PROJECT : **LAKE MAUREPAS FRESHWATER DIVERSION**
CLIENT : **LOUISIANA DEPARTMENT OF NATURAL RESOURCES**
LOCATION : **METAIRIE, LOUISIANA**
URS JOB NO.: **10001431**
PREPARED BY: **J. P. PERCY**

The freshwater diversion control structure for Lake Maurepas will contain three hydraulically operated sluice gates. The gates will be ten-foot by ten-foot each. The calculations below approximate the loads and sizes of the hydraulic equipment. These calculations are only approximations; the Gate and Hydraulic system vendor will supply calculations for his gate and equipment.

SLUICE GATE CALCULATIONS

GATE LOADS

CONDITIONS

Bottom Gate Elevation: $B := -7$ feet

Top of Gate Elevation: $T := 3$ feet

Downstream water elevation: $El_{down} := 0$ feet

Upstream high water: $El_{up} := 31$ feet

Gate Width and Height $W := 10$ feet $H := 10$ feet

GATE WEIGHT

Davis pond gates had a weight of 41 KIPS. These were 14' x 14' gates. Our weight will be approximately proportional.

$Weight := 41 \cdot \left(\frac{10}{14}\right)^2$ $Weight = 20.9$ KIPS

HYDRAULIC LOAD

Coefficient of friction: $\mu := 0.35$

$$Load_{hyd} := \mu \cdot \left[\frac{(El_{up} - El_{down} + El_{up} - T)}{2} \cdot (T - El_{down}) + (El_{up} - El_{down}) \cdot (W - T)\right] \cdot W \cdot \frac{62.4}{1000}$$

$Load_{hyd} = 66.7$ KIPS

ROD WEIGHT

$\text{Dia} := 5$

$\text{Rod} := \pi \cdot \frac{\text{Dia}^2}{4} \cdot \left(\text{El}_{up} - T\right) \cdot 12 \cdot \frac{0.283}{1000}$ $\text{Rod} = 1.9$ KIPS

HYDRAULIC DOWN PULL (10%)

$\text{Hyd}_{down} := 0.1 \cdot (\text{Weight} + \text{Rod})$ $\text{Hyd}_{down} = 2.3$ KIPS

WEDGE RELEASE FORCE (50% WEIGHT)

$\text{Wedge} := 0.5 \cdot (\text{Weight} + \text{Rod})$ $\text{Wedge} = 11.4$ KIPS

TOTAL LIFTING LOAD

$\text{TOTAL}_{load} := \text{Weight} + \text{Rod} + \text{Load}_{hyd} + \text{Hyd}_{down} + \text{Wedge}$

$\text{TOTAL}_{load} = 103.2$ KIPS

Inclusion of both Wedge Release and Hydraulic Down Pull is conservative.

DOWN THRUST (Approximate required down thrust)

$\text{Down} := \text{Load}_{hyd} - \text{Weight} - \text{Rod} + \text{Wedge}$ $\text{Down} = 55.3$ KIPS

Based on these loads and the required 10-foot stroke, a tentative cylinder sizing would be a 10-inch cylinder with a 5-inch rod. Rod size could potentially be smaller - perhaps 4-1/2", and, if loads have been overly conservative the cylinder might be reduced to 8-inch. However, a 10-inch cylinder and 5-inch diameter rod appear to be the likely choice.

CALCULATE CYLINDER OPERATING PRESSURE

Cylinder Diameter:

$\text{Cyl} := 10$ inches

Pull Stroke Pressure (raise gate):

$$\text{Pull} := \frac{\text{TOTAL}_{load} \cdot 1000}{\left[\left(\frac{\text{Cyl}}{2.}\right)^2 - \left(\frac{\text{Dia}}{2}\right)^2\right] \cdot \pi} \qquad \text{Pull} = 1752 \quad \text{psi}$$

Push Stroke Pressure (lower gate):

$$\text{Push} := \frac{\text{Down} \cdot 1000}{\left[\left(\frac{\text{Cyl}}{2}\right)^2\right] \cdot \pi} \qquad \text{Push} = 704 \quad \text{psi}$$

PUMP REQUIREMENT

At the given gate speed requirement, the required pump rate is:

Required Gate Speed:

$S := 20$ inches / minute

$$\text{Vol}_{up} := \left[\left(\frac{\text{Cyl}}{2}\right)^2 - \left(\frac{\text{Dia}}{2}\right)^2\right] \cdot \pi \cdot \frac{S}{231} \qquad \text{Vol}_{up} = 5.1 \quad \text{gpm}$$

$$\text{Vol}_{down} := \left(\frac{\text{Cyl}}{2}\right)^2 \cdot \pi \cdot \frac{S}{231} \qquad \text{Vol}_{down} = 6.8 \quad \text{gpm}$$

Hydraulic pumps are constant volume pumps therefore, the volume will be the maximum of Vol.up or Vol.down.

Pump Efficiency: $\text{eff} := 0.94$

Assuming pressure losses of 25% within hydraulic system (a conservative assumption):

PUMP HORSEPOWER

$$\text{HP} := \frac{\text{Vol}_{down} \cdot \text{Pull} \cdot 1.25}{1714 \cdot \text{eff}} \qquad \text{HP} = 9.241$$

Motor will be 10 horsepower.

HYDRAULIC RESERVOIR SIZING

RETURN OIL VOLUME

The total return oil volume would be the volume displaced by all three gates going from the fully closed position to the fully open position.

$$Return := 3\left(\frac{Dia}{2}\right)^2 \cdot \pi \cdot \frac{H \cdot 7.4805}{144} \qquad Return = 30.6 \quad \text{gallons}$$

In cubic feet:

$$V_{return} := \frac{Return}{7.4805} \qquad V_{return} = 4.091 \quad \text{cubic feet}$$

This is a relatively small volume. In order to allow sufficient space on the top of the reservoir to mount the hydraulic pumps and valves, the reservoir should be about 2-foot by 3-foot. With the gates in their fully closed position there should be eight inches of hydraulic fluid in the reservoir. This will supply sufficient level for the two low level alarms, maintain intake and return lines off bottom, and adequate submergence of suction lines. Return volume will result in another 8-1/4", and a vapor space over the fluid of 4", results in a total reservoir depth of 20 inches.

HYDRAULIC RESERVOIR ISOLATOR SIZING

Size reservoir isolator for 20% more than return volume:

$$Iso := 1.2 \cdot Return \qquad Iso = 36.72 \quad \text{gallons}$$

Based on a Parker Kleen Vent the next larger size reservoir isolator would have an actual capacity of 54 gallons. It is 22" diameter and 48" tall.

PIPING SIZING

The field piping will serve both as pressure and return line piping depending on whether the gate is being raised or lowered. The hydraulic pumps will be sized based on the greater of the required volume for raising or lowering, which in this case is the volume for lowering.

$$Return_{up} := \left[\frac{\left(\frac{Cyl}{2}\right)^2}{\left(\frac{Cyl}{2}\right)^2 - \left(\frac{Dia}{2}\right)^2}\right] \cdot Vol_{down} \qquad Return_{up} = 9.1 \quad \text{gpm}$$

$$\mathrm{Return}_{down} := \left[\frac{\left[\left(\frac{Cyl}{2}\right)^2 - \left(\frac{Dia}{2}\right)^2\right]}{\left(\frac{Cyl}{2}\right)^2}\right] \cdot \mathrm{Vol}_{down} \qquad \mathrm{Return}_{down} = 5.1 \quad \text{gpm}$$

$$\mathrm{Pressure} := \mathrm{Vol}_{down} \qquad \mathrm{Pressure} = 6.8 \quad \text{gpm}$$

Allowable velocity in return lines is 10 feet per second. Allowable velocity in pressure lines is 15 feet per second.

$$\mathrm{TopCylinder}_{return} := \left[\frac{\left(\frac{\mathrm{Return}_{up}}{7.4805}\right) 144}{10 \cdot 60 \cdot \pi}\right]^{0.5} \cdot 2 \qquad \mathrm{TopCylinder}_{return} = 0.609 \quad \text{inches}$$

$$\mathrm{BotCylinder}_{return} := \left[\frac{\left(\frac{\mathrm{Return}_{down}}{7.4805}\right) 144}{10 \cdot 60 \cdot \pi}\right]^{0.5} \cdot 2 \qquad \mathrm{BotCylinder}_{return} = 0.456 \quad \text{inches}$$

$$\mathrm{TopCylinder}_{press} := \left[\frac{\left(\frac{\mathrm{Pressure}}{7.4805}\right) 144}{15 \cdot 60 \cdot \pi}\right]^{0.5} \cdot 2 \qquad \mathrm{TopCylinder}_{press} = 0.43 \quad \text{inches}$$

$$\mathrm{BotCylinder}_{press} := \left[\frac{\left(\frac{\mathrm{Pressure}}{7.4805}\right) 144}{15 \cdot 60 \cdot \pi}\right]^{0.5} \cdot 2 \qquad \mathrm{BotCylinder}_{press} = 0.43 \quad \text{inches}$$

Therefore the line to the top of the cylinders should have a minimum ID of 0.609 inches and the line to the bottom of the cylinders should have a minimum ID of 0.456 inches. The lines are to have a minimum burst pressure of six times the operating pressure of 2500 psig. The piping material will be stainless steel (304 or 316) which has a minimum tensile strength of 70,000 psi.

For the line to the top of the cylinders we will assume a 3/4-inch line:

$$\mathrm{tmin}_{top} := \frac{(2500 \cdot 1.050)}{2 \cdot \left[\left(\frac{70000}{6}\right) \cdot 1 + 2500 \cdot 0.4\right]} \qquad \mathrm{tmin}_{top} = 0.104 \quad \text{inches}$$

For mechanical strength reasons, a minimum Schedule 80 piping should be used. This has a wall thickness of 0.154 inches, which exceeds the requirement due to pressure design. The ID of 3/4-inch, Schedule 80 pipe is 0.742 inches, which exceeds the required piping ID.

For the line to the bottom of the cylinders we will assume a 1/2-inch line:

$$tmin_{bottom} := \frac{(2500 \cdot 0.840)}{2 \cdot \left[\left(\frac{70000}{6} \right) \cdot 1 + 2500 \cdot 0.4 \right]} \qquad tmin_{bottom} = 0.083 \qquad \text{inches}$$

For mechanical strength reasons, a minimum Schedule 80 piping should be used. This has a wall thickness of 0.147 inches, which exceeds the requirement due to pressure design. The ID of 1/2-inch, Schedule 80 pipe is 0.546 inches, which exceeds the required piping ID.

The cost differential between 3/4-inch and 1/2-inch piping is minimal. Therefore, assume that all of the field piping will be 3/4-inch, Schedule 80 piping.