement because the warmer temperature of the return air does not create a condensation risk.

All ducts (supply and return) must be installed in accordance with all other applicable IRC and local requirements for duct construction [1,2].

Table 1. Common duct insulation types and example methods to achieve R-13 duct insulation.

Duct Construction/Insulation (commonly available R-values)	Example Methods to Achieve R-13 Duct Insulation ^a
Flex Duct: prefabricated, round, flexible duct with a wire helix for support, commonly available with fiberglass insulation between the inner “liner” and outer “jacket” vapor barriers. (R4.2, R6, R8)	<ul style="list-style-type: none"> • Concentric flex ducts: R-8 within R-6 • R-5 (installed R-value) duct wrap over R-8 flex ducts • R-13 (installed R-value) duct wrap over uninsulated flex duct • R-13 flex duct when it becomes available
Duct Board: shop fabricated using foil-faced rigid fiberglass sheets. (R-4.2, R-6, R-8.7)	<ul style="list-style-type: none"> • R-13 duct board is available but not common • R-6 duct board over R-8 duct board • R-5 (installed R-value) duct wrap over R-8 duct board
Duct Wrap: flexible rolls of foil-faced fiberglass insulation installed over metal ducts and fittings in the shop or field. Use the “installed” R-value on the label or the manufacturer’s specification.	<ul style="list-style-type: none"> • R-13 (installed R-value) is available but not common • R-5 (installed R-value) duct wrap over R8 (installed R-value) duct wrap

^a Layering duct insulation over duct insulation can create a double vapor barrier configuration. This is not considered a concern provided the outer layer is properly sealed to protect against moisture drive from the attic. The inner layer acts a back-up layer of protection.

Deeply Buried Ducts – Energy Analysis Criteria for 2018 IRC Compliance

When using a simulated energy performance analysis, an effective duct insulation value of R-25 may be used in the energy model for sections of ducts that comply with the general buried duct criteria above and these three additional requirements (see Figure 4):

1. the duct is located directly on the ceiling or within 5.5 in. of the ceiling
2. the duct is surrounded with ceiling insulation of at least R-30
3. the duct is covered on top with at least 3.5 in. of ceiling insulation (approximately R-11 assuming a minimum R-value of R-3.2 per in.)

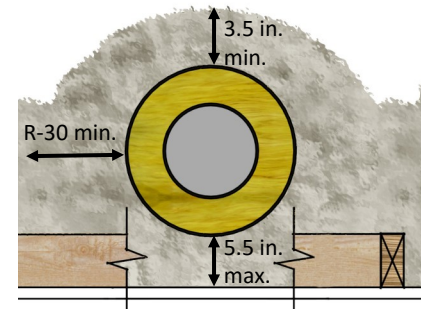


Figure 4. Example deeply buried duct.

Buried Ducts considered Inside Conditioned Space – Energy Analysis Criteria for 2018 IRC Compliance

When using a simulated energy performance analysis, buried ducts may be considered as ducts inside conditioned space (ICS) provided the air distribution system complies with the general buried duct criteria above (need not comply with deeply buried ducts) and these additional requirements:

1. the air handler is located inside conditioned space (not in the attic)
2. duct leakage is within prescribed, more stringent limits (see sidebar for details)
3. the R-value of insulation above the duct is at least the proposed ceiling insulation R-value, used in the model, less the R-value of the duct insulation (Figure 5)

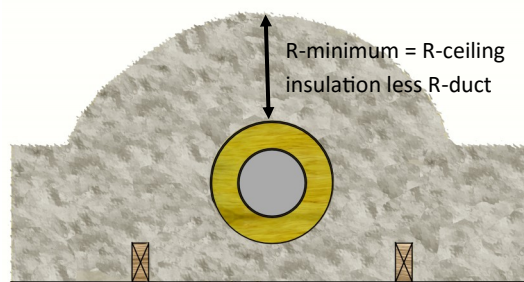


Figure 5. Example buried duct considered inside conditioned space.

Duct Leakage. For buried ducts to be considered inside conditioned space, the 2018 IRC specifies a maximum duct leakage of 1.5 CFM25/100SFcfa (cubic feet per minute, at a test pressure of 25 Pascals, per 100 square feet of conditioned floor area served by the duct system). The duct leakage can be measured either by a rough-in stage test or post-construction stage total-system-leakage-to-outdoors test. The total system leakage must still be within the current IRC requirement of 4.0 CFM25/100SFcfa, measured at rough-in or post-construction, or 3 CFM25/100SFcfa when the air handler is not installed during a rough-in test.

Buried ducts must be particularly well sealed because leakage results in energy loss outside the building envelope and can increase condensation potential. Conventional duct sealing methods can provide sufficiently low leakage rates when done in strict accordance with manufacturers' instructions and industry standards [3,4]. Performing duct leakage testing at rough-in stage allows for re-sealing ducts, when necessary. Note: a duct leakage test does not measure the continuity of the outer vapor barrier of the duct insulation (except for duct board), so a visual inspection is important to ensure that the outer vapor barrier is well sealed to prevent condensation.

Ceiling Insulation

Table 2 shows minimum required levels of ceiling insulation above buried ducts by climate zone. It is important to implement quality control measures to ensure sufficient insulation above and below buried ducts. One method is to install fiberglass batts above the ducts, and below the ducts as needed, then install loose ceiling insulation (Figure 6). Another method is to install insulation depth marker flags on the ducts about every 10 feet and then mound ceiling insulation (Figure 7). In areas with potential for very high wind, consideration should be given to use of batts to prevent shifting of loose-fill over time, in addition to proper use of baffles to mitigate effect of wind.

Table 2. Minimum levels of ceiling insulation required above buried ducts by climate zone.

Duct Insulation	Duct Location ^a	CZ 1: R30 Ceiling Insulation			CZ 2-3: R38 Ceiling Insulation			CZ 4-8: R49 Ceiling Insulation		
		Buried ^b	Deeply Buried ^c	Buried ICS ^d	Buried ^b	Deeply Buried ^c	Buried ICS ^d	Buried ^b	Deeply Buried ^c	Buried ICS ^d
R8 Duct	Ceiling	R19	R19	R22	R19	R19	R30	R19	R19	R41
	Truss, R11	R8	R11	R22	R8	R11	R30	R8	R11	R41
	Truss, R13	R6	R11	R22	R6	R11	R30	R6	R11	R41
R13 Duct	Ceiling	R19	R19	R19	R19	R19	R25	n/a	n/a	n/a
	Truss, R11	R8	R11	R17	R8	R11	R25	n/a	n/a	n/a
	Truss, R13	R6	R11	R17	R6	R11	R25	n/a	n/a	n/a

^a Duct location: on ceiling or on 3.5 in. truss bottom chord with R11 loose insulation (at R-3.2/in.) or R13 batt insulation below the duct.

^b Buried ducts: minimum R-19 total ceiling insulation counting insulation both above and below the duct.

^c Deeply buried to comply with effective R-25 provision: min. 3.5 in. ceiling insulation above duct (R11 at R-3.2/in.); must meet R-19 total above/below.

^d Considered inside conditioned space (ICS): ceiling insulation value less duct insulation value; must still meet R-19 total above/below.

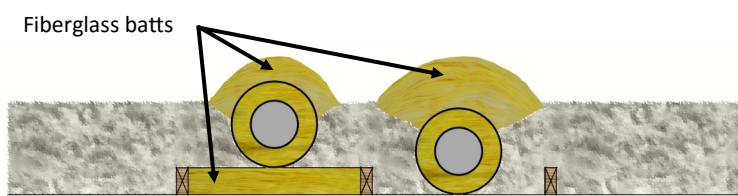


Figure 6. Example quality control using fiberglass batts installed above ducts, and below ducts as required, to ensure sufficient ceiling insulation levels.

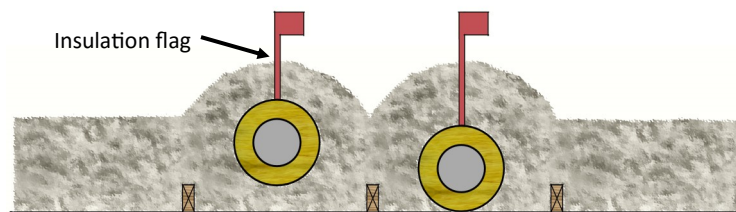


Figure 7. Example quality control using flags installed at ducts and marked to indicate sufficient ceiling insulation above duct.

Air Handler Location

For buried ducts to be considered inside conditioned space, the air handler must be installed inside conditioned space. This practice typically requires constructing a mechanical closet below the ceiling plane (Figure 8). Installing the air handler inside conditioned space reduces system energy losses due to conduction and leakage and is recommended for all buried duct applications as a best practice. For air handlers installed in attics, the unit should not be buried in insulation (Figure 9) to ensure access for maintenance and proper function of the equipment.

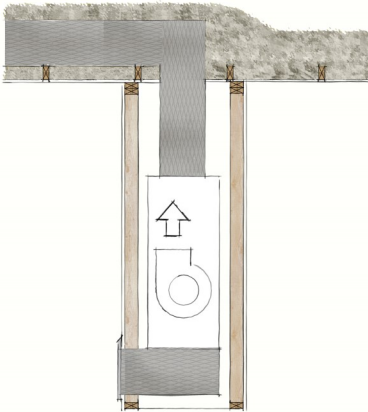


Figure 8. Air handler installed inside conditioned space.

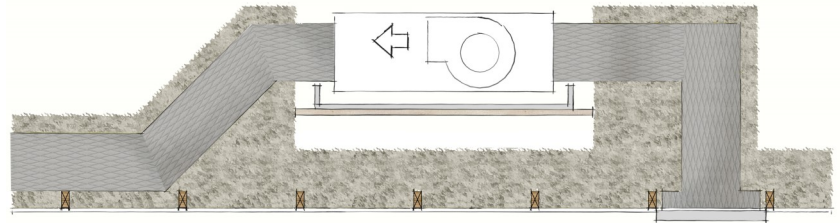


Figure 9. Air handler installed in the attic.

Table 3. Summary of estimated energy and estimated cost for example attic/duct designs.

Estimated Energy and Cost Summary	Jacksonville, FL (CZ-2A)		Baltimore, MD (CZ-4A)					
	Annual heat/cool site energy (kWh/r)	Heat/cool site energy savings (%)	Annual heat/cool operating cost (\$)	Incremental installed cost (\$)	Annual heat/cool site energy (kWh/r)	Heat/cool site energy savings (%)	Annual heat/cool operating cost (\$)	Incremental installed cost (\$)
AHU indicates air handling unit ICS indicates inside conditioned space								
Duct Design	Jacksonville, FL (CZ-2A)		Baltimore, MD (CZ-4A)					
Standard: attic ducts installed above ceiling insulation, AHU attic (baseline)	9,229		1,292		9,950		1,393	
Deeply Buried, AHU attic	8,471	8.2	1,186	2,230	9,014	9.4	1,262	394
Deeply Buried, AHU ICS –OR– Deeply Buried, better sealed, AHU attic	8,021	13.1	1,123	2,731	8,579	13.8	1,201	895
Unvented (encapsulated attic)	7,786	15.6	1,090	9,124	8,571	13.9	1,200	12,917
Deeply Buried, AHU & return ICS	7,814	15.3	1,094	2,625	8,479	14.8	1,187	789
Compact Deeply Buried, AHU attic	7,729	16.3	1,082	1,472	8,264	16.9	1,157	725
Compact Deeply Buried, AHU & return ICS	7,629	17.3	1,068	1,945	8,186	17.7	1,146	697
Ducts ICS	6,757	26.8	946	3,511	7,186	27.8	1,006	3,511
Buried Ducts ICS ^a				2,791				1,107
Compact Buried Ducts ICS ^a				2,058				913

^a estimated energy costs for Buried Ducts ICS are not provided because: 1) the effective R-value has not been established; and 2) software does not currently have the capability to accurately model the energy performance of this distribution system. It is acknowledged that there will be some level of duct losses compared to ducts ICS.

Energy/Cost Evaluation

Table 3 compares estimated energy savings and estimated incremental installed costs for an example house configuration (one-story slab-on-grade, 2,428 SF) in two climate zones (2A and 4A) for various attic/duct designs [5].

The energy/cost results for a two-story design are proportional to the percentage of living area on the second floor.

References

- [1] The IRC Chapter 16 Duct Systems specifies duct construction in accordance with: SMACNA *Fibrous Glass Duct Construction Standards* or NAIMA *Fibrous Glass Duct Construction Standards* for duct board; SMACNA *Duct Construction Standards – Metal and Flexible* for metal and flex ducts
- [2] For example, California Title 24 requirements for buried ducts
- [3] *Compact Buried Ducts in a Hot-Humid Climate House*, Mallay, D. 2016
- [4] Additional industry standards: NAIMA *Insulation Facts: #64/#67 Fibrous Glass Duct System (Rigid Duct Board); #66: Fibrous Glass Duct Wrap; ADC Air Duct Council Manual: Flexible duct performance and installation standards*
- [5] Incremental installed costs were estimated by Home Innovation Research Labs using *Residential Costs with RSMeans Data 2017*. Energy costs were estimated by Home Innovation Research Labs using Wrightsoft® Corporation HVAC software based on ACCA Manual J and ACCA Manual D.