GENERAL DYNAMICS
Electric Boat

NSRP | National Shipbuilding Research Program

Cooling Suits for Increased Worker Efficiency

General Dynamics Electric Boat

William P. Robinson

Distribution Statement A. Approved for public release: distribution is unlimited.

Purpose

- This project aims to increase the comfort, safety, and efficiency of shipyard workers performing hot-work in constrained spaces.
  - Welding, grinding, gouging, etc.

- Goal: provide cooling to alleviate the affects of high heat on the human body.

Background

- Current State: Hot workers in constrained spaces have to work 30 min. on, 30 min. off due to high heat and fatigue.
  - Especially a concern in the hot summer months.
- Proposed OSHA regulation to limit high heat exposure on the horizon [1].
- Legacy air cooled Allegro Vortex suit were implemented to mitigate heat experienced by workers.
  - Not fully adopted due to design/functional limitation.

[1] Occupational Safety and Health Administration, "Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings Rulemaking," U.S. Department of Labor, [Online]. Available: https://www.osha.gov/sites/default/files/publications/heat-rulemaking-factsheet.pdf. Accessed 8 October 2024].

Proposed OSHA Regulation

- "Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings" [1].
  - Implement control measures at heat index of 80°F.
    - Cool water, break areas, acclimatization protocols, etc.
  - Additional control measures at heat index of 90°F.
    - Mandatory rest breaks, observation for signs and symptoms, hazard alerts.
- EB environments often exceed these temps., preventative action must be taken.

[1] Occupational Safety and Health Administration, "Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings Rulemaking," U.S. Department of Labor, [Online]. Available: https://www.osha.gov/sites/default/files/publications/heat-rulemaking-factsheet.pdf. Accessed 8 October 2024].

Summer Temperatures

- Quonset Point, RI – July ave. high of 82°F, felt like 84°F [2].
- Pascagoula, MS – July ave. high of 91°F, felt like 98°F [3].

- Steel temperatures measured up to 199.8°F through testing.

- These temperatures are subject to proposed OSHA control measures.

[2] "Airport Forecast: Historical, Quonset, RI," The Weather Network, Available: https://www.theweathernetwork.com/us/forecasts/airport-forecast/historical/rhode-island/n-kingston-quonset Accessed 8 January 2025.
[3] "Forecast: Historical, Pascagoula, MS," The Weather Network, Available: https://www.theweathernetwork.com/us/historical/mississippi/pascagoula Accessed 8 January 2025.

Allegro Air Cooled Vortex Suit (Legacy)

- The suit is easy to setup, utilizing pneumatic hoses which exist all over the shipyard.
- Design features that limit effectivity:
  - Intake air is ambient and requires tether - hot in the summer.
  - Suit inflates reducing mobility.
  - Non-Fire Resistant material cannot be used for gouging work – most strenuous.
- Shipyard workers choose not to use this suit, need an improved product.

Allegro Air Cooled Vortex Suit

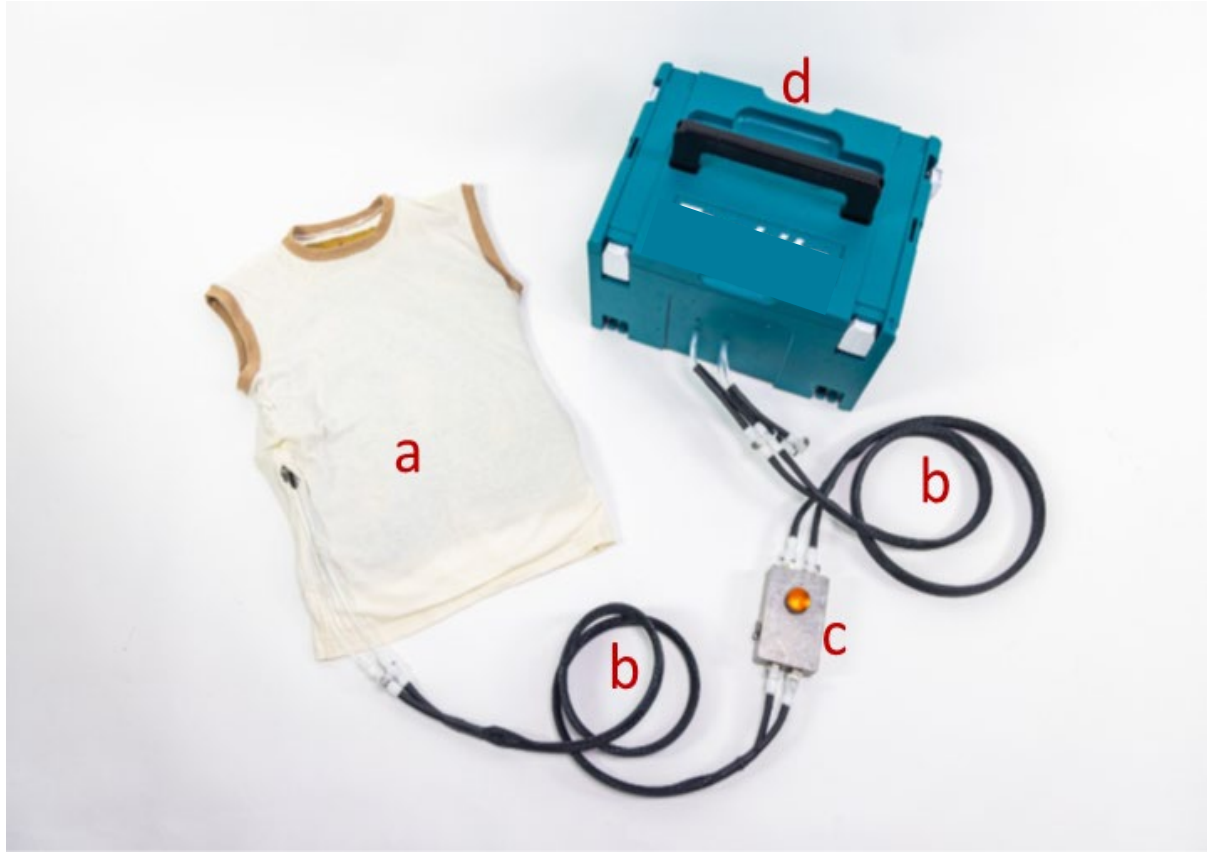
Panel Project Task 1: Down-select

Suit				
Make	TDA	Oceanit	Nanohmics	Nanohmics
Cooling Type	Evaporative	Circulated Water + Ice	Forced Air	Cooled Air on Respirators

Cooling systems down-selected from small business innovation research (SBIR) funded projects.

Oceanit Cooling Suit Testing – Process and Setup

- Setup: Baseline
  - Measure biometric parameters and testing conditions.
  - Send participants into work area to perform their task as normal.
- Setup: Experimental Suit
  - Pre-freeze icepacks, acquire DI water, charge batteries.
  - Fit participant in the suit and prime it.
  - Help participant get into their working area and operate system.



(a) Cooling Vest; (b) Water Lines; (c) Pump; (d) Reservoir

Oceanit Cooling Suit Testing – Data Collection

- Measure biometrics for conditions in similar working environments with no suit (baseline), Allegro Air-cooled suit and Oceanit suit.
  - Compare individuals to themselves.
  - Collect before and after body weight and inner ear temperature.
  - Collect pulse rate, electro-dermal activity, and acceleration over time using Empatica EmbracePlus watch.
  - Collect survey results for perceived impact.

Oceanit suit on test subject.

Allegro suit on test subject.

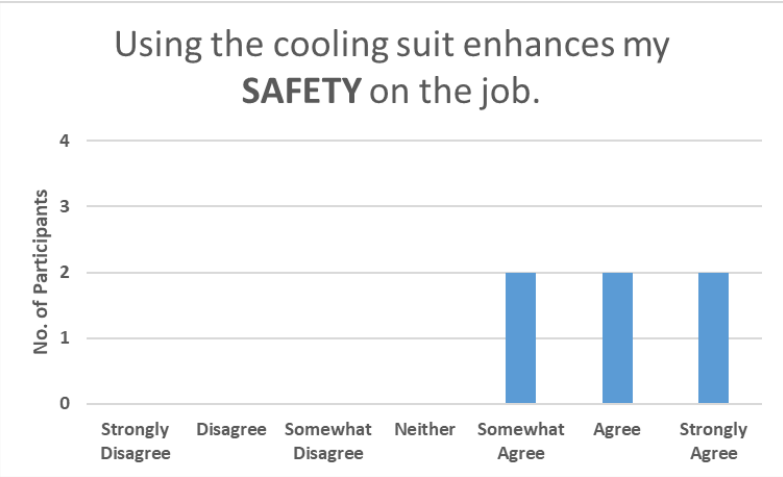
Empatica EmbracePlus.

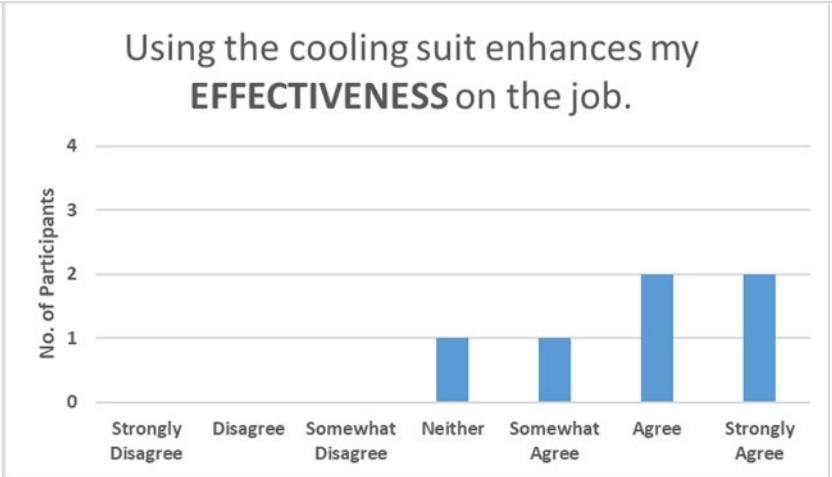
Objective Results

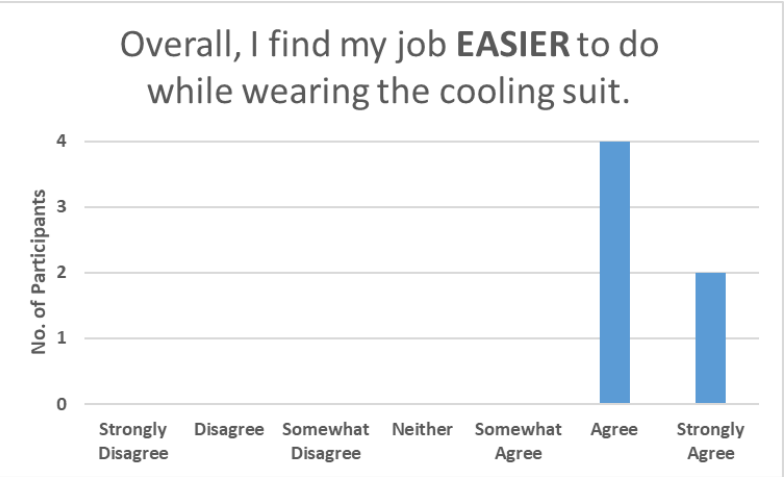
- No discernable trends, empirical data does not show an appreciable decrease in pulse rate or sweat.
  - Data is limited by sample size and variability of work.

Subjective Results

- Surveys showed that workers were generally in favor of the Oceanit suit, feeling safer, more effective, and that their task was easier.



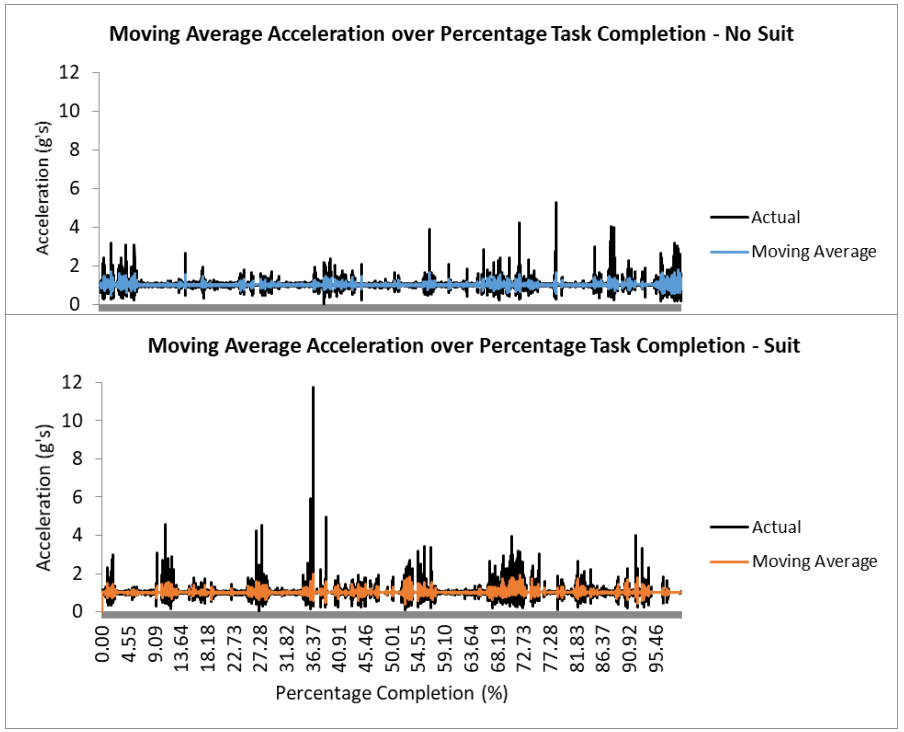




- All those sampled gave a positive evaluation of the Oceanit product.

Accelerometer Comparison - Gouging

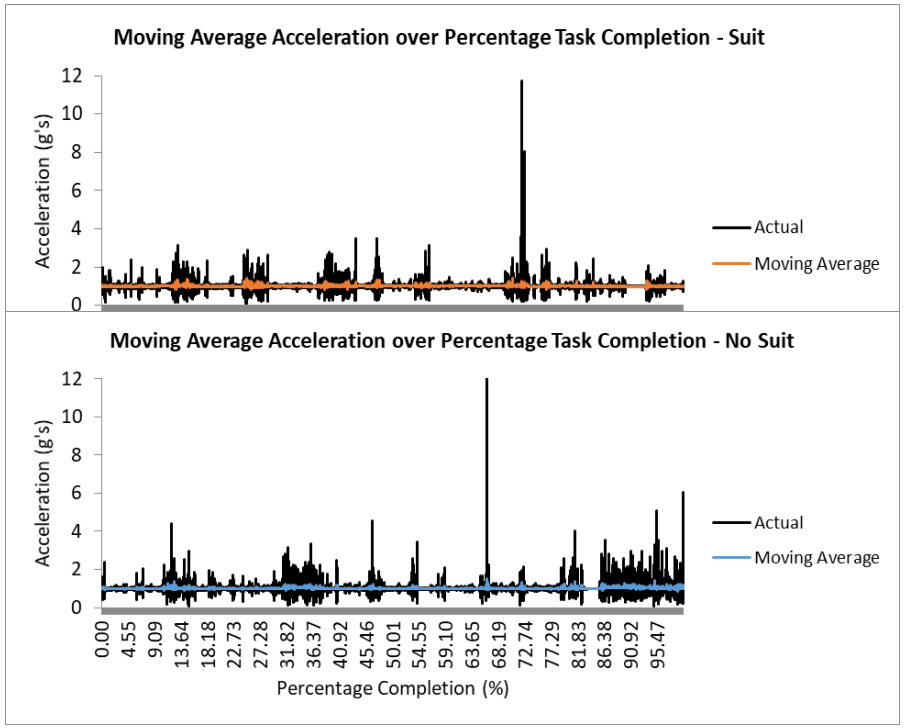
Session 1: 9.13.24



Body Weight	
-0.67%	-0.34%
Inner Ear Temp.	
+2.14%	+2.98%

Body Weight	
-0.44%	-0.34%
Inner Ear Temp.	
+0.20%	+1.54%

Session 2: 10.17.24



- Both sessions show that more work was done in the latter condition.
- Change in body weight and inner ear temperature follow a similar trend, slightly favors Oceanit suit.

Observations

- Use of ice packs and DI water poses a logistics concern for workers that will have to setup the suits.
- Suits are recommended to be hand wash only.
- Pump, reservoir, and water lines are cumbersome and get in the way.
- Anti-chaffing guard is not fire resistant.
- Missing safety release mechanism.
- Circulating water got warm after a relatively short time in a constrained space (~45 min.).
- Ambient conditions during testing and sample size were not representative of desired work conditions.

Conclusions

- Surveys show that workers preferred the Oceanit suit to other conditions, but empirical data was inconclusive.
- A significant amount of improvements need to be made to the existing system for viability in a shipyard environment.
- Next steps include developing an improved cooling suit and improved test procedures based on lessons learned from the first test.
- Potential for follow-on efforts pending results of HII/BIW Body Cooling Technology Study Panel Project

Questions?

Distribution Statement A. Approved for public release: distribution is unlimited.

Back-up

Distribution Statement A. Approved for public release: distribution is unlimited.

Body Weight and Inner Ear Temp.

Percentage Change of Body Weight		
Participant	**Condition**	**Percent Change**
1	**No Suit**	-1.00%
1	**Oceanit**	-0.57%
2	**No Suit**	-0.10%
2	**Oceanit**	-0.10%
2	**Vortex**	-0.19%
3	**No Suit**	0.25%
3	**Oceanit**	-0.49%
3	**Vortex**	-1.62%
4	**Oceanit**	-0.63%
4	**No Suit**	-0.32%
4	**Vortex**	-0.53%
5	**No Suit**	-0.67%
5	**Oceanit**	-0.44%
6	**No Suit**	-0.95%
6	**Oceanit**	-0.61%
5'	**Oceanit**	-0.34%
5'	**No Suit**	-0.34%

Percentage Change of Ear Temp		
Participant	**Condition**	**Ear Temp**
1	**No Suit**	1.03%
1	**Oceanit**	0.41%
2	**No Suit**	0.61%
2	**Oceanit**	0.61%
2	**Vortex**	0.71%
3	**No Suit**	-0.20%
3	**Oceanit**	0.40%
3	**Vortex**	-0.20%
4	**Oceanit**	2.17%
4	**No Suit**	0.61%
4	**Vortex**	1.22%
5	**No Suit**	2.14%
5	**Oceanit**	0.20%
6	**No Suit**	1.43%
6	**Oceanit**	1.32%
5'	**Oceanit**	2.98%
5'	**No Suit**	1.54%

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Preamble Survey

Final Assessment Survey

This survey is designed to capture your feedback. Please answer all of the following questions.

ID#: _____ **Date (MM/DD/YY & Time (HH:MM (AM/PM):** _____

How would you describe your current mood? (Circle one):

Rate how you feel about doing your job considering the following factors:

About completing my job including all job demands while using the cooling suit.	Doubtful			Neither			Confident
About completing the job despite any surprise difficulties or demands that might face you while using the cooling suit.	Doubtful			Neither			Confident
How the cooling suit was in helping you complete your job.	Incapable			Neither			Useful
How the cooling suit worked with your other equipment (ex. PPE, tools, fall protection, vehicles, … etc.)	Incompatible			Neither			Compatible
If the cooling suit helped you in different situations. (ex. Did it help in completing different tasks and/or subtasks?)	Just my main task			Neither			Many other tasks/subtasks
Your AGE because you are wearing the cooling suit.	Anxious			Neither			Relaxed
Your GENDER because you are wearing the cooling suit	Anxious			Neither			Relaxed
What your co-workers or others might think of you because you are wearing the cooling suit.	Anxious			Neither			Relaxed
Because you believe your organization wants you to use the cooling suit.	Anxious			Neither			Relaxed

1

Rate the following statements:

The cooling suit helps increase my productivity.	Strongly Disagree			Neither			Strongly Agree
Using the cooling suit enhances my effectiveness on the job.	Strongly Disagree			Neither			Strongly Agree
Using the cooling suit enhances my safety on the job.	Strongly Disagree			Neither			Strongly Agree

Rate the following statements:

It was easy to don (put on) the cooling suit.	Strongly Disagree			Neither			Strongly Agree
It was easy to doff (take off) the cooling suit.	Strongly Disagree			Neither			Strongly Agree
After adjustment, I didn't remember I was wearing the cooling suit.	Strongly Disagree			Neither			Strongly Agree
Please Comment:							
Overall, I find my job easier to do while wearing the cooling suit.	Strongly Disagree			Neither			Strongly Agree

Rate the following statements:

The cooling suit affected my awareness of objects touching me in my work environment.	Not at all			Neither			A lot
I felt like the cooling suit was a part of me.	Not at all			Neither			A lot
I felt safe using the cooling suit.	Not at all			Neither			A lot

2

I understood everything the cooling suit did.	Strongly Disagree			Neither			Strongly Agree
I trust the cooling suit	Not at all			Neither			A lot
I intend to wear the cooling suit in the future.	Strongly Disagree			Neither			Strongly Agree

Any additional feedback? _____

3

Intermittent Survey

Cooling Suit Post Task Survey

ID#: _____ Date (MM/DD/YY & Time (HH:MM (AM/PM): _____

This Task is	Very Difficult							Very easy
	O	O	O	O	O	O	O	

This Task is	Very uncomfortable							Very comfortable
	O	O	O	O	O	O	O	

This Task is	Very strained							Very relaxed
	O	O	O	O	O	O	O	

Energy exerted	10%								90%
	O	O	O	O	O	O	O	O	O

Any additional comments: _____

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Final Assessment Survey

Final Assessment Survey

This survey is designed to capture your feedback. Please answer all of the following questions.

ID#: _____ **Date (MM/DD/YY & Time (HH:MM (AM/PM):** _____

How would you describe your current mood? (Circle one):

Rate how you feel about doing your job considering the following factors:

About completing my job including all job demands while using the cooling suit.	Doubtful			Neither			Confident
About completing the job despite any surprise difficulties or demands that might face you while using the cooling suit.	Doubtful			Neither			Confident
How the cooling suit was in helping you complete your job.	Incapable			Neither			Useful
How the cooling suit worked with your other equipment (ex. PPE, tools, fall protection, vehicles, … etc.)	Incompatible			Neither			Compatible
If the cooling suit helped you in different situations. (ex. Did it help in completing different tasks and/or subtasks?)	Just my main task			Neither			Many other tasks/subtasks
Your AGE because you are wearing the cooling suit.	Anxious			Neither			Relaxed
Your GENDER because you are wearing the cooling suit	Anxious			Neither			Relaxed
What your co-workers or others might think of you because you are wearing the cooling suit.	Anxious			Neither			Relaxed
Because you believe your organization wants you to use the cooling suit.	Anxious			Neither			Relaxed

Rate the following statements:

The cooling suit helps increase my productivity.	Strongly Disagree			Neither			Strongly Agree
Using the cooling suit enhances my effectiveness on the job.	Strongly Disagree			Neither			Strongly Agree
Using the cooling suit enhances my safety on the job.	Strongly Disagree			Neither			Strongly Agree

Rate the following statements:

It was easy to don (put on) the cooling suit.	Strongly Disagree			Neither			Strongly Agree
It was easy to doff (take off) the cooling suit.	Strongly Disagree			Neither			Strongly Agree
After adjustment, I didn't remember I was wearing the cooling suit.	Strongly Disagree			Neither			Strongly Agree
Please Comment:							
Overall, I find my job easier to do while wearing the cooling suit.	Strongly Disagree			Neither			Strongly Agree

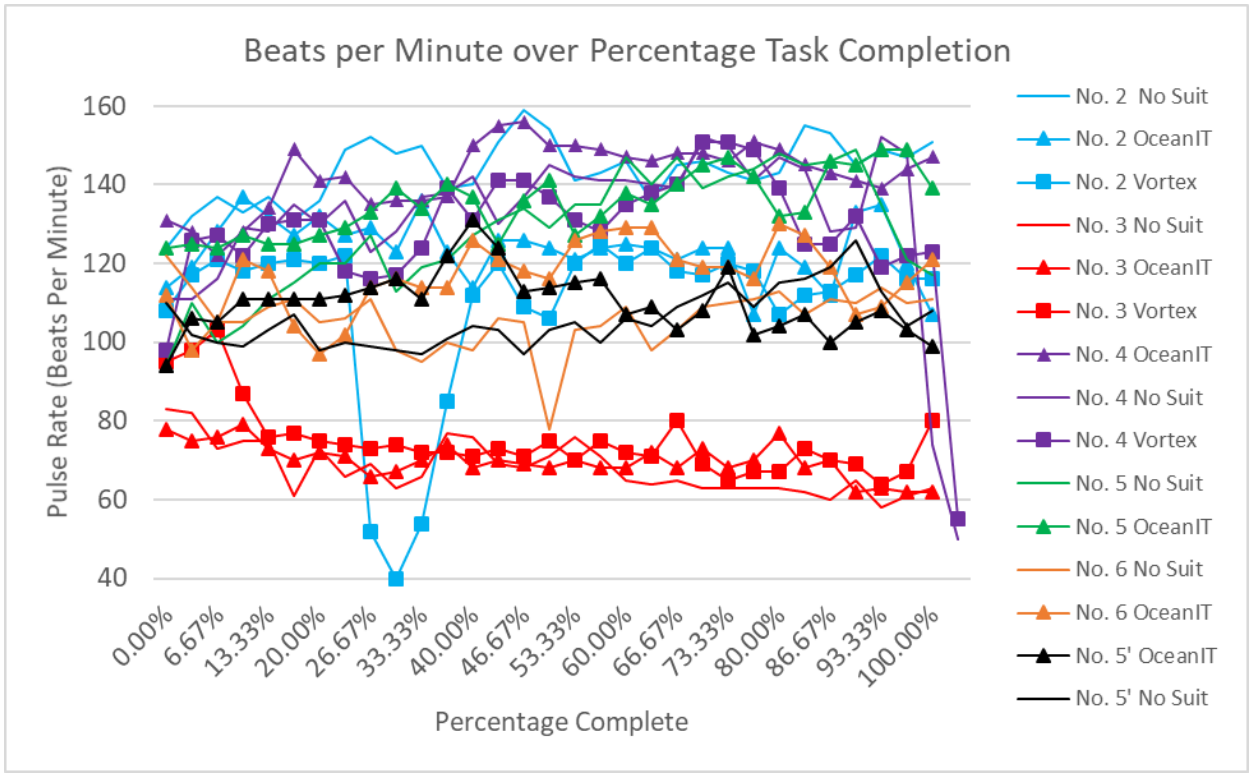
Rate the following statements:

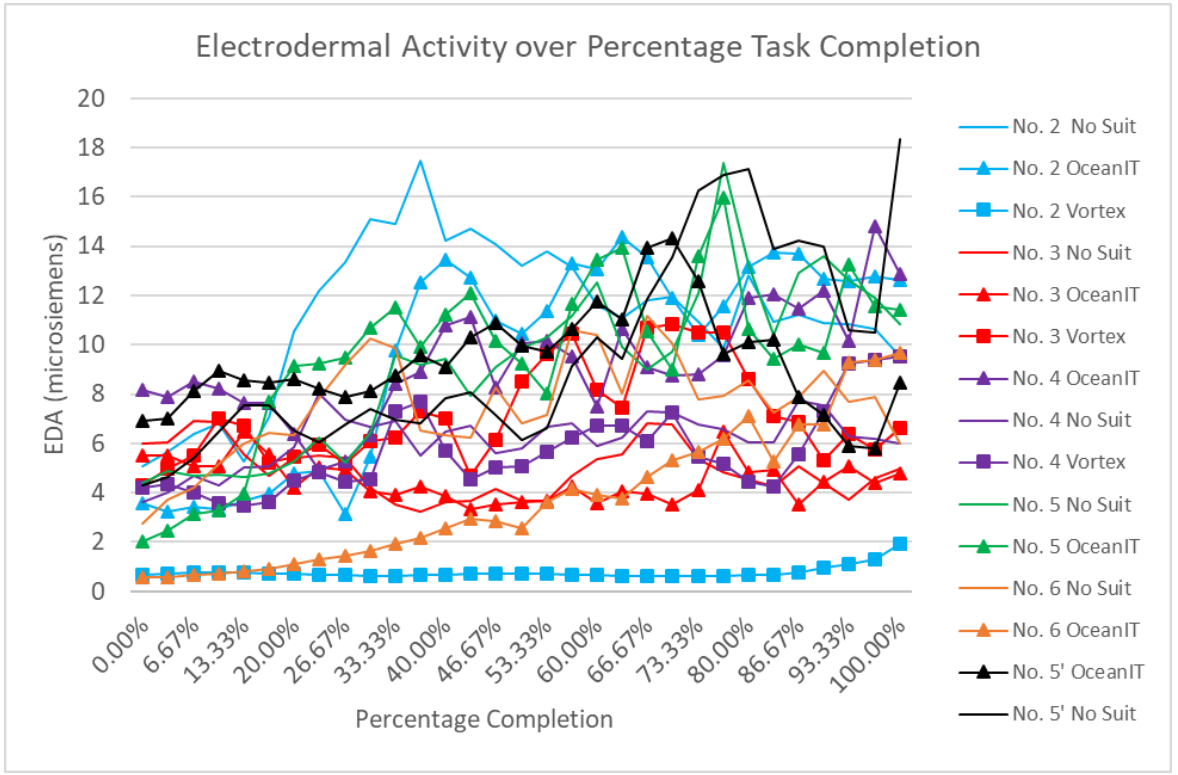
The cooling suit affected my awareness of objects touching me in my work environment.	Not at all			Neither			A lot
I felt like the cooling suit was a part of me.	Not at all			Neither			A lot
I felt safe using the cooling suit.	Not at all			Neither			A lot

I understood everything the cooling suit did.	Strongly Disagree			Neither			Strongly Agree
I trust the cooling suit	Not at all			Neither			A lot
I intend to wear the cooling suit in the future.	Strongly Disagree			Neither			Strongly Agree

Any additional feedback? _____

Empirical Data





OSHA Regulation

PROPOSED RULE

FACT SHEET

Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings

OSHA® Occupational Safety and Health Administration

Why a Standard is Needed:

Heat is the leading cause of weather-related deaths in the United States. Excessive heat in the workplace can cause a number of adverse health effects, including heat stroke and even death, if not treated properly. While heat hazards impact workers in many industries, workers of color have a higher likelihood of working in jobs with hazardous heat exposure. OSHA published in the Federal Register a Notice of Proposed Rulemaking (NPRM) titled *Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings*, a significant step toward a federal heat standard, which proposes protective measures that the agency has preliminarily determined would significantly reduce heat-related injuries, illnesses, and fatalities in the workplace. The NPRM is available for viewing on the Federal Register web page at https://federalregister.gov/d/2024-14824 and https://www.regulations.gov/document/OSHA-2021-0009-4761. OSHA encourages the public to submit comments to the Heat Injury and Illness Prevention rulemaking docket at https://www.regulations.gov/commenton/OSHA-2021-0009-4761. The comment period is open until December 30, 2024.

Scope of the Standard:

The proposed standard would apply to all employers conducting outdoor and indoor work in all general industry, construction, maritime, and agriculture sectors where OSHA has jurisdiction. OSHA is proposing to exclude from the rule: short duration employee exposures to heat, emergency response activities, work at indoor sites kept below 80°F, telework, and indoor sedentary work activities. The proposed standard would more clearly set employer obligations and the measures necessary to effectively protect employees from hazardous heat. Employers would be required to create a plan to evaluate and control heat hazards in their workplace.

What the Standard Requires:

The proposed standard would require employers to:

- Develop and implement a work site heat injury and illness prevention plan (HIIPP) with site-specific information to evaluate and control heat hazards in their workplace.
- Identify heat hazards in both outdoor and indoor work sites.
  - For outdoor work sites, employers would be required to monitor heat conditions by tracking local heat index forecasts or measuring heat index or wet bulb globe temperature.
  - For indoor work sites, employers would be required to identify work areas with the potential for hazardous heat exposure, develop and implement a monitoring plan, and seek employee input.
- Implement control measures at or above the Initial Heat Trigger (i.e., a **heat index of 80°F** or a wet bulb globe temperature equal to the NIOSH Recommended Action Limit) that include providing employees:
  - cool drinking water;
  - break areas with cooling measures;
  - indoor work area controls;
  - acclimatization protocols for new and returning unacclimatized employees;
  - paid rest breaks **if needed** to prevent overheating; and
  - regular and effective two-way communication.
- Implement additional control measures at or above the High Heat Trigger (i.e., **heat index of 90°F** or wet bulb globe temperature equal to the NIOSH Recommended Exposure Limit) that include providing employees:
  - **mandatory** rest breaks of 15 minutes at least every two hours (unpaid meal break may count as a rest break);
  - observation for signs and symptoms of heat-related illness;
  - a hazard alert to remind employees of key parts of the HIIPP; and
  - warning signs at indoor work areas with ambient temperatures that regularly exceed 120°F.

Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings

- Take steps if an employee is experiencing signs and symptoms of a heat-related illness or a heat emergency, and develop a heat emergency response plan.
- Provide initial and annual refresher training for supervisors, heat safety coordinators, and employees, as well as supplemental training after changes in exposure to heat hazards, policies and procedures, or the occurrence of a heat injury or illness.
- Have and maintain, for a minimum of six months, written or electronic records of indoor monitoring data.
- Ensure that all requirements are at no cost to employees.

These requirements of the proposed standard are summarized in the table below:

Provision	All Covered Employers (See Scope)	At or Above Initial Heat Trigger	At or Above High Heat Trigger
Identifying heat hazards	●	●	●
Heat illness and emergency response procedures	●	●	●
Training for employees and supervisors	●	●	●
Heat injury and illness prevention plan (HIIPP)	●	●	●
Recordkeeping	●	●	●
Drinking water		■	■
Break area		■	■
Indoor work area controls		■	■
Acclimatization plan for new or returning workers		■	■
Rest breaks (if needed)		■	■
Effective communication means with employees		■	■
Rest breaks (minimum 15 minutes every 2 hours)			▲
Supervisor or buddy system to observe for signs and symptoms			▲
Hazard alert			▲

Stakeholder Participation:

OSHA encourages the public to participate in this rulemaking by submitting comments. Your input will help OSHA develop a final rule that adequately protects workers, is feasible for employers, and is based on the best available evidence. You may submit comments and attachments electronically at www.regulations.gov, Docket No. OSHA-2021-0009. When submitting comments or recommendations, commenters should explain their rationale and, if possible, provide data and information to support their comments or recommendations. The comment period is open until December 30, 2024.

All comments, including any personal information you provide, will be placed in the public docket without change and, with the exception of copyrighted materials, will be publicly available online at www.regulations.gov. Therefore, OSHA cautions commenters about submitting information they do not want to be made available to the public or submitting materials that contain personal information (either about themselves or others) such as Social Security Numbers, birthdates or confidential medical information. All comments and submissions are listed in the www.regulations.gov index; however, some information (e.g., copyrighted material) is not publicly available to read or download through that website. All submissions, including copyrighted material, are available for inspection at the OSHA Docket Office. Contact the OSHA Docket Office at 202-693-2350 (TTY number: 877-889-5627) for assistance in locating docket submissions.

For more information on how to engage with this stage of the rulemaking process, visit: https://www.osha.gov/laws-regs/rulemakingprocess#v-nav-tab2.

- Proposed to CFR (Code of Federal Regulations)