Hawkeye Model 1200 Skimmer: Flow Rate

Introduction

The Model 1200 Floating Skimmer is used to draw fluid from the top of a fluid column and transport it to a tank outlet located below the fluid surface. Flow is often powered by gravity drainage; therefore the fluid flow rate is strongly dependent on the elevation difference between the fluid surface and outlet, the fluid properties, outlet piping and temperature. This study provides an estimate of the flow rate of medium crude oil through the skimmer at a sample condition.

Method

Fluid flow rate can be determined by means of an energy balance such as Bernoulli's equation, but one value must either be estimated or experimentally derived. This value is the head loss due to friction which depends on the sum of the minor loss coefficients, the roughness of all contact surfaces and the fluid viscosity and density. The Model 1200 Skimmer was tested in 16˚C water at multiple elevation differences and hose lengths to derive an expression for the frictional head loss. The flow rate of a fluid with a specific density and viscosity and powered through gravitational drainage can be expressed as:

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_L \quad \text{(eq.1)}$$

Units:

Each subscript denotes a distinct point along the flow path (Fluid surface: 1, Tank outlet: 2).

P: Pressure (Pa)

α: Kinetic Energy Correction Factor (unitless)

V: Velocity (m/s)

z: Elevation (m)

ρ: Fluid Density (kg/m^3)

g: Gravitational Acceleration (m/s^2)

h_L: Frictional Head Loss (m)

(eq.1) Yunus A. Cengal, J. M. (2010). *Fluid Mechanics: Fundamentals and Applications, Second Edition.* New York: McGraw-Hill.
Internal flow behavior determined using method described in chapter 8.

Results

An expression for the frictional head loss was derived through testing with water and extrapolated for use with a medium weight crude oil with ˚API of 22.3 (920 kg/m^3) and a dynamic viscosity of 0.075 kg/m·s. Figure 1 depicts the minimum and maximum flow rates for the Model 1200 Skimmer up to 32 feet of fluid surface to outlet elevation difference. The proposed curves were derived on the following and all previously stated assumptions: the tank is 32 feet tall by 160 m^3, there is no back pressure or outlet piping, the flow is steady and incompressible and the tank is at atmospheric pressure.

Discussion

Flow rate through a system of fittings and hoses depends on many factors; one of which is the flow regime that the fluid is in. Three possible flow regimes are laminar, transitional and turbulent. The Reynolds number gives an indication of the flow regime at a given point, but due to the randomness and complicated nature of fluid dynamics the regime boundaries are only estimates and no accepted mathematical model for the transitional regime exist. In the case of medium crude oil draining from a 32 foot skimmer setup, the flow passes through the transitional regime and into laminar. As a result, the best estimate for the flow rate must span the laminar and turbulent regimes as well as include error that may arise from variation in the hose diameter and geometry of the system.

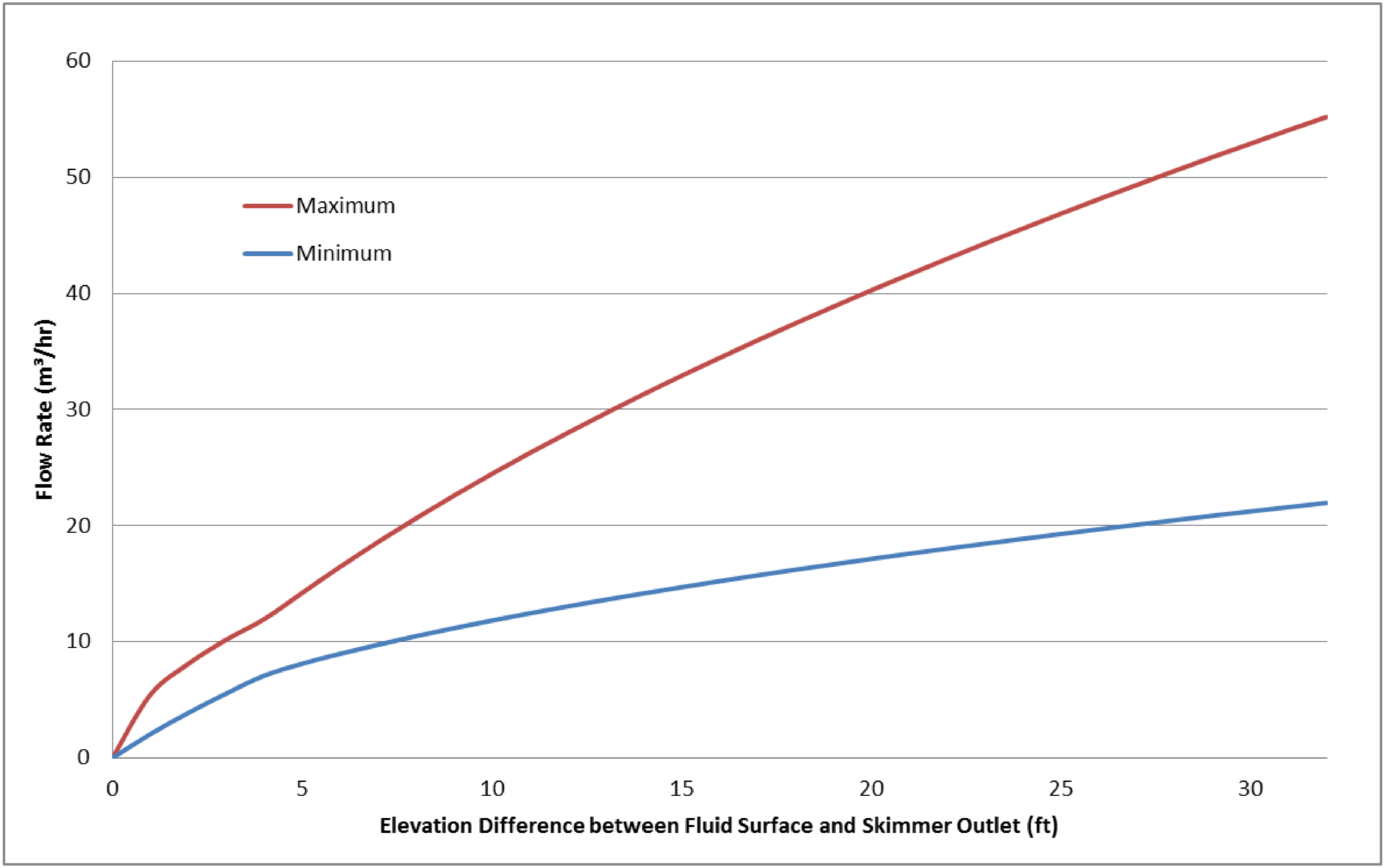

Figure 1: Extrapolated skimmer flow rate for medium-heavy crude oil at room temperature.