INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1913-TRP, Study of the Corrosion Impact on Information Technology Equipment in Data Centers Located in Coastal Regions with High Sea Salt Concentration

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment
Co-sponsored by, TC 2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equipment
TC 2.4 Particulate Air Contaminates and Particulate Contaminant Removal Equipment

Budget Range: $280,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2025** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, December 16, 2024. NO EXCEPTIONS, NO EXTENSIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 1913-TRP, Study of the Corrosion Impact on Information Technology Equipment in Data Centers Located in Coastal Regions with High Sea Salt Concentration, and *"Bidding Institutions Name"* (electronic pdf format, ASHRAE's server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters
Technical Contact
Vali Sorell
Phone: 415-307-9834
e-Mail: vali.sorell@oracle.com

For Administrative or Procedural Matters:
Manager of Research & Technical Services (MORTS)
Steve Hammerling
ASHRAE, Inc.
180 Technology Parkway, NW
Peachtree Corners, GA 30092
Phone: 404-636-8400
Fax: 678-539-2111
E-Mail: MORTS@ashrae.net

Contractors intending to submit a proposal should notify, by mail or e-mail, the Manager of Research by December 1st, 2024 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

All proposals must be submitted electronically. Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below. **ALL electronic proposals are to be sent to rpbids@ashrae.org.**

All other correspondence must be sent to ddaniel@ashrae.org. In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 16, 2024.
NO EXCEPTIONS, NO EXTENSIONS.

The following forms (Application for Grant of Funds and the Additional Information form have been combined) must accompany the proposal:

(1) ASHRAE Application for Grant of Funds (electronic signature required) and
(2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)
high humidity can experience corrosion related hardware failures, especially as hardware manufacturers continue reducing circuit board feature sizes and miniaturize components. There are no guidelines on what environmental conditions (temperature, humidity, wet/dry cycles, etc) are acceptable for operating data centers in marine environments. This research is focused on providing those guidelines.
The following are examples of IT failures in marine environments.

IT corrosion fails in marine environments.

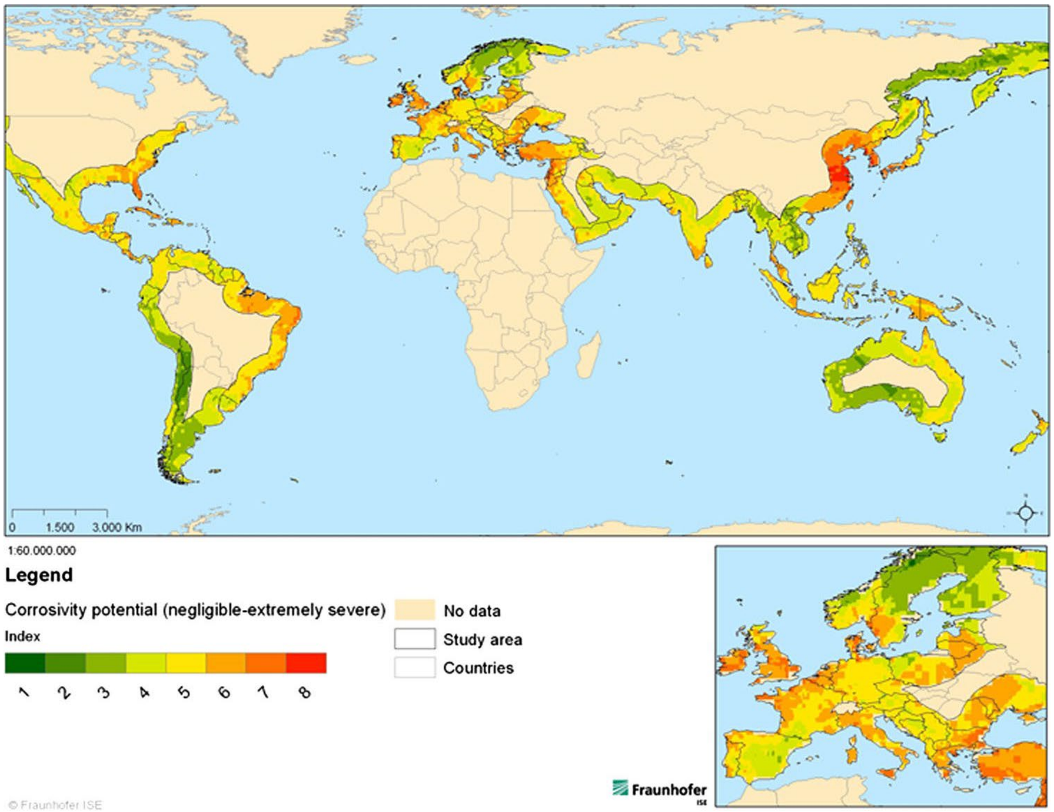
1. The concern of the use of economizers for data centers located in marine environments was presented in Seminar 34 at the 2023 ASHRAE conference in Tampa. The seminar was entitled "The Impact of Hot and Humid and Corrosive Environment on Data Center Equipment: Recent Research/Activities on Data Centers". In his portion of the seminar, Chris Muller of AAF International presented data from measurements made in fifty-nine coastal locations using copper and silver coupons where 50 locations reported datacom failures due to corrosion. The nine locations without failures all employed enhanced air cleaning to remove particulates and corrosive gases. All locations with failures were within 15 miles of the coast. Chlorine corrosion was found on almost 50% of indoor coupons. The failed components included servers, HDDs, and network gear.

2. IBM showed high levels of contamination of sea salts coating printed circuit boards causing high levels of fails. This data center was within a mile of the coast. SEM/EDS analysis showed high levels of Na, Cl, Ca, S, and Mg, all characteristics of sea salts. In addition, high levels of NaCl in the range of 148 - 1417 mg NaCl equivalent/cm2 were measured where levels greater than 10 mg/cm2 are considered corrosive to electronic hardware.

3. Microsoft Amsterdam hyperscale data center - A data center located in a coastal region and running in economizer mode in the month of Oct showed high levels of chlorine even with two levels of filtration. Copper and silver coupon measurements over the course of one month showed corrosion thicknesses exceeding acceptable limits. Using RH limit of 60% deliquescence (Ref. Sandia work) there are no fewer than 46 wet dry cycles inside the data center during the month of Oct.

4.Gerardo Alfonso (Columbia, S.A.) A survey of some data centers in Columbia near the coastline found issues with corrosion of IT equipment (failed memory cards, processor modules, PCI cards, whatever) and UPS and other electronic equipment. In addition, he reported that they have issues with electronics in UPS's and cooling units. Analysis showed high levels of chlorides on the failed components. Many of these data centers were running in economizer modes to save energy and without any chemical filtration.

Airborne salinity is the essential factor determining atmospheric corrosion in marine regions (Vashi and Kadiya, 2009). Salt chloride deposition maps for the US and world-wide show sea salts traveling up to 100 km inland (Slamova, 2012; Harkel, 1997) where about 40% of the world's population live [https://sedac.ciesin.columbia.edu/es/papers/Coastal_Zone_Pop_Method.pdf]. This region contains an enormous amount of electronic equipment, not the least of which is in data centers. Slamova, 2012 created a map of the world showing the extent of corrosion in marine environments. The assessment of the atmospheric corrosion in coastal regions is based on the international standard ISO 9223 where the corrosivity classification is defined by three parameters: SO2 pollution, airborne salinity, and time of wetness. According to these conditions, the map estimating the rate of atmospheric corrosion in the coastal regions has been created and is shown in the figure below.



A large part of the world's coastal regions and almost all of Europe are shown to have corrosivity indexes in the highest categories (C5 to C8).

Many corrosion studies have been performed on materials other than what is used in IT equipment, and those studies can be used to guide this research of corrosion on the materials used in IT equipment – principally copper and silver. Alcantara, Jenifer, et al., 2017 provided an excellent technical review paper on marine atmospheric corrosion of carbon steel. They state that half of the world's population lives in coastal regions and the industrialization of developing countries tends to concentrate production plants close to the sea. They go on to state in their summary that "…it is surprising that marine atmospheric corrosion has until recently received little attention by corrosion scientists. This is therefore a young scientific field, where there continues to be great gaps in knowledge." It goes on to say "Experimentation in this field is carried out at atmospheric testing stations and in the laboratory by means of wet/dry cyclic tests – need to do more experiments with high Cl- ; need to standardize testing" indicating a broad need for corrosion testing to understand the impact of salts such as Cl-. Cole, et.al. 2004 investigated how deposited marine aerosols react with metal surfaces (zinc, galvanized steel, aluminum, and gold). Marine aerosols consisting of wet, partially wet, and non-equilibrium aerosols depending on the atmospheric humidity are carried by the wind and can reach offshore structures and accelerate the corrosion of metals. Sandia National Labs, 2013 and 2017 investigated the cracking of steel container tanks of spent nuclear fuel. They determined that a substantial portion of the sea salts that were deposited on the container surface were of aerosol form given the low deliquescence of the combination of salts. Many more studies include the chemistry of the salt deposited on the metal and resulting corrosion resulting from the wet/dry cycles common in marine environments. The review of many of these research studies do not provide any conclusive evidence of those environmental parameters that are most damaging in causing corrosion.

Research continues in this arena in very general HVAC applications. Antonopoulos, et.al., funded by the US Dept of Energy Building America Program within the Building Technology Office will be analyzing more data from homes in the hot-humid climates of the Southeast US. The future work will be analyzed to study the contributions of outdoor vs indoor pollutant sources and the benefits of controls including venting range hoods to remove pollutants.

Justification and Value to ASHRAE

The results of this project will provide data that will be used to verify or modify the ASHRAE Thermal Guidelines for Data Processing Equipment located in marine environments. These guidelines are made available in the ASHRAE handbooks, special publications, and standards. Potential benefits of the project include:

- Justification for the acceptable temperature, humidity, salinity levels, and wet/dry cycles for marine environments.

- Improved reliability of data center information technology equipment including those that require a high level of resilience.

- Reduction in dehumidification energy use in data centers

- Increased use of economizers to coincide with the adoption of Standard 90.1 and 90.4 for data centers

- Previous gaseous pollutant research funded by ASHRAE (1755RP) found that there were no standards that provided a ready-made design of the testing that could be used for that research. For the proposed research of corrosion in marine environments the work that was done and reported in ASHRAE report 1755 will be an excellent guide to developing the test apparatus for testing that mimic marine environments. Throughout the Scope/Technical Approach it is strongly recommended to build on this test apparatus for gaseous pollutants and to expand it to include marine environments. Standards for testing for corrosion of electronics in gaseous pollutants did not exist. But these two pieces of research combined will most likely result in a standard for testing corrosive environments.

Objectives

The objectives to be met by this project are:

1. Conduct a literature survey to understand the importance of field variables – such as temperature, moisture content, wet/dry cycles, and salt concentration (fine particulates and airborne water droplets) – and their effects on corrosion to design a set of experiments. The gaseous pollutant SO_2 should also be included to the list of field variables since some of the literature suggest that it can be a large contributor to enhancing corrosion in marine environments.

2. Develop a draft test methodology and establish minimum specifications for the test facility and instrumentation.

3. Based on the literature survey create a design of experiments that includes the key parameters for this study and the range of parameters to be tested. To mimic the marine environment as realistically as possible it may require supplementing the literature information with some environmental measurements from a few available data centers located in coastal areas.

4. Develop a test facility capable of monitoring and controlling the test parameters determined from the literature survey. Consideration should be given to using a similar testing apparatus that was designed and built to perform research on the effects of gaseous pollutants on the corrosion of copper and silver materials used in IT equipment. The reference is ASHRAE 1755-RP, Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers. The time it takes to cause corrosion of the IT equipment in marine environments is a key element of the testing. For the gaseous pollutant study referenced here tests were performed for various testing times of 2 days up to 1 month to develop degradation due to corrosion vs time plot. This should also be an element of the proposed plan.

5. Document the results of the effect on corrosion of electronic equipment from the sea salts. Provide the tool/s for measuring corrosion of IT equipment in marine environments including recommendations on where the measurements should be made and to determine the environmental limits to prevent further degradation of reliability or resilience depending on the data center objectives.

6. Develop new guidelines for operating data centers and other electronics in marine environments.

The following items comprise the technical approach of the project. Upon completion of each task and deliverable, PMS review and approval is required before proceeding to the next task.

Task 1. Perform and document a detailed literature review of:

a) Determine the most prominent chemical composition of sea salts and those that testing will provide the most relevant results for data center operators with data centers located in marine environments.

b) Prior studies regarding the relationship between humidity, form (wet aerosol, partially wet aerosol, dry aerosol) of salt pollutant, mass, or salt concentration of salt pollutant (including diameter of particles if a solid), versus distance from coastline.
c) Prior studies detailing the environmental characteristics of inlet conditions to a data center in a coastal region. These conditions would include but not limited to temperature, humidity, salinity levels, air velocity, SO2 levels, and wet/dry cycles over a 24 hr period.
d) Testing standards and best practices that provide a representative environment mimicking marine environments. This should include temperature and humidity profiles over an extended period.
e) Best practices for determining the level of corrosion of IT equipment in these marine environments which may include copper, silver and PCB coupons, all representative of components used to manufacture IT equipment.
f) Corrosion chemistry based on copper and silver coupon testing and electrical conductivity measurements of PCB's.

Scope:
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f) Corrosion chemistry based on copper and silver coupon testing and electrical conductivity measurements of PCB's.

A deliverable of this task is a report that summarizes the literature review.

Task 2. Develop a test facility capable of monitoring and controlling dry bulb temperature, dew point, air flow velocity, sea salt concentration, and time of exposure that mimics the environmental conditions of data centers in marine environments.

a) Consideration should be given to using a similar testing apparatus that was designed and built to perform research on the effects of gaseous pollutants on the corrosion of copper and silver materials used in IT equipment. This research was documented in the final report entitled: ASHRAE 1755-RP, Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers by Rui Zhang, Jensen Zhang (PI), Roger Schmidt (Co-PI), Jeremy Gilbert (Co-PI) and Beverly Guo, April 2018.
b) vehicles to understand the impact of bias on the acceleration of corrosion.

A deliverable of this task is a report that summarizes the test facility design and method to vary the various test parameters over the range of environmental parameters exhibited by data centers in coastal regions.

Task 3. Experimentally characterize copper and silver corrosion of the test coupon samples using conditions appropriate to cover the ASHRAE thermal guidelines. At a minimum, these conditions would be 20 – 35oC, 40 – 85% relative humidity, range of salinity levels, range of SO2 levels and wet/dry cycles experienced by coastal data centers in a 24 hr period. It is expected that the total number of tests performed will be in the range of 150 to 200 tests over the expected 2-year research period. The researcher should carefully review the proposed test plan after the completion of Task 1 to determine if interactions between any factors can be eliminated. The scope of the experimental characterization is as follows:

a) Coulometric reduction should be used to characterize the rate of corrosion on copper and silver coupons.

b) Select samples to perform advanced surface analysis using techniques such as XPS and TOFSIMS to better understand the mechanisms and evolution of corrosion products. These tools are available measurement tools employed for characterizing the corrosion of the materials are scanning electron microscopy, (SEM) equipped with EDXA, Raman spectroscopy, and FTIR should be considered.
c) The literature survey may also provide some insight into the tools to best characterize the corrosion.

A deliverable of this task is a report that summarizes corrosion test results over the range of environmental parameters experienced in coastal data centers. Highlight those parameters or group of parameters having the most destructive effect on IT equipment reliability. Include the effect of makeup air in your comments regarding the test results.

Task 4. Understand and perform experiments to elucidate the relationship between the rate the change of humidity on the corrosion rates of copper and silver. For a direct air side economizer these changes can occur in minutes or hours depending on the weather patterns of the data center location and would impact the IT equipment housed within the data center.

A deliverable of this task is a report of the effect that rate of change of humidity (wet/dry cycles) has on the corrosion of the IT materials.

Task 5. Develop an updated set of thermal guidelines for coastal locations of data centers and specific guidelines that may focus on those data centers where resiliency may be the primary operational goal and not energy efficiency.

A deliverable of this task is a report of the thermal guidelines for coastal data centers with those environmental conditions providing the highest reliability for IT equipment. In addition, a set of guidelines for coastal data center where resiliency is the primary operational goal should also be reported.

Task 6. Provide guidance on what tool/s to use for quantifying corrosion in coastal data centers. In addition, provide recommendations on where those measurements should be made.

A deliverable of this task is a report summarizing the tool/s for measuring corrosion in data centers and the optimum location for those measurements.

<u>Deliverables</u>:
Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically, on or before each January 1, April 1, June 10, and October 1 of the contract period.

The following deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available:

Furthermore, the Institution's Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

-An executive summary in a form suitable for wide distribution to the industry and to the public.
-Two copies; one in PDF format and one in Microsoft Word.

c. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the “ASHRAE Manuscript Central” website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in “Manuscript Central” for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1913-RP) at the end of the title in parentheses, e.g., (1913-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

d. Data

Data is defined in General Condition VI, “DATA”

e. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society’s ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort

The estimated cost is $280,000 including the cost of the test facility, materials, and supplies, travels to ASHRAE for reporting as well as the personnel salaries, fringe benefits and overhead. Fringe and overhead cost typically are about 50% of the proposed budget in most research active universities in the U.S. The project is expected to take 24 months. Significant cost sharing is provided in terms of equipment and personnel by the sponsoring companies. The details of the cost are provided in the following table.

The exact payment schedule will be negotiated between the contractor and ASHRAE.

Co-funding company - Mississippi Power – contact – Grey Cumbest, Lum <LGCUMBES@southernco.com>

1.Company provides failed hardware for analysis (max. of 4 failed parts for analysis); provide detail of where fails were located, T & RH data at location; analysis performed with available measurement equipment such as scanning electron microscopy (SEM) equipped with EDXA, Raman spectroscopy, and FTIR measurements.
2.Provide T & H measurements at selected locations – specify measurement locations, location of monitors (monitors located in outside ambient and correspondingly inside locations where equipment is located), T & H readings (reading every 5 minutes) over a month duration for different seasons of the year
3.Provide silver and copper coupon measurements at same locations as T & H measurements as stated above; have coulometric analysis performed on coupons; additional analysis performed with available measurement equipment such as scanning electron microscopy (SEM) equipped with EDXA, Raman spectroscopy, and FTIR measurements.
Co-funding - Pure Air – contact – Kevin Jameson – kjameson@pureairfiltration.com - In kind sponsor for $25k
1.Provide 25% cost reduction on purchased of 25 sets or more of coupons – includes analysis, report and shipping. For our proposal it is estimated that the research will require 200 sets of coupons (this is the same number used in the prior research on gaseous pollution. The cost of the coupons quoted by Pure Filtration is $30k for 200 sets.
Co-funding – Camfil USA – contact :Adams Wiggins/Data Center Segment Manager

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Deliver detailed literature review results	4
2	Develop a test facility capable of monitoring and controlling dry bulb temperature, dew point, air flow velocity, wet/dry cycles, and sea salt concentration.	12
3	Complete copper, silver and PCB corrosion tests using conditions to cover the ASHRAE Thermal Guidelines and complete corrosion analysis to document relationship between environmental conditions and corrosion.	22
4	Complete humidity variation impact on corrosion rate experiments and explain relationship	24
5	Complete an updated set of thermal guidelines	24
6	Final Report	24

Proposal Evaluation Criteria
Proposals submitted to ASHRAE for this project should include the following minimum information:

No.	Proposal Review Criterion	Weighting Factor
1	Contractors understand of work statement as revealed in proposal ▪ Logistical problems associated ▪ Technical problems associated	15%
2	Quality of methodology proposed for conducting research. ▪ Organization of project ▪ Management plan	20%
3	Contractor's capability in terms of facilities ▪ Managerial support ▪ Data collection ▪ Technical expertise	20%
4	Qualifications of personnel for this project ▪ Project team 'well rounded' in terms of qualifications and experience in related work ▪ Project manager directly responsible with experience ▪ Team members' qualifications and experience ▪ Time commitment of Principal Investigator	15%

5	Student Involvement ▪ Extent of student participation on contractor's team ▪ Likelihood that involvement in project will encourage entry into HVAC&R industry	5%
6	Probability of contractor's research plan meeting the objectives of the Work Statement ▪ Detailed and logical work plan with major tasks and key milestones ▪ All technical and logistic factors considered ▪ ▪ Reasonableness of project	15%
7	Performance of contractor on prior ASHRAE or other projects (No penalty for new contractors)	10%

References:

1. Alcantara, J., D. Fuente, B. Chico, J. Simancas, I. Diaz and M. Morcillo, Marine Atmospheric Corrosion of Carbon Steel: A Review, Materials 2017, 10, 406, 67 pages.
2. ASHRAE Standard 90.4-2019 -- Energy Standard for Data Centers- (ANSI Approved)
3. ASHRAE Special Publication, 2015. Thermal Guidelines for Data Processing Environments, 3rd Edition, ASHRAE Datacom Series Book 1: Atlanta.
4. ASHRAE Special Publication, 2013. Particulate and Gaseous Contamination in Datacom Environments ASHRAE Datacom Series Book 8: Atlanta.
5. ASTM D1141-98(2008). Standard Practice for the Preparation of Substitute Ocean Water.
6. Cole, I.S., D. Lau, and D.A. Paterson, Holistic model for atmospheric corrosion Part 6 – From wet aerosol to salt deposit, Corrosion Engineering, Vol. 39, No. 3, 2004, 209-218.
7. Harkel, M.J., The Effects of Particle Size Distribution and Chloride Depletion of Sea Salt Aerosols on Estimating Atmospheric Deposition at a Coastal Site, Atmospheric Environment, Vol. 31, No. 3, pp. 417- 427, 1997.
8. Sandia National Lab, 2017., UFD Expert Panel on Chloride Induced Stress Corrosion Cracking of Interim Storage Containers for Spent Nuclear Fuel, Sandia Report, https://www.osti.gov/servlets/purl/1505413, 2017
9. Sandia National Lab, 2013. DATA REPORT ON CORROSION TESTING OF STAINLESS STEEL SNF STORAGE CANISTERS https://www.energy.gov/sites/prod/files/2013/12/f5/CorrosionTestStainlessSteelSNFStorContainer.pdf,
10. Slamova, K., et.al, Mapping atmospheric corrosion in coastal regions: methods and results, Journal of Photonics for Energy, Vol. 2, 2012, 13 pages.
11. VASHI, R.T.and H. K. KADIYA, "Corrosion Study of Metals in Marine Environment" E-Journal of Chemistry, 2009, **6(4),** 1240-1246.
12. Zhang, R., J. Zhang, R. Schmidt, J. Gilbert, and B. Guo, ASHRAE 1755-RP, Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers, April, 2018.