Developed by 2015 Submarine Force Library and Museum STEM –H Teacher Fellow
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Lesson Name ______Pure Water______ **Number of minutes in the Lesson __90____**

Intended Audience _______Grades 7-9__

Content Standards:
Identify state **CCSS content and literacy standards** (when applicable) **and** national curricular standards this lesson is designed to help students attain. Also include **state and district standards** as well as the **Technology Standards** and **CCSS Math Standards** when applicable.

CCSS.ELA-LITERACY.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context

CCSS.ELA-LITERACY.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

CCSS.ELA-LITERACY.RST.9-10.5
Analyze the structure of the relationships among concepts in a text, including relationships among key terms

CCSS.ELA-LITERACY.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

5-PS1-4.
Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

MS-PS1-4.
Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-PS1-6.
Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

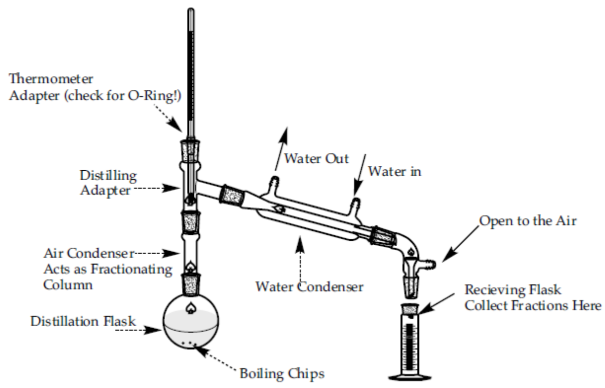
HS-PS1-3.
Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

Pre-Visit Materials/Activities:
Describe the students' prior knowledge or skill related to the learning objective(s) and the content of this lesson, using data from pre-assessment as appropriate. What background knowledge or skills do you want students' to come to the museum prepared with, and what materials will you provide to groups ahead of time so they are prepared for this lesson?

Students should have basic knowledge of the difference between physical and chemical changes, and understand the various phase changes that can occur as heat is added to or removed from a system.

Set up Before the Lesson Begins: Describe any preparation that is necessary before the lesson.

PART I:
Distillation Apparatus



1. Assemble distillation apparatus as shown in diagram.
    a. Note – you may consider using a ring stand to help secure the assembly
    b. Be sure to use a graduated receiving container to be able to measure the solvent
    c. Be sure to use a scale to mass the empty distillation flask

Content Objective(s): Identify specific and measurable learning objectives for this lesson. Remember only one for a 45 minute class, two for a 90 minute class.

In this lesson students will be able to….
1. Connect the physical property of boiling point to the process of distillation
2. Relate simple distillation to the workings of a Model S submarine Distillation Unit

Language Objective(s): Distinguish between receptive skills (**listening and reading**) and productive skills (**speaking and writing**). Please **include how you would use them <u>all</u> where appropriate**: Listening, reading, speaking and writing.

Students will work collaboratively in small lab groups, therefore required to implement the following skills:

1. **Collective Intelligence:**
    a. Students will be able to work respectfully and responsibly with others, exchanging and evaluating ideas to achieve a common objective.
        i. Student works respectfully and responsibly with others to achieve a common objective by:
            1. exchanging and evaluating ideas critically and respectfully with a keen sense of which ideas will best achieve a common objective
            2. listening carefully to and valuing other members' contributions and synthesizing them with personal knowledge and insightful ideas
            3. showing leadership by employing the expertise of members when equitably dividing the roles/responsibilities.

2. **Suspending Judgment:**
    a. Students will be able to forgo decision making while considering and finding value in the contributions of other team members in order to grapple with complex issues.
        i. Student is able to grapple with complex issues by:
            1. actively valuing and seeking contributions from others
            2. synthesizing them with personal knowledge/ideas, as a way of reaching a well-informed decision,
            3. addressing complex issues in a comprehensive manner from various angles/viewpoints.

3. **Justifying & Contextualizing**
    a. Students will be able to choose and justify the most effective medium to interactively and purposefully share important findings in various contexts as well as adjust style and tone with consideration to audience and purpose.
        i. Student chooses the most effective medium
            1. to share findings and present them in an interactive, engaging, purposeful manner, choosing more than one medium, when appropriate,
            2. to clearly communicate important findings, adjusting style and tone with clear focus on audience and purpose,
            3. can clearly explain why a medium was chosen in regard to audience and purpose.

Differentiation: Think about:

Students with special needs How will you differentiate this lesson for special education students?

Gifted students- Students can be given specific tasks within a collaborative group that suits their learning style and academic aptitude

Regular education students: Think about how you would differentiate the lesson for all students on all levels:

High- Webb DOK level 3 or 4 (Short-Term Strategic Thinking and Extended Thinking)
Middle- Webb DOK level 2 or 3 (Skills and Concepts and Short-Term Strategic Thinking)
Low- Webb DOK level 1 or 2 (Recall and Reproduction and Skills and Concepts)

*The DOK level should reflect the complexity of the cognitive processes demanded by the task outlined by the objective, rather than its difficulty. Ultimately the DOK level describes the kind of thinking required by a task, not whether or not the task is "difficult"

Sheltered Instruction Observation Protocol (SIOP) Strategies for ELL and regular Ed Students:

Identify the S.I.O.P features that support English Learners and all learners including thorough and accurate explanations on how they will assist English Learners. Identify Sheltered Instruction strategies throughout the lesson.

- Preparation
- Building Background
- Comprehensible Input
- Strategies
- Interaction
- Practice/Application
- Lesson Delivery
- Review/Assessment

Initiation: Briefly describe how you will initiate the lesson. (Set expectations for learning; articulate to learners what they will be doing and learning in this lesson, how they will demonstrate learning, and why this is important)

1. Initiate the lesson by reviewing key concepts in the prior knowledge requirements: **(5 min)**
    a. Students should have basic knowledge of the difference between physical and chemical changes, and understand the various phase changes that can occur as heat is added to or removed from a system.

2. Articulate the collaborative working expectations by reviewing the **Language Objectives** **(5 min)**

3. Only people with their basic needs satisfied, bother to think about 'human needs' (desperate persons have to act without much thinking):. Once material needs satisfied, we may discover some intangible needs, like being valued by others, and self-esteem, although it is sometimes difficult to discern the difference between needs and wants or desires. In some cases, even the differences between needs and desires are not clear. For example; people's migration towards large cities accounts for needs or for desire? Human needs can be sorted from the most basic and immediate, to the most ambitious, according to the classical Maslow's pyramid. **(10 min)**
    a. The Classification of human needs falls into one of three categories:
        i. Physiological
        ii. Emotional
        iii. Transcendental (personal achievement)

    Ask student to collaborate with members of your group to form a list of the basic physiological human needs.

    The basic physiological needs of humans includes air, food, water, and temperature/heat

4. Explain the learning activities, their purpose, and the culminating design application and how it relates to the critical function of a submarine. **(5 min)**

Lesson Development: **(Add a Time for Each Segment of the Lesson)**

Performance Tasks: Describe in outline how you will develop the lesson and what learning activities students will be engaged in order to gain the key knowledge and skills identified in the student learning objective(s).

PART I – Introduction to the process of distillation (50 min)

INTRODUCTION/DISCUSSION (Teacher initiated):
Only people with their basic needs satisfied, bother to think about 'human needs' (desperate persons have to act without much thinking):. Once material needs satisfied, we may discover some intangible needs, like being valued by others, and self-esteem, although it is sometimes difficult to discern the difference between needs and wants or desires. In some cases, even the differences between needs and desires are not clear. For example; people's migration towards large cities accounts for needs or for desire? Human needs can be sorted from the most basic and immediate, to the most ambitious, according to the classical Maslow's pyramid.
The Classification of human needs falls into one of three categories: **(student brainstorming)**

- Physiological
- Emotional
- Transcendental (personal achievement)

1. Collaborate with members of your group to form a list of the basic physiological human needs.

The basic physiological needs of humans includes air, food, water, and temperature/heat

BACKGROUND:
Although we assume the natural environment on Earth by default, human needs become more apparent, and difficult to provide in closed artificial environments such as a submarine or in space. One of the basic needs, fresh water, has always been a major item aboard ship; in fact, until recent times it was the factor that limited the length of time a ship could remain at sea. In the era of sailing ships, it was necessary to spread canvas whenever it rained, and to catch the rain water in canvas water bags in order to replenish the supply of fresh water on board. This water was used only for cooking and drinking purposes, there being no need then for fresh water in the operation of steam-driven propulsion machinery.
On modern vessels fresh water is not only used for drinking, cooking, and bathing, but also in boilers, storage batteries, and as a cooling agent for modern Diesel engines. All large naval vessels have distilling plants. (submarine)
"Distillation of Seawater." *Submarine Distilling Systems*. Washington: Bureau, 1955. 1-2. Print.

2. Review what you learned from **Lesson: It's Not Your Property!** about physical properties, and physical and chemical changes. Collaborate with members of your group to identify a physical property that can be used successfully to separate salt from seawater. Explain your reasoning.

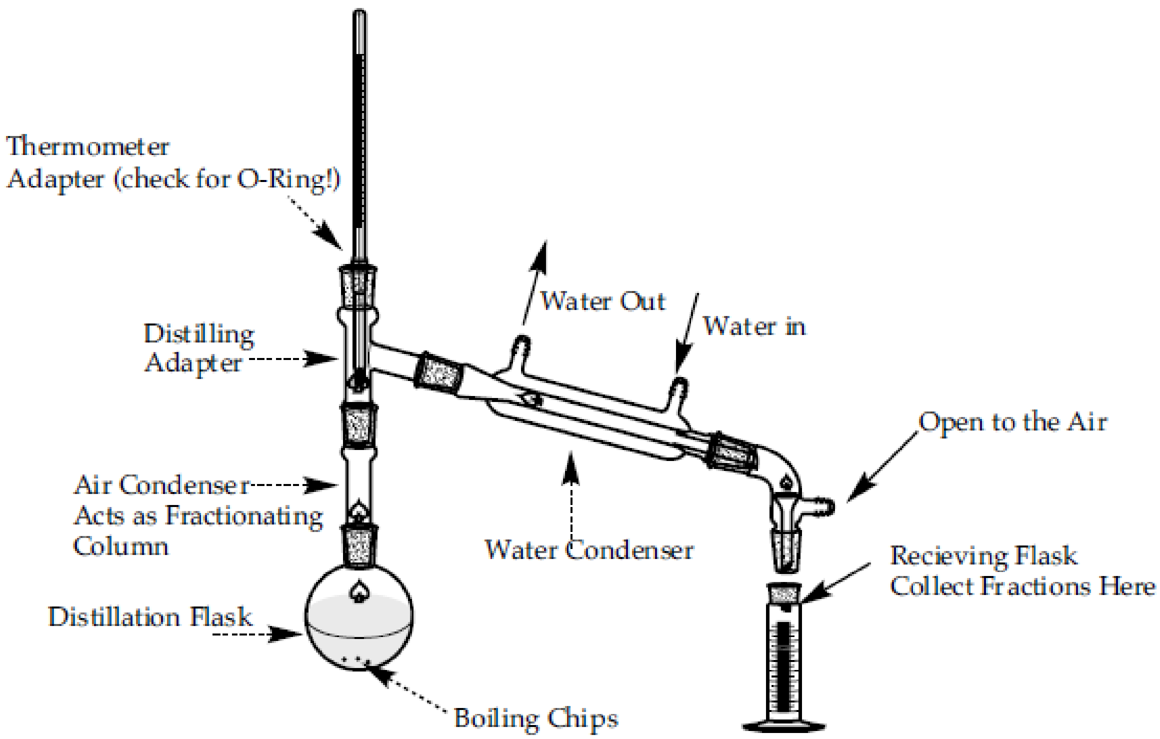
Boiling point - Heat separates liquid mixtures (solutions) because the liquid with the lower boiling point vaporizes leaving behind the substance with the higher boiling point. Cooling reverses the process by condensing the vapor back to liquid. Fractional distillation separates complex solutions one by one as the temperature rises.

BACKGROUND:
On heating, the temperature of the liquid increases until the **boiling point** is reached. Additional heating causes the liquid to vaporize accompanied by vigorous bubbling of the liquid. The **boiling point** of a substance is a physical property of a substance and can be useful for characterizing that substance. The fact that different substances have different boiling points allows us to separate them. The process of heating a substance until it is vaporized, cooling the vapors, and collecting the condensed liquid is the basis of a commonly used purification technique called **distillation**. If a liquid is placed in a closed container, some molecules at the surface of the liquid evaporate into the space above the liquid. If this didn't happen, you wouldn't be able to smell a liquid. Once vaporized, some of the molecules in the vapor condense back into the liquid in a competing process. As the space above the liquid becomes occupied with molecules of vaporized liquid, the pressure of the vapor above the liquid (the liquid's **vapor pressure**) rises until it reaches a certain value. When the pressure stabilizes, the rates of evaporation and condensation are equal and the system is at equilibrium. The **equilibrium vapor pressure** of a liquid increases with increasing temperature. As the temperature of the liquid is raised, more molecules vaporize and the equilibrium vapor pressure increases. Again, think about boiling water, it steams more and more as it gets hot, and then eventually it boils. When the vapor pressure of a liquid is equal to the pressure of the atmosphere above the liquid, it boils. The temperature no longer rises. The normal boiling point of a substance is defined as the temperature at which the vapor pressure of that substance equals standard atmospheric pressure, 760 mmHg.

3. **Introductory Activity:** Review the process of distillation
Distillation I | MIT Digital Lab Techniques Manual https://www.youtube.com/watch?v=GtuMlWMajtw#t=452

BACKGROUND:
Simple Distillation - Single Volatile Liquid
The vaporization of a liquid, relocation, and condensation of the resulting vapor is the basis for a method of purification called distillation. Liquids containing very small amounts of impurities are easily purified by "simple" distillation. Liquids containing numerous different impurities can be separated in more complex process called **fractional distillation.** As the liquid vaporizes and the vapor comes into contact with the thermometer bulb, the temperature rises. The temperature stabilizes at the boiling point and most of the liquid distills. Therefore, if you were to graph the data you would see an increase in **distillate**, but a plateau in the temperature. The temperature drops when there is no liquid left in the distillation flask. In the distillation process it is possible to separate out several dissolved substances

Procedure:
1. Setup the distillation apparatus as shown in the diagram. Your setup should include the following items
   a. Distillation flask – to hold the solution
   b. Distillation adapter – connects the distillation flash, condenser and thermometer
   c. Condenser – cools the vapor and directs condensate to receiving flask
   d. Receiving flask – collects the condensate



2. Create a "known concentration" solution. Record the volume of solvent (water) and mass of solute (salt) used. A solution that fills 1/2 of the flask's capacity is sufficient.

Amount of Solute (g)	Amount of Solvent (mL)	Concentration (g/mL)
25	125	.17

NOTE
Removing the salt at the end of the investigation is problematic. You may consider massing the empty distillation flask, which will allow you to determine the mass of the substance remaining in the distillation flask at the end of the experiment. This data can help validate that the substance left behind is indeed the salt that was initially added to the solution.

3. Apply heat to the distillation flask. The amount of heat to apply is determined by the rate of distillation. The liquid should gently bubble and vaporize. As vapor rises from the liquid, it moves up the apparatus raising the temperature of the apparatus. The vapor will fill the distillation flask and most of the distillation head. The thermometer bulb should be completely surrounded by the vapor. The vapor condenses in the condenser and drips into the receiving flask. The liquid should drip into the receiving flask at a rate of about 10 drops per minute. If the rate of distillation is too rapid, the heat applied to the distillation flask should be decreased. With too rapid a rate, the measured boiling point is likely to be inaccurate and the purity of the distilled liquid will be compromised

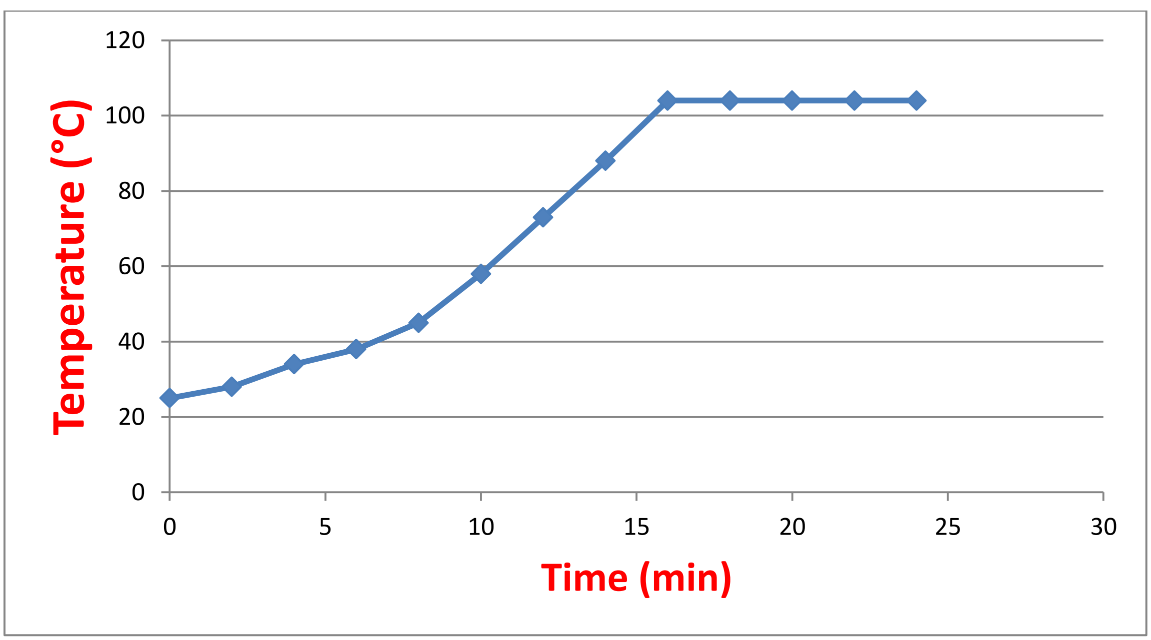
4. Record the temperature and volume of distillate at start and again every 2 minutes.

Time (minutes)	**Temperature (°C)**	**Distillate (mL)**
0	**25**	**0**
2	**28**	**0**
4	**34**	**0**
6	**38**	**0**
8	**45**	**1**
10	**58**	**7**
12	**73**	**16**
14	**88**	**26**
16	**104**	**36**
18	**104**	**46**
20	**104**	**56**
22	**104**	**66**
24	**104**	**81**

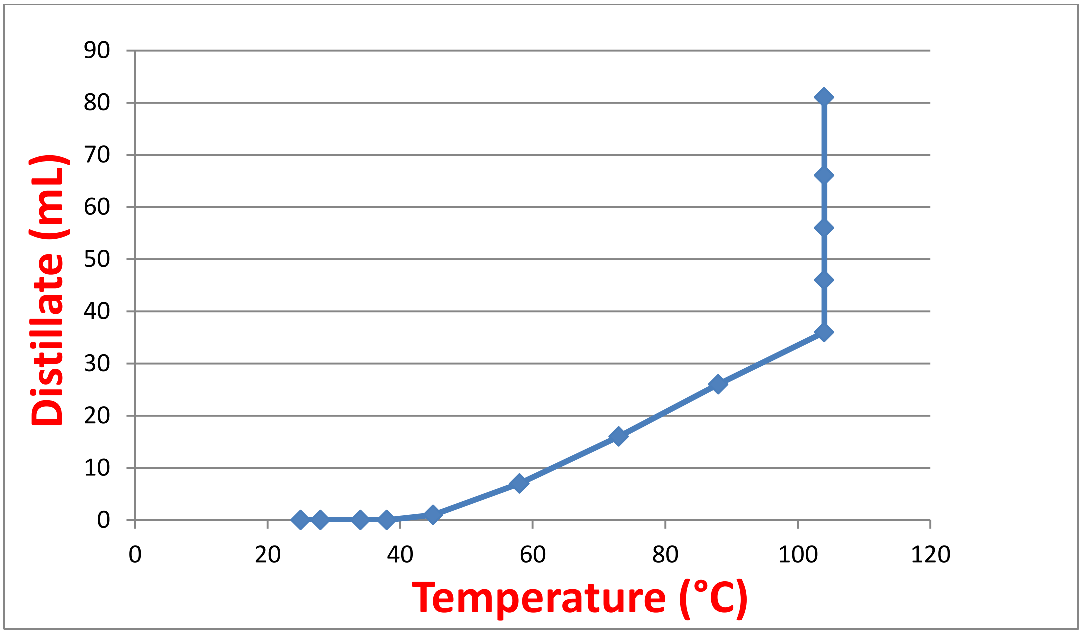
Data may vary depending on start temperature. However, you can decrease the time by decreasing the solvent used in the solution.

Post-Lab Questions:

1. Construct a graph that relates the time and temperature throughout the investigation.



2. Construct a graph that relates temperature and distillate formed.



3. Examine the two graphs. Did the temperature change significantly during the peak of the **collection phase**? Explain why or why not.

The temperature did not change much during the time that most of the distillate was collected. This occurred because the liquid with the lower boiling point vaporizes leaving behind the substance with the higher boiling point. The temperature does not change until all of the substance has vaporized.

4. Explain why the salt does not distill along with the water

The salt has a higher boiling point than the water it was dissolved in. Therefore, the water boils first.

5. Examine your data, and compare your results to the **starting** concentration of the sugar/water solution. How do your results (amount of solute and amount of solvent) compare?

The amount of distillate is very close to the amount of solvent we started with. *NOTE* If the initial mass of the distillation flask was recorded, then the mass of the solute can be determined.

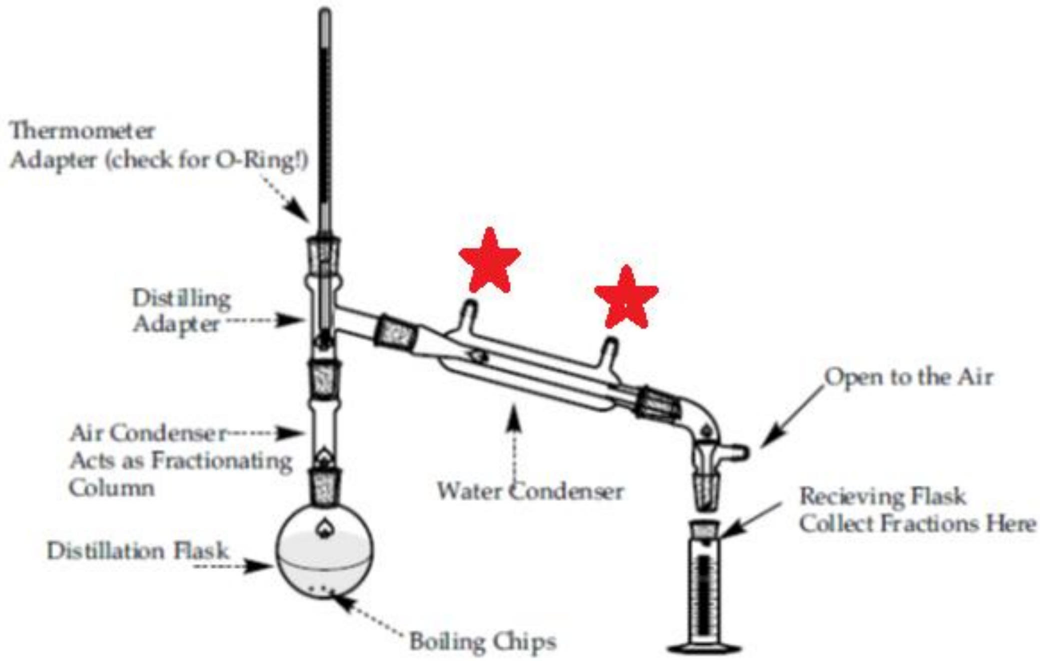
6. Examine your distillation apparatus setup. What would happen if the cold water moving through the condensing tube was warmed, reduced, or removed altogether?

The water vapor would not condense as rapidly as it traveled through the condensing tube. Most of the condensation would occur instead after the vapor exited the condensing tube in came in contact with the surrounding atmosphere

PART I B: Relate Process of Distillation to Model S Distillation Unit (20 min)

7. ***Critical Thinking/Engineering***:

Aside from the contact with the atmosphere, the distillation apparatus used in the investigation was essentially a linear, closed system except at the exit of the condensing tube. Although a submarine's internal environment operates as a closed system, the vessel itself interacts readily with the surrounding environment. Fresh water needs in a submarine are continual; therefore the distillation of seawater is a continuous process. Your group's task is to reconstruct the distillation apparatus setup to form a closed loop system where incoming seawater can "theoretically" be continually distilled without the aid of a separate cold water intake points traveling through the condensing tube, and with minimal heat input into the system. Illustrate your design change, and include any additional components that may be required.



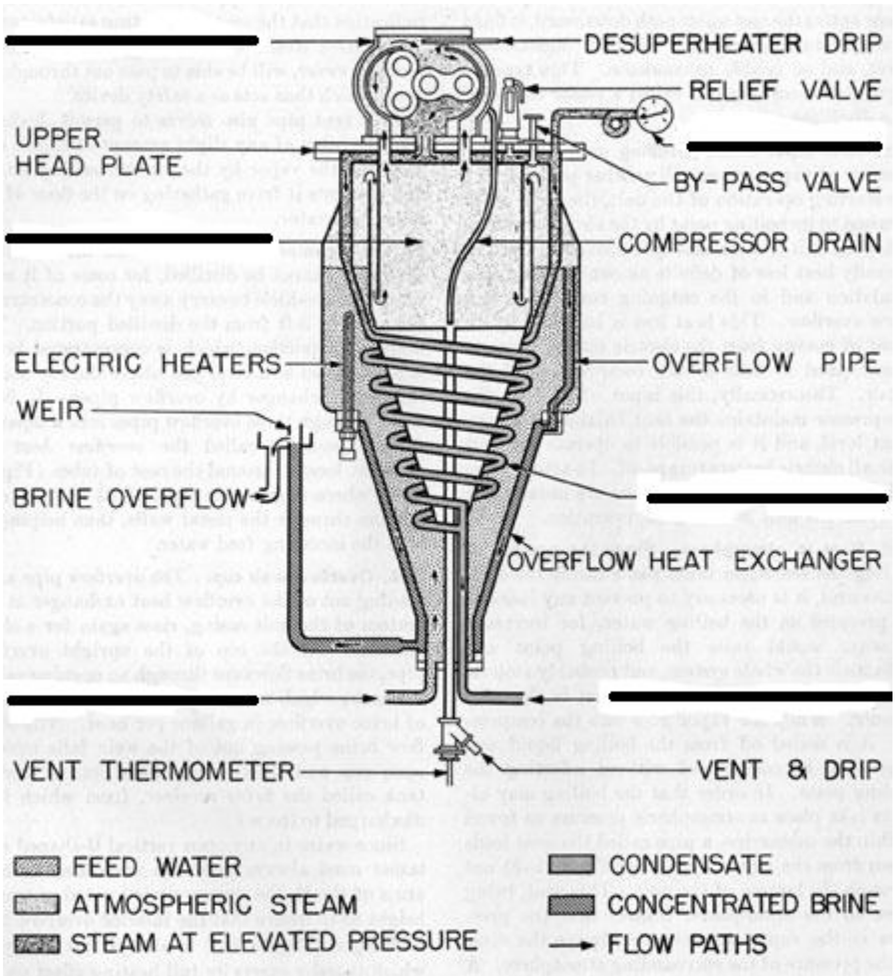
Conceptual Expectation:
The expectation is for students to recognize that heat must be released in order for the steam to condense, and that heat must be added to the system in order to raise the saltwater to its vaporization/boiling point. Encourage students to recognize that if the vapor cannot be exported, then equilibrium will be reached and the vaporization point will increase, which will require heat to be added to the system.

Design Expectation:
The expectation is for students to change the design by routing the condensing tube around the distillation flask so that heat contained within the distillate vapor can be released to the saltwater solution. The released heat will increase the temperature of the saltwater solution to reach the vaporization point.

The two expectations will meet the NGSS performance standard MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

3. Based on your group's redesign of the distillation setup, take your design changes and apply them to a basic, electrically operated distilling unit, a Model S submarine Distillation Unit, originally used on older submarines. Your task is to fill in the missing labels on the diagram using the terms below:

Pressure Gauge	**Compressor**
Vapor Collector	**Distillate outlet**
Seawater feed inlet	**Heat Exchanger**



Submarine Force Museum Lesson Plan

Teaching and Learning Strategy: Strategies that you used during the lesson, including **modeling, guided practice and independent practice** where applicable.

1. **Teaching Clarity** - Provide explicit criteria on how students can be successful. Present **models** or examples (exemplars) to students so they can see what the end product looks like.

2. **Feedback** - provide whole-group feedback on patterns observed. Students also need to be given opportunities to provide feedback to the teacher to be able to adjust the learning process, materials, and instruction accordingly

3. **Formative Assessment** - assess frequently and routinely where students are in relation to the lesson's learning goals or end product (summative assessment).
    a. Use of white-boards and response cards can be useful tools for formative assessments

4. **Independence, control and active engagement –** Give students opportunities to plan and organize, monitor their own work, direct their own learning, and to self-reflect.

Monitoring and Adjusting: How do you know the students have learned what you taught them and that they have achieved the objective?

1. Questioning students during classroom discussions to check their understanding of the material being taught Circulating around the
2. Conducting periodic reviews (during lesson) with students to confirm their grasp of learning material and identify gaps in their knowledge and understanding
3. Reviewing student performance data collected and recorded and using these data to make needed adjustments in instruction
4. Paying close attention to who is answering questions during classroom discussion and calling upon non volunteers
5. Asking students to comment or elaborate on one another's answers
6. Initiate more interactions with students, rather than waiting for students to ask for help
7. Have systematic procedures for supervising and encouraging students while they work
8. Asking students to interpret or summarize material presented to them in the lesson

Assessment: How will you ask students to demonstrate mastery of the student learning objectives? Attach a copy of any assessment materials you will use, along with assessment criteria.

1. Evaluate students' understanding by examining performance data and response to performance data questions

Closure: Briefly describe how you will close the lesson and help students understand the purpose of the lesson. (Interact with learners to elicit evidence of student understanding of purpose(s) for learning and mastery of objectives)

One of the most effective methods to assessing student learning in a short-term period of time is to develop a set of assessment questions using response cards, or more traditional use of small white boards. If applicable, visit the Submarine Force Museum exhibits to show application of student learning objectives

Submarine Force Museum Lesson Plan

Post-Visit Materials/Activities: Provide additional materials if they would reinforce a good learning experience

Post-Visit Materials/Activities: Provide additional materials if they would reinforce a good learning experience after leaving the museum.

Technology: Please explain the technology used: why you will use it, how you will use it and how you will assess the results of using this technology.

Key Vocabulary: Words students need to know in order to reach the objectives.

1. Boiling point
2. Distillate
3. Condensation
4. Equilibrium
5. Fractional distillation
6. Vapor pressure
7. Distillation flask
8. Distillation adapter
9. Condenser
10. Receiving flask

Extension: What do you have in place in case during the lesson you finish early, run out of time or need to accommodate students who complete the class work before other students, or your technology fails?

Finish Early:
Run out of time:
Technology Fails:

Materials: List the materials you will use in each learning activity.

PART I:

1. Organic distillation set **FLINN CATALOG # AP6351** or comparable equipment
2. Graduated receiving flask (200 mL)
3. Hot plate **FLINN CATALOG # AP7233**
4. Boiling chips (optional)
5. Sample of Salt Water
6. Sample of Dr. Pepper or other soda with molasses additive (enrichment activity option)

Resources: Include any resources you may use such as textbooks and any technological resources.