DESIGN & CONSTRUCTION METHODS GEOTHERMAL STANDING COLUMN WELLS & STATUE of LIBERTY ISLAND

STEVE GROSS, PE, CertainTeed
Valley Forge PA www.certainteed.com

CARL ORIO, CGD, AI, Water Energy Dist Inc
Hampstead NH www.northeastgeo.com

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

3D-501-1

DESIGN & CONSTRUCTION METHODS
GEOTHERMAL
STANDING COLUMN WELLS
&
STATUE of LIBERTY ISLAND

STEVE GROSS, PE, CertainTeed
Valley Forge PA www.certainteed.com

CARL ORIO, CGD, AI, Water Energy Dist Inc
Hampstead NH www.northeastgeo.com

WATER ENERGY NORTHEASTGEO.COM
CertainTeed SAINT-GOBAIN

3D-501-2

PVC Well Casing

- Used as both Casing & Liner
  - Domestic, Public Supply, Ag Irrigation, Geothermal, Environmental Monitoring
- Successfully used for over thirty years – believed to be the most commonly specified casing material in almost all parts of the U.S.
- Available from numerous qualified and reputable suppliers
  - Produced with a variety of strengths (wall thicknesses) to suit a wide range of application conditions
  - Typical sizes 2” – 16” O.D.

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

2

New - - - - - - - - -
24” Certa-Lok Well Casing

PVC Well Casing

- Used as both Casing & Liner
  - Domestic, Public Supply, Ag Irrigation, Geothermal, Environmental Monitoring
- Successfully used for over thirty years – believed to be the most commonly specified casing material in almost all parts of the U.S.
- Available from numerous qualified and reputable suppliers
  - Produced with a variety of strengths (wall thicknesses) to suit a wide range of application conditions
  - Typical sizes 2” – 16” O.D.
- Engineered continuous water-tight system that maintains integrity of the well, thus protecting natural resources
  - Corrosion-resistant material does not degrade with time
  - Leak-free joint
- PVC is generally a more affordable option, making it easier for homeowners that need a well to have one on their property

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

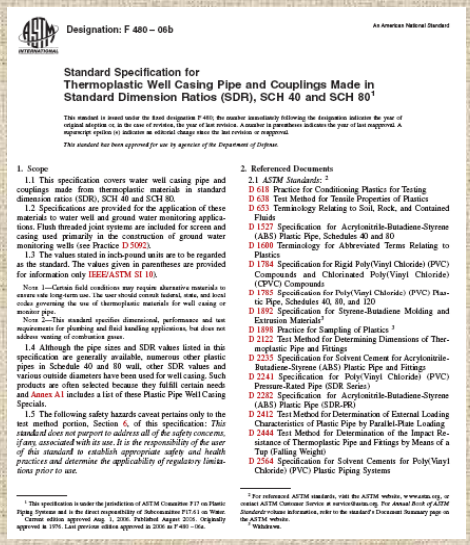
2

PVC Well Casing

Made to accepted national standards that control:

- Material composition and properties
  - Tensile Strength, Elastic Modulus, Impact Strength
- Precise dimensions and tolerances
- Quality control and marking requirements

NSF International tested, approved, and listed as safe for use with potable water



Designation: F 480 – 06b

An American National Standard

Standard Specification for
Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80[1]

This standard is issued under the fixed designation F 480; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers water well casing pipe and couplings made from thermoplastic materials in standard dimension ratios (SDR), SCH 40 and SCH 80.

1.2 Specifications are provided for the application of these materials to water well and ground water monitoring applications. Flush threaded joint systems are included for screen and casing used primarily in the construction of ground water monitoring wells (see Practice D 5092).

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only (IEEE/ASTM SI 10).

Note 1—Certain field conditions may require alternative materials to ensure safe long-term use. The user should consult federal, state, and local codes governing the use of thermoplastic materials for well casing or monitor pipe.

Note 2—This standard specifies dimensional, performance and test requirements for plumbing and fluid handling applications, but does not address venting of combustion gases.

1.4 Although the pipe sizes and SDR values listed in this specification are generally available, numerous other plastic pipes in Schedule 40 and 80 wall, other SDR values and various outside diameters have been used for well casing. Such products are often selected because they fulfill certain needs and Annex A1 includes a list of these Plastic Pipe Well Casing Specials.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 6, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 618 Practice for Conditioning Plastics for Testing
D 638 Test Method for Tensile Properties of Plastics
D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 1527 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80
D 1600 Terminology for Abbreviated Terms Relating to Plastics
D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D 1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
D 1892 Specification for Styrene-Butadiene Molding and Extrusion Materials[3]
D 1898 Practice for Sampling of Plastics [3]
D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D 2235 Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
D 2241 Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
D 2282 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)
D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D 2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
D 2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water. Current edition approved Aug. 1, 2006. Published August 2006. Originally approved in 1976. Last previous edition approved in 2006 as F 480 – 06a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

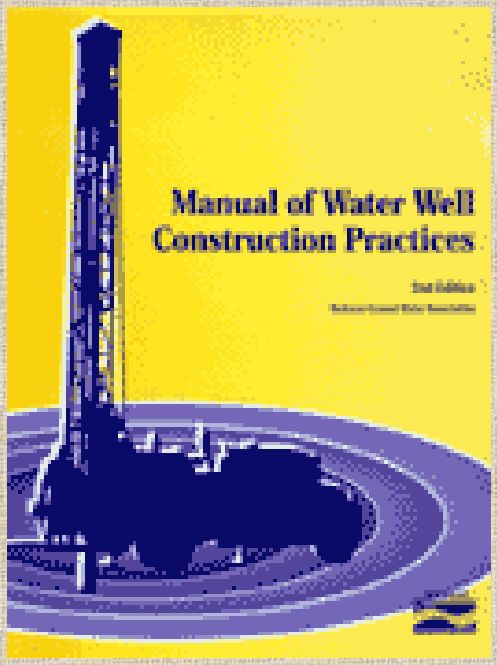
[3] Withdrawn.

ASTM F480

Construction Practices

NGWA Manual of Water Well Construction Practices

- Includes PVC, with solvent weld and spline-lock joining systems



WATER ENERGY NORTHEASTGEO.COM

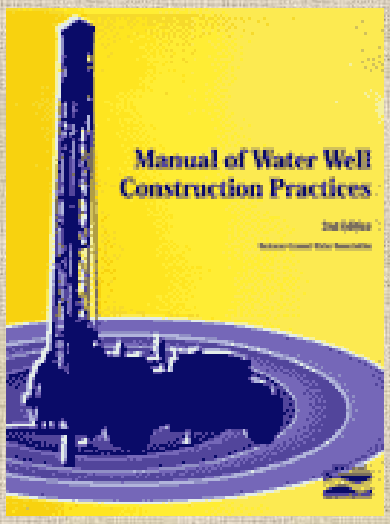
CertainTeed SAINT-GOBAIN

5

Construction Practices (continued)

Well Screens & Intakes

- Engineered screen should be used with Casing
  - Maximizes open area for flow performance
  - Protects against entrance of fines during pumping



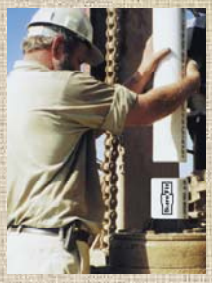
WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

6

Available with a Variety of Approved and Proven Joining Systems

U.S. Patent Number 6,086,297

Solvent Weld
Belled End



Spline-Lok Mechanical Joining System

WATER ENERGY
NORTHEASTGEO.COM

CertainTeed
SAINT-GOBAIN

4

Drop Pipe – PVC Options

Kwik-Set Threaded
Drop Pipe (1” – 2”)

Spline Lock
Drop Pipe
(2” – 8”)

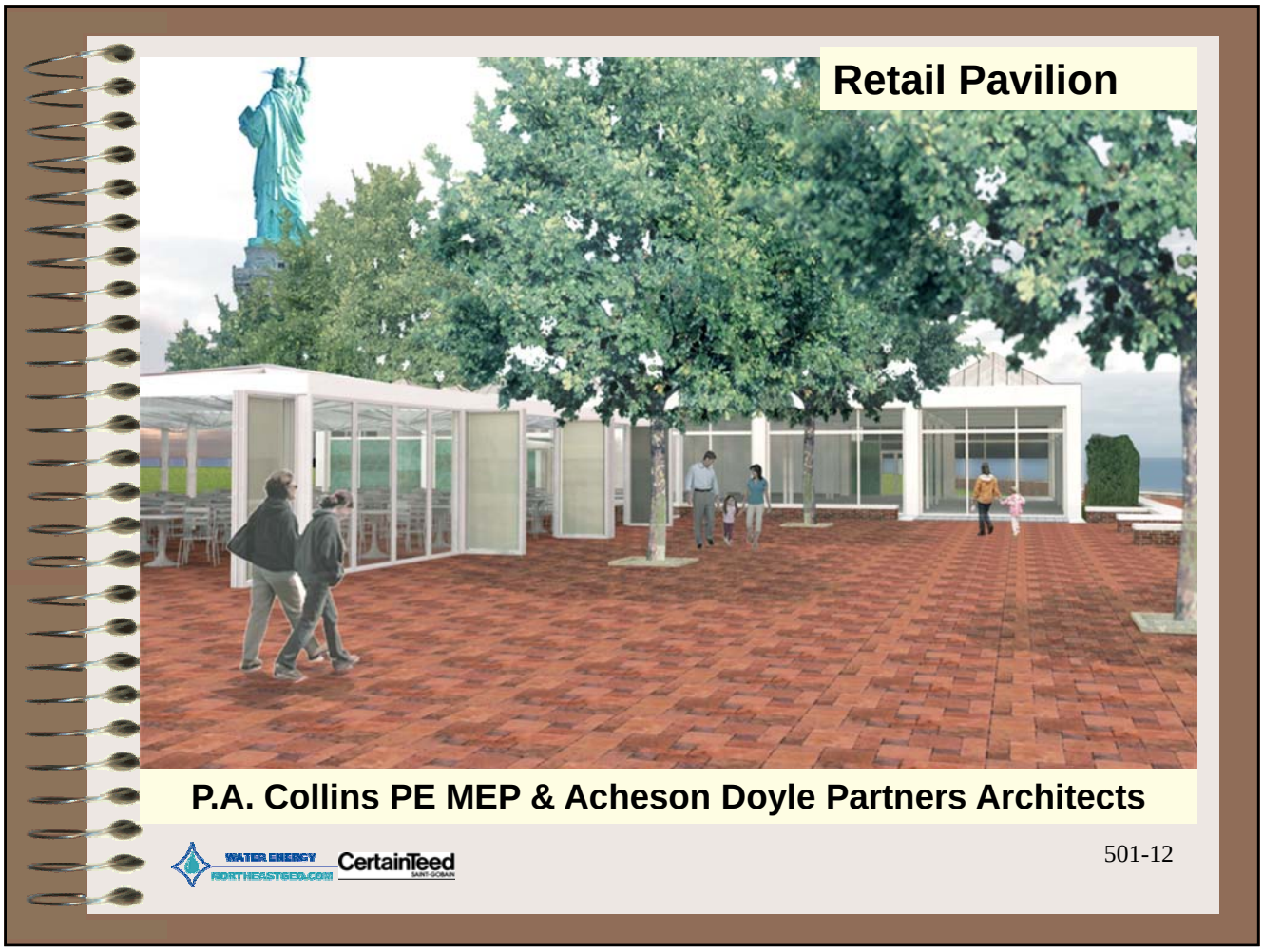
DESIGN & CONSTRUCTION METHODS
GEOTHERMAL
STANDING COLUMN WELLS
&
STATUE of LIBERTY ISLAND

STEVE GROSS, PE, CertainTeed
Valley Forge PA www.certainteed.com

CARL ORIO, CGD, AI, Water Energy Dist Inc
Hampstead NH www.northeastgeo.com

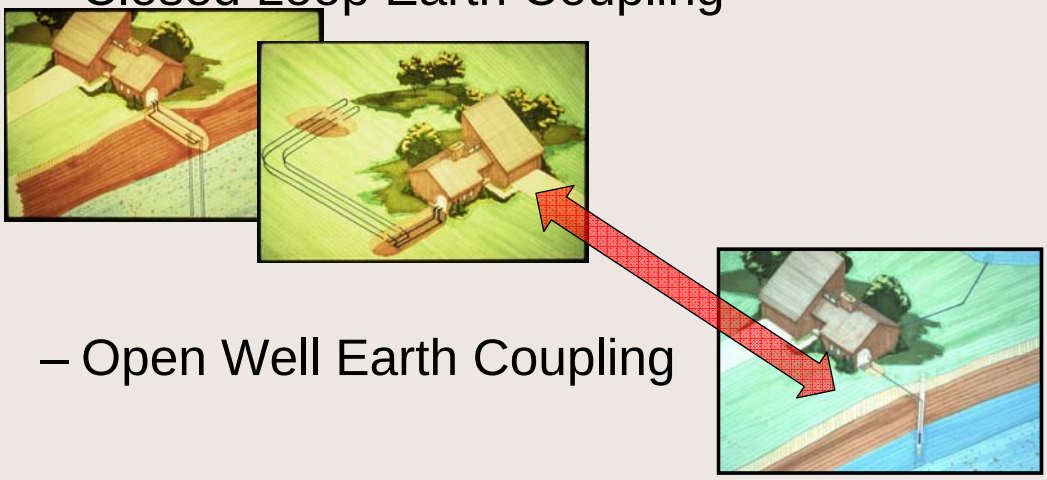
WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

3D-501-11


Retail Pavilion
P.A. Collins PE MEP & Acheson Doyle Partners Architects
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-12

A STANDING COLUMN WELL

- **BRIDGES THE GAP BETWEEN**:
  - Closed Loop Earth Coupling

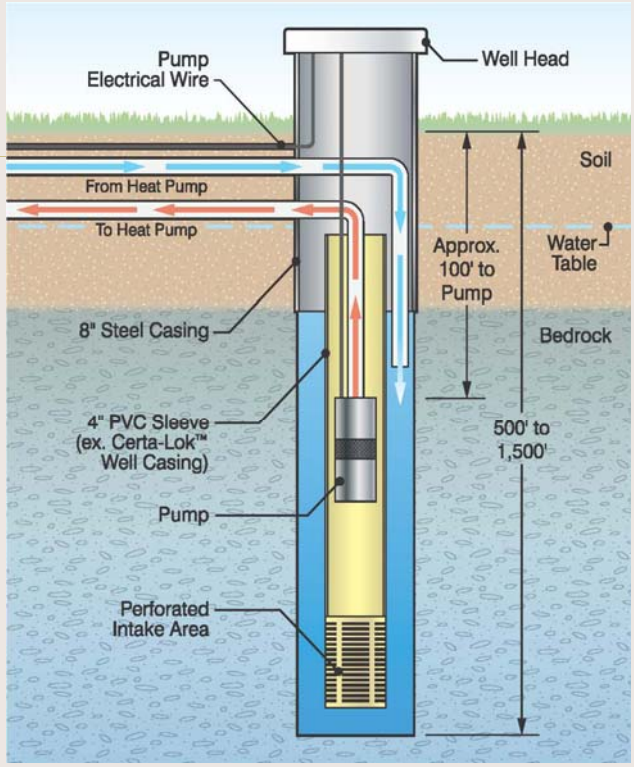


  - Open Well Earth Coupling

501-13

A Standing Column Well is:

- Vertical Re-circulating water filled bedrock bore hole
- Heat Exchange occurs when water is removed from one end of bore and returned to the other end.
- Periodic removal of small amounts of water from the well greatly enhances heat transfer



Courtesy of CertainTeed

501-14

NEAR-SURFACE BEDROCK in the U.S.

- Near-Surface Bedrock is Defined by Competent Rock within ~ 200 ft. of Surface
- Approximately 62% of the Continental U.S. has Near-Surface Bedrock

501-15

GEOTHERMAL HEAT PUMPS

Standing Column Wells

- Higher Capacity
- Higher Efficiency
- Lower First Cost

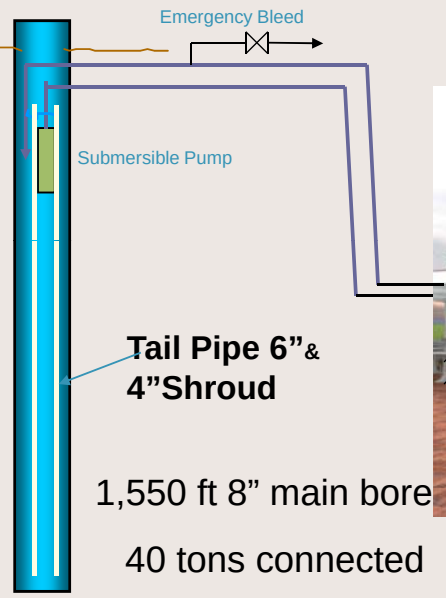
than

a Closed Loop

501-16


Miss LIBERTY Goes GEOTHERMAL
ONE Standing Column Well for a 32 ton LOAD
Courtesy Connecticut Wells, Inc
501-17

LIBERTY ISLAND Pavalion Geothermal

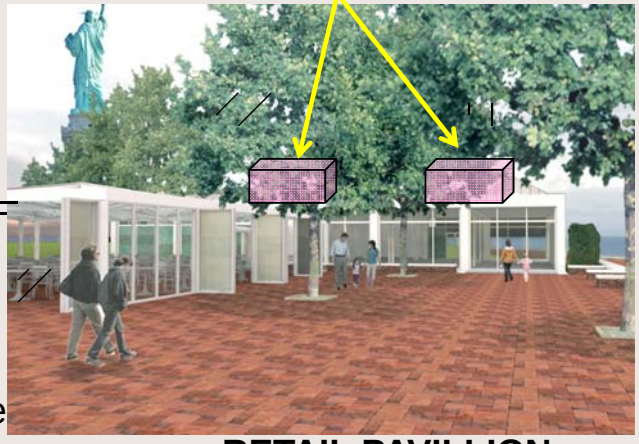


Tail Pipe 6”& 4”Shroud

1,550 ft 8” main bore

40 tons connected

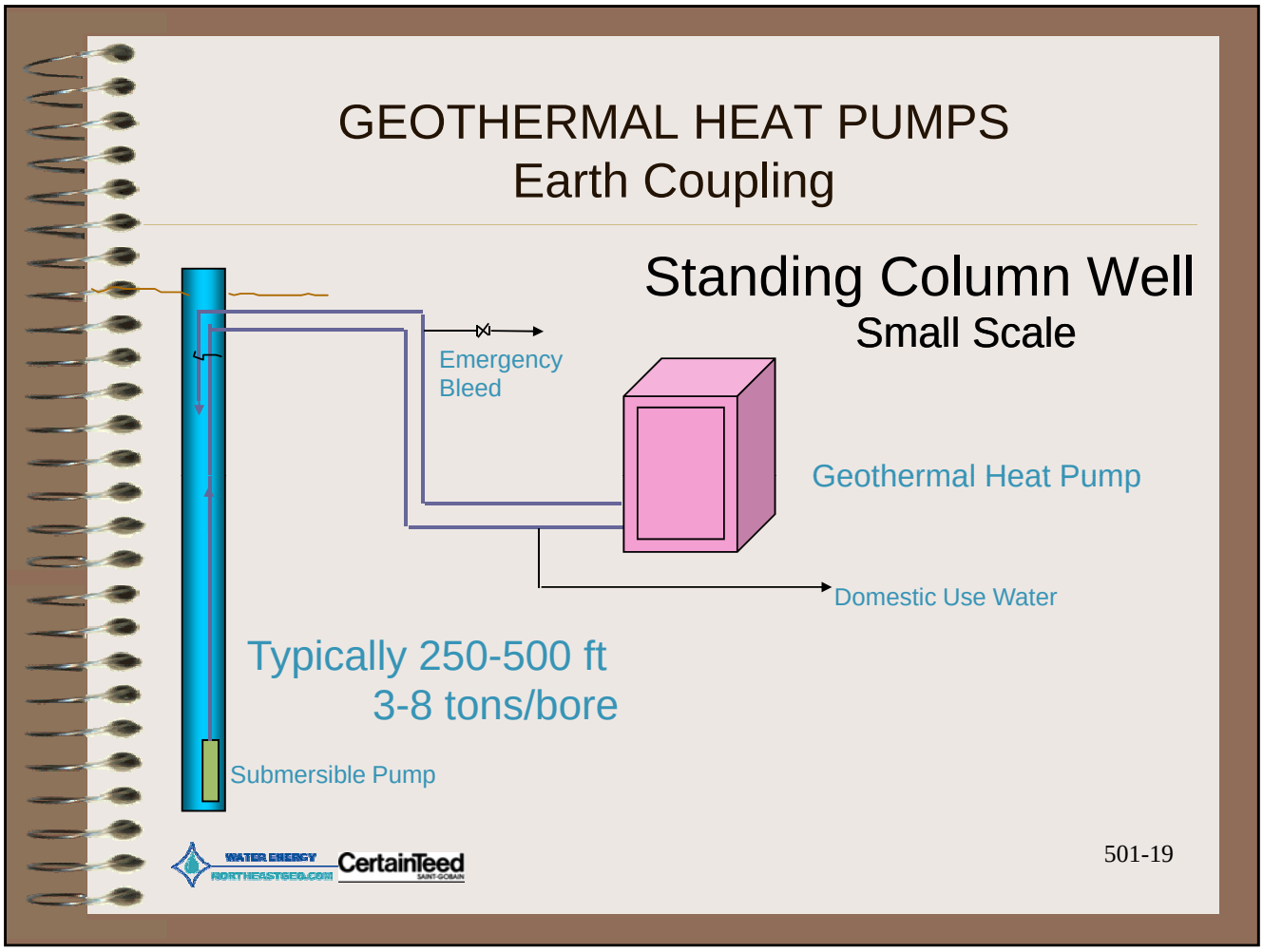
TWO 20 Ton Roof top ClimateMaster Geothermal Heat Pumps

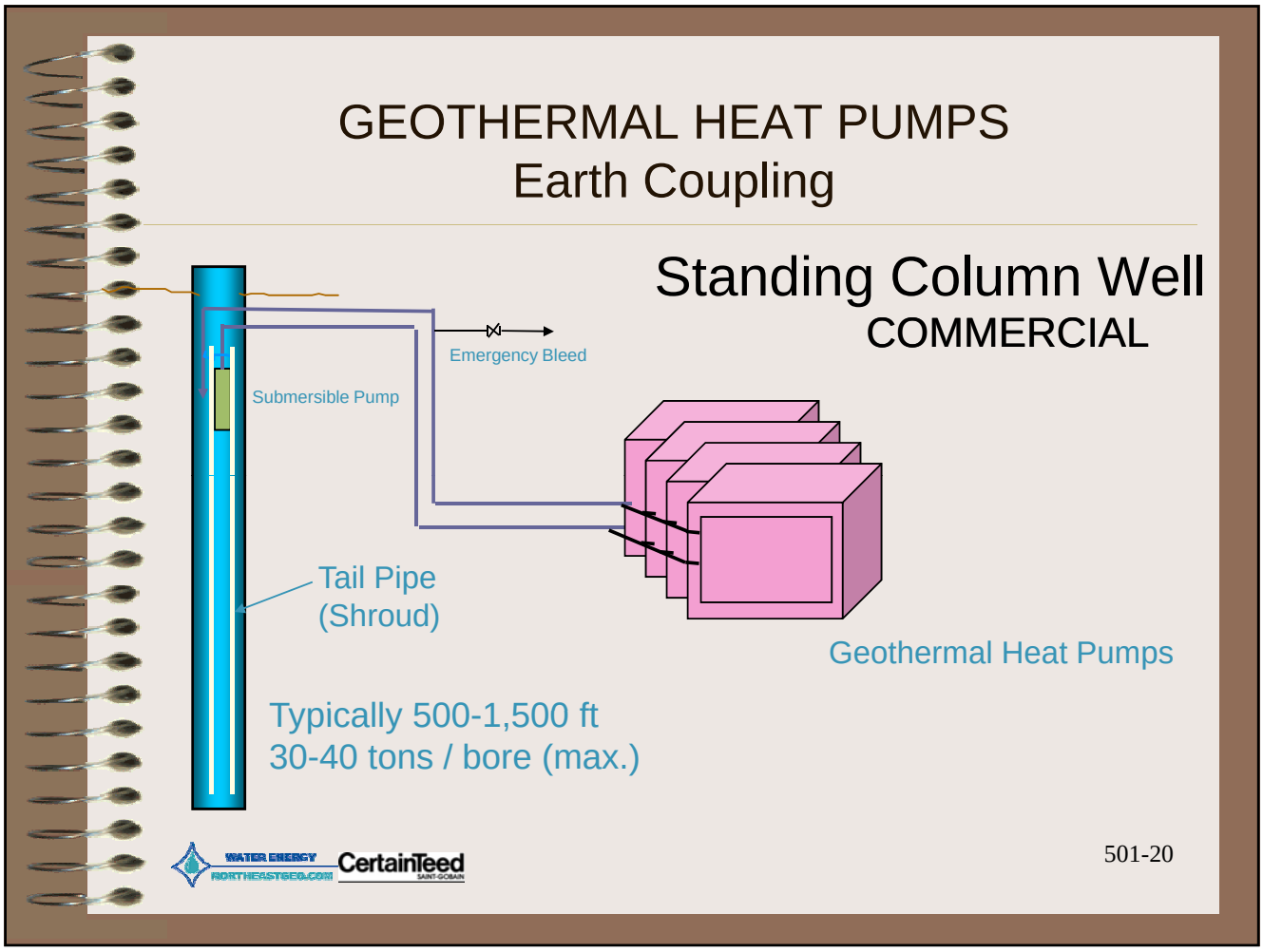


RETAIL PAVILLION

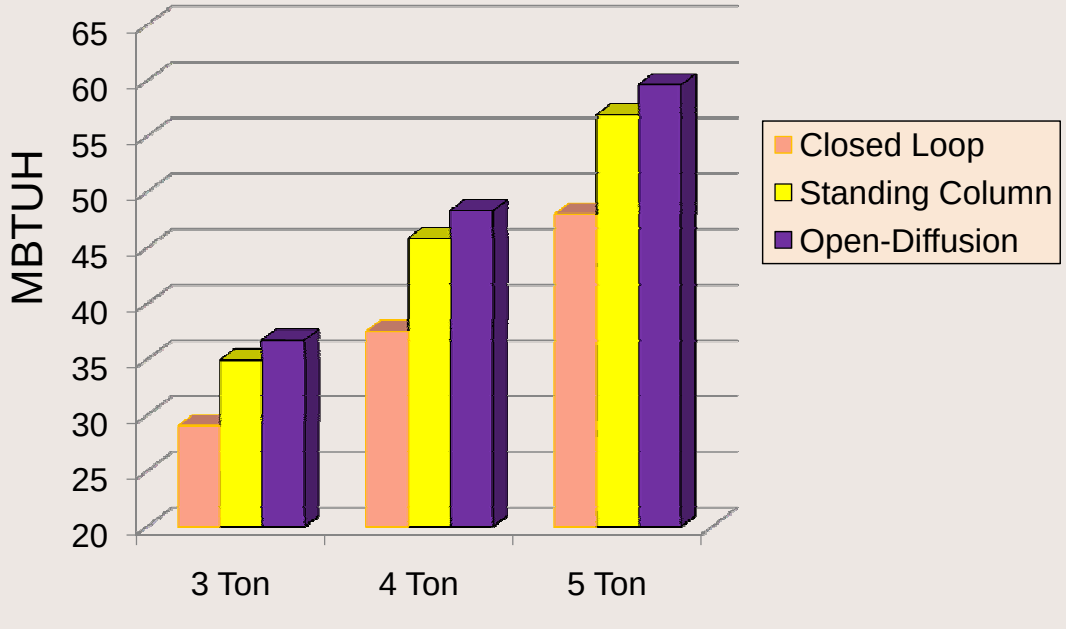
note – NO Intermediate Heat Exchanger for Well Water

501-18


GEOTHERMAL HEAT PUMPS
Earth Coupling
Standing Column Well
Small Scale
Emergency
Bleed
Geothermal Heat Pump
Domestic Use Water
Typically 250-500 ft
3-8 tons/bore
Submersible Pump
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-19

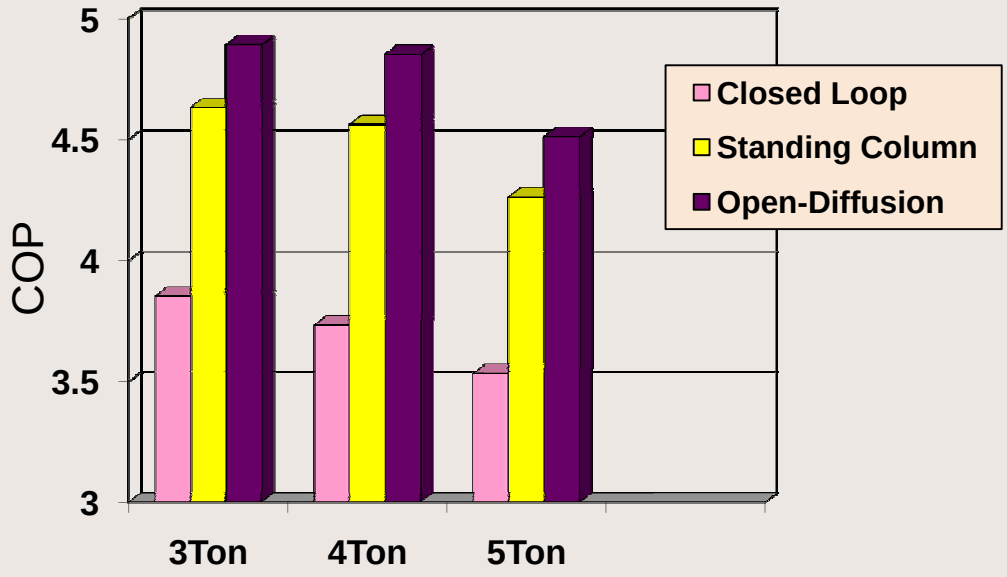

GEOTHERMAL HEAT PUMPS
Earth Coupling
Standing Column Well
COMMERCIAL
Emergency Bleed
Submersible Pump
Tail Pipe
(Shroud)
Geothermal Heat Pumps
Typically 500-1,500 ft
30-40 tons / bore (max.)
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-20

SCW has HIGHER CAPACITY than Closed Loop



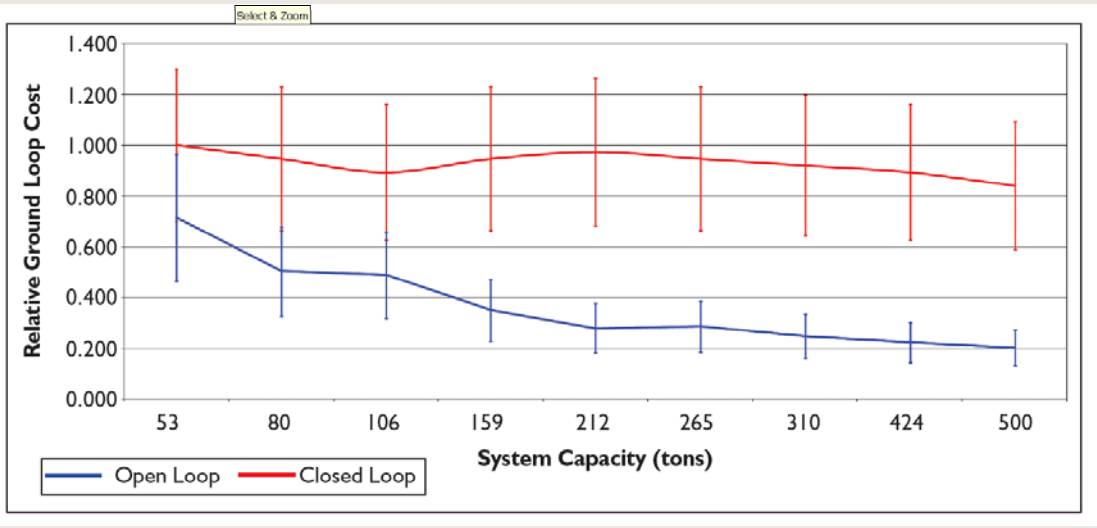
3D-501-21

SCW has HIGHER EFFICIENCY than Closed Loop



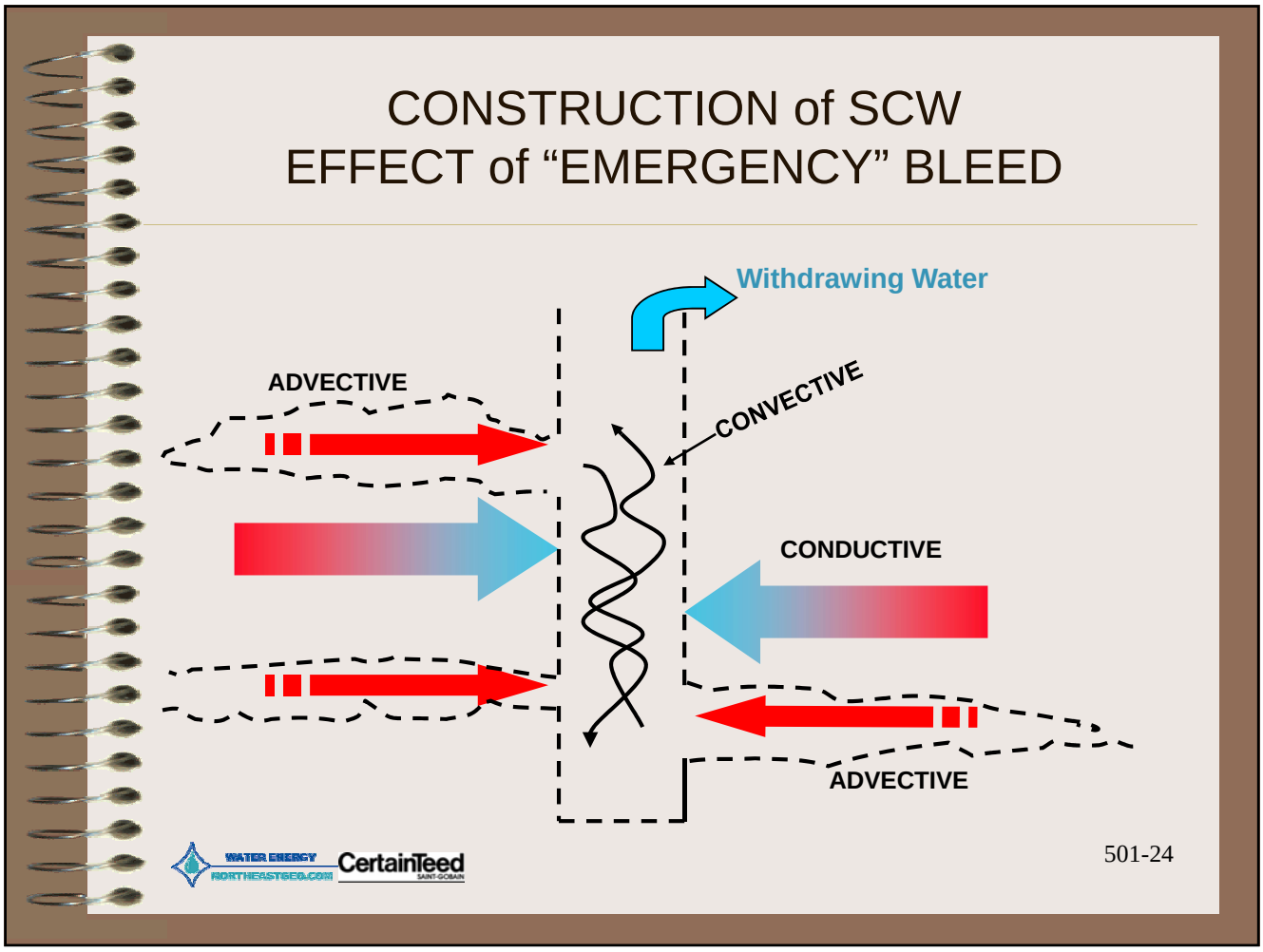
3D-501-22

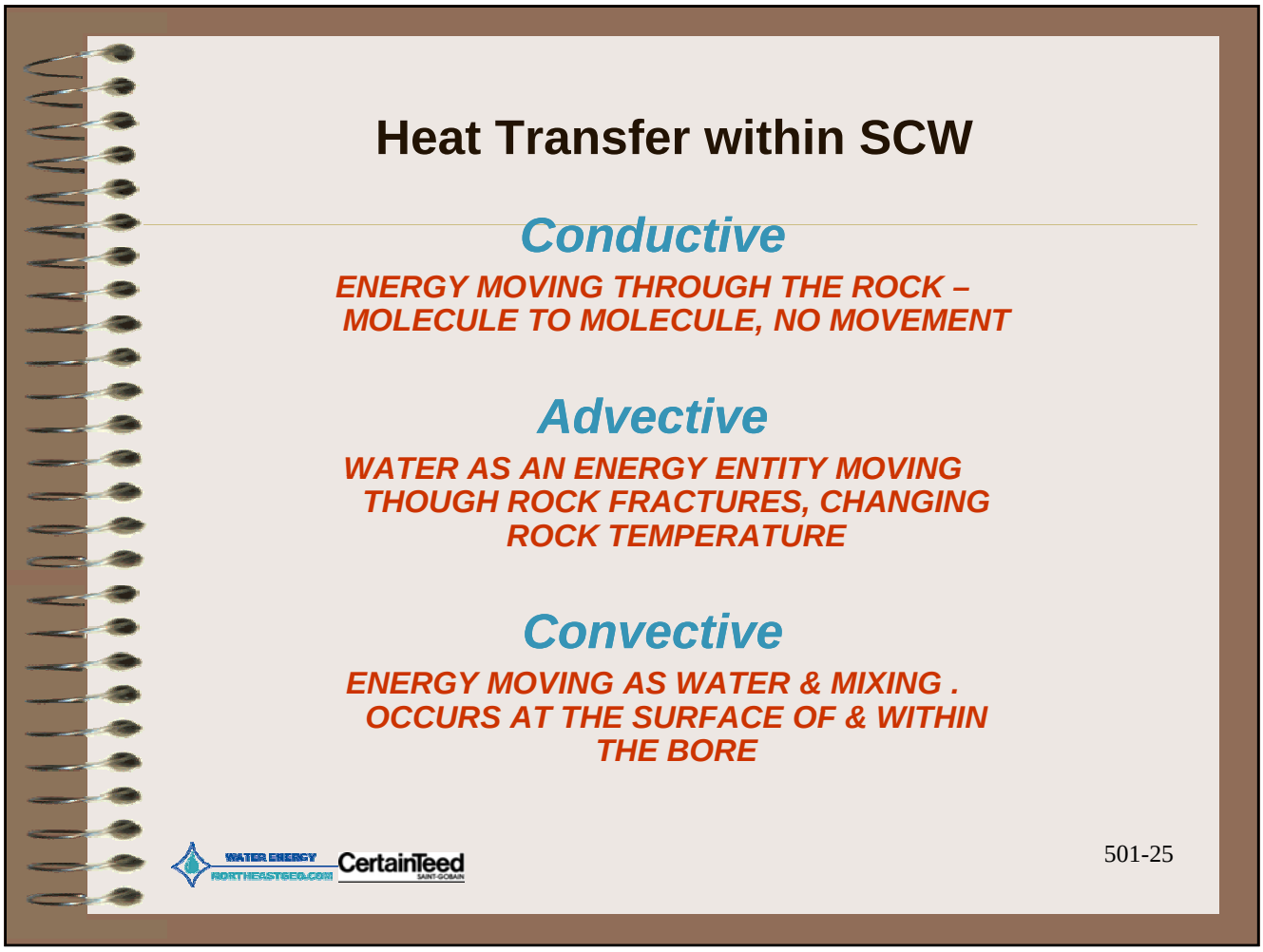
Comparative Cost of OPEN vs. CLOSED LOOP



Rafferty -ASHRAE Journal March 2009

3D-501-23


CONSTRUCTION of SCW
EFFECT of "EMERGENCY" BLEED
Withdrawing Water
ADVECTIVE
CONVECTIVE
CONDUCTIVE
ADVECTIVE
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-24

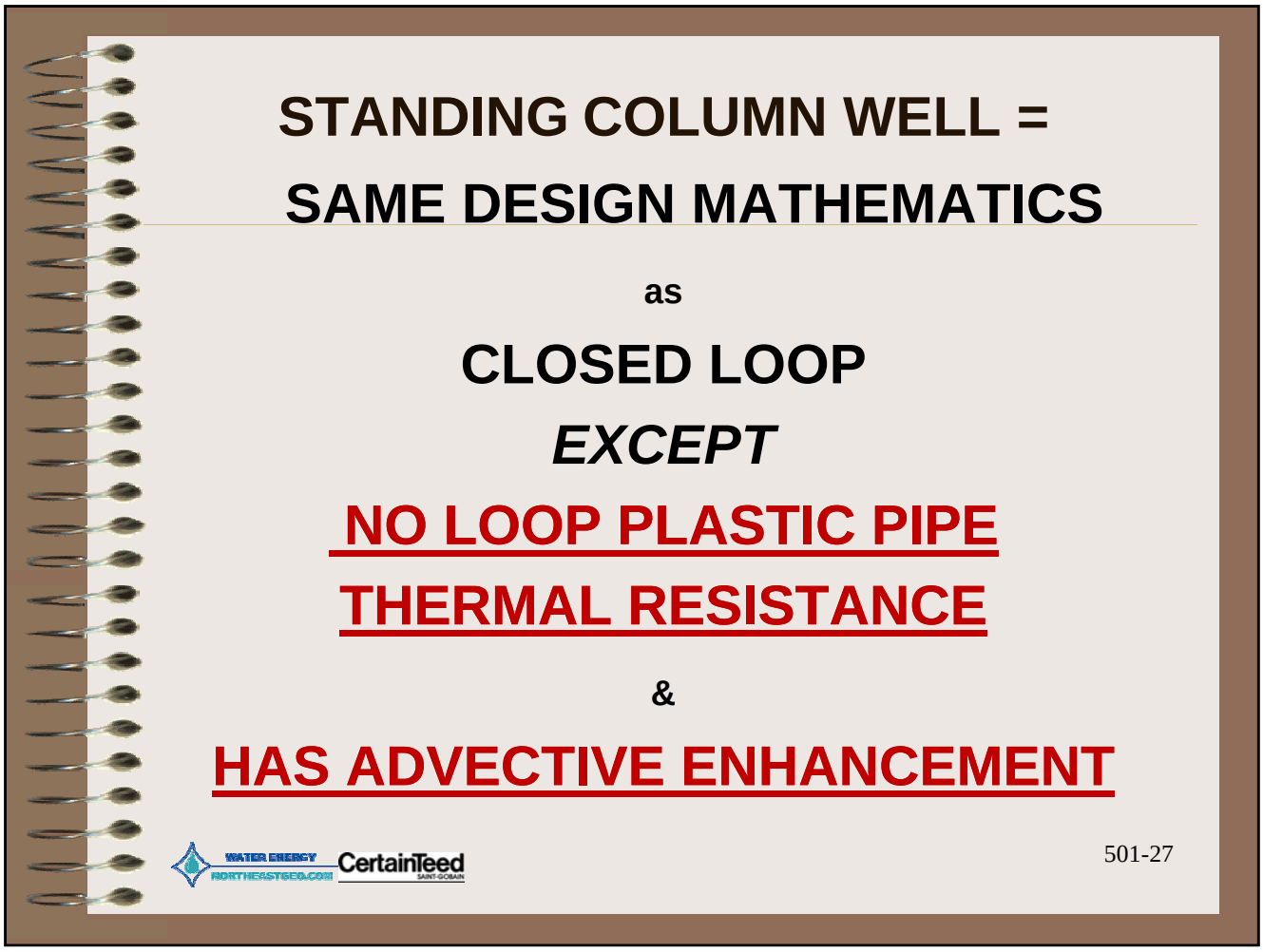

Heat Transfer within SCW
Conductive
ENERGY MOVING THROUGH THE ROCK – MOLECULE TO MOLECULE, NO MOVEMENT
Advective
WATER AS AN ENERGY ENTITY MOVING THOUGH ROCK FRACTURES, CHANGING ROCK TEMPERATURE
Convective
ENERGY MOVING AS WATER & MIXING . OCCURS AT THE SURFACE OF & WITHIN THE BORE
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-25

Designing a **STANDING COLUMN WELL**

1. Heating & Cooling WRITTEN Loads by ASHRAE, Manual-J or N (Commercial)
2. Determine Month by Month Load Profiles
3. Access Long Term Geologic Thermal Effects
4. Issue Preliminary Bid/Drill Specifications
5. Monitor Drilling
6. Report to State/Federal Agencies on Basis of Class V UIC Wells

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

501-26


STANDING COLUMN WELL =
SAME DESIGN MATHEMATICS
as
CLOSED LOOP
EXCEPT
NO LOOP PLASTIC PIPE
THERMAL RESISTANCE
&
HAS ADVECTIVE ENHANCEMENT
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-27

STANDING COLUMN WELL SAME DESIGN MATHEMATICS as CLOSED LOOP

SAME INPUTS

T = Soil Temp - deg

Q'= Heat Transferred - btu/hr/Lft

r = Radial Dist from Line - ft

K_s = Thermal conductivity - btu/ft-deg

a = Thermal Diffusivity - sqft/hr

ρ = Rock Density - lb/cuft

C_p = Rock Specific Heat = btu/lb-deg

t = Heat Pump Run time - hours

B = Integration Variable

501-28

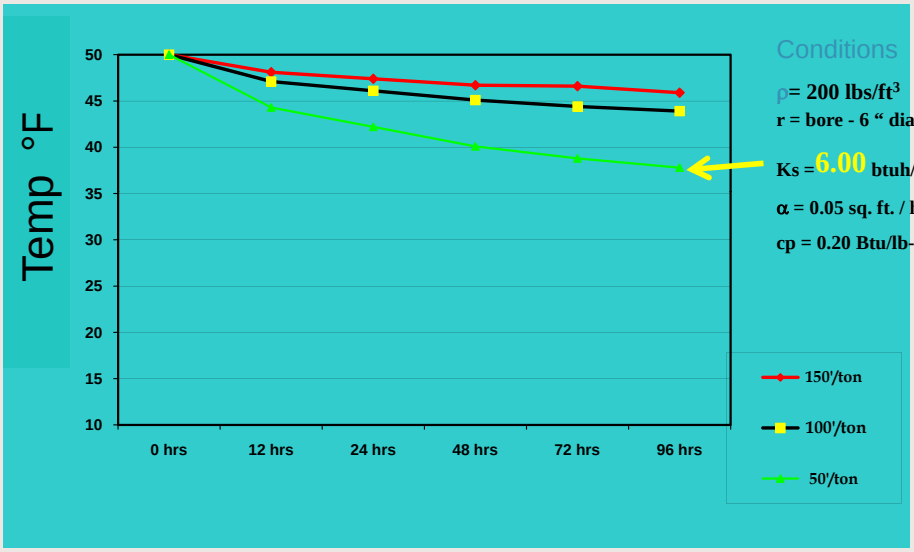
STANDING COLUMN WELLS

Typical **NO BLEED** RESULTS

501-29

STANDING COLUMN WELLS

Typical **10% BLEED** RESULTS



501-30

Specification Bid/Drill

Consider a Drilling of Test Well?

- The “First Well” is the “Test” Well

  Drill it as if it were the ***first*** well, not a test well to be abandoned. Drilled as a water supply well.

  From that well determine:

  – ***Rock Characteristics***

  – ***Well Yields & Locations***

  – ***Ambient Static***

  – ***Draw Down Statics****

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

501-31

LIBERTY - Standing Column Well

- **Depth** 1,550 feet
- **Over burden** -17 feet
- **Water Zones** -600 to 1,300 feet
- **Bedrock Schist** ~150 #/ft^3
- **Ambient Static** - 12 feet
- **Drawdown Static** - 183 feet*
- **Water Quality** - Brackish

Cu-Ni HX Required

501-32

What it Takes

- **Capability of the Rig**
  - Pull Back
  - Air Compressor
- **Capability of Driller**
  - Deep Bore Experience

- **Bore Rod**
  - -1,500 feet
- **Handling of Water**
  - -Temporary Run Off

Liberty Island

501-33

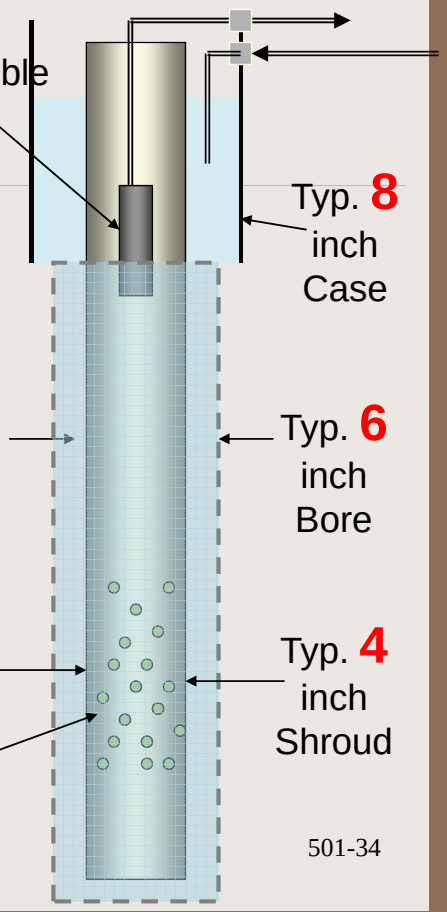
TYPICAL SCW

- Lightweight (PVC) plastic tube to bottom of bore.
  (e.g. CertainTeed Certa-Lok ™)
- Allows pump, riser pipe and wires to be shortened
- Pump at top for ease of service

An

8 – 6 – 4

SCW



501-34

Shroud

- **8-6-4-** Residential & Light Commercial

  Typically up to 80 gpm pumping –
  typical 2-8 gpm bleed –

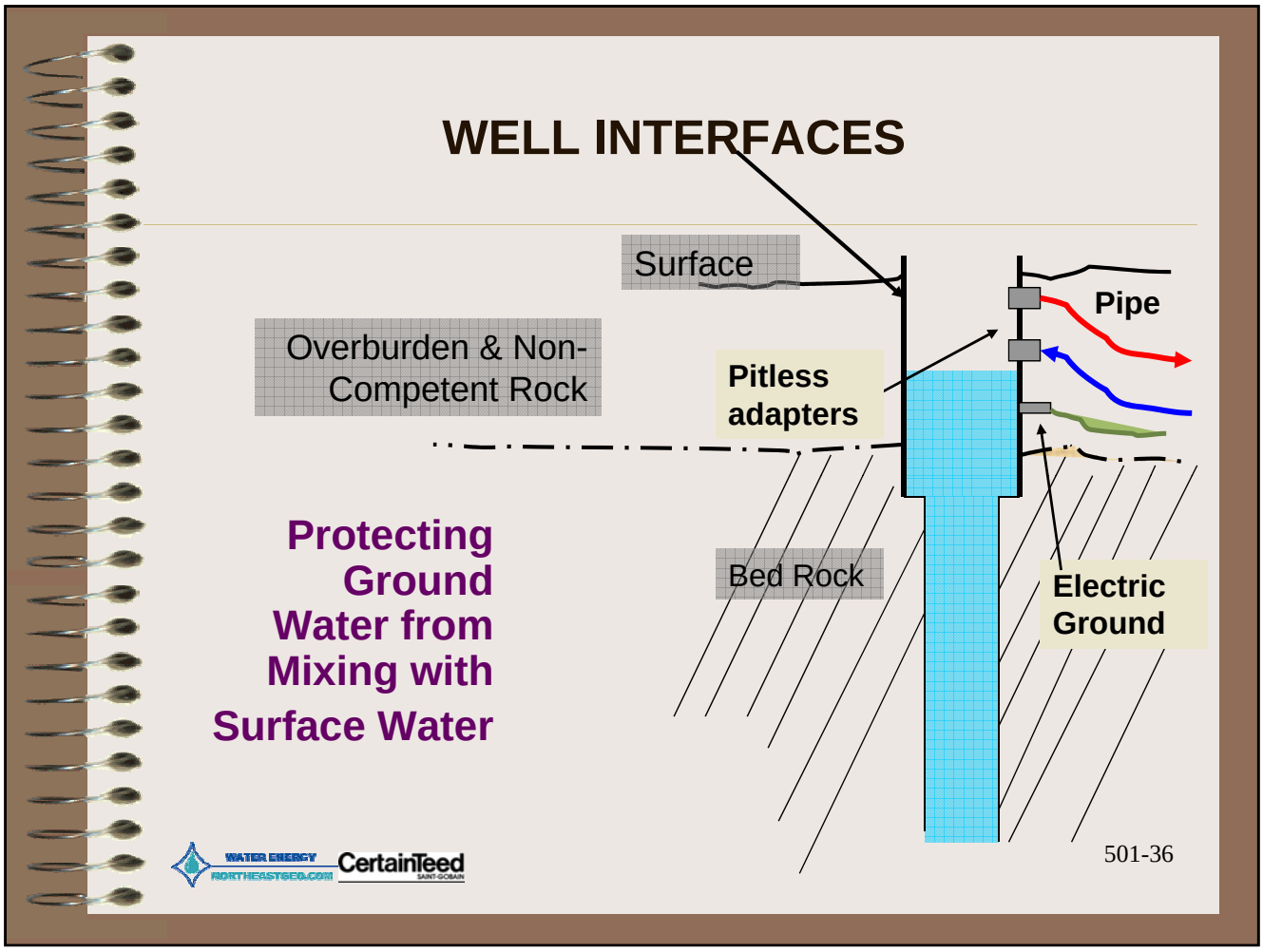
  4” submersible pump

- **10-8-6** – Commercial

  Typically up to 130 gpm –
  13-35 gpm bleed

  6” Submersible Pump

501-35


WELL INTERFACES
Surface
Overburden & Non-Competent Rock
Pitless adapters
Pipe
Bed Rock
Electric Ground
Protecting Ground Water from Mixing with Surface Water
501-36

CASING OPTIONS

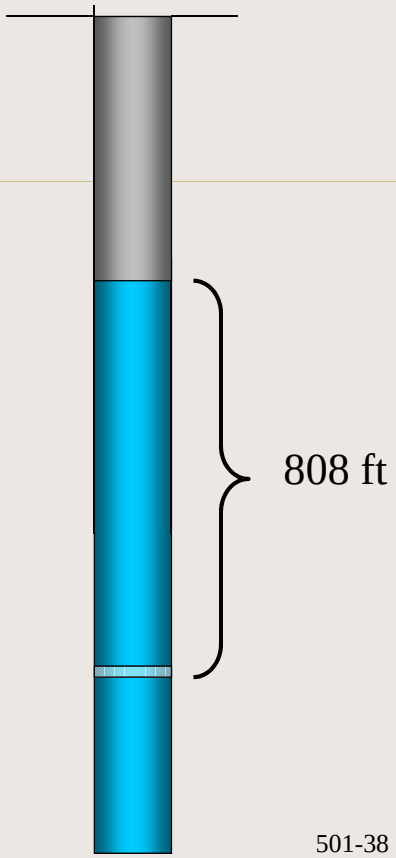
STEEL – 8 inch casing 19#/ft minimum and 26#/ft desirable on large commercial

PVC –recommended if water has conductivity greater than 3,000-5,000⁺ µmho/cm (10% sea water)

501-37

EXCESS WATER

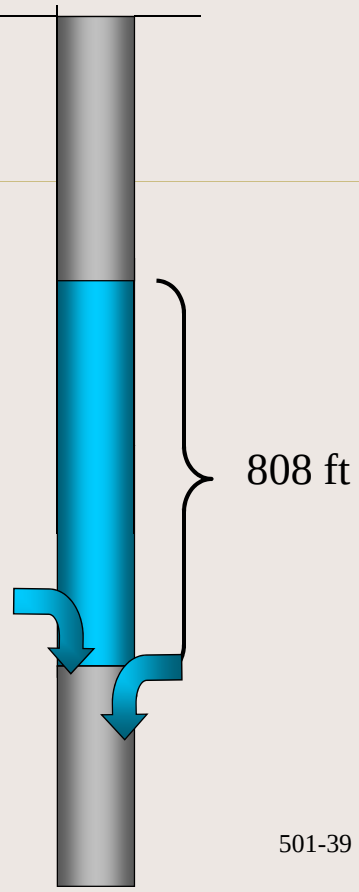
- Typical On-Rig Compressor = 350 psig
- Water Lift = 808 feet
- How to drill a 1,500 foot bore?



501-38

HANDLING EXCESS WATER

- Auxiliary Compressor
  >350 psig
- Temporary Dewatering
- Skill – Staying Ahead of inflow water



501-39

FIRST WELL IS THE "TEST" WELL

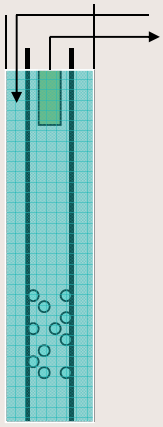
- Logging
- Draw Down Test at Bleed Rate
- Taking Rock Spoils Samples
  - Typical 3-4 ozs of Spoils for Density Analysis

501-40

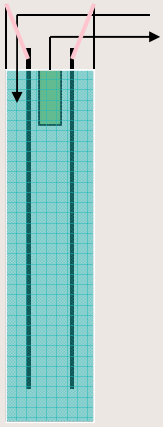
TYPES OF SHROUDS USED

The CASING, SUPPORT & ADAPTERS

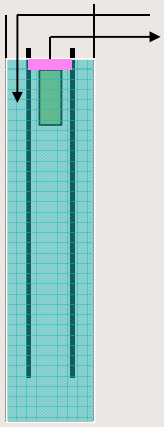
Bottom Set



Hanging



Supported



501-41

Shroud Connections

GLUE & SCREW

501-42

Shroud, Riser & Drop Connections

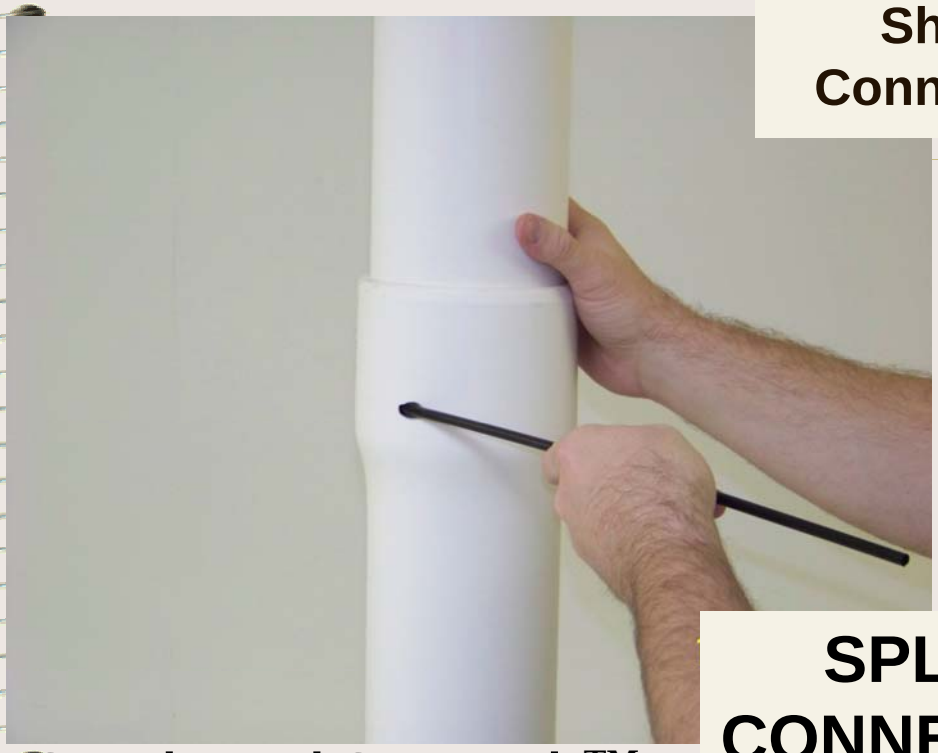
SPLINE CONNECTION

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN Certa Lok™

501-43


Shroud Connections
SPLINE CONNECTION Clean & Align
WATER ENERGY NORTHEASTGEO.COM
CertainTeed
Certa Lok™
501-44

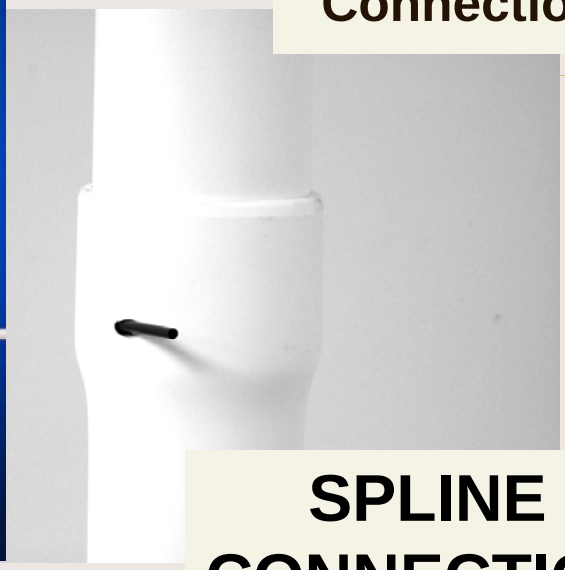
Shroud Connections



CertainTeed Certa Lok ™

SPLINE CONNECTION Inserting

Shroud Connections



Certa-Lok Riser (Drop Pipe) Connection

SPLINE CONNECTION Connected

WATER ENERGY NORTHEASTGEO.COM CertainTeed Certa-Lok™

501-46

Shroud, Riser & Drop Connections

	GLUE & SCREW	SPLINE
• FREE of GLUE VOC	NO	YES
• DIS-ASSEMBLY	NO	YES
• ASSEMBLY	SLOW	FAST
• GLUE SENSITIVITY	Temperature	

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

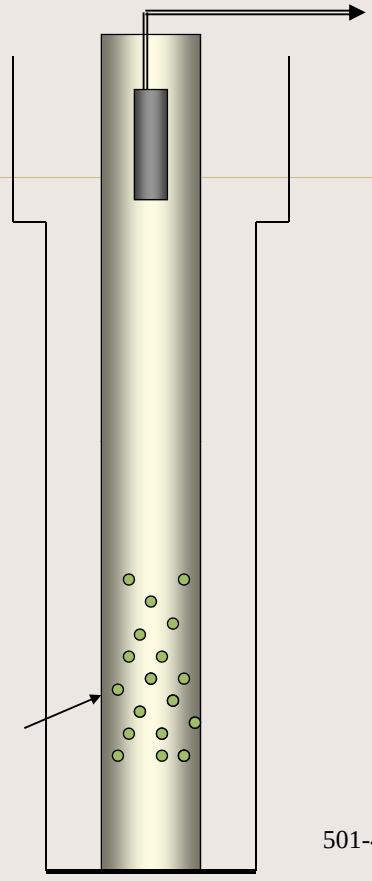
501-47

Shroud DIFFUSION

***8-6-4** 120 1 INCH HOLES OVER 40 FEET*

***10-8-6** 180 1 ¼ INCH HOLES OVER 60 FEET*

20'-60' or 80'FROM BOTTOM



501-48

Shroud

TYPICAL

8-6-4

DIFFUSER (4” Shroud)

501-49

COMMERCIAL SUBMERSIBLE PUMP SELECTION

Pump Rate & Pump Head:

- Total Dynamic Head (TDH)
  - Static Lift – at bleed rate*
  - Riser Pipe PD
  - Both Offset Pipes PD
  - Solids Trapper PD, If used
  - Building Riser, if used
  - Heat Pump HX PD
  - Misc. Trim PD
  - Drop Pipe PD
  - Suction Effect –PD
- **TYPICAL 3 - 10 Hp Pump**

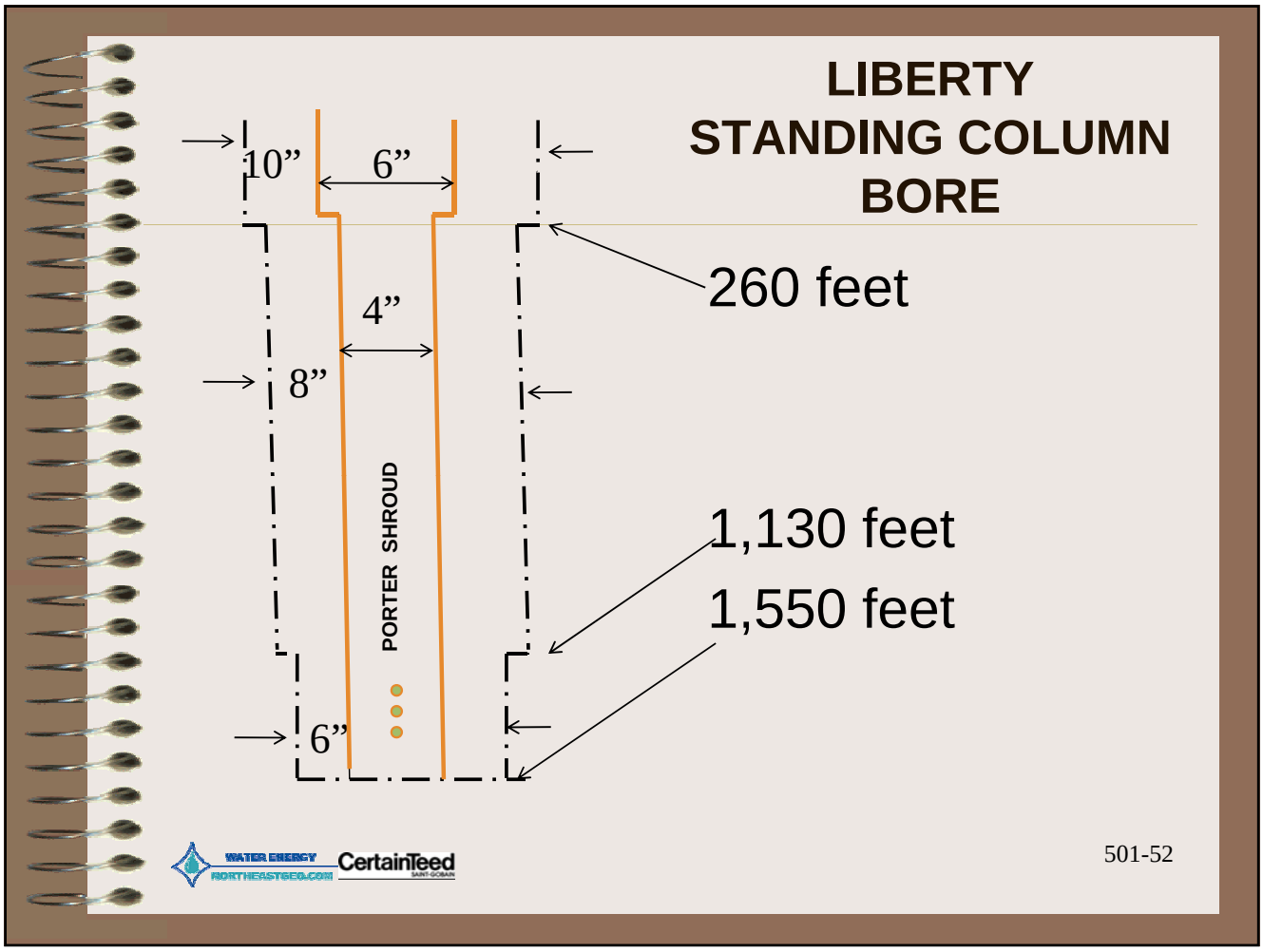
Liberty - 132 gpm@360 ft TDH = 20Hp

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

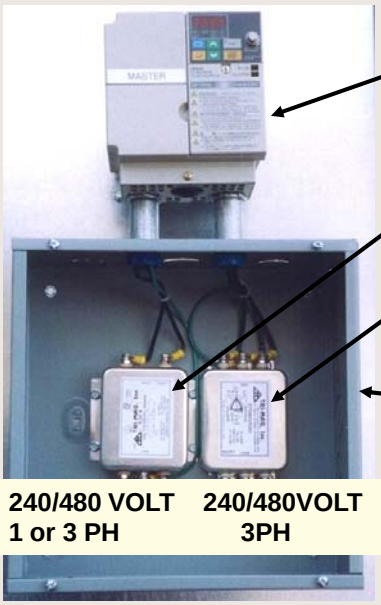
501-50

6” Shroud to 4” Shroud an Unusual Requirement Easily Met with the Spline Connection Method

501-51


LIBERTY
STANDING COLUMN
BORE
10”
6”
4”
8”
6”
PORTER SHROUD
260 feet
1,130 feet
1,550 feet
WATER ENERGY
NORTHEASTGEO.COM
CertainTeed
501-52

Variable Frequency Drive



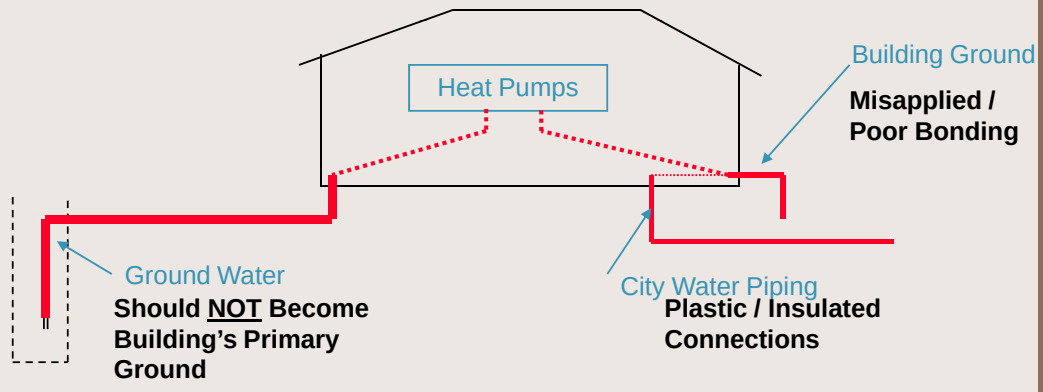
- **VFD** Must Have:
  - Power Service RFI **FILTER**
  - Well Pump Cable
  - **REACTOR**
  - Programmed for ≥30 Hz.
  - Over Pressure Inhibit
  - Electric Ground Plane Connected to HP, Well Casing & Well Pump
  - Shielded Load Cable

WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

501-53

IMPORTANCE of EARTH BOND

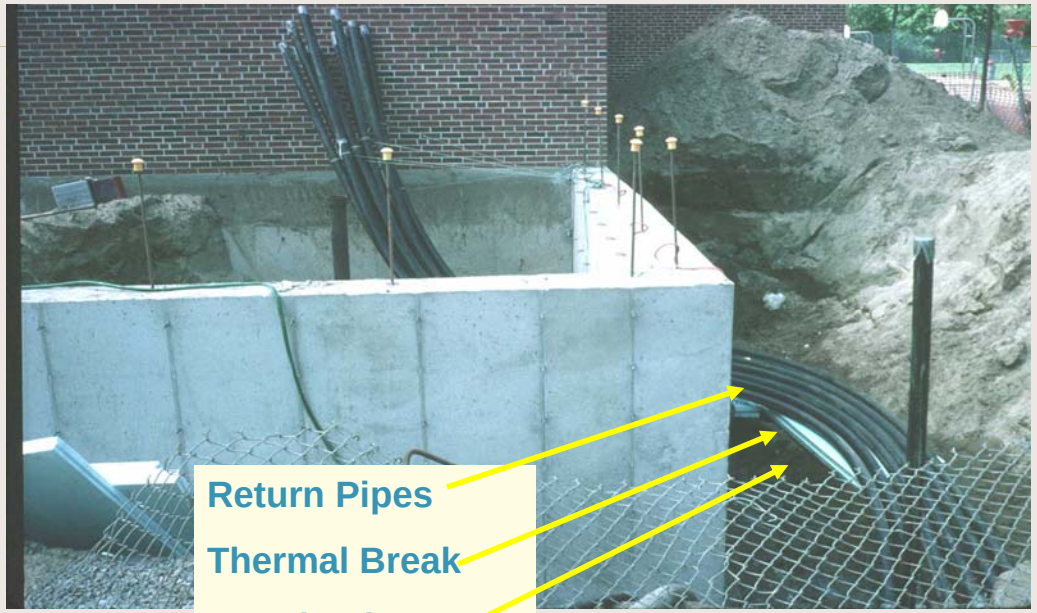
- EARTH BOND - National Electric Code Section 1999
  - "shall be grounded…(when).located in a wet or damp location and not isolated" -*section 250-110(2)*
  - "….non-current-carrying metal parts of equipment and enclosures….shall be grounded regardless of voltage." - *section 250-112(4)(a)*
  - "The (grounding) connection shall be made by bonding the equipment grounding conductor to the grounding electrode conductor" - *section 250-130(a), (b)*



501-54

RETROFIT SCHOOL

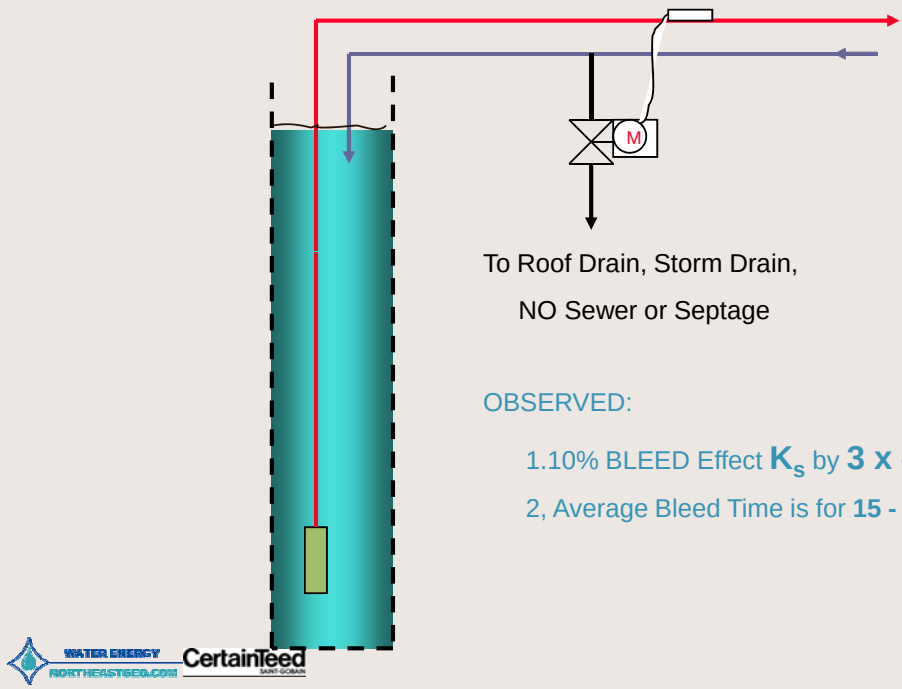
Six SCW Piping Typical Layout 3” HDPE Pipe



WATER ENERGY NORTHEASTGEO.COM CertainTeed SAINT-GOBAIN

501-55

CONVECTIVE/ADVECTIVE BLEED SYSTEM



To & From Heat Pumps

To Roof Drain, Storm Drain,
NO Sewer or Septage

OBSERVED:

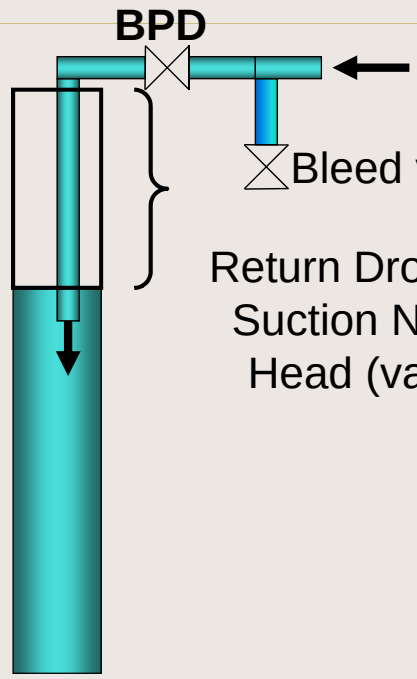
1.10% BLEED Effect K_s by **3 x -**

2, Average Bleed Time is for **15 - 60** minutes

501-56

SUCTION EFECT on DROP PIPE

- **Suction Drop can be as much as a complete vacuum, i.e. 34 feet**
- **Insure return to well line has adequate back pressure devices (BPD) to permit use of bleed circuit**



Return Drop Pipe = Suction Negative Head (vacuum)

501-57

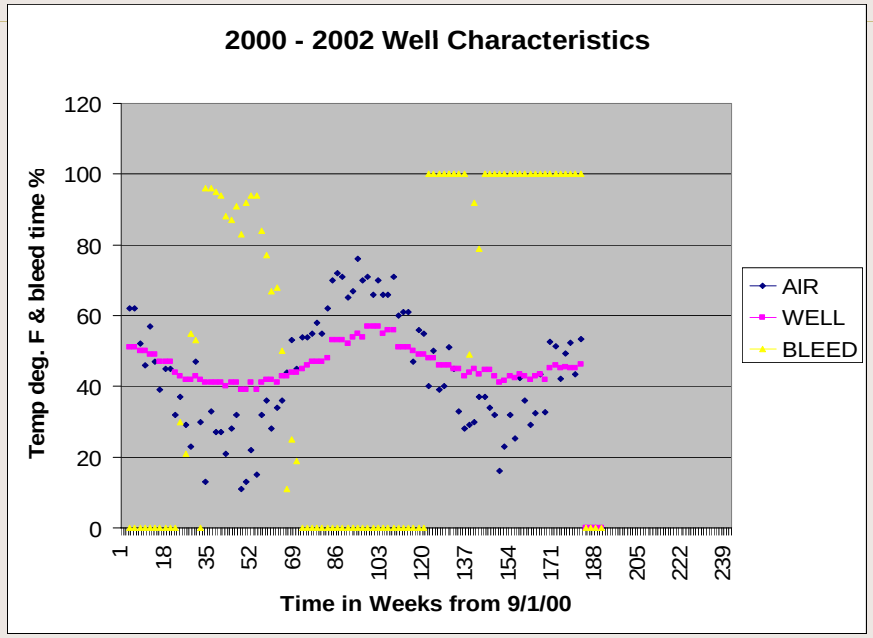
REGULATORY

CLASS V Underground Injection Control (UIC)

- Class V is a re-injection of “non-contact” drinking quality water to the earth via injection well(s)
- Re-injection of Heat Pump water is specifically allowed as a “non-contact cooling water” – type 5A7 under Federal & many State Regs.
- Varies from State to State – many States do not require any registration or permits for residential re-injection
- Usually requires registration for medium installations & permit information for large commercial & SOME LARGE RESIDENTIAL FOR DOUBLETS

501-58

Effects of Low Bleed Rate – 2 Years Raymond Maine

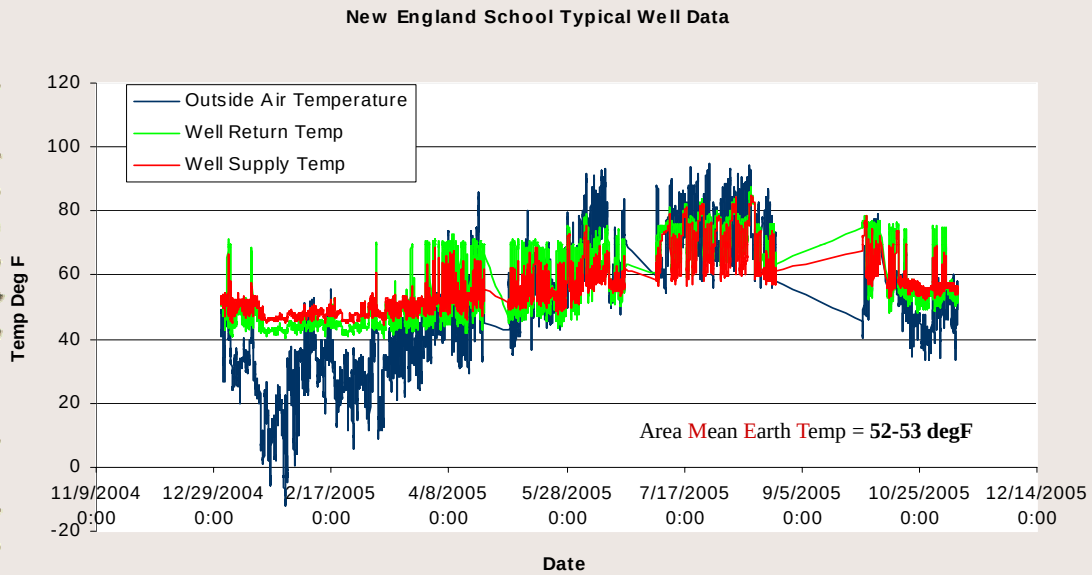


- Total 7 tons, Low Production Well, 600ft SCW
- First Year, **5%** Bleed when Required
- Second Year, **5%** Bleed winter months when HP is On

501-59

Most Recent Standing Column Well Performance

note: After Ten Years MET is Retained



ASHRAE Transactions 006-06

501-60

WHAT to EXPECT from a PROPER DESIGN

- ***Relatively Small Annual Change in Entering Water Temperature***
- ***30-40 heating tons per 1,500 foot Bore (5%-10% Bleed)***
- ***Higher Heat Exchange with Higher Bleed Rates***

501-61

A PROPER DESIGN

AND

A

HAPPY

CUSTOMER

501-62

GEOTHERMAL HEAT PUMPS
Earth Coupling

Standing Column Wells

High Capacity

Lower First Cost

Higher Efficiency

501-63