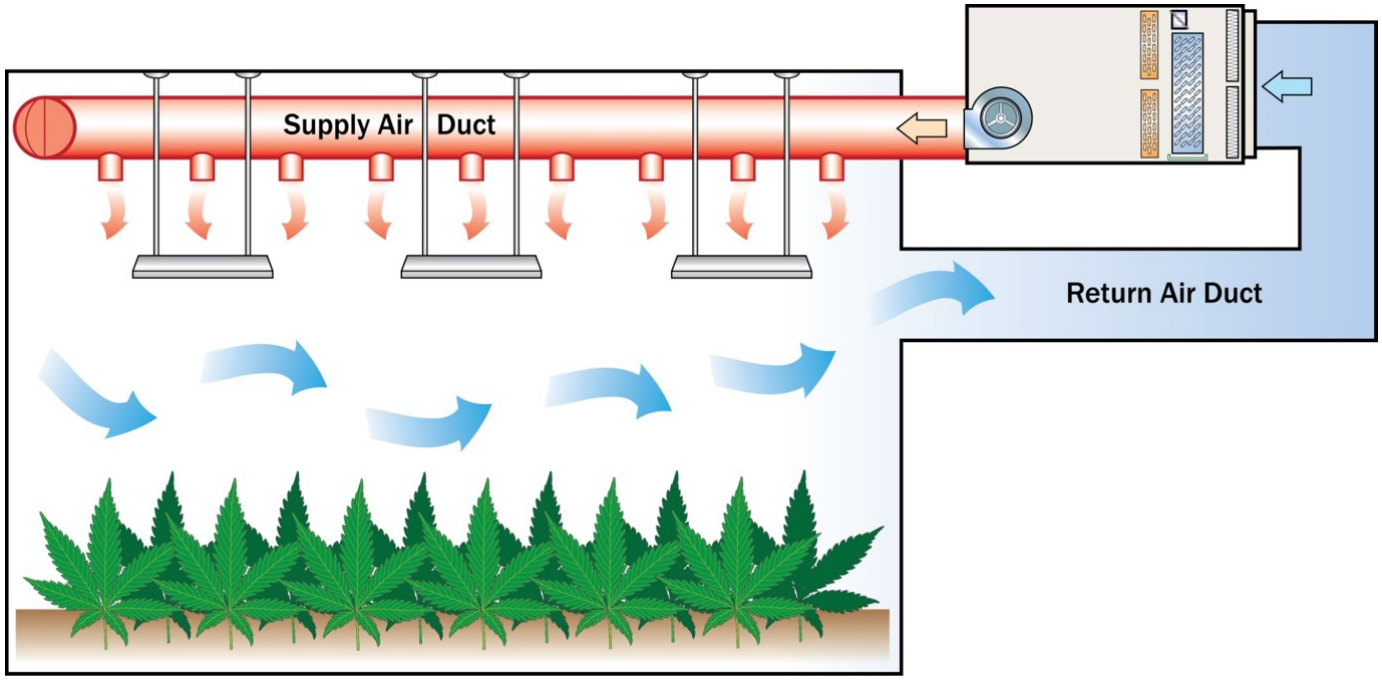


INDOOR MARIJUANA GROW FACILITY DESIGN

Presented by

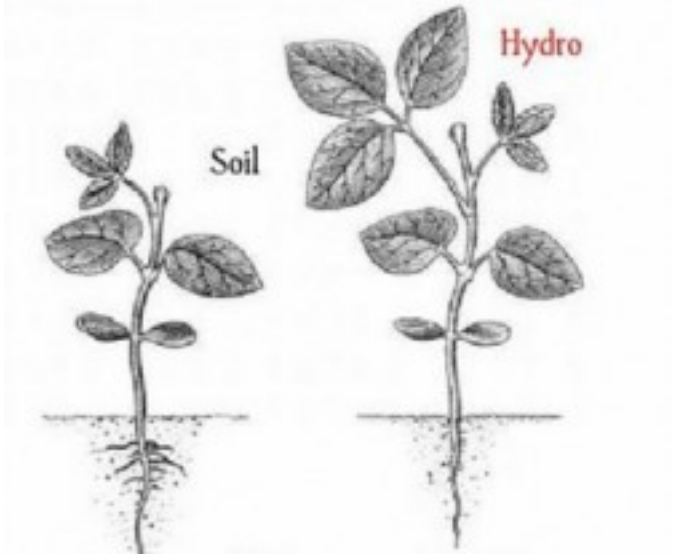
Bruce Dobbs, P.E.

Mechanical Systems Engineering

Advantages of Indoor Growing

- Better Control of Growing Environment
  - Better quality product
  - Not at whim of seasons
  - Can plant and harvest throughout the year

Indoor Grow Considerations



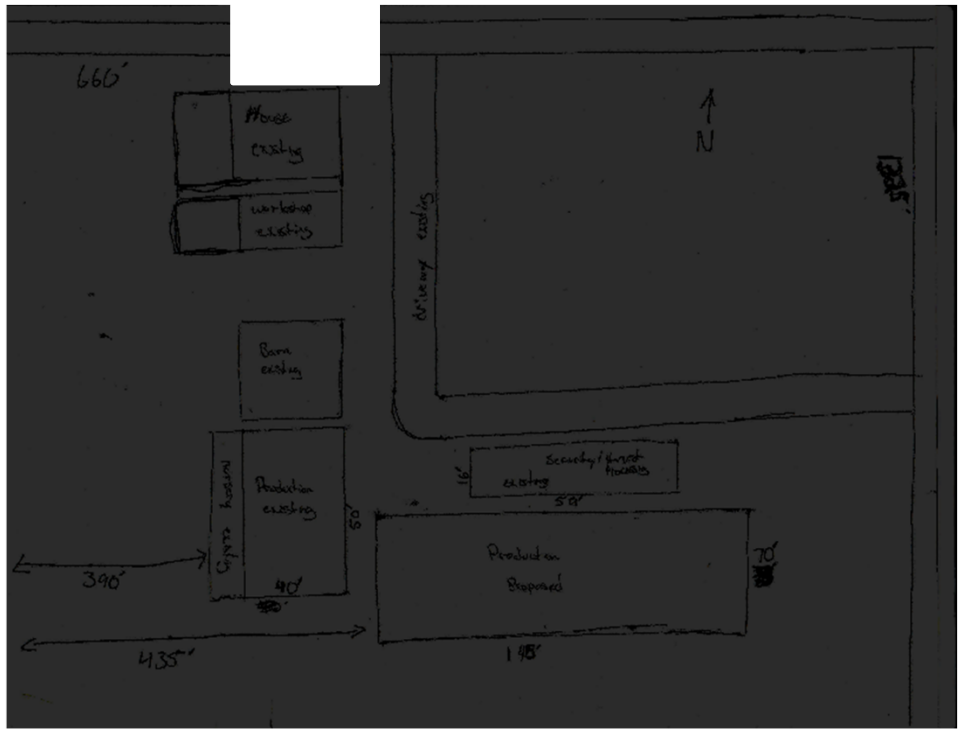
- Soil or Hydroponics
  - Hydroponics produce larger yields
  - Soil growth is easier and less expensive

- **Client considerations**
  - Security & confidentiality
  - Lack of construction experience
  - Low budget minded
  - Subject to extreme sticker shock
  - Deal in cash
  - Extrapolate small scale grow approaches into large scale projects
  - Inadequate consideration of utility availability (especially electric power)

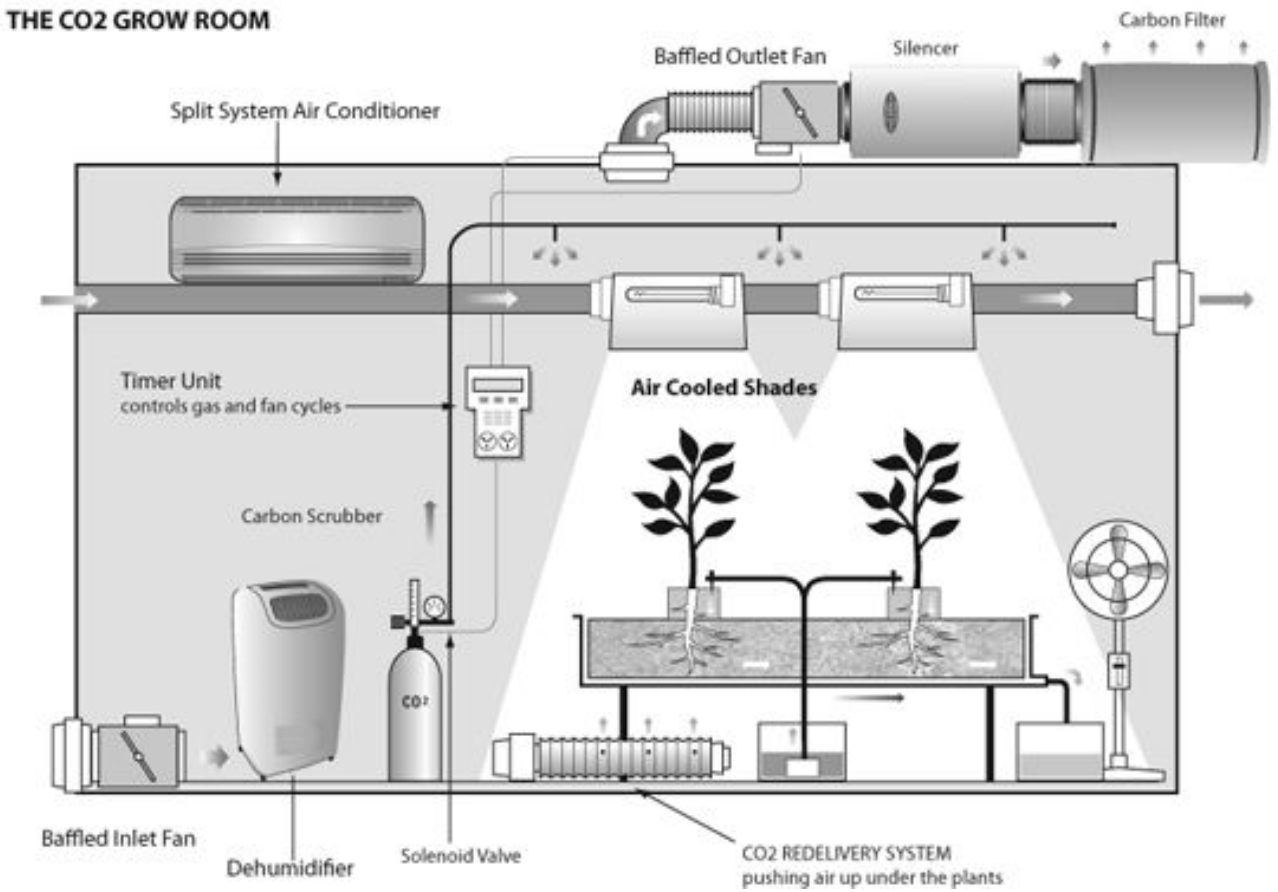
- **Power Availability**
  - Have you confirmed that power is available?
  - What voltage/phase is available?
  - Will your budget allow for new power service if utility does not have adequate capacity?
  - Is CHP and option?

- Typical Power Requirement for 10,000 sf facility
  - Lights 160 kW
  - AC/Dehumidifier 77 kW
  - Electric Heat 10 kW
  - Recirculation Fans 20 kW
  - Exhaust Fans 5 kW
  - Miscellaneous 20 kW
  - **Total: 787 kW**

- **Client Considerations**
  - Minimal Architectural & Civil Design

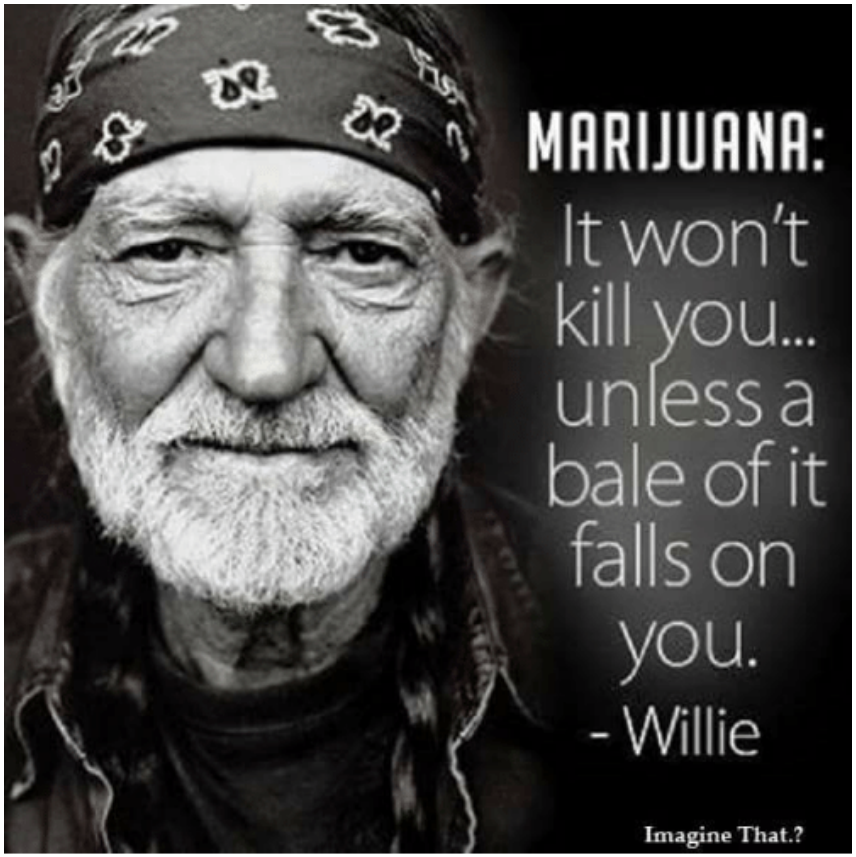


Grow Room Layout



Design Considerations

- Odor control
- Temperature & humidity control
- THC resin adhesion to surfaces
- Utility availability
  - Electricity
  - Gas
  - Water
- Client budget
- Annual energy costs

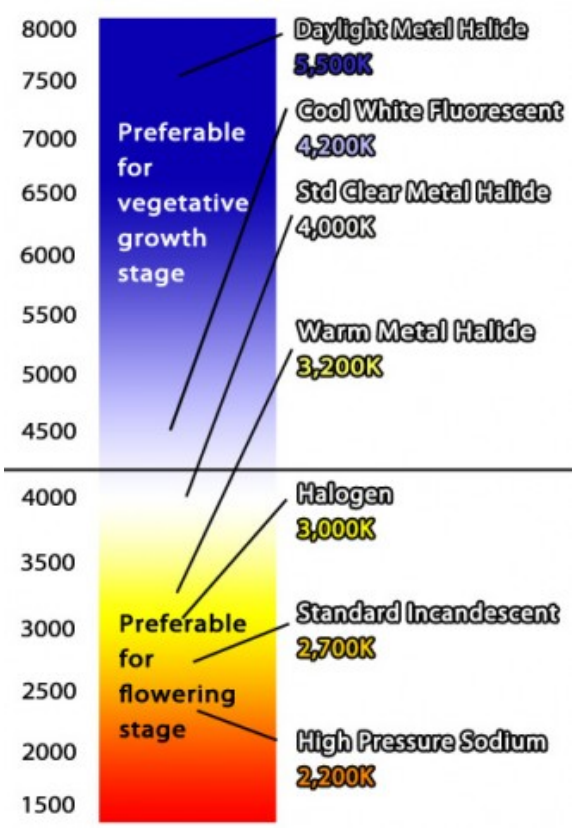


Types of Lighting

- Three Main Types of Lighting
  - Compact Fluorescent Lights
  - Light Emitting Diode (LED)
  - High Intensity Discharge (HID)

Cannabis Lighting

- Lumens & Kelvin
  - Lumens measure brightness of light
  - Kelvin measures color temperature emitted by bulb



Cannabis Lighting

- **LED Lighting**
  - Low heat production
  - Reduced A/C Load
  - 60,000 hour life
  - Slow early adoption

Flowering & Light Cycles

- Flowering Marijuana
  - Female plant starts to produce buds
- When is Plant Ready for Flowering
  - Cannabis doesn't flower because of size or age
  - Flowers as function of light cycles

Flowering & Light Cycles

- Vegetative growth of 4 – 5 weeks is recommended
- Bring plant to flower when ½ the size you want it to be during flowering
  - Plant will grow to 2 to 2 ½ times it's vegetative size

Flowering & Light Cycle

- Flowering Timeline
  - Varies by strain
- Rough Guidelines
  - **1 to 2 Weeks:** 1st flowers start to show after switching to 12/12 light cycle
  - **3 to 5 Weeks:** Plants stretch for light and flowers appear at nodes
  - **5+ Weeks:** Buds start to thicken. Flowers close. Leaves will yellow as energy used to make flowers. Plant reaches its flowering peak
  - **Final 2 Weeks:** Flush the plants using clean water
  - **Final 48 Hours:** Further flush nutrients and unwanted sugars by turning out all light

Flowering & Light Cycle

- Types of Flower
  - Female
    - Main aim for growers
  - Sensimilla
    - Marijuana flowering that has not been pollinated
    - Most potent (most THC)
    - Most prized of plants
  - Male
    - Doesn't produce buds for smoking
    - Produce pollen used for seed production
  - Hermaphrodite
    - Created thru stress during early flowering. Lacks potency of Sensimilla.

Flowering & Light Cycle

Growth stage	Hours of light	Hours of darkness	Light in Kelvin
Seedling	16-24	8-0	2700k
Clone	18-24	6-0	2700k
Vegetative	18	6	6500k
Flowering	12	12	2700k

- Lighting Cycle
  - Mimic Fall/Winter Lighting Conditions
- Vegetative Growth Stage
  - 18/6 hour cycle
- Flowering Stage
  - 12/12 hour cycle
  - Reduce number of lumens
    - Change from 6500k to 2700k
  - Marijuana a fall flowering plant so we're reproducing fall lighting conditions

Indoor Climate Considerations

- Photosynthesis
- Evapotranspiration
- Lighting Loads
- Irrigation Methods
- Properly Directed Air Movement
  - Beneficial vapor differentials
  - Improved transpiration rates
- Changing SHF
  - Vary depending on plant growth & levels of vegetation and whether lights on or off

Clackamas County Code

G. Odor. As used in Subsection 841.03(G), building means the building, or portion thereof, used for marijuana production or marijuana processing. However, Subsection 841.03(G) does not apply to a building approved as part of outdoor production pursuant to Subsection 841.03(A)(2)(b).

1. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter.

2. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM.

3. The filtration system shall be maintained in working order and shall be in use. The filters shall be changed a minimum of once every 365 days.

4. Negative air pressure shall be maintained inside the building.

5. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building.

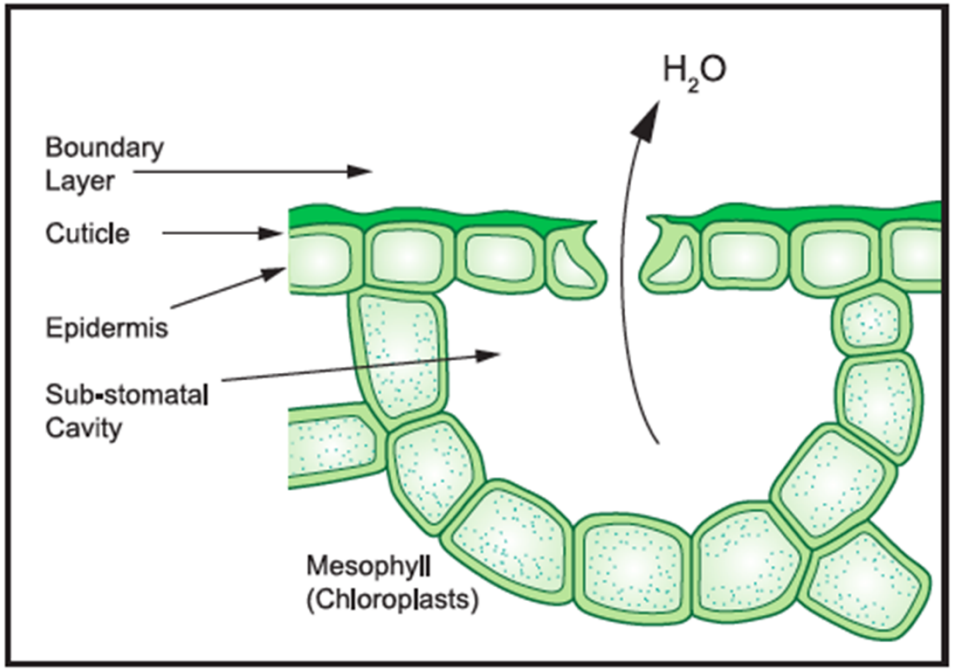
6. The filtration system shall be designed by a mechanical engineer licensed in the State of Oregon. The engineer shall stamp the design and certify that it complies with Subsection 841.03(G).

7. An alternative odor control system is permitted if the applicant submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required.

Marijuana Odor Control

- Strong odor production must be controlled
- Carbon Filtration
  - Recirculated air
    - Filtration Rate = (Room Volume)/3
  - Exhaust air
    - Filtrate air being exhausted from space
- Ozone Generator
  - Neutralizes odor by oxidizing bad smells with ozone
  - Extra Oxygen molecule attaches to contaminants and O_3 turns to O_2, creating safer work environment

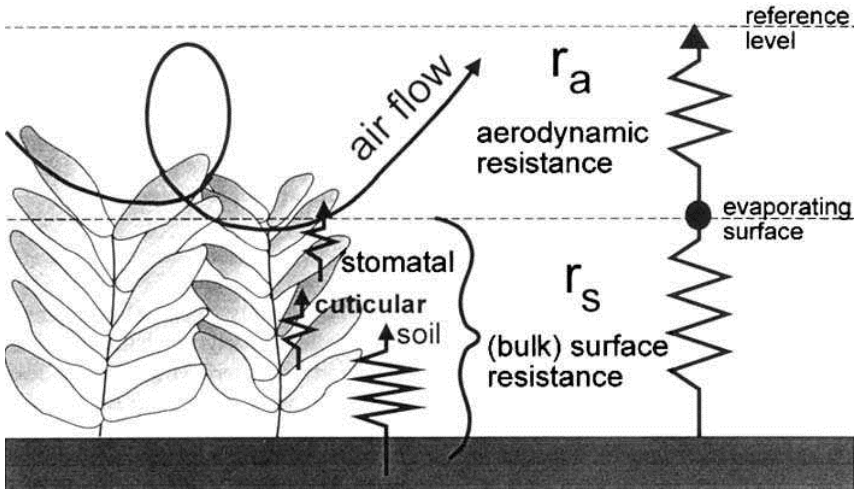
- Photosynthesis
  - When exposed to light, plant converts CO_2 and water into food
- Transpiration
  - Plant uses water to carry nutrients throughout their tissues then release water as water vapor via stomata to surrounding boundary layer air



Transpiration Through Stomata

- **Vapor Pressure Differential**
  - Drives respiration
  - Temperature of leaves affects transpiration
  - Internal plant temperature regulated by water evaporating within the plant
  - VPD must be properly controlled to avoid heat stress to plant

- **Latent load Determination**
  - Option 1: Equals the difference in the amount of water added through irrigation and the amount of water that goes to drain
  - Option 2: Calculate using Penman-Monteith Formula
  - Option 3: Use industry averages
    - 0.25 to 0.50 gal/plant/day
    - 2 sf/plant



Penman-Monteith Formula

- **Penman Monteith Formula**
  - Used to calculate TR

John Monteith

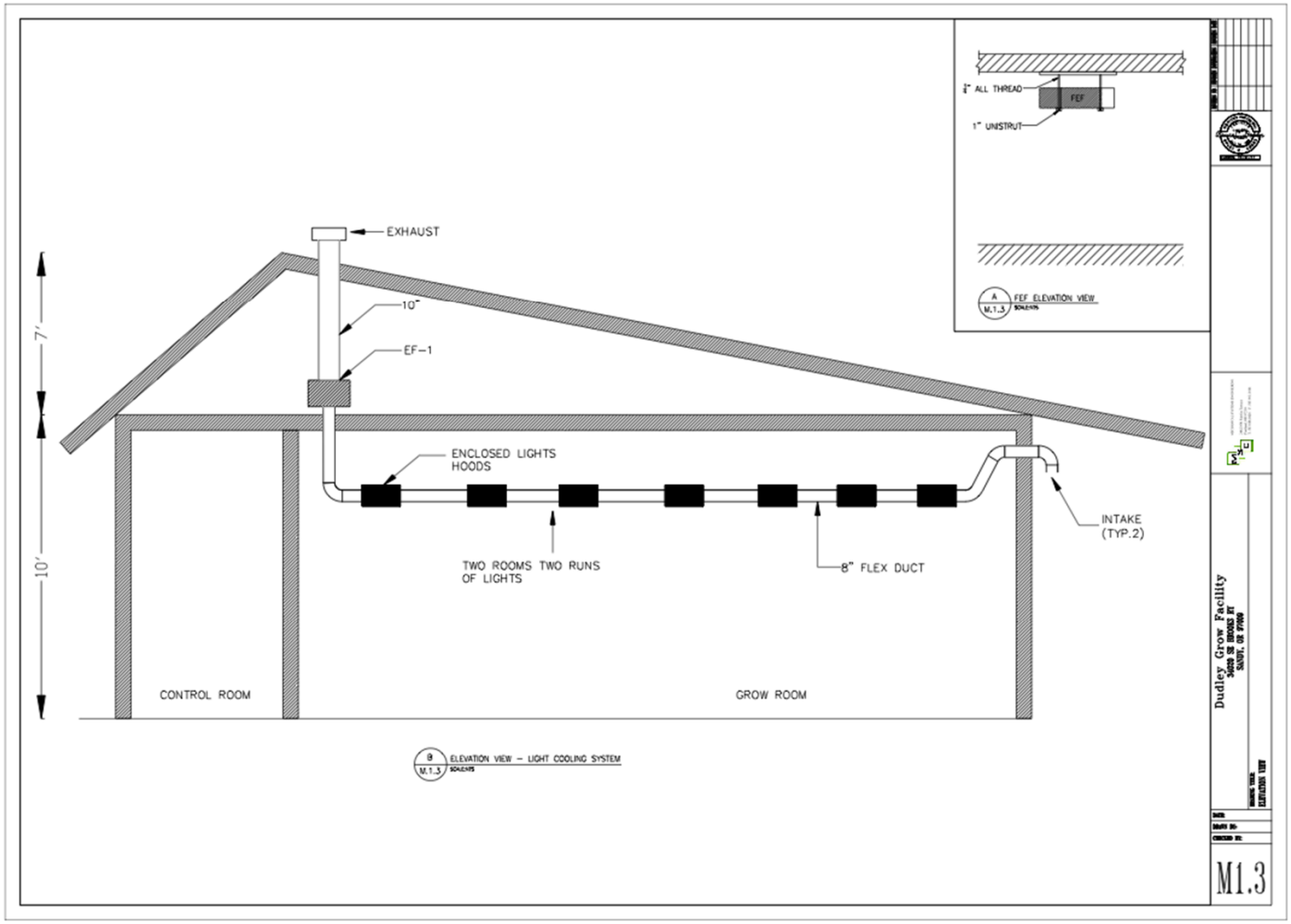
Howard Penman

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (6)$$

where

ET_o reference evapotranspiration [mm day^{-1}],
R_n net radiation at the crop surface [MJ m^{-2} day^{-1}],
G soil heat flux density [MJ m^{-2} day^{-1}],
T mean daily air temperature at 2 m height [°C],
u_2 wind speed at 2 m height [m s^{-1}],
e_s saturation vapour pressure [kPa],
e_a actual vapour pressure [kPa],
e_s - e_a saturation vapour pressure deficit [kPa],
D slope vapour pressure curve [kPa $°C^{-1}$],
g psychrometric constant [kPa $°C^{-1}$].

Air Cooled Lighting



- **Modulating Sensible Heat Ratios**
  - Plant moisture release changes as they grow
    - Evapotransrespiration higher as plants grow
  - Lighting loads vary depending on whether on or off
  - Problems occur when lights turned off before moisture (latent heat) has been absorbed
    - Thermostat satisfied and unit goes off before removing latent load

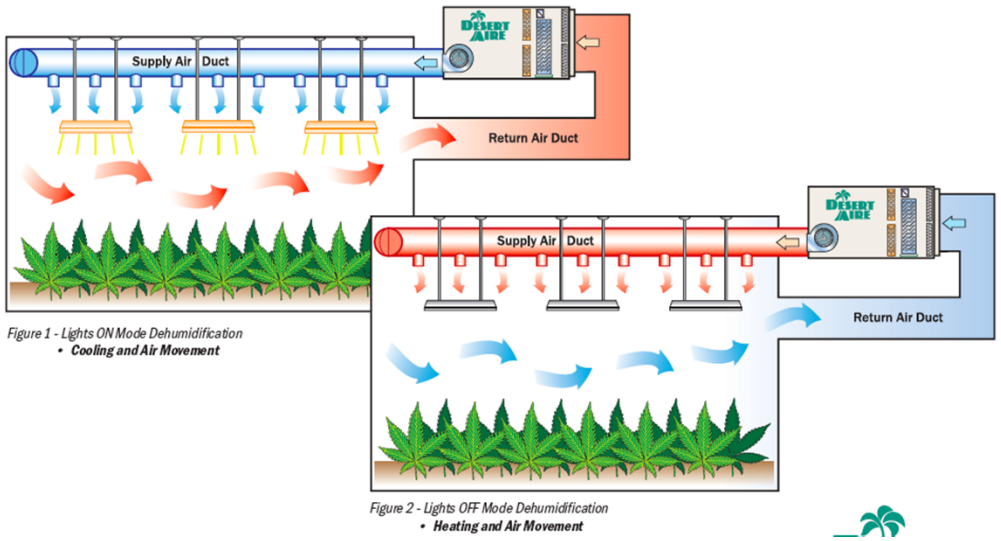
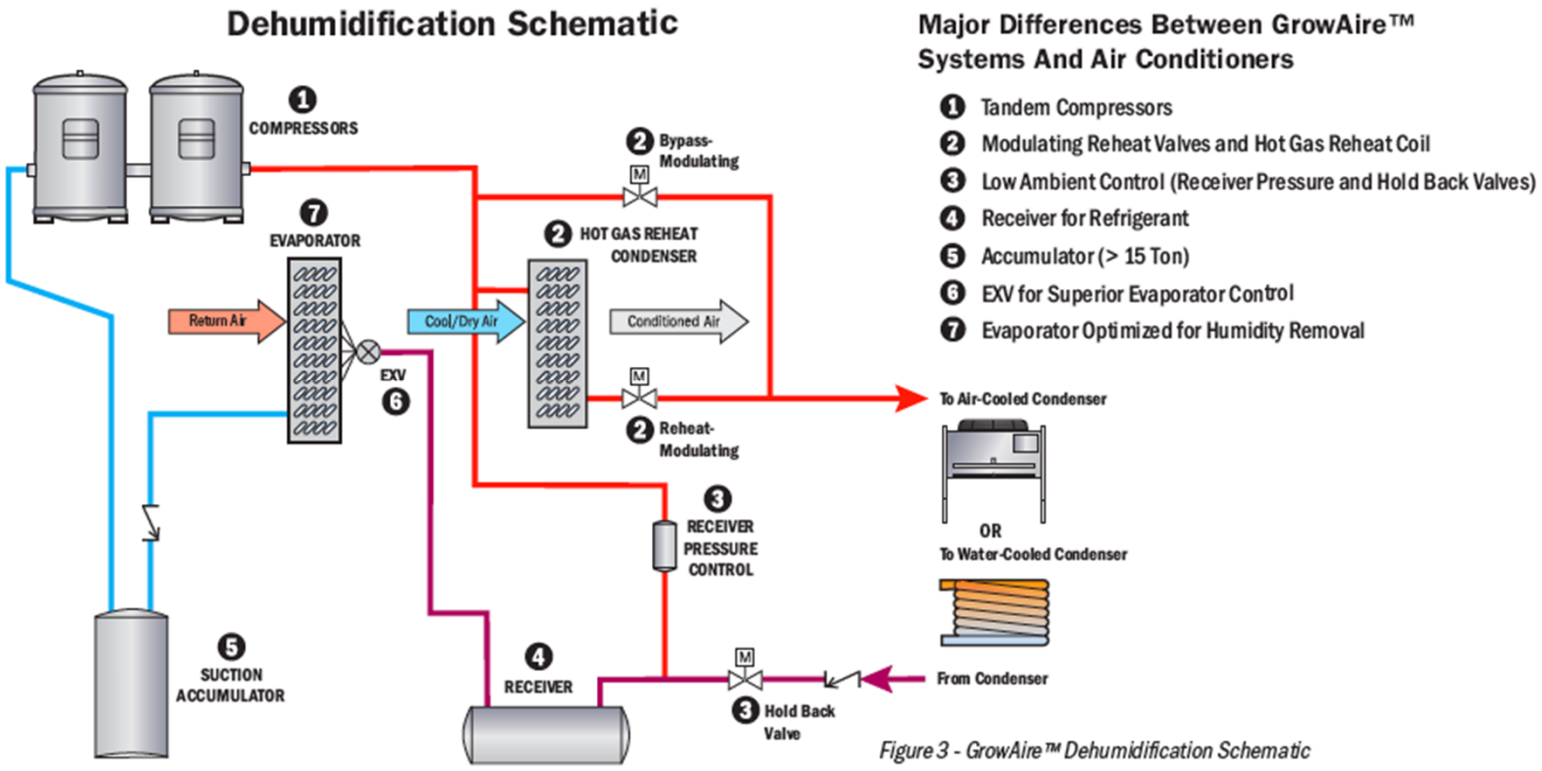


Figure 1 - Lights ON Mode Dehumidification
• Cooling and Air Movement

Figure 2 - Lights OFF Mode Dehumidification
• Heating and Air Movement

Dehumidifier Schematic



Major Differences Between GrowAire™ Systems And Air Conditioners

1. Tandem Compressors
2. Modulating Reheat Valves and Hot Gas Reheat Coil
3. Low Ambient Control (Receiver Pressure and Hold Back Valves)
4. Receiver for Refrigerant
5. Accumulator (> 15 Ton)
6. EXV for Superior Evaporator Control
7. Evaporator Optimized for Humidity Removal

Figure 3 - GrowAire™ Dehumidification Schematic

- **Dehumidifier Selection**
  - Quantities/Types of lights
  - Heat loss when lights off
  - Type of watering system
  - Amount of water evaporated/transpired
  - Grow room volume
  - Optimal air circulation
  - Temp/RH in each grow phase

Air Circulation

- **Air Circulation**
  - Cannabis plant uses substantial amount of CO_2
  - Laminar flow air movement minimizes stress on plant
  - Recirculate air for odor control

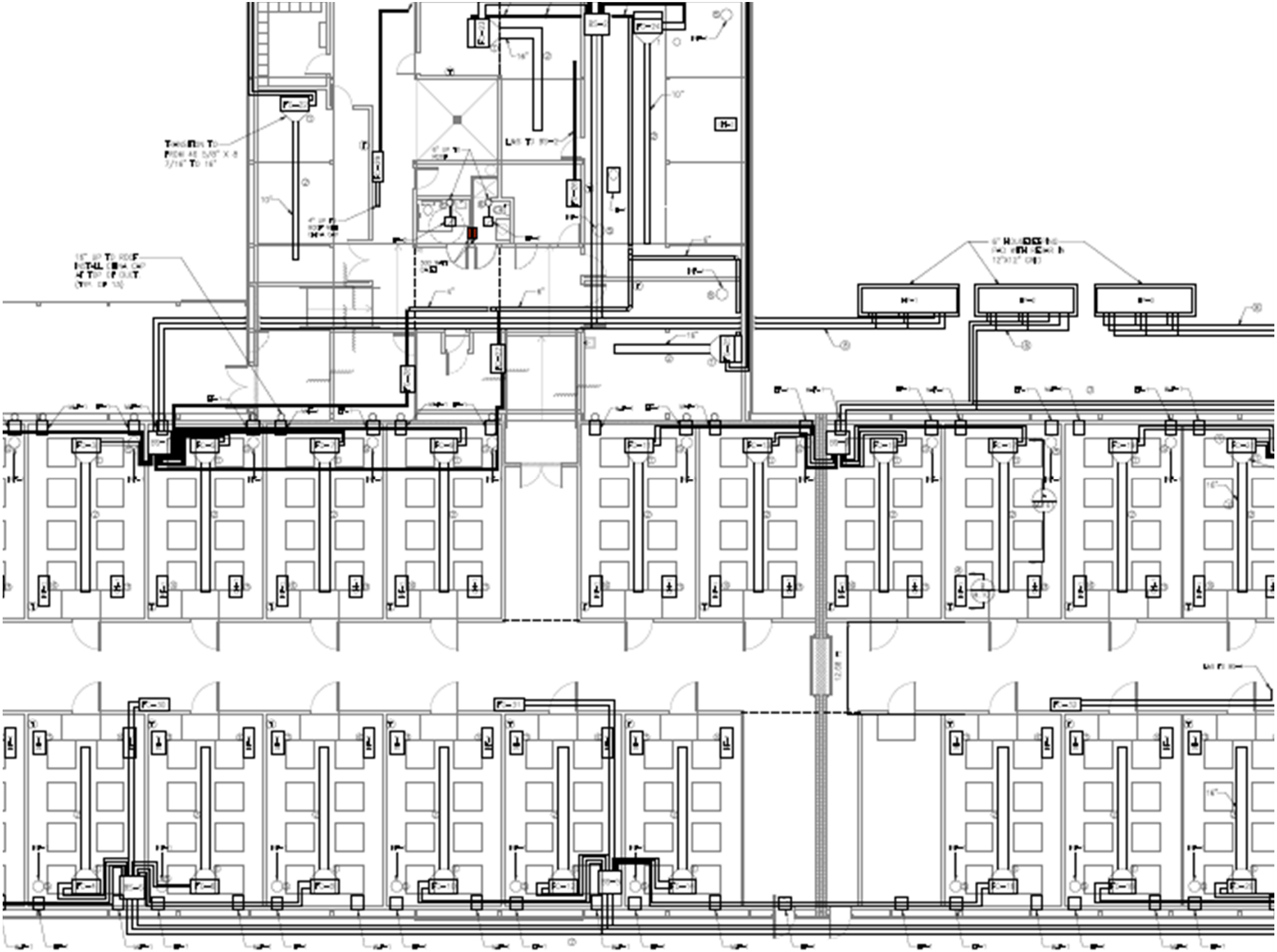
Marijuana Drying

- Ideal Environmental Conditions
  - Temperature: 65F to 75F
  - Humidity: 45% to 55%
- Drying period is 5 to 9 days
- Maintain slow air velocities
  - High velocities dry the product too quickly (causes bad tasting cannabis)

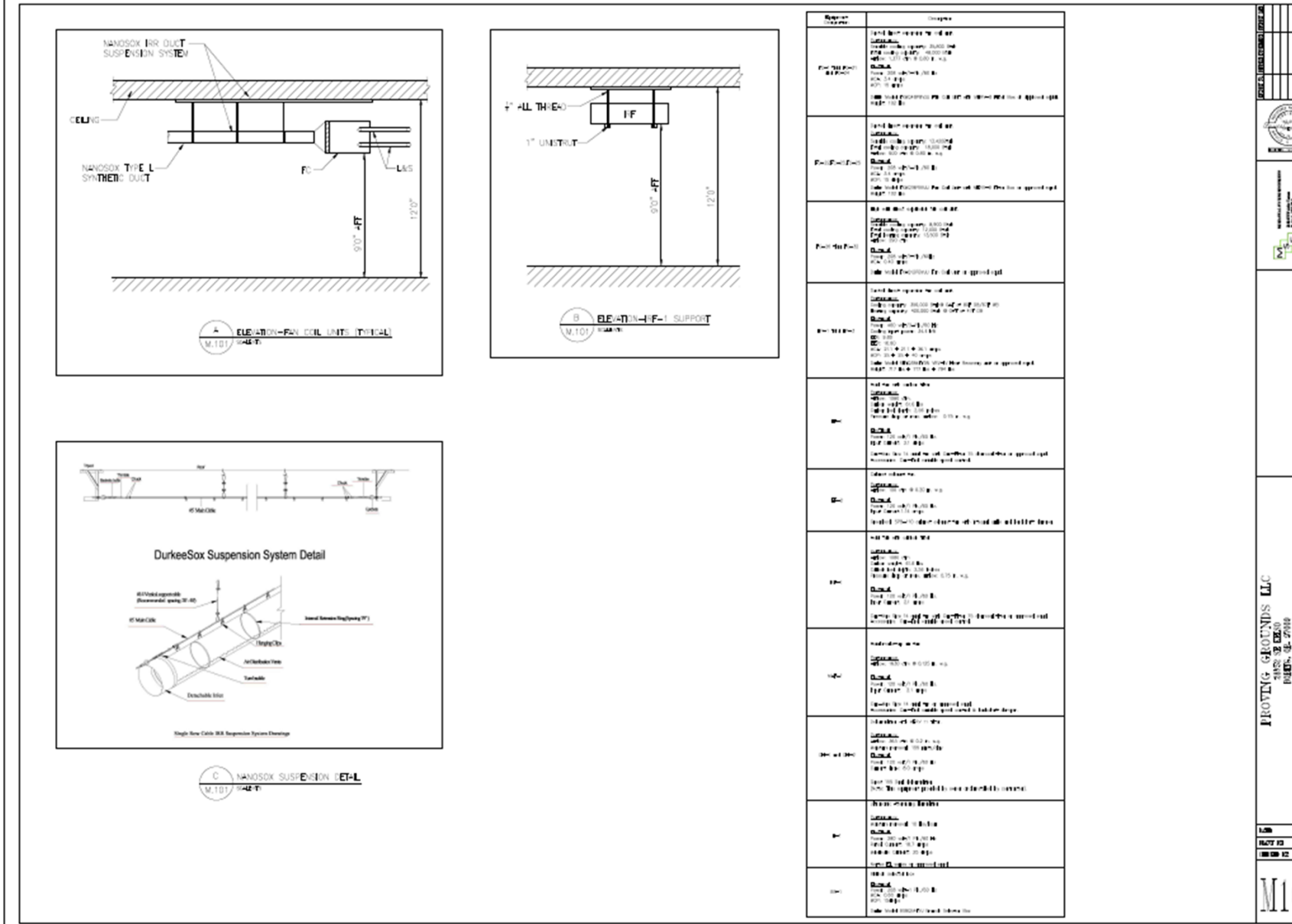
Proving Grounds

- 22 grow rooms
  - (8) 1000 watt HID lights
  - 30,000 Btuh cooling load
  - Design Conditions: 75F/50%
- Drying room
  - Design Conditions: 75F/50%

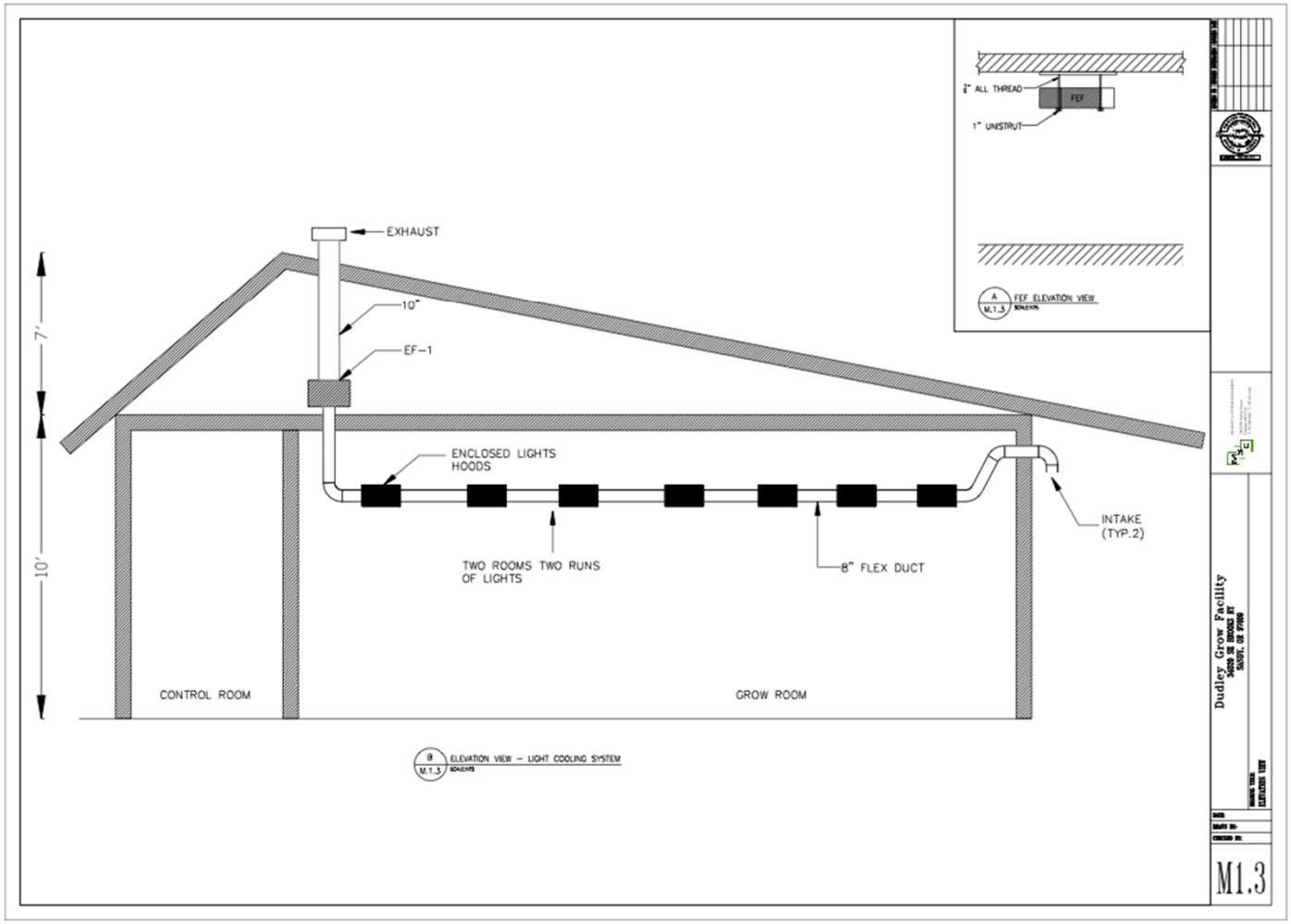
Proving Grounds Floor Plan



Proving Grounds Details and Elevations

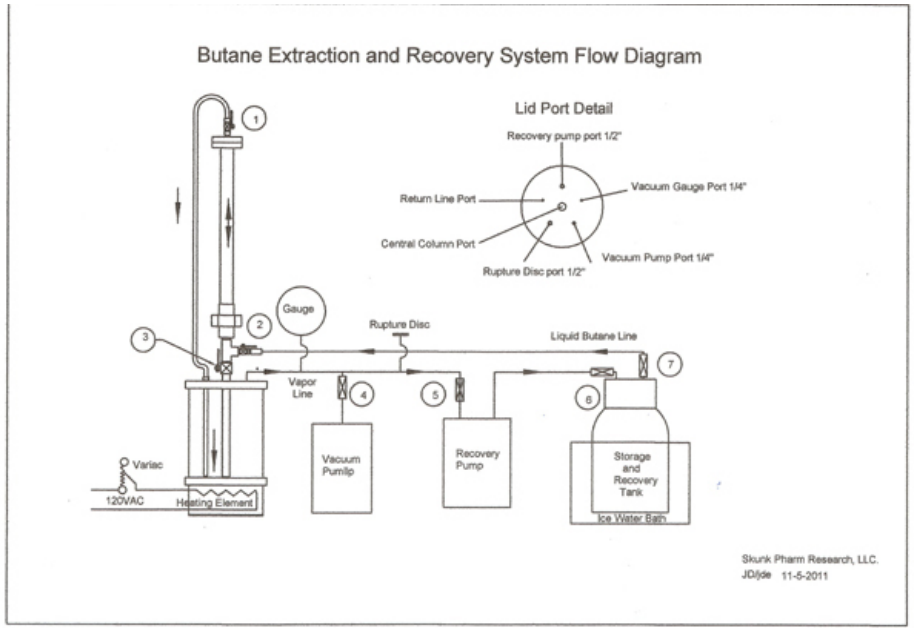


Air Cooled Lighting



Extraction Facilities

- Extraction oils significantly more potent than buds
- Usually used for medical marijuana
- Extraction of pure THC
- Methods
  - CO_2
  - Butane (Volatile)

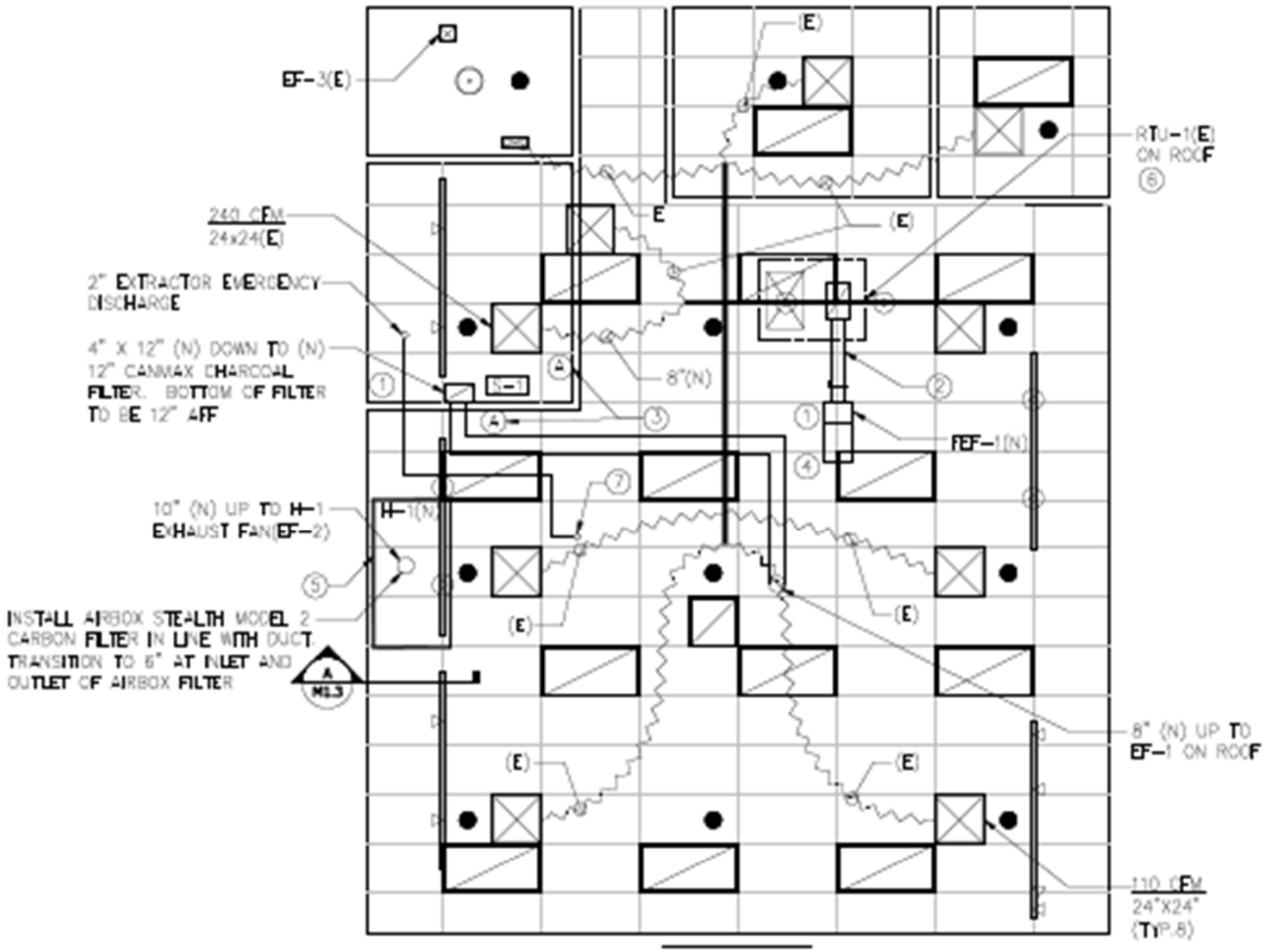


Butane Extraction Process

Extraction Facilities

- **Design considerations**
  - Dedicated exhaust and makeup air serving extraction room
  - Extraction room 1-hour rated
  - Exhaust fan to be Class 1 Div 2 rated.
  - All electrical equipment within 10’ of extraction equipment to be Class 1 Div 2
  - Charcoal filtered exhaust and return air

CO_2 Extraction System



CO2 Extraction Facility