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MIXING MOCK-UP STUDY OF THE SODIUM CHEMICAL TECHNOLOGY FACILITY SODIUM RESERVOIR

D. H. Lester and W. F. Smith

March 1970

AEC RESEARCH & DEVELOPMENT REPORT

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ABSTRACT

The possibility of using free jets to agitate 1200 °F liquid sodium in a 1500 gal tank was investigated. Tracer tests were made in a 54 gal water model of the jet mixing tank using jets 0.26 in. to 0.38 in. diameters and flow rates from 4.4 to 8.8 gal/min. The impulse response of the tank was measured at the outlet and various internal points. Acceptable agitation over a wide range of flow rates was obtained.

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MIXING MOCK-UP STUDY OF THE SODIUM CHEMICAL TECHNOLOGY FACILITY SODIUM RESERVOIR

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INTRODUCTION

The program at Battelle-Northwest for chemical studies in large sodium systems has as its major objectives the development and testing of procedures and equipment for the measurement and control of sodium purity, and the characterization of the interrelationships of impurities in engineering scale systems. This program will utilize the Sodium Chemical Technology Facility (SCTF). The SCTF will consist of a reservoir containing about 1500 gal of sodium, a 2-in. diam circulation loop with 200 gpm capacity, and associated purification and analytical subsystems. Experimental work in sodium purification, sodium sampling, in-line analysis of impurities, cover gas purity control and analysis, and characterization of impurities in the system will be carried out in the SCTF.

The 1500-gal SCTF reservoir will have a number of functions. Primarily, it will provide a large volume with large inertia in order to provide a stable platform for chemical studies and simulate the effect of volume on large system dynamics. In keeping with its purpose, the reservoir must be well mixed. Any noise signal, i.e., concentration disturbance, entering the reservoir should be diluted into the total volume within a small fraction of the reservoir turnover time. Immediate dilution of a noise signal will minimize its effects on experiments. A well mixed environment in the reservoir will also provide a uniform temperature in the reservoir. It may be advantageous, at a later date, to insert auxiliary loops into the system by lowering dip tubes into the reservoir through nozzles provided in the cover gas head. The success of such an activity would require the reservoir to be homogeneous as much of the time as possible.

Studies of gas-liquid equilibria require good transport characteristics between the gas and the liquid. Therefore, rapid turnover of the surface, i.e., continuous formation of a new interface, is a necessary reservoir mixing criterion. Rapid surface turnover may alleviate scum formation, a common problem with liquid metal surfaces, and also aid rapid dilution of gas phase disturbances as part of the large inertia criterion. Nevertheless, rapid surface turnover should not be accompanied by large amounts of gas entrainment such as would be evidenced by continuous foaming and bubble formation at the surface. Extensive gas entrainment would result in frequent loop shut-downs induced by gas buildup in other parts of the system, and could result in more serious effects such as hot spots or cold spots in the loop and pump starving (leading to pump duct burnout). Although the cover gas region of the reservoir is to be the high point in the system, large amounts of gas entrainment could result in the entrapment of gas in valve stems and other similar locations. Therefore, surface renewal must be rapid but without bubble formation and foaming. This requirement would forbid the presence of vortices on the surface.

The foregoing requirements cannot be satisfied by the use of impellers. Although an impeller-baffle system could produce the desired turbulence pattern, rotating seals and/or bearings under sodium would add significant design complexity and possible experimental difficulties to the SCTF operation. Many maintenance problems created by rotating machinery would seriously limit access to the tank and probably impair use of the side loops discussed previously. The added complication of providing in-tank baffles also creates construction problems that would best be avoided.

This study was undertaken to investigate the use of nozzles to stir the tank by means of circulation momentum of the driver loop. Since sodium is to be pumped in and out of the tank continuously, the proper nozzle arrangement on the inlet and outlet lines should produce the desired mixing characteristics. The system would then provide the obvious engineering advantages of no moving parts.

The state-of-the-art in agitation does not provide design equations for nozzle mixing of tanks, nor can any reasonable approximate theories be applied. In order to answer the questions posed by the nozzle mixing problem, design of a model system reasonably considered a scaled-down SCTF reservoir and study of its behavior under conditions corresponding to the operating environment of the SCTF was necessary. Water mockups used as scaled down versions of sodium systems has been established as quite a reliable method.[1]

In this study, a water loop was constructed with a large, transparent, acrylic plastic tank. Tracer was injected and observed both visually and with conductivity cells.

The tests were conducted to ascertain whether the design criteria could be met by such a system without using a prohibitive pressure drop across the reservoir. At the same time, the results were to provide design dimensions for the arrangement.

SUMMARY AND CONCLUSIONS

The test results showed that nozzles can be used to meet the needs of mixing the sodium reservoir in the Sodium Chemical Technology Facility (SCTF). A system producing a rapid dilution and mixing rate was designed. Time to steady-state after a disturbance was less than one-tenth of the tank turnover time.

The tank followed the same dilution pattern as would an ideal mixer within the experimental error, i.e., the measured time constant was within 20% of an ideal mixer time constant. Good surface renewal was evidenced by rapid dilution of tracer floated on the tank surface and by visual evaluation of surface circulation patterns. The absence of appreciable frothing, bubbling, or large-scale surface distortion led to the conclusion that no gas entrainment problems would be encountered. The pressure drop across the tank, of the order of one or 2 $lb/in.^2$ was equal to entrance and exit losses and presented no prohibitive pumping problems.

The system incorporated two nozzles and a deflector plate. The nozzles were centered in the tank approximately half way between the liquid level and tank bottom. One nozzle impinged on the tank bottom and the other impinged on the deflector plate set a few inches below the liquid surface. The deflector plate allowed rapid surface turnover without the upward nozzle stream breaking through the surface. The arrangement produced a high degree of large scale turbulence in the tank.

A 0.35-in. nozzle size in the 2-ft diameter mockup tank was scaled to a 1.05-in. nozzle in the SCTF with a tank diameter of 6 ft. The 2-in. diameter deflector plate in the mockup was scaled to a 6-in. diameter plate in the SCTF. At 200 gal/min, the SCTF nozzle velocity would be 37 ft/sec. The system should work well between 100 and 300-gal/min flow rates, and over a broader range by changing the nozzle size and/or deflector position.

The system should not present any other operational problems. Tests intended to check for cavitation showed no jet cavitation under any conditions tried. The system was characterized by generally large tolerances, i.e., the system was not fine tuned but rather worked well even when many conditions and dimensions varied significantly from the recommended design values.

The nozzle deflector arrangement, so designed that the entire assembly could be withdrawn through a 6-in. port in the SCTF reservoir, served to facilitate changes in jet size and deflector plate position.

DISCUSSION

THEORY

Scaling Criteria

Some years ago, a very similar study was undertaken by Fossett [2,3] and Prosser.[2] They were concerned with mixing large, underground petroleum tanks using nozzles. The results of model studies conducted in a small water tank were scaled up to the large tanks. The scale-up was very successful and excellent performance was obtained. The same basis of scale-up used by Fossett and Prosser, except for neglecting the Froude number, was employed in the sodium mixing tank studies. Mixing times predicted by the empirical results of Fossett and Prosser display striking agreement with the times measured in the SCTF mockup work.

According to Fossett and Prosser, for scale-up to be valid, care must be taken to preserve the relationship of all forces acting on the fluid. The forces to be considered in the mixing tanks are inertia, viscosity, and gravity. If density of the fluid jetted into the tank is significantly different from the fluid in the tank, then gravitational effects must be considered. In the case of the SCTF sodium system, gravitational effects can be neglected.

Two similar paths in the model and full-sized prototype will be related by the linear scale ratio, S. Then the time for completion of any dynamic event in the model and full-sized system will be related by:

$$\frac{t_M}{t_F} = \frac{1}{S}\frac{V_F}{V_M} \tag{1}$$

where t = time, and V = mean velocity. If F = flow rate (volumetric) through a nozzle, U = the nozzle velocity, and A = cross section of the induced stream, then by conservation of momentum

$$FU = A\ V^2$$

and

$$\frac{F_M U_M}{F_F U_F} = \frac{A_M V_M{}^2}{A_F V_F{}^2}. \tag{2}$$

Since

$$S^2 = \frac{A_F}{A_M}$$

Then

$$\left(\frac{V_F}{V_M}\right)^2 = \left(\frac{1}{S}\right)^2 \quad \frac{F_F U_F}{F_M U_M} \tag{3}$$

and, substituting Equation (1)

$$\frac{t_M}{t_F} = \frac{1}{S^2} \sqrt{\frac{F_F U_F}{F_M U_M}} \tag{4}$$

Equation (4) is then the relation between time for completion of a given event in the small system and in the large system.

Valid scale-up also requires preservation of geometric similarity, i.e., the relationship of all dimensions to one another must be the same. Therefore, the length-to-diameter ratio (L/D) must be the same for both the model and the full-sized system.

A good understanding of the behavior of the large system can be obtained if the times of both the model and full-scale reservoir are equivalent. Equivalent time is obtained if Equation (4) is applied with the time ratio equal to one, so that

$$S^2 = \sqrt{\frac{F_F U_F}{F_M U_M}} \qquad (5)$$

If the scale-up is to apply over a wide range of flow rates, then it should be made independent of flow rate by requiring identical turnover times at a given flow rate in both the large and small systems. If Q = volume of the reservoir and F is the flow rate then

$$\frac{Q_F}{Q_M} = \frac{F_F}{F_M}$$

and

$$\frac{Q_F}{F_F} = \frac{Q_M}{F_M} = \tau \qquad (6)$$

which defines the universal turnover time, τ.

The nozzles are cylindrical and there are the same number of nozzles in both systems therefore

$$\frac{F_F U_F}{F_M U_M} = \frac{F_F{}^2 \; d_M{}^2}{F_M{}^2 \; d_F{}^2} \qquad (7)$$

where d = nozzle diameter. Therefore, from Equation (5),

$$S^2 = \frac{F_F d_M}{F_M d_F}$$

or

$$dF = \frac{1}{S^2} \left(\frac{F_F}{F_M}\right) d_M \qquad (8)$$

Note that the constraint of Equation (6) makes the flow rate ratio identical with the volume ratio.

Therefore, if geometric similarity is preserved and Equations (8) and (6) are satisfied, then the behavior of the small system in terms of velocities, mixing times, and flow patterns will be identical.

Fossett[2,3] and Prosser[2] found that the jet Reynolds number was not important in scaling nozzle entrainment (jet) mixers of this type in the range of parameters studied. The results of the SCTF mock-up work support this finding.

Ideal Mixers

Some of the experimental results from this work were used to compare the bahavior of the final configuration choice with the behavior of an "ideal" mixer. An ideal mixer is an open loop, continuous stirred system which responds to an impulse concentration, Co, by the relation

$$C(t) = C_o \exp[\frac{t}{T}] \quad (9)$$

where C(t) is the concentration at any time, t. This system is called ideal because the response implies use of the entire mixer volume at all times, i.e., the mixer is homogeneous at all times. The effluent concentration in an ideal mixer is identical to the concentration at any point in the mixer at all times.

An examination of the requirements of the SCTF mixing reservoir (see INTRODUCTION) reveals that an ideal mixer would meet most of the requirements. To test for requirements such as surface action (no gas entrainment, etc.) and pumping power requires evaluation of other criteria in addition to ideal mixing. The requirements could be summarized as an ideal mixer with good surface action and low pumping power consumption.

EQUIPMENT AND PROCEDURE

System Description

The system consisted of an 80-gal acrylic plastic mixing tank, a self-priming centrifugal pump, two flow control valves, a flow meter, three solenoid valves, a dye-injection tank, two pressure gages, and a system drain valve.

Figure 1 is a photograph of the mockup system and Figure 2 is a schematic flow diagram of the system. During the open-loop

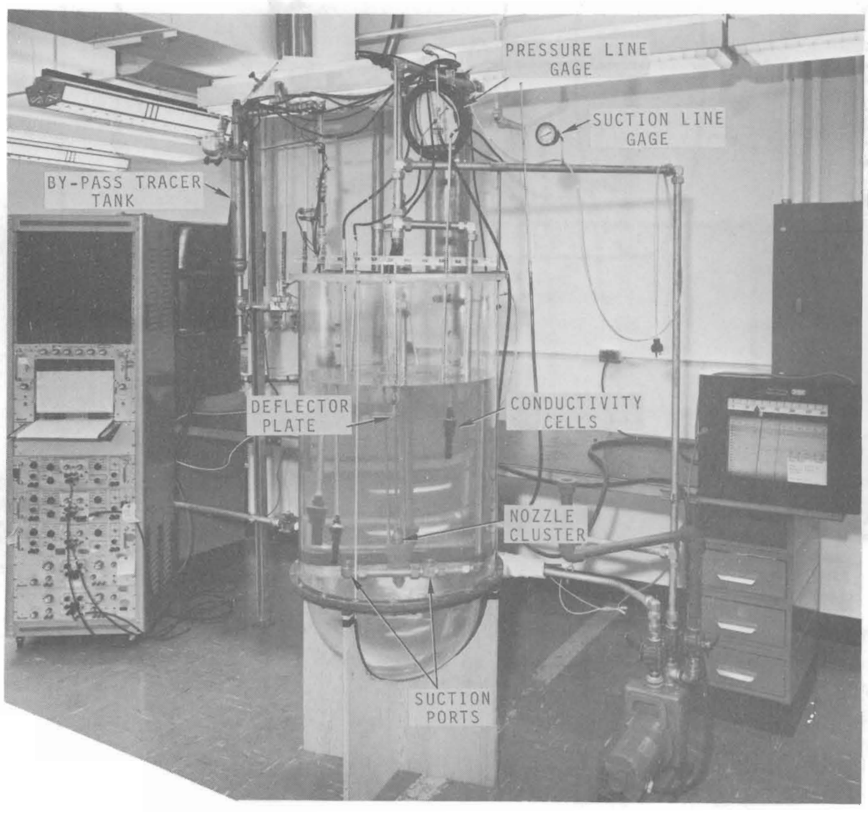

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FIGURE 1. SCTF Mixing Mock-Up

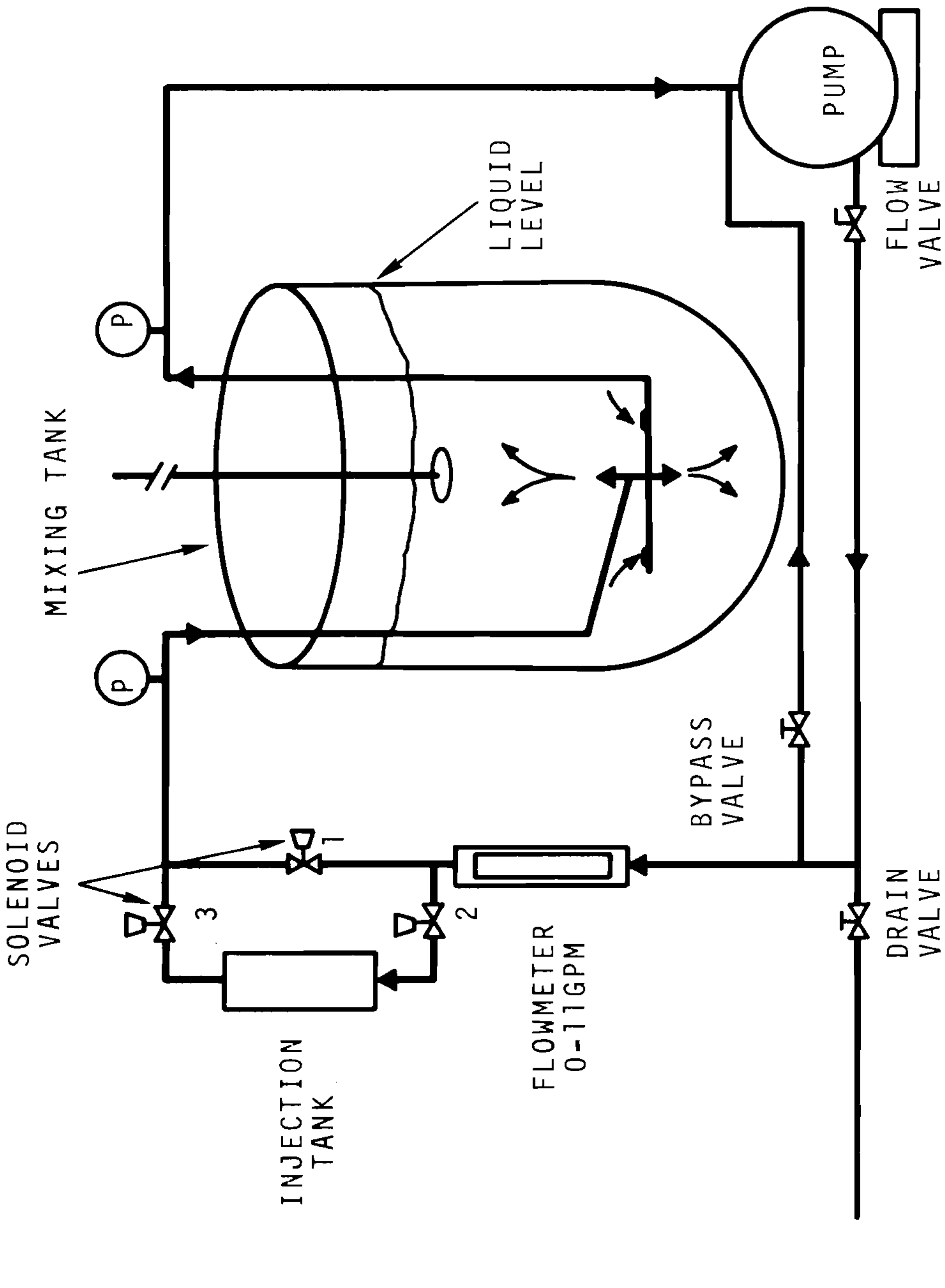

FIGURE 2. Mixing Tank System Schematic

tests, the piping was disconnected at the junction of the return line and flow meter inlet and a fresh tap water line was connected to the flow meter. The tank was filled to various levels to observe various L/D ratios.

Tracer Injection Techniques

Two methods of tracer injection were used to predict the results of the introduction of impurities in the mixing tank or piping system of the SCTF.

System Bypass Injection

The mixing tank was filled to a pre-measured level with solenoid No. 1 energized (open). The pump was started and the flow rate adjusted. When the system had stabilized (all air removed), a switch was closed to open solenoid valves 2 and 3 and to close solenoid valve No. 1, thus injecting dye tracer from the injection tank into the system.

In-Tank Injection

Dye tracer was introduced into the tank directly with a wand at various locations. A pressure tank, controlled by a solenoid and pulsed with an adjustable timer, was used to supply dye to the wand.

Test Program

Two methods were used in observing the mixing capabilities of the tank. The first was by visually observing the time of injection, the time to steady-state, extent of surface turnover and gas entrainment, and paths of dye tracer filaments within the tank. High speed movies were made at several angles to record the mixing action.

The second method employed conductivity cells located in the suction line and at as many as four in-tank positions. The in-tank cells could be located at any depth and at any cross-section location. An oscillograph was used to record the imbalance of the conductivity cell bridge. The dye tracer used in the visual studies contained sufficient amounts of sodium chloride to activate the instruments so that conductivity measurements were supported by simultaneous visual observation of the mixing.

The possibility of nozzle cavitation was tested by several runs made with the water at 100 °F to enable the water vapor pressure to equal that of 1200 °F sodium.

RESULTS AND CONCLUSIONS

Several different mixing configurations were tested in the closed loop with visual dye evaluation. Systems with jets pointed on tangents were tried both with and without baffles, and with from 2 to 6 jets in sizes varying from 0.25 to 0.10 in. diameter. Also, combinations of jets pointed vertically and tangentially, using combinations of varying numbers of jets and jet sizes with conventional mixing tank baffles and without baffles, were tried. It was found that the "stirred" or "rotating" systems resulting from tangential jet placement had a number of dead spots and produced poor surface action. The smaller jet sizes, necessary to obtain good mixing in the rotating flow, resulted in impractical pressure drop values. The screening tests led to progressively less complex systems and eventually to the discovery that a simple, two-nozzle, deflector plate arrangement would satisfy all the requirements and permit a compact and simple design. The accepted system is pictured in Figure 1 and sketched in Figure 2.

Visual Studies

The visual studies revealed a number of key attributes of the two-nozzle, deflector plate arrangement. The tank was found, over a wide range of flow rates, to be visibly homogeneous in less than one minute while the turnover time, τ, was several minutes. A typical run is seen in the picture sequence in Figure 3. This run represents a model of the SCTF 1500-gal tank with a 200-gal/min flow rate and, therefore, with a 7.5-min turnover time. The brief mixing time, compared to a turnover time, can be noted. The surface action displayed by this system gives good surface turnover rates with no visible gas entrainment.

It was concluded, from exhaustive probing with the injection wand, that no channeling from the input to the output of the reservoir exists. Dye injected an inch from the suction ports will travel throughout the tank before coming back to the ports.

The significance of tank length to diameter ratio was evaluated by filling the tank to 70, 54, and 40 gal, and adjusting flow rate to maintain turnover time to give ratios of 1.0, 1.25, and 1.8 respectively. There was no observable difference. Mechanical design considerations and space allocation for SCTF led to a design L/D of 1.25.

Many geometric parameters were adjusted over a wide range to test the design latitude since a "fine-tuned" system would be undesirable. The centering of the nozzles and the deflector plate, the angle of the nozzles from the vertical, the deflector plate orientation and size, the nozzle position and the nozzle size were all fixed at out-of-design values in many combinations. The tolerances specified in the design recommendations (Table 1) are well within the observed permissible latitude of the system. It was found that most values could be far off standard without damaging performance significantly.

Short Time Studies

Numerous runs were made with the closed loop configuration using the conductivity cells. The purpose of these tests was

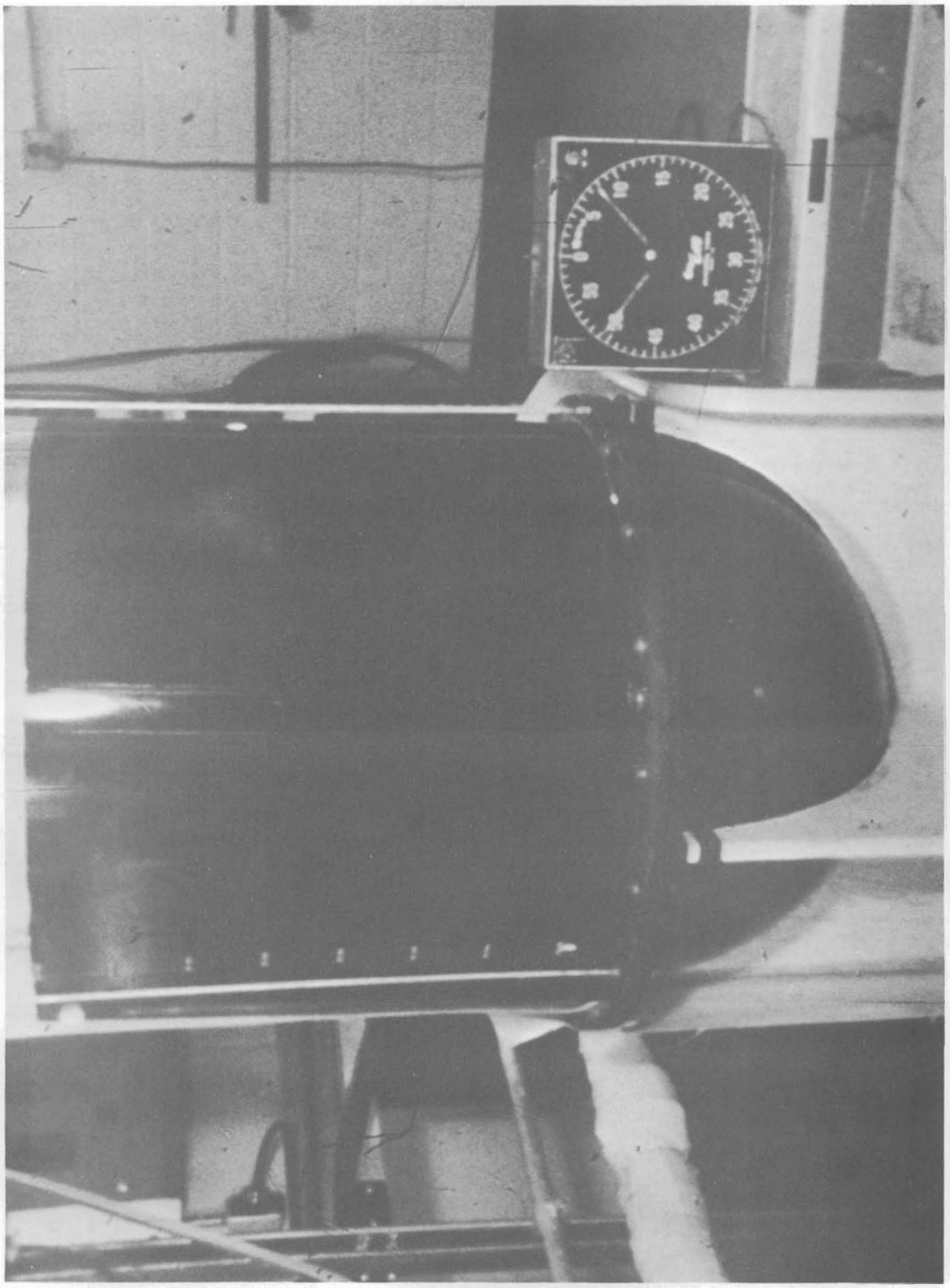

FIGURE 3. (contd)

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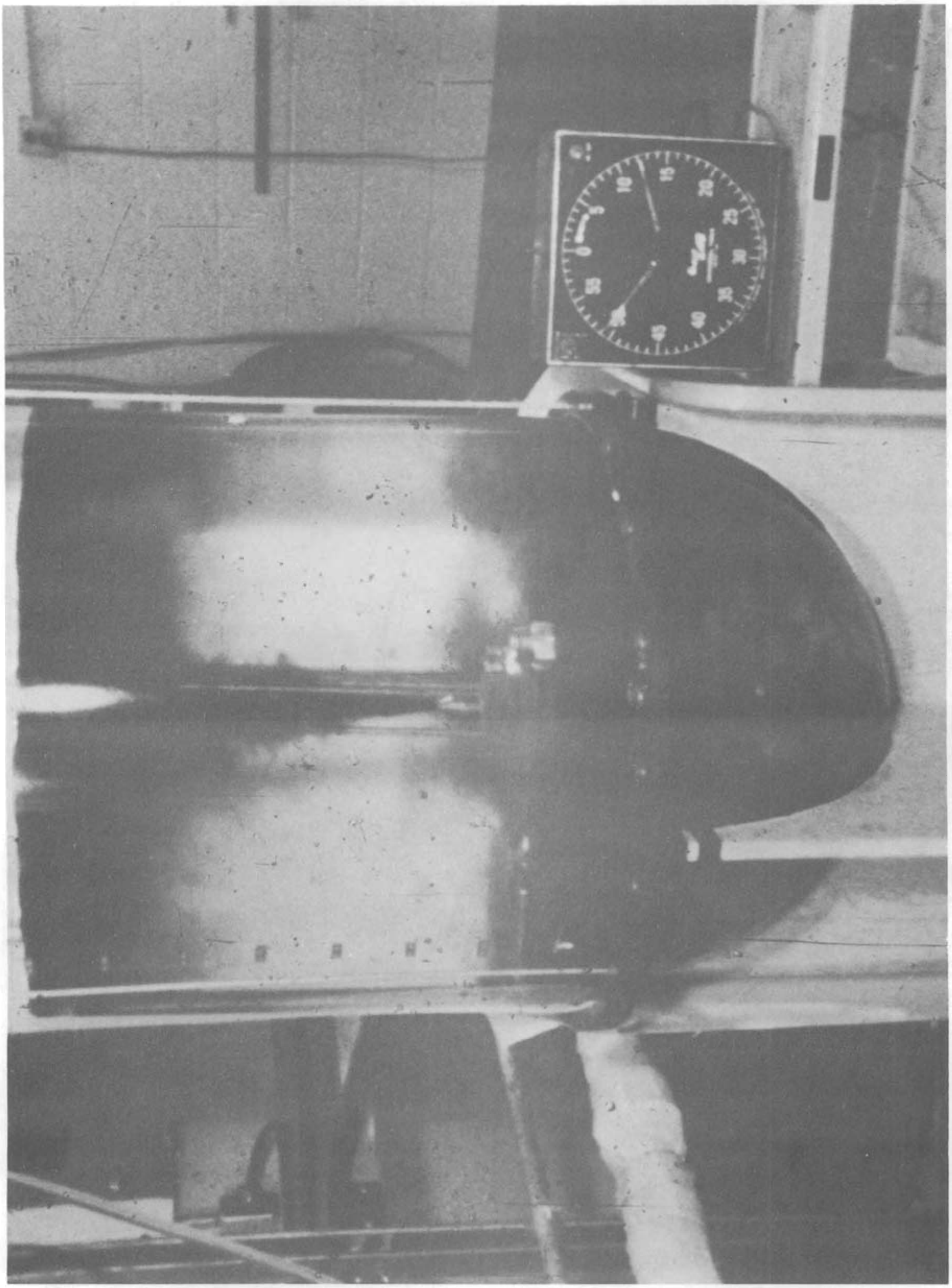

FIGURE 3. (contd)

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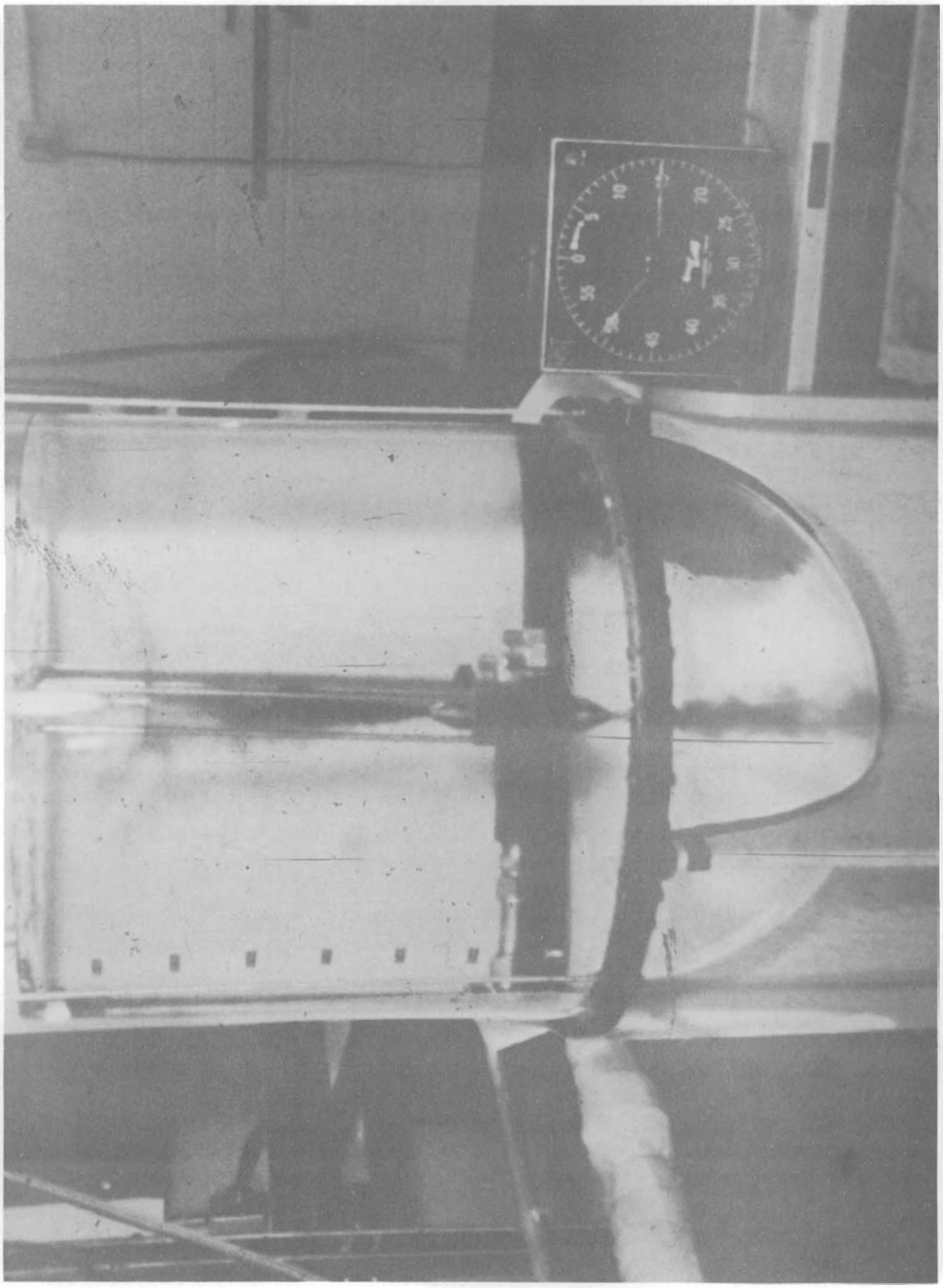


Neg 0695482-3 FIGURE 3. Sequential Pictures of a Typical Mixing Run to observe in detail the short time (less than one minute) effects of the system. Cell depth was measured from the liquid level to the top (vent holes) of the dip cell. Cell location on the cross section was specified by a letter-number coordinate system shown in Figure 4 as, for example, the center of the nozzle cluster by F6 at 18 inches.

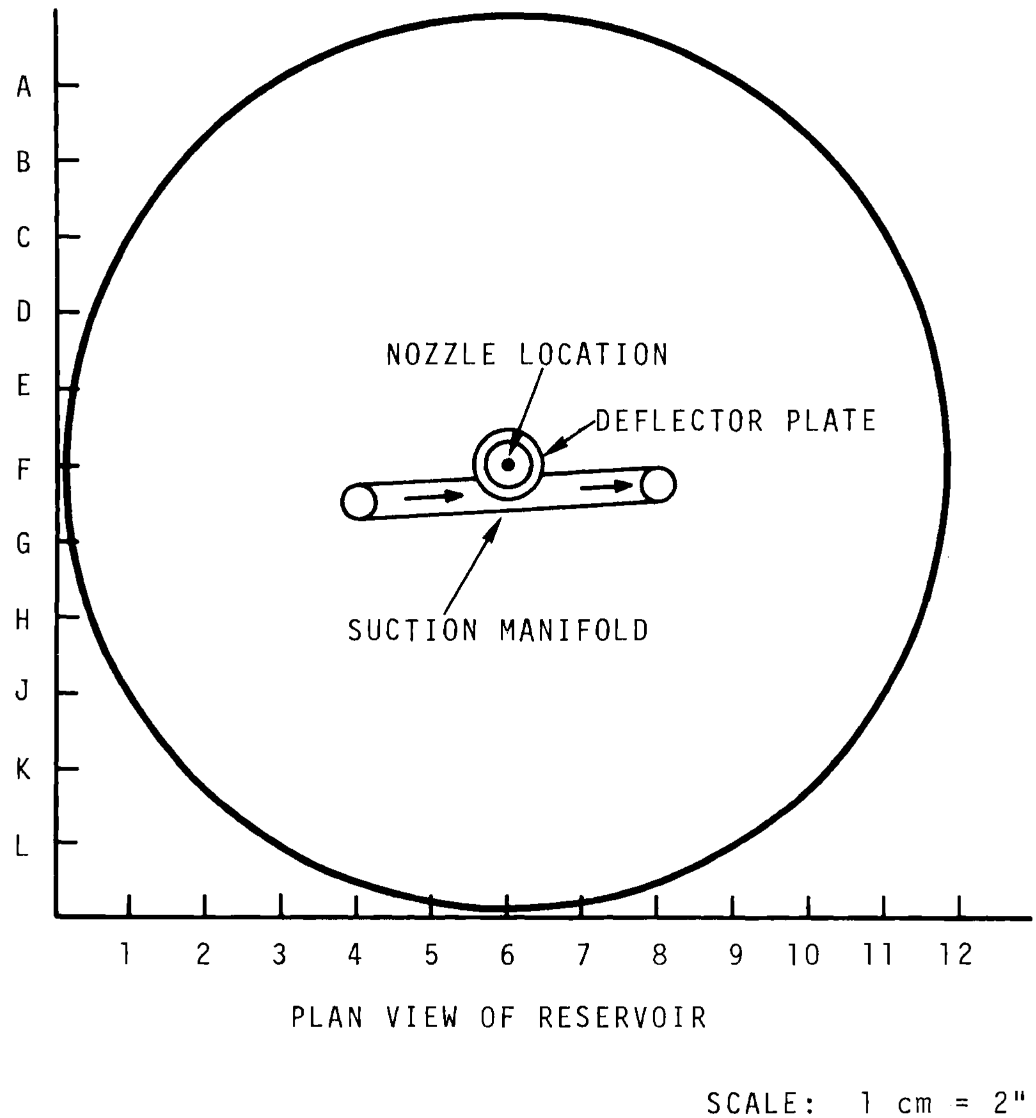


FIGURE 4. Mixing Tank Coordinate System of SCTF Mixing Mock-Up

Comparison of Injection Sources

Tests were run to compare the response of the tank to loop-originated disturbances with the response to tank-originated disturbances. Figures 5 and 6 show a typical comparison of the two responses. Data for three tank levels and the suction line are shown. Note that time zero for the system bypass injection case is taken as the time the pulse begins to enter the tank through the nozzles. Both the time of first response and the order of response are almost identical in both cases. The peaks for the loop injection (system bypass) case are wider and decay more slowly because of the wideness of the input peak. Whereas the tank injection is all in the tank in less than one second, the loop-originated peak takes up to 10 sec to get into the tank completely. The time to steady-state is of the order of 30 sec in both cases.

Uniformity on the Tank Cross Section

Figures 7 and 8 show the system bypass injection response of three cross section positions at two different levels. Widely spread locations at a given level respond almost identically. The data shown are typical of many other tests so that, at 7.7 gpm (corresponding to 200 gpm in the SCTF), the tank can be concluded to be uniform on its cross section in less than 10 sec after the pulse is started. Again, steady-state is reached after about 30 sec.

Effect of Flow Rate

A comparison of Figures 9 and 10 with Figures 5 through 8 shows some of the effects of decreasing the flow rate. Note that, at 4.8 gal/min there was less uniformity on the cross section but that steady-state was still evident in 30 or 40 sec. Therefore, unless nonuniformity of a cross section

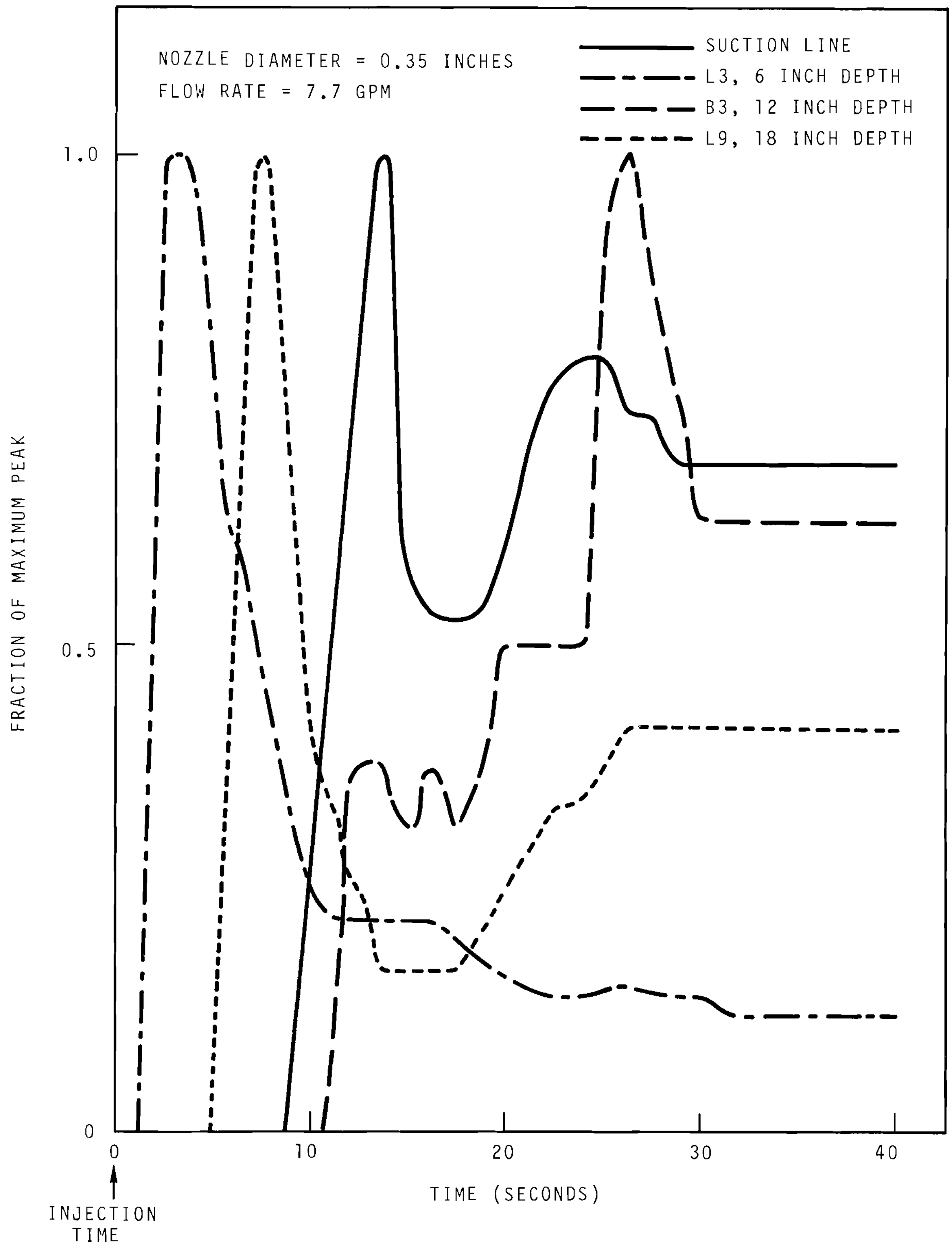


FIGURE 5. SCTF Mixing Mock-Up Closed Loop Response to In-Tank Injection at the Surface

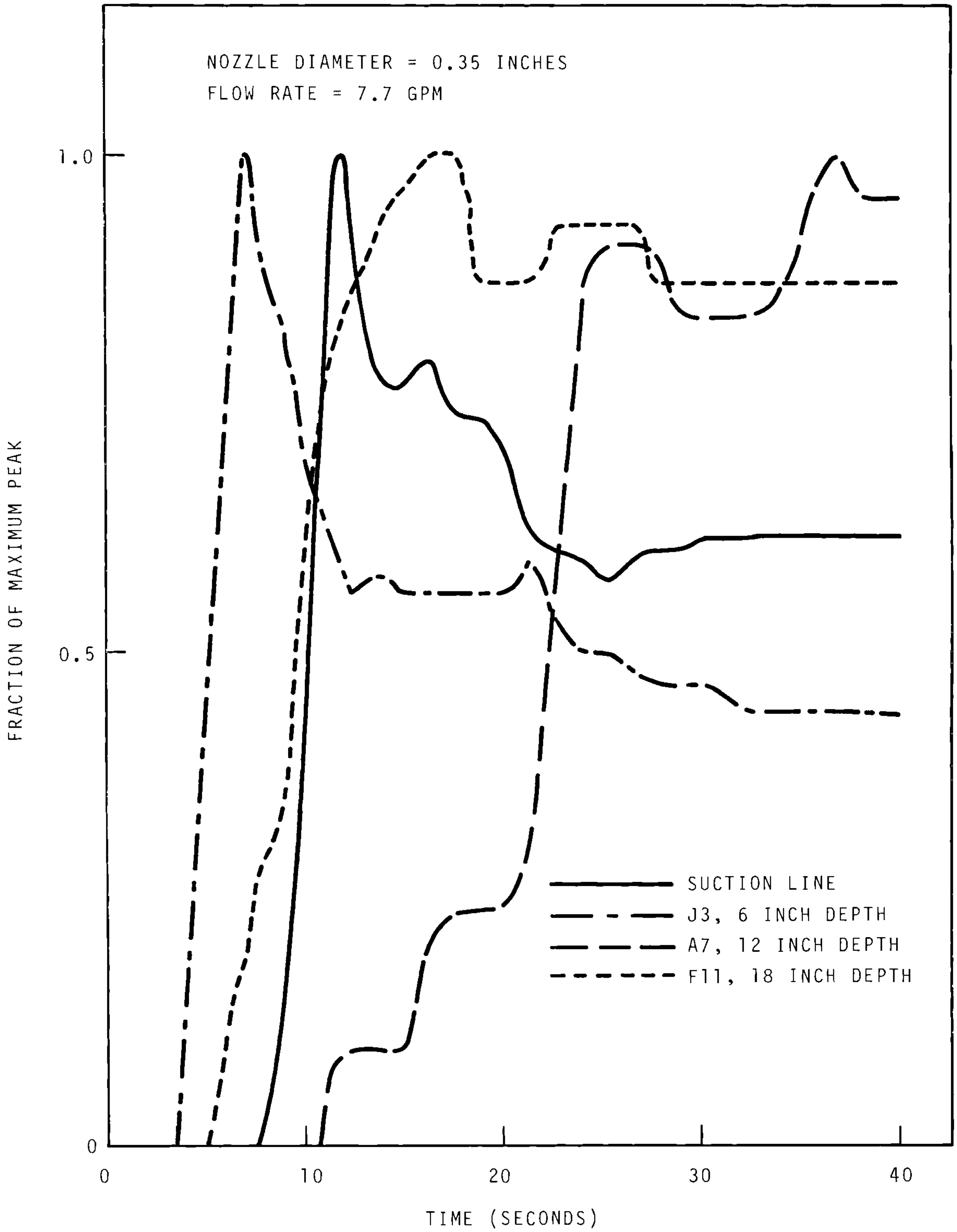


FIGURE 6. SCTF Mixing Mock-Up Closed Loop Response to System Bypass Injection at Time Zero

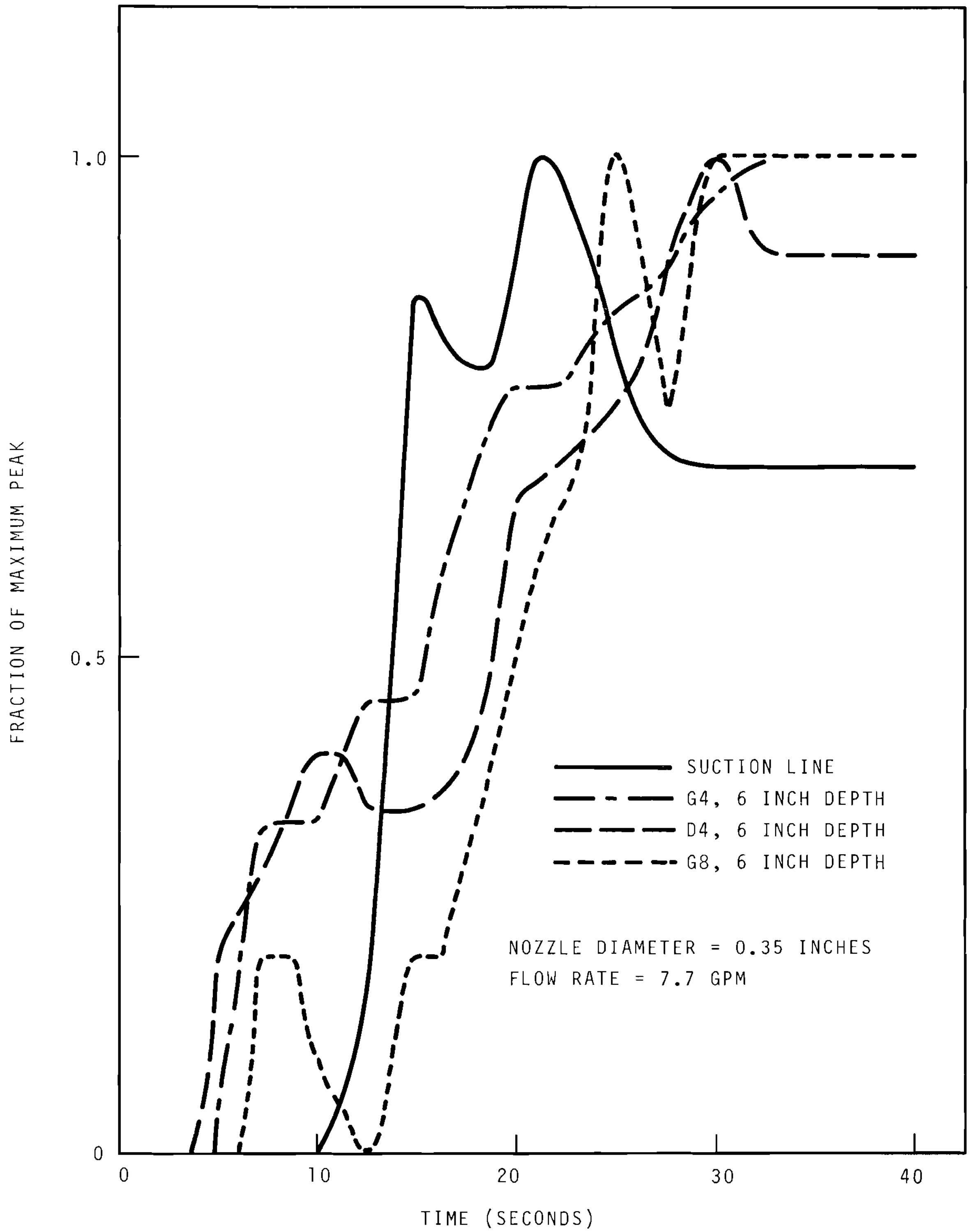


FIGURE 7. SCTF Mixing Mock-Up Closed Loop Response to System Bypass Injection at Time Zero

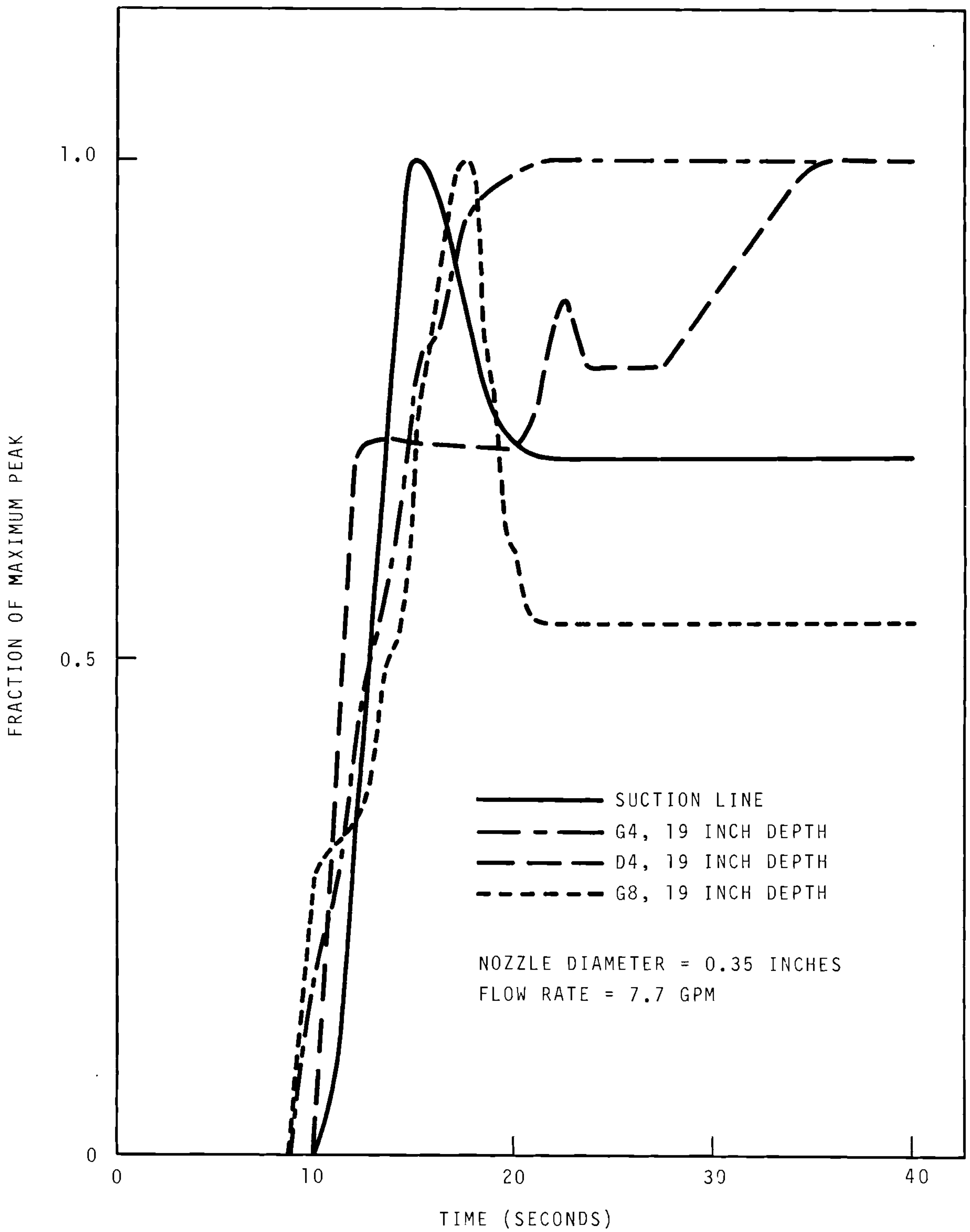


FIGURE 8. SCTF Mixing Mock-Up Closed Loop Response to System Bypass at Time Zero

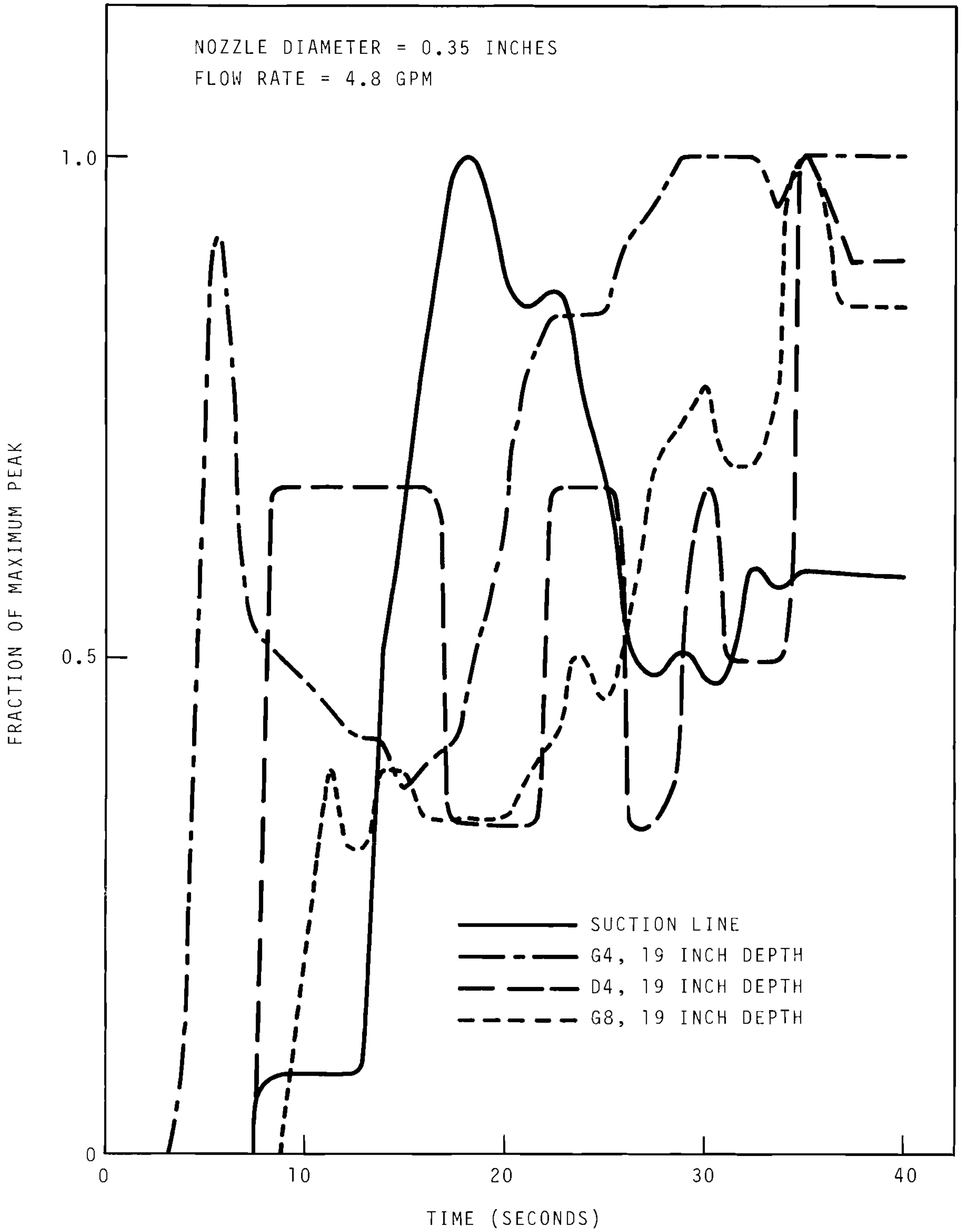


FIGURE 9. SCTF Mixing Mock-Up Closed Loop Response to In-Tank Injection at the Surface

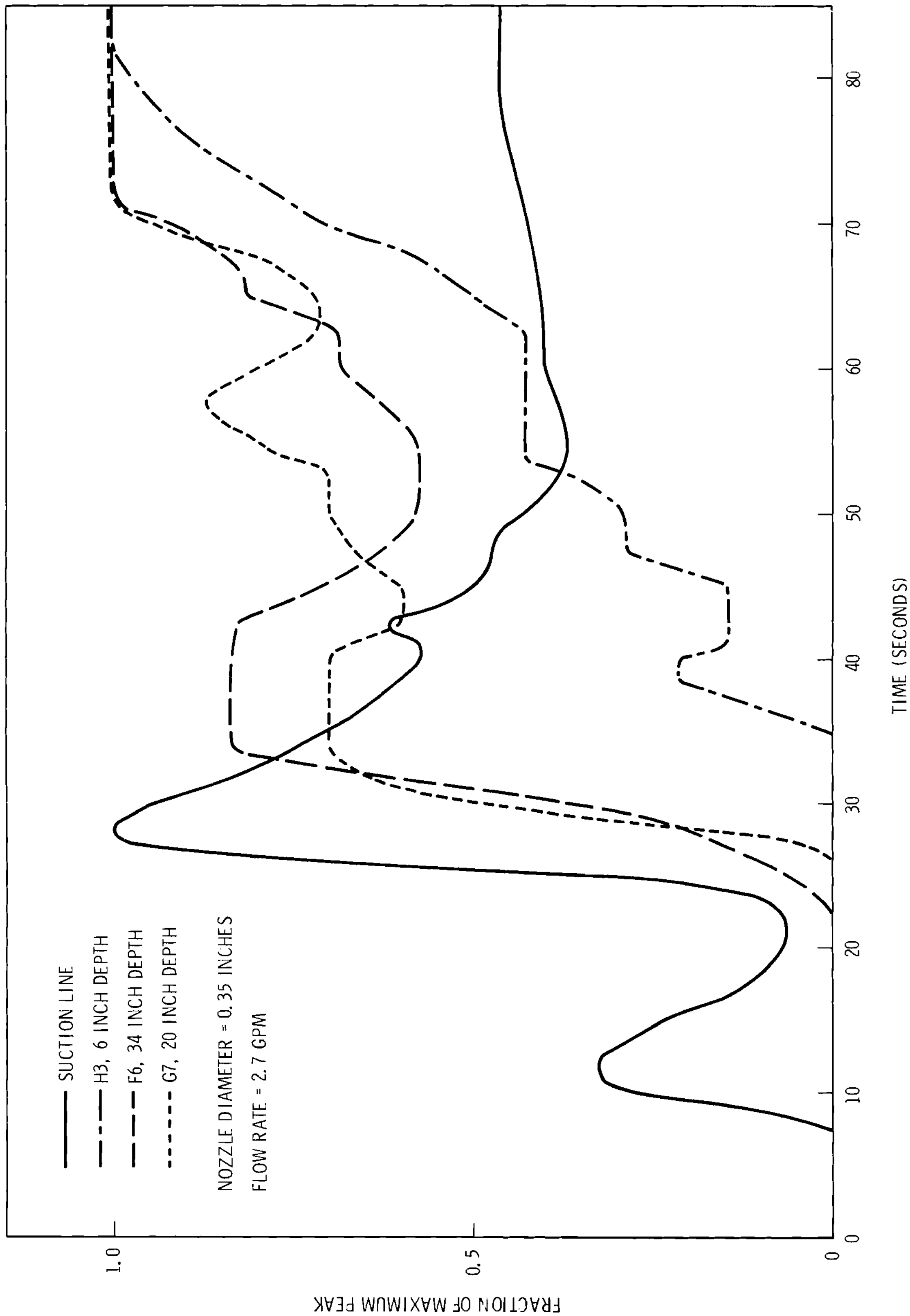


FIGURE 10. SCTF Mixing Mock-Up Closed Loop Response to In-Tank Injection at the Surface

in the first 30 sec is important to a given test in the SCTF, 133 gal/min (corresponding to 4.8 gal/min in the mock-up) will be acceptable since steady-state is attained in a short time.

Data for the 2.7 gal/min flow rate displayed some poor mixing behavior. Time to steady-state was 70 or 80 sec. Symptoms of large unmixed filaments circulating in the tank were evident. Although the injection was made at the center surface of the tank, the 6-in. depth was the last to respond. The peaks were wide and the response was generally lazy. Visually, large filaments of tracer were seen to radiate from the center surface and roll down the tank walls to the tank bottom (34-in. depth) and then float upward through the center. This pattern can be seen in the quantitative data as well.

Another important phenomenon is evident in the 2.7 gal/min data. The SCTF reservoir will have syphon break holes in the inlet and outlet pipes just below liquid level. The mock-up contained corresponding syphon holes. The early suction line peak, at about 11 sec, is due to channeling of the pulse, injected on the tank surface directly to the suction line syphon hole which is near the surface. This observation was made repeatedly at low flow rates but not at high flow rates. The peak was eliminated by covering the holes. This double peak is another manifestation of nonhomogeneous tank behavior.

The short time data discussed in the foregoing indicates that a low limit should be set on the flow rate at about 100 gal/min in the SCTF.

Open Loop, Long Time Studies

As discussed in the theory section, comparison of the dilution response of the tank to the dilution response of an ideal mixer provides an indication of the long time homogeneity of the mixing tank.

The following data were generated with an open loop configuration, i.e., the nozzles were fed fresh tap water and the suction line was fed to the drain. After a tracer impulse, the tank gradually returned to the tap water concentration. The dilution behavior was compared to Equation (9) by plotting the log of the probe response against time.

The short time response of the open loop system did not differ significantly from the closed loop responses in terms of rise times and response times.

It was observed that, by 50 sec, all runs had entered a dilution cycle. Therefore, the peak height at 50 sec was taken as the initial concentration, and all readings standardized to it and expressed as fractions of the "initial concentration."

Design System Behavior

A flow rate of 7.7 gal/min (corresponding to about 200 gal/min in the SCTF) with a nozzle diameter of 0.35 in. was considered as the "design system," and a number of runs were made to determine the dilution behavior.

Figure 11 shows a semi-log plot of the response of the design system. Two different deflector depths are shown for both in-tank and system bypass injections. A number of observations evident from the data were that:

- There is no consistent difference between the in-tank and system bypass injection cases.
- There is no consistent difference between the 2-in. and 4-in. deflector depth.
- An ideal mixer dilution line represents the data within the experimental error.
- The scatter of data from run to run is considerable but the scatter of data within a given run is small.

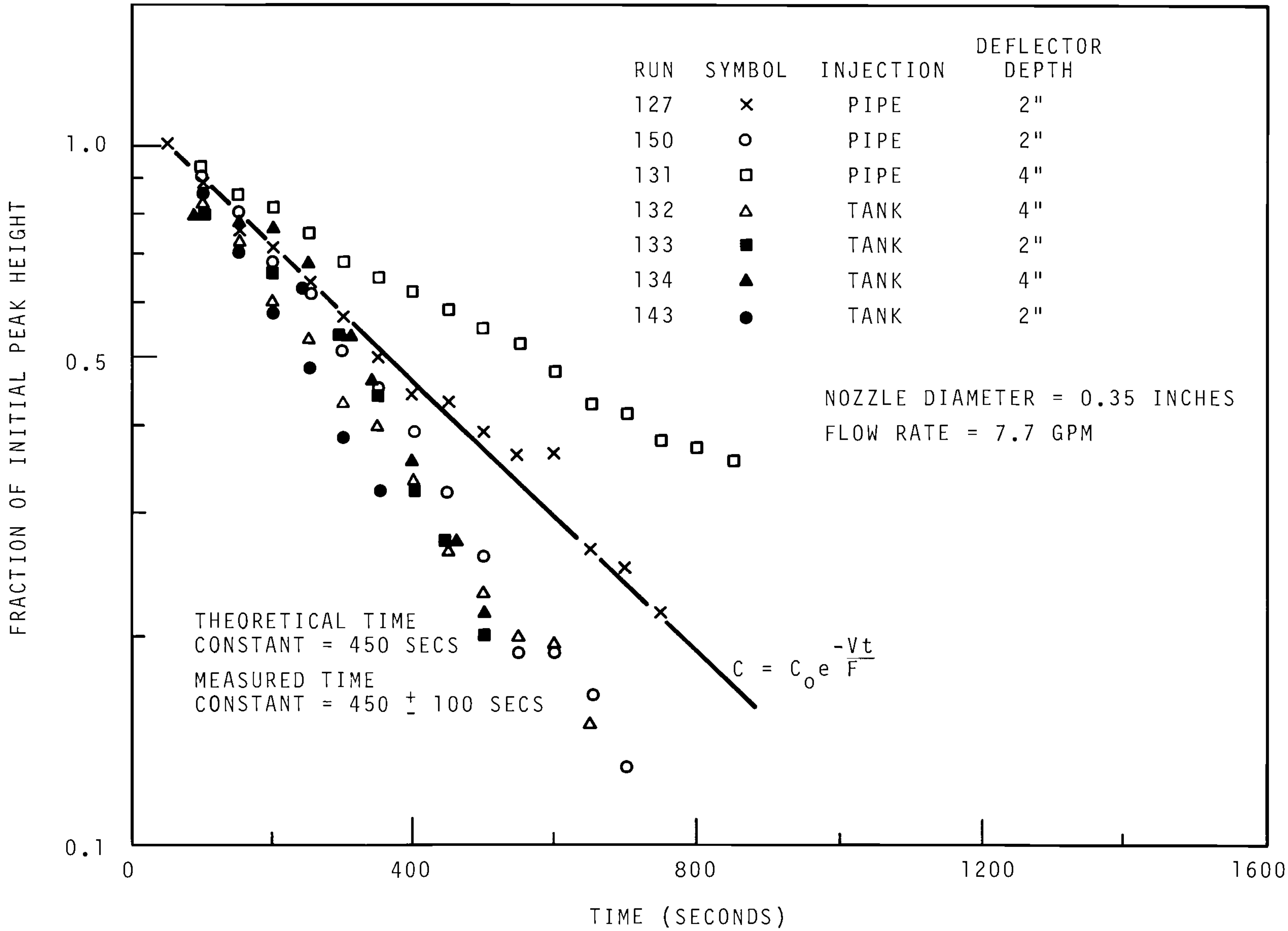


FIGURE 11. SCTF Mixing Mock-Up Open Loop Response of Suction Port

The last observation is not surprising since neither the instrumentation or the experimental technique was very accurate. The main objective of the study was to determine gross problems, gross departure from ideality, etc. The data were sufficiently accurate to establish reasonable homogeneity of the tank throughout dilution.

Effect of Flow Rate

Figures 12, 13, and 14 show mixer behavior close to the ideal over a wide range of flow rates. These data confirmed earlier conclusions that a flow rate as low as 4 gal/min could be used.

Effect of Nozzle Size

Two other nozzle sizes, 0.38 and 0.26 in. in diameter, were investigated to establish the effect of off-standard nozzle size.

Figures 15 and 16 show that a 0.38-in. nozzle worked well at both high and low flow rates. Therefore, considerable erosion of the nozzles would not result in a degradation of the mixing behavior.

The smaller nozzle (0.26-in.) behaved very well at 4.4 gal/min as shown in Figure 17.

Some departure from ideality displayed by the small nozzle at 7.7 gal/min may be due to data scatter. The results of the runs shown in Figure 18 remain somewhat of a puzzle. Although such results would indicate channeling, i.e., the full volume of the tank in use, observation of this case (including observation of high speed movies) showed no evidence of channeling or gross heterogeneity.

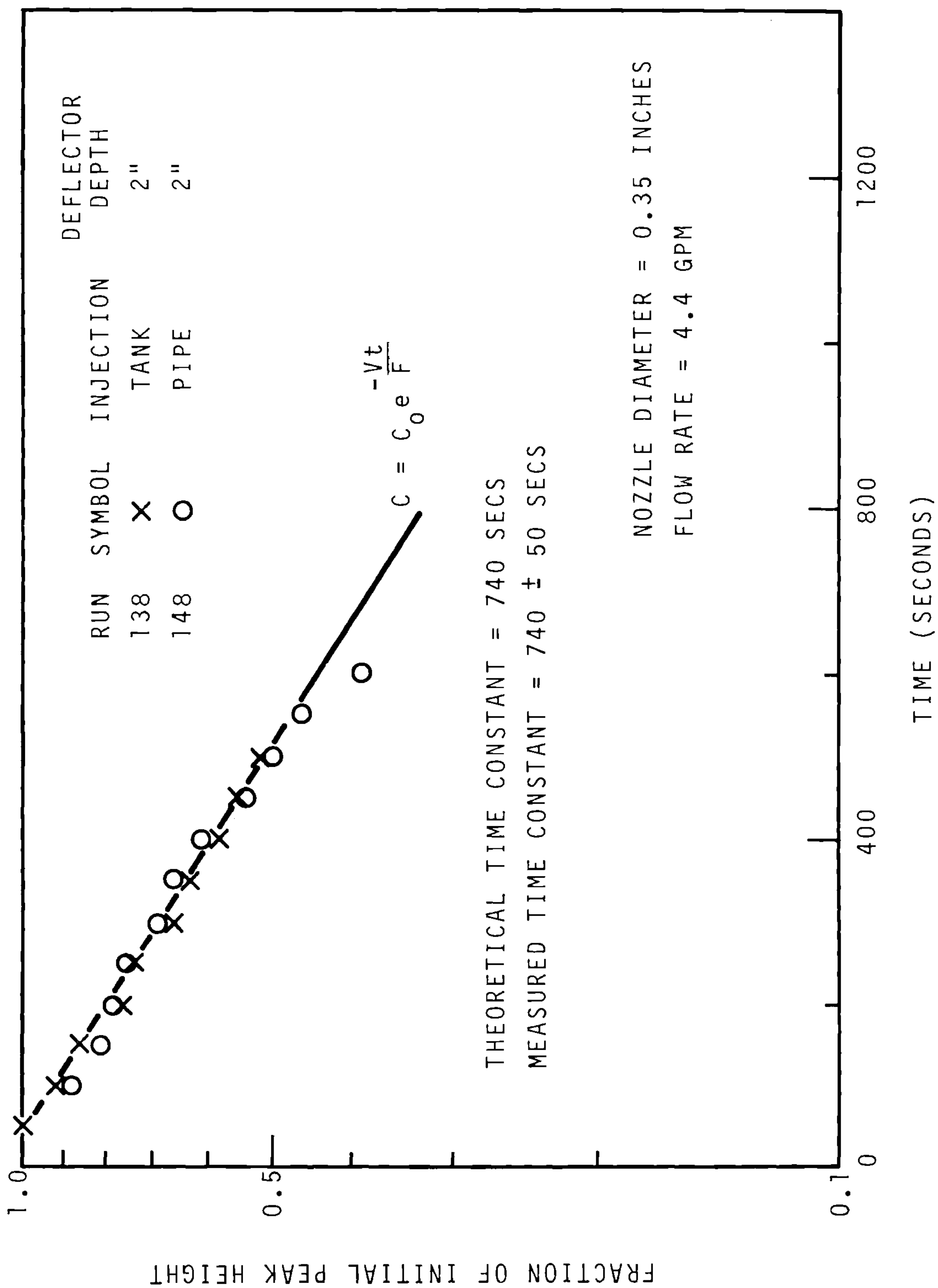


FIGURE 12. SCTF Mixing Mock-Up Open Loop Response of Suction Port

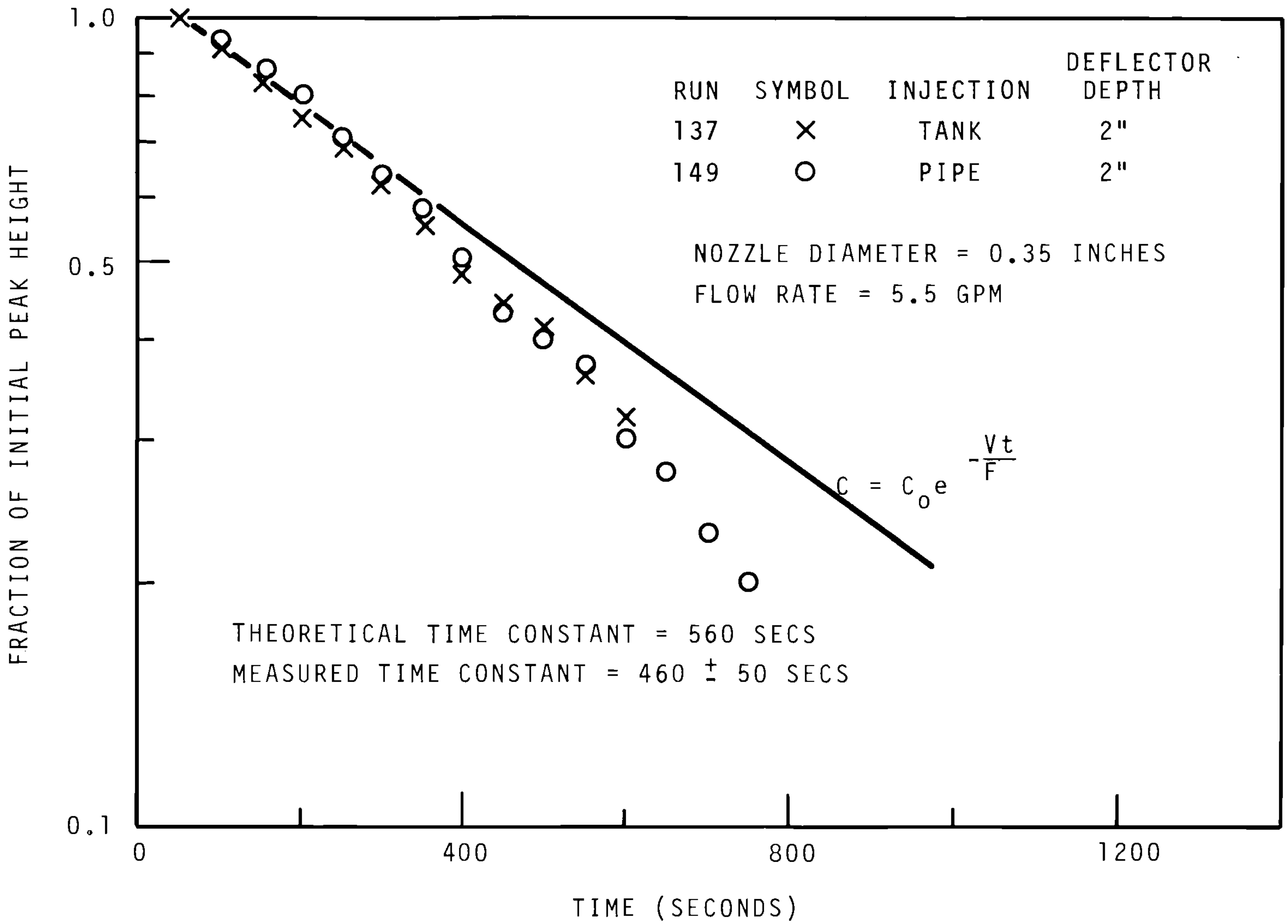


FIGURE 13. SCTF Mixing Mock-Up Open Loop Response of Suction Port

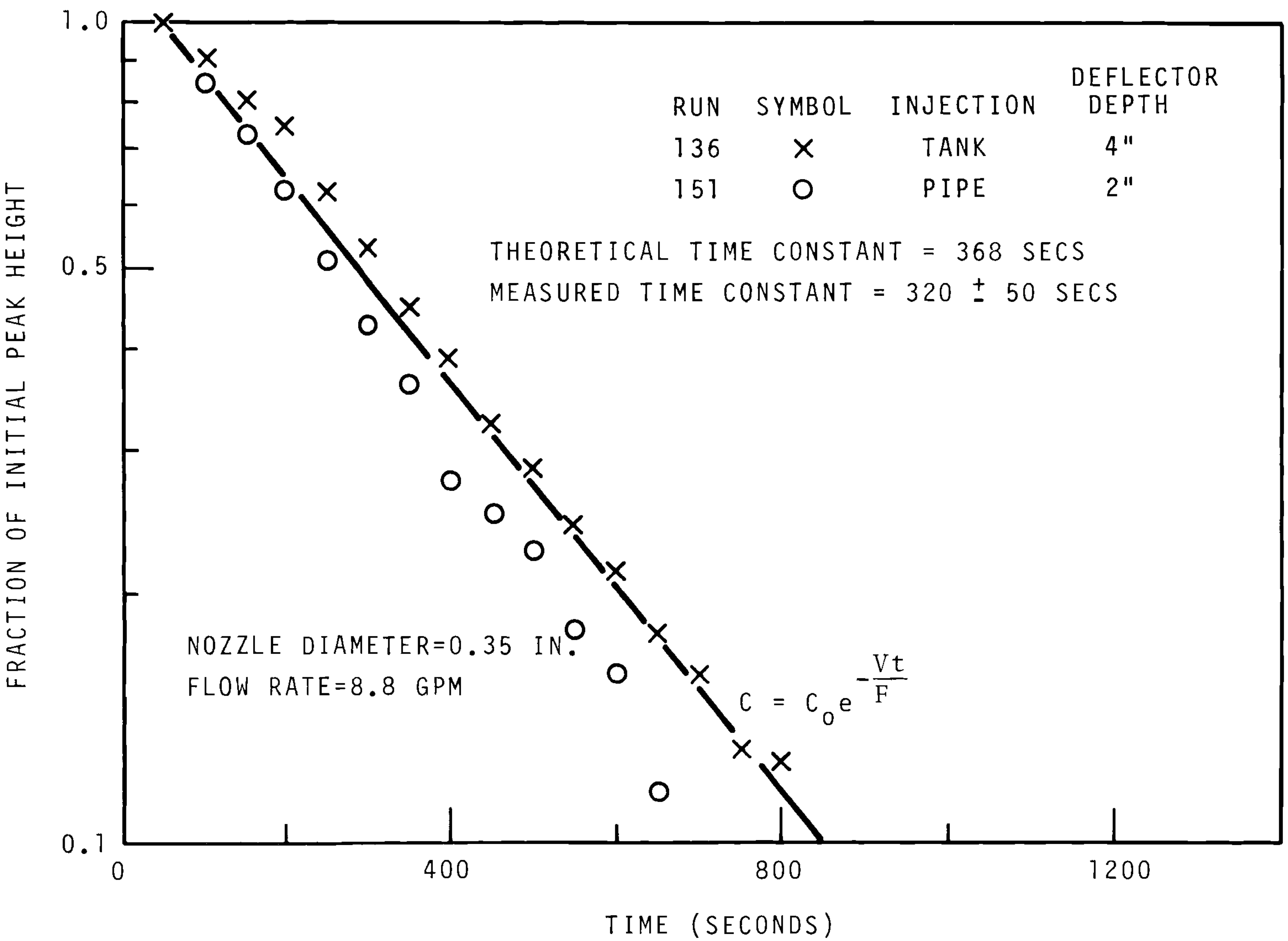


FIGURE 14. SCTF Mixing Mock-Up Open Loop Response of Suction Port

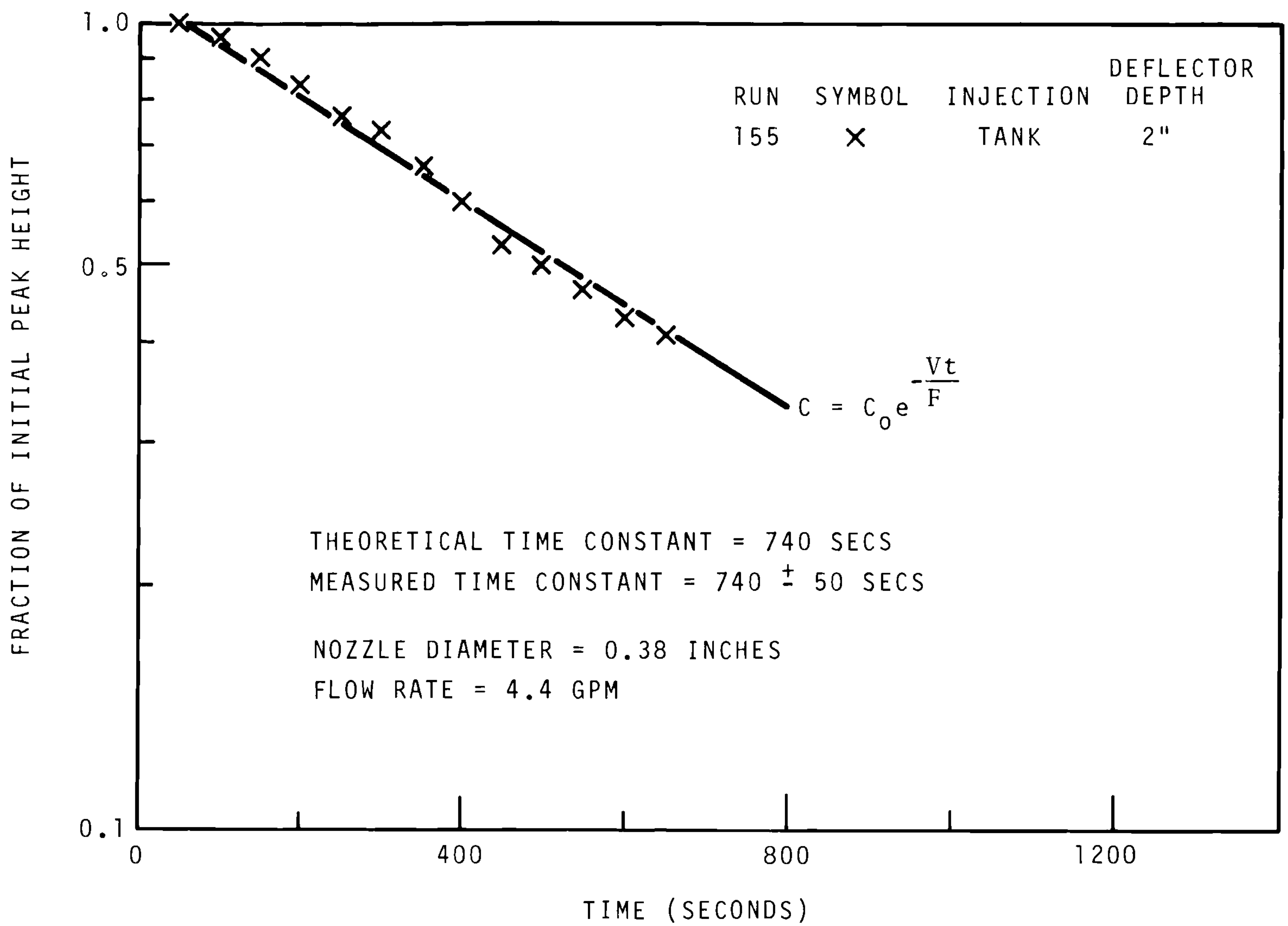


FIGURE 15. SCTF Mixing Mock-Up Open Loop Response of Suction Port

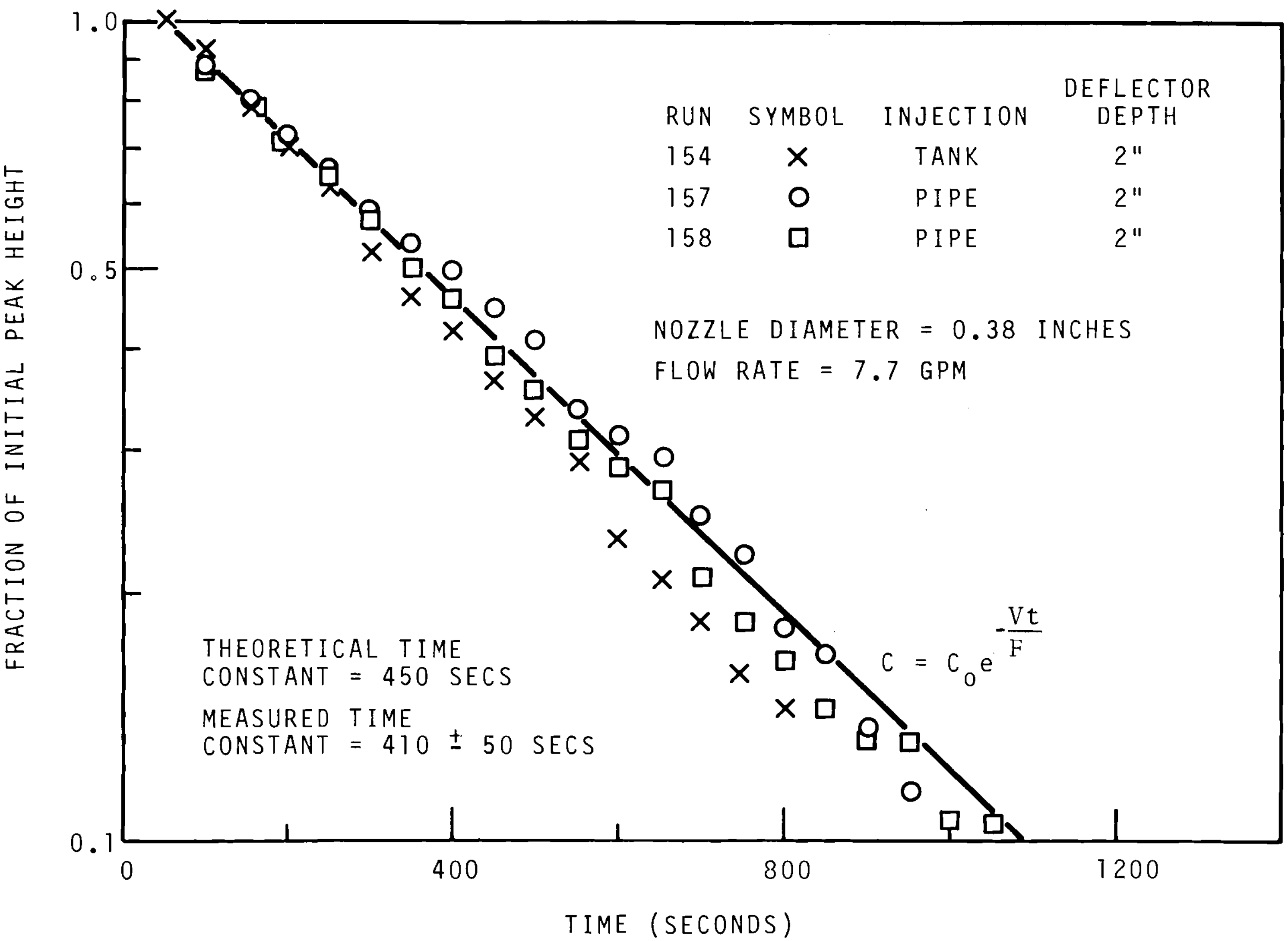


FIGURE 16. SCTF Mixing Mock-Up Open Loop Response of Suction Port

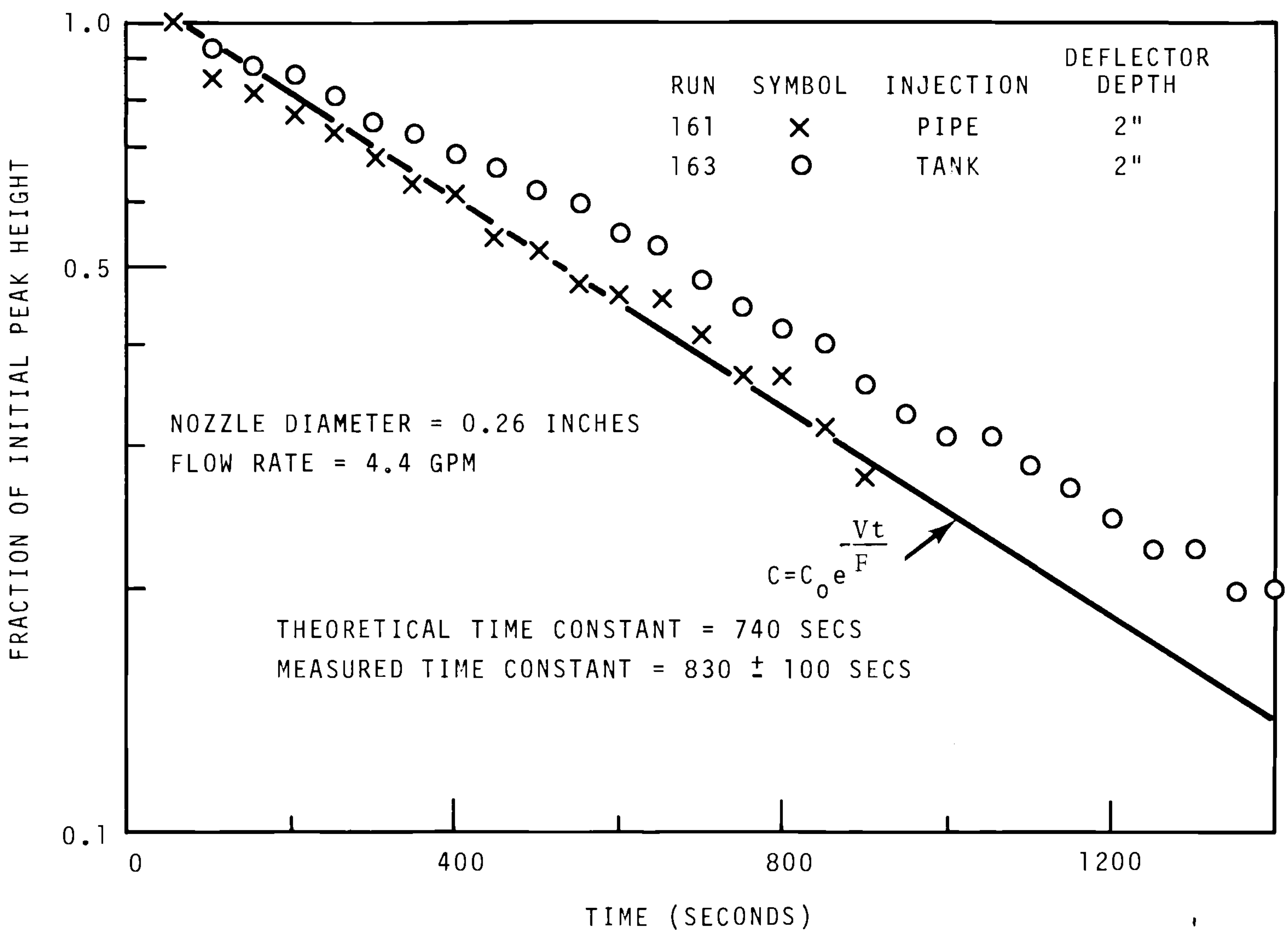


FIGURE 17. SCTF Mixing Mock-Up Open Loop Response of Suction Port

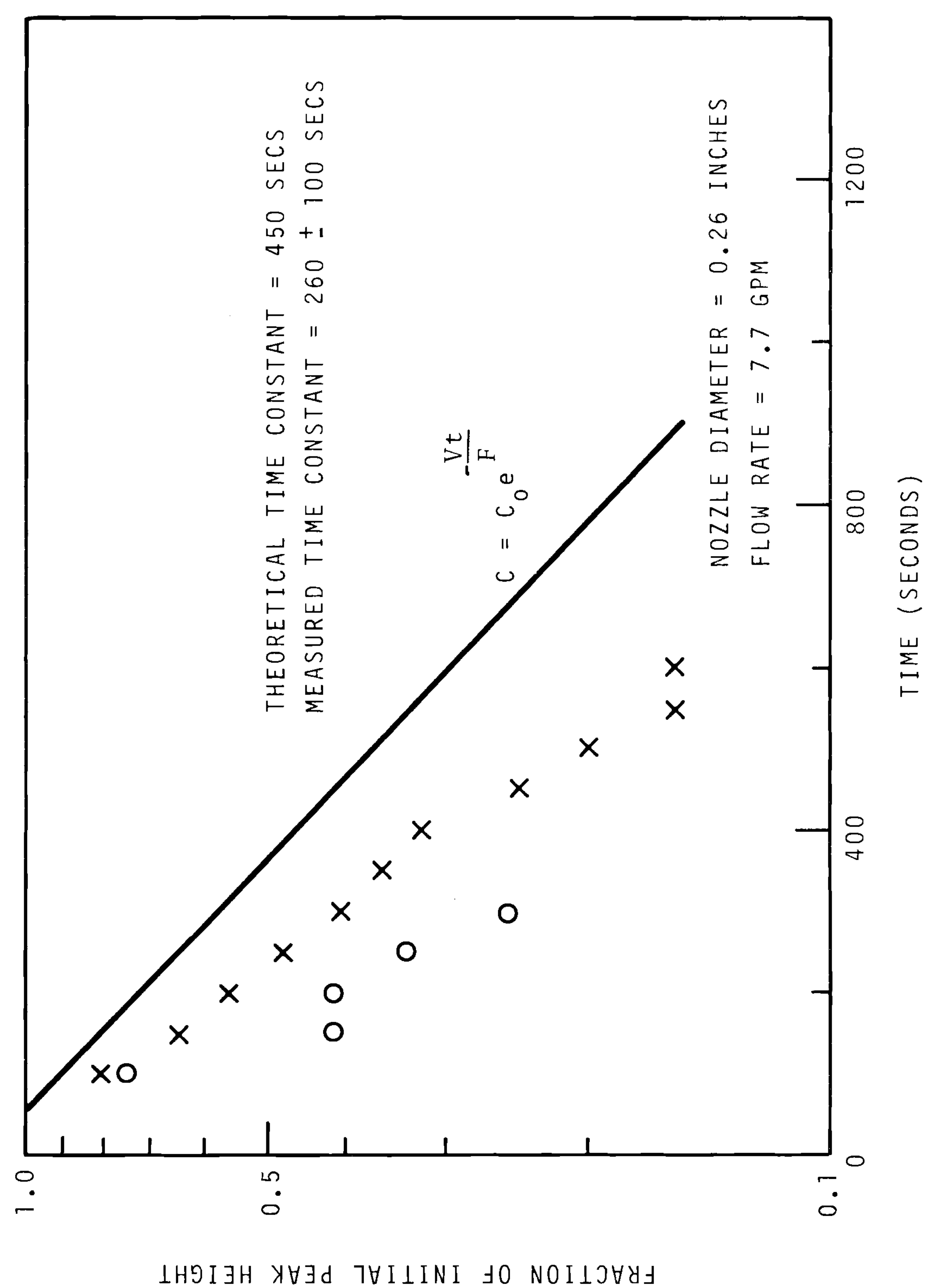


FIGURE 18. SCTF Mixing Mock-Up Open Loop Response of Suction Port

Conclusions

In general, the open loop test showed that the mixing results were concluded to demonstrate satisfactory operation of the mixing system in meeting the functional criteria required over a wide range of conditions. Conclusions based on the closed loop tests were confirmed by the open loop tests.

The system was characterized by a fast recovery time (less than one minute) from an initial transient, a homogeneous condition at all times, good surface renewal without visible gas entrainment, and no operational problems such as cavitation, high pressure drop, or critical tolerances. No "fine tuning" effect in the design or operation of the mixing reservoir is discernible because of system operating capabilities over a wide range of conditions.

DESIGN RECOMMENDATIONS

Before the design is fixed for the Sodium Chemical Technology Facility (SCTF), small scale proof testing of the mixing system in sodium can possibly be achieved. Figure 19 is a sketch of the basic mixing system and Table I gives the recommended dimensions. Results and conclusions of this study have led to the following design recommendations:

- Nozzle Changeout and Deflector Plate Adjustment Capability

  The nozzles should be cylindrical with length, lj, and diameter, dj, as indicated. The nozzle cluster and pressure line are to be constructed so that the nozzles can be disconnected from the pressure line and withdrawn together with the deflector plate through a port of sufficient size in the top of the tank. To facilitate this requirement, the deflector plate and nozzle cluster may be connected by three vertical rods 3/8-in. or less in

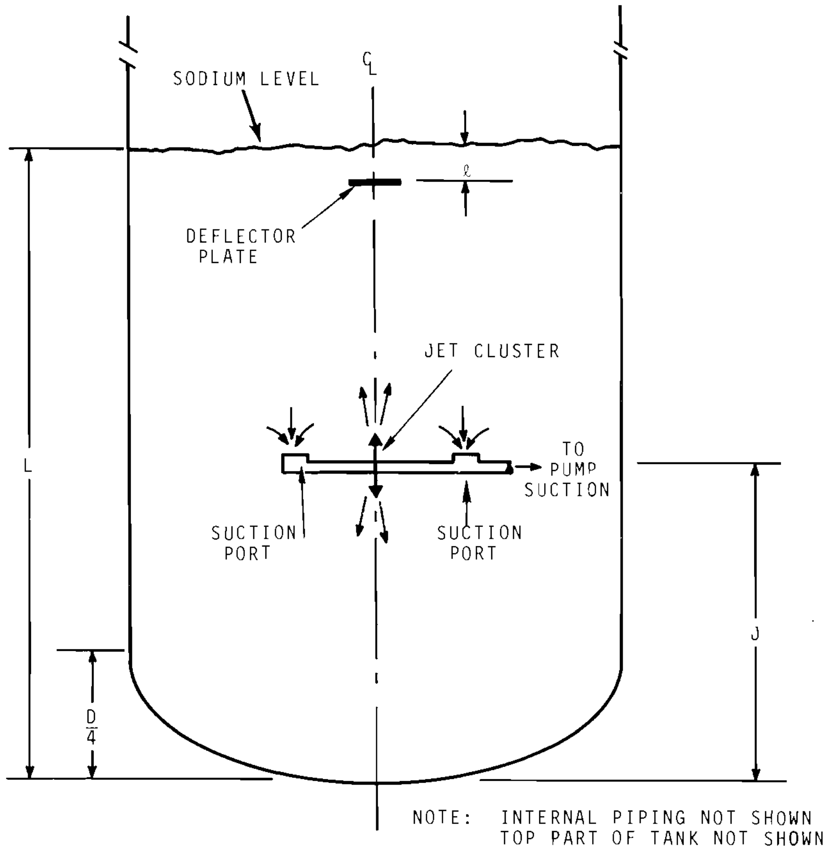
TABLE I. Sodium Mixing Reservoir: SCTF Specifications of Dimensions and Tolerances

Dimension	Reduced Value	SCTF Value Preliminary
L	--	7.5 ft
D	--	6 ft
ℓ	0.067 L	12 in.
r	0.042 D	3 in.
J	$0.5(L-\ell)$	3.25 ft
P_1	0.333 D	24 in.
P_2	0.333 D	24 in.
ℓ_j*	5.0 d_j	5.25 in.
d_j*	--	1.05 in.
d_p*	0.042 D	3 in.
L/D	1.25	1.25

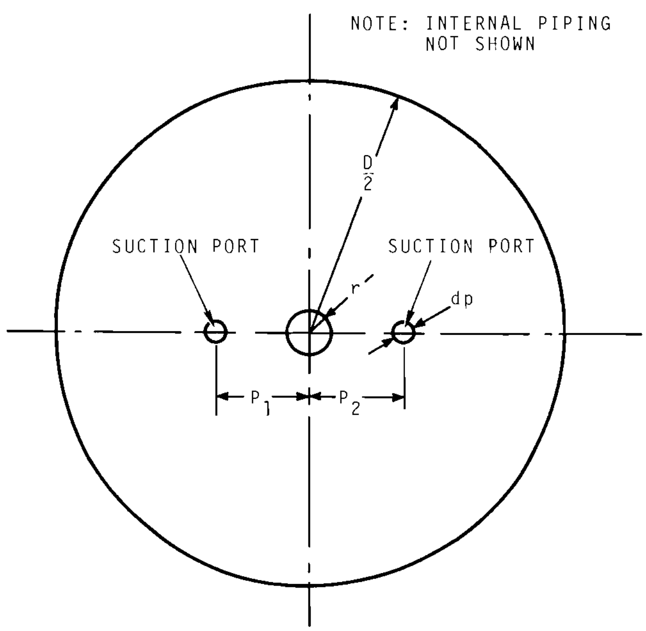
* ℓ_j = *jet length*
* d_j = *Jet diameter*
* d_p = *suction port diameter*

Tolerance Values

Item	Reduced Tolerance	SCTF
Jet centering	±0.01 D	±0.3 in.
Deflector centering	±0.01 D	±0.3 in.
Jet vertical	$\pm \text{Arc Tan}(\frac{r}{L})$	±2°



19a. ELEVATION VIEW (NO SCALE)



19b. PLAN VIEW (NO SCALE)

FIGURE 19. Sodium Mixing Reservoir (PAL and SCTF)

diameter (SCTF) arranged about the perimeter of the jet cluster and deflector plate. The deflector plate depth should be as readily adjustable as other requirements in the reservoir will permit.

- Suction Ports

Suction ports need not be cylindrical as shown in Figure 19, but must be pointed upward and have the given dimensions. Holes cut in the top of a horizontal pipe run would be acceptable. It is suggested that the suction line be made part of the pressure line nozzle cluster holder assembly for better structural stability and strength.

REFERENCES

1. H. J. Bommelburg. *Evaluation of the Applicability of Water Model Testing to Liquid Metal Engineering Problems*, LMEC-68-4. Atomics International, Canoga Park, California, February 26, 1968.

2. H. Fossett and L. E. Prosser. "The Application of Free Jets to the Mixing of Fluids in Bulk," *Trans. Inst. Mech. E.* vol. 160, pp. 224-232. 1949.

3. H. Fossett. "The Action of Free Jets in the Mixing of Fluids," *Trans. Instr. Chem. Engrs.*, vol. 29, pp. 322-332. 1951.

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