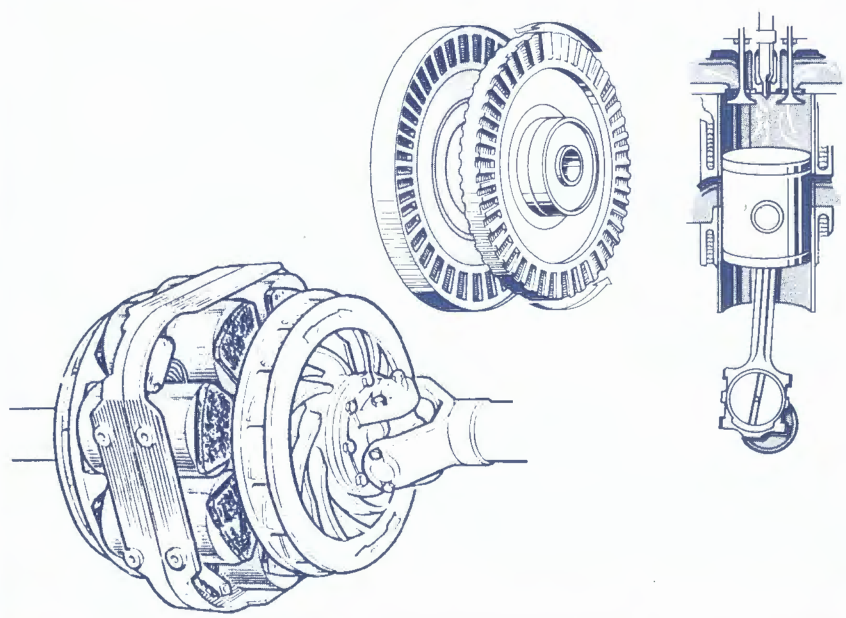
UMTA-MI-06-0025-83-1

U.S. Department of Transportation
Urban Mass Transportation Administration

Evaluation of Retarders for Transit Buses

Prepared by:
Michigan Department of Transportation

Interim Report
June 1983



UMTA Technical Assistance Program

U.S. Department
of Transportation

**Urban Mass
Transportation
Administration**

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Lansing, MI 48909

Interim Report

Office of Technical Assistance
Office of Bus and Paratransit Systems
Washington DC 20590

PREFACE

This interim report presents the progress to date on the "Evaluation of Vehicle Retarders" program and includes background information, a summary of retarder types and theory of operation, a description of the testing methodology, and summaries of installation requirements and costs, preliminary results, verification tests provided, and maintenance experience for three different types of retarders installed in advanced design buses.

Although brake lining life extension factors and cost savings are projected for each of the retarder types tested, it should be noted that these are preliminary data, since the testing process in revenue service is not completed. Thus, these factors and savings should not be used or quoted as final data.

ACKNOWLEDGMENT

This work is sponsored by the Urban Mass Transportation Administration (UMTA) funding 80 percent of the total cost of the program with 20 percent participation by the Michigan Department of Transportation (MDOT). Detroit Department of Transportation (DDOT), Grand Rapids Transit Authority (GRATA), and Capital Area Transportation Authority (CATA) contributed to the program by conducting the tests using their coaches and facilities. The principal investigator is Kamel Boctor, Transit System Engineering Division, Bureau of Urban and Public Transportation (UPTRAN), MDOT; Director of MDOT is Mr. James P. Pitz; Deputy Director for UPTRAN is Ms. Carol C. Norris; Acting Administrator of the Division is Mr. John Kazenko.

Specific acknowledgment is provided to Messrs. Thomas Norman, Director of the Office of Bus and Paratransit, and Steve Asatoorian, Program Manager, UMTA, for their support. This program would not have been possible without the cooperation and assistance of Messrs:

Thomas Okasinski and Kalyan Ramakrishnan, SEMTA
Richard Golembiewski and William Swanger, DDOT
David Needham and Charles Creech, GRATA
Gordon Szlachetka and James Cox, CATA

This report is authored by Kamel Boctor. Many people contributed to the preparation of this report. Analysis of the data collected on the brake lining system was provided by Dr. Wen Kuo of the Statistical Analysis Unit, Testing and Research Division, MDOT. Assistance with the Life Cycle Cost Analysis was provided by Mr. Tom Comparato and his staff, Transportation Systems Center, Cambridge, Massachusetts.

A. EXECUTIVE SUMMARY AND CONCLUSION

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A.1 EXECUTIVE SUMMARY

Advanced Design Buses (ADBs) are obtaining lower brake lining life than earlier New Look buses, due primarily to their increased weight, higher operating speeds, and use of "softer" brake lining materials (to meet Federal Motor Vehicle Safety Standards). Transit agencies are reacting to this problem by examining and evaluating various alternatives to improve lining life, namely harder lining materials, bonded (rather than bolted) linings, and vehicle retarders, the subject of this report.

A vehicle retarder, when actuated, provides an auxiliary, yet completely independent, braking system to the existing service brake system and helps to absorb kinetic energy from the moving vehicle when not under power. By sharing the braking function with the service brake system, the retarder offers cooler service brakes and, thus, increased life.

MDOT has received a grant from UMTA's Office of Technical Assistance to fund a program to evaluate the use of retarders on ADBs in revenue service. There are two specific objectives of this program: one to determine the adaptability of various vehicle retarders to ADBs and the other to evaluate the impact of retarders on the performance, durability, and maintenance cost of the existing service brake system.

Three types of retarders were selected for testing: engine brake (Jacobs); hydraulic retarder (Detroit Diesel Allison); and electric retarder (TELMA).

Testing is being performed on coaches of the transit systems of Detroit, Grand Rapids, and Lansing, Michigan. Retarder-equipped coaches are driven on the same routes as equivalent coaches not so equipped; each of the test and control buses is brought in for four inspections, spaced through the life of their brake linings. Measurements are made at four points on each brake lining on each bus, with the data recorded for use in cost analysis. Maintenance activity is also recorded for each of the test and control buses. Retrofit installation cost for each retarder type was recorded directly from invoices.

The preliminary data (with many tests still in process) show these results:

> The brake life extension factor (computed by dividing brake wear without retarder by brake wear with retarder) is 1.3-1.65 for Jacobs and 4-6 for both TELMA and DDA, depending on the type of service.
>
> Assuming a 12-year bus life at an average mileage of 50,000/year and using current costs of brake repairs plus a 10 percent annual inflation factor, the Jacobs retrofit would provide a net savings over 12 years of up to $18,792. The TELMA or DDA retrofit would provide a net savings over 12 years of up to $39,550.

Additionally, over the life of the bus, 596 labor hours would be saved by retarder use, and downtime of up to 108 days would be avoided.

Cost allowance must also be made in favor of the retarder, on grounds of improved availability, resulting from reduced downtime. In a large fleet, the reduction in downtime could reduce the number of vehicles required.

Controlled fuel economy testing showed that retarders do not produce a significant change in fuel consumption.

Nearly all the initial problems in adapting ADBs for retarder usage have been satisfactorily solved through manufacturer and supplier cooperation.

A.2. CONCLUSION

Experience in the retarder evaluation projects so far has shown that retarders are adaptable to ADBs' installation and usage and that retarders do provide substantial brake maintenance savings.

Additionally, the project has provided comparative performance and cost-effectiveness data on the retarder types tested, and has given both transit systems and retarder manufacturers useful experience data which will afford savings of time and cost in future installations.

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1.0. INTRODUCTION

1.1 BACKGROUND

Urban transit operators who utilize ADBs have noted a dramatic decline in the brake lining life of these coaches compared with early "New Look" coaches. The frequent brake work required for ADBs has increased their maintenance costs and has reduced the availability of equipment. Major factors attributing to this decline in brake life appear to be:

Increased gross vehicle weight;

Increased operating speed; and

Softer brake linings to meet Federal Motor Vehicle Safety Standards (FMVSS-121).

Several transit systems have achieved a marginal improvement in brake life by substituting a harder brake lining for the original brake lining. Harder linings accelerate drum wear and will not meet FMVSS-121. In another approach to extend the brake lining life, Southeastern Michigan Transportation Authority (SEMTA) and the Detroit Department of Transportation (DDOT) have replaced the standard linings, which are bolted to the brake shoes, with bonded linings. Bonded brake linings are attached to the brake shoes with a special bonding adhesive. The overall lining dimensions of both types are the same. The bonded brake, however, has a longer life than the bolted brake because of the greater wear depth, due to the deletion of the bolt heads. Figure 1.1 shows RTS II - bolted vs bonded brake system.

Even with the marginal improvements, brake performance was still considered substandard. Transit systems were still motivated to achieve better performance.

1.2 VEHICLE RETARDER

Evidence indicates that the use of retarders in transit coaches prolongs the brake life and reduces maintenance costs.

A retarder is defined as an auxiliary braking system (separate from the foundation brakes) which, when actuated, absorbs kinetic energy from the moving vehicle when not under power. The more the retarder is used, the less the foundation brakes are in operation.

A vehicle retarder is a completely independent braking system and may become the primary braking source. The foundation brakes are used to complete the stop and hold the vehicle on a grade. While the two braking systems blend their operation, the retarder may absorb up to 80 percent of the braking energy. This keeps the foundation brakes cool and greatly increases their life. It is estimated that when the retarder is used properly, brake life can be increased by a factor of up to six times the normal brake life. The retarder can also increase tire life, as tires can be damaged by hot brakes. Vehicle downtime due to brake maintenance is also greatly reduced.

1.3 EVALUATION PROGRAM

MDOT has received a grant from UMTA's Office of Technical Assistance to fund the "Evaluation of Vehicle Retarders" program.

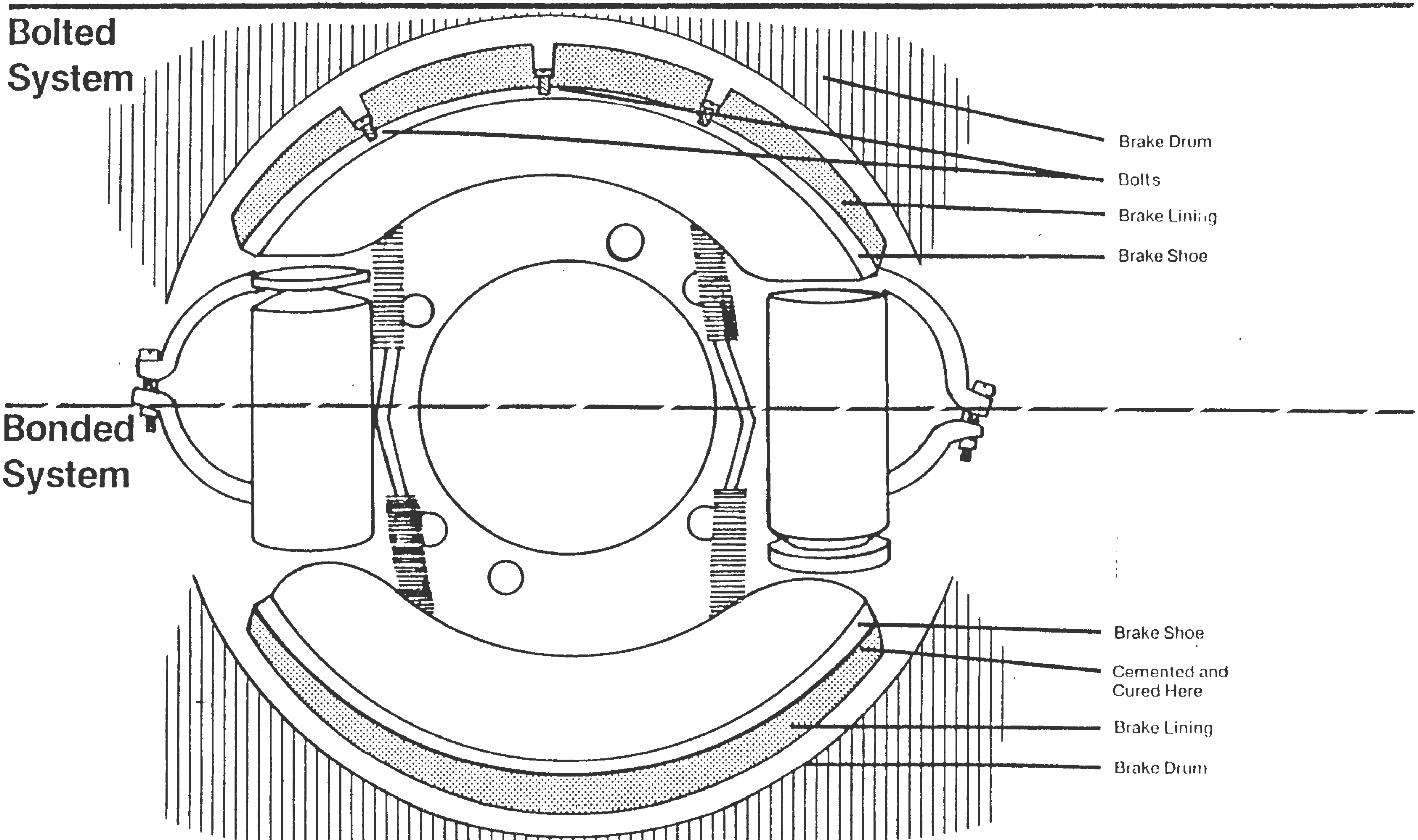
Objectives of the program are to:

- Determine the adaptability of vehicle retarders in ADBs.
- Evaluate the impacts of retarders on the performance, durability, and maintenance cost of the vehicle service brake in intracity service.

The data collected from this testing program, with the addition of a benefit cost analysis, conclusions, and recommendations, will provide as benefits of the program:

- An opportunity for transit operators to form a greater consensus on the most efficient and economical programs to reduce brake system maintenance costs.
- An opportunity for transit operators to assess the cost and effort implications of retrofitting different types of retarders in transit coaches.
- An opportunity for bus manufacturers to assess the marketability and acceptability of brake retarders for transit coaches.
- Actual operational experience on the use of different types of retarders in the U.S. market. This revenue service data will assist the retarder manufacturers to improve their products prior to the introduction of brake retarders in widespread service.

RTS II-Bolted vs Bonded Brake Systems



RTS II - BOLTED vs BONDED BRAKE SYSTEM

FIG. 1.1

2.0 RETARDER TYPES AND THEORY OF OPERATION

2.0 RETARDER TYPES AND THEORY OF OPERATION

Retarders are not new in the market and have been widely used in Europe for years (Figure 2.1). Several countries have passed regulations requiring retarders on all buses and coaches above certain weights.

2.1 TYPES

There are several different types of retarders. Each of these has its advantages and limitations when used for a particular application. Figures 2.2 through 2.10 show a variety of retarders now available on the market. These retarders can be classified into four basic types: exhaust brake, engine brake, hydraulic retarder, and electric retarder.

2.2 THEORY OF OPERATION

The theory of operation of each of the four basic types and the advantages and disadvantages for each when used in transit bus application are summarized as follows:

2.2.1 THE EXHAUST BRAKE

The exhaust brake is a valve fitted into the exhaust pipe between the manifold and the muffler. When the valve is actuated, it restricts the exhaust and causes a pressure build-up in the exhaust manifold. Back pressure build-up retards the engine speed.

No modification to the engine is required except for a device to cut the fuel injection.

Advantages:

a. Unit simple in construction, light and inexpensive.

Disadvantages:

a. Use limited to four-cycle engines.
b. Low braking power compared to other types of retarders.
c. "On" and "Off" operation. The driver must continually activate and deactivate the system to adjust for required braking power level.

2.2.2 THE ENGINE BRAKE

The engine brake converts the diesel engine into a power absorbing compressor. Retardation is activated by a master-slave piston arrangement that opens the exhaust valves at or near top-dead-center of the compression stroke, releasing the compressed air and its potential energy throughout the exhaust system. The energy required to return the piston to its bottom position is now derived from the momentum of the vehicle. The release of compressed air and the use of vehicle momentum to return the piston retard the "free wheeling" of the drive wheels and provide the braking action.

Advantages:

a. Light weight.
b. Relatively inexpensive.
c. Easily adapted to most diesel engines.

Disadvantages:

a. Brake cut-off below approximately 750 rpm makes it less effective in urban bus application.
b. Valve timing alteration produces noise in operation which could be objectionable.
c. Braking effort is limited to 80 percent of the engine power.

2.2.3 THE HYDRAULIC RETARDER

Hydraulic retarders make use of oil which is pumped through restricted passages to pressurize it and to provide a retarding effort on a vaned rotor connected to the drive system. By actuating a control valve, the driver introduces fluid into the cavity enclosing the rotor. The oil in the cavity, under pressure and working against the rotor vanes, slows the rotor and provides braking power. As the braking power forces develop in the retarder, the oil absorbs the heat generated. It is then circulated to the heat exchanger and the heat is dissipated through the cooling system.

Advantages:

a. High braking power.
b. Continuous modulating type brake.
c. Retarder is usually either a separate unit, an integral part of the engine or an integral part of the transmission. If the retarder is a separate unit, it can be adapted to any system if space is available.
d. The retarder's breaking effort can be adjusted, increased, or reduced. The braking effort can be increased up to a certain limit without changing the physical size of the retarder.
e. The retarder is independent of the electrical system and will not affect the electrical system or be affected by it.
f. Braking power will stay constant after continuous operation if the cooling system is capable of dissipating the required amount of heat.
g. Quiet in operation.

Disadvantages:

a. Breaking power is dependent on the functioning of the cooling system and is limited to the capability of the cooling system to dissipate the required amount of heat.
b. Slow reaction. Output retarders usually have better response time compared with input retarders.
c. Increases vehicle weight.

2.2.4 THE ELECTRIC RETARDER

The electric retarder is a drive line device installed between the transmission and the axle. Two discs driven directly by the vehicle transmission revolve in the magnetic field created by electromagnets which are held stationary and energized by the vehicle electrical system. Rotation of the rotor in the magnetic field generates eddy currents in the rotors which produce a counterforce to the direction of the rotary motion. Braking effort is dependent upon the amount of electrical power applied to the field coils and upon the rpm of the rotor.

Advantages:

a. High braking power.
b. Modulating type brake.
c. Quiet in operation.
d. May be adapted to any system if space is available.
e. Braking power is independent of engine and transmission. Engine and transmission can fail or transmission can be in neutral and retarder can still bring the vehicle down several mph.
f. Self air cooled. No heat is transmitted to the engine and transmission.

Disadvantages:

a. Braking power capability is reduced to half after continuous operations of more than 15 minutes.
b. Increases the vehicle weight.
c. Requires some maintenance.
d. May cause battery drainage in the event of retarder control malfunction.

2.3 RETARDERS SELECTED FOR TESTING

Three types of retarders, listed below, have been selected for testing:

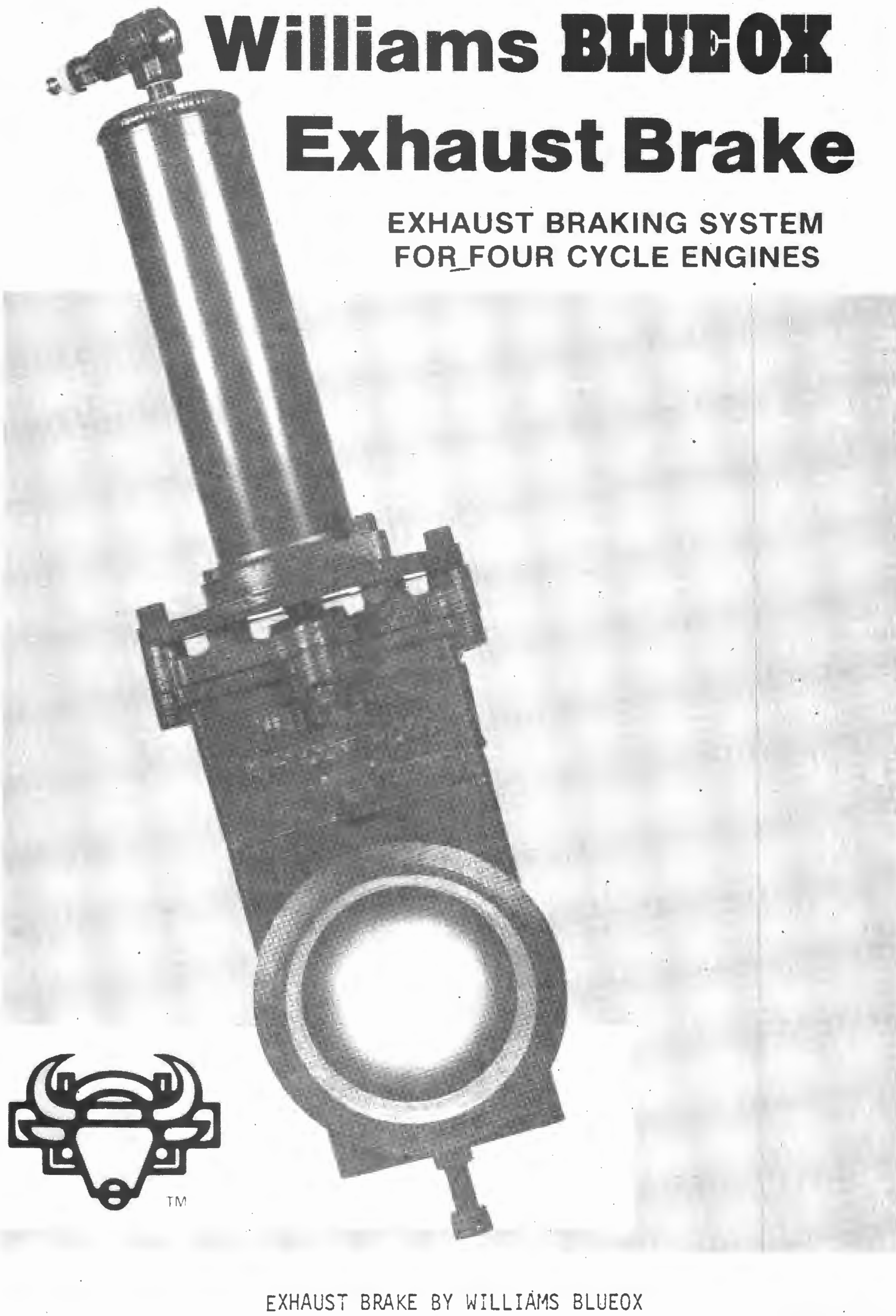
Retarder Type	Manufacturer
Engine Brake	Jacobs
Hydraulic Retarder	Detroit Diesel Allison (DDA)
Electric Retarder	TELMA

The exhaust brake system is limited to four-cycle engines and, therefore, cannot be considered for use in transit operation since most transit coaches are powered with two-cycle engines.

2.4 PERFORMANCE CURVES FOR THE RETARDERS SELECTED

Figure 2.11 through 2.13 show performance curves for the three types of retarders selected as provided by the manufacturers.

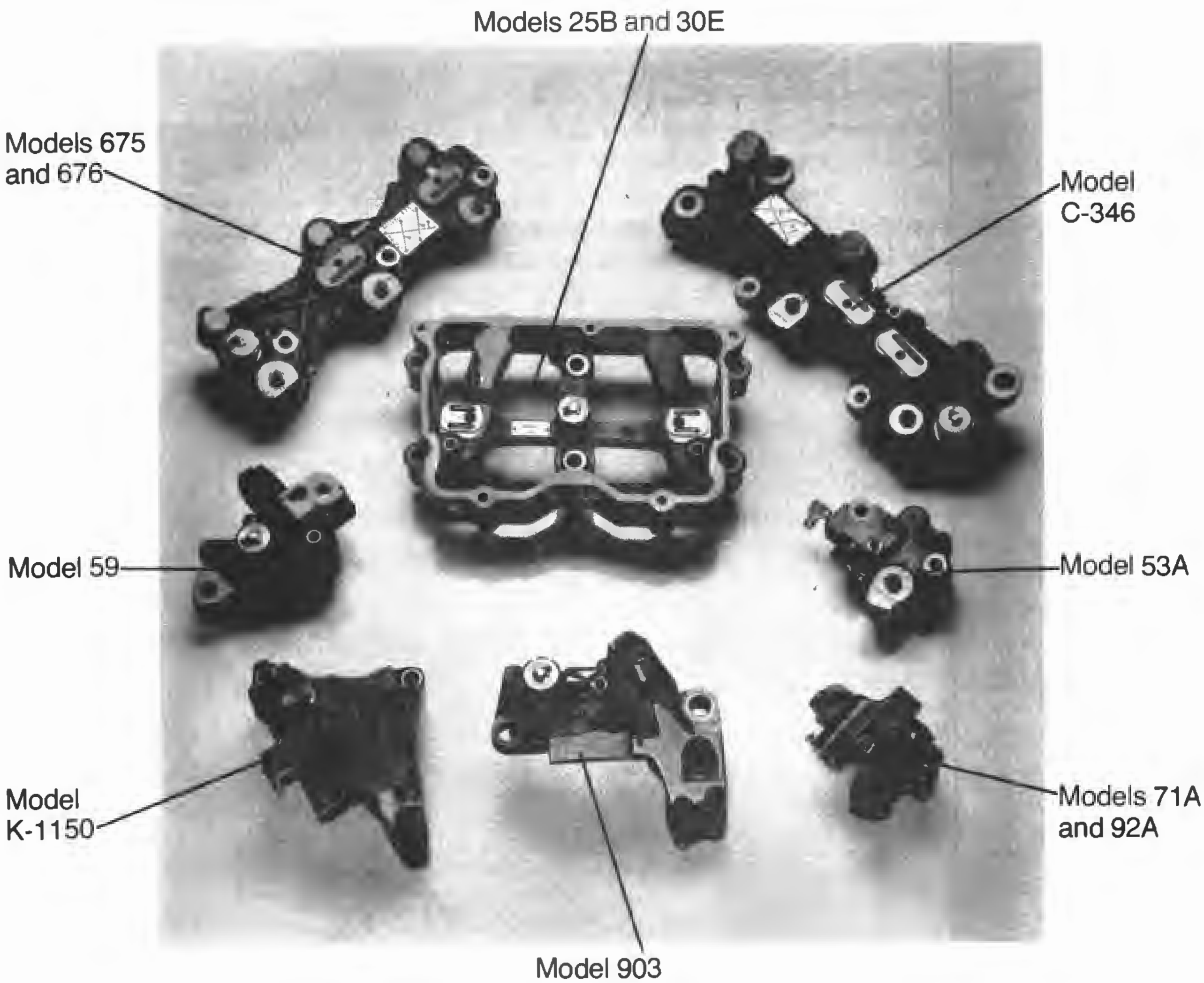
BUSES BUILT THROUGHOUT THE WORLD EQUIPPED WITH RETARDERS
AS STANDARD EQUIPMENT
FIG. 2.1



EXHAUST BRAKE BY WILLIAMS BLUEOX

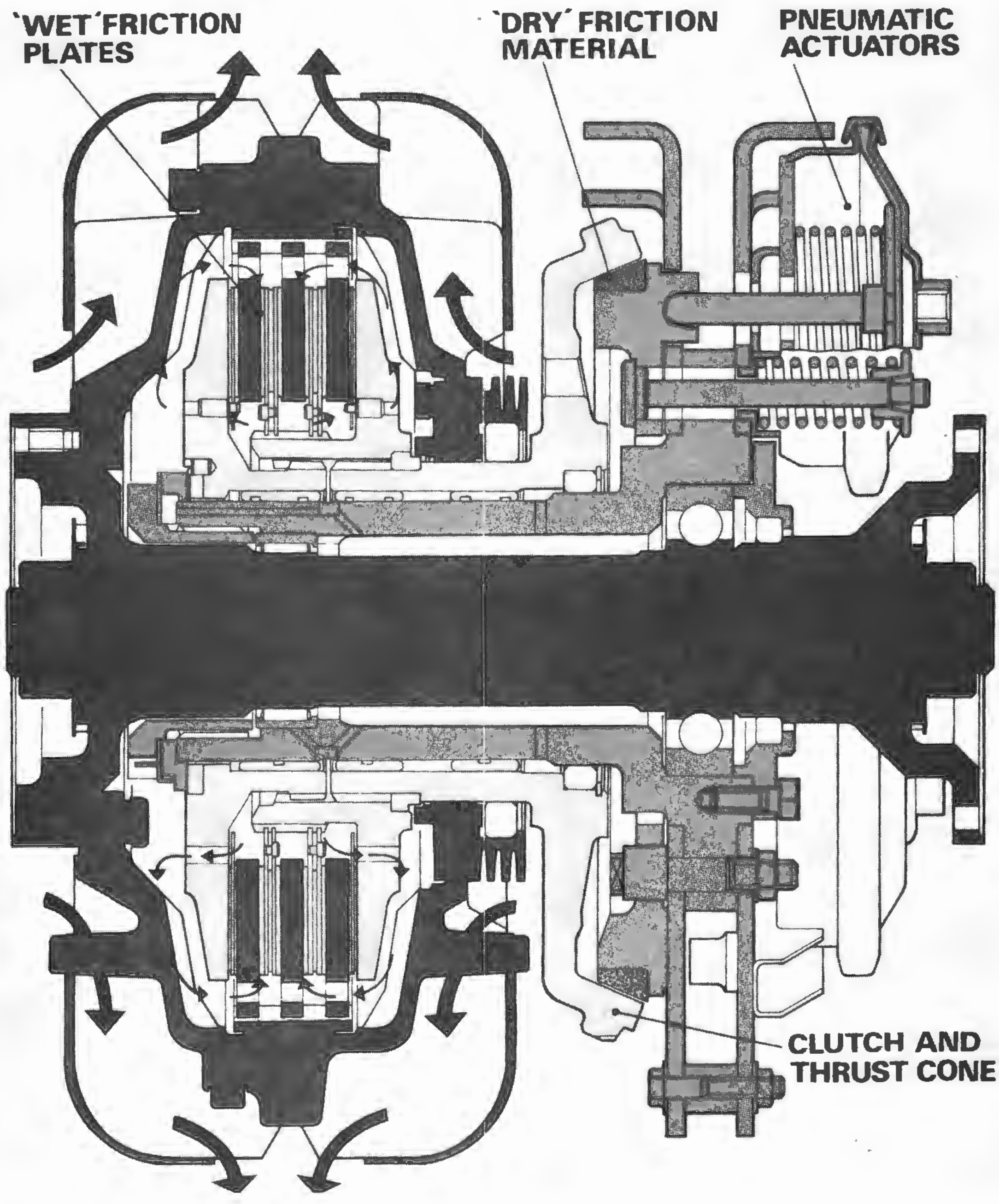
FIG. 2.2

Jacobs® ENGINE BRAKES



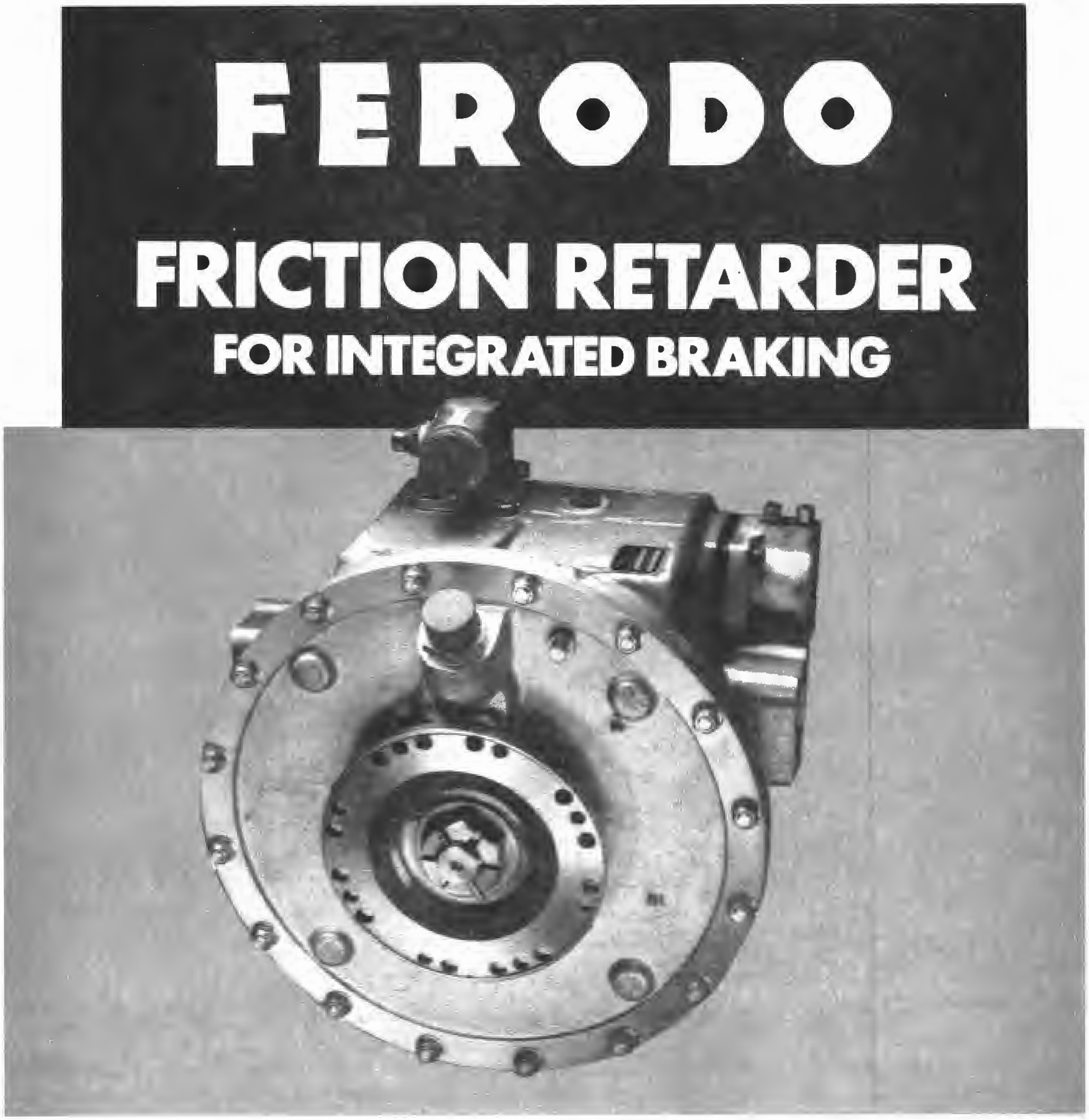
ENGINE BRAKES BY JACOBS

FIG. 2.3



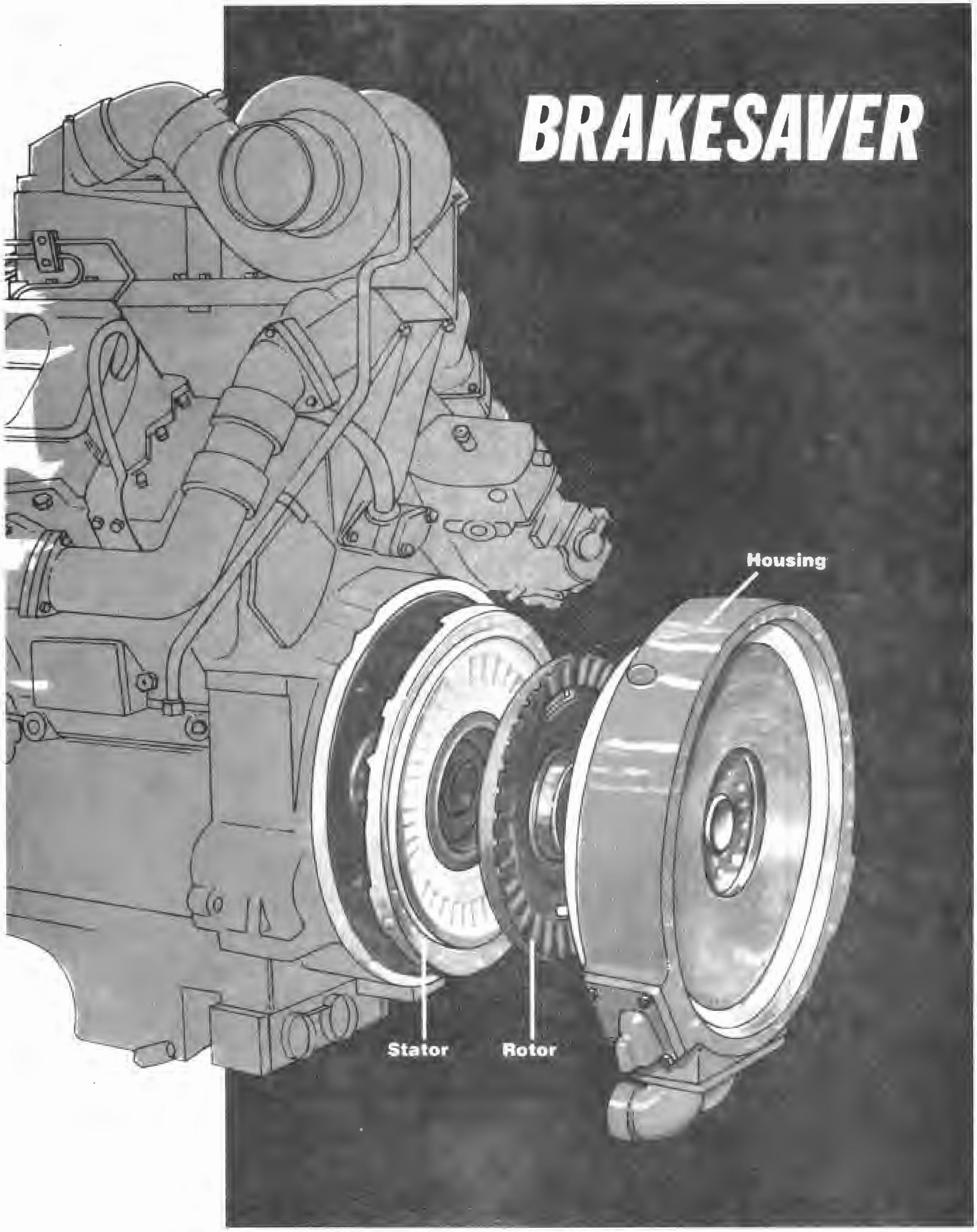
HYDRAULIC RETARDER BY A&P

FIG. 2.4

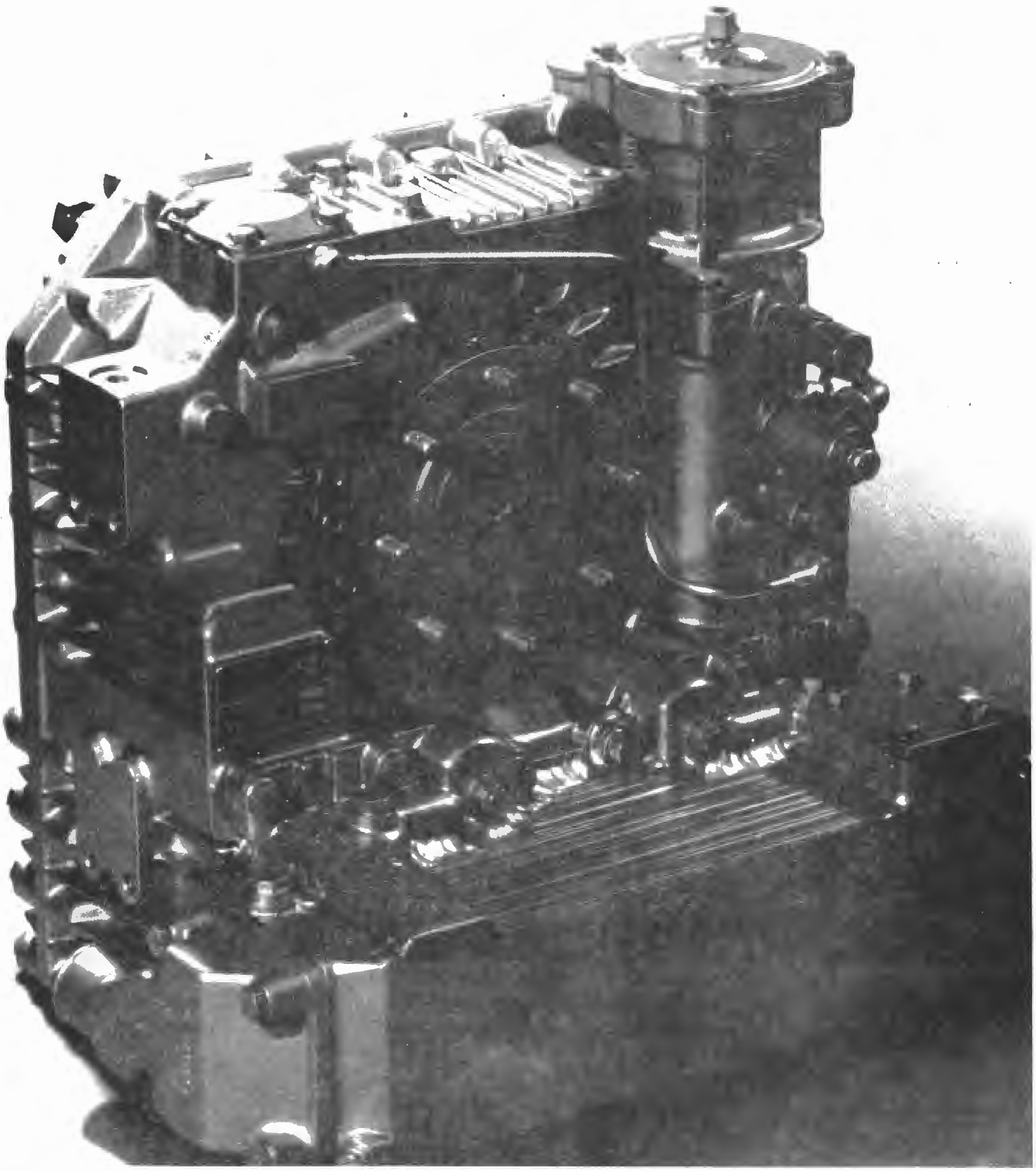


HYDRAULIC RETARDER BY FERODO

FIG. 2.5

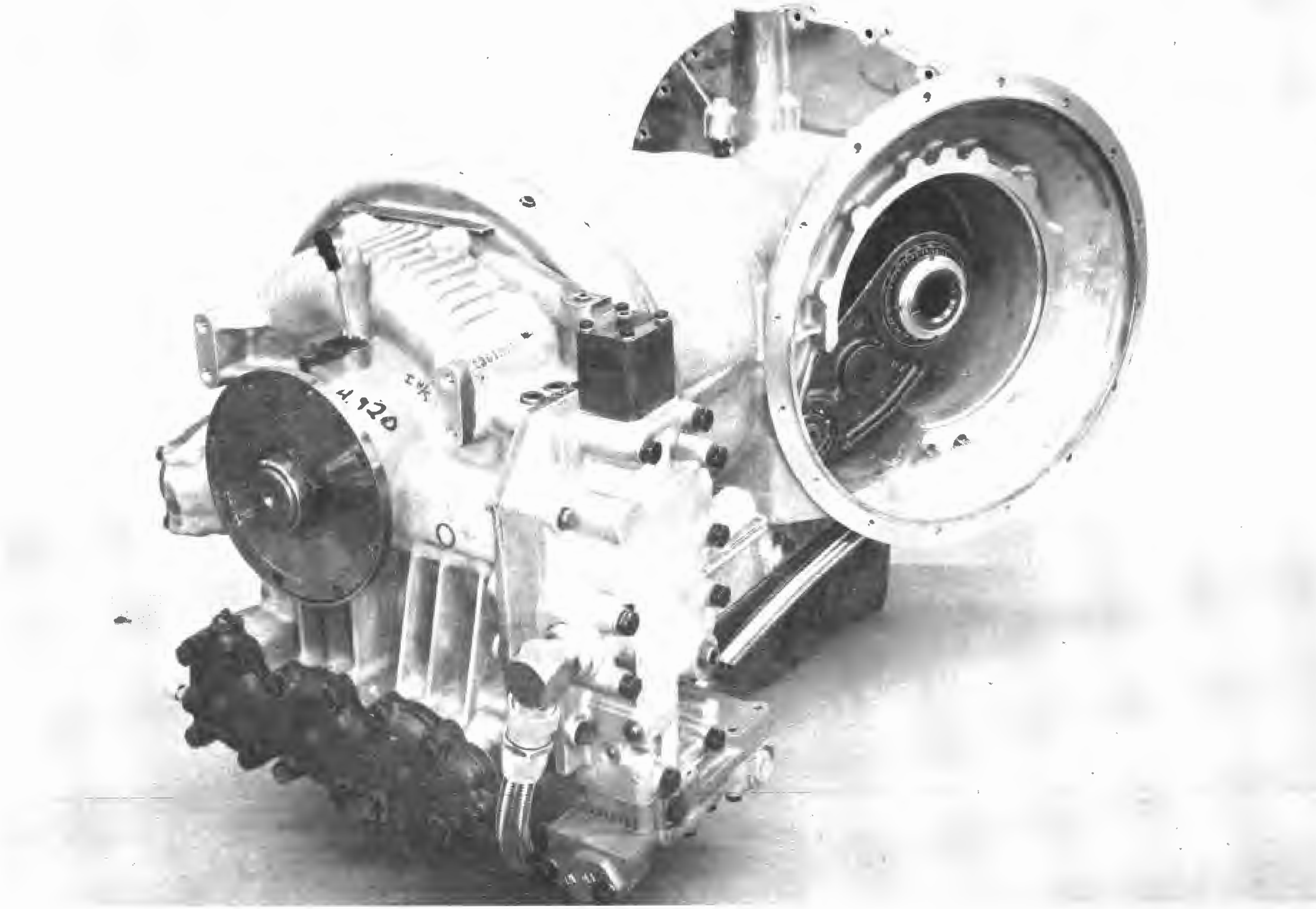


HYDRAULIC RETARDER BY CATERPILLAR
FIG. 2.6



HYDRAULIC RETARDER BY VOITH

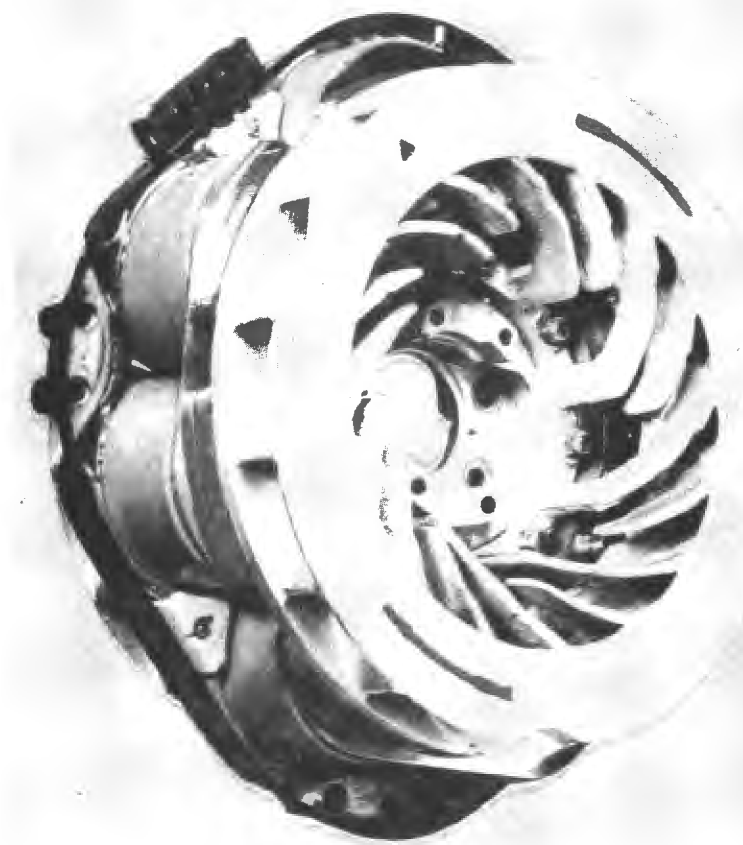
FIG. 2.7



HYDRAULIC RETARDER BY DETROIT DIESEL ALLISON
FIG. 2.8

ELECTRIC RETARDER BY JACOBS

FIG. 2.9



ELECTRIC RETARDER BY TELMA
FIG. 2.10

TELMA ELECTRIC RETARDER

DATA SHEET N° 011 1/4

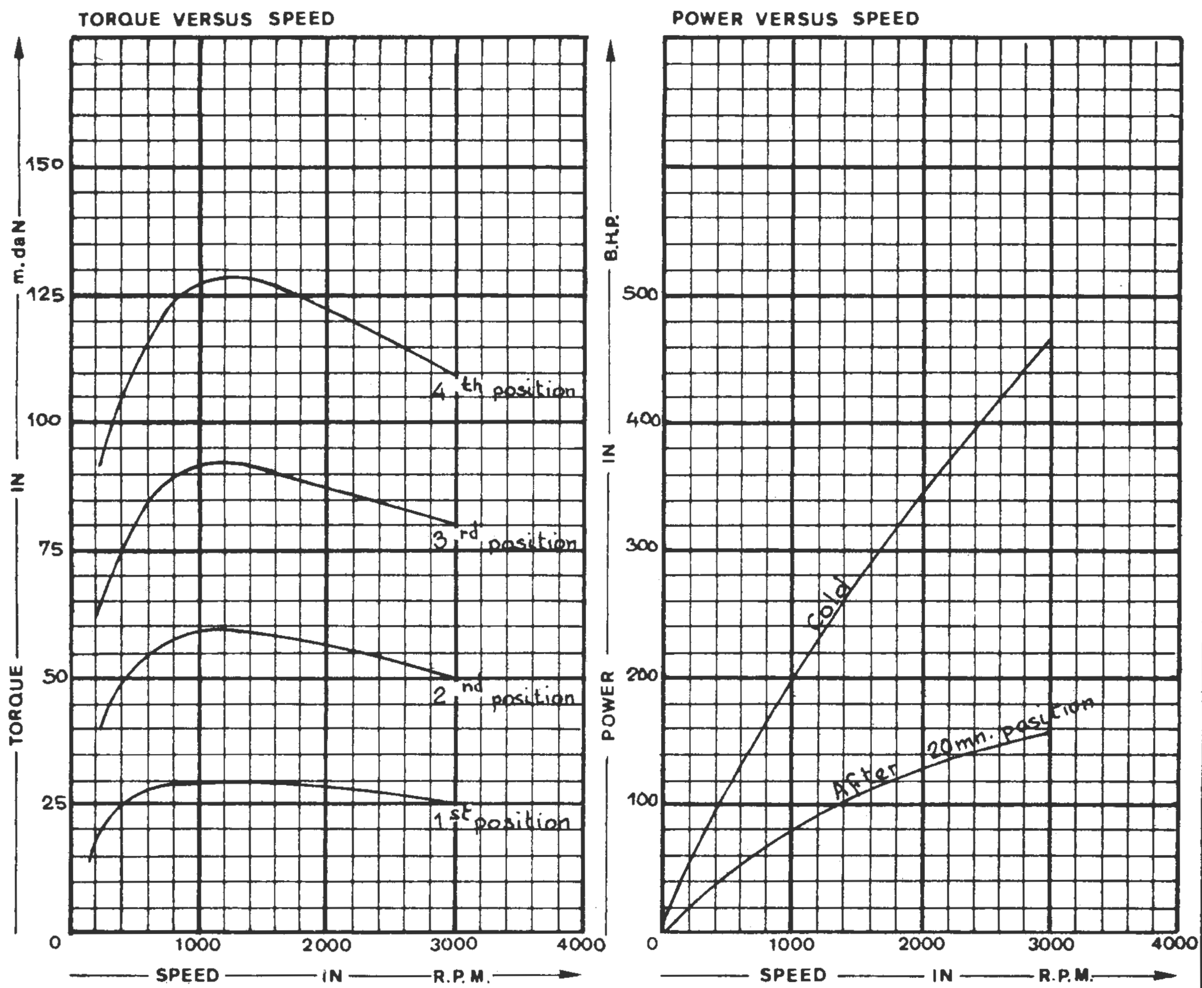
FOCAL 130 RETARDER TYPE 0355

APPLICATION RANGE : 11 to 15 Ton vehicles

(Indication only. Consult us for each vehicle type)

WEIGHT		MECHANICAL DATA	
Rotors	52 Kg	Maximun transmission torque	..... m.daN
Stator	78 Kg	" Allowable speed	3000 r.p.m
Total with coupling flanges	130 Kg	Rotor inertia .... (MKSA)	1,4 Kgm²

PERFORMANCE

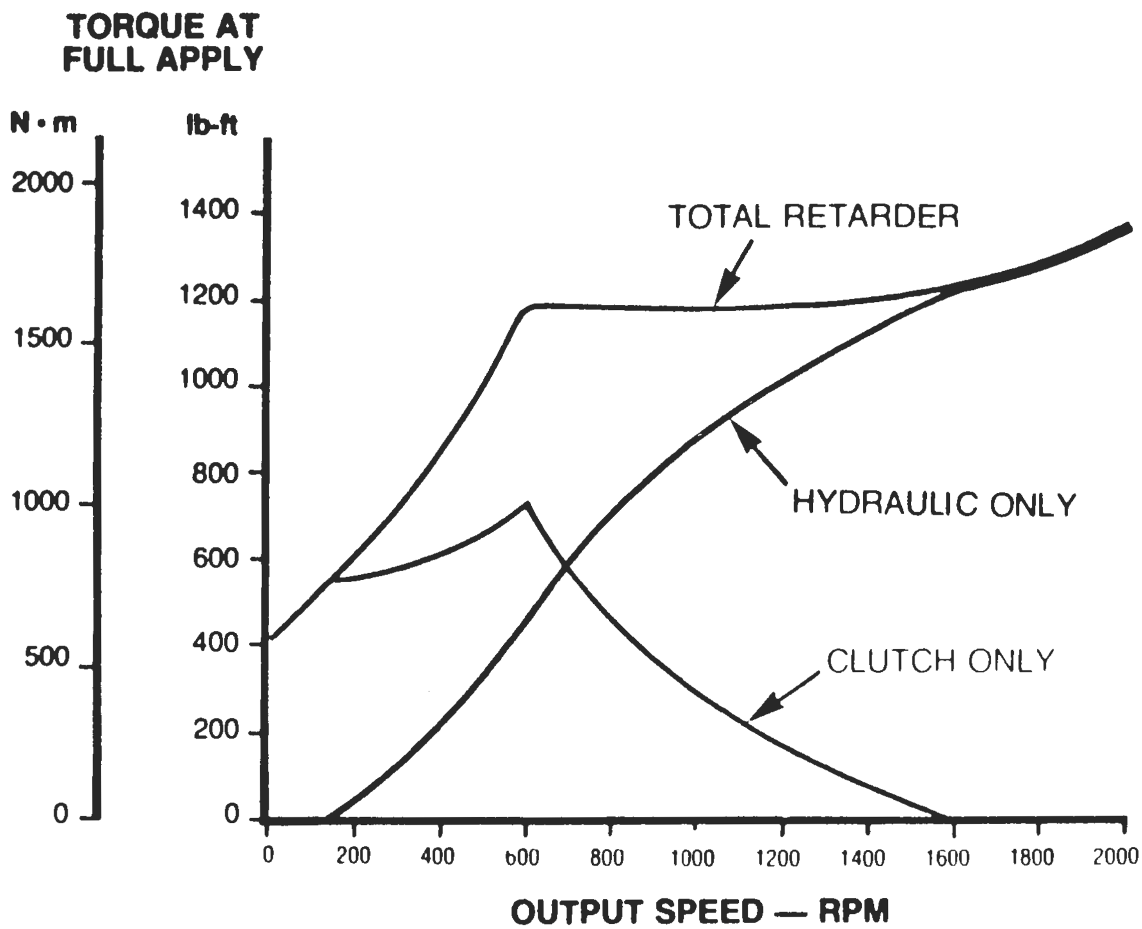


At nominal 24 Volts

Compagnie Française **TELMA** BP 692 95004 Cergy Cedex
28 rue Paul Painleve PME ZA du vert galant
95004 Saint OUEN L AUMONE Tel 037 92 42

Edition : 3/77

FIG. 2.11



RETARDER PERFORMANCE CURVES-
DDA-MTB-600

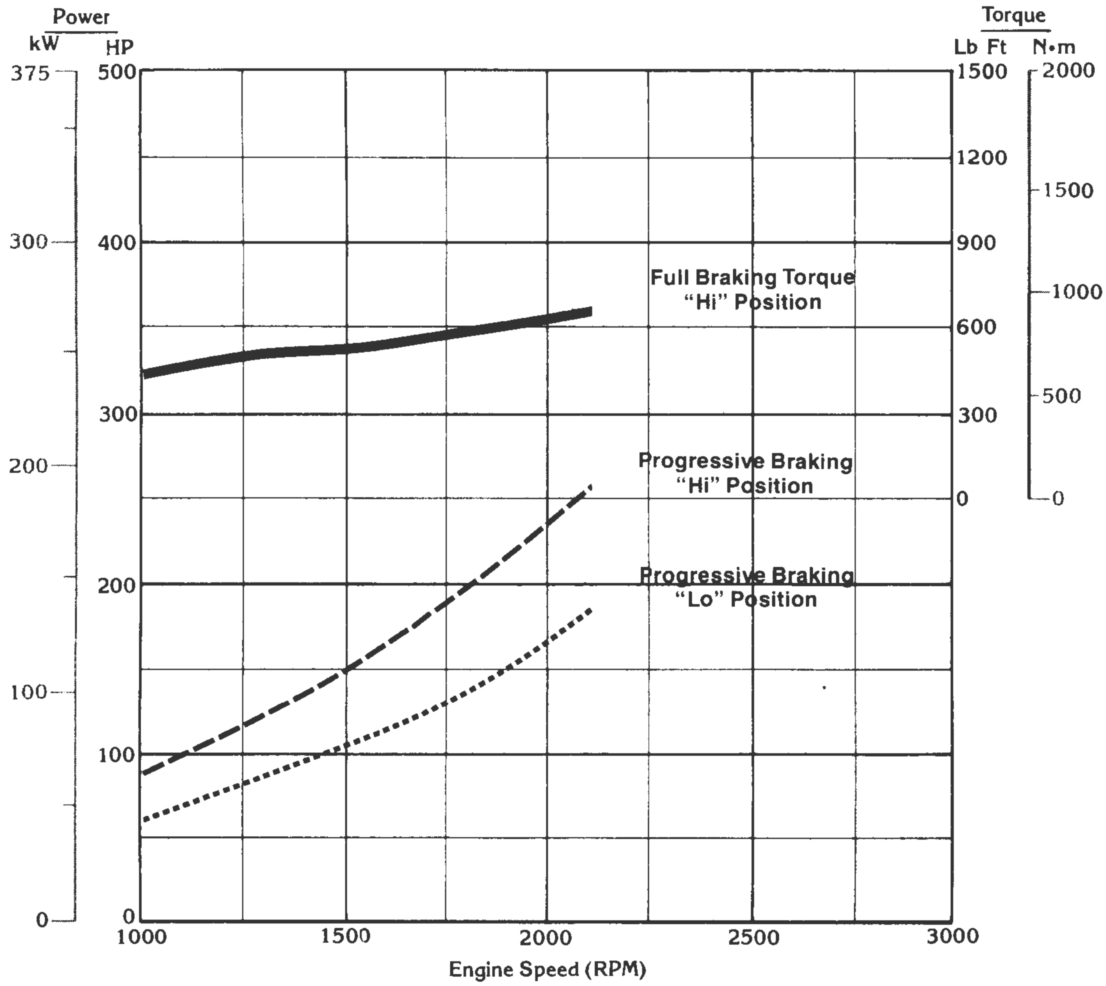
FIG. 2.12

Jacobs® ENGINE BRAKE PERFORMANCE DATA*

Model 71A

RATED ENGINE PERFORMANCE		
Engine ID	Detroit Diesel Allison 8V-71TA	
No. of Cylinders	8	
Bore & Stroke	4.25 × 5.00 in 108 × 127 mm	
Turbocharger ID	DDA TV7101 1.23 A/R	
	English	SI
Power @ Speed	370 HP @ 2100 RPM	276 kW @ 35.0 RPS
Torque @ Speed	1059 Lb Ft @ 1200 RPM	1440 N · m @ 20.0 RPS

Jake Brake® PERFORMANCE		
	English	SI
Slave Piston Lash	.059 in	1.50 mm
Power @ Speed	261 HP @ 2100 RPM	195 kW @ 35.0 RPS
Torque @ Speed	652 Lb Ft @ 2100 RPM	887 N · m @ 35.0 RPS



ENGINE BRAKE PERFORMANCE CURVES - JACOBS

FIG. 2.13

3.0 APPROACH

3.0 APPROACH

This chapter discusses the approach used to conduct the "Evaluation of Retarders" program.

3.1 TRANSIT SYSTEMS

The following transit systems in the State of Michigan are participating in the program and conducting the test on their coaches:

Detroit Department of Transportation (DDOT) (Figure 3.1)
Grand Rapids Area Transit Authority (GRATA) (Figure 3.2)
Capital Area Transportation Authority (CATA) (Figure 3.3)

Line characteristics for each of the three participating systems are summarized in Table 3.1.

3.2 TEST METHODOLOGY

Retarder and coach types were selected for testing in each transit system (Table 3.2). Coach characteristics are detailed in Table 3.3. The retarders were procured and installed in ADBs. All installations have been completed. Table 3.4 shows the actual completion date of the installations. The buses with retarders installed were put in revenue service along with equivalent buses of the same models without retarders, designated as control buses, driving the same routes.

Each of the test and control buses was scheduled to be brought in for four inspections, spaced through the life of their brake linings. At each inspection, full brake lining data were collected, with brake lining thickness measured at points A, B, C, and D (Figure 3.4) for the upper and lower brake linings, for the left and right wheels of front and rear axles.

For each bus in the test and control groups, a report form is used to record brake lining data upon installation of each new set of brake lining and at each inspection. Table 3.5 shows a sample of actual data collected.

In addition, all maintenance activities for the test and control buses are monitored and recorded.

RTS-II COACH - DDOT

FIG. 3.1

870 GRUMMAN FLXIBLE COACH - GRATA

FIG. 3.2

RTS-II COACH - CATA
FIG. 3.3

SYSTEMS LINE CHARACTERISTICS

Transit Agency	Daily Runs	Trippers		Coach Requirements			Total No. Lines	Route Miles	Revenue Speed MPH	Revenue Hours	Total Coach Stops	Stops Per Mile	Remarks
		AM	PM	AM	BASE	PM							
DDOT	650	71	90	454	304	497	54 8* 62	1457	13.4	6295	6700	7.0	Night Service Along 15 Lines
CATA	567	3	3	49	39	42	22 2* 24	230	14.0	482	1500	6.5	Limited Service On Saturdays
GRATA	121	39	48	63	34	59	15	155.7	13.7	553	1600	10.3	Limited Service On Saturdays

*Express buses

TABLE 3.1

TEST SET-UP

RETARDER TYPE	COACH		TRANSIT SYSTEM	BRAKE SYSTEM		REMARKS
	TYPE	NUMBER		TYPE	LINING	
TELMA (Focal 130)	RTS-II	1804	DDOT	Wedge	Bonded	DDOT Installed
	RTS-II	1807	DDOT	Wedge	Bonded	DDOT Installed
	RTS-II	1817	DDOT	Wedge	Bonded	Converted to OEM Type
	870	80	GRATA	S-Cam	Bolted	OEM Type Installation
	870	81	GRATA	S-Cam	Bolted	OEM Type Installation
	870	82	GRATA	S-Cam	Bolted	OEM Type Installation
	RTS-II	310	CATA	Wedge	Bolted	OEM Type Installation
Jacobs	RTS-II	1538	DDOT	Wedge	Bonded	
	RTS-II	1543	DDOT	Wedge	Bonded	
DDA	RTS-II	1865	DDOT	Wedge	Bonded	
	RTS-II	1869	DDOT	Wedge	Bonded	
Control	RTS-II	1377	DDOT	Wedge	Bonded	
	RTS-II	1385	DDOT	Wedge	Bonded	
	RTS-II	1801	DDOT	Wedge	Bonded	
	RTS-II	1873	DDOT	Wedge	Bonded	
	870	83	GRATA	S-Cam	Bolted	
	870	84	GRATA	S-Cam	Bolted	
	RTS-II	301	CATA	Wedge	Bolted	

TABLE 3.2

CHARACTERISTICS	DDOT	GRATA	CATA
TYPE LENGTH WIDTH	RTS II-03 (Fig. 3.1) 40FT. 102 IN.	FLXIBLE 870 (Fig. 3.2) 40FT. 96 IN.	RTS II-03 (Fig. 3.3) 40FT. 102 IN.
ENGINE TRANSMISSION	ALLISON 8V-71 ALLISON V-730	ALLISON 8V-71 ALLISON V-730	ALLISON 8V-71 ALLISON V-730
REAR AXLE	ROCKWELL A-3200-N-1262	ROCKWELL	ROCKWELL A-3200-N-1262
BRAKES	ROCKWELL WEDGE	BENDIX S-CAM	ROCKWELL WEDGE
BRAKE LINING	BONDED WORLK BESTOES 2 AM 159	BOLTED AMERICAN BRAKES BLOCK 80-20 MIX	BOLTED
TIRE SIZE	12.5 X 22.5	12.5 X 22.5	12.5 X 22.5

TABLE 3.3 - CHARACTERISTICS OF COACHES IN TEST AND CONTROL GROUPS.

RETARDER TYPE	TRANSIT SYSTEM	DATE INSTALLATION COMPLETED
TELMA	DDOT	FEBRUARY, 1982
	GRATA	NOVEMBER, 1982
	CATA	JANUARY, 1983
JACOBS	DDOT	DECEMBER, 1981
DDA	DDOT	JANUARY, 1983

RETARDER INSTALLATIONS: ACTUAL COMPLETION SCHEDULE

TABLE 3.4

1. WHEEL FRICTION BRAKES

	START	INSPECTION 1ST	2ND	3RD	4TH
DATE	7-6-82	10-25-82	2-1-83	3-7-83	
MILEAGE	59,178	64,818	73,032	78,788	
NUMBER OF STOPS					
NUMBER OF STOPS/MILE					
VISUAL INSPECTION					
BRAKES AND RELATED EQUIPMENT					
TRANSMISSION AND DIFFERENTIAL					
REAR AXLE SUPPORT STRUCTURE					
SEALS AND BEARINGS					
RETARDER AND CONTROL					

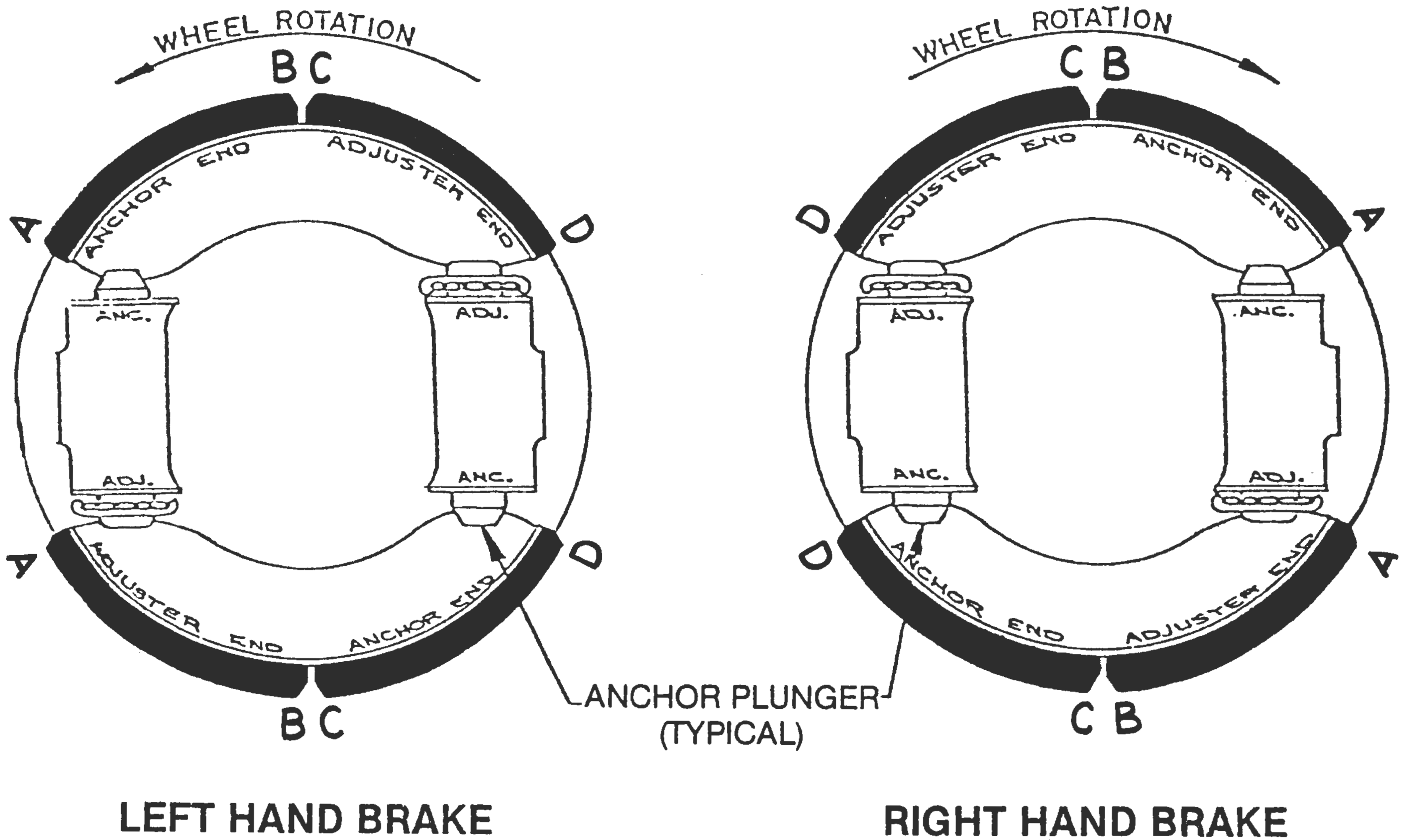
FUEL ECONOMY

	START	1ST	2ND	3RD	4TH
FUEL CONSUMPTION (GALLONS)	X				
MILES PER GALLON	X				

LINING THICKNESS			START	1ST	2ND	3RD	4TH
FRONT AXLE LT. HAND	UPPER	A	.781	.761	.709	.707	
		B	1.005	.989	.944	.941	
		C	1.005	.989	.944	.941	
		D	.865	.850	.835	.833	
	LOWER	A	.813	.805	.800	.800	
		B	1.027	.992	.939	.936	
		C	1.027	.992	.939	.936	
		D	.824	.822	.743	.740	
FRONT AXLE RT. HAND	UPPER	A	.899	.856	.749	.749	
		B	1.011	1.005	.965	.964	
		C	1.011	1.005	.965	.964	
		D	.837	.830	.807	.806	
	LOWER	A	.864	.857	.840	.837	
		B	1.055	1.011	.965	.960	
		C	1.055	1.011	.965	.960	
		D	.910	.893	.783	.783	
REAR AXLE LT. HAND	UPPER	A	.752	.724	.699	.697	
		B	.943	.900	.880	.794	
		C	.943	.900	.880	.794	
		D	.782	.743	.693	.690	
	LOWER	A	.776	.750	.704	.700	
		B	.937	.909	.861	.861	
		C	.937	.909	.861	.861	
		D	.755	.734	.680	.682	
REAR AXLE RT. HAND	UPPER	A	.811	.790	.750	.748	
		B	.925	.895	.885	.880	
		C	.925	.895	.885	.880	
		D	.809	.789	.734	.731	
	LOWER	A	.733	.730	.709	.707	
		B	.931	.915	.890	.890	
		C	.931	.915	.890	.890	
		D	.739	.735	.686	.680	

REPORT FORM FOR BRAKE
INSPECTION DATA
TABLE 3-5

Wedge Brake on RTS II Coach



BRAKE LINING MEASUREMENT POINTS

FIG. 3.4

4.0 INSTALLATION

4.0 INSTALLATION

This chapter discusses the installation requirements and costs of the three types of retarders selected for the test program. Manuals listing required hardware and detailing installation instructions are available from the manufacturer for the Jacobs brake and TELMA retarder. The DDA retarder installation manual is being developed. All the material in the chapter relates to retrofit; if the bus manufacturer installed retarders, the parts cost and time required would be considerably less.

4.1 JAKE BRAKE (JACOBS)

4.1.1 INSTALLATION

The Jake brake is much less expensive to install than either electric or hydraulic retarders and does not require any major bus modifications. Most diesel engines could be retrofitted with a standard brake kit. Deeper engine valve covers are used for the added brake height (Figures 4.1, 4.2).

4.1.2 CONTROLS

An accelerator pedal switch, in combination with buffer and transmission switches, controls the Jake brake. The brake is energized whenever the driver's foot is completely removed from the accelerator pedal and the switch is turned on. The brake is de-energized by pressure on the accelerator during shifting or when the engine speed is below 750 rpm.

4.1.3 INSTALLATION COSTS

Parts	$1,760[1]
Labor	8-10 man-hours[2]

4.2 ELECTRIC RETARDER (TELMA)

Three basic different ways are used worldwide to install TELMA retarders (Figure 4.3):

Chassis mounted,
Transmission mounted, or
Rear axle mounted

The first installation is usually used for vehicles with a front engine. The other two types of installation are used for vehicles powered with a rear engine. In Europe, a transmission mounted retarder is the most commonly used type of installation in rear engine coaches.

102" wide New Look coaches can accommodate a TELMA retarder easily; but because of the space limitations, ADBs require some modifications before the retarders can be installed.

4.2.1 INSTALLATION IN GMC RTS II COACHES

The short drive-shaft and the absence of the chassis make it next to impossible to permit a chassis mounting. Transmission mounting would interfere with the bulkhead and has been rejected by the transmission manufacturer, DDA. GMC has installed the parking brake on the differential where the retarder would be mounted. In order to install the retarder in the RTS, the parking brake has to be relocated on the wheel drums to provide the space required for rear axle mounting (Figures 4.4, 4.5).

Because of space limitations the maximum size of TELMA retarder that can be installed in GMC RTS II coach is the "Focal 130."

The OEM-type installation of TELMA "Focal 130" retarder (Figure 2.10) in GMC-RTS II coach includes the following work:

a. Remove parking brake assembly installed on the differential. A new parking brake system consisting of four 16" x 16" spring brake chambers, added to the nonpressure housing of the original brake chambers, is used. New air line hoses are required (Figure 4.6).

b. Move the rear suspension air bags 1" away from the centerline of the axle to provide enough space for the four parking brake chambers, and 3/4" out from the centerline of the coach for adequate clearance between the retarder and the rear right-hand air bag.

c. Rebuild differential according to Rockwell's specifications. Pinion bearing preload higher than the standard is needed.

d. Reroute air and fluid lines under the floor in the retarder area.

e. Shorten the drive shaft by 1 7/8". Replace the original journal-cross needle bearings and tube-yoke by strap bearing type tube-yoke and needle bearings in order to accommodate the drive shaft connecting system of the retarder (Figure 4.7).

f. Install retarder bracket and retarder assembly on the differential housing of the rear axle (Figure 4.8).

g. Install the retarder control consisting of four pressure switches, relay box, zero speed switch, signal generator, and the required wiring (Figures 4.9, 4.10).

Note: The first installation of TELMA retarders in RTS II coaches was performed in the DDOT maintenance shop by its personnel. This installation was not an easy task because it was the first time a TELMA unit had ever been installed in a GMC RTS II coach. Parts required for OEM-type installation, as described above, were not available at the time of first installation. These parts became available about one year after the test started in Detroit and were designed and developed by Rockwell and TELMA engineering departments as product improvements to DDOT installation. As a result, different types of installation utilizing readily available parts at that time were used to start the test in Detroit. The retarder starter assembly was mounted on the pinion cage instead of the differential housing. A special drive line, using a combination of American and European made parts, to fit the inside diameter of the retarder outboard rotor was used. Also two dual chambers were used for the parking brake instead of four. No air bag displacement as described in 4.2.1 was performed.

Recently, one of the DDOT RTS II test coaches, equipped with a TELMA retarder, was converted to OEM-type installation.

The OEM-type installation has been also used for CATA's RTS II coach in Lansing.

4.2.2 INSTALLATION IN FLXIBLE 870 COACH

A TELMA retarder installation in the Flxible 870 coach will have no interference problem with the air bag or parking brake, but will interfere with the floor. An 11" x 15" x 1 7/16" deep recess in the floor, and a ½" restriction of the axle travel are needed to keep the retarder from hitting the floor, in case the axle would reach the metal/metal position (Figures 4.11, 4.12).

Because of space limitations the maximum size of TELMA retarder that can be installed in Flxible 870 coach is the "Focal 130".

The installation of the TELMA "Focal 130" retarder in Flxible 870 coach includes the following work:

a. Rebuild differential according to Rockwell's specifications. Pinion bearing preload higher than the standard is needed.

b. Restrict the axle travel by installing two air bag ½" spacers between the bottom of each bag and its mount.

c. Shorten the drive shaft by 1 7/8". Replace the original journal-cross needle bearings and tube-yoke by strap bearing type tube-yoke and needle bearings in order to accommodate the drive shaft connecting system of the retarder (Figure 4.7).

d. Install retarder bracket and retarder assembly on the differential housing of the rear axle.

e. Install the retarder control consisting of four pressure switches, relay box, zero speed switch, and the required wiring (Figures 4.9, 4.10).

Note: To permit this installation, special permission was secured from the Flxible Grumman engineering department to remove the K-brace which had been added to reinforce the A-frame.

4.2.3 CONTROLS

The braking air pressure (increasing with increasing depression of the service brake pedal) actuates four normally open pressure switches which have progressively increasing settings and each controls one stage of the retarder.

A zero speed switch disconnects the retarder circuit when the coach is in complete stop to avoid battery drainage with the engine at idle (Figure 4.13). Four pilot lights mounted on the driver's dashboard indicate the operation of the retarder.

4.2.4 INSTALLATION COSTS

	RTS II	870
Retarder	$2,534.74	$2,534.74
Hardware required for retrofit	3,984.79 (3)	3,433.89 (3)
Total parts cost	$6,519.53 (2)	$5,968.63 (2)
Labor (man-hours)	80-90	50-60

4.3 HYDRAULIC RETARDER (DDA)

4.3.1 INSTALLATION

The heat removed from the retarder by the oil is normally transferred to the engine cooling water system by means of an oil-to-water heat exchanger; the existing radiator and fan is then used to dissipate the heat to the atmosphere. Proper attention to cooling is, therefore, essential.

One way to increase the limited cooling capacity of the GMC RTS II 03 model, before hydraulic retarder installation, is to relocate the A/C condenser from the front of the radiator in the engine compartment to the top of the rear end of the coach (Figures 4.14).

Relocating the A/C condenser improved the cooling efficiency of the coach by about 20 percent.

Installing the Allison Hydraulic retarder also needs engine cradle modification. The engineering of the modification required to retrofit the retarder in the RTS II coach has been developed by DLMA & Associates, Inc., of Troy, Michigan.

The installation of the DDA hydraulic retarder in GMC's RTS II coach includes the following work:

a. Modify the engine cradle for the retarder installation (Figure 4.15, 4.16).

b. Relocate the engine cradle mount on the bulkhead. Increase the size and strengthen the opening in the bulkhead to provide access and clearance for drive line.

c. Shorten the muffler and cut off the RH exhaust manifold to provide space for a 3" copper water pipe.

d. Install the Stewart Warner oil-to-water cooler.

e. Modify engine cooler housing and elbow to accommodate the auxiliary cooler.

f. Shorten the drive shaft by 2.71".

g. Install control valve.

Note: Installation of the oil-to-air Hayden cooler, model 308, was originally recommended by DDA. The DDA report on fluid temperature test suggested the elimination of this cooler in future installations. The test was conducted by DDA engineers on an RTS II coach equipped with hydraulic retarder, in revenue service, to evaluate the impact of using hydraulic retarder on the transmission fluid temperature and coolant efficiency of the bus.

4.3.2 CONTROLS

A valve controls the retarder braking power according to the main braking air pressure. Figure 4.17 shows the controls for the hydraulic retarder using a WABCO valve. Because of problems encountered with the use of this valve, it has been replaced by an amplifying relay valve (see Section 7.1).

4.3.3 INSTALLATION COSTS

Retarder	\$3,000.00	(4)
Hardware required for retrofit	\$1,588.22	(3) (5)
Total parts cost	\$4,588.22	
Labor (man-hours)	130-170	(2) (5)

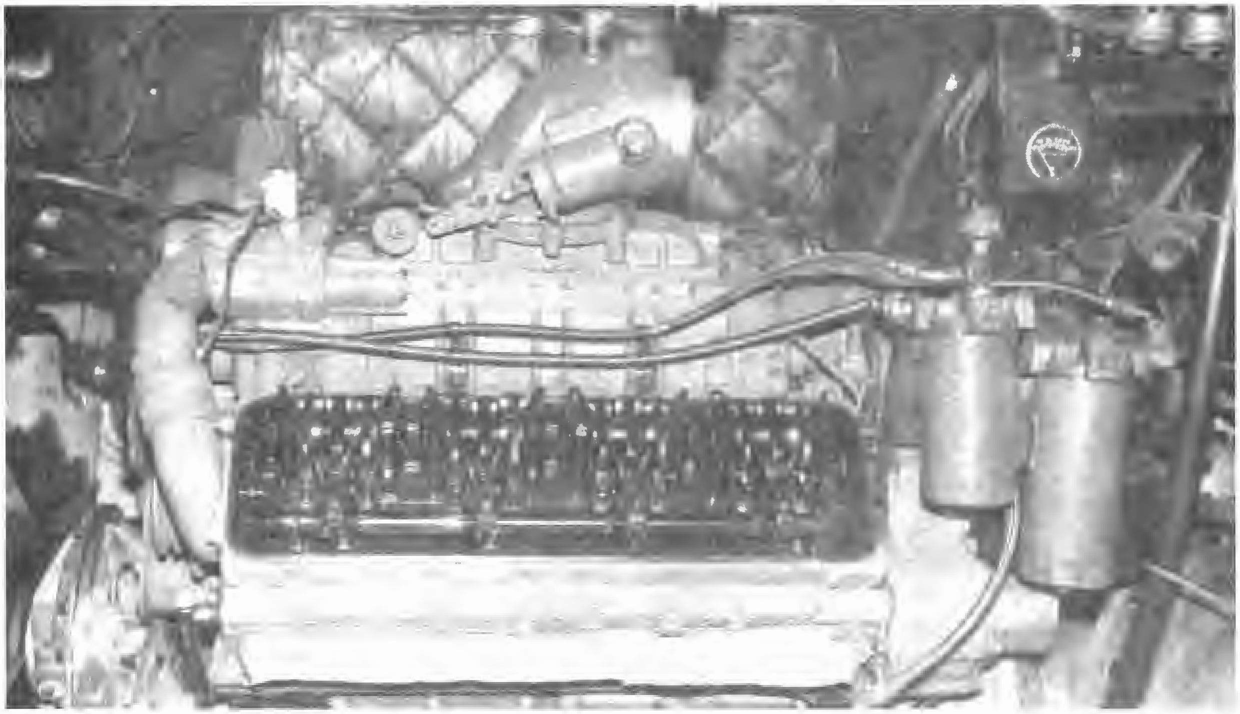
(1) Parts cost data are based on manufacturer's suggested user list price.

(2) Labor costs data from average hours invoiced by vendor for actual installation.

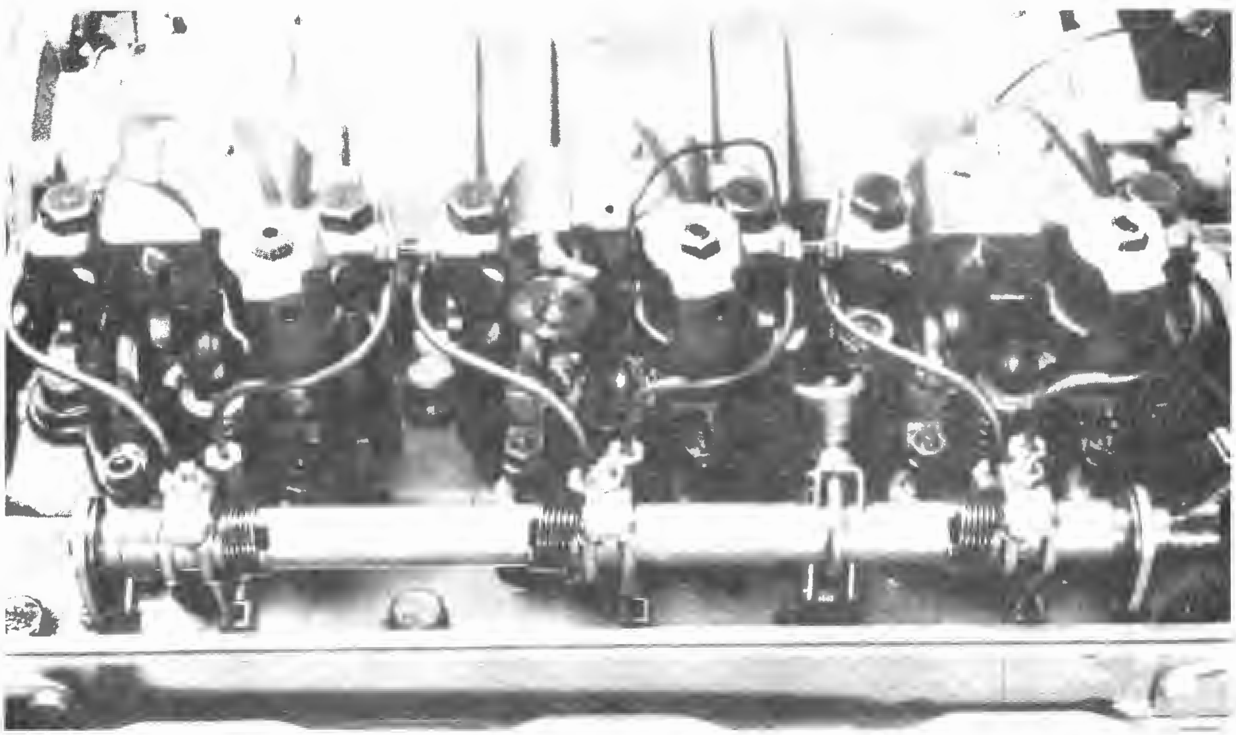
(3) Parts cost data from invoices actually incurred.

(4) The DDA program on the VB-730 is inactive, no list price is available. The figure given is the production cost estimated by DDA. Option prices are available on the MT and HT output retarder. Contact OEM for prices.

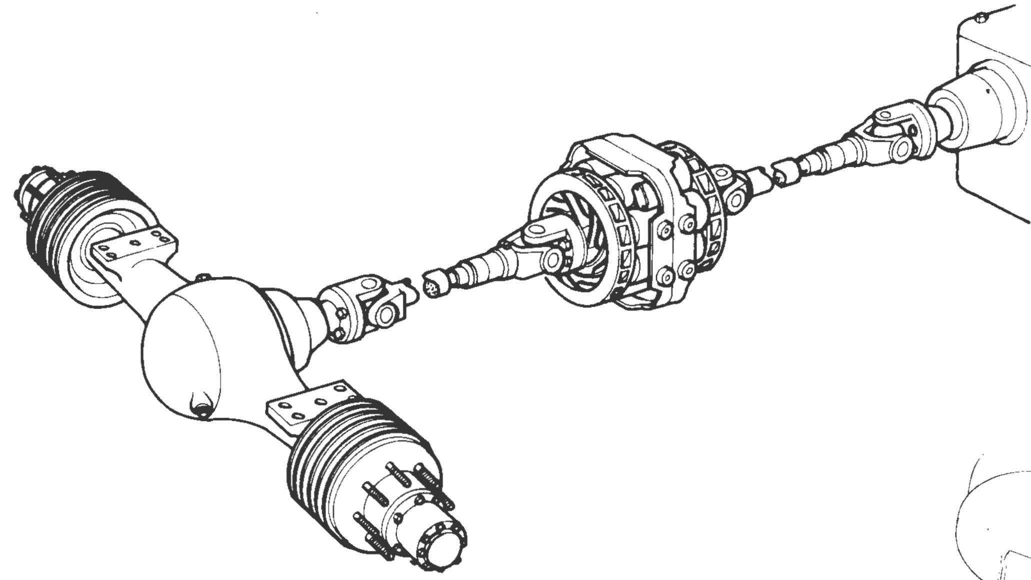
(5) Although the Hayden cooler was actually installed by DDA, the parts and labor required for installation of the cooler are not included in the installation costs at 4.3.3. since future installations will not include the cooler.



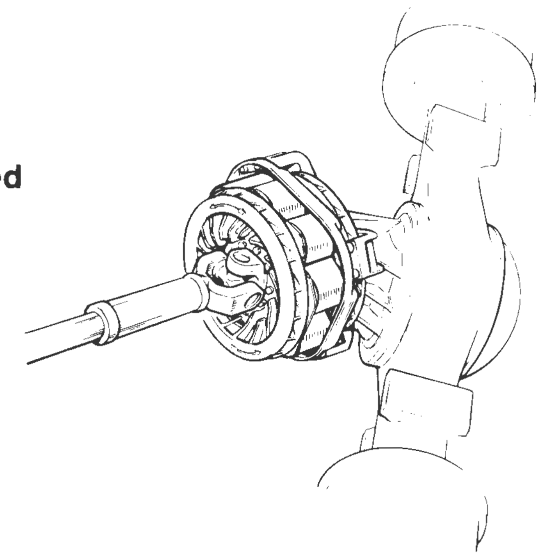
8V-71 ENGINE BEFORE JACOBS BRAKE INSTALLATION
FIG. 4.1



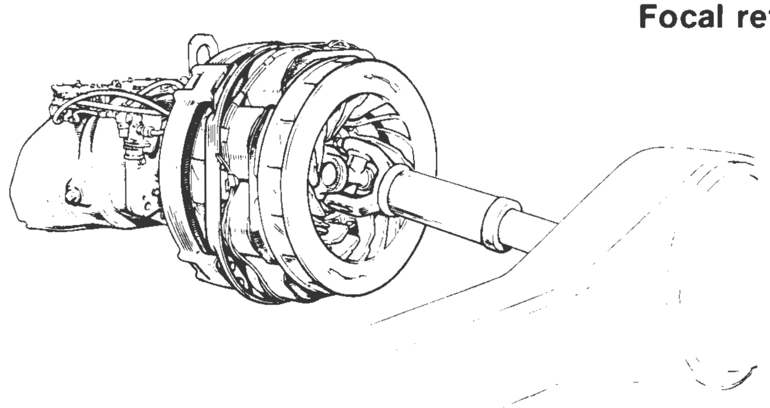
JACOBS BRAKE INSTALLATION ON 8V-71 ENGINE
FIG. 4.2



CC or CA retarder chassis mounted



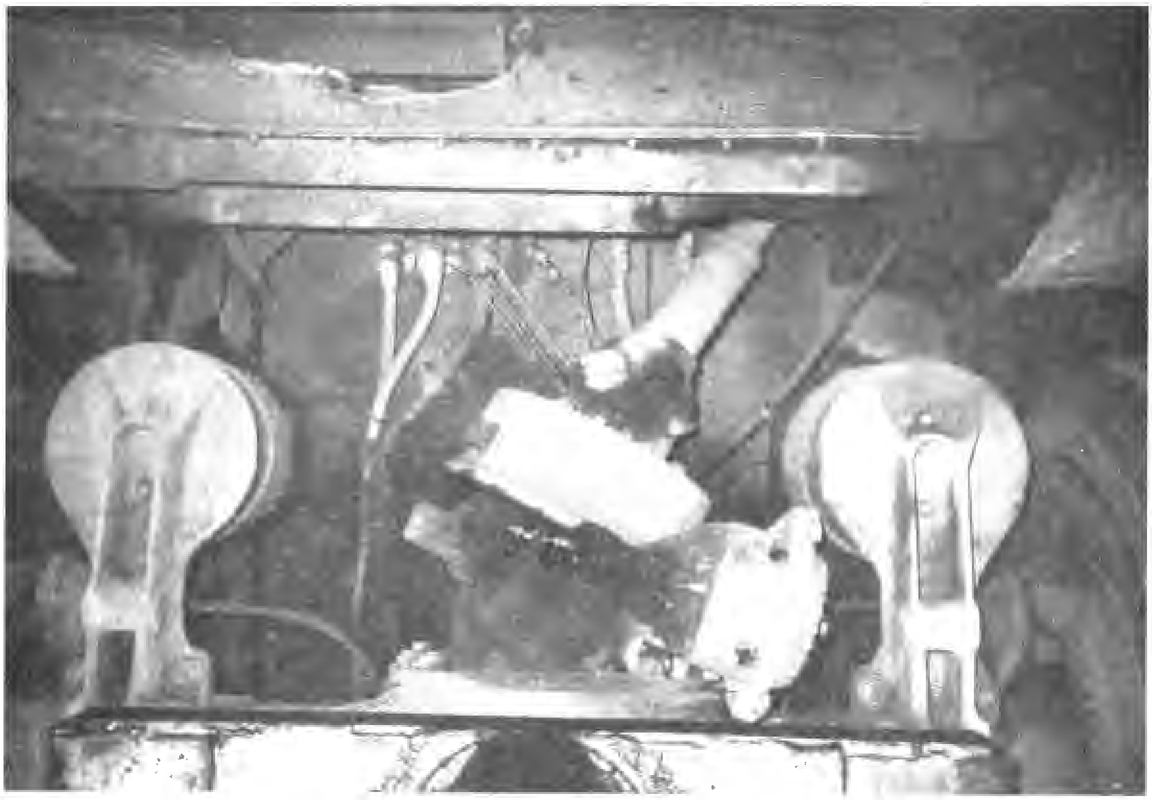
Focal retarder axle mounted



Focal retarder gearbox mounted

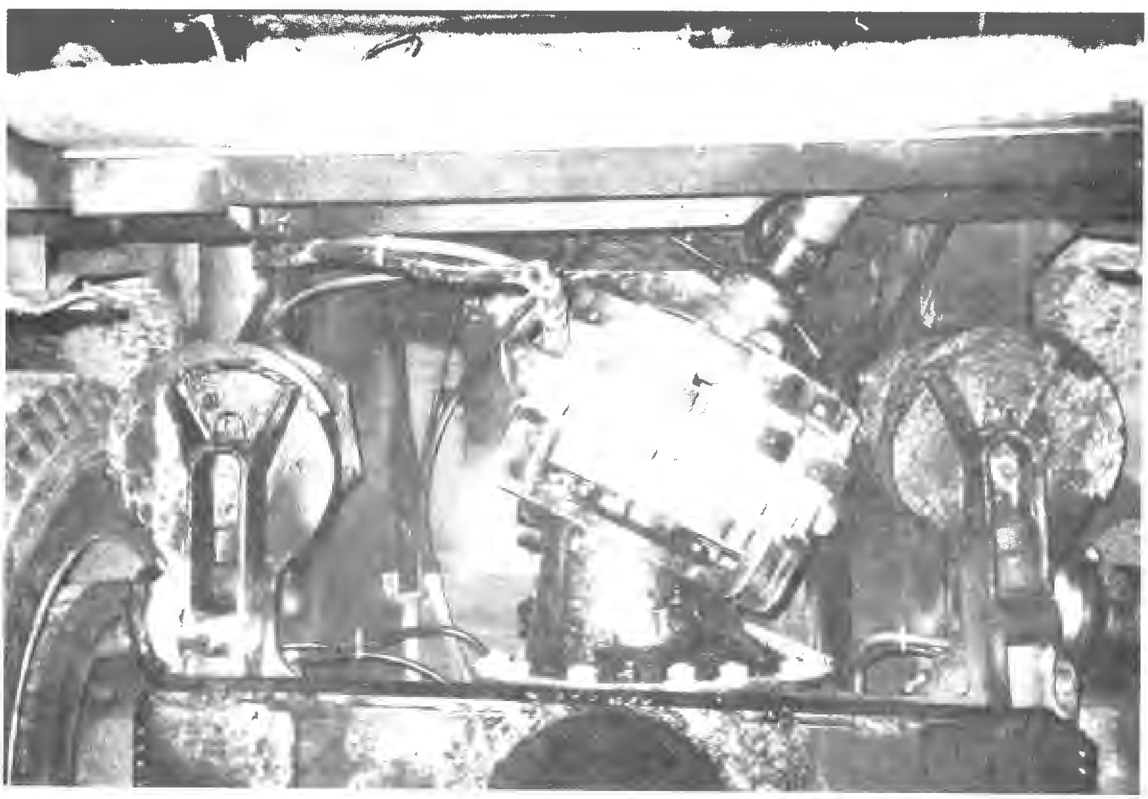
DIFFERENT WAYS OF TELMA RETARDER INSTALLATION

FIG. 4-3



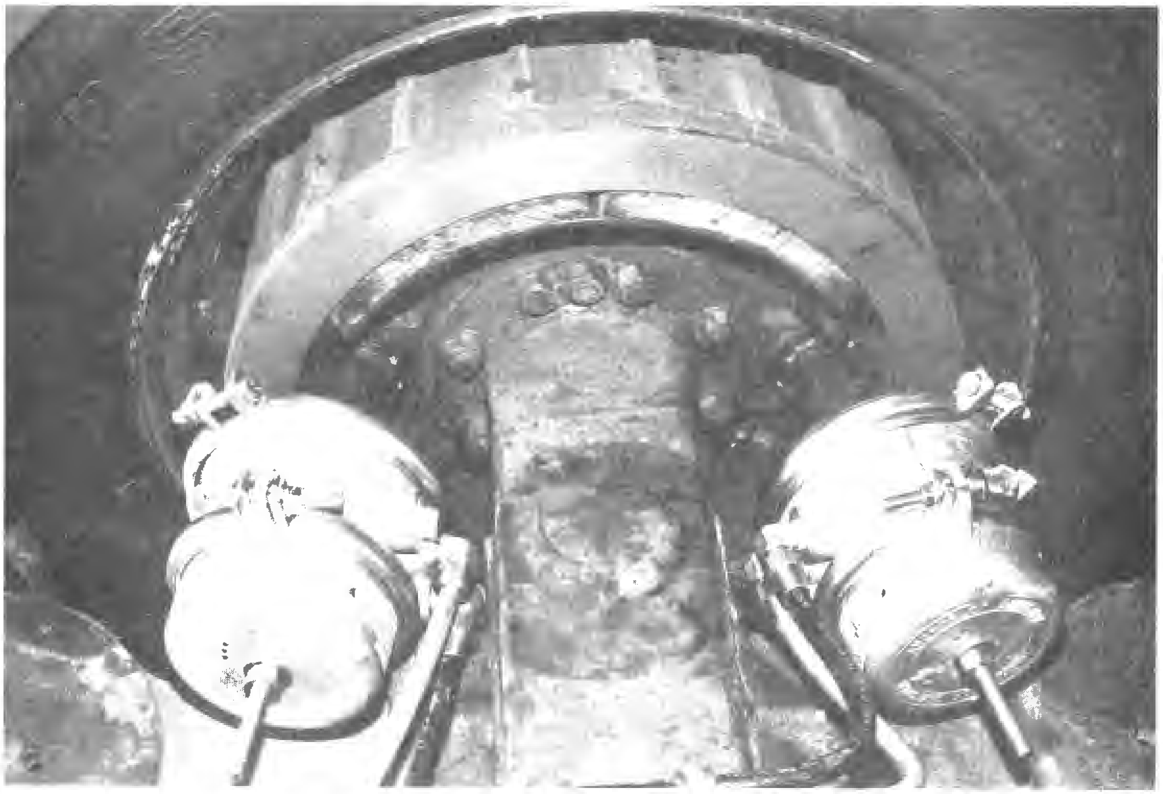
RTS II PRIOR TO INSTALLATION OF TELMA RETARDER

FIG. 4.4



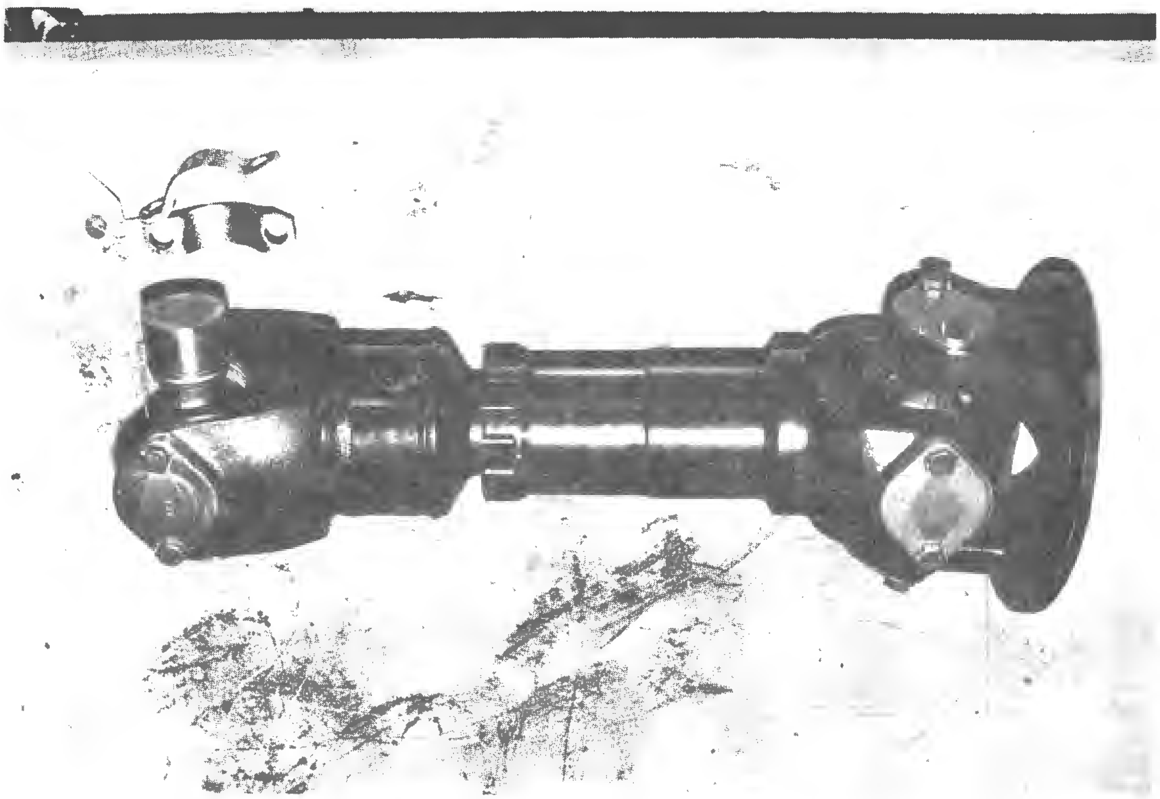
RTS II AFTER TELMA RETARDER INSTALLATION

FIG. 4.5

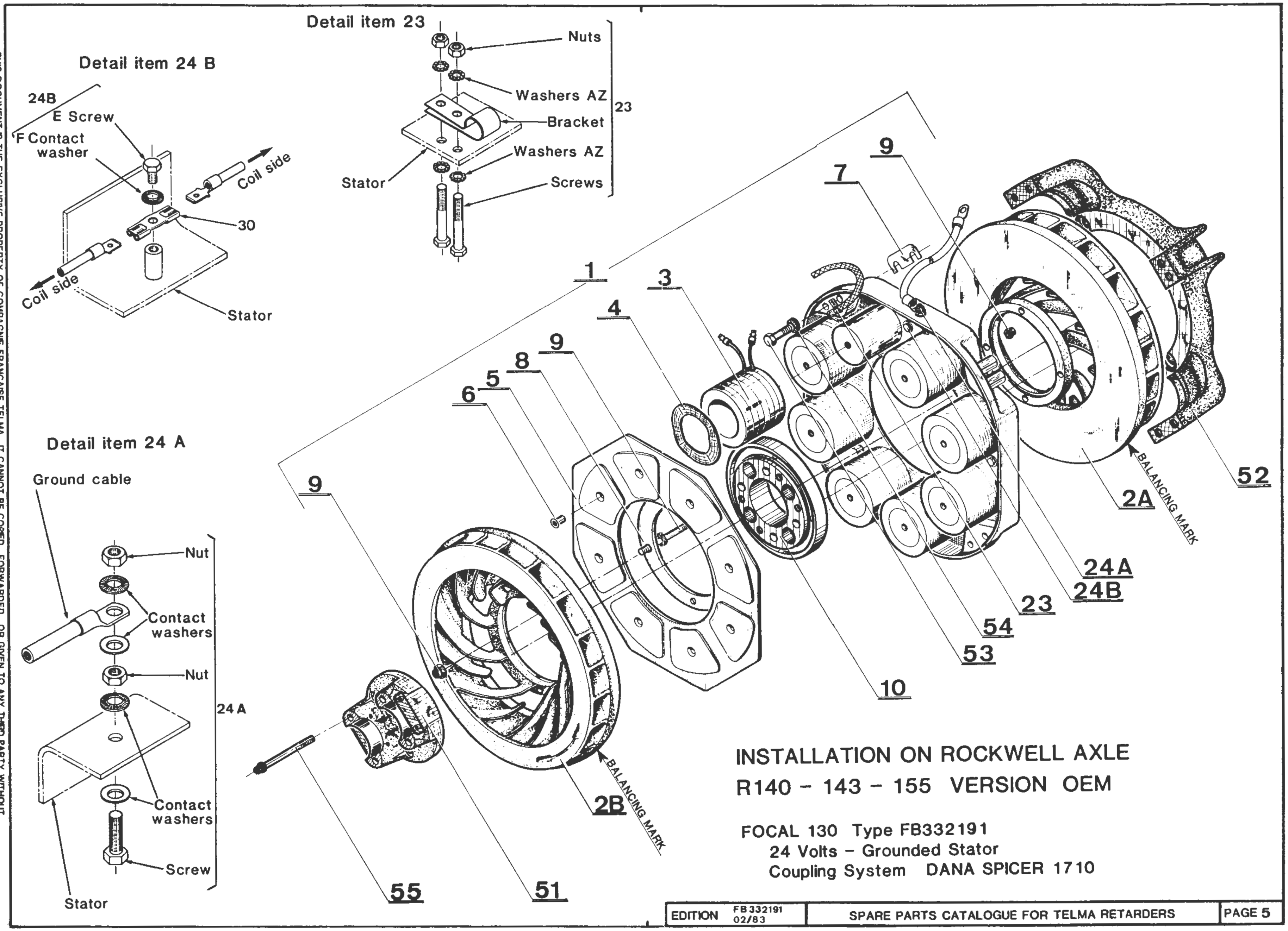


RELOCATED PARKING BRAKE

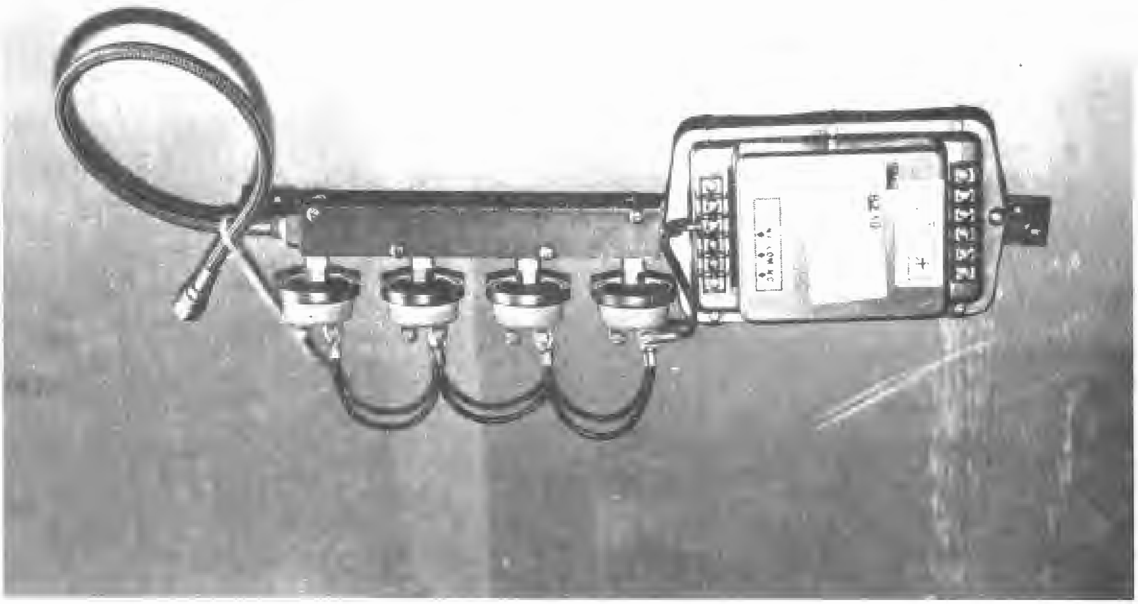
FIG. 4.6



SHORTENED DRIVE SHAFT, WITH
STRAP BEARING TYPE YOKE
AND NEEDLE BEARING
FIG. 4.7

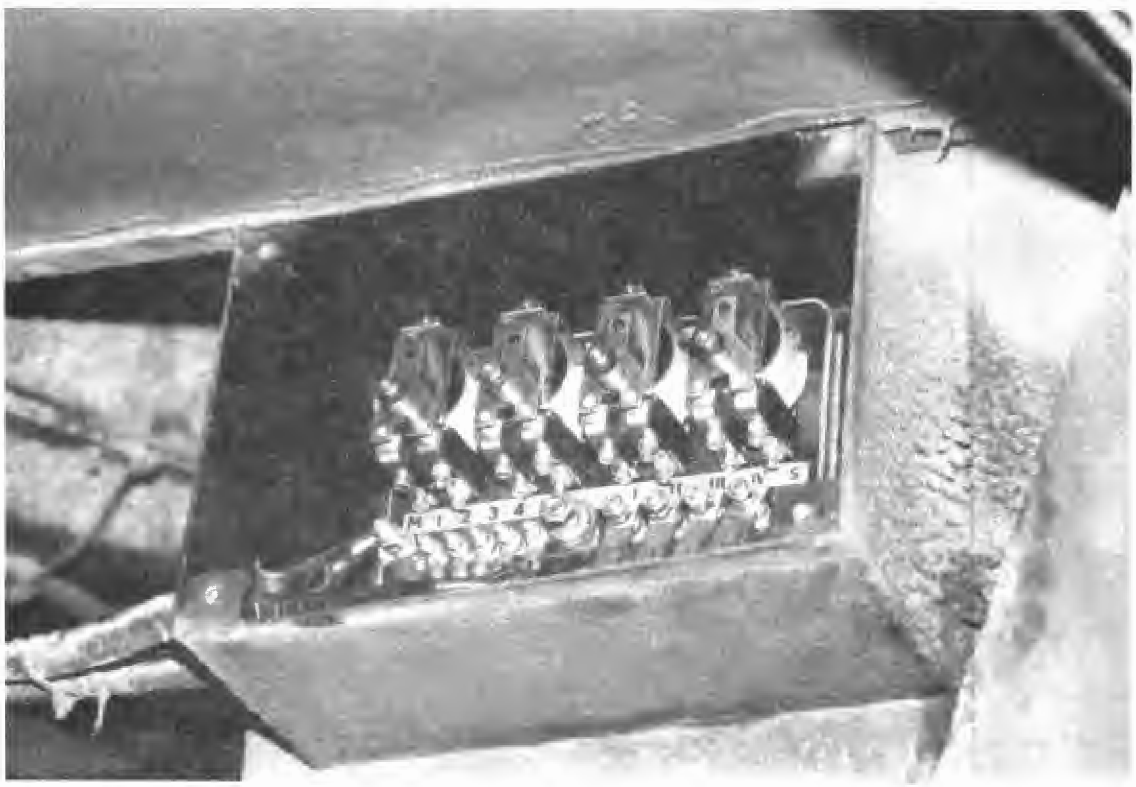


INSTALLATION ON ROCKWELL AXLE
FIG. 4-8



PRESSURE SWITCHES TO CONTROL TELMA RETARDER

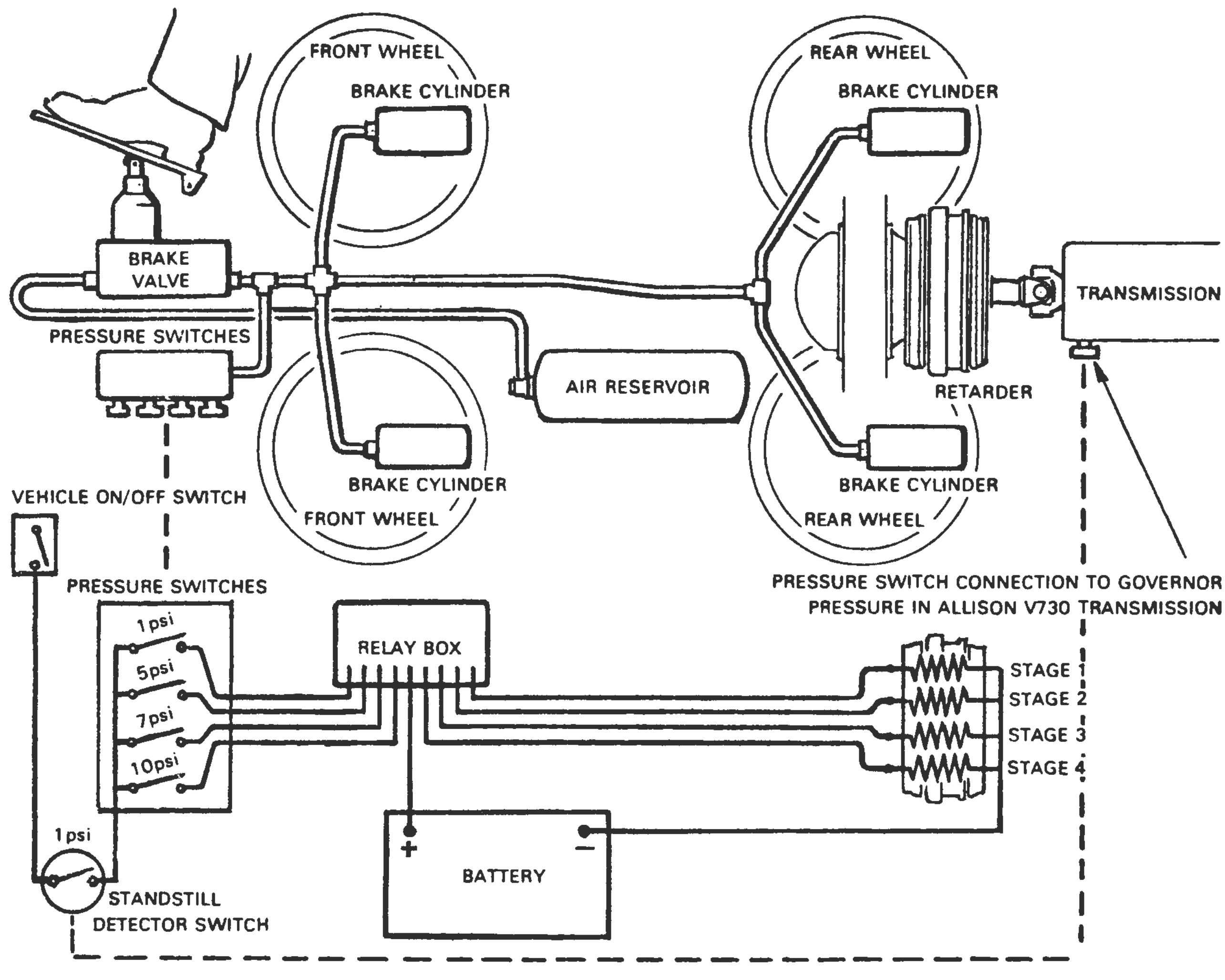
FIG. 4.9



RELAY BOX FOR TELMA RETARDER
FIG. 4.10

870 GRUMMAN FLXIBLE PRIOR TO INSTALLATION OF TELMA RETARDER
FIG. 4.11

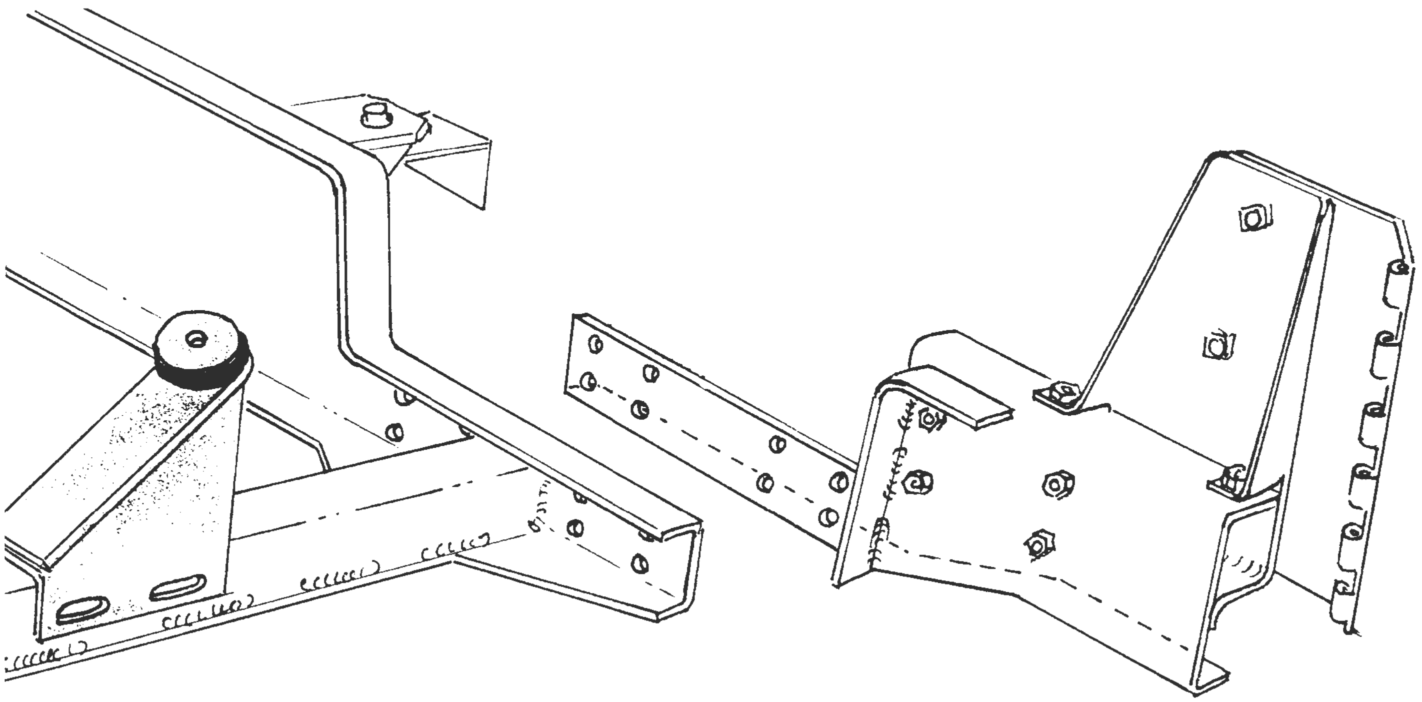
870 GRUMMAN FLXIBLE AFTER TELMA RETARDER HAS BEEN INSTALLED
FIG. 4.12



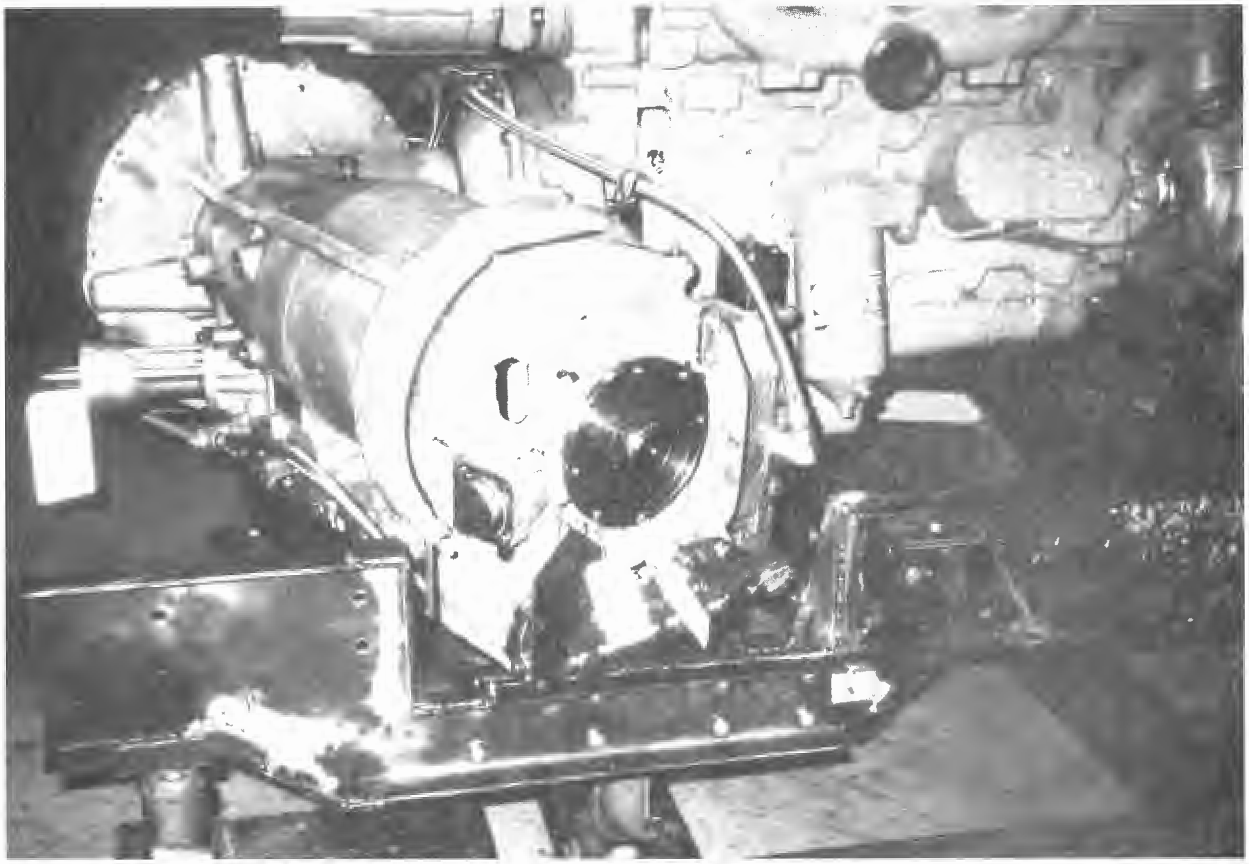
TELMA RETARDER CONTROL
FIG. 4.13

A/C CONDENSER RELOCATION

FIG. 4.14

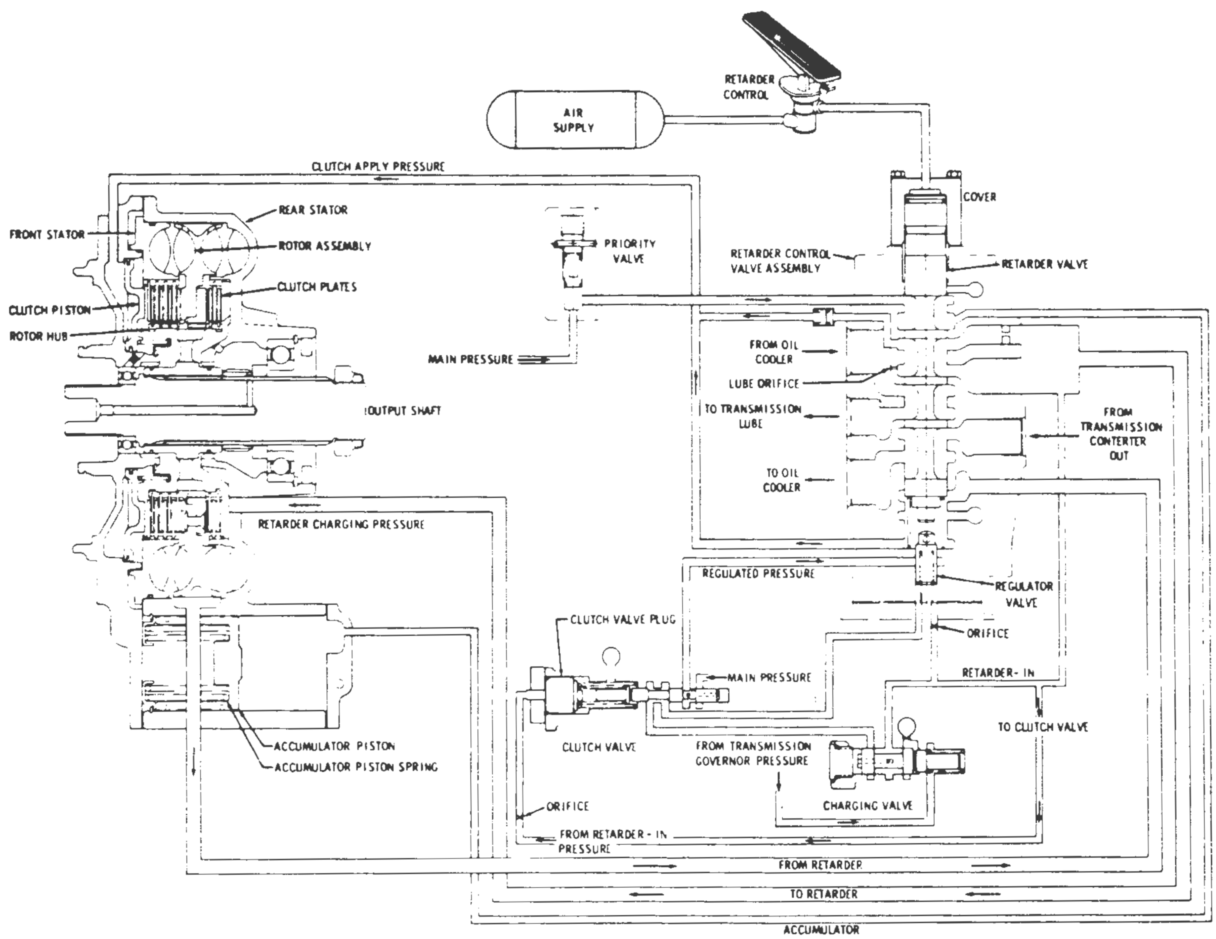


ENGINE CRADLE MODIFICATION
FIG. 4.15



DDA HYDRAULIC RETARDER INSTALLATION ON RTS - II COACH

FIG. 4.16



HYDRAULIC RETARDER CONTROL

FIG. 4.17

5.0 PRELIMINARY RESULTS

5.0 PRELIMINARY RESULTS

At the present stage of progress of the testing program, the data reported can be only preliminary; the final report will provide complete actual data and actual brake wear averages.

We have accumulated enough mileage to replace the brake lining for control buses and for Jacobs-equipped buses.

For the individual TELMA-equipped buses, up to 50,000 miles have accumulated and brake linings have not yet required replacement. For the individual DDA hydraulic retarder-equipped buses, about 21,000 miles have accumulated and brake linings have not yet required replacement.

Therefore, the data shown for brake lining life on the TELMA-equipped and DDA-equipped buses are necessarily based on estimated life, projecting the brake wear experience so far recorded through the life of the brake linings.

5.1 BRAKE LINING TEMPERATURE

Friction brakes generate intense heat which it is hard to dissipate because of their restricted size and their location within the road wheels. High temperature accelerates wear and induces brake fade. The retarder will reduce the maximum operating temperatures of the foundation brakes, thus extending brake lining life, in addition to ensuring that the brakes are maintained at their maximum efficiency. The retarder can also increase tire life, as tires can be damaged by hot brakes.

As a part of the testing program, the brake lining temperatures of a DDOT coach were measured and recorded in actual revenue service with and without the TELMA retarder. Brake lining temperature measurements were obtained from resistive temperature transducers installed in the lining as shown in Figure 5.1. Transducer outputs were conditioned, amplified, and scaled for recording on magnetic tapes. Data were recorded on a 14 channel FM recorder (Honeywell 5600C).

Peak brake lining temperatures recorded were 110°C (230°F) in one run with the retarder in operation, and 175°C (347°F) in a second run when the retarder was not in operation. The maximum brake lining temperature was reduced by 65°C (149°F) as the result of using the Telma retarder.

Similar brake lining temperature measurements in revenue service will be conducted for coaches equipped with hydraulic retarders and Jake brakes.

5.2 BRAKE LIFE EXTENSION FACTOR

The rate of brake wear is a function of frequency and intensity of use. With the use of the retarder, the brake wear is affected by the amount of energy the retarder absorbs. The increase in brake life resulting from the installation of a retarder is commonly referred to as the retarder brake life extension factor.

$$\text{Brake life extension factor:} \quad = \quad \frac{\text{Brake wear without a retarder}}{\text{Brake wear with a retarder}},$$

Revenue service data being collected by transit systems include lining thicknesses for the upper and lower brakes of the left and right wheels of the front and rear axles. Each lining is measured at points A, B, C, and D shown in Figure 3.4. Several graphic representations of the results of such measurements are shown in the appendix.

The charts (Figures 5.2 through 5.7) show typical brake lining wear rate for RTS-II coaches equipped with the three different types of retarders and for control coaches.

Preliminary test data show the following ranges of extension factors. The variation within the range depends on the type of bus and the type of service the bus encounters:

Retarder Type	Extension Factor
Jake Brake	1.3 - 1.65
TELMA	4-6
DDA	4-6

Figure 5.8 represents graphically the comparison of brake life extension factors provided by the three retarder types selected.

5.3 COST ANALYSIS

A primary use of the brake life extension factor is in the projection of maintenance costs over the life of a vehicle. These projections are made on assumptions of a 12-year bus life with an average of 50,000 miles per year:

Cost of brake overhauls per axle used in this analysis is summarized in Table 5.1.

Figures 5.9 to 5.11 represent graphically the difference in service brake maintenance costs projected year-by-year over the life of each bus in each transit system participating, with no retarder or with extension factors representing the range of brake lining of life provided by each of the three retarders tested. These projected costs assume a 10 percent yearly inflation rate. The time value of the original investment and of the periodic expenditures for maintenance have not been considered in this analysis.

Tables 5.2 to 5.4 summarize the savings projected for retarder-equipped buses based on a range of extension factors justified by the data so far gathered in the transit systems conducting the test.

Note that the savings from labor hours saved and for avoided downtime are not translated into dollars and are not added into the "average yearly savings" column. Each transit system using this analysis may wish to use its own experience in making such a translation into dollars.

Installed cost in the tables above is estimated actual installed cost to a transit system retrofitting existing buses with retarders in 1983. It is expected that retrofitting costs will be reduced somewhat as installers become familiar with the process and learn to do it faster.

Original equipment installation of TELMA and DDA retarders is expected to cost about $3,000 less than retrofit; this $3,000 may be added to the net savings column on Tables 5.2, 5.3, and 5.4.

Many operators tend to look at braking cost as consisting of the cost of the linings and the labor charge of fitting them. However, relatively major repair costs are incurred on an irregular basis, when brake drums must be replaced when damaged by overheating or shoe or drum damage occurs as a result of premature lining wear.

Reduced downtime of buses represents a more significant economy over the long range, in a bus fleet, than may seem apparent. In a fleet of reasonable size, it would be possible to reduce the number of vehicles required on grounds of improved operational availability.

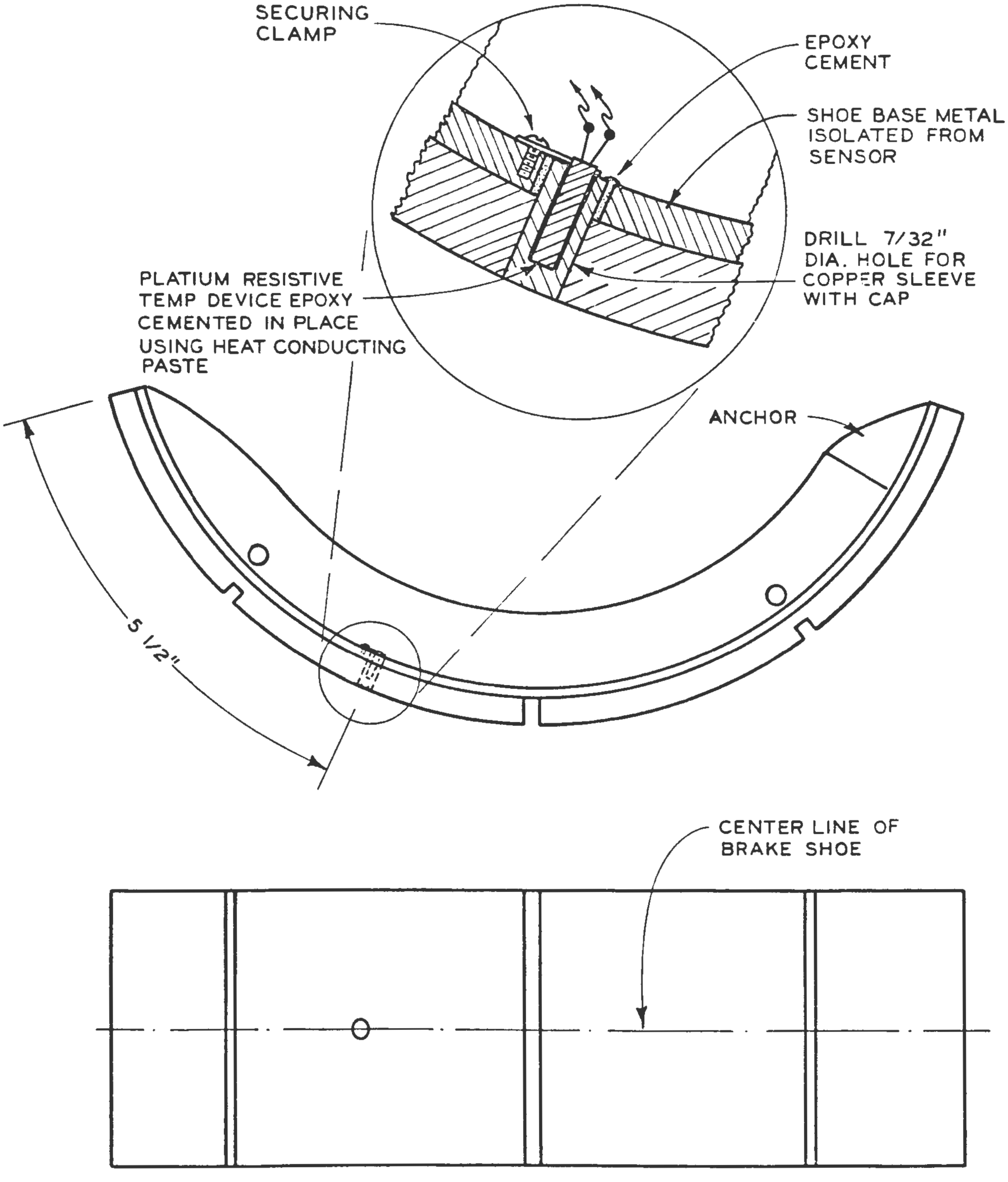
5.4 OTHER BENEFITS

Although benefits in the area of added safety and comfort are outside the range of our program, retarder use throughout the world has generally established these added benefits:

(1) A properly sized retarder can slow a bus down to a safe speed in the event of service brake failure.

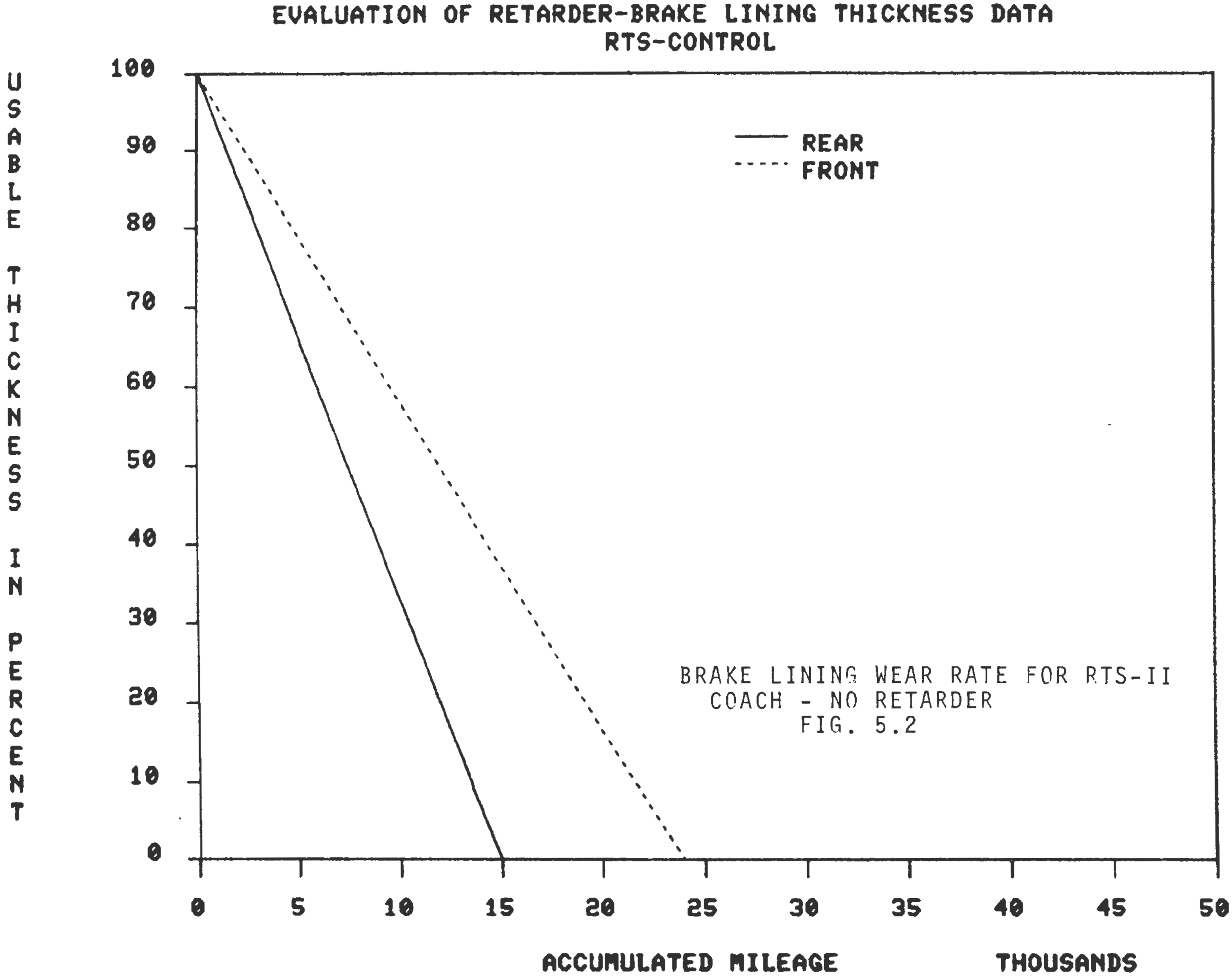
(2) A retarder-equipped bus provides smoother driving and a more comfortable ride for passengers, along with a reduction in driver fatigue.

(3) A retarder provides added safety, unrelated to the viability of any other brake system, under downhill driving conditions.

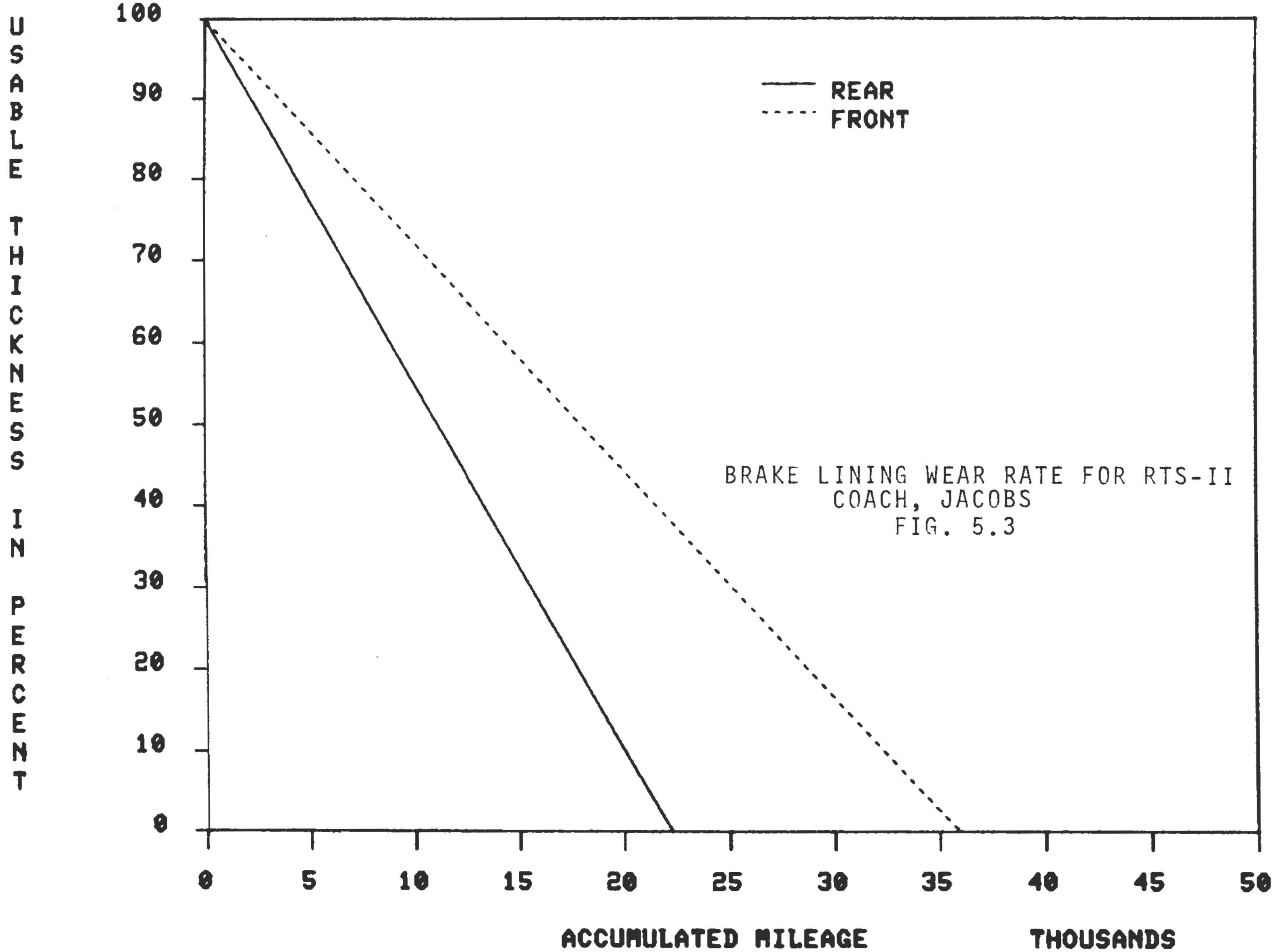


BRAKE LINING TEMPERATURE MEASUREMENTS

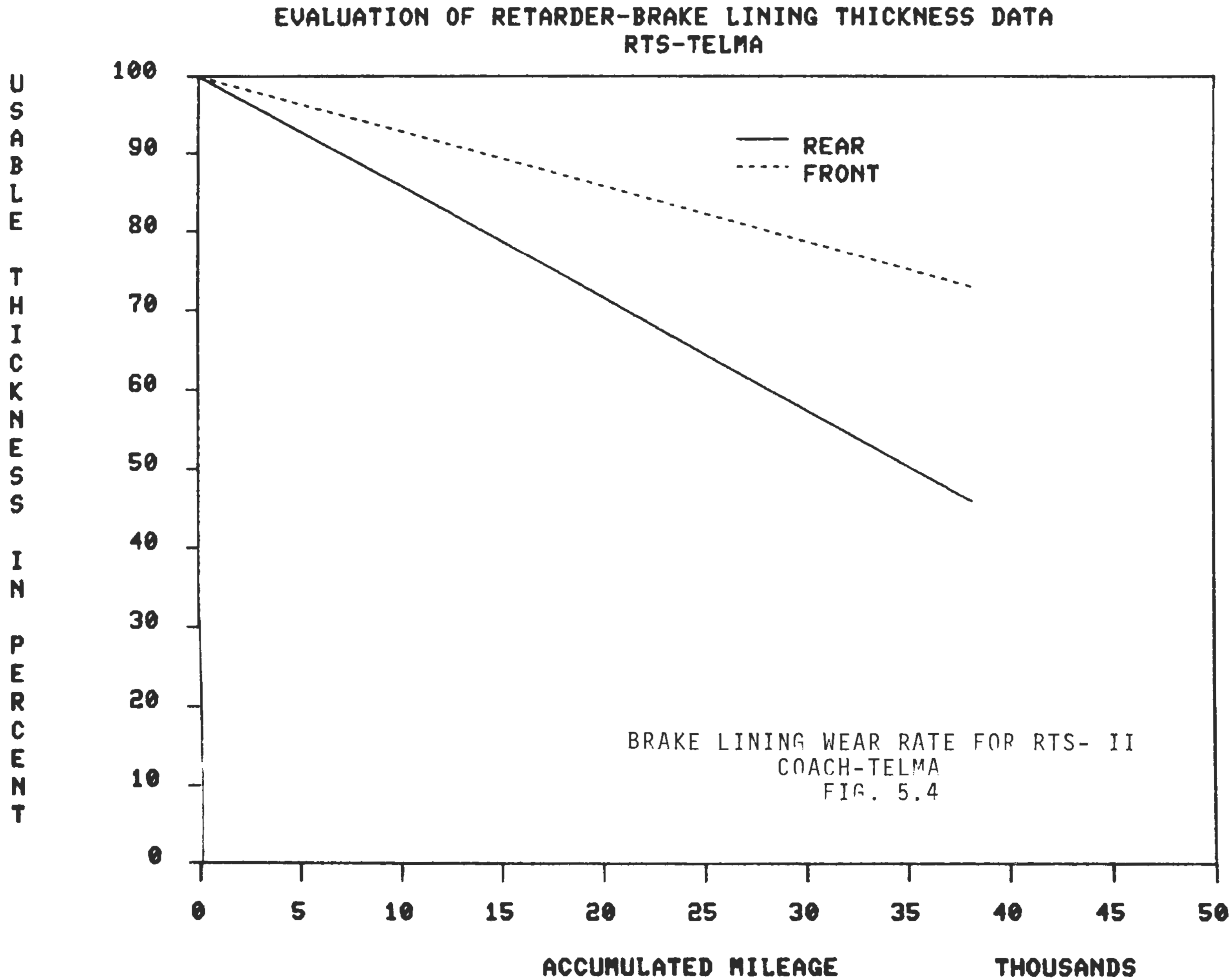
FIG. 5.1


EVALUATION OF RETARDER-BRAKE LINING THICKNESS DATA
RTS-CONTROL
USABLE THICKNESS IN PERCENT
100
90
80
70
60
50
40
30
20
10
0
REAR
FRONT
BRAKE LINING WEAR RATE FOR RTS-II
COACH - NO RETARDER
0
5
10
15
20
25
30
35
40
45
50
ACCUMULATED MILEAGE
THOUSANDS
FIG. 5.2

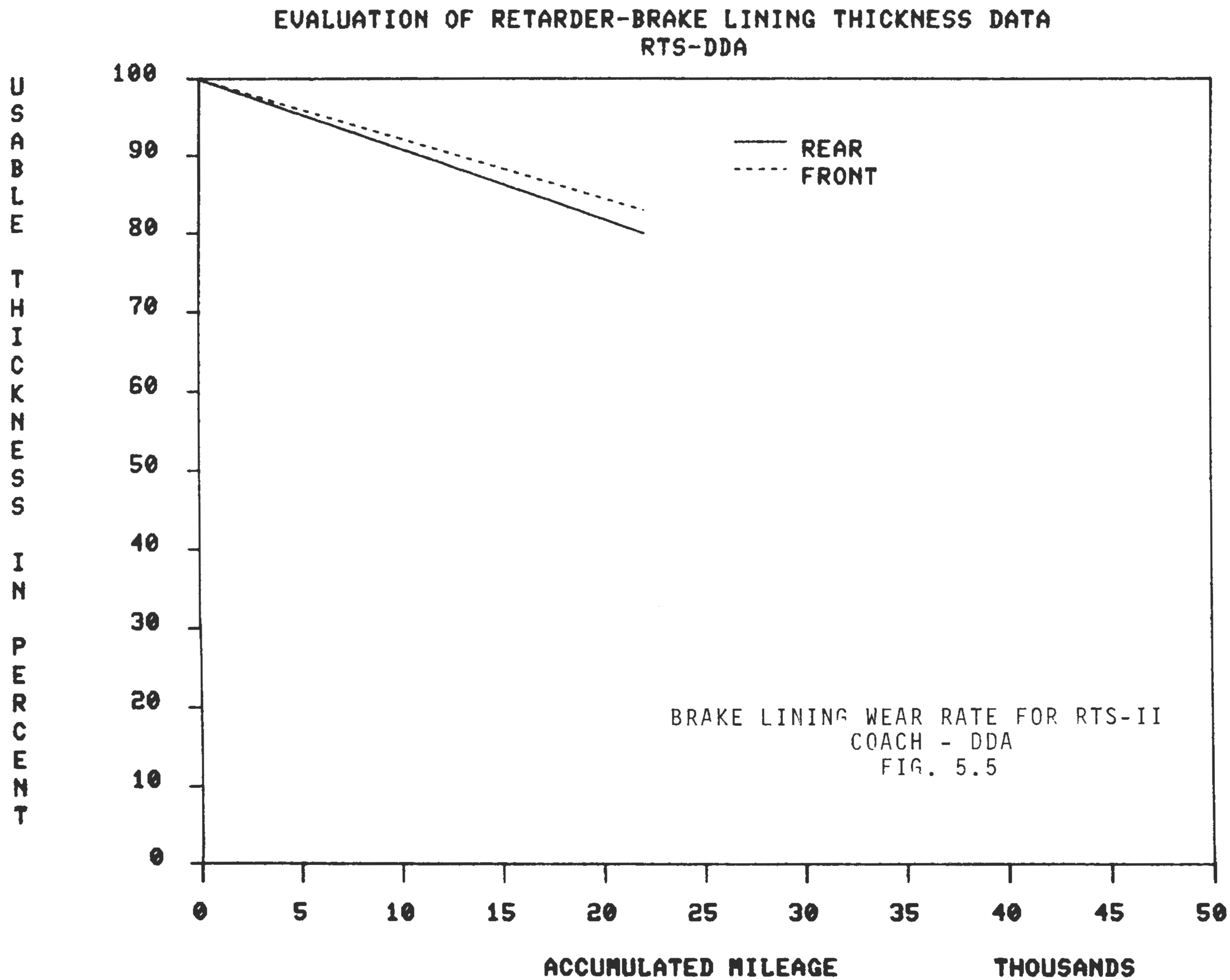
EVALUATION OF RETARDER-BRAKE LINING THICKNESS DATA
RTS-JACOBS



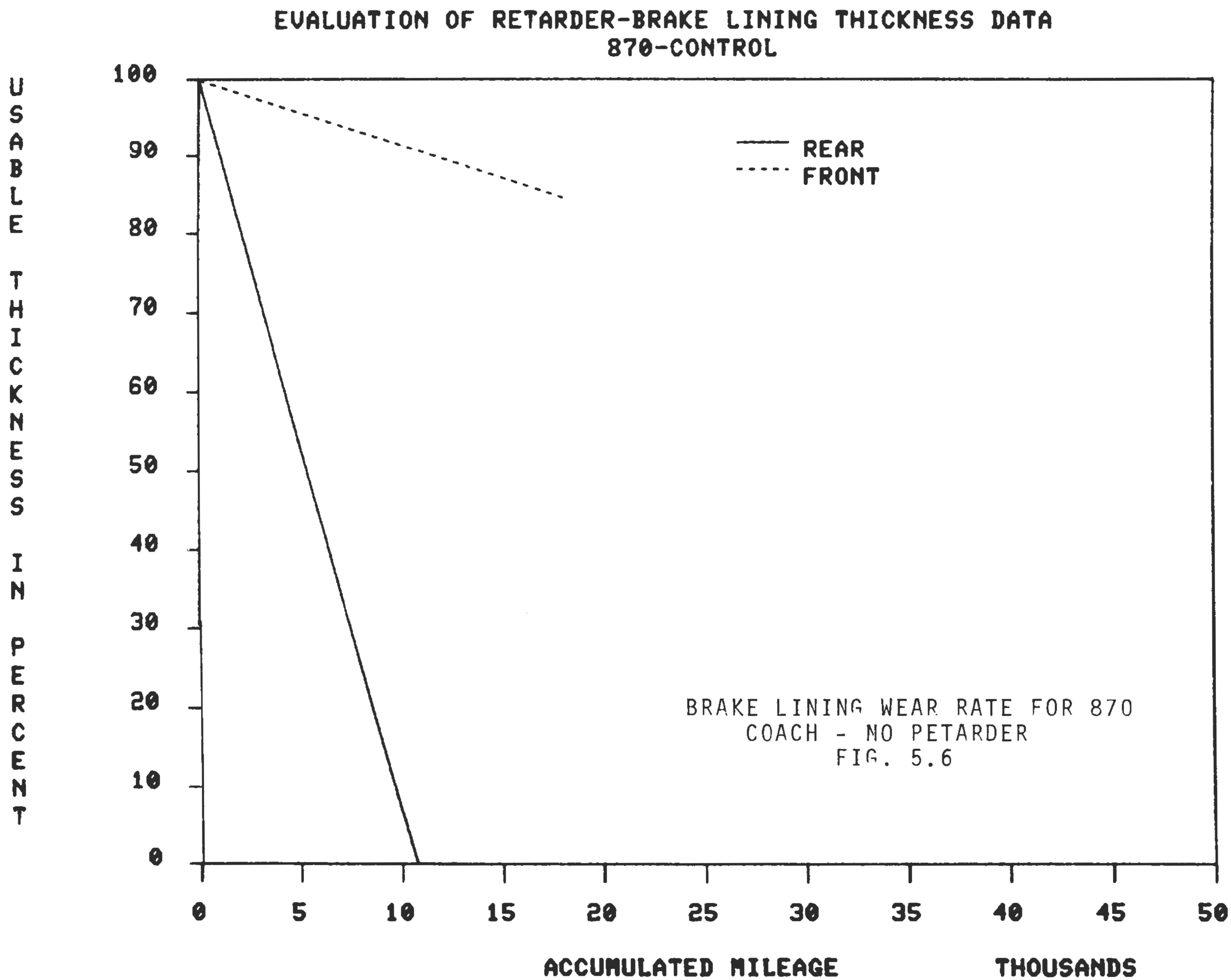
BRAKE LINING WEAR RATE FOR RTS-II
COACH, JACOBS
FIG. 5.3



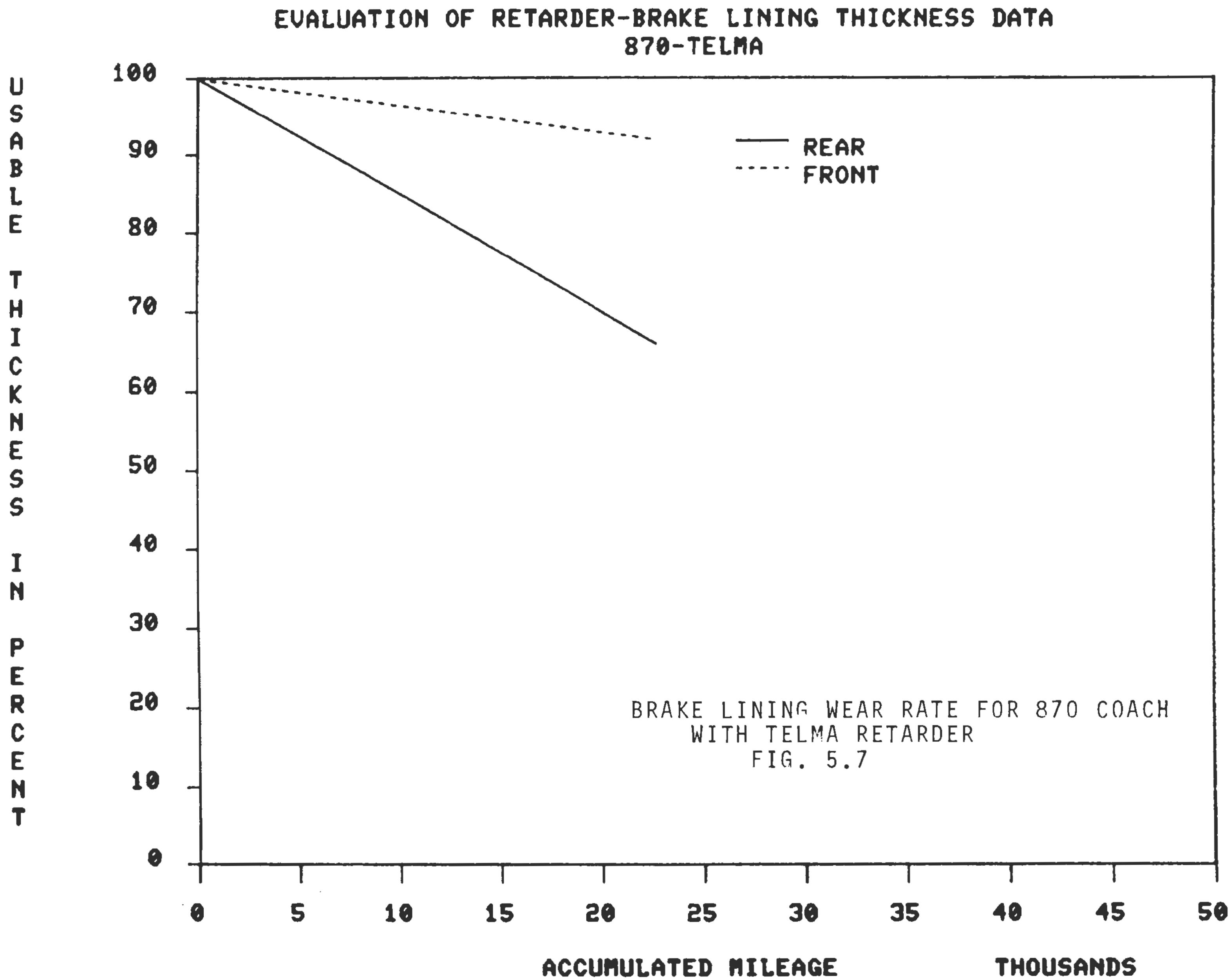
BRAKE LINING WEAR RATE FOR RTS- II
COACH-TELMA
FIG. 5.4



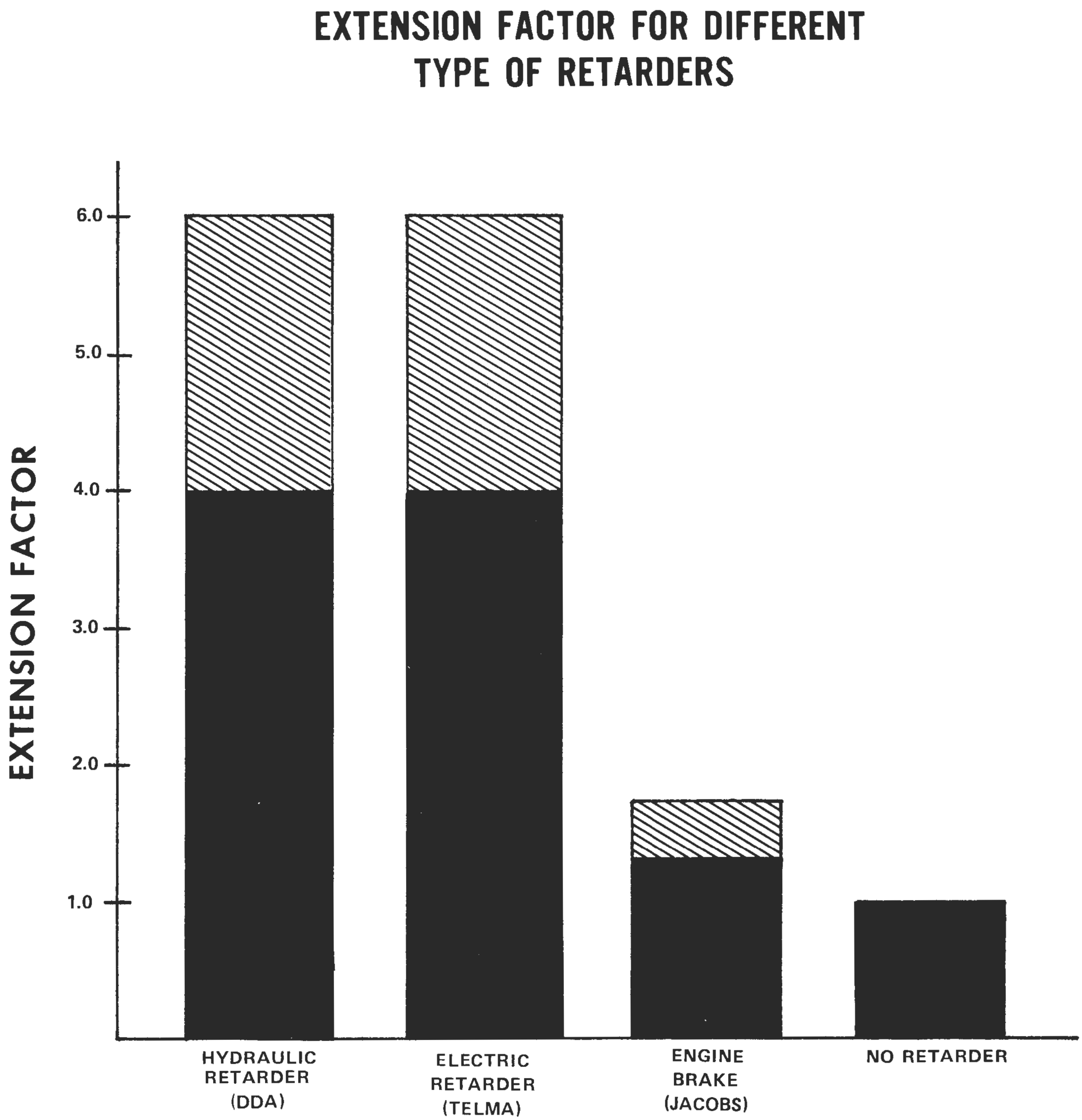
BRAKE LINING WEAR RATE FOR RTS-II
COACH - DDA
FIG. 5.5



BRAKE LINING WEAR RATE FOR 870
COACH - NO PETARDER
FIG. 5.6



BRAKE LINING WEAR RATE FOR 870 COACH
WITH TELMA RETARDER
FIG. 5.7



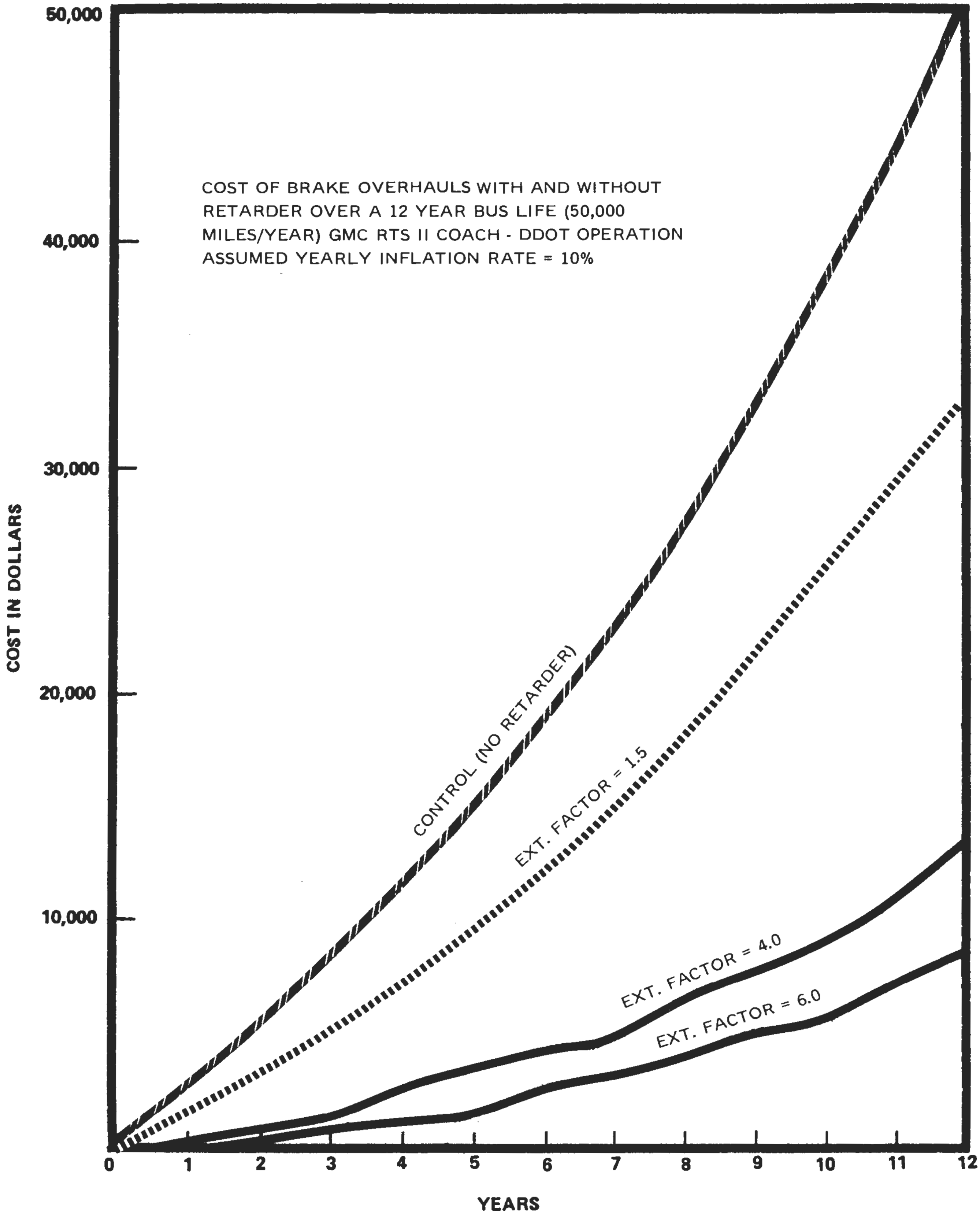
COMPARISON OF BRAKE LIFE EXTENSION FACTORS
FIG. 5.8

TRANSIT AUTHORITY	BUS MAKE	AXLE	MINOR	MAJOR	COST OF DRUMS	DOWN TIME
DDOT	RTS	FRONT	220.00	450.00	210.00	4 DAYS
		REAR	250.00	480.00	320.00	4 DAYS
GRATA	870	FRONT	320.00	330.00	240.00	2 DAYS
		REAR	350.00	390.00	270.00	2 DAYS
CATA	RTS	FRONT	250.00	480.00	210.00	2 DAYS
		REAR	310.00	540.00	320.00	2 DAYS

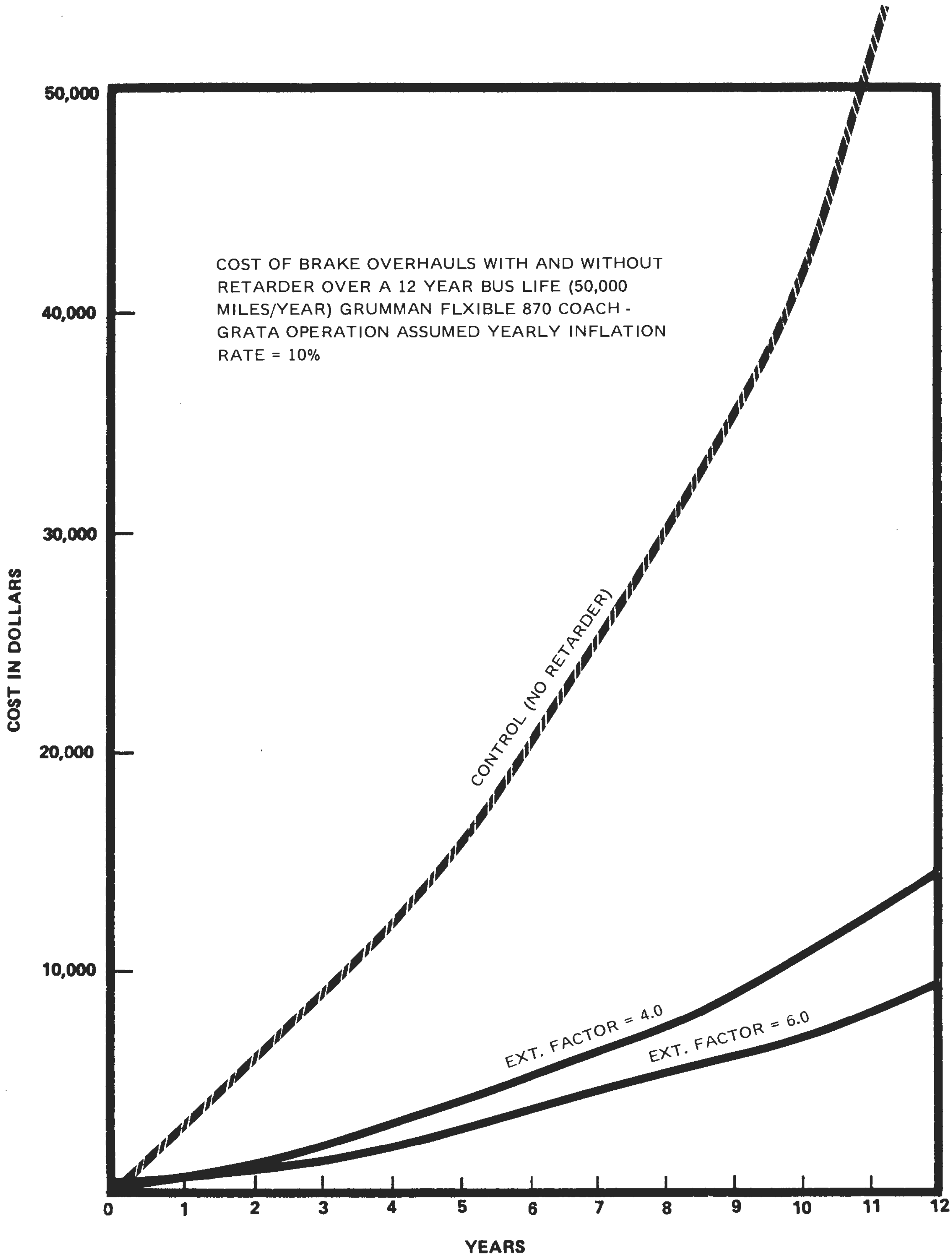
(1983 Costs; 10% annual inflation factor should be allowed in projecting costs in future years)

COST OF BRAKE OVERHAULS PER AXLE

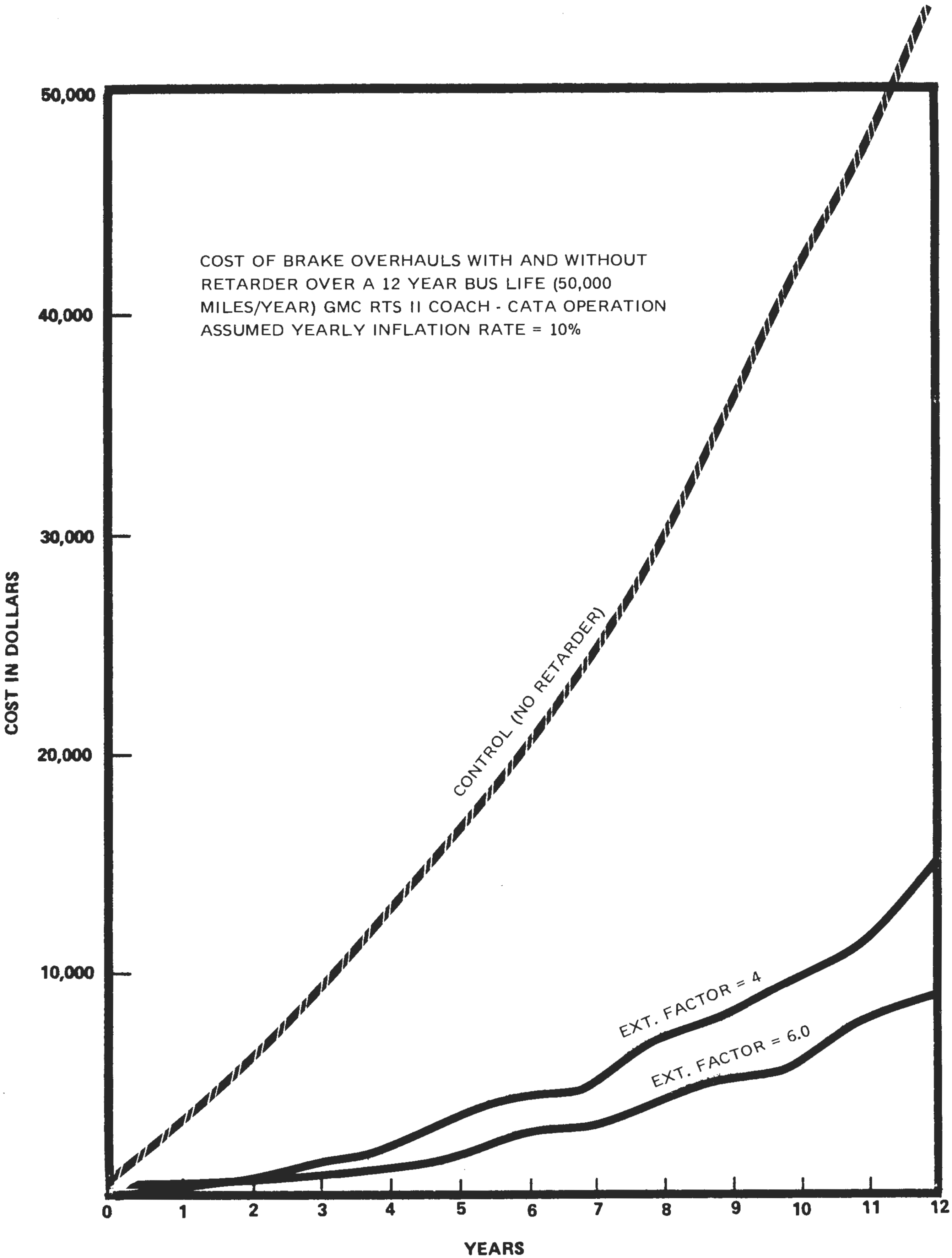
TABLE 5.1



SERVICE BRAKE MAINTENANCE COST PROJECTED OVER THE LIFE OF THE BUS - DDOT
FIG. 5.9



SERVICE BRAKE MAINTENANCE COST PROJECTED
OVER THE LIFE OF THE BUS-GRATA
FIG. 5-10



SERVICE BRAKE MAINTENANCE COST PROJECTED OVER THE LIFE OF THE BUS - CATA

FIG. 5.11

SUMMARY OF RETARDER BENEFITS

DETROIT DOT

GMC RTS II COACHES

RETARDER			SERVICE BRAKE MAINTENANCE COSTS		RESULTING SAVINGS					
Type	Installed Cost $	Ext. Factor	No Retarder $	With Retarder $	Gross Savings $	Avg. Yrly. Savings $	Net Savings $	Savings Per Mile $	Labor Hrs. Saved	Avoided Down Time Days
JACOBS	1960	1.5	51,961	33,251	18,710	1,559	16,750	0.028	244	87
TELMA	8645	4.0	51,961	13,607	38,354	3,196	29,709	0.050	548	195
		5.0	51,961	10,135	41,826	3,486	33,181	0.055	585	208
		6.0	51,961	8,575	43,386	3,616	34,741	0.058	609	217
DDA	8838	4.0	51,961	13,607	38,354	3,196	29,516	0.049	548	195
		5.0	51,961	10,135	41,826	3,486	32,988	0.055	585	208
		6.0	51,961	8,575	43,386	3,616	34,548	0.058	609	217

TABLE 5.2

SUMMARY OF RETARDER BENEFITS

GRATA

870 GRUMMAN COACHES

RETARDER			SERVICE BRAKE MAINTENANCE COSTS		RESULTING SAVINGS					
Type	Installed Cost $	Ext. Factor	No Retarder $	With Retarder $	Gross Savings $	Avg. Yrly. Savings $	Net Savings $	Savings Per Mile $	Labor Hrs. Saved	Avoided Down Time Days
TELMA	8645	4.0	51,389	13,210	38,179	3,182	29,534	0.049	683	98
		5.0	51,389	10,163	41,226	3,436	32,581	0.054	728	104
		6.0	51,389	8,185	43,204	3,600	34,559	0.058	758	108

TABLE 5.3

SUMMARY OF RETARDER BENEFITS

CATA

GMC RTS II COACHES

RETARDER			SERVICE BRAKE MAINTENANCE COSTS		RESULTING SAVINGS					
Type	Installed Cost $	Ext. Factor	No Retarder $	With Retarder $	Gross Savings $	Avg. Yrly. Savings $	Net Savings $	Savings Per mile $	Labor Hrs. Saved	Avoided Down Time Days
TELMA	8645	4.0	57,648	15,059	42,589	3,549	33,944	0.057	536	98
		5.0	57,648	11,326	46,322	3,860	37,677	0.063	572	104
		6.0	57,648	9,453	48,195	4,016	39,550	0.066	596	108

TABLE 5.4

6.0 VERIFICATION TESTS

6.0 VERIFICATION TESTS

6.1 FUEL ECONOMY

The installation of vehicle retarders on transit coaches results in changes in the coach's curb weight, drive line inertia, heat rejection to the cooling system, and/or engine valve timing. These changes could have an effect on the coaches' fuel economy. Measurement of these changes in fuel consumption is an important factor in evaluating the braking devices. However, the uncontrollable variables associated with revenue service preclude accurate measurements of the fuel consumption changes. Therefore, a formal test in a controlled environment, using the general procedures of SAE J1321, Type II test, was conducted.

The fuel economy test was conducted in Michigan by DDOT. Booz, Allen & Hamilton, Inc., was responsible for planning and directing the test program and evaluating the test results.

The conclusion that can be drawn from the test data is that retarders do not produce a significant change in fuel consumption. The following is a summary of the test results as reported by Booz, Allen & Hamilton, Inc.:

Coach #	Type of Retarder	Change in Fuel Consumption
1543	Jacobs	+0.2%
1817	TELMA	-0.7%
1865	DDA	+1.8%

(Test level of accuracy ± 1 percent)

6.2 COMPONENTS ADJACENT TO THE ELECTRIC RETARDER

The electric retarder produces heat which may affect components adjacent to it. As a part of this program, the temperatures of the coach floor directly above the retarder and that of the right rear air bag, adjacent to the retarder (Figure 6-1), were measured in revenue service. Maximum temperatures recorded with retarder in operation were 39°C (102°F) for the air bag and 47°C (117°F) for the floor.

To date, no evidence of any damage to the floors or air bags of TELMA retarder equipped coaches, as a result of excess heat, has been reported.

6.3 FLUID TEMPERATURE

The heat removed from the hydraulic retarder by the oil is normally transferred to the engine cooling water system by means of an oil-to-water heat exchanger; the existing radiator and fan are then used to dissipate the heat to the atmosphere. Proper attention to cooling is, therefore, essential.

DDA's engineers have measured and recorded the temperatures of transmission fluid, engine oil, and coolant for a hydraulic retarder test coach in revenue service. All fluid temperatures measured were within acceptable limits.

DDA's engineers recommended the elimination of the Hayden cooler in future hydraulic retarder installations for the 36,000-lb. GVW US transit coach in duty cycles similar to Detroit operation.

7.0 RETARDER ADAPTABILITY TO ADBs

7.0 RETARDER SYSTEMS ADAPTABILITY TO ADB

The "Evaluation of Retarders" program, representing as it does the first installations of retarders ever made in ADB, inevitably encountered problems in adapting ADB to retarder installation.

Valuable experience has resulted from the joint effort of all personnel concerned--in transit systems, retarder manufacturers and their suppliers--during the retarder adaptation and revenue service testing. The considerable body of work which would have been necessary at any future time to retrofit ADB with retarders has largely been accomplished.

7.1 START-UP PROBLEMS ENCOUNTERED

To date, all the retarders, Jacobs, TELMA, and DDA have been functioning very well. Some start-up problems, however, have been encountered with both TELMA and DDA retarders.

TELMA has encountered differential problems and control problems.

All RTS coaches equipped with TELMA retarders have experienced differential problems at the beginning of the test. TELMA engineers determined that the pinion flanges were not properly refaced during the installation. After all of the flanges were refaced and the retarders re-installed, differential problems have not recurred.

Based on the experience gained from the original Detroit installation, TELMA and Rockwell engineers have designed and developed a different type of installation called the OEM-type which includes parts manufactured by Rockwell specifically designed to adapt the TELMA retarder to the coach differential.

One of the original DDOT TELMA installations has been converted to the OEM-type installation. All GRATA and CATA installations are of the OEM-type.

TELMA's control problems included defective pressure and speed switches and relays. With TELMA's recent modification of its control system and the additional training of mechanics on how to maintain and trouble-shoot the electrical components, control problems have been significantly reduced. However, there is still room for further improvement in the TELMA retarder control system.

The DDA retarder provides high braking power and is fast in response compared to other hydraulic retarders. However, a number of test days were lost from the DDA retarder coaches because of control problems.

First, as recommended by DDA, the WABCO valve (Figure 7.1) was installed to control the retarder. This valve is commonly used in Europe and is designed to delay the foundation brakes until the retarder is fully activated for maximum utilization of retarder braking efforts (Figure 7.2). Detroit drivers claimed that the brakes felt different with WABCO and some refused to drive the bus. Next, DDA recommended a proportioning valve. The proportioning valve (Figure 7.3) controlled the retarder in a satisfactory manner but has been demonstrating low reliability in revenue service. We have worked with Bendix Corporation; they have developed an alternative: a new amplifying relay valve (Figure 7.4) designed to control the DDA retarder. The valve has been installed in one DDOT RTS-II coach and is now being tested in revenue service.

Nearly all the start-up problems that we have encountered have been resolved through the cooperation of retarder manufacturers and suppliers.

7.2 RETARDER RETROFIT EVALUATION

The first of the two objectives of "Evaluation of Vehicle Retarders" program , as stated in Section 1.3, is this:

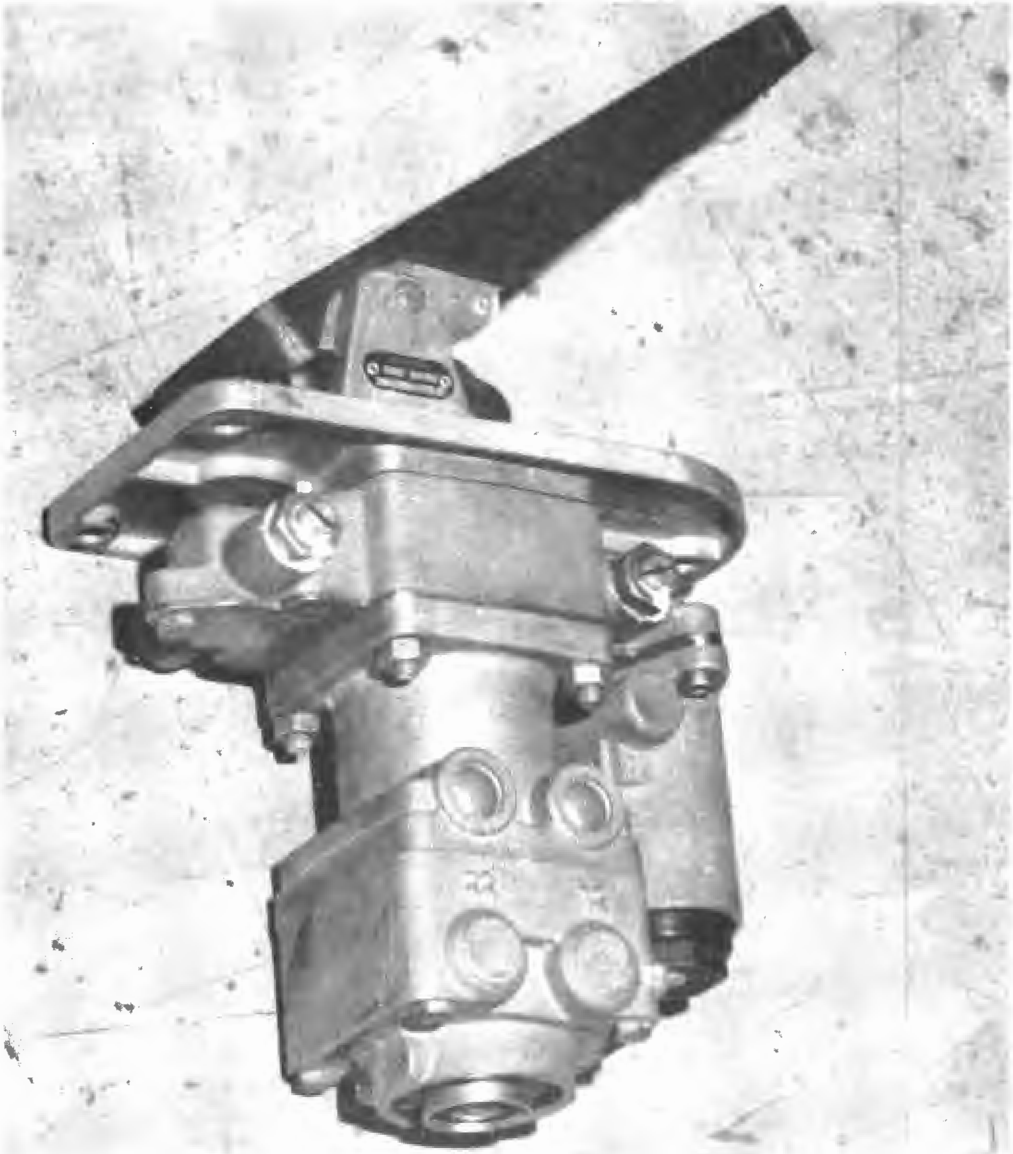
> "Determine the adaptability of vehicle retarders in advance design buses (ADB)."

The experience of these first years of the program has demonstrated that retarders are adaptable to ADB installation and use.

The second and fourth of the four benefits expected from the program, as stated in Section 1.3, are these:

> "An opportunity for transit operators to assess the cost and effort of retrofitting different types of retarders in transit coaches."
>
> "Actual operational experience on the use of different types of retarders in the U.S. market. This revenue service data will assist the retarder manufacturers to improve their products prior to the introduction of brake retarders in widespread service."

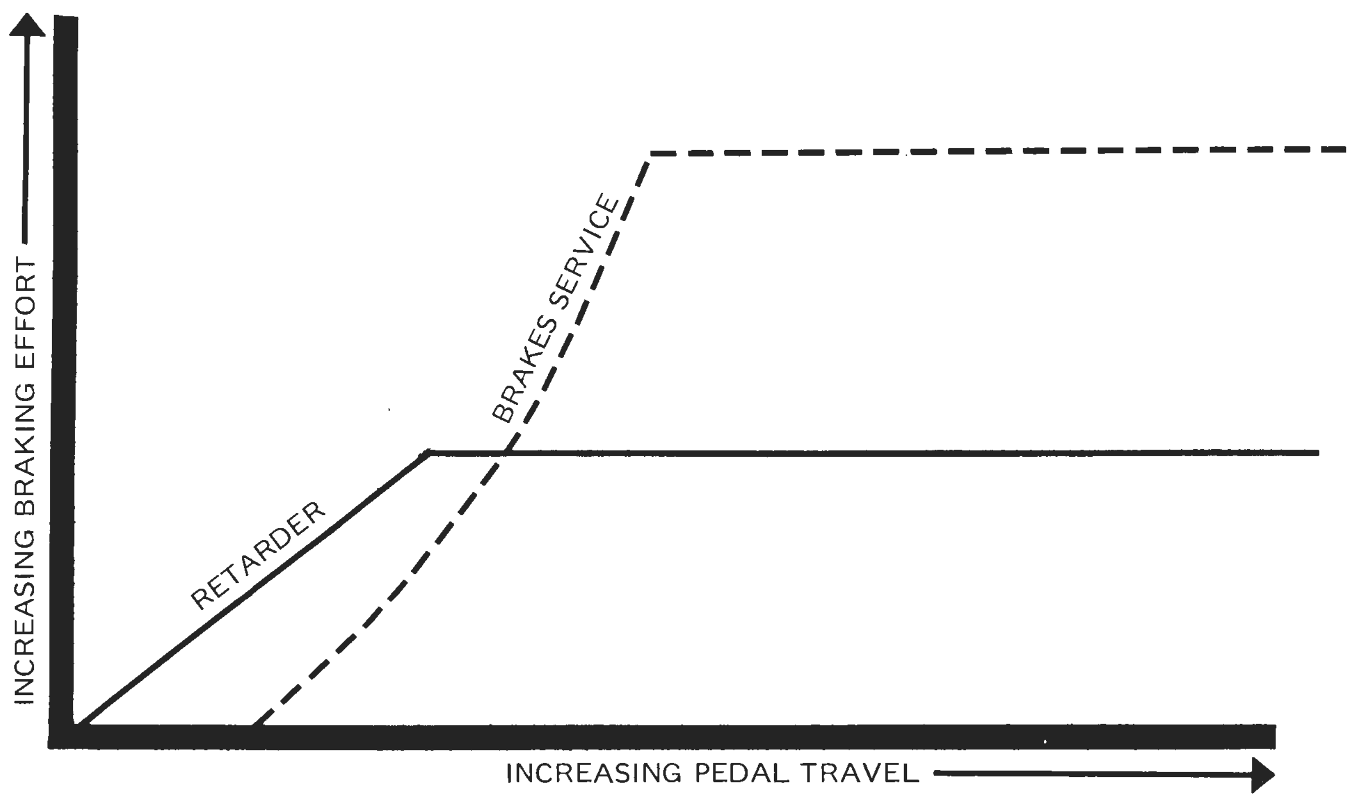
The actual process of retrofitting ADBs for the program, route testing, and adjusting the retrofit and auxiliary equipment problems shown up by the testing has already accomplished both these benefits, for the present, and has laid the groundwork for further engineering requirements directed at making retrofitting easier and less costly and manufacturers' products more readily adaptable.



WABCO VALVE FORMERLY USED TO CONTROL DDA RETARDER

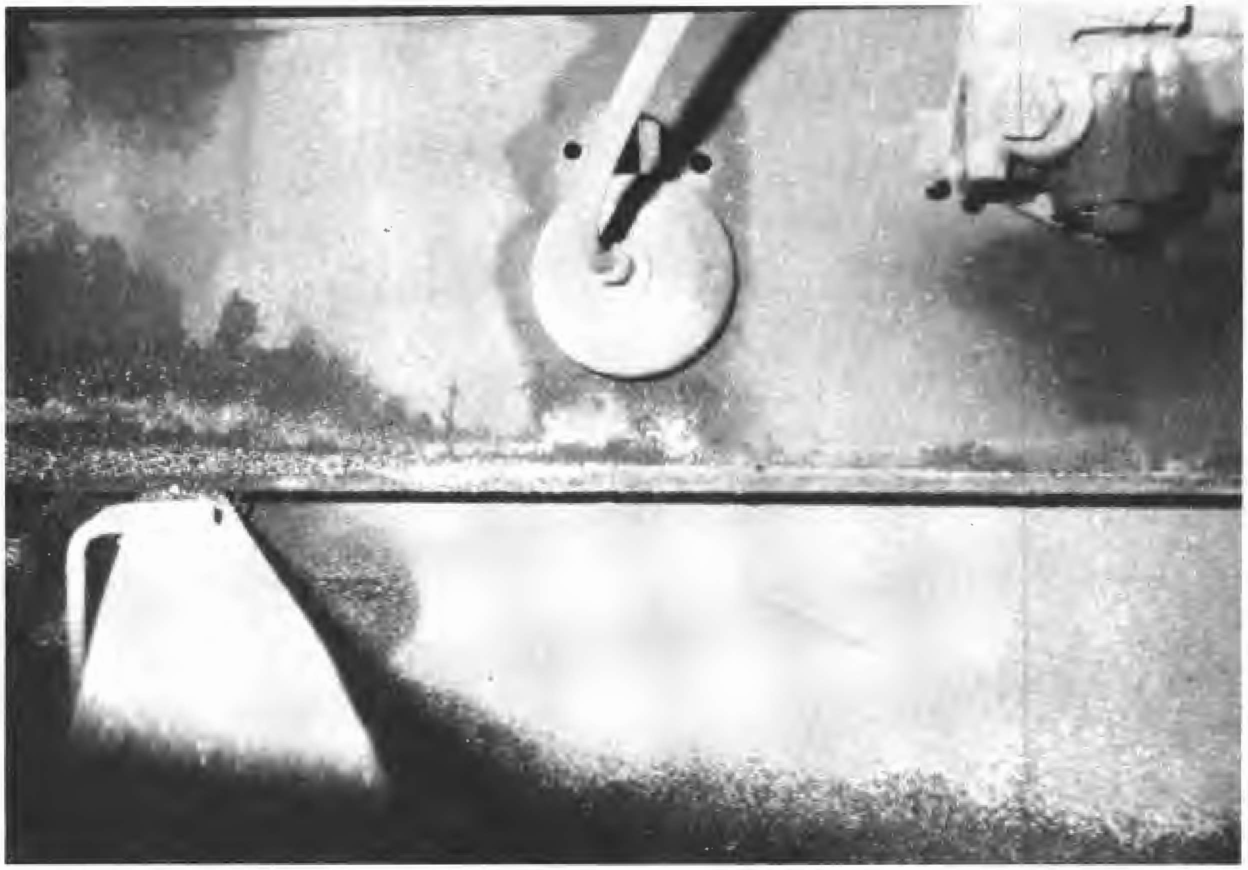
FIG. 7.1

COMMON MT RETARDER CONTROL SYSTEM



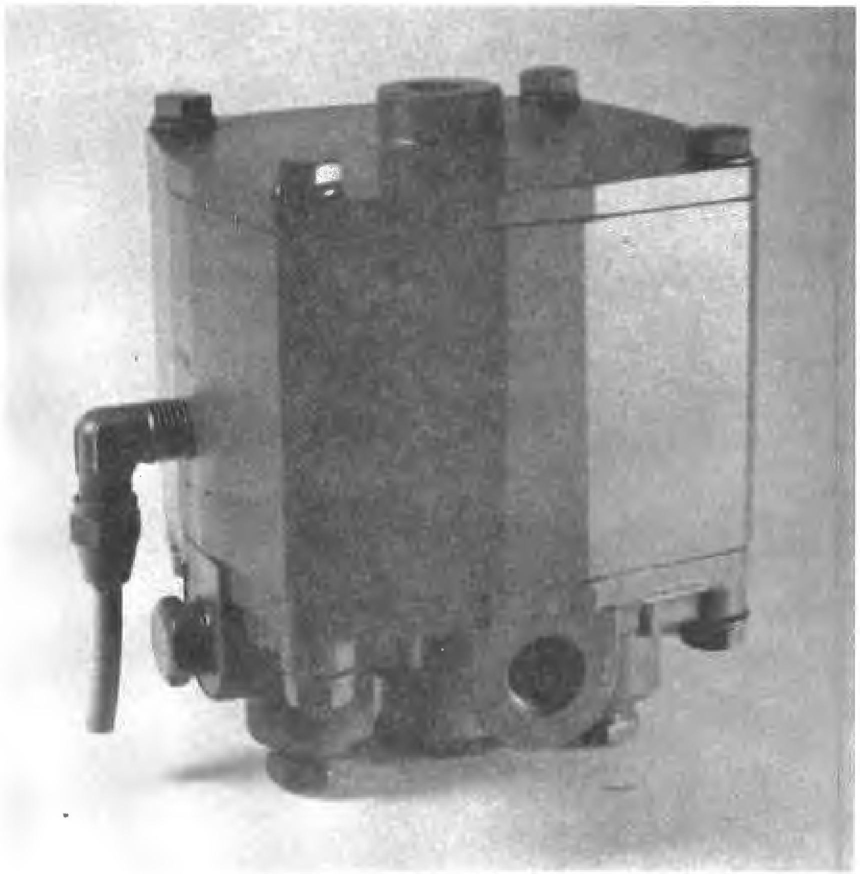
RETARDER BRAKING EFFORT USING WABCO VALVE

FIG. 7.2



PROPORTIONING VALVE

FIG. 7.3



BENDIX AMPLIFYING RELAY VALVE

FIG. 7.4

8.0 OTHER TRANSIT SYSTEMS' RETARDER INSTALLATIONS

8.0 OTHER TRANSIT SYSTEMS' RETARDER INSTALLATIONS

This chapter provides information supplied by retarder manufacturers on use of their retarders by transit systems in the USA, including number of retarders in use, type of retarder, and when available, type of bus.

TELMA Retarders

Transit system installation of TELMA retarders had been limited to older design, new look, or small buses until DDOT, GRATA, and CATA installations in ADBs for this evaluation project. Following is a listing of transit systems with their TELMA retarder installations.

REGIONAL TRANSIT DISTRICT - Denver, CO

127	F155 retarder, G.M., Ltd., 102" width
2	F155 retarder, AMG 102" width

ORANGE COUNTY TRANSIT DISTRICT - Garden Grove, CA

95	CE30 retarder, Fort cut-away van
1	CE30 retarder, Dodge cut-away van
1	F155 retarder, New Look Flxible 102" width
2	F130 retarder, RTS coach 102" width
67	CA65 and CA100 Transcoach buses

UTAH TRANSIT AUTHORITY - Salt Lake City, UT

30	F155 retarder, G.M. Ltd. 102" width

A.C. TRANSIT - Oakland, CA

141	F130 retarder, Gillig
60	F155 retarder, Neoplan
19	F155 retarder, Flyer 102" width
11	F130 retarder, Flyer 102" width
1	F155 retarder, GMC 102" width

MARTA - Atlanta, GA

49	F155 retarder, Neoplan
46	F170 retarder, Neoplan articulated coaches

PORT AUTHORITY OF ALLEGHENY COUNTY - Pittsburgh, PA

1	F155 retarder, GMC New Look 102" width
100	F155 retarder, Neoplan

SEPTA - PA

25	F155 retarder, Neoplan

KANSAS CITY TRANSIT - MO

28	CE30 retarder, Coach and Equipment

MILWAUKEE TRANSIT - WI

1	F155 retarder, Flxible New Look 102" width
10	F155 retarder, Neoplan

MADISON TRANSIT - WI

4	CC80 retarder, Chance

SANTA CRUZ - CA

4	F130 retarder, Gillig

LYNCHBURG - VA

5	F155 retarder, Neoplan

ROCKFORD - IL

24	F155 retarder, Neoplan

CITY/COUNTY OF HONOLULU - HA

1	F155 retarder, AMG 102" width
10	CC80 retarder, Chance

SACRAMENTO REGIONAL TRANSIT - CA

1	F155 retarder, Flxible New Look 102" width
23	F130 retarder, Gillig

UTICA - NY

4	F130 retarder, Orion

ANCHORAGE - AK

23	F155 retarder, Flyer

IOWA CITY - IA

7	F155 retarder, Neoplan

SAN MATEO - CA

22	F130 retarder, Gillig

SIMI VALLEY - CA

4	F130 retarder, Gillig

LAREDO - TX

12 F130 retarder, Gillig

RICHMOND - CA

2 CE30 retarder, CMC

PORTLAND - OR

3 CE30 retarder, Wide-One

BI-STATE DEVELOPMENT AGENCY - St. Louis, MO

1 F155 retarder, Flxible New Look 102" width

COUNTY OF SANTA CLARA - San Jose, CA

1 F155 retarder, GMC 102" width

GOLDEN GATE BRIDGE TRANSPORTATION - San Rafael, CA

1 F155 retarder, GMC 102" width

GREATER RICHMOND TRANSIT - Richmond, VA

1 F155 retarder, Flxible 102" width

SEATTLE METRO - Seattle, WA

1 F155 retarder, AMG, 102" width

NEW YORK CITY TRANSIT AUTHORITY - New York, NY

2 F155 retarder, Flxible New Look 102" width

SAN DIEGO TRANSIT - CA

1 F155 retarder, Flxible New Look 102" width

SORTA - Cincinnati, OH

1 F155 retarder, Flxible New Look 102" width

CHICAGO TRANSIT - Chicago, IL

1 F155 retarder, GMC New Look 102" width

DETROIT-DOT - Detroit, MI

3 F130 retarder, RTS II

GRAND RAPIDS TRANSIT - Grand Rapids, MI

3 F130 retarder, Flxible 870

CAPITAL AREA TRANSIT AUTHORITY - Lansing, MI

JACOBS

The information supplied by Jacobs Manufacturing Company did not include type of bus.

SAN FANSISCO MUNICIPAL TRANSIT - San Fransisco, CA

540 Engine Brakes

CITY OF HONOLULU TRANSIT - Honolulu, HI

100 Engine Brakes

LOS ANGELES RAPID TRANSIT DISTRICT - Los Angeles, CA

2 Engine Brakes

22 Electric Retarders

CITY OF COMMERCE TRANSIT - City of Commerce, CA

5 Engine Brakes

ALOQUIPA COUNTY TRANSIT AUTHORITY - PA

3 Electric Retarders

REGIONAL TRANSPORT DISTRICT - Denver, CO

50 Engine Brakes

UTAH TRANSPORTATION AUTHORITY - Salt Lake City, UT

40 Engine Brakes

KING COUNTY TRANSIT - Seattle, WA

90 Engine Brakes

DALLAS TRANSIT - Dallas, WA

20 Engine Brakes

DETROIT DOT - Detroit, MI

2 Engine Brakes

DDA Retarder

V-730 transmissions with DDA retarders have been placed in service on DDOT routes. There is also one VB-730 in service at Montreal Transit. Two hundred MTB644 hydraulic retarders have been running in Europe in city bus applications. There are two MTB644 in transit service in Windsor and Toronto, Canada. Twenty-two MTB644's in Orion (OBI) buses are in service at Indianapolic Public Transportation Corporation.

DETROIT DOT - Detroit, MI

2 V731 retarder, RTS II

9.0 RECOMMENDATION AND WORK PLANNED FOR THE NEXT SIX MONTHS

9.0 RECOMMENDATION AND WORK PLANNED FOR THE NEXT SIX MONTHS

9.1 RECOMMENDATIONS

a. It is less expensive to purchase the retarder as an option on a new coach compared to retrofit type installation. We feel, therefore, that transit systems considering the use of a retarder should specify the retarder during the new coach purchases, if possible.

b. A retarder is another piece of equipment in the coach which requires maintenance and which mechanics are not familiar with. Transit systems should be aware of this fact and be prepared to offer additional training to their mechanics.

c. When a retarder is used in a vehicle, it is considered as an integral part of the entire coach braking system. Safety regulations governing the brake systems of vehicles equipped with retarders should, therefore, be developed. Such regulations are already in existence in Europe.

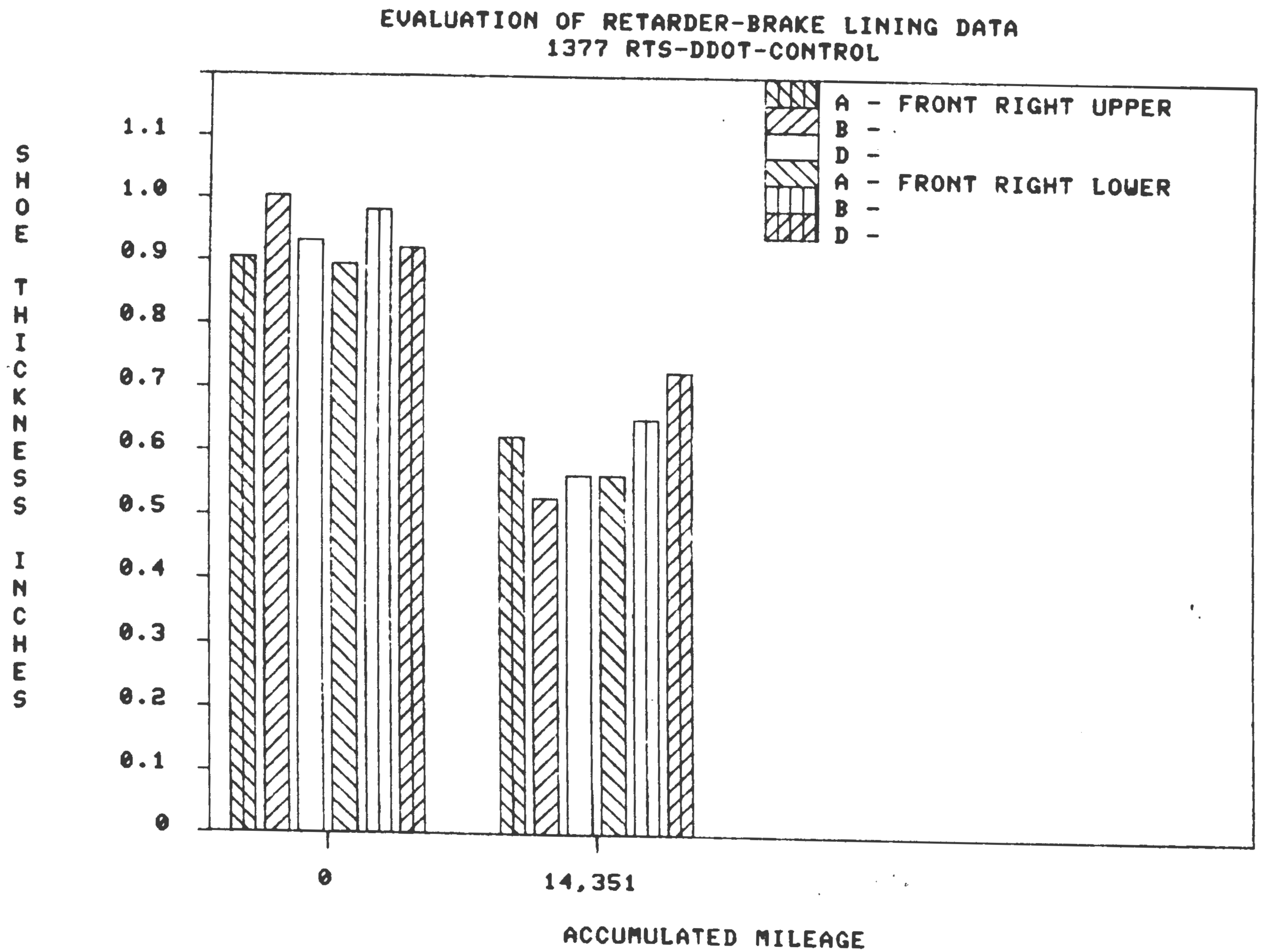
9.2 WORK PLANNED FOR THE NEXT SIX MONTHS

- Evaluate the new amplifying relay valve developed by Bendix Corporation to control the hydraulic retarder.
- Measure, in revenue service, the brake lining temperatures for coaches equipped with hydraulic retarders and Jake brakes.
- Continue monitoring brake lining wear data and maintenance activities of all test and control coaches with emphasis on new TELMA OEM-type installations and control improvements.
- Develop a complete life cycle cost analysis for the use of vehicle retarder in coaches.
- Prepare the final report.

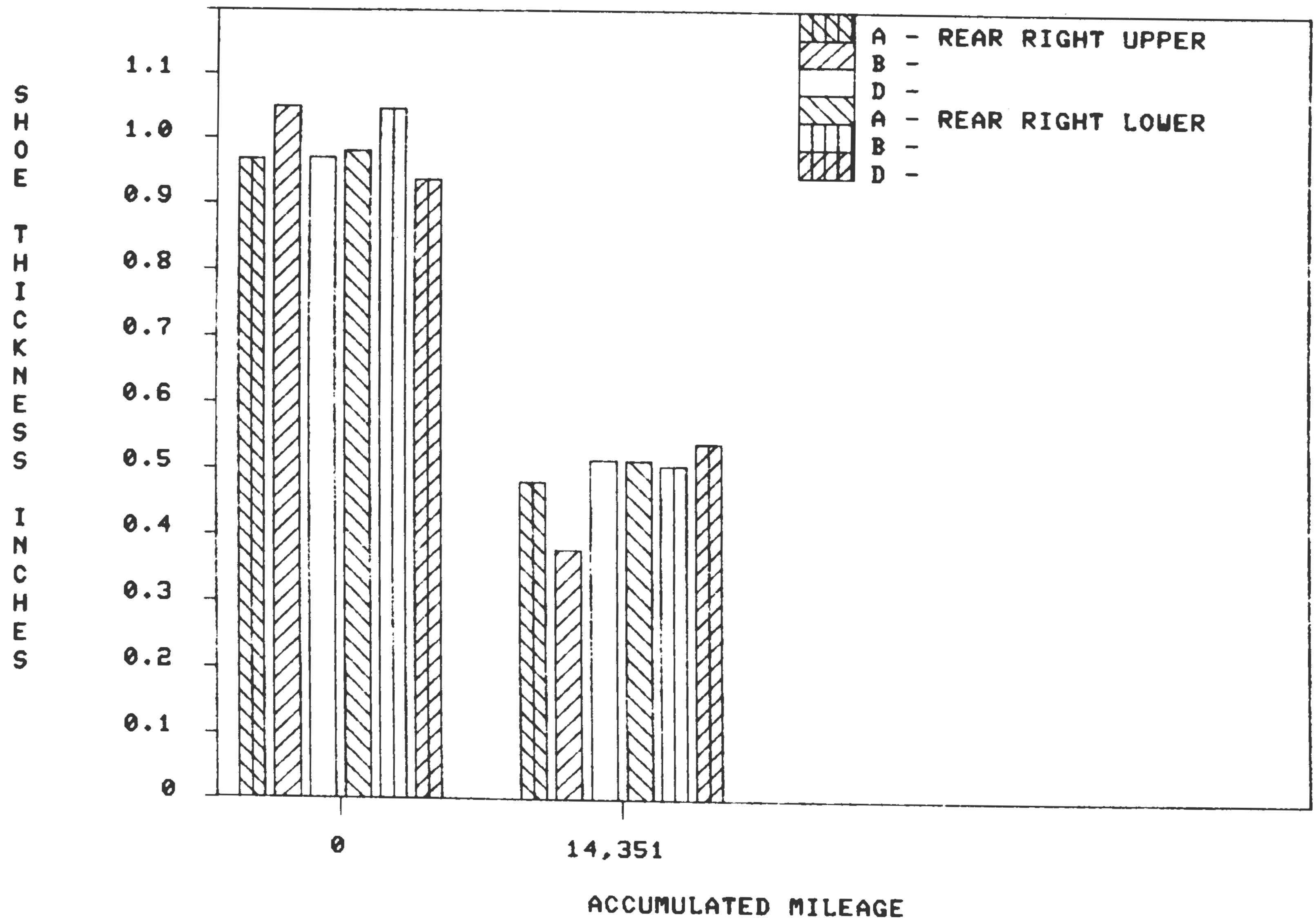
828-9

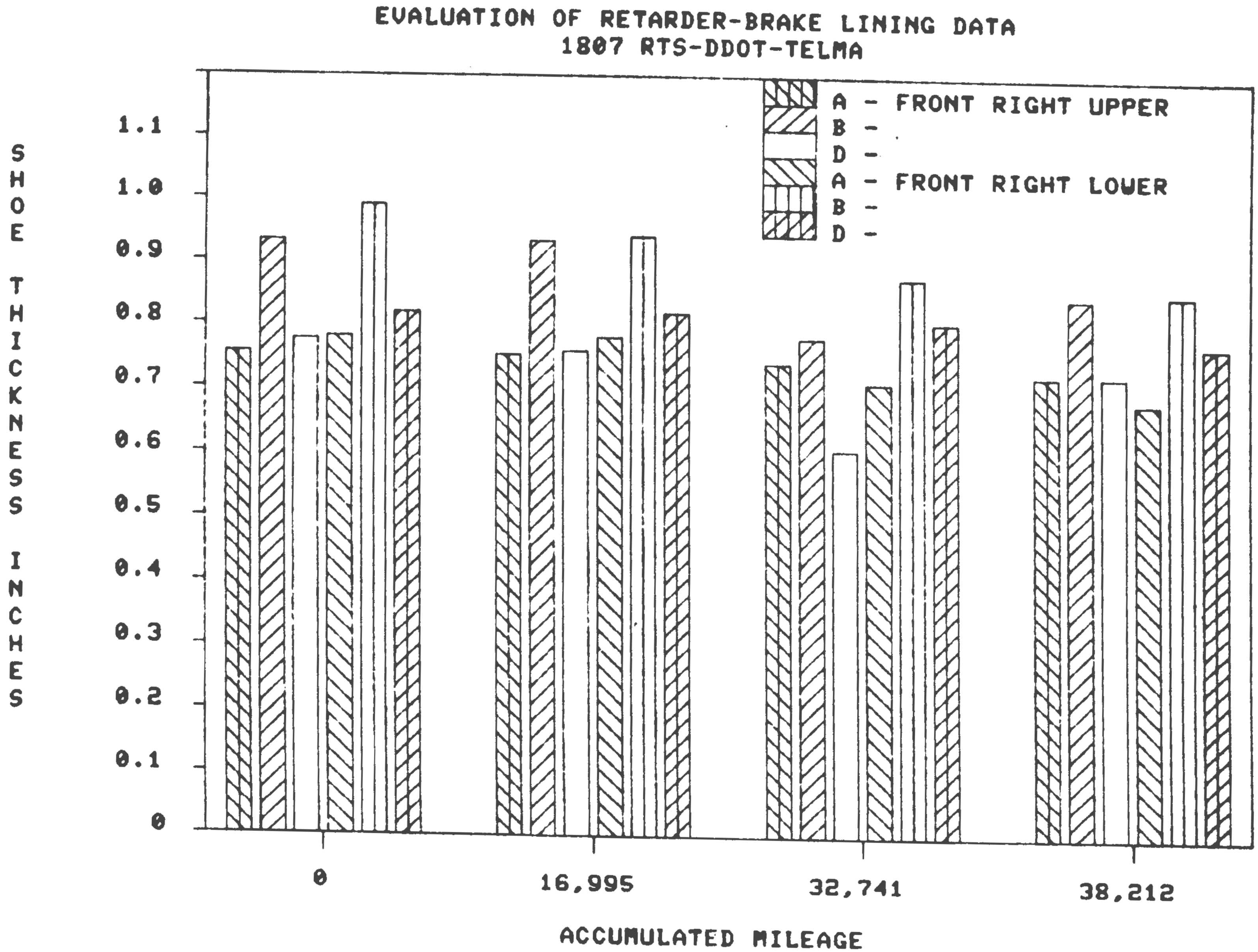
APPENDIX

BRAKE LINING DATA

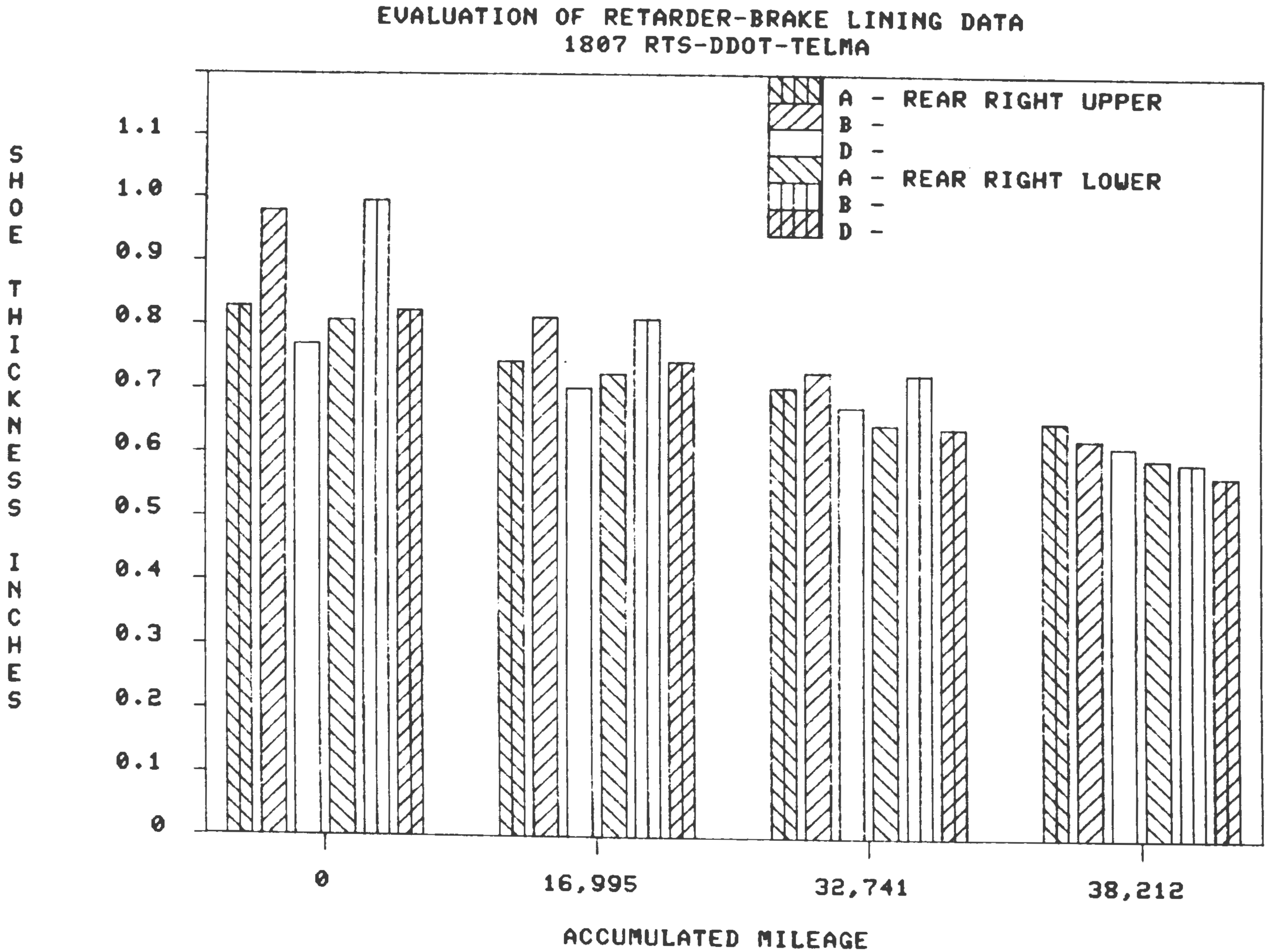

EVALUATION OF RETARDER-BRAKE LINING DATA
1377 RTS-DDOT-CONTROL
A - FRONT RIGHT UPPER
B -
D -
A - FRONT RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
14,351
ACCUMULATED MILEAGE

EVALUATION OF RETARDER-BRAKE LINING DATA
1377 RTS-DDOT-CONTROL

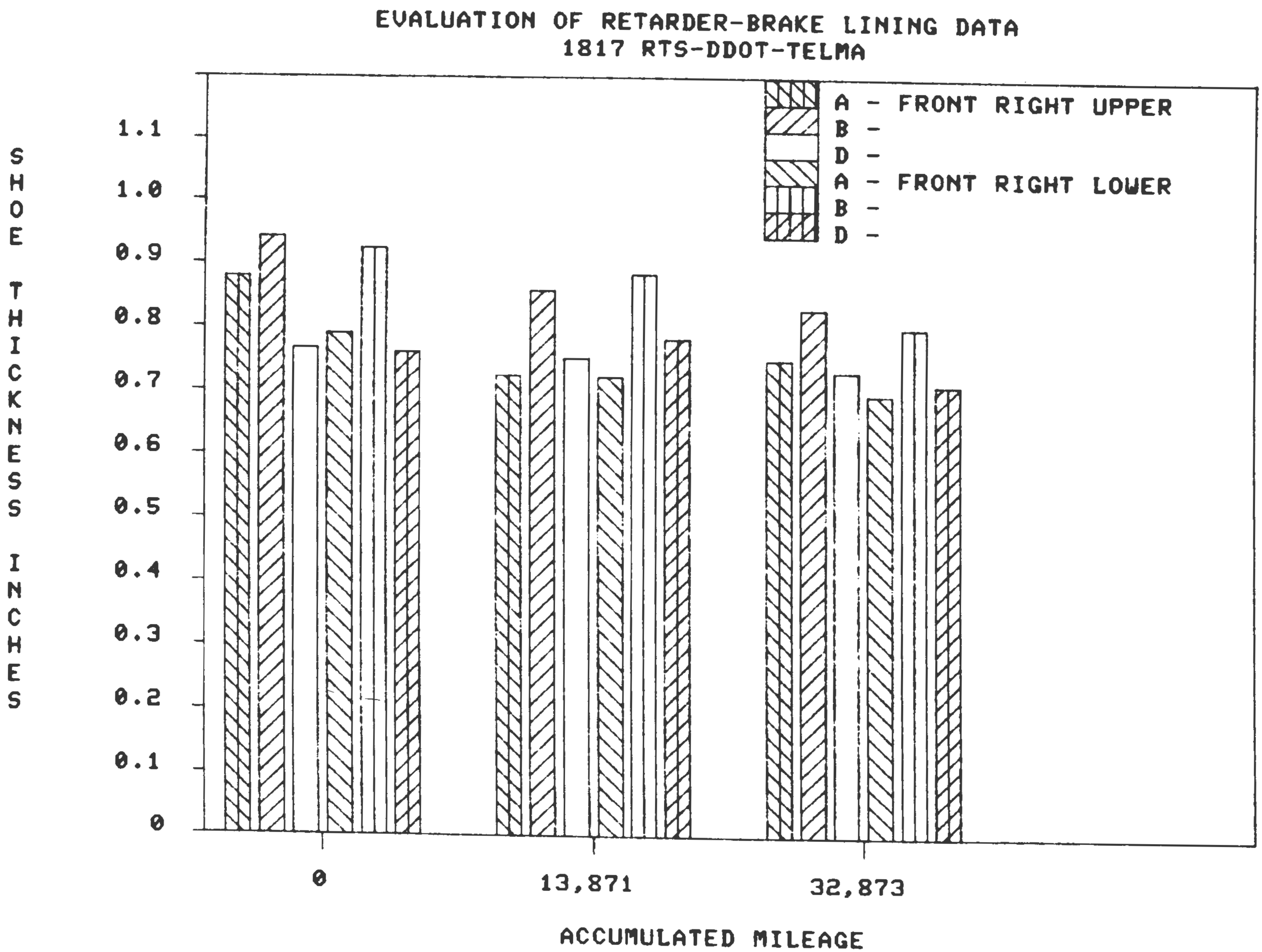


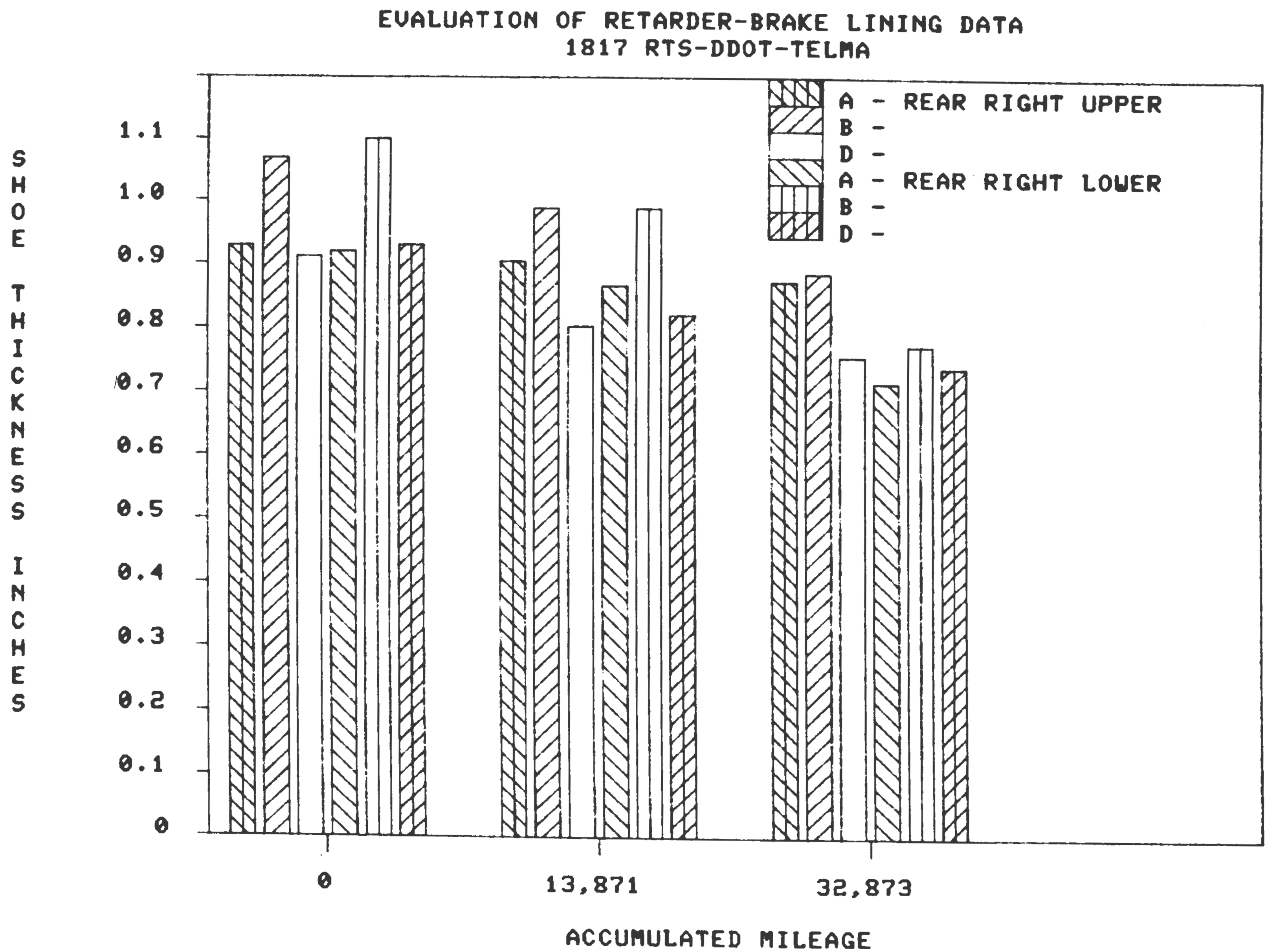


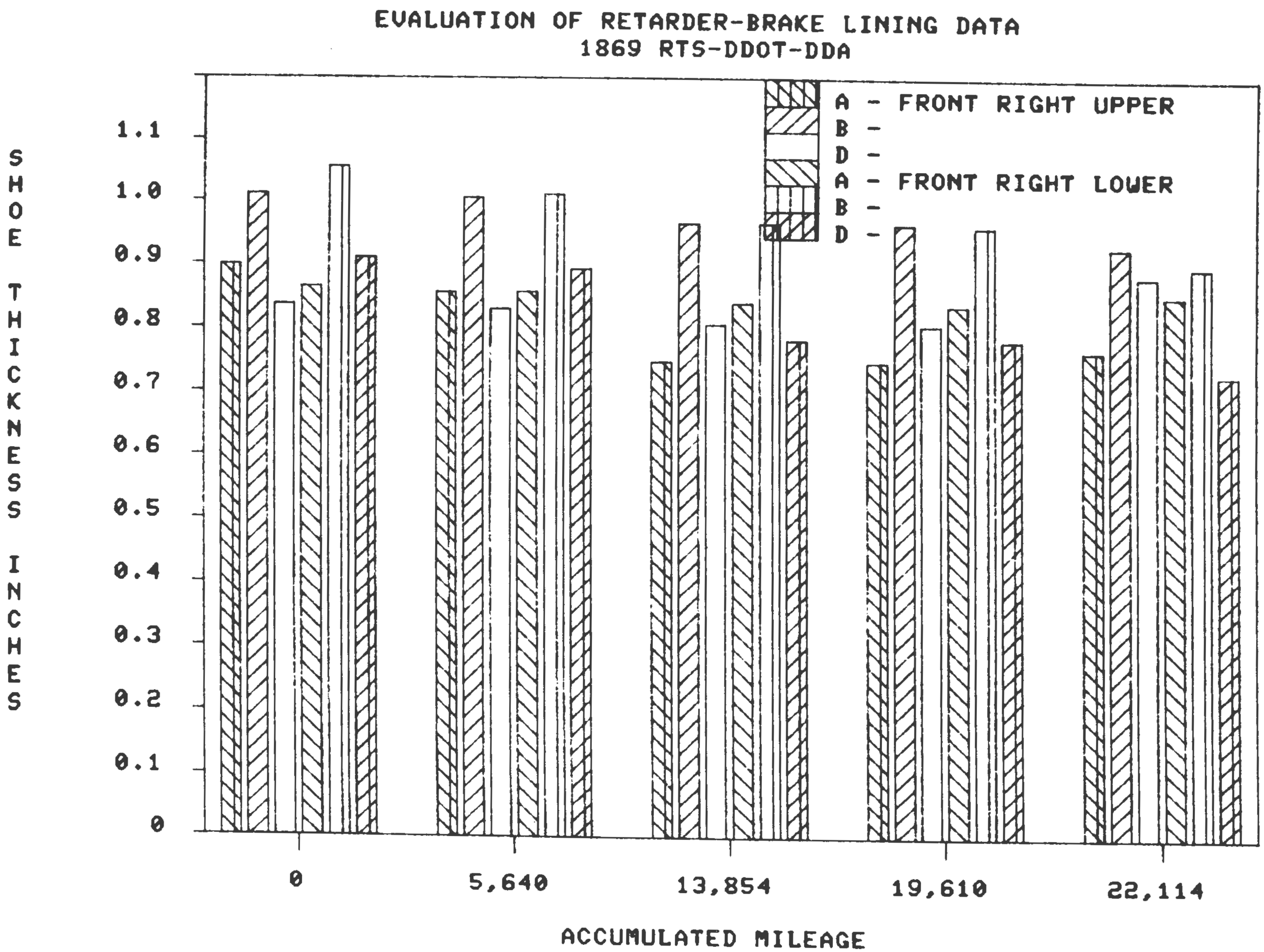
EVALUATION OF RETARDER-BRAKE LINING DATA
1807 RTS-DDOT-TELMA
A - FRONT RIGHT UPPER
B -
D -
A - FRONT RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
16,995
32,741
38,212
ACCUMULATED MILEAGE

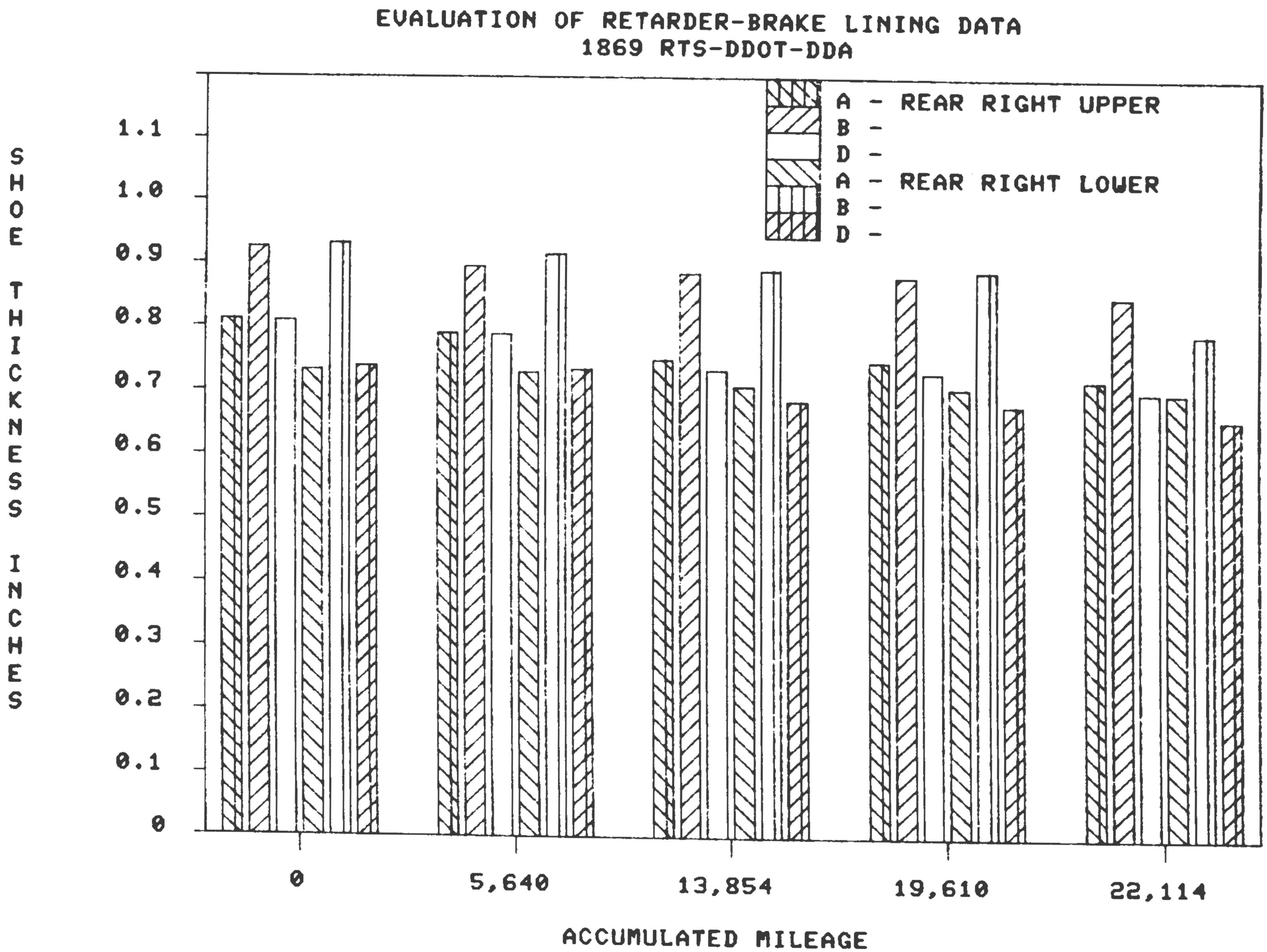


EVALUATION OF RETARDER-BRAKE LINING DATA
1807 RTS-DDOT-TELMA
A - REAR RIGHT UPPER
B -
D -
A - REAR RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
16,995
32,741
38,212
ACCUMULATED MILEAGE

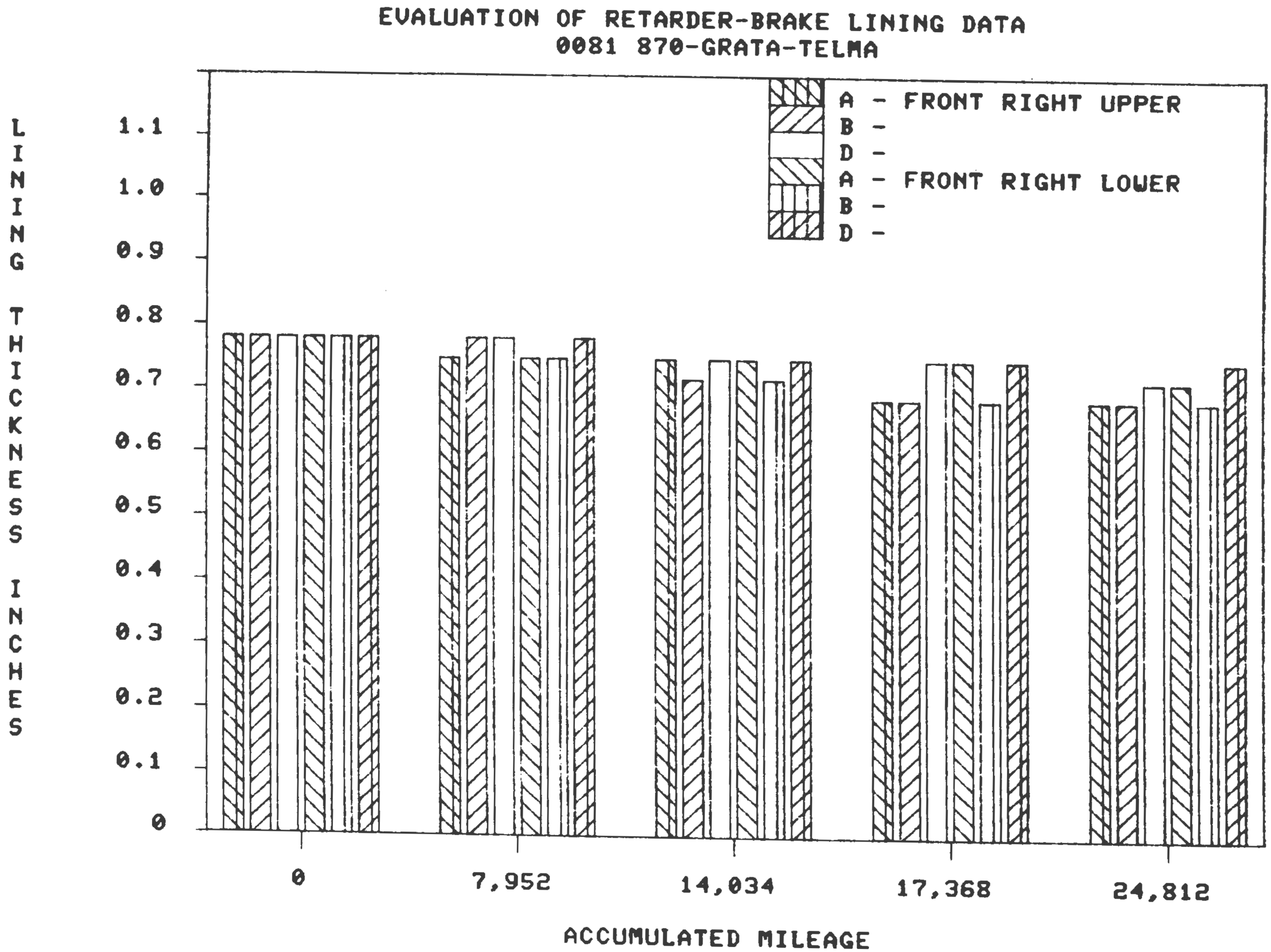

EVALUATION OF RETARDER-BRAKE LINING DATA
1817 RTS-DDOT-TELMA
A - FRONT RIGHT UPPER
B -
D -
A - FRONT RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
13,871
32,873
ACCUMULATED MILEAGE

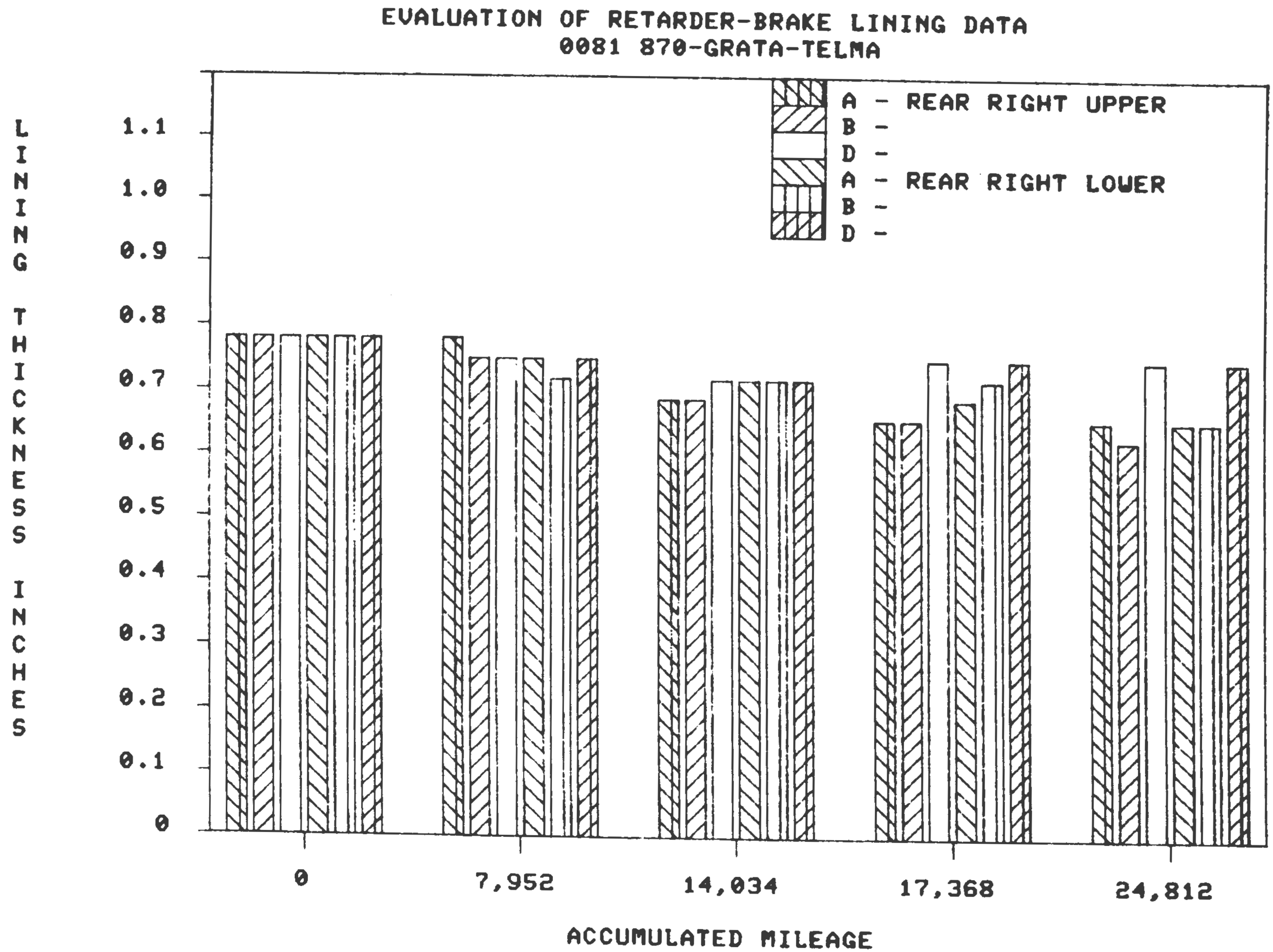

EVALUATION OF RETARDER-BRAKE LINING DATA
1817 RTS-DDOT-TELMA
A - REAR RIGHT UPPER
B -
D -
A - REAR RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
13,871
32,873
ACCUMULATED MILEAGE

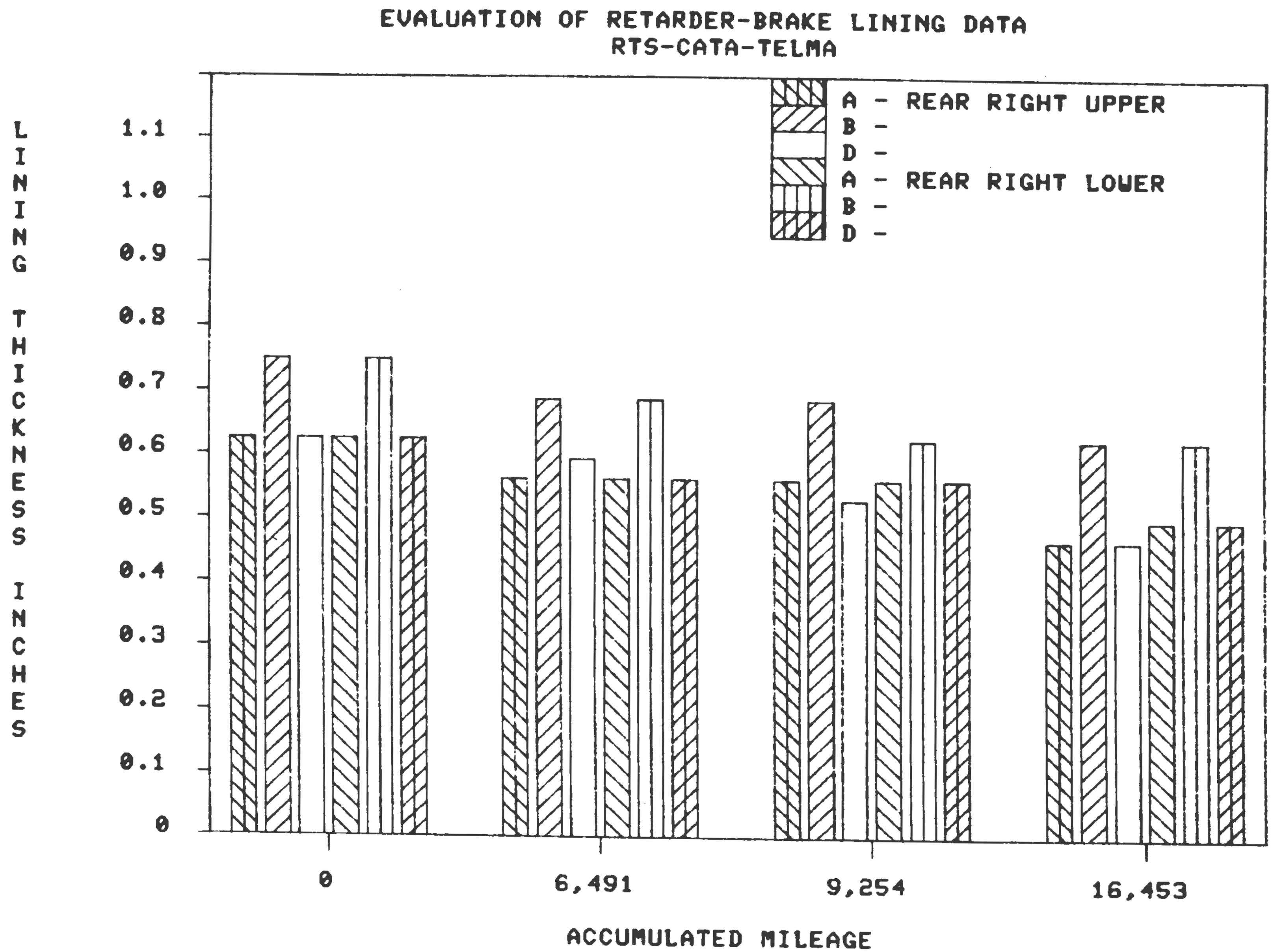

EVALUATION OF RETARDER-BRAKE LINING DATA
1869 RTS-DDOT-DDA
A - FRONT RIGHT UPPER
B -
D -
A - FRONT RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5,640
13,854
19,610
22,114
ACCUMULATED MILEAGE

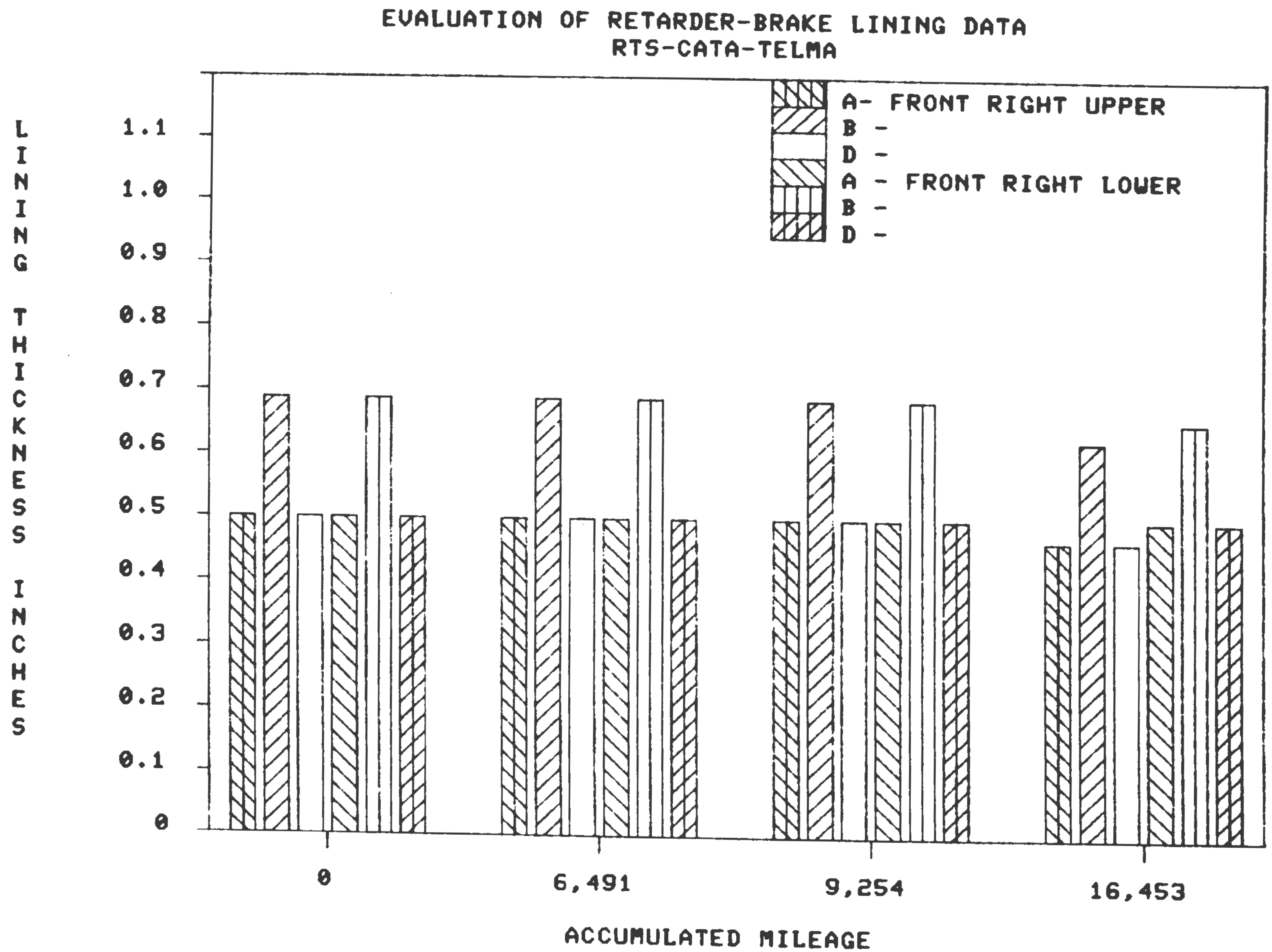


EVALUATION OF RETARDER-BRAKE LINING DATA
1869 RTS-DDOT-DDA
A - REAR RIGHT UPPER
B -
D -
A - REAR RIGHT LOWER
B -
D -
SHOE THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5,640
13,854
19,610
22,114
ACCUMULATED MILEAGE


EVALUATION OF RETARDER-BRAKE LINING DATA
0081 870-GRATA-TELMA
A - FRONT RIGHT UPPER
B -
D -
A - FRONT RIGHT LOWER
B -
D -
LINING THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
7,952
14,034
17,368
24,812
ACCUMULATED MILEAGE


EVALUATION OF RETARDER-BRAKE LINING DATA
0081 870-GRATA-TELMA
A - REAR RIGHT UPPER
B -
D -
A - REAR RIGHT LOWER
B -
D -
LINING THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
7,952
14,034
17,368
24,812
ACCUMULATED MILEAGE


EVALUATION OF RETARDER-BRAKE LINING DATA
RTS-CATA-TELMA
A - REAR RIGHT UPPER
B -
D -
A - REAR RIGHT LOWER
B -
D -
LINING THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
6,491
9,254
16,453
ACCUMULATED MILEAGE



EVALUATION OF RETARDER-BRAKE LINING DATA
RTS-CATA-TELMA
A- FRONT RIGHT UPPER
B -
D -
A - FRONT RIGHT LOWER
B -
D -
LINING THICKNESS INCHES
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
6,491
9,254
16,453
ACCUMULATED MILEAGE