ENCLOSURE 1

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Scope

Building Research LLC (BRLLC) has been asked to develop a preliminary report for the residence at [redacted]. BRLLC visited this home as part of an investigative team on April 4, 2025. The scope of this preliminary report is limited to addressing concerns regarding the building envelope and HVAC systems.

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Recommendations made by BRLLC, if implemented, shall be verified, performed, and confirmed as compliant with all applicable practices, laws, and building codes by professionals licensed for such work. Post-remediation inspection and monitoring is required, during which additional recommendations may be made based on new or supplemental findings.

Reports Reviewed

Reports reviewed include but are not limited to:

Construction Defect Consultants report, 2/5/2025 (inspection 6/21/2024)
AQ Testing Services Mold Remediation Protocol, 8/24/2024 (inspection 6/27/2024)
EBE/I-ENG-A Investigative Report, 10/18/2024 (inspection 8/28/2024)
Apollo BBC report, 10/29/2024 (inspection 9/17/2024)

Other documents reviewed will be cited where referenced.

Note: Each of these reports relies heavily on information contained in photographic and/or thermographic images for their conclusions. For this reason BRLLC reserves the opportunity to revise this report once the original image files are made available.

Applicable Building Code

Based on available information the applicable building code in effect with respect to the scope of this report is determined to be the 2015 IECC (International Energy Conservation Code)[1].

HVAC System

Attic installation

The HVAC system is installed in an attic that is insulated using spray foam at the underside of the roof decking; thus the HVAC system and supply/return ducts are installed within the thermal envelope but in unconditioned space (the attic is not itself directly conditioned). This is sometimes referred to as semi-conditioned space, since the attic floor is uninsulated and heat/humidity do flow passively between the unconditioned attic and the conditioned interior space.

Primary components

HVAC services are provided by a single system. The primary components of this system as of 4/4/2025 are detailed below in Table 1.

Table 1: HVAC system components

Component	Manufacturer	Model	Serial number
Furnace	Lennox	EL296UH090XV48C	5922G188706
Evaporator coil	Lennox	CHX35-42C-6F-10	1522H28058
Condenser	Lennox	ML18XC2-36-230A01	1922J72138
Thermostat	Honeywell	TH8321WF1001	2249

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[1] 2015 International Energy Conservation Code. 3rd ed. Illinois, USA: International Code Council, Jan 2016.

The system is a high-quality two-stage system (two-stage for both heating and cooling). The furnace is a sealed combustion unit; it draws fresh air from, and expels exhaust gases to, the outside via separate ducts. This allows the furnace to operate in the sealed attic within the environmental envelope.

Thermostats

A single thermostat located in the entry hall at the kitchen/family room controls the HVAC system. The thermostat is conventionally wired for two stage heating and cooling (R, C, G, Y1, Y2, W1, W2). This model (see Table 1) has no logging capabilities.

Thermostat fan mode

The 2024 H5 Climate Consulting LLC report noted that the thermostat had been found set for the fan to be on continuously. The normal mode is for the fan to be set to “auto” rather than “on”, which has the fan run only during heating or cooling operation. This is an important observation; when the fan is set to run continuously the dehumidification capability of the HVAC system is severely hampered.

Water condenses on the evaporator coil during normal cooling operations; this is what allows the HVAC system to remove humidity from the air. When enough water collects it begins to run off of the coil into a drain pan and is removed from the system. Between cooling cycles the water on the coil remains; in subsequent cooling operations water begins running off of the coil as soon as condensation from the airstream resumes.

However, when the fan remains on after the cooling cycle ends then warm indoor air continues to flow across the coil – even though the coil is no longer cold. The result is that the water on the coil, instead of remaining on the coil until the next cooling cycle, evaporates into the air stream and re-humidifies the home. Also, when the next cooling cycle starts the coil must once again become saturated before water removal resumes. The net effect is a significant decrease in dehumidification capabilities of the HVAC system. This will cause many of the very specific symptoms experienced by this homeowner, including condensation on supply registers and an inability to control humidity.

The homeowner should be advised that it is important to leave the fan operation set to “auto” on the thermostat.

Fresh air system

The fresh air duct and damper are connected to a separate dehumidifier. The fresh air system will be described in the dehumidifier section of this report.

Ducts and plenums

The ducts overall are well installed and routed, with only a couple of minor exceptions with respect to hanging that are of no consequence in an insulated and sealed attic. The ducts are insulated to R-6, which is allowed under the 2015 IECC for ducts installed entirely within the building thermal envelope (as here, due to the foam-sealed attic). Return and supply register boxes are well distributed throughout the home and installed in the ceiling of the living space.

Plenums are well-sealed to their HVAC system components. Ducts are well-sealed to the register boxes and supply/return plenums. Since the register boxes are all installed within the building thermal envelope, no sealing of the registers to the ceiling is required.

While the inner liner is sealed to the start collar or register box duct connection for each duct (the air carried by the duct travels only within the inner liner), the outer liner of some ducts is secured using a nylon strap but is not sealed to the plenum or register box. This is normally of no concern when the ducts are located fully within the building thermal/air envelope, as is the case here. However, due to the homeowner frequently running the HVAC system at far below the code-mandated[2] design set point of 75°F it would be prudent to seal any duct outer liners not already sealed.

The 2024 EBE report identified what it deemed to be *"…locations where ducts were constricted and insulation compressed at support straps…"*, as a result of routing or hanging. However, only 3 very minor examples were provided where the outer duct liner and insulation are slightly compressed. While the outer insulation appears to be slightly compressed the inner liner – which carries the conditioned air – is typically left untouched. Given that these ducts are all installed within the building envelope this is a trivial point that will result in no issues for air flow or performance.

HVAC system performance data

Static pressures and air flow

Static pressures and air flows measured on 4/4/2025 are shown in Table 2. The air flows are taken from the furnace manufacturer's published specifications[3]. This Lennox furnace uses a constant flow rate fan system; so long as the total external static pressure is within the allowed range then the flow rate is determined by dip[4] switches set at the furnace control board. At the time of our inspection the furnace flow rate was configured for 1265 cfm at 2nd stage operation, however this was not confirmed via measurements.

Note that we can only estimate the flow rate as configured at the time of inspection; the dip switches may well have been altered in the past to other flow rates. This is suggested by data contained in other reports, where the measured flow rate did not match the dip switch settings found during our inspection.

No issues were noted with the performance of the system during these tests. The system maintained acceptable temperatures and humidity levels, and effectively pulled the temperature and humidity values down when it operated.

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[2] "Table R405.5.2(1) Specifications for the Standard Reference and Proposed Designs." 2015 International Energy Conservation Code. 3rd ed. Illinois, USA: International Code Council, Jan 2016.

[3] "Lennox Service Literature: EL296UHV(X)." Lennox Industries, Inc., June 2021.

[4] DIP refers to the term "Dual In-line Package". A DIP switch refers to a type of small switch intended to be installed on printed circuit boards (PCB). They are used for the configuration of electronically-controlled devices.

Table 2: System static pressures and air flow

Parameter	Value	Units
Total External Static Pressure	0.49	inWC
Return plenum	-0.19	inWC
Pressure across filter	0.15	inWC
Pressure at furnace return	-0.34	inWC
Pressure at furnace supply	0.15	inWC
Pressure across coil	0.12	inWC
Supply plenum	0.03	inWC
Air flow (est.)[5]	1265	cfm

Refrigerant and psychrometric data

The refrigerant and psychrometric data in Tables 3 and 4 was recorded during our inspection 4/4/2025.

Table 3: Refrigerant data

Measurement	Value	Units
Outdoor Tdb	86.3	°F
Pressure, low	125.4	psig
SLT	56.5	°F
Vsat	43	°F
Superheat	13.5	°F
Pressure, high	307.2	psig
LLT	89.4	°F
Lsat	97.5	°F
Subcooling	8.1	°F

Table 4: Psychrometric data

Measurement	Value	Units
Return temperature	69.8	°F
Return RH	58.6	% RH
Supply temperature	49.4	°F
Supply RH	92.6	% RH
Delta T	20.4	°F

This is appropriate performance data for a nominal 3 ton HVAC system under the test conditions. However, the test conditions are not the same as the design conditions for the system.

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[5] Air flow is taken from data provided by the manufacturer based on DIP switch settings at the furnace unit. This assumes that the furnace fan is operating without fault. Verification is typically made using TESP values, but that is not possible with the constant flow fan system utilized here. Air flow should be verified by direct measurement.

Dehumidifier

Description

An Ultra-Aire XT155H dehumidifier (Table 5) is installed in the attic and plumbed to the occupied space, the HVAC system and a fresh air inlet. It is controlled by a separate humidistat controller and humidity sensor; the humidity sensor is installed next to the thermostat while the controller itself is installed in the sealed attic along with the dehumidifier and HVAC system (Figure 1).

Table 5: Dehumidifier data

Make	Model	Part number	Serial number
Ultra-Aire	XT155H	4031070	B2205763

Figure 1: *On the left: the attic-mounted DEH3000R humidistat; on the right, the thermostat and humidity sensor. The round humidity sensor is wired directly to the DEH3000R controller.*

The dehumidifier is equipped with an interlock that prevents operation at the same time as the HVAC cooling system. Whenever the HVAC system is engaged in cooling mode the dehumidifier will stop and/or not run until the cooling system cycles back off.

The dehumidifier includes a fresh air input, a return air input, and a supply air output. The fresh air input is ducted to an outdoor air inlet on the right side of the home. The duct includes a damper to control outdoor air flow, which is wired to the DEH3000R humidistat controller. However, every photograph of the controller in any report shows that the dehumidifier is either disabled, or when enabled that the fresh air ventilation option is disabled. But even if the fresh air system had been enabled on the controller it would not have opened the damper; the fresh air damper has been incorrectly wired at the DEH3000R controller and will not operate. As shown in Figure 2, the fresh air damper is wired to the vent and fan terminals of the DEH3000R, rather than the vent and common terminals. While this has not contributed to the humidity concerns raised, it should be corrected by properly wiring the fresh air damper and verifying that the ventilation configuration meets building code and design requirements.

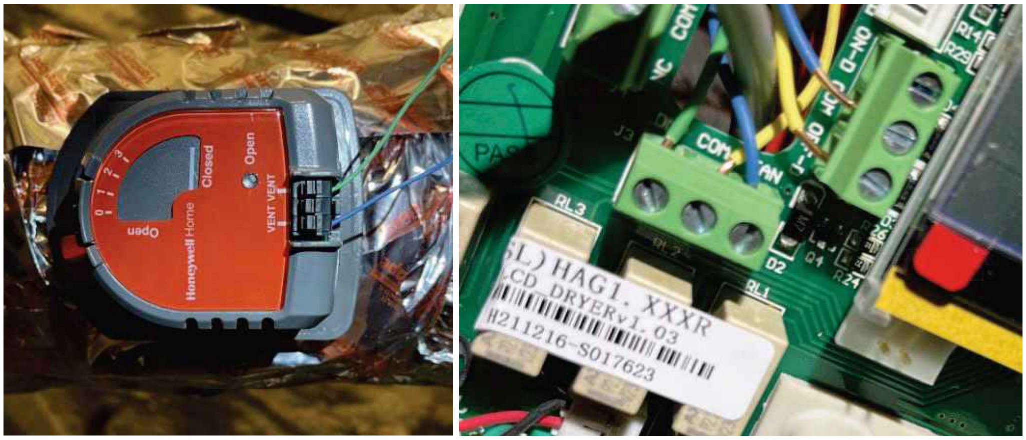

Figure 2: *The fresh air damper on the right is using the green and blue wires; these are wired to the DMP and FAN terminals on the DE3000R controller, effectively disabling the fresh air damper.*

The supply and return of the dehumidifier are unconventionally ducted; the installation does not match the recommendation provided in the manufacturer's installation guide[6], although the recommendation is not mandatory. The manufacturer's recommended installation is shown in Figure 3.

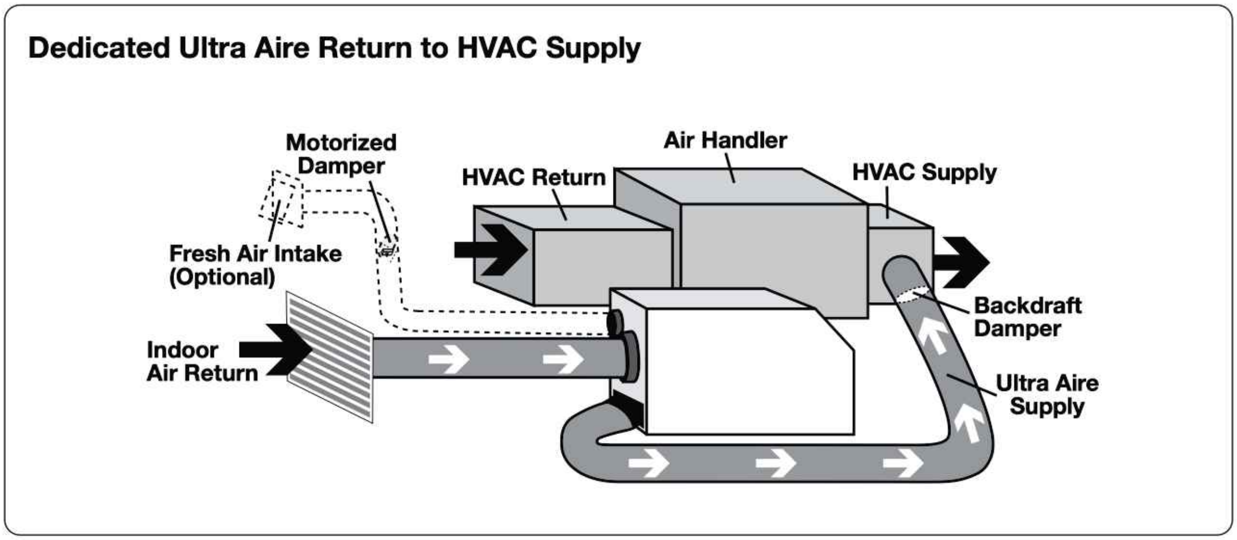

Figure 3: *The manufacturer recommended installation for the dehumidifier. In the installation at this home the return and supply duct connections have been reversed.*

As installed, the supply and return duct connections are reversed. While this ducting may temporarily impact thermal comfort near the dehumidifier discharge at the powder bath alcove between HVAC system cycles (a complaint voiced by the homeowner in the 2025 CDC report), it will have no impact on the overall performance of the dehumidifier when operating.

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[6] "Ultra-Aire XT105H, XT155H, XT205H Installation and Operation Instructions." TS-1159. Therma-Stor LLC, Madison WI. Aug 2020.

A backdraft damper is installed at the location shown in Figure 3; however, its direction is reversed by necessity (the dehumidifier would not function as plumbed if the backdraft damper were not reversed). One impact of this is that some air from the supply plenum is routed through the dehumidifier to be exhausted at the powder bath alcove when the HVAC system runs. This will help distribute the warm, dry air exhausted here by the dehumidifier and aid in its distribution throughout the home. However, the operating pressures of the supply plenum are very low (0.03 inWC; see Table 2), which will limit this air flow.

A side effect of low temperature operation of the HVAC system by the homeowner (see the Discussion and Observations – HVAC section) coupled with the reverse flow configuration is that very cold air may flow backwards through the dehumidifier when the HVAC cooling system operates. The result could be that the dehumidifier at times may believe that it needs to run a defrost cycle before operating due to having sensed a low temperature. This will delay operation of the dehumidifier and reduce its daily capacity. However, at low interior temperatures the dehumidifier will become less effective, as the air will already be very dry (regardless of the indicated RH value, which is highly temperature dependent).

Some concern was raised in the 2024 EBE report regarding the dehumidifier's operation, stating:

> *"The dehumidifier seemed to be operational, but when it operated, hot air was supplied to the occupied space through the ceiling grille."*

Hot air exiting the dehumidifier is normal. Dehumidifiers work by removing heat energy from the airstream, reducing its temperature to below the dew point so that water can be condensed from the air. However, the heat removed must be expelled from the system at the end of the process. Unlike a cooling system, the dehumidifier has no way to expel this heat to the outdoors; it must return the heat to the original air stream, including the latent heat associated with water removal as well as the heat from electric power used by the dehumidifier. The result is that the air leaving the dehumidifier is typically 10° to 30°F higher than the air it takes in. A psychrometric process modeled after the XT155H installed in this home and operating at its rated water removal capacity is shown in Figure 4.

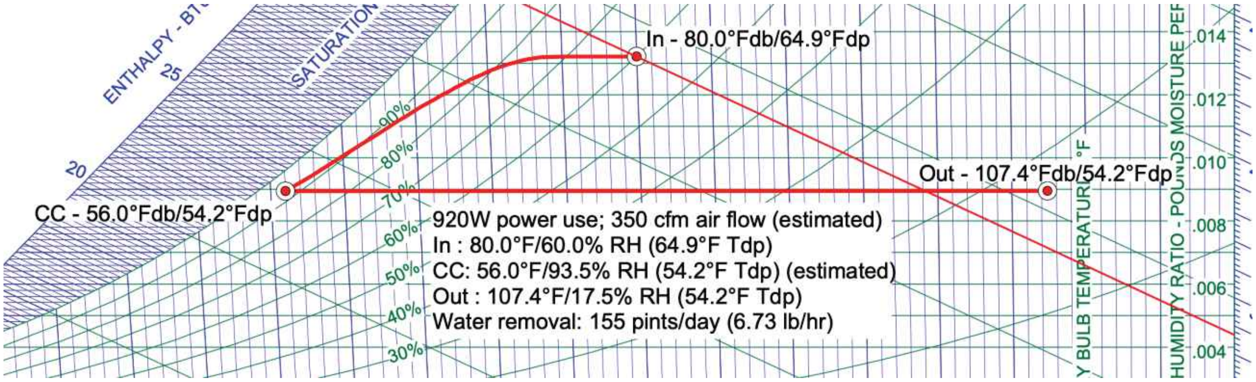

Figure 4: *A psychrometric chart showing the temperature fall and rise as the air flows through a dehumidifier. Data (except estimated output dew point) is taken from the manufacturer specifications*[7] *or estimated using standard psychrometric methods.*

The EBE report's concern regarding hot air being supplied to the occupied space by the dehumidifier is inconsequential; this is normal behavior for a dehumidifier.

Performance

The dehumidifier did not have ports to measure psychrometric or pressure data. Normally we would simply make holes where needed for these measurements, but we were cautioned that no destructive testing could be performed. As a result we were unable to determine the capacity of the dehumidifier in its current configuration and condition.

Discussion and Observations - HVAC

Environmental conditions

During our testing on 4/4/2025 between the hours of 9:45 am and 12:15 pm, the outdoor temperature ranged from approximately 80°F to 83°F with a relative humidity of between 75% and 65%. During this same time the indoor conditions remained between approximately 71°F to 72°F with a relative humidity of between 58% and 49%. The sealed attic conditions ranged from a temperature of approximately 72°F and 73°F with a relative humidity of between 53% and 58%. The HVAC system and dehumidifier were off for much of the physical inspection, and blower door/duct pressurization tests were run; these actions resulted in a wide range of interior conditions. However, the operational tests later during the inspection show that the HVAC system quickly removed heat and moisture when operating (Figure 5).

No issues were noted with the performance of the system during these tests. The system maintained acceptable temperatures and humidity levels when operating.

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[7] "Ultra-Aire XT105H, XT155H, XT205H Installer's and Owner's Manual." Therma-Stor LLC, Madison WI, Sep 2012.

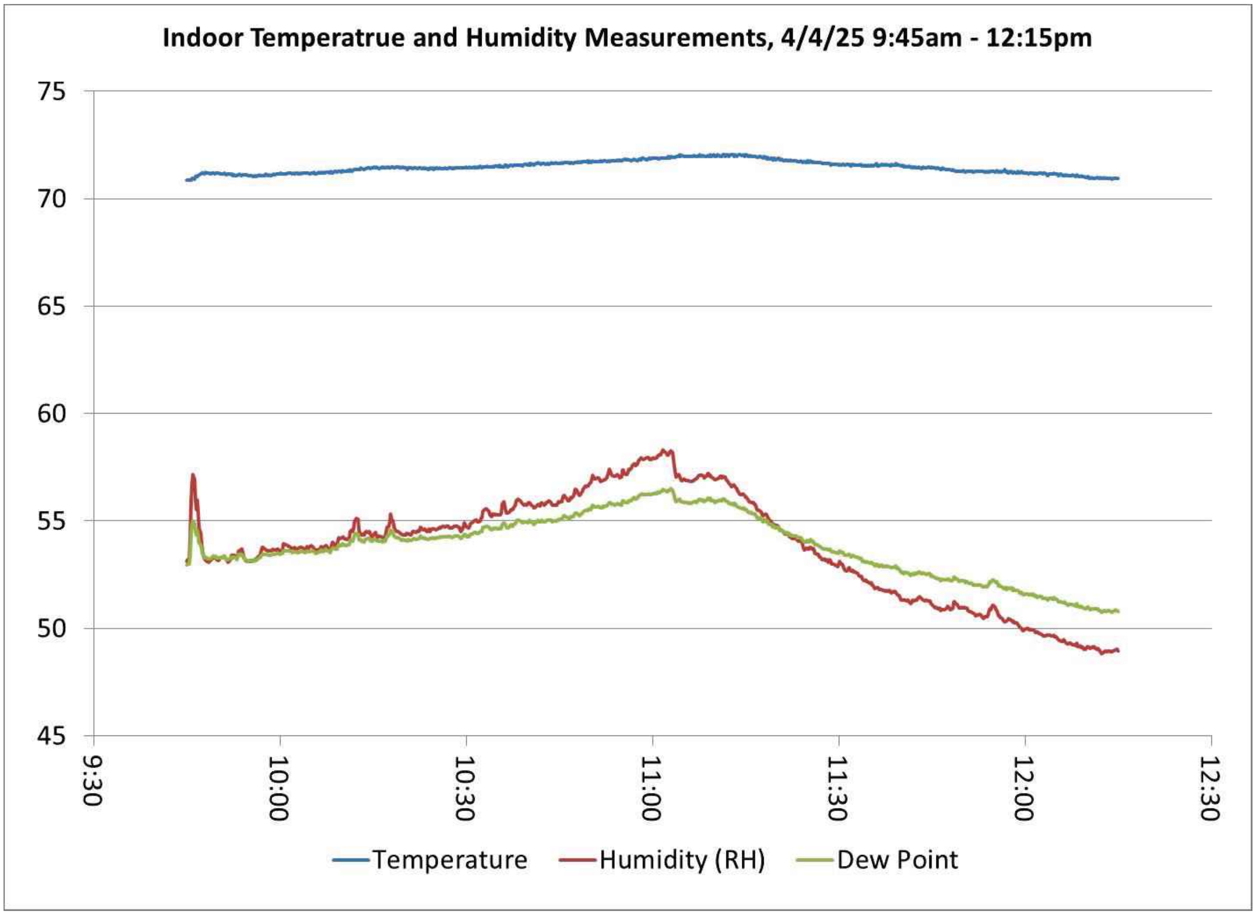

Figure 5: *Temperature and humidity in the home during the inspection on 4/4/2025. Note how the HVAC system rapidly removed humidity from its peak once the system was engaged.*

Sizing

The 2024 EBE report concludes that the HVAC system is undersized, and offers performance data as well as a set of Manual J/S/D calculations[8] as evidence. However, the performance data relied upon by the EBE report is inconclusive, and its use suggests a failure to consider the dynamic nature of vapor compression cooling systems. In addition, the Manual J calculations by EBE do not accurately reflect the construction of the home; specifically the foamed-in attic, the HVAC system having been installed inside of the thermal envelope, and the addition of the dehumidifier to assume some of the latent cooling load. Finally, evidence from the Apollo BBC report suggests that the HVAC system is adequately sized for this home.

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[8] Manual J/S/D calculations refer to calculation for building HVAC system loads (J), HVAC system sizing (S), and duct design (D). The calculations were developed and are maintained by the ACCA (Air Conditioning Contractors of America). Learn more at www.acca.org.

Performance data

EBE alleges that the "…air conditioning system is not operating in optimal fashion…", specifically that the temperature of the air leaving the evaporator coil (supply) as "…not low enough to meet room design conditions..." while citing a temperature differential of ~19°F across the system.

The performance data utilized by EBE in support of this allegation is included in the text of their report but is actually drawn from their Attachment D, a report by Always Cool Heating and Air Conditioning. The data from this supplemental report is summarized in Table 6.

Table 6: Performance data from the EBE report

Parameter	Value	Units
Outdoor dry bulb temperature	84.9	°F
Return air dry bulb temperature	75.9	°F
Return air wet bulb temperature	67.5	°F
Supply dry bulb temperature	56.9	°F
Supply wet bulb temperature	55.9	°F
Air flow	1080	cfm

Note that EBE cites the air flow as 1080 cfm, based on measurements taken by Thermal Dynamics, rather than the 1235 cfm recorded by Always Cool Heating and Air Conditioning. However, it is likely that the 1235 cfm value was estimated by Always Cool from furnace manufacturer literature rather than taken from an actual measurement. Since EBE chose to use the measured value of 1080 cfm we'll use that value in our analysis here as well.

Figure 6 is a psychrometric chart of the conditions identified by EBE during their analysis. Also included is the expected output of the installed equipment under the same input conditions, taken from extended data tables on the cooling system performance provided by the manufacturer[9]. What this chart shows is that the HVAC system is performing *almost exactly as expected for the conditions.* The reason that the temperature is "…not low enough to meet room design conditions…", i.e., the temperature difference, or "delta", between the incoming and outgoing HVAC system air flow as alleged by EBE, is the high humidity of the air at the input (return) to the HVAC system.

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[9] Lennox ACCA Capacity Calculator. https://apps.lennoxpros.com/ACCAManualHeatCool/Prod.aspx.

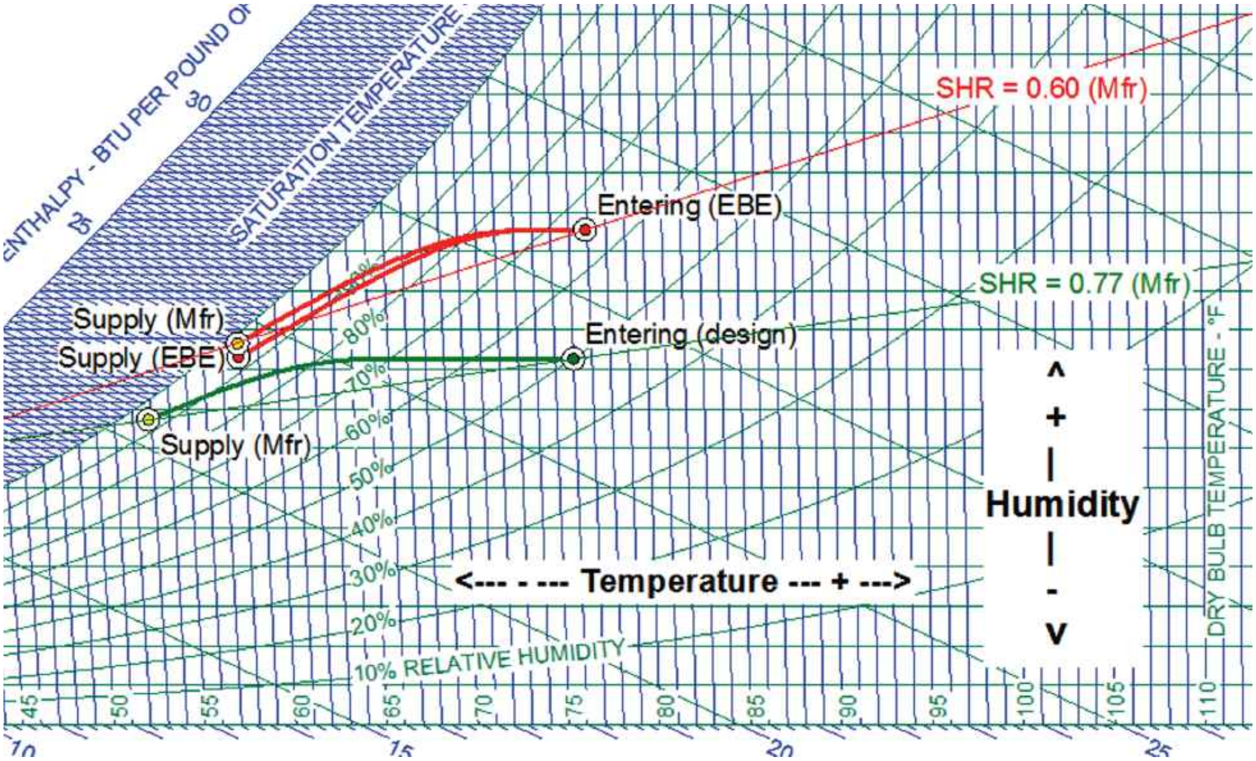

Figure 6: *Psychrometric chart showing the actual and expect performance of the HVAC system during the EBE inspection (red lines). Note that the actual and expected performance is nearly identical. The reason for the low delta-T is the high humidity of the air at the input (return) side of the HVAC system.*

Vapor compression cooling systems are highly dynamic; they respond as conditions change. In this case the high humidity of the incoming air has resulted in the HVAC shifting its operation towards removing water rather than cooling the air. This is represented by the SHR (Sensible Heat Ratio[10]) of the system shifting downward, as shown by the red diagonal line in Figure 6 marked “SHR = 0.60”. The SHR represents the fraction of the available capacity that is removing “sensible” heat (lowering the temperature of the air); in this case 60% of the available capacity is lowering the temperature of the air, while the remaining 40% is removing heat associated with dehumidification efforts.

Figure 6 also includes a plot (green lines) that predict how this HVAC system would perform (using manufacturer extended coil data) under the code-mandated interior design conditions (75°F/50%RH) and the outdoor conditions recorded by Always Cool on the day of their investigation (84.9°F outdoor dry bulb temperature). The results show that under these conditions the HVAC system would have had a SHR of 0.77, which demonstrates the capacity shift back towards temperature reduction (77% of capacity) and away from humidity removal (23%). Under these conditions the HVAC system would have

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[10] The Sensible Heat Ratio, or SHR, is the ratio or fraction of the capacity associated with “sensible” (temperature change) heat removal to the total capacity of the system under the specified conditions. The remaining fraction (1 – SHR) of the capacity is associated with “latent” (water) heat removal.

produced a temperature differential of 23°F, rather than the 19°F as observed by EBE, and well within the >20°F temperature differential demanded by the EBE report.

The water removal performance of the HVAC system at the time of the EBE measurements was excellent – it was removing latent (moisture) energy at a rate of more than 17,000 BTU/hr. This is almost 400% of the maximum latent load predicted by the Houk Manual J calculations at peak summer conditions, and 175% of that predicted by EBE. Given that the maximum predicted latent loads are far smaller than the latent capacity measured by EBE, the system would have eventually pulled the humidity levels down. As it did so the performance would once again shift back towards removing sensible (temperature) heat loads, producing an increased temperature differential as demanded by the EBE report.

The reality is that the HVAC system was not operational for some time during the EBE inspection, likely resulting in the high humidity initially encountered during the HVAC system testing. This is documented by EBE (photo #11 in the EBE report) showing the HVAC system was off and that temperatures in the home had risen to almost 84°F. Note, too, that the dehumidifier was acknowledged as being off on the day of the EBE inspection (photo #7 of the EBE report, and also as noted by Thermal Dynamics in EBE report Attachment D). However, under these conditions and acknowledging the high latent energy removal rate of the HVAC system (as recorded by EBE), all that would have been needed to record a more representative performance of the HVAC system was to let it run longer. As the humidity fell – as it must, given the high rate of water removal by the HVAC system at the time of the EBE testing – the humidity and temperatures would have fallen to normal and expected levels.

The EBE report conclusions regarding performance of the HVAC system are not supported by the evidence, and instead suggest a failure to allow for the dynamic nature of HVAC systems when encountering greater-than-design latent loads, and/or not allowing sufficient time for the HVAC system to normalize conditions in the home after an excursion from standard conditions prior to assessing its performance.

Manual J/S/D calculations

The documents provided to BRLLC for their review include a partial Manual J/S/D report produced by Houk; these are assumed to be the calculations performed for original construction. The Houk Manual J/S/D calculations are incomplete, and do not provide details on the construction of the home sufficient to validate the calculations. It also does not appear to include the impacts of the dehumidifier installed in addition to the HVAC system, although a separate document records “points” for the dehumidifier, possibly with respect to an energy program.

The Houk Manual S document includes a specification for a different, larger system than that installed in the home. This system is documented below in Table 7.

Table 7: Houk Manual S system specifications

Component	Manufacturer	Model
Furnace	Lennox	EL296UH090XV60C
Evaporator coil	Lennox	CHX35-51/61C
Condenser	Lennox	16ACX-48-230A

This system has a nominal capacity of 4 tons. When evaluated at the conditions noted in the Houk calculations, which include the impact of duct leakage, infiltration, the fresh air system, and fan energy this system has a capacity of ~ 3.7 tons of cooling with a SHR of 0.79 per the Houk Manual J/S/D. Pertinent design specifications from the Houk calculations are listed in Tables 8, 9 and 10. This system does appear to meet the ACCA sizing requirements for multi-speed cooling equipment.

Table 8: Design conditions

Parameter	Value	Units
Design dry bulb	75	°F
Design wet bulb	62.5	°F
Entering dry bulb	78.2	°F
Entering wet bulb	64.5	°F
Outdoor dry bulb	96.8	°F
Outdoor wet bulb	76.6	°F

Table 9: Building loads

Sensible load	32750	BTU/h
Latent load	4325	BTU/h
Total load	37075	BTU/h
SHR (load)	0.88	NU

Table 10: System performance – Manual S

Flow rate	1277	Cfm
Sensible capacity	35310	BTU/h
Latent capacity	9390	BTU/h
Total capacity	44700	BTU/h
SHR (capacity)	0.79	NU
% of sensible load	110%	%
% of latent load	217%	%
% of total load	122%	%

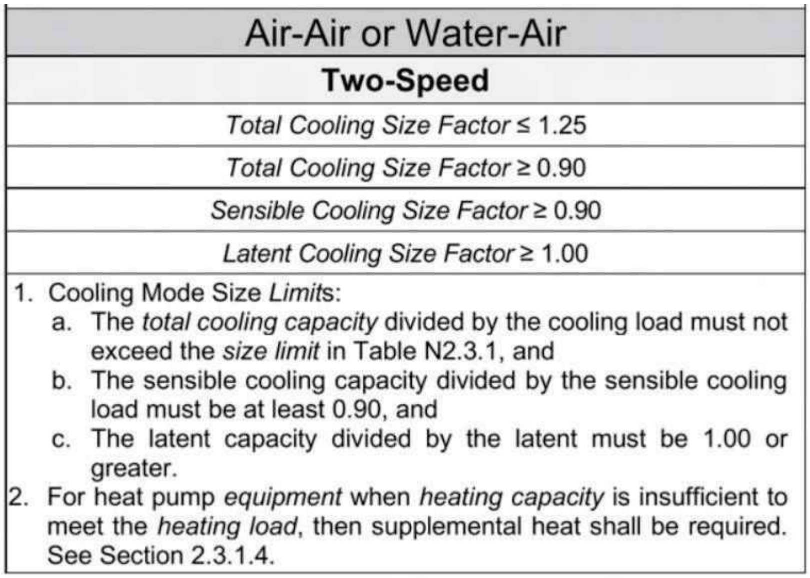
The system installed in the home, as described in previous sections of this report, is smaller than that specified in the Manual S with a nominal size of 3 tons. However, this may be the result of the dehumidifier also installed in this home, which might shift the load calculations and take some of the latent workload away from the HVAC system.

Without considering the dehumidifier, the estimated performance of the installed HVAC system, evaluated at the same conditions indicated in the Manual J/S/D report, is provided in Table 11. This system also appears to meet the ACCA sizing requirements for multi-speed cooling equipment.

Table 11: System performance – installed

Flow rate	1277	Cfm
Sensible capacity	29310	BTU/h
Latent capacity	6440	BTU/h
Total capacity	35750	BTU/h
SHR (capacity)	0.82	NU
% of sensible load	91%	%
% of latent load	149%	%
% of total load	98%	%

Figure 7 shows the sizing requirements of the latest ACCA Manual S standard[11].



Air-Air or Water-Air
Two-Speed
Total Cooling Size Factor ≤ 1.25
Total Cooling Size Factor ≥ 0.90
Sensible Cooling Size Factor ≥ 0.90
Latent Cooling Size Factor ≥ 1.00

1. Cooling Mode Size *Limits*:
   a. The *total cooling capacity* divided by the cooling load must not exceed the *size limit* in Table N2.3.1, and
   b. The sensible cooling capacity divided by the sensible cooling load must be at least 0.90, and
   c. The latent capacity divided by the latent must be 1.00 or greater.
2. For heat pump *equipment* when *heating capacity* is insufficient to meet the *heating load*, then supplemental heat shall be required. See Section 2.3.1.4.

Figure 7: *An excerpt of Table N2.3.1 from the 2023 ACCA Manual S showing the requirements for 2-speed HVAC systems (cooling). Note that the installed system meets these requirements (Table 11).*

Based on the available information, the smaller system coupled with the added dehumidifier is a good choice for this home. The HVAC system will operate for longer intervals during nominal conditions,

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[11] "Normative Sections of ANSI/ACCA Manual S - 2023." 3rd edition, Version 1.02. Alexandria, VA: Air Conditioning Contractors of America, Sep 2023. Accessed 4/10/2025. https://www.acca.org/standards/technical-manuals/manual-s.

thanks to the smaller HVAC system size and 2-speed operation, ensuring good dehumidification performance. In addition, when cooling is not needed – for instance, during winter or humid but mild spring weather – the dehumidifier will manage humidity independent of the HVAC system.

However, neither of the Manual J/S/D calculations available (Houk or EBE) can currently be confirmed as correct. The Houk Manual J/S/D report is only a summary; the complete report will need to be assessed to determine if it accurately represents the home as built. The EBE manual J/S/D, on the other hand, does not: accurately represent the roof design; account for the HVAC system being installed inside of the thermal envelope (which significantly reduces losses from the HVAC system); include the ventilation system; or take account of the installed dehumidifier.

The size of the installed system, particularly when coupled with the dehumidifier, appears to be the better option for this home. This can be confirmed by a complete Manual J/S/D that incorporates the unique features of this home's construction.

Empirical evidence of correct sizing

The Apollo BBC report contains useful information to support the position that the HVAC system as installed is correctly sized.

The Apollo BBC report notes that on the day of their inspection the outdoor temperature was 101.9°F with a relative humidity of 40.6%. This equates to a wet bulb temperature of 80.4°F. These conditions are compared to the outdoor design conditions called out by the two Manual J/S/D calculations available (Houk, EBE), as well as the design conditions for the local ASHRAE[12] accepted weather station at the Conroe-North Houston Regional Airport[13] in Table 12.

Table 12: Observed and design conditions for the home

Source	Dry bulb [°F]	Wet bulb [°F]
Apollo inspection	101.9	80.4
Houk Manual J/S/D	96.8	76.6
EBE Manual J/S/D	96.0	80.5
ASHRAE design cond.[14]	95.7	75.9

These values are plotted on a psychrometric chart in Figure 8. These show that on the day of the Apollo inspection the total enthalpy[15] of the outdoor air was higher than either the ASHRAE or Houk design values, and approximately equal to the design values used by EBE. This means that the effective

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[12] ASHRAE – American Society of Heating, Refrigeration and Air-conditioning Engineers. ASHRAE weather design guidelines are well-established and widely used in Manual J/S/D calculations.

[13] The Conroe-North Houston Regional Airport is the closest AHRAE-approved weather station to the subject property for design conditions.

[14] *2021 ASHRAE Handbook: Fundamentals.* Atlanta, GA: American Society of Heating, Refrigeration and Air-conditioning Engineers, 2021. Design conditions for Conroe-North Houston Regional Airport.

[15] Enthalpy is a means of comparing the relative energy of a material on a per-mass basis. Differences between enthalpy indicate a change in energy.

outdoor conditions on the day of the Apollo BBC inspection were equal to or greater than the expected design criteria, no matter which of these outdoor design condition sources is used. Note, too, that the sun was shining, as noted by Apollo BBC in their report ("…clear with scattered clouds…").

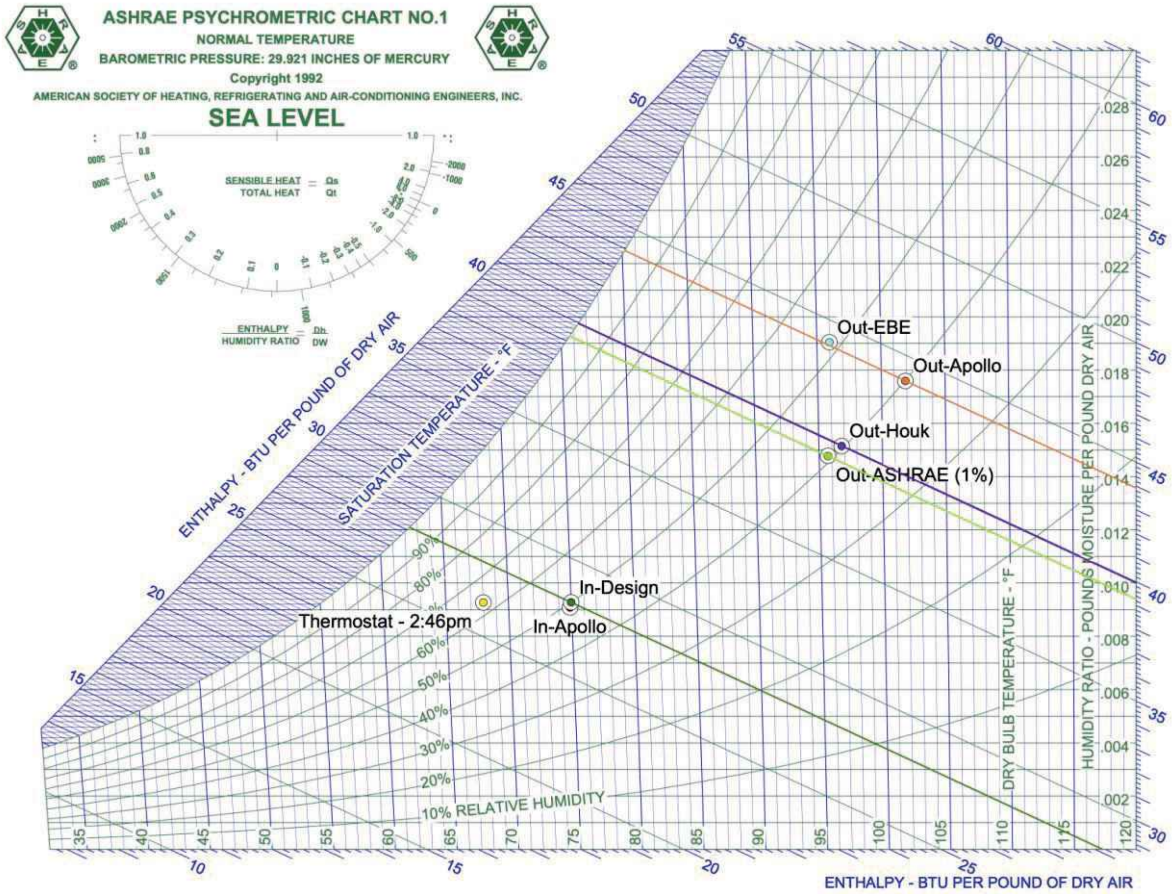

__Figure 8:__ This shows the relative state of the outdoor air at design conditions, plus the outdoor and indoor air on the day of the Apollo BBC inspection. Note that the thermostat value is assuming 63% RH.

What this means is that the outdoor conditions during the Apollo BBC inspection met or exceeded the design criteria regardless of which standard is considered[16] – that used by EBE, Houk, or as specified by ASHRAE. And yet on this very warm, humid and sunny day the HVAC system of the home managed to maintain interior design conditions of approximately 75°F at 50% RH. This is empirical confirmation that the system as installed is sufficiently sized for the expected load.

Not only did the home reach the interior design guidelines of 75°F/50% RH while under outdoor design conditions, photographs included with the Apollo BBC report show that the HVAC system actually

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[16] It is unclear why the ASHRAE standards were not used by either Manual J/S/D report.

reached and held 68°F – fully 7°F *lower* temperature than required by the design conditions specified in the 2015 IECC under which this home was built. Also note that the accuracy of the thermostat at 68°F has been proven by the CDC report, which includes a photo confirming the thermostat readings using what CDC alleges is a calibrated meter[17].

This evidence from the Apollo BBC report suggests that the HVAC is sufficiently sized for the expected environmental loads.

Operation of the HVAC and Dehumidifier

The reports for this home contain evidence that it was operated at temperatures far below the criteria under which it was designed, which can lead to moisture and humidity problems. In addition, these same reports show that the dehumidifier was frequently disabled, preventing it from maintaining appropriate indoor humidity levels.

Photographs[18] (ostensibly from the homeowner) dated 5/28/24 show the HVAC system set to and holding 68°F – fully 7°F below the design set point of 75°F. Other photographs from the homeowner[19] dated 5/30/24 show the HVAC system being operated at a set point temperature of 66°F (confirmed in the associated email as an intentional temperature setting). Still others[20] dated 5/31/24 show the thermostat set for and holding 65°F (Figure 9).

Figure 9: *A photograph, ostensibly from the homeowner and dated 5/31/2024, showing the thermostat set to (and holding) a permanent temperature setting of 65°F.*

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[17] Construction Defect Consultants report, page 19, shows what CDC claims is the calibrated meter being used to validate the thermostat readings.

[18] File "[redacted]k - CCR Pictures 5-28-2024.pdf"

[19] Email from Edwin Medina to "HoustonCustomerCare" dated 5/30/24, forwarding an email from [redacted].
File "[redacted] - HO Original email 5-30-2024.pdf"

[20] File "[redacted] - Mold pictures 5-31-2024.pdf"

Photos contained in the 2025 CDC report show the thermostat set to and holding 68°F on 6/21/24; this is also confirmed in the text of the CDC report. This report also compares the thermostat readings to a “calibrated meter”, indicating that the temperature shown on the thermostat is very close to the actual reading. The CDC report also notes that the dehumidifier was turned off at the time of their inspection (Figure 10).

Figure 10: *This photo excerpt from the 2025 CDC report shows that the dehumidifier has been turned off. This was confirmed in the text of the CDC report.*

The 2024 H5 Climate Consulting LLC report notes that they found the thermostat set to and holding 65°F during their inspection on 5/31/24. They also found the thermostat fan set to “ON” rather than “AUTO”. Setting the fan to “ON”, as discussed earlier in this report, ***dramatically hinders the ability of the HVAC system to dehumidify the air***. During their inspection they did find the dehumidifier was enabled; however, due to the low temperature of the HVAC system the dehumidifier likely did not run often. This is due to an interlock that prevents the dehumidifier from operating when the HVAC system is running.

The 2024 EBE/I-ENG-A (EBE) report includes a photograph showing the dehumidifier was off on the day of their inspection, although they mis-identify the controller as the “Outdoor air controller”. While this is one of the functions of the dehumidifier controller, it is not its primary function.

These comprise direct evidence that the homeowner operates the HVAC system at far lower temperatures than for which the HVAC system or home was designed. In addition, the dehumidifier is frequently left off, disabling its operation. There is also indirect evidence of low temperature operation.

For instance, the homeowner's email dated 5/30/2024 includes a photograph of the rear door at the living room (Figure 11). This figure shows condensation on the outside of the double-pane glass installed in the rear door[21]. This indicates that the interior temperature is so low that – even through a double-pane insulated glass assembly – the outdoor air is condensing on the external glass surface. The importance of this discovery is in what this means for infiltration air: if the air outside will condense on the outer pane of a *dual-pane insulated* window, it will also condense on interior surfaces when they are exposed to acceptable levels of normal outdoor air infiltration.

Figure 11 *Note the lack of distortion in the reflections of the interior lights on this door's window; this indicates that the condensation is outside, not inside, the home.*

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[21] Reflections from the interior lights on the rear door glass are undistorted, indicating that the condensation is on the external pane rather than the internal pane.

Operating a home – particularly in a hot-humid climate like Houston – at temperatures far lower than the design conditions for extended periods can lead to dangerously low interior surface temperatures; these surfaces would be highly susceptible to condensation from even nominal amounts of normal infiltration. Acceptable levels of infiltration typically disperse and mix with the indoor air, lowering its potential for condensation and allowing the HVAC system to remove the added humidity. However, when the outdoor infiltration air contacts sub-cooled surfaces it will instead condense before it is able to mix with the indoor air. Disabling the dehumidifier and operating the HVAC fan in the "ON" mode both aggravate the issue by increasing humidity levels.

This is not to say that you cannot operate your HVAC system or home at lower-than-design temperatures. However, just as operating your automobile under "severe" service conditions requires that you perform more frequent service and inspections, so too does operating your HVAC system and home continuously at lower-than-design temperatures require more care. The homeowner must be aware of possible complications of low temperature operation, and be on the lookout for signs of condensation on the HVAC system or other components of the home that are subject to the extreme temperatures created during extended low temperature operation.

The homeowner must also request more frequent servicing of the HVAC system, and heed the advice and recommendations of HVAC service personnel. They should also advise the HVAC service company of their intent and ask what changes, additions, or supplemental service would be required to operate the system outside of its design criteria. For instance, a larger HVAC system might be in order, or a distribution system with a greater level of insulation. Perhaps even a supplemental dehumidification system might be required. Failing to request and heed the advice of HVAC system professionals when operating the HVAC system and home outside of its design criteria will have the same impact as driving your automobile under severe conditions without the required service and inspections: it will likely fail to operate in the manner expected.

Other (miscellaneous) observations

There were signs of past condensation at the back of the supply register boxes on the attic side. As the condensation forms in the attic it runs down the side of the register box and wets the surrounding drywall. This shows as staining on the drywall around the supply register when viewed from the interior.

This is the result of low temperature operation of the HVAC system. Contributing factors are the disabling of the dehumidifier and the operation of the HVAC system fan in "ON" mode rather than "AUTO" mode. While the register boxes are appropriately insulated for normal HVAC system operation, extreme low temperature operation will push their outer surface temperatures low enough to result in condensation. In addition, running the HVAC fan continuously will noticeably increase indoor humidity, as will disabling the dehumidifier.

There were also signs of condensation on the face of the register grills in some locations. There are two causes for this that involve different physical mechanisms to varying degrees: low temperature operation, and running the HVAC system fan continuously.

For cases where the condensation is on the face of the supply grill in bathrooms with exhaust vents, the problem is primarily due to low temperature operation. Low temperature operation increases air infiltration as a result of the "stack" effect (Figure 12). The stack effect is a natural phenomenon that occurs when the indoor air temperature differs from the outdoor air temperature. In the summer, the cooler indoor air is denser than the outdoor air; the indoor air tends to "fall" towards the bottom of the home and leak out through low air paths at the base of walls, windows or doors. This results in a negative pressure developing at the ceiling, which in the case of the bathroom exhaust fan causes small amounts of air to "back-draft" into the bathroom from the exhaust fan. When these small amounts of back-drafted outdoor air encounter the cold surface of the supply register it tends to condense water on its surface.

While exhaust fans have dampers to prevent back-drafting, these are simple gravity affairs that are design to stop large bulk transfers and not small amounts of normal air infiltration. In this case the exhaust fans have dual gravity dampers (one on the outside as well as one in the fan), but as expected they do not stop small, expected levels of infiltration. When combined with an increased stack effect and lower-than-normal surface temperatures they cannot prevent condensation from even normally-acceptable levels of air infiltration.

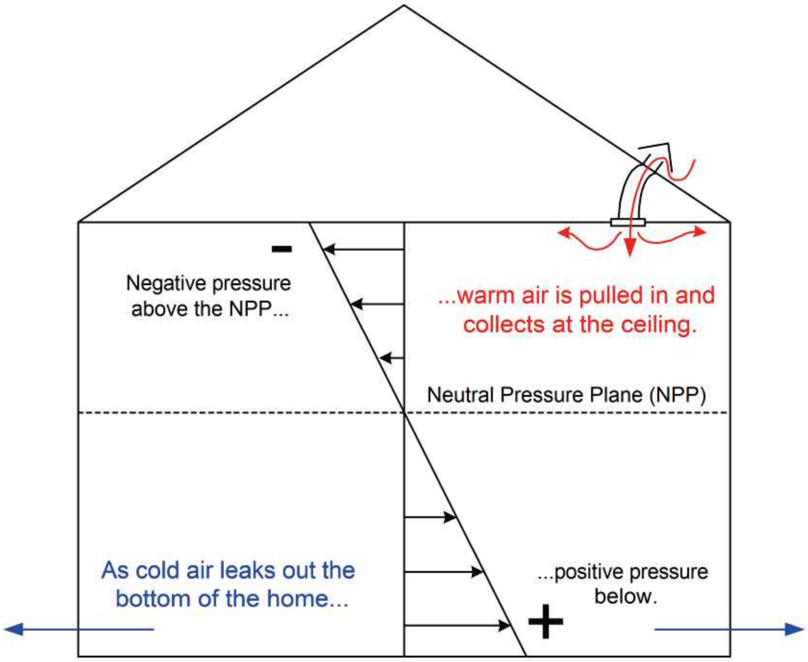
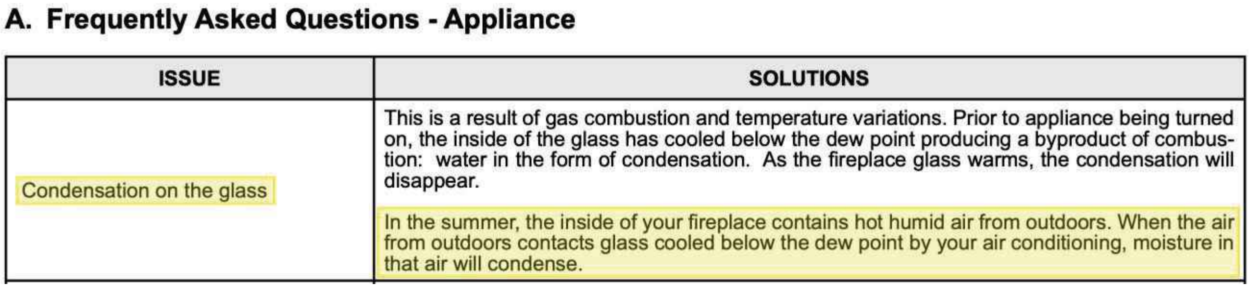


Figure 12: *A diagram depicting the "stack" effect. Note that in one story homes the stack effect is typically small; however, extreme low temperature for extended periods can lead to back-drafting.*

For other supply register grills far away from a source of infiltration air the cause is generally running the HVAC system fan continuously, as confirmed by the H5 Climate Consulting report. This occurs when the HVAC fan continues to pass air over the wet HVAC system evaporator coil after the cooling cycle has ended (the outdoor compressor turns off). The air evaporates water from the coil and passes through the ducts to the still-cold supply register grills, resulting in condensation. It can also increase the humidity levels in the home. Unfortunately, this often results in the homeowner solution utilized in this case: running extremely low temperatures on the HVAC system thermostat.

Because the home is only re-humidified by the evaporator coil water when the HVAC system is not cooling, temporary relief can be found by forcing the HVAC system to run continuously. This is done by pushing the thermostat temperature as far down as possible. This works because the longer the system runs between cycles the more effective it is at removing moisture from the air, partially compensating for the use of the continuous fan. Also, as long as cooling does not stop the water from the coil is not evaporated back into the air stream. However, as noted earlier, low temperature operation of the HVAC system brings its own unique set of problems, i.e.: condensation on interior surface near natural infiltration sources.

Finally, some have noted that condensation has at times formed on the inside of the glass of the sealed-combustion fireplace. However, some condensation here is normal; it is the result of outdoor air entering the fireplace and condensing on the cold glass. Operating the home at lower-than-design temperatures will increase the potential for condensation. We did not record the brand of the fireplace in this home during our inspection, but Figure 13 below contains an excerpt from a Heat & Glo fireplace manual[22] that explains the causes of condensation.



A. Frequently Asked Questions - Appliance

ISSUE	SOLUTIONS
Condensation on the glass	This is a result of gas combustion and temperature variations. Prior to appliance being turned on, the inside of the glass has cooled below the dew point producing a byproduct of combustion: water in the form of condensation. As the fireplace glass warms, the condensation will disappear. In the summer, the inside of your fireplace contains hot humid air from outdoors. When the air from outdoors contacts glass cooled below the dew point by your air conditioning, moisture in that air will condense.

Figure 13: *An excerpt from a Heat & Glo fireplace operator manual.*

It should be noted that we found the fan set to the “AUTO” position during our inspection. We also found the HVAC system set to a reasonable 73°F set point. Finally, we also found the dehumidifier enabled, although it was set for a humidity level that it was unlikely to ever reach (36% RH). This caused the dehumidifier to run whenever the HVAC system did not. As a result we did not see any signs of active condensation in the home or excessive humidity levels, even though the outdoor dew point hit almost 72°F.

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[22] “Primo-II Owner’s Manual – 2670-981, Rev. F.” Hearth and Home Technologies, January 2024. https://downloads/hearthnhome.com/installManuals/2670_981_PRIMO-II_OWNER.pdf

Summary – HVAC System

There is evidence to support the conclusion that the HVAC system is appropriately sized for the home, but a full, complete and correct Manual J/S/D – one that accounts for the unique construction and HVAC system components of this home – should be commissioned to confirm.

There is also evidence suggesting that the home has in the past been operated at extremely low temperature for extended periods during hot/humid weather. There is also evidence to suggest that the dehumidifier has been disabled at times, and the HVAC system fan set to run continuously. All of these, together and/or separately, can lead to moisture issues in the home.

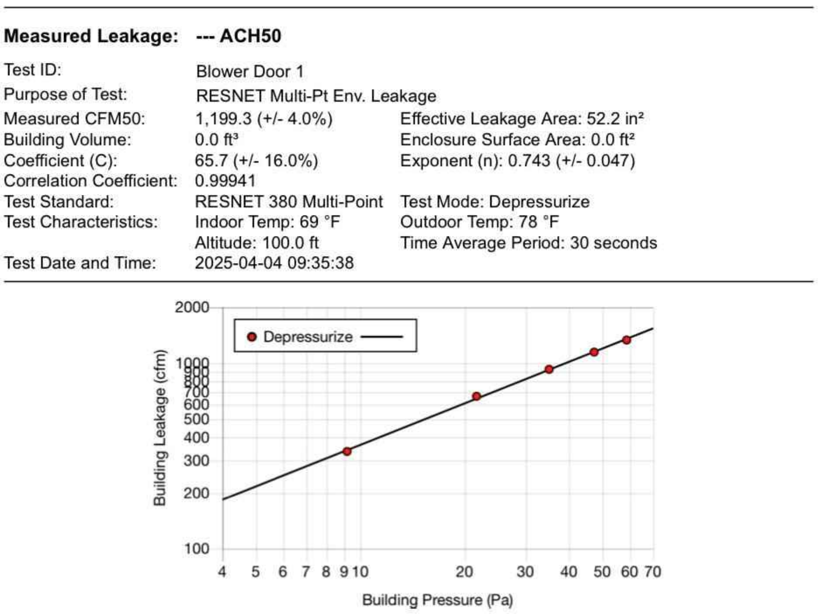
Finally, no signs of current condensation or high humidity conditions were encountered during our inspection. However, the following conditions applied during our inspection:

- HVAC system was operating at a reasonable temperature (73°F);
- The HVAC fan was in auto mode (rather than continuous mode); and
- The dehumidifier was operating (at a set point of 36% RH)

Building Envelope

Blower Door Test

The internationally-recognized test for building air leakage is the blower door test. A blower door test was performed during our inspection on 4/4 2025. The results are shown in Figure 14.



Measured Leakage: --- ACH50

Test ID:	Blower Door 1	
Purpose of Test:	RESNET Multi-Pt Env. Leakage	
Measured CFM50:	1,199.3 (+/- 4.0%)	Effective Leakage Area: 52.2 in²
Building Volume:	0.0 ft³	Enclosure Surface Area: 0.0 ft²
Coefficient (C):	65.7 (+/- 16.0%)	Exponent (n): 0.743 (+/- 0.047)
Correlation Coefficient:	0.99941	
Test Standard:	RESNET 380 Multi-Point	Test Mode: Depressurize
Test Characteristics:	Indoor Temp: 69 °F	Outdoor Temp: 78 °F
	Altitude: 100.0 ft	Time Average Period: 30 seconds
Test Date and Time:	2025-04-04 09:35:38	

Figure 14: *Blower door test results 4/4/2025.*

The result, 1199 cfm50, is excellent. This equates to approximately 2.6 ACH50 (Air Changes per Hour at a 50Pa pressure difference). This is nearly half of the 2015 IECC allowed air leakage rate of 5.0 ACH50, and indicates an extraordinarily well-sealed home. This score is confirmed by a test performed during construction by Environments for Living, which indicated a score of 2.9 ACH50[23] – again, far below the 2015 IECC building code requirement of 5.0 ACH50.

A primer on air leakage testing

Building air leakage is measured by pressurizing the building to a specific pressure level using a fan, and then measuring the amount of air passing through the fan to maintain the specified level of pressurization. Results are initially presented as a cfm50 score (Cubic Feet per Minute at 50Pa pressure difference), then converted to an ACH50 score (Air Changes per Hour at 50Pa pressure difference). The ACH50 score is compared to energy program or building code requirements. For this home the maximum allowed air leakage rate is 5.0 ACH 50 (2015 IECC).

An "air change" here represents the volume of air comprising the interior conditioned space of the home. This information can be gleaned from building plans or other construction documents. For this home the total volume is taken from the original Houk Manual J/S/D calculations, where it is listed as having a conditioned volume of 28050 ft^3. Thus this home is allowed to leak 5 times 28050 ft^3 per hour, or ~140,000 cubic feet per hour, when subjected to a pressure difference of 50Pa. This is a substantial amount of allowed air leakage, but only applies while the home is depressurized to 50Pa. It does not represent actual expected in-use air infiltration rates.

It's important to understand why 50Pa of pressure is used for these tests. It's not because it accurately represents conditions or air flows that the home is expected to encounter; it's because the air leakage produced by 50Pa of pressure *is so much greater than that produced by natural infiltration that the factors that drive infiltration (weather, temperature, geography) become insignificant by comparison.* The result is an air leakage representation that characterizes the *home*, independent of other factors. This is what makes the ACH50 test result so valuable – it is relatively independent of the location or conditions at the time of testing. This allows an objective evaluation of the home's air tightness, which can then be used to predict natural air infiltration under location and design specific conditions.

The ACH50 test result is converted to an "effective leakage area", or ELA, that represents the net effect of all the leaks in the home's air barrier. The ELA can be described as the size of an "ideal" hole (one with no viscous effects) that would result in the same leakage as the home under a specific reference pressure (4Pa in the U.S.). The ELA is then used to calculate the expected air infiltration rate for the home using a model originally developed at Lawrence Berkeley Laboratory[24] that accounts for weather, design, and geographic variables. This calculated air infiltration rate is what is used by some HVAC

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[23] The score was actually 2.6 ACH50; however, it was done as a single-point test under the ANSI/RESNET 380 standard which requires that the score be multiplied by 1.1 to compensate for uncertainty in the measurement.

[24] Sherman, Max H., and D.T. Grimsrud. "Measurement of Infiltration Using Fan Pressurization and Weather Data." Windsor, England: Lawrence Berkeley Laboratory,1980.

system design software to account for the effects of air infiltration. The estimated air infiltration rate is typically 14 to 20 times less than the air flow recorded (in CFM) during the ACH50 test[25].

It is important to recognize here the ACH50 test requirement demonstrates that *homes are not required to be hermetically sealed*. They are expected to leak air, and at a 50Pa pressure difference they are expected to leak a *lot* of air – in this case up to 140,000 cubic feet per hour. This is important because when a home is subjected to a large pressure difference, such as used by Apollo BBC during their thermal image evaluation of the home[26], leaks will occur. It's not that these allowed leaks are discoverable using a thermal camera that is relevant; it's whether or not the net effect of the leaks is excessive. This is determined by the quantitative blower door test (and not by qualitative thermal imaging), which in this case clearly shows that the net leakage is well within the required guidelines and building code requirements.

The Apollo BBC report cites "Excessive air infiltration" for this home. "Excessive" implies a comparison to a standard or allowed limit; however, such a comparison is only possible using a quantitative method where air leakage rates can be determined and compared to an acceptable value – something not possible with the qualitative thermal assessment performed by the Apollo BBC report.

The qualitative-only nature of thermography when used to characterize air leakage is confirmed by multiple international standards developed for thermographic techniques, such as ISO 6781[27] and ASTM E1186[28]. Each expressly limits thermography to a qualitative analysis when investigating air leakage:

> "Thermography will not calculate infiltration leakage flow." (ISO 6781)
>
> "The practices described are of a qualitative nature in determining the air leakage sites rather than determining quantitative leakage rates." (ASTM E1186)

Since it is impossible to quantify air leakage rates from thermography, any claims of "excessive" infiltration based on a thermographic exam alone must be viewed with skepticism – particularly when the claims are disputed by a quantitative evaluation (the ACH50 tests previously identified) that shows the home passes the airtightness standards in place at the time of construction by a large margin.

There is no justification for claims of excessive air leakage such as contained in the Apollo BBC report. The thermal images presented in their report identify allowed, not "excessive", air leakage sites. The

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[25] Sherman, Max H. "Estimation of Infiltration from Leakage and Climate Indicators." Energy and Buildings 10, no. 1 (February 1987): 81–86. https://doi.org/10.1016/0378-7788(87)90008-9.

[26] Apollo BBC did not record the depressurization level used their report, in defiance of the international standards for thermography that require this information be reported (ex.: ISO 6781, ASTM E1186). However, in past cases they have acknowledged using 50Pa as the pressure difference during their thermography sessions.

[27] "ISO 6781-1:2023(E): Detection of Heat, Air and Moisture Irregularities in Buildings by Infrared Methods Part 1: General Procedures." The International Organization for Standardization (ISO), 2023.

[28] "ASTM E1186: Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems." American Society for Testing and Materials (ASTM), 2017.

blower door tests for this home confirm and directly dispute the Apollo BBC report's conclusions of excessive air leakage.

Duct leakage testing

The Apollo BBC report includes photographs and readings taken during what appears to be a duct leakage test of the HVAC system. However, no specific duct leakage score is required when following the "performance" compliance path of the 2015 IECC under which this home was constructed. In addition, since the HVAC system and ducts are all installed within the thermal envelope, any leakage would be within the thermal envelope as well and thus render them inert. Leaks to the inside of the thermal envelope have no impact on overall performance of the HVAC system.

Finally, their photographs suggest that the test was performed incorrectly making the score irrelevant. As shown in Figure 15, the duct pressurization fan appears to have been connected to a return duct in the kitchen. However, this is not a return; it is instead the makeup air duct for the kitchen vent hood. The test as pictured would simply blow air past the duct damper and to the outdoors. This has no connection whatsoever to the HVAC system.

Figure 15: *This photograph from the Apollo BBC report appears to show a duct pressurization test being performed. However, the connection is to an outdoor vent, not to a return duct of the HVAC system.*

Summary – Building Envelope

The home scores exceedingly well on the internationally recognized and code required blower door test, with barely half of the allowed air leakage at 50Pa. This indicates a well-sealed home.

Notwithstanding the conclusions of the Apollo BBC report, which makes a quantitative claim using a qualitative method, there is no support for allegations of excessive air leakage with this home.

Conclusions

Multiple blower door tests conclusively show that the home is well sealed, resulting in barely 50% of the allowed leakage during blower door tests. This is a well-sealed home.

The empirical evidence contained in the available reports suggests that the HVAC system as installed is sufficiently sized for the home. A complete and correct Manual J/S/D would serve to verify correct system sizing.

Existing data suggests that long-term low temperature operation of the home has occurred in the past (65°F to 68°F). This has led to condensation and humidity issues as a result of normal and acceptable levels of air infiltration. The humidity issues have been aggravated by operating the HVAC system fan in continuous mode, as noted in the H5 report. The humidity issues were further exacerbated by the periodic disabling of the dehumidifier, as identified during multiple inspections.

The dehumidifier has been plumbed incorrectly (supply and return have been swapped), resulting in the dehumidifier output being sent to one area rather than being distributed throughout the home. However, this reverse ducting of the dehumidifier would not impact its ability to dehumidify the air.