Final Project

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1 Introduction

Wisconsin Power and Light studied the effectiveness of two devices for improving the efficiency of gas home-heating systems. The electric vent damper (EVD) reduces heat loss through the chimney when the furnace is in its off cycle by closing off the vent. It is controlled electrically. The thermally activated vent damper (TVD) is the same as the EVD except it is controlled by the thermal properties of a set of bimetal fins set in the vent. Ninety test houses were used, 40 with EVDs and 50 with TVDs. For each house, energy consumption was measured for a period of several weeks with the vent damper active and for a period with the damper not active. This should help show how effective the vent damper is in each house. Both overall weather conditions and the size of a house can greatly affect energy consumption. A simple formula was used to try to adjust for this. Average energy consumed by the house during one period was recorded as (consumption)/ [(weather)(house area)], where consumption is total energy consumption for the period, measured in BTU's, weather is measured in number of degree days, and house area is measured in square feet. In addition, various characteristics of the house, chimney, and furnace were recorded for each house. A few observations were missing and recorded as .

This report should answer the following questions: (a) Is either damper effective? Effectivity is measured by energy consumption; less consumption means more effective. You may use BTUIN-BTUOUT (Change from Baseline) to measure this. (b) Is there a difference in effectivity between the two types of dampers? Do any differences depend on type of house? (For instance, you might conclude that ranch houses should have one type of damper while two story houses should have another type of damper. Do any differences depend on chimney area, shape, height, or liner ? (c) Is there a difference in energy consumption between the three types of furnaces? Do any differences depend on type of house, chimney area, shape, height, or liner ? (d) Does adjusting for age of house affect the analyses? In what way?

2 Effectiveness in Dampers

- Goal: Test to see if Damper 1 or Damper 2 is effective in conserving energy.
- Methodology: One Paired Sample T-Test
- Variables: Change, BTUin, BTUout, Damper.
- Hypothesis: H0: Dampers have no significant impact on energy conservation. Ha: Dampers have a significant impact on energy. Measered at an alpha of 0.05.

  We are going to see if either Damper is effective in conserving energy. This was measured by a variable we will call "change" which is equal to BTUin - BTUout. We look for significance in both Dampers 1 and 2.
- SAS CODE:

```
PROC TTEST H0=0;
 VAR change;
 BY Damper;
 RUN;
```

- Results

Change in Damper 2

N	Mean	Std Dev	Std Err	Minimum	Maximum
50	-0.8652	0.6855	0.0969	-3.98	0.8700

Mean	95% CL Mean	Std Dev	95% CL Std Dev
-0.8652	-1.0600 -0.6704	0.6855	0.5726 0.8542

DF	t Value	Pr > t
49	-8.93	<.0001

Change in Damper 1

N	Mean	Std Dev	Std Err	Minimum	Maximum
40	-0.6615	0.5106	0.0807	-2.2900	0.3800

Mean	95% CL Mean	Std Dev	95% CL Std Dev
-0.6615	-.8248 -0.4982	0.5106	0.4183 0.6557

DF	t Value	Pr > t
39	-8.19	<.0001

- Conclusions: Based on the high T values for both Damper 1 (8.19) and Damper 2 (8.93), we can say there is significance in our Change variable. Therefore we can safely conclude that our Dampers were effective in conserving energy.

3 Effectiveness Between Dampers and Analysis of Factors

Goal: To see if there is significant difference between the two dampers. We also want to see if factors such as house, type of furnace used, Chimney Liner and Chimney Shape played apart in influencing the effectiveness of these dampers.

Methodology: We are going to use a two sample t-test to see if our test the differences in effectiveness between dampers. After that we will use two way anova tests to examine significance in our factors and their interactions.

SAS CODE

```
PROC TTEST;
CLASS Damper;
VAR change;
RUN;

PROC GLM;     /* Reduces to t-test when only two groups */
CLASS Damper;
MODEL change=Damper;
MEANS Damper / t;
RUN;

    PROC GLM;
Class Damper;
MODEL BTUin = Damper;
means  Damper;
lsmeans Damper;
run;

proc glm;
class Type Damper;
model BTUin = Type Damper Damper*Type;
run;

proc glm;
class ChShape Damper;
model BTUin = ChShape Damper Damper*ChShape;
run;

proc glm;
class ChShape Damper;
model BTUin = ChShape Damper Damper*ChShape;
run;
```

```
proc glm;
class ChLiner Damper;
model BTUin = ChLiner Damper Damper*ChLiner;
run;

    proc glm;
class House Damper;
model BTUin = House Damper Damper*House;
run;
```

TTEST Procedure

Damper	N	Mean	Std Dev	Std Err	Minimum	Maximum
1	40	-0.6615	0.5106	0.0807	-2.2900	0.3800
2	50	-0.8652	0.6855	0.0969	-3.9800	0.8700
Diff (1-2)		0.2037	0.6141	0.1303		

Damper	Method	Mean	95% CL Mean	Std Dev	95% CL Std Dev
1		-0.6615	-0.8248 -0.4982	0.5106	0.4183 0.6557
2		-0.8652	-1.0600 -0.6704	0.6855	0.5726 0.8542
Diff (1-2)	Pooled	0.2037	-0.0552 0.4626	0.6141	0.5353 0.7205
Diff (1-2)	Satterthwaite	0.2037	-0.0470 0.4544		

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	88	1.56	0.1215
Satterthwaite	Unequal	87.599	1.61	0.1100

Equality of Variance				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	49	39	1.80	0.0596

GLM Procedure

Source	DF	Sum Of Squares	Mean Square	F Value	Pr > t
Model	1	0.92208	0.92220	2.44	0.1215
Error	88	33.1913	0.377		
Corrected Total	89	34.11344			

R-Square	Coeff Var	Root MSE	change Mean
0.027	-79.27866	0.614145	-0.774667

Source	DF	Type I SS	Mean Square	F Value	Pr > t
Damper	1	0.922	0.922	2.44	0.1215

Source	DF	Type III SS	Mean Square	F Value	Pr > t
Damper	1	0.922	0.922	2.44	0.1215

BTUin Means Within Dampers

Level of Damper	N	Mean	Std Dev
1	40	9.9077500	3.01986796
2	50	10.1430000	2.76701950

Type I Interaction between Damper and House Type

Source	DF	Type I SS	Mean Square	F Value	Pr > F
House	4	57.19759766	14.29939942	1.81	0.1344
Damper	1	1.16942356	1.16942356	0.15	0.7012
House*Damper	4	42.73032374	10.68258094	1.35	0.2572

Type III Interaction between Damper and House Type

Source	DF	Type III SS	Mean Square	F Value	Pr > F
House	4	74.35412103	18.58853026	2.36	0.0606
Damper	1	0.37588027	0.37588027	0.05	0.8277
House*Damper	4	42.73032374	10.68258094	1.35	0.2572

Type I Interaction between Damper and Chimney Liner

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ChLiner	2	52.42145067	26.21072533	3.54	0.0334
Damper	1	4.39001223	4.39001223	0.59	0.4433
ChLiner*Damper	2	33.86117012	16.93058506	2.29	0.1078

Type III Interaction between Damper and Chimney Liner

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChLiner	2	51.63439765	25.81719883	3.49	0.0351
Damper	1	10.12508727	10.12508727	1.37	0.2454
ChLiner*Damper	2	33.86117012	16.93058506	2.29	0.1078

Type I Interaction between Damper and Chimney Shape

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ChShape	2	57.35190954	28.67595477	3.75	0.0276
Damper	1	5.89607468	5.89607468	0.77	0.3825
ChShape*Damper	2	6.60756182	3.30378091	0.43	0.6507

Type III Interaction between Damper and Chimney Shape

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChShape	2	52.17357223	26.08678612	3.41	0.0377
Damper	1	5.31398662	5.31398662	0.69	0.4069
ChShape*Damper	2	6.60756182	3.30378091	0.43	0.6507

Type I Interaction between Damper and Furnace Type

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Type	2	17.23113185	8.61556592	1.03	0.3617
Damper	1	3.54983010	3.54983010	0.42	0.5167
Type*Damper	2	8.23995056	4.11997528	0.49	0.6130

Type III Interaction between Damper and Furnace Type

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	15.21073752	7.60536876	0.91	0.4070
Damper	1	1.97509900	1.97509900	0.24	0.6284
Type*Damper	2	8.23995056	4.11997528	0.49	0.6130

Results: Based on the results of our GLM procedure, we have an F value of 2.44 and a P value of .1215 for both our Type I and Type III tests. Therefore we can conclude that there is no significant difference between both types of dampers. Upon observation of the means Within Dampers, we see that Damper 1 has a slightly lower energy consumption mean of 9.90 compared to our Damper 2, that has an energy consumption average of 10.143. Using alpha of 0.05 to define a level of significance, we can see that there is no significance between all four factors. When it comes to the analysis of our cofactors, there is no significant interaction between them and our dampers. However, upon examination of our ChShape factor, we find that it has a Type I p-value of 0.0276 and a Type III p-value of 0.0377. Same thing with our ChLiner factor, which has a Type I p-value of 0.0334 and a Type III p-value of 0.0351. This tells us that both ChLiner and ChShape have some association with different strengths. We will do an analysis of these variables later on in our report.

4 Effectiveness Between Furnace Types and Analysis of Factors

- Goal: To test if there is any differences in energy consumption between furnaces.
- Methodology: We want to see if there is any differences between the the means of energy consumption in all three furnaces. We are going to run a pairwise comparison between all three dampers. Then we will run two way anova test between the other factors such as Chimney Liner and Chimney Shape, to determine if they somehow have any effect on the energy consumption.
- SAS CODE

```
   Proc GLM;
   Class TYPE;
   MODEL BTUin = Type;
   means Type / T BON TUKEY;
   run;

   PROC GLM;
Class Type;
MODEL BTUin = Type;
means  Type;
lsmeans Type;
run;

    proc glm;
  class Type ChLiner;
model BTUin = ChLiner Type Type*ChLiner;
run;

proc glm;
class Type House;
model BTUin = House Type Type*House;
run;

proc glm;
class Type ChShape;
model BTUin = ChLiner Type Type*ChLiner;
run;
```

- Results

Alpha	0.05
Error Degrees of Freedom	87
Error Mean Square	8.216398
Critical Value of t	1.98761

Comparisons significant at the 0.05 level are indicated by ***.

Type Comparison	Difference Between Means	95% Confidence Intervals
3 - 2	0.4457	-2.5996 3.4911
3 - 1	1.4055	-0.8448 3.6559
2 - 3	-0.4457	-3.4911 2.5996
2 - 1	0.9598	-1.2906 3.2102
1 - 3	-1.4055	-3.6559 0.8448
1 - 2	-0.9598	-3.2102 1.2906

BTUin Means Within Types

Level of Furnace Type	N	Mean	Std Dev
1	76	9.854	2.9029
2	7	10.814	2.7874
3	7	11.26	2.460

Type I SS For Interaction Effect on Type of Furnace and Liner

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ChLiner	1	44.51816743	44.51816743	5.75	0.0187
Type	2	3.79573111	1.89786556	0.25	0.7831
ChLiner*Type	2	14.10029566	7.05014783	0.91	0.4061

Type III SS For Interaction Effect on Type of Furnace and Liner

Source	DF	Type III SS	Mean Square	F Value	Pr ¿ F
ChLiner	1	0.50440827	0.50440827	0.07	0.7991
Type	2	2.09956353	1.04978176	0.14	0.8733
ChLiner*Type	2	14.10029566	7.05014783	0.91	0.4061

Type I SS For Interaction Effect on Type of Furnace and House

Source	DF	Type I SS	Mean Square	F Value	Pr > F
House	4	57.19759766	14.29939942	1.84	0.1285
Type	2	16.09250178	8.04625089	1.04	0.3589
Type*House	4	46.43161400	11.60790350	1.50	0.2109

Type III SS For Interaction Effect on Type of Furnace and House

Source	DF	Type III SS	Mean Square	F Value	Pr > F
House	4	46.03537185	11.50884296	1.48	0.2147
Type	2	8.27828191	4.13914096	0.53	0.5884
Type*House	4	46.43161400	11.60790350	1.50	0.2109

Type I SS For Interaction Effect on Type of Furnace and ChShape

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ChShape	2	57.35190954	28.67595477	3.75	0.0278
Type	2	1.27096280	0.63548140	0.08	0.9203
Type*ChShape	4	34.26637891	8.56659473	1.12	0.3529

Type III SS For Interaction Effect on Type of Furnace and ChShape

Source	DF	Type III SS	Mean Square	F Value	Pr> F
ChShape	2	4.97952870	2.48976435	0.33	0.7231
Type	2	17.86088621	8.93044310	1.17	0.3163
Type*ChShape	4	34.26637891	8.56659473	1.12	0.3529

- Conclusions Given our multiple comparisons test on furnaces, we can say that there is no significant difference between the effectiveness of our 3 furnaces. Upon observation of the means within the Furnace Types, we see that Type 1 has a slightly lower energy consumption mean of 9.854 compared to our Type 2, that has an energy consumption average of 10.814 and our Type 3 that has a mean of 11.26. We can also see from our two way anova tables that there is no significant interaction between our furnaces and co-factors. However, upon examination of our ChShape factor, we find that it has a Type I p-value of 0.0278 and a Type III p-value of 0.7231. Same thing with our ChLiner factor, which has a Type I p-value of 0.0187 and a Type III p-value of 0.7991. This tells us that both ChLiner and ChShape have some association with different strengths. We will do an analysis of these variables later on in our report.

5 Analysis of Variance Between ChLiners and ChShapes

- Goal: Earlier in our examinations of Dampers and Furnace types, we saw some level of significance when it comes to using ChLiners and ChShapes within our Dampers and Furncace Type variables. We are going to examine the means of these factors.
- Methodoly: We are going to run an PROC LSMeans test and examine our means to see if there is significant change in our values.
- SAS CODE:

```
   PROC GLM;
Class Damper ChShape;
MODEL BTUin = Damper ChShape Damper * ChShape;
means  Damper ChShape Damper * ChShape /T Bon Tukey;
lsmeans Damper ChShape Damper * ChShape;
run;

PROC GLM;
Class Damper ChLiner;
MODEL BTUin = Damper ChLiner Damper * ChLiner;
means  Damper ChLiner Damper * ChLiner /T Bon Tukey;
lsmeans Damper ChLiner Damper * ChLiner;
run;

PROC GLM;
Class Type ChShape;
MODEL BTUin = Type ChShape Type * ChShape;
means  Type ChShape Type * ChShape / T BON TUKEY;
lsmeans Type ChShape Type * ChShape;
run;

PROC GLM;
Class Type ChLiner;
MODEL BTUin = Type ChLiner Type * ChLiner;
means  Type ChLiner Type * ChLiner / T Bon Tukey;
lsmeans Type ChLiner Type * ChLiner;
run;
```

- : Results

T-Test LSD for Damper and ChShape

Alpha 0.05	
Error Degrees of Freedom	83
Error Mean Square	7.648699
Critical Value of t	1.9889

Comparisons(ChShape/Damper) significant at the 0.05 level are indicated by ***.

ChShape Comparison	Difference Between Means	95%Confidence Limits	
2 - 3	0.1822	-1.4385 1.8029	
2 - 1	1.6781	0.3661 2.9901	***
3 - 2	-0.1822	-1.8029 1.4385	
3 - 1	1.4959	-0.0715 3.0633	
1 - 2	-1.6781	-2.9901 -0.3661	***
1 - 3	-1.4959	-3.0633 0.0715	

T-Test LSD for ChShape Type

Alpha	0.05
Error Degrees of Freedom	80
Error Mean Square	7.647604
Critical Value of t	1.99006

Comparisons(ChShape/Type) significant at the 0.05 level are indicated by ***.

ChShape Comparison	Difference Between Means	95%Confidence Limits	
2 - 3	0.1822	-1.4393 1.8036	
2 - 1	1.6781	0.3654 2.9907	***
3 - 2	-0.1822	-1.8036 1.4393	
3 - 1	1.4959	-0.0723 3.0641	
1 - 2	-1.6781	-2.9907 -0.3654	***
1 - 3	-1.4959	-3.0641 0.0723	

T-Test LSD for Liner Damper

Alpha	0.05
Error Degrees of Freedom	83
Error Mean Square	7.397891
Critical Value of t	1.98896

Comparison (Liner/Damper)significance is marked by ****

ChLiner Comparison	Difference Between Means	95%Confidence Limits	
0 - 1	0.3487	-1.0852 1.7825	
0 - 2	1.8956	0.3086 3.4826	***
1 - 0	-0.3487	-1.7825 1.0852	
1 - 2	1.5469	0.1311 2.9627	***
2 - 0	-1.8956	-3.4826 -0.3086	***
2 - 1	-1.5469	-2.9627 -0.1311	***

T-Test LSD for Liner Type

Alpha	0.05
Error Degrees of Freedom	82
Error Mean Square	7.792956
Critical Value of t	1.98932

Comparisons(Liner/Type) significant at the 0.05 level are indicated by ***.

ChLiner Comparison	Difference Between Means	95%Confidence Limits	
0 - 1	0.3487	-1.0481 1.7455	
0 - 2	1.8956	0.3496 3.4415	***
1 - 0	-0.3487	-1.7455 1.0481	
1 - 2	1.5469	0.1677 2.9261	***
2 - 0	-1.8956	-3.4415 -0.3496	***
2 - 1	-1.5469	-2.9261 -0.1677	***

Means in Type and Liner

Type	ChLiner	BTUin LSMEAN
1	0	10.7661111
1	1	10.1661765
1	2	8.7291667
2	0	10.3783333
2	1	13.4300000
3	1	10.7480000
3	2	9.8400000

Means in Type and ChShape

Type	ChShape	BTUin LSMEAN
1	1	8.9359459
1	2	10.9612000
1	3	10.3057143
2	1	13.4200000
2	2	9.7700000
2	3	13.4300000
3	1	9.8400000
3	2	10.5950000
3	3	10.8500000

Means in Damper ChLiner

Damper	ChLiner	BTUin LSMEAN
1	0	9.4109091
1	1	10.7022222
1	2	8.4910000
2	0	11.7338462
2	1	10.0081818
2	2	8.9620000

Means in Damper ChShape

Damper	ChShape	BTUin LSMEAN
1	1	9.0646667
1	2	10.0557143
1	3	10.4320000
2	1	9.0800000
2	2	11.2938889
2	3	10.7425000

- Conclusion Based on our finding, we found that there is a significant impact on ChLiner and ChShape on Dampers and Furnace Types. In our Furnace Type findings, we noticed how it is better to use Chimney Liner 2 and Chimney Shape 1 with Furnace Type 1 to achieve optimal energy conservation. In our Damper findings, we notice how it is better to use Chimney Liner 2 and Chimney Shape 1 along with Damper 1 to achieve optimal energy consumption.

6 Effects of Age on Analysis

- Goals: We want to see what kind of affect age has on energy consumption.
- Methodology: We are going to run a one-way anova and test for significance of age on our analysis.
- SAS CODE: Proc GLM; model BTUin = age; run;
- Results

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	15.6624806	15.6624806	1.92	0.1689
Error	88	716.3953017	8.1408557		
Corrected Total	89	732.0577822			

Parameter	Estimate	Standard Error	t Value	Pr > t
Intercept	9.518110895	0.48081137	19.80	<.0001
Age	0.013491795	0.00972690	1.39	0.1689

- Conclusion: Given that there is not a significant p-value on Age, we can conclude that the age of the house doesn't play a huge role in energy consumption.