ECHOGEN

sCO2 Safety

Over Pressure Protection and Dispersion

Echogen has developed a platform sCO_2 technology to **reduce industrial emissions** and enable the energy transition

Long Duration Energy Storage

Nuclear and other Primary Cycles

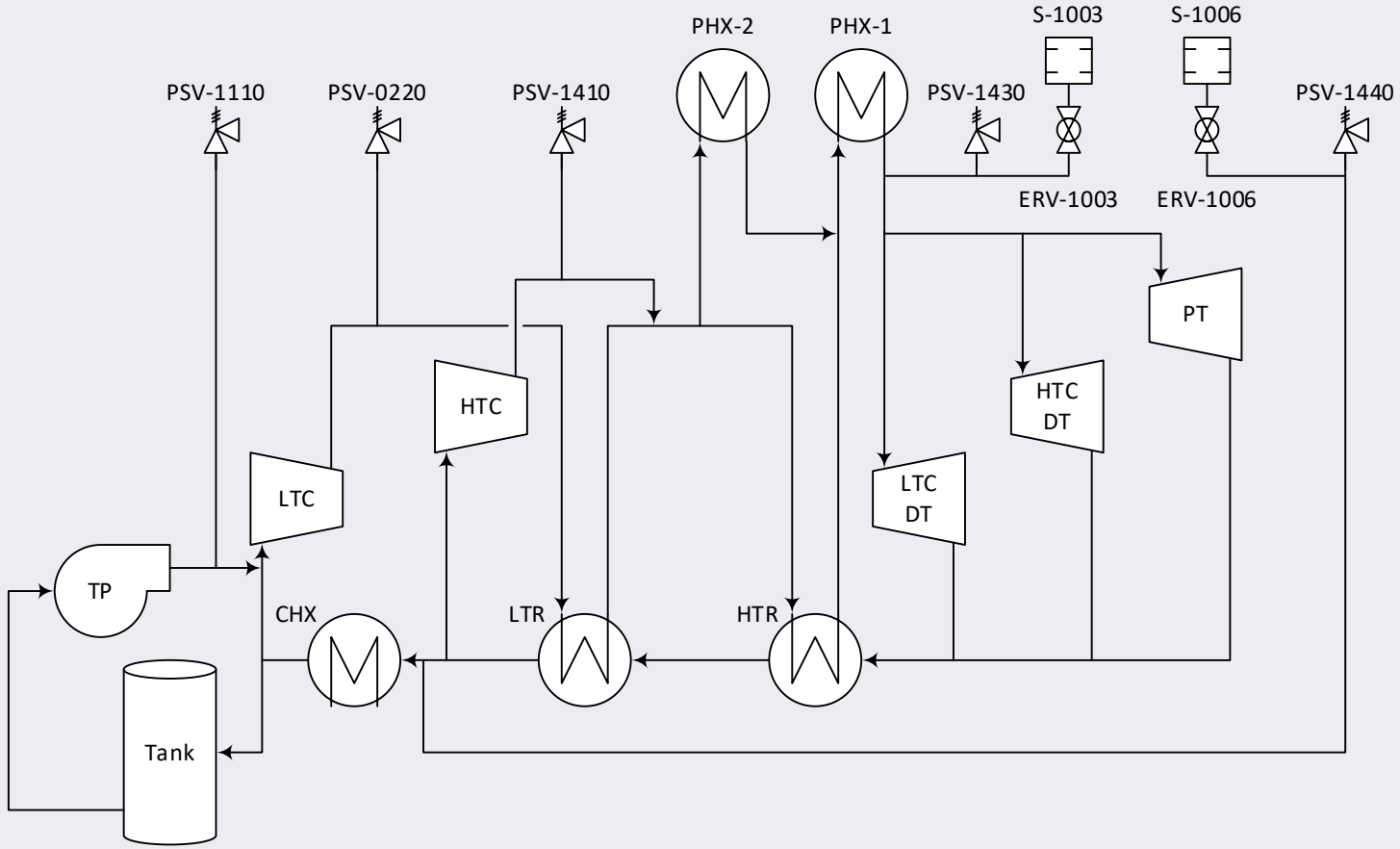
Waste Heat Recovery

Industrial Heating

Relief Systems

System Summary

- Mechanical / spring release (PSVs)
  - Inventory control system (1)
  - Low pressure piping (1)
  - High pressure piping (3)
- Electronic / pneumatically controlled (ERVs)
  - Low pressure piping (1)
  - High pressure piping (1)



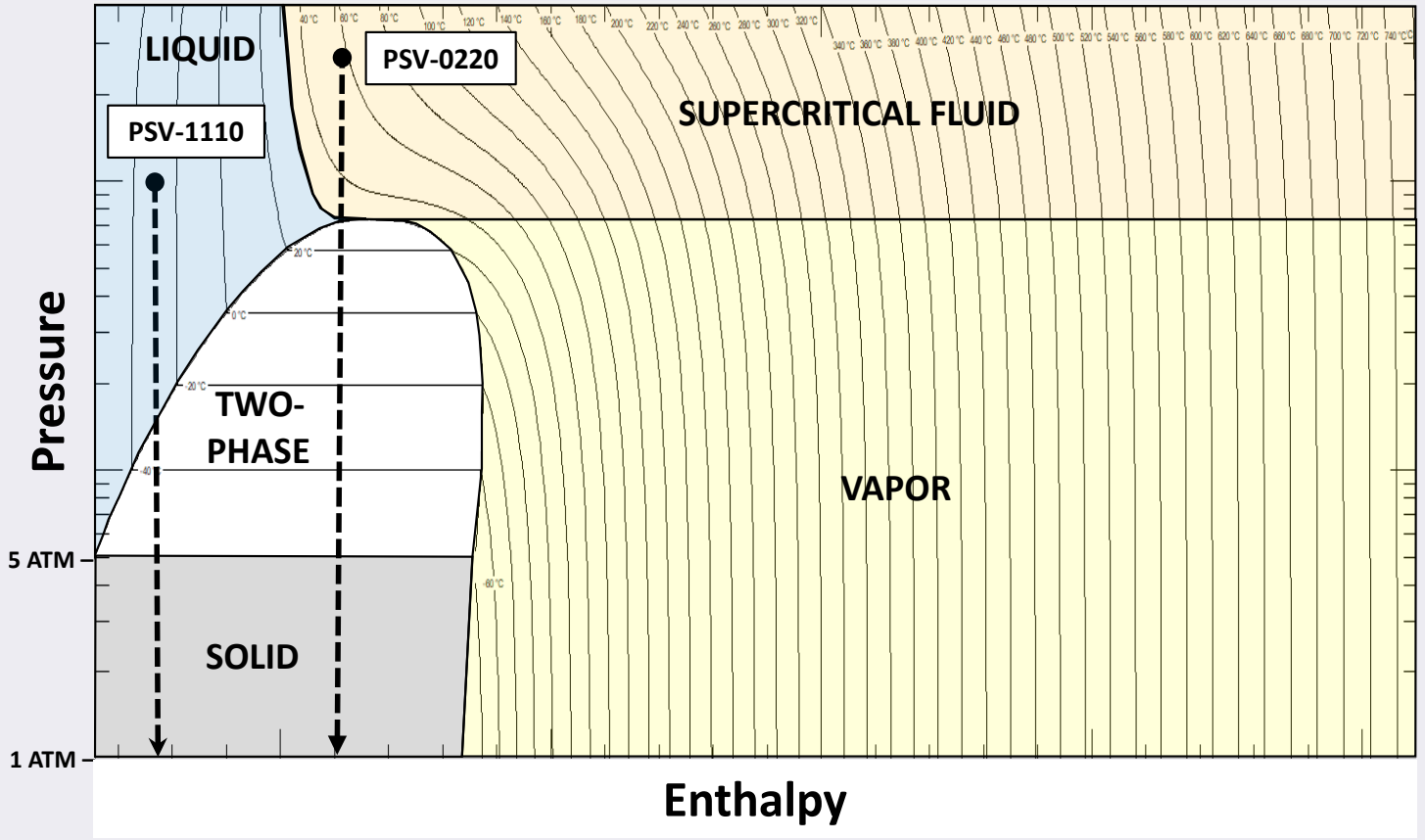
Typical Sizing Cases

Condition	Vapor Relief Guidance	Applicability
Closed Outlets	Total incoming steam and vapor plus that generated therein at relieving conditions	• Pump / Compressor PSVs • Heater PSV
Cooling Failure	Total vapor to condenser relieving conditions	• Condenser inlet PSV
Power Failure	Size relief valve for worst case condition that can occur	• Heater ERV / PSV

Note: Piping design pressure a minimum of 10% above normal operating pressure

Solid-State Discharge

- Liquid CO_2 or dense sCO_2 depressurized below ~5 atm becomes solid
- Standoff pipes required (direct vent to atmosphere)

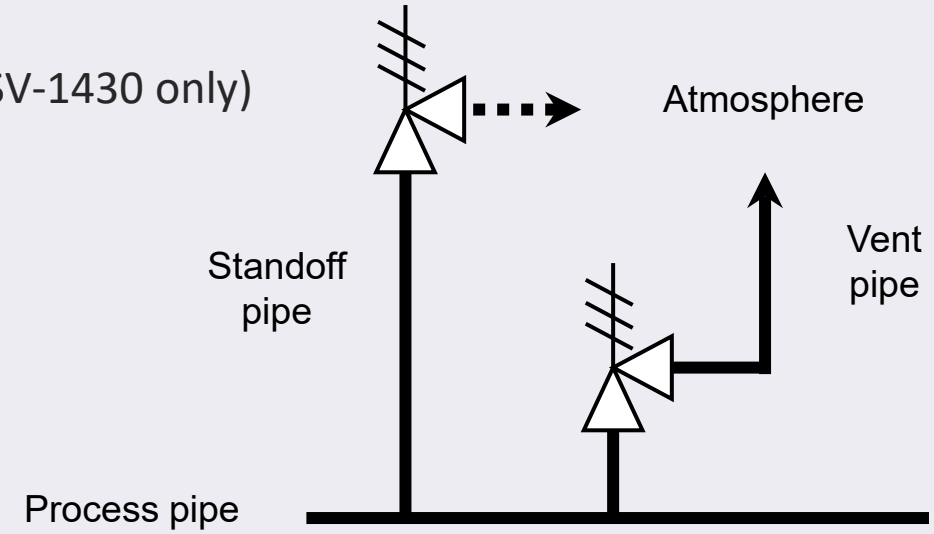


Vents vs Standoffs

- Vent pipes (downstream of PSVs)
  - Lower pressure → Lower pipe schedule
  - Lower pressure/temperature → Lower alloy material (PSV-1430 only)
- Standoff pipes (upstream of PSVs)
  - Higher density → SIGNIFICANTLY smaller pipe diameter

Description	PSV-1410		PSV-1430		PSV-1440	
	Vent	Standoff	Vent	Standoff	Vent	Standoff
Size	20"	6"	34"	8"	24"	6"
Schedule	10	160	40	160	10	80
Material	CS	CS	9C	NA	CS	CS

CS = Carbon Steel
NA = Nickel Alloy
9C = 9-Chrome



Things to Consider

Proven solutions for high temperature PSV limited

Potential for solid discharge

PSV standoffs for low temperature relief

Dense Phase Vapor Dispersion

Silencer requirements

CO2 Dispersion

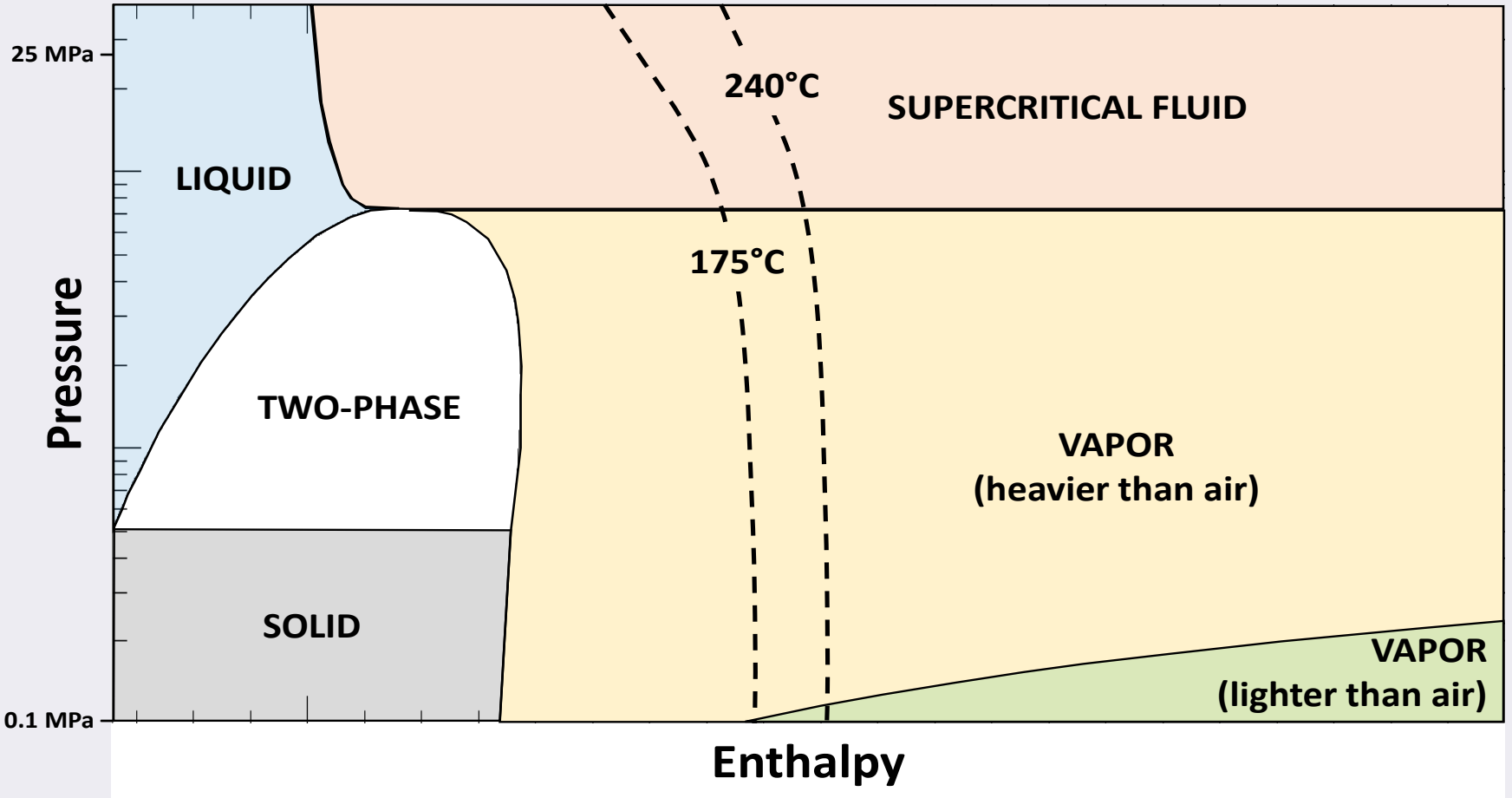
CO2 Exposure Thresholds

Carbon Dioxide Concentration		Exposure Time	Effects
Percent in Air	ppmv		
0.025-0.05%	250-500	Indefinite	Typical outdoor air concentrations.
0.10%	~1,000	Indefinite	Decreased mental performance, Sick Building Syndrome complaints
0.10-0.14%	1,000-1,400	Work day	Decreased mental performance in an office environment
0.10-0.15%	1,000-1,500	Indefinite	Recommendation of upper limit for indoor space (700 ppm above outdoor air levels)
0.50%	5,000	8 hours	NIOSH recommended time-weighted average threshold limit value
0.70%	7,000	Weeks	Acidosis
1.00%	10,000	Indefinite	Decreased mental performance, Sick Building Syndrome complaints
2.00%	20,000	Several hours	Headache, dyspnea upon mild exertion
3.00%	30,000	15 minutes	NIOSH recommended short-term exposure limit
		1 hour	Mild headache, sweating, and dyspnea at rest
4.00%	40,000	Immediate	NIOSH immediately dangerous to life or health
4.00-5.00%	40,000-50,000	Within minutes	Headache, dizziness, increased blood pressure, uncomfortable dyspnea
6.00%	60,000	1-2 minutes	Hearing and visual disturbances
		~15 minutes	Headache, dyspnea
		Several hours	Tremors
7.00-10.00%	70,000-100,000	< 3 minutes to 1 hour	Headache, increased heart rate, dyspnea, dizziness, sweating, unconsciousness
10.00-15.00%	100,000-150,000	1 to several minutes	Dizziness, drowsiness, severe muscle twitching, unconsciousness
17.00-30.00%	170,000-300,000	< 1 minute	Loss of controlled and purposeful activity, unconsciousness, convulsions, coma, death

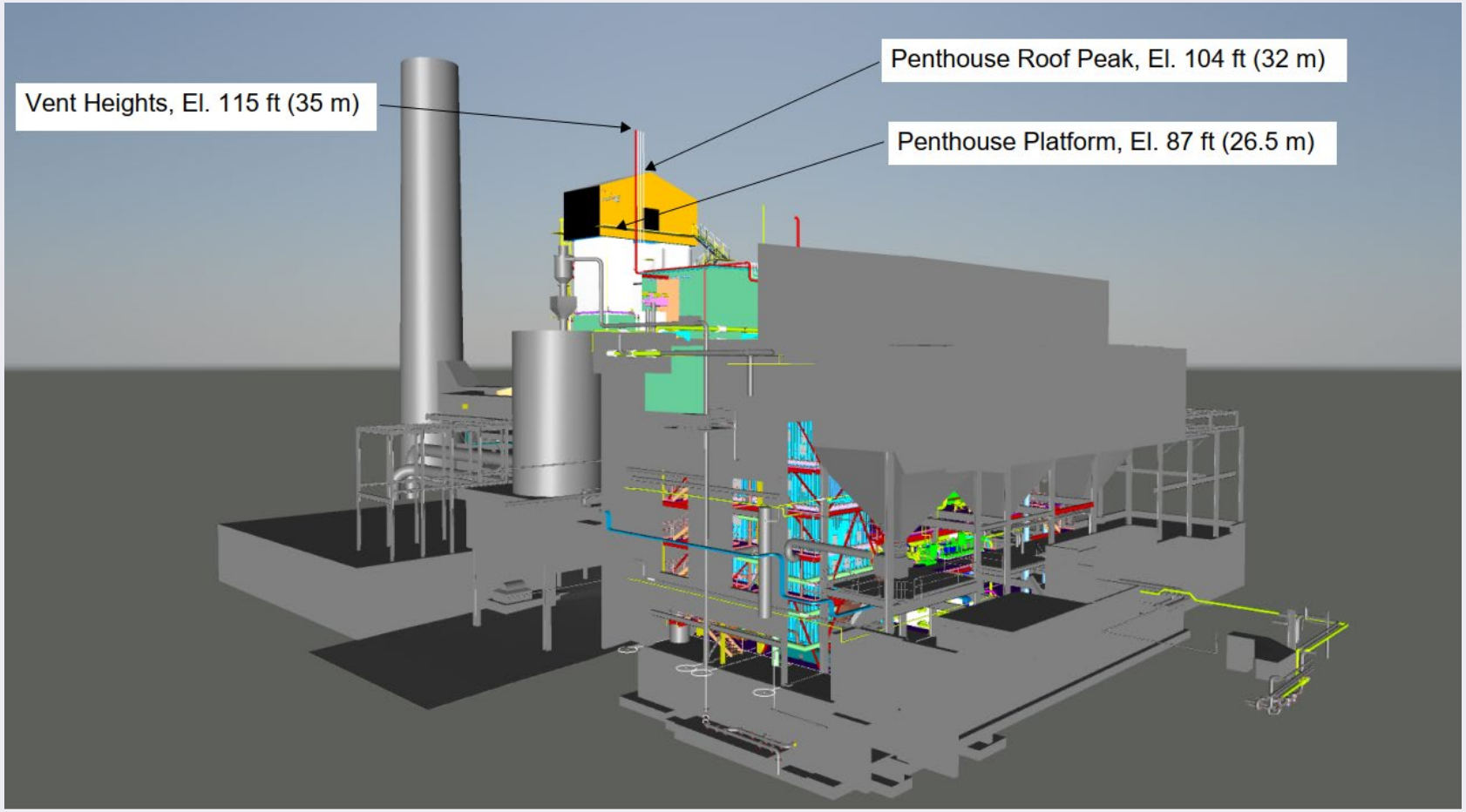
Required Exposure Thresholds

Concentration (ppmv)	Max Duration – On Site (mins)	Max Duration – Off Site (mins)
40,000	0	0
30,000	15	0
5,000	60	15
1,000	No Limit	60

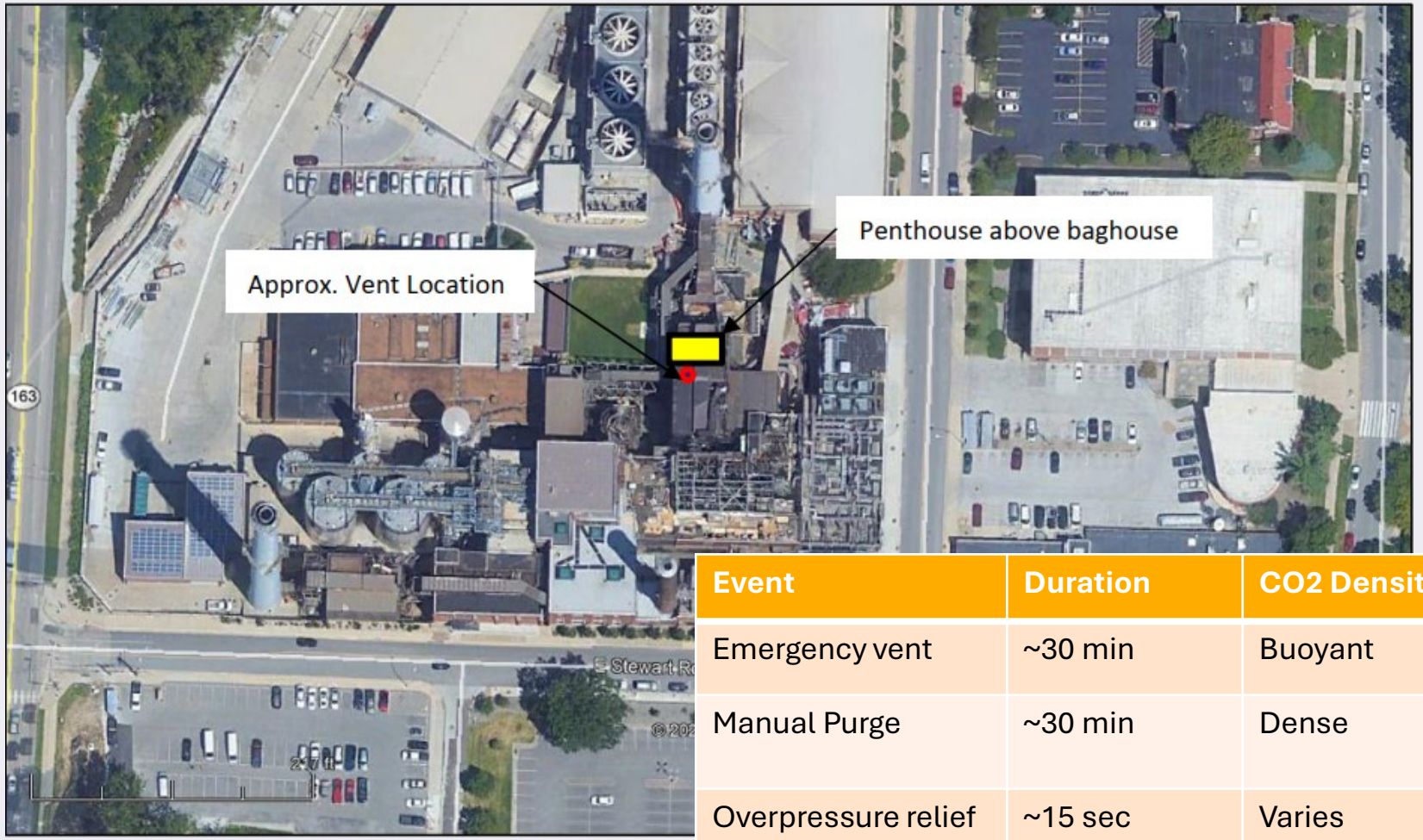
CO2 Atmospheric Buoyancy



Vent Locations and Scenarios



Vent Location



Event	Duration	CO2 Density	Recommendations
Emergency vent	~30 min	Buoyant	Verify plume temp.
Manual Purge	~30 min	Dense	Raise stack (115’ to 167’) Add vent fan (1250 CFM)
Overpressure relief	~15 sec	Varies	None

Things to Consider

Prolonged CO_2 venting in operational environment

Distance from populated areas

Mitigation methods

- Extend height of vents / add CO_2 boost fan to discharge

Short duration events of little concern

Placement of CO_2 equipment

Thank You

Questions?