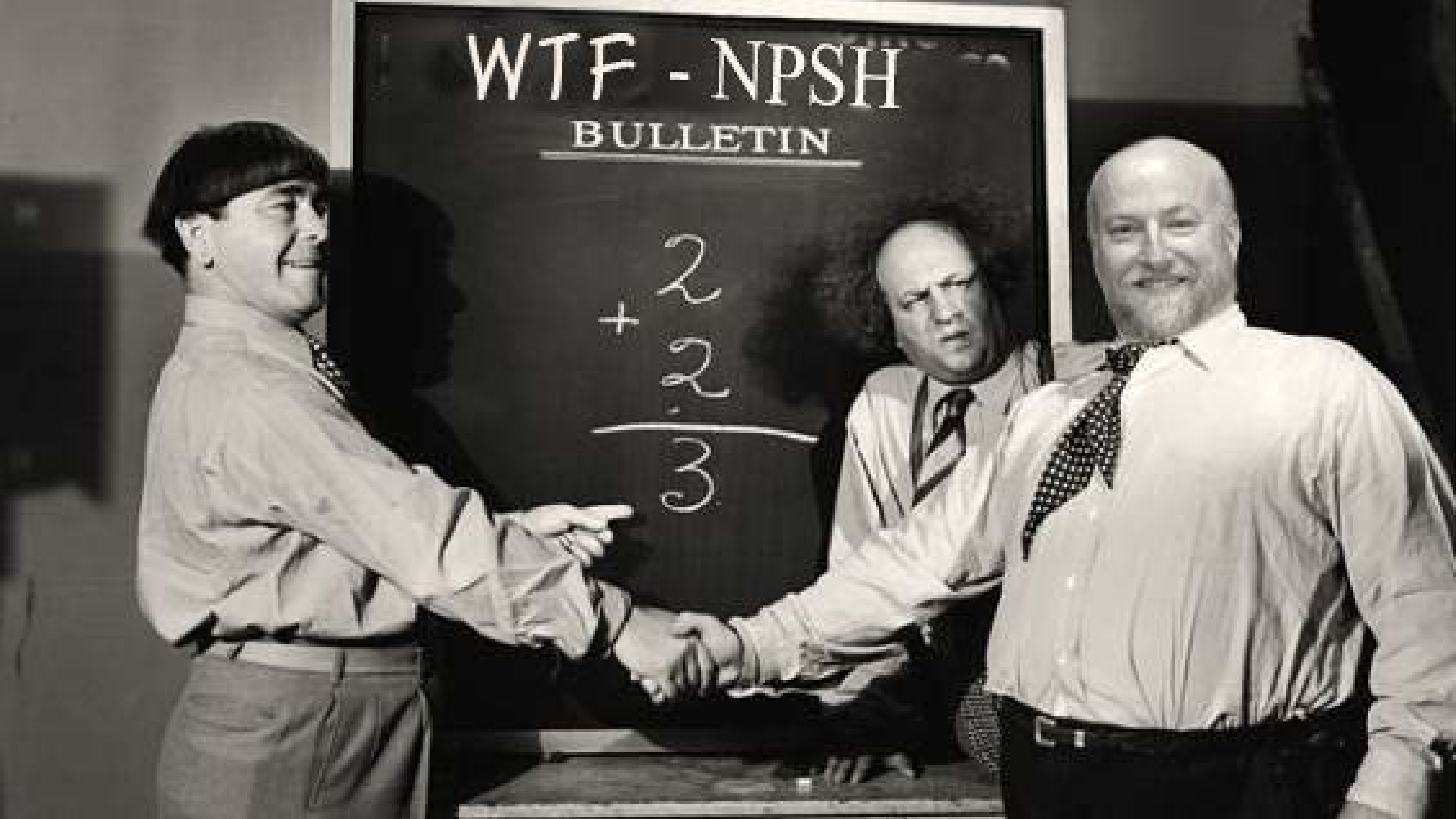

WTF - NPSH
BULLETIN
2
+ 2
3

PUMP NPSH REQUIRED

NPSH

PUMP NPSH AVAILABLE

Cavitation

WHAT THE HELL DOES ALL THIS MEAN ANYWAY?

NPSH3

Let us call it:

CAVITATION – A LOOK UNDER THE HOOD

OUR APPROACH TO LEARNING AT THIS PRESTIGIOUS W.T.F.

- ~~FORMULAS~~
- ~~DEFINITIONS~~
- T.I.T.S OH YES !
- T.I.T.S = think it through stupid

B.U.T.Ts

Broadly Useful Technical Tips

LOOK AT THIS ASHRAE NPSHA FORMULA

The following equation may be used to determine the NPSHA in a proposed design:

$$NPSHA = h_p \pm h_z - h_{vpa} - h_f \qquad (6)$$

Where

h_p = absolute pressure on surface of liquid that enters pump, ft of head

h_z = static elevation of liquid above center line of pump

(h_z is negative if liquid level is below pump center line), ft

h_{vpa}= absolute vapor pressure at pumping temperature, ft

h_f = friction and head losses in suction piping, ft

2012 ASHRAE Handbook—HVAC Systems and Equipment 44.10

Screw 👎
ASHRAE
Just
listen
to
what MAT
has to ☺ say

AND HERE IS THE SIMPLE MESSAGE FROM MAT:

DO NOT LET THE WATER IN YOUR PUMP

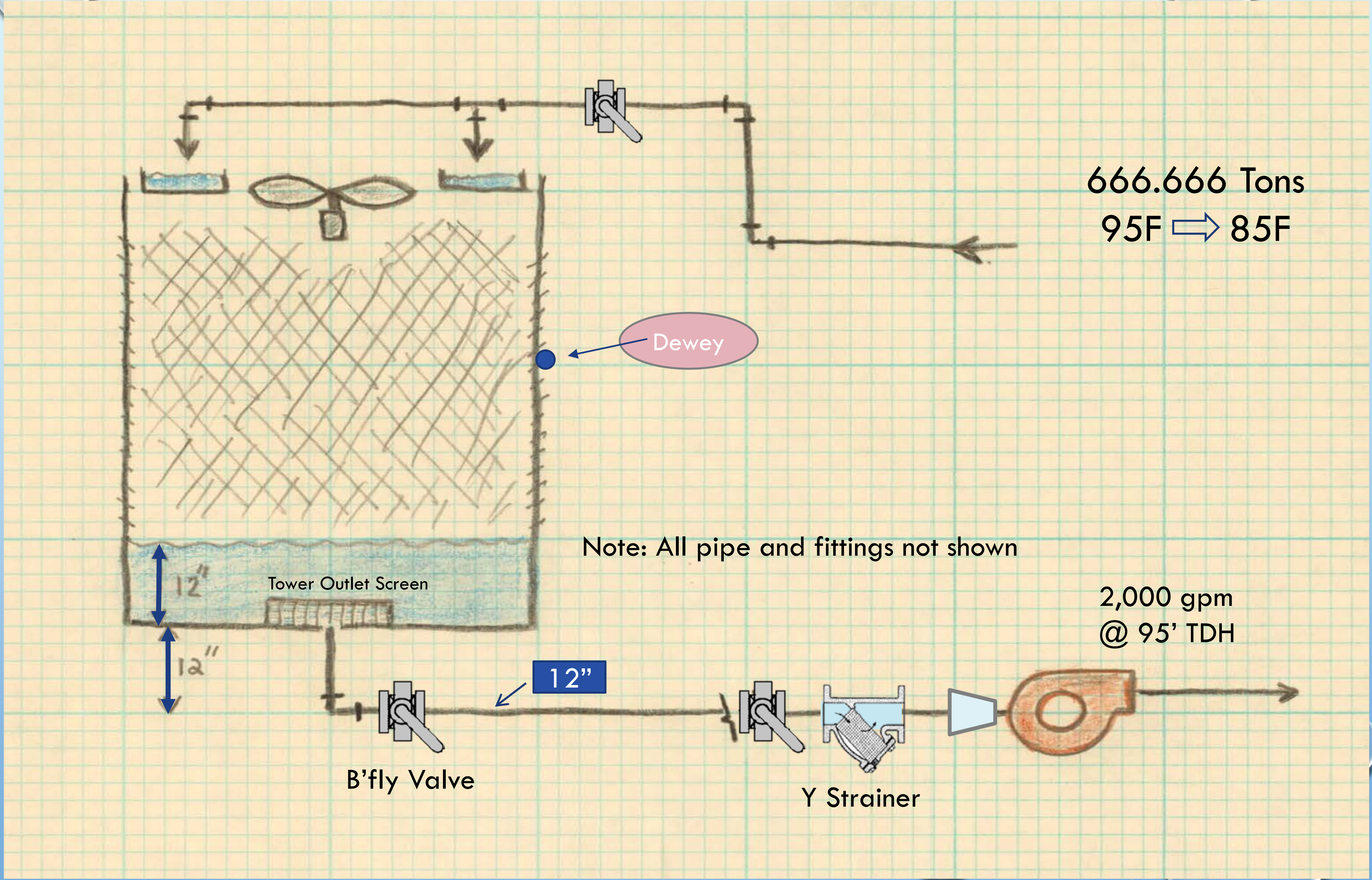
BOIL!

Some here may ask: Are you serious?

YES – I AM DEAD SERIOUS!

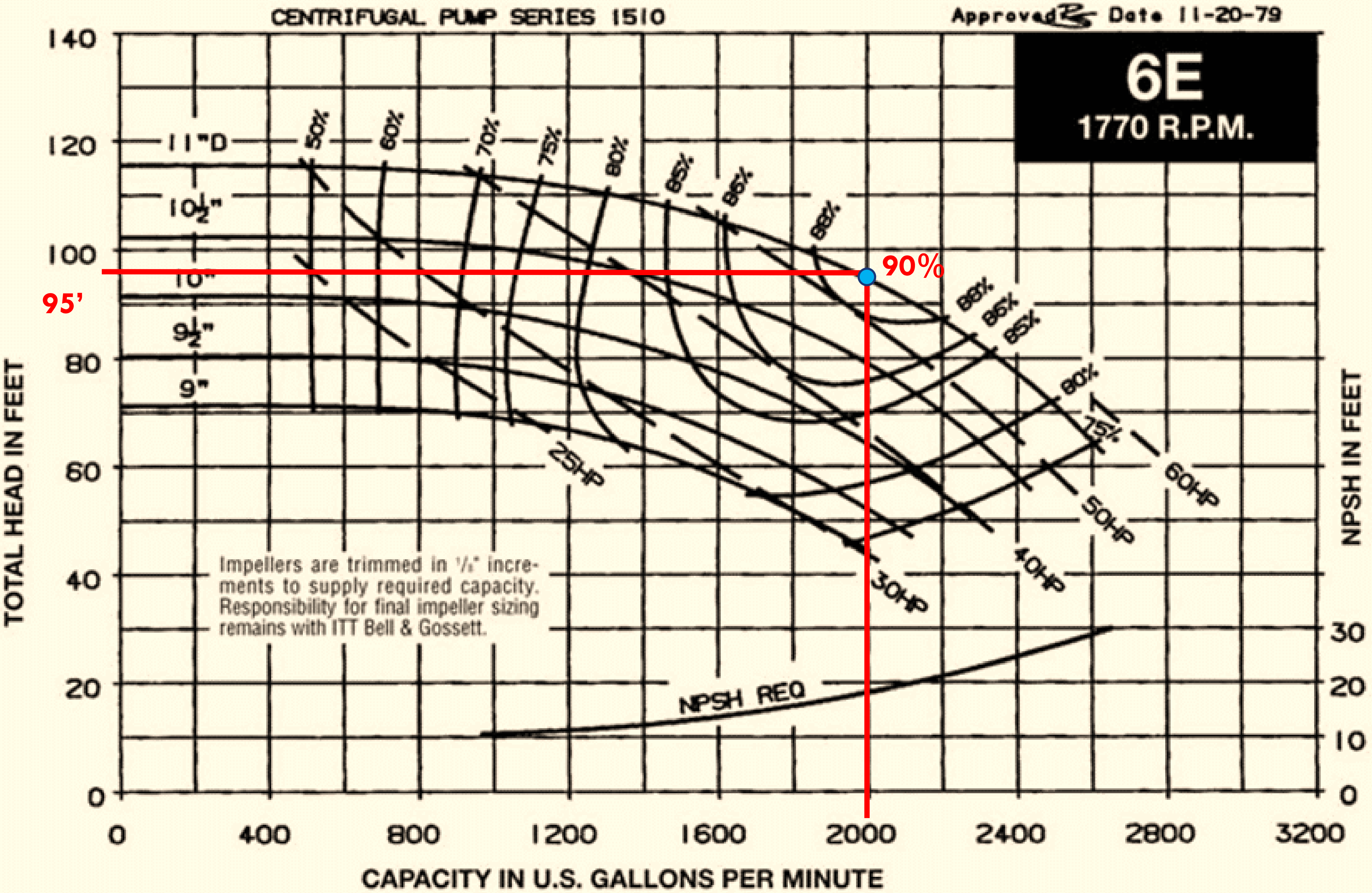
I can end the presentation right now and the essence of my message would have been conveyed!

THE SYSTEM



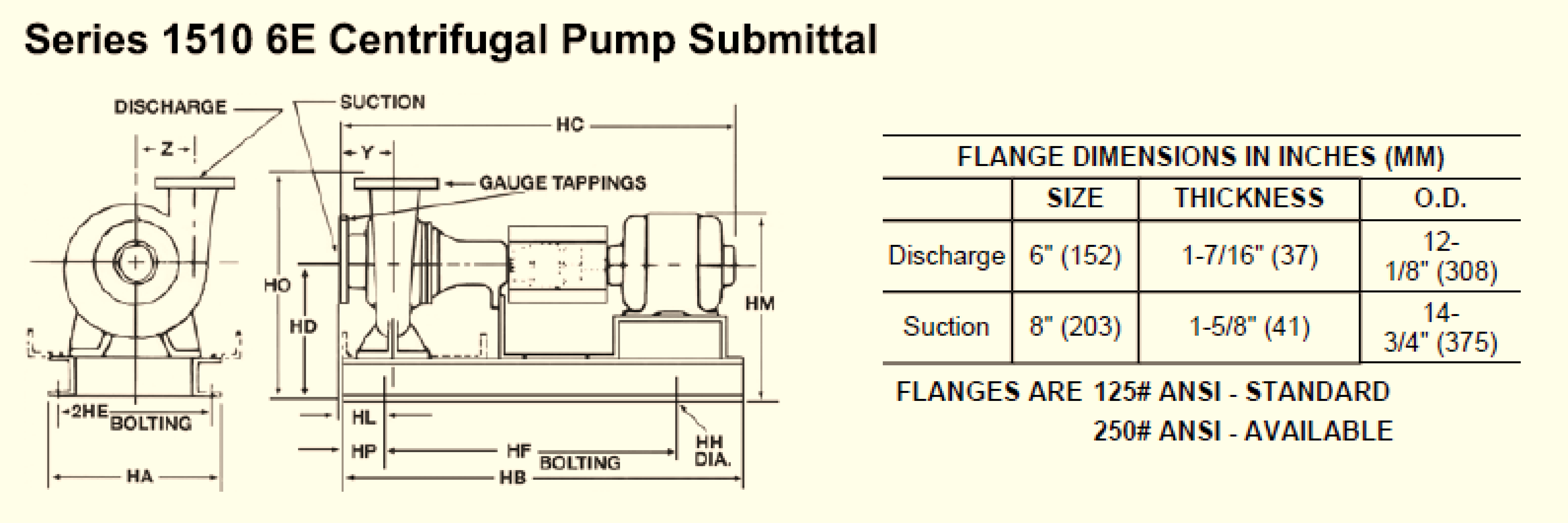
Note: All pipe and fittings not shown

PUMP CURVE 2000 GPM @ 95’TDH 90% EFF.



Impellers are trimmed in ¼" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

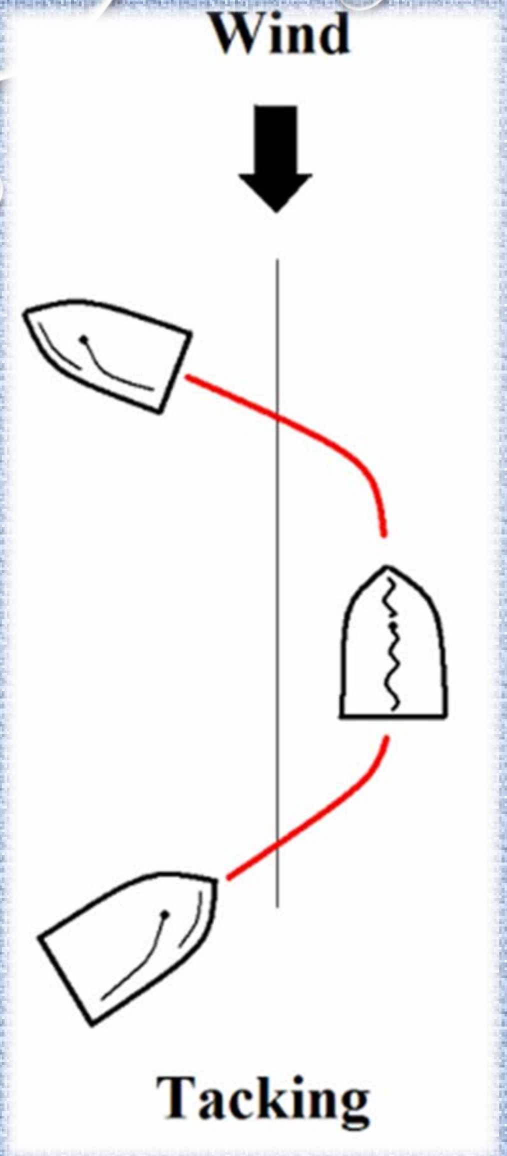
THE PUMP



Series 1510 6E Centrifugal Pump Submittal

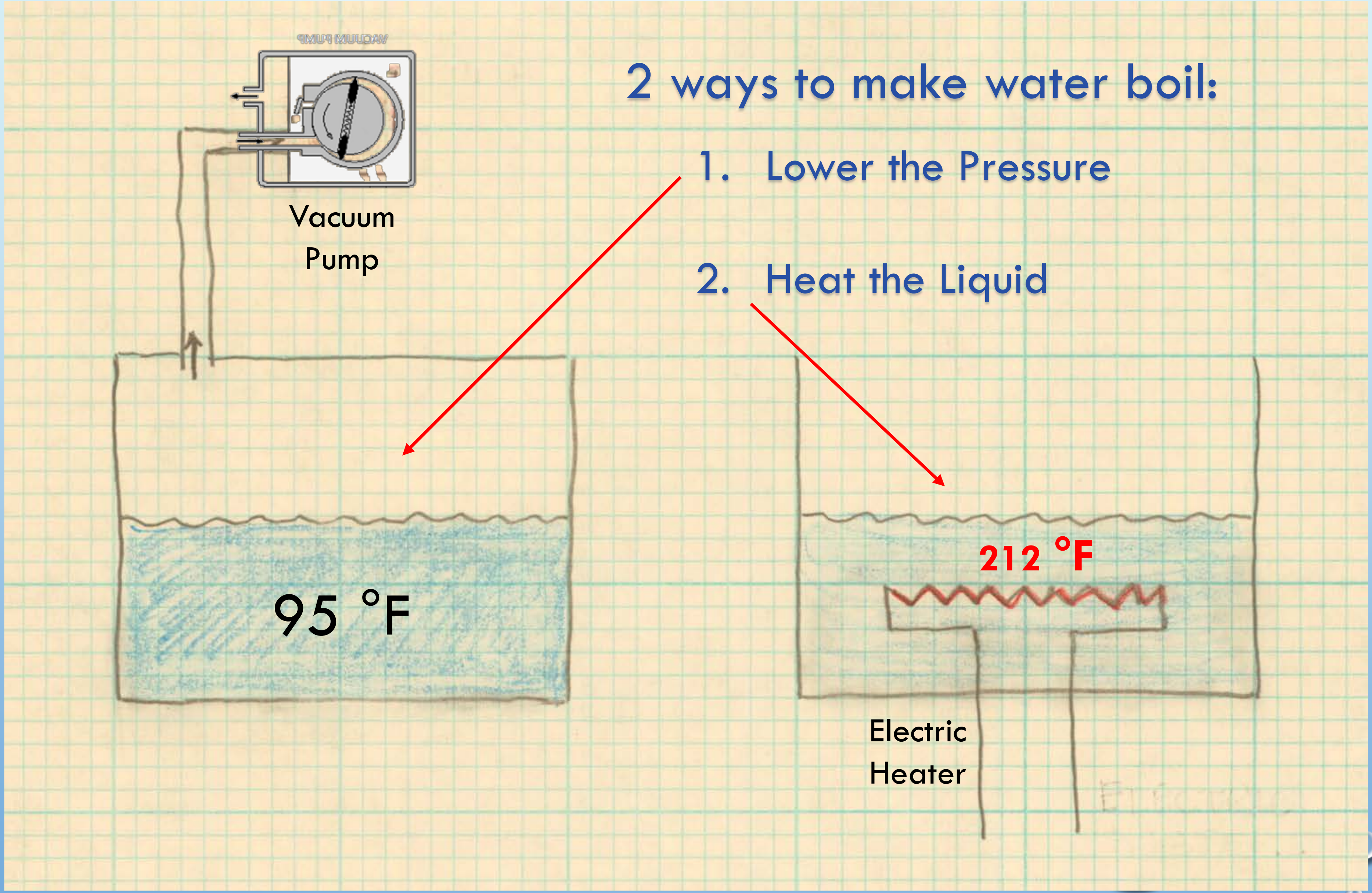
FLANGE DIMENSIONS IN INCHES (MM)			
	SIZE	**THICKNESS**	**O.D.**
Discharge	6" (152)	1-7/16" (37)	12-1/8" (308)
Suction	8" (203)	1-5/8" (41)	14-3/4" (375)

FLANGES ARE 125# ANSI - STANDARD
250# ANSI - AVAILABLE



Let us change tacks And Talk a Little Basic physics

2 WAYS TO BOIL WATER -1



2 ways to make water boil:

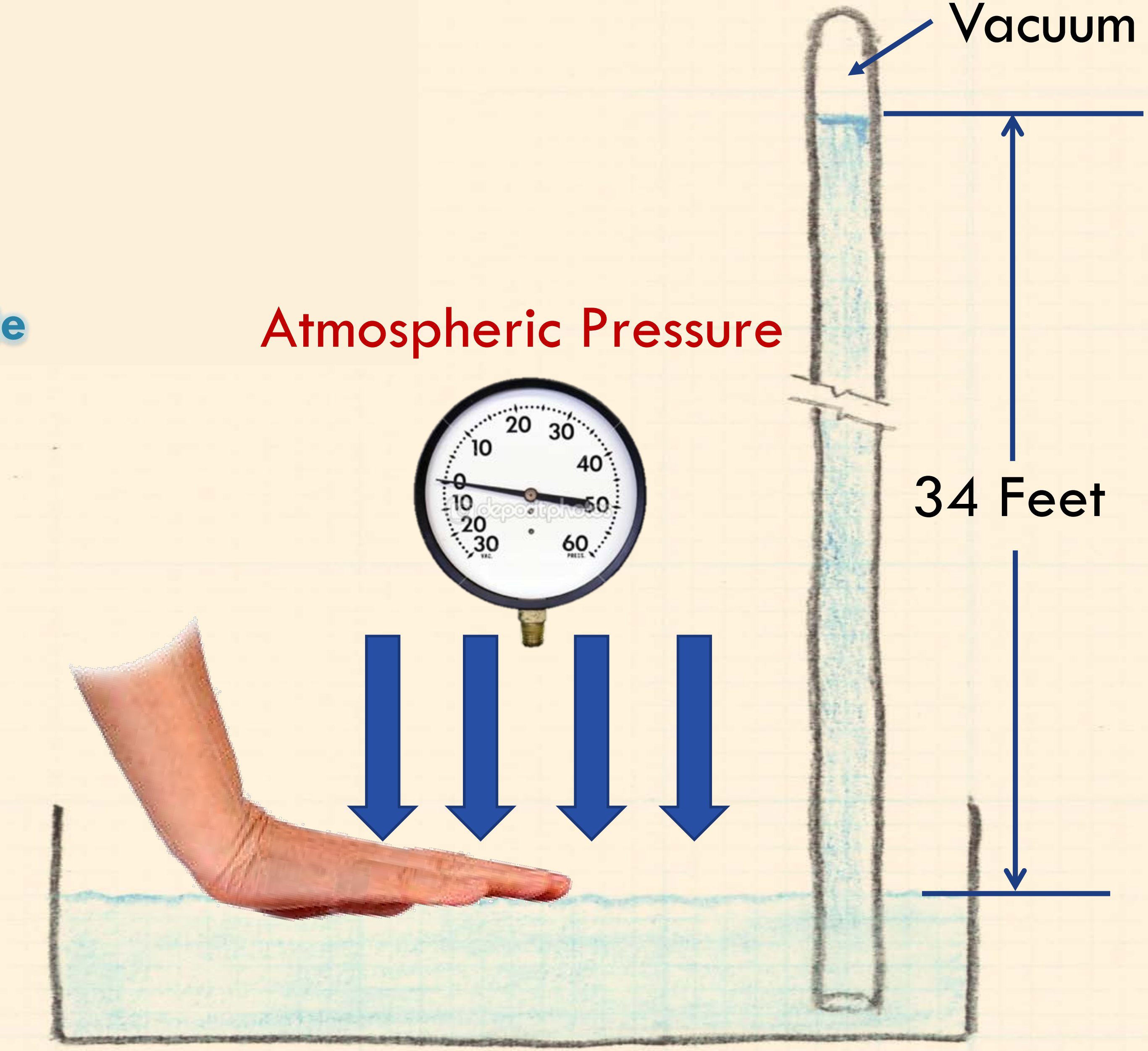
1. Lower the Pressure
2. Heat the Liquid

2 WAYS TO BOIL WATER

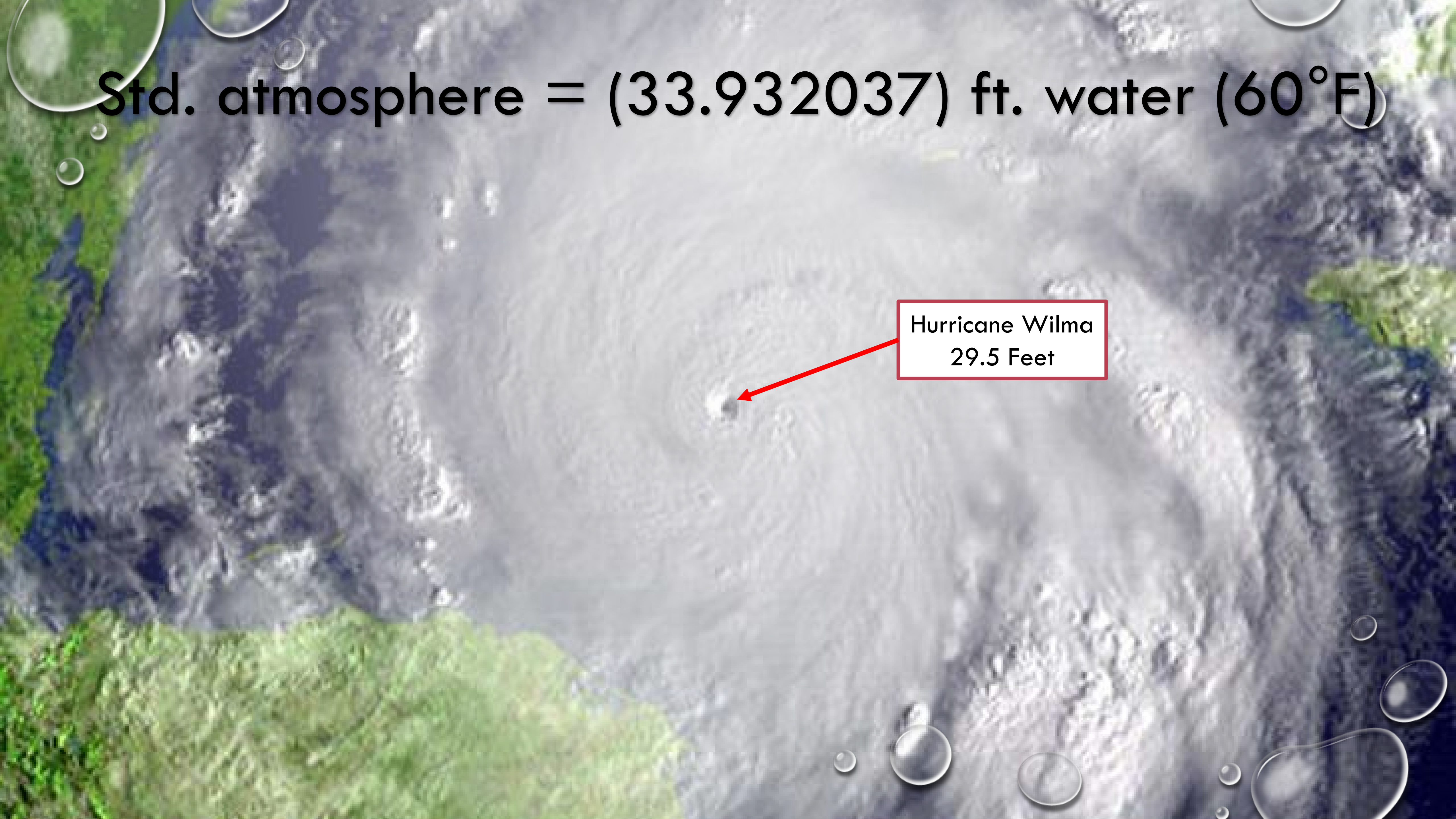
PART-2

1 atm
= 0 PSIG
= 14.7 PSIA (Absolute)
= 2,116 PSFA (Absolute)
= 34 Feet H_2O Absolute
= 30 Inches of Hg Absolute

Note: Above numbers are rounded.



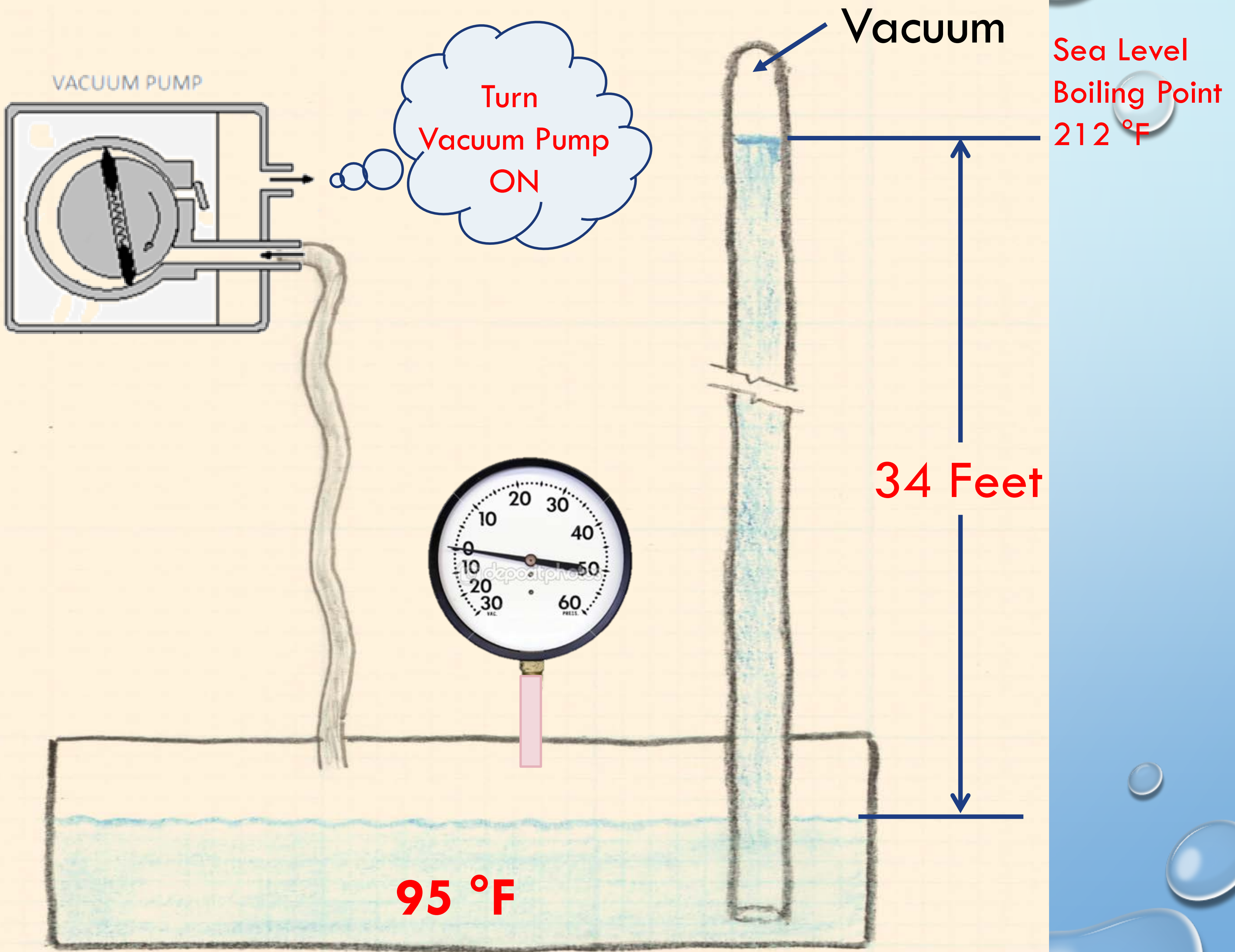
Std. atmosphere = (33.932037) ft. water (60°F)



Hurricane Wilma
29.5 Feet

2 WAYS TO BOIL WATER

PART - 3



Turn Vacuum Pump ON

Vacuum

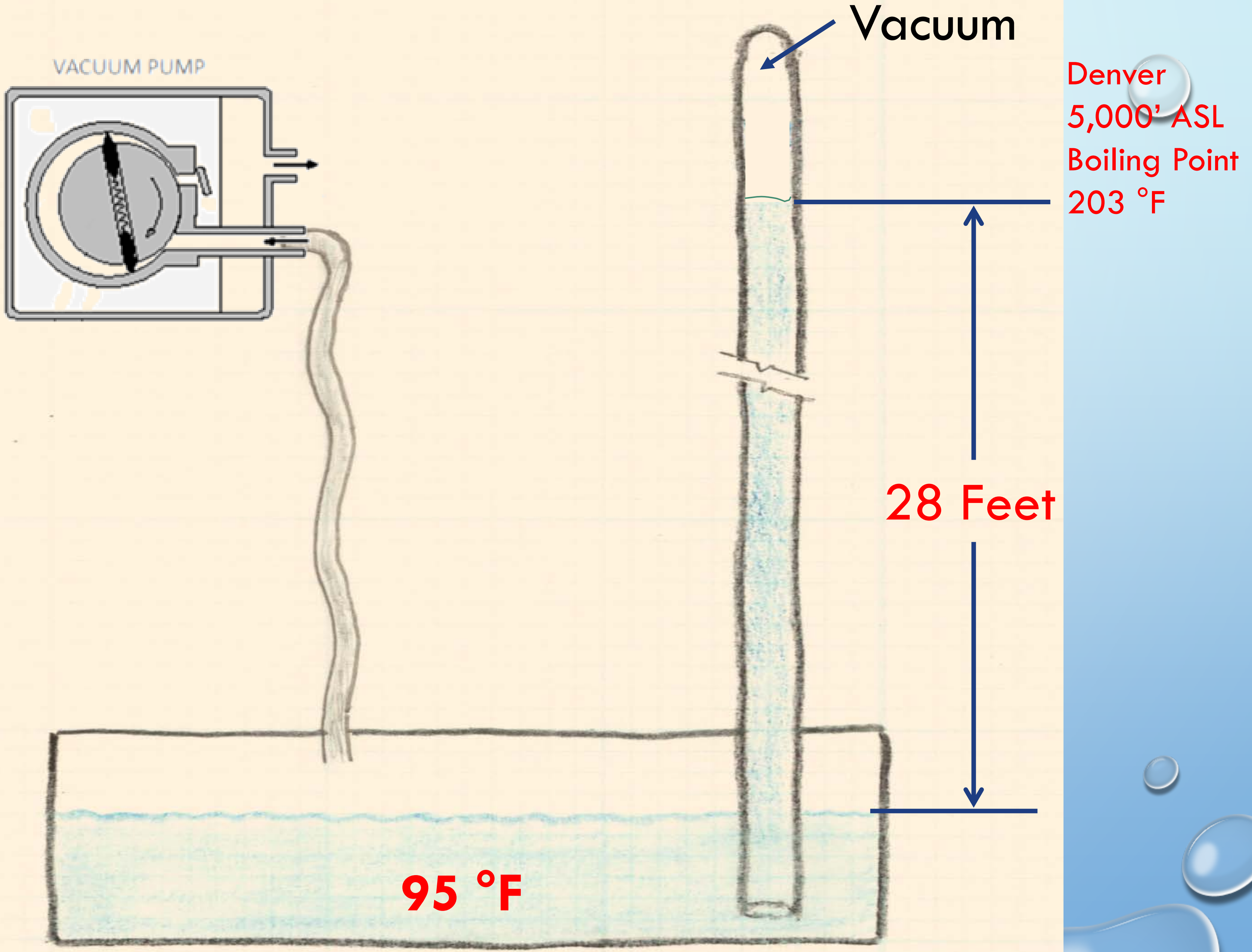
Sea Level
Boiling Point
212 °F

34 Feet

95 °F

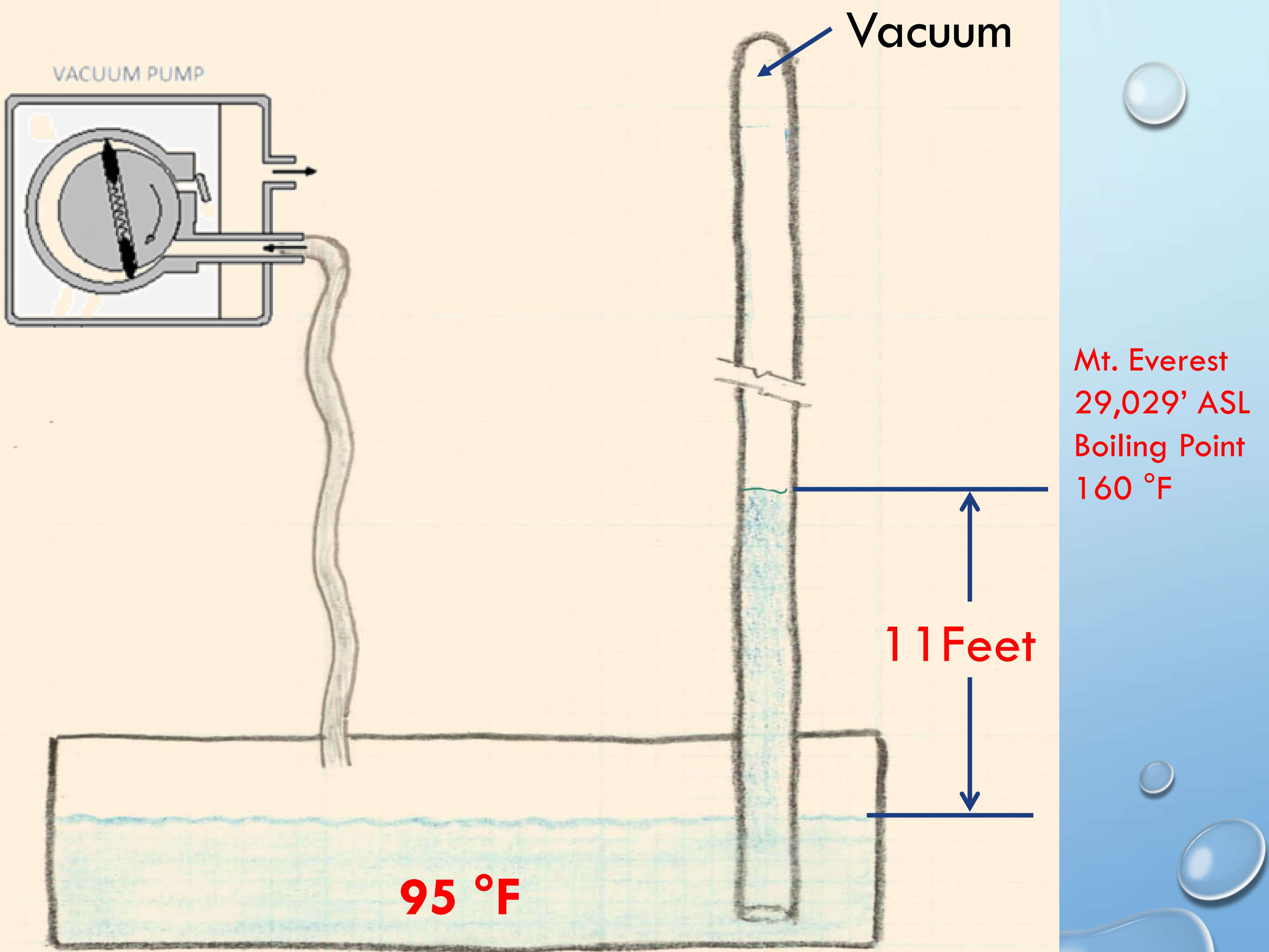
2 WAYS TO BOIL WATER

PART - 4



2 WAYS TO BOIL WATER

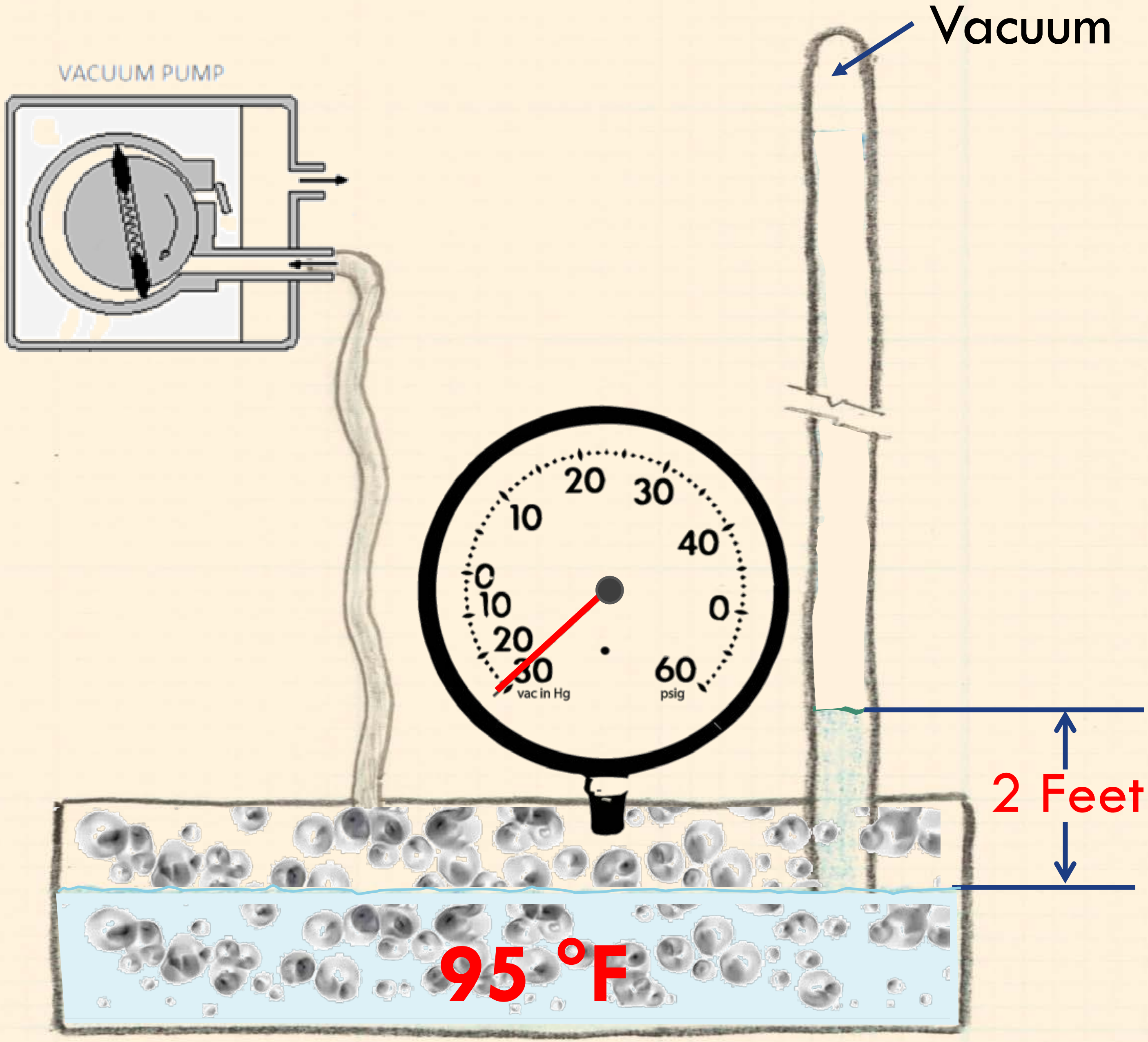
PART - 5



Mt. Everest
29,029' ASL
Boiling Point
160 °F

2 WAYS TO BOIL WATER

PART - 7



COMPOUND PRESSURE GAGE FOUND ON PUMP SUCTIONS

2 Feet H_2O Absolute =

28.2 Inches Of Hg Gauge

125 PSF Absolute

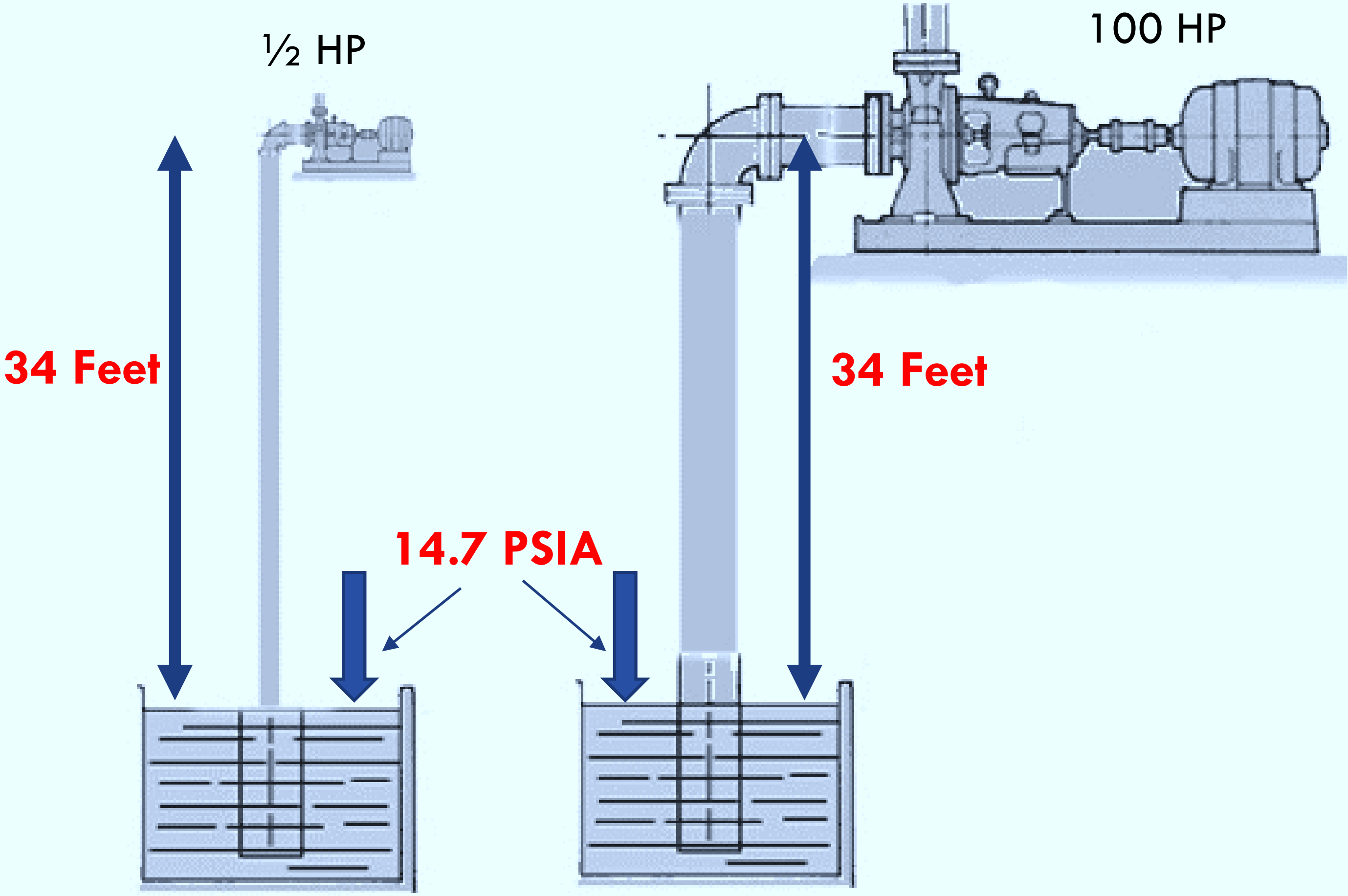
For Chino Romo

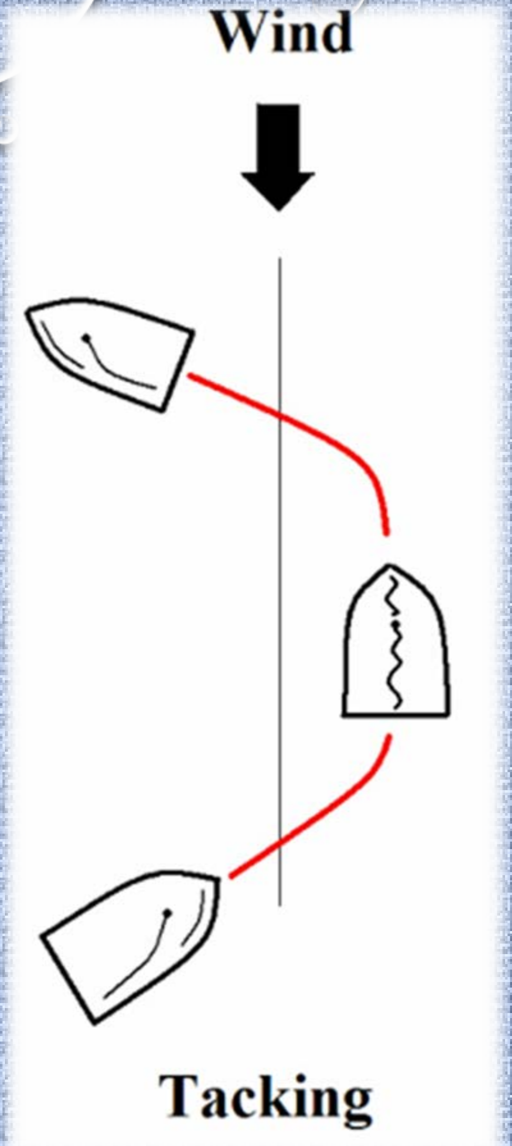
44,800 microns

Typical Compound Gage

SIDE NOTE: PUMPS CAN NOT "PULL" WATER

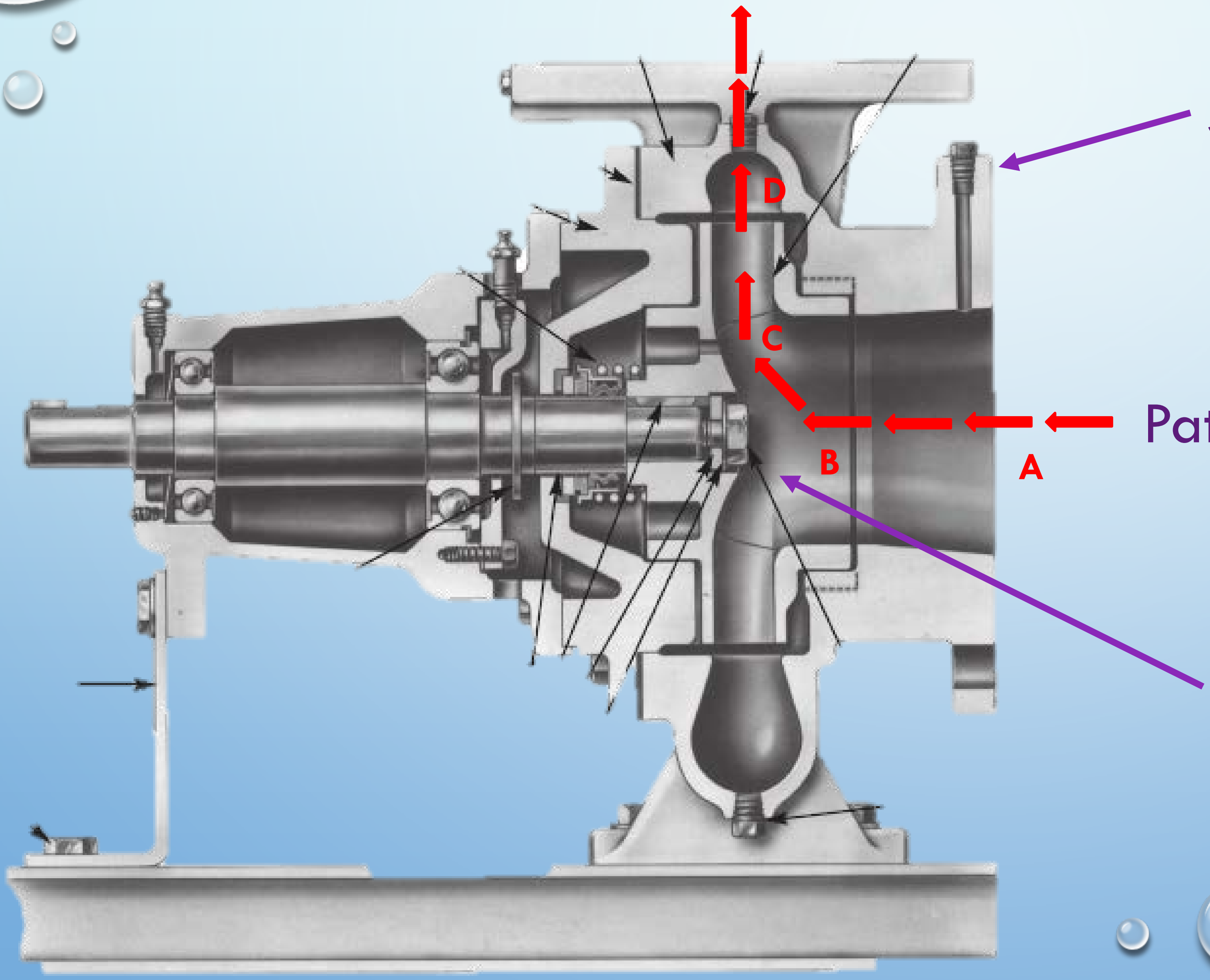
- THEY CAN ONLY EVACUATE THE PIPE TO MAKE ROOM
- SOME OTHER FORCE NEEDS TO "PUSH" THE WATER INTO THE EVACUATED SPACE





What Is Happening Inside The Pump?

SECTIONAL VIEW OF AN END SUCTION PUMP

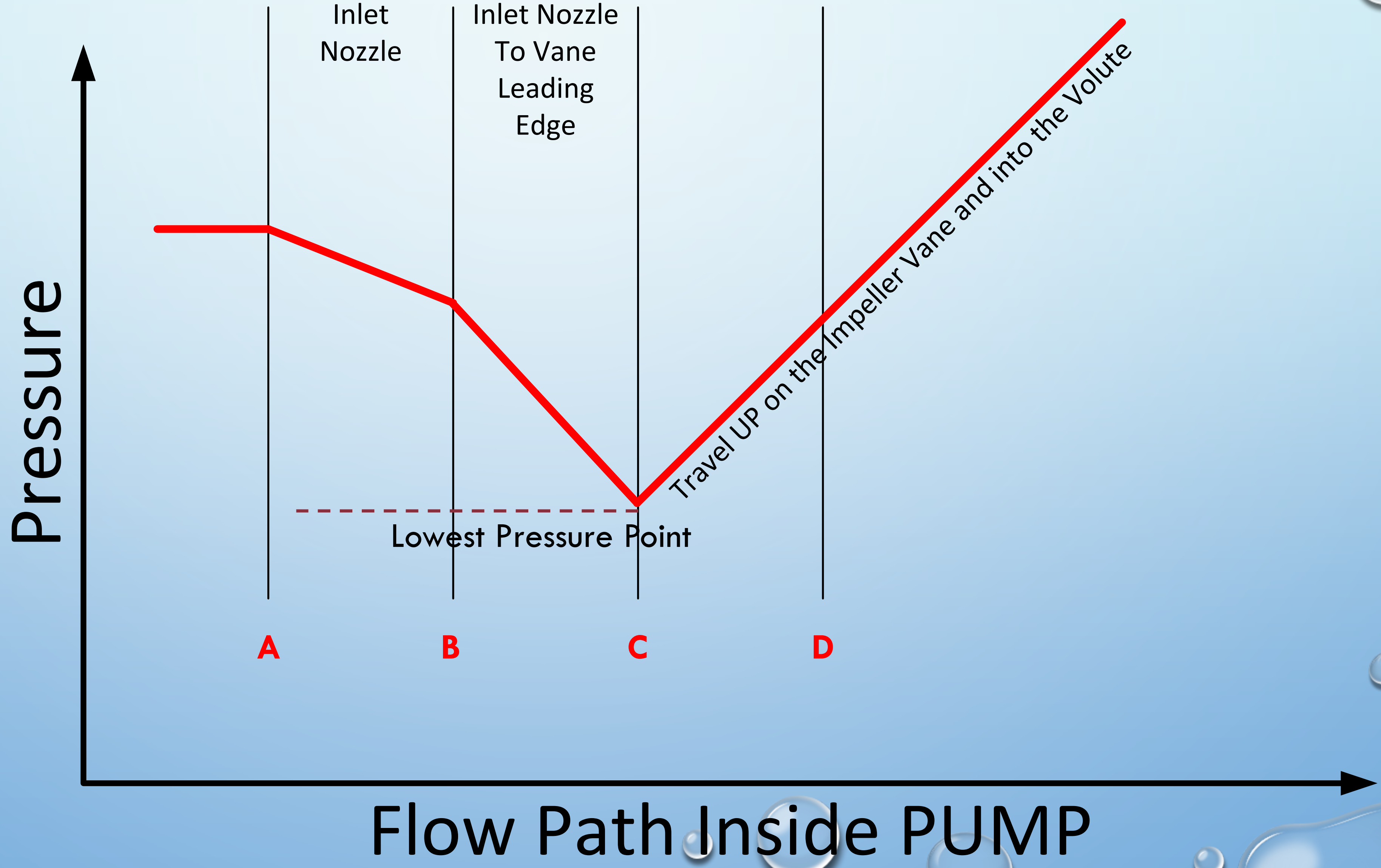


Suction Flange

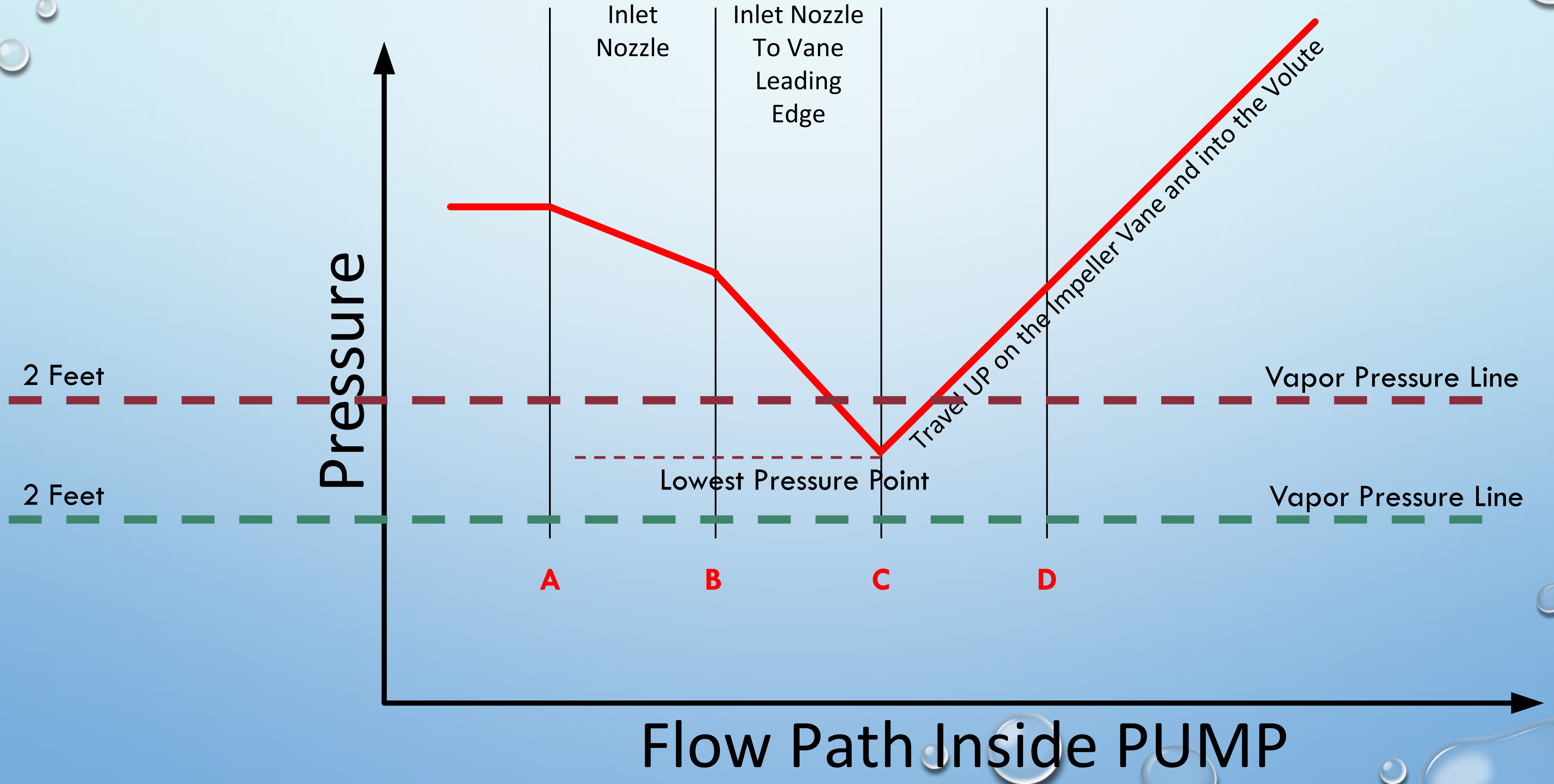
Path of Water Flow

Impeller

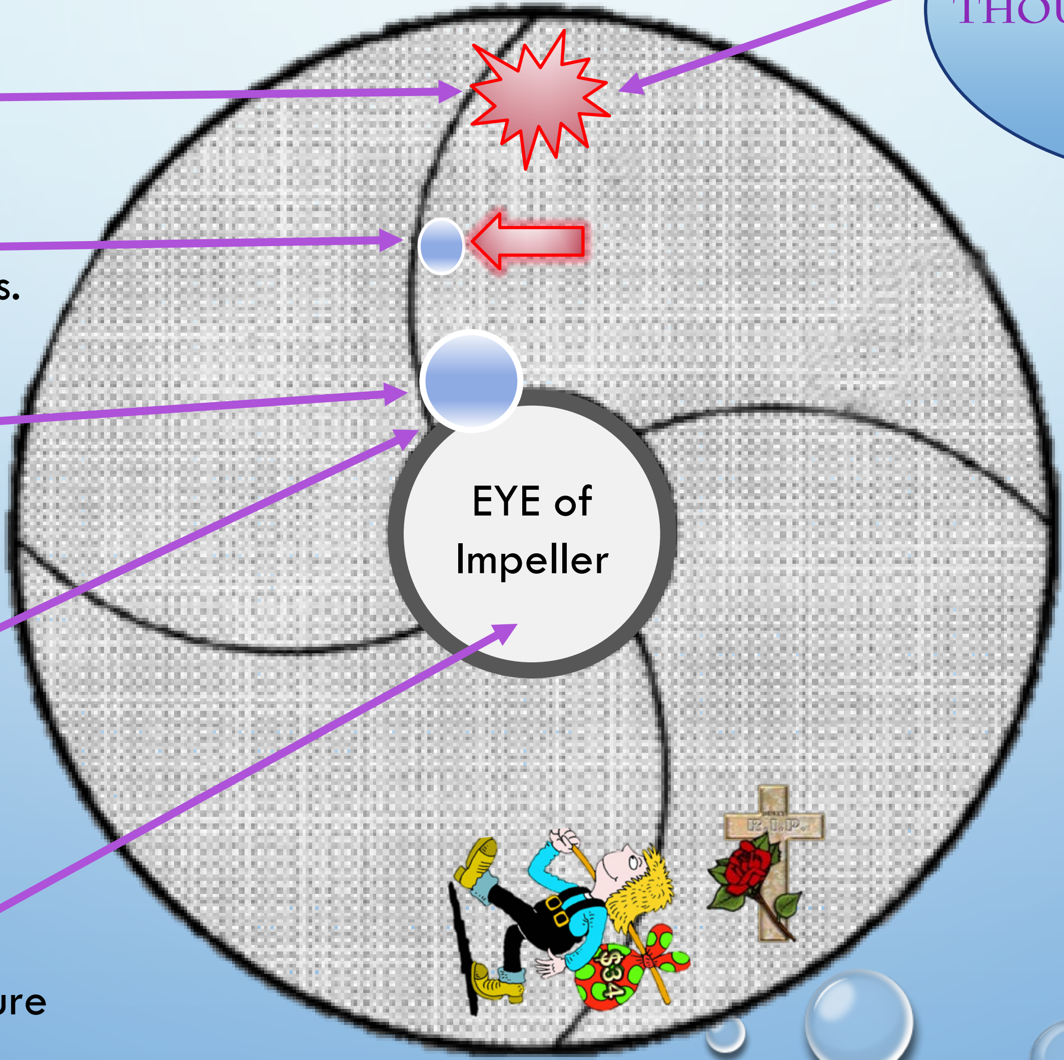
PRESSURE PROFILE INSIDE A PUMP



PRESSURE PROFILE INSIDE A PUMP



WHAT IS CAVITATION?



MINI EXPLOSION !!!

"Pump Action" Slings the Drop
On the Vane. Pressure Increases.

Bubbles Form Here First

Lowest Pressure Point
Inside a Centrifugal PUMP

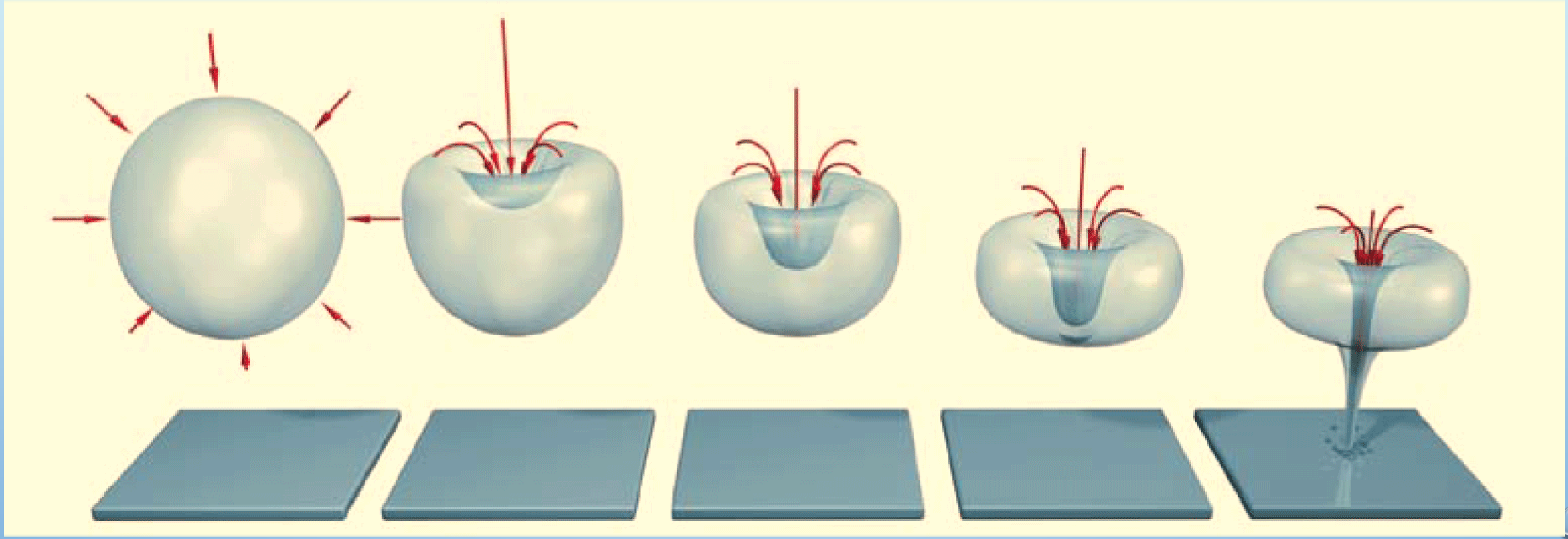
If you allow Water Pressure
To drop below its VAPOR Pressure

60,000 PSI
PIN-PRICK SHOCK WAVE
THOUSANDS OF BUBBLES
PER SECOND

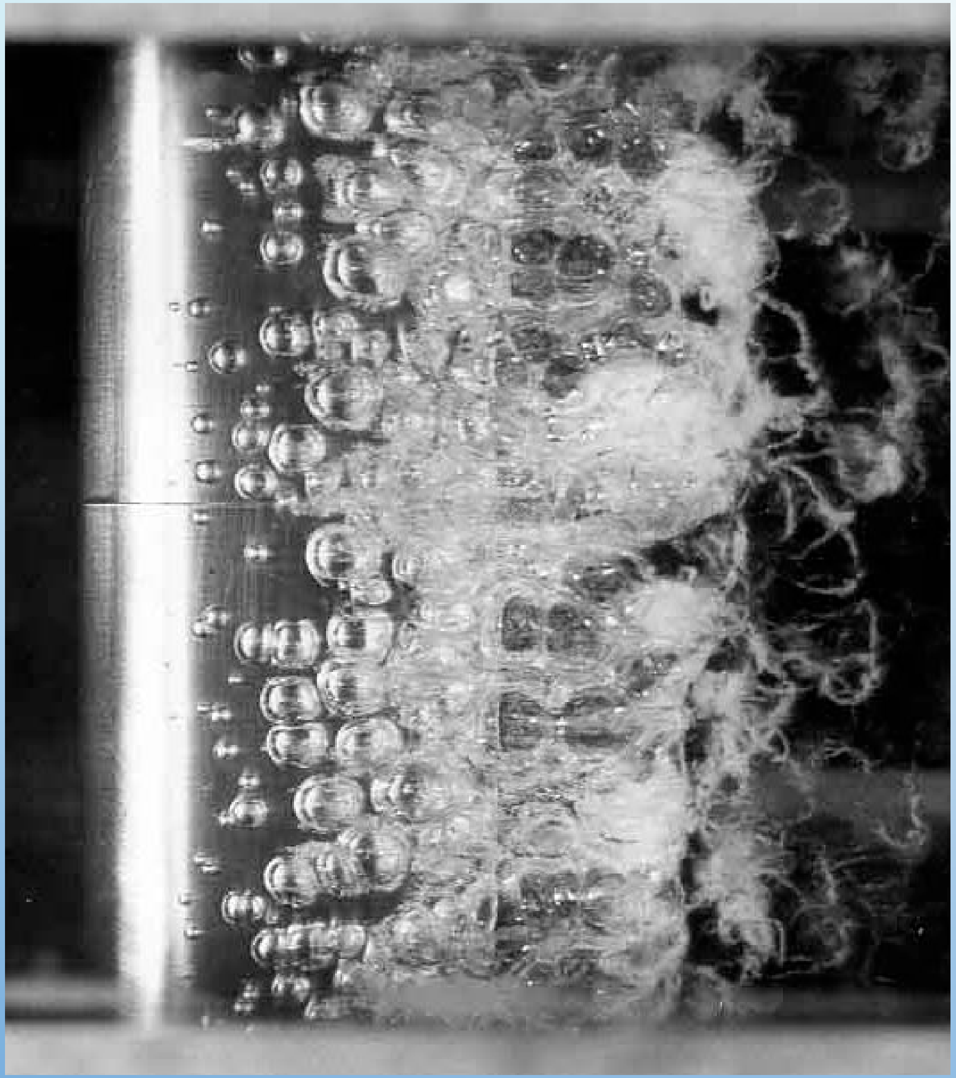
What is Cavitation?
Nasty crackling sound
First damage starts due to vibration:
Seals
Bearings
Then metal pitting starts
Metal loss can happen anywhere
but usually starts as shown on the left

And always accompanied by LOSS of
Capacity --- drop in head and flow

CAVITATION BUBBLES - 1



CAVITATION BUBBLES - 2

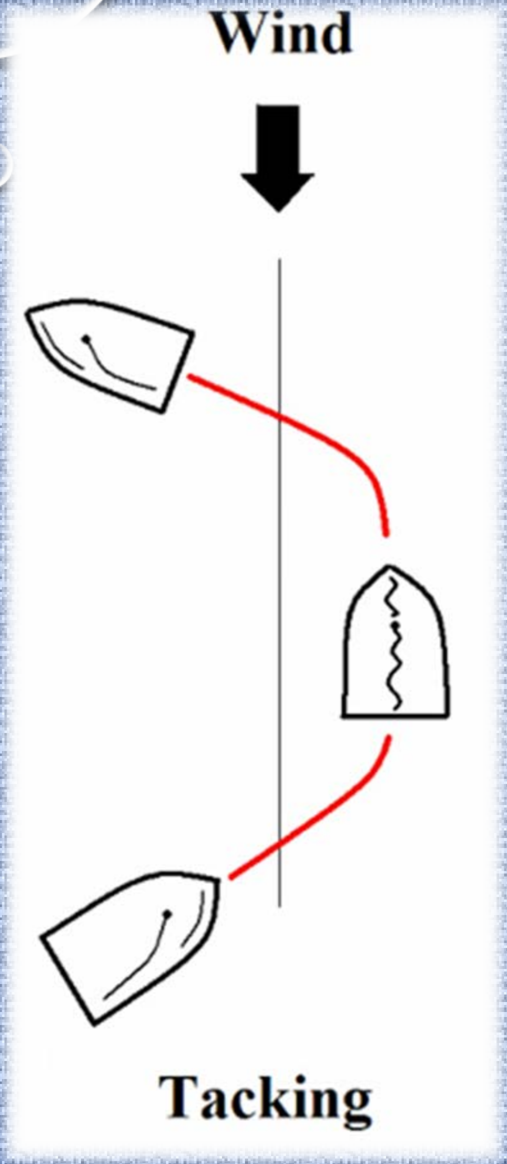


Super high speed photography of CAVITATION bubbles on an Impeller Vane.

Water Temperature 85 °F

Magnified image.

CAVITATION DAMAGE



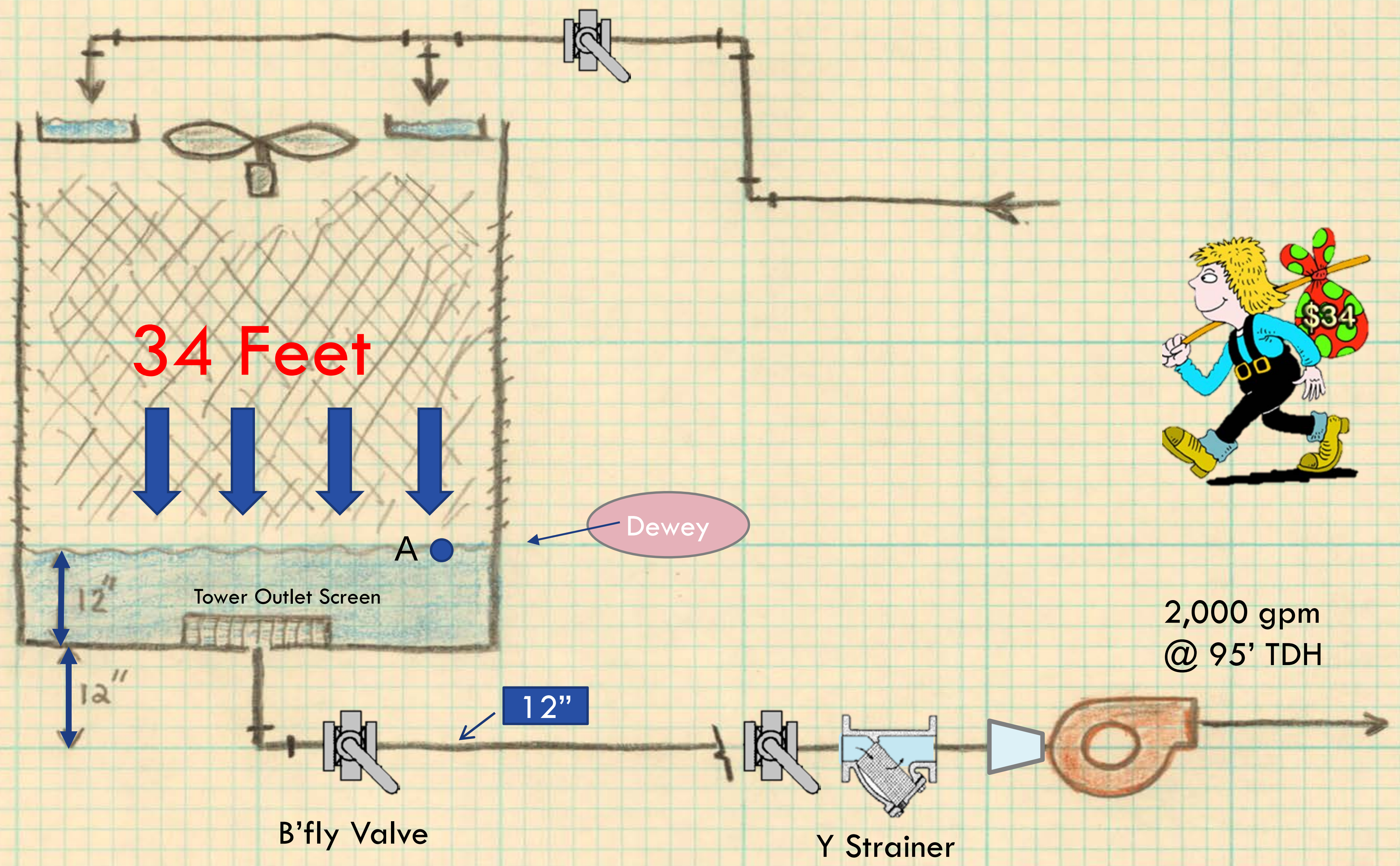
Dewey's Story

DEWEY THE LITTLE DROP & THE EVIL PROJECT MANAGER

EVIL PM'S INSTRUCTIONS TO DEWEY

- I WILL GIVE YOU A TOOTSIE ROLL AND $34 EXPENSE MONEY TO GO ON A SMALL MISSION FOR ME,
- YOUR JOB IS TO GO THROUGH THE SYSTEM AND REPORT ON WHAT IS CAUSING ALL THIS RACKET. IT SOUNDS LIKE THIS PUMP IS PUMPING GRAVEL.
- "IS THERE ANYTHING DANGEROUS ABOUT THIS JOURNEY?" ASKS DEWEY.
- "NAH, NOT REALLY," ANSWERS EPM, "JUST KNOW THAT ALONG THE WAY THERE ARE SOME TOLL COLLECTORS AND YOU WILL HAVE TO PAY TOLL. NOW, I AM GIVING YOU PLENTY OF MONEY TO COVER THAT, **BUT JUST DON'T LET YOUR POCKET BALANCE DROP BELOW $2 WHEN INSIDE THE PUMP OR YOUR HEAD WILL GET BLOWN UP**." AND THEN HE ADDED, "NOT THAT THERE IS ANY CHANCE OF THAT HAPPENING TO YOU, BUT JUST BE CAREFUL ABOUT HOW YOU SPEND YOUR MONEY."
- "NOW VAYA CON DIOS MY LITTLE FRIEND, JUMP IN AND I WILL MEET YOU AT THE OTHER END."
- AND SO YOUNG DEWEY JUMPS INTO THE TOWER SUMP.

THE SYSTEM



34 Feet

A

Dewey

Tower Outlet Screen

12”

B’fly Valve

Y Strainer

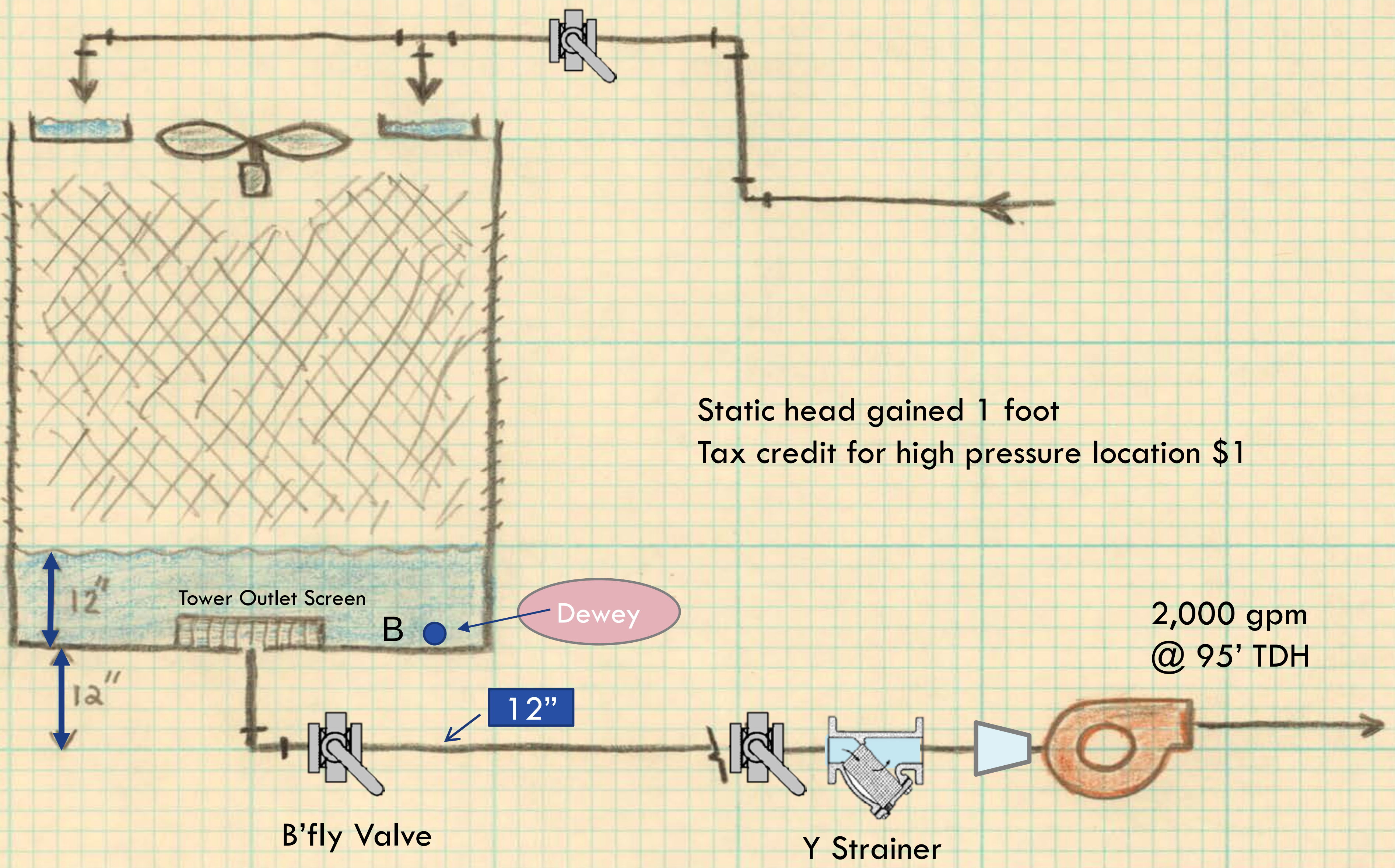
2,000 gpm
@ 95’ TDH

TALLY SHEET – 1

DEWEY AT POINT - A

Dewey cannot let his balance fall below this level or his head will get smashed!

THE SYSTEM



Static head gained 1 foot

Tax credit for high pressure location $1

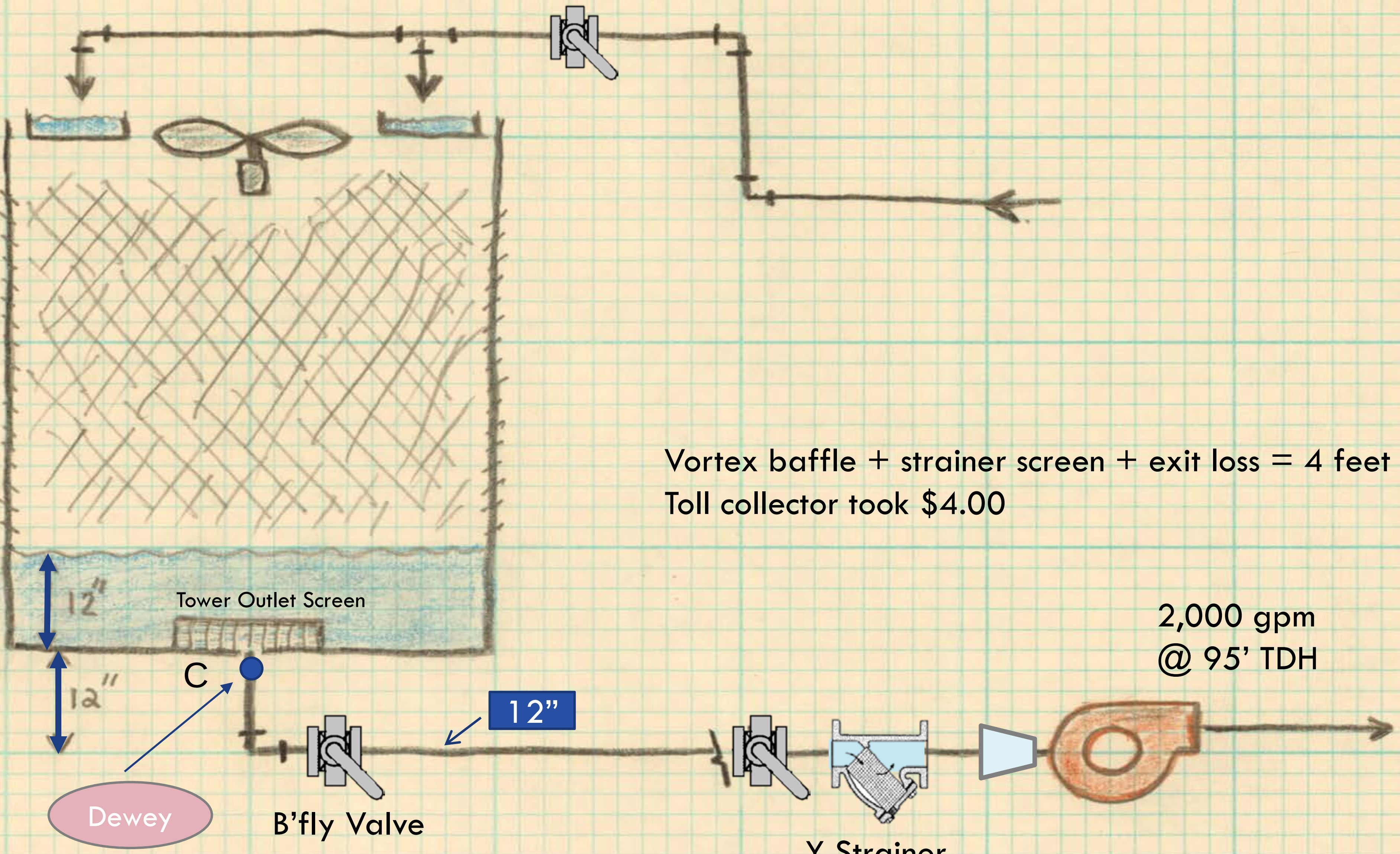
TALLY SHEET – 2

DEWEY AT POINT - B

Things are
looking good!
Got an extra $

Dewey cannot let his balance fall below this level or his head will get smashed!

THE SYSTEM



Vortex baffle + strainer screen + exit loss = 4 feet

Toll collector took $4.00

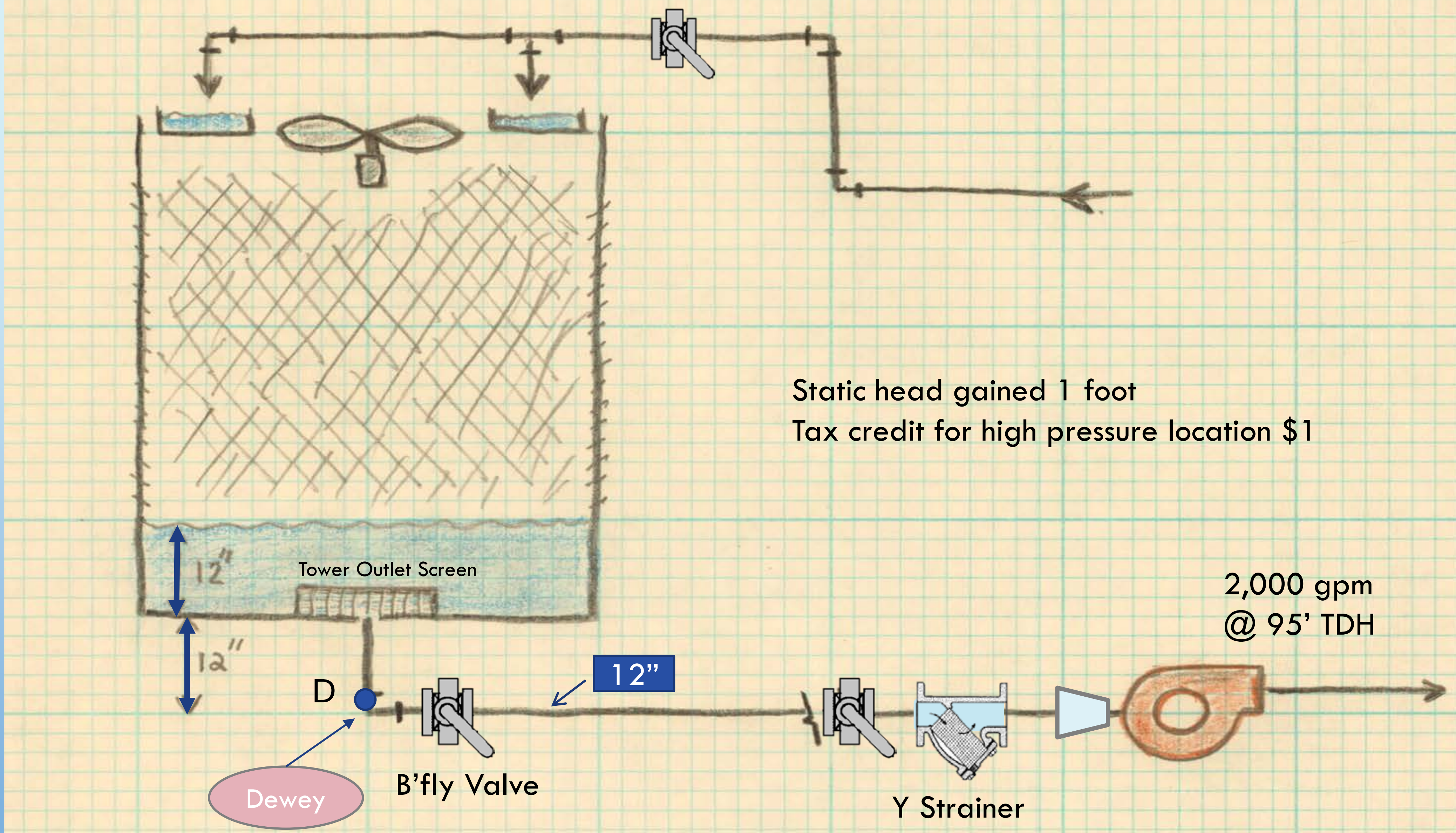
TALLY SHEET – 3

DEWEY AT POINT - C

Not bad!
The pump is right there,
and I still have $31

Dewey cannot let his balance fall below this level or his head will get smashed!

THE SYSTEM

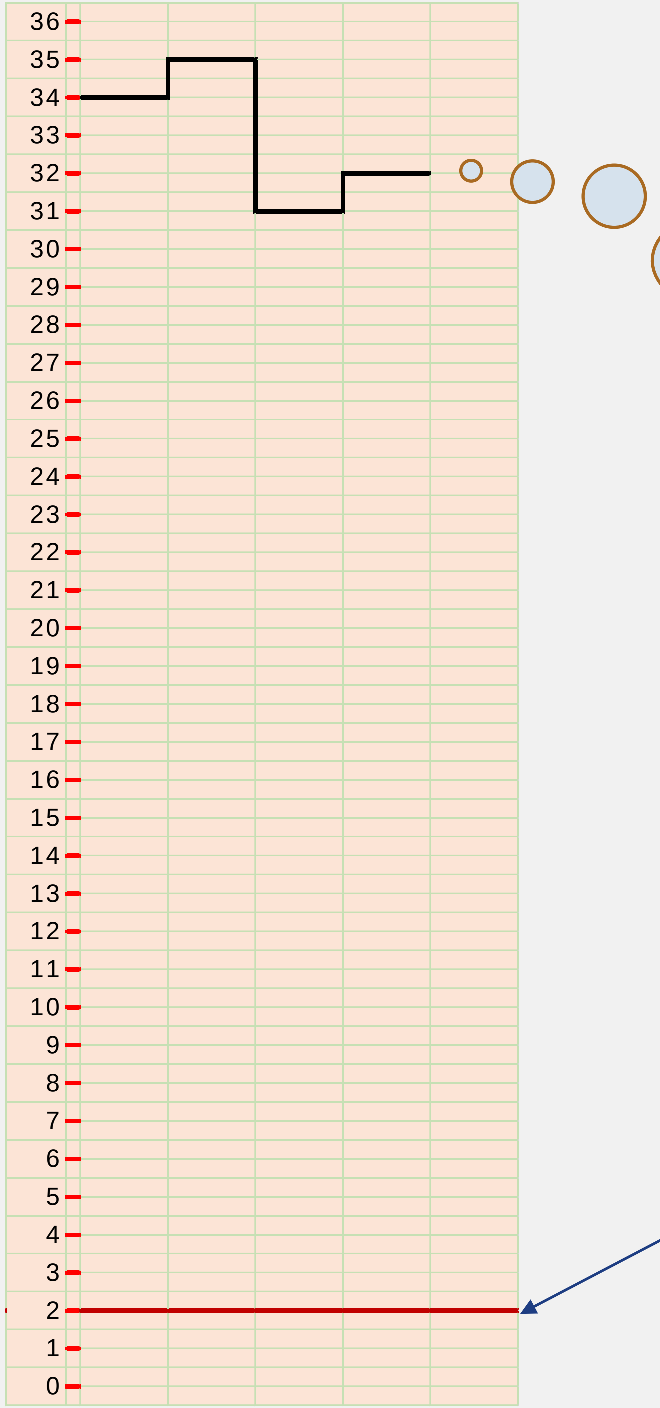


2,000 gpm
@ 95' TDH

Static head gained 1 foot
Tax credit for high pressure location $1

TALLY SHEET – 4

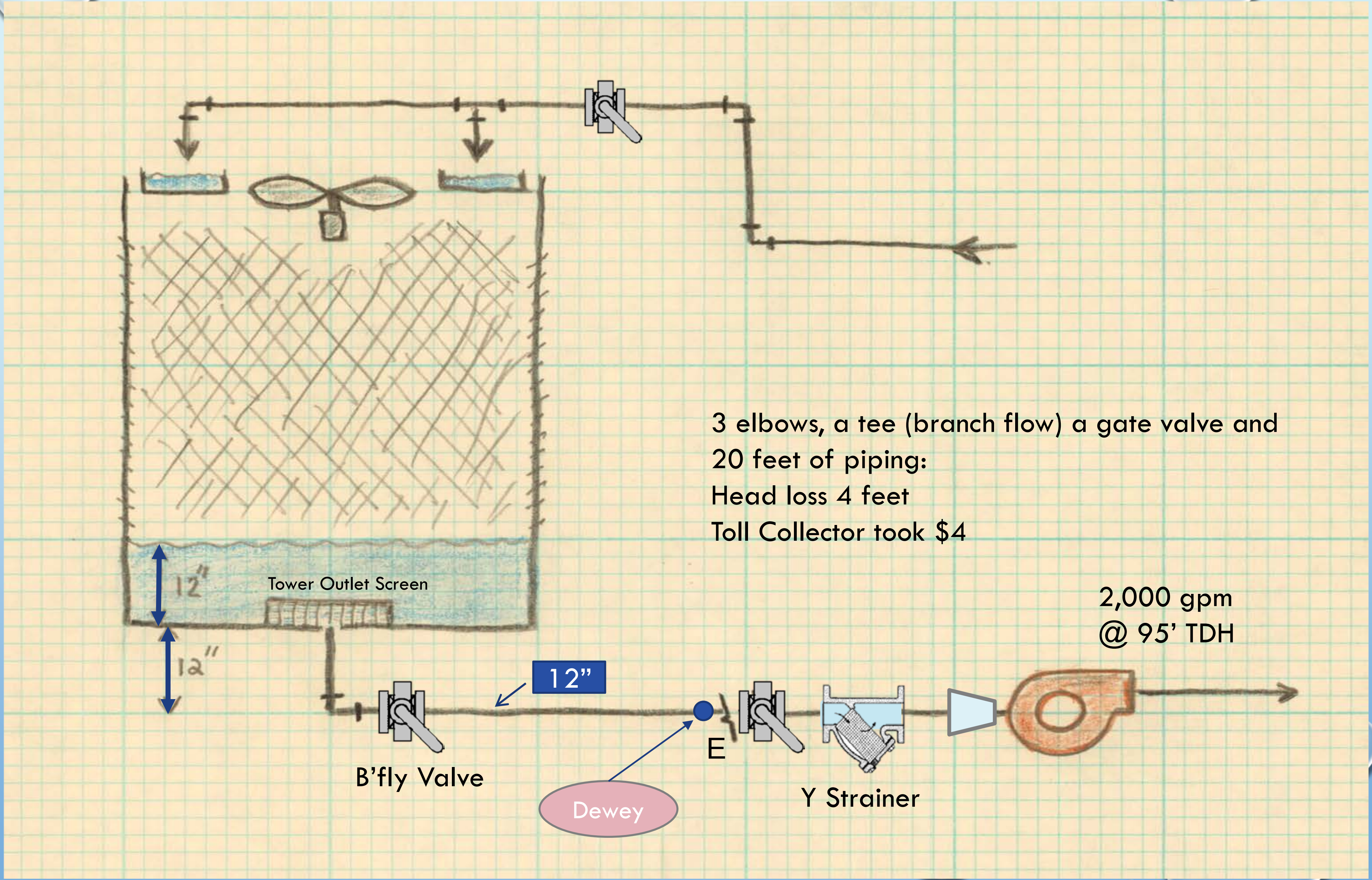
DEWEY AT POINT - D



Another buck!
I think I have it under control now.

Dewey cannot let his balance fall below this level or his head will get smashed!

THE SYSTEM



3 elbows, a tee (branch flow) a gate valve and 20 feet of piping:

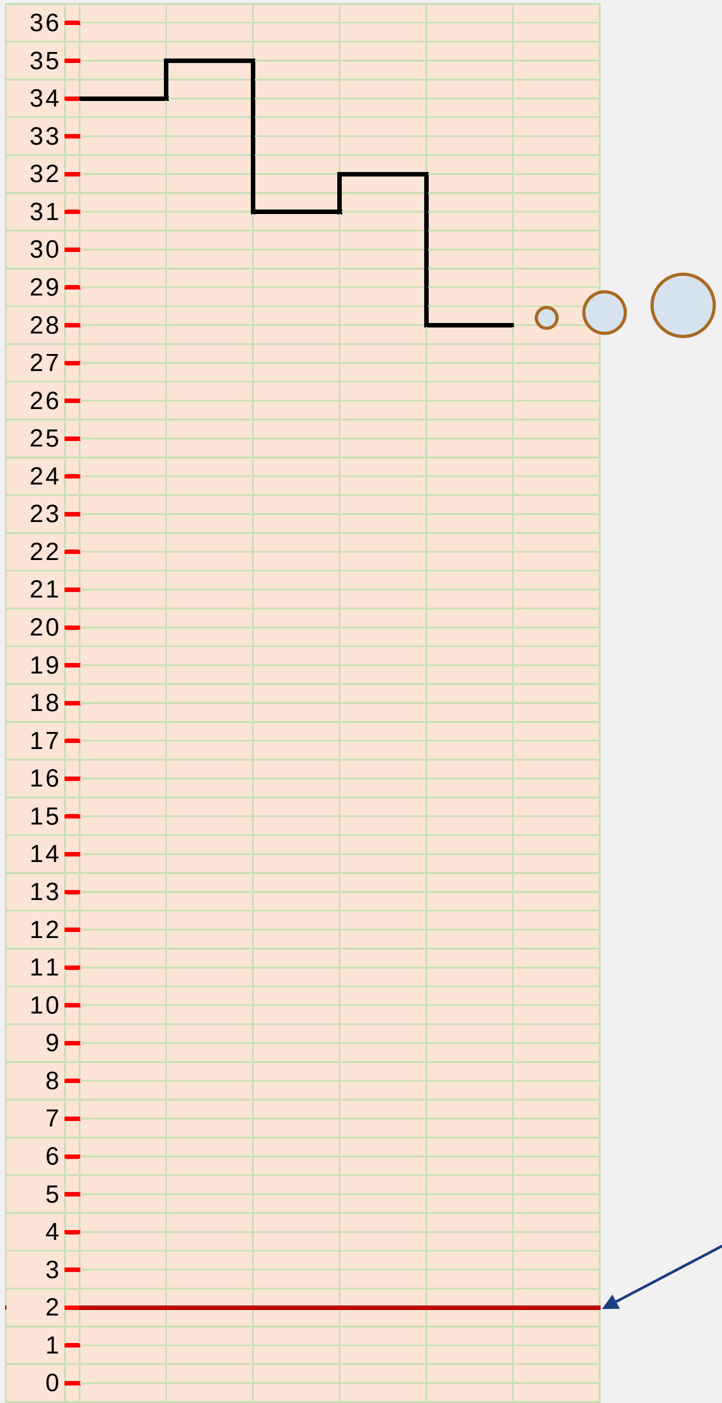
Head loss 4 feet

Toll Collector took $4

2,000 gpm
@ 95' TDH

TALLY SHEET – 5

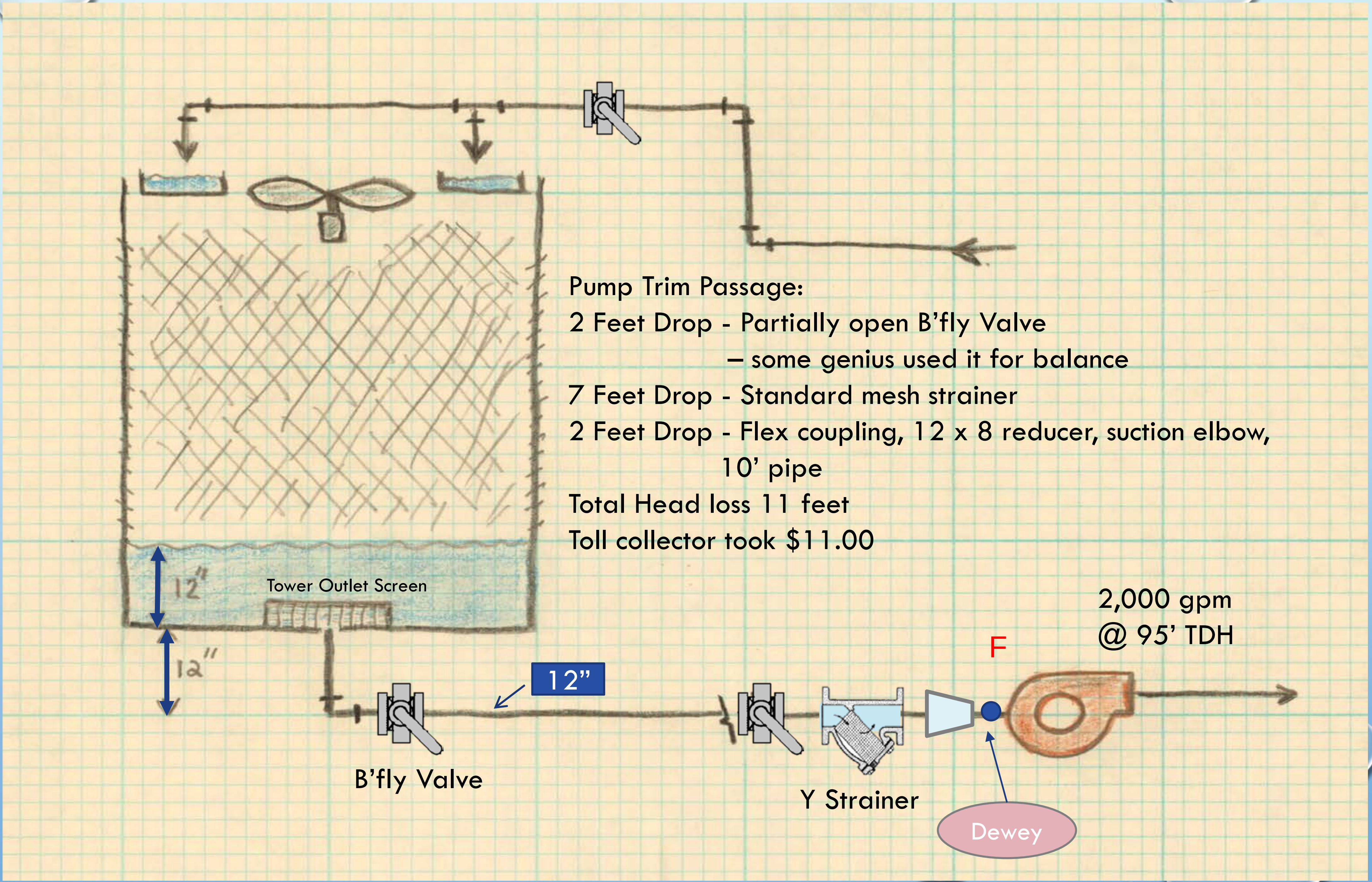
DEWEY AT POINT - E



Four Dollars!
Damn these toll collectors!
I am a little nervous right now.

Dewey cannot let his balance fall below this level or his head will get smashed!

THE SYSTEM



Pump Trim Passage:

2 Feet Drop - Partially open B'fly Valve
– some genius used it for balance

7 Feet Drop - Standard mesh strainer

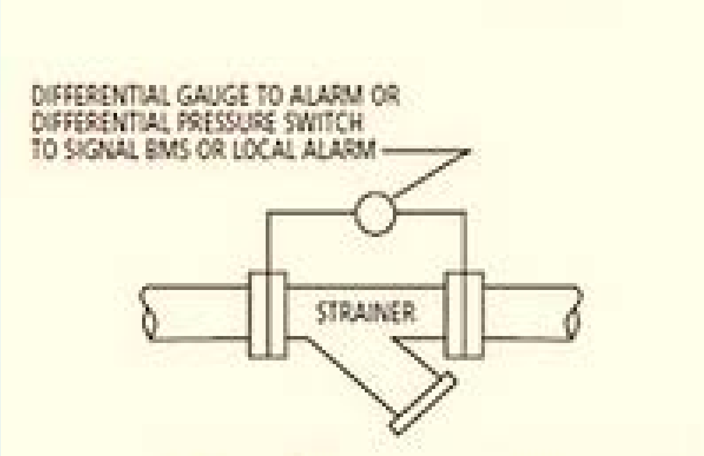
2 Feet Drop - Flex coupling, 12 x 8 reducer, suction elbow, 10' pipe

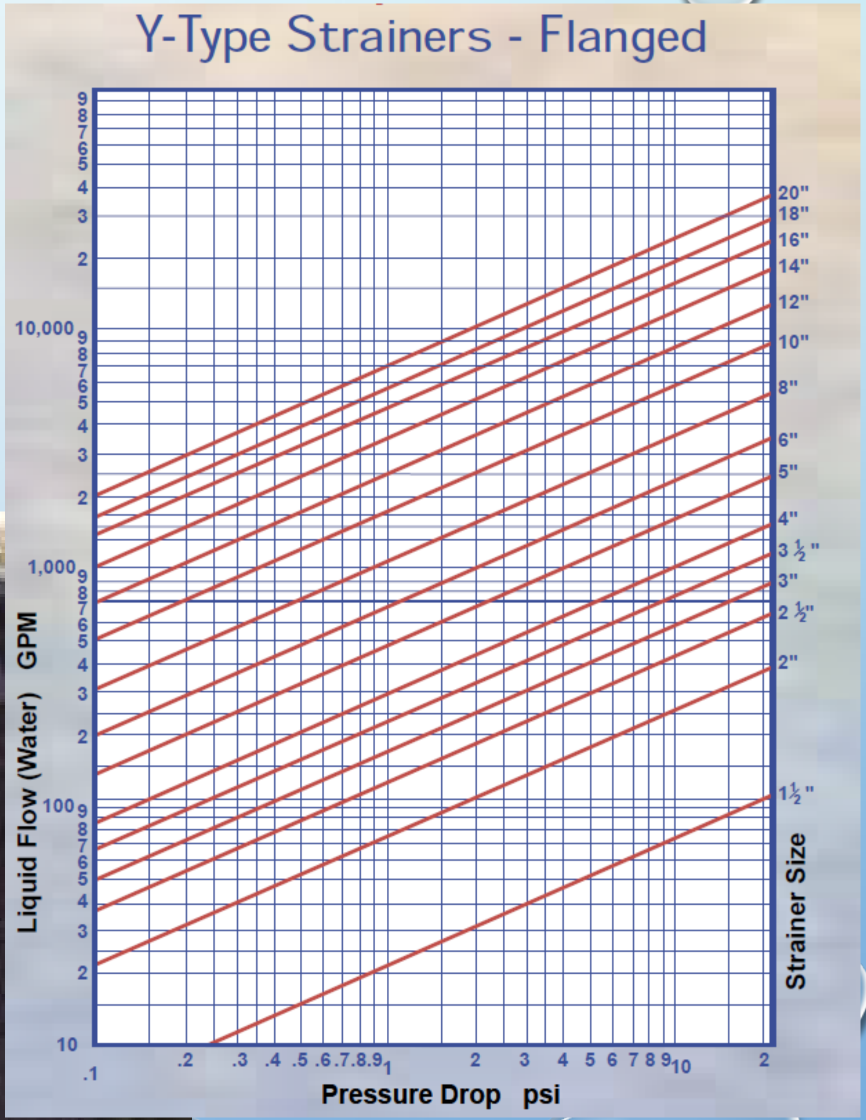
Total Head loss 11 feet

Toll collector took $11.00

STRAINER DESIGN PRESSURE DROP

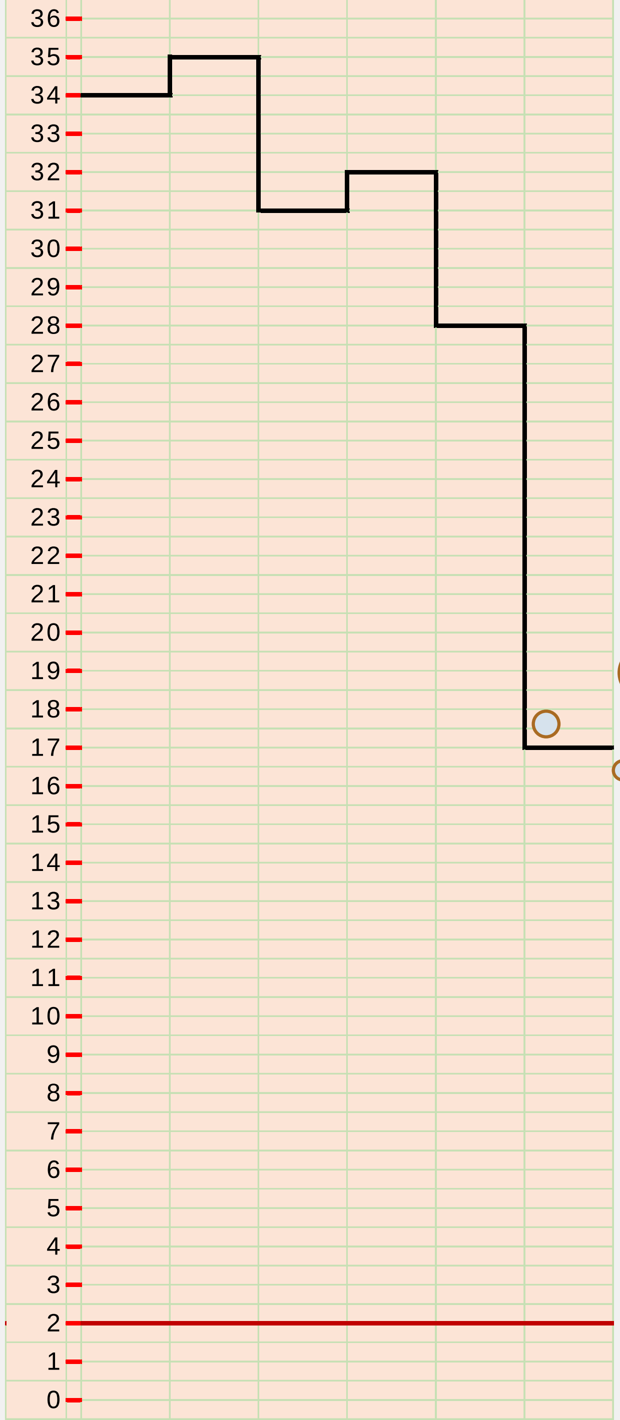
- A 12” clean Y strainer handling 2000 gpm will have about 1 psi drop.
- In real life it can be anything from the CLEAN value to totally plugged or ∞
- What should our design allow without a drop in pump capacity?
- 3 times clean pressure drop (for cooling towers) is a good starting point.
- That means 3 psi or 7 Feet of WC.
- A pressure transducer across the strainer should alert BMS to clean the strainer.





TALLY SHEET – 6

DEWEY AT POINT - F

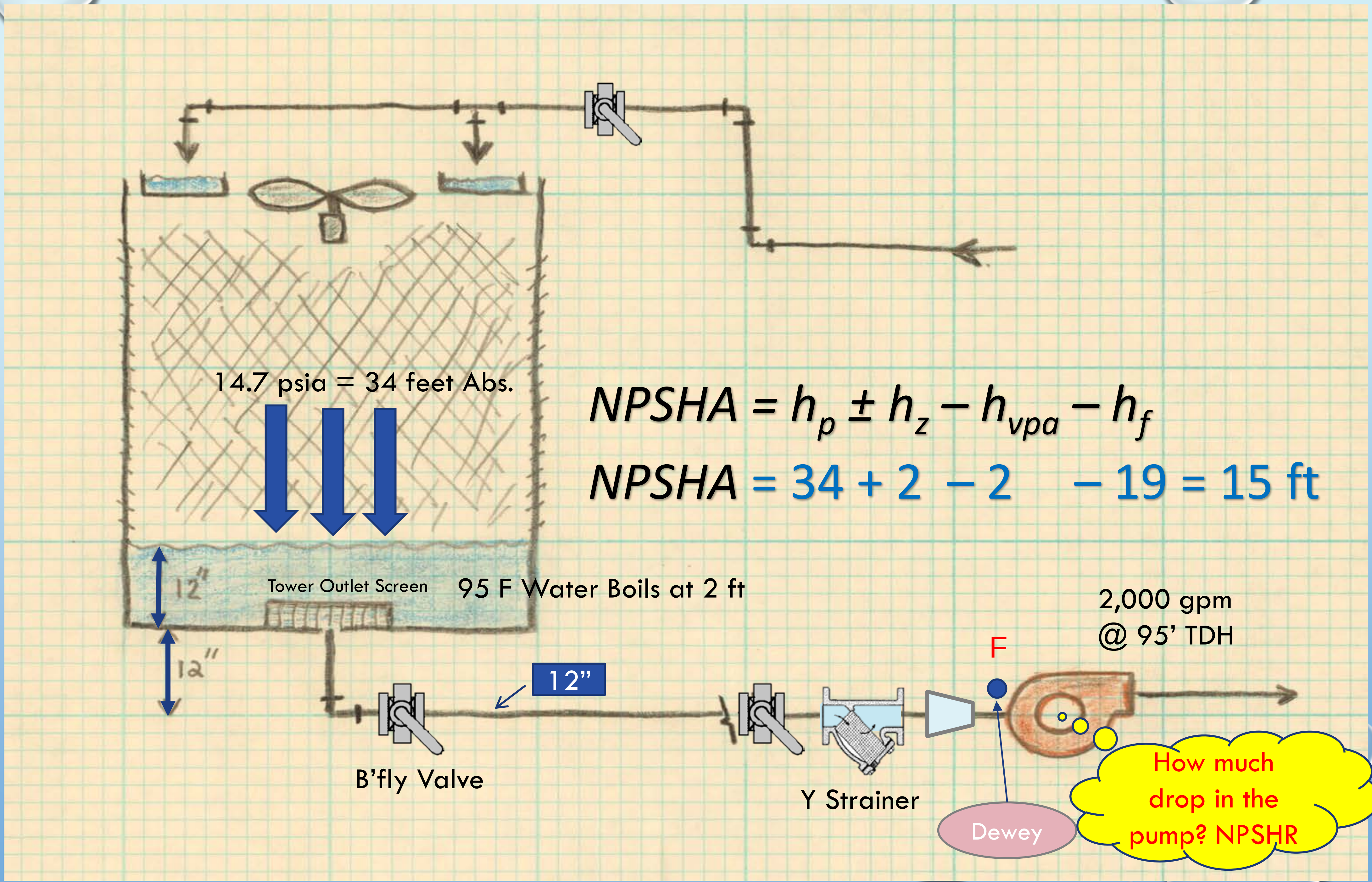


$11! Are you kidding me? Is this a "happenstance" that I am at Point **"F"**? This is NOT good!

Next I wonder what the PUMP toll is going to be – My life will depend on that!

Dewey cannot let his balance fall below this level or his head will get smashed!

THE SYSTEM



14.7 psia = 34 feet Abs.

$$NPSHA = h_p \pm h_z - h_{vpa} - h_f$$

$$NPSHA = 34 + 2 \; - 2 \quad - 19 = 15 \text{ ft}$$

Tower Outlet Screen

95 F Water Boils at 2 ft

2,000 gpm
@ 95’ TDH

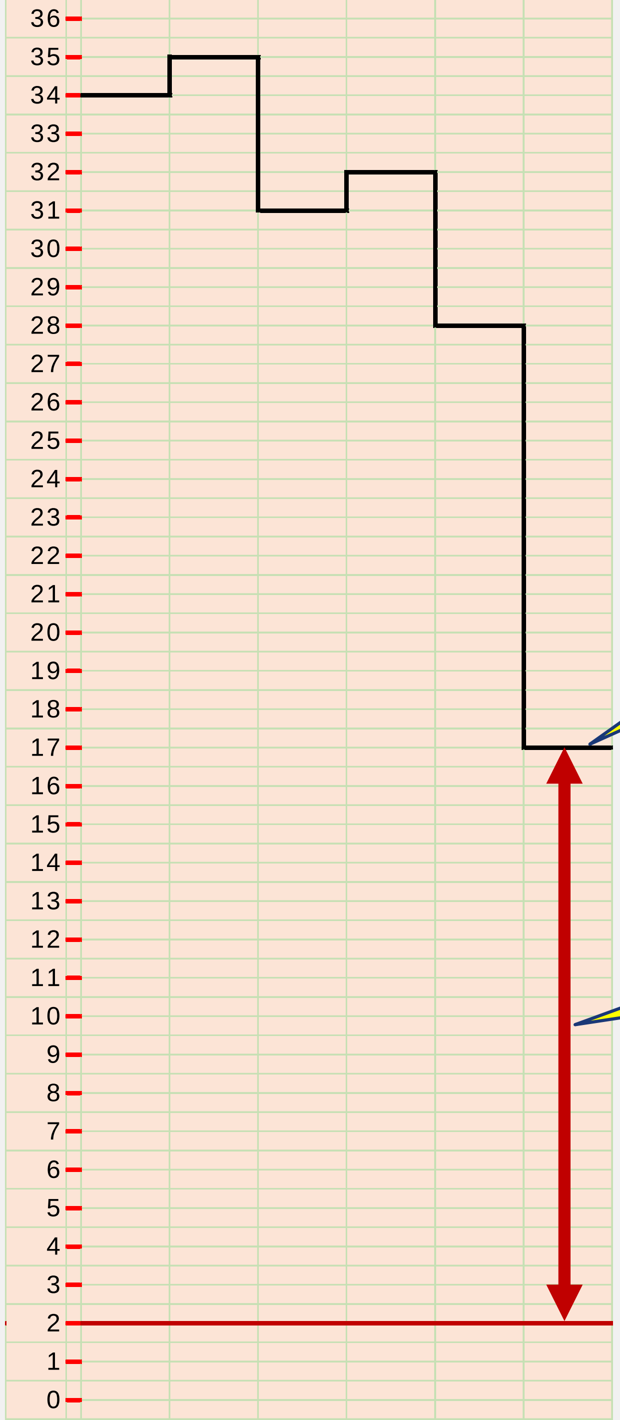
B’fly Valve

Y Strainer

How much drop in the pump? NPSHR

TALLY SHEET – 6

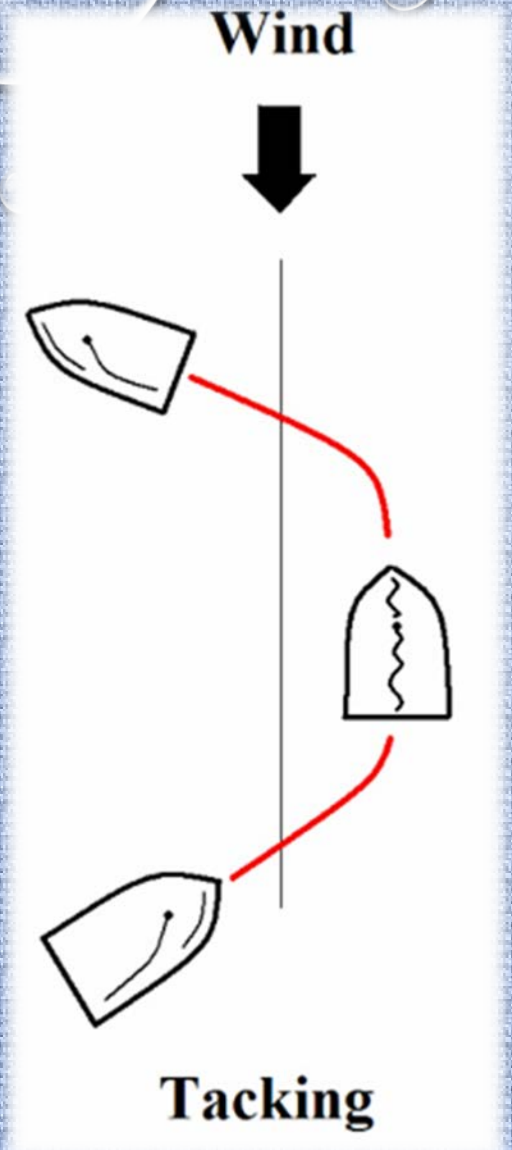
DEWEY AT POINT - F



This is
Dewey's Bank Balance
As he stands at "F"
= $17

This is
NPSHA
Net Positive Suction Head
AVAILABLE
=$15

Dewey cannot let his balance fall below this level or his head will get smashed!



Closing The Loop

CLOSING THE LOOP

The following equation may be used to determine the NPSHA in a proposed design:

$$NPSHA = h_p \pm h_z - h_{vpa} - h_f \qquad (6)$$

Where

h_p *= absolute pressure on surface of liquid that enters pump, ft of head*

h_z *= static elevation of liquid above center line of pump*

(h_z *is negative if liquid level is below pump center line), ft*

h_{vpa}*= absolute vapor pressure at pumping temperature, ft*

h_f *= friction and head losses in suction piping, ft*

2012 ASHRAE Handbook—HVAC Systems and Equipment 44.10

We now
KNOW
every term in
this equation!

2 WAYS TO BOIL WATER

PART-2

1 atm

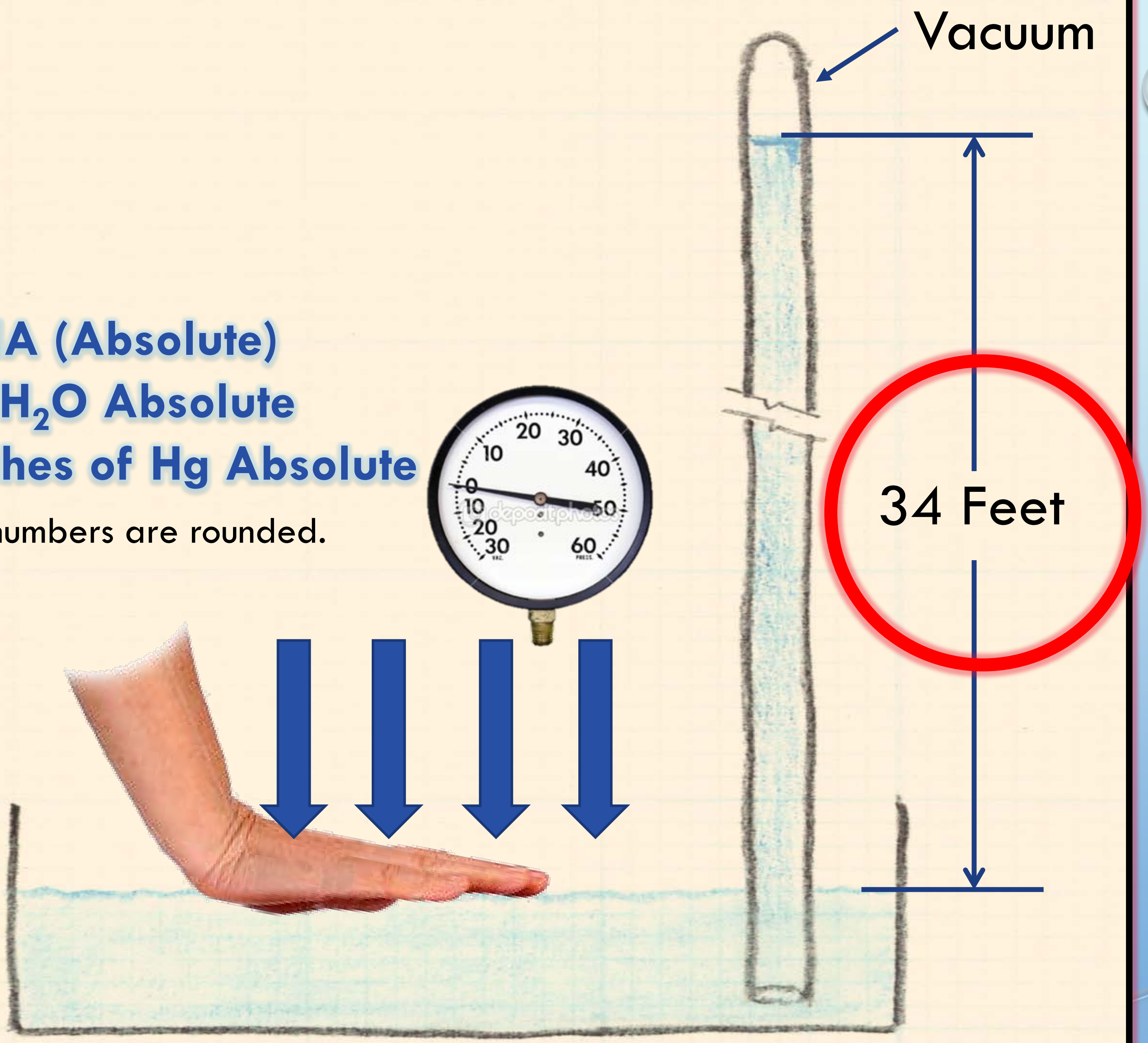
= 0 PSIG

= 14.7 PSIA (Absolute)

= 34 Feet H_2O Absolute

= 29.9 Inches of Hg Absolute

Note: Above numbers are rounded.



CLOSING THE LOOP

$$NPSHA = \overset{34}{h_p} \pm h_z - h_{vpa} - h_f \qquad (6)$$

Where

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2012 ASHRAE Handbook—HVAC Systems and Equipment 44.10

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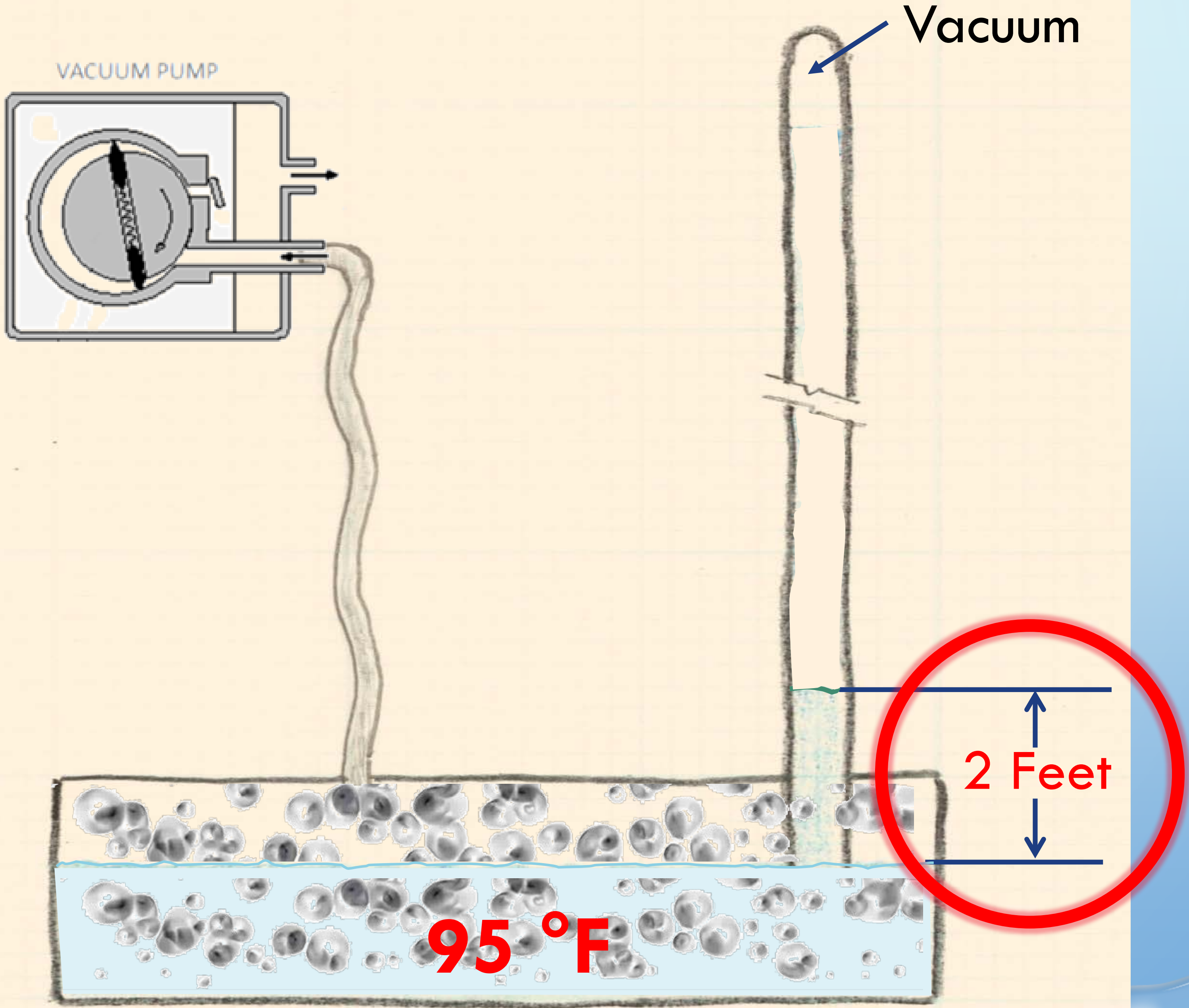
2 WAYS TO BOIL WATER

PART - 7



CLOSING THE LOOP

$$NPSHA = \overset{34}{h_p} \pm h_z - \overset{2}{h_{vpa}} - h_f \qquad (6)$$

Where

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h_z = *static elevation of liquid above center line of pump*

(h_z is negative if liquid level is below pump center line), ft

h_{vpa}= *absolute vapor pressure at pumping temperature, ft*

h_f = *friction and head losses in suction piping, ft*

2012 ASHRAE Handbook—HVAC Systems and Equipment 44.10

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KNOW
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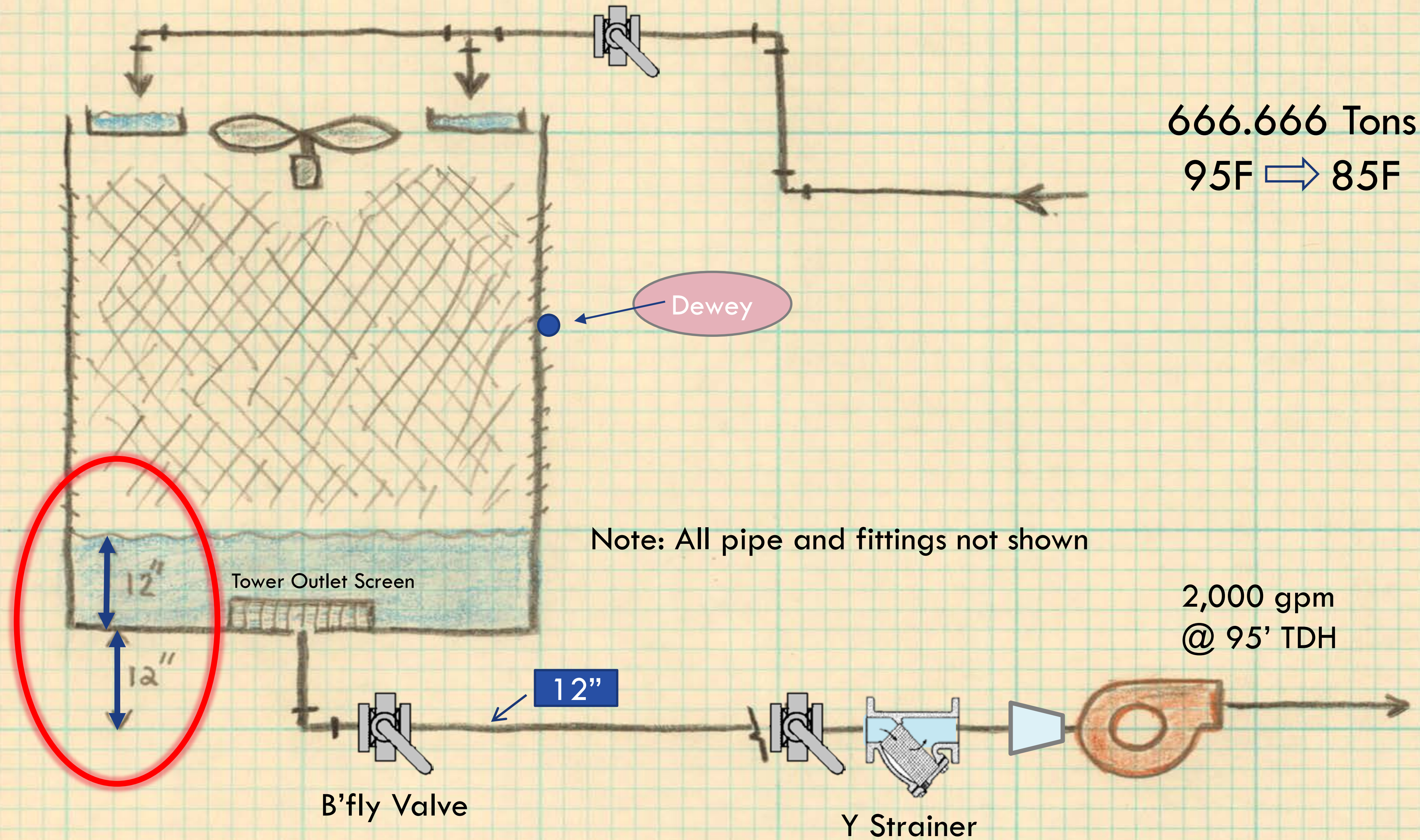
THE SYSTEM



666.666 Tons

95F ⇨ 85F

Dewey

Note: All pipe and fittings not shown

Tower Outlet Screen

12”

2,000 gpm
@ 95’ TDH

B’fly Valve

Y Strainer

CLOSING THE LOOP

$$NPSHA = \overset{34}{h_p} \pm \overset{2}{h_z} - \overset{2}{h_{vpa}} - h_f \qquad (6)$$

Where

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2012 ASHRAE Handbook—HVAC Systems and Equipment 44.10

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KNOW
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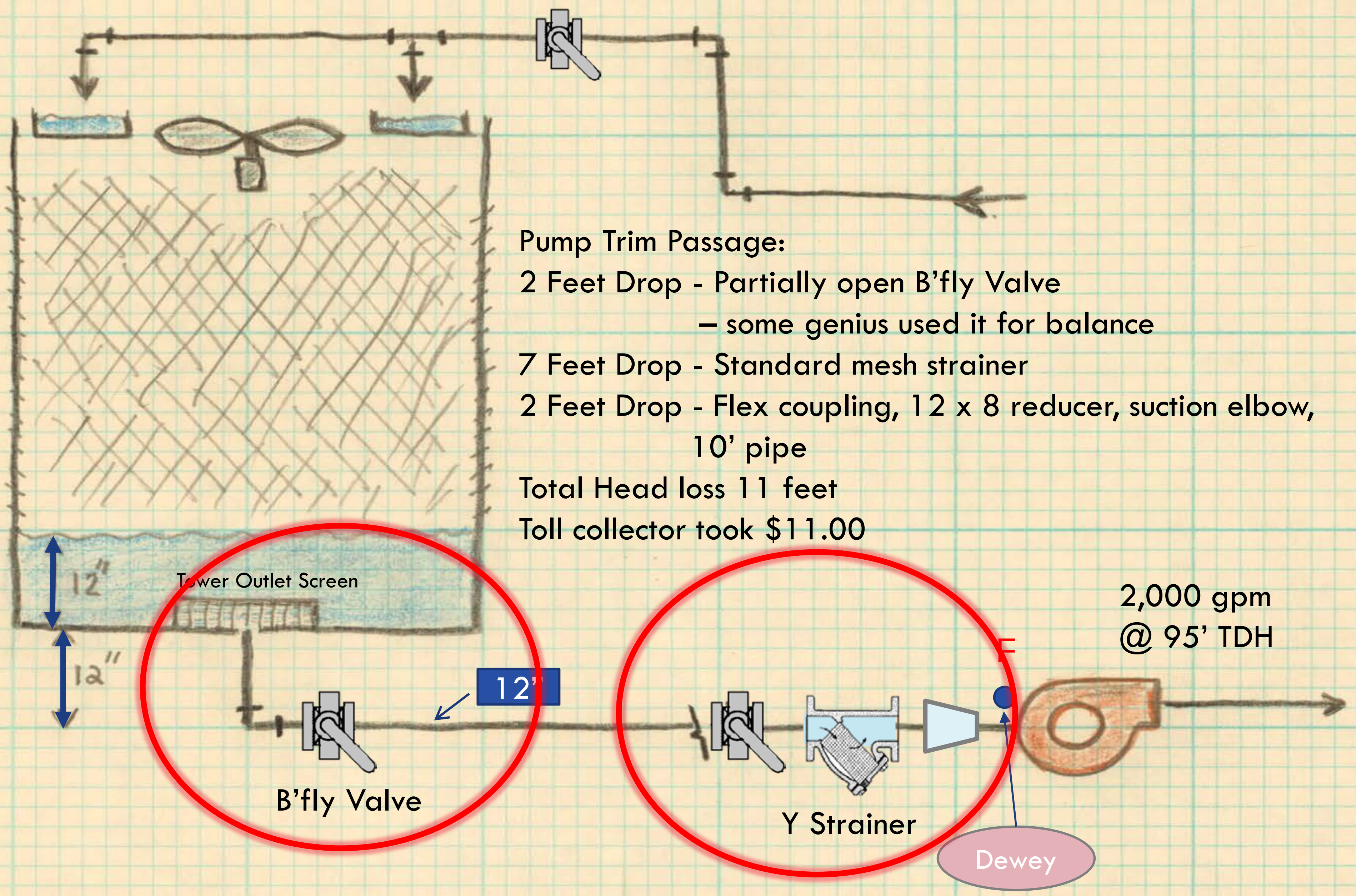
THE SYSTEM



Pump Trim Passage:

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– some genius used it for balance

7 Feet Drop - Standard mesh strainer

2 Feet Drop - Flex coupling, 12 x 8 reducer, suction elbow, 10' pipe

Total Head loss 11 feet

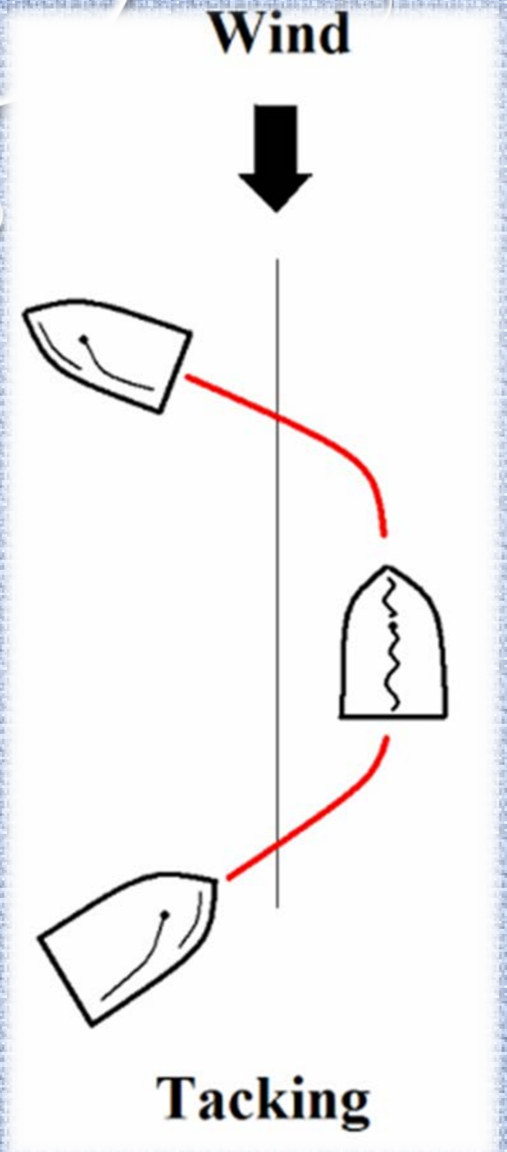
Toll collector took $11.00

CLOSING THE LOOP

$$NPSHA = \overset{+34}{h_p} \pm \overset{-2}{h_z} - \overset{-2}{h_{vpa}} - \overset{-15}{h_f}$$

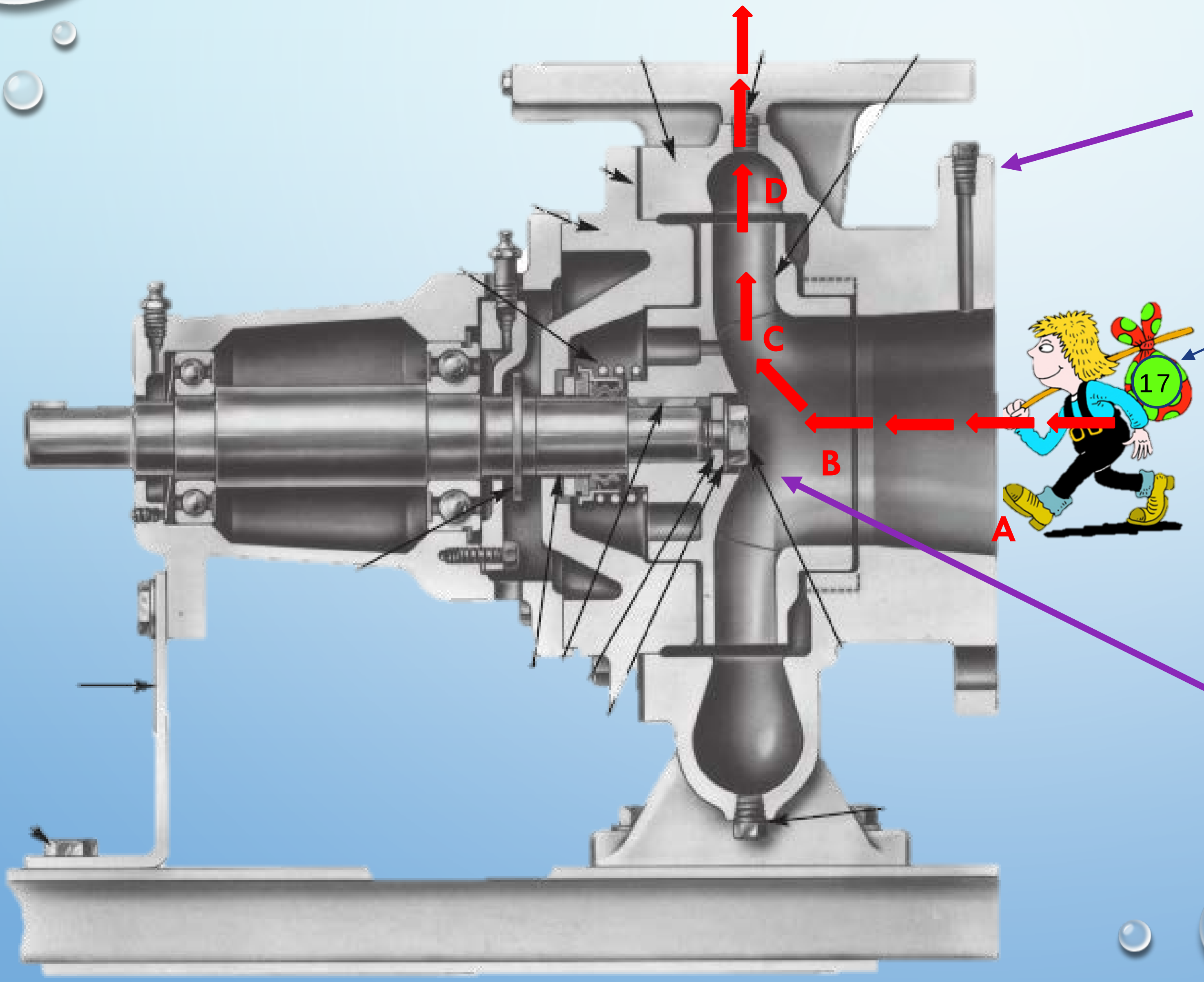
= 15 feet

DONE



How Much Is The Pressure Going To Drop In The Pump -- BEFORE It Starts To Increase?

SECTIONAL VIEW OF AN END SUCTION PUMP



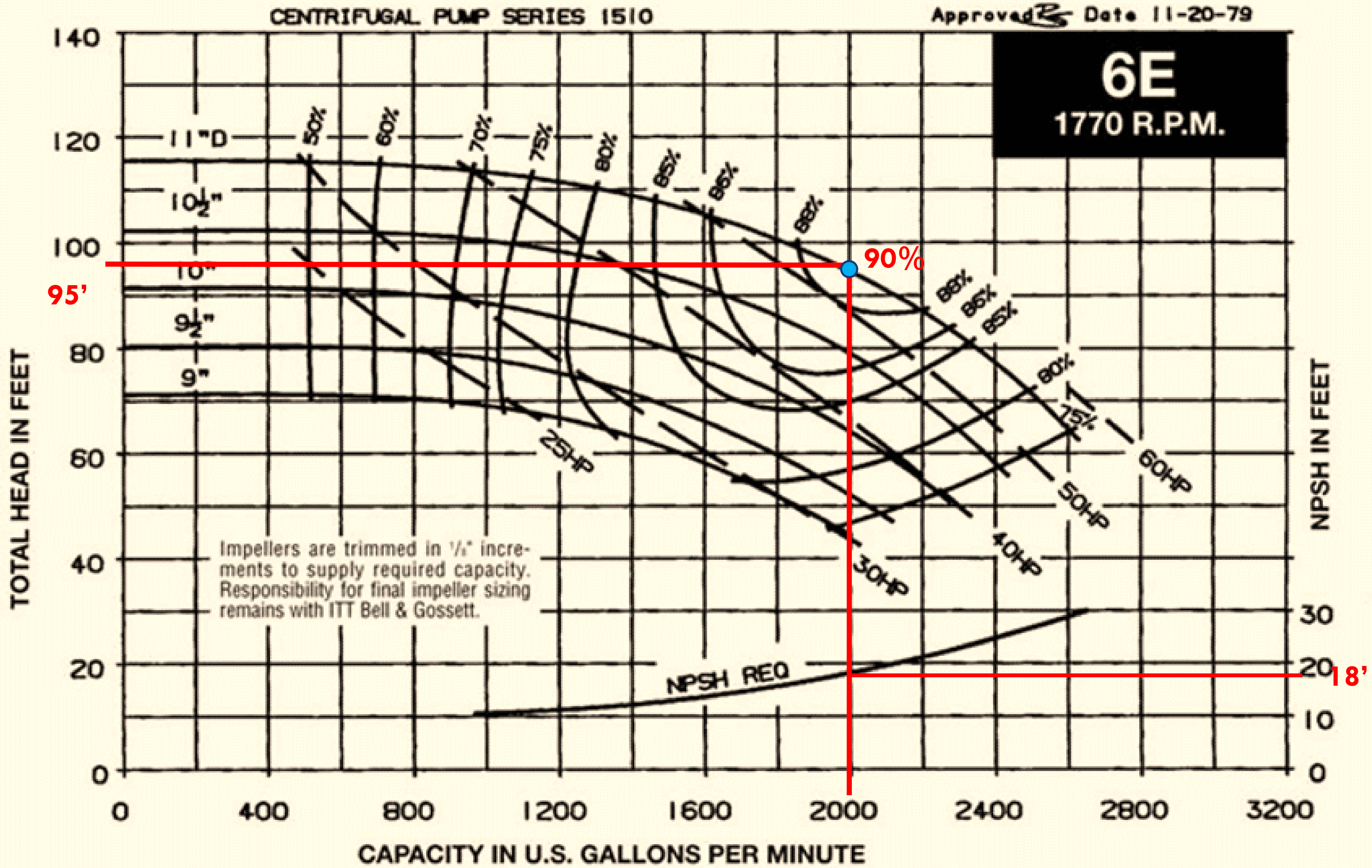
Suction Flange

NPSH AVAILABLE
= 17 - 2 =15

Path of Water Flow

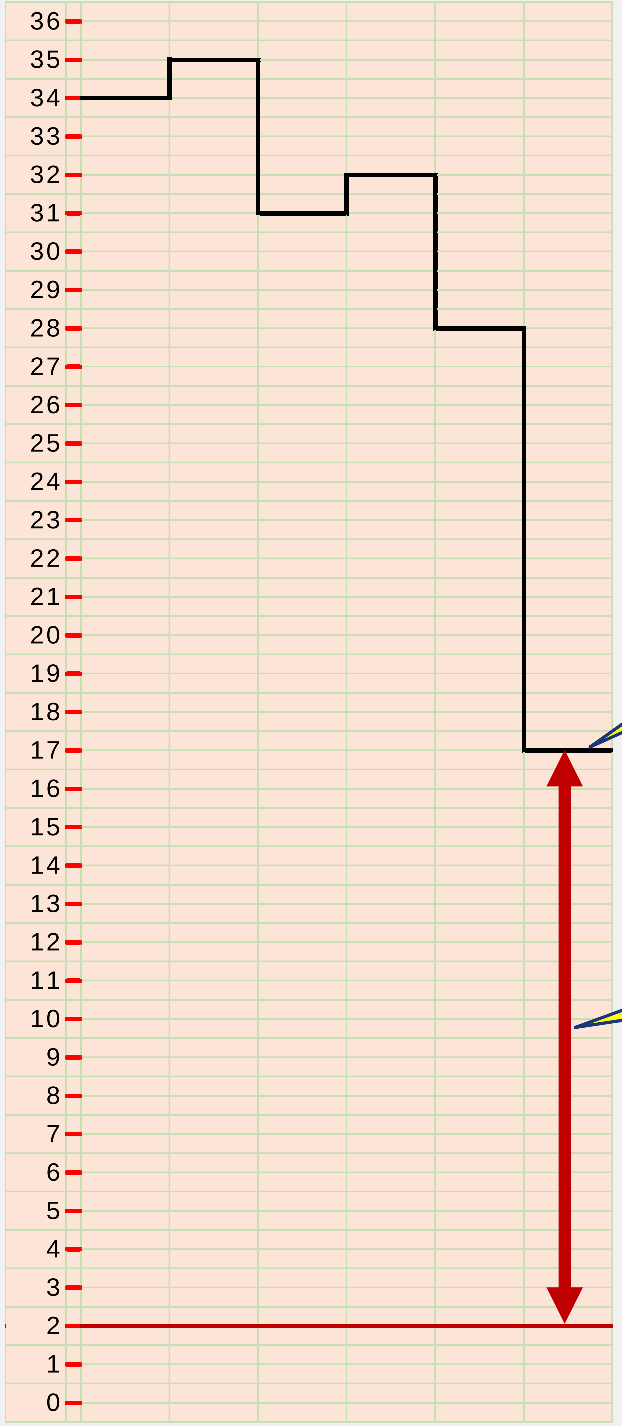
Impeller

PUMP CURVE 2000 GPM @ 95'TDH 90% EFF.



TALLY SHEET – 6

DEWEY AT POINT - F

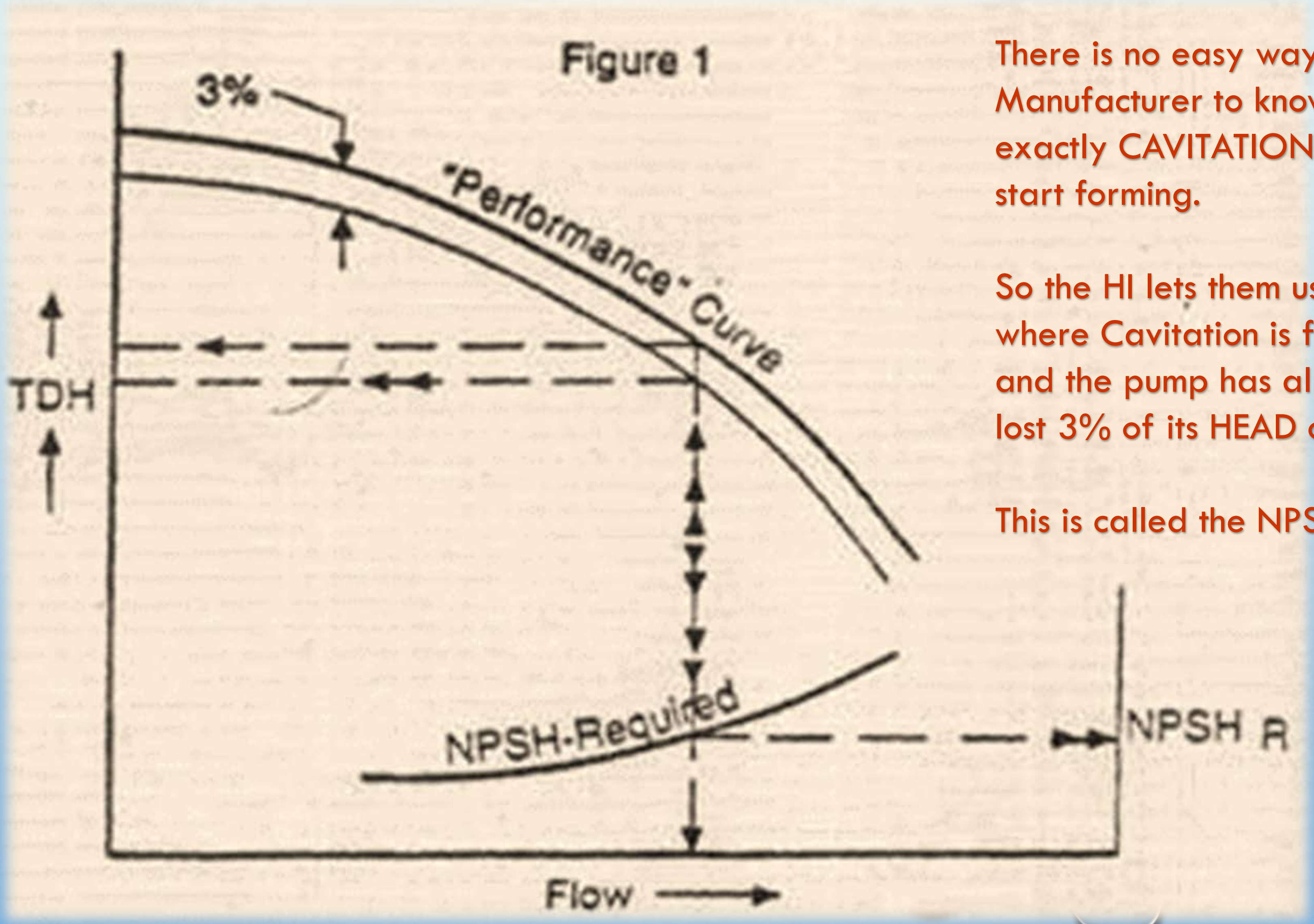


This is
Dewey’s Bank Balance
As he stands at “F”
= $17

This is
NPSHA
Net Positive Suction Head
AVAILABLE
=$15

Dewey cannot let his balance fall below this level or his head will get smashed!

WHAT IS HAPPENING AT THE STATED NPSH VALUE?

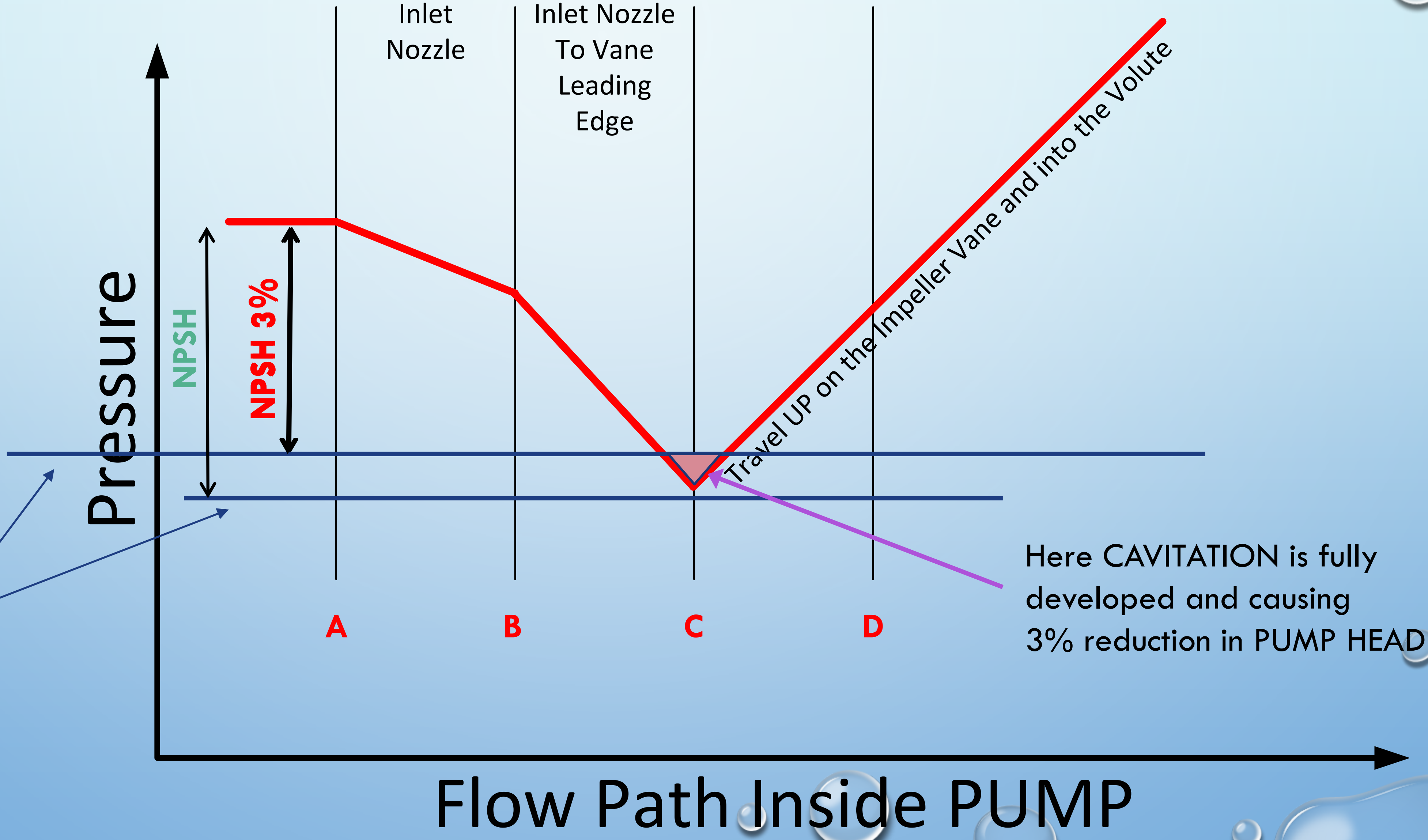


There is no easy way for a Manufacturer to know when exactly CAVITATION bubbles start forming.

So the HI lets them use a point where Cavitation is fully developed and the pump has already lost 3% of its HEAD capacity.

This is called the NPSH3 point.

NPSH ON THE GRAPH



Vapor Pressure
Of Water
2 Feet in our case

Here CAVITATION is fully
developed and causing
3% reduction in PUMP HEAD

ANSI/HYDRAULIC INSTITUTE NPSH SAFETY FACTOR GUIDELINES

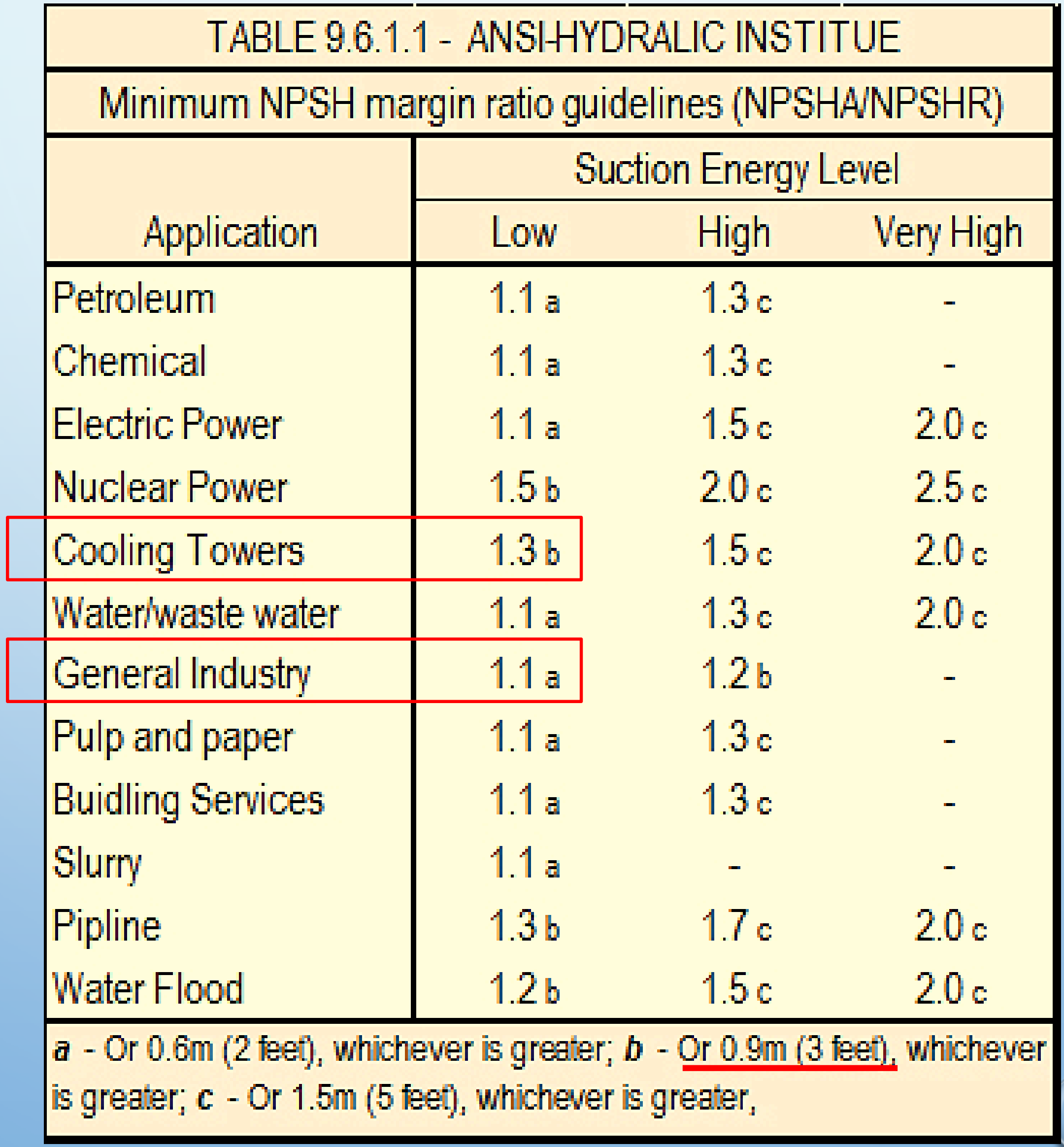


TABLE 9.6.1.1 - ANSI-HYDRALIC INSTITUE

Minimum NPSH margin ratio guidelines (NPSHA/NPSHR)

Application	Suction Energy Level		
	Low	High	Very High
Petroleum	1.1 a	1.3 c	-
Chemical	1.1 a	1.3 c	-
Electric Power	1.1 a	1.5 c	2.0 c
Nuclear Power	1.5 b	2.0 c	2.5 c
Cooling Towers	1.3 b	1.5 c	2.0 c
Water/waste water	1.1 a	1.3 c	2.0 c
General Industry	1.1 a	1.2 b	-
Pulp and paper	1.1 a	1.3 c	-
Buidling Services	1.1 a	1.3 c	-
Slurry	1.1 a	-	-
Pipline	1.3 b	1.7 c	2.0 c
Water Flood	1.2 b	1.5 c	2.0 c

a - Or 0.6m (2 feet), whichever is greater; *b* - Or 0.9m (3 feet), whichever is greater; *c* - Or 1.5m (5 feet), whichever is greater,

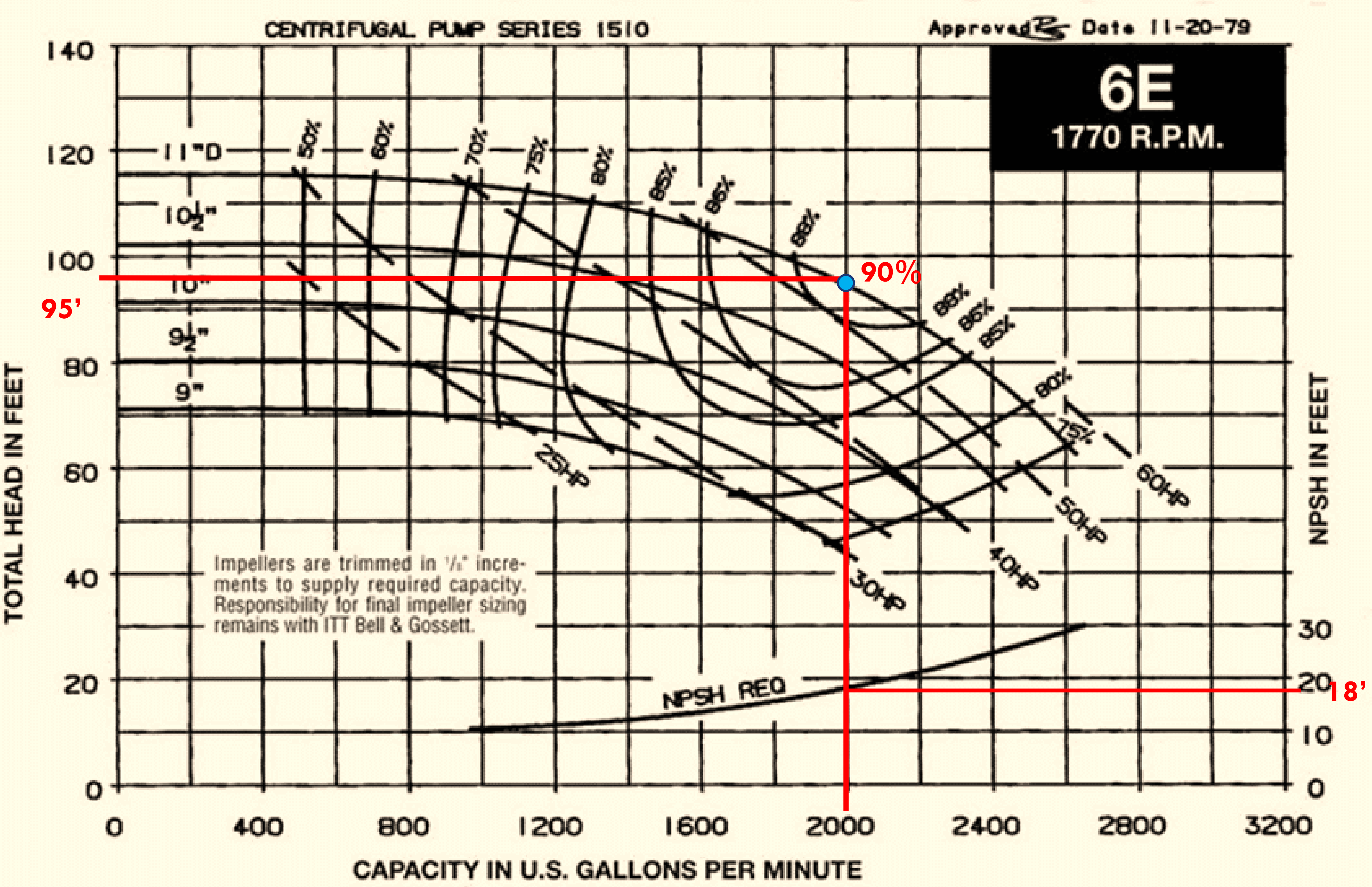
RULES OF THUMB:

USE 10% SF FOR ALL CLOSED SYSTEMS, LIKE CHILLED WATER AND HOT WATER

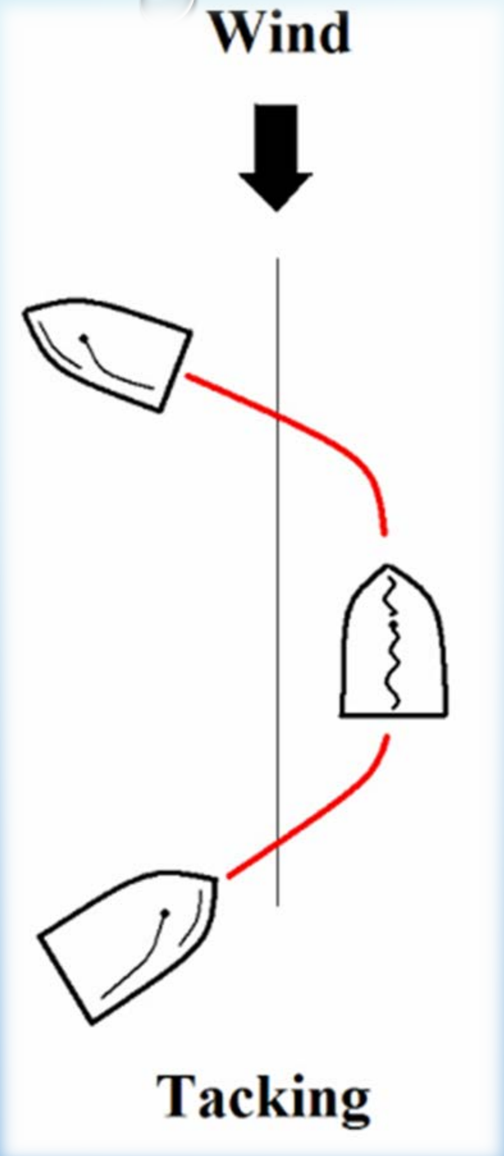
USE 30% SF FOR OPEN SYSTEMS LIKE COOLING TOWER WATER

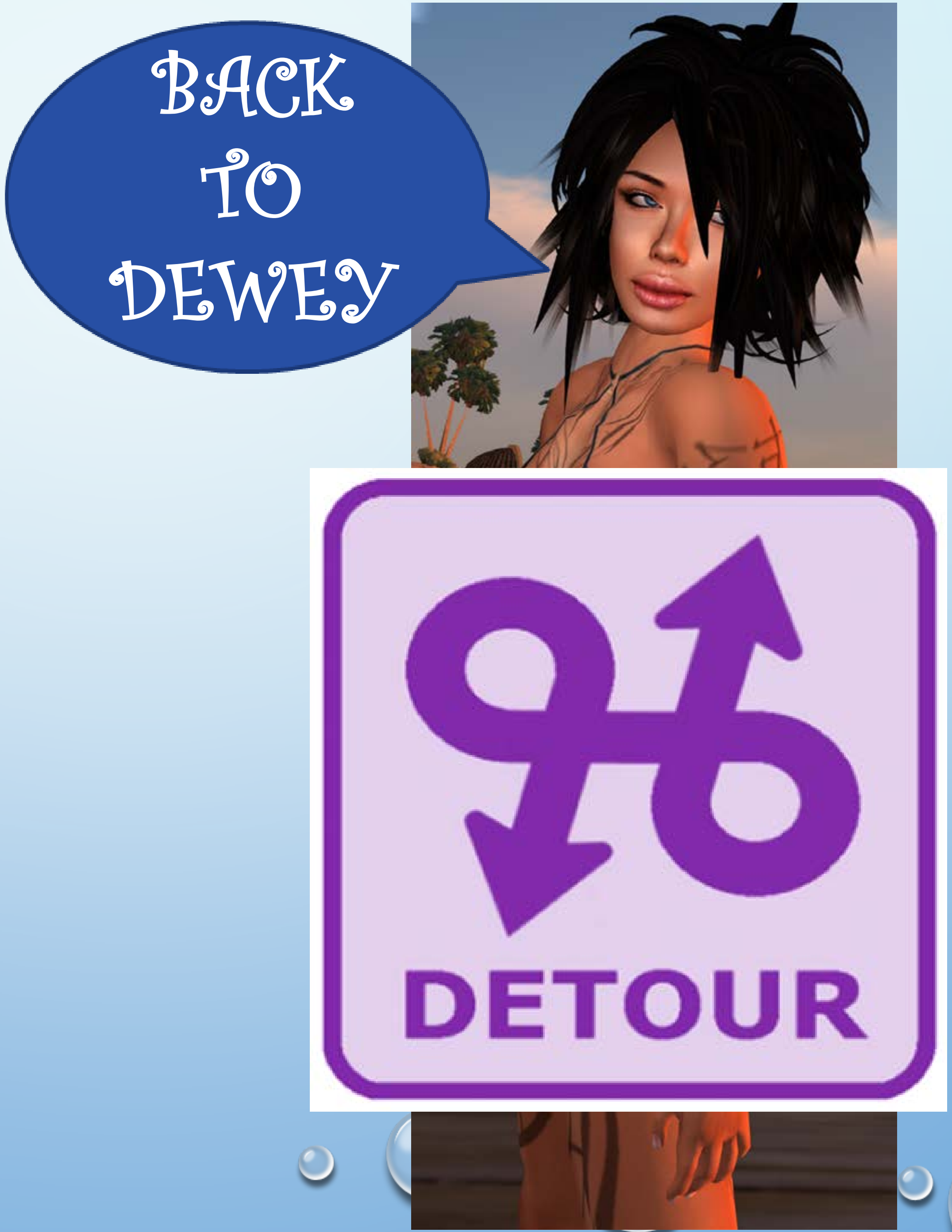
In our case:
18 x 1.3 = 23.4 Feet (NPSHR)
This is Net Positive Suction Head REQUIRED at the pump inlet.

PUMP CURVE 2000 GPM @ 95'TDH 90% EFF.



Impellers are trimmed in ¼" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.


Wind
Tacking


BACK TO DEWEY
DETOUR

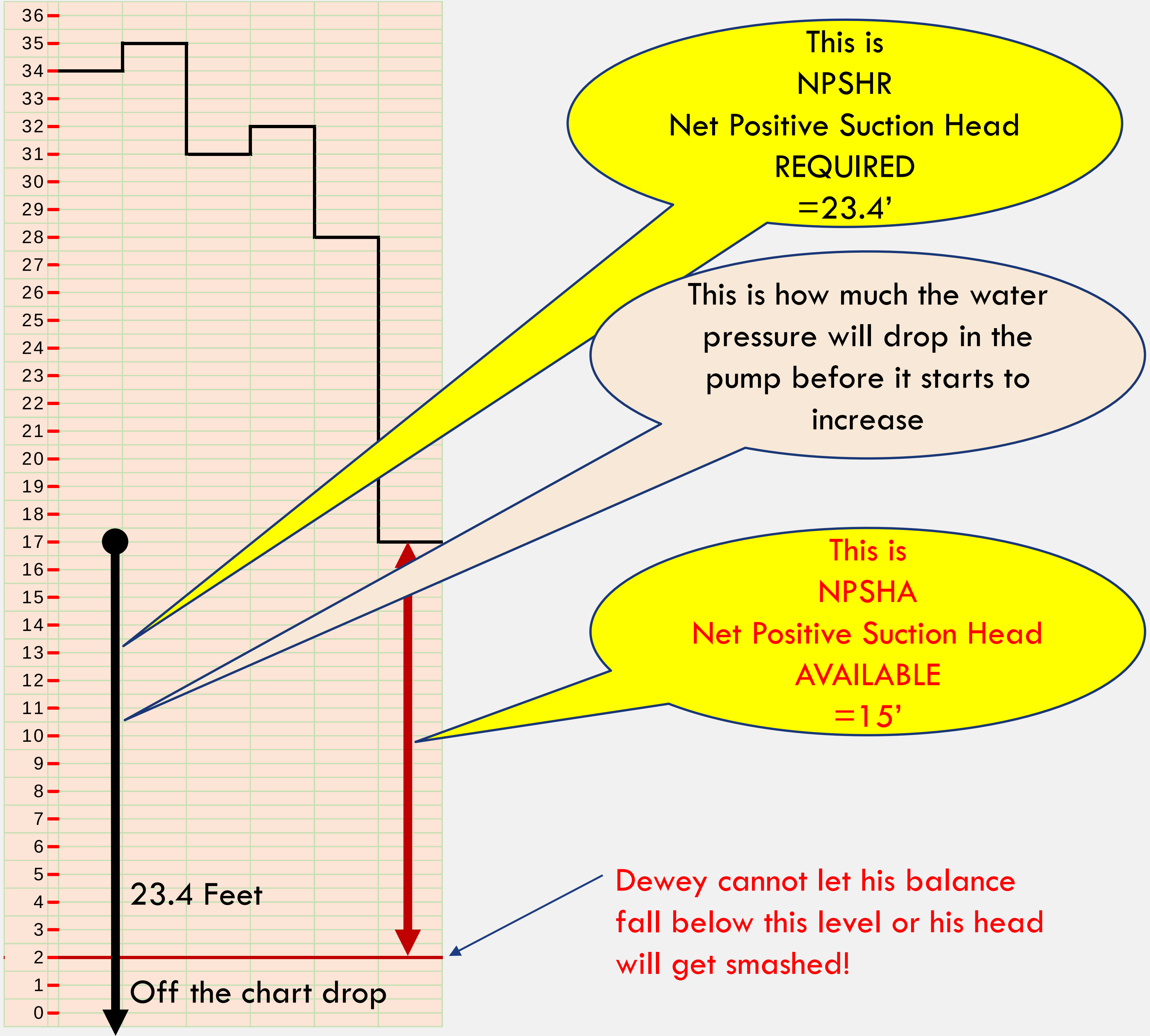
BAD NEWS FOR DEWEY!

The pressure drop in the pump will drop the water pressure below the vapor pressure of 2 Feet.

Water will BOIL furiously and vigorously inside the pump and the pump will CAVITATE.

☹ Poor Dewey ☹

R.I.P.



This is
NPSHR
Net Positive Suction Head
REQUIRED
=23.4'

This is how much the water pressure will drop in the pump before it starts to increase

This is
NPSHA
Net Positive Suction Head
AVAILABLE
=15'

Dewey cannot let his balance fall below this level or his head will get smashed!

WHAT CAN BE DONE – SOME SUGGESTIONS

- KEEP SUCTION LINE VELOCITY LOW – 4 FPS
- KEEP SUCTION LINE SHORT & DIRECT
- KEEP PIPING SYMMETRICAL BETWEEN PUMPS AND BETWEEN TOWER CELLS
- MINIMIZE FITTINGS IN THE SUCTION LINE.
- KEEP PUMP AS CLOSE AS POSSIBLE TO THE TOWER HORIZONTALLY AND AS LOW AS POSSIBLE VERTICALLY
- SEE IF STRAINER CAN GO ON THE DISCHARGE SIDE OF PUMP
- YOU MUST KNOW WHAT DIRTY STRAINER DROP YOU ARE DESIGNING TO – DOCUMENT IN O & M
- STRAINER PD IS A VERY USEFUL AI POINT TO PICK UP IN THE BMS
- YOU MUST SPECIFY MAX NPSHR ON DWGS.
- YOU MAY HAVE TO USE A LARGER SUCTION SIZE PUMP
- PUMP TYPE – SPLIT/DOUBLE SUCTION HAS LOWER NPSHR
- PARALLEL PUMPING. SMALLER PUMPS HAVE LESS NPSHR.

CROCODILE TEARS?

The End