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INTRODUCTION TO QUANTITATIVE MODELLING OF FIRE FIGHTING FOAM

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INTRODUCTION TO

FIRE FIGHTING FOAM

Foam consists of millions of different size air bubbles, surrounded by a mixture of water and surfactant. The United States Department of Agriculture - Forest Service recognizes five different types of foam, dependent on water, air, and surfactant concentration. The structure of the foam bubbles are either spherical (perfectly round) or polyhedral (many flat sides). Spherical bubbles are separated by thick walls of solution, while Polyhedral bubbles are separated by very thin walls of solution.

The solution is continuously draining through the foam, carrying the smaller bubbles to the bottom of the foam. Enough solution drains from around the top bubbles, leaving a thin wall of solution, that eventually breaks. The draining solution surrounds other bubbles lower in the foam. The bubbles themselves never change in size only their **solution** wall thickness around the bubble changes. Eventually the wall of solution becomes too thin to support the bubble and it breaks. This process continues until the solution is completely drained from the bubbles and the foam is gone.

The foam has certain measurable properties such as drainage rate, and electrical conductivity. We are able to quantify, with actual field measurements, the drainage rate of different foam types and the electrical conductivity of the solution in the foam over time. These measurements are important in characterizing the different foam types for more accurate equipment design and field personnel training. But the most important field measurement turned out to be the drainage of solution over two specific time periods, 30 minutes and 60 minutes.

GENERAL FOAM MODEL PER TIME

FOAM TYPE 5 (WET FOAM)

TYPICAL QUALITATIVE CHARACTERISTICS:

- Watery
- Very runny on vertical surfaces
- Bubble size varies from large to small
- More water than air
- No "body"

QUANTITATIVE CHARACTERISTICS:

TIME = 0 minutes

The bubbles of the "TYPE 5" foam are spherical and evenly dispersed throughout the solution. The bubbles are separated by a large amount of solution, relative to other foam types. The solution content is at a maximum with the ratio being 1 gallon solution to 8.8 gallons foam. The drainage rate and electrical conductivity are at a maximum.

TIME = 0 to 10 minutes

With gravity acting on the solution, the solution begins to drain. As the solution drains from the foam, the solution content of the foam changes from a "TYPE 5" to a "TYPE 4".

TIME = 10 to 30 minutes

The drainage rate and electrical conductivity decrease. The solution in the foam continues to drain at a medium rate and the solution content becomes a "TYPE 3". With the reduction in the amount of solution, the bubbles become closer packed.

TIME = 30 TO 60 minutes

The drainage rate and electrical conductivity continue to decrease until they reach their minimum. When this point is reached, the "TYPE 5" foam has the characteristics of a "TYPE 2" foam.

FOAM TYPES 4 AND 3 (MEDIUM FOAM)

TYPICAL QUALITATIVE CHARACTERISTICS:

TYPE 4

- Very wet
- Runny on vertical surfaces
- Medium large to small bubbles
- Has little "body"

TYPE 3

- Watery shaving cream
- Does not hold peaks
- Immediately runs on vertical surfaces
- Medium to small bubbles

QUANTITATIVE CHARACTERISTICS:

TIME = 0 minutes

The bubbles of "TYPE 4 AND 3" foams are still spherical, the bubble walls are not touching. With the bubble wall thickness moderate the electrical conductivity is great, due to the large amount of solution and the great number of paths around the bubbles in the foam. The solution content is medium with the ratio being 1 gallon solution to 11 gallons foam for "TYPE 4" and 1 gallon solution to 14.6 gallons foam for "TYPE 3". The drainage rate and electrical conductivity are high.

TIME = 0 to 20 minutes

With gravity acting on the solution, the solution begins to drain. As the solution drains from between the bubbles, the solution content of the foam changes from "TYPE 4" to "TYPE 3".

TIME = 20 to 35 minutes

The drainage rate and electrical conductivity have decrease to a minimum. The solution in the foam continues to drain at a slow rate and the solution content becomes "TYPE 2". With the reduction in the amount of solution, the bubbles become closer packed and start to become polyhedral in shape.

TIME = 35 to 60 minutes

The drainage rate and electrical conductivity continue at a minimum. At this point "TYPE 4 AND 3" foams have the characteristics of "TYPE 2" foam.

FOAM TYPES 2 AND 1 (DRY FOAM)

TYPICAL QUALITATIVE CHARACTERISTICS:

TYPE 2

- Shaving or whipped cream
- Holds peaks
- Does not run immediately on vertical surfaces
- Medium small to small bubbles

TYPE 1

- Mostly air
- Very "dry" and fluffy
- Blows away in wind
- Clings to vertical surfaces
- Holds peaks for a long time
- Small bubbles

QUANTITATIVE CHARACTERISTICS:

TIME = 0 minutes

The bubbles of "TYPE 2 AND 1" foams are no longer spherical. The bubbles are now polyhedral in shape. Bubble walls are very thin due to the small amounts of solution between the bubbles. The solution content is at a minimum with the ratio being 1 gallon solution to 22 gallons foam for "TYPE 2" and 1 gallon solution to 44 gallons foam for "TYPE 1". The drainage rate is minimum but the electrical conductivity is moderate.

TIME = 0 to 30 minutes

With gravity acting on the solution, the very small amount of solution begins to drain. As the solution drains from the top of the foam, the solution content of the foam changes from "TYPE 2" to "TYPE 1". The bubbles remain in the polyhedral shape. Because the bubble size is so small, very thin walls of solution can still contain the air inside, thus breaking of "TYPE 1" bubbles occurs very slowly, compared to any other foam "TYPE".

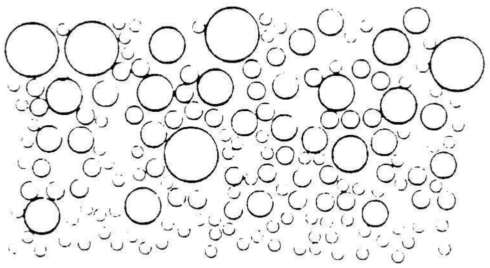
TIME = 30 to 60 minutes

The drainage rate decreases to a minimum but the electrical conductivity remains fairly constant. The solution in the foam continues to drain at an extremely slow rate in fact the solution content becomes so low that the solution stops draining.

DRAINAGE RATE MODEL

TYPE 5

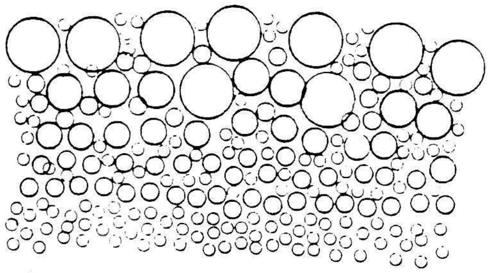
TIME = 0 to 30 minutes



The drainage rate is fast (initially 1.7 gallons/minute). This is due to the great amount of solution in the foam, and the large space between the bubbles which allows the solution to drain. (see FIGURE 1)

FIGURE 1

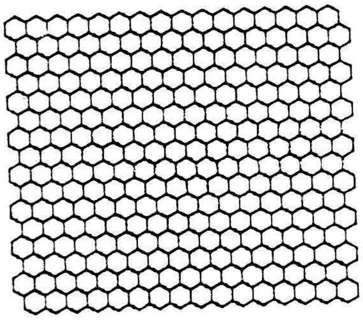
TIME = 30 to 60 minutes



The drainage rate is low (initially 0.15 gal/minute). This is due to the smaller amount of solution in the foam, and a greater concentration of smaller bubbles left in the foam. The bubbles are polyhedral in shape which allows much less solution to drain. (see FIGURE 2)

FIGURE 2

TIME = 60 minutes to 24 hours



The drainage has stopped. This is due to the very small amount of solution left in the foam. The foam consists of very small bubbles with very thin walls of solution. (see FIGURE 3)

FIGURE 3

DRAINAGE RATE

TYPE 4 AND 3

TIME = 0 to 30 minutes

The drainage is moderate (initially 0.4 gallon/minutes). This is due to the amount of solution surrounding a lot of medium sized bubbles that dominate the foam. The bubbles are just beginning to touch, due to the reduction in the amount of solution in the foam. (see FIGURE 4)

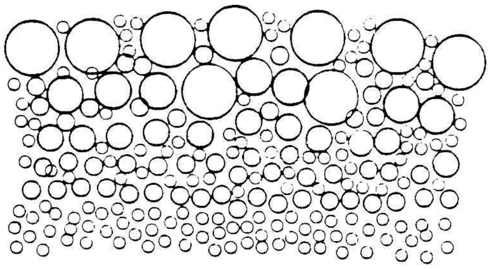


FIGURE 4

TIME = 30 to 60 minutes

The drainage rate is slow (initially 0.02 gallon/ minutes). This is due to the very small amount of solution in the foam. The bubbles are polyhedral in shape which allows much less solution to drain. (see FIGURE 5)

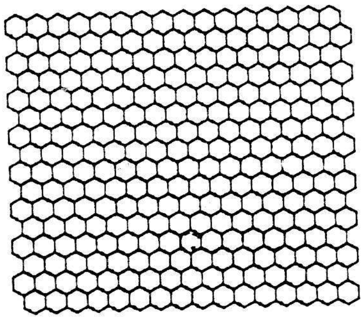


FIGURE 5

TIME = 60 minutes to 24 hours

The drainage has stopped. This is due to the very small amount of solution left in the foam. The foam consists of very small bubbles with very thin walls of solution. (see FIGURE 5)

DRAINAGE RATE MODEL

TYPE 2 AND 1

TIME = 0 to 30 minutes

The drainage rate is low (initially 0.05 gallons/minutes). This is due to the small amount of solution in the foam. The bubbles are polyhedral in shape, allowing small amounts of solution to drain. (see FIGURE 6)

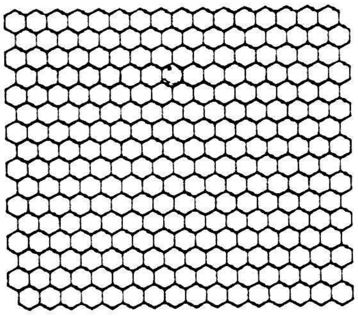


FIGURE 6

TIME = 30 to 60 minutes

The drainage rate is very low (initially .01 gallons/minute). This is due to the small amount of solution in the foam, and the polyhedral shape of the small bubbles. (see FIGURE 6)

TIME = 60 minutes to 24 hours

The drainage has stopped. This is due to the very small amount of solution left in the foam. The foam consists of very small bubbles with very thin walls of solution. (see FIGURE 6)

ELECTRICAL CONDUCTIVITY MODEL

TYPE 5

TIME = 0 to 30 minutes

Conductivity is relatively high (about 17x10-6 mhos) because of the large amount of conductive solution between the bubbles. The solution itself is the path for conductivity. The relatively large amount of big bubbles in a type five foam, causes fewer conductive paths which decreases the initial conductivity, but only slightly. (see FIGURE 7)

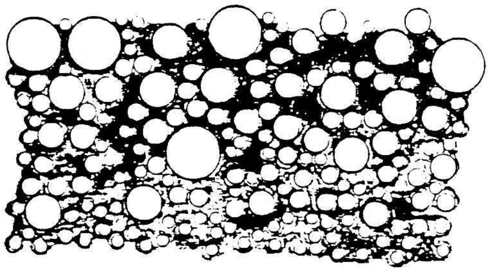


FIGURE 7

TIME = 30 to 60 minutes

Conductivity is low (about 1x10-6 mohs), because the solution has drained separating the bubbles into three layers. The big bubbles at the top, medium bubbles in the middle and small bubbles at the bottom. There are more conductive paths in the middle of the foam at this time, but the paths are thin. (see FIGURE 8) The conductivity stabilizes at this time.

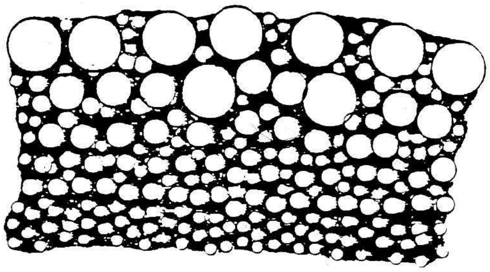


FIGURE 8

TIME = 60 minutes to 24 hours

Conductivity remains low (about 1x10-6 mhos), because 99% of the solution has drained, and the conductive paths are fewer and very thin. (see FIGURE 9)

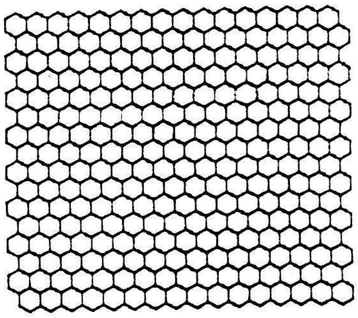


FIGURE 9

ELECTRICAL CONDUCTIVITY MODEL

TYPE 4 AND 3

TIME = 0 to 30 minutes

The conductivity is high (about 20x10-6 mhos) because of the large amount of conductive solution between the medium sized and small bubbles. (see FIGURE 10)

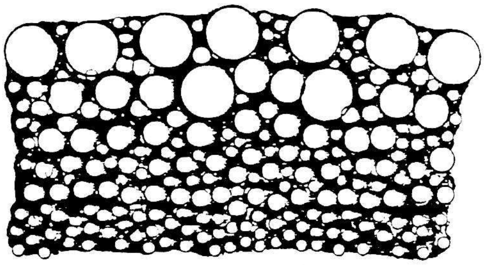


FIGURE 10

TIME = 30 to 60 minutes

The conductivity is low (about 1.7x10-6 mhos) because the solution has drained, separating the bubbles into two layers. The medium bubbles at the top and the small bubbles at the bottom of the foam. The conductive paths are many but very thin. The conductivity stabilizes at the end of this time interval. (see FIGURE 11)

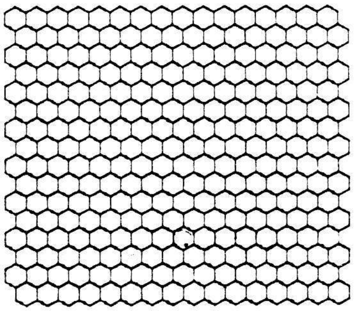


FIGURE 11

TIME = 60 minutes to 24 hours

Conductivity remains low (about 1.7x10-6 mhos), because 99% of the solution has drained, and the conductive paths are fewer and very thin. (see FIGURE 11)

ELECTRICAL CONDUCTIVITY MODEL

TYPE 2 AND 1

TIME = 0 to 30 minutes

Conductivity is moderate (about 8.3x10-6 mhos) because of the tremendous number of conductive paths available, even though each is very thin. The bubbles are polyhedral in shape and the walls of the small bubbles are touching each other. (see FIGURE 12)

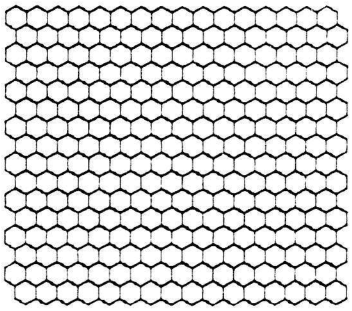


FIGURE 12

TIME = 30 minutes to 24 hours

Conductivity is moderate (about 6x10-6 mhos) and most of the excess solution has drained from between the bubbles. The small bubbles are very stable, with very thin walls of solution able to maintain the polyhedral bubble shape for long periods of time.
(see FIGURE 12)

FOAM TO SOLUTION RATIO

TYPE 5

TIME = 0 TO 30 minutes

The ratio of the volumes of foam to solution is between 1 and 9.3 which is low, because of the large amount of solution present in the foam. The different size bubbles are mostly spherical and they are separated by large amounts of solution. By the end of this time period most of the solution has drained from the foam.

TIME = 1 TO 24 HOURS

The ratio of the volumes of foam to solution has stabilized between 1 and 8.8, because of the completeness of the draining process after one hour.

TYPE 4

TIME = 0 TO 30 minutes

The ratio of the volumes of foam to solution is between 9.3 and 12. This is because the foam had a moderate amount of solution to begin with and most of it has drained from between the medium sized spherical bubbles, during this time period.

TIME = 1 TO 24 hours

The ratio of ;the volumes of foam to solution has stabilized between 8.8 and 11, because of the completeness of the draining process after one hour.

FOAM TO SOLUTION RATIO

TYPE 3

TIME = 0 TO 30 minutes

The ratio of the volumes of foam to solution is between 12 and 16.5. This is because the foam had a moderate amount of solution to begin with and most of it has drained from between the medium sized spherical bubbles, during this time period.

TIME = 1 TO 24 hours

The ratio of the volumes of foam to solution has stabilized between 11 and 14.6, because of the completeness of the draining process after one hour.

TYPE 2

TIME = 0 TO 30 minutes

The ratio of the volumes of foam to solution is between 16.5 and 23.5 which is high, because of the smaller amount of solution present in the initial foam. The foam has a majority of small polyhedral shaped bubbles that are separated by thin walls of solution.

TIME = 1 TO 24 hours

The ratio of the volumes of foam to solution has continues to be stable between 14.6 and 22, because of the structure of the small polyhedral bubbles.

FOAM TO SOLUTION RATIO

TYPE 1

TIME = 0 TO 30 minutes

The ratio of the volumes of foam to solution is between 23.5 and 44, which is the highest ratio yet. The foam is very stable from the beginning, with very small polyhedral bubbles holding the very thin walls of solution into the foam.

TIME = 1 TO 24 hours

The ratio of the volumes of foam to solution remains stable between 22 and 44, because of the completeness of the draining process.

CONCLUSION:

FIRE FIGHTING FOAM

DRAINAGE RATE

The drainage rate as a field measurement required very fine graduations of the volume scale. The volume scale accuracy is only a half gallon. The drainage rate also failed to identify TYPE 4 from TYPE 3 and TYPE 2 from TYPE 1. This is not adequate with the desire to identify each **"TYPE"** of foam available.

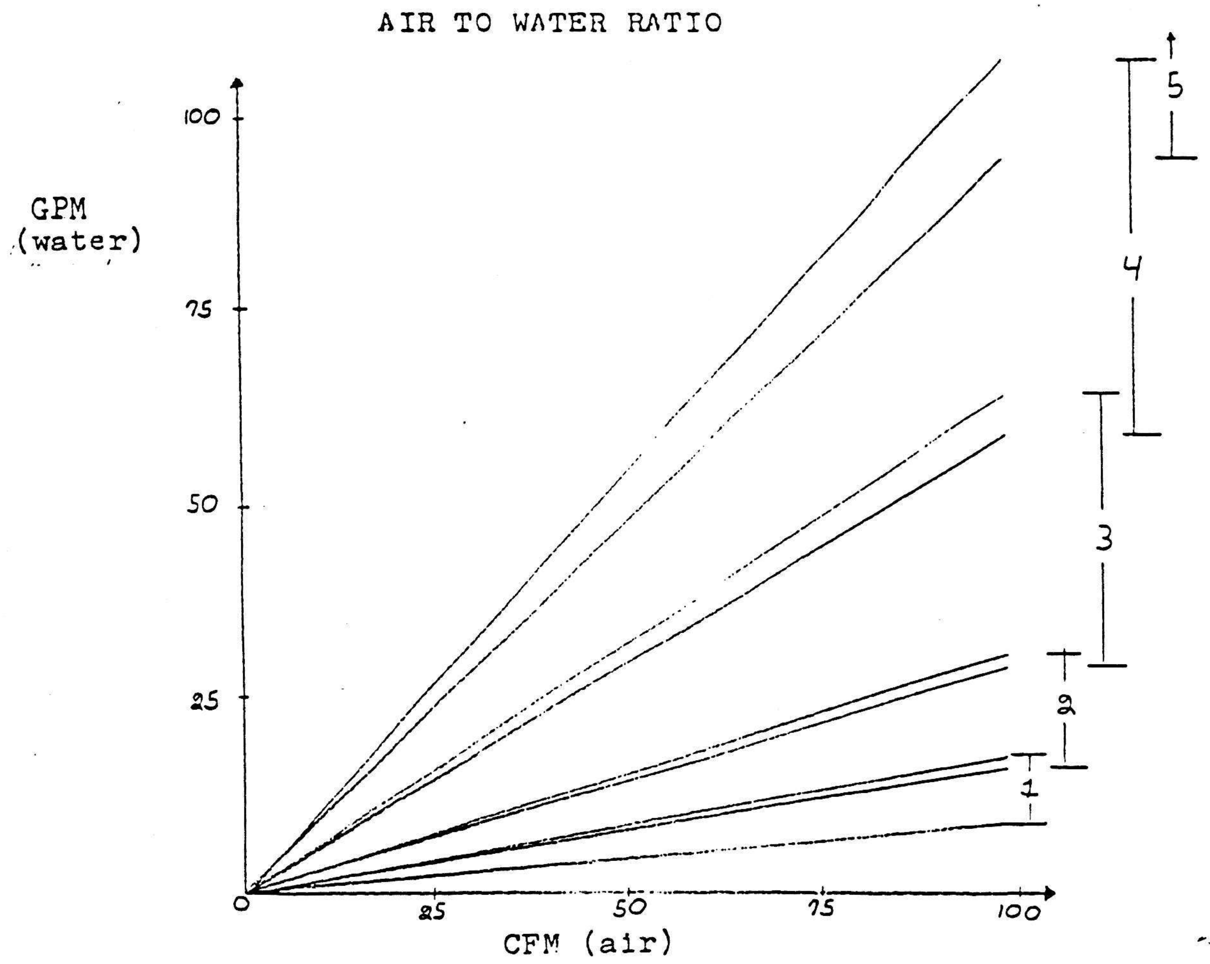
ELECTRICAL CONDUCTIVITY

The conductivity as a field measurement failed to identify TYPE 4 from TYPE 3 and TYPE 2 from TYPE 1. The conductivity is changed rapidly by wind. The temperature also effects the electrical conductivity of each type, requiring tests to be performed in the field always at the same temperature. This would be to restrictive for field training purposes.

FOAM TO SOLUTION

As a result of field tests on the fire fighting foam, it was found that solution drainage during a specified time is the most repeatable field measurement. The **FIREFIGHTING FOAM (F F) ANALYZER** is based on this technique, rather than the valve settings of the foam generating equipment, as previously taught (see FIGURE 13).

NOTE: The previous was a summary of the field research conducted by **C.I.L. INSTITUTE** during the summer of 1988 that led to the development of the **F F ANALYZER** by **IMAGINEERING.**


AIR TO WATER RATIO
100
75
50
25
GPM
(water)
0
25
50
75
100
CFM (air)
5
4
3
2
1

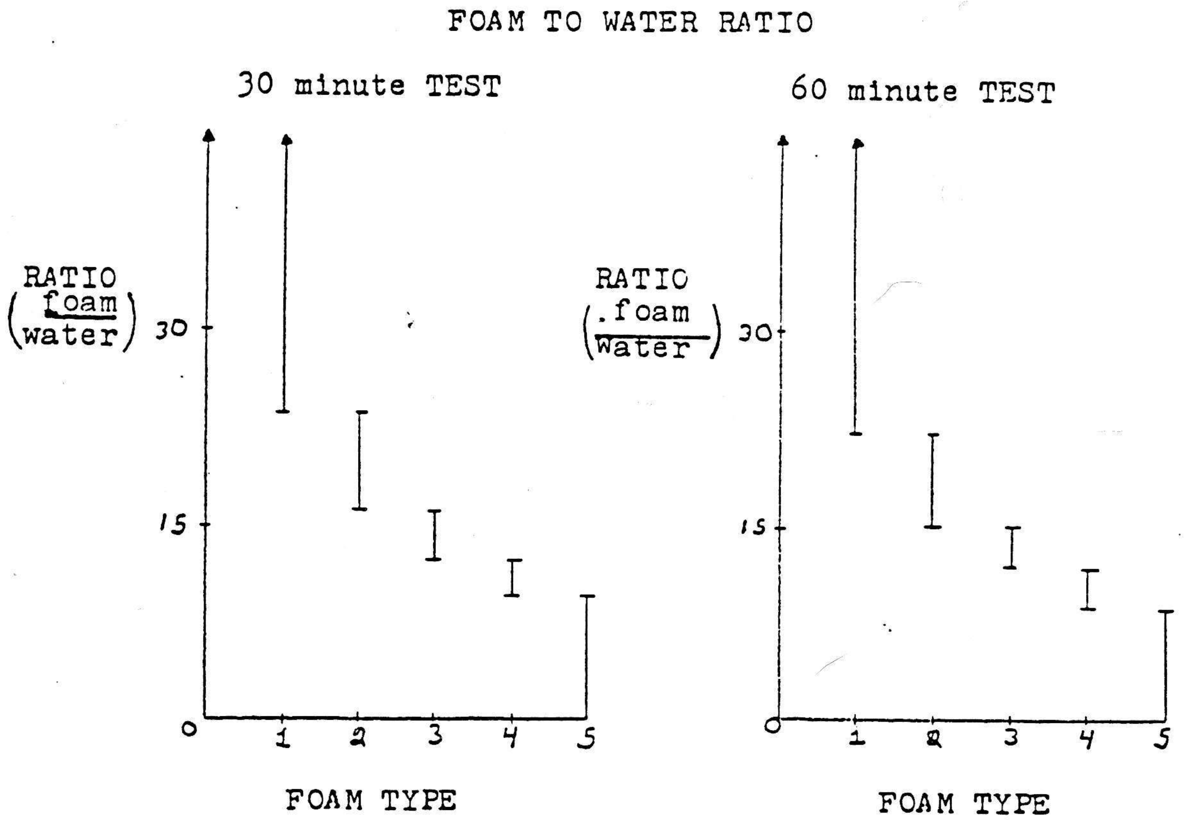

FOAM TO WATER RATIO
30 minute TEST
60 minute TEST
RATIO
(foam/water)
30
15
0
1
2
3
4
5
FOAM TYPE
RATIO
(foam/water)
30
15
0
1
2
3
4
5
FOAM TYPE

FIGURE 13

APPENDIX A

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