DOT/FAA/AR-02/115

Office of Aviation Research
Washington, D.C. 20591

Evaluation of Conductivity Meters for Firefighting Foams

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October 2002

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/AR-02/115	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EVALUATION OF CONDUCTIVITY METERS FOR FIREFIGHTING FOAMS		5. Report Date October 2002
		6. Performing Organization Code AAR-411
7. Author(s) Keith Bagot		8. Performing Organization Report No. DOT/FAA/AR-02/115
9. Performing Organization Name and Address Federal Aviation Administration William J. Hughes Technical Center Airport and Aircraft Safety Research and Development Division Airport Technology Research and Development Branch Atlantic City International Airport, NJ 08405		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, DC 20591		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code AAS-300
15. Supplementary Notes		

16. Abstract

This evaluation was conducted to comparatively test various conductivity meters and refractometers used in testing airport rescue and firefighting (ARFF) vehicle foam-proportioning systems. The amount of foam concentrate fed to the foam proportioner of a firefighting system is critical, not only in the making of foam with the proper expansion and drainage rate, but also in making a fire-resistant foam. Therefore, it is essential that correct proportioning is maintained and that the concentration meets the required level. During the annual certification inspection of an airport fire department, refractometer and conductivity meter tests are conducted to test the foam concentrate and foam-proportioning systems of the ARFF apparatus.

Historically, refractive index has been used to determine the proportioning of foam-generating systems. Recently, the accuracies of the refractometer tests have come into question. The National Fire Protection Association (NFPA) now requires the use of conductivity meters in NFPA 412, Standard for Evaluating Aircraft Rescue and Firefighting Foam Equipment, 1998 edition. The refractometer gives readings with an accuracy of ±0.3%, whereas conductivity meters can give accuracies greater than 0.05%.

Five conductivity meters were evaluated against the standard refractometer. There were some variations to the operation and calibration of the conductivity meters that made some meters slightly better than others. It was determined, however, that all five conductivity meters were more accurate and easier to use for conducting tests on foam-proportioning systems than the refractometer.

17. Key Words Conductivity meter, Proportioner, Refractometer, ARFF, NFPA		18. Distribution Statement This document is available to the public through the National Technical Information Service (NTIS) Springfield, Virginia 22161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 15	22. Price

Form DOT F1700.7 (8-72) Reproduction of completed page authorized

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EXECUTIVE SUMMARY

This evaluation was conducted to comparatively test various conductivity meters and refractometers for use in testing airport rescue and firefighting (ARFF) vehicle foam-proportioning systems. The amount of foam concentrate fed to the foam proportioner of a firefighting system is critical, not only in the making of foam with the proper expansion and drainage rate, but also in making a fire-resistant foam. Therefore, it is essential that correct proportioning is maintained and that the concentration meets the required level.

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INTRODUCTION

BACKGROUND.

This evaluation was conducted to comparatively test various conductivity meters and refractometers used in testing airport rescue and firefighting (ARFF) vehicle foam-proportioning systems. The amount of foam concentrate fed to the foam proportioner of a firefighting system is critical, not only in the making of foam with the proper expansion and drainage rate, but also in making a fire-resistant foam. Therefore, it is essential that correct proportioning is maintained and that the concentration meets the required level.

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OBJECTIVE.

The evaluation was conducted at the request of the Office of Airport Safety and Standards (AAS). The purpose of this evaluation was to comparatively test several conductivity meters against the standard refractometer. The tests specified in this report were adapted from NFPA 412. The data from this evaluation will be used to update the current guidelines under Federal Aviation Administration (FAA) Order 5280.5B, Airport Certification Program Handbook. The handbook currently requires the use of refractometers for testing the foam-proportioning systems of airport fire apparatus.

TEST METHOD.

The selection of foam concentrates were taken from a random sample of an unopened supply from the FAA William J. Hughes Technical Center's ARFF Research Program's inventory. Samples ranged from various manufacturers, types of concentrate, and percentages of concentration. This was done to test the conductivity meters with the largest range of available products. For 6-percent concentrates, the concentrations tested were 5, 6, and 7 percent. For 3-percent concentrates, the concentrations tested were 2, 3, and 4 percent.

The hand-held refractometer used in this evaluation was a Fisher Scientific Hand Refractometer (Brix 0% - 25%). Five hand-held conductivity meters were evaluated. They were the Omega Model CDH-70, Orion Model 105, Oakton CON 5, VWR Conductivity Meter, and a Hanna Instruments Model HI 8733. Figure 1 shows the five meters and the refractometer evaluated.

In preparing for the test samples, the following apparatus were used:

- Four 100-mL graduates
- One measuring pipette (10-mL capacity)
- Conductivity meters and refractometer
- Calibration constant solution
- Distilled water

FIGURE 1. CONDUCTIVITY METERS AND REFRACTOMETER

Using water and foam concentrate, three standard solutions were made into three 100-mL graduated cylinders. Volumes of foam concentrate were added in milliliters equal to the following:

- The nominal concentration of the foam concentrate (3 or 6 mLs)
- One percent more than the nominal concentration (4 or 7 mLs)
- One percent less than the nominal concentration (2 or 5 mLs)

The graduated cylinders were then filled to the 100 mL mark with water. The foam solution concentration was then tested using the following methods.

<u>REFRACTOMETER</u>. A refractive index test was conducted using the following procedure. The refractometer was first calibrated using distilled water to set the zero reference. After thoroughly mixing the solution, a refractive index reading was taken of each mixture. Refractive index readings were taken by placing a few drops of solution on the refractometer prism and closing the cover plate. The readings were taken by observing the scale reading at the dark field intersection. A plot was made on the graph portion of the data sheet at each of the known foam solution concentrates.

CONDUCTIVITY METER. The conductivity meter was first calibrated using the calibration constant solution. The probes from various conductivity meters were dipped into the calibration solution. The units were calibrated by adjusting the value on the meter to read the value of the constant (0.1413 milli-siemens (mS)). This was done by using either the increase/decrease buttons on the meter or by using a small tool supplied with the meters to adjust the potentiometer.

Care was taken to ensure that the conductivity measurements were made when the water and foam solution were at the same temperature. Small differences in temperature can substantially change conductivity measurements. The Omega Model CDH-70 meter automatically compensates for different temperatures. When the other meters were used, the instructions for the conductivity meter calibration and temperature compensation were carefully followed. There were two options to compensate for temperature variations. One method requires the water and foam concentrate temperatures be measured and then entered into a mathematical equation. The other method was to adjust an offset on the meter to a range that would encompass the largest temperature range and make the necessary compensation to the readings. This method has a minimal effect on the accuracies of the readings. The second method was chosen for this evaluation because of the fact that these units would be used in the field and not in a lab. The second method is the easiest method to use in a field application and it was determined that the small effect on accuracies was acceptable. As long as the same procedure is used in the field for each of the test samples, the upward trend of the data as the concentrations increased would be maintained.

The conductivity meter readings were taken by dipping the conductivity probe into the sample and the digital scale read. It is important to ensure that any air bubbles are removed from the probe. To do this, the probe was gently tapped on the sides of the graduates. The readings on the meter were then allowed to stabilize and the value recorded.

DATA COLLECTION.

The refractive index readings were recorded on the graph portion of the data sheet. A sample of the data sheet is shown in figure 2. Conductivity values for each solution were also recorded on these data sheets. Comments were recorded by each evaluator regarding the ease of use and the pros and cons of each device.

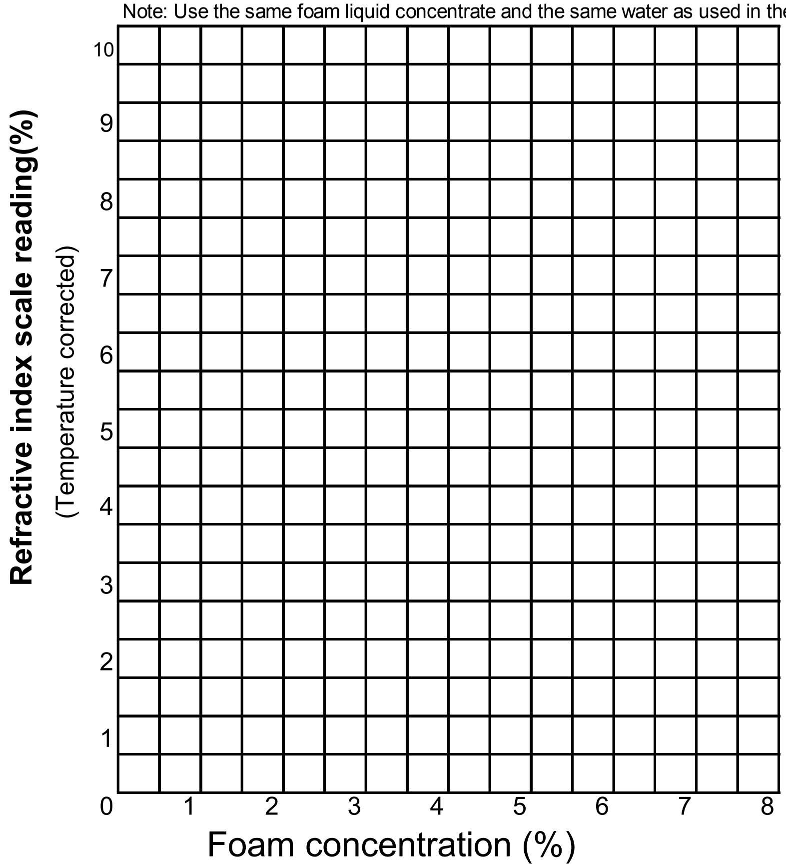
RESULTS

The data from the conductivity meter tests were collected on the data sheets and then plotted. Figures 3 through 8 show the conductivity readings of the six different foam products. Figures 9 and 10 show the refractometer readings for the 3- and 6-percent solutions, respectively. The data from the five conductivity meter tests show very close readings to one another. Typically, the units read within 0.2 mS. More importantly, all five conductivity meters exhibited the same trends in the readings from one foam product to the other. As can be seen by the refractometer data, the same point cannot be made.

EVALUATION OF CONDUCTIVITY METERS
DATA SHEET

Variation in refractive index (using juice refractometer) with different foam concentrations

Note: Use the same foam liquid concentrate and the same water as used in the other foam sets



Foam Liquid Concentrate

Make:

Batch:

Date of Manufacture:

Conductivity Meter	**VALUE** H$_2$0	**2%**	**3%**	**4%**
Omega Model CDH-70	____	____	____	____
Orion Model 105	____	____	____	____
Oakton Con 5	____	____	____	____
VWR Conductivity Meter	____	____	____	____
Hanna Instruments Model HI 8733	____	____	____	____

COMMENTS:____

FIGURE 2. SAMPLE DATA SHEET

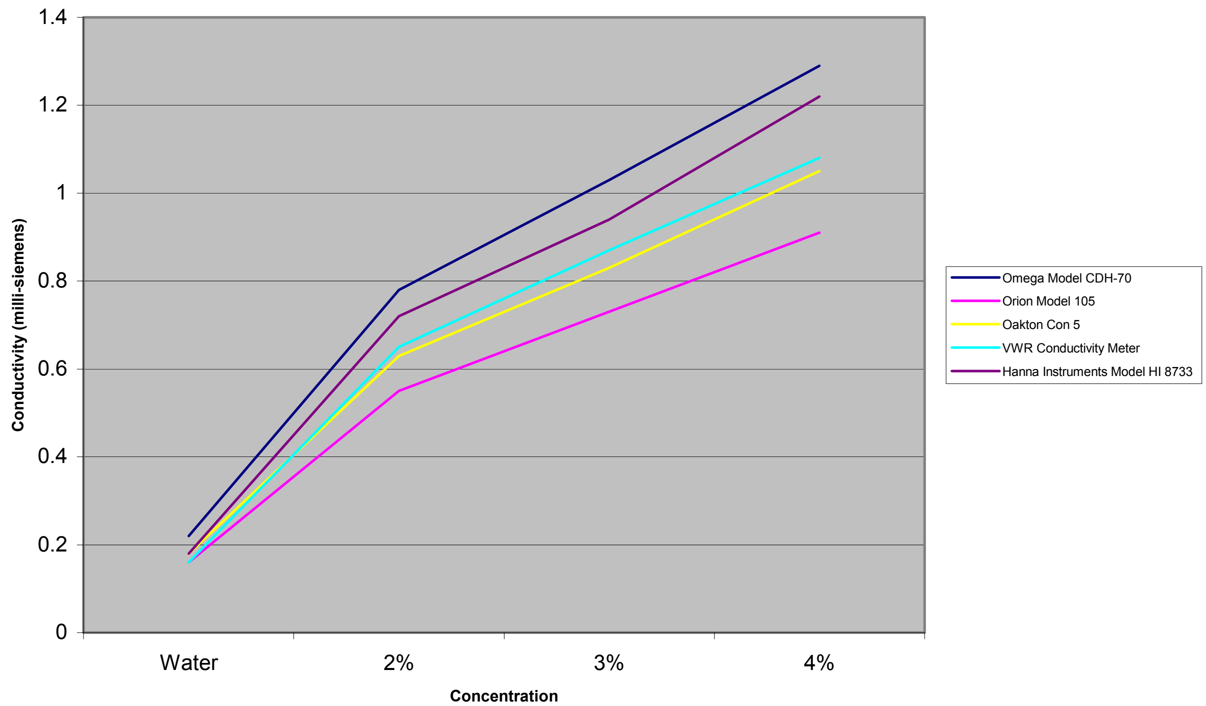


FIGURE 3. TRIMAX-40 ARCTIC AFFF, 3% CONCENTRATE

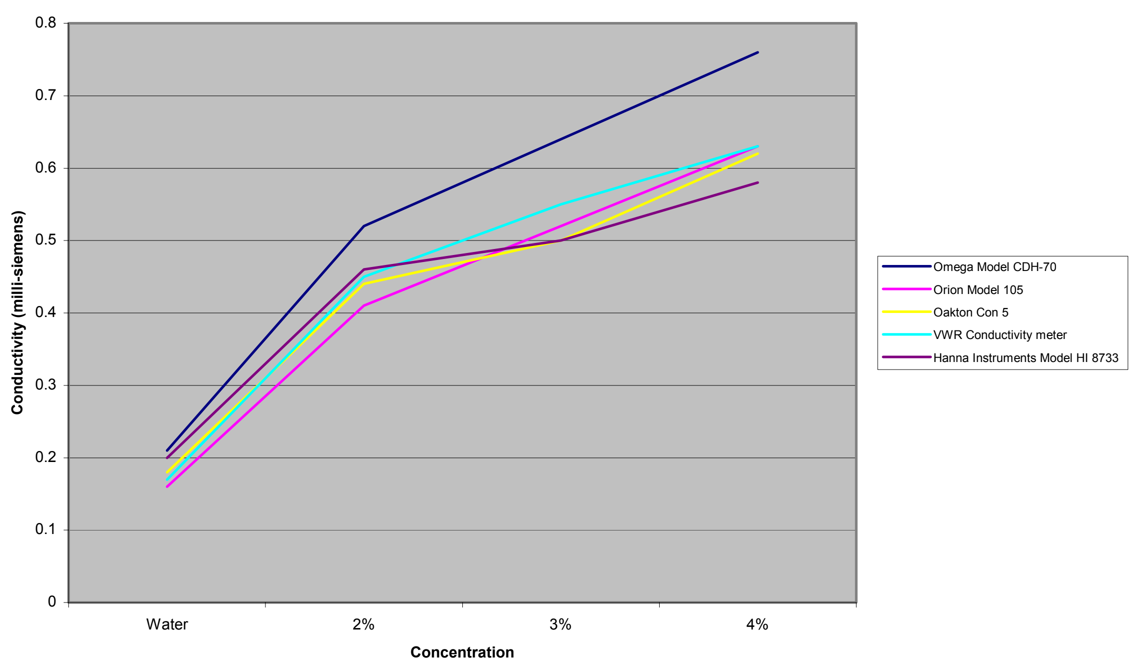


FIGURE 4. CHEMGUARD 3% - 6% ALCOHOL-RESISTANT AFFF, 3% CONCENTRATE

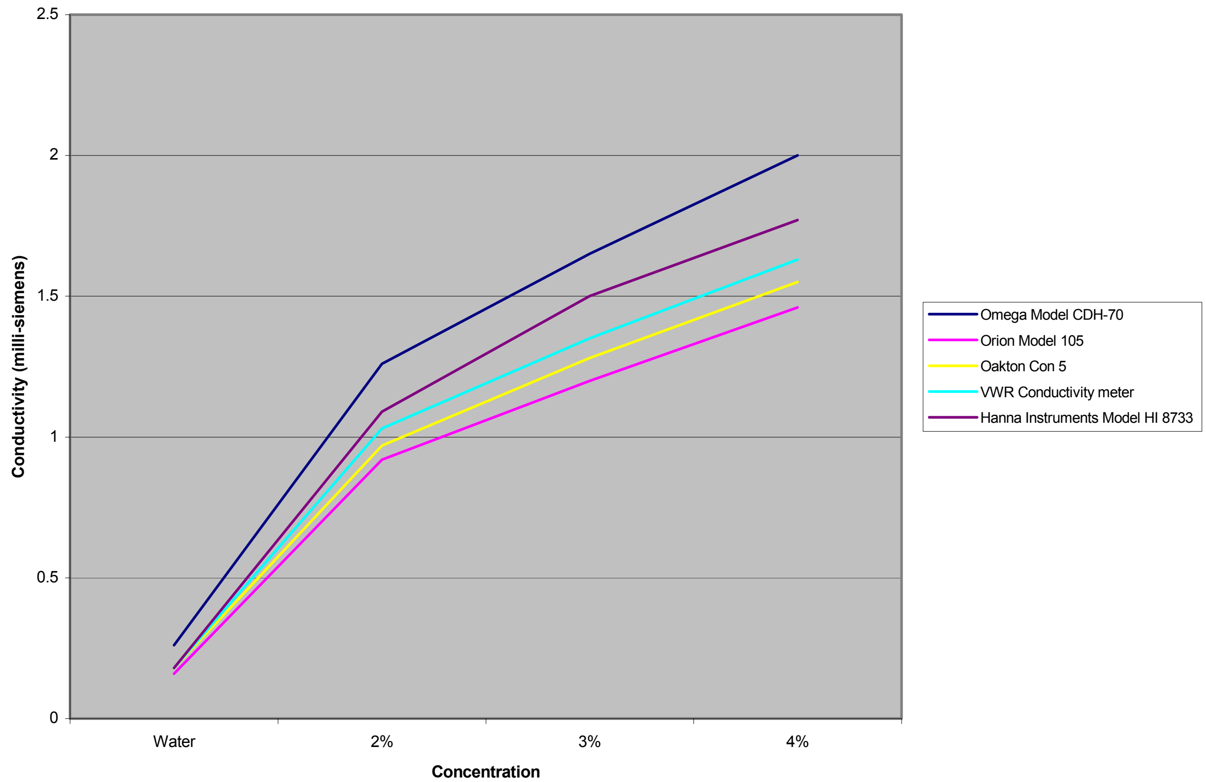


FIGURE 5. CHEMGUARD 3% MIL-SPEC AFFF

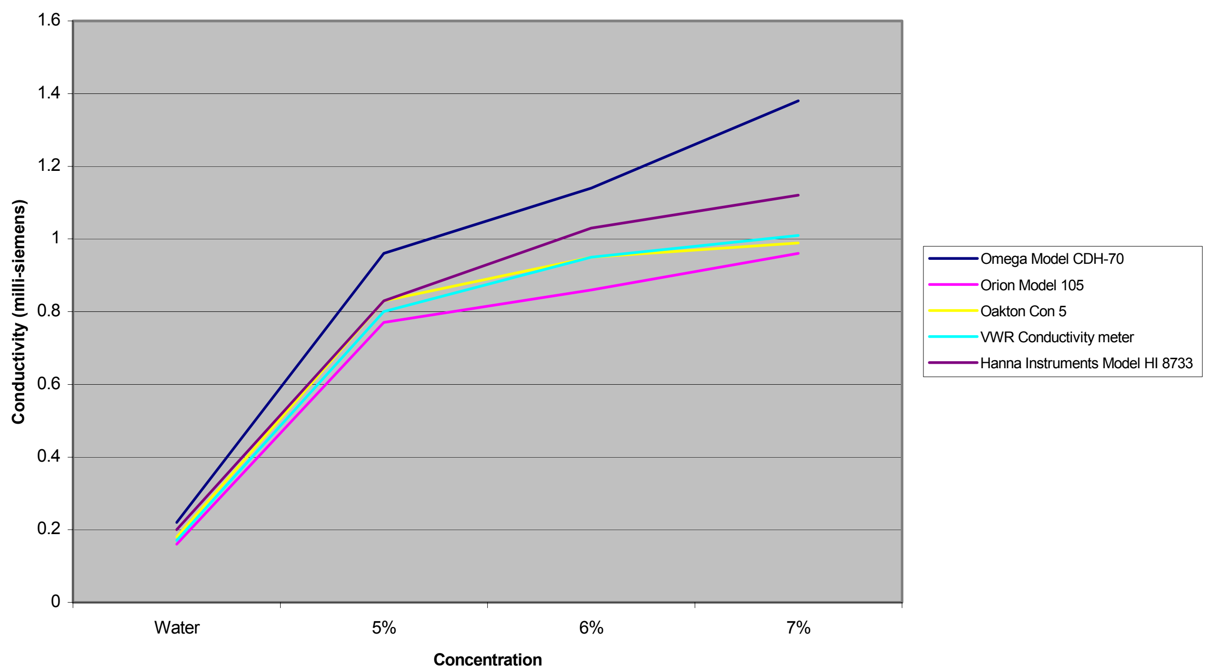


FIGURE 6. CHEMGUARD 3% - 6% ALCOHOL-RESISTANT AFFF, 6% CONCENTRATE

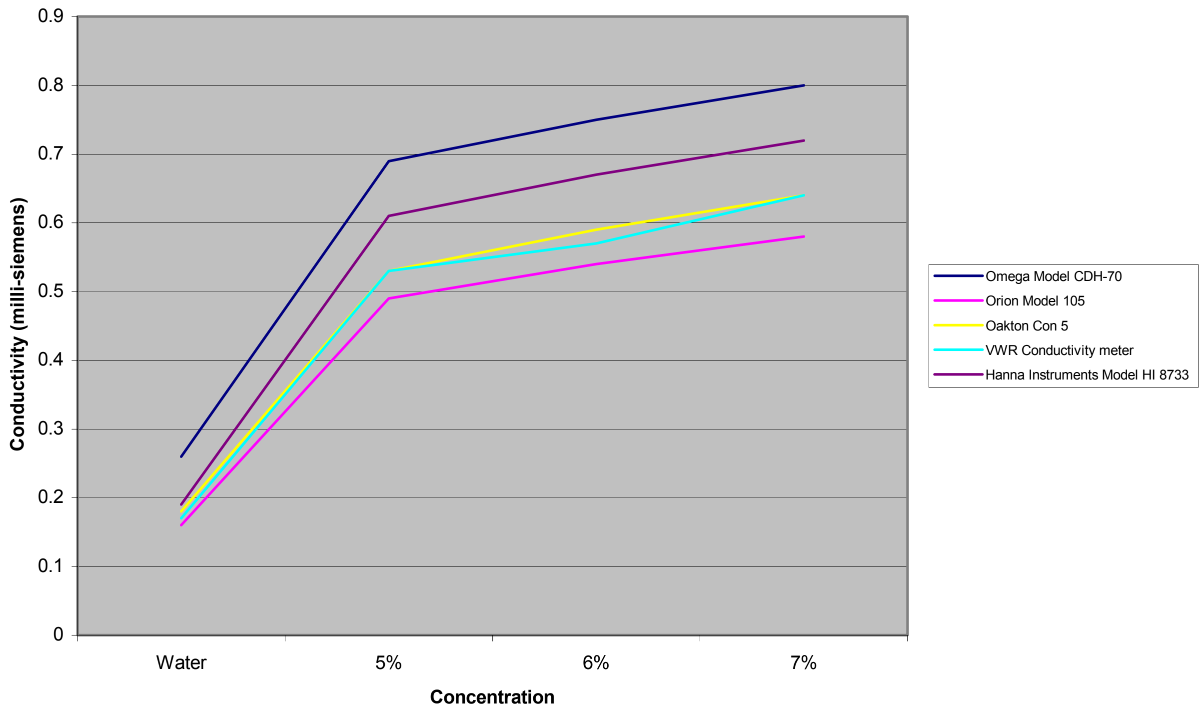


FIGURE 7. CHEMGUARD 6% AFFF

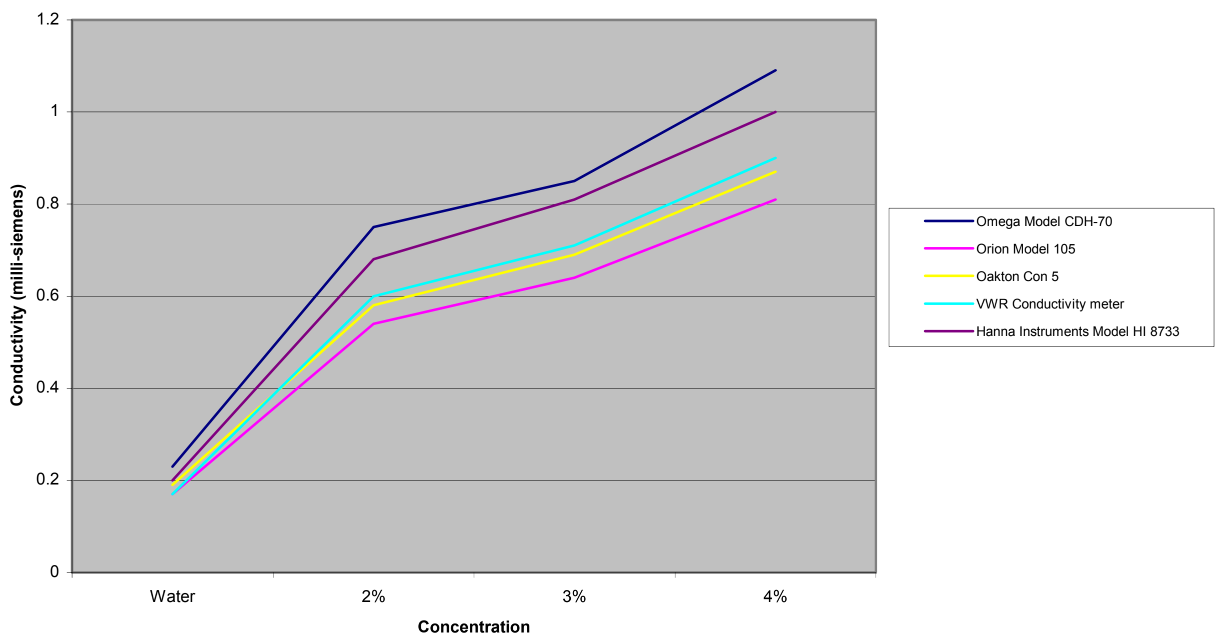


FIGURE 8. 3M LIGHTWATER AFFF, 3% CONCENTRATE

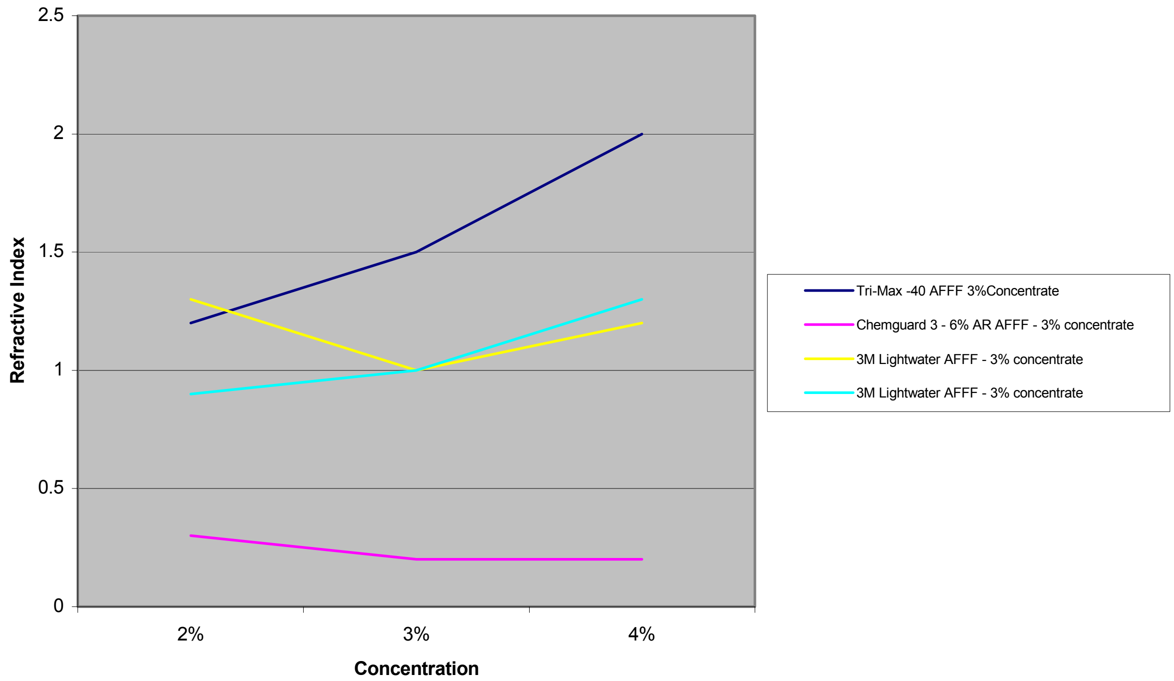


FIGURE 9. SAMPLE REFRACTOMETER READINGS, 3% CONCENTRATE

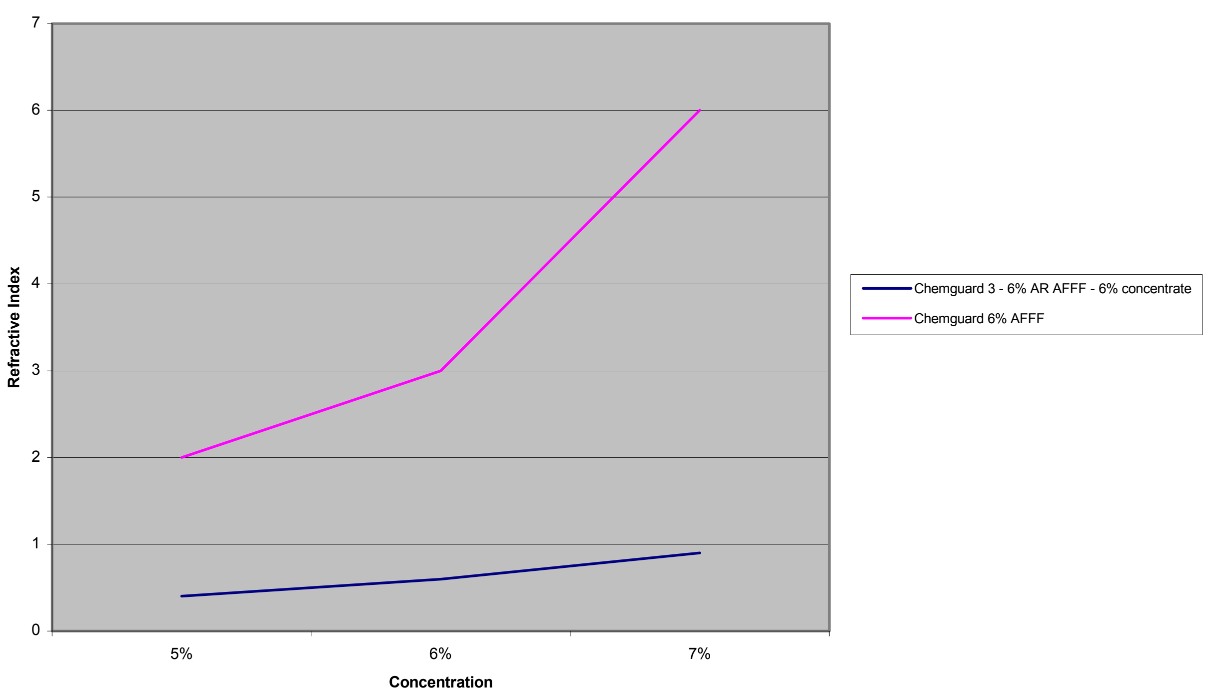


FIGURE 10. SAMPLE REFRACTOMETER READINGS, 6% CONCENTRATE

A significant factor in the use of the refractometer is the fact that the readings can be interpreted differently by several evaluators during the same test. The digital readings from the conductivity meters removed the interpretive errors and proved to have very good repeatability between tests.

When analyzing the data for this evaluation there were two concerns that applied to this type of test that must be addressed.

1. The actual data point value is insignificant to the actual test. What is most important to the testing of the foam-proportioning system is not the numerical value of the test, but that the slope of the data is consistent with the increase in foam concentration of the solution. When testing the foam solutions from 2- to 4-percent or 5- to 7-percent concentration, one should see an increase in the slope of the readings when plotted. There is a common misinterpretation that when taking a refractometer reading of a solution with 3-percent foam concentrate that the refractometer should read 3. This is not the case and indicates a misunderstanding of the use of the test devices.

2. When using a refractometer or conductivity meter as an inspection tool, it is important to understand that the values from the previous inspection must not be taken into consideration. There are many variables within the fire apparatus's water and foam tanks and the associated plumbing that could change the actual conductivity value from one inspection period to another. Therefore, the data obtained is only valid for that apparatus on that day.

When evaluating the various conductivity meters for usability and accuracy, it was determined that all five units were considered better tools for inspecting the foam-proportioning systems than refractometers.

There were some aspects of the various conductivity meters that made some meters slightly better than others. The accuracies of the conductivity meters can be greatly affected by variations between the temperature of the solution and conductivity probe. Care should be taken that conductivity measurements are made when the solution and conductivity probe are at the same temperature.

NFPA 412, Standard for Evaluating Aircraft Rescue and Firefighting Foam Equipment, recommends the Omega Model CDH-70. This unit is recommended over the other units because it automatically compensates for different temperatures. If other meters are used, the instructions for the conductivity meter calibration and temperature compensation should be carefully followed.

Most of the meters were easy to calibrate, except for the VWR unit. The VWR's calibration potentiometer is located in the battery compartment (requiring the removal of the battery) along with other potentiometers. Because of the close proximity of the potentiometers, it is possible to inadvertently adjust the wrong potentiometer during calibration, i.e., holding the adjustment tool on the potentiometer and viewing the liquid crystal display (LCD) display at the same time. The Omega CDH-70 maintained its calibration between tests, while the Oakton Con 5 did not maintain its calibration between tests.

Both the VWR and the Hanna Instruments Model HI 8733 had larger probes. The VWR probe displaced too much sample foam solution when small beakers were used for testing. The Hanna probe required a higher level (depth) of sample foam solution to ensure that all the sensors along the probe are within the solution.

CONCLUSIONS

The objective of this evaluation was to comparatively test several conductivity meters against the standard refractometer. The data from this evaluation will be used to update the current guidelines under FAA Order 5280.5B, Airport Certification Program Handbook, which currently requires refractometers for testing the foam-proportioning systems.

Five conductivity meters were evaluated against the standard refractometer. There were some variations to the operation and calibration of the conductivity meters that made some meters slightly better than others. It was determined, however, that all five conductivity meters were more accurate and easier to use for conducting field tests on foam-proportioning systems than the refractometer.

As was seen in figure 1, the conductivity meters are larger than the refractometer; however, they are still compact enough for inspectors to carry. The cost of the conductivity meters tested ranged from $200 to $350, making them affordable enough to outfit the inspectors within each region.

The Omega CDH-70 proved to be the easiest unit to operate and calibrate and was the most consistent throughout the evaluation. The VWR was an acceptable alternative to refractometer testing but was determined to be the least favorable unit among the evaluators.

NFPA 412, Standard for Evaluating Aircraft Rescue and Firefighting Foam Equipment, Appendix A, Explanatory Material, is a very good alternative source for information regarding the operation of foam-proportioning system testing using conductivity meters. Potential changes made to the FAA Order should reference this material.