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SMALL-SCALE FIRE EXTINGUISHMENT TEST ON MECHANICAL FOAM

PART I

by

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PREFACE

Foam is one of the more important fire extinguishing agents and is used extensively on flammable liquid fires. It is necessary to be able to define and to measure the suitability of a given foam for a given application. Until such time as it becomes possible to predict foam properties from measured physical properties it is necessary to rely, as at present, upon performance-type tests employing standard fires set in tanks containing a flammable liquid. Preliminary studies, which it is hoped will lead to the development of an improved fire tank test for mechanical foam, are now reported. The author, a chemical engineer and a research officer in the Fire Research Section of the Division, is engaged in studies of various aspects of fire extinguishment.

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June 1961

N. B. Hutcheon,
Assistant Director.

SMALL-SCALE FIRE EXTINGUISHMENT TEST ON MECHANICAL FOAM

PART I

by

K. Sumi

The Fire Section of the Division of Building Research, National Research Council, has been assisting the Royal Canadian Air Force for several years with tests on foam-generating equipment installed in their crash trucks. This work, and associated experience, indicated a need for a better method for evaluation of foam, and it was decided to conduct studies directed toward the development of a fire extinguishment test suitable for assessing the performance potential of foam.

One of the most widely used of the extinguishment tests for foam available at present is the fire test described in JFMC Specification No. 260.00 (which was adopted from JAN-C-266 of the United States) (1, 2). This "go-no go" test for foam liquid is considered unsuitable for assessing the potential extinguishing effectiveness of foam because the characteristics of foam cannot be varied (in this test). In practice there is considerable variation in the characteristics of foam, with the result that there is a need for a method to assess the performance potential of foam over a wide range of characteristics.

It was the purpose of the present investigation to carry out studies towards development of a small-scale fire extinguishment test, in contrast to the large 10- by 10-ft fire test used in the JFMC specification. A small-scale fire test which could be conducted in a laboratory on a year-round basis would not only be useful for research investigations but could also be considered either as a replacement or as an alternative for the fire test of JFMC Specification No. 260.00 if it proved to be suitable.

The present report deals with studies to determine suitable experimental conditions for extinguishment of 2- by 2-ft flammable liquid fires.

FIRE TEST IN JFMC SPECIFICATION NO. 260.00

The fire test is one of the most important tests described in JFMC Specification No. 260.00. Briefly, the test procedure is as follows:

A minimum of 150 gal* of gasoline is floated on 200 gal of water in a fire tank 10 by 10 by 3 ft deep. After a pre-burn period of 60 sec, foam is discharged through a standard nozzle at 5 gal per minute supplied with water at a pressure of 100 psi. The foam stream is directed from a position just above the side of the tank across the fire in order to strike the approximate centre of the opposite tank wall at right angles. Foam is applied for 5 minutes. Visual observations are recorded during the test.

The fire test has served a useful purpose over a number of years by making possible the identification of poor quality in foam liquid. It appears suitable for differentiating between good and bad quality foam liquid. Its weakness, however, appears to exist in the classification of foam liquids that fall between the two extremes. The criteria for failure of a sample of foam liquid are based largely on visual observation and place a great deal of responsibility on observers. Some of the requirements given in the specification are:

1. The foam shall spread over the tank in not more than 2 min.

2. The fire shall be controlled, i.e., extinguished except for licks of flame at the edges of the foam blanket, in not more than 4 min.

3. The fire shall be completely extinguished in not more than 5 min.

4. The foam shall not spread along in slip planes over the gasoline surface.

5. The foam shall protect the gasoline from re-ignition by a lighted torch for a period of not less than 15 min.

Experience was gained in applying these criteria in the course of a number of fire tests, carried out in accordance with JFMC Specification No. 260.00, on a foam liquid which had met the requirements of the specification. The foam appeared to satisfy the first two requirements without difficulty, although the actual times recorded for coverage and control, particularly the latter, are at the discretion of the observer. In most cases the requirement

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* Imperial gallons are used in this report.

for complete extinguishment was not satisfied. It may be questioned whether this requirement is a reasonable criterion for failing a sample, because flickers of flame may remain at the corners or edges of the tank even though the fire has been controlled for some time. Foam did spread along in slip planes but only to a very limited degree. Interpretation of this requirement is also at the discretion of the observer. The foam did not give protection against re-ignition at the corners and edges of the tank where flickers of flame had to be extinguished after foam application had terminated. These experiences illustrate the difficulties arising from reliance upon visual observation and observer's judgment in determining test criteria.

The use of a fire tank 10 by 10 by 3 ft deep raises further problems. Because of the relatively large size of the tank, tests are usually conducted outdoors where changes in both speed and direction of wind may affect the results. A foam liquid which could meet the requirements under ideal weather conditions might fail because of the influence of wind. A further disadvantage of such a large test is the expense incurred. Capital expense will, of course, be high, but in addition a minimum of 150 gal of gasoline is required for each test.

The fire test is not intended for evaluating relative quality of foam liquid nor for assessing the potential extinguishing ability of a foam of given characteristics. Its use as a research tool is therefore very limited.

PRESENT INVESTIGATION

It was decided to retain the performance aspects of the 10- by 10-ft fire test, but to attempt to scale it down in order to overcome several of the problems inherent in the use of a large tank. A tank size of 2 by 2 ft which is small enough to permit testing in a laboratory, was selected for detailed investigation.

The standard nozzle used in the large fire test produces foam with one set of characteristics. In order to vary the parameters of foam characteristics it was decided to use a laboratory foam generator capable of producing foam over wide ranges of expansion ratio, 25 per cent drainage time and solution rate of application with respect to the size of the fire. Expansion ratio is the ratio of final foam volume to the original foam solution volume. The 25 per cent drainage time is the time at which 25 per cent of foam solution may be drained from a sample of foam in a standard foam container (3), and is an index of the degree of stability and fluidity of the foam. The influence of variation in these factors upon extinguishment was determined.

In an attempt to find a more objective end-point for the test, it was decided to use a radiometer to assess progress of extinguishment, thus eliminating inconsistencies resulting from visual observation and dependence upon observer's judgment. It was decided also to use "control" time, as determined by the use of a radiometer, rather than "extinguishment" time as the end-point for the phase of the investigation now reported.

EXPERIMENTAL DETAILS

Apparatus

1. Foam Generator

An adjustable foam generator capable of producing foam over wide ranges of expansion and fluidity at different rates of flow was constructed; its design is similar to that used by Tuve and Peterson (4).

A pre-mixed foam solution is pumped through a flowmeter into the foam mixing chamber of the generator and compressed air is fed through another flowmeter into the same mixing chamber. The flow rates of the two fluids and the input pressures are controlled by appropriate valves to give the desired rates of discharge, from which expansion ratio of the foam can also be determined. The mixing chamber pressure can be varied to control the fluidity of foam by the use of interchangeable orifices at the inlet and outlet of the mixing chamber and with interchangeable perforated discs at right angles to the direction of flow in the mixing chamber. The foam produced in the mixing chamber passes through a $\frac{1}{2}$-in. diameter rubber hose and discharges through interchangeable nozzles.

The size of nozzle to be used for a particular fire extinguishment test was selected, in general, on the basis of the largest nozzle which would project a solid stream of foam to the opposite side of the tank. It was sometimes necessary to use a smaller nozzle to avoid appreciable fluctuations during the initial stages of foam application.

2. Fire Tank

The fire tank, 2 by 2 by 1 ft deep, was constructed of steel.

3. Fuel

The fuel used was commercial grade heptane. It was considered that it had certain advantages over the gasoline used in the fire test described in JFMC Specification No. 260.00. It has a much narrower distillation range than gasoline and is believed to provide more reproducible conditions, particularly when the unburnt fuel of one test is used together with fresh fuel for a succeeding test. In addition, the properties of gasoline are known to vary seasonally and with the producer and point of origin (5).

4. Radiometer

Radiation from a fire was measured by means of a gold disc radiometer (6) connected to a millivolt recorder. The radiometer was placed 6 ft from one side of the tank at an elevation of 2 ft above the top of the tank.

5. Twenty-five Per Cent Drainage Time

The 25 per cent drainage time was used as a measure of the fluidity of foam, determined according to the method developed by Tuve and Peterson (3, 4). This test is easy to perform and requires very simple apparatus. The expansion ratio of foam was also determined using the 1400-ml pan for the drainage tests, but the use of this method was confined to checking the values obtained from the flowmeter readings for air and for foam solution.

Method

Four gallons of heptane, the volume equivalent of a 2-in. layer in the 2-by 2-ft fire tank floated on 2 in. of water, was used as fuel. After a pre-burn period of 60 sec, foam produced by the generator was discharged through a nozzle from a position directly above the mid-point of one wall of the tank and directed across the fire to strike the opposite side about 4 in. above the fuel surface.

"Control time", defined as the time after foam application at which the radiation intensity from the fire was decreased to 10 per cent of the maximum value reached during the pre-burn period, was determined for each test.

A protein base foam liquid, which had met the requirements of JFMC Specification No. 260.00, was used at a 6 per cent by volume concentration. The tests were conducted at expansion ratios of 6, 8, 10, 12, 14, 16 and 18, solution rates of discharge of 7, 8, 10, 14 and 18 gal/hour (0.029, 0.033, 0.042, 0.058 and 0.075 gal/min/sq ft of fuel surface) and 25 per cent drainage times ranging from 0.5 to 20 min.

RESULTS AND DISCUSSION

The adoption of control time as a test end-point had two distinct advantages: it permitted the use of a radiometer, thus providing an objective measure of the end of the test; control time was reached much before complete extinguishment so that there was a great saving in time and materials. Its use was considered justified in these tests, since no fully acceptable reasons could be found to support the use of complete extinguishment in a square tank as a good measure of foam quality. As it is entirely possible that different properties may be involved depending on the end-point used, it will be necessary to carry out further investigations to determine the relationship. All results reported for this series of tests are based on "control" time as defined.

"Control" time varied appreciably when the rate of application of foam was low. This behaviour is not surprising for rates of flow just above the "critical rate of application", because any interference such as a slight draught could increase the control time significantly. For the worst conditions, e.g., at low expansion ratios of 6 and 8 and at a low rate of application of 0.029 gal/min/sq ft of fuel surface, the results had to be discarded because of excessive scatter and consequent unreliability.

The experimental results were plotted on graphs of control time as a function of 25 per cent drainage time at expansion ratios of 6, 8, 10, 12, 14, 16 and 18 and solution rates of application of about 0.029, 0.033, 0.042, 0.058 and 0.075 gal/min/sq ft. Drainage times ranging from 0.5 to 20 min were examined. The range of drainage time values obtainable is, however, limited by the design of the foam producing equipment. At low expansion ratios and low solution rates of application the limit occurs in producing foam of high drainage times, while at high expansion ratios and high solution rates the limit occurs in producing foam of low drainage times. Some extrapolation of the curves was carried out when the trends were clear, into these regions for which foam of desired characteristics could not be produced.

The graphs were used as a basis for plotting the six graphs included in this report (Fig. 1 to 6). The quantity of solution required to control fire, as one of the coordinates of each of these graphs, is the criterion for assessing the effectiveness of fire suppression. Portions of the curves obtained by extrapolation are shown dashed.

Observations made from the six graphs are given below.

Figure 1:

Solution rate of application of foam of 0.058 gal/min/sq ft was more effective than any of the other solution rates investigated at any drainage time between 2 and 20 min with foam having an expansion ratio of 12. The difference in effectiveness of varying the solution rates from 0.030 to 0.075 gal/min/sq ft was very small for drainage times of foam between 2 and 5 min. This difference, however, increased appreciably with increase in drainage time from 5 to 20 min, particularly at low solution rates.

The influence of changes in drainage time on the quantity of foam solution required to control the fire was at a minimum for a solution rate of 0.058 gal/min/sq ft. The influence of changes in drainage time was small for drainage times between 2 and 5 min, but increased at higher drainage times.

Figure 2:

Optimum expansion ratio of foam having a 25 per cent drainage time of 4 min depended on the solution rate of application. The optimum value was very distinct at low solution rates of 0.030 and 0.033 gal/min/sq ft. The quantity of solution required to control fire above an expansion ratio of 12 varied very little at higher solution rates of application. In general, the optimum expansion ratio appears to be about 12 or 14.

Figure 3:

Foams with expansion ratios of 12 and 14 were more effective than those with expansion ratio of 10 at constant solution rate of application of 0.058 gal/min/sq ft. Foams of high expansion ratios of 16 and 18 obtainable were limited to those with high apparent viscosity. As the curves for these two expansion ratios were based largely on extrapolation, they cannot be given much weight.

The influence of changes in 25 per cent drainage time on quantity of solution required was small for expansion ratios of 10, 12 and 14, but was much greater for the lower expansion ratios of 6 and 8.

Figure 4:

The order of decreasing effectiveness of foam having a 25 per cent drainage time of 4 min based on expansion ratio was: expansion 12, 14, 10, 8, 6. Again, expansion ratios of 16 and 18 were not considered in the comparison because a greater portion of curves at these expansion ratios were plotted by extrapolation.

The influence of changes in solution rate of application on the quantity of foam solution required was smallest when the expansion ratio of foam was 12.

Figure 5:

The influence of changes in solution rate of application on the quantity of solution required was smaller for foam with drainage times of 2 and 4 min than for foam with drainage times of 10 and 20 min.

Figure 6:

The difference in effectiveness was small between drainage times of 2 and 4 min for foams with expansion ratios of 10, 12 and 14. The influence of drainage time on effectiveness decreased as expansion ratio of foam increased. Foams of low drainage times were not obtainable for expansion ratios of 16 and 18.

CONCLUSIONS AND RECOMMENDATIONS

1. A small-scale fire extinguishment test such as that described in this report offers some promise for assessing the performance potential of foam over a wide range of foam characteristics.

2. The new fire test has a number of advantages over the original 10- by 10-ft fire test. Because the fire tank is small, the test can be conducted in a laboratory in an atmosphere absent from the influence of weather. The reduction in expense for conducting small tests is significant. The use of a radiometer for determining the end-point of a test reduces reliance on visual observation and the responsibility placed on the observer.

3. The following experimental conditions appeared optimum for the suppression of 2- by 2-ft flammable liquid fire by foam, using the method described in this report:
   (a) Solution rate of application = 0.06 gal/min/sq ft of fuel surface. (Figs. 1, 2, 4, 5)
   (b) Expansion ratio of foam = 12.(Figs. 2, 3, 4, 6)
   (c) 25 per cent drainage time = 2 to 4 min. (Figs. 1, 3, 5, 6)
In general, under the conditions given above the three variables were least dependent on one another with respect to effectiveness in the control of fires. The expansion ratio shown to be optimum in the present investigation is higher than expected.

4. The reliability of the 2- by 2-ft fire test will be further examined by carrying out a series of repeat tests with not only the 2- by 2-ft tank but also with a 3- by 3-ft tank and a 10- by 10-ft tank. It is hoped that completion of the contemplated investigation will lead to a test procedure that may be considered either as a replacement or an alternative for that given in JFMC Specification No. 260.00.

REFERENCES

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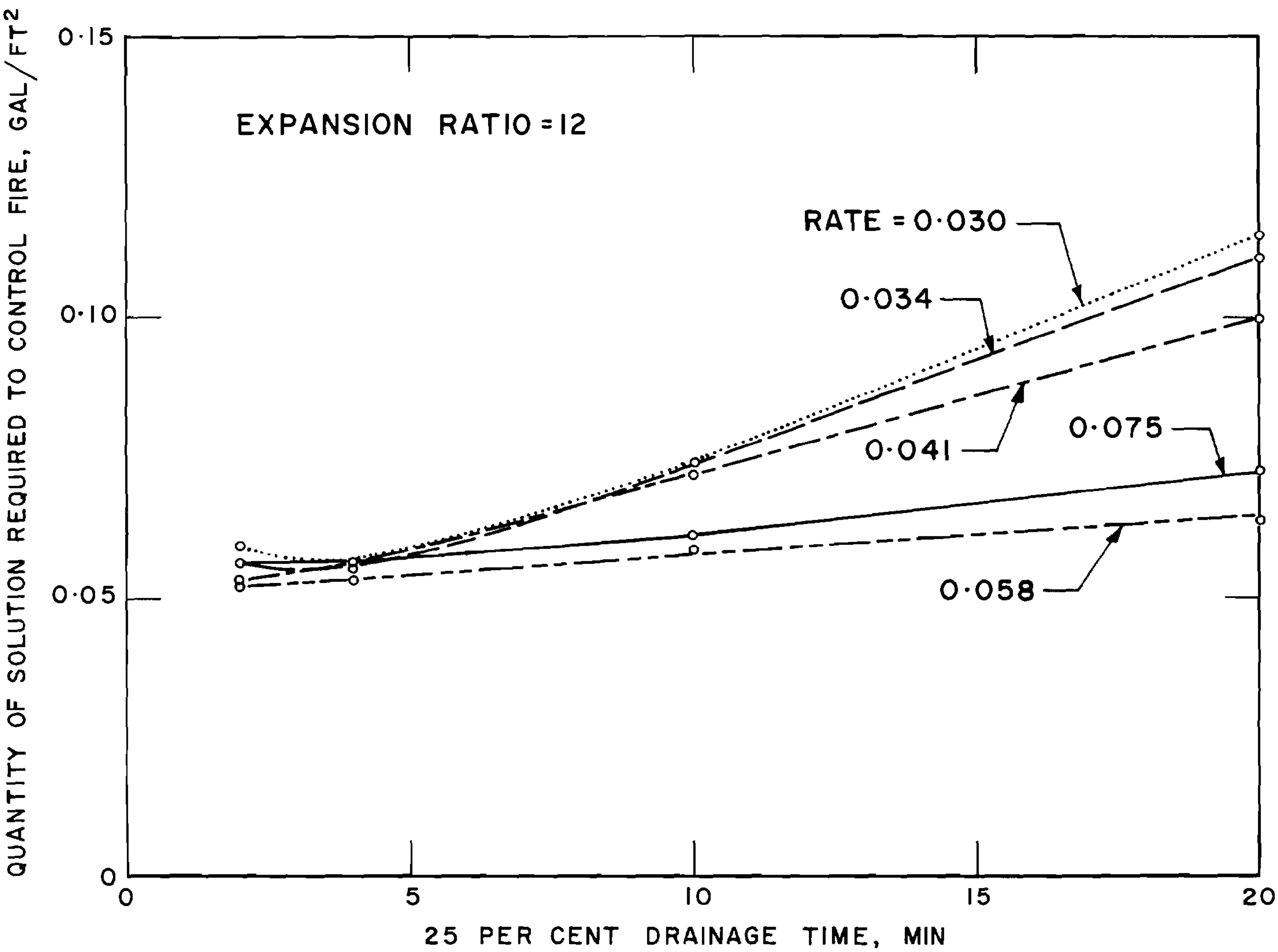

FIGURE 1
CONTROL QUANTITY AS A FUNCTION OF DRAINAGE TIME AT CONSTANT EXPANSION RATIO

BR 2456-1

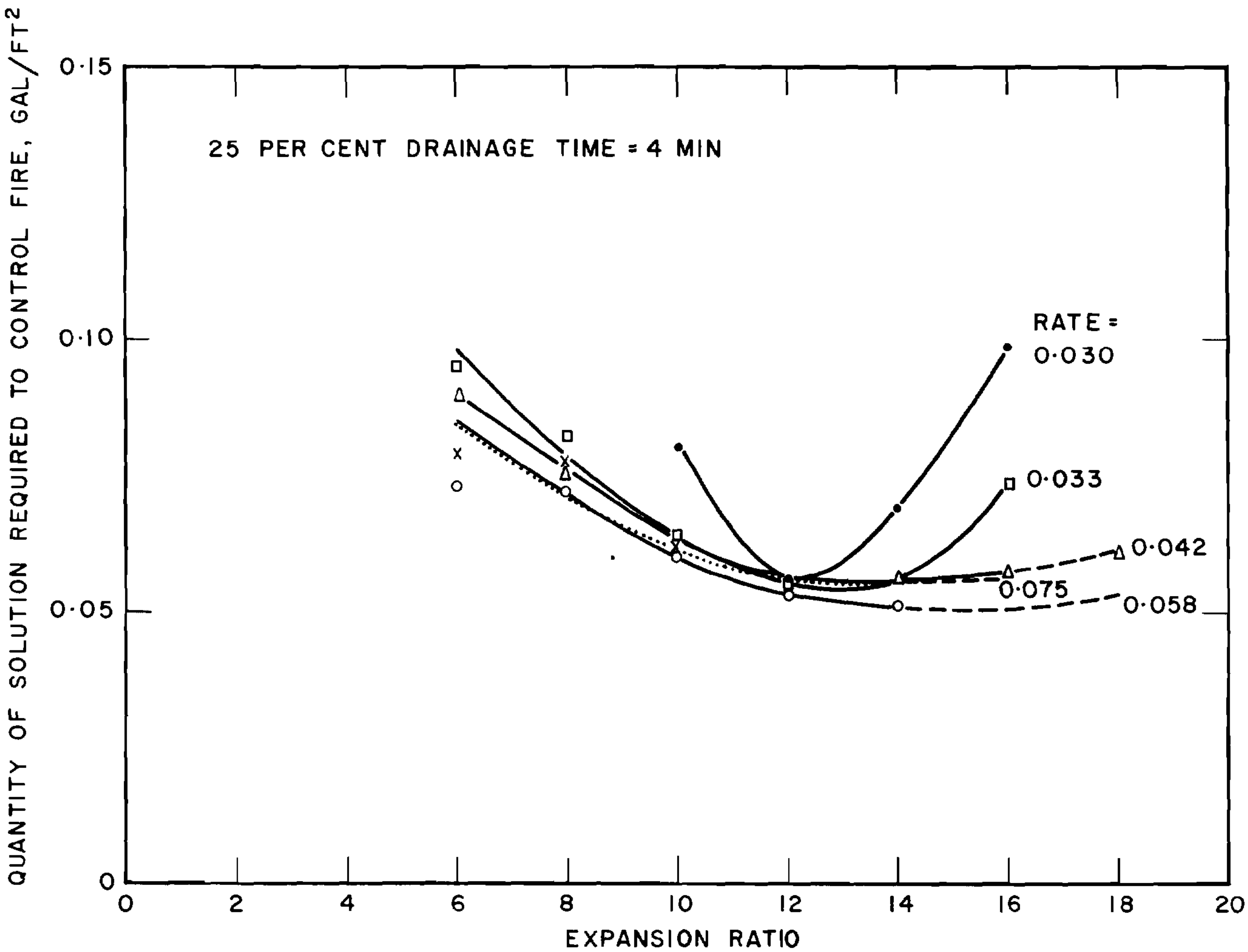

FIGURE 2

CONTROL QUANTITY AS A FUNCTION OF EXPANSION RATIO AT CONSTANT DRAINAGE TIME

BR 2456-2

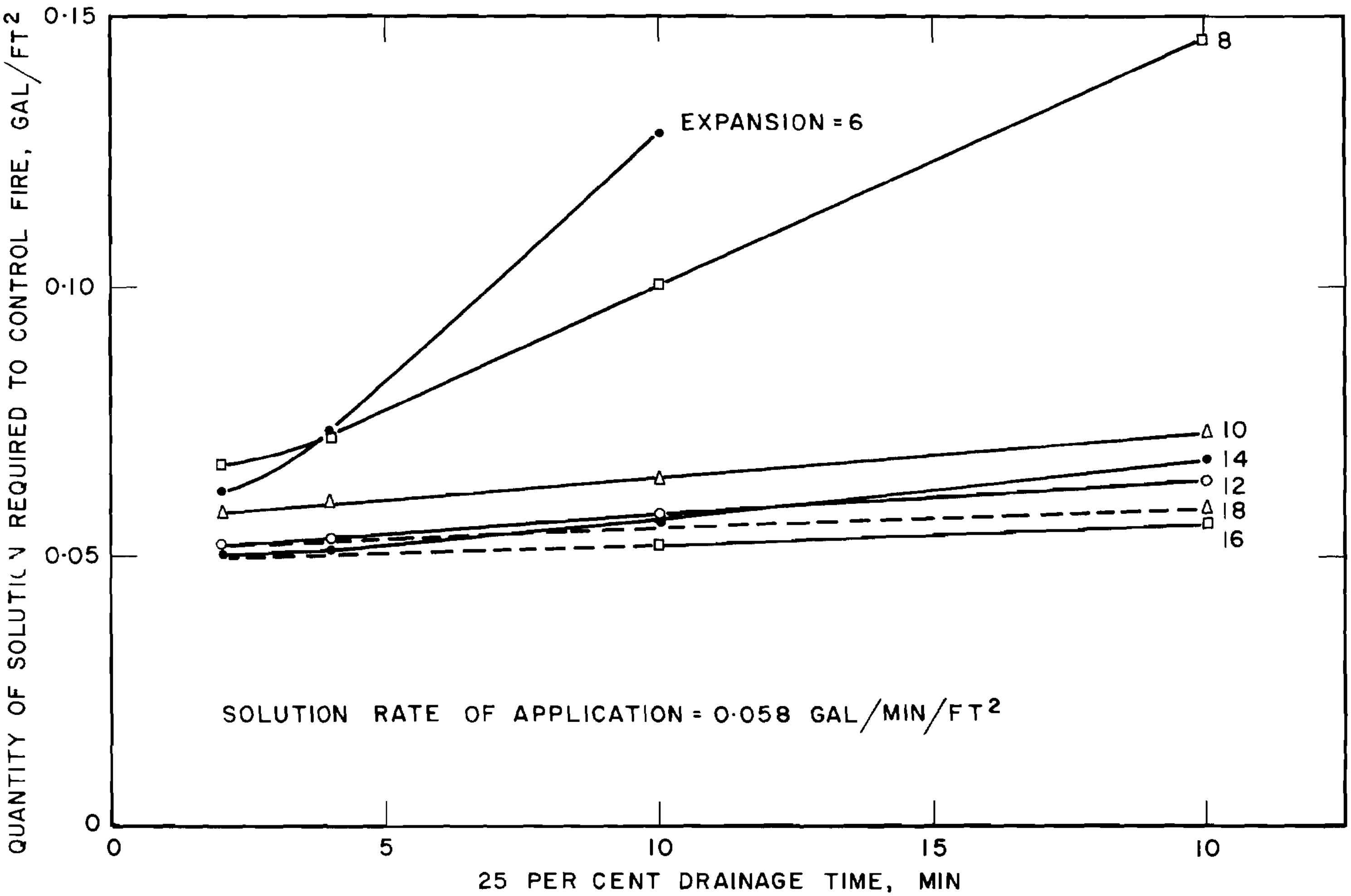

FIGURE 3
CONTROL QUANTITY AS A FUNCTION OF DRAINAGE TIME AT CONSTANT SOLUTION RATE

BR 2456-3

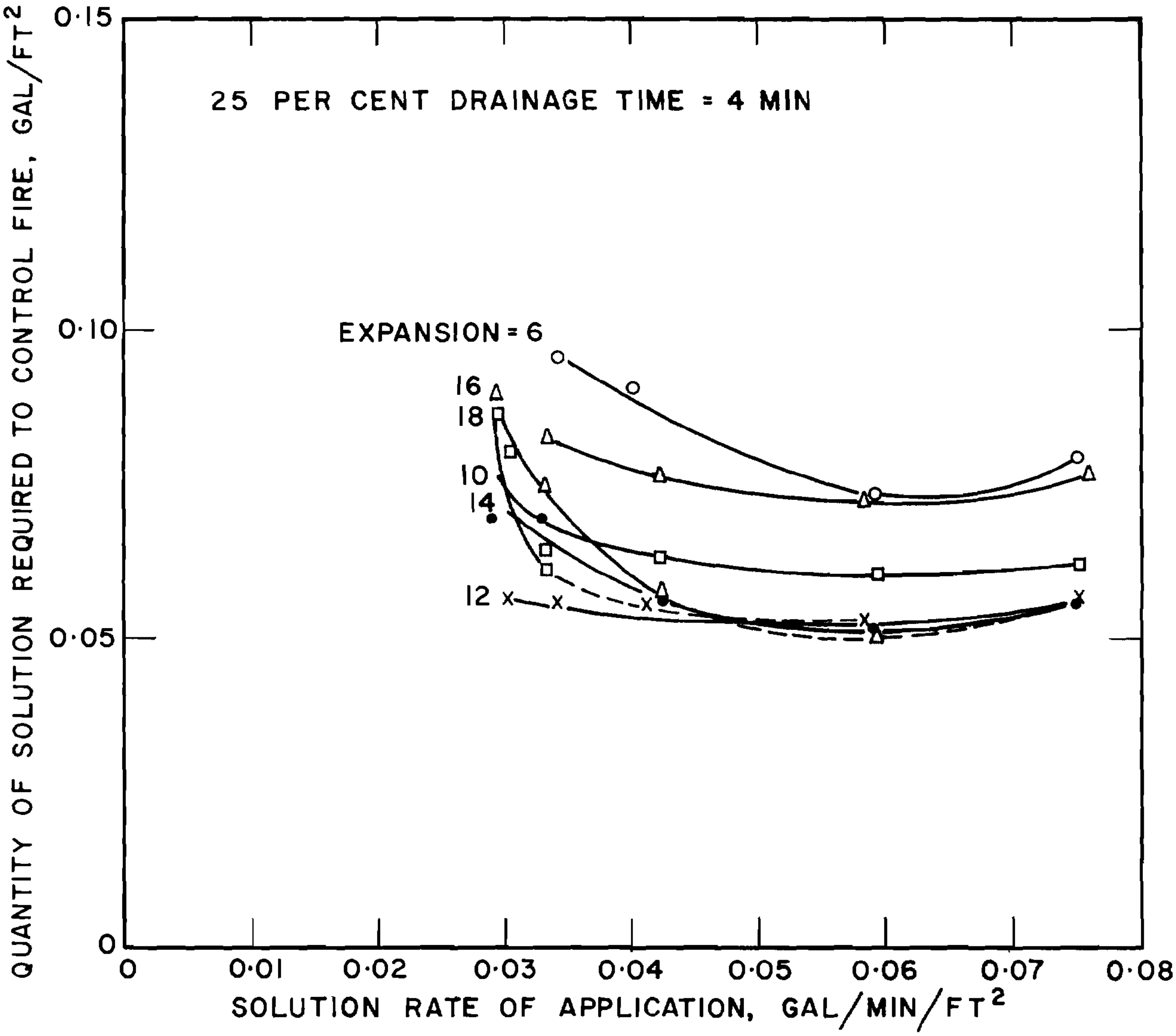

FIGURE 4
CONTROL QUANTITY AS A FUNCTION OF SOLUTION RATE AT CONSTANT DRAINAGE TIME

BR 2456-4

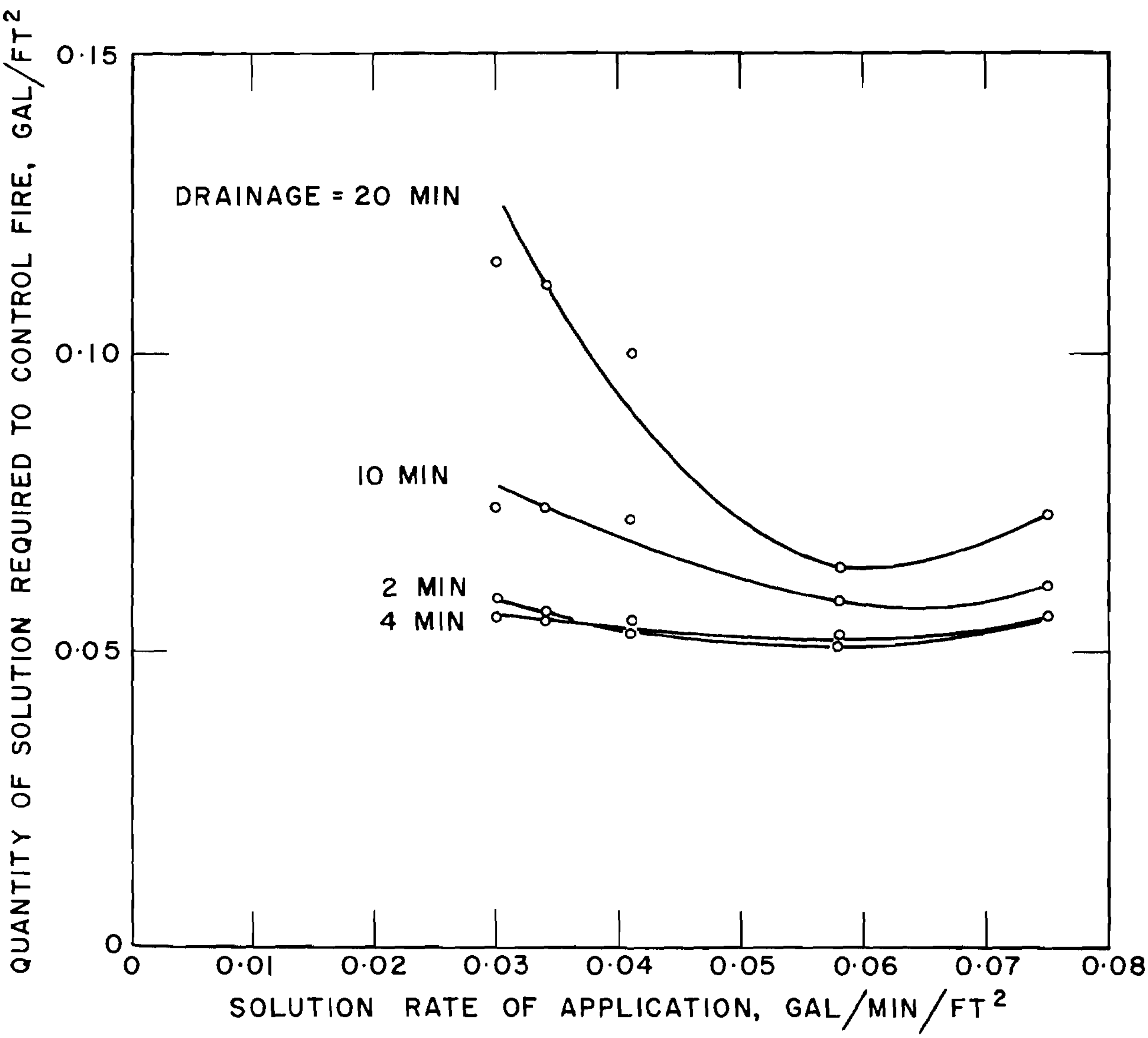

FIGURE 5
CONTROL QUANTITY AS A FUNCTION OF SOLUTION RATE AT CONSTANT EXPANSION RATIO

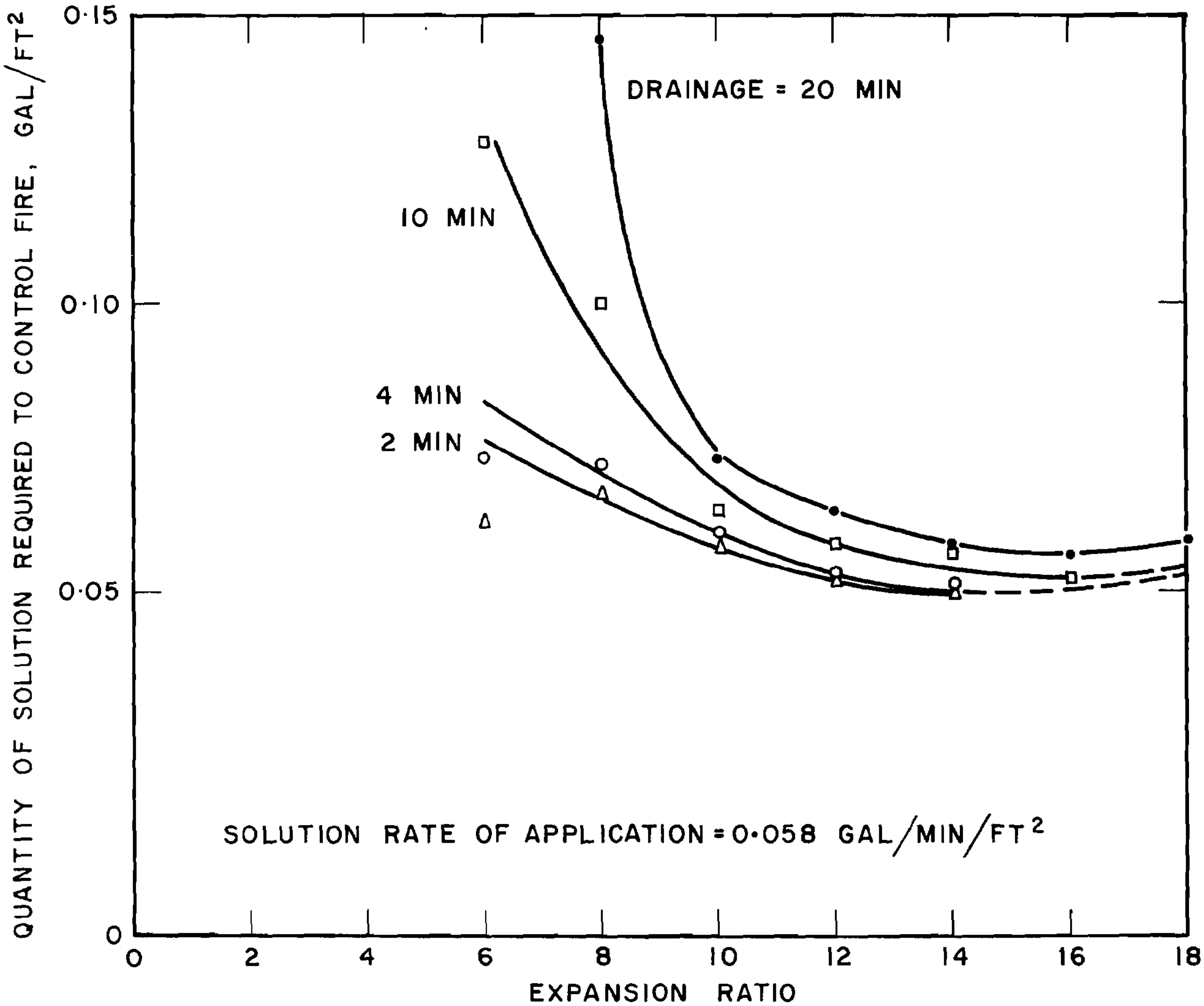

FIGURE 6

CONTROL QUANTITY AS A FUNCTION OF EXPANSION RATIO AT CONSTANT SOLUTION RATE

BR 2456-6