Curing

American
Concrete Pipe
Association

Curing

- Hardening of concrete
- Hydration→ CSH gel
- Accelerated curing
  - The rate of hydration increases as the ambient temperature increases
- Maintaining moisture in the concrete is critical

Proper Curing is Essential

- Reduces permeability
  - Essential for structure watertightness
  - Improves durability

- Optimal strength achieved

Essentials for Proper Curing

- Maintain moisture
- Maintain temperature


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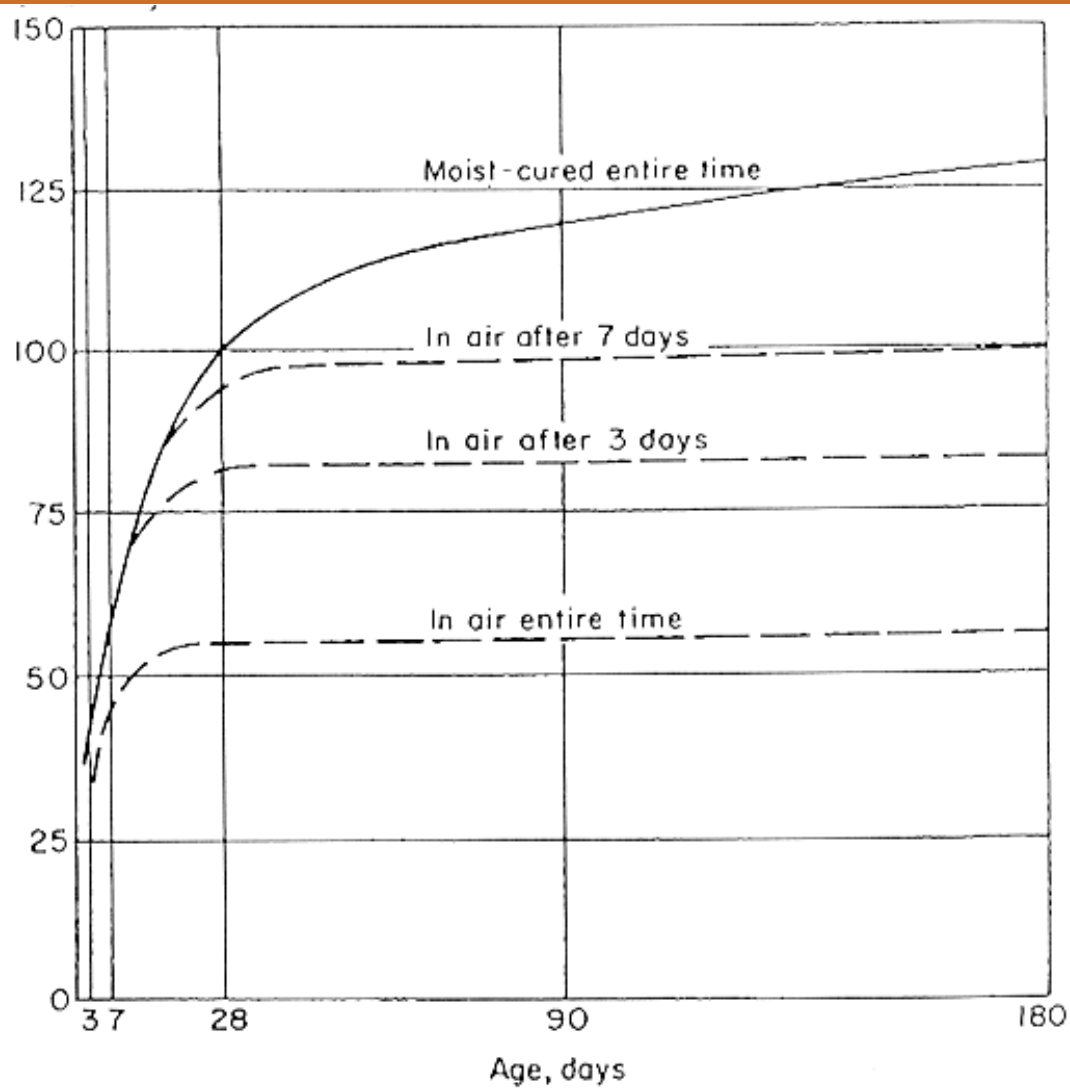
Concrete Strength vs Moisture Condition

Proper moisture and temperature result in increased concrete strength



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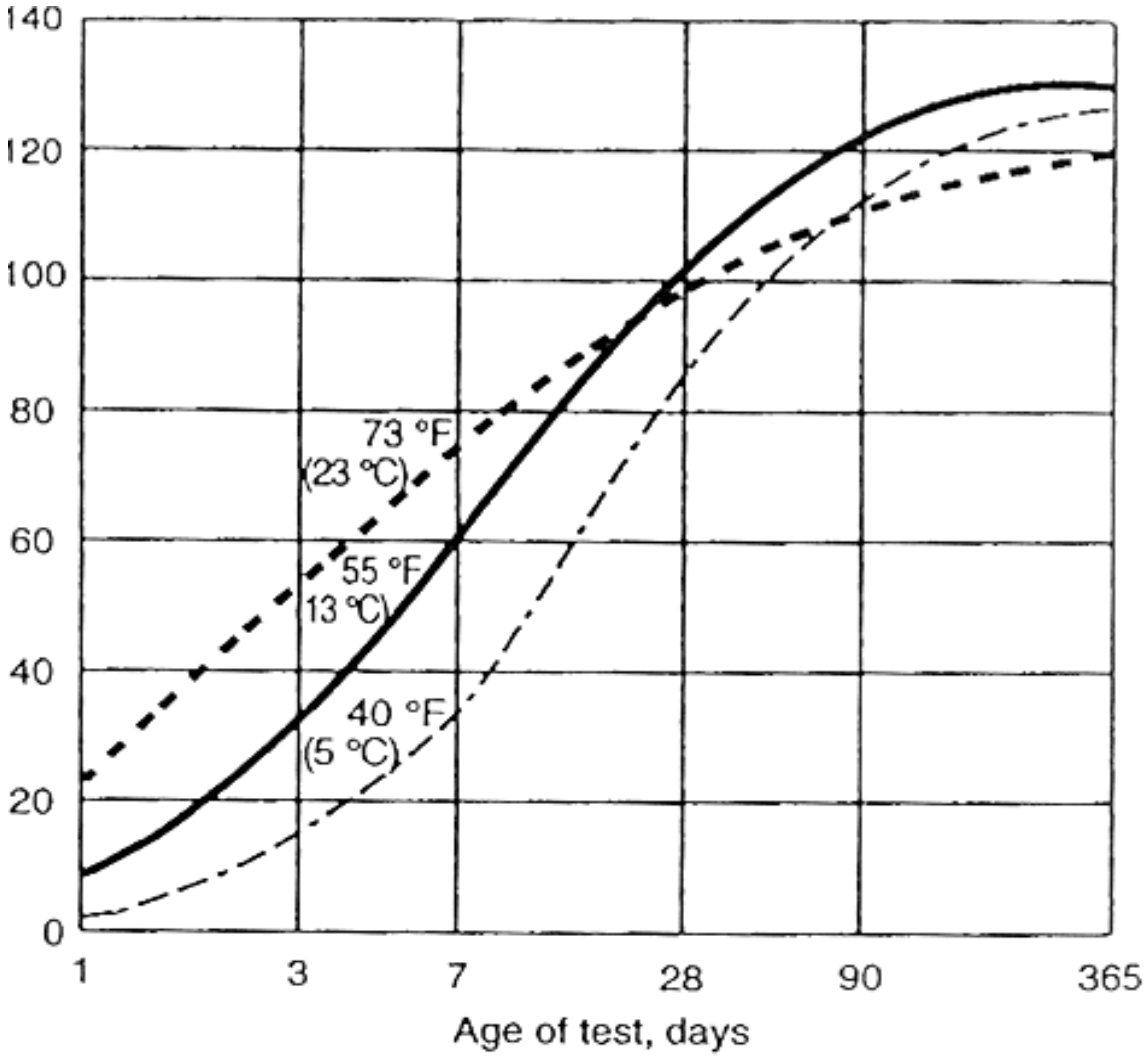
Low Temperature vs Strength

Compressive Strength

% of 28 day

73°F(23°C) concrete



Curing Methods

- Maintaining moisture by wetting
- Prevent moisture loss by sealing
- Accelerated curing

Maintaining Moisture by Wetting

- Wet burlap
- Spraying/Misting
- Fogging

Spraying/Misting

- Cold or hot
- Very fine droplets
- Air pressure
- Effective for higher cement content and warmer climates

Prevent Moisture Loss by Membrane Sealing

- Forms
- Tarps / Polyethylene
- Curing Compounds
  - Caution:
    - If w/c <0.5
    - With pozzolanic mixes

Accelerated Curing

- Dry Heat
  - Use with caution: difference between accelerated curing and maintaining heat
  - Heated beds (hollow core)
  - Electric or gas heaters – convection heat
  - Infrared heating – radiant heat
- Low pressure steam
  - Boilers
  - Steam generators
- Admixtures

Note: Raise concrete temperature while maintaining high humidity

Accelerating Admixtures

- 2 Classes of Admixtures:
  - Set Accelerator
  - Strength Accelerator (Early Age)

- Calcium Chloride is the most common in Ready mix, but **BEWARE** should not be used in precast reinforced concrete

- Several non-chloride, non-corrosive accelerators, but generally most are not as effective as calcium chloride

Considerations for Accelerated Curing

- As a rule of thumb, a temperature increase of 18°F doubles rate of hydration
- High temperatures with low humidity can crack the product
- The lower the curing temperature, the longer the product must be cured to achieve comparable early strengths

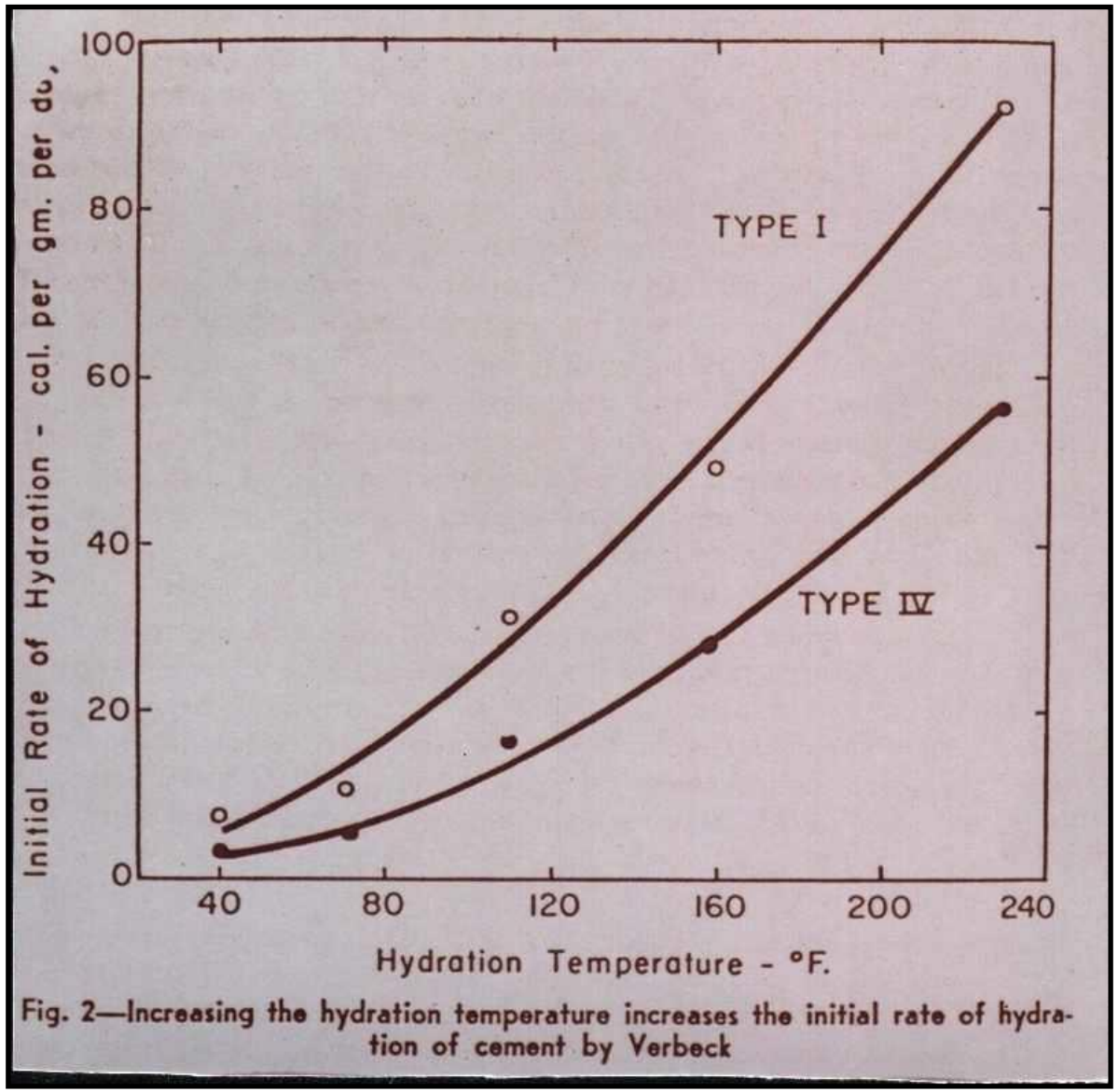


Fig. 2—Increasing the hydration temperature increases the initial rate of hydration of cement by Verbeck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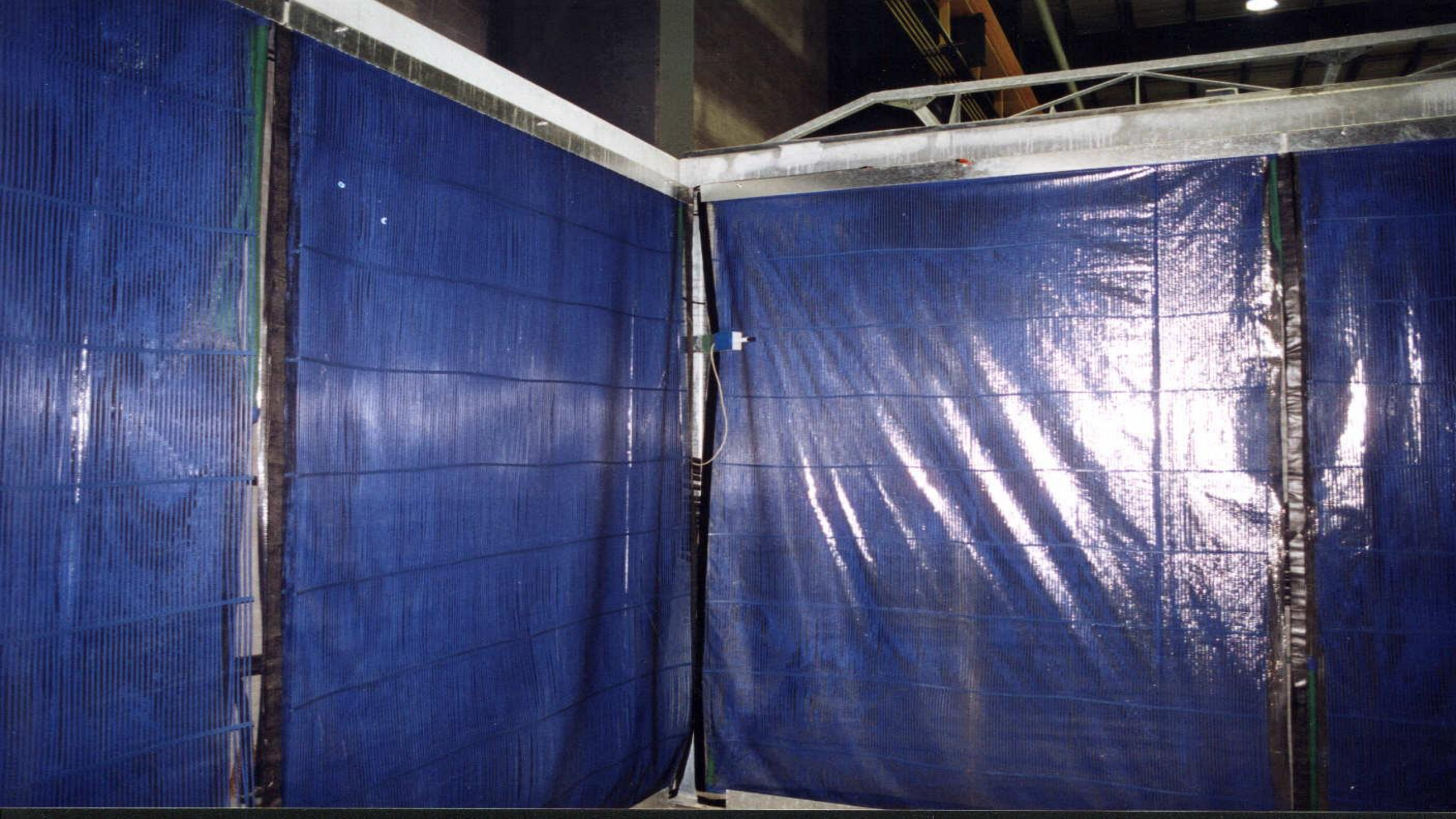


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Low Pressure Steam Curing

- Provides both heat and humidity
- Product is heated by the warmer steam condensing on it
- Moisture evaporation is minimized

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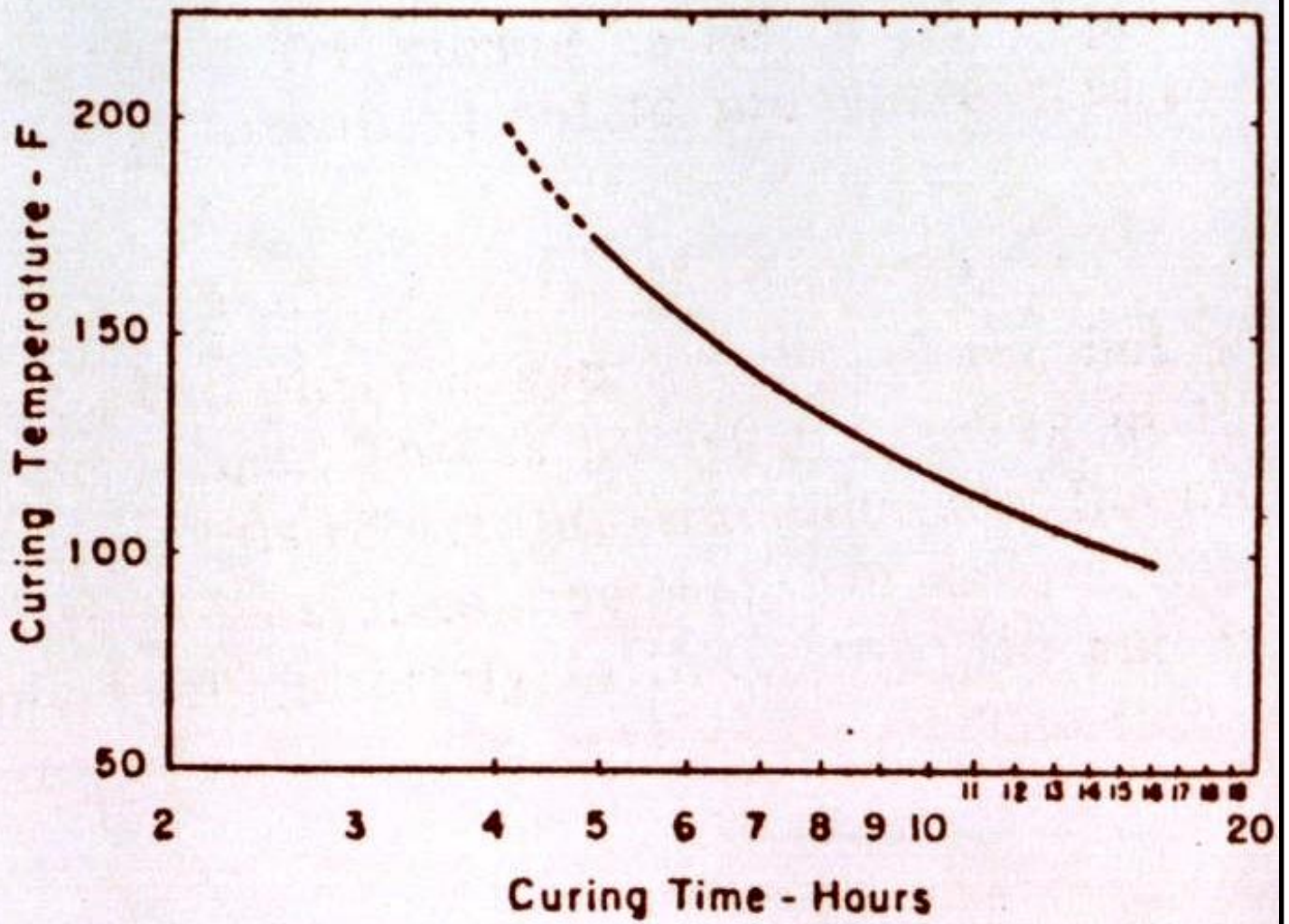
Fig. 13—Minimum low pressure steam curing of concrete sewer and culvert pipe

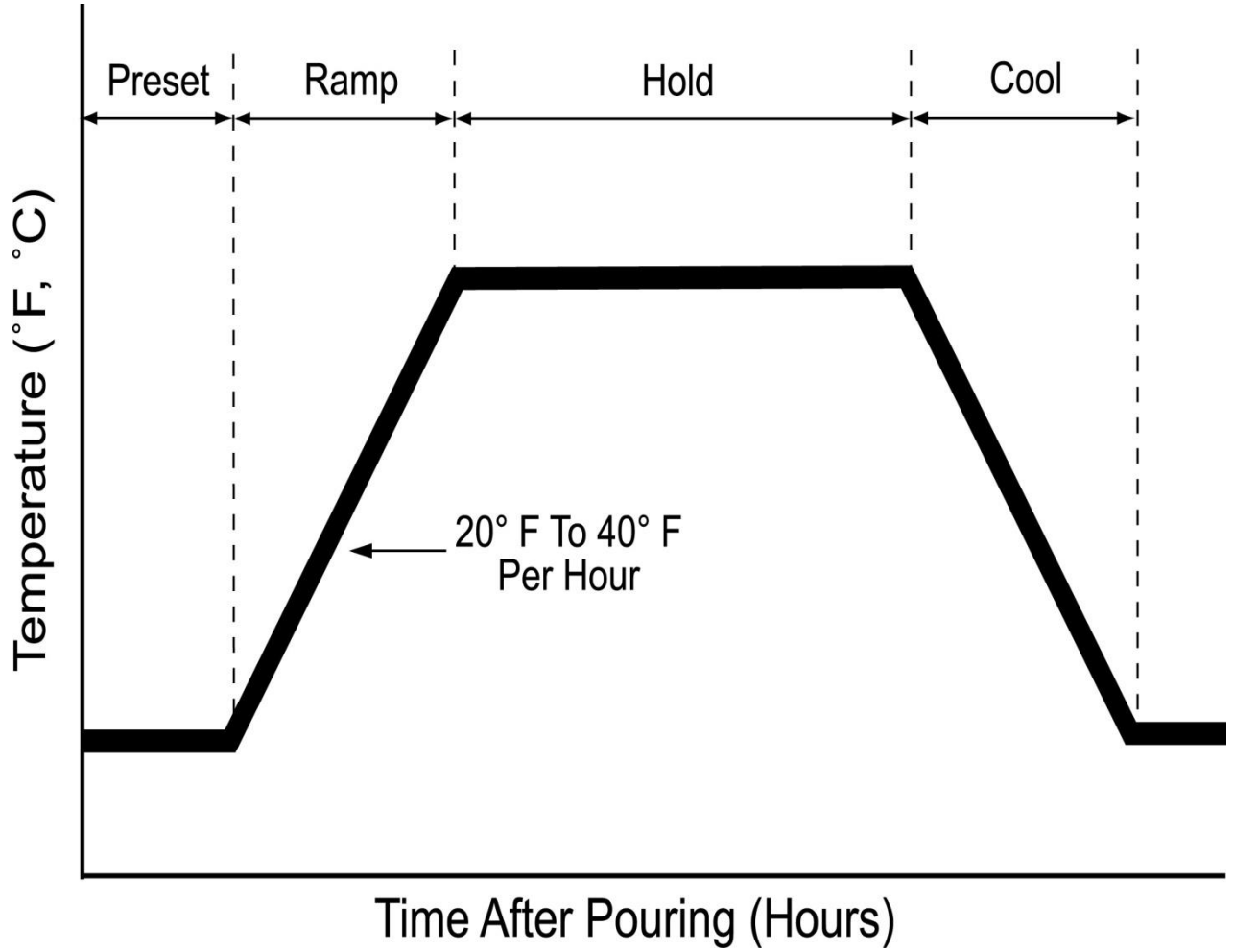


Typical Accelerated Steam Curing Cycle

- Preset (< 90 degrees) – at least one hour
- Ramp (Temperature Rise) – at 20F to 40F per hour
- Hold / Soak (at target temperature) – varies with the product
- Cool Down

Idealized Accelerated Steam Curing Cycle

- 1) Preseting
- 2) Ramping
- 3) Holding
- 4) Cooling



Concrete Target Temperatures

- Concrete Pipe (Typical for Accelerated)
  - 120° F to 140° F (50º C to 60º C)
  - 4 to 6 hours

- Precast (including Pipe)/Prestress limits (ACI)
  - 160° F (71° C) in Canada
  - 160° F (71° C) in USA
  - 8 to 12 Hours

Wet Cast Products

- Leave forms on as long as possible

- Check with supplier when using accelerated admixtures

Dry Cast Products

- Require 90 to 100% humidity

- Must protect from drafts

Special Conditions

Hot weather curing

- Shade, sprinkle coarse aggregates
- Add ice to mix water or use water chiller
- Shelter product from direct sunlight

Special Conditions

Cold weather curing

- Keep fresh concrete temperature > 50°F
- Heat aggregates
- Heat water

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Temperature Control of Concrete Mixes

Note: Of the ingredients used for making concrete, mixing water is the easiest and most practical to heat. The weight of aggregates and cement in the average mix is much greater than the weight of water. However, water can store five (5) times as much heat as can solid materials of the same weight. The average specific heat [heat units required to change the temperature of one (1) lb (kg) of material one (1) °F (K)] of the solid materials in concrete (cement and aggregates) may be assumed as 0.22 Btu/[lb·°F] (920 J/[kg·K]) compared to 1.0 (4,200) for water.

Determine by calculation combined temperature of coarse aggregate, sand and cement using batch weights, observed temperatures of the mix components and their specific heat.

Example:

a

Material	Weight (lb/yd³)	Weight (kg/m³)
Cement	470	(280)
Aggregates	3,300	(1,960)

b

Material	Specific Heat (Btu/lb·°F)	Specific Heat (J/[kg·K])
Cement	0.22	(920)
Aggregates	0.22	(920)

c

Material	Water Equivalent (A x B) Btu/°F/yd³	Water Equivalent (A x B) (MJ/[K·m³])
Cement	103.4	(0.26)
Aggregates	726.0	(1.80)
	829.4	(2.06)

d

Material	Temperature °F	°C
Cement	150	(66)
Aggregates	10	(4)

e

Material	Stored Heat (C x D) Btu/yd³	(MJ/m³)
Cement	13,536	(17.0)
Aggregates	29,850	(17.1)
	43,350	(34.2)

Combined Temperature of Aggregates and Cement

Temperature of Water

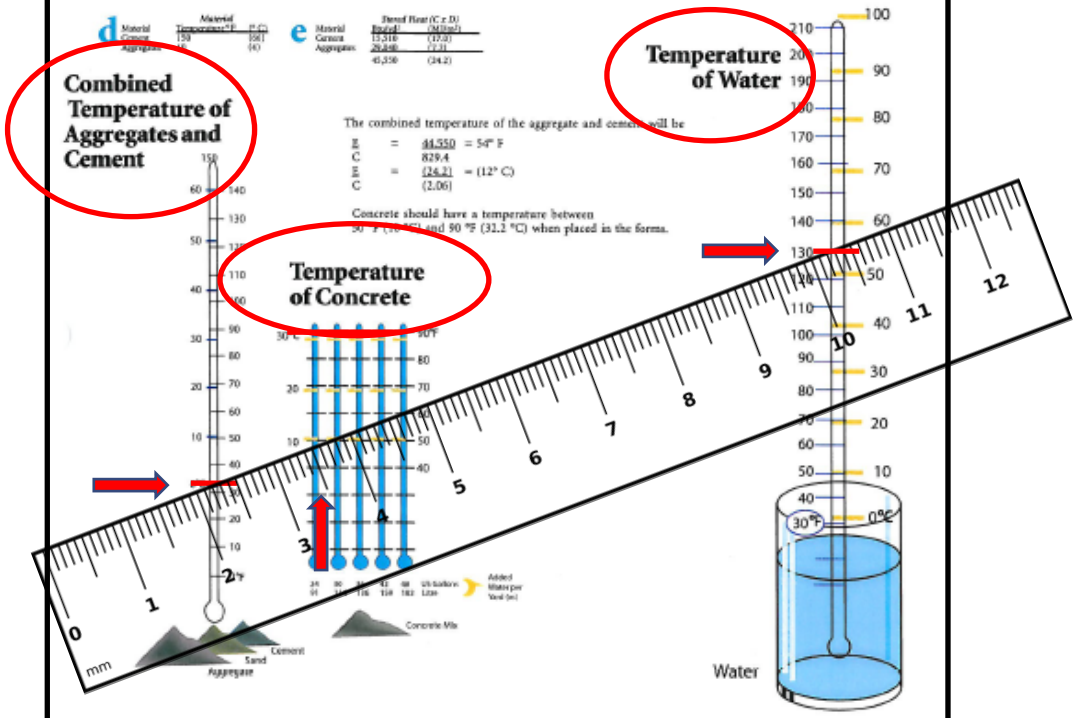
The combined temperature of the aggregate and cement will be

$$\frac{E}{C} = \frac{44,550}{829.4} = 54°\,F$$

$$\frac{E}{C} = \frac{(24.2)}{(2.06)} = (12°\,C)$$

Concrete should have a temperature between 50 °F (10 °C) and 90 °F (32.2 °C) when placed in the forms.

Temperature of Concrete



How to use chart

1. Place rule on the blue thermometer at the desired temperature of the concrete.
2. Pivot rule at this point and swing the left end of the rule to the calculated combined temperature of the aggregates and cement
3. The temperature of the mixing water is read on the right, at the point where the rule crosses the thermometer.

Note *(a) If sand is surface dry, use the solid line on the body of the blue thermometer as pivot point.*
(b) If there is free moisture in the sand, use dotted line.

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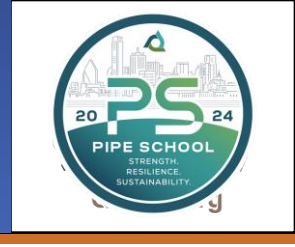

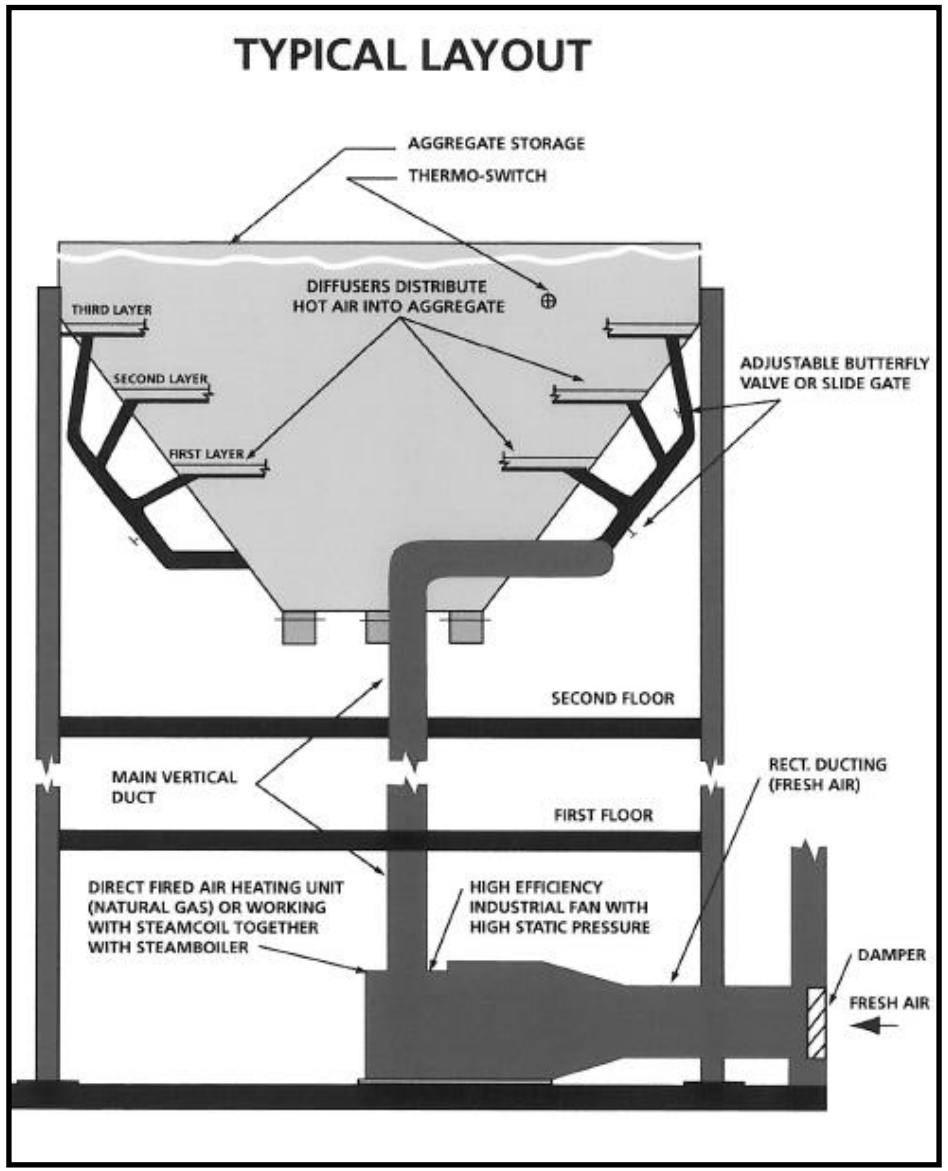

Reducing Energy Costs

- Determine actual curing cost
- Review curing cycle
  - Preset, ramp, hold
- Curing chambers
  - Insulation, partitions, canopies
- Prevent flueing
  - Direct steam flow out curing cell bottom only
  - No steam leakage along the sides or through the top

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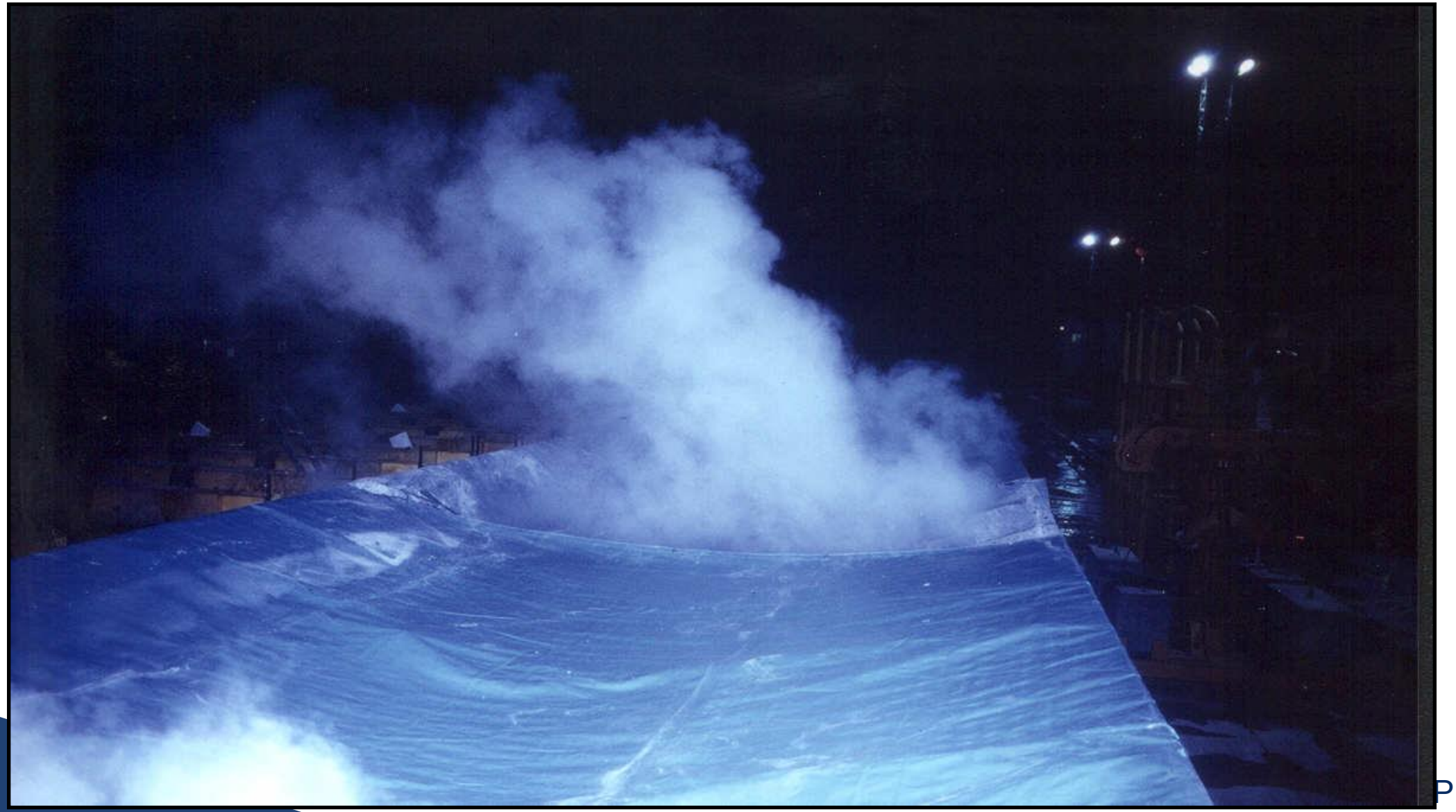

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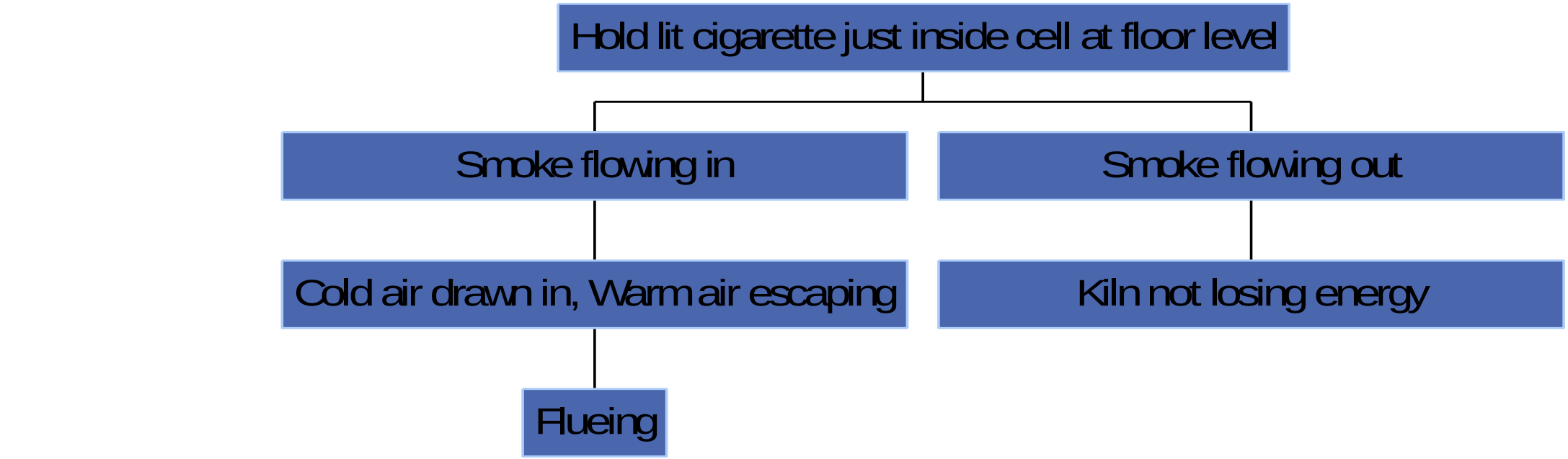

Conclusion: Want smoke flowing out of cell

Additional checks for Flueing

- Light a match
  - Flame flows in if Flueing

- If the floor of the cell is cold and dry
  - Cold air pulled into the cell
  - Flueing.

- If the floor is warm and wet
  - Steam flowing out of the kiln bottom
  - Not flueing

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Questions?

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