

Sizing a Power-Limited Steering System

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ABSTRACT

Hydraulic power steering systems traditionally are sized in a straightforward manner with easily verifiable results. The source of power in conventional systems is an engine driven pump that is effectively a source of hydraulic flow. As energy consumption of auxiliary functions becomes significant, on-demand power sources are considered. Best typified by hydraulic pumps driven by electric motors, these on-demand sources are often power limited, and established sizing practices should be re-visited.

CONVENTIONAL STEERING SYSTEM

CONVENTIONAL SYSTEM SIZING – The conventional hydraulic steering system, shown in Figure 1 is sized to produce steering performance at different portions of the vehicle duty cycle. First, the hydraulic gearbox is selected to have the capability to completely static-steer (or “dry-park”) the heavily laden front axle from one axle stop to the opposite axle stop. The output torque required is a function of axle load and front end geometry, and often requires specialized tools and experience for optimization. For the purposes of this work a TRW TAS 65 gear is assumed; this gear is usually appropriate for the 12,000 lb front axle typical of a line-haul semi-tractor. Such a gear has a maximum pressure rating of 2175 psi (150 bar).ⁱ

Conventional hydraulic steering gearboxes include an open center valve. Such a valve requires a specific flow through it. The vehicle handwheel displaces the rotary

valve so restricting the flow and thereby builds a hydraulic pressure. This pressure creates a force on a piston that assists the driver in turning the roadwheels. This system can be called a servo-position follower, as the output position proportionally follows the input. The flow is conventionally produced by an engine driven sliding vane pump described in Figure 2. The sliding vane pumping element discharges a specific volume of fluid for each engine revolution. Therefore, the faster the engine speed, the more flow Q_F produced. Since the gear requires a constant flow, the output of the pumping element is directed through a flow control orifice. A hydro-mechanical valve regulates the pressure across this orifice, and therefore the flow Q through it that is discharged to the gear. If there is too much pressure the flow control valve allows increased bypass flow Q_B to the reservoir prior to the orifice, and if there is too little

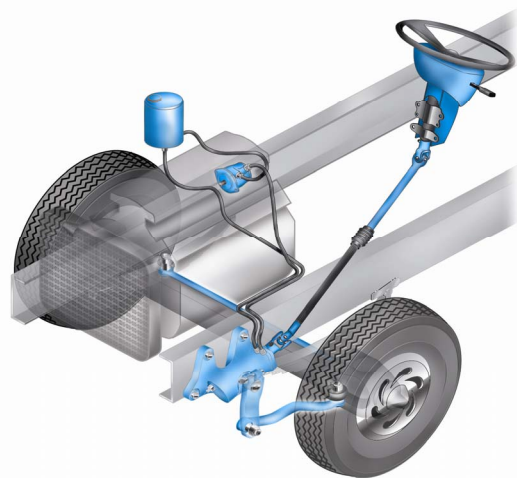


Figure 1: Conventional Steering System

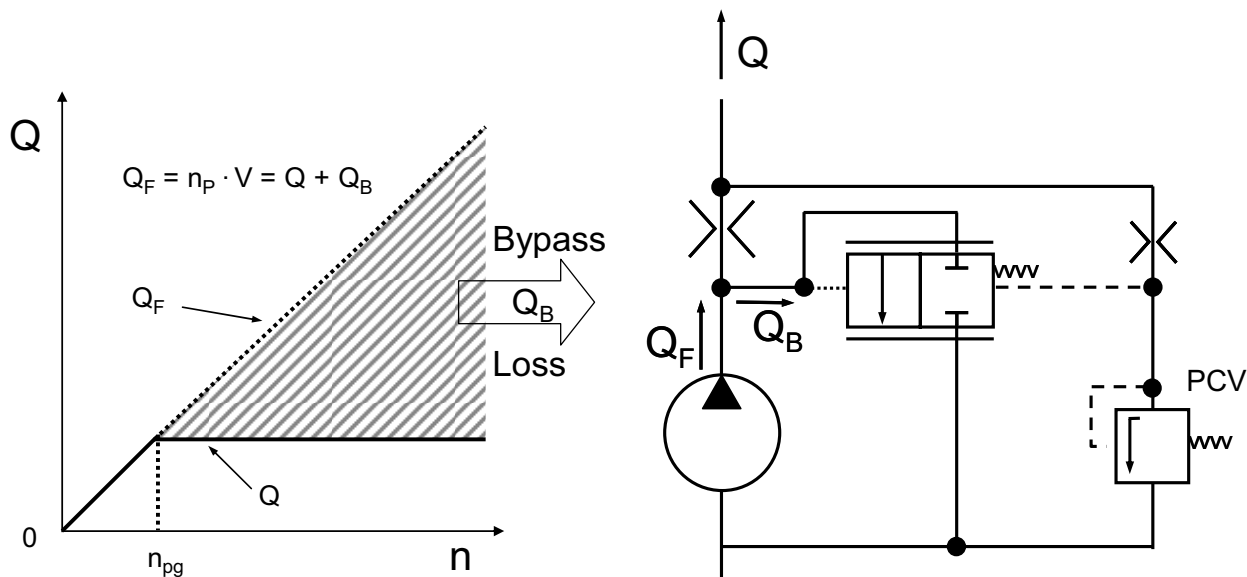


Figure 2: A Conventional Engine Driven Pump

pressure it restricts this bypass flow. The pump is sized to provide acceptable flow at engine idle, so that at highway cruising speed it could be dumping twice the flow through the bypass valve as it usefully discharges to the steering gear, and at the governed speed three times the useful flow is bypassed.

Once the size of the steering gear is derived from axle loadings and front end geometry, required flow can be established using the guideline that sufficient flow should be available from the pump to allow the output to follow the quickest possible handwheel input. Such an input would occur in a sudden lane change or obstacle avoidance maneuver. Failure to accommodate this guideline results in “catching the pump,” and is considered to be objectionable as the extreme torque discontinuity can be disconcerting to the driver that is already in an emergency situation. It is accepted in the industry that the driver does not reasonably produce a steering input greater than 90 rpm (1½ handwheel turns per second), therefore the engine driven pump must be sized to provide a minimum of 3 gallons per minute (11.3 lpm) to the TAS 65 gear under all conditions, allowing for internal gear leakage and the recommended controlled flow from the pump is 3.5 gpm.ⁱⁱ

POWER CONSUMPTION OF CONVENTIONAL SYSTEM – Typically a semi-tractor is driven in a lane maintenance mode for the vast majority of time. The pressure drop of the steering gear in series with the flow control valve of the pump additively create a pressure drop of less than 100 psi as seen by the pumping element or approximately 0.2 HP for the given rated flow through the gear. At an engine cruising speed where three times the required flow is produced, the resulting on-center power consumption is approximately half a horsepower.

Since the pressure developed to static-steer the axle can be 2175 psi for an optimized system, a 90 rpm handwheel input will consume approximately 4 HP at engine idle as shown in Figure 3. Thus the static-steer maneuver at engine idle could consume an order of magnitude more energy than keeping a lane at high speed. If the static steer was performed at a governed speed of as much as four times idle, the maximum power consumption in the traditional power steering system could be 16 HP. The traditional system does not have the capacity to reject this amount of heat energy; therefore operation in this state for an extended period of time would damage the steering system. The inefficiency of the bypass flow Q_B in Figure 2 can be seen in Figure 3 in the difference in energy consumed for a given maneuver at idle and the engine governed

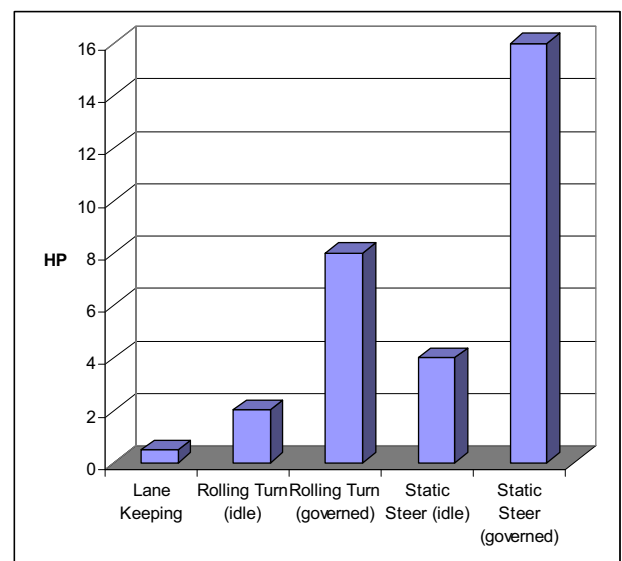


Figure 3: Power Consumption of Conventional Hydraulic System for Various Maneuvers