

TM-13

DETERMINING THE LIMITING TGI VALUES ON VARIOUS ROUTES OF INDIAN RAILWAYS.

1.0 Introduction:

1.1 Track Monitoring on Indian Railways has undergone a substantial change within last few decades when it started with mechanical TRC generating the analogue output and now it has micro processor based TRC which generate the block wise (200 m) standard deviation value of each track parameter both on short and long chord. Till recently, overall health of the track was being assessed with the help of CTR formula which is exceedence based. As with the present TRC it has become possible to calculate the standard deviation of each parameter within a block of 200 meters, a more rational SD based track geometry index has been devised for assessing the health of the track. This index, known as Track Geometry Index (TGI) has been introduced on BG routes of Indian Railways. Railway Board has issued instruction for its adoption vide its letter No. 94/Track-III/TK/23 dated 30.12.96. A report No.TM-11 titled "Booklet of instructions for implementation of standard deviation based assessment of track geometry using Track Geometry Index" was prepared and circulated to all the Zonal Railways vide RDSO's letter No.TM/TM/TRC/TGI dated 7.4.97.

1.2 In 1967 an effort was made to prescribe the track tolerances in the form of exceedences for the operation of WDM4 locomotive and the ICF all coil coaching stock at a speed of 120 kmph. These tolerances are described in RDSO's Report No. C&M - I and are popularly known as C&M-I tolerances. Even though these tolerances were prescribed for a speed of 120 kmph, the same have been extended for Rajdhani/Shatabdi route for speeds upto 140 kmph.

1.3 CCRS vide his letter No.K11022/1/94-RS dated 19.1.98 (copy enclosed as annexure-1) desired that the speed potential of the track sections should be linked with TGI value. It has been suggested to prescribe the recommended, accepted and the slow down values of TGI for the three speed bands of 120-140, 110 and 100 kmph.

1.4 Railway Board under their letter No.98/ME/Mis/1 dated 20.2.98 has also directed to carry out regression analysis between RI and TGI for arriving at the recommended and accepted limits of TGI. An extract of the relevant item 3 is placed at Annexure-2.

1.5 In this report, regression analysis between TGI value and ride index for four different representative section of Indian Railways has been attempted to work out the limiting TGI values for Shatabdi, Rajdhani and other BG routes covering the speed band of 120-140 kmph, upto 110 kmph and 100 kmph.

2.0 Test sections and recording:

2.1 Mughalsarai-Howrah (Rajdhani route), Bhopal-Tughlakabad (Shatabdi route), Gudur-Madras (GT route), Howrah-Nagpur (Geetanjali route) and Delhi-Ambala sections has been selected for the regression analysis. These routes are generally recorded by phase-II upgraded TRC, TRC225/TRC2500 which has the facility of simultaneously recording the Ride Index as well as the TGI value of each block. No special recording runs have been carried out for this purpose and the latest regular recording results of the above sections have been considered for present analysis.

3.0 Criteria of Vehicle Ride and Safety on Track:

3.1 The track geometry standards should be such that the following three criteria are met:

- i. The variation in vertical and lateral wheel loads should not reach levels where the wheel can derail by mounting the rail. The derailment coefficient found in the form of ratio between the lateral force (Y) and instantaneous wheel load (Q) should not exceed 1.
- ii. The magnitude of lateral forces lasting for more than 2 meters should not exceed Prud Homme's limit for ensuring lateral stability of track.
- iii. The oscillation of the vehicle on track should be such that the passengers travel in generally satisfactory level of comfort. The human body response to vibration is dependent on the frequency of vibration. On the Indian Railways, ride index is calculated after applying the ride factors for various range of frequency. The following values of ride index and accelerations have been laid-down as per recommendations contained in the second report of the Criteria Committee.

Parameter	Locomotive		Coaches	
	Preferable value	Desirable max	Preferable value	Desirable max
i. Ride index	3.75	4.0	3.25	3.5
ii. Acceleration				
a) Vertical	0.30g	0.35g	0.30g	0.35g
b) Lateral	0.30g	0.35g	0.30g	0.35g

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4.0 Methodology for the analysis of TRC results:

Following methodology has been adapted for the analysis of TRC results as reported in this work.

4.1 For each section a best fit line is drawn between maximum ride index (i.e maximum of vertical and lateral ride indices) and the TGI of each block. Enveloping line are also drawn to cover atleast 95 per cent of the data samples.

4.2 The values of TGI corresponding to RI of 3.25 and 3.5 on the best fit line as well as on the enveloping line for each section has been arrived at. In most of the cases TGI corresponding to RI of 3.25 and 3.5 on the enveloping curve is very much on the higher side and, therefore, the TGI corresponding to RI of 3.25 and 3.5 on the best fit line has been considered. Value of TGI corresponding to RI as 3.25 is considered as recommended and the range of TGI corresponding to RI as 3.25 and 3.5 is considered as acceptable. TGI value falling below the corresponding RI of 3.5 on the best fit line is considered as a slow down tolerances.

4.3 It is also checked from the maintainability point of view that not more than 5% section should fall below the lower limit of the range prescribed for acceptable limit. For this pupose Cumulative Frequency Diagram (CFD) of the TGI for each section has been plotted. It is checked that not more than 5% of the total section should have TGI value lesser than the lower limit of the acceptable limit range.

5.0 Discussion of the Results:

5.1 Correlation of vehicle ride with Track Geometry Index:

5.1.1 The graph between maximum RI and TGI has been plotted for Tughlakabad-Bhopal (Up/Dn), Howrah-Mughalsarai (Up/Dn), Madras-Gudur (Up/Dn), Delhi-Ambala (Up/Dn) and Nagpur-Howrah (Dn). A best fit line and the enveloping line covering more than 95% of the data has been drawn. These graphs are placed at annexure 3.1 to 3.9. TGI value corresponding to RI of 3.25 and 3.5 on the best fit line as well as on the enveloping curve has been derived from the concerned graph and these are tabulated below:

Section	Up/ Dn	Month of recording	TGI on best fit line		Enveloping line	
			RI 3.25	RI 3.5	RI 3.25	RI 3.5
NGP-HWH	Dn		87	57	-	131
UMB-DLI	Dn	Jan., 98	48	26	76	53

Section	Up/ Dn	Month of recording	TGI on best fit line		Enveloping line	
DLI-UMB	Up	Jan., 98	50	18	102	72
MAS-GDR	Dn	Feb., 98	64	34	116	87
GDR-MAS	Up	Feb., 98	58	34	107	80
HWH-MGS	Up	Jan., 98	68	42	124	98
MGS-HWH	Dn	Jan., 98	72	46	132	108
TKD-BPL	Up	Jan., 98	68	41	127	98
BPL-TKD	Dn	Jan., 98	58	29	112	84

5.2 From the above table it is seen that TGI corresponding to RI of 3.5 on the enveloping curve is very much on the higher side and very small portion of each section satisfies this criteria indicating thereby that it is not practicable to achieve these value in field. The values of TGI corresponding to RI = 3.25 and RI = 3.5 on the best fit line have, therefore, been considered.

5.3 For Bhopal-Tughlakabad section (max. speed 140 kmph) value of TGI obtained is 58 and 68 on the up and down line respectively and, therefore, a value of 65 can be adopted corresponding to the value of RI = 3.25 as a limit of recommended TGI. TGI achieved is 29 and 41 on down and up line respectively corresponding to RI = 3.50 and, therefore, the acceptability range can be taken as 40 to 65. On the Howrah-Mughalsarai section (max. speed 130 kmph), TGI corresponding to RI 3.25 is equal to 68 and 72 and corresponding to 3.5 is 42 and 46.

5.4 As both the above sections fall in the speed band of 120 to 140 kmph recommended value of TGI for this speed band may be kept as 70 and the range of acceptable value can be kept between 45 and 70. Cumulative frequency diagram has also been drawn and are enclosed as Annexure No. 4.1 to 4.8. A table has also been enclosed as Annexure-5 containing the details of percentage of section, TGI of which is under a particular value. It is found from this table that for Howrah-Mughalsarai and Tughlakabad-Bhopal section generally 95% of the track is having TGI value more than 45. Therefore, lower limit of the acceptable TGI range as 45 also seems to be reasonable.

5.5 On Madras-Gudur section (max. speed 110 kmph) the TGI value corresponding to RI = 3.25 is 58 and 64 and, therefore, an average value of 60 can be adopted while a value of TGI 34 is obtained corresponding to RI = 3.5. From the CFD chart as well table on Annexure-5 of Gudur-Madras, it is seen that 95% of the track is generally having TGI more than 45 and, therefore, the recommended value for sections for a speed upto 110 kmph can be more than 60 and acceptable value can be between 45 to 60.

68.1

5.6 For other routes like Ambala-Delhi it is found that a value of 50 is found for TGI corresponding to RI of 3.25 and approximately 25 corresponding to RI of 3.5. From the view of maintainability it is examined from the Ambala-Delhi section that approximately a TGI of 40 is achievable and only 5% of the section will have TGI value less than this. So far other BG routes, the recommended TGI value can be more than 50 and acceptable value can be in the range of 40 to 50.

6.0 Recommendation:

6.1 It is found from the regression chart between maximum RI and TGI that the R^2 value (goodness of fit) is generally around .5 which is indicative of a lot of scatter on data samples. This may be because the RI is recorded at varying speed and speed factor plays an important role in determining the RI. If the RI is recorded at a constant speed then there is likelihood of reduction in the scatter and improvement in the R^2 (goodness of fit) value. A detailed trial of TRC run along with oscillograph car run is required to be planned for recording the RI value at the maximum permissible speed of the section along with TGI.

6.2 As the R^2 value between composite TGI and RI has not been found very good, it is proposed to carry out the regression analysis between vertical RI with individual unevenness index and twist index and lateral RI with twist index, gauge index and alignment index. The results of this analysis will be reported in next Progress Report.

6.3 Based on the limited study detailed in this report, the following values of recommended and acceptable range of TGI values are suggested for different range of maximum permissible speed:-

Maximum permissible speed	TGI value	
	Recommended	Acceptable
120-140	> 70	45-70
110	> 60	45-60
100	> 50	40-50

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DR. P. M. MARI
CHIEF COMMISSIONER OF RAILWAY SAFETY



भारत सरकार
वायव्य विमानन विभाग
(रेल सुरक्षा आयोग)
GOVERNMENT OF INDIA
MINISTRY OF CIVIL AVIATION
(COMMISSION OF RAILWAY SAFETY)

असोक मार्ग, लखनऊ-228 001
Asok Marg, Lucknow-228 001.

क्र. मा. संख्या/O. O. No. K. 11022/1/94-RS.

2

दिनांक/Date 19-1-98.

Dear Shri Agnichota, -
Subject:- Track Monitoring on Indian Railways.

ME
Urgent
Call record
to RDSO
admission. He
should be
fully aware of track
condition.
CAECE
visit site
EPTK(MC)
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23/1

You are aware that at present, as per CRS's stipulations for running high speed trains on nominated routes, the track on such sections is being monitored with Track Recording/Oscillograph Car/TOMS-2000 equipment at certain specified intervals. In the earlier days the track recording charts used to be classified under A, B, C & D categories based on tolerances specified in RDSO's CM-I Report along with spot exceedances beyond B category and the results were advised to the Railways for taking prompt follow-up action whenever the track was found inferior to the standards prescribed. Subsequently, a concept of CTR formula was introduced for assessing condition of track vide Railway Board's letter no. 90/Track-III/TG/72 dated 18.7.90, pursuant of the CTR values obtained on track recording charts taken on limited routes of Indian Railways during 1990-93, have indicated that on many of the tracks where speed had been authorised by the Commission upto 140 kmph, the CTR values were not only quite low, but were on the negative side. The above issue was raised by the then CCRS/Lucknow in his letter no. K.11022/1/94-RS dated 25.5.94 addressed to the then Member/Engg./Rly. Board/New Delhi, who had given his reply vide letter nos. 94/CE-III/TG/45c dated 11.7.97 & 12.12.97 that the above CTR formula is under replacement by a more scientific assessment of the track recording charts.

2.0 Subsequently, the RDSO/Lucknow had evolved a "Track Quality Index (TQI)" based on standard deviation values of Track Geometry parameters. Unlike the CTR index, TQI gives higher values for inferior tracks and lower values for good tracks, since the value of the index goes down with reduction in the SD values. The formula was eventually not accepted as discussed at the 66th Track Standards Committee, who advised RDSO/Lucknow to evolve a new formula. Based on studies conducted by RDSO subsequently during 1995-96, a new index called TGI (Track Geometry Index) has been evolved and its implementation on Indian Railways has been approved by Railway Board vide their letter no. 97/Track-III/TG/23 dated 30.12.96. As desired by Railway Board, a booklet had been prepared by RDSO/Lucknow titled "Instructions For Implementation of Standard Deviation Based Assessment of Track Geometry Using Track Geometry Index", which has been circulated to all Zonal Railways vide their letter no. TM/147 TRC/TGI dated April '97.

(3)

3.0 In the above booklet of RDSO Lucknow, track was classified as "Very Good", "Good", "Fair" and "Poor" based on certain range of values of TGI, which the Railway Board vide their letter of 30.12.96 quoted above, had modified the classification as under :-

<u>Band Width of TGI</u>	<u>Maintenance Requirement of the Track</u>
TGI value of 80 and above	- No maintenance required
50 to 80	- Need based maintenance
36 to 50	- Planned maintenance
Below 36	- Urgent maintenance

Extract of para 1.0-3 of the Four Notes of Member

4.0 The following aspects need clarification :-
Engineer-in-charge's visit to RDSO of 10.9.97

4.1 As per RDSO's speed certificates for introduction of new rolling stock/upgradation of track for higher speeds, track should conform to tolerances laid down in RDSO Lucknow's CM-I Report of 1989. It is felt, that with the introduction of TGI values on a more scientific and national basis, the certificates of track based on CM-I tolerances needs to be switched over to that based on TGI values. The safety certificates issued by Zonal Railways should specify the minimum value of TGI to be maintained for permitting the rolling stock at certain nominal speeds. To start with, the following ranges of TGI values are suggested for different speed groups :-

Max. Permissible Speed (km/h)	TGI VALUES	Recommended	Acceptable	Slowdown Limits
120-140	> 95	70-95	< 70	50
110	> 70	50-70	< 60	
100	> 60	50-70	< 50	36

On tracks with TGI values less than the slowdown limits, the maximum permissible speed must be reduced till track is attended to and brought upto recommended standards as reflected by subsequent recording.

Kindly consider and advise further.

With regards,

Yours sincerely,

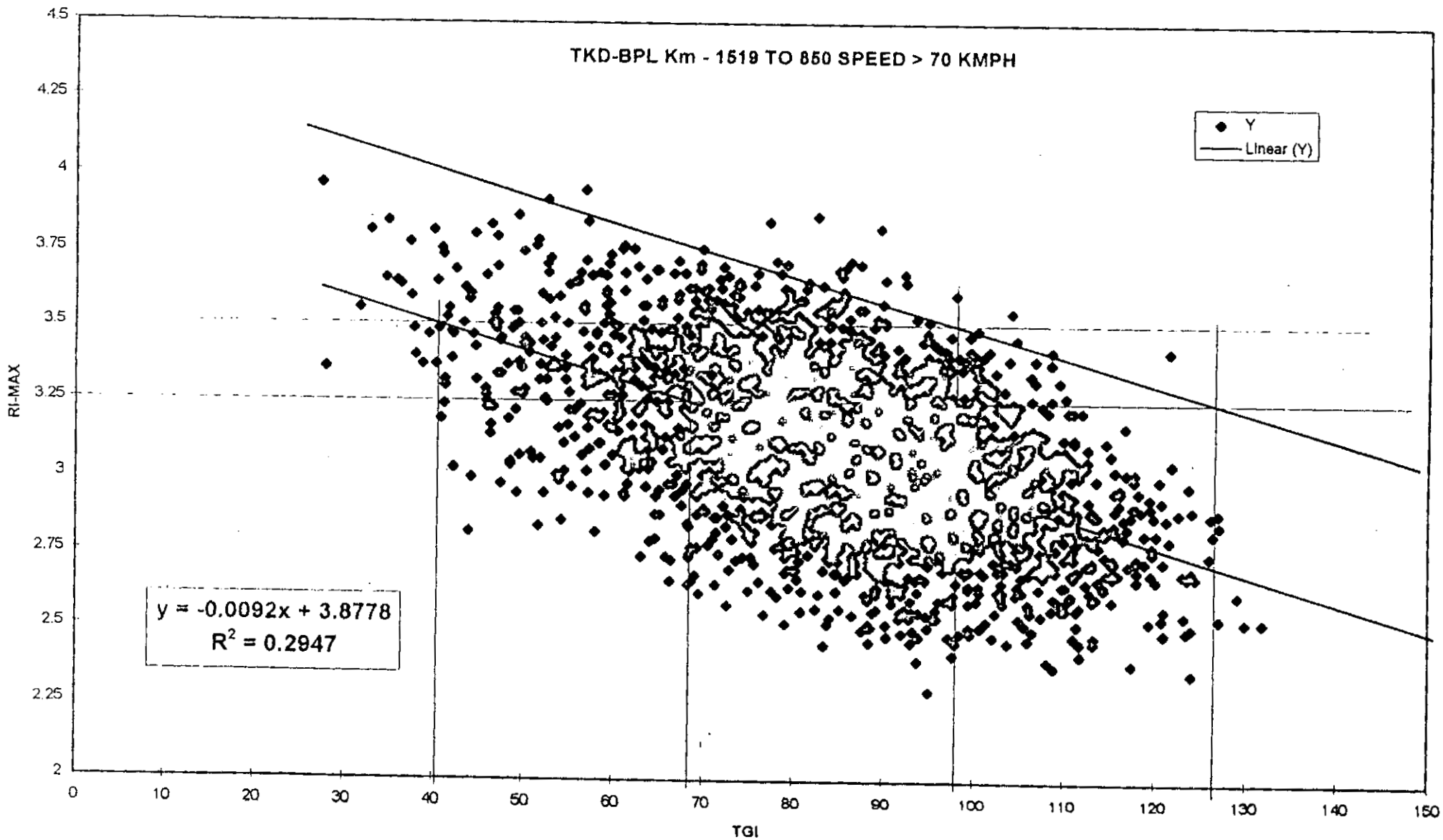
(Signature)
 15/1/97
 (Dr. M. Mani)

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Shri V.K. Agnihotri,
 Member (Engineering),
 Railway Board,
 Rail Bhavan,
 New Delhi-110011.

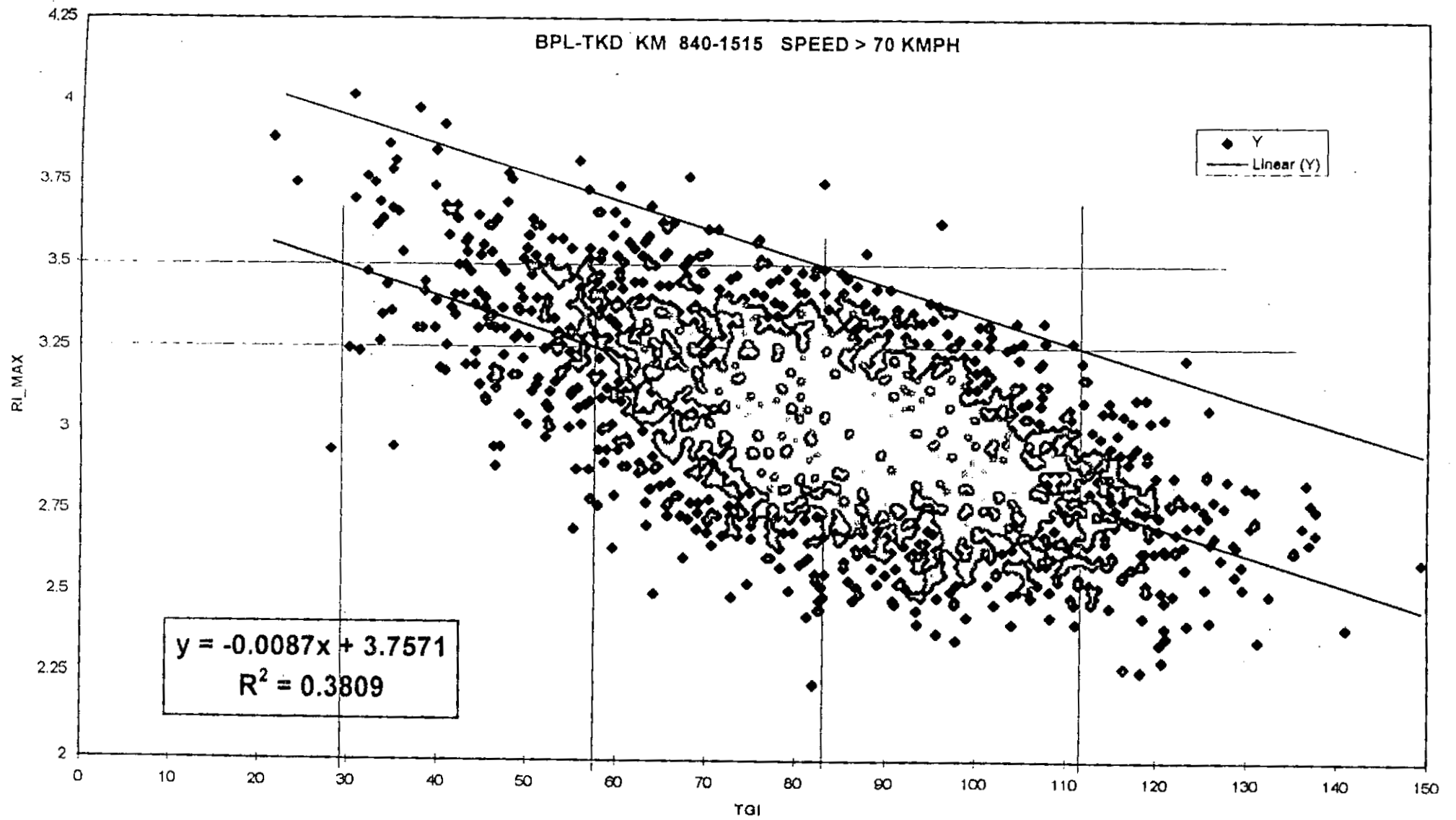
Extract of item no.3 of the Tour Notes of Member Engineering on his visit to RDSO on 18.02.1998.

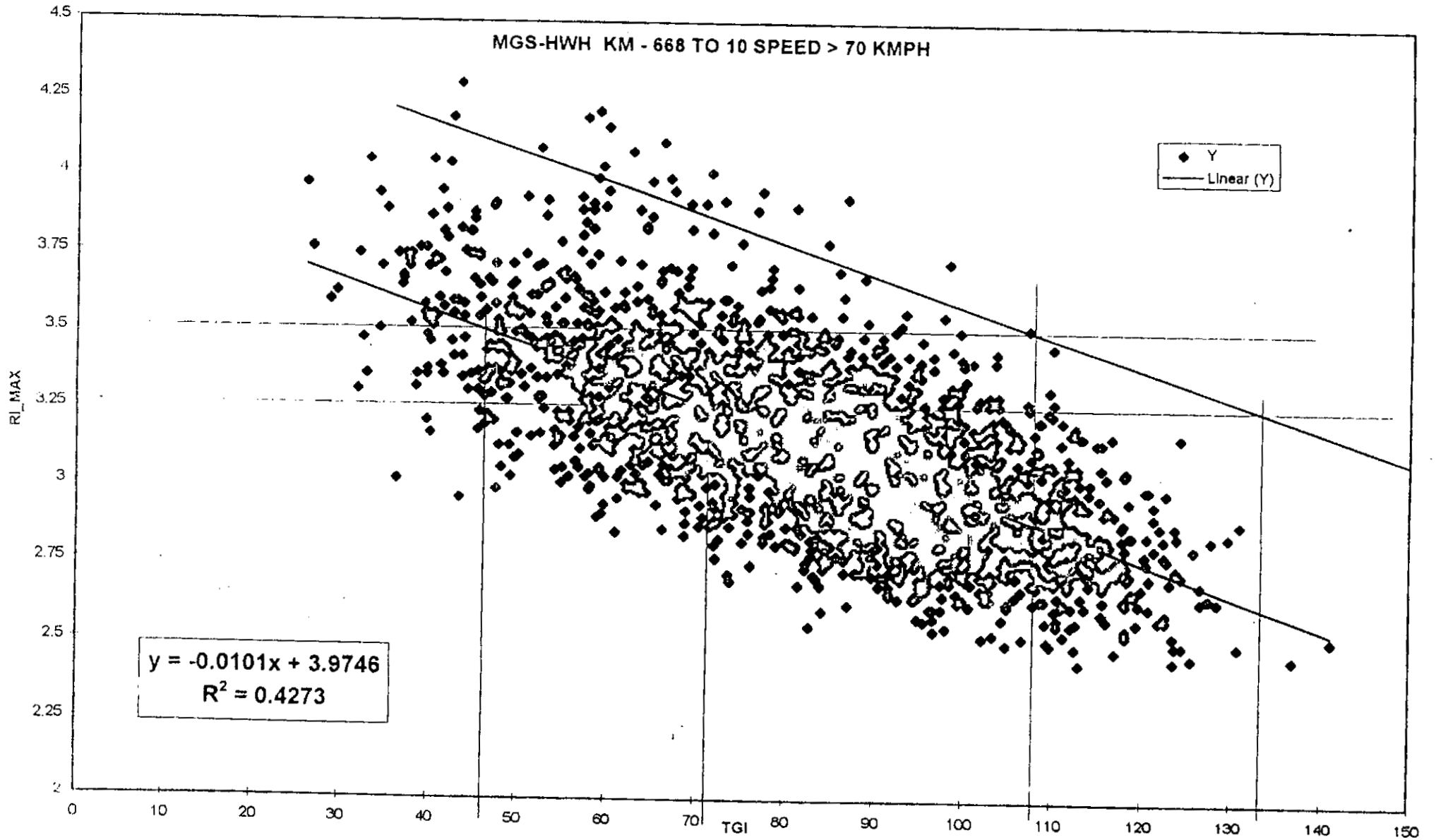
“Speed certificates for various rolling stocks are based on C&M-1 report though track is not being maintained to these tolerances now. CCRS has already objected to this. Ride Index may be correlated with TGI by doing regression analysis etc. and speed certificates will also have to be issued on this basis.”



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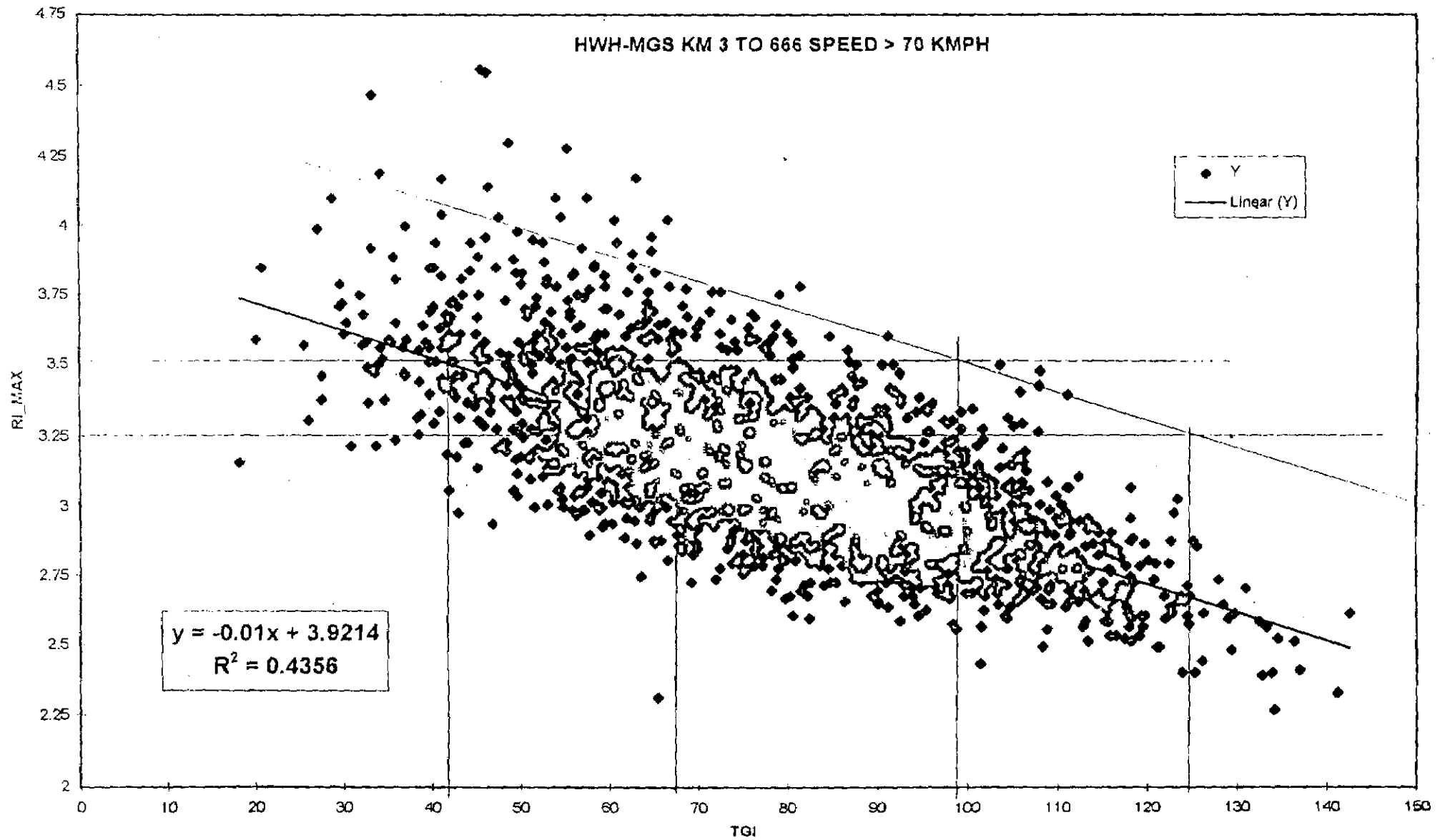
Sheet1 Chart 1



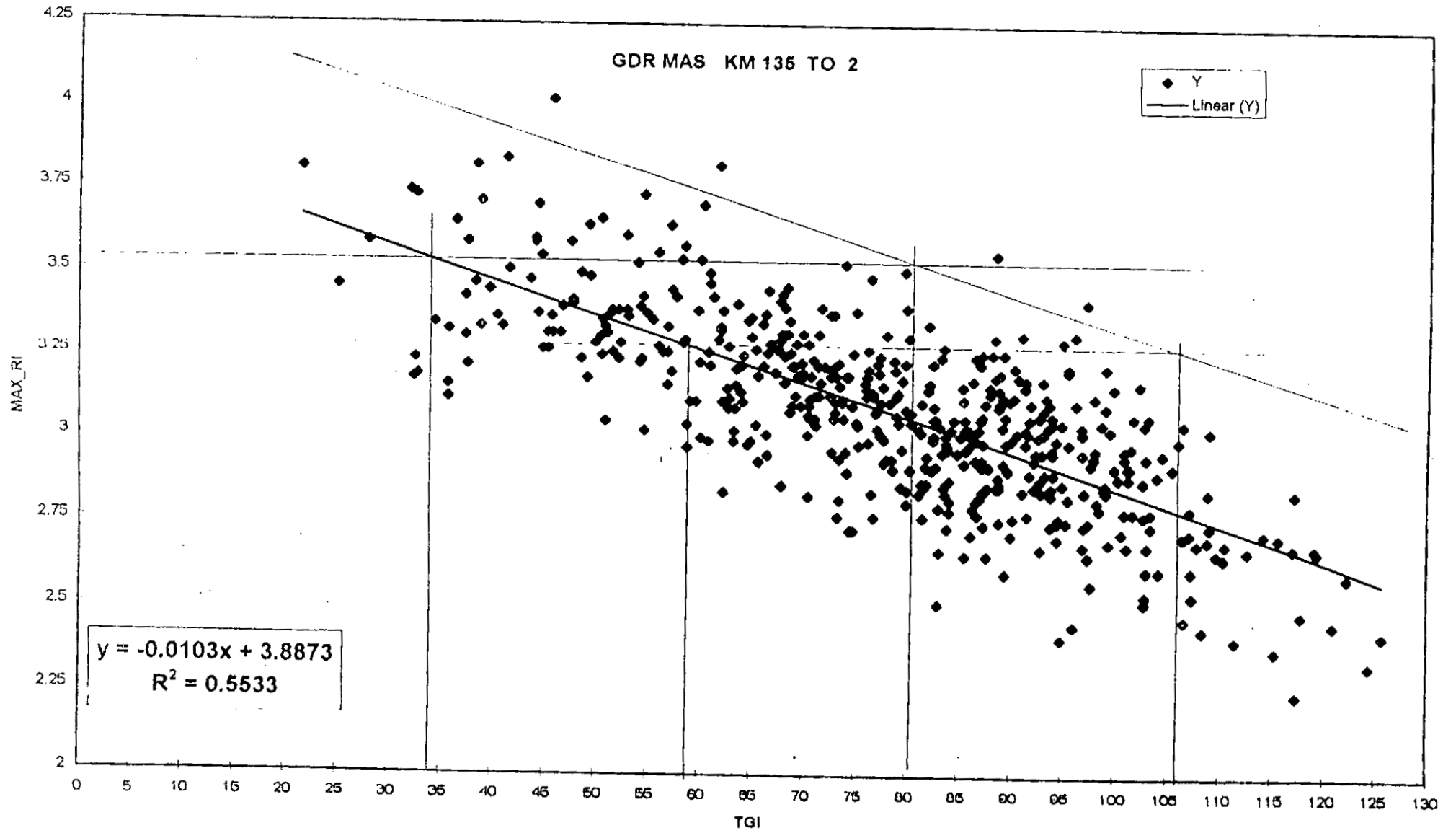


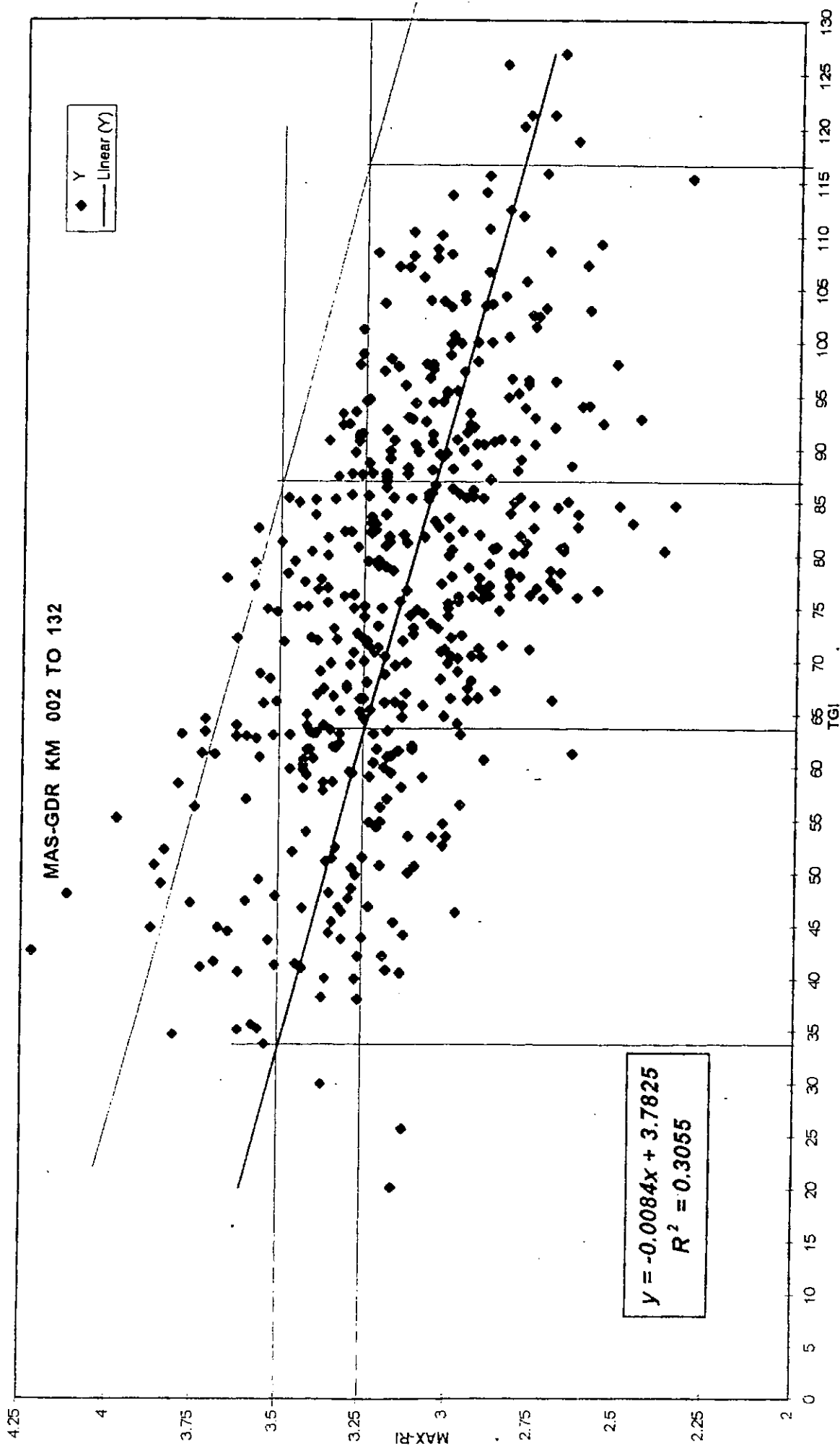
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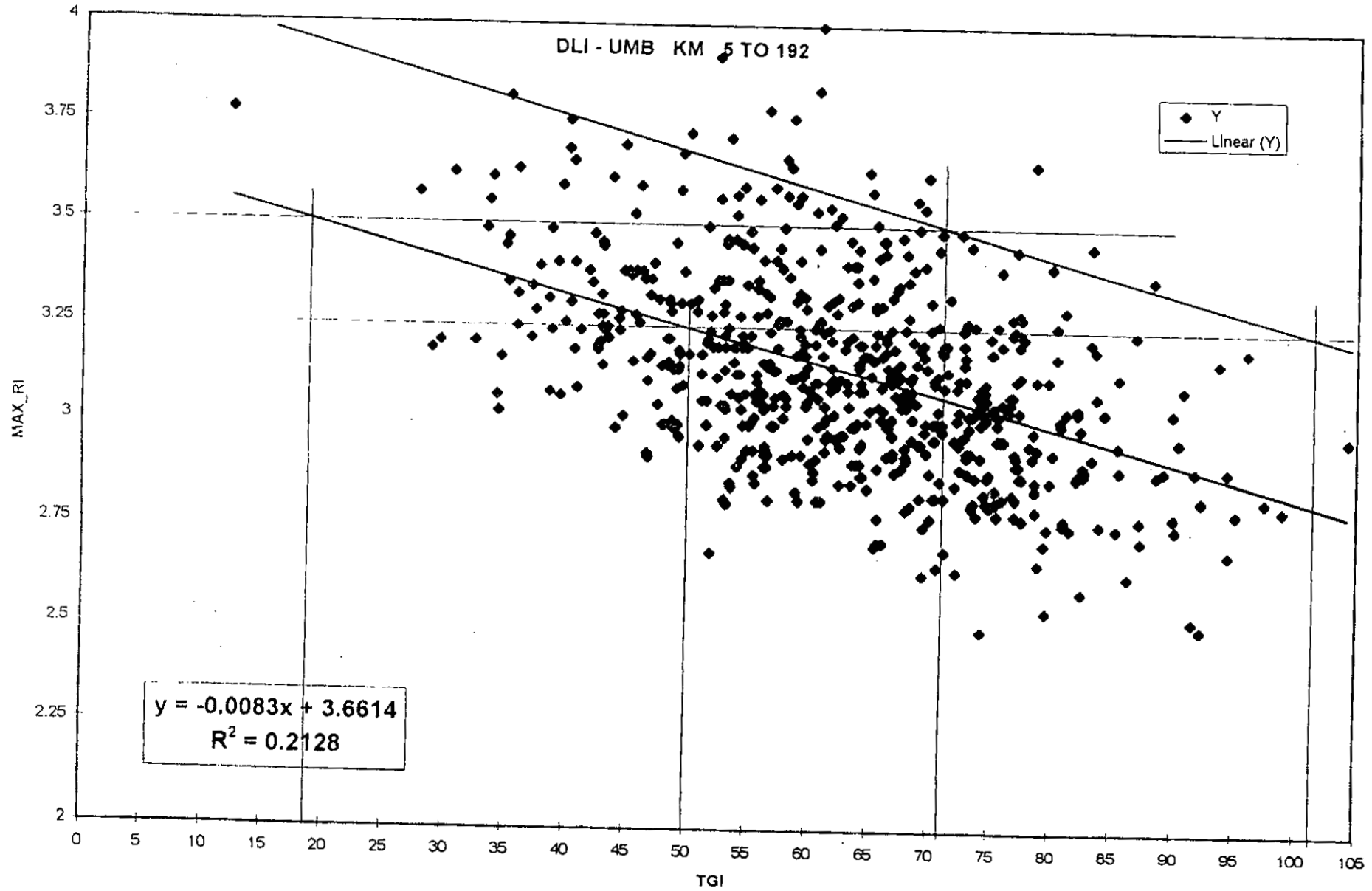
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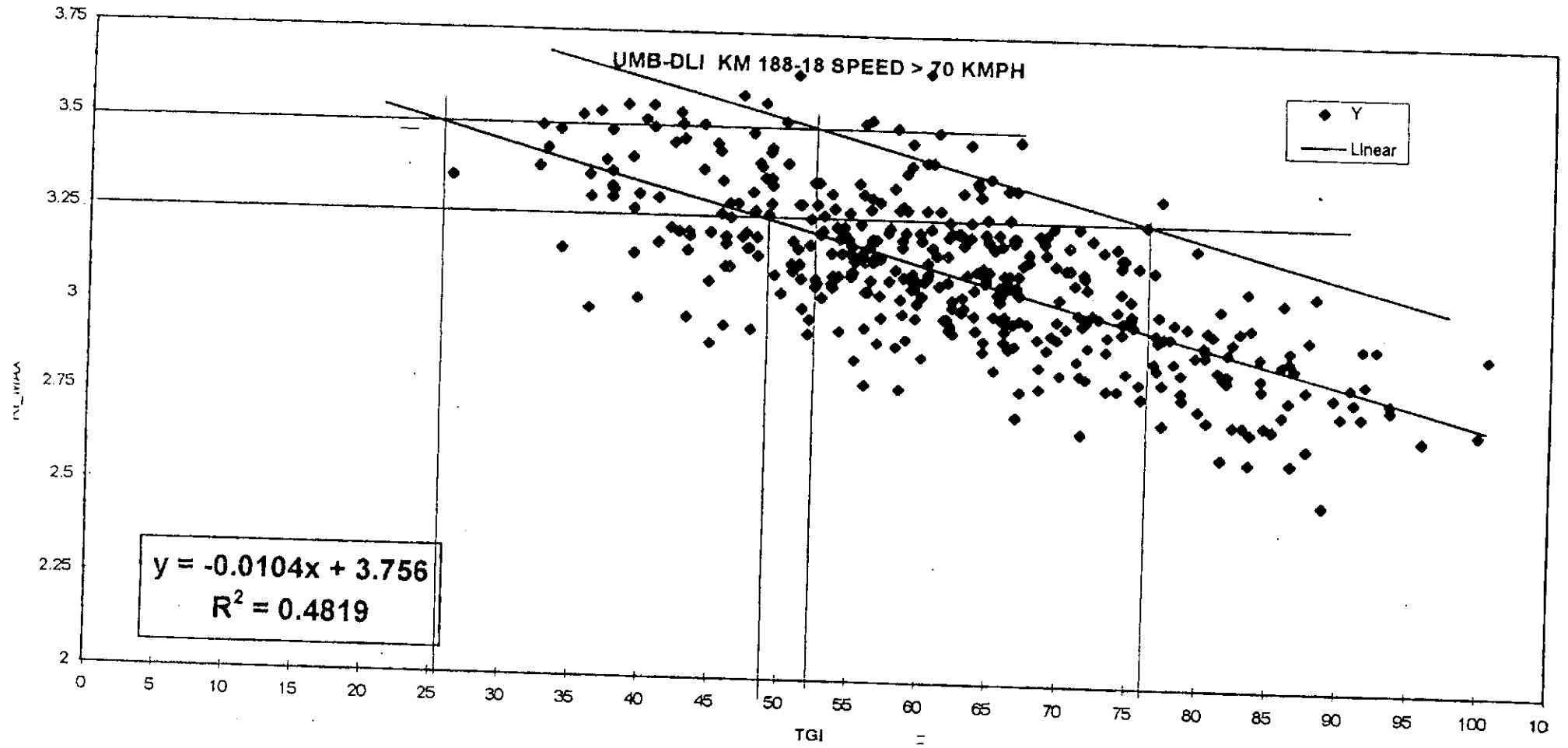
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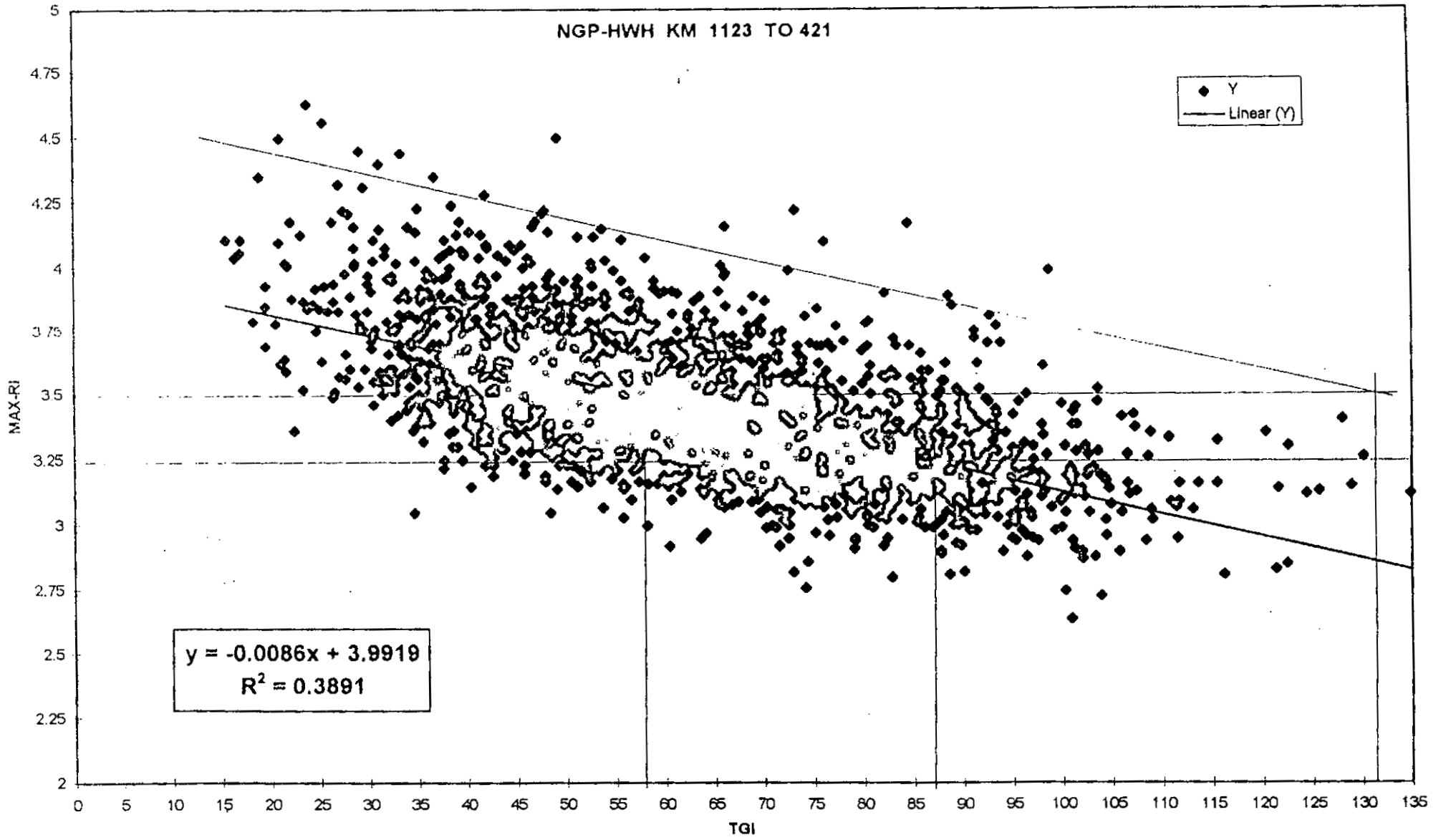






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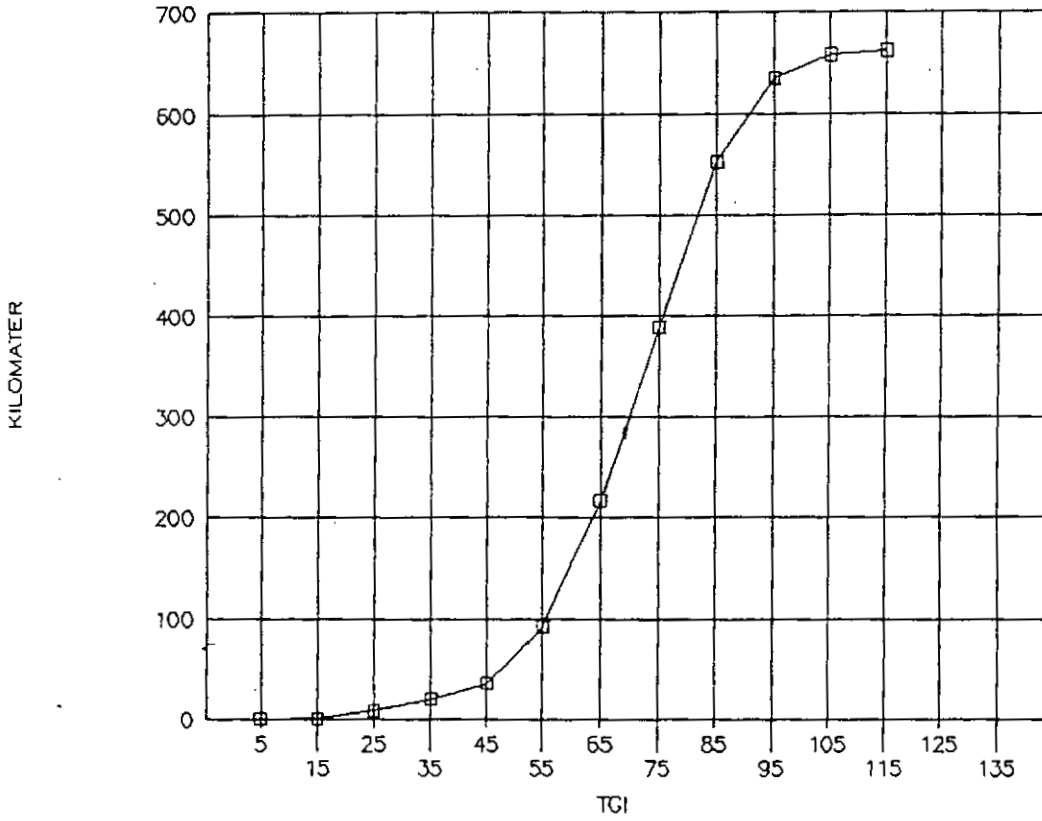




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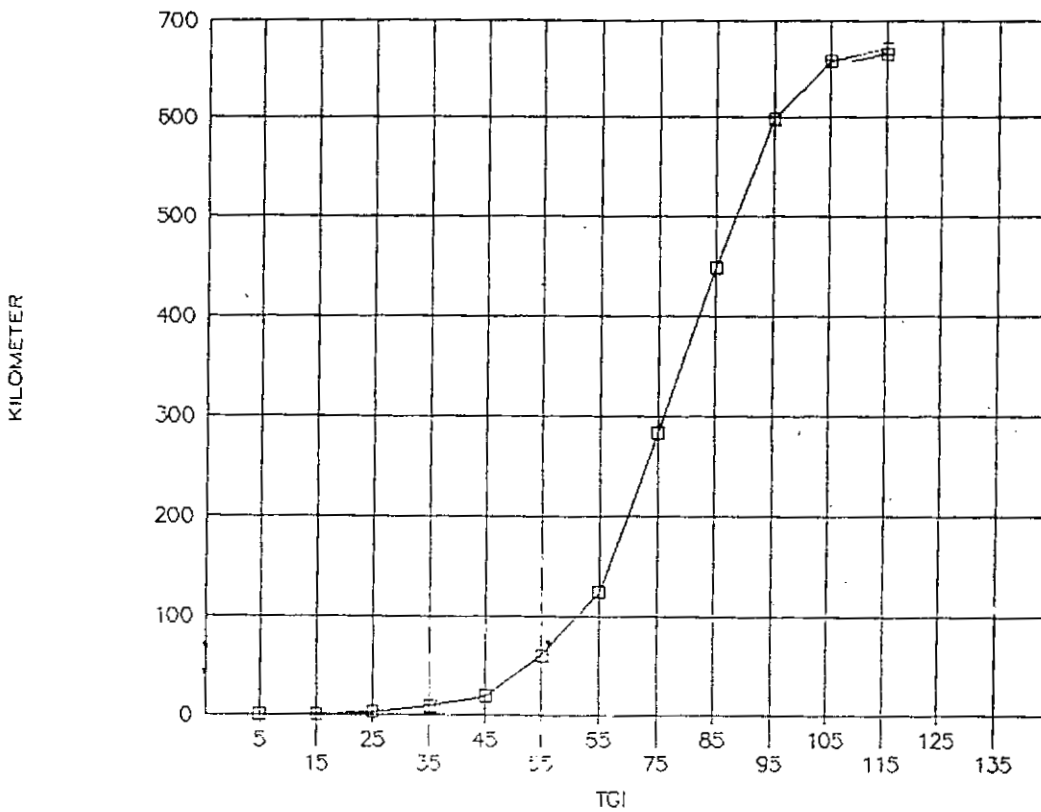
CFD OF SHATABDI ROUTE C.RLY UP LINE

TRC 2500 OCT'97 TKD-BPL KM 1520-835



CFD OF SHATABDI ROUTE C.RLY UP LINE

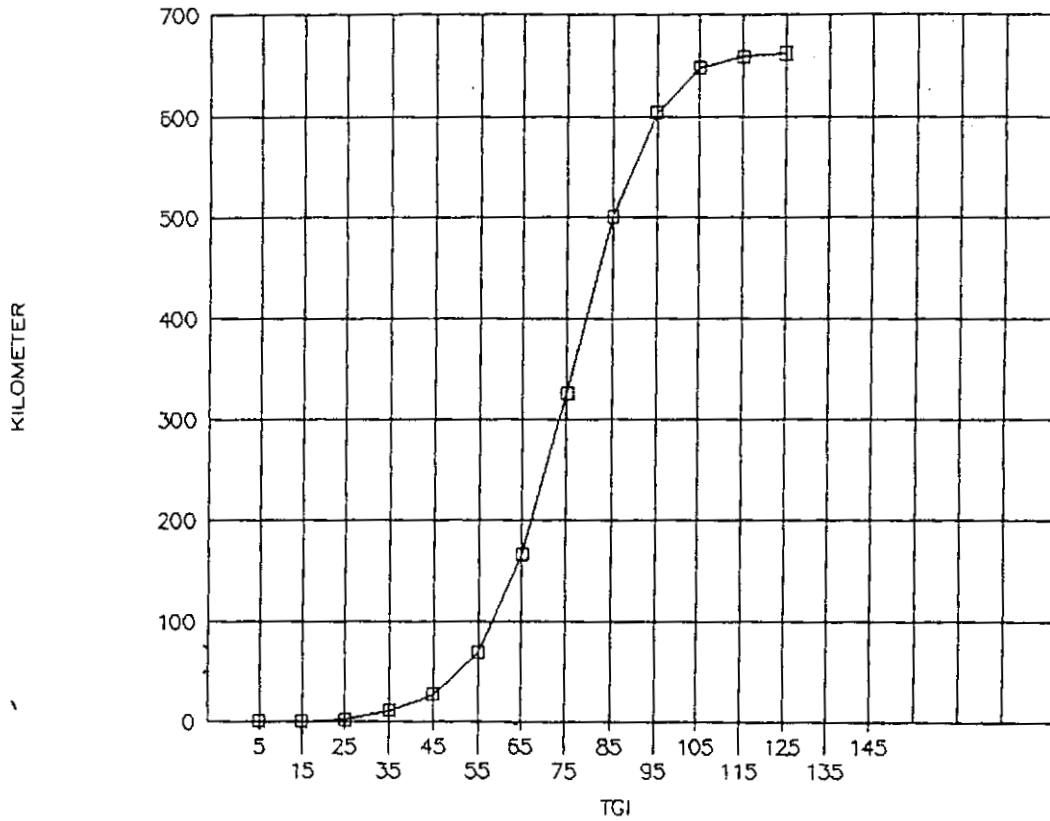
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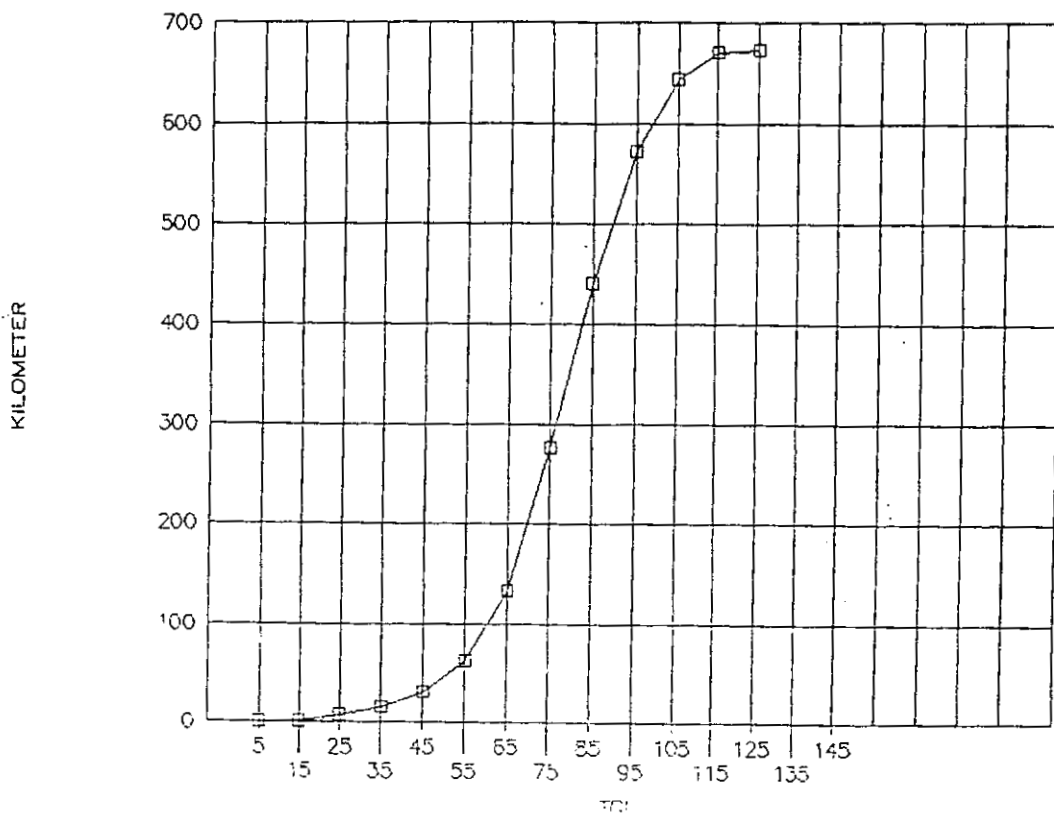
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CFD OF SHATABDI ROUTE C.R.LY DN LINE

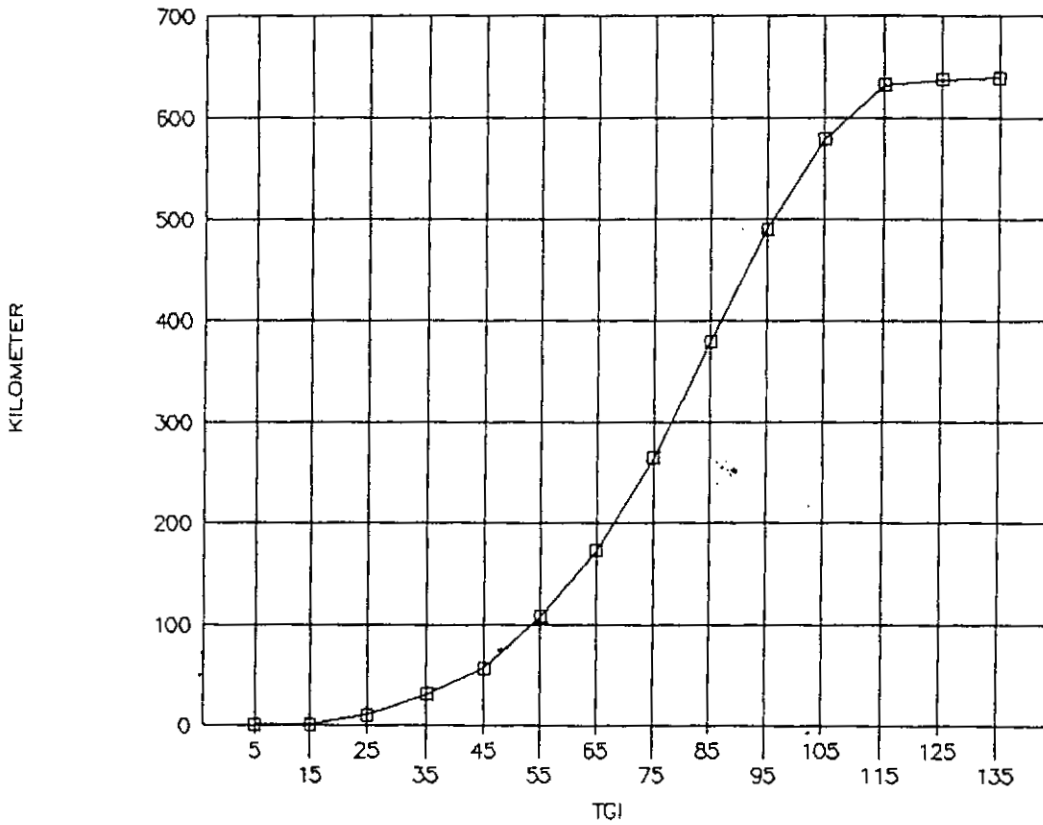
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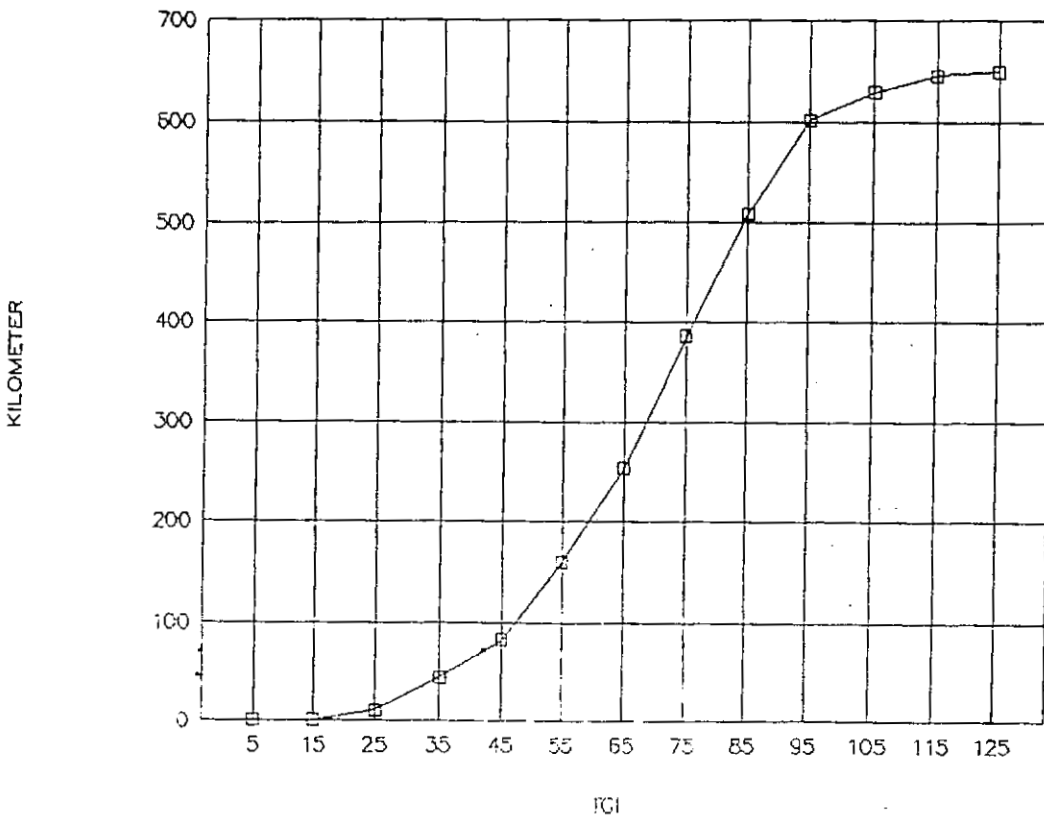
CFD OF RAJDHANI ROUTE E.RLY UP HWH-MGS

TRC-2500 JAN-98 KM 000 - 673



CFD OF RAJDHANI ROUTE UP LINE HWH-MGS

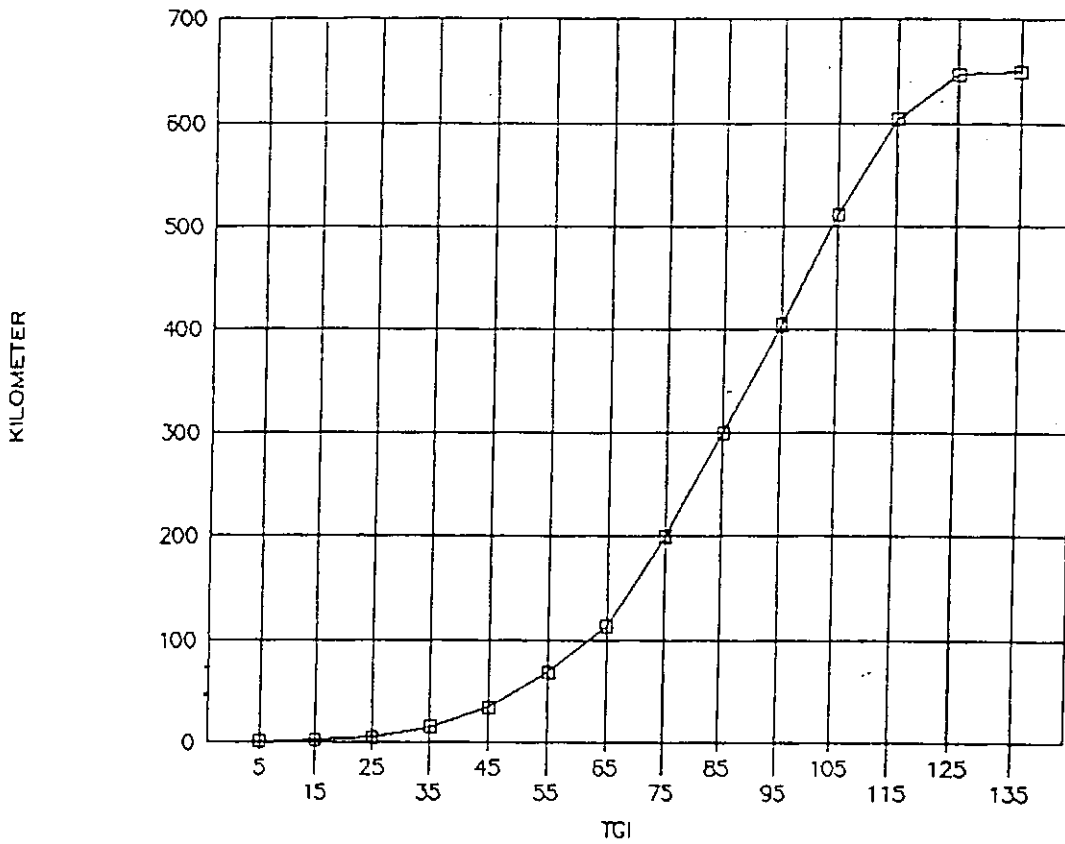
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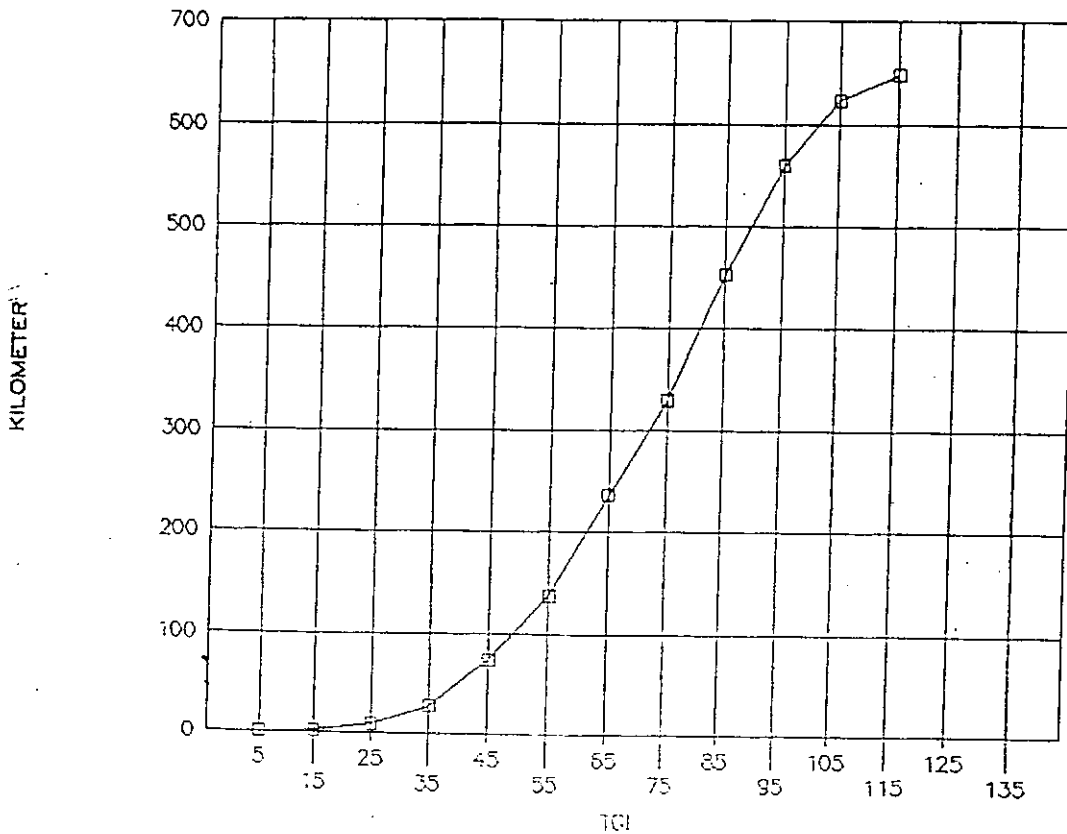
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TRC -2500 MGS - HWH KM 673 - 000



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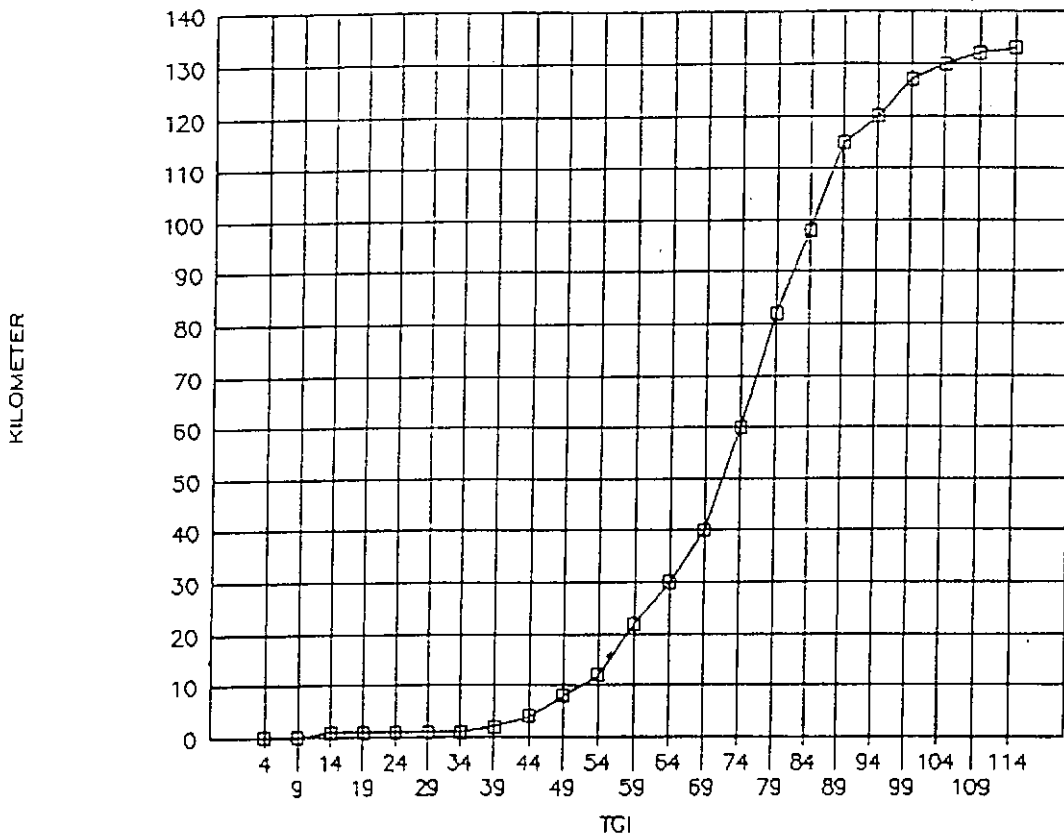
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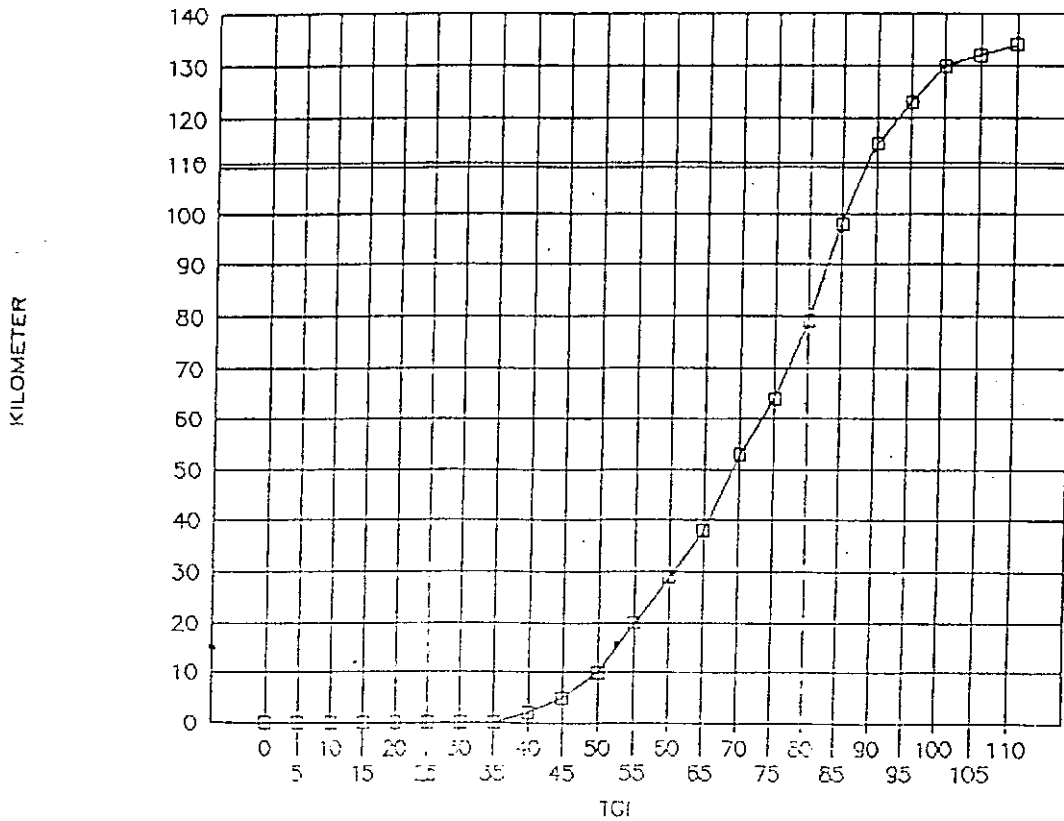
CFD TABLE OF GDR-MAS SECTION

TRC-2500 FEB'98 KM 135-0



CFD TABLE OF GDR-MAS SECTION

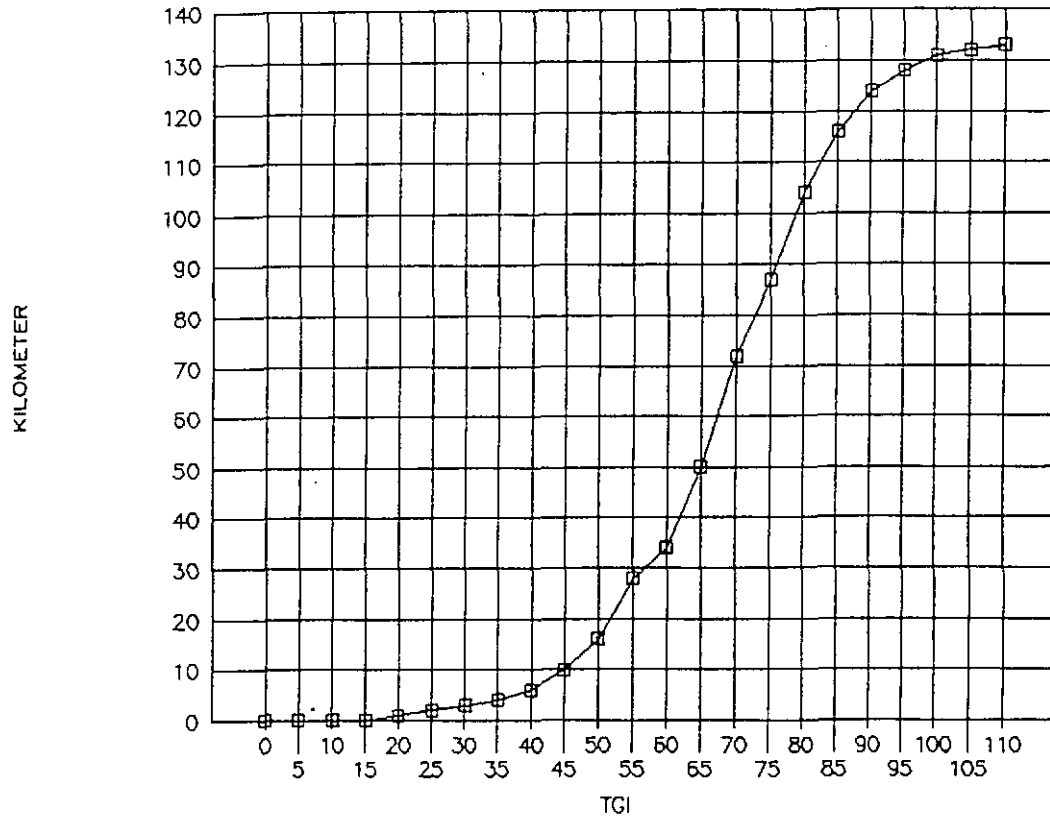
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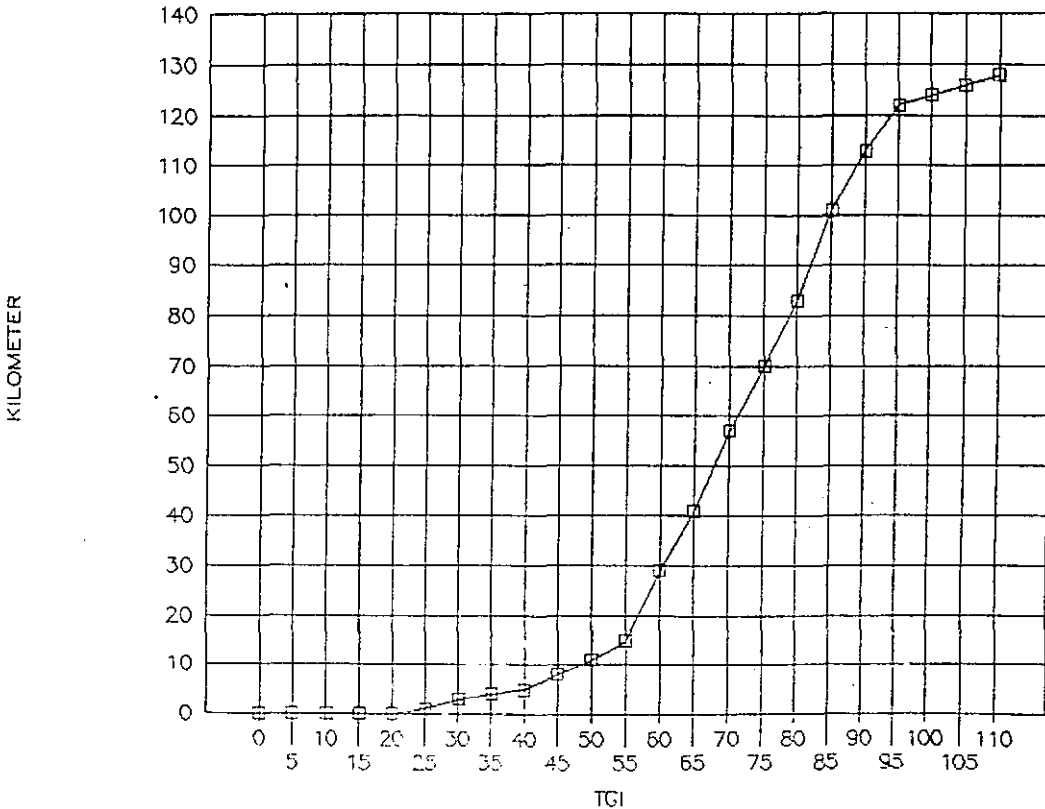
CFD OF TGI OF MAS-GDR

TRC-2500 FEB'98 KM 1-135



CFD OF TGI OF MAS-GDR

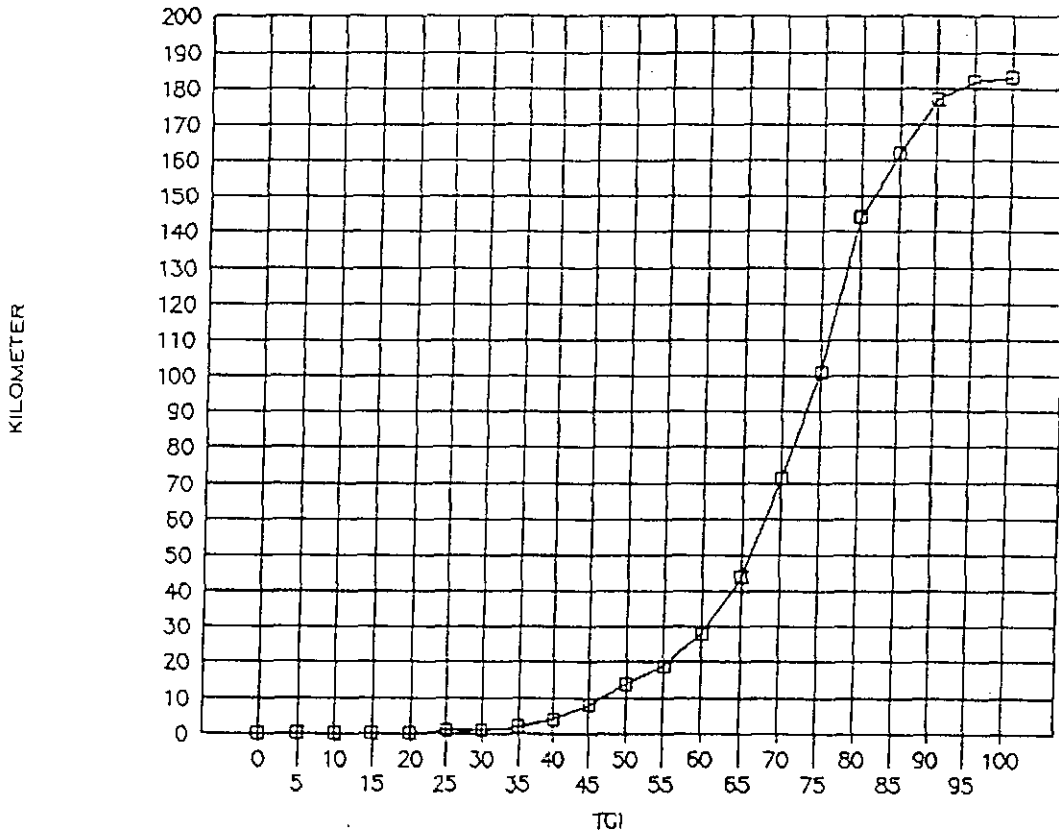
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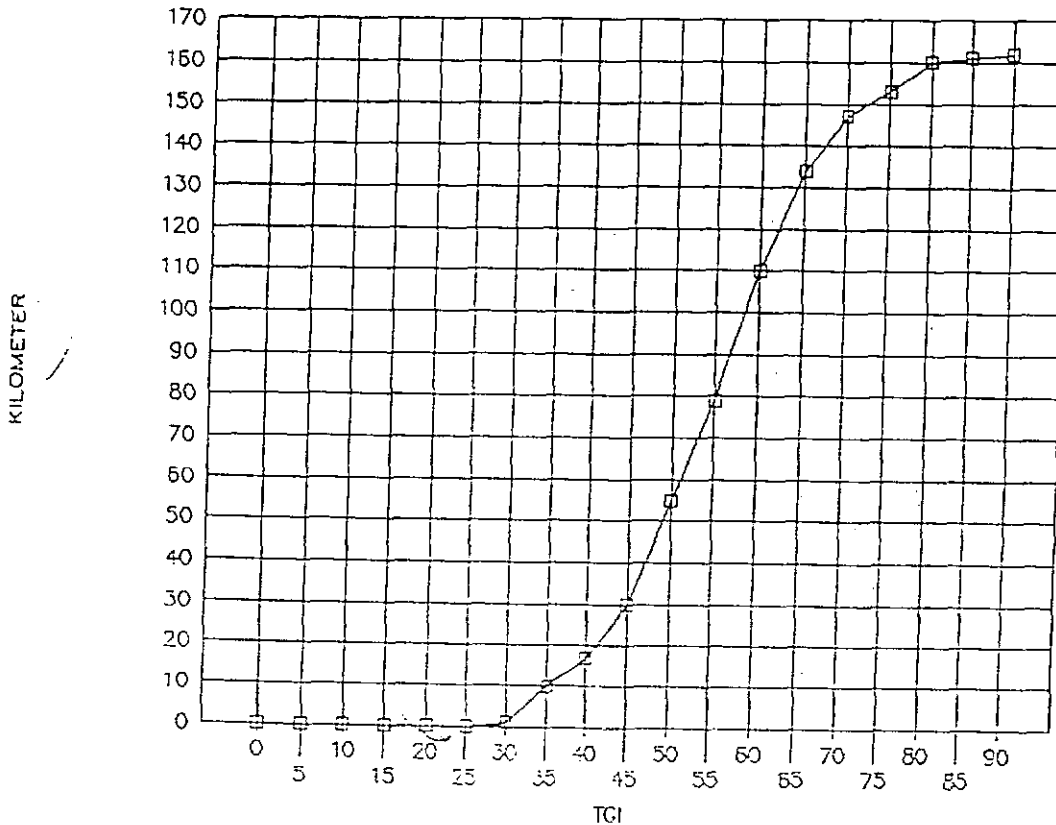
CFD OF DLI-UMB ROUTE OF N.R.LY

TRC-2500 JAN'98 KM 1-191



CFD OF DLI-UMB SECTION

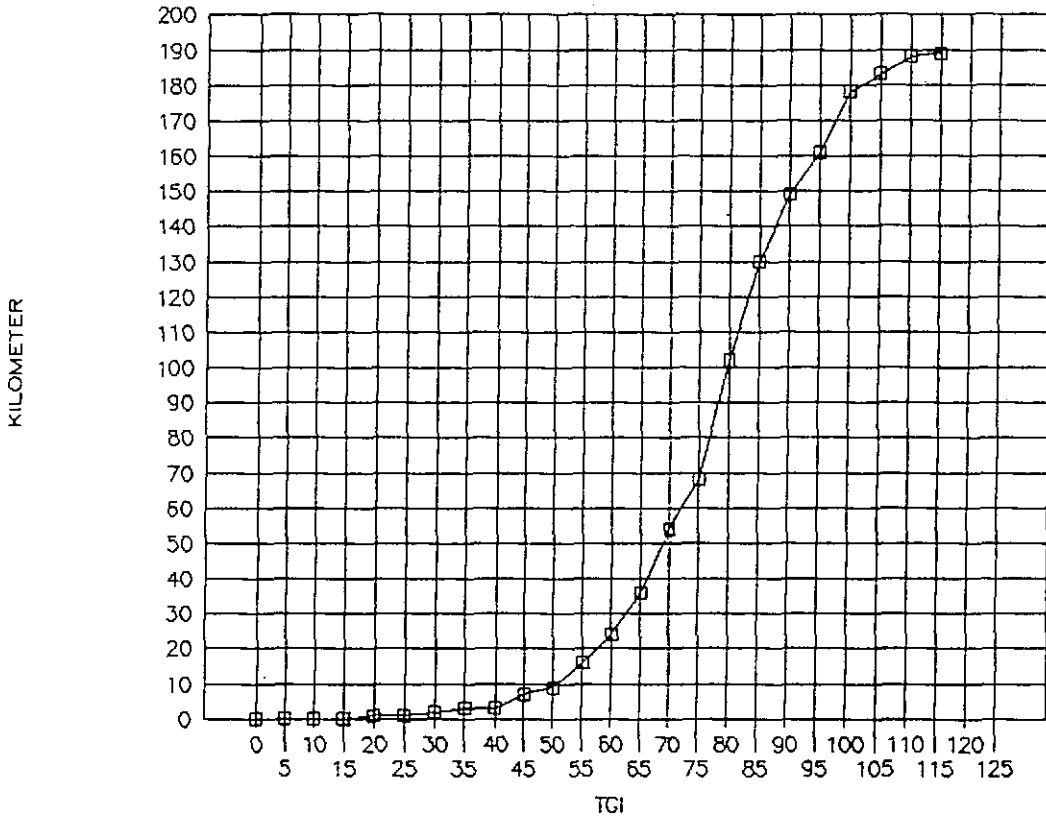
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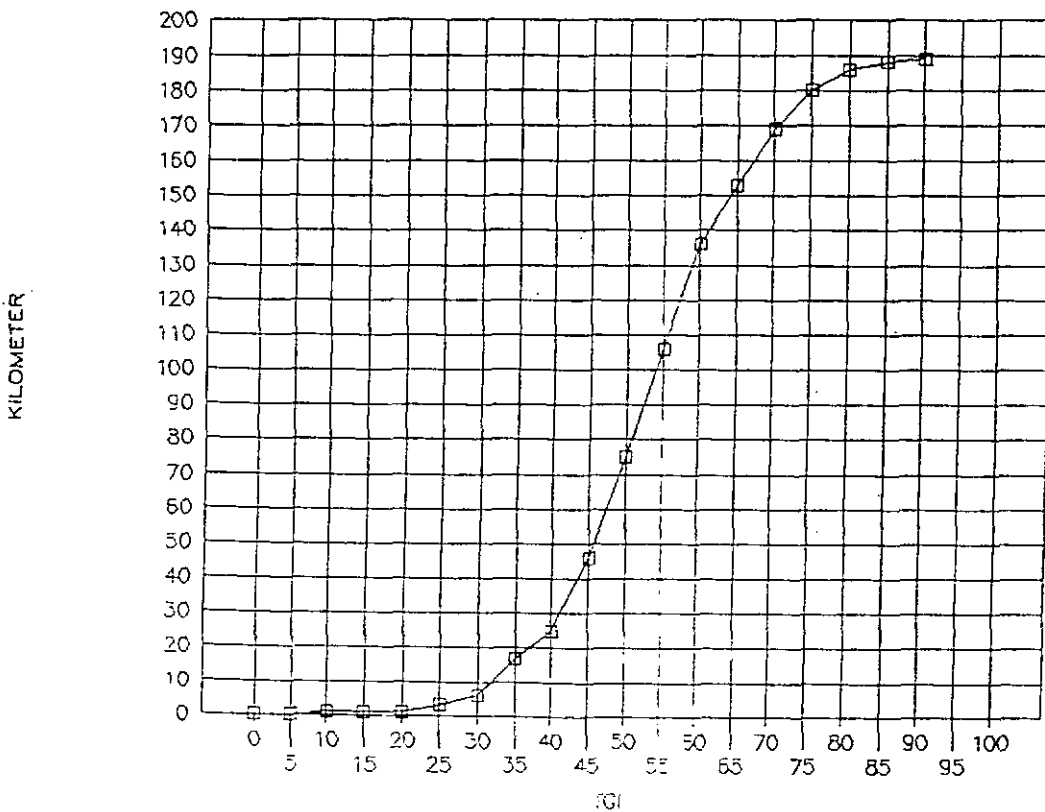
CFD OF TGI OF UMB-DLI SECTION

TRC-2500 JAN'98



CFD OF TGI OF UMB-DLI SECTION

TRC-225 OCT'97 KM 191-1



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Cumulative frequency distribution (in percentage) of TGI in selected sections

Class intervals Section	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
TKD-BPL	0	0	0	.2	.6	1.4	2.4	3.0	4.2	5.4	8.5	13.9	20.7	32.8	46.4	58.9	72.2	83.5	90.8	95.9
BPL-TKD	0	0	0	0	.3	.3	1.2	1.7	3.2	4.1	6.8	10.4	16.5	25.1	35.5	49.2	61.2	75.7	84.1	91.2
HWH-MGS	0	0	.2	.3	.6	.8	1.5	2.3	2.9	5.2	7.2	10.6	13.5	17.5	23.8	30.8	32.0	46.2	54.8	62.2
MGS-HWH	0	.2	.2	.2	.3	1.6	3.0	3.3	5.2	7.5	10.8	15.6	19.7	25.9	31.8	40.5	50.4	58.7	68.5	76.3
GDR-MAS	0	0	.8	.8	.8	.8	.8	1.5	3.0	6.0	9.0	16.5	22.6	30.1	45.1	61.7	73.7	86.5	90.2	95.5
MAS-GDR	0	0	0	.8	.8	1.5	2.3	3.0	4.5	7.0	12.0	21.1	25.6	37.6	54.1	65.4	78.2	87.5	93.2	96.2
DCP-UMB	0	0	0	.2	.2	.2	.6	2.0	4.8	9.8	17.1	27.4	41.2	55.6	70.1	82.4	91.2	95.2	97.2	99.2
UMB-DLI	0	0	0	0	0	0	.2	2.0	6.6	13.0	21.0	33.5	47.7	62.6	73.1	81.9	88.5	94.4	97.8	99.5