NATIONAL BUREAU OF STANDARDS REPORT

10 567

INTERIM PROGRESS REPORT OF RESEARCH ACTIVITY
TRUCK TIRE NOISE INVESTIGATION

Office of Vehicle Systems Research

and

Sensory Environment Branch
Building Research Division

Prepared for

Office of Noise Abatement
Department of Transportation
Washington, D. C. 20590

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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INTERIM PROGRESS REPORT OF RESEARCH ACTIVITY
TRUCK TIRE NOISE INVESTIGATION

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IMPORTANT NOTICE

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ABSTRACT

This interim report presents an inventory or "catalog" of peak A-weighted sound levels measured during an extensive parametric study conducted to characterize the noise generated by typical rib, cross-bar, and retread type truck tires. A test sample of nine tread designs, estimated to represent 70-80% (these exact designs) of the truck tire population on the road today, was investigated considering the following variables: wear, loading, speed, pavement surface, and tire location. Test vehicles included both single-chassis vehicles and a tractor-trailer.

The results show that the A-weighted sound level increases with either an increase in load or speed. The pocket retread design always produced the highest level followed by the cross-bar tires and then the rib tires. This ranking held for both new and half-worn tires. The influence of wear and pavement surface is more complex. Depending on the specific tread design the noise levels either increased or decreased with increasing wear. For all of the tread designs except one there was an increase in noise level between the new and the half-worn states. No apparent trend exists between the half-worn and fully-worn condition. The results for different pavement surfaces are much the same as with wear. The generated noise appears to depend on both the specific tread design and the surface roughness. Individual tires do contribute differently to the overall level depending on their location on the vehicle. In some cases, significant reductions in the noise level are possible by mounting "noisy" tires inboard of "quieter" tires.

The report includes a discussion of the measurement and analysis techniques utilized for the establishment of this data base.

1. Introduction

Vehicular traffic noise continues to be a major source of complaint, especially near high-speed highways. Of all vehicles on the road today, many consider trucks to be the major offender. Engine operating noise, exhaust noise, brake noise, and tire noise each contribute to the overall noise level produced by trucks (see Figure 1); however, at speeds of 50 mph and greater, which are quite prevalent on today's interstate highways, the noise from tires predominate provided the truck has a reasonably good exhaust muffler and is in a good state of repair. Users and manufacturers of truck tires, state lawmakers and enforcement agencies, and urban planners have been hampered in their efforts by the lack of an information base of tire noise data available in the public domain.

For this reason, the National Bureau of Standards, under the sponsorship of the Office of Noise Abatement, Department of Transportation, is conducting an 18-month research program 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.

The data base has been obtained through an extensive field study which investigated the influence of the following parameters: tread design, tread depth (wear), type of pavement surface, vehicle speed, loading, and tire location. The data base is comprised of three types of analysis -- (1) peak A-weighted sound levels, (2) 1/3-octave spectral data, and (3) directionality information in the form of equal sound level contour plots.

The inventory of truck tire noise levels will supplement the existing data on total vehicle noise. This information, in conjunction with that developed concerning testing procedures, can serve as a basis for meaningful vehicle noise regulations. The spectral and directionality data will provide the groundwork for understanding the generation mechanisms by which tires produce noise and thus will provide the scientific basis for the design of quieter tires. In addition, this information is vital to the urban planner in the prediction of noise levels in nearby communities at various distances from present and proposed highways. The highway designer also can utilize this information as the basis for optimum location of roadways and for the proper design of roadside barriers to lower overall community noise levels.

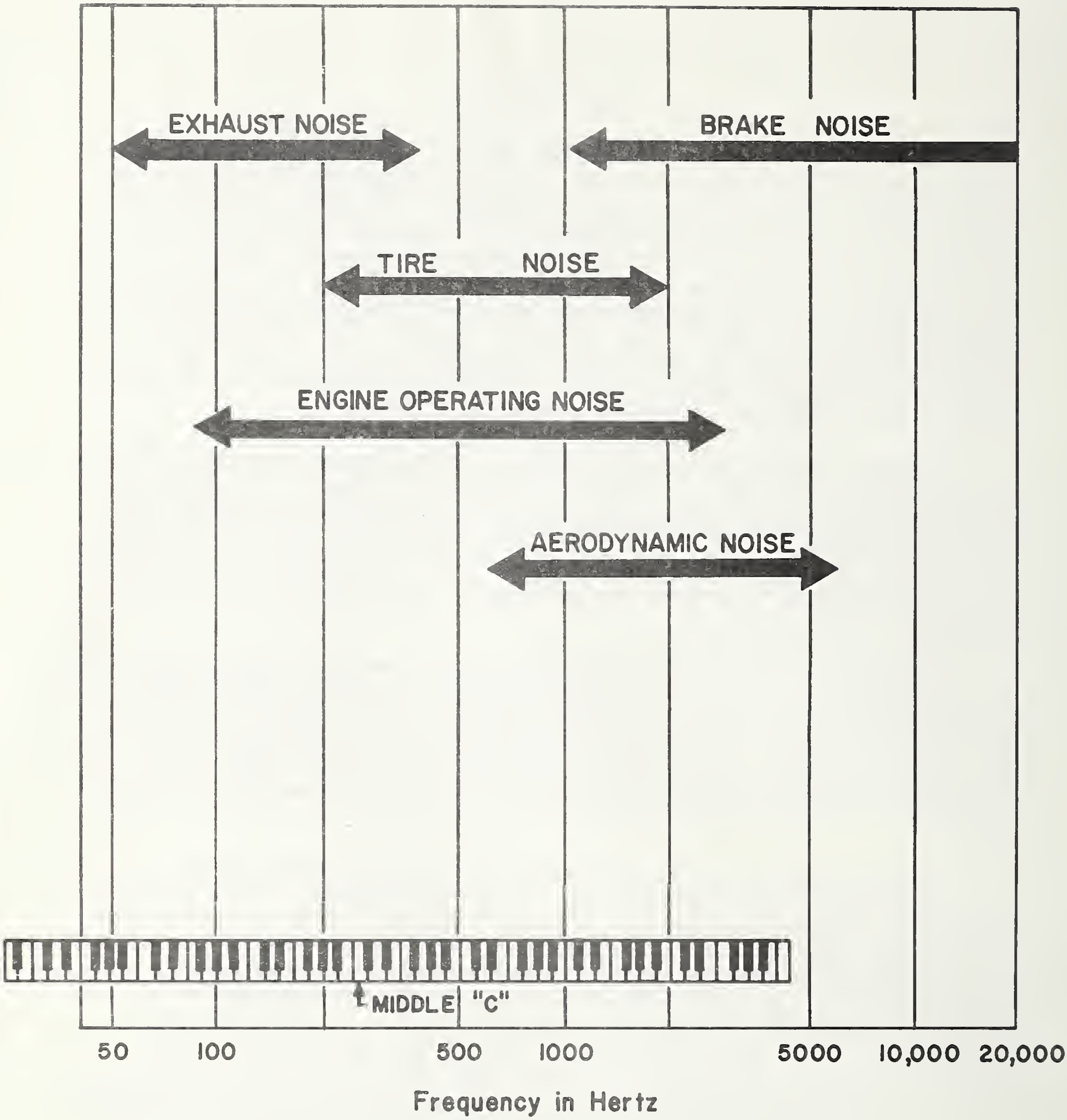


Figure 1. A diagram indicating the range of common truck noise sources in terms of frequency (hertz) and musical pitch. These are the frequency ranges in which one would expect most of the sound energy for sideline measurements taken 50 to 100 feet from the source. The relative intensity of the noise sources is not implied by their relative location on the graph[1].1/

1/ Figures in brackets indicate the literature references at the end of this report.

This interim report presents the initial catalog of peak A-weighted sound levels as measured during the extensive field investigation. The measurements were made utilizing an array of six microphones at a height of 48 inches above the roadway surface and spaced between 6 and 130 feet from the centerline of the truck lane. The results are presented in both tabular and graphical form as well as in the form of cross-plots showing general trends.

Much additional analysis is necessary before any conclusions can be drawn as to the influence of surface roughness, the effect of tread spacing, the directionality of truck tire generated noise, the variation of sound level with time, and the frequency spectra of tire noise. Future reports will provide information in these areas.

1.1. Summary of Existing Data Base

As discussed in the introduction, at moderate to high speeds tire noise is predominant. Past studies indicate tire noise is primarily produced by the tire coming in contact with the road surface, interacting with it, and then leaving it. The tire tread is designed to provide a high degree of stability and road holding, particularly on wet roads, and this necessarily means that under certain conditions energy will be dissipated as noise. As a tire runs straight ahead on a relatively smooth surface, any regularity in the tread pattern causes the generation of discrete tonal noise associated with the compression and release of the air trapped in the grooves as the tread makes and breaks contact with the surface. Most of the available data in the public domain relate to the discussion of the generation modes and abatement procedures of "tread pattern noise". A solution which is widely utilized by automobile tire manufacturers is the introduction of some degree of randomness in the tread element spacing. This spreads the sound energy over the entire spectrum and tends to lower or eliminate annoying tonal peaks. Random tread spacing is not as prevalent with truck tires.

An automobile or truck when cornering may generate a "squeal" due to slip, or road/tread surface friction interaction. To prevent the independent vibration of the tread elements, irregular tread patterns and other fixes are utilized. Softer tread material also helps this problem since it tends to produce sounds having a lower frequency which are less annoying.

"Rumble" or "thump" is another typical tire sound which is caused by slight imperfections or discontinuities around the circumference of the tire. Aside from making more nearly perfect tires, the solution must lie in the elimination or reduction of the disturbance as it is transmitted through the suspension and structural system. Unlike squeal and whine, thump is transmitted through the chassis (structure-borne) rather than through the air. Thump is characterized by cyclic vibrations whose period equals that of the revolutions of the tire itself.

Another noise produced is caused by the flow of air over the tires. It is felt that this is only a minor contributor to the overall tire noise when compared with the other sources.

There are numerous parameters which are believed to contribute to tire noise levels. At this point it must be stressed that the following discussion of principal influencing parameters and the conclusions drawn are based on the results of limited exploratory testing. There is a great possibility that the parameters listed do not completely cover all factors contributing to tire noise; however, at this early stage of experimentation no definite assertions can be made.

As stated previously, the tread design is the primary factor in the production of tire noise and contributes greatly to the frequency of the noise emitted from tires. Cross-bar tires and certain retreads have been found to be much noisier than rib type tires. Although rib patterns are known to generate a comparatively lower noise level, many feel that they are inferior in durability and driving characteristics to the lug pattern. These same people imply by their comments that noisy tires are necessary to provide safety.

The influence of the road surface on truck tire noise has been questioned by some observers. They feel that since truck tires usually have a coarser tread than do passenger car tires, truck tire noise would be expected to be independent of the nature of the road surface. Results from past studies, however, indicate that there is a relationship between pavement roughness and tire noise. For instance, a half-worn cross-bar tire appears quieter on a smooth surface than on a medium or rough surface, while the opposite is true for certain retread tires. For these retreads, the "pockets" seal better on a smooth surface than on a rougher surface.

Wear is an additional influencing factor. Worn tires are usually noisier than new tires. This is especially true with cross-bar tires. Some investigators have suggested that the curvature across the width of the tire may be the significant factor where wear is concerned. The reason the curvature is so important on the cross-bar tires is that this determines how much load is carried on the outer sections of the tread where the major discontinuities in tread pattern exist. Since the tread pattern on a rib tire is essentially the same across the width of the tires, the curvature is not nearly as influential.

There are fluctuations in the noise level from truck tires associated with variations of the loading. Recent studies have shown as much as a 15 dB(A) difference in the noise produced by a "pocket" type retread between the no-load and fully loaded condition. Load compresses the tire and allows for a more perfect sealing of air in the pockets. Cross-bar tires also exhibit a tendency for the noise to increase with load. Load appears to act in a similar manner to wear in that the increased load flattens the contour of the tire and places more loading on the outer edges of the tread. Rib tires are less influenced by a variation in loading, the only effect being an increase of the contact area.

Speed also affects the level of tire noise. There appears to be a direct correlation between the speed of a vehicle and the noise emanating from the tires; however, there are considerable differences in the trends for individual tires.

These five parameters -- tread design, road surface, wear, speed, and load -- appear to affect most greatly the overall noise level. However, other parameters also can have an influence. Secondary parameters with possible influence include inflation pressure and carcass design. Increasing the inflation pressure increases the noise slightly, apparently as a result of an increase in vibrational frequencies. As the number of plys in the tire increases, there is a slight decrease in the noise, i.e., a six ply tire will produce more noise than an eight ply tire. This is apparently due to lower hysteresis losses in the tire as a result of the lower rubber content, and consequently the high frequency road-induced vibrations are damped by them to a lesser extent[2]. Tread rubber composition and reinforcing fabric material appear to have little influence on noise level produced. One study[3] of the effect of various tire constructions on the noise level revealed remarkable constancy of the noise spectrum with respect to changes in the fiber material of the tire-reinforcing fabric and tread rubber composition for a given set of operating conditions. Nylon appears to be slightly noisier than rayon, and the damping characteristics of the cord seem to play some part in the noise and vibration output of the tires.

The references [7-41] included at the end of this report include numerous papers and articles which discuss the truck tire noise problem in extreme generalities. Although only a small amount of data is available in the public domain, tire noise is indeed a very real problem and much work is necessary before tire manufacturers and the buying public can be given the information necessary for the design and purchase of quieter tires, thus assuring a measure of environmental quality improvement.

Serendipity, Inc., in a quarterly report of a <u>Study of the Magnitude of Transportation Noise Generation and Potential Abatement</u>[4] prepared for the Department of Transportation, state: "The entire area of tire noise and its potential abatement is clouded by the extreme lack of data which describe the generated noise."

J. H. Venema[5] of the Ford Motor Company reinforces this by the following words, "For the immediate task, we need to agree upon and define the objectives, and standardize test methods and acceptance criteria." He further states, "Because of the directivity of the sound pattern from a vehicle, the intensity of sound depends not only on the proximity but also on the position of the observer with respect to the vehicle. Maximum noise is not usually experienced when the vehicle is closest to the observer, but somewhat after it passes."

Finally, Lewis J. Kibbee[6], director of the Engineering Department of the American Trucking Association, Inc., recommends, "Tire manufacturers must devote a great deal more effort to the control of truck tire noise by designing quietness into truck tires in the same manner that has been done in passenger car tires."

A careful review of the presently available information and the above comments provide the basis for the following conclusions:

a. There is a definite lack of data in the public domain on the characteristics of noise generated by truck tires. A "catalog" or data inventory on the noises generated by typical rib, cross-bar, and retread tires utilized today by the trucking industry is a necessity. These data would provide law enforcement agencies and lawmakers with the information which they need to draft and enforce meaningful noise ordinances. In the past, due to the inexperience of the lawmakers in the control of noise, the laws were vague and indefinite. It is extremely difficult to issue citations on the terms "excessive", "unusual", or "unnecessary" noise. The present California law, which may prove to be a model one, is handicapped by the fact that no information is available to enable enforcement of a vehicle noise limitation when tires are the culprit. If tire whine is heard by the state trooper, no citation is given. A data base is needed to supply state and local officials with the information they need for the full enforcement of their laws.

b. Three types of analysis should be made at a minimum. Peak A-weighted sound levels must be measured so that correlation can be made with past as well as future studies -- especially since A-weighted sound level is emerging as the criterion most often utilized in objective and subjective studies. In addition, frequency analysis (octave, one-third octave, or finer) is necessary since it is only through this type of analysis that an understanding of the generation mechanisms by which tires produce their noise can be obtained. Finally, directionality information is needed so that sound propagation characteristics of truck tire noise can be identified. The prediction of noise levels in nearby communities depends heavily on the directional characteristics of the noises produced.

c. In addition to the data obtained to date, more research will be necessary to fully define the generation modes. Such items as tire structure, materials, stress relationships, tread and sidewall patterns and other design factors must be considered if the entire problem is to be understood and effective solutions implemented.

Once this information becomes available, it appears that a satisfactory model could be developed to enable prediction of noise generation characteristics from the tread design and other information concerning the tire's construction. The basis would then be established to enable the design of quieter tires -- the eventual goal.

2. Field Test Program (Data Acquisition)

The definite lack of data in the public domain on the noise generation characteristics of truck tires necessitated the development and conduct of an extensive field investigation to obtain the information needed for the establishment of a physical data base on the noise generated by typical tires utilized today by the trucking industry. Before actual road testing could be initiated, the following program accomplishments were necessary: (1) the selection of a suitable road test site which provided a choice of pavement surfaces and a flat terrain, (2) the selection of a sample of tire tread designs which represented a cross-section of typical over-the-road tires, (3) the gaining of an understanding of the standard operating procedures concerning the handling, e.g., break-in and warmup, of truck tires, (4) the specification of single-chassis and tractor-trailer combination test vehicles, (5) the development of a test procedure, and (6) the definition of the instrumentation needs and the assembly of a field test unit (both manpower and equipment). A discussion of the details associated with the establishment of an appropriate and effective field test program follows.

2.1. Field Test Site

The research runway at the Wallops Island, Virginia, facility of the National Aeronautics and Space Administration was chosen as the test site for the road testing phase of the program. This location provided an adequate stretch of pavement (8750 feet), several different types of pavement surfaces, and a flat terrain providing a well-defined reflecting surface without any unusual reflection and attenuation effects. An agreement was reached with NASA for utilization of this facility for the data acquisition phase of the program.

On the 8750 foot length of research runway 4-22 (bearing 040° and 220°), two 1000 foot test sections were established. One test area was designated as the concrete test section while the other was the asphalt test section. The nominal runway width was 150 feet with a center section (50 foot wide located at the center of the runway) of specially constructed substrates including some grooved sections. Although no lanes, such as one thinks of as being present on highways, were marked on the runway, the concrete on either side of the special pavement area was laid in sections 12 feet wide and 20 feet long. For this test program, the truck ran in one of these 12 foot lanes. Due to the deteriorated condition of the pavement surface near the edge of the runway, the truck ran one lane in from the edge. On the asphalt surface a lane was marked which corresponded to the location of the concrete lane. Figure 2 shows an overall view of the research runway with the locations of both test sections noted. Appendix D contains a detailed discussion of the composition of each test section.

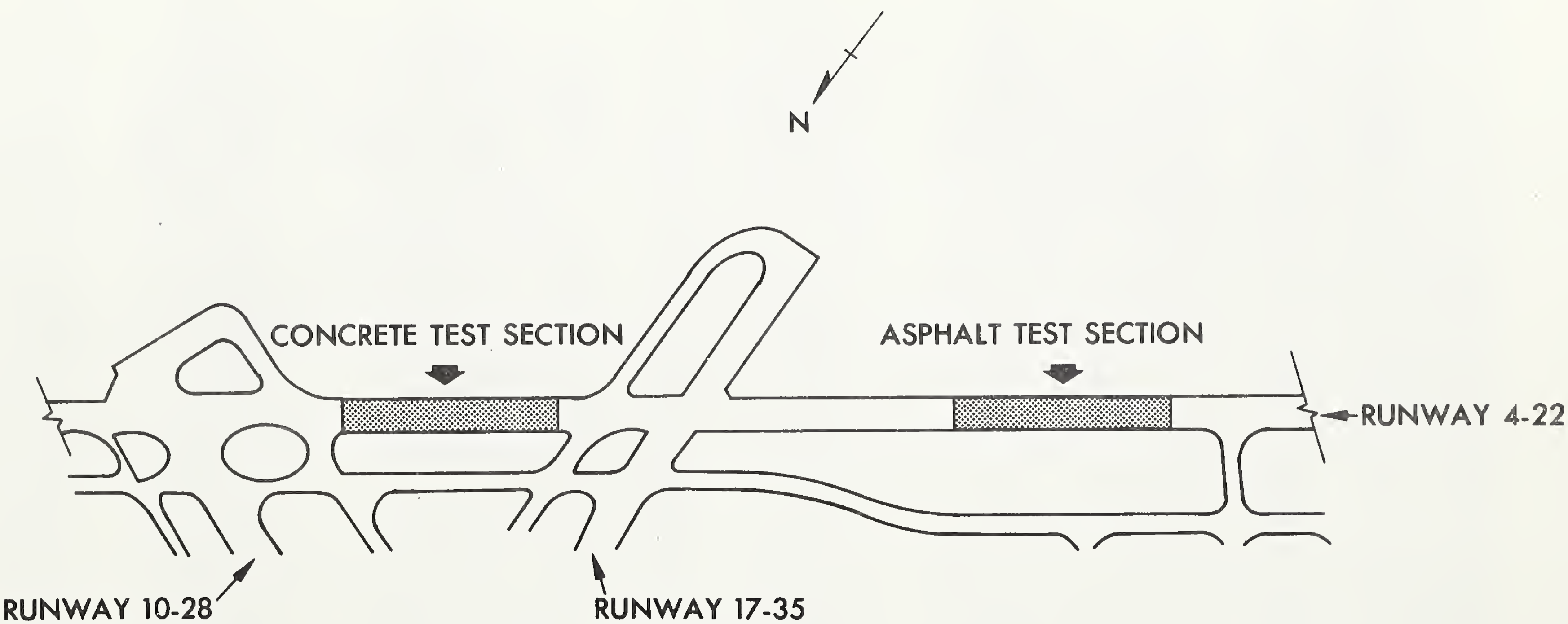


Figure 2. Plan of research runway 4-22 Wallops Station, Virginia, showing the locations of the concrete and asphalt test sections.

The concrete test section began 2650 feet from the northeast end of runway 4-22 and extended to 3650 feet. It consisted of a substrate of reinforced, air-entrained Portland Cement concrete with two types of finishes. They were "C" finish or smooth concrete and "D" finish or textured concrete. The only difference between the two surface finishes was the method of final finishing. To the untrained eye, there appears to be no difference between the two sections. The "C" finish section of pavement was smoothed with a belt of canvas composition while the "D" finish section utilized a finishing belt of burlap. Figure 3 is a detailed layout of the concrete test area while Figure 4 shows the actual surface in the smooth concrete section. Three grooved pavement sections existed on this portion of the runway. One grooved section extended 75 feet into the test area but did not interfere with the line-of-sight from the truck to the microphone array. However, the other grooved sections (grooved smooth concrete and grooved textured concrete) did lie between the truck and a portion of the microphone array.

The asphalt test section began 5700 feet from the northeast end of runway 4-22 and extended to 6700 feet. It consisted of a substrate of "B" surface coarse bituminous concrete -- also referred to as "textured asphalt". Reference to Figure 5 shows that the test section was a continuous surface of textured asphalt with the exception of a grooved textured asphalt section 150 feet long and 50 feet wide along the centerline of the runway. Only a small corner of this grooved section was in the line of sight path from the test vehicle to the microphone array. Figure 6 shows the texture of the asphalt test section.

The effect of the grooves on reflection of sound has not been established at this time; however, the width and spacing of the grooves (1/4 inch and 1 inch respectively) appears to be such that only high frequencies would be affected. It is felt that the grooves would have little or no effect at those frequencies (200-2000 Hz) where most of the tire noise is concentrated. More research will be conducted in this area and results will be presented in future reports.

2.2. Test Tires

Truck tires are characterized by their tread design, structure, and material composition. The noise generation characteristics of truck tires are probably influenced by the rubber formulation, carcass design, number of plys, and other fabrication considerations; however, the limited data available in the public domain indicate that the tread design is most likely the principal factor influencing tire-generated noise.

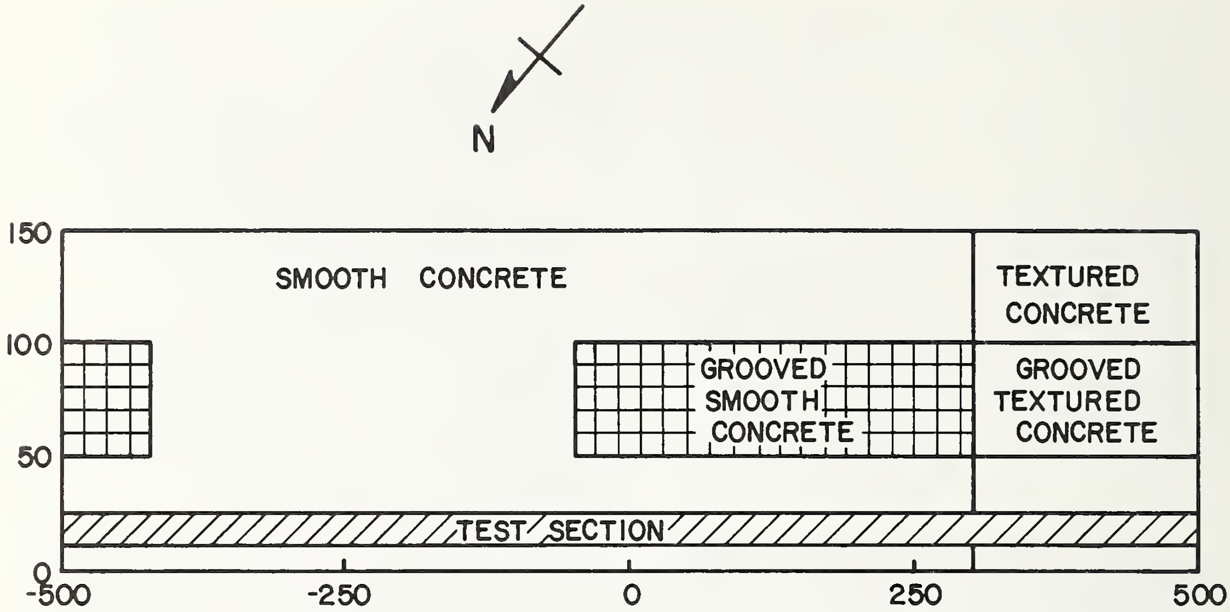


Figure 3. Plan of concrete test area on runway 4-22. Distances are in feet.

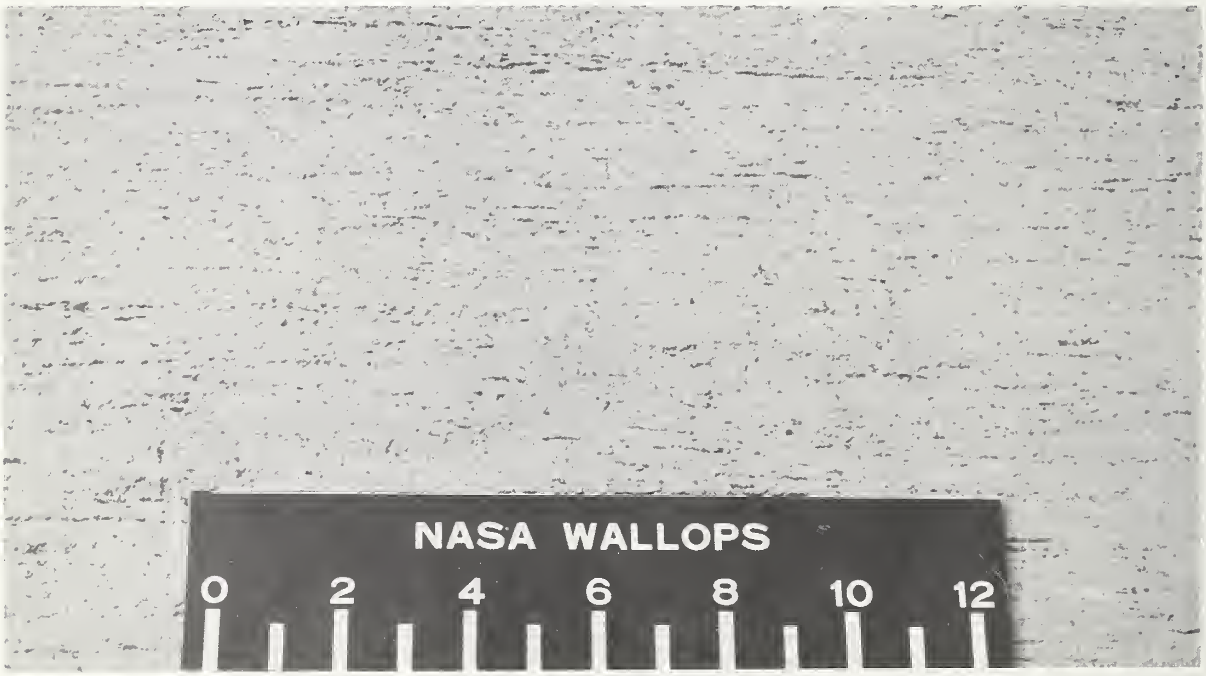


Figure 4. Smooth concrete surface on runway 4-22. Scale is in inches.

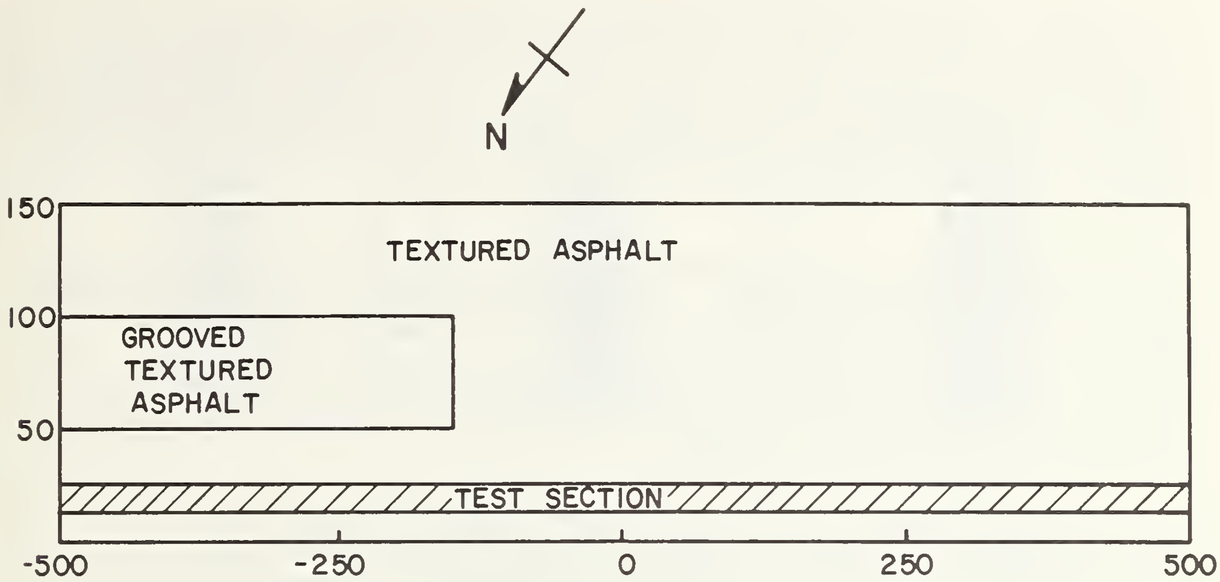


Figure 5. Plan of asphalt test area on runway 4-22. Distances are in feet.

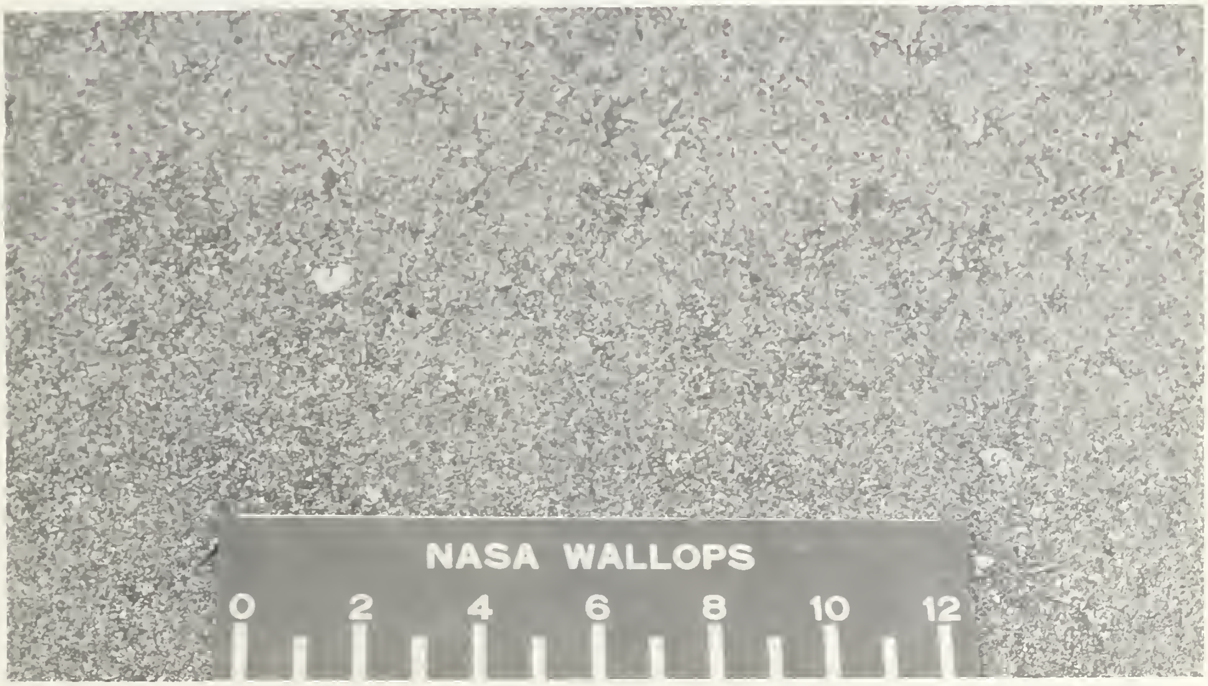


Figure 6. Textured asphalt surface on runway 4-22. Scale is in inches.

Tread design if simply the division of a smooth tread into smaller elements. The elements are usually arranged in repetitive patterns of ribs (circumferential) and cross-bars (lateral). The spaces between the raised tread elements are referred to as grooves or sipes. The tread elements are usually arranged within the pattern to give the tread design directional tractive characteristics as well as a specific ratio of net-to-gross contact area.

Tread patterns can be categorized into three basic types -- rib, cross-bar, and special service. Special service tires typically possess deep, open designs and are used in off-the-road operations or where unusual mud or snow conditions occur. For this study the interest was in typical over-the-road tires; therefore, special service treads were not included. Rib and cross-bar patterns are typical for both original tires and for retreads.

Although hundreds of tread patterns exist for truck tires, this study attempted to select a relatively small sample which would be representative of a large percentage of today's tire population.

The economic operation of a large fleet of trucks is dependent upon the selection of tires having performance properties and endurance characteristics matched to the intended service condition so that maximum tire mileage and lowest cost per tire mile will be ensured.

Discussions with fleet operators provided an opportunity to gain and apply their knowledge gained through years of operating experience toward the proper selection of tire types representing a cross-section of tires utilized by over-the-road trucks.

a. Tire Selection

For this study a total of nine tread designs was chosen -- three rib, three cross-bar and three retread patterns. The retread designs included a rib type, a cross-bar type, and a "pocket design" which was neither rib or cross-bar in nature. In our estimation, these exact tread designs represented 70-80% of the total truck tire population in use on the road today.

A detailed discussion of the selected test tires follows with the tread patterns shown in Figure 7. The footprints show the tread element patterns of the nine test tires in a new state under dynamic conditions with a loading of 4430 pounds on the tire.

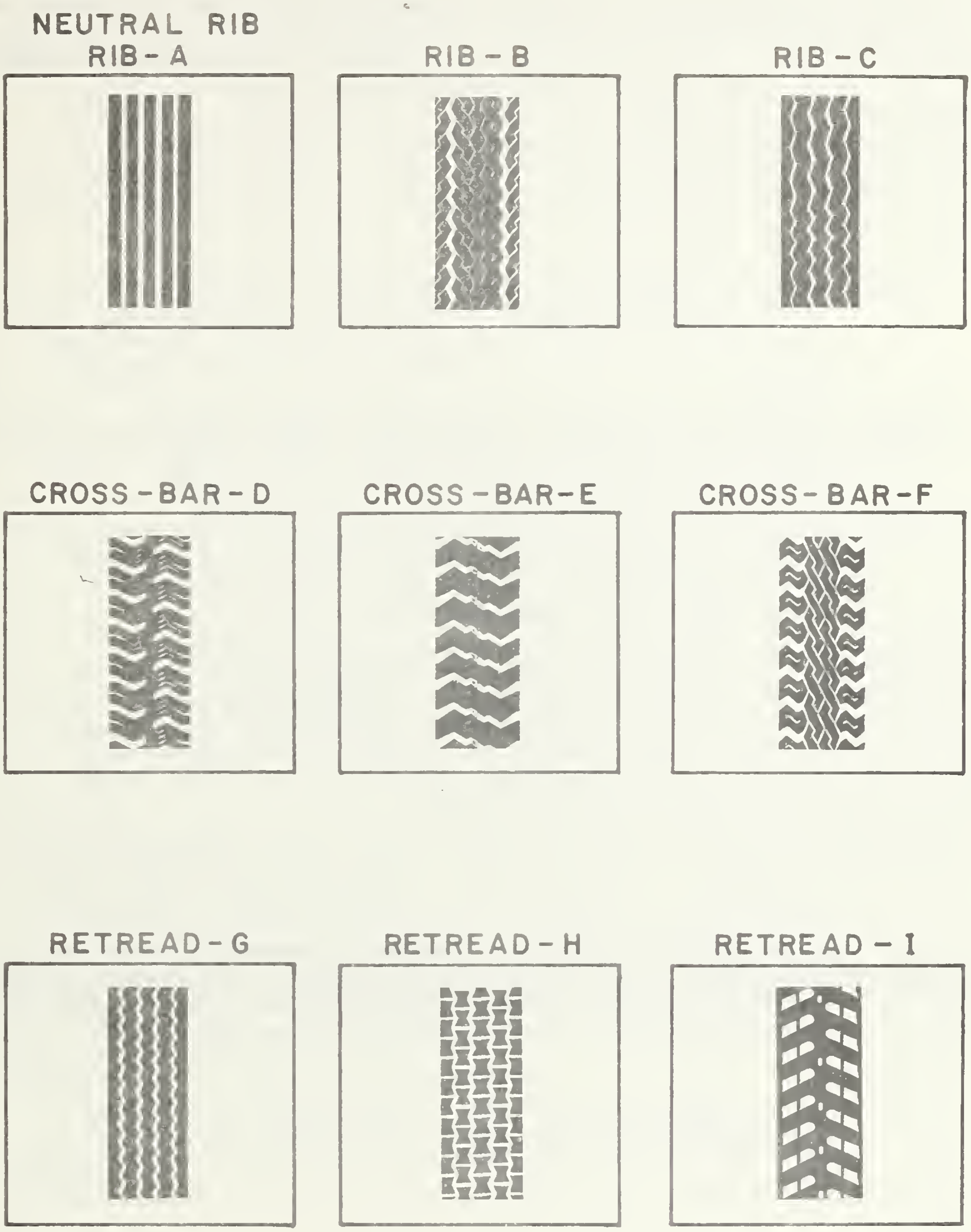


Figure 7. Test tire tread designs. These exact tread patterns represent 70-80% of the total truck tire population in use on the road today.

Rib designs are the most common type and possess characteristics that provide overall service for all wheel positions. With the major tread elements oriented in the circumferential direction, these tires are noted for their lateral traction and uniform wear characteristics. Sipes are usually added to the basic rib pattern to provide greater traction on wet surfaces. Although they can be used on all axle positions, rib tires typically are seen on steering and trailer axles. The three rib tread patterns selected included a neutral rib, an inexpensive rib, and a premium rib:

Rib-A. This neutral rib pattern is similar to the SAE or ASTM[42] test tire and has circumferential tread only. It was felt that due to the total absence of any sipes or cross-bars this tire would provide a lower bound on truck tire noise levels.

Rib-B. This premium tire has ribbed, multi-siped, rounded shoulders. This tire represents a type often found on over-the-road semi-trailer applications.

Rib-C. This is a ribbed pattern with a limited number of sipes and rounded shoulders with no sipes. It is a lower priced tire typically used for urban and suburban applications, e.g., delivery and dump trucks.

Cross-bar tires, with the major tread elements oriented in the lateral direction, are used primarily on the drive axles. This design gives maximum driving traction and provides a much more rigid tread structure plus added original design tread depth. The deeper tread design gives these tires much improved wear characteristics. Three highway usage cross-bar tires were selected:

Cross-Bar D and F. These two exact tread designs represent over 85% of the cross-bar tires on the road today. Both have circumferential tread face centers (central rib) for lateral traction with shoulders of laterally aligned bars with sipes for added traction. These two tires are similar in overall design with variations of ribs, sipes, and cross-bars depending on manufacturer preference.

Cross-Bar E. To cover the urban-suburban on and off road category, e.g., dump trucks, this pattern was chosen. It also has a circumferential tread center with lateral bars in the shoulder area but with little siping present in the heavy bar areas.

Retreads may possess tread patterns which are either rib or cross-bar in nature. In addition, retreads exist with a "pocket design" which is neither rib type nor cross-bar type. Retread tires chosen for test purposes represented each type:

Retread-G. This rib type retread has a simple zig-zag or saw-tooth tread pattern with few sipes. It is a relatively inexpensive retread.

Retread-H. A bow-tie or hour-glass tread design was chosen as representative of a cross-bar type. This also is an economical retread designed to provide both forward and lateral traction. There are no closed areas or pockets on the tread face.

Retread-I. A full traction retread with a pocket design was chosen to provide an upper bound on truck tire noise levels. The tread pattern is not a design used by major tire manufacturers but represents the work of independent retread companies. For this reason, many varieties exist and the tire is known to different people under different titles. The design utilized during this investigation was a directional (should be mounted one way for most efficient operation), full-traction tire having slanted cups or pockets, with a bar across the center of the pocket, and a shoulder rib. This design traps air in the pockets as it seals against the road surface and releases the entrapped air when the pocket unseals -- resulting in the generation of a noise which has led truckers to refer to this design as "Singing Sam".

b. Tire Preparation and Break-In

In accordance with standard operating procedure the tires utilized during this test program were not balanced.

Unlike the normal practice with automobile tires, only front (steering) tires are ever balanced on trucks. When new tires are installed on a vehicle, balancing is not performed unless there is a definite handling problem or severe vibration reported which might jeopardize the safety of the vehicle. When such a problem arises, the entire front end assembly, not just the tires, is checked.

A majority of tires loaned to the project had previously been in over-the-road service and had not presented any handling or vibration problem.

A tire was not considered acceptable as a test specimen for the truck tire noise investigation until it had undergone a break-in period of 100-200 miles under actual driving conditions. The break-in procedure is necessary to ensure the removal of all mold marks and manufacturing irregularities.

All of the tires utilized during this test program, with the exception of the neutral rib (rib-A), were loaned to the project by two motor freight companies through an agreement with the American Trucking Associations. The rib and cross-bar tires supplied were in over-the-road service prior to their use in this program and therefore were considered to be fully broken in. Only the new retread tires and the neutral rib tires had never been in service before.

The neutral rib tires, purchased for the project, were mounted on one of the test vehicles and driven from Washington, D.C., to the Wallops Island field test site, a distance of approximately 185 miles.

When new retread tires were received, all protruding rubber was trimmed off, the tires were mounted on a test vehicle, and were run for 100-200 miles at the test site.

c. Tire Warmup

Throughout this investigation a warm-up procedure was followed immediately prior to the actual testing of a given set of tires. This was done to eliminate the periodic vibrations caused by flatspots typically present on cold tires. Flat spotting is a phenomena caused by a thermal shrinkage property common to some fabric-cord materials. The cord material shortens slightly when hot and as the loaded tire cools while stationary, the cords temporarily "set" at the shorter length in the road-contact area (flatspot) and do not equalize until their temperature has again been raised.

The normal procedure required a minimum of five round trips over the length of the research runway at the field test site (a total of approximately 10 miles). If the driver could sense any "thumping" or heavy vibration, as could be expected if the tires were cold, he then would continue the procedure until he felt that the vibration had been eliminated.

d. Tire Characteristic Measurements

Two measurements were made for each test tire -- tread depth and Shore hardness. The resulting data are tabulated in Appendix A.

Tread depth measurements were taken at four equally spaced locations around the tire circumference. The device utilized for this measurement was simply a depth gage with 1/32 inch graduations. The operator located the depth gage over a major groove (not over sipes or other small grooves), depressed the probe into the groove, and noted the tread depth directly from the instrument.

The Shore hardness of the tread rubber was determined by ASTM test method D-2240-68[43]. A type A durometer (for soft materials) was utilized in the following manner: the durometer was held in a vertical position with the point of the indentor at the center of the tread face. The presser foot was applied to the specimen as rapidly as possible without shock, keeping the foot parallel to the specimen surface. The scale was read five seconds after the presser foot was in firm contact with the specimen. The reported values represent the average for readings taken at approximately the same four locations as the tread depth measurements.

2.3. Test Vehicles

Two types of vehicles were utilized throughout this test program -- a single-chassis vehicle and a tractor-trailer combination vehicle. The test tires were always mounted on the drive axles, or in the case of the tractor-trailer, on both the drive and trailer axles. Neutral rib tires (quiet tires having only a circumferential tread pattern) were always mounted on the steering axle of both types of test vehicles.

For single vehicle testing, two International[2/] Model #1890 chassis equipped with 20 foot stake bodies were rented from Ryder Truck Rental, Inc., Baltimore, Maryland. These vehicles were equipped with 9,000 pound front axles, V-345 gasoline engines, 13-inch clutch, 5-speed transmission, 2-speed 23,000 pound rear axle, heavy duty springs, heavy-duty brakes, West Coast mirrors, and 11.00 x 22.5 tires. These vehicles had a gross weight capacity of 32,000 pounds. Figure 8 gives an overall view of one of the single-chassis test trucks.

[2/] The commercial vehicles utilized are identified in this report in order to adequately describe the vehicles on which the test tires were mounted throughout this program. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that these vehicles were necessarily the best available for the purpose.

Figure 8. An International Model #1890 chassis equipped with a 20-foot stake body served as the single-chassis test vehicle.

One truck was operated in the unloaded condition, while the other carried 15,000 pounds of load. Figure 9 shows the loading arrangement. Thirty 500 pound weights were distributed to develop maximum loading on all tires. Both the loaded and unloaded single-chassis test vehicles were weighed at a scale in the State of Virginia near the Wallops Station test site resulting in the following weight breakdown:

Truck #1 (loaded)

front axle	7,920 pounds	(3,960 pounds/tire)
rear axle	17,720 pounds	(4,430 pounds/tire)
gross vehicle weight	25,640 pounds	

Truck #2 (unloaded)

front axle	4,680 pounds	(2,340 pounds/tire)
rear axle	6,120 pounds	(1,530 pounds/tire)
gross vehicle weight	10,800 pounds	

Tires on the loaded test vehicle were inflated to an air pressure of 70 pounds per square inch as specified by the Tire and Rim Association recommendations for the above loading conditions. The tires on the unloaded vehicle also were inflated to 70 pounds per square inch even though the loading was significantly less. This follows standard operating procedure since the driver of an unloaded truck returning to a freight depot would not lower the air pressure in his tires simply because he had no load.

For the tractor-trailer phase of the program 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 test purposes. 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 11.00 x 22.5 tires. The trailer (rented from Ryder Truck Rental, Inc.) was a 40 foot Fruehauf tandem flat-bed trailer that also utilized 11.00 x 22.5 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 loaded vehicle is shown in Figure 10. The resulting weight distribution was as follows:

front axle	9,240 pounds	(4,620 pounds/tire)
drive axles	29,000 pounds	(3,625 pounds/tire)
trailer axles	26,840 pounds	(3,355 pounds/tire)
gross vehicle weight	65,080 pounds	

Following Tire and Rim Association recommendations, the tractor-trailer tires were all inflated to an air pressure of 50 pounds per square inch.

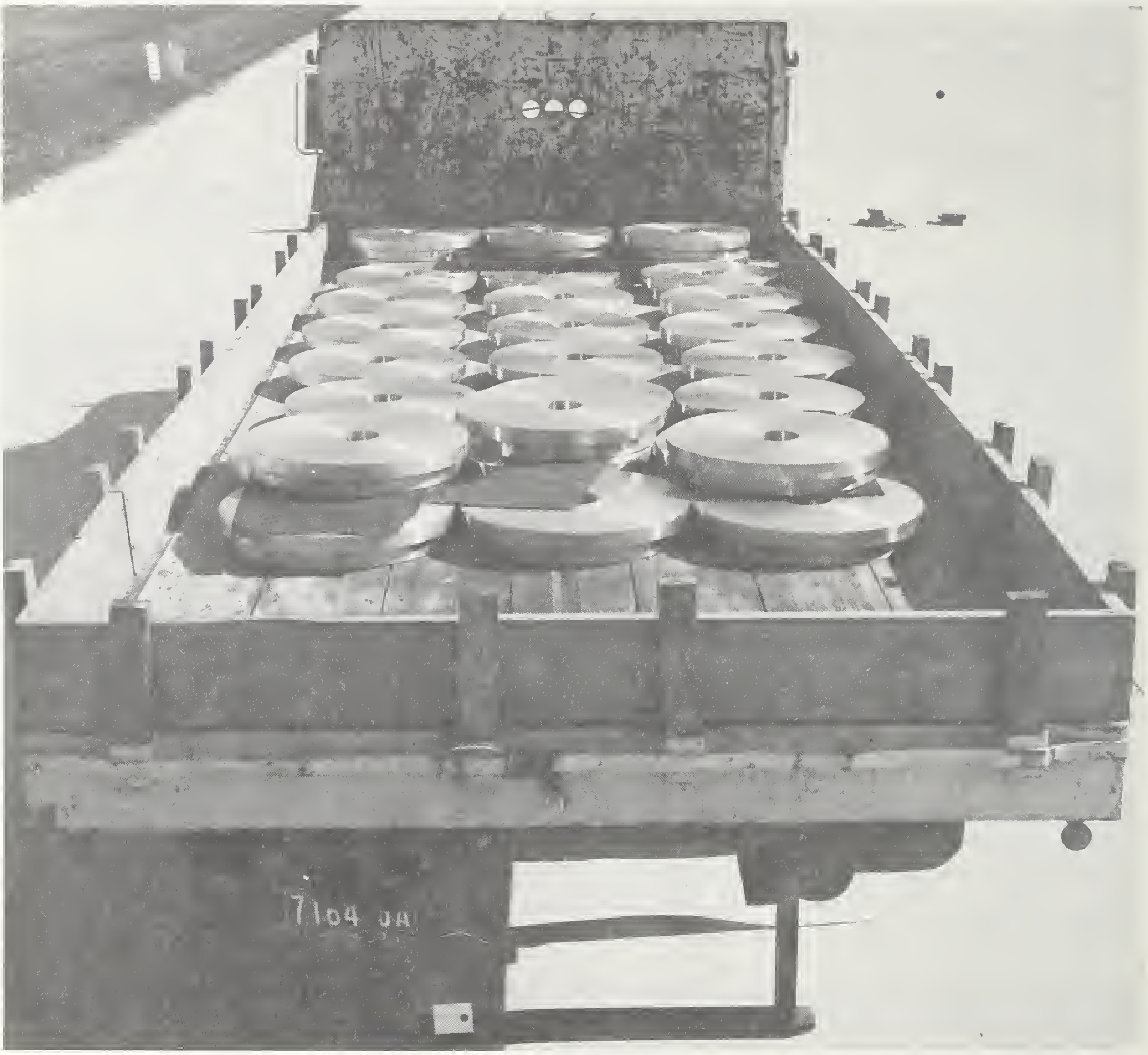


Figure 9. A view of the test vehicle body showing the placement of the thirty 500 pound weights used to provide maximum tire loading.

Figure 10. Shown is the tractor-trailer test vehicle in its fully loaded condition. The combination unit possessed a gross vehicle weight of 65,080 pounds.

2.4. Test Procedure

Prior to a discussion of the test procedure, a few words of description are necessary to establish the placement of all instrumentation within the test section. Figure 11 shows the placement of the microphones, photosensors, and the path of the test vehicle.

The microphones, six in all, were located along a line perpendicular to the path of travel of the test vehicle. The array itself was located midway in the test section. Photosensors, activated by a light beam produced by a spotlight mounted on the side of the truck, were located along the test lane parallel to the path of the vehicle. Although not shown in Figure 11, the mobile instrumentation van was located 500 feet back from the edge of the runway. Coaxial cables connected the microphones and photocells with the tape recording and monitoring equipment housed in the instrumentation van. The 500 feet distance was dictated because of an airfield ruling and also to avoid unwanted reflection effects.

For a nominal 40 mph run (the truck should be travelling at 40 mph as it passed the microphone array) the driver of the test vehicle accelerated the truck to slightly more than the desired speed to compensate for the deceleration characteristics of the particular vehicle. As the truck passed the initial photocell, the tape recorder in the instrumentation van was remotely commanded to turn on.

Since tire noise was being investigated, the testing was performed with the truck in a coasting mode and the engine shut off. The driver shut down the engine prior to entering the test section. The initial photocell, which turned on the recorder, was located so that when the truck passed photocell No. 2 the tape recorder was up to speed (servo-control system in phase lock) and data could be recorded. Data from each microphone were recorded on six channels of an F.M. tape recorder. The truck tire noise was recorded during the entire passby over the 1000 foot section. The light beam striking the photocells caused voltage spikes which were recorded on the seventh channel (direct record) of the tape recorder. The photocells (photocells No. 2, 3, 4, 5, 6) were located 250 feet apart along the test section; the "blips" produced by the photocells provided information on truck position versus time which was used for the calculation of vehicle speed and position. As the truck left the test section, a final photocell was triggered which remotely stopped the tape recorder.

a. Recording Instrumentation

Figure 12 identifies the components that constituted the data acquisition system. To describe the workings of the system, the following example is cited with the contribution of each component discussed.

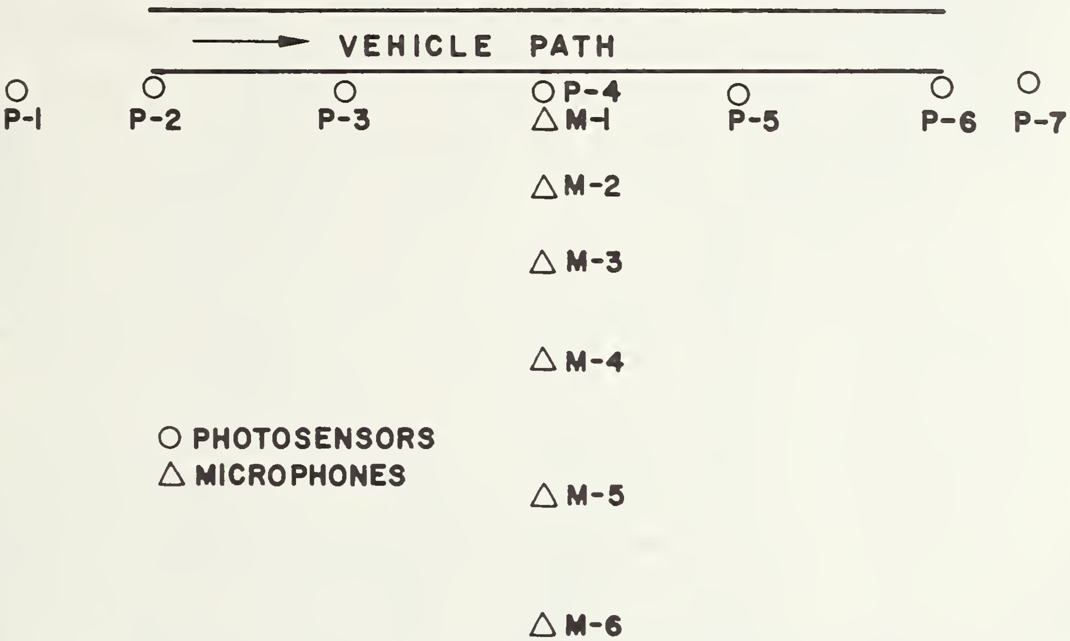


Figure 11. View of test section showing instrumentation placement plus vehicle path. (not to scale) Microphones were spaced at various distances as measured from the centerline of the lane in which the truck travelled and along a line perpendicular to the path of the vehicle. Photocells 2, 3, 4, 5, and 6 were spaced 250 feet apart. Photocell No. 1, which remotely turned on the tape recorder, was placed 440 feet before photocell No. 2. At a vehicle speed of 60 mph (88 ft/sec), this distance provided the five seconds necessary for the tape recorder to come up to an operating speed of 30 in./s. The final photocell, located immediately adjacent to photocell No. 6, remotely turned off the tape recorder.

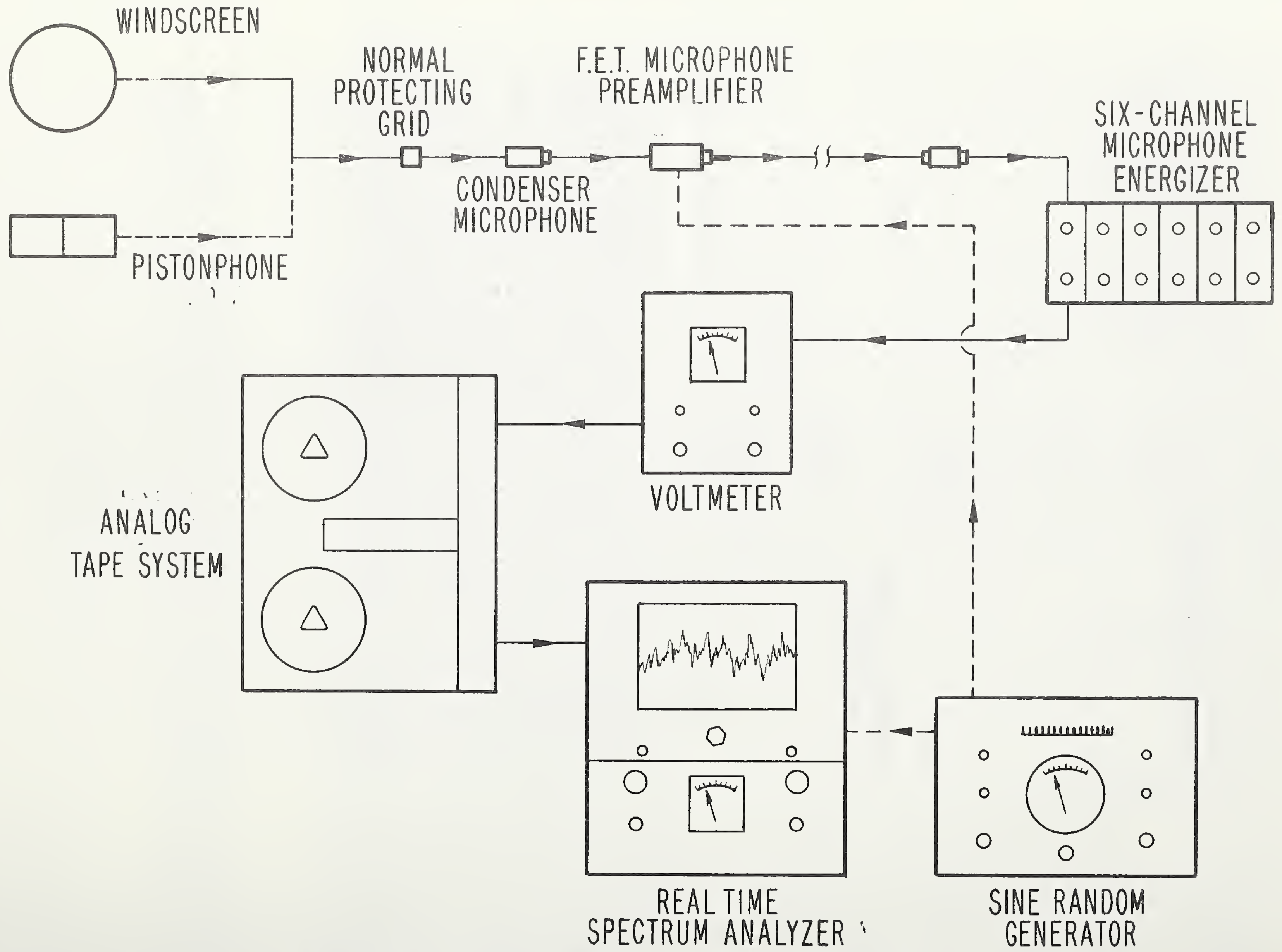


FIG. 12- DATA ACQUISITION & RECORDING SYSTEM

Consider a truck passing an array of microphones (Figure 13). As the truck moved forward, it caused pressure fluctuations which travelled as waves and activated the microphone's diaphragm into vibration. These variations were transduced into an AC voltage which could be recorded for analysis at a later time. The microphone itself was a three-part subsystem comprised of a free-field microphone cartridge, protecting grid, and a microphone preamplifier. It was not practical to locate the tape recorder next to the microphone array since one wanted to minimize undesired reflection effects; therefore, long cables carried the signal from the microphone to the recording facility. To maintain the voltage level of the signal, some line amplification was mandatory. The microphone energizers, in addition to supplying the polarization voltage to the microphones, provided the capability for 20 dB amplification. Once the signal reached the tape recorder, there existed a need for signal conditioning prior to actual recording. The electronic voltmeters provided the capability for amplification/attenuation. The meter scale provided an indication as to whether or not a tape channel had become saturated (i.e., the signal had exceeded the dynamic range of the recorder) and thus the data were not acceptable. The signal was then recorded on one track of the F.M. tape recorder. The measurements were performed out-of-doors; therefore, windscreens were placed over the microphones to minimize the noise produced by wind passing over the microphone.

Figure 14 gives an overall view of the equipment arrangement within the mobile instrumentation van. All instruments were mounted in such a manner as to be easily accessible to the operator. Shown in Figure 15 is a view of the instrument racks which contained the F.M. tape recorder as well as some calibration and system checkout instrumentation.

Calibration and system checkout were performed in two steps. The pistonphone produced a 124 dB sound pressure level (re 20 $\mu N/m^2$) at a frequency of 250 Hz. This single point calibration was used for system calibration in the field. Figure 16 shows a pistonphone calibration being performed on one of the microphones. The system checkout also involved running a frequency response on the system. To perform this checkout, the microphone cartridge was removed and replaced with an adapter which allowed the sine-random signal generator to be coupled into the system. The sine-random generator was capable of producing wide band "pink noise" which is white noise passed through a network which weights at -3 dB per octave. When a display unit, such as a real-time analyzer was coupled to the output terminals of the tape recorder, a flat frequency response (constant energy per octave of bandwidth) could be observed. In general, a lack of low frequency response would be indicative of overloading of an amplifier and a lack of high frequency response would be indicative of an amplifier failure. This operation also established the integrity of all connecting cables. During actual testing, the real-time analyzer was used to provide some data with which to judge the progress of the testing prior to the later reduction and analysis of the data on the computer.

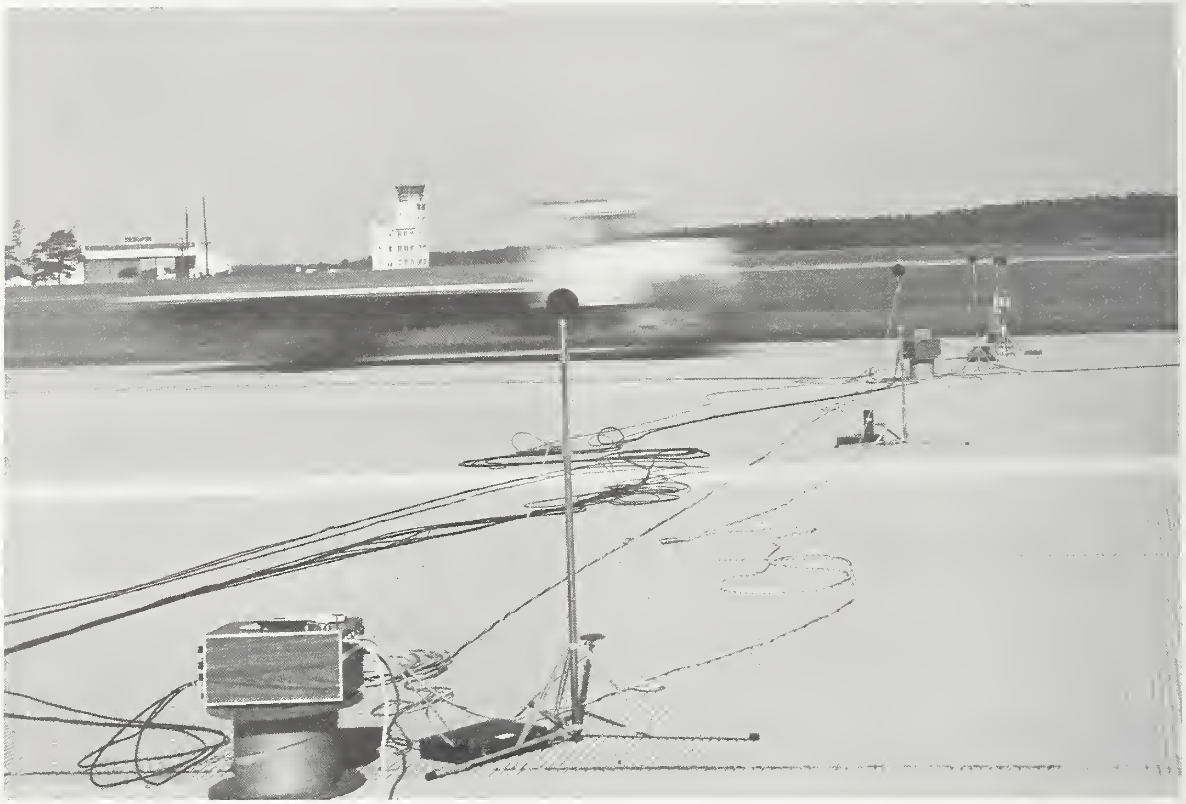


Figure 13. Overall view of the microphone array with the test vehicle approaching. The array consisted of six tripod-mounted microphones located at various distances from the center-line of vehicle travel along a line perpendicular to the vehicle path.

Figure 14. The interior of the mobile instrumentation van showing the instrument mounting arrangement. The operator is adjusting the gain of the signal conditioners to insure optimum signal-to-noise radio.

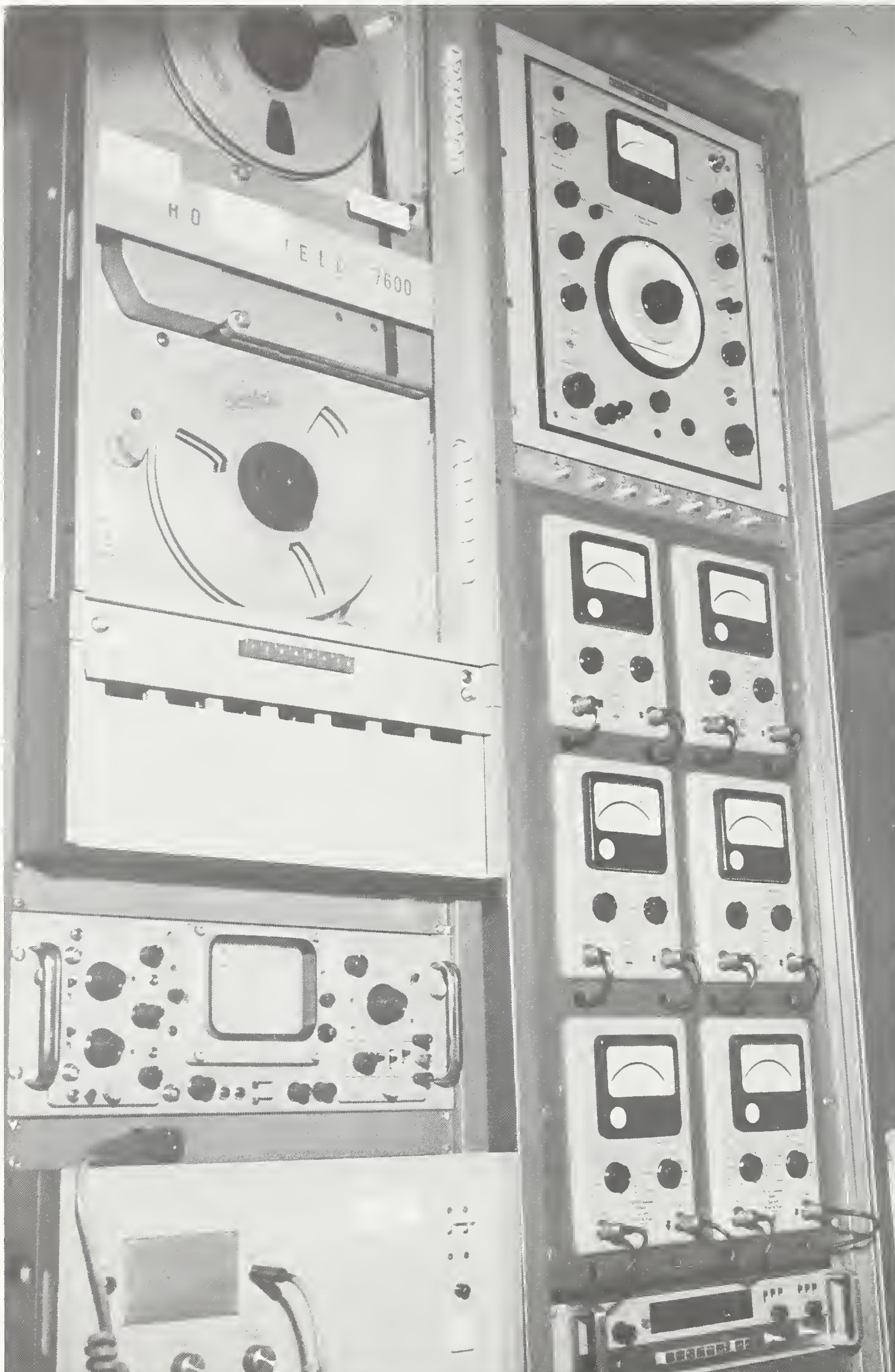


Figure 15. A detailed view of the recording and system checkout instrumentation. The left rack contains the seven channel F.M. tape recorder plus an oscilloscope. A signal generator, six signal conditioners, and a digital counter are housed in the remaining rack.

Figure 16. The pistonphone, which delivers a 124 dB sound pressure level at 250 Hz, is shown being coupled to the microphone for the one-point calibration.

The real-time analyzer in its mounted configuration is shown in Figure 17. The instrumentation van in its field configuration is shown in Figure 18. Brief descriptions of the instruments are contained in Appendix C. Reference to the schematics provides an understanding of the contribution of each instrument to the overall system.

Once the data had been recorded, the analog tapes were returned to NBS for reduction and analysis. Figure 19 defines the equipment which was utilized for analysis purposes. Each tape was played back a channel at a time through the real-time analyzer. An interface-coupler was necessary to make the real-time analyzer compatible with a mini-computer. When a timing signal appeared on the analog tape, the real-time analyzer was commanded to begin analysis; once all data had been analyzed in one-third octave bands, the computer stored the data and dumped it onto digital magnetic tape. This tape was formated to be acceptable to the large NBS computer which was utilized for further analysis and graphical plot generation. This instrumentation system provided for efficient data acquisition and data handling for the thousands of data points generated for each truck passby.

b. Position-Velocity Sensing System

A battery-operated photosensor system for the determination of truck velocity and position with time during each run was designed and is shown in Figure 20. A light source on the truck activated the photosensor and an appropriate signal was recorded on the direct channel of the tape recorder. The first sensor the truck passed was interfaced with the analog tape system so that activation of this sensor remotely started the tape transport and record electronics. This sensor was appropriately located so that when the truck passed the second sensor, the tape system was up to speed and data were taken. The final photosensor commanded the tape system to stop. Appendix E contains a detailed technical discussion of the photosensor, start-stop circuitry, and line amplifiers as well as schematics or block diagrams for each.

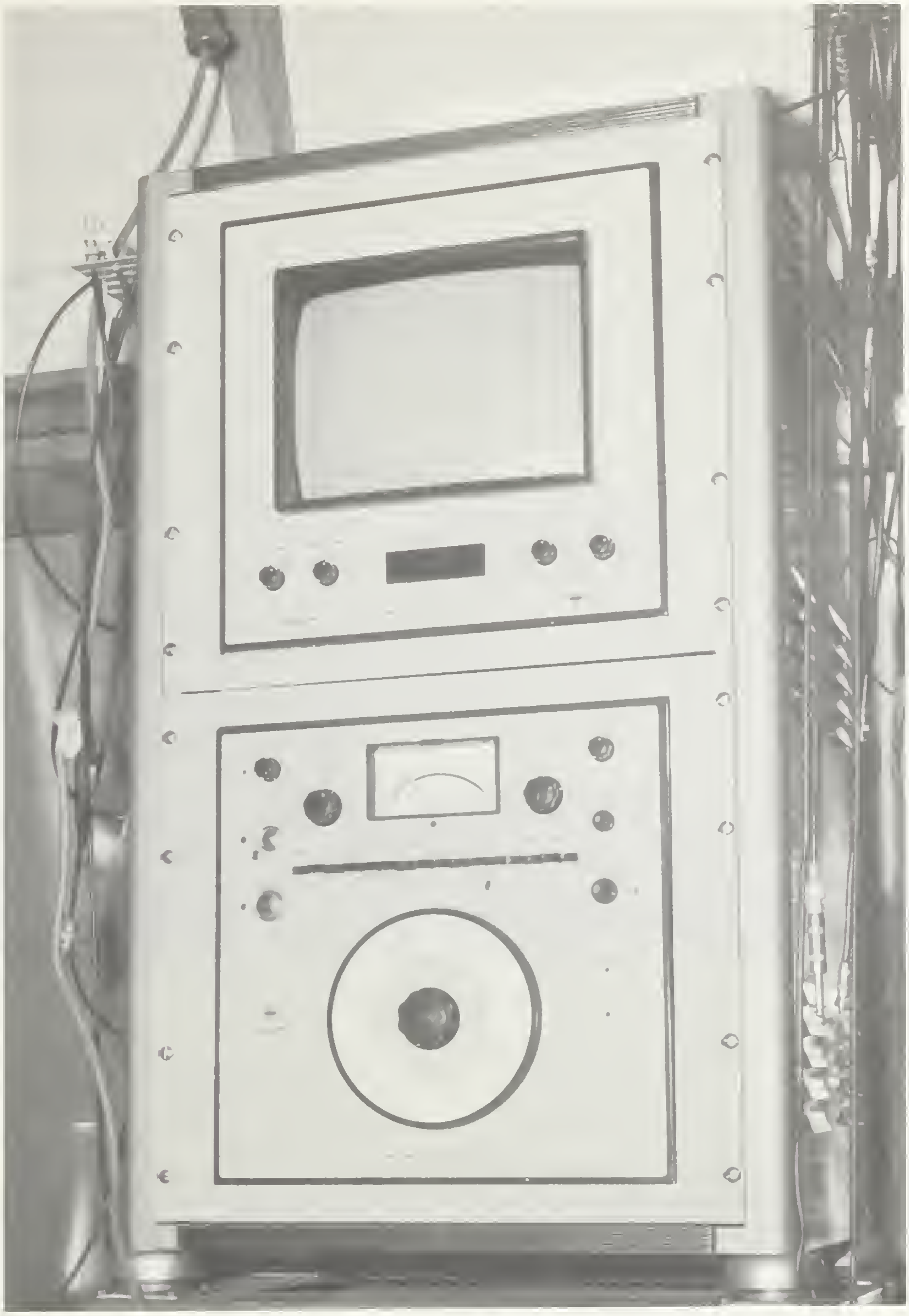


Figure 17. A view of the real time spectrum analyzer showing both the amplifier-filter section and the CRT display unit.

Figure 18. The mobile instrumentation van is shown in its field location. The wires strung on stakes in front of the truck are the signal wires between the microphone array and the recording facility within the van.

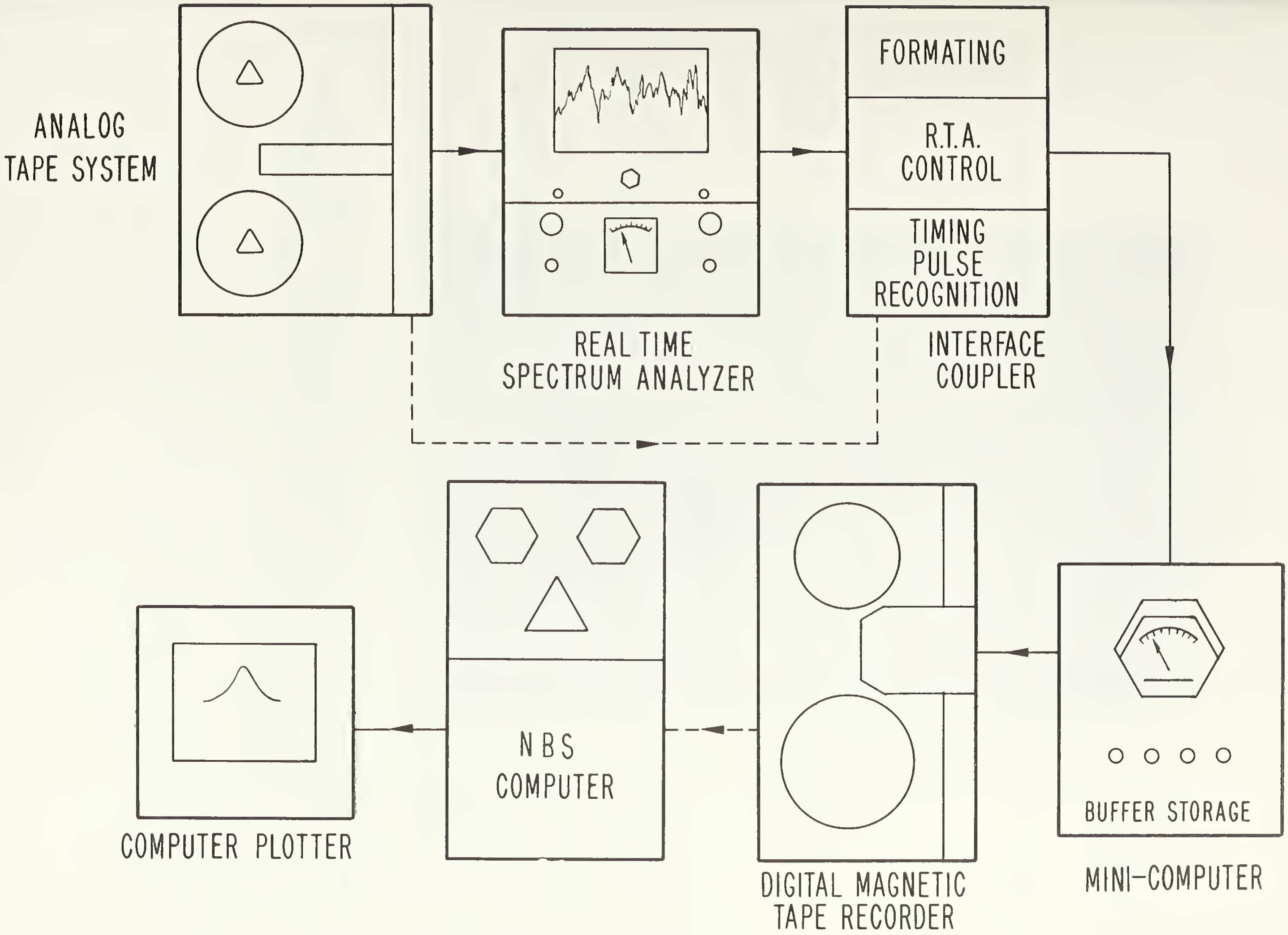


FIG. 19-DATA REDUCTION & ANALYSIS SYSTEM

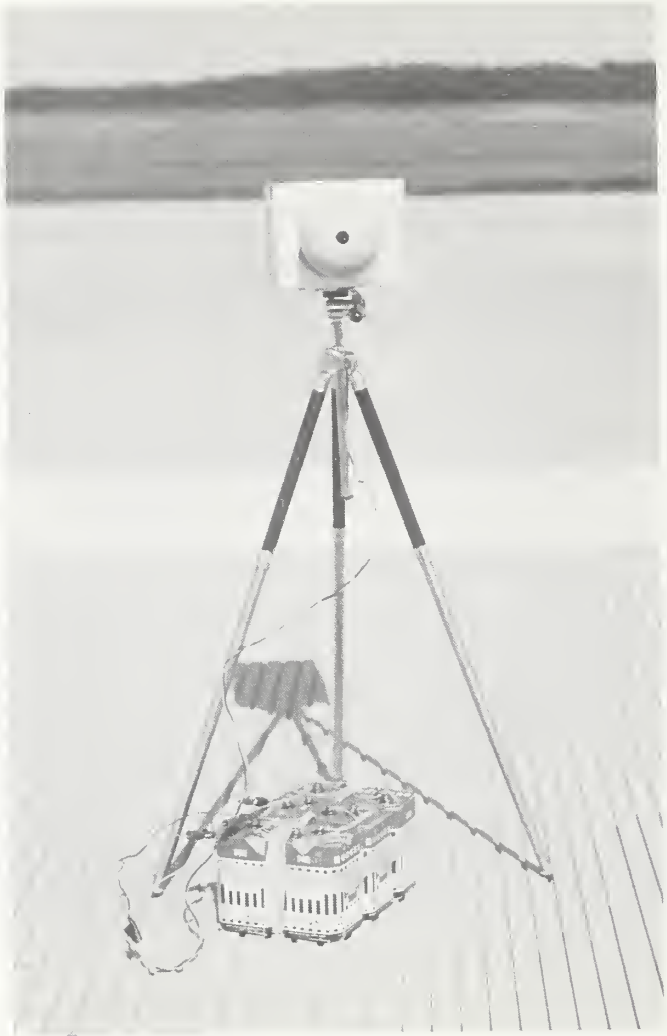


Figure 20. A closeup of the photosensor shows the ± 18 volt battery pack and the tripod-mounted photodetector. The minibox contains the electronics while the integrating sphere houses the photodetector.

3. Test Results

The test program was carried out in two phases: (1) a feasibility test program was conducted to establish an optimum test design and (2) an extensive parametric field study was conducted which included investigations of the influence of tread design, degree of wear, speed, load, pavement surface, and tire location on the noise generated by truck tires.

This interim report presents only peak A-weighted sound level data as measured. Typically data taken in the field have not been corrected to account for the effect of windscreens and the directionality of the microphone. The magnitude of these corrections will determine the uncertainty limits which must be applied to data when no corrections are considered. It should be noted that the peaks measured do not occur at the same time at each microphone. The time of flight from the source to the receiver and the directionality of the source result in the peaks at the far microphones either lagging or leading those at the near microphones. The detailed results are presented in both tabular and graphical form in Appendices A and B. In this section the general trends are investigated through cross-plots of the detailed data.

3.1. Feasibility Test Program

Rather than arbitrarily establish a test array and test conditions, a feasibility test program was devised to address some of the questions which required answers prior to the finalization of the test design.

What horizontal spacing of microphones should be utilized? At what height above the road surface should the microphones be placed? Is vertical directionality important? How repeatable are the data at each microphone location for a given set of test conditions? What effect does grass have on the attenuation of sound generated by truck tires? What signal amplification is necessary to assure optimum data acquisition? Is there a significant difference in sound level with truck windows open or closed? What are the deceleration characteristics of the test vehicles?

Once these questions had been answered, an optimum test program could confidently be established. At this point in the program the position-velocity sensing system was not operable and the capability for coupling the spectrum analyzer to a computer did not exist. For these reasons, the decisions were based on the evaluation of the peak A-weighted sound level results of the feasibility study. Data from previous studies on truck tire noise have been reported as peak A-weighted sound level as measured at a given distance from the source (usually 50 feet). A-weighted sound level is frequently utilized for both objective and subjective studies and forms the basis for existing motor vehicle noise ordinances.

Throughout the feasibility test program, measurements were made utilizing various microphone array configurations for repeated passbys for a given set of test conditions. The loaded, single chassis vehicle, equipped with new rib-A (quiet) and new cross-bar-F (noisy) tires on the drive axle (new rib-A tires were mounted on the steering axle), ran past the microphone arrays, which were located on concrete, asphalt, and a newly-mown grassy field, at speeds of 30 and 50 mph. The details of the feasibility test program are contained in Appendix B. A careful evaluation of these data led to the establishment of the following test conditions for the parametric study:

1. All microphones were located on the hard surface, be it concrete or asphalt.

2. All microphones were mounted on tripods at a height of 48 inches above the surface of the roadway. This height corresponded to the height recommended by the S.A.E., I.S.O., and the California state law governing motor vehicle noise.

3. All microphones were located along a line perpendicular to the path of the vehicle and spaced at distances of 6, 12, 25, 50, 80, and 130 feet as measured from the centerline of the lane in which the truck travelled. The rationale of the horizontal locations was as follows: The 6-foot location was as near as the microphone could be placed to the passing truck. The 130-foot location represented the limit of the hard surface before the grass began. The 50-foot location is that specified in the existing California and New York state laws on motor vehicle noise. In addition, much of the research work that has been performed and is in the public domain has utilized a microphone placed 50 feet from the centerline of the highway. The 25-foot location was that utilized during some recent traffic noise studies in Connecticut. The remaining two locations at 80 and 12 feet were selected to fill in the gaps in the array -- thus ensuring adequate coverage between 6 feet and 130 feet.

3.2. Parametric Study

The extensive data acquisition program, which followed well-defined test matrices (described in detail later), was divided into two phases according to the test vehicle utilized -- (1) single-chassis vehicle testing and (2) tractor-trailer testing. For single-chassis vehicle testing, the test tires were always mounted on the drive axle. In the case of the tractor-trailer, the test tires were mounted either on the drive or the trailer axles. Neutral rib (rib-A) tires were always mounted on the steering axle.

The detailed peak A-weighted sound level data for all the completed test runs are presented in both graphical and tabular form in Appendix A. Also included are tire footprints showing characteristic tread design patterns of the test tires and the associated tread depth and rubber hardness.

For ease in comparison and establishment of some general trends, cross-plots of the detailed data were developed. A majority of the data on truck tire noise available in the public domain consists of A-weighted sound level as measured 50 feet from the centerline of the lane in which the vehicle travelled. Therefore, the data for the 50 foot microphone location were chosen as the basis for the cross-plots. Except in the case where load is considered as a variable, the data correspond to the loaded vehicle. Figures 21-41 show the effect of all the parameters studied on the generated tire noise.

a. Single-Chassis Vehicle Testing

Table 1 shows the test matrix for single-chassis vehicle testing. The test tires (tires with identical tread designs) were mounted on the drive axle of the vehicle, either in dual pairs or singly. A matrix intercept represents a tread design in a given state of wear being run at speeds from 30 to 60 mph in 5 mph increments. Both loaded and unloaded test vehicles ran on concrete and asphalt surfaces. It was proposed to test the tires in three states of wear -- zero-worn (new), half-worn, and fully-worn (the neutral rib (rib-A) control tires were only tested in a new state). Tire loading varied according to the test vehicle utilized and the number of tires mounted on the drive axle. The resulting loading was as follows:

	Dual Loaded	Dual Unloaded	Single Unloaded
Gross Vehicle Weight	25,640 pounds	10,800 pounds	10,800 pounds
Load on Drive Axle	17,720 pounds	6,120 pounds	6,120 pounds
Load Per Tire	4,430 pounds	1,530 pounds	3,060 pounds

Figures 21-36 present the cross-plotted single-chassis vehicle data. A comparison of the levels measured for new tires with those measured for half-worn tires, with tread design as a variable, shows a definite trend. The pocket retread (retread-I) always produced the highest level. Cross-bar tires produced a lower level than the pocket retread but a higher level than the rib tires (Figures 21-24). These rankings held whether the tires were running on concrete or asphalt surfaces; however, within each of the generic categories (rib, cross-bar, pocket retread) specific tire types did not always maintain their same ranking.

A review of the data shows that speed has a very definite influence on the noise produced. In every case an increase in speed resulted in an increase in the peak A-weighted sound level.

TEST TIRES			CONCRETE			ASPHALT		
	Degree of Wear	Tread Design	Dual Loaded	Dual Unloaded	Single Unloaded	Dual Loaded	Dual Unloaded	Single Unloaded
	New	Rib-A	X	X	X	X	X	X
RIB	New	Rib-B	X			X		
	50% Worn		X			X		
	100% Worn							
	New	Rib-C	X	X	X	X	X	X
	50% Worn							
	100% Worn							
CROSS BAR	New	Cross-bar-D	X			X		
	50% Worn		X			X		
	100% Worn		X			X		
	New	Cross-bar-E	X			X		
	50% Worn							
	100% Worn							
	New	Cross-bar-F	X	X	X	X	X	X
	50% Worn		X	X	X	X	X	X
	100% Worn							
RETREAD	New	Retread-G	X			X		
	50% Worn							
	100% Worn							
	New	Retread-H	X			X		
	50% Worn		X					
	100% Worn		X					
	New	Retread-I	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 under the indicated test conditions. The tires were mounted on the truck's drive axle either in dual pairs or singly.

The influence of wear is presented in Figures 25-29. To determine the general trends, a speed of 55 mph was chosen and the corresponding values of the peak A-weighted sound levels were obtained from the previous graphs by interpolation. These sound levels were then plotted versus tread depth (Figures 30 and 31). With the exception of retread-I on a concrete surface, each tire type produced a higher noise level when half-worn than when in a zero-worn condition. The limited data on fully-worn tires show no trend developing.

Unlike wear, the effect of load is quite definite. The data in Figures 32-34 indicate that, for all tires tested, an increase in load resulted in an increase in the peak A-weighted sound level. The differences that exist in the data between the loaded and unloaded test conditions are small for rib tires; however, for cross-bar and retread tires, the difference is significant.

The influence of pavement surface (surface roughness) on the generated noise depends on the specific tire design utilized. For instance, the pocket retread (retread-I) is noisier on the smoother surface (in this test program - concrete) since more effective sealing can take place. A review of the data for new tires (Figures 23 and 24) indicate that retread and cross-bar tires produce higher levels running on concrete, while the rib tires produce higher levels running on asphalt. More research is necessary on surface texture characterization before the influence of the surface roughness and its interaction with the tread elements can be fully understood.

The single-chassis vehicle was also utilized for the test phase referred to as "mix-and-match". Since some tires may contribute differently to the overall noise level depending on their location on the vehicle, selected tires with representative rib, cross-bar and pocket retread tread designs were mounted in various locations to determine what noise reduction, if any, could be obtained by mounting "noisy" tires in-board of "quieter" tires on a drive axle. The test tires were mounted on the right inside and outside drive axle positions only (drive pair nearest the microphone array) with neutral rib tires at all other axle positions. All tires utilized for mix-and-match testing were new with the exception of the cross-bar-F tires. The added tread depth present on a new cross-bar-F tire made it necessary to test this type in a half-worn condition so that the diameter of the tires would correspond to the diameters of the other selected test tires. Through this test phase the test vehicle was the loaded truck (17720 lb. on the rear axle) at a nominal speed of 60 mph on a concrete surface. The selected tread designs were grouped into two categories -- baseline tires and variable tires. Three different tires -- rib-A, rib-C, and cross-bar-F -- served as the baseline tires for test purposes.

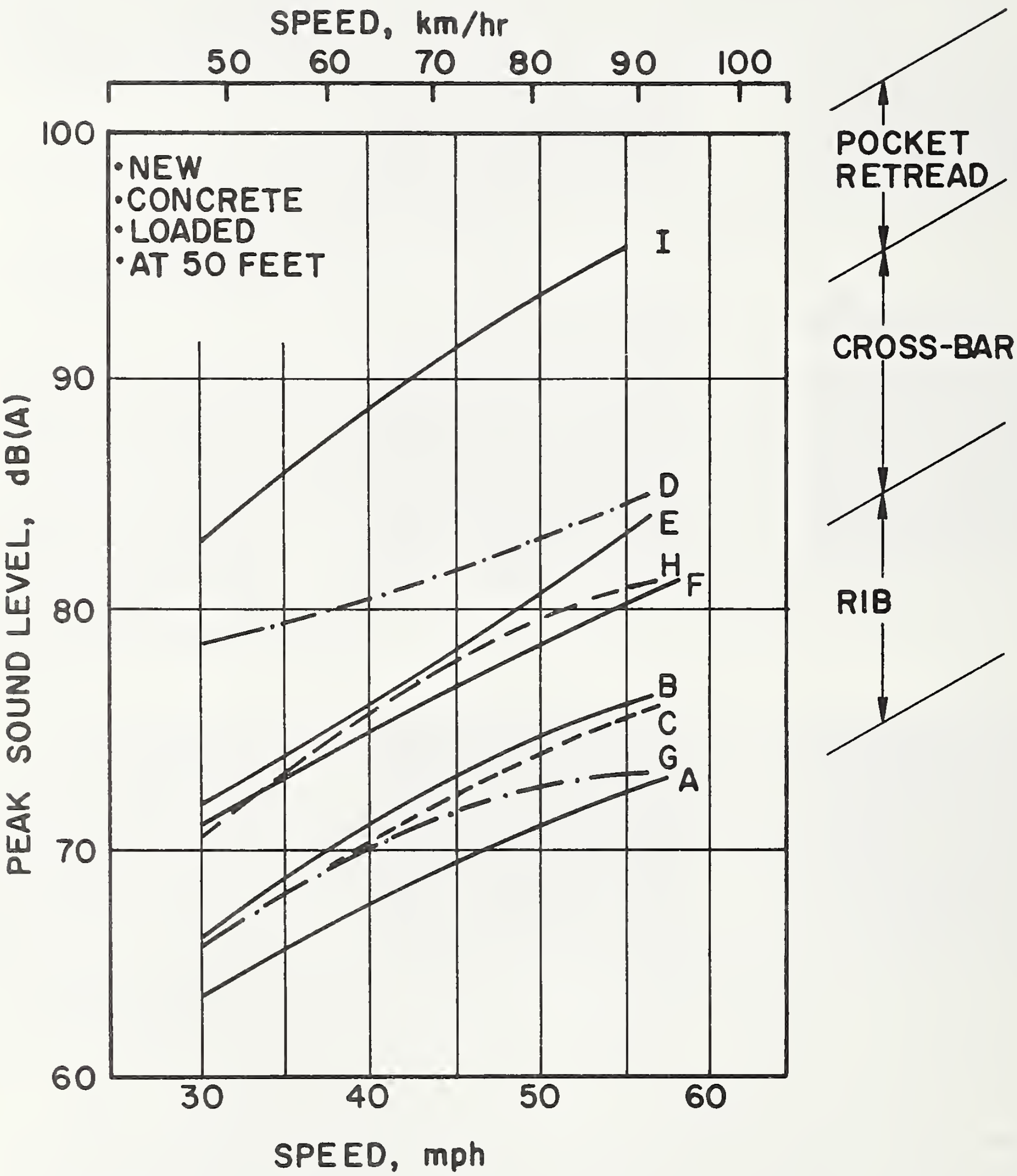


Figure 21. Peak A-weighted sound level, as measured at 50 feet, versus speed for a loaded single-chassis vehicle running on a concrete surface. Various types of new tires were mounted on the drive axle. Letter designations for each curve correspond to the tire types shown previously in Figure 7.

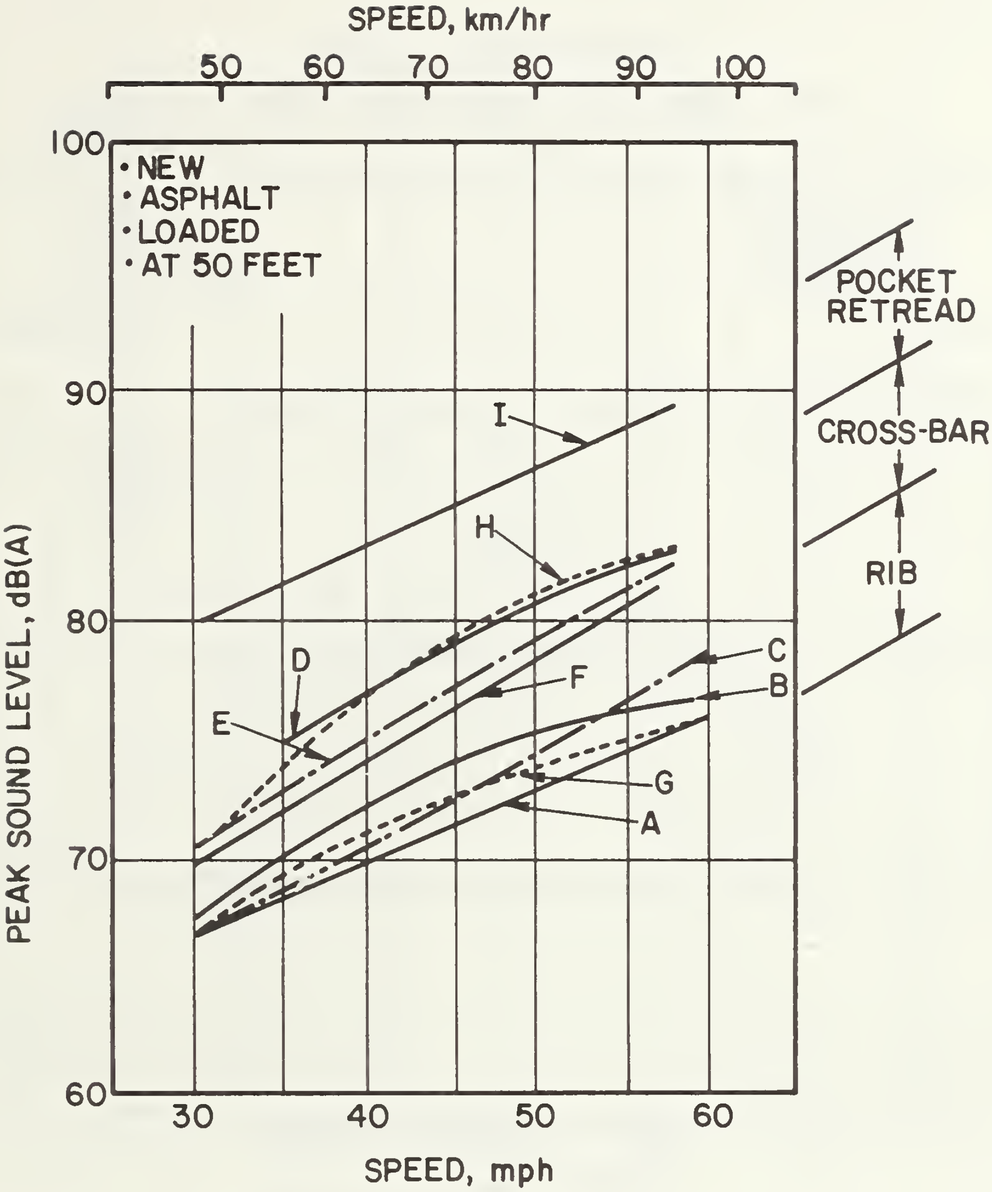


Figure 22. Peak A-weighted sound level, as measured at 50 feet, versus speed for a loaded single-chassis vehicle running on an asphalt surface. Various types of new tires were mounted on the drive axle. Letter designations for each curve correspond to the tire types shown previously in Figure 7.

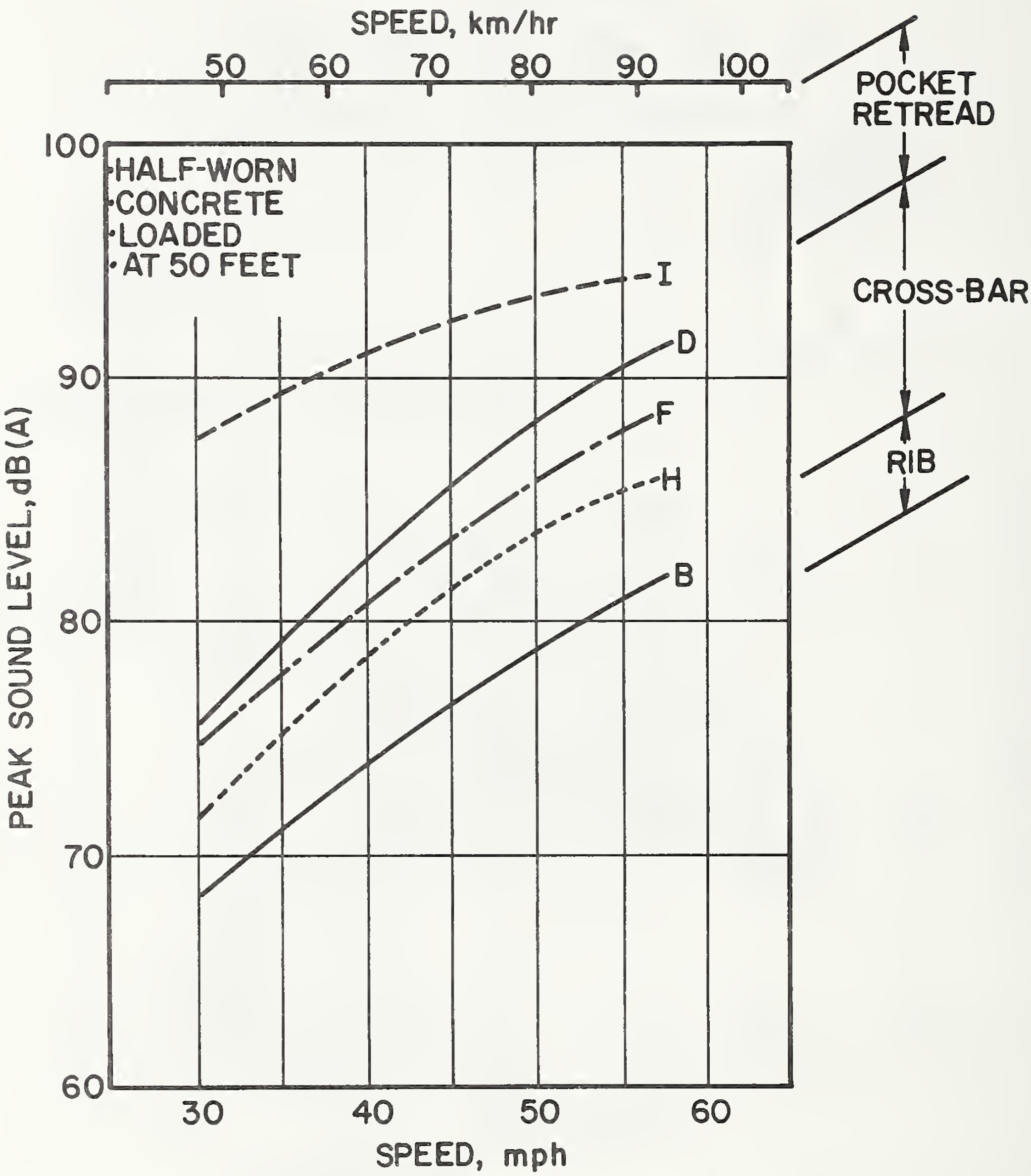


Figure 23. Peak A-weighted sound level, as measured at 50 feet, versus speed for a loaded single-chassis vehicle running on a concrete surface. Various types of half-worn tires were mounted on the drive axle. Letter designations for each curve correspond to the tire types shown previously in Figure 7.

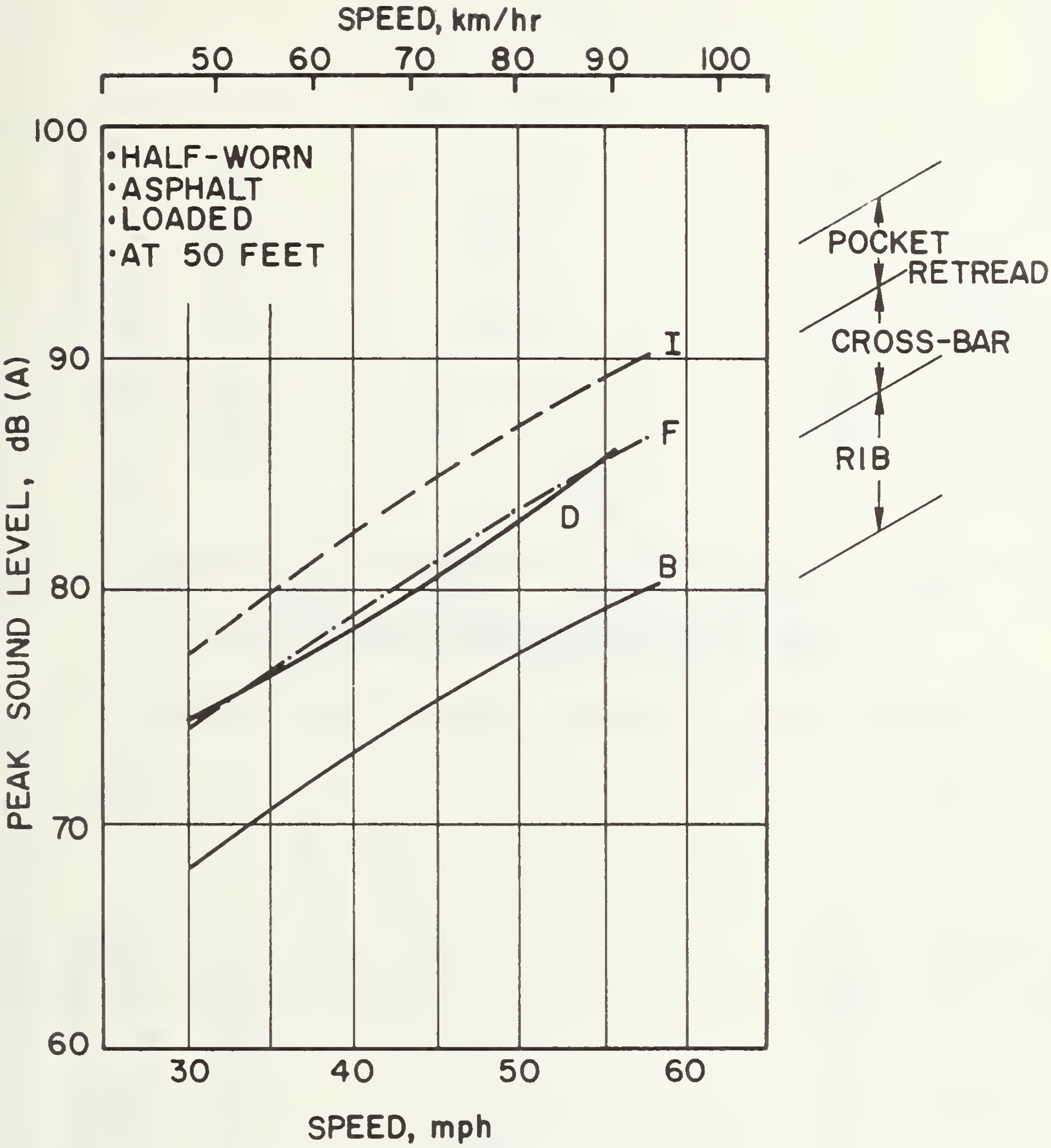


Figure 24. Peak A-weighted sound level, as measured at 50 feet, versus speed for a loaded single-chassis vehicle running on an asphalt surface. Various types of half-worn tires were mounted on the drive axle. Letter designations for each curve correspond to the tire types shown previously in Figure 7.

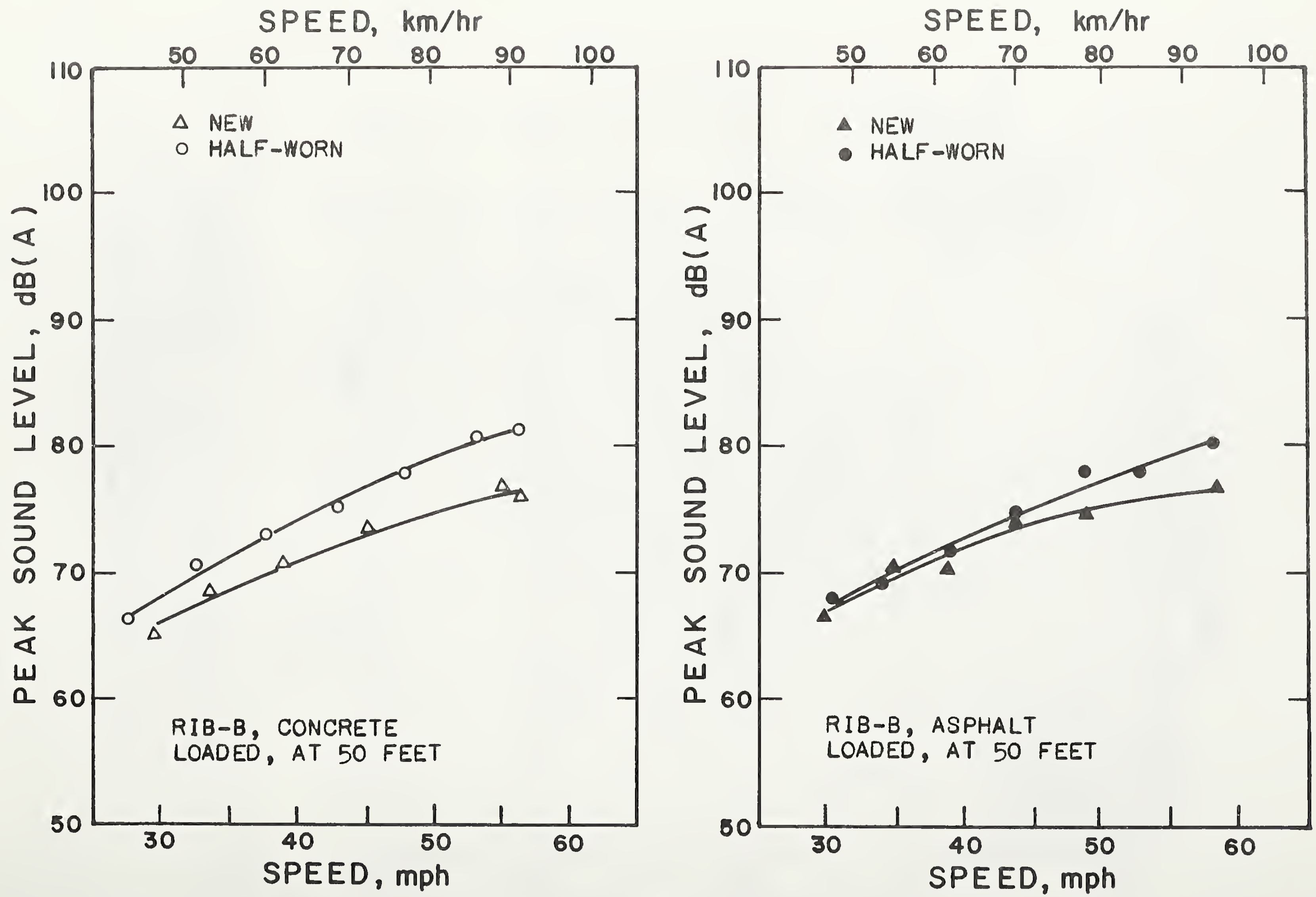


Figure 25. The peak A-weighted sound level, as measured at 50 feet, versus speed for rib-B tires in various states of wear. The left and right-hand figures present the data for the loaded single-chassis vehicle running on concrete and asphalt surfaces respectively.

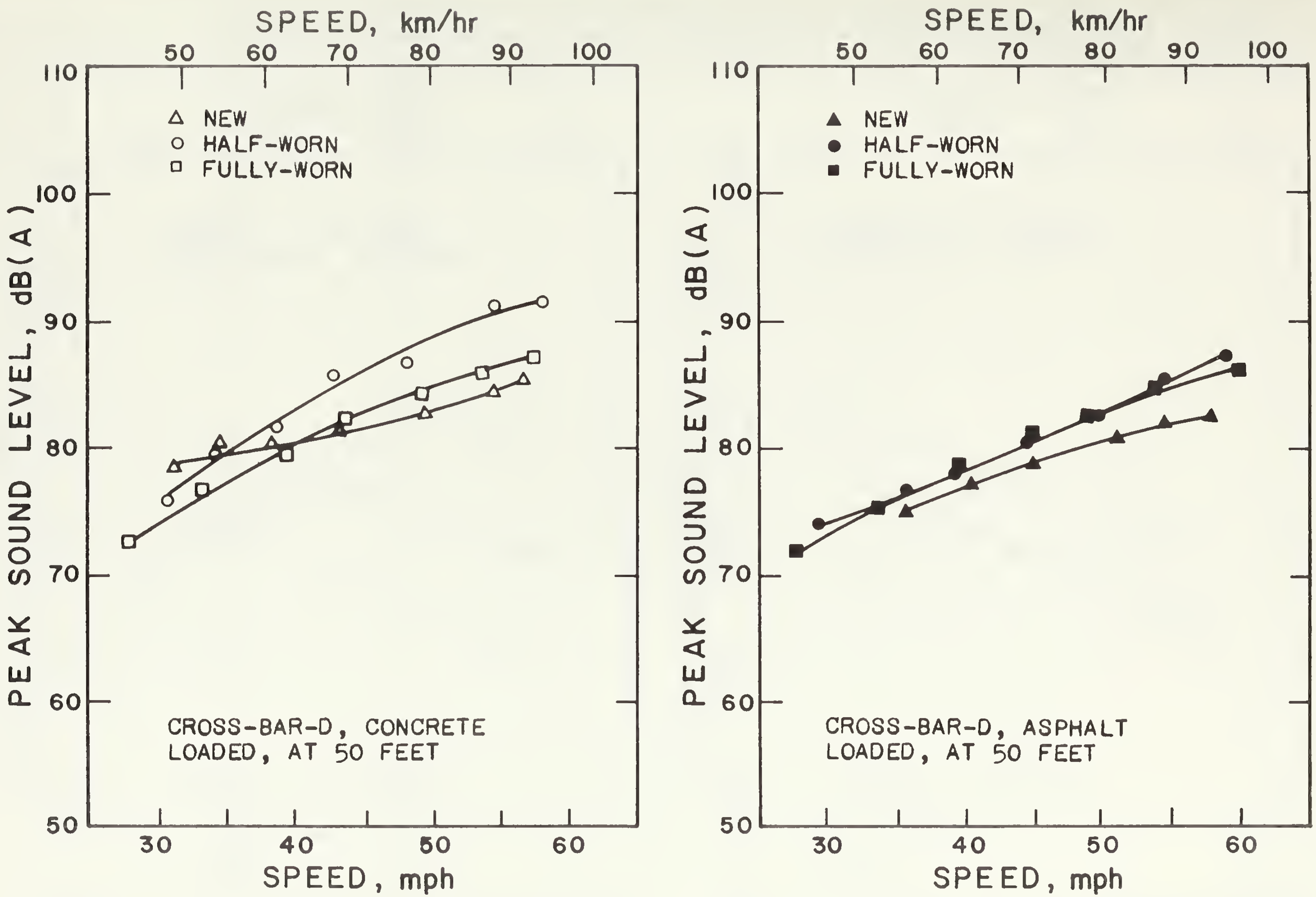


Figure 26. The peak A-weighted sound level, as measured at 50 feet, versus speed for cross-bar-D tires in various states of wear. The left and right-hand figures present the data for the loaded single-chassis vehicle running on concrete and asphalt surfaces respectively.

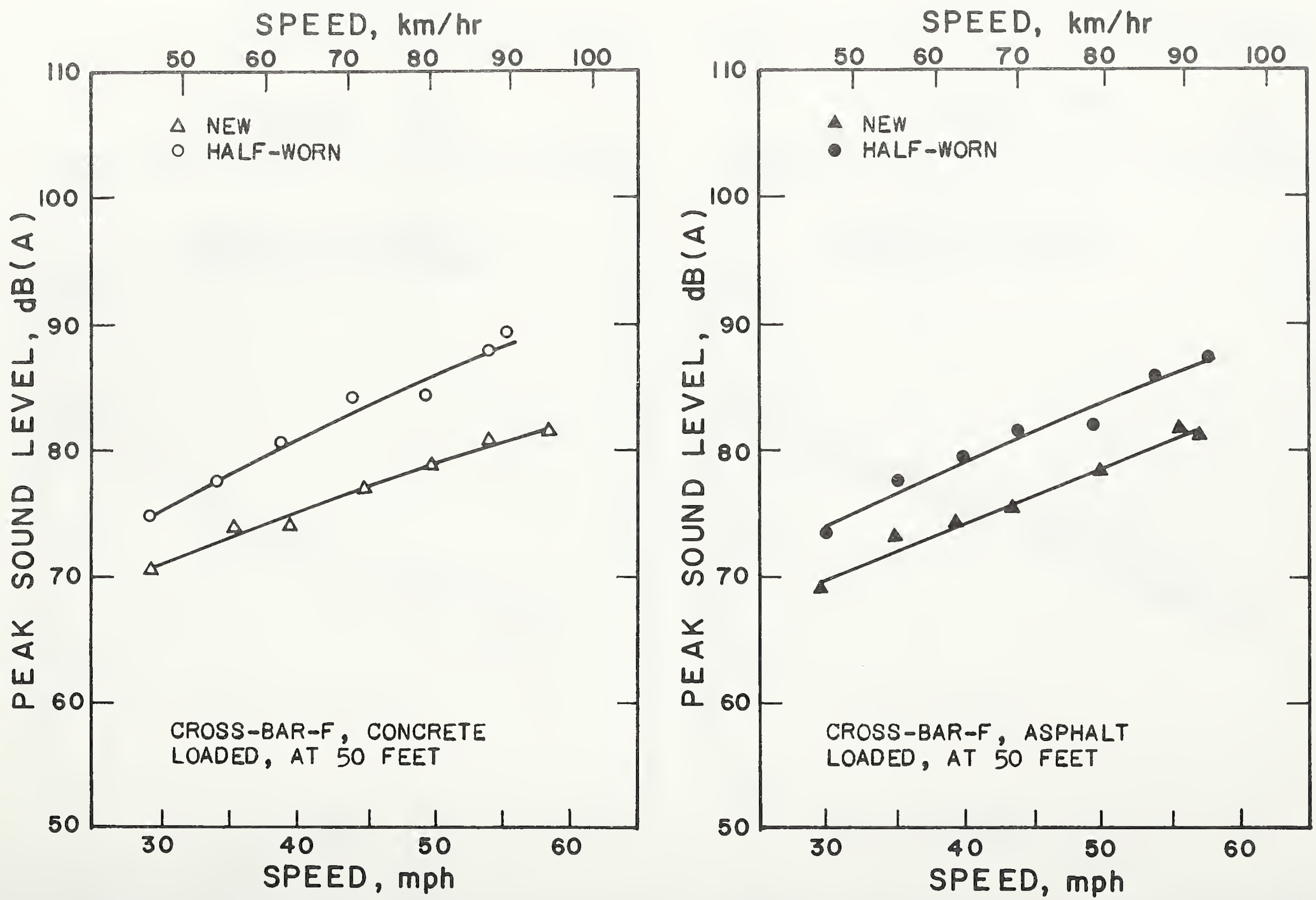


Figure 27. The peak A-weighted sound level, as measured at 50 feet, versus speed for cross-bar-F tires in various states of wear. The left and right-hand figures present the data for the loaded single-chassis vehicle running on concrete and asphalt surfaces respectively.

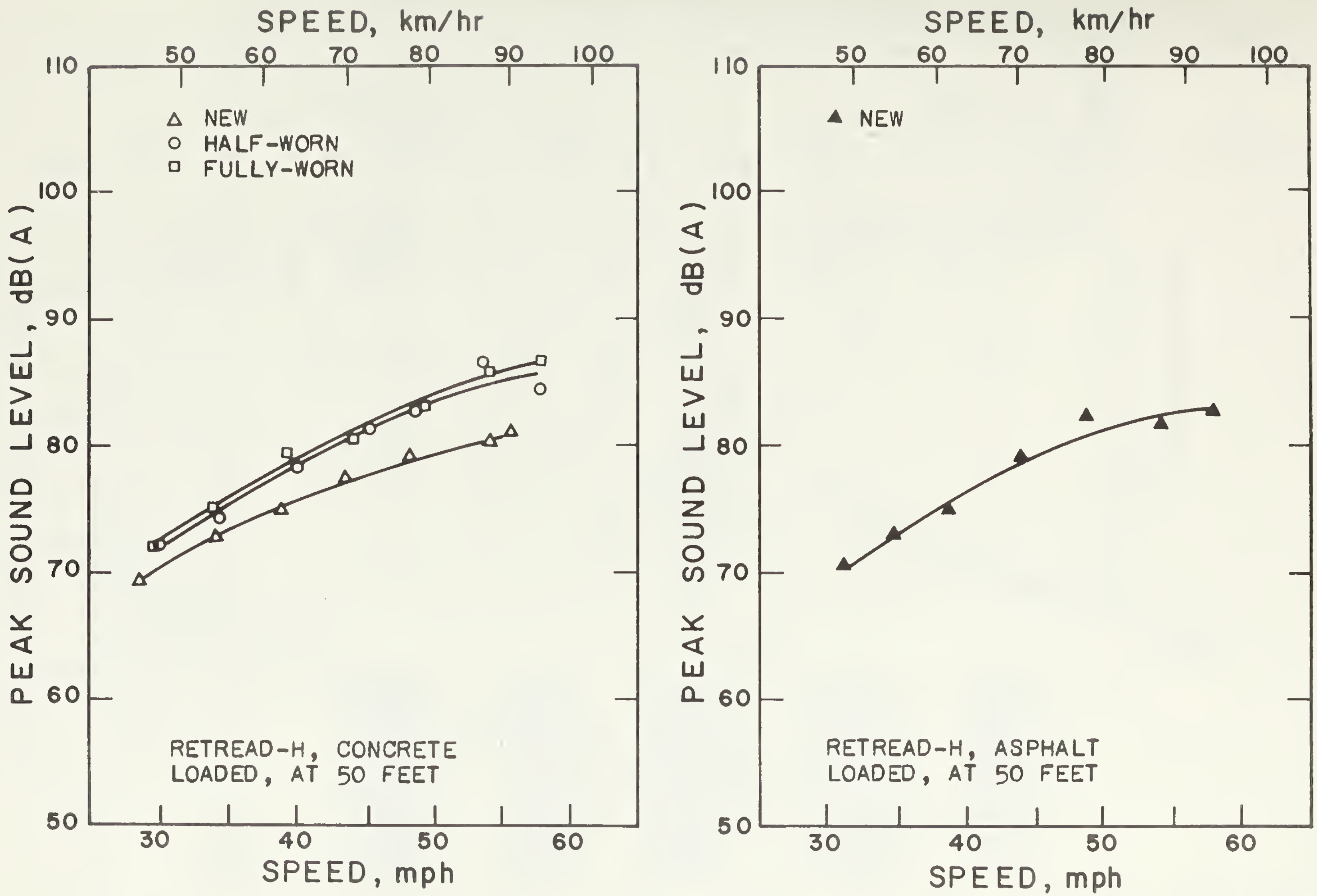
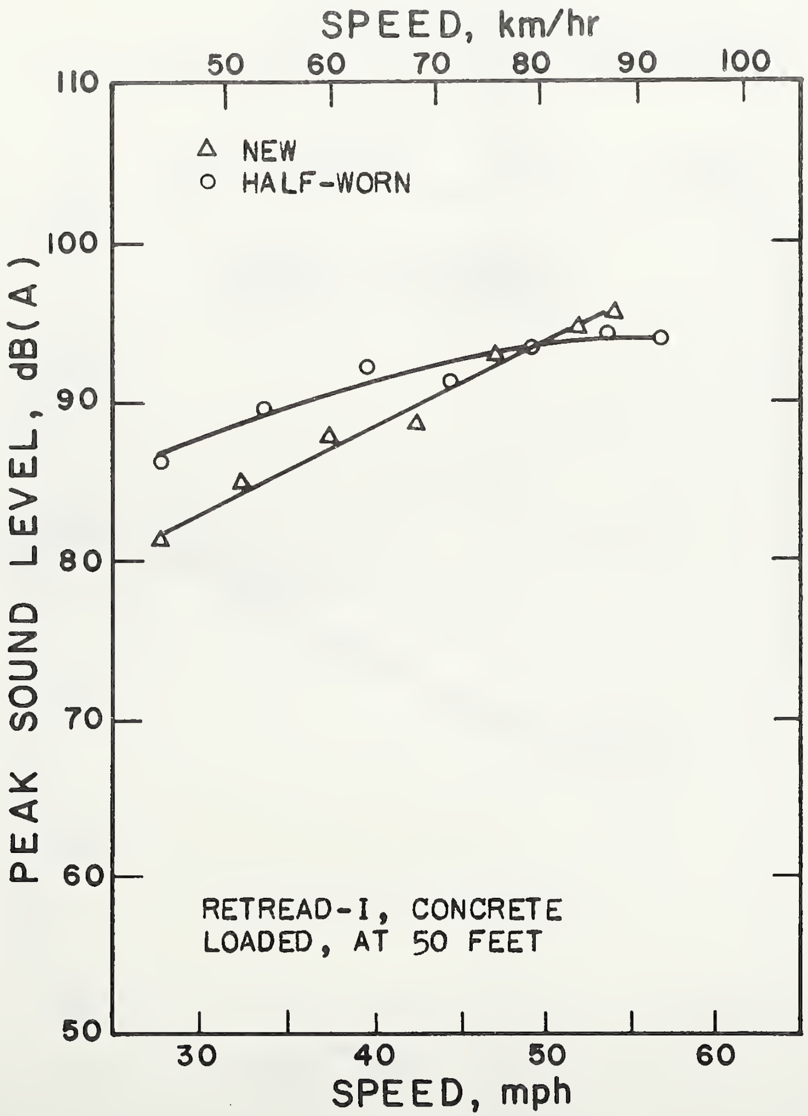


Figure 28. The peak A-weighted sound level, as measured at 50 feet, versus speed for retread-H tires in various states of wear. The left and right-hand figures present the data for the loaded single-chassis vehicle running on concrete and asphalt surfaces respectively.



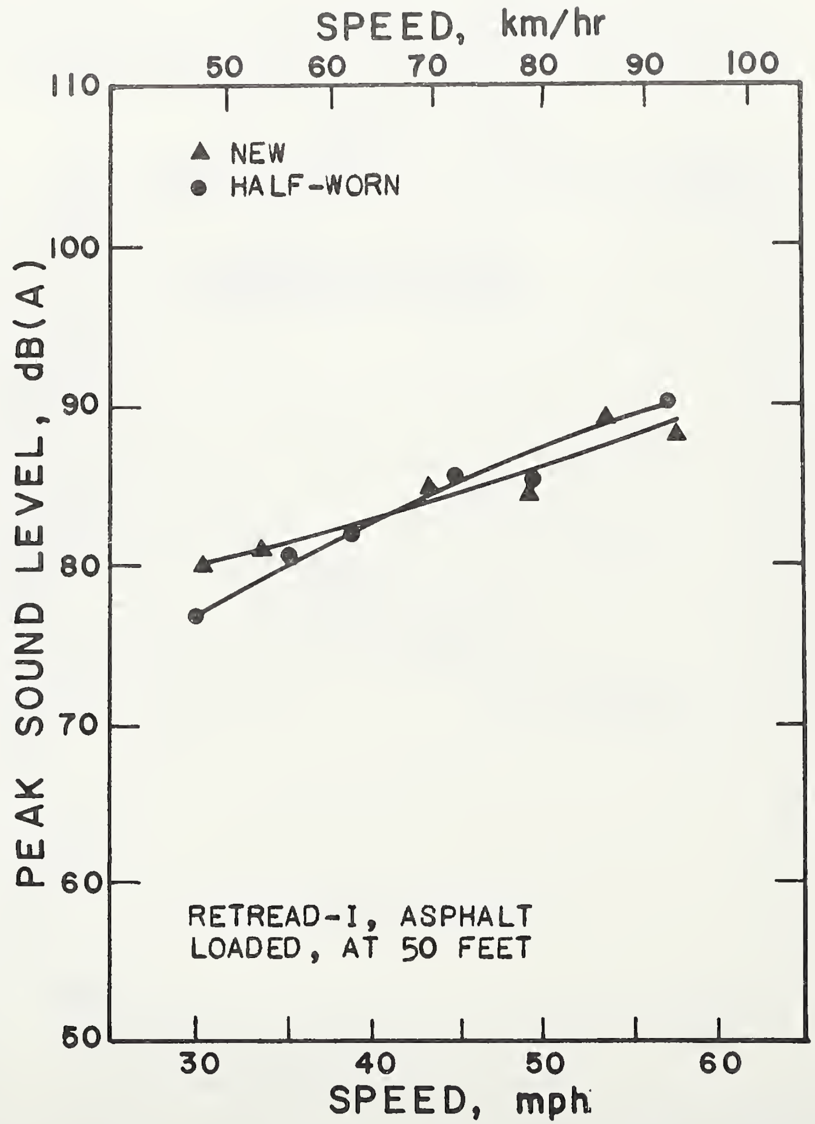


Figure 29. The peak A-weighted sound level, as measured at 50 feet, versus speed for retread-I tires in various states of wear. The left and right-hand figures present the data for the loaded single-chassis vehicle running on concrete and asphalt surfaces respectively.

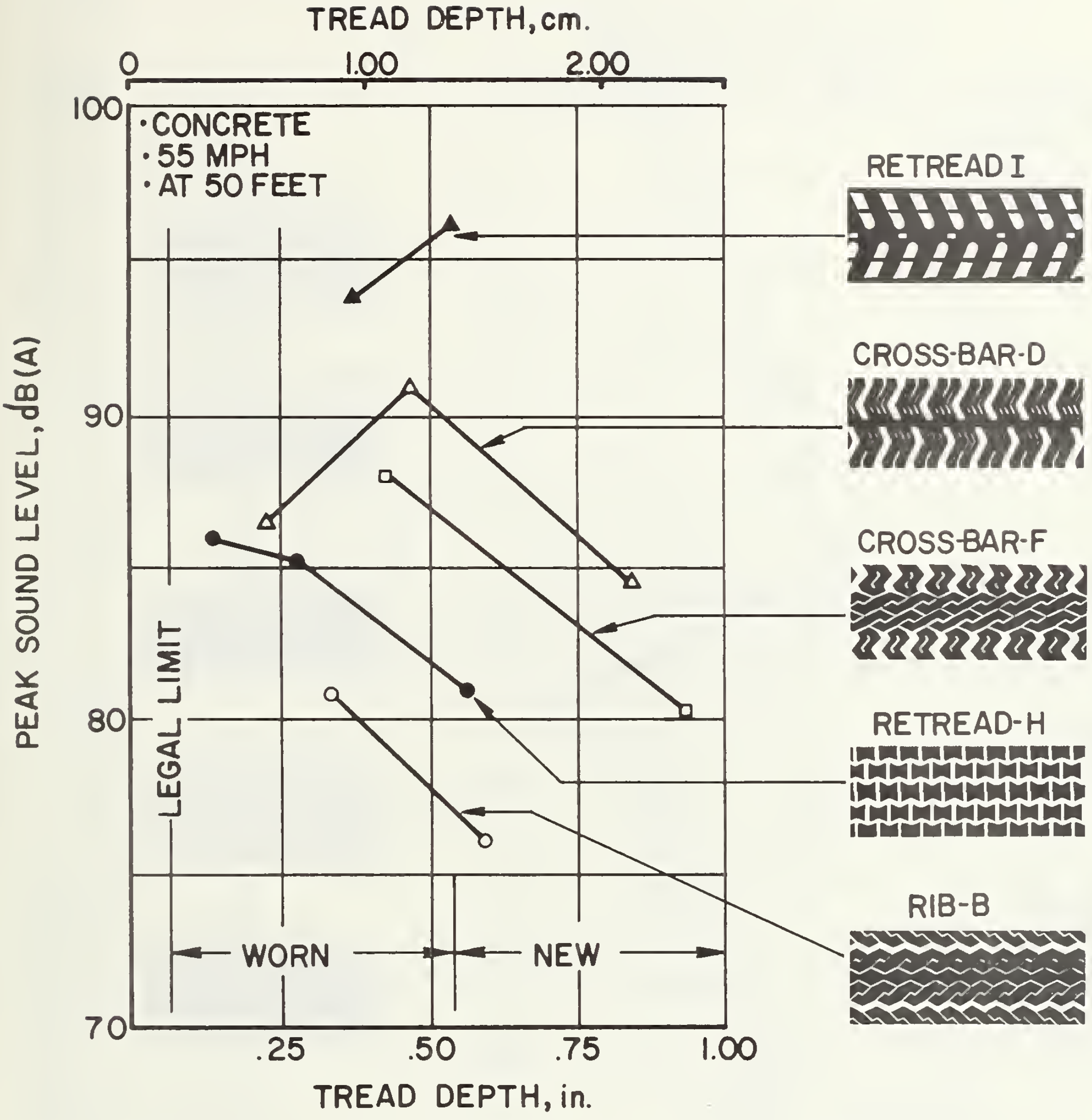


Figure 30. Peak A-weighted sound level, as measured at 50 feet, versus nominal tread depth of the tires on the drive axle. The loaded single-chassis vehicle was running on a concrete surface at a speed of 55 mph. The tread designs shown are for the tires in a new state.

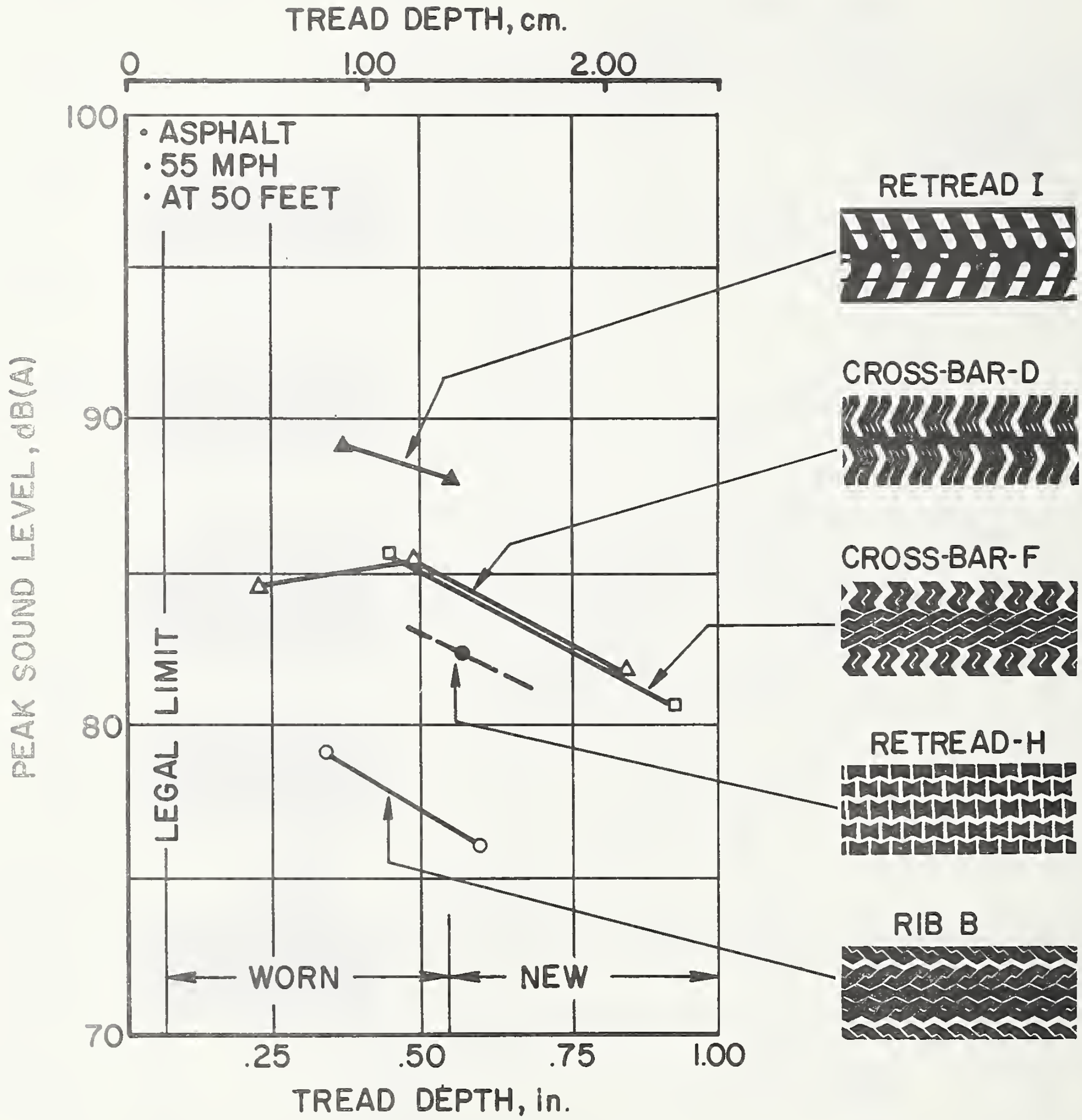


Figure 31. Peak A-weighted sound level, as measured at 50 feet, versus nominal tread depth of the tires on the drive axle. The loaded single-chassis vehicle was running on an asphalt surface at a speed of 55 mph. The tread designs shown are for the tires in a new state.

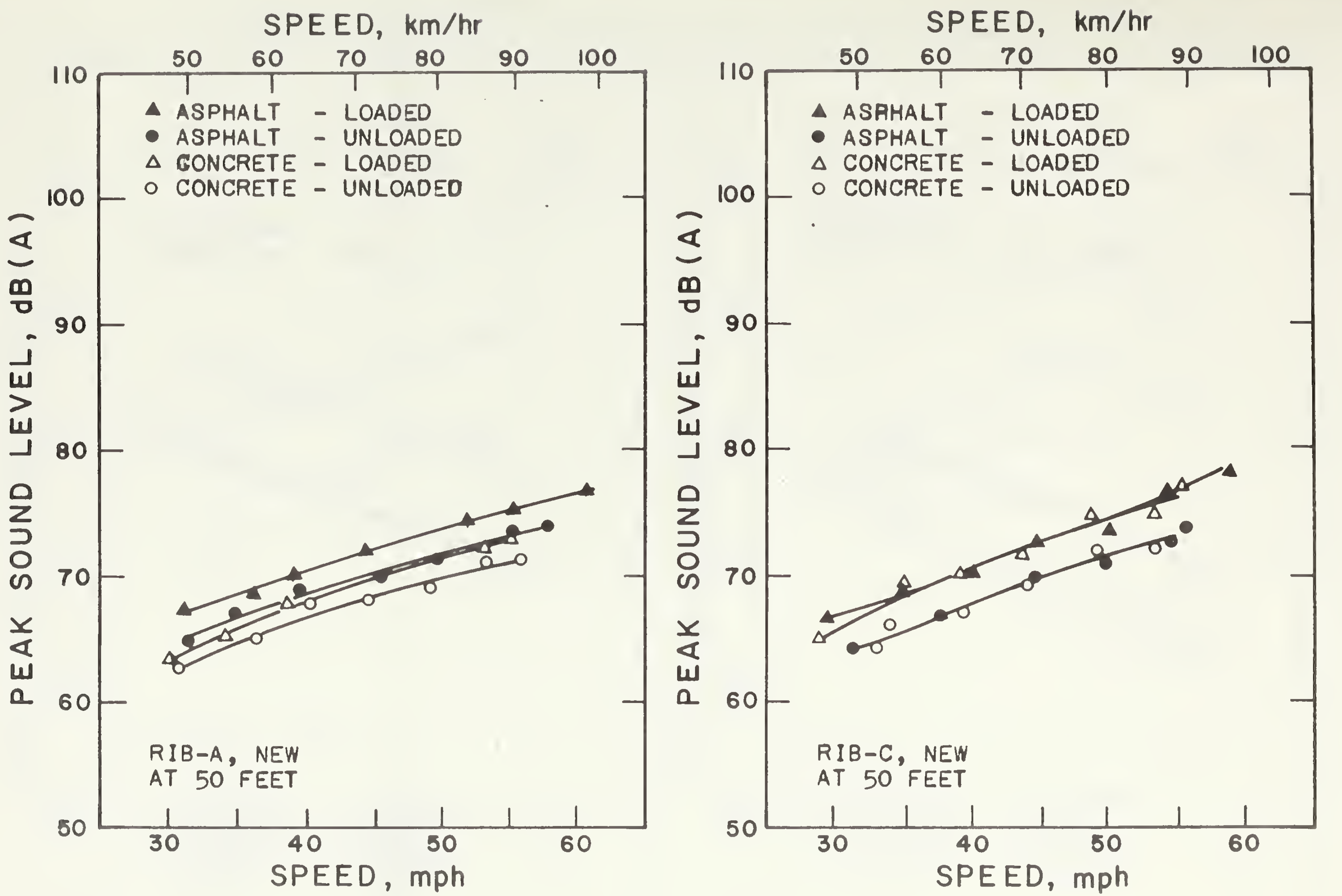


Figure 32. Peak A-weighted sound level, as measured at 50 feet, versus speed for a single chassis vehicle with the test tires mounted on the drive axle. (loaded - 17720 lb/axle; unloaded - 6120 lb/axle).

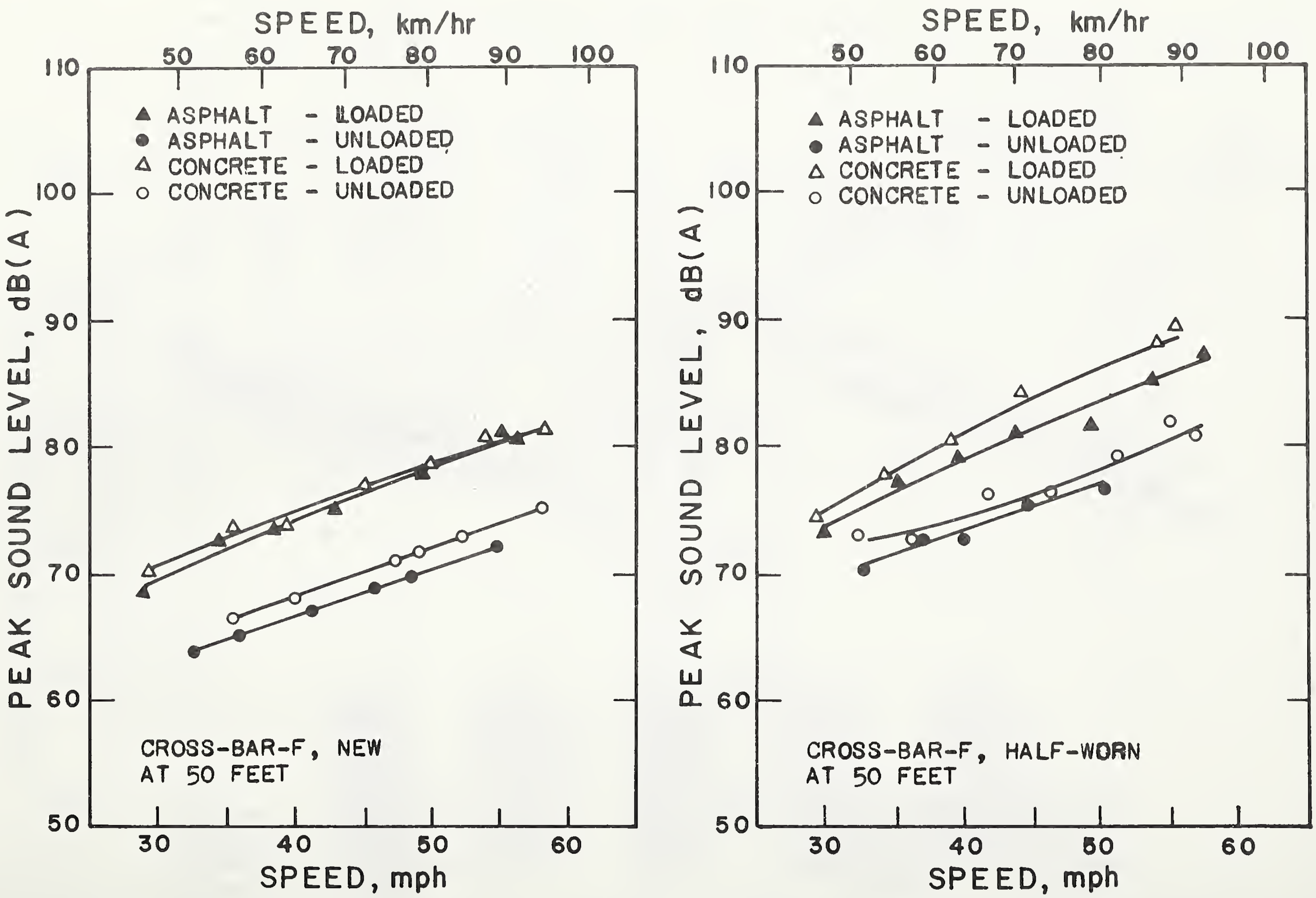


Figure 33. Peak A-weighted sound level, as measured at 50 feet, versus speed for a single chassis vehicle with the test tires mounted on the drive axle. (loaded - 17720 lb/axle; unloaded - 6120 lb/axle).

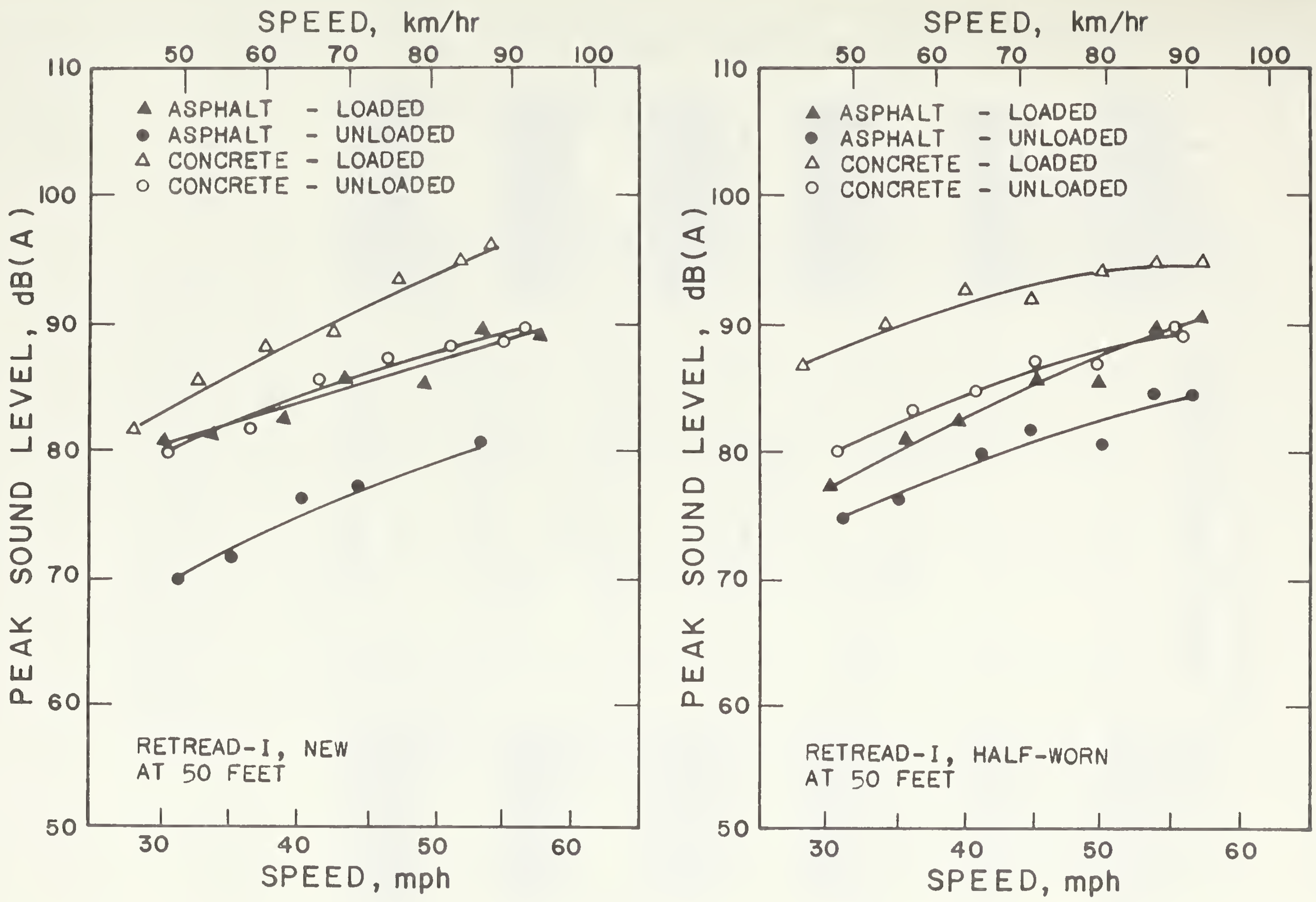


Figure 34. Peak A-weighted sound level, as measured at 50 feet, versus speed for a single chassis vehicle with the test tires mounted on the drive axle. (loaded - 17720 lb/axle; unloaded - 6120 lb/axle).

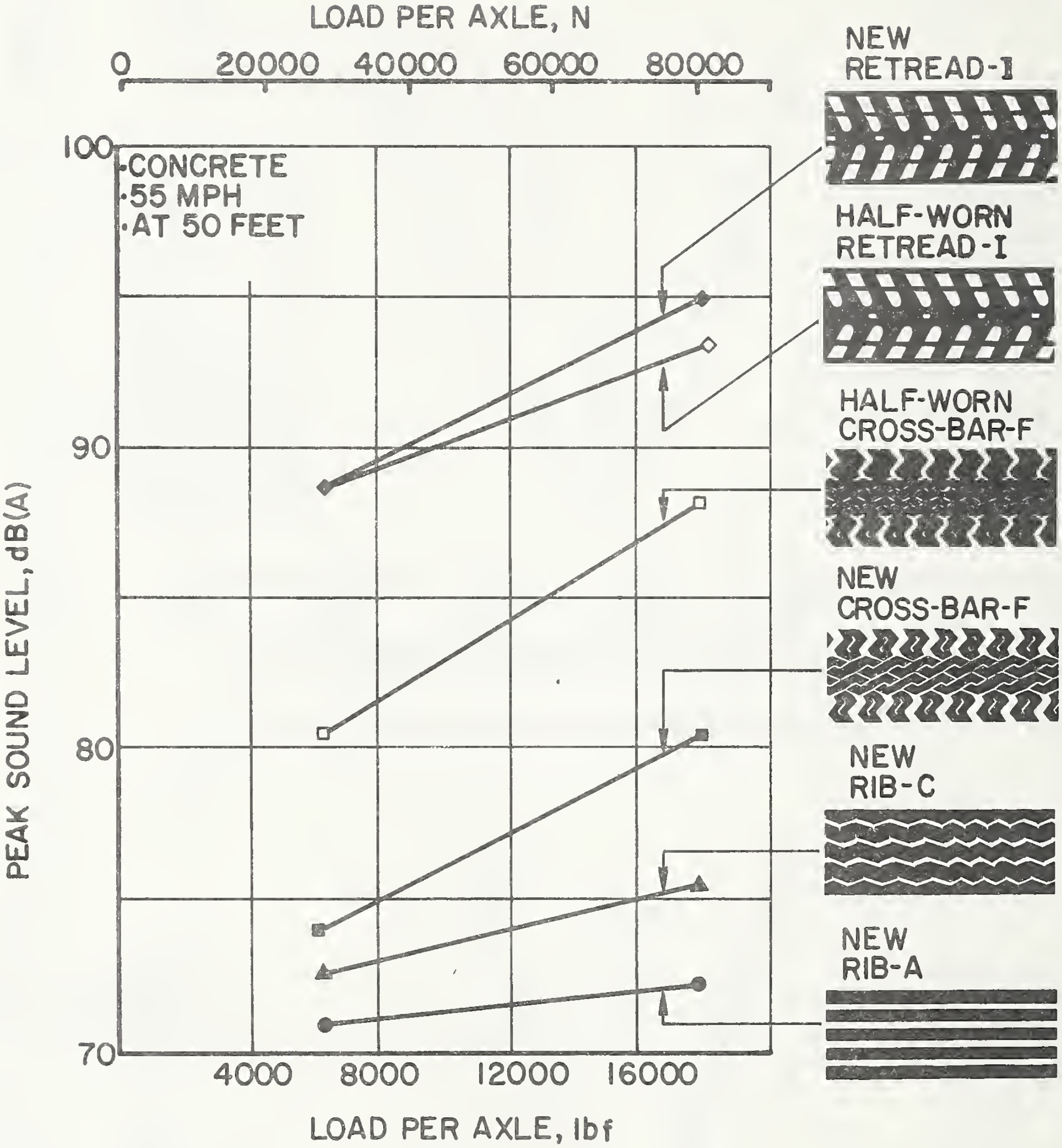


Figure 35. Peak A-weighted sound level, as measured at 50 feet, versus the load on the drive axle. The single-chassis vehicle was running at 55 mph on a concrete surface.

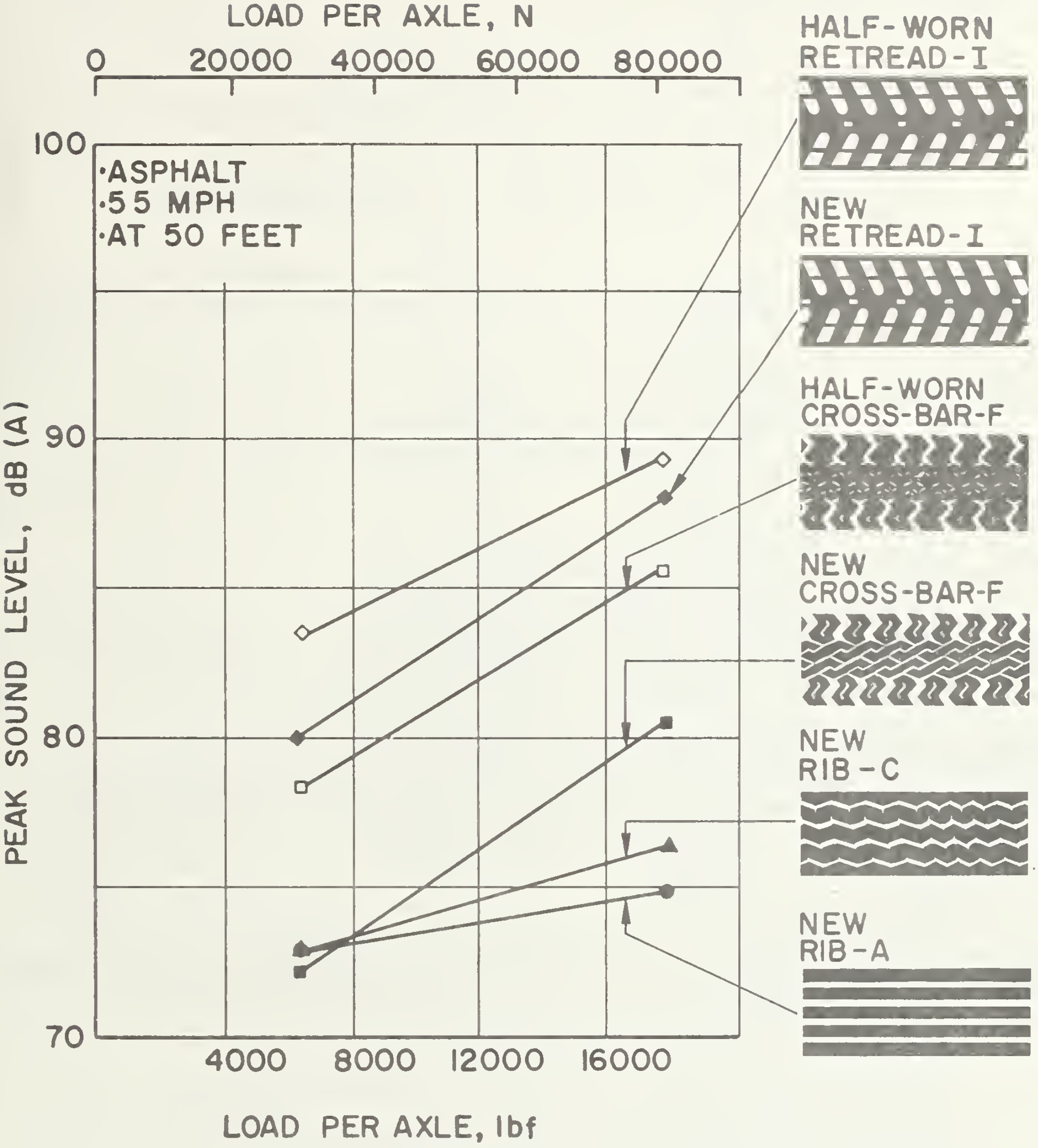


Figure 36. Peak A-weighted sound level, as measured at 50 feet, versus the load on the drive axle. The single-chassis vehicle was running at 55 mph on an asphalt surface.

The results of the neutral rib (rib-A) base tests are presented in Figure 37. The variable tires in this case were rib-C, cross-bar-F, and retread-I. The mounting configurations for the four groupings on the bar chart are as follows:

1. neutral rib tires at both positions
2. neutral rib tires at the outside position and either rib-C, cross-bar-F, or retread-I at the inside position
3. neutral rib tires at the inside position and either rib-C, cross-bar-F, or retread-I at the outside position
4. rib-C, cross-bar-F, or retread-I tires at both positions.

A review of the data shows that in all cases there was a reduction in the overall sound level when a "quieter" tire was mounted outboard of a "noisy" tire. In some cases, e.g., retread-I, the decrease in overall sound level was very significant.

Figure 38 presents the results for the testing which utilized rib-C as the baseline tire. For these tests the mounting configuration and variable tires were as follows:

1. rib-C tires at both positions
2. rib-C tires at the outside position and either cross-bar-F or retread-I tires at the inside position
3. rib-C tires at the inside position and either cross-bar-F or retread-I tires at the outside position
4. cross-bar-F or retread-I tires at both positions.

This test situation is a little more germane to the "real world" since all of the tires utilized are typically seen on over-the-road trucks. (The neutral rib tires are not usually seen on trucks and when they are, they would strictly be utilized as steering tires).

To complete the mix-and-match test program, runs were made which utilized cross-bar-F tires as the baseline (see Figure 39). For this series of runs the variable tire was the pocket retread-I mounted in the following configurations:

1. cross-bar-F tires at both positions
2. cross-bar-F tires at the outside position and retread-I tires at the inside position
3. cross-bar-F tires at the inside position and retread-I tires at the outside position
4. retread-I tires at both positions.

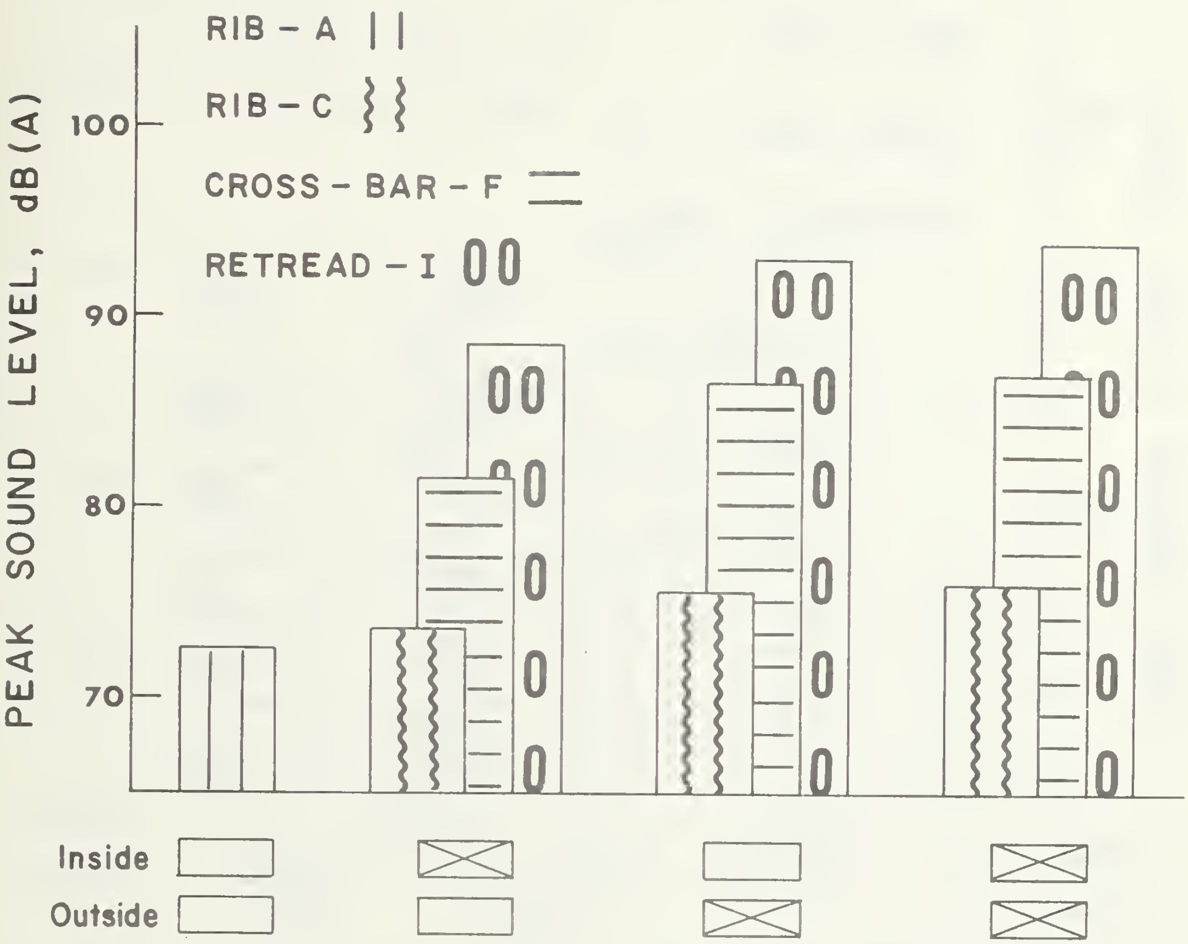


Figure 37. Peak A-weighted sound level for various mounting configurations of selected baseline and variable test tires. The test tires were mounted on the inside and outside positions on the right side of the drive axle (side nearest the microphone array). Below each of the four groupings on the bar chart are two rectangles labelled inside and outside which correspond to the mounting positions. An unmarked rectangle indicates that the baseline tire is mounted in that position. An X in the rectangle indicates that the variable tire is mounted at that position. The baseline tire in this case is rib-A (neutral rib) while the variable tires are rib-C, cross-bar-F, and retread-I. The tires were mounted on the loaded single-chassis vehicle which ran on a concrete surface at a nominal speed of 60 mph. Neutral rib (rib-A) tires were mounted at all other axle positions.

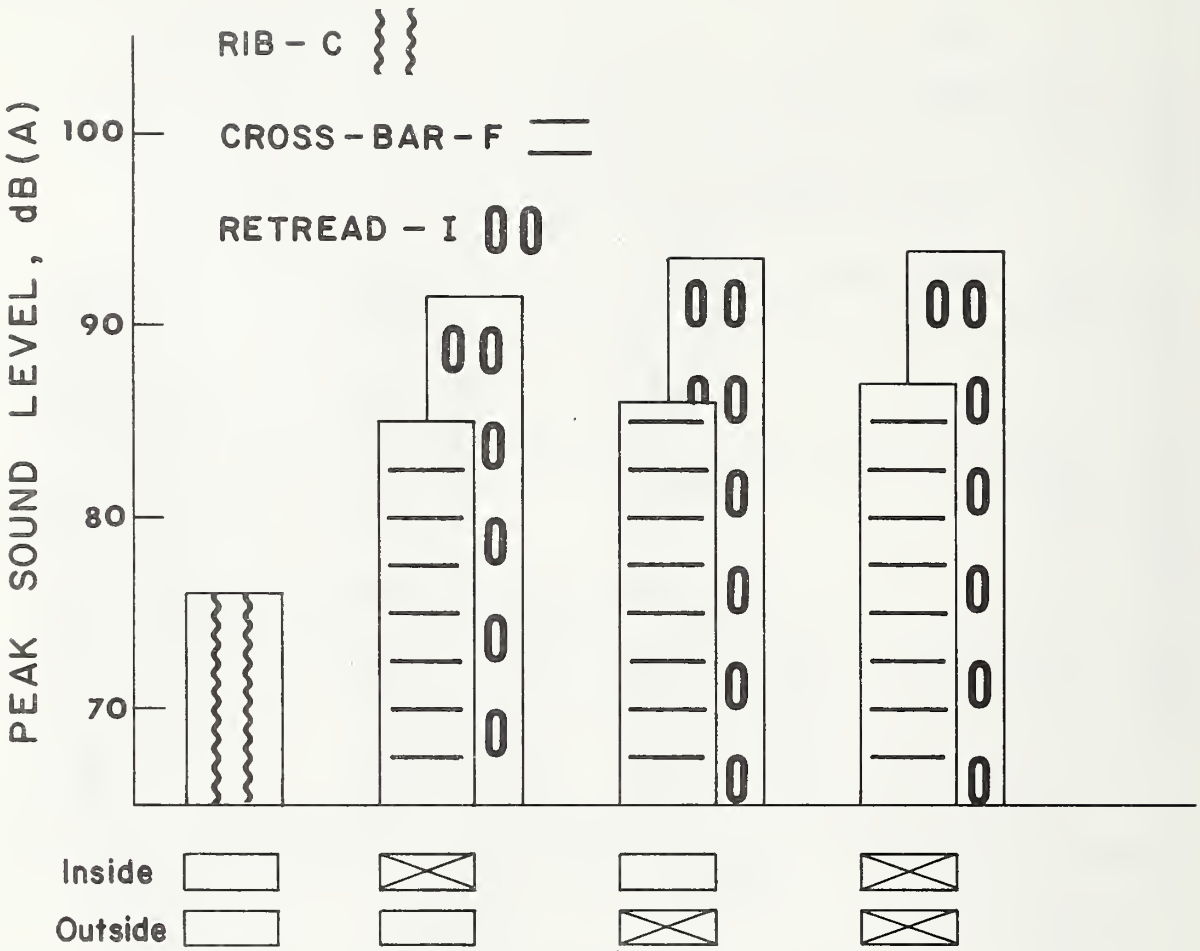


Figure 38. Peak A-weighted sound level for various mounting configurations of selected baseline and variable test tires. The test tires were mounted on the inside and outside positions on the right side of the drive axle (side nearest the microphone array). Below each of the four groupings on the bar chart are two rectangles labelled inside and outside which correspond to the mounting positions. An unmarked rectangle indicates that the baseline tire is mounted in that position. An X in the rectangle indicates that the variable tire is mounted at that position. The baseline tire in this case is rib-C while the variable tires are cross-bar-F and retread-I. The tires were mounted on the loaded single-chassis vehicle which ran on a concrete surface at a nominal speed of 60 mph. Neutral rib (rib-A) tires were mounted at all other axle positions.

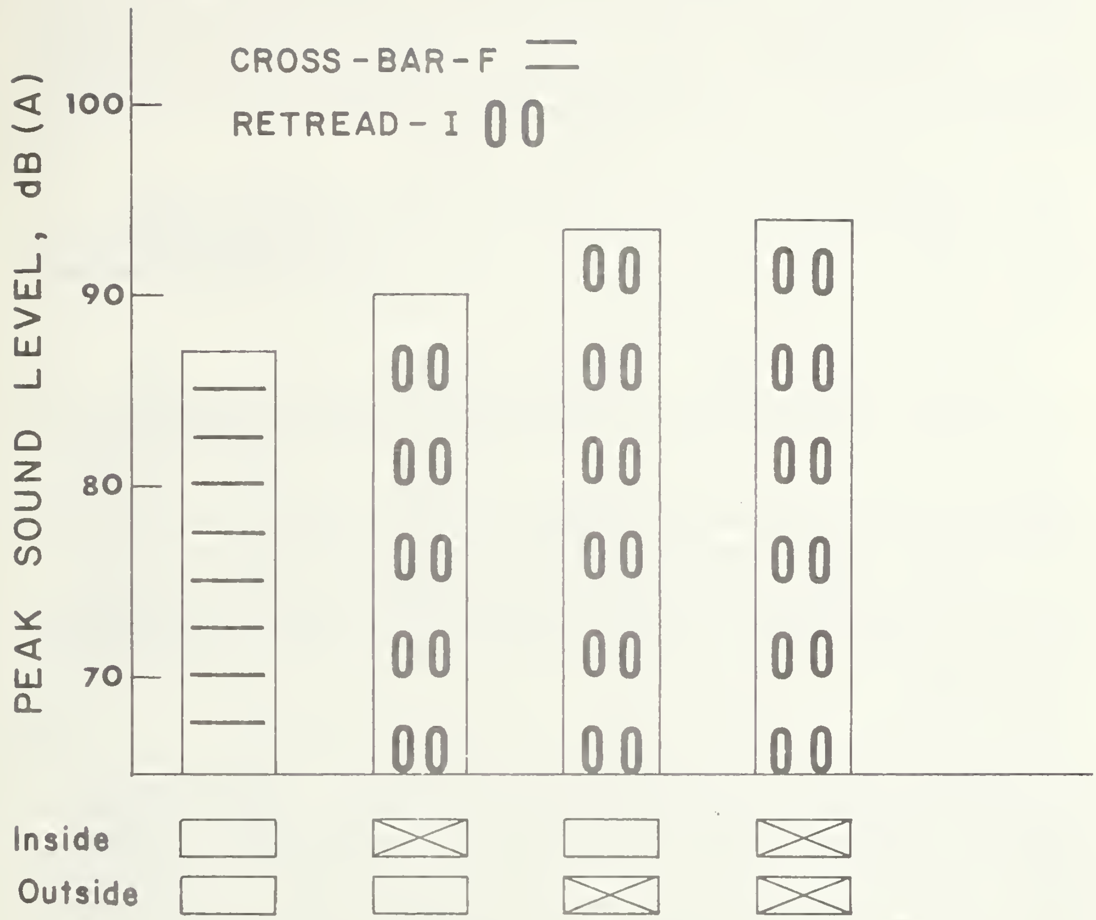


Figure 39. Peak A-weighted sound level for various mounting configurations of selected baseline and variable test tires. The test tires were mounted on the inside and outside positions on the right side of the drive axle (side nearest the microphone array). Below each of the four groupings on the bar chart are two rectangles labelled inside and outside which correspond to the mounting positions. An unmarked rectangle indicates that the baseline tire is mounted in that position. An X in the rectangle indicates that the variable tire is mounted at that position. The baseline tire in this case is cross-bar-F while the variable tire is retread-I. The tires were mounted on the loaded single-chassis vehicle which ran on a concrete surface at a nominal speed of 60 mph. Neutral rib (rib-A) tires were mounted at all other axle positions.

b. Tractor-Trailer Testing

The tractor-trailer test matrix was more complex to develop since there existed eighteen possible tire positions. A test matrix with two distinct parts was developed (see Table 2). First the test tires were mounted on the tractor drive axles while the steering and trailer axle tires were held constant. Then the steering and drive axle tires were held constant and the trailer tires were varied.

Only a limited portion of the tractor-trailer test matrix was completed. Eleven conditions were run, all on a concrete surface, and these are marked by asterisks on Table 2. All runs utilized a loaded test vehicle with the following weight distribution:

Gross Vehicle Weight - 65,080 pounds
Load on Drive Axles - 14,500 pounds (1812.5 lb/tire)
Load on Trailer Axles - 13,420 pounds (1677.5 lb/tire)

Figure 40 shows the peak A-weighted sound level versus speed for the four different tire tread designs mounted on the tractor drive axles. As was the case in single-chassis vehicle testing, the ranking from highest to lowest noise level was (a) pocket retread, (b) cross-bars, and (c) ribs, respectively. New retread-G control tires were mounted on the trailer axles and new neutral rib (rib-A) control tires were on the steering axle.

The trailer test program (runs 12-17 of the matrix) was quite similar to the single-chassis vehicle mix-and-match program. Six different combinations were tested with either two or four new retread-I test tires used in conjunction with new retread-G control tires. The exact locations of each tire type are shown in the test matrix. New neutral rib (rib-A) tires were mounted on the steering axle and new cross-bar-D tires on the drive axles. As the vehicle passed the microphone array, the right side of the truck was nearest the array. The highest A-weighted sound level (see Figure 41) was produced by the configuration in which the four pocket retread (retread-I) test tires were mounted on the rear trailer axle. The configuration with four pocket retread tires on the front trailer axle and the two conditions where two pocket retread tires were mounted on the right side on the front and rear trailer axles respectively, all produced approximately the same overall level. The lowest levels were produced when the test tires were mounted on the left side of the vehicle (away from the microphones).

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

Table 2. The proposed tractor-trailer test matrix. Each of the eighteen tire tread combinations were to be run on both a concrete and an asphalt surface at speeds of 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. Each tread design is letter coded in accordance with the designations shown in Figure 7. The numbers associated with the tire tread code designate the state of wear as either new (1-10), half-worn (11-20), or fully-worn (21-30). For example, F-11 would be a half-worn cross-bar-F tire. The tire positions on the vehicle 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 drive axle position on the outside. Completed runs are marked with asterisks.

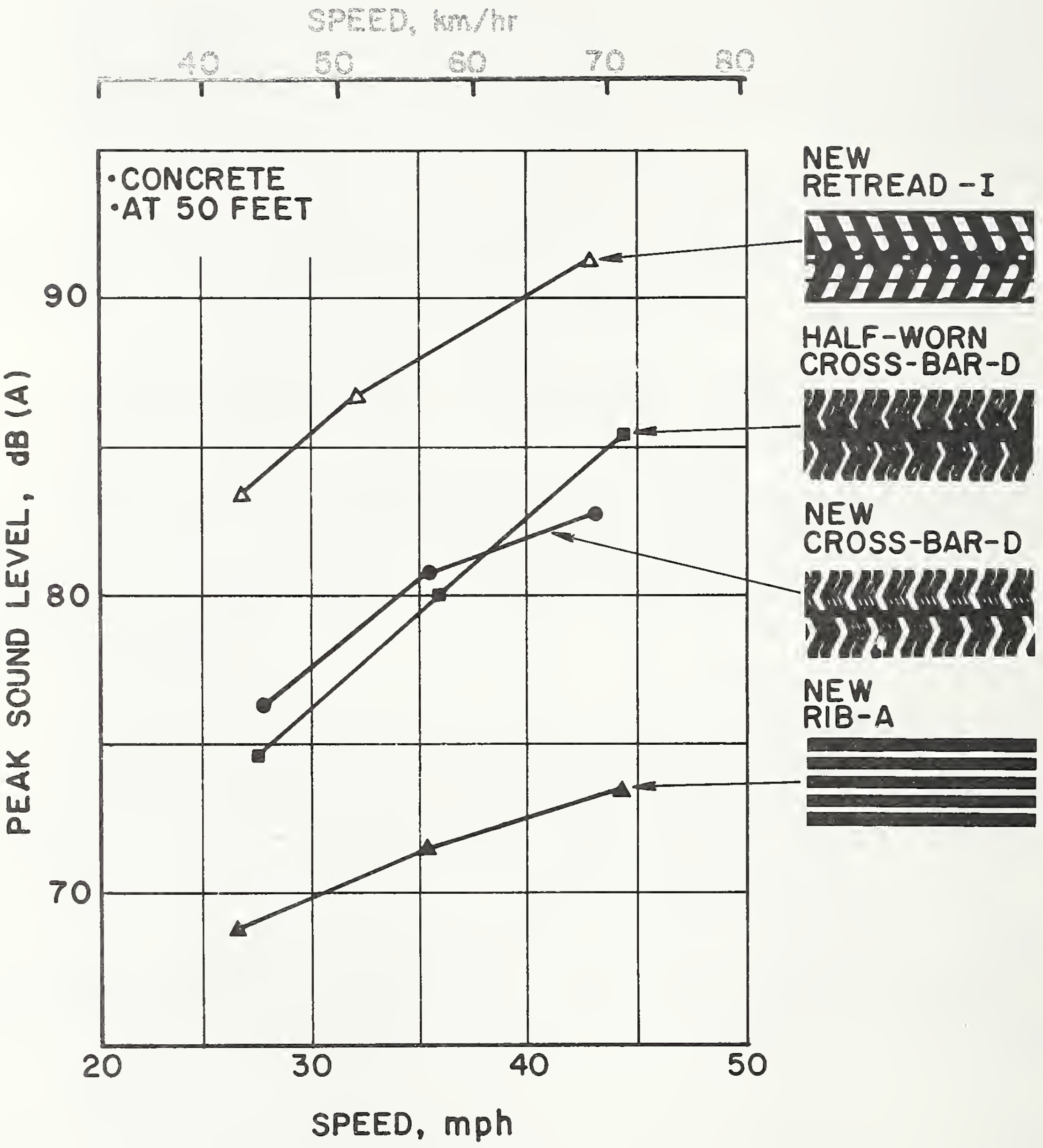


Figure 40. Peak A-weighted sound level, as measured at 50 feet, versus speed for a tractor-trailer running on a concrete surface. The various tires shown were mounted on the tractor drive axles with control tires (identified in the text) mounted on the trailer and steering axles.

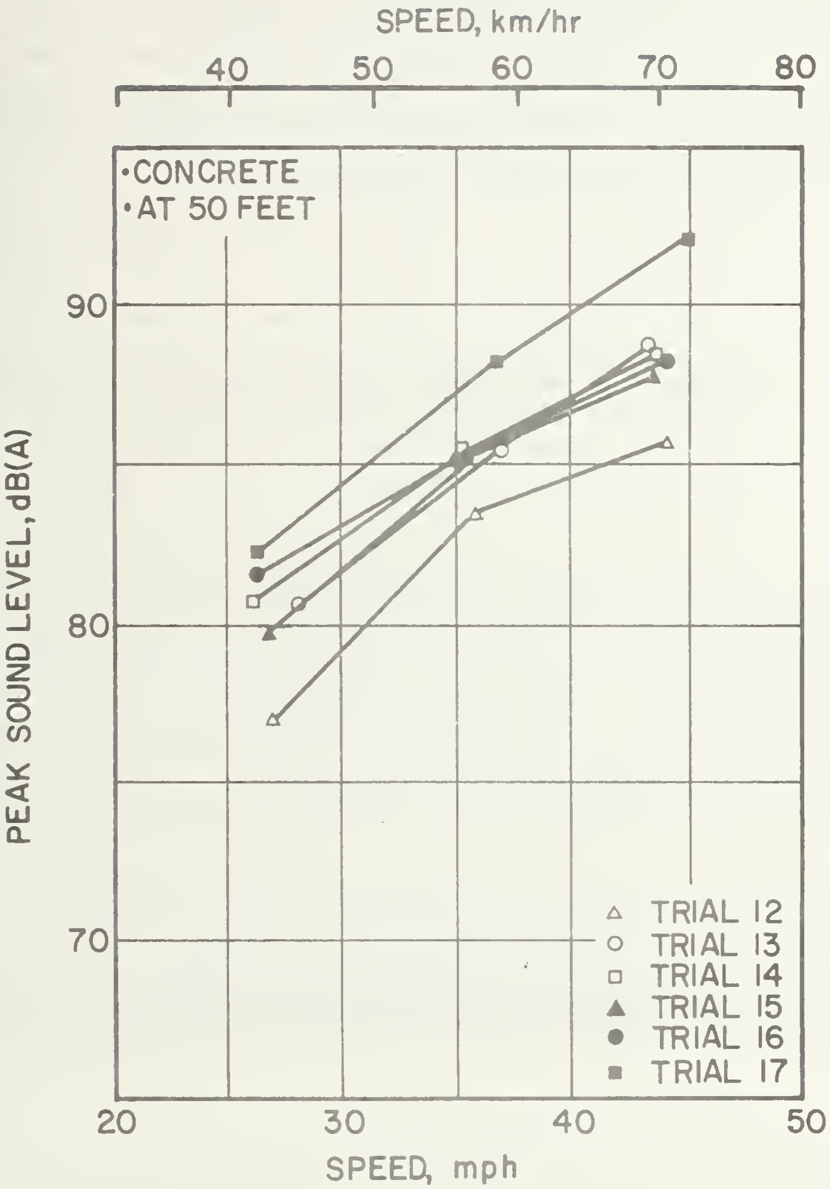


Figure 41. Peak A-weighted sound level, as measured at 50 feet, versus speed for the tractor-trailer running on a concrete surface. Various combinations of retreads I and G were mounted on the trailer axles (see table 2 for exact configurations). Control tires (identified in the text) were mounted on the steering and drive axles.

Due to the limited number of runs, the low maximum attainable speed of 45 mph, and the fact that the tires were run on only one surface, many questions remain unanswered. For instance, four new retread-I tires mounted across the rear trailer axle generated almost the identical peak A-weighted sound levels as eight new retread-I tires mounted on the tractor drive axles. It is anticipated that the possible masking effect which the trailer seems to have on the noise radiated from the tires mounted on the drive axles will be better understood once the directionality contour plots have been completed and once more data can be taken and evaluated during the upcoming second phase of field testing.

4. Appendix A

Parametric Study Results

The inventory or "catalog" of data on the noise generated by typical rib, cross-bar, and retread truck tires is presented in both tabular and graphical form. Test results for the single-chassis vehicle (when tires with identical tread designs were mounted on the drive axle) and tractor-trailer are presented on computer-generated plots showing peak A-weighted sound level versus microphone distance and vehicle speed. As defined previously, microphone distance was measured from the centerline of the lane in which the truck travelled. The vehicle speed, in this case, was the average speed of the truck while travelling over the 1000 foot test section. The data for single-chassis vehicle (mix-and-match) are presented as peak A-weighted sound level versus distance only since all test runs were made at one speed (nominally 60 mph). These plots were not computer generated. The peak sound levels are "as measured" (no corrections applied to account for windscreens and microphone directionality) and are not coincident in time (peaks at each microphone do not occur at the same time due to time of flight considerations and the directionality of the source).

For plots of peak A-weighted sound level versus distance (distance on a logarithmic scale) a straight line was fitted to the data for the microphones between 25 feet and 130 feet using the method of least squares. The change in sound level for a doubling of the distance for each curve is also presented. As an aid to the eye, a smooth curve was drawn through the data at a particular microphone location for peak A-weighted sound level versus vehicle speed to show the general trends. No theoretical significance should be attached to the shape of these curves.

Each figure in this appendix is composed of a data page in addition to each of the graphs. This page contains the tabulated sound level values plus additional information associated with the characteristics of the test tires. A discussion follows which presents additional detailed information necessary for a clearer understanding of the data presented.

a. Single-Chassis Vehicle

The results for the completed test runs of the single-chassis vehicle test matrix (Table 1) are presented in both tabular and graphical form in Figures A-1 through A-54. As stated previously, tires with identical tread designs were mounted on the drive axle of the test vehicle either in dual pairs or singly. These were the test tires. New neutral rib (rib-A) control tires were mounted on the steering axle for all tests.

Each figure is comprised of two separate facing pages. One page contains computer-generated plots of peak A-weighted sound level versus both vehicle speed and microphone distance. To ensure clear presentation only every other speed was plotted on the graphs of peak sound level versus distance. The accompaning page presents the tabulated values of the peak A-weighted sound levels as measured at the six microphone locations during passbys at seven different speeds. This matrix of forty-two values formed the basis for the graphical plots. Also included is a tire footprint of one of the actual test tires utilized showing the characteristic tread element pattern in its given state of wear. The specific tread design and associated degree of wear are defined in the title at the top of the page. Also defined are the loading condition, the pavement surface on which the tires ran, and information as to whether the tires were mounted in dual pairs or singly. Tread depth and Shore hardness readings were taken for each test tire and are tabulated according to the tire location on the drive axle of the vehicle.

The coding used to designate tire locations on the single-chassis vehicle is as follows: The first letter gives the side of the truck, right (R) or left (L), the second letter designates either the front steering (F) or the rear drive (R) axle, and the third letter indicates either the inside (I) or outside (O) position of a dual pair. For example, the right, rear, inside position would be coded RRI. To provide some information regarding the attenuation of the tire noise with distance, the change in sound level associated with a doubling of the distance (dB/distance doubling) for the data at each test speed is presented.

The single-chassis truck also served as the test vehicle for the mix-and-match test phase during which tires with different tread designs were mounted on the drive axle. Throughout this phase the test vehicle operated at a nominal speed of 60 mph while running on a concrete surface. Since the right side of the truck was nearest the microphone array, the test tires were mounted at the right inside and outside drive-axle positions with new neutral rib (rib-A) control tires mounted on the steering axle and at the left drive-axle positions. Figures A-55 through A-60 are plots of the peak A-weighted sound levels versus distance for the following four sequences of tire combinations: (1) dual baseline tire; (2) baseline tire outside with variable tire inside; (3) baseline tire inside with variable tire outside; and (4) dual variable tire. The following chart defines the baseline and variable tires utilized.

Variable / Baseline	New Rib C	Half-Worn Cross-bar-F	New Retread-I
New Rib-A	X	X	X
New Rib-C		X	X
Half-worn Cross-bar-F			X

The accompaning data pages provide the vehicle speed, tire characteristics of the two test tires (tread depth and Shore hardness), and the value of the peak A-weighted sound levels corresponding to each microphone location. Footprints of the baseline and variable tires are also shown. These plots were not computer-generated.

b. Tractor-Trailer

The results for the eleven completed test runs of the tractor-trailer test matrix (Table 2) are presented in Figures A-61 through A-71. These eleven runs fall into three categories: (1) test tires mounted on drive axles (trials 1, 2, 3, and 10); (2) test tires mounted on trailer axles (trials 12-17); and (3) test tires mounted on both tractor drive axles and trailer axles (trial 18). Control tires were mounted at all other axle positions.

Utilizing a data presentation similar to that used for the single-chassis vehicle results, the tractor-trailer data are presented as computer-generated plots of peak A-weighted sound level versus both vehicle speed and microphone distance. The tabulated values of the peak A-weighted sound levels, the changes in sound level corresponding to a doubling of the distance, and the tread depth and Shore hardness of the tires in their appropriate axle positions are presented on an accompaning page. The tire positions on the tractor-trailer are letter coded. The first letter represents either the right (R) or left (L) side of the test vehicle, the second either the front (F) or rear (R) axle, the third either the drive axle (D) or the trailer axle (T), and the fourth either the inside (I) or outside (O) position. Thus, LFDO would represent the left forward drive axle position on the outside.

RIB-A, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 30.1	34.4	38.9	53.2	55.3
6	78.4	80.2	80.6	85.4	85.4
12	75.2	77.6	77.0	82.0	82.0
25	70.2	72.0	72.8	76.8	77.0
50	63.8	65.0	67.6	72.0	72.6
80	63.6	63.8	65.6	69.0	69.6
130	58.4	59.8	61.2	66.6	67.0

SPEED	30.1	34.4	38.9	53.2	55.3
DB/DOUBLING	4.61	4.91	4.72	4.33	4.23

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	15 15 15 15	A/61/5
LRI	15 15 15 15	A/61/5
RRO	15 15 15 15	A/60/5
RRI	15 15 15 15	A/60/5

NOMINAL NEW TREAD DEPTH - 15/32INCH

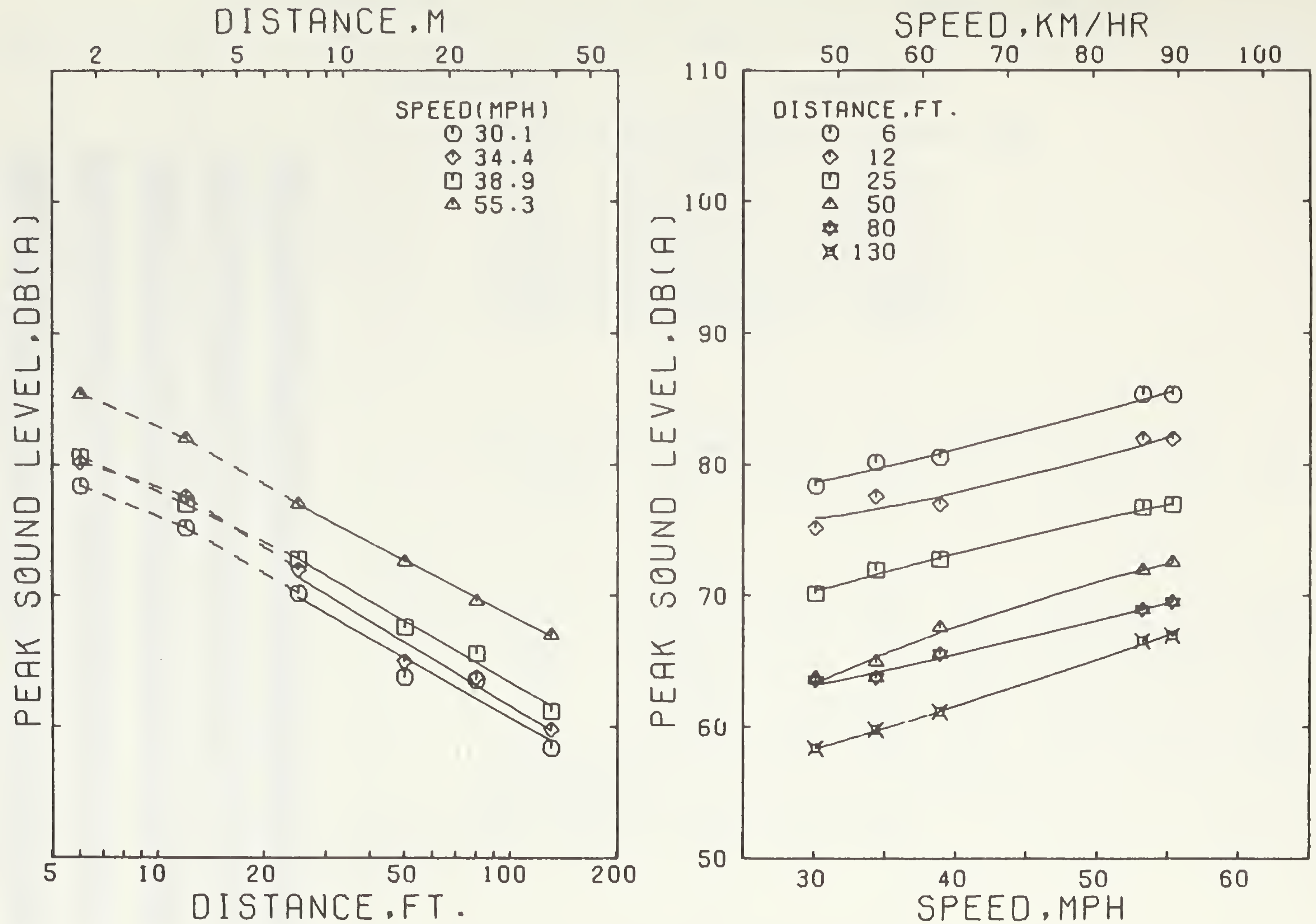
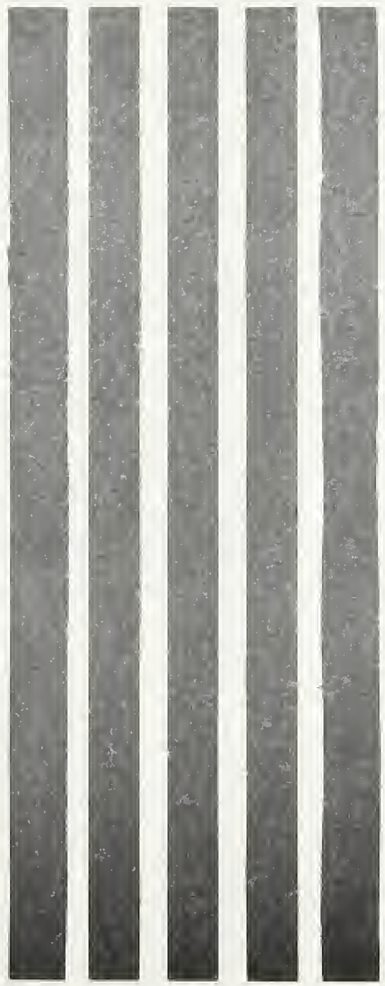


Figure A-1. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib (rib-A) tires on the steering axle and dual, new, neutral rib tires on the drive axle.



RIB-A, NEW, DUAL, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 31.0	36.7	40.4	45.1	49.6	53.9	56.0
6	77.2	79.2	80.4	82.2	83.6	84.8	85.6
12	74.4	76.2	77.2	79.0	80.8	80.6	81.4
25	68.2	69.8	73.2	73.0	76.4	75.2	75.4
50	62.6	64.6	67.4	68.0	68.8	71.2	71.0
80	60.6	61.4	53.4	64.8	66.8	68.0	68.4
130	56.0	58.6	60.0	62.0	62.4	63.4	63.8

SPEED	31.0	36.7	40.4	45.1	49.6	53.9	56.0
DB/DOUBLING	4.95	4.73	5.59	4.65	5.70	4.89	4.76

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	15 15 15 15	A/61/5
LRI	15 15 15 15	A/61/5
RRO	15 15 15 15	A/60/5
RRI	15 15 15 15	A/60/5

NOMINAL NEW TREAD DEPTH - 15/32 INCH

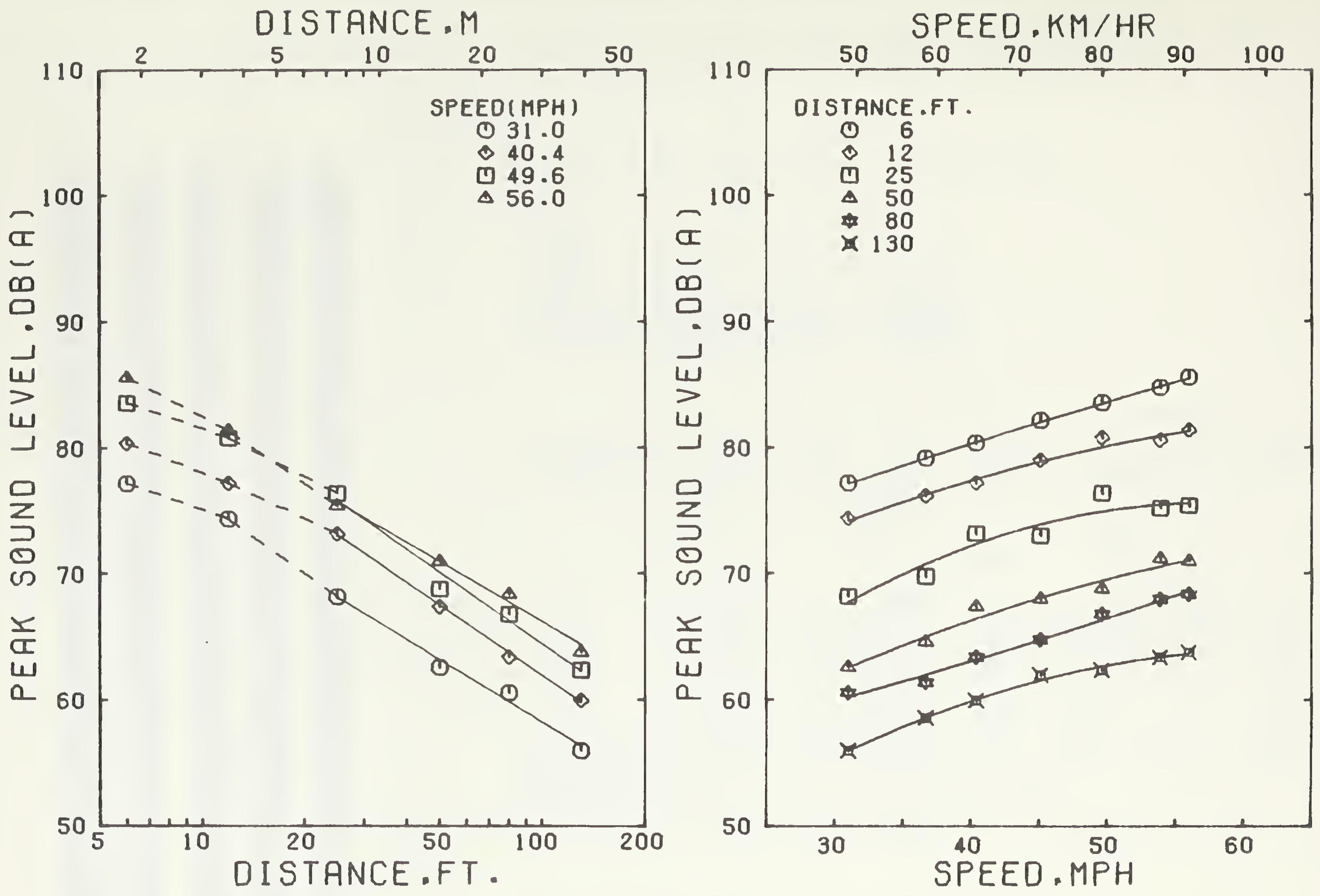


Figure A-2. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib (rib-A) tires on the steering axle and dual, new, rib-A tires on the drive axle.

RIB-A, NEW, SINGLE, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE	SPEED,MPH						
LOCATION,FT	32.1	34.0	41.4	51.3	51.9	55.0	58.0
6	75.6	77.0	80.4	81.6	81.6	82.8	83.4
12	72.2	74.6	75.8	77.8	78.4	79.8	81.0
25	66.8	69.0	71.2	73.0	73.6	75.6	74.8
50	62.0	64.8	65.4	68.8	68.6	69.8	70.4
80	59.2	60.6	62.8	65.8	65.6	66.4	66.4
130	55.4	57.4	58.6	61.8	62.6	63.2	64.0

SPEED	32.1	34.0	41.4	51.3	51.9	55.0	58.0
DB/DOUBLING	4.73	4.96	5.19	4.66	4.62	5.22	4.66

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO LRI	15 15 15 15	A/60/5
RRO RRI	15 15 15 15	A/60/5

NOMINAL NEW TREAD DEPTH - 15/32 INCH

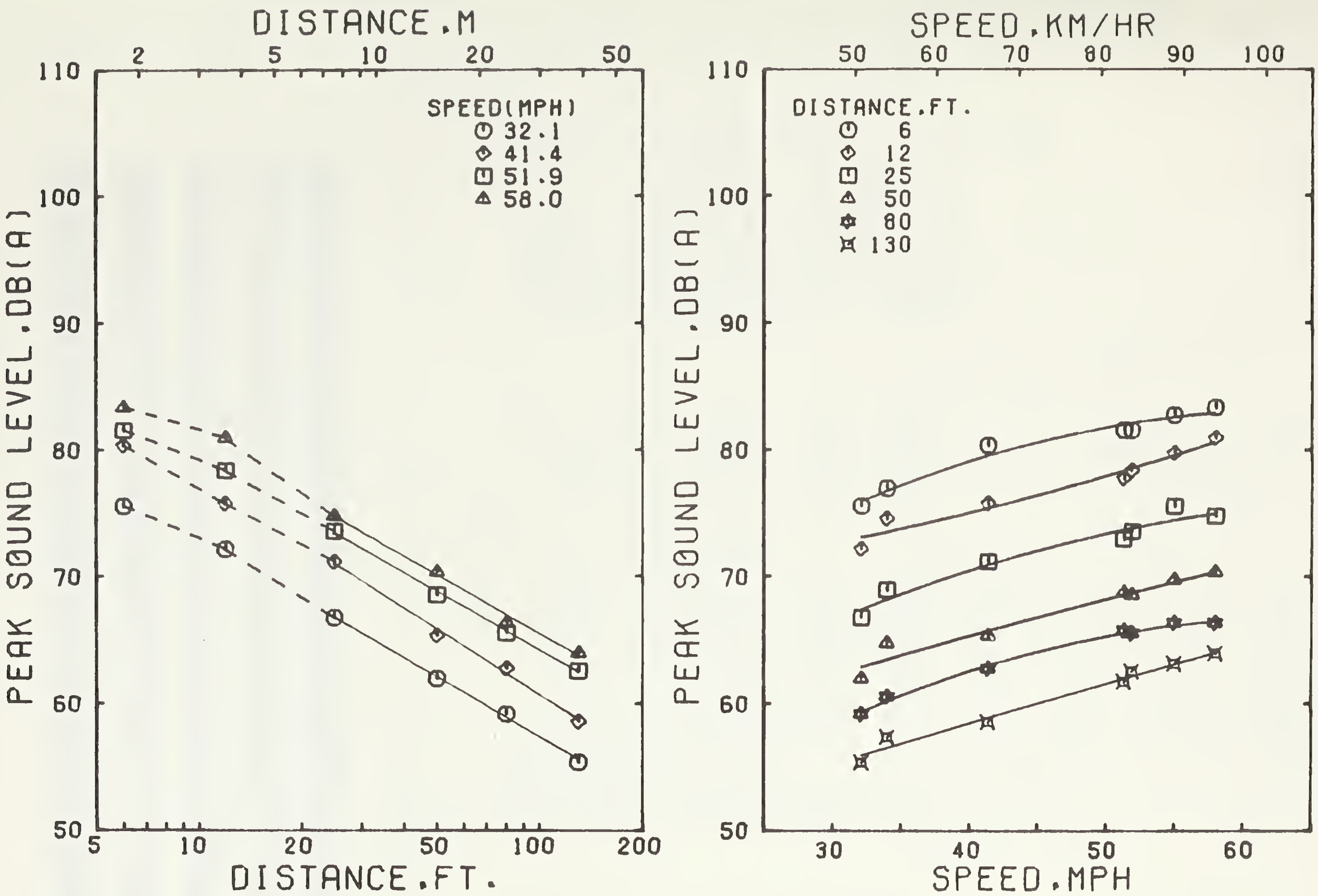
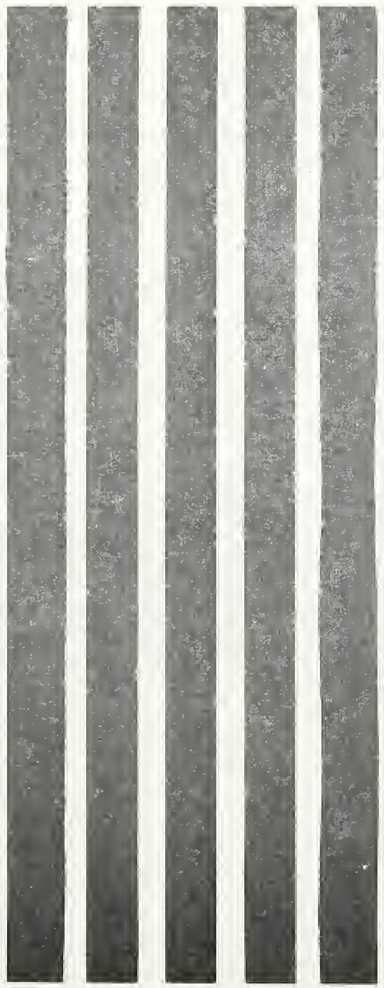


Figure A-3. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib (rib-A) tires on the steering axle and single, new, rib-A tires on the drive axle.



RIB-A, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	31.2	36.3	39.3	44.6	52.0	55.2	60.6
6	80.0	82.4	82.6	84.6	86.4	88.6	89.4
12	75.2	79.6	79.4	82.8	82.0	85.4	87.0
25	71.8	73.4	75.2	77.0	79.4	80.4	81.2
50	67.0	68.2	69.2	71.8	74.2	74.6	76.2
80	64.2	64.8	67.0	68.8	71.6	72.2	74.0
130	61.8	60.8	62.8	65.0	68.0	69.0	71.4

SPEED	31.2	36.3	39.3	44.6	52.0	55.2	60.6
DB/DOUBLING	4.23	5.27	5.07	5.00	4.72	4.73	4.08

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	15 15 15 15	A/61/5
LRI	15 15 15 15	A/61/5
RRO	15 15 15 15	A/60/5
RRI	15 15 15 15	A/60/5

NOMINAL NEW TREAD DEPTH - 15/32 INCH

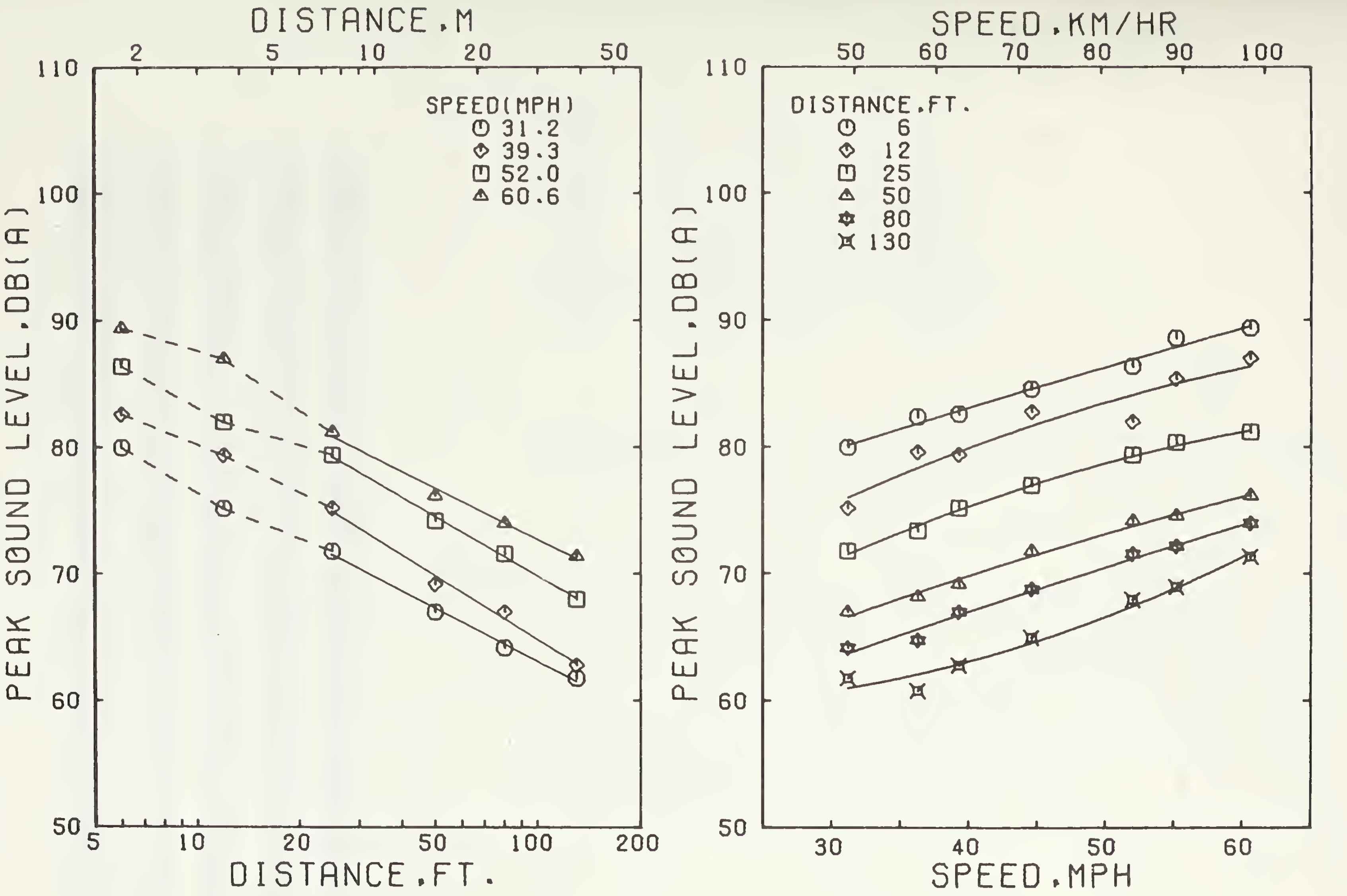
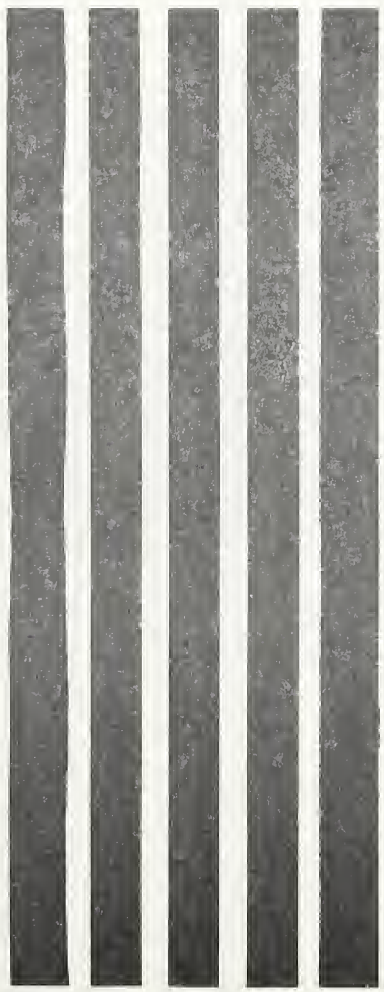


Figure A-4. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib (rib-A) tires on the steering axle and dual, new, rib-A tires on the drive axle.

RIB-A, NEW, DUAL, UNLOADED, ASPHALT



A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 31.3	35.0	39.6	45.3	49.8	55.1	57.4
6	78.4	80.6	83.0	83.4	85.2	86.6	87.4
12	75.6	78.2	79.8	81.0	81.8	83.4	84.0
25	69.2	70.8	73.2	74.6	75.8	78.2	78.2
50	64.2	66.6	68.4	69.4	70.8	72.8	73.4
80	61.8	63.0	64.4	66.0	69.0	69.4	69.2
130	58.0	60.4	61.0	64.6	64.6	67.2	66.6

SPEED	31.3	35.0	39.6	45.3	49.8	55.1	57.4
DB/DOUBLING	4.62	4.45	5.18	4.33	4.54	4.70	4.99

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	15 15 15 15	A/61/5
LRI	15 15 15 15	A/61/5
RRO	15 15 15 15	A/60/5
RRI	15 15 15 15	A/60/5

NOMINAL NEW TREAD DEPTH - 15/32 INCH

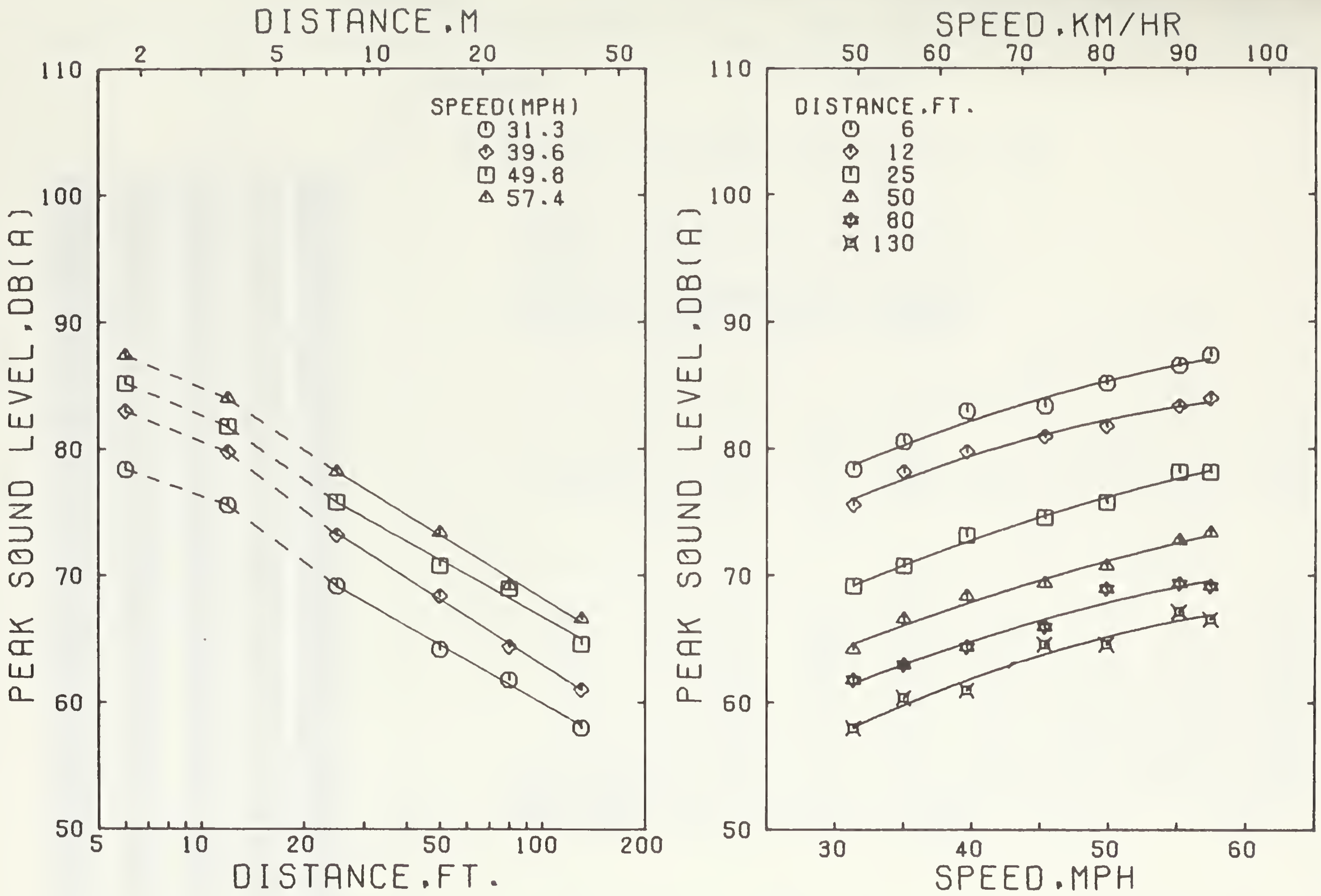
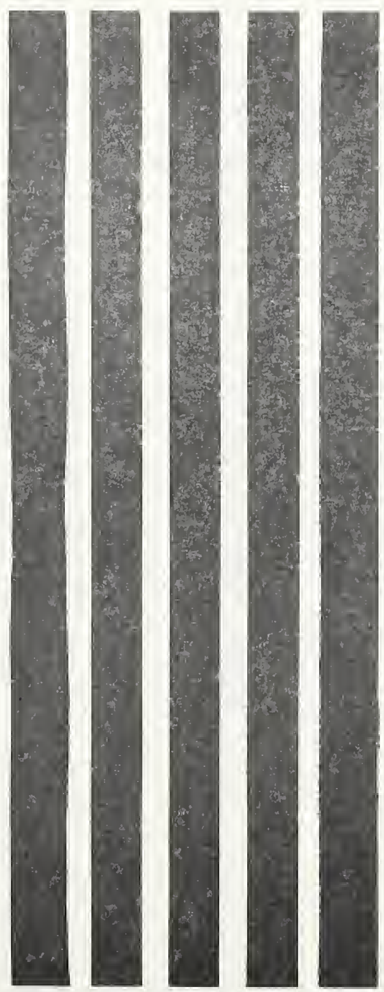


Figure A-5. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib (rib-A) tires on the steering axle and dual, new, rib-A tires on the drive axle.



RIB-A, NEW, SINGLE, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE	SPEED,MPH						
LOCATION,FT	30.4	35.6	40.4	45.3	50.6	54.3	57.5
6	79.0	81.8	82.2	84.0	86.6	88.2	88.4
12	76.8	78.8	80.2	82.6	83.4	85.0	86.0
25	71.0	73.8	74.4	76.6	78.0	80.0	81.4
50	64.2	67.4	69.4	71.4	73.2	73.8	76.6
80	60.6	64.2	65.6	67.2	68.8	69.6	72.4
130	61.8	60.2	61.2	62.2	65.2	68.4	68.4

SPEED	30.4	35.6	40.4	45.3	50.6	54.3	57.5
DB/DOUBLING	4.14	5.66	5.53	6.02	5.45	5.06	5.50

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	15 15 15 15	A/60/5
LRI		
RRO	15 15 15 15	A/60/5
RRI		

NOMINAL NEW TREAD DEPTH - 15/32 INCH

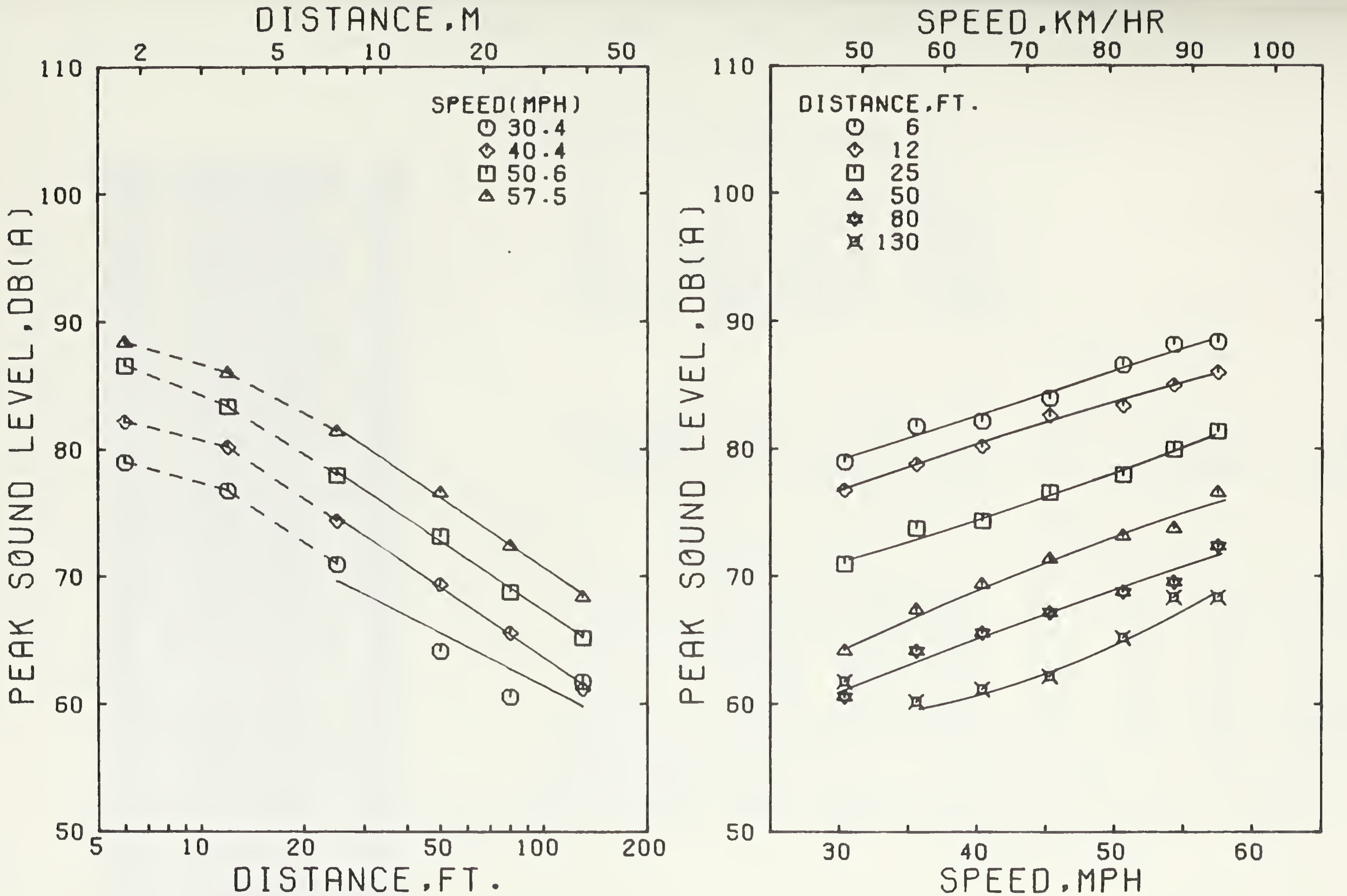


Figure A-6. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib (rib-A) tires on the steering axle and single, new, rib-A tires on the drive axle.

RIB-B, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH						
	29.4	33.5	38.9	45.1	47.5	55.1	56.6
6	78.0	82.3	83.0	85.4	86.2	88.4	88.2
12	75.4	73.9	80.8	81.8	81.6	86.4	85.2
25	69.8	73.6	74.4	78.8	76.8	80.8	80.4
50	65.0	68.4	70.6	73.6	72.2	77.0	76.0
80	62.4	64.8	67.0	70.6	70.0	72.2	72.0
130	57.4	61.0	63.2	65.2	65.4	69.4	70.6

SPEED	29.4	33.5	38.9	45.1	47.5	55.1	56.6
DB/DOUBLING	5.07	5.29	4.72	5.57	4.64	4.95	4.30

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	19 19 19 19	A/62/5
LRI	19 19 19 19	A/62/5
RRO	19 19 19 19	A/62/5
RRI	19 19 19 19	A/62/5

NOMINAL NEW TREAD DEPTH - 19/32 INCH

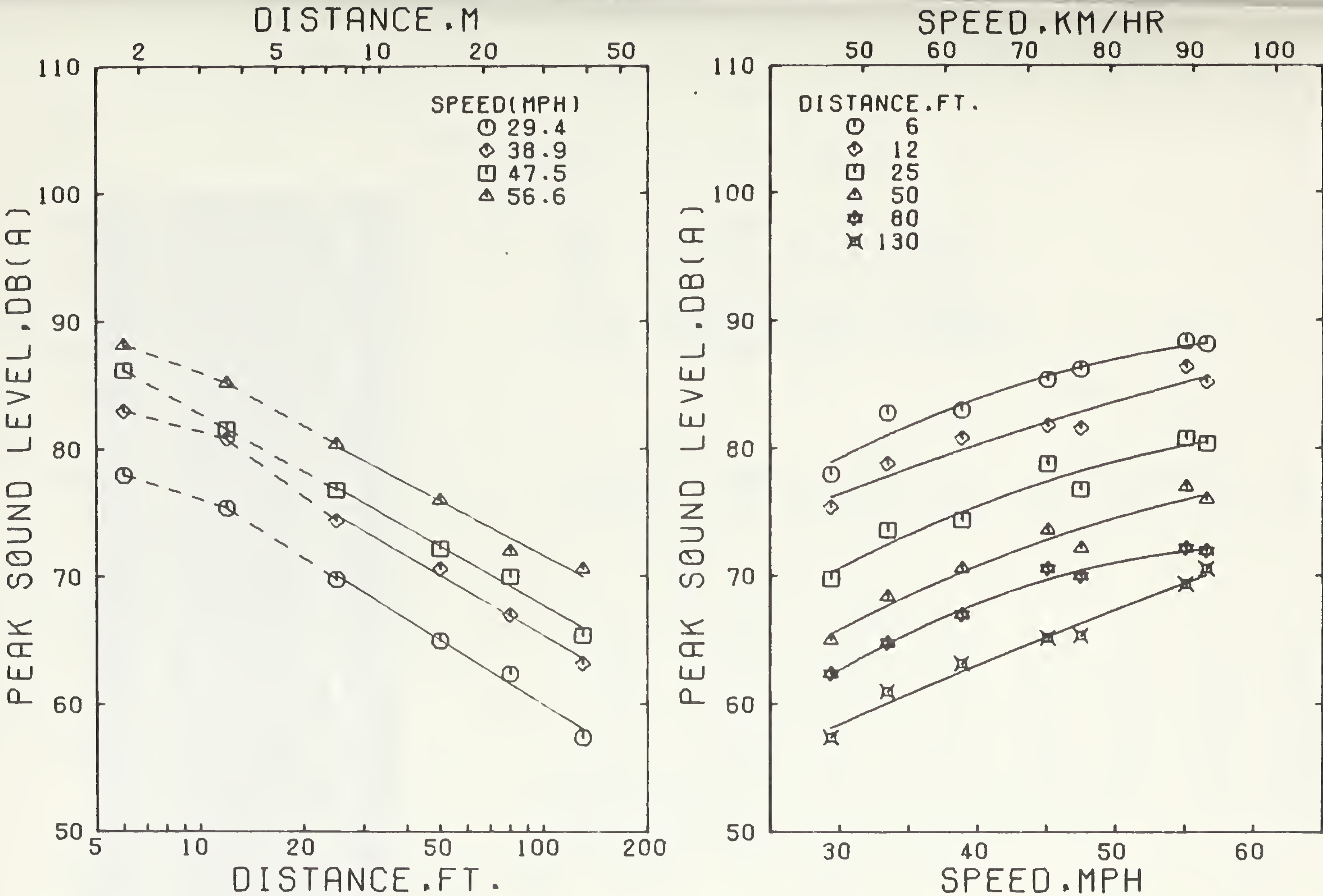


Figure A-7. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, rib-B tires on the drive axle.

RIB-B, HALF-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	28.0	33.0	38.0	43.3	48.2	53.5	56.6
6	78.8	82.2	85.8	89.8	90.8	91.2	93.0
12	75.6	79.8	83.0	86.0	86.8	89.0	92.4
25	72.2	74.8	77.4	80.0	82.4	85.0	86.8
50	66.2	70.6	73.0	75.2	77.8	80.8	61.2
80	63.0	68.4	69.0	72.4	74.8	77.2	78.4
130	*****	*****	*****	*****	*****	*****	*****

SPEED	28.0	33.0	38.0	43.3	48.2	53.5	56.6
DB/DOUBLING	5.52	3.84	4.96	4.55	4.53	4.61	5.05

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	10	10	10	10	A/65/5
LRI	11	11	11	11	A/63/5
RRO	12	12	12	12	A/65/5
RRI	10	10	10	10	A/65/5

NOMINAL NEW TREAD DEPTH - 19/32 INCH

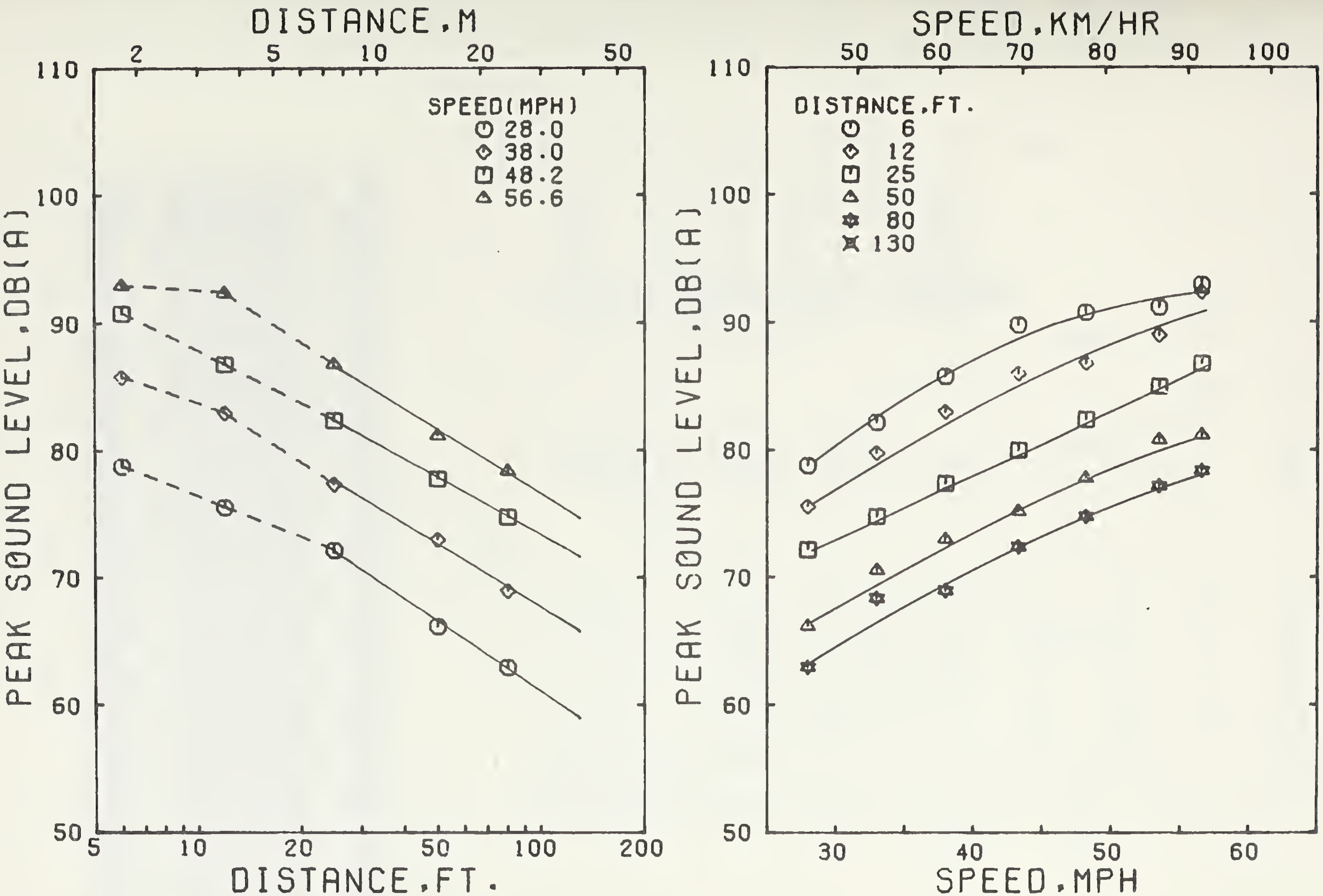


Figure A-8. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, rib-B tires on the drive axle.

RIB-B, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.5	34.7	38.4	43.7	48.8	53.2
6	79.6	83.0	88.5	91.4	87.0	90.8
12	75.8	82.0	84.6	84.6	86.0	88.6
25	71.6	76.4	76.0	79.4	78.8	82.4
50	66.6	70.6	70.2	74.2	74.8	76.8
80	62.0	65.8	66.2	69.8	70.4	73.2
130	56.6	60.6	60.4	67.0	63.6	67.4

SPEED	29.5	34.7	38.4	43.7	48.8	58.2
DB/DOUBLING	6.29	6.54	6.46	5.33	6.28	6.18

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	19 19 19 19	A/62/5
LRI	19 19 19 19	A/62/5
RRO	19 19 19 19	A/62/5
RRI	19 19 19 19	A/62/5

NOMINAL NEW TREAD DEPTH - 19/32 INCH

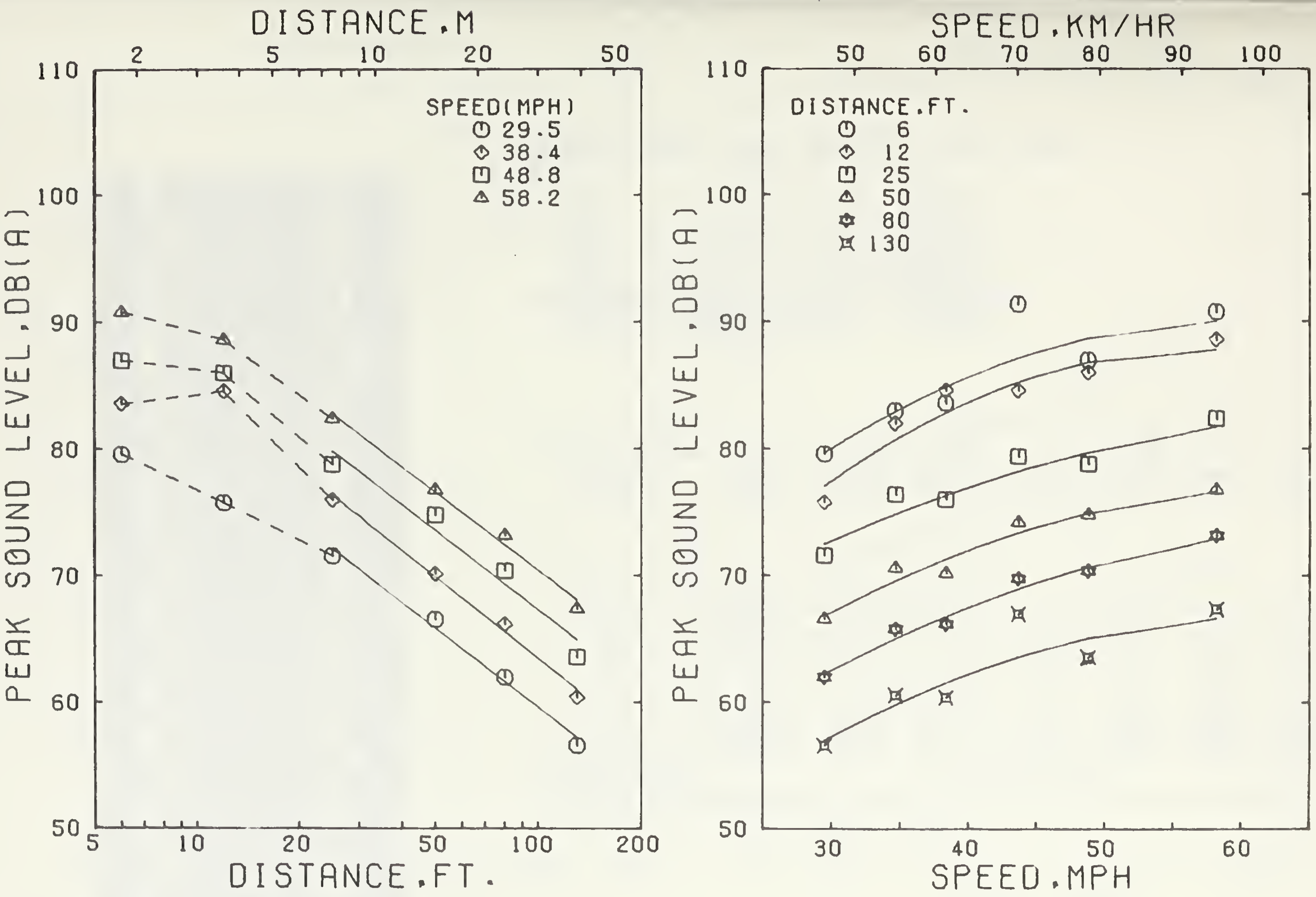


Figure A-9. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, rib-B tires on the drive axle.

RIB-B, HALF-WORN, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH						
	30.3	33.8	38.8	43.6	48.6	52.7	58.1
6	82.0	83.6	85.6	88.6	88.6	91.8	93.4
12	78.2	79.0	83.0	84.0	87.0	89.0	90.6
25	72.8	74.4	77.2	78.4	81.6	83.2	85.2
50	68.0	69.4	71.6	74.8	78.2	78.2	80.4
80	*****	*****	*****	*****	*****	*****	*****
130	59.0	62.0	63.2	66.4	68.6	71.8	73.2

SPEED	30.3	33.8	38.8	43.6	48.6	52.7	58.1
DB/DOUBLING	5.85	5.22	5.90	5.11	5.56	4.78	5.06

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	10	10	10	10	A/65/5
LRI	11	11	11	11	A/63/5
RRO	12	12	12	12	A/65/5
RRI	10	10	10	10	A/65/5

NOMINAL NEW TREAD DEPTH - 19/32 INCH

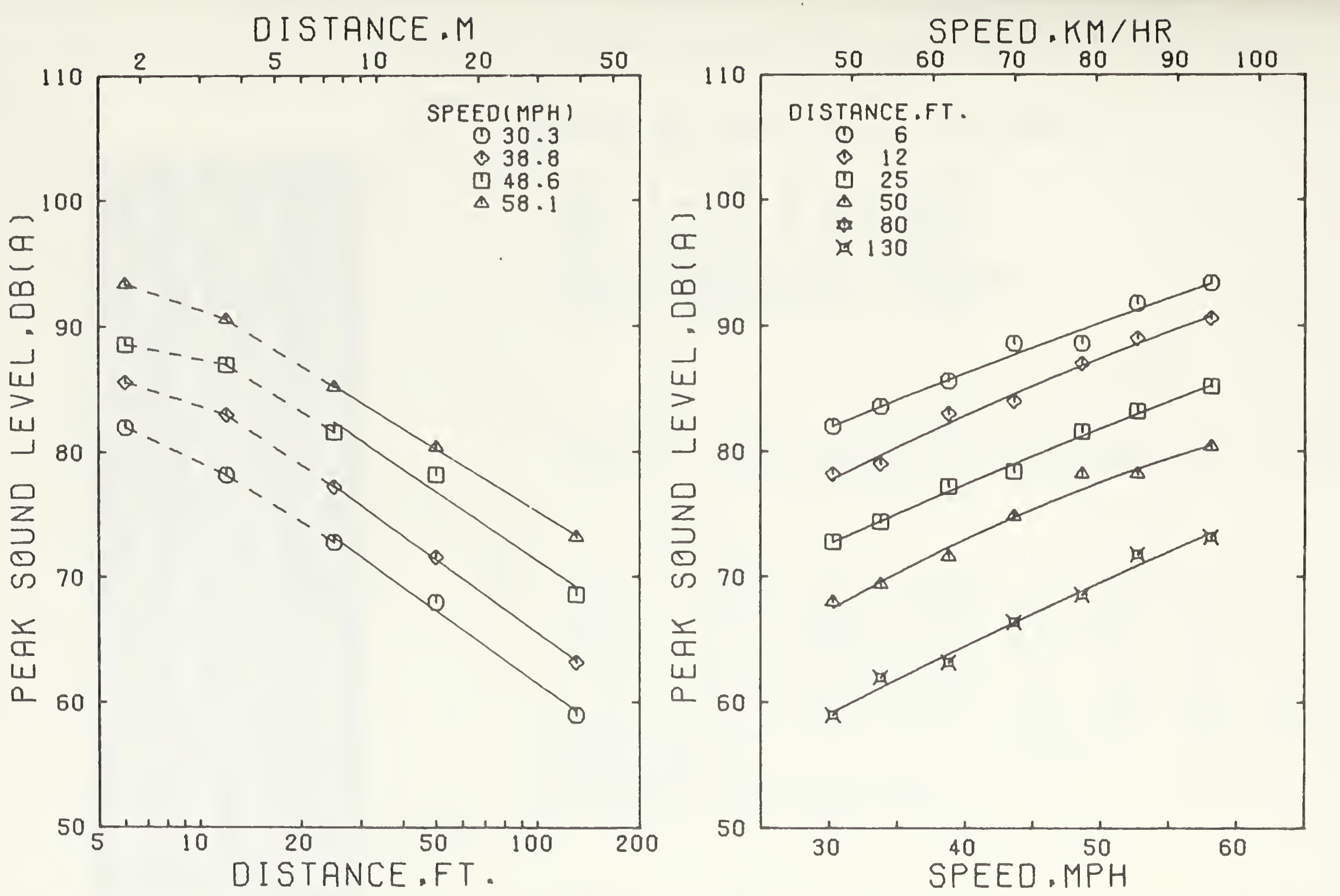
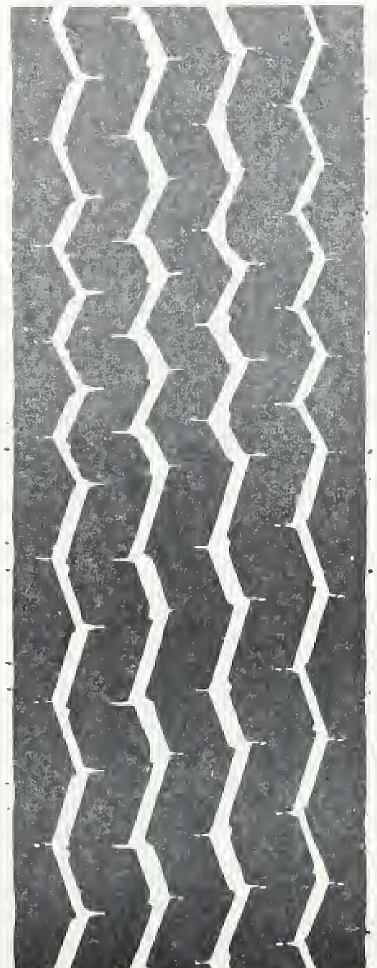


Figure A-10. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, rib-B tires on the drive axle.



RIB-C, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 28.6	35.3	39.1	43.9	49.0	53.5	55.5
6	77.6	81.0	83.0	83.8	85.6	86.4	89.2
12	74.8	78.4	78.8	80.2	83.0	83.4	85.4
25	70.2	74.0	75.2	76.0	77.2	78.6	80.6
50	64.6	69.2	69.6	71.2	74.4	74.4	76.6
80	63.0	65.4	68.2	68.6	70.6	71.8	73.6
130	59.6	61.6	63.6	64.8	65.2	69.0	68.6

SPEED	28.6	35.3	39.1	43.9	49.0	53.5	55.5
DB/DOUBLING	4.32	5.23	4.66	4.63	4.99	4.03	4.94

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	16	16	16	16	A/63/5
LRI	16	16	16	16	A/63/5
RRO	16	16	16	16	A/63/5
RRI	16	16	16	16	A/63/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

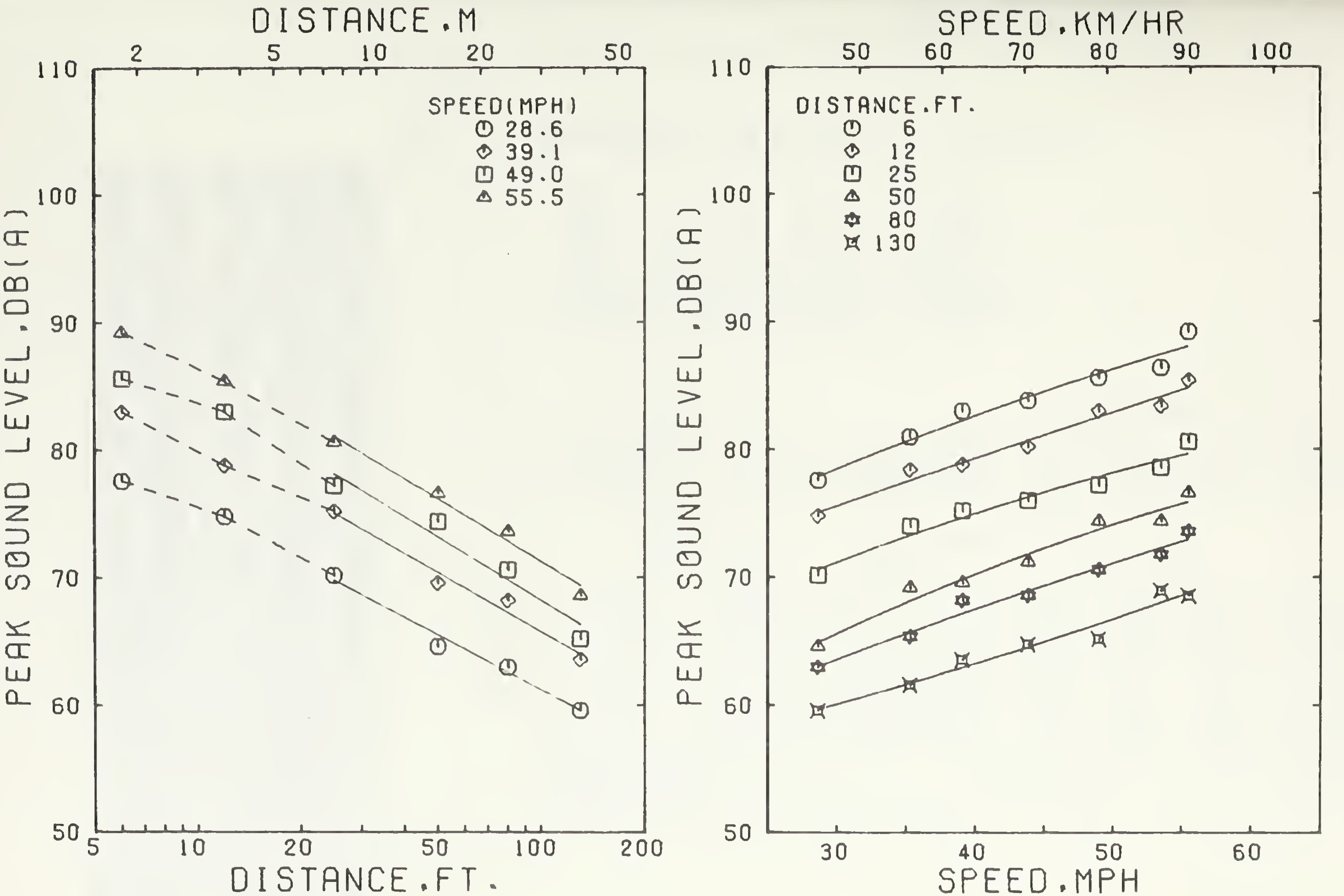


Figure A-11. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, rib-C tires on the drive axle.

RIB-C, NEW, DUAL, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 33.6	34.3	39.8	44.3	49.4	53.6	55.8
6	80.0	79.4	81.2	82.8	82.4	85.8	86.8
12	76.2	76.6	78.4	78.6	80.0	82.8	83.0
25	70.2	71.6	73.0	74.0	75.6	77.0	77.2
50	64.2	65.8	67.0	69.0	72.0	72.0	73.4
80	60.6	62.6	63.2	65.8	67.0	69.2	68.8
130	56.4	58.6	59.2	62.2	63.6	64.4	65.4

SPEED	33.6	34.3	39.8	44.3	49.4	53.6	55.8
DB/DOUBLING	5.77	5.41	5.79	4.94	5.19	5.18	5.07

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	16 16 16 16	A/63/5
LRI	16 16 16 16	A/63/5
RRO	16 16 16 16	A/63/5
RRI	16 16 16 16	A/63/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

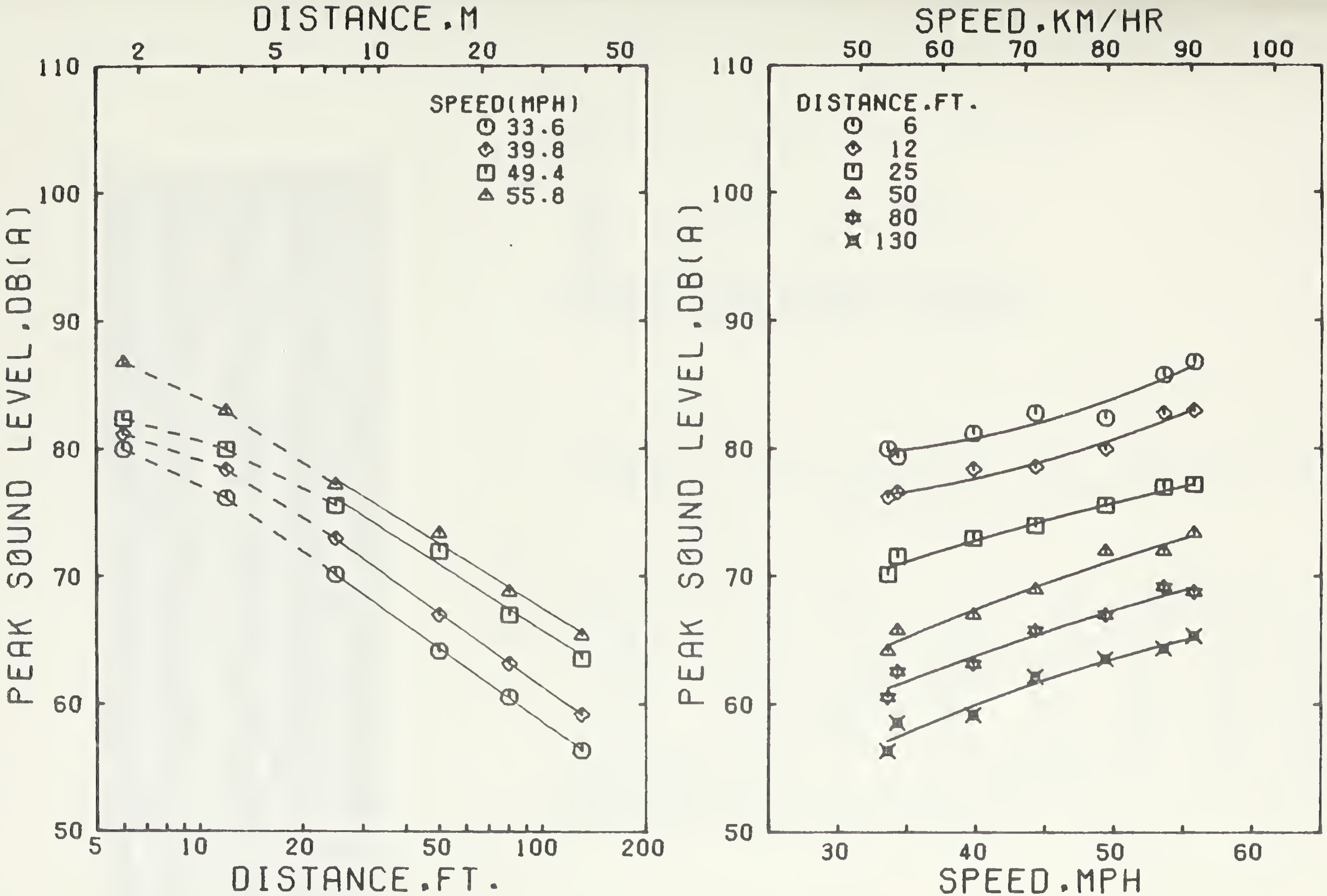


Figure A-12. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, rib-C tires on the drive axle.

RIB-C, NEW, SINGLE, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	29.4	36.7	40.9	44.8	49.0	52.6	55.3
6	75.4	80.4	81.8	81.8	86.0	86.3	86.6
12	72.0	77.6	77.4	77.8	80.6	82.6	83.6
25	67.8	73.2	72.6	74.4	76.0	77.8	77.8
50	62.4	65.8	67.4	70.0	70.6	71.6	73.4
80	60.2	63.0	64.4	55.8	66.8	68.2	70.4
130	57.8	60.0	61.4	62.6	65.0	66.6	67.6

SPEED	29.4	36.7	40.9	44.8	49.0	52.6	55.3
DB/DOUBLING	4.17	5.51	4.71	5.05	4.75	4.81	4.31

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	16 16 16 16	A/63/5
LRI		
RRO	16 16 16 16	A/63/5
RRI		

NOMINAL NEW TREAD DEPTH - 16/32 INCH

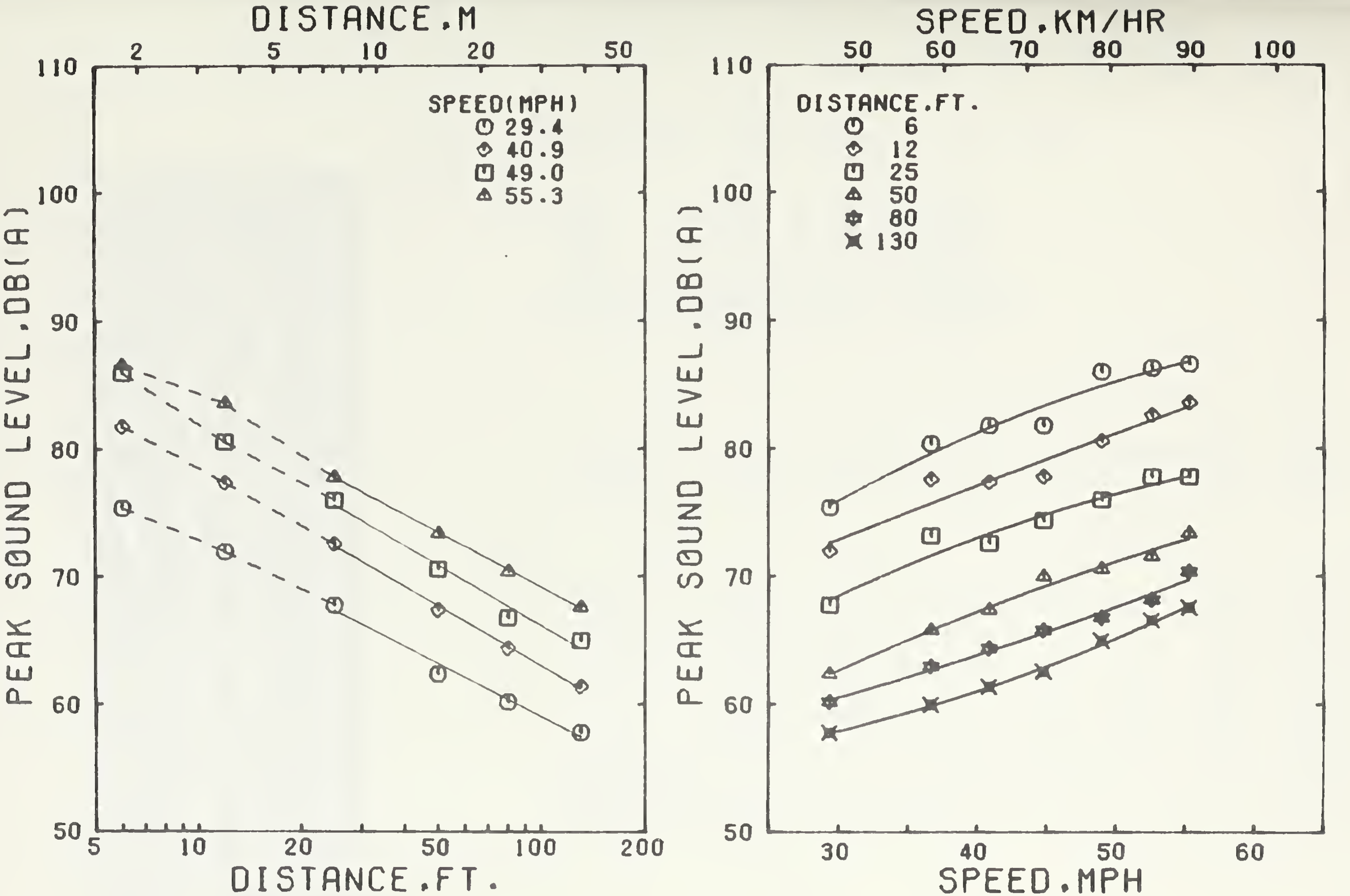


Figure A-13. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and single, new, rib-C tires on the drive axle.

RIB-C, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	29.2	34.8	39.4	44.5	50.1	54.1	58.6
6	80.0	82.8	84.6	84.8	87.4	89.0	90.0
12	77.4	79.4	80.6	82.8	84.0	85.4	87.2
25	71.4	73.4	75.4	77.2	80.2	80.8	81.8
50	66.2	68.6	69.8	72.4	73.4	76.6	78.2
80	63.0	64.8	67.8	69.2	71.8	72.2	74.0
130	60.4	62.6	64.4	66.6	69.2	70.2	70.0

SPEED	29.2	34.8	39.4	44.5	50.1	54.1	58.6
DB/DOUBLING	4.66	4.65	4.52	4.50	4.52	4.63	5.01

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	16 16 16 16	A/63/5
LRI	16 16 16 16	A/63/5
RRO	16 16 16 16	A/63/5
RRI	16 16 16 16	A/63/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

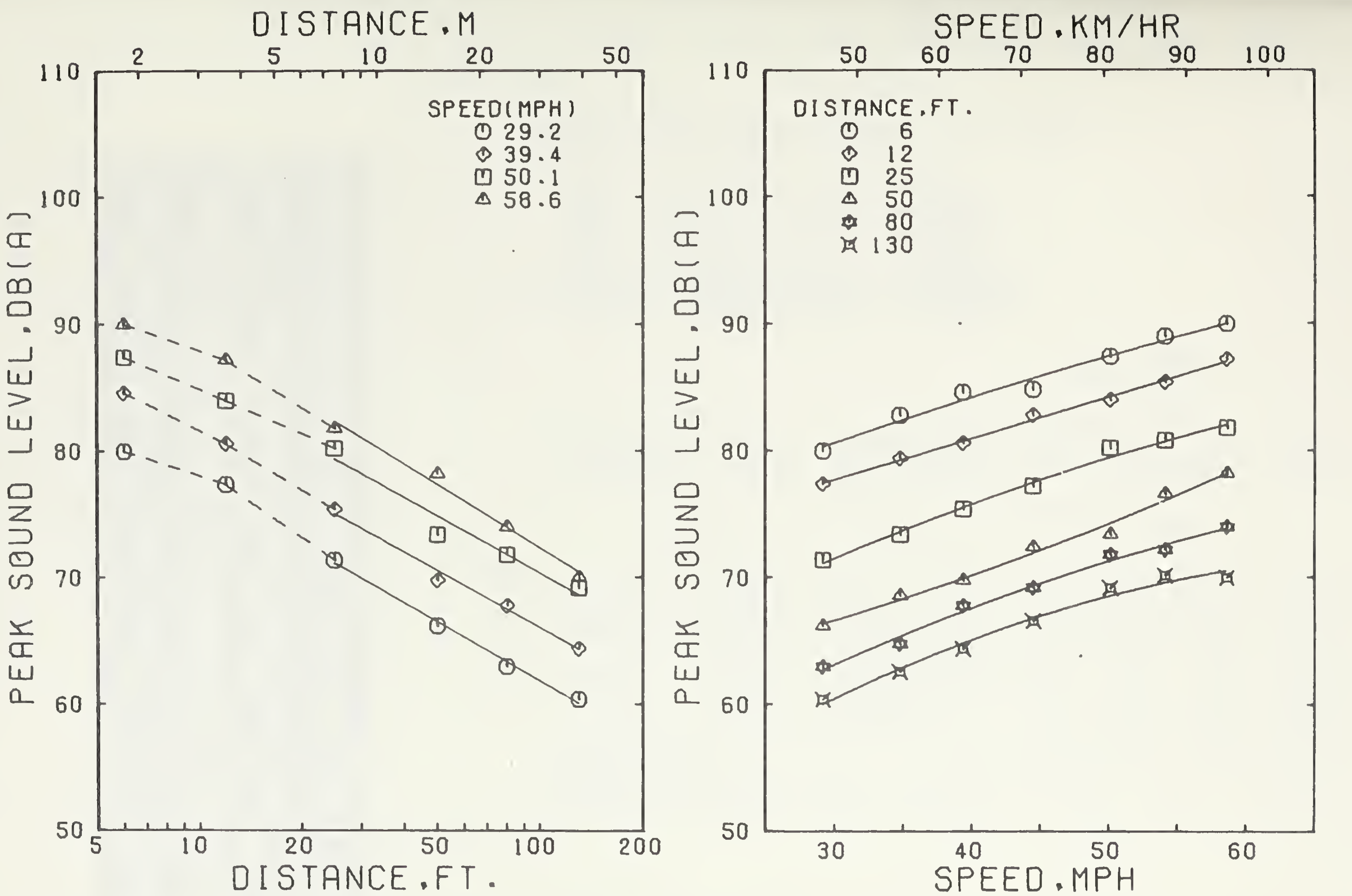
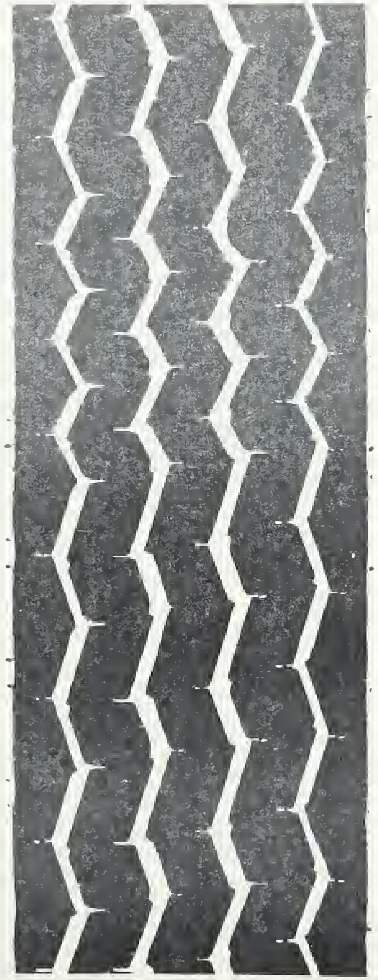


Figure A-14. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, rib-C tires on the drive axle.



RIB-C, NEW, DUAL, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	31.2	34.1	38.0	44.4	49.7	54.1	55.9
6	79.0	79.2	80.8	82.4	85.0	85.4	86.8
12	75.4	75.6	78.4	79.2	82.6	81.6	83.6
25	69.6	70.8	73.2	74.0	76.4	76.8	78.0
50	64.0	64.6	66.6	69.6	71.0	72.6	73.4
80	62.2	61.4	63.6	65.8	69.0	69.2	69.6
130	59.4	58.2	61.4	62.4	65.2	66.0	66.0

SPEED	31.2	34.1	38.0	44.4	49.7	54.1	55.9
DB/DOUBLING	4.20	5.29	4.99	4.92	4.58	4.57	5.07

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	16 16 16 16	A/63/5
LRI	16 16 16 16	A/63/5
RRO	16 16 16 16	A/63/5
RRI	16 16 16 16	A/63/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

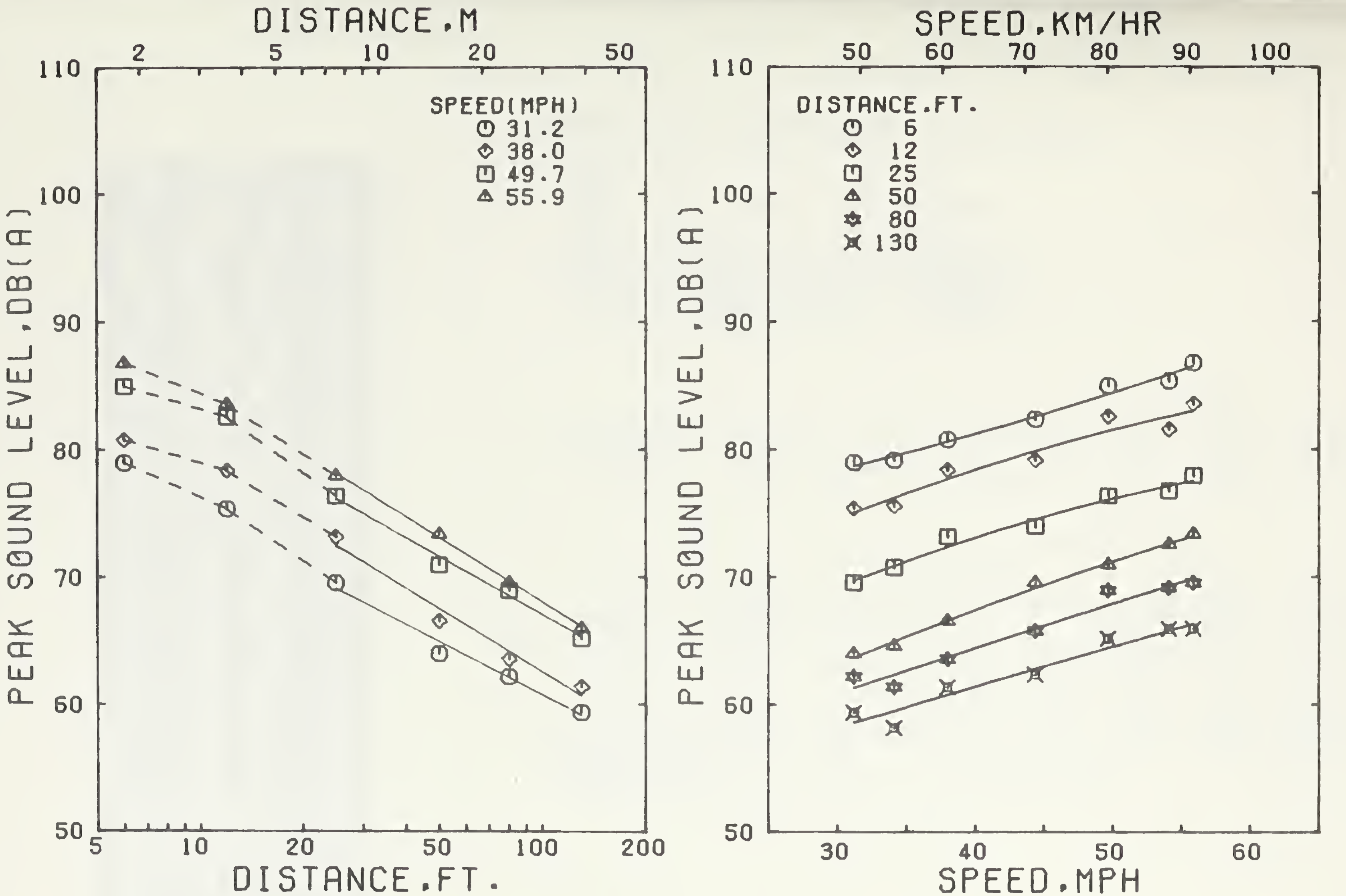
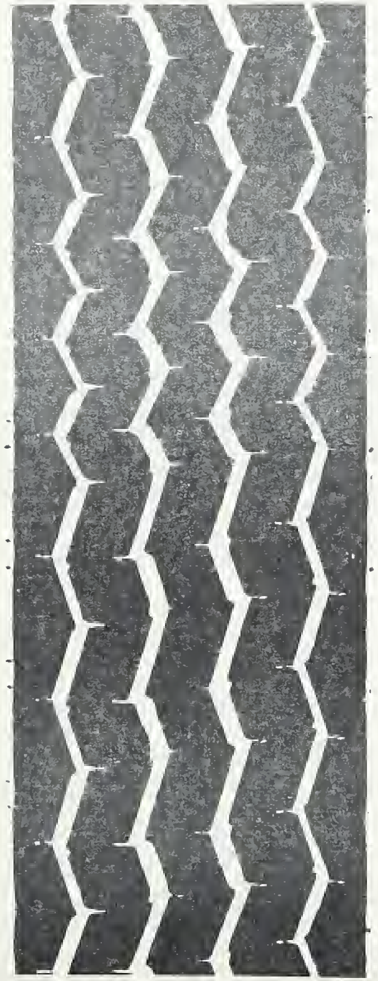


Figure A-15. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, rib-C tires on the drive axle.



RIB-C, NEW, SINGLE, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 30.2	35.1	40.0	44.0	49.0	53.5	57.4
6	79.2	79.8	81.8	82.6	83.8	85.0	86.2
12	77.4	75.8	78.8	79.8	80.4	81.8	84.0
25	71.0	69.6	73.6	73.4	74.8	76.2	78.4
50	64.0	65.2	67.8	68.8	69.4	71.6	72.8
80	60.2	61.8	65.2	64.4	66.2	68.2	69.0
130	56.8	59.2	62.0	60.8	64.2	64.0	67.2

SPEED	30.2	35.1	40.0	44.0	49.0	53.5	57.4
DB/DOUBLING	5.99	4.43	4.83	5.37	4.53	5.09	4.83

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO LRI	16 16 16 16	A/63/5
RRO RRI	16 16 16 16	A/63/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

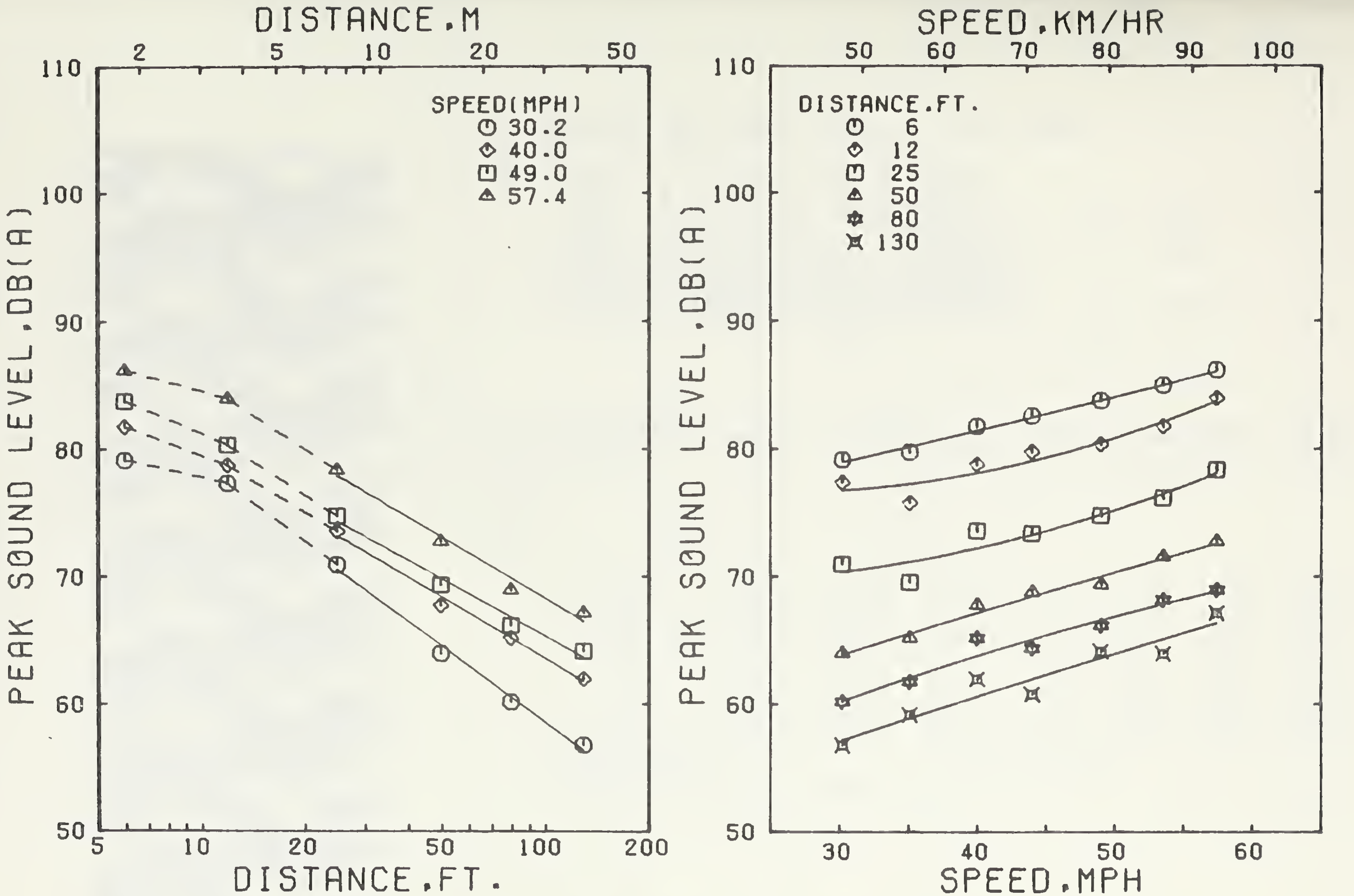
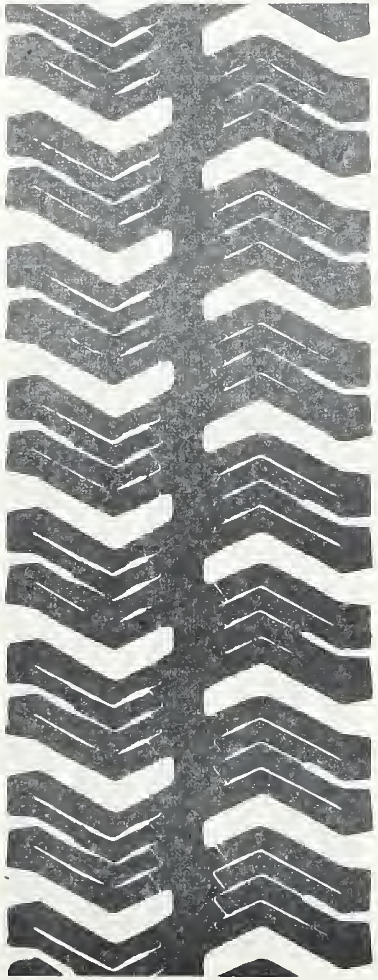


Figure A-16. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and single, new, rib-C tires on the drive axle.



CROSS-BAR-D, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE	SPEED,MPH						
LOCATION,FT	31.5	34.9	38.7	43.7	49.9	55.0	56.9
6	90.2	91.4	93.6	96.0	97.2	98.8	98.4
12	87.4	89.8	92.4	91.4	92.2	95.6	94.2
25	79.4	83.2	84.2	86.4	86.6	90.0	90.4
50	78.4	80.2	80.2	81.6	82.6	84.4	85.4
80	73.0	76.6	76.6	77.6	79.6	80.6	81.2
130	65.4	71.4	72.2	73.6	*****	77.0	78.2

SPEED	31.5	34.9	38.7	43.7	49.9	55.0	56.9
DB/DOUBLING	5.84	4.90	5.02	5.40	4.16	5.48	5.22

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	27 27 27 27	A/65/5
LRI	27 27 27 27	A/64/5
RRO	27 27 27 27	A/65/5
RRI	27 27 27 27	A/65/5

NOMINAL NEW TREAD DEPTH - 27/32 INCH

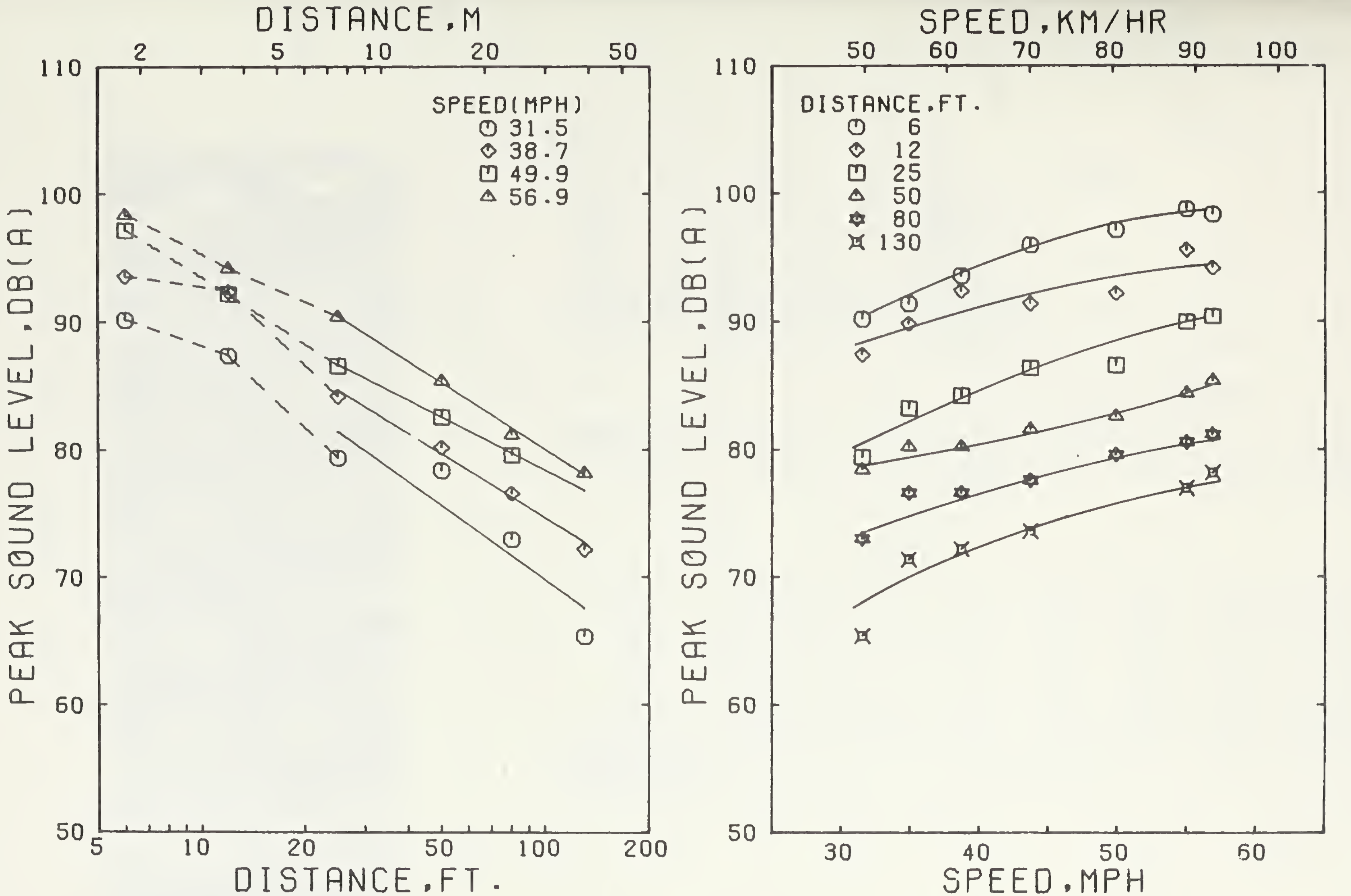
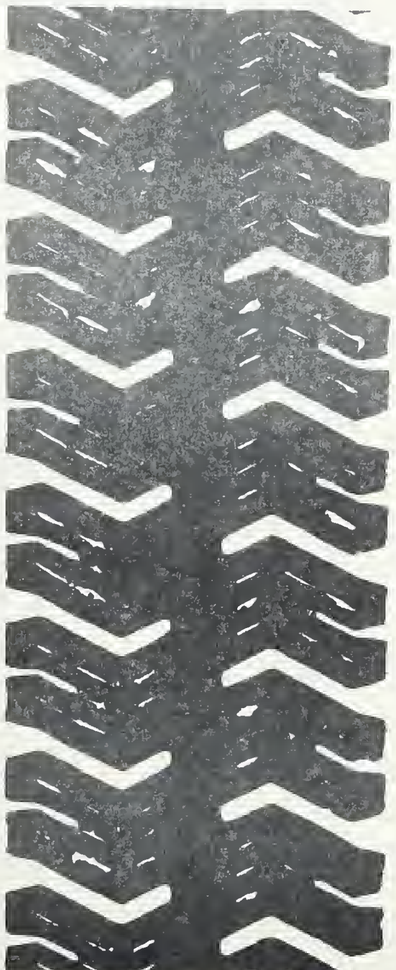


Figure A-17. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-D tires on the drive axle.



CROSS-BAR-D, HALF-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 30.9	34.4	39.0	43.0	48.4	54.7	58.2
6	90.2	93.2	95.8	98.4	101.4	105.2	104.6
12	84.4	89.0	90.0	92.8	96.4	98.6	100.2
25	81.0	82.0	85.0	87.8	91.8	94.4	94.4
50	75.6	79.4	81.4	85.6	86.6	91.0	91.2
80	72.6	75.8	78.4	82.6	83.8	87.8	88.4
130	70.2	72.6	76.0	80.0	81.4	34.6	85.4

SPEED	30.9	34.4	39.0	43.0	48.4	54.7	58.2
DB/DOUBLING	4.57	4.01	3.83	3.33	4.39	4.14	3.79

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	15	14	15	15	A/63/5
LRI	17	17	17	17	A/63/5
RRO	15	15	15	14	A/65/5
RRI	15	16	15	15	A/64/5

NOMINAL NEW TREAD DEPTH - 27/32 INCH

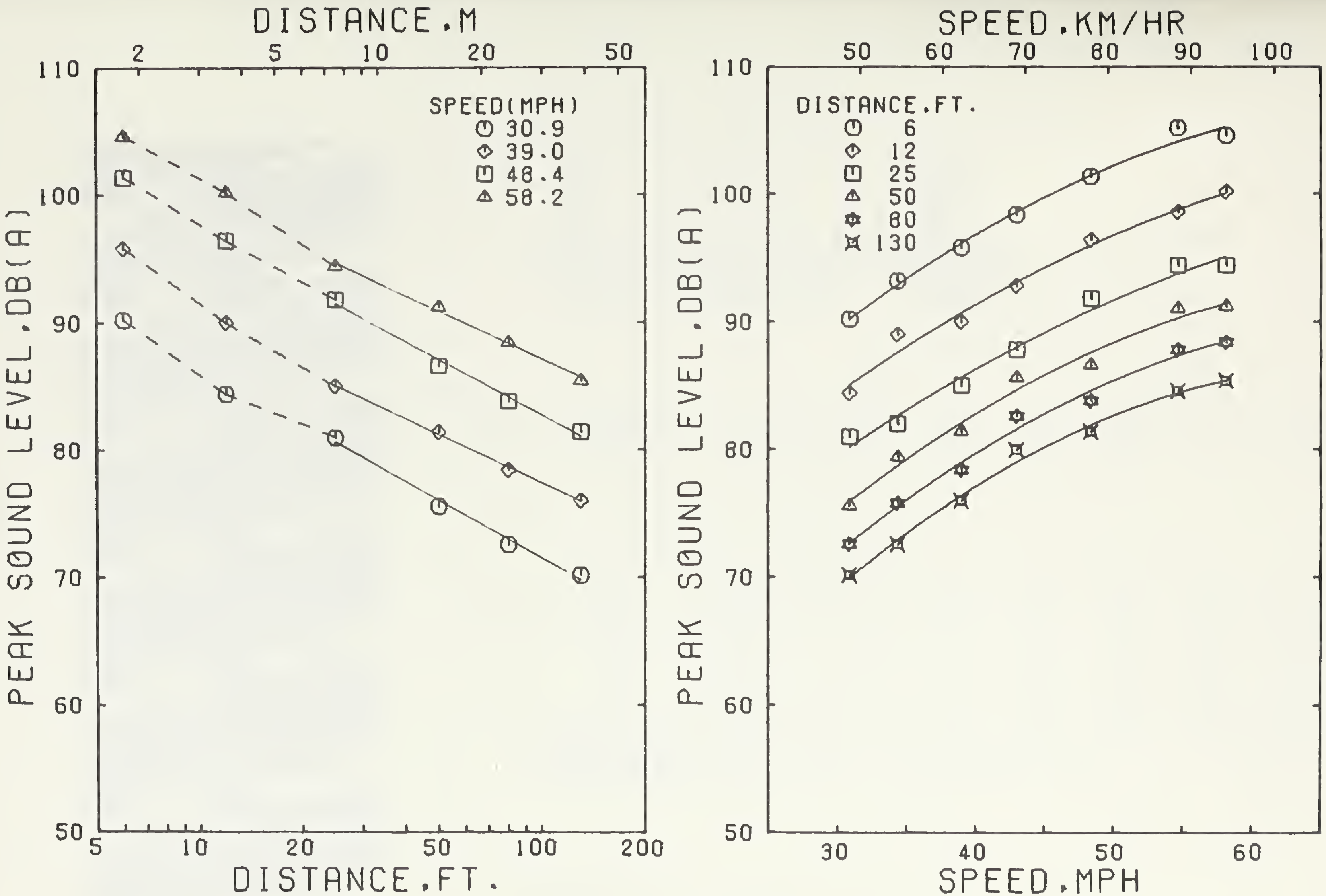
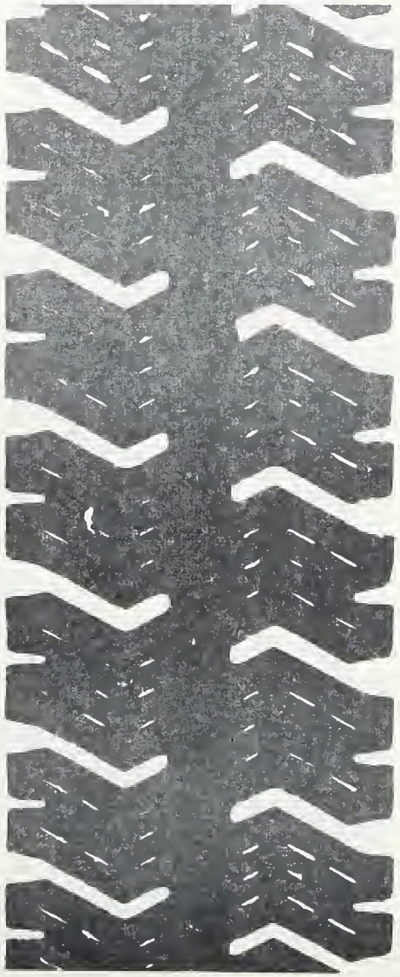


Figure A-18. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, cross-bar-D tires on the drive axle.



CROSS-BAR-D, FULLY-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 28.1	33.4	39.3	43.9	49.3	53.6	57.3
6	83.0	86.3	91.6	93.2	96.6	97.8	99.5
12	80.4	84.2	88.2	92.2	92.0	94.8	96.4
25	76.6	81.6	83.4	87.0	88.8	91.0	92.2
50	72.4	76.9	79.4	82.6	84.4	86.0	87.6
80	69.2	72.6	75.6	80.2	80.6	83.0	84.4
130	*****	*****	*****	*****	*****	*****	*****

SPEED	28.1	33.4	39.3	43.9	49.3	53.6	57.3
DB/DOUBLING	4.39	5.32	4.60	4.08	4.85	4.78	4.64

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	8	8	8	8	A/65/5
LRI	7	7	7	7	A/65/5
RRO	8	8	8	8	A/65/5
RRI	6	6	6	6	A/65/5

NOMINAL NEW TREAD DEPTH - 27/32 INCH

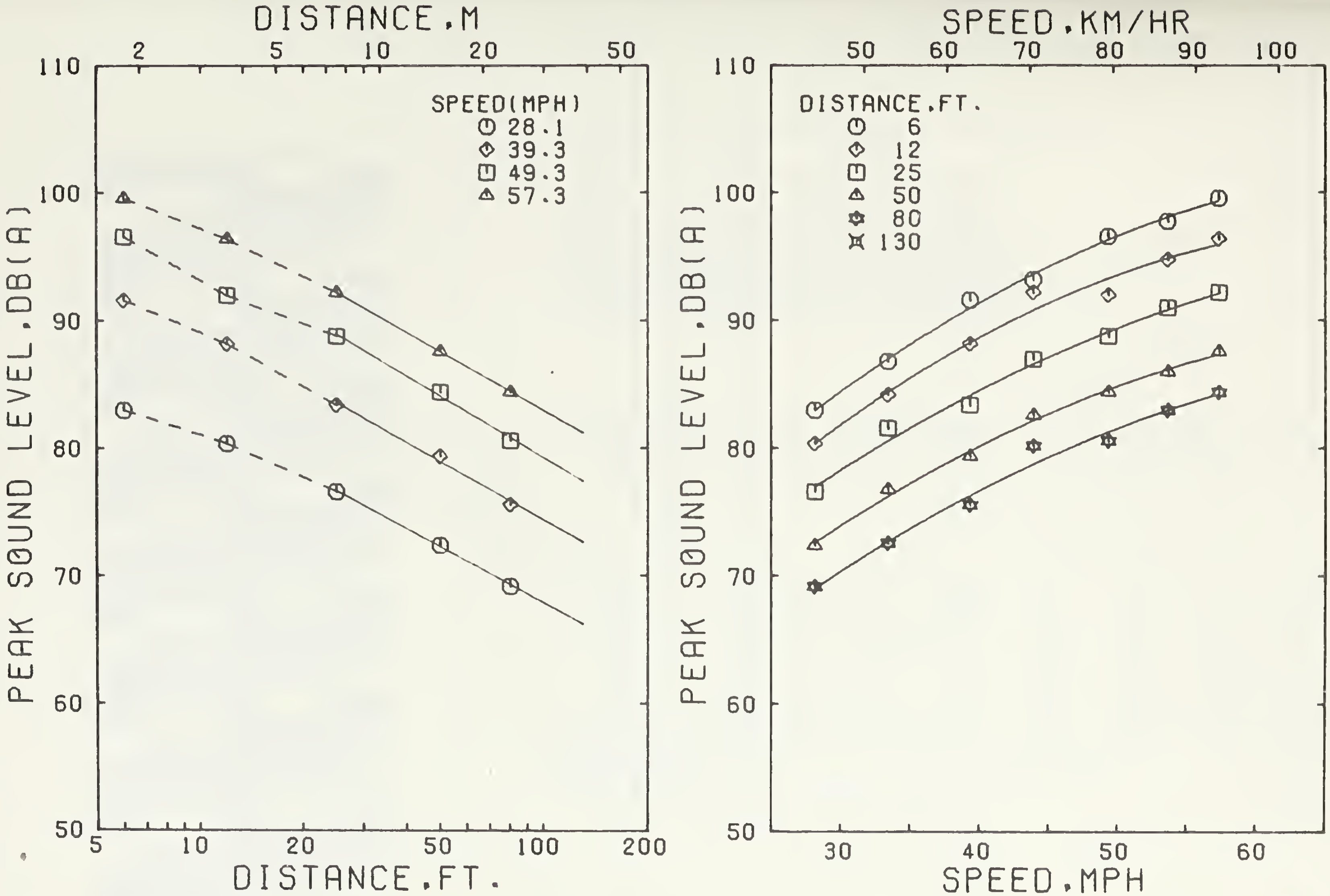


Figure A-19. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, fully-worn, cross-bar-D tires on the drive axle.

CROSS-BAR-D, NEW, DUAL, LOADED, ASPHALT

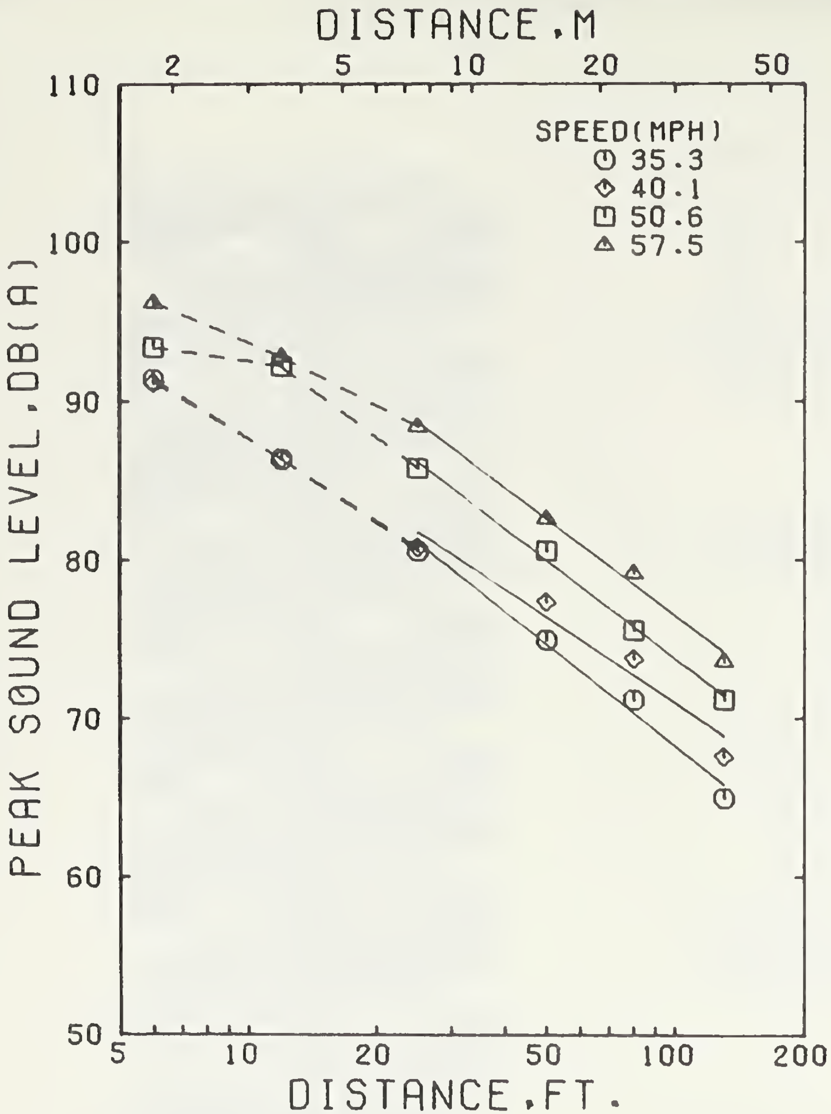
A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 35.3	35.2	40.1	44.7	50.6	54.3	57.5
6	91.4	91.4	91.2	93.8	93.4	97.0	96.2
12	86.4	86.2	86.4	89.6	92.2	94.2	92.8
25	80.6	80.4	80.8	83.8	85.8	87.4	88.4
50	75.0	74.8	77.4	78.8	80.6	82.4	82.6
80	71.2	71.8	73.8	74.6	75.6	77.8	79.2
130	65.0	65.6	67.6	72.0	71.2	71.0	73.6

SPEED	35.3	35.2	40.1	44.7	50.6	54.3	57.5
DB/DOUBLING	6.42	6.03	5.42	5.07	6.20	6.79	6.09

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	27 27 27 27	A/65/5
LRI	27 27 27 27	A/64/5
RRO	27 27 27 27	A/65/5
RRI	27 27 27 27	A/65/5

NOMINAL NEW TREAD DEPTH - 27/32 INCH



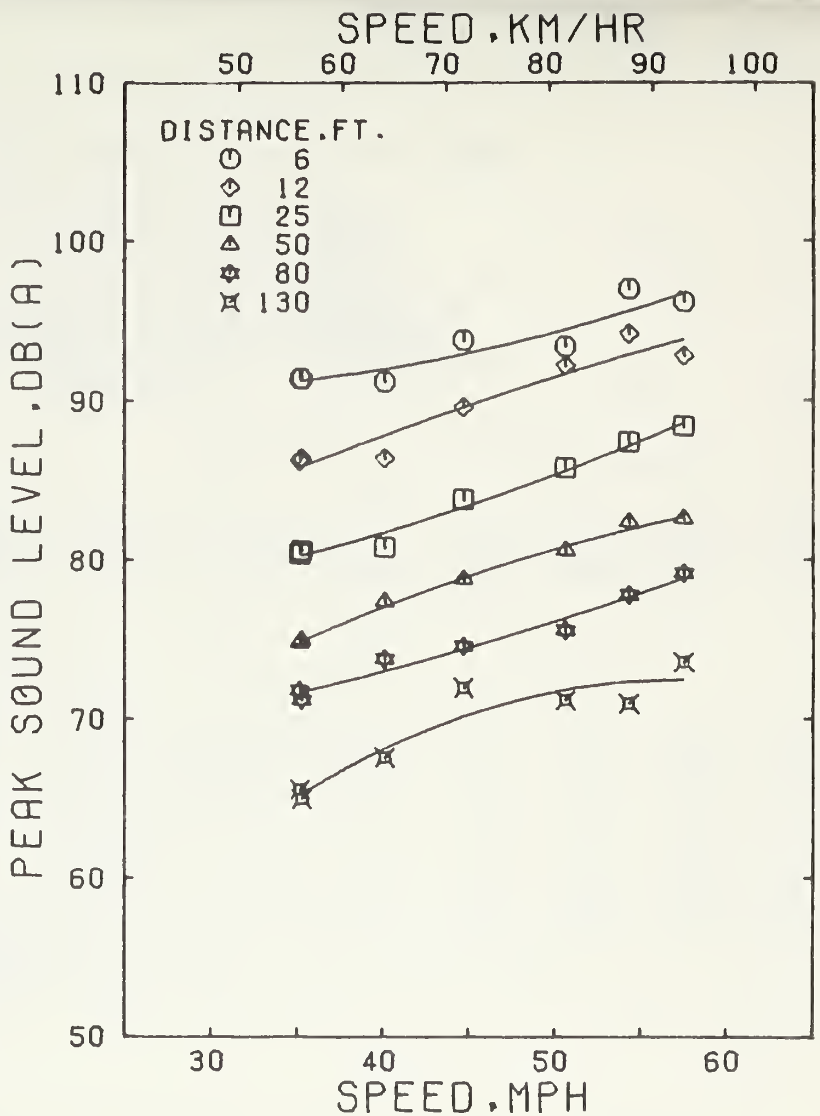


Figure A-20. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-D tires on the drive axle.

CROSS-BAR-D, HALF-WORN, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	29.4	35.5	39.1	44.2	49.4	54.2	58.6
6	86.2	91.2	93.0	95.4	99.4	99.8	100.6
12	84.6	86.6	88.8	91.4	94.2	96.2	96.8
25	78.8	80.8	83.2	86.6	87.0	90.6	92.2
50	74.0	76.8	78.0	80.4	82.4	85.4	87.2
80	69.0	72.0	74.8	77.4	79.2	80.8	82.8
130	65.8	67.4	68.6	69.4	72.4	75.0	76.8

SPEED	29.4	35.5	39.1	44.2	49.4	54.2	58.6
DB/DOUBLING	5.61	5.69	5.96	6.92	5.93	6.51	6.40

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	15 14 15 15	A/63/5
LRI	17 17 17 17	A/63/5
RRO	15 15 15 14	A/65/5
RRI	15 16 15 15	A/64/5

NOMINAL NEW TREAD DEPTH - 27/32 INCH

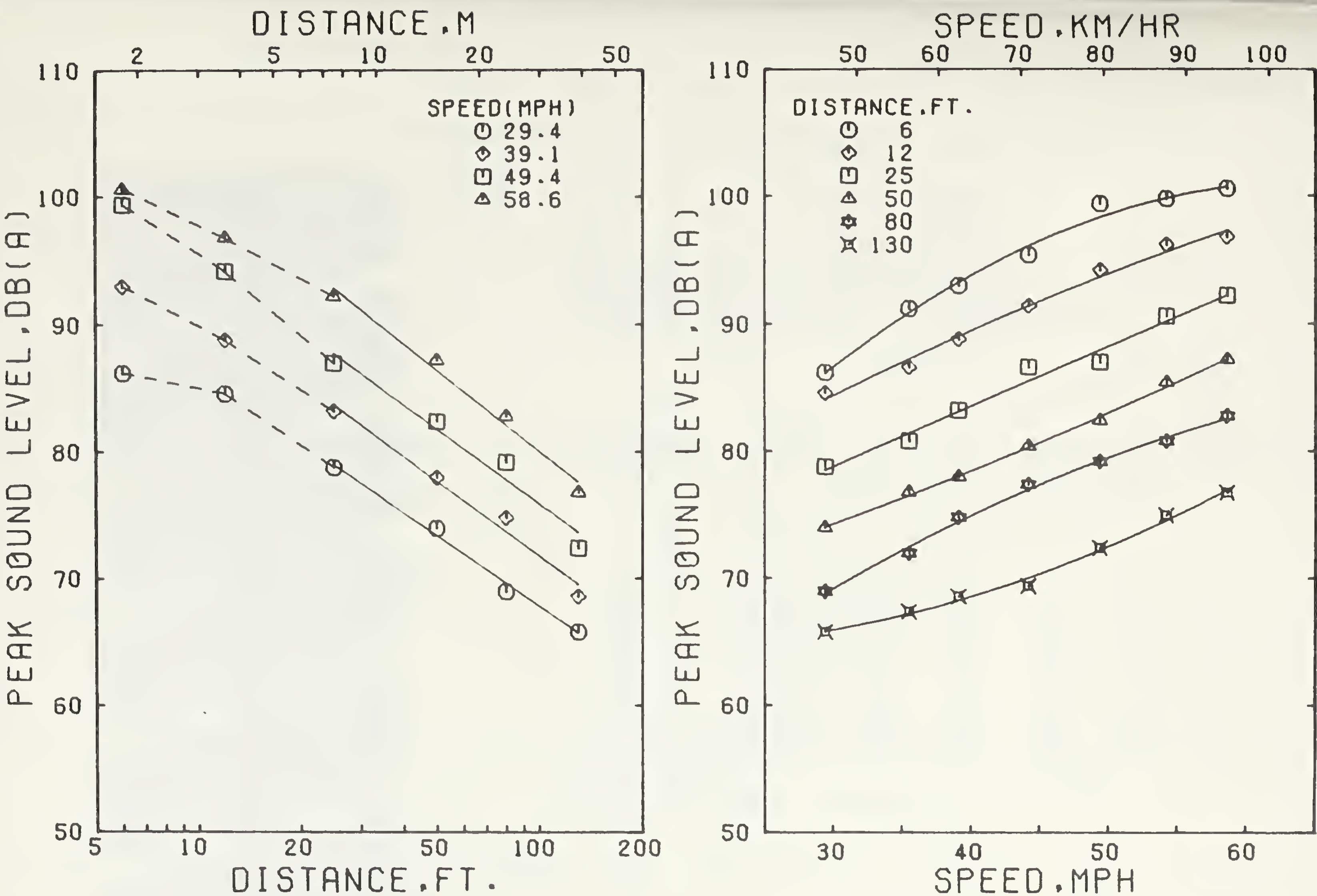
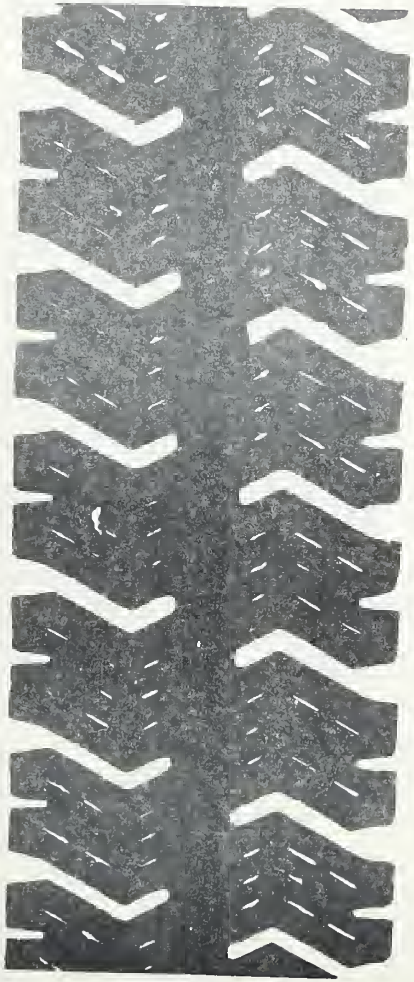


Figure A-21. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, cross-bar-D tires on the drive axle.



CROSS-BAR-D, FULLY-WORN, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH						
	27.4	33.1	39.1	44.4	48.4	53.6	59.3
6	85.0	88.6	90.0	92.8	93.8	96.6	97.8
12	82.2	86.4	87.6	91.8	92.4	93.4	95.6
25	76.0	79.2	82.0	85.0	87.0	88.2	90.2
50	71.8	75.0	78.2	80.6	82.4	84.6	86.2
80	68.6	71.8	75.6	77.6	79.0	80.8	82.8
130	64.0	68.2	72.2	75.0	77.2	78.0	81.6

SPEED	27.4	33.1	39.1	44.4	48.4	53.6	59.3
DB/DOUBLING	4.97	4.61	4.08	4.23	4.22	4.37	3.76

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	8	8	8	8	A/65/5
LRI	7	7	7	7	A/65/5
RRO	8	8	8	8	A/65/5
RRI	6	6	6	6	A/65/5

NOMINAL NEW TREAD DEPTH - 27/32 INCH

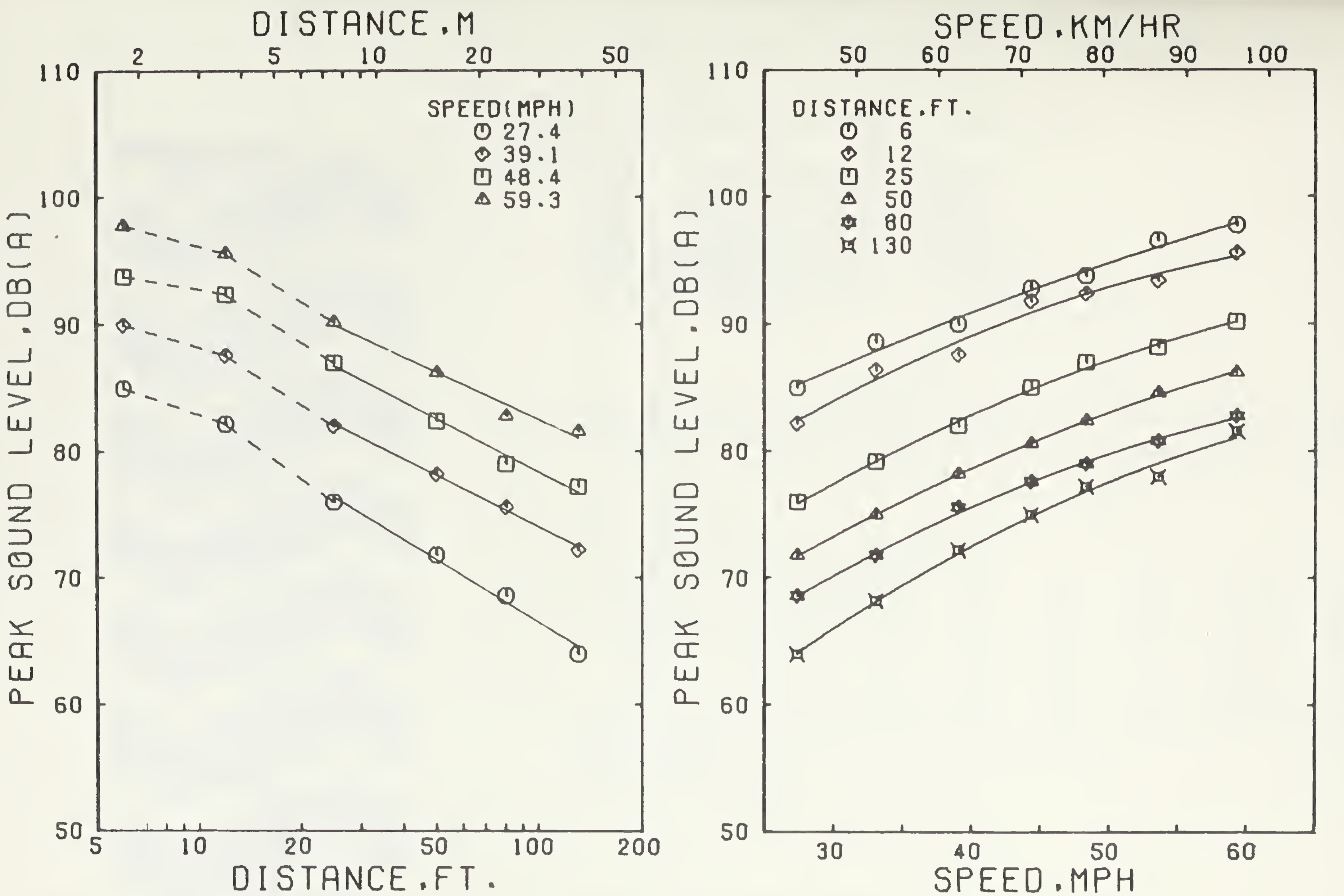
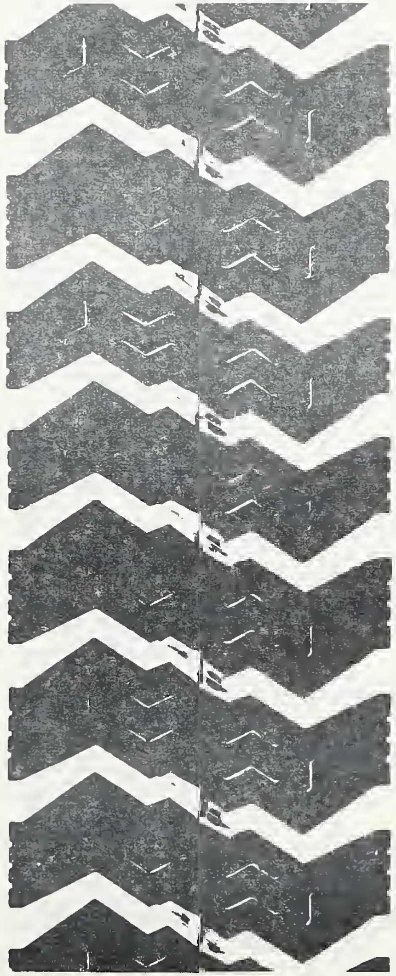


Figure A-22. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, fully-worn, cross-bar-D tires on the drive axle.



CROSS-BAR-E, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.6	35.0	38.6	43.5	48.2	52.7	56.8
6	84.4	86.4	88.8	91.4	93.8	96.2	96.0
12	80.6	84.0	86.2	88.2	89.4	91.8	93.4
25	75.2	78.6	81.4	82.8	84.6	86.4	88.8
50	71.0	74.0	75.6	78.0	79.8	81.6	84.4
80	68.0	71.6	73.0	75.0	77.0	79.2	80.2
130	66.4	70.2	71.2	73.0	74.4	77.6	79.4

SPEED	29.6	35.0	38.6	43.5	48.2	52.7	56.8
DB/DOUBLING	3.79	3.58	4.32	4.18	4.30	3.74	4.18

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	25 25 25 25	A/59/5
LRI	25 25 25 25	A/59/5
RRO	25 25 25 25	A/58/5
RRI	25 25 25 25	A/60/5

NOMINAL NEW TREAD DEPTH - 25/32 INCH

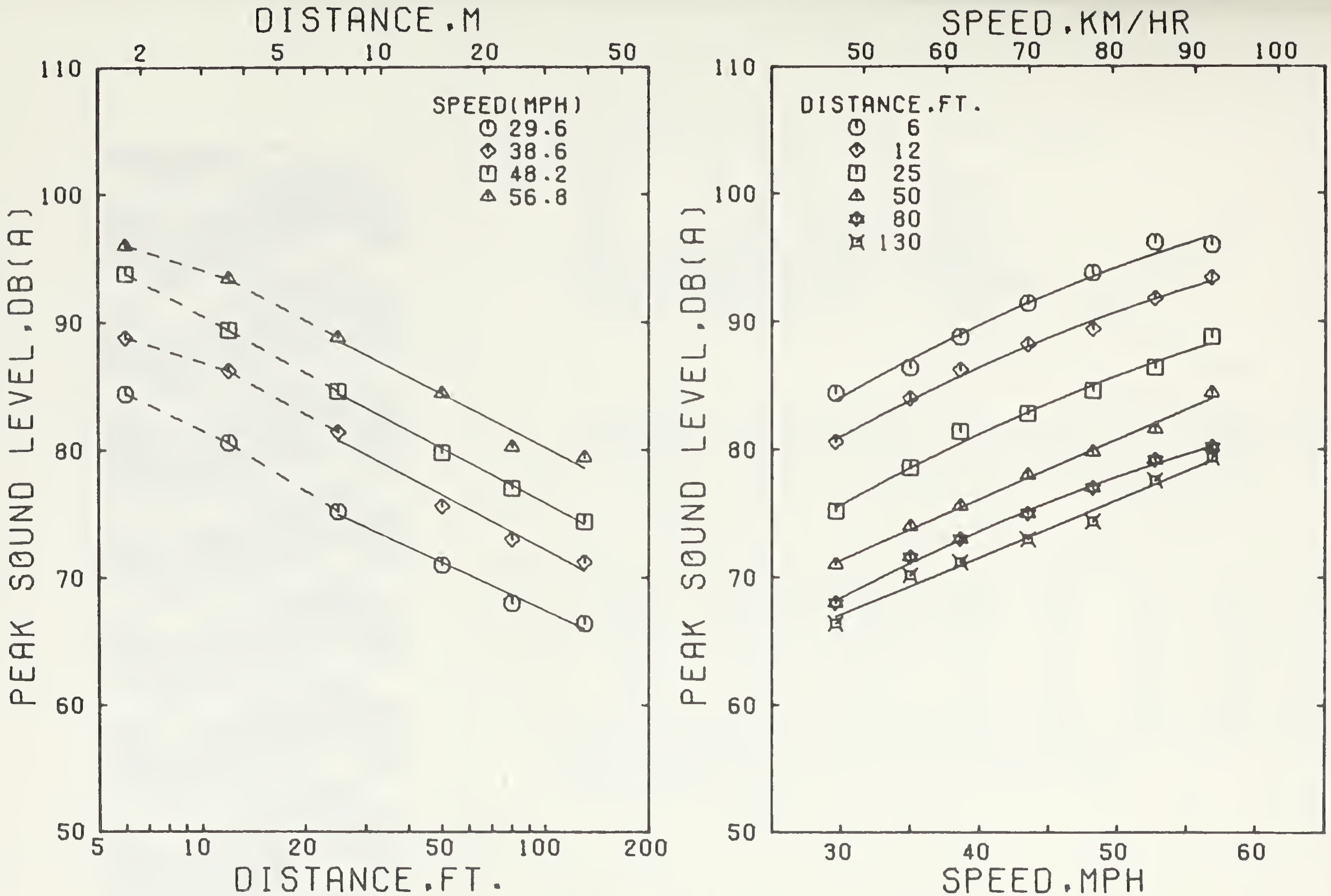
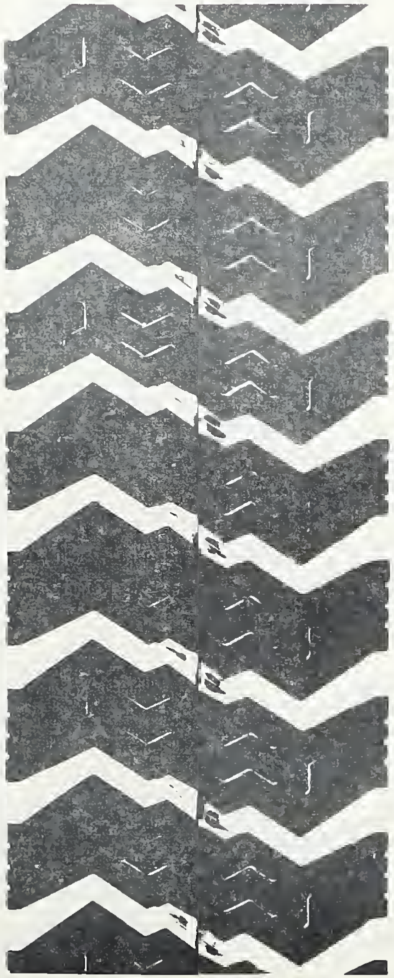


Figure A-23. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-E tires on the drive axle.



CROSS-BAR-E, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 30.3	36.2	39.8	44.6	49.5	54.2	58.3
6	83.8	87.6	88.8	91.6	91.4	96.2	96.8
12	81.0	84.0	86.4	88.0	89.6	94.2	95.0
25	75.4	78.8	80.4	81.4	82.8	87.6	86.4
50	70.2	73.8	75.8	76.2	79.0	81.0	82.8
80	67.2	70.8	71.2	72.2	76.2	78.2	81.0
130	63.4	66.6	67.6	70.6	71.2	74.0	76.2

SPEED	30.3	36.2	39.8	44.6	49.5	54.2	58.3
DB/DOUBLING	5.00	5.06	5.47	4.70	4.76	5.62	4.11

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	25 25 25 25	A/59/5
LRI	25 25 25 25	A/59/5
RRO	25 25 25 25	A/58/5
RRI	25 25 25 25	A/60/5

NOMINAL NEW TREAD DEPTH - 25/32 INCH

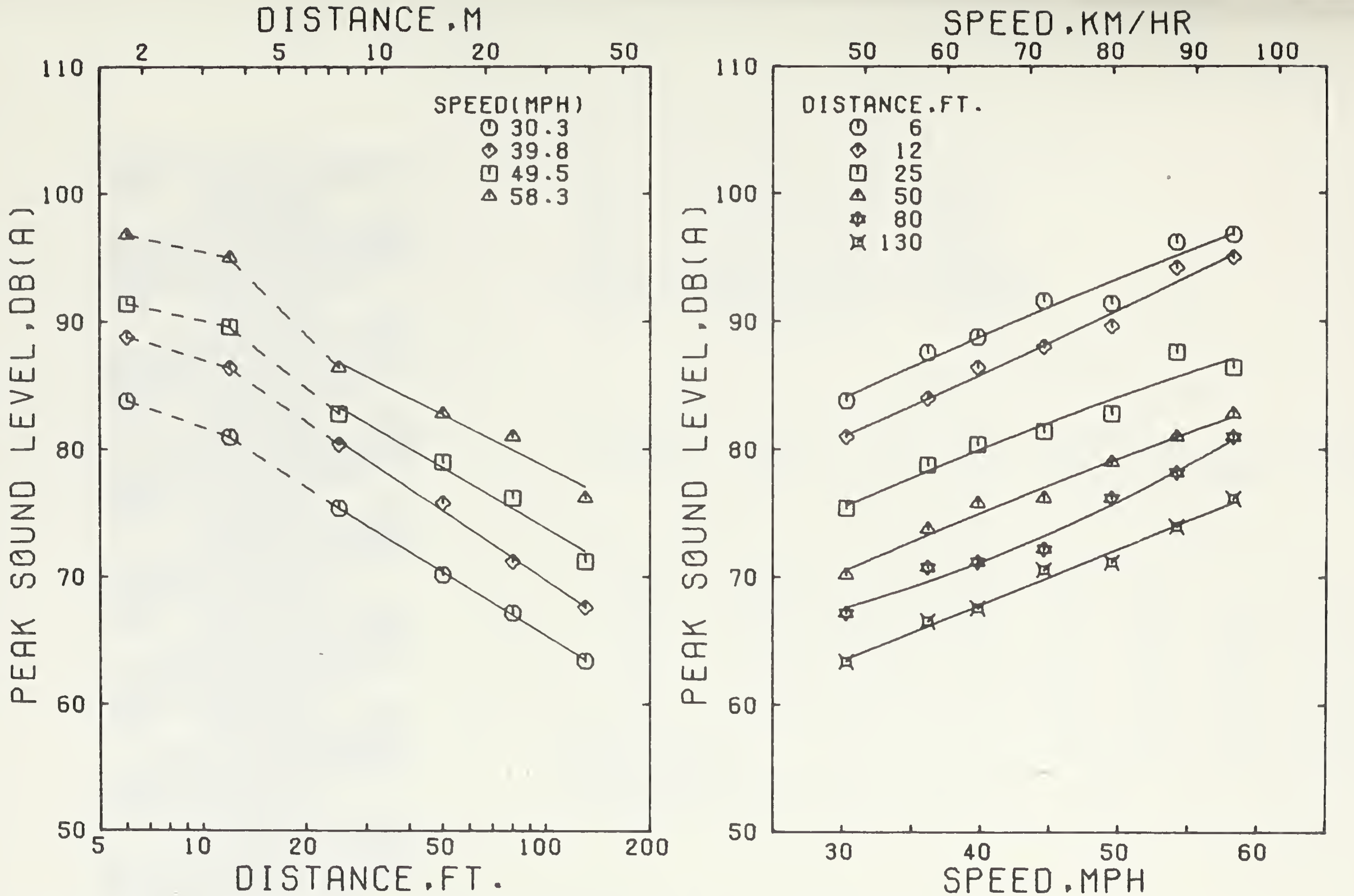


Figure A-24. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-E tires on the drive axle.

CROSS-BAR-F, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.5	35.7	39.6	45.2	50.2	54.3	58.6
6	82.8	85.8	87.0	89.2	91.0	93.8	96.2
12	81.0	81.8	83.6	86.6	87.2	90.8	91.2
25	75.4	77.8	78.2	80.6	82.4	85.2	86.6
50	70.4	73.8	73.8	77.0	78.6	80.8	81.2
80	65.8	69.4	71.0	73.2	75.0	77.8	78.0
130	61.6	66.2	67.2	68.8	72.0	73.6	74.2

SPEED	29.5	35.7	39.6	45.2	50.2	54.3	58.6
DB/DOUBLING	5.85	4.98	4.57	4.95	4.43	4.81	5.18

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	30 30 30 30	A/64/5
LRI	30 30 30 30	A/64/5
RRO	30 30 30 30	A/64/5
RRI	30 30 30 30	A/64/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

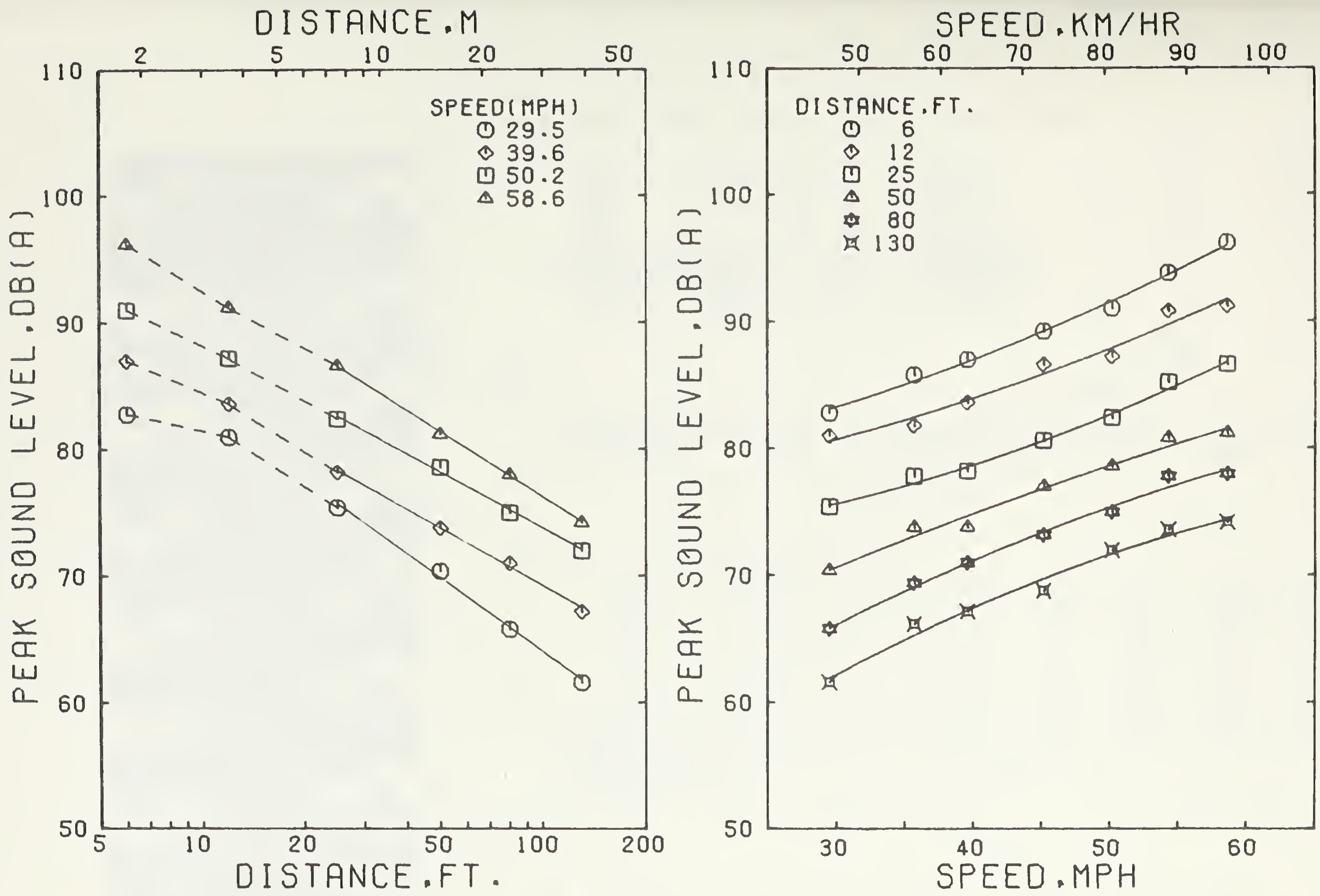
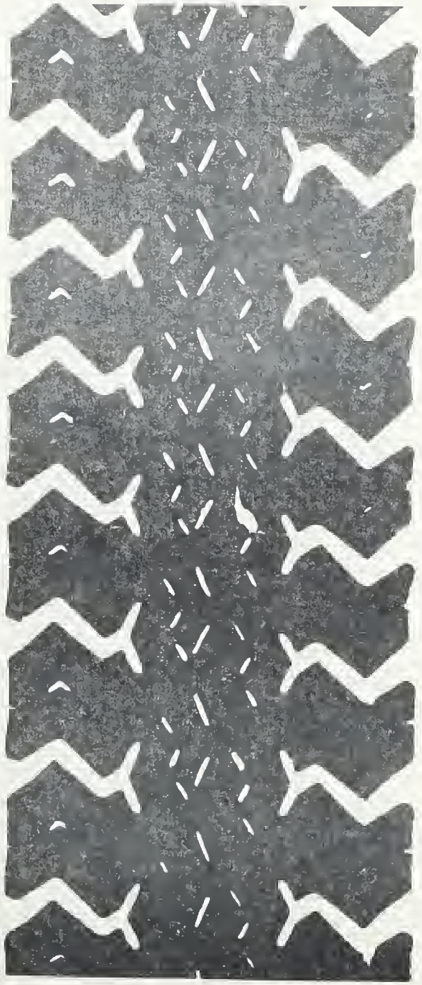


Figure A-25. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-F tires on the drive axle.



CROSS-BAR-F, HALF-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.4	34.3	39.1	44.2	49.8	54.4	55.7
6	87.2	89.0	96.2	95.6	98.8	100.6	102.0
12	83.0	86.2	90.4	91.0	95.0	97.0	98.0
25	79.0	81.6	85.0	87.6	88.8	93.0	94.8
50	74.4	77.4	80.4	84.0	84.0	87.8	89.2
80	71.4	75.2	77.8	80.6	84.0	83.8	86.0
130	69.6	71.6	75.4	77.2	80.2	83.2	84.4

SPEED	29.4	34.3	39.1	44.2	49.8	54.4	55.7
DB/DOUBLING	4.03	4.12	4.04	4.39	3.34	4.33	4.46

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	13	13	13	13	A/60/5
LRI	10	10	10	10	A/60/5
RRO	16	16	16	16	A/65/5
RRI	17	17	17	17	A/63/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

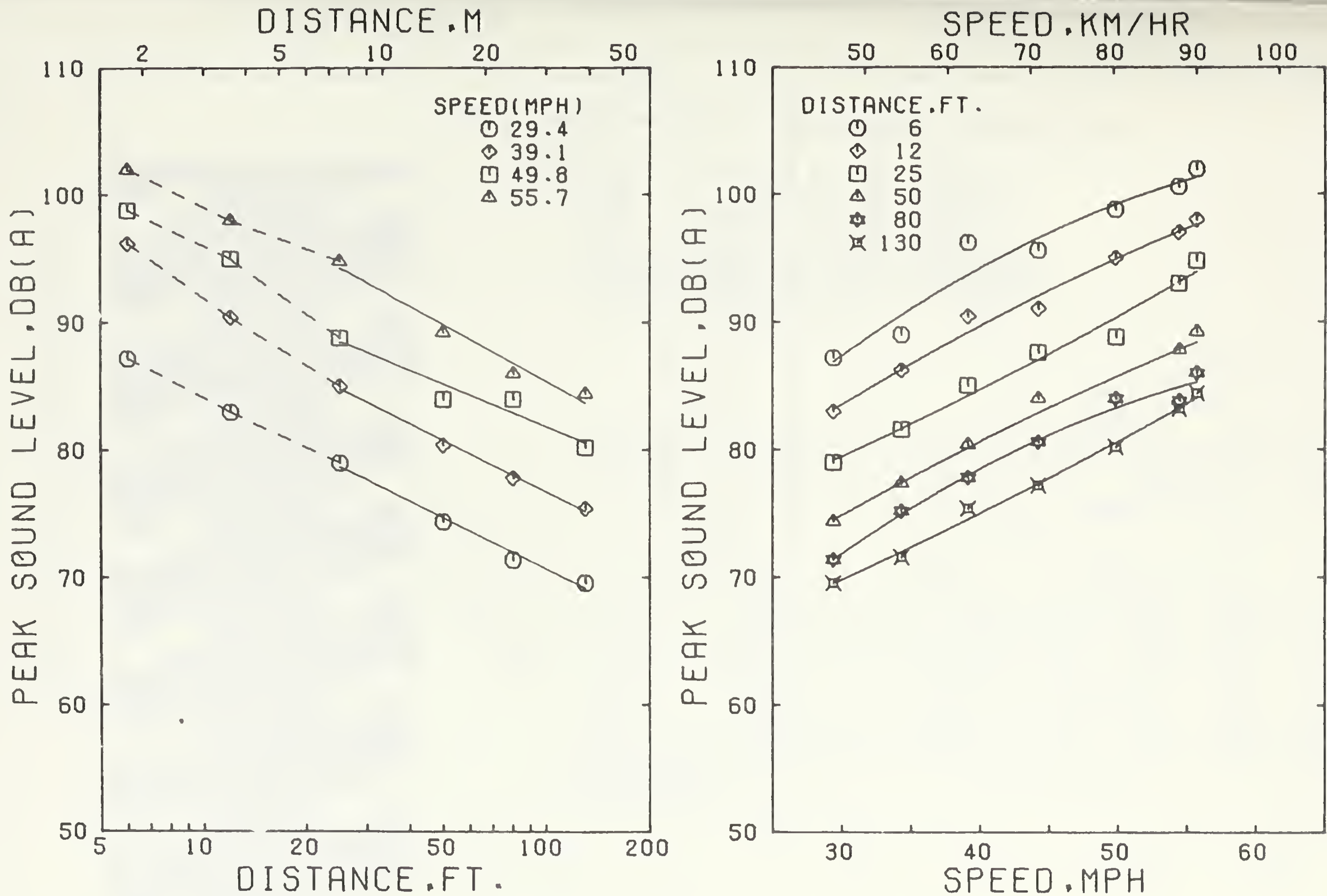


Figure A-26. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, cross-bar-F tires on the drive axle.

CROSS-BAR-F, NEW, DUAL, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 35.8	35.9	40.7	47.8	49.4	52.9	58.8
6	80.8	79.6	83.2	84.8	84.8	86.4	88.8
12	76.8	76.8	78.4	82.2	82.4	83.8	85.6
25	72.4	71.6	74.4	75.8	76.2	78.2	80.4
50	66.6	65.6	68.2	71.2	71.8	73.0	75.2
80	62.8	63.0	64.4	67.0	68.2	69.2	71.8
130	60.6	58.2	59.2	62.0	63.6	64.2	68.0

SPEED	35.8	35.9	40.7	47.8	49.4	52.9	58.8
DB/DOUBLING	5.06	5.57	6.31	5.78	5.25	5.83	5.19

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	30 30 30 30	A/64/5
LRI	30 30 30 30	A/64/5
RRO	30 30 30 30	A/64/5
RRI	30 30 30 30	A/64/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

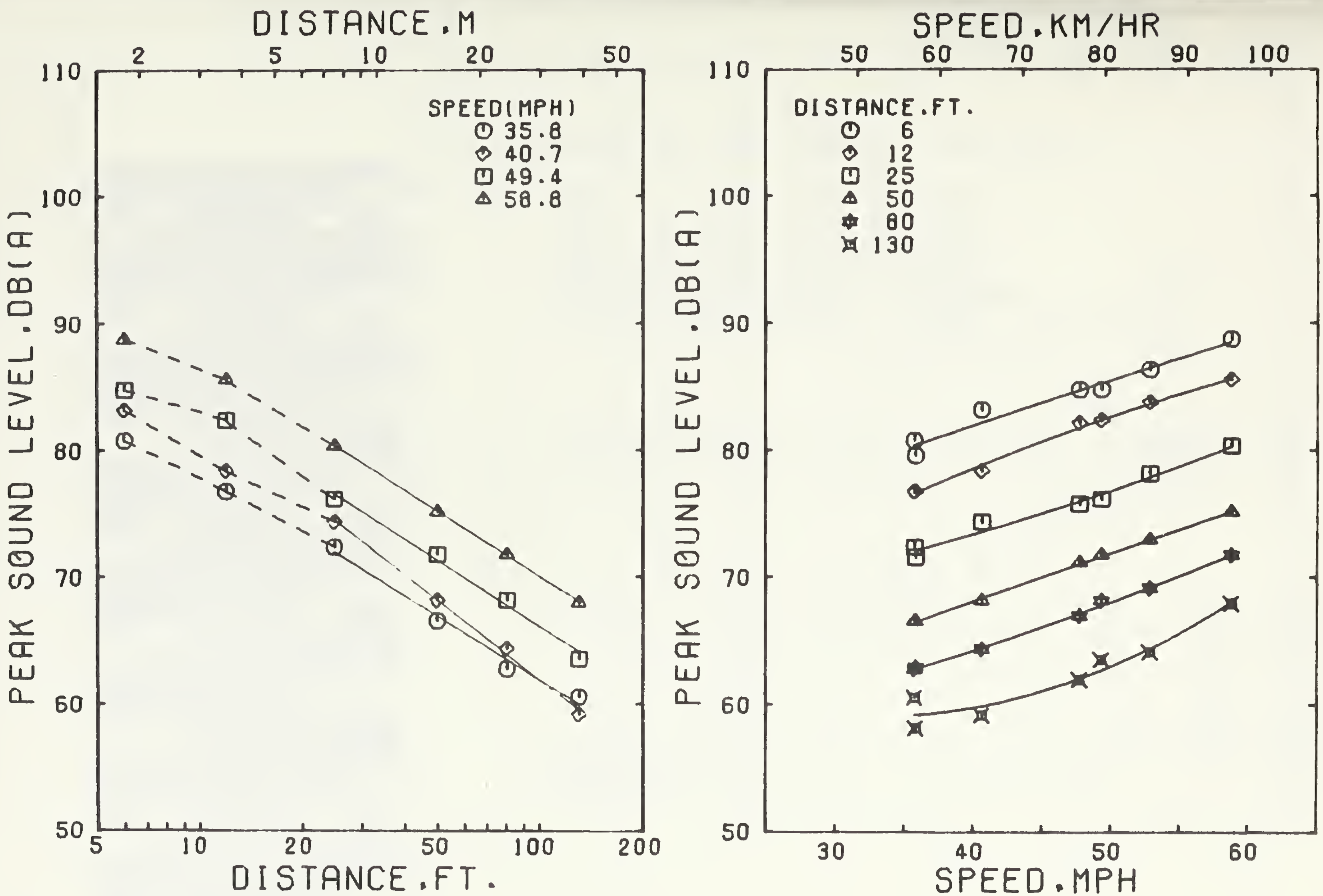


Figure A-27. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-F tires on the drive axle.

CROSS-BAR-F, HALF-WORN, DUAL, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	32.3	36.3	41.7	46.3	51.1	55.1	56.8
6	87.0	88.2	88.4	91.0	91.4	93.2	93.8
12	82.6	83.4	86.2	87.6	88.4	90.2	91.6
25	76.2	80.0	81.0	82.4	83.8	87.2	88.2
50	72.8	72.4	75.8	76.0	78.6	81.2	80.8
80	70.4	70.8	71.4	75.2	76.4	80.2	80.0
130	66.4	66.[illegible]	69.8	72.6	74.5	77.4	78.4

SPEED	32.3	36.3	41.7	46.3	51.1	55.1	56.8
DB/DOUBLING	4.03	5.65	4.89	3.96	3.88	3.97	4.01

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	13	13	13	13	A/60/5
LRI	10	10	10	10	A/60/5
RRO	16	16	16	16	A/65/5
RRI	17	17	17	17	A/63/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

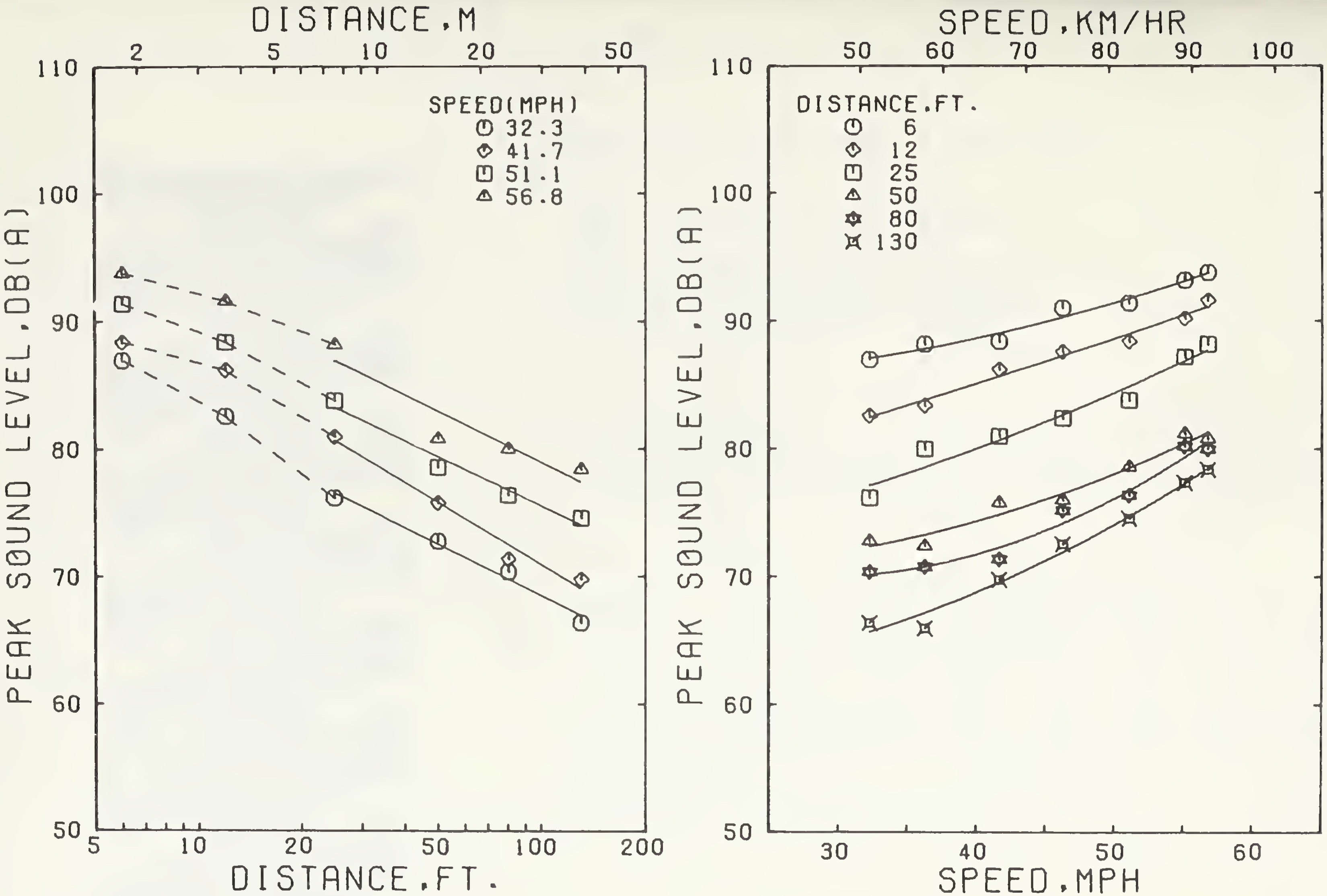


Figure A-28. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, cross-bar-F tires on the drive axle.

CROSS-BAR-F, NEW, SINGLE, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	30.6	37.6	41.7	46.5	50.4	55.2	55.7
6	82.4	85.4	86.6	88.0	89.6	90.8	92.6
12	76.8	79.2	82.2	82.4	84.4	87.2	87.4
25	71.6	74.4	76.2	77.2	78.2	81.2	82.0
50	66.8	68.6	70.4	71.4	73.2	76.8	77.0
80	63.8	65.2	66.8	67.6	71.8	71.8	74.4
130	59.2	62.2	64.0	65.4	66.6	69.0	70.8

SPEED	30.6	37.6	41.7	46.5	50.4	55.2	55.7
DB/DOUBLING	5.12	5.15	5.13	5.06	4.63	5.30	4.64

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	30 30 30 30	A/64/5
LRI		
RRO	30 30 30 30	A/64/5
RRI		

NOMINAL NEW TREAD DEPTH - 30/32 INCH

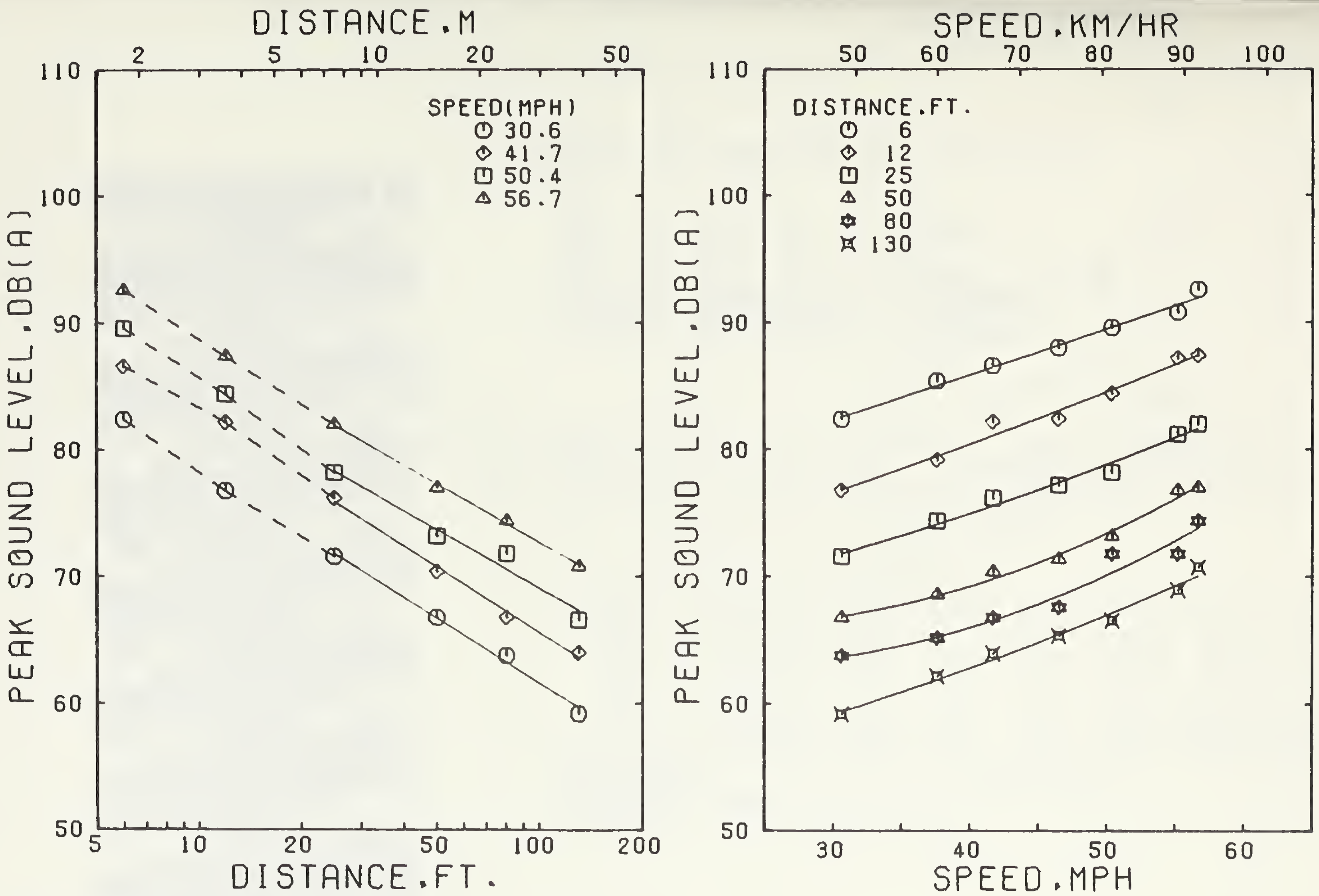


Figure A-29. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and single, new, cross-bar-F tires on the drive axle.

CROSS-BAR-F, HALF-WORN, SINGLE, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 31.3	36.8	42.6	45.7	49.7	54.6	55.9
6	85.8	86.0	92.4	94.8	93.6	107.2	101.0
12	82.2	84.6	89.2	91.8	94.0	95.4	97.8
25	78.0	80.4	83.4	85.6	87.8	91.0	92.0
50	72.4	74.8	79.4	79.4	82.6	86.0	85.8
80	70.6	73.6	76.2	76.6	78.6	83.6	81.6
130	67.2	70.4	74.2	74.2	77.6	81.0	80.2

SPEED	31.3	36.8	42.6	45.7	49.7	54.6	55.9
DB/DOUBLING	4.42	4.05	3.95	4.80	4.48	4.18	5.13

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO LRI	17 17 17 17	A/63/5
RRO RRI	16 16 16 16	A/65/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

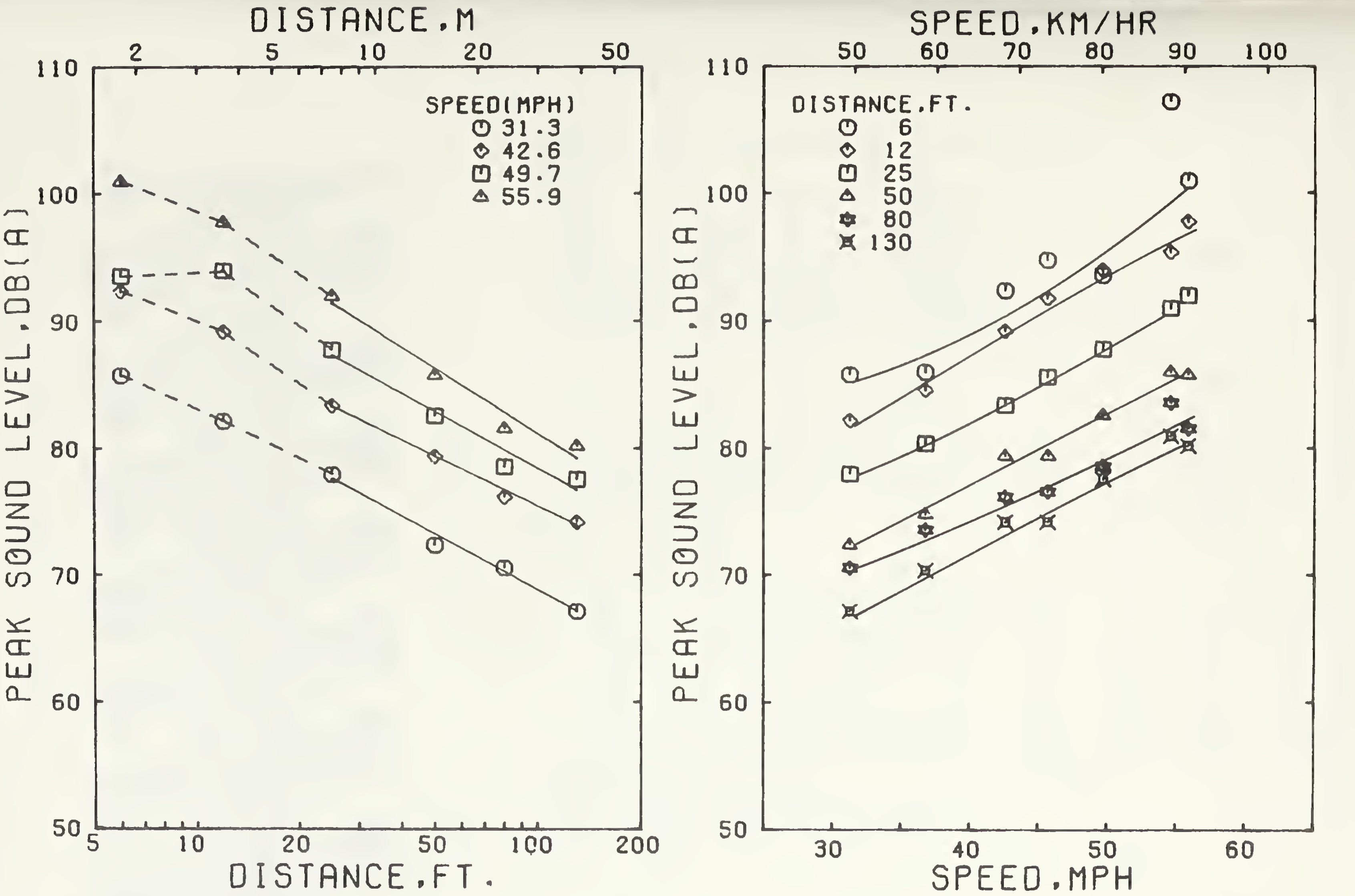


Figure A-30. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and single, half-worn, cross-bar-F tires on the drive axle.

CROSS-BAR-F, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH						
	29.3	34.7	38.9	43.2	49.6	55.5	56.7
5	82.6	88.4	87.8	89.8	90.8	94.8	95.4
12	80.6	84.0	84.4	86.4	88.2	92.0	93.4
25	75.0	77.4	79.6	80.8	82.0	85.2	85.2
50	68.8	72.8	73.6	75.0	78.0	81.4	80.8
80	65.2	69.4	69.2	71.6	74.0	76.4	76.2
130	62.2	65.6	67.8	67.4	71.6	72.6	72.8

SPEED	29.3	34.7	38.9	43.2	49.6	55.5	56.7
DB/DOUBLING	5.41	4.95	5.15	5.58	4.49	5.41	5.32

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	30 30 30 30	A/64/5
LRI	30 30 30 30	A/64/5
RRO	30 30 30 30	A/64/5
RRI	30 30 30 30	A/64/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

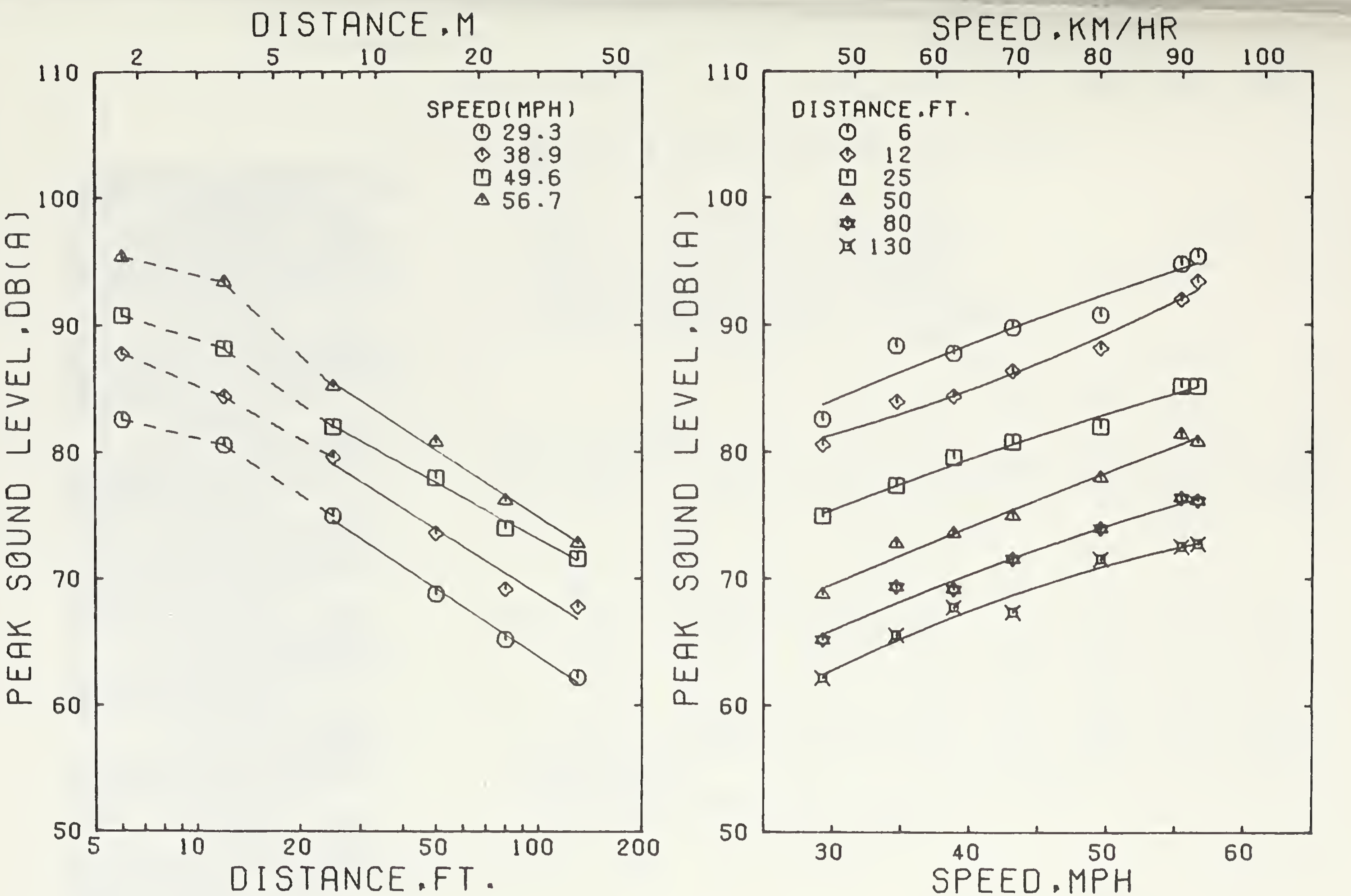


Figure A-31. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-F tires on the drive axle.

CROSS-BAR-F, HALF-WORN, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.7	35.0	39.6	43.7	49.2	53.7	57.5
6	86.4	91.2	91.8	93.0	94.6	96.6	100.8
12	82.6	86.6	88.6	90.0	90.4	94.6	97.8
25	77.0	82.0	83.2	86.0	86.0	90.0	90.2
50	73.0	77.4	79.2	81.2	81.4	85.2	87.2
80	68.6	72.6	75.6	76.6	78.8	80.6	82.2
130	*****	68.2	70.4	72.2	73.4	76.2	77.0

SPEED	29.7	35.0	39.6	43.7	49.2	53.7	57.5
DB/DOUBLING	4.93	5.86	5.31	5.84	5.13	5.84	5.59

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	13	13	13	13	A/60/5
LRI	10	10	10	10	A/60/5
RRO	16	16	16	15	A/65/5
RRI	17	17	17	17	A/63/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

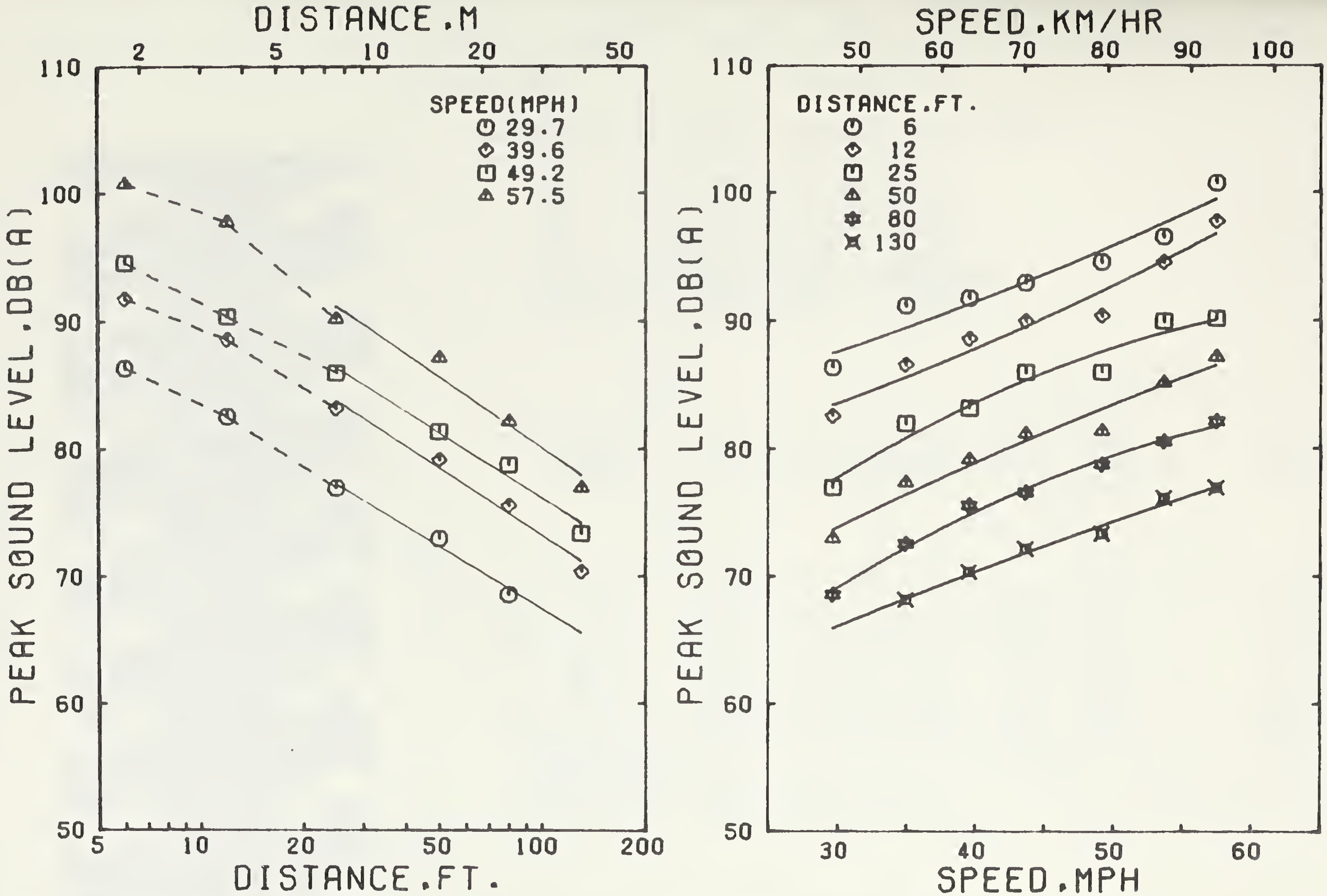


Figure A-32. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, cross-bar-F tires on the drive axle.

CROSS-BAR-F, NEW, DUAL, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 32.7	36.1	41.5	45.8	48.6	54.4
6	77.8	79.6	82.8	82.0	83.0	85.4
12	75.4	76.6	78.4	78.4	80.0	83.8
25	69.0	70.6	73.0	73.8	75.4	77.4
50	64.2	65.4	67.4	69.2	70.0	72.2
80	59.6	61.4	64.2	64.8	66.0	67.0
130	55.4	57.4	59.4	60.0	61.2	62.6

SPEED	32.7	36.1	41.5	45.8	48.6	54.4
DB/DOUBLING	5.77	5.56	5.62	5.81	5.94	6.30

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	30 30 30 30	A/64/5
LRI	30 30 30 30	A/64/5
RRO	30 30 30 30	A/64/5
RRI	30 30 30 30	A/64/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

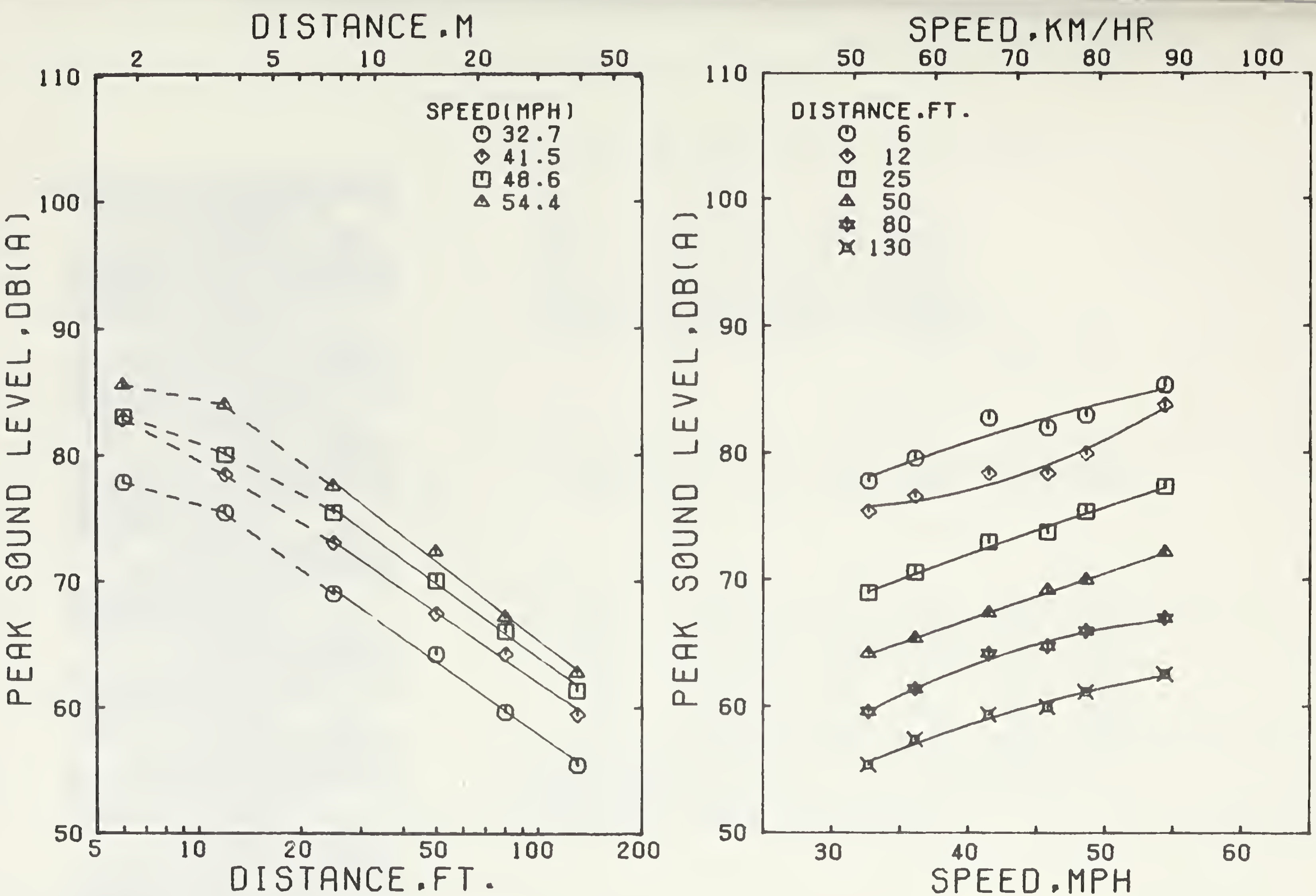


Figure A-33. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, cross-bar-F tires on the drive axle.

CROSS-BAR-F, HALF-WORN, DUAL, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 32.4	36.7	39.7	44.2	49.8
6	83.6	84.6	86.6	88.8	89.6
12	81.0	81.2	84.0	86.2	86.8
25	75.4	76.8	78.4	79.6	81.2
50	70.2	72.6	72.6	75.4	76.8
80	*****	*****	*****	*****	*****
130	63.4	65.6	65.0	67.0	69.0

SPEED	32.4	36.7	39.7	44.2	49.8
DB/DOUBLING	5.04	4.73	5.63	5.35	5.16

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	13 13 13 13	A/60/5
LRI	10 10 10.10	A/60/5
RRO	17 17 17 17	A/63/5
RRI	16 16 16 16	A/65/5

NOMINAL NEW TREAD DEPTH - 30/32 INCH

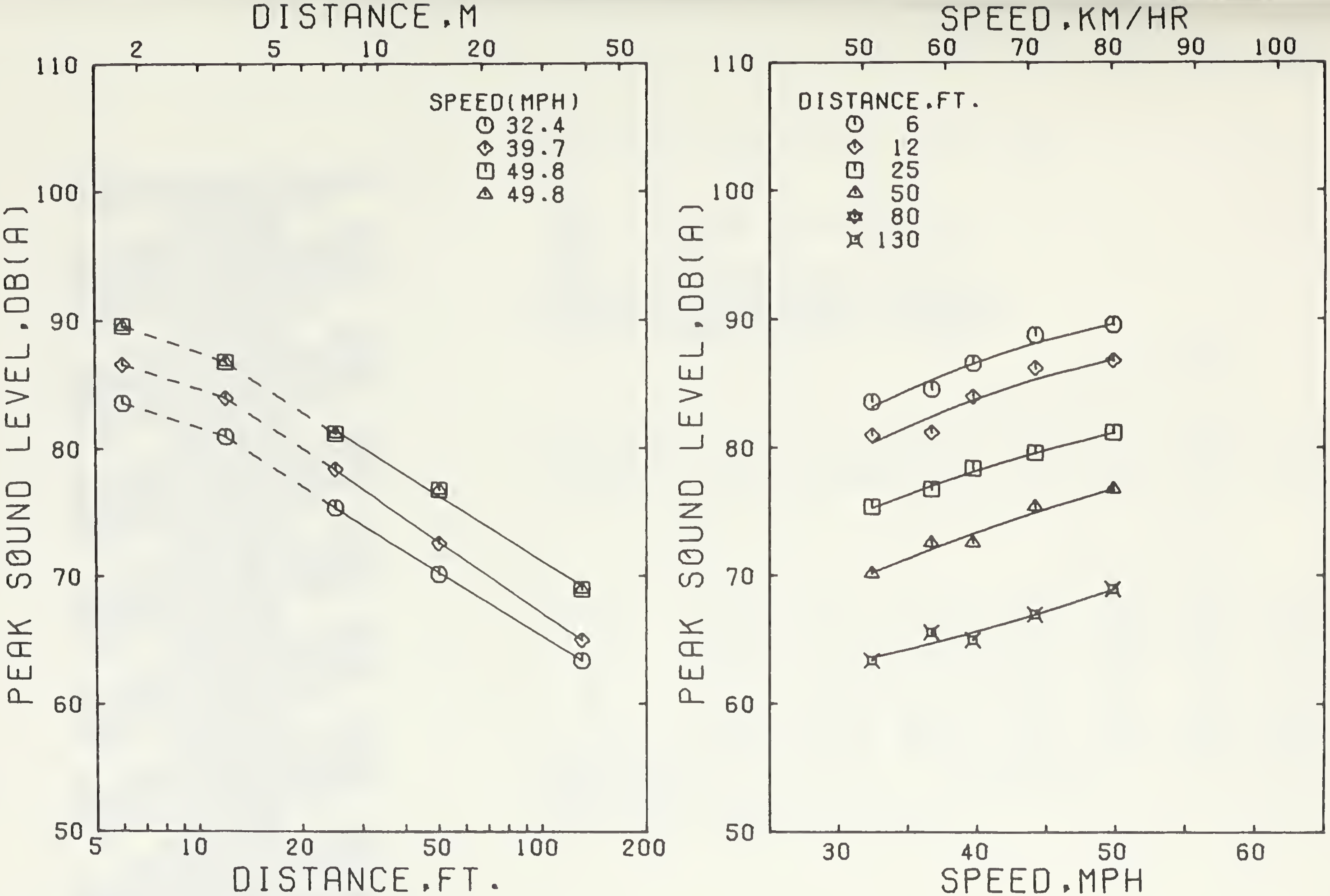


Figure A-34. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, cross-bar-F tires on the drive axle.

CROSS-BAR-F, NEW, SINGLE, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	29.5	35.6	41.0	45.4	49.0	54.5	57.0
6	78.0	81.4	84.4	85.0	89.6	87.6	89.0
12	76.0	79.0	80.4	81.0	83.0	86.2	86.2
25	69.6	73.2	75.2	75.4	77.6	79.2	81.2
50	63.4	66.0	68.8	71.0	72.0	74.0	74.8
80	60.2	63.0	64.8	65.8	68.6	70.0	71.2
130	55.0	58.4	60.0	62.4	63.0	65.6	66.6

SPEED	29.5	35.6	41.0	45.4	49.0	54.5	57.0
DB/DOUBLING	6.91	6.11	6.35	5.61	6.01	5.71	6.07

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	30 30 30 30	A/64/5
LRI		
RRO	30 30 30 30	A/64/5
RRI		

NOMINAL NEW TREAD DEPTH - 30/32 INCH

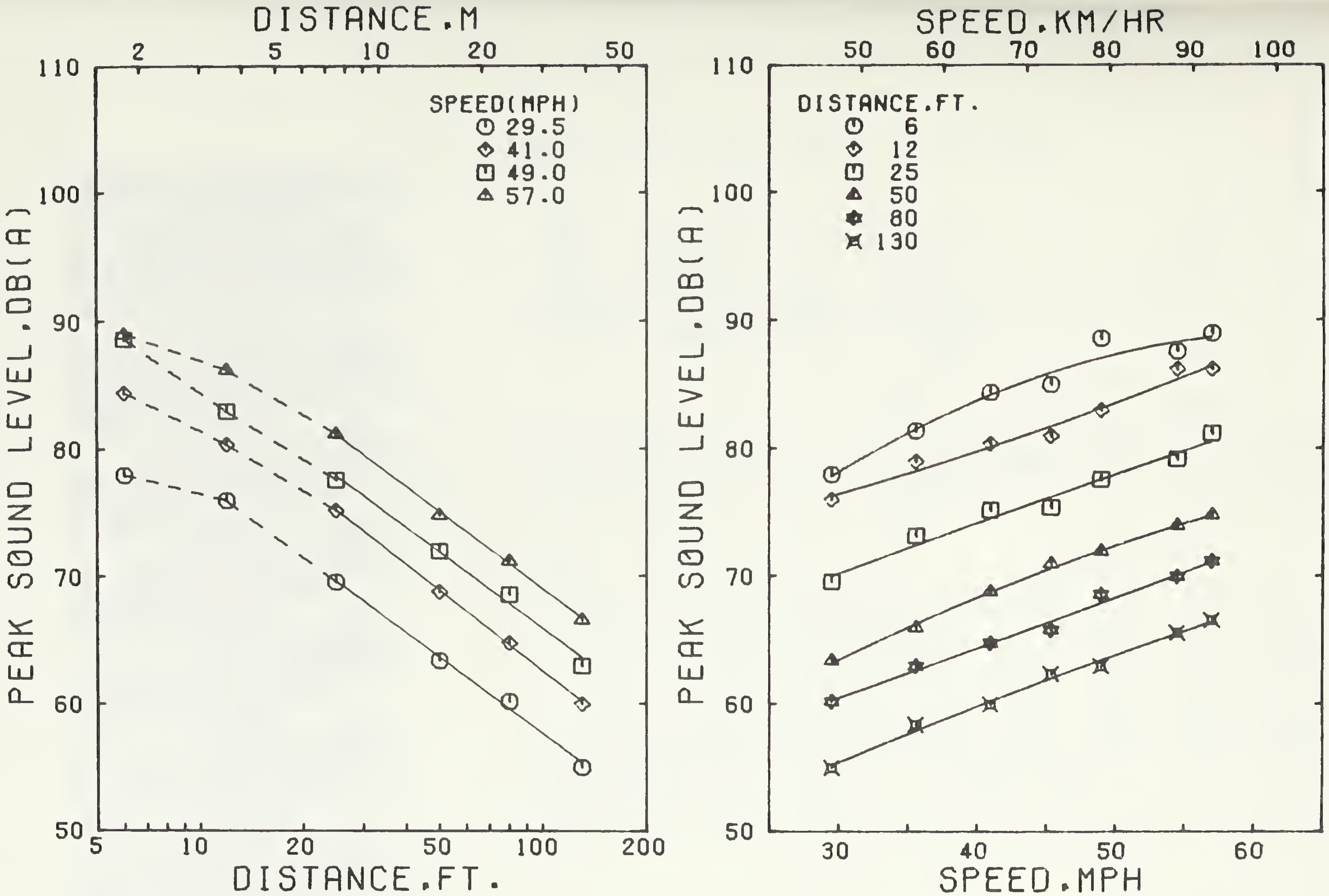


Figure A-35. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and single, new, cross-bar-F tires on the drive axle.

CROSS-BAR-F, HALF-WORN, SINGLE, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 34.3	37.3	40.0	43.9	48.2	54.9	56.8
6	83.2	87.4	87.6	88.8	91.2	95.2	96.0
12	82.8	85.0	85.2	86.4	87.6	92.0	92.6
25	77.0	79.0	81.0	82.2	84.4	86.6	87.0
50	74.0	76.4	76.8	78.4	78.8	83.0	83.8
80	*****	*****	*****	*****	*****	*****	*****
130	64.0	63.8	68.0	68.8	70.6	73.0	73.6

SPEED	34.3	37.3	40.0	43.9	48.2	54.9	56.8
DB/DOUBLING	5.57	6.56	5.52	5.71	5.81	5.81	5.74

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	17 17 17 17	A/63/5
LRI		
RRO	16 16 16 16	A/65/5
RRI		

NOMINAL NEW TREAD DEPTH - 30/32 INCH

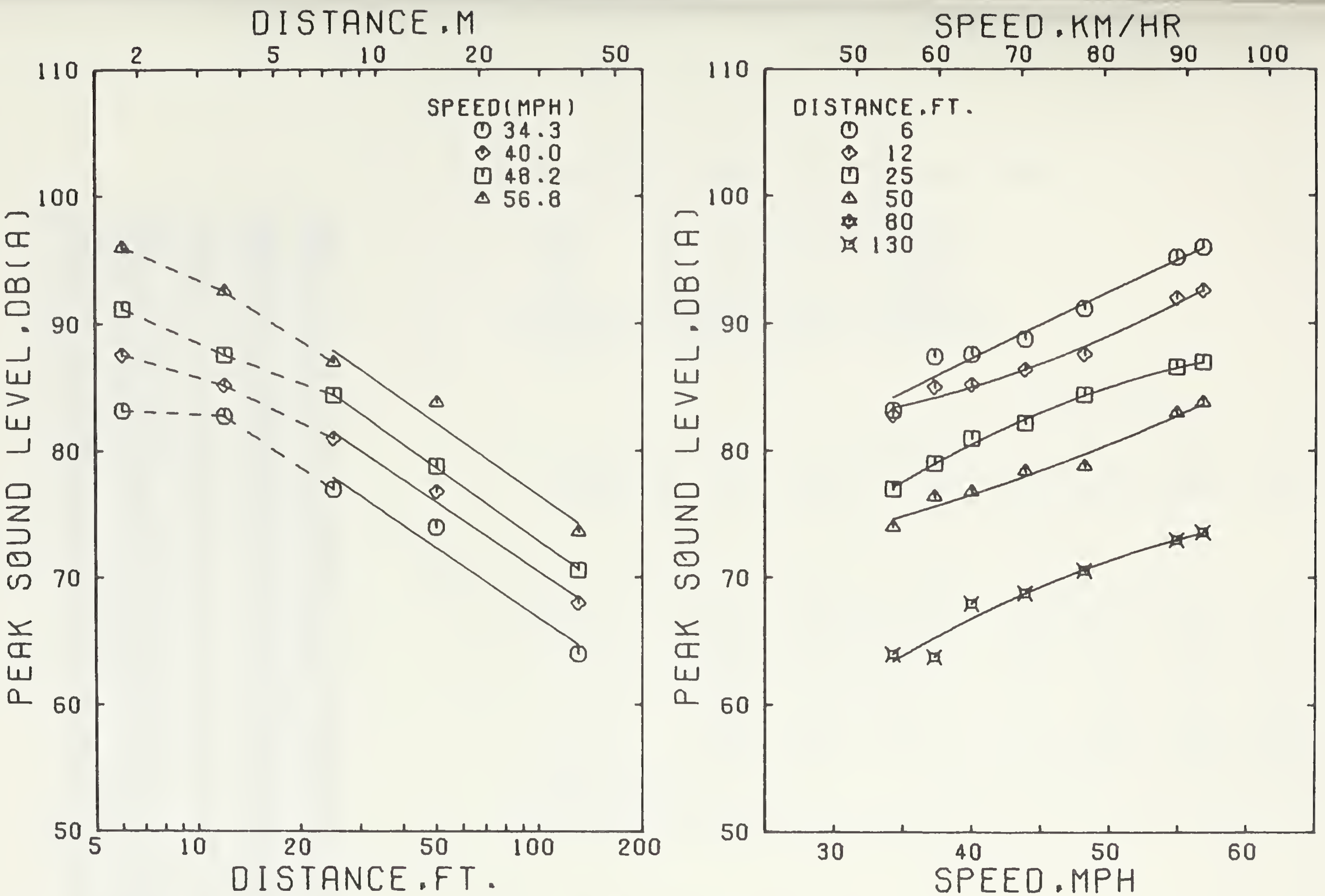


Figure A-36. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and single, half-worn, cross-bar-F tires on the drive axle.

RETREAD-G, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	28.6	33.7	37.9	44.7	47.9	52.8	57.3
6	78.4	80.6	81.4	82.0	82.4	84.8	86.8
12	75.4	77.8	79.2	82.8	80.0	82.8	83.4
25	70.4	72.0	76.6	76.6	77.0	77.2	78.0
50	65.8	65.2	70.0	72.2	71.6	72.6	73.2
80	65.6	64.6	67.8	68.6	68.8	70.0	71.0
130	58.4	60.4	64.6	65.2	65.6	67.6	68.4

SPEED	28.6	33.7	37.9	44.7	47.9	52.8	57.3
DB/DOUBLING	4.59	4.69	4.96	4.82	4.76	4.04	4.00

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	16 16 16 16	A/57/5
LRI	16 16 16 16	A/59/5
RRO	16 16 16 16	A/60/5
RRI	16 16 16 16	A/55/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

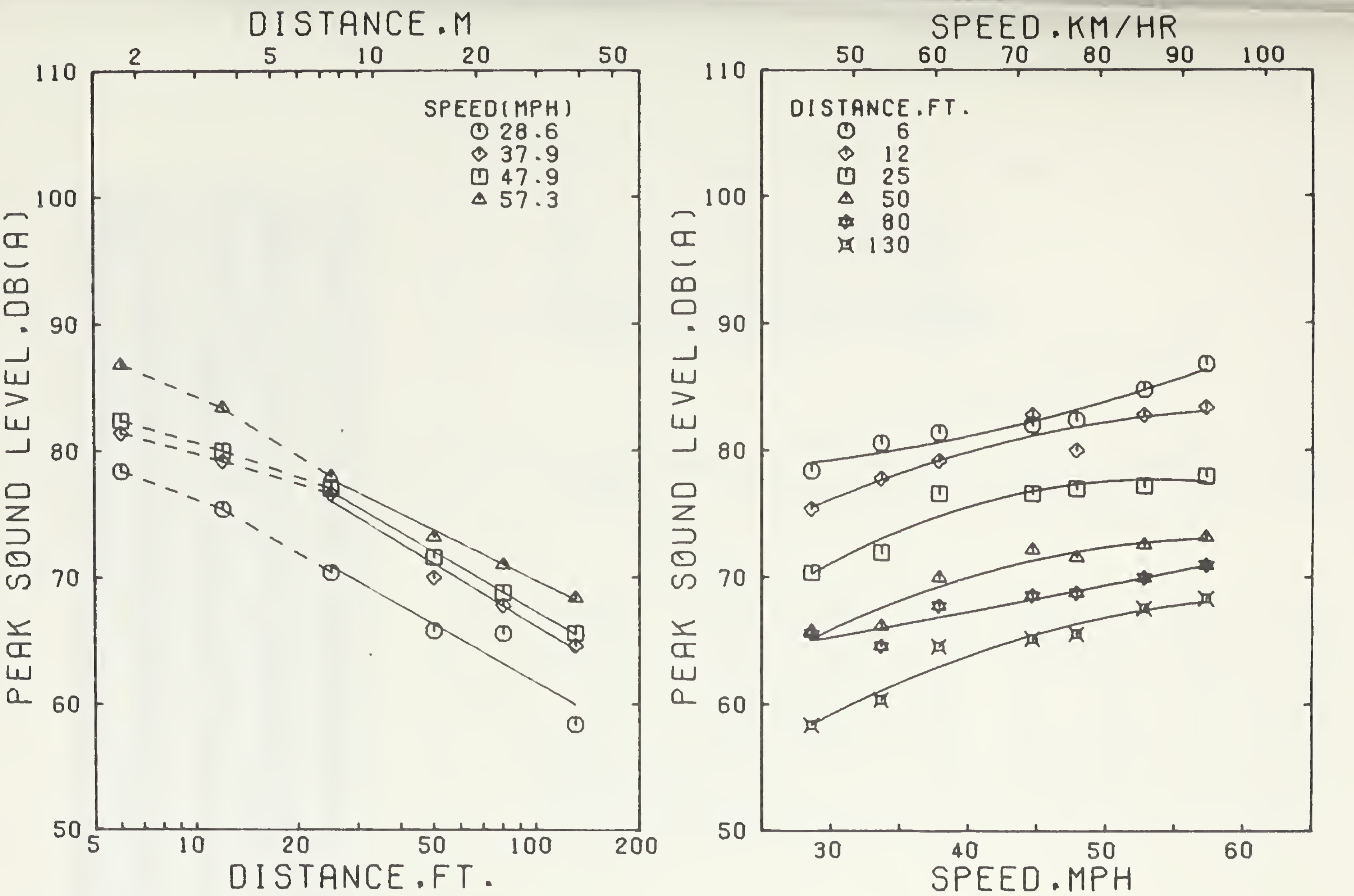


Figure A-37. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-G tires on the drive axle.

RETREAD-G, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	28.7	34.7	39.5	44.2	48.3	53.5	58.1
6	80.2	81.8	84.4	84.8	86.8	87.0	88.6
12	76.6	73.8	81.8	82.4	83.2	85.6	86.2
25	71.0	74.2	77.8	76.4	77.6	79.8	80.2
50	66.0	69.4	71.6	71.8	72.8	74.4	75.8
80	61.4	65.6	67.0	66.8	68.2	71.0	71.0
130	57.0	60.6	62.8	62.8	63.8	66.4	66.2

SPEED	28.7	34.7	39.5	44.2	48.3	53.5	58.1
DB/DOUBLING	5.92	5.66	6.34	5.81	5.84	5.57	5.92

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	16	16	16	16	A/57/5
LRI	16	16	16	16	A/59/5
RRO	16	16	16	16	A/60/5
RRI	16	16	16	16	A/55/5

NOMINAL NEW TREAD DEPTH - 16/32 INCH

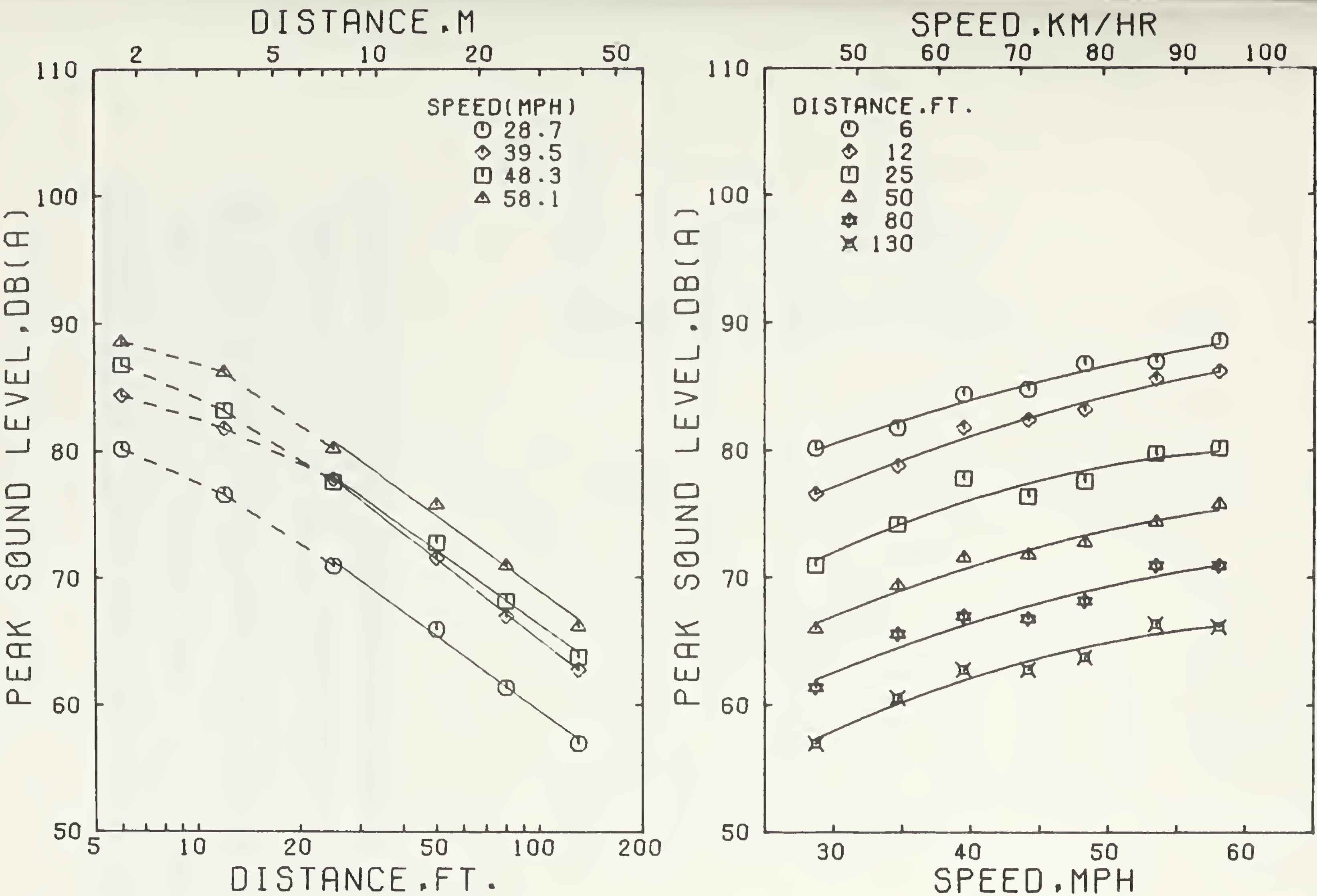


Figure A-38. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-G tires on the drive axle.

RETREAD-H, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 28.5	34.3	39.0	43.5	48.2	54.1	55.7
6	82.6	86.0	86.2	88.8	91.0	92.2	92.2
12	79.4	83.4	83.4	86.4	88.2	89.0	91.4
25	74.0	78.6	79.6	80.8	83.4	84.8	85.6
50	69.4	73.0	75.0	77.6	79.2	80.2	81.2
80	65.2	73.0	71.3	71.8	75.0	77.0	77.4
130	61.8	65.4	66.4	66.6	70.6	73.0	72.4

SPEED	28.5	34.3	39.0	43.5	48.2	54.1	55.7
DB/DOUBLING	5.20	5.05	5.43	6.07	5.40	4.92	5.50

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	18	18	18	18	A/60/5
LRI	18	18	18	18	A/59/5
RRO	18	18	18	18	A/60/5
RRI	18	18	18	18	A/60/5

NOMINAL NEW TREAD DEPTH - 18/32 INCH

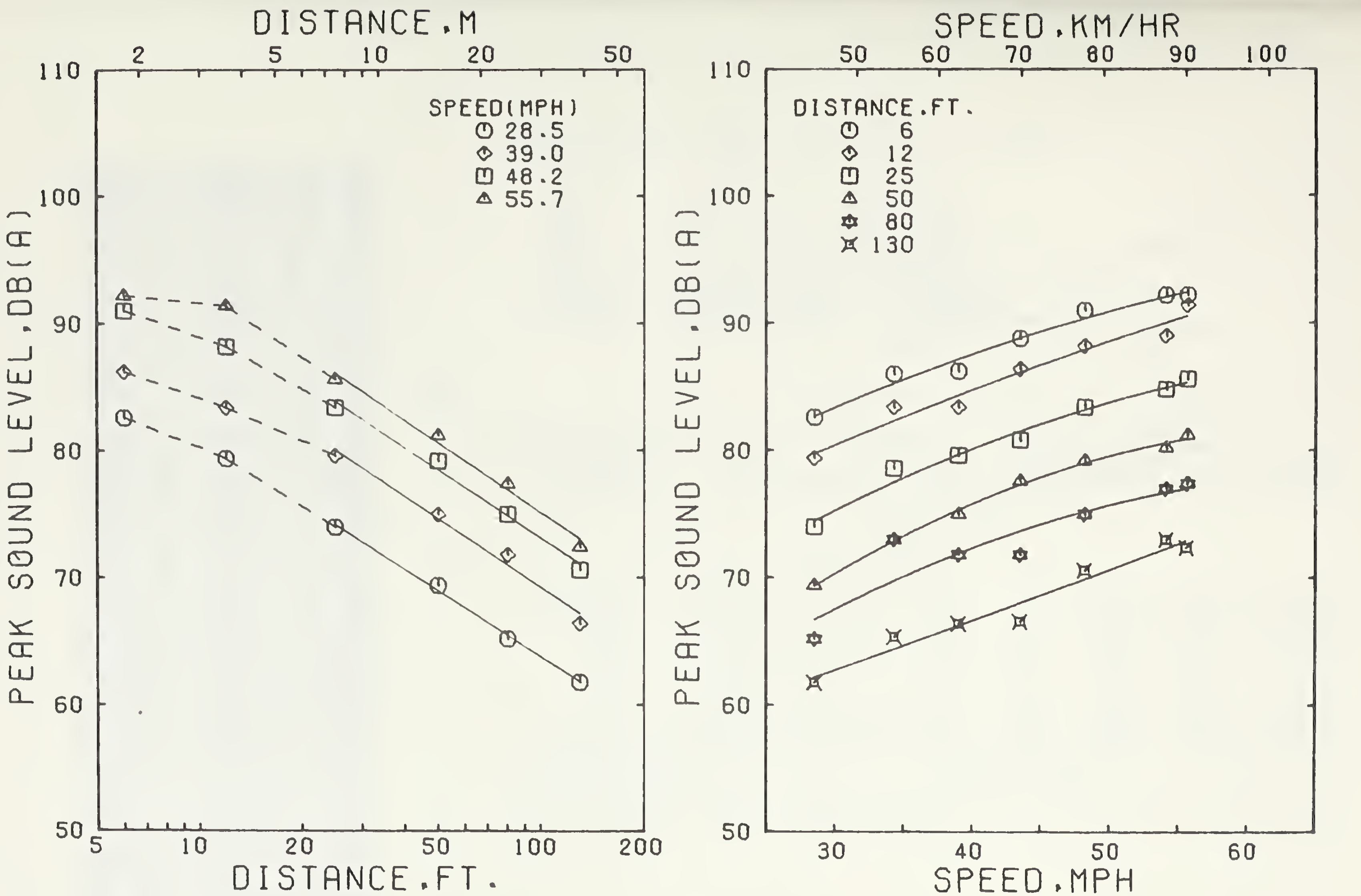


Figure A-39. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-H tires on the drive axle.

RETREAD-H, HALF-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.8	34.4	40.0	45.4	48.6	53.7	57.9
6	84.0	87.4	91.4	92.6	92.6	96.0	96.2
12	81.8	84.6	87.4	90.2	92.8	92.4	93.0
25	77.4	80.4	84.8	86.0	88.0	89.0	89.2
50	72.2	74.4	78.4	81.6	82.8	86.8	84.6
80	70.8	71.6	74.8	78.8	79.6	81.0	82.8
130	67.0	70.0	73.0	76.2	77.2	79.0	80.6

SPEED	29.8	34.4	40.0	45.4	48.6	53.7	57.9
DB/DOUBLING	4.20	4.43	5.06	4.13	4.59	4.50	3.58

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	9	9	9	9	A/55/5
LRI	10	10	10	10	A/61/5
RRO	9	9	9	9	A/60/5
RRI	8	8	8	8	A/61/5

NOMINAL NEW TREAD DEPTH - 18/32 INCH

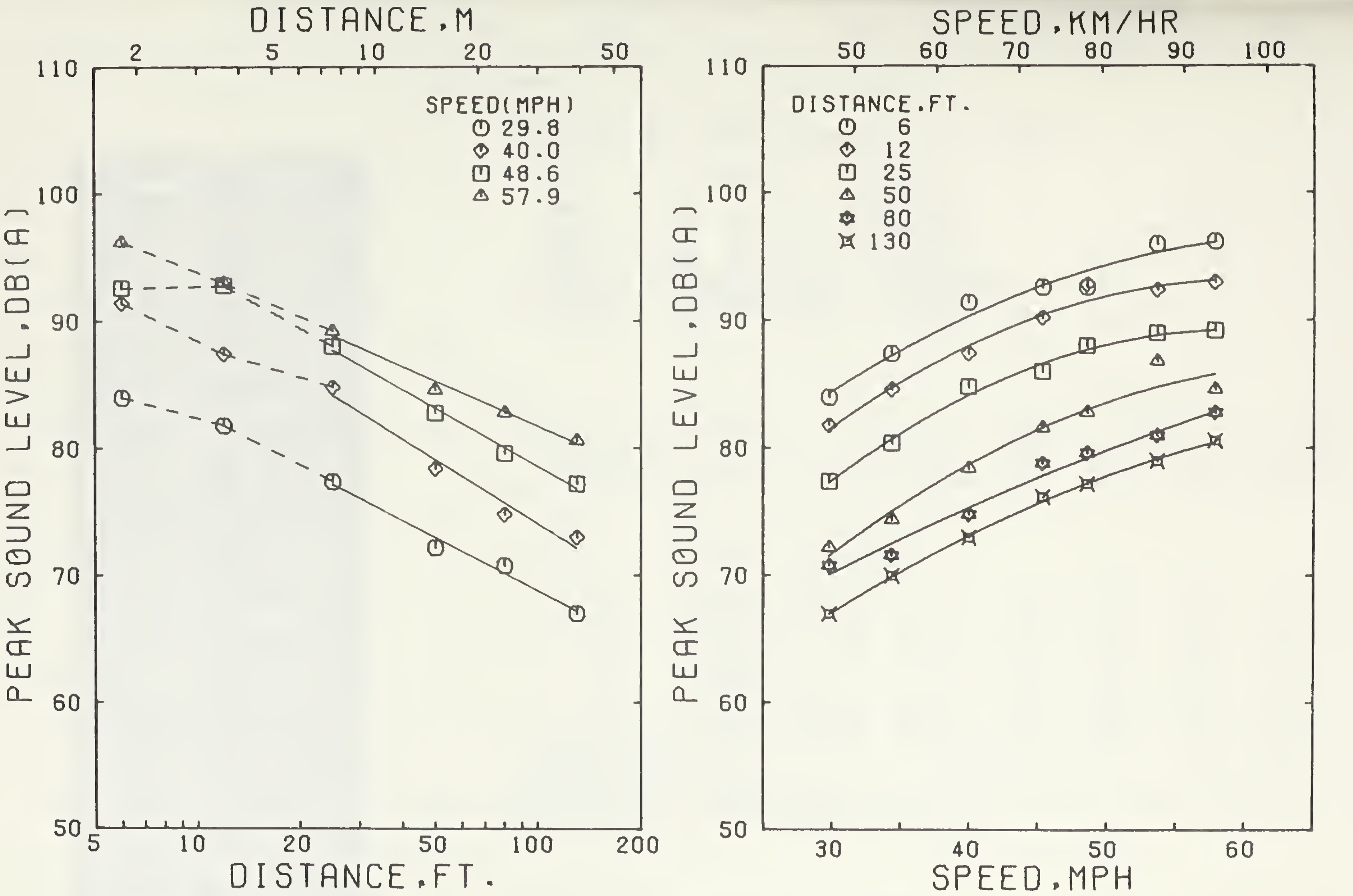
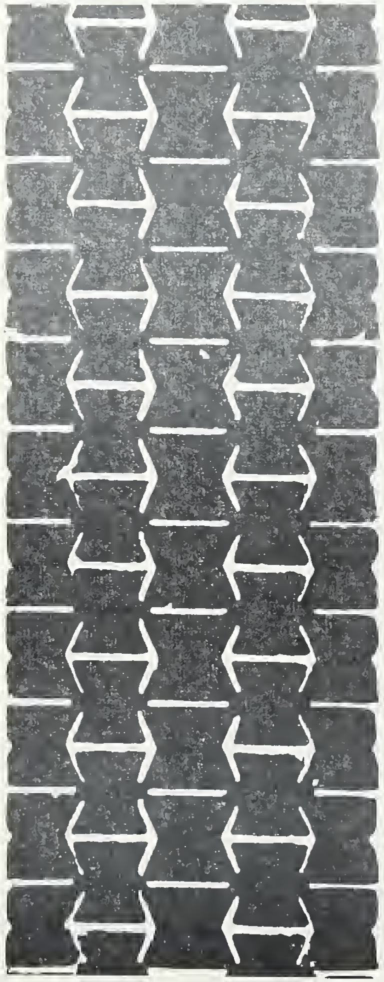


Figure A-40. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, retread-H tires on the drive axle.



RETREAD-H, FULLY-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH						
	29.7	34.1	39.4	44.1	49.6	54.3	58.0
6	84.0	85.6	89.0	91.2	93.4	95.4	98.4
12	81.6	83.6	87.6	89.2	91.8	94.0	94.4
25	76.8	79.4	82.2	86.0	89.4	89.2	92.6
50	72.2	75.4	79.8	80.8	83.4	86.0	86.8
80	70.0	71.0	75.8	77.4	81.0	81.4	83.2
130	68.4	69.6	72.4	74.6	76.2	78.8	79.0

SPEED	29.7	34.1	39.4	44.1	49.6	54.3	58.0
DB/DOUBLING	3.56	4.33	4.20	4.83	5.39	4.53	5.68

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	6	6	6	6	A/62/5
LRI	3	3	3	3	A/65/5
RRO	5	5	5	5	A/70/5
RRI	3	3	3	3	A/67/5

NOMINAL NEW TREAD DEPTH - 18/32 INCH

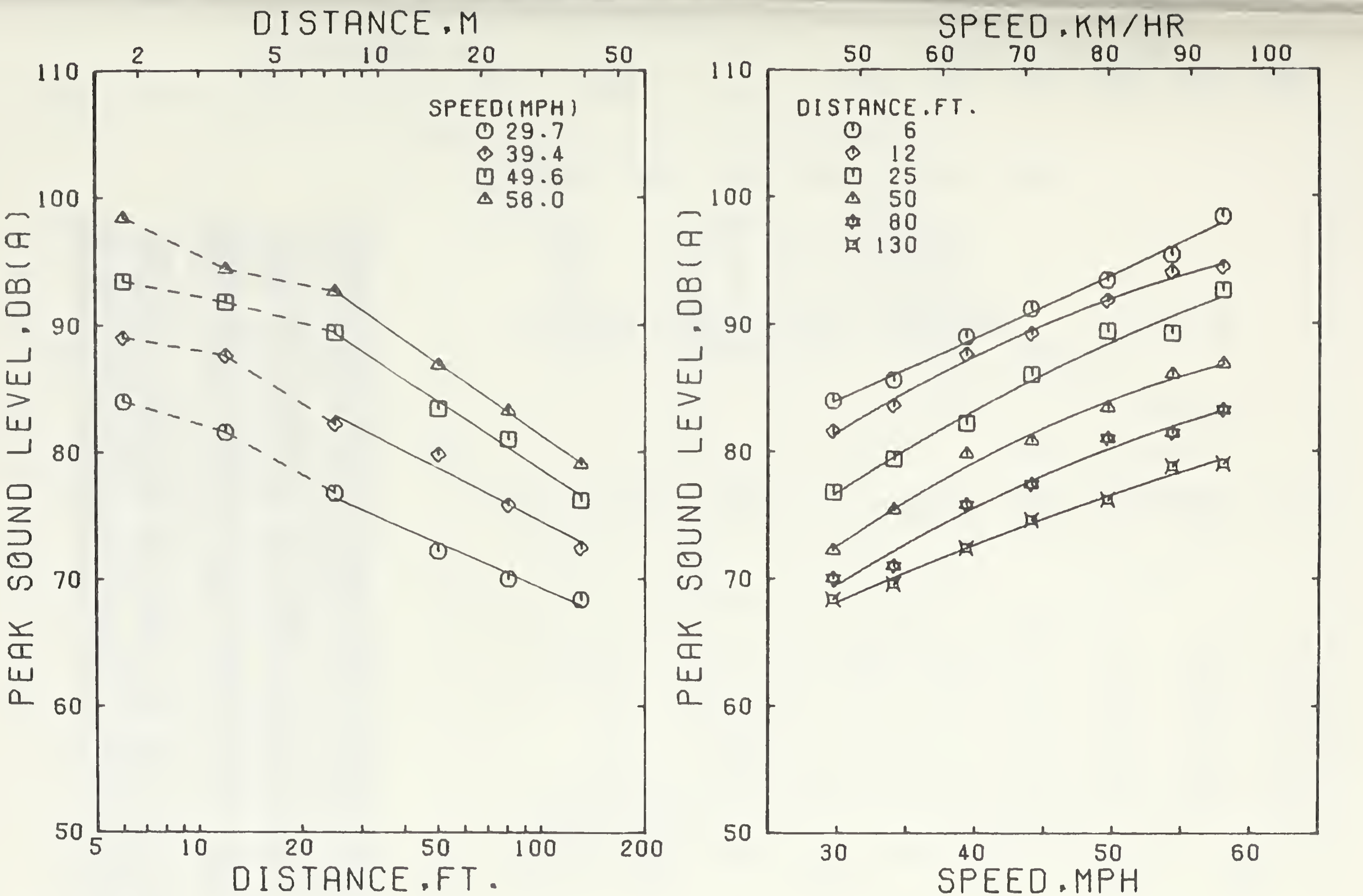


Figure A-41. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, fully-worn, retread-H tires on the drive axle.

RETREAD-H, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	31.1	34.7	38.7	43.9	48.7	54.1	57.9
6	83.6	86.6	87.2	90.0	91.6	92.4	93.4
12	81.0	82.4	85.0	87.2	89.8	91.0	91.6
25	75.0	77.8	78.6	82.2	89.0	85.2	86.0
50	71.0	73.0	74.8	79.0	82.2	81.8	82.8
80	67.0	63.4	71.2	76.8	78.6	78.6	76.8
130	65.8	66.8	65.4	69.0	71.8	73.2	73.8

SPEED	31.1	34.7	38.7	43.9	48.7	54.1	57.9
DB/DOUBLING	4.06	4.83	5.44	5.22	7.03	4.94	5.37

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	18	18	18	18	A/60/5
LRI	18	18	18	18	A/59/5
RRO	18	18	18	18	A/60/5
RRI	18	18	18	18	A/60/5

NOMINAL NEW TREAD DEPTH - 18/32 INCH

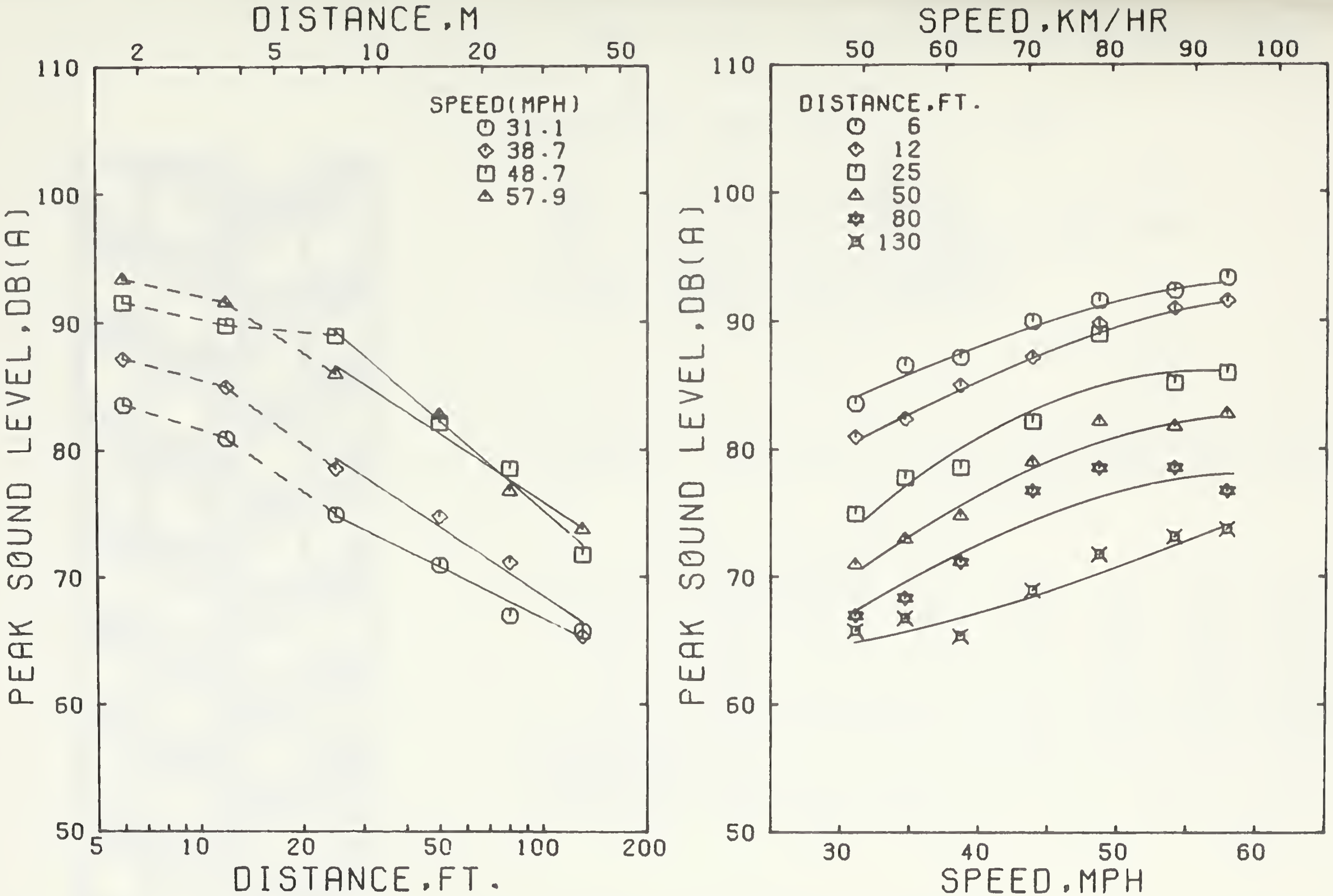
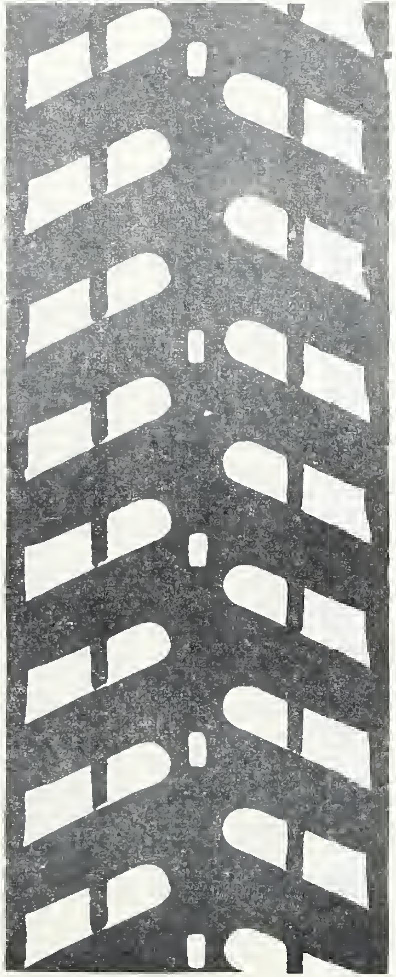


Figure A-42. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-H tires on the drive axle.



RETREAD-I, NEW, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 28.1	32.8	37.9	43.1	47.7	52.4	54.4
6	99.4	102.2	104.8	105.0	107.2	109.4	109.6
12	95.0	98.4	100.6	103.4	103.8	106.2	106.0
25	89.2	92.0	93.8	96.8	98.0	99.8	100.2
50	81.4	85.2	87.8	88.8	93.0	94.6	95.6
80	79.0	81.0	86.0	85.4	88.4	90.2	92.8
130	76.8	78.8	80.2	84.0	85.0	87.2	87.4

SPEED	28.1	32.8	37.9	43.1	47.7	52.4	54.4
DB/DOUBLING	5.19	5.67	5.45	5.34	5.56	5.40	5.23

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	17 17 17 17	A/60/5
LRI	17 17 17 17	A/60/5
RRO	17 17 17 17	A/60/5
RRI	17 17 17 17	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

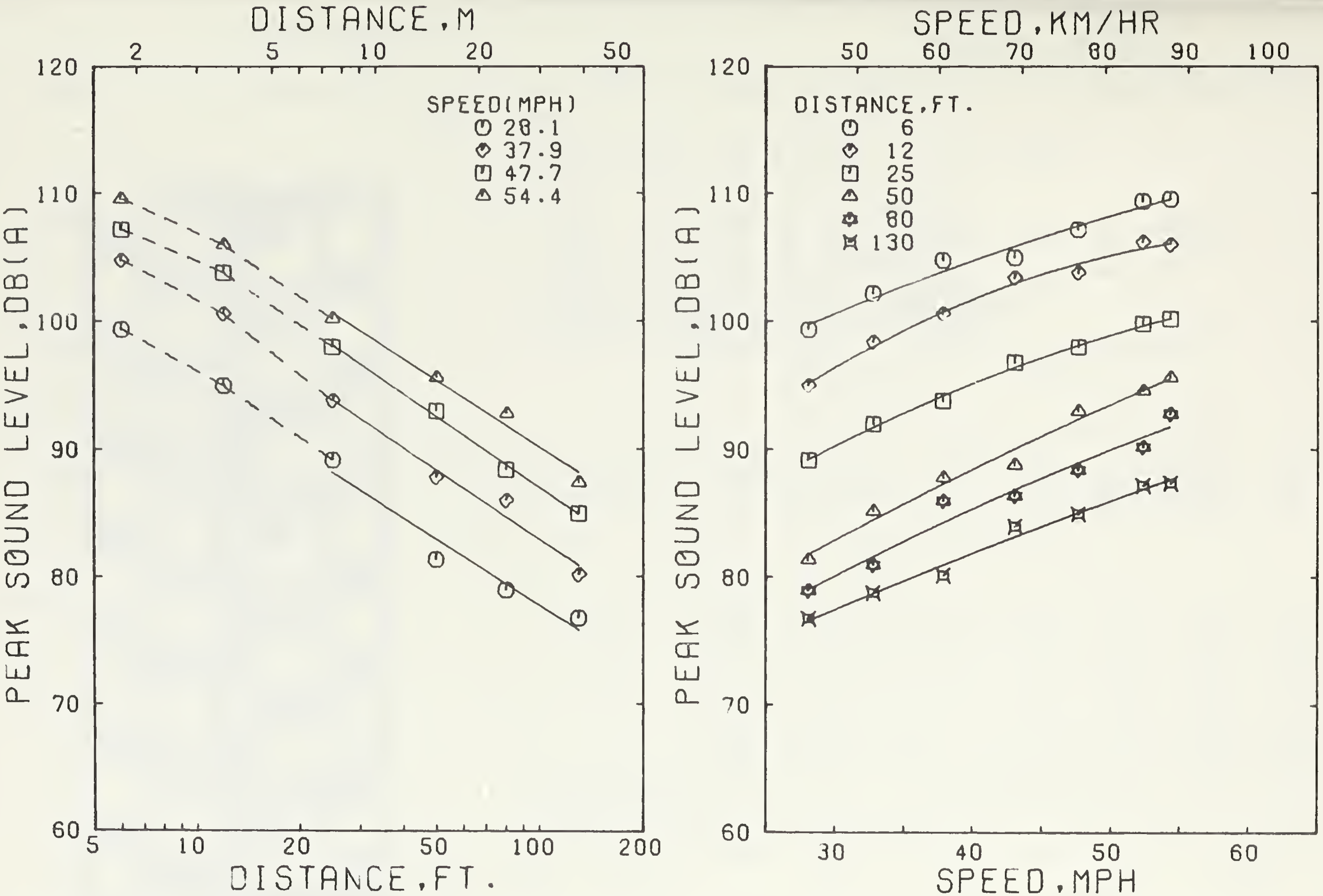
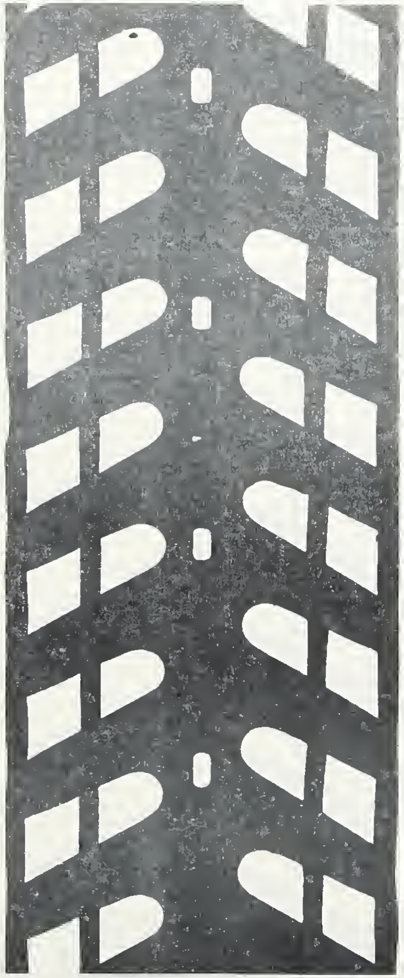


Figure A-43. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-I tires on the drive axle.



RETREAD-I, HALF-WORN, DUAL, LOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH						
	28.0	34.1	40.0	45.0	49.8	54.1	57.2
6	98.2	102.6	107.0	108.6	107.6	108.8	109.6
12	95.4	99.0	103.4	104.4	105.6	106.4	108.0
25	90.0	95.6	96.8	97.8	99.2	99.8	100.2
50	86.2	89.6	92.2	91.4	93.6	94.4	94.0
80	81.8	85.2	86.8	87.6	88.8	90.6	90.8
130	78.4	83.2	84.6	84.6	87.2	89.0	87.8

SPEED	28.0	34.1	40.0	45.0	49.8	54.1	57.2
DB/DOUBLING	4.97	5.37	5.36	5.60	5.26	4.68	5.22

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	12 12 12 12	A/60/5
LRI	12 12 12 12	A/60/5
RRO	12 12 12 12	A/60/5
RRI	12 12 12 12	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

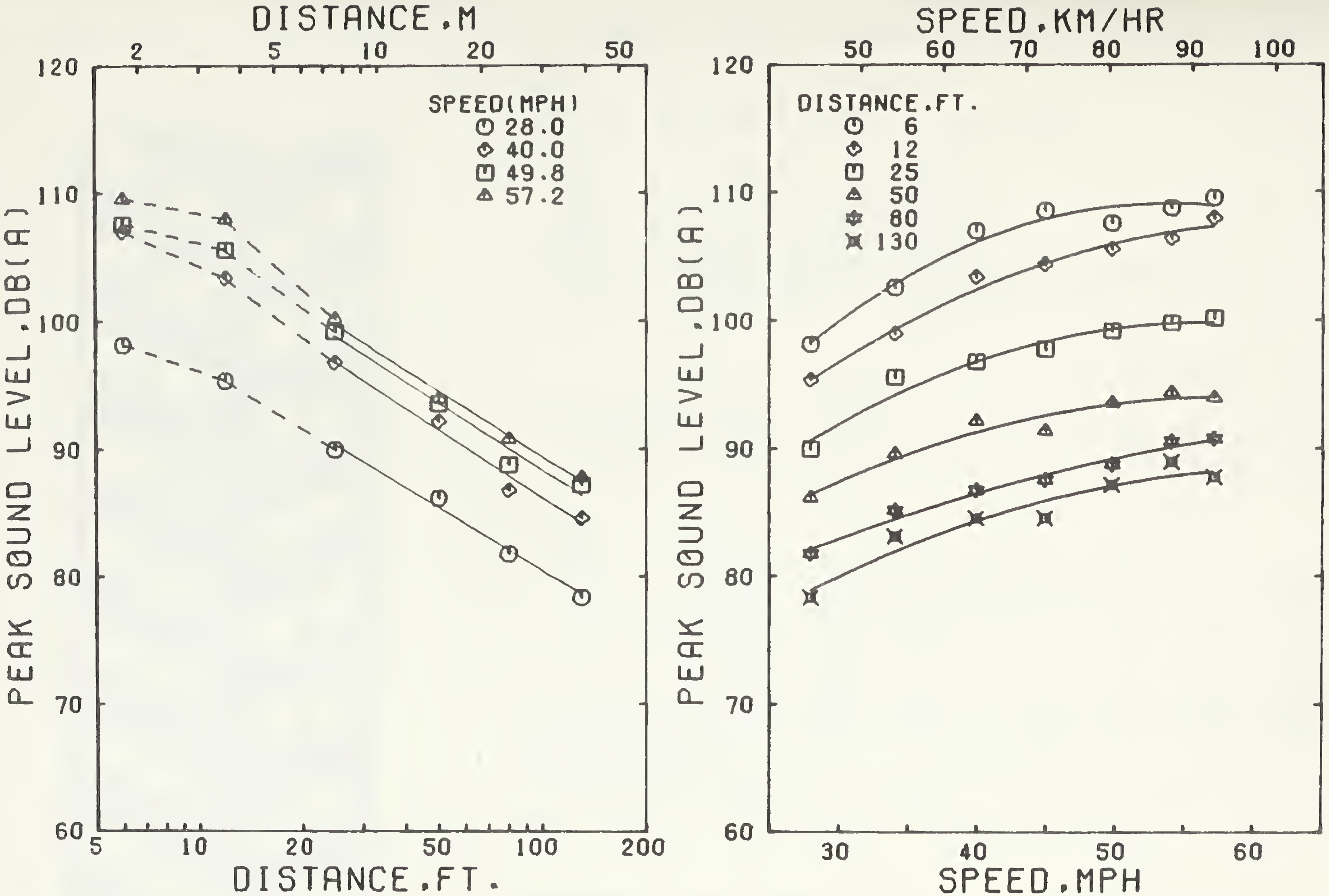
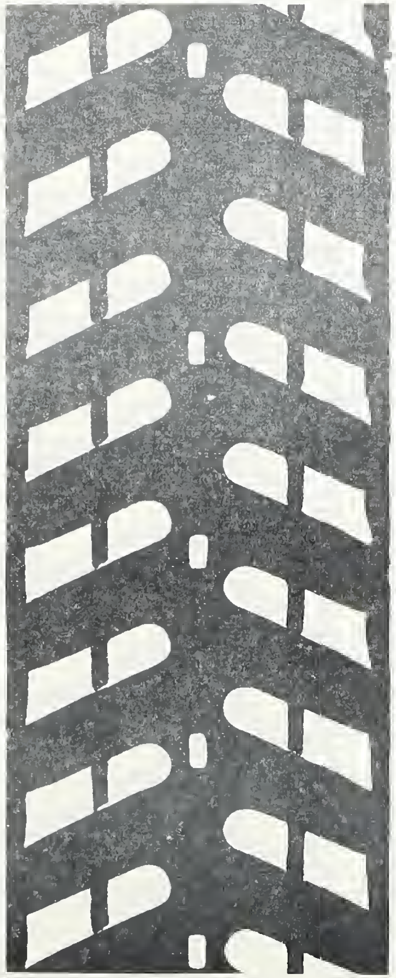


Figure A-44. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, retread-I tires on the drive axle.

RETREAD-I, NEW, DUAL, UNLOADED, CONCRETE



A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	30.6	36.8	41.8	46.6	51.2	55.5	56.5
6	94.8	97.2	101.8	98.6	102.4	103.2	103.4
12	92.0	93.2	95.6	96.0	98.0	98.6	100.8
25	85.4	86.8	90.6	91.2	93.2	93.6	94.4
50	80.0	81.6	85.4	86.8	88.2	88.4	89.4
80	77.4	78.4	81.6	82.4	83.0	85.2	84.0
130	72.6	76.0	78.4	78.2	81.2	81.8	82.6

SPEED	30.6	36.8	41.8	46.6	51.2	55.5	56.5
DB/DOUBLING	5.24	4.59	5.18	5.51	5.28	4.95	5.24

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	17 17 17 17	A/60/5
LRI	17 17 17 17	A/60/5
RRO	17 17 17 17	A/60/5
RRI	17 17 17 17	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

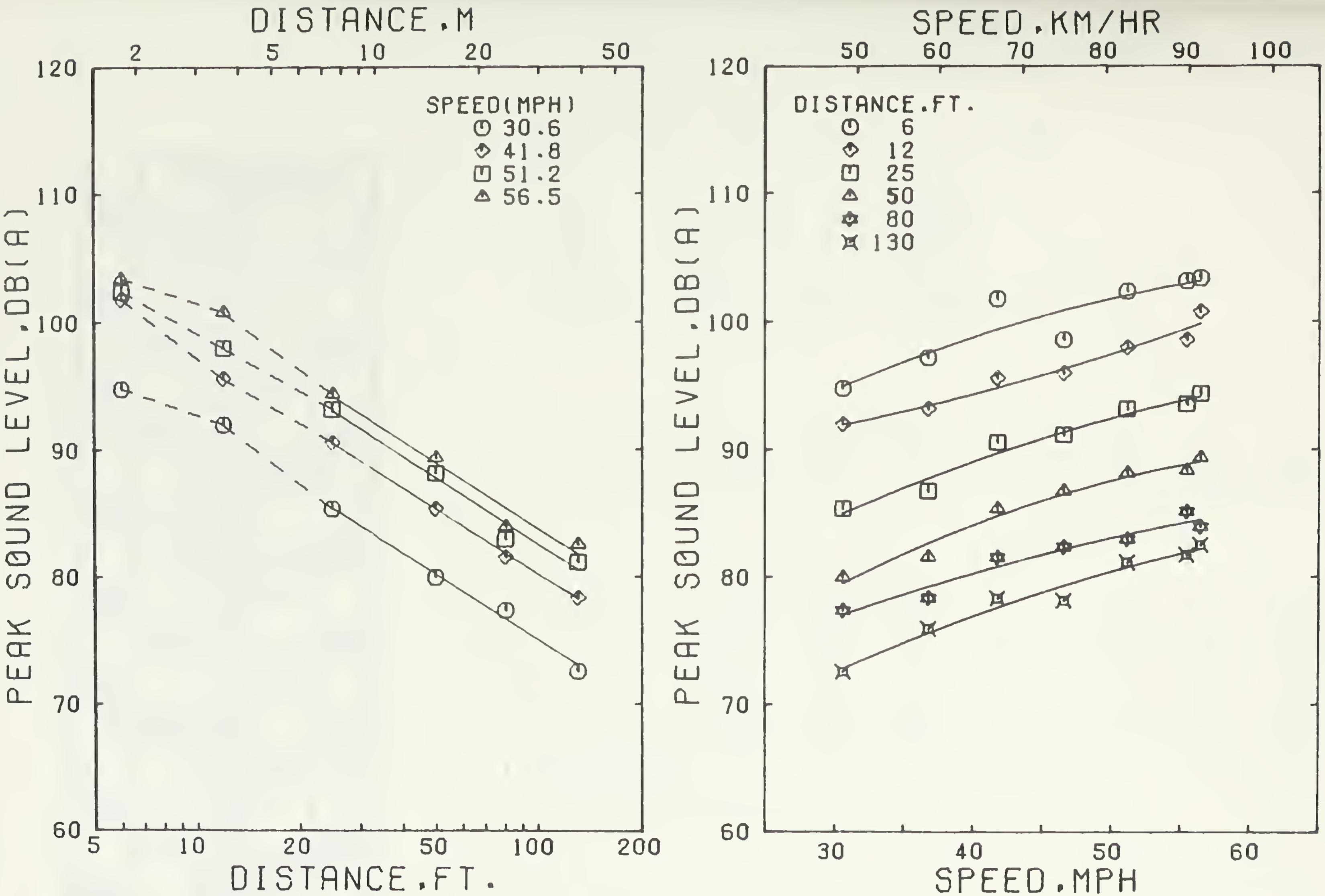
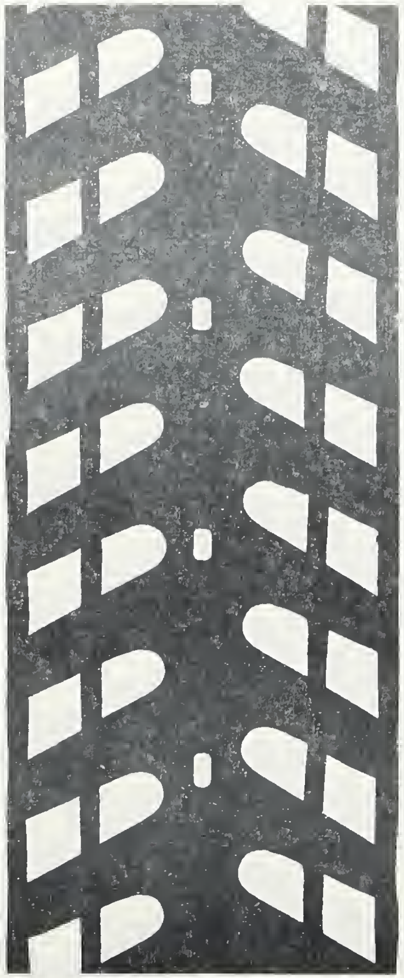


Figure A-45. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-I tires on the drive axle.



RETREAD-I, HALF-WORN, DUAL, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	30.3	35.8	40.4	44.7	49.3	55.0	55.4
6	93.8	97.0	101.0	99.8	103.8	105.0	104.8
12	91.2	92.2	95.0	96.0	99.8	99.4	100.6
25	85.0	87.6	91.2	91.0	91.2	94.2	94.6
50	79.4	82.8	84.2	86.6	86.2	89.0	88.2
80	76.4	78.4	80.4	82.2	83.2	85.4	83.6
130	*****	*****	*****	*****	*****	*****	*****

SPEED	30.3	35.8	40.4	44.7	49.3	55.0	55.4
DB/DOUBLING	5.16	5.43	6.48	5.18	4.78	5.24	6.54

TIRE LOCATION	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LRO	12	12	12	12	A/60/5
LRI	12	12	12	12	A/60/5
RRO	12	12	12	12	A/60/5
RRI	12	12	12	12	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

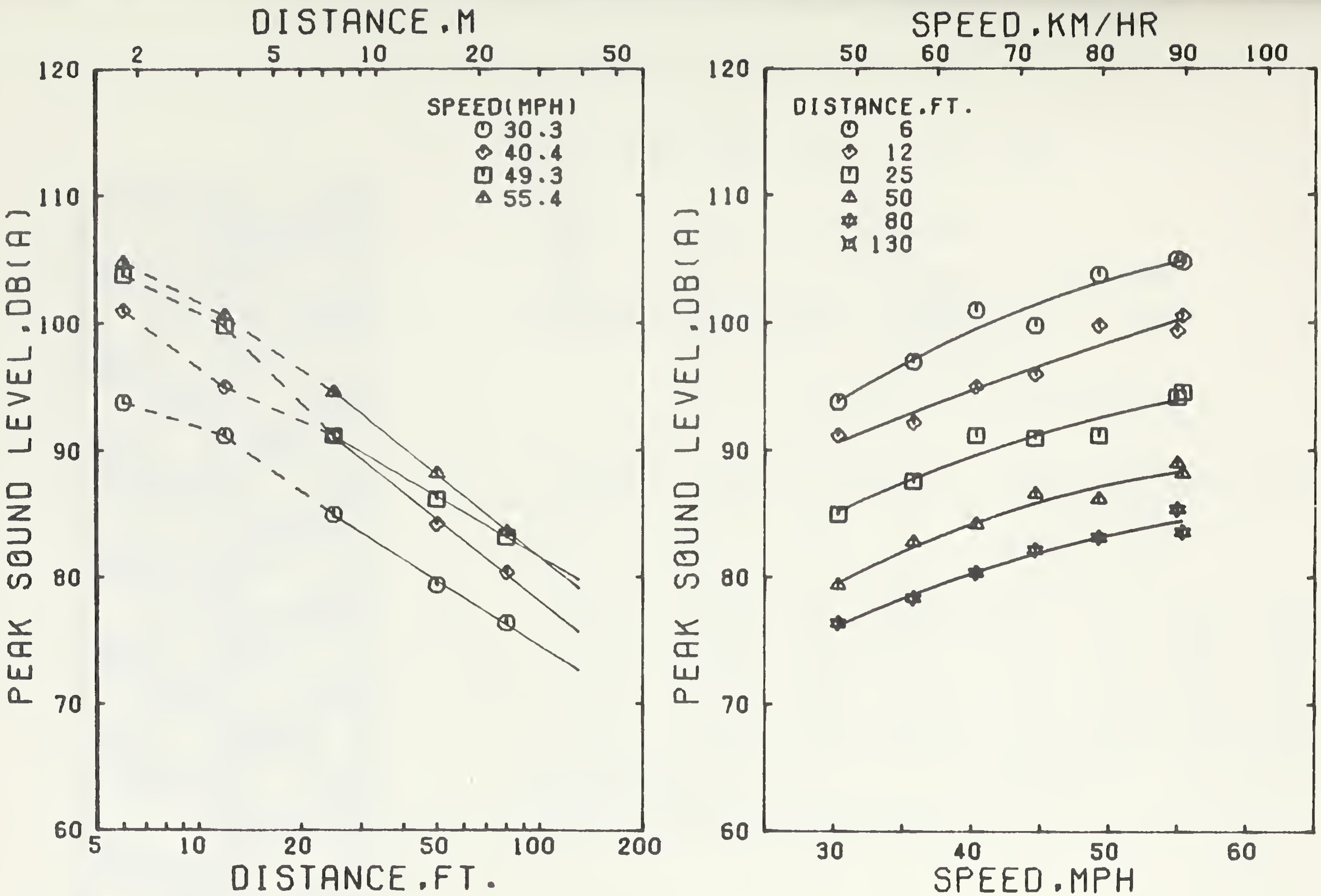
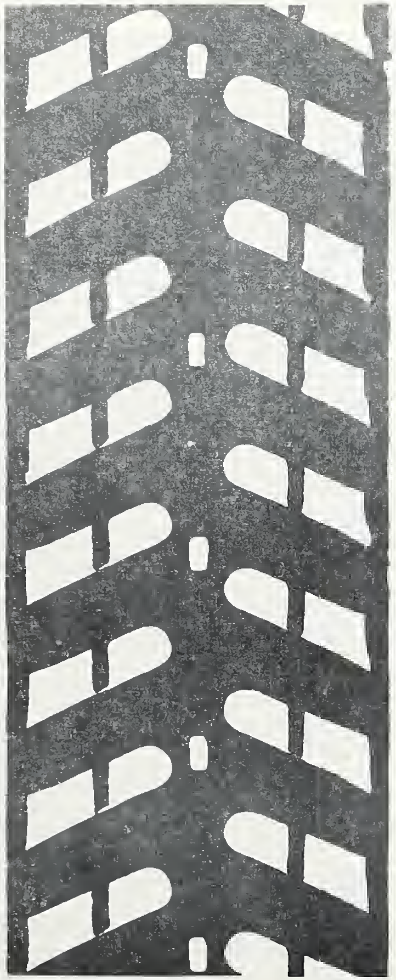


Figure A-46. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, retread-I tires on the drive axle.



RETREAD-I, NEW, SINGLE, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 29.2	34.5	40.1	44.7	48.8	54.2	52.5
6	92.4	98.6	101.2	101.6	104.5	104.8	103.6
12	92.0	95.2	97.2	99.6	99.8	100.8	100.6
25	83.8	88.8	90.2	93.4	93.2	94.8	96.0
50	78.4	82.2	83.6	87.8	87.0	89.0	89.0
80	70.6	79.4	80.8	82.4	83.6	87.2	85.8
130	73.4	76.4	78.4	80.2	81.4	83.8	83.6

SPEED	29.2	34.5	40.1	44.7	48.8	54.2	52.5
DB/DOUBLING	5.07	5.18	4.96	5.77	5.03	4.50	5.25

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO LRI	17 17 17 17	A/60/5
RRO RRI	17 17 17 17	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

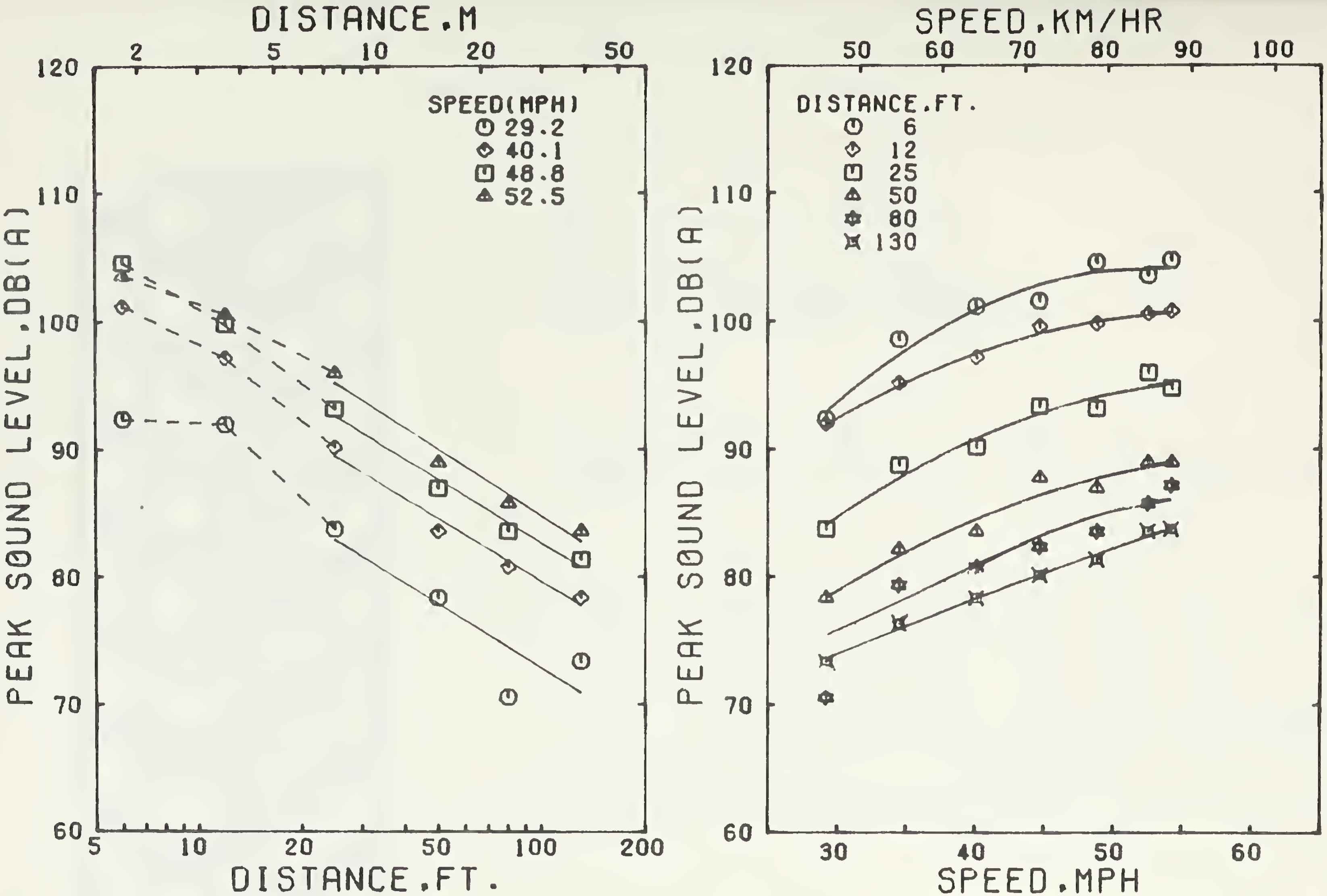
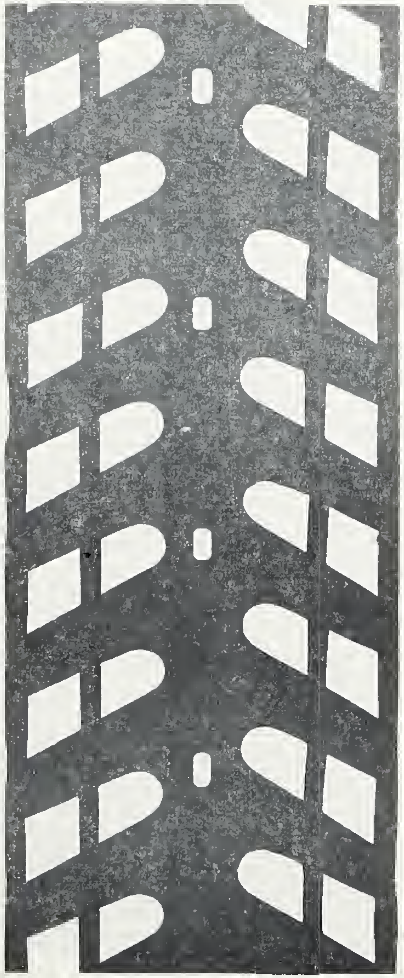


Figure A-47. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and single, new, retread-I tires on the drive axle.



RETREAD-I, HALF-WORN, SINGLE, UNLOADED, CONCRETE

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	30.8	35.2	39.7	44.5	48.9	54.3	55.0
6	92.0	97.6	100.4	100.8	102.6	104.2	104.6
12	90.0	94.0	95.4	97.8	99.2	100.2	101.4
25	84.6	88.6	89.0	91.0	93.0	93.6	93.6
50	78.2	81.4	82.8	85.8	86.6	88.2	88.2
80	76.0	78.0	80.0	81.0	84.0	83.8	83.8
130	72.2	75.6	77.0	78.4	80.0	81.8	82.2

SPEED	30.8	35.2	39.7	44.5	48.9	54.3	55.0
DB/DOUBLING	5.09	5.51	5.02	5.45	5.36	5.12	4.98

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	12 12 12 12	A/60/5
LRI		
RRO	12 12 12 12	A/60/5
RRI		

NOMINAL NEW TREAD DEPTH - 17/32 INCH

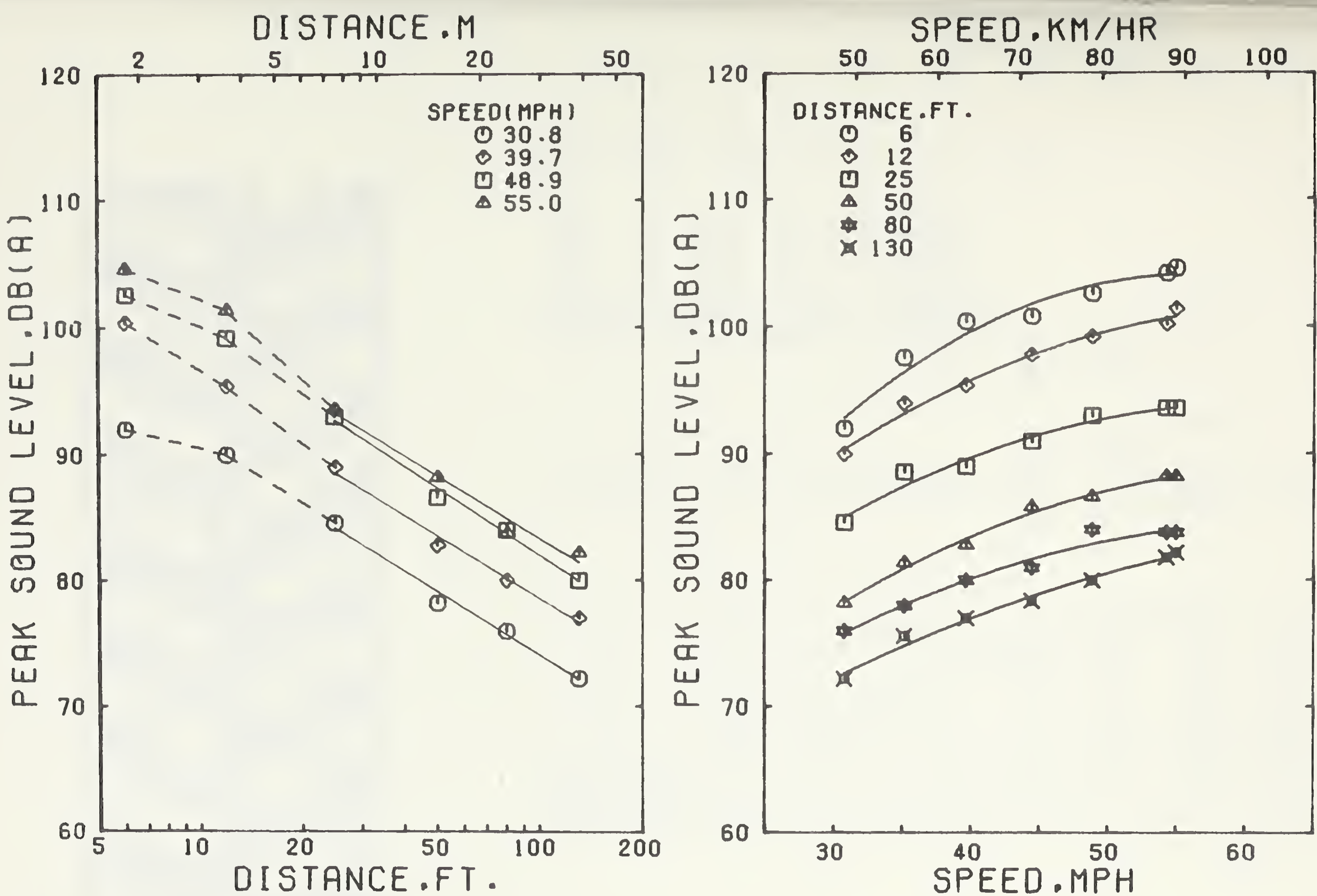
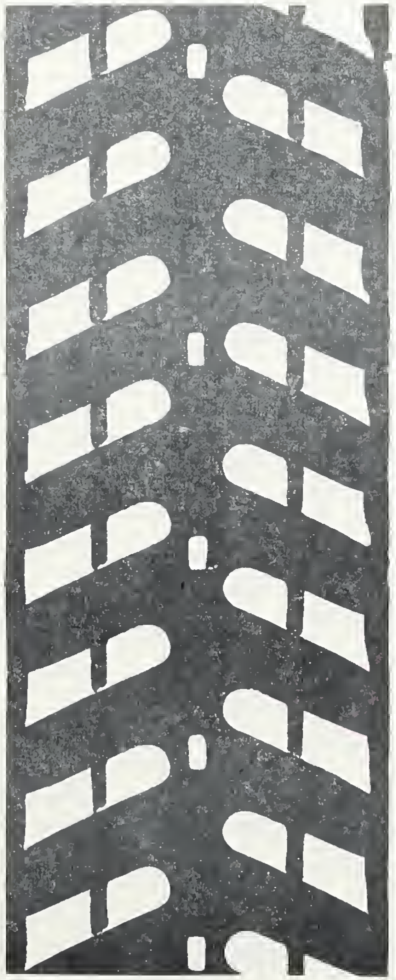


Figure A-48. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on a concrete surface. The truck was equipped with new neutral rib tires on the steering axle and single, half-worn, retread-I tires on the drive axle.



RETREAD-I, NEW, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE	SPEED,MPH						
LOCATION,FT	30.3	34.0	39.2	43.5	49.3	53.6	57.8
6	95.4	98.8	101.6	97.2	98.8	102.2	104.2
12	92.8	93.8	96.2	95.2	96.6	99.0	101.0
25	87.2	87.8	88.4	89.8	91.0	93.2	93.2
50	80.2	81.0	82.2	85.2	85.0	89.0	88.6
80	75.8	76.8	79.0	82.0	82.2	85.4	86.2
130	69.6	72.0	74.8	75.4	76.8	78.2	79.8

SPEED	30.3	34.0	39.2	43.5	49.3	53.6	57.8
DB/DOUBLING	7.30	6.61	5.65	5.86	5.80	6.11	5.39

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	17 17 17 17	A/60/5
LRI	17 17 17 17	A/60/5
RRO	17 17 17 17	A/60/5
RRI	17 17 17 17	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

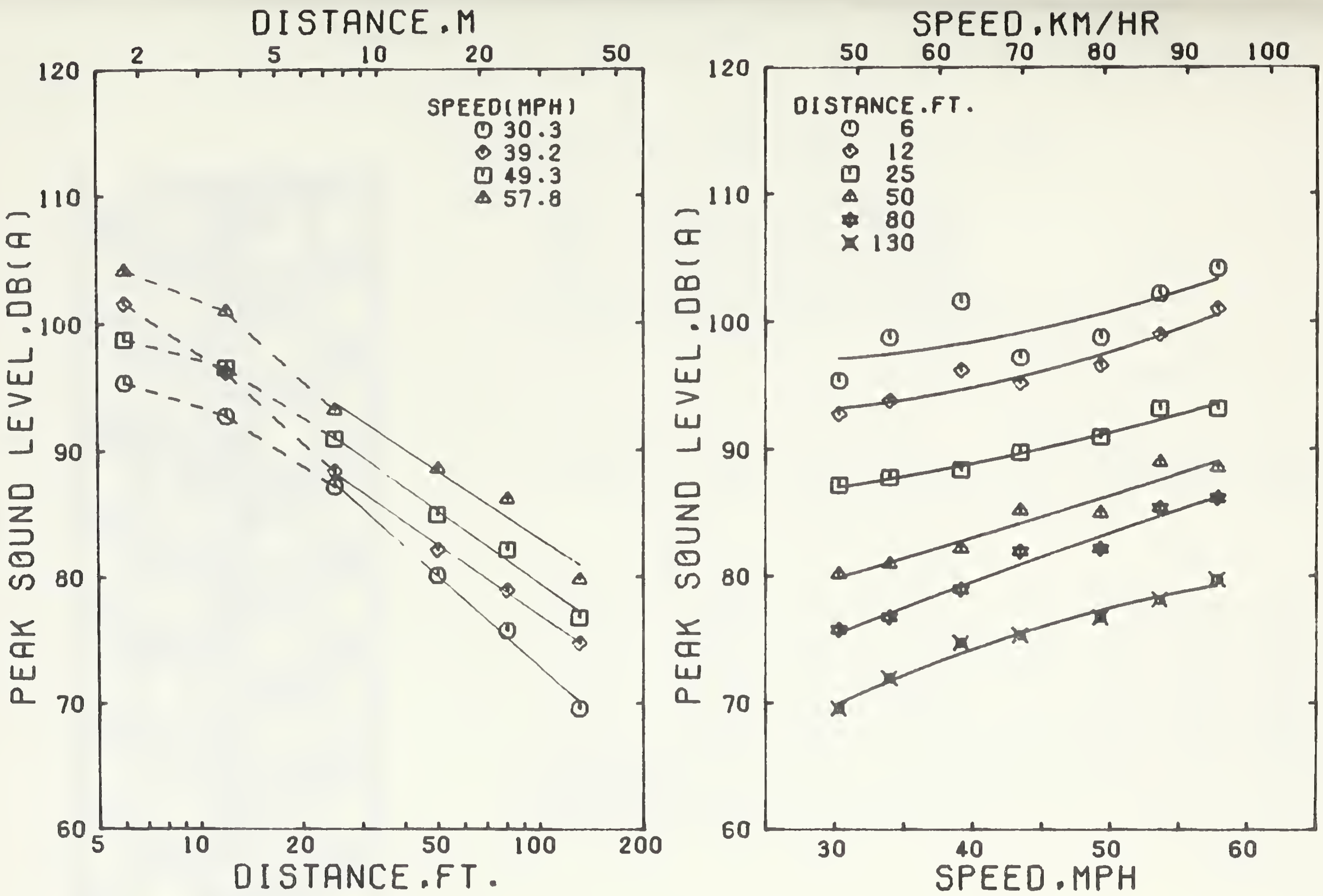
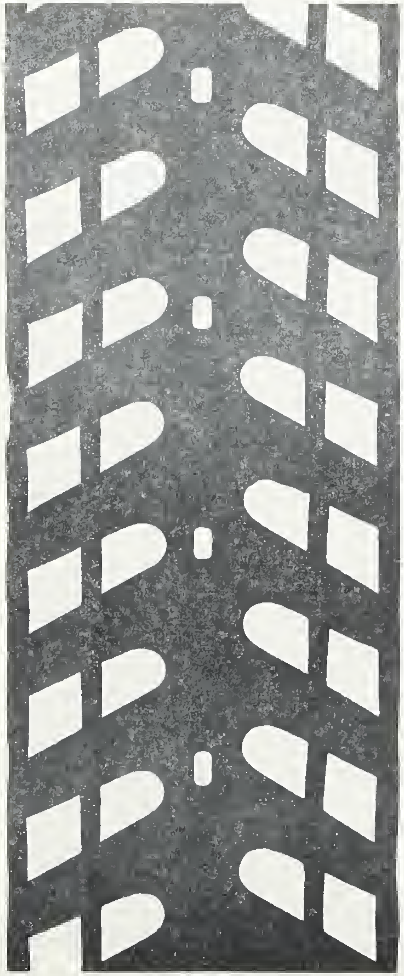


Figure A-49. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-I tires on the drive axle.



RETREAD-I, HALF-WORN, DUAL, LOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	29.7	35.1	38.9	44.8	49.4	53.5	57.0
6	94.6	96.8	97.6	100.4	101.0	105.6	103.8
12	89.2	92.2	93.8	98.6	97.2	102.8	102.2
25	83.4	85.2	88.2	92.4	91.4	96.2	97.4
50	76.8	80.6	82.0	85.6	85.0	89.0	90.0
80	*****	*****	*****	*****	*****	*****	*****
130	69.2	71.4	73.0	76.0	77.8	79.6	81.4

SPEED	29.7	35.1	38.9	44.8	49.4	53.5	57.0
DB/DOUBLING	5.94	5.85	6.40	6.90	5.69	6.97	6.70

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	12 12 12 12	A/60/5
LRI	12 12 12 12	A/60/5
RRO	12 12 12 12	A/60/5
RRI	12 12 12 12	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

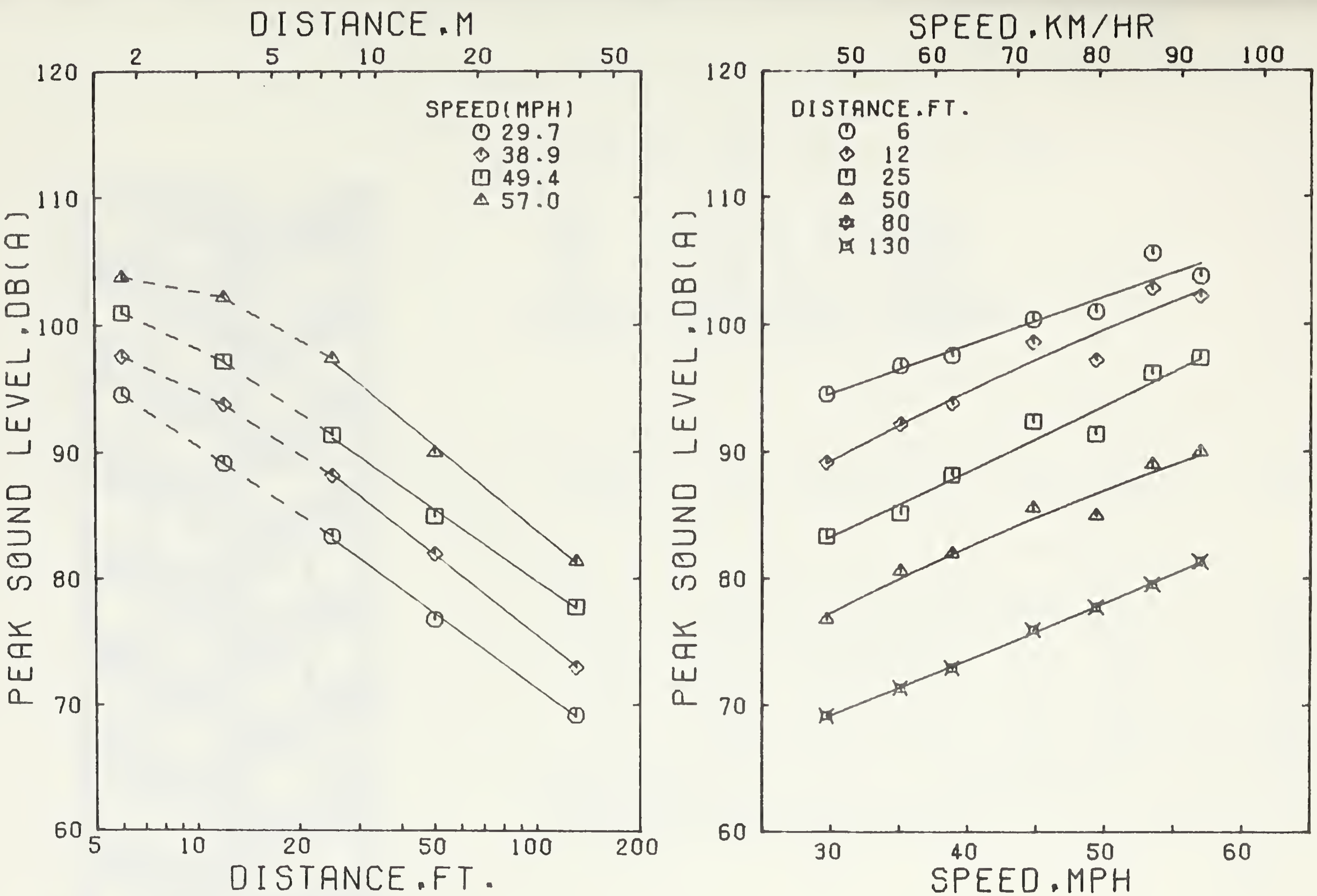
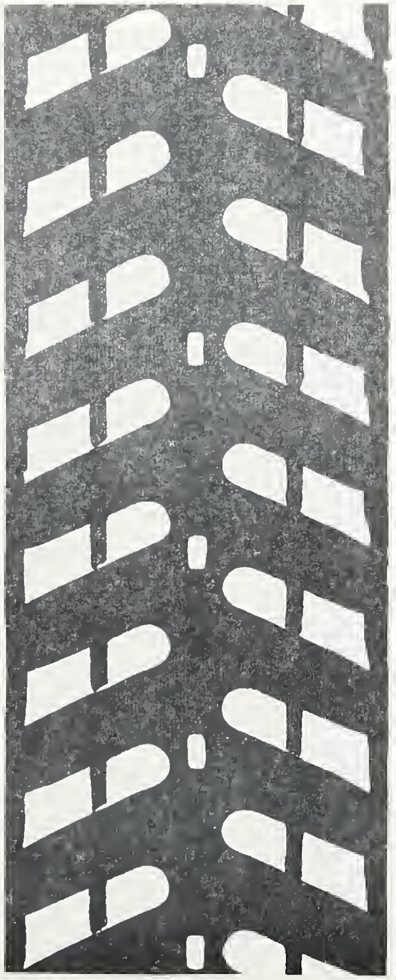


Figure A-50. Peak A-weighted sound levels versus microphone distance and speed for a loaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, retread-I tires on the drive axle.

RETREAD-I, NEW, DUAL, UNLOADED, ASPHALT



A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH					
LOCATION, FT	31.0	35.3	40.4	44.3	49.5	53.3
6	88.6	87.2	89.6	94.2	93.6	96.4
12	84.4	82.6	86.0	90.4	88.8	92.4
25	76.2	79.0	80.0	83.0	83.2	86.0
50	69.6	71.2	76.0	76.8	76.4	80.2
80	65.6	66.2	72.4	72.8	73.4	77.2
130	62.4	63.6	67.2	67.2	70.2	71.0

SPEED	31.0	35.3	40.4	44.3	49.5	53.3
DB/DOUBLING	5.85	6.62	5.31	6.55	5.44	6.11

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	17 17 17 17	A/60/5
LRI	17 17 17 17	A/60/5
RRO	17 17 17 17	A/60/5
RRI	17 17 17 17	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

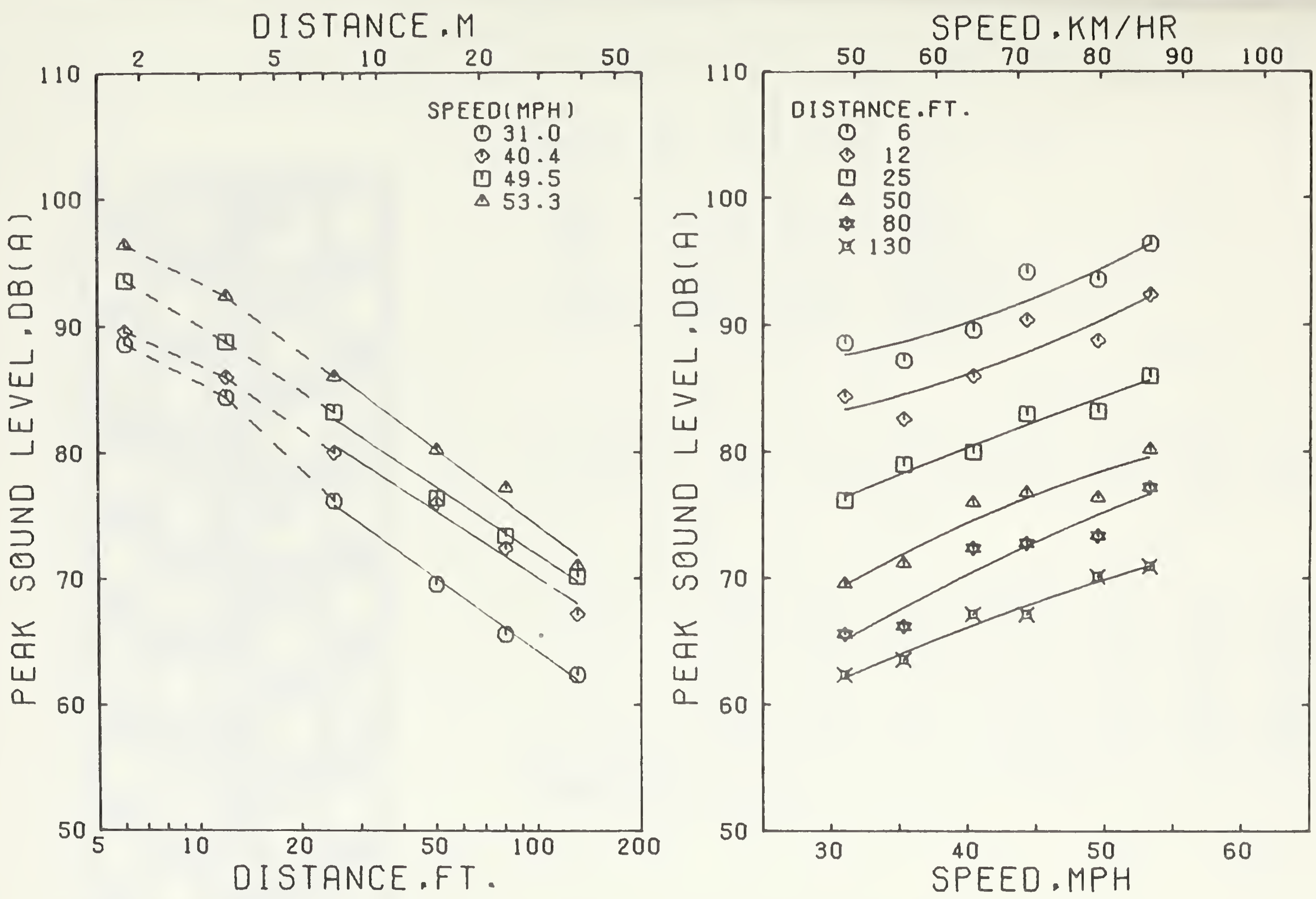
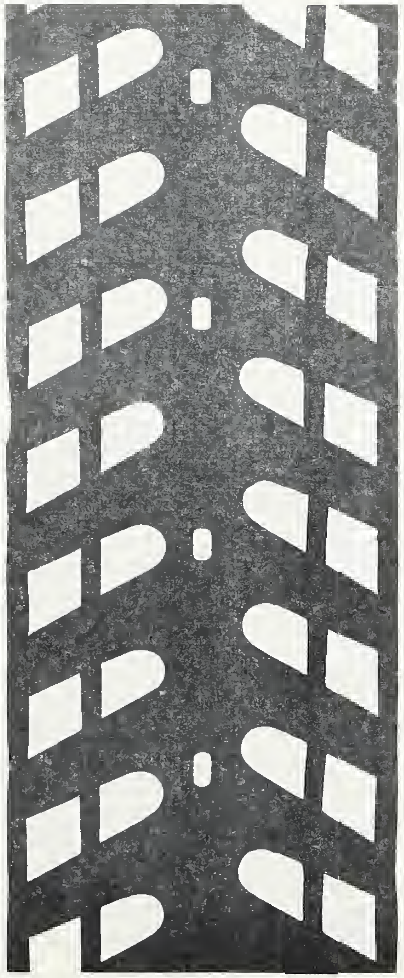


Figure A-51. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, new, retread-I tires on the drive axle.



RETREAD-I, HALF-WORN, DUAL, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	30.8	34.8	40.8	44.4	49.8	53.5	56.4
0	87.6	91.6	95.2	96.2	95.0	99.6	103.2
12	85.2	89.2	89.8	91.2	93.2	96.4	97.0
25	79.6	82.0	83.8	86.4	85.6	89.6	89.0
50	74.0	75.4	79.2	81.0	79.6	83.6	83.6
80	*****	*****	*****	*****	*****	*****	*****
130	64.2	66.4	69.4	70.0	70.4	73.8	75.4

SPEED	30.8	34.8	40.8	44.4	49.8	53.5	56.4
DB/DOUBLING	6.51	6.56	6.12	6.96	6.41	6.67	5.73

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	12 12 12 12	A/60/5
LRI	12 12 12 12	A/60/5
RRO	12 12 12 12	A/60/5
RRI	12 12 12 12	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

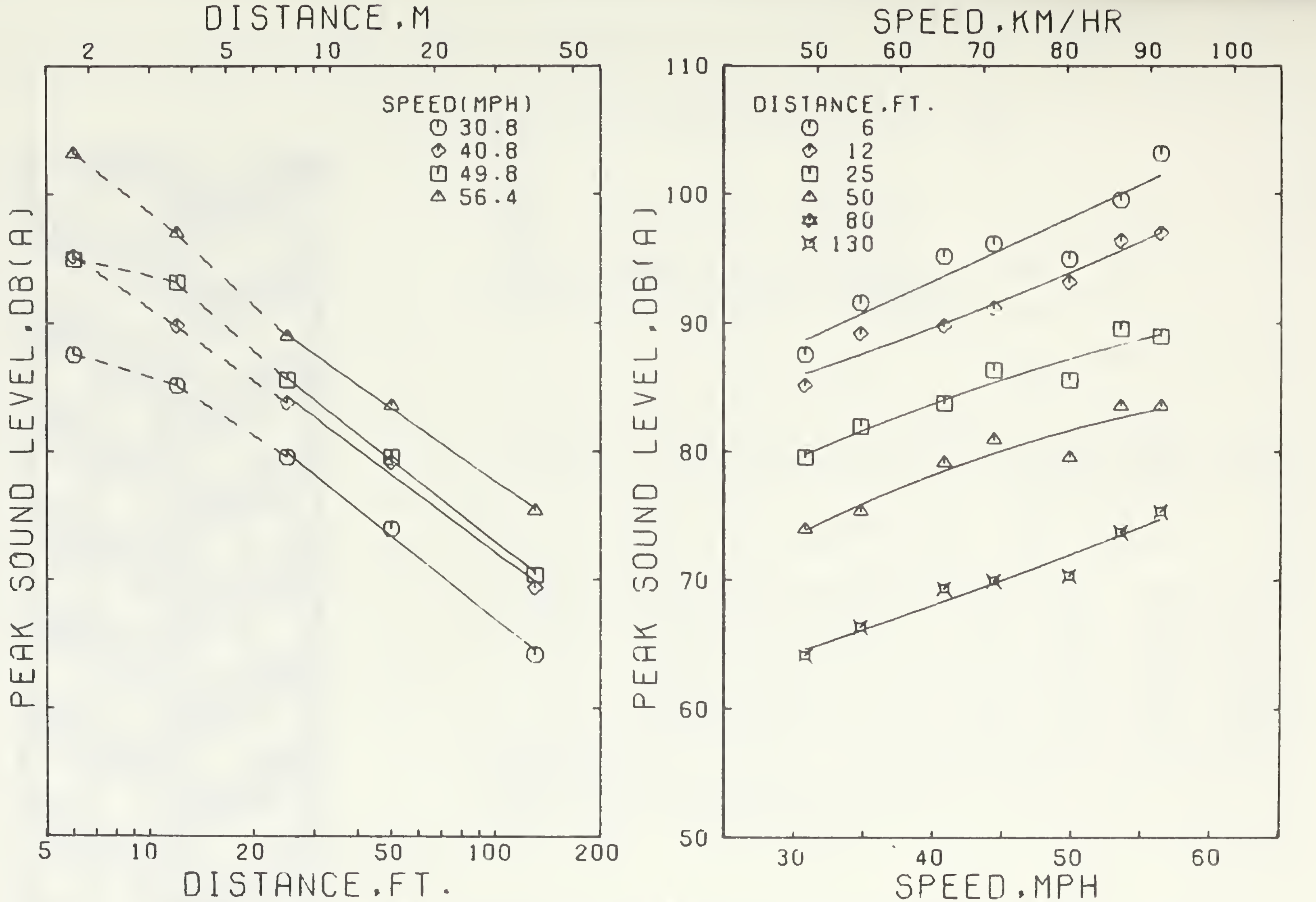
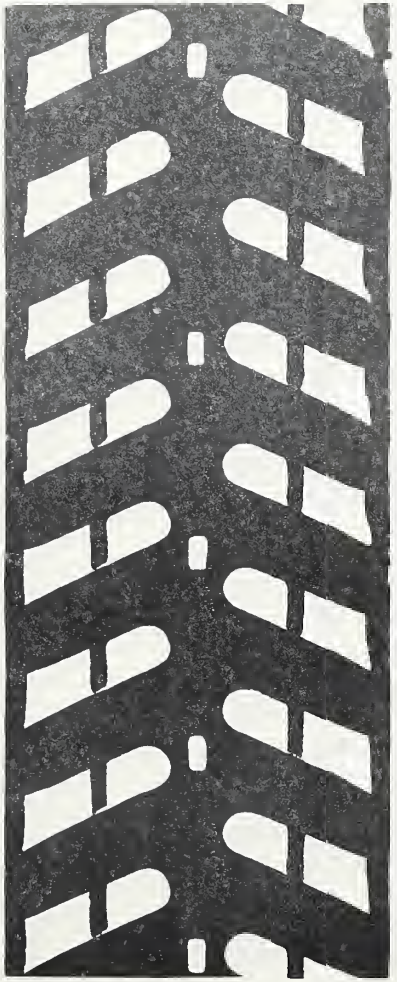


Figure A-52. Peak A-weighted sound levels versus micrcphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and dual, half-worn, retread-I tires on the drive axles.



RETREAD-I, NEW, SINGLE, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	29.4	34.6	39.3	46.0	47.0	52.3	55.6
6	91.2	92.0	91.8	94.2	97.8	96.0	98.0
12	66.0	87.8	87.8	90.6	94.0	92.6	95.0
25	79.4	80.8	81.8	84.2	87.0	87.2	88.6
50	72.2	75.0	77.0	78.2	80.0	82.6	83.2
80	67.8	71.4	73.4	75.4	74.8	77.2	78.2
130	65.2	66.0	69.4	71.8	70.6	72.6	73.8

SPEED	29.4	34.6	39.3	46.0	47.0	52.3	55.6
DB/DOUBLING	6.08	6.12	5.20	5.15	6.97	6.23	6.29

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO LRI	17 17 17 17	A/60/5
RRO RRI	17 17 17 17	A/60/5

NOMINAL NEW TREAD DEPTH - 17/32 INCH

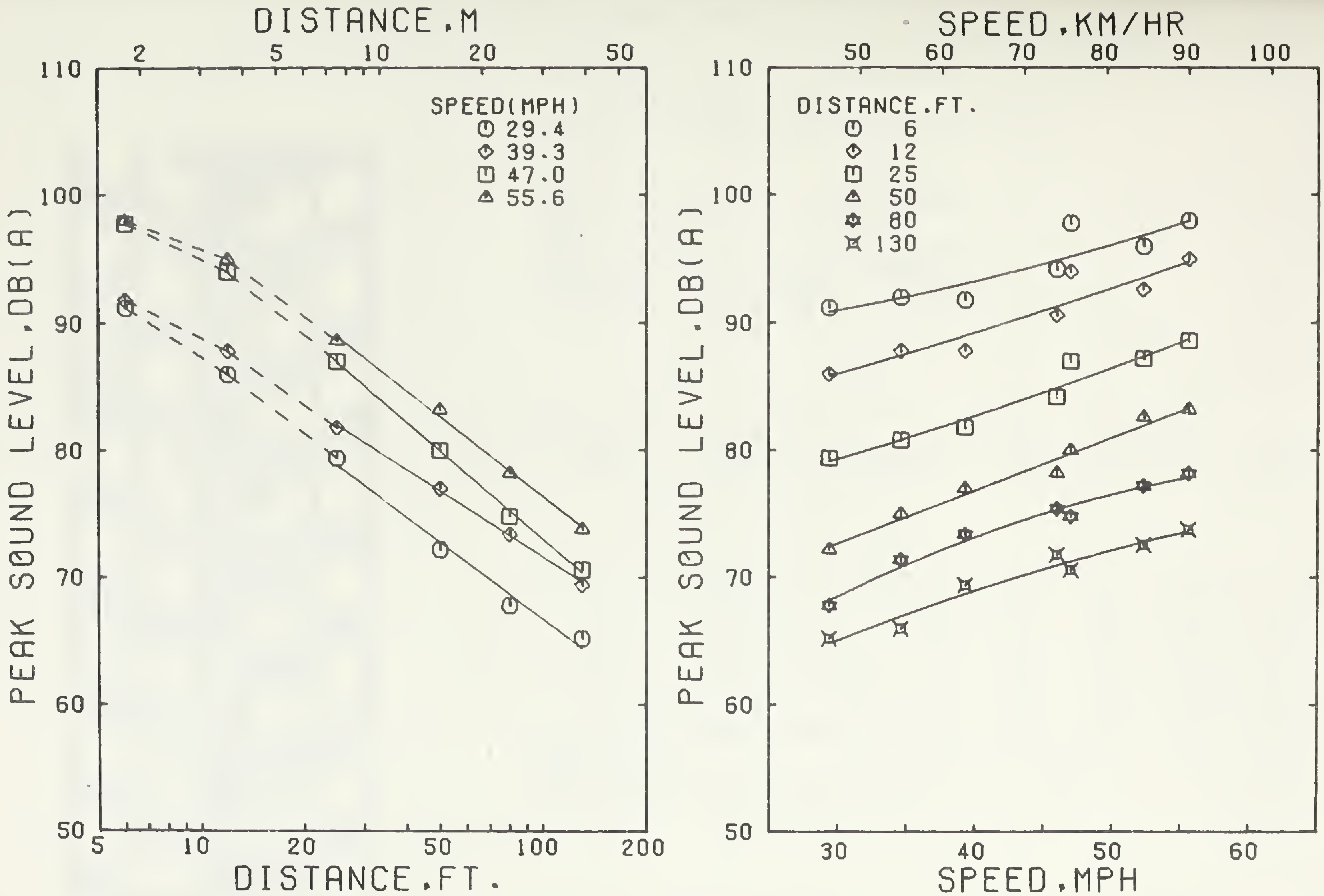
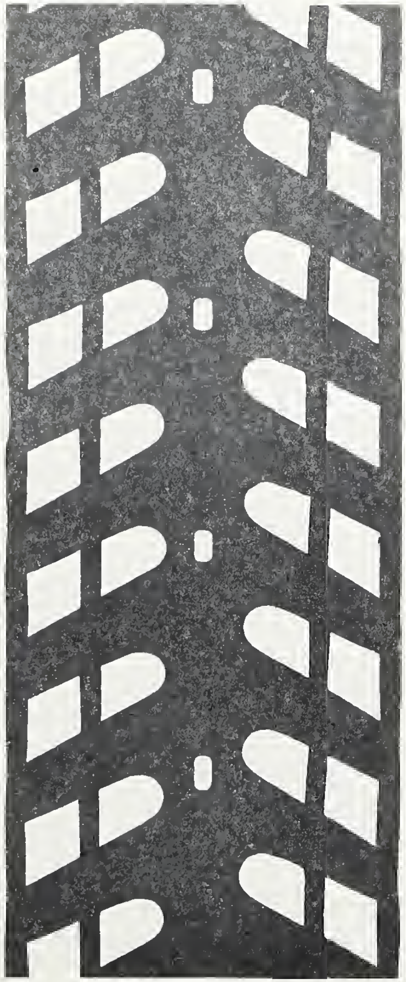


Figure A-53. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and single, new, retread-I tires on the drive axle.



RETREAD-I, HALF-WORN, SINGLE, UNLOADED, ASPHALT

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH						
LOCATION, FT	30.2	35.3	39.7	43.9	49.0	53.4	56.0
6	88.4	87.2	96.2	92.2	99.6	99.2	98.2
12	88.8	84.4	90.6	88.8	95.8	95.8	93.6
25	79.0	79.6	82.8	83.8	88.6	89.2	90.4
50	72.8	74.4	77.2	79.2	82.8	82.2	85.2
80	68.4	70.0	73.8	75.0	77.0	77.6	81.4
130	63.6	65.0	68.2	69.4	73.0	72.8	73.8

SPEED	30.2	35.3	39.7	43.9	49.0	53.4	56.0
DB/DOUBLING	6.39	6.12	6.01	6.00	6.70	6.89	6.77

TIRE LOCATION	TREAD DEPTH 32ND OF INCH	SHORE HARDNESS
LRO	12 12 12 12	A/60/5
LRI		
RRO	12 12 12 12	A/60/5
RRI		

NOMINAL NEW TREAD DEPTH - 17/32 INCH

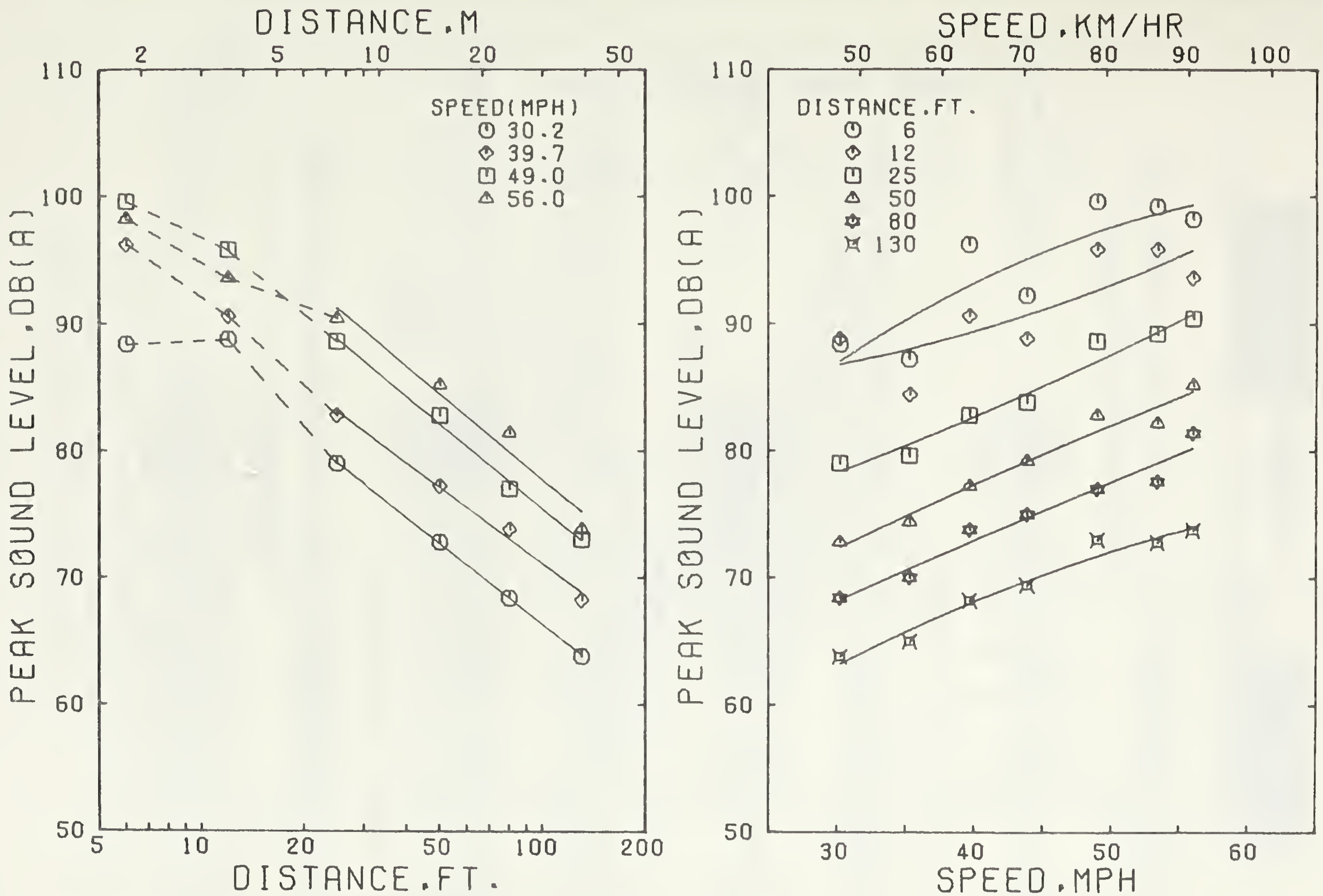
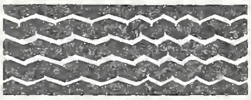


Figure A-54. Peak A-weighted sound levels versus microphone distance and speed for an unloaded single chassis vehicle running on an asphalt surface. The truck was equipped with new neutral rib tires on the steering axle and single, half-worn, retread-I tires on the drive axle.

MIX-AND-MATCH

RIB-C  RIB-A 

RIB-C INSIDE, RIB-C OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	89.6	85.0	80.2	76.0	72.2	

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	C-1	16 16 16 16	A/63/5
RRI	C-2	16 16 16 16	A/63/5

VEHICLE SPEED 57.5 mph

RIB-A INSIDE, RIB-C OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	87.4	84.4	79.4	75.4	72.0	70.6

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	C-1	16 16 16 16	A/63/5
RRI	A-4	15 15 15 15	A/60/5

VEHICLE SPEED 57.0 mph

RIB-C INSIDE, RIB-A OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	85.0	81.8	78.0	73.4	72.2	68.6

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	A-4	15 15 15 15	A/60/5
RRI	C-1	16 16 16 16	A/63/5

VEHICLE SPEED 55.9 mph

RIB-A INSIDE, RIB-A OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	85.4	82.0	77.0	72.6	69.6	67.0

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	A-4	15 15 15 15	A/60/5
RRI	A-3	15 15 15 15	A/60/5

VEHICLE SPEED 55.3 mph

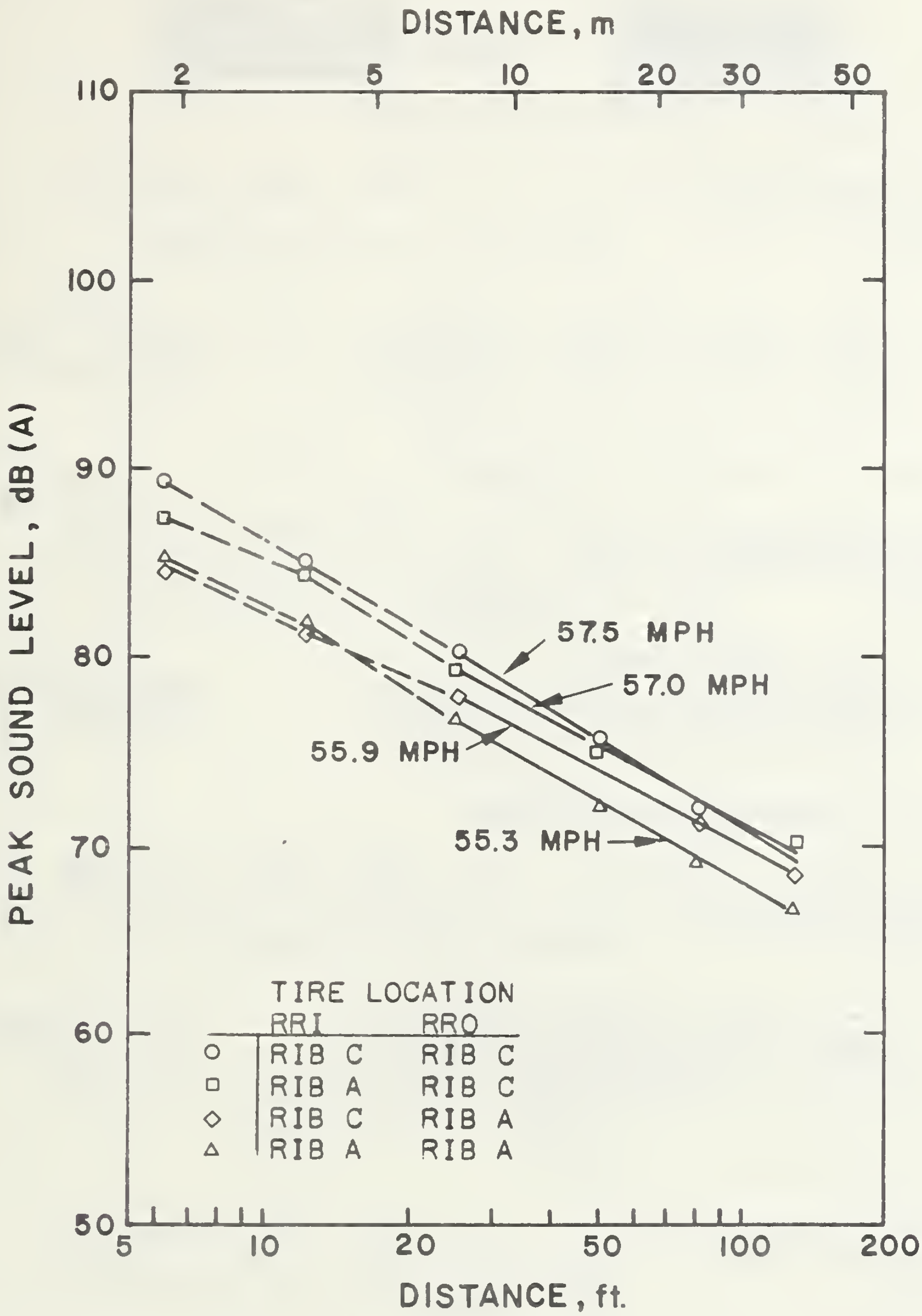
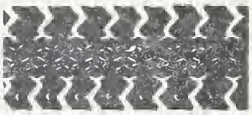


Figure A-55. Peak A-weighted sound level versus distance for a loaded single chassis vehicle running on a concrete surface. Combinations of new rib-A and new rib-C tires were mounted on the right rear dual position (nearest the microphone array) with new neutral rib (rib-A) tires at all other positions.

MIX-AND-MATCH

CROSS-BAR-F  RIB-A 

CROSS-BAR-F INSIDE, CROSS-BAR-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	103.6	98.8	91.6	87.0	82.0	

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	F-14	16 16 16 16	A/65/5
RRI	F-13	17 17 17 17	A/63/5

VEHICLE SPEED 57.5 mph

RIB-A INSIDE, CROSS-BAR-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	99.2	96.0	91.6	86.6	82.4	80.6

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	F-13	17 17 17 17	A/63/5
RRI	A-4	15 15 15 15	A/60/5

VEHICLE SPEED 57.0 mph

CROSS-BAR-F INSIDE, RIB-A OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	94.8	91.0	87.0	81.6	78.0	74.8

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	A-4	15 15 15 15	A/60/5
RRI	F-13	17 17 17 17	A/63/5

VEHICLE SPEED 57.7 mph

RIB-A INSIDE, RIB-A OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	85.4	82.0	77.0	72.6	69.6	67.0

Tire Location	Tire TYPE	Tread Depth 32nd of inch	Shore Hardness
RRO	A-4	15 15 15 15	A/60/5
RRI	A-3	15 15 15 15	A/60/5

VEHICLE SPEED 55.3 mph

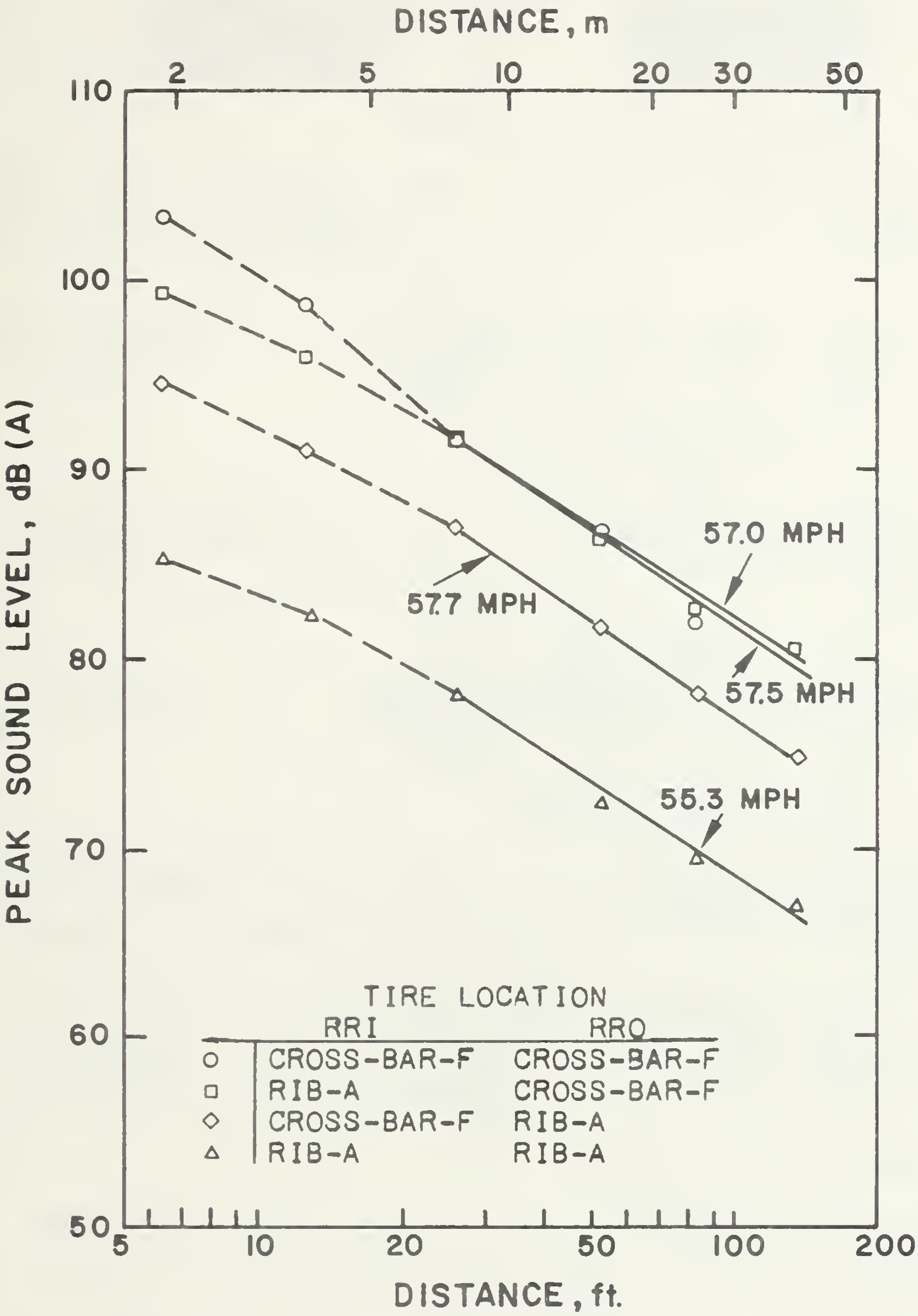
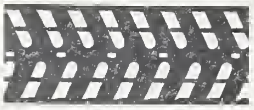


Figure A-56. Peak A-weighted sound level versus distance for a loaded single chassis vehicle running on a concrete surface. Combinations of new rib-A and half-worn cross-bar-F tires were mounted on the right rear dual position (nearest the microphone array) with new neutral rib (rib-A) tires at all other positions.

MIX-AND-MATCH

RETREAD-I  RIB-A 

RETREAD-I INSIDE, RETREAD-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	108.8	105.4	100.4	94.0	89.6	86.2

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	I-4	17 17 17 17	A/60/5
RRI	I-3	17 17 17 17	A/60/5

VEHICLE SPEED
58.4 mph

RIB-A INSIDE, RETREAD-I OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	105.2	104.4	98.4	93.2	87.2	

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	I-4	17 17 17 17	A/60/5
RRI	A-4	15 15 15 15	A/60/5

VEHICLE SPEED
58.7 mph

RETREAD-I INSIDE, RIB-A OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	103.6	98.2	93.8	88.4	84.8	80.8

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	A-4	15 15 15 15	A/60/5
RRI	I-3	17 17 17 17	A/60/5

VEHICLE SPEED
58.2 mph

RIB-A INSIDE, RIB-A OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	85.4	82.0	77.0	72.6	69.6	67.0

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	A-4	15 15 15 15	A/60/5
RRI	A-3	15 15 15 15	A/60/5

VEHICLE SPEED
55.3 mph

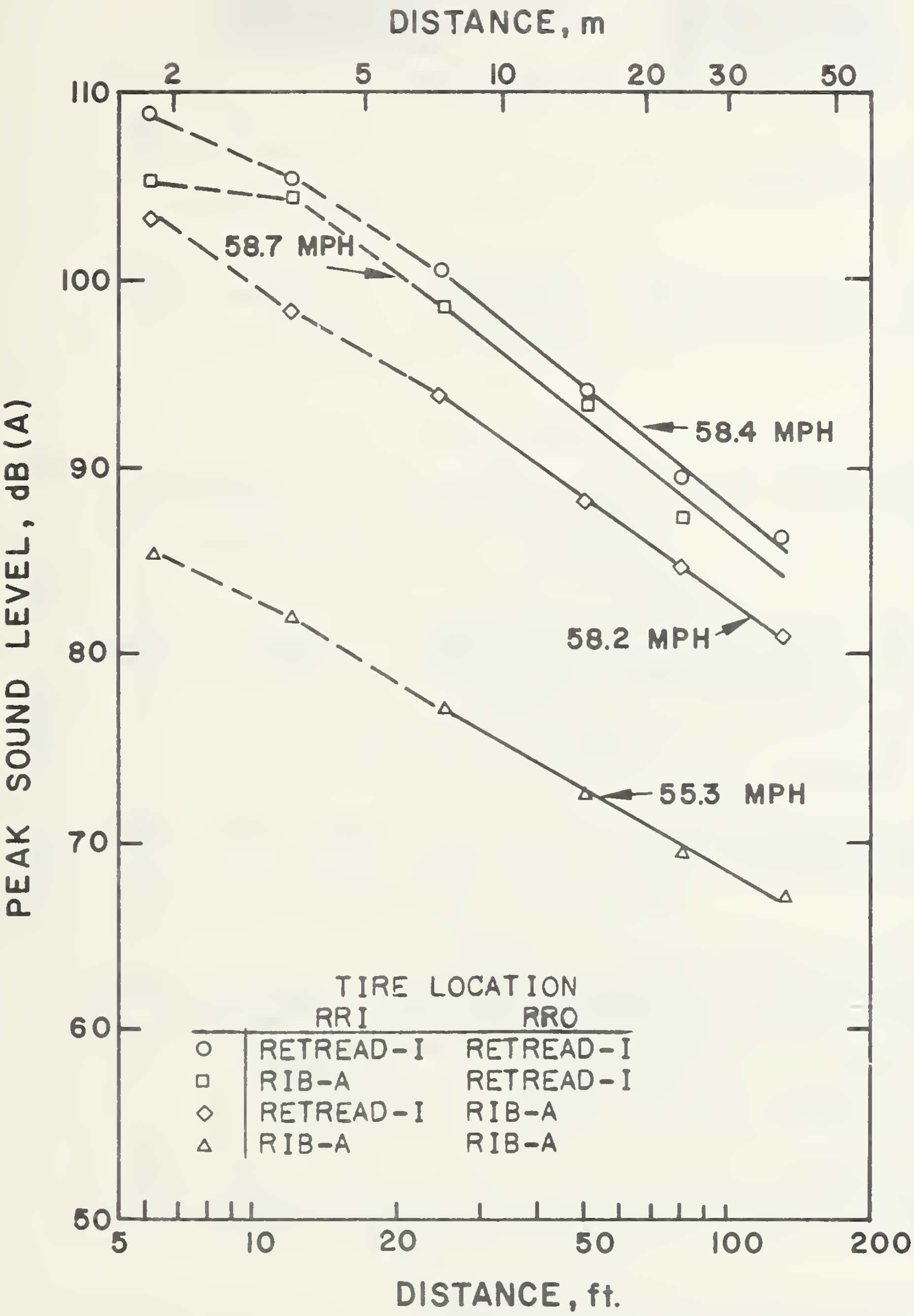
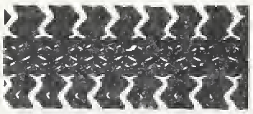
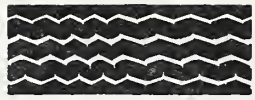


Figure A-57. Peak A-weighted sound level versus distance for a loaded single chassis vehicle running on a concrete surface. Combinations of new rib-A and new retread-I tires were mounted on the right rear dual position (nearest the microphone array) with new neutral rib (rib-A) tires at all other positions.

MIX-AND-MATCH

CROSS-BAR-F  RIB-C 

CROSS-BAR-F INSIDE, CROSS-BAR-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	103.6	98.8	91.6	87.0	82.0	

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	F-14	16 16 16 16	A/65/5
RRI	F-13	17 17 17 17	A/63/5

VEHICLE SPEED 57.5 mph

RIB-C INSIDE, CROSS-BAR-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	100.8	97.0	92.0	86.2	82.8	78.8

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	F-13	17 17 17 17	A/63/5
RRI	C-1	16 16 16 16	A/63/5

VEHICLE SPEED 58.8 mph

CROSS-BAR-F INSIDE, RIB-C OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	95.0	92.4	88.2	84.8	81.4	76.6

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	C-1	16 16 16 16	A/63/5
RRI	F-13	17 17 17 17	A/63/5

VEHICLE SPEED 58.0 mph

RIB-C INSIDE, RIB-C OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	89.6	85.0	80.2	76.0	72.2	

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	C-1	16 16 16 16	A/63/5
RRI	C-2	16 16 16 16	A/63/5

VEHICLE SPEED 57.5 mph

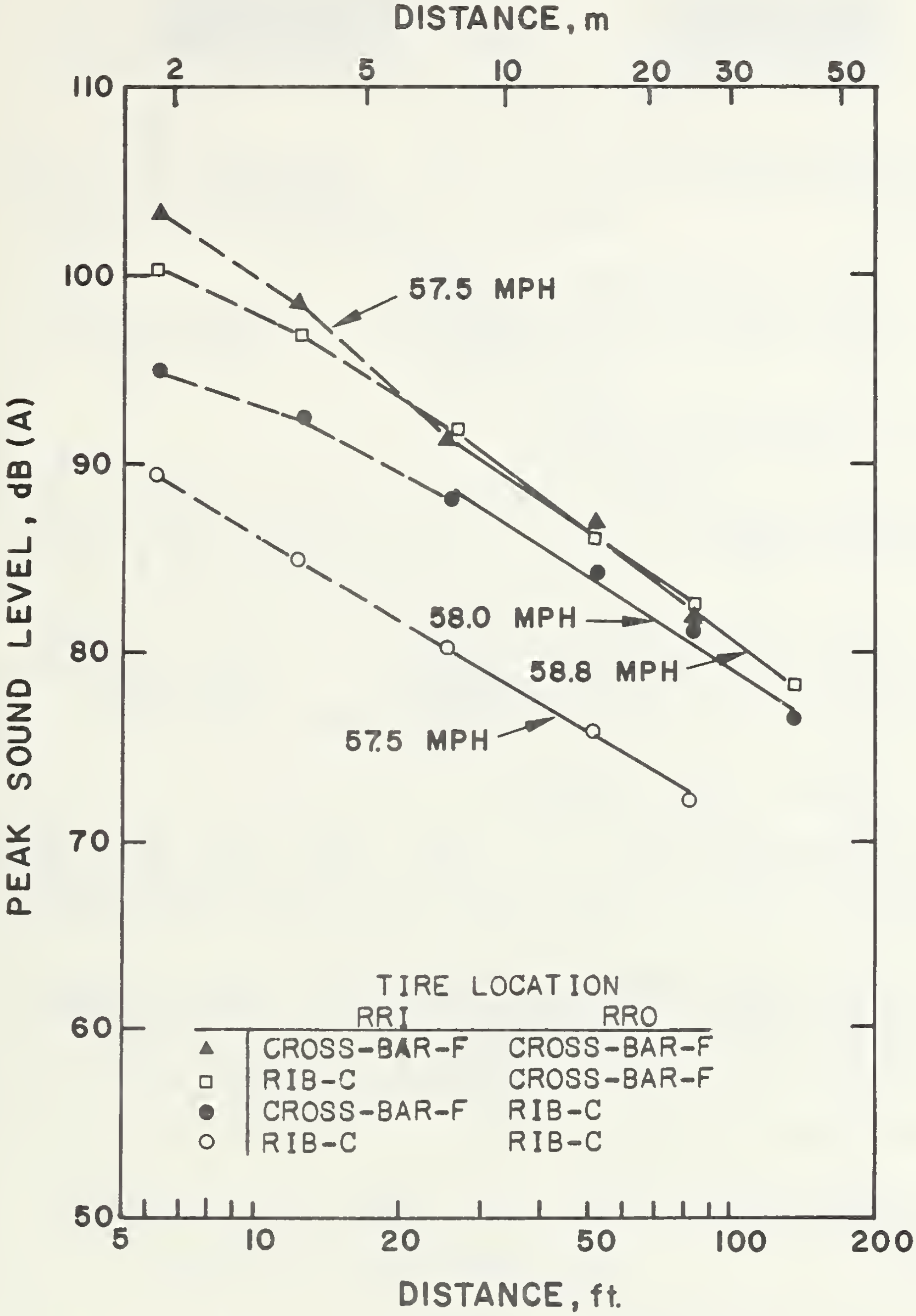
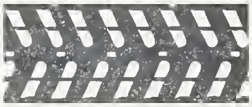
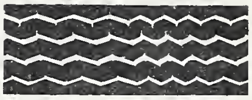


Figure A-58. Peak A-weighted sound level versus distance for a loaded single chassis vehicle running on a concrete surface. Combinations of new rib-C and half-worn cross-bar-F tires were mounted on the right rear dual position (nearest the microphone array) with new neutral rib (rib-A) tires at all other positions.

MIX-AND-MATCH

RETREAD-I  RIB-C 

RETREAD-I INSIDE, RETREAD-I OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	108.8	105.4	100.4	94.0	89.6	86.2

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	I-4	17 17 17 17	A/60/5
RRI	I-3	17 17 17 17	A/60/5

VEHICLE SPEED
58.4 mph

RIB-C INSIDE, RETREAD-I OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	107.6	104.0	99.2	93.4	88.8	83.2

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	I-4	17 17 17 17	A/60/5
RRI	C-1	16 16 16 16	A/63/5

VEHICLE SPEED
58.7 mph

RETREAD-I INSIDE, RIB-C OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	106.2	101.2	100.0	91.6	87.6	82.8

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	C-1	16 16 16 16	A/63/5
RRI	I-3	17 17 17 17	A/60/5

VEHICLE SPEED
58.8 mph

RIB-C INSIDE, RIB-C OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	89.6	85.0	80.2	76.0	72.2	

Tire Location	Tire Type	Tread Depth 32nd of inch	Shore Hardness
RRO	C-1	16 16 16 16	A/63/5
RRI	C-2	16 16 16 16	A/63/5

VEHICLE SPEED
57.5 mph

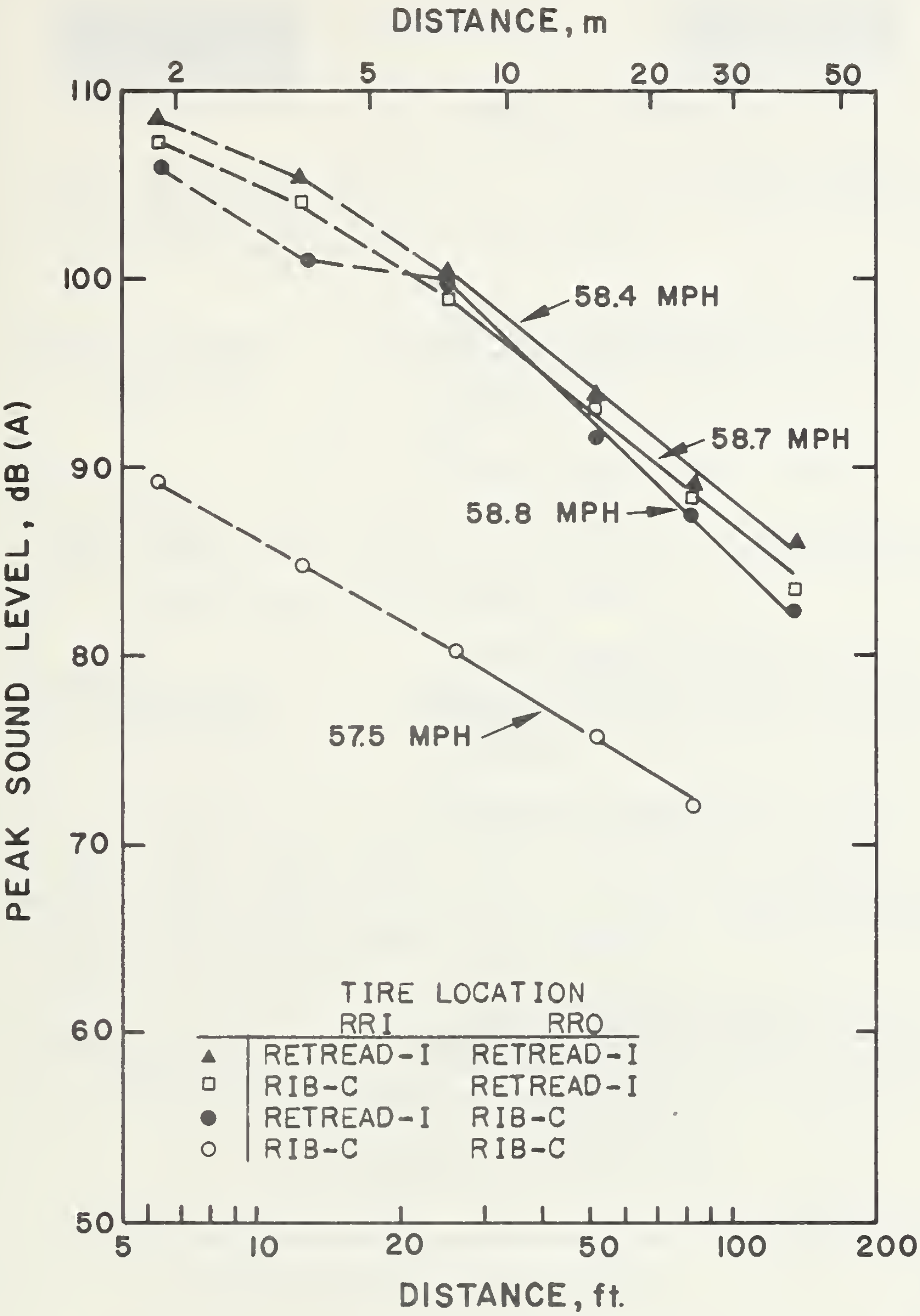
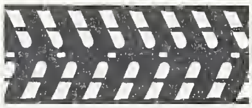
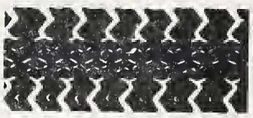


Figure A-59. Peak A-weighted sound level versus distance for a loaded single chassis vehicle running on a concrete surface. Combinations of new rib-C and new retread-I tires were mounted on the right rear dual position (nearest the microphone array) with new neutral rib (rib-A) tires at all other positions.

MIX-AND-MATCH

RETREAD-I  CROSS-BAR-F 

RETREAD-I INSIDE, RETREAD-I OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	108.8	105.4	100.4	94.0	89.6	86.2

Tire Location	Tire Type	Tread Depth 32nd of inch				Shore Hardness
RRO	I-4	17	17	17	17	A/60/5
RRI	I-3	17	17	17	17	A/60/5

VEHICLE SPEED
58.4 mph

CROSS-BAR-F INSIDE, RETREAD-I OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	107.2	103.0	99.4	93.4	88.0	

Tire Location	Tire Type	Tread Depth 32nd of inch				Shore Hardness
RRO	I-4	17	17	17	17	A/60/5
RRI	F-13	17	17	17	17	A/63/5

VEHICLE SPEED
58.3 mph

RETREAD-I INSIDE, CROSS-BAR-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	105.4	101.6	96.8	90.2	85.8	80.8

Tire Location	Tire Type	Tread Depth 32nd of inch				Shore Hardness
RRO	F-13	17	17	17	17	A/63/5
RRI	I-3	17	17	17	17	A/60/5

VEHICLE SPEED
58.1 mph

CROSS-BAR-F INSIDE, CROSS-BAR-F OUTSIDE

Microphone Location, ft.	6	12	25	50	80	130
Peak A-weighted Sound Level dB(A)	103.6	98.8	91.6	87.0	82.0	

Tire Location	Tire Type	Tread Depth 32nd of inch				Shore Hardness
RRO	F-14	16	16	16	16	A/65/5
RRI	F-13	17	17	17	17	A/63/5

VEHICLE SPEED
57.5 mph

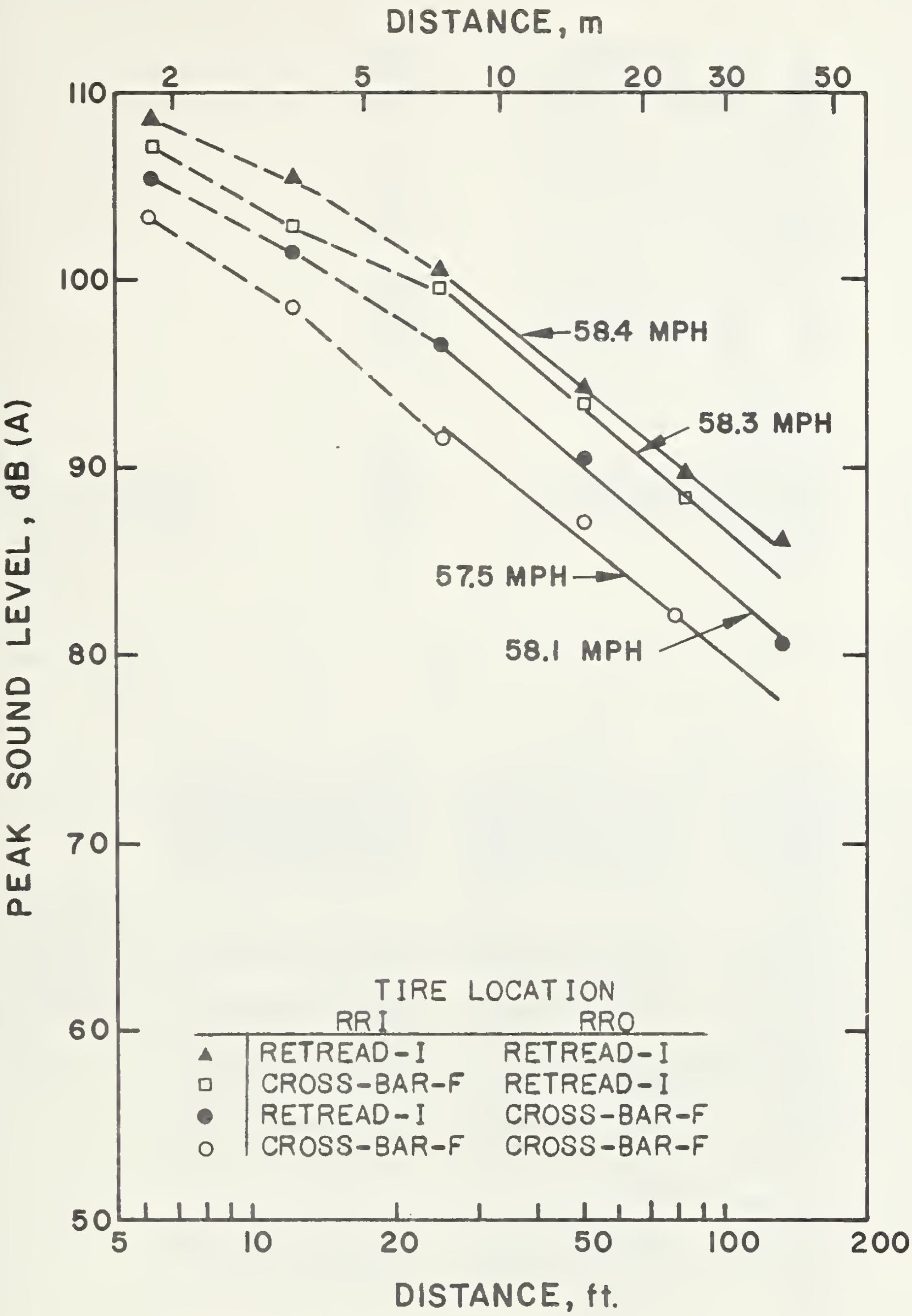


Figure A-60. Peak A-weighted sound level versus distance for a loaded single chassis vehicle running on a concrete surface. Combinations of half-worn cross-bar-F and new retread-I tires were mounted on the right rear dual position (nearest the microphone array) with new neutral rib (rib-A) tires at all other positions.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	A-1	15	15	15	15	A/61/5
LFDI	A-2	15	15	15	15	A/61/5
RFDO	A-3	15	15	15	15	A/60/5
RFDI	A-4	15	15	15	15	A/60/5
LRDO	A-5	15	15	15	15	A/60/5
LRDI	A-6	15	15	15	15	A/60/5
RRDO	A-7	16	16	16	16	A/60/5
RRDI	A-8	15	15	15	15	A/60/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 25.8	35.0	44.2
6	79.6	83.2	85.2
12	77.0	81.0	82.2
25	73.2	77.6	79.4
50	68.8	71.8	73.6
80	65.2	68.2	71.8
130	61.0	65.4	67.2

SPEED	25.8	35.0	44.2
DB/DOUBLING	5.11	5.18	4.94

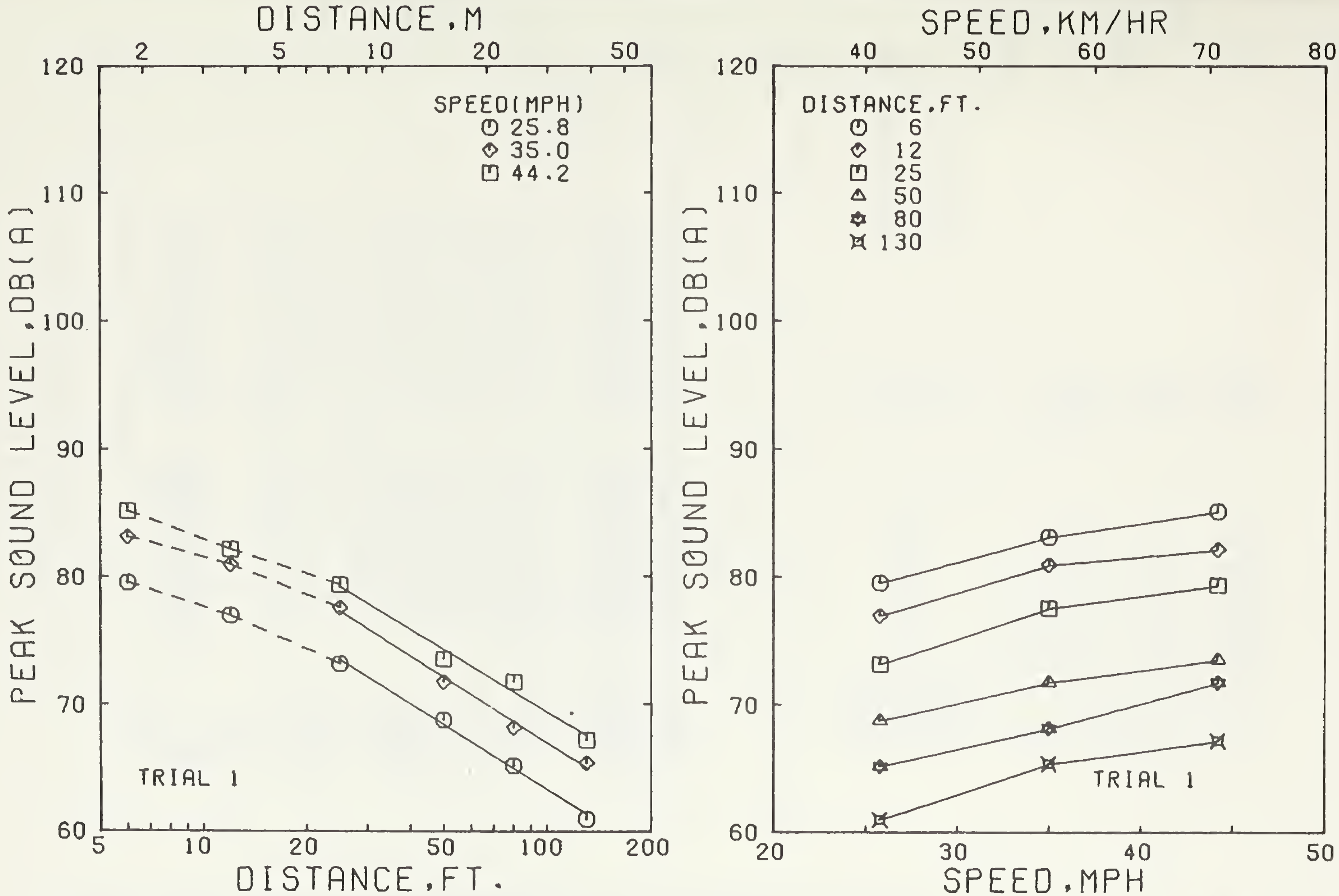


Figure A-61. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new, neutral rib tires on the drive axles, and eight new retread-G tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	·A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 26.6	35.3	43.1
6	86.2	93.6	96.8
12	64.0	91.6	93.6
25	80.4	84.4	89.2
50	76.2	80.4	82.8
80	72.2	77.8	79.0
130	70.6	74.6	75.8

SPEED	26.6	35.3	43.1
DB/DOUBLING	4.29	4.09	5.67

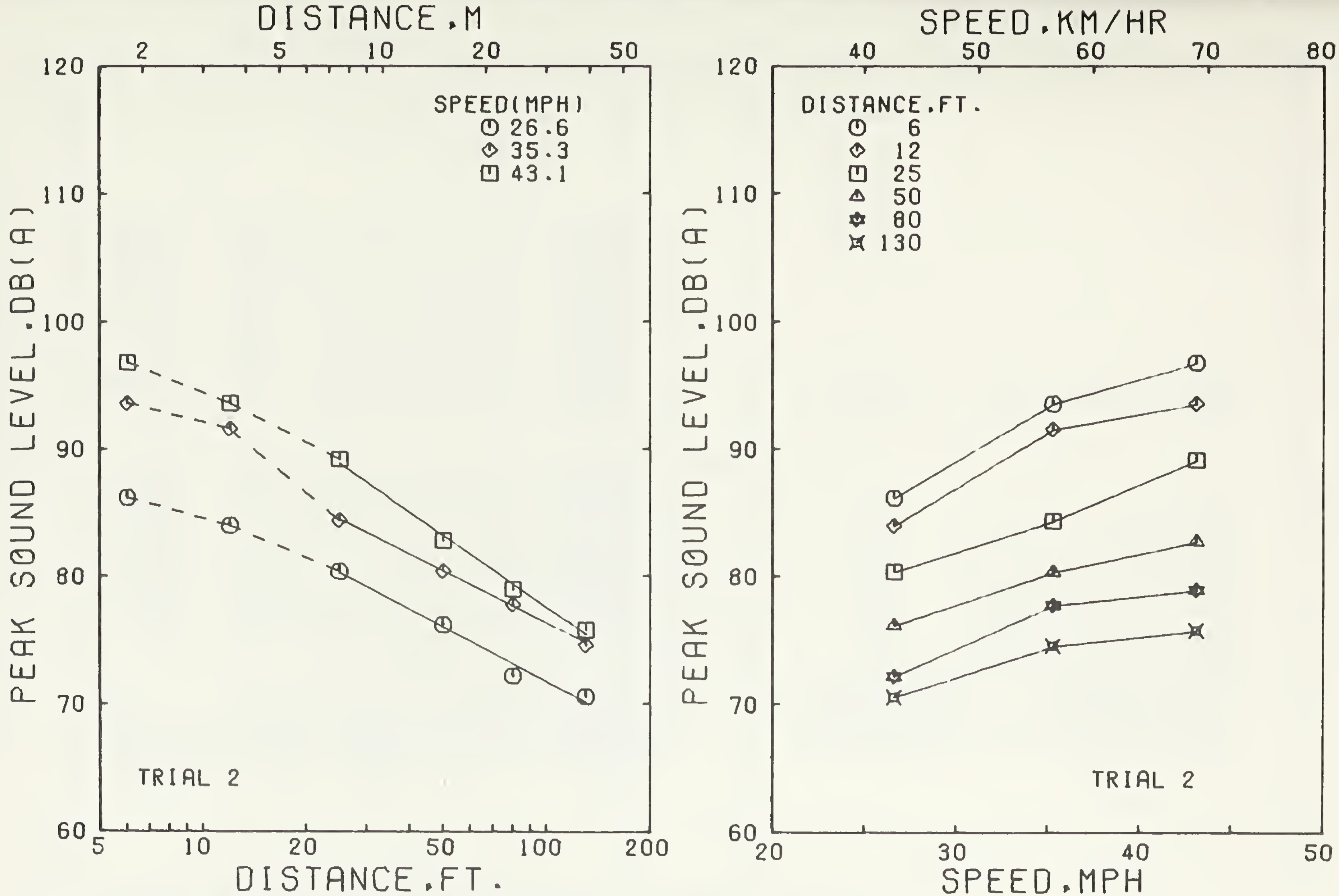


Figure A-62. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new, cross-bar-D tires on the drive axles, and eight new retread-G tires on the trailer axles.

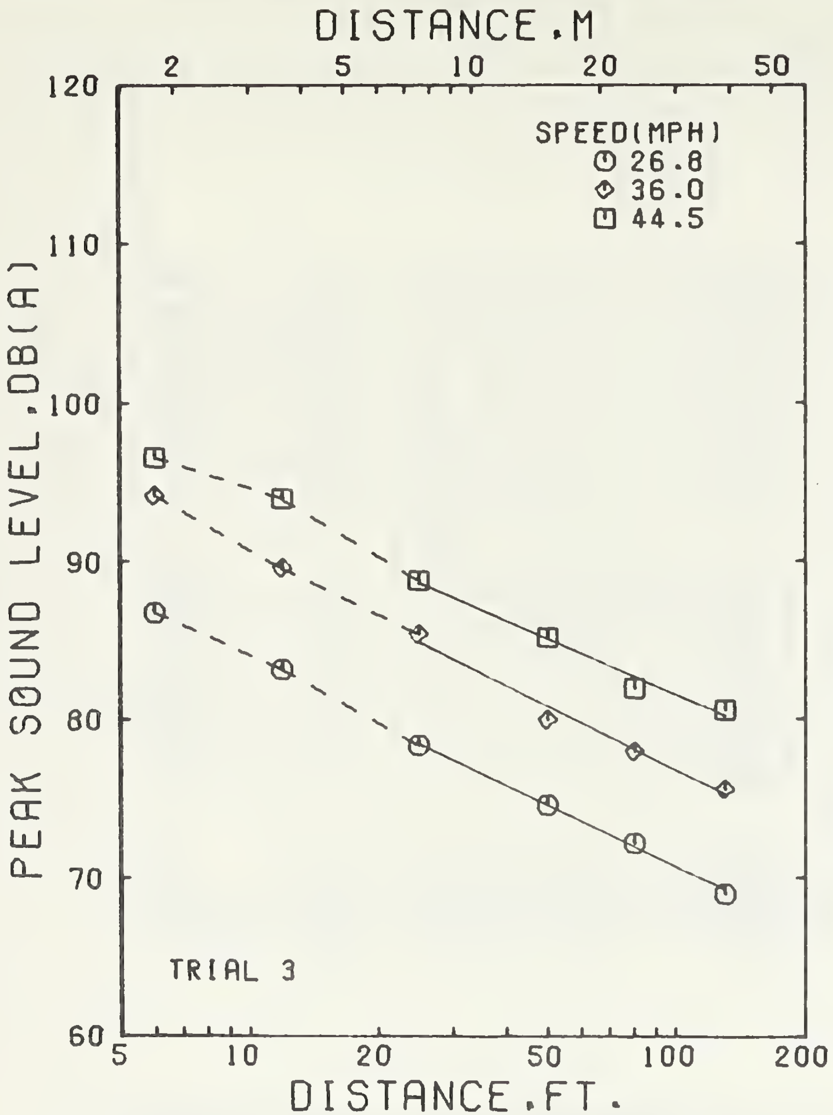
LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-11	15	14	15	15	A/63/5
LFDI	D-12	17	17	17	17	A/63/5
RFDO	D-13	15	16	15	15	A/64/5
RFDI	D-14	15	15	15	14	A/65/5
LRDO	D-15	17	17	17	17	A/65/5
LRDI	D-16	16	16	16	16	A/65/5
RRDO	D-17	10	10	10	10	A/65/5
RRDI	D-18	11	11	11	11	A/65/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 26.8	36.0	44.5
6	86.8	94.2	96.6
12	83.2	89.6	94.0
25	78.4	85.4	88.8
50	74.6	80.0	85.2
80	72.2	78.0	82.0
130	69.0	75.6	80.6

SPEED	26.8	36.0	44.5
DB/DOUBLING	3.91	4.08	3.57



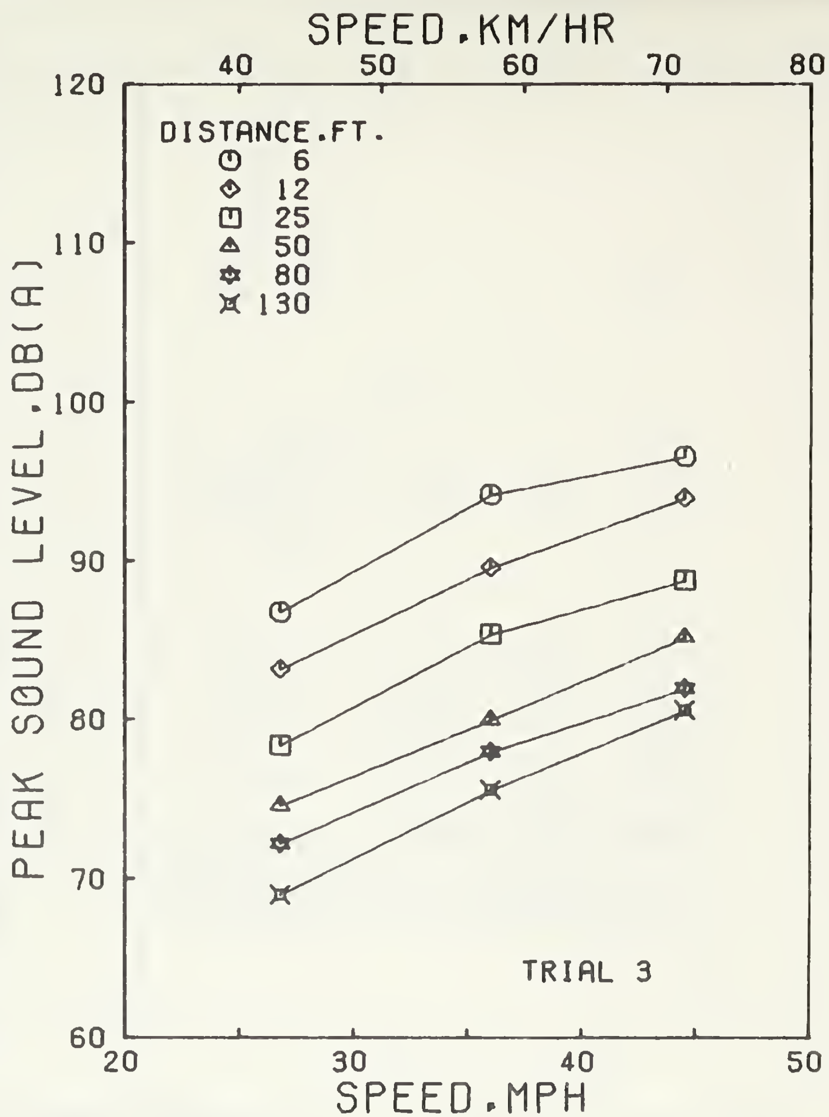


Figure A-63. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight half-worn, cross-bar-D tires on the drive axles, and eight new retread-G tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	I-1	17	17	17	17	A/60/5
LFDI	I-2	17	17	17	17	A/60/5
RFDO	I-3	17	17	17	17	A/60/5
RFDI	I-4	17	17	17	17	A/60/5
LRDO	I-5	16	16	16	16	A/60/5
LRDI	I-6	16	16	16	16	A/60/5
RRDO	I-7	16	16	16	16	A/60/5
RRDI	I-8	16	16	16	16	A/60/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 26.2	31.8	42.9
6	97.0	101.4	107.4
12	95.2	98.8	103.0
25	90.2	91.6	98.2
50	83.4	86.8	91.4
80	79.6	81.4	87.8
130	75.4	78.4	82.8

SPEED	26.2	31.8	42.9
DB/DOUBLING	6.19	5.73	6.38

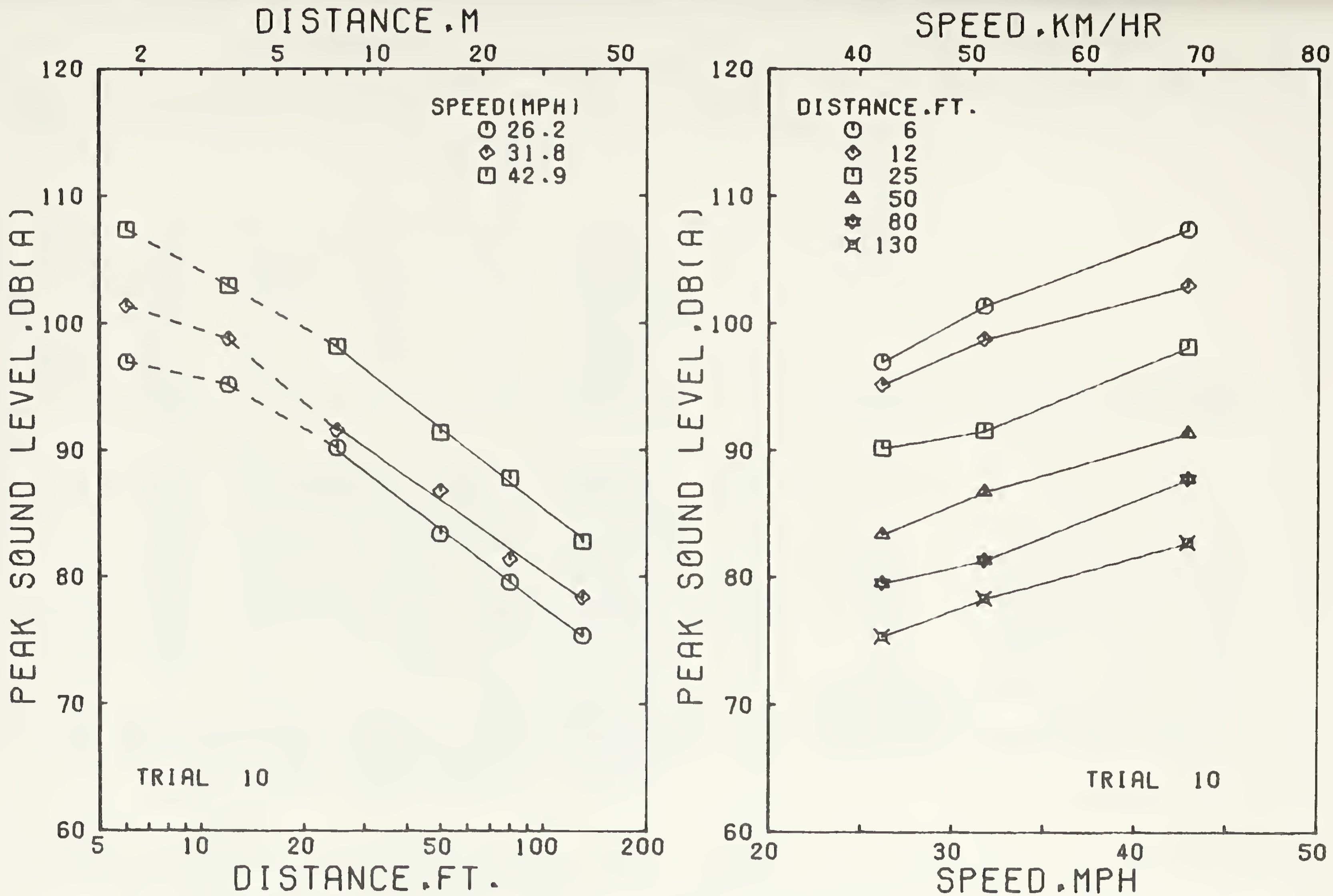


Figure A-64. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new, retread-I tires on the drive axles, and eight new retread-G tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	I-3	17	17	17	17	A/60/5
LFTI	I-4	17	17	17	17	A/60/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 25.9	35.4	44.1
6	90.2	95.6	98.6
12	87.8	92.0	95.2
25	81.8	87.8	90.0
50	76.8	83.2	85.4
80	73.4	79.6	82.8
130	72.0	77.0	80.6

SPEED	25.9	35.4	44.1
DB/DOUBLING	4.24	4.61	3.97

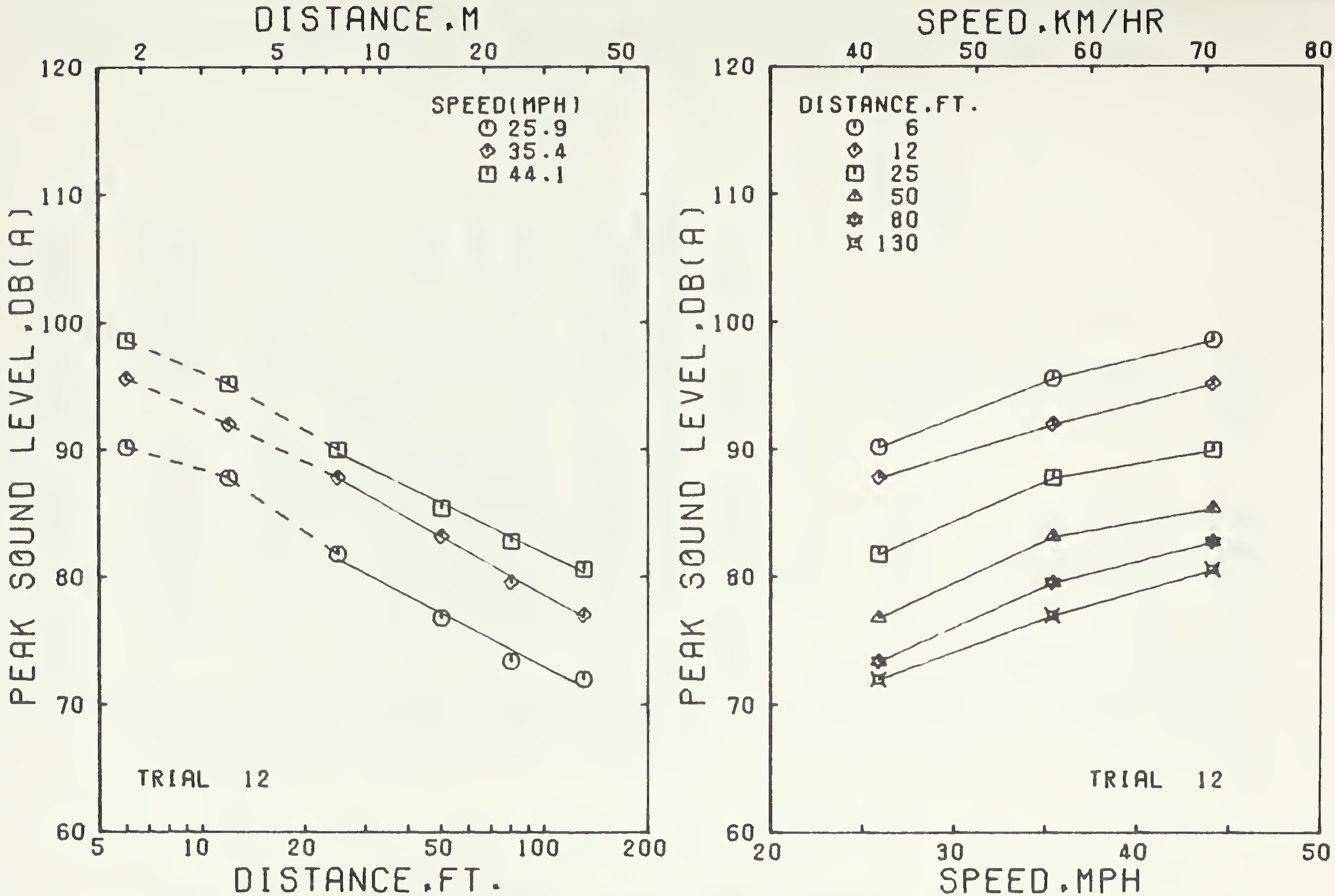


Figure A-65. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new cross-bar-D tires on the drive axles, and six new retread-G and two new retread-I tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	I-1	17	17	17	17	A/60/5
RFTI	I-2	17	17	17	17	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE	SPEED, MPH		
LOCATION, FT	27.9	36.7	43.8
6	96.8	99.4	104.2
12	91.0	95.8	99.4
25	86.4	91.8	93.2
50	80.6	85.4	88.8
80	77.4	82.6	84.4
130	74.6	78.8	81.8

SPEED	27.9	36.7	43.8
DB/DOUBLING	4.98	5.39	4.93

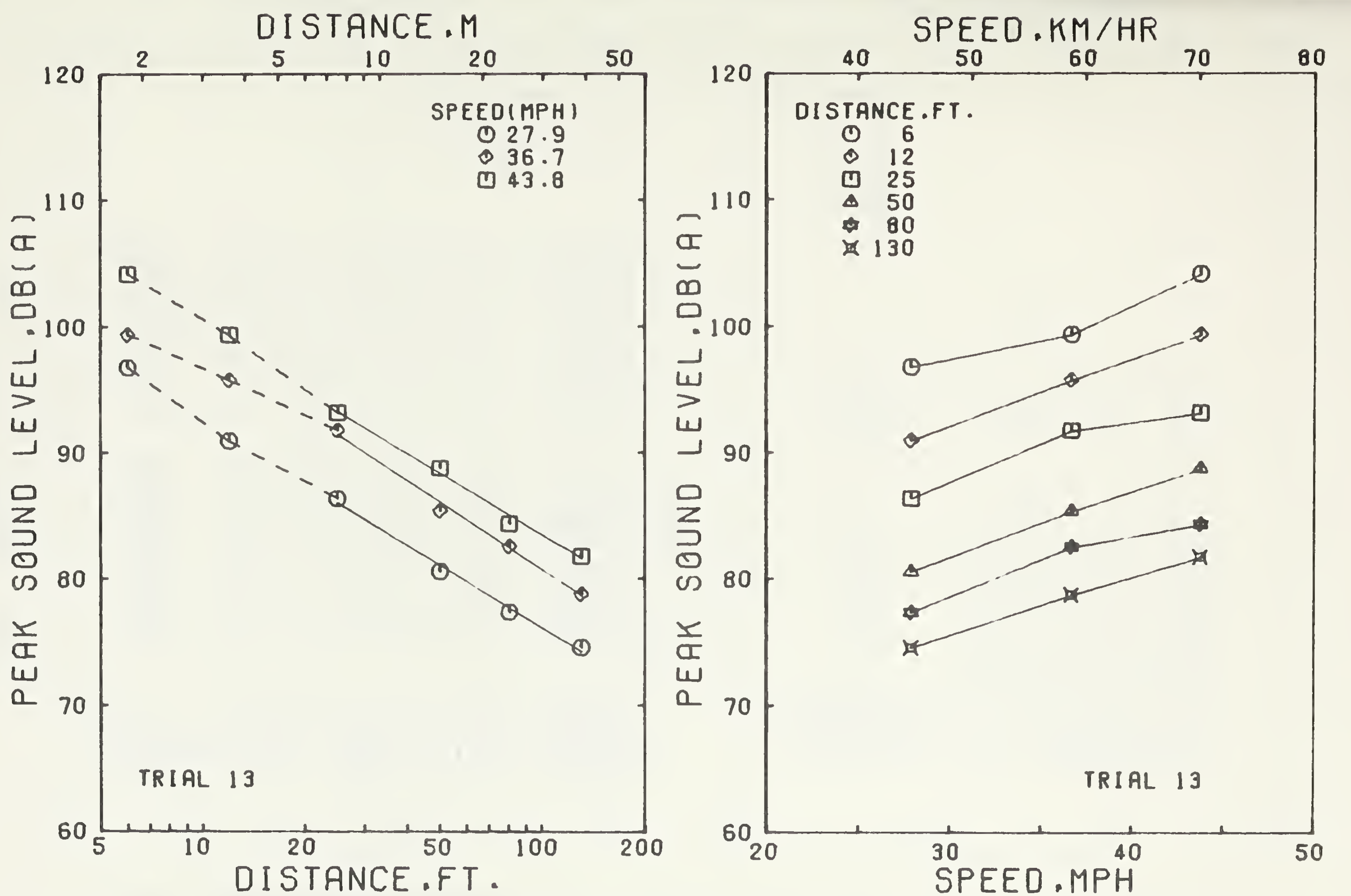


Figure A-66. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new cross-bar-D tires on the drive axles, and six new retread-G and two new retread-I tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	I-1	17	17	17	17	A/60/5
LFTI	I-2	17	17	17	17	A/60/5
RFTO	I-3	17	17	17	17	A/60/5
RFTI	I-4	17	17	17	17	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 26.0	35.3	43.7
6	95.6	100.4	105.6
12	91.8	97.4	100.8
25	86.8	90.8	95.8
50	80.6	85.2	88.4
80	78.2	83.8	84.4
130	75.0	79.4	83.0

SPEED	26.0	35.3	43.7
DB/DOUBLING	4.89	4.58	5.53

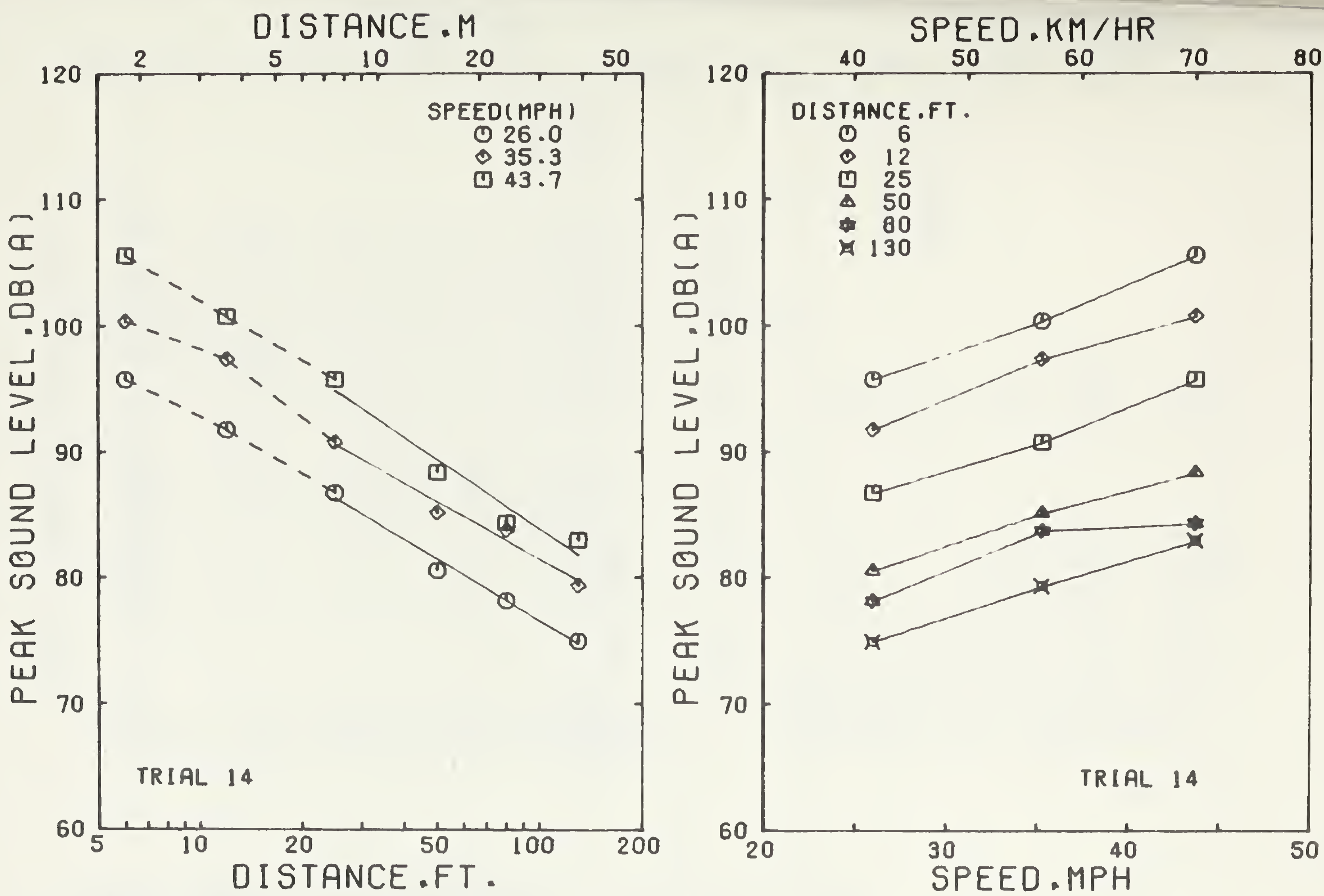


Figure A-67. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new cross-bar-D tires on the drive axles, and four new retread-G and four new retread-I tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	I-1	17	17	17	17	A/60/5
LRTI	I-2	17	17	17	17	A/60/5
RRTO	G-7	16	16	16	16	A/63/5
RRTI	G-8	16	16	16	16	A/63/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 26.6	35.5	43.6
6	92.8	97.8	100.6
12	89.4	95.0	97.8
25	85.2	90.4	93.2
50	79.6	85.2	87.4
80	75.8	82.0	84.6
130	73.2	79.8	82.0

SPEED	26.6	35.5	43.6
DB/DOUBLING	5.12	4.52	4.71

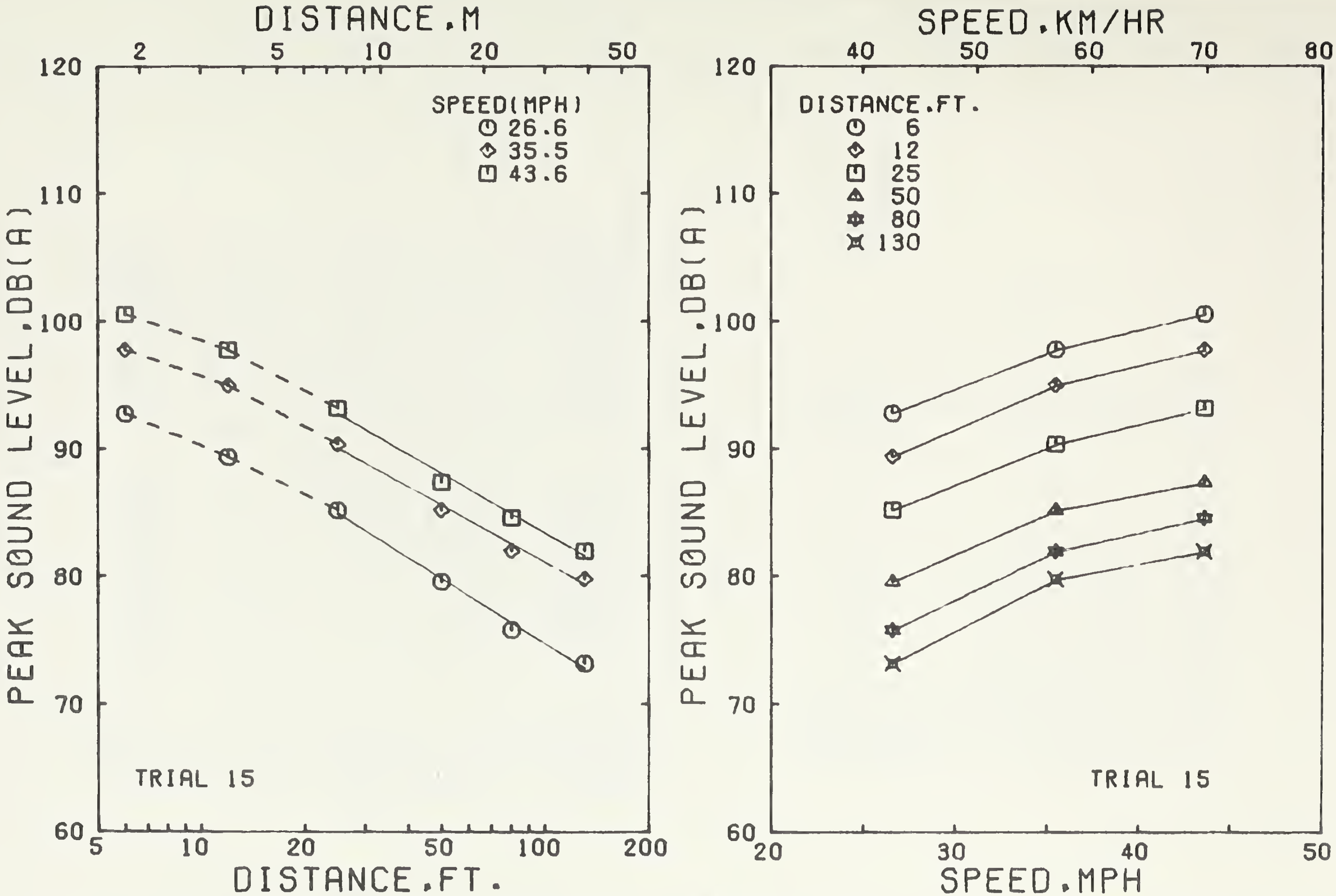


Figure A-68. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new cross-bar-D tires on the drive axles, and six new retread-G and two new retread-I tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	G-5	16	16	16	16	A/60/5
LRTI	G-6	16	16	16	16	A/60/5
RRTO	I-3	17	17	17	17	A/60/5
RRTI	I-4	17	17	17	17	A/60/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH		
	26.2	34.9	43.9
6	96.0	101.8	104.6
12	92.2	97.0	98.8
25	87.6	90.8	95.8
50	81.6	85.2	88.4
80	77.4	82.2	85.0
130	75.2	79.0	83.6

SPEED	26.2	34.9	43.9
DB/DOUBLING	5.34	4.94	5.23

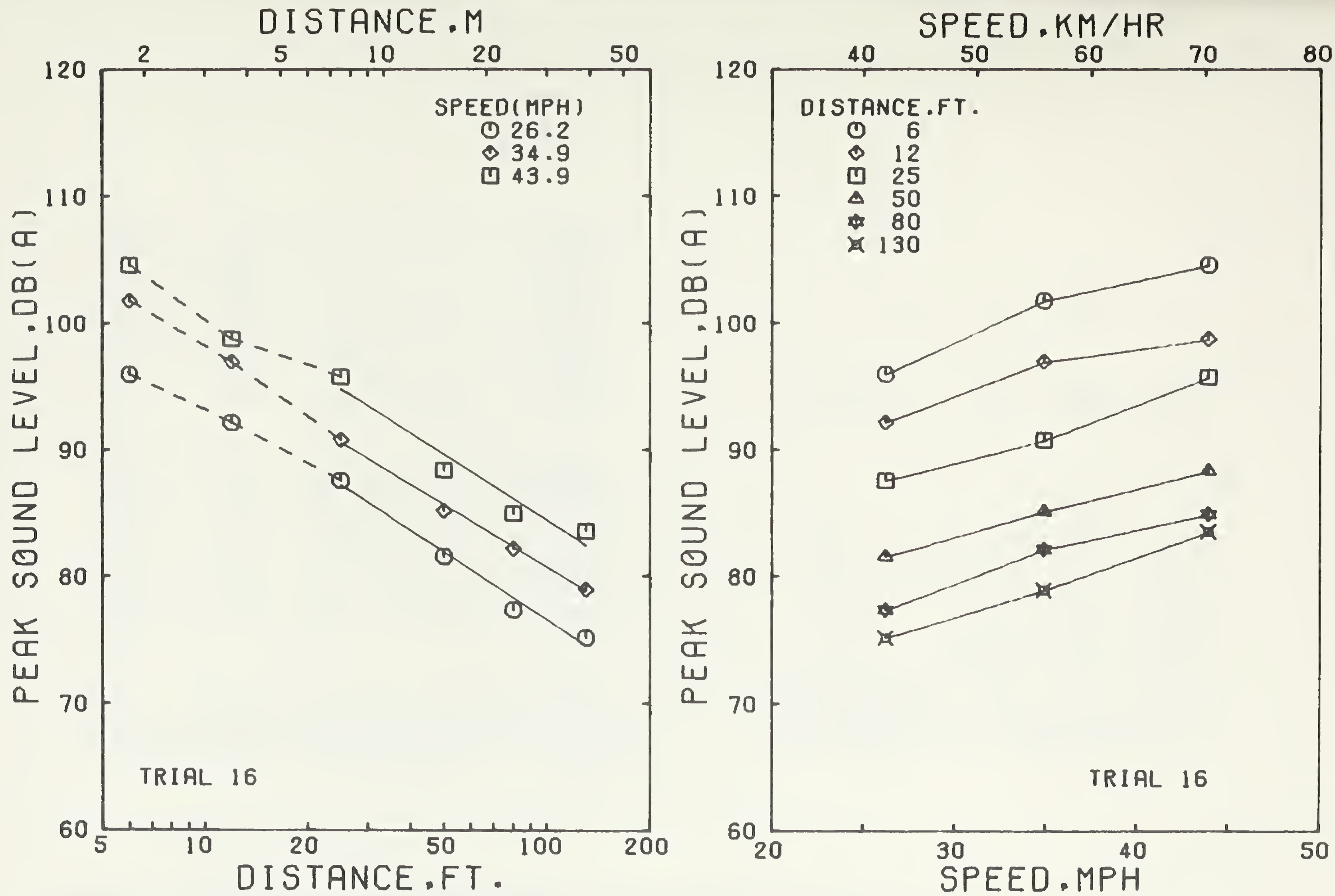


Figure A-69. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new cross-bar-D tires on the drive axles, and six new retread-G and two new retread-I tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-1	27	27	27	27	A/65/5
LFDI	D-2	27	27	27	27	A/64/5
RFDO	D-3	27	27	27	27	A/65/5
RFDI	D-4	27	27	27	27	A/65/5
LRDO	D-5	26	26	26	26	A/65/5
LRDI	D-6	26	26	26	26	A/64/5
RRDO	D-7	26	26	26	26	A/64/5
RRDI	D-8	26	26	26	26	A/65/5
LFTO	G-1	16	16	16	16	A/57/5
LFTI	G-2	16	16	16	16	A/59/5
RFTO	G-3	16	16	16	16	A/55/5
RFTI	G-4	16	16	16	16	A/60/5
LRTO	I-1	17	17	17	17	A/60/5
LRTI	I-2	17	17	17	17	A/60/5
RRTO	I-3	17	17	17	17	A/60/5
RRTI	I-4	17	17	17	17	A/60/5

A-WEIGHTED SOUND LEVELS, DB(A)

MICROPHONE LOCATION, FT	SPEED, MPH 26.4	36.7	44.8
6	99.6	102.8	106.2
12	95.0	100.4	103.0
25	88.8	93.6	97.0
50	82.2	88.2	92.0
80	79.8	85.2	88.6
130	79.6	84.0	87.0

SPEED	26.4	36.7	44.8
DB/DOUBLING	3.97	4.14	4.32

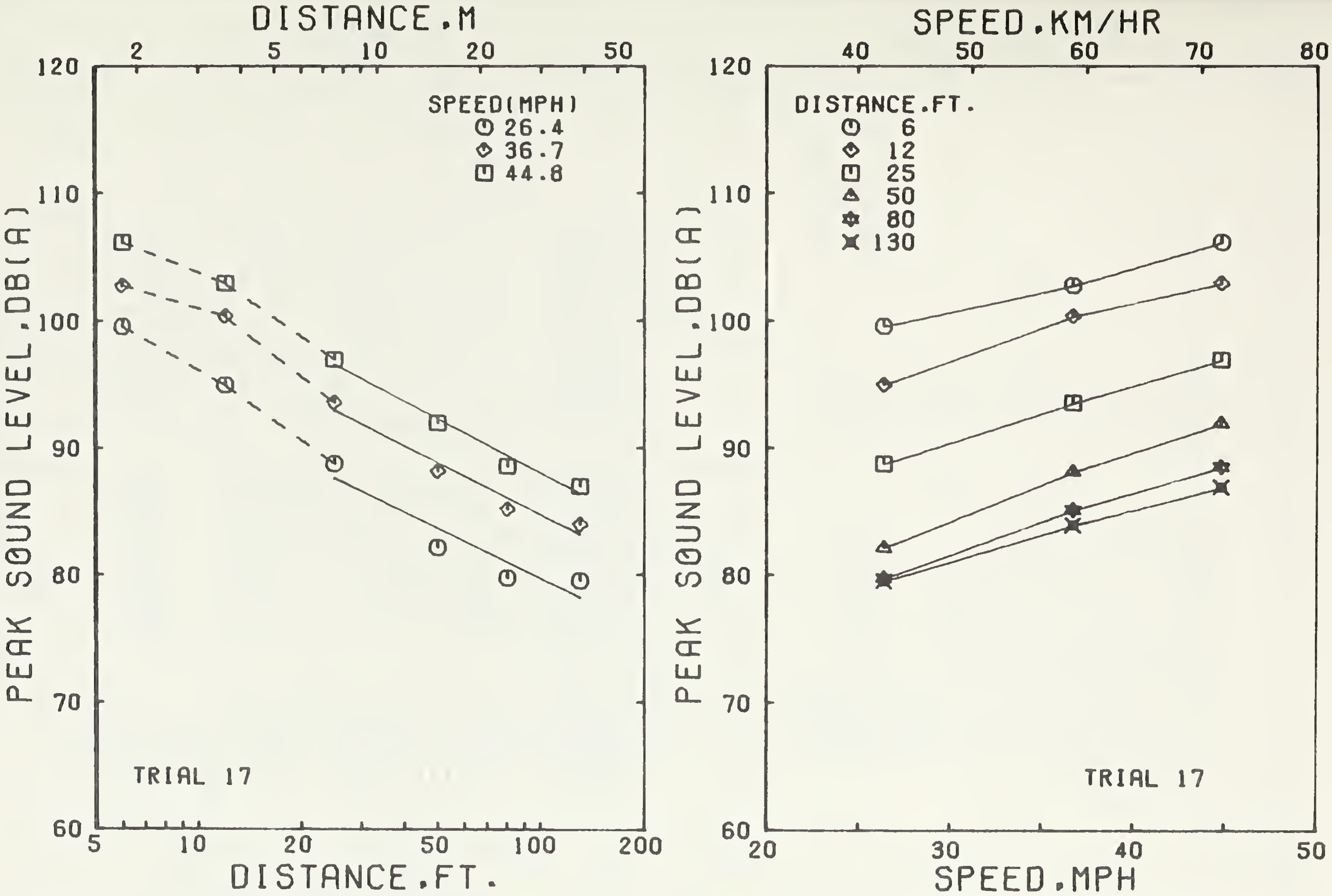


Figure A-70. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight new cross-bar-D tires on the drive axles, and four new retread-G and four new retread-I tires on the trailer axles.

LOADED TRACTOR-TRAILER RUNNING ON A CONCRETE SURFACE

TIRE LOCATION	TIRE TYPE	TREAD DEPTH 32ND OF INCH				SHORE HARDNESS
LF	A-9	15	15	15	15	A/60/5
RF	A-10	15	15	15	15	A/60/5
LFDO	D-11	15	14	15	15	A/63/5
LFDI	D-12	17	17	17	17	A/63/5
RFDO	D-13	15	16	15	15	A/64/5
RFDI	D-14	15	15	15	14	A/65/5
LRDO	D-15	17	17	17	17	A/65/5
LRDI	D-16	16	16	16	16	A/65/5
RRDO	D-17	10	10	10	10	A/65/5
RRDI	D-18	11	11	11	11	A/65/5
LFTO	I-1	17	17	17	17	A/60/5
LFTI	I-2	17	17	17	17	A/60/5
RFTO	I-3	17	17	17	17	A/60/5
RFTI	I-4	17	17	17	17	A/60/5
LRTO	I-5	16	16	16	16	A/60/5
LRTI	I-6	16	16	16	16	A/60/5
RRTO	I-7	16	16	16	16	A/60/5
RRTI	I-8	16	16	16	16	A/60/5

A-WEIGHTED SOUND LEVELS,DB(A)

MICROPHONE LOCATION,FT	SPEED,MPH 31.1	36.0	44.4
6	96.0	104.2	108.4
12	92.8	99.2	102.8
25	87.0	94.2	97.0
50	81.4	88.0	93.2
80	78.8	85.6	90.2
130	76.0	83.4	86.2

SPEED	31.1	36.0	44.4
DB/DOUBLING	4.60	4.53	4.49

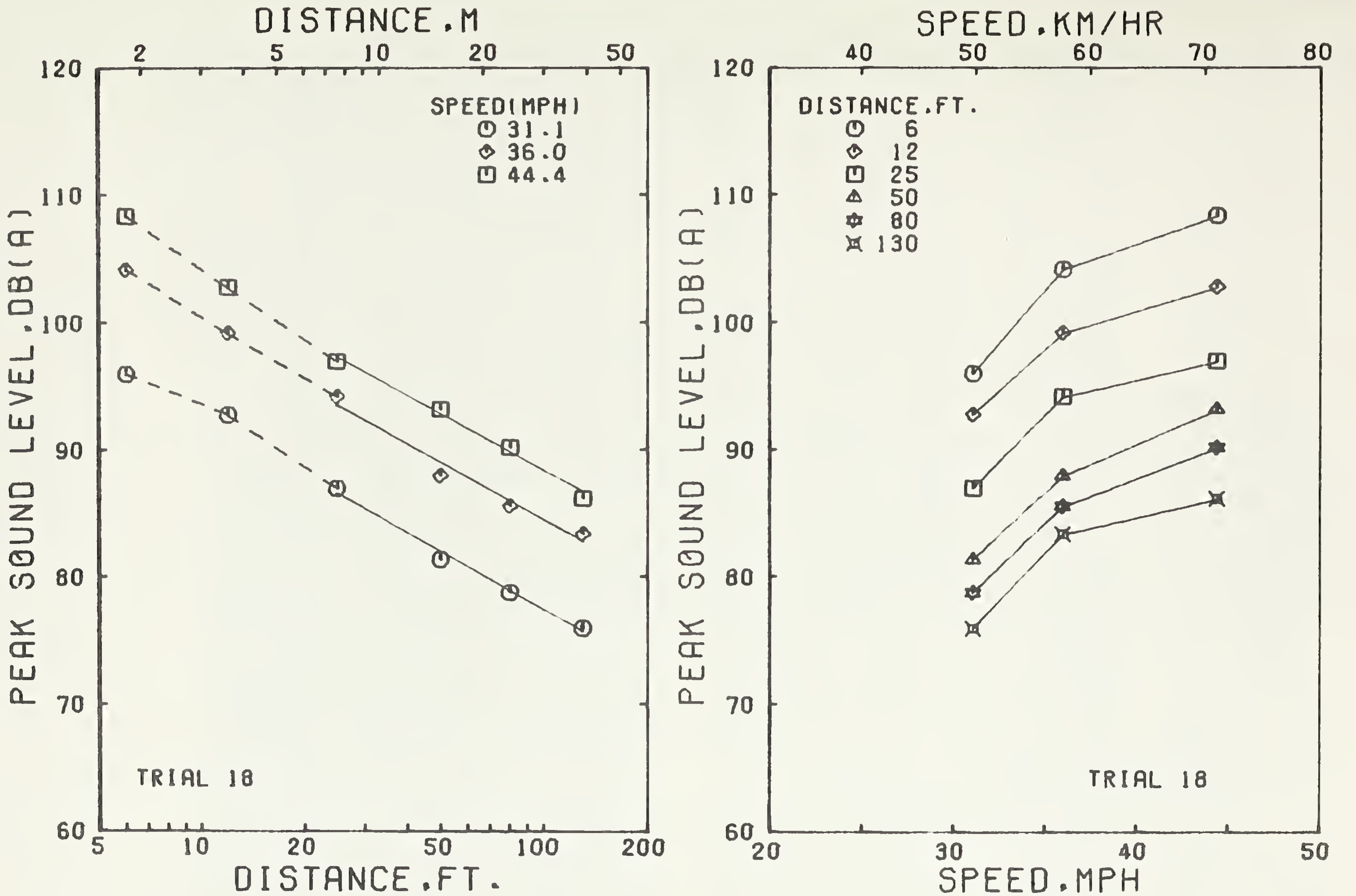


Figure A-71. Peak A-weighted sound levels versus microphone distance and speed for a loaded tractor-trailer running on a concrete surface. The truck was equipped with two new neutral rib tires on the steering axle, eight half-worn, cross-bar-D tires on the drive axles, and eight new retread-I tires on the trailer axles.

5. Appendix B

Feasibility Test Results

As described earlier in the report, the feasibility test program provided the data which served as the basis for establishment of an overall test design.

Five different microphone array configurations were utilized to evaluate the following parameters: (1) microphone height, (2) vertical directionality, (3) microphone horizontal spacing, and (4) hard versus soft reflecting surface. The microphone heights and horizontal spacing (distance was measured from the centerline of the lane in which the truck travelled) for each array are shown in Table B-1.

Microphone Spacing, ft	Microphone Height, in.				
	Array #1	Array #2	Array #3	Array #4	Array #5
6	60	50	38	50	6
18	60	50	38	50	18
25	60	50	38	--	25
30	--	--	--	50	--
43	--	--	--	50	--
50	60	50	38	--	50
81	--	--	--	50	--
100	60	50	38	--	96
131	--	--	--	50	--
200	60	50	38	--	--

Table B-1. Microphone heights and horizontal location (as measured from the centerline of the truck lane) for the five microphone arrays tested.

These five microphone arrays were placed on a concrete surface, an asphalt surface, and on a newly mown grassy field. The test vehicle, equipped with either dual new rib-A or dual new cross-bar-F tires, ran past the array at speeds of 30 and 50 mph.

Utilizing the array with all microphones at a height of 50 inches and spaced between 6 and 200 feet, the test vehicle equipped with rib-A tires was tested first with its windows open and then with it windows closed. At this time the position-velocity sensing system was not operable so that the speeds shown are the nominal speeds as read from the truck's speedometer as the vehicle passed the microphone array. The nearly exact agreement of the data (see Figure B-1) for the microphones located between the truck and the 50-foot location for the two conditions indicated the windows had little effect on the overall levels. The slight differences at the two far microphones is attributable to the fact that these are very quiet tires and at 100-200 feet from the truck the tire noise is approaching the level of the background noise of the surroundings.

The evaluation of the influence of microphone height was investigated with all six microphones at 60 inches, 50 inches, and 38 inches above the surface. An additional array was tested which utilized microphone heights from 6 inches to 96 inches. For this sloping array each microphone tripod was adjusted so that the microphones were located on a line drawn from the pavement surface at the centerline of the truck lane through the 50 foot microphone at 50 inches above the roadway. The peak A-weighted sound levels for all microphone locations for the four arrays just described are shown in Figures B-2 and B-3. The curves shown represent the average of two runs for each test condition. A review of the data shows that for the height range studied, the peak A-weighted sound level was little influenced by microphone height changes.

The range of microphone heights studied -- 38 inches, 50 inches, and 60 inches at the 50 foot microphone location -- was not great; therefore, further studies were undertaken to determine the influence of microphone height as a parameter. A test was devised in which microphones were located at heights from 50 inches to 50 feet. A pole was fabricated from 10 foot sections of electrical conduit. The 10 foot sections were connected using regular tee fittings. The microphones were placed 18 inches away from the pole on an "L" shaped piece of conduit extending from each tee. This placed microphones at 50, 40, 30, 20, and 10 feet above the surface. In addition, a microphone on a tripod at 50 inches height was placed at the base of the pole. The microphone array was located at the edge of the runway and was hoisted into place, held during the runs, and then lowered with the assistance of a 65 foot cherry-picker. The test vehicle was the unloaded single-chassis truck equipped with 50% worn cross-bar-F tires. In order to avoid the grooving in the center of the runway, the truck ran past the array at distances of 42 feet and 107 feet (first lane before and first lane after the grooves) as measured from the base of the array to the centerline of the truck lane.

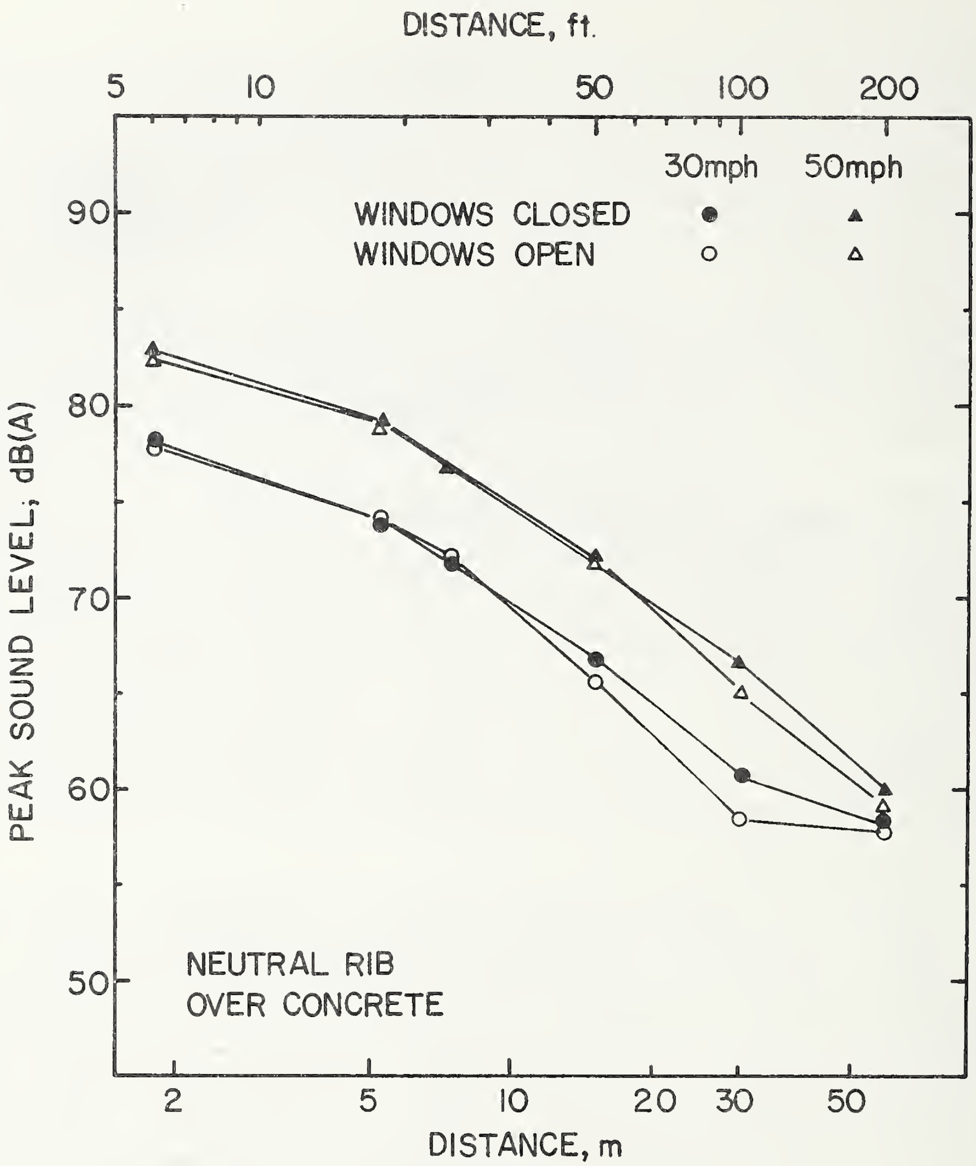


Figure B.1. Effect of open and closed windows on the peak sound level. The microphone height was 50 inches. The test vehicle was the loaded truck with neutral rib tires on a concrete surface.

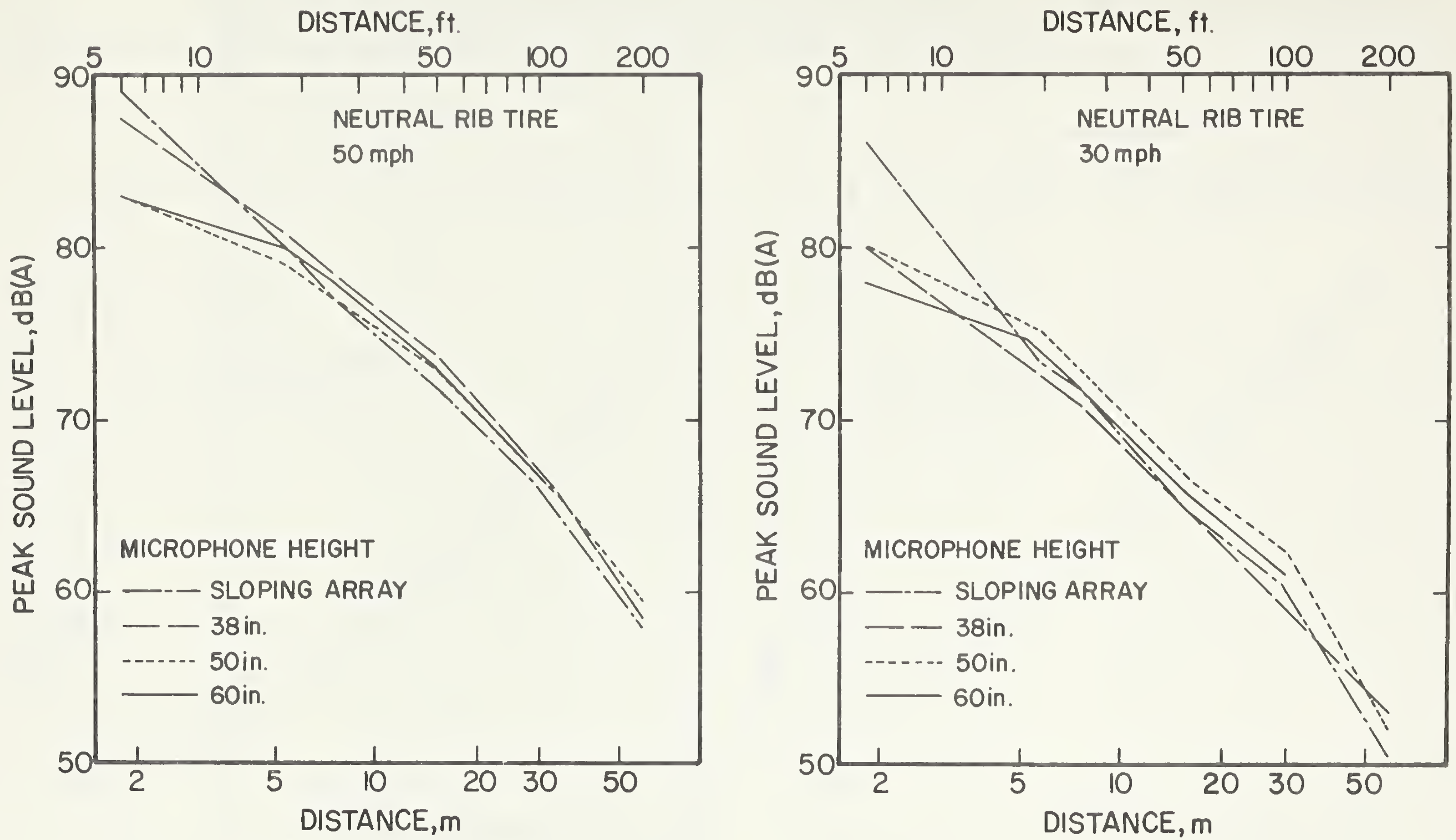


Figure B.2. Peak A-weighted sound level versus distance with microphone height as a variable. The loaded single-chassis vehicle, equipped with new neutral rib (rib-A) tires at all axle positions, ran on a concrete surface at speeds of 30 and 50 mph.

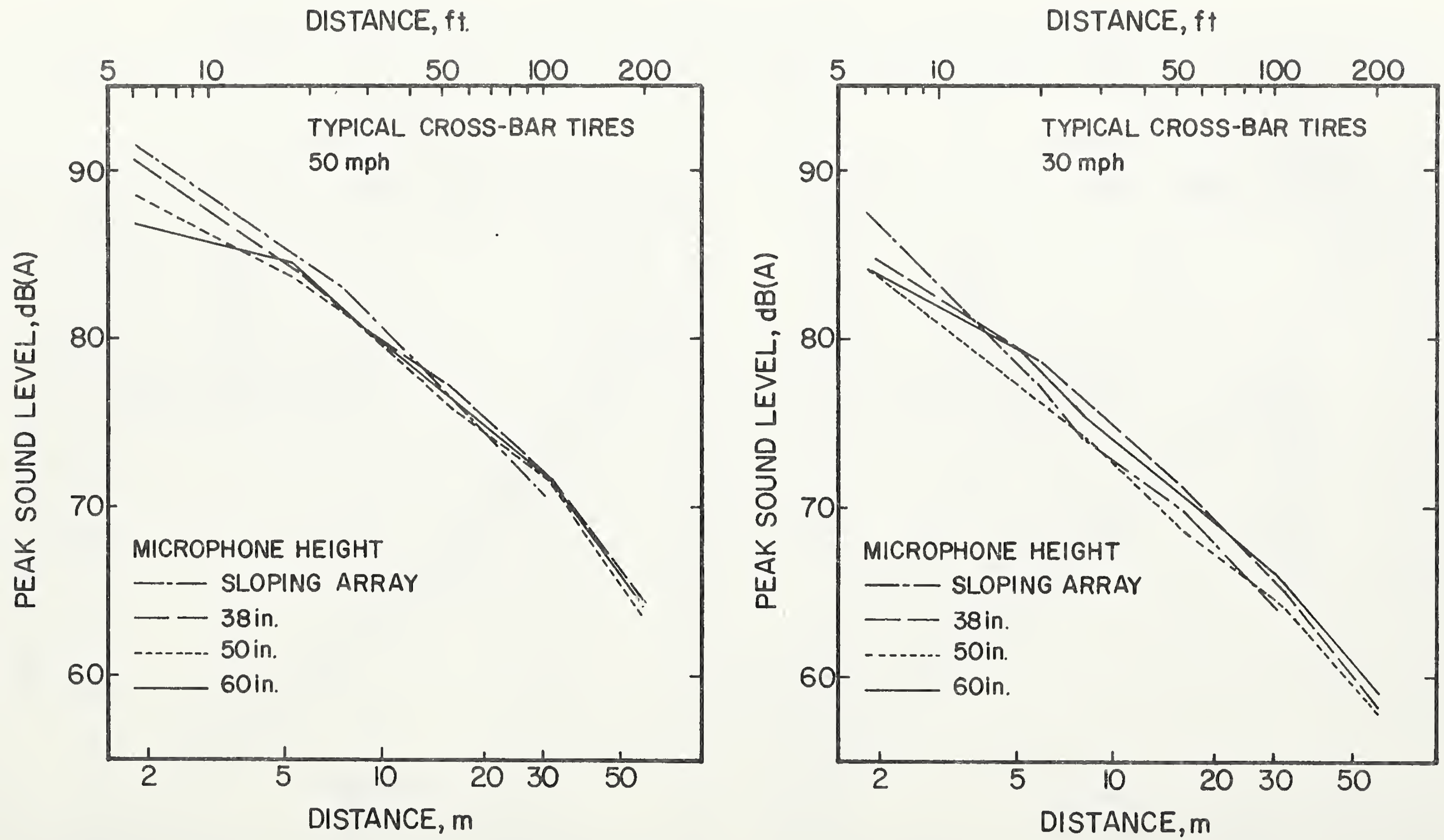


Figure B.3. Peak A-weighted sound level versus distance with microphone height as a variable. The loaded single-chassis vehicle, equipped with dual new cross-bar-F tires on the drive axle (new rib-A tires were mounted on the steering axle), ran on a concrete surface at speeds of 30 and 50 mph.

Figures B-4 and B-5 present the results of the 50 foot pole test. The peak A-weighted sound levels measured during multiple runs at a given vehicle speed were averaged[3/] for each microphone location. Initially these levels were plotted against the vertical height of each microphone. The line-of-sight distance from the centerline of truck travel through a given angle was calculated and the intersection point on the pole array was noted. Using this new height dimension (measured from ground level to the intersection point along a given angle), the A-weighted sound levels were obtained by interpolation from the plot discussed above. The resulting A-weighted sound levels were then plotted against the line-of-sight distance (distance on a log scale). As can be seen from the graphs, the A-weighted sound level is relatively independent of angle for the range of angles investigated.

Figure B-6 shows the effect various reflecting surfaces have on the propagation of noise generated by truck tires. When any surface other than a hard reflecting surface existed between the produced sound and the microphone array, the sound decayed faster; i.e., showed a larger attenuation with distance. This is evident when a comparison is made between the data for sound propagating over concrete and over a newly mown grassy field. It is further evidenced by the distinct change in slope (steeper slope over grass) between the 100 and 200 foot microphone locations on the combination concrete and grass data curve. In this case all the microphones were located on the concrete with the exception of the 200 foot microphone which was located in the grass.

Throughout the feasibility test program, the test vehicles were all equipped with standard rubber mud flaps. No investigation had been made as to the attenuation effect the flaps had on the noise 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 burlap sacks weighted so that they kept approximately the same shape as a regular rubber flap. The test truck was a fully loaded single-chassis vehicle equipped with dual rib-B tires on the drive axle. 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 using a spectrum analyzer. The peak A-weighted sound level was read directly from the digital section of the analyzer. The following table shows the results for duplicate runs at 30 and 50 mph.

[3/] The A-weighted sound levels were converted to power ratios, averaged, and then reconverted to A-weighted sound levels in decibels.

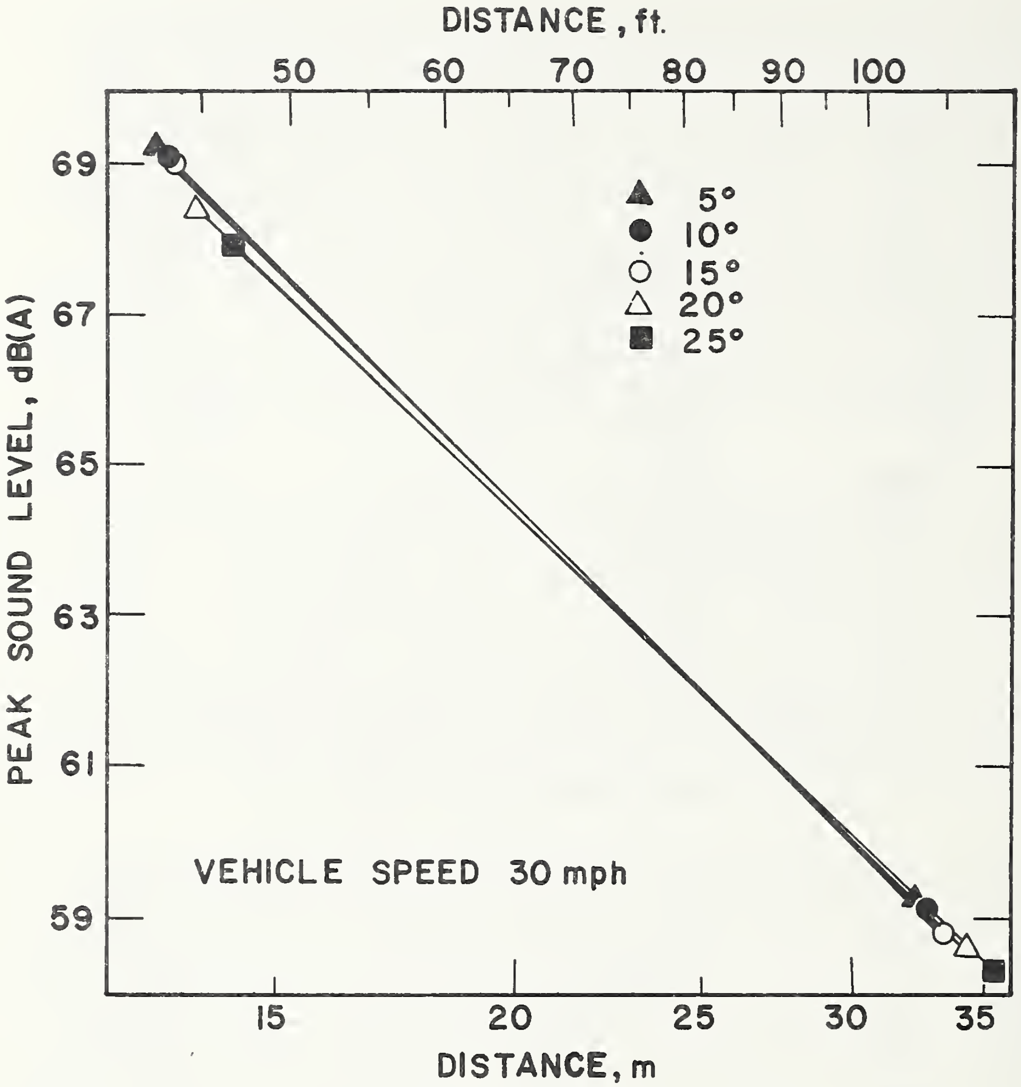


Figure B.4. Peak A-weighted sound level versus the line-of-sight distance from the centerline of vehicle path to the pole on which the microphones were attached along various angles. The test vehicle was the unloaded truck with 50% worn cross-bar-F tires. Vehicle speed was 30 mph.

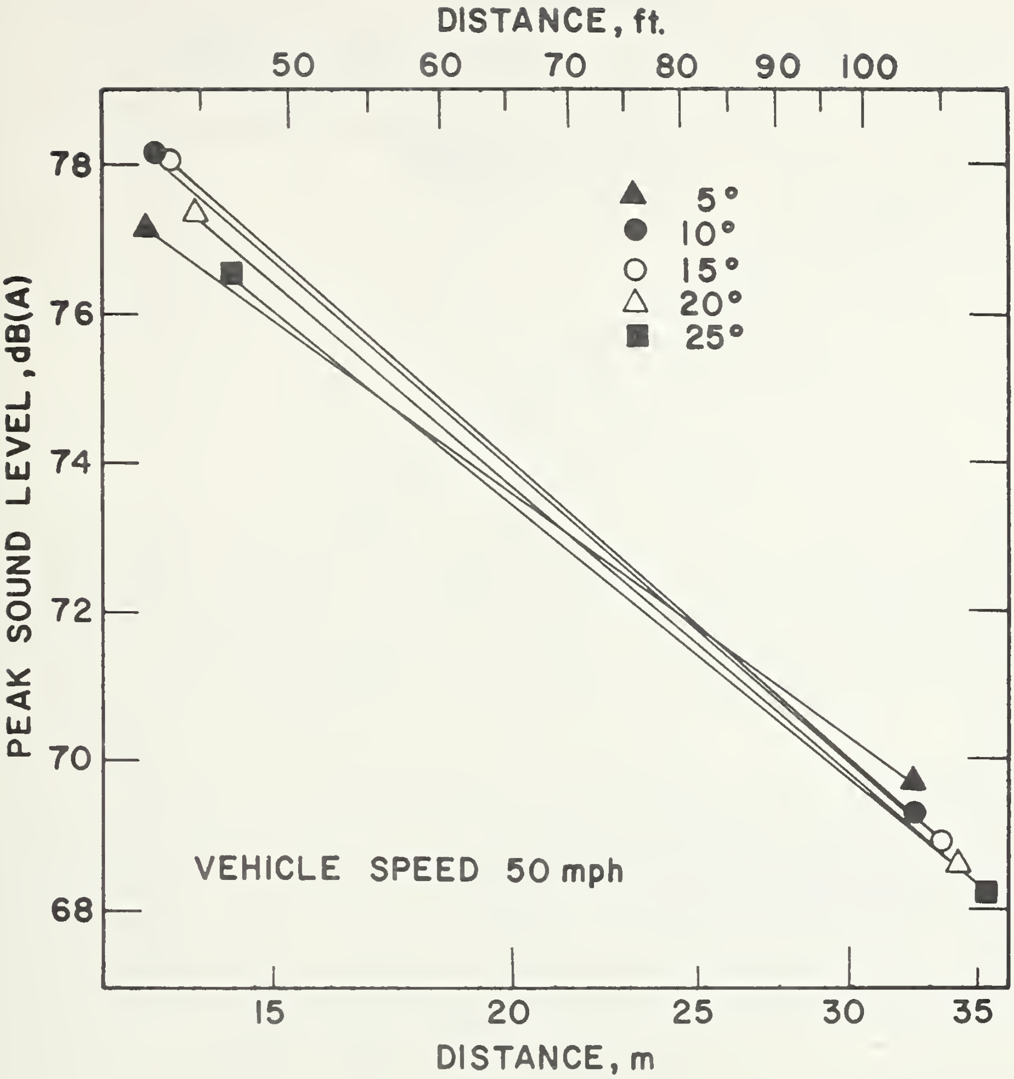


Figure B.5. Peak A-weighted sound level versus the line-of-sight distance from the centerline of vehicle path to the pole on which the microphones were attached along various angles. The test vehicle was the unloaded truck with 50% worn cross-bar-F tires. Vehicle speed was 50 mph.

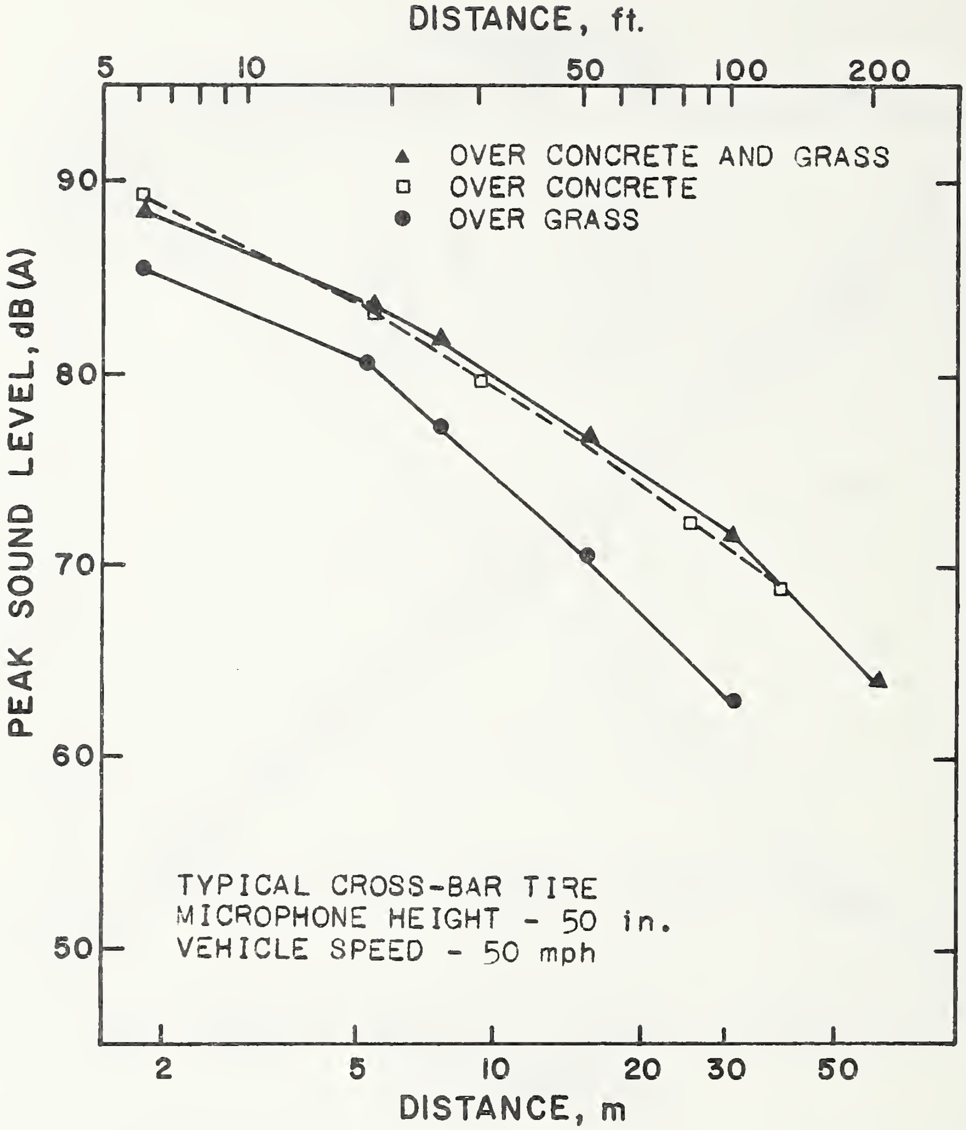


Figure B.6. Effect of various reflecting surfaces on the peak A-weighted sound levels generated by typical cross-bar tires running on a concrete surface at a speed of 50 mph.

Speed \ Flap Type	Rubber	None	Burlap Sack
50 mph	74 dB(A)	74 dB(A)	74 dB(A)
50 mph	74 dB(A)	75 dB(A)	73 dB(A)
30 mph	66 dB(A)	67 dB(A)	65 dB(A)
30 mph	66 dB(A)	66 dB(A)	66 dB(A)

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

The results for the 50 foot microphone location show that the flaps do not appear to attenuate significantly the noise 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.

In addition to providing the data necessary for the establishment of the test plan, the feasibility testing afforded an opportunity for a thorough checkout of all instrumentation and evaluation of test vehicle characteristics. It was found that the maximum attainable speed over the allowable runway length for both the loaded and unloaded single-chassis vehicles was 60 mph. For the loaded truck the characteristic deceleration with the engine shut off was a loss of 1 mph every 200 feet. This figure was little influenced by vehicle speed. The unloaded vehicle dropped in speed at a much faster rate.

The evaluation of these data obtained during feasibility testing led to the establishment of the test design utilized throughout the parametric study.

6. Appendix C

Instrument Descriptions

Unless otherwise stated, all instruments are Brüel and Kjaer[4/] (B & K).

Type UA 0207 Windscreen: When a microphone is exposed to wind, the turbulence created around the microphone and wind velocity variations cause a noise to be generated due to a variation of air pressure on the diaphragm. To reduce this extraneous wind noise, a spherical windscreen constructed of specially prepared porous polyurethane sponge was utilized.

The use of any windscreen requires that corrections be made to the sound pressure level measured to account for the presence of the windscreen. Free-field corrections for the windscreen will be made.

Type 4220 Pistonphone: This instrument is a small, battery-operated precision sound source which provides quick and accurate direct calibration of sound measuring equipment. When fitted to a B & K microphone, the pistonphone produces a sound pressure level of 124 $\pm$ 0.2 dB, re 20 $\mu N/m^2$, at a frequency of 250 Hz $\pm$ 1% (controlled by means of a transistor circuit). Maximum stability and very low distortion (less than 3% at 250 Hz) result from the piston arrangement consisting of two pistons moving in opposite phase. The calibration of the pistonphone is performed at normal atmospheric pressure. Ambient pressure corrections are necessary for pressures other than 760 mm Hg. This calibration is not influenced by relative humidities up to 100% or temperatures within the range of 0 - 60 °C (32 - 140 °F).

Microphone: When one speaks of a microphone, a three part system is implied: (1) a protecting grid; (2) a condensor microphone cartridge; and (3) a microphone preamplifier or cathode follower. For this testing the following components were utilized.

Type 4145 one-inch condensor microphone

The one-inch free-field condensor microphone is of the omnidirective type possessing relatively high sensitivity and covering a range of applicability from 20 Hz to 18 kHz (frequency) and 15 dB to 146 dB (pressure). The most outstanding feature of these microphones is long-term stability under a variety of environmental conditions and insensitivity to temperature variations. Condensor microphones, in addition, were chosen because of their higher dynamic range, ease in calibration, and uniform frequency response. The cartridge which houses the microphone diaphragm is protected by the grid on one side and on the other is screwed onto the preamplifier.

[4/] Commercial instruments are identified in this report in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the equipment identified is necessarily the best available for the purpose.

Type 2619 half-inch FET preamplifier

This preamplifier features a very high input impedance field-effect transistor input, which presents virtually no load to the microphone cartridge. To mate the 2619 with the 4145 a suitable adapter must be utilized (Model DB-0375).

Built into the preamplifier itself is a 6.3V heating coil to prevent condensation when operation must be carried out in cold or humid environments.

The above described microphone subassembly provides reliable operation over a wide range of temperature, humidity, and vibration and allows precision sound pressure measurements to be made over a wide frequency and dynamic range.

Type 221 microphone energizer: This unit houses a six channel microphone power supply with individual line driving amplifiers. In conjunction with the type 2409 signal conditioners, the microphone energizer provided the necessary gain and impedance match to supply the multi-channel tape recording system.

Type 2409 electronic voltmeter: These vacuum tube voltmeters cover the frequency range from 2 Hz to 200 kHz and provide signal conditioning (signal amplification or attenuation) prior to F.M. tape recording. The instrument consists of a calibrated attenuator, a stabilized amplifier with cathode-follower stages in the input and output circuits and a moving coil meter equipped with special rectifier circuits for the measurement of true RMS, average, or peak values with either small or high meter damping characteristics. The screened output terminal enables the instrument to operate as a calibrated amplifier featuring a low output impedance and an amplification of 60 dB max., variable in 10 dB steps. A built-in reference voltage makes it possible to check the sensitivity of the instrument by simply turning a knob. A screwdriver operated potentiometer is available to correct any possible deviations.

Frequency response	:	Linear to within $\pm$ 0.2 dB from 2 Hz to 200 kHz.
Meter accuracy	:	Better than 1% of full scale at 1000 Hz.
Distortion	:	Less than 0.2% with an output voltage of 10 volts.
Stability	:	For a 10% variation in the line voltage the meter deflection will change less than 2%.

Model 7610 medium band magnetic tape system (Honeywell): A seven-channel instrumentation tape recorder with a bandwidth range from 0 - 80 kHz was selected for this program because of its low and uniform frequency response. The model purchased can be expanded to a full fourteen channels with the addition of the record/reproduce electronics for the additional channels and a modification of the heads and hub to accommodate the one-inch tape (7 channel recording utilizes 1/2 inch tape).

The wide bandwidth range results from a feature which allows the selectability of three different modes of operation:

(1) Standard : 0 - 20 kHz at 120 ips
(2) Extended : 0 - 40 kHz at 120 ips (0 - 10 kHz at 30 ips)
(3) Double Extended: 0 - 80 kHz at 120 ips

The present unit has six channels of F.M. record electronics and one channel of direct record electronics. One channel of F.M. and one channel of direct reproduce electronics are in the system. In addition, a voice record/reproduce amplifier unit is included. The voice is recorded on the edge track of the tape.

Additional features include a phase lock servo control system, a tape footage counter, a shuttle, electrically selectable tape speeds (seven in all) ranging from 1-7/8 ips to 120 ips, and pushbutton selectability of the reproduce channel.

Type 3347 real time analyzer: The real time analyzer is composed of two basic units: (1) type 2130 frequency analyzer and (2) type 4710 control and display unit.

The 2130 contains a measuring amplifier, filter channels with 1/3-octave bandwidth, a linear channel, weighting channels, true RMS detectors, and the synchronization system for scanning the channels.

The analyzer contains 38 parallel channels. 33 of these channels contain 1/3-octave filters with center frequencies from 12.5 Hz to 20 kHz. The remaining five channels are reserved for the four weighting network filters -- A, B, C, and D -- and one linear response channel.

The 4710 contains the circuitry for the 12-inch cathode ray tube (CRT), the Nixie displays, digital readout, and the logic control. The logic control section controls the analog/digital conversion and the communication sequence for external systems, as well as the internal synchronization in the 3347 during display or read-out modes.

The level in each channel can be read in dB directly on the screen, while a Nixie display shows the output level of any selected channel. This channel is indicated on the CRT as a brighter trace. The complete channel display is renewed every 20 msec.

Outputs are provided for both analog instruments (X-Y or level recorders) as well as digital (on-line computer or tape puncher). The digital output is in binary coded decimal (BCD) code.

Time constants may be selected from 20 msec to 20 sec so that confidence limits can be maintained throughout the frequency range.

Type 1024 sine-random generator: This audio frequency generator is a multipurpose signal source. It covers a frequency range extending from 20 to 200 kHz and consists of a wide band noise generator, a beat frequency oscillator, several filters, amplifiers and an automatic output regulator. It is capable of producing three types of output signals: (1) sine waves, (2) narrow bands of random noise, and (3) wide band random noise. Since this unit was utilized for calibration purposes (frequency response testing), wide band random noise or "pink noise" was generated. Pink noise is noise whose spectrum level decreases with increasing frequency to yield constant energy per octave of bandwidth. When in the wide band random noise mode, the frequency range is 20 Hz to 20 kHz with the frequencv spectrum flat to within $\pm$ 1 dB.

Model 704 Raytheon Computer System: The Raytheon 704 computer system is a general purpose digital system that provides a 16-bit central processor unit with 900 nanosecond cycle time for on-line, real time applications.

The hardware configuration includes an 8K (expandable to 32K) memory system, direct input/output bus, automatic priority interrupt, direct and indexed addressing, and byte and word addressing and instructions. Standard peripherals such as high speed paper tape, ASR-33 teletype, card equipment, and a magnetic tape unit are also included.

7. Appendix D

Photosensor System for Position-Velocity Determination and Tape Recorder Actuation

The system for position and velocity determination consisted of three units; a photosensor, start-stop circuitry for the tape recorder, and a digital line driver.

The block diagram of the photosensor is shown in Figure D-1. The photosensor contains a photo detector, two clipping amplifiers and a monostable multivibrator. Whenever a light source is moved across the photo detector surface, a change in the output voltage of the detector is obtained. The output voltage is capacitance coupled to an operational amplifier with a gain of 100. The capacitance coupling is necessary to avoid amplification of ambient light effects. To avoid over-driving of the amplifier, and subsequent saturation, and for signal shaping purposes, two Zener diodes are used in the feedback loop of the first amplifier. The output of the first amplifier is coupled to the second amplifier by a diode such that only negative pulses are amplified. The second amplifier has a gain of ten and uses a Zener diode in the feedback loop for the previous mentioned reasons. The second amplifier is connected to a Schmitt trigger and monostable multivibrator. The multivibrator has the advantage over other circuitry that the period of the time pulse can be accurately determined by external passive components. A pulse period of 28 milli-seconds was chosen on the basis of analysis time; however, any pulse period between 40 ns and 40 seconds can be obtained by changing the timing resistors and capacitors of the multivibrator. The entire photosensor system is powered by batteries using matched Zener diodes for voltage regulation.

The Honeywell 7610 magnetic tape system requires actuation of first the record mode and then the forward drive mode. The time required between modes is a minimum of 50 milliseconds. This functional switching may take place external to the recorder. The timing system consists of digital networks; the block diagram of the system and timing are shown in Figure D-2. When a pulse is applied to the monostable multivibrator from a photosensor, monostable one and monostable two are turned "on". The output of monostable one (Q) is connected to a grounded emitter circuit which in turn activates a record mode relay. The duration of the "on" state is approximately 200 milliseconds. The Q output of the first multivibrator is connected to an AND gate of a third multivibrator. When the second multivibrator is triggered a pulse of 100 milliseconds is generated. The output Q of the second multivibrator is connected to a NOR gate of the third multivibrator. The output of the NOR gate is connected to the AND gate previously described. Thus, the third multivibrator has an output only when the first multivibrator is "on" and the second multivibrator is "off". A delay of 100 milliseconds between Record and forward drive functions is achieved. The output of the third multivibrator is also connected to a grounded emitter circuit which in turn activates the forward drive mode relay. The action of the start circuitry may be overridden at any time by use of the normal tape recorder function switches. The stop circuitry consists of a multivibrator and grounded emitter circuit for actuating a stop relay.

The digital line driver is useful for long cables as might be encountered in the start stop circuitry previously described. The line driver consists of a multivibrator and a grounded emitter for impedance matching. The output of the circuit is 6 volts. This circuit easily drives 1 mile of RG58C/U cable.

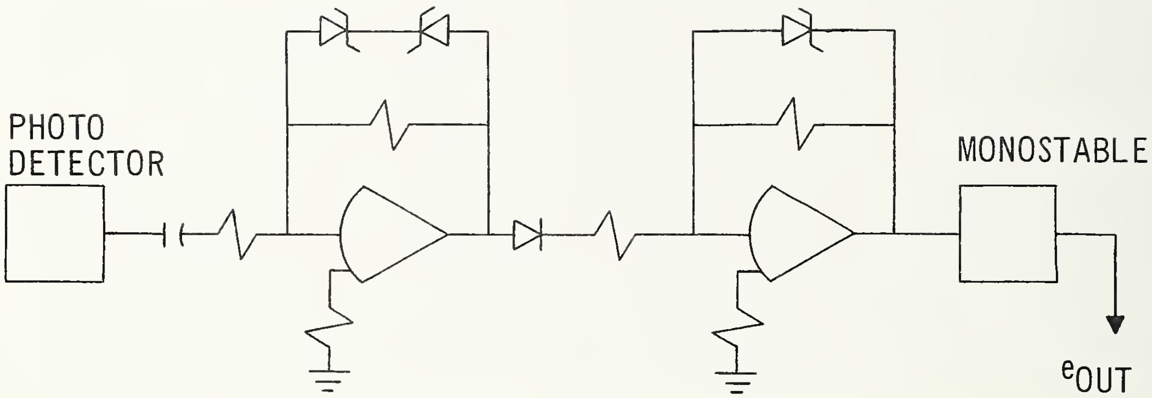


Figure D-1. Block Diagram of Photodetector.

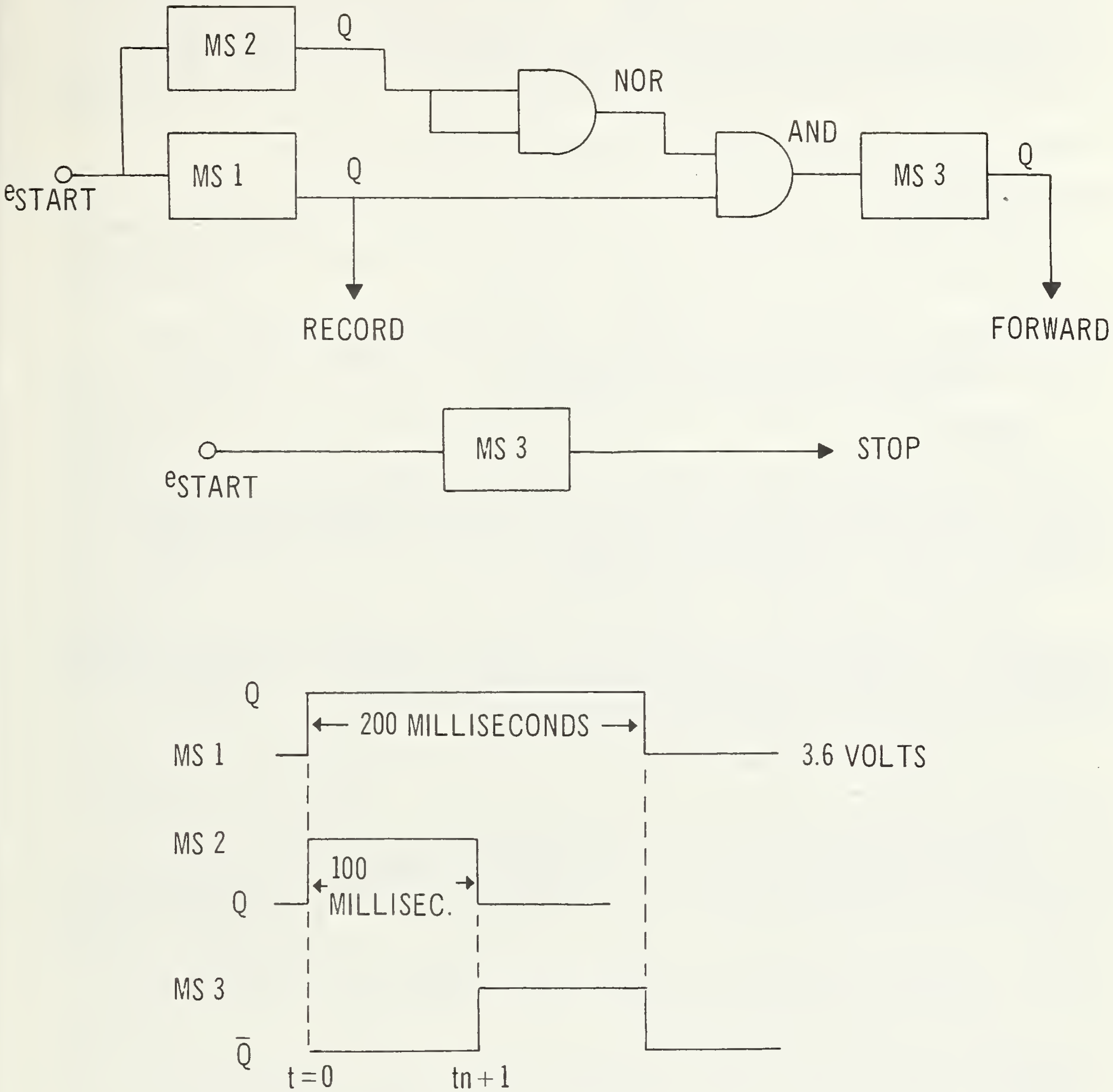


Figure D-2. Block Diagram and Timing of Start-stop Circuitry.

8. Appendix E

Test Sections Substrate Details[5/]

Substrate details discussed in this appendix are not the exact details of the test pavements; however, they represent the specifications followed in the construction of the pavements. Since surface details are most important when considering the effect of the pavement on noise generation characteristics of truck tires, special note should be taken of the discussion of surface finishing techniques.

1. Asphalt Test Section (Bituminous binder and surface course).

A. Description

This test section consists of a "B" surface course of bituminous concrete otherwise known as "textured asphalt".

This section consists of binder and surface courses composed of mineral aggregate and bituminous material.

B. Materials

The aggregate consists of crushed stone, crushed gravel, screenings, gravel, sand-gravel, sand and other natural granular material having essentially the same qualities and meeting all the requirements when combined within the limits for gradation.

For the surface course, one hundred percent by weight of the mineral aggregate including filler was produced by the crushing of stone and gravel. When produced from gravel, only those particles having one or more fractured faces were considered as crushed.

The aggregate is tough, durable and sound and consists of angular fragments reasonably uniform in density and quality and contains no more than eight percent of either thin, elongated and soft pieces, or dirt or other objectionable matter. The coarse aggregate was tested in accordance with the Los Angeles Abrasion Test. After five hundred revolutions the percent of wear was less than forty-five according to the A.A.S.H.O. Method T-96.[6/] The coarse aggregate showed no evidence of disintegration, nor a total loss greater than twelve percent when subjected to five cycles of the sodium sulphate accelerated soundness test using A.A.S.H.O. Method T-104.

[5/] Details of the composition of each test section were taken from a National Aeronautics and Space Administration, Wallops Station, Virginia, Specification numbered P-1643, entitled "Modification to Runway 4-22", and dated April 18, 1967.

[6/] Details of these test methods are contained in references [1]-[17] cited at the end of Appendix E.

The portion of the materials retained on a No. 4 sieve was known as coarse aggregate; that portion passing as No. 4 sieve was known as fine aggregate, and the material passing the No. 200 sieve was known as filler. The composite material met the gradation requirements discussed later which were determined by A.A.S.H.O. Methods T-11 and T-27.

That portion of the fine aggregate, including any blended filler passing a No. 40 sieve had a plasticity index of not more than six, as determined by A.A.S.H.O. T-89.

The composite aggregate was free from vegetable matter, lumps or balls of clay, adherent films of clay, or other material that would prevent thorough coating with bituminous material. The bituminized aggregate had a swell of less than one and one-half percent as determined by A.A.S.H.O. Method T-101.

Prior to final acceptance of the aggregate, the inherent characteristics of the aggregate relative to stripping were determined by the contractor. This was done by preparing a test sample of the paving mixture in conformity with the following specifications. After the mixture was made, it was spread out in a loose thin layer and allowed to air season for twenty-four hours before testing. A suitable size sample (approximately one-half of the contents of container) was tested by placing it in a glass jar fitted with a tight screw cap. The sample was completely covered with distilled water at a temperature between 80°F and 100°F. The jar must be thoroughly cleaned and free from any traces of soap or other saponaceous material. The jar and contents were allowed to stand for a period of twenty-four hours. Then the sample was vigorously shaken for a period of fifteen minutes. The sample was then examined for stripping. If stripping or sloughing off of the bituminous coating occurred, it would be necessary to treat said aggregate by a method which has proven successful in changing the material from a hydrophilic to a hydrophobic state or the aggregate was rejected.

If filler in addition to that naturally present in the aggregate was necessary, it consisted of stone dust, Portland Cement or other standard approved types. The filler met the requirements of A.A.S.H.O. Specification M-17.

The bituminous material was mixed with the mineral aggregate conformed to the requirements of A.A.S.H.O. Specification M-20, penetration grade 85-100. In addition, the material showed a negative spot when determined by A.A.S.H.O. Method T-102, using standard naphtha.

C. Composition of Mixture

The mineral aggregates for the binder and surface course was of such size that the percentage composition by weight, as determined by laboratory sieves, conformed to the following gradations. The percent by weight for the bituminous material was within the limits given below.

Square Sieve Sizes	Binder Course	"B" Surface Course
1 inch	100	-
3/4 inch	82-100	100
1/2 inch	70-90	82-100
3/8 inch	60-82	68-90
No. 4	42-70	50-79
No. 10	30-60	36-67
No. 20	-	-
No. 40	15-40	17-44
No. 80	8-26	9-29
No. 200	3-8	3-8
Percent Bituminous Material	4.0-6.0%	5.0-7.5%

The gradations above represent the limits which determined the stability of the aggregate. The final gradations were uniformly graded from coarse to fine, and did not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa.

A sample of the coarse and fine aggregates was washed to determine the percentage of the total material passing the No. 200 mesh sieve. Of the amount passing the No. 200 mesh sieve, at least one-half passed by dry sieving.

D. Determination of Percentage of Bituminous Material and Stability

The percentage of bituminous material, by weight, to be added to the approved aggregate was fixed on the basis of several laboratory tests which allowed for plotting a Marshall Stability curve and to determine the maximum stability attainable and the corresponding density. In no event was the Marshall Stability less than 1800.

E. Weather Conditions

Binder and surface course were constructed only when the surface on which they were placed was dry, when the atmospheric and underlying course temperatures were above 40°F, and when the weather was not foggy or rainy.

2. Concrete Test Section (Reinforced Portland Cement Concrete Pavement)

A. Description

This test section consists of a wearing surface of reinforced air-entrained Portland Cement concrete pavement with two types of finishes on a suitably prepared subbase.

B. Materials

The cement used in this work was a standard brand of Portland cement with air-entraining properties. The air-entrained cement conformed to A.S.T.M. designation C-175.

In no case was the use of pit run or naturally mixed coarse aggregates permitted. Naturally mixed aggregates were in every case screened and washed and all fine and coarse aggregates were stored separately and kept clean. In no case were aggregates containing lumps of frozen or partially cemented material used.

The coarse aggregate conformed to the requirements of A.A.S.H.O. Specification M-80. Also, at least sixty percent of the gravel aggregate had at least one fractured face. The coarse aggregate had no more than one percent of material removable by the decantation test, using A.A.S.H.O. Method T-11 nor more than one percent of shale, nor more than one percent of clay lumps. Chart did not exceed one percent. The total of shale, coal, clay lumps, chart, soft fragments, and other deleterious materials did not exceed five percent. The coarse aggregate did not show evidence of disintegration nor show a total loss greater than twelve percent when subjected to five cycles of the Sodium Sulfate Soundness test using A.A.S.H.O. T-104.

The coarse aggregate conformed to the following gradations:

Sieve Size Square Mesh	Percent Passing by Weight Gradation A	Gradation B
2 inch	100	-
1 1/2 inch	90-100	-
1 inch	20-55	100
3/4 inch	0-15	90-100
3/8 inch	0-15	20-55
No. 4	-	0-10
No. 8	-	0-5

The coarse aggregate were batched in two separate sizes which could be varied within a range from forty to sixty percent by weight to secure the most desirable and uniform gradation of the combined mix.

The fine aggregates conformed to the requirements of A.A.S.H.O. Specification M-6.

When subjected to five cycles of the sodium sulfate soundness test using A.A.S.H.O. Method T-104, the fine aggregate had a total loss less than ten percent by weight. It also contained less than three percent of meterial removable by a decantation test, using A.A.S.H.O. Method T-11. Percentages of shale, clay lumps, etc. permissible were the same as for the coarse aggregate.

The fine aggregate was well graded from fine to coarse and met the following gradation requirements, using A.A.S.H.O. Method T-27.

Sieve Designation (Square Mesh)	Percentage Passing by Weight
3/8 inch	100
No. 4	95-100
No. 16	45- 80
No. 30	25- 55
No. 50	10- 30
No. 100	2- 10

The water used in the concrete and for curing was clean, clear, and free of injurious amounts of sewage, oil, acid, strong alkalies, or vegetable matter, and, also, free of clay and loam.

C. Composition of Mixture

The weights of fine and coarse aggregate and the quantity of water per bag of cement were determined from the weights given in the following table:

Type of Aggregate	Minimum Cement Content Per Cubic Yard of Concrete	Maximum Net Water Content, Gallons Per Bag	Weights in pounds of dry Aggregate per bag of cement			Slump Range, Inches
			Fine Aggregate	Coarse Aggregate	Total	
Gravel	5.8 bags	5 1/2	169	394	563	1-1/2
Crushed Stone	5.8 bags	5 3/4	195	366	561	1-1/2

Yield tests in accordance with ASTM Specification C-138 were made to determine the cement content per cubic yard of concrete. If at any time, the content was found to be less than that specified, the batch weights were reduced until the requirements were met.

Air-entrained Portland cement concrete causes a bulking of the mortar of the concrete due to the amount of entrained air. To keep the cement factor specified at the correct amount, the weight of the fine aggregate was reduced as required. The air content of the fresh concrete was determined by ASTM Designation C-231.

The proportions in the above table produced a concrete of satisfactory plasticity and workability which attained, after fourteen days, a minimum compressive strength of 3000 pounds per square inch and a modulus of rupture of 700 pounds per square inch after twenty-one days. The specimens were cured and tested in accordance with A.A.S.H.O. Methods T-22, T-23, and T-97.

D. Placing and Finishing

The concrete was deposited and spread so that any segregation would be corrected and a uniform layer of concrete whose thickness was approximately one inch greater than that required for the finished pavement.

After the first operation of the finishing machine, additional concrete was added to all low places and the concrete rescreeded.

After the final pass of the finishing machine, the placing of all joints longitudinal and transverse, and the concrete had started to dry, the surface of the pavement was finished with a longitudinal float.

After the concrete was brought to the required grade, contour, and smoothness, it was finished by means of a finishing belt. The belt was eight to twelve inches in width and at least two feet longer than the width of the pavement section to be finished. On the "C" (smooth) finish section of pavement a belt of canvas composition was used. On the "D" (regular) finish section of pavement the finishing belt was of burlap composition. The three-ply burlap belt was worked with a combined longitudinal and transverse motion, until all surface irregularities were eliminated.

References for Appendix E

[1] American Association of State Highway Officials, T-96-65, Standard Method of Test for Resistance to Abrasion of Course Aggregate by Use of the Los Angeles Machine (ASTM designation: C-131-64T), Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[2] American Association of State Highway Officials, T-104-65, Standard Method of Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[3] American Association of State Highway Officials, T-11-60, Standard Method of Test for the Amount of Material Finer than No. 200 Sieve in Aggregate, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[4] American Association of State Highway Officials, T-27-60, Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[5] American Association of State Highway Officials, T-89-60, Standard Methods of Determining the Liquid Limit of Soils, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[6] American Association of State Highway Officials, T-101-64, Standard Method of Determining Swell Characteristics of Aggregates When Mixed with Bituminous Materials, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[7] American Association of State Highway Officials, M-17-42, Standard Specifications for Mineral Filler for Sheet Asphalt and Bituminous Concrete Pavements, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[8] American Association of State Highway Officials, M-20-63, Standard Specifications for Asphalt Cement (Prepared from Petroleum), Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[9] American Association of State Highway Officials, T-102-57, Standard Method of Spot Test of Asphaltic Materials, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[10] American Society for Testing and Materials, C-175-69, Standard Specification for Air-Entraining Portland Cement in Part 10, Book of ASTM Standards, 1970 (ASTM, Philadelphia, Pennsylvania).

[11] American Association of State Highway Officials, M-80-51, Standard Specification for Portland Cement Concrete, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[12] American Association of State Highway Officials, M-6-65, Standard Specification for Fine Aggregate for Portland Cement Concrete, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[13] American Society for Testing and Materials, C-138-63 (1969), Standard Method of Test for Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete in Part 10, Book of ASTM Standards, 1970, (ASTM, Philadelphia, Pennsylvania).

[14] American Society for Testing and Materials, C-231-68, Standard Method of Test for the Air Content of Freshly Mixed Concrete by the Pressure Method, Book of ASTM Standards, 1970 (ASTM, Philadelphia, Pennsylvania).

[15] American Association of State Highway Officials, T-22-64, Standard Method of Test for Compressive Strength of Molded Concrete Cylinders (ASTM designation: C-39-66), Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[16] American Association of State Highway Officials, T-23-65, Standard Method for Making and Curing Concrete Compression and Flexural Test Specimens in the Field, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

[17] American Association of State Highway Officials, T-97-64, Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) (ASTM designation: C-78-64), Standard Specifications for Highway Materials and Methods of Sampling and Testing, Ninth Edition, 1966 (AASHO, Washington, D.C.).

9. References

[1] Goodfriend, Lewis S., "Control of Highway Noise", Goodfriend-Ostergaard Associates, Cedar Knolls, New Jersey, Sound and Vibration, July 1957.

[2] Yurkovski, B., Astrov, V. A., and Ivanteev, A. V., "The Influence of Design Parameters on the Shock-Absorbing Capacity, Road-Holding, and Noise Level of Car Tyres", (translated by P. G. Williams), Kavchuk i Rezina, 26, No. 5, 30-33, 1967.

[3] Wiener, Francis M., "Experimental Study of the Airborne Noise Generated by Passenger Automobile Tires", Bolt, Beranek & Newman, Inc., Cambridge, Massachusetts; reprint Noise Control, 161-164, July/August 1960.

[4] Serendipity, Inc., "A Study of the Magnitude of Transportation Noise Generation and Potential Abatement", Third Quarterly Report, March 15, 1970.

[5] Venema, J. H., Surface Transportation Noise, Ford Motor Company, Dearborn, Michigan, 1970.

[6] Kibbee, Lewis C., The Noise Truck Make -- Report of Tests, American Trucking Association, Inc., Washington, D.C., September 1964.

[7] Abbott, Ernest, J., Why Not Quiet Those Trucks?, Physicists Research Co., presented at the Society of Automotive Engineers National Transportation Meeting, Hotel Statler, New York, New York, October 16-18, 1950, SAE Report No. 520.

[8] Apps, David C., Quieter Automotive Vehicles, General Motors Proving Ground, Noise and Vibration Lab., Warren, Michigan; reprint Noise Control, 1, No. 2, 41-44, 64, March 1955.

[9] Bonvallet, G. L., Levels and Spectra of Traffic, Industrial, and Residential Area Noise, Armour Research Foundation, Illinois Institute of Technology, Chicago, Illinois; reprint The Journal of the Acoustical Society of America, 23, No. 4, 435-439, May 1956.

[10] Brasch, Jerome K., "Vehicular Traffic Noise near High Speed Highways", Sound and Vibration, December 1967.

[11] Chiesa, Arturo, Vehicle Vertical Vibration and Tire Performance, Pirelli Rubber Laboratories, presented at the Society of Automotive Engineers National Automobile Week, Detroit, Michigan, March 12-16, 1962, SAE Report No. 490C.

[12] Davisson, J. A., Design and Application of Commercial Type Tires, Goodyear Tire & Rubber Company, Tire Development Div., Tire Design Research, Akron, Ohio, Society of Automotive Engineers, Inc., January 1969, SP-344.

[13] Donley, Ray, Equipment and Techniques for Noise Measurement, Goodfriend-Ostergaard Associates, Cedar Knolls, New Jersey, Sound and Vibration, January 1967.

[14] Finch, D. M., The Regulatory Aspects of Surface Transportation Noise, University of California, Los Angeles, California; reprint Noise Control, 2, 28-31, 94, July 1956.

[15] Galloway, W. J. and Clark W. E., Prediction of Noise from Motor Vehicles in Freely Flowing Traffic, Bolt, Beranek & Newman, Inc., Los Angeles, California, presented at the 4th International Congress on Acoustics, August 1962.

[16] Goodfriend, Lewis S., Control of Highway Noise, Goodfriend-Ostergaard Associates, Cedar Knolls, New Jersey, Sound and Vibration, July 1957.

[17] Joy, T. J. P., Hartley, D. C., and Turner, D. M., High Speed Tire Performance, Avon India Rubber Company, Ltd.; reprint Society of Automotive Engineers Journal, 64, No. 4, 26-27, March 1956.

[18] Klein, Stanley, "Connecticut May Ban Noisy Vehicles", Machine Design, April 16, 1970.

[19] Lippmann, Seymour A., Tires in Automotive Vibration Problems, United States Rubber Company, Detroit, Michigan; reprint Noise Control, 2, 41-43, May 1956.

[20] Lippmann, S. A. and Ferguson, K. A., Tire Tread Noise Analyzer, United States Rubber Company, Tire Development Department, Detroit, Michigan; reprint Electronics, 23, 84-87, November 1950.

[21] Loye, Donald P., The Legal Aspects of Noise Control, presented at the Second West Coast Noise Symposium, Los Angeles, California, December 2, 1955; reprint Noise Control, 2, 56-60, July 1956.

[22] McDaniel, D. W., Hushing Automotive Noises, General Motors Corporation, Detroit, Michigan, presented at the Society of Automotive Engineers Automotive Engineering Congress, Detroit, Michigan, January 8-12, 1962, SAE Report No. 477A.

[23] Miller, R. F. and Slaby, J. G., Probing Mechanics of Tire Squeal, B. F. Goodrich Company, Research Center; SAE Journal, October 1960.

[24] Mills, C. H. G. and Aspinall, D. T., Some Aspects of Commercial Vehicle Noise, Motor Industry Research Association, Lindley, Warwickshire, England; Applied Acoustics, 1, No. 1, 47-66, January 1968.

[25] Nickson, A. F., Can Community Reaction to Increase Traffic Noise be Forecast, Commonwealth Scientific and Industrial Research Organization, Division of Building Research Australia, Proceedings of the 5th Congress International d'Acoustique, September 1965.

[26] Objective Limits for Motor Vehicle Noise, Bolt Beranek & Newman, Inc., Cambridge, Massachusetts, Job No. 163327, prepared for California Highway Patrol, Sacramento, California, Report No. 824, December 1962.

[27] O'Connor, Bernard and Schuster, James J., Measurement of Vehicle Noise and Control by Legislation, Villanova University, Institute for Transportation Studies, Villanova, Pennsylvania, April 1968.

[28] Parry, J. R. K., Tyre Tread Pattern Noise, Avon Rubber Company, Ltd.; Motor Trader, 68, September 1968.

[29] Richards, Karl M., Vehicle Noise Legislation: A Paradox of Perplexities, Automobile Manufacturers Association, Detroit, Michigan; reprint Noise Control, 2, 28-33 & 77, May 1956.

[30] Robertson, T. A. and Cox, J. H., Truck Tire Noise -- Problems and Solutions, Firestone Tire & Rubber Company, Akron, Ohio, presented at the Society of Automotive Engineers Summer Meeting, Atlantic City, New Jersey, June 8-13, 1958, SAE Report No. 56B.

[31] Salmon, Vincent, Surface Transportation Noise -- A Review, Stanford Research Institute, Menlo Park, California; reprint Noise Control, 2, 21-27 & 94, July 1956.

[32] Simulation of Tyre Tread Pattern Noise, Plastics & Rubber Weekly, October 1968.

[33] Sogoian, A. M. and Paliga, W. V., Tools and Methods for Automotive Vehicle Noise and Vibration Testing, Ford Motor Company, Test Engineering Department, Dearborn, Michigan, presented at the Society of Automotive Engineers Automotive Engineering Congress, Detroit, Michigan, January 9-13, 1967, SAE Report No. 670162.

[34] Swart, Bernie, "Truck Noise Control: Decibels, Dollars, and You", Fleet Owner, 58, No. 1, 57-70, January 1963.

[35] Thiessen, G. J. and Olson, N., Community Noise -- Surface Transportation, National Research Council, Ottawa, Canada; Sound and Vibration, 10-16, April 1968.

[36] Tire Noise Problem - I, Bolt, Beranek & Newman, Inc., Cambridge, Massachusetts, prepared for E. I. du Pont de Nemours Company, Industrial Products Lab., Newport, Delaware, Job No. 5011, Report No. 458, January 31, 1957.

[37] Tire Noise Problem - II, Bolt, Beranek & Newman, Inc., Cambridge, Massachusetts, prepared for E. I. du Pont De Nemours & Company, Industrial Products Lab., Newport, Delaware, Job No. 20024, Report No. 523, October 16, 1957.

[38] Tire Noise Problem - III, Bolt, Beranek & Newman, Inc., Cambridge, Massachusetts, prepared for E. I. du Pont de Nemours & Company, Industrial Products Lab., Newport Delaware, Job No. 20088, Report No. 545, February 12, 1958.

[39] Tire Noise Research -- The Determination of the Damping Characteristics of Tire Cord and Tire Rubber, Bolt, Beranek & Newman, Inc., Cambridge, Massachusetts, prepared for E. I. du Pont de Nemours & Company, Industrial Products Lab., Newport, Delaware, Job No. 20156, Report No. 597, November 18, 1958.

[40] Tompkins, E. S., Tyres for Modern Roads, Dunlop Rubber Co., Ltd., Tyre Technical Division, Birmingham, England; reprint Proc. Institution of the Rubber Industry, 12, No. 2, 69-84, April 1965.

[41] Varterasian, John H., Queiting Noise Mathematically -- Its Application to Snow Tires, General Motors Corp., Research Labs., Warren, Michigan, Society of Automotive Engineers Report No. 690520.

[42] American Society for Testing and Materials, E249-66, Specification for Standard Tire for Pavement Tests in Part 11, Book of ASTM Standards, 1970 (ASTM, Philadelphia, Pennsylvania).

[43] American Society of Testing and Materials, D2240-68, Standard Method of Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer in Part 27, 28, Book of ASTM Standards, 1970 (ASTM, Philadelphia, Pennsylvania).

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