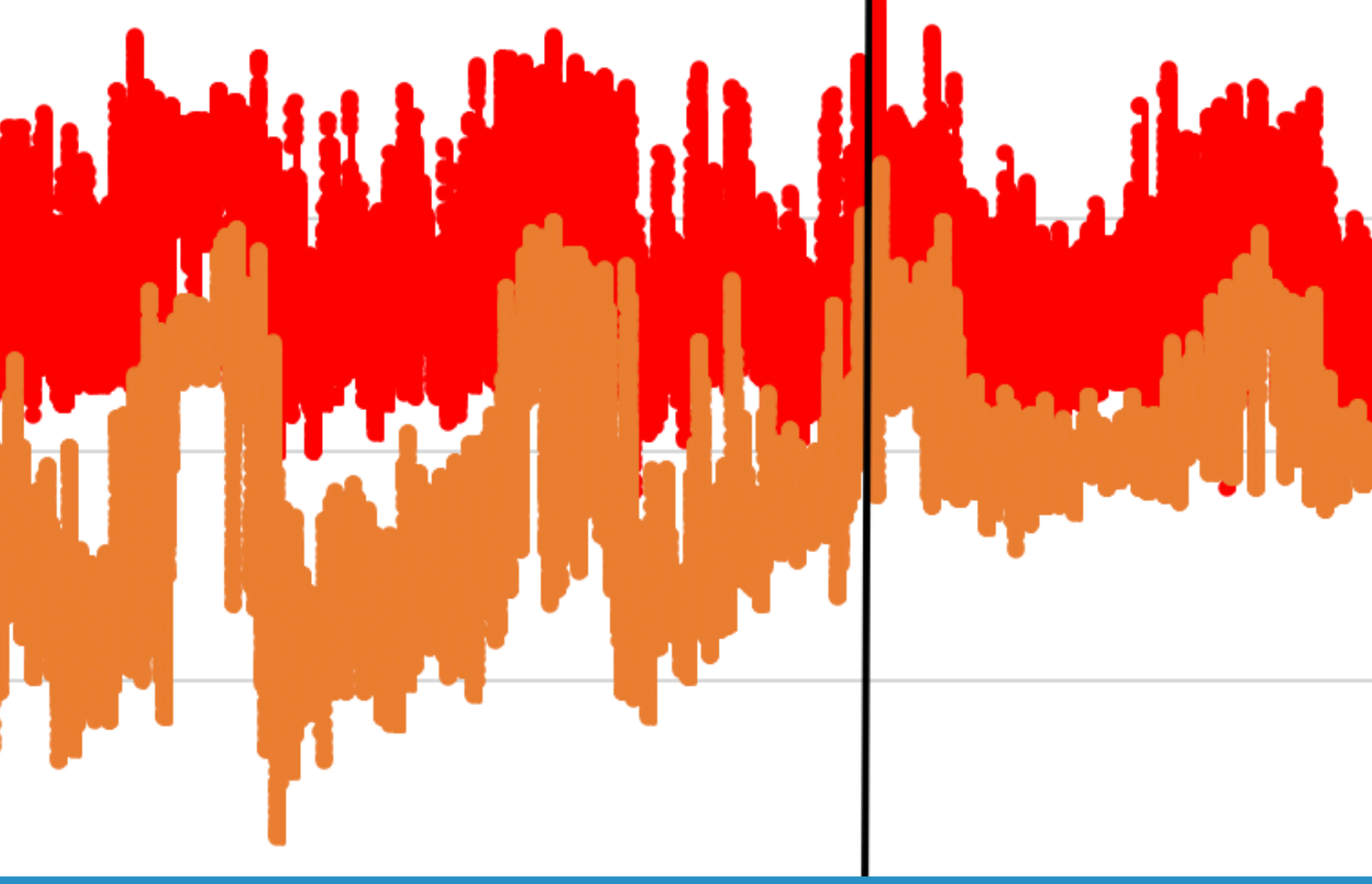


JUNE 2020

Crossover: Testing Solutions and Assessing Savings for Water and Energy in Low-Income Multifamily Affordable Housing

A report by the Association of Energy Affordability and the California Housing Partnership for the San Francisco Foundation

California Housing Partnership
California's Experts on Affordable Housing Finance, Advocacy & Policy

ASSOCIATION FOR ENERGY AFFORDABILITY INC.

CALIFORNIA HOUSING PARTNERSHIP

www.chpc.net

The California Housing Partnership creates and preserves affordable and sustainable homes for Californians with low incomes by providing expert financial and policy solutions to nonprofit and public partners. Since 1988, the Partnership's on-the-ground technical assistance, applied research, and legislative leadership has leveraged more than $20 billion in private and public financing to preserve and create more than 75,000 affordable homes. In 2010, the Partnership convened the Green Rental home Energy Efficiency Network (GREEN), with more than 50 nonprofit affordable housing organizations in California, to collaboratively increase access to climate, energy and water resources for affordable housing properties and residents. The Partnership works in coalition with Energy Efficiency For All (EEFA) California to advance energy equity programs and policies.

ASSOCIATION FOR ENERGY AFFORDABILITY Inc.

aea.us.org

The Association for Energy Affordability, Inc. is a 501(c)(3) not-for-profit organization dedicated to achieving energy efficiency in new and existing buildings in order to foster and maintain affordable and healthy housing for low-income communities. AEA representatives engage in a broad range of educational and technical services to promote this mission and develop the industry that advances and sustains it. The California Department of Community Services and Development selected the Association for Energy Affordability to implement the statewide Low-Income Weatherization Program for Multifamily Properties.

Report Contributors

Jack Aitchison, Association for Energy Affordability
John Neal, Association for Energy Affordability
Srinidhi Sampath Kumar, California Housing Partnership

Graphic Design: Christina Gotuaco, California Housing Partnership

This report is supported by a grant from the San Francisco Foundation. The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the San Francisco Foundation.

The authors also wish to thank Mercy Housing for being a champion in collaborating to address crossover issues and making two of their developments available as case studies.

Photographs courtesy of Mercy Housing.

TABLE OF CONTENTS

Photographs courtesy of Mercy Housing.

EXECUTIVE SUMMARY

JUNE 2020

Presentation Senior Apartments
Mercy Housing

Domestic hot water crossover has the potential of being a severe issue in all multifamily housing properties with central domestic hot water systems. Residents waiting longer for hot water leads to dissatisfaction, and water and energy waste. This also leaves property owners with higher utility bills and operating expenses. In addition to the water and energy waste, crossover prevents properties from upgrading to high efficient water heater systems and recirculation distribution control strategies.

Part I of this report is an owner-focused handout, which program implementers, owners, and advocacy groups can use to educate building owners, maintenance staff, and their service contractors regarding crossover issues that may be occurring in their properties. It also provides them with initial tools to investigate and repair most crossover issues.

Part II of this report will validate or update the recommended owner-focused investigation and repair strategies based on results from testing potential solutions in the two case study properties.* The case studies will also serve to uncover typical barriers encountered when performing crossover retrofits, and can serve to inform a broad coalition of industry stakeholders in crafting appropriate interventions.

The domestic hot water distribution issues encountered by the two case study buildings are pervasive across multifamily properties. Implementing preventive domestic hot water crossover measures in maintenance plans and during building rehabilitation projects needs to become standard practice for multifamily buildings. Resolving existing crossover issues and executing preventive maintenance is critical for California to meet its goal of decarbonizing existing buildings.[1]

Programs that incentivize central domestic hot water systems in new construction should also take into account the costs of preventing these crossover issues by installing appropriate equipment. Those incentivizing system upgrades in existing buildings should incorporate the identification and addressing of these crossover issues before the installation of newer systems. Contractors must be trained to perform commissioning work to eliminate the possibility of crossover issues in the property.

State policies must treat crossover as a barrier to both energy efficiency and decarbonization. Policies and programs should be designed in a way that address the upstream, midstream and downstream issues associated with crossover, as presented in this report. Funding should be made available for existing low-income multifamily properties to address this issue, where necessary, and track the costs and the methods used to identify and fix the issue. As the state is looking at its existing building stock to push California's climate goals forward, addressing such barriers should be given sufficient thought and consideration.

California State Capitol

**Implementation of the owner and professional investigation and repair plans for the two case study properties will be completed once the 2020 COVID-19 pandemic has subsided. The validity of the owner investigation and repair plans will be determined. An amendment will be made to this report, which will include a description of the effectiveness of the proposed owner investigation and repair plans, and tracking of the utility benchmarking data to quantify the effect of the repairs.*

[1] CA has 25 years to be carbon neutral by 2045 (EO B-55-18), which will mean electrification of nearly every building and Assembly Bill (AB) 3232 (Friedman, Chapter 373, Statutes of 2018) which requires the CEC to prepare Building decarbonization Assessment for existing buildings.

PART I

CROSSOVER DIAGNOSIS AND REPAIR FOR BUILDING OWNERS

INTRODUCTION

Central domestic hot water systems have hot and cold-water pipes that are connected at specific locations – for example, shower mixing valves where hot and cold water are mixed at point of use. Crossover in plumbing systems typically occurs when valves fail or leak and water mixes between a building's hot and cold water pipes, with hot water entering the cold pipes or cold water entering the hot pipes. Symptoms of crossover include:

- Hot water coming out of cold water taps or vice versa
- Longer than expected wait times for hot water
- Water that never gets sufficiently hot
- Unexpected water temperature fluctuations (user experiences "plugs" of cold or hot water)
- Unpredictable hot water availability

Crossover has presented a significant issue for tenant comfort, energy efficiency, and the reduction of greenhouse gas emissions (GHG) in multifamily housing in California. It is a prevalent issue in multifamily buildings with central Domestic Hot Water (DHW) systems with recirculation of all ages and sizes. In a study commissioned by the California Energy Commission (CEC)[2], of the approximately 100 multifamily buildings in which crossover detection methods were tested, about 50% of multifamily buildings tested positive for the issue. Often crossover leads to increased energy bills, high water use, and resident discomfort. Identifying the source of crossover is a crucial step to containing the issue, leading to significant savings in energy and water. In the same CEC study, repairing crossover resulted in an average natural gas savings of 16% from the baseline natural gas usage of the water heating system.

This report summarizes relevant crossover information for multifamily building owners, presents a targeted crossover investigation and repair strategy for those owners, and as a case study, applies this strategy on two affordable multifamily properties with known crossover issues.

A subsequent addendum to this report is anticipated after repairs at the case study locations have been completed.

[2] Ayala, Gabriel, Derek Zobrist (Enovative Group, Inc.). 2017. *Crossover Study for Multifamily Buildings.* California Energy Commission. Publication Number: CEC-XXX-2017-XXX.

MISDIAGNOSIS OF CROSSOVER

Crossover issues are often misdiagnosed, leading to solutions that are expensive and do not address the issue.

Table 1. Common types of misdiagnosis are described below.

Common Misdiagnosis	Result
Set point too low	• Property maintenance team increases water heater set point – increasing the set point dilutes the impact from cold water entering hot water lines which helps mask the symptoms of crossover. • Increases water heating cost. • Increases risk of scalding.
Recirculation pump needs to run constantly	• Property maintenance team overrides recirculation pump controls to make recirculation pump run continuously – this also dilutes the impact from cold water entering the hot water lines. • Increases water heating cost.
Recirculation pump too small	• Property maintenance team installs larger pump – this often exacerbates crossover issues by creating even larger pressure differences between the cold and hot water piping forcing more crossover to occur. • Increases utility cost. • Increases piping wear and tear.
Undersized water heater	• Property maintenance team installs larger water heater – no impact.
Repairing the wrong plumbing fixture(s)	• Property maintenance team repairs a plumbing fixture in the apartment with the comfort complaint (that hot water is coming out of the cold tap or vice versa) but the source of the crossover is actually located upstream. • Lack of success in repair leads staff to believe issue is another problem from this list – no progress made.
Water leak or faulty water meter	• Causes the expense of looking for a water leak that does not exist or fixing a water meter which is working properly.

OWNER IDENTIFICATION AND REPAIR STRATEGIES

Despite the numerous operational issues and common misdiagnosis, options do exist to help proactive building owners locate and correct crossover. This section discusses options for first-tier investigation and repair strategies that can be pursued by an owner and their staff.

A) Building-Wide Investigation and Repair Strategies

Table 2. Outlines building-wide and common area investigation and repair strategies, which can be significant contributors to crossover.

Location	Investigation Strategy	Conclusion/Repair
Building-Wide	Tenant surveys inquiring on domestic hot water delivery issues. A sample tenant survey can be found in the Appendix of this report.	Tenant surveys can help inform the owner if crossover is occurring in a specific unit stack or wing of a building based on which tenants are experiencing crossover issues.
	Look for unintentional hot and cold plumbing cross connections (Figure 1).	Repair unintentional hot and cold plumbing cross connections and determine if it fixed the crossover by redistributing the tenant surveys.
Boiler Room	Confirm functioning check valve is located on recirculation line prior to connection to water heating plant or cold water makeup line to plant. Test noninvasively by turning off the pump and feeling the pipe upstream. Does it get cooler within a few minutes? This could mean cold water moving backwards through the return line.	Install check valve on recirculation line to eliminate the potential of cold water moving backwards through the recirculation line.
Laundry Room	Investigate whether internal washing machine shut off water valves have failed, allowing hot to enter cold line or vice versa. Touch the hoses behind the washing unit and if the cold line is hot or hot line is colder than ambient temperatures, then the shut off water valves have failed.	Replace or repair washing machines.
Janitor/Mop Sinks	Confirm no pause valves have been installed at the end of the faucet on janitor sinks (allows hot and cold to mix through fixture).	Remove pause valve.

Figure 1. Example of a source of crossover found in a laundry room. The hose was used to temporarily solve a leaking hose bib issue but in practice allowed a cross connection to be made between the cold and hot lines of the building. By touching both valves and testing their temperatures, it was confirmed that hot water was entering the cold plumbing line and contributing to the crossover issues in the building.

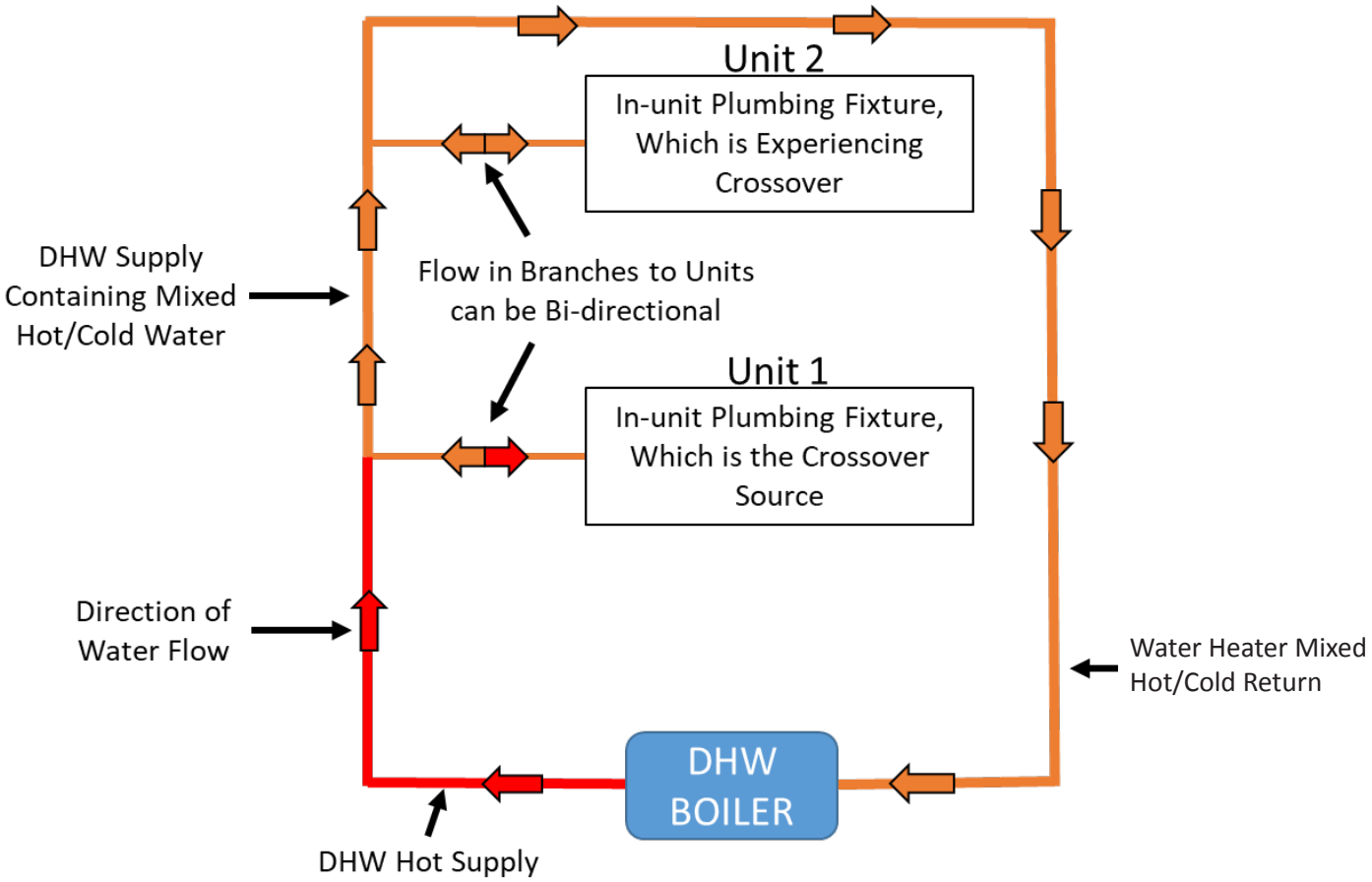
OWNER IDENTIFICATION AND REPAIR STRATEGIES

B) In-unit Investigation and Repair Strategies

In-unit investigation strategies can help identify systemic sources of crossover, which can lead to repairs to fixtures in each dwelling unit. Similar to tenant surveys, in-unit crossover investigation can inform the location of crossover sources. **It is a common misconception that locations in the building experiencing crossover symptoms are also the source of crossover issues.**

Figure 2 below illustrates this. Unit 2 is suffering from a lack of hot water which is a result of a failed fixture upstream in unit 1 that is allowing cold water to bleed into the hot water line. At the same time, unit 1 is still able to receive acceptable hot water and does not have any complaints. Contrary to this, if an apartment has trouble getting hot water at a specific fixture and there are no other signs of crossover at the property, the repair may be limited to fixing that specific fixture only.

Figure 2. Shows an example DHW distribution for two dwelling units and illustrates how a unit which is experiencing crossover is typically not the source of the issue.



OWNER IDENTIFICATION AND REPAIR STRATEGIES

Table 3. In-unit Investigation and Repair Strategies. Details of investigation strategies can be found below.

Location	Investigation Strategy	Conclusion/Repair
Unit-Wide	Single-handle fixtures are the primary concern for investigating crossover in dwelling units because they have internal mixing cartridges. If these cartridges fail, hot and cold water may mix unintentionally. Identify the following conditions to determine if a mixing cartridge has failed: • Leaky single-handle fixtures or shower valves • Hard to turn single-handle fixtures or shower valves	Replace mixing cartridge or rebuild with new seals (or change fixture). Single-handle faucet mixing cartridges can be replaced with the same or newer model of the existing cartridge. Shower valve mixing cartridge replacements are show in Table 5.
	In-Unit Time to Temperature Testing: An owner can better understand DHW distribution issues in their building by measuring the time it takes for hot water to be delivered to a representative sample of units. Detailed step by step instructions for in-unit time to temperature testing can be found in the section below.	If time to temperature values vary drastically or if a particular group of units doesn't reach the temperature desired within the expected wait time (Table 4), then crossover or another DHW distribution issue is likely occurring in the building or that stack of units.
Kitchen	Portable dishwashers and washing machines connected by residents to faucets.	Remove portable dishwashers from unit. Educate tenant on issues portable dishwashers can cause to DHW distribution system.
	Confirm no pause valves have been installed on faucets.	Remove pause valves or replace faucet. Educate tenant on issues pause valve can cause to DHW distribution system.
Shower	***Identifying Crossover Susceptible Shower Cartridges:*** Shower cartridges are the most prone to being a significant source of crossover. Table 5 lists common shower valve and cartridge types and whether they are known to be susceptible to crossover. Single-handle shower valves have not been routinely maintained or replaced every 3-5 years may be susceptible.	If the shower cartridge types have been identified as susceptible to crossover or the shower valves had not been routinely replaced then it is recommended that the owner replace all shower cartridges at the property with their recommended replacements (Table 5). Start with a single stack of units and monitor if the crossover condition improves for those units. If so, replace all shower cartridges in the building.

OWNER IDENTIFICATION AND REPAIR STRATEGIES

In-Unit Time to Temperature Testing

The following outlines a methodology for in-unit time to temperature testing:

1. Select a few hot water risers/branches and test the bottom, middle, and top unit.
2. Include risers/units with known issues and those without known issues.
3. Estimate the pipe length from the plumbing fixture to the recirculated hot water supply/riser.
4. Using a stopwatch and a thermometer, record the time it takes for the water to reach a certain temperature at the same fixture in each apartment (e.g.: time to reach 110 degrees at the showerhead or kitchen faucet).
5. Refer to Table 4 to determine if measured time to receive hot water is reasonable.
6. Confirm resident hasn't used hot water in past hour to ensure lines are not already hot.

Table 4. Outlines reasonable times to get hot water with varying pipe lengths. (Assumed 1/2 - 3/4 inch diameter piping and 1.5 GPM to 2.0 GPM fixture flow rates.)

Distance from Hot Water Supply/Riser (ft.)	Expected Hot Water Delivery Time (sec)
5'	5 - 30 sec
10'	10 - 60 sec
15'	20 - 100 sec

Identifying Crossover Susceptible Shower Cartridges

The majority of shower valves have their brand printed either below the handle or directly on top. Figure 3 is an example of a Moen shower valve.

Table 5. Lists different shower valve types, whether they are more susceptible to crossover and their recommended replacements. Note that all shower valves are susceptible to crossover if they have not been maintained or replaced every 3-5 years.

Shower Valve Types	Shower Cartridge Model	More Susceptible to Crossover?	Recommended Replacement
Moen	**Moen 1200**	**Yes**	Moen 1225 or NoMix Cartridge
Mixet	**All**	**Yes**	NoMix Cartridge
Delta	**All**	**No**	Same or Newer Version of Existing Cartridge
Pfister	**All**	**No**	Same or Newer Version of Existing Cartridge
American Standard	**All**	**No**	Same or Newer Version of Existing Cartridge
Kohler	**All**	**No**	Same or Newer Version of Existing Cartridge

Figure 3. Moen Push/Pull shower valve containing a Moen 1200 cartridge. Unless the cartridge has been replaced with a Moen 1225 cartridge, it can be assumed all Moen shower valves contain Moen 1200 cartridges.

OWNER IDENTIFICATION AND REPAIR STRATEGIES

C) Professional Crossover Testing Methods

If the first-tier testing and investigation strategy described in the previous section are too burdensome or yield inconclusive results, more advanced professional diagnostic tests are available. Quantitative testing methods for crossover that professionals can perform are listed in Table 3 (CEC).[3] Each of these methods require some specialty equipment or should be performed by trained professionals. Various options are available and are often used in combination. The best method (or methods) for a given property depends on a combination of factors, including a property's design, budget, and findings during occupant surveys or visual inspections.

Table 6. Professional Qualitative Crossover Testing Procedures

Testing Method	Description
Pressure Gauge Test	The Pressure Gauge Test is building-wide test which isolates the hot water side of a DHW distribution system and depressurizes it. Since the hot water lines are isolated, the only way pressure can build back up is if crossover is occurring through the cold lines.
Water Flow Test	Water Flow Tests can be a building-wide test but are typically performed in a unit or on a small distribution system. The hot water side of a distribution system is isolated and hot water is drained from a nearby faucet or hose spout. If cold water begins to flow out of the faucet or hose spout then crossover is occurring.
Etherton Test	The Etherton Test is a fixture level test, where a mixing cartridge on a fixture is exposed. The hot water distribution is isolated and hot water is drained from a nearby faucet. If the exposed mixing cartridge becomes cold as hot water is draining from the nearby faucet, then the mixing cartridge is a source of crossover.
Temperature Data Logging Test	The Temperature Data Logging Test deploys temperature data loggers throughout a DHW distribution system. If the temperature data shows unexpected fluctuations in temperature or cold water slugs in the distribution system, then crossover is occurring in the building.
Janitor/Mop Sinks	Confirm no pause valves have been installed at the end of the faucet on janitor sinks (allows hot and cold to mix through fixture).

[3] Ayala, Gabriel, Derek Zobrist (Enovative Group, Inc.). 2017. *Crossover Study for Multifamily Buildings.* California Energy Commission. Publication Number: CEC-XXX-2017-XXX.

OTHER COMMON CAUSES OF DOMESTIC HOT WATER DELIVERY COMPLAINTS

There are several other DHW distribution issues, which cause similar hot water delivery complaints as crossover. These include:

- **Distribution heat losses:** Large distribution heat losses from uninsulated piping and underground piping can result in lower delivered water temperatures and longer wait times. Have maintenance check for uninsulated piping in the crawlspace, attic, or risers and verify there is no underground DHW piping.
- **Low flow fixture retrofits:** Low flow fixtures may increase wait times for hot water delivery due to constricted flow throughout the system. The wait times for hot water delivery should still fall within the expected wait times in Table 4.
- **Domestic hot water distribution imbalance:** Varying lengths of recirculation zones and risers in a DHW distribution system will cause longer hot water wait times, specifically in units farthest from the main DHW distribution and return lines. Time to temperature measurements should be taken throughout the building. If wait times for hot water exceed the ranges outlined in Table 4, water temperatures vary greater than 5°F in different building locations, and there is no uninsulated or underground piping, then the distribution system is likely imbalanced.

PART II

CASE STUDIES: CROSSOVER INVESTIGATION AND TESTING

Crossover investigation and repairs outlined in **Owner Identification and Repair Strategies** will be performed on two case study properties in conjunction with the **Professional Comprehensive Crossover Investigation Methodology** outlined in this section:

1. Professional Comprehensive Crossover Investigation Methodology
2. Case Studies Introduction
3. Benchmarking
4. Presentation Senior Crossover Investigation and Repair Plan
5. Padre Apartments Crossover Investigation and Repair Plan

The goal of these case studies is to validate the effectiveness of the Owner Identification and Repair Strategies that owners and maintenance staff can complete, and update those recommendations if needed based on results.

Amendments are anticipated to be made to the Owner Identification and Repair Strategies section in this report after the investigation and repairs have been implemented, in addition to documenting the effect the repairs had on energy use and tenant comfort at the case study properties, given the properties pursue the recommended repairs.

1) PROFESSIONAL COMPREHENSIVE CROSSOVER INVESTIGATION METHODOLOGY

1. **Perform recommended owner tests/investigation noted earlier.**
2. **If possible, perform a building-wide pressure gauge test to verify crossover is prevalent and determine its severity – false negatives for crossover are possible with this test.**
3. **Review the building plans (where available) and survey the property to:**
   - a) Create a list of typical plumbing cross connections including in-unit and common fixtures and appliances and boiler room connections which are potential sources of crossover.
   - b) Understand potential for distribution issues other than crossover (long piping runs, uninsulated piping, etc).
4. **Deploy temperature data loggers on representative piping locations at the property to monitor water temperature upstream and downstream of plumbing cross connections.**
   - a) Select risers/wings that have known issues and those that do not have known issues (control group).
   - b) Monitor a DHW distribution riser's supply line before the first connected unit and after the last connected unit before connection to the building return line to determine if in-unit plumbing cross connections are sources of crossover issues.

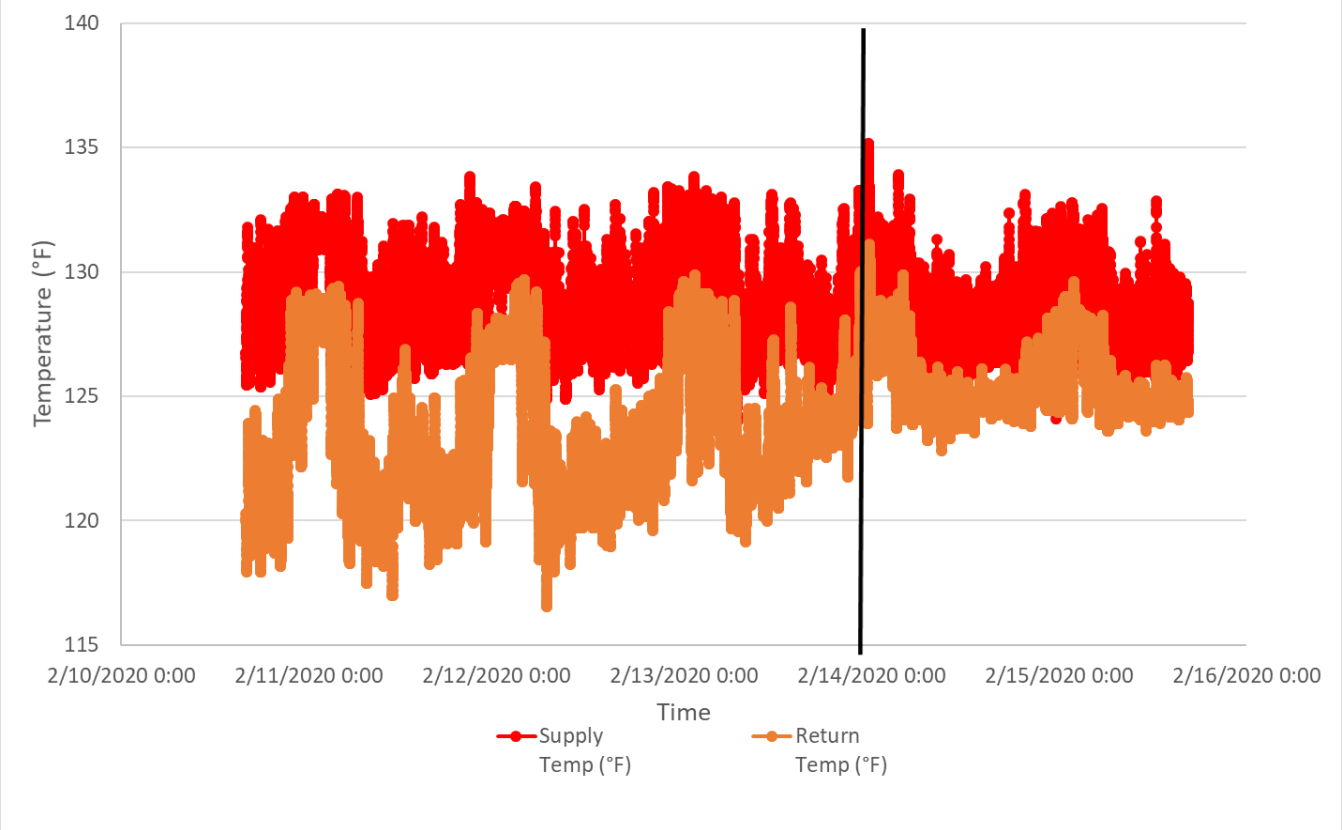
Figure 4. Temperature Data Logger Monitoring a Return Riser

5. **Interpret temperature data:**
   - a) The more granular the data is, the easier it is to interpret (10 second interval recommended).
   - b) Hypothesize locations where crossover is occurring and which plumbing cross connection types are in those locations.
   - c) Confirm the presence of crossover by comparing supply water temperatures upstream of plumbing cross connections and return water temperatures downstream of the plumbing cross connections.
     - If temperature differences are greater than what would be anticipated from conductive heat losses through the pipe, or return water temperatures are showing evidence of cold water slugs in the return, then crossover is present.
   - d) Confirm the presence of DHW distribution imbalance by comparing DHW supply pipe water temperatures, which are close to the main supply line to supply pipe water temperatures, which are far from the main supply line.
     - If the water temperature of the supply line, which is further from the main supply is significantly ($\Delta T \geq 5°F$) colder than the supply line close to the main supply, then DHW imbalance is present.

1) PROFESSIONAL COMPREHENSIVE CROSSOVER INVESTIGATION METHODOLOGY

Figure 5 is an example of temperature logger data from a property that implemented the strategy outlined above. The deployed temperature data loggers captured an existing source of crossover and continued to record temperatures after the crossover issue was repaired. The data presented includes the main supply temperature and the main return temperature for a period of one week at 10 second intervals. The black line indicates the day the crossover repairs were fully completed. There is a definitive difference between the temperature ranges pre and post crossover repairs. Prior to the crossover repairs, the return line fluctuates in temperature dramatically, while the supply fluctuates, but not to the same extent. This variation between supply and return temperature ranges is attributed to crossover, and the reduction in variation is due to repair of cross connections.

Figure 5. Main supply and main return water temperatures over a week-long period.



2) CASE STUDIES INTRODUCTION

Two Mercy Housing multifamily properties were chosen as case studies for crossover investigations and repairs: **Presentation Senior** and **Padre Apartments**. Both properties were chosen because of known crossover issues and their recent participation in an energy efficiency program. The properties were having trouble maintaining adequate hot water delivery due to crossover and/or distribution imbalance. Unfortunately, access to the properties was restricted in 2020 due to the COVID-19 pandemic. Once it is safe to do so, the investigation, testing, and desired repair plans outlined in this report may be pursued as recommended, given which repair costs are feasible for the owner. An amendment will be made to the report with updated findings.

Mercy Housing is a national affordable housing developer and manager with a large portfolio of affordable, sustainable buildings in California. Mercy Housing has conducted deep energy retrofits in several of its existing properties in California. While completing deep energy retrofits in six of the properties, Mercy Housing found that four of the six properties had moderate to severe crossover (including Presentation Senior and Padre Apartments).

With resident complaints about not getting adequate hot water, Mercy Housing management staff turned up the outlet temperature coming out of the hot water heating system or bypassed recirculation pump controls to mask the issue. This had the net effect of undoing most of the energy savings related to the hot water heating system improvements that were made at some of the sites and suppressing savings at others. The barriers Mercy has encountered to fix these issues have been: uncertainty in the repair solution(s) proposed to date, availability of contractors to bid on repairs, and additional cost burden to the property.

2) CASE STUDIES INTRODUCTION

Presentation Senior

Presentation Senior is a six-story, 93-unit low-income senior facility constructed in 2001 and located in San Francisco. As part of its enrollment in an energy efficiency program, the property installed a central Heat Pump Water Heating system (HPWH), a domestic hot water recirculation pump demand controller, and low flow fixtures. Pre-existing crossover and imbalance issues became apparent after the upgrades were completed, and the HPWH and demand controller have been bypassed until distribution issues can be resolved. Some residents have also removed the new low flow aerators and showerheads. Since the issue was first identified, a building-wide pressure gauge crossover test was performed (by Bright Power, installing contractor) which has confirmed a severe crossover issue exists.

Figure 6. Presentation Senior Apartments

Padre Apartments

Padre Apartments is a low-income multifamily building mostly accommodating families. Built in 1928, the seven-story apartment complex has several similarities with Presentation Senior, including its location in San Francisco, its recent participation in an energy efficiency program including a similar scope of work to Presentation Senior, and signs of crossover and potential imbalance issues.

A building-wide pressure gauge test performed by Bright Power was conducted and the results were inconclusive due to a missing check valve on the recirculation pump, which could potentially be contributing to the crossover issues experienced at the property. Additional qualitative evidence of crossover was observed at the property including the presence of known “bad” mixet shower valves in one wing of the building, and evidence showing an increase in water consumption after efficiency measures were implemented. The building’s heat pump water heater is still providing all domestic hot water needs and there are no active complaints from residents.

Figure 7. Padre Apartments

3) BENCHMARKING

Benchmarking refers to tracking the utility data of a property over time and using that data to compare a property against its own past performance or the performance of peer properties. It is a useful practice to ensure that energy conservation measures installed at a property are performing properly.

Presentation Senior

Figure 8. Presentation Senior Benchmarking Data

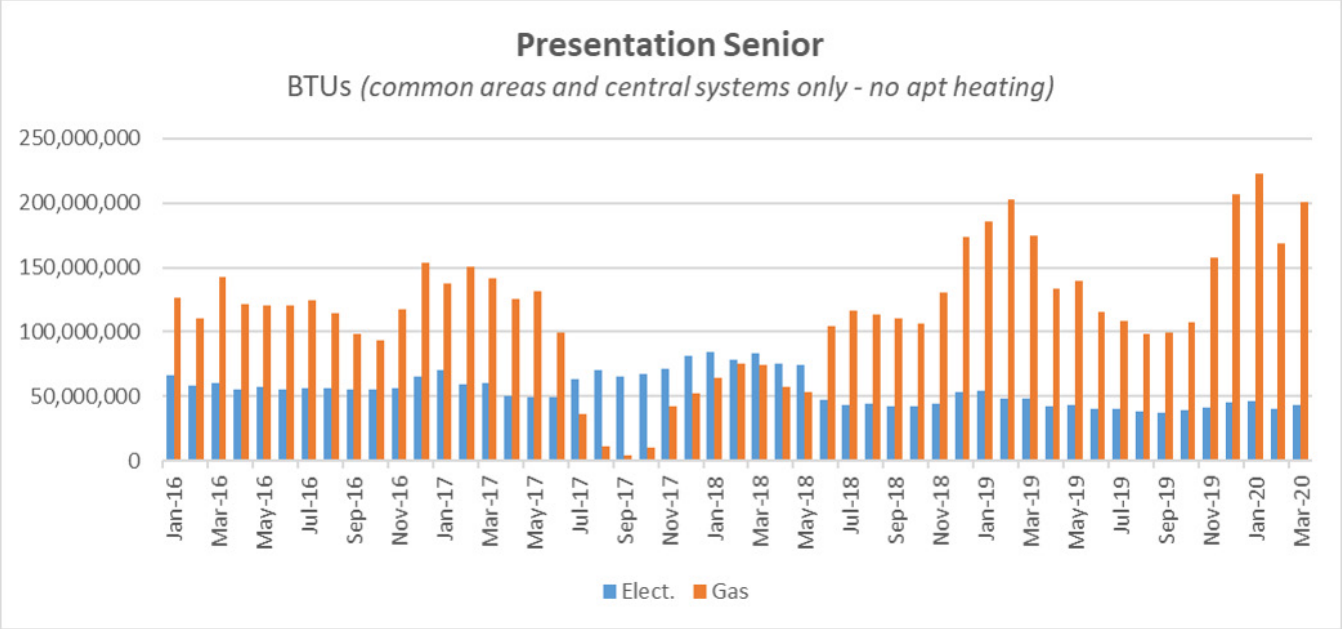


Figure 8 shows the benchmarking data for Presentation Senior from January 2016 to March 2020. Common area electricity use is in blue and common area gas use is in orange. Prior to the electric HPWH installation, the main commodity on the common area electrical meter was the exterior and common area lighting. The common area gas usage at the property is primarily the existing gas water heaters, which were replaced by electric heat pump water heaters in July 2017. Due to the severity of the crossover issues, the heat pump water heaters were turned off and the gas water heaters were turned back on fully in July of 2018 (estimated) to provide domestic hot water to the property. August, September, and October of 2017 are good representations of what the monthly gas and electrical usage should be at the property if the crossover was identified and repaired prior to the installation of the heat pump water heaters and demand controller.

3) BENCHMARKING

Padre Apartments

Figure 9. Padre Apartments Benchmarking Data

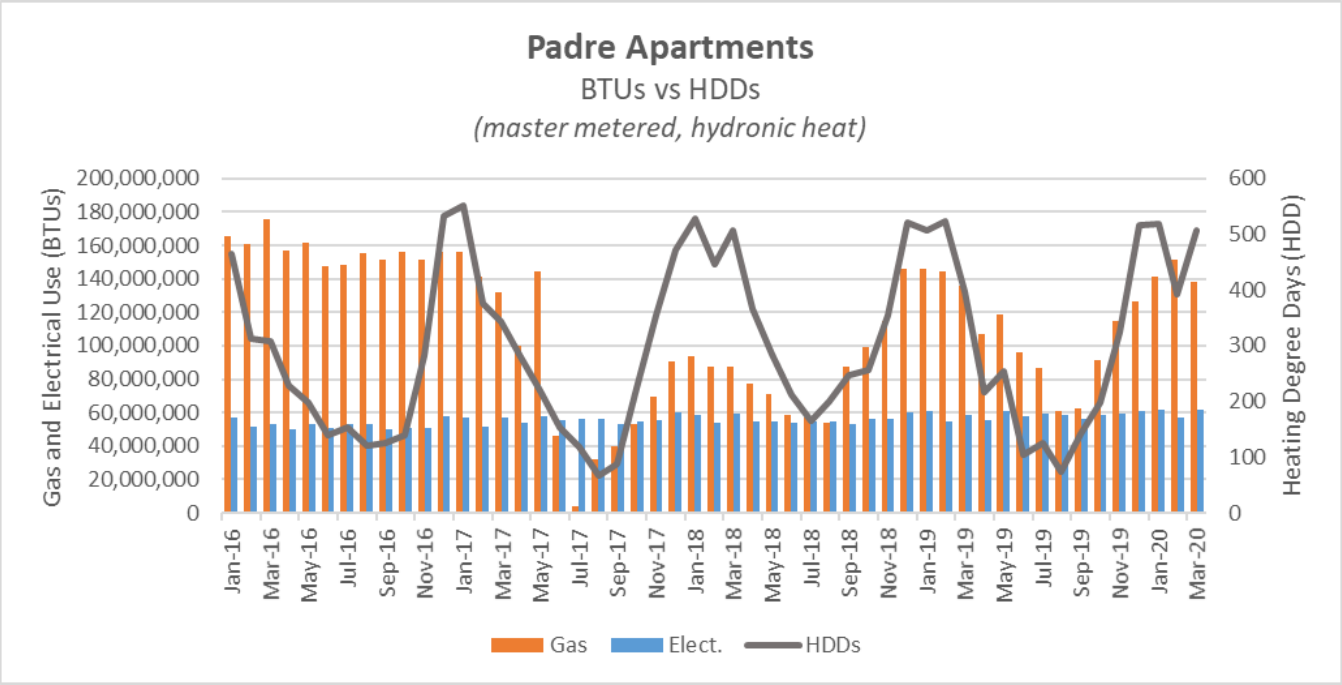


Figure 9 shows the benchmarking data for Padre Apartments from January 2016 to March 2020. Unlike Presentation Senior, Padre Apartments is a master metered building, meaning this benchmarking data reflects the whole building's energy use. Similar to Presentation Senior's benchmarking data, orange represents gas usage and blue represents electrical usage. The gas master meter includes the hydronic (space heating) hot water boiler and the existing central DHW gas boiler. The electric master meter includes all in-unit plug loads, lighting (in-unit and common area) and the new heat pump water heaters that were installed in July 2017. Since Padre Apartments is master metered, it is important to note the gray line, which represents the heating degree days (right axis) which is a measurement used to help quantify how much heating energy will be required throughout the year. Heating degree days is an important consideration when looking at Figure 8 because the space heating boiler is on the gas meter. As the heating degree day value goes up, the gas usage for space heating should also rise. November 2018 through May 2019 illustrate this.

The effect of the heating hot water efficiency measures shows a reduction of gas usage overall and specifically in the summer months when the space heating boiler's usage is significantly reduced. The space heating efficiency measures made a large impact from July 2017 through the July 2018. However, gas usage has begun to increase potentially because some of the space heating efficiency measures have been overridden.

4) PRESENTATION SENIOR: CROSSOVER INVESTIGATION AND REPAIR PLAN

The following section outlines the Owner Identification and Repair Strategies and the Professional Comprehensive Crossover Investigation Methodology, which will be applied at Presentation Senior. The two testing and investigation strategies will be compared to determine the validity of the owner testing and investigation strategies. Expected repair recommendations based on anticipated results of both testing methodologies are listed in Table 9 further below. Table 9 will be updated once both testing and investigation strategies are completed.

Owner Testing and Investigation Strategies

Table 7. Describes the partially completed owner testing and investigation strategies which have been completed as well as recommended future tasks to complete the investigation strategy.

Test/ Investigation	Known Information	Plausibility to be a Source of Crossover	Future Task
Identified In-unit Plumbing Cross Connections	Single-handle kitchen (Figure 10) • Cartridge Model: Unknown • Pause Button: Unknown	High if pause button present, low otherwise	Investigate cartridge model and presence of pause buttons
	Single-handle bathroom faucets (Figure 11) • Cartridge Model: Unknown	Low	Investigate cartridge model
	Single-handle Shower Valves (Figure 12) • Cartridge Model: Unknown	High	Investigate cartridge model
Identified Common Area Plumbing Cross Connections	Mop Sinks Located on Each Floor • Pause Button: Unknown	High if pause button present, low otherwise	Investigate presence of pause buttons
	Domestic Hot Water Mixing Valve • Failure: Unknown	Medium	Investigate if mixing valve has failed
	Laundry Sinks • Pause Button: Unknown	High if pause button present, low otherwise	Investigate presence of pause buttons
	Laundry Clothes Washing Machines • Presence of Failed Internal Shutoff Valves: Unknown	High if failed internal shutoff valves are present, low otherwise	Investigate presence of failed internal shutoff valves

Figure 10. Presentation Senior Single Handle Kitchen Faucet

Figure 11. Presentation Senior Single Handle Bathroom Faucet

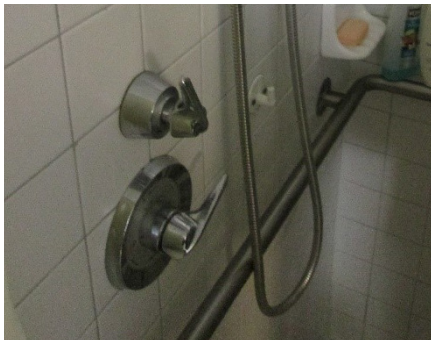


Figure 12. Presentation Senior Shower Valve

4) PRESENTATION SENIOR: CROSSOVER INVESTIGATION AND REPAIR PLAN

The following is a list of owner testing and investigation strategies, which have yet to be performed at Presentation Senior:

- Tenant Survey
- Investigation of unintentional hot and cold plumbing cross connections (Figure 1)
- Confirm functioning check valves in the boiler room
- Identify in-unit leaky or hard to turn single-handle fixtures
- Identify in-unit portable dishwashers

Professional Comprehensive Crossover Investigation Methodology

Table 8. Completed or Partially Completed Professional Crossover Testing and Investigation Strategies at Presentation Senior

Test/Investigation	Known Information	Future Task
Building-Wide Pressure Gauge Test	Crossover test showed signs of severe crossover	N/A
DHW Temperature Data Monitoring Plan	There are 30 domestic hot water risers. Some risers serve a variety of fixtures types while others serve one fixture type.	Data loggers will be installed on the supply and return of representative risers and will be installed upstream and downstream of plumbing cross connections. Prioritize risers that contain plumbing cross connections, which are more likely to be a source of crossover.
Interpretation of the temperature logger data	N/A	Supply temperatures will be compared to return temperatures to determine the presence of crossover. If a riser is hypothesized as not experiencing crossover is can be used as a control to compare to other risers.

Recommended Crossover Repairs Based on Hypothesized Results of Both Testing and Investigation Methods

Correctly interpreting the results of the owner investigation strategies and the temperature data from the professional investigation strategies will eliminate some of the possible sources of crossover listed in Table 7 and help develop a targeted plan for fixing the source of the issue. Table 9 lists example recommendations dependent on the results of both the owner and professional investigation and testing methods.

4) PRESENTATION SENIOR: CROSSOVER INVESTIGATION AND REPAIR PLAN

Table 9. Presentation Senior Crossover Repair Recommendations

Proven Source of Crossover	Recommended Repair
Shower Cartridges	If the crossover investigation suggests that risers which serve in-unit showers are showing signs of crossover and the cartridges have either not been frequently replaced(every 3-5 years) or are known to be susceptible to crossover then the shower cartridges should be replaced with newer versions of the same brand or a version of that cartridge that is known to be less susceptible to crossover (Table 5).
Mop Sinks	If the DHW risers, which serve the mop sinks show signs of crossover in the temperature data then determine why these mop sinks are a source of crossover and repair them accordingly. This would likely be the result of a faulty mixing valve. Check valves can also be installed on the hot and cold water lines connected to the mop sink.
Laundry Rooms	If the temperature data or visual inspections showed signs of crossover occurring in the laundry rooms, then there are two potential repair options: 1. Conduct more diagnostic testing or visual inspections to determine if the crossover is occurring at a specific fixture and then complete the necessary repairs to fix it 2. Install check valves on the cold and hot plumbing lines, which branch off a riser. These check valves should be accessible for maintenance.
All Three In-Unit Fixture Types	Determine which riser/stack of units is experiencing the most severe crossover utilizing the water temperature logging data and time to temperature data. Apply the following to each unit in the stack of units: 1. Install new cartridges in shower valves. 2. If existing shower valve contains known susceptible to crossover cartridge, then replace with retrofit cartridge (refer to shower cartridge section above). 3. Service or replace faucet mixing cartridges. 4. If working with the existing fixtures isn't possible, install check valves at the hot supply and cold supply lines to each unit. Check valves should be accessible for maintenance. 5. Test riser using either the time to temperature method or the temperature data logging method to verify the repair improved the crossover issues. If the fixes above improved the crossover symptoms then expand scope to the rest of the building.

It is likely that several sources of crossover are all contributing to the issues at the property. If so, then the repairs should be prioritized based on the ease of the repair and the likelihood that it is a primary cause of the issue. Common area repairs are typically the easiest to implement since the quantity of repairs is usually much smaller than in-unit repairs. Building-wide pressure gauge testing should be performed intermittently between each repair to check if the repair solved the crossover issue or to gauge whether the severity of crossover has been reduced.

5) PADRE APARTMENTS: CROSSOVER INVESTIGATION AND REPAIR PLAN

Similar to Presentation Senior, owner and professional investigation and repair strategies will be completed at Padre Apartments and then compared to confirm the validity of the owner investigation and repair strategies. Repair recommendations based on hypothesized results of both testing methods are included in Table 12 further below.

Owner Testing and Investigation Strategies

Table 10 describes the partially completed owner testing and investigation strategies which have been completed as well as recommended future tasks to complete the investigation strategy.

Table 10. Partially Completed Owner Testing and Investigation Strategies, Including Known Information and Future Tasks

Test/ Investigation	Known Information	Plausibility to be a Source of Crossover	Future Task
Identified In-unit Plumbing Cross Connections	Single-handle kitchen (Figure 13) • Cartridge Model: Unknown • Pause Button: Unknown	High if pause button present, low otherwise	Investigate cartridge model and presence of pause buttons
	Single-handle bathroom faucets (Figure 14) • Cartridge Model: Unknown	Low	Investigate cartridge model
	Single-handle Shower Valves (Figure 15) • Cartridge Model: 30% of Showers Contain Mixet Cartridges and 70% Contain Delta Cartridges	Mixet Cartridges: High Delta Cartridges: Medium	Confirm proper no mix valve replacement option
Identified Common Area Plumbing Cross Connections	Domestic Hot Water Mixing Valve • Failure: Unknown	Medium	Investigate if mixing valve has failed
	Check Valve on Recirculation System in Boiler Room • Missing: Confirmed	Medium	Investigate if missing check valve is contributing to crossover issues
	Laundry Sinks • Pause Button: Unknown	High if pause button present, low otherwise	Investigate presence of pause buttons
	Laundry Clothes Washing Machines • Presence of Failed Internal Shutoff Valves: Unknown	High if failed internal shutoff valves are present, low otherwise	Investigate presence of failed internal shutoff valves

Left to right:

Figure 13. Padre Apartments Single Handle Kitchen Faucet

Figure 14. Padre Apartments Single Handle Bathroom Faucet

Figure 15. Padre Apartments Delta Shower Valve

5) PADRE APARTMENTS: CROSSOVER INVESTIGATION AND REPAIR PLAN

The following is a list of owner testing and investigation strategies, which have yet to be performed at Padre Apartments:

- Tenant Survey
- Investigation of unintentional hot and cold plumbing cross connections (Figure 1)
- Identify in-unit leaky or hard to turn single-handle fixtures
- Identify in-unit portable dishwashers

Professional Comprehensive Crossover Investigation Methodology

Table 11 Completed or Partially Completed Professional Crossover Testing and Investigation Strategies at Padre Apartments

Test/Investigation	Known Information	Future Task
Building-Wide Pressure Gauge Test	Inconclusive pressure gauge test results due to a missing check valve on the recirculation pump.	Install check valve and re-preform test
DHW Temperature Data Monitoring Plan	There are 10 domestic hot water risers. Some risers serve a variety of fixtures types while others serve one fixture type, including risers that only serve Mixet Shower Valves and Delta Shower Valves.	Data loggers will be installed on the supply and return of representative risers and will be installed upstream and downstream of plumbing cross connections. Prioritize risers that contain plumbing cross connections, which are more likely to be a source of crossover. A data logger will also be installed on the supply to the laundry room.
Interpretation of the temperature logger data	N/A	Supply temperatures will be compared to return temperatures to determine the presence of crossover. If a riser is hypothesized as not experiencing crossover is can be used as a control to compare to other risers

5) PADRE APARTMENTS: CROSSOVER INVESTIGATION AND REPAIR PLAN

Recommended Crossover Repairs Based on Hypothesized Results of Both Testing and Investigation Methods

Table 12 lists example recommendations dependent on the results of both the owner and professional investigation and testing methods.

Table 12. Padre Apartments Repair Recommendations

Proven Source of Crossover	Recommended Repair
Mixet Shower Valves	If crossover investigation suggests crossover is prevalent on risers that only serve in-unit Mixet shower valves, then the recommendation would be to only replace the Mixet shower cartridges with NoMix cartridges. NoMix develops shower cartridges that are specifically designed to replace Mixet cartridges and are impervious to crossover. Unlike other shower cartridges, NoMix cartridges do not need to be replaced every 3-5 years. However, a small rubber O-ring will need to be replaced on the cartridge at the same frequency to ensure its imperviousness to crossover.
Mixet and Delta Shower Valves	If crossover investigation suggests crossover is prevalent on all risers which serve in-unit showers, then replace all the shower cartridges in the building and implement a maintenance plan to replace or maintain each cartridge every 3-5 years to avoid crossover issues in the future. The Delta cartridges can be replaced with newer versions of the same Delta cartridge model, the Mixet cartridges should be replaced with NoMix cartridges and follow the maintenance plan described above.
Laundry Rooms	Refer to Table 9 in **Presentation Senior: Recommended Crossover Repairs Based on Hypothesized Results**
All Three In-Unit Fixture Types	Refer to Table 9 in **Presentation Senior: Recommended Crossover Repairs Based on Hypothesized Results**

Similar to Presentation Senior, if several sources of crossover are all contributing to issues at the property, then repairs should be prioritized based on the ease of the repair and the likelihood that it is a primary source of the issue. Building-wide pressure gauge testing should be performed intermittently between each repair to check if the repair solved the crossover issue or gauge how the severity of crossover has been decreased.

APPENDIX

EXAMPLE CROSSOVER SURVEY

See next page.

APPENDIX
Example Crossover Survey

Apartment Unit Number: _____

1. How long does it typically take you to get hot water at the kitchen sink?
   - ☐ 0 – 15 Seconds
   - ☐ 16 – 30 Seconds
   - ☐ 31 – 60 Seconds
   - ☐ > 60 Seconds

2. How long does it typically take you to get hot water at the bathroom sink?
   - ☐ 0 – 15 Seconds
   - ☐ 16 – 30 Seconds
   - ☐ 31 – 60 Seconds
   - ☐ > 60 Seconds

3. How long does it typically take you to get hot water in the shower?
   - ☐ 0 – 15 Seconds
   - ☐ 16 – 30 Seconds
   - ☐ 31 – 60 Seconds
   - ☐ > 60 Seconds

4. Are any of these faucet handles difficult to turn?
   - ☐ Kitchen
   - ☐ Bathroom
   - ☐ Shower

5. Do any of these fixtures drip when off?
   - ☐ Kitchen
   - ☐ Bathroom
   - ☐ Shower

6. Does hot water ever come out of the cold tap of these faucets, even briefly? Check box if yes.
   - ☐ Kitchen
   - ☐ Bathroom
   - ☐ Shower

7. While taking a shower do you get a consistent water temperature?
   - ☐ Yes
   - ☐ No

   If you answered No, please explain:

_____

_____

_____

_____

8. Is there any particular time of day where you cannot get hot water or there are extremely long wait times?
   - ☐ Yes
   - ☐ No

   If you answered Yes, please explain:

_____

_____

_____

_____