Case Study: CO_2 Removal and Stripping Column Ventilation at Bell Aquaculture

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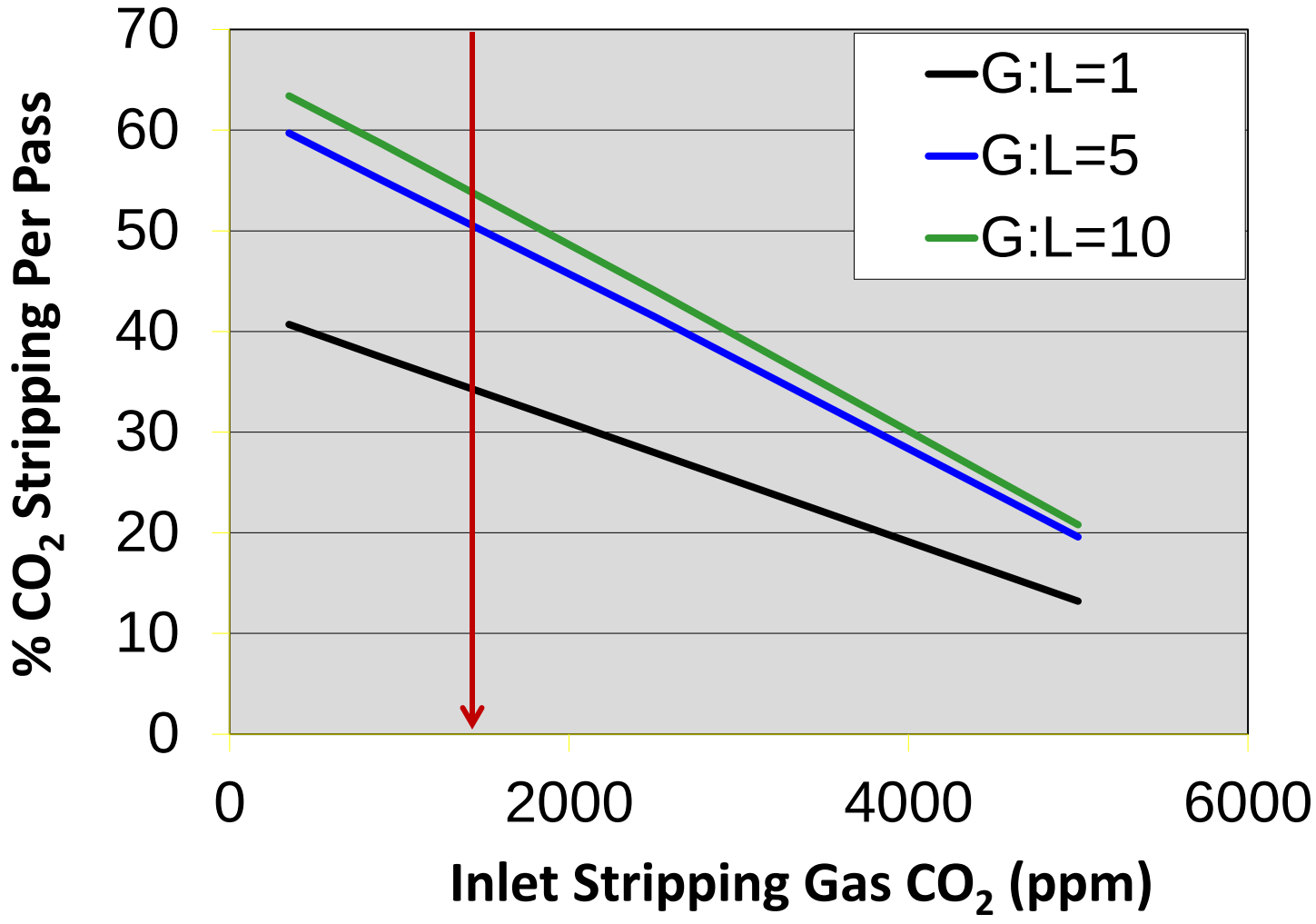
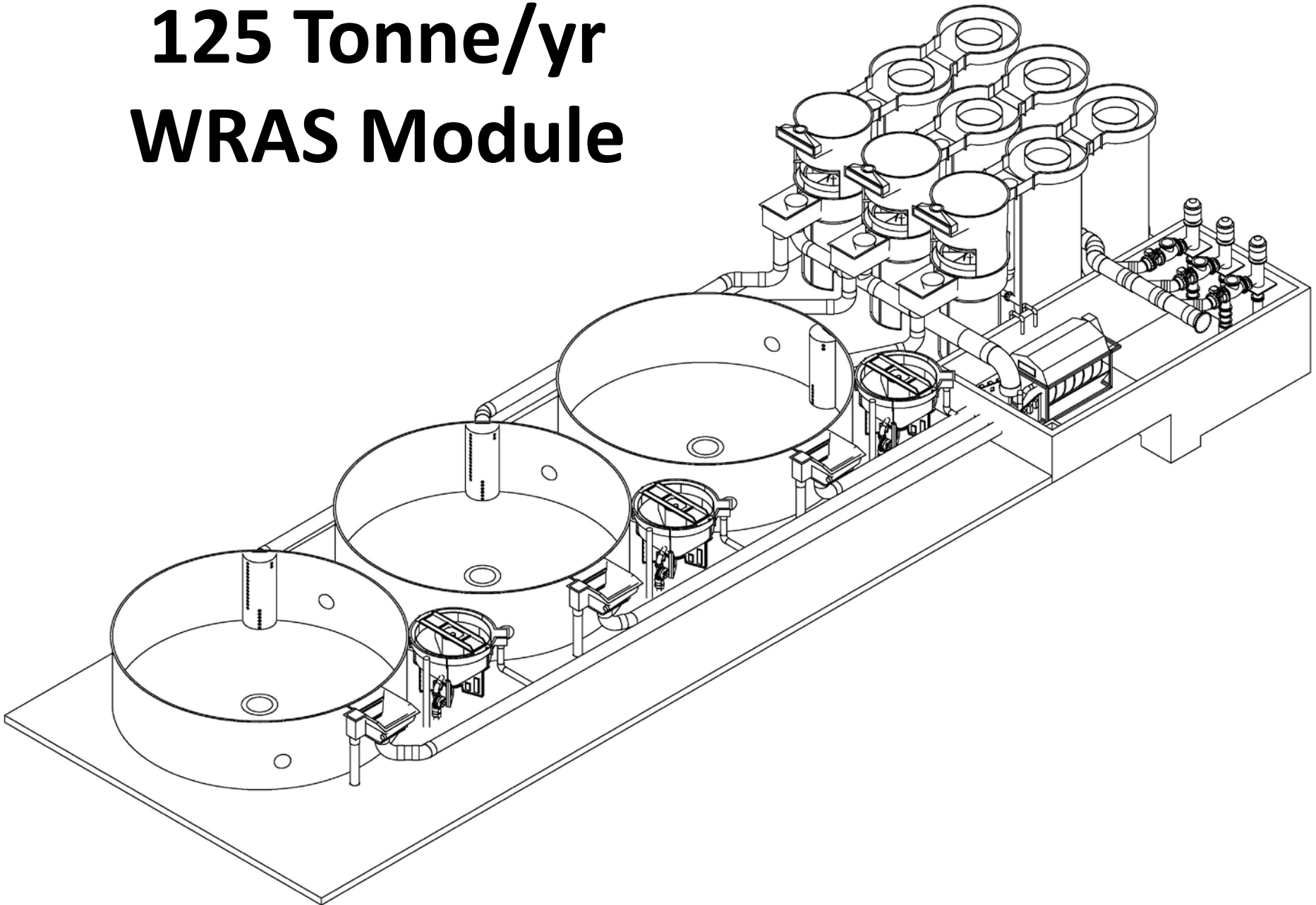
Conflicting Goals

- 25 to 35 mg/L CO_2 concentration begins to reduce rainbow trout
- CO_2 removal requires contacting large volumes of air with cascading water
- Heating & cooling costs increase with increased cascade column ventilation

Air Ventilation Considerations



125 Tonne/yr WRAS Module



Design of Bell Aquaculture Growout WRAS for Yellow Perch

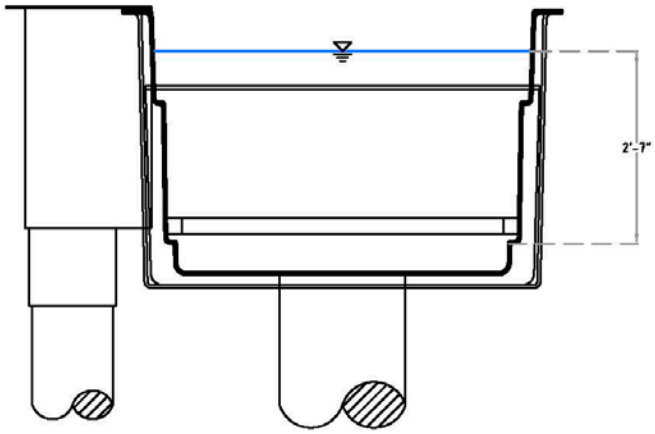
- 26 m^3/min (6,900 gpm) total water recirculating flow rate in each WRAS
  - 85 HP energy for water recirculation
    - Pumping, aeration, drum filtration, oxygenation
  - 30 minute culture tank retention time
  - 2,300 gpm/tank
  - 20 to 40 gpm makeup flow per WRAS

Trout & Salmon Production Tanks (10.7 m ϕ x 3.05 tall; 260 m^3 culture volume)

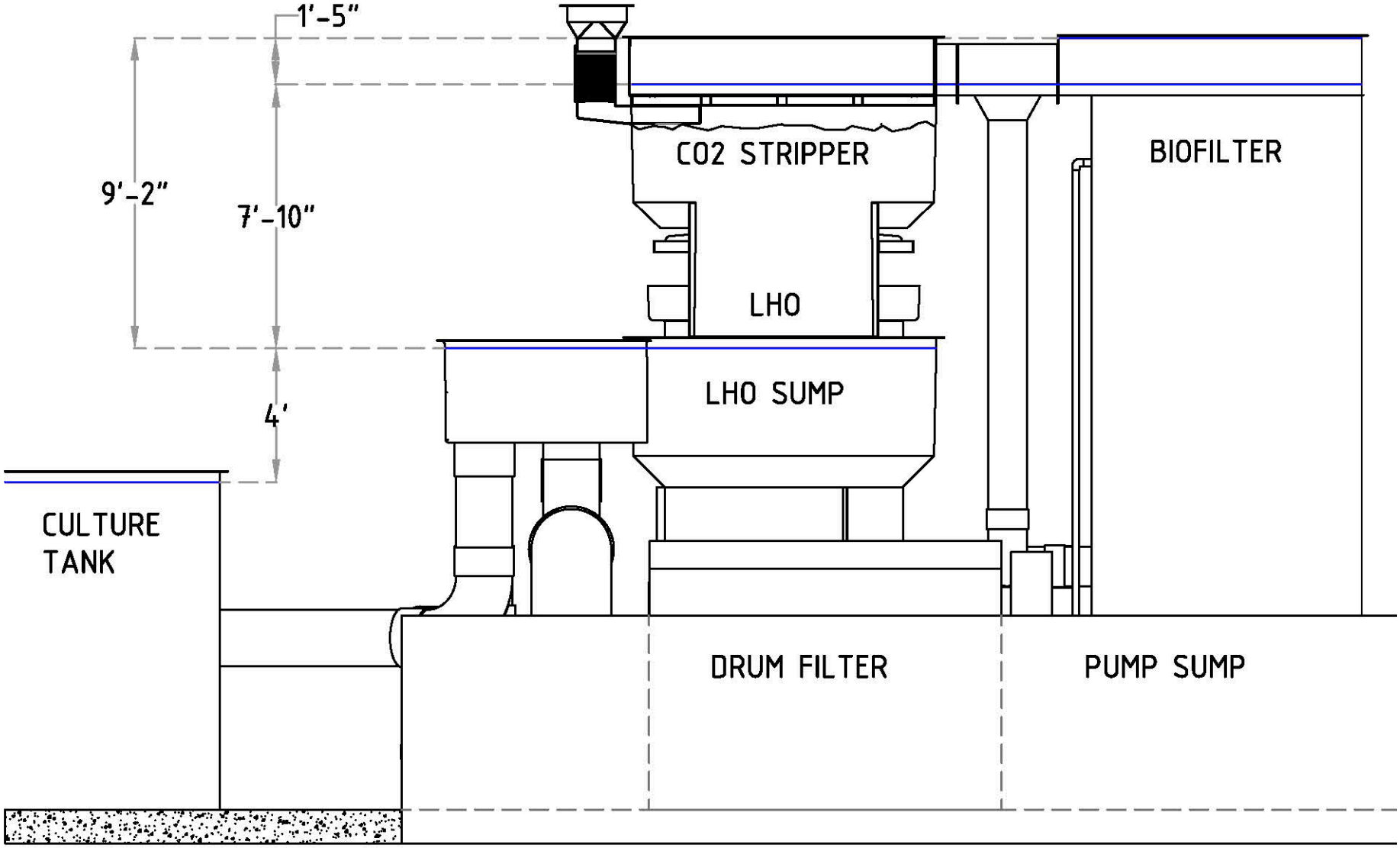
24-hr light and feeding every 2 hrs

CO_2 Production & Removal

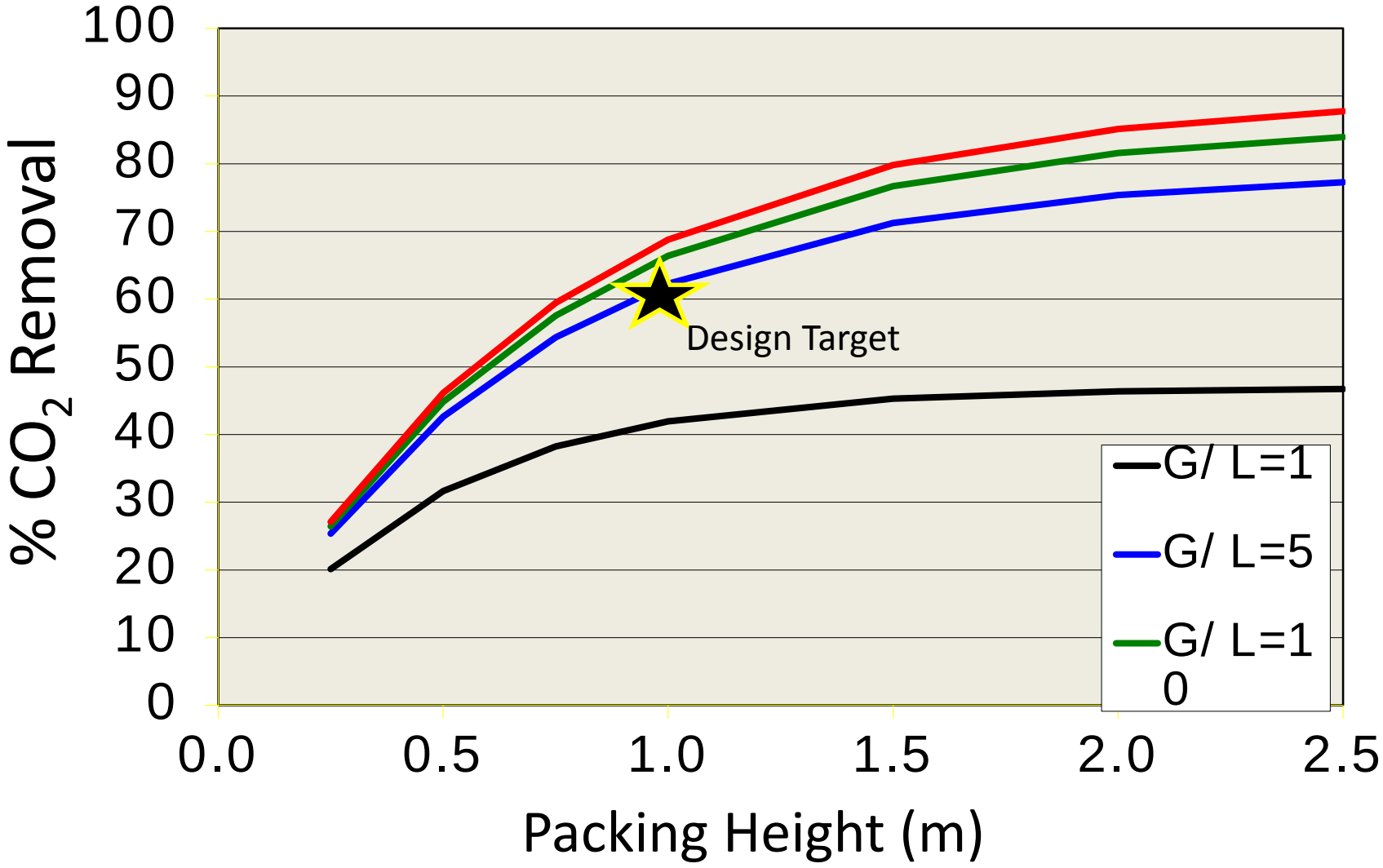
- CO_2 produced in culture tank & biofilter
- CO_2 removed during plunge into sidewall box



CO_2 Stripping Across Gas Balancing Unit



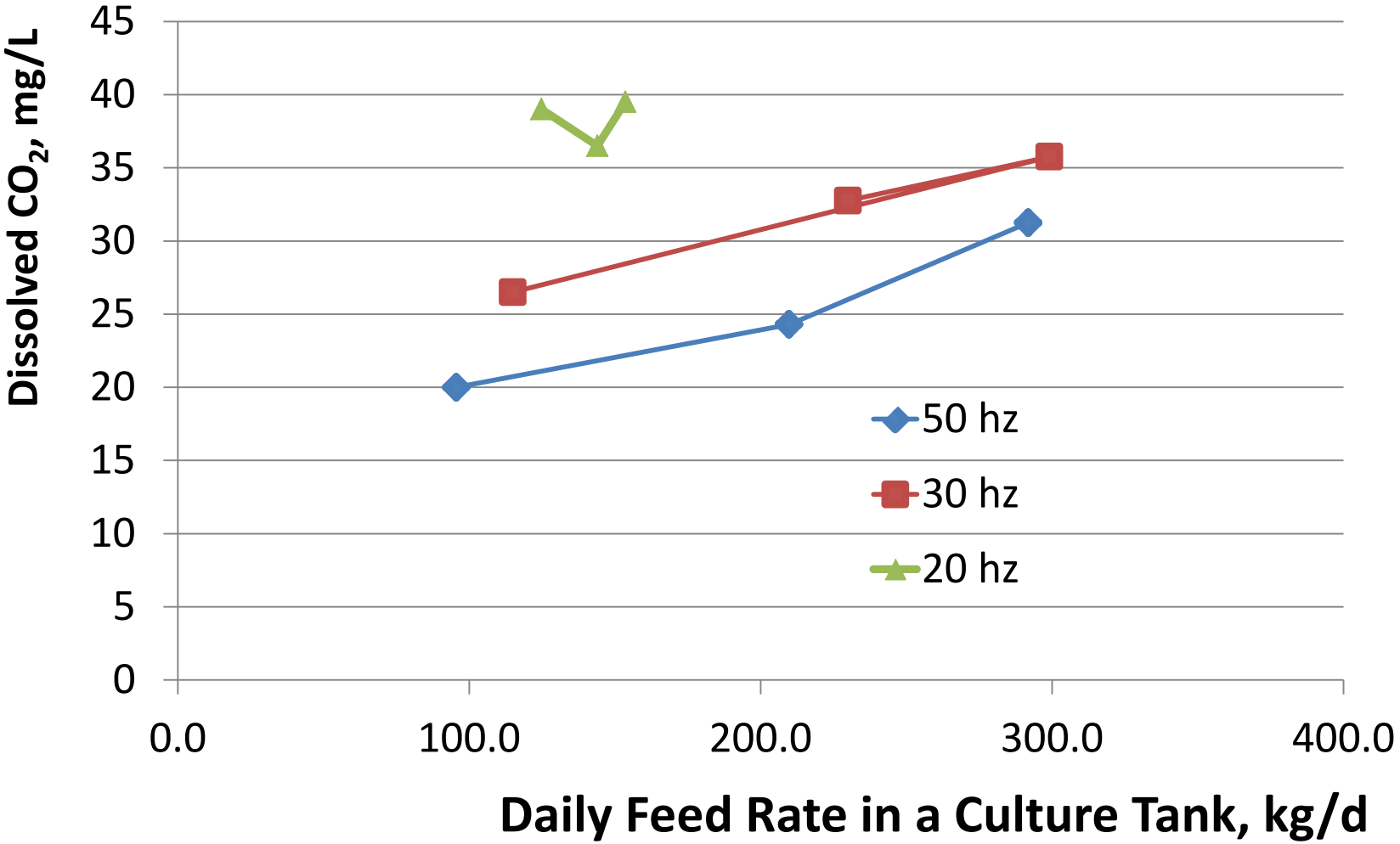
CO2 Stripping Depends on Packing Height and Air:Water (G:L)



Ventilation Fan on CO_2 Stripping Column

- Variable Frequency Drive (VFD) used to adjust fan motor speed and air flow ventilated through stripping columns in each RAS
- Observational data collected from all tanks in two identical RAS modules
  - fan speed adjusted using VFD to three set-points
    - 20, 30, & 50 hz
  - 15.5˚C water temp
  - 1300 to 1500 ppm CO2 in room air

Culture Tank CO_2 Depends on Daily Feed Load and Fan Speed



Culture Tank CO_2 Depends on Tank Specific Feed Load and Fan Speed

- Feed and Fan Speed significantly affect CO_2 in the culture tank (ANCOVA, $P < 0.01$)

	Fan - 50 hz	Fan - 30 hz	Fan - 20 hz
Feed, kg/d	CO2, mg/L	CO2, mg/L	CO2, mg/L
150	22	28	38
200	25	31	NA

  - CO_2 stripping across cascade aeration column
    - 45±1% at 50 hz
    - 24±1% at 30 hz
    - Not measured at 20 hz (but very little stripping)
  - 15± 6% CO_2 stripped across sidewall box plunge

Culture Tank CO_2 Depends on Daily Feed Load and ΔO_2 across Culture Tank

	RAS #1 Fan - 50 hz	RAS #4 Fan - 30 hz
Tank - Heavy		
Feed, kg/d	292	299
CO2, mg/L	31.3	35.8
ΔO2, mg/L	16.0	13.9
Tank - Medium		
Feed, kg/d	210	230
CO2, mg/L	24.8	32.8
ΔO2, mg/L	11.2	11.5
Tank - Light		
Feed, kg/d	96	115
CO2, mg/L	20.0	26.5
ΔO2, mg/L	6.8	7.7

Air Ventilated out the Stripping Column Requires Energy

Control Strategy:

Set VFD on CO2 stripper exhaust fans to achieve target CO2 removal.

The associated makeup air units are ran from a building pressure controller. Maintain building pressure neutral to slightly negative.

Air Ventilated out the Stripping Column Significantly Affects Energy

- CO2 Exhaust fan energy in Row 3*
  - Full Capacity-81,000 cfm (60hz)= $29,025 Yr
  - 85% Capacity-68,850 cfm (51hz)= $17,760 Yr
  - 55% Capacity-45,000 cfm (33hz)= $6,450 Yr

- Associated Makeup Air Cost in Row 3*
  - 100% 69,000 cfm= $226,500 Yr
  - 85% 58,522 cfm= $192,000 Yr
  - 55% 38,250 cfm= $125,000 Yr

- Based on ASHRAE weather bin data for Fort Wayne, IN.; $0.07 kWh electric rate; $0.90 therm NG rate; water set point 15 C; Room set point 15.56 C

Design Conclusions

- Ventilation fans must operate near full-speed to control CO_2 at 25 mg/L in culture tanks when a tank is operated at ≈ 200 kg/d feed
  - Reduced air flow creates problems at high feed load
  - Air flow can be reduced to save energy when tank CO_2 levels are below 25 mg/L
    - Real time monitoring of pump sump CO_2 concentration could be used in a feed-back control loop to adjust ventilation rate to minimize building air exchange

Design Conclusions-Energy

- Even small reductions in exhaust rates can have significant influence on operational costs.
  - VFD's are essential on the CO2 stripper exhaust fans and on the makeup air units.

Thank You!