F. R. Note 379

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

THE BASE INJECTION OF FOAM INTO PETROL STORAGE TANKS

LARGE SCALE TESTS AT I.C.I. LTD., BILLINGHAM

by

P. Nash, D. Hird and R. J. French

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Fire Research Station,
Boreham Wood,
HERTS.

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Introduction

During 1953 some small-scale tests were made on the base injection of foam into petrol storage tanks (1). These tests, which were made in a 9 ft diameter by 30 ft high tank, with a depth of petrol from injection point to surface of approximately 27 ft, suggested that the properties of the foam at injection needed to be controlled within certain limits, if the petrol picked up by the foam at the surface should not exceed a critical value of 10 per cent by volume, above which extinction could not be achieved.

While these tests were a valuable pointer to the possibilities of using base injection, it was realised that the tests on a larger tank would be necessary, since the 9 ft diameter tank represented only some 1/250th of the petrol surface area present in the largest storage tanks.

During 1958, Messrs. I.C.I. (Heavy Organic Chemicals) Ltd., made available a 45 ft diameter x 30 ft high petrol storage tank for further experiments, that is, a tank of 1/10th the free petrol surface area of the largest tanks in use. This has made possible a valuable extension of the original work, and has given some further useful information and the effect of tank size on the petrol picked up by the foam.

Description of Tank

The tank was of the fixed-roof type with two 2 ft diameter manhole covers at the top. There were several pipe lines leading into the tank at points 2 ft above the tank bottom; only three of the these were of 8 in. clear diameter so as to give an injection velocity of the same order as that of the earlier tests. One of these three inlets was connected to a swing arm which opened out at the end in the form of an elbow, with a downward-facing 12 in. diameter outlet. This swing arm extended $31\frac{1}{2}$ ft into the tank, i.e. 9 ft beyond the tank centre. The position of the inlets and the manholes and the arrangement of the swing arm are shown in fig. 1.

Petrol

The petrol in the tank had the following properties:-

I.B.P.	-	30.5°C
F.B.P.	-	184°C
R.V.P.	-	10.2 lb/in^2

Ether content - trace (probably less than 1%)

Foam-making equipment

The foam was produced by an in-line foam generator, and in all but one of the tests, the generator was used in conjunction with a centrifugal pump. In this arrangement, developed by the Joint Fire Research Organization (2), the foam generator is connected directly to the suction eye of a centrifugal pump, in which further work is done on the foam so as to reduce its drainage rate. The pump speed and the pump delivery valves are set to give a foam pressure of about 60 lb/in^2 and a back pressure on the foam generator such that the expansion of the foam produced is from $3\frac{1}{2}$ to 4 at atmospheric pressure. The compound pick-up is restricted to 3 per cent in order to limit the critical shear stress of the foam.

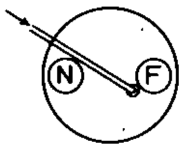
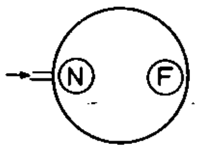
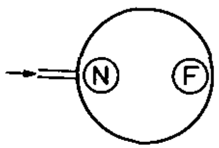
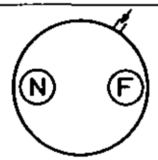
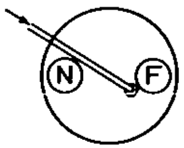
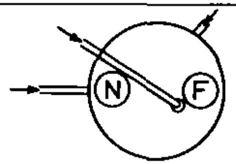
The relevant details of the foam production systems used and the characteristics of the foams produced are given in Table I.

TABLE I

FOAM PRODUCTION SYSTEMS

No. of applicable test	Water throughput of foam generator (gal/min)	Nominal water capacity of centrifugal pump at 100 lb/in^2 (gal/min)	Back pressure on foam generator (lb/in^2)	Liquid rate of injection into tank gal. ft^{-2} min^{-1}	Foam characteristics		
					Expansion	Critical shear stress (dyne/cm^2)	25% drainage time (min)
1, 2, 4 and 6	125	250 - 300	22 to 23	0.079	4	125	8 to 10
5	125	Generator only	19	0.079	4	70	2 (approx)
3	56	250 - 300	13 to 14	0.035	4	125	8 to 10

TABLE 2

TEST No.	POINT(S). OF INJECTION	METHOD OF PRODUCTION	RATE OF INJECTION gl/ ft²/min	SHEAR dyne/cm²	25% DRAINAGE TIME (min.)	PETROL PICK-UP AT N (% by volume)	PETROL PICK-UP AT F (% by volume)	EXPANSION AT SURFACE AT N	EXPANSION AT SURFACE AT F
1		Generator + centrifugal pump	0·074 (Generator operating at 135 lb/in²)	125	8-10	4·4	1·8	6·0	5·8
2		Generator + centrifugal pump	0·08	125	8-10	7·7	25·3	6·3	7·3
3		Small generator + centrifugal pump	0·04	125	8-10	7·6	22·2	5·8	6·5
4		Generator + centrifugal pump	0·08	125	8-10	14·8	20·8	6·8	6·7
5		Generator only	0·08	70	2	7·8	12·0	8·2	8·4
6		Generator + centrifugal pump	0·08	125	8-10	40·9	30·8	6·7	6·6

Where only one point of injection was used, the foam was delivered through twin 150 ft lengths of $2\frac{3}{4}$ in. rubber-lined hose and in the one test in which three injection points were used, the foam was delivered through triple lengths of similar hose.

<u>Water</u>

The water used to produce the foam was taken from the River Tees and contained 1.2 per cent w/v sodium chloride.

<u>Foam compound</u>

The foam compound was of a protein type in common use.

<u>Test Procedure</u>

Although fire tests could not be carried out on this tank, the petrol content of the foam at the surface is a guide (1) to its ability to extinguish a fire. Foams containing less than 10 per cent of petrol by volume of foaming liquid have been shown likely to extinguish the fire.

The foam was injected for periods between 4 and 7 min. and samples were collected from the petrol surface as soon as a layer of sufficient depth had been formed. Six samples were taken from the petrol surface through each of the manholes by means of polythene dustpans, and were transferred to 1 litre flasks. These were immediately corked and retained for subsequent petrol content determinations. Three further samples from each point were collected in small tins (to be weighed) for measurement of the foam expansion.

<u>Foam analysis</u>

The determination of the petrol content of the foam was carried out by a simple distillation method (1).

<u>Test programme</u>

A total of six tests were carried out, four using the combination of the larger generator and the pump, one with the smaller generator and the pump and one with the larger generator only. The number and position of the injection points used for the individual tests are shown in Table II in relation to the sampling points.

<u>Test results</u>

The results of these tests are given in Table II.

<u>Formation of foam blanket</u>

The foam reached the petrol surface in flakes, very similar in size to those in the tests on the 9 ft diameter x 30 ft high tank (1). Whereas on the small tank, the flakes joined together at the periphery to form an annular blanket which ultimately closed at the centre on the large tank the flames first formed into "rafts" of 1-2 sq. ft in area and about $\frac{1}{2}$ in. thick, almost immediately outside the column of rising foam above the foam inlet. These rafts then joined to form the foam blanket. In some cases the foam blanket was clearly seen to be increased in thickness by the rafts being swept underneath the foam already in fruition. In other cases, the foam blanket was thickened by the rafts being concertinaed on impact. The surface directly above the point of inlet was not covered by the foam until injection ceased, when the foam rapidly spread to complete the blanket.

Discussion of results

The results of the tests must be interpreted cautiously since the sampling areas were restricted to the areas immediately beneath the manholes, a very small part of the total surface of the petrol.

The only conditions under which extinction of a fire was likely were those of Test I and possibly Test 5. In these tests the near-central inlet only was used and the foam properties at injection were approximately those found acceptable on the smaller scale tests. Comparison of Tests 2 and 3 shows that injection rate within the range used had little effect on petrol pick-up. The use of multiple inlets (Test 6) shows greatly increased pick-ups possibly due to the agitation on the petrol surface caused by the interference of the circulating petrol from the different foam columns.

Test I by comparison with Test 5 illustrates the improvement which can be gained by using the centrifugal pump in conjunction with the foam generator to produce foam with a lower drainage rate, giving a correspondingly lower surface expansion.

The petrol content of the foam directly above the injection point in Tests 2 and 3 agrees reasonably well with the results for the 9 ft diameter tank, whereas the petrol content at points distant from the inlet is much higher. The difference may be explained by the fact that the foam layer above the inlet is formed directly from flakes, whereas on the farther side it is formed from rafts.

Conclusions

The following conclusions are drawn from these tests:-

(a) The formation of a foam blanket on larger diameter tanks is more complex than on small diameter (9ft) tanks already tested. The difference lies in the preliminary formation of rafts of foam from the discrete flakes which reach the surface.

(b) The petrol picked up by the foam may lie within acceptable limits in certain circumstances, but in others, may far exceed the limit suggested by the small scale tests (approx. 10 per cent. by volume of foaming liquid.

(c) Acceptably low concentrations occurred with a single near-central inlet and it is likely that a fire in the tank under test could be extinguished by injection at this point.

(d) Where side inlets were used, with or without the central inlet, the petrol pick-up was much greater and outside the acceptable limit. The highest petrol pick-up occurred when the foam input was divided between the maximum number of inlets used (3 inlets, Test 6). The high contamination of the foam appeared to be due to the manner of coalescence of the foam rafts in forming the blanket.

(e) Neither injection rate nor injection velocity, within the range tested, had much effect on the petrol content of the foam.

(f) Controlling the foam properties at inlet to those suggested by small-scale tests helps in reducing the petrol pick-up.

Acknowledgment

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References

1. FRENCH, R. J. and HINKLEY, P. L. The Extinction of Fires in Petrol Storage Tanks by the Base Injection of Air-foam. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 100, July 1954.

2. FRENCH, R. J. and HINKLEY, P. L. The Production of Foam for Injection at the Base of Petrol Tanks. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 271, September 1956.

3. THOMAS, P. H. The Circulation of Fuel in Tanks and the Pick-up of Petrol by Foam. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 282. January 1957.

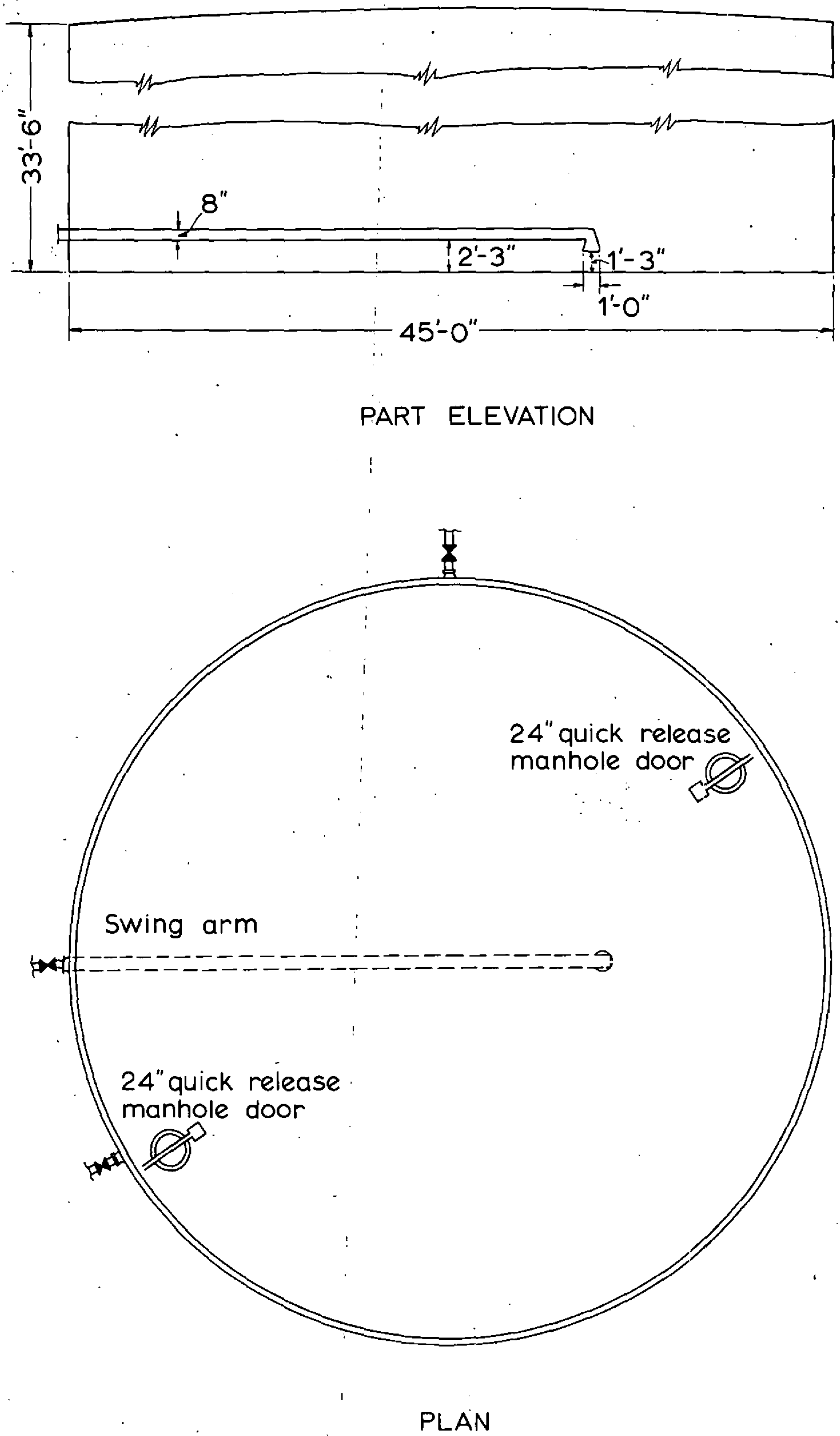

Fig. 1 ARRANGEMENT OF SWING ARM AND SIDE INLETS