Blower Door and Duct Leakage Testing for Energy Code Compliance

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Home Energy Technologies LLC

2015 Design & Trades Conference
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Outline

- Energy Codes Overview
  - 2009 IECC and 2009 IRC
  - 2012 & 2015 IECC codes
- Air Sealing Requirements
  - Code requirements
  - Blower door testing
- Duct Sealing Requirements
  - Code requirements
  - Duct leakage testing
- Incentives for DET testing

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Energy Codes Implementation Timetable

- Current CT State Building Code compliance options
  - 2009 IRC for homes ≤ 15% window/wall area
    - Homes permitted after 2/28/2014
    - Prescriptive only
  - 2009 IECC
    - Homes permitted after 10/7/2011
    - Prescriptive or Performance options
- 2015 CT State Building Code
  - Will incorporate 2012 IECC and 2012 IRC
  - Expected adoption late 2015/early 2016

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Compliance Options for 2009 & 2012 IECC/IRC

Mandatory Provisions

- Labeling
- Air sealing
- Duct leakage
- Programmable thermostats
- Building cavities
- Equipment sizing
- Ventilation (2012)

Prescriptive Path Option

Prescriptive Envelope Specs
Or
Total UA Alternative (IECC)
Plus
Specific Insulation, Fenestration and Lighting Provisions

or

Performance Path Option

Simulated Cost Performance Alternative

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Compliance Options for 2015 IECC

Mandatory Provisions

- Labeling
- Air sealing
- Duct leakage
- Programmable thermostats
- Building cavities
- Equipment sizing
- Ventilation

Prescriptive Path Option

Prescriptive Envelope Specs
Or
Total UA Alternative (IECC)
Plus
Specific Insulation, Fenestration and Lighting Provisions

or

Performance Path Options

Simulated Cost Performance Alternative **or** Energy Rating Index Alternative (ERI ≤ 55)

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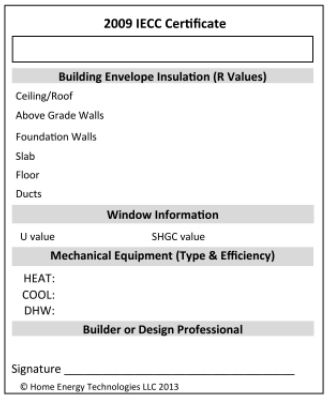
Labeling - Mandatory



2009 IECC Certificate

Building Envelope Insulation (R Values)

Ceiling/Roof
Above Grade Walls
Foundation Walls
Slab
Floor
Ducts

Window Information

U value SHGC value

Mechanical Equipment (Type & Efficiency)

HEAT:
COOL:
DHW:

Builder or Design Professional

Signature _____

- 2009 IECC 401.3 requires
  - A permanent certificate shall be posted on or in the electrical distribution panel
  - It shall be completed by the builder or registered design professional
  - It shall list predominant R-values, fenestration U and SHGC values, and types and efficiencies of heating, cooling and water heating equipment
- 2012 IECC additions
  - Air leakage test results
  - Duct leakage test results

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Prescriptive Insulation for CZ5

Component	2009 IECC	2012/2015 IECC	2015 IECC ERI Option
Fenestration U-factor	0.35	0.32	Same as 2009 IECC
Ceiling	38	49	
Framed wall	20 or 13+5	20 or 13+5	
Basement/crawl wall	10/13	15/19	
Frame floor	30	30	
Slab R & depth	10, 2’	10, 2’	

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HVAC - Mandatory

	2009 IECC	2012/2015 IECC
Load & sizing calculations	Manual J & S (Manual S is a CT code addition)	Manuals J & S
Mechanical ventilation	Not required	Mandatory
Duct insulation	R8 in unconditioned attics. R6 in other unconditioned spaces	
Building cavities	Building framing cavities shall not be used as supply or return ducts (CT code addition)	
Programmable thermostats	Required for all forced-air systems	

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Air Sealing - Mandatory

2009 IECC	2012/2015 IECC	2015 ERI Option
Air sealing mandatory *Verification by* Tested Leakage ≤ 7 ACH50 **OR** Completed Inspection Checklist	Air sealing mandatory *Verification by* Tested Leakage ≤ 3 ACH50 **AND** Completed Inspection Checklist	Same as 2009 IECC

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402.4 Air leakage (Mandatory)

The building thermal envelope shall be durably sealed to limit infiltration. The following shall be caulked, gasketed, weatherstripped or otherwise sealed with an air barrier material, suitable film or solid material

1. All joints, seams and penetrations
2. Site built windows, doors and skylights
3. Openings between window & door assemblies and their respective jambs and framing
4. Utility penetrations
5. Dropped ceilings or chaises adjacent to the thermal envelope
6. Knee walls
7. Walls and ceilings separating a garage from conditioned spaces
8. Behind tubs and showers on exterior walls
9. Common walls between dwelling units
10. Attic access openings
11. Rim joist junction
12. Other sources of infiltration

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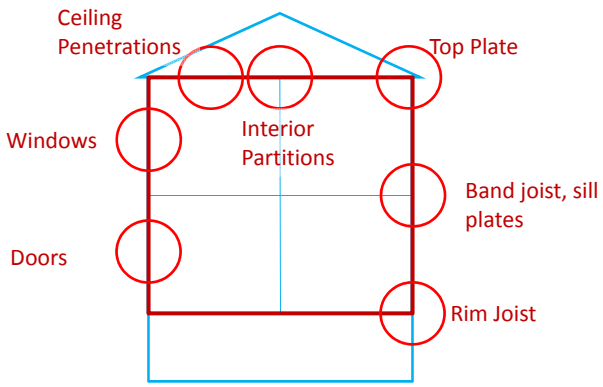
Critical Air Sealing Points



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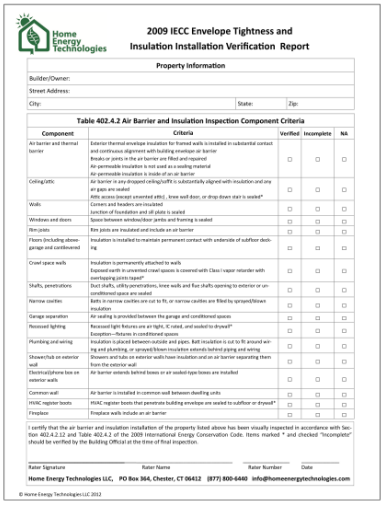
Air Barrier & Insulation Inspection Report



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2009 IECC Envelope Tightness and Insulation Installation Verification Report

Property Information		
Builder/Owner:		
Street Address:		
City:	State:	Zip:

Table 402.4.2 Air Barrier and Insulation Inspection Component Criteria

Component	Criteria	Verified	Incomplete	NA
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier Breaks or joints in the air barrier are filled and repaired Air-permeable insulation is not used as a sealing material Air-permeable insulation is inside of an air barrier	□	□	□
Ceiling/attic	Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any air gaps are sealed Attic access (except unvented attic), knee wall door, or drop down stair is sealed*	□	□	□
Walls	Corners and headers are insulated Junction of foundation and sill plate is sealed	□	□	□
Windows and doors	Space between windows/door jambs and framing is sealed	□	□	□
Rim joists	Rim joists are insulated and include an air barrier	□	□	□
Floors (including above-garage and cantilevered	Insulation is installed to maintain permanent contact with underside of subfloor decking	□	□	□
Crawl space walls	Insulation is permanently attached to walls Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped*	□	□	□
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed	□	□	□
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation	□	□	□
Garage separation	Air sealing is provided between the garage and conditioned spaces	□	□	□
Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall* Exception—fixtures in conditioned spaces	□	□	□
Plumbing and wiring	Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring	□	□	□
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall	□	□	□
Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed	□	□	□
Common wall	Air barrier is installed in common wall between dwelling units	□	□	□
HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall*	□	□	□
Fireplace	Fireplace walls include an air barrier	□	□	□

I certify that the air barrier and insulation installation of the property listed above has been visually inspected in accordance with Section 402.4.2.12 and Table 402.4.2 of the 2009 International Energy Conservation Code. Items marked * and checked "Incomplete" should be verified by the Building Official at the time of final inspection.

Rater Signature | Rater Name | Rater Number | Date

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- Report format defined in Table 404.4.2 of the 2009 IECC or Table N1102.4.2 of the 2009 IRC

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Blower Door Testing - Equipment

Rings are installed as necessary to ensure adequate air flow for accurate flow readings

Manometer

Manometer measures pressure differences

- Left channel: Between inside house and outside
- Right channel: Measures fan pressure
  - Automatically converted to CFM of air flow based on ring size used

Blower Door Testing - Timing

- Code states:
  - "Testing shall occur after rough-in and after installation of penetrations in the building envelope, including penetrations for utilities, plumbing, electrical, ventilation and combustion appliances"
- In practice
  - Test immediately before final CO
    - Duct boots sealed to air barrier
    - Attic hatch gasketed
    - Door & window seals in place

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Test preparation

2009 IECC Section 402.4.2.1 requires that

1. Exterior windows and doors, fireplace and stove doors shall be closed but not sealed
2. Dampers shall be closed, but not sealed, including exhaust, intake, makeup air, backdraft and flue dampers
3. Interior doors shall be open
4. Exterior openings for continuous ventilation systems and heat recovery systems shall be closed and sealed
5. Heating, cooling and ventilation system(s) shall be turned off
6. HVAC ducts shall not be sealed; and
7. Supply and return registers shall not be sealed

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Test protocol

RESNET Standard Section 802.5 Procedure for Conducting a One-Point Depressurization Air Tightness Test

1. With fan sealed, measure baseline inside/outside pressure differential and set in manometer
2. Unseal fan, turn on and increase exhaust flow until inside/outside pressure differential equals 50 Pascals
3. Record fan flow in CFM from manometer (minimum 10 second average), inside & outside temperatures, fan and manometer model and serial numbers
4. Calculate corrected CFM50 value if inside/outside ΔT > 30 degrees

While fan is running it is good practice to show builder any notable sources of air infiltration

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Interpretation

$$ACH50 = \frac{CFM50 \times 60}{\text{Volume of Enclosure}}$$

- ACH50 is the number of complete air exchanges the home would experience in one hour with a 50 Pascal inside/outside pressure differential
- Volume may be calculated from (conditioned floor area) x (average ceiling height)
  - Includes all volume within the thermal envelope, e.g. insulated basements and crawlspaces, sealed attics

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Benchmarks

ACH50	CFM/sf*	ELA (sq. in.)	Example
15+	2.0+	150	Older homes, balloon framed
10	1.3	100	Recent code-built homes
7	0.93	70	2009 IECC standard
4	0.53	40	ENERGY STAR v3 prescriptive standard
3	0.4	30	2012 IECC standard
0.6	0.08	6	Passive House standard
0.05	0.007	0.5	Claimed record (Dillingham, Alaska)

* 8' ceiling height

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ACH50 and ACHn

The natural rate of air exchange (ACHn) can be estimated from the ACH50 results:

$$ACHn = ACH50 / n$$

In Connecticut, for a normally exposed, 2-story building n=14.8 so

7 ACH50 = (7/14.8) ACHn **= 0.47 ACHn**

and

3 ACH50 = (3/14.8) ACHn **= 0.20 ACHn**

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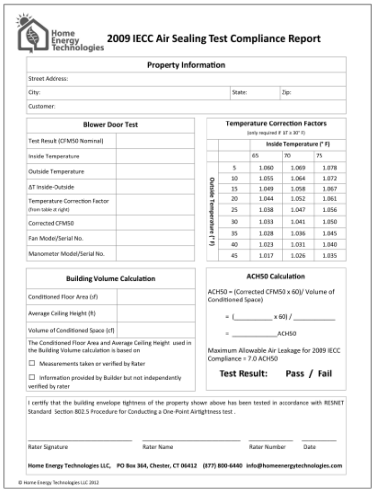
Envelope Leakage Test Reporting



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2009 IECC Air Sealing Test Compliance Report

Property Information

Street Address:

City: State: Zip:

Customer:

Blower Door Test

Test Result (CFM50 Nominal)	
Inside Temperature	
Outside Temperature	
ΔT Inside-Outside	
Temperature Correction Factor (from table at right)	
Corrected CFM50	
Fan Mode/Serial No.	
Manometer Model/Serial No.	

Temperature Correction Factors

(only required if ΔT ≥ 30° F)

Outside Temperature (° F)	Inside Temperature (° F)		
	65	70	75
5	1.060	1.069	1.078
10	1.055	1.064	1.072
15	1.049	1.058	1.067
20	1.044	1.052	1.061
25	1.038	1.047	1.056
30	1.033	1.041	1.050
35	1.028	1.036	1.045
40	1.023	1.031	1.040
45	1.017	1.026	1.035

Building Volume Calculation

Conditioned Floor Area (sf)	
Average Ceiling Height (ft)	
Volume of Conditioned Space (cf)	

The Conditioned Floor Area and Average Ceiling Height used in the Building Volume calculation is based on

☐ Measurements taken or verified by Rater

☐ Information provided by Builder but not independently verified by rater

ACH50 Calculation

ACH50 = (Corrected CFM50 x 60)/ Volume of Conditioned Space)

= (_____ x 60) / _____

= _____ACH50

Maximum Allowable Air Leakage for 2009 IECC Compliance = 7.0 ACH50

Test Result: Pass / Fail

I certify that the building envelope tightness of the property shown above has been tested in accordance with RESNET Standard Section 802.5 Procedure for Conducting a One-Point Airtightness test .

Rater Signature Rater Name Rater Number Date

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- No specific format stated in code
- We have developed our own report form
  - Property information
  - Test results
  - Volume calculation
  - ACH50 calculation
  - Rater certification

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Health & Safety

- Ventilation
  - Build tight, ventilate right
  - Mandatory in 2012 IECC
  - ASHRAE 62.2 is industry standard
  - Three types: Exhaust only, air cycler, balanced
- Combustion appliances
  - Must ensure adequate combustion air supply if any open or atmospheric combustion appliances installed
  - CAZ testing recommended

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Duct Leakage - Mandatory

2009 IECC	2012 IECC	2015 IECC
Post Construction DLO ≤ 8 CFM25/100SF or TDL ≤ 12 CFM25/100 SF Or **Rough In** TDL ≤6 CFM25/100 SF including air handler or TDL ≤ 4 CFM25/100SF excluding air handler	**Post Construction** TDL ≤4 CFM/100SF Or **Rough In** TDL ≤ 4 CFM/100 SF including air handler or TDL ≤ 3 CFM25/100SF excluding air handler	Same as 2012 IECC
Duct leakage testing not required if air handler and all ductwork are inside the conditioned space		

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Leakage Test Types

- Duct testing is done at 25 Pascals (0.1" wc), similar to normal operating pressure
- Total Duct Leakage
  - All leakage from the duct system regardless of whether the loss is to conditioned or unconditioned space
- Leakage to Outside
  - That part of total duct leakage that is outside the conditioned space

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Duct Leakage Testing - Equipment

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Test Preparation

- Turn off HVAC systems
- Turn of fans, ventilation systems
- Remove filters
- Open windows, doors, access panels to outside of unconditioned spaces where ducts are run
- Seal supply registers and return grills
  - Rough-in: Seal boots with duct sealing tape
  - Post-Construction: Seal registers with register sealing tape
- Connect Duct Blaster to
  - Major return closest to air handler, or
  - Air handler cabinet, or
  - Duct plenum (Rough-in test if air handler not installed)
- Insert test probe to measure duct system pressure
  - Largest supply register close to air handler
  - Main supply trunk line

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Test Protocol – Total Duct Leakage Test

- Open at least one door or window between building and outside
- Turn on fan. Increase speed until pressure in duct system is +25 Pascals with respect to the building
- Record fan flow CFM reading, fan and manometer model and serial numbers

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Test Protocol – Leakage to Outside Test

- Ensure all doors and windows to outside are closed
- Reverse direction of blower door fan (installed as for blower door test) so that building will be pressurized rather than depressurized
- Turn on blower door fan. Increase speed to make building pressure +25 Pascals with respect to outside
  - Pressure in duct system will be negative with respect to the building if there is any leakage outside the conditioned space
- Turn on and increase Duct Blaster fan speed to blow air into duct system until the pressure in the duct system is equal to the building pressure (zero pressure differential)
- Record fan flow CFM, fan and manometer model and serial numbers

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Interpretation

Duct leakage test result is normalized for building size by dividing by the Conditioned Floor Area:

$$\text{Leakage/100 sf CFA} = \frac{\text{CFM25 Leakage Test Result}}{\text{Conditioned Floor Area}}$$

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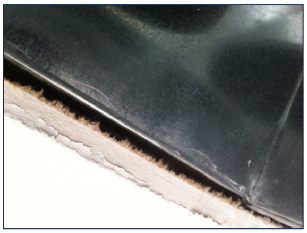
Duct Leakage Failures



The vast majority of failures are due to the contractor's failure to seal the duct boots to the building thermal/pressure envelope allowing leakage into unconditioned spaces. Fortunately this is (usually) easy to correct

Less common problems are due to:
- Toe kick ducts not connected
- Buried ducts
- Disconnected fittings
- Unsealed connections

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Recommendations

- Keep all ducts and air handlers in conditioned space
- Test ducts at rough-in
  - Problems easier to find and fix
  - Sealing boots during installation keeps duct systems clean
  - OK for code compliance, ENERGY STAR still requires post construction testing
- Use mastic!
- Ensure boots are sealed to floor or drywall
  - Ensure cabinet installer aware of proper toe kick duct installation requirements

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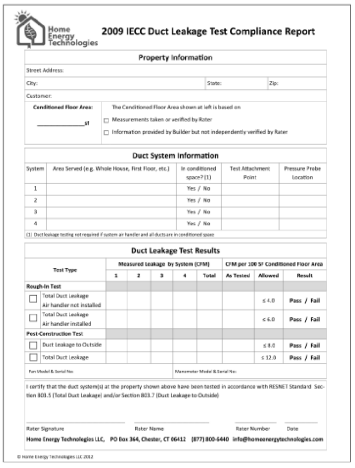
Duct Leakage Test Reporting



2009 IECC Duct Leakage Test Compliance Report

Property Information

Street Address:

City: State: Zip:

Customer:

Conditioned Floor Area: _____ sf

The Conditioned Floor Area shown at left is based on:

☐ Measurements taken or verified by Rater

☐ Information provided by Builder but not independently verified by Rater

Duct System Information

System	Area Served (e.g. Whole House, First Floor, etc.)	In conditioned space? (1)	Test Attachment Point	Pressure Probe Location
1		Yes / No		
2		Yes / No		
3		Yes / No		
4		Yes / No		

(1) Duct leakage testing not required if system air handler and all ductwork in conditioned space.

Duct Leakage Test Results

Test Type	Measured Leakage by System (CFM) 1	2	3	4	Total	CFM per 100 SF Conditioned Floor Area As Tested	Allowed	Result
Rough-In Test								
☐ Total Duct Leakage Air handler not installed							≤ 4.0	Pass / Fail
☐ Total Duct Leakage Air handler installed							≤ 6.0	Pass / Fail
Post-Construction Test								
☐ Duct Leakage to Outside							≤ 8.0	Pass / Fail
☐ Total Duct Leakage							≤ 12.0	Pass / Fail

Fan Model & Serial No: Manometer Model & Serial No:

I certify that the duct system(s) at the property shown above have been tested in accordance with RESNET Standard Section 803.5 (Total Duct Leakage) and/or Section 803.7 (Duct Leakage to Outside)

Rater Signature Rater Name Rater Number Date

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- No specific format stated in code
- We have developed our own test report covering
  - Property information
  - Duct system information
  - Test results
  - Rater certification and signature

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Incentives for Duct & Envelope Tightness Testing

In 2015 the CT Energy Efficiency Fund is offering a $300 rebate for homes that meet the 2009 IECC Duct & Envelope tightness standards.

Testing must be performed by a qualified verifier. Applications and information may be obtained at www.EnergizeCT.com.

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Recap

- Duct and Envelope Tightness standards account for the majority of the energy efficiency gains in the 2009 and 2012 IECC
  - 2009 Standards: A learning opportunity
  - 2012 Standards: The bar is raised
- Reducing Duct and Envelope Leakage is the most cost effective energy efficiency improvement in most homes
  - Success requires paying attention to details, not expensive upgrades

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Questions?

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