

# OPERATOR SAFETY

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- SPOKANE'S WASTER WATER TREATMENT PLANT INCIDENT AND THE WATER DEPARTMENT'S LINCOLN HEIGHTS BOOSTER STATION INCIDNET.

# The Accident Investigation

- Labor & Industries
- Exponent
- Insurers
- Spokane Police Department
- Spokane Fire Department
- Mayor's Oversight Committee

# May 10th 2004

Digester #3 overfilled  
with sludge

Large surface area little  
force required to lift  
700,000 pound dome  
plus overcome the  
attachment rods



May 10<sup>th</sup> 2004 at 3:10 pm

Fail safe overflow system disabled years ago due to leaks allowing methane out and oxygen in.

Potential overflow  
Alternative was not  
configured to compensate.







Depth monitors failed in a very subtle way

Depth monitor redundancy was not available

The operator was unable to accurately determine sludge levels



Extremely complex valve system

Many valves inoperable

Partial SCDA/Manual valve system

Continual Construction



# Contributing Human Factors



- Training & SOP documentation did not keep up with changes in process
- Transfer of information between operating crews was insufficient
- Documentation of operating issues (logs) insufficient
- Insufficient cross group communication

# Contributing Human Factors cont.

Need to reconcile conflicting data.

Insufficient valve and line labeling/coding.

Key functions need individual focus/responsibility.

Understaffing.





# Process Safety Management

- Came into existence in 1992
- Created to improve deficiencies common to industrial/chemical facilities
- **Large complicated, continuously operating systems have a tendency to evolve towards disorder without input of substantial resources**
- Basic idea makes sense for any operation

# Process Safety Management

## Some key elements...

- Must involve staff from all levels
- Must have current Process & Instrumentation Drawings (P&Ids)
- Must have Equipment Lists (with operating limits)
- Must conduct in-depth Process Hazard Analysis (What - If ? Scenarios)
- Must develop & Implement recommendations to reduce/eliminate specific hazards

# Process Safety Management

## Some key elements...

- Must develop current Standard Operating & Maintenance Procedures
- Must formally document (through testing or demonstration of knowledge) training of every employee
- Must maintain system integrity (document)
- Review procedures at least annually
- Retrain every 3 years, or earlier as required by specific WAC's (example; respirator fitness testing), or when asked to do so by workers



# Process Safety Management

## Some key elements...

- Retrain when changes are made
- Continuously update SOP's & SMP's
- Conduct PSM Management of Change activities whenever you make a change to a covered process
- It's a very detailed and methodical method of reducing the risk associated with process changes
- Accountability

# Some Lessons Learned

- Understanding Process Safety Management & Management of Change
- Because we've done it this way for 25 years...
- For facility upgrades, take a systematic approach
- Can you document when & how your people were trained?

# Some Lessons...

- Are your SOP's / SMP's mostly residing inside someone's head?
- Are valves clearly marked, and lines labeled and color coded?
- Can one person operate your valves & do you have a valve exercise program?
- Do you know the engineered operating limits of your equipment?



# Some Lessons...

- Backup pumps & piping alternatives were not created so systems could be abandoned
- During construction, slow down!
- Don't rely on a lone device for important data, have a parallel system
- Don't let the prospect of permit non-compliance hasten a process modification



May 4<sup>th</sup> 2004

Three workers went out on the dome to divert leaking scuppers to the plant's drain system and away from the Spokane River.

# Chain of Events - May 10<sup>th</sup> 2004

- Digester 3 sludge levels substantially higher than SCADA indicated
- Sludge, thought to be foam, observed dripping from PRVs on Digester 3
- Sludge feed to digester believed to have been terminated
- Catastrophic dome collapse at 3:10 PM
- Estimated 200,000 gallons of sludge to river



May 4<sup>th</sup> 2004 3:10 pm

The impending collapse was not at all obvious  
No history of this risk in the industry

The Dome collapsed killing one employee and severely  
Injuring the other two.





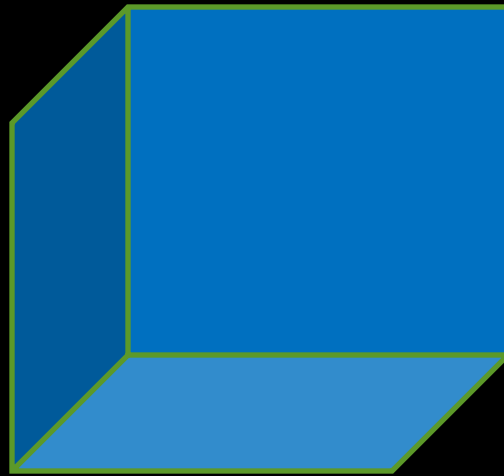
# Hydraulic Safety Lincoln Heights



# FIRST A QUICK MATH REFRESHER







One Cubic foot of water contains 7.48 gallons of water at a weight of 8.34 lbs/gallon or 62.4 lbs/ft<sup>3</sup>

If you divide 62.4 by the bottom surface area in inches (144) you arrive at .433psi per foot of water

$$1\text{psi} = 2.31\text{ft} \quad (1 \div .433)$$

A tank with 120 feet of water has a pressure of 52psi

$$120 \div 2.31 = 52\text{psi}$$

EVERYONE LOVES  $\pi$

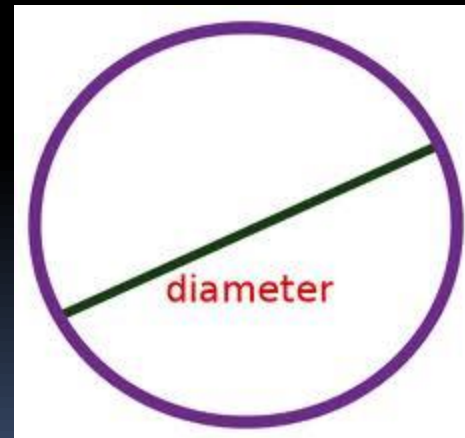
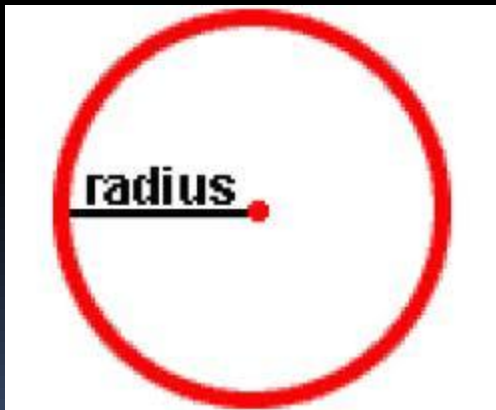


# Area of a circle

$$A = \pi r^2$$

Or

$$.785 d^2$$



An 18 inch water main

$$9 \times 9 \times 3.14 = 254.34 \text{ in}^2$$

$$18 \times 18 \times .785 = 254.34 \text{ in}^2$$

How to get a quick estimate

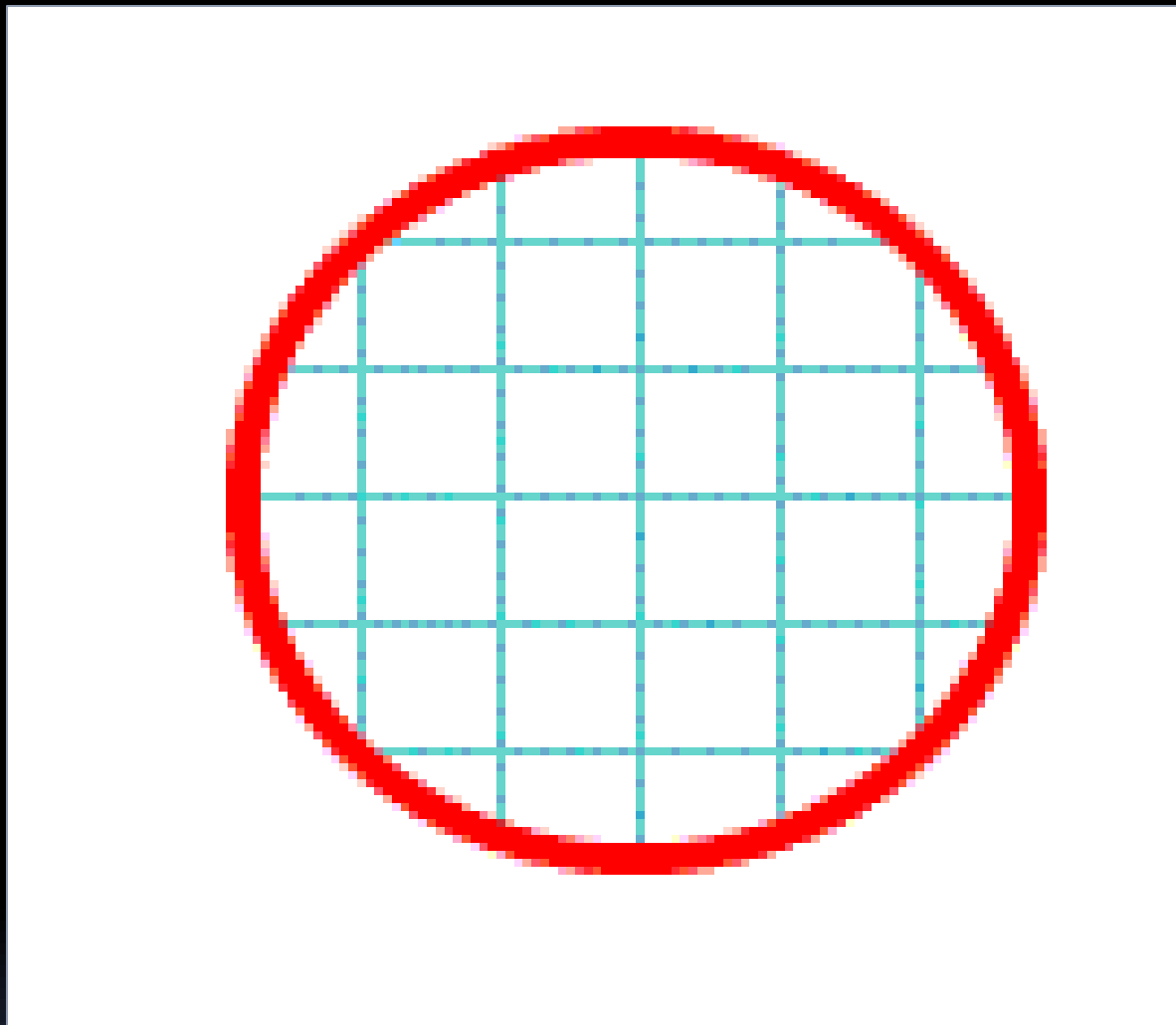
$$9 \times 9 = 81 \quad 81 \times 3 = 243 \text{ in}^2$$

(8 x 3 = 24 in tens 240 add 3)

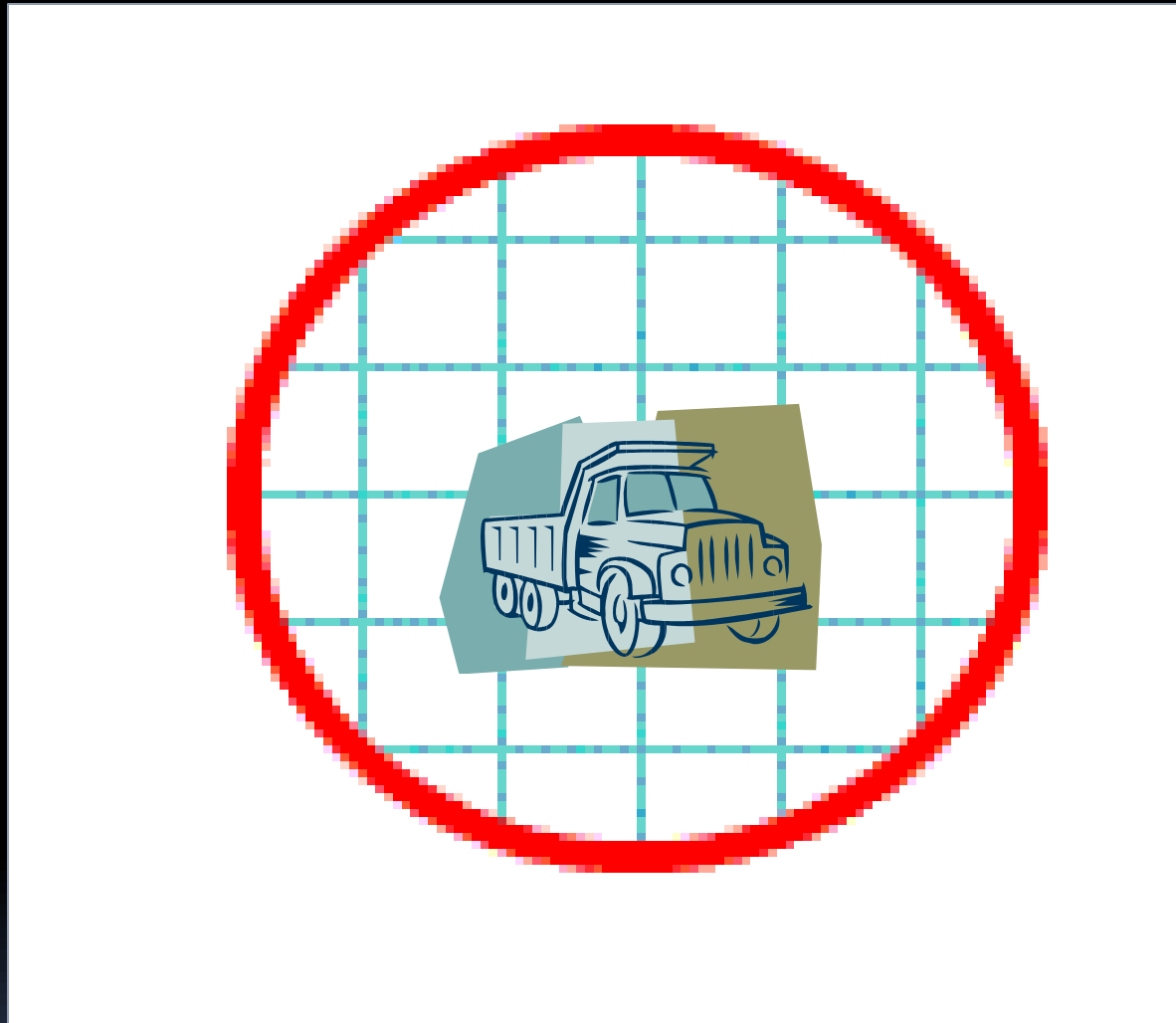


# POTENTIAL ENERGY





Surface area in square inches times the  
Pounds per Square Inch = Stored Energy



$254.34 \times 100 \text{ psi} = 25,434$  pounds of pressure against an 18" closed valve.

# LINCOLN HEIGHTS THE PLAN

Following a recent repair to the suction header for pump #1 at Lincoln Heights Booster Station it was put back in service. The Valve Crew quickly found another leak, this time on the discharge of pump #1. After evaluating the pipe it was decided to replace all steel from the discharge header to inside the basement.

Asbuilts were reviewed of the pipe installation completed in May of 2000

It was discussed that they would leave Annex pumps 5,6,7 and 8 in service and only take pumps 1,2,3 and 4 offline.



# Lincoln Heights







Construction of the  
discharge header





## ASBUILT FILES PHOTOS

- A false sense of security

**INCIDENT:** On Friday, October 19, 2007 at approximately 9:10am while replacing the 18" inlet and 18" discharge lines at Lincoln Heights Booster Station, on Pump #4, the 18" discharge valve and spigot pipe blew out of the 36"x18" TR Flex Tee. Two workers were able to get clear of the excavation with minor bumps and bruises. Two workers were instantly trapped in the basement.



# Failed Restraint





# FORCES AT WORK

140 PSI AGAINST AN 18" CLOSED VALVE

- $254.34 \times 140 = 35,607.6$  **POUNDS OF PRESSURE** AGAINST THE VALVE.
- Water hammer occurred with the starting and stopping of the pumps in the Annex.
- Over 27,000 gallons per minute flooding the basement, the workers were instantly trapped.

# Water Hammer Force

Formula:  $P_{wh} = (0.07 \cdot V \cdot L) / t + p_1$

$P_{wh}$  = pressure resulting from water hammer

$V$  = velocity of water

$L$  = length of pipe

$t$  = time for valve to close

$P_1$  = pressure before the event

$$(0.070 \cdot 3 \cdot 150) / 0.1 + 140 = 455$$

$$455 \cdot 254.34 = 115,724.7 \text{psi (estimated force)}$$

# Water Everywhere





# Transformers next to Lincoln Heights





# FRUSTRATION





DANGER High Voltage 23,000 volts



# Response to the situation

## POSITIVE FACTORS:

All workers responded appropriately to the emergency. They notified the operators at Upriver, Station A and 911.

After notifications, the priorities were:

- Control the Water
- Get the doors open to release water and get to the trapped employees
- Get the two trapped employees out of the basement, administer First aid
- Secure the area



# Water Controlled





# Back Door Torn Down





# Area Secured









# CONTRIBUTING FACTORS

- **Policy**: Although it is not that common, it is not unusual to leave the discharge header in service while being worked on. There has been no policy or procedure to limit or turn off a header before it is worked on.
- **Water Hammer**: Water Hammer occurred when pumps were turned off.
- **Limited egress from basement**: All doors in the basement opened inward. Due to the large amount of water entering the basement, the doors could not be opened
- **False sense of security**: The discharge valve on pump #4 was installed in May of 2000 with a TR Flex gripper ring. At the crew meeting to discuss the project, employees had 8x10 color pictures of the 2000 installation. Although a couple of the workers remember talking about taking the header off line, it was never specifically addressed

# RECOMMENDATIONS MADE

- Suction and discharge headers will be taken out of service or controlled to ensure the safety of employees, when piping is being worked on.
- Precautions will be taken for limited egress. All confined space procedures will be followed. The doors broken down during the incident will be replaced with a roll-up door and with a man sized walk-through door beside it that will open out.
- Formal training, specific to each crew, will be afforded employees.
- Lock out –Tag out procedures will be implemented on suction and discharge headers.
- To help control water hammers, an engineered surge tank will be installed on pumps 1, 2, 3, and 4 and controlled valves will be installed on pumps 5, 6, 7, and 8.
- Gripper ring restraint will no longer be accepted.

# THE REST OF THE STORY









# Gripper ring scars







MID-MOUNTAIN  
MACHINERY











# Lincoln Heights

























