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Urban Mass
Transportation
Administration

Air Conditioning Modifications for the GMC RTSII Series 01 Coach (Model TH-8201)

Office of Technical Assistance
Office of Bus and Paratransit
Systems

Prepared by:
Transportation Systems Center
Urban Systems Division

October 1982
Final Report



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16. Abstract This report presents the documentation and evaluation of air conditioning modifications devised by San Antonio VIA Metropolitan Transit for the General Motors RTS-11 Series 01 advanced design bus. The objective of these modifications was to reduce bus air conditioning system failures. Major modifications have included replacement and relocation of the condenser, replacement of certain components, including the compressor, and alteration of the control system. The documentation of the air conditioning modifications consists of detailed narrative descriptions, photographs and drawings (with major reference dimensions), parts list, and procedures. The baseline bus, for which the modifications are applicable, is described together with a discussion of the objectives and goals of the modifications. The documentation material is sufficiently detailed so that other transit properties, if they so choose, may implement the same changes to their coaches. The evaluation of the air conditioning modifications focuses on their impact on component reliability and fuel economy. Data for the evaluation are from records normally maintained by San Antonio VIA Metropolitan Transit. These records include repair history cards, fuel consumption records, and bus mileages.					
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PREFACE

The Transportation Systems Center acknowledges the fine efforts by the Technology Research and Analysis Corporation (TRAAC) of Arlington, Virginia which formed the basis for this report. Personnel from TRAAC include Joel Edelman and Arne Hungerbuhler. TRAAC was responsible for developing the documentation package and evaluating the air conditioning modifications. This document represents a joint effort by TRAAC and TSC.

Gratitude is expressed to the personnel of San Antonio VIA Metropolitan Transit for their immeasurable cooperation and support. This report would not exist without the assistance and time provided us by Messrs. Wayne Cook, General Manager, Wayne Hale, Manager of Maintenance, and Marvin Bielefeld, Maintenance Coordinator.

We also thank Mr. Douglas Peck of San Antonio VIA Metropolitan Transit and personnel from UMTA's Office of Bus and Paratransit Systems for their review of and comment on the draft report.

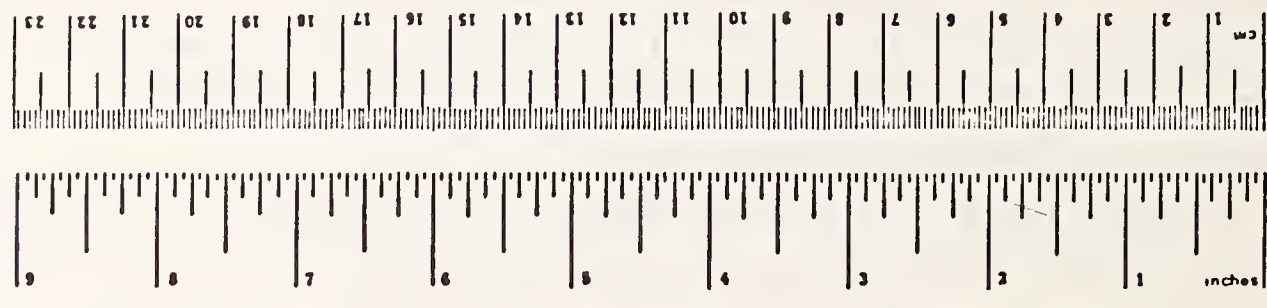
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<u>LENGTH</u>				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<u>AREA</u>				
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	acres	0.4	hectares	ha
<u>MASS (weight)</u>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<u>VOLUME</u>				
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
<u>TEMPERATURE (exact)</u>				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<u>LENGTH</u>				
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
<u>AREA</u>				
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	acres
<u>MASS (weight)</u>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	short tons
<u>VOLUME</u>				
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
<u>TEMPERATURE (exact)</u>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



*1 in = 2.54 (exact). 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, O-286.

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Executive Summary

Air conditioning and ventilating system problems are some of the most urgent problems of the transit operator in terms of general reliability, maintainability, and efficiency. In an effort to improve the air conditioning system, a number of transit properties have made modifications to their coaches. One of these properties, VIA Metropolitan Transit of San Antonio, Texas, has devised, implemented, and tested modifications for their General Motors RTS II Series 01 advanced design bus. The primary objective of these modifications was to reduce the down-time of coaches (all of which are equipped with air conditioning) caused by air conditioning system failures. Major modifications included replacement and relocation of the condenser, replacement of certain components including the compressor, and alteration of the control system.

As part of its bus and paratransit technology research and development efforts, the Urban Mass Transportation Administration (UMTA) is conducting the Bus Subsystems Technology Project to help the transit bus industry solve serious equipment problems. The principal objective of this project to reduce the recurring costs necessary to operate the U.S. bus fleet by developing improved subsystem technologies that can be adopted by operators and manufacturers in the near future. An important element of the program is to foster communication among and disseminate information to the transit community on progress and results of bus technology projects. Consequently, UMTA's Office of Bus and Paratransit Systems sponsored the Department of Transportation's Transportation Systems Center (TSC) to undertake a project to document and evaluate the San Antonio VIA Metropolitan Transit's air conditioning modifications.

The objectives of the project were twofold. First, the modifications were to be sufficiently documented so that other transit properties, if they so choose, could implement the same changes to their coaches. Significant interest has been expressed by many operators to learn details of the San Antonio VIA Metropolitan Transit air conditioning modifications. Further, many RTS-II Series 01 coaches are in operation and, at the time the effort was initiated, General Motors indicated they would not market a retrofit kit. Secondly, the modifications were to be evaluated to determine their impact on both component reliability and fuel economy.

The most important step of the approach was acquiring the required information from San Antonio VIA Metropolitan Transit. This was accomplished through field visits to San Antonio for extensive discussions with VIA personnel, review of the implemented air conditioning modifications, review of available drawings/sketches, and detailed examination of bus maintenance records and fuel economy data. The data/information thus obtained was the foundation for developing the documentation material and evaluating the modifications. No data were collected beyond what was available at the transit property. The developed documentation materials were reviewed thoroughly with San Antonio VIA Metropolitan Transit for completeness and accuracy.

The air conditioning modifications are documented by this report, which includes a detailed narrative, photographs and drawings (with major reference dimensions), a parts list, and a description of the necessary procedures. The baseline bus, for which the modifications are applicable, is described and a discussion is presented on the objectives and goals of the modifications.

The evaluation of the air conditioning modifications concludes that:

- The San Antonio VIA Metropolitan Transit air conditioning modification had a substantial impact in improving component reliability.

- The six-cylinder replacement compressor exhibited a significantly better unit life than the O.E.M. unit.
- Based on an analysis of the various aspects of the air conditioning modification, the changes made by San Antonio VIA Metropolitan Transit should result in some improvement in coach fuel economy. However, it was not possible to confirm this with the available data and within the scope of the study.
- The six-cylinder replacement compressor did not impact the overall coach fuel economy.

1.0 Introduction

The San Antonio metropolitan area covers approximately 190 square miles and contains more than one million people whose only form of public transportation is San Antonio VIA Metropolitan Transit's bus fleet. Situated in south central Texas, the region averages more than 80 days per year when the mean temperature is above 90⁰ F. This has meant that all 555 of VIA's buses are equipped with air conditioning.

Subsequent to the delivery of their General Motors RTS II Advanced Design Buses, the number of VIA's missed trips began climbing at an alarming rate. This increase was due almost exclusively to the failures of several coach subsystems to perform reliably and adequately in the extreme heat of the summer cooling season. The problem of ambient heat is aggravated by the original design of the air conditioning on the RTS II bus. The refrigerant condenser is located next to the engine coolant radiator, which results in both components being cooled by the same stream of air. Because of their close proximity, the radiator and condenser both lose the ability to radiate heat. In an attempt to achieve adequate cooling, the system includes a large radiator fan which revolves somewhat faster than the engine. Debris is stirred up from the street below by the flow of air created by this fan. The debris is drawn into the engine compartment through the condenser coil where much of it becomes lodged, reducing air flow and often damaging the condenser. In addition, the air that is drawn through the condenser is above ambient temperature because of its proximity to the hotter street surface.

Consequently, the air flowing into and through the engine compartment often reaches very high temperatures. Readings taken near the face of the condenser have indicated air temperatures as high as 180⁰ F. An internal pressure in excess of 500 psi is required to condense refrigerant-22 at this temperature. Head pressures in this range adversely

affect air conditioning system component reliability. In the engine compartment, air temperature has been measured at up to 300⁰ F near the transmission and air conditioning compressor. These high temperatures contribute to shortened component service life and degraded component performance.

In an effort to alleviate these problems, San Antonio VIA Metropolitan Transit maintenance personnel have developed and implemented modifications to some of the RTS II subsystems. The major air conditioning modification involved replacing the refrigerant condenser with a smaller unit and relocating it outside the engine compartment. The new condenser was mounted along with 2 electric-motor-driven cooling fans just below roof level at the rear of the bus. This modification is illustrated in Figures 1 and 2, which show both the unmodified and modified versions of the RTS II Series 01 coach.

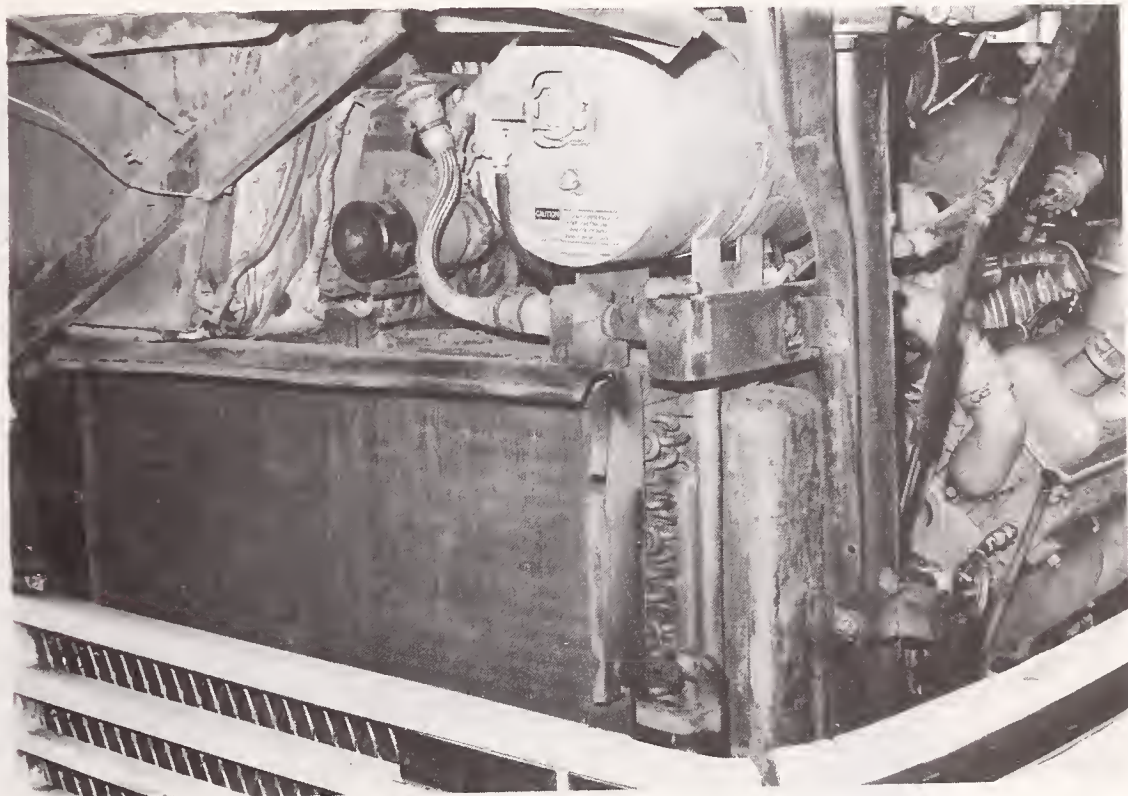
Concurrently, some other changes were incorporated in the air conditioning modification because of their relevance to the performance of this system. These changes include the following:

- The Honeywell control was replaced with a solid state unit fabricated in-house.
- The engine cooling fan drive was modified to reduce unit failures by increasing internal lubrication.
- A smaller, pusher-type engine cooling fan was installed along with a thermostat to activate the fan drive, thereby minimizing fan use.
- The blank plate on the inside of the engine right-side closure door was replaced with a mesh grill to increase the flow of ambient air into the engine compartment.
- The suction accumulator (heat exchanger) was removed and discarded with no apparent loss in system efficiency, since liquid floodback is not a problem and the change eliminates four plumbing connections.

These modifications are documented in detail in Section 4.0.



Coach Exterior



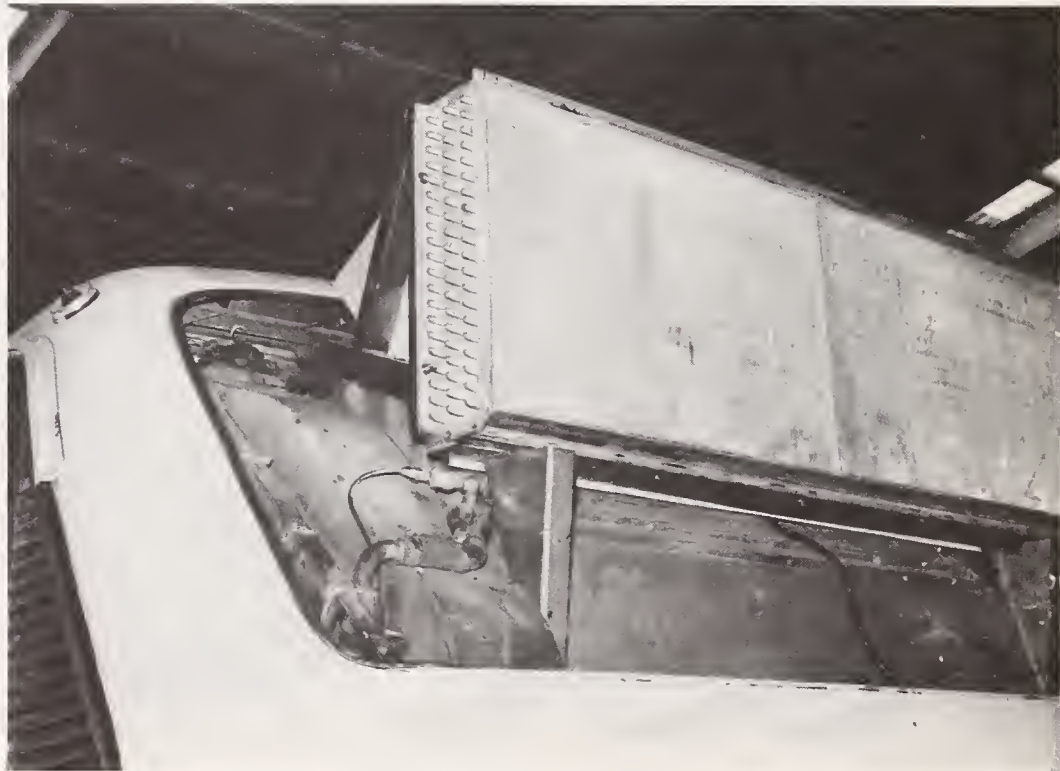
Condenser

FIGURE 1

Unmodified RTS II Series 01 Coach



Coach Exterior



Condenser

FIGURE 2

Modified RTS II Series 01 Coach

In a parallel effort to improve system reliability, the standard four-cylinder air conditioning compressor was replaced with a six-cylinder unit of similar capacity, but requiring less torque to operate, thereby reducing the load on the transmission. No documentation is provided for this simple compressor exchange.

2.0 Objective

As part of its bus and paratransit technology efforts, the U.S. Department of Transportation's Urban Mass Transportation Administration (UMTA) has a responsibility to assist the transit industry in dealing with serious problems in bus system and subsystem hardware. The objective of this work is to reduce the costs associated with the operation of urban transit buses through the development of more reliable and efficient mechanical and electrical system components.

One method of aiding the transit industry in this endeavor is to publish information on methodology developed, and results achieved, in any successful attempt to increase component operating life, fuel economy, and/or efficiency. Publication of such information in detailed form will thus enable the transit industry to utilize the developed technology to achieve similar results.

In an effort to assist other transit properties having problems with the air conditioning in RTS II Series 01 coaches, the U.S. Department of Transportation's Transportation Systems Center (TSC), under the sponsorship of UMTA's Office of Bus and Paratransit Systems, has undertaken a project to document the methods and procedures used, and the results obtained, by San Antonio VIA Metropolitan Transit in their Series 01 bus air conditioning modifications.

3.0 Approach

In order to obtain the necessary information, several visits were made to the property at San Antonio. Extensive discussions were held with garage and office personnel in the maintenance department. Measurements and photographs were taken of the various new and relocated air conditioning components on the modified bus. Required data were obtained in raw form directly from existing maintenance records routinely compiled by VIA maintenance personnel. Subsequently, further discussions were held to review and refine the final report.

4.0 Description of the Air Conditioning Modification

4.1 General

This section describes the modifications made to the air conditioning system of the GMC RTS II Series 01 coach by San Antonio VIA Metropolitan Transit. The objectives of these modifications are described in Section 4.2. Section 4.3 describes the baseline bus and Section 4.4 describes in detail the modifications to the bus. The costs of the modifications are presented in Section 4.5. A complete parts list is included as Appendix A of this report; detailed assembly procedures for the modifications comprise Appendix B.

4.2 Objectives

The objectives of the San Antonio VIA Metropolitan Transit modification were to correct the deficiencies in coach air conditioning performance and reliability which stemmed from inadequate cooling of the refrigerant condenser. The primary goal was to reduce the frequency of failures of the air conditioning system resulting from high operating temperatures and the associated high head pressures. Secondary goals were to reduce the frequency of other component failures, to increase fuel economy, and to reduce operating costs. The air conditioning modification was devised with the following specific considerations in mind:

- To be retrofittable with minimal complexity to all San Antonio VIA Metropolitan Transit RTS II Series 01 coaches, using as many GMC parts as possible and requiring only hand tools for installation.
- To not increase total coach weight.
- To reduce life-cycle operating costs.
- To cost less than \$2,500 per unit (1979 dollars), for parts, materials and labor.

- To decrease horsepower requirements, thus allowing derating of the engine and improving fuel economy.
- To reduce the frequency of engine and transmission failures by decreasing operating temperatures.
- To reduce drive-by noise levels by reducing cooling fan size and use.

4.3 Baseline Bus

The air conditioning modification was made to a GMC RTS II Series 01 coach, San Antonio VIA Metropolitan Transit bus number 205. The configuration of this bus is as follows:

GMC Coach Type:	RTS II
Series:	01*
Model:	TH 8201
Year Manufactured:	1978
Length:	40 feet
Width:	102 inches
Engine:	8V71N
Transmission:	V730
Seats:	47

4.4 Modification

The air conditioning modification consists primarily of the removal of the condenser from its location adjacent to the radiator and the replacement of the condenser with a smaller unit mounted near roof level on the back of the bus and cooled by two electric blowers. Several ancillary improvements were incorporated in the air conditioning modifications. These improvements included:

* It is important to note that the Series 01 and the similar Series 03 coaches were subject to numerous factory specification changes throughout their production history. It is undetermined whether any of these changes significantly affect the application of the San Antonio VIA modifications.

- Relocation of the refrigerant liquid receiver and dryer outside of the engine compartment;
- Modification of the control system;
- Modifications to the engine cooling fan system; and
- Installation of supplementary air intake vents for the engine compartment.

4.4.1 Condenser

The principal alteration to the RTS II air conditioning system was the mounting of a smaller refrigerant condenser near the coach roof at the rear of the bus, as shown in Figure 3. The components required for the condenser relocation are the following:

- "New Look" condenser
- Condenser mounting frame
- Blowers
- Blower housing
- Side extension panels
- Air intake panel and clamp
- Rear cover
- Drain pans

A detailed description of each of these items follows.

"New Look" Condenser

Because the shape of the original condenser on the Series 01 coaches was not suitable, a smaller, 62-inch wide, standard coil assembly from a "New Look" coach was used to replace the original condenser. This condenser is shown in Figure 4 as installed at the rear of bus #205. The condenser is originally manufactured with a light-weight frame around its perimeter. This frame is used for attachment purposes in the New Look bus and it is retained on the condenser for the same purpose in this application. The condenser is bolted to a mounting frame designed and fabricated by San Antonio VIA Metropolitan Transit.

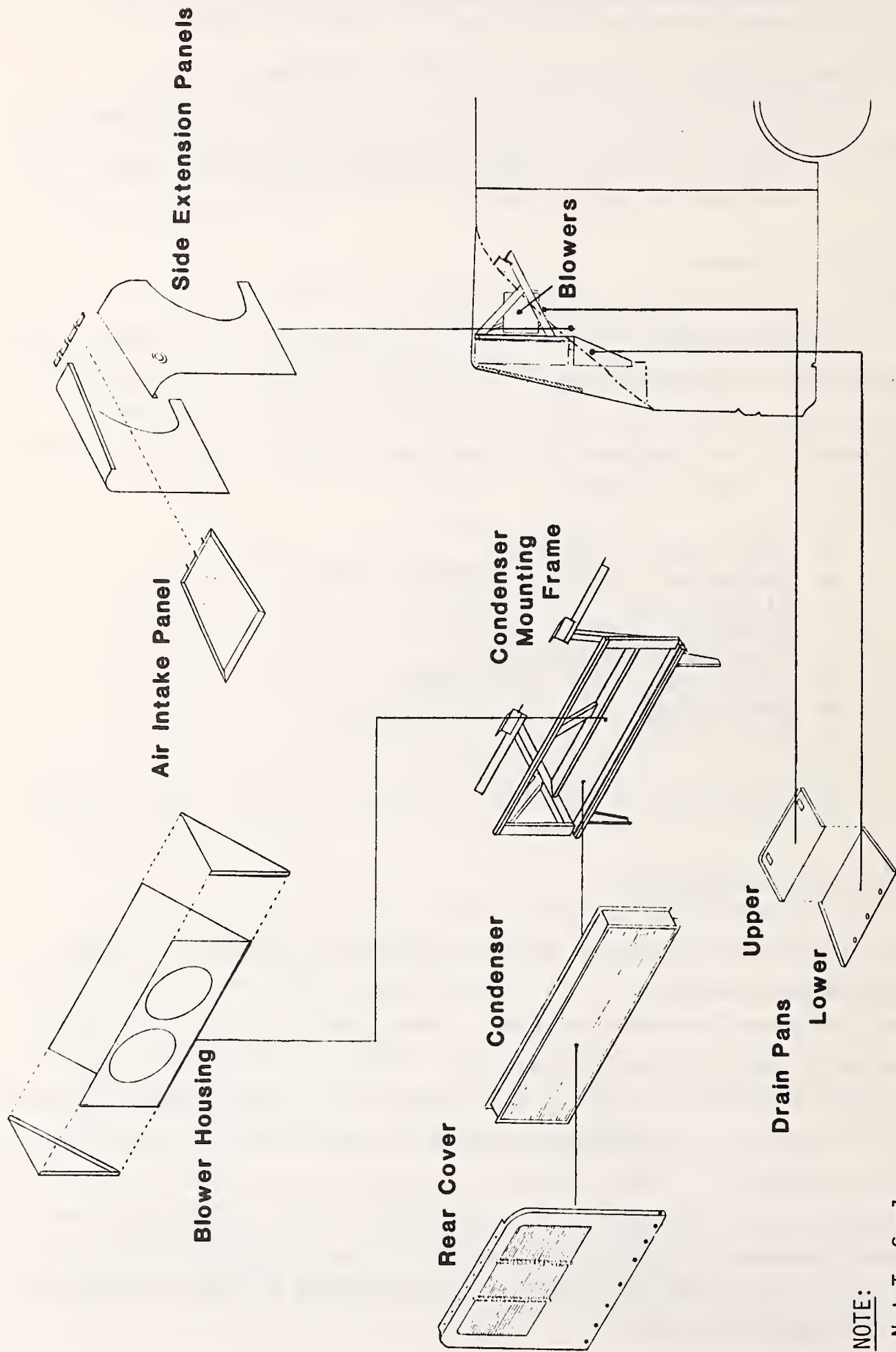
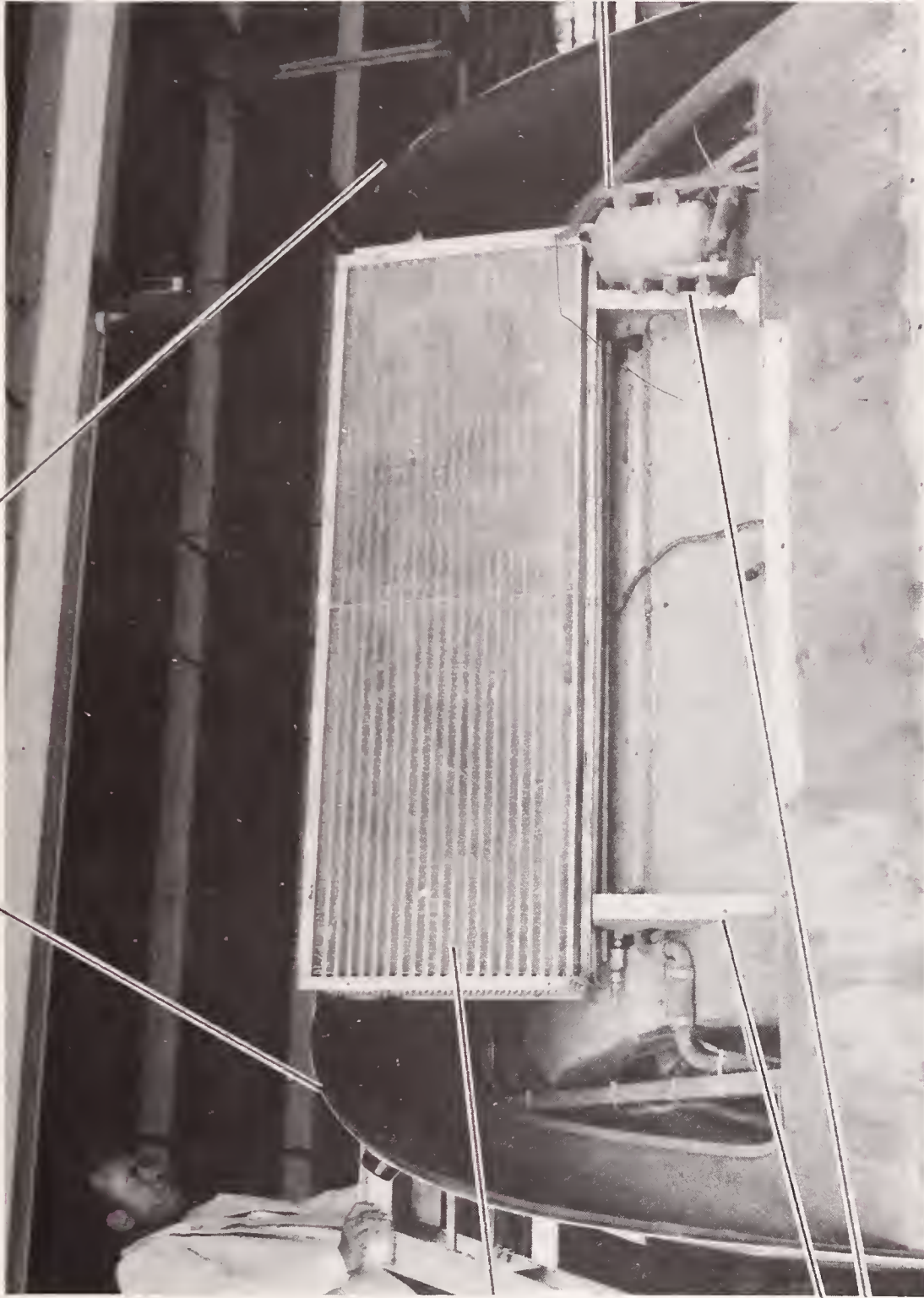


FIGURE 3
 Assembly of Condenser Relocation Components

SIDE EXTENSION PANELS



**NEW LOOK
CONDENSER**

**LIQUID RECEIVER
TANK**

**LOWER FRAME
SUPPORTS**

FIGURE 4

New Look Condenser Mounted on RTS II Series 01 Coach

Condenser Mounting Frame

The mounting frame is attached to the bus in three locations: the mounting plates to which the two rear hatch hinges were originally bolted, existing holes in the diagonal frame member in both upper corners of the bus, and the evaporator housing near the original location of the Honeywell control box. The mounted condenser and mounting frame are illustrated in Figure 5. The two upper attachment locations provide most of the support for the assembly; the lower attachment provides lateral fix points. An isometric view of the mounting frame is shown in Figure 6.

Blowers

The condenser blower motors are cradled on a cross member in the mounting frame. The assembly of the mounting frame and blower motors is shown in Figures 7 and 8. The blowers consist of two GE motors with cast aluminum fans of four blades each. The motors are each less than one-third horsepower and operate directly from the main power supply. The addition of a circuit breaker is the only modification to the electrical system.

Blower Housing

The blower housing consists of three pieces of flat ABS plastic; the center piece is bent into a V contour with holes cut in two places for the fan blades. These pieces are illustrated in Figure 9.

Side Extension Panels

The side extension panels for the bus are composed of two pieces of sheet metal cut to an appropriate contour and bent in one simple curve. This assembly is shown in Figures

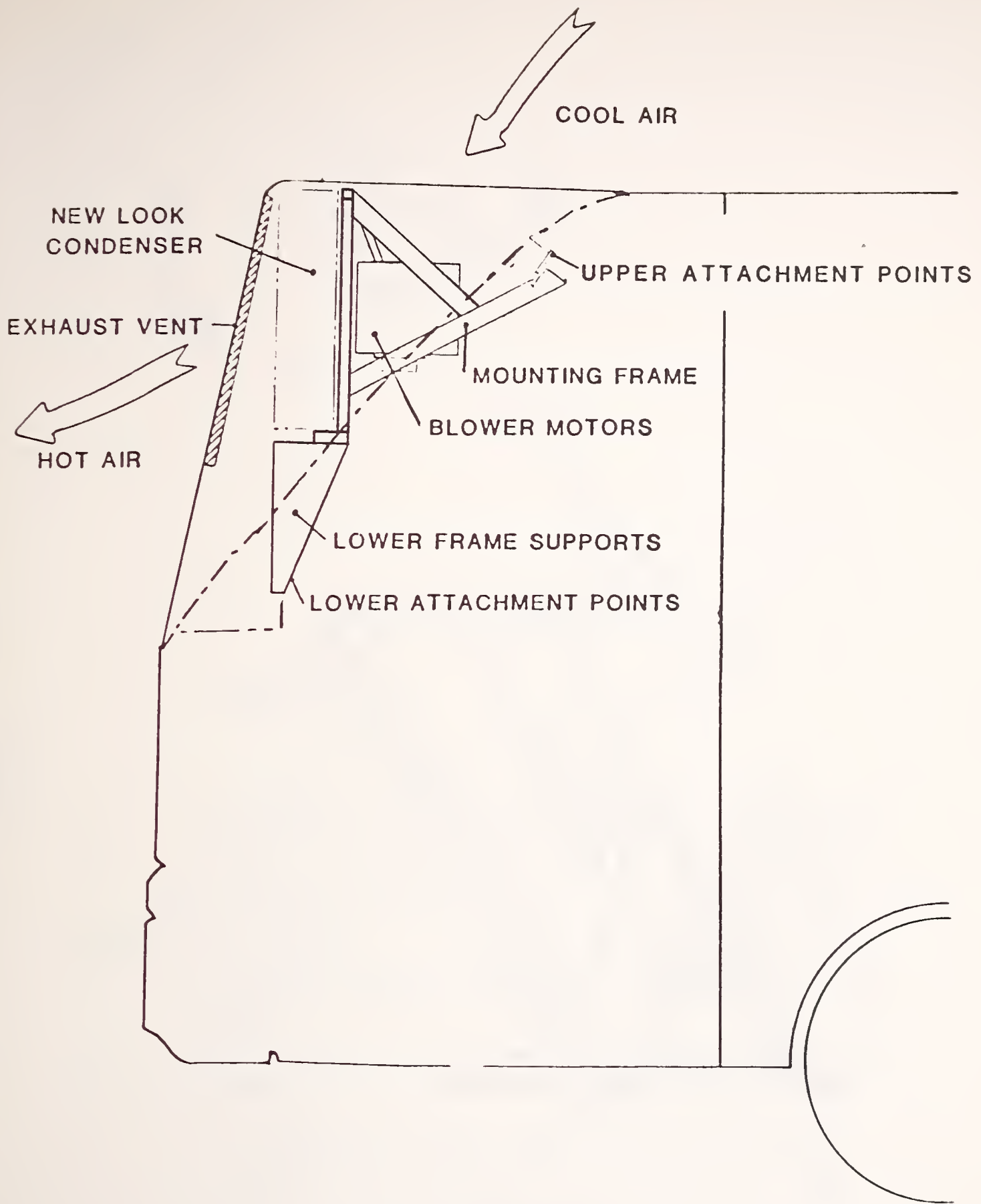
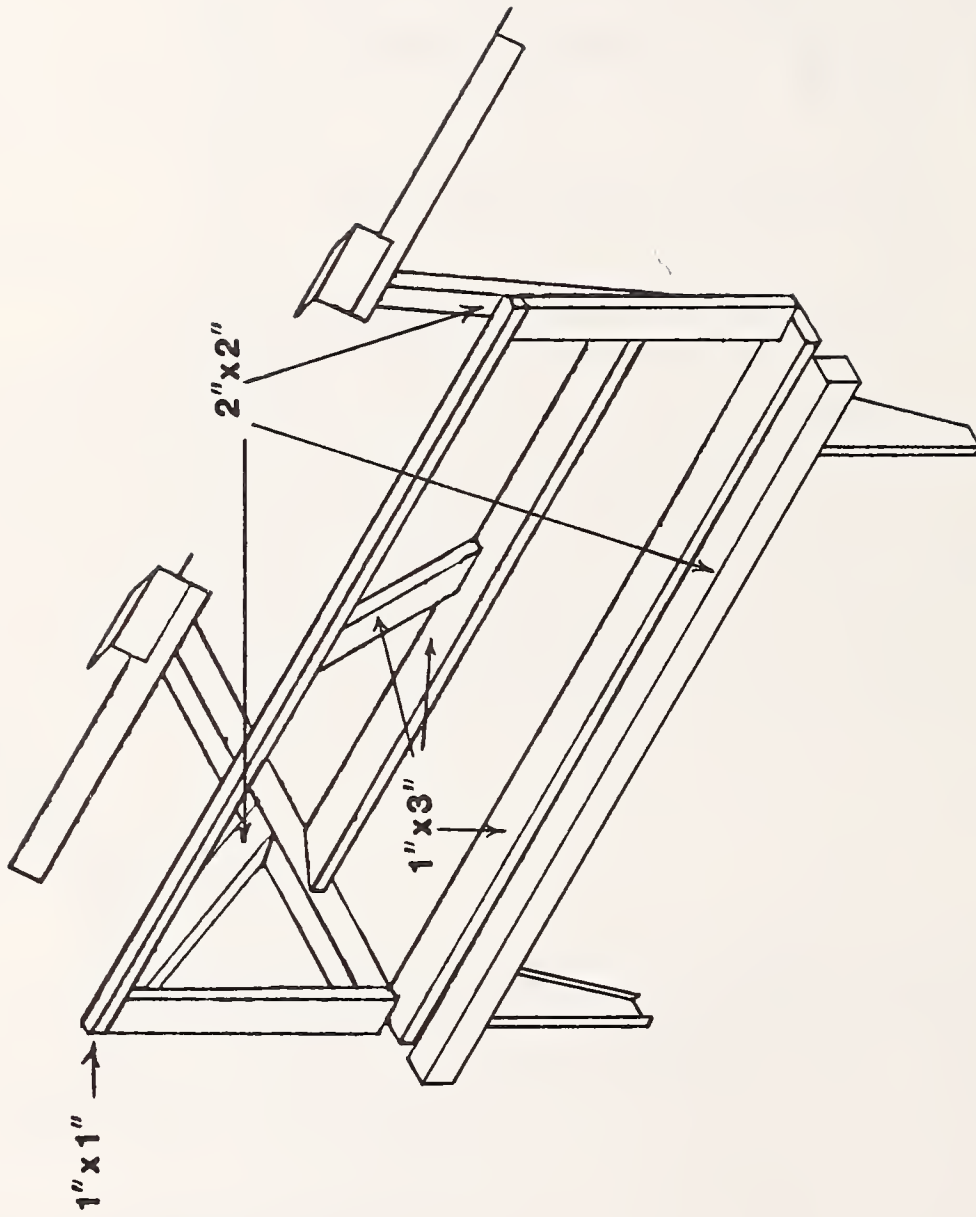


FIGURE 5

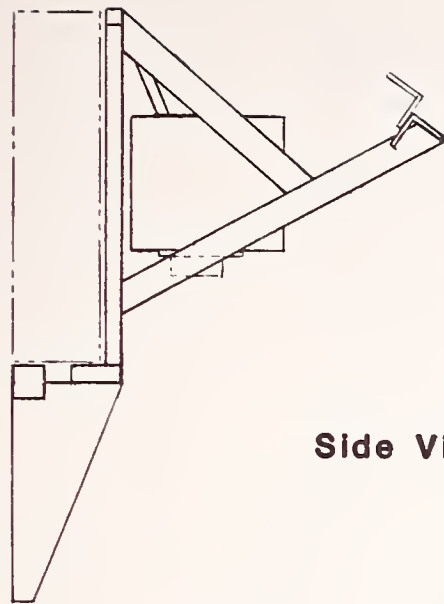
Side View of Relocated Condenser

NOTE:
Not To Scale

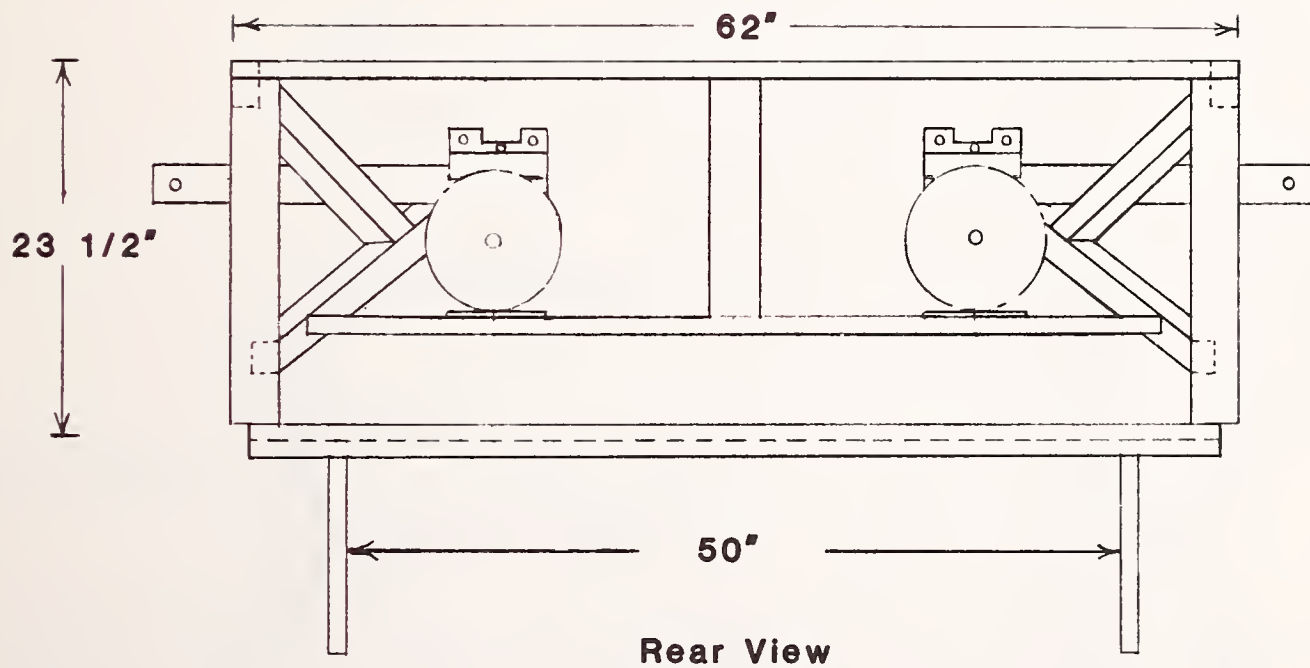


NOTE:
Not To Scale

FIGURE 6
Condenser Mounting Frame



Side View



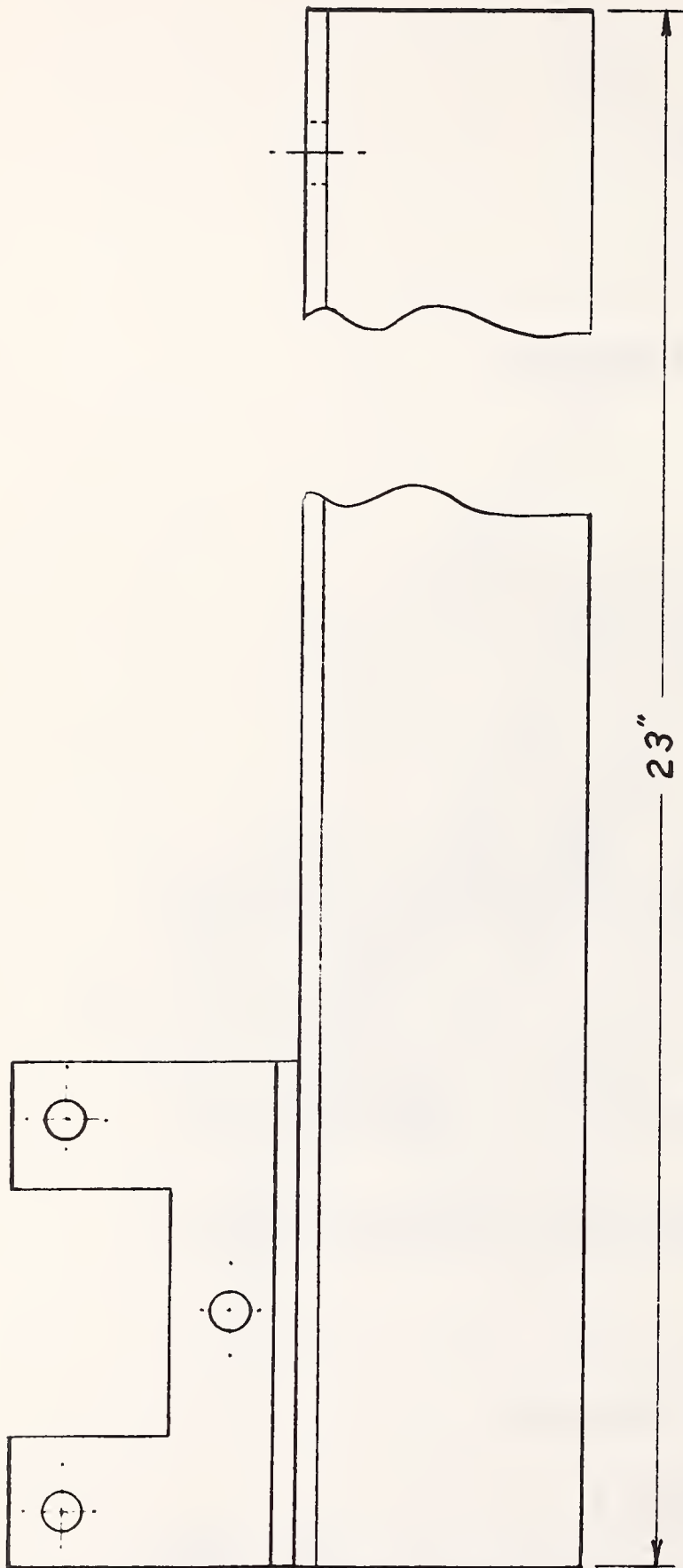
Rear View

FIGURE 7

Blowers and Condenser Mounting Frame Assembly

NOTES:

1. Not To Scale
2. Dimensions Are For Reference Only

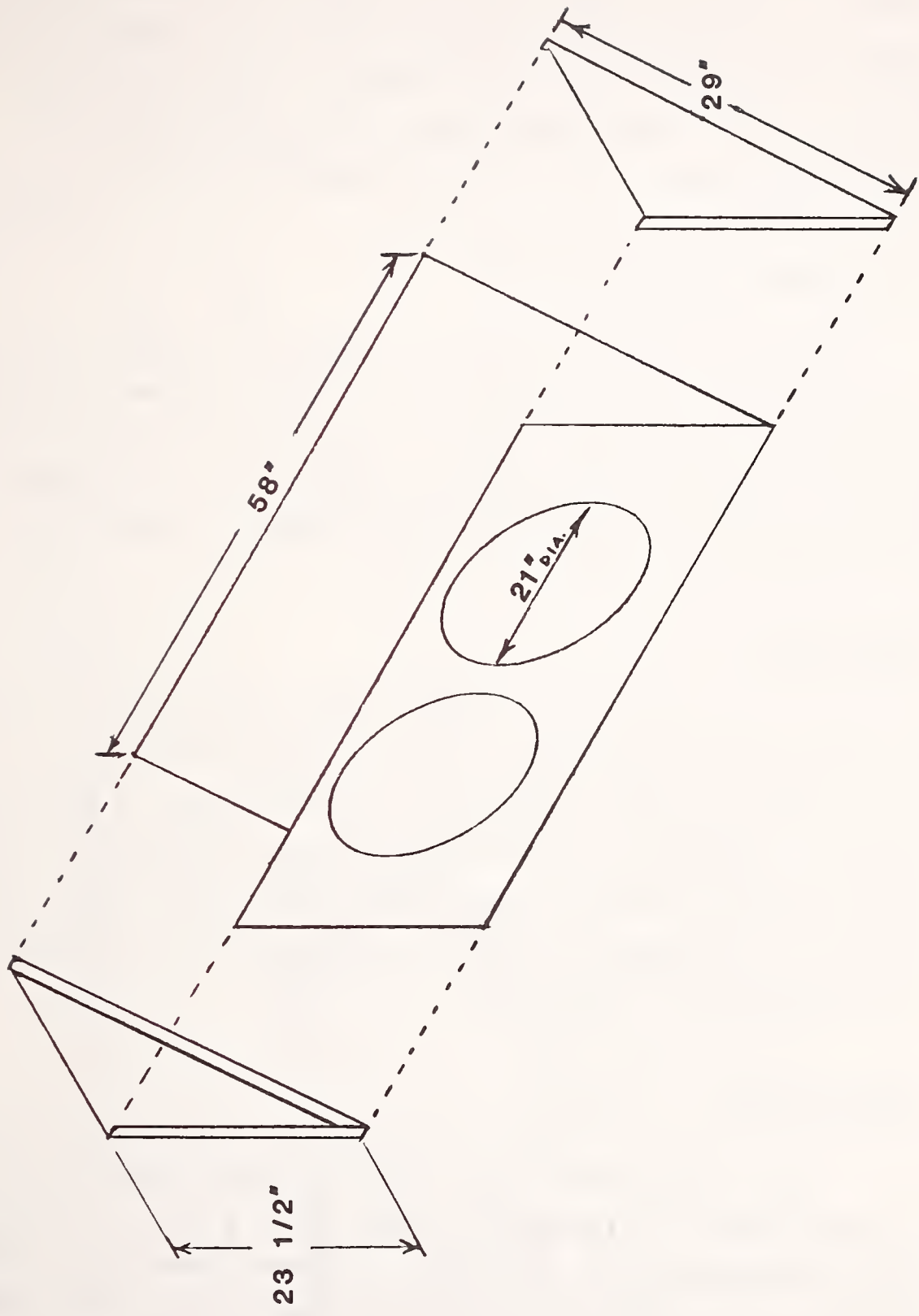


NOTES:

1. Not To Scale
2. Dimensions Are For Reference Only

FIGURE 8

Mounting Frame Upper Attachment Detail



NOTES:

1. Not To Scale
2. Dimensions Are For Reference Only

FIGURE 9

Blower Housing Panels

10 and 11. Appropriate holes are drilled for attachment to the bus via eight bolts across the top. The forward edges of the side extension panels slide beneath the loosened edge of the existing side skin of the bus and are fastened with pop rivets. The rear edge of each panel is crimped to form a flange into which the molded plastic rear cover fits.

The top surface of each panel rises gradually from front to rear, to a level 3/8" above the roof contour but still below the level of the top of the roof hatches.

Air Intake Panel and Clamp

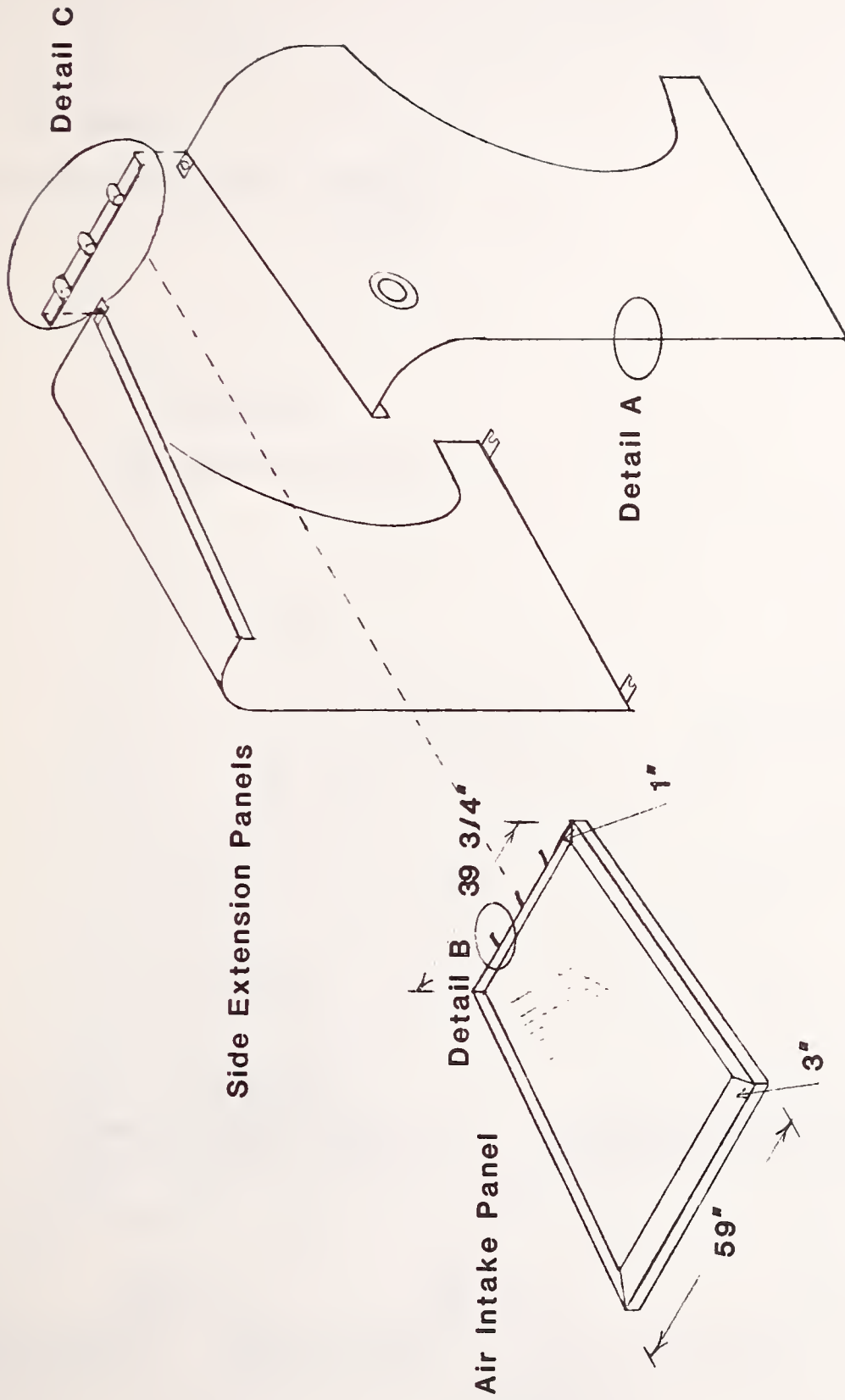
The air intake cover for the top of the extension is expanded metal grating held in a light frame with three pins attached to its front edge. These pins slide into a clamp which is directly mounted to the bus at the leading edge of the extension. These items are shown in Figures 10 and 11.

Rear Cover

The rear cover is molded ABS plastic and is illustrated in Figure 12. The rear cover is given rigidity by its fit in the flange of the sheet-metal side extension panels. Additional rigidity is provided by the attachment of 3/4" aluminum channel strips to the inner face using pop rivets. The cover is fastened with half-inch quarter-turn fasteners, as illustrated in Figure 13.

Drain Pans

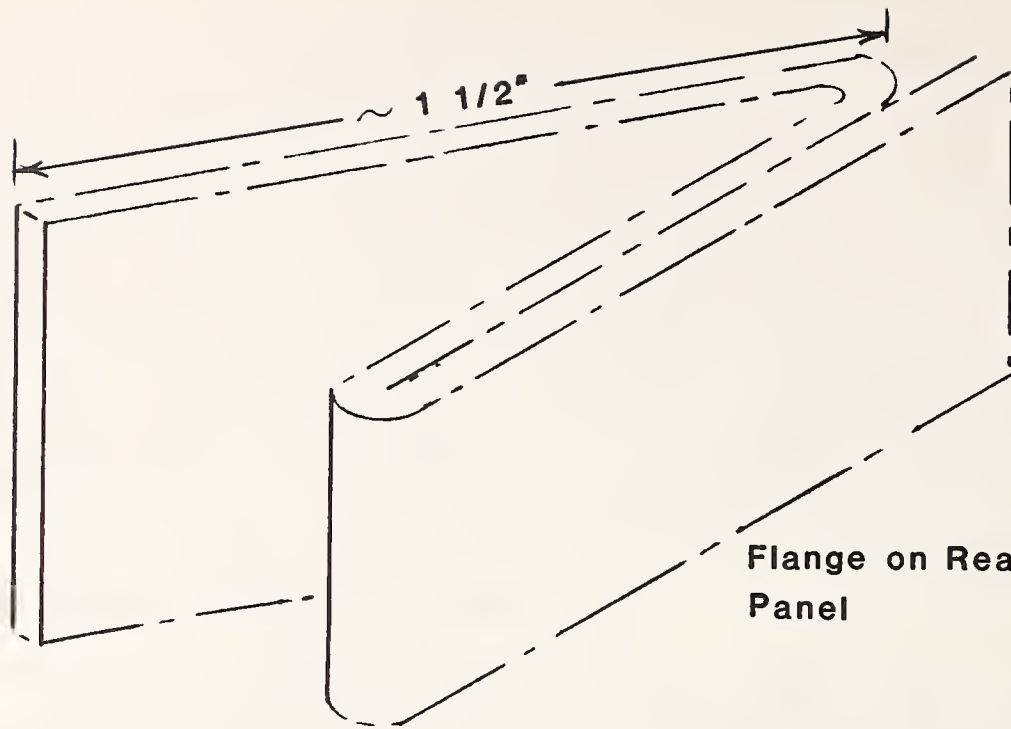
The drain pans are also molded ABS plastic and are illustrated in Figure 12. The upper pan contains two openings through which the main condenser mounting frame diagonals pass. The drain pan contains a slit from each opening to the nearest side as a provision for mounting the pan on the assembled condenser mounting frame. Following assembly,



NOTES:

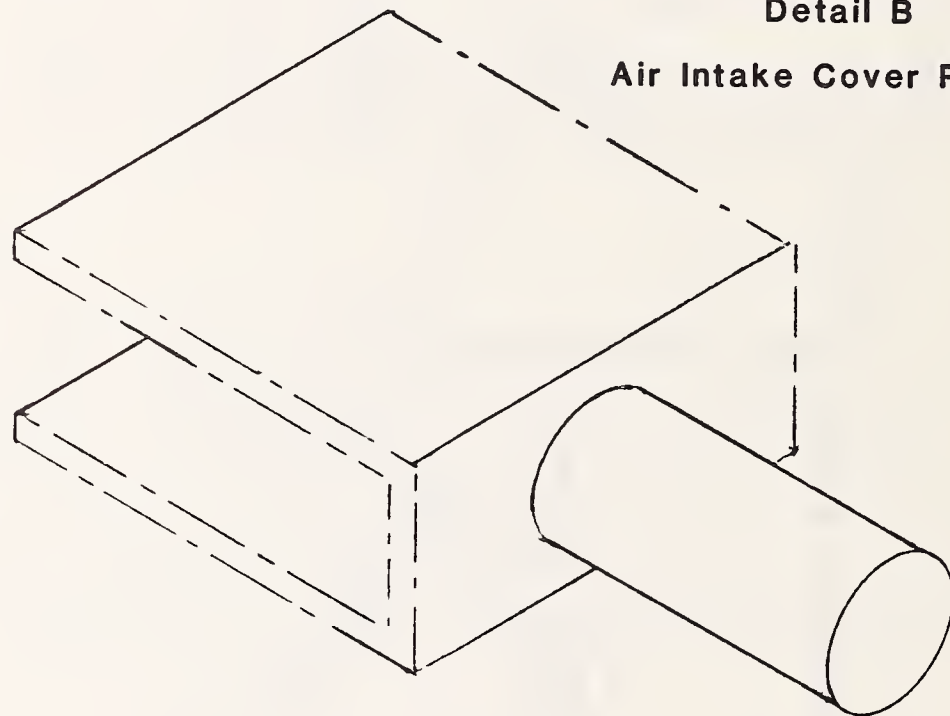
1. Not To Scale
2. Dimensions Are For Reference Only

FIGURE 10
Side Panels and Air Intake Assembly



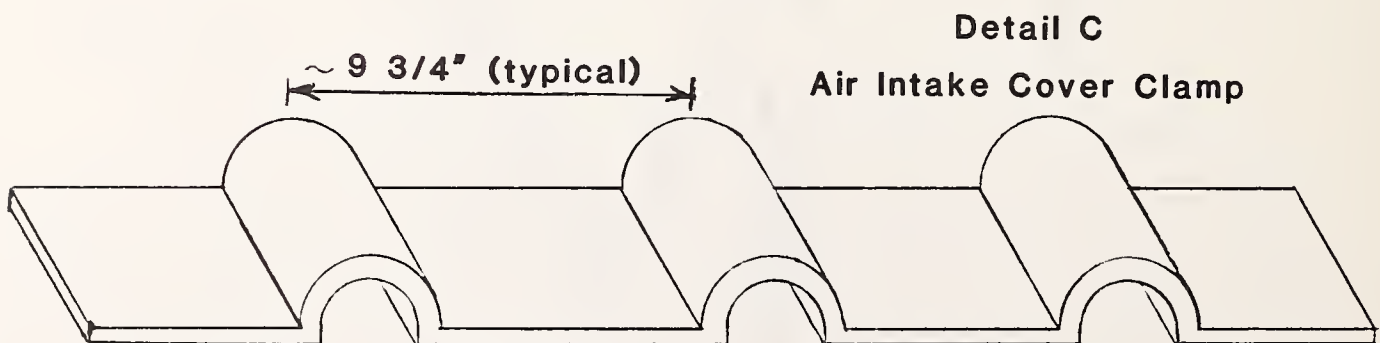
Detail A

Flange on Rear of Side Extension Panel



Detail B

Air Intake Cover Pin



Detail C

Air Intake Cover Clamp

FIGURE 11

Details of Side Panels and Air Intake Assembly

- NOTES:**
 1. Not To Scale
 2. Dimensions Are For Reference Only

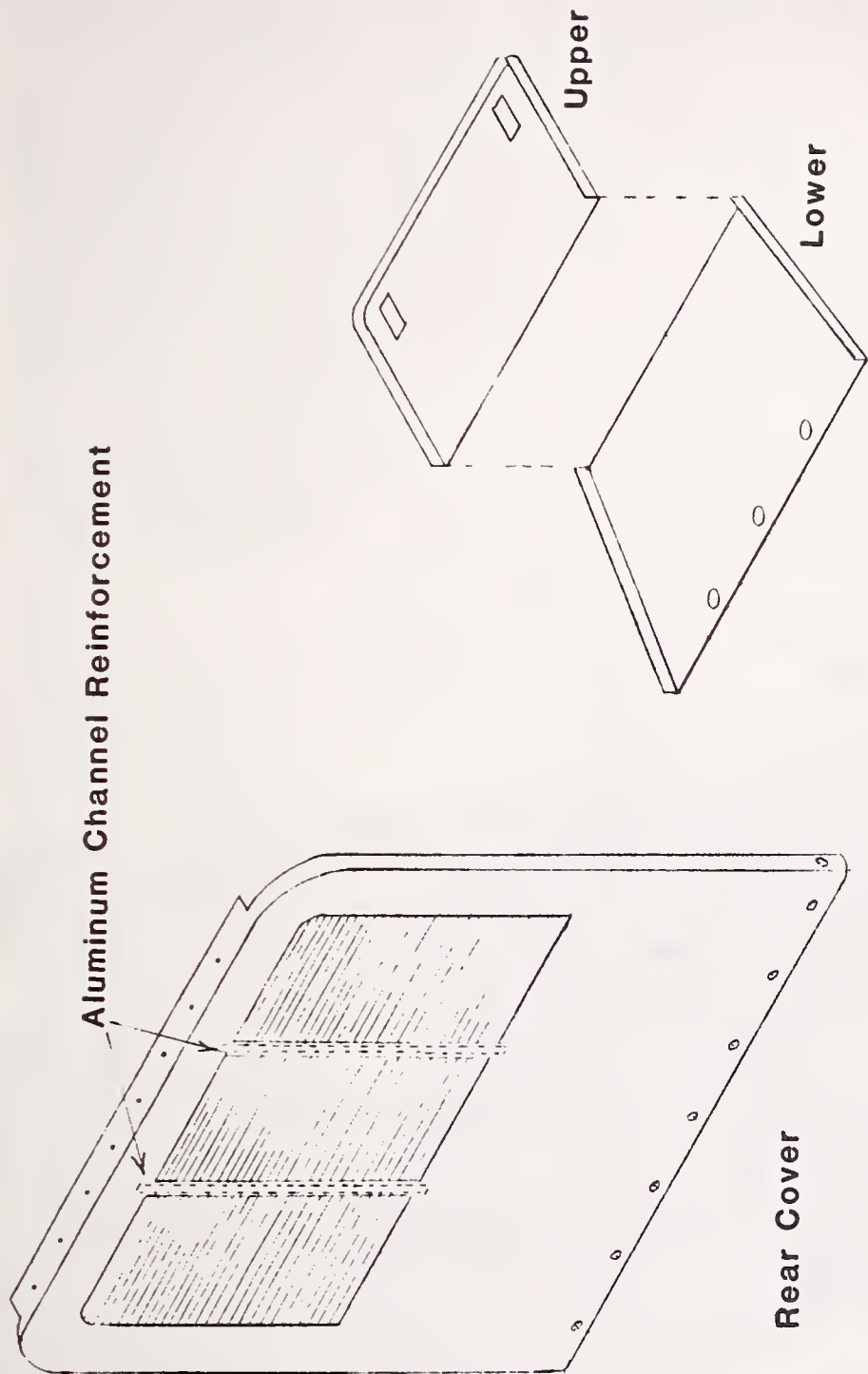


FIGURE 12

Molded Plastic Components

NOTE:
Not To Scale



FIGURE 13
Rear Cover Fasteners

the slit and opening are sealed against water leakage with an ABS chemical sealant.

The lower drain pan is attached by quarter-turn fasteners, also to the rear cover. It is easily removed in order to provide access to the evaporator blower motors.

4.4.2 Receiver and Dryer

The refrigerant liquid receiver and dryer are both relocated from the engine compartment to a location below the replacement condenser in the upper right rear corner of the bus. These components are shown installed in Figure 14.

Solid state high and low pressure cutout switches are incorporated in the relocated assembly. The high pressure switch is attached to the receiver tank, and the low pressure switch is tapped into the suction line below the evaporator.

The suction accumulator was removed from the system and direct connections were made between the liquid receiver and dryer in the high pressure line, and between the evaporator and the compressor in the low pressure line.

Whenever possible, original refrigerant piping was reused, in part or in whole, to minimize the final cost of the modification. A schematic of the resulting refrigerant system is shown in Figure 15.

4.4.3 Control System

The Honeywell control box was replaced by a solid state unit fabricated in-house which is very similar to the Vapor Corporation unit used on the newer GMC RTS II Series 04 buses. The replacement unit was located behind the return air grill in the rear interior of the bus.

The Honeywell control box can be modified rather than replaced. Because it is functionally equivalent and more easily accomplished in most circumstances, this alternative is the one documented below in detail.

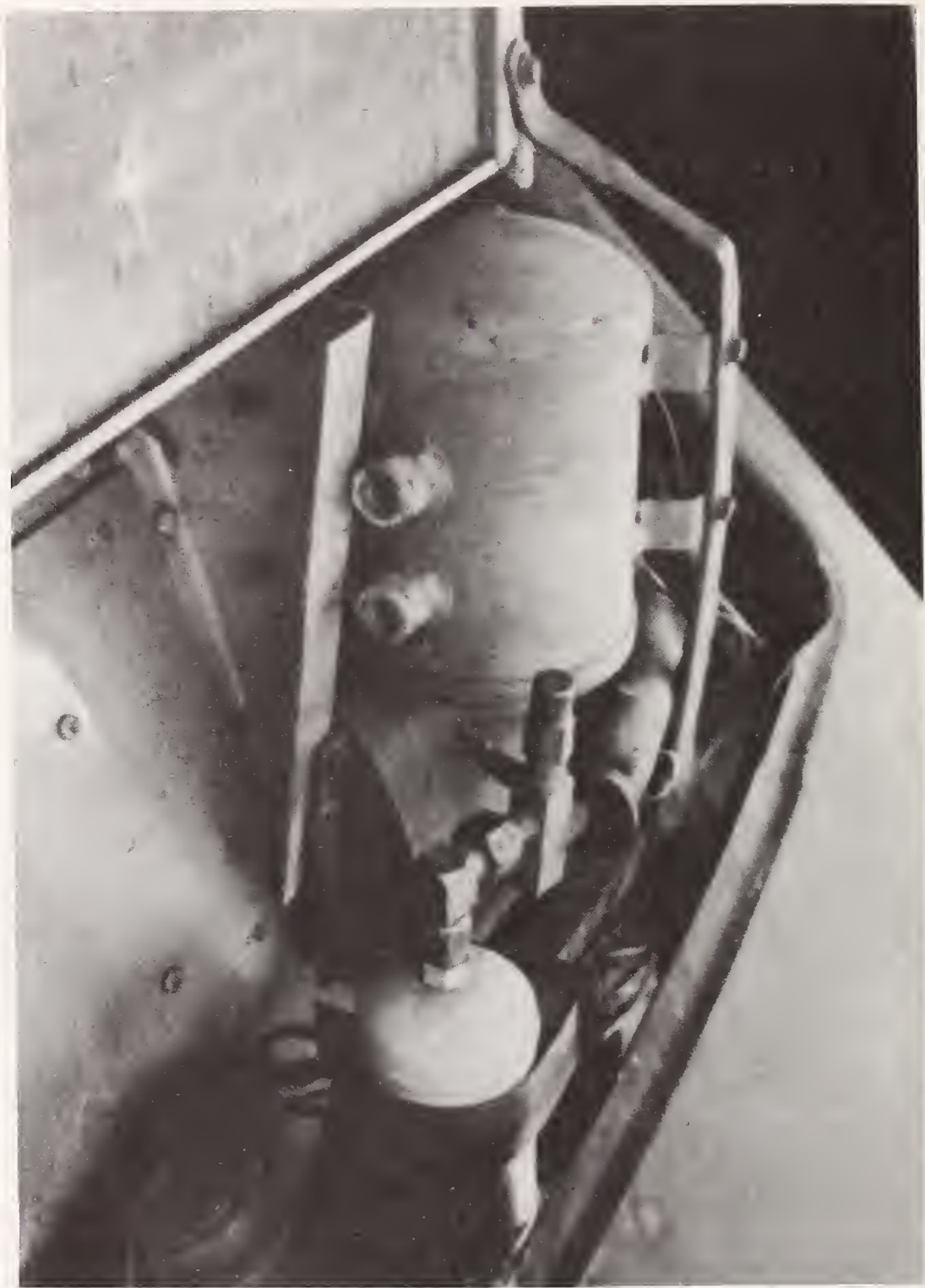


FIGURE 14

Relocated Liquid Receiver and Dryer

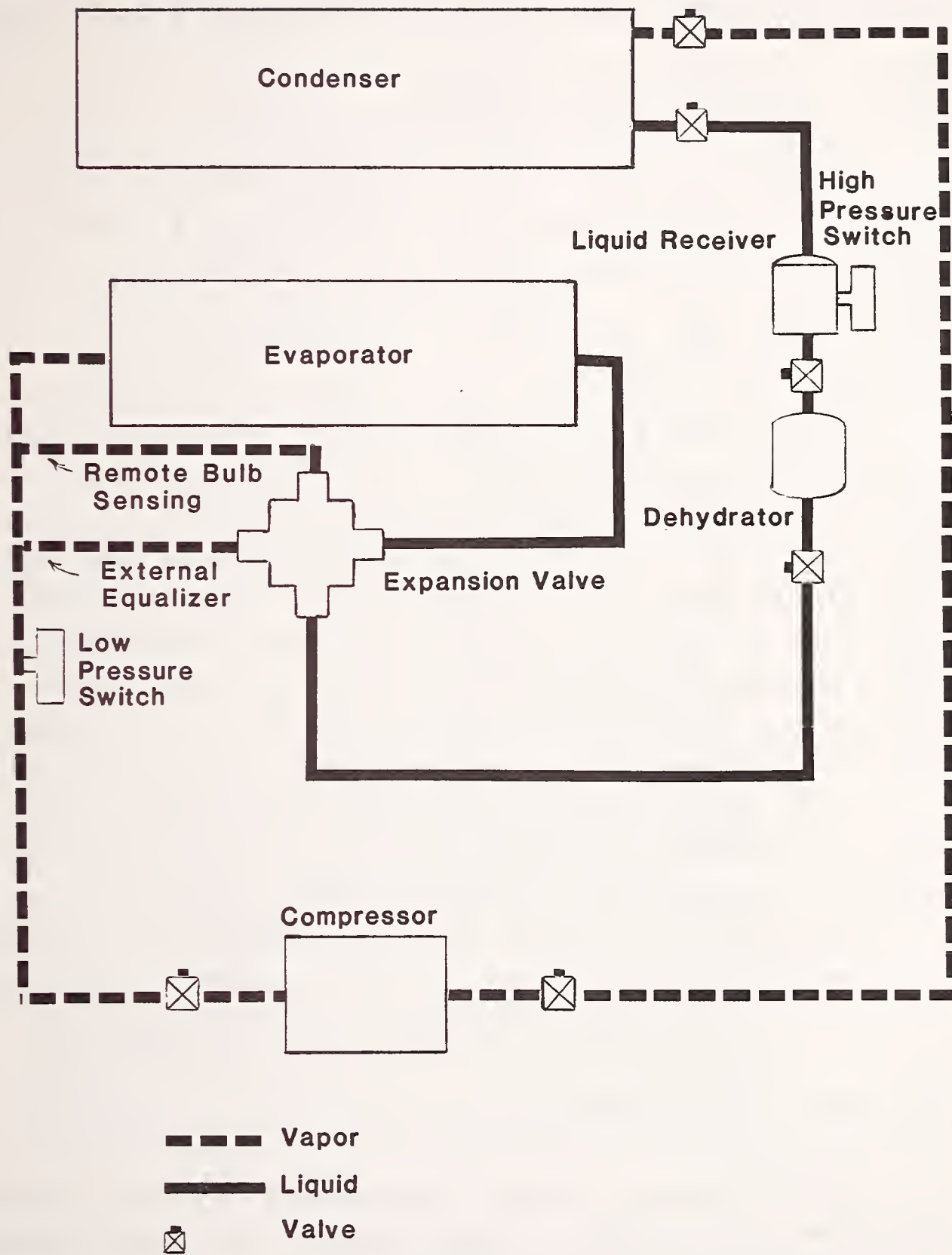


FIGURE 15
Modified Refrigerant Schematic

The modifications to the Honeywell control are a composite of recommendations from GMC (Field Service letter 78-23) and San Antonio VIA Metropolitan Transit. These modifications are described in Figures 16 and 17. The control box must be relocated in a lower position to allow clearance for the condenser mounting frame and drain pans.

4.4.4 Engine Cooling Fan System

The engine cooling fan is replaced with one of smaller diameter (26 inches) than the original fan (34 inches). The new fan, a stock item, reverses the direction of air flow through the radiator, blowing the heated air out the left side of the coach. The fan has six blades, two fewer than the larger fan. The two fans are shown in Figure 18.

A thermostatic switch controls the fan drive, activating the drive only when the engine operating temperature is above 195⁰ F (inactivated again at 190⁰ F). When the fan drive is inactive, slight fan rotation occurs because of the residual level of oil within the drive mechanism. This rotation creates an adequate air flow for most conditions and the fan rarely has been observed to be activated. This control replaces the solenoid which previously activated the engine cooling fan whenever the air conditioning was in operation.

A flat metal ring was attached to the original fan shroud to provide tight clearances with the new fan and thus maximize its efficiency. This is shown in Figure 19.

The engine cooling fan drive was modified to increase oil flow and reduce failures of the component. These modifications are detailed in Appendix C of this report.

4.4.5 Air Intake Vents

The solid metal plate(s) are removed from the engine right side closure door and rear bumper right side extension (if applicable) to allow ambient air to be drawn into the

1. Remove tape and the #8907496 Diode Plug Connector so that the circuit will be eliminated from the system. Removal of the Diode Plug Connector eliminates air conditioning stoplight on dash from activating due to diode failure. The Plug Connector is located in the upper LH corner of the Honeywell Control Box and is the only component with a green wire going to it.
2. Remove and tape green wire at return air damper solenoid (EP5). This will keep the return air shutters open at all times to prevent the possibility of the evaporator icing under certain conditions. Disconnect EP3, side-wall heater solenoid - tape terminals.
3. Reset the outside air thermostat (T3) from 65 to 55 degrees to compensate for solar heating.
4. Star type lockwashers should also be added to the screw type electrical connections in the Honeywell Control Box.

FIGURE 16

Changes to the Honeywell Air Conditioning Control

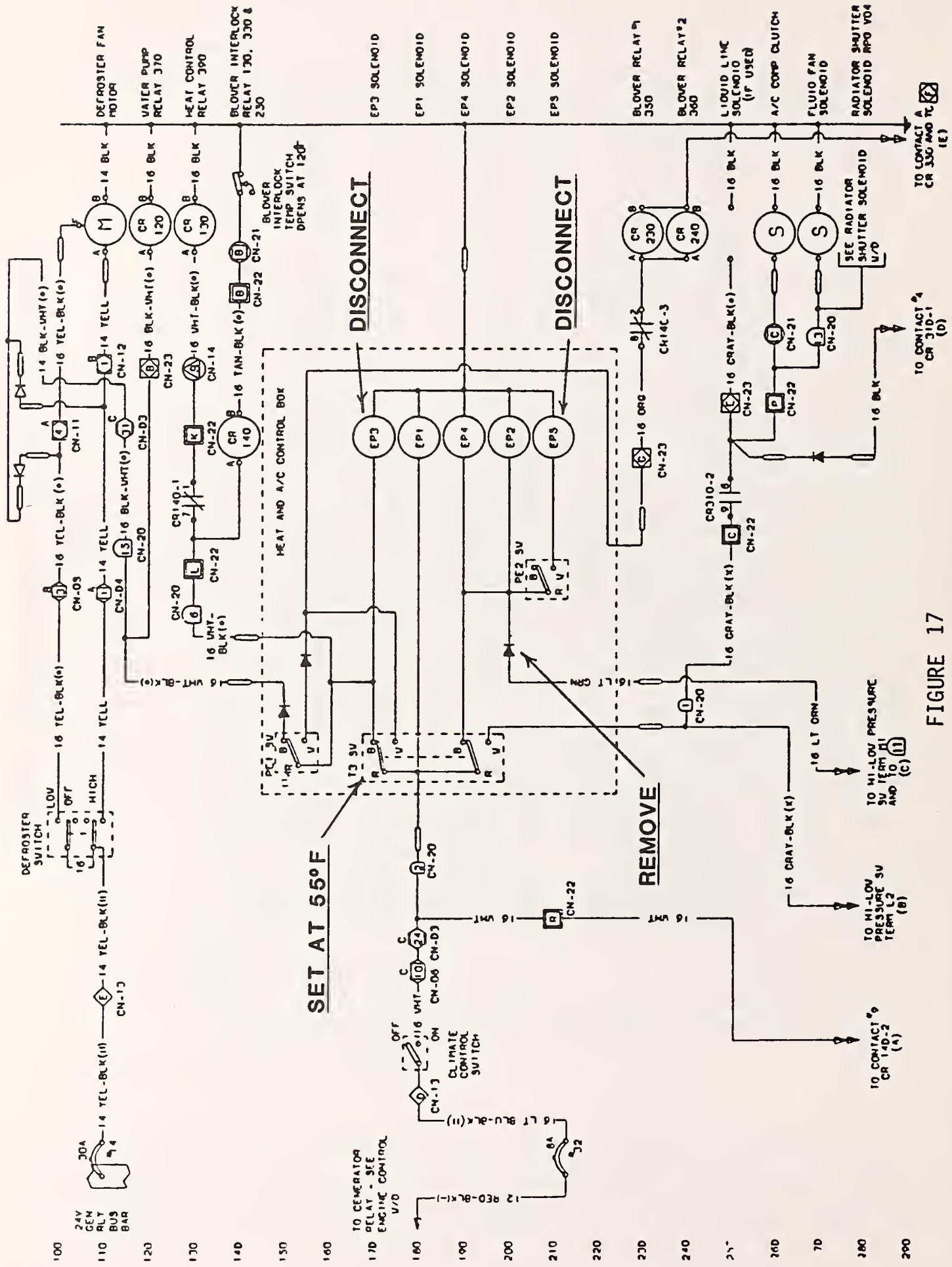


FIGURE 17

Changes to the Honeywell Air Conditioning Control



FIGURE 18
Eight-Blade Original and Six-Blade Replacement
Engine Cooling Fans

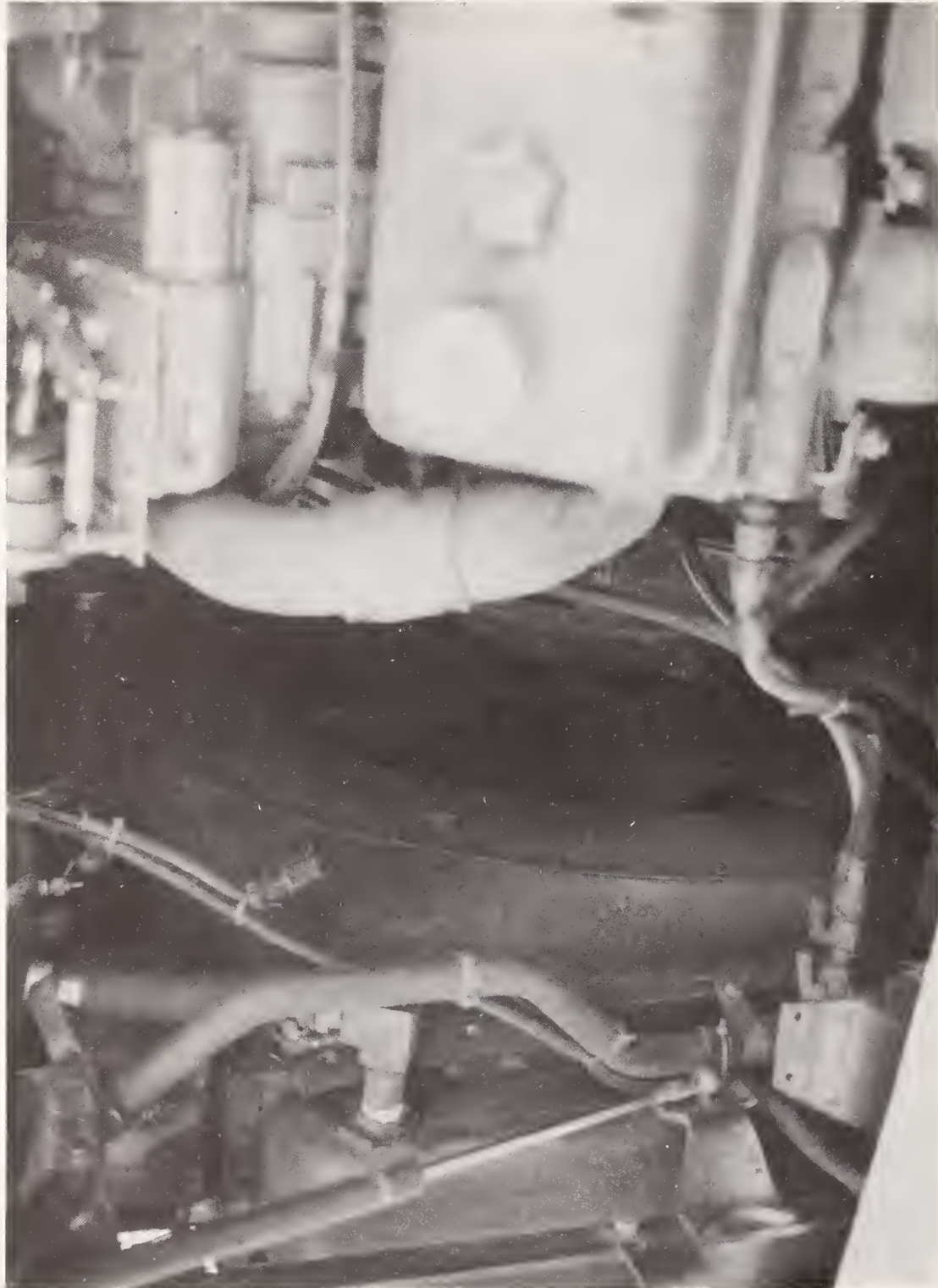


FIGURE 19
Modified Engine Cooling Fan Shroud

engine compartment past the transmission and the air conditioning compressor. The metal plate(s) are replaced with an expanded metal grill, shown in Figure 20. Noise levels are reduced because of the combined effects of decreased fan size, thermostatic control, and air flow direction.

4.4.6 Miscellaneous Modifications

An opening is made in the interior of the bus to provide access to the expansion valve. This opening is made in every bus when expansion valve service is first needed. The original 10-ton capacity expansion valve cage is replaced with a 12-ton capacity cage, to further reduce head pressures.

Smaller C 50 fuel injectors replace C 60 fuel injectors on the modified bus, thus derating the engine and providing additional fuel savings.

4.5 Modification Costs

Cost estimates were developed by San Antonio VIA Metropolitan Transit for the air conditioning modification. These estimates are shown below in Table 1. Material costs are based on the acquisition of supplies and parts in quantity and by competitive bid, although not necessarily through the OEM source indicated on the parts list (Appendix A). The labor hours include time for component fabrication and assembly on the coach; the time estimates are based on assembly line quantity production. Labor costs are based on an average hourly wage rate of seven dollars.



FIGURE 20
Modified Right Side Air Intake Vents

Table 1
Air Conditioning Modification Costs

Description	Material Cost	Labor		Total Cost
		Hours	Cost	
Engine fan and fuel injectors	\$139	16	\$112	251
Condenser coil	486	0	0	486
Condenser fans and motors	411	27	189	600
Condenser framework and mountings	276	44	308	584
Electrical wiring and controls	135	10	70	205
Housing and body modifications	325	40	280	605
Refrigerant circulation system	69	10	70	139
Miscellaneous hardware and fasteners	100	0	0	100
TOTALS	\$1941	147	\$1029	\$2970

5.0 Evaluation of Air Conditioning Modifications

5.1 General

Evaluations were performed on the San Antonio VIA Metropolitan Transit "air conditioning modification" and compressor replacement to determine their impact on overall coach fuel economy and component reliability. As discussed earlier, "air conditioning modification" refers to the changes documented in Section 4.0. Compressor replacement refers to the substitution of the standard four-cylinder compressor by a six-cylinder compressor of similar capacity.

5.2 Detailed Approach

The evaluations were based solely on raw data which have been recorded over a period of time by the San Antonio VIA Metropolitan Transit Maintenance Department as part of its standard procedures. No additional data beyond what was available were specifically collected for the evaluations. These data were examined on location and summaries were compiled for subsequent analysis. The data used in the evaluation included the following:

- Monthly mileage accumulation reports for each bus
- Daily fuel consumption reports for each bus
- Repair history cards for the air conditioning system for each bus
- Repair history cards for all other repairs for each bus

The fuel economy evaluations were based on the mileage accumulation and fuel consumption reports. The time frame of the fuel economy evaluations was the four-month period from May 1, 1981 through August 31, 1981. The component reliability evaluation was based on the repair history cards. In general, data were examined for the modified buses over the time period the changes were implemented until December,

1981, when the evaluation occurred. The specific time frames are indicated in the various sections below. The control buses were evaluated over their entire operating life, approximately four years.

For the evaluation, buses of interest were organized into four groups:

- Group A - Control Buses

This group includes ten coaches on which the air conditioning system was not modified in any way. These buses were selected as control buses because they were similar to the buses under evaluation (i.e., buses in Groups B, C and D) and also have approximately the same delivery and start-up dates.

- Group B - Air Conditioning Modification Bus

This group comprises the one bus with the San Antonio VIA Metropolitan Transit air conditioning modification.

- Group C - Compressor Replacement Buses

This group includes six buses with the original four-cylinder compressor replaced by the six-cylinder compressor.

- Group D - Air Conditioning Modification and Compressor Replacement Bus

This group includes the one bus with both the San Antonio VIA Metropolitan Transit air conditioning modification and six-cylinder compressor replacement.

All the buses in the above groups are General Motors RTS II Series 01 coaches. Table 2 summarizes the groups and identifies the specific buses. Fuel economy calculations were made for all buses. Component reliability was determined for five of the ten buses in Group A and all of the buses in Groups B, C, and D. Component reliability for buses in Group C, the buses with the compressor replacement, was limited to compressor-related items only.

Fuel economy is defined as the ratio of fuel consumed to the mileage accumulated. In the evaluation, the fuel economy was calculated for each bus for each of the four months. In

Table 2
Evaluation Groups

Group	San Antonio VIA Bus Identification Numbers	San Antonio VIA Air Conditioning Modification	Compressor Replacement
A	300 301 303-310		
B	314	X	
C	207 208 225 267 287 290		X X X X X X
D	205	X	X

addition, two other calculations were made. A fuel economy figure for the entire four-month period was determined for each bus. A fuel economy figure was also determined for each group of buses, i.e., Groups A, B, C and D.

For the component reliability evaluation, seven categories of component failures were defined:

- Category 1 - All Compressor-Related Failures

This category includes failures of the compressor body and internal parts, mounting bracket, bearings, seals and clutch mechanism. The drive belt and fittings are not included.

- Category 2 - Compressor Replacement

This category includes only failures of the compressor requiring removal and replacement of the unit.

- Category 3 - Refrigerant Circulation System Failures

This category includes failures of fittings, hoses, condenser, evaporator, and other components in the refrigeration system. Not included are electronic control failures or thermostat adjustments.

- Category 4 - All Other Air Conditioning Failures

This category includes all failures recorded on the air conditioning repair history cards not included in Categories 1, 2, or 3.

- Category 5 - Hot Engine Failures

This category includes all failures in which the hot engine warning light was activated. Also included in this category are cooling system leaks.

- Category 6 - Transmission-Related Failures

This category includes all failures involving the transmission including fluid leaks. Not included are transmission removals and replacements.

- Category 7 - Transmission Replacement

This category includes only failures resulting in the removal and replacement of the transmission unit.

Using the repair history cards, failures were tabulated by date within the appropriate category. Multiple failures occurring on a single repair listing within one category were not tabulated separately. In some cases, sequences of failures stemming from a single malfunction could not be correctly diagnosed at the outset. For the purposes of this evaluation, these series of failures were identified and treated as a single failure.

For each bus and each failure category, the mean time between failure (MTBF) was calculated. MTBF for this evaluation is defined as follows:

$$\text{MTBF} = \frac{\text{Time in service for the given bus (days)}}{\text{Number of failures recorded in the given category for the given bus}}$$

A review of the data indicated that most repairs required a maximum of one day. This allowed the total time in service to be approximated by total calendar time since the bus was put into operation. Since this calculation is uniformly applied to all buses, no biases are introduced into the comparison of component reliability of any one bus group relative to another.

5.3 Air Conditioning Modification

5.3.1 Fuel Economy

Table 3 shows the results of the fuel economy evaluation for the control buses (Group A), the air conditioning modification bus (Group B), and the air conditioning modification and compressor replacement bus (Group D). As discussed above, fuel economy was calculated for each bus for each month, each bus for the entire four-month period, and each group for the four-month period. (Since there is only one bus in Group B and Group D, the fuel economy figure for the individual bus over the four-month period is the same as the

TABLE 3

Fuel Economy Of
Air Conditioning Modification
And Control Buses

Group	Bus No.	May		June		July		August		4 Month Period		4 Month Group	
		Miles	MPG	Miles	MPG	Miles	MPG	Miles	MPG	Total Miles	Avg. MPG	Total Miles	Avg. MPG
A	300	3035	3.06	3244	3.35	3705	3.34	3765	3.49	13749	3.31	141580	3.31
	301	2677	3.32	2982	3.38	3353	3.32	3622	3.32	12634	3.33		
	303	4955	3.90	5025	3.97	5301	3.71	4970	3.89	20251	3.86		
	304	3602	3.79	2805	3.52	3448	3.11	3017	3.85	12872	3.54		
	305	3116	3.28	4225	3.89	4381	2.99	3878	3.14	15600	3.29		
	306	4785	3.51	3549	3.48	3592	3.38	2571	3.09	14497	3.39		
	307	3870	2.63	4447	4.15	3960	2.98	2840	3.11	15117	3.16		
	308	4183	3.13	3170	3.20	3453	2.88	2962	2.81	13768	3.01		
	309	3426	2.84	3468	3.12	3054	3.10	1195	3.11	11143	3.02		
	310	3536	2.92	2786	3.24	2919	3.02	2708	3.30	11949	3.10		
B	314	2536	2.82	4196	3.10	3639	2.98	2841	3.09	13212	3.01	13212	3.01
D	205	2624	3.54	3321	3.53	2657	3.63	3156	4.00	11758	3.67	11758	3.67

Group A - Control Buses
Group B - Air Conditioning Modification Bus
Group D - Air Conditioning Modification & Compressor Replacement Bus

group figure.) "Miles" indicates the mileage accumulated by the given bus for the given time frame.

As can be seen in the table, there is a variance in the calculated fuel economy figures as well as some unexpected results. Referring to the buses in Group A, the control buses, the "best" fuel economy (of any bus in any of the four months) of 4.15 miles per gallon was attained by bus #307 in June. Conversely, the "worst" fuel economy of 2.63 miles per gallon was attained by the same coach one month earlier. The higher figure is more than one and one-half times greater than the other extreme. The spread in the fuel economy figures is also seen in the four-month period with a low value of 3.01 miles per gallon and a high value of 3.86 miles per gallon. The range here ($3.86 - 3.01 = .85$) is almost 30% of the low value.

It is noted, however, that the fuel economy of Group A, as a whole, is near the reported fleet average of 3.5 miles per gallon for San Antonio VIA Metropolitan Transit. Bus #314 (Group B) and bus #205 (Group D) appear to exhibit fairly consistent fuel economy figures from month-to-month with small ranges of 0.28 and 0.47 miles per gallon, respectively.

The bus with the air conditioning modification, i.e., bus #314, had a four-month average fuel economy that was less than the four-month average of Group A, the control buses. Although the difference is small, the expectation was to see bus #314 exhibit a better MPG figure than that for Group A. This expectation was based on an "engineering judgement" of the impact of the air conditioning modifications on overall fuel economy and is discussed below.

The bus with both the air conditioning modification and the compressor replacement (bus #205 in Group D) fared better in fuel economy than the control buses over the four-month period. Since this bus has both modifications, it is not possible to attribute its apparent better fuel economy to any specific factor. This is further compounded by the fact that

bus #314, with the air conditioning modification, did not exhibit better fuel economy.

The variance and unexpected results discussed above can, for the most part, be reconciled with the evaluation approach. Due to the scope of the overall effort, several factors which can significantly affect fuel economy could not be isolated from or normalized out of the evaluation. Principal among these is the type of routes to which the buses are assigned -- leading to many positive or negative impacts on fuel economy. Different routes can lead to heavier or lighter passenger loads, more or fewer stops/starts, and more or less requirements on the engine, e.g., presence or absence of grades. The main limitation in the evaluation approach lies in the use of available data. It is felt that a specific and organized data collection effort, with the above factors taken into consideration, and coupled with a larger sample size, would lead to more definitive results. It must be remembered that the sample size here was confined to the sole bus as modified by the transit property.

As mentioned earlier, it was expected that the air conditioning modification should increase overall fuel economy. This was based on an initial understanding of the modification and knowledge gained from the documentation aspect of this study. In general, the elements of the modification which would affect fuel economy were all of a nature that would improve fuel economy. Specifically, fuel economy is positively affected by:

- Reduced engine cooling fan size and number of blades
- Reduced engine cooling fan usage
- Lower refrigerant head pressures
- Smaller fuel injectors

In summary, it is concluded that the air conditioning modification should result in some improvement in overall bus fuel economy. It was not possible, however, to verify this with the available data and within the scope of the study.

5.3.2 Component Reliability

The results of the component reliability evaluation on the San Antonio VIA air conditioning modification (bus #314 in Group B) and five of the control buses (from Group A) are presented in Table 4. The failure categories shown in the table are as defined earlier in Section 5.2.

As shown on the table, the bus with the air conditioning modification did not have any failures in the first two categories, "all compressor-related" failures and "compressor replacement". It must be kept in mind, as mentioned earlier, that the evaluation on bus #314 covers the time when it was a modified bus, i.e., from August, 1979 (when the air conditioning modification was completed), to December, 1981 (when the evaluation took place). The elimination of compressor failures for a period of almost 2.5 years is a significant fact. This result can be attributed to the operation of the system at reduced head pressures.

For the refrigerant circulation system failures, category 3, the modified bus experienced a MTBF more than triple that of the control group as a whole. These effects may be attributed to the reduced head pressures in combination with the reduced number of refrigerant line connections -- potential sources of refrigerant losses.

The MTBF for "all other air conditioning" failures is, for all intents and purposes, the same for both the modified bus and the control group. This similarity in the MTBF figures is reasonable since the failure category includes components not affected by the air conditioning modification.

With respect to category 5, hot engine failures, the MTBF figures for the modified bus were better than the control group by almost 60 percent. This improvement reflects the changes made to reduce engine compartment temperatures despite the smaller size of the engine cooling fan and reduced usage.

TABLE 4

MEAN TIME BETWEEN FAILURE (BUS-DAYS)

Group A and Group B Buses

Failure Category	Group A					Group B
	300	301	303	304	305	GROUP
1. All Compressor-Related Failures	146	346	138	345	197	201
2. Compressor Re-placement	658	692	1377	1378	*	1139
3. Refrigerant Circulation System Failures	77	77	66	55	38	58
4. All Other Air Conditioning Failures	42	41	36	48	31	39
5. Hot Engine Failures	73	73	172	77	86	86
6. Transmission Related Failures	88	198	153	138	73	114
7. Transmission Replacement	1315	692	689	1378	459	759
						314
						*
						*
						202
						48
						135
						270
						*

*No failures reported
 Group A - Control Buses
 Group B - Air Conditioning Modification Bus

The MTBF of transmission-related failures (category 6) for the modified bus was more than double that of the control group. No failures resulting in replacement of the transmission unit (category 7) were reported for the modified buses. These improvements can be attributed, again, to the reduced engine compartment temperatures.

Although the primary intent was to evaluate the impact of the San Antonio VIA Metropolitan Transit air conditioning modification on component reliability, as discussed above, it was of interest to examine bus #205 as well. This coach has the six-cylinder replacement compressor and the air conditioning modification (defined earlier as Group D). The MTBF calculations for this bus are shown in Table 5 together with the results for the five control buses. (The figures for the control buses are repeated here for convenience).

Certain points need to be discussed about bus #205. The reliability data shown on Table 5 represent a 16-month period only, from September, 1980 (modification completed) to December, 1981. In general, its reliability, as measured by its MTBF value, is the same or better than that for the control group except for one category -- transmission replacement. In this category, the Group D bus exhibited a much worse record than the control group. Since this bus was operated for nearly two years prior to implementation of the air conditioning modification, it is believed that the MTBF figure is conservative and the recorded transmission failures are the result of wear accumulated prior to the modification.

In summary, it is concluded that the air conditioning modification (as represented by bus #314) had a substantial impact in improving component reliability. Significant increases in mean time between failure figures were seen in almost all failure categories.

TABLE 5

MEAN TIME BETWEEN FAILURE (BUS-DAYS)
Group A and Group D Buses

Failure Category	Group A							Group D
	300	301	303	304	305	GROUP	205	
1. All Compressor-Related Failures	146	346	138	345	197	201	*	
2. Compressor Re-placement	658	692	1377	1378	*	1139	*	
3. Refrigerant Circulation System Failures	77	77	66	55	38	58	60	
4. All Other Air Conditioning Failures	42	41	36	48	31	39	34	
5. Hot Engine Failures	73	73	172	77	86	86	161	
6. Transmission Related Failures	88	198	153	138	73	114	121	
7. Transmission Replacement	1315	692	689	1378	459	759	241	

*No failures reported
Group A - Control Buses
Group D - Air Conditioning Modification and Compressor Replacement Bus

TABLE 6

Fuel Economy of
Compressor Replacement
And Control Buses

Group	Bus No.	May		June		July		August		4 Month Period		4 Month Group	
		Miles	MPG	Miles	MPG	Miles	MPG	Miles	MPG	Total Miles	Avg. MPG	Total Miles	Avg. MPG
A	300	3035	3.06	3244	3.35	3705	3.34	3765	3.49	13749	3.31	141580	3.31
	301	2677	3.32	2982	3.38	3353	3.32	3622	3.32	12634	3.33		
	303	4955	3.90	5025	3.97	5301	3.71	4970	3.89	20251	3.86		
	304	3602	3.79	2805	3.52	3448	3.11	3017	3.85	12872	3.54		
	305	3116	3.28	4225	3.89	4381	2.99	3878	3.14	15600	3.29		
	306	4785	3.51	3549	3.48	3592	3.38	2571	3.09	14497	3.39		
	307	3870	2.63	4447	4.15	3960	2.98	2840	3.11	15117	3.16		
	308	4183	3.13	3170	3.20	3453	2.88	2962	2.81	13768	3.01		
	309	3426	2.84	3468	3.12	3054	3.10	1195	3.11	11143	3.02		
	310	3536	2.92	2786	3.24	2919	3.02	2708	3.30	11949	3.10		
C	207	3104	3.33	3121	3.89	3778	3.54	3311	3.30	13314	3.50	84187	3.33
	208	3286	2.52	5906	4.08	6556	3.75	4613	3.50	20361	3.50		
	225	2720	2.96	1745	2.83	1545	2.74	1982	3.53	7992	3.00		
	267	4156	3.14	4101	3.45	4418	3.53	5064	3.56	17739	3.42		
	287	2782	2.70	3154	3.44	1532	3.09	2227	3.14	9695	3.08		
290	1586	2.72	4460	3.32	5141	3.16	3899	3.40	15086	3.21			

Group A - Control Buses
Group C - Compressor Replacement Buses

5.4 Compressor Replacement

5.4.1 Fuel Economy

The fuel economy calculations for the buses with the standard four-cylinder compressor replaced by a six-cylinder compressor of similar capacity (Group C) are shown in Table 6. Also shown are the fuel economy calculations for the control buses (Group A).

As shown on the table, the buses with the compressor replacement exhibit a variance in fuel economy (of any given bus for any given month) very similar to that seen in the control buses. The range of fuel economy for the entire four-month period for the compressor replacement buses is again very consistent with the control group. The spread in the four-month period averages is 3.00 to 3.5 miles per gallon for Group C and 3.01 to 3.86 miles per gallon for Group A. Finally, there are no discernible differences in the four-month group average figures.

It is concluded, based on the available data, that the six-cylinder replacement compressor did not impact overall coach fuel economy. However, the discussion in Section 5.3.1 regarding factors that influence fuel economy is certainly applicable here. As in the case of the air conditioning modifications, it is not unreasonable to expect an improvement in fuel economy. One of the major differences between the two compressors is the lower torque requirement of the six-cylinder compressor. This should translate to some improvement in fuel economy.

5.4.2 Component Reliability

The results of the component reliability evaluation on the compressor replacement buses are tabulated in Table 7. For comparison, the MTBF data for the five control buses (from Table 4) are included in the last column. Since the

TABLE 7

MEAN TIME BETWEEN FAILURE (BUS-DAYS)
Compressor Replacement Buses

Failure Category	Group C							Group A
	207	208	225	267	287	290	GROUP	
1. All Compressor-Related Failures	494	237	245	182	191	229	239	201
2. Compressor Replacement	*	*	*	*	*	*	*	1139
3. Refrigerant Circulation System Failures	35	39	27	45	51	51	39	58
4. All Other Air Conditioning Failures	23	59	29	24	33	65	33	39

*No failures reported
Group C - Compressor Replacement Buses
Group A - Control Buses

compressor replacement was limited in scope and did not affect bus operating parameters such as engine operating temperature or air conditioning head pressures, the evaluation was confined to the air conditioning system. Specifically, failure categories 1 through 4 were considered.

With the exception of the compressor replacement category, the MTBFs for the buses with the six-cylinder compressors are fairly similar to those for the control buses. In the all-compressor-related category, the buses with the compressor replacement fared slightly better than the control group. Of more significance, however, is the elimination of compressor replacements in every coach operating with a six-cylinder replacement unit. The six coaches listed in Group C have been in service with the compressor replacement since April, 1979. (The evaluation period is 33 months, from April, 1979 to December, 1981). This improved reliability was achieved while maintaining the same high head pressures and operating temperatures as the control buses.

The similarity in the MTBF figure in the two groups of buses for the all-other-air-conditioning category is reasonable. As was the case for the air conditioning modification, this category encompasses items not affected by the compressor change.

The evaluation concludes that the six-cylinder compressor exhibited a significantly better unit life over the original unit. Particularly noteworthy is the elimination of compressor replacements after the six-cylinder unit was installed.

Appendix A

Parts Lists

Parts List

The following parts were incorporated in the San Antonio VIA Metropolitan Transit air conditioning modification. Because of factory modifications to the Series 01 and 03 coaches, the applicability of these parts must be verified individually.

Parts with no listed source are generic.

Refrigerant Flow System		
<u>Qty.</u>	<u>Source</u>	<u>Description/Part Number</u>
1	GMC	New Look Condenser; P/N 2425216
1	Alco	12 ton capacity expansion valve cage assembly; P/N B-8B
1		20PS003MB375K265K (high side) switch for condenser and liquid receiver tank.
1		20PS003MA035E015E (low side) switch.
1		31 inch #16 teflon hose with straight swivel fitting.
1		14" of 5/8" copper tubing with #8 nut and sleeve (flared) for dryer-to-receiver tank connections.
1		18" of 3/4" copper tubing with two #10 nuts for connections from receiver tank to condenser.
2	GMC	P/N 2376095 valve for high/low switch at receiver tank and condenser outlet.

1		11" x 14" 18 gauge sheet (expansion valve cover plate inside bus).
4		10-32 "Nut-Serts" for expansion valve compartment cover.
3	GMC	90 ⁰ (swivel one end) fitting for dryer and receiver tank with #10 flared fitting on opposite end.
1	GMC	Valve assembly, refrigerant dryer shutoff; P/N 2018979.
1	GMC	90 ⁰ condenser return line outlet adapter fitting (to adapt from #20 to #16 hose).
1	GMC	31" conduit, P/N 12013948 for condenser inlet hose teflon line.

Electrical

<u>Qty.</u>	<u>Source</u>	<u>Description/Part Number</u>
2	GE/Thermo King	0.32 HP electric blower motors. (These motors are not presently marketed.)
1	GMC	9'-10" conductor (P/N 8919354) for wiring from Honeywell control and power supply to condenser blower motors.
4		1/4-20 NC x 1 1/4" bolts with flat and lock washers for condenser blower motor relays.
2	GMC	Essex condenser blower relays; P/N 2035465
4		1/4-20 NC x 3/4" bolts for condenser blower motor mounting.

4		1/4-20 NC x 1 1/2" bolts for condenser blower motor mounting.
16		1/4" flat washers for condenser blower motor mounting.
8		1/4" lock washers and nuts for condenser blower motor mounting.
1	GMC	Circuit breaker (P/N 12204011) for condenser blower motors.
1		#3/0 battery eye terminals.
5		#4 electrical eye terminal connectors.
4		#16-14 gauge tongue ring connector.
3		#16-14 gauge butt connectors.
6		#10 gauge eye terminals.
1	GMC	Rectifier assembly; P/N 12006377.
1	GMC	Connector (P/N 269782) for receiver tank high/low switch.

Materials

<u>Qty.</u>	<u>Source</u>	<u>Description/Part Number</u>
		9' of 6 gauge stranded wire for condenser blower motor power supply.
		10' of 14 gauge stranded wire for AC control box, condenser and refrigerant receiver high/low switch connections.
		5" of #10 gauge stranded wire.

2		Sheets galvanized metal, 4' x 8' - 22 gauge.
2	Imron (DuPont)	Qts. white paint.
2	Imron (DuPont)	Qts. reducer.
1	Imron (DuPont)	Qt. primer/sealer.
1		Sheet expanded metal 1/2" - 20 gauge, 4' x 8'.
2		ABS plastic sheet 4' x 8' x 1/4".
3		7/16" dia. x 12" long C.R.S. rod for pins.
1		2 1/4" x 2 1/4" x 1/4" angle iron 5' long.
1		12' of 3/4" x 3/4" x 1/8" angle iron for air intake panel frame.
1		Qt. ABS chemical sealant.
1		.075 stainless steel tubing 1" x 3" x 20' long.
1		.075 stainless steel tubing 2" x 2" x 12' long.
3		Aluminum channels for plastic cover rigidity, 1/8" x 3/4" x 3/4" x 30".
2		14" x 9" x #14 gauge stainless steel sheet for lower frame supports.

Attachment Parts

<u>Qty.</u>	<u>Source</u>	<u>Description/Part Number</u>
2		Condenser angle iron corner support bolts, each 7/16-14 NC x 1 1/4" hex head.

6	Condenser angle iron center bolts (at existing door hinges). 3/8-16 NC x 1" hex head with lock washers.
4	1/4-20 NC x 1 1/2" bolts hex head with flat and lock washers and nuts for 1" tubing at condenser for mounting support.
4	5/16-18 NC x 1" hex head bolts with lock and flat washers for condenser lower support.
1	5/16-18 NC x 1" hex head bolt for dryer and liquid receiver.
2	1/4-20 NC x 1 1/4" hex head bolts for dryer and liquid receiver.
6	5/16-18 NC x 3/4" hex head bolts with flat and lock washers, for dryer and liquid receiver.
1	13 3/4" of 1" x 3/16" angle iron, 1" x 3/16" x 3" metal strap, 2 1/2" x 3/16" x 3" metal plate, all for dryer mounting bracket.
1	21" x 3/16" x 1" steel strip for receiver tank mounting.
2	6" x 6" x 1/8" steel plates for mounting blower motors.

Miscellaneous

<u>Qty.</u>	<u>Source</u>	<u>Description/Part Number</u>
2		Boxes pop rivets, 1/8" x 7/16" AD44ABS.
7		12" plastic ties.

1	GMC	Engine cooling fan (New Look), P/N 2386644.
2	W.W. Grainger	20-inch aluminum fan blade assembly; P/N 4C143.
16		1/2" quarter turn fasteners and clips.
8	DDA	C 50 fuel injectors.

Appendix B

Procedures for Air Conditioning Modification

Procedures

Removal of Original Equipment

- Evacuate refrigerant from the air conditioning system.
- Remove the original condenser and its plumbing; remove 10 ton capacity expansion valve cage assembly (P/N B-7B).
- Remove the original engine cooling fan, the fan shroud, and the fan drive.
- Remove the rear hatch over the evaporator compartment; remove the hinges for the cover.
- Remove the thermostatic control box.
- Remove the liquid receiver, the suction accumulator, and the dryer.
- Remove the engine right side closure door.

Assembly of the Replacement Condenser

- Mount the condenser frame at upper and lower attachment points.
- Mount the blowers to the frame crosspiece. The motor relays are also mounted on the crosspiece adjacent to each motor.
- Attach the replacement condenser to the rear of the condenser mounting frame.
- Install the plastic air intake panels and seal with ABS chemical sealant.
- Drill holes for quarter turn fasteners at the bottom edge of the lower drain pan. Mount upper and lower drain pans; seal the upper drain pan around the diagonal condenser frame member with ABS chemical sealant.
- Install the liquid receiver and dehydrator in their relocated positions. Install refrigerant plumbing to connect all air conditioning components. Install 12 ton capacity expansion valve cage assembly.

- Relocate modified Honeywell control below the condenser assembly and reconnect electrical connectors.
- Complete wiring connections including the circuit breaker between the blower motors and the coach main electrical system.
- Mount side extension panels and air intake grate at roof level; attach rear cover using quarter turn fasteners along the lower edge.
- Recharge refrigerant system.

Ancillary Modifications

- Modify engine cooling fan drive and re-install.
- Attach extension ring to radiator fan shroud and re-install.
- Install smaller six-blade fan.
- Connect thermostatic control for engine fan drive.
- Attach expanded metal mesh to the engine right side closure doors and remount.

Appendix C

Detailed Procedures for the

Fan Drive Modification

Fan Drive Modification

The following instructions found in Figures C-1 through C-13, in conjunction with factory specifications, depict the procedures for building an engine fluid fan drive utilizing most parts from previously failed fan drives. This configuration utilizes tapered bearings in place of ball and ball-thrust bearings.

Figure C-1: Enlarge the bearing bore in the front housing to provide .0008" press interference fit for bearing, GMC P/N 908332. Install bearing with shield toward torus.

Figure C-2: Modify front and rear torus by drilling 6 each .66" diameter holes equally spaced. See detail in Figure C-2.

Figure C-3: Rework shaft, GMC P/N 790442, removing orifice by drilling out shaft to .468" diameter. See detail in Figure C-3.

Figure C-4: Manufacture or substitute a spacer 3.150" O.D. X 2.500" I.D. X .050" thick for front tapered bearing cup, Timken P/N Y-30208. It is possible to use GMC P/N 2463532 ring for this spacer.

Figure C-5: Manufacture a spacer 2.000" O.D. X 1.575" I.D. X .125" thick to properly space front tapered bearing cone, Timken P/N X-30208. The purpose of this spacer is to replace the .125" removed from driven gear (Figure C-6).

Figure C-6: Machine .125" off the front center of the driven gear. Note: Consideration should be given to the amount of wear on this surface. The wear can be part of the .125" to be removed.

Figure C-7: The front bearing will be a Timken, cone #X-30208 and cup #Y-30208. Be sure to use .050" spacer, Figure C-4, under cup #Y-30208 and .125" spacer under cone #X-30208.

Figure C-8: The rear bearing is a Timken, cone #X-30207 and cup #Y-30207.

Figure C-9: The original GMC P/N 127710 rear retaining nut has a 45⁰ chamfer toward the bearing side of the nut. The 45⁰ chamfer should be machined to a 90⁰ step to keep the Timken bearing cone #X-30207 clear.

Figure C-10: Inspect rear bearing cap P/N 790561 to determine if it is the latest style. If so, remove .030" from the mounting flange increasing that dimension to .190". At time of assembly, shim rear bearing cap to preload tapered bearings to 0 end play -.002" by selecting various gasket thicknesses. Preload should be 3 lbs. pull on torus O.D.

Figure C-11: The oil supply line must be restricted in some way, and this is very important because all internal restriction has been removed. Several choices are available: (1) Use injector tube line P/N 2050798 with regular fittings. (2) Restrict elbow with silver solder, drill to .80" and manufacture a 7" #4 stainless steel teflon double swivel line and assemble with necessary fittings.

Figure C-12: The driving gear tangs in some cases are not machined correctly and when the fan drive is bolted to the engine, it will thrust the crankshaft. To alleviate these problem cases, machine .060" from the tang base of the driving gear.

Figure C-13: Experiencing a high failure rate with spiral snap ring P/N 2050680, the drive gear P/N 2033519 is modified as follows using a Waldes snap ring #5000-575. Machine gear as follows:

Machine Gear I.D. _____	6.055"
Machine Sleeves - O.D. _____	6.057"
I.D. Rough Finish _____	5.850"
Sleeve Width _____	1.000"
Press Sleeve in Gear & Finish Bore I.D. _____	5.903"
Machine Snap Ring Groove Depth from Brg. Seat_	.350"
Depth from Outer Gland Seat _____	.210"
Machine Groove from Inter Bearing Face to	
Inter Snap Ring Face _____	.943"

MACHINE SLEEVES FROM SEAMLESS STEEL TUBING

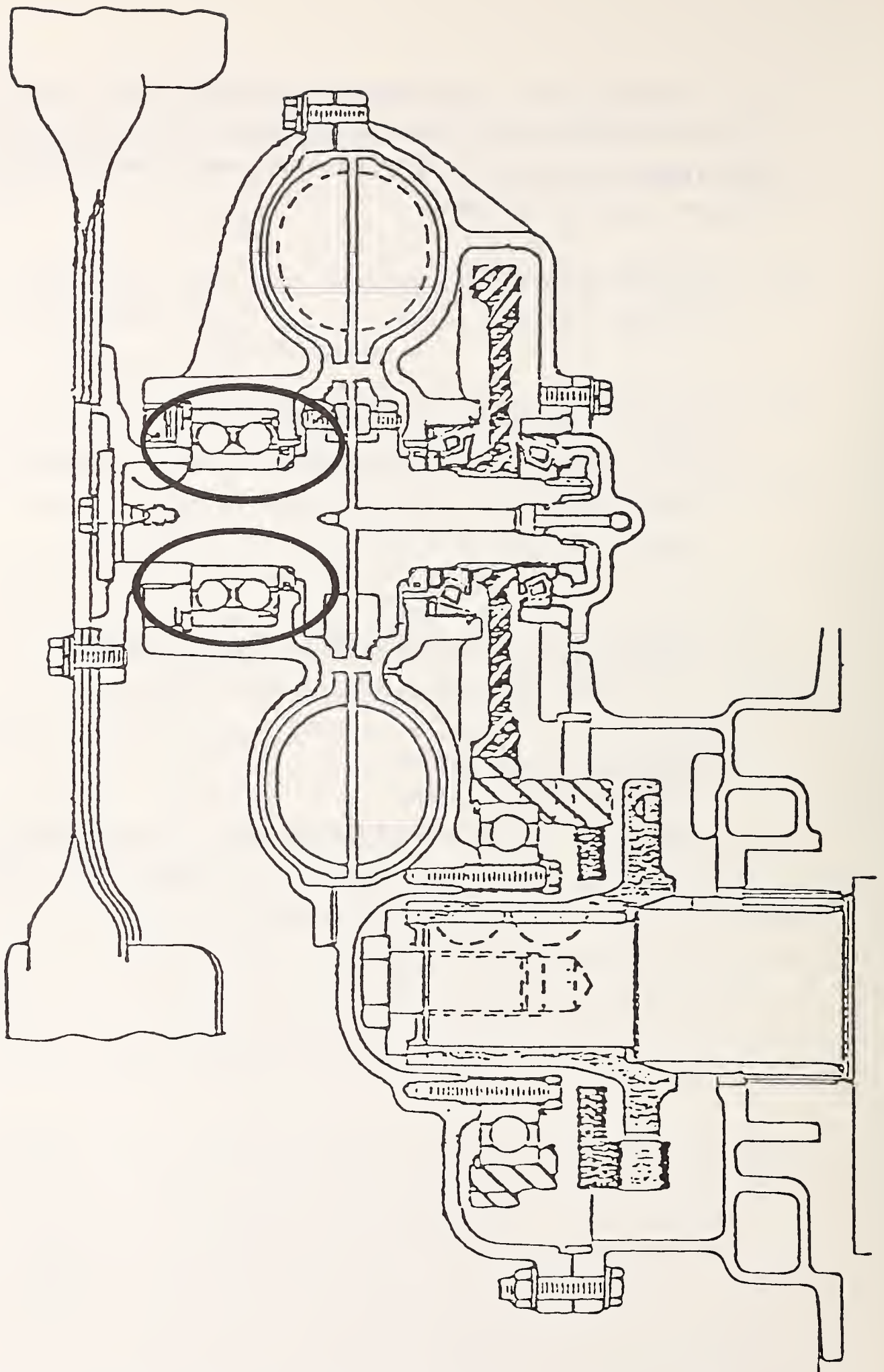
1020 DOM TUBE 6 1/4" x 1/4" x 10'

BEARING O.D. = 5.904"

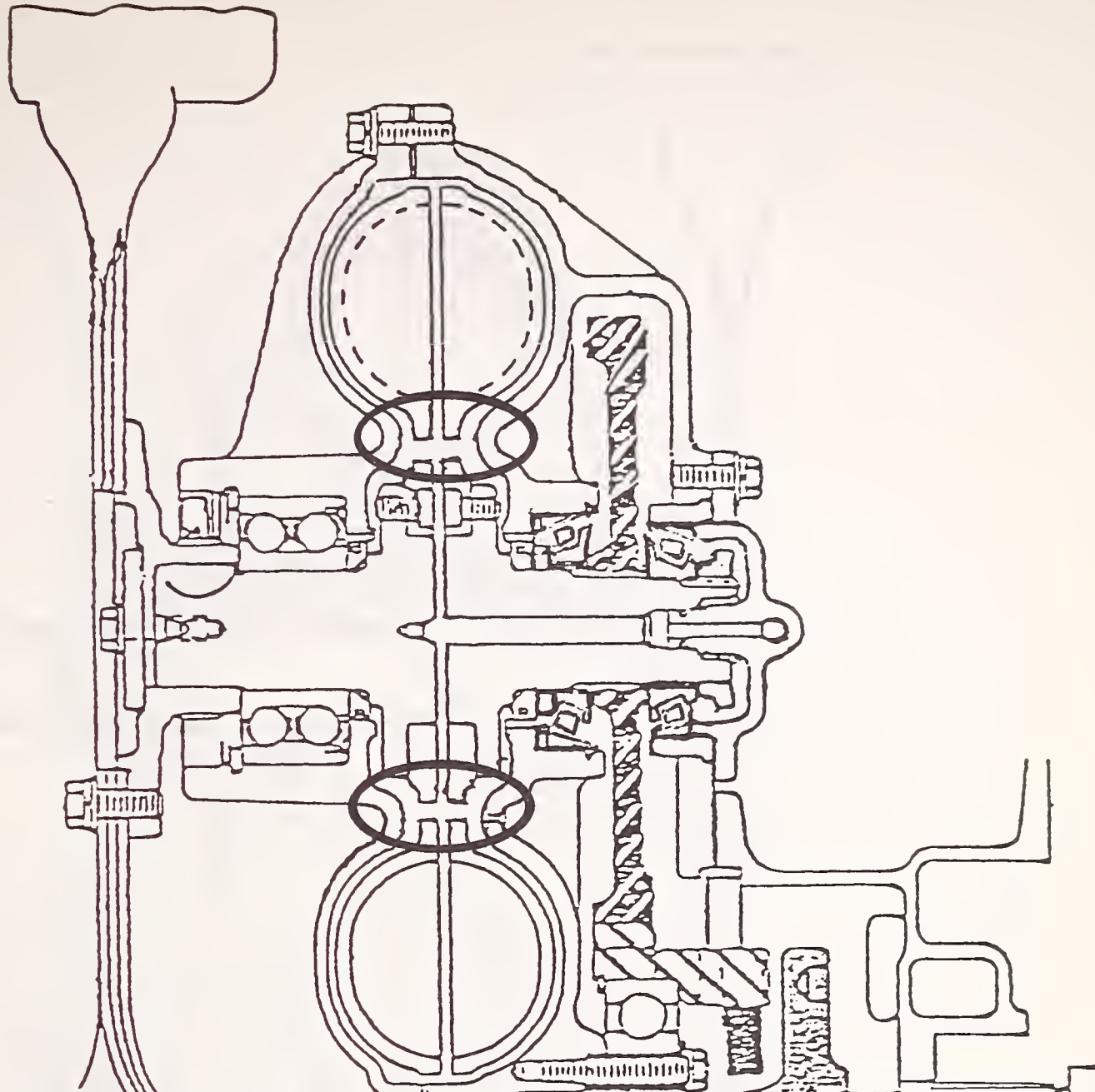
BEARING WIDTH = .940"

SNAP RING FLUID FAN DRIVE GEAR: Waldes #5000-575

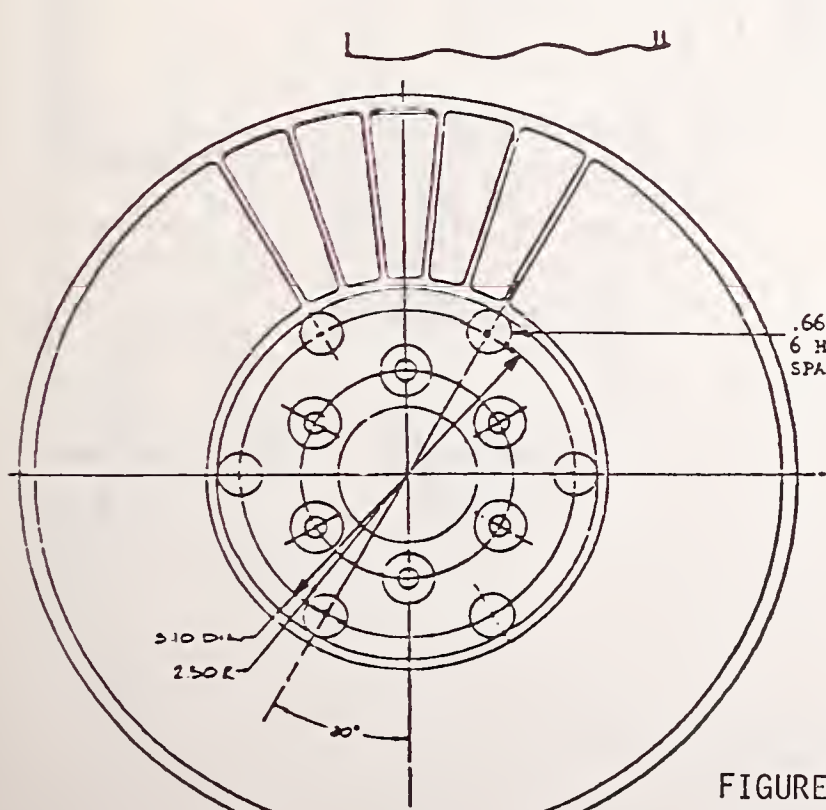
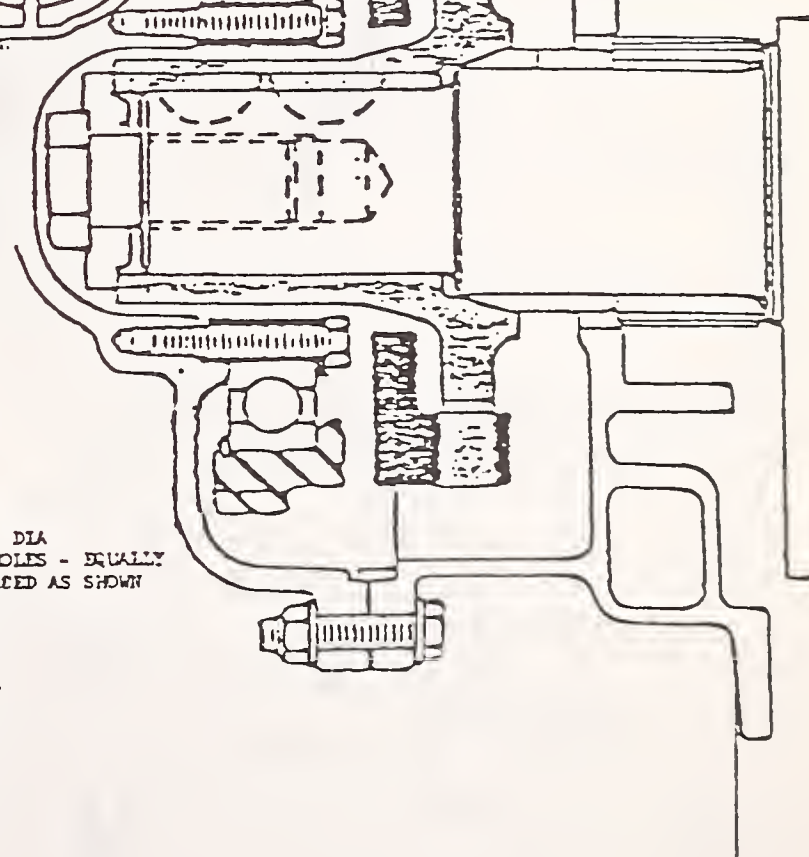
VIA #1457 R5-UG



Front Housing: Enlarge bearing bore to provide .0008" press interference fit.

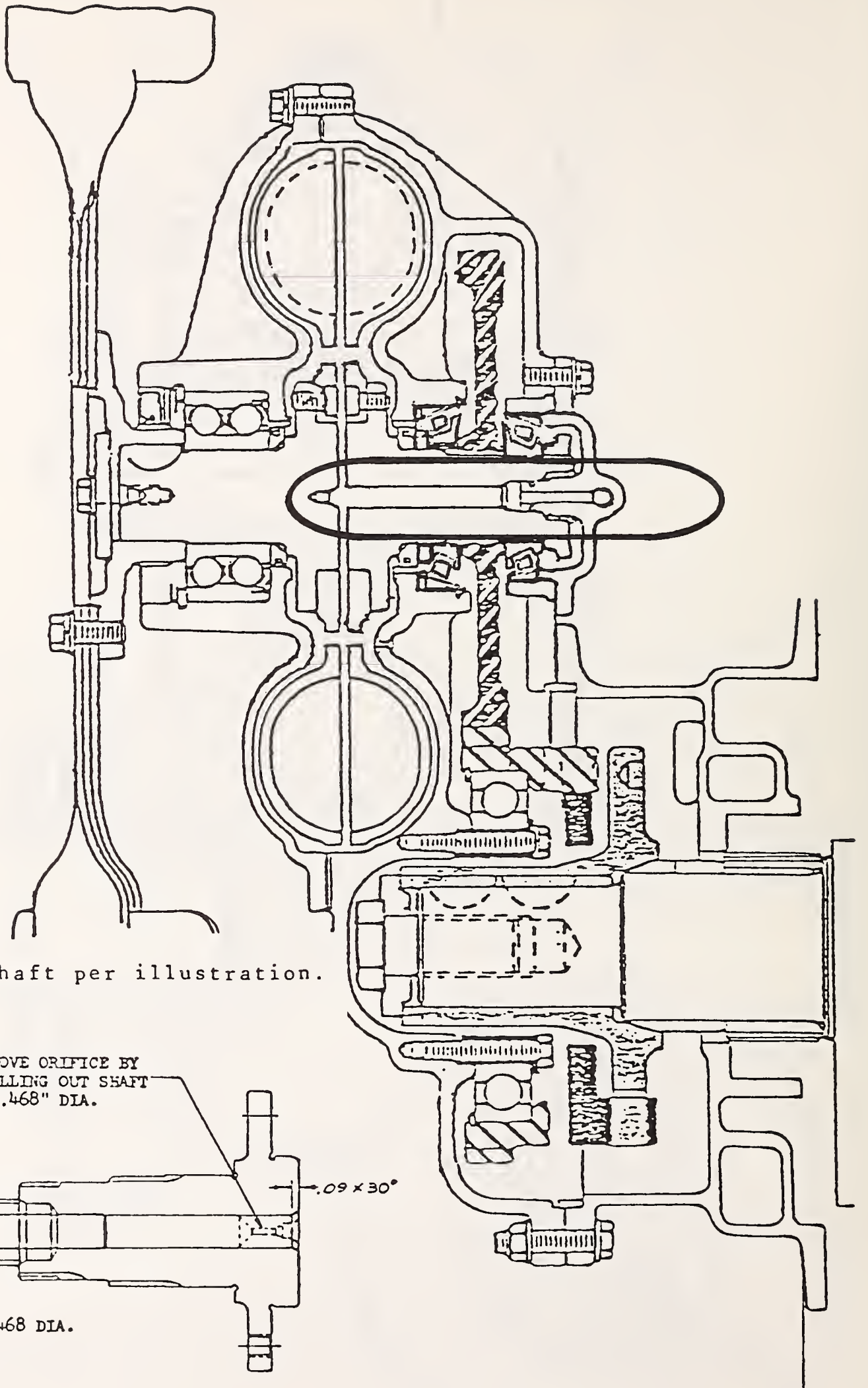


Front & Rear Torus: Enlarge bleed holes to .66". Drill 4 more .66" holes 60° apart. See illustration.



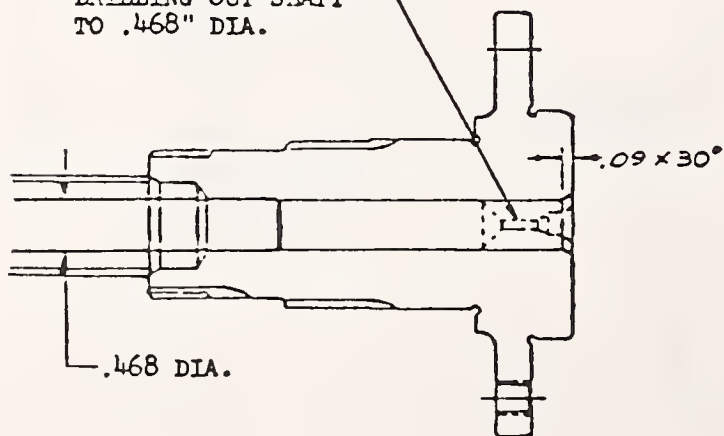
.66 DIA
6 HOLES - EQUALLY
SPACED AS SHOWN

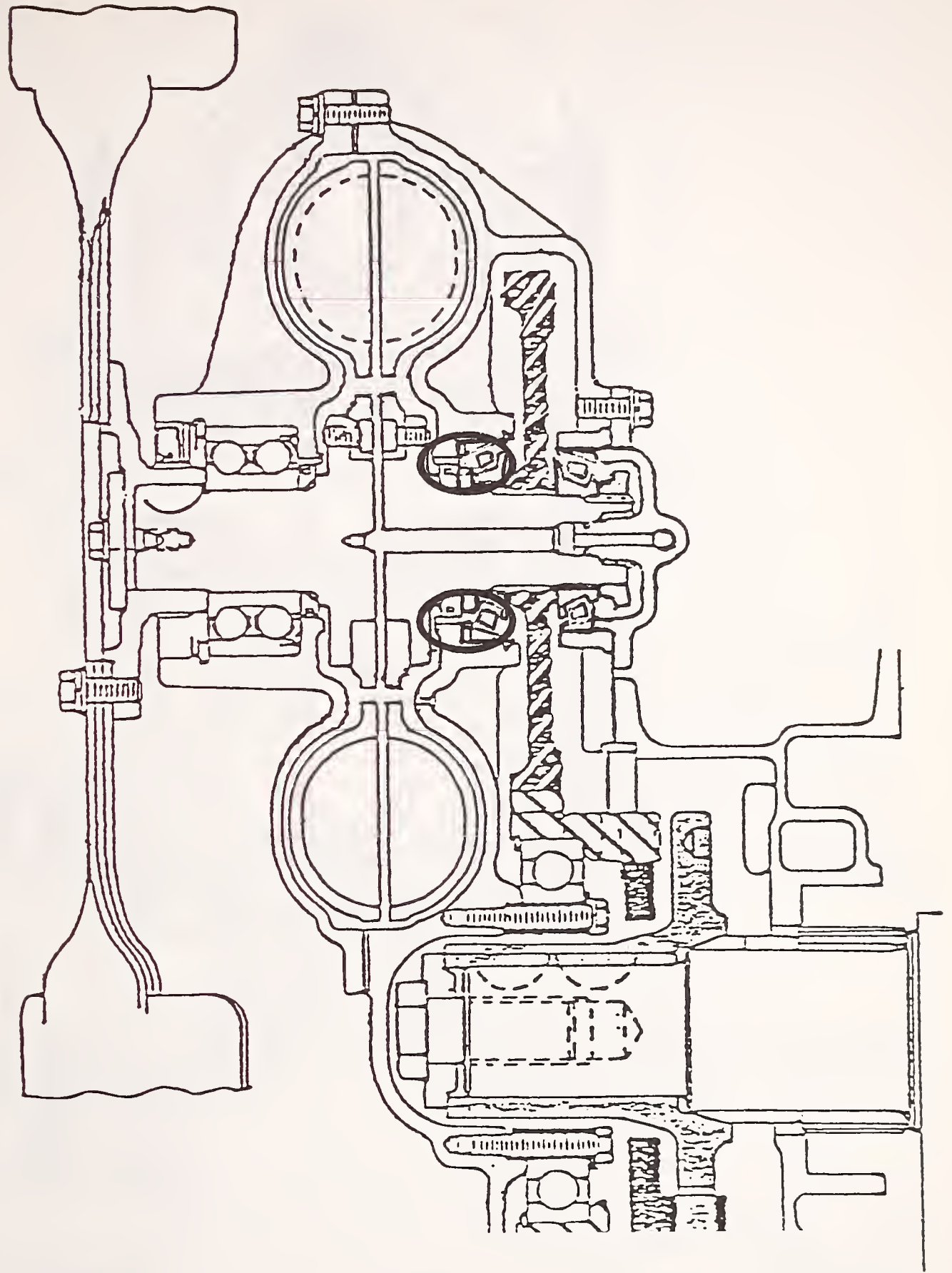
FIGURE C-2



Rework shaft per illustration.

REMOVE ORIFICE BY
DRILLING OUT SHAFT
TO .468" DIA.

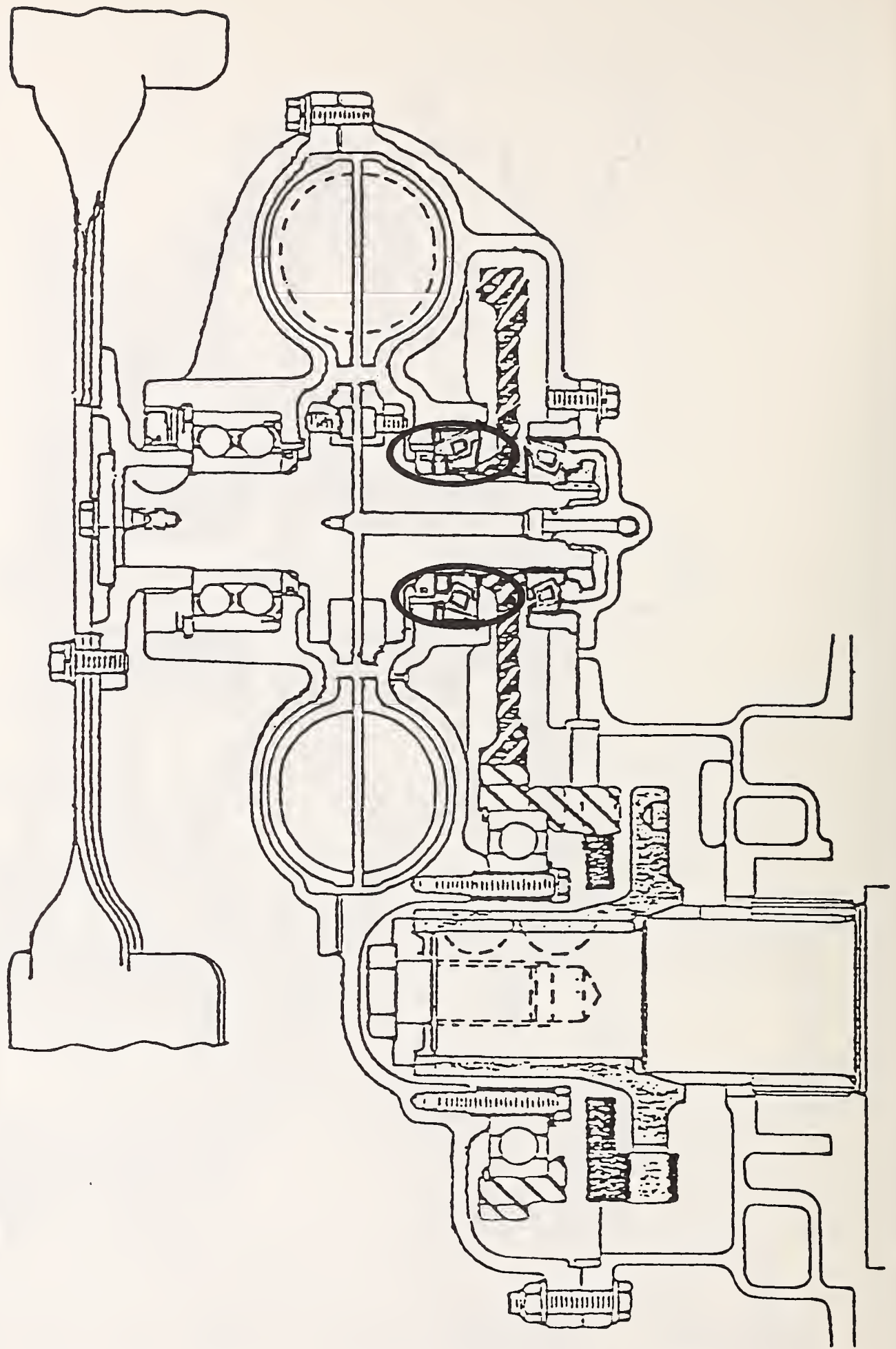




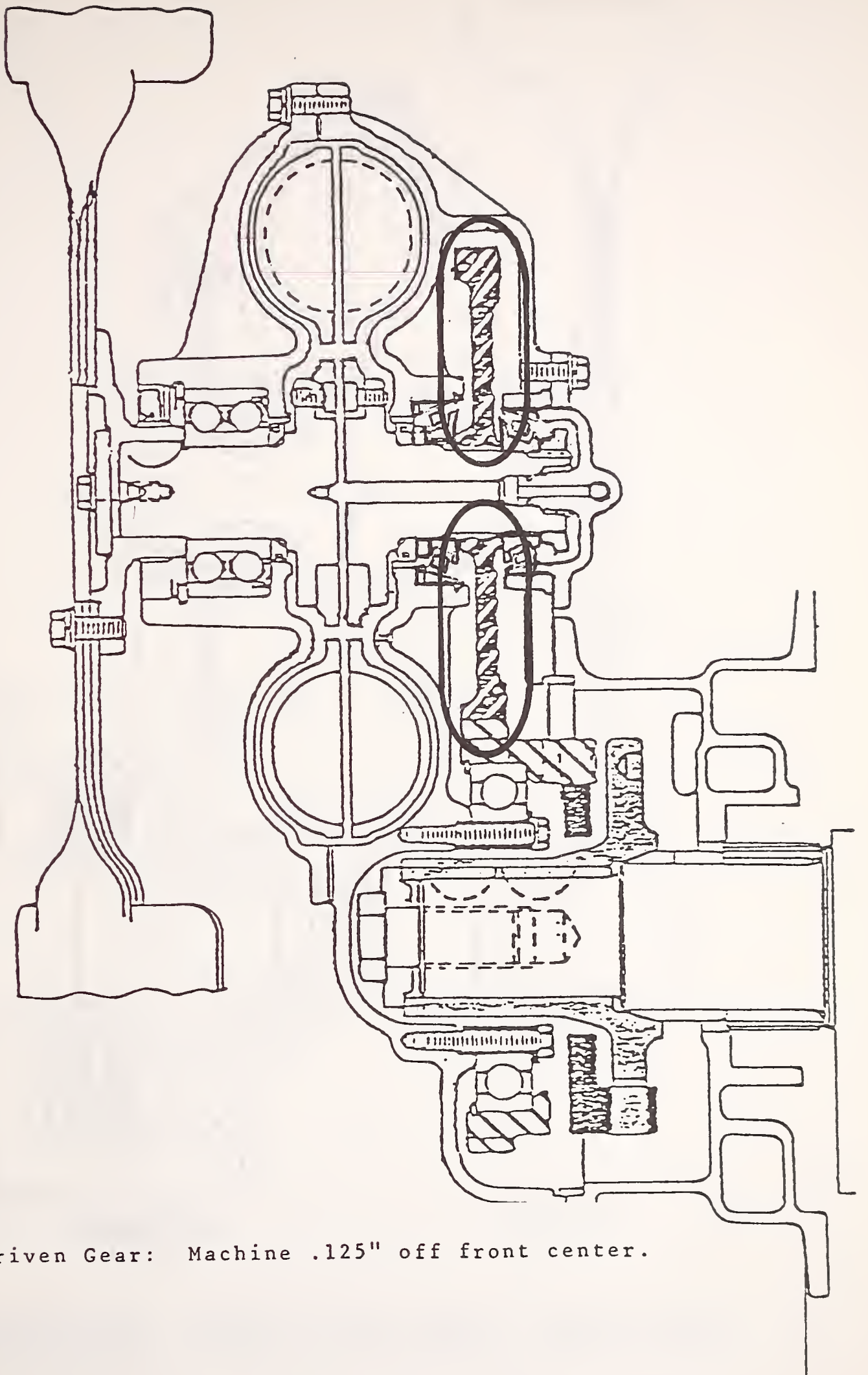
Manufacture or Substitute Spacer: 3.150" O.D. X 2.500" I.D. X .050" thick.

Sub: GMC P/N 2463532

FIGURE C-4

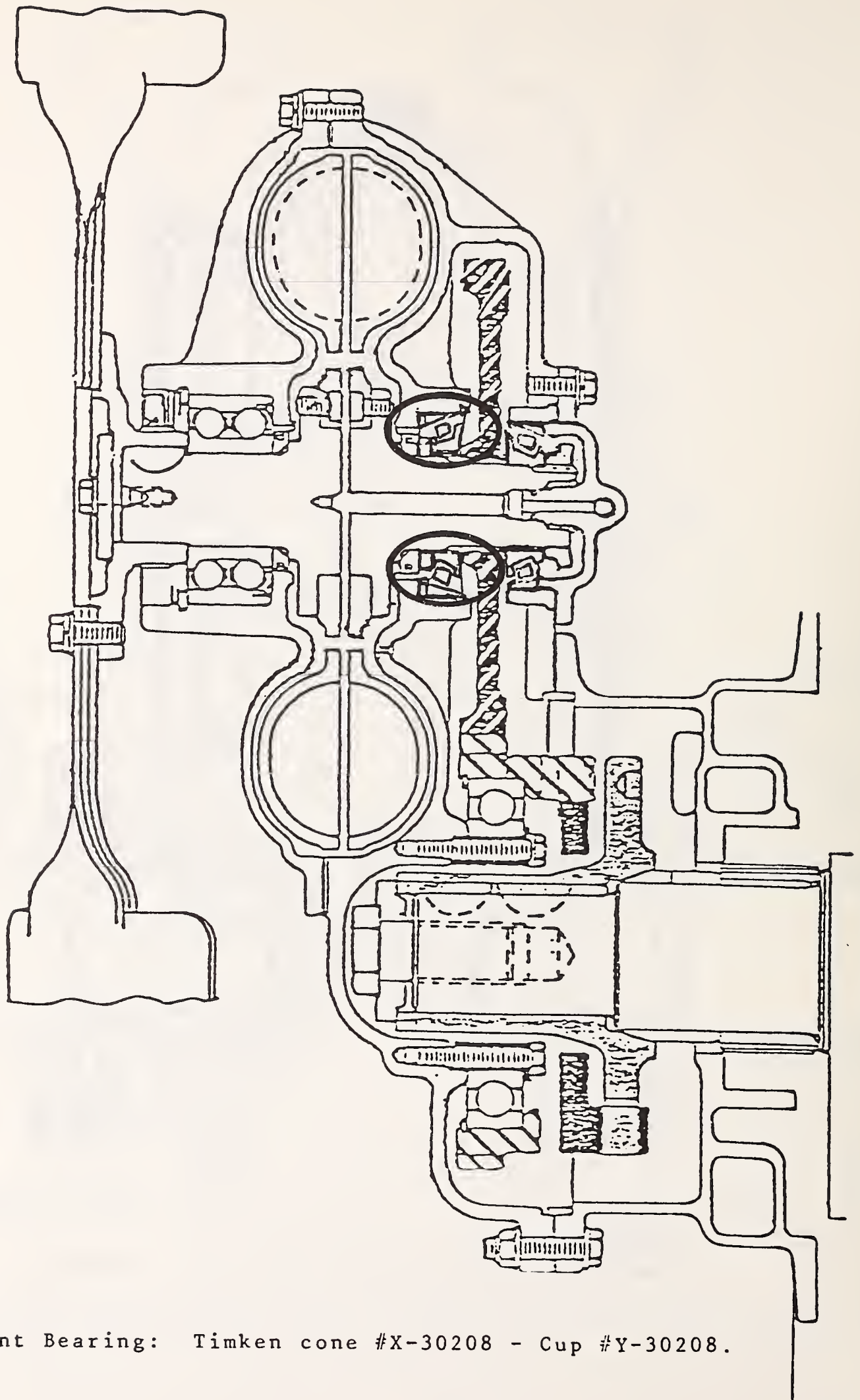


Manufacture and Install Spacer: 2.000" O.D. X 1.575" I.D. X .125" thick.

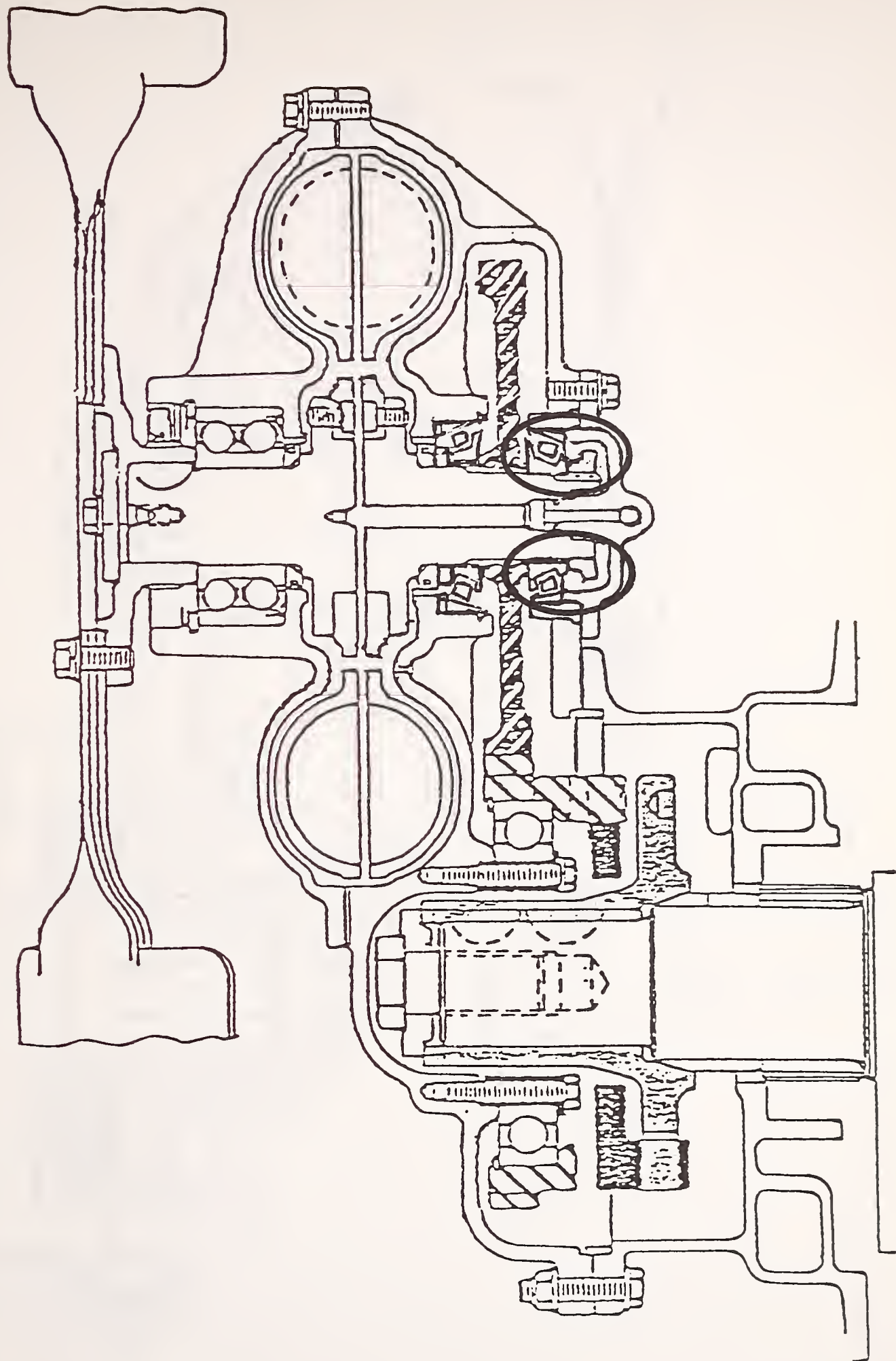


Driven Gear: Machine .125" off front center.

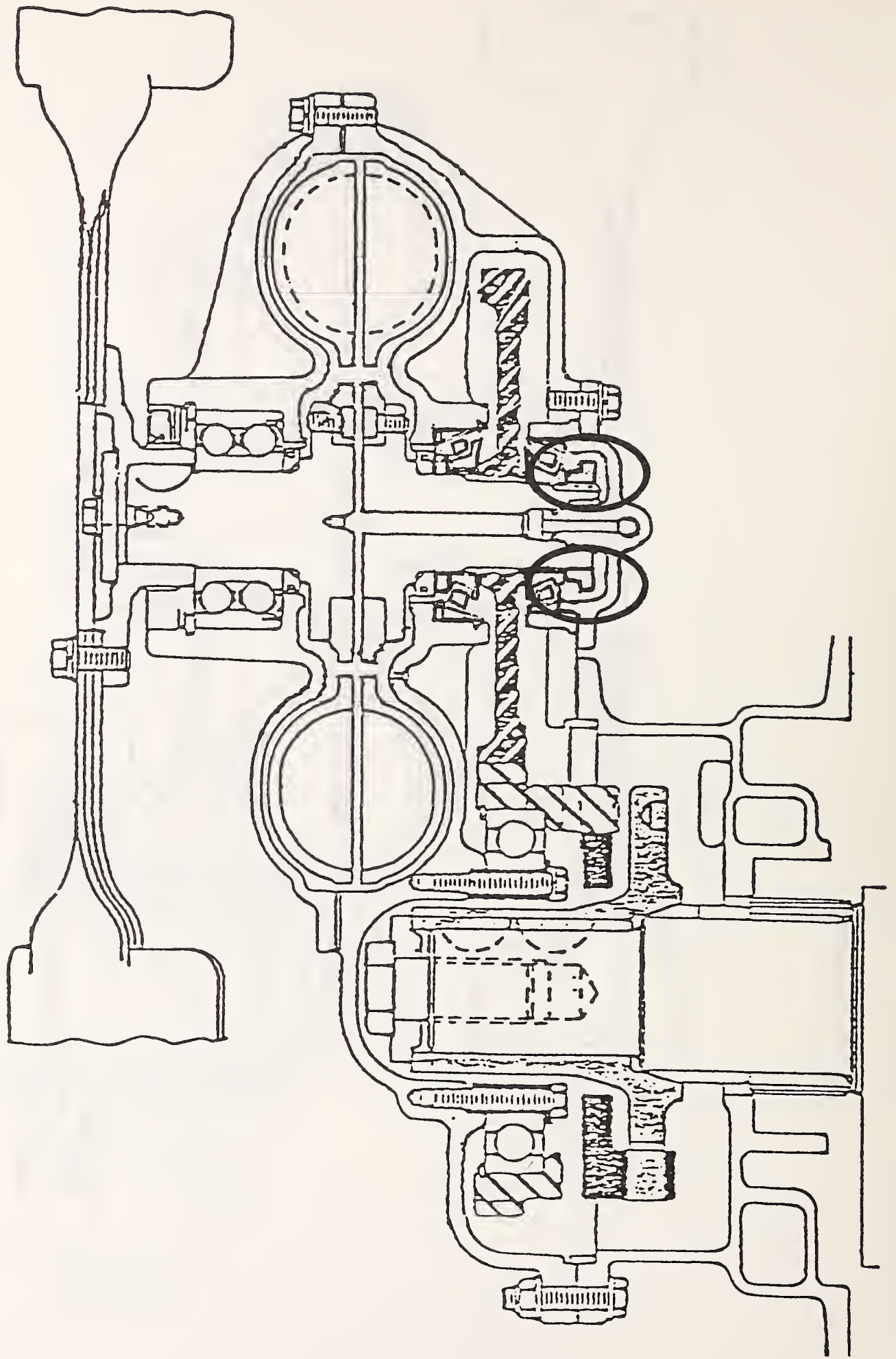
FIGURE C-6



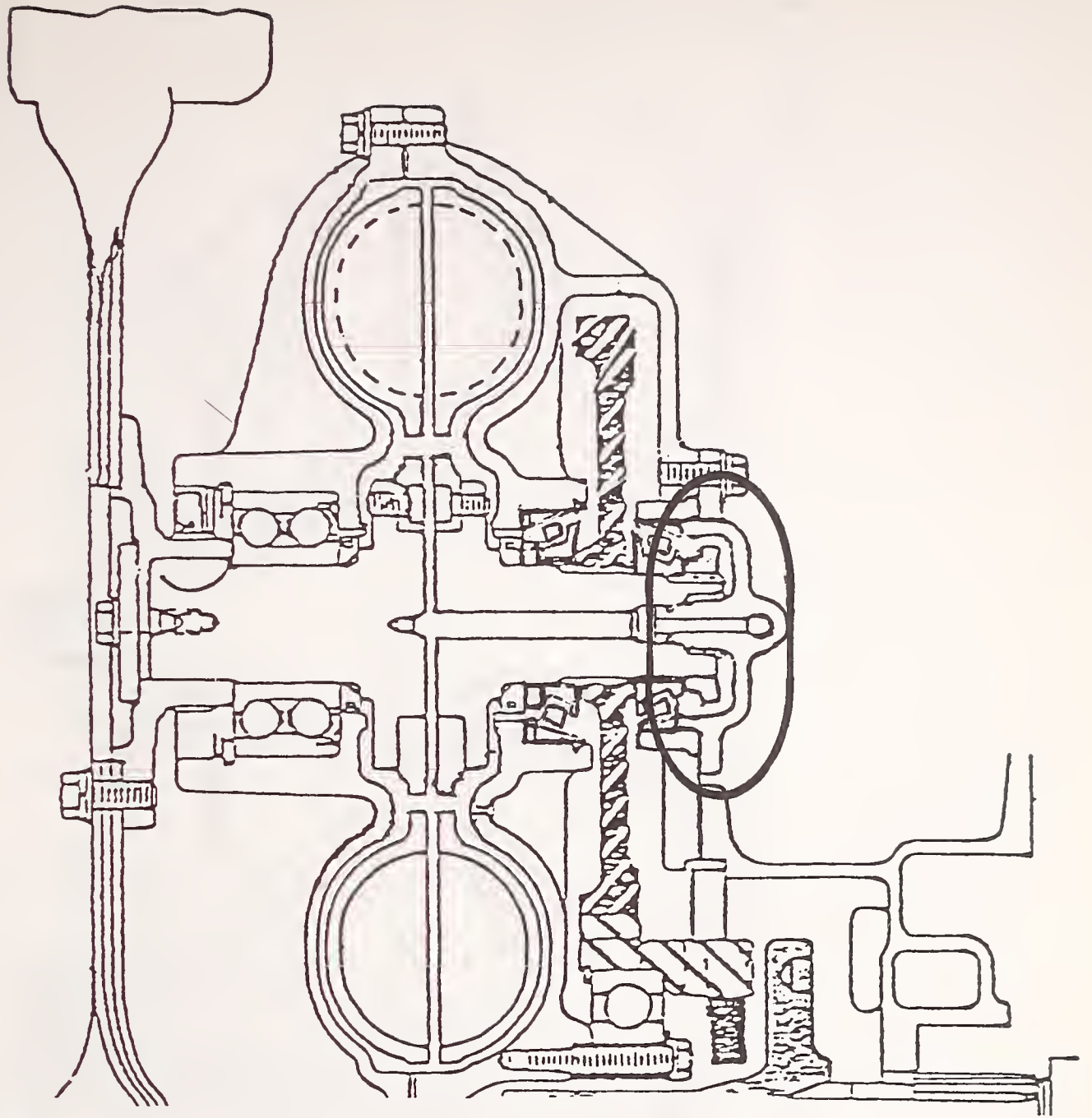
Front Bearing: Timken cone #X-30208 - Cup #Y-30208.



Rear Bearing: Timken cone #X-30207 - Cup #Y-30207.



Rear Bearing Retaining Nut: Machine 45° chamfer to 90° step. Discard lock or wave washer, torque to 150 ft. lbs. - stake nut to shaft.



Rear Bearing Retainer: See illustration for machining instructions. Shim to 0 end play $-.002''$. Selective gasket thickness used for preload. Preload on bearings: 3 lbs. pull on torus O.D.

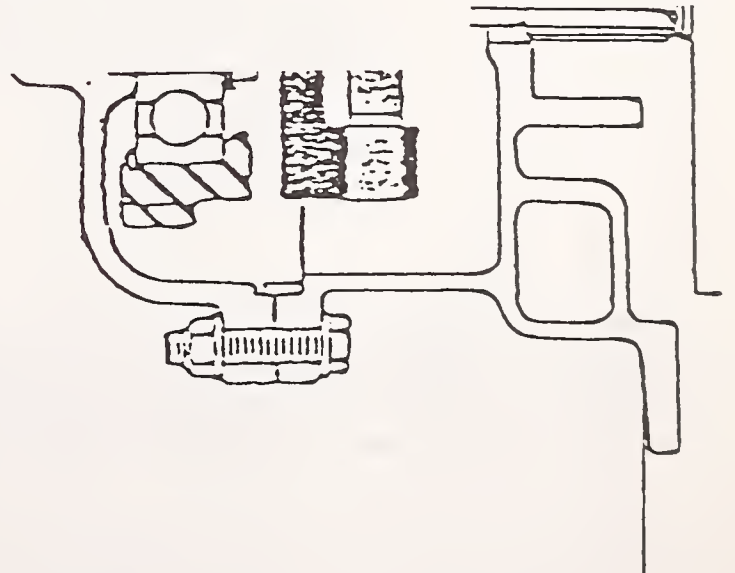
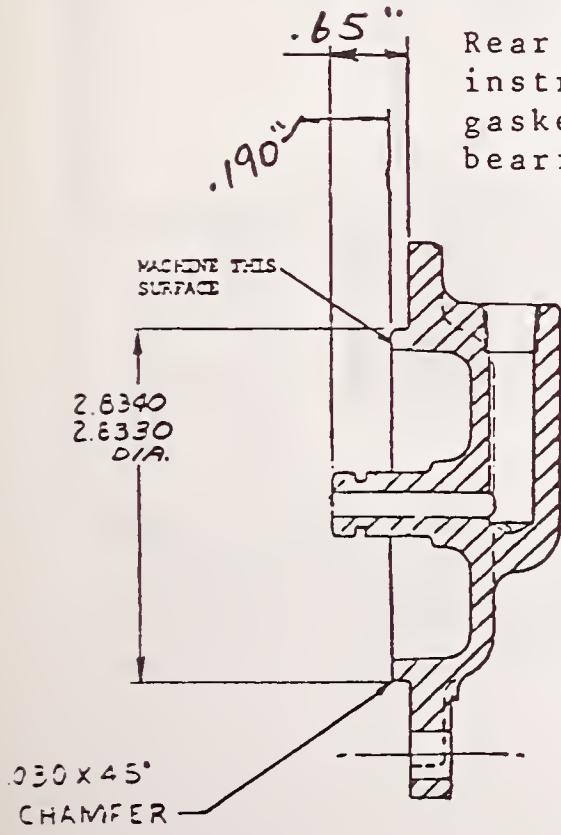
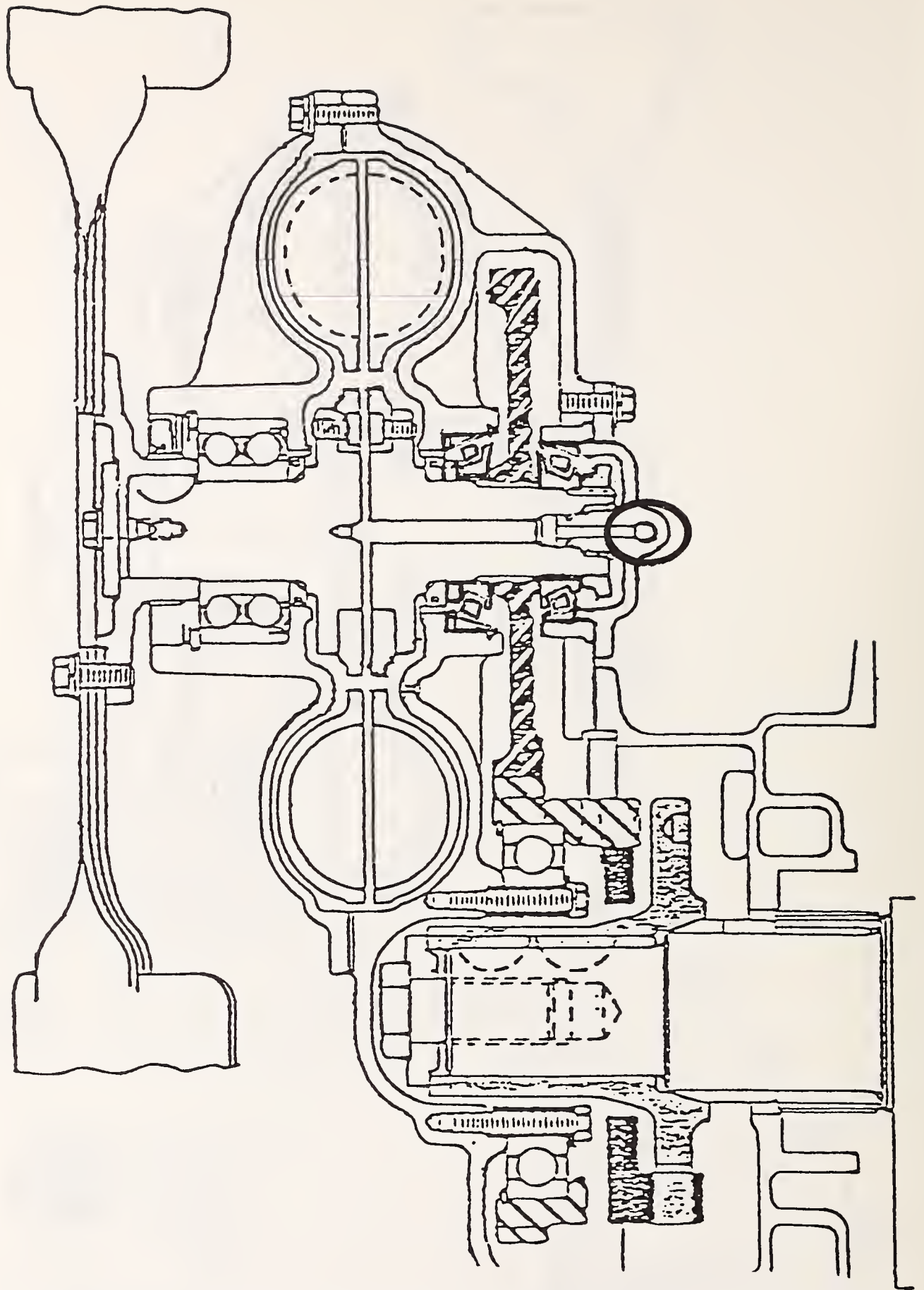
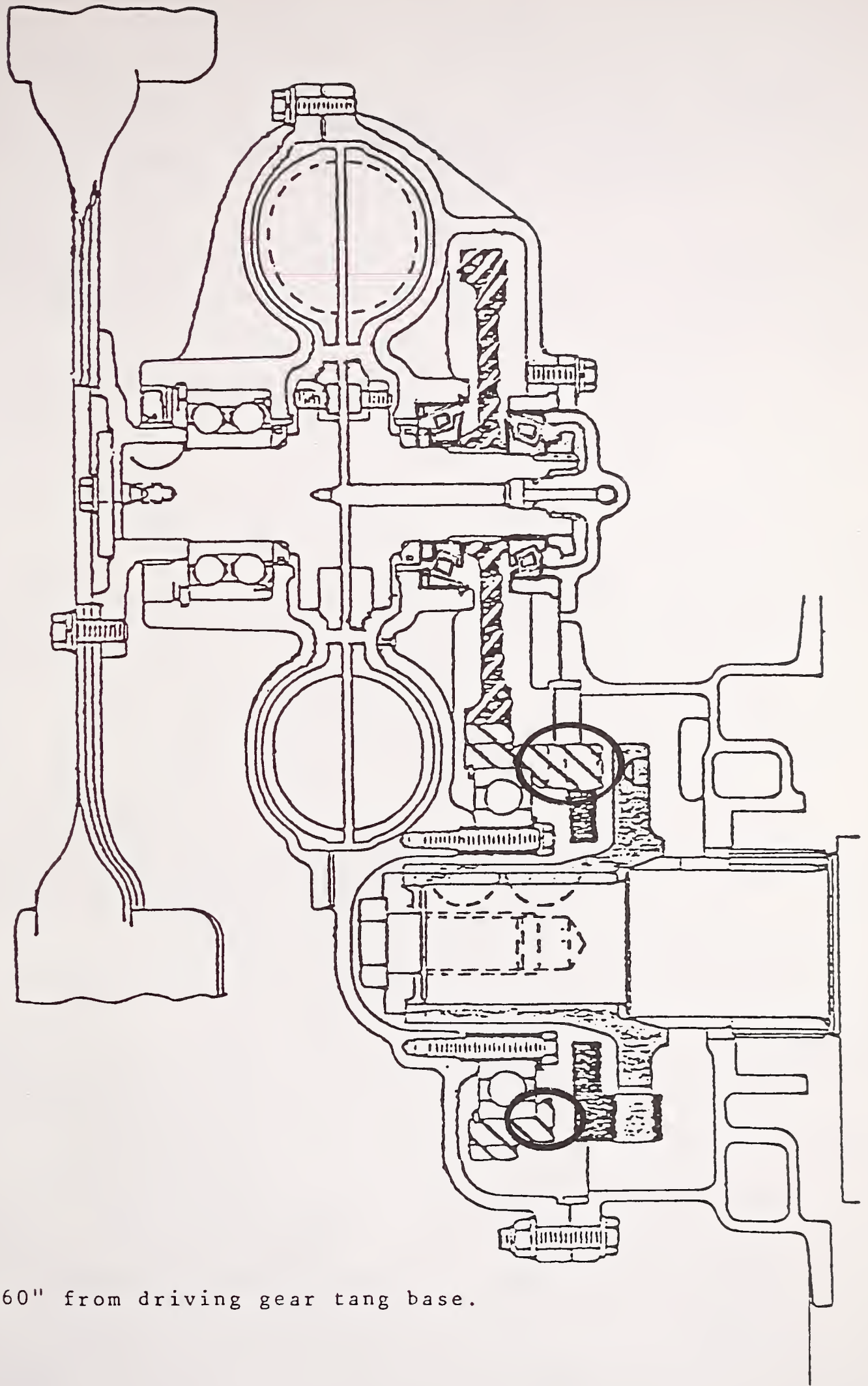


FIGURE C-10

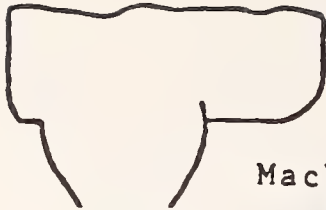


Restrict Oil Supply: (1) Use injector tube line P/N 2050798 with regular fittings. (2) or Restrict elbow with silver solder and drill to .80. Manufacture 7" #4 stainless steel teflon double swivel line and assemble with necessary fittings.

FIGURE C-11



Machine .060" from driving gear tang base.



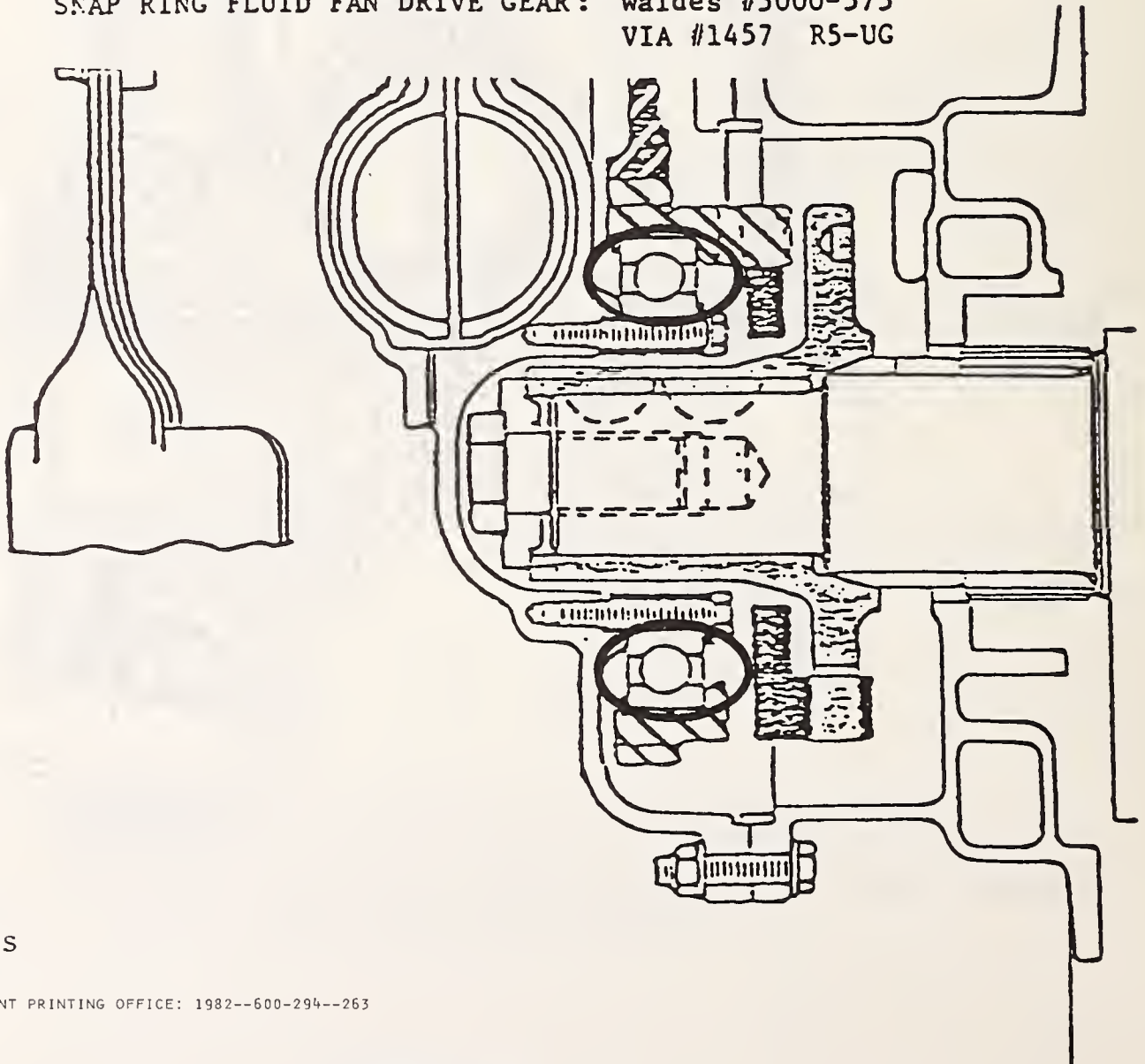
Machine Per Instructions.

Machine Gear I.D. -----	6.055"
Machine Sleeves - O.D. -----	6.057"
I.D. Rough Finish -----	5.850
Sleeve Width -----	1.000"
Press Sleeve in Gear & Finish Bore I.D. -----	5.903"
Machine Snap Ring Groove Depth from Brg.Seat----	.350"
Depth from Outer Gland Seat -----	.210"
Machine Groove from Inter Bearing Face to Inter Snap Ring Face -----	.943"

MACHINE SLEEVES FROM SEAMLESS STEEL TUBING
1020 DOM TUBE 6½" x ½" x 10'

BEARING O.D. = 5.904"
BEARING WIDTH = .940"

SNAP RING FLUID FAN DRIVE GEAR: Waldes #5000-575
VIA #1457 R5-UG



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FIGURE C-13

HE 18.5 .A3
UMTA - 82

Air conditi
modificati

Form DOT F 17
FORMERLY FORM



