# Mechanical, Plumbing and Energy Assessment Report

**Prepared For:**

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## Introduction

We have surveyed the Unitarian Universalist Church of Sacramento to determine ways to increase comfort and provide energy savings that can be implemented during the upcoming renovation. The intent of this survey was to assist with determining the most beneficial changes that could be made during the remodel.

Through discussions with Jeff Gold, review of the archival plans, and a site visit to the church we have determined several important building & mechanical issues that should be analyzed in greater detail. All of the potential modifications listed below will improve comfort and energy performance. Further site visits and building analysis will be required to determine the calculated energy savings and cost effectiveness of some of the proposed modifications.

The following buildings were inspected on October 13, 2010:

- Main Hall
- F.A.H.S. Room & Offices
- Classrooms “6” through “12”

A summary of our survey follows.

**Main Hall – 8,230 Square Feet**

HVAC SYSTEM

Existing System

The existing heating system for the entire building consists of a large air handler in the basement with duct furnaces. There are two (2) duct furnaces, each with a heating capacity of 160 kBtu/Hr. It is the original heating system and is approximately 50 years old.

The supply air distribution consists of below slab ducting with perimeter floor diffusers. The majority of floor diffusers are damaged with bent louvers adversely affecting the airflow. The return air ducting is also below slab with low sidewall grilles located on the face of the Stage Platform wall. The grilles are currently disconnected from the return air ducting, so that the space between the Platform and slab is a return air plenum. Any leaks between that space and the outside, of which there are many, are drawn into the return air.

The outside air intake to the air handler is drawn from the stairway which connects the Mechanical Room to the Service Court. There is a janitor's closet in the Service Court where cleaning supplies are stored. There are also two (2) exhaust fans from the adjacent bathrooms terminate in the Service Court. This is not an appropriate area to be drawing outside air into the unit.

There is no central air conditioning in the building.

To provide cooling, two (2) evaporative coolers were added approximately 10 years ago. The coolers supply air to the space between the Stage Platform and the slab, utilizing the same space as a supply plenum that the central heating system uses as a return air plenum. The supply air from the evaporative coolers is supplied through removed glass panes in the concrete tilt-up wall. Each cooler supplies air through six (6) wall openings, which amounts to 2.8 square feet of free area, probably limiting the supply air from each cooler to approximately 3000 CFM. This is grossly undersized for the Social Hall.

The openings in the wall provide increased air infiltration into the return air plenum of the central heating system, effectively drawing uncontrolled amount of outside air into the return air plenum.

In conjunction with the evaporative, two exhaust fans have been installed in the storage area above the Platform to relieve the supply air from the evaporative coolers and exhaust hot, stratified air from the Social Hall.

The bathroom exhaust fans for the bathrooms adjacent to the Lobby appear to be adequate. The exhaust fans for the bathrooms adjacent to the Kitchen are sidewall fans and terminate directly to the Service Court.

The Foyer and Kitchen are also served by the same central heating system with no air conditioning. The Kitchen has a commercial exhaust hood with no make-up air unit. The make-up air is provided through leaks in the building envelope. Current code requires separate make-up air be provided to the Kitchen.

An air conditioning system was installed approximately 10 years ago supplying the Library and Offices. The system consists of an air handler located in the Electrical Room with a remote condensing unit located on the roof. The system is divided into two (2) thermostatically controlled zones:

- The Office.
- The Library.

These areas are also heated by the central heating system.

For purposes of our analysis we have divided the main building into the following zones:

**Table 1 – Building Zoning and Heating & Cooling Loads**

| Zone | Floor Area (Sq.Ft.) | Heat Load (kBtu/Hr) | Cool Load (Tons) |
|---|---|---|---|
| Social Hall and Supporting Areas | 5,400 | 218.7 | 20.8 |
| Foyer | 720 | 28.4 | 3.4 |
| Kitchen & Pantry | 758 | 29.0 | 3.2 |
| Library & Offices | 1,343 | 54.9 | 4.8 |
| Total | 8,221 | 331.0 | 31.9 |

Notes

(1) The tabulated heating and cooling loads are for the existing, unimproved, building envelope. Refer to Table 2 of this report for loads with an improved building envelope.

Recommendations for Main Hall HVAC system

The recommendations are divided into Tier #1, Tier #2 and Tier #3. The three "Tier" groups are defined in the Executive Summary of this report.

Social Hall & Foyer

Tier #1

1) Duct test the existing system and provide a detailed assessment to determine whether or not the existing air distribution can be reused with a new HVAC system.
2) The return air grilles at the Stage Platform should be reconnected to the ducting so that space under the Stage Platform is not a return air plenum. This would decrease the amount of unconditioned outside air into the return air.
3) Replace exhaust fans in bathrooms adjacent to the Kitchen, which currently terminate in the Service Court, with new fans and terminate ducting to the exterior.

Tier #2

None

Tier #3

4) Install a new rooftop package HVAC system for the Social Hall and Foyer. The HVAC system would include an economizer and $CO_2$ demand ventilation. The Economizer brings up to 100% outside air as the first stage of cooling if ambient conditions are favorable. For example, if the outside temperature is 55°F and there is call for cooling, the economizer will bring in 100% outside air for "free" cooling. The $CO_2$ demand ventilation system modulates the outside air introduced into the HVAC unit, based on the $CO_2$ level inside. If there are only a few occupants in the space, only a minimal of outside air is introduce into the space. A rooftop package unit would provide the following benefits:
   - Ease of serviceability.
   - It is the most cost effective system for providing an economizer and demand ventilation cooling.
   - It is the most cost effective heating and cooling equipment for a 20-ton cooling load.

   There are some potential obstacles to rooftop equipment, such as, structural requirements for rooftop equipment, space for ducting, and aesthetics.

   Further assessment of the existing system is required before a final decision is made on the type of HVAC system that is best suited for this building.
5) The existing supply air distribution for these areas appears to be adequately sized. However, further field verification will be required to ensure that the sizes indicated on the mechanical plans are accurate, and a duct test should be performed to measure the air leakage of the existing air distribution system. A duct chase from the roof to the basement would have to be provided. The supply air and return air duct would each be approximately 30"x30", or equivalent area.
6) The existing system was designed to bring in a fixed amount of outside air. With the large group occupancy of this space, the amount of outside air for adequate ventilation is significant. The total supply air is equal to the return air + ventilation air, which is why the return air ducting below slab is considerably smaller than the supply air ducting. A new demand control ventilation system modulates the amount of outside air based on actual occupancy. Therefore, when there is minimal occupancy, there is a small amount of outside air required and the majority of the supply air is returned. If the existing return air distribution system is reused it will have to be augmented with additional return air ducting and grilles. Should the existing ducting (supply & return) be found as inadequate, duct soffits could be created around the perimeter of the Social Hall for new ducting.
7) Remove the evaporative coolers and seal the openings.
8) The existing exhaust fans used as a relief for the evaporative coolers and can be reused as relief to the ventilation air from the central HVAC system. The exhaust fans could be energized by a pressure

sensor. The sensor would energize the exhaust fans when there is a positive pressure in the space from increased ventilation air being introduced to the HVAC system.

Kitchen
Tier #3

1) Replace the hood with a "compensating" hood. A "compensating" provides make-up air directly at the face of the hood and is not circulated throughout the Kitchen. A compensating lessens the heating load of make-up air provided to the Kitchen and increases comfort.
2) Disconnect the Kitchen from the central heating system.
3) Install a new "ductless" heat pump for heating and air conditioning the Kitchen and Pantry. The indoor unit could be mounted on an interior wall. The outdoor unit could be ground mounted or roof mounted. The heat pump allows the kitchen to be conditioned when the hood is not turned on.

Library & Offices
Tier #3

1) Provide a separate heating and air conditioning system for this area similar to what is there now but with heating as well. This could be provided by a split system heat pump or gas furnace with remote condensing unit. The decision on what type of heating would depend on the ease of providing gas piping, flue venting and combustion air
2) Disconnect this area from the central heating system.
3) We did not trace the ducting for this area and can not comment on the adequacy of the existing air distribution system. Further investigation will be required.

We have reviewed the 10/23/2008 proposal the church received to provide air conditioning and conclude that the proposed solution does not adequately address the following issues:

- The existing location of outside air intake is inadequate.
- The existing outside air intake louver and ducting is unable to provide 100% outside air for economizer cooling and $CO_2$ demand ventilation.
- The proposed system does not provide adequate air conditioning for the Social Hall.

Main Hall: Building Envelope

Existing Conditions
Windows: Single Pane, wood frame window walls and doors. Estimated U-value = 1.04, Estimated (Solar Heat Gain Coefficient) SHGC = 0.85,
Exterior Walls: 8 inch concrete walls with yellow acrylic panes imbedded in the wall. The area acrylic panes are 20% of the exterior wall area and were assumed to have a U-value = 1.19/ SHGC = 0.45.
Ceiling/Roof: R-7 (1" rigid) with built-up roofing. This value was assumed.

Recommendations
Furr in exterior wall and provide and insulate with R-19 insulation. Insulate exterior walls wherever possible.
Insulation should be added to the roof. If a new roof is installed, this could be done with additional rigid foam insulation, approximately 3-1/2" of rigid. Otherwise, the insulation could be added from underneath with R-30 fiberglass batts.

The effect of adding R-19 to exterior walls and R-30 to the roof or ceiling is tabulated below.

**Table 2 - Peak Heating and Cooling loads for Equipment Sizing**

| Zone | Floor Area (Sq.Ft.) | Existing Envelope Heat Load (kBtu/Hr) | Existing Envelope Cool Load (Tons) | Insulated Envelope Heat Load (kBtu/Hr) | Insulated Envelope Cool Load (Tons) |
|---|---|---|---|---|---|
| Social Hall and Supporting Areas | 5,400 | 218.7 | 20.8 | 174.0 | 17.4 |
| Foyer | 720 | 28.4 | 3.4 | 27.0 | 3.2 |
| Kitchen & Pantry | 758 | 29.0 | 3.2 | 13.3 | 2.2 |
| Library & Offices | 1,343 | 54.9 | 4.8 | 43.6 | 3.8 |
| Total | 8,221 | 331.0 | 31.9 | 257.9 | 26.6 |

**Table 3 - Estimated Annual Heating and Cooling loads**

| Zone | Floor Area (Sq.Ft.) | Existing Envelope Heat Load (kBtu/Yr) | Existing Envelope Cool Load (kW-Hr/Yr) | Insulated Envelope Heat Load (kBtu/Yr) | Insulated Envelope Cool Load (kW-Hr/Yr) |
|---|---|---|---|---|---|
| Social Hall and Supporting Areas | 5,400 | 106,578 | 15,311 | 46,845 | 12,539 |
| Foyer | 720 | 8,835 | 3,393 | 6,331 | 3,241 |
| Kitchen & Pantry | 758 | 13,761 | 2,633 | 1,300 | 2,434 |
| Library & Offices | 1,343 | 32,385 | 3,949 | 17,539 | 3,381 |
| Total | 8,221 | 161,559 | 25,286 | 72,105 | 21,595 |

Notes
(1) Peak heating and cooling loads are reduced by 22% and 17% respectively.
(2) Annual heating and cooling loads, i.e., operating costs, are reduced by 55% and 15% respectively.
(3) The HVAC system modeled for both the Existing Envelope and Insulated Envelope is a new gas-electric package unit with demand ventilation and economizer operation.
(4) Refer to Appendix A at the end of this report, for further details on load calculations.

## Main Hall: Plumbing

### Plumbing Fixture Requirements

From Table-A: Group A – Worship (no fixed seating) = 30 SF / Person
8230 S.F. / 30 = 274 Occupants

Minimum fixtures requirements:

| 137 Male | 137 Female |
|---|---|
| 1 WC (1 per 150) | 2 WC (1 per 75) |
| 1 UR (1 per 150) | 1 LAV (1 per 25) |
| 1 LAV (1 per 2 WC) | |

2 DF (1 per 150)

Installed Fixtures:

| Male | Female |
|---|---|
| 2 WC (1 per 150) | 4 WC (1 per 75) |
| 2 UR (1 per 150) | 2 LAV (1 per 25) |
| 2 LAV (1 per 2 WC) | |

1 DF

The Social Hall is deficient one Drinking Fountain.
Water closets are low flow pressurized flush tank type. Urinals are standard flush valve type.

### Pipe sizing

#### Waste

Waste piping is manufactured of cast iron. According to the existing plans there is a 4" waste pipe entering the front of the building (Lobby) and another 4" waste pipe entering the back of the building next the Service Court. This is oversized for the current fixture load and could handle a significant increase in plumbing fixtures.
There is a 3" waste pipe dedicated to the Kitchen leaving the building. This is adequately sized. If there is a remodel done, to the Kitchen, a Grease Interceptor will be required, by code, to be installed on that line, outside the building, upstream of the connection to main sewer.

#### Water

The water piping specified on the plans is copper. According to the existing plans there is a 1-1/2" water pipe entering the front of the building (Lobby) and another 2" water pipe entering the back of the building next the Service Court. This is considerably oversized for the current flush tank water closets and could handle additional load. If the piping installed is galvanized steel piping, which was common at this time, there would be mineral deposit buildup rendering the effective area far less than the original pipe size.

#### Water Heating

There is a gas fired water heater supplying the Kitchen and adjacent bathrooms. Water heating for the front bathrooms is provided by instantaneous electric water heaters, one for each bathroom. Hot water piping is properly insulated.

Recommendations

1. The water heating system is adequate. If the storage type water heater fails in the basement, replacing it with a high efficient, condensing gas fired water heater is recommended.
2. Flush valve water closets would be more appropriate for public toilets, however, replacing them may require different piping configuration and does not seem practical.
3. If the existing piping is determined to be steel instead of copper, we recommend replacing the water piping with cross-linked polyethylene (PEX) piping.
4. Waterless urinals would be a good option for water conservation. For public installations waterless urinals can save 40,000 gallons of water per year. There is some maintenance involved, but it is minimal and can be done when the facilities are cleaned.

**F.A.H.S. Room& Offices Building – 1,700 Square Feet**

HVAC SYSTEM

Existing System

The existing HVAC system consists of two (2) split systems with furnaces located in a mechanical room and roof mounted condensing units. One furnace is a down-flow furnace with an estimated capacity of 48 kBtu/Hr heating capacity and the second is an up-flow furnace with an estimated capacity of 80 kBtu/Hr heating capacity. The furnaces are approximately 10 years old with efficiency (AFUE) = 80%. The cooling capacities of the down-flow split system and the up-flow split systems are 2 tons and 5 tons, respectively.

The down-flow furnace serves Classroom #1 with below slab supply air ducting and perimeter floor diffusers. The flue for the furnace is disconnected and is exhausting flue gases in the mechanical room. This condition is in clear violation of the mechanical code and may be drawing flue gases into the return air of the two (2) furnaces.

The return air grille for Classroom #1 is in the sidewall between the existing rigid ceiling and the new drop T-bar ceiling. The space between the T-bar ceiling and original ceiling is being used a return air plenum. The lighting and wiring above the T-bar are likely not "plenum rated", and, as a result, not code compliant.

The outside air is provided through one 9-1/2" diameter wall opening in the exterior wall; there is no means of controlling the amount of outside air being introduced to the furnace.

The up-flow furnace serves the offices with high sidewall and ceiling diffusers. One of the high sidewall supply air diffusers is located next to the return air grille for Classroom #1.

The small minister's office (80 Sq.Ft.), adjacent to the mechanical room, is supplied by one floor diffuser from the down-flow furnace and one high sidewall diffuser from the up-flow furnace.

Recommendations

Tier #1

1) Reconnect flue for furnace and extend through roof.
2) Provide complete ducted return for down-flow furnace and eliminate above ceiling return air plenum.
3) Provide further investigation to determine exactly which areas are served by the down-flow furnace and how these areas can be isolated from this system.

Tier #3

4) Dedicate down-flow furnace to Classroom #1. Reconfigure ducting to provide adequate ventilation air. The existing duct system for this unit should be tested for air leakage.
5) Remove the upflow furnace serving the offices and the high sidewall diffuser in Classroom #1 and replace with a new system as noted in note #6, below.
6) Install new multi-zone ductless split system for offices. Each office would have its own thermostatically controlled indoor unit.

F.A.H.S. Room& Offices: Building Envelope

Existing Conditions
Windows: Single Pane, wood frame window walls and doors. Estimated U-value = 1.04, Estimated (Solar Heat Gain Coefficient) SHGC = 0.85. Many windows are leaky with missing weather-stripping.
Exterior Walls: 8 inch concrete walls with yellow acrylic panes imbedded in the wall. The area acrylic panes are 20% of the exterior wall area and were assumed to have a U-value = 1.19/ SHGC = 0.45.
Ceiling/Roof: R-7 (1" rigid) with built-up roofing. This value was assumed.

Recommendations
Tier #1
1) Provide new weather stripping around doors and windows.

Tier #3
2) Insulate exterior walls wherever possible.
3) Since a new roof has recently been installed, provide additional insulation above the ceiling wherever possible.

## **Classrooms "6" through "12" – 3,050 Square Feet**

HVAC SYSTEM

Existing System

The existing HVAC system consists of split systems with furnaces, located in furnace closets in the classroom, and roof mounted condensing units. The equipment is approximately 10 years old. Each system has a heating capacity of 64 kBtu/Hr and a 4 ton cooling capacity. The equipment is adequately sized. The inadequacies found with each system are as follows:

1) Each furnace supplies two separate classrooms. Therefore, half of the classrooms do not have their own temperature controls. The varying exposure and occupancy of each classroom could create an uncomfortable condition in the classroom without the thermostat.
2) There are noticeable air leaks between the cooling coil and the supply air plenum.
3) There are no filters installed in the return air. The lack of filtration will cause dirt to build up on the cooling coil and heat exchanger, and will affect the performance and efficiency of the equipment. In the current configuration, the outside air is ducted directly into the side of the furnace, while the return air is ducted into the bottom of the unit. Therefore, two filters would have to be installed for each furnace, one in the return air plenum and one in the outside air plenum.

Recommendations

In order to provide thermostatic control for each classroom a new system would have to be installed for each classroom. Replacing all the equipment would be costly and may not be within the church's budget. We do not recommend reusing the existing systems for one of the classrooms, as they would be grossly oversized and would operate very inefficiently. A zone control system for the existing furnaces would require a larger furnace closet and space for new ducting.

Other measures which could be taken to increase the performance and the efficiency of the existing systems are as follows:

1) Reconfigure the return air plenum and provide a mixing box with an outside air damper and a return air damper. This would entail providing a new outside air louver at the same height of the return air grille. It may also require an alteration to the furnace closet to make room for the mixing box. This would allow the use of a single filter. Furthermore, economizer and demand ventilation controls could be added in conjunction with the mixing box. The economizer could bring up to 100% outside air for "free" cooling if ambient conditions are favorable. The $CO_2$ demand ventilation system modulates the outside air introduced based on the $CO_2$ level inside.
2) Seal all gaps in supply air plenum with mastic sealant.

Classrooms “6” through “12”: Building Envelope

Existing Conditions
Windows: Single Pane, metal frame window walls and doors. Estimated U-value = 1.29, Estimated (Solar Heat Gain Coefficient) SHGC = 0.85. Many windows are leaky with missing weather-stripping.
Exterior Walls: 8 inch concrete walls with yellow acrylic panes imbedded in the wall. The area acrylic panes are 20% of the exterior wall area and were assumed to have a U-value = 1.19/ SHGC = 0.45.
Ceiling/Roof: R-7 (1” rigid) with built-up roofing. This value was assumed.

Recommendations
Tier #1
1) Provide new weather stripping around doors and windows.

Tier #3
2) Insulate exterior walls wherever possible.
3) Since a new roof has recently been installed, provide additional insulation above the ceiling wherever possible.
4) Replace existing windows with new double-pane, Low-E windows.

F.A.H.S. Room& Offices Building and Classrooms "6" through "12": Plumbing

Plumbing Fixture Requirements
F.A.H.S Room & Classrooms
From Table-A: Group A – Educational (no fixed seating) = 30 SF / Person
4738 S.F. / 30 = 158 Occupants

Minimum fixtures requirements:

| 79 Male | 79 Female |
|---|---|
| 1 WC (1 per 150) | 2 WC (1 per 75) |
| 1 UR (1 per 150) | 1 LAV (1 per 25) |
| 1 LAV (1 per 2 WC) | |

2 DF (1 per 150)

Installed Fixtures:

| Male | Female |
|---|---|
| 2 WC (1 per 150) | 3 WC (1 per 75) |
| 1 UR (1 per 150) | 2 LAV (1 per 25) |
| 2 LAV (1 per 2 WC) | |

1 DF
The Classroom building complex is deficient one (1) Drinking Fountain.
Water closets are low flow pressurized flush tank type. Urinals are standard flush valve type.

Pipe sizing
Waste
Waste piping is manufactured of cast iron. According to the existing plans there is a 4" waste pipe entering the F.A.H.S. room and another 4" waste pipe entering the bathrooms adjacent to Classroom #10. This is oversized for the current fixture load and could handle a significant increase in plumbing fixtures.
Water
The water piping specified on the plans is copper. According to the existing plans there are two (2) water pipes serving the F.A.H.S. building. One is 1-1/2" and the other is ¾". In addition, there is a 1" pipe entering the bathrooms adjacent to Classroom #10. The water piping is oversized for the current flush tank water closets and could handle and additional load. If the piping installed is galvanized steel piping, which was common at this time, there would be mineral deposit buildup rendering the effective area far less than the original pipe size.
Water Heating
Water heating for bathrooms in F.A.H.S. building is provided by instantaneous electric water heaters, one at each Lav/sink. There is a small electric water heater in the Janitor's closet providing hot water for the classroom bathrooms and the Janitor's sink. The hot water piping is properly insulated.
Recommendations
1) The water heating system is adequate.
2) Flush valve water closets would be more appropriate for public toilets, however, replacing them may require different piping configuration and does not seem practical.
3) If the existing piping is determined to be steel instead of copper, we recommend replacing the water piping with cross-linked polyethylene (PEX) piping.
4) Waterless urinals would be a good option for water conservation. For public installations waterless urinals can save 40,000 gallons of water per year. There is some maintenance involved, but it is minimal and can be done when the facilities are cleaned.

**Renewable Energy**

HVAC

If the long term goal of the church is to be "zero energy" and produce on-site renewable energy with a solar photovoltaic system, then the HVAC system type should utilize electricity for heating. For that application we recommend a geo-thermal heat pump system.

A geo-thermal heat pump system is a water source heat pump, which uses the earth to absorb heat of the condenser water in the summer, and in the winter the earth heats the cold water from the evaporator. The water is cooled or heated through piping buried in the ground. The heat transfer between water and refrigerant is more efficient than air and refrigerant.

The ground loops can be either horizontal loops approximately 6 feet below grade or vertical loops through a series of wells 100-175 feet deep. Horizontal ground loops are less expensive but require large surface areas and are much more disruptive to the site than vertical ground loops. Some preliminary ground loop calculations are required to determine if there is adequate space for horizontal ground loops. Since the cooling load for this occupancy is larger than heating load, we recommend sizing the ground loop for the heating load and augmenting the cooling with a cooling tower located in a mechanical yard. Similar equipment configurations are available for geo-thermal heat pumps as are available for traditional HVAC equipment.

More analysis is required to explore this option.

Water Heating

For water heating we recommend a solar water heating system with electric back-up for the central water heater in the basement mechanical room serving the Kitchen, bathrooms and Janitor's closet. All other water heaters should remain as electric instantaneous water heaters.

**Further Investigation**

It is imperative that some further investigation is done before a final decision is made on the design of mechanical system(s). Through our initial site survey and analysis we have identified areas which require more detailed investigation and analysis. The areas that we feel require further investigation are as follows:

1) Provide duct pressure test on existing air distribution systems. The duct leakage for a system should not exceed 6% of total supply air. The results of these tests will help us identify which systems can be reused and which systems should be abandoned.
2) Verify zoning in F.A.H.S. Room and adjacent offices.
3) Verify actual pipe material.
4) Provide annual operating cost and life cycle cost analysis for various HVAC options.
5) Preliminary design of ground loop for geo-thermal heat pumps system.
6) Research available utility incentives and tax rebates for HVAC and energy options.
7) Provide life cycle cost analysis for geo-thermal heat pumps system with utility provided electricity and with electricity provided by solar photovoltaic system.

Some of these investigations could be conducted during the master plan process in order to clarify recommendations for future actions, and their associated costs.