ROSEBUD
OPERATING SERVICES, INC.

Protecting An Air-Cooled Condenser from Hail Damage
An Innovative Solution

ACCUG – LAS VEGAS
WESTIN HOTEL : October 2-4, 2017

ACC HAIL PROTECTION SYSTEM
U.S. PATENT PENDING

Yellowstone Power Plant

Dan Gray - Director, Tom Shaw - Plant Mgr, Craig Ripley - Operations Mgr.

Presented by Daniel Burns, Burns Engineering Services

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YELLOWSTONE POWER PLANT

ACC Users Group

PLANT

- GENERATES 65 MW
- 2 X TAMPELLA, PETROLEUM COKE FIRED BOILERS
- 2 x 5 CELL AIR COOLED CONDENSER (ACC)
- COMMISSIONED ~1995

ACC

- ORIGINAL ZBDT @ Plan Area ~70’ x ~200’
- HUDSON TUF-LITE2 Fans (ø=26’)
- MODULAR REPLACEMENT OF ZBDT BUNDLES w/GEA 2014
- SINGLE CS TUBE with ALUM. FINS (GEA ALEX SYSTEM)
- Aluminum Fin Dimensions @ 190 x 19 mm x 0.25 mm THICK
- RETROFITTED W/VFD MOTORS
- Facility supports nearby Exxon-Mobil refinery operations

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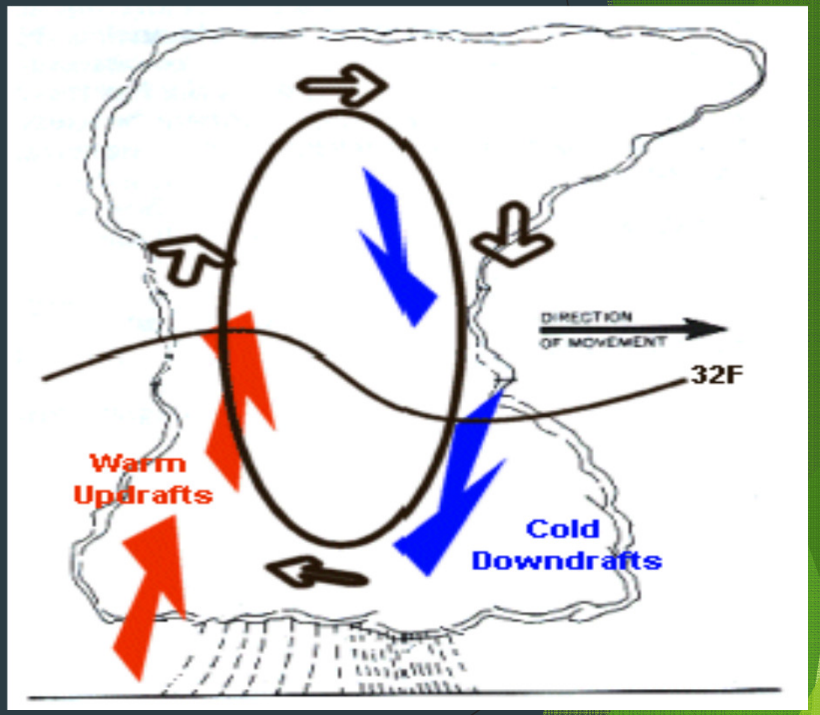
HAIL STORMS

Hail is formed in thunderstorms when:

- Warmer updrafts laden with raindrops are frozen/coalesce in the cold upper atmosphere.
- Layers freeze over the droplet as it goes round until it drops out of the sky.
- The phenomena is often difficult to predict.

The National Oceanic & Atmospheric Administration (NOAA) reported that over 5,600 severe hail storms occurred in 2016.



Source: NOAA Hail Awareness Webpage

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HAIL STORMS IN NORTH AMERICA

- Hardest hit states include Colorado, Texas, Kansas, Illinois, Minnesota, Missouri, Oklahoma, South Dakota, Illinois, Ohio, Georgia, New York, Nebraska, Massachusetts & Pennsylvania.
- Storms are increasing in size, frequency & severity in certain areas (ie. Texas, Colorado, Oklahoma…etc) over the past decade.

- In 2014, one hailstorm over a 5-day period resulted in over $2.9 billion of property damage in Colorado to Pennsylvania.
- IN 2016, OVER $1.3 BILLION IN DAMAGE OCCURRED IN 2 TEXAS STORMS SEPARATED BY ~1 WEEK.
- In Canada, damaging hail storms have taken their toll from BC, Alberta (esp. Calgary) through Ontario to Nova Scotia.
- For Mexico, Puebla through Mexico City are occasionally impacted.

Hail storm areas listed are not meant to be all-inclusive as many other regions are affected.

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Hail Storm – May 18, 2014
Billings, Mt.

Most damage to buildings (roofs, windows, siding) cars, and to the city's largest ACC.
In all, more than 30,000 claims.

- Hail typ. Marble to Golf ball in Size,
- Max. Diameter found @ ~2.5"
- Storm resulted in over ~$500 Million of claims in and around Billings
- Almost 1/1000 th's of ALL Storm Damages from this one small ACC !

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GEA ALEX Tube Bundles

- Single CS Tube coated w/alum. Backing…Alum. fins braze welded to Backing.
- Exposed Curved areas of Single CS tubes were dented by hail in many instances.
- INTEGRITY OF TUBES/FIN ATTACHMENTS FOUND UNCHANGED POST EVENT.

ACC Hail Damage

ACC Hail Damage

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ACC Hail Damage

- Severe damage estimated between ~7% to ~10% of Aluminum finned surface area.
- Equates to a similar section (~7% to ~10%) blocked x-sect. Airflow.
- Based on examination of 4 square foot randomly selected areas in different bundles.

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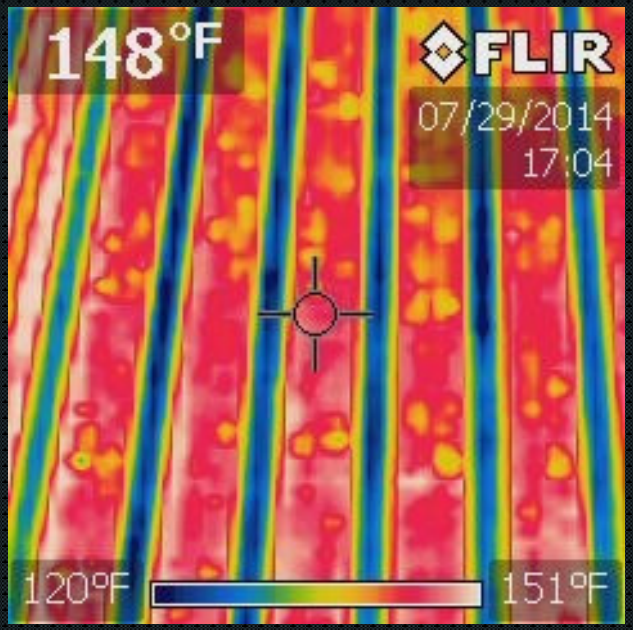
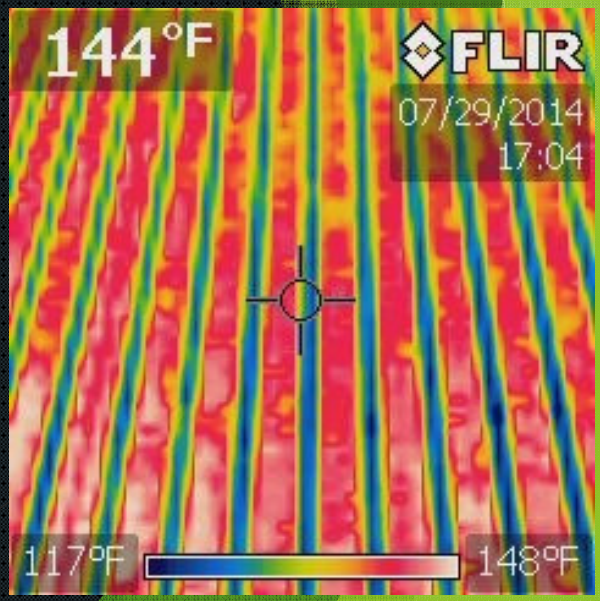
Thermographic Images of Fin Damage

Distribution, Distribution, Distribution…

ACC Performance is all about distribution, air-steam dist. inter-related.

- Airflow takes path of least resistance, any local change in DP changes overall flow pattern.
- Total Fan Discharge Head typ. @ no greater than 0.5“ water (ie. mainly DP across tube bundle). Damaged fins result in blockage/disturbance in flow field.
- Many local disturbances in flow field result in distribution losses/loss of heat transfer surface area…rate of condensation significantly reduced.





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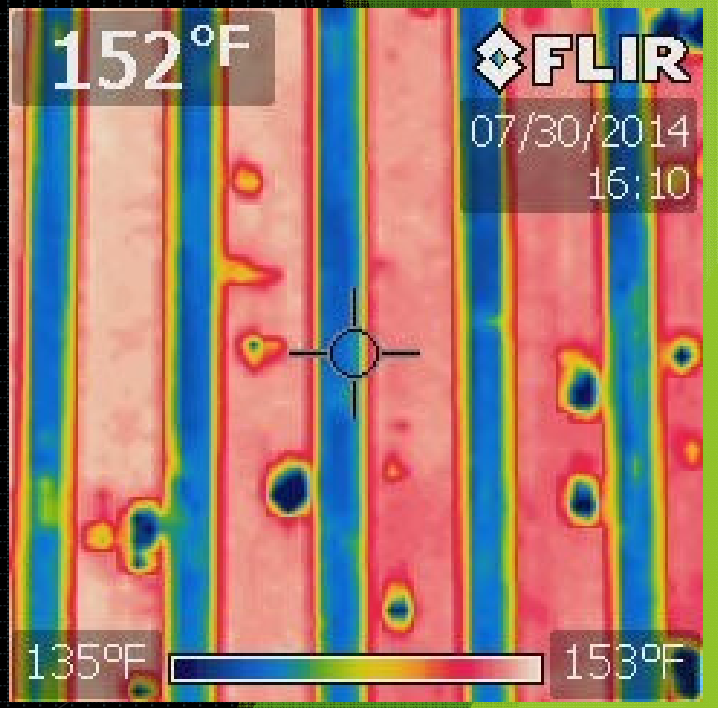
PERFORMANCE IMPACT

- Thermography Shows Much Heat ***Not*** Conveyed thru Damaged Fin Sections, worse @ Warmer Inlet Temps
- Condensation SET by Heat Flowing thru Finned Tubes
- A 10˚F Colder FIN Surface Condition Represents an Increase in **~1.5 inhg** higher BP (from 130˚F steam temp (4.65 inhga). Worse @ elevated steam temp/BP.
- Higher BP estimated @ **~0.20 inhg** based on reduced finned surface areas & airflow.
- Equates to ~0.30 MW or (2,628 MW-hrs/yr.)
- Lost revenue @ 2,628 MW * $35/MW= ~$92,000/yr.
- Not much but this is for clean unit. Once fouling begins (cottonwood, feathers, dirt) that exacerbates performance losses.
- No estimates considered for DERATING impact



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FIN REPAIR PROCESS

- Evaluated various methods of repair. Tested shooting metal darts, pressurized air/water from fan enclosure side through fins. These repair processes failed.
- Final repair process employed butter knife welded on end of pliers to spread fins open.
- Crew of 10 manual laborers/10 hr. shift per day over ~3 months to repair.
- Often Laborers could not work more than 30 min. at a time to minimize heat stress.

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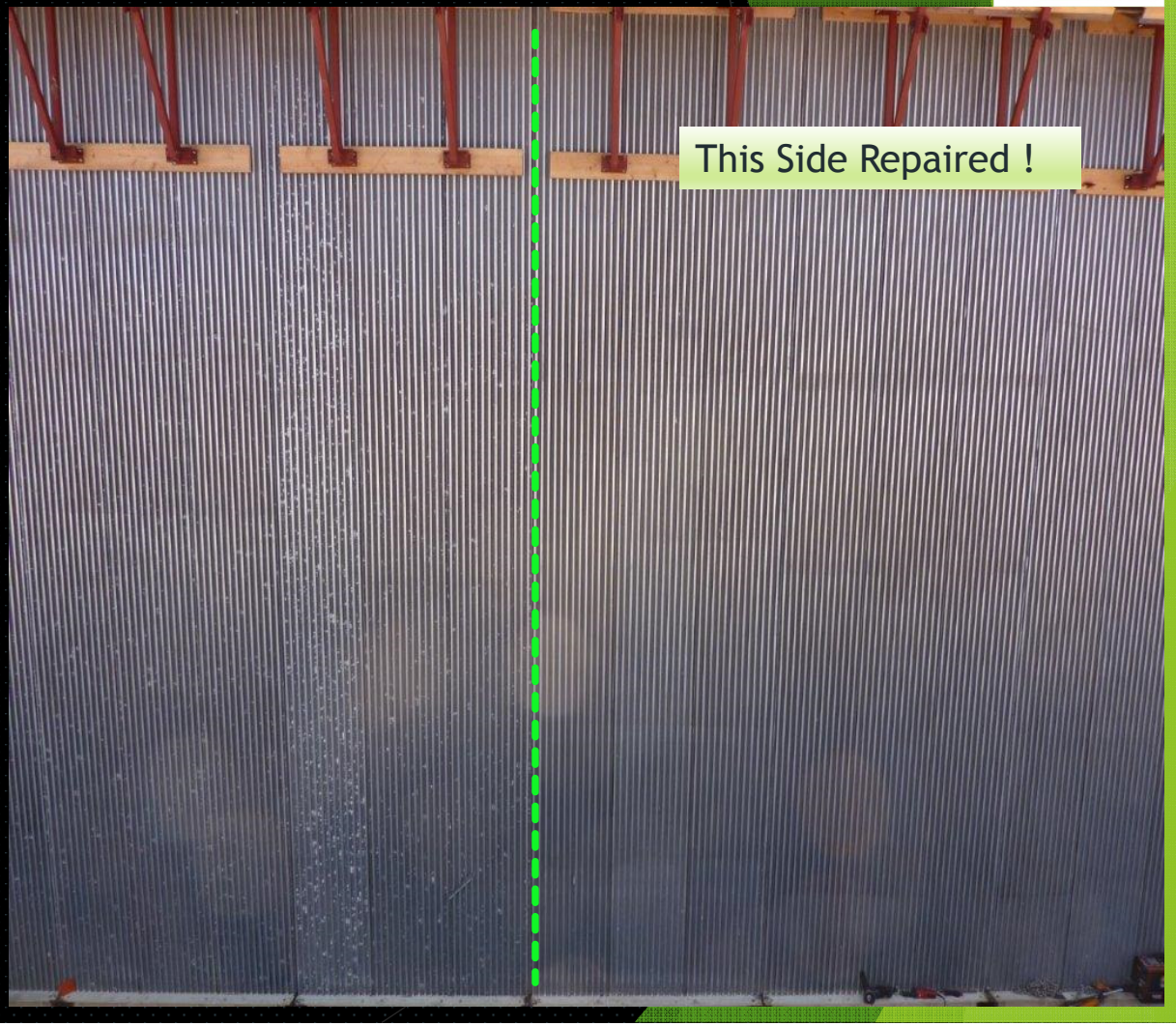
ACC Hail Damage

- Comparison of Repaired Section versus Damaged Section. (Green Dotted Line is Border).
- Repairs time consuming
- Fins not perfect after completed.
- Repair Project Cost @ ~$500,000


Inset of Repaired Section



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Impetus for Hail Screens

Impact on Performance

- Maintain Best Possible Performance.
- Minimize Derates @ Warm Inlet Temperatures.

Critical Equipment Protection

- Avoid potential of damage to ACC
- Owners did not want to go thru the process when the next hailstorm hit.

GEA Guarantee/Warranty

Reviewed by GEA

not impacted

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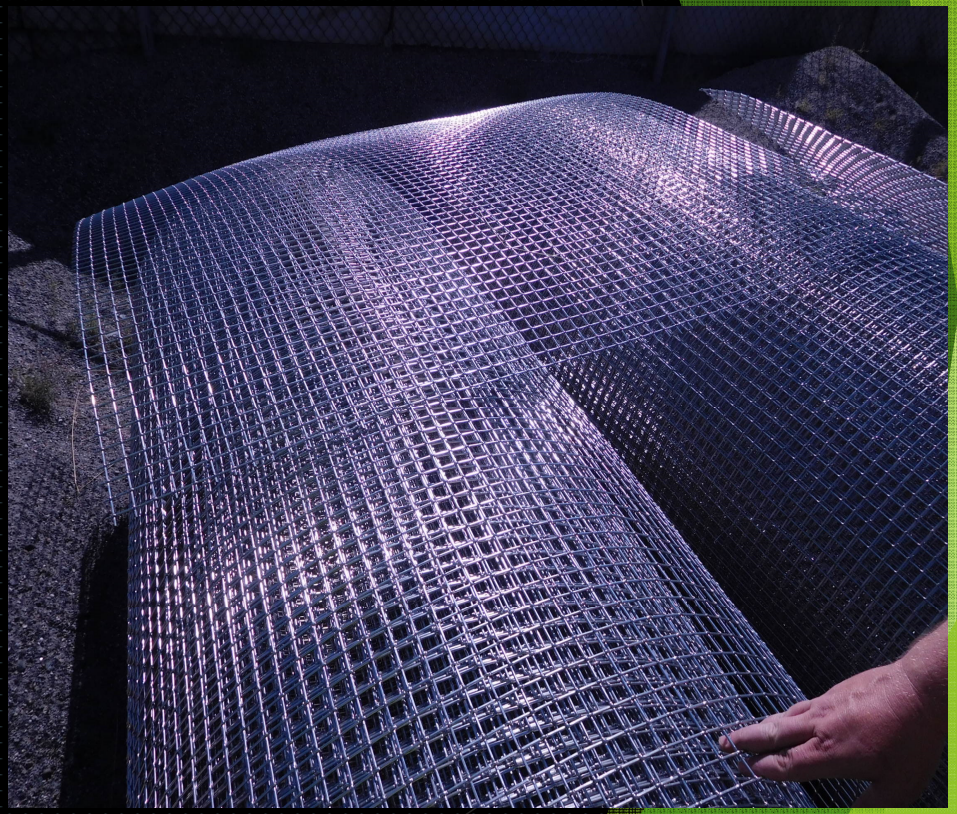
Hail Screen Design

- Standard SS316L metal wire screen
- Special Support Structure
- Clamp bar assembly used to install screening over acc
- Screens Tensioned
- Custom Fit Design
- US Patent Pending
- Total Installed Costs ~$350,000



Patent Pending Hail Protective System

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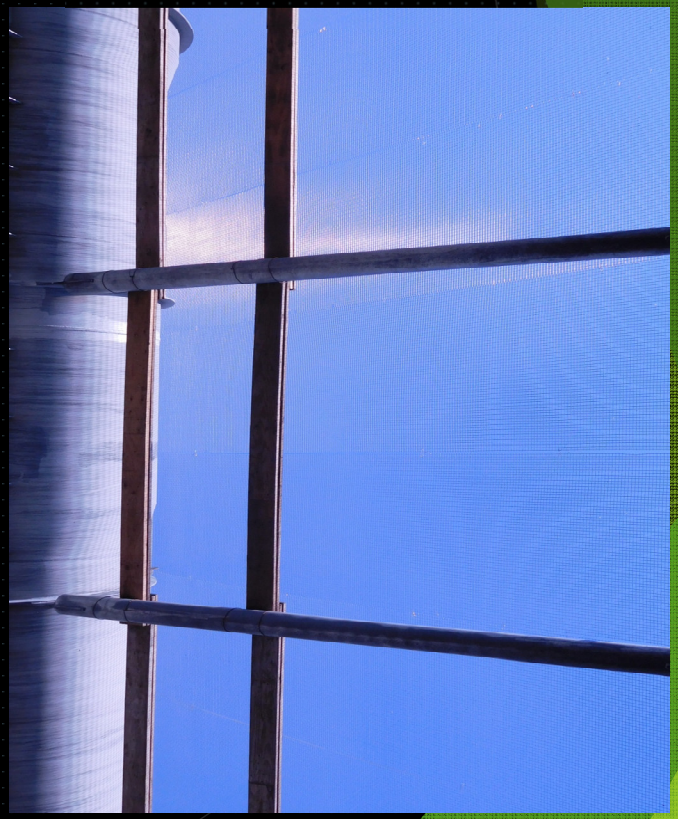
Installation

Center In Between Streets

On Perimeter



Patent Pending Hail Protective System

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Installation

Screen Elevation on Perimeter @ ~65 ft (above grade)

Screen Elevation above Steam Distribution Duct @ ~75 ft (above grade)

Patent Pending Hail Protective System

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Ready for Action…..

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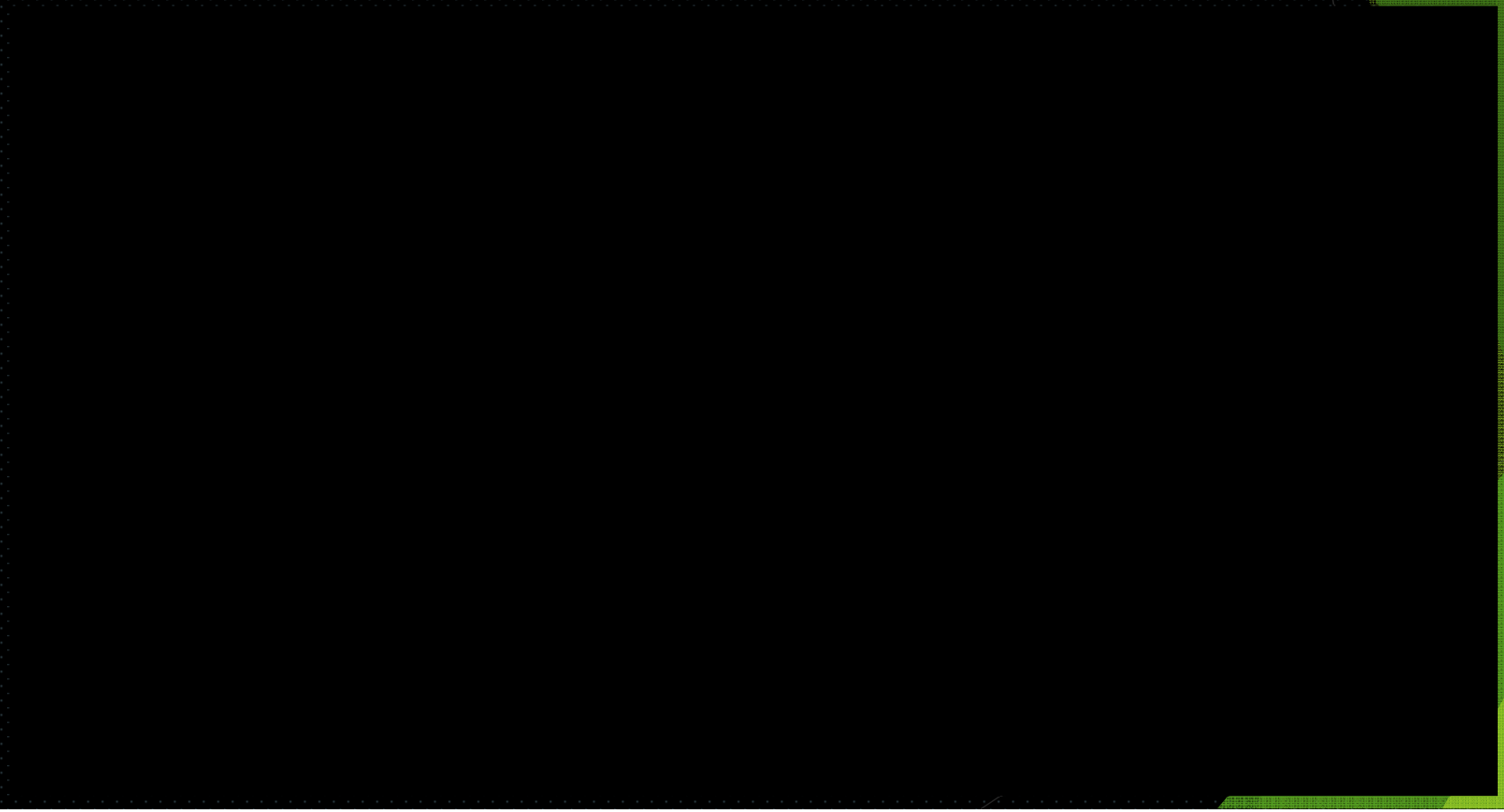
Are You Prepared for the Next Hailstorm ?



Burns Engineering Services, Inc

Your one-stop shop for air-cooled, & steam surface condenser technical services.

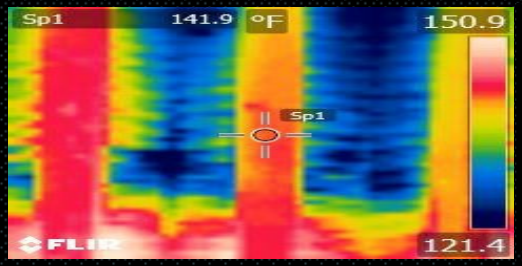
Our engineering staff combined have over 180 years in optimizing reliability & performance in cooling systems or on average over 25 years per staff member !

Services ⇒

♦ Inspection & Condition Assessment - Online & Offline Surveys

♦ Solutions to Minimize Reliability & Performance Impact of:
Wind Effects · High Air Inleakage · Corroded Tubes/fins
Tube Freeze Damage Events · Air Removal System Deficiency

♦ Performance Evaluation & Testing using Thermography surveys coupled with other PLANT data
♦ Correcting Multi-Row Tube Bundle Design Flaws
♦ Comparison of Tube Bundle Retrofit & Replacement Options
♦ Design & Modification of Spray Enhancement System
♦ Project Bid Specifications



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