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# RATS - ROTATING & TURBOMACHINERY SOCIETY

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MRO 2023

MAINTENANCE
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## TECHNICAL CONFERENCE & WORKSHOPS

# MACHINERY GROUTING BEST PRACTICES TO OPTIMZE EQUIPMENT PERFORMANCE

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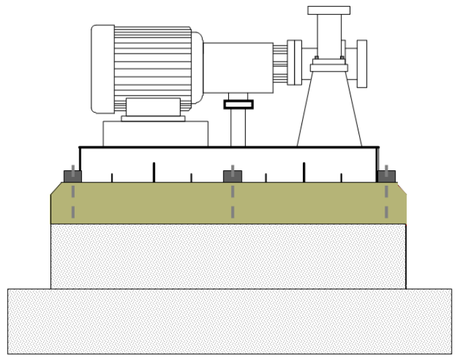
# Grouting Skid – Mounted Equipment

- ***Requirements, Designs***
- ***Grout Products & Guidelines***
- **Installation Techniques**

# Proper grouting provides . . .

- Precise equipment alignment –
  - Positioning critical to efficient performance
- Increased stiffness, damping natural frequency of the fabricated equipment platform.
- Superior connection with the foundation –
  - Monolithic contact between equipment (dynamic) and foundation (absorbing) masses for efficient load transfer and dissipation
  - Steadfast adhesive bond of epoxy grout to steel and concrete
  - Enhanced vibration damping properties of epoxy grout
- Chemical resistance –
  - Extends the service longevity of the grout
  - Can protect concrete to maintain integrity of the foundation mass



- Achieving the above helps to provide key essential benefits –
  - Optimum Equipment Performance
    - Decreased Life-Cycle Costs

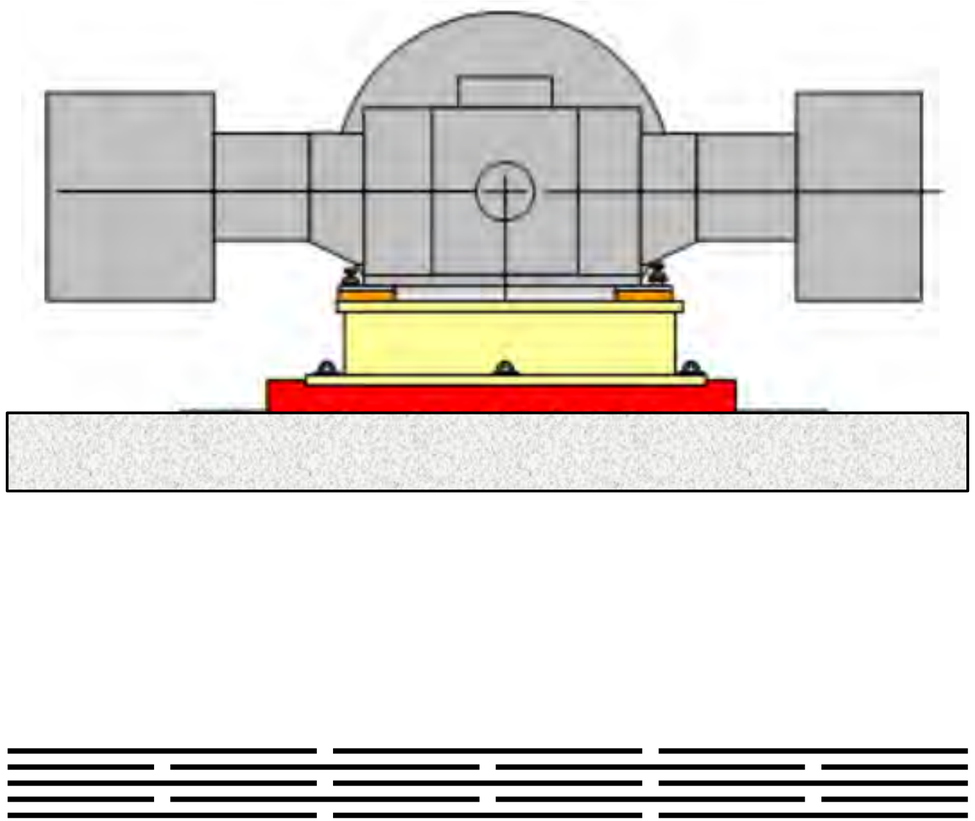
# Follow standards, guidelines & recommendations. . .

Whatever standard(s) you choose to follow. . . . .follow them.

- **API 610 -** Centrifugal Pumps for General Refinery Service
- **API 686 -** Recommended Practices for Machinery Installation and Installation Design
- ACI 351 - Foundations for Dynamic Equipment
- PIP STS03601 - Epoxy Grout Specification
- In-house Standards - Your own established guidelines
- **Grout recommendations -** for storage, handling, mixing, placement, curing and testing of grouting materials

# The Equipment System

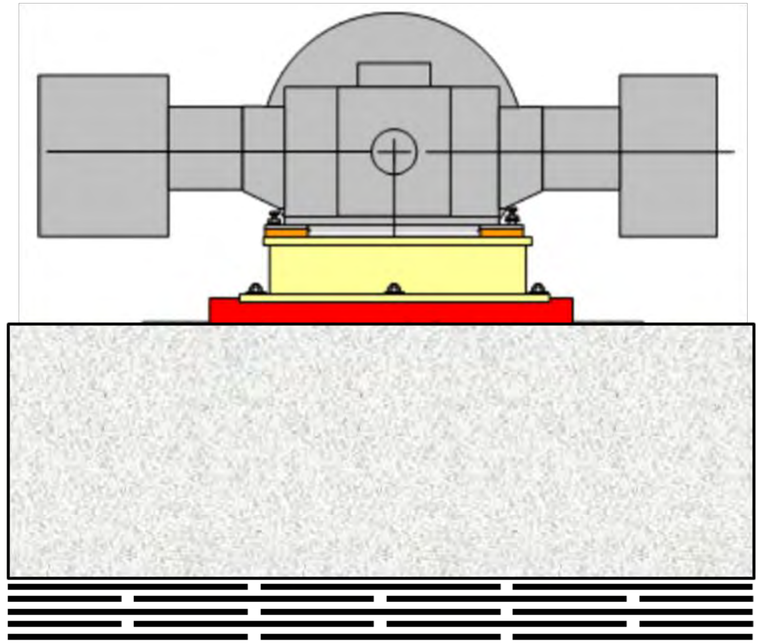
- Compressor, Driver
- Epoxy / Steel Chocks
- Fabricated Structural Platform ("Skid")
- Epoxy Grout (CJ)
- Leveling / Anchor bolts
- Foundation (Block, Mat)
- Sub-surface conditions



All components must be considered and properly engineered as a system when designing for optimum equipment performance.

# Sub-surface Conditions

Proper attention to subsurface conditions and preparations can have a positive effect on Compressor performance.



Geotechnical data is collected and used for evaluating the soil / pile stiffness and damping coefficients.  This data is required for both static and dynamic design and analysis of equipment foundations.

# Foundations / Design

A block foundation consists of massive concrete blocks, piers and mat which are intended to absorb static loads and dynamic energies generated by the operating equipment.

- Weight of the block foundation - 5-8 times the weight of reciprocating machine.
- The width of foundation - 1.5 times the vertical distance from the bottom of foundation to the center line of the shaft / rotor.
- The center of mass of machine foundation (machine+foundation system) - coincide with the centroid of the soil foundation or pile group resistance.
- Minimum mat thickness - 1/5th of least foundation dimensions or 1/10th of largest foundation dimensions, whichever is greater.

# Foundations / Materials

**Freshly poured concrete must be allowed time to cure sufficiently. The moisture content and shrinkage of the concrete must be at its minimum prior to applying epoxy grout.**

Concrete Testing:

- Compression Strength (ASTM C39)
- Splitting Tensile Strength (ASTM C496)
- Shrinkage / Moisture (ASTM C157)

Typical foundation concrete shall be a minimum 4,000 psi design strength.

Mix options and cure duration:

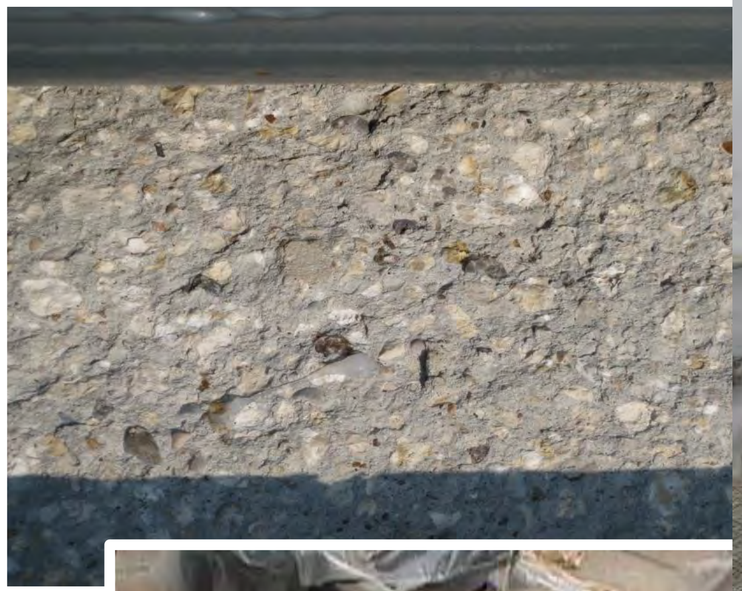
- Standard - 28 days
- Hi-early - 7 days

Reinforcement shall be provided per project approved design code.

Minimum reinforcement guidelines are as follows:

- 0.2% rebar on all face of concrete block and mat
- 1% rebar for all concrete pedestal
- Rebar spacing should not be more than 300 mm

# Foundations / Preparation

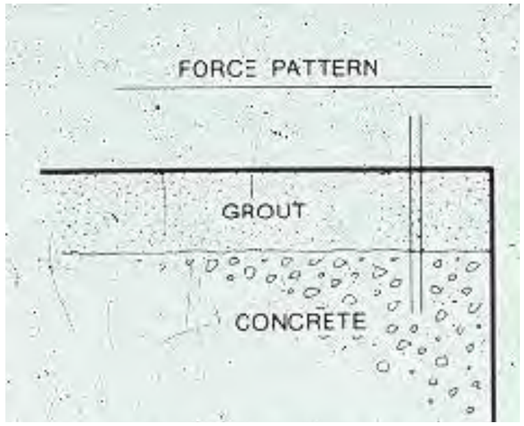


- **Use a hand-held pneumatic chipping hammers with a point (“moil”) or chisel bit to remove all cement-rich laitance from the top of the foundation.**
- **Sufficient chipping will expose a high percentage of the coarse aggregate and a good surface profile.**

- This is the strongest part of the foundation…….
- …….which is the best link for the grout

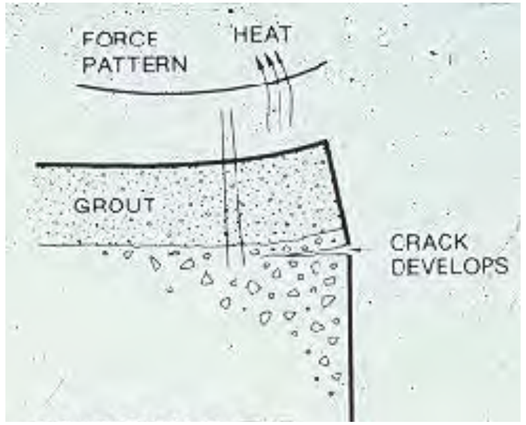
# Foundations / Preparation

Edge lifting trigger mechanism is when decreasing temperatures cause epoxy grout to contract faster than the concrete un-loaded / un-reinforced shoulder areas at the top of the concrete block:



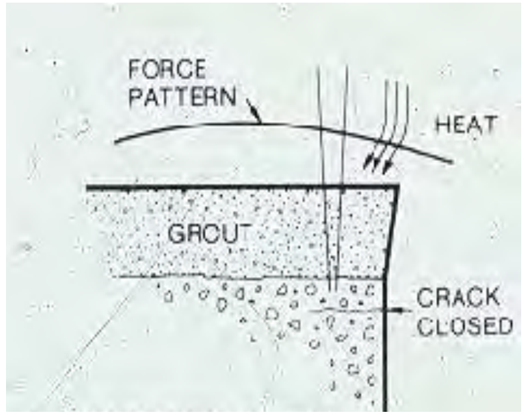

Condition A

The System at Thermal Equilibrium




Condition B

The System During the Cooling Cycle

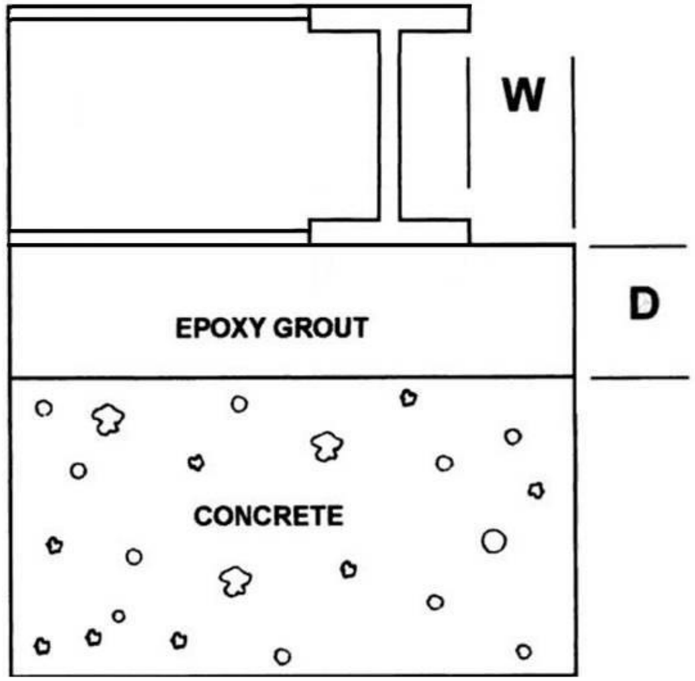



Condition C

The System During the Heating Cycle

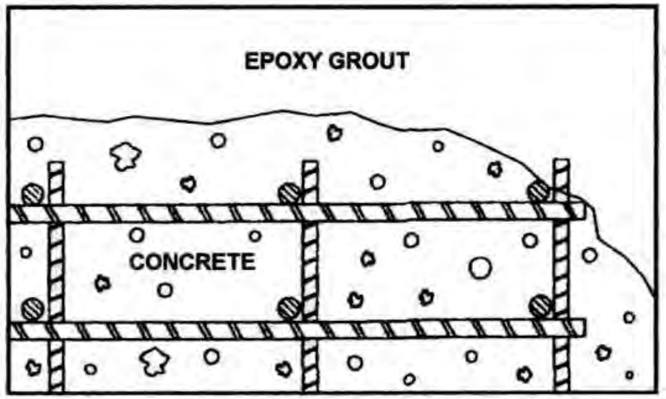
# Foundations / Preparation

Edge lifting prevention can be planned for by one or more of the following:

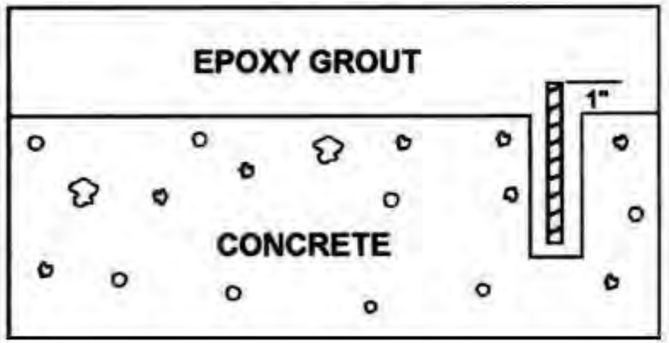



- Reduce unconfined shoulder width (W) to a value nearer to the grout depth (D)

- 45° Chamfer around foundation perimeter
- Expose existing rebar



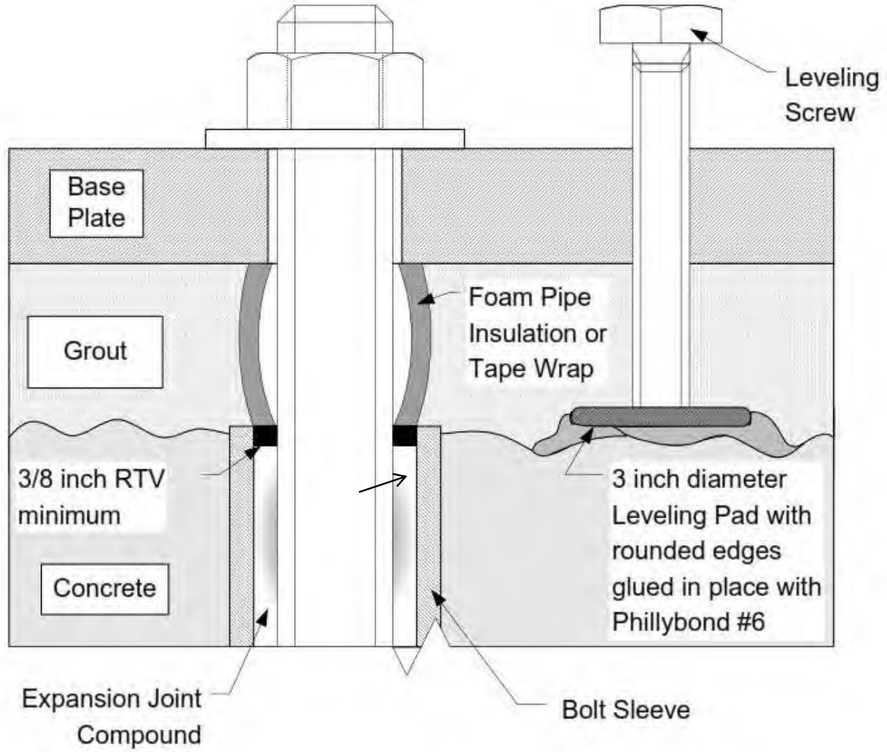

- Dowel pins drilled and placed in concrete around Foundation Perimeter

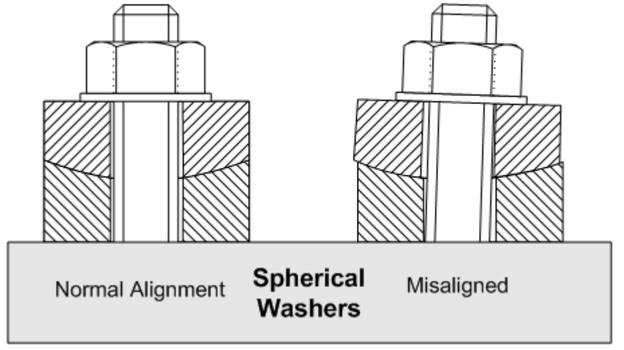


# Leveling / Anchor Bolts

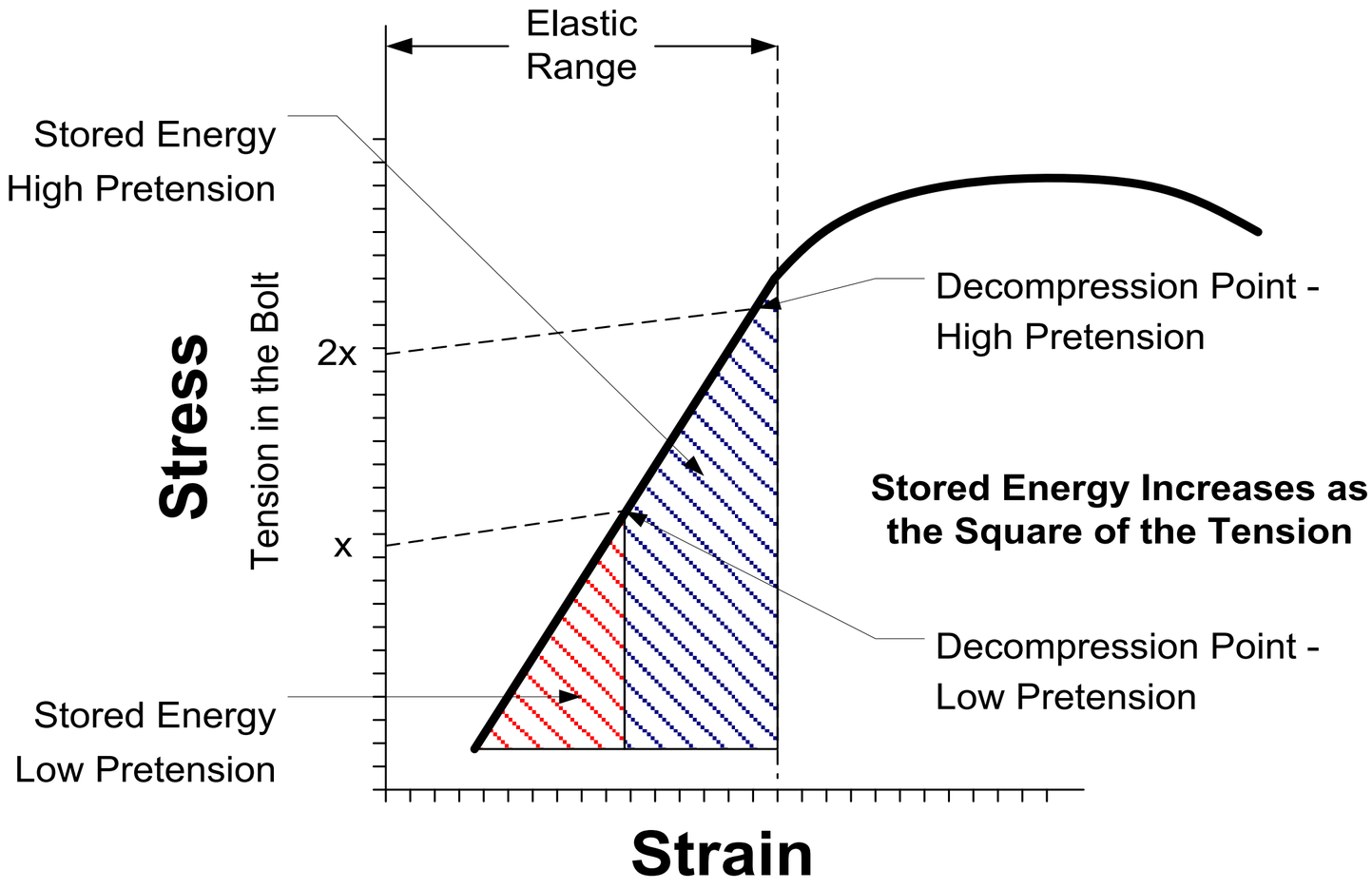
Anchor bolts serve to resist the upward and lateral forces imposed by the dynamic loads produced by the equipment.

- Locate and install all anchor bolts to the specified position and within tolerance
- Bolt - 4140 ASTM A193 B7
- Nuts - ASTM A194 – 2H - High Strength
- Washers - Spherical
- Minimum 10x bolt diameter of embedment into foundation
- 12x bolt diameter of isolation for free stretch in reciprocating applications
- Nut tensioned per OEM established guidelines
- Anchor bolts should not be used for leveling; use leveling bolts
- The package is 100% supported by the grout and not the leveling screws. (Back ‘em off!)



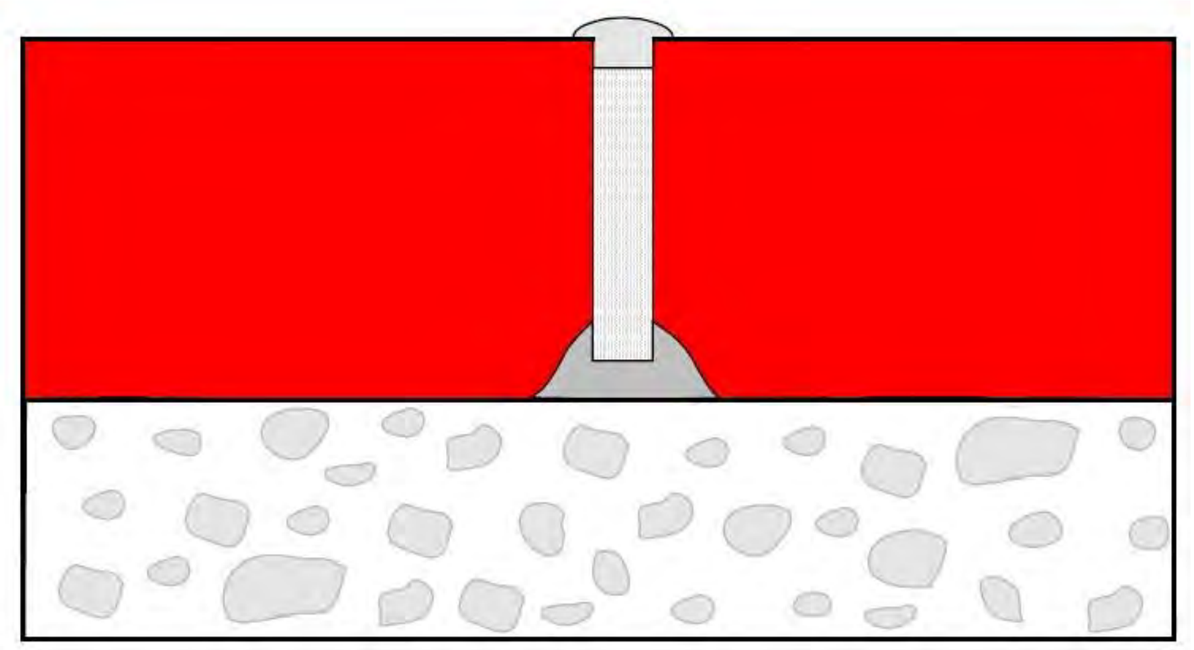
# The Benefits Of Bolt Tension

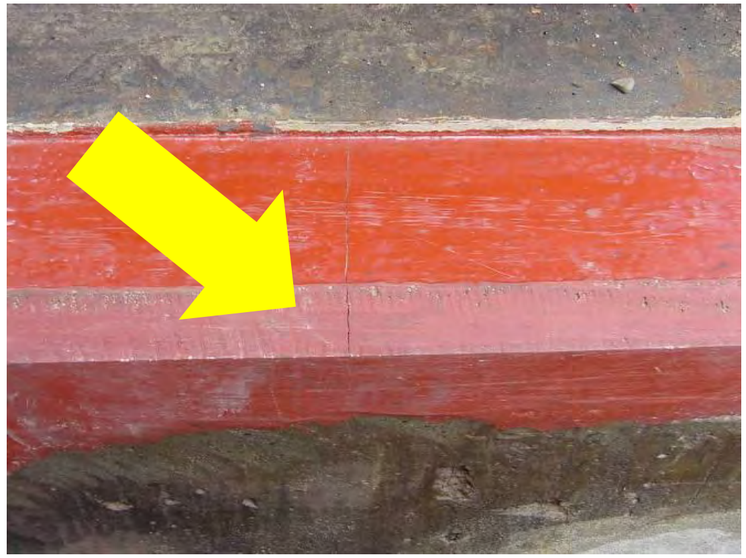


# Control Joints

Thermal cracks can and will occur, but they can be anticipated and planned for through the considerate and intentional placement of prefabricated control joints (sometimes more commonly referred to as expansion joints) in the epoxy grout. Control joints can also be thought of as an “engineered crack”.

Joint placement and frequency may be determined with careful consideration to the following variables:





- Initial cure environment of the epoxy grout
- Equipment type and configuration
- Operating temperatures of the equipment and its environment
- Magnitude and frequency of possible thermal changes that may occur in the operating environment
- Coefficient of Thermal Expansion of the Epoxy Grout

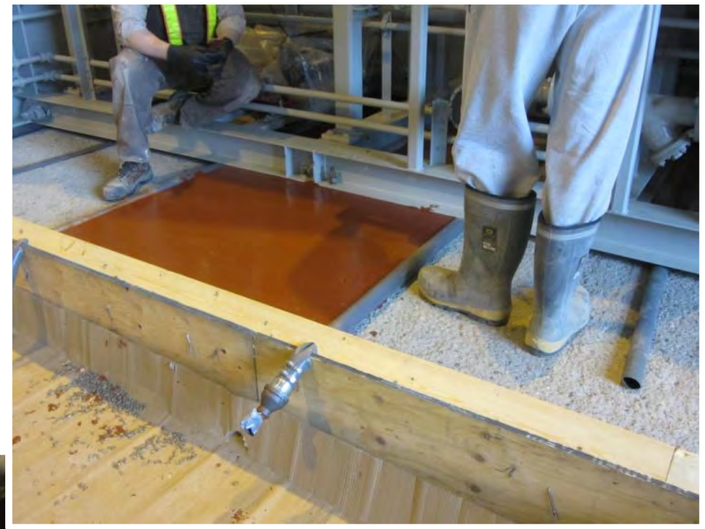
# Control Joints

Control joints can be used play a more critical role as a bulkhead for dividing the pour area under the skid into smaller, more manageable sections.  Segmentation facilitates more controlled placement and deliberate movement of the grout over the large area under the skid.

Joint placements made before the skid is set.

# Control Joints

Joint placements made after the skid is set.




In-situ (pumped) joints

# Epoxy Grout

Three part epoxy grouts are typically packaged in the following ways:

- **Two part packaging**
  - Resin and Hardener components packaged in the same container. Often referred to as “unit” packaging. The resin is typically found slack filled in a metal or plastic pail while the hardener is typically housed in a plastic tray located above the resin within the same container.
  - Aggregate is packaged in individual bags. Some epoxy grout systems have four bags of aggregate per unit while other systems have five bags of aggregate per unit.
- **Three part packaging**
  - The resin (part A) component is packaged in one or two metal/plastic containers while the hardener (part B) is packaged in a smaller metal or plastic container.
  - Aggregate is packaged in individual bags. Some epoxy grout systems have four bags of aggregate per unit while other systems have five bags of aggregate per unit.

Epoxy Grout provides support for applied loads generated from equipment deadweight, anchor bolt tension and operating dynamics.

It provides an excellent layer for effective dynamic dissipation during transfer of energies to the foundation for final absorption.

- 3 - Component, 100% Solids, Epoxy Resin Grouts
- Resists Vibration, Chemical Attack, & High Torque Loads
- High EBA
- Fluid consistency
- Low Exothermic Cure
- Deeper Monolithic Pours (18”+)
- Extended Placement Time
- Easy Water Clean up

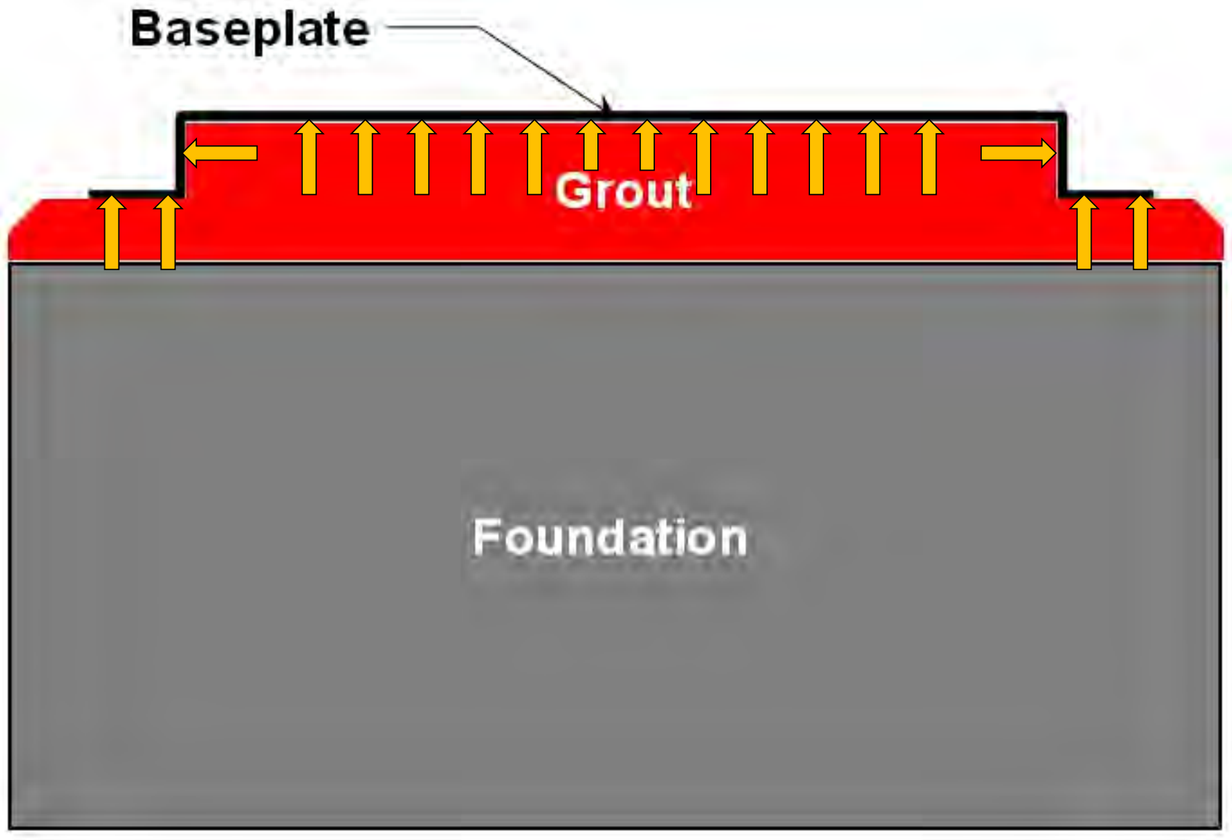
# Fabricated Structural Platform (“Skid”)

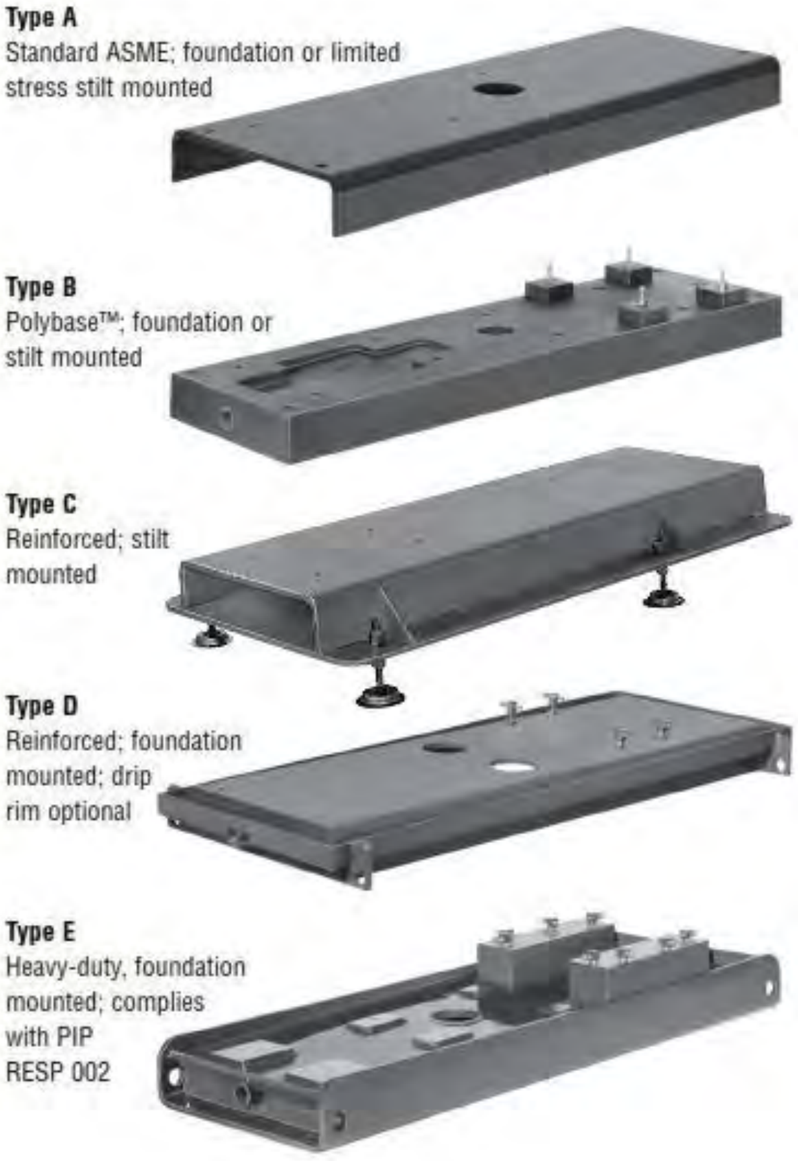
**Fabricated platforms for compressor packages come in a variety of types, sizes** depending on the requirements of the end-user.


The skid functions to support and consolidation of all equipment system components for modularization.

A concrete slug is typically placed under driver and compressor for added mass & skid stiffness

# Fabricated Structural Platform (“Skid”)



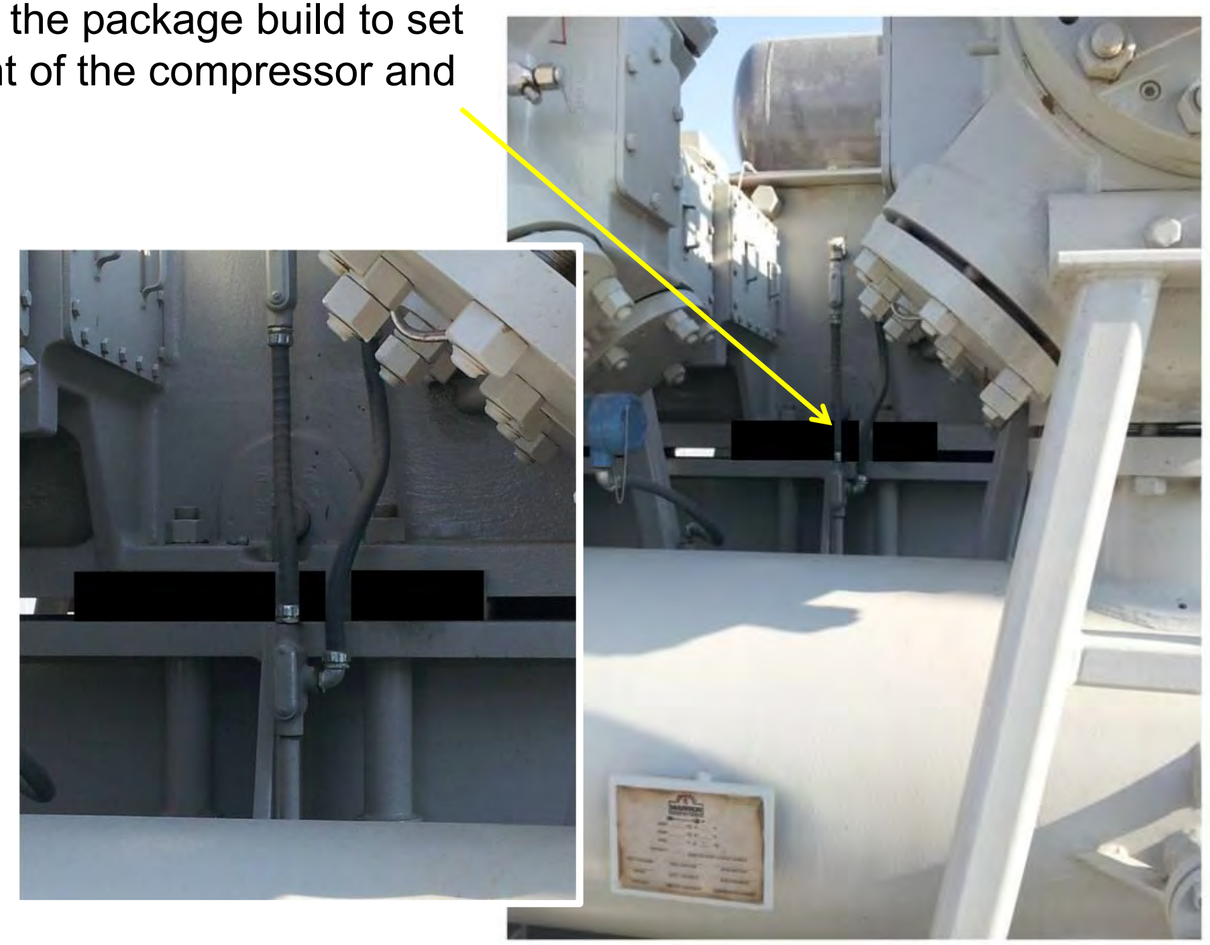




The key is contact!

- Increase stiffness, minimize natural frequency of the base plate
- Provide Additional Damping Mass

# Chocking / Pipe Supports

Epoxy chocks are routinely installed during the package build to set and maintain precise support and alignment of the compressor and driver on the platform structure.



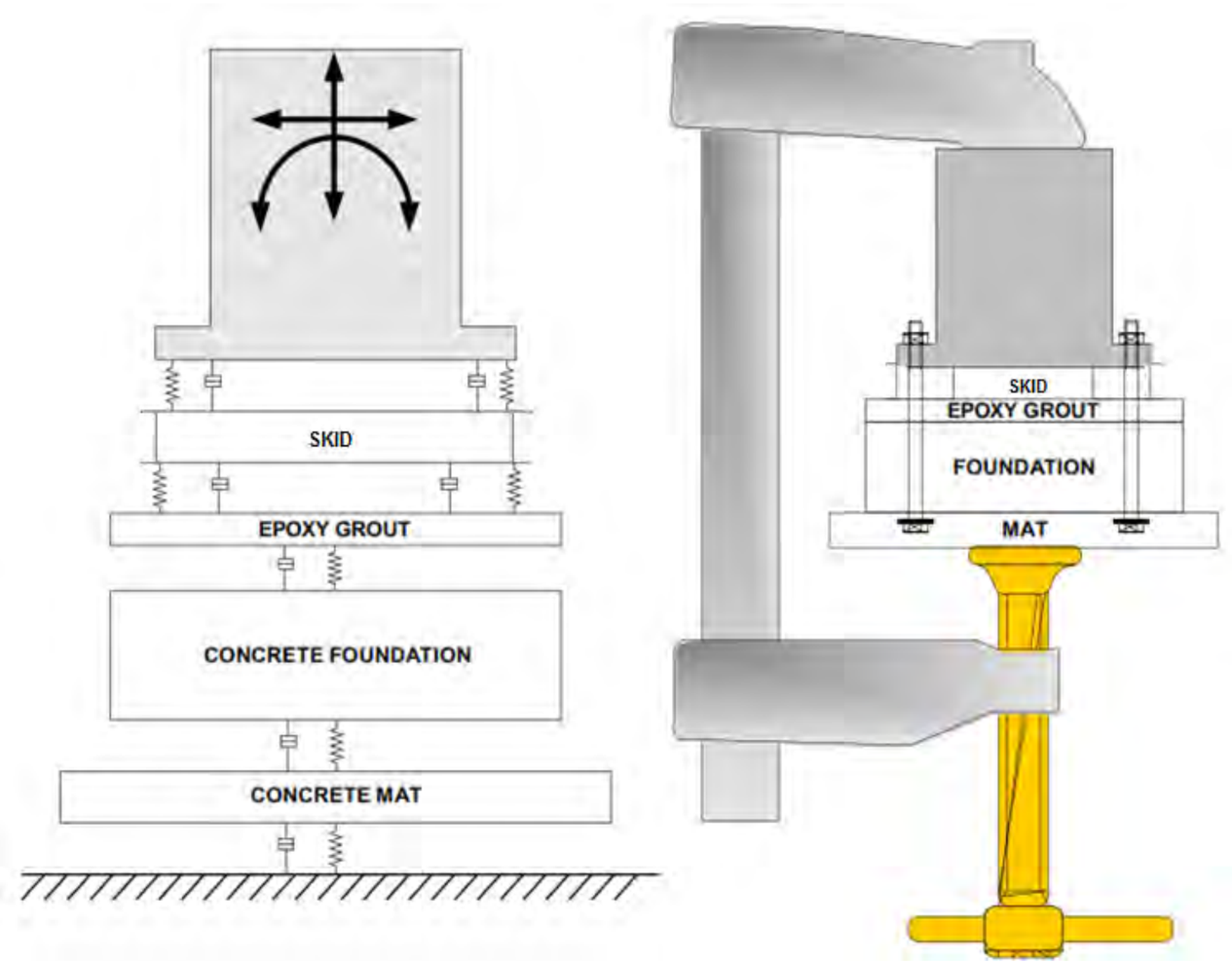
**Epoxy pipe supports are also installed during the package build to provide support and alignment of bottles and piping on the platform structure.**

# The Equipment System

Enhanced equipment performance requires effective cooperation between all equipment system components for:

- Efficient transference of static loads and dynamic energy from the energy source to the absorbing mass. Epoxy grout, chocks and pipe supports are critical to completing this passage.

- In order to make this possible, full contact between equipment, supports, platform, epoxy grout, concrete foundation and terra firma is essential.

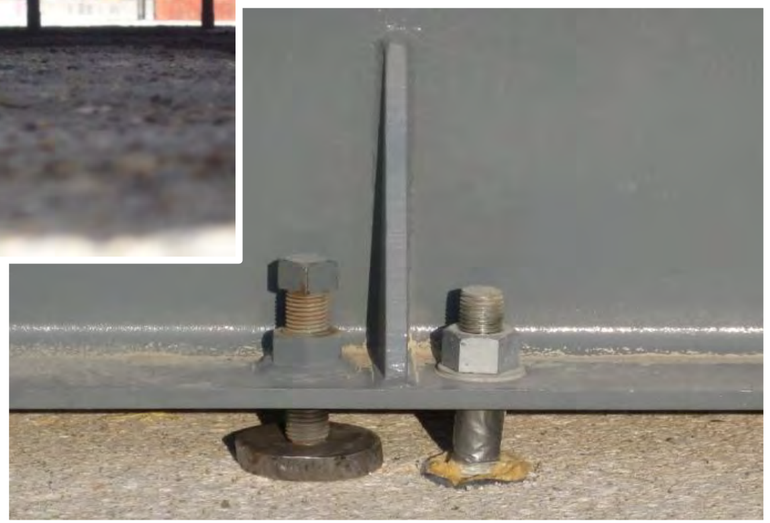



The key is contact!

# Field Preparations

**Complete and conform to all field preparations in accordance with applied standards:**

- Foundation - Concrete surface is properly chipped and stays clean & dry throughout
- Control Joints - Applicable control joints in place
- Skid -
  - bond surfaces underside flanges of the skid are properly inspected and cleaned maintaining a dry & clean surface throughout.
  - Compressor package is properly leveled to tolerance and allowing for a minimum of 3” clearance between the underside of the flange and the prepared concrete.
- Anchor and leveling bolts - Properly wrapped and sealed.



# Field Preparations

**Small equipment sole plate fabrication:**

- Radius edges and corners for all embedded features
- Anchor bolt clearance holes
- Jack screw assemblies
- Epoxy primer properly applied


# Field Preparations

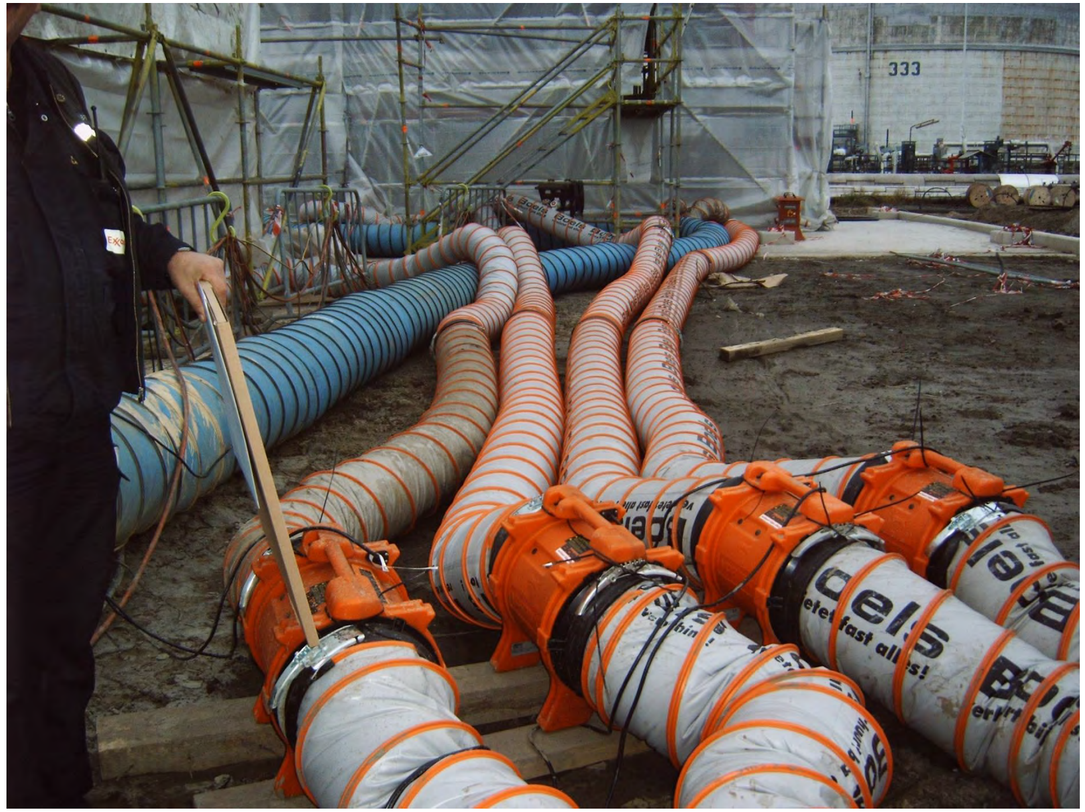
**Complete and conform to all field preparations in accordance with applied standards:**

- **Formwork -**
  - The forms shall be leak free and sturdy - constructed from suitable forming materials
  - Coat any surface with at least three coats of paste wax only.
  - Place 45º chamfer strip on all outside and inside corners
- **Tools & Equipment -** All tools and equipment necessary to ensure proper mixing, installation and cure of the grout
- **Grouting Materials -** Dry and adequately conditioned
- **Work area -** Properly staged and conditioned



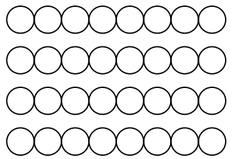

Checklist

# Field Preparations


Heating and Hoarding Example

# Grout Preparation



Evenly
Disperse Cans
(if possible)

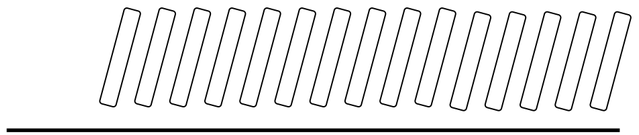
When pre-conditioning grout components, all materials should be removed from their pallets and placed appropriately to allow air circulation around cans and bags for faster, even conditioning. Pre-conditioning area should be large enough to accommodate this.

During of extreme hot or cold seasons, sheltering & preconditioning of <u>all grouting materials and equipment</u> are required for controlling temperatures of product during the installation and cure cycle.

It is also important to protect the materials from the undesired elements such as rain, snow, and wind.

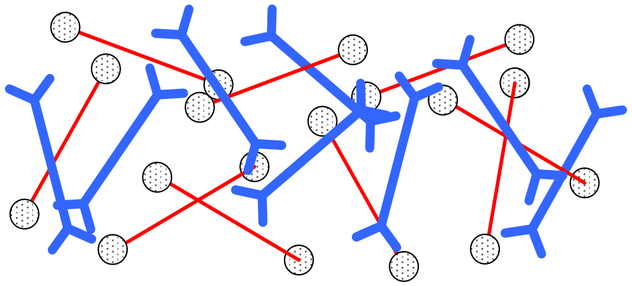
Established preconditioning temperature of the grouting materials shall be achieved and maintained at least 24 hours <u>prior</u> to mixing and use.

'Dominoe"Stack
Aggregate Bags
(if possible)

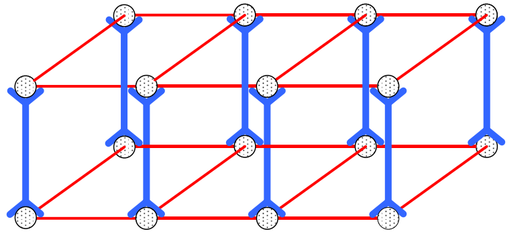


# Grout Preparation

Mixing an epoxy resin and hardener creates a chemical reaction where the epoxy molecules to "cross-link" with each other, forming a rigid, structural lattice.



Before



After

The epoxy groups are like chemical springs storing energy. The hardener releases the spring causing the chain reaction that forms the long molecular chains.

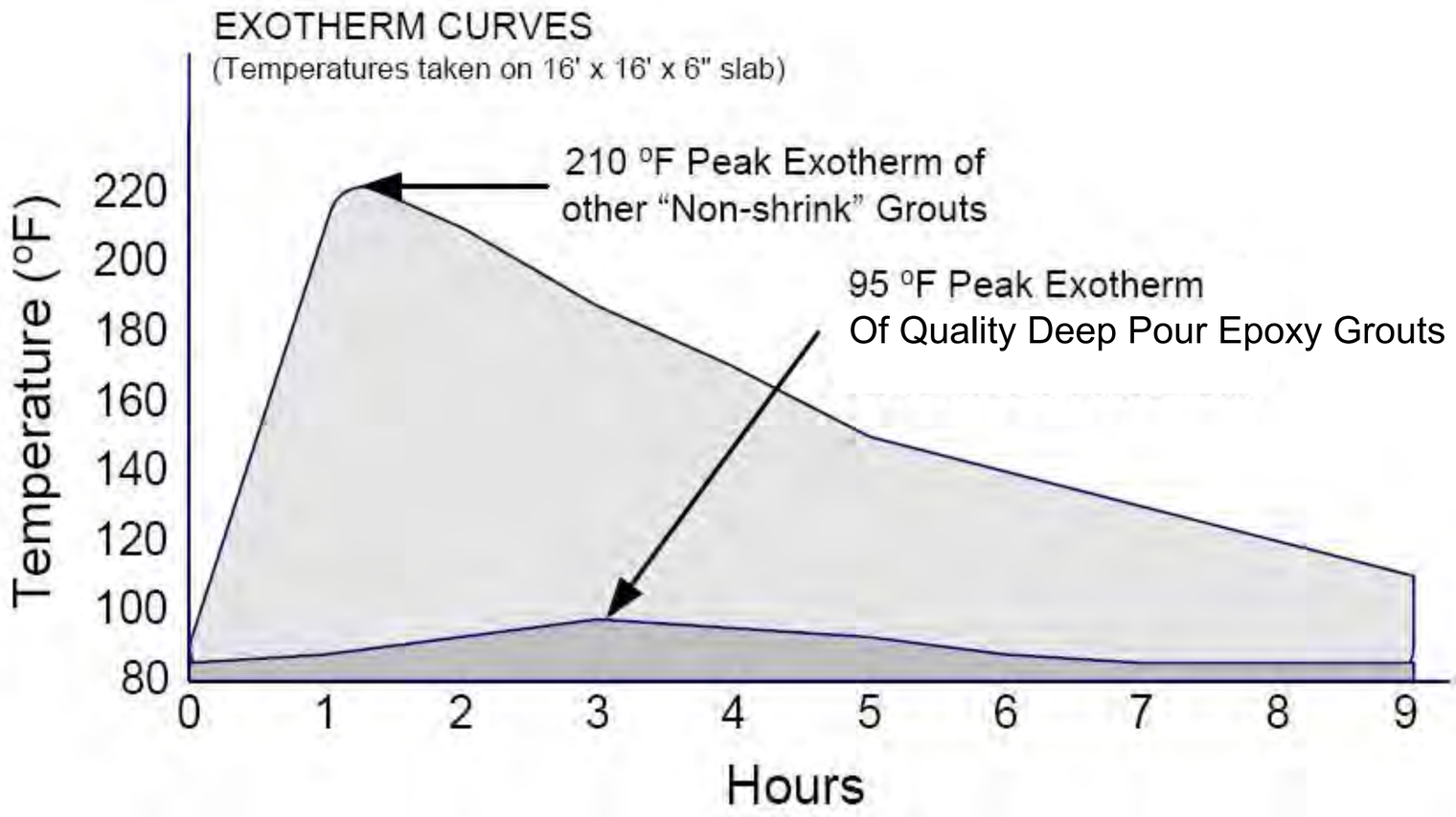
The release of energy is in the form of heat. A reaction that releases heat is called “ exothermic”

The practical amount of heat that is experienced as the temperature rises depends upon several things:

- Chemical formulation of the epoxy and component temperatures at time of mixing
- Amount (mass) of epoxy
- Ambient (surrounding) temperature
- Ability of the surrounding surfaces to absorb heat

# Grout Preparation

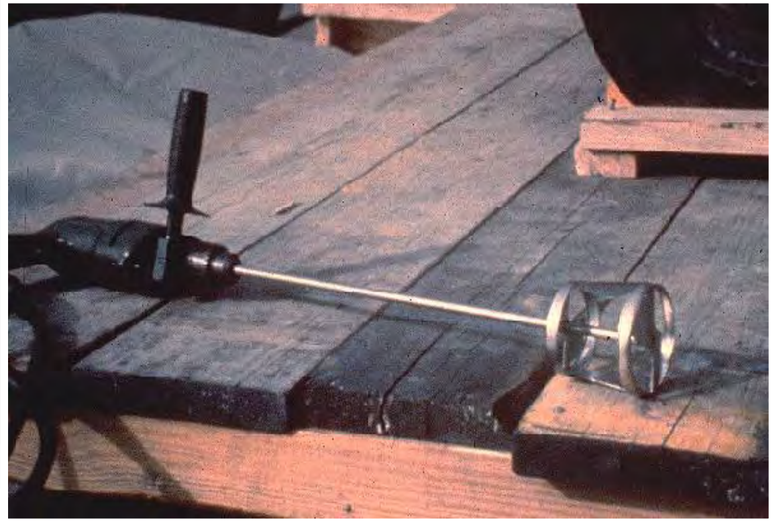
A high exothermic cure temperature can both help and hurt an epoxy grout installation. The higher the exothermic cure temperature, the faster the epoxy grout will cure. However, the higher the exothermic cure temperature, the more the epoxy grout will shrink and contract as it cools to ambient.



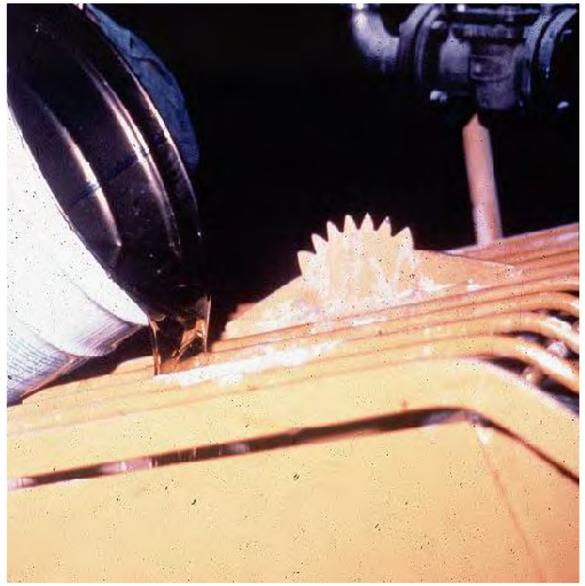
# Grout Preparation


A&B liquids are mixed together first for approximately 3 minutes with a variable-speed drill and “jiffy”-type mixer

Using a “jiffy” mixer helps to lessen air entrapment in the liquids



# Grout Preparation



After the mixing of A&B liquids is complete, add the A/B liquid blend to a mortar mixer.


<u>Only</u> mortar mixers are recommended for mixing Part C aggregates with the A/B liquid blend

# Grout Preparation

After adding the A/B liquid blend to mortar mixer, Part C aggregate is slowly added……..one bag at a time

# Grout Preparation

Mixing is complete when all Part C aggregate is placed in the mortar mixer and wetted by the resin system. Over-mixing can entrain excess air into the grout

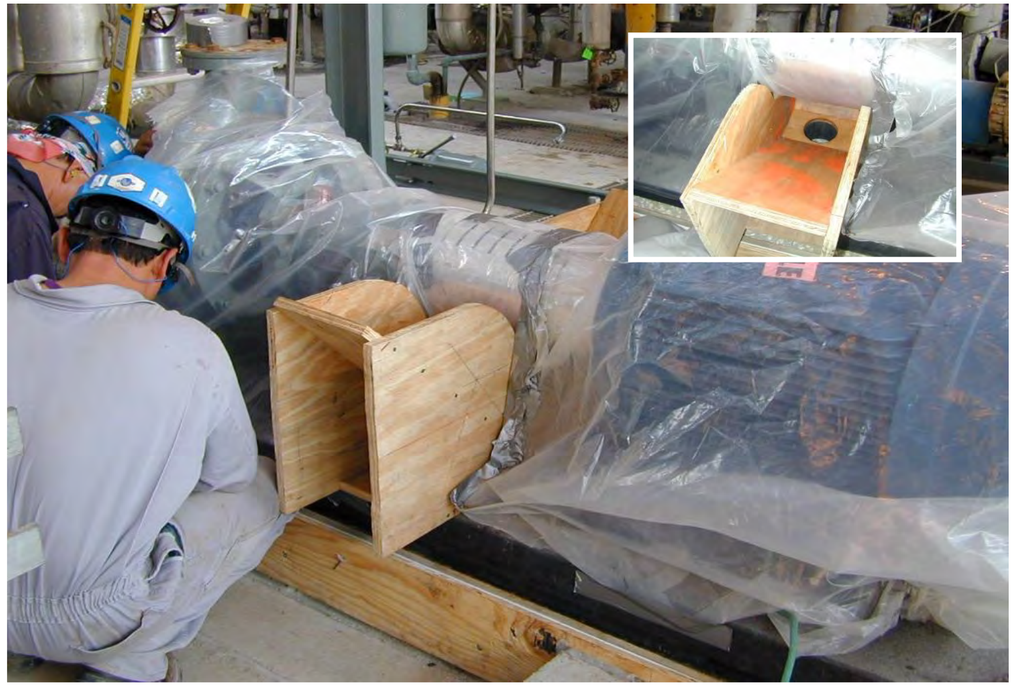
# Grout Placement

Head boxes, standpipes or troughs serve to load the epoxy grout with consistent hydraulic head pressure to assist in the movement and strategic placement of epoxy grout

They can be constructed in whatever configuration to fit the application and are a key component and essential part of any successful grout pour.

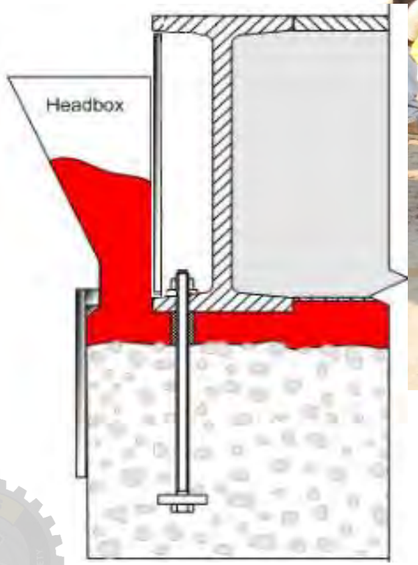
# Grout Placement

Additional head box and standpipes examples

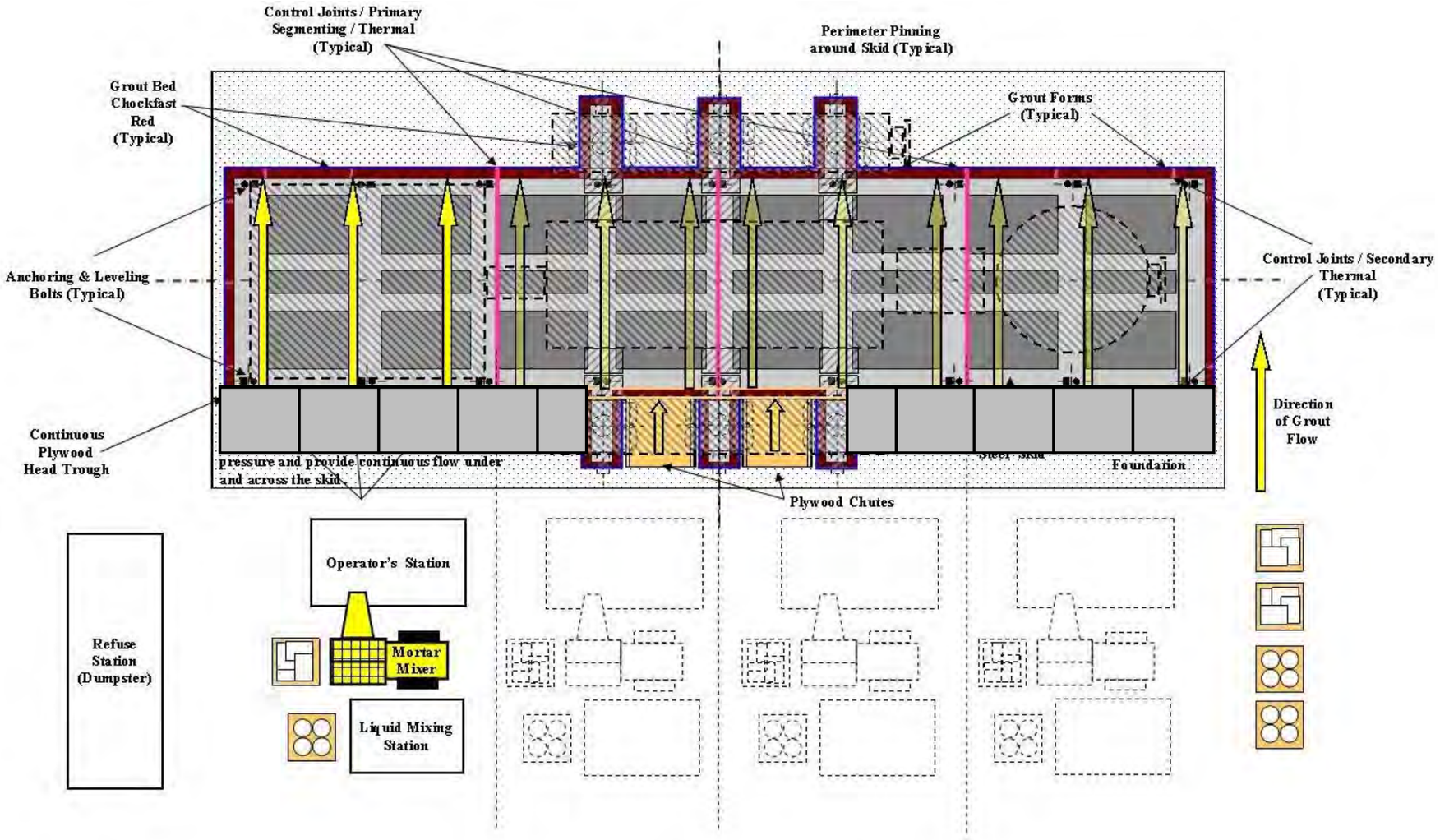


# Grout Placement

Epoxy grout is continuously mixed and placed - maintaining positive head pressure until all areas requiring grout are completely filled and contact is made between the grout and all structural flanging.



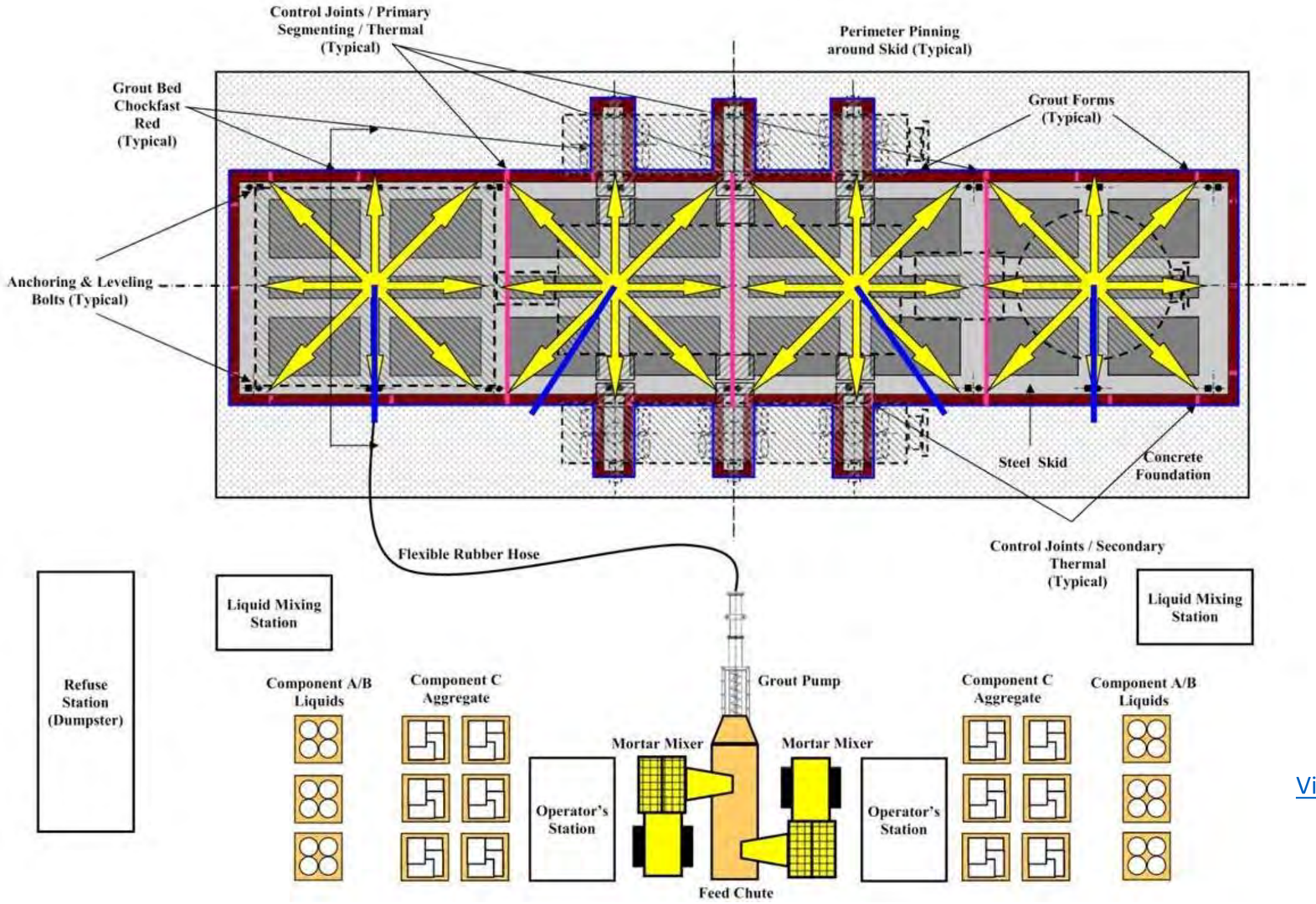

# Grout Placement






Options - Conventional placement

# Grout Placement



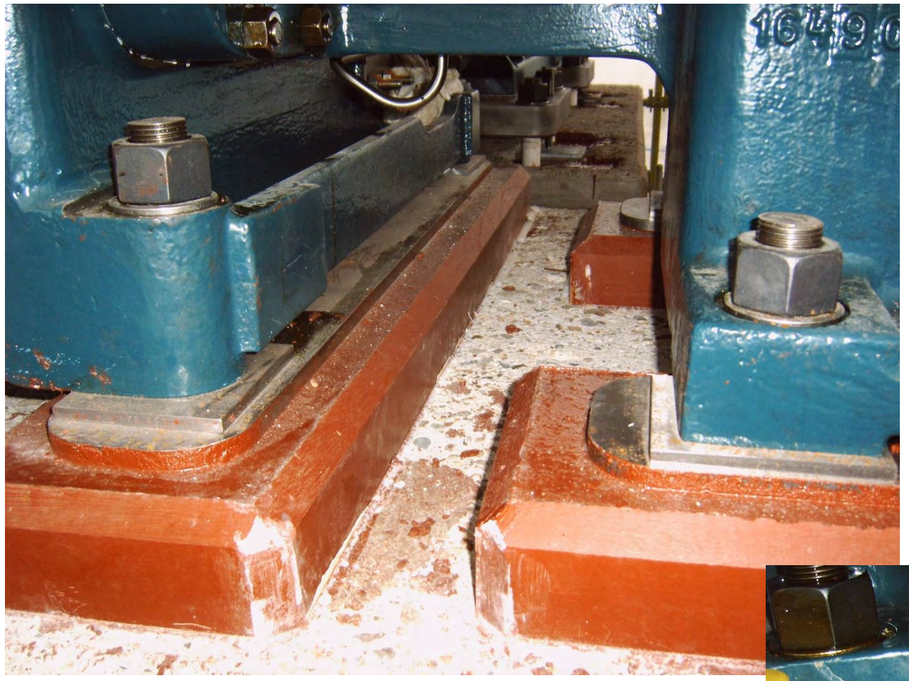

Video Link

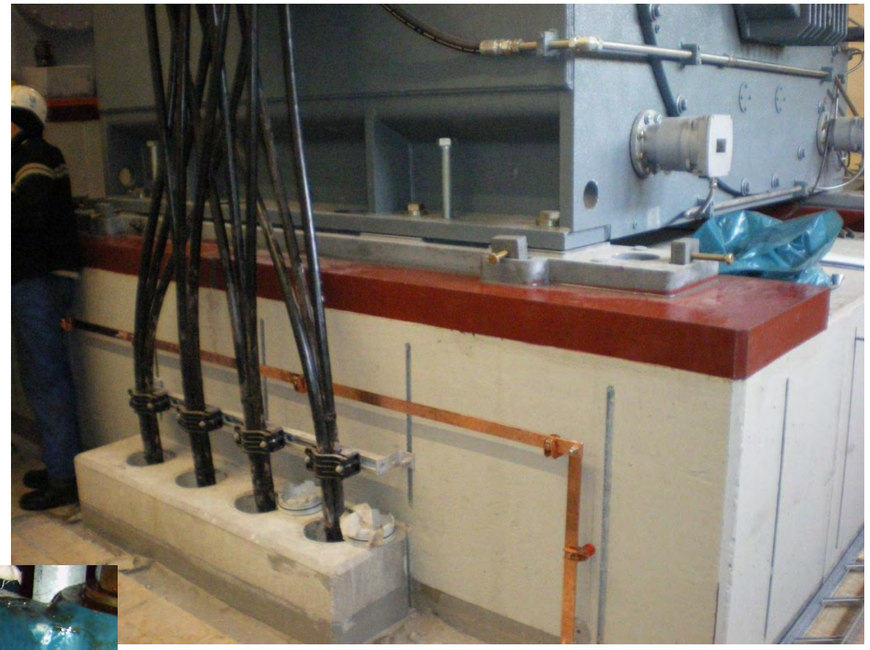
# Coating and Sealing the Foundation

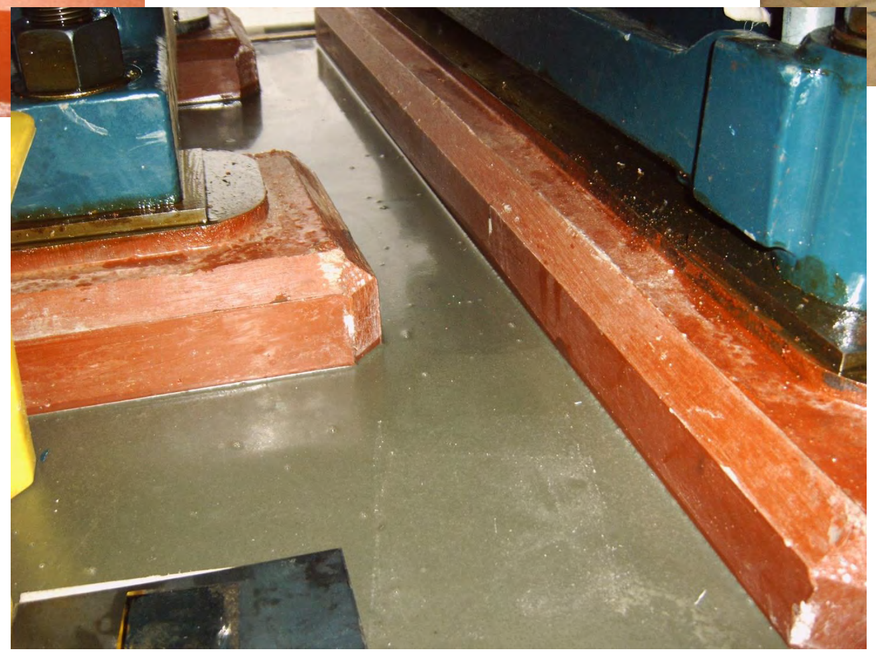
- After Grouting – Seal Surrounding Concrete
  - Prepare surface
  - Address cracks and expansion joints
  - Epoxy primer and epoxy top coat
- Seal Mounting Feet and Sole Plates
- Seal Control Joints
- Install Drip Pan
- Remove sharp edges around perimeter of the pour.

# Finished Installations

# Finished Installations





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- ITW Performance Polymers Machinery Grouting Manual
- ITW Performance Polymers Technical Bulletins
- ITW Performance Polymers Technical Letters (authored by James A. Kuly, Former Chief Engineer at ITW)
- ITW Performance Polymers Technical Letters (authored by Christopher R Matthews-Ewald, Industrial Applications Engineer, ITW Performance Polymers)
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