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Correlation of Tire Intensity Levels and Passby Sound Pressure Levels

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CORRELATION OF TIRE INTENSITY LEVELS AND PASSBY SOUND PRESSURE LEVELS

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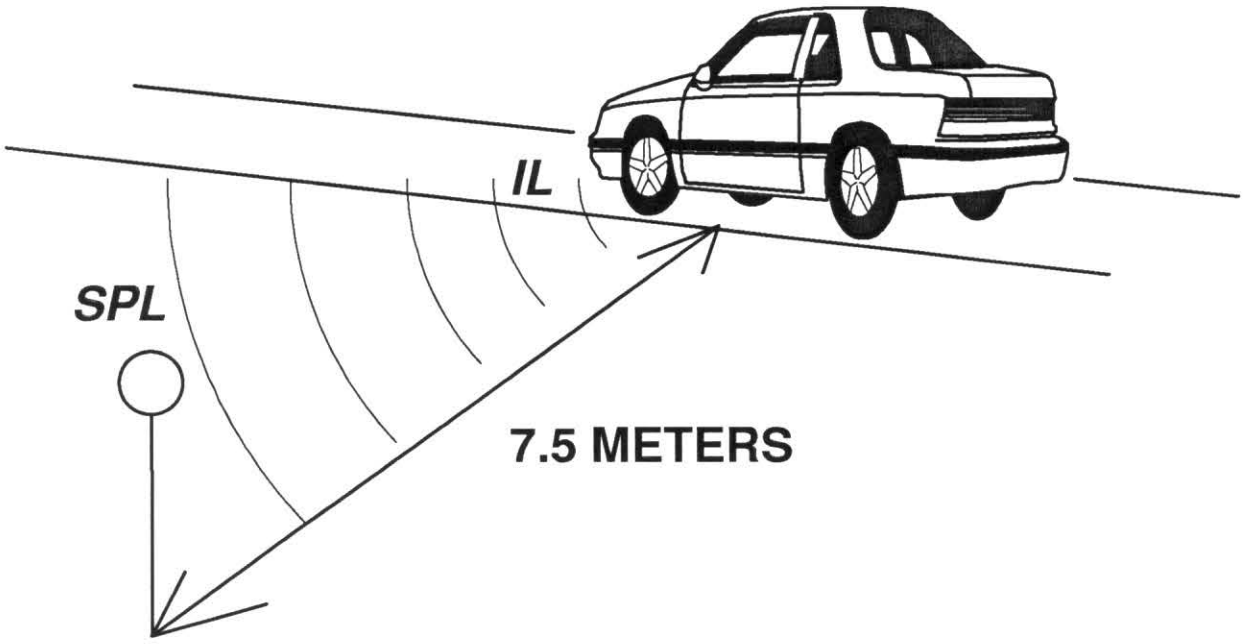
GENERAL MOTORS PROVING GROUND

OBJECTIVES

- **Relate contact patch acoustic intensity level (*IL*) to passby sound pressure level (*SPL*) during coast and cruise at ISO and SAE sites**

- **Use that information to estimate tire noise contribution to passby sound pressure levels during acceleration**



CONCLUSIONS

- **Tire noise contribution to passby *SPL* lies within 4 dB to 7 dB of overall A-weighted *SPL***
- **Coast and Cruise *SPL*'s 1.4 dB lower at ISO than SAE sites (Acceleration *SPL*'s 0.5 dB lower)**

TEST SUMMARY

- Five Vehicles tested at fourteen passby sites
- Coast, cruise and acceleration tests performed
- *IL* measured near driven wheel contact patch
- *SPL* measured at 7.5 m sideline
- 800 data sets obtained

TEST SITES

Location	Surface Type	Dates (1993)	Number of Tests
A	SAE sealed	September 30	36 retained 54 total runs
B	SAE unsealed	September 24	56 / 108
C	SAE sealed	September 16 & 17	60 / 102
D	ISO	November 23	48 / 54
E	ISO	September 18	60 / 92
F	SAE unsealed	October 18	60 / 74
G	ISO	October 12 & 13	44 / 58
H	SAE sealed	October 22	60 / 73
I	SAE unsealed	October 25 & 26	64 / 92
J	SAE sealed	September 19	60 / 84
K	SAE unsealed	October 14 & 15	96 / 109
L	SAE sealed	September 20 & 21	60 / 75
M	SAE sealed	October 19	60 / 71
N	SAE unsealed	October 1	48 / 55
	14 tracks		812 / 1101

Table 1. Test track summary.

VEHICLES TESTED

	Vehicle I	II	III	IV	V
TYPE	production compact 2 door hatchback	production midsize 4 door sedan	near production midsize 2 door sedan	prototype small passenger van	near production midsize 4 door sedan
ENGINE	4 cylinder	6	4	4	6
TRANS-MISSION	5 speed manual	4 speed automatic	3 speed automatic	5 speed manual	3 speed automatic
TIRE	production touring	production touring	production aggressive sport	production European tread	production touring
SIZE	P175/70 R13	P205/70 R14	P215/60 R14	P205/65 R15	P195/70 R14
PRESSURE	32 psi	35	30	35	32

Table 2. Vehicle and associated tire type.

TEST TRACK

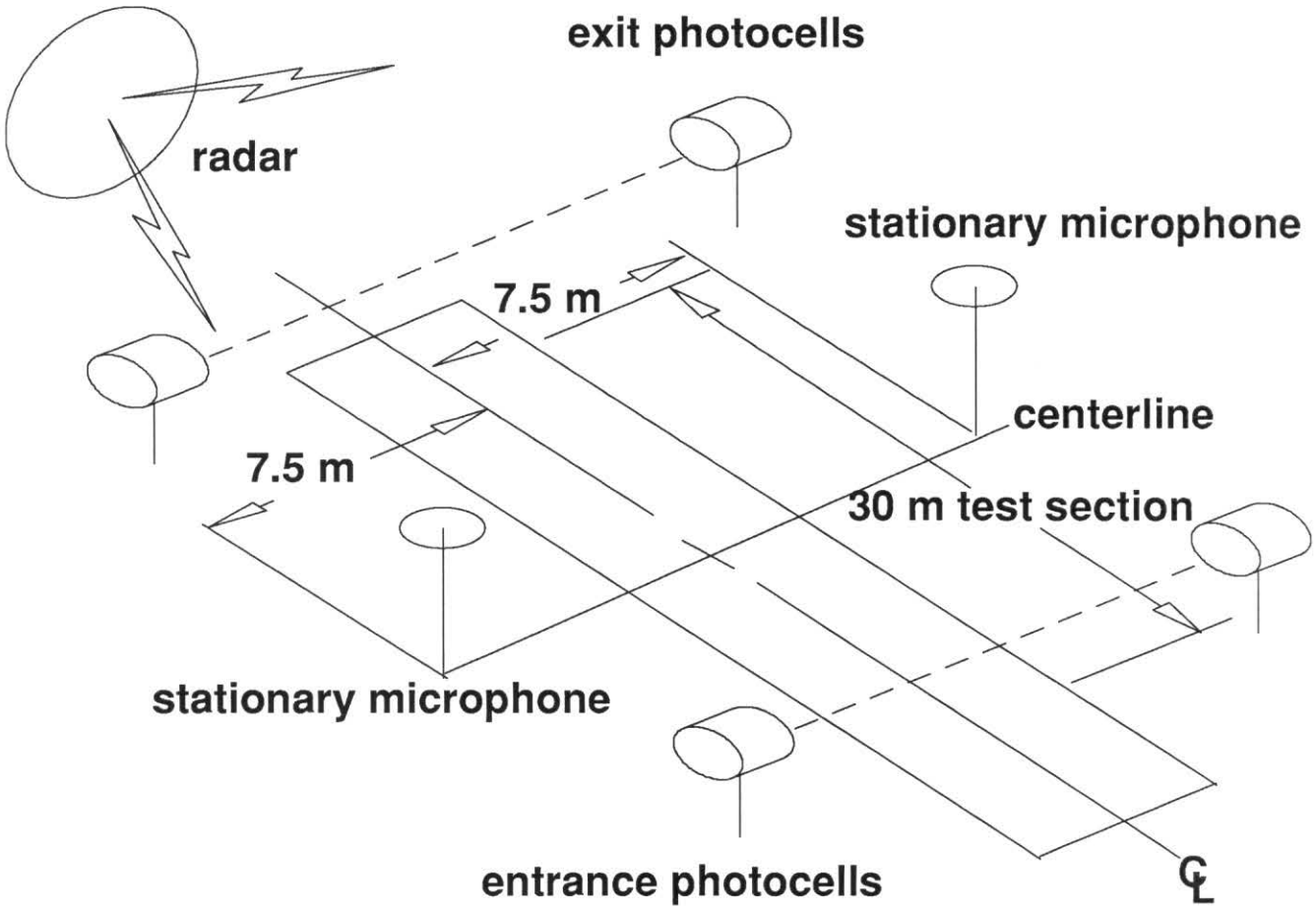
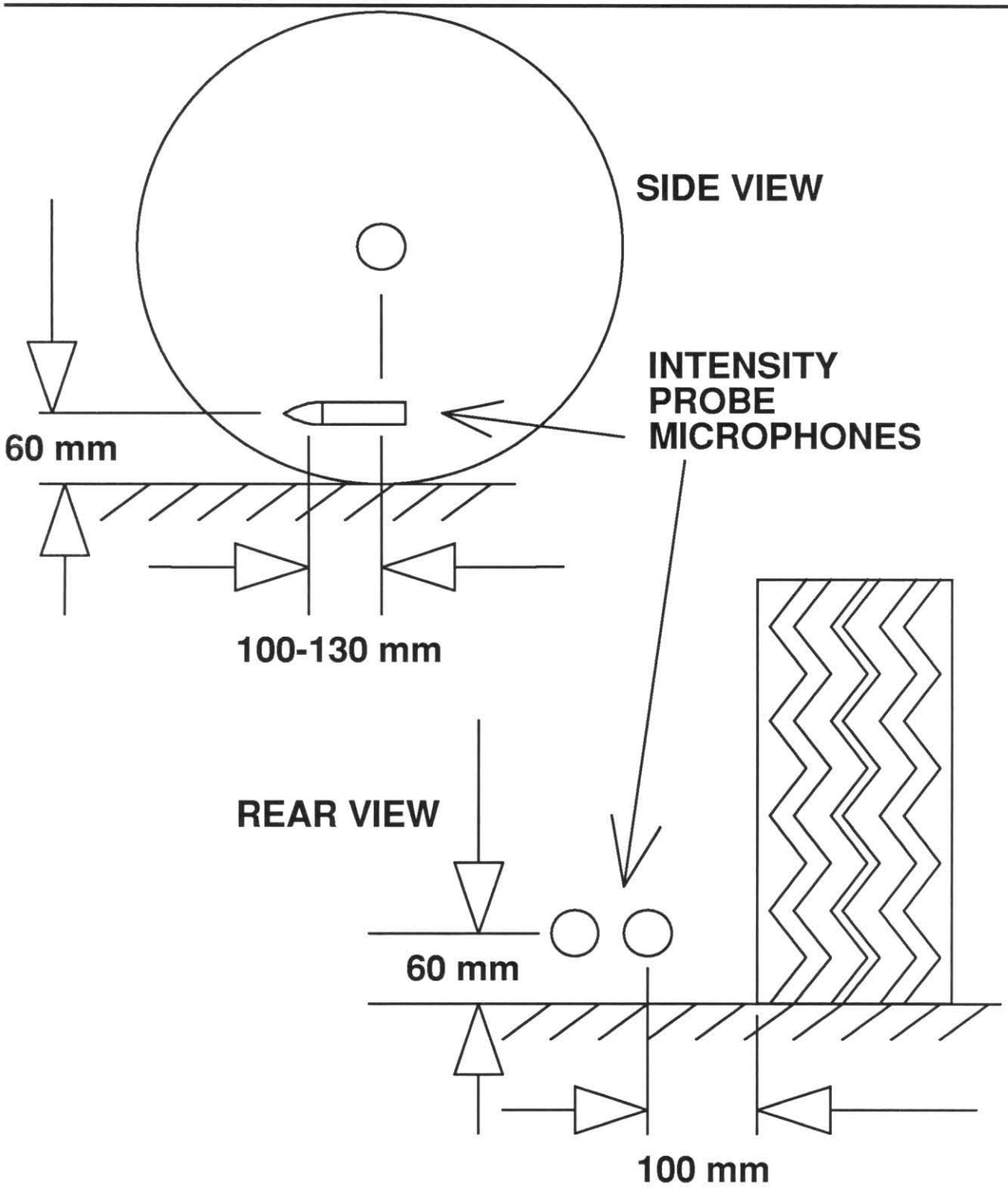
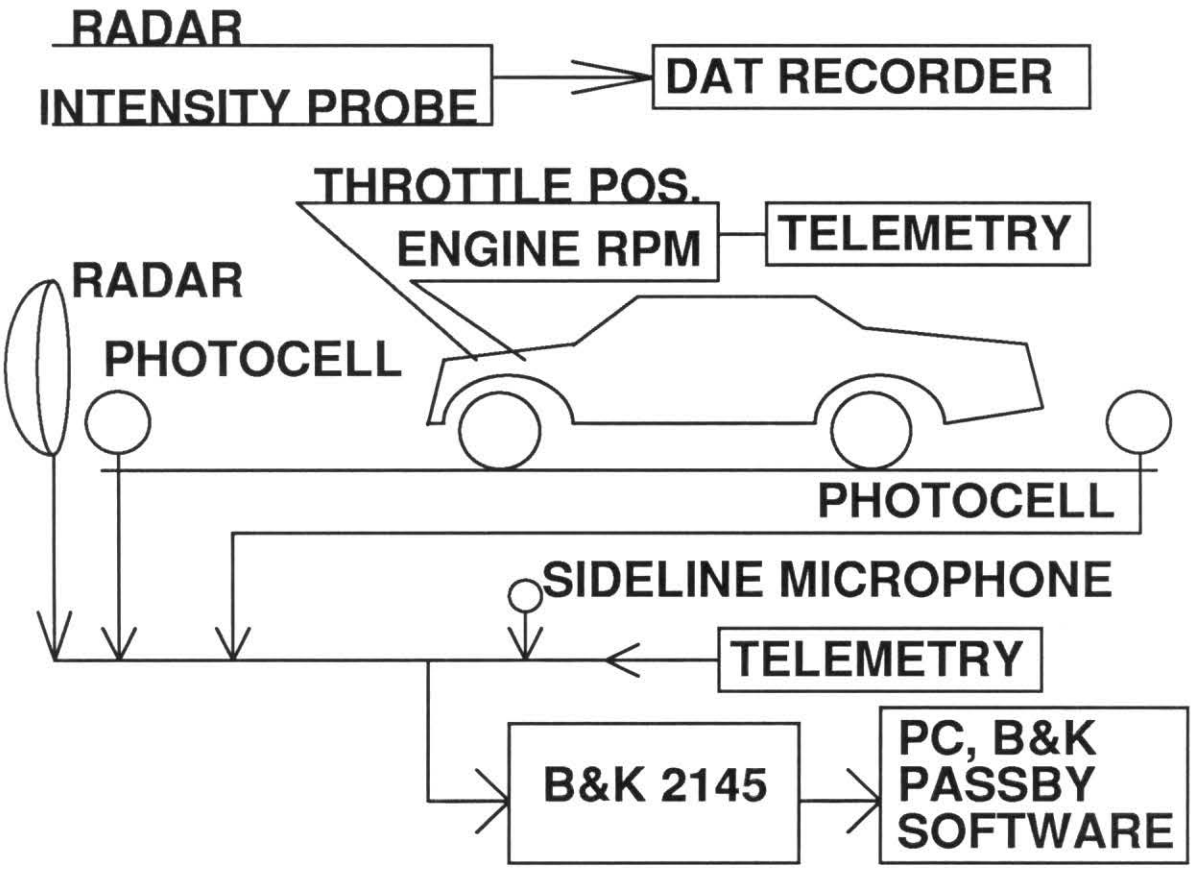


Figure 1. Test track schematic.

INTENSITY MEASUREMENT



DATA ACQUISITION



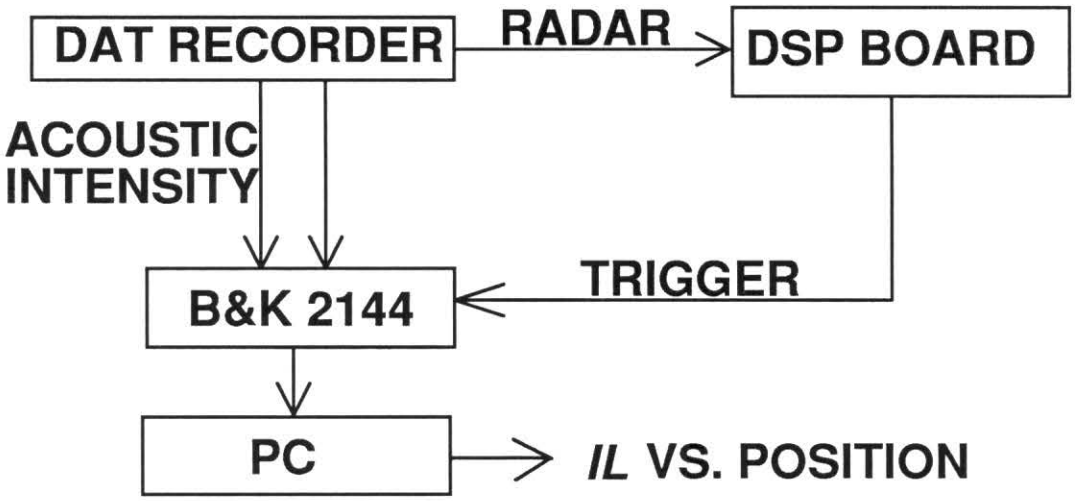
DATA RECORDED EVERY 0.25 m ON PC

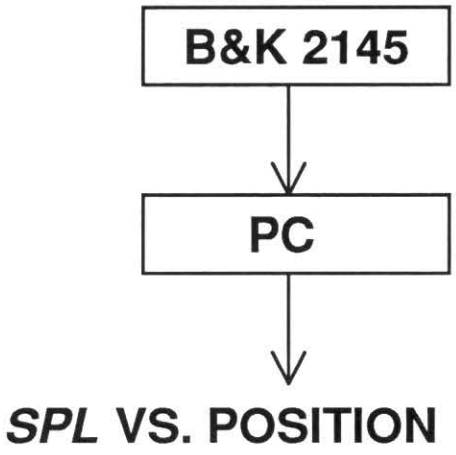
- VEHICLE SPEED
- 1/3 OCTAVE A-WEIGHTED *SPL*
- THROTTLE POSITION
- TRANSMISSION GEAR

DATA RECORDED ON DAT RECORDER IN VEHICLE

- RADAR TIME HISTORY
- MICROPHONE OUTPUTS

DATA ANALYSIS





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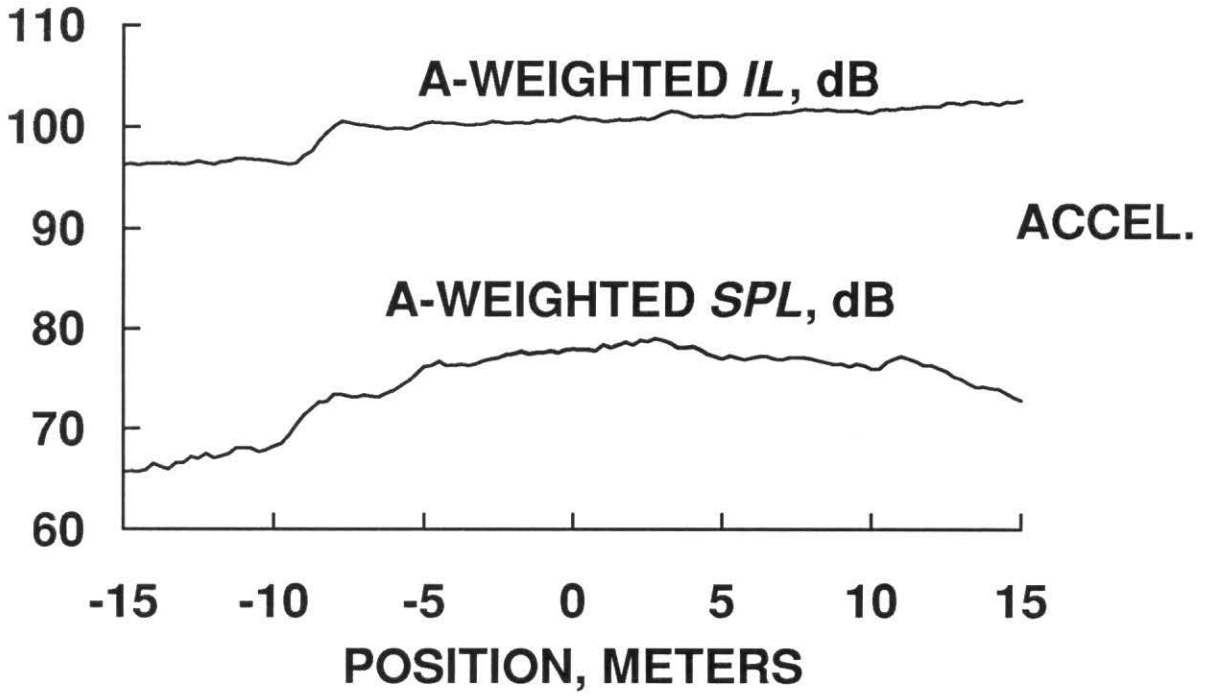
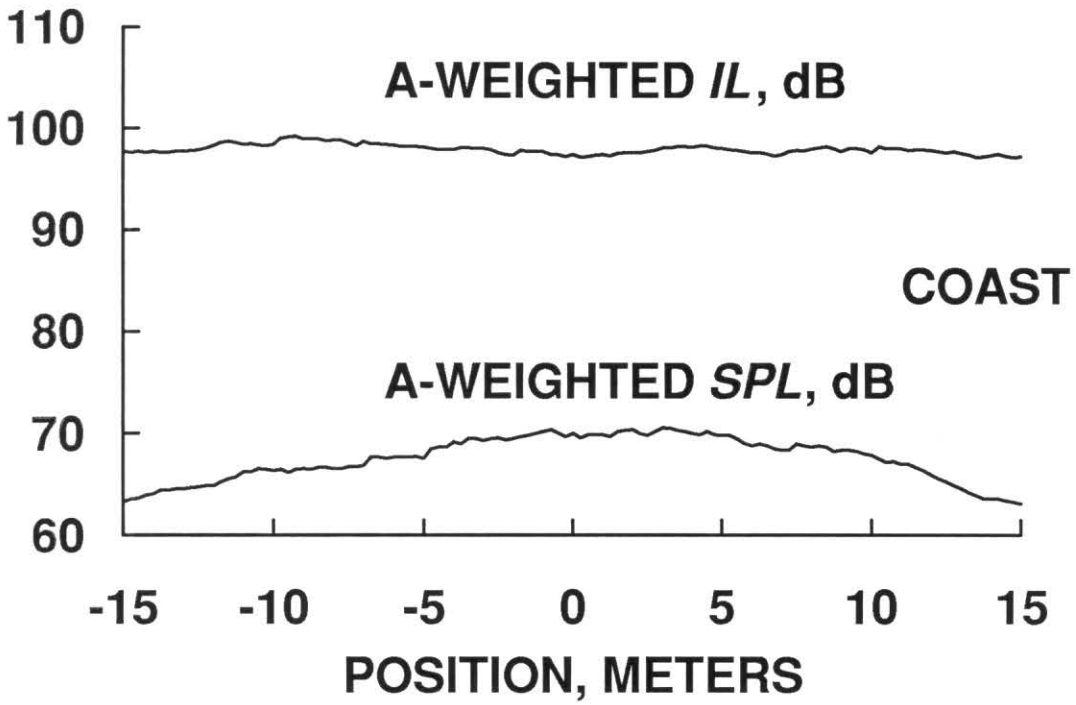
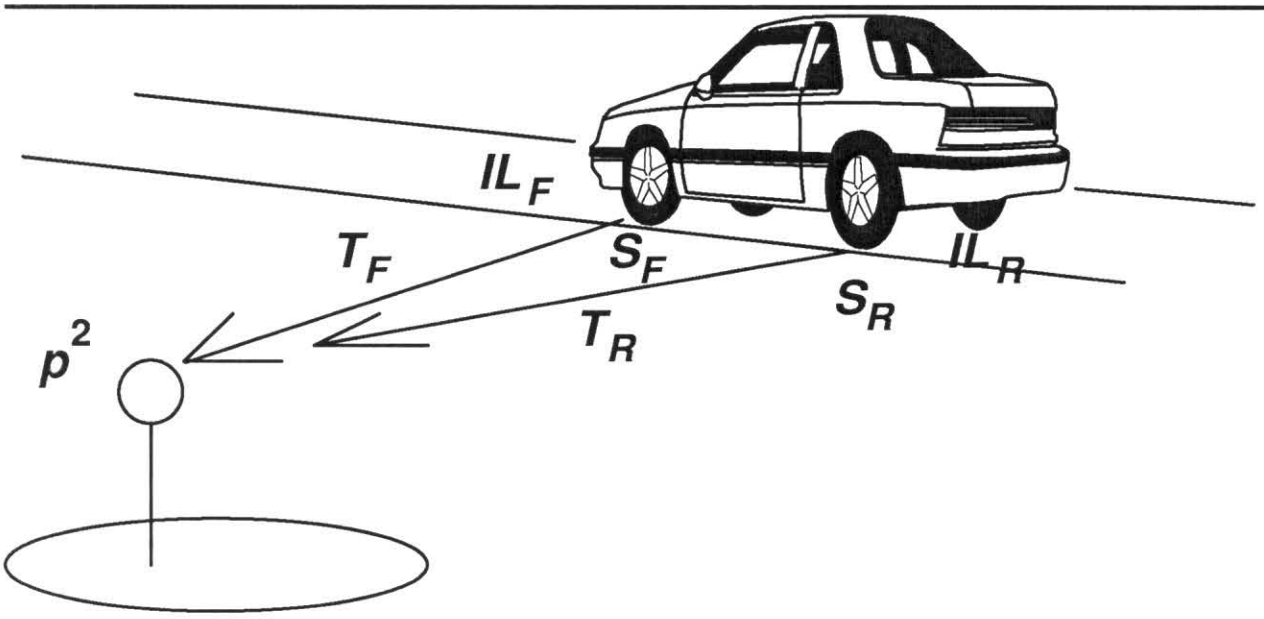




COAST/CRUISE TRANSFER FUNCTIONS



$$\boxed{\begin{aligned} p^2 &= p_F^2 + p_R^2 \\ &= S_F T_F + S_R T_R \end{aligned}}$$

ASSUME: (i) $S_F \cong S_R$

(ii) $T_F \cong T_R$

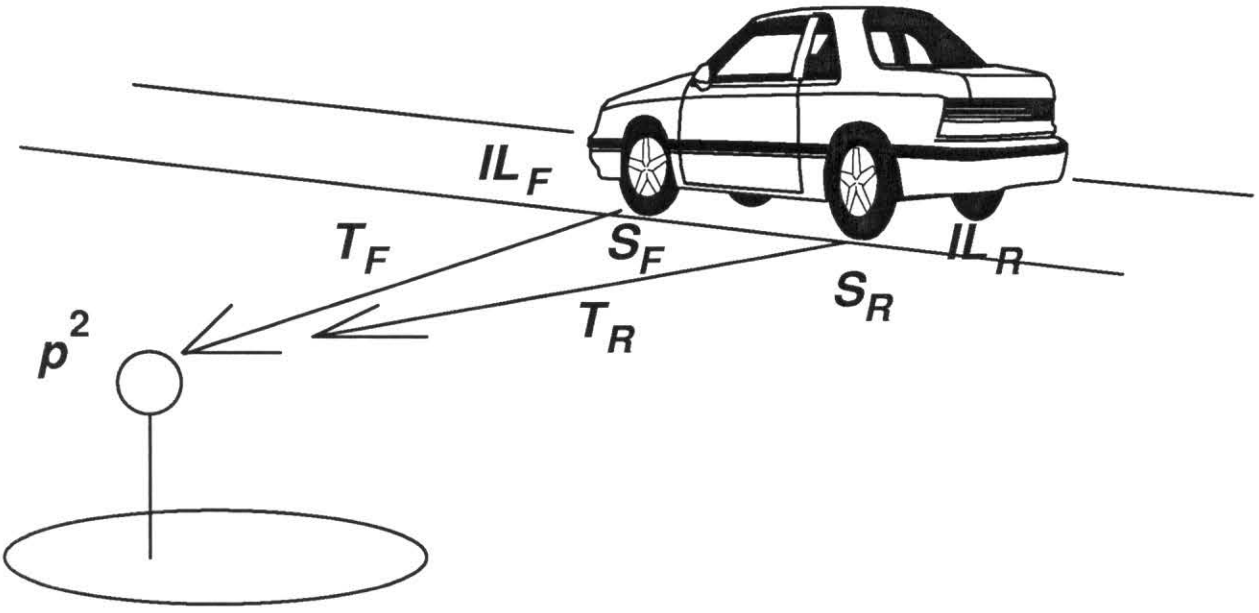
$$\boxed{p^2 \cong 2 S_F T_F}$$

WHERE: $S_F = p_0^2 10^{\left(IL/10\right)}$

COAST/CRUISE TRANSFER FUNCTION

$$H_{COAST/CRUISE} = 10 \log T_F$$

COAST/CRUISE TRANSFER FUNCTIONS



$$SPL_{COAST/CRUISE} = IL_{COAST/CRUISE} + H_{COAST/CRUISE} + 3\ dB$$

$$H_{COAST/CRUISE} = SPL_{COAST/CRUISE} - IL_{COAST/CRUISE} - 3\ dB$$

COAST/CRUISE TRANSFER FUNCTIONS

$SPL_{COAST/CRUISE}$

	Vehicle I	II	III	IV	V
ISO	67.0	66.9	69.8	70.3	66.5
SAE	68.4	68.5	71.0	72.0	68.1

$IL_{COAST/CRUISE}$

	Vehicle I	II	III	IV	V
ISO	93.3	91.0	95.0	96.2	92.6
SAE	94.4	91.6	95.9	97.2	93.6

$H_{COAST/CRUISE}$

	H_{COAST}		H_{CRUISE}	
	ISO	SAE	ISO	SAE
mean	-28.4	-28.3	-28.3	-27.7
standard deviation	0.8	1.4	1.0	1.6

PASSBY LEVELS

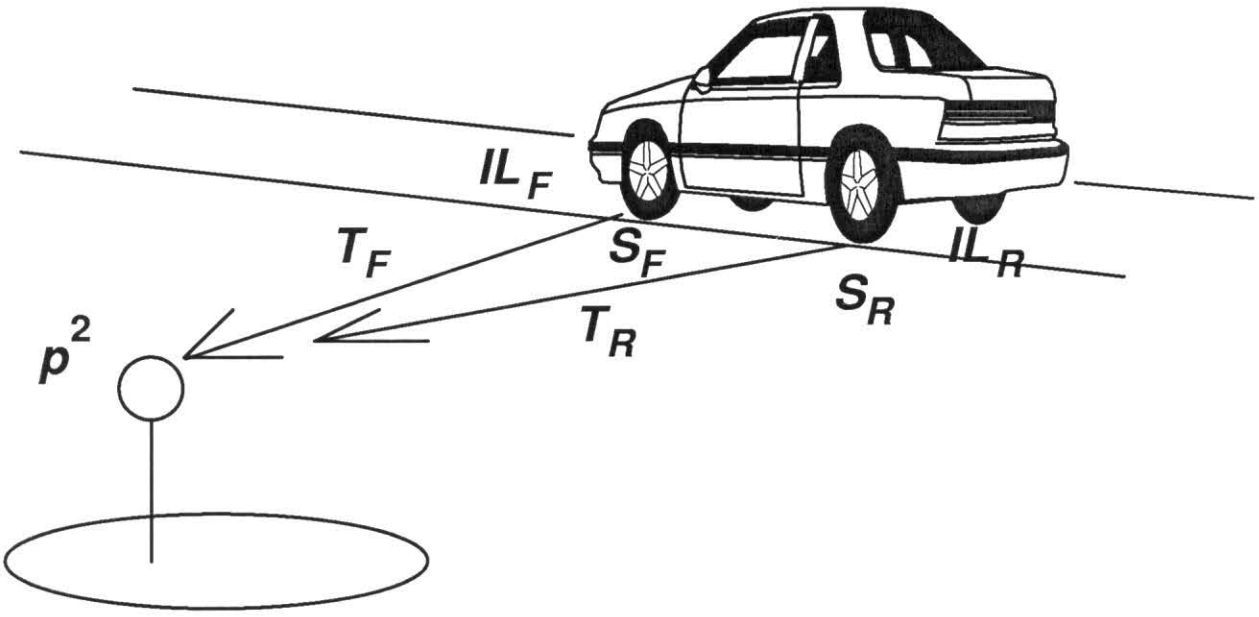
AVERAGE SPL_{PASSBY}

	Vehicle I	II	III	IV	V
ISO	75.6	72.8	78.7	78.2	72.3
SAE	76.1	73.4	78.4	79.1	73.0

SPL_{PASSBY}

	Vehicle I	II	III	IV	V
Site A	76.6	73.7	81.6	79.1	72.9
B	77.7	75.1	78.5	80.4	74.5
C	77.2	74.2	78.1	79.3	73.1
D	74.7	71.7	76.6	77.8	
E	76.6	73.9	78.0	79.0	72.7
F	74.8	72.0	76.6	78.0	71.5
G	75.4	72.6	81.0	77.7	71.8
H	76.2	74.2	78.3	79.7	73.3
I	75.8	73.7	77.7	79.0	73.4
J	76.2	73.0	77.5	78.5	72.5
K	76.1	72.6	76.4	78.4	72.4
L	77.0	73.7	77.9	78.8	73.0
M	75.5	73.6	77.9	79.6	72.7
N	72.5	70.7	80.2		

TIRE NOISE CONTRIBUTION TO PASSBY LEVEL



SOUND PRESSURE DUE TO TIRE NOISE:

$$\boxed{p_t^2 = S_{PASSBY} T_F + S_{COAST/CRUISE} T_R}$$

ASSUME: $T_F \cong T_R \cong T_{COAST/CRUISE}$

$$\boxed{p_t^2 \cong (S_{PASSBY} + S_{COAST/CRUISE}) T_{COAST/CRUISE}}$$

WHERE: $S_{PASSBY} = p_0^2 10^{\left(IL_{PASSBY}/10\right)}$

$$S_{COAST/CRUISE} = p_0^2 10^{\left(IL_{COAST/CRUISE}/10\right)}$$

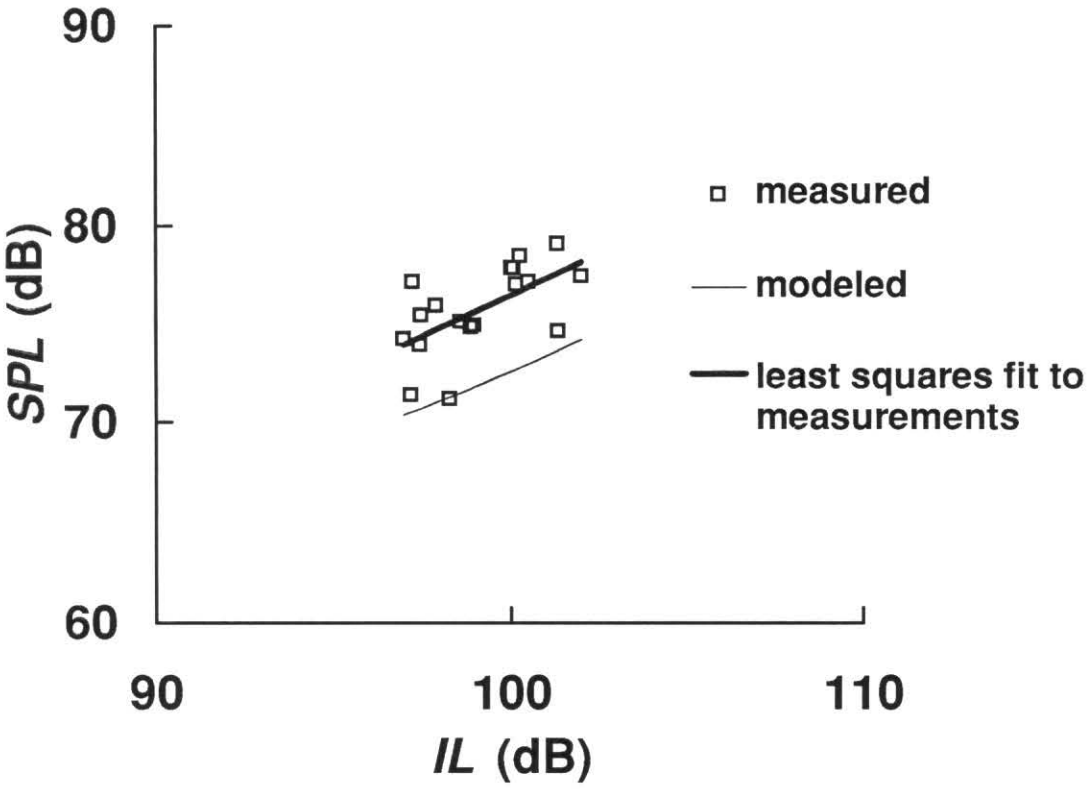
TIRE NOISE CONTRIBUTION TO PASSBY LEVEL

$$SPL_{PASSBY/TIRE} = 10\log_{10}\left(10^{IL_{PASSBY}/10} + 10^{\langle IL_{COAST/CRUISE}\rangle/10}\right) + \langle H_{COAST/CRUISE}\rangle$$

WHERE:

- IL_{PASSBY} — **MEASURED DURING ACCELERATION TEST FOR VEHICLE OF INTEREST**
- $\langle IL_{COAST/CRUISE}\rangle$ — **AVERAGE OF MEASURED COAST AND CRUISE *IL*'s FOR VEHICLE OF INTEREST**
- $\langle H_{COAST/CRUISE}\rangle$ — **VEHICLE'S AVERAGE COAST/CRUISE TRANSFER FUNCTION**

TIRE NOISE CONTRIBUTION TO PASSBY LEVEL



TIRE NOISE CONTRIBUTION TO PASSBY LEVEL

	I	II	III	IV	V
Average Passby Level	76.3	73.7	78.1	79.3	73.1
Estimated Tire Noise	72.2	69.4	72.2	72.7	71.4
All Other Sources	74.2	71.7	76.8	78.3	68.1

TIRE NOISE CONTRIBUTION TO PASSBY LEVELS:

≈ 72 dB

CONCLUSIONS

- COAST AND CRUISE LEVELS MEASURED ON ISO SITES APPROXIMATELY 1 - 1.5 dB LESS THAN THOSE MEASURED ON SAE SITES

TIRE NOISE LEVELS MEASURED ON SAE AND ISO SITES MAY DIFFER

- PASSBY LEVELS APPROXIMATELY 0.5 dB LESS ON ISO SITES THAN ON SAE SITES

- FOR 4 OF 5 VEHICLES TESTED, TIRE NOISE CONTRIBUTION TO PASSBY *SPL* WAS 4 dB TO 7 dB LESS THAN OVERALL A-WEIGHTED SPL

TIRE NOISE PASSBY LEVEL APPROXIMATELY 72 dB