

ConcreteWorks



IHEEP Conference
September 29, 2009
San Antonio, TX



Outline

- Concrete and early-age heat generation
- Heat Prediction Methods
- ConcreteWorks



Early Age Curing Temperature: A Blessing and a Curse

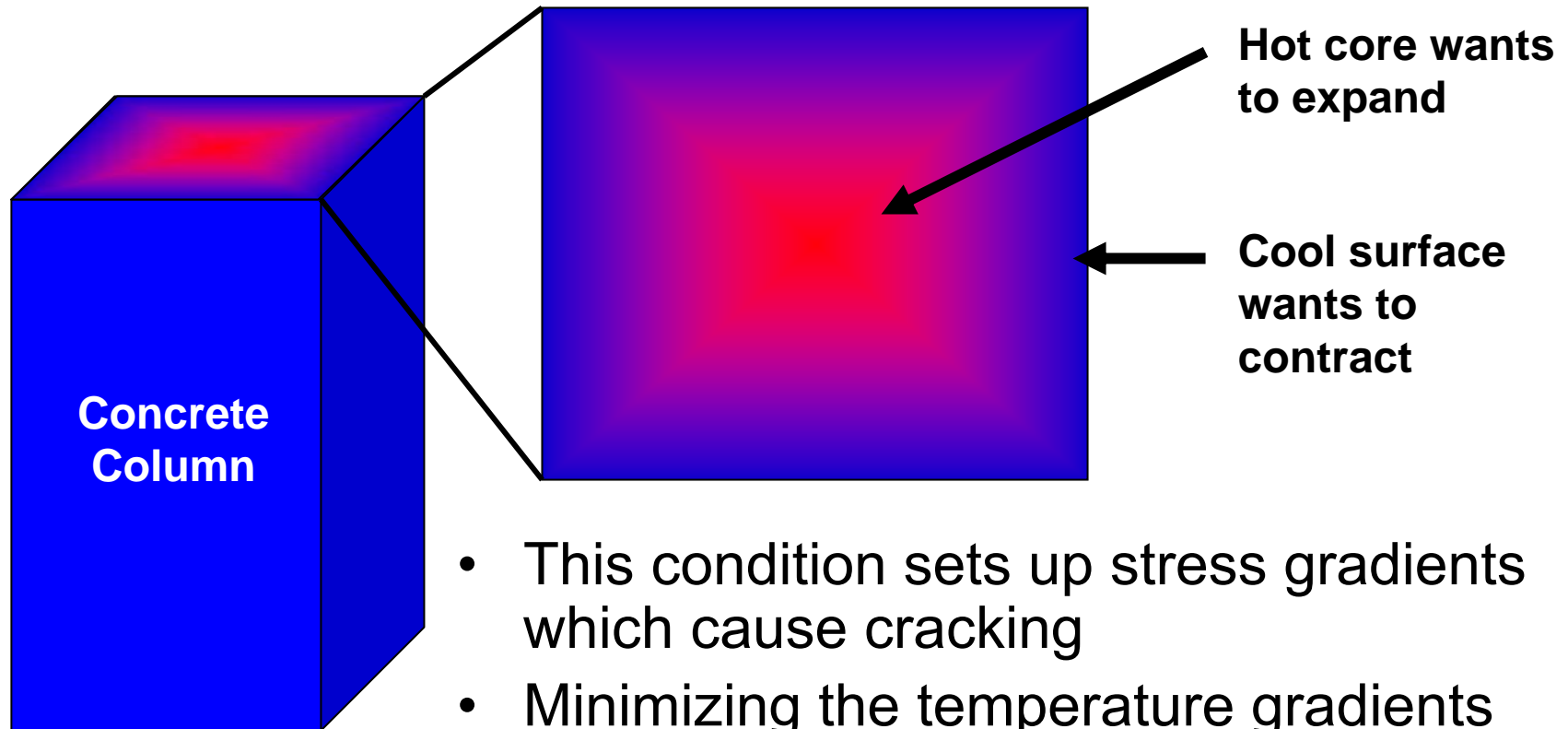


- Heat generated increases the rate of the reaction and rate of strength gain
- Too much heat too early can cause problems especially in large sections



Thermal Cracking

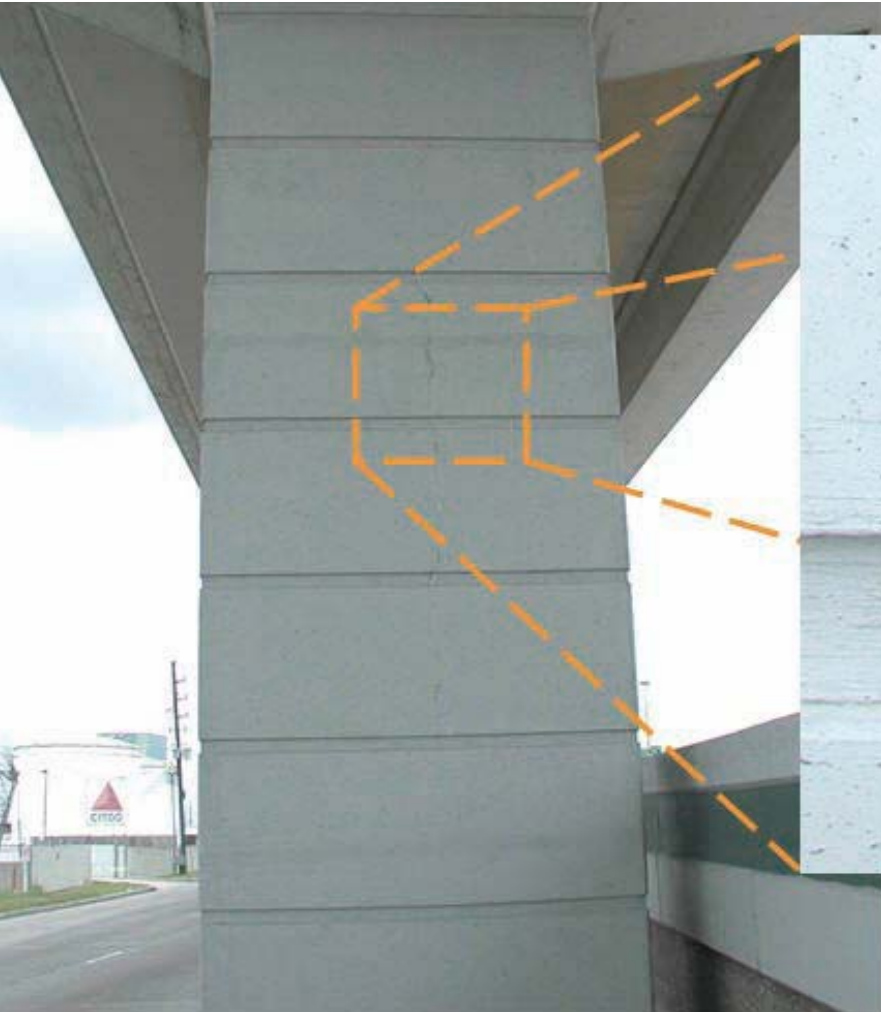
- Cracking that results from having large differences between core temperature and surface temperature



- This condition sets up stress gradients which cause cracking
- Minimizing the temperature gradients reduces the potential for cracking to occur



Thermal Cracking

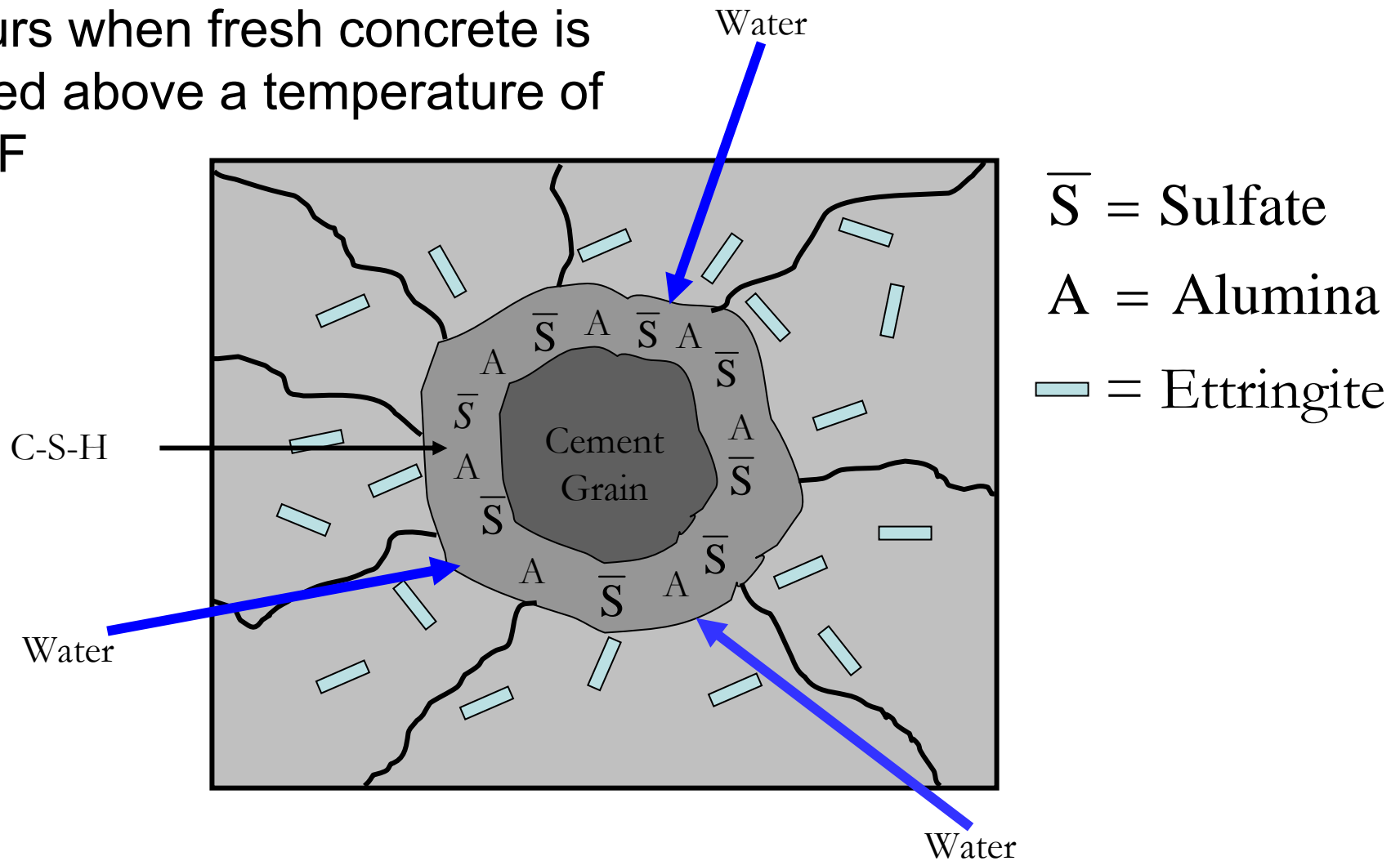




Premature Concrete Deterioration

“Delayed Ettringite Formation”

Occurs when fresh concrete is heated above a temperature of 158°F



Premature Concrete Deterioration “Delayed Ettringite Formation”





Heat Prediction Methods



Methods for Predicting Heat Generation

- PCA Method
 - Calculates $\sim 10^{\circ}\text{F}$ temperature rise for every 100lb of cement
 - Assumes a least dimension of 6ft
 - Does not calculate time to maximum temperature
 - No temperature differential calculation
 - Does not account for differences in cement composition
 - Adjustments for SCM's (fly ash , slag, etc.) are crude at best



Methods for Predicting Heat Generation

- ACI 207.2R “Graphical Method”
 - Uses charts and equations based on empirical data
 - Assumptions for boundary conditions
 - Cement fineness based on test method rarely used anymore
 - Generally underestimates maximum temperature
 - Poor prediction of time to maximum temperature



Methods for Predicting Heat Generation

- Schimdt's Method
 - Developed in the 1920's as a simplified finite difference method
 - Little guidance for boundary conditions and difficult to model
 - Adjustments for SCM's are crude
 - Method can be complicated and should be performed by an experienced engineer

ConcreteWorks





What is ConcreteWorks?

- Software package that was a result of project 0-4563 “Prediction Model for Concrete Behavior” UT @ Austin
- Program is capable of predicting heat generated during early ages of concrete
- Other features
 - Mixture Proportioning
 - Cracking Probability
 - Chloride Concentration Prediction



| | | Initial Chloride Profile Input for Existing Structures | Chloride Service Life | Thermal Cracking Probability | Temperature Prediction |
|--------------------------|---|--|-----------------------|------------------------------|------------------------|
| Mass Concrete | Rectangular Column | | X | X | X |
| | Rectangular Footing | | X | X | X |
| | Partially Submerged Rectangular Footing | | X | X | X |
| | Rectangular Bent Cap | | X | X | X |
| | T-Shaped Bent Cap | | X | | X |
| | Circular Column | | X | | X |
| | Drilled Shaft | | X | | X |
| Precast Concrete Members | Box Beam (Type 5B40) | | | | X |
| | Type IV I-Beam | | | | X |
| | U40 Beam | | | | X |
| | U54 Beam | | | | X |
| Bridge Deck Types | Pre-cast 1/2 Depth Panels | X | X | | X |
| | Permanent Metal Decking | X | X | | X |
| | Removable Forms | X | X | | X |
| | User-Defined | X | X | | X |
| Pavements | User-Selected Layers | | | | X |



Mix Design Proportioning

ConcreteWorks
File Tools Help

General Inputs | Shape Inputs | Member Dimensions | Mixture Proportions | Material Properties | Mechanical Properties | Construction Inputs | Environment Inputs | Corrosion Inputs | Input Check

Mixture Proportion Inputs

Mix Proportion Inputs

| | | |
|--------------------------|-----------------------------------|--------------------|
| Cement Content | <input type="text" value="705"/> | lb/yc ³ |
| Water Content | <input type="text" value="211"/> | lb/yc ³ |
| Coarse Aggregate Content | <input type="text" value="1800"/> | lb/yc ³ |
| Fine Aggregate Content | <input type="text" value="1100"/> | lb/yc ³ |
| Air Content | <input type="text" value="2"/> | % |

Supplementary Cementing Materials

Click on the check to indicate if an admixture is in the mix -

| | | | | | |
|---|----------------------|--------------------|--|----------------------|--------------------|
| <input checked="" type="checkbox"/> Class C Fly Ash | <input type="text"/> | lb/yc ³ | <input type="text" value="29"/> | % CaO | |
| <input checked="" type="checkbox"/> Class F Fly Ash | <input type="text"/> | lb/yc ³ | <input type="text" value="19"/> | % CaO | |
| <input checked="" type="checkbox"/> Grade 120 Slag | <input type="text"/> | lb/yc ³ | | | |
| <input checked="" type="checkbox"/> Silica Fume | <input type="text"/> | lb/yc ³ | <input checked="" type="checkbox"/> Ultra Fine Fly Ash | <input type="text"/> | lb/yc ³ |

Chemical Admixture Inputs

| | | | |
|--|--|---|---|
| <input type="checkbox"/> Low Range Water Reducer(Type A) | <input type="checkbox"/> Mid-Range Water Reducer | <input type="checkbox"/> Napthalene High-Range Water Reducer (Type F) | <input type="checkbox"/> Polycarboxylate High-Range Water Reducer(Type F) |
| <input type="checkbox"/> Retarder (Type B) | <input type="checkbox"/> Accelerator (Type C) | | |

Need Help with Chemical Admixture Inputs?

Mix Proportions (% by weight)

| | |
|-------------|--------|
| cement | 18.47% |
| water | 5.53% |
| coarse agg | 47.17% |
| fine agg | 28.83% |
| c ash | |
| f ash | |
| slag | |
| silica fume | |
| ultra fine | |

Calculated Mixture Proportion

| | |
|---------------------------------|----------------------------------|
| Sacks of Cement/yc ³ | <input type="text" value="7.5"/> |
| Gallons of water/sack of Cement | <input type="text" value="3.4"/> |
| Water/Cement | <input type="text" value="0.3"/> |
| Water/Cementitious | <input type="text" value="0.3"/> |

Go to Design of Mixture Proportion

Back Next



Mix Design Proportioning

ConcreteWorks - [Design of Mixture Proportion]

File Tools Help

General Inputs Shape Inputs Member Dimensions Mixture Proportions Material Properties Mechanical Properties Construction Inputs Environment Inputs Corrosion Inputs Input Check

General Mix Information Aggregate Properties Water Adjustment Final Volumes Power 45 Chart Agg. Coarseness % Retained

Basic Specifications

Slump in

Air Content %

w/cm

*max w/cm ratio determined using ACI 211 Table 6.3.4(a), Table 4.2.2, and Table 4.3.1

Strength Requirement

Specified f'c psi

Minimum f'c

Target Strength psi

Number of Tests Used to Determine Standard Deviation

Standard Deviation psi

ACI 318-02 Sulfate Exposure Conditions (Table 4.3.1)

Check the sulfate exposure conditions

Negligible

Moderate

Severe

Very Severe

ACI 318-02 Special Exposure Conditions (Table 4.2.2)

Check any severe exposure conditions that apply

Intended to have low permeability when exposed to water

Exposed to freezing and thawing in a moist condition or to deicing chemicals

Corrosion protection of reinforcement in concrete exposed to chlorides from deicing chemicals, salt, salt water, brackish water, seawater, or spray from these sources

Material Properties

ConcreteWorks - [Material Properties]

File Tools Help

General Inputs Shape Inputs Member Dimensions Mixture Proportions **Material Properties** Mechanical Properties Construction Inputs Environment Inputs Corrosion Inputs Input Check

Cement Chemical/Physical Properties

Cement Type Check to manually enter cement chemical/physical properties Blaine(m²/kg)

Bogue Calculated Values (%)

| C ₃ S | C ₂ S | C ₃ A | C ₄ AF | Free CaO | SO ₃ | MgO | Na ₂ O | K ₂ O |
|-----------------------------------|---------------------------------|----------------------------------|-----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| <input type="text" value="60.2"/> | <input type="text" value="13"/> | <input type="text" value="6.1"/> | <input type="text" value="10.9"/> | <input type="text" value="0.9"/> | <input type="text" value="2.7"/> | <input type="text" value="1.7"/> | <input type="text" value="0.1"/> | <input type="text" value="0.5"/> |

Aggregate Factors

of Coarse Aggregate Types

First Coarse Aggregate Type

of Fine Aggregate Types

First Fine Aggregate Type

Check to Manually Enter the Concrete Coefficient of Thermal Expansion and Thermal Properties

CTE 10⁻⁶/°F

Concrete k BTU/hr/ft²/°F

Combined Aggregate Cp BTU/lb/°F

Hydration Calculation Properties

Check to manually enter hydration properties

Activation Energy J/mol

Tau Hrs

Beta

Alpha (ultimate):

Hu J/kg

Mechanical Properties

ConcreteWorks - [Mechanical Properties]

File Tools Help

General Inputs Shape Inputs Member Dimensions Mixture Proportions Material Properties Mechanical Properties Construction Inputs Environment Inputs Corrosion Inputs Input Check

Maturity Functions

Check to calculate thermal stresses when temperatures are calculated

Select the type of maturity function

Nurse-Saul Method

Equivalent Age Method

Nurse-Saul Strength Inputs

To calculate strength data from maturity, enter in the appropriate parameters

$S_m = a + b \log_{10}(M)$
Where, S_m is Strength, a and b are constants, and M is Maturity

a Psi

b Psi / °F / Hr

Equivalent Age Elastic Modulus Inputs

$$E = E_c \cdot f_c^{E_e} \cdot w^{1.5}$$

Where, w is the unit weight (calculated from the mixture proportions), f_c is the compressive strength, E is the elastic modulus, and E_c and E_e are fit parameters

Check to manually input the relationship between compressive and Elastic Modulus

E_c

E_e

Equivalent Age Splitting Tensile Strength Inputs

$$f_t = f_{tc} \cdot f_c^{f_{te}}$$

Where, f_c is the compressive strength, f_t is the splitting tensile strength, and f_{tc} and f_{te} are fit parameters

Check to manually input the relationship between compressive and splitting tensile strengths

f_{tc}

f_{te}

Early Age Creep Parameters

Check to manually input the Modified Linear Logarithmic Model Inputs

Δ_0 days

Δ_1 days

$a1_{min} \cdot 10^{-12}$ 1/Pa

$a1_{max} \cdot 10^{-12}$ 1/Pa

$ta1$ days

$na1$

$a2_{min} \cdot 10^{-12}$ 1/Pa

$a2_{max} \cdot 10^{-12}$ 1/Pa

$ta2$ days

$na2$

$T_{adjfactor}$

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Construction Inputs

ConcreteWorks - [Construction Inputs]

File Tools Help

General Inputs Shape Inputs Member Dimensions Mixture Proportions Material Properties Mechanical Properties Construction Inputs Environment Inputs Corrosion Inputs Input Check

Concrete Placement Temperature
Click the method of calculating the concrete fresh temperature

Calculated from individual constituent material temperatures Change Constituent Material Temperatures

Concrete fresh temperature is equal to ambient temperature at time of placement

Manually enter concrete fresh temperature

Estimated Placement Temperature °F

After Forms Are Stripped
Select the correct combination of curing methods on concrete exposed after forms are stripped

White Curing Compound Black Plastic

Wet Curing Blanket White or Clear Plastic

Time between form removal and curing method applied hrs

Form Liners
Check which sides have form liners

Width Depth

Formwork
Concrete age at Form Removal hrs

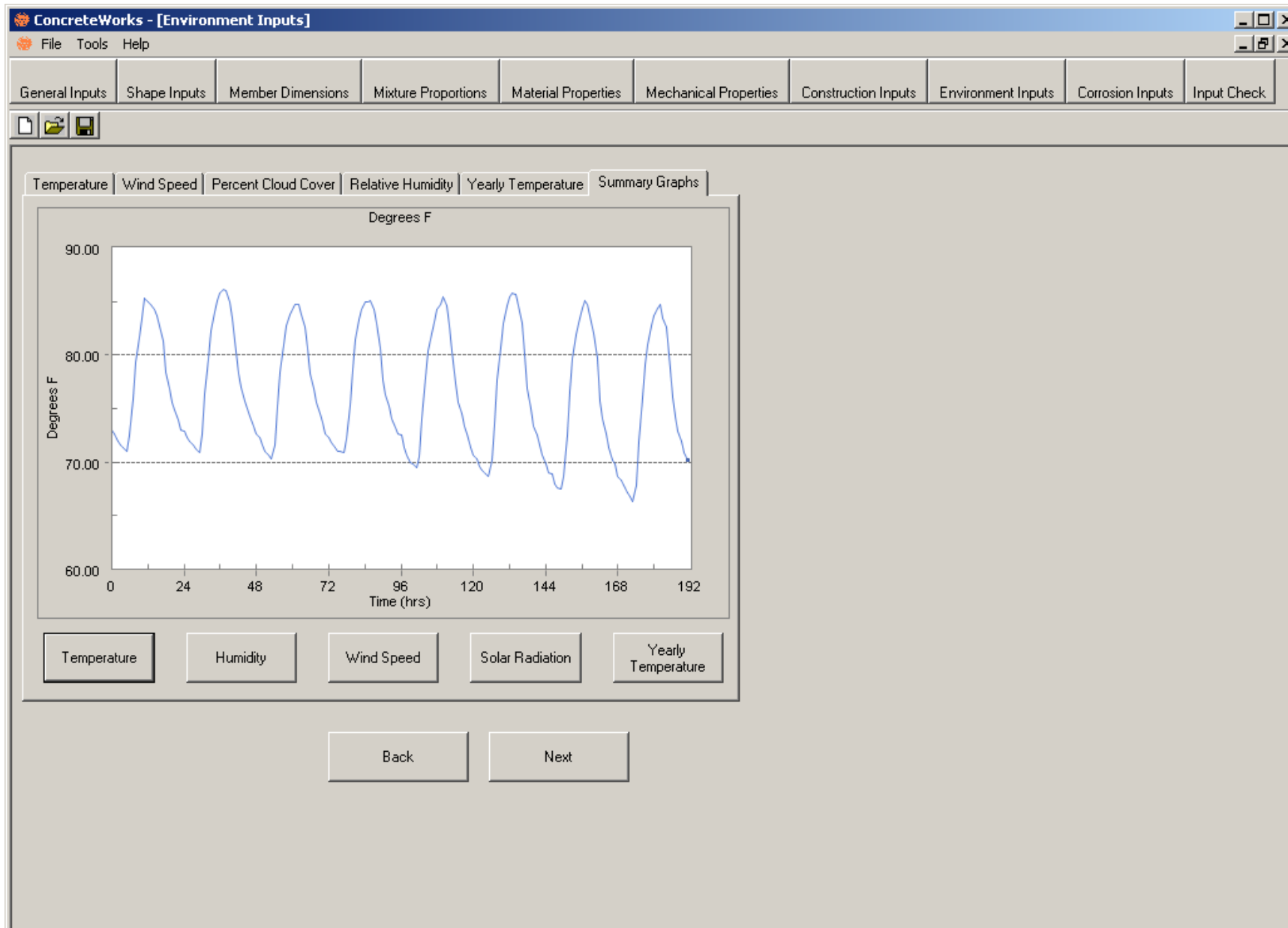
Form Type

Form Color

Blanket Insulation R-Value
Blanket R-Value (Thickness / Thermal Conductivity) hr-ft²-°F/BTU

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Environmental Inputs





| Parameter | Value | Units |
|------------------------------|----------------------|--------------------|
| General Inputs | | |
| Project Location | Houston | |
| Unit System | English | |
| Chloride Units | Percent of Concrete | |
| Life Cycle Analysis Duration | 75 | Years |
| Analysis Duration | 7 | days |
| Concrete placement time | 7 | am |
| Concrete placement date | 9/15/2009 | |
| Member Inputs | | |
| Shape Choice | Rect. column | |
| Member width | 10 | ft |
| Member depth | 10 | ft |
| Mixture Proportions | | |
| Cement Content | 705 | lb/yc ³ |
| Water Content | 217 | lb/yc ³ |
| Coarse Aggregate Content | 1800 | lb/yc ³ |
| Fine Aggregate Content | 1100 | lb/yc ³ |
| Air Content | 2 | % |
| Material Properties | | |
| Cement Type | I/II | |
| Cement Chemistry Values | Default | |
| Hydration Parameter Values | Default | |
| Coarse Agg. type | Limestone | |
| Fine Agg. type | Siliceous River Sand | |
| Coarse Agg. type | Limestone | |
| Fine Agg. type | Siliceous River Sand | |
| Mechanical Properties | | |
| Maturity Method | Nurse-Saul | |

| Parameter | Value | Units |
|-----------------------------------|-------------|---------------------|
| Environment Inputs Summary | | |
| Ave. Daily Max Temp. | 85.7 | *F |
| Ave. Daily Min Temp. | 70.5 | *F |
| Ave. Max Daily Solar Radiation | 665.3 | W/m ² |
| Ave. Max Daily Wind Speed | 10.9 | m/s |
| Ave. Max Relative Humidity | 91.6 | % |
| Ave. Min Relative Humidity | 58.2 | % |
| Construction Inputs | | |
| Concrete Fresh Temperature | 72.7 | *F |
| Blanket R-Value | 2.91 | *F |
| Forms are stripped after | 96 | hrs |
| Form Color | Red | |
| Form Type | Steel | |
| No Cure Method Chosen | | |
| Corrosion Inputs | | |
| Steel Type | Black Steel | |
| Steel Cover | 2 | |
| Dref | 65.9 | x 10 ^{...} |
| m | 0.26 | |
| No Barrier Method Selected | | |
| Exposure Class | Urban Road | |

Default values are indicated by green

Questionable input values are indicated by red

Back

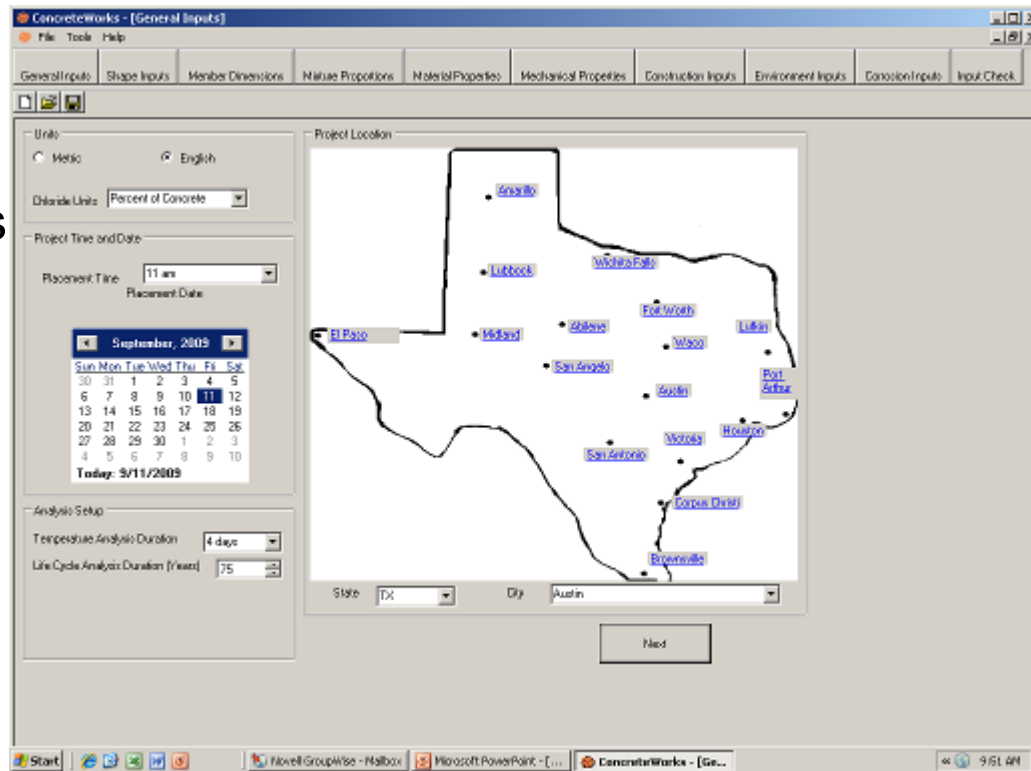
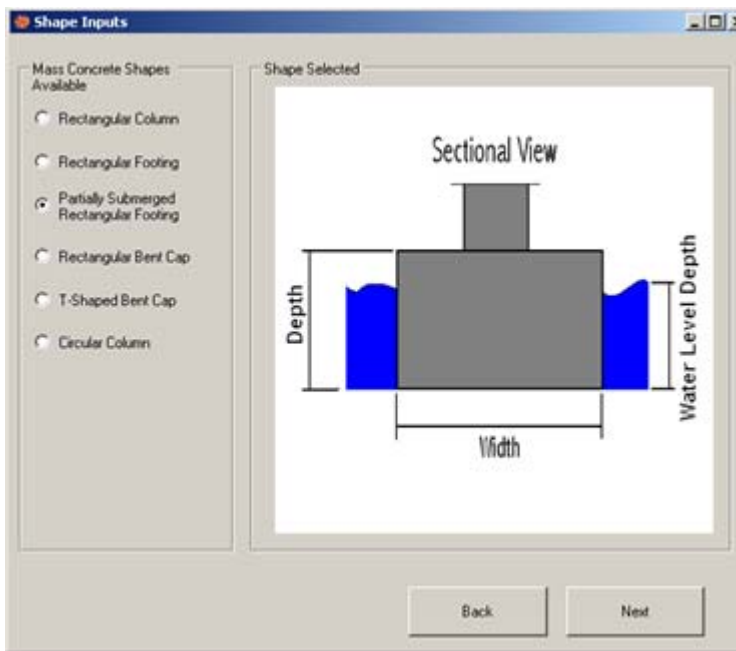
Calculate
Temperatures

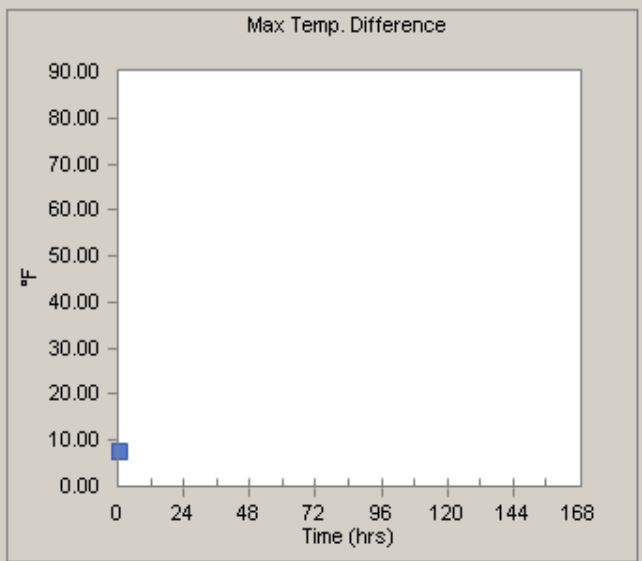
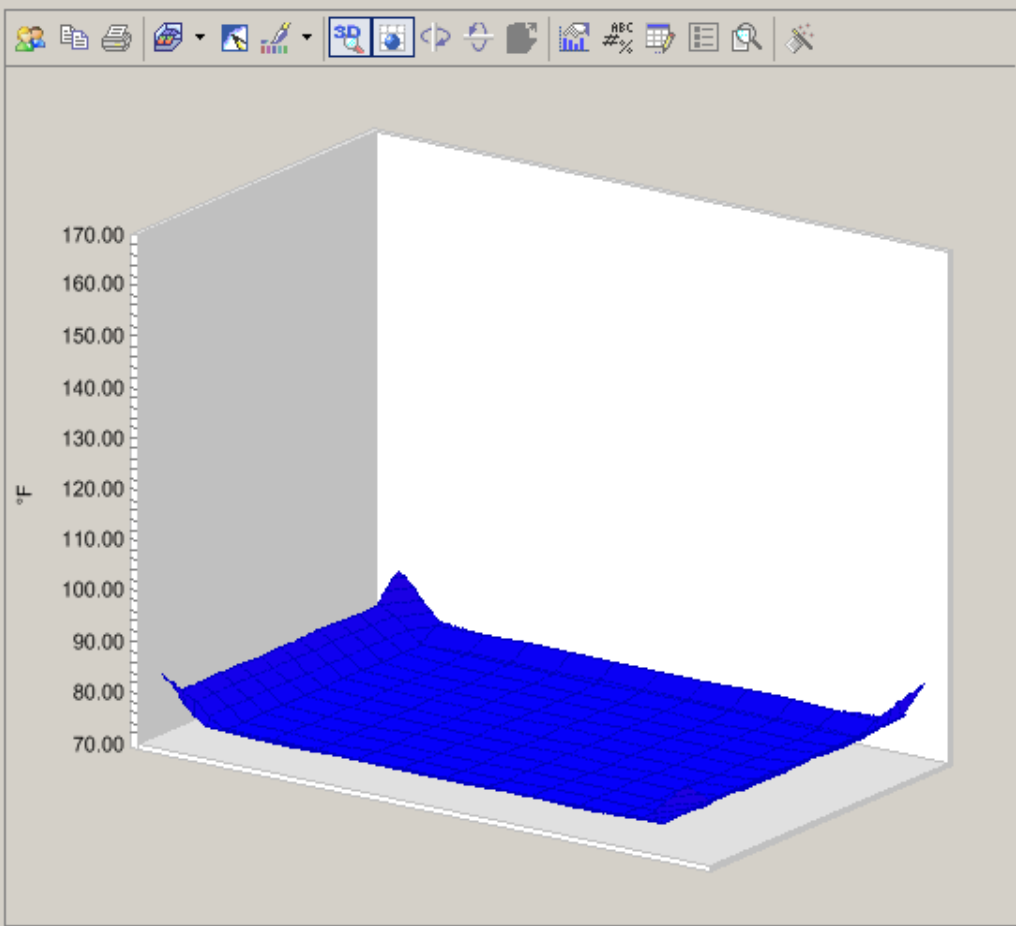


Temperature Predictions

- Temperature Predictions for Various Section Shapes and Location around the State

- Mass Concrete Sections
- Pavement & Bridge Decks
- Precast Bridge Girders





What to animate?

- Temperature
- Maturity
- Comp. Strength
- Chloride Profile

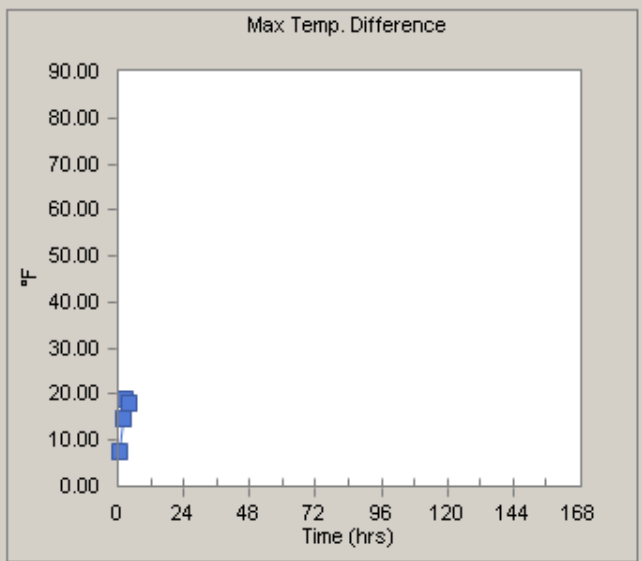
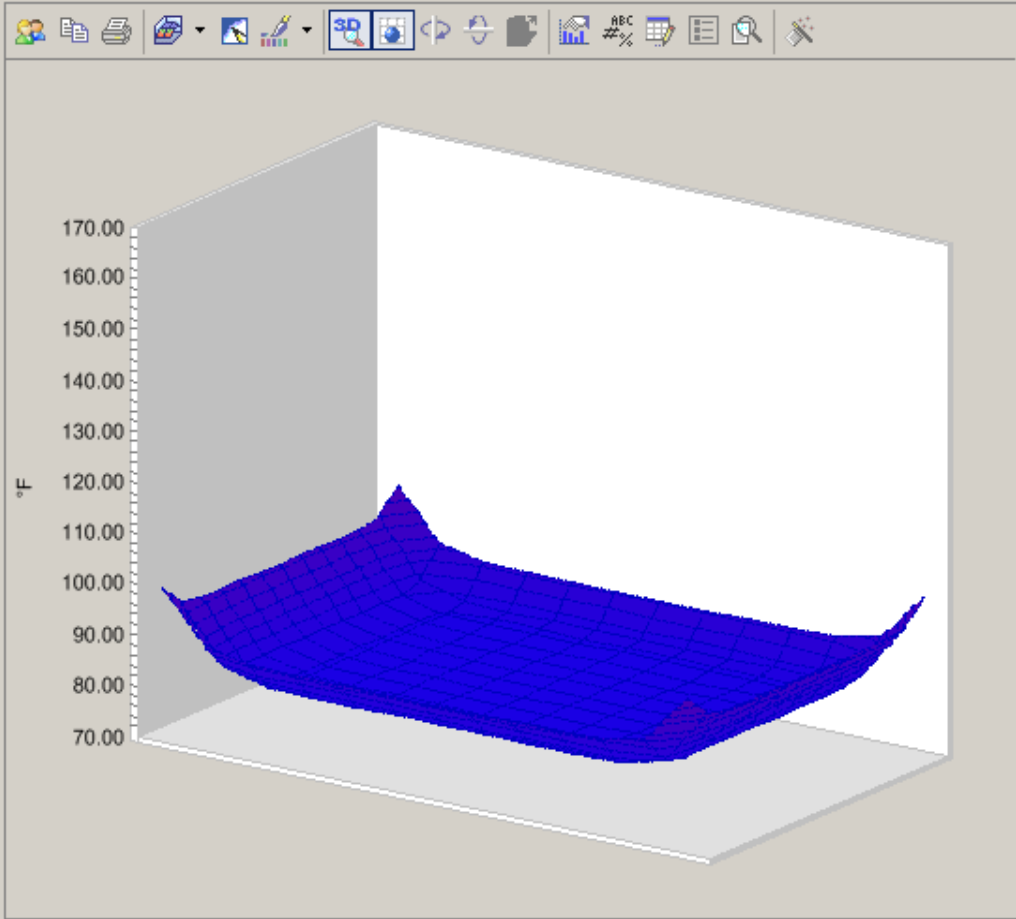
Animate

Stop Animation

Show Comparison Chart

Back to Inputs

Export Temp. Data



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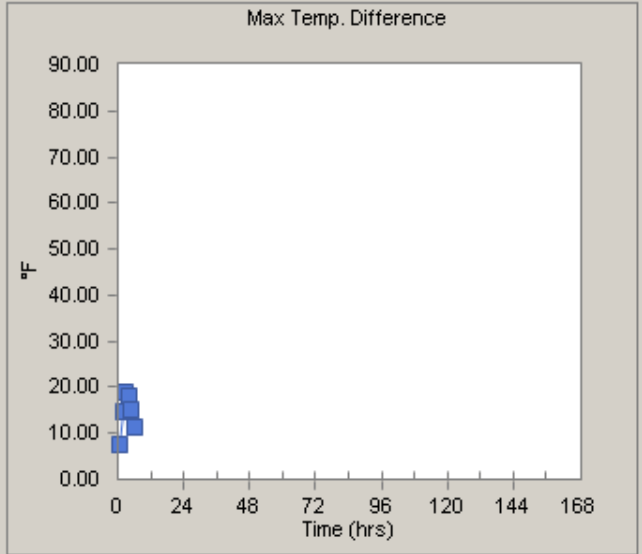
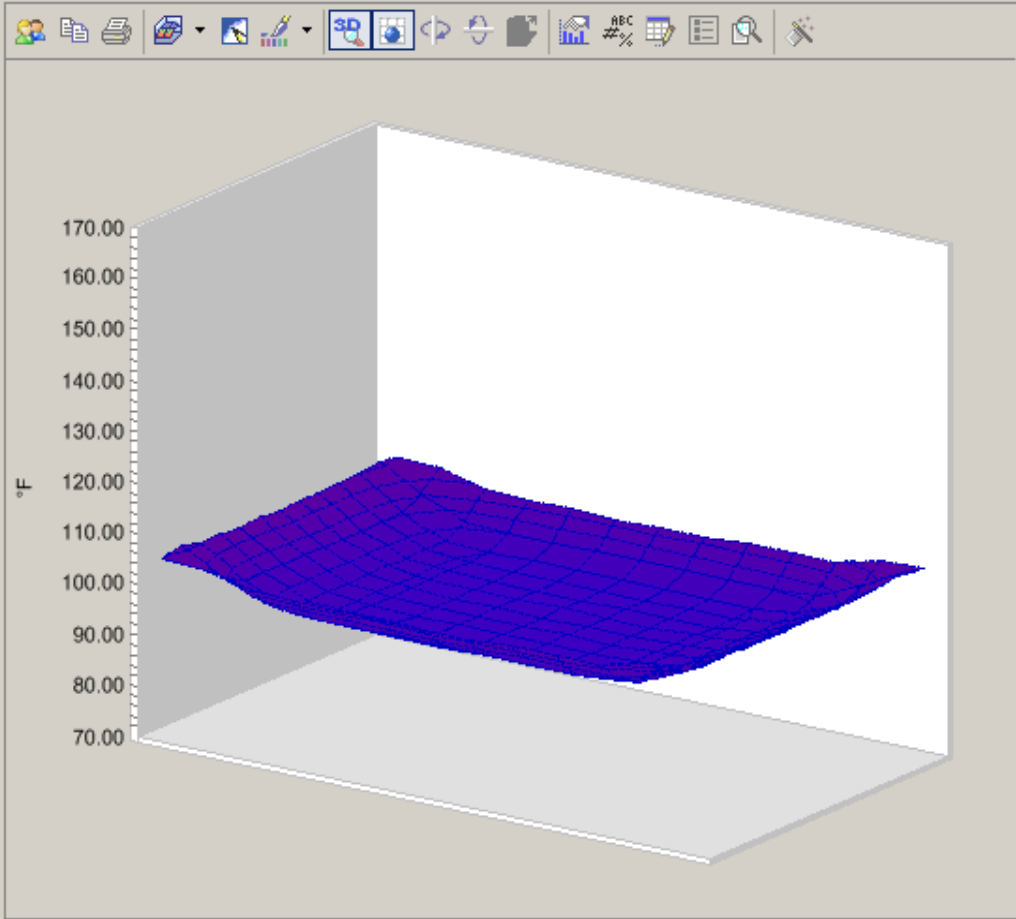
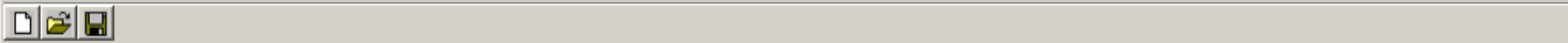
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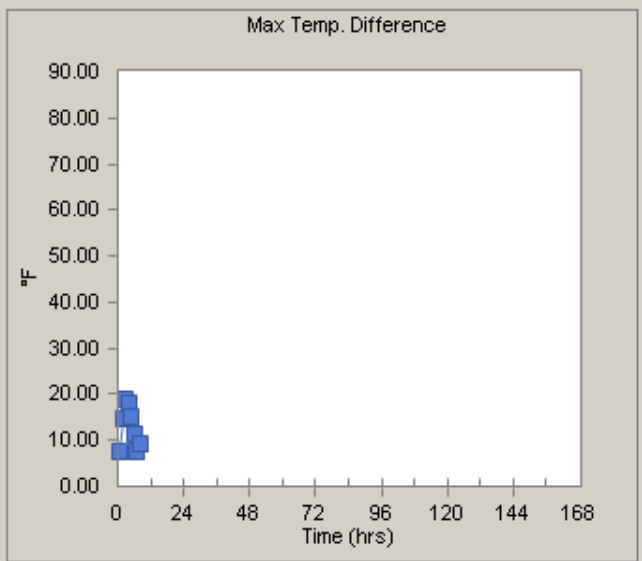
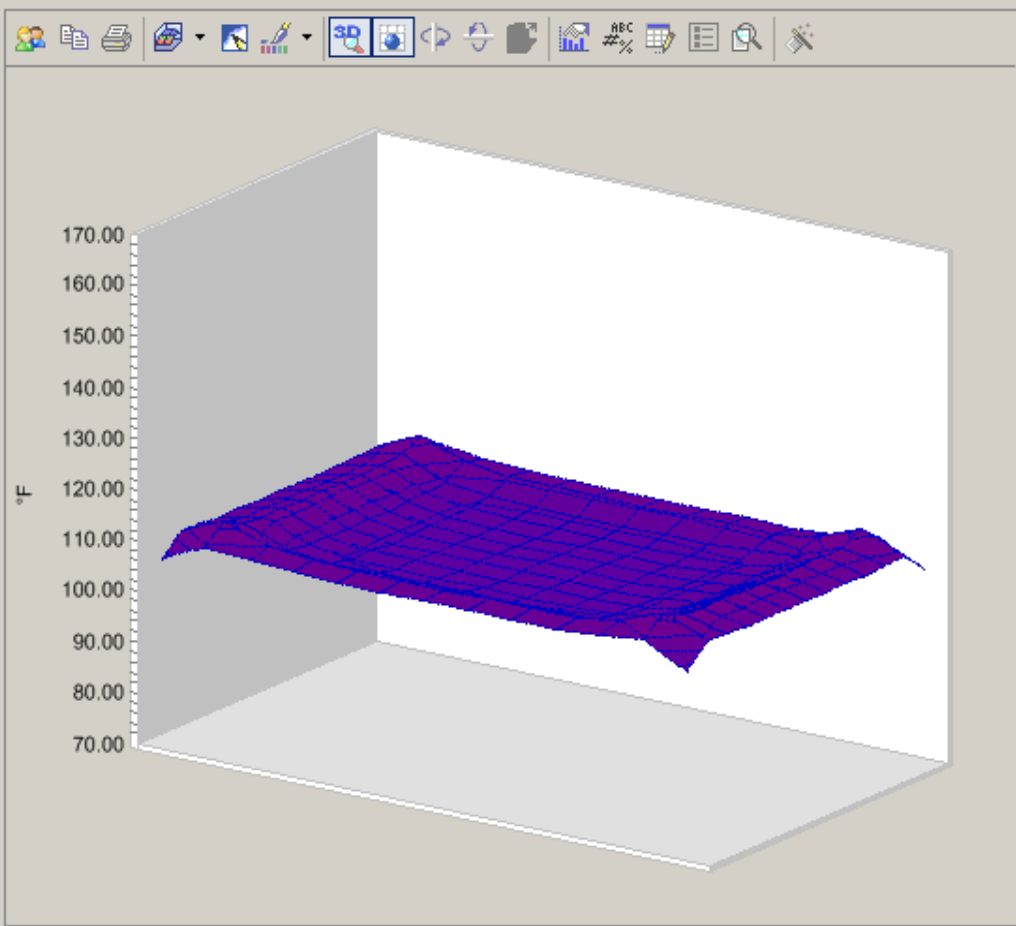
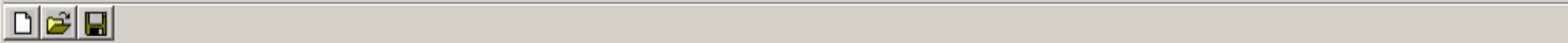
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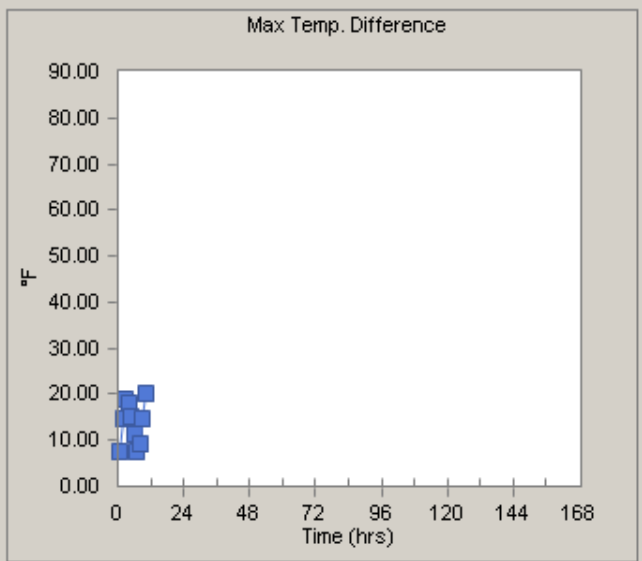
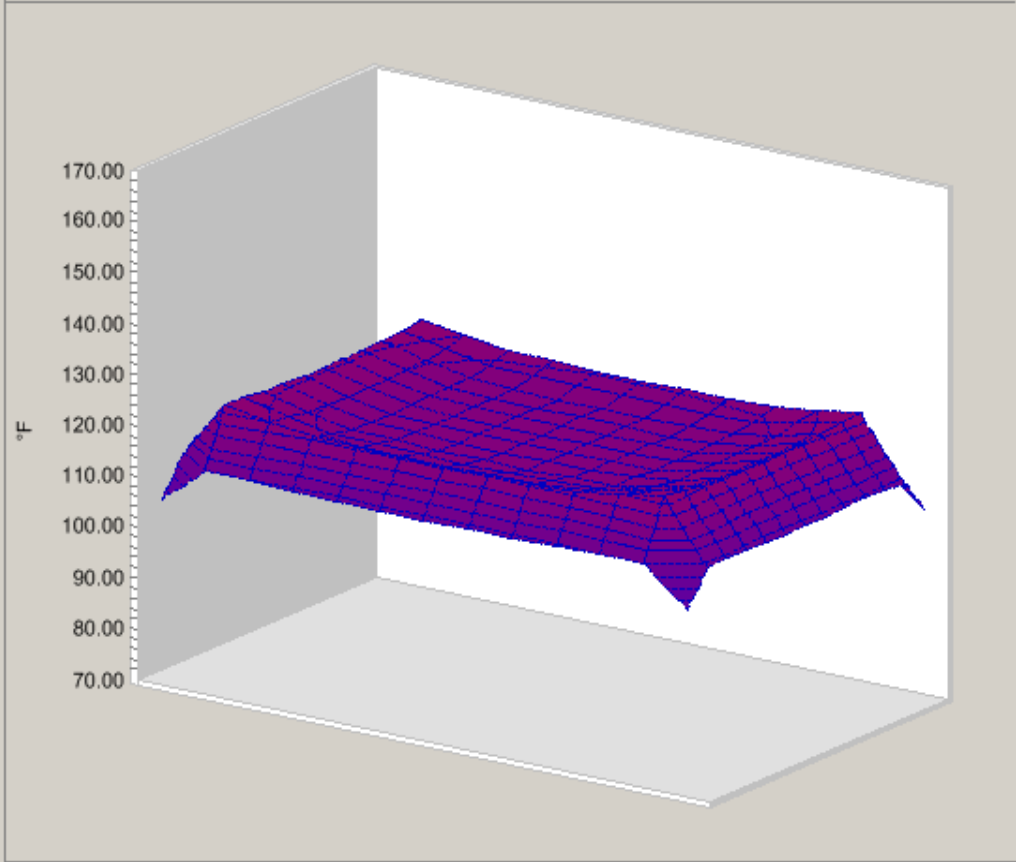
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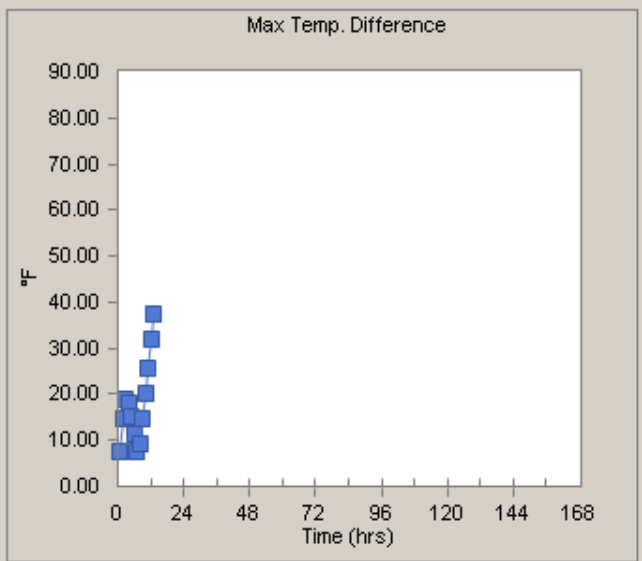
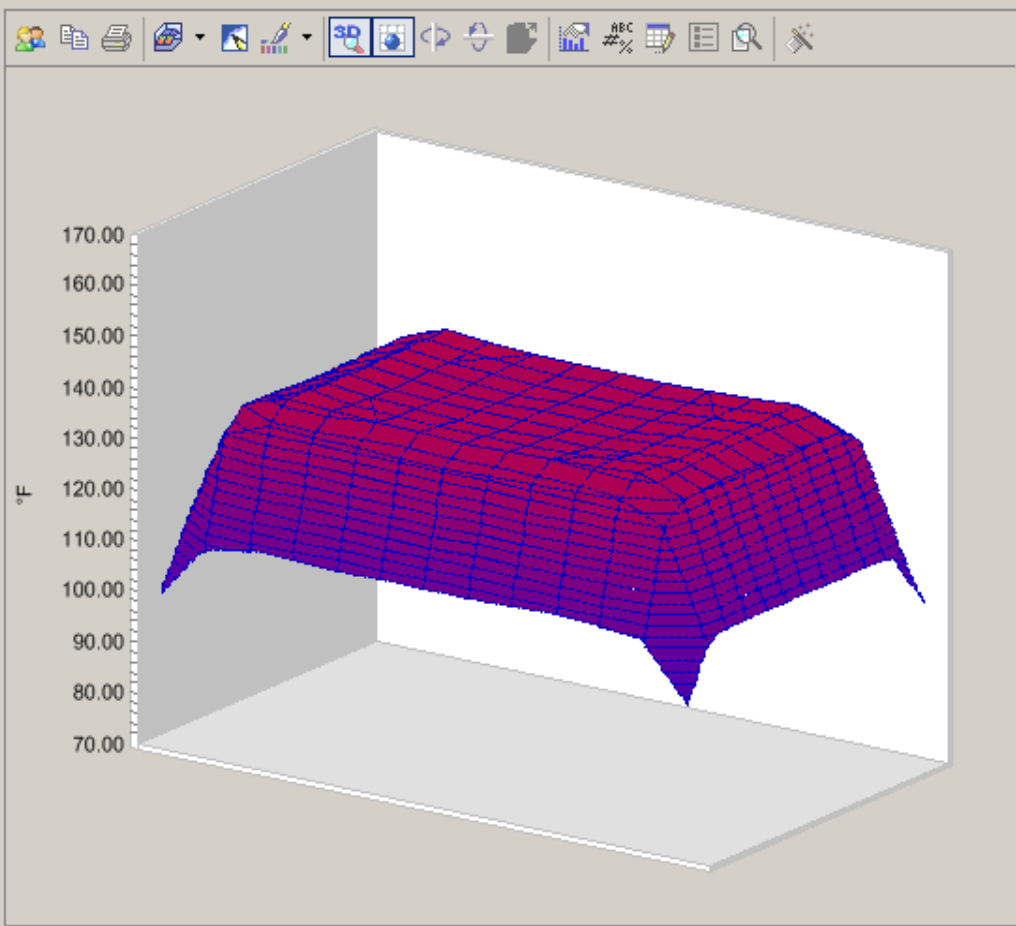
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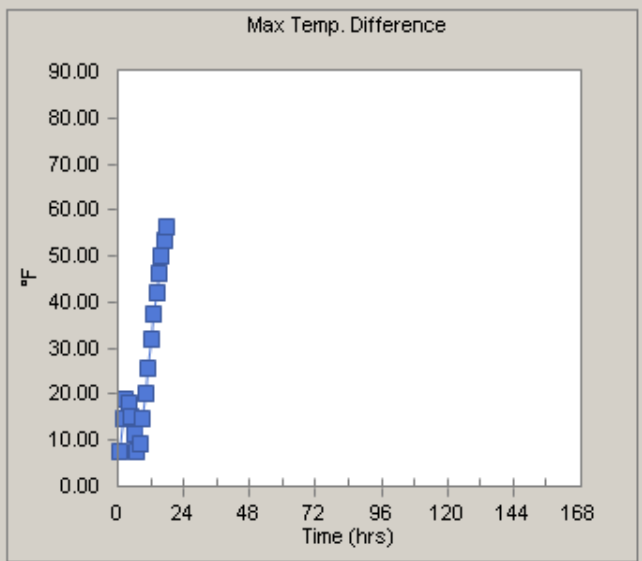
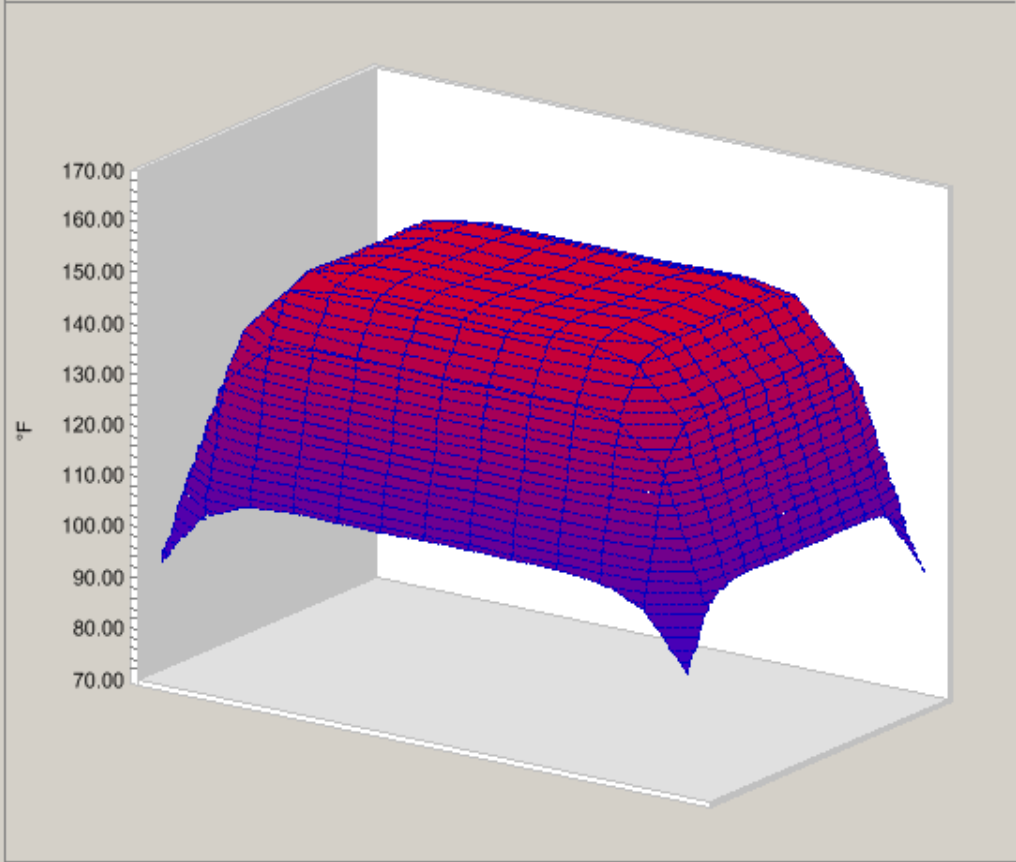
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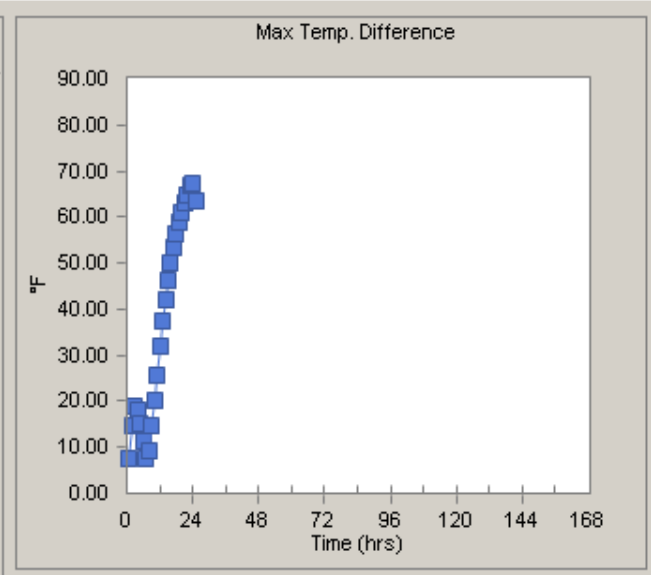
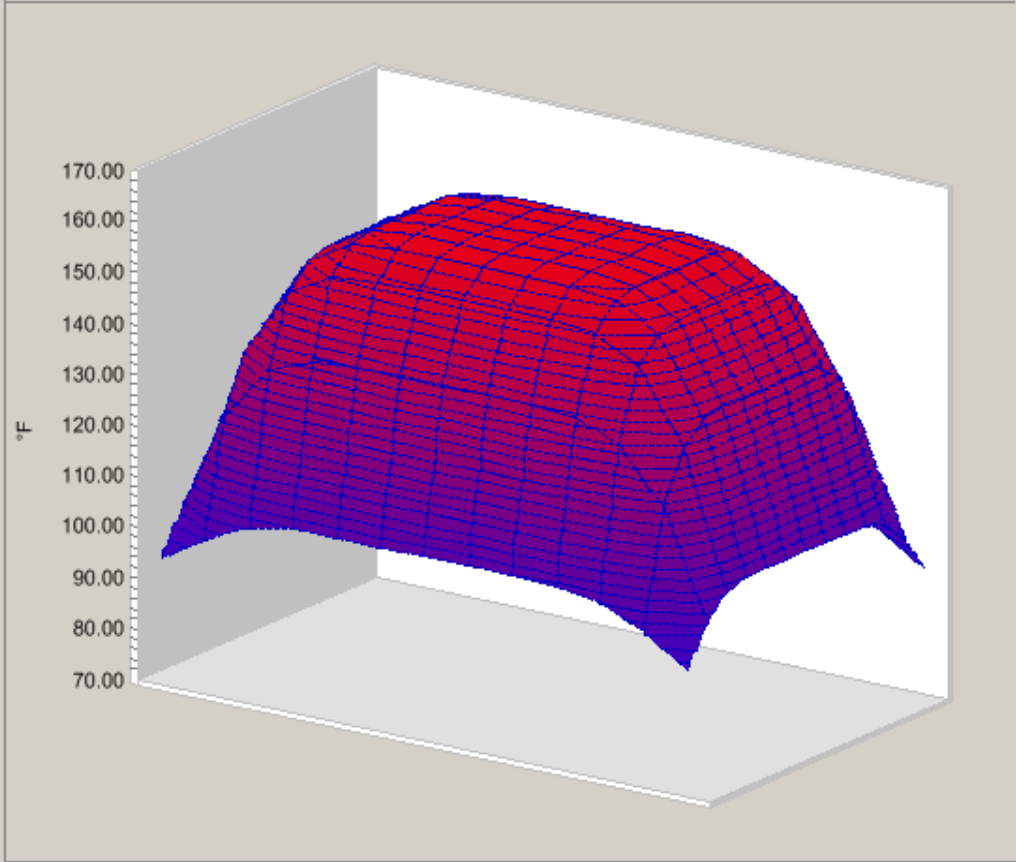
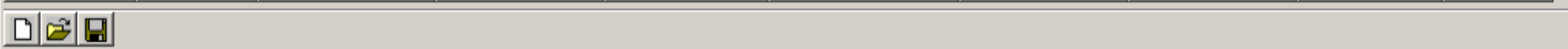
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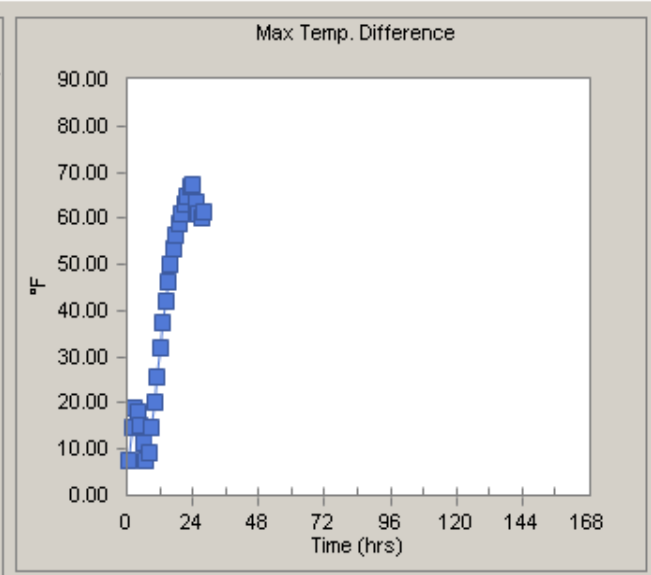
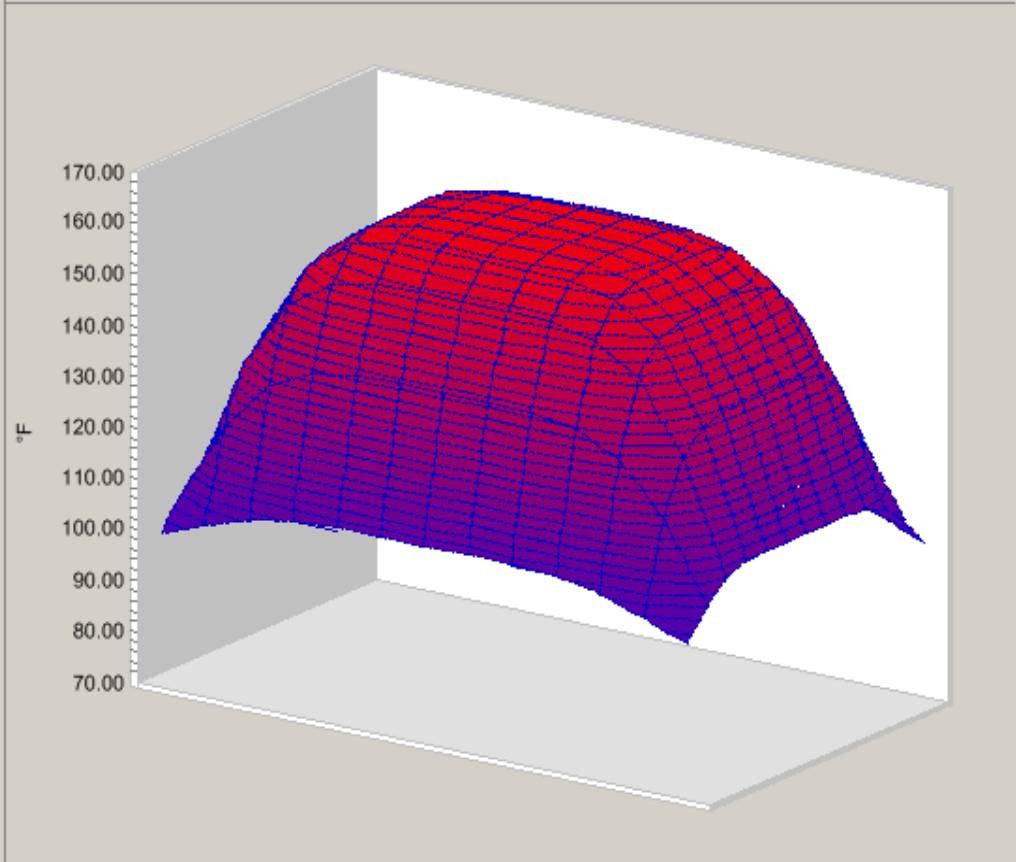
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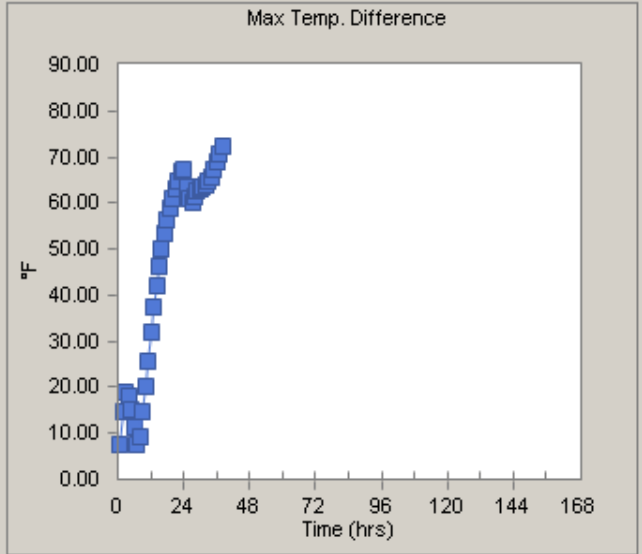
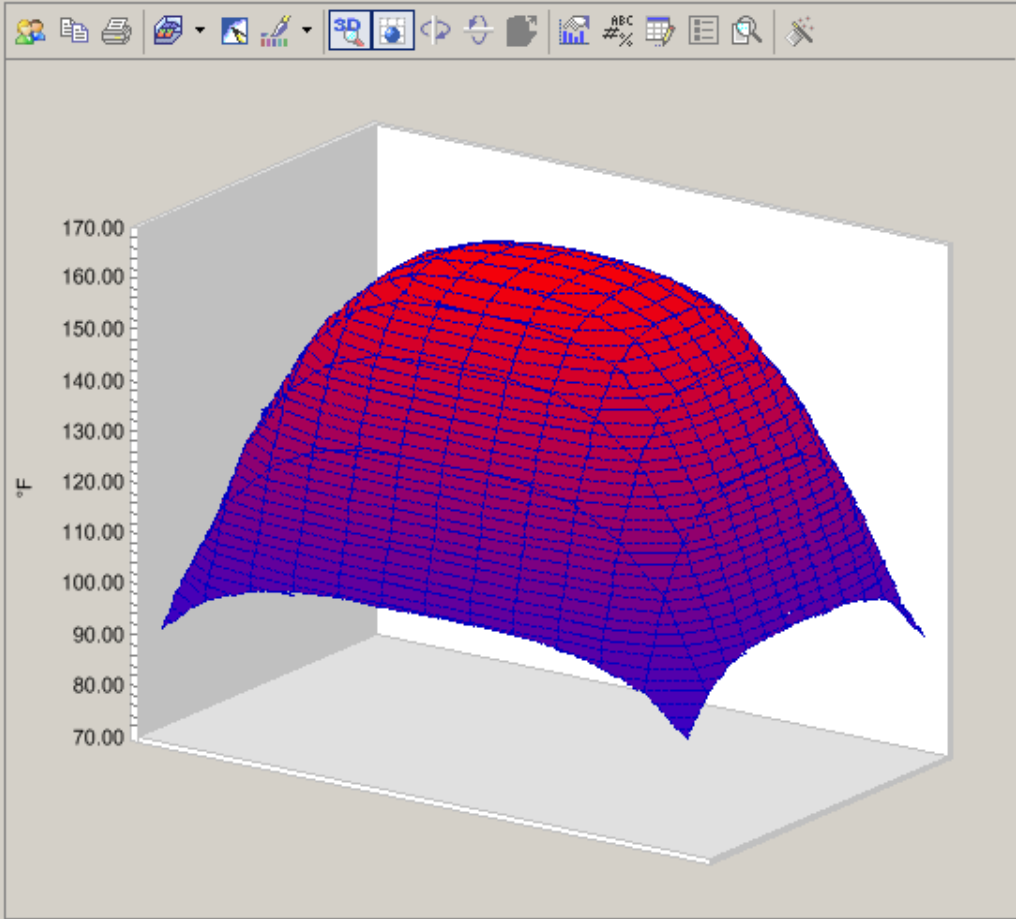
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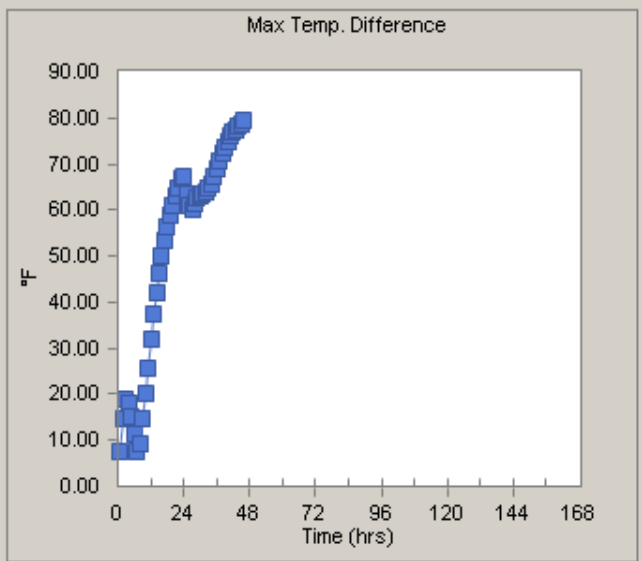
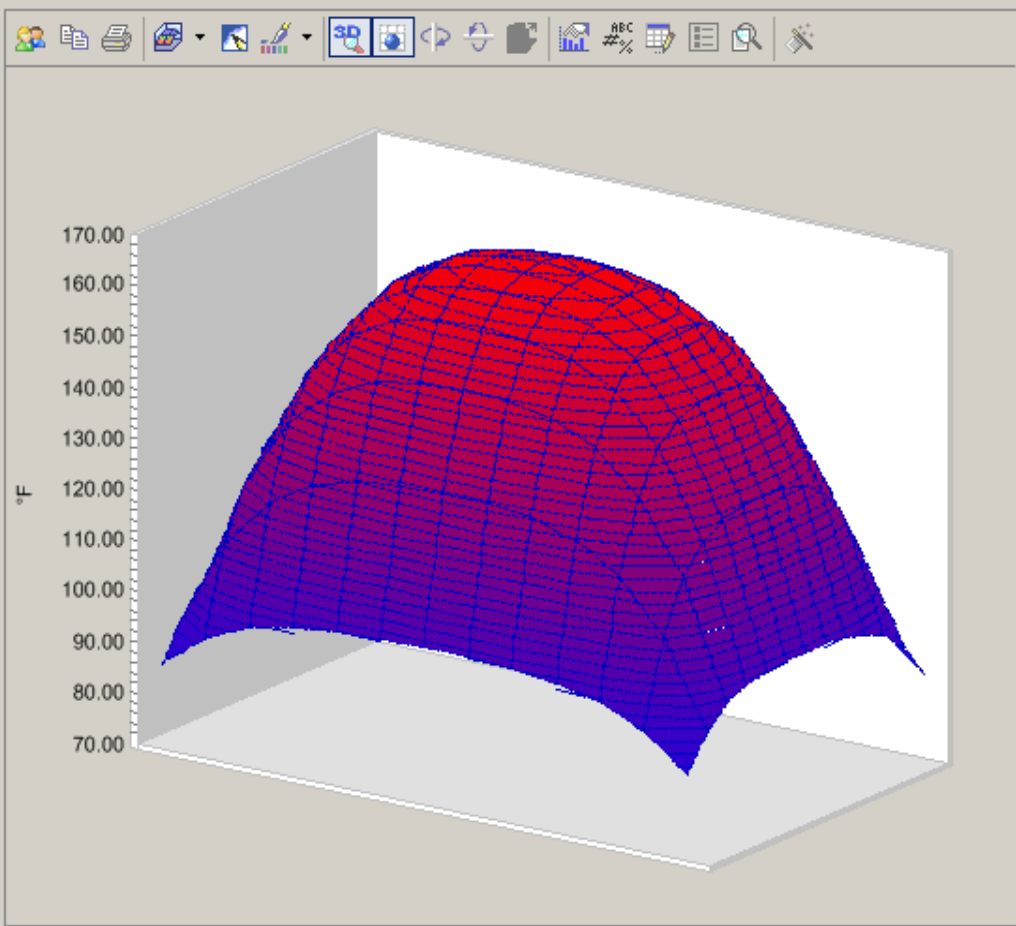
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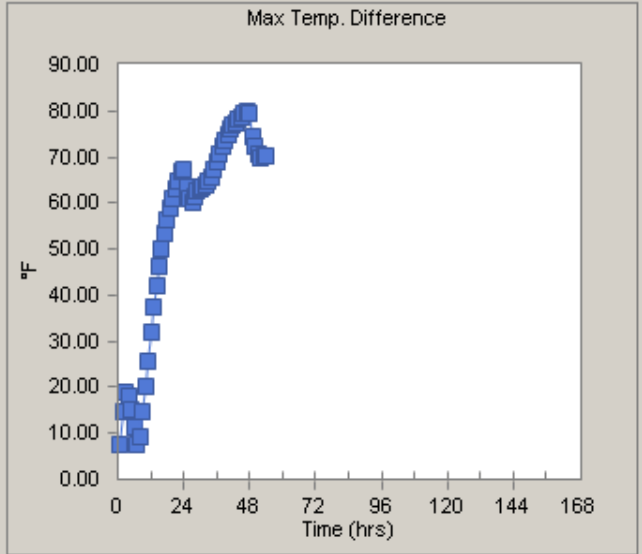
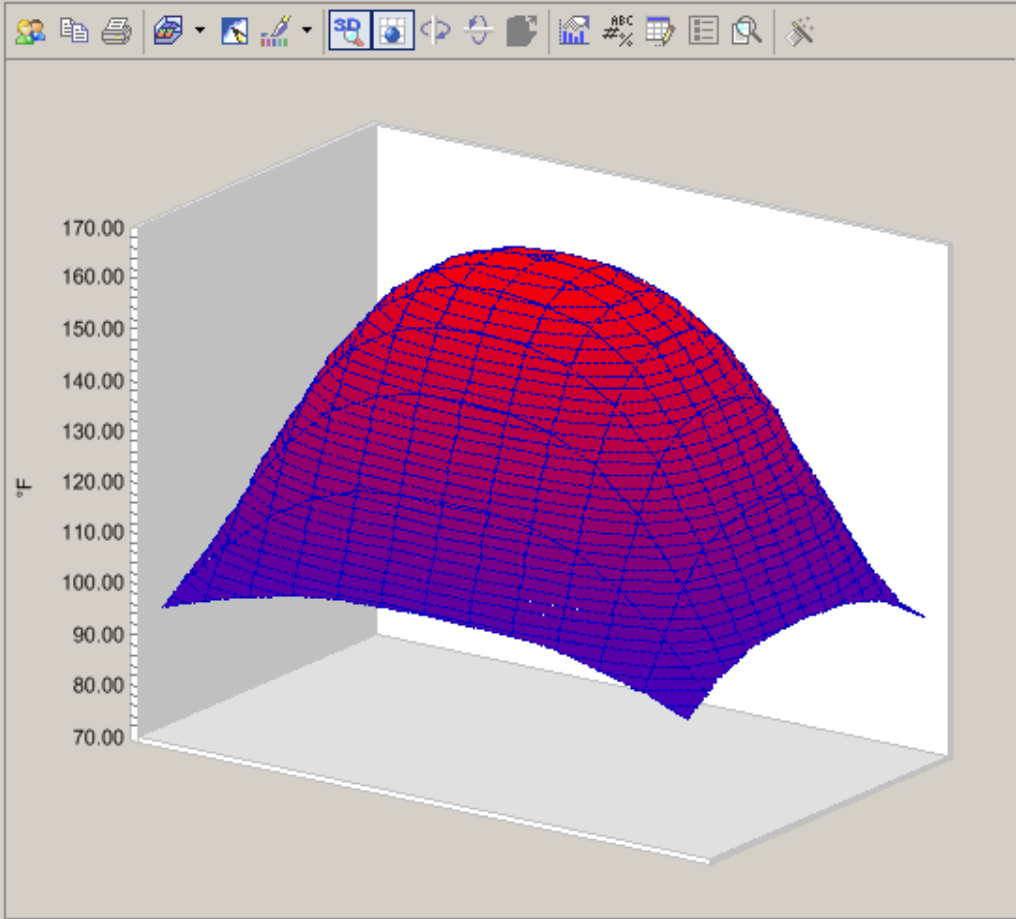
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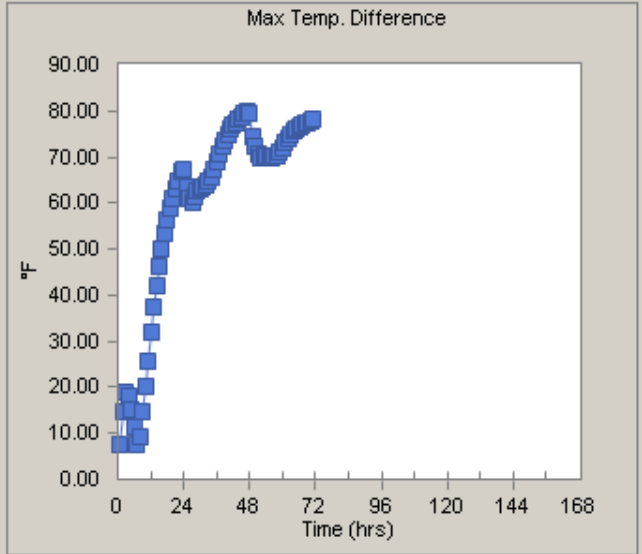
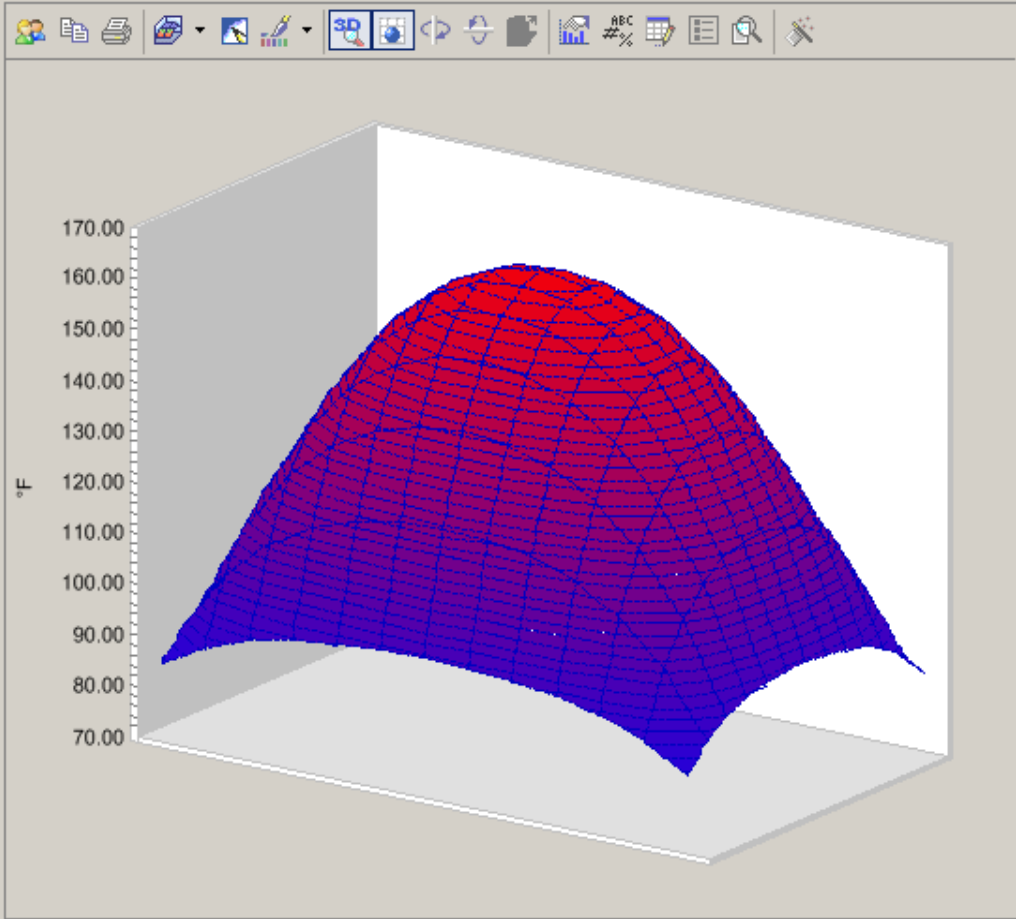
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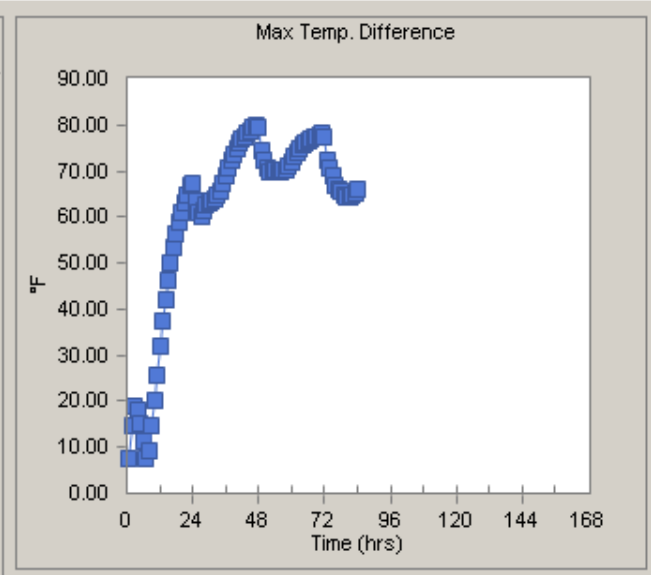
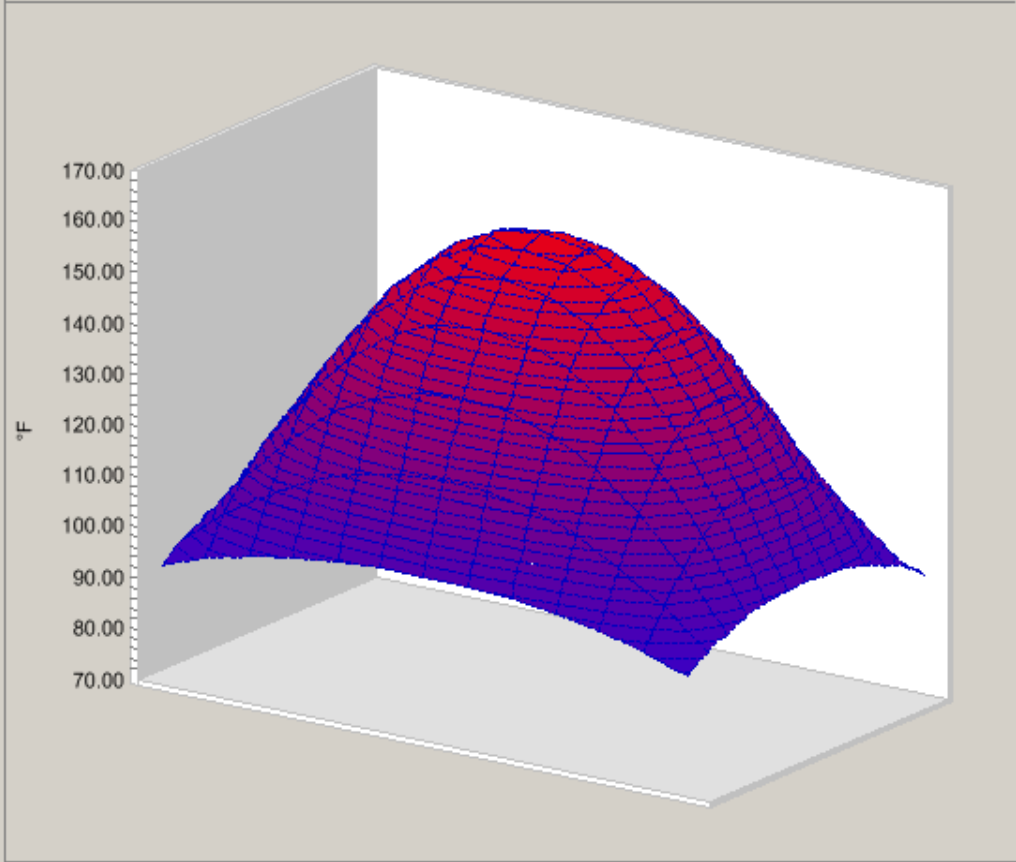
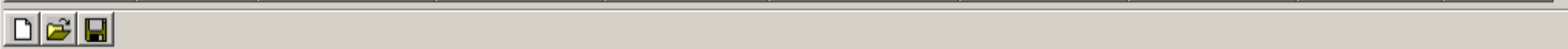
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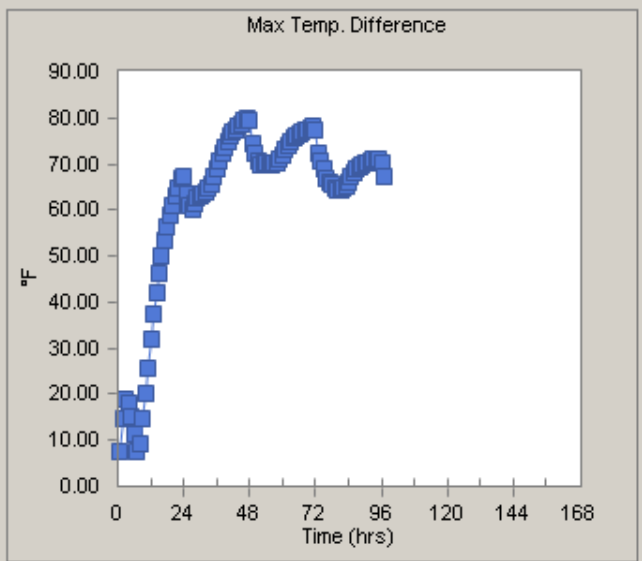
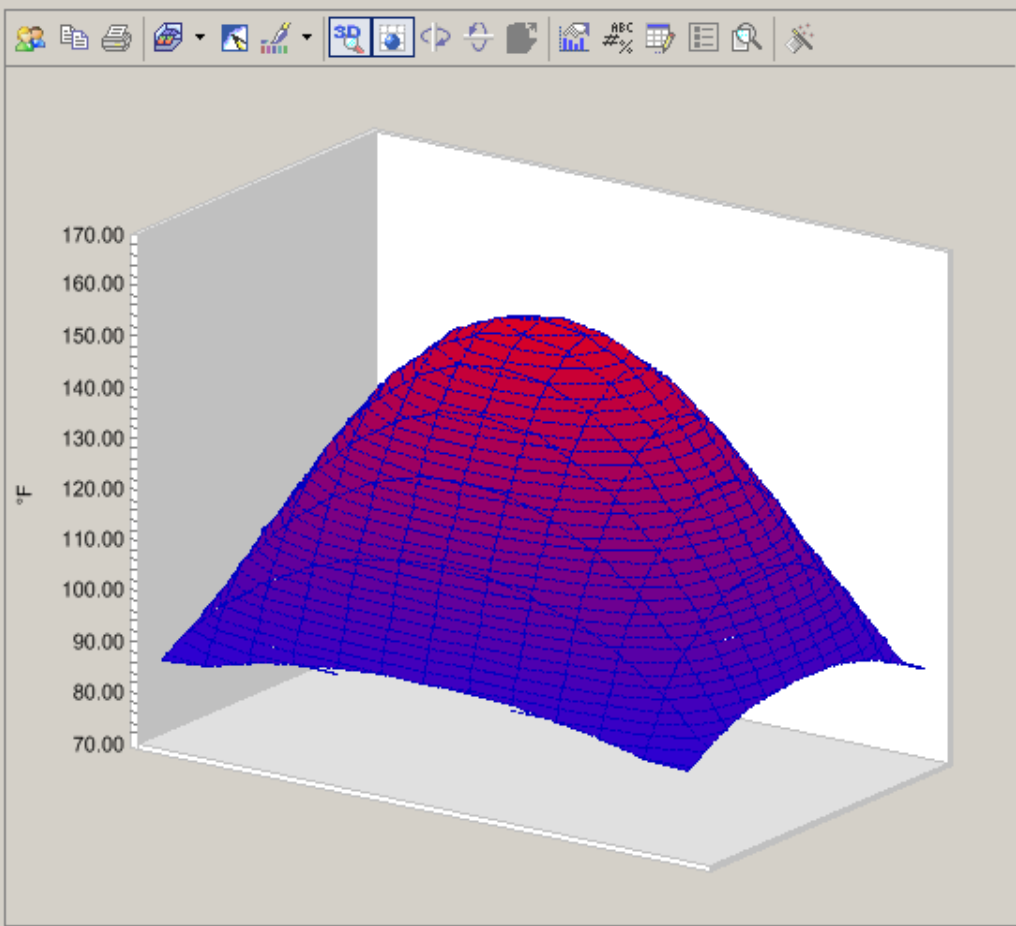
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Animate

Stop Animation

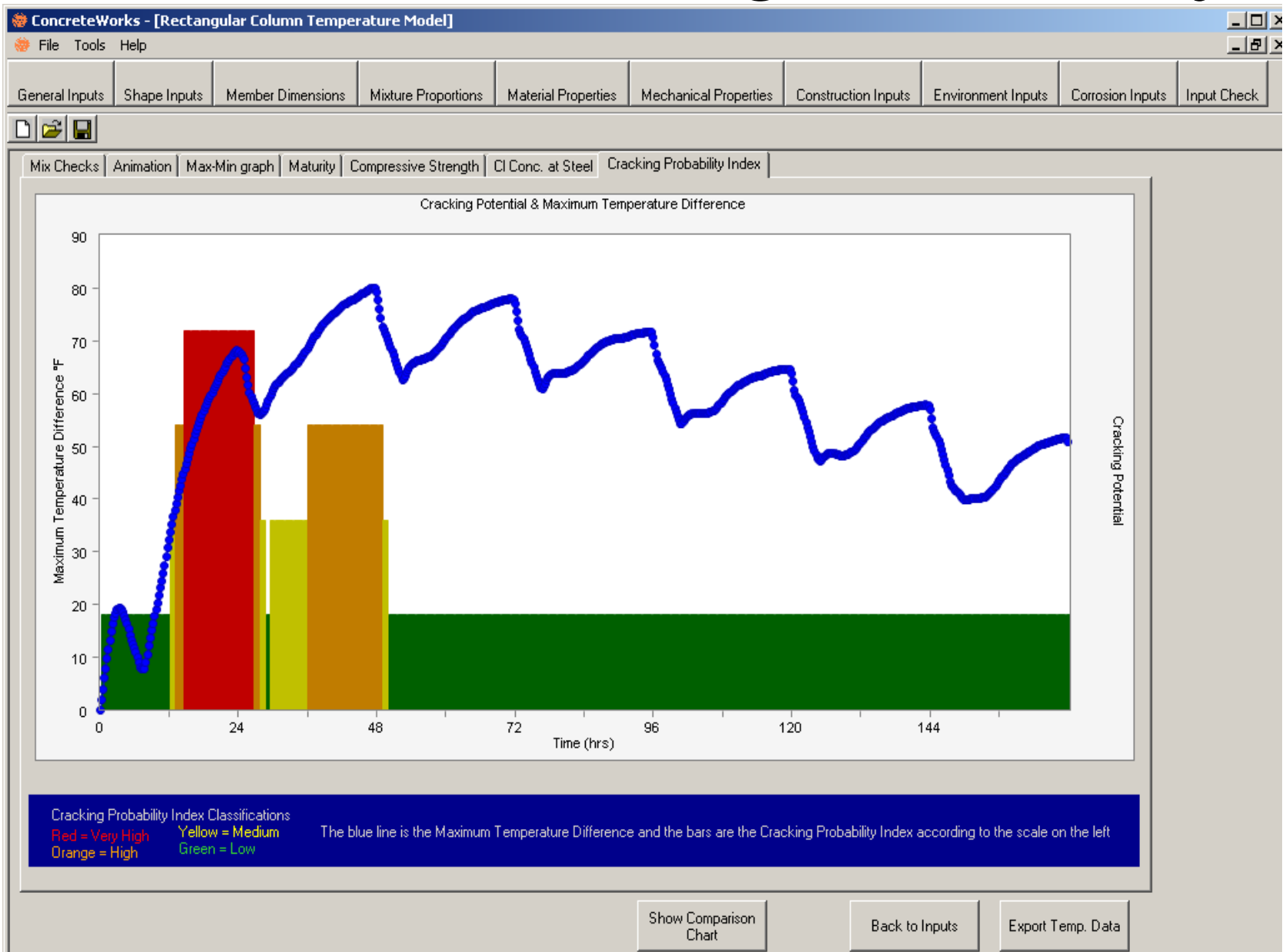
Show Comparison Chart

Back to Inputs

Export Temp. Data

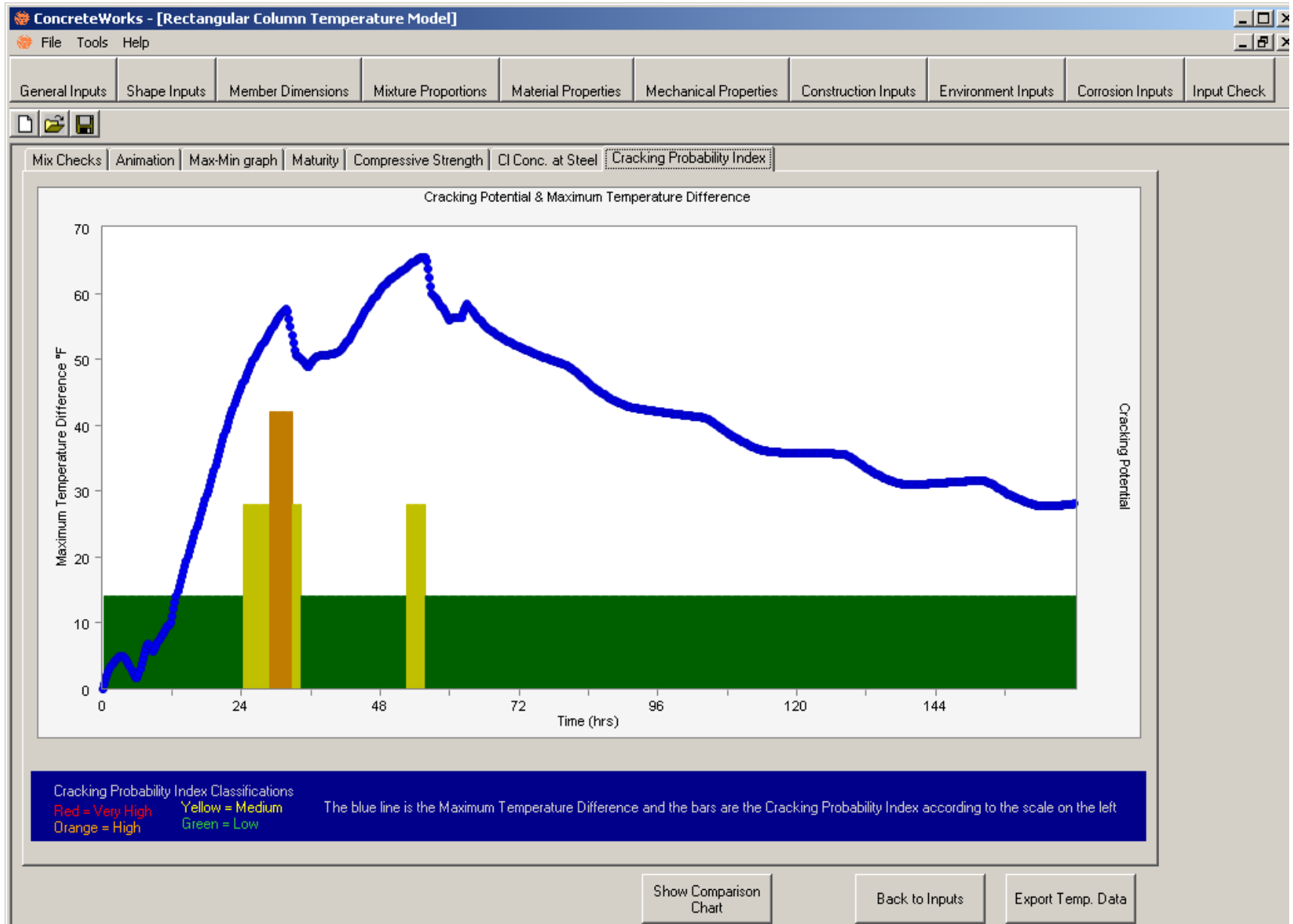


Thermal Cracking Probability



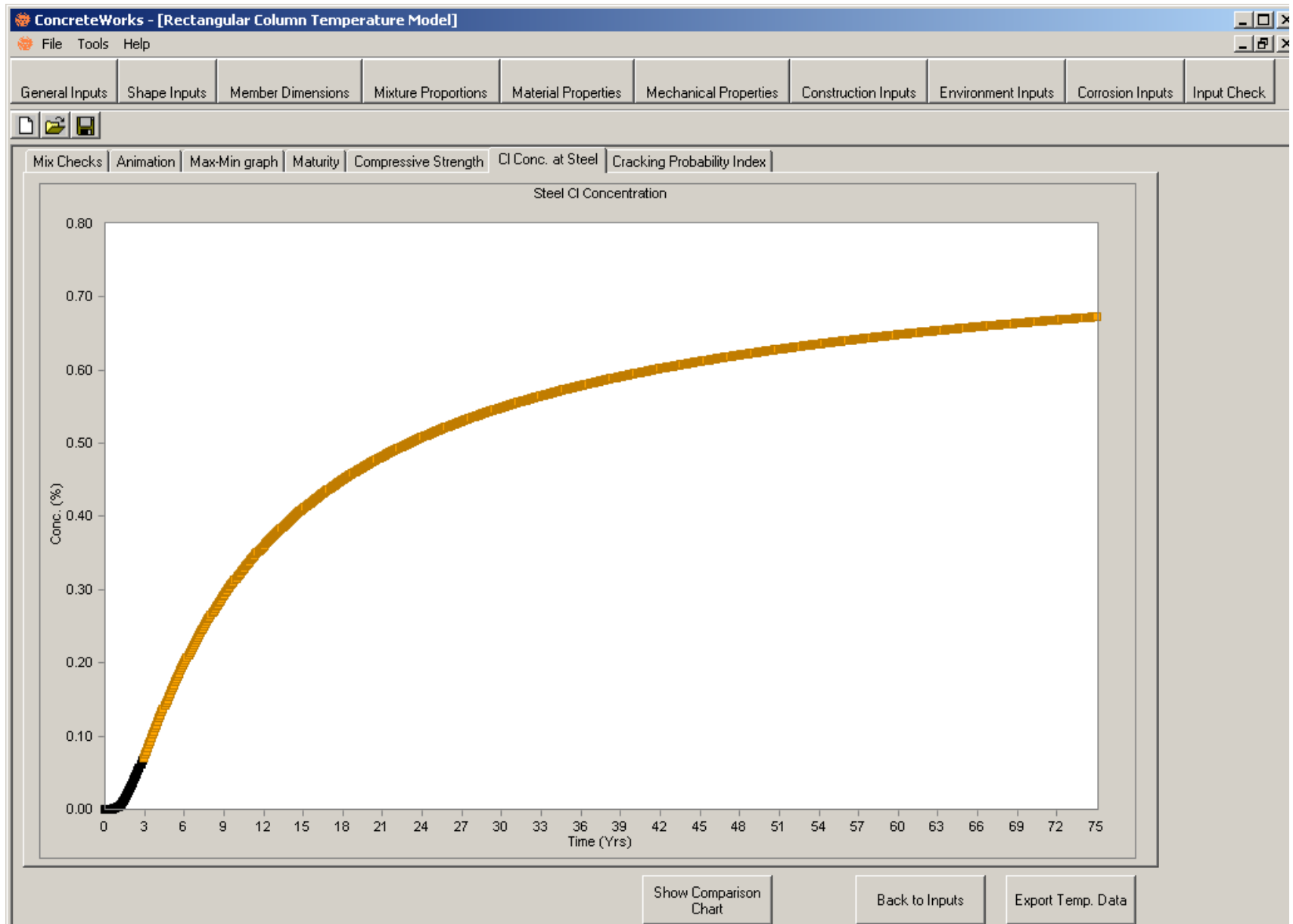


Thermal Cracking Probability





Chloride Prediction





Where do I get ConcreteWorks?

- TxDOT Employees
 - Contact your IRA
- Non-TxDOT Employee
 - www.texasconcreteworks.com
 - Site hosted and managed by UT-CMRG



What's Next?

- Training program for TxDOT and Contractors currently being developed
- Research on crack probability for bridge decks is ongoing

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Thank You

