Culture tank room

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Detailed Report: HVAC Load Calculations for Room in Newville, PA

1. Project Overview

This report calculates the winter heating and summer cooling loads for a room located in Newville, PA, used for milk processing. The room is inside an unconditioned, insulated building and features specific internal heat sources (tanks, lines, motors, COP vat), ventilation requirements, and a controlled indoor environment. The goal is to determine the total HVAC loads, including sensible and latent components, to maintain setpoints of 65°F (heating), 70°F (cooling), and RH ≤ 55%.

2. Room and System Specifications

- Room Dimensions: 50’ × 44’ × 16’ = 35,200 ft³.
- Envelope:
  - Floor: On-grade, 6” concrete (R-0.48) with 2” crushed stone (R-0.16), total R-0.64, U = 1.5625 BTU/hr·ft²·°F, area = 2,200 ft².
  - Walls: 4” cooler panels, R-28, U = 0.0357 BTU/hr·ft²·°F, area = 3,008 ft².
  - Ceiling: 4” cooler panels, R-28, U = 0.0357 BTU/hr·ft²·°F, area = 2,200 ft².
- Setpoints: 65°F (heating), 70°F (cooling), RH ≤ 55% (no humidification required).
- Ventilation: 1,850 cfm constant outside air via HVAC unit (~6.3 air changes/hr).
- Internal Heat Sources:
  - Tanks: Six 4,300-gallon tanks, R-10 insulation, filled daily with 25,800 gallons of milk at 108° F, washed with 600 gallons at 140°F.
  - Lines: 100’ of 2” uninsulated stainless steel, milk at 108°F (3 ft/s), cleaned twice daily at 180° F (3 ft/s, 40 min each).
  - Motors: Six 10 HP agitators (2 hr/day), one 15 HP pump (24 hr/day).
  - COP vat: 50 gallons twice daily at 140°F, 30 min each, 50°F loss (open vat).
- Location: Newville, PA (Cumberland County, cold humid continental climate).
- Climate Data:
  - Winter (January, ASHRAE 99% design): Outdoor 15°F, 80% RH; building 40°F; ground 52°F.
  - Summer (July, ASHRAE 1% design): Outdoor 87°F, 60% RH; building 90°F (walls), 95°F (ceiling); ground 52°F.

3. Calculation Methodology

The total HVAC load is the sum of envelope loads, internal heat loads, and ventilation loads, calculated for winter and summer design conditions. Loads are expressed in BTU/hr, with sensible and latent components separated.

- Envelope Loads: $Q = U \times A \times \Delta T$, where U is the thermal transmittance, A is the surface area, and ΔT is the temperature difference.
- Internal Loads: Heat from tanks, lines, motors, and COP vat, calculated using heat transfer equations or power consumption (motors).
- Ventilation Loads:
  - Sensible: $Q_{sensible} = 1.08 \times cfm \times \Delta T$.
  - Latent: $Q_{latent} = 0.68 \times cfm \times \Delta W$, where ΔW is the humidity ratio difference (grains/lb).
- Assumptions:
  - Ground temperature: 52°F (stable, based on Pennsylvania geothermal data).
  - Building temperatures: 40°F (winter), 90°F/95°F (summer), based on insulation and internal gains.
  - Psychrometrics: Humidity ratios approximated (winter: outdoor ~6 grains/lb, indoor ≤ 40 grains/lb; summer: outdoor ~110 grains/lb, indoor ≤ 55 grains/lb).
  - Motor efficiency: 90%, with losses as heat.
  - No infiltration, as ventilation is controlled.
  - COP vat latent load assumed negligible (no evaporation data).

    - Conversions: 1 HP = 746 watts, 1 watt = 3.412 BTU/hr.

4. Internal Heat Load Calculation

The internal heat load accounts for heat from tanks, lines, motors, and the COP vat, averaged over 24 hours.

- Tanks (Milk Fill, 25,800 gallons/day at 108°F, R-10):
    - Tank surface area: ~510 ft²/tank (estimated, cylindrical, h = 2d), 6 × 510 = 3,060 ft² total.
    - U = 0.1 BTU/hr·ft²·°F, ΔT = 108°F – 70°F = 38°F.
    - Q = 0.1 × 3,060 × 38 = 11,628 BTU/hr.
    - Operation: 15.58 hr/day (based on 25,800 gallons ÷ 0.460 gal/s flow rate).
    - Daily: 11,628 × 15.58 = 181,164 BTU/day.
    - Per hour: 181,164 ÷ 24 = 7,549 BTU/hr.
- Tank Wash (600 gallons/day at 140°F, R-10):
    - ΔT = 140°F – 70°F = 70°F, 1 hr/day.
    - Q = 0.1 × 3,060 × 70 = 21,420 BTU/hr.
    - Daily: 21,420 × 1 = 21,420 BTU/day.
    - Per hour: 21,420 ÷ 24 = 892.5 BTU/hr.
- Milk Fill Line (100', 2" uninsulated, 108°F, 3 ft/s):
    - Pipe surface area: 62.2 ft², U = 5 BTU/hr·ft²·°F, ΔT = 38°F.
    - Q = 5 × 62.2 × 38 = 11,818 BTU/hr, 15.58 hr/day.
    - Daily: 11,818 × 15.58 = 184,124 BTU/day.
    - Per hour: 184,124 ÷ 24 = 7,672 BTU/hr.
- Cleaning Line (100', 2" uninsulated, 180°F, 3 ft/s, 2 × 40 min/day):
    - ΔT = 180°F – 70°F = 110°F, 1.333 hr/day.
    - Q = 5 × 62.2 × 110 = 34,210 BTU/hr.
    - Daily: 34,210 × 1.333 = 45,582 BTU/day.
    - Per hour: 45,582 ÷ 24 = 1,899 BTU/hr.
- Agitator Motors (6 × 10 HP, 2 hr/day):
    - Power: 44,760 watts, 10% heat (90% efficiency).
    - Q = 44,760 × 0.1 × 3.412 = 15,271 BTU/hr.
    - Daily: 15,271 × 2 = 30,542 BTU/day.
    - Per hour: 30,542 ÷ 24 = 1,273 BTU/hr.
- Pump Motor (15 HP, 24 hr/day):
    - Power: 11,190 watts, 10% heat.
    - Q = 11,190 × 0.1 × 3.412 = 3,818 BTU/hr.
- COP Vat (100 gallons/day, 140°F, 50°F loss):
    - Weight: 100 × 8.34 = 834 lb.
    - Q = 834 × 1 × 50 = 41,700 BTU/day.
    - Per hour: 41,700 ÷ 24 = 1,737.5 BTU/hr.
- Total Internal Load:
    - 7,549 + 892.5 + 7,672 + 1,899 + 1,273 + 3,818 + 1,737.5 = 25,841 BTU/hr (sensible).

5. Envelope Load Calculation

- Winter (65°F, building 40°F, ground 52°F):
    - Walls: 0.0357 × 3,008 × (65 – 40) = 2,686 BTU/hr (loss).
    - Ceiling: 0.0357 × 2,200 × (65 – 40) = 1,964 BTU/hr (loss).
    - Floor: 1.5625 × 2,200 × (65 – 52) = 44,687 BTU/hr (loss).
    - Total: 2,686 + 1,964 + 44,687 = 49,337 BTU/hr (loss).
- Summer (70°F, walls 90°F, ceiling 95°F, ground 52°F):
    - Walls: 0.0357 × 3,008 × (90 – 70) = 2,149 BTU/hr (gain).
    - Ceiling: 0.0357 × 2,200 × (95 – 70) = 1,964 BTU/hr (gain).
    - Floor: 1.5625 × 2,200 × (52 – 70) = –61,875 BTU/hr (loss).
    - Total: 2,149 + 1,964 – 61,875 = –57,762 BTU/hr (net loss).

6. Ventilation Load Calculation

- Winter (65°F, RH ≤ 55%, outdoor 15°F, 80% RH):
    - Sensible: 1.08 × 1,850 × (65 – 15) = 99,900 BTU/hr.
    - Latent: Outdoor ~6 grains/lb, indoor ≤ 40 grains/lb. At 65°F, 6 grains/lb → RH ~10% (< 55%), no humidification needed.
    - Q_latent = 0 BTU/hr.
    - Total: 99,900 BTU/hr.
- Summer (70°F, RH ≤ 55%, outdoor 87°F, 60% RH):
    - Sensible: 1.08 × 1,850 × (87 – 70) = 33,966 BTU/hr.
    - Latent: Outdoor ~110 grains/lb, indoor ≤ 55 grains/lb. ΔW = 110 – 55 = 55 grains/lb.
    - Q_latent = 0.68 × 1,850 × 55 = 69,190 BTU/hr.
    - Total: 33,966 + 69,190 = 103,156 BTU/hr.

7. Total HVAC Loads
- Winter (Heating):
    - Envelope: 49,337 BTU/hr (loss).
    - Internal: –25,841 BTU/hr (gain).
    - Ventilation: 99,900 BTU/hr (sensible).
    - Sensible: 49,337 – 25,841 + 99,900 = 123,396 BTU/hr.
    - Latent: 0 BTU/hr.
    - Total: 123,396 BTU/hr.
- Summer (Cooling):
    - Envelope: –57,762 BTU/hr (loss).
    - Internal: 25,841 BTU/hr (gain).
    - Ventilation: 103,156 BTU/hr (33,966 sensible + 69,190 latent).
    - Sensible: –57,762 + 25,841 + 33,966 = 2,045 BTU/hr.
    - Latent: 69,190 BTU/hr.
    - Total: 2,045 + 69,190 = 71,235 BTU/hr.

8. HVAC Sizing and Recommendations
- Winter:
    - Load: 123,396 BTU/hr (~10.3 tons or ~36.2 kW), all sensible.
    - System: Gas or electric heater, no humidifier.
    - Safety factor (10–20%): ~135,000–148,000 BTU/hr.
- Summer:
    - Load: 71,235 BTU/hr (~5.9 tons or ~20.9 kW), 2,045 sensible, 69,190 latent.
    - System: DX cooling with reheat or dedicated dehumidifier to handle large latent load with minimal sensible cooling.
    - Safety factor (10–20%): ~78,000–85,000 BTU/hr.
- Energy Recovery: An energy recovery ventilator (ERV) could reduce ventilation loads (99,900 BTU/hr winter, 103,156 BTU/hr summer).
- Floor: Uninsulated floor (R-0.64) contributes significant winter heatThe floor remains a significant heat loss path in winter (44,687 BTU/hr). Adding insulation (e.g., 2” foam, R-14) could reduce this load.
- Ventilation: 1,850 cfm (~6.3 air changes/hr) is high. If reducible (e.g., per code or process needs), loads could decrease significantly.

9. Notes and Assumptions
- Floor: The 2” crushed stone (R-0.16) increases floor R-value to R-0.64, reducing winter heat loss (44,687 BTU/hr vs. 59,560 BTU/hr) and summer cooling benefit (–61,875 BTU/hr vs. –82,487 BTU/hr).
- Tanks: R-10 insulation lowers internal heat load (25,841 BTU/hr vs. 44,760 BTU/hr with previous 3° F loss assumption).
- Ventilation: Drives winter sensible load (99,900 BTU/hr) and summer latent load (69,190 BTU/hr).
- RH: No humidification needed (winter RH ~10% < 55%). Summer requires dehumidification to maintain RH ≤ 55%.
- Assumptions:

    - Tank surface area (~510 ft²/tank) estimated. Exact dimensions would improve accuracy.
    - Crushed stone R-value (0.08/inch) typical for dry gravel. Moisture content could alter this.
    - Psychrometric data approximated. Precise outdoor RH/wet-bulb data would refine latent loads.
    - COP vat latent load assumed negligible. Evaporation data would allow inclusion.
    - No infiltration or exhaust fans assumed. If present, provide details.
- Newville, PA: Winter (15°F, 80% RH) requires high heating; summer (87°F, 60% RH) demands significant dehumidification.

10. Final Results
    - Winter Heating Load: 123,396 BTU/hr (all sensible, no latent load, as RH < 55%).
    - Summer Cooling Load: 71,235 BTU/hr (2,045 BTU/hr sensible, 69,190 BTU/hr latent for dehumidification).