SRI

MEMO

TO: Project 7663 Team

DATE: Dec. 6, 1978

FROM: William Stock

LOCATION: 202B

SUBJECT: Preliminary Statistical Study of Elkhart Rolling Resistance Data

CC:

Introduction

This note reports on a preliminary statistical study of rolling resistance data. The data employed were taken an Conrail's Elkhart, Indiana, yard October 25 and 26, 1978, by Messrs. Jim Wetzel, Jack Delaney and Gerald Brubaker of Conrail.

The Data

The data consists of three separate test runs of cars switched over the hump and rolled into a single destination class track. Two of the runs were done on October 25, using the same train of cars; the third run was done on October 26, using a different train of cars. A vector of observations is available for each tested car. Such a vector of observations is referred to as a "case". The basic observations for each car are given in Table I, together with shorthand names for each observed quantity (or variable) that will, for convenience, be used to refer to each. The weight and length of each car were collected by machine; the speeds reported were taken manually by timing the cars through selected speed traps with a stopwatch.

Starting from these basic variables as a base, additional variables can be derived; these are shown in Table II. Some of the derived variables are simply changes in units, such as converting the weight in pounds to weight in tons. However, some of the derived variables are more complex,

Table I--Basic Variables Available for Each Test Car

Variable Name	Description of Observed Quantity
WTLBS	Weight of car in lbs.
LENG	Length of car in feet
VELC	Velocity at crest - mph
VELS	Velocity at scale - mph
VELM	Velocity at master ret. - mph
VELG	Velocity at group ret. - mph

Table II--Combined List of Basic and Derived Variables Available for Study

Variable Name	Description
RRCS	Rolling res. crest to scale - lb. per ton
RRMG	Rolling res. mast. to group - lb. per ton
WTLBS	Weight of car in lbs.
WTTONS	Weight of car in tons
LENG	Length of car in feet
HEADC	Vel. head at crest - feet
HEADS	Vel. head at scale - feet
HEADM	Vel. head at master ret. - feet
HEADG	Vel. head at group ret. - feet
VELC	Velocity at crest - mph
VELS	Velocity at scale - mph
VELM	Velocity at master ret. - mph
VELG	Velocity at group ret. - mph
AVEVELCS	Ave. vel. crest to scale - mph
AVEVELMG	Ave. vel. master to group - mph

such as the rolling resistance. An average rolling resistance, in pounds per unit weight of car, can be derived from the speeds at the two ends (surrogate acceleration) of a track section of known, constant grade*. Using energy considerations, and ignoring other resistances, such as wind and switches, the formula employed is:

$$R = \frac{V_A^2 + V_B^2}{2gL_{AB}} + G_{AB}$$

where R=Average resistance between points A and B

V_A=Speed at an upstream point A

V_B=Speed at a downstream point B

L_{AB}=Distance between A and B

G_{AB}=Grade between A and B (downgrades positive)

g=Acceleration of gravity.

For convenience, R is usually taken in pounds per ton of car; this is done here. The above calculations were performed to obtain rolling resistance values for each car in the area between the crest and the scale, RRCS, and in the area between the master and group retarders, RRMG.

Missing Observations

An attempt was also made to observe velocities and therefore calculate the rolling resistance on the tangent track. However, numerous

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*It is possible to generalize the equation for track sections of varying grade, for other resistances, and for energy stored in the wheels due to their rotation.

stalls and collisions precluded taking any but a couple of observations in this area. Therefore, tangent track rolling resistance has not been considered in this study.

For Run 3, no velocity observations were taken between the master and group retarders; consequently, the RRMG values are unavailable for Run 3.

Finally, scattered data values were, for one reason or another, not recorded for a few observations of most all of the variables. Those cases with missing values have, of course, not been included in an analysis wherever a missing variable value would be involved.

The Analyses

The statistical analyses were performed using a widely available computer package, SPSS*. All the analyses performed were regressions, with simple bivariate regressions being performed by a routine that also plots a scatter diagram of one variable versus another.

Because the rolling resistances were each computed directly from a combination of two speed observations, the rolling resistances are related to these two speed observations by a definite mathematical relationship given earlier. Therefore, it would be pointless to include these speed observations in any regression with rolling resistance. Although instantaneous rolling resistance is often regarded as a function of speed, separate observation(s) of speed not used in computing

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*Nie, Hall, Jenkins, Steinbrenner, and Bent, Statistical Package for the Social Sciences (SPSS), 2nd ed., McGraw Hill, 1975.

The rolling resistances would be required to assess this effect.

Following is a brief description of each analysis performed.

Analysis 1

Analysis 1 (Figure 1) plots the rolling resistance between the master and group retarder, RRMG, as a function of the rolling resistance from crest to scale, RRCS, for the same car. Only Run 1 data are considered in this analysis. From the scatter of points in the plot and from the regression output given below the figure, the correlation is positive, as expected. The relation is significant at the 5% level. However, the R-squared value reports that RRCS can explain only about 11% of the variation in RRMG, which means that knowing RRCS does not allow us to predict RRMG from RRCS with much accuracy.

Analysis 2

Analysis 2 (Figure 2) plots the same variables as in Figure 1, but for Run 2. Even though the train of cars tested is the same as in Run 1, no statistically significant relationship is found.

Analysis 3

Analysis 3 (Figure 3) again plots the same variables as in Analysis 1, but with Runs 1 and 2 forming a combined sample. The conclusions are similar to those given in Analysis 1.

Analysis 4

Analysis 4 (Figure 4) attempts to see if a relation exists between the weight and the rolling resistance. From theory, the rolling resistance should be proportional to the reciprocal of the weight, so that a negative correlation would be expected when regressing rolling resistance directly against weight. Figure 4 plots RRCS against the weight of the car in tons (WTTONS) for Run 1. As can be seen, the expected negative correlation does result, but the relationship only explains about 20% of the variation* in RRCS.

Analysis 5

Analysis 5 (Figure 5) is similar to Analysis 4, but for Run 2. The results are essentially the same as for Analysis 4.

Analysis 6

Analysis 6 (Figure 6) is also similar to Analyses 4 and 5, but is addressed to Run 3. The same relation as in Analyses 4 and 5 seems to exist, but it appears to be much weaker.

Analysis 7

Analysis 7 (Figure 7) is similar to Analyses 4,5, and 6, but with Runs 1, 2, and 3 treated as a combined sample. Again, a statistically significant, but poor from the standpoint of explaining variation in the data, relationship appears to exist. One interesting feature obvious in this combined plot of the three runs is the natural division of the data into two weight groups. These probably correspond to loaded and empty cars.

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*A regression against 1/WTTONS should result in explaining somewhat more of the variation in RRCS.

Analysis 8

Analysis 8 (Figure 8) treats the combined sample of Runs 1, 2, and 3. It attempts to see whether a relationship exists between car length and weight. In an overall sense, such a relationship does appear to exist, with a postive correlation as is intuitive. However, the car's being loaded or empty* can be seen by eye to have a much more critical bearing on the weight. By eye, a much stronger relation between weight and car length appears to exist for the subset of cars which are felt to be unloaded. It is also obvious from the plot that most cars tend to fall into discrete lengths; this is to be expected for a manufactured entity such as a rail car.

Analysis 9

Analysis 9 (Figure 9) explores the self-consistency of the rolling resistance of each car with itself between Runs 1 and 2. This analysis examines the rolling resistance between crest and scale, RRCS. RRCS in Run 2 is plotted down the Y-axis against RRCS in Run 1 across the X-axis. As can be seen, a statistically significant relation, with a positive correlation as expected, appears to exist. However, RRCS in Run 1 explains only 25% of the variation of the same quantity in Run 2. This implies that the rolling resistance of a car is indeed the result of many random phenomena operating and probably will not be easy to predict.

Analysis 10

Analysis 10 (Figure 10) is similar to Analysis 9 except that RRMG

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*Those cars weighing more than about 50 tons are conjectured to be loaded.

is the variable compared between Runs 1 and 2. The conclusions are similar to those arrived at in Analysis 9.

Analysis 11

Analysis 11 (Figure 11) is a multiple regression analysis to investigate the predictability of a downstream rolling resistance (RRMG) from an upstream rolling resistance (RRCS) and another known variable, WTTONS. Although it would also have been desirable to have included the car length, LENG, in this analysis, too many missing values for the variable* precluded its inclusion. A dummy variable**, RUN1DUM was also included in the regression to assess whether any significant difference existed between Runs 1 and 2. Run 3 was not included in the analysis because all of its values of RRMG were missing.

Figure 11, Part 1, shows the correlation matrix between the four variables involved in the regression. The relatively high correlation

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*Were LENG included, only 39 complete cases would have been available for analysis, rather than the 64 available otherwise.

**A set of dummy variables is "created" by treating each category of a nominal variable as a separate variable and assigning arbitrary scores for all cases depending upon their presence or absence in each of the categories. For example, the dummy variable considered here is given the score of 1 if the case is a member of Run 1, and 0 if it is a member of Run 2. The newly created dichotomous variables are called dummy variables because their scores have no meaning other than representing or standing for a particular category in the original nominal variable.

between the independent* variables WTTONS and RRCS implies some confounding of their effects. This means that it may be relatively difficult or impossible to judge their separate effects on RRMG, but only their joint effect.

Figure 11, Part 2, shows the three steps of the regression. As can be seen, only the first variable to enter the equation, WTTONS, has any appreciable explanatory effect on RRMG. The variables entered into the equation on steps 2 and 3 increase the R^2 value (percent of variation in RRMG explained by the independent variables) only slightly. These results imply that, at least for the variables at hand, the predictability of RRMG is poor, and adding additional variables to the equation after the first one adds little to our prediction of RRMG. The poor predictability of RRMG is further illustrated by the analysis of residuals in Figure 11, Part 3. As can be seen there, the estimated values of RRMG (denoted as "Y ESTIMATE") are quite poor. Also, the dummy variable RUN1DUM is not significant, indicating that the analysis has failed to detect any significant difference between Runs 1 and 2.

Concluding Remarks

The statistical analyses of the rolling resistance data have shown that statistically significant relationships exist among most of the variables analyzed. At the same time, however, the predictability of any of the dependent variables studied from one or more independent

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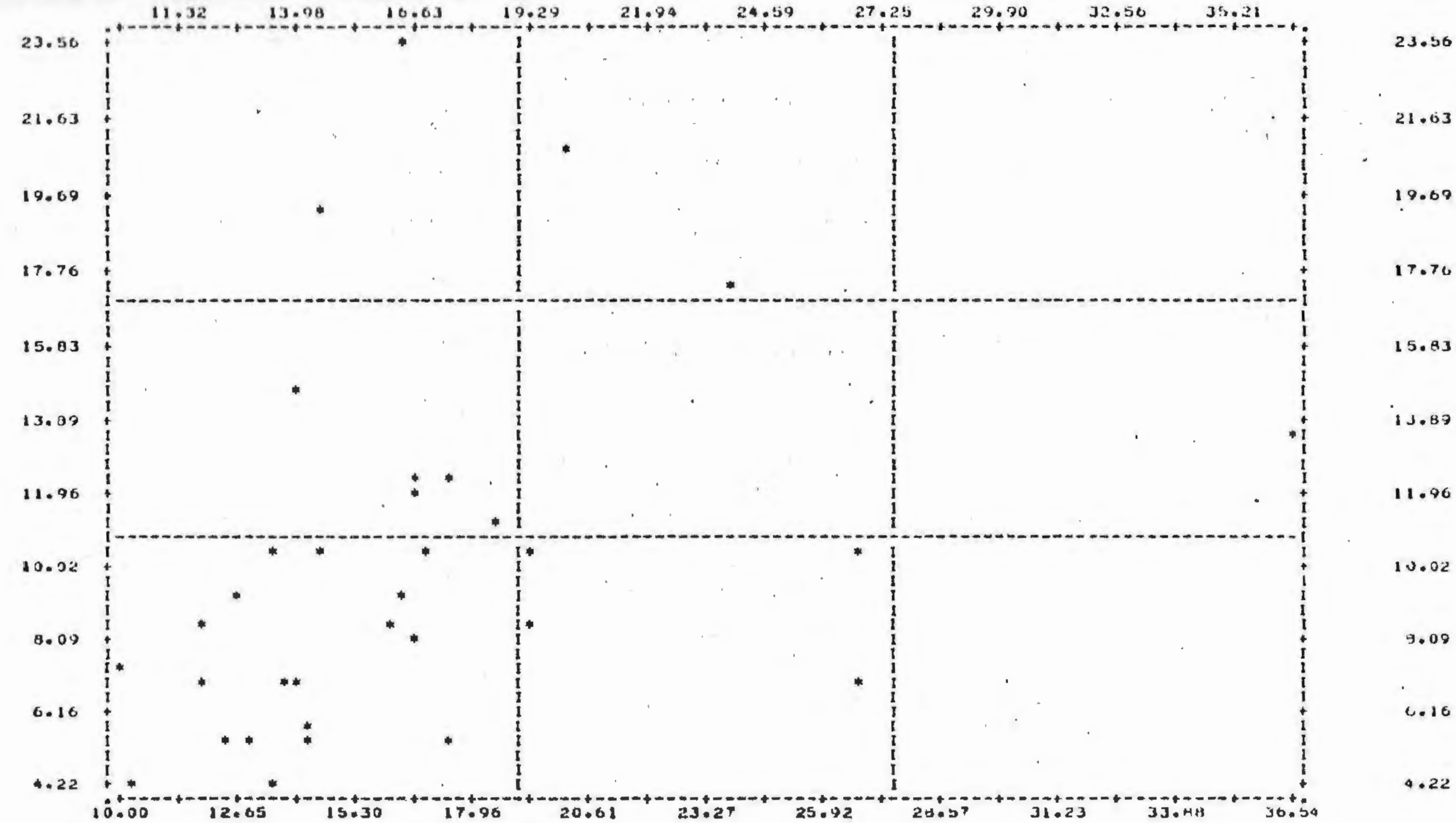
*Independent from the standpoint of RRMG. This does not necessarily imply that RRCS and WTTONS are independent of each other.

variables is poor.

In particular, it is desirable to be able to predict a car's tangent track rolling resistance. However, as mentioned earlier, this rolling resistance was not available for study. The rolling resistance between the master and group retarders was used as a sort of surrogate in these analyses. These analyses imply that the rolling resistance results from a complex interplay of many random phenomena; indeed, even the rolling resistances of the same cars measured at the same location are not predictably consistent from one run to the next. These results imply that, even given more independent variables than were available for this study, so long as the independent variables are of the nature studied here, a good prediction of a car's rolling resistance may prove difficult to obtain.

SCATTERPLOTS 78/11/15. 17.3 PAGE 3

FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1
SCATTERGRAM OF (DOWN) RRMG ROLLING RES. MAST. TO GROUP - LB. PER TO (ACROSS) RRCS ROLLING RES. CREST TO SCALE - LB. PER T



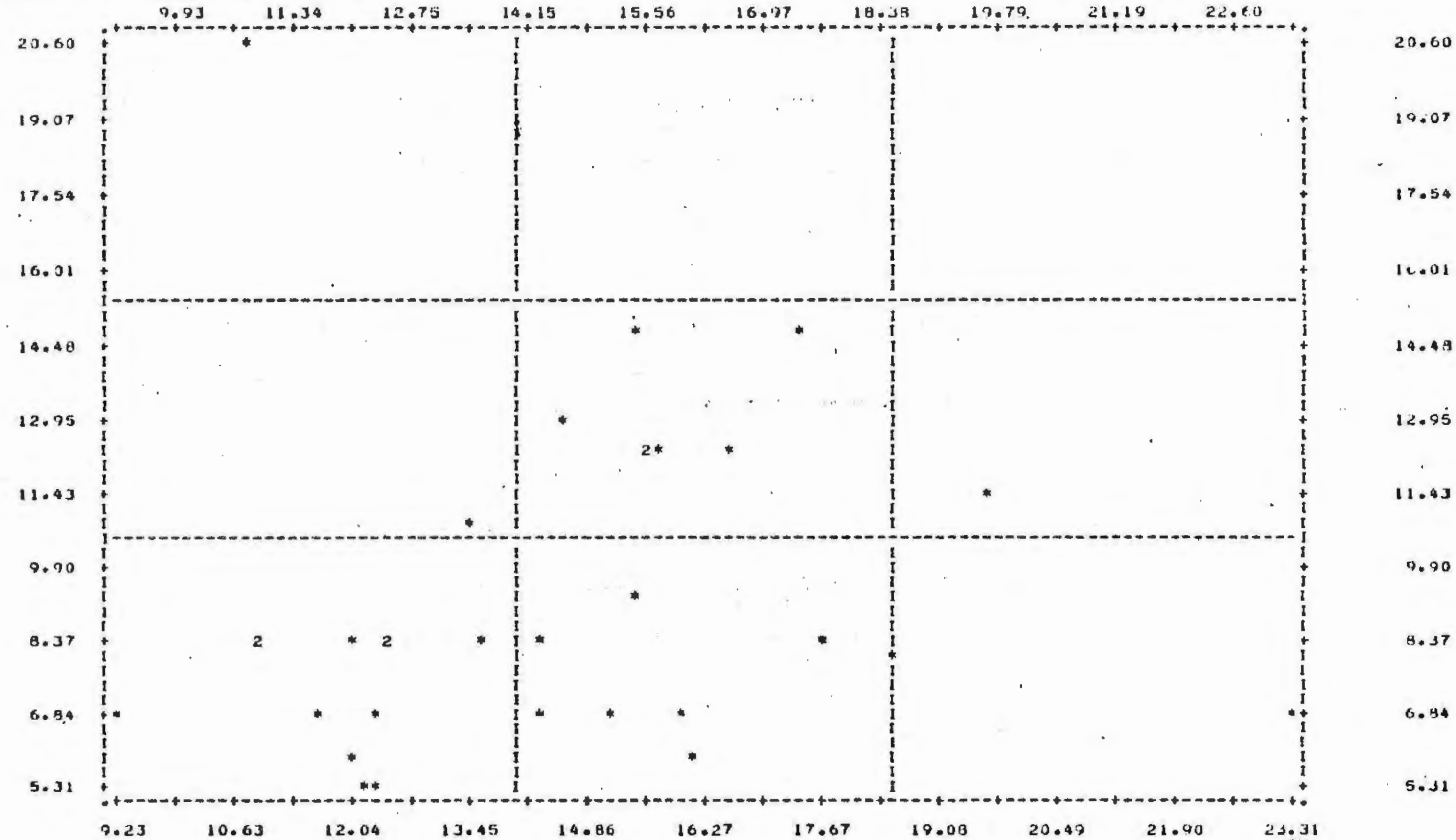
SCATTERPLOTS 78/11/15. 17.3 PAGE 4

STATISTICS..

CORRELATION (R)-	.32939	R SQUARED -	.10850	SIGNIFICANCE R -	.03061
STD ERR OF EST -	4.55459	INTERCEPT (A) -	5.36424	STD ERROR OF A -	2.61722
SIGNIFICANCE A -	.02447	SLOPE (B) -	.29107	STD ERROR OF B -	.14985
SIGNIFICANCE B -	.03061				
PLOTTED VALUES -	33	EXCLUDED VALUES-	0	MISSING VALUES -	0

FIGURE 1 - Analysis 1

FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN2
SCATTERGRAM OF (DOWN) RRMG ROLLING RES. MAST. TO GROUP - LB. PER TO (ACROSS) RRCS ROLLING RES. CREST TO SCALE - LB. PER T

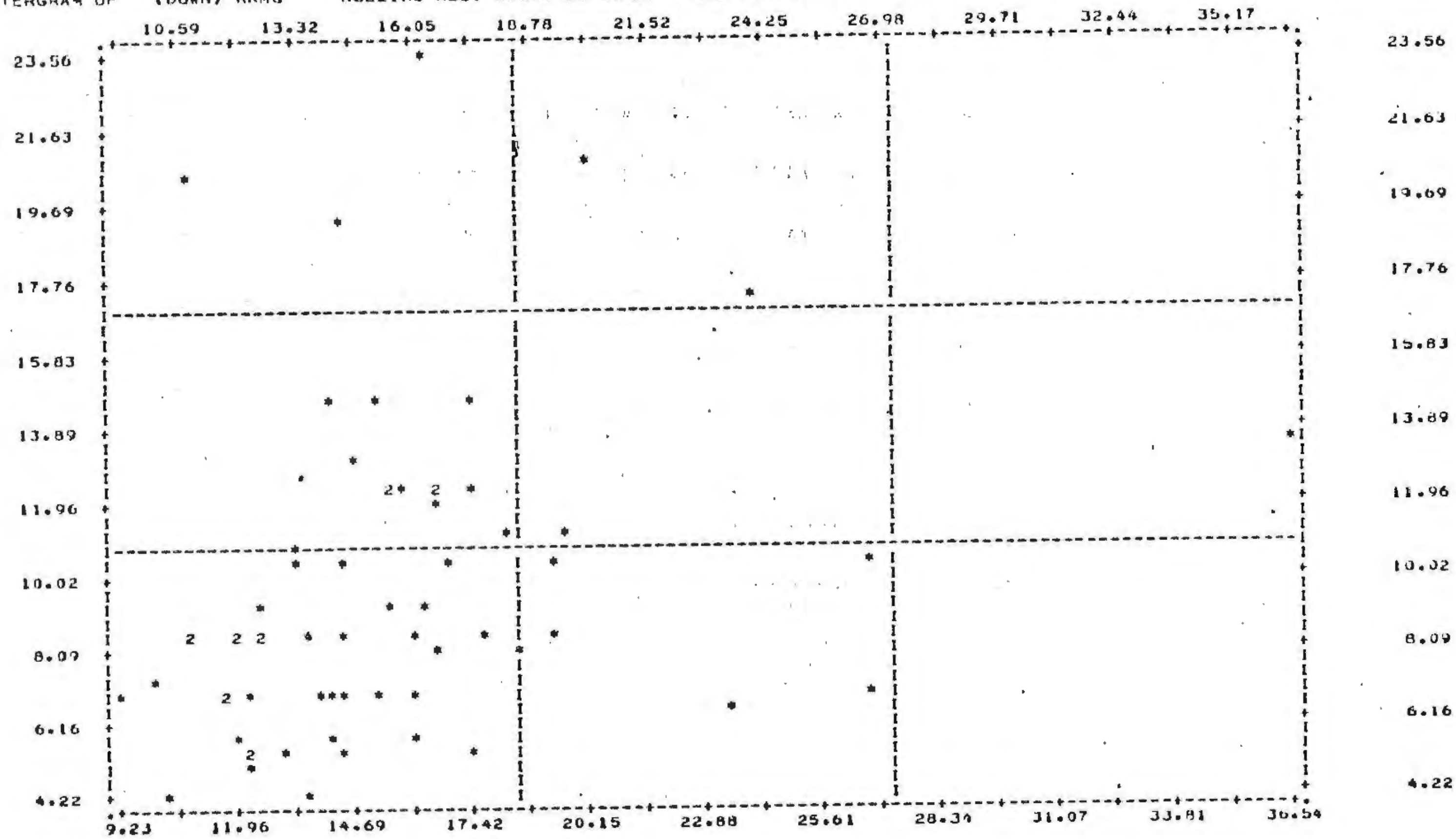


STATISTICS..

CORRELATION (R)-	.09402	R SQUARED -	.00884	SIGNIFICANCE R -	.30745
STD ERR OF EST -	3.49089	INTERCEPT (A) -	7.95675	STD ERROR OF A -	3.10925
SIGNIFICANCE A -	.00799	SLOPE (B) -	.10731	STD ERROR OF B -	.21099
SIGNIFICANCE B -	.30745				
PLOTTED VALUES -	31	EXCLUDED VALUES-	0	MISSING VALUES -	2

FIGURE 2 - Analysis 2

FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2
SCATTERGRAM OF (DOWN) RRMG ROLLING RES. MAST. TO GROUP - LB. PER TO (ACROSS) RRCS ROLLING RES. CREST TO SCALE - LB. PER T



STATISTICS..

CORRELATION (R)-	.27566	R SQUARED -	.07599	SIGNIFICANCE R -	.01374
STD ERR OF EST -	4.00760	INTERCEPT (A) -	5.91163	STD ERROR OF A -	1.02263
SIGNIFICANCE A -	.00095	SLOPE (B) -	.25403	STD ERROR OF B -	.11250
SIGNIFICANCE B -	.01374				
PLOTTED VALUES -	64	EXCLUDED VALUES-	0	MISSING VALUES -	2

FIGURE 3 - Analysis 3

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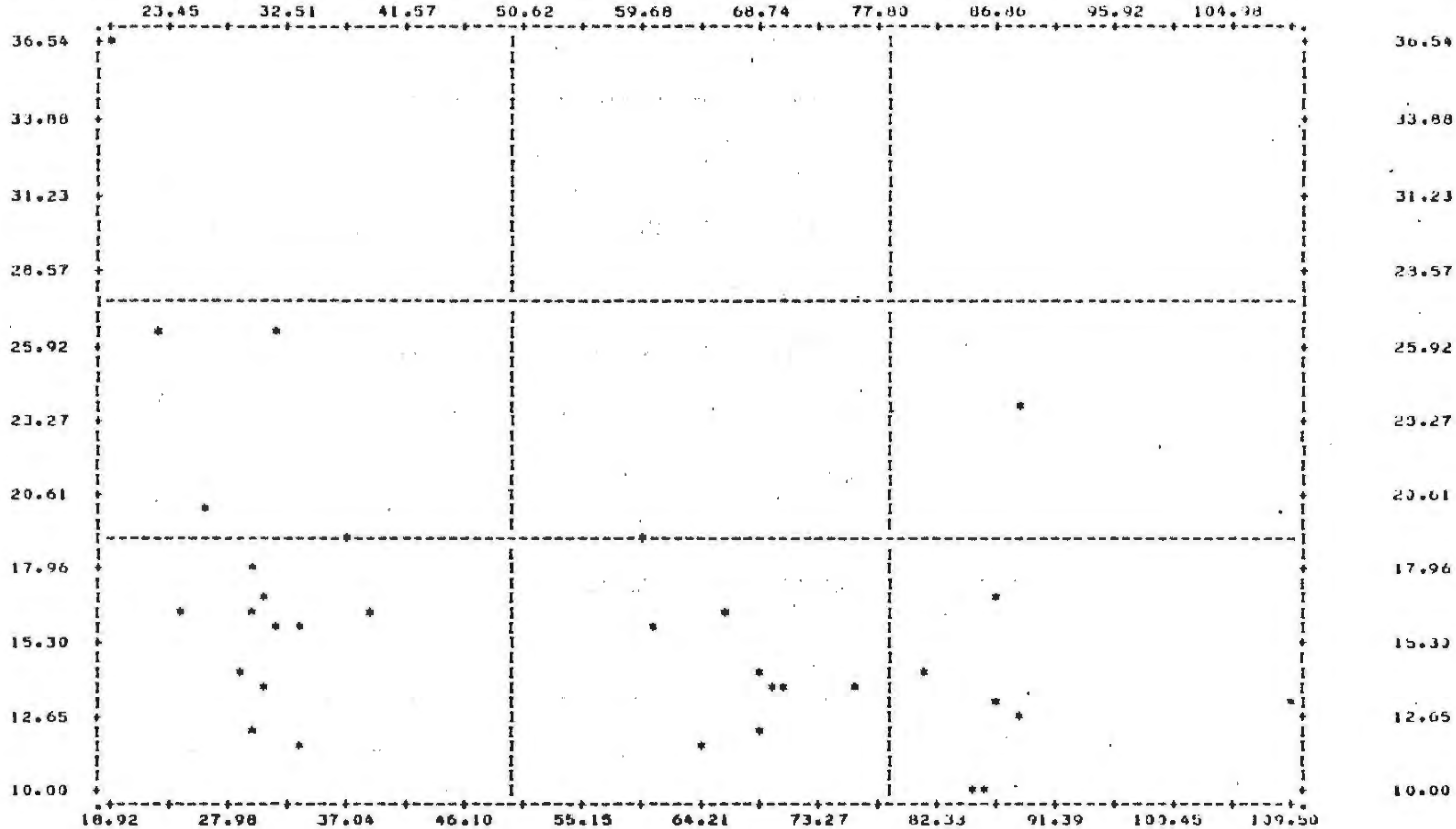
FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1
SCATTERGRAM OF (DOWN) RRCS ROLLING RES. CREST TO SCALE - LB. PER TO (ACROSS) WTTONS WEIGHT OF CAR IN TONS



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STATISTICS..

CORRELATION (R)-	-.44635	R SQUARED -	.19923	SIGNIFICANCE R -	.00461
STD ERR OF EST -	4.88504	INTERCEPT (A) -	21.61992	STD ERROR OF A -	1.98234
SIGNIFICANCE A -	.00001	SLOPE (B) -	-.09151	STD ERROR OF B -	.03295
SIGNIFICANCE B -	.00461				
PLOTTED VALUES -	33	EXCLUDED VALUES-	0	MISSING VALUES -	0

FIGURE 4 - Analysis 4

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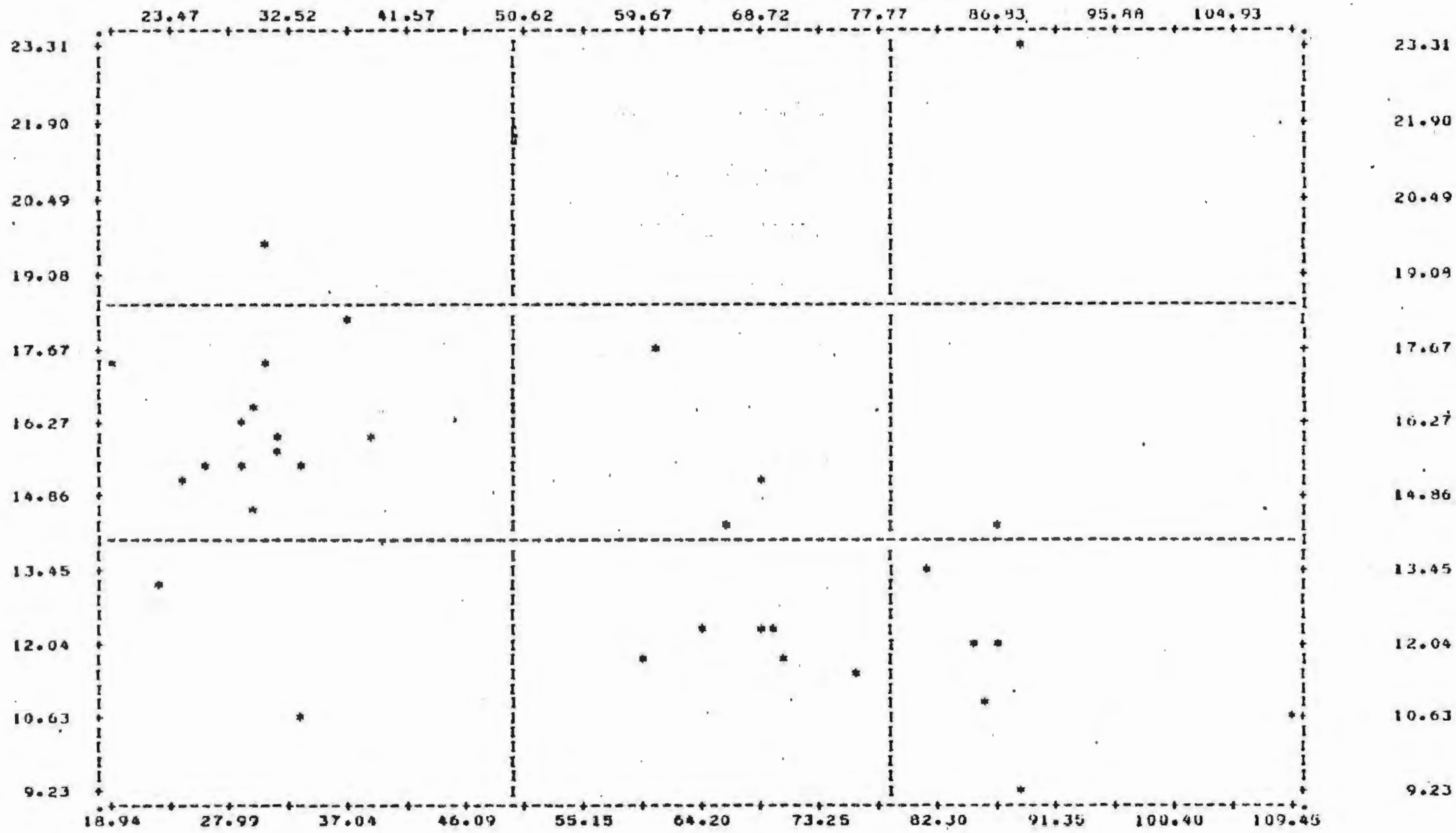
FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN2
SCATTERGRAM OF (DOWN) RRCS ROLLING RES. CREST TO SCALE - LB. PER TO (ACROSS) WTTONS WEIGHT OF CAR IN TONS



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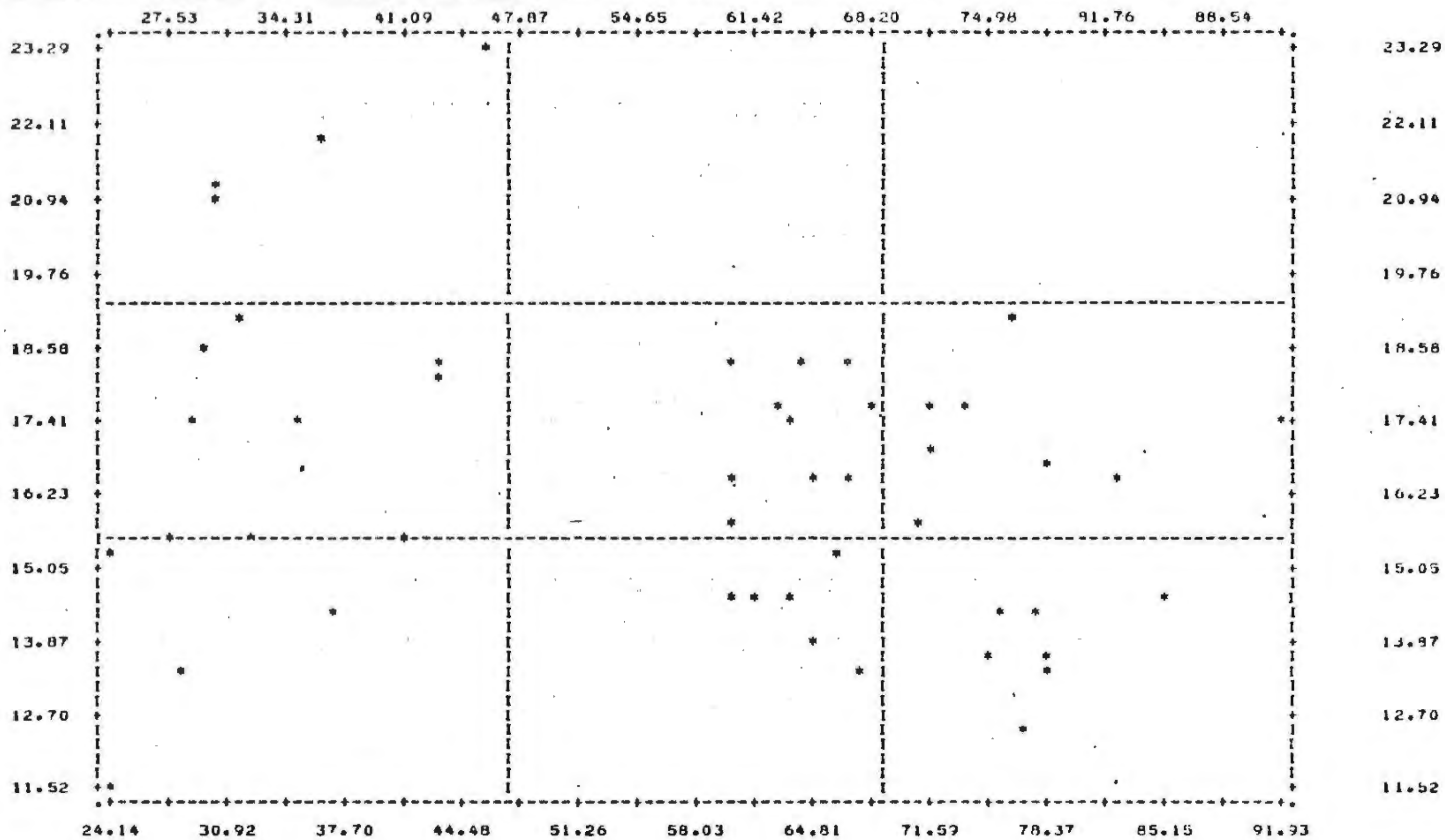
STATISTICS..

CORRELATION (R)-	-.43729	R SQUARED -	.19122	SIGNIFICANCE R -	.00547
STD ERR OF EST -	2.69942	INTERCEPT (A) -	17.26874	STD ERROR OF A -	1.09572
SIGNIFICANCE A -	.00001	SLOPE (B) -	-.04929	STD ERROR OF B -	.01820
SIGNIFICANCE B -	.00547				
PLOTTED VALUES -	33	EXCLUDED VALUES-	0	MISSING VALUES -	0

FIGURE 5 - Analysis 5

FILE FLKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN3
SCATTERGRAM OF (DOWN) RRCS ROLLING RES. CREST TO SCALE - LB. PER TO (ACROSS) WTTONS WEIGHT OF CAR IN TONS

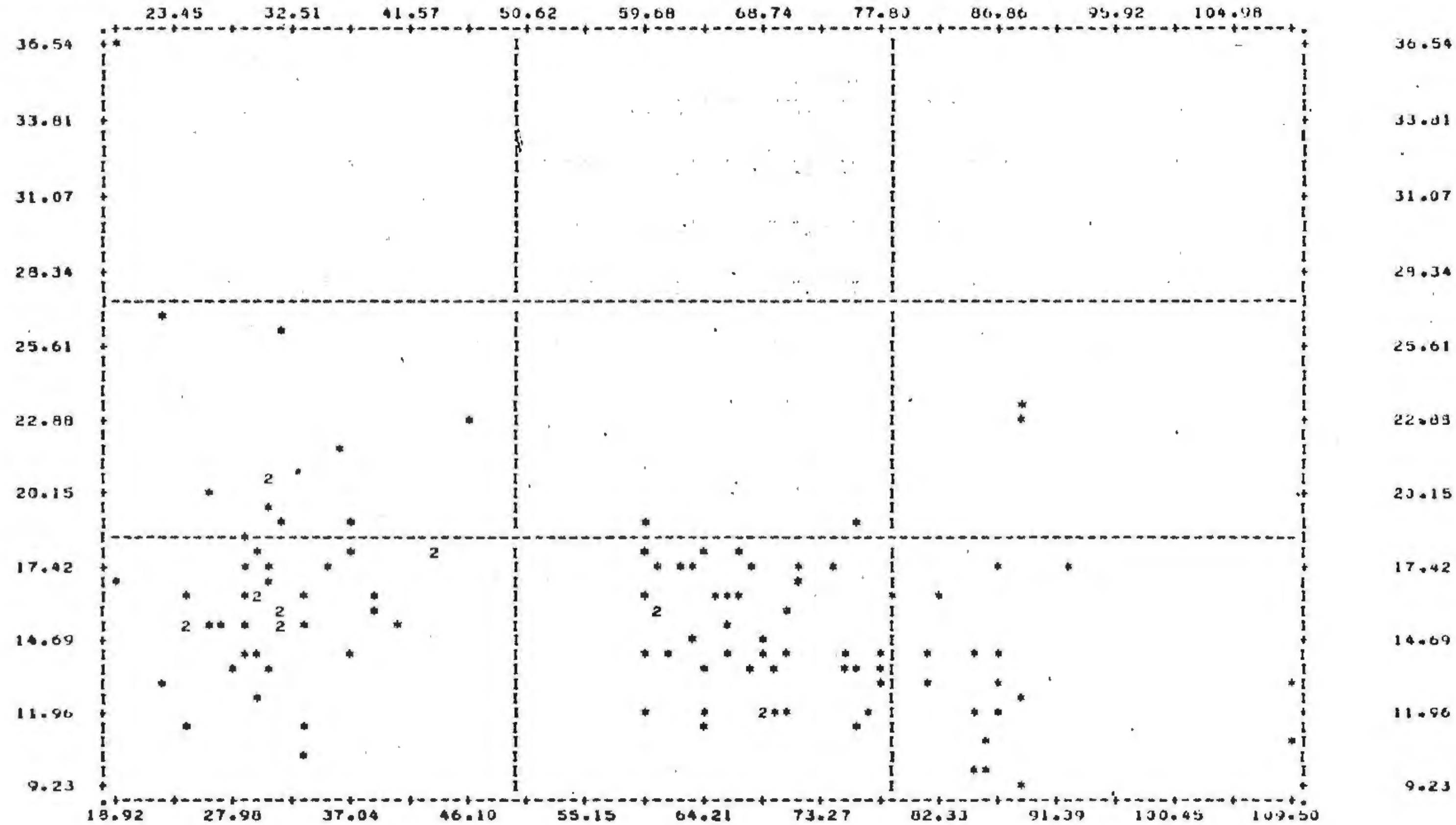


STATISTICS..

CORRELATION (R)-	-.24497	R SQUARED -	.06001	SIGNIFICANCE R -	.04666
STD ERR OF EST -	2.41715	INTERCEPT (A) -	18.35554	STD ERROR OF A -	1.09601
SIGNIFICANCE A -	.00001	SLOPE (B) -	-.03105	STD ERROR OF B -	.01812
SIGNIFICANCE B -	.04666				
PLOTTED VALUES -	48	EXCLUDED VALUES-	0	MISSING VALUES -	2

FIGURE 6 - Analysis 6

FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2 RUN3
SCATTERGRAM OF (DOWN) PRCS ROLLING RES. CREST TO SCALE - LB. PER TO (ACROSS) WTTONS WEIGHT OF CAR IN TONS



STATISTICS..

CORRELATION (R)-	-.36008	R SQUARED -	.12966	SIGNIFICANCE R -	.00004
STD ERR OF EST -	3.50878	INTERCEPT (A) -	19.22163	STD ERROR OF A -	.84083
SIGNIFICANCE A -	.00001	SLOPE (B) -	-.05756	STD ERROR OF B -	.01403
SIGNIFICANCE B -	.00004				
PLOTTED VALUES -	114	EXCLUDED VALUES-	0	MISSING VALUES -	2

FIGURE 7 - Analysis 7

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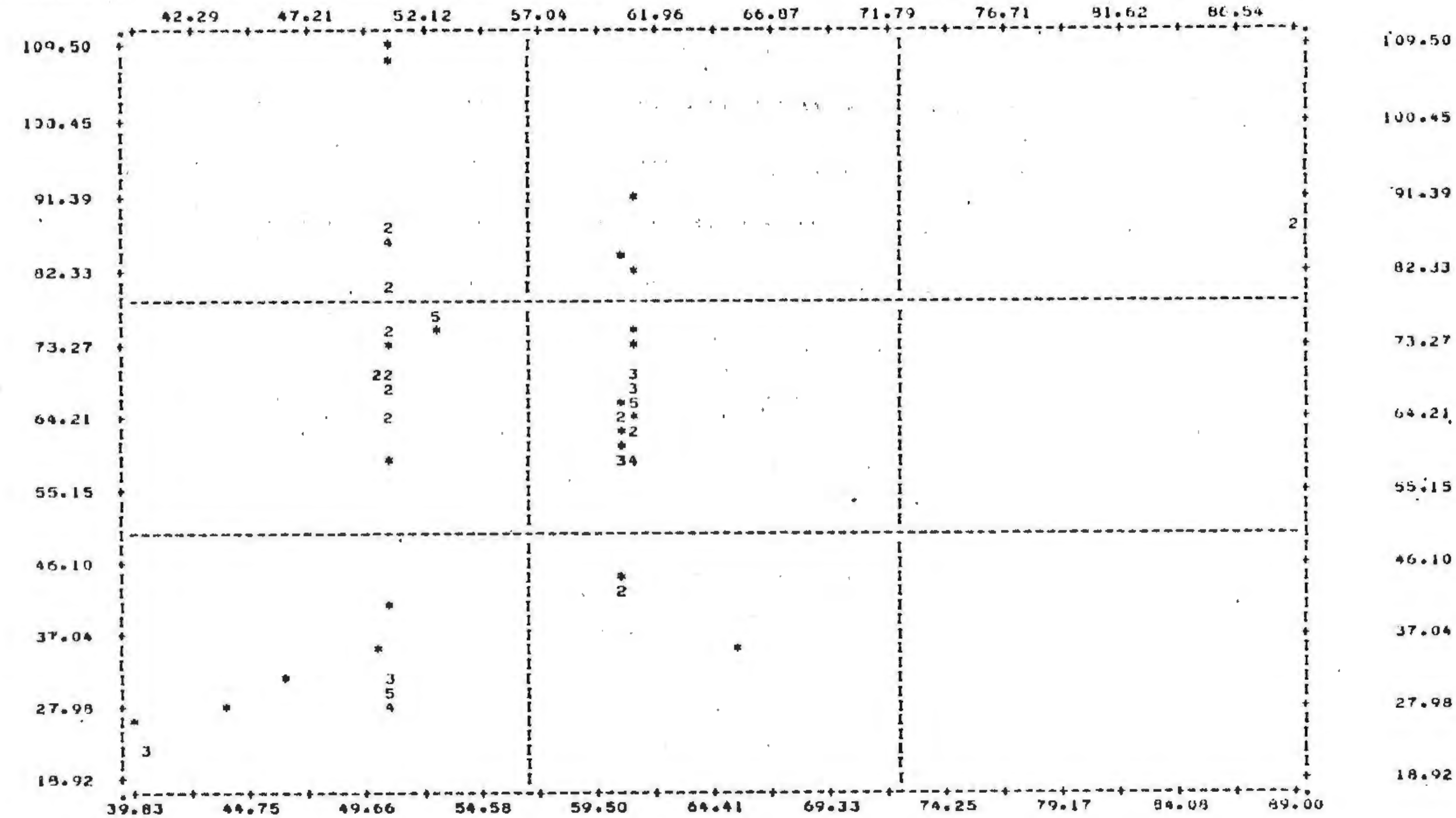
FILE ELKROLPS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2 RUN3
SCATTERGRAM OF (DOWN) WTTONS WEIGHT OF CAR IN TONS (ACROSS) LENG LENGTH OF CAR IN FEET



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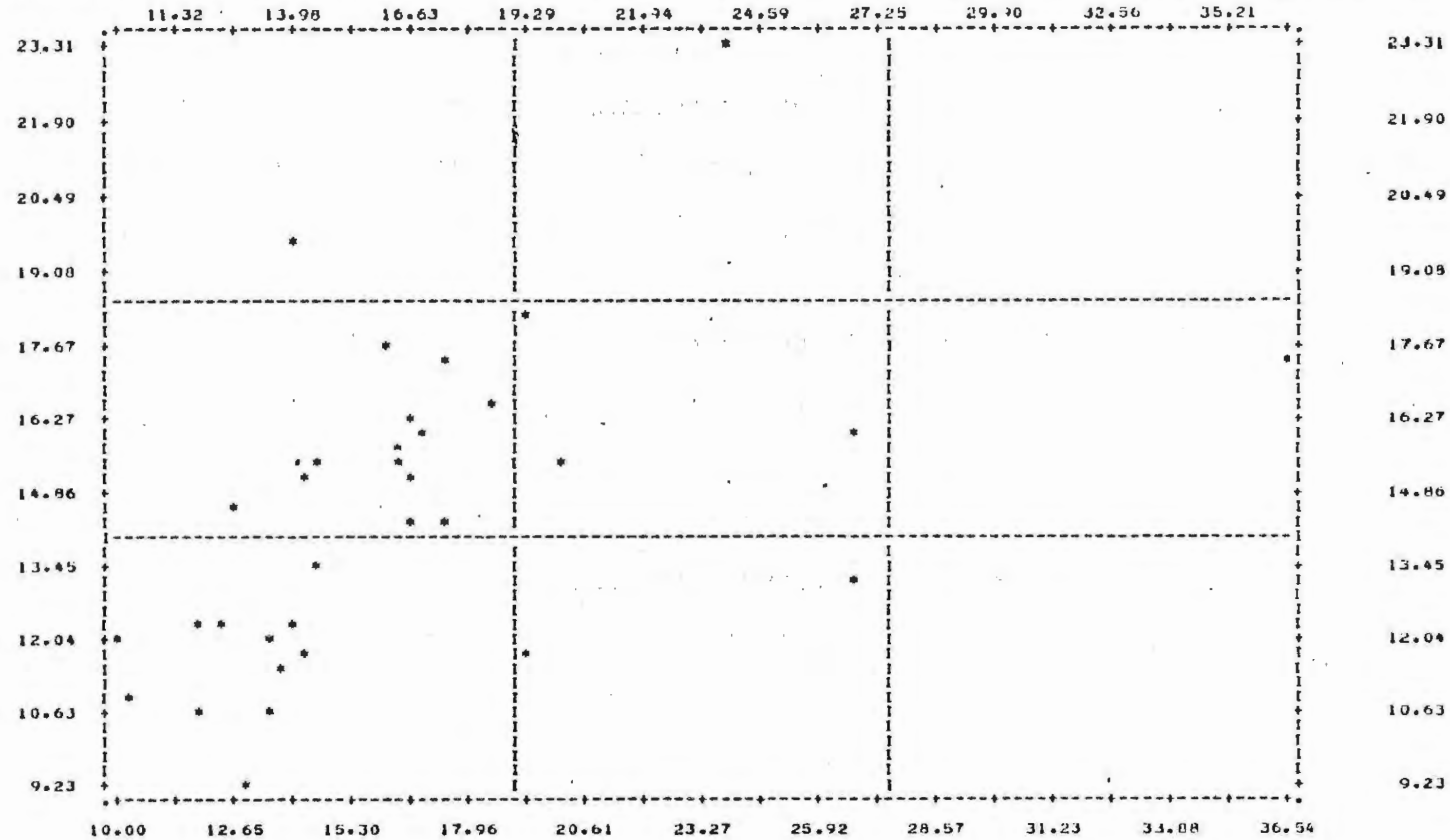
STATISTICS..

CORRELATION (R)-	.35376	R SQUARED -	.12515	SIGNIFICANCE R -	.00045
STD ERR OF EST -	19.95800	INTERCEPT (A) -	9.94147	STD ERROR OF A -	15.19955
SIGNIFICANCE A -	.25744	SLOPE (B) -	.93912	STD ERROR OF B -	.27254
SIGNIFICANCE B -	.00045				
PLOTTED VALUES -	85	EXCLUDED VALUES-	0	MISSING VALUES -	31

FIGURE 8 - Analysis 8

FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1
SCATTERGRAM OF (DOWN) RRCS2 ROLLING RES. CREST TO SCALE - RUN 2 (ACROSS) RRCS ROLLING RES. CREST TO SCALE - LB. PER T



STATISTICS..

CORRELATION (R)-	.50029	R SQUARED -	.25029	SIGNIFICANCE R -	.00151
STD ERR OF EST -	2.59899	INTERCEPT (A) -	10.01018	STD ERROR OF A -	1.49347
SIGNIFICANCE A -	.00001	SLOPE (B) -	.27509	STD ERROR OF B -	.08551
SIGNIFICANCE B -	.00151				
PLOTTED VALUES -	33	EXCLUDED VALUES-	0	MISSING VALUES -	0

FIGURE 9 - Analysis 9

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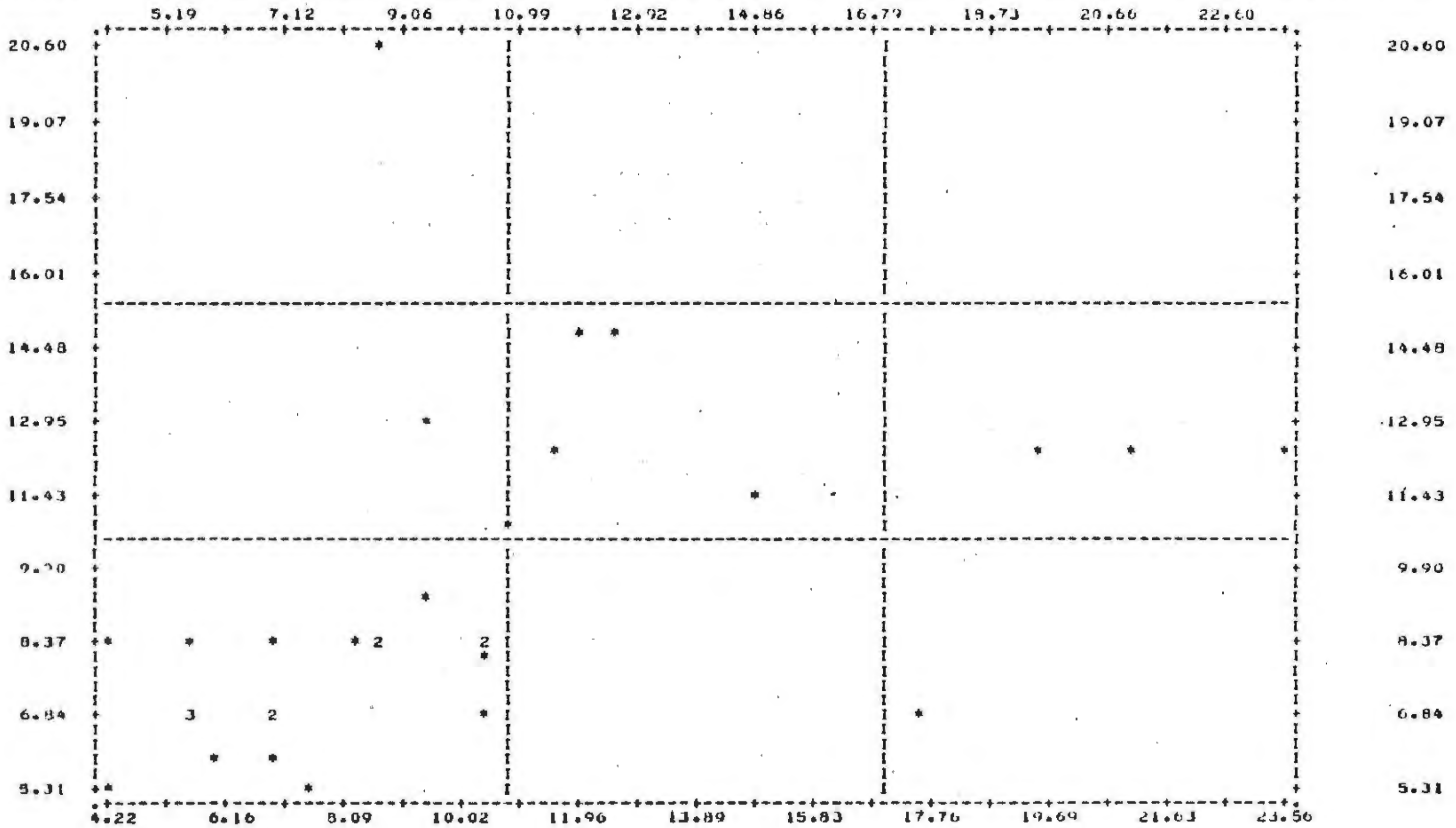
FILE ELKROLRS (CREATION DATE = 78/11/15.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1
SCATTERGRAM OF (DOWN) RRMG2 ROLLING RES. MAST. TO GROUP - RUN 2 (ACROSS) RRMG ROLLING RES. MAST. TO GROUP - LB. PER T



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STATISTICS..

CORRELATION (R)-	.45758	R SQUARED -	.20938	SIGNIFICANCE R -	.00482
STD ERR OF EST -	3.08207	INTERCEPT (A) -	6.27786	STD ERROR OF A -	1.28978
SIGNIFICANCE A -	.00002	SLOPE (B) -	.32206	STD ERROR OF B -	.11621
SIGNIFICANCE B -	.00482				
PLOTTED VALUES -	31	EXCLUDED VALUES-	0	MISSING VALUES -	2

FIGURE 10 - Analysis 10

FILE ELKROLRS (CREATION DATE = 78/11/17.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2

* M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * *

VARIABLE	MEAN	STANDARD DEV	CASES
RRMG	9.8686	4.1359	64
RRCS	15.5772	4.4881	64
WTTONS	55.3147	25.8290	64
RUNIDUM	.5156	.5037	64

CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

	RRMG	RRCS	WTTONS
RRCS	.27566		
WTTONS	-.56440	-.41223	
RUNIDUM	.08559	.24742	-.03816

FIGURE 11 - Analysis 11
Part 1

FILE ELKROLRS (CREATION DATE = 78/11/17.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. RRMG ROLLING RES. MAST. TO GROUP - LB. PER TO

MEAN RESPONSE 9.86864 STD. DEV. 4.13591

VARIABLE(S) ENTERED ON STEP NUMBER 1.. WTTONS WEIGHT OF CAR IN TONS

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.56440	REGRESSION	1.	343.29215	343.29215	28.98277	.000
R SQUARE	.31855	RESIDUAL	62.	734.37130	11.84470		
ADJUSTED R SQUARE	.30756	COEFF OF VARIABILITY	34.9 PCT				
STD DEVIATION	3.44161						

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
WTTONS	-.90376240E-01	.16787435E-01	28.982768 / .000	-.5644044 / -.50657
(CONSTANT)	14.867774	1.0234041	211.05595 / 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
RRCS	.05716	.83007	.19999045 / .656
RUNIDUM	.07765	.99854	.36999389 / .545

* *

VARIABLE(S) ENTERED ON STEP NUMBER 2.. RUNIDUM

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.56803	REGRESSION	2.	347.71960	173.85980	14.52913	.000
R SQUARE	.32266	RESIDUAL	61.	729.94384	11.96629		
ADJUSTED R SQUARE	.30045	COEFF OF VARIABILITY	35.1 PCT				
STD DEVIATION	3.45923						

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
WTTONS	-.89984333E-01	.16885679E-01	28.398589 / .000	-.5619569 / -.50437
RUNIDUM	.52667855	.86586135	.36999389 / .545	.0641434 / .02752
(CONSTANT)	14.574527	1.1360137	164.59696 / 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
RRCS	.03880	.77631	.90442404E-01 / .765

FILE ELKROLRS (CREATION DATE = 78/11/17.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. RRMG ROLLING RES. MAST. TO GROUP - LB. PER TO

VARIABLE(S) ENTERED ON STEP NUMBER 3.. RRCS ROLLING RES. CREST TO SCALE - LB. PER TO

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.56893	REGRESSION	3.	348.81824	116.27275	9.57181	.000
R SQUARE	.32368	RESIDUAL	60.	728.84520	12.14742		
ADJUSTED R SQUARE	.28986	COEFF OF VARIABILITY	35.3 PCT				
STD DEVIATION	3.48531						

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
WTTONS	-.87643657E-01	.18708803E-01	21.945678 / .000	-.5473392 / -.49125
RUNIDUM	.45763920	.90238937	.25736371 / .614	.0557352 / .02391
RRCS	.33394691E-01	.11104305	.90442434E-01 / .765	.0362384 / .05271
(CONSTANT)	13.960456	2.3408095	35.568620 / .000	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	STD ERROR B	T	95.0 PCT CONFIDENCE INTERVAL	
WTTONS	-.87643657E-01	.18706803E-01	-4.6845214	-.12500684	, -.50220483E-01
RUNIDUM	.45763920	.90208937	.50731027	-1.3468082	, 2.2620866
RRCS	.33394691E-01	.11104305	.30073644	-.18672448	, .25551386
CONSTANT	13.960456	2.3408095	5.9639434	9.2781393	, 18.642772

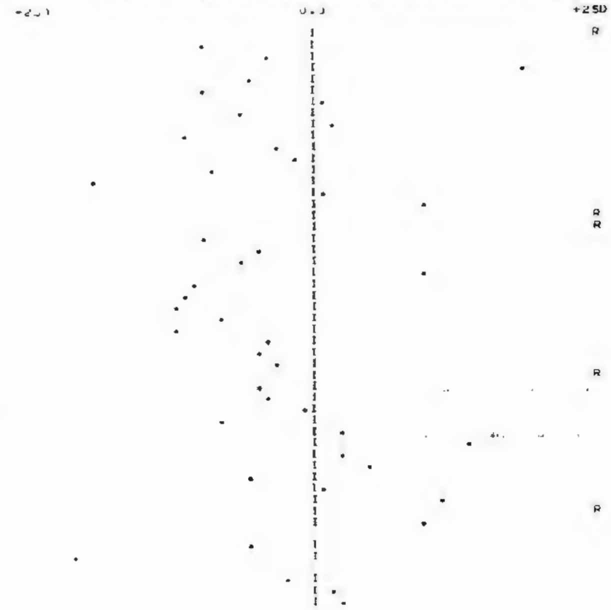
FIGURE 11 - Analysis 11
Part 2

MULT. REGRESSIONS

FILE ELKROLRS (CREATION DATE = 78/11/17.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2

* M U L T I P L E R E G R E S S I O N *

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
1.	17.50800	7.425729	10.08227
2.	9.479000	12.06977	-2.590770
3.	11.47500	12.45011	-.9751115
4.	10.49600	5.268365	5.227635
5.	5.546000	7.072937	-1.526937
6.	9.479000	12.26244	-2.783437
7.	7.504000	7.289051	.2149494
8.	5.546000	7.400315	-1.854315
9.	12.56700	12.32031	.2466913
10.	8.658000	11.88327	-3.225273
11.	12.04200	12.83324	-.7912408
12.	13.57900	13.98002	-.4010185
13.	10.77500	13.30863	-2.533629
14.	7.017000	12.54866	-5.531657
15.	12.56700	12.40040	.1666024
16.	14.90400	12.21607	2.687934
17.	21.00000	12.83702	8.162980
18.	19.50400	12.39956	7.104439
19.	5.925000	8.690175	-2.765175
20.	7.017000	8.209760	-1.192760
21.	7.017000	8.753703	-1.736703
22.	10.49600	7.788519	2.707481
23.	4.221000	7.200419	-2.979419
24.	4.221000	7.259930	-3.038930
25.	5.546000	8.802609	-3.256609
26.	7.017000	9.180918	-2.163918
27.	5.546000	8.861169	-3.315169
28.	8.658000	9.675991	-1.017991
29.	8.658000	9.851329	-1.193329
30.	8.375000	9.147169	-.7721686
31.	23.56300	12.16542	11.39758
32.	10.49600	11.78805	-1.292054
33.	10.49600	11.55695	-1.060949
1.	6.904000	6.953838	-.4983772E-01
2.	9.404000	11.58267	-2.178673
3.	12.56700	11.93401	.6329865
4.	8.658000	4.731889	3.926111
5.	7.017000	6.484888	.5321117
6.	13.20000	11.87027	1.327728
7.	5.313000	6.910778	-1.597778
8.	7.017000	6.832517	.1844832
9.	14.90400	11.86387	3.040132
10.	20.59600	11.39106	9.204939
11.	14.90400	12.32994	2.574061
12.	CASE DELETED DUE TO MISSING DATA.		
13.	10.86300	12.40330	-1.540296
14.	5.925000	11.74315	-5.818153
15.	CASE DELETED DUE TO MISSING DATA.		
16.	11.47500	11.94786	-.4728621
17.	12.56700	12.22336	.3436389
18.	12.56700	11.98114	.5858646

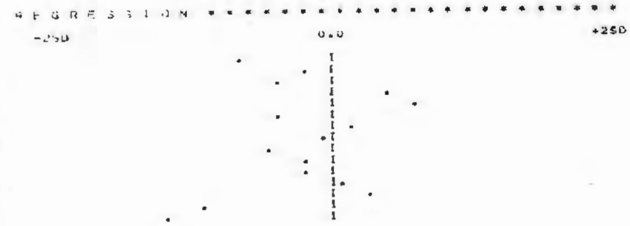


MULT. REGRESSIONS

FILE ELKROLRS (CREATION DATE = 78/11/17.) ELKHART ROLLING RESISTANCE DATA
SUBFILE RUN1 RUN2

* M U L T I P L E R E G R E S S I O N *

OBSERVATION	Y VALUE	Y ESTIMATE	RESIDUAL
19.	5.925000	8.161146	-2.236146
20.	7.019000	7.675815	-.6568147
21.	7.017000	8.240654	-1.223654
22.	8.658000	7.298805	1.359195
23.	8.658000	6.766632	1.891368
24.	5.546000	6.751486	-1.205486
25.	8.658000	8.349570	.3084297
26.	8.658000	8.747034	-.8903429E-01
27.	7.017000	8.431235	-1.414235
28.	8.658000	9.268415	-.6104153
29.	8.658000	9.147363	-.4893627
30.	8.658000	8.613436	.4456410E-01
31.	12.53800	11.68817	.8498274
32.	8.129000	11.29810	-3.169101
33.	7.017000	11.07259	-4.055590



NOTE - (*) INDICATES ESTIMATE CALCULATED WITH MEANS SUBSTITUTED
R INDICATES POINT OUT OF RANGE OF PLOT

NUMBER OF CASES PLOTTED 64.
NUMBER OF 2 S.D. OUTLIERS 5. OR 7.81 PERCENT OF THE TOTAL

VON NEUMANN RATIO 1.52009 DURBIN-WATSON TEST 1.49634

NUMBER OF POSITIVE RESIDUALS 25.
NUMBER OF NEGATIVE RESIDUALS 39.
NUMBER OF RUNS OF SIGNS 26.

EXPECTED NUMBER OF RUNS OF SIGNS 31.
EXPECTED S.D. OF RUN DISTRIBUTION 3.77518
UNIT NORMAL DEVIATE-
Z=(EXPECTED-OBSERVED)/S.D. -1.31616
PROBABILITY OF OBTAINING .GE. ABS(Z) .09406

FIGURE 11 - Analysis 11
Part 3