U.S. Department of Transportation
Urban Mass Transportation Administration

Reliability Evaluation of V730 Transmission

Office of Technical Assistance
Office of Bus and Paratransit Systems

Prepared by:
Transportation Systems Center
Urban Systems Division

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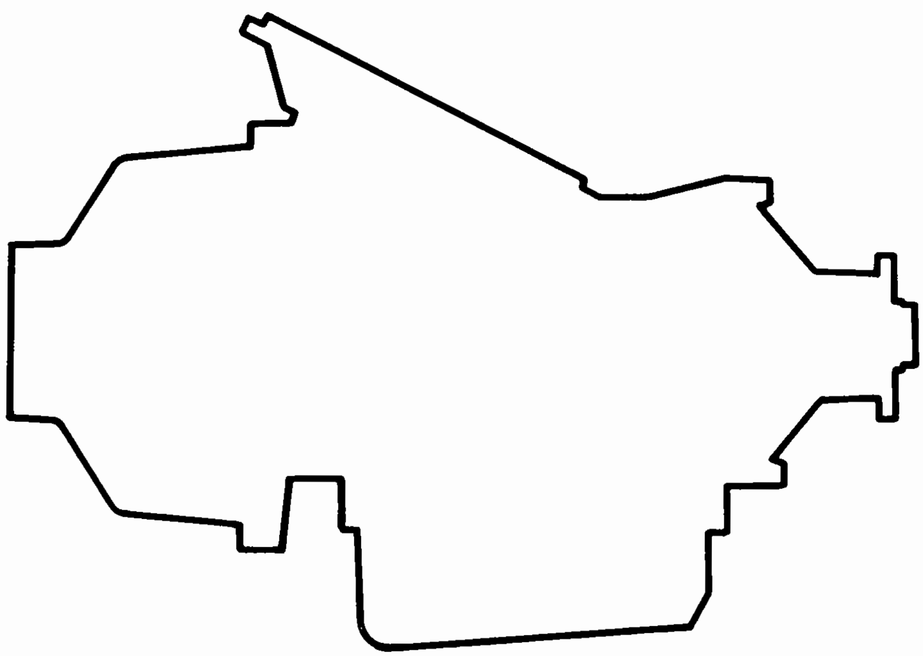

TECHNOLOGY SHARING A PROGRAM OF THE UNITED STATES DEPARTMENT OF TRANSPORTATION

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J.S. Department
of Transportation

Urban Mass
Transportation
Administration

Reliability Evaluation of V730 Transmission

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Project Memorandum

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PREFACE

Gratitude is expressed to all the transit properties who provided V730 transmission failure data to TSC. They are too numerous to mention here but are listed in the report. We recognize the amount of time and effort required on the part of these properties to assimilate the requested information. The reliability analysis of the V730 transmission would not have been possible without their cooperation and support.

We also thank the personnel of Detroit Diesel Allison for their assistance and time provided us throughout this project. They include Messrs. James Swaim, William Clark, and Joseph Krutulis.

Many people from TSC contributed to the preparation of this report. In particular, the authors thank Leon Freeman (a Northeastern University co-op student working at TSC) for his fine efforts on data analysis and reduction.

METRIC CONVERSION FACTORS

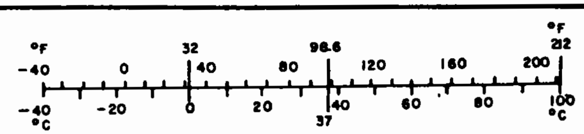
Approximate Conversions to Metric Measures

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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

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)	2.5	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



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INTRODUCTION

The Detroit Diesel Allison V730 transmission is a heavy duty, automatic, 3-speed, hydraulic transmission, currently installed in full size (35′ and 40′) transit buses with transverse mounted rear engines. Since its introduction in late 1976, the V730 transmission has exhibited generally unreliable performance -- reports of service life ranging from 2,000 to 45,000 miles. Transit properties have experienced a wide spectrum of problems: fluid leaks, material failures, parts/component failures, and excessive maintenance requirements. Cited causes for the problems have varied from inadequate maintenance by the properties to poor design by the manufacturer.

In support of the Urban Mass Transportation Administration's (UMTA) Office of Bus and Paratransit Systems, the Department of Transportation's Transportation Systems Center (TSC) conducted an initial assessment of the V730 transmission. The objective of the effort was to characterize the problems and insure that resolution was underway. The time frame and scope of this assessment dictated a qualitative approach whereby information was obtained through telephone calls and visits to transit properties, comprehensive discussions with the manufacturer, review of his facilities and a survey of available literature. In October 1981, TSC completed its assessment and prepared an interim report. Among other findings, the assessment concluded that, although many design modifications had been made by Detroit Diesel Allison, there still remained, amongst the transit properties, mixed feelings about whether the transmission was indeed improving. This controversy was fostered by continued reports of buses out of service due to V730 transmission problems and by lack of quantifiable failure data.

Consequently, and in coordination with the American Public Transit Association's (APTA) Bus Technology Liaison Board, TSC structured and initiated the second phase of its assessment to focus on the collection and analysis of transmission failure data.

OBJECTIVE

The objective of the second phase of TSC's transmission assessment was to establish, through collection and analysis of actual transmission failure information from the field, whether the service life of the V730 is improving. This second phase directly fulfills the need for an independent, objective, and data-supported basis (in marked contrast to varied judgements and opinions) for determining whether the reliability of the V730 transmission is or is not improving.

This report summarizes the general approach and results of the second phase. It provides a concise and current picture of the V730 performance as seen from an independent perspective. The following sections cover:

- Background
- Overall Approach
- Analytical Approach
- Results
- Conclusions
- Recommendations

BACKGROUND

History

Several power train arrangements have been utilized through the years by various coach manufacturers. The V-drive transmission (the V indicating the angle between the input engine power and the output transmission power) was first produced as a mechanical transmission in 1935. The General Motors Truck and Coach Division first introduced an automatic V-drive transmission for buses in 1948 and then refined the design in 1959 with a hydraulic configuration known as the VH series. In response to a demand by transit operators for more powerful engines (6 cylinder to 8 cylinder) to handle air conditioning equipment and highway operation, a heavier-duty transmission series, known as the Super V Series (VS), was introduced in 1965. An automatic overdrive option was provided with this series, the VS2 providing overdrive and the VS1 without.

The above transmissions were designed by General Motors Truck and Coach Division and manufactured by the Allison Division (now Detroit Diesel Allison). During the period just preceeding the introduction of the V730 transmission, Allison was producing four different models of V-drive transmissions for the transit industry, namely:

VH9	- for use with 6V-71 engine - without overdrive
VS1	- for use with 8V-71 engine - without overdrive
VS2-6	- for use with 6V-71 engine - with overdrive
VS2-8	- for use with 8V-71 engine - with overdrive

It is important to the understanding of the problems now associated with the V730 transmission to remember that the VH series transmissions also experienced several problems initially and went through a rather lengthy evolution period between the first model VH (1959) and the last model VH9 transmission (1976). The reliability that the VH series transmissions now enjoys was acquired quite gradually and not without several product improvements.

The V730 transmission was both designed and manufactured by Detroit Diesel Allison. Following relatively limited transit field testing, the V730 was introduced in 1976 to the urban transit industry with deliveries of American

General (AMG) Model B buses to Miami and Boston. During this same period, GMC Truck and Coach Division was phasing out their New Look model coaches in preparation for producing only the Advanced Design Bus (ADB) and, therefore, did not "engineer" the V730 transmission into their last production of "New Look" coaches.

Today, the V730 is the only production angle drive automatic transmission produced by Allison. Excluding military equipment, Allison builds many more automatic transmissions, with straight-in drive, for a variety of bus, truck and off-highway applications than V730 automatic transmissions for bus applications. Figure 1 shows that, for the model year 1981, Allison's production of V730 transmissions was approximately 7 percent of its total production of 78,000 units (both highway and off-highway applications). This figure also notes the representative application for each transmission type. In considering the problems of the V730 transmission, it is important to keep in mind that this transmission represents a very small fraction of Allison's production. This is particularly significant in terms of the resources that the manufacturer can normally allocate to developing both products and problem solutions.

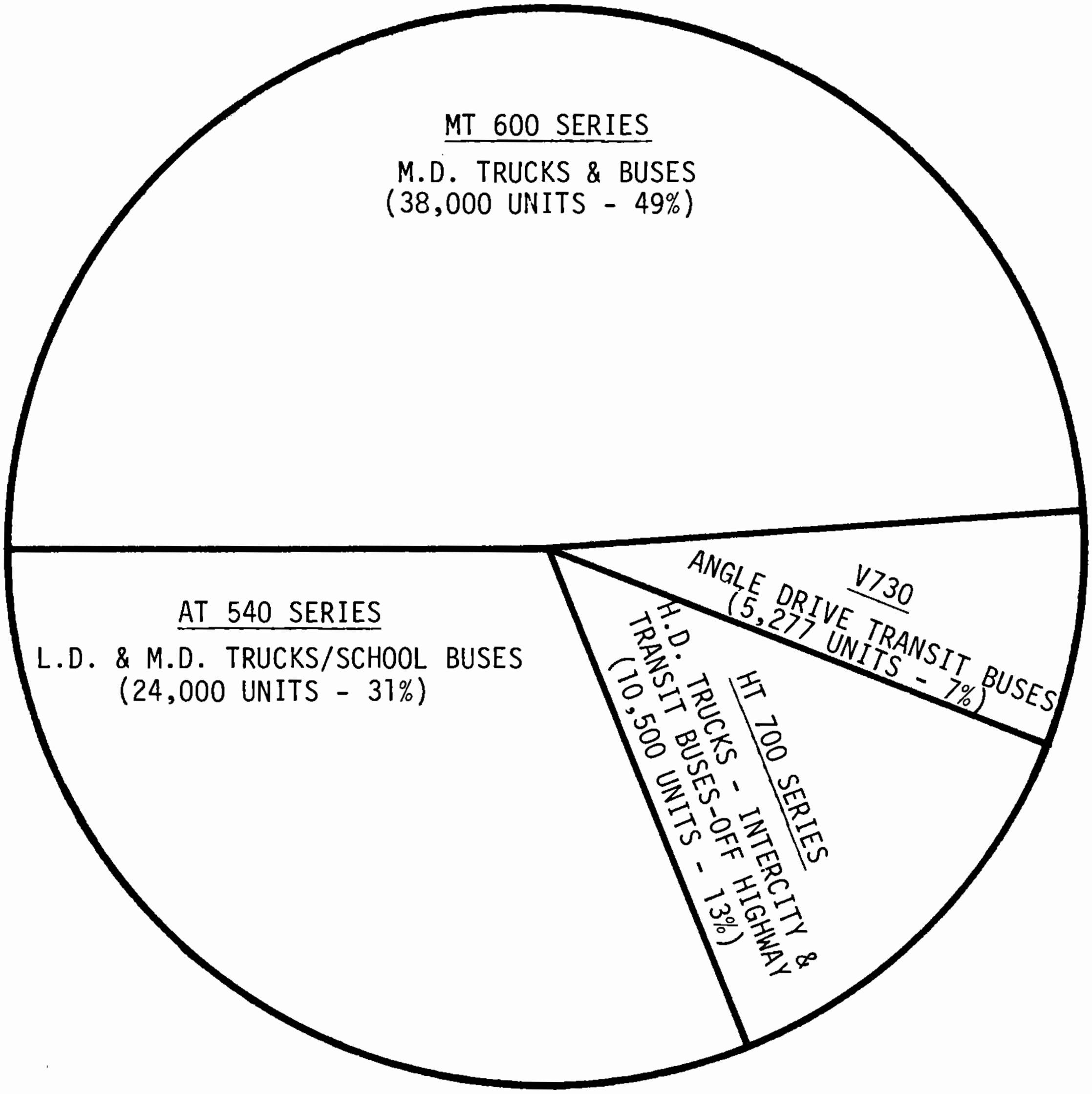
The number of V730 transmissions produced for model years 1975 through 1981 is shown in Figure 2. The V730 production to date is approximately 23,000 units.

V730 Description

The V730 transmission promised improved fuel efficiency, highway speed capability and an improved matching of output speeds and torque to varying road and traffic conditions. It also made available, as an option, a power take-off (PTO) unit that would permit relocation of the air conditioning compressor, driving it off the transmission instead of the engine. The "all-purpose" design of the V730 emphasized manufacturing and multi-service operational performance efficiencies as well as the capability of operating with either the 6 or 8 cylinder engine.

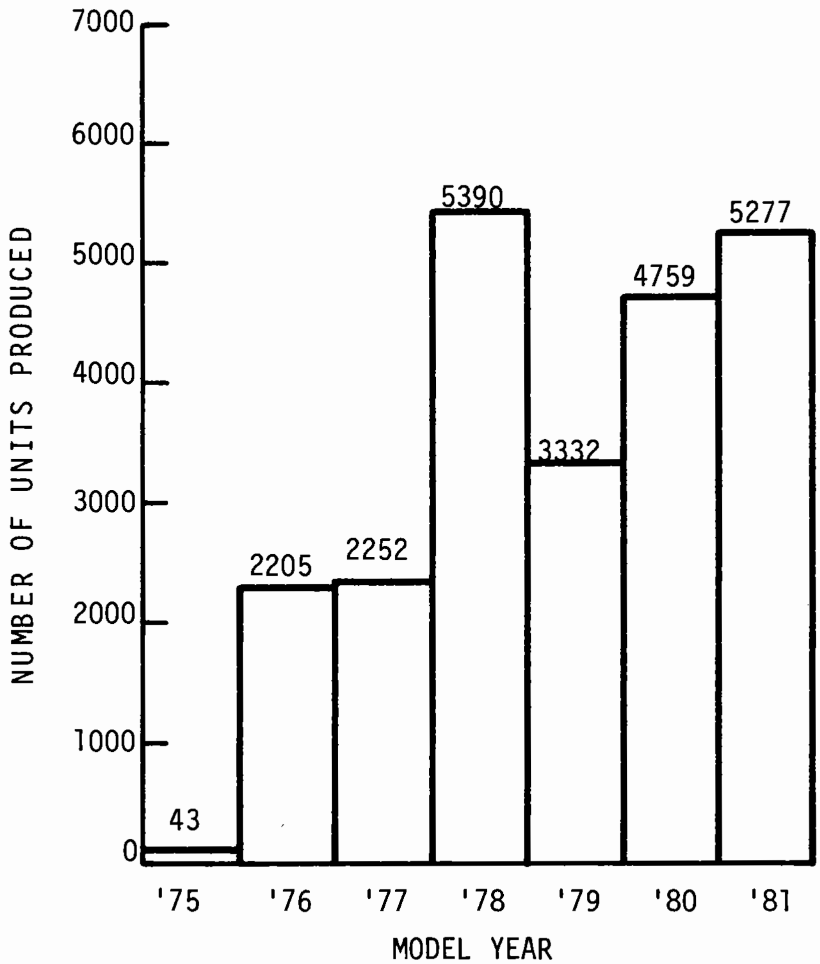
The V730 provides additional shift positions compared to previous automatic transmissions. The VH/VS series transmissions had a basic drive selector with only Reverse-Neutral-Forward (R-N-F) drive positions. The overdrive, when

PRODUCTION: V730 VS. "STRAIGHT-IN" DRIVE
ALLISON TRANSMISSIONS MY81
TOTAL PRODUCTION: 78,000 UNITS (APPROX.)
HIGHWAY & OFF HIGHWAY



Source: Detroit Diesel Allison

FIGURE 1. TYPICAL APPLICATIONS AND APPROXIMATE QUANTITIES PRODUCED



Source: Detroit Diesel Allison

FIGURE 2. V730 PRODUCTION BY YEAR

applicable (VS2-6 or VS2-8), was automatic and achieved the higher road speed at the expense of power (torque to the wheels). The V730 transmission, however, provides the operator with greater selectivity as to driving ranges with three (3) forward speeds, Neutral and Reverse, using a five position (R-N-D-2-1) drive selector. With the drive selector in "1st," the driver has the ability to keep the transmission in low gear for pulling through mud or snow or for driving on steep grades. This position also provides maximum engine braking with the lockup clutch engaged. Second gear (2nd) is best used for heavy traffic conditions such as inner city operation. It also provides limited engine braking for speed control on downgrades. The (D) drive position is used for all normal driving. With the drive selection in (D), the transmission will automatically upshift or downshift to the correct gear consistent with the demands of traffic. A cut-away view of the V730 transmission is shown in Figure 3.

The torque path through the V730 varies with the clutches engaged. Figure 4 illustrates the basic path of the torque flow from the engine crankshaft into the V730 transmission through the bevel gears (angle drive). Torque flow is initially rearward into the converter assembly and then forward and axially through the applicable clutches and gearing to the output flange, the propeller shaft and the rear axle. Unlike the popular Allison AT, MT and HT series truck and bus transmissions with straight-through torque flow, the torque flow in all V series bus transmissions changes direction twice -- initially at the angle drive (input end) and then in the converter assembly.

The V730 is considerably larger and heavier than its predecessors:

VH/VS1	539 lbs. (dry)
VS2	595 lbs. (dry)
V730	926 lbs. (dry)

Many major components of the V730 transmission are the same or similar to components used in previously successful and popular transmissions such as the VH/VS series bus transmissions and the heavy duty HT-740 truck and intercity bus transmission. The commonality of components the V730 shares with other Allison transmissions is shown in Table 1. Because of this commonality,

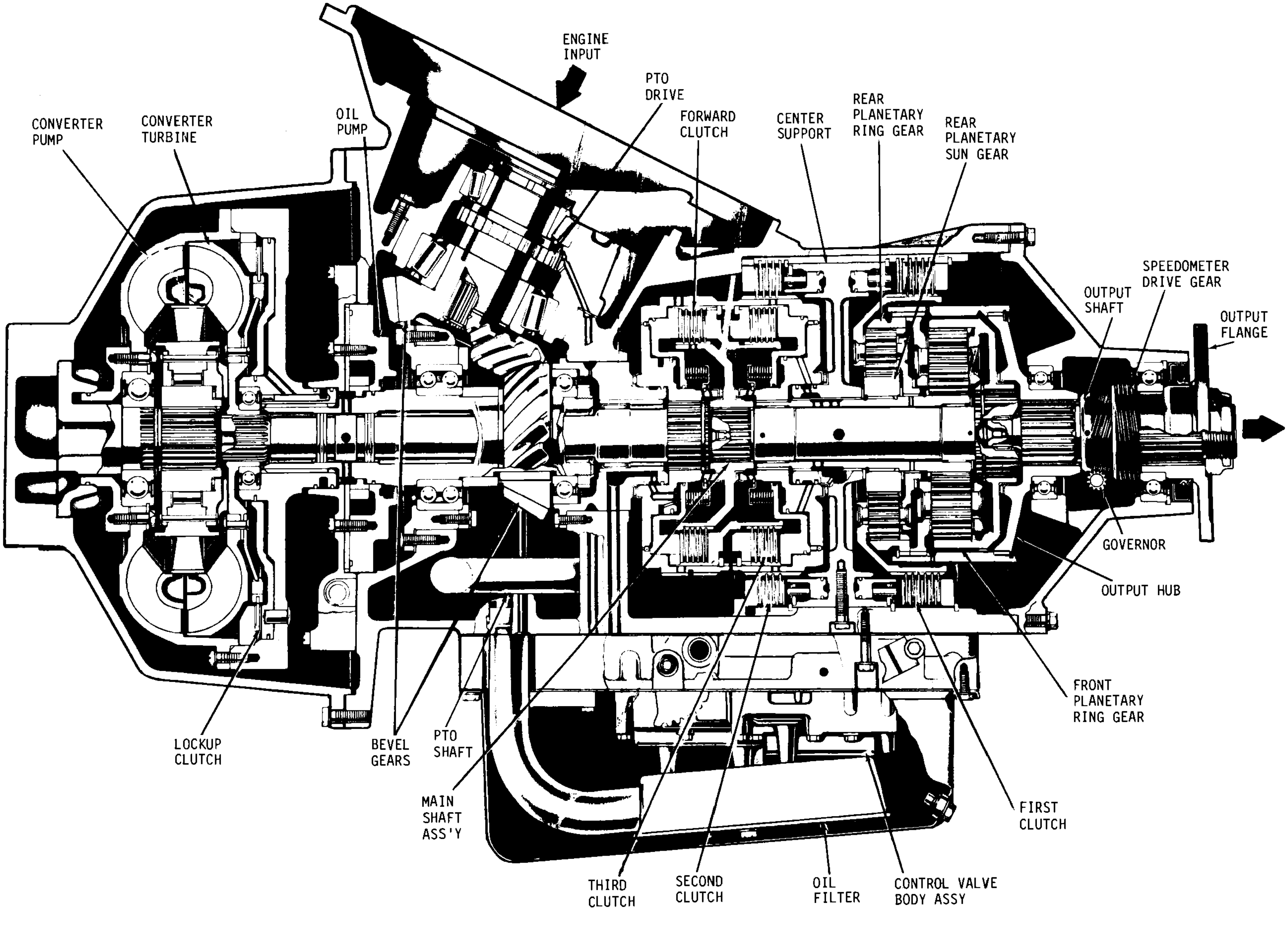


FIGURE 3. DETROIT DIESEL ALLISON V730 TRANSMISSION

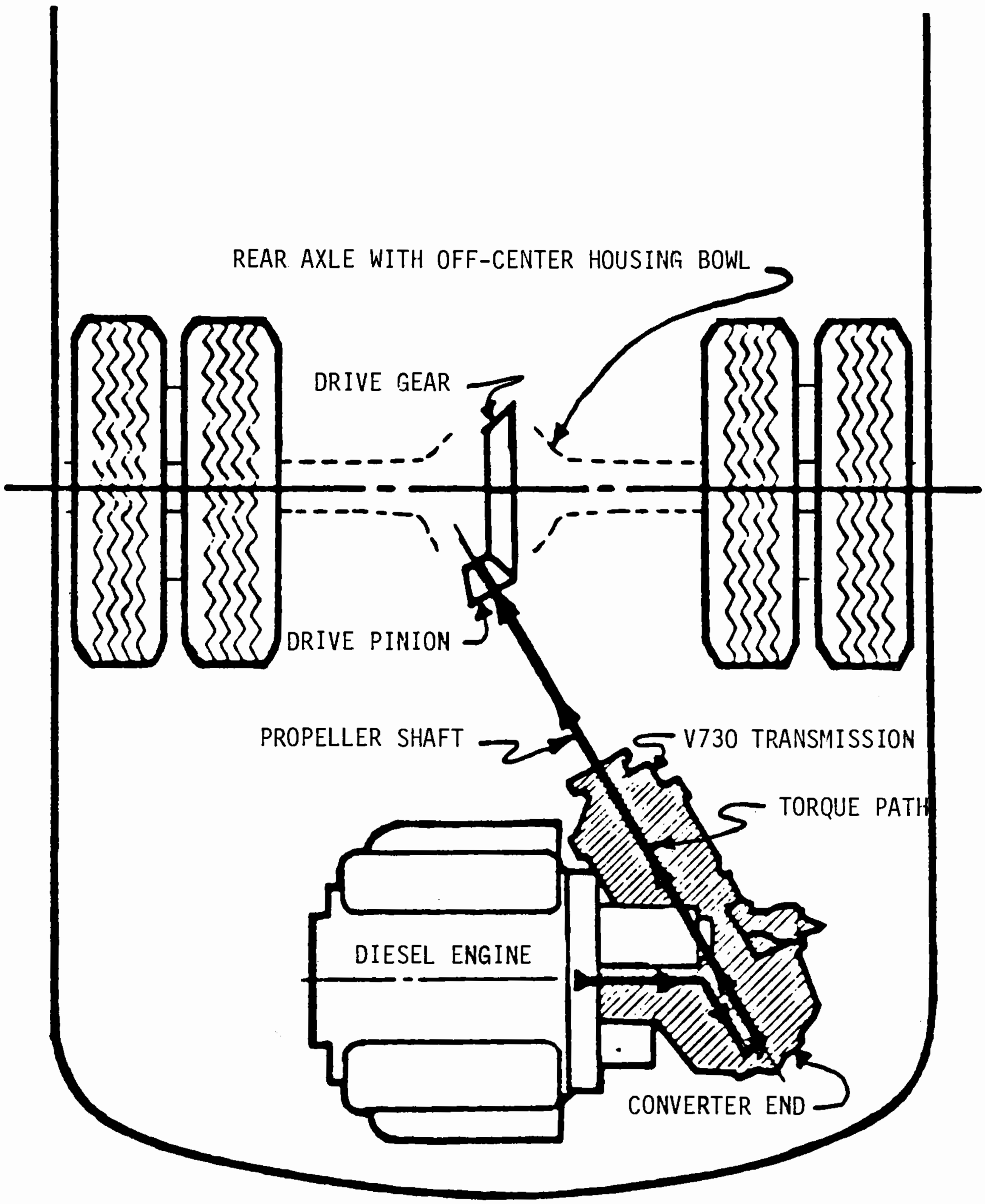


FIGURE 4. POWER TRAIN ARRANGEMENT AND TORQUE PATH

Allison did not anticipate significant problems with the V730 in an urban transit environment.

TABLE 1. COMMONALITY OF V730 TRANSMISSION COMPONENTS

V730 Component	Source
o Bevel gear assembly	VS
o Input drive adaption	VS
o Spicer 1700 output flange	VH/VS
o Single Stage, two-phase torque converter with lock-up clutches	HT-740
o Oil pump, planetary gearing	HT-740
o Clutches, governor, valve body and throttle modulation	HT-740
o Shift lever, neutral start and dip stick fill tube provisions	HT-740
o Three-bolt handling provision	VH/VS

V730 Problems

Almost immediately upon being placed in urban transit service, the V730 transmission began to develop reliability problems. Warranties were handled between the transit property, the bus manufacturer (through the field service representative) and the local Detroit Diesel Allison dealer or distributor who was, at the time, totally inexperienced in handling large scale urban transit bus warranty problems. Allison was initially not provided with sufficient information to properly judge the magnitude and causes of the problems that were developing and, as a result, was late initiating comprehensive corrective action.

The number of warranty claims received by Allison for early life failures of the V730 transmission resulted in a series of product improvements (modifications) to correct each problem area identified. This included changing materials to extend the service life of individual components, design changes to "beef up" specific areas and continued attempts to stop fluid leaks. A listing of these product improvements is attached as Appendix A which also shows the serial number at which the corrective change first went into production transmissions. Of the 34 corrective changes listed, 12 are believed to have had significant impact on the reliability of the V730 transmission. Not all, however, had a positive effect. Two engineering changes, both concerned with the scarf cut seal and introduced into production at serial numbers 9943 (model year 1978) and 13044 (model year 1979) to improve assembly operations, actually had a negative significance. The scarf cut seal caused new problems and set back Allison's efforts to improve the reliability of the V730 transmission. The scarf-cut seal was replaced beginning with production serial number 18481 (model year 1981). For each change, Allison provided their dealers, rebuilders, bus manufacturers and transit properties with all necessary information and part numbers to update existing V730 transmissions to the latest production configuration.

The elimination of the scarf-cut seal is believed to have solved the major remaining problem affecting the reliability of the V730 transmission. As of February 24, 1982, factory production of V730 transmissions had reached serial number 25631. However, the number of V730 transmissions in revenue service with serial numbers above 18481 or units rebuilt to the latest configuration have not yet accumulated sufficient mileage to confirm this belief.

OVERALL APPROACH

The approach used in acquiring and analyzing the transmission failure information took into consideration:

- The need for a reliability and performance indicator that is straightforward

- The evolution of design changes to the transmission

- The need for data with minimum biases and data that are normally kept by transit properties.

A simplified reliability analysis was devised to satisfy all the above considerations. The mileage at the first-time failure of new transmissions was used as the reliability indicator. Examining the first-time failure only (and not including subsequent failures) eliminates the variables associated with transmission repairs and re-installation in the bus. The focus on new transmissions eliminates any variability and uncertanintes on configuration differences from unit to unit as a result of various repairs/retrofits. Further, with this approach, it is known that all failures analyzed involved transmissions as installed by the bus manufacturer.

It was anticipated that the mileage at the first-time failure of given transmissions would be part of the data normally kept by transit properties. The request for such data would not cause any significant pertubations on the properties.

In view of the many manufacturer modifications, the analysis used an increasing transmission serial number as the indicator of a greater potential for an improved design. It is logical that the "newer" transmissions incorporate more of the manufacturer's improvements.

The foundation of this simplified reliability analysis is the correlation of serial numbers with achieved mileage (to first-time failure) and this is used as an indicator of improvement in the transmission. That is, a transmission with a higher serial number is expected to exhibit a greater achieved mileage.

It was apparent that there are many environmental and operational factors which may influence the performance of the transmission, but more importantly, these factors vary from property to property. Examples of these factors include: passenger loads, route characteristics (grades, number of stops per mile, etc.), driver characteristics, and maintenance strategies. Consequently, data for the analyses were sought from a mix of transit properties with the expectation that, on balance, a representative sample is achieved and biases are minimized. The collection of data from many properties also provided a data base that covered a range of transmission serial numbers, both 35′ and 40′ buses, and four different bus manufacturers. A summary of the collected data and sources is shown in Table 2. As shown, data were collected from 15 properties on 3,244 transmissions.

TABLE 2. SUMMARY OF DATA AND SOURCES

PROPERTY	NUMBER OF TRANSMISSIONS ANALYZED	TRANSMISSION SERIAL NUMBER RANGE	MAKE OF BUS	LENGTH OF BUS
ATLANTA, GA	50	21000-22000	NEOPLAN	40′
	100	5000-9000	FLXIBLE 870	40′
BOSTON, MA	125	11000-14000	GMC CANADA NEW LOOK	40′
	27	11000	GMC CANADA NEW LOOK	35′
BRIDGEPORT, CT	25	13000	GMC-RTS-II	35′
	12	13000	GMC-RTS-II	40′
DETROIT DOT	109	8000	GMC-RTS-II	40′
	120	12000	GMC-RTS-II	40′
	72	16000	GMC-RTS-II	40′
LOS ANGELES, CA	940	18300-22000	GMC-RTS-II	40′
LOWELL, MA	10	13000	GMC-RTS-II	35′
MIAMI, FL	274	17000	GMC-RTS-II	40′
MICHIGAN	45	6500-8500	GMC-RTS-II	40′
	33	9500-12000	GMC-RTS-II	40′
	22	16000-17000	GMC-RTS-II	40′
NORWALK, CT	19	12000	GMC-RTS-II	35′
PHILADELPHIA, PA	298	15500-16500	GMC-RTS-II	40′
PROVIDENCE, RI	72	7500-9000	GMC-RTS-II	35′
	34	21500-22000	GMC-RTS-II	40′
SAN ANTONIO, TX	116	6000	GMC-RTS-II	40′
	145	16500	GMC-RTS-II	35′
SPRINGFIELD, MA	65	8000-9000	GMC-RTS-II	35′
UNIV. OF MASS.	28	9000-17500	GMC-RTS-II	35′
WASHINGTON, DC	388	3500-8500	FLXIBLE 870	40′
	115	11000	GMC-RTS-II	40′
	3,244			

ANALYTICAL APPROACH

General

Reliability has been defined as the ability of a product to perform, without failure, a specified function under given conditions for a specified period of time. This definition is commonly utilized in the military/aerospace industry where a product's function, design requirements and operating environment are explicitly defined, controlled and verified to insure that a specified level of reliability is achieved. In addition, once the product is delivered to the field, the degree of maintenance is tightly controlled to insure that no degradation in performance occurs. In such cases, much attention and resources are devoted, during the development process, to controlled tests where a statistically chosen number of samples are cycled through well-defined environments for specified periods of time.

In contrast, the bus industry and its associated products are part of a commercial world where the degree and extent of research and development (R&D) and the emphasis on reliability is a prime function of the market place. To what extent a company specifies, controls and verifies reliability in its products is a function of their perceived share of the market, the market's demands for reliability, and its warranty strategy. Cost and performance are frequently traded-off in the design and evaluation of new products; limited numbers of prototypes are tested under limited environments with reliance on similar components and/or subsystems used for other applications. Generally, the amount of testing is often bounded by economic concerns of getting products competitively into the marketplace.

V730 Reliability

In view of the above, a discussion of reliability as it relates to buses and those subsystems within buses, such as the V730 transmission, needs to consider the definition and application of reliability within the context of the public transportation industry. For example, for a bus transmission, the "specified function" involves the stop/start/acceleration profile and accessory loads required by the bus. This profile and the resulting impact on the transmission's reliability can vary significantly, depending upon, to what degree, a bus is used in express service versus a downtown type of service.

The "given conditions" reflect the operating environment of the V730 and include route-related factors (grades, street conditions, passenger loading, bus drivers' habits), climate factors, (hot, cold, humidity), and installation factors (type of bus, interfacing subsystems such as air conditioning and engine). All of these can have an impact on the transmission's reliability. The last term in the definition, "a specified period of time", is associated with the 100,000 mile transmission requirement called out in the ADB "White Book" specification. It assumes that the transmission is adequately maintained to the degree specified by the manufacturer. In the real world, however, the degree to which maintenance is provided to bus equipment can vary significantly from one transit property to another, depending on the resources available and the strategy of the management.

Therefore, many factors, in addition to the design and the ability to produce the design consistently (quality control), can vary the reliability of bus equipment and particularly, the V730 transmission, from one transit property to another. Besides the usage, operating environment and maintenance factors discussed above, there are numerous differences in V730 configurations in the field, resulting from both varying configuration updates being delivered by the manufacturer and varying corrective maintenance modifications being made by the properties. All of these variations would have to be isolated, controlled and accounted for in a rigid reliability analysis, commonly performed by the military. Considering the time, resources and data available in this study, a simplified reliability approach is more practical and useful as long as the following three conditions are met: 1) the information used in the evaluation has a direct, simple correlation to the reliability of the transmission; 2) the amount of information evaluated is representative of the total population of V730's that exist today; 3) the sources of collected information on the V730 represent a viable cross section of usage, operating environment and degree of maintenance to minimize any bias of data.

On this basis, then, mileage to first-time failure of a new V730 transmission is used as an indicator of reliability for this study. (Repaired, rebuilt and retrofitted transmissions are excluded from the analysis, emphasis being on the design configuration and factory quality of a new transmission.) The serial number of the V730 transmission is used as a potential indicator of its level of design improvement with the intent to correlate it with the mileage to first failure (reliability). Data were gathered from a consciously-chosen wide range of properties, large and small, with various geographical and climatic conditions, route characteristics and maintenance strategies. Failure and mileage information normally recorded by each property for each new V730 provided the basis for analysis.

RESULTS

It was anticipated that, as transmission serial number increased and thus more design improvements were added to the transmission, the reliability of the transmission would improve. Figure 5 demonstrates this expected trend with a pattern plot using three groups of transmission serial numbers. For each new V730 transmission, a point is plotted using the transmission serial number and the mileage accumulated on the transmission at its first failure. Figure 5 does not depict actual data but hypothetical information for indicating the type of trend expected.

Figures 6 through 11 are based on actual data obtained from operating experience at several transit properties and, in addition to the pattern plots, include bar-chart type histograms of the same data. A discussion of each figure is provided below.

Figure 6 represents actual transmission first-failure information collected from two transit properties on 281 V730 transmissions and shows three distinct groups of serial numbers (reflecting three different time periods when new buses with V730's were purchased by these properties). All of these transmissions were operated in the same geographical area and should have theoretically received the same level of maintenance.

Three important points should be noted regarding Figure 6. First, the wide range of first-failure mileage exhibited at the same (approximate) level of serial number (i.e., similar transmission design) reflects the variation in factors that can impact transmission reliability (such as factory quality control, number of failure mechanisms, operating environment, etc.). Secondly, and more importantly, the achieved mileages tend to drift to the left as the design matures (increasing serial number), a trend opposite to the expected trend of Figure 6. (Also, it should be noted that a number of these transmissions are failing before the 10,000 mile point is reached.) Finally, it should be emphasized that Figure 6 focuses on failure data. There are some transmissions at these two properties, although a small percentage, that have not experienced their first failure; these obviously are not accounted for in

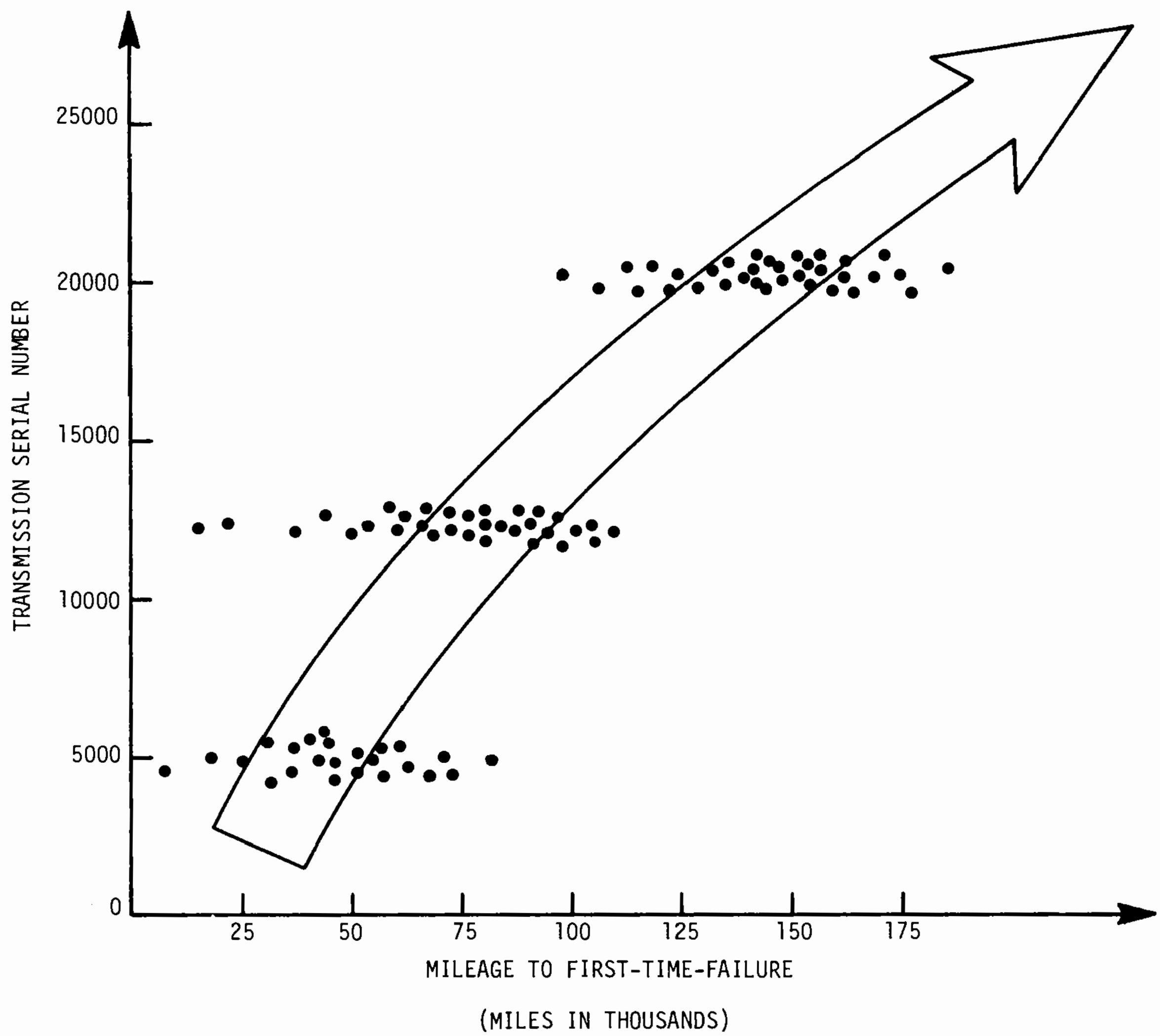


FIGURE 5. EXPECTED TREND OF MILEAGE TO FIRST-TIME V730 FAILURE

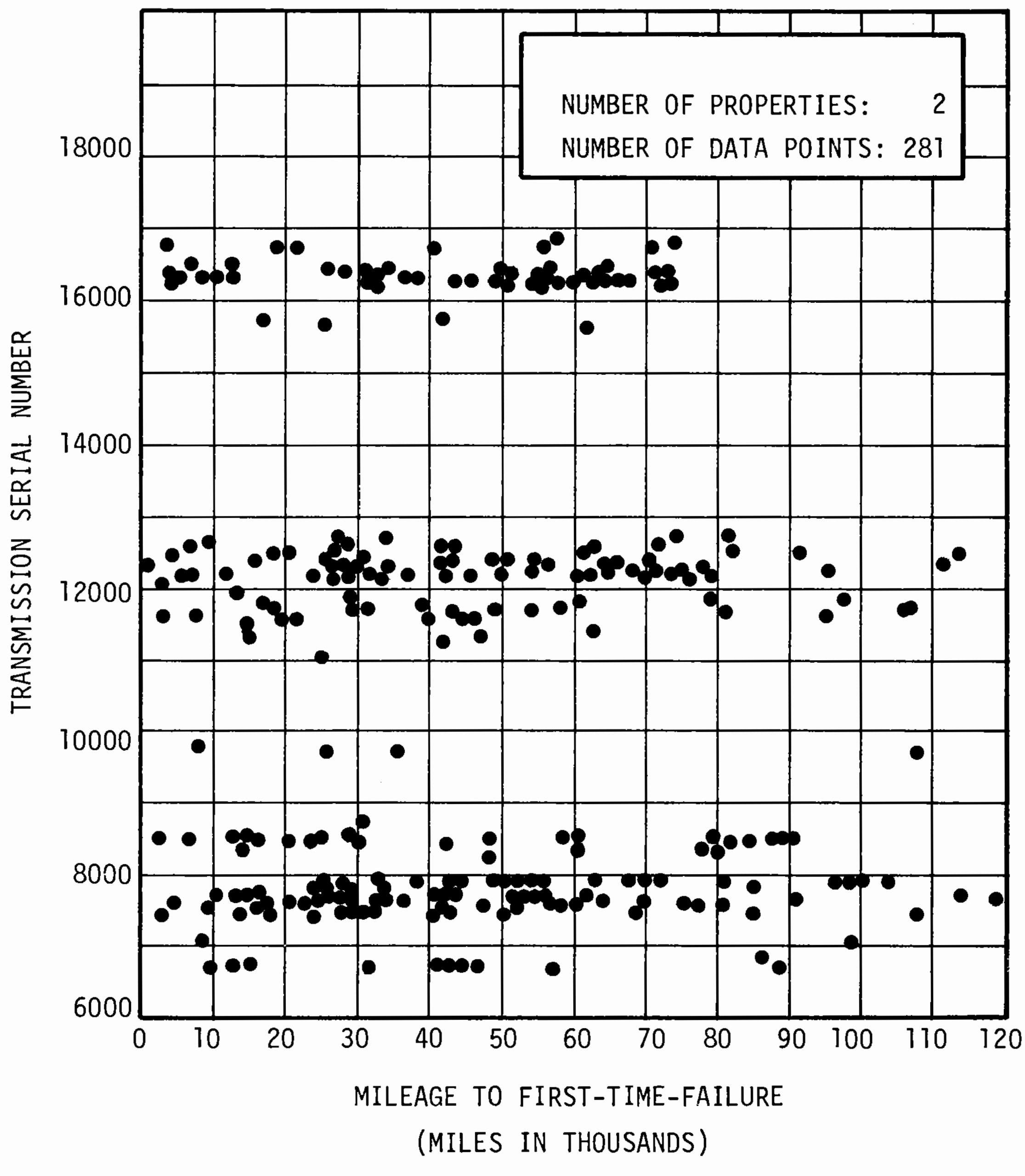


FIGURE 6. ACTUAL PATTERN OF MILEAGE TO FIRST-TIME V730 FAILURE

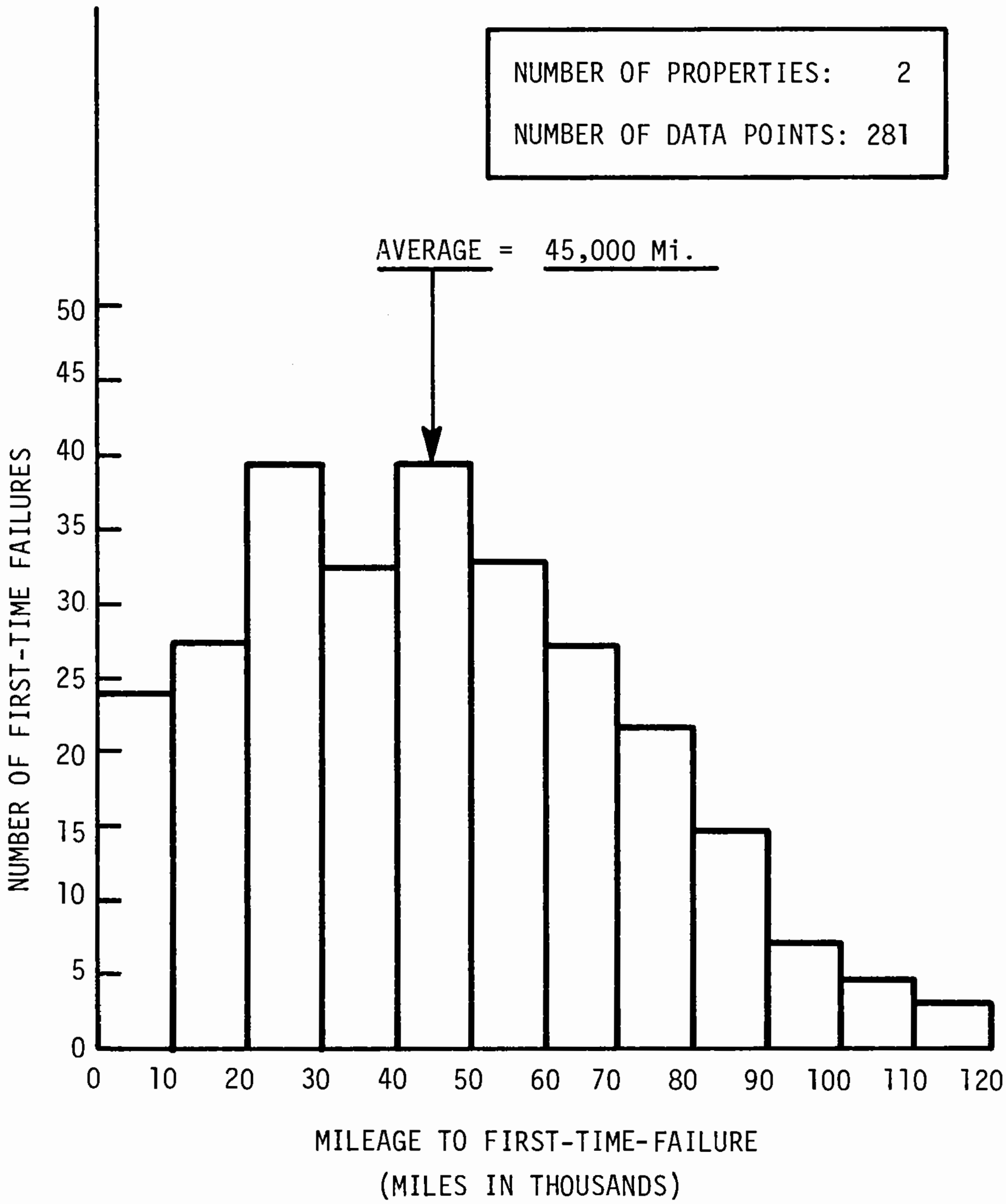


FIGURE 7. DISTRIBUTION OF ACTUAL V730 MILEAGE

this failure plot. This is an important consideration to keep in mind and will be discussed later.

These pattern plot data were also combined into a bar chart (Figure 7) to illustrate the distribution of failures versus mileage achieved and to indicate the average failure point. By this type of plot, it can be shown that early failures, those under ten thousand miles, amount to approximately 9 percent for the two properties involved and that the average life achieved is about 45,000 miles.

Similar plots were prepared for all V730 first-failure information obtained during the study (Table 2), namely, 937 first-failures at 15 transit properties in this country; these plots are provided as Figures 8 and 9. In contrast to Figures 6 and 7 which presented data from only two properties having similar geographical and operating environments, Figures 8 and 9 include V730 data from a variety of geographical, operating and maintenance conditions. Yet, as in Figure 6, the overall trend of mileage to failure is in the less desirable direction as transmission serial number increases. Likewise, Figure 9 indicates a similar distribution and average mileage to failure as Figure 7, with similar evidence of early failures.

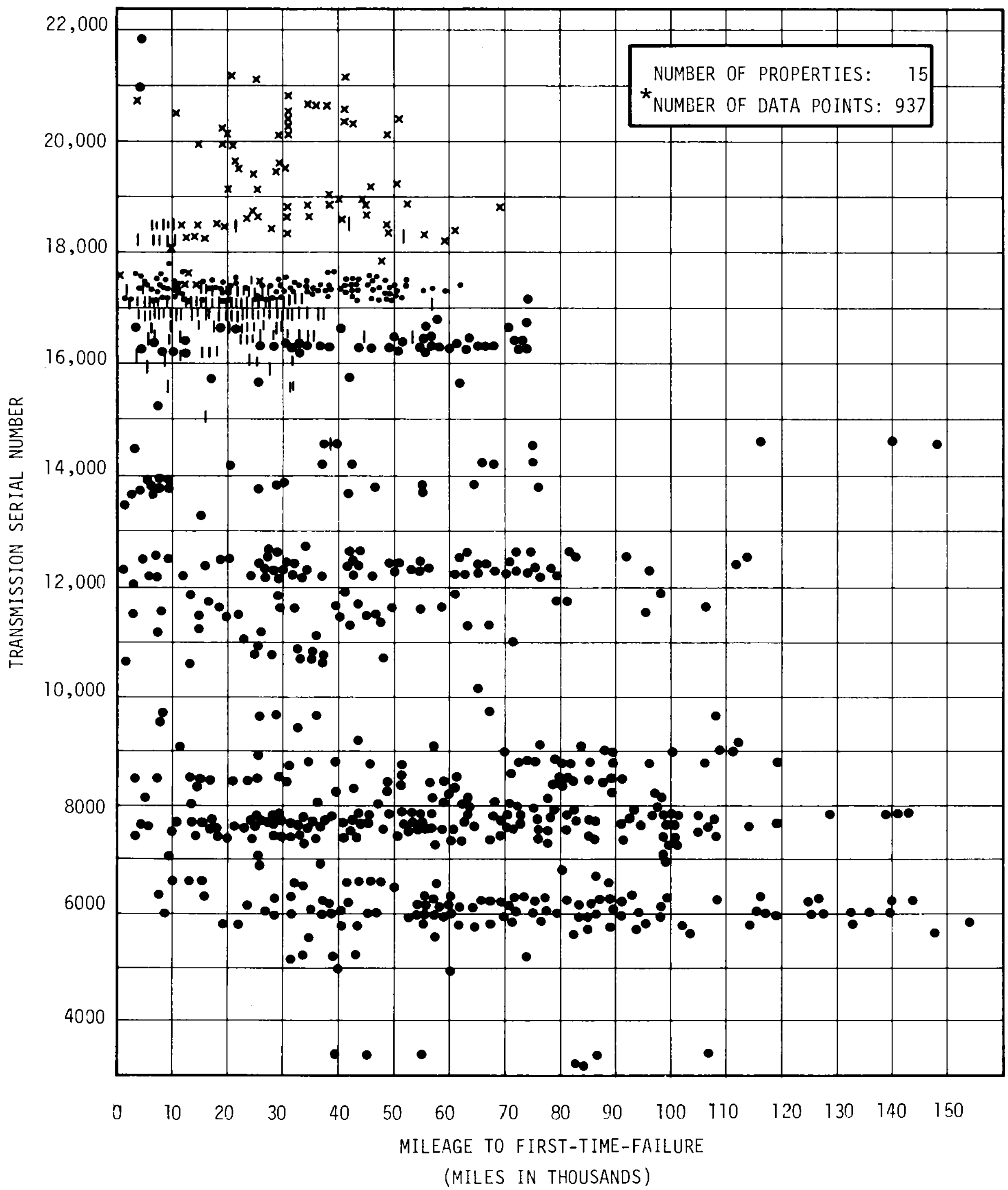
Some key points should be noted regarding Figure 8. First, the large predominance of transmission serial numbers presented on the plot is below 18481, the number at which a very significant improvement regarding the scarf-cut seal was incorporated into the transmission (see Appendix A). Below 18481, the trend shown by the plot confirms the feelings expressed by many operators that some modifications to the transmission actually worsened the reliability of the transmission rather than improving it. Approximately 40% of the transmissions evaluated in this study under serial number 18481 had experienced a first failure, some at as low a mileage as 2,000 miles and some at as high a mileage as 150,000 miles.

Above serial number 18481, there is still evidence of early failures, but the percentage of transmissions still running without experiencing first-failure is much higher. These transmissions, being relatively new at the time of this study, have not accumulated very high mileages, but the indicated trends are already favorable and there are early signs of improved reliability. These favorable trends are indicated in Figure 10 and in Table 3. For example, Figure 10 illustrates the dramatic reduction in failed transmissions with serial numbers above 18481 in comparison to serial numbers below 18481. (Mileage level of 23,000 miles is used since it represents the average mileage accumulated on the new transmissions.) Table 3 provides a list of properties having transmissions above serial number 18481 and is a further indication of the trend toward improved reliability.

TABLE 3. LIST OF PROPERTIES WITH NEWER TRANSMISSIONS
(Serial number above 18481)

Los Angeles	854 coaches	47 failed	42,500 avg. miles
Denver	125	0	35,000
Dayton	51	0	30,000
Atlanta	50	3	7,800
Cincinnati	85	0	11,500
Long Island	125	1	12,000
Birmingham	38	0	8,000
Providence, RI	34	0	21,350
Ft. Wayne	28	0	9,000
Worcester, MA	19	0	20,000
Toronto (New Look)	42	1	15,000
Toronto (Flyer)	106	2	11,000
Long Beach	51	0	22,500
	1608	56	23,000 avg. miles

As an additional point of interest, Figure 11 presents a histogram comparison of V730 first-failures on 35-ft. buses versus 40-ft. buses. The data were collected from three properties, each having some 35-ft. and 40-ft. buses, thus being exposed to the same environment, routes and degree of maintenance. All three properties were northern cities; in addition, the "New Look" buses did not have any air conditioning. Thus, the results are not strongly influenced by power take-off problems associated with the air conditioning system. A note of interest is the very high percentage of failures with the 40-ft. bus



*SYMBOLS VARY FOR CLARITY

FIGURE 8. ACTUAL PATTERN OF MILEAGE TO FIRST-TIME V730 FAILURE

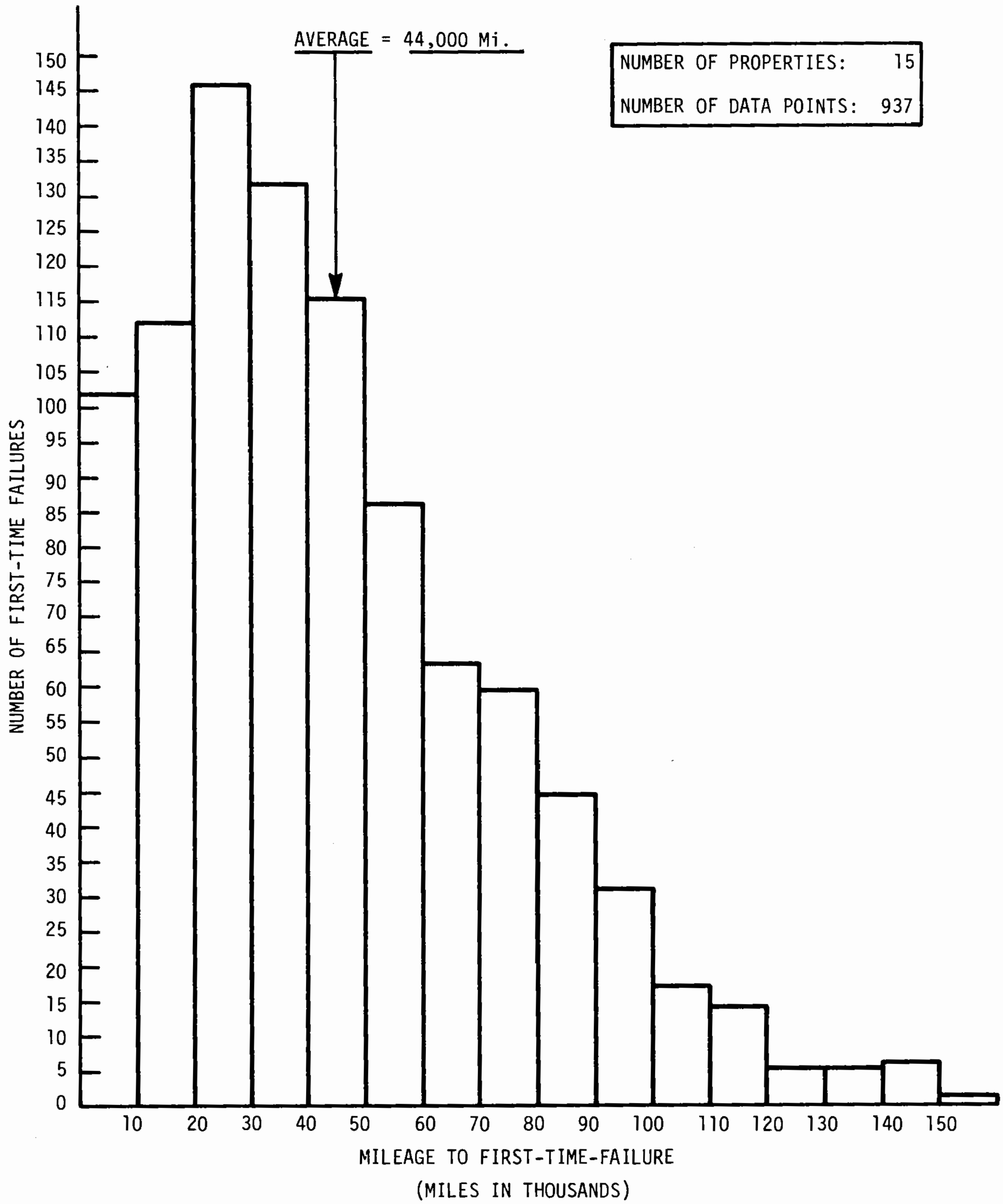


FIGURE 9. DISTRIBUTIONS OF ACTUAL V730 MILEAGE -- ALL PROPERTIES COMBINED

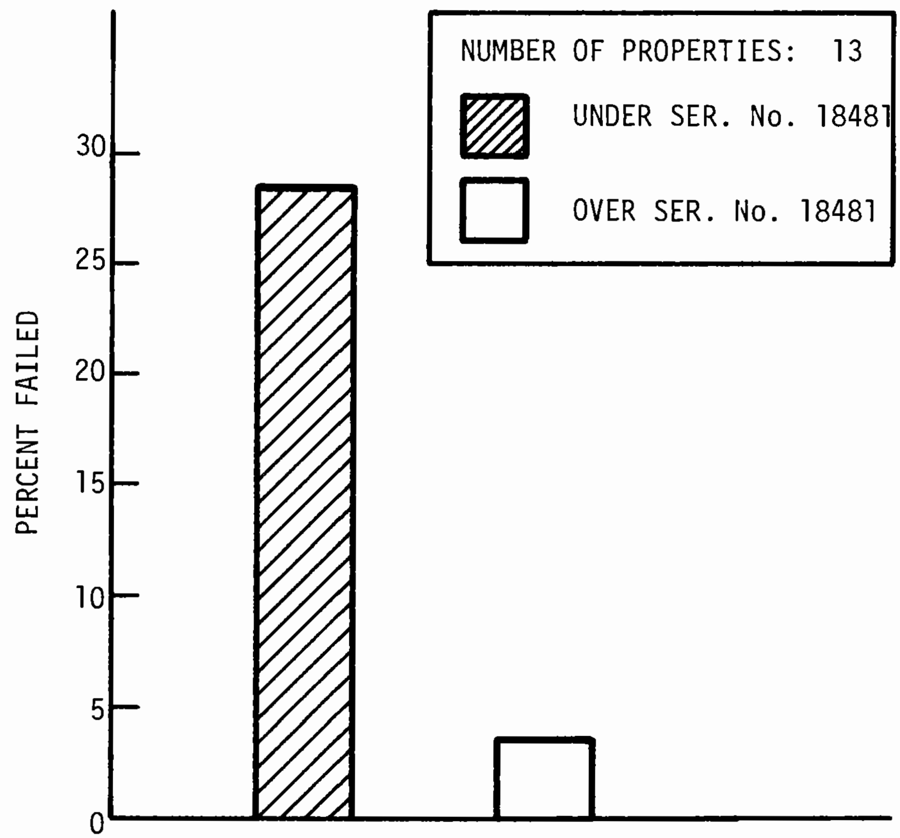


FIGURE 10. PERCENTAGE OF FAILED TRANSMISSIONS AT 23,000 MILES

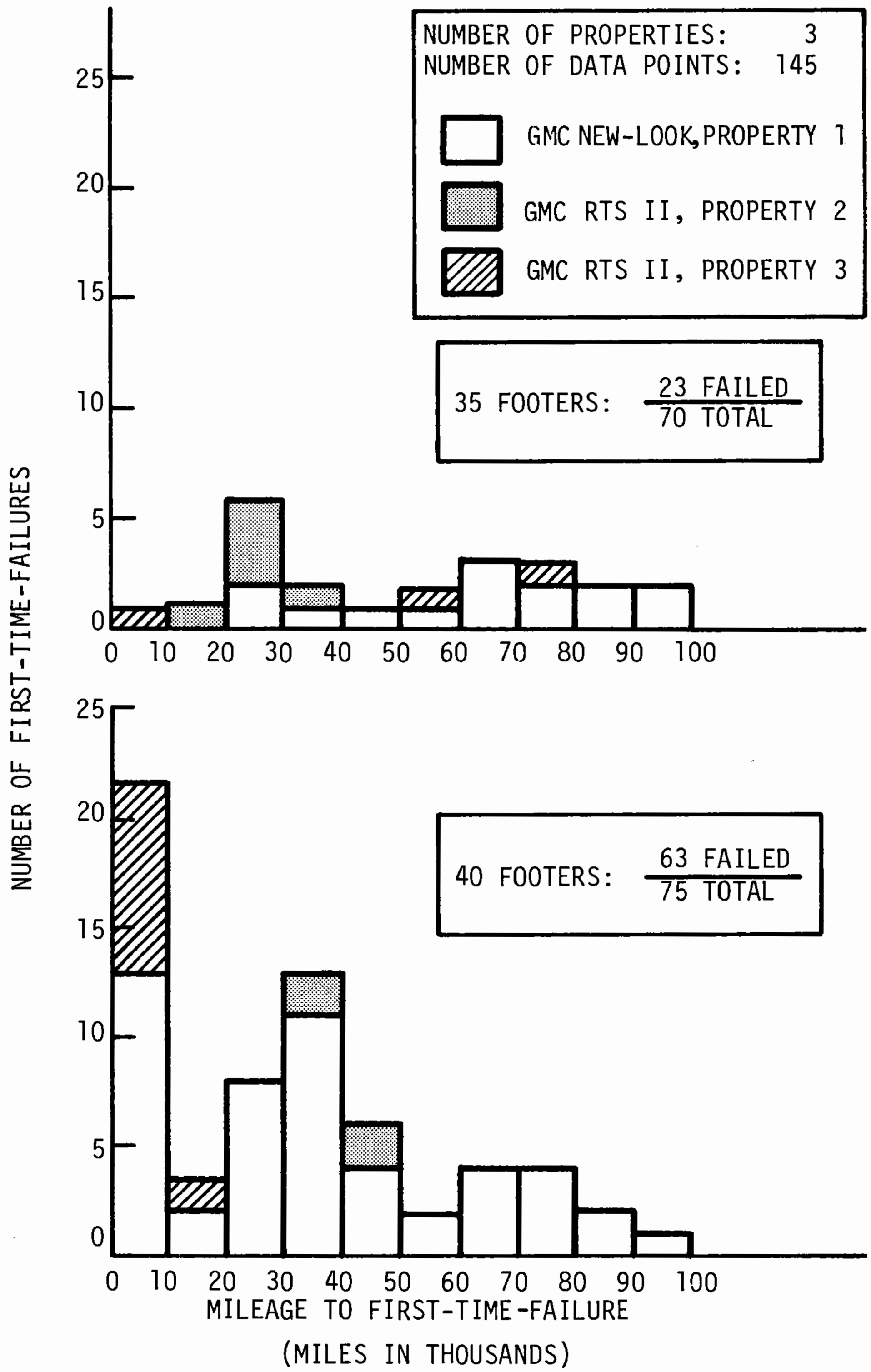


FIGURE 11. COMPARISON OF ACTUAL V730 MILEAGE DISTRIBUTIONS — 35FT. vs 40FT. BUS

installations (63 out of 75) in contrast to the 35-ft. installations (23 out of 70). The best looking group of 35-ft. installations, i.e., Property 1, showed an average V730 life of 64,000 miles. Perhaps the most specific conclusion that can be stated about this comparison is that the V730 lasted longer in a lighter duty environment, but still fell short of the 100,000 mile objective.

CONCLUSIONS

Based on the analysis of data in this study and the review of other information gathered during the evaluation, the following conclusions are drawn:

- Until the more recent changes made in 1981, the reliability of the V730 did not improve since its introduction in 1976, despite numerous modifications made by Detroit Diesel Allison. As confirmed by DDA, some modifications actually made matters worse (i.e., the scarf-cut seal change). This trend is in contrast to the evolutionary trend of previous transmissions where reliability improved as a function of time.

- Though data are limited, there is definite evidence that, after the modifications made in 1981 (transmission serial number 18481 and beyond), the reliability of the V730 has improved in terms of higher accumulated mileage at first-time failure and a larger percentage of V730s surviving beyond 23,000 miles (approximately one year of operation) without a failure. More mileage needs to be accumulated on these newer transmissions before the V730's improved performance can be confirmed.

- Some evidence of V730s failing in their early life (below 10,000 miles) still exists with the newer configurations, but to a lesser degree than with the earlier designs. Considering that design problems have been addressed and are being resolved with the newer transmissions, the implication is that quality control remains as a contributing factor.

- Variances in reliability among V730s having the same serial number range (i.e., design) at the same transit property is a result of being utilized in different buses (varying weight, varying engine configurations, with or without air conditioning, varying driver habits) and/or being operated on different routes (varying stop/start cycles, varying passenger loading, varying grades).

- In addition, two key factors which can vary the reliability of the V730 <u>from one property to another</u> are the degree of maintenance provided to the transmission and the environmental conditions at each property.

Those properties that operated buses under less severe environmental conditions and who provided the additional maintenance that the V730 required had fewer overall problems and greater service life.

- o Based on a very limited data sample, it appears that higher mileages to first failure are achieved with V730s in smaller buses.

- o A key contributor to the poor reliability record of the V730 was the lack of sufficient testing and evaluation in the revenue service operating environment, prior to full production commitment and its introduction into the market by the manufacturer.

- o Though starting slowly during the early years of the V730, it is felt that Detroit Diesel Allison, through a considerable commitment of funds and manpower, has finally "turned the corner" on the V730 reliability. It is also apparent that their capability to react to problems is a function, to a large extent, of the level of detail and accuracy of information received from the transit properties.

RECOMMENDATIONS

- With information collected to date, many of the newer V730 transmissions are beginning to show an improved service life in contrast to the older V730s. Special emphasis by DDA and the federal government, as well as the transit authorities, should be continued in tracking the reliability performance of the V730 transmissions, particularly with transmissions having serial numbers above #18481. Attention should be focused on the extent of early-life failures and on the mileage achieved before major repair. In addition, older transmissions that have been updated through DDA's Customer Support Program should be monitored to assess the degree of service-life and improvement achieved by these transmissions.

- In order to obtain more realistic test experience on new products prior to commitment for full production, DDA has initiated a test and evaluation program for improved transmissions whereby several production type units are installed in buses and operated in revenue service for over a year. The federal government, through UMTA, should support this activity by cooperatively funding the program with DDA and by providing technical support where needed and desired. Through this additional funding, further emphasis can be given to the scope and accuracy of data necessary to provide early warning of reliability problems and to demonstrate the overall cost-effectiveness of the new products.

- Proper corrective action on a transmission problem can only occur when details associated with a problem are known (type of problem, frequency of occurrence, symptons, etc). Collecting this type of information in a disciplined manner is of paramount importance in diagnosing the severity of the problem and working out the solution with the manufacturer. It is recommended that transit properties review the data system they currently use when problems occur with a V730 transmission and determine if fundamental information is being collected. Transit properties are also encouraged to contact Detroit Diesel Allison or UMTA/TSC for any technical assistance in establishing an adequate data collection system on transmissions.

APPENDIX A

ALLISON V-730 TRANSMISSION

SERIAL NUMBER "BREAK POINTS"

(Source: Detroit Diesel Allison)

This listing includes Allison engineered changes to production V730 transmission units and the serial number of the production transmission in which the change first occured.

CHANGE DESCRIPTION	NEW P/N	SERIAL NUMBER
First (Model Year 1975) Unit		501
First (Model Year 1976) Unit		543
First (Model Year 1977) Unit		2748
Double Row Ball Bearing Heat Stabilized Material	908251	2803
→ TurbineHub Grind/polish to remove white layer	6837034	3498
First (Model Year 1978) Unit		5000
Spring, Control Valve Shot peen spec.	6884701	5475
→ Bolt, Center Support Increased strength	6884960	5625
PTO Shaft Increased gear locating area	6880867	5821
Thrust Washers Change to bronze	6883492	7664
Pan Gasket One piece cork/rubber	6885423	8207
→ Double Row Ball Bearing Hardened Separator	908303	8276
Separator Plate To reduce main pressure regulator valve buzz	23010182	8325
Low Shift Valve Spring To reduce shift shock by lowering 2-1 shift point	23010383	8620
PTO Idler Shaft Increased hardness	6838959	8989

→ Denotes change that had significant impact on transmission reliability.

CHANGE DESCRIPTION	NEW P/N	SERIAL NUMBER
PTO Driven Gear Bearing Improved construction	9416195	8989
PTO Lip Seal Changed material	6838972	9065
Spring New shot peen requirements	6885166	9065
Scarf Cut Seal Ring Improved assembly operations	6773483	9943

First (Model Year 1979) Unit		10390
Lock-up Clutch Backing Plate New material	23010300	11113
Gear, PTO Driven Increase tooth width	23010105	11532
Gear, PTO Drive Increase tooth width	23010107	11651
Gear, PTO Idler Increase tooth width	23011232	11651
Third Clutch Assembly Increase Backing Plate Strength	23011236	11788
Dry-up Kit		12047
Seal Rings	23011454	12101
Seal Rings	23011453	12101
Seal Rings	23011457	12675
Seal Rings	23011456	12689
Piston seals with increased thickness at flexible section.		
Piston, Lock-up Clutch Forged piston	23011093	12753
Lock-up Clutch Plate Improved bonding	23010437	12904
Scarf Cut Seal Rings Improve assembly operations	6775517	13044

First (Model Year 1980) Unit		13722
O-Ring-Suction Tube Assure proper seal	23013114	13737

CHANGE DESCRIPTION	NEW P/N	SERIAL NUMBER
Forward Clutch Housing & Shaft Improved assembly to eliminate shavings	6880996	16548
Low Oil Sensor (Hook-up optional)		16910
→ Bevel Gear Retainer Bolt Improved bolt retention	23013525	16764
→ Detent Assist Spring Increased detent force	23013851	17302
Suction Filter Screen Add machined end fitting to suction tube	23013674	17457
Washer, Center Support Bolt Chamfer to clear bolt radius	23013841	17685
First (Model Year 1981) Unit		17810
→ Center Support Shim Improve sun gear bushing life	23013880	18037
→ Seal Ring (SP-21) Improve seal life	23014441 23014442	18481
First (Model Year 1982) Unit		23734

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