AREN 4570

Electrical Systems Audit

Project 1

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The purpose of Project 1 was to audit and critique an existing electrical system in a single-family detached residence. The goal was to determine and show that the house either meets or does not meet NEC code requirements.

Executive Summary

The goal of the project was to audit the existing electrical system of a single family detached dwelling based on NEC standards. The dwelling being audited is located at 1912 9th Avenue in Longmont, CO and was originally built as a nunnery in 1904. Since this is near to the era that electricity was first introduced into homes, it is surprising that the house meets code as well as it does. We have performed the necessary calculations and evaluations to ensure the residence meets code and the only major code violation we found is the lack the G.F.C.I.'s in the house. The audit also revealed feeder lines sized for a 200A circuit breaker as opposed to the 100A circuit breaker that is present. More about this will be explained later.

One problem we ran into was figuring out which circuit breakers were used and which were not used. There are various extra circuit breakers in the panel that do not connect to any appliances or fixtures in the house. We discovered that this is due to the fact that there have been many changes to the appliances that are currently being used in the residence. Overall, the wiring is relatively up to date and we will show that the house has met NEC requirements other than one code violation.

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Dwelling Description

The old nunnery is located on the corner of 9th ave. and Tulip st. in Longmont Colorado. It retains a few characteristics of the old victorian style but has been remodeled so many times that it no longer classifies as a historic building. The roof has a steep pitch in comparison with todays standards and and the windows are tall. The electric supply comes in from above and goes to the panel box and meter shown in Figure 1. The inside consists of two bedrooms and two bathrooms. There is also a loft overlooking the kitchen and most of the wall outlets are clean and white, indicating that they have been updated in the last 20 years. The furnace and water heater in the basement look brand new and the rest of the appliances are up to date as well. There is a fireplace in the house but it is no longer used because it doesn't work. The total area of the house is approximately 1700 SF.

A recent blower door test was performed on the building resulted in a large ACH with numerous leaks. This indicates the quality of the remodels that have been performed on the residence. It would be consistent to assume that the quality of the electrical system is comparable

Figure 1: Panel and Meter

Major Loads

This dwelling has a fair amount of major loads, many of which are not included in the NEC definition of fixed and special appliance. Many of these loads, particularly kitchen appliances are connected directly to the convenience receptacles that share a branch circuit. It is important to consider these loads when considering the flexibility of the design as over use of such appliances could cause over-current protection devices to interrupt circuit operation. These loads are summarized in the Table 1.

Table 1: Major Loads			
Load	**Voltage**	**Amperage**	**Power**
	Receptacle Loads		
Total Lighting/Receptacles	120V	42.5 A	5100 W
Refrigerator	120V	6.5 A	780 W
Microwave	120 V	12 A	1440 W
Toaster	120V	9.6 A	1150 W
Toaster Over	120 V	10 A	1200 W
	Other Loads		
Dishwasher	120 V	17.5 A	2100W
Water Heater	240 V	18.75 A	4500 W
Vent Fan	120 V	6.7 A	800 W
Disposal	120 V	6.9 A	828 W
Washing Machine	120V	10A	1200 W
Dryer (Elements)	240 V	23 A	5520 W
Dryer (Motor)	120 V	4 A	480 W
Gas Furnace (Motor)	240 V	24 A	5760 W

National Electric Code Compliance

To determine whether the dwelling is in compliance, the 2011 version of the National Electric code was examined. Though the electrical design was fairly safe, convenient, and flexible, there were a few key provisions of the National Electric code that were not fully met. This is likely due to the age of the house and the fact the electrical systems were installed as a retrofit, rather than with the original construction. Though the electrical systems have certainly been updated since they were installed in the early 20th century, they are not up to current electrical standards in some respects. Overall, however, it is a good electrical design that provides safety and functionality.

Article 210: Branch Circuits

As can be seen in the table below, all circuits are in compliance with the NEC requirements that over current protection exceed the connected load. The only potential concern occurs in the load on the receptacles located in the kitchen. The load estimated in the tables below was determined based on the convention of assuming each receptacle carries 180 VA. However, several of the counter top appliances, such as the toaster and toaster oven carry loads that greatly exceed this assumption. If both the toaster and toaster oven are operated simultaneously, the load on the circuit will be 19.6 A (See Major Loads section). If a third appliance is plugged in in the kitchen that exceeds a mere 0.4A, the breaker will trip, leading to inconvenience and frustration. This is a minimal concern; however, as typically only one counter-top appliance will be used at a time, in which case the 20A breaker should be sufficient. Only in specialized application will this problem manifest into a tripped breaker.

Table 2: Breaker Compliance Verification

Circuit	Rating	Connected Load (VA)	Current (A)	Compliant?
Master Bedroom	20 A/ 1P	1100	9.2	Yes
Spare Bedroom	20 A/ 1P	1440	12	Yes
Family Room	20A/ 1P	1800	15	Yes
Living Room	20A/ 1P	1140	9.5	Yes
Dryer	50A/2P	5520	23	Yes
Water Heater	30A/2P	4500	18.75	Yes
Gas Furnace Motor	30A/2P	5760	24	Yes
Disposal	15A/1P	828	6.9	Yes
Kitchen Outlets	20A/1P	900	7.5A	Yes*
Microwave	15A/1P	1440	12	Yes
Laundry Room	20A/1P	1300	10.83	Yes
Kitchen Lights	20A/2P	580	4.833	Yes
Basement	20A/1P	380	3.1667	Yes

Though all the branch circuit breakers are sized properly, the dwelling is vastly deficient with respect to ground fault circuit protection. The following provisions of section 210.8 (paraphrased) are not met within the dwelling. Instances of non-compliance with these codes are documented in Figures 3 and 4.

- GFCI is required for all receptacles installed in bathrooms.
- All single phase outlets located in the basement for be GFCI
- All kitchen receptacles must be GFCI (Refrigerator excepted).
- All receptacles within 6’ of a sink must be GFCI

Figure 2: Non-GFCI outlet within 6’ of sink, in kitchen

Figure 3: Non-GFCI outlet within 6’ of sink in bathroom.

Article 220: Branch Circuit, Feeder and Service

The methodology used to determine the minimum service entrance size was based on the standard and optional methods described in Article 220 of the national electric code. The calculations used for this analysis are detailed in appendix B with only the results discussed here. The house was up to code when analyzed using the optional method, but had an undersized main service breaker compared to the requirements of the standard method. The main service entrance, however, appears to be sized to meet a 175 A load which far exceeds the minimum as determined by either method. This adds to the flexibility of the design as additional branch circuits could be added with additional loads simply by upsizing the main circuit breaker.

Table 3: Wire Sizes			
Component	**Std. Requirement**	**Optional Requirement**	**Actual**
Wire size (A&B)	#1 THW (Cu)	#4 THW (Cu)	2/0 THW(Cu)
Wire size (N)	#6 THW (Cu)	N/A	#4 THW (Cu)
Wire size (Ground)	#6 THW (Cu)	N/A	#4 THW (Cu)
Main Breaker	125A/2P	70A/2P	100A

Article 230: Services

Analysis of the dwelling indicated that all the provisions required in Article 230 of the NEC code appear to be met. This dwelling has an overhead point of attachment, so the primary concern was that the service drop meet the overhead minimum clearance requirements prescribed in NEC 230.24. The service drop is required to have a minimum of 10 ft. to ground clearance at all points along the wire. A visual inspection of the service drop indicated that this requirement is exceeded at all portions of the wire of interest (see below). In addition to this, it appears all other NEC 230 requirements were met or exceeded with this design.

Figure 4: Typical Connection From Overhead Power Lines

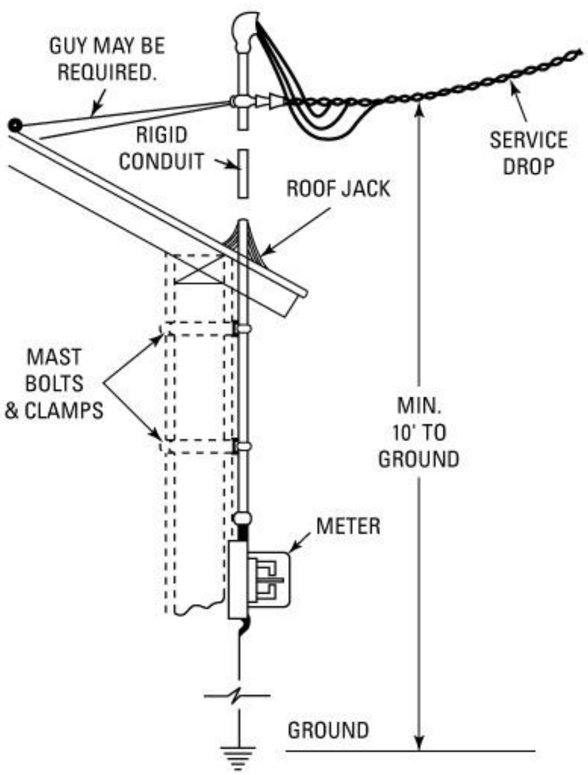


Figure 5: Main Service Entrance

Article 240: Over Current Protection

The dwelling meets all over current protection requirements prescribed by Article 240 of the NEC. This article relates to, among other thing, access and ease of use of over current protection devices, examples of which are shown in the picture below. The only potential problem, with regard to over current protection was the fact that the breakers on the panel were incorrectly and ambiguously labeled. Many of the labels indicating the branch circuits did not clearly indicate which branch circuit was served and thus, required manual operation of the breaker to determine which circuits were controlled. An improvement could be made by redoing the panel board schedule to accurately and clearly represent the panel.

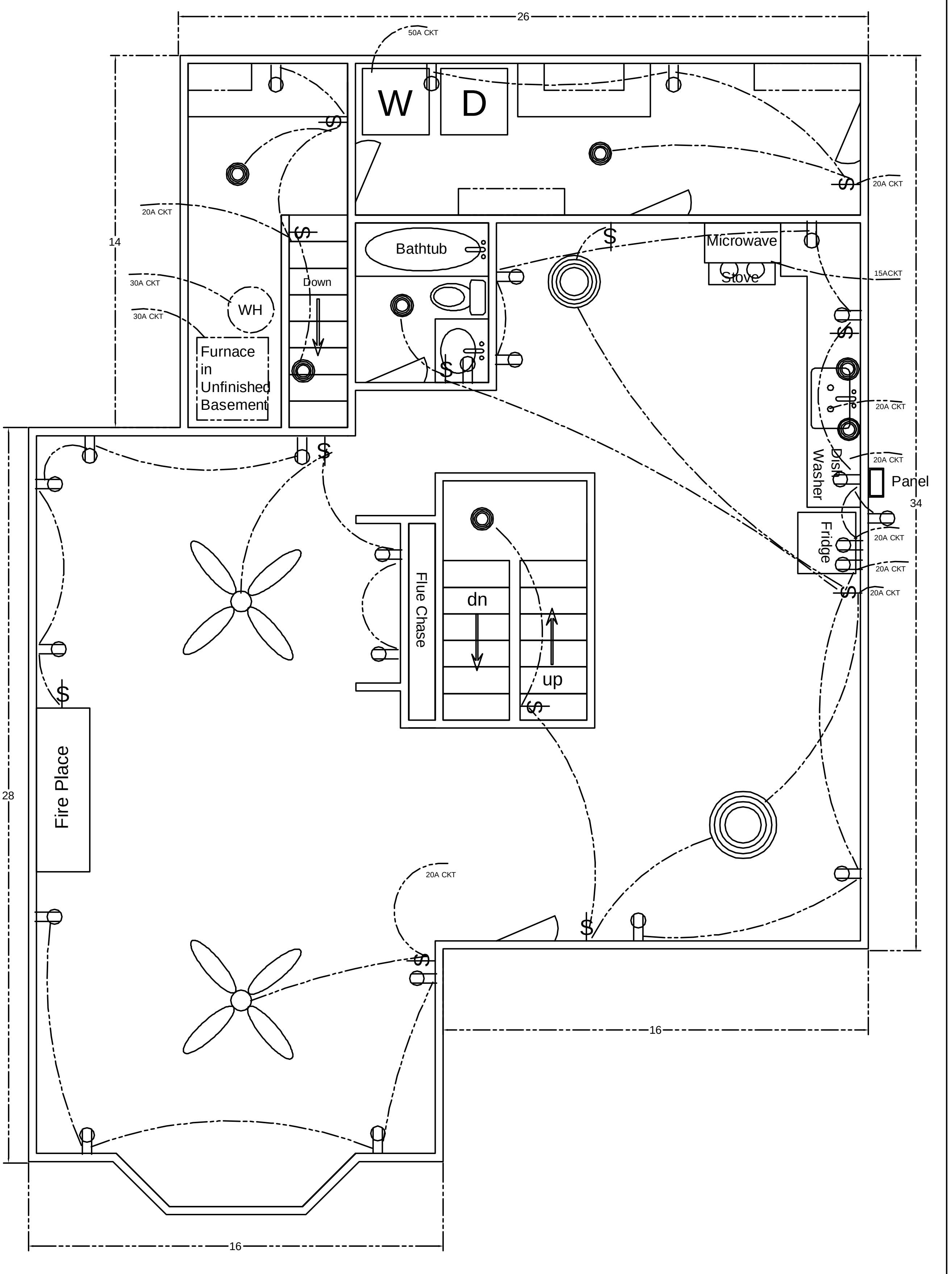
Section 240.24 requires that the panel board for a dwelling be "readily accessible" which is a requirement that is met for this dwelling. The panel board was located just outside the backdoor for easy access during an emergency. Additionally, it was determined during the audit that it is unpleasant to access the panel board on a cold, snowy day. A possible improvement would be to move the panel board to the interior to allow occupants access without facing the frigid temperatures of Colorado. Additionally, section 240.80 requires that circuit be operable by hand, without the use of pneumatic or electric devices, which was the case with this dwelling. All circuit breakers were inspected and were indeed operable. It is also required that the rating of each breaker be clearly labeled on the switch, which was the case (Figure 6A).

Figure 6: Readily accessible panel.

Critique of Existing Design

Overall, the dwelling has a well implemented electrical system that is flexible, and complies with most key provisions of the National Electric Code (2011). The only overt violation of the National Electric Code was the pervasive lack of ground fault circuit interrupters on the dwellings convenience receptacles. This lack of secondary over current protection presents a hazard to the building occupants, particularly near the sinks in the dwellings. It is recommended that adequate GFCI receptacles be added to meet or exceed the NEC requirements. In addition to the added safety benefits of GFCI, they also can add to the flexibility of the electrical system. GFCI trips prevent the circuit breaker from tripping and can typically be reset at the receptacle itself, without the nuisance of accessing the service panel. Additionally, it is recommended that the ampacity of the kitchen branch circuit be increased to allow for the operation of all counter-top appliances simultaneously. This will allow occupants to enjoy the convenience of blending a smoothie, making toast, and cooking a hot pocket without the need to stage the circuit loads.

First Floor electrical layout



E-1

SHT NO. 1 OF 4

Travis's House
1912 9th ave
Longmont CO 80501

First Floor Electrical

9

REVISIONS		
DATE	REVISION	BY
2/24/13	None	TJM
DRAWN BY:	PROJECT NUMBER	
Travis, Janay, Matt	1	

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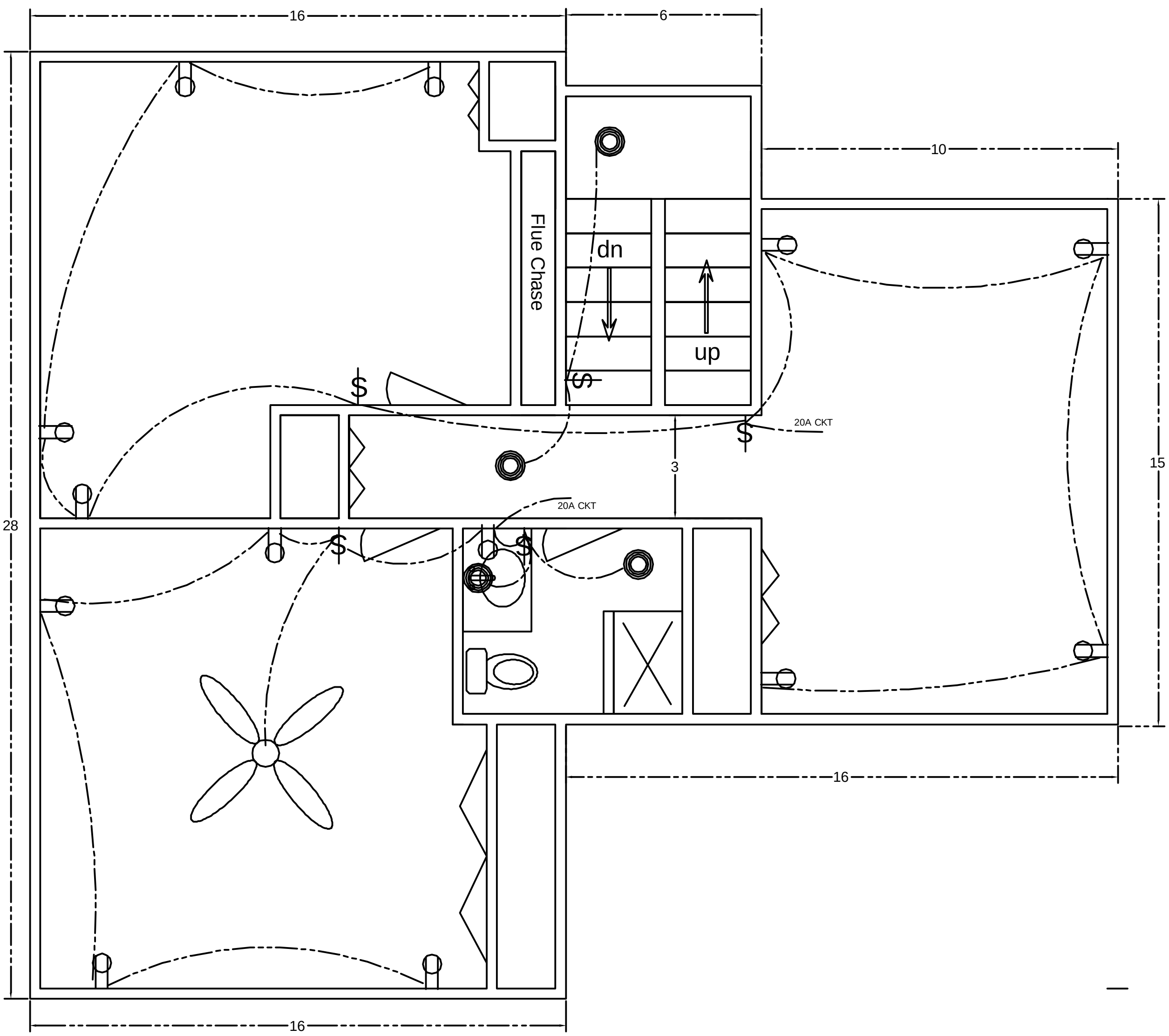
Second Floor Electrical Layout

Legend	
	Wall Outlet
	Switch
	Sink
	Upper Cabinet
	Fan
	Light Fixture
	Toilet
	Shower
	Electrical Panel
	Meter



Travis's House
1912 9th ave
Longmont CO 80501

Second Floor Electrical

REVISIONS		
DATE	REVISION	BY
2/24/13	None	TJM
DRAWN BY: Travis, Janay, Matt	PROJECT NUMBER 1	

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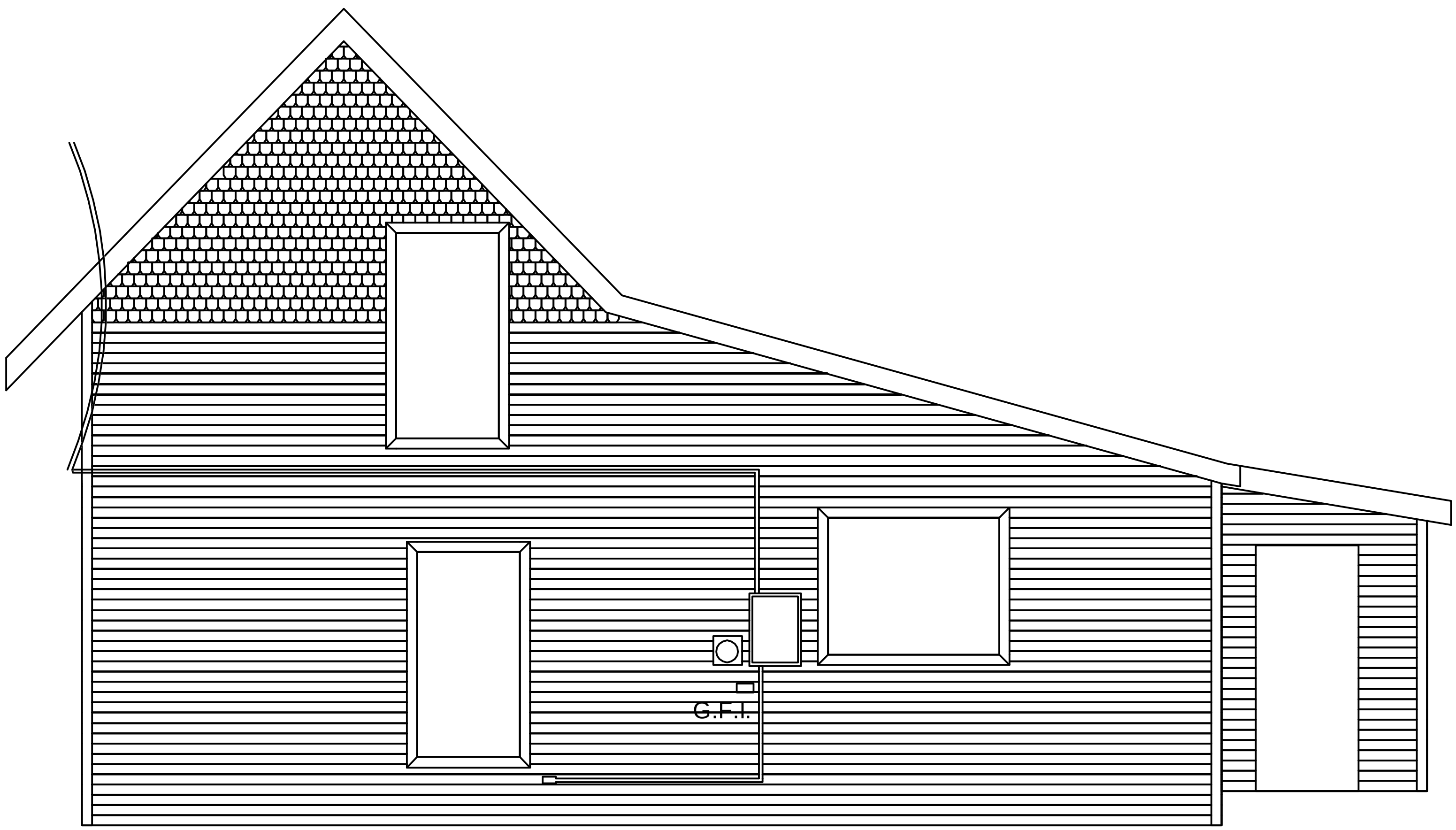
Side Elevation



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REVISIONS		
DATE	REVISION	BY
2/24/13	None	TJM

DRAWN BY: Travis, Janay, Matt
PROJECT NUMBER: 1

Side Elevation

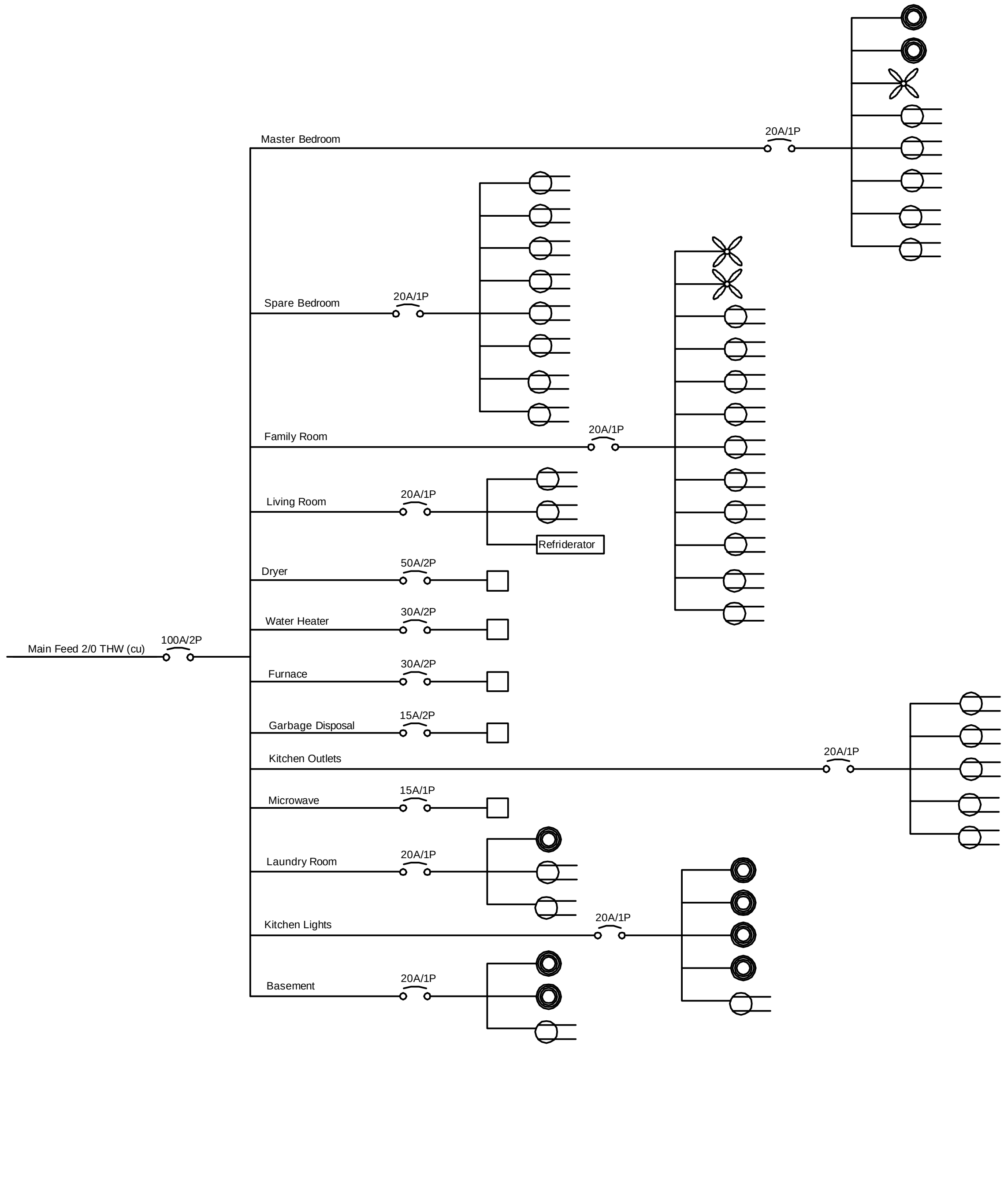
Travis's House
1912 9th ave
Longmont CO 80501

SHT NO. 3 OF 4

E-3

11

One Line Diagram of House



E-4	SHT NO. 4 OF 4	Travis's House 1912 9th ave Longmont CO 80501	One Line Diagram	12	REVISIONS DATE: 2/24/13 — REVISION: None — BY: TJM DRAWN BY: Travis, Janay, Matt — PROJECT NUMBER: 1	COLORADO REMODELING ENGINEERS FOR ENVIRONMENTAL KINDNESS 1260 ELDER AVE. BOULDER, COLORADO 80304 303.533.4822 marcillatravis@yahoo.com	CREEK

Panel Board Description

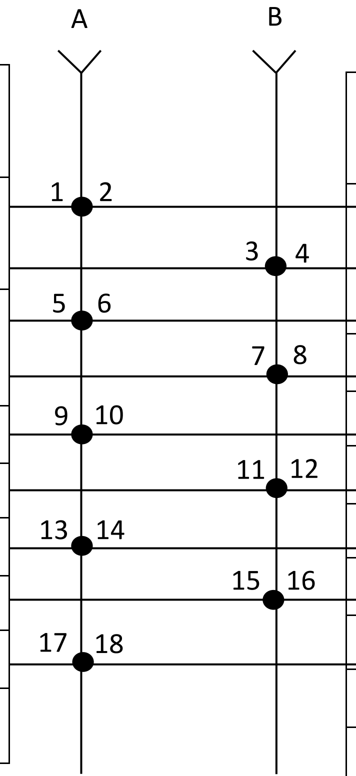
As mentioned above, there are circuit breakers that do not connect to any of the appliances or fixtures in the house. There are a total of seven, single phase breakers that are labeled as “Extra”. We began by testing each of the breakers and found that several led to major loads in the house such as the garbage disposal. There were a total of three breakers that do not appear to be connected to anything in the house. One of these “extra” circuit breakers is to allow residents the option to install an electric range in the house. The current range is a gas stove. Having this extra breaker specifically for an electric range allows some flexibility within the system. The house does have a fireplace but it does not work and hasn’t been operable for many years. We assume that another “extra” breaker was used in the past to connect to the fireplace but that is no longer the case. In the past the house also used to have a hot tub. The third and final breaker was used specifically for the hot tub and after it was taken out, the breaker remained an extra. This also allows for some flexibility which means that changes to the system can be made, if desired. Shown below in is a picture of the existing panel schedule.

Panel Schedule

After finding the actual current load of all major loads and appliances, the panel schedule was made and is shown below in Appendix A. The minimum number of circuits needed is 17. Calculations for this can be seen in Appendix A. The percent unbalanced between phases A and B needs to be less than 10%. After performing all of the necessary calculations, the percent unbalanced of this system is 2.98% which meets regulations.

Appendix A: Panel Schedule

Description	Load (A)		CB
	A	B	
Furnace	24 A		30A/2P
		24 A	
Dryer	27 A		30A/2P
		27 A	
L & R	15 A		15A/1P
Disposal		6.9 A	15A/1P
K-CKT	20 A		20A/1P
Microwave		12 A	15A/1P
Vent Fan	3.33 A		15A/1P
	89.33 A	69.9 A	



CB	***Load (A)***		***Description***
	A	***B***	
30A/2P	***18.75 A***		***Water Heater***
		18.75 A	
20A/1P	***11.5 A***		***Dishwasher***
15A/1P		***15 A***	***L&R***
20A/1P	***20 A***		***L-CKT***
20A/1P		***20 A***	***K-CKT***
15A/1P	***3.33 A***		***Vent Fan***
15A/1P		***15 A***	***L&R***
			Spare
	53.58 A	***68.75 A***	

$$\left.\begin{aligned} I_{L,A} &= 89.33\ A + 53.58\ A = 142.91\ A \\ I_{L,B} &= 69.9\ A + 68.75\ A = 138.65\ A \end{aligned}\right\} \ \%\ unbalanced = \frac{I_{L,A} - I_{L,B}}{I_{L,A}} = \frac{142.91 - 138.65}{142.91} = \underline{\mathbf{2.98\%}}$$

<u>CALCULATIONS</u>

<u>General Lighting and Receptacles:</u>

CL = 5100 VA

Number of CKTS: 5100 VA / (120 V)(15 A) = 2.83 CKTS → **3** -15 A CKTS

<u>Kitchen and Laundry</u>: **3** – 20 A CKTS

<u>Appliances:</u>

Dishwasher – 1 CKT

Disposal – 1 CKT

Microwave – 1 CKT

Dryer – 2 CKTS

Gas Furnace – 2 CKTS

Water Heater – 2 CKTS

Vent Fan – 1 CKT

Vent Fan – 1 CKT

11 CKTS

Minimum number of circuits: TOTAL = 3+3+11 = **<u>17 CKTS</u>**

Appendix B: Sizing the Service Entrance – Standard Method

Standard Method:

A 1700 ft^2 house with a 2100 VA dishwasher, 120 V; 828 VA disposal, 120 V; 1440 VA microwave, 120 V; 6480 VA dryer, 240 V; 5760 VA gas furnace, 240 V; 4500 VA water heater, 240 V; 2 x 400 VA vent fans, 120 V.

1) *General Lighting and Receptacles*

3 VA/ft^2*1700 ft^2 = 5100 VA
Kitchen and Laundry
3 CKTS*1500 VA = 4500 VA
Total CL = 5100 VA + 4500 VA = 9600 VA
DL = (3000*100%) + (9600 – 3000)*35% = **5310 VA**

2) *Fixed Appliances*

2100 VA dishwasher
828 VA disposal
1440 VA microwave
4500 VA Water heater
800 VA Vent fan
5760 VA gas furnace

CL = 15428 VA
DF = 75%
DL = **11571 VA**

3) *Special Appliances*

Dryer (1): DF = 100%
DL = **6480 VA**

4) *Largest Motor*

Gas Furnace - 5760 VA * 25% = **1440 VA**

Total Connected Load: 5310 VA + 11571 VA + 6480 VA + 1440 VA = 24801 VA

$I_{L,A\&B}$ = 24801 VA/ 240 V = 103.3375 A

T8.1 – 125A/2P
T310.15(B)(16) - 1 THW (Cu)
T 250.66 - #6 (Cu)

<u>Sizing the Neutral:</u>

1) *<u>General Lighting and Receptacles:</u>* DL = **5310 VA**

2) *<u>Fixed Appliances</u>*

15428 VA – 4500 VA – 5760 = 5168 VA
DF = 75%
DL = 5168 VA * 75% = **3876 VA**

3) *<u>Special Appliances</u>*

Dryer 6480 VA
70%*6480 VA = **4536 VA**

4) *<u>Largest Motor</u>*
Gas Furnace: DL = **1440VA**

Total Demand Load = 5310 VA + 3876 VA + 4536 VA + 1440 VA = 15162 VA

$I_{L,N}$ = 15162/240 = 63.175 A

T310.15(B)(16) – 6 THW (Cu)
T 250.66 - #8 (Cu)

Check that Neutral => Ground
→upsize to #6 (Cu) wire

Appendix C: Sizing the Service Entrance – Optional Method

Optional Method:

1) *General Lighting and Receptacles*
3 VA/ft^2*1700 ft^2 = 5100 VA
Kitchen and Laundry
3 CKTS*1500 VA = 4500 VA
Total CL = 5100 VA + 4500 VA = 9600 VA

Fixed Appliances
CL = 15428 VA

Total CL = 9600 +15428 VA = 25025 VA
DL = (10000*100%) + (25025-10000)*40% = 16010 VA

2) *DL for Heating and A/C Systems*
None – Gas furnace is included in the fixed appliances since it is not electric

Total DL = 16010 VA

$I_{L,A\&B}$ = 16010 VA/240V = 66.71 A

T8.1 – 70A/2P
T310.15(B)(16) - 4 THW (Cu)
T 250.66 - #8 (Cu)

Appendix D: Major Loads and Appliances

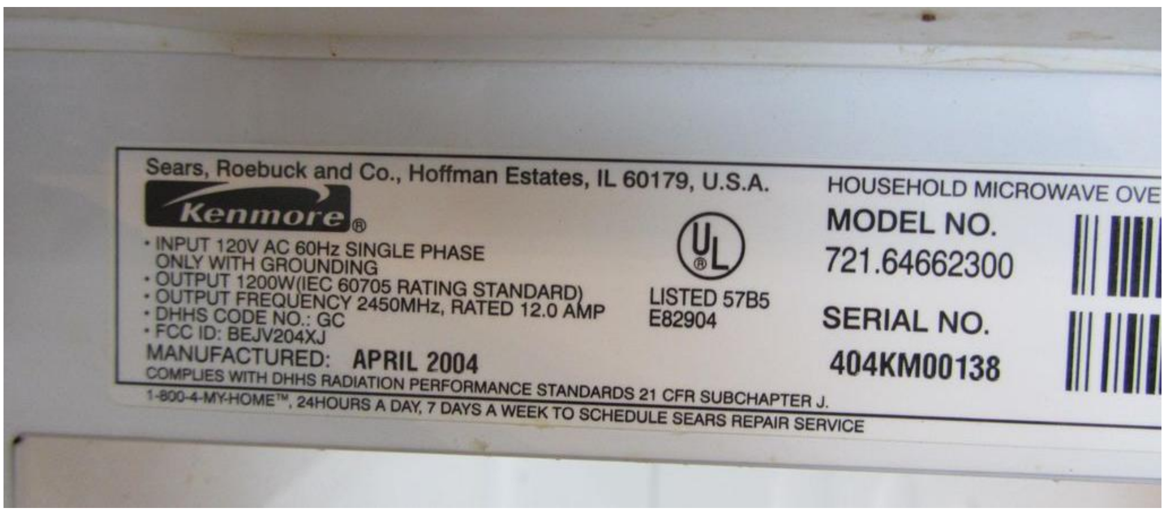
Microwave

Labeling Information:

120 V

60 Hz

Single Phase



Furnace

Labeling Information:

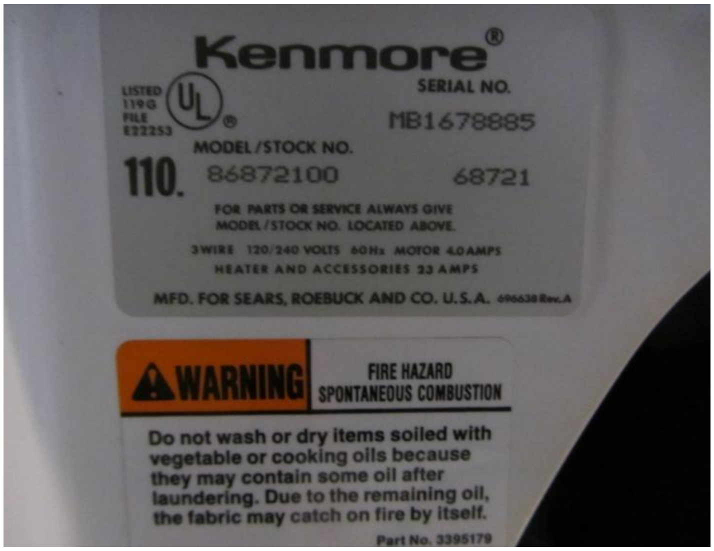
120 V

60 Hz

Single Phase

12 A

*NOTE: May be the incorrect label.



Dryer

Labeling Information:

3 wire

120/240 V

Motor – 4 A

Heater and Accessories – 23 A

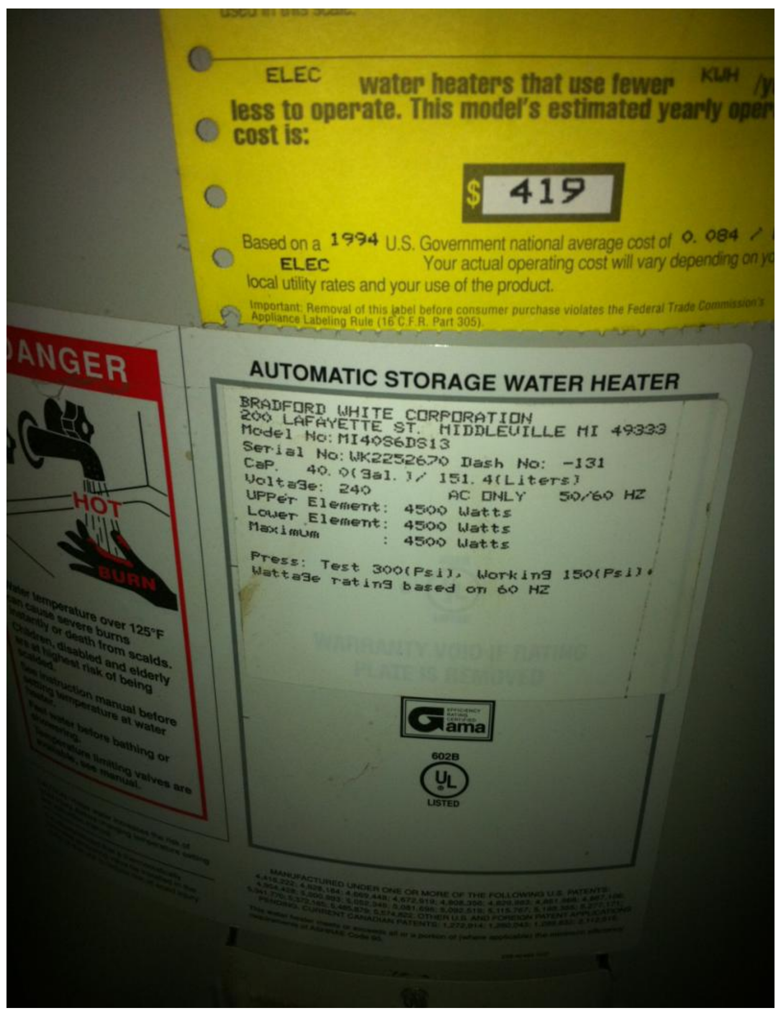
Water Heater

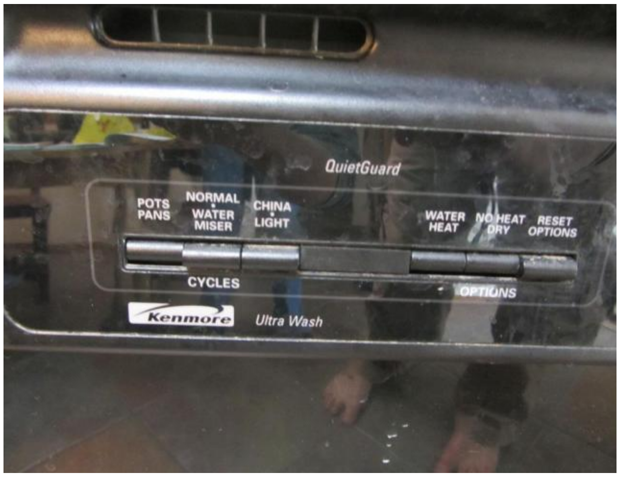
Labeling Information:

240 V

50/60 Hz

4500 Watts





Dishwasher

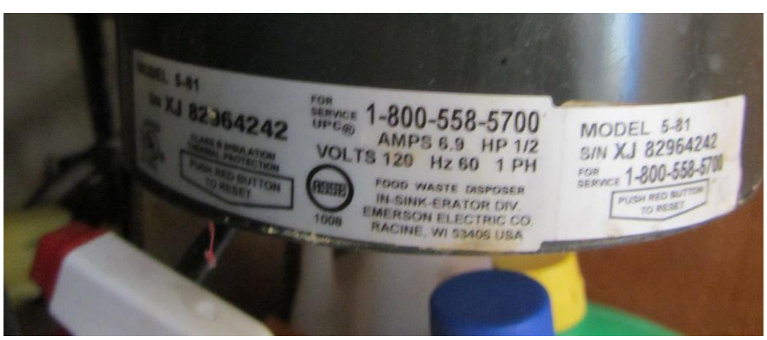
Labeling Information:

120 V

60 Hz

Motor – 6 A

Total Amps – 11.5



Disposal

Labeling Information:

120 V

60 Hz

6.9 A

Single Phase