```
title1 'Analysis of Covariance - Oyster Data';
options nodate nonumber ls=80 nocenter;
data oyster;
input trt  initial  final @@;
datalines;
1     27.2   32.6     1     32.0   36.6
1     33.0   37.7     1     26.8   31.0
2     28.6   33.8     2     26.8   31.7
2     26.5   30.7     2     26.8   30.4
3     28.6   35.2     3     22.4   29.1
3     23.2   28.9     3     24.4   30.2
4     29.3   35.0     4     21.8   27.0
4     30.3   36.4     4     24.3   30.5
5     20.4   24.6     5     19.6   23.4
5     25.1   30.3     5     18.1   21.8
;

proc  glm data=oyster;
class trt;
model final = trt initial trt*initial; ** test for same slope **;
run;

proc glm data=oyster;
class trt;
model final = trt initial / solution;
lsmeans trt /pdiff cl adj=bon;

** understanding unadj mean vs. adj mean **;
estimate 'trt 1 adj mean' intercept 1 trt 1 0 0 0 0 initial 25.76;
estimate 'trt 2 adj mean' intercept 1 trt 0 1 0 0 0 initial 25.76;
estimate 'adj trt diff 1-2' trt 1 -1 0 0 0;

estimate 'trt 1 unadj mean' intercept 1 trt 1 0 0 0 0 initial 29.75;
estimate 'trt 2 unadj mean' intercept 1 trt 0 1 0 0 0 initial 27.175;
estimate 'unadj trt diff 1-2' trt 1 -1 0 0 0 initial 2.575;
** understanding unadj mean vs. adj mean **;

run;
```

Analysis of Covariance - Oyster Data

The GLM Procedure

Class Level Information

Class	Levels	Values
trt	5	1 2 3 4 5

Number of Observations Read 20
Number of Observations Used 20

Analysis of Covariance - Oyster Data

The GLM Procedure

Dependent Variable: final

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	355.8354908	39.5372768	139.51	<.0001
Error	10	2.8340092	0.2834009		
Corrected Total	19	358.6695000			

R-Square	Coeff Var	Root MSE	final Mean
0.992099	1.725901	0.532354	30.84500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
trt	4	198.4070000	49.6017500	175.02	<.0001
initial	1	156.0401767	156.0401767	550.60	<.0001
initial*trt	4	1.3883141	0.3470785	1.22	0.3602

Source	DF	Type III SS	Mean Square	F Value	Pr > F
trt	4	1.69618688	0.42404672	1.50	0.2752
initial	1	68.52892317	68.52892317	241.81	<.0001
initial*trt	4	1.38831410	0.34707852	1.22	0.3602

Analysis of Covariance - Oyster Data

The GLM Procedure

Dependent Variable: final

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	354.4471767	70.8894353	235.05	<.0001
Error	14	4.2223233	0.3015945		
Corrected Total	19	358.6695000			

R-Square	Coeff Var	Root MSE	final Mean
0.988228	1.780438	0.549176	30.84500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
trt	4	198.4070000	49.6017500	164.47	<.0001
initial	1	156.0401767	156.0401767	517.38	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
trt	4	12.0893593	3.0223398	10.02	0.0005
initial	1	156.0401767	156.0401767	517.38	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		2.494859769	B	1.02786287	2.43	0.0293
trt	1	-0.244459378	B	0.57658196	-0.42	0.6780
trt	2	-0.280271345	B	0.49290825	-0.57	0.5786
trt	3	1.654757698	B	0.42943036	3.85	0.0018
trt	4	1.107113519	B	0.47175112	2.35	0.0342
trt	5	0.000000000	B	.	.	.
initial		1.083179819		0.04762051	22.75	<.0001

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Analysis of Covariance - Oyster Data

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Bonferroni

trt	final LSMEAN	LSMEAN Number
1	30.1531125	1
2	30.1173006	2
3	32.0523296	3
4	31.5046854	4
5	30.3975719	5

Least Squares Means for effect trt
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: final

i/j	1	2	3	4	5
1		1.0000	0.0099	0.0613	1.0000
2	1.0000		0.0030	0.0315	1.0000
3	0.0099	0.0030		1.0000	0.0176
4	0.0613	0.0315	1.0000		0.3417
5	1.0000	1.0000	0.0176	0.3417	

trt	final LSMEAN	95% Confidence Limits	
1	30.153113	29.436931	30.869294
2	30.117301	29.510894	30.723707
3	32.052330	31.452584	32.652075
4	31.504685	30.911849	32.097522
5	30.397572	29.620733	31.174411

Least Squares Means for Effect trt

i	j	Difference Between Means	Simultaneous 95% Confidence Limits for LSMean(i)-LSMean(j)	
1	2	0.035812	-1.318500	1.390124
1	3	-1.899217	-3.422446	-0.375989
1	4	-1.351573	-2.746258	0.043112
1	5	-0.244459	-2.161996	1.673077
2	3	-1.935029	-3.286978	-0.583080
2	4	-1.387385	-2.684290	-0.090479
2	5	-0.280271	-1.919534	1.358992
3	4	0.547644	-0.774051	1.869339
3	5	1.654758	0.226603	3.082912
4	5	1.107114	-0.461787	2.676014

Analysis of Covariance - Oyster Data

The GLM Procedure

Dependent Variable: final

Parameter	Estimate	Standard Error	t Value	Pr > |t|
trt 1 adj mean	30.1531125	0.33391743	90.30	<.0001
trt 2 adj mean	30.1173006	0.28273504	106.52	<.0001
adj trt diff 1-2	0.0358120	0.40722674	0.09	0.9312
trt 1 unadj mean	34.4750000	0.27458811	125.55	<.0001
trt 2 unadj mean	31.6500000	0.27458811	115.26	<.0001
unadj trt diff 1-2	2.8250000	0.38832623	7.27	<.0001

The five treatments can also be looked upon as a 2X2 factorial plus a control. The adjust treatments from the ANCOVA can be analyzed further with 4 orthogonal contrasts [see section 9.2] implemented by the following CONTRAST statements in the proc glm …

```
contrast ‘control vs. treatment’ trt -1 -1 -1 -1 4;
contrast ‘bottom vs. top’ trt 1 -1 1 -1 0;
contrast ‘intake vs. discharge’ trt 1 1 -1 -1 0;
contrast ‘interaction’ trt 1 -1 -1 1 0;
```

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
control vs. treatment	1	0.52000411	0.52000411	1.72	0.2103
bottom vs. top	1	0.33879074	0.33879074	1.12	0.3071
intake vs. discharge	1	8.59108077	8.59108077	28.49	0.0001
interaction	1	0.22934155	0.22934155	0.76	0.3979