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RESEARCH LABS

INSTALLATION TIME STUDY OF COMMERCIAL PLUMBING SYSTEMS

Sponsored by:

REHAU

2/7/2018

Project MR1106

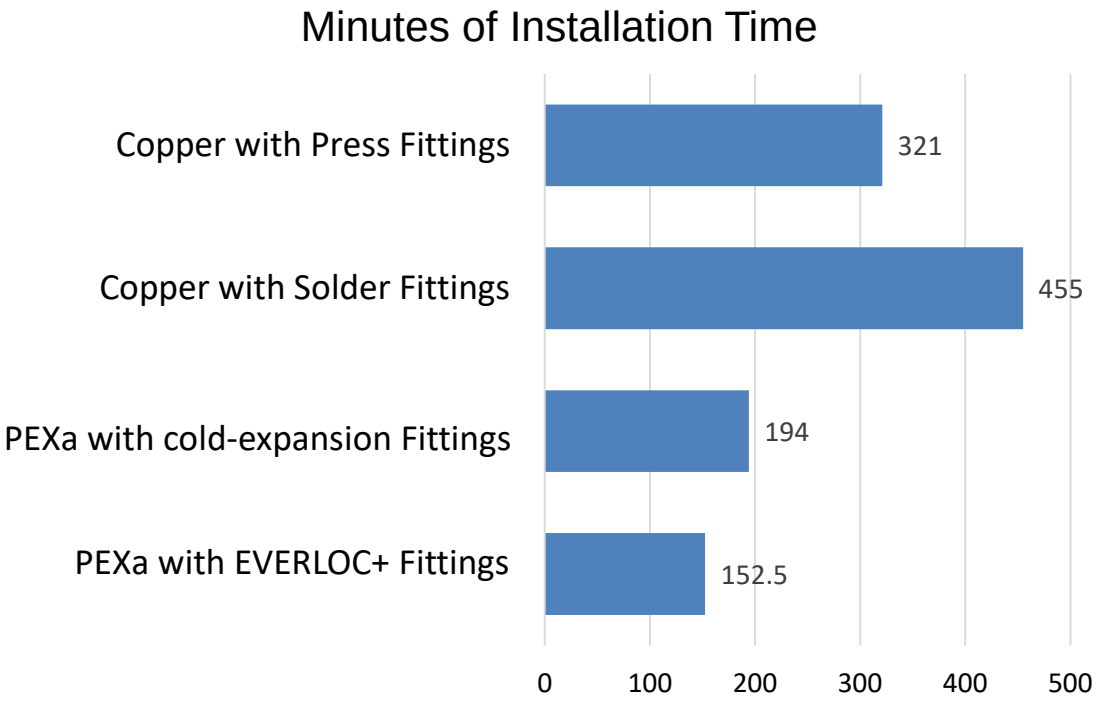
Finding Innovation a Home

Plumbing Piping Installation Research

- REHAU commissioned Home Innovation Research Labs to conduct a side-by-side installation time study of four plumbing system "rough-ins" in a mockup of a section of a hotel built in Home Innovation's lab:
  - REHAU RAUPEX PEXa piping with engineered plastic EVERLOC+ compression sleeve fittings
  - PEXa piping with cold-expansion fittings
  - Copper piping with solder fittings
  - Copper piping with press fittings
- Home Innovation built the structure using light-gauge steel framing in its research laboratory, including two hallways and eight guest room suites with a total of 40 plumbing fixtures
- The installations included a representative mix of 1/2, 3/4, 1, 1 1/4, and 2 in. piping
- Plumbers installed each plumbing system on identical sections of the structure, from riser to stub-outs, while a researcher recorded time

Summary of Research Findings

- The study found that the EVERLOC+™ system installed 21% faster than PEXa with cold-expansion fittings, due primarily to large reduction in installation time of EVERLOC+ for larger diameter piping (1 ¼ in. and up)
- The EVERLOC+ system installed in about 50% the time of the copper piping with press fittings and about 1/3 the time of copper piping with solder fittings



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Objectives and Research Plan

- The primary objective of this research was to determine whether REHAU's EVERLOC+ system will result in installation time savings in a typical commercial new construction setting compared to PEXa cold-expansion, copper with soldered fittings and copper with press fittings
- In order to make a reliable and fair comparison, the study was designed to have contractors complete identical installations
  - Same dimensions for rooms and hallways; locations of fixtures were all the same
  - Equivalent numbers of fixtures, identical distances from supply to fixtures
  - Each system included connections to supply/riser, main piping, hot water recirculation, run-outs, and branches to fixtures, tees, elbows and others
  - Piping sizes in study were common to commercial buildings: 2, 1 1/4, 1, 3/4 and 1/2 in.
  - A complete cycle of piping installation was evaluated – obtaining materials, measuring, cutting, attaching fittings, cleaning up and performing pressure test
  - Participants were instructed on use of the specific tools and materials if they had not used them in the past
- This study was conducted over the course of three days

Research Structure & Design and Setup

- The mockup floor plan and plumbing fixture layout were from an actual new-build hotel project
- The mockup was split into two halves – each with four guest suites and 20 ft. of hallway
- Proportions of large to small diameter piping were reflective of the hotel plan used

- The as-built mockup had a higher density of piping connections than the hotel plan in order to get time measurements on as many connections as possible within the mockup space
  - Based on a take-off of the hotel plans compared to the mockup as-built, there were about 70% - 75% more large and small diameter piping connections per suite in the mockup
  - Hence, the comparison between installation times in this study is reflective of a comparable non-residential project

Study Structure Located in Home Innovation's Lab

- Walls were 20-gauge steel framing
- Studs were C-channel and 3 5/8 in. deep, 16 in. spacing
- Walls were 9 ft. tall
- Blocking and supports for piping were pre-installed by the contractor

- Framing for the ceiling was installed 12 in. down from the upper floor, giving a 12 in. space to install piping
  - Ceiling was light-gauge steel material, same material as walls, with 2 ft. spacing for ceiling joists
  - No drilling for pipe chases or pipe hangers from ceiling was needed in the plumbing time study
- The fixtures in each guest room were a toilet, bathtub, dual sink lavatories and a kitchenette sink
- There were two 20 ft. hallways – with hot and cold mains and recirculation piping

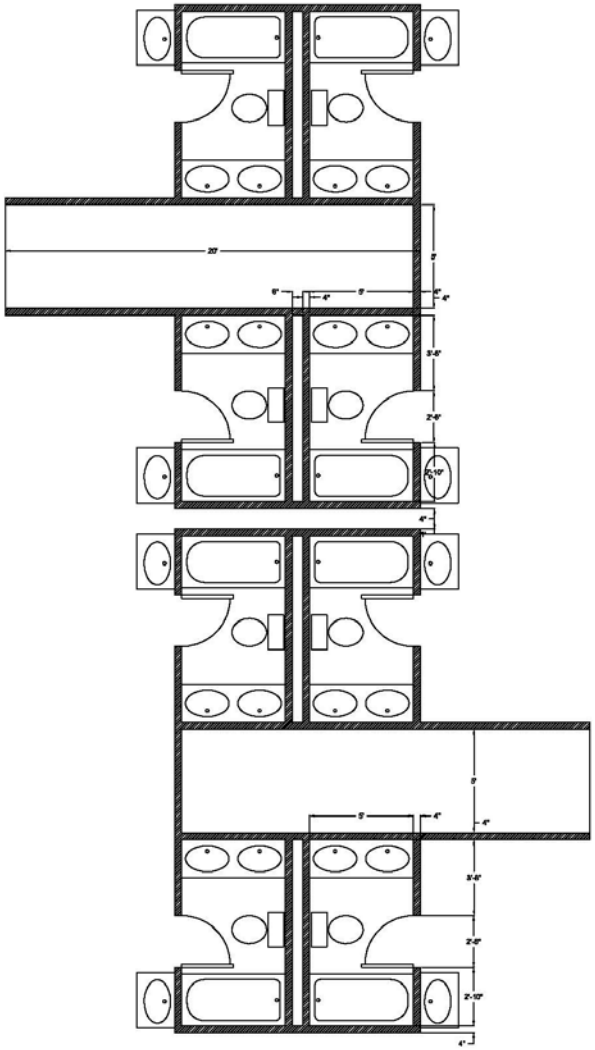
GTT Time Study Methodology

- Installation time data were collected using Group Timing Technique (GTT), a work sampling methodology widely-used by industrial engineers
  - This method is ideal for measuring work crew activities that are non-repetitive in nature, such as the installation of building materials
- GTT allows an observer to:
  - Record the installation time of multiple participants working simultaneously, distinguishing between productive and non-productive time, and record the specific details of each worker's activities
  - Each worker's activity is recorded at regular time intervals (every 60 seconds for this study) during the entire installation process
- GTT is a fixed-interval work sampling procedure based on probability sampling theory – and data analysis applies principles of statistics
- This installation time study accurately depicts the crew's performance on this specific study structure
  - Owing to the study method, mockup specifications, time-keeping parameters and the crew's proficiency with piping installation, we expect that other similarly skilled contractors will have comparable installation times on non-residential buildings

Plumbing Crew Recruitment & Description

- Home Innovation identified, screened and hired a large plumbing contractor located in the Washington, DC metro area to participate in this study
- The contractor was selected because of their willingness to commit time and expertise to this study, drawing participants from their approximately 100 piping installers with experience in all primary piping materials
- Two highly experienced piping installers (15+ years) were selected
  - Each had recent experience with piping in single-family, multi-family and commercial buildings
- The pair of installers had their greatest concentration of experience in CPVC piping with glued fittings; secondarily with copper solder fittings and PEXa with cold-expansion fittings; and neither had experience with EVERLOC+ fittings
- These workers normally were paid by piece-rates for piping installation
  - Hence, their work process was very efficient and their pace of work was quick

Wall and Fixture Layouts of the Mockup



This is the as-built floor plan for the mockup – a total of eight guest suites with five fixtures per suite:

One toilet
Twin-basin lavatory
One bath
One kitchenette sink

Work Area Preparation Before Start of Piping Installations

- The focus of this study was on piping installation – aspects not directly related to piping installation were completed beforehand by the plumbing contractor, such as:
  - Layouts of piping and locations of fittings and fixtures were determined and marked by the plumbing contractor supervisor prior to beginning the timed installation
  - Blocking and supports for all piping were installed (PEX used turnouts at fixtures)
- Fitting-system appropriate tools were provided to installers (e.g., expanders) and practice sessions were provided for all unfamiliar tools on the day of the installation
- Fittings were sorted and placed on a table for ready access
- Pipe was placed in an accessible location for each installer
- Plumbers were briefed on the layouts by their supervisor

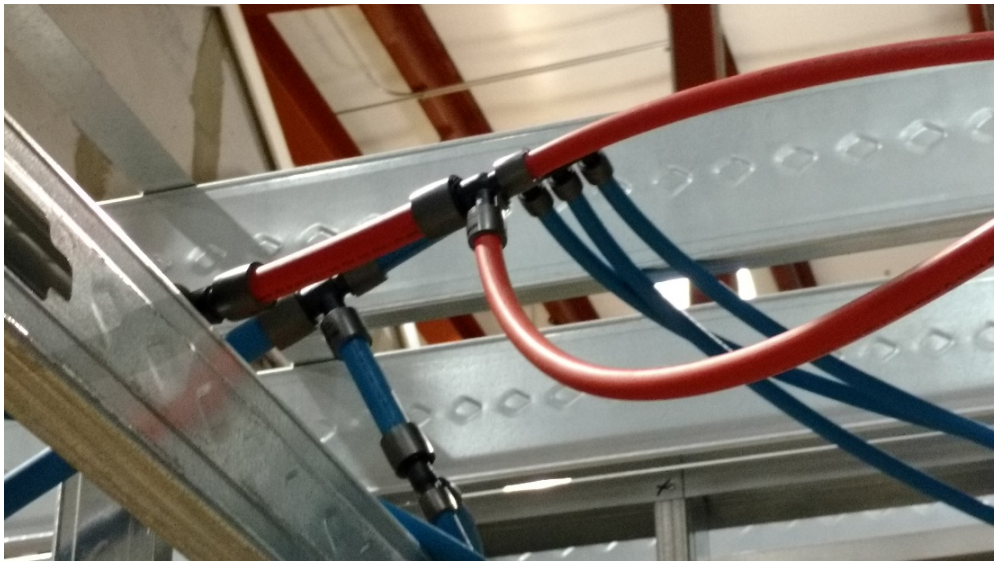
Installation Schedule

To avoid learning-curve, installers rotated between PEXa fitting systems:

- **Day 1:** Installer 1 on REHAU EVERLOC+ on Section 1 of the mockup and Installer 2 on PEXa with cold-expansion fittings on Section 2
- **Day 2:** Installer 1 on PEXa with cold-expansion fittings on Section 2 and Installer 2 on REHAU EVERLOC+ on Section 1
- **Day 3 morning:** Installers 1 and 2 work together on copper pipe with solder fittings on Section 1
  - Installers agreed that with larger diameter copper piping, working as a 2-man team was more reflective of how they would normally approach a job
- **Day 3 afternoon:** Installers 1 and 2 work together on copper pipe with press fittings on Section 2

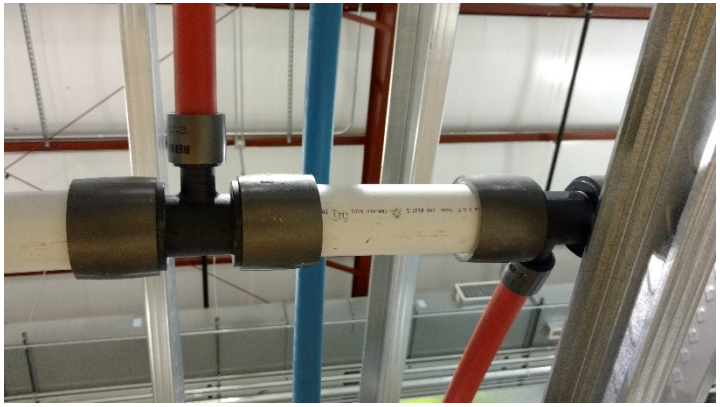
Installation of RAUPEX PEXa Piping with EVERLOC+ Fittings

- Workers trained on two tools for EVERLOC+ fittings – one for large diameter piping (1 ¼ and 2 in.) and one for smaller diameter piping (1 in. and smaller)
- Installers used ¾ in. and larger piping in straight sections and 1/2 in. piping from coils
- Large piping connections for riser and mains were made while piping was on the floor or supports, then the completed assembly was lifted to the ceiling*
- A total of 158 EVERLOC+ connections were made by each installer
- Each of the two EVERLOC+ systems passed a 60 psi pressure test on first attempt



* Pre-assembly of piping runs was the plumbers' choice. They stated that they commonly do this in the field at any part of the installation that would make it easier or faster

Expanding RAUPEX PEXa Piping and Compressing Sleeve Using EVERLOC+ Compression-sleeve Tools



Installation of PEXa Piping with Cold-expansion Fittings

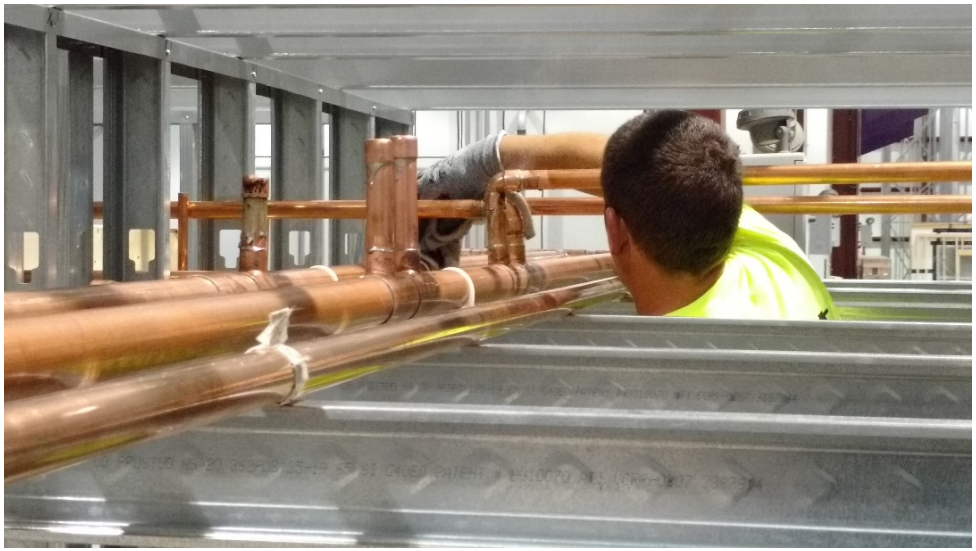
- Workers were supplied with two tools for cold expansion fittings – one for large diameter piping (1 1/4 and 2 in.) and one for smaller diameter piping
- Installers used 1 in. and larger piping in straight sections and 3/4 and 1/2 in. diameter piping from coils
- Installers noted they had prior experience with the smaller expander tool
- Large connections were made while piping was on the floor, then the completed assembly was raised to the ceiling*
- 155 (side 1) and 158 (side 2) connections were made
- Both passed a 60 psi pressure test on first attempt

*Pre-assembly of piping runs was the plumbers' choice. They stated that they commonly do this in the field at any part of the installation that would make it easier or faster

Installation of PEXa Piping with Cold-expansion Fittings

Installation of Copper Piping with Solder Fittings

- Workers were very familiar with installing copper piping of all diameters using solder connections
- The contractor and installers chose to work together, believing it was more productive working in pairs with this material and fitting method
  - One measured, cut, prepped and supplied pipe/fittings while the other soldered
- For the hallway and two guest rooms, the pair completed the piping
  - Final comparison made by using hallway-installation time and doubling guest-room pipe-installation time to equal 4 rooms
- 166 total connections made
- Passed pressure test (60 psi) on first attempt



Installation of Copper Piping with Solder Fittings

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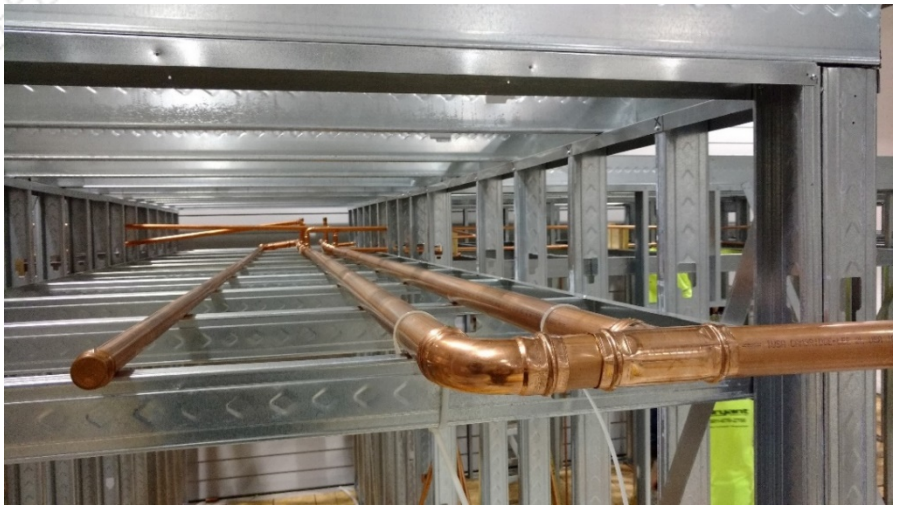
Installation of Copper Piping with Press Fittings

- Workers had seen but never used copper piping with press fittings
- Crew members were shown how to operate and practiced with the press tool before starting the installation
- As with the solder fittings, workers chose to work together – one measured, cut, prepped and supplied piping, fittings while the other used the press tool to make the connections
- As with solder connections, the pair completed the piping for the hallway and two guest rooms
- 166 total connections made
- Two unpressed fittings were discovered during the pressure test, which had to be pressed before the system would pass the pressure test

Installation of Copper Piping with Press Fittings



Gathering Installation Time Data and Calculating the Results

- Before beginning installations, workers were asked to place their tools, equipment and materials at the installation site where they would normally place them after unloading from their truck
  - Workers were instructed to wait until the Home Innovation observer signaled to start, after which they began to set up the work area
- Every 60 seconds, the time keeper would "tally" each worker's activity
  - Each "tally" represents 60 seconds of work
  - A total of 12 pre-determined activities were chosen, and all productive and non-productive activities could be placed into one of these categories
- Non-productive time was omitted from the study comparison
  - This included personal breaks, re-work, workers temporarily leaving the jobsite or remaining idle when there were obvious activities to perform
- Each material and fitting type was installed by both workers. When workers installed piping separately, an average of their two installation times was used for comparisons

Activities Tracked for Time Study

All crew activity during the installations was categorized as one of the following:

Activities Included in Productive Installation Time Comparisons

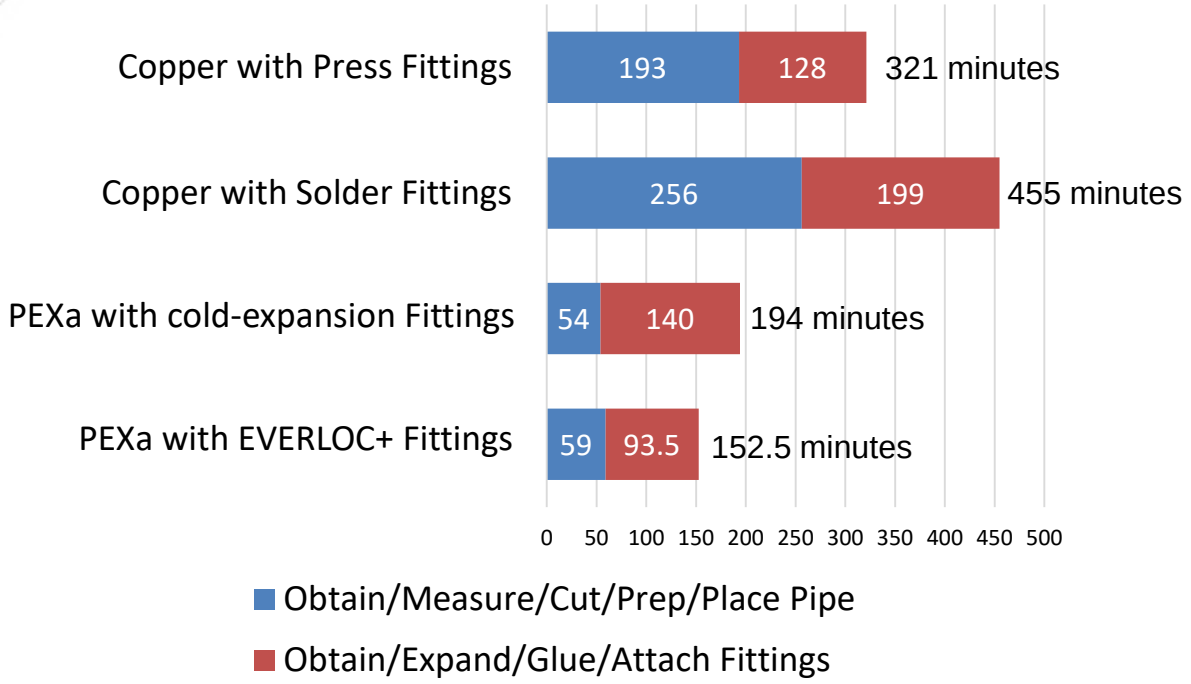
- Obtain pipe
- Measure, Cut and Prepare Pipe
- Place or Pull Pipe
- Obtain and Prep Fittings
- Expand or Attach Fittings

Activities Not Included in Productive Installation Time Comparisons

- Layout or Discussion
- Setup of Tools, Equipment and Work Area
- Wait for Coworker
- Takedown or Cleanup of Jobsite
- Stoppage, Breaks, Re-work or Non-Work Activity
- Set-up or Conduct Pressure Test

TOTAL Productive Installation Time Summary

Average Man-minutes for One Hallway, Four Guest Suites



PEXa with EVERLOC+ primary advantage over PEXa with cold expansion was a faster installation of large diameter pipes

Copper press fittings benefitted from eliminating steps in installation (flux) and a faster connection time

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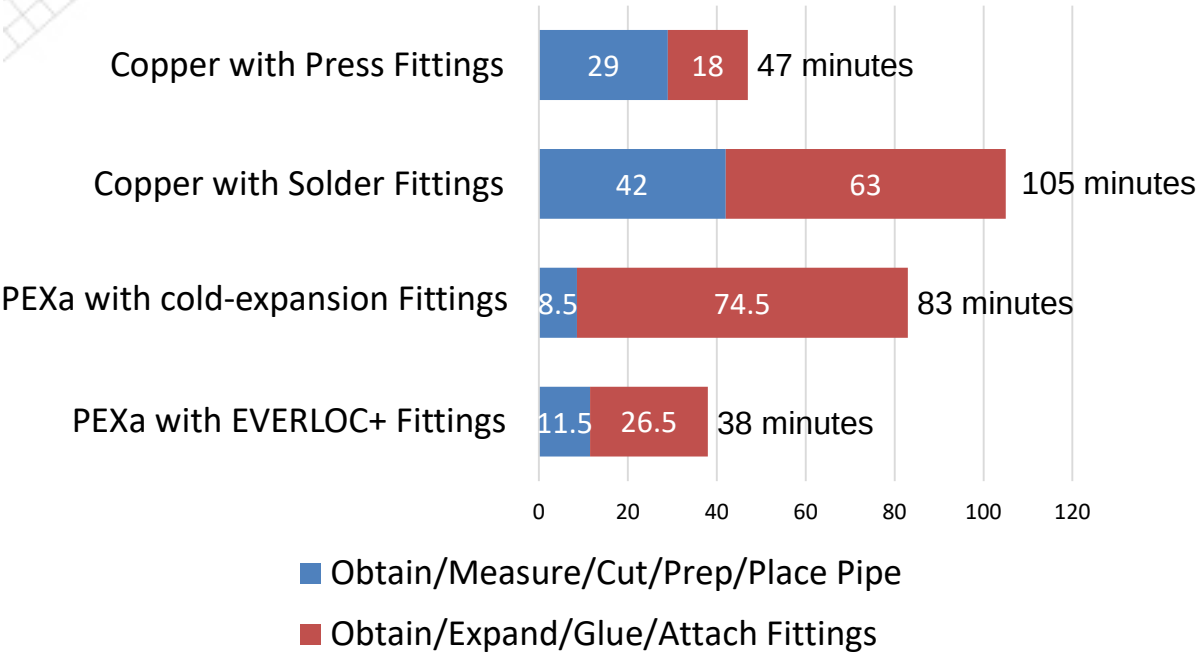
HALLWAY Productive Installation Time Summary*

Average Man-minutes for One 20 ft Hallway to Four Guest Suites



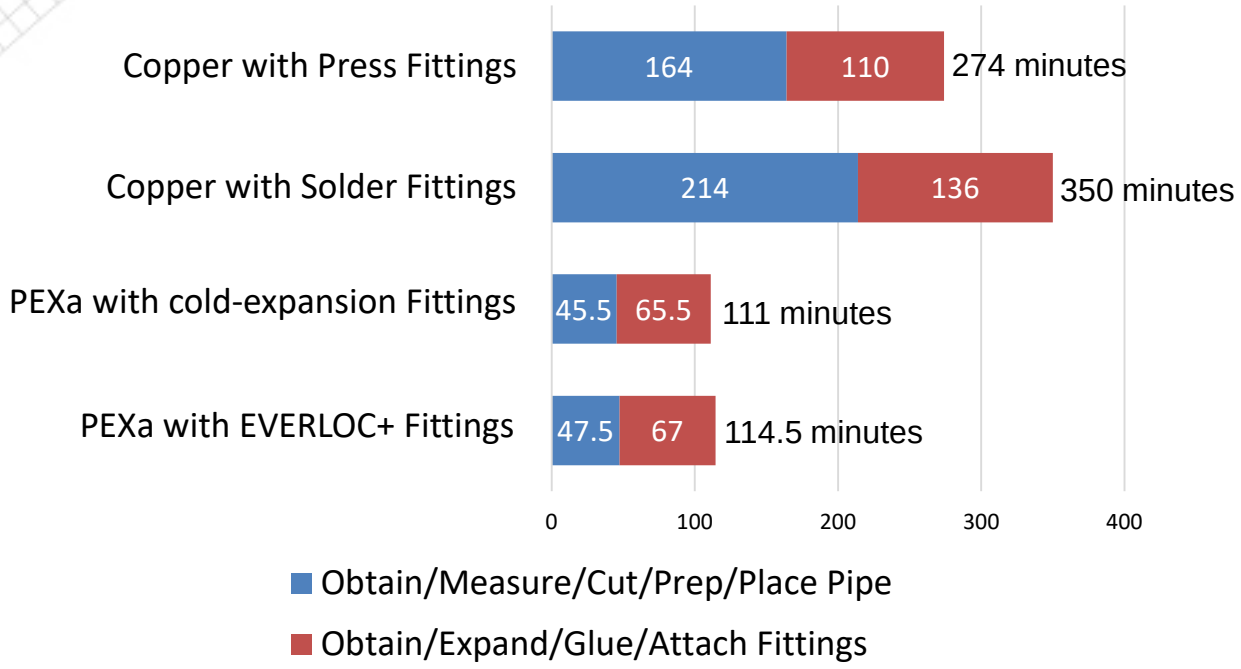
PEXa with EVERLOC+ was fastest in the hallway with large-diameter fittings. This fitting assembly was 3x faster than PEXa with cold expansion

Copper press fittings were next fastest. This press connection was more than 3x faster than copper with solder fittings.

*All pipe and fittings were 1 1/4 in. or larger

GUEST SUITE Productive Installation Time Summary*

Average Man-Minutes for Four Guest Suites



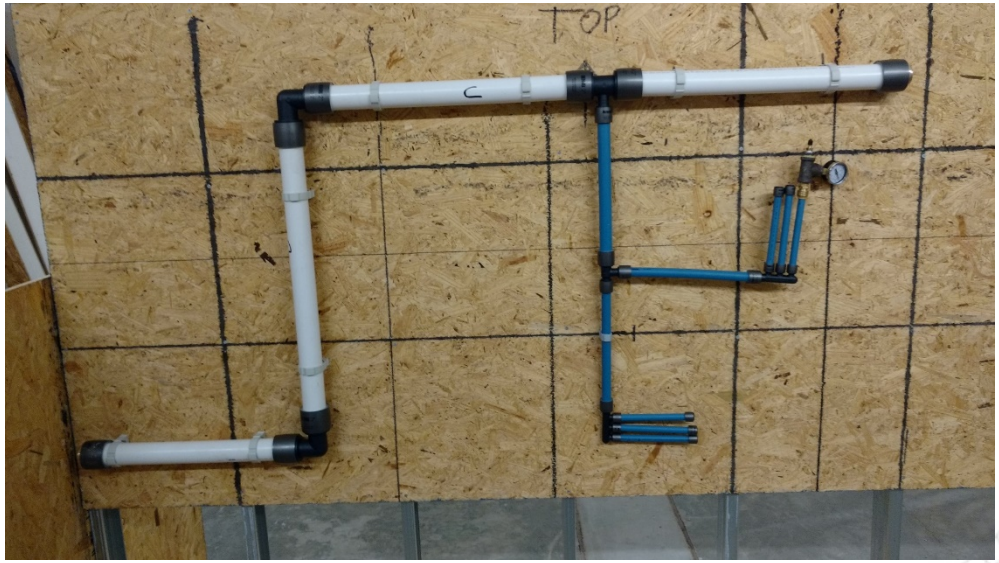
PEXa with cold expansion and PEXa with EVERLOC+ had virtually the same installation time for small-diameter piping. PEXa with cold expansion was slightly (~3%) faster.

Copper with press fittings still held an installation-time advantage over copper with solder fittings, but less than with large-diameter piping.

*All pipe and fittings were 1 in. and smaller

Cold-room Installation Time Comparison

- A fittings-only time comparison between EVERLOC+ fittings and cold-expansion fittings was done in a cold room at slightly above freezing (33°F)
- The purpose was to determine whether there was any additional installation-time savings for EVERLOC+ fittings in cold temperatures
- 25 connections of various-diameter fittings were made of both systems—pipe was cut prior to the cold room study so as to primarily focus on fitting assembly
- EVERLOC+ fittings were first
- Room, fittings and pre-cut plumbing piping was conditioned to 33°F
- After completing each, a pressure test was done



Cold-room Study

- This entire cold-room installation took 26 minutes for PEXa with cold-expansion fittings and 12 minutes for PEXa with EVERLOC+ fittings
- There was no difference in installation speed between EVERLOC+ fittings in the 70°F temperature versus in the 33°F temperature
- In contrast, the PEXa with cold-expansion fittings installation time increased from 0.81 to 1.08 minutes per fitting between normal and cold temperatures
- This time increase, if extrapolated to the entire mockup installation, would increase the PEXa with cold-expansion fitting installation time by 42 man-minutes
- Extrapolating the cold-room test, PEXa with EVERLOC+ fittings labor savings would increase from 21% to 35%

Fitting Attachment Time	**In 70°F** (in minutes)	**In 33°F** (in minutes)	**Δ**
PEXa with EVERLOC+	0.50	0.50	-
PEXa with cold-expansion	0.81	1.08	+35%

Cold-room Study (continued)

- When the cold room installation of each system was completed, the researchers conducted a 60 psi pressure test) on the piping 1) immediately and 2) at 10 minute intervals for first two hours
  - The EVERLOC+ fitting system immediately passed the pressure test
  - The cold-expansion fitting system failed the first test at several fittings
- Over the next 30 minutes, the PEXa with cold-expansion fittings continued to fail the pressure test, but with progressively fewer leaking fittings
- After the fourth test, all but one fitting had sealed
- Tests at the end of the first day and throughout the second day failed
- On the morning of the third day, after failing a pressure test, the piping was removed from the cold room to a room with 70°F
- Pressure tests failed from 6:30am until noon, but passed after 1:00pm
- An inspection of the leaking fitting showed that the pipe was not seated completely – it had come up about 3/16 in. short of the stops, which was an installer error

Post-installation Discussion w/ Installers: General Comments

- They lived and worked in Northern Virginia
- They had both started their plumbing careers with copper, but about 15 years ago, they switched primarily to CPVC
  - Materials they install now include CPVC, cast iron, copper, Corzan, PEX
- They occasionally install PEXa with cold-expansion fittings
- Both had extensive experience in single family, but in recent years, they were doing mostly multifamily projects
- When they begin a new condo project, they first lay out a unit by themselves, which takes a little time
- Each of the first few units takes about 10% longer than the remaining
- At the beginning of a job, they choose a room in a central area of a unit or floor, then put boxes of fittings in the room for easy access
- The setup for this study was similar to a typical job

Post-installation Discussion w/ Installers: Copper with Solder Fittings

- Their least favorite of the materials installed was copper with solder connections
  - It doesn't look as neat as other piping
  - Pipe gets hot to touch – need to cool it down with rag
  - Hot solder drops on things below including themselves
  - Flux gets on hands and makes pipe slippery
  - Greater security of jobsite needed so people don't steal it

Post-installation Discussion w/ Installers: Copper with Press Fittings

- Installers preferred copper with press fittings to copper with solder fittings
  - It was cleaner, faster and posed no fire hazard
  - They had one issue with press fittings: the pressing tends to re-direct pipe a little, and the direction was not predictable
  - It was hard to see press on smaller pipe to know that it has been done – as a result, they had two "blowouts" during the pressure test
  - It was hard to get the pressing tool into some tighter areas
  - Tool is heavy, and it can be tiring to work with
- They believe that installing any kind of copper piping is best done as two-man job – one to cut, prep and supply pipe and the other to join fittings

Post-installation Discussion w/ Installers: PEXa with EVERLOC+ Fittings

- Least concerned about long-term health with PEXa compared to other piping
- Liked PEXa in general because it had fewer fittings, was easier to keep them sorted and required less measuring/cutting/attaching
- Of the four systems, the plumbing installers stated they liked the REHAU RAUPEX PEXa with EVERLOC+ fittings best
- They believed using this plumbing system would result in the fastest installation times and they trust the fitting system is reliable
  - Expanding the pipe was easier with PEXa with EVERLOC+ than with the PEXa with cold-expansion
  - Compressing the sleeve actually pulled the pipe and fitting together, making it more snug and reducing the chance of not sealing the connection properly
- Also liked blue and red colors of the piping – less chance of making the mistake of crossing hot and cold water pipes
- EVERLOC+ tools were easy to handle and of very good quality
- Small-diameter tool was a good size; the large-diameter tool was a little heavy – but not to a point where they thought it would fatigue them

Post-installation Discussion w/ Installers: PEXa with Cold-expansion Fittings

- Liked this system, especially for small-diameter pipe (expansion was fairly easy, one step)
  - Had not used this before with large-diameter piping; it was hard to expand and battery capacity of the large expansion tool was too small
  - Single color tubing has advantages – less waste and hot/cold come from the same coil
- Didn't like the wait time for the material to shrink down onto the fitting after expanding – but it allowed them to twist/adjust pipe at the last second
- Sometimes after expanding pipe, it shrinks too quickly and it is hard to insert the fitting completely against the stops
- In the cold-room installations, they believed it took the same amount of times to expand the PEXa pipe for cold-expansion and PEXa with EVERLOC+ fittings
  - However, they reported with the cold-expansion, they had to hold the connections together longer waiting for piping to shrink back down, which increased installation time
- The 3/4 in. piping in a coil was more difficult to install than straight pipe because the piping's memory caused recoiling

Post-installation Discussion w/ Installers: Final Remarks

- They stated the short training time they received before the time study was sufficient
- Referring to using the assembly tool, they just need to "do it a couple times and that's all". For skilled plumbers, there's not much to explain
- When asked how much training they would think a plumber needs, they stated "about 30 minutes at the start of the first job"
- They would rather learn in the field than in classroom – training needs to be hands-on
- They thought the time study was a realistic study, reflective of the field with one exception:
  - They would need to install bracing and hangers in the field

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THANK YOU

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Total Piping Installation Time Details

in Man-minutes

COMBINED HALLWAY & GUESTROOMS	PEXa with EVERLOC+	PEXa with cold-expansion	Copper with solder	Copper with press
Setup of Tools, Equipment, Work Area	14.5	8	86	77
Obtain Pipe	12.5	10	22	17
Measure/Cut/Prepare Pipe	17	17	168	91
Place/Pull Pipe	29.5	27	66	85
Obtain/Prep fittings	14.5	12.5	46	26
Expand/Attach fittings	79	127.5	153	102
Wait Time for Coworker	0	0	37	13
Takedown/Cleanup of Jobsite	6	3.5	20	10
Stoppage/Breaks/Unrelated Activity	101.5	70.5	3	286
Re-work	6	1.5	2	4
Layout/Discussion	1	0.5	48	5
TOTAL PRODUCTIVE TIME	**152.5**	**194**	**455**	**321**

Hallway Piping Installation Time Details

in Man-minutes

HALLWAY	PEXa with EVERLOC+	PEXa with cold-expansion	Copper with solder	Copper with press
Setup of Tools, Equipment, Work Area	2	0.5	2	3
Obtain Pipe	0.5	1.5	2	1
Measure/Cut/Prepare Pipe	6	3	34	17
Place/Pull Pipe	5	4	6	11
Obtain/Prep fittings	2.5	1.5	20	2
Expand/Attach fittings	24	73	43	16
Wait Time for Coworker	0	0	15	7
Takedown/Cleanup of Jobsite	0	0	0	0
Stoppage/Breaks/Unrelated Activity	0	10	3	0
Re-work	2	0	0	0
Layout/Discussion	0	0	16	5
TOTAL PRODUCTIVE TIME	**38**	**83**	**105**	**47**

Guest Room Piping Installation Time Details

in Man-minutes

GUEST ROOMS	PEXa with EVERLOC+	PEXa with cold-expansion	Copper with solder	Copper with press
Setup of Tools, Equipment, Work Area	12.5	7.5	84	74
Obtain Pipe	12	8.5	20	16
Measure/Cut/Prepare Pipe	11	14	134	74
Place/Pull Pipe	24.5	23	60	74
Obtain/Prep fittings	12	11	26	24
Expand/Attach fittings	55	54.5	110	86
Wait Time for Coworker	0	0	22	6
Takedown/Cleanup of Jobsite	6	3.5	20	10
Stoppage/Breaks/Unrelated Activity	101.5	60.5	0	286
Re-work	4	1.5	2	4
Layout/Discussion	1	0.5	32	0
TOTAL PRODUCTIVE TIME	**114.5**	**111**	**350**	**274**