AD-A080 518 ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND ST LO--ETC F/G 1/3

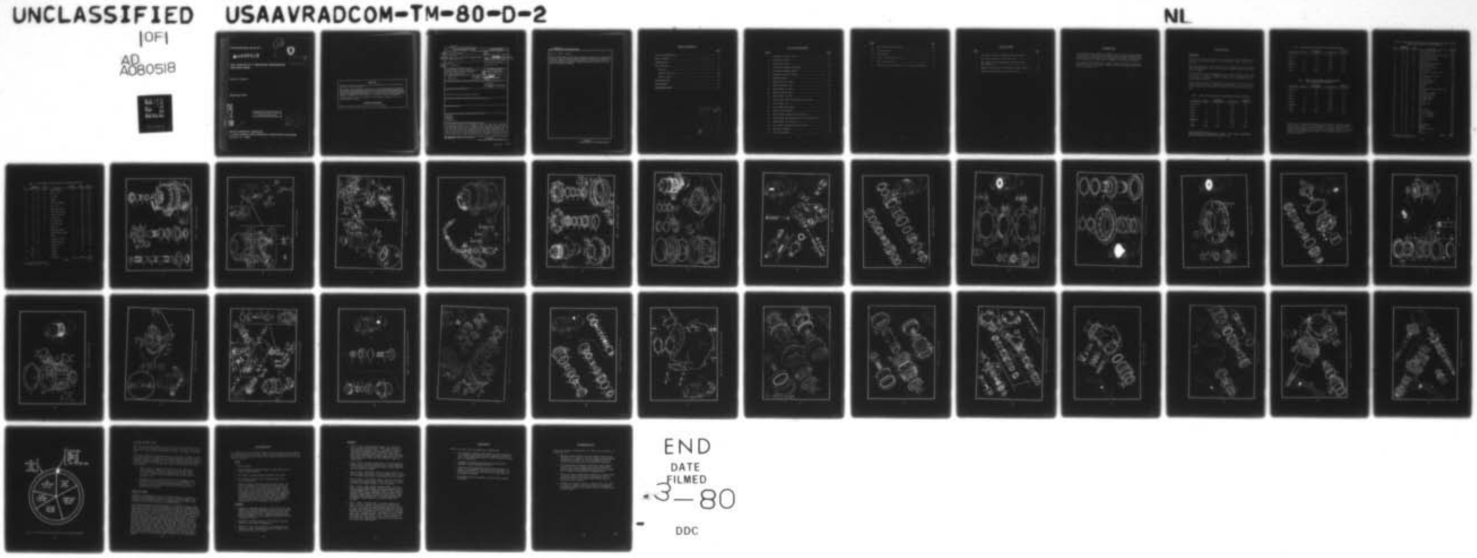
COST ANALYSIS OF A HELICOPTER TRANSMISSION AND DRIVE TRAIN. (U)

NOV 79 R F MULLIKEN

UNCLASSIFIED USAAVRADCOM-TM-80-D-2 NL

1 OF 1

AD A080518

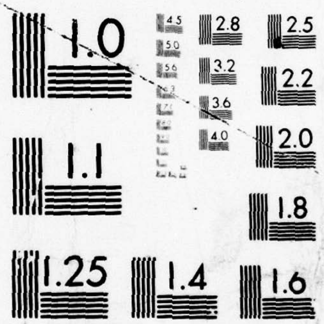


END

DATE FILMED

3-80

DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

USAAVRADCOM TM 80-D-2

COST ANALYSIS OF A HELICOPTER TRANSMISSION AND DRIVE TRAIN

Richard F. Mulliken

November 1979

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (14) USAAVRADCOM-TM-80-D-2	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER (9)	
4. TITLE (and Subtitle) (6) COST ANALYSIS OF A HELICOPTER TRANSMISSION AND DRIVE TRAIN	5. TYPE OF REPORT & PERIOD COVERED Technical [redacted] memo
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Richard F. Mulliken	8. CONTRACT OR GRANT NUMBER(s) House Task 78-13
9. PERFORMING ORGANIZATION NAME AND ADDRESS Applied Technology Laboratory, US Army Research and Technology Laboratories (AVRADCOM) Fort Eustis, Virginia 23604	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 62209, 1L162209AH76 00 248
11. CONTROLLING OFFICE NAME AND ADDRESS (12) 46 (17) 00	12. REPORT DATE (11) Nov [redacted] 79
	13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Helicopter
Transmission
Drive train
Acquisition cost

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A cost analysis was conducted on a transmission and drive train system from a single-engine helicopter with an input of 1134 hp at 6600 rpm. Main rotor speed was 325 rpm. Details and subassemblies of this system were identified using the Army Technical Manual. Prices of spare parts were obtained from the Army Master Data File (AMDF). Irregularity in the prices found showed that it was impossible to identify specific cost drivers or to develop any valid cost baseline or to obtain valid comparative detail costs using this data base. In view of this situation, plans to analyze a second system were abandoned. A detailed review of

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

410 330

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Block 20. Abstract - Continued.

the data obtained strongly indicated that gears, forgings, and castings are the cost drivers in this system. Since all such systems employ components of similar nature and function, this indication is applicable to other transmission systems and should therefore be useful as an aid in directing cost-reduction efforts. Manufacturing approaches by which costs on such parts may be reduced are suggested.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure		Page
23	Drive shaft illustration, tail rotor	34
24	Gearbox assembly	35
25	Quill assembly	36
26	Gearbox assembly, tail rotor drive	37
27	Quill assembly, gearbox	38
28	Transmission and tail rotor drive price and quantity breakdown	39

LIST OF TABLES

INTRODUCTION

No systematic analysis of helicopter transmission and drive train costs has previously been undertaken. Information on the identity of the acquisition cost drivers and on possible means by which their costs can be reduced was needed. The present study was therefore initiated. Army inventory helicopters were selected for the analysis.

The objective of the program was to conduct a detailed cost analysis on helicopter drive systems in order to establish a baseline for drive system manufacturing development and acquisition costs.

COST ANALYSIS

PROCEDURE

A detailed cost analysis was conducted on a single-engine helicopter transmission and drive train system with an input of 1134 hp at 6600 rpm. Main rotor speed was 325 rpm.

Details and subassemblies of the transmission and drive train were identified using the Army Technical Manual.[1] Prices of spare parts were obtained from the Army Master Data File (AMDF).

All detail parts were counted, including nuts, bolts, washers, decals, etc. Where parts were listed not as details in the AMDF, but only as parts of subassemblies, the price of the detail was estimated on the basis of the prices of the subassembly and such of its details as were listed.

Tables 1 and 2 group parts by price range for the transmission and tail rotor drive systems, respectively. Table 3 combines the previous tables. It is noted that overall, 3.2 percent of the parts account for 78.3 percent of the summation of the detail prices.

TABLE 1. PRICE RANGES OF PARTS FOR TRANSMISSION AND MAST ASSEMBLY

Price Range ($)	Quantity	Percentage of Total Quantity	Total Price ($)	Percentage of Total Cost
1000 and over	7	0.4	15,265	43.2
750-999	7	0.4	5,739	16.3
500-749	4	0.2	2,454	7.0
300-499	13	0.8	4,763	13.5
100-299	9	0.5	1,939	5.5
SUBTOTAL	40	2.3	30,160	85.5
0-100	1,664	97.7	5,142	14.5
TOTAL	1,704	100.0	35,302	100.0

[1] TM-55-1520-221-34P-1, HELICOPTER, ATTACK - AH-1G (BELL); HELICOPTER, FLIGHT TRAINER - TH-1G (BELL), December 1972.

TABLE 2. PRICE RANGES OF PARTS FOR TAIL ROTOR DRIVE TRAIN

Price Range ($)	Quantity	Percentage of Total Quantity	Total Price ($)	Percentage of Total Cost
500 and over	3	0.6	1,789	14.6
300-499	11	2.0	4,121	33.6
100-299	17	3.3	3,022	24.6
SUBTOTAL	31	5.9	8,932	72.8
0-100	477	94.1	3,341	27.2
TOTAL	508	100.0	12,273	100.0

TABLE 3. PRICE RANGES OF PARTS FOR TRANSMISSION AND TAIL ROTOR DRIVE COMBINED

Price Range ($)	Quantity	Percentage of Total Quantity	Total Price ($)	Percentage of Total Cost
1000 and over	7	0.3	15,265	32.1
750-999	7	0.3	5,739	12.1
500-749	7	0.3	4,243	8.9
300-499	24	1.1	8,884	18.7
100-299	26	1.2	4,961	10.4
SUBTOTAL	71	3.2	39,092	82.2
0-100	2,142	96.8	8,483	17.8
TOTAL	2,213	100.0	47,575	100.0

Tables 4 and 5, covering the transmission and tail rotor drive, respectively, identify all items priced at $100 or more in descending order of their prices and identify the nature of the part (gear, other forging, casting, etc.). Figures 1 through 27, taken from the Technical Manual, serve to clarify the identifications. Figure 28, a pie chart, breaks out and combines data from Tables 4 and 5, presenting relative costs and quantities by part type.

TABLE 4. HIGHEST COST DETAIL PARTS FOR TRANSMISSION AND MAST ASSEMBLY (BASED ON QUANTITY OF ONE PER AIRCRAFT)

Entry	Reference Figure	Reference Item	Type Part*	Part Name	Price ($)
1	6	26	F	Case, transmission, main support	2,768
2	14	21	C	Case, transmission, main	2,645
3	10	16	F	Shaft (planetary, flanged, main drive quill)	2,451
4	5	56	F/G	Case (2 integral ring gears)	2,413
5	1	33	F	Shaft (main output) (mast)	2,307
6	9	15	F	Spider (lower)	1,437
7	11	8/11	F	Spider and web assembly (upper)	1,244
8	27	12	G	Gear assembly (bevel)	895
9	8	16		Bearing, main input pinion	869
10	5	31	G	Gear, lower sun	821
11	20	15	C	Case, accessory and tail rotor drive	819
12	12	17	G	Gear shaft	808
13	5	11	C	Case, transmission (cover only)	772
14	18	33	C	Sleeve, gear case	755
15	8	29	G	Gear pinion (main input)	657
16	13	20	C	Sleeve, gear support	633
17	18	17	G	Gear (spur)	584
18	10	12		Bearing	580
19	8	22	C	Housing, main input (gear support sleeve)	456
20	10	15	G	Gear (bevel)	432
21	5	24	G	Gear, upper sun, planetary	407
22	10	4	C	Case, gear support sleeve	405
23	17	6	C	Sleeve (gear support)	378
24	19	17	C	Sleeve (gear support)	378
25	18	21	G	Gear, spur	366
26	4	9		Transmitter, press	346
27	8	9		Liner	332
28	19	24	G	Gear	328
29	18	20	G	Pinion assembly	322
30	13	4	G	Gear, spur, transmission	313
31	13	15	G	Gear, spur, transmission	300
32	18	24	G	Gear, spur, transmission	291
33	1	28	C	Plate	289
34	1	16		Bearing	271
35	18	6	C	Cover	258
36	5	21	G	Adapter (spline)	252
37	7	22	C	Manifold	204
38	19	9	G	Coupling, male, spherical	151
39	2	7		Plate	116
40	8	26		Liner, sleeve	107
				TOTAL	30,160

*F = Forging, C = Casting, G = Gear

TABLE 5. HIGHEST COST DETAIL PARTS FOR TAIL ROTOR DRIVE TRAIN

Entry	Reference Figure	Reference Item	Type Part*	Part Name	Quantity Per Aircraft	Price Each ($)	Total Price ($)
1	27	17	F	Shaft, shouldered	1	735	735
2	27	45	G	Gear, bevel	1	546	546
3	25	16	G	Gear, bevel	1	508	508
4	21	31	G	Adapter	1	435	435
5	17	6	C	Sleeve, bearing HHS	1	425	425
6	25	16	G	Gear, bevel	1	410	410
7	25	21	C	Sleeve, gear support	2	378	756
8	27	16		Liner, bearing housing	1	361	361
9	22	8	G	Coupling, main drive	2	355	710
10	27	2	G	Gear (pinion)	1	355	355
11	26	31	C	Case (upper gear)	1	353	353
12	24	22	C	Case (lower gear)	1	316	316
13	22	14		Drive shaft	1	272	272
14	27	47	C	Sleeve, gear support	1	238	238
15	27	11		Ring, externally threaded	1	193	193
16	23	2		Shaft	5	186	930
17	22	9	G	Coupling, main drive	2	175	350
18	27	46		Bearing ball, annular	1	173	173
19	21	7		Coupling, static	1	156	156
	25	11		Coupling			
20	23	16	G	Coupling	4	151	604
	27	38		Coupling			
21	27	13		Nut, splined	1	106	106
				TOTAL	31		8932

*F = Forging, G = Gear, C = Casting

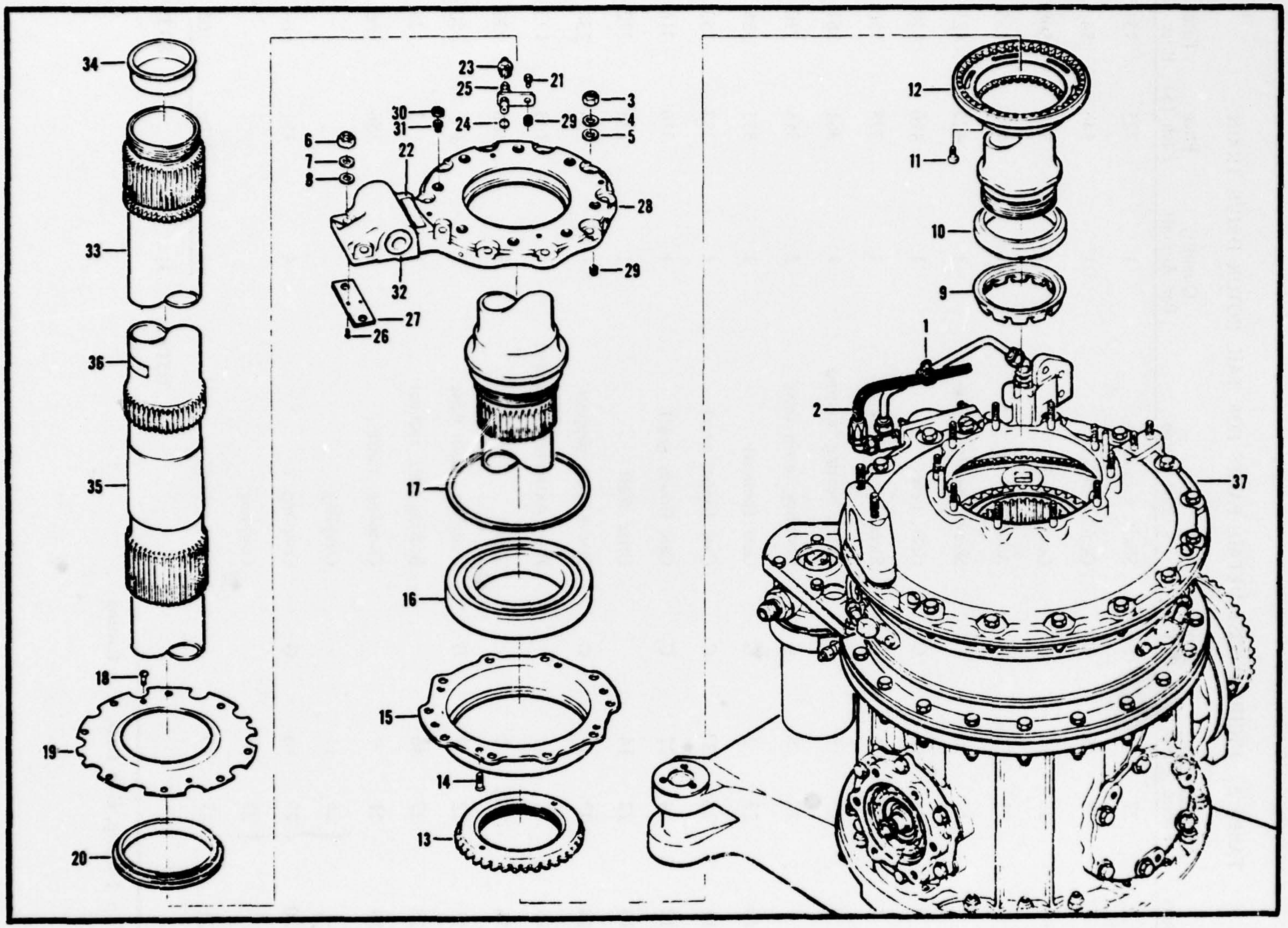


Figure 1. Transmission and mast assembly.

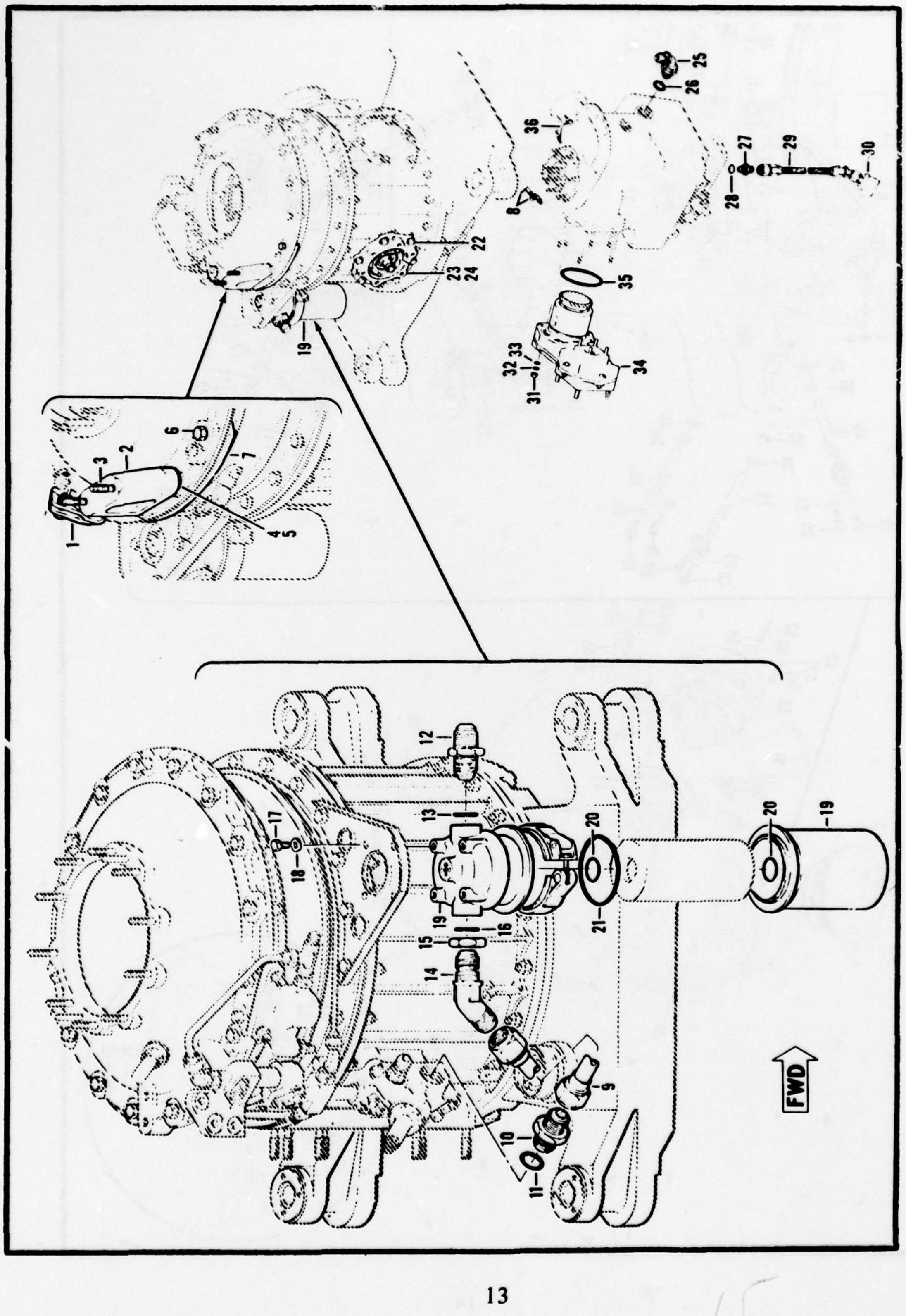


Figure 2. Transmission assembly.

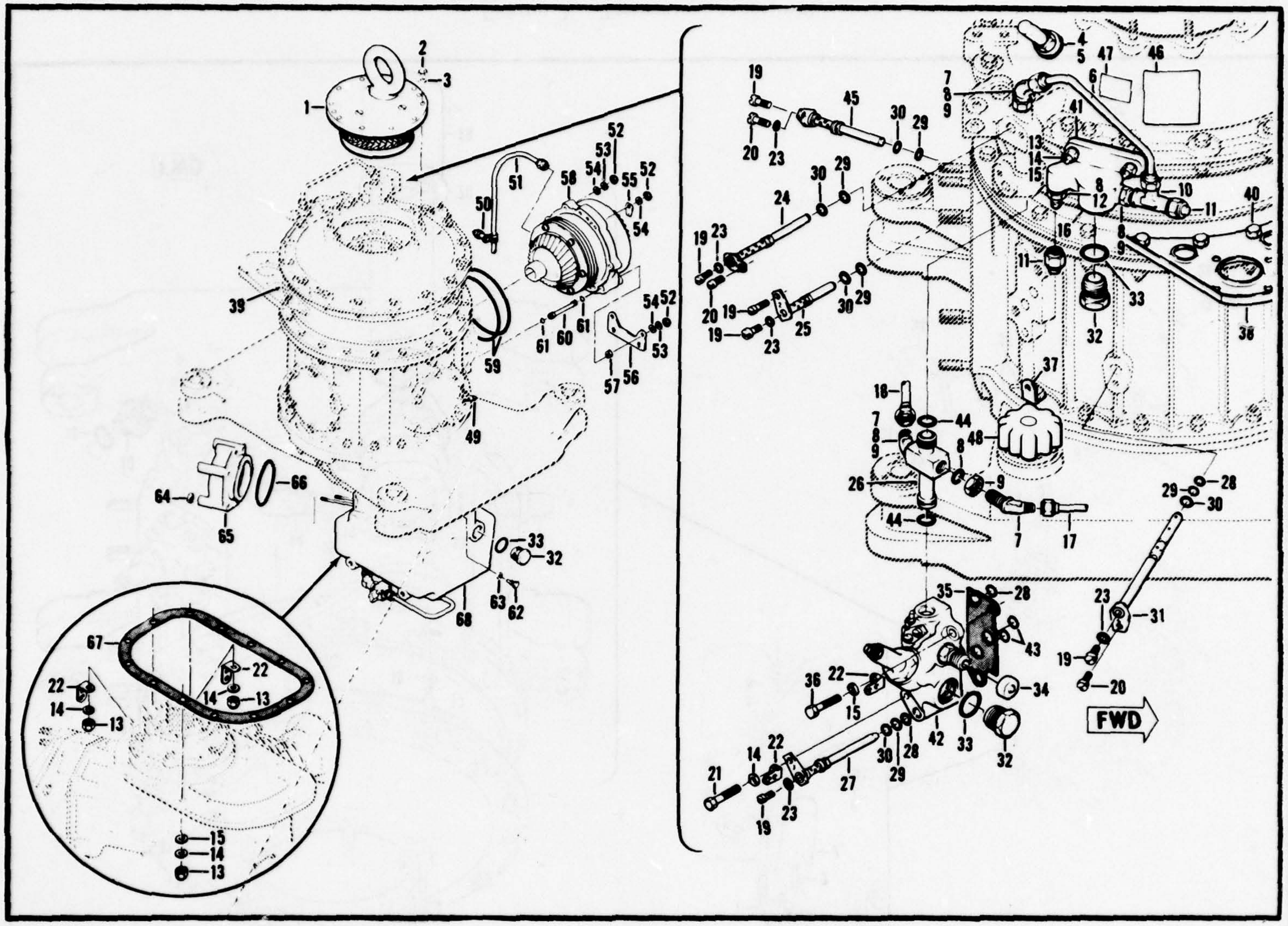


Figure 3. Transmission, universal.

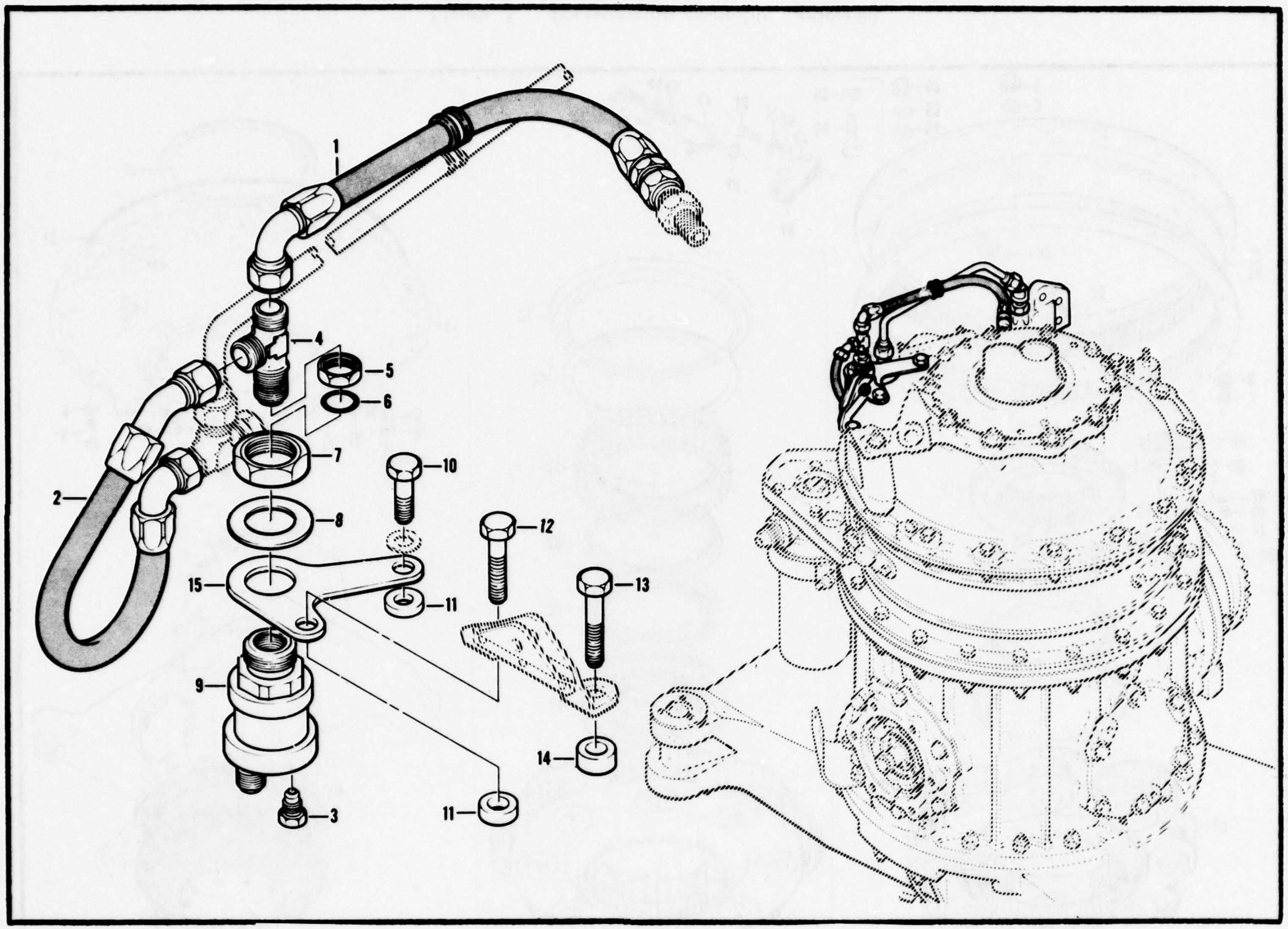


Figure 4. Lube system installation, transmission.

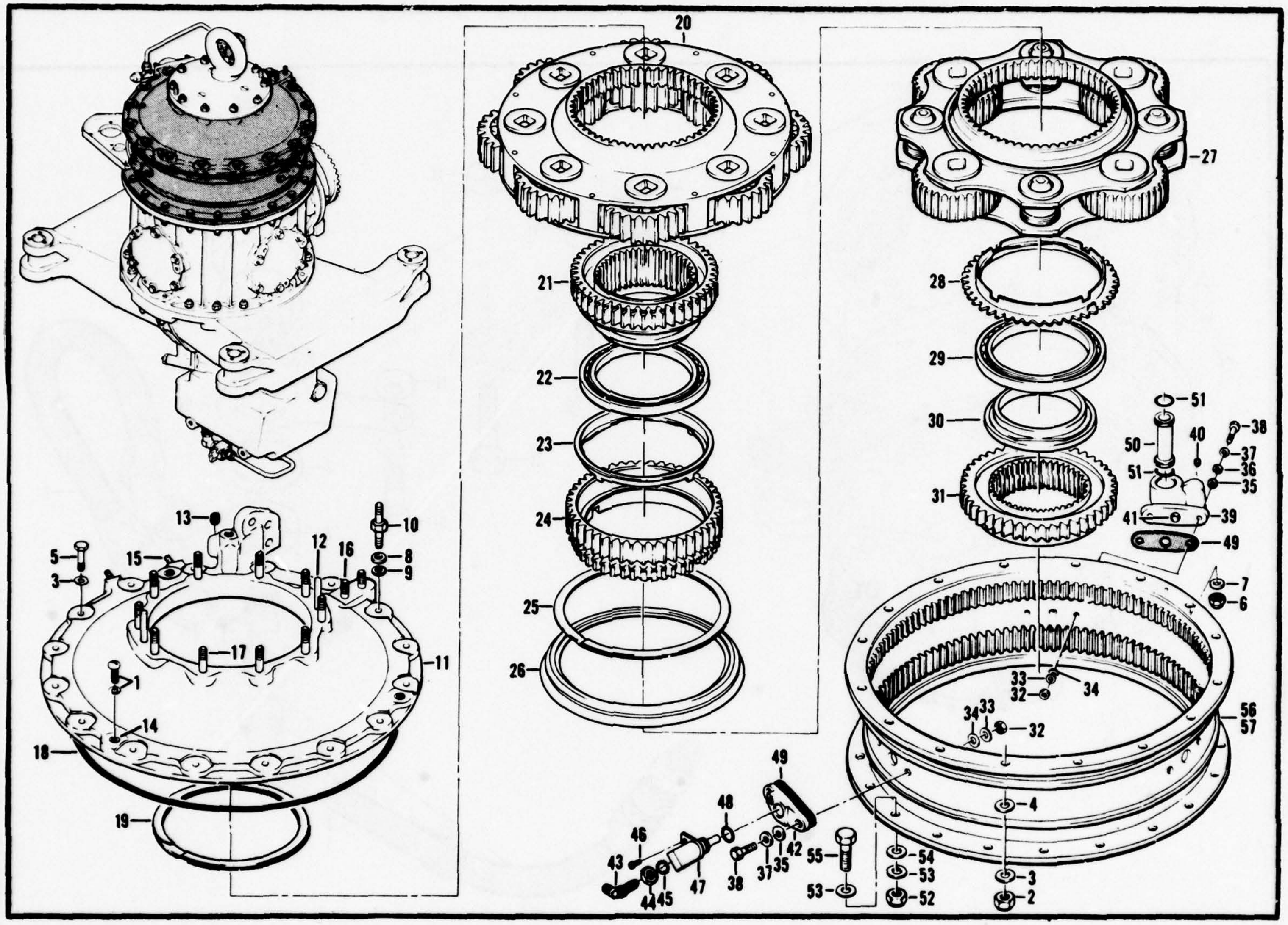


Figure 5. Transmission assembly, universal.

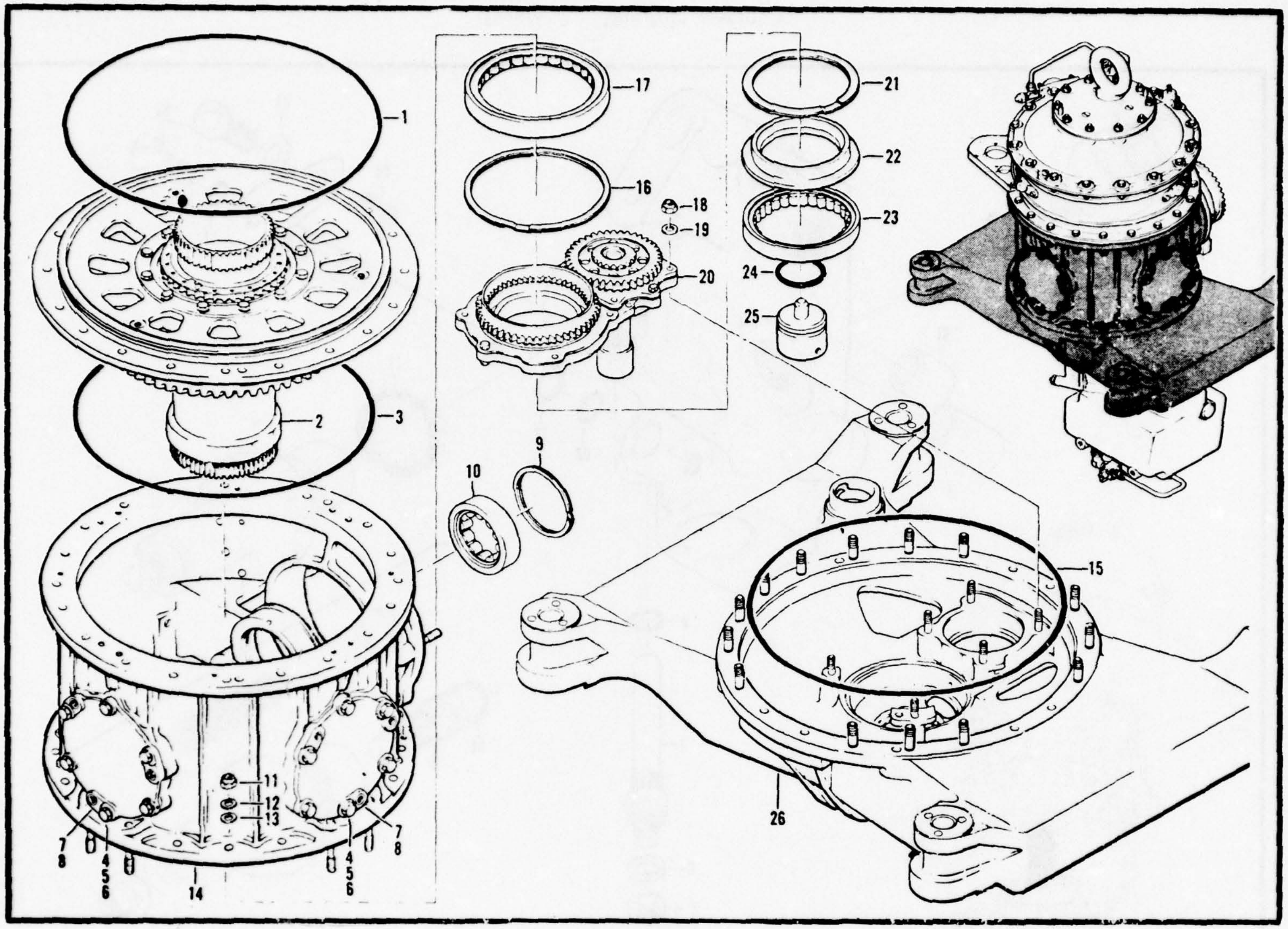


Figure 6. Transmission assembly, universal.

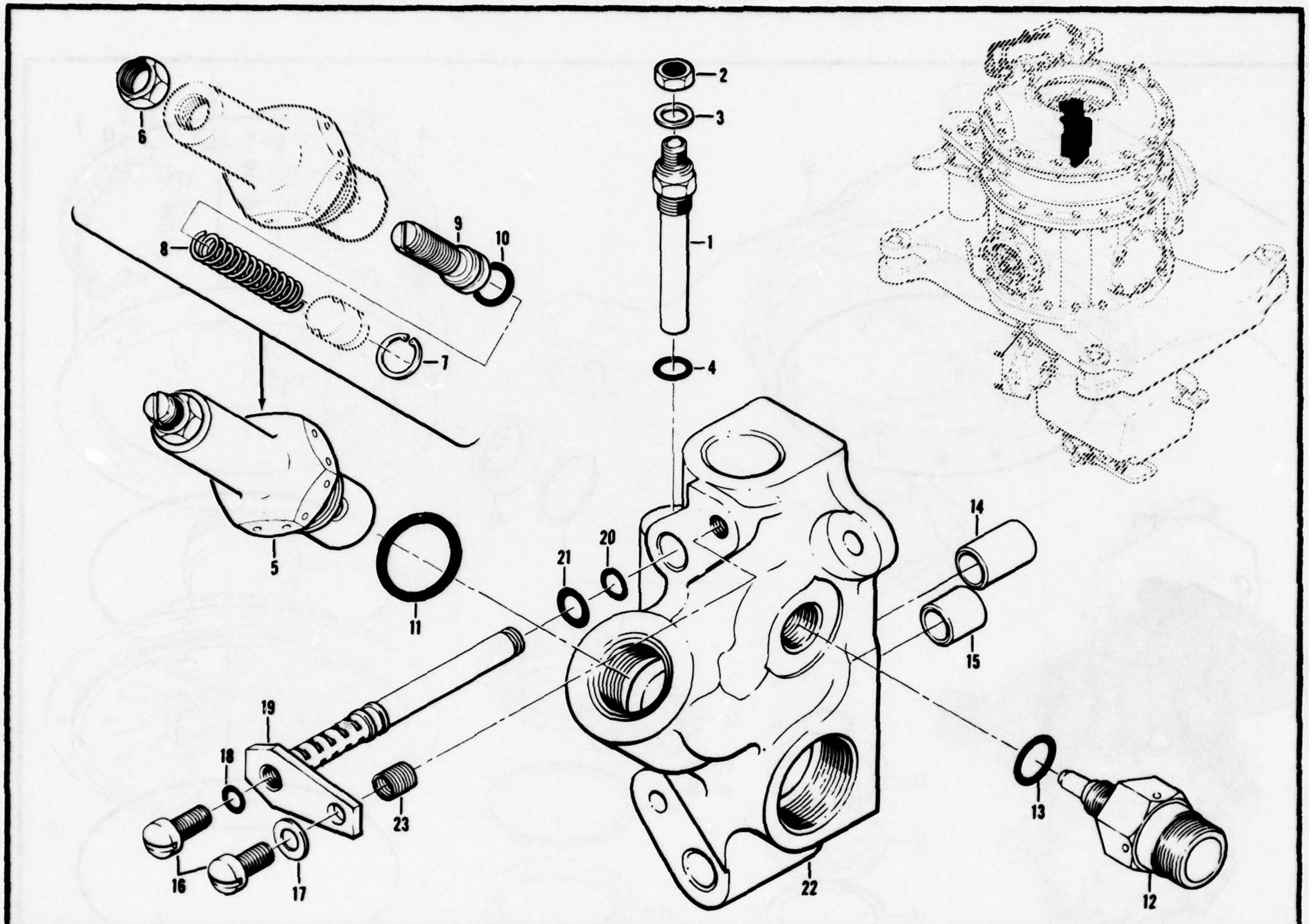


Figure 7. Manifold assembly.

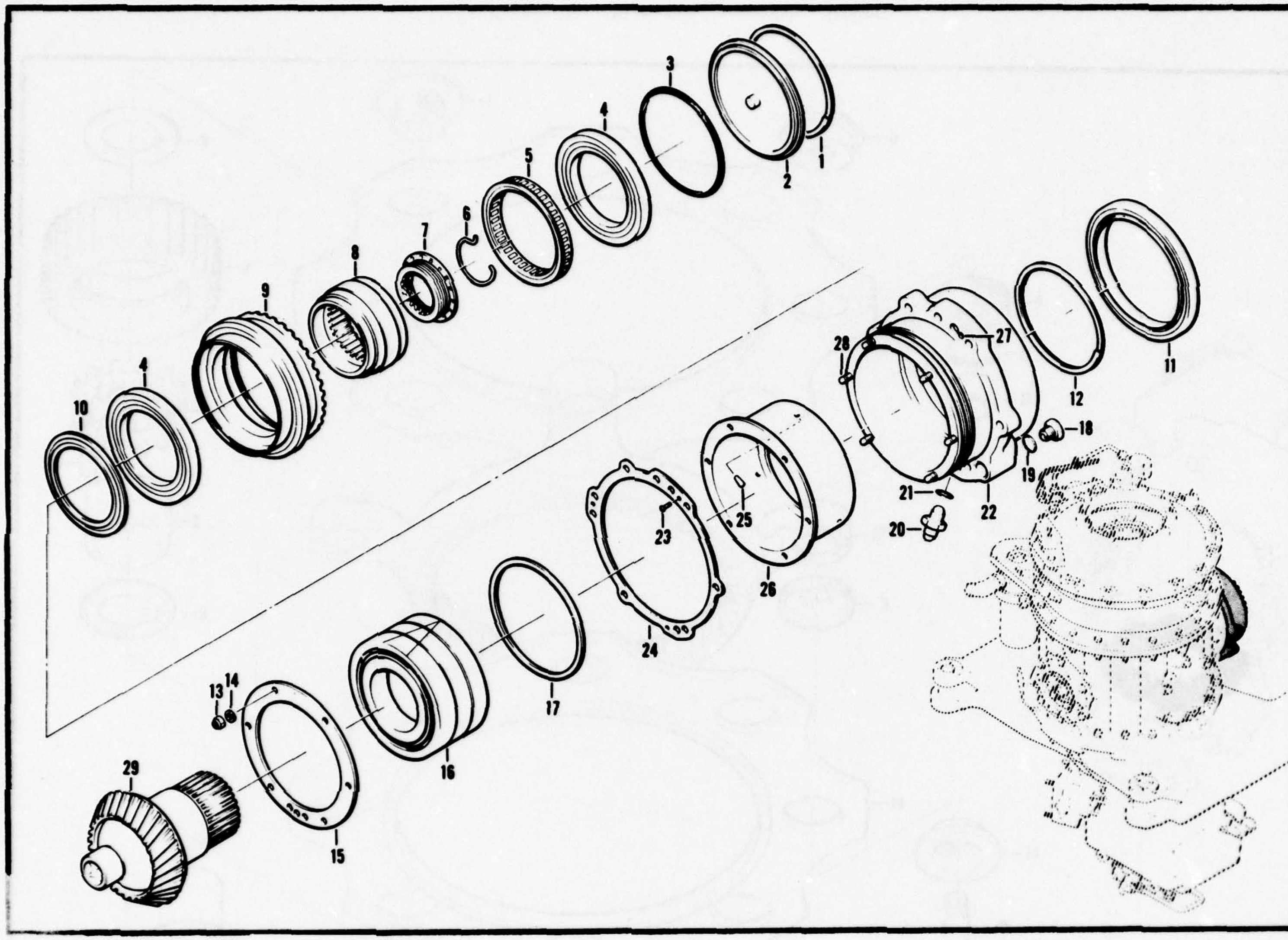


Figure 8. Quill assembly, main input.

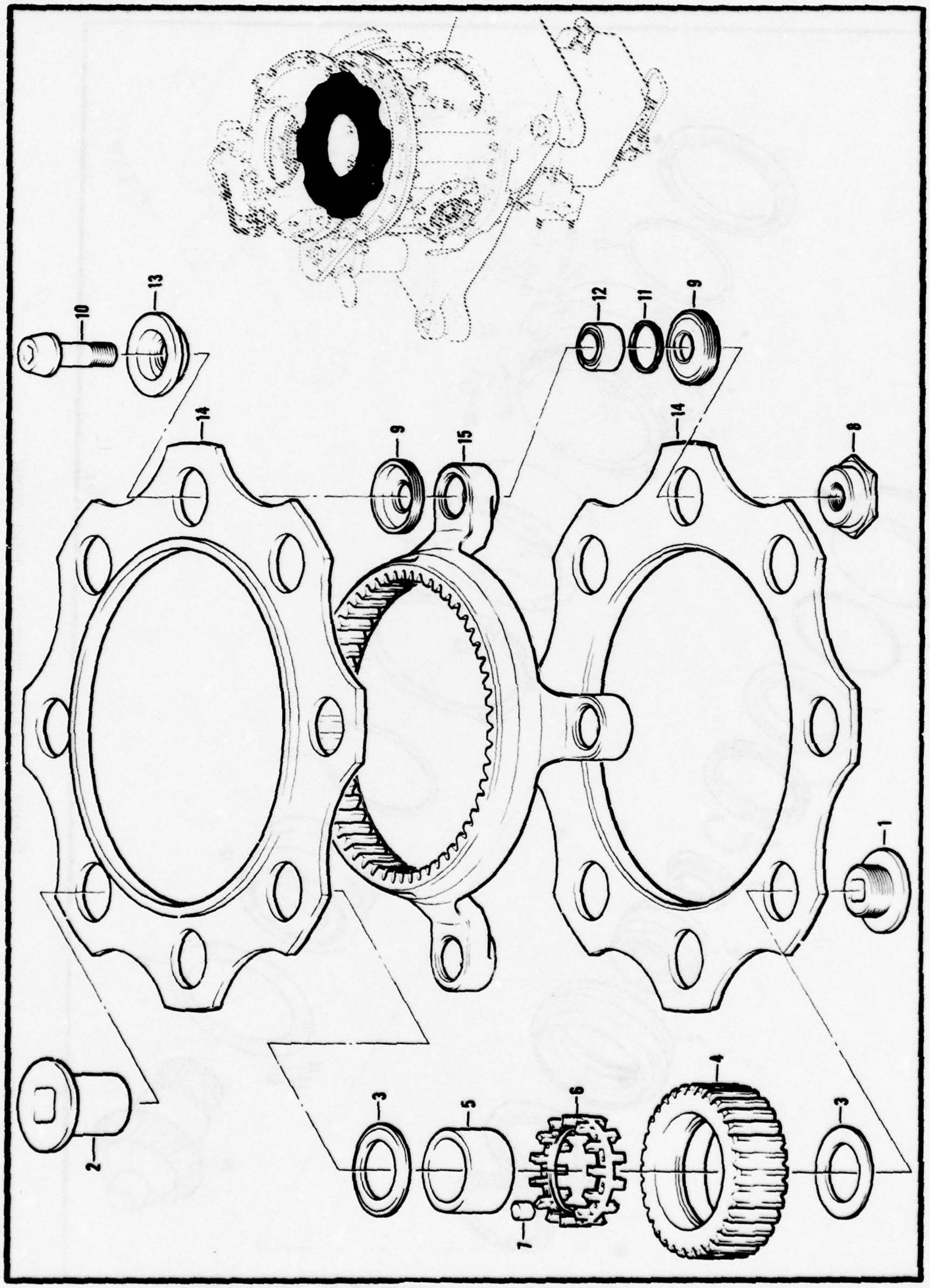


Figure 9. Planetary assembly, lower.

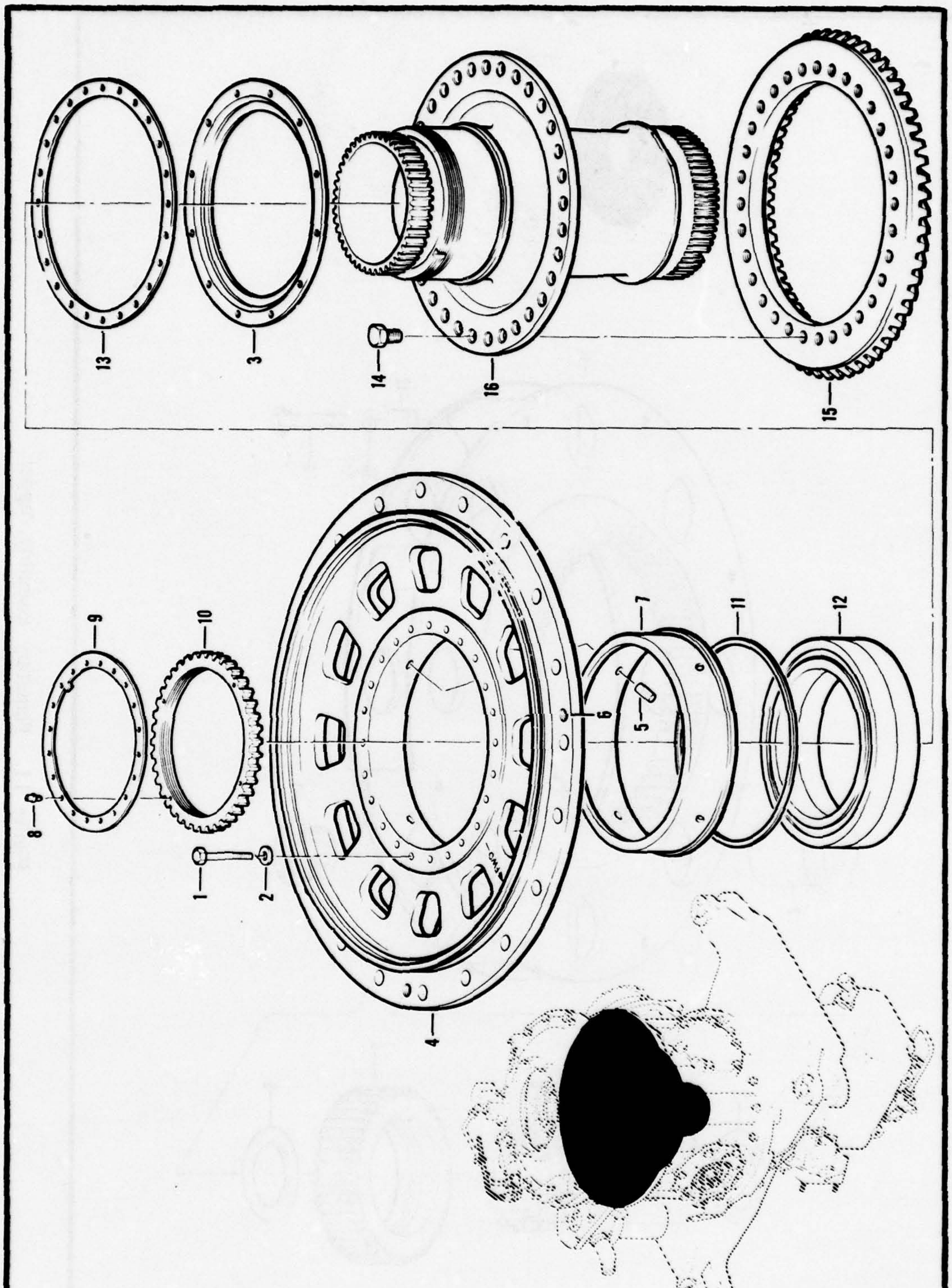


Figure 10. Quill assembly, main drive.

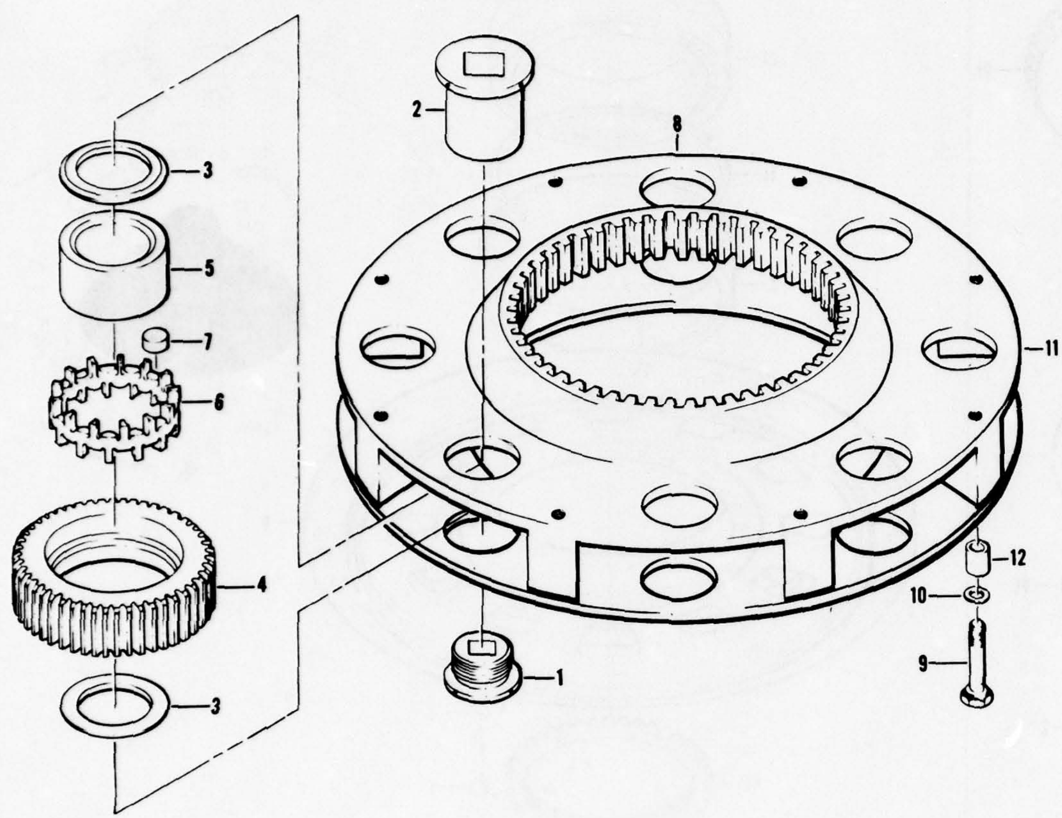


Figure 11. Planetary assembly, upper.

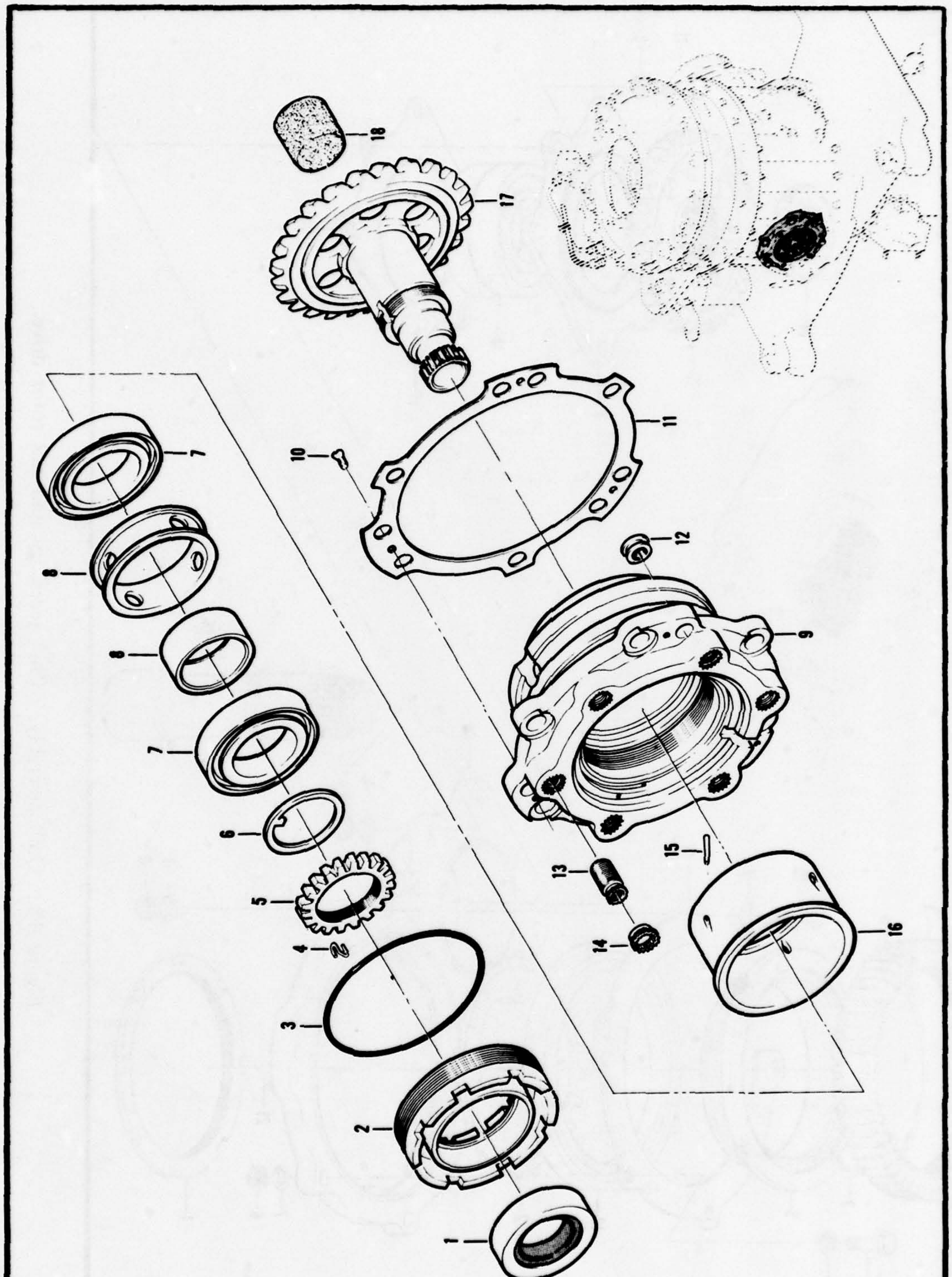


Figure 12. Quill assembly, fan drive.

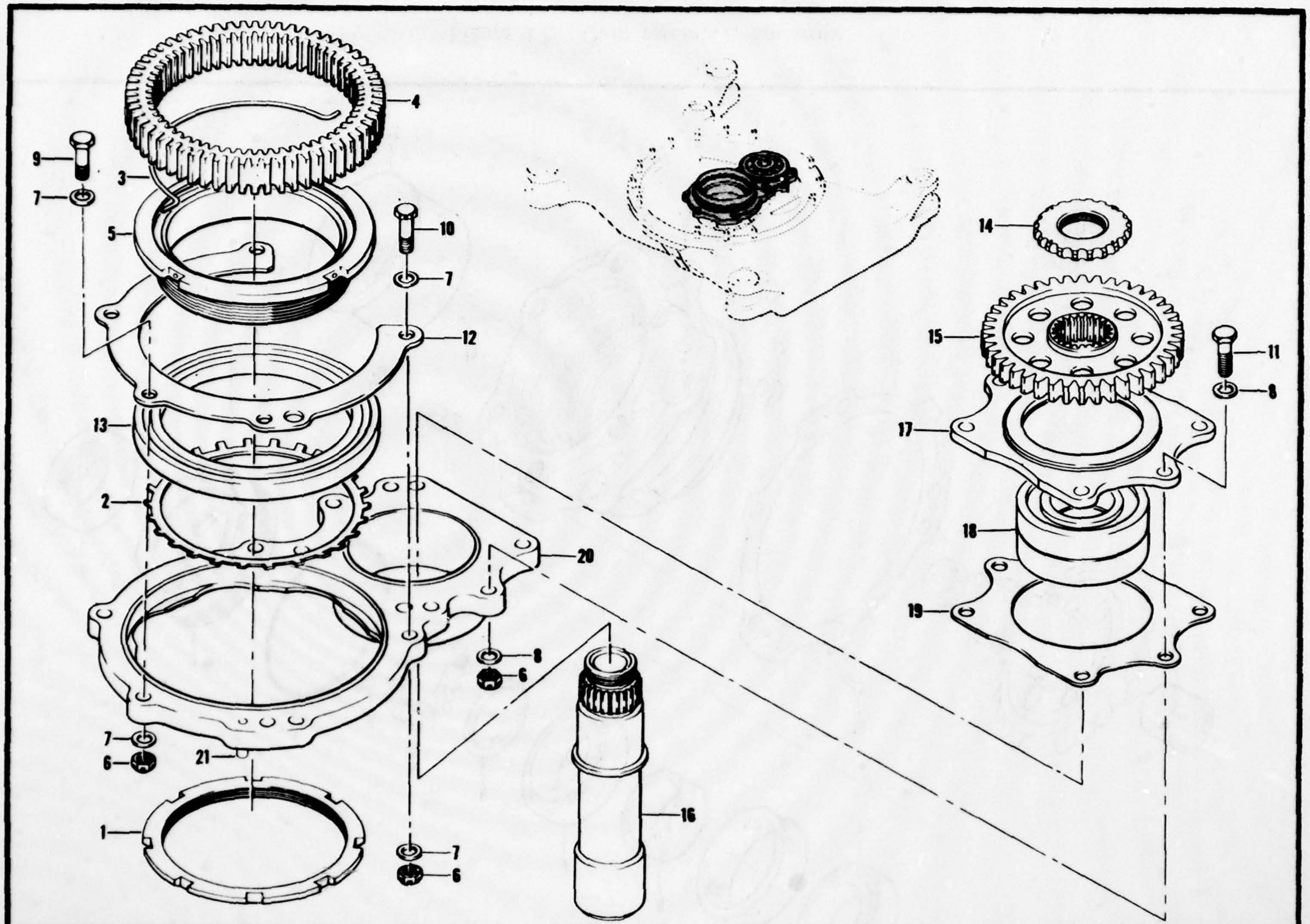


Figure 13. Quill assembly, offset accessory and tail rotor drive.

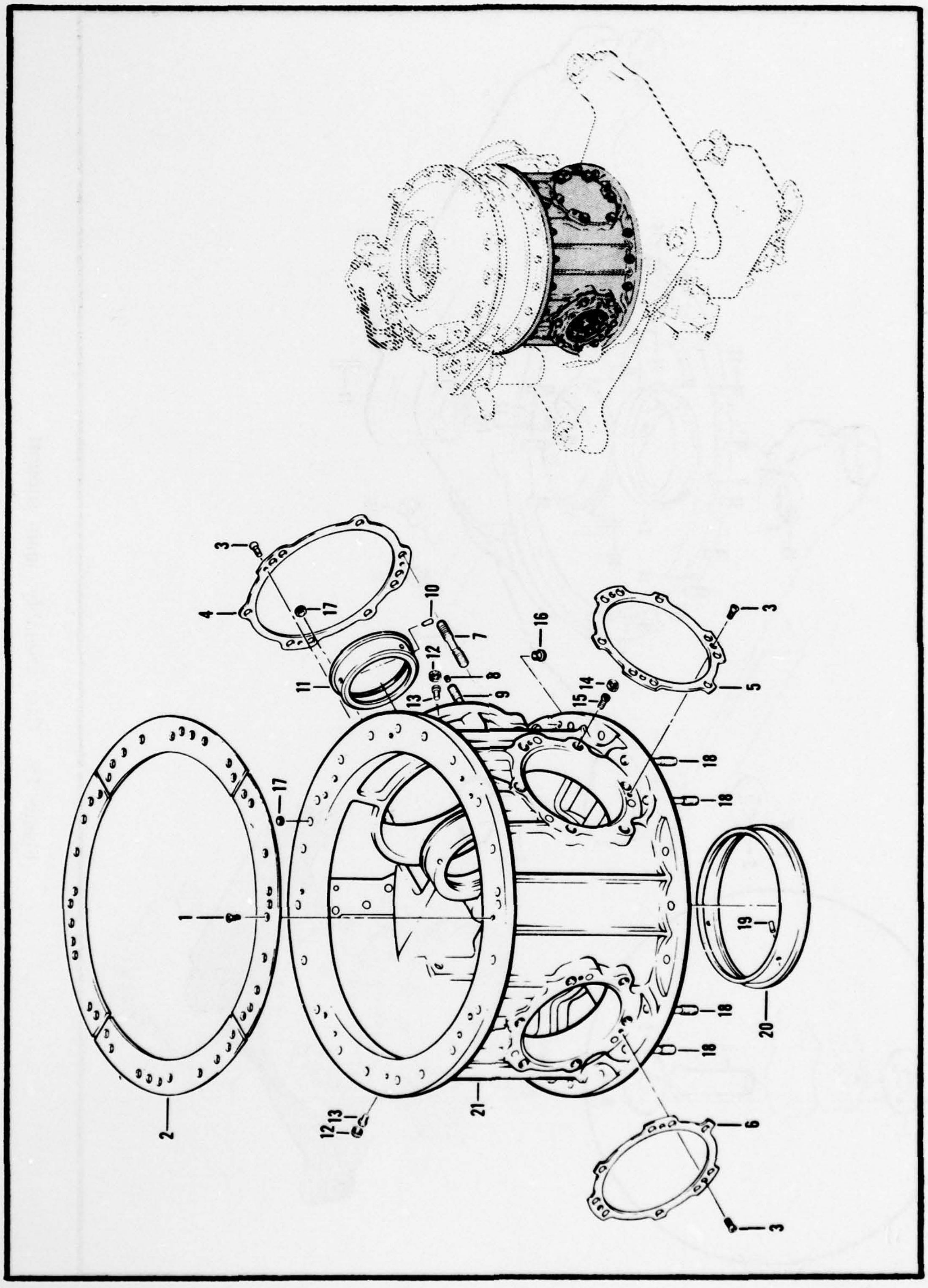


Figure 14. Case assembly, main.

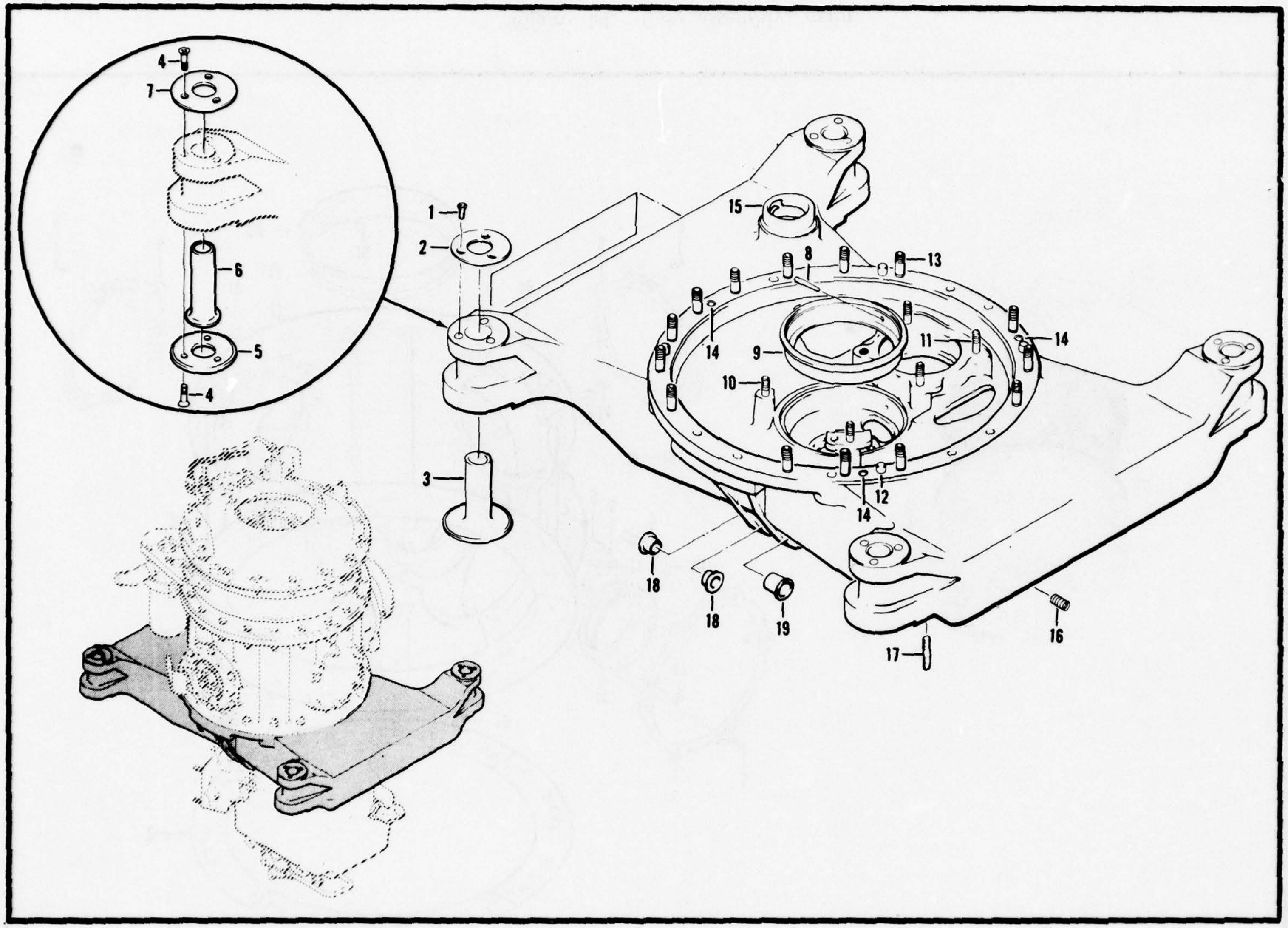


Figure 15. Case assembly, main support.

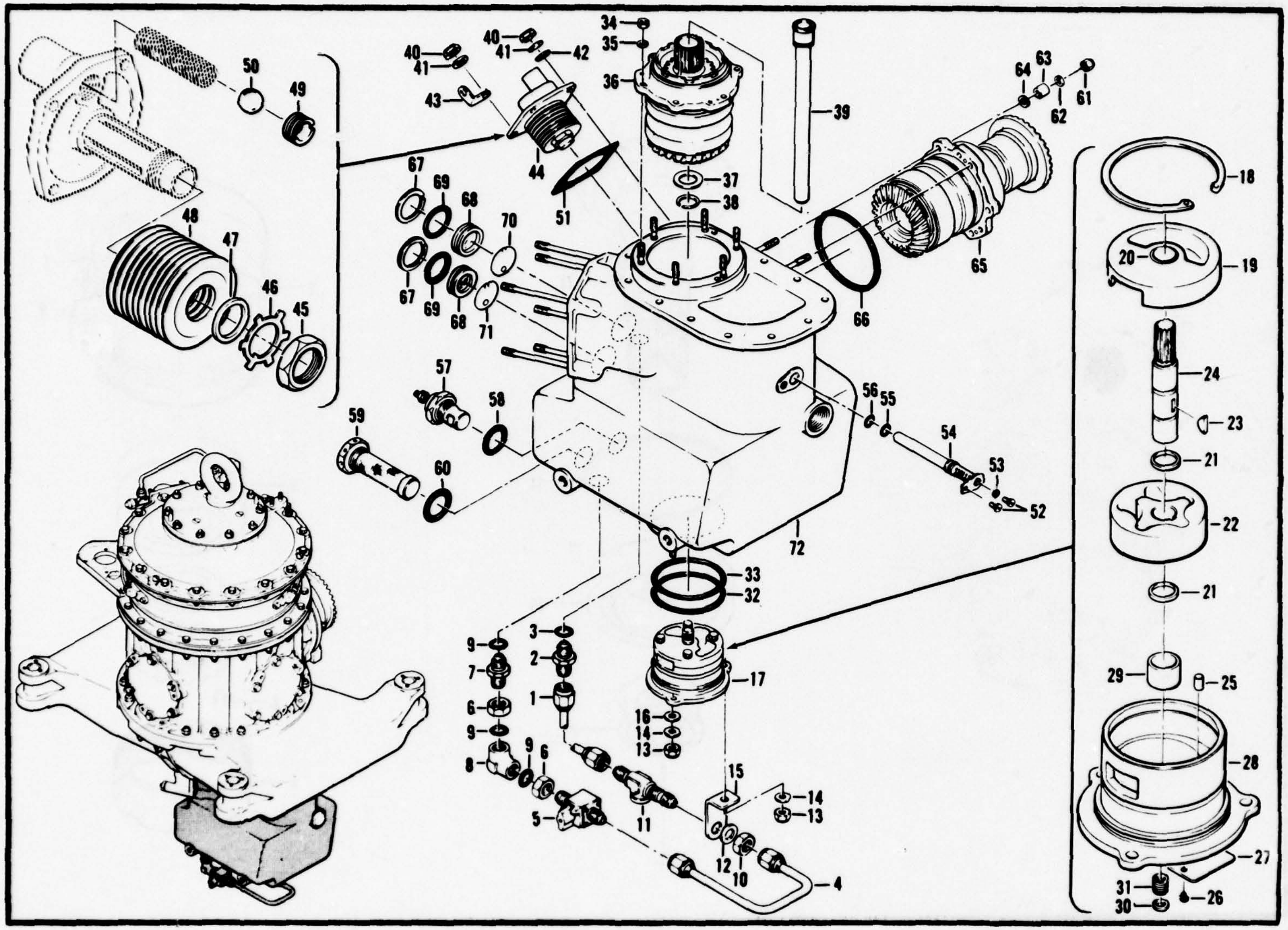


Figure 16. Drive and sump assembly.

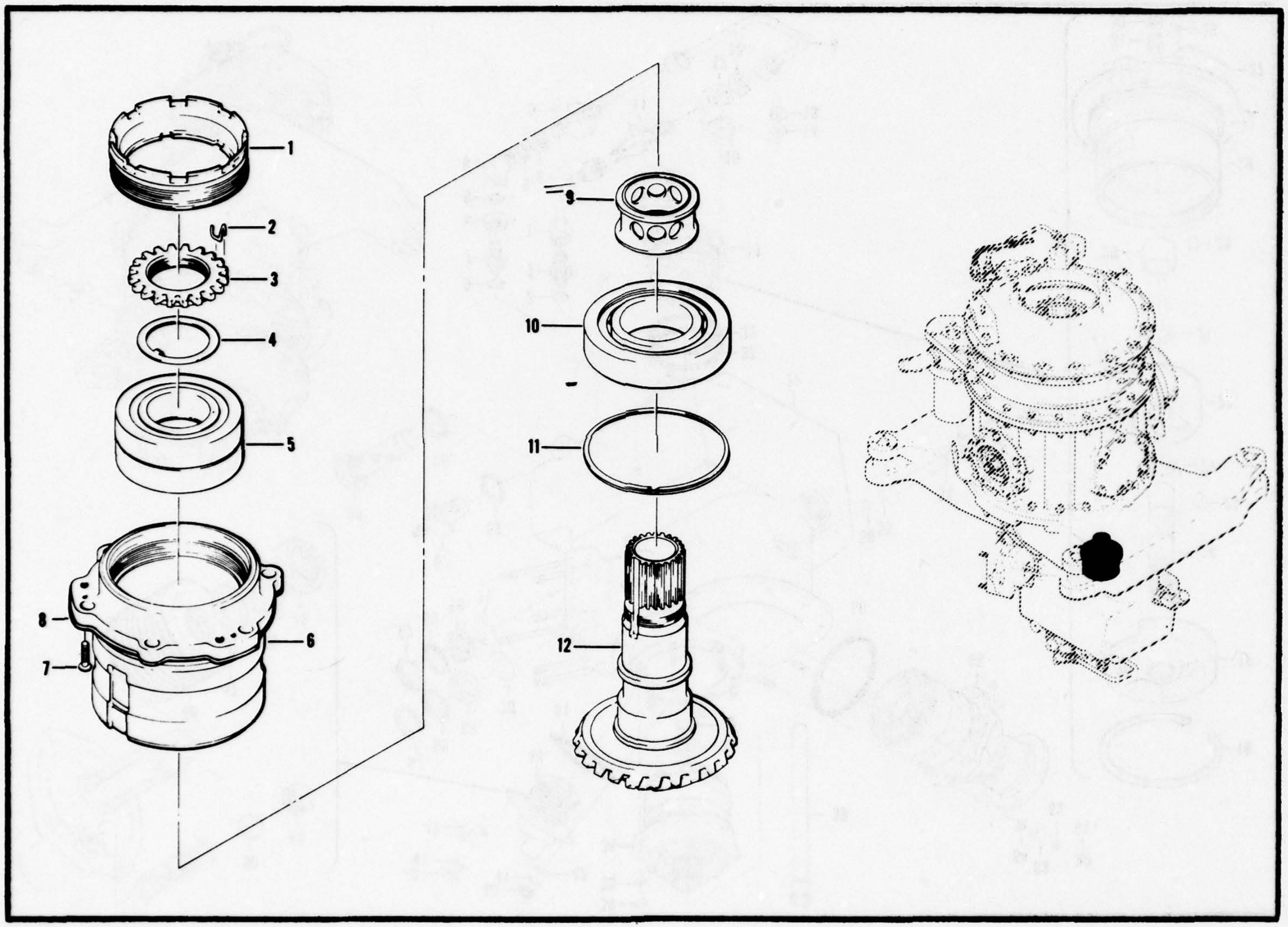


Figure 17. Quill assembly, accessory and tail rotor drive.

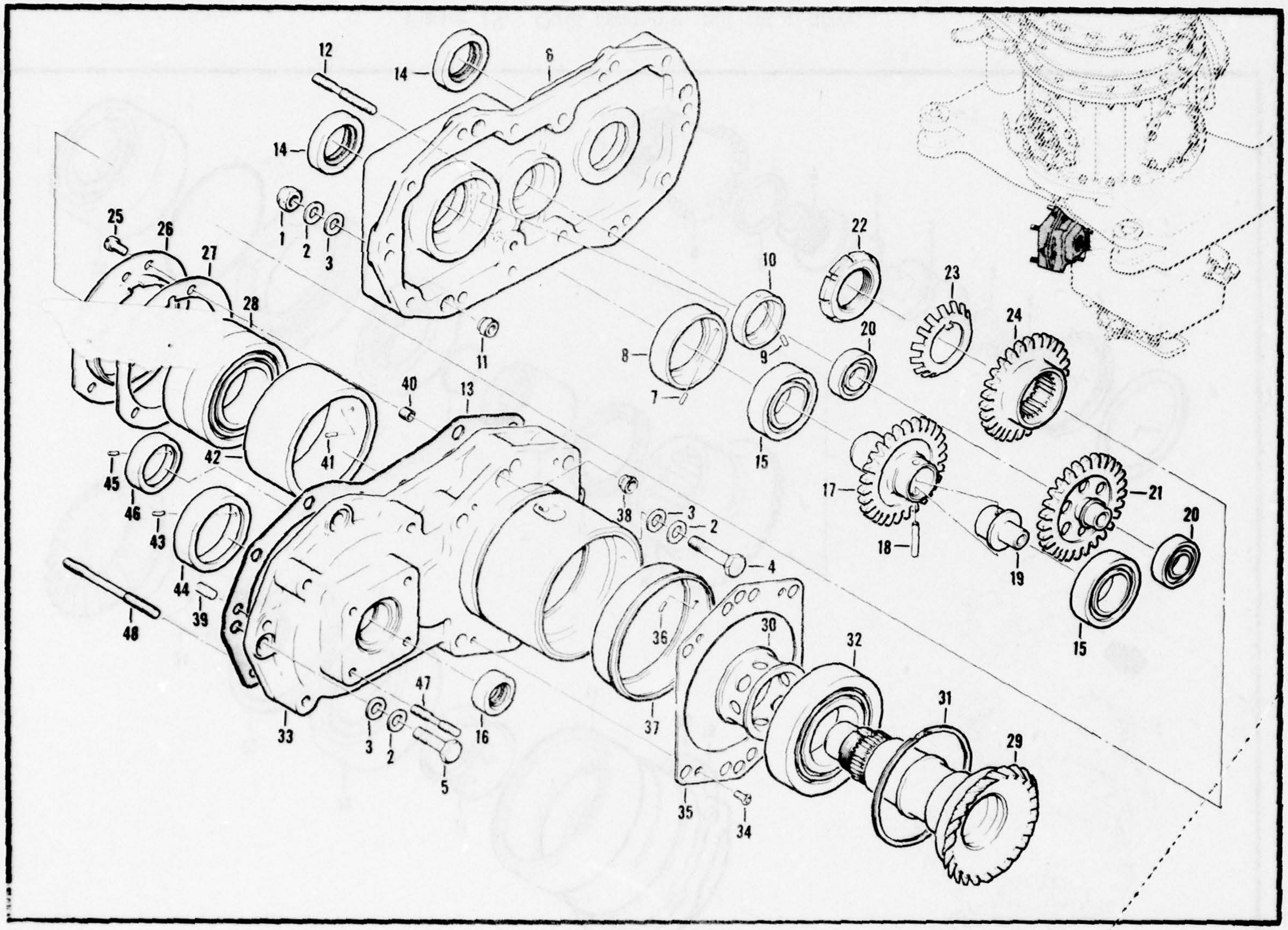


Figure 18. Quill assembly, dual hydraulic pump and tachometer drive.

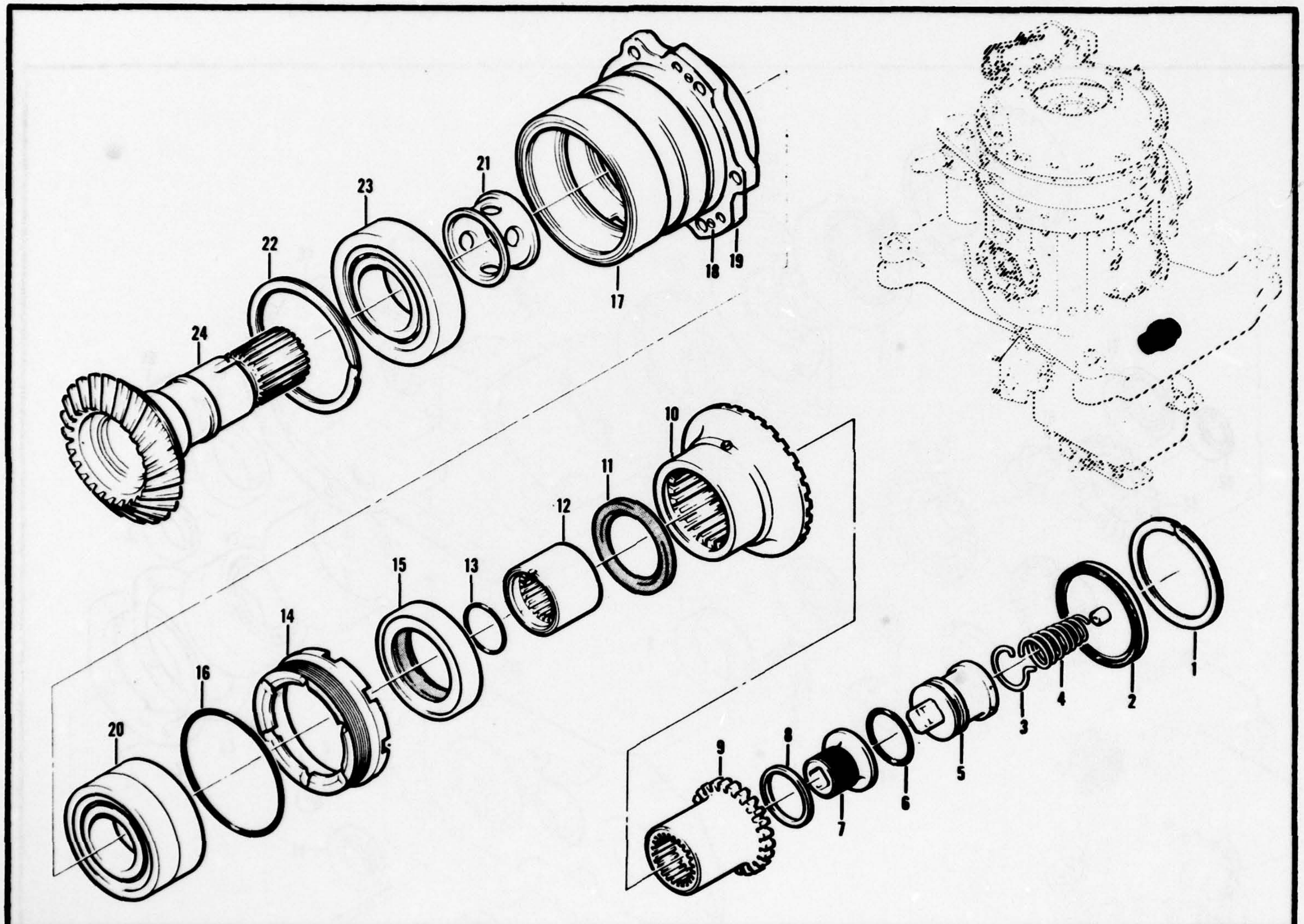


Figure 19. Quill assembly, tail rotor drive.

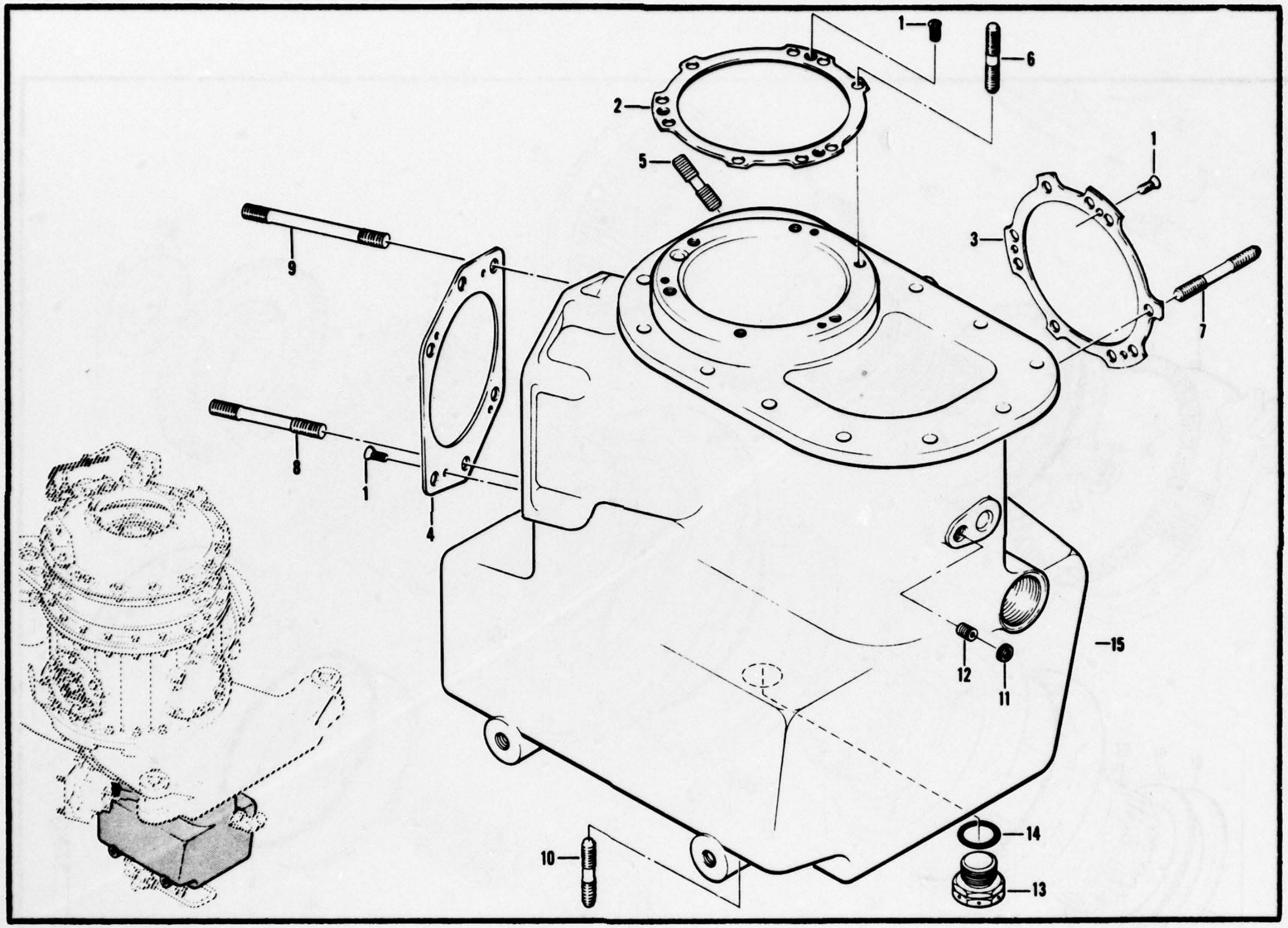


Figure 20. Case assembly, accessory and tail rotor drive.

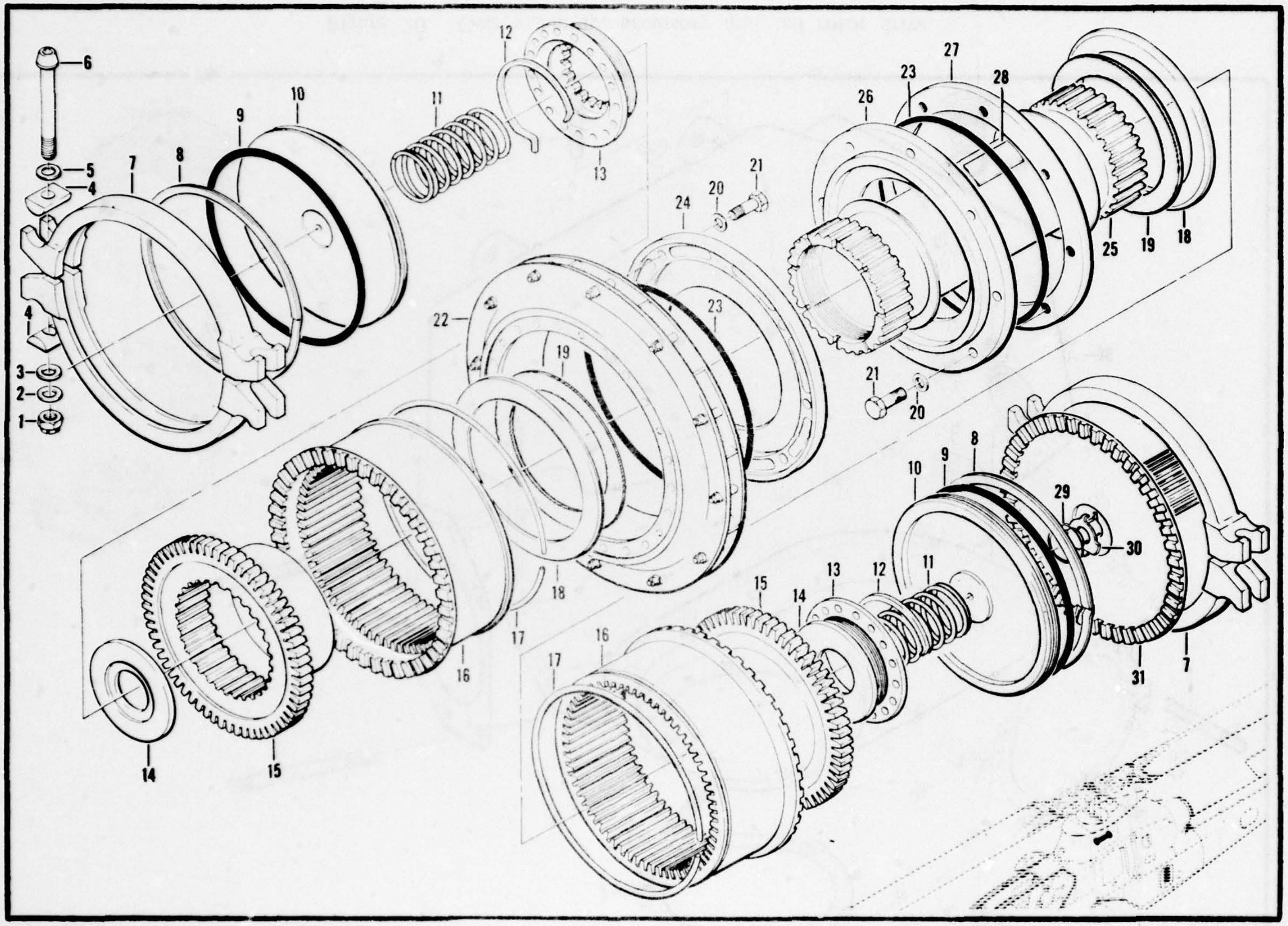


Figure 21. Drive shaft installation.

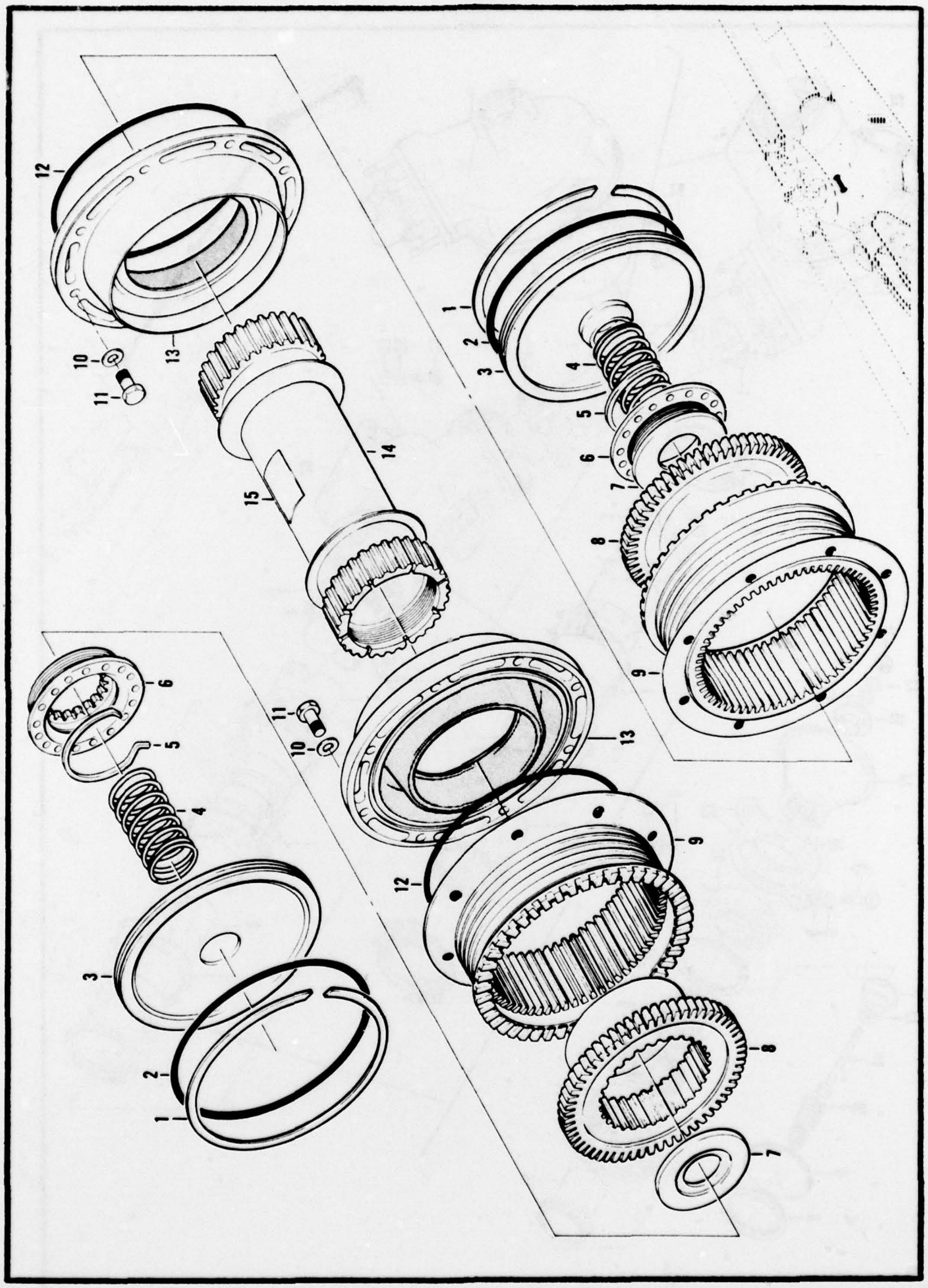


Figure 22. Drive shaft assembly.

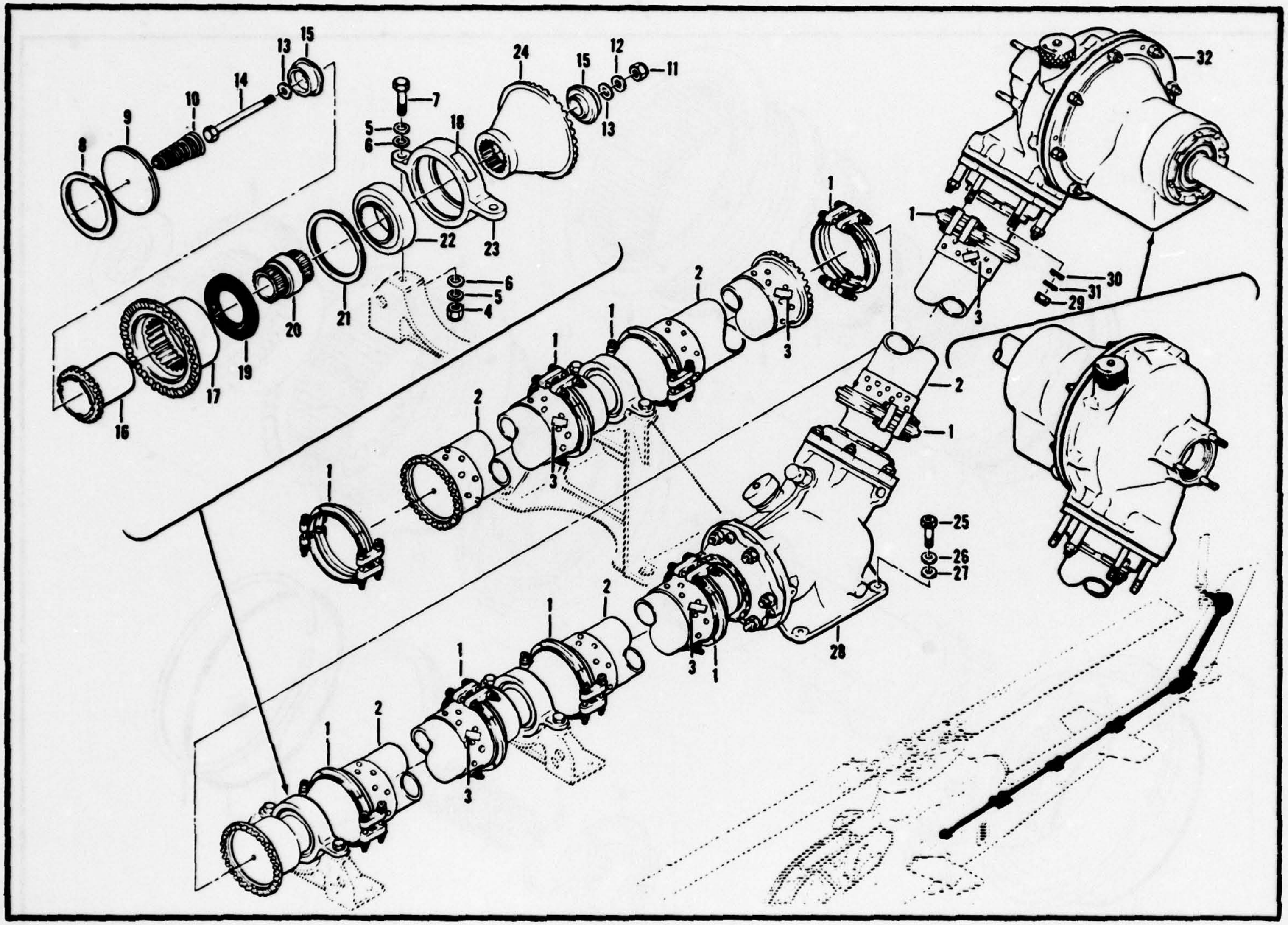


Figure 23. Drive shaft installation, tail rotor.

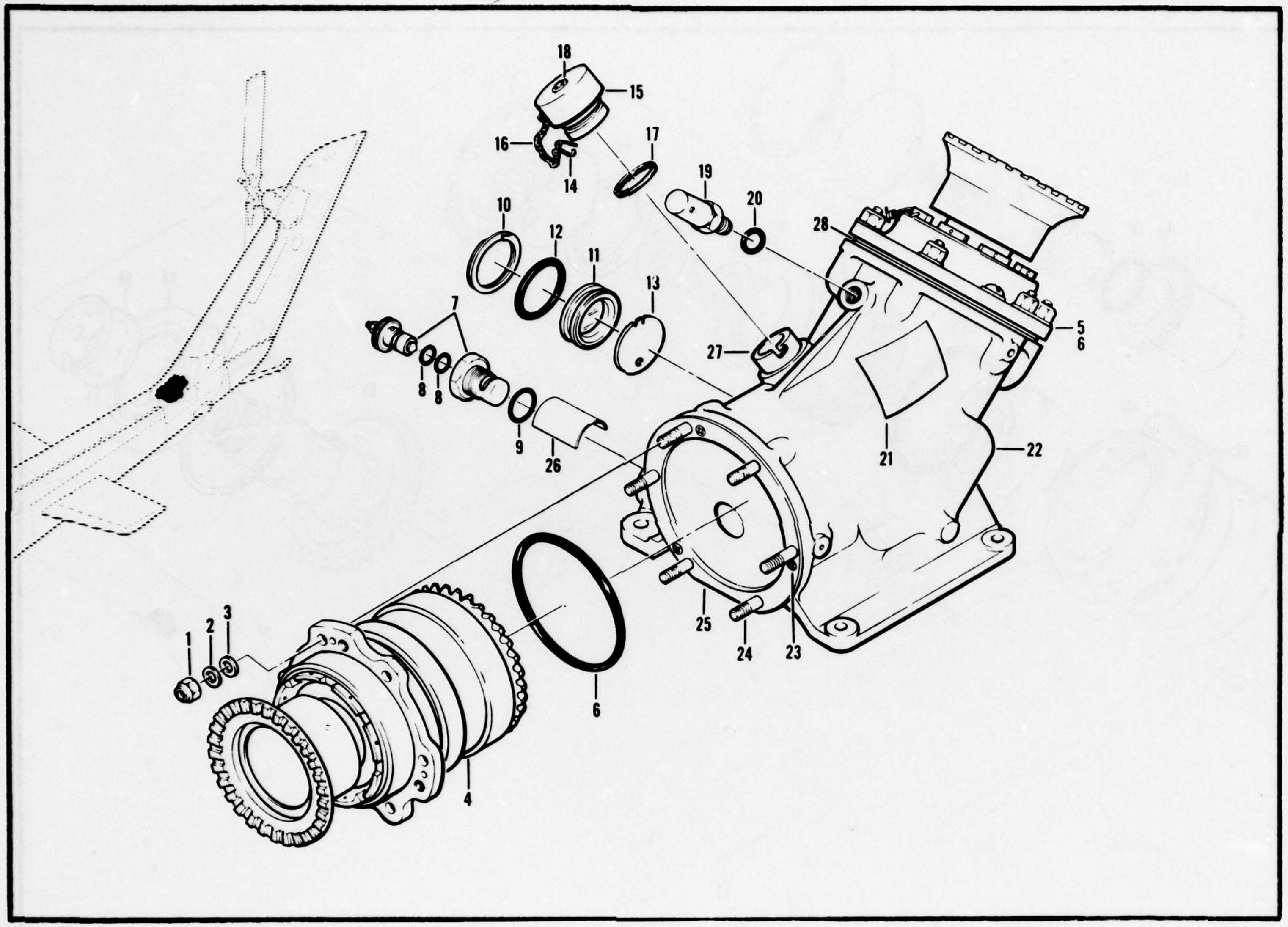


Figure 24. Gearbox assembly.

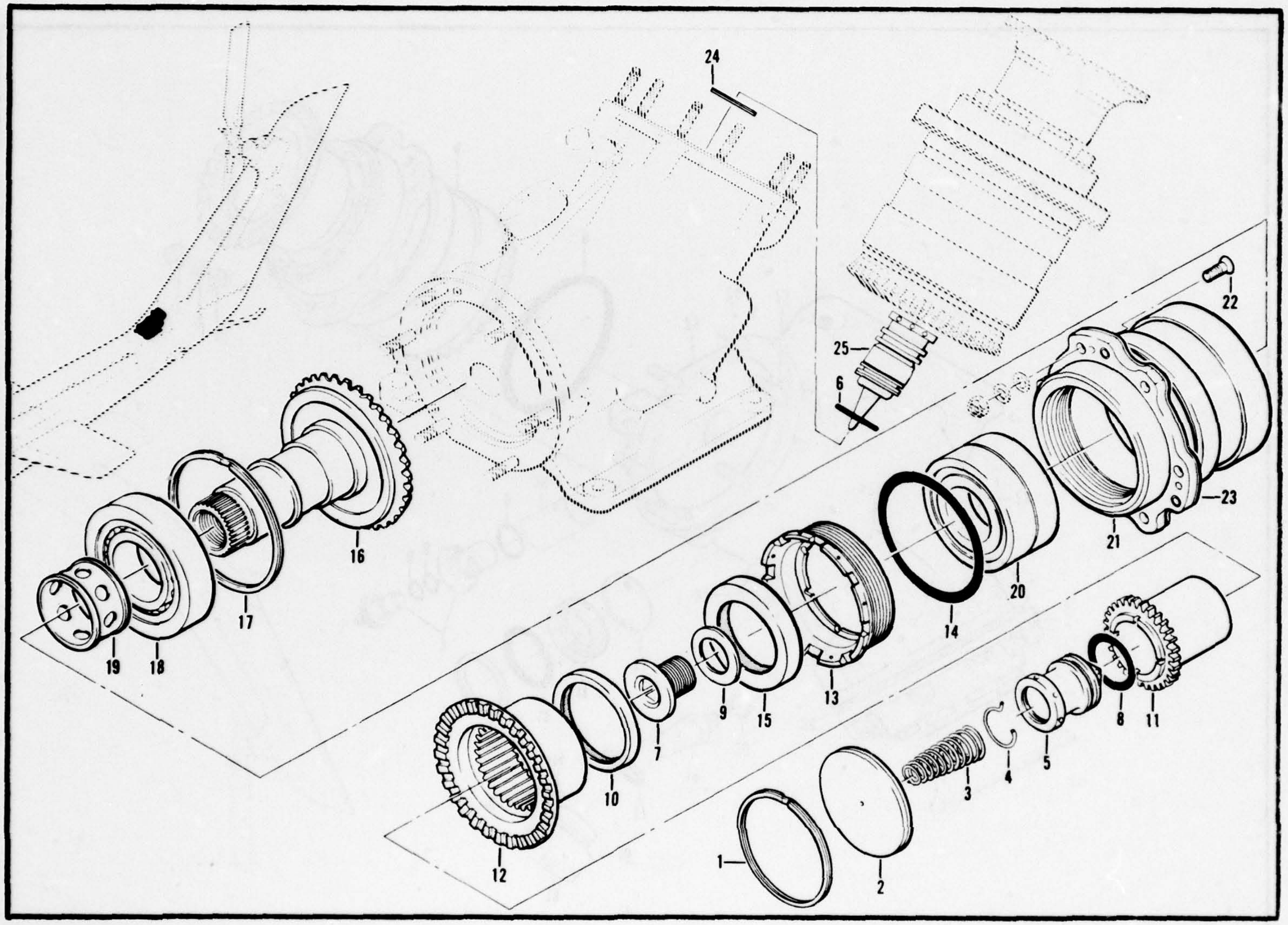


Figure 25. Quill assembly.

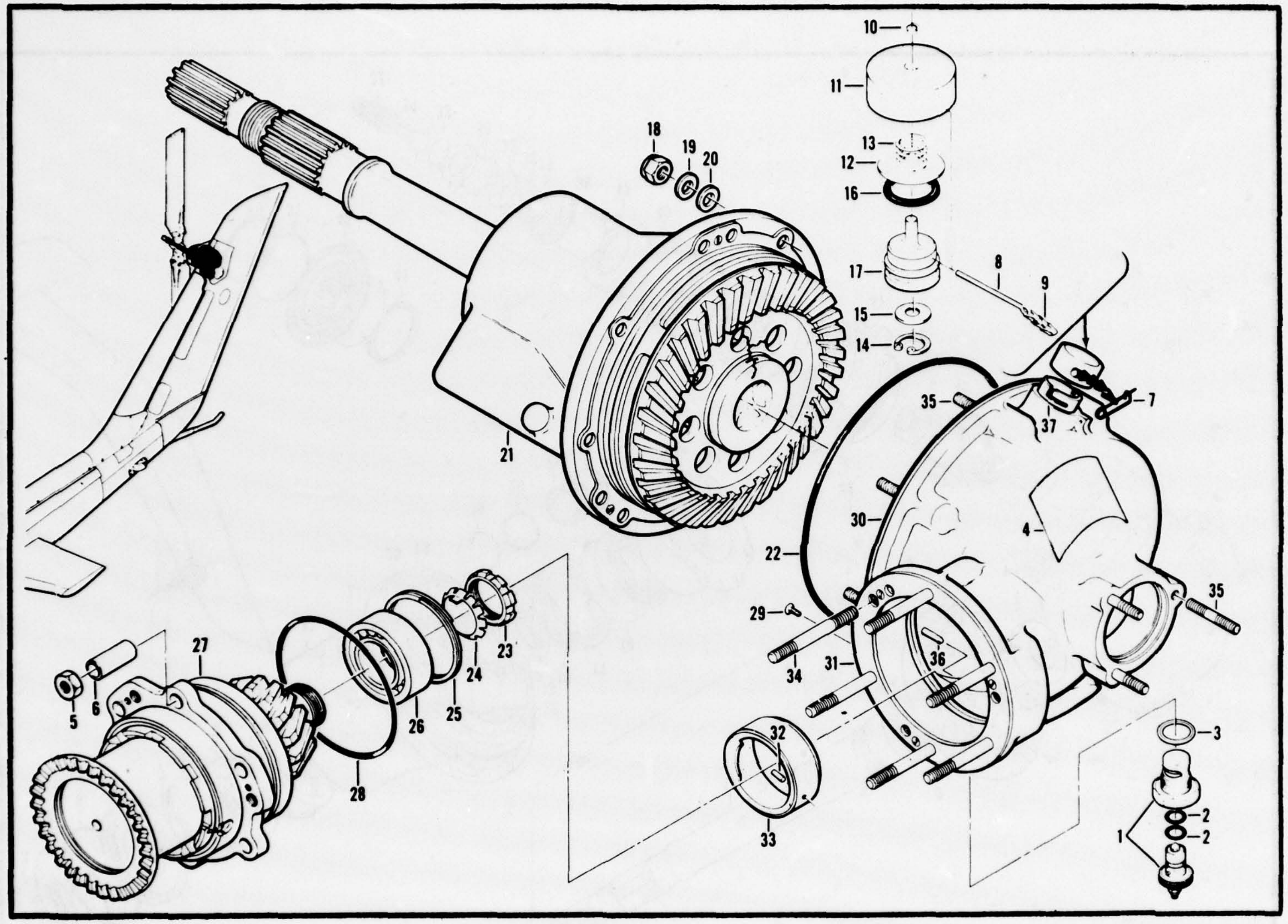


Figure 26. Gearbox assembly, tail rotor drive.

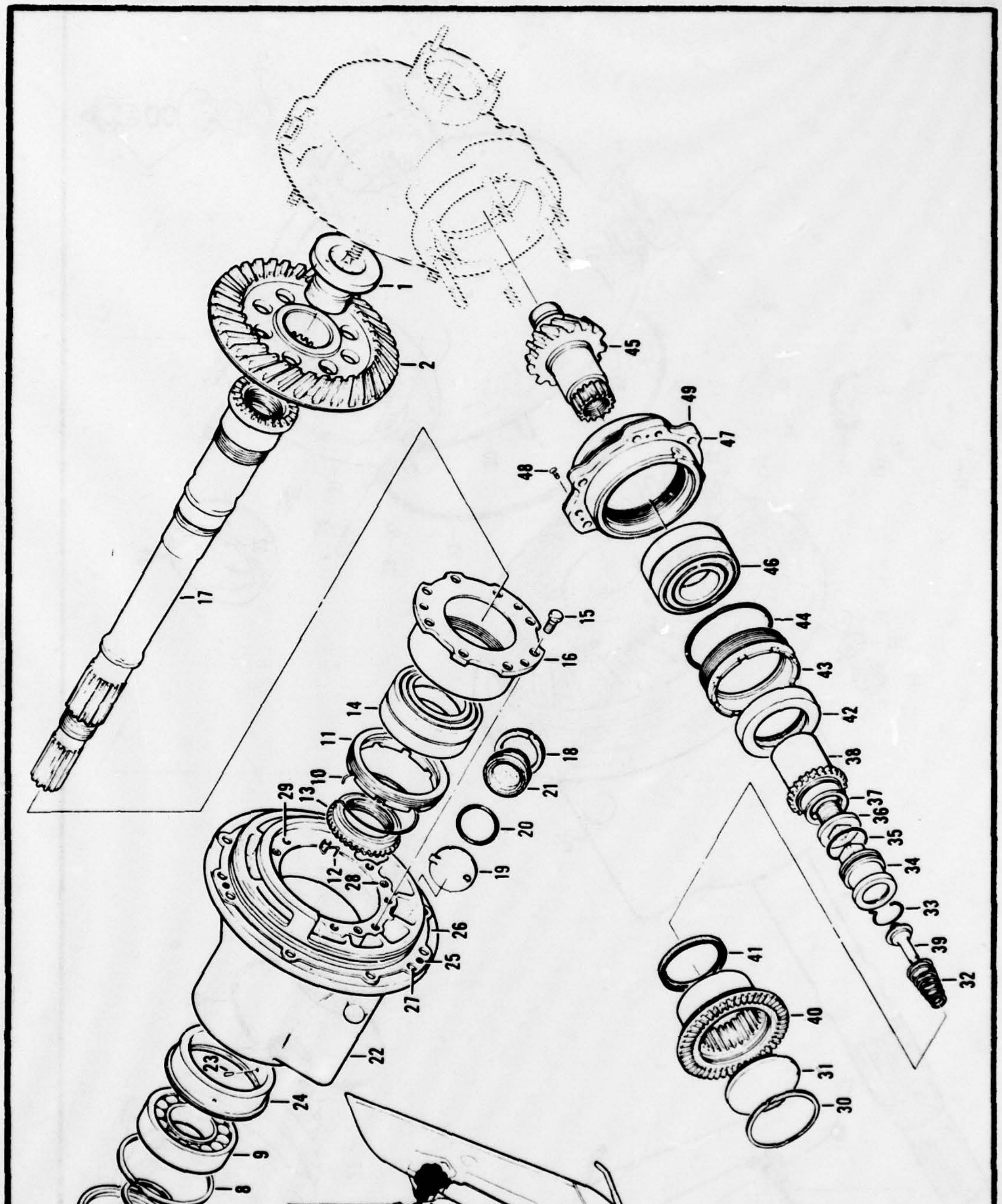


Figure 27. Quill assembly, gearbox.

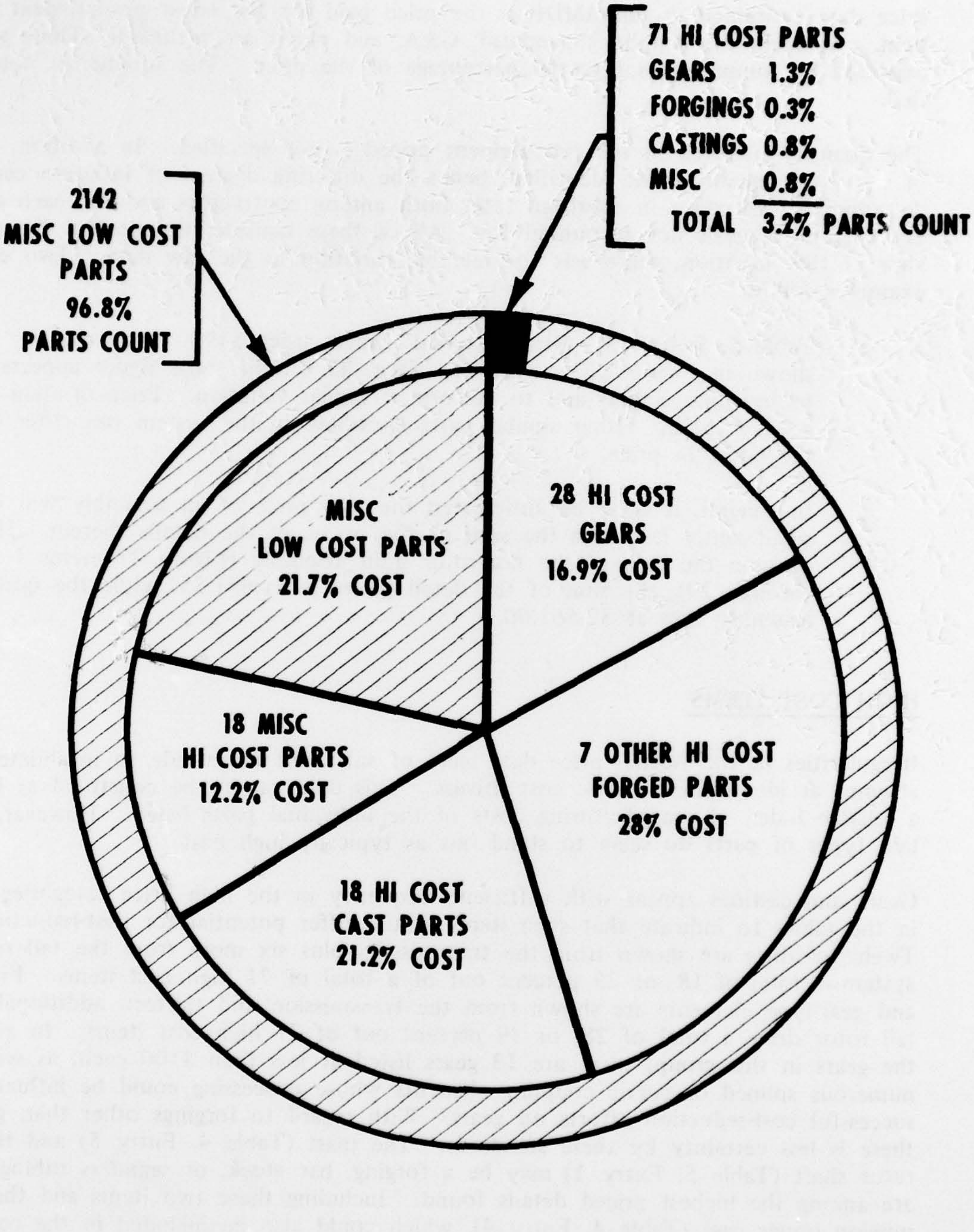


Figure 28. Transmission and tail rotor drive price and quantity breakdown.

VALIDITY OF PRICE DATA

Price data contained in the AMDF is the price paid for the latest procurement of each item. As such, the supplier's overhead, G&A, and profit are included. These may be expected to comprise a substantial percentage of the price. The supplier is not identified.

The quantity involved in the procurement priced is not specified. In addition, the date of the procurement is not identified; hence the differing degrees of inflation cannot be determined. Variation in overhead rates both among contractors and for each contractor at different times is not accounted for. All of these considerations affect the price. In view of this situation, there was considerable variation in the raw data. Two extreme examples follow:

1. Table 5, Entry 15 - Ring, external thread, price $193. This ring is shown in Figure 27 as item 11. Item 43 on the same figure appears to be quite similar and to perform a similar function. Price of item 43 is $15.32. Other similar parts elsewhere in the system run close to the latter in price.

2. In general, it is to be anticipated that the price of an assembly will be significantly less than the sum of the prices of the details therein. However, in the case of the tail rotor quill assembly (Figure 27, items 1 through 29), the sum of the detail prices is $1,651.55, while the quill assembly lists at $2,561.00.

HIGH COST ITEMS

Irregularities in the AMDF price data were of sufficient magnitude to invalidate any attempt at identifying specific cost drivers. This data cannot be construed as being a reliable index of manufacturing costs of the individual parts listed. However, certain types of parts do seem to stand out as typically high cost.

Gears and castings appear with sufficient frequency in the high price categories shown in the tables to indicate that such items should offer potential for cost-reduction efforts. Twelve castings are shown from the transmission plus six more from the tail rotor drive system--a total of 18, or 25 percent out of a total of 71 high cost items. Fifteen gears and gear-type elements are shown from the transmission and thirteen additional from the tail rotor drive--a total of 28, or 39 percent out of 71 high cost items. In addition to the gears in this group, there are 13 gears listed at less than $100 each, as well as numerous splined or curvic coupling elements whose processing could be influenced by successful cost-reduction efforts on gears. With regard to forgings other than gears, there is less certainty by these standards. The mast (Table 4, Entry 5) and the tail rotor shaft (Table 5, Entry 1) may be a forging, bar stock, or seamless tubing. Both are among the highest priced details found. Including these two items and the transmission upper case (Table 4, Entry 4), which could also be included in the count of gears, six high cost forgings are found in the transmission and one in the tail rotor drive system. All of these are among the highest priced items. These three types of parts--gears, castings, and forgings--should provide appropriate areas for cost-reduction efforts.

COST REDUCTION

It is highly probable that cost-reduction work in the areas of gears, castings, and forgings would significantly benefit costs of new designs, not only for helicopter transmissions and drive trains but for many other products as well. Means by which cost may be reducible include the following:

GEARS

1. Precision forging.
2. Powder metallurgy, including development of higher yield, lower cost powder production methods.
3. New alloys for improved operating temperature range and life.
4. Less costly heat treat and surface hardening methods such as laser or electron beam.
5. Integrated Computer Aided Manufacturing Methods (ICAM). This concept is appropriate to the manufacture of gear-type elements and is suited to short runs on wide varieties of similarly shaped parts, as well as to mass production of identical parts. Variations in processing to suit a variety of operations and sequencing can be programmed depending on the system provided, thus automatically accommodating parts of different design. Profitable application will require some specific level of utilization in terms of hours in use/hours available and will probably be most beneficial where aircraft gears are not the sole purpose of the gear line.

CASTINGS

1. Application of fiber-plastic composites to replace some of the small castings such as the gear support sleeves (of which there are several in this design) and items 6 and 33 in Figure 18, as well as the gearboxes in Figures 24 and 26. Ambient temperatures and heat rejection considerations, as well as loading, must influence the choice of materials in all cases.
2. Application of precision casting to nearer net shape of parts now sand-cast to reduce required machining time.
3. Integration of certain cast components; e.g., gear support sleeves with major castings. Assembly and servicing accessibility to gears, bearings, and seals must be considered.

FORGINGS

1. Entry 3, Table 4, Shaft (Planetary, Flanged). The transmission drive quill forging drawing indicates a hollow shaft with the full flange integral at midlength. There is a possibility of simplifying the forging and decreasing required machining by using tubing upset at the appropriate location to form a stub flange and attaching the body of the flange by welding, forging only one end of the shaft integral with the flange and inertia welding the longer end tubing in place.

2. Entry 4, Table 4, Transmission Upper Case. The case includes two integral ring gears for the two planetary stages. Possible application of one of the precision ring rolling processes to form the blank for such parts should be considered.

3. Entry 5, Table 4, Shaft (Mast). The use of tubing should be considered for parts of this nature if adequate properties can be obtained. It is not entirely clear that this is not already the case on this part.

4. Entry 6, Table 4, Lower Planetary Spider. Some cost benefit may be realized from precision forging to nearer net shape or, if allowable stress-wise, from casting, precision, or some other method.

5. Entry 7, Table 4, Spider and Web Assembly (Upper). The web is forged with spacer bosses integral. Were bosses separately precision cast, the forging would be considerably simplified. Both surfaces of the plate could be turned. Machining on the cast spacers would be confined to facing, drilling, and reaming for bolts and pins. Such a combination should provide savings. It is believed improbable that the necessary torsional stability of the assembly would not be attainable.

6. Entry 1, Table 5, Tail Rotor Shaft. No specific suggestions are made for this part. Details of processing the raw stock are not known, nor is it certain that individual forgings rather than bar stock are used. Savings might result from precision forging, thus reducing machining costs; but turning, which would be reduced, is a relatively cheap means of removing material. Gun drilling the bore is probably fairly costly. Although the shaft is tapered, the use of heavy wall tubing might give some reduction in cost. Powder metallurgy may also provide relief. Required physical properties may not permit the use of other than forged material.

CONCLUSIONS

Based on the results of the cost analysis, it is concluded that:

1. It is impossible to develop a valid detailed cost analysis of helicopter drive systems from the in-house data base employed, as there is no way to isolate manufacturing costs nor to reduce the price data available to a common base.

2. Irregularities in the basic data employed in this study made it impossible to identify individual cost drivers.

3. Castings, gears, and forgings other than gears are the typical cost drivers in the acquisition of transmission and tail rotor drives. The frequencies with which these types of parts occur among high cost items validate this finding.

4. Cost-reduction efforts are warranted in the areas of gears, castings, and forgings.

RECOMMENDATIONS

Based on the preceding conclusions drawn as a result of the cost analysis, it is recommended that:

1. Helicopter airframe contractors and their suppliers of gears, castings, and forgings be encouraged to review their designs and manufacturing methods, and to estimate costs involved in alternative design and manufacturing approaches such as those identified in this report.

2. Gear manufacturers be surveyed to evaluate their present situations and plans with respect to ICAM and to provide a firm basis for decisions relative to Army-furnished financial support for its introduction or expansion in the manufacture of helicopter gears.

3. Future cost analyses on drive system components be conducted using an approach permitting the isolation of manufacturing costs at a known point in time. This strongly implies that such efforts be executed by prime contractors.

4. Additional cost analyses of helicopter transmission drive train systems be conducted to determine specific cost drivers and recommended cost-reduction programs, and to establish baselines for estimating costs of future designs.