PUMP INSTALLATION

NOTES, COMMENTARY, AND DISCUSSION

Brad M. Cassolato, P.Eng.
Rotating Equipment Specialist
WCI Limited
403-475-2534
cassolato@shaw.ca

3rd Calgary Pump Symposium – Nov 13 2009

SAFETY

“A good pump installation improves safety, reliability, and asset life cycle cost.”

- ✓ Equipment location (grade / mezzanine) (indoor / outdoor)
- ✓ Proximity to personnel / work areas
- ✓ Prevailing wind
- ✓ Structural-borne vibration
- ✓ Guarding CSA / OSHA compliance
- ✓ Ambient temperature

SAFETY (cont'd)

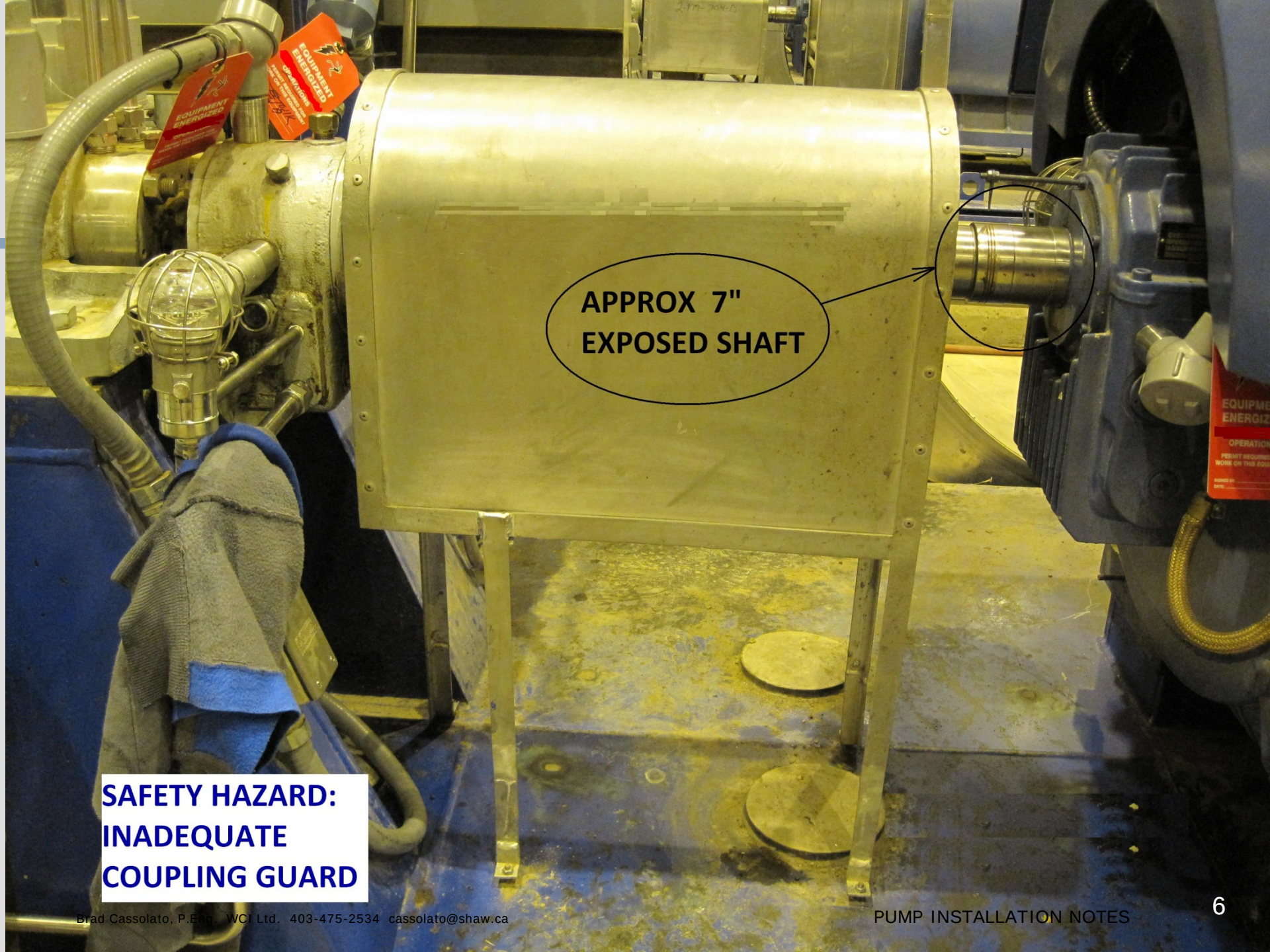
- ✓ Drainage (leakage) off to a safe place (sewers / dikes / trenches)
- ✓ Personnel unobstructed access / egress needed around machinery, piping, structures, start/stop, instruments, seal pots, and valves
- ✓ Ergonomics of PM and PdM activities
- ✓ Adequate lighting
- ✓ Housekeeping simplified
- ✓ Detectors (eg. LEL / H2S / fire)

SAFETY (cont'd)

- ✓ Adequate ventilation
- ✓ Visible / audible alarms
- ✓ Slips / trips / falls all hazards removed
- ✓ Adequate work area (crane / truck access) around machinery and building
- ✓ Signs / instructions / labels etc
- ✓ Noise level precautions
- ✓ Vents and drains piped (to a safe place) (supports / bracing / gussetting)
- ✓ Burn hazards

SAFETY (cont'd)

- ✓ Floor drain locations
- ✓ Provision for storage of working materials
- ✓ Preservation hazards
- ✓ Obvious tripping hazards (raised lip edges / lifting lugs / valve stems / etc)
- ✓ Appropriate monitoring (criticality ranking / reliability program)
- ✓ Mounting instrumentation on vibrating equipment


APPROX 7"
EXPOSED SHAFT
SAFETY HAZARD:
INADEQUATE
COUPLING GUARD

REFERENCES

- ✓ API-610
- ✓ API RP 686
- ✓ Pump manufacturers IOM
- ✓ EPC / Contractor specs procedures
- ✓ End user specs procedures
- ✓ QA checks and acceptance standards
- ✓ Grout manufacturer instructions: http://www.chockfastgrout.com/2008pdf/PTIG_MGM_1108_O.pdf

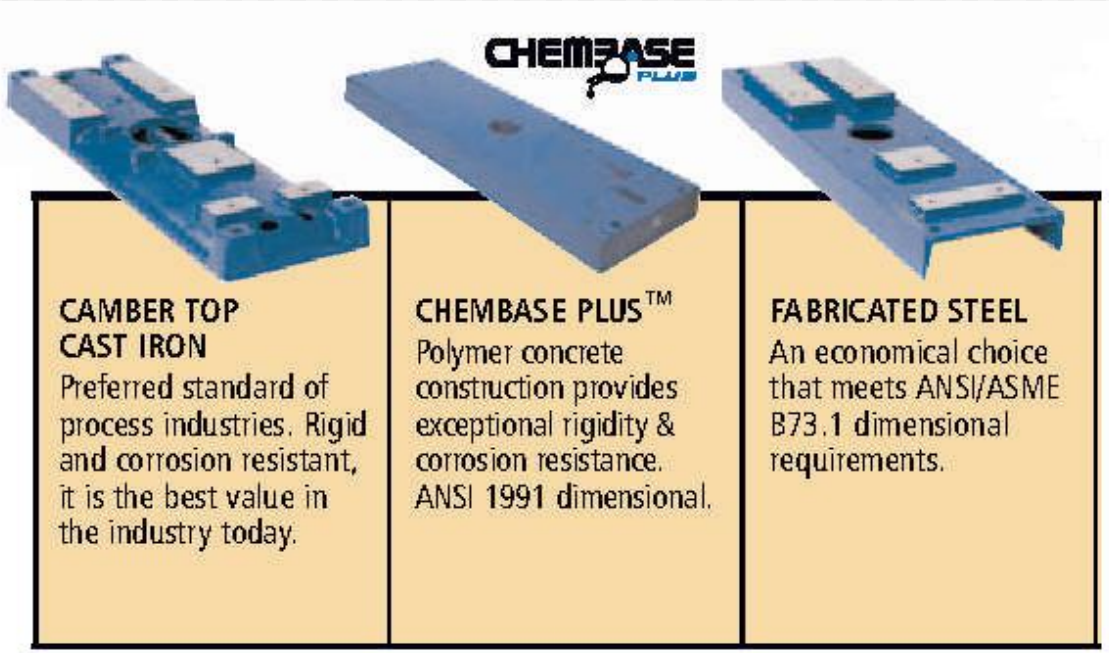
BASEPLATES

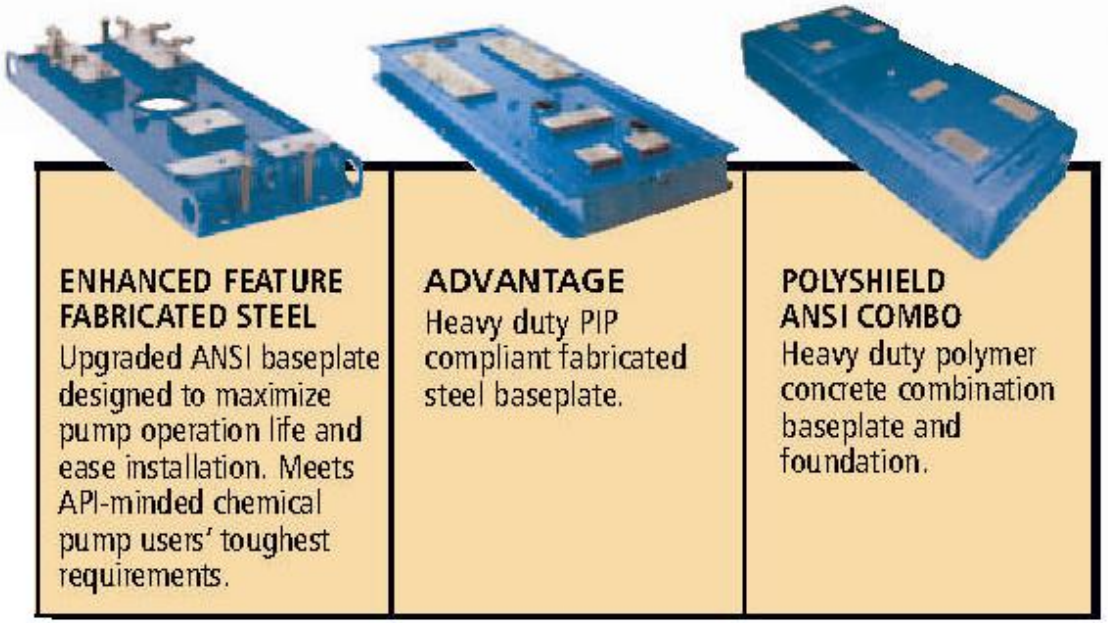
Industry choices:

- ✓ No baseplate
- ✓ Pedestal rails
- ✓ Soleplates
- ✓ FRP
- ✓ Cast iron
- ✓ Channel / formed / block pedestals (ANSI market)

BASEPLATES
(cont'd)

Literature courtesy of ITT Goulds





Brad Cassolato, P.Eng.
WCI Ltd. 403-475-2534
cassolato@shaw.ca

BASEPLATES (cont'd)

Fabricated steel (API market):

- ✓ Sloped drain pan top / channel or angle construction
- ✓ Flat top / sloped drain rim / I-beam construction
- ✓ Drilled and tapped for equipment hold down bolts (not thru bolted)
- ✓ Box pedestal construction (thick plate)
- ✓ Pedestal pad thickness
- ✓ Stress relieving of fabricated steel

BASEPLATES (cont'd)

Approach to quality and cost:

1. Specify baseplate design /construction
   Review fabrication drawings
   Inspect during construction, etc.

2. Accept vendor standard design and construction

Sloped drain pan – channel sides – full box pedestals – full seam welded

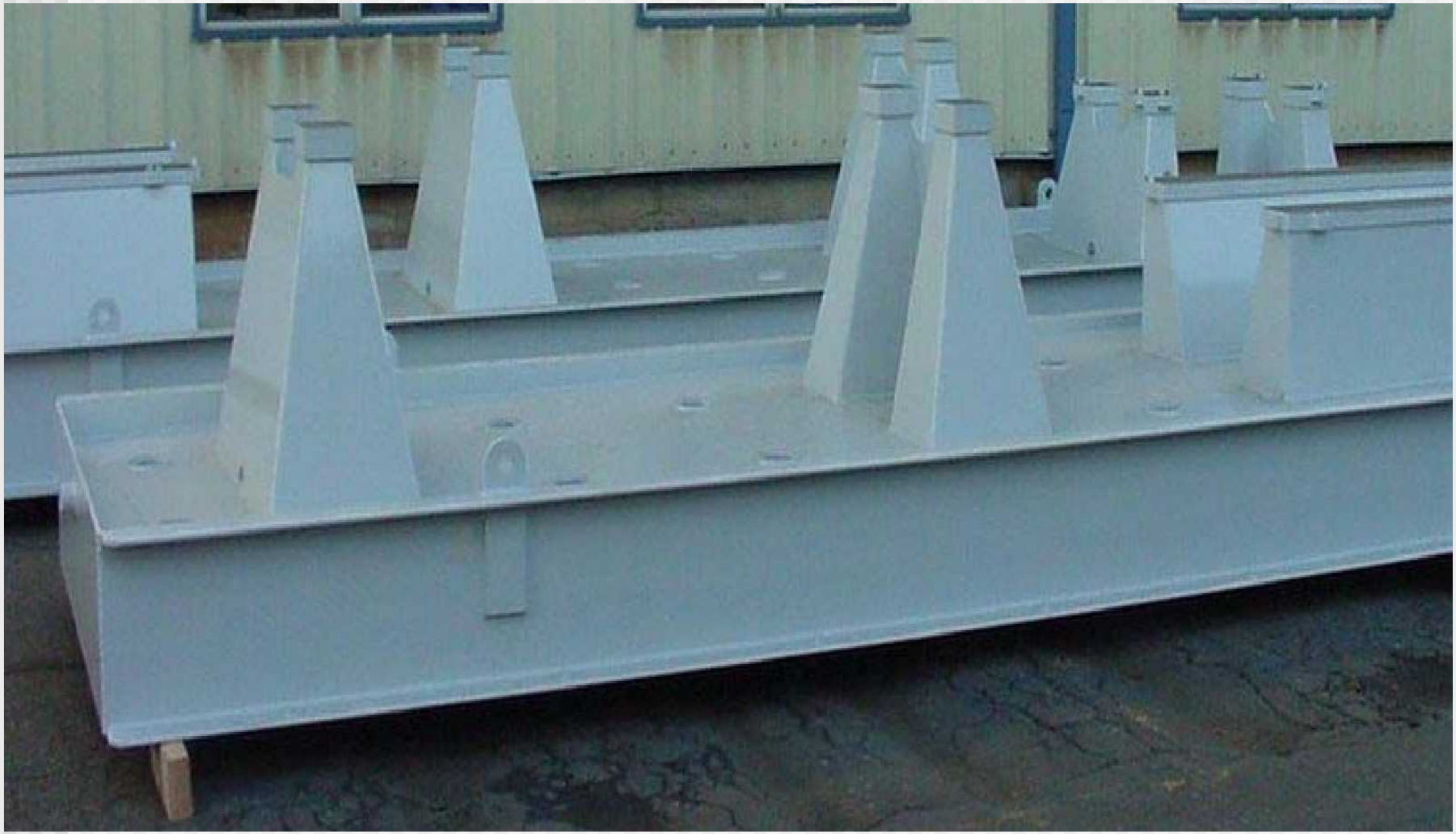


Photo courtesy of Sulzer Pumps

Open top – drain rim - angle sides – full box pedestals – full seam welded

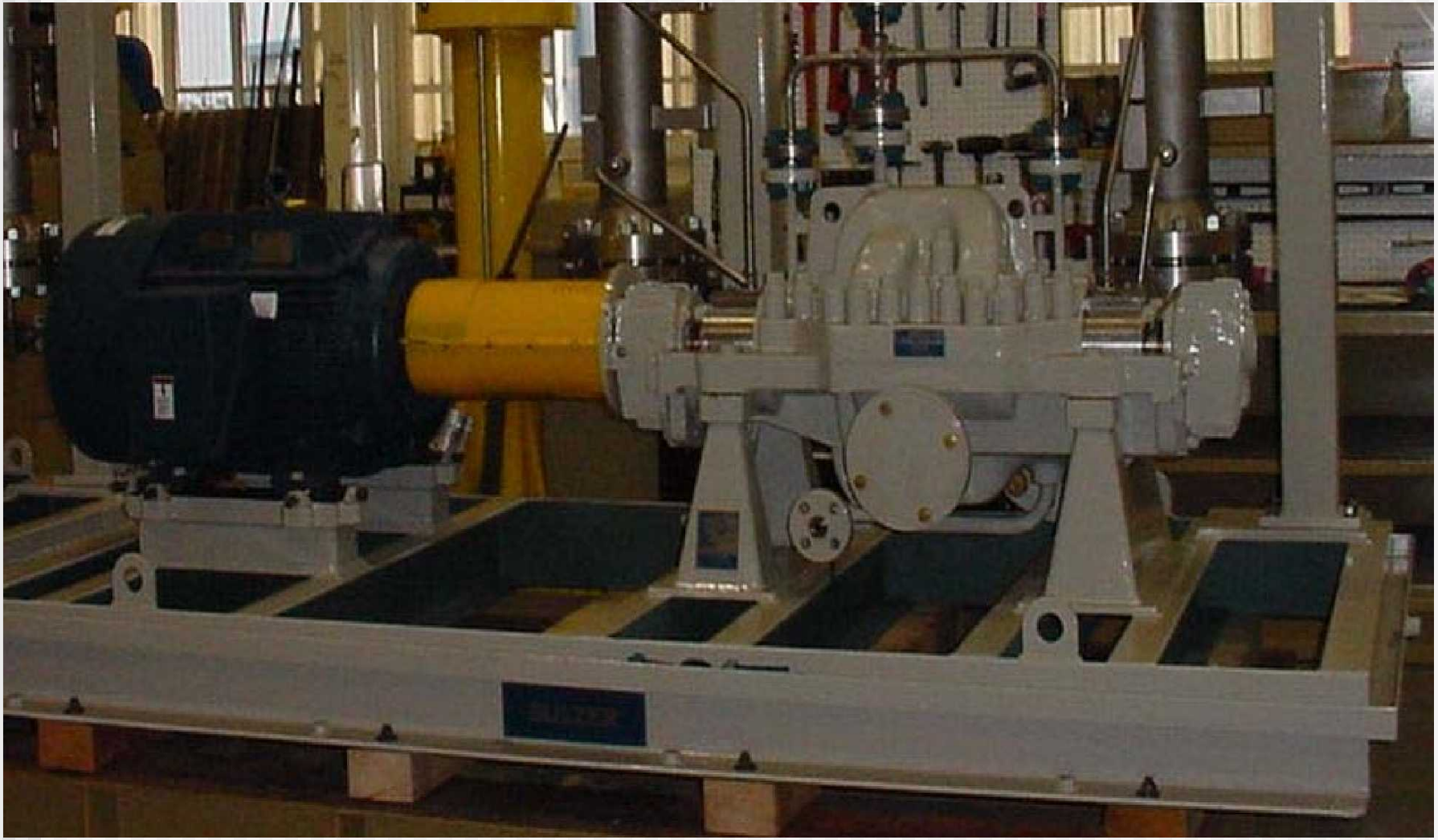


Photo courtesy of Sulzer Pumps

Skid construction – sloped drain pan – I-beam sides – full box pedestals – full seam welded – portable - self-supporting – grouting not intended

Photo courtesy of Sulzer Pumps

Brad Cassolato, P.Eng. WCI Ltd. 403-475-2534 cassolato@shaw.ca

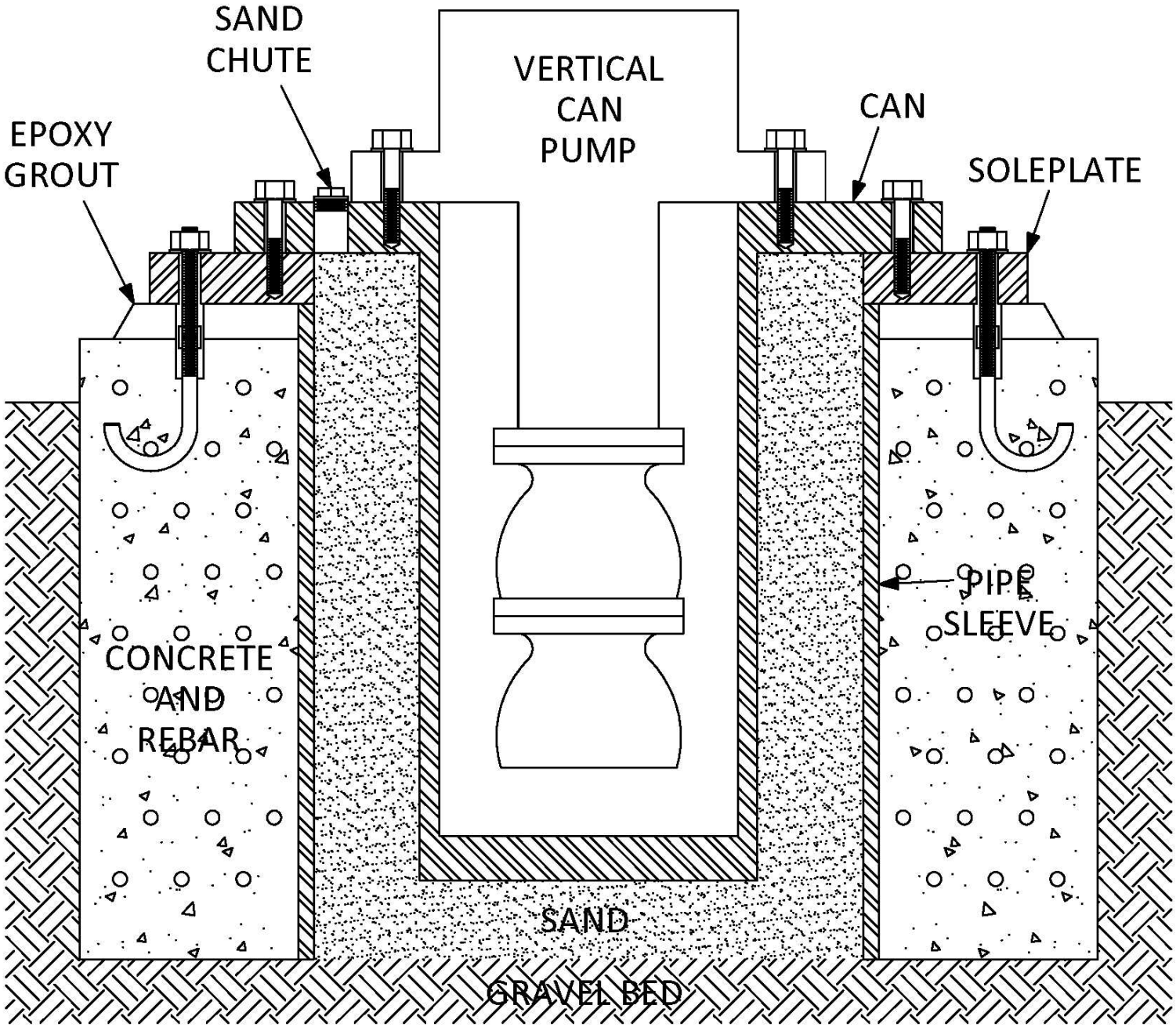
Full I-beam construction – full seam welded – self-supporting – full grouting not required – 3-point mounting or perimeter mounting

Photo courtesy of Sulzer Pumps

Open top with grating – no drain rim - channel sides – full box pedestals – full seam welded

Photo courtesy of Sulzer Pumps

Non-slip grating example


SAND
CHUTE
VERTICAL
CAN
PUMP
CAN
EPOXY
GROUT
SOLEPLATE
PIPE
SLEEVE
CONCRETE
AND
REBAR
SAND
GRAVEL BED

RECEIVING EQUIPMENT

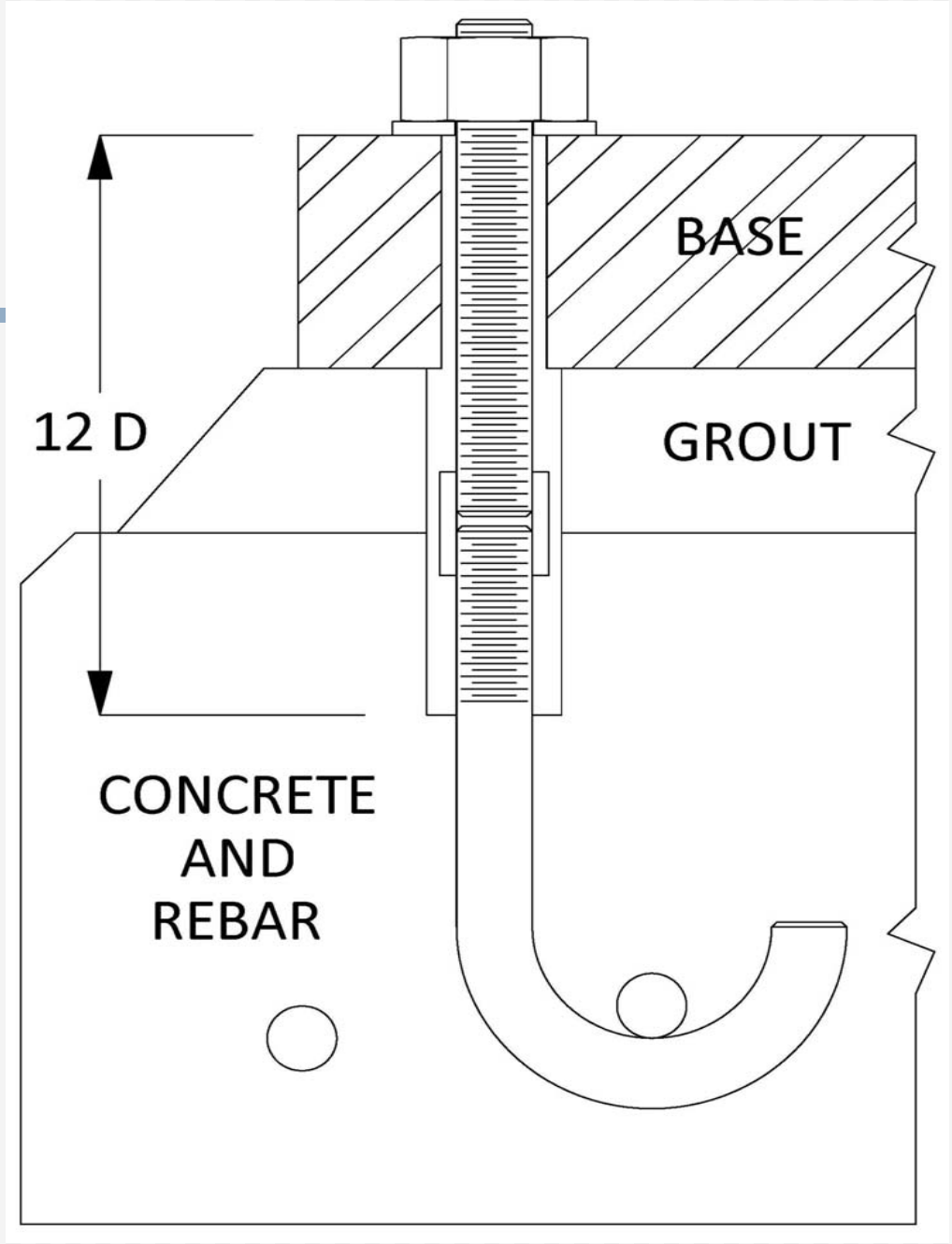
- ✓ Check against drawings, BOMs, specs
- ✓ Check damage / errors / data (IOM QA)
- ✓ Manufacturer instructions for handling
- ✓ Storage indoor / outdoor / photos
- ✓ Check preservation / N_2 blanket / oil mist
- ✓ Interval inspection (vendor warranty)
- ✓ Special pre-commissioning
- ✓ Notes on blocking, shipping keepers, etc.
- ✓ Equipment tagging

FOUNDATIONS

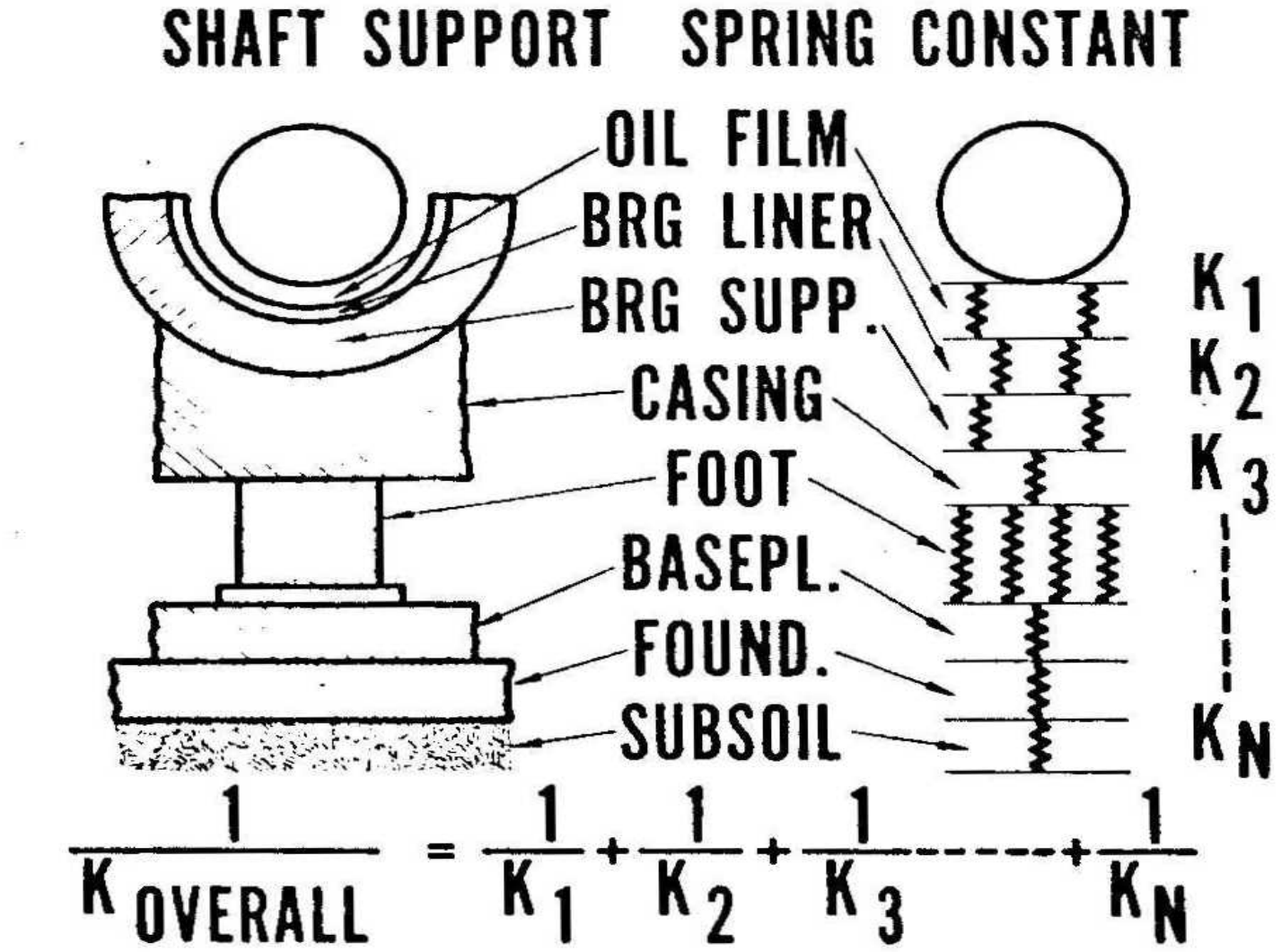
- ✓ Civil engineer and grout specialist
- ✓ Sub-soil testing / minimum depth consideration
- ✓ Concrete formulation and curing time
- ✓ Curb height / load bearing footing shape
- ✓ Foundation bolts and rebar
- ✓ “Deep block” rule of thumb: 5X weight
- ✓ Concrete preparation for grout
- ✓ Translational = in-phase Torsional = out-of-phase
- ✓ Vibratory effects on adjacent structures / members
- ✓ Arya / O’Neill / Pincus “Design of Structures and Foundations for Vibrating Machines” 1979 Gulf Publishing

FOUNDATIONS
(cont'd)

- ✓ Foundation and hold down bolts
- supply
- material
- bearing surface
- torquing



FOUNDATIONS (cont'd)



INSTALLATION

- ✓ Contractor qualifications / craft skills
- ✓ Task and site project planning
- ✓ Installation procedures
- ✓ QA checklist / safety review / holdpoints
- ✓ Ready for operation
- ✓ Operating procedures
- ✓ Cold run-in

INSTALLATION (cont'd)

- ✓ Vertical levelling jackbolts
- ✓ Levelling pucks
- ✓ Guidelines (0.002" per foot rule)
  - Precision levels (OK)
  - Optical transits (better)
  - Laser transits (best)
- ✓ Flatness checking and corrections

Levelling pucks

Photo courtesy of Sulzer Pumps

Brad Cassolato, P.Eng. WCI Ltd. 403-475-2534 cassolato@shaw.ca

Level baseplate front to back

Photo courtesy of Sulzer Pumps

Level baseplate side to side

Photo courtesy of Sulzer Pumps

Brad Cassolato, P.Eng. WCI Ltd. 403-475-2534 cassolato@shaw.ca

Check pedestal flatness by group

Photo courtesy of Sulzer Pumps

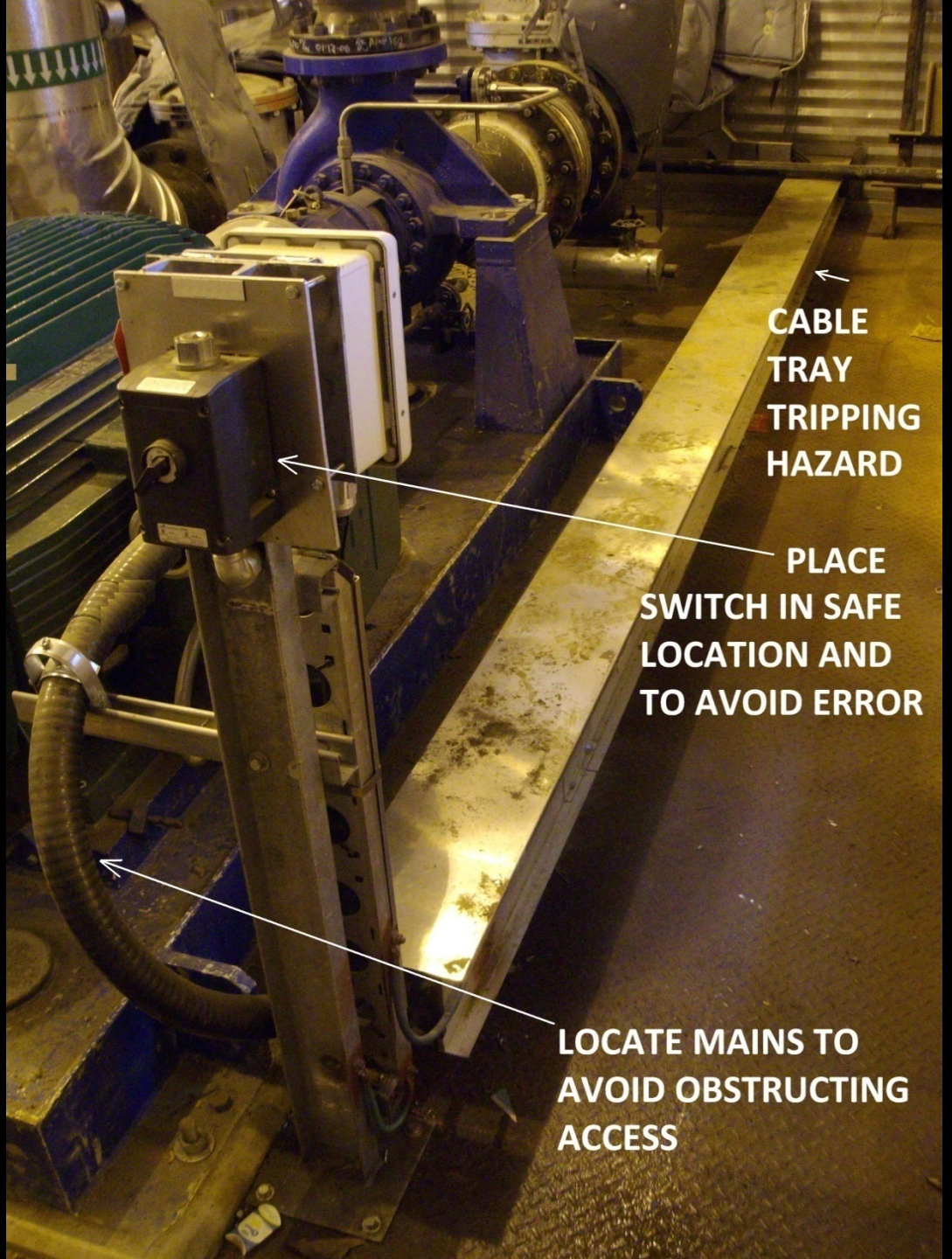
Brad Cassolato, P.Eng. WCI Ltd. 403-475-2534 cassolato@shaw.ca

ELECTRICAL

- ✓ Ground the equipment:
  - Motor stator ground in T-box
  - Motor frame lug
  - Baseplate frame
  - Steam turbine static charge
- ✓ Check ground continuity
- ✓ Insulated motor bearings
- ✓ Location of start-stop station

ELECTRICAL

(cont'd)



Brad Cassolato, P.Eng.
WCI Ltd. 403-475-2534
cassolato@shaw.ca

PUMP INSTALLATION NOTES

GROUTING

- ✓ “For a given baseplate construction, grouted machinery will always have lower vibration”.

Discussion of API-610 para 6.3.13 for large baseplates

- ✓ Heavier structural steel and more rigid machinery pedestals.
- ✓ Option to not grout fill (bottom chock only) for capex saving.
- ✓ Open baseplate structure is easier to install and chock (or grout fill if desired). If full grouting is specified, open construction allows for partial fill with cementitious grout.
- ✓ Grating provides more tooth for personnel safety against slipping (oil, ice etc doesn’t collect on surface) vs diamond checkerplate.
- ✓ Liquids drained from machinery pass through grating to drain out beneath baseplate structure (versus draining across top plate).
- ✓ Heavy welded galvanized steel floor grating is load bearing and removable for access to baseplate compartments as required.

GROUTING (cont'd)

- **Example of cost saving**

Estimate for full epoxy grout filling of baseplates for a large pump

Material cost ….……	$275/cu ft
Labour cost @ 40% of material cost……..……..	$110/cu ft
Installation ……..…….…….…….…….…….……..	$385/cu ft
Pump baseplate volume 18"H X 260L X 100W……..	271 cu ft
Oil system baseplate volume 14"H X 180L X 96W……..….	140 cu ft
Total volume……..…….…….…….…….…….……..	411 cu ft
Estimated cost to grout fill 411 cu ft X $385…….……..	$160K

- WILL THE MACHINERY RELIABILITY BE COMPROMISED ?
- WILL THERE BE INCREASED LIFE CYCLE COSTS ?

GROUTING (cont'd)

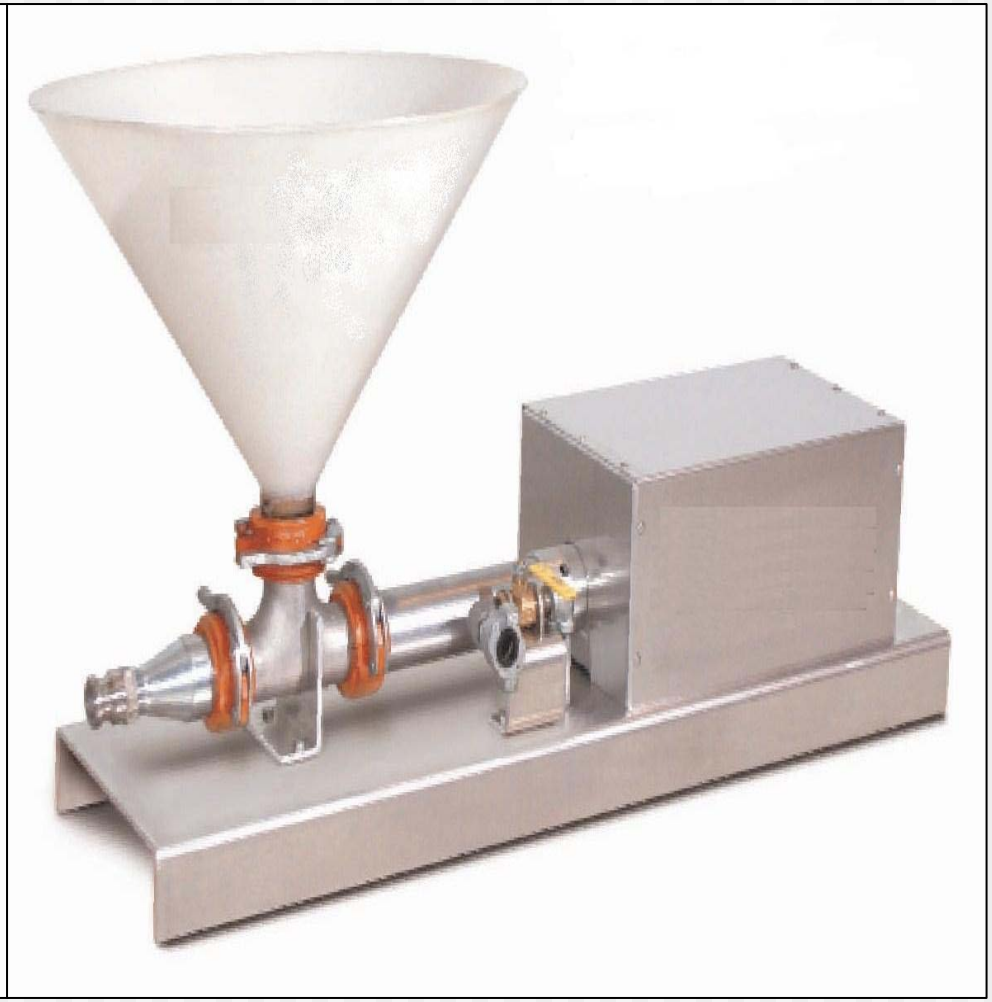
- ✓ Cementitious grout only forms a mechanical bond to the underlying concrete and baseplate
- ✓ Cementitious grout shrinks and recedes from structures
- ✓ Epoxy grout forms both a mechanical and adhesive bond to the underlying concrete and baseplate
- ✓ May require sandblast and prepare underside at site
- ✓ Layering epoxy on top of cementitious grout can be done if there is internal access to chip surface.
- ✓ Diamond plate slippery when oily (personnel safety).
- ✓ Diamond plate full seam welded to all underlying structures or the plate will flex and "drum".
- ✓ Final pressure grout injection of top voids required.
- ✓ Pedestal deflection may result from distortion of the top plate due to grout shrinkage.
- ✓ Allow minimum 1-1/2" for base chock

GROUTING (cont'd)

GROUTING (cont'd)

MANUAL POUR

GROUTING (cont'd)



GROUTING (cont'd)

GROUTING (cont'd)

- ✓ 3% improvement in compressive strength for each percent of air liberated

EPOXY GROUT

- ✓ Epoxy grout preferred in hydrocarbon, corrosives/chemicals, high temperature services. Superior resistance, high bond/compressive strength
- ✓ Caps and seals the foundation
- ✓ Must chip the underlying concrete to remove laitance and create “tooth”
- ✓ Use low exotherm / thin consistency mix
- ✓ Low sheer / short mixing time / air entrainment
- ✓ Minimum ambient temperature for pour
- ✓ Allergenic (safety precaution)

EPOXY GROUT (cont'd)

"PREPARATION OF NEW CONCRETE:

Cure Time

It is recommended that a shrinkage test as per ASTM-C157-80 be performed. Epoxy grout should never be poured on "green" or uncured concrete. If a hydration test is not performed, concrete cure times can be approximated by the following:

1. Standard concrete: 5 bag mix, 21-28 days,

depending on climate and mix ratio;

2. High early concrete: 6-7 bag mix, 7 days,

depending on climate and mix ratio.

3. The compressive strength of all new concrete should be a minimum of 3,500 psi with a minimum tensile strength of 350 psi before pouring epoxy grout."

Instructions courtesy of ITW Resins

EPOXY GROUT (cont'd)

"Concrete Surface Preparation

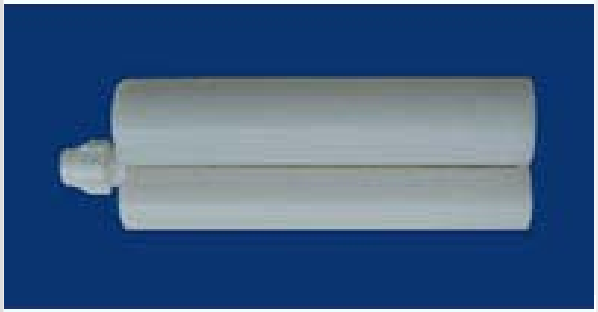
1. All laitance must be removed and good aggregate exposed. This is usually achieved by light chipping to a depth that exposes 50% aggregate. This chipping is done after the concrete is sufficiently cured. Chipping should be accomplished using hand held chipping guns. (Never use jackhammers on new concrete.)"

Instructions courtesy of ITW Resins

Brad Cassolato, P.Eng. WCI Ltd. 403-475-2534 cassolato@shaw.ca

EPOXY GROUT (cont'd)

INJECTION ACCESSORIES



2:1 CARTRIDGE

5:1 CARTRIDGE

STATIC MIXER

DUAL CARTRIDGE
CAULKING GUN

PIPING

- ✓ Good piping design and installation has a profound influence on pump reliability and performance
- ✓ Damaging piping forces due to thermal growth and misalignment – stress analysis
- ✓ Standing and reflected waves
- ✓ Static weight / dynamic excitation forces
- ✓ Center of gravity
- ✓ Use of hanger vs stantion
- ✓ Expansion joints

PIPING (cont'd)

- ✓ Slurry and erosion concerns (velocity)
- ✓ Corrosion concerns
- ✓ Minimum flow recycles / instrumentation
- ✓ Strainers / instrumentation
- ✓ Warm-up loops / controls
- ✓ Slope
- ✓ Priming / venting
- ✓ Open clear access on one side
- ✓ Waterhammer

PIPING (cont'd)

API RP686 SUCTION PIPING DESIGN RECOMMENDATIONS FOR CENTRIFUGAL PUMPS

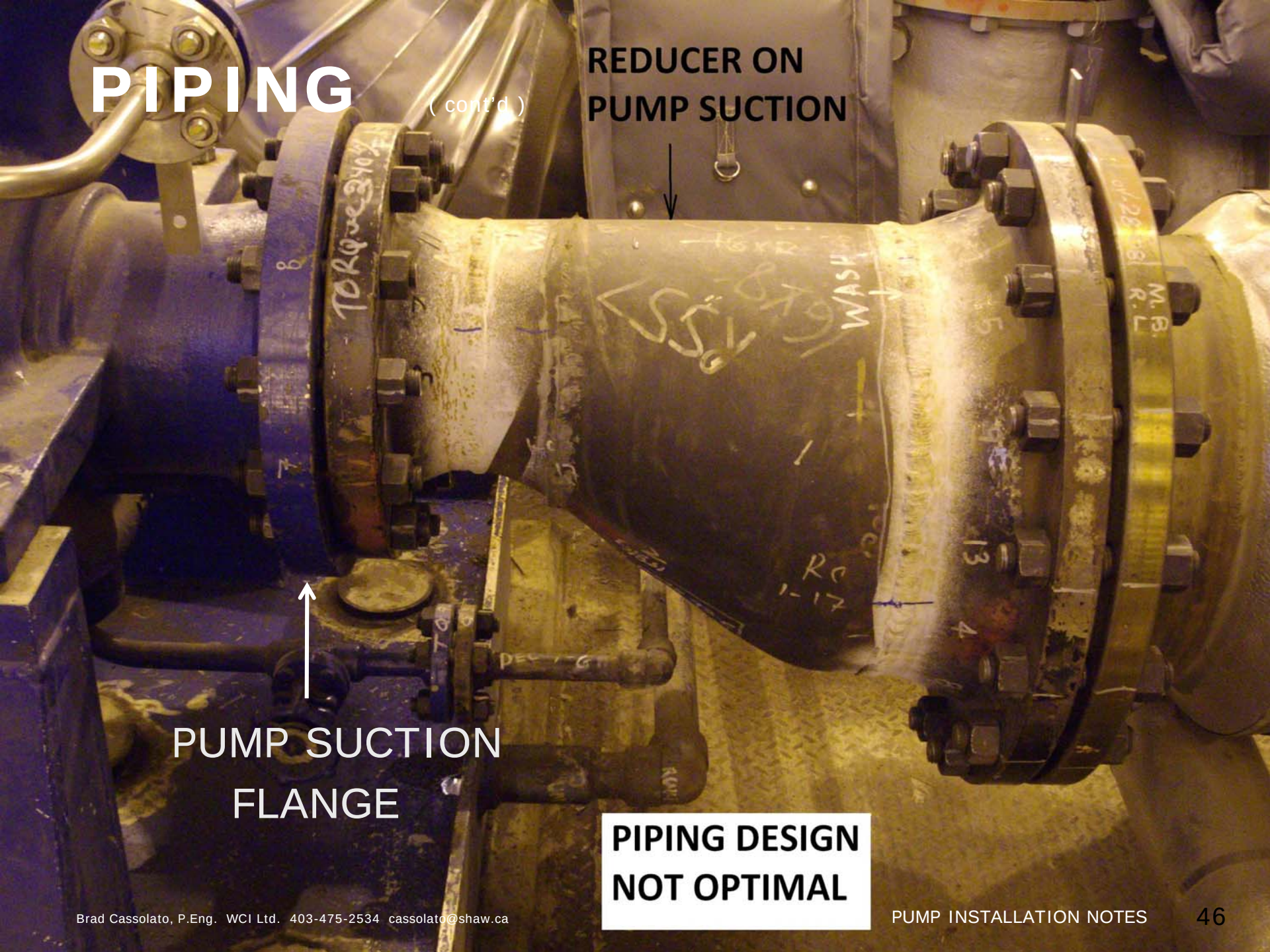
"3.1.2.1 Pump suction piping shall be arranged such that the flow is as smooth and uniform as practicable at the pump suction nozzle. To accomplish this, the use of tees, crosses, valves, reduced port valves, strainers, near run-size branch connections, and short radius elbows shall be avoided near the suction nozzle."

"3.1.2.3 Suction piping shall be designed with no high points to collect vapors."

"3.1.2.6 The pump suction line shall have a straight run (typically five pipe diameters) between the suction flange and first elbow, tee, valve, reducer, permanent strainer, or other obstruction sufficient to ensure stable and uniform flow at the pump suction nozzle." "Note: A piping straight run length of five pipe diameters, based on the pump suction nozzle size, is usually sufficient to ensure stable and uniform flow at the pump suction nozzle. In some situations, the type and orientation of valves and elbows in the pump suction line may affect the flow distribution to the impeller and necessitate a longer piping straight run length. Flow straighteners may also be utilized to reduce the piping straight run length."

"3.1.2.7 The last pipe elbow in the suction line to a pump shall be a long radius elbow."

PIPING (cont'd)



PIPING (cont'd)

"4.6.2 Pipe flange bolt holes shall be lined up with machinery nozzle bolt holes within 1/16" maximum offset from the center of the bolt hole to permit insertion of bolts without applying any external force to the piping."

"4.6.3 The machine and piping flange faces shall be parallel to less than 0.001" per inch of pipe flange outer diameter up to a maximum of 0.030". For piping flange outer diameters smaller than 10" the flanges shall be parallel to 0.010" or less."

"4.6.4 Flange face separation shall be within the gasket spacing plus or minus 1/16". Only one gasket per flanged connection shall be used."

"4.7 Piping Alignment … The basic method of verifying pipe strain consists of bolting up the

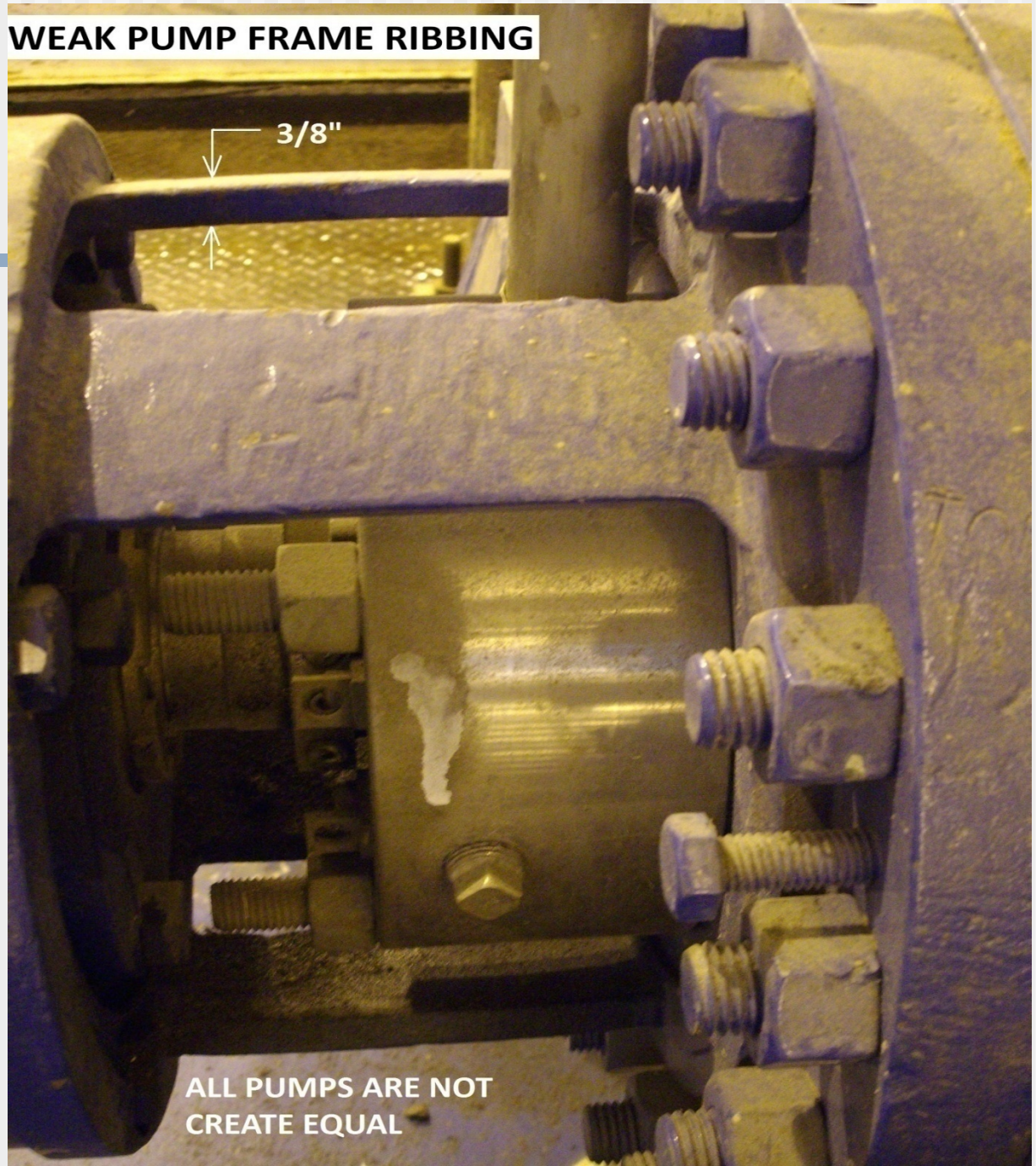
piping to the machine flanges while measuring the deflection of the machine shaft with dial indicators. This is done with (piping supports installed and energized). Excessive movement of the machine shaft as the piping is bolted up indicates that the pipe is imposing excessive strain on the machine." "4.8.5 The maximum shaft movement in either the vertical or horizontal directions after the flange is tightened shall be 0.002" or less."

"4.7.1 Moving the machinery to achieve piping alignment is not acceptable and shall not be permitted."

"4.7.3 Adjusting the spring tension of spring hangers or spring supports as a method of achieving piping alignment is not acceptable."

PIPING

(cont'd)



Brad Cassolato
403-475-2534
cassolato@shaw.ca

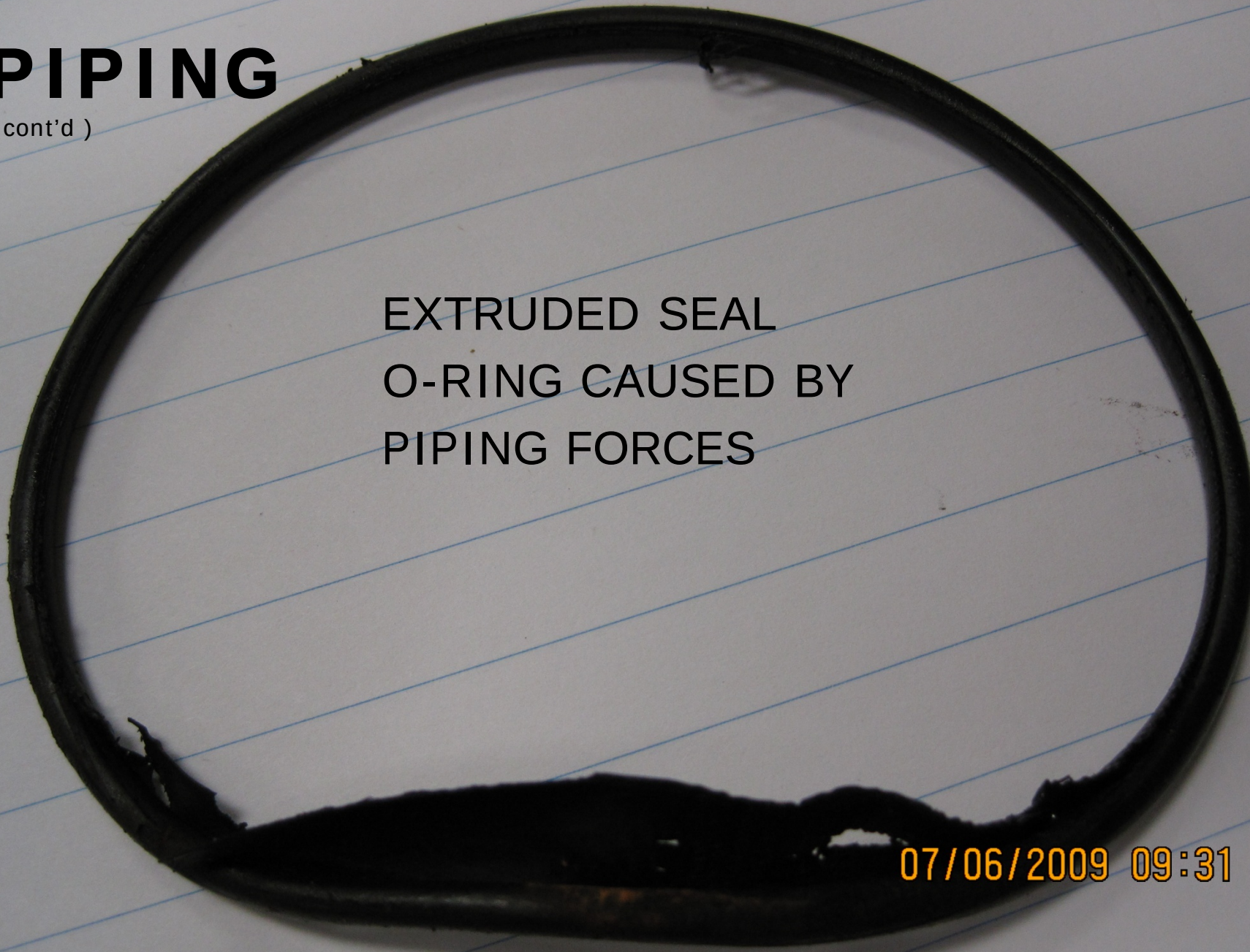
PIPING

(cont'd)

Brad Cassolato
403-475-2534
cassolato@shaw.ca

PIPING

(cont'd)



PIPING (cont'd)

Don't forget the auxiliary piping connections:

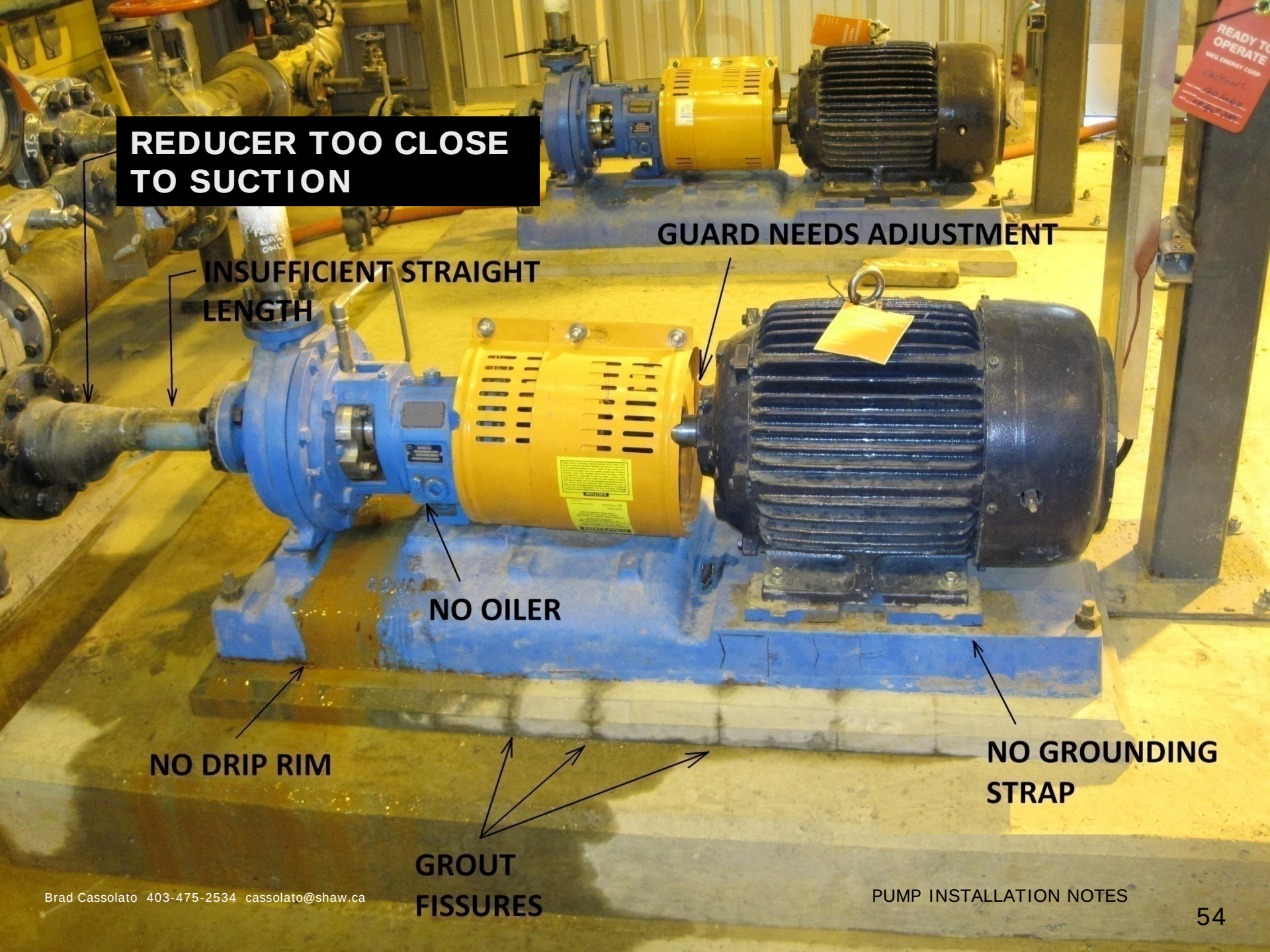
- ✓Casing drain / casing vent / priming connections / drips
- ✓Instrument take-offs
- ✓Baseplate drain
- ✓Bearing housing drains / cooling connections
- ✓Constant level oilers / oil level gauges
- ✓Pressurized oil feed and drain header connections
- ✓Mechanical seal vents and/or drains
- ✓Flush and barrier plan connections
- ✓Driver piping (eg. a typical single-stage steam turbine has up to 12 auxiliary connections – more with gland condenser, etc.)

Is the auxiliary piping seal welded, flanged, valved, gusseted, plugged, supported, etc ? Tubed or hard piped. Plan the small piping runs to not obstruct machinery access, create tripping hazards. Protect from mechanical damage, and make suitable for vibrating service, etc.

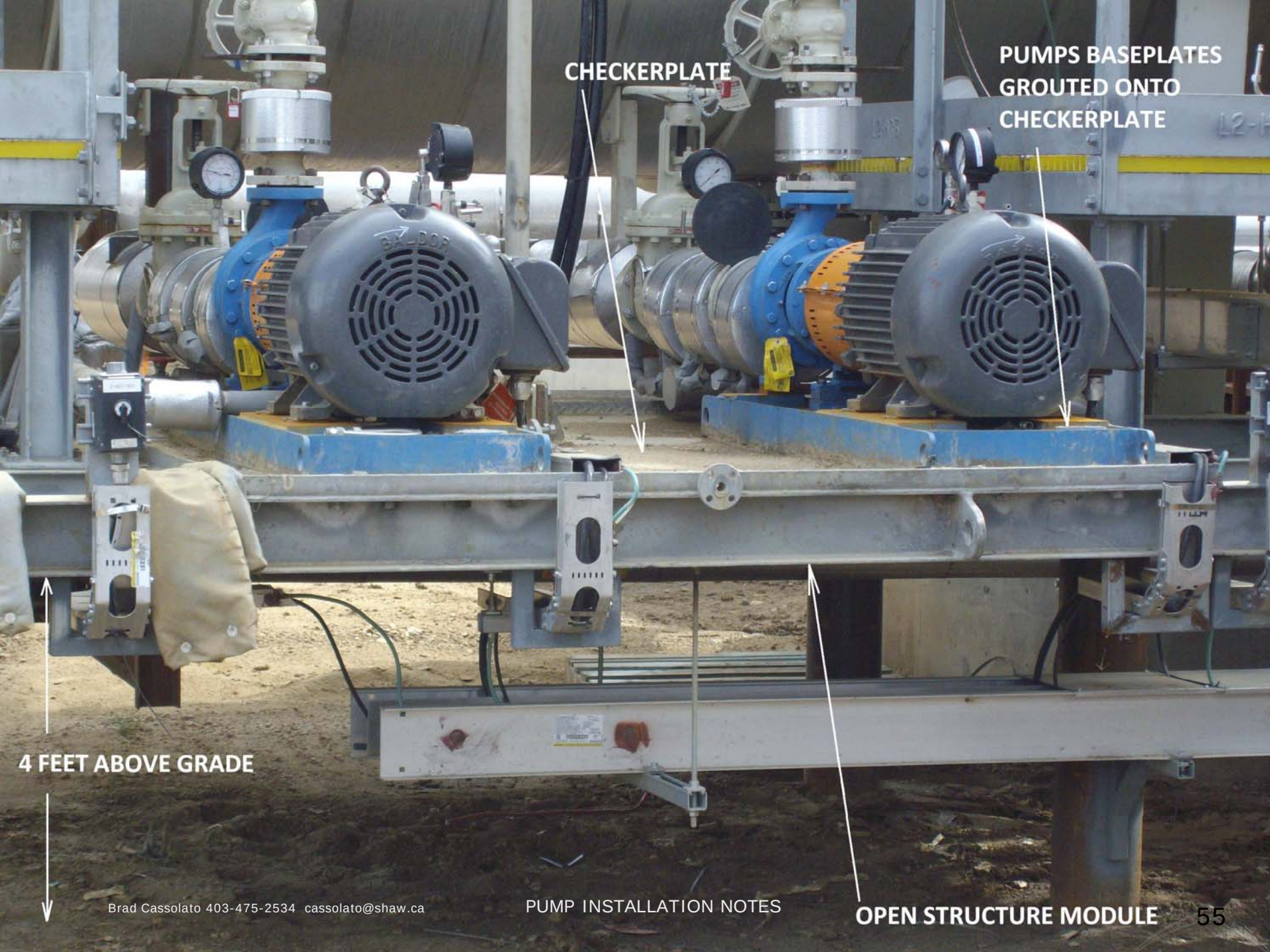
POST INSTALLATION (such as)

- ✓ Options for top sealant with polymer coating
- ✓ Install stairs, railings, etc accessibility aids
- ✓ Remove tripping hazards
- ✓ Lubricate and torque foundation bolts 3X
- ✓ Trim foundation bolts / remove vertical jackbolts
- ✓ Check pedestal flatness
- ✓ Check soft foot
- ✓ Perform resonance / forced response analysis
- ✓ Perform machinery and piping deflection testing
- ✓ Options to stiffen machinery pedestal
- ✓ Run-in to check bearing fault frequencies and verify / compare with test stand results
- ✓ Record the baseline vibration data

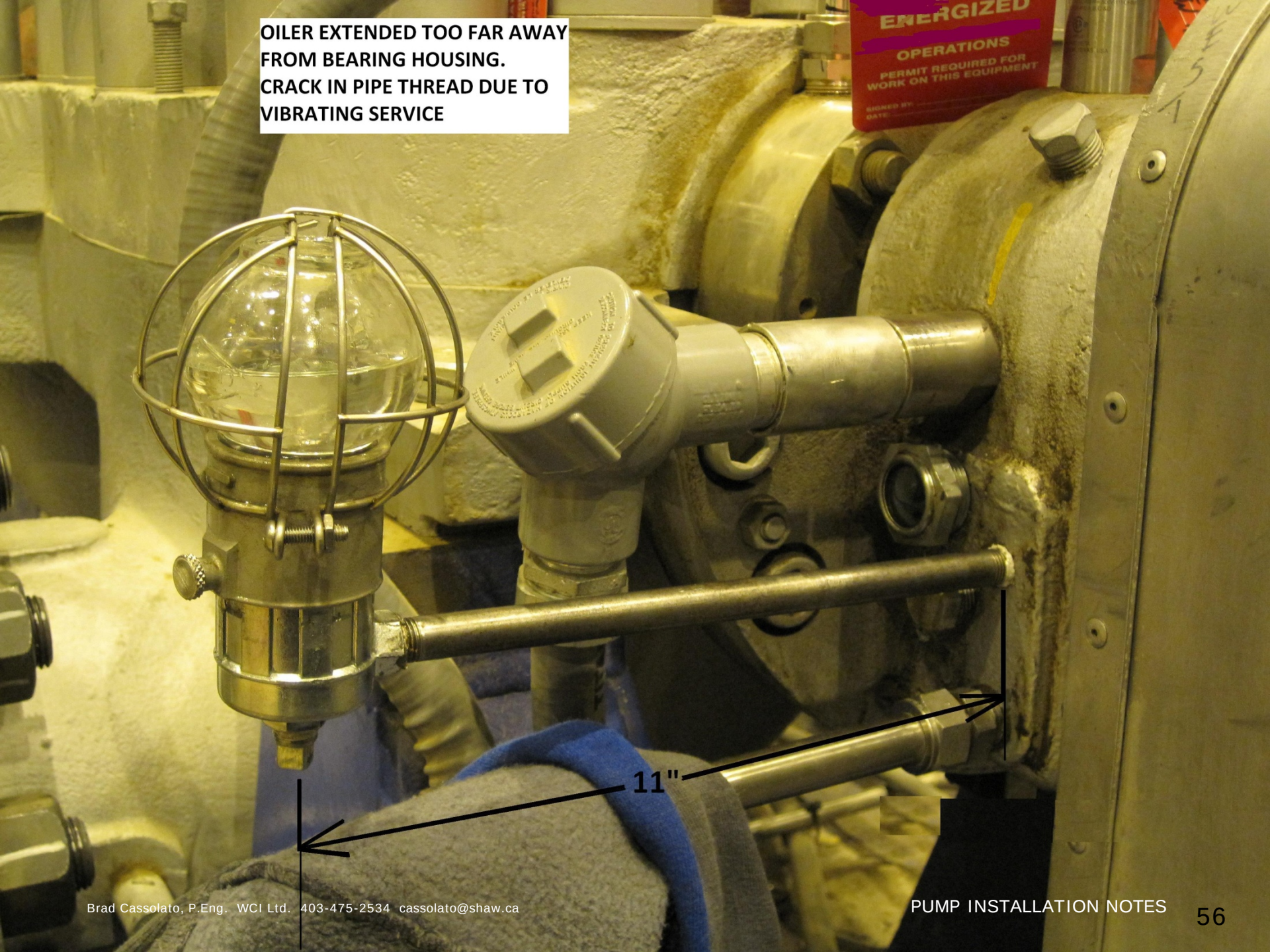

GALLERY

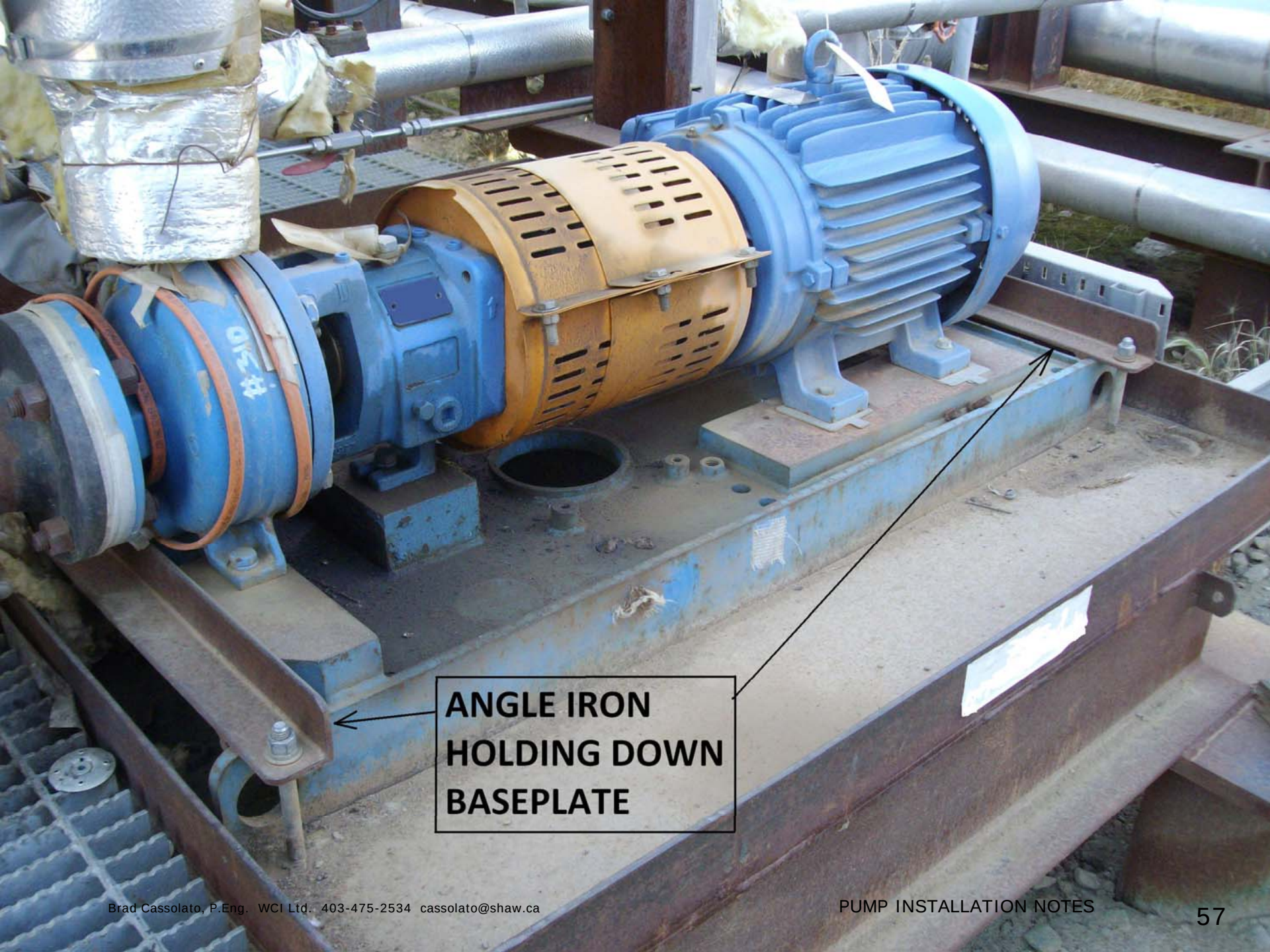


Brad Cassolato 403-475-2534 cassolato@shaw.ca



Brad Cassolato 403-475-2534 cassolato@shaw.ca

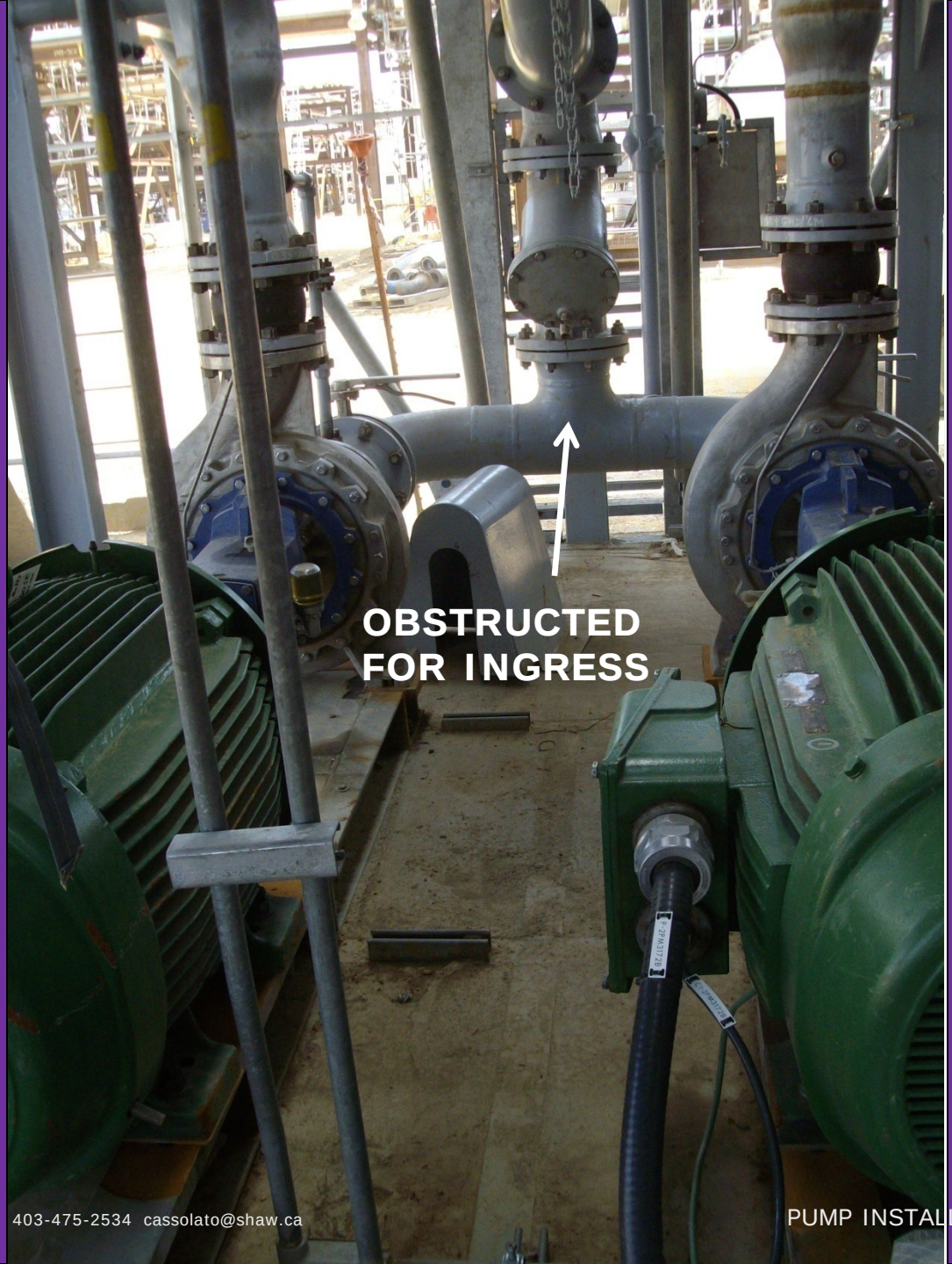

OILER EXTENDED TOO FAR AWAY FROM BEARING HOUSING.
CRACK IN PIPE THREAD DUE TO VIBRATING SERVICE
ENERGIZED
OPERATIONS
PERMIT REQUIRED FOR WORK ON THIS EQUIPMENT
11"


ANGLE IRON
HOLDING DOWN
BASEPLATE


TOO CLOSE
TOGETHER
10"


OBSTRUCTED
FOR LIFTING


OBSTRUCTED
FOR INGRESS


OBSTRUCTED
FOR INGRESS


END