NATIONAL BUREAU OF STANDARDS REPORT

10502

PROGRESS REPORT OF RESEARCH ACTIVITY
TRUCK TIRE NOISE INVESTIGATION

September 1, 1970 – October 31, 1970

Office of Vehicle Systems Research

and

Sensory Environment Branch
Building Research Division

Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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September 1, 1970 – October 31, 1970

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1. Program Objective

To identify and quantify the physical parameters which affect the noise generation characteristics of truck tires and to develop an information base that may lead to standardized tire-noise testing procedures and to highway noise reduction criteria, standards, and regulations.

2. Progress This Period

The major emphasis this period has centered upon field testing (i.e., data acquisition rather than analysis) because of the impending unfavorable weather conditions associated with late Fall. For this reason no data, with the exception of the flap test (influence of rubber flaps on the peak A-weighted sound level at 50 feet), are reported this period.

Single vehicle testing initiated during the previous reporting period has continued. In addition to testing dual tires with matched tread designs on the drive axles, single tires on the drive axles plus mix-and-match combinations of tread designs were tested. Ideally one would like to measure the noise generated by a single tire rolling down a road; therefore, some tests were run using selected tires singly on the drive axles rather than as a dual pair. Also, some tires may contribute differently to the overall noise level depending on their location on the vehicle. Therefore, selected tires were tested in various locations to determine their contributory effect to the overall noise level.

Early in the reporting period a question arose as to the effect the rubber mud flaps, which are standard equipment on today's trucks, might have on the noise generated by the truck tires. Through real time analysis, peak A-weighted sound levels were obtained utilizing a single microphone located 50 feet from the centerline of truck travel. No significant effect was observed; therefore, the standard rubber flaps were left on the vehicles during testing.

A test vehicle for the tractor-trailer test phase was located and a test matrix developed. The matrix reflects the general practice of trucking firms by specifying cross-bar tires on the drive axles of the tractor and retreads on the trailer. The control General HCR tires were used on the steering axle. In addition a "quiet" (new General HCR's on the tractor, new Rib Saw Tooth retreads on the trailer) and a "noisy" (50% worn Goodyear Custom Cross Rib Hi Milers on the tractor, 50% worn Hawkinson retreads on the trailer) configuration, were included in the matrix in an attempt to provide some feeling for the upper and lower bounds which can be expected. As soon as additional tires were received, tractor-trailer testing commenced.

Testing continued until late October when the unfavorable weather conditions associated with late Fall and the increasingly more difficult task of locating tires in the 50% and fully worn conditions, especially the large number of tires necessary for tractor-trailer testing, forced the termination of field testing until the Spring of next year.

Work has continued on the data reduction phase of the program and this effort will be increased with the suspension of field testing. Programs for (1) converting the analog data into a formatted digital form, (2) acceptance and recognition of timing pulses, (3) analyzer control, and (4) position-velocity calculations are now operable.

2.1. Single Vehicle Testing

At the conclusion of field testing for this year, 70% of the matrix proposed for single vehicle testing had been completed. Table 1 shows the present status of the program for both single and dual wheel configuration testing.

In addition, the mix-and-match testing was fully completed. This test phase consisted of the mounting of General HCR tires of all wheel locations with the exception of the right rear dual pair. At these two positions, which were on the side facing the microphone array, selected tires (rib, cross-bar, and pocket retread) were mounted in various combinations. Table 2 shows the combinations which were tested. All mix-and-match testing was conducted with the loaded truck at a speed of 60 mph on a concrete surface. All tires were new (zero wear) with the exception of the Firestone T-200's. Because of their larger circumference it was necessary to test these tires in a 50% worn condition so that they could be matched with the other selected test tires.

		Tread Design	CONCRETE			ASPHALT		
			Dual Loaded	Dual Unloaded	Single Unloaded	Dual Loaded	Dual Unloaded	Single Unloaded
	New	General HCR	X	X	X	X	X	X
RIB	New	Firestone T-150	X			X		
	50% Worn		X			X		
	100% Worn							
	New	General Power Jet Nylon	X	X	X	X	X	X
	50% Worn							
	100% Worn							
CROSS BAR	New	Goodyear Hi Miler	X			X		
	50% Worn		X			X		
	100% Worn		X			X		
	New	Uniroyal Fleet Traction	X			X		
	50% Worn							
	100% Worn							
	New	Firestone T-200	X	X	X	X	X	X
	50% Worn		X	X	X	X	X	X
	100% Worn							
RETREAD	New	Rib Saw Tooth	X			X		
	50% Worn							
	100% Worn							
	New	Bow Tie	X			X		
	50% Worn		X					
	100% Worn		X					
	New	Hawkinson AR	X	X	X	X	X	X
	50% Worn		X	X	X	X	X	X
	100% Worn							

Table 1. The proposed single vehicle test matrix. For a given tire tread design in any of three states of wear, an X represents the completion of tests using this tire type at seven speeds from 30 to 60 mph in 5 mph increments on a concrete or asphalt surface either in a fully loaded or an unloaded condition. The tires were mounted on the truck's drive-axle either in dual pairs or singly.

Right rear inside	Right rear outside
General HCR	General Power Jet Nylon
General Power Jet Nylon	General HCR
General Power Jet Nylon	General Power Jet Nylon
General HCR	Firestone T-200
Firestone T-200	General HCR
Firestone T-200	Firestone T-200
General HCR	Hawkinson Retread
Hawkinson Retread	General HCR
Hawkinson Retread	Hawkinson Retread
General Power Jet Nylon	Firestone T-200
Firestone T-200	General Power Jet Nylon
General Power Jet Nylon	Hawkinson Retread
Hawkinson Retread	General Power Jet Nylon
Firestone T-200	Hawkinson Retread
Hawkinson Retread	Firestone T-200

Table 2. Mix-and-Match test matrix. To determine whether tires contribute differently to the overall noise level depending on their location on the vehicle, the tires listed in this table were mounted on the right rear dual position with General HCR tires at all other positions. This was the location nearest the microphone array.

2.2. Flap Test

Throughout the feasibility test program the test vehicles were all equipped with standard rubber mud flaps. No investigation had been made as to the effect the flaps have on the sound level generated by truck tires. To determine this effect a test was devised which included runs with (1) standard rubber flaps, (2) no flaps at all, and (3) flaps constructed of potato sacks with a two-by-four attached to keep them in relatively the same shape as a regular rubber flap. The test truck was a single vehicle fully loaded and equipped with dual Firestone T-150 tires. A single microphone located 50 feet from the centerline of truck travel at a height of 48 inches was utilized during measurement. The analysis was performed in real time by depressing the peak hold button of the real time analyzer at the beginning of the passby and once the truck had coasted through the test section with its engine shut off the peak A-weighted sound level was read from the digital section of the real time analyzer. The following table shows the results for duplicate runs at 50 mph and 30 mph.

Flap Type / Speed	Rubber	None	Potato Sack
50 mph	74.2	73.8	74.4
50 mph	74.4	75.0	73.2
30 mph	66.4	66.6	65.4
30 mph	66.4	66.2	65.6

Table 3. Peak A-weighted sound levels produced by a test vehicle equipped with (1) standard rubber flaps, (2) no flaps at all, and (3) flaps fabricated from potato sacks as measured by a single microphone located 50 feet from the centerline of truck travel at vehicle speeds of 30 and 50 mph.

The results show that for the 50 foot microphone location the flaps appear to have little affect on the A-weighted sound levels generated by truck tires. Although the data in individual one-third octave bands may be influenced by the presence of the flaps, it was decided that the testing would continue with vehicles equipped with rubber flaps since this is the "real-world" situation. This is consistant with earlier decisions which were based on the peak A-weighted sound levels.

2.3. Combination Vehicle Testing

An agreement was negotiated with the Ford Motor Company (Ford Division, Ford Marketing Corporation, Falls Church, Virginia) for the loan of a 1970 Ford tandem tractor model LT-9000 to the government for the duration of the tractor-trailer phase of the truck tire noise investigation.

This was a service school unit equipped with an 8V71 Detroit Diesel engine that developed 318 HP at 2150 RPM. It had a 10 speed Roadranger transmission and 10.00 x 20 tires.

The trailer (leased from the Ryder Truck Rental, Inc., Baltimore, Maryland) was a 40 foot Fruehauf tandem flat-bed trailer that also utilized 10.00 x 20 tires.

The tractor-trailer was loaded to a gross vehicle weight of 65,080 pounds by the appropriate placement of two 20,000 pound concrete slabs. The resulting weight distribution was as follows:

front axle	9,240 pounds
drive axles	29,000 pounds
trailer axles	26,840 pounds
gross vehicle weight	65,080 pounds

Table 4 shows the proposed matrix for the tractor-trailer test phase of the program. The goal of this phase of the program is the determination of the contribution of the tires on the tractor drive axles and the trailer axles to the overall noise level. To accomplish this the following were tested in addition to the quiet and noisy combinations previously discussed: (1) rib tires, pocket retreads, and cross-bar tires were mounted on the tractor drive axles while the trailer tires were held constant (rib saw tooth retreads) and (2) pocket retreads were mounted at various locations on the trailer while the tractor tires were held constant (cross-bars).

Runs 1, 2, 3, 10, 12, 13, 14, 15, 16, 17 and 18 were completed at speeds of 30, 40 and 50 mph on a concrete surface. The unavailability of new Firestone T-200, 50% worn Goodyear Custom Cross Rib Hi-Miler, and 50% worn Hawkinson retreads in the numbers necessary for tractor-trailer testing caused some necessary modifications to the proposed matrix. For runs 12-17 the 50% worn Hawkinson retreads were replaced by new Hawkinson retreads. In addition, the tractor tires were new Goodyear Custom Cross Rib Hi-Milers rather than new Firestone T-200's. The substitution of new Hawkinson retreads in place of 50% worn Hawkinson retreads was also made for run 18. All other runs were made with the tire combinations originally proposed.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LF	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1	A-1
RF	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2	A-2
LFDO	A-3	D-1	D-11	D-21	F-1	F-11	F-21	B-1	B-11	I-1	I-11	F-1	F-1	F-1	F-1	F-1	F-1	D-11
LFDI	A-4	D-2	D-12	D-22	F-2	F-12	F-22	B-2	B-12	I-2	I-12	F-2	F-2	F-2	F-2	F-2	F-2	D-12
RFDO	A-5	D-3	D-13	D-23	F-3	F-13	F-23	B-3	B-13	I-3	I-13	F-3	F-3	F-3	F-3	F-3	F-3	D-13
RFDI	A-6	D-4	D-14	D-24	F-4	F-14	F-24	B-4	B-14	I-4	I-14	F-4	F-4	F-4	F-4	F-4	F-4	D-14
LRDO	A-7	D-5	D-15	D-25	F-5	F-15	F-25	B-5	B-15	I-5	I-15	F-5	F-5	F-5	F-5	F-5	F-5	D-15
LRDI	A-8	D-6	D-16	D-26	F-6	F-16	F-26	B-6	B-16	I-6	I-16	F-6	F-6	F-6	F-6	F-6	F-6	D-16
RRDO	A-9	D-7	D-17	D-27	F-7	F-17	F-27	B-7	B-17	I-7	I-17	F-7	F-7	F-7	F-7	F-7	F-7	D-17
RRDI	A-10	D-8	D-18	D-28	F-8	F-18	F-28	B-8	B-18	I-8	I-18	F-8	F-8	F-8	F-8	F-8	F-8	D-18
LFTO	G-1	G-1	G-1	G-1	G-1	G-1	G-1	G-1	G-1	G-1	G-1	I-11	G-1	I-11	G-1	G-1	G-1	I-11
LFTI	G-2	G-2	G-2	G-2	G-2	G-2	G-2	G-2	G-2	G-2	G-2	I-12	G-2	I-12	G-2	G-2	G-2	I-12
RFTO	G-3	G-3	G-3	G-3	G-3	G-3	G-3	G-3	G-3	G-3	G-3	G-3	I-13	I-13	G-3	G-3	G-3	I-13
RFTI	G-4	G-4	G-4	G-4	G-4	G-4	G-4	G-4	G-4	G-4	G-4	G-4	I-14	I-14	G-4	G-4	G-4	I-14
LRTO	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	G-5	I-11	G-5	I-11	I-15
LRTI	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	G-6	I-12	G-6	I-12	I-16
RRTO	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	G-7	I-13	I-13	I-17
RRTI	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	G-8	I-14	I-14	I-18

Table 4. The proposed tractor-trailer test matrix. Each of the eighteen tire tread combinations were to be run on both a concrete and asphalt surface at speeds from 30 mph to the maximum attainable speed in 10 mph increments. The body of the matrix contains the tire tread designs tested plus the degree of wear of each tire represented as letter and number combinations. The coding for the tread designs are as follows: A - General HCR; B - Firestone T-150; D - Goodyear Custom Cross Rib Hi-Miler; F - Firestone T-200; G - Rib Saw Tooth Retread; and I - Hawkinson Retread. The numbers associated with the tire tread code designate the state of wear as either new (1-10), 50% worn (11-20), or fully worn (21-30). For example, F-11 would be a 50% worn Firestone T-200 tire. The tire positions on the vehicles are also letter coded. The first letter represents either left or right, the second front or rear, the third driver or trailer, and the fourth inside or outside. Thus, LFDO would represent the left forward driver outside.

3. Scheduled Work for Next Period

Since unfavorable weather conditions have caused a suspension of field testing until next Spring, the major program emphasis is shifted from data acquisition to data reduction and analysis. Immediate priorities include: (1) conversion of analog data recorded during field testing into digital form acceptable to the NBS Univac 1108; (2) preparation of tables and graphs illustrating A-weighted sound levels for all test conditions; and (3) development of computer programs for evaluating the directional characteristics of truck tire generated noise.

Once the data have been digitized, appropriate correction factors must be applied in each one-third octave band to account for (1) variations in atmospheric pressure, (2) the directivity of microphones and protection grids, and (3) the presence of a windscreen over the microphone during measurements.

Pistonphones utilized for the system calibration produce a nominal 124 dB re 20 $\mu N/m^2$ at a frequency of 250 Hz. Each pistonphone was individually calibrated (the exact value of calibration can deviate a few tenth of dB from the nominal) and certified by Brüel and Kjaer. The certified calibration was performed at standard atmospheric pressure. When ambient pressures occur during field measurements which are other than standard atmospheric pressure, correction factors must be applied.

The microphone (cartridge plus protecting grid) used during field measurements are essentially omnidirectional at frequencies below 1 kHz. At frequencies above 1 kHz the directional characteristics of the microphone must be considered and appropriate free-field corrections applied to account for diffraction of the sound waves by the microphone. In addition, correction factors must be applied to account for the pertibations due to the presence of the windscreen.

Although the major effort next period will be concentrated on obtaining the peak A-weighted sound levels, work will continue on the computer programs necessary for the generation of equal sound level contour plots showing the directionality of truck tire generated noise.

The goal is to generate these plots for a given speed and vehicle position. Since the truck was decelerating as it coasted through the test section with its engine shut off, all data must be adjusted to obtain the sound levels which would be measured if the truck speed had been constant during testing. Once all corrections have been made, a matrix of data will be available for further analysis. Interpolation, curve-fitting, and graphical display programs will be developed to convert the data matrix into equal sound level contour plots.

In addition to field testing, some laboratory studies will be conducted. Actual truck tires which were utilized during road testing at Wallops Station will be run on the 17.6 foot circumference steel endurance wheel at NBS. The results from the in-door laboratory testing will be compared with the results of the road test phase to determine the correlation, if any, existing between the two test procedures.

The operational machinery for the wheel (i.e., D.C. motor, V-belt drives, centrifugal air blower, etc.) is quite noisy. Measurements were made and an evaluation has been completed as to the effort necessary to quiet the associated machinery to a level whereby the truck tire noise measurements will be meaningful. As soon as recommended modifications can be made and evaluated, in-door testing will begin.

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