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Replacement of the High-Pressure Air Tanks for Sandia's Wind Tunnels

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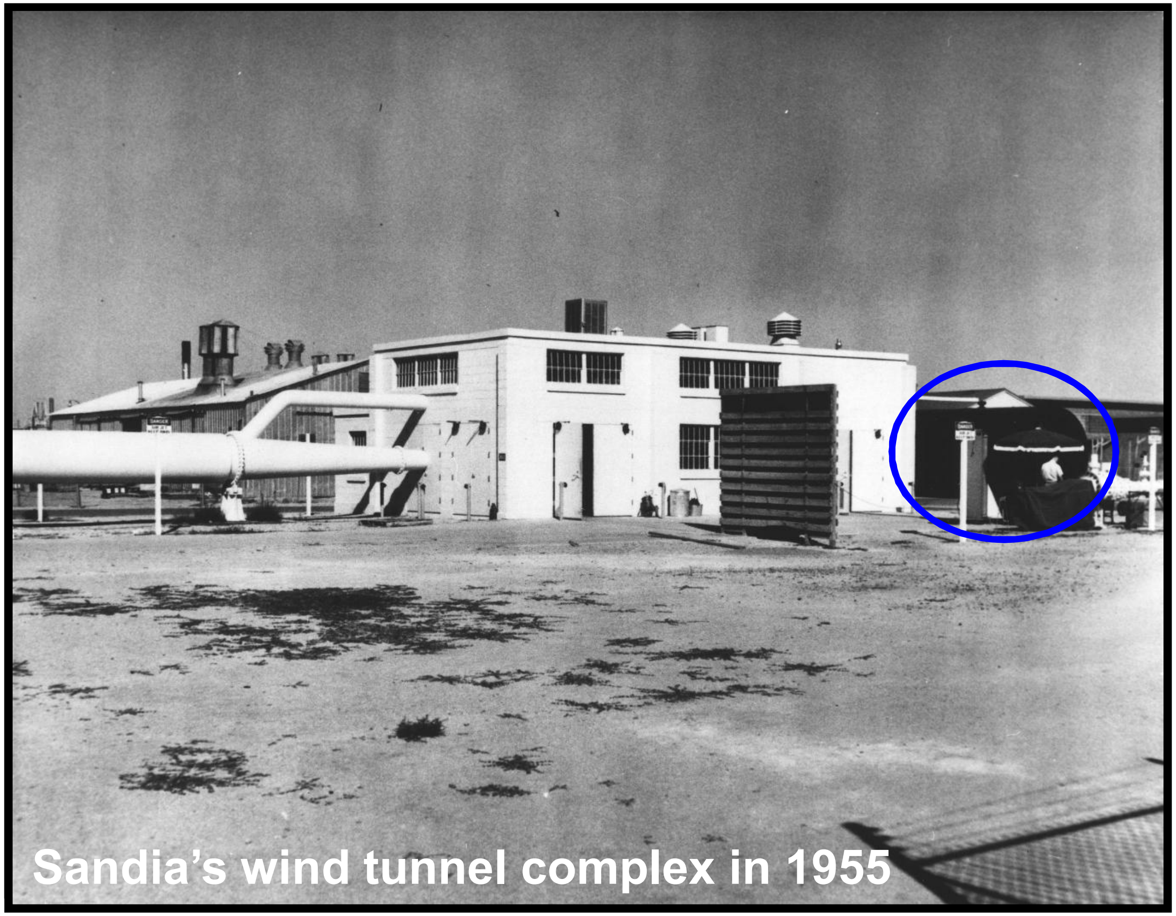
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

A Brief History of the Air Tanks

Sandia began its career in the wind tunnel business in 1955.

Installation of what eventually became the Trisonic Wind Tunnel (TWT).



Initially driven by a single tank of 2600 ft^3 volume, pressurized to 300 psig (74 m^3, 2 MPa).

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A Brief History of the Air Tanks

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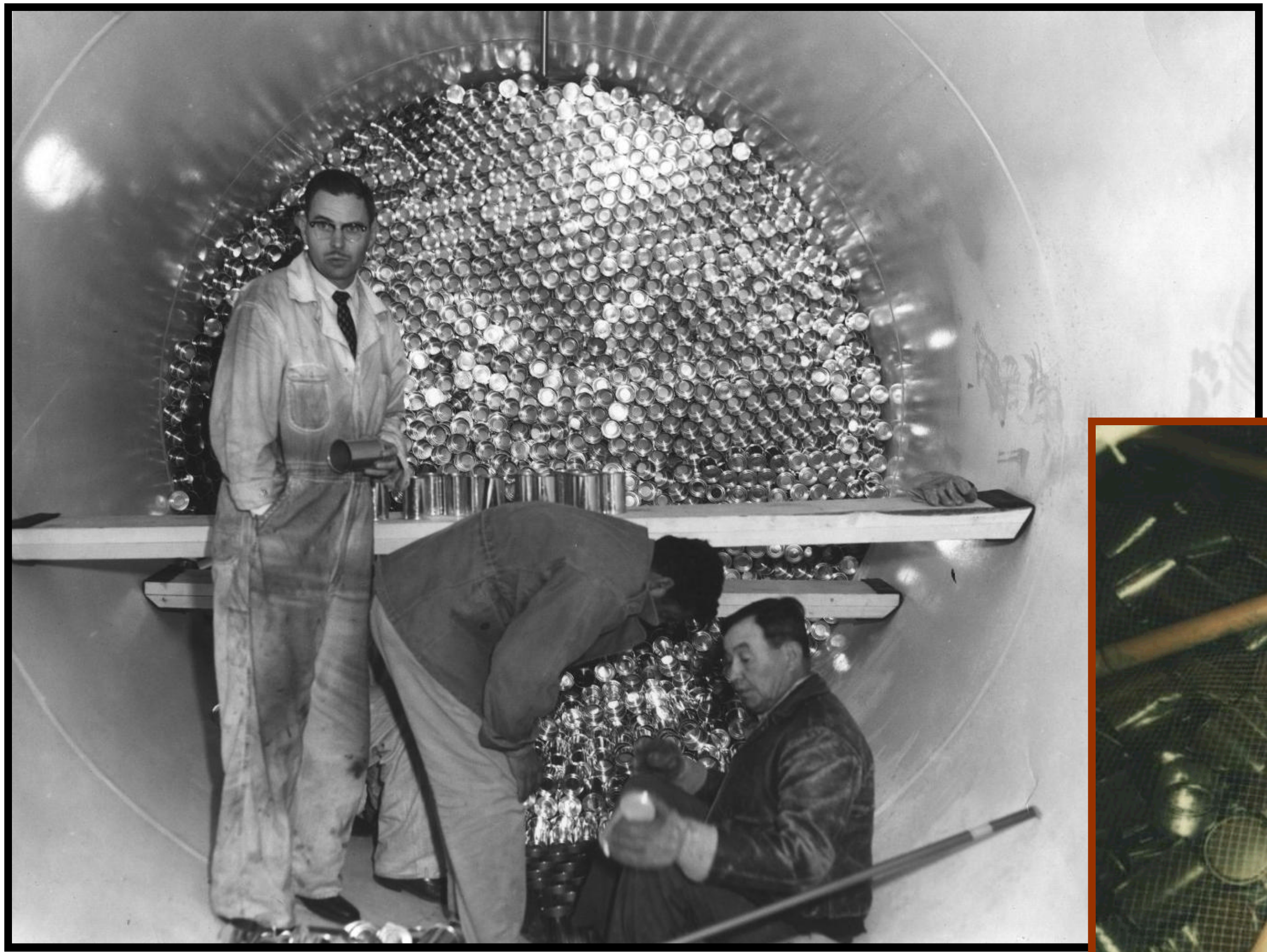
Sandia's wind tunnel complex in 1955

Initially driven by a single tank of 2600 ft^3 volume, pressurized to 300 psig (74 m^3, 2 MPa).

In 1958, an identical second tank was added.

Also served the Hypersonic Wind Tunnel.

The air tanks were filled with "thermal mass" to maintain the temperature during the gas expansion.



Thermal mass:

100,000 lidless dog food cans *per tank*

Tank Temperature

Sandia's wind tunnel complex circa 19

Tanks fabricated from Liberty Steel.

- Prone to brittle failure under cold conditions.

Analysis shows leak before burst and risk is only at sub-freezing.

- A winter safety risk exists.

This tank design was unaltered from ~1960 until the present.

The tanks were fitted with steam jackets for 180 F (80 C).

- Maintain 24/7/365 elevated temperature to prevent failure.
- Also maintain a constant stagnation temperature regardless of ambient conditions.

Pressure Safety Concerns

The wind tunnels are an anomaly in that they are a major testing facility located within Sandia's most populated area.

We are confident they would remain safe to operate:

- Pressure safety analysis
- Constant elevated temperature (thermocouples interlock compressors)
- Routine inspections reveal no degradation

We had a little administrative incident…

- No actual compromise of safety

Despite a favorable outcome, pressure mounted to replace the air tanks.

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Test Capabilities Revitalization (TCR)

Throughout the 1990's, Sandia decided that henceforth everything could be computed.

Most Sandia testing facilities were neglected.

These facilities date from the 1950's and 1960's and already had aging infrastructure issues.

TCR: A Congressional line item to refurbish Sandia's testing facilities.

Extend life to 2030.

Will not pay to enhance capability, only to maintain and modernize it.

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TCR Aero Renovation

TCR addressed several modernization needs in our building:

- ADA compliance
- New bathrooms and plumbing
- Electrical system and cooling water loop
- *New high-pressure air tanks*
- Replace electrical source for hypersonic heaters

Design Requirements

Cannot increase pressure.

Cannot increase footprint.

Cannot increase heating capacity.

Design and engineering by a contracted firm.

(Not selected by the wind tunnel team.)

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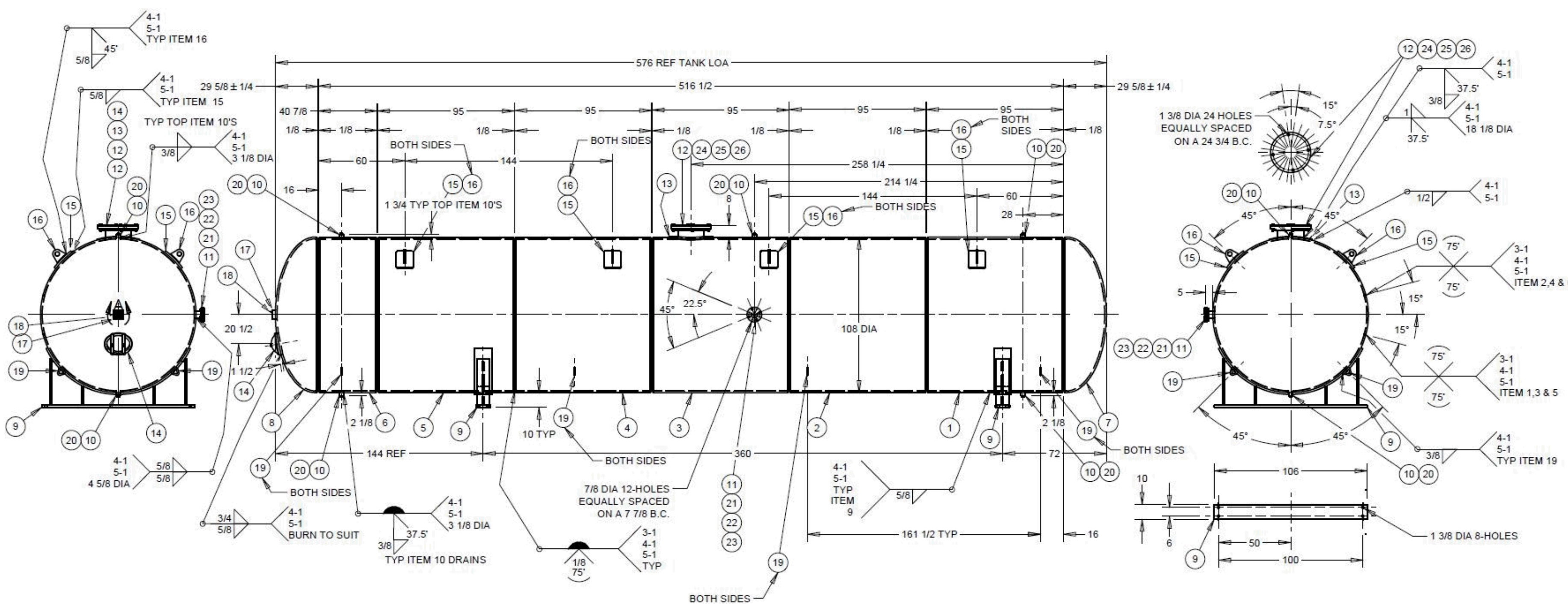
New Tank Properties

- Same diameter
- Increase length by 8 feet
- Increase volume to
  2880 cu ft (+11%)
- Pressure rating of 350 psig
- Larger manhole

Procured from Silvan Industries in Wisconsin.

Pressure relief, steam system, and controller designed by contractor.



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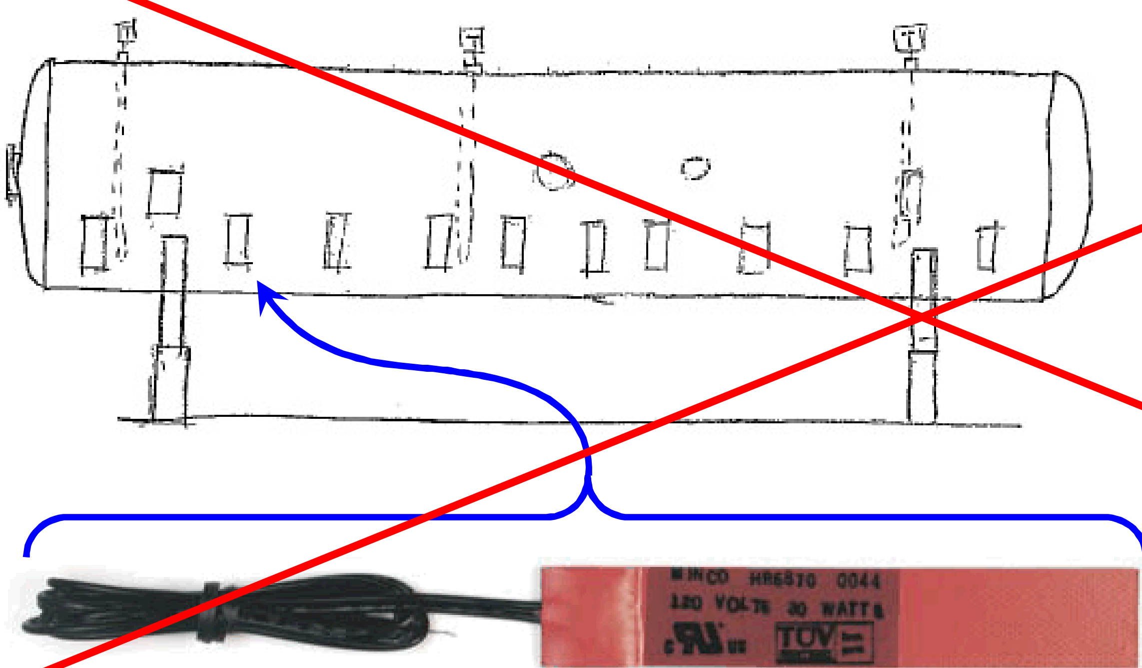
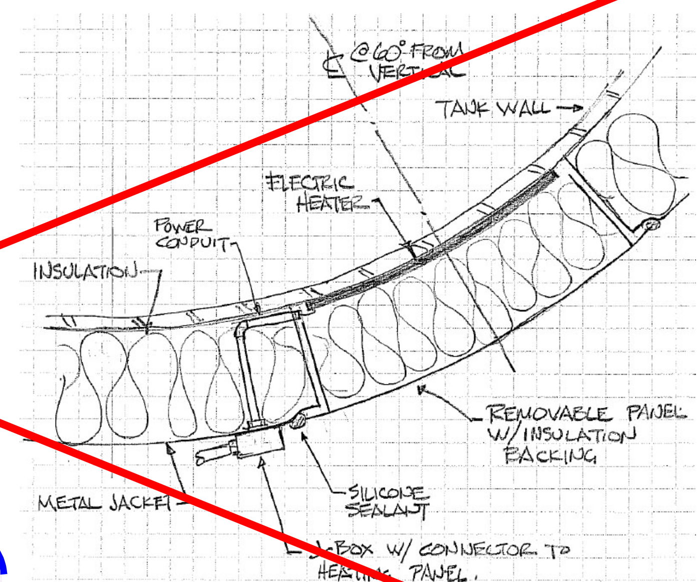
The First Tank Heater Design

Contractor proposed electrical heaters to maintain tank temperature.

- Electrical heaters were grossly undersized based on flawed thermal analysis.
- Heater manufacturer did not recommend use for such large tanks.





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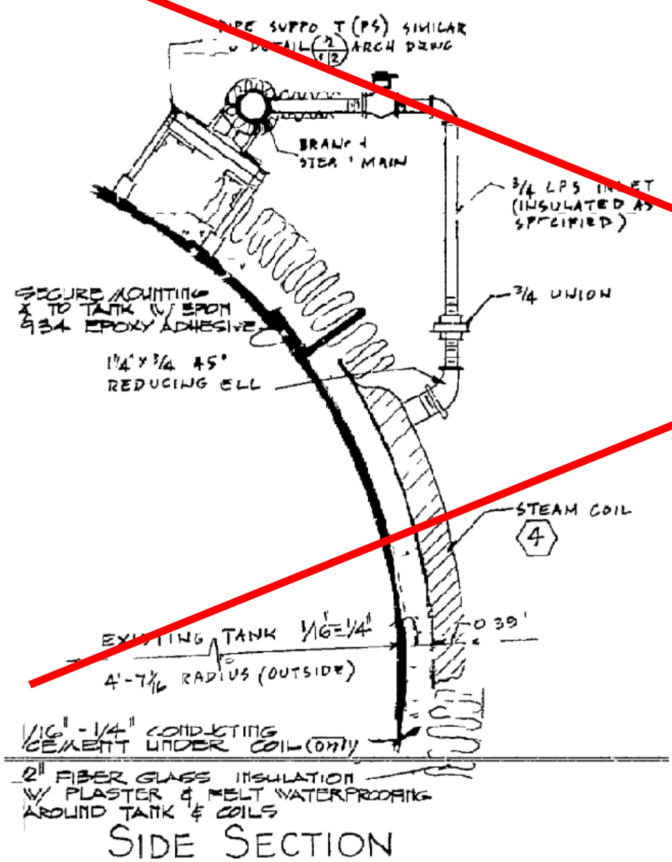
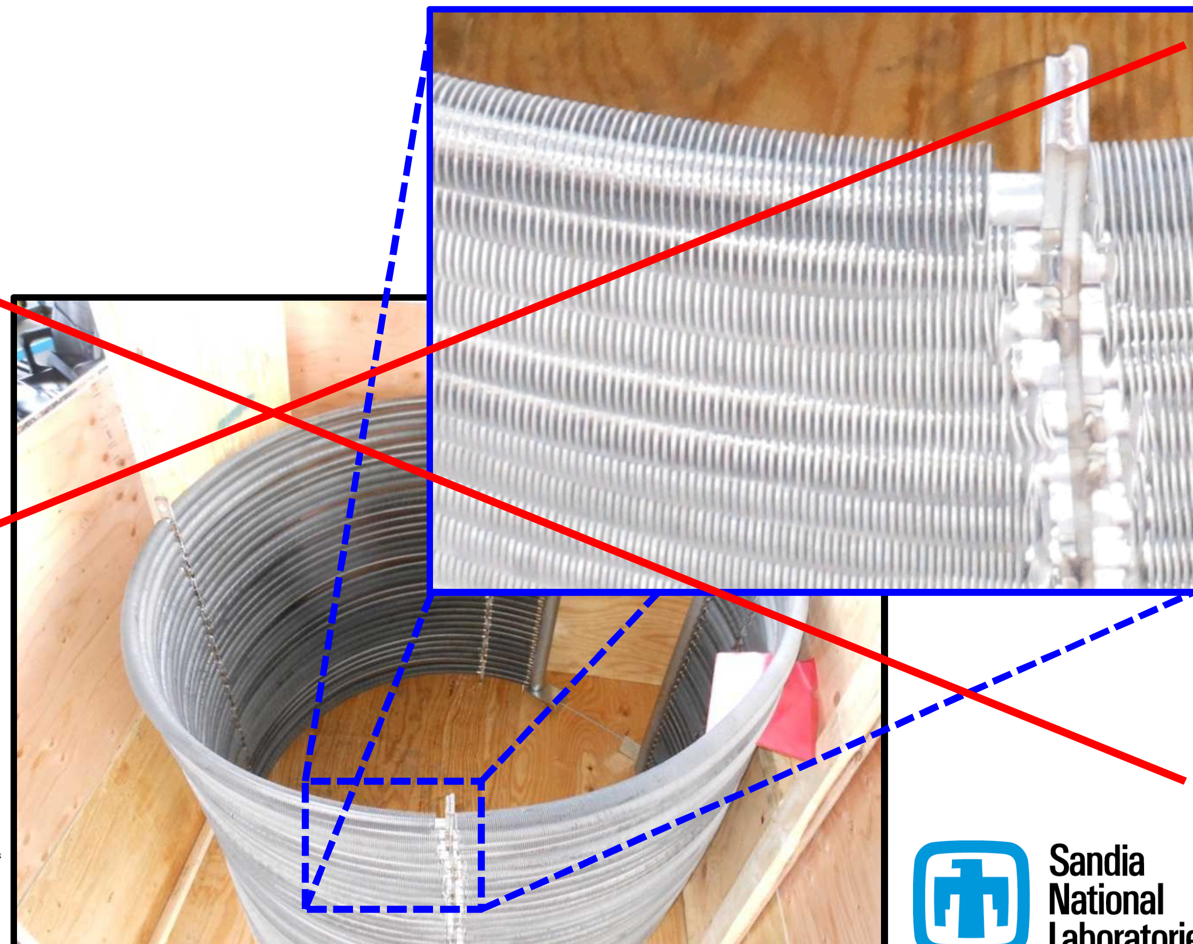
The Second Tank Heater Design

Next the contractor proposed a steam heat exchanger using convective fins and radiative coupling.

Convective heat transfer is much less efficient than conduction and radiative heat transfer is negligible here.





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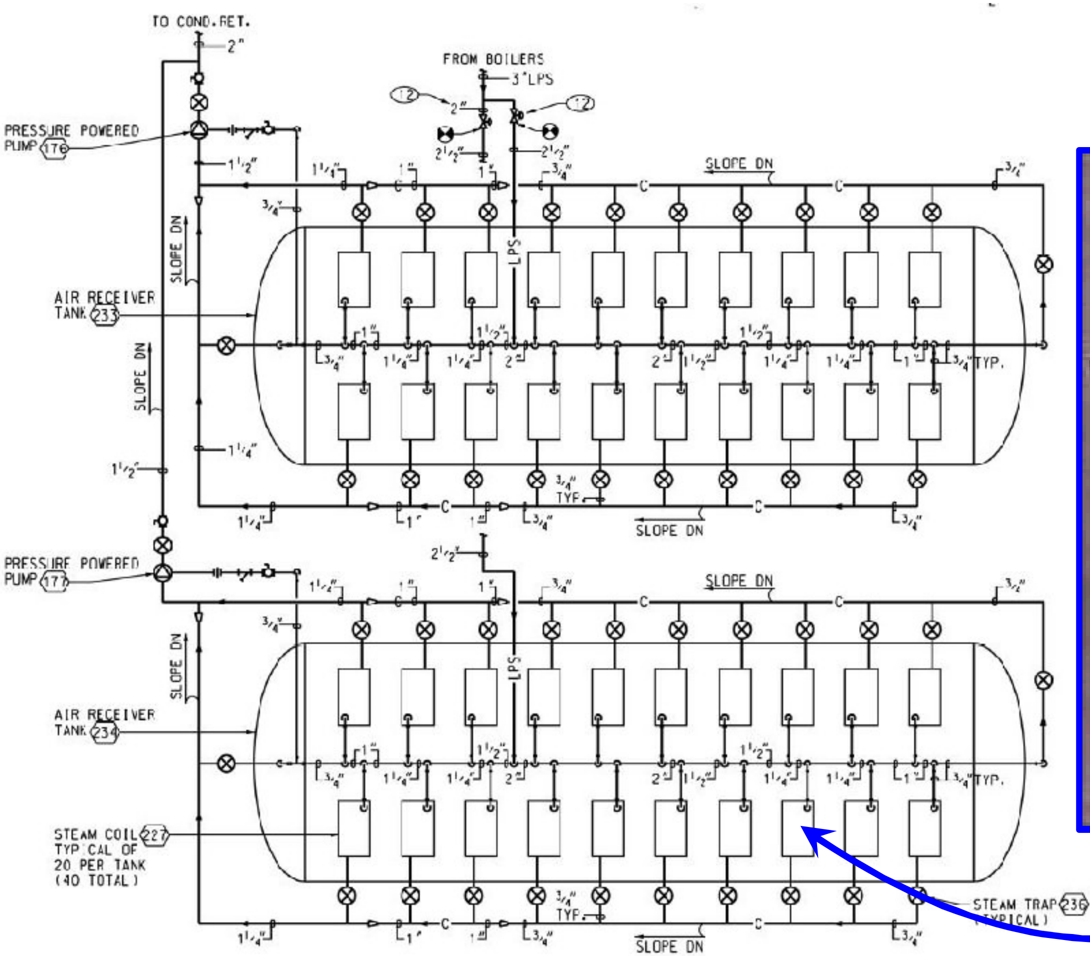
Our Tank Heater Design

We redesigned the steam jackets to use conductive plate coils.

- Rolled to match tank diameter and contact by thermal paste.
- Fed by existing boilers but all new steam piping.



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Thermal Fill Material

Specify new fill material to act as thermal mass (cans).

Analyze heat transfer performance of old cans, then specify new cans to match (plus margin).

Consider using metal random packing, which is designed for this purpose.

Too expensive for the required quantity.

In the end, we went back to cans: *empty, lidless pint-size paint cans*.

Our analysis says 78,000 cans per tank.

(Contractor ordered 230,000.)

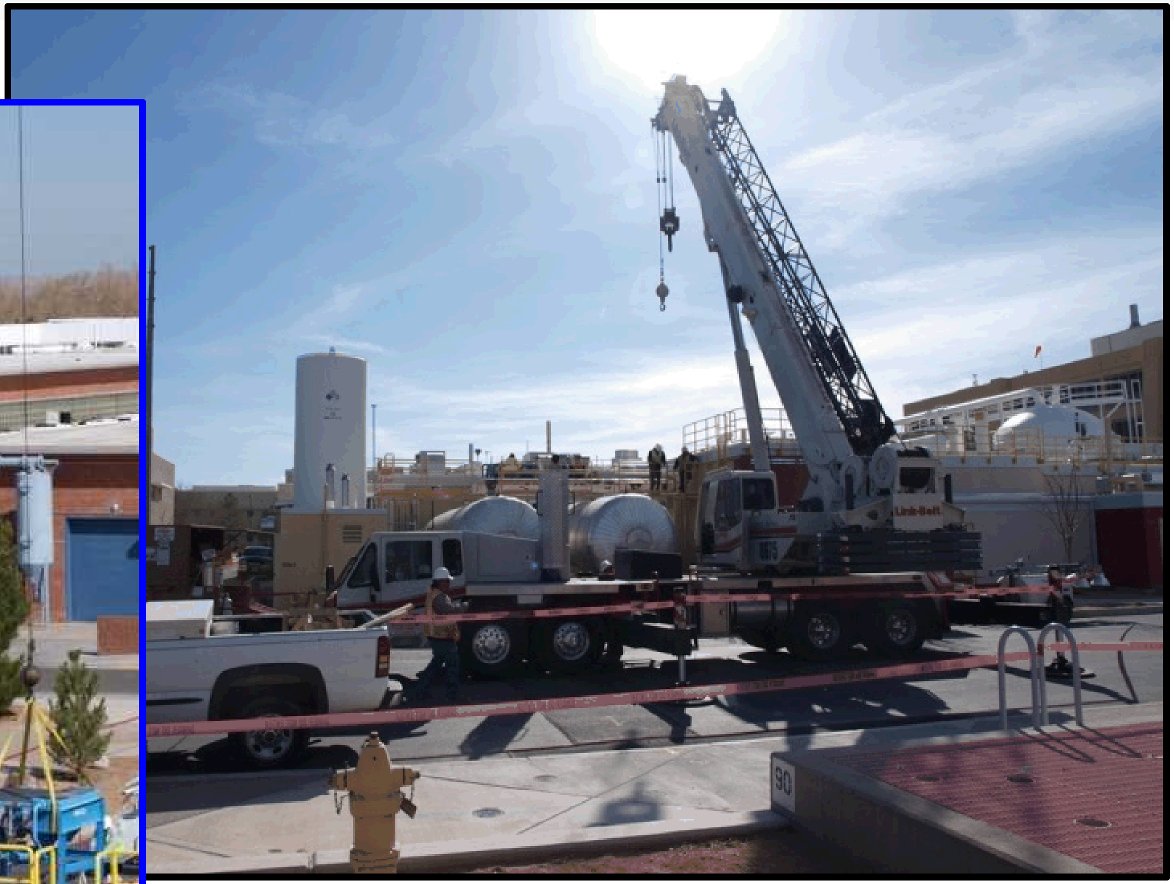
Contractor provides weight, dimensions, and material properties.

First to arrive were the cans… 230,000 of them!

Other new equipment was stored in a yard across the street.

Available as we sequence the installation.

Start by removing the infrastructure surrounding the old tanks.



- Steam piping
- Oil coolers
- Gantries
- Instrumentation

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All plumbing was decoupled.

Main pressure lines were cut away as the tank junction.

Render unfit for service so tanks can be scrapped.

A large capacity crane was brought in to move the tanks.

The new tanks were installed the next day.

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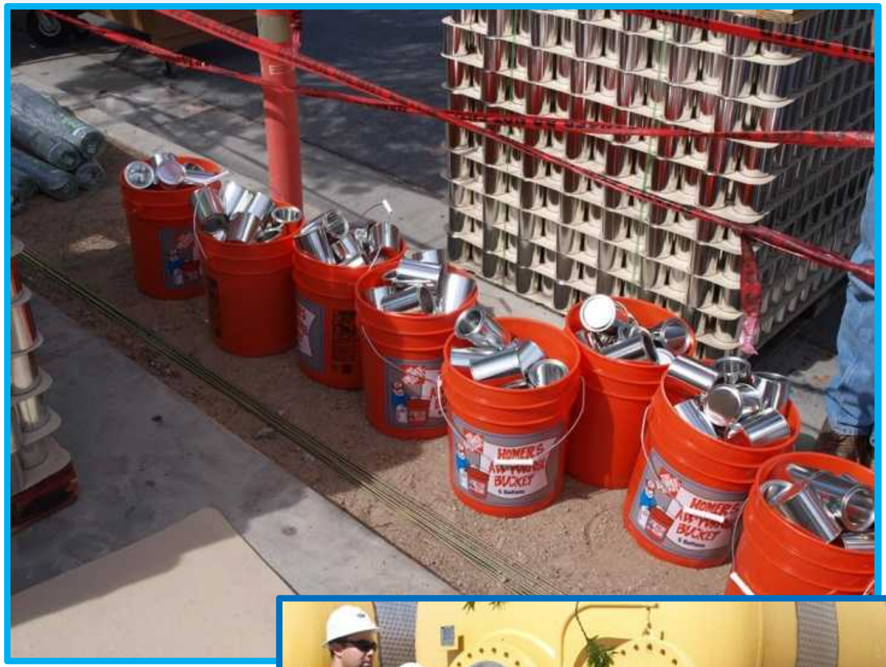
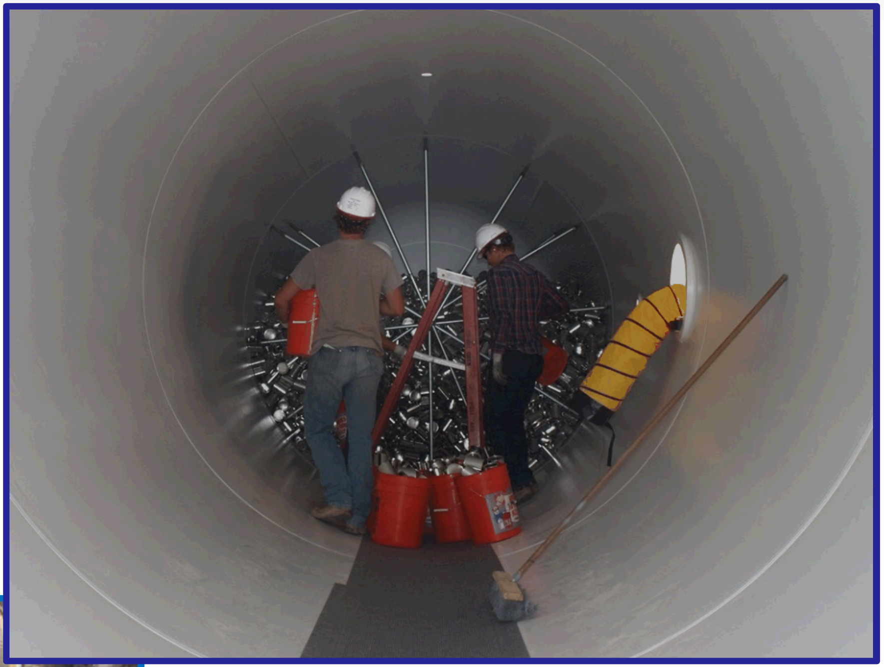
The cans were installed via "bucket brigade."





Chicken wire every 8 feet provided support.

It required about 6-8 workers and four days.

Steam jackets were installed.

Plumbed to a steam system upgraded a few years ago.

2 boilers of 224 MBH

Insulation designed with access panels for the steam jackets.

4” thick R17.5 fiber with aluminum jacket

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That gives us our final tank configuration.

But do they work?

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No, not really.

We had a few problems:

- Several tank temperature sensors were biased due to shell conduction.
- Controller ineffective at responding to tank temperature.
- Steam valves sticky.

It required several months of iteration and adjustment:

- New controller settings.
- Insulated sensor mounts.
- Steam valve repair.

Now do they work?

Can Characteristics

As per our contractor:

Empty, lidless can weighs 0.247 lb = 112 g

Our measurement:

0.151 lb = 68 g

The contractor did not subtract the weight of the lid as they claimed.

Perform a new analysis with the correct mass:

We should be ok.

We built in so much margin that even with the reduced mass, we should get performance equivalent to the old cans.

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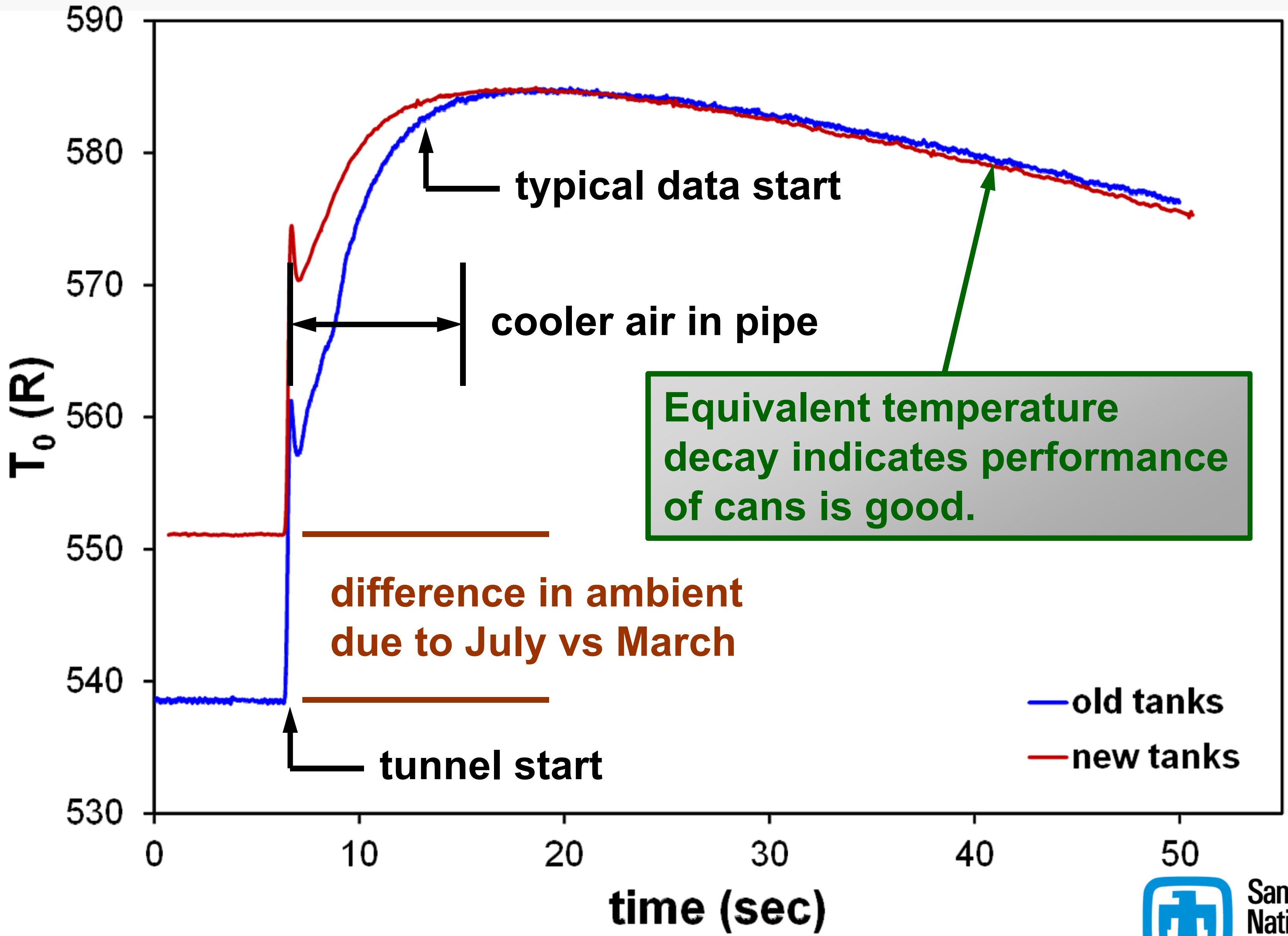
Stagnation Temperature During a Tunnel Run



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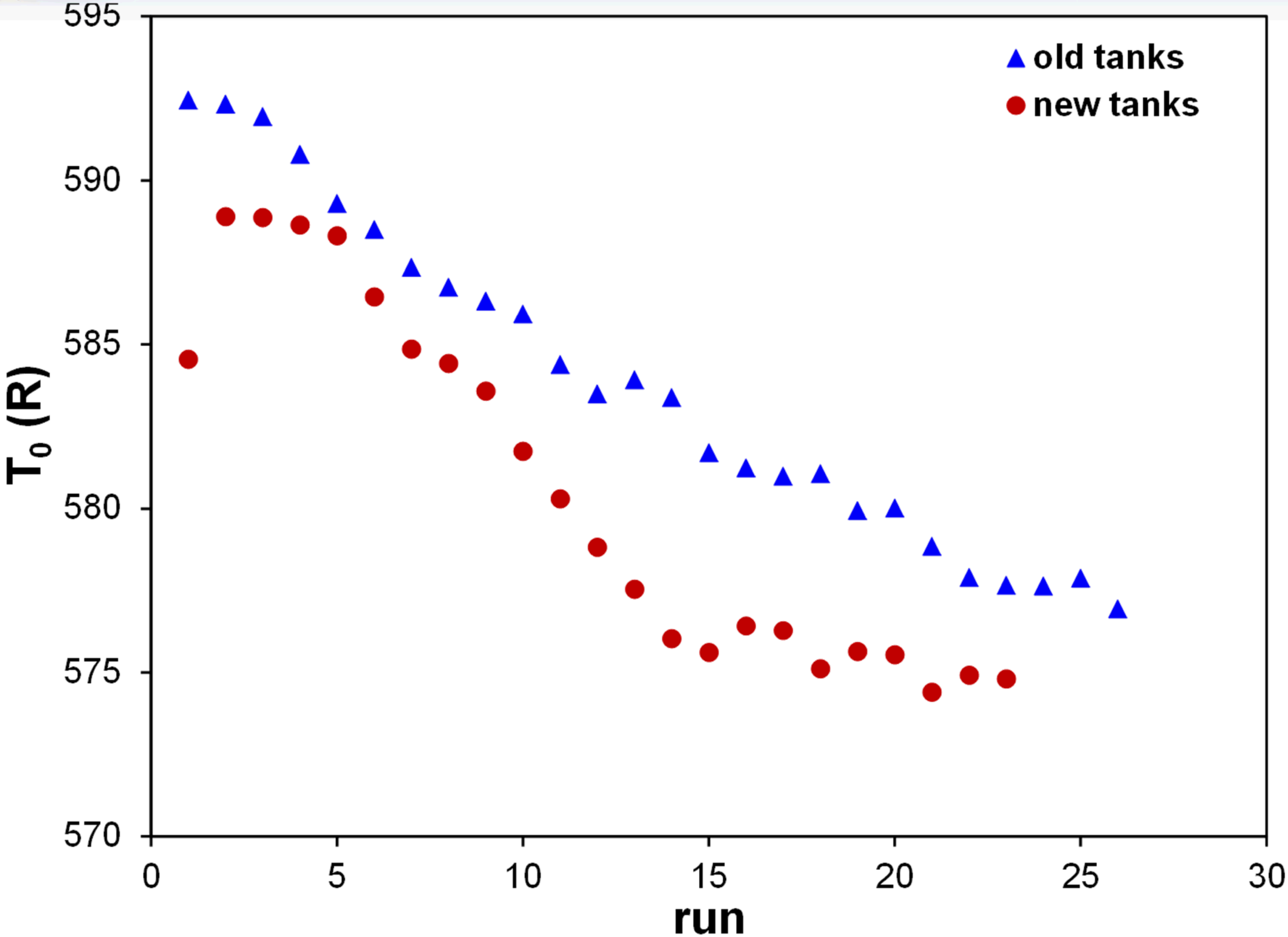
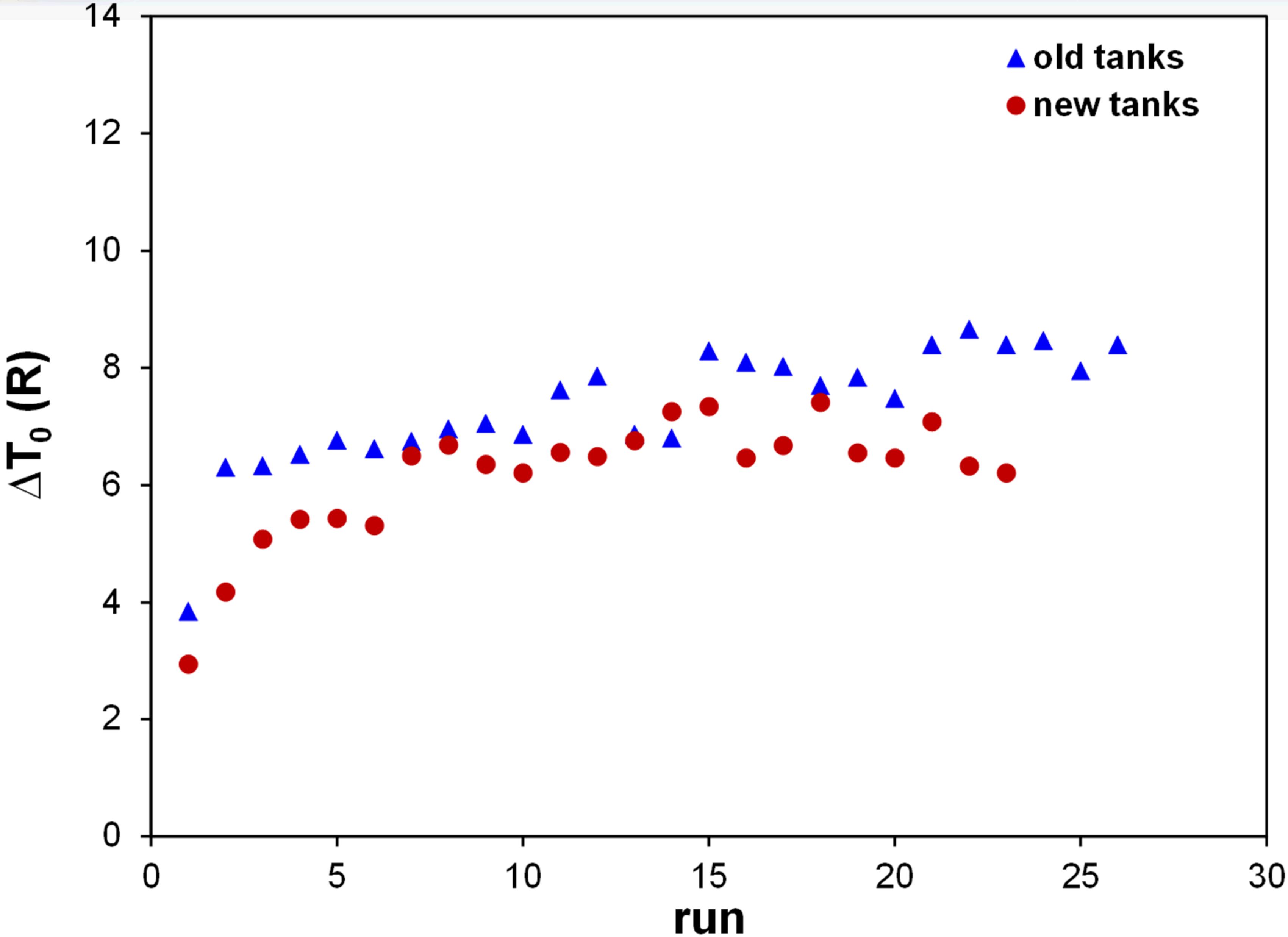
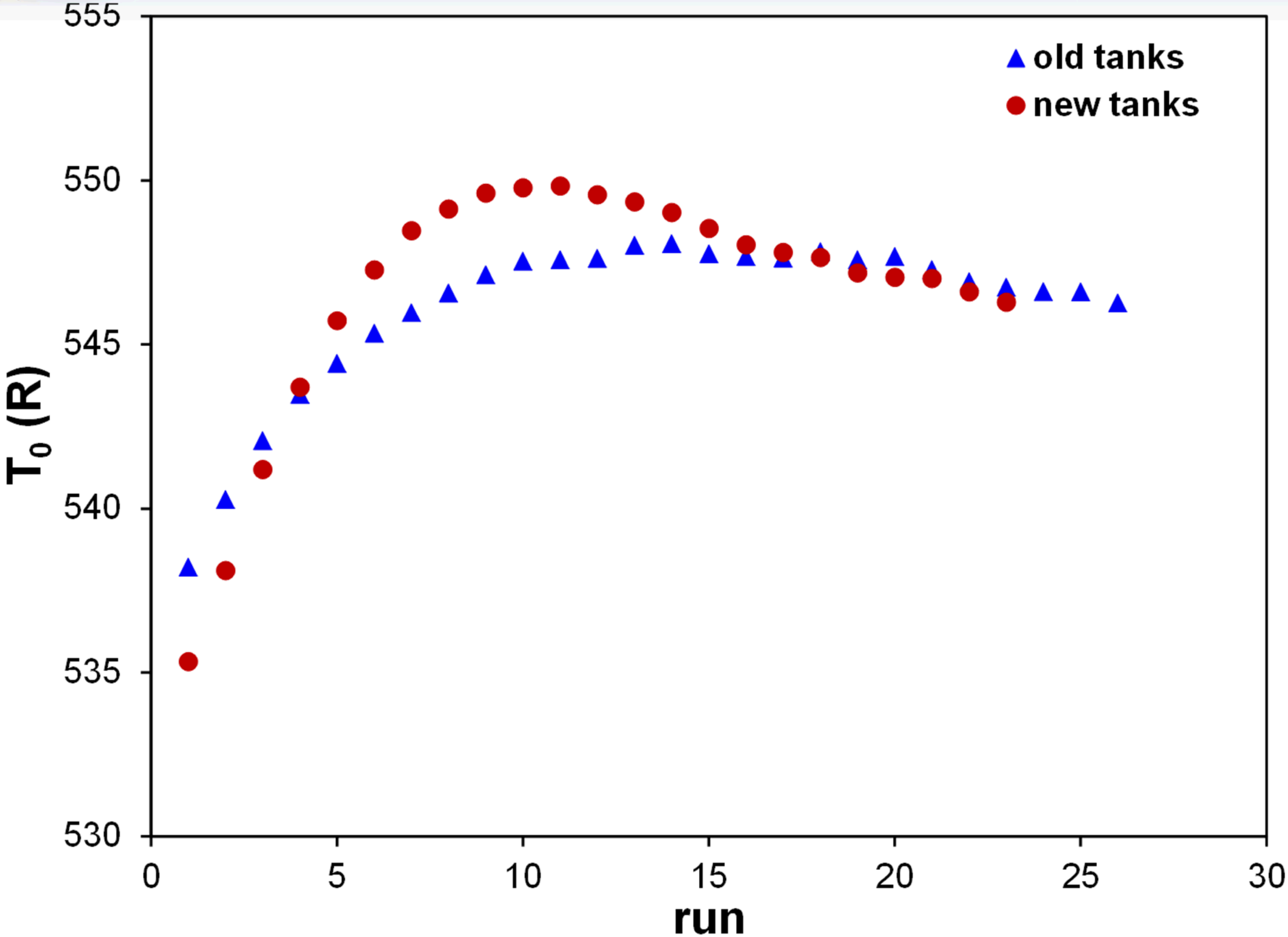
Peak Stagnation Temperature During A Day



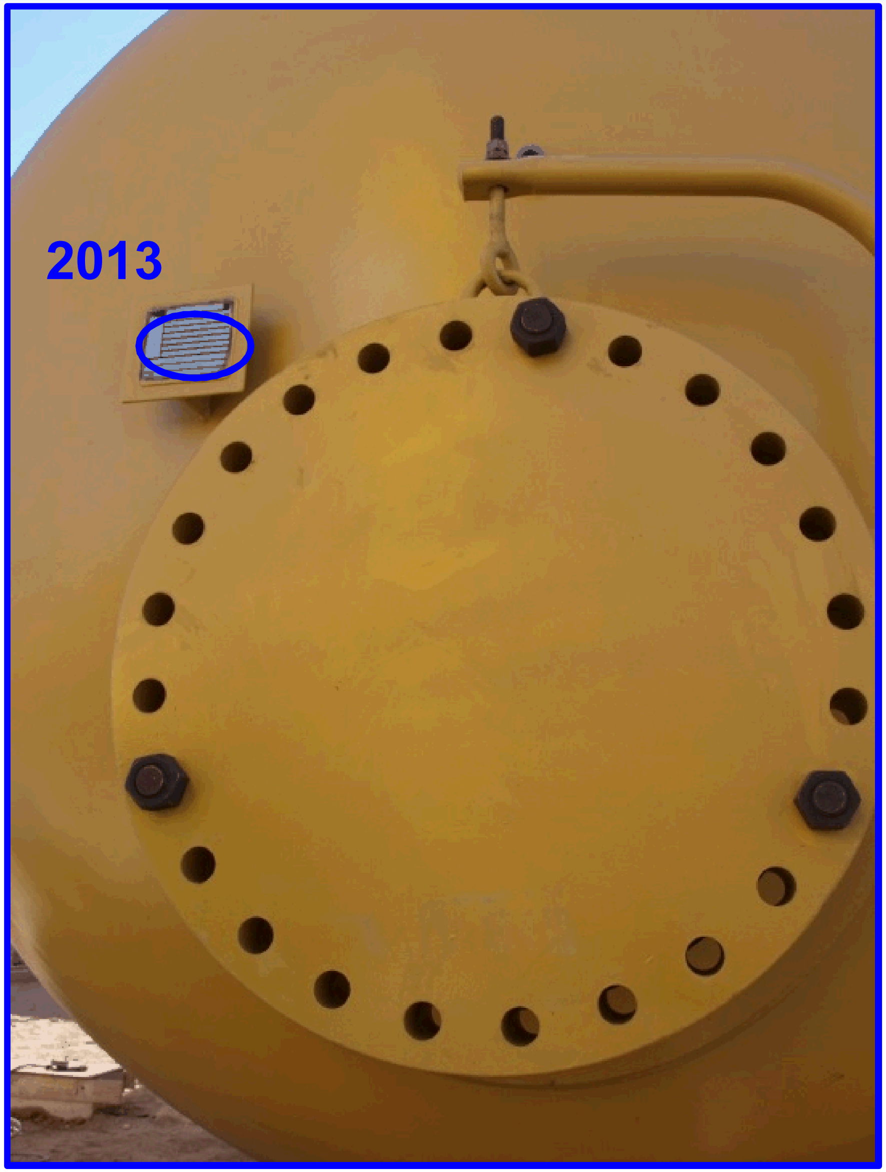
Temperature Decay During a Tunnel Run



Test Section Wall Temperature



What has improved?



Total cost: about $1.2M.