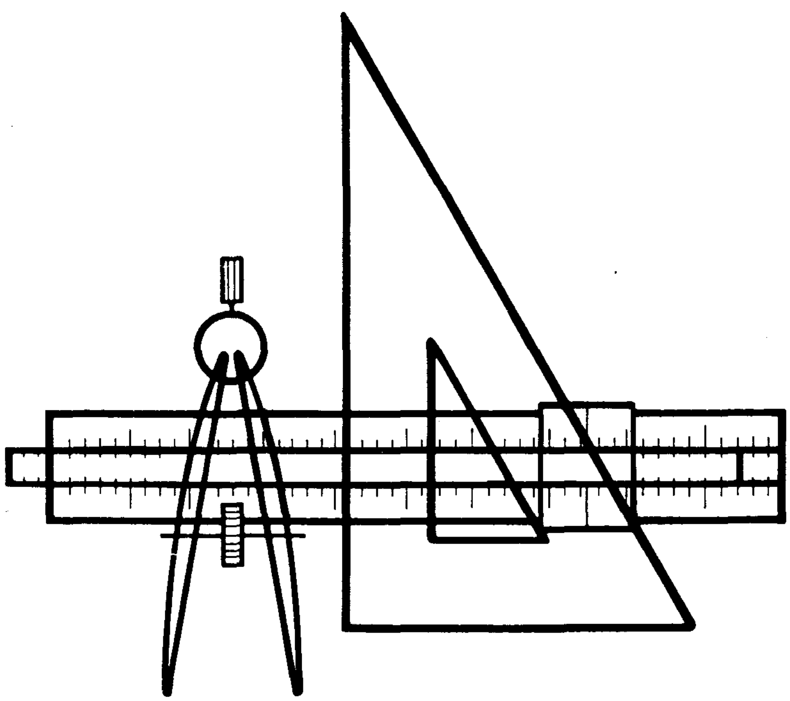
Bulletin 9565
Rev. F
October, 1976

HEAVY DUTY TRANSMISSIONS

WORLD'S MOST COMPLETE FAMILY OF HYDROSTATIC TRANSMISSIONS & CONTROL SYSTEMS



Sundstrand Hydro-Transmission
AMES, IOWA 50010
unit of Sundstrand Corporation

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I. INTRODUCTION

Hydraulic propulsion has been receiving increasing attention from the agricultural and construction equipment fields in the past several years. This sudden interest might lead one to believe it is a new development. However, the first designs were begun in the early 1800's. Acceptance was slow at first due to several original design disadvantages. Among these were reliability, high cost, and prohibitive weight. As years passed, improvements in design and manufacturing procedures eliminated these original faults and then opened the way to allow hydraulic drives, with their advantages of precise speed and torque control to replace the brute force methods of yesteryear.

Sundstrand has developed a family of hydrostatic transmissions suitable for working vehicles in the Agricultural, Construction Machinery, and Material Handling markets. Thousands of operating hours in these areas on many applications have proven these transmissions to be rugged and reliable.

The versatility in hydrostatic transmissions makes them the most flexible and intriguing power transmission devices available to the modern engineer.

The information in this guide is designed for each reference and should enable you to pick the transmission best suited for your needs. To offer you additional assistance and advise based on our experience, we request the privilege of having one of our Sales Engineers assist you.

For further information, contact:

SUNDSTRAND HYDRO-TRANSMISSION
2800 East 13th Street
Ames, Iowa 50010
Attention: Marketing Department
PHONE: Area (515) 232-3370

OR

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Anchor Street
Lincoln, England
Phone: (0522) 29438
Telex: 56381

II. GENERAL INFORMATION

Greatly increased productivity and reliability are the key benefits that Sundstrand hydrostatic transmissions bring to Agricultural, Construction Machinery, Industrial and Material Handling Applications.

Simplicity. No clutch is required - no gear changing during operation. A single lever control provides infinitely variable forward and reverse speeds and dynamic braking. Rapid reversals of direction can be made without damage to the drive.

Operation is almost effortless. Response is immediate and positive. Even unskilled personnel can master operation in a very short time.

Maneuverability is greatly improved over conventional systems. Greatly increased loads can be moved from a standing start, and there is no surge or speed change when loads are suddenly released. Constant ground speeds can be maintained.

Speeds can be varied "on the go" while working mechanism is independently operated at its most efficient speed. The prime mover also can be run at optimum speeds regardless of mechanism speed. In short, a totally new and almost limitless control of all functions is achieved for maximum vehicle efficiency.

Reports from users are universal in emphasizing dramatically increased productivity, ease of handling, and elimination of major maintenance problems.

Sundstrand hydrostatic transmissions have been expressly designed to provide the long life and reliability required in work related applications. Extended fatigue life, minimum deflection of parts, and adequate reserve capacity to absorb shock loads are features that keep machines on the job.

The 230,000 sq. ft. plant in Ames, Iowa is headquarters for all marketing, engineering, testing and assembly procedures, supported by a world wide sales and service network. The 270,000 sq. ft. plant in LaSalle, Illinois is devoted exclusively to the manufacture of Sundstrand hydrostatic transmission systems.

II. GENERAL INFORMATION

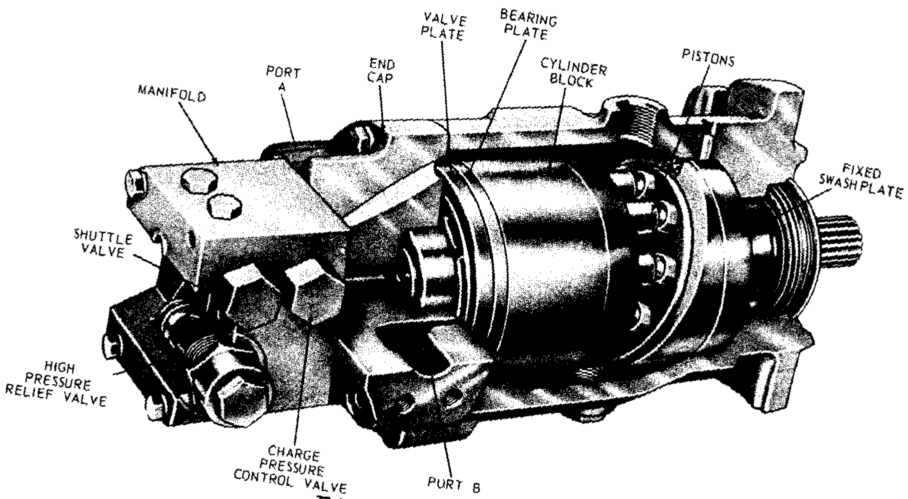
The hydrostatic transmission offers infinite control of speed and direction. The operator has complete control of the system with one lever for starting, stopping, forward motion, or reverse motion. The dynamic braking capabilities inherent with the closed circuit hydrostatic transmission may provide normal braking requirements. This capability is dependent upon the transmission size, including relief valve settings, as well as the retarding characteristics of the prime mover. Stopping time will be related to the momentum of the mechanism. When negotiating downgrades at top speed, there is a greater probability that the prime mover braking will be inadequate to restrain the mechanism speed and a runaway condition could result. Negotiating such a downgrade can be safely accomplished at lower speeds. In any event, the inherent braking capabilities of the transmission should not be construed as a substitute for service brakes.

Control of the variable displacement, axial piston pump is the key to controlling the vehicle. Prime mover horsepower is transmitted to the pump. When the operator moves the control lever, the swashplate in the pump is tilted from neutral. The position of the control lever will determine the angle of the swashplate and, therefore, the volume of oil displaced by the pump. The control lever is stepless, therefore, the direction and speed of the vehicle is infinitely variable from zero to maximum.

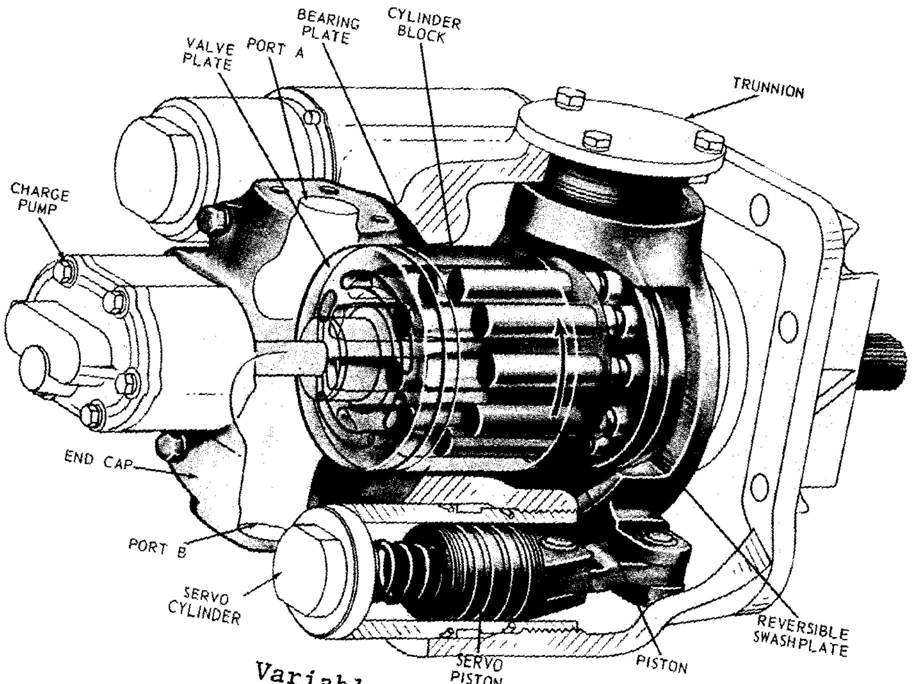
The variable displacement, reversing swashplate pump is controlled and positioned by a servo system. The control lever can be moved rapidly to some predetermined position with the servo follow-up system moving the swashplate of the pump to this predetermined point. The use of a servo system on the variable pump controls allows a minimum force to move the control handle.

When the variable pump swashplate is tilted, a positive stroke to the pistons is created. This, in turn, at any given input speed, produces a certain flow from the pump. This flow is transferred through high pressure lines to the motor. The ratio of the volume of flow from the pump to the displacement of the motor will determine the speed of the motor output shaft. Moving the control lever to the opposite side of neutral, the flow from the pump is reversed and the motor output shaft turns in the opposite direction. Speed of the output shaft is controlled by adjusting the displacement (flow) of the transmission. Load (working pressure) is determined by the external conditions, (grade, ground conditions, etc.) and this establishes the demand on the system.

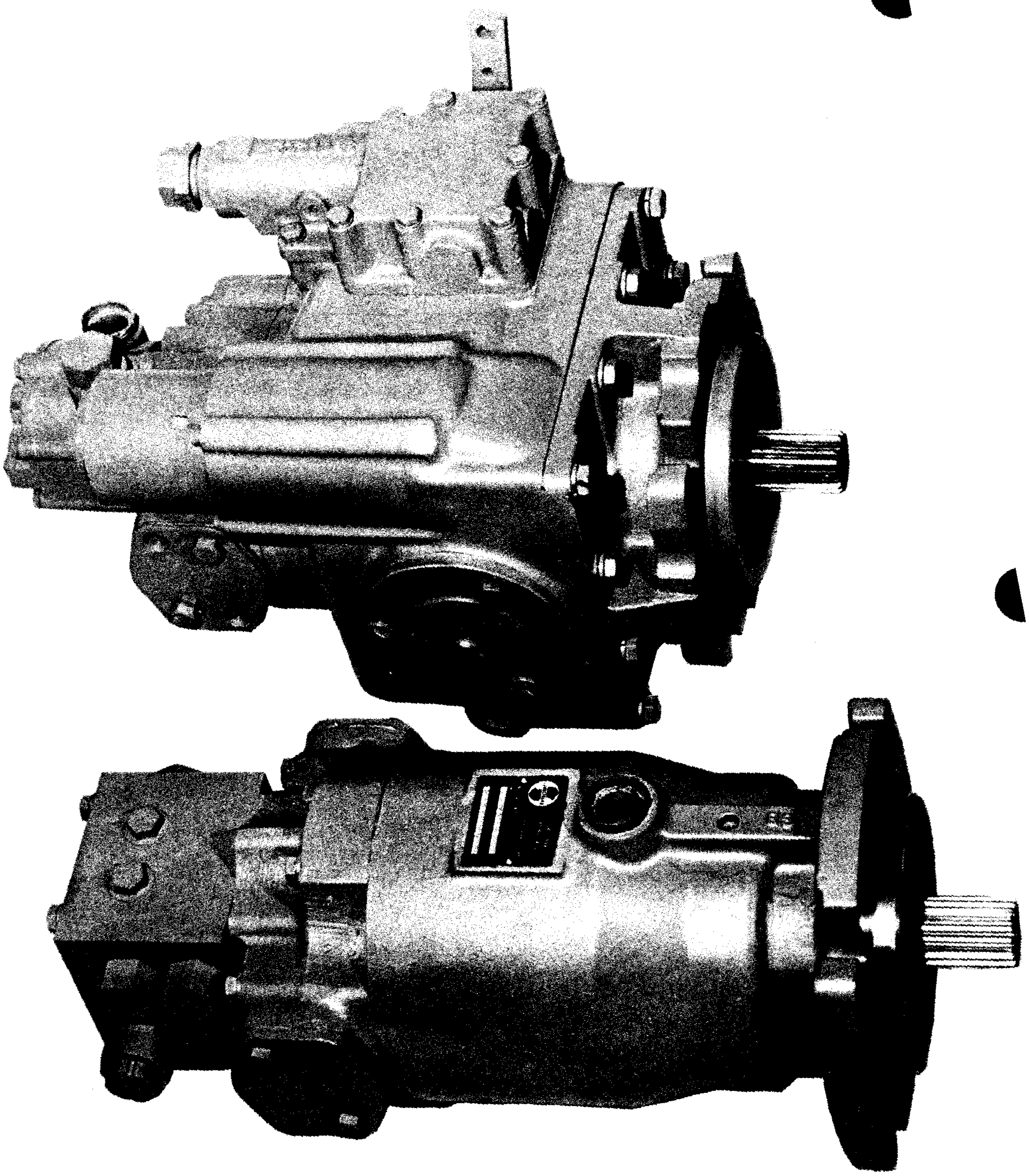
Pumps and motors are contained in separate housings or may be connected by a common end cap. All valves required for a closed loop circuit are included in either the pump or motor assemblies. A reservoir, filter, cooler, and lines complete the circuit.



Fixed Displacement Motor



Variabl



III. CIRCUITS AND CHARACTERISTICS

There are only 4 basic components involved in HYDROSTATIC TRANSMISSIONS:

VARIABLE DISPLACEMENT PUMPS

FIXED DISPLACEMENT PUMPS

VARIABLE DISPLACEMENT MOTORS

FIXED DISPLACEMENT MOTORS

These basic components can be combined into 4 circuits:

VARIABLE DISPLACEMENT PUMP driving a

VARIABLE DISPLACEMENT MOTOR

VARIABLE DISPLACEMENT PUMP driving a

FIXED DISPLACEMENT MOTOR

FIXED DISPLACEMENT PUMP driving a

VARIABLE DISPLACEMENT MOTOR

FIXED DISPLACEMENT PUMP driving a

FIXED DISPLACEMENT MOTOR

Each of these four circuits offer different performance characteristics. In the following descriptions, the input speed is constant. When you consider varying the input speed and introducing various control methods, the possible applications rapidly broaden. The horsepower at any given working pressure is directly proportional to pump flow. The torque of the motor depends on its displacement and the working pressure established.

III. CIRCUIT #1

Variable Displacement Pump - Variable Displacement Motor Characteristics:

1. Maximum efficiency occurs near mid-speed.
2. The efficiency is highest over a broad part of the speed range.
3. Output speed is controlled by both pump displacement and motor displacement. (And Input Speed)
4. For optimum hydraulic sizing, the pump is approximately one-half the size (displacement) of the motor.
5. This circuit has the widest output speed range.

SEE PERFORMANCE CURVES

POINT A

The Variable Displacement Pump is at minimum (zero) displacement thus there is no flow and no transmission output. The Variable Displacement Motor is in maximum displacement. This provides maximum starting torque at the motor output shaft and makes it possible to utilize the entire range of the transmission.

POINT B'

Point B' shows the point at which input horsepower reaches maximum. This shows that maximum horsepower can be reached before the pump reaches maximum angle or flow. Pressure was at maximum up to B' and falls off between B' and B, and is constant from B to C. Between Points B' and C the transmission is a constant horsepower transmission assuming constant working pressure conditions.

POINT B

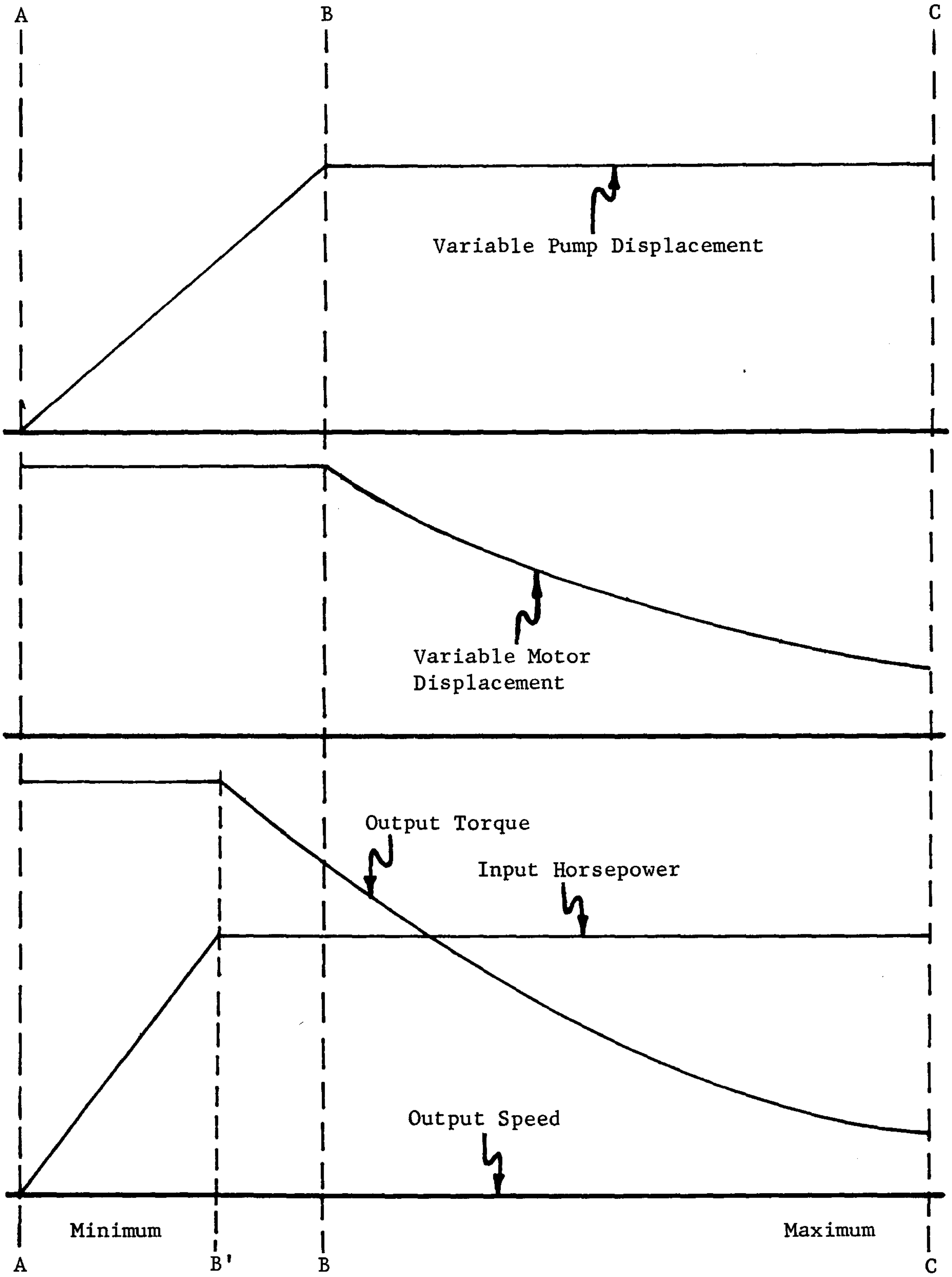
The pump displacement has increased to maximum. The motor displacement has remained constant but the motor output speed has increased. For any given pressure, no further increase in output horsepower is possible since horsepower is a function of flow and pressure. (We reached our maximum pump flow at Point B). The motor displacement goes from maximum to minimum with the resulting decrease in output torque and increase in output speed.

POINT C

The transmission has reached its maximum output speed and the horsepower output is the same as it was at Point B'. A good example of the use of a transmission with a variable pump and variable motor is to propel a crawler tractor. Two transmissions of equal size could be used - one driving each track. This arrangement would provide:

1. Independent control of each track for steering.
2. Tracks can be operated in opposite directions for "spin" turns.
3. Infinite speed control by varying the pump and motor displacement.
4. High output torques for starting, bulldozing, and towing.
5. High speed for traveling.

The use of a variable displacement motor in a transmission, where the output speed will be varied, requires lower circuit flows than are possible with a fixed displacement motor; allowing smaller pumps to be used. The Variable Pump - Variable Motor combination has maximum efficiency at mid-speed range rather than at maximum speed range as with the Variable Pump - Fixed Motor combination.



Circuit #1

Variable Displacement Pump - Variable Displacement Motor

CIRCUIT #2

Variable Displacement Pump - Fixed Displacement Motor

CONSTANT INPUT SPEED

Characteristics

1. Maximum efficiency occurs near top input speed.

2. Output speed is controlled by pump displacement (and input speed).

3. For optimum hydraulic sizing, the pump size (displacement) is equal to motor size (displacement).

4. This is the simplest system providing infinite control. It is the most frequently used system.

SEE PERFORMANCE CURVES

POINT A

Pump displacement is minimum (zero); therefore, there is no output from the transmission. As the pump is put in stroke, maximum starting torque will be available, since the motor is in maximum displacement.

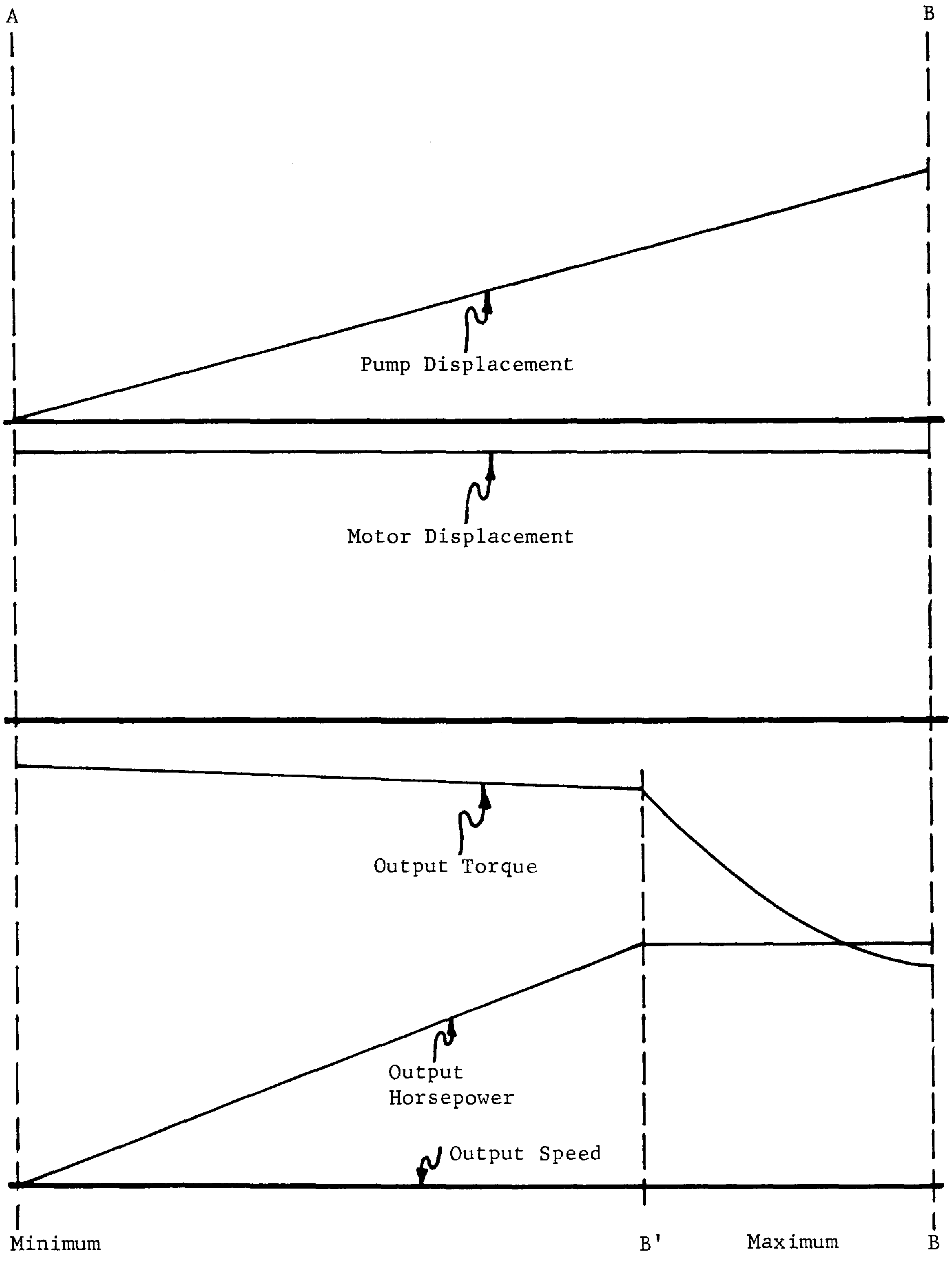
POINT B'

The torque has remained basically constant, while the horsepower has increased from minimum to maximum assuming constant working pressure.

POINT B

The pump displacement is now at maximum. The motor displacement has remained constant, since it is fixed. The motor is now at full speed, since the pump displacement is at maximum. The torque is reduced because horsepower was constant from B' to B.

Typical applications of this transmission are conveyor drives, combine drives, and road roller drives. Varying the pump displacement provides an infinite number of output speeds, while the fixed displacement motor provides a constant torque capability.



Variable Displacement Pump - Fixed Displacement Motor

CIRCUIT #3

Fixed Displacement Pump - Fixed Displacement Motor

This combination is the hydraulic equivalent of a mechanical shaft and gear drive. It can be used to transmit power without altering the speed or horsepower between the engine and the load. This transmission would be convenient if the power source is remote from the load.

CIRCUIT #4

Fixed Displacement Pump - Variable Displacement Motor

With the pump driven at a constant speed, the circuit is a constant horsepower, variable speed, variable torque transmission. Output speed is controlled by changing the displacement of the motor. As motor speed increases, output torque decreases. The system has no neutral because of the fixed displacement in the pump.

The foregoing illustrates basic arrangements of hydrostatic transmissions. A simple system of one pump and one motor was used to illustrate basic circuits. It must be realized that many variations of circuits are possible. By this we mean, it is possible to use one pump with two motors -- two pumps and two motors, etc... It is also common practice to use different sizes of pumps and motors in combinations. Regardless of the pumps and motors used, the basic characteristics apply.

IV. SUNDSTRAND HYDROSTATIC TRANSMISSION DESIGN PARAMETERS

3,000 p.s.i.	Continuous working pressure at maximum shaft speed.
5,000 p.s.i. *	Heavy duty capability. Normal relief valve setting.
10,000 p.s.i.	Shock load capability. Proof pressure rating.
20,000 p.s.i.	Safety limit (Actual Test).

* Operating of pressures above 5,000 p.s.i. requires written Engineering approval.

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V. SIZES AVAILABLE

(PUMPS AND MOTORS)

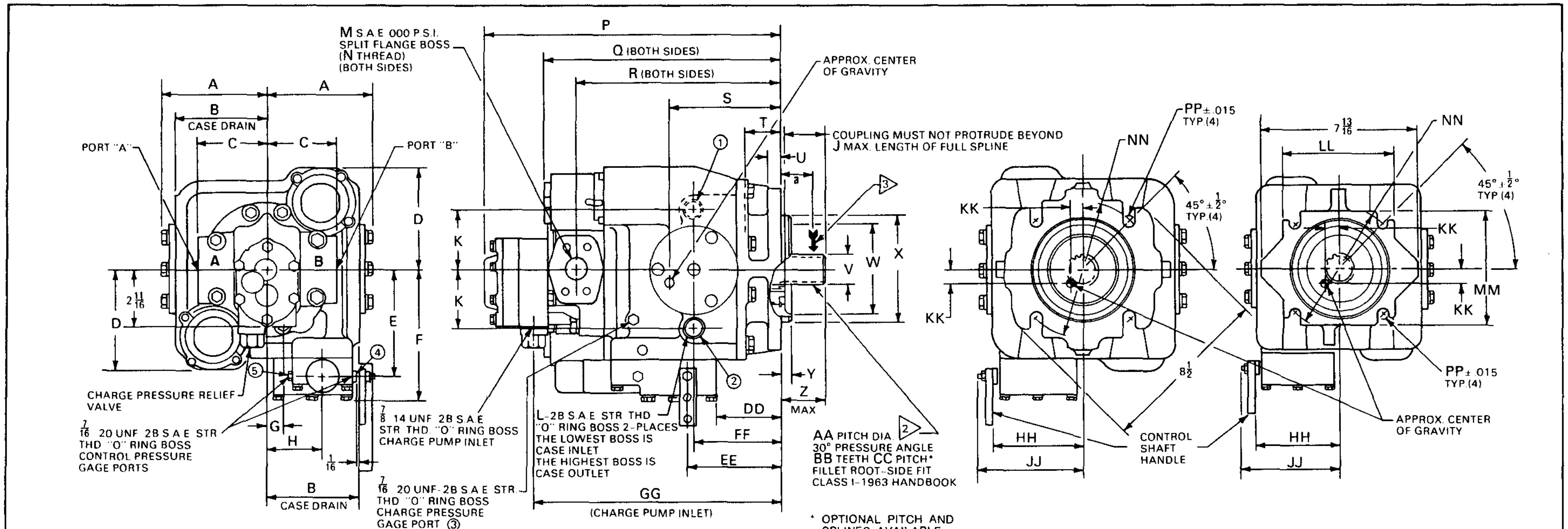
SERIES	DISPLACEMENT CU. IN./REV. 18°	MAXIMUM SHAFT SPEED**	FLOW GPM PER 1000 RPM * 18°(U.S.)	WEIGHT LBS.	(LB. FT.) TORQUE* PER 1000 P.S.I. 18°	WEIGHT LBS.
20	2.03	3800	8.8	97	27.0	60
21	3.15	3500	13.6	118	41.8	76
22	4.26	3200	18.4	135	56.6	88
23	5.43	2900	23.5	173	72.0	104
24	7.24	2700	31.3	273	96.0	154
25	10.12	2400	43.8	359	134.5	175
26	13.87	2100	60.0	515	184.0	230
27	20.36	1900	88.1	592	270.0	338

* Theoretical

** These speeds effective only on units factory built after Jaunary 1, 1971, Serial #LA40000

Revised 6-72

VARIABLE DISPLACEMENT PUMP INSTALLATION OUTLINE DIMENSIONS*

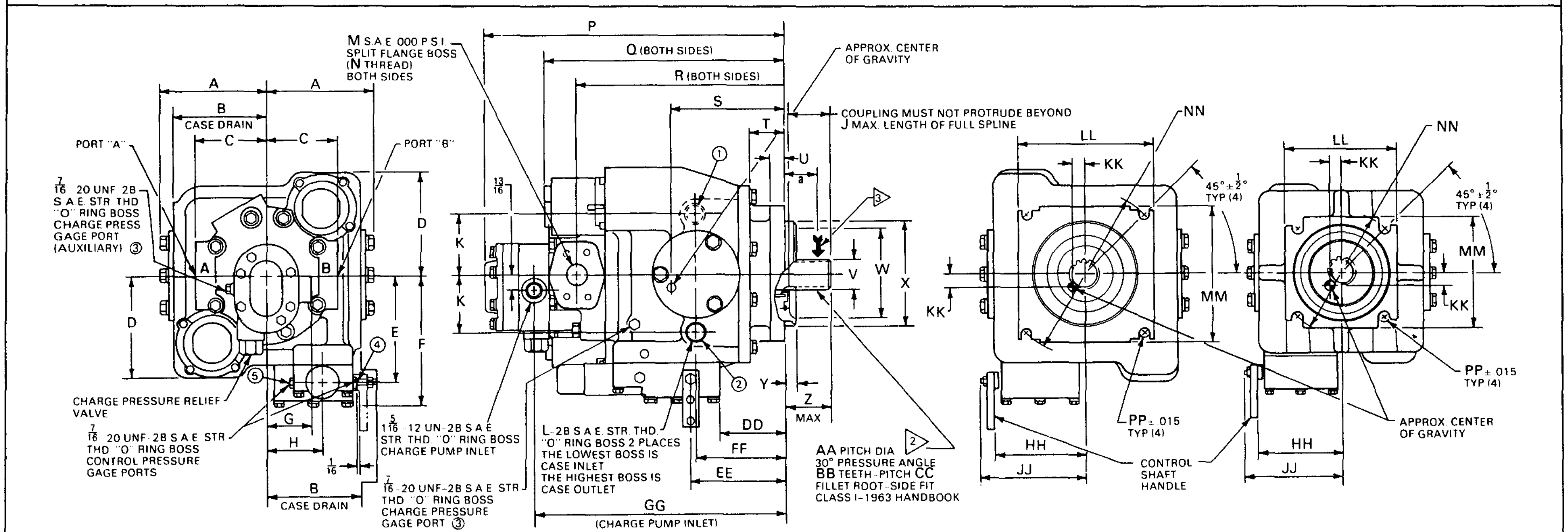


REAR VIEW OF 20 23 SERIES

SIDE VIEW OF 20-23 SERIES

FRONT VIEW OF 22-23 SERIES

FRONT VIEW OF 20-21 SERIES



REAR VIEW OF 24-27 SERIES

SIDE VIEW OF 24-27

FRONT VIEW OF 25–27 SERIES

FRONT VIEW OF 24 SERIES

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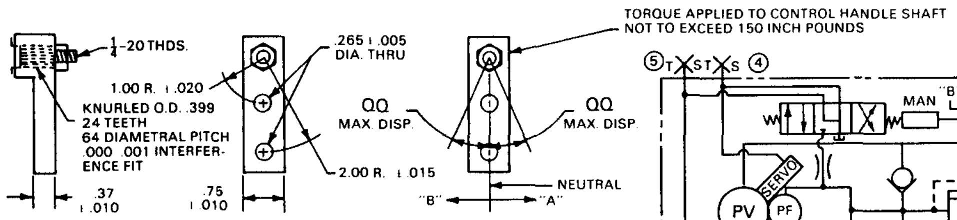
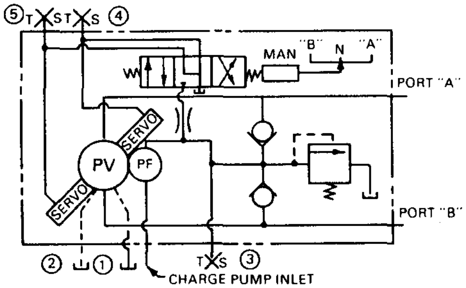




ROTATING CONTROL SHAFT IN DIRECTION "A" PRODUCES FLOW OUT OF PORT "A".
ROTATING CONTROL SHAFT IN DIRECTION "B" PRODUCES FLOW OUT OF PORT "B".
RIGHT HAND INPUT UNITS ONLY

TYPICAL 20–27 SERIES

MAX. DISPLACEMENT RR IN.³/REV. (18°)
CHARGE PRESSURE RELIEF VALVE SET AT 190-210 P.S.I. ABOVE CASE PRESSURE.
MAX. PRESSURE RATING 5000 Δ P.S.I.
MAX. CASE PRESSURE 40 P.S.I.G.
MIN. MAIN PORT PRESSURE 130 P.S.I. ABOVE CASE PRESSURE.
MAX. CASE OIL TEMPERATURE 180°F.
BEARING LIFE SS HRS. B_{10} AT 3000 P.S.I. AND TT R.P.M. WITH NO EXTERNAL SHAFT LOAD.
MAX. SHAFT SPEED: TT R.P.M.

CHECK VALVE FLOW RATING = VV R.P.M.
CHARGE PUMP DISPLACEMENT = WW IN.³/REV. (OPT. DISP. CHARGE PUMPS AVAILABLE)

ALL NOTES–"UNLESS OTHERWISE SPECIFIED"

2. NOTED SPLINE WILL FIT EITHER A FILLET ROOT OR FLAT ROOT FEMALE SPLINE.

3. MAXIMUM RADIAL SHAFT LOAD (F) CALCULATED BY (F)(a + XX) = YY IN.-LBS. AT ANY ANGULAR POSITION

REF.	OUTLINE 20 SERIES	OUTLINE 21 SERIES	OUTLINE 22 SERIES	OUTLINE 23 SERIES	OUTLINE 24-SERIES	OUTLINE 25-SERIES	OUTLINE 26-SERIES	OUTLINE 27-SERIES
A	4 7/16	5	5-1/4	5 15/16	6-11/16	7-1/8	7-13/16	8-7/16
B	3 13/16	4 3/8	4-1/2	5-1/8	5-13/16	6-1/8	6-3/4	7-7/16
C	3 1/4	3 7/16	3-7/16	3 13/16	4-1/4	5-3/16	5-11/16	6-5/16
D	4 5/8	4-3/4	5	5 7/16	6-3/16	7-1/8	8-1/2	8-11/16
E	4 9/16	5 1/16	5-1/16	5 1/2	6	6-1/2	6-9/16	7-1/2
F	6	6 1/2	6-1/2	6-15/16	7-7/16	7-7/8	8	8-15/16
G	3/4	3/4	3/4	3/4	3	3	3	3
H	2 3/16	2 9/16	2-11/16	3-1/16	3-7/16	3-13/16	4-1/4	5
J		—	—	—	—	—	—	—
K	2 7/16	2 11/16	2 13/16	3 1/16	3-1/4	3-7/8	3-15/16	4-9/16
L	7/8 14UNF	7/8 14UNF	7/8-14UNF	7/8 14UNF	7/8-14UNF	1-5/16-12UN	1-7/8-12UN	1-5/16-12UN
M	1 3000	1 3000	1 3000	1 3000	1 3000	1-1/2-6000	1-1/2-6000	1-1/2-6000
N	3/8 16	3/8 16	3/8-16	3/8 16	3/8 16	1/2-13	5/8-11	1/2-13
P	13 3/8	14 3/8	14 7/8	15 3/8	19 13/16	22-1/16	23-5/16	24-7/8
Q	10 3/8	10 15/16	11 15/16	12 1/4	15-1/16	16-3/16	17-7/8	19
R	8 13/16	9 5/8	10 3/16	10 5/8	12 1/2	14-3/8	15-1/4	17-1/16
S	6 1/4	6	5 3/4	5 1/2	6 13/16	8-5/8	9-1/4	9-11/16
T	1 7/8	1 7/8	1 7/8	1 15/16	2 3/4	3-1/8	2-13/16	3-3/8
U	5/8	5/8	5/8	11/16	15/16	7/8	15/16	1
V	1.2293/1.2223	1.2293/1.2223	1.2293/1.2223	1.2293/1.2223	1.7210/1.7140	1.7210/1.7140	1.7210/1.7140	1.9710/1.9640
W	4 1/4	4 1/4	4-1/4	4 1/4	4 3/4	5	5	5-1/2
X	5.000 4.998	5.000 4.998	5.000 4.998	5.000 4.998	6.000 5.998	6.500-6.498	6.500/6.498	7.000-6.998
Y	500 480	500 480	500 480	500 480	500 480	625-605	625-605	625-605
Z	2.220	2.220	2.220	2.220	2.962	3.021	3.021	3.021
** AA	1.1667	1.1667	1.1667	1.1667	1.6250	1.6250	1.6250	1.8750
** BB	14	14	14	14	13	13	13	40
** CC	12/24	12/24	12/24	12/24	8/16	8/18	8/16	8/16
DD	2 1/16	2 9/16	3 1/16	3 5/16	5	6-1/8	6-7/8	7-15/16
EE	3 11/16	4 1/8	4 11/16	5	6 5/8	7 11/16	8 7/16	9-9/16
FF	3 15/16	4 3/16	4 3/8	4 5/8	5 13/16	6-3/4	6 3/8	7-13/16
GG	11 3/16	11 13/16	12 3/8	12 7/8	16	17 13/16	18 15/16	20-5/8
HH	3 15/16	4 5/16	4 7/16	4 7/8	5 3/16	5 9/16	6	6-13/16
JJ	4 13/16	5 1/4	5 5/16	5 3/4	6 1/8	6 1/2	6 15/16	7-11/16
KK	1/8	1/4	3/8	1/2	9/16	5/8	9/16	11/16
LL	6 1/16	6 1/16			8 3/4	11 7/8	11 7/8	12 1/2
MM	6 1/16	6 1/16			8 5/16	11 7/16	10 5/16	11-1/8
NN	6.375	6.375	6.375	6.375	9.000	12.500	12.500	13.781
PP	.59	.59	.59	.59	.84	.84	.84	1.09
QQ	22	26	26	30	25	28	27	30
RR	2.03	3.15	4.26	5.43	7.24	10.12	13.87	20.36
SS	8640	6270	8480	5880	10610	10710	7820	6580
TT	3800	3500	3200	2900	2700	2400	2070	1900
UU								—
VV	10	10	10	10	20	20	20	20
WW	.50	.75	.75	.75	1.15	2.0	2.0	2.0
XX	1.95	1.92	1.80	1.82	2.73	3.33		3.84
YY	2620	4650	6500	8620	9900	17700		51800

** OTHER SHAFTS AVAILABLE

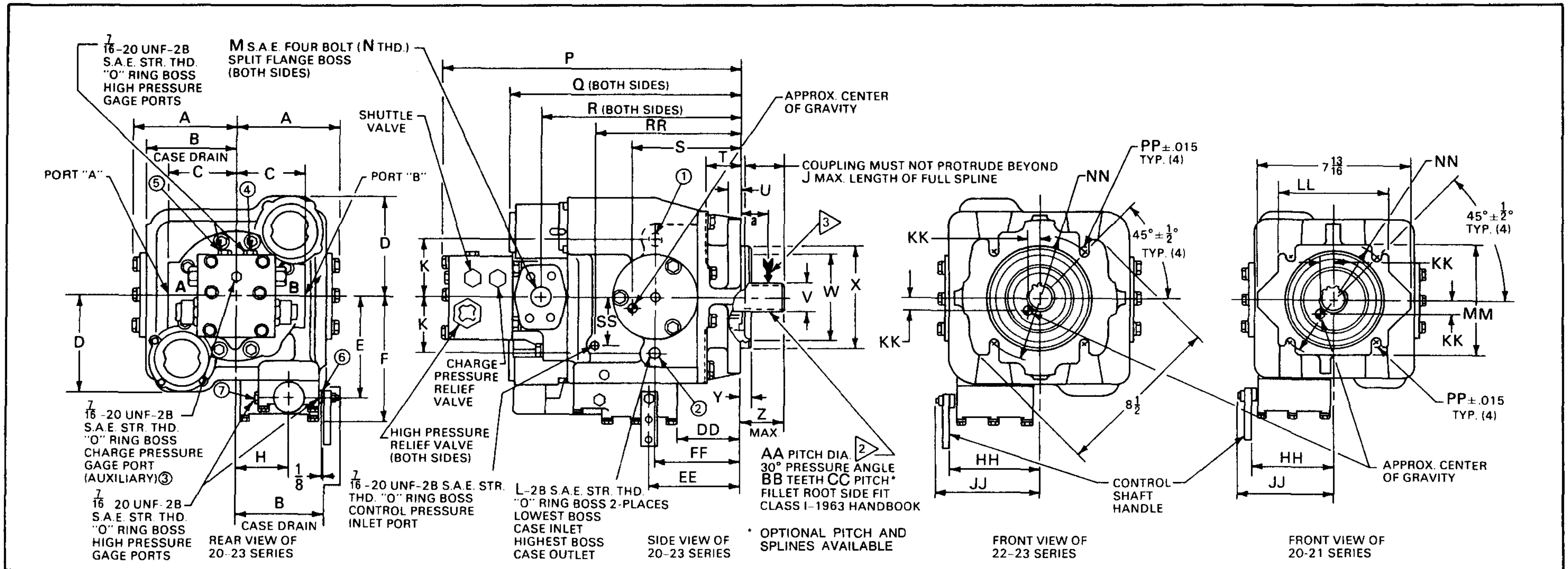
VARIABLE DISPLACEMENT PUMP

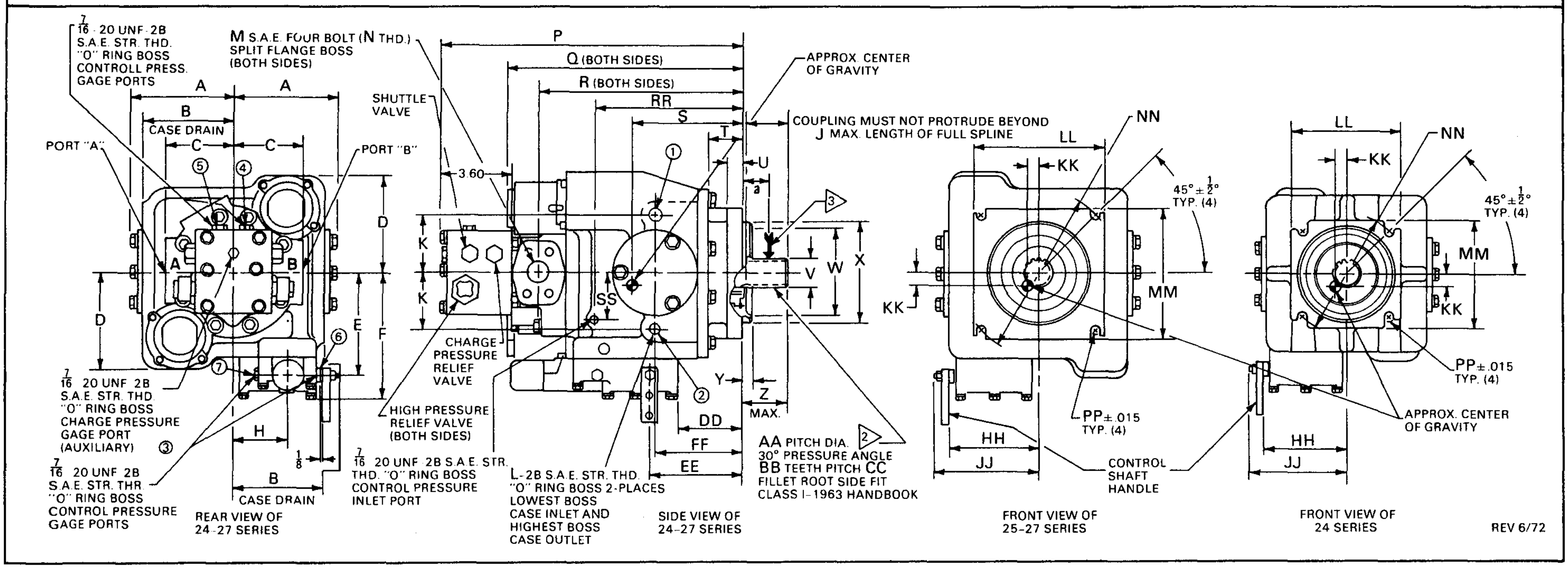
(RIGHT AND LEFT HAND ROTATION AVAILABLE)

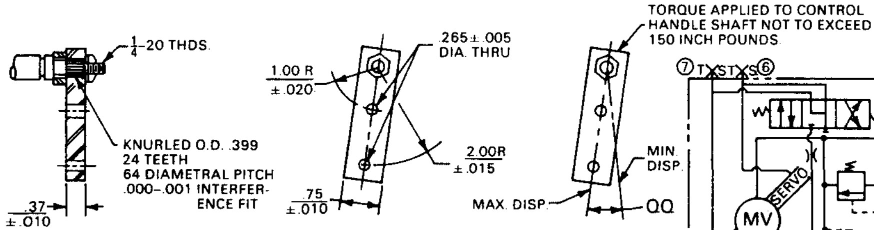
FOR REFERENCE ONLY

REV. 10/76

VARIABLE DISPLACEMENT MOTOR INSTALLATION DIMENSIONS*





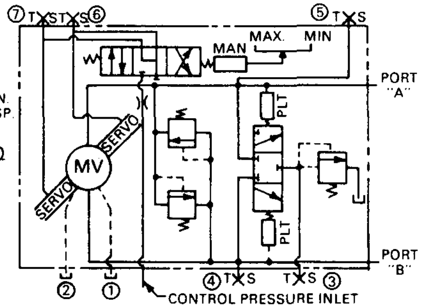


HIGH PRESSURE APPLIED AT PORT "A" PRODUCES A RIGHT HAND SHAFT ROTATION

HIGH PRESSURE APPLIED AT PORT "B" PRODUCES A LEFT HAND SHAFT ROTATION

SHAFT ROTATION IS DETERMINED BY VIEWING MOTOR FROM OUTPUT SHAFT END

TYPICAL 20-27 SERIES



MAX. DISPLACEMENT TT IN.³/REV. (18°)
MIN. DISPLACEMENT UU IN.³/REV. (7°)
CHARGE PRESSURE RELIEF VALVE SET AT 160–180 P.S.I. ABOVE CASE PRESSURE.
HIGH PRESSURE RELIEF VALVES SET AT 5000 Δ P.S.I. (STANDARD)
MAX. CASE PRESSURE 40 P.S.I.G.
MIN. MAIN PORT PRESSURE 130 P.S.I. ABOVE CASE PRESSURE.
MAX. CASE OIL TEMPERATURE 180°F.
BEARING LIFE = VV HRS. B_{10} AT 3000 P.S.I. AND WW R.P.M. WITH NO EXTERNAL SHAFT LOAD.
MAX. SHAFT SPEED: WW R.P.M. AT NO LOAD

CHARGE PRESSURE RELIEF VALVE FLOW RATING = 10 G.P.M.

ALL NOTES–"UNLESS OTHERWISE SPECIFIED"

2 — NOTED SPLINE WILL FIT EITHER A FILLET ROOT OR FLAT ROOT FEMALE SPLINE.

3 — MAXIMUM RADIAL SHAFT LOAD (F) CALCULATED BY (F)(a + YY) = ZZ IN.-LBS. AT ANY ANGULAR POSITION.

REF.	OUTLINE 20-SERIES	OUTLINE 21-SERIES	OUTLINE 22-SERIES	OUTLINE 23-SERIES	OUTLINE 24-SERIES	OUTLINE 25-SERIES	OUTLINE 26-SERIES	OUTLINE 27-SERIES
A	4-7/16	5	5-1/4	5-15/16	6-11/16	7-1/8	7-13/16	8-7/16
B	3-13/16	4-3/8	4-1/2	5-1/8	5-13/16	6-1/8	6-3/4	7-7/16
C	3-1/4	3-7/16	3-7/16	3-13/16	4-1/4	5-3/16	5-11/16	6-5/16
D	4-5/8	4-3/4	5	5-7/16	6-3/16	7-1/8	8-1/2	8-11/16
E	4-9/16	5-1/16	5-1/16	5-1/2	6	6-1/2	6-9/16	7-1/2
F	6	6-1/2	6-1/2	6-15/16	7-7/16	7-7/8	8-1/16	8-15/16
G	—	—	—	—	—	—	—	—
H	2-3/16	2-9/16	2-11/16	3-1/16	3-7/16	3-13/16	4-1/4	5
J	1.88	1.88	1.88	1.88	2.63	2.64	2.64	2.64
K	2-7/16	2-11/16	2-13/16	3-1/16	3-1/4	3-7/8	3-15/16	4-9/16
L	7/8-14UNF	7/8-14UNF	7/8-14UNF	7/8-14UNF	7/8-14UNF	1-5/16-12UN	1-7/8-12UN	1-5/16-12UN
M	1-3000	1-3000	1-3000	1-3000	1-3000	1-1/2-6000	1-1/2-6000	1-1/2-6000
N	3/8-16	3/8-16	3/8-16	3/8-16	3/8-16	3/8-16	5/8-11	3/8-16
P	14	14-11/16	15-3/16	15-3/4	18-1/2	20-5/16	21-3/8	23-1/16
Q	10-3/8	10-15/16	11-15/16	12-1/4	15-1/16	16-3/16	17-7/8	19
R	8-13/16	9-5/8	10-3/16	10-5/8	12-1/2	14-3/8	15-1/4	17
S	6-1/4	6	5-3/4	5-1/2	6-13/16	8-5/8	9-1/4	9-11/16
T	1-7/8	1-7/8	1-7/8	1-15/16	2-3/4	3-1/8	2-13/16	3-3/8
U	5/8	5/8	5/8	11/16	15/16	7/8	15/16	1
V	1.2293/1.2223	1.2293/1.2223	1.2293/1.2223	1.2293/1.2223	1.7210/1.7140	1.7210/1.7140	1.7210/1.7140	1.9710/1.9640
W	4-1/4	4-1/4	4-1/4	4-1/4	4-3/4	5	5	5-1/2
X	5.000-4.998	5.000-4.998	5.000-4.998	5.000-4.998	6.000-5.998	6.500-6.498	6.500-6.498	7.000-6.998
Y	.500-.480	.500-.480	.500-.480	.500-.480	.500-.480	.625-.605	.625-.605	.625-.605
Z	2.220	2.220	2.220	2.220	2.962	3.021	3.021	3.021
** AA	1.1667	1.1667	1.1667	1.1667	1.6250	1.6250	1.6250	1.8750
** BB	14	14	14	14	13	13	13	40
** CC	12/24	12/24	12/24	12/24	8/16	8/16	8/16	8/16
DD	2-1/8	2-9/16	3-1/16	3-5/16	5	6-1/8	6-7/8	7-15/16
EE	3-11/16	4-1/8	4-11/16	5	6-5/8	7-11/16	8-7/16	9-9/16
FF	3-15/16	4-3/16	4-3/8	4-5/8	5-13/16	6-3/4	6-3/8	7-13/16
GG	—	—	—	—	—	—	—	—
HH	3-15/16	4-5/16	4-7/16	4-7/8	5-3/16	5-9/16	6	6-13/16
JJ	4-13/16	5-1/4	5-5/16	5-3/4	6-1/8	6-1/2	6-15/16	7-11/16
KK	1/8	1/4	3/8	1/2	9/16	5/8	9/16	11/16
LL	6-1/16	6-1/16	—	—	8-3/4	11-7/8	11-7/8	12-1/2
MM	6-1/16	6-1/16	—	—	8-5/16	11-7/16	10-5/16	11-1/8
NN	6.375	6.375	6.375	6.375	9.000	12.500	12.500	13.781
PP	.59	.59	.59	.59	.84	.84	.84	1.09
QQ	12°	14°	14°	17°	14°	16°	19°	17°
RR	—	6-7/8	7-3/8	10-5/8	9-5/8	10-3/8	11-1/8	12-1/4
SS	—	2-1/8	2-3/8	2-9/16	2-11/16	2-15/16	3-1/8	3-3/4
TT	2.03	3.15	4.26	5.43	7.24	10.12	13.87	20.36
UU	.76	1.19	1.61	2.05	2.73	3.82	5.24	7.69
VV	8640	6270	8480	5880	10610	10710	7820	6580
WW	3800	3500	3200	2900	2700	2400	2070	1900
XX	—	—	—	—	—	—	—	—
YY	1.95	1.92	1.80	1.82	2.73	3.33	—	3.84
ZZ	2620	4600	6500	8620	9900	17700	—	51800

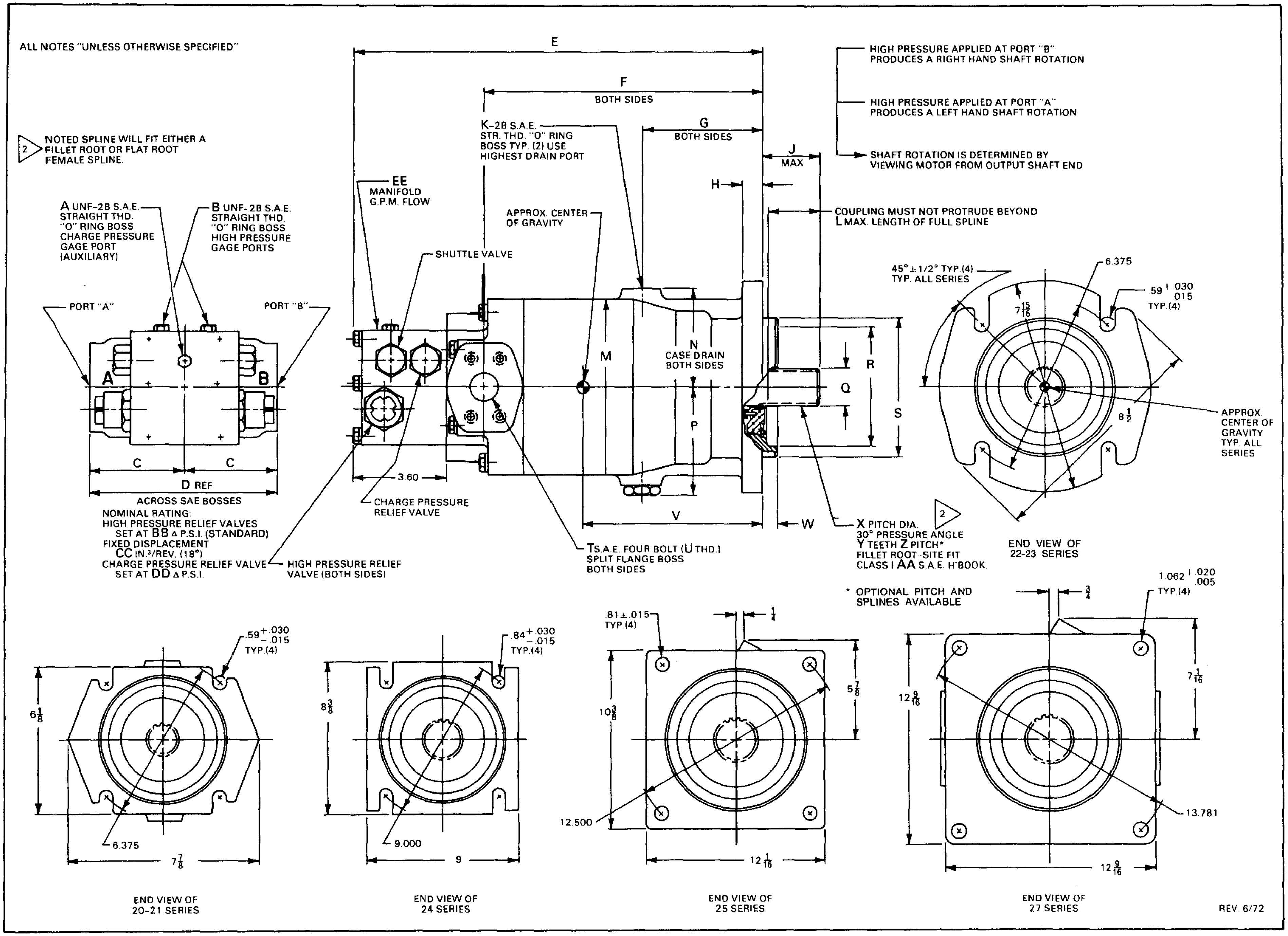
** OTHER SHAFTS AVAILABLE

VARIABLE DISPLACEMENT MOTOR

*FOR REFERENCE ONLY

REV. 10/76

FIXED DISPLACEMENT MOTOR INSTALLATION OUTLINE DIMENSIONS*



REF.	OUTLINE 20-SERIES	OUTLINE 21-SERIES	OUTLINE 22-SERIES	OUTLINE 23-SERIES	OUTLINE 24-SERIES	OUTLINE 25-SERIES	OUTLINE 26-SERIES	OUTLINE 27-SERIES
A	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20
B	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20	7/16-20
C	3-1/4	3-7/16	3-7/16	3-13/16	4-1/4	5-3/16	5-3/4	6-5/16
D	6-1/2	6-7/8	6-7/8	7-5/8	8-1/2	10-3/8	11-1/2	12-5/8
E	13-9/16	14-5/16	15-1/16	15-3/4	17-5/8	18-15/16	19-3/4	21-5/16
F	8-7/16	9-1/4	10-1/16	10-5/8	12	13	13-5/8	15-1/4
G	3-1/2	3-13/16	4-1/4	4-5/8	4-15/16	5-3/8	5-1/2	6-1/16
H	5/8	5/8	5/8	11/16	1	7/8	1-1/16	1-1/2
J	2.220	2.220	2.220	2.220	2.962	3.021	3.021	3.021
K	7/8-14UNF	7/8-14UNF	7/8-14UNF	7/8-14UNF	7/8-14UNF	1-5/16-12UN	1-7/8-12UN	1-5/16-12UN
L	1.88	1.88	1.88	1.88	2.64	2.64	2.64	2.64
M	5-13/16	6-3/8	6-11/16	7-7/16	8-3/16	9-5/16	10-11/16	11-13/16
N	3	3-5/16	3-3/4	4-1/16	4-1/16	5	5-7/16	5-7/8
P	3-7/16	3-11/16	4-1/8	4-7/16	4-7/16	5-1/2	6-1/8	6-5/16
Q	1.2293/1.2223	1.2293/1.2223	1.2293/1.2223	1.2293/1.2223	1.7210/1.7140	1.7210/1.7140	1.7210/1.7140	1.9710/1.9640
R	4-1/4	4-1/4	4-1/4	4-1/4	4-3/4	5	5	5-1/2
S	5.000/4.998	5.000/4.998	5.000/4.998	5.000/4.998	6.000/5.998	6.500/6.498	6.500/6.498	7.000/6.998
T	1-3000	1-3000	1-3000	1-3000	1-3000	1-1/2-6000	1-1/2-6000	1-1/2
U	3/8-16	3/8-16	3/8-16	3/8-16	3/8-16	1/2-13	5/8-11	1/2-13
V	6-1/8	6-5/16	6-1/2	6-11/16	6-7/8	8-5/8	9	10-15/16
W	.500/.480	.500/.480	.500/.480	.500/.480	.500/.480	.625/.605	.625/.605	.625/.605
** X	1.1667	1.1667	1.1667	1.1667	1.6250	1.6250	1.6250	1.8750
** Y	14	14	14	14	13	13	13	40
** Z	12/24	12/24	12/24	12/24	8/16	8/16	8/16	8/16
AA	1963	1963	1963	1963	1963	1963	1963	1963
BB	5000	5000	5000	5000	5000	5000	5000	5000
CC	2.03	3.15	4.26	5.43	7.24	10.12	13.87	20.36
DD	160/180	160/180	160/180	160/180	160/180	160/180	160/180	160/180
EE	10	10	10	10	10	10	10	0
FF	3-7/8	4-1/16	4-1/4	4-13/16	4-15/16	——	6-11/16	7-3/16

** OTHER SHAFTS AVAILABLE

FIXED DISPLACEMENT MOTOR

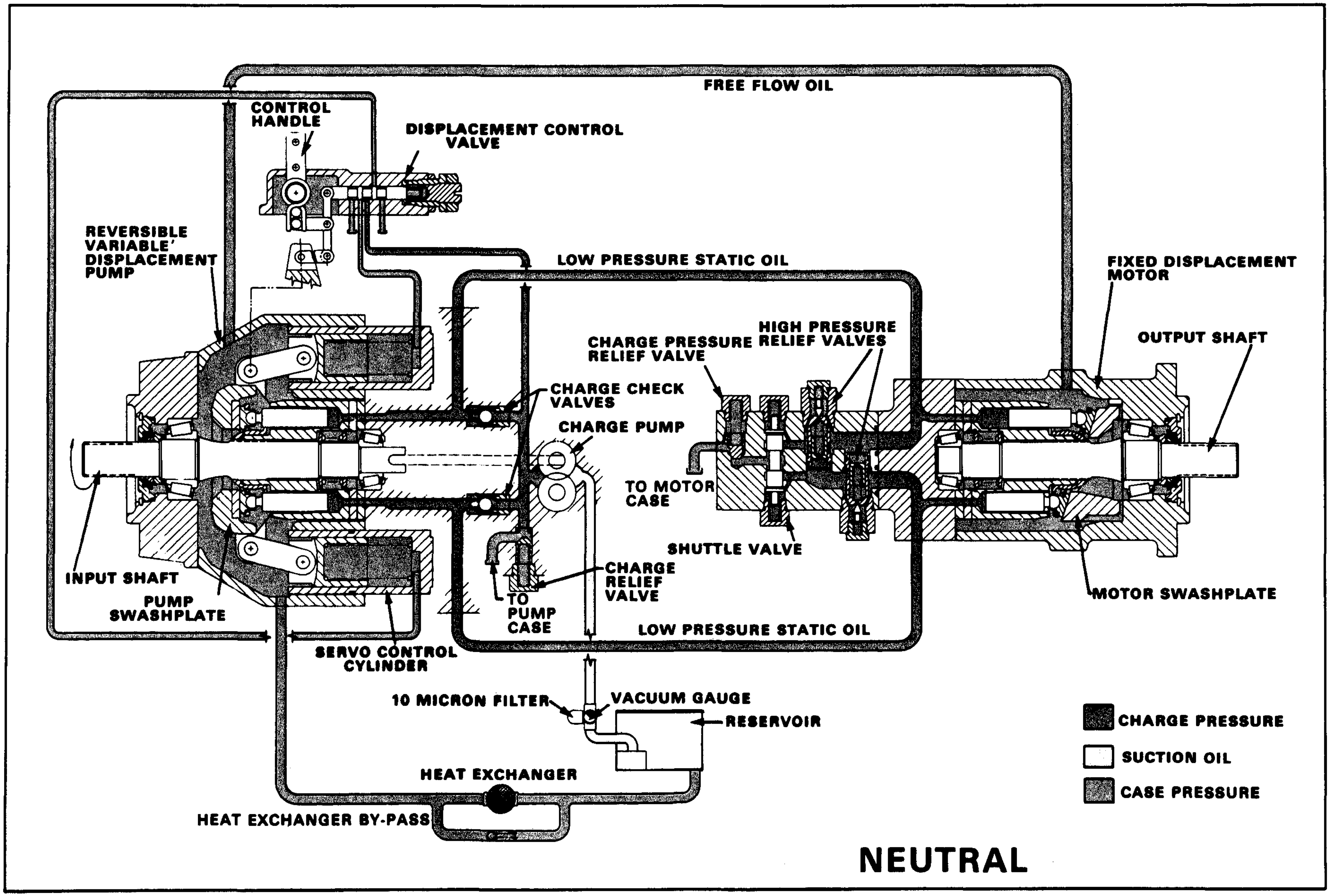
*FOR REFERENCE ONLY

REV. 10/76

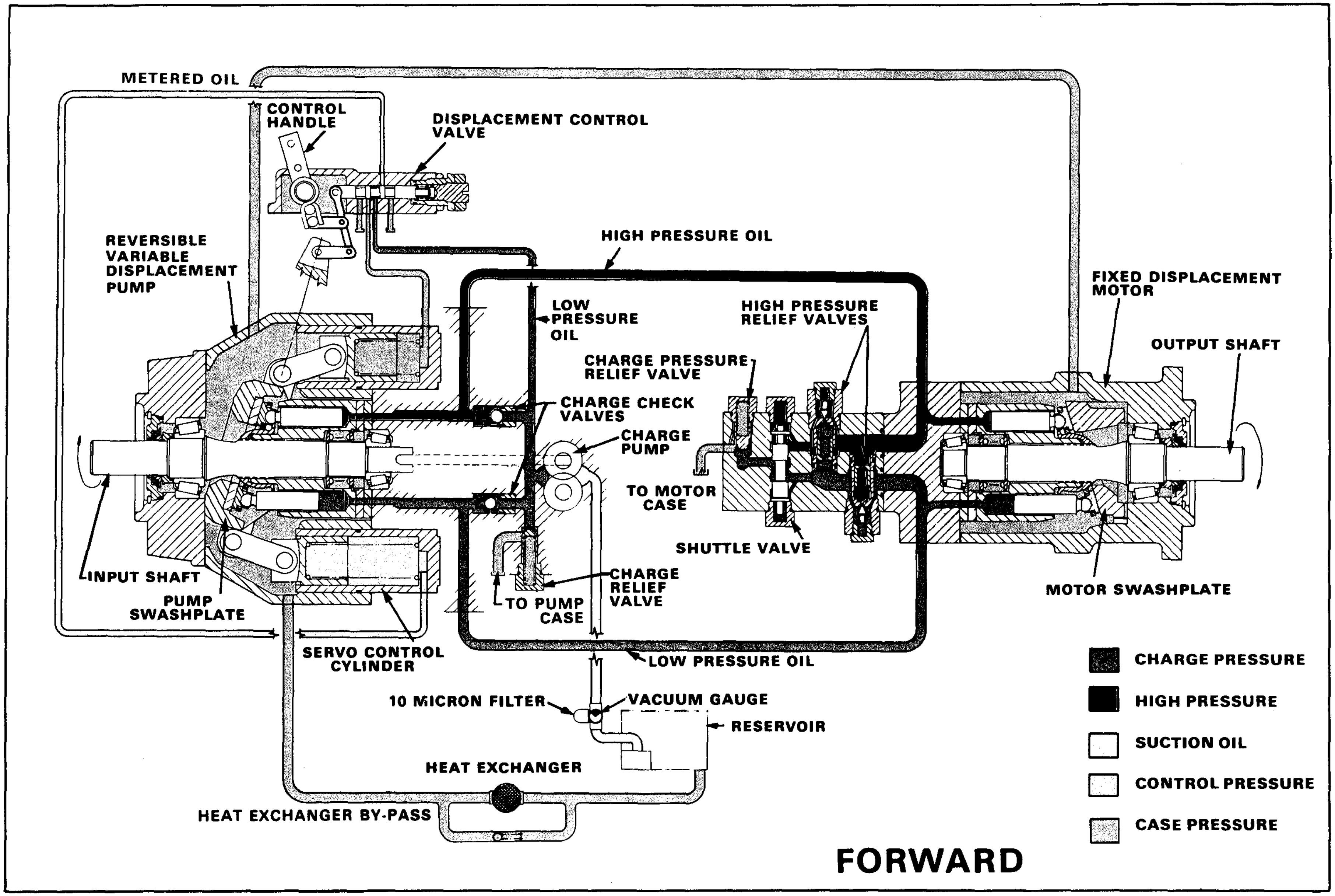
KITS

Sub-assemblies of the units are also available as kits. Kits include the internal rotating parts, valve plates, swashplates, and trunnions. Kits are used when the application has a cavity suitable to house the internal parts and valves. This greatly increases the versatility and flexibility of applying Sundstrand Hydrostatic Transmissions.

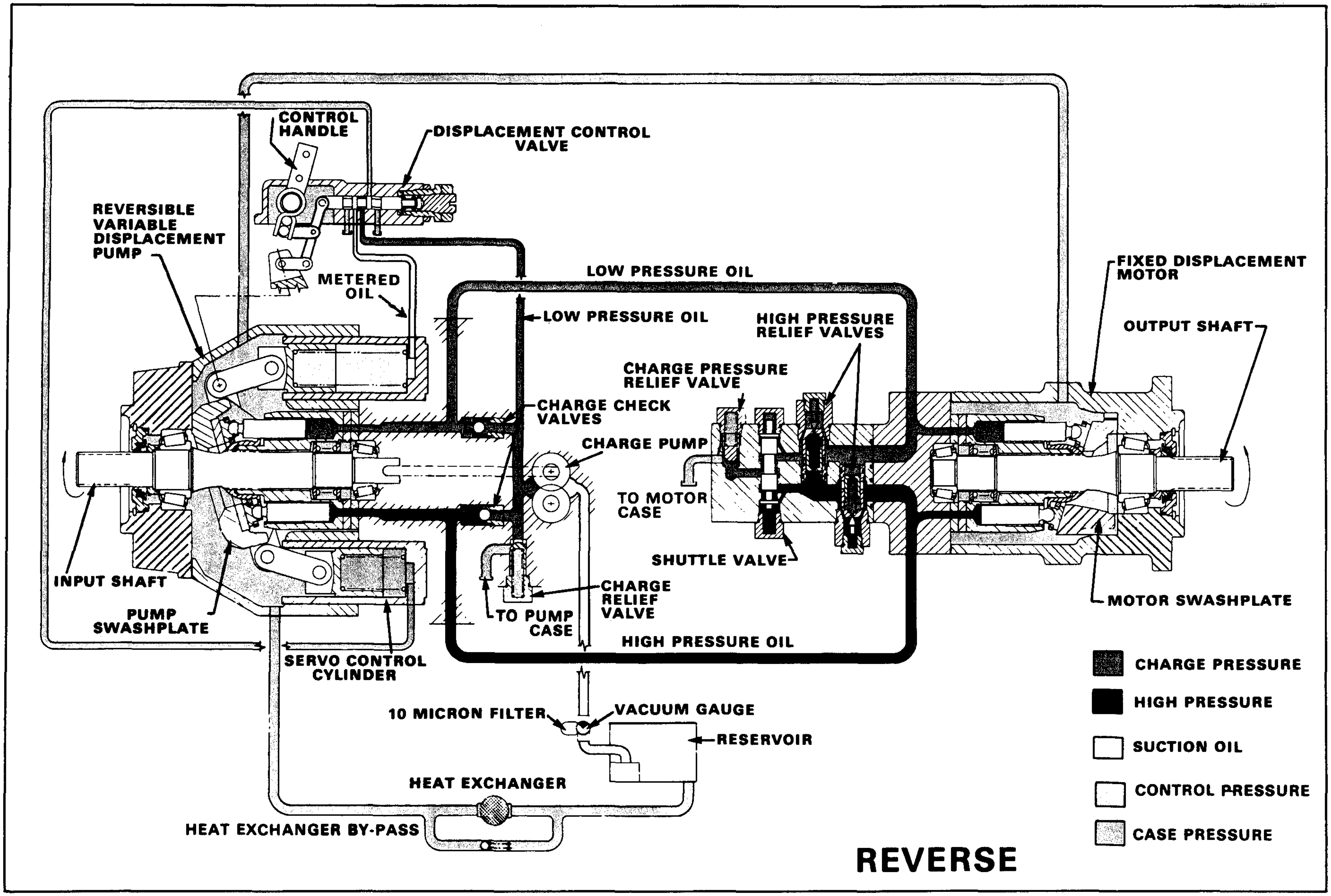
TYPICAL HEAVY DUTY VARIABLE PUMP—FIXED MOTOR TRANSMISSION SCHEMATIC



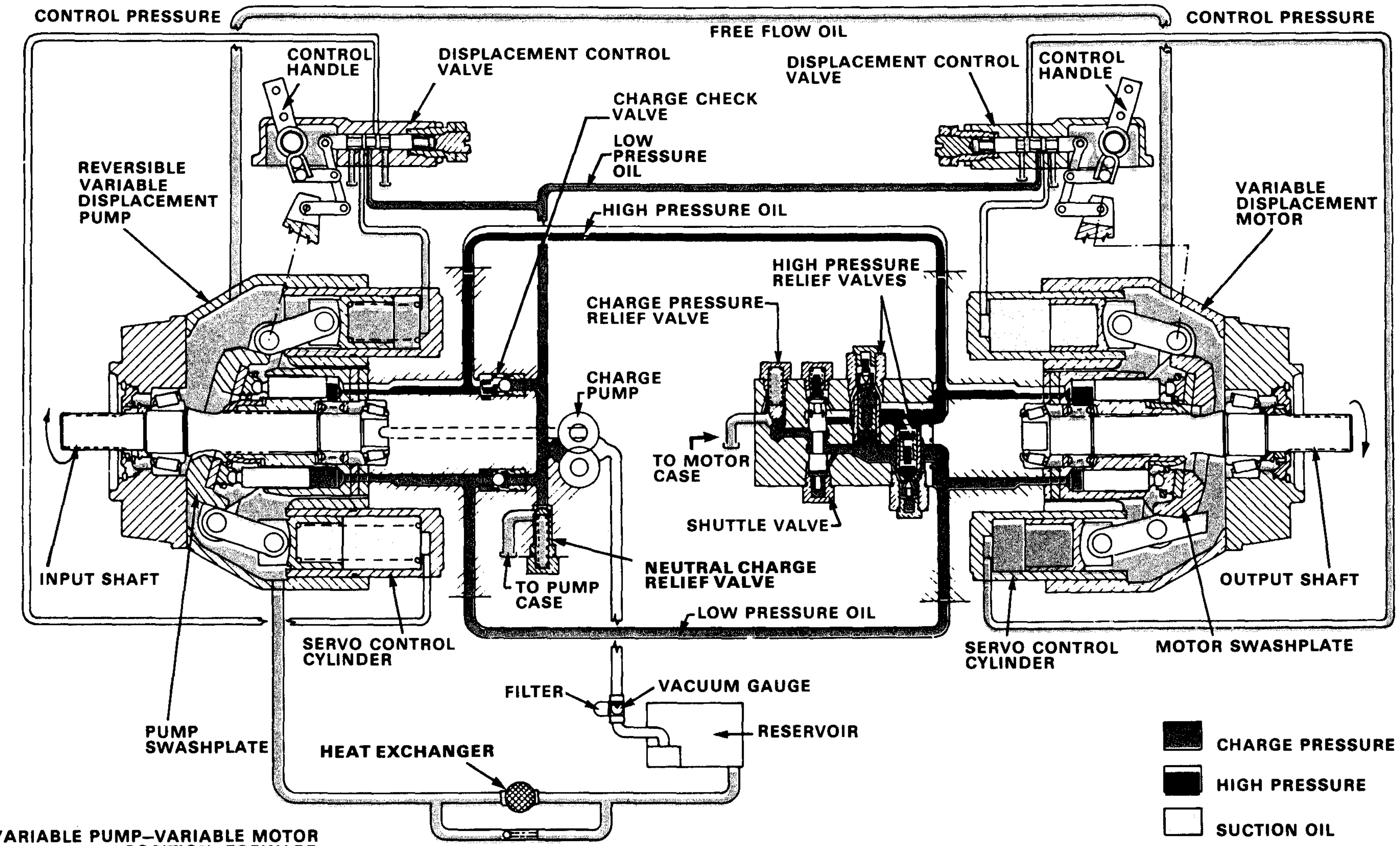
TYPICAL HEAVY DUTY VARIABLE PUMP–FIXED MOTOR TRANSMISSION SCHEMATIC



TYPICAL HEAVY DUTY VARIABLE PUMP—FIXED MOTOR TRANSMISSION SCHEMATIC



TYPICAL HEAVY DUTY VARIABLE PUMP VARIABLE MOTOR TRANSMISSION SCHEMATIC



VARIABLE PUMP–VARIABLE MOTOR
POSITION: FORWARD

Sundstrand Hydro-Transmission
AMES, IOWA 50010
unit of Sundstrand Corporation

Bulletin 9582-A
January 1972

VII. EXPLANATION OF SCHEMATIC

Charge Pump Circuit

Oil flows from the reservoir through a filter to the inlet of the Charge Pump mounted on the main Pump which is driven at Pump shaft speed. The purpose of the Charge Pump is to provide a flow of oil through the transmission for cooling purposes, to supply oil under pressure to maintain a positive pressure on the low pressure side of the main Pump/Motor circuit, to provide sufficient oil under pressure for control purposes, and for internal leakage makeup.

Main Pump and Motor Circuit

Oil from the Charge Pump is directed to the low pressure side of the main circuit by means of one of two Check Valves. The second Check Valve is held closed by the oil under high pressure on the other side of the main circuit.

Oil flows in the main circuit in a continuous closed loop. The quantity of oil flow is determined by pump speed and displacement while direction of flow is determined by the swashplate angle from neutral.

A Manifold Valve Assembly, connected across the main circuit, includes elements essential to provide the proper operation of the transmission. The manifold valve contains two pilot operated high pressure relief valves which serve to prevent sustained abnormal pressure surges in either of the two main hydraulic lines by dumping oil from the High Pressure Line to the Low Pressure Line during rapid acceleration, abrupt braking, and sudden application of load.

Also provided in the Manifold Valve Assembly is a Shuttle Valve and a charge pressure relief valve. The Shuttle Valve functions to establish a circuit between the main line that is at low pressure, and the Charge Pressure Relief Valve to provide a method of controlling the Charge Pressure level and also a means of removing the excess cooling oil added to the circuit by the Charge Pump. The Shuttle Valve is spring centered to a closed position so that during the transition of the reversing of pressures in the main lines, none of the high pressure oil is lost from the circuit.

COOLING CIRCUIT

Excess cooling oil from the manifold Charge Pressure Relief Valve enters the Motor Case, then flows through Case Drain Lines to the Pump Case. In this way the Charge Pump cooling oil is circulated through each of the hydraulic elements in series to aid in cooling. The cooling oil then exits from the Pump Case, passes through the heat exchanger and is returned to the reservoir. The By-Pass Valve is to prevent high case back pressure at the heat exchanger due to cold oil or a restricted cooler. During periods of operation when the main pump is in neutral, the Shuttle Valve will be closed and the excess from the Charge Pump is directed to the cooling circuit by the Neutral Charge Relief Valve in the Charge Pump. When operating at this condition, cooling flow is not admitted to the motor (s) because it is at rest.

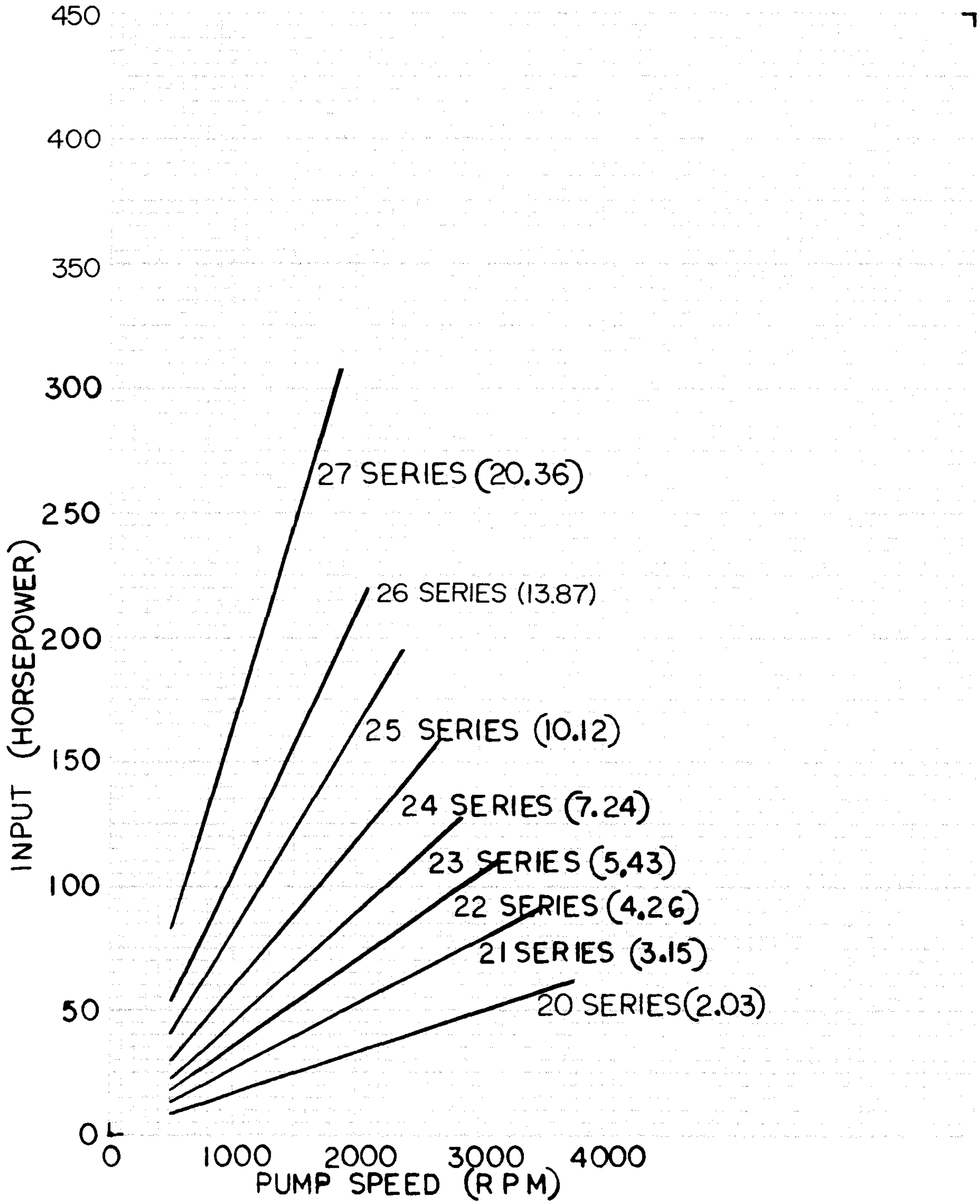
CONTROLS

Control of speed and direction is accomplished by the movement of a single Control Lever from a neutral position. The pump swashplate is spring loaded to neutral position to insure positive neutral. The swashplate is provided with two opposed single acting Servo Cylinders to move the Swashplate and thus vary pump displacement. Pressurizing one of the Cylinders while exhausting the other will move the swashplate from its neutral position. To obtain the reverse direction from neutral, the opposite cylinder is pressurized and the other is exhausted. Oil is directed to the desired Servo Cylinder by the Control Valve which is activated by a signal from the operator through the Control Lever or from the Swashplate and its feed-back linkage system. If the circuit pressures tend to overcome the Swashplate-Servo Piston preset position, the feed-back linkage connecting the Swashplate to the Control Valve will activate the Control Valve and supply adequate pressure to the Servo Piston and maintain the Swashplate in its position determined by the operator. The Control Valve is spring centered and contains sufficient underlap to open both Servo Cylinders to drain when the Control Lever is in neutral. This permits the Servo Cylinder Centering Springs to move the Swashplate to the zero stroke position insuring a positive neutral.

Various types of controls are available: i.e. displacement (described above), pressure override, torque, etc. to provide the drive best suited for the application.

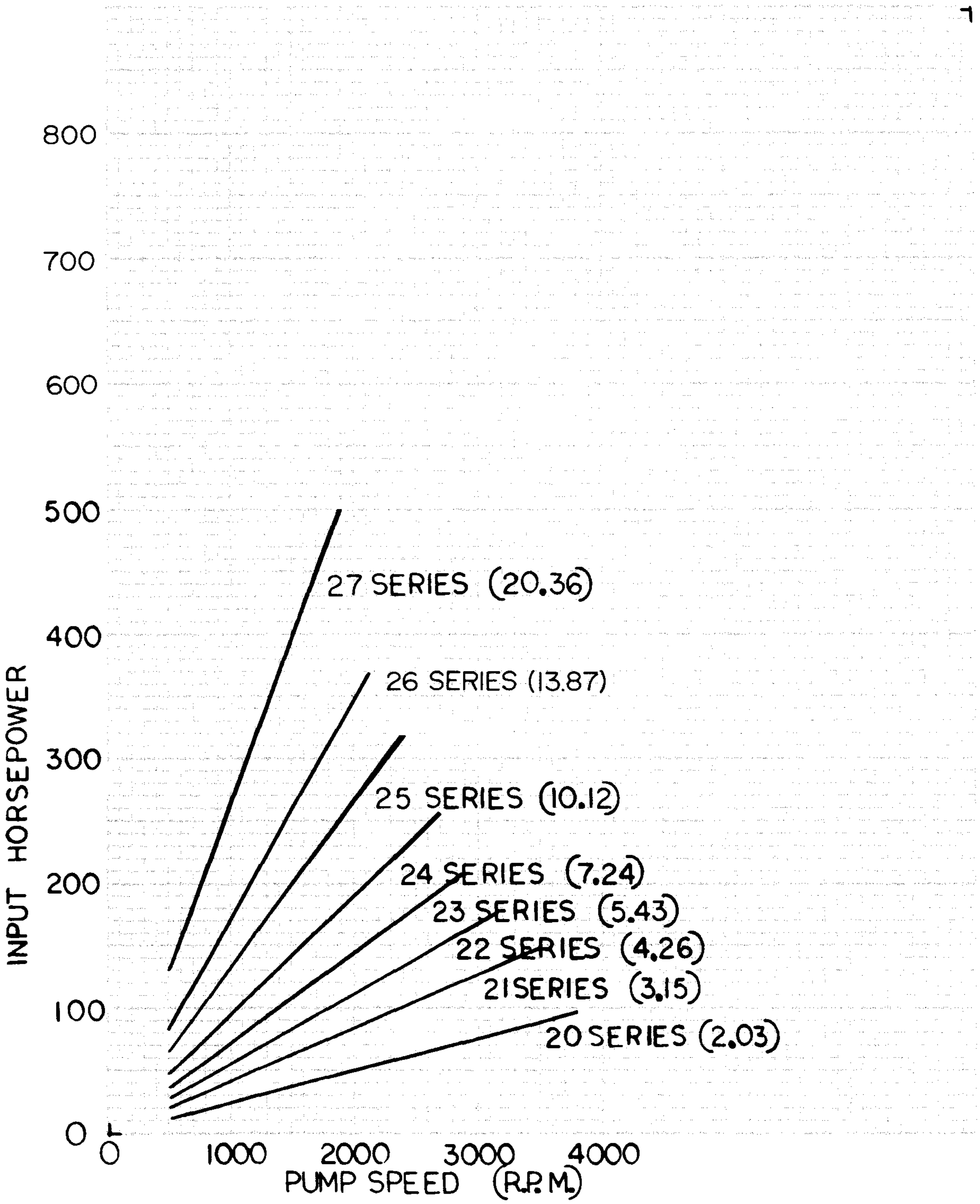
Revised 6-70

HORSEPOWER INPUT TO PUMP AT 3000 PSI
18° SWASHPLATE ANGLE



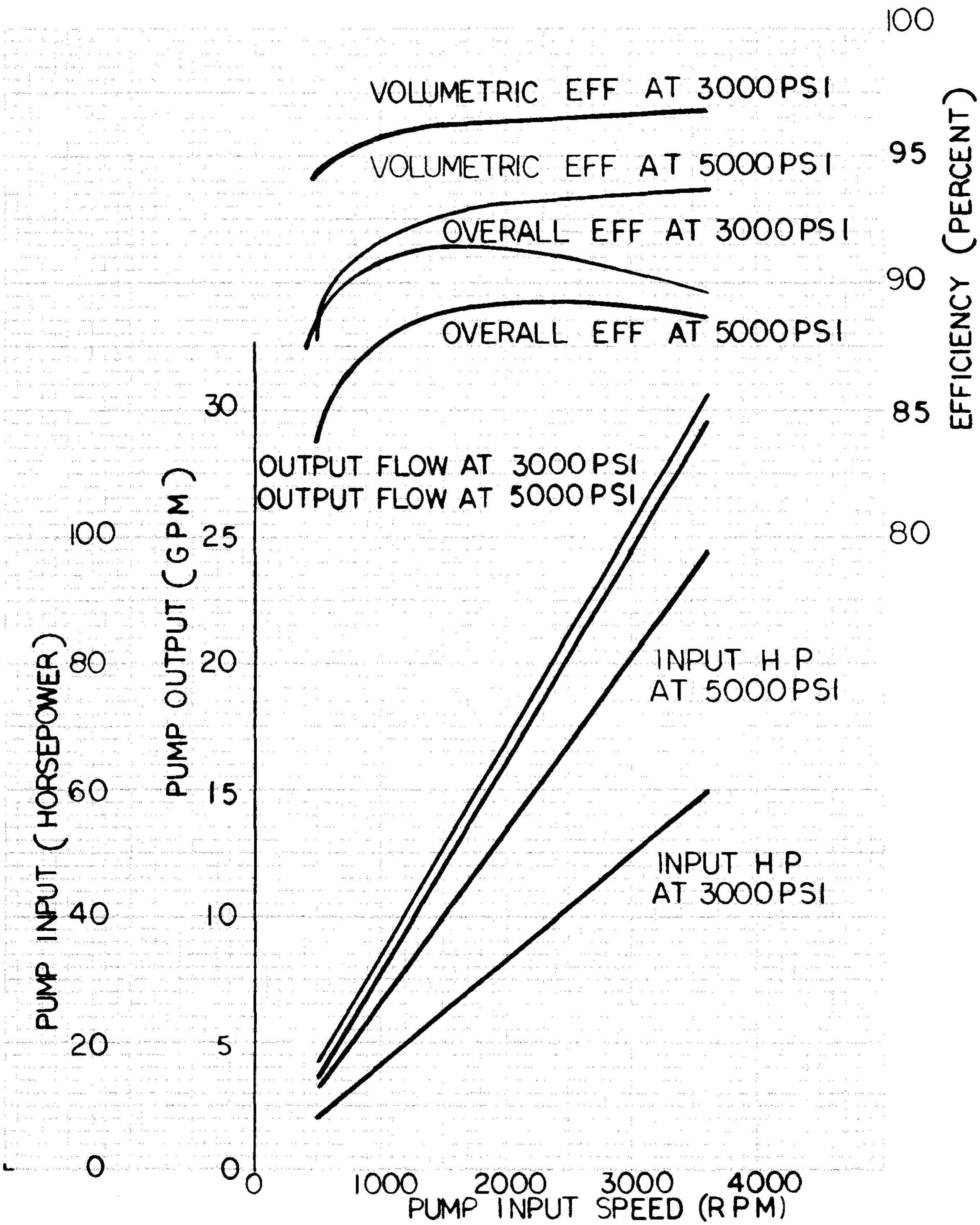
THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

HORSEPOWER INPUT TO PUMP AT 5000PSI
18° SWASHPLATE ANGLE



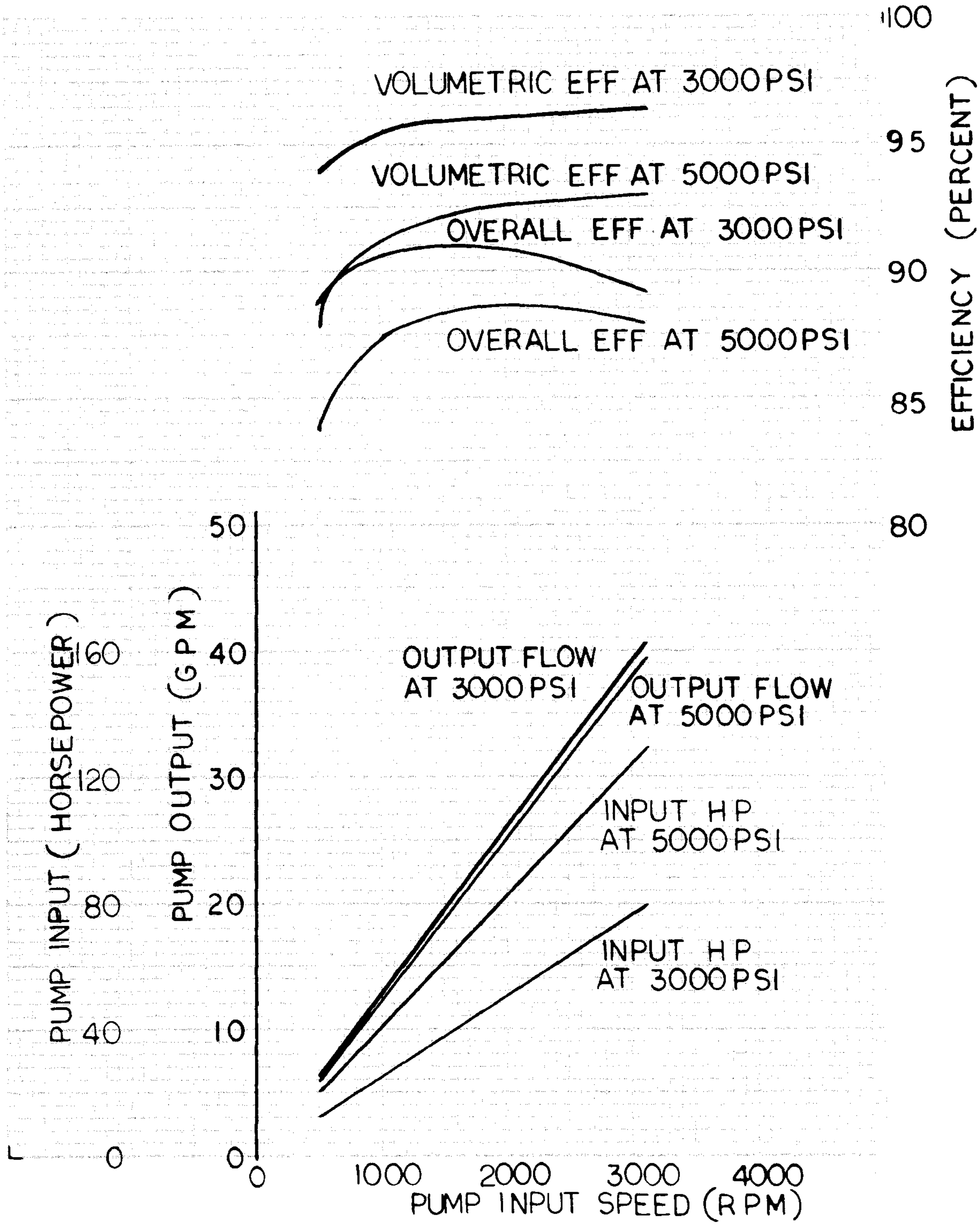
THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 20 SERIES PUMP
18° SWASHPLATE ANGLE



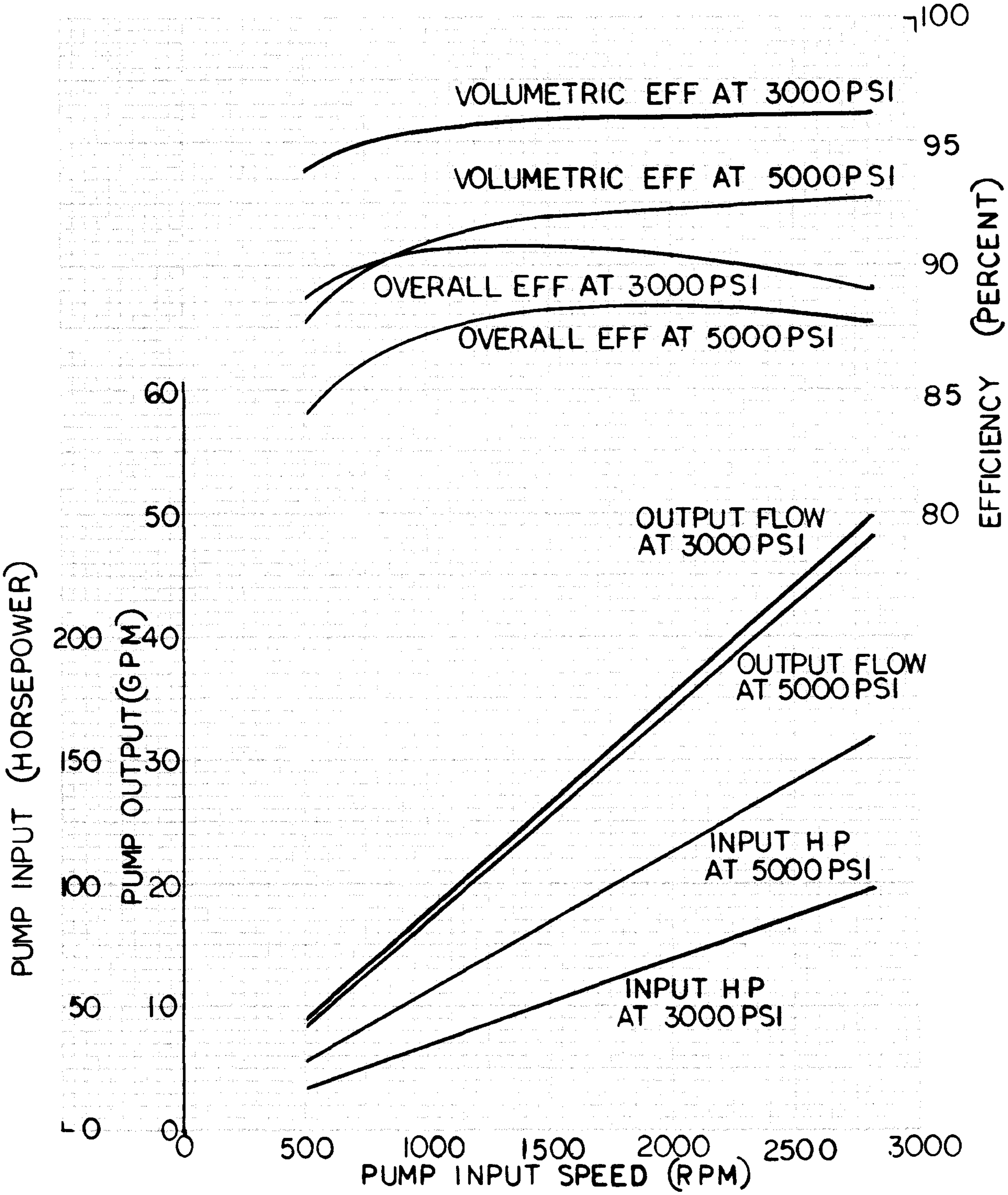
THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 21 SERIES PUMP
18° SWASHPLATE ANGLE



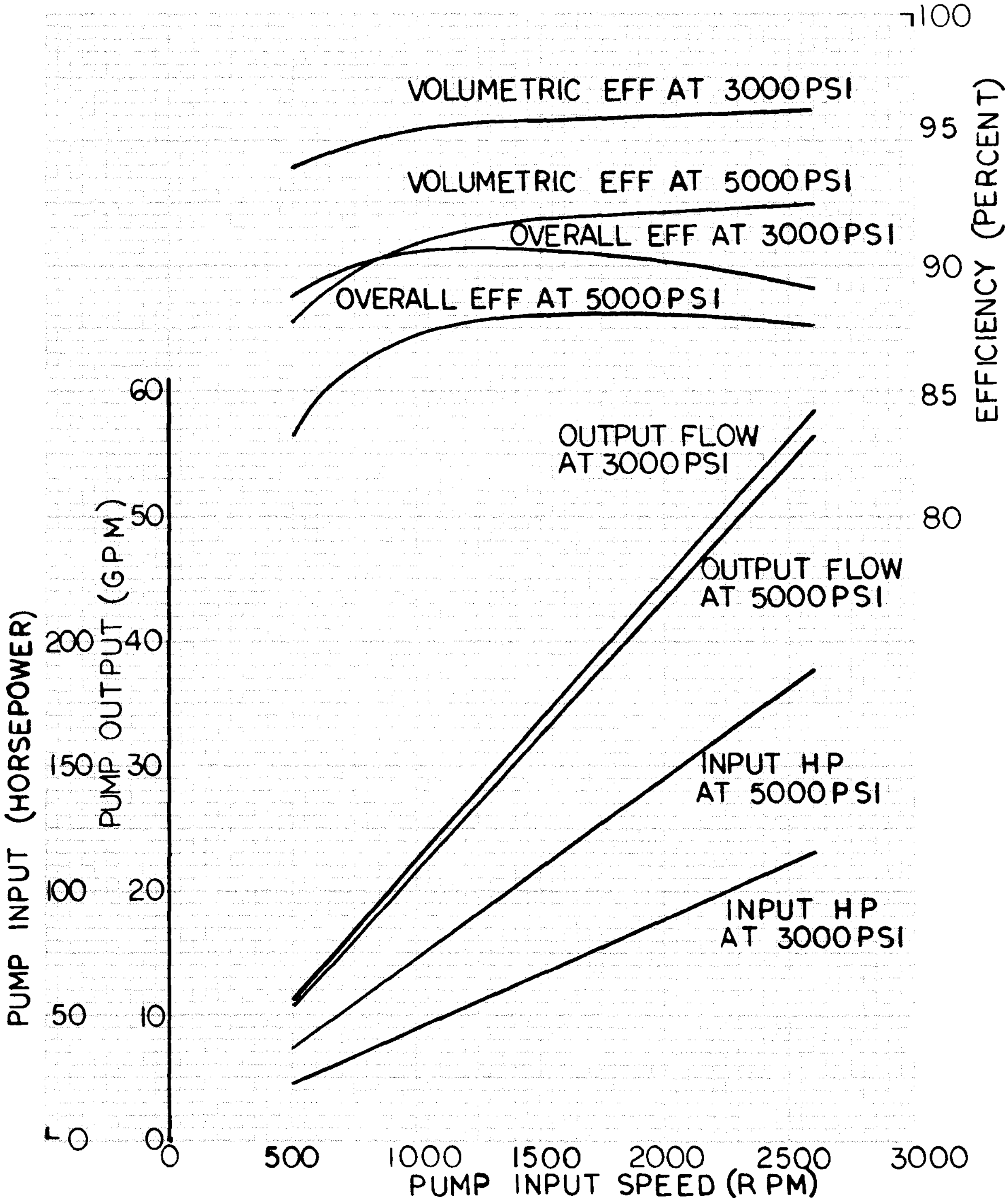
THESE CURVES DO NOT TAKE INTO ACCOUNT
LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 22 SERIES PUMP
18° SWASHPLATE ANGLE



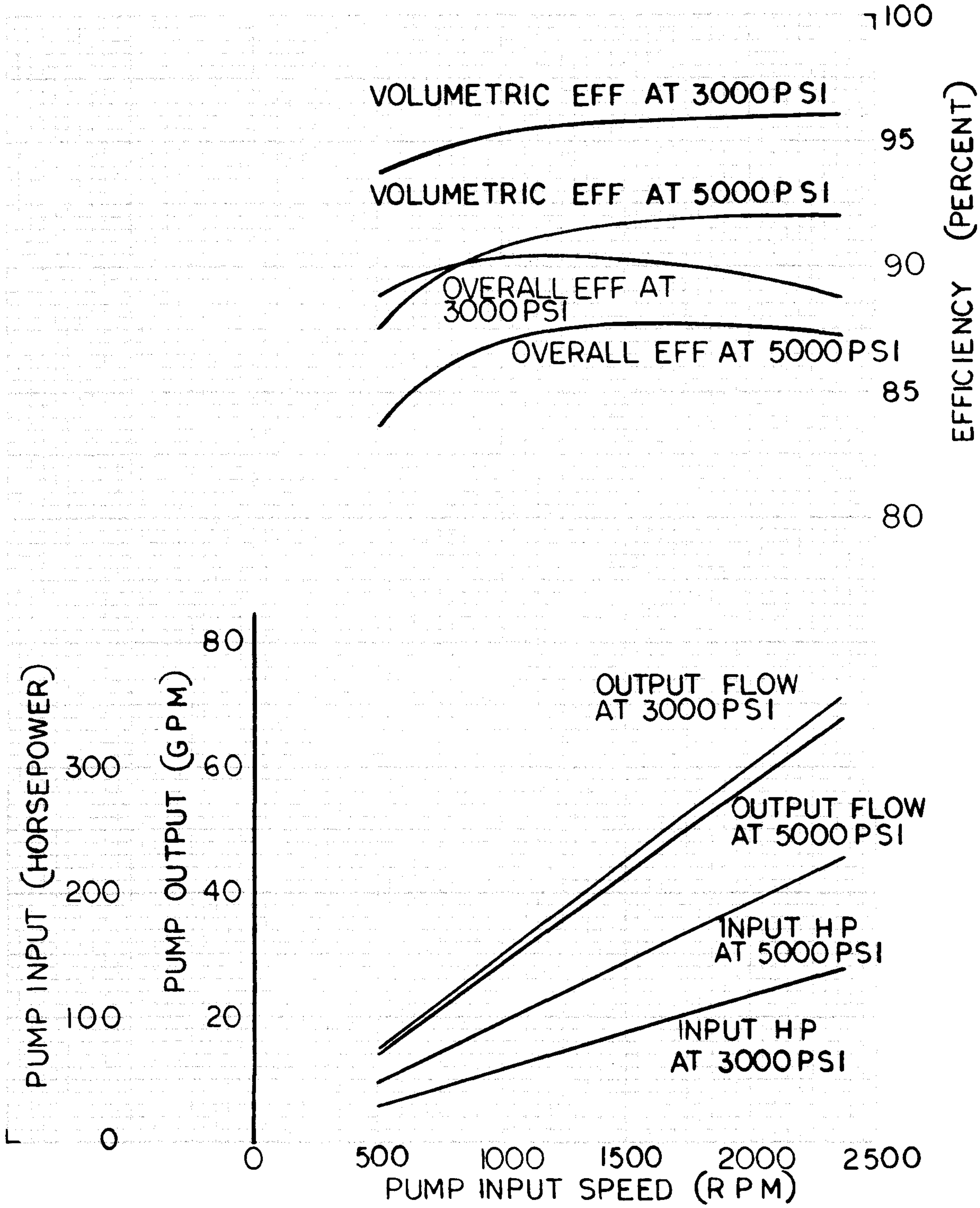
THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 23 SERIES PUMP
18° SWASHPLATE ANGLE



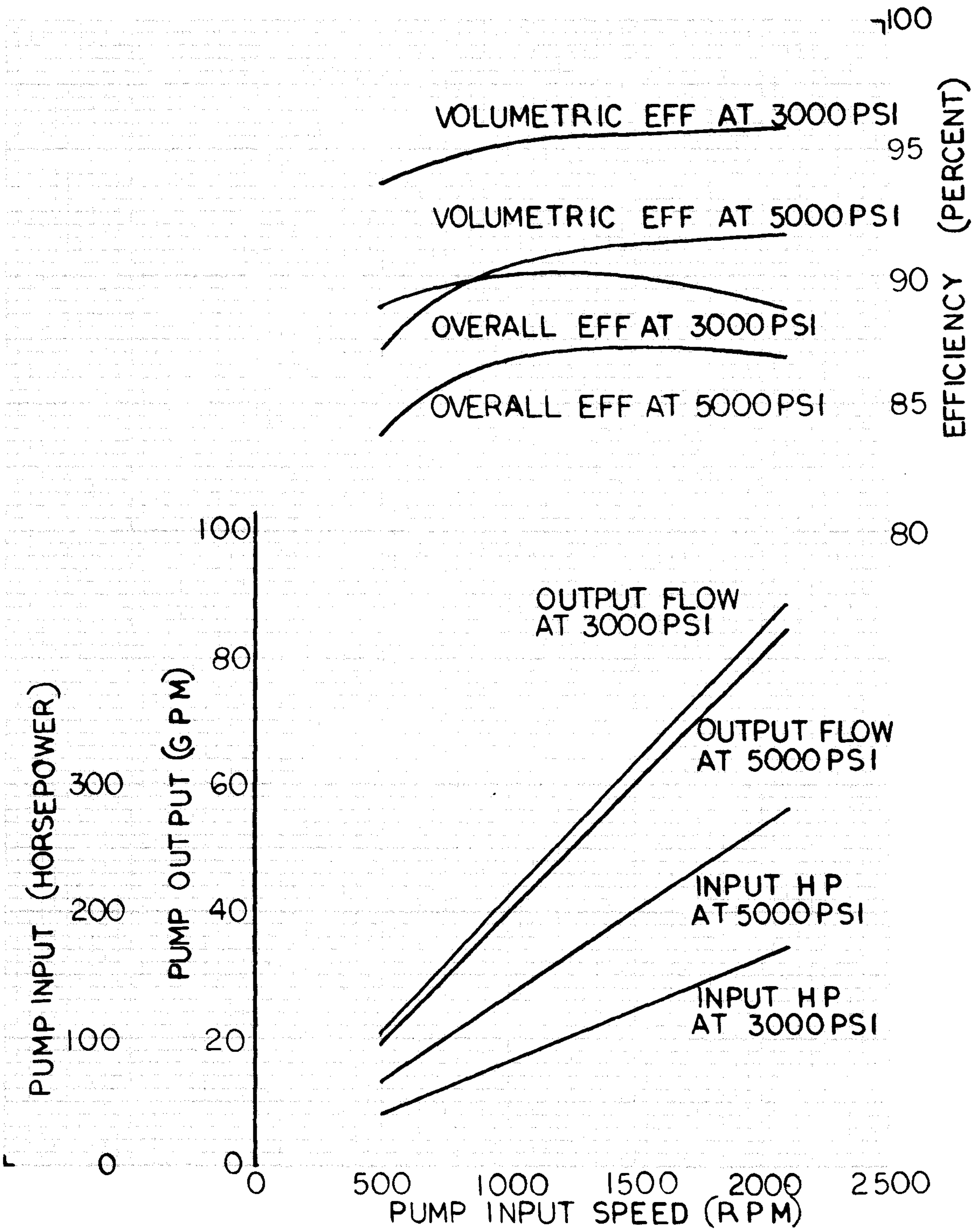
THESE CURVES DO NOT TAKE INTO ACCOUNT
LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 24 SERIES PUMP
18° SWASHPLATE ANGLE

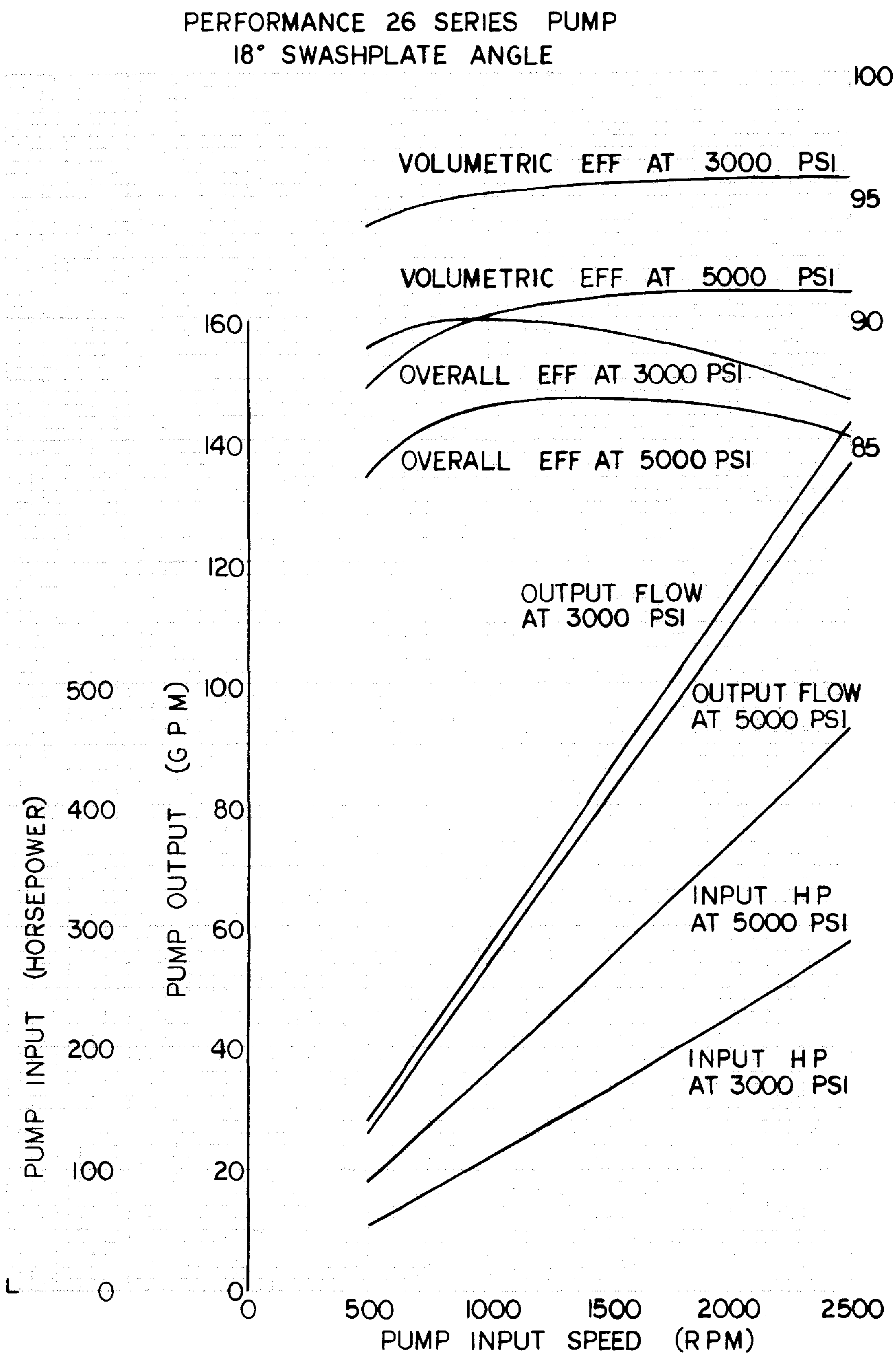


THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 25 SERIES PUMP
18° SWASHPLATE ANGLE

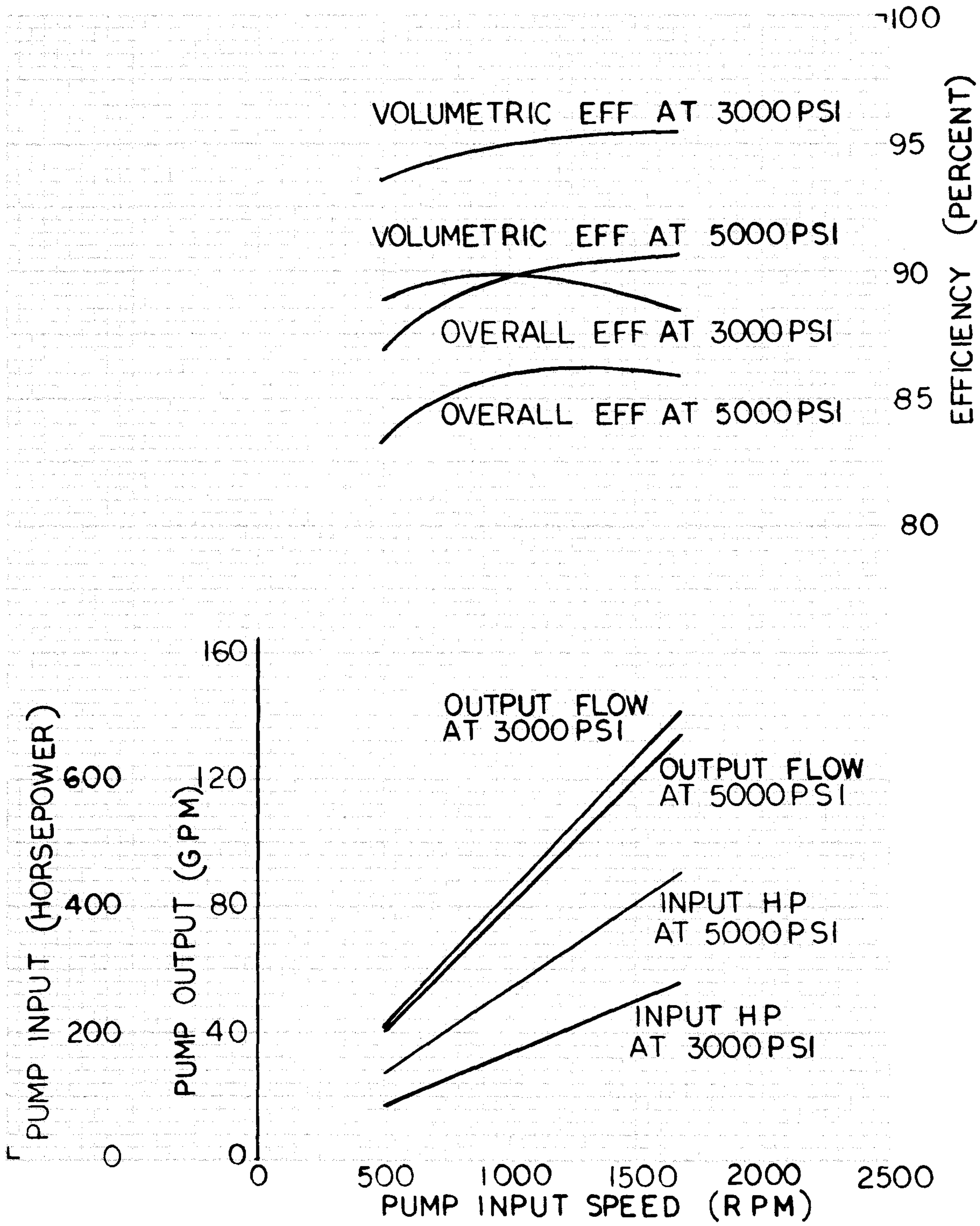


THESE CURVES DO NOT TAKE INTO ACCOUNT
LOSSES DUE TO THE CHARGE PUMP



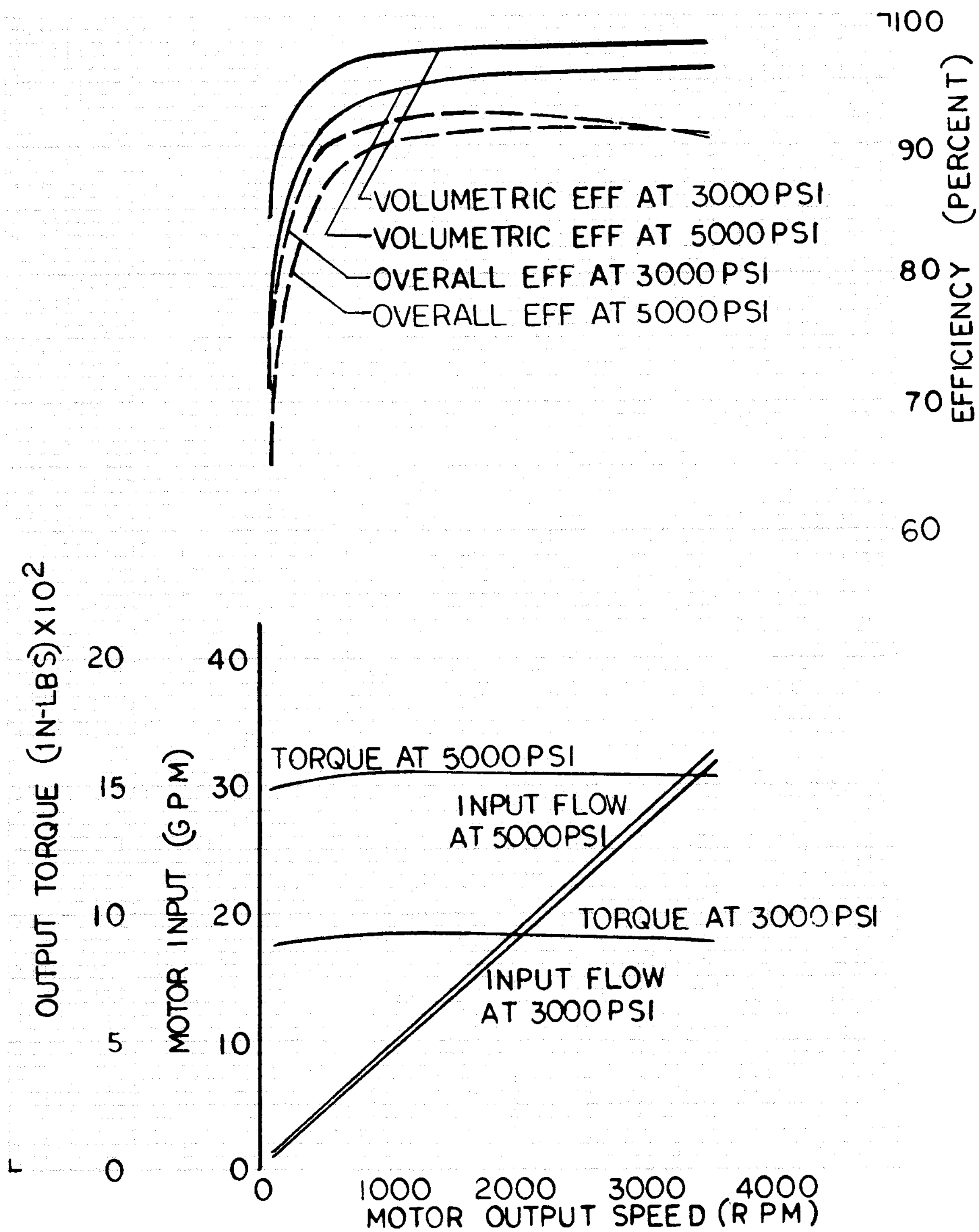
THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

PERFORMANCE 27 SERIES PUMP
18° SWASHPLATE ANGLE

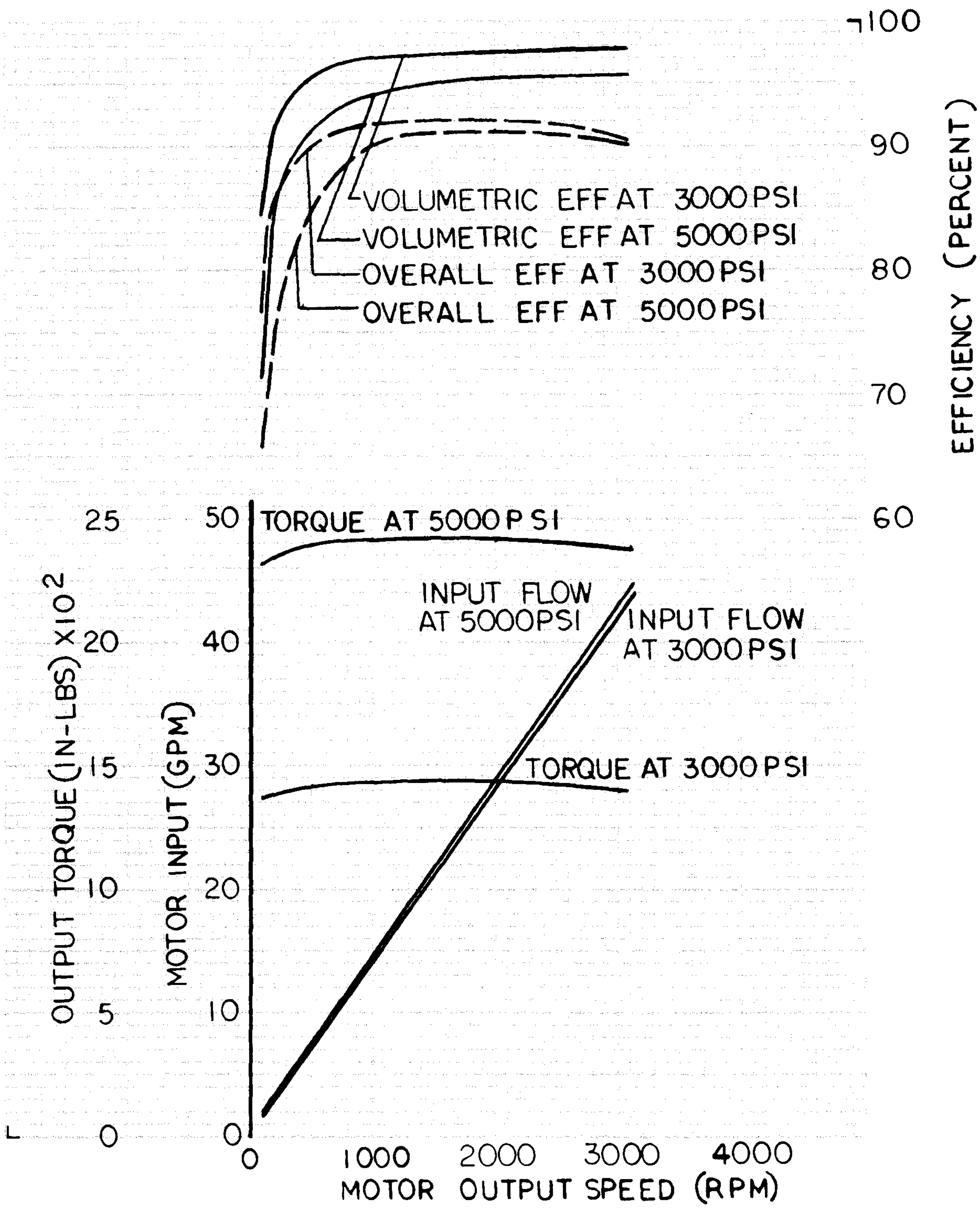


THESE CURVES DO NOT TAKE INTO ACCOUNT LOSSES DUE TO THE CHARGE PUMP

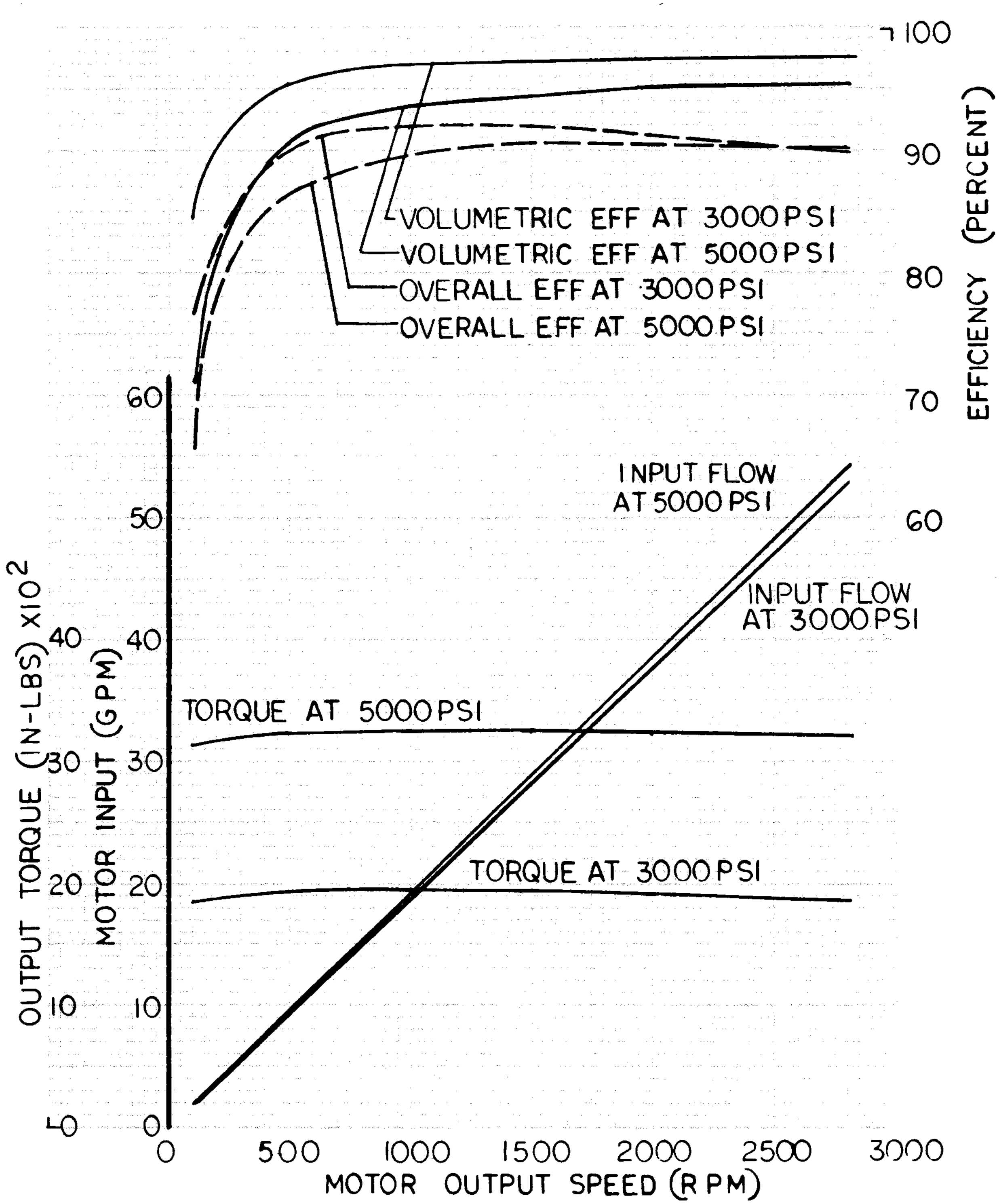
PERFORMANCE 20 SERIES MOTOR
18° SWASHPLATE ANGLE



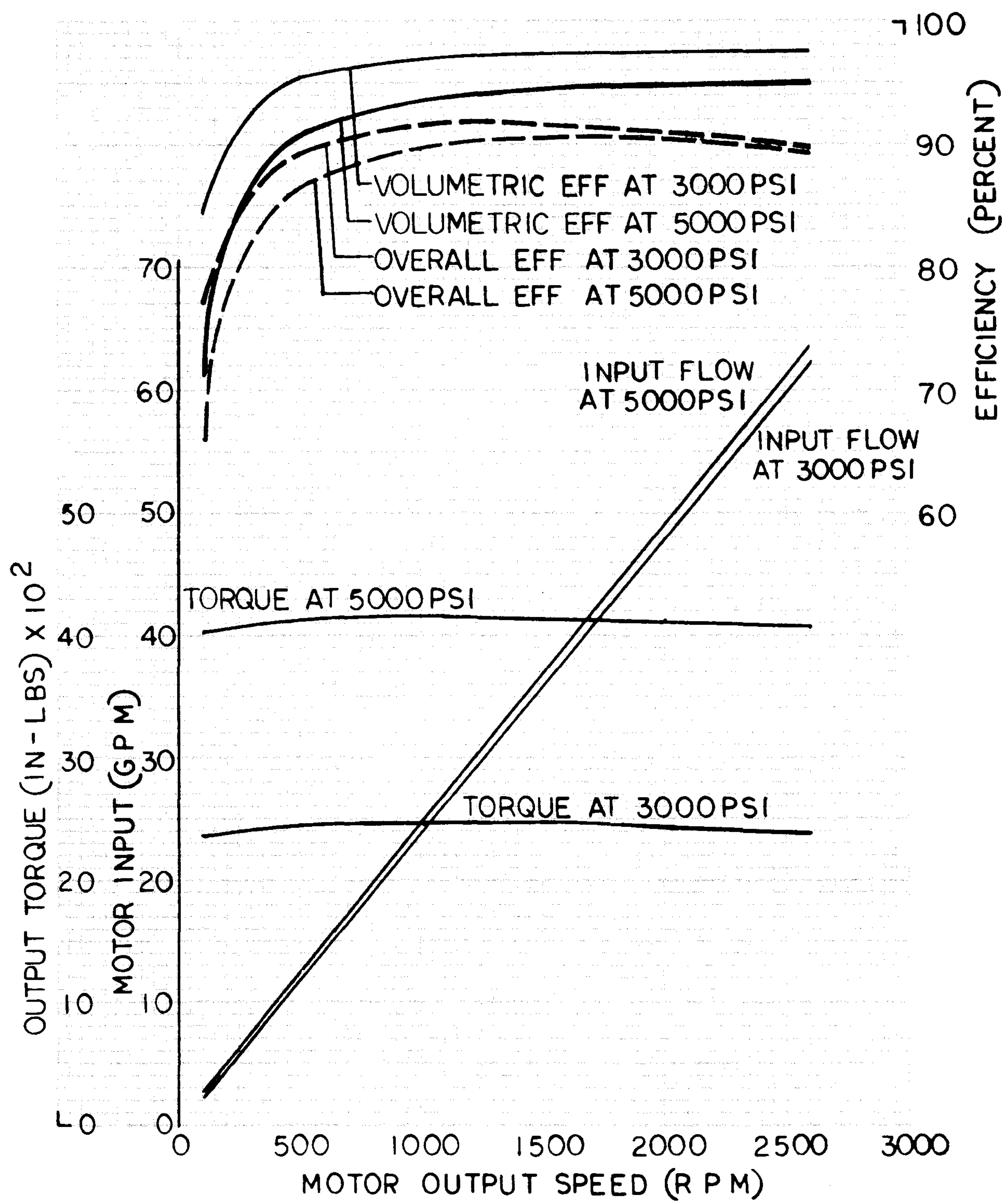
PERFORMANCE 21 SERIES MOTOR
18° SWASHPLATE ANGLE



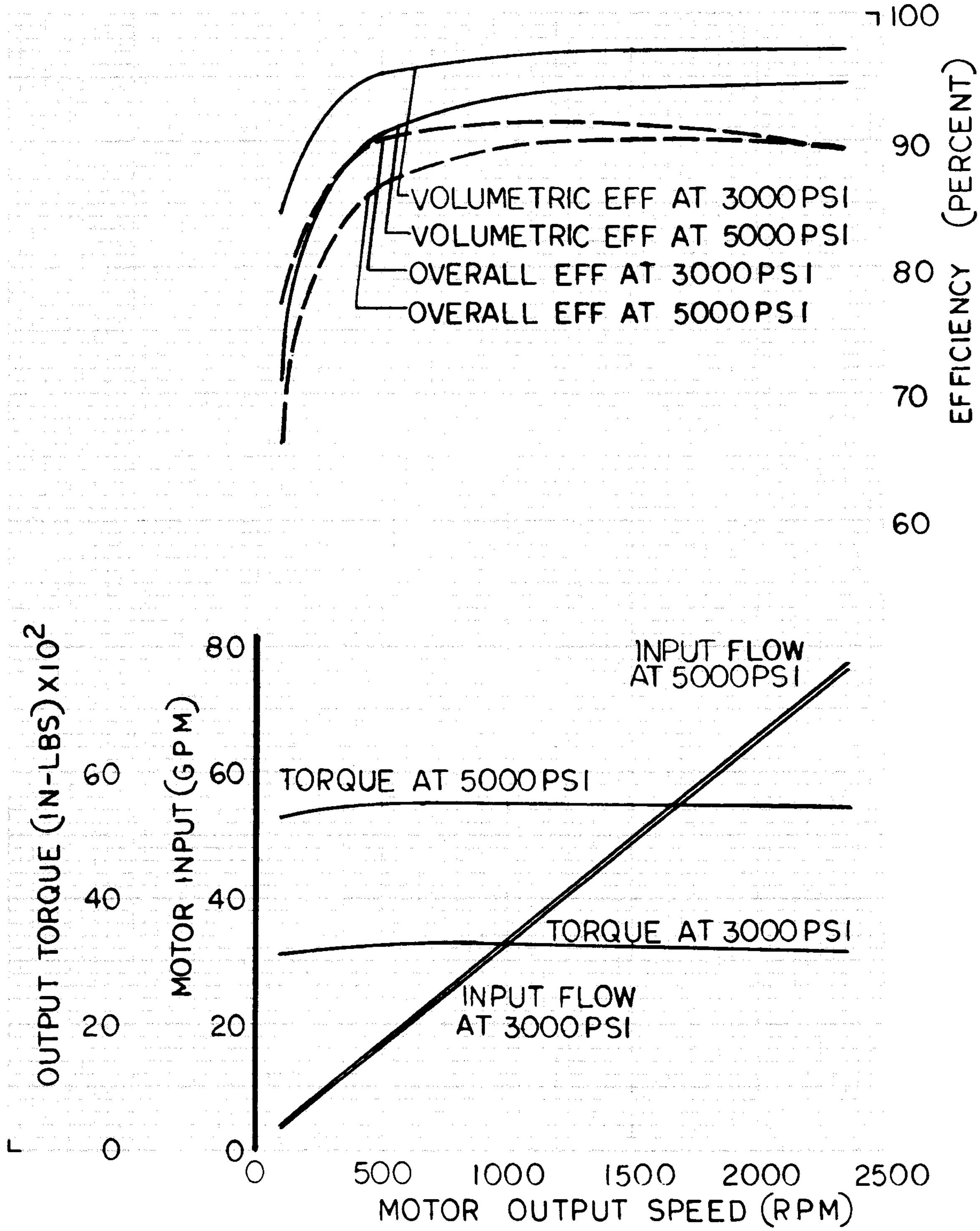
PERFORMANCE 22 SERIES MOTOR
18° SWASHPLATE ANGLE



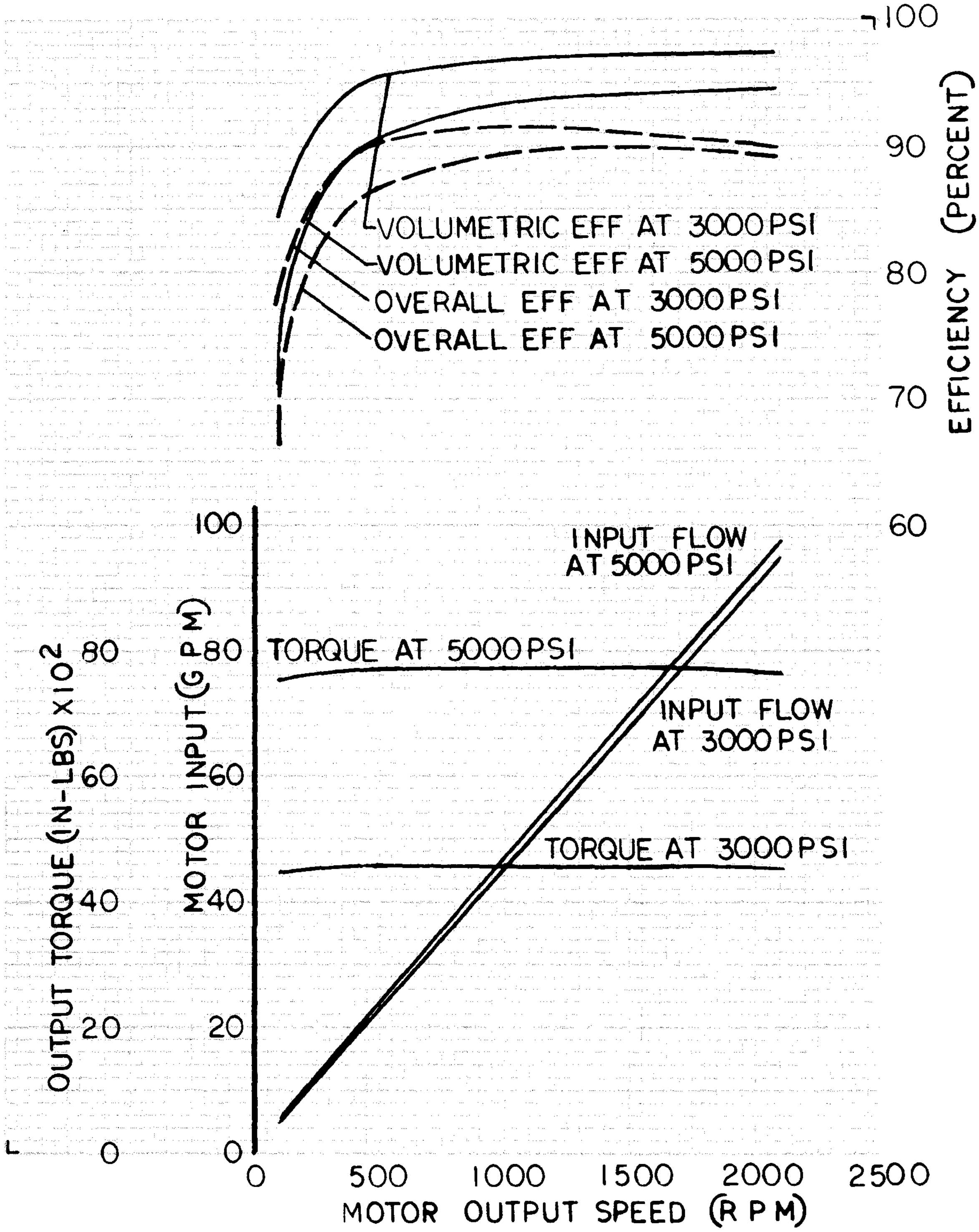
PERFORMANCE 23 SERIES MOTOR
18° SWASHPLATE ANGLE

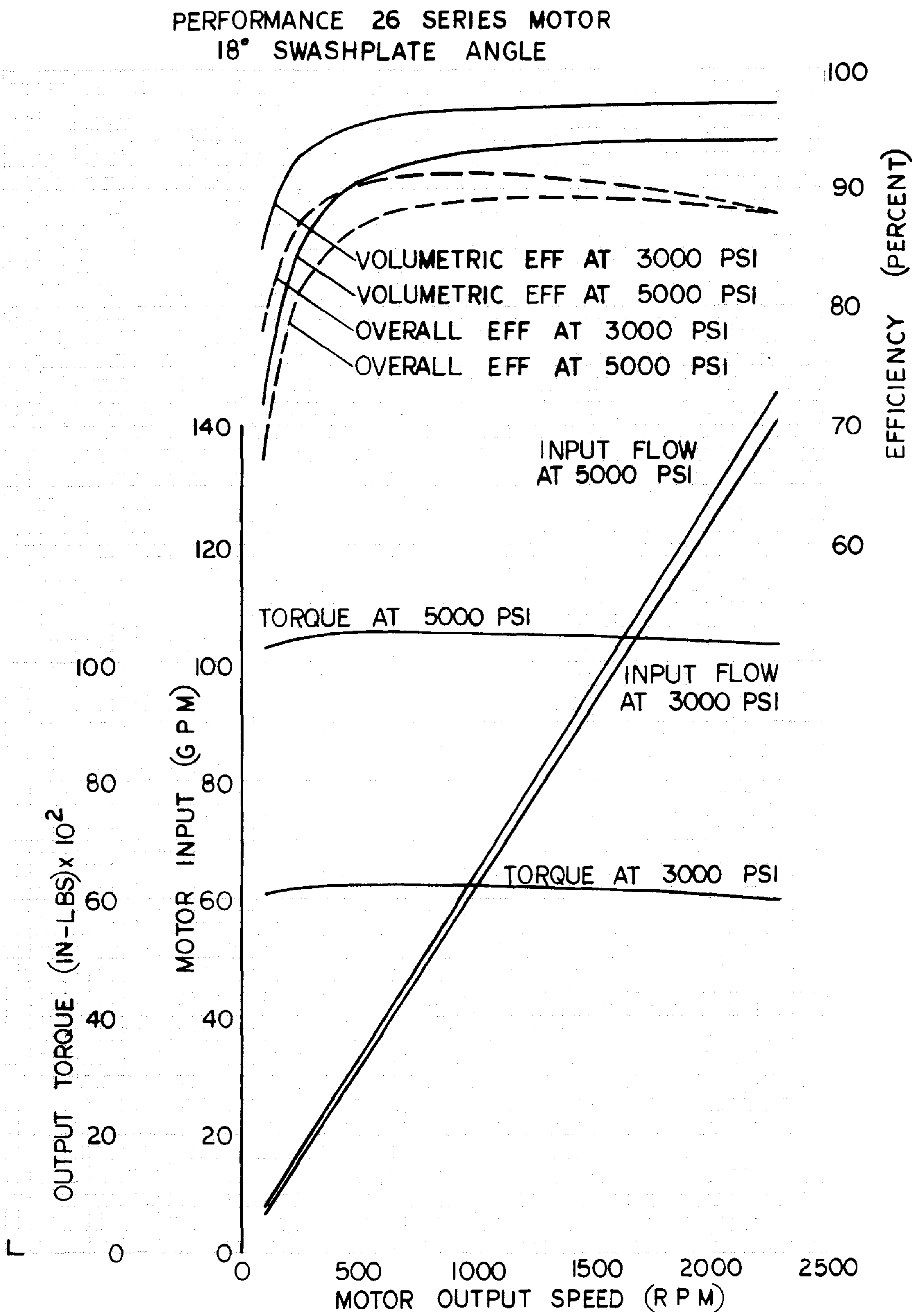


PERFORMANCE 24 SERIES MOTOR
18° SWASHPLATE ANGLE

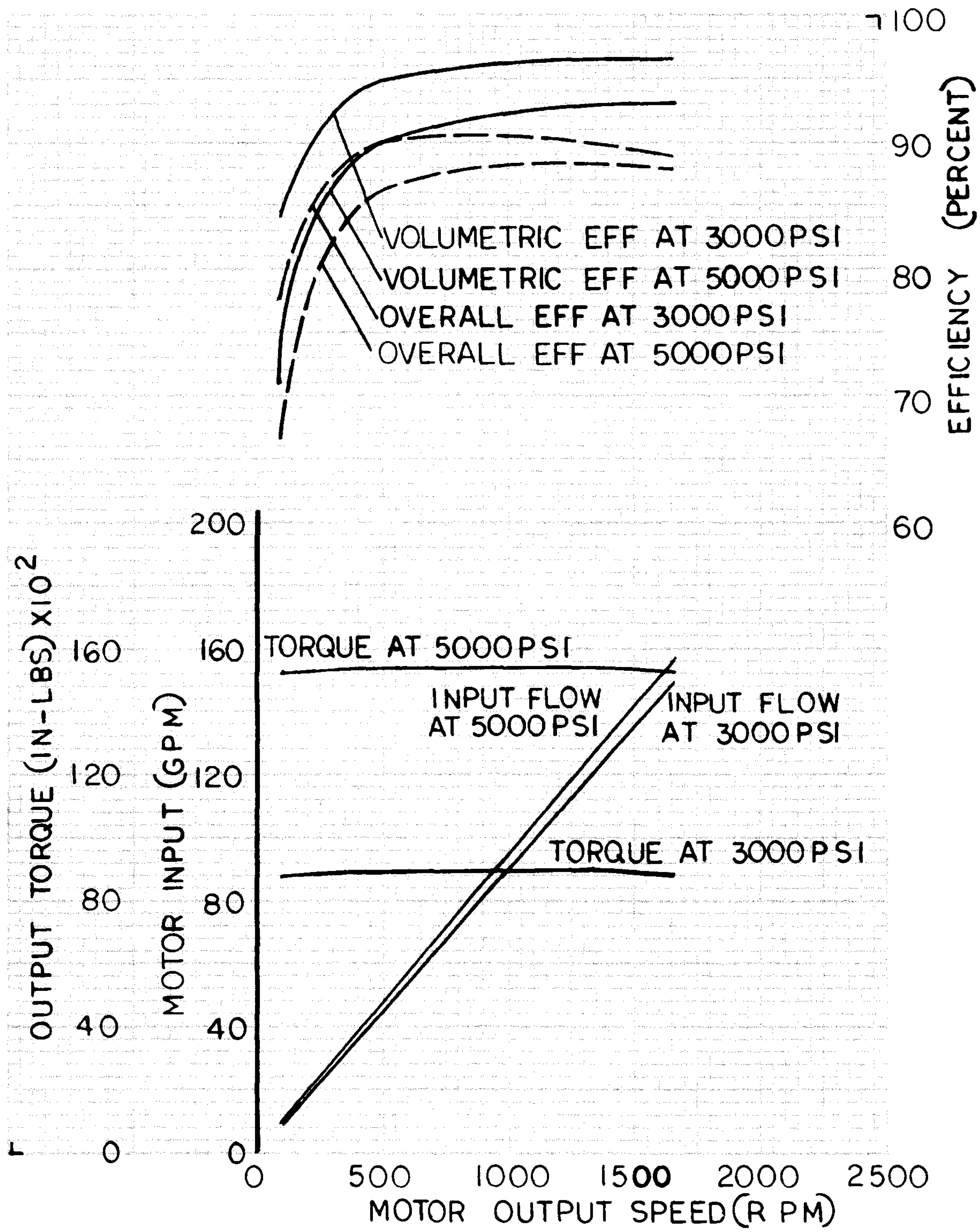


PERFORMANCE 25 SERIES MOTOR
18° SWASHPLATE ANGLE

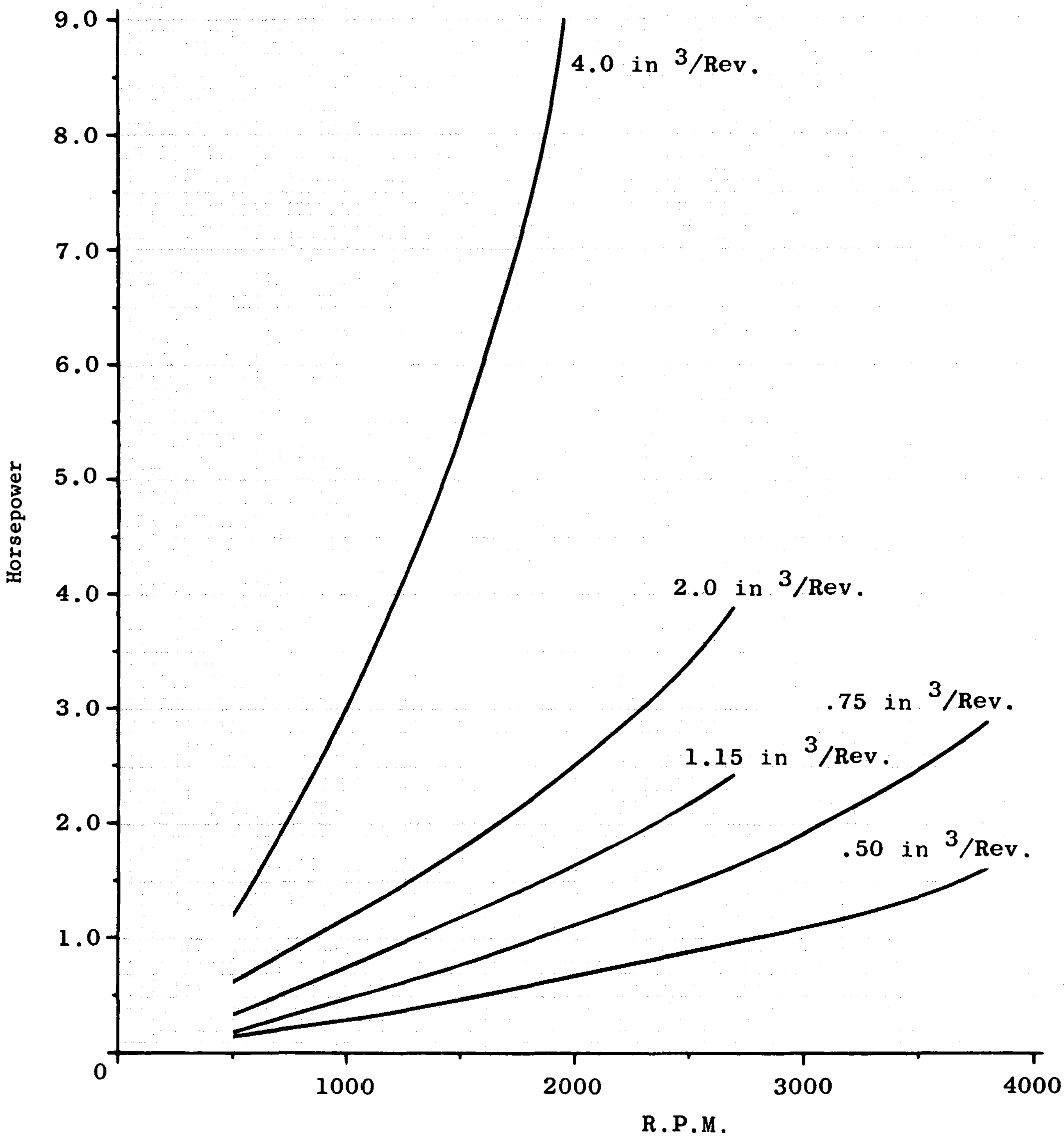



PERFORMANCE 26 SERIES MOTOR
18° SWASHPLATE ANGLE
VOLUMETRIC EFF AT 3000 PSI
VOLUMETRIC EFF AT 5000 PSI
OVERALL EFF AT 3000 PSI
OVERALL EFF AT 5000 PSI
INPUT FLOW AT 5000 PSI
TORQUE AT 5000 PSI
INPUT FLOW AT 3000 PSI
TORQUE AT 3000 PSI
EFFICIENCY (PERCENT)
100
90
80
70
60
MOTOR INPUT (G P M)
140
120
100
80
60
40
20
0
OUTPUT TORQUE (IN-LBS) x 10²
100
80
60
40
20
0
MOTOR OUTPUT SPEED (R P M)
0
500
1000
1500
2000
2500

PERFORMANCE 27 SERIES MOTOR
18° SWASHPLATE ANGLE



CHARGE PUMP HORSEPOWER
(ESTIMATED)



Nominal Charge Pressure = 160 -180 PSI

TRANSMISSION LIFE:

The transmission operating life is dependent on the B-10 rating of the bearings. These bearings are designed to provide the B-10 bearing lives as shown on page 16, item SS.

Where external side loads are applied to the drive shafts, the bearing life will be reduced accordingly. The factory should be contacted for the maximum allowable shaft loading and the corresponding bearing life information.

The life of the sliding surfaces within the hydraulic unit is dependent upon the degree of contamination in the hydraulic fluid. The related wear on these parts will be negligible when observing recommended operating conditions. Furthermore, there will be no rupture or breakage of internal parts when observing recommended operating conditions since the fatigue limit on all parts exceeds the normal relief valve setting of 5,000 p.s.i.

RATING CHART

Series	Displacement Cu.In./Rev.	Max. Shaft Speed*	Corner Horsepower (CHP) 18° (PV/MF) Theo. (At Max. Shaft Speed and 5000 p.s.i.)
20	2.03	3800	97
21	3.15	3500	140
22	4.26	3200	173
23	5.43	2900	199
24	7.24	2700	247
25	10.12	2400	308
26	13.87	2100	368
27	20.36	1900	490

Contact Factory for Speed Limits on MV Transmissions.

*These speeds effective only on units factory built after January 1, 1971, Serial #LA40000

Revised 6-72

IX. HOW TO SELECT THE PROPER PUMP AND MOTOR SIZE

The Sundstrand heavy duty series offers a range of nine (9) sizes, from 2 in.3/rev. to over 34.08 in.3/rev. These pumps and motors can be used in various combinations to provide maximum performance at minimum drive line cost. To properly size a transmission requires accurate knowledge of pump input conditions and motor output requirements. This includes common parameters as:

1. Power source, horsepower rating, high idle (unloaded) speed, and torque characteristics.
2. Horsepower available to pump at rated R.P.M. after deducting parasitic losses.
3. Motor Output Torque
   A. Maximum Required
   B. Normal Operating Level
4. Motor Output Speed
   A. Maximum Required
   B. Normal Operating Level
5. Transmission Life Requirements

To properly evaluate these output conditions, information must be known on gear ratios and efficiency, wheel load radius, rolling resistance, etc.

To select the proper transmission, the motor size is first determined:

1. Calculate the required maximum motor torque and speed using desired gear ratios, etc.
2. Select the required motor size using the motor performance curves. Also determine maximum motor flow from curve.
3. Select the pump size from the pump performance curves to provide the maximum flow required by the motor.

If the pump is to be direct driven, the pump speed may not be adequate to drive the motor. Several corrective routes are possible.

1. Change the final drive ratio to match the motor speed requirements to that available at the pump.
2. Increase the speed of the power plant.
3. Select a larger pump.

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IX. A quick method of determining the minimum transmission size is the corner horsepower method (CHP), as follows: (Refer to equations)

1. Calcuate the required CHP of the system output (i.e. DBP x mph/375, etc.)
2. Select a motor with a CHP equal or greater than the system requirement (see chart), including final drive efficiency.
3. Select the final drive ratio to match motor output (speed or torque) to system requirement (MPH or rim pull, etc.)
4. Select a pump of equal size to the motor.
5. Select input ratio to drive the pump at a speed approximately 5% faster than the maximum required motor speed (refer to chart for pump and motor speed limits).
6. Check maximum output speed and load using efficiencies from performance charts. Adjust gear ratio selections, if necessary.

SPEED LIMIT

To insure proper functioning of the hydrostatic transmission, the listed maximum speed limits for pumps and motors must never be exceeded.

When determining the maximum speed, the following factors must be determined:

The ability of the transmission to over drive the maximum prime mover governed speed in a braking condition, will determine the maximum pump speed (n_p).

The maximum motor speed, when the motor is acting as a pump can be determined by the following equation:

$$n_m = n_p \frac{D_p}{D_m} \frac{1}{n_{vm} \times n_{vp}}$$

The above equation can be rearranged and solved for n_p for those cases where the engine does not have sufficient capability to limit the speed of the pump.

LOW SPEED OPERATION

Proper functioning of the hydrostatic transmission, under load, at low input speed is dependent upon supplying sufficient charge flow to the system to insure adequate leakage make up, control flow, and cooling flow requirements. Having sufficient charge flow under load at low speed will insure that adequate flow will be available at rated speed conditions.

If one or more of the following items are common to your application, Sundstrand should be contacted to assist in evaluating charge flow requirements:

1. Operation, under load, near engine idle with a 1:1 speed ratio or reduction between the engine and pump.
2. Operation under load at low speed with system operating near specified temperature limits.
3. Operation without a displacement control valve orifice.
4. Operation of a system with one pump and multiple motors.

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5. Operation with an external discharge charge pump where some of the total charge flow is being used for an auxiliary function.
6. Operation of a PV-MV circuit where control flow to the motor is being supplied by the charge pump.
7. Operation of a circuit incorporating auxiliary valves, etc. that allow leakage to reservoir.

IX. MULTIPLE PUMP OR MOTOR CIRCUITS

Multiple pumps or motors can be combined in the same closed loop circuit, but should only be used in a parallel (not series) hookup.

If two (2) pumps are used in parallel, the swashplate controls can be operated in phase or in sequence, whichever is more suitable.

When using pumps or motors in parallel, the following precautions should be taken:

1. Motors should be sized to prevent overspeeding in the event that one motor should stall out. This results from the hydraulic parallel acting as a frictionless differential, resulting in motor speeds that are related only to the output conditions. Flow limiting valves may be suitable in each motor mainline to prevent overspeed. This will allow the usage of a smaller sized motor; however, if these valves operate too frequently, overheating of the main circuits may result.

2. The charge pump flow available must be checked against the leakage requirements of the total number of hydraulic units used in the same circuit. Similarly, the charge flow, when using multiple pumps, may be greater than the capacity of the manifold causing a need for additional or larger manifolds. (Contact Sundstrand Engineering Department for details).

3. When using one pump with multiple motors, the case drain line should be routed from the most distant motor and through the remaining motors in series and finally through the pump. With multiple pumps, the case drain flow may be too great for a series drain line hookup and, therefore, a series-parallel or parallel hookup is satisfactory. In any event, each pump and motor should be checked for proper cooling when testing the prototype circuit.

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IX. TRANSMITTED HORSEPOWER

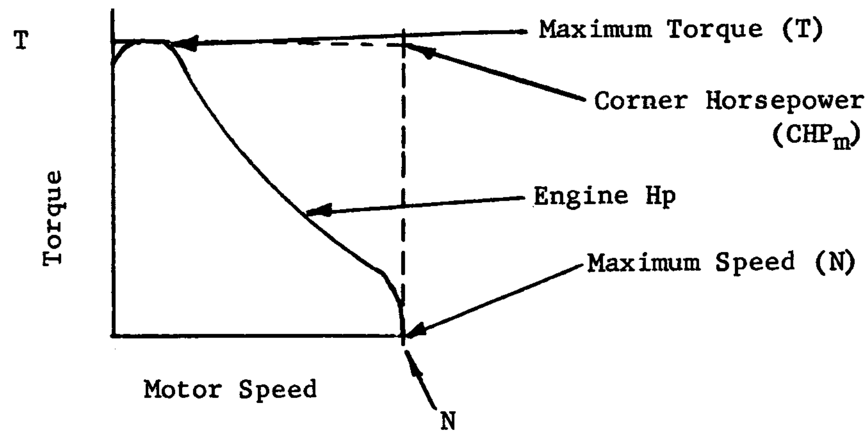
Transmitted horsepower is the steady state power being transmitted from engine to meet a specific operating condition.

CORNER HORSEPOWER (CHP)

Corner Horsepower is a numerical value describing the capability range of a transmission. The range being the maximum torque and the maximum speed available, not necessarily simultaneously. Corner Horsepower is normally greater than the transmitted horsepower. Corner Horsepower is a power value used for sizing the transmission. Corner Horsepower is obtained from the maximum required hydraulic motor torque and speed (CHP_m). Corner Horsepower can also be obtained from maximum axle torque and speed (CHP_a) or maximum tractive effort and speed (CHP_v) as long as the corresponding efficiencies are accounted for and the proper units are used to obtain horsepower.

Example I

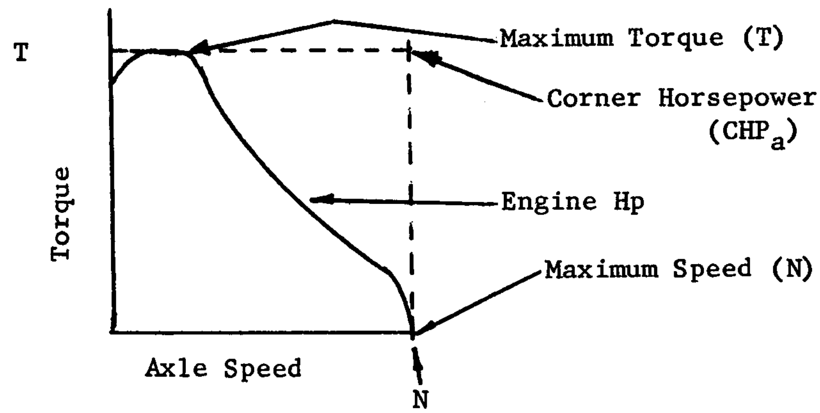
Motor Shaft



$$(CHP_m) = \frac{(T)\ (N)}{63025}$$

Example II

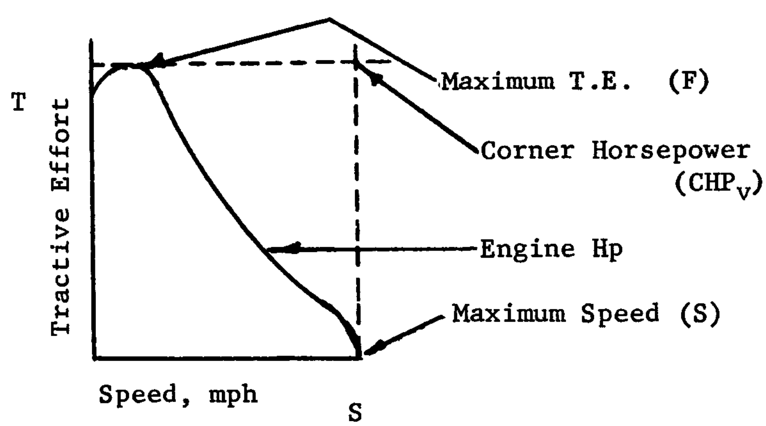
Axle Torque



$$(CHP_a) = \frac{(T)\ (N)}{63025}$$

Example III

Vehicle Performance



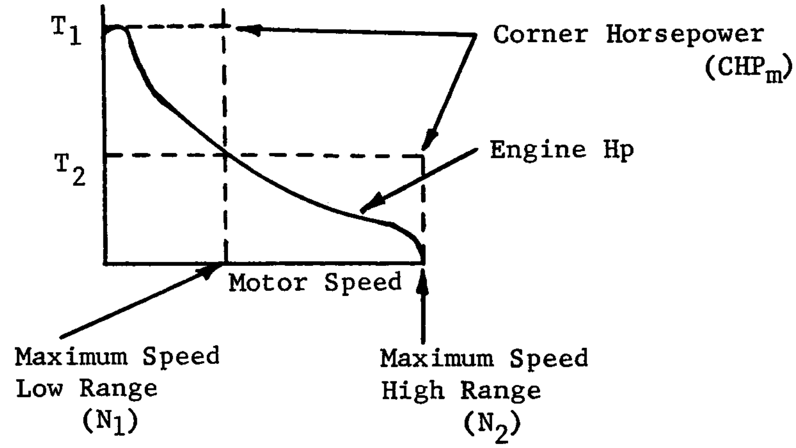
$$(CHP_V) = \frac{(F)\ (S)}{(375)}$$

Example IV

Motor Shaft With Two Speed Gear Box

Maximum Torque Low Range

Maximum Torque High Range



$$CHP_m = \frac{(T_1)\ (N_1)}{63025}$$

$$CHP_m = \frac{(T_2)\ (N_2)}{63025}$$

Use larger CHP_m Value for Sizing.

If corner horsepower is calculated at the axle or the wheel, it can be converted to the corner horsepower at the transmission hydraulic motor shaft as follows:

$$CHP_m = \frac{CHP_a}{\text{Final Drive Efficiency}}$$

$$CHP_m = \frac{CHP_v}{\text{Final Drive Efficiency}}$$

X. SYSTEM INSTALLATION AND OPERATION REQUIREMENTS

The system in which the hydrostatic pump and motor is operated should provide an environment compatible with the requirements of the transmission. Our experience with these transmissions has produced application guidelines which will insure proper operation with long life. The requirements of the auxiliary equipment necessary to complete the hydraulic circuitry are described below. Equipment to meet these requirements is readily available from a number of sources.

When deviations from conventional practice are necessary, the user should take appropriate steps to insure that damaging conditions have not been created.

Operational Limits - Pump and Motor

Speed limits: The maximum speeds at which these hydraulic units can operate are described on page 14. To assure the proper functioning of a hydrostatic transmission, maximum speed of the pump (s) and motor (s) must be evaluated in both the power and braking modes (Ref. pag. 52). These speeds are based on internal functions of piston type equipment.

Low speed operation, under load, is dependent upon supplying sufficient charge flow to insure adequate leakage makeup, control flow and cooling requirements. Having sufficient charge flow under load at low speed will insure adequate flow will be available at maximum speed conditions (Ref. pg. 52).

Pressure Limits:

a. Closed loop circuit: The maximum pressure in the closed loop circuit shall be controlled by a high pressure relief valve to a value not greater than 5000 psi. The gauge pressure will read approximately 150 psi higher than the relief valve setting, due to the addition of charge pressure in the low pressure loop. The minimum pressure in the closed loop must not be less than 130 psi above case pressure. This allows for a 30 psi drop in the hydraulic lines between the pump and motor.

b. Charge pressure settings: The minimum charge pressure setting shall be not less than 160 psi above case pressure. This is required to provide adequate control pressure and closed loop pressures. Hydraulic units supplied by the factory which incorporate charge relief valves are adjusted to provide these charge pressure levels.

c. Case pressure: The transmission case pressures should not exceed 40 psi gauge under any operating conditions. The case drain system (hydraulic lines, heat exchanger, etc.) must be designed so as not to exceed this limit. In addition the line losses between the pump and motor cases should not exceed 10 psi at normal operating conditions.

d. Charge Pump inlet pressure: The maximum vacuum at the charge pump inlet should not exceed 10 inches Hg at normal operating conditions. It is acceptable for the inlet vacuum to exceed 10 inches Hg during cold start up. The normal design requirements should be three (3) to five (5) inches Hg at normal conditions with a new filter. When the filter becomes clogged to the extent of 10 inches Hg at the charge pump inlet, the filter should then be replaced.

Temperature Limits: The maximum continous operation temperature shall not exceed 180°F. at the hottest point in the circuit. Intermittent temperatures at 200°F. are acceptable for periods not to exceed five (5) minutes. Although the highest system temperature will normally occur in the closed loop circuit, it is acceptable to measure this temperature in either the pump or motor case drain when testing to establish cooling requirements.

Charge Pump flow: Charge Pump flow must be sufficient to maintain both the minimum closed loop pressure requirements and the maximum temperature requirements. Factory transmission systems that include charge pumps are designed to fulfill these requirements.

Filtration: The fluid supplied to the conventional charge pump system shall be filtered by a good quality 10 micron nominal rated filter and shall not incorporate a bypass valve. This type of filtration system will give the greatest degree of reliability in keeping the system free of contamination. Filter clogging causing reduced inlet pressure to the pump beyond limits specified will eventually result in reduced transmission control pressure to the point where transmission speed control response will become slow and sluggish. This will occur before any damage to the transmission results and provides ample indication that a filter element change is required.

If an external charge source is used, a filter may be placed in the charge pump outlet circuit. This circuit requires a filter indicator to show the condition of the filter element.

Regardless of the location, all filter cartridges should be sufficiently strong to prevent collapse or rupture under the most adverse operating conditions.

Hydraulic Fluids: The hydraulic fluids for usage in Sundstrand heavy duty transmissions are listed under "Fluid Recommendations." Although there are a number of acceptable fluids available on the market that are compatible with this equipment, it is beyond our capabilities to test each fluid. The user should take appropriate steps, including testing, to insure the compatibility with the hydraulic equipment.

Reservoir: A suggested minimum reservoir volume (in gallons) is .625 of the total charge pump flow per minute (in GPM) with a minimum fluid volume equal to .5 charge pump flow. This minimum reservoir volume will provide for a minimum of 30 seconds fluid dwell for removing entrained air at the maximum return flow to be encountered in the system. This expansion volume noted above is adequate to allow usage of a "closed" reservoir (no breather) in most installations.

The reservoir outlet to the charge pump inlet should be positioned above the bottom to take advantage of gravity separation and prevent any large foreign particles from entering the outlet line. A 100 mesh screen is recommended over the outlet port to further assist large particle separation prior to fluid leaving the reservoir. The oil level in the reservoir should be above the charge pump inlet. If this is impractical, a foot valve may be required to prevent drainback of the charge pump suction line.

The reservoir inlet (fluid return) should be positioned in such a way that inlet flow is discharged below the normal fluid level. Further, it should be directed into the interior of the reservoir to provide for maximum dwell and most efficient de-aeration of the fluid.

A drain in the reservoir is recommended which would permit a complete fluid change without disconnecting other normal hydraulic connections. This would also permit flushing in the event of excess system or component contamination.

A filler port should be provided that minimizes the potential for contamination entering the system during servicing or during operation. We recommend that a closed reservoir be used to reduce introduction of contamination and be designed so that the recommended charge pump inlet and case drain pressures are not exceeded.

Heat Exchanger: Provisions should be made in the system to insure that neither the pump nor motor case drain temperatures exceed the stated limits. This may or may not require the use of a heat exchanger in the reservoir return flow circuit, dependent upon the specific system duty cycle and design. The fluid restriction resulting from the case drain lines and heat exchanger should not exceed the 40 psi case pressure. This may require the use of a bypass (pressure or thermal) around the heat exchanger.

X. TRANSMISSION START-UP PROCEDURE

1. After the transmission has been installed, remove the threaded plug from the side of the main pump housing. For reading charge pressure at this port, install a 600 p.s.i. gage, with a short section of hose. The threaded port is 7/16 x 20 straight thread "O" ring. Also, install at the charge pump inlet a vacuum gage for reading inlet vacuum.

2. Check all fittings to be sure they are tight.

3. Fill the pump and motor cases through the upper case drain openings with a recommended fluid. It is recommended that all fluid be passed through a ten (10) micron filter. Reinstall and tighten case drain lines.

4. Loosen the charge pump line, coming from the filter/reservoir, at the inlet to the charge pump.

5. Fill the reservoir with fluid. When fluid appears at the loosened hose at the charge pump inlet, install and tighten the hose and continue filling the reservoir. Leave reservoir cap loose so air will escape.

6. It is recommended that the control linkage to the pump control valve be left disconnected until after the initial start-up. This will allow the pump to remain in positive neutral.

7. If the prime mover is:

   Engine: (Diesel, gasoline or LP) - Remove the coil wire, close the injector rack or leave the gas turned off, turn the engine over until the charge pressure reaches 30 p.s.i. or more.

   Electric Motor: Jog the starting circuit until the charge pressure reaches 30 p.s.i. or more.

8. Start the prime mover and if possible, maintain a 750 RPM pump shaft speed for five (5) minutes. This will allow the system to fill properly. During this phase, pressure surges may be seen on 600 p.s.i. gage. <u>THIS IS NORMAL</u>.

   While running at 750 RPM idle, the pump charge pressure must be at least 100 p.s.i. above case pressure. If it is not, shut down and trouble shoot.

9. Increase pump speed to approximately 1000 RPM; charge pressure on the 600 p.s.i. gage should be 190-210 p.s.i. above pump case pressure. NOTE: SEE BELOW*

10. Shut down prime mover and connect linkage to the displacement control valve handle. <u>CAUTION - if the motor shaft is connected to the drive mechanism, the necessary safety precautions must be considered</u>.

11. Check fluid level in reservoir and add if necessary.

12. Start prime mover and run the pump at 1500 to 1800 RPM; charge pressure should be 190-210 p.s.i. above pump case pressure.

13. Move the pump control handle slowly to the forward and then the reverse position. Charge pressure will drop to 160-180 p.s.i. above motor case pressure.

    Repeat or continue to cycle for approximately five (5) minutes.

14. Should the charge pressure fall below 100 p.s.i. above motor case pressure, discontinue start-up until trouble has been found.

15. Run the prime mover at maximum RPM with the pump in neutral. Observe the reading at the vacuum gage connected to the charge pump inlet. This reading should not exceed ten (10) inches Hg. at normal operating conditions.

16. Shut down prime mover, remove all gages and replace all plugs or lines. Check reservoir fluid level and thighten oil fill cap. the machine is now ready for operation.

    *NOTE: <u>On those pumps equipped with a four (4) cubic in/Rev. charge pump, the charge pressure should be</u>:

    A. 210-240 p.s.i. above pump case pressure - pump in neutral at 1000 RPM.
    B. 300-385 p.s.i. above pump case pressure - pump in neutral at 1500-1800 RPM.
    C. 230-250 p.s.i. above motor case pressure - pump in stroke at 1500-1800 RPM.

HEAVY DUTY VARIABLE DISPLACEMENT PUMP

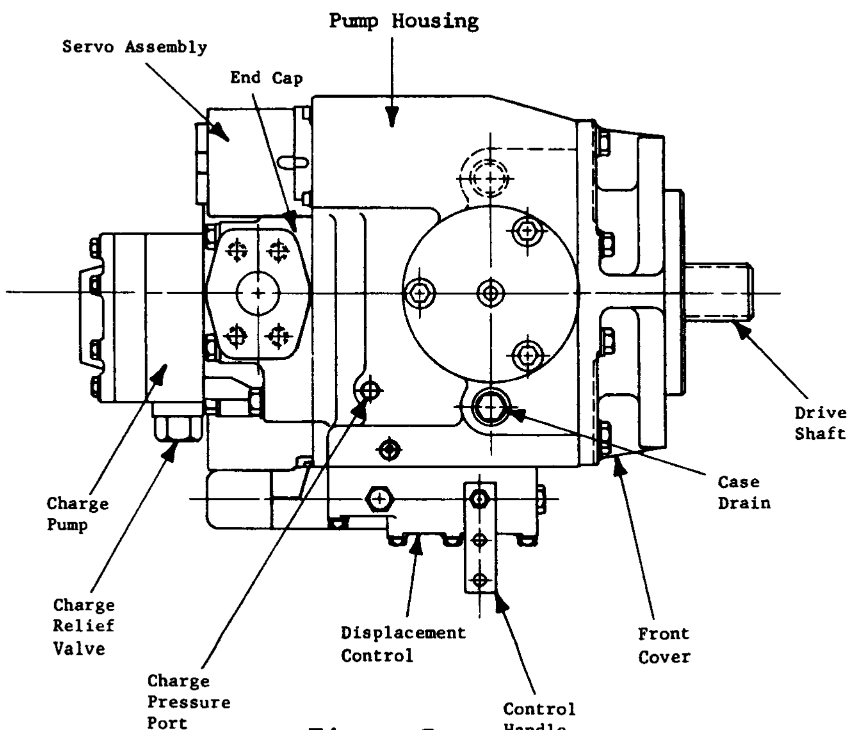


Figure I.

FLUID RECOMMENDATIONS

SUNDSTRAND HYDROSTATIC TRANSMISSIONS

Hydraulic fluids selected for use with the Sundstrand hydrostatic transmission should be a quality product carefully selected with assistance from a creditable supplier.

Characteristics of the fluid selected should include:

Viscosity
Oxidation
Thermal Stability
Shear Stability
Low Temperature Fluidity
Anti-wear
Anti-corrosion
Anti-foam
Seal Conditioning For Buna-N and Viton Elastomers

The following types of fluids have been used successfully in the hydrostatic transmission; (1) anti-wear hydraulic oil, (2) automatic transmission fluid - Type "F", and (3) hydraulic transmission fluid (type used by the Agricultural industry for combined transmission, hydraulic and wet brake systems). If a fire resistant fluid is required, Pydraul 312 has been satisfactory.

Most of the above fluid types have acceptable viscosity characteristics in the operating range of 0°F. to 200°F. The fluids selected should provide a minimum viscosity of 47 SUS at 210°F. and a maximum measured viscosity of 6,000 SUS at the lowest expected startup temperature. Typical fluid properties are listed on the attached table.

Your best assurance for a quality product is the assistance that can be offered in its selection by a fluid supplier. The major oil companies are capable of providing suitable products.

Fluid Type	Typical Viscosity SUS 0°F.	100° F.	210° F.	Viscosity Index	Pour Point °F.	Operating Range (Typical °F.
Anti-Wear Hydraulic Oil	7,000	200	50	132	-30	0-200° F.
Type "F"	3,200	212	57.2	208	-40	-15-200° F.
Hydraulic Transmission Oil	12,000	233	49	100 Min.	-35	0-200° F.
*Pydraul 312	100,000	312	51	77	-10	50-200° F.

*Fire Resistant Fluid

SYSTEM MAINTENANCE

Fluid: Generally, a fluid change interval of 2000 hours is adequate with a sealed reservoir system. A more frequent fluid change is required if the fluid has become contaminated by water or other foreign material or has been subjected to abnormal operating conditions.

An open reservoir system with an air breathing filler cap requires the fluid to be changed every 500 hours.

More specific practices should be developed as a function of vehicle design, applied use and experience in operation.

Filter: As a general recommendation, with a sealed reservoir system, the 10 micron inlet filter should be changed each spring or every 1,500 hours, whichever occurs first. With an open reservoir system utilizing an air breathing filler cap, the filter should be changed every 500 hours.

Reservoir: The reservoir should be checked daily for the proper fluid level and the presence of water in the fluid. If fluid must be added to the reservoir, use only filtered or strained fluid. Drain any water as required.

Hydraulic Lines & Fittings: Visually check daily for any fluid leakage. Tighten, repair or replace as required.

Heat Exchanger: The heat exchanger core and cooling fins should be kept clean at all times for maximum cooling and system efficiency. Inspect daily for any external blockage and clean as required.

XI. DEFINITION OF TERMS

GRADEABILITY:

Gradeability is expressed in per cent grade and represents the feet of rise per 100 feet of horizontal travel. For a given power and weight, the gradeability is the maximum slope a vehicle can ascend with an assumed zero wheel slip.

TRACTIVE EFFORT:
(T. E.)

Tractive effort is the axle torque divided by the rolling radius. Tractive effort represents the maximum possible pull a vehicle could exert if it had no resistance to movement. The term "rim-pull" is used synonymously with tractive effort.

ROLLING RESISTANCE:

Rolling resistance is the force required to move the vehicle over a given terrain. Rolling resistance is obtained by multiplying the gross vehicle weight times the rolling resistance coefficient.

ROLLING RESISTANCE COEFFICIENT:

The rolling resistance coefficient is a proportionality constant between the gross vehicle weight and the total vehicle rolling resistance for a specific surface, wheel condition.

DRAWBAR PULL:
(DBP)

Drawbar pull is the effective pull a vehicle can exert on a load. Drawbar pull is the tractive effort less the rolling resistance.

ROLLING RADIUS:

Rolling radius is the vertical distance from the center of the axle to the surface of ground contact.

FINAL DRIVE RATIO:

Final drive ratio is the total ratio between the hydraulic motor shaft and the driving wheels.

FINAL DRIVE EFFICIENCY:

Final drive efficiency is the total combined efficiency of the drive train between the driving wheels and the hydraulic motor shaft.

DEFINITION OF SYMBOLS

P_h	-	Working pressure, lbs. per square inch (psi)
P_l	-	Charge pressure, lbs. per square inch (pw)
P	-	Delta system pressure, P_h - P_l (psi)
D	-	Displacement per revolution, cubic inch per revolution
q	-	Flow, cubic inch per minute
Q	-	Flow, gallons per minute
T	-	Torque inch lb.
N	-	Shaft Speed revolution per minute
n	-	Total Efficiency (^{v}tm x ^{n}tp x ^{n}vm x ^{n}vp)
^{n}tm	-	Torque efficiency of motor
^{n}tp	-	Torque efficiency of pump
^{n}m	-	Volumetric Efficiency of motor
^{n}p	-	Volumetric Efficiency of pump
CHP	-	Corner Horsepower hp
CHP_m	-	Corner Horsepower at Hydraulic Motor Shaft hp
CHP_a	-	Corner Horsepower at Axle hp
CHP_v	-	Corner Horsepower at Wheels hp
T.E.	-	Tractive Effort, lbs.
S.	-	Speed Vehicle, mph
g	-	Gradeability in % grade
W	-	Total Vehicle Weight lbs.
R.R.	-	Total Vehicle Rolling Resistance
C_{rr}	-	Rolling Resistance Coefficient

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BASIC EQUATIONS

HYDRAULIC

Theoretical Torque, T = $\frac{(P \times D)}{2^{n}}$ in. lb.

Theoretical Flow, q = (D) (N) $in^{3}/min.$

Theoretical Flow, Q = $\frac{(D)\ (N)}{231}$ gpm

Power, hp = $\frac{(Qgpm)\ (P)}{1714}$ hp

Actual Motor Torque (Output) = (T) (^{n}tm) in. lb.

Actual Pump Torque (Input) = $\frac{(T)}{n_{tp}}$ in. lb.

Actual Flow from Pump = (Q_p) (^{n}vp) gpm

Actual Flow to Motor = $\frac{(Q_m)}{n_{vm}}$ gpm

MECHANICAL

Power, hp = $\frac{(T)\ (N)}{63025}$ hp

Power @ Wheel, hp = $\frac{(T.E.)\ (S)}{375}$ hp

Gradeability, g = (100) (Tan) = $\frac{(\text{Feet rise})}{(\text{Feet horizontal})}$

Tractive Effort Required to ascend given gradeability T.E. = W sin + R.R. cos , lbs.

Rolling Resistance, R.R. = (W) (^{C}rr)