Specification:
Design Considerations of a Day Tank Pump / Fuel Transfer System

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This general guide is designed to assist the designer in the proper specification of the fuel transfer system. The three main areas to be covered by this paper are pump lift, pump head and pump prime. In critical or borderline applications, an experienced hydraulic engineer should always be consulted.

Pump Lift
A pump will lift fuel by displacing air from suction to discharge line. This creates low pressure in the suction line which allows the higher atmospheric pressure (14.7 psi at sea level) to lift liquid into this vacuum. If a perfect vacuum could be created and maintained fuel could theoretically be lifted to 34 feet. Since a perfect vacuum cannot be created, the lift a pump can actually achieve is approximately 50% of theoretical lift or 17 feet (7.4 psi). To determine the total available lift, the following factors need to be considered:

1. The **vertical distance** the pump needs to lift fuel is the main factor in lifting capabilities. This measurement should be taken from the bottom of the main tank to the pump's inlet port.
2. The **total length of piping and size** is important due to internal friction. This will reduce lift and must be considered. (See table one) All calculations are based on 60°F temperature. Frictional resistance will increase as temperature decreases.
3. **Fitting in the line** will disrupt flow and create friction. These fittings include elbows, tees and unions. (See table two) Valves also need to be checked for possible pressure drops.
4. **Elevation above sea level** is important since the atmospheric pressure acting against the pump's vacuum is reduced, thereby reducing lift. (See table three)

Example One
Given:

Vertical distance	12 feet
Total length of pipe	100 feet
Pipe size	1" in diameter
Pump size	2 GPM
Fitting in line	3 elbows,no valves
Elevation above sea level	3,000 feet

Solution:
Referring to table two, an elbow equals 2.6 feet of pipe. (2.6 x 3 elbows = 7.8 feet) The corrected length of pipe is now 107.8 feet. Referring to table one, the 107.8 feet is divided by 100 and multiplied by the .5 our actual head loss is .54 feet. Therefore, the total lift needed for this system is the vertical distance plus .54 feet or 12.54 feet. Since the pump is safely capable of lifting 15 feet at a 3,000 foot elevation, (see table three), the previous example will perform satisfactorily. However, if a 3/8" diameter pipe would have been used, the head loss would have been 17.63 feet. Adding the vertical distance to this figure equals 29.63 feet. The pump would not be able to lift the fuel. If the plumbing system cannot be built under a 17 foot lift limitation (at sea level), a remote pumping station must then be used. This will be placed between the main tank and the day tank. The proper placement is determined by the pump lift calculation and the following pump head calculations.

Pump Head
the pump's head is the theoretical vertical distance a pump will push fuel. Day tank standard (2 GPM/ 1/3 HP) pumps have 231 feet of head (100 psi). Refer to table four for larger pump and motor discharge rates. Because of electrical convenience the pump is normally located on the day tank, but when pump lift demands are exceeded the remote pumping station is required. This allows us to utilize the head (pushing) capabilities of the pump.

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To determine the total available head three factors need to be considered:

1. The **vertical distance from the pump to the day tank** needed to push the fuel, is the main factor in head capabilities. This measurement should be taken from the output port on the pump to the day tank's upper most piping connection.
2. The **length and size of pipe** need to be considered in the same manner as the lift calculations.
3. **Fittings** also are calculated in the same manner.

Note: Elevation does not need to be considered in head calculations.

Example Two
Given;

Vertical distance:	150 feet
Total pipe length:	175 feet
Pipe size:	3/4" in diameter
Fittings:	2 elbows,1 check & 1 solenoid valve
Pump:	7 GPM

Solution:
Referring to table two, a 3/4" elbow equals 2.1 feet of pipe (2.1 x 2= 4.2). The check valve equals 5.3 feet of pipe. Also, the solenoid valve has a 3 psi drop, (consult manufacturer), or 6.93 feet (3 x 2.31). The total adjusted length of pipe is: 175 + 4.2 + 5.31 + 6.93 = 191.4 feet. Referring to table one, 191 feet of 3/4" pipe with a 7 GPM pump interpolates to 29.2 feet of head loss (1.91 x 15.3). Therefore, total equivalent height is (150 + 29.2) 179.2 feet. Note: The resulting pressure at day tank is (231 feet - 179.2 feet) divided by 2.31 = 22 psi. Since the pump will push fuel to a height of 231 feet, this system will work.

Pump Prime
Maintaining the prime on a pump is of critical importance. Fuel must be maintained in the suction side pipe with no air pockets. Foot valves at the main tank or check valves at the day tank can be used to prevent fuel flowing back to the main tank and losing prime.

Pump cavitation is the inability for a pump to discharge fuel properly and can occur for many reasons:

1. Total equivalent lift too high for pump
2. Total equivalent head too high for pump
3. Restrictions in lines
4. Air leaks
5. Improperly plumbed systems

Cavitation can occur gradually and will eventually ruin a pump. Vertical piping loops or "traps" should be avoided when designing a pumping system. Air pockets can become trapped in the high point of the vertical loop, resulting in pump cavitation.

A hand pump is recommended for initial priming to avoid undue wear on the fuel pump. If the fuel pump must be used for initial priming, do not run for more than 60 seconds. Fuel should be flowing within that time.

A fuel strainer is also recommended on the inlet side of the pump. Foreign particles entering the pump chamber will diminish its life expectancy. The strainer should be checked periodically to avoid particle build-up, which would limit pumping capabilities.

Summary
Proper engineering practices should always be used when calculating pump head and especially pump lift. By following these guidelines, costly repair due to improper installations can be avoided.

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Notes:

1. 1 psi = 2.31 feet of head is the conversion for water. As a general rule, this is a safe conversion for #2 diesel fuel.
2. For more precise calculations refer to the formulas and conversions listed below.

   A. Head in feet = $\frac{\text{PSI x 2.31}}{\text{Specific Gravity}}$

   B. PSI = $\frac{\text{Head x Specific Gravity}}{2.31}$

   C. Specific Gravity of #2 diesel fuel - .88 at 60°F

   D. Weight of #2 diesel fuel - 7.3 lbs/gallon

3. All calculations are based on a 60°F temperature. Allowances must be made for extreme temperature variances.

A. Viscosity of #2 diesel fuel 35 @ 100°F
40 @ 70°F
60 @ 20°F
80 @ 0°F
200 @ -30°F

B. An immersion heater is recommended for below 32°F applications.

Table One
Frictional Head Loss (in feet) for 100 feet of standard weight pipe at 60°F at sea level - diesel fuel

	Pipe Size						
GPM	⅜	½	¾	1	1 ¼	1 ½	2
2	15.2	5.5	1.1	.5	.2		
4	55.5	20.3	5.1	1.4	.5	.2	
7		61.0	15.3	4.6	1.2	.5	
10			26.3	8.5	2.5	.9	2
19				28.5	7.5	3.5	1.2

Table Two
Frictional loss in pipe fittings in terms of equivalent feet of straight pipe

Pipe Size (in.)	Ball Valve	45° Elbow	Std Elbow	Std Tee	Check Valve	Angle Valve	Globe Valve	Diaphragm Valve
⅜	.28	.70	1.4	2.6	3.6	8.6	16.5	
½	.35	.78	1.7	3.3	4.3	9.3	18.6	40
¾	.44	.97	2.1	4.2	5.3	11.5	23.1	
1	.56	1.23	2.6	5.3	6.8	14.7	29.4	
1 ¼	.74	1.6	3.5	7.0	8.9	19.3	38.6	
1 ½	.86	1.9	4.1	8.1	10.4	22.6	45.2	
2	1.1	2.4	5.2	10.4	13.4	29.0	58.0	

Table Three
Lifting Capacities at various elevations

Elevation	Atmospheric Pressure	Available Lift
Sea level	14.7 psi	17'
1000'	14.2 psi	16'
2000'	13.6 psi	15.5'
3000'	13.1 psi	15'
4000'	12.6 psi	14.5'
5000'	12.1 psi	14'
6000'	11.7 psi	13.5'

Table Four
Pump discharge pressure (psi)

Motor	Nominal Pump Size (GPM) at 1725 RPM					
H.P.	2	4	7	10	19	23
⅓	100	60	2			
½		100	20	2		
¾			40	20		
1			100	40	20	2
1 ½				80	40	40
2				125	60	60
3				150	100	125

Note: Pump discharge volumes (GPM) can decrease by as much as 25% when higher pressures are required. Please consult factory for borderline consumption rates.