PSU Burrowes Rd Steam Manhole Repair

Presented by:

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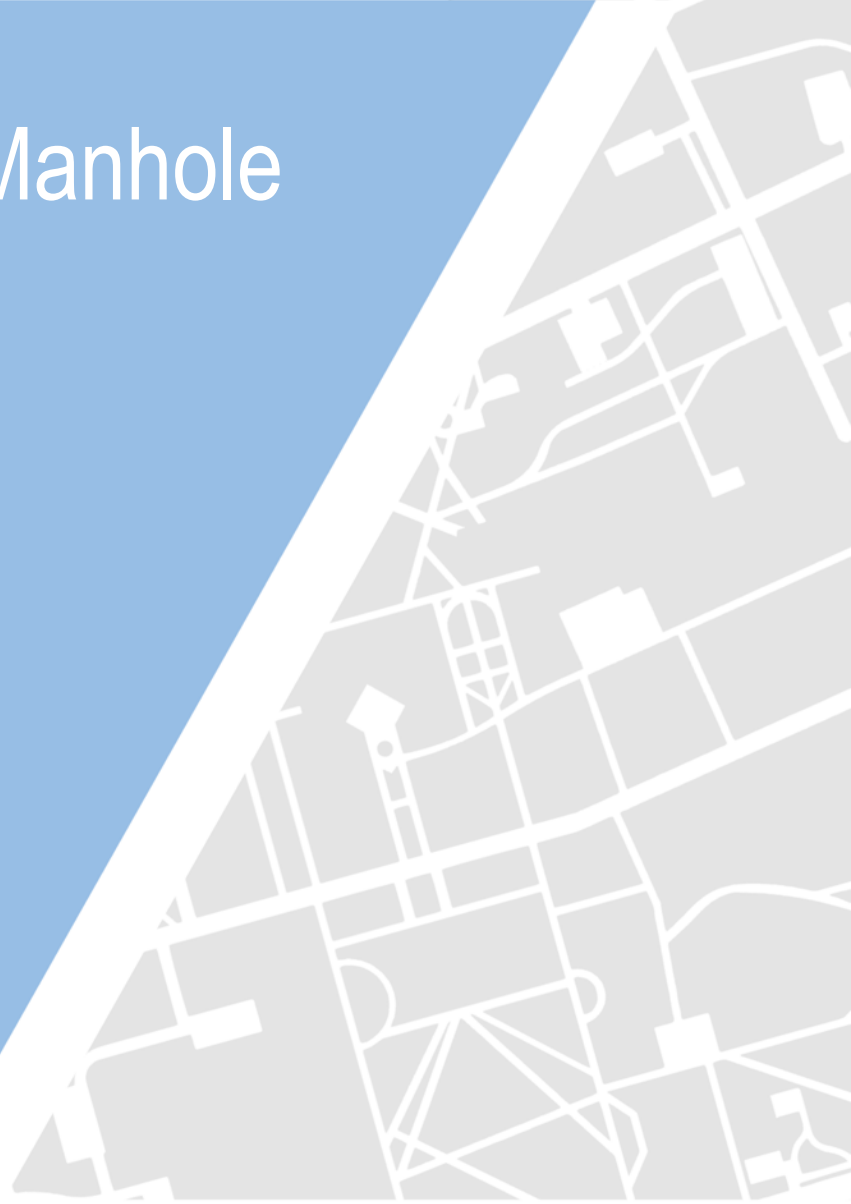
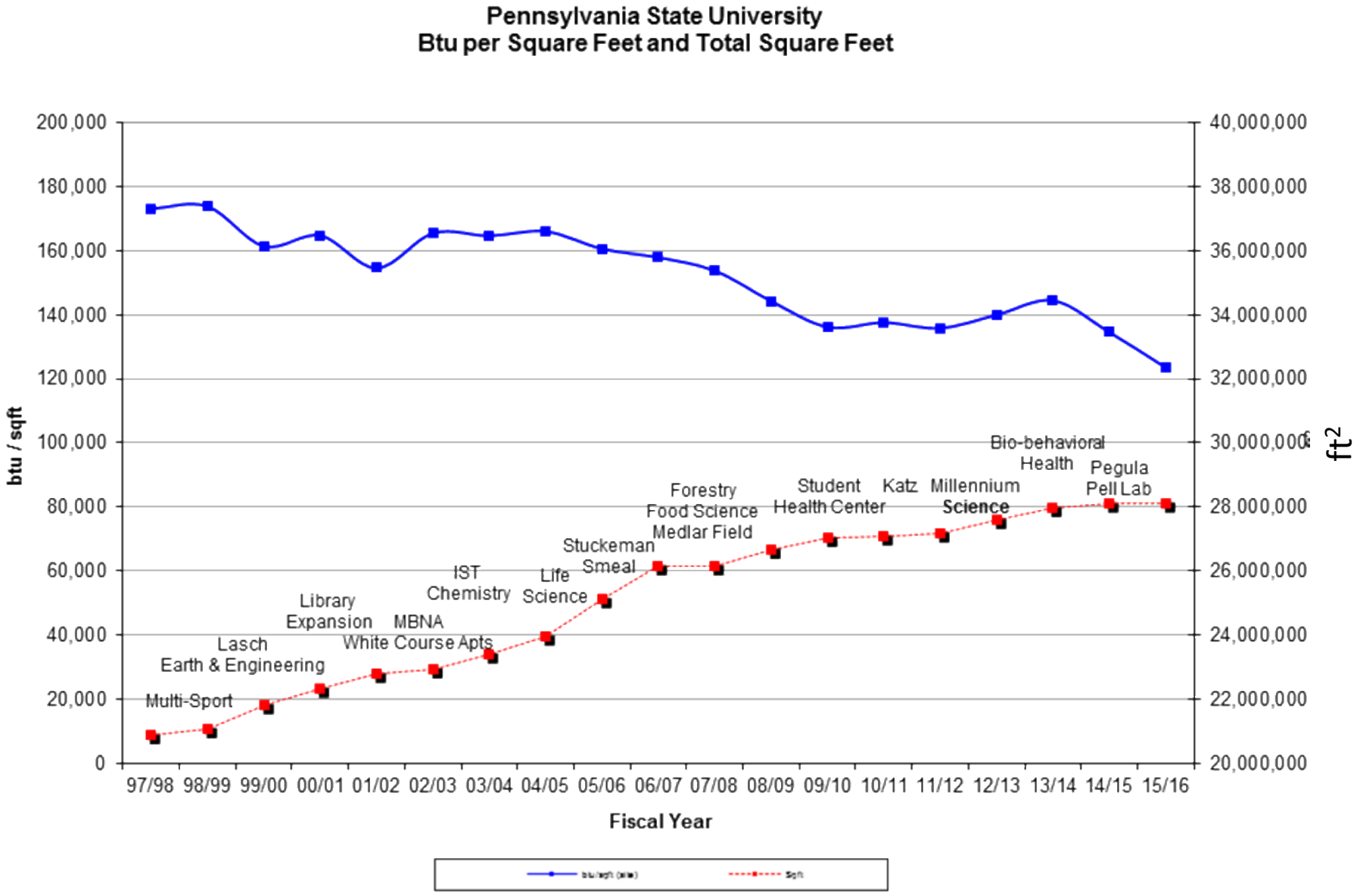


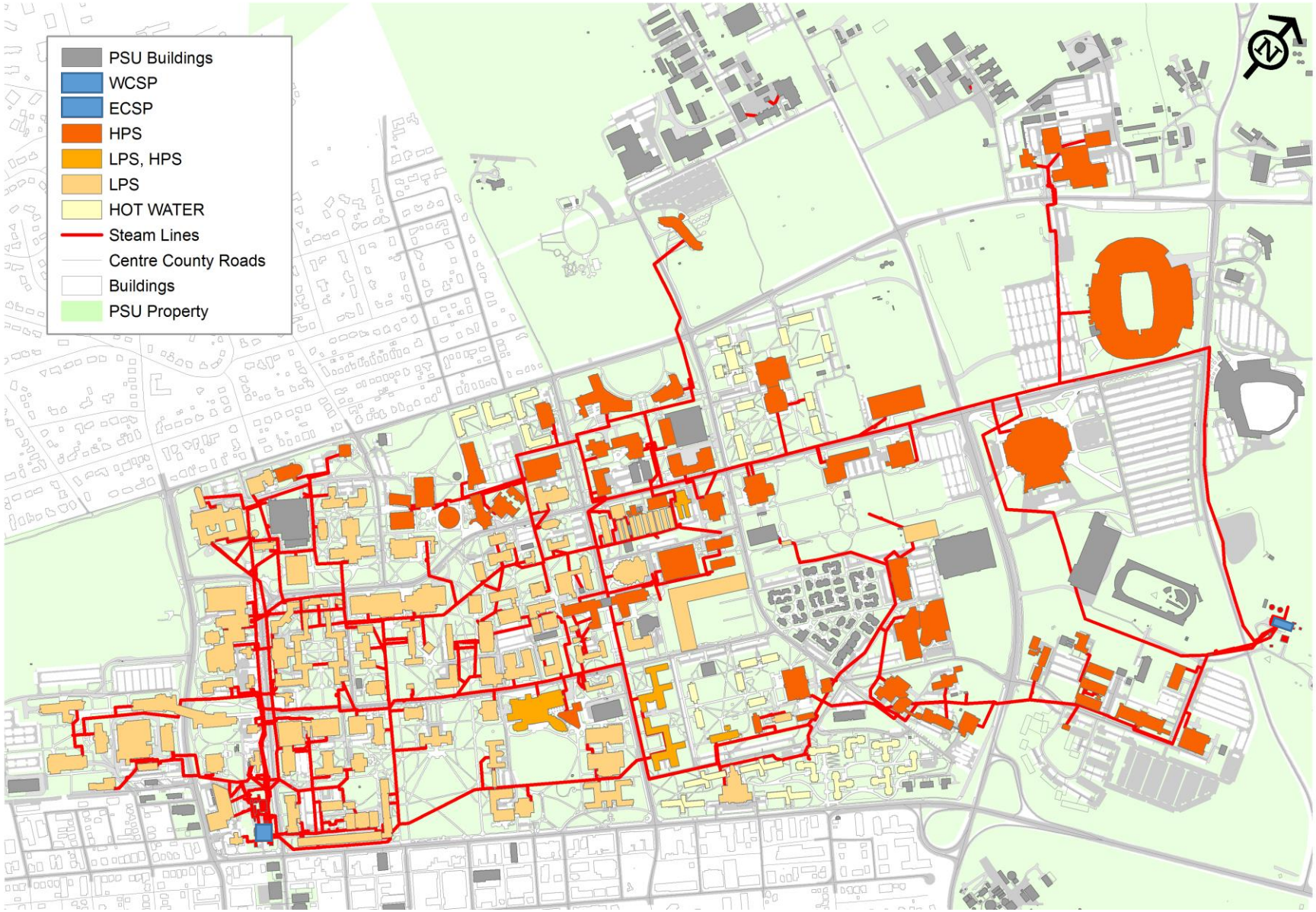
International District Energy Association
Campus Energy 2017
February 20-24, 2017

Penn State University

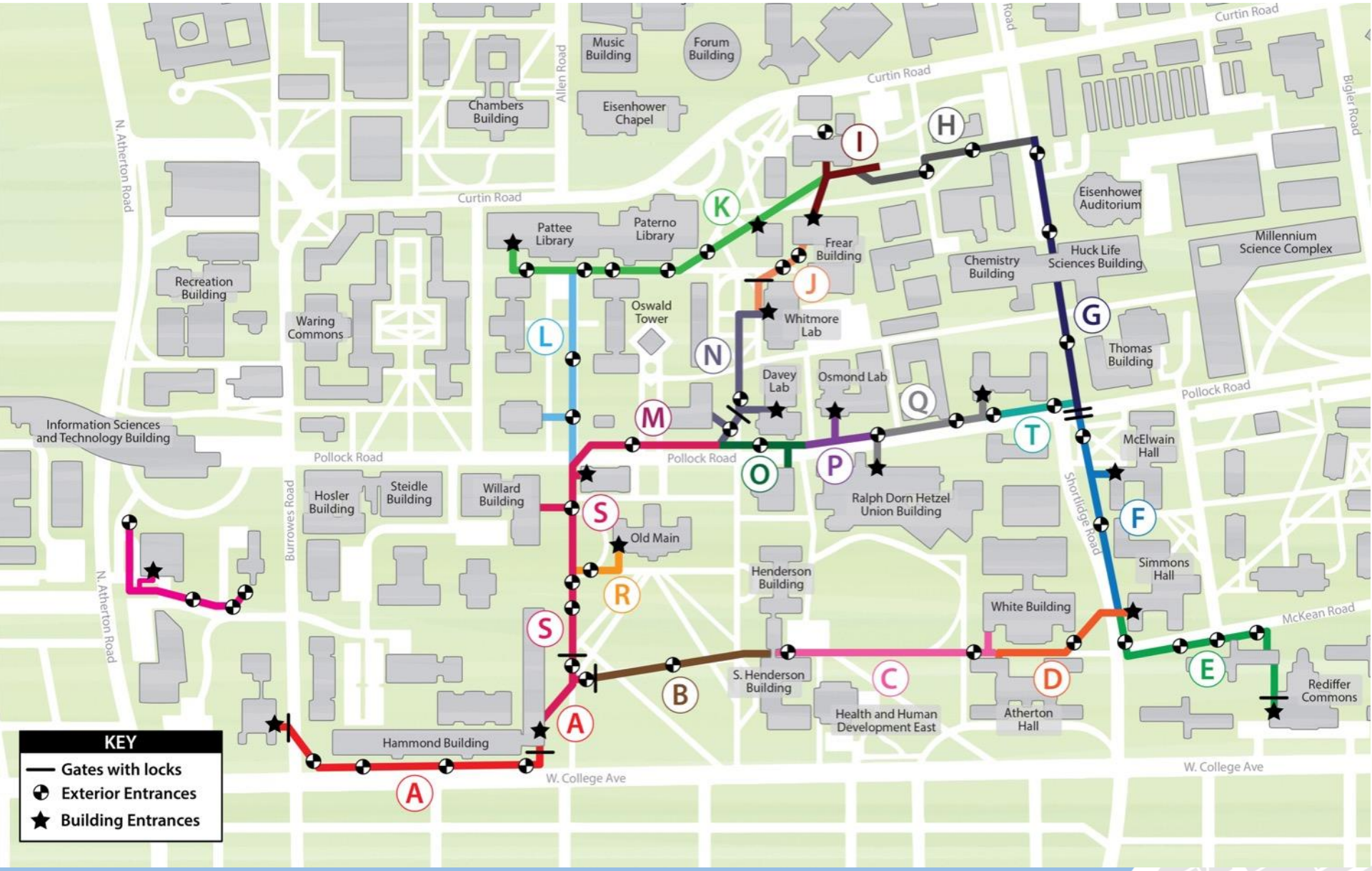
- West Campus Steam Plant
  - 338,000 pph steam production
  - 5.2 MW electric production
- East Campus Steam Plant
  - 317,000 pph steam production
  - 7.0 MW electric production
- Distributed Central Chilled Water System
  - Three plants produce 18,800 tons chilled water


Pennsylvania State University
Btu per Square Feet and Total Square Feet
btu / sqft
ft2
Fiscal Year
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
40,000,000
38,000,000
36,000,000
34,000,000
32,000,000
30,000,000
28,000,000
26,000,000
24,000,000
22,000,000
20,000,000
97/98 98/99 99/00 00/01 01/02 02/03 03/04 04/05 05/06 06/07 07/08 08/09 09/10 10/11 11/12 12/13 13/14 14/15 15/16
Multi-Sport
Lasch
Earth & Engineering
Library
Expansion
MBNA
White Course Apts
IST
Chemistry
Life
Science
Stuckeman
Smeal
Forestry
Food Science
Medlar Field
Student
Health Center
Katz
Millennium
Science
Bio-behavioral
Health
Pegula
Pell Lab

PSU Steam Distribution



PSU Steam Tunnels



Low Pressure Steam System

- Superheated steam is produced at 250 psig, 540°F
  - Turbine driven equipment
  - Backpressure turbines
  - Pressure reducing valves
- High pressure steam distributed at 150 psig, (400°F)
- Low pressure steam distributed at 13 psig, saturation (230°F)
  - Multiple design conditions used over history of University
  - Distribution system includes pressure reducing stations in manholes and tunnel zones. Pressure reducing stations do not include desuperheaters.

High Temperature Event

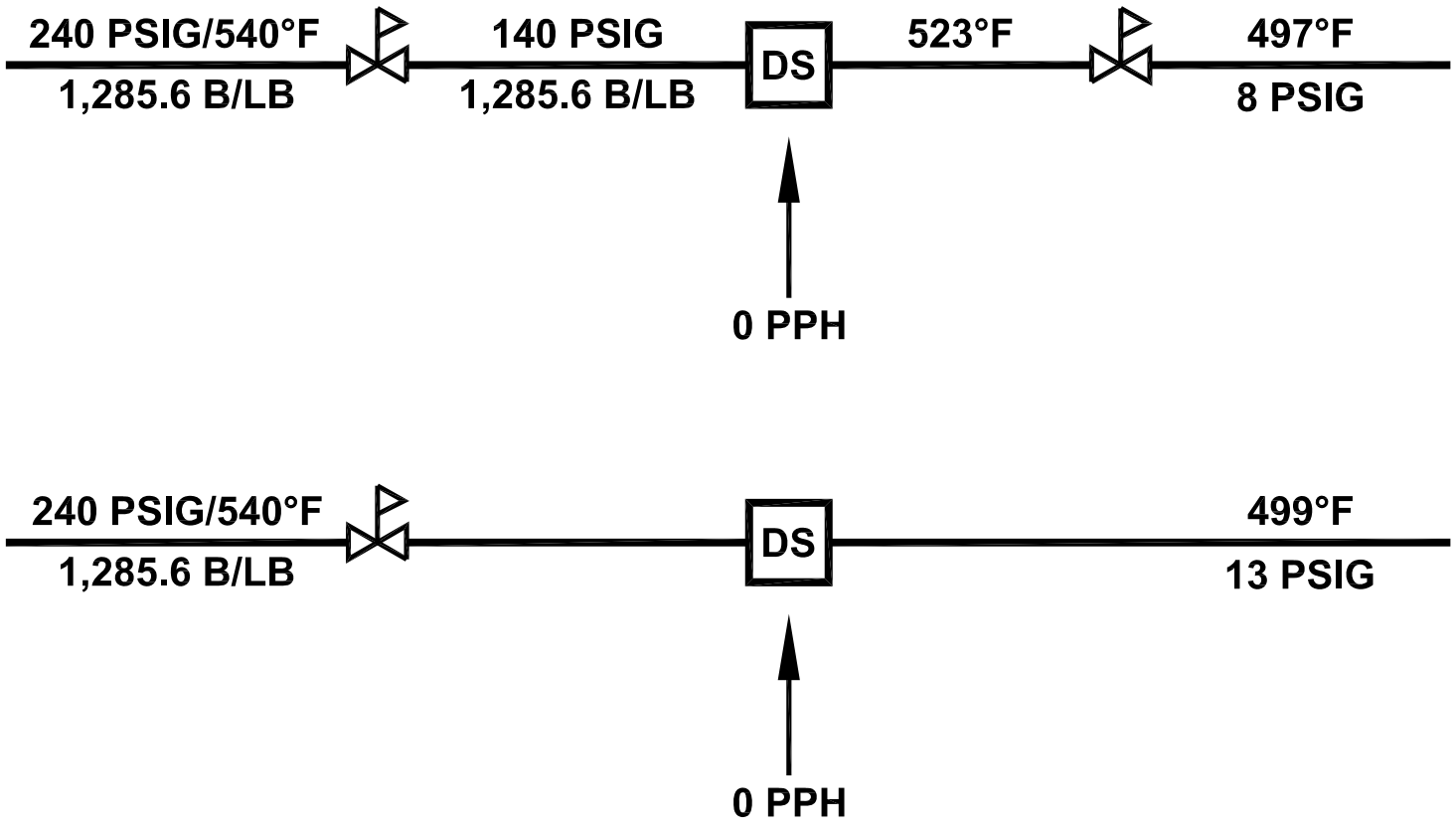
High Temperature Event

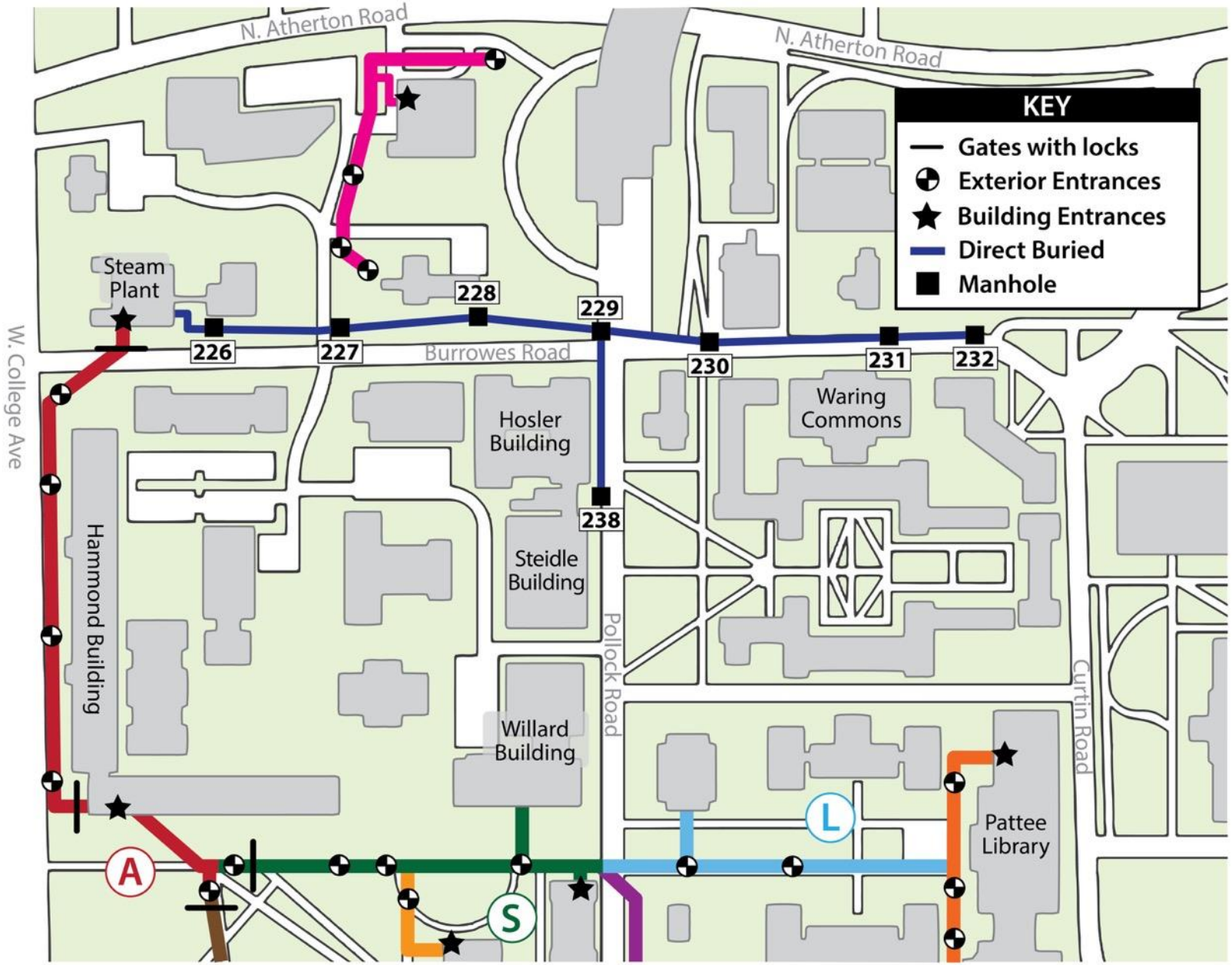
- During routine preventative maintenance, steam crew observed damage to piping systems in manholes along Burrowes Road including
  - Concrete manhole damage
  - Broken concrete pedestals
  - Sheered steel anchors
  - Bent all-thread
  - Disconnected steel supports

High Temperature Event

- High pressure is supplied along Burrowes Rd to manhole 138 where it is reduced in pressure to supplement the low pressure system.
- Plant trend data shows high steam temperatures
- High Pressure Desuperheater discharge temperatures in excess of 500°F
- High to Low Desuperheater discharge temperatures in excess of 450°F

Existing System




N. Atherton Road
N. Atherton Road
KEY
Gates with locks
Exterior Entrances
Building Entrances
Direct Buried
Manhole
Steam Plant
228
229
226
227
Burrowes Road
230
231
232
W. College Ave
Hosler Building
Waring Commons
238
Steidle Building
Hammond Building
Pollock Road
Curtin Road
Willard Building
L
Pattee Library
A
S

System Failures

THERMAL EXPANSION OF PIPE PENN STATE UNIVERSITY			
PIPING SEGMENT	DISTANCE (FT)	EXPANSION	
		DESIGN TEMP (240°F STEAM) (IN)	HIGH TEMP (500°F STEAM) (IN)
PLANT TO MH-226	139	2.1	5.3
MH-226 TO MH 227	171	2.6	6.5
MH-227 TO ANCHOR	118	1.8	4.5
ANCHOR TO MH-228	128	1.9	4.8
MH-228 TO ANCHOR	60	0.9	2.3
ANCHOR TO MH-229	118	1.8	4.7
MH-229 TO ANCHOR	78	1.2	3.0
ANCHOR TO MH-230	86	1.3	3.3
MH-230 TO MH-231	361	5.4	13.7
MH-231 TO MH-232	141	2.1	5.3

- Manholes
  - 227
  - 229
  - 230
  - 231
  - 238
- Tunnel Zone S

MH 227

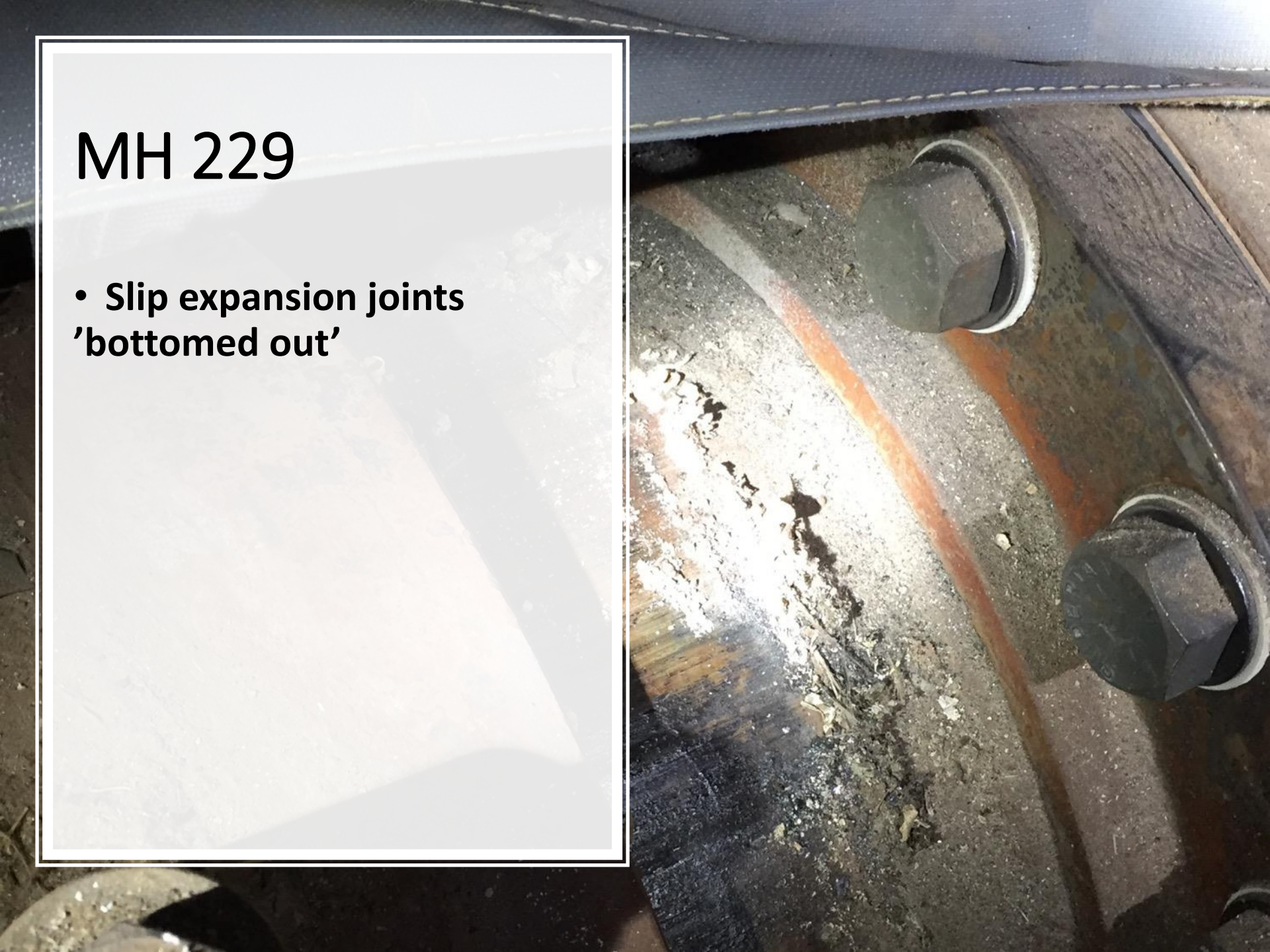
Spalling at MH entrances

MH 227

- **Expansion Joints reached limit stops**
- **Additional force exceeded concrete pedestal design**

MH 229

- **Slip expansion joints ’bottomed out’**



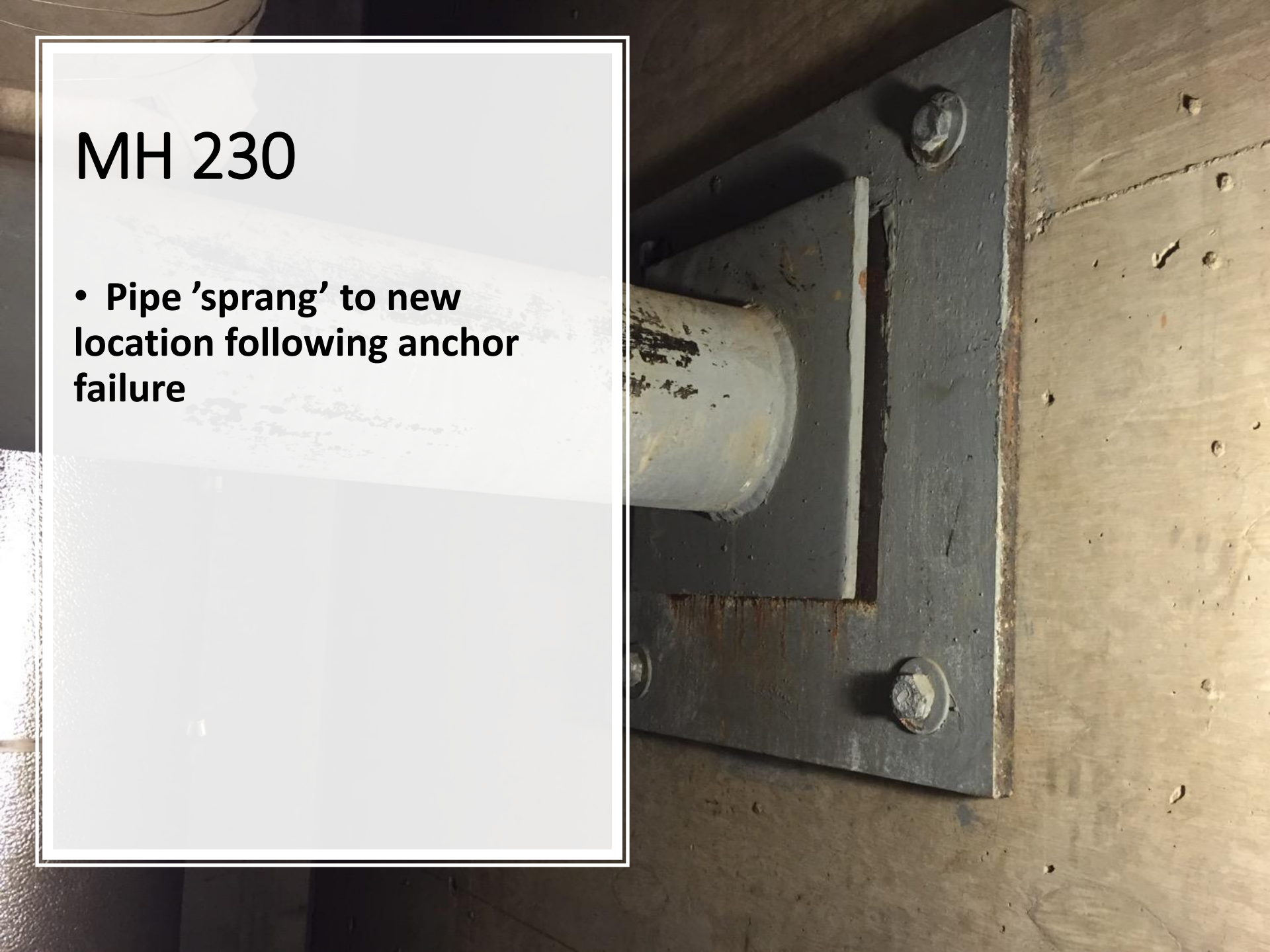
MH 229


MH 230


MH 230

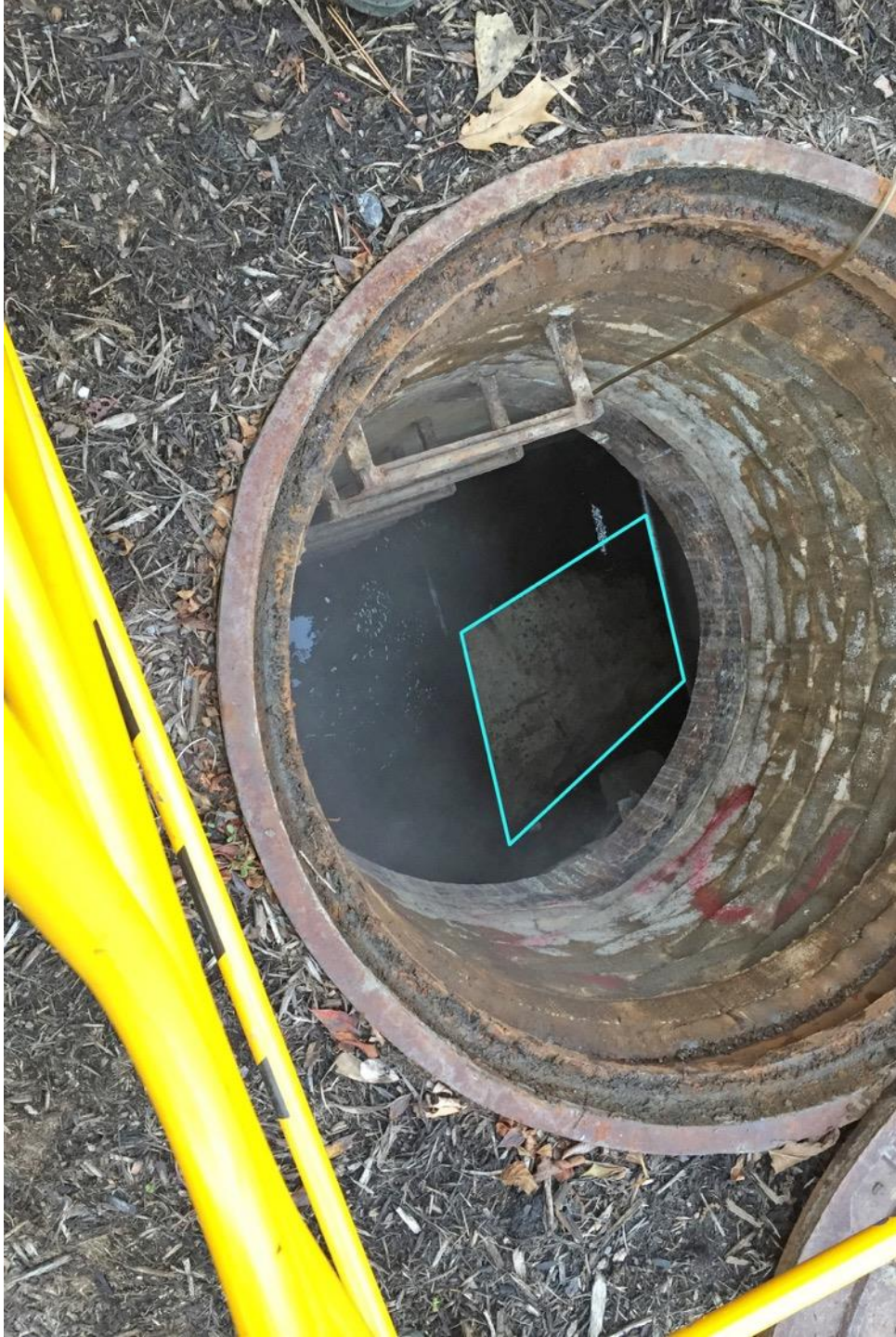
MH 230

- **Pipe ’sprang’ to new location following anchor failure**



MH 231

Large concrete pedestal sheared at location of embeds




MH 231


MH 231

MH 231

- **Bent, then sheared ¾” embeds**

MH 231

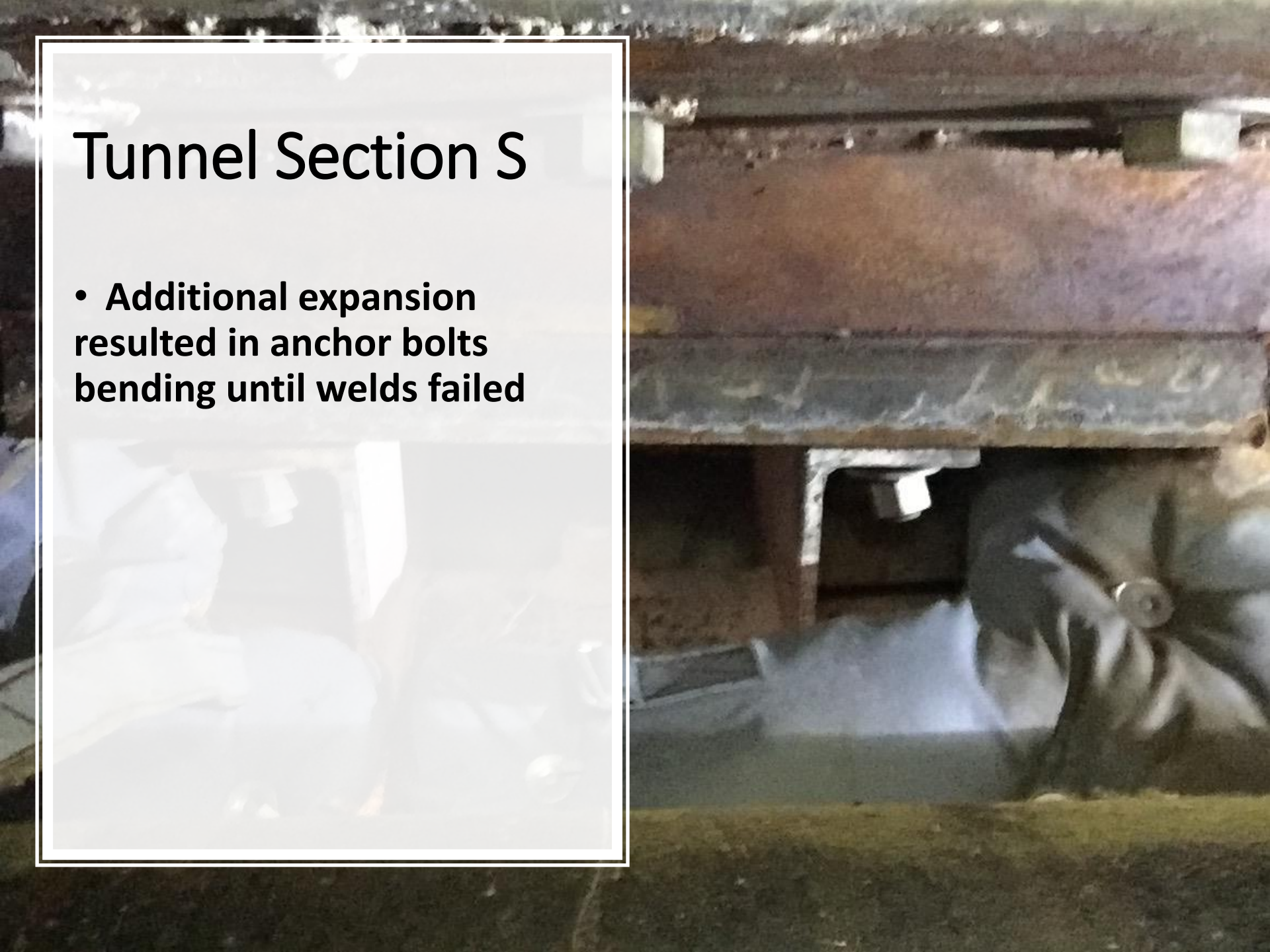
- Pipe moved laterally after anchor failure

MH 238

- **Event ‘tested’ designs of piping systems further away from Power Plant**
- **Elbow replaced with tee in field without calculating new pipe stress**
- **Computerized pipe stress analysis *below* allowable stress with elbow, *above* allowable stress with tee**

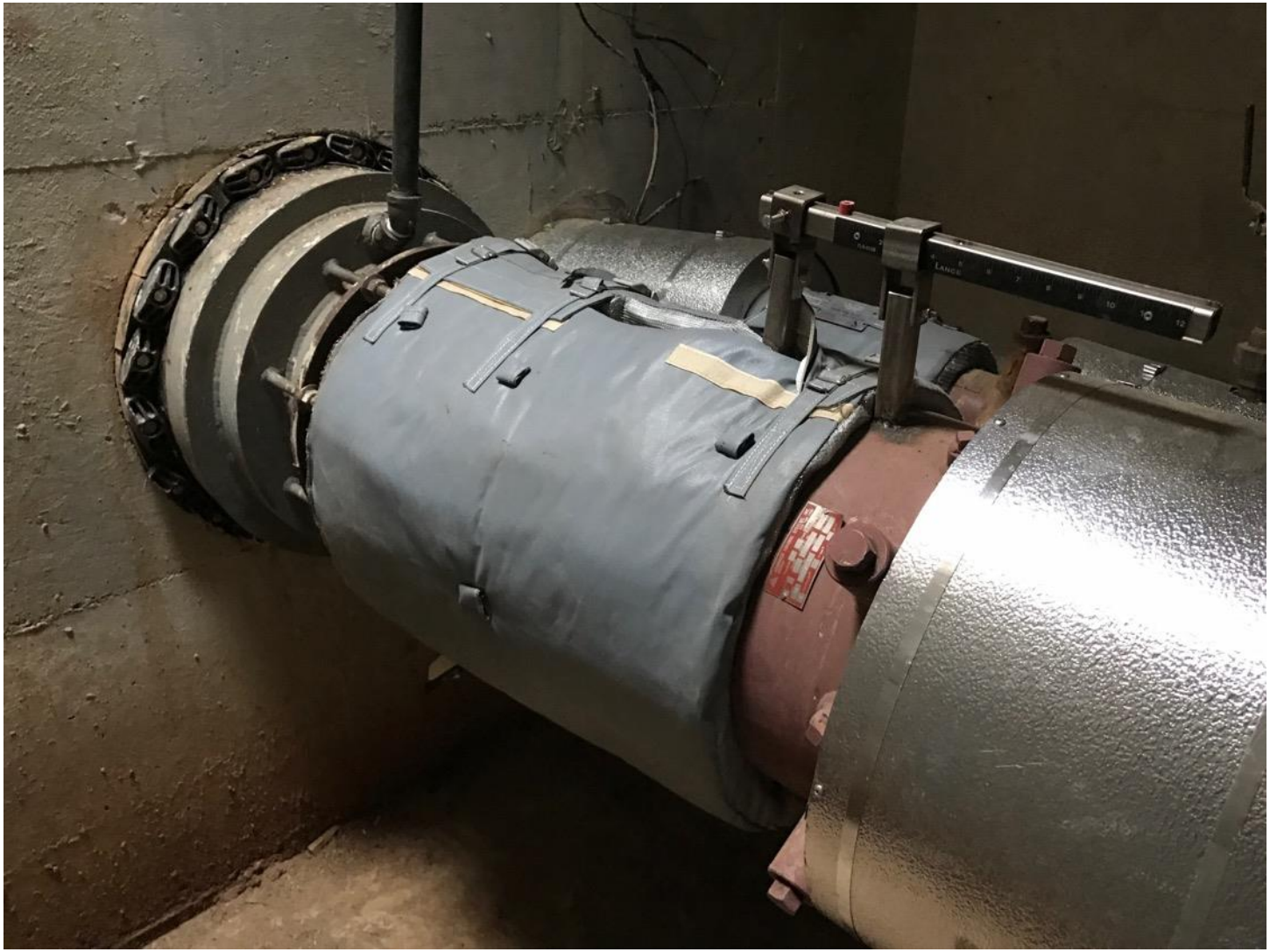
Tunnel Section S

- **Additional expansion resulted in anchor bolts bending until welds failed**



MH 227

MH 230



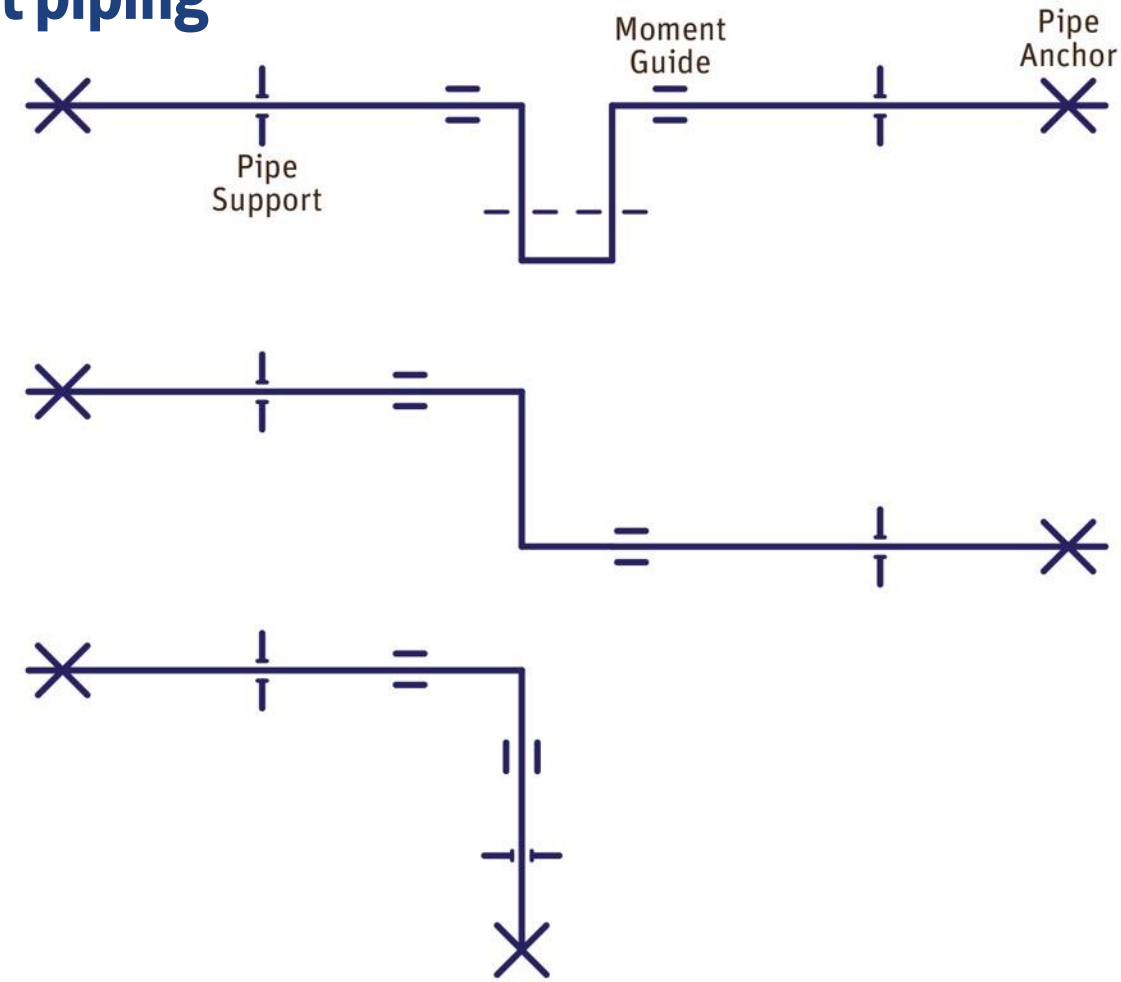
Design Standards

Design Standards

- While normally saturated, due to the fact that the LPS is a byproduct of the co-generation steam turbines, this system could experience a temperature excursion. Temperature of the steam can reach 450°F if the desuperheater fails. As such, all LPS piping in the tunnels shall be designed for expansion associated with an excursion temperature of 450°F. Cast iron, malleable iron, brass and bronze components are prohibited.
- HPS shall be designed for expansion associated with a design temperature of 500°F.

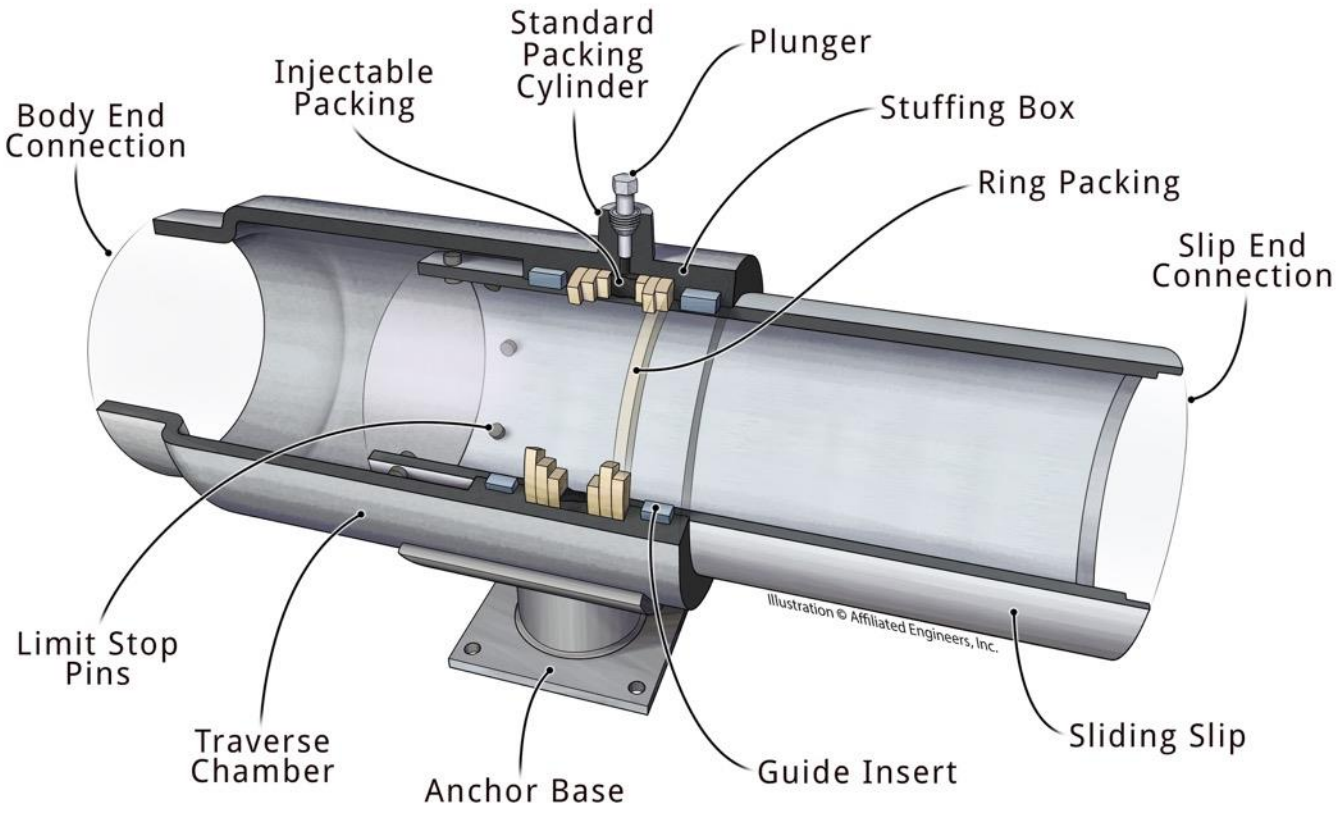
Expansion Compensation – Natural Flexibility

- Loops, z-bends, L-bends – used with direct buried or conduit piping



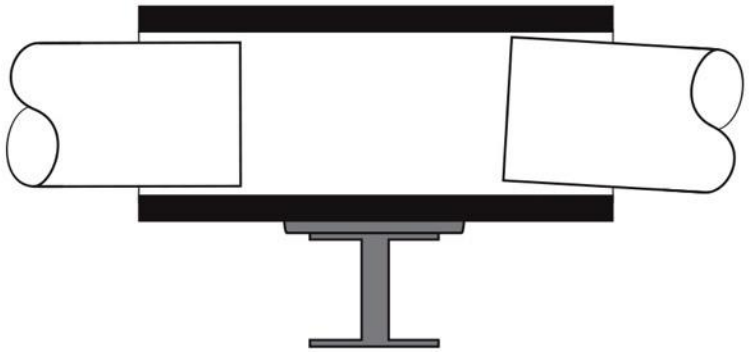
Expansion Compensation – Slip Joints

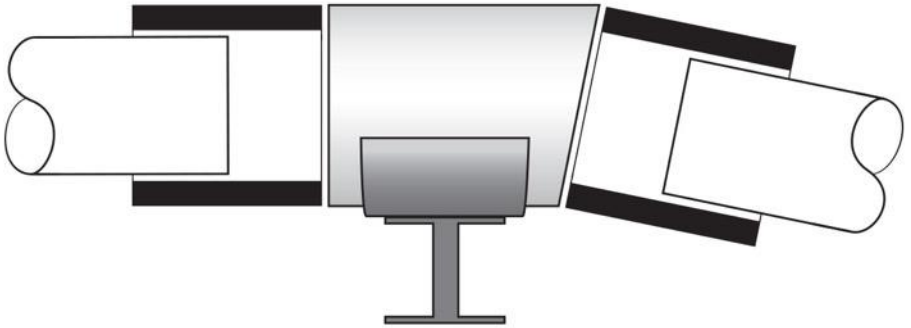
- **Select with sufficient travel,**
  i.e. do not 'over engineer' a selection



Expansion Compensation

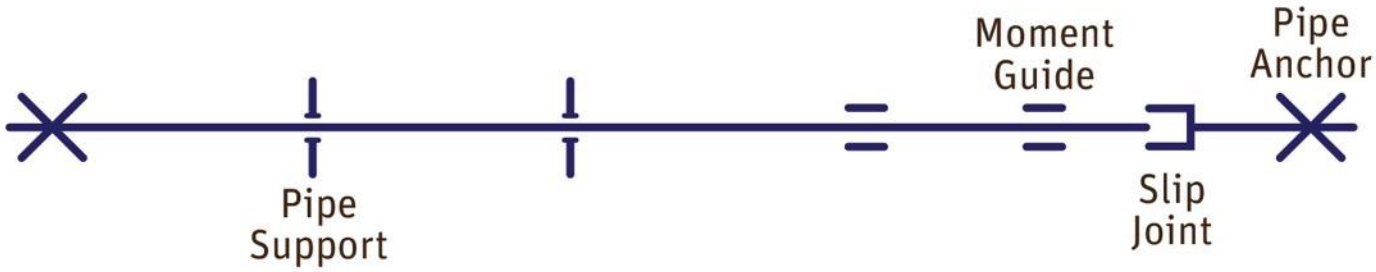
- Double Slip Type Expansion Joints should not be used in tunnel or manholes.
- Preferred method is two single slip expansion joints with anchored spool piece
  - Order slips without reducers
  - Good location for building take-off and drip legs





Expansion Compensation – Slip Joints

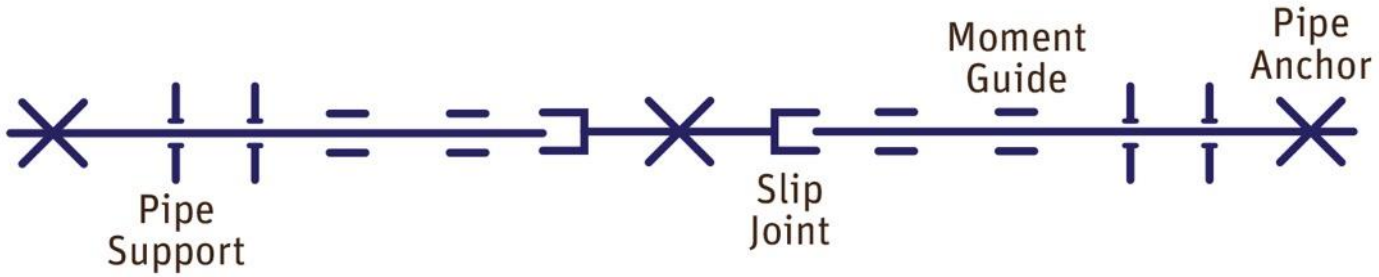
- Pipe must be aligned with slip joint for proper performance



- Guide pipe according to manufacturer's recommendations

Forces on Anchors

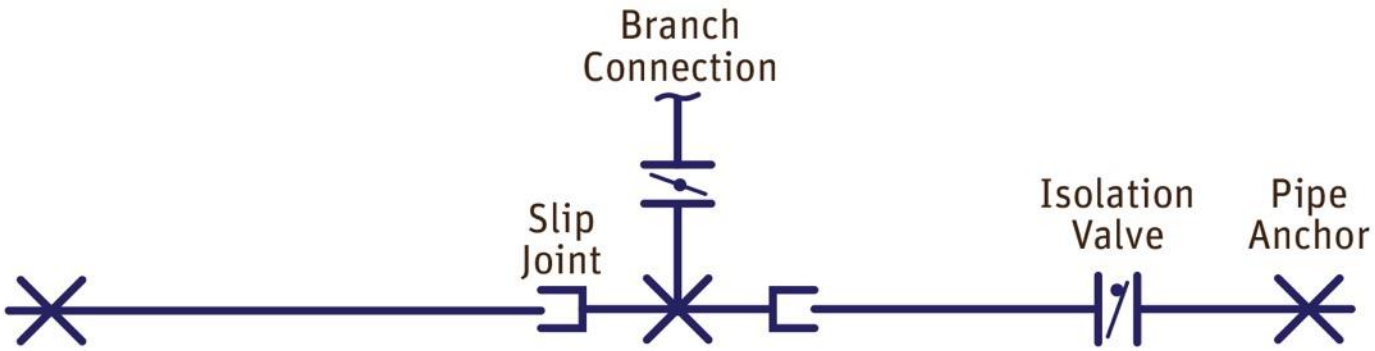
- Anchor must withstand pressure force, friction force in the expansion joint, and friction force from contact between pipe and pipe supports and guides
- Force on Anchor → $F_A = F_P + F_C + F_S$
  - Pressure force, F_P
  - Force of compression, F_C
  - Friction force from supports, F_S



Forces on Anchors

- **Anchor design must consider warm up and isolation conditions**

  i.e. forces may not be equal and opposite



Questions?