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URBAN RAIL NOISE ABATEMENT PROGRAM

A DESCRIPTION

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Research and Special Programs Administration
Transportation Systems Center
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16. Abstract

This report presents the background, current activities, and future plans for the Urban Rail Noise Abatement Program. This program, sponsored by the Office of Technology Development and Deployment of the Urban Mass Transportation Administration (UMTA) was initiated in 1972 and has been technically managed since its inception by the Transportation Systems Center. The problem of urban rail noise and vibration is described and the rationale for the UMTA funded program is given. The body of the report presents a definition of the program objectives, a discussion of the program organization, and a description of past, current, and future program activities. Major accomplishments of the program to date are listed in the final section.

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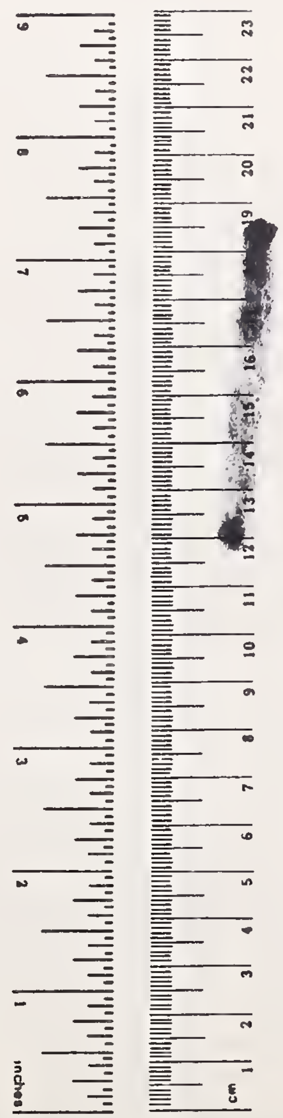
METRIC CONVERSION FACTORS

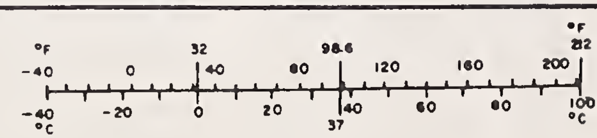
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.6	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



URBAN RAIL NOISE ABATEMENT PROGRAM

OVERVIEW

The Urban Rail Noise Abatement Program being carried out under the technical direction of the Transportation Systems Center (TSC), is composed of research, development, and evaluation efforts directed towards the introduction of improved technology in urban rail systems applications. This program is sponsored by the Urban Mass Transportation Administration, Office of Rail and Construction Technology.

The purpose of the Urban Rail Noise Abatement Program is to make available, in a form useful to existing and planned urban rail systems, a technology for predictable control of acoustic noise and vibration. This technology comprises: design criteria for establishing noise abatement goals, noise assessment procedures, test procedures and test results, noise control theory, design methods and appropriate documentation.

This report presents the scope, organization, past history, current activities, and future plans for the Urban Rail Noise Abatement Program. The first sections describe the problem of urban rail noise and vibration and the rationale for an UMTA funded program. Following sections present a definition of the program objectives, a discussion of the program organization, and a description of past, current, and future program activities. Some of the major accomplishments of the program to date are listed in the final section.

PROBLEM DESCRIPTION AND SCOPE

Noise and vibration are the major sources of environmental impact from urban rail transit operations, impacting patrons waiting in stations, passengers in transit cars and people in the community. A comparison of typical noise levels from rail transit vehicles and other sources impacting the community is shown in Figure 1.

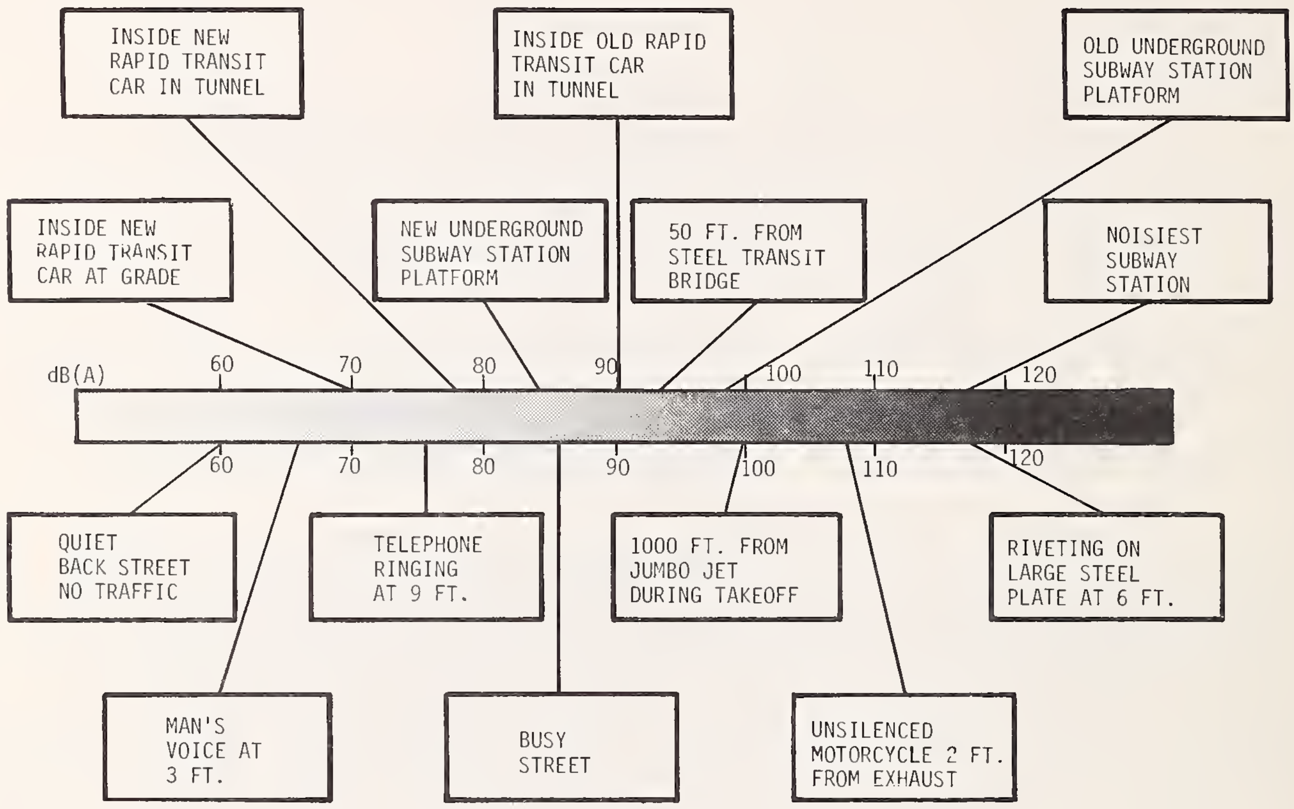


FIGURE 1. TYPICAL NOISE LEVELS IN dB(A)

Recent census statistics and noise assessments indicate that in New York City alone, over 500,000 people live close enough to the elevated track to be exposed to noise between 85 and 100 dBA inside their homes. The frequency of train operations coupled with these noise levels result in noise exposures in some instances which are in excess of the Environmental Protection Agency (EPA) criteria for levels which cause permanent hearing loss over long periods of time.

There are presently about 570 miles of rail transit line (generally double track) with over 800 stations and about 10,000 rapid transit cars in the United States. These operate on ten systems in eight U.S. metropolitan areas. Planned new rapid transit systems and additions to present systems will result in construction of about 325 track miles and the purchase of more than 2000 new cars by the end of this century. Current transit system costs are on the order of 10, 35, and 70 million dollars per mile for at-grade, elevated and tunnel construction, respectively. These figures include route construction, guideway, signal, power and land costs. Rapid transit cars cost on the order of $600,000 each.

For new systems or additions to existing systems, the selection of route construction among tunnel, open cut, at-grade, or elevated (a selection which greatly affects systems capital costs) is usually dictated by requirements for both non-interference with existing facilities and minimizing environmental impact. This latter requirement, which includes noise considerations, has resulted in several decisions to construct subway track as opposed to the less expensive forms of route construction.

An analysis of transportation development in urban areas indicates that the future trend will be towards upgrading existing systems (as opposed to construction of totally new systems). This implies that many systems will be using existing (noisy) car fleets on new or upgraded track, or vice versa. In either case, demonstrated technology for quieting existing facilities will be needed to provide a basis for specifying system changes during refurbishment programs which can result in reduced noise at little or no extra cost.

An example of such technology (discussed later in this paper) is the introduction of the "ring-damped" wheel to the U.S. transit industry. This technique, which still requires some additional evaluations, effectively reduces wheel squeal noise and is easily and cheaply adaptable to existing car fleets. The new Chicago transit cars are being equipped with ring-damped wheels, and the New York City Transit Authority (NYCTA) and the Southeastern Pennsylvania Transportation Authority (SEPTA) are considering the use of these wheels.

NECESSITY FOR AN URBAN RAIL NOISE ABATEMENT PROGRAM

Urban rail transit operators, their patrons, and wayside communities are well aware that rail transit noise problems exist. Transit operators and community groups alike have identified noise as a high priority area for applied research and engineering development, and capital improvement programs have begun to address noise specifically. During the formative years of the UMTA R&D programs, a survey of all existing and emerging U.S. rail rapid transit properties was conducted to determine the research requirements of the rapid rail industry. Noise emerged as the most consistantly cited high priority area for Federally funded R&D. Public reaction to transit system noise in New York City has resulted in the state legislature drafting a noise code requiring the NYCTA to reduce noise levels in stations, in cars, and in the community along the transit system over a seven-year period. This legislation has passed the state assembly and is now in the state senate.

During the past few decades, the financing of urban rail transit service has shifted from the private sector to combined Federal and regional responsibility. During this same period, environmental concern and community participation in transportation planning have increased, linking Federal financial and environmental responsibilities. This is reflected in the Urban Mass Transportation Administration's general mandate to develop mass transportation, and in its specific charge to conserve the urban environment. The Noise Control Act of 1972 made control of undesirable noise a government policy. Section 103 of the National Mass Transportation Act of 1974 which amends Section 5 of the Urban Mass Transportation Act of 1964, entitled "Urban Mass Transit Program," states:

"In approving any project under this section, the Secretary shall assure that possible adverse economic, social and environmental effects relating to the proposed project have been fully considered in developing the project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe and efficient transportation, public services, and CONSERVATION OF ENVIRONMENT AND NATURAL RESOURCES, AND THE COSTS OF ELIMINATING OR MINIMIZING ANY SUCH ADVERSE EFFECTS INLCUDING-AIR, NOISE, AND WATER POLLUTION....."

UMTA/TSC has unique abilities and expertise among Federal agencies in the area of rail transit noise as a result of the Urban Rail Noise Abatement Program. This program, which began in 1972, has provided key technological data for the design of noise control in both existing and newly planned systems [1]*. However, significant technological voids still exist. Reliable data on costs and long-term performance of currently available treatments and noise control designs are needed; the current state-of-the-art is insufficient for quieting elevated structures and for selecting optimum track constructions to reduce ground vibration; and the available noise and vibration data are not being optimally utilized because of insufficient documentation. These needs together with the congressional nandate, increasing public concern, potential state and local regulations, and the anticipated push toward refurbishment of existing systems define the necessity for the Urban Rail Noise Abatement Program.

PROGRAM OBJECTIVES

The Urban Rail Noise Abatement Program addresses the problems of environmental impact, cost, and control of rail

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*Numbers appearing in brackets refer to references listed in the Reference section, p. 18. (References are in approximate chronological order).

transit noise. The purpose of the program is to reduce the noise of existing transit systems and to minimize noise control costs for existing and future systems through the development and deployment of new and improved noise control methods, data, and hardware.

The program is organized into four broad categories, three associated with the collection and the development of technology (assessment of existing conditions, development of new technologies and in-service test and evaluation), and the fourth dealing with communication and deployment of technology. The relationship between the program categories is illustrated in Figure 2, and the goals of each of these program areas are described below.

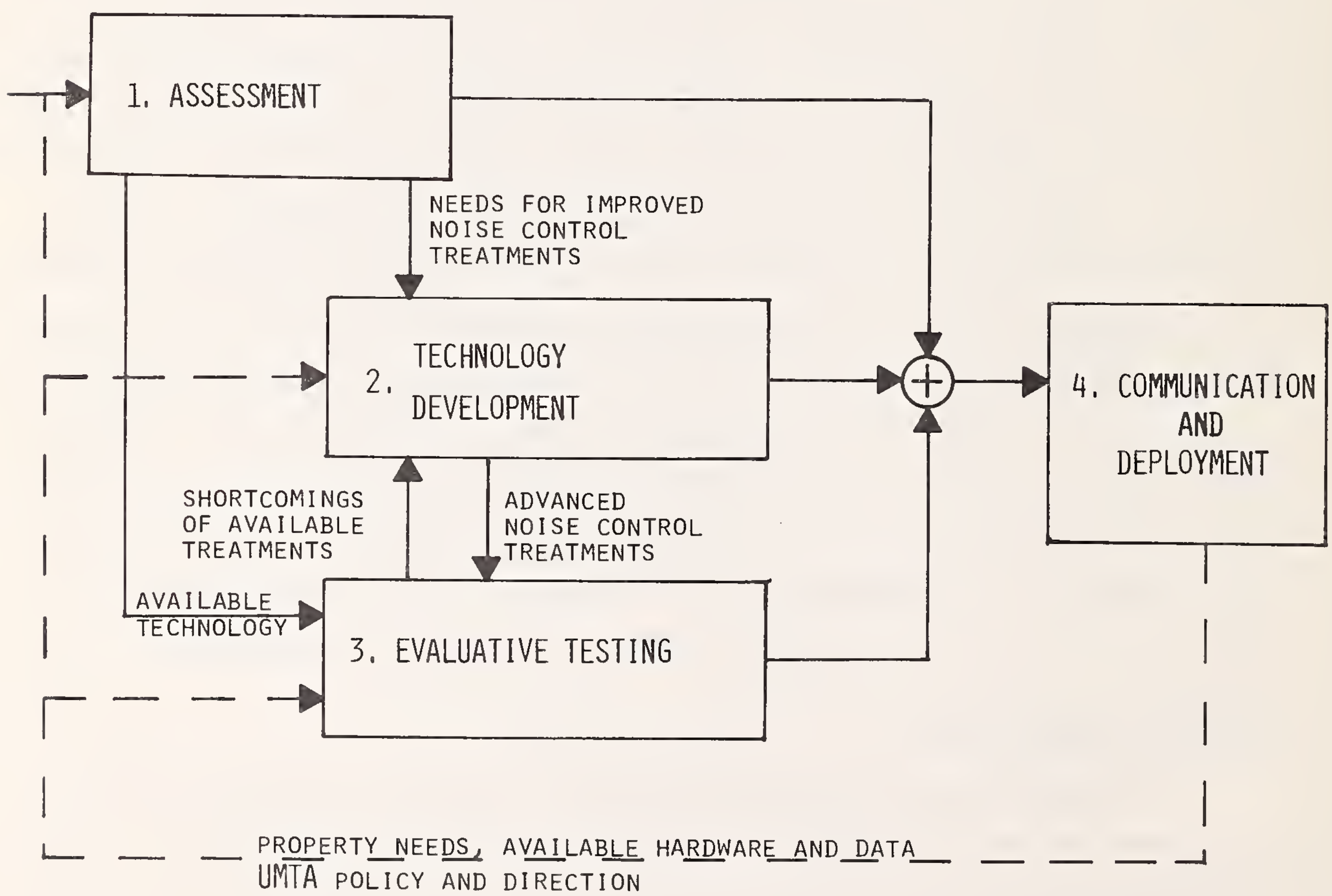

FIGURE 2. RELATIONSHIP AMONG URBAN RAIL NOISE ABATEMENT PROGRAM AREAS

(1) Assessment - Quantify the overall size of the urban rail transit noise problem and its distribution among U.S. systems.

(2) New Technology - Develop or stimulate development of noise control methods and hardware in key technical areas where significant cost savings or significantly improved noise reduction can be achieved.

(3) Evaluative Testing - Develop data, in a form appropriate to those who use it, on what noise levels can be achieved realistically with available technology and at what cost.

(4) Communication and Deployment - Establish and maintain channels of communication necessary (1) to keep program efforts technically current, and (2) to encourage the adoption of program-developed technology where it is applicable.

PROGRAM AREA ACTIVITIES

1. Assessment

The activity under this program area is intended:

- To provide an assessment of noise due to urban rapid transit rail vehicles with respect to riders in transit cars, patrons on station platforms, and nearby community residents.
- To compile and summarize information on existing noise control treatments of demonstrated or potential use to transit systems.
- To estimate the cost of achieving lower levels of noise in and around rapid transit systems.
- To study the sensitivity of noise abatement cost to variations in noise control strategy.

In 1972, TSC developed a prototype methodology for measuring noise on rail transit systems [8] and estimating costs for noise control [4,16]. The techniques were applied to assess noise on eight U.S. rapid transit systems.

The individual assessment reports have been published [3,7, 26-31], and several reports on the cost of noise abatement [35-37] are currently being reviewed for publication.

The individual system assessment reports have been used to select priorities for technical development and evaluative testing. They also form the data base from which a national assessment report has been drafted [34]. The National Assessment provides an overview of the urban rail noise problem and its distribution among U.S. transit systems. The information presented is needed for a) evaluating the impact resulting from proposed regulations and/or application of noise abatement, b) distributing noise control capital assistance, and c) establishing guidelines or equipment specifications with regard to rail noise.

As an example of the type of information gained from the assessment activity, distributions of in-car noise levels in New York City Transit Authority vehicles are compared with those of other systems in Figure 3 [34].

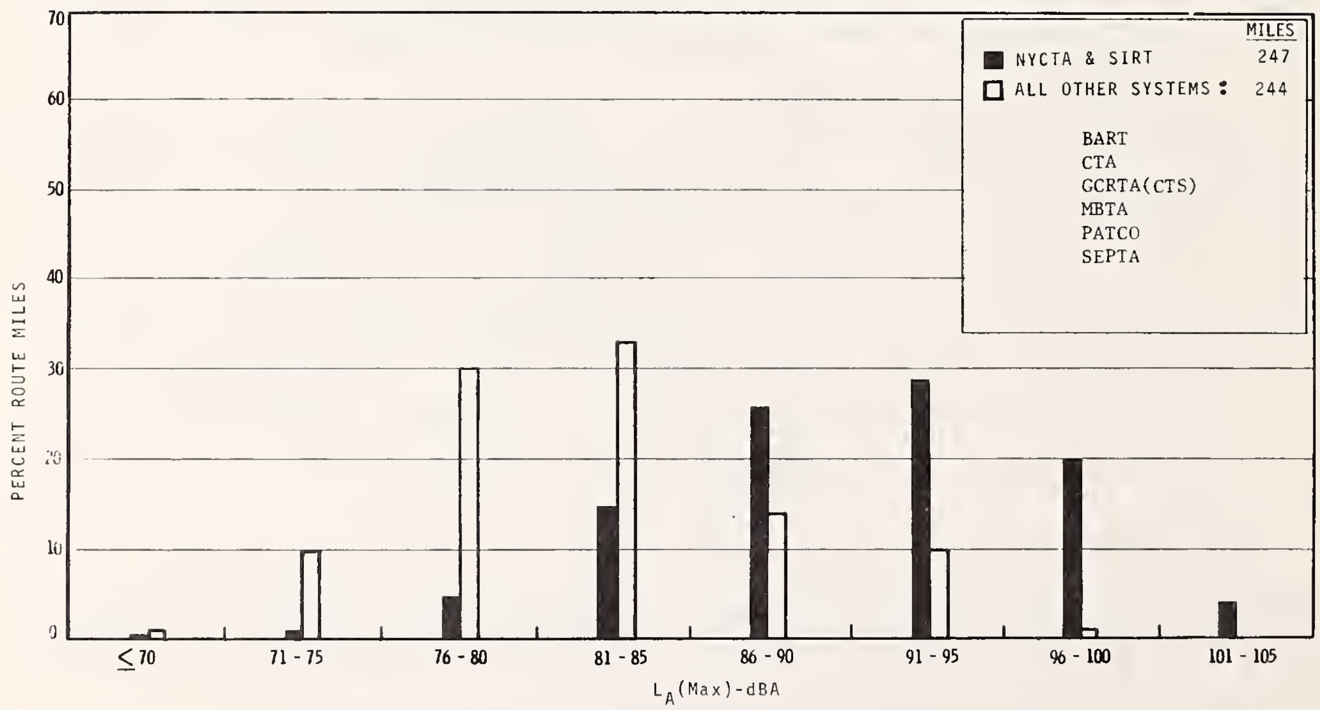

FIGURE 3. DISTRIBUTION OF IN-CAR NOISE LEVELS : COMPARISON OF COMBINED NEW YORK TRANSIT AUTHORITY (NYCTA) AND STATEN ISLAND RAPID TRANSIT OPERATING AUTHORITY (SIRT) WITH SIX OTHER SYSTEMS.

Because of the complexity of the noise control problem on urban rail systems, additional work on the costs and optimum strategies of reducing noise on existing systems are planned. This information will assist UMTA in allocating resources for noise control. In addition, a Compendium of Acoustical Materials for use in rail transit systems will be developed as an aid to transit operators responsible for implementation of noise control.

2. Technology Development

In the long term, a major reduction in the noise and vibration output of urban rail transit can come only through substantive research and development of a new generation of noise control techniques. Such substantial efforts cannot be undertaken by manufacturers of railcars, rail, or track structure products. UMTA's commitment to long-term projects in these areas is consistent with the realization that other modes of transportation, such as jet engine aircraft, have achieved lower noise through persistent federally-funded applied research and development.

Noise radiated from the wheel and rail, noise radiated from elevated structures, noise resulting from vibrations transmitted through the ground (ground-borne noise), and vehicle propulsion system noise constitute the most severe portions of the urban rail noise problem.

a. Wheel-Rail Noise Control - Wheel-rail interaction is the origin of the first three problem areas above. Previous project efforts [2,5,9,11] established the technical basis for developing modifications to wheels, rails, and other important dynamic elements which would reduce wheel-rail noise at the source. Key physical and geometric parameters of the wheel-rail noise were identified and quantified in engineering math models.

The objective of planned work on wheel-rail noise control is to develop techniques for control of noise from conventional wheels and rails and to develop new low-noise designs for trucks, wheels, rails or other dynamically important elements. The approach will be to use the experimental data and engineering math models already developed, together with direct feasibility investigations for a number of generically different techniques, such as changes to the wheel/rail interface material, enclosure of noise radiating surfaces, and increased vibration damping. Initial full-scale testing will probably take place at the Transportation Test Center (TTC), in Pueblo, where one or more of the most effective candidate treatments will be identified. These will then be designated for prototype evaluation in an in-service evaluative test program (see discussion under Evaluative Testing).

b. Elevated Structure Noise Control - Recent noise assessments of all the U.S. urban rail transit systems reveal that 30% of the route miles on these systems are on elevated structures. The noise levels adjacent to these structures range from 2 to 20 dB(A) greater than the levels near track at grade level. Among much of the elevated portion of these systems, the wayside community is within 50 feet of the elevated structures and experiences train pass-by noise levels exceeding 90 dB(A). In New York City alone, there are 65 route miles of steel elevated structure. The cost of reducing the noise levels near the NYCTA structures to 85 dB(A) is estimated to be well over $150 million [36]. Even with this kind of expenditure, current technology is insufficient to achieve 85 dB(A) near all of the existing structures. Clearly more cost-effective ways of reducing elevated structure noise would have substantial economic impact in any program to reduce noise in communities near elevated transit lines.

The objective of the work planned in the area of elevated structure noise control is to develop a Guide for Noise Control on Existing Elevated Strutures. The development of the Guide is planned in several stages. The first stage, completed in Fiscal Year 1976 [6,12,14], resulted in the development of analytical models and techniques capable of estimating effects of various design and noise control parameters on the noise radiated from several types of elevated structures. The second phase is now making use of these analytical models and data from a number of previously performed tests of noise control on elevated structures [14]. These will be combined with additional testing and cost data to develop recommended strategies for noise control of existing elevated structures.

The final phase (see discussion under Evaluative Testing) will obtain, through actual application on a transit system, essential data on both the acoustical and nonacoustical properties (such as costs, operating constraints, and maintainability) of selected elevated structure noise control treatments.

c. Ground-borne Noise from Subways - For subway systems, the primary cause of community complaints is the noise and vibration induced in the community as a result of vibration transmitted through the ground from the subway tunnels. For example, this is the single largest source of noise-related complaints for the NYCTA. Presently available technology for predicting and controlling this major source of environmental impact [6,13,20] is inadequate for planning and achieving cost-effective reduction of ground-borne noise.

The objective of this activity is to develop Guidelines for the Control of Ground-borne Noise from Subways. This is to be accomplished in two stages. The first will involve the evaluation and/or development and validation of techniques for predicting vibration generation in and propagation from subway tunnels. In addition, existing vibration control treatments will be assessed. In the second stage (discussed under evaluative testing), selected treatments will be field tested to obtain both performance and cost data.

d. Propulsion System Noise Control - Recent tests in Philadelphia (see SEPTA Test Program described below) and in New York City have indicated that on older model transit cars propulsion system noise can exceed wheel/rail generated noise. The objective of this activity is to develop and demonstrate the technology for retrofitting existing vehicles in order to abate propulsion system noise. This will be accomplished through a three-phased effort: first, the specific noise generating sources in propulsion systems will be identified; second, various techniques for controlling these sources will be evaluated; and finally, the best techniques will be demonstrated in an in-service test.

3. Evaluative Testing

Reliable cost and acoustic performance data on available noise control treatments as well as alternate design and/or construction techniques are required for the planning and engineering of quieter urban rail transit systems. Also required are data on the reliability, compatibility, and safety of the noise control treatments. For greatest benefit the data should be widely applicable to existing and future U.S. rail transit systems. Projects to provide these data lie in the category of evaluative testing.

For urban rail transit noise control treatments which are available now, the need for cost and performance data is immediate. Two projects address this need directly:

a. SEPTA Test Program - Tests are presently nearing completion in Philadelphia in cooperation with the Southeastern Pennsylvania Transportation Authority (SEPTA), to evaluate costs and performance of "off-the-shelf" treatments to reduce wheel-rail noise [17-19, 22,23]. Conclusions from this study include:

1) Propulsion noise is a major source of noise on the SEPTA system.

2) Resilient wheels (See Figure 4) reduce or eliminate wheel squeal and significantly reduce ground vibration on SEPTA. However, as currently configured, they do not appear compatible with transit cars using tread brakes.

3) Ring-damped wheels (see Figure 4) significantly reduce wheel squeal and appear to be a suitable method for retrofitting existing vehicles. Further study is required to fully evaluate the stress concentrations induced by the ring grooves and to assure that the rings do not become frozen into the grooves.

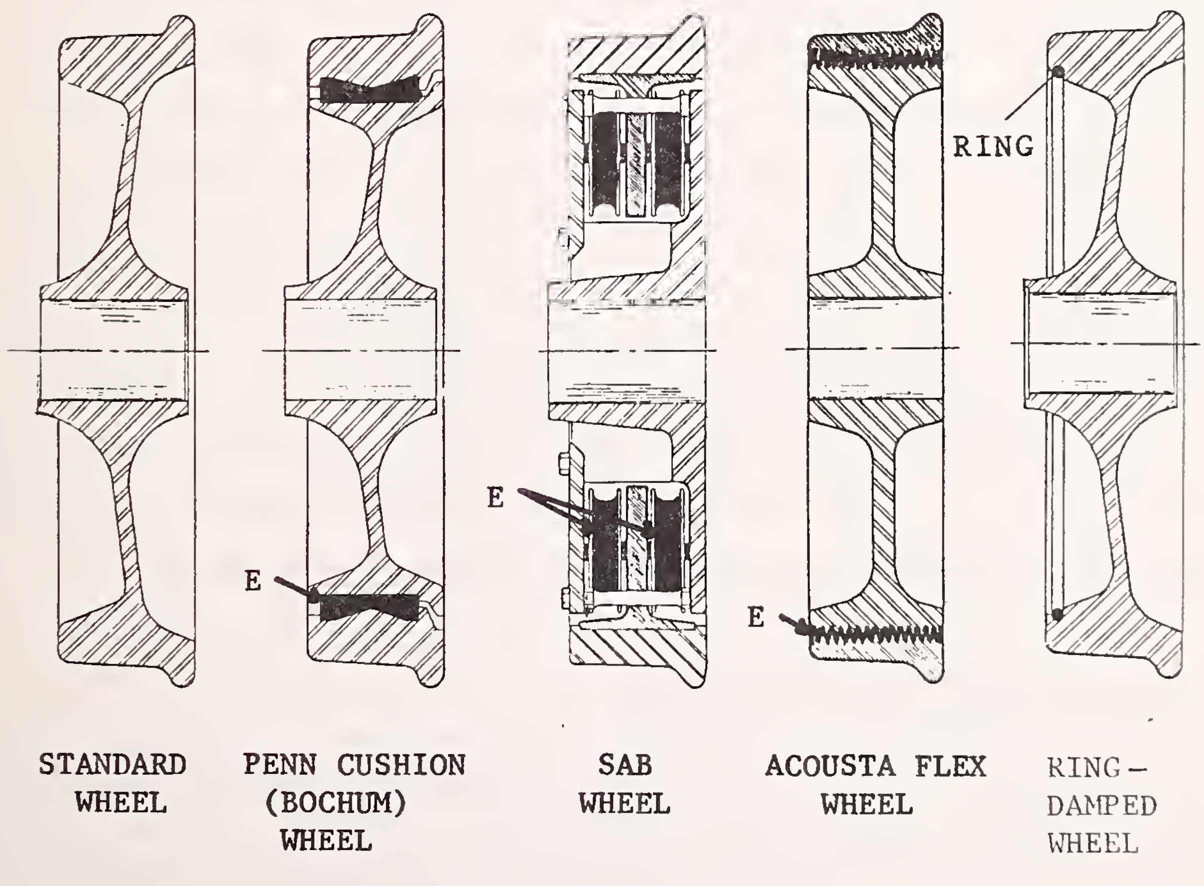

FIGURE 4. STANDARD, RESILIENT, AND RING-DAMPED WHEELS TESTED AT SEPTA. (E INDICATES THE LOCATION OF ELASTOMERIC MATERIAL ON THE RESILIENT WHEELS).

b. Resilient Fastener Evaluation - Cost and performance data are needed as a basis of selection among the various commercially available rail fastening systems. Such an evaluation project is being planned in a cooperative effort with the Chicago system (CTA). The funding for track construction required to test various types of resilient rail support systems will be provided through an UMTA Section 6 grant. The evaluation of the noise and vibration performance of these track structures will be coordinated with the UMTA sponsored track research efforts.

For urban rail transit noise control treatments being developed under this program, evaluative field testing is a key step between development and deployment. The evaluative testing for the four major developmental activities in the program include: wheel-rail noise control; elevated structure noise control; ground-borne noise control; and propulsion system noise control. For each area, a comprehensive, user-oriented testing project will be set up. Its purpose will be to evaluate the effectiveness of the new technology under realistic operating conditions, to communicate the results of the testing to potential users, and to encourage the deployment of improved methods for urban rail system noise control where they are applicable.

4. Communication and Deployment

The ultimate success of this program in reducing noise and noise control costs for urban rail systems will be largely dependent on the ability to establish and maintain channels of communication with the transit industry. Communication of the results of all program efforts to users, such as transit system personnel, planners, and acoustic consultants, has been affected through direct mailing of DOT reports, telephone consultation, American Public Transit Association (APTA) Project advisory board meetings, publication in noise control conference proceedings [3,4,9,10,14, 15,16,18,20,21], and personal visits by TSC and users to each other's organizations.

Program technical results as communicated through these channels during past years have been the basis for major noise control capital planning by transit systems (e.g., the 6-year, 100 million dollar New York City Transit Authority Noise Abatement Program [30,32,33,36]) as well as for direct noise control design and engineering (e.g., introduction of snap-ring damped wheels to U.S. transit suppliers, leading to the improvement and utilization of these wheels by Boeing on the cars now being delivered to the Chicago Transit Authority). Other modes of communication currently being pursued include preparation of a slide-tape presentation depicting the results of the evaluative testing program in Philadelphia, representation on the Noise Committee of the Office of Research and Experiments of the International Union of Railways, publication of a Handbook of Urban Rail Noise and Vibration Control, and sponsoring of workshops and seminars.

a. <u>Handbook of Urban Rail Noise and Vibration Control</u> - The considerable volume of existing data generated both outside and within the UMTA Urban Rail Noise Abatement Program is not presently summarized in a single document. Some of this material has been summarized and simplified through the efforts of TSC personnel [24,25]. The profusion of recent literature (for example, see attached for reference list of currently available and soon-to-be-published program-sponsored reports) makes it difficult for transit properties to select and use the best available technology for noise and vibration prediction and control. The intent of the Handbook is to provide a self-contained document which is useable by both transit property personnel and their consultants. Two editions of the Handbook are planned. The first, in early Fiscal Year 1980, will summarize the most useful rail transit noise control data and procedures as of Fiscal Year 1979. The second edition will expand and update the first to include the final results of the program. In each case, distribution of the Handbook will be integrated with a seminar describing its content and use.

b. Workshops and Seminars - Each year, at least one workshop will be held for the dissemination of UMTA/TSC sponsored or developed technology, and for the exchange and discussion of data and ideas related to rail transit noise. Presently planned presentations include seminars for disseminating results of individual contracted activities, and large-scale workshops for introducing and explaining the material in the Handbook.

The participation of APTA in an advisory capacity on major program projects will be continued in order to assure the usefulness and rapid dissemination and deployment of program-developed technology.

MAJOR PROGRAM ACHIEVEMENTS

The major accomplishments of the Urban Rail Noise Abatement Program have included:

- Providing NYCTA with noise data and minimum cost strategies for the formulation and implementation of their $100 million noise abatement program.
- Introduction and in-service evaluation of ring-damped wheels on U.S. transit systems.
- In-service testing of resilient wheels, which resulted in documentation of the operational and structural problems associated with the use of these wheels on U.S. systems.

- Developing and communicating technology which has been used to write environmental impact assessments for new lines and to design noise control for these systems, e.g., the MBTA Red Line Extension, the MBTA North Shore Transit Improvement Project, and the Miami (Dade County) system.
- Developing fundamental understanding of wheel/rail noise generation.
- Developing fundamental understanding of elevated structure noise generation.
- Quantifying the noise environment of eight U.S. urban rail transit systems.

March, 1979

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