

# Flow Studies by Water Table Technique for Incinerator Furnaces

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## INTRODUCTION

The basis of the principles of similitude in fluid motion lies in the assumption that when a force is applied to a fluid mass, the resulting acceleration assumes a direction dependent upon the boundaries of the system and the physical properties of the fluid.

Boundaries take into account the shape, size and location of all components in the system.

Physical properties include specific weight, density, viscosity, surface tension and compressibility.

The basic relations of similitude require equal ratios of dimensions, flows and forces for corresponding points in two systems.

For quantitative analysis three-dimensional models are required with consideration given to all the above factors.

For qualitative analysis several forms of two-dimensional models can be used and some of these are relatively inexpensive since all that is required is geometric similarity. The two have been the smoke table and the water table.

The smoke table had certain disadvantages which led to the development of another means of making two-dimensional flow studies, i.e., a water table.

We will describe a two-dimensional water table and discuss some test work as applied to the study of an incinerator furnace design.

The chief advantages of the water table techniques are as follows:

- 1) The time required to produce a test model is relatively short. Even complicated designs are easily modeled by forming thin gage metal strips to the desired outline.
- 2) Relatively small quantities of inexpensive material are used in making the model.
- 3) Flow patterns developed in a particular model are clearly defined by photographs taken at long exposure rates. They appear to be much sharper than similar patterns shown in photographs of smoke table tests.

The technique utilizes an open channel water table method for obtaining quick answers to air or gas flow problems where a two-dimensional study would be adequate.

## DESCRIPTION OF APPARATUS

A general view of the "dry" water table with the arrangement of a gas duct model installed prior to testing is shown in the photograph, Figure 1. Overall dimensions are 6 ft. in length by 3 ft. - 6 inches in width by 3 inches in depth.

The water table can be mounted in a portable stand as shown in Figure 2. The top level of this stand provides facilities for mounting a camera that is used to photograph flow conditions during a test.

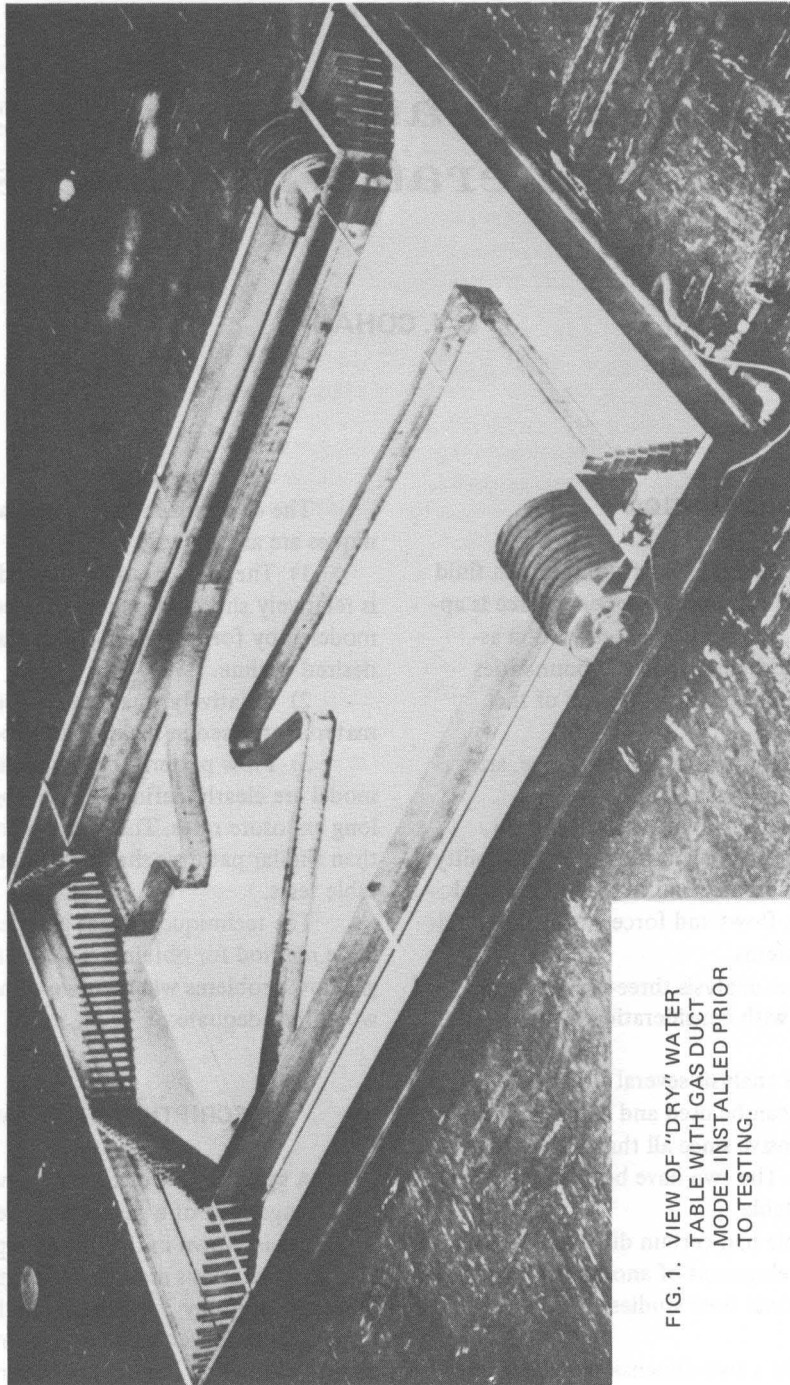
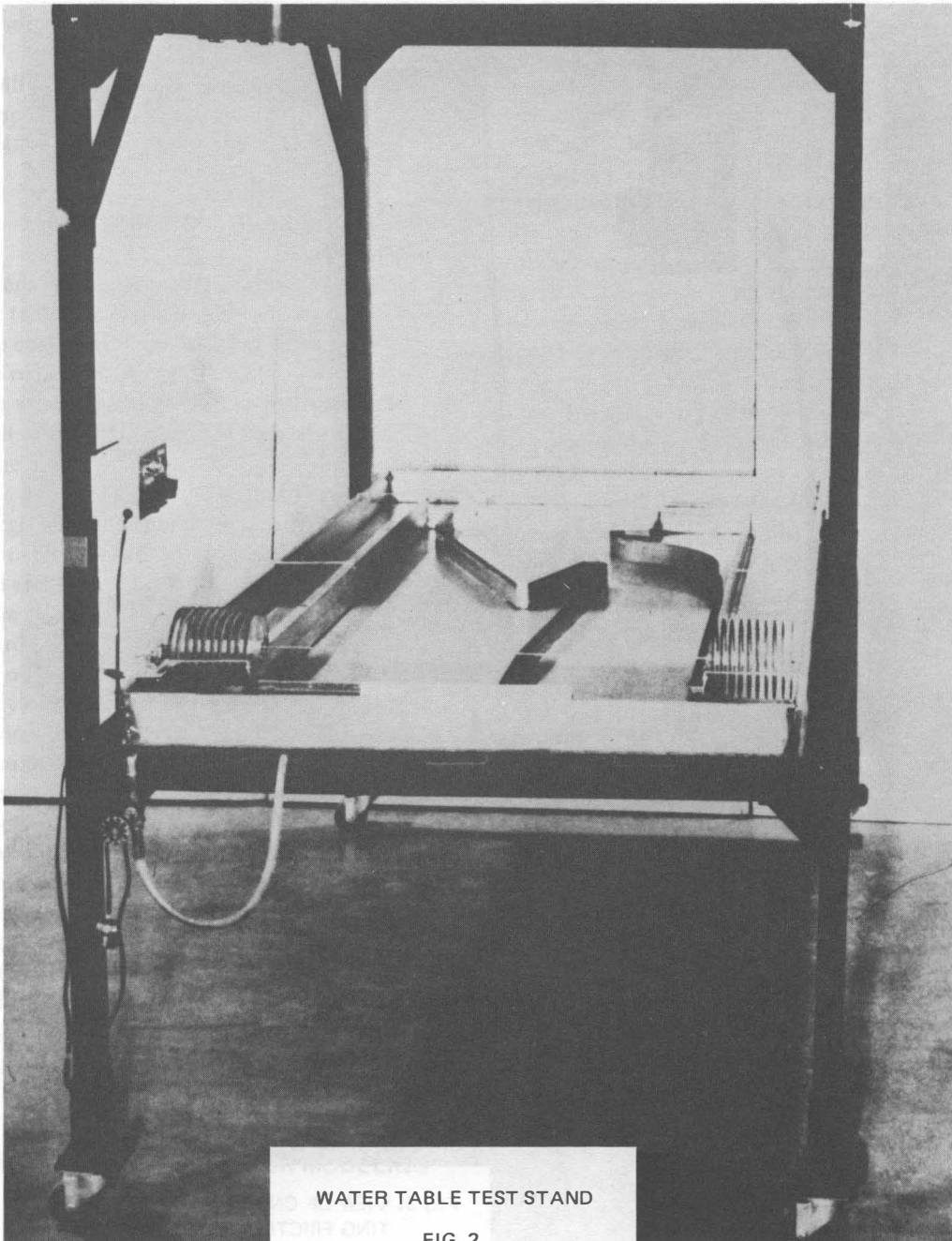


FIG. 1. VIEW OF "DRY" WATER TABLE WITH GAS DUCT MODEL INSTALLED PRIOR TO TESTING.



WATER TABLE TEST STAND  
FIG. 2.

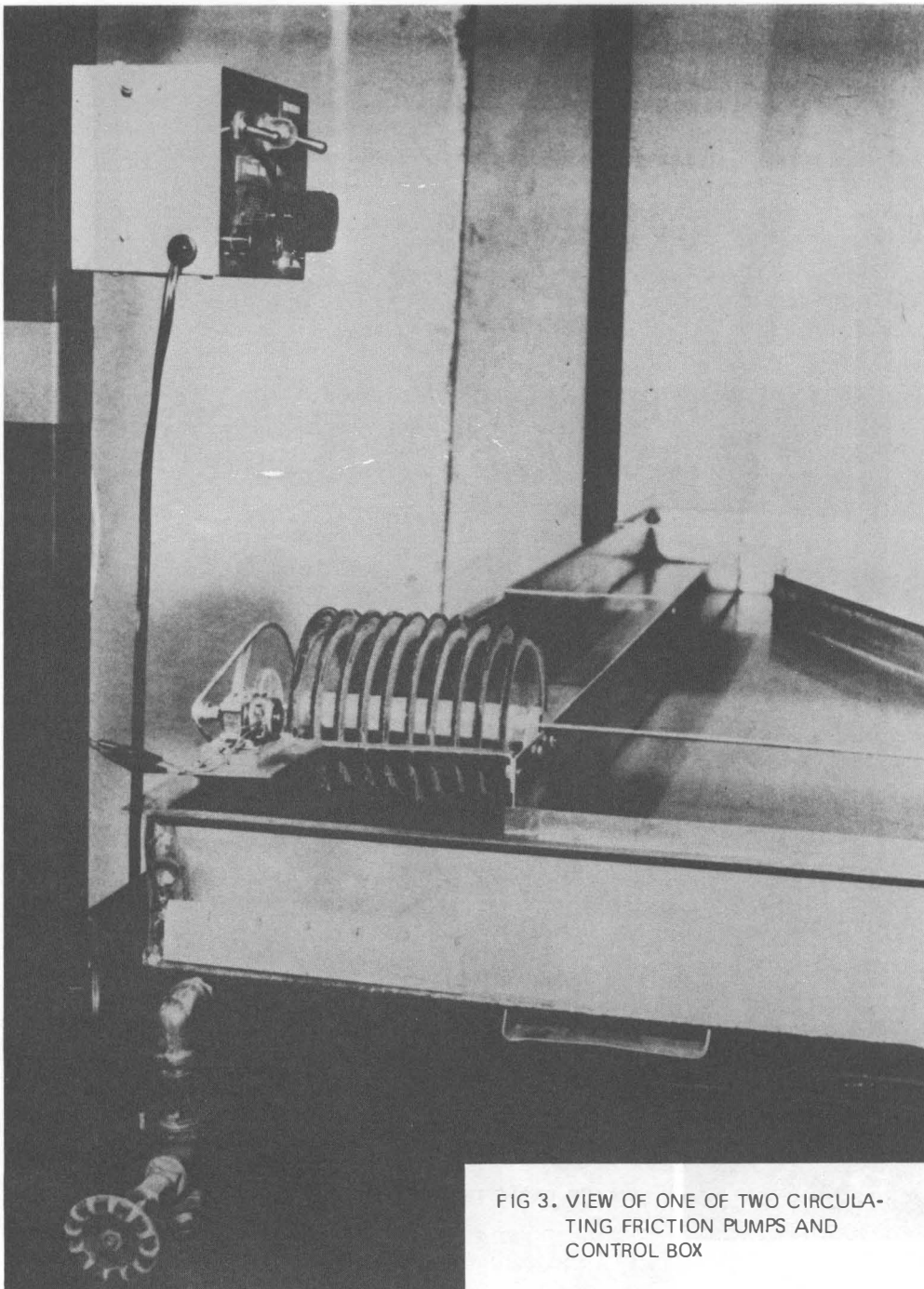


FIG 3. VIEW OF ONE OF TWO CIRCULATING FRICTION PUMPS AND CONTROL BOX

Figure 3 is a close-up photograph of one of two electrically driven friction pumps that produce flow of the test fluid through the closed test circuit. Both pumps are connected by a common shaft and therefore, rotate at the same rate of speed. The pump speed, however, may be varied by adjusting the current load on the pump motor. For purposes of flexibility, both pumps may be combined to form one large pump, and the pumps, or pump, may be located at any point across the width of the water table.

### TESTING PROCEDURE

After a particular model has been installed in the water table, the channel side surfaces of the model are coated with a solution of silicone and xylene to reduce surface tension.

The water table is then filled with city water to a height of approximately 1/4 inch below the top edge of the model.

Blue dye is added to the water to produce a dark background, and aluminum powder is then sprinkled onto the dyed water and allowed to distribute evenly over the surface.

Flow of the test fluid travels from the two pumps through canals that extend part way along each side of the model area. The width of these canals may be varied to accommodate the particular size of model being tested.

Turning vanes located at the end of the canals divert the flow back into the model area, and are used only to provide the desired entrance condition.

Flow leaving the model continues on to the inlet side of the pumps, thus completing the closed test circuit.

Each particle of aluminum is carried along through the model at a rate corresponding to the flow of fluid in its respective area.

After flow conditions have been established, photographs having relatively long exposure rates are made of the test as a form of record.

### DESCRIPTION OF INCINERATOR MODELING TECHNIQUE

A model test of a proposed incinerator design was run to provide information concerning the general flow distribution in the unit. An inspection of the initial results suggested several modifications which were also tested. A two-dimensional water table model of the incinerator side elevation was used to produce the information.

The refuse incinerator design as conceived, Figure 4, provides a refractory furnace with three traveling grate stokers. Incoming refuse from a holding and blending silo is fed through a charging chute to the first stoker. Here it is dried and ignited. An ignition arch located above this grate is used to initiate and stabilize combustion. The refuse then drops to the grate of the main stoker where the incineration occurs. Final burnout is accomplished on a third stoker which discharges to an ash hopper. Air flow may be varied in each stoker to accommodate the material fed. Provision for recirculation of hot gas is made to improve drying, also overfire air is introduced to increase turbulence and insure burnout of volatile matter. The hot gases travel from the incineration zone to a secondary zone where, depending upon operation, combustion is completed and/or the hot gas temperature is reduced by spray water. The secondary chamber also provided a drop-out zone for the major portion of entrained ash and cinder particles.

By use of a water table flow patterns can be produced in a two-dimensional model that are representative of flow in a prototype. This technique allows rapid screening of a number of shapes and configurations. Permanent photographic records may be made of the flow distribution for each model or test run. The flow patterns produced by water table techniques will provide a conservative indication, eddies and areas of flow separation are over emphasized in the model.

The envelope of the incinerator model was made from strips of sheet metal. Strips of perforated plate were used to form weirs which simulate the stoker grates. All dimensions were scaled directly from study drawing. A model of the side elevation was made since it was judged that this was the pertinent geometry influencing flow. It was assumed that flow would turn upward after leaving the secondary chamber and the model arranged accordingly.

### DESCRIPTION OF CONFIGURATIONS TESTED AND RESULTS

The modifications described as follows were left in place for subsequent tests except as noted. Refer to Figure 4.

Test 1. This test was run on the as proposed study indicated in Figure 4. Figure 5 shows the flow patterns produced in the model. Flow in the primary combustion furnace was judged to be good. Flow in the secondary chamber indicated an undesirable

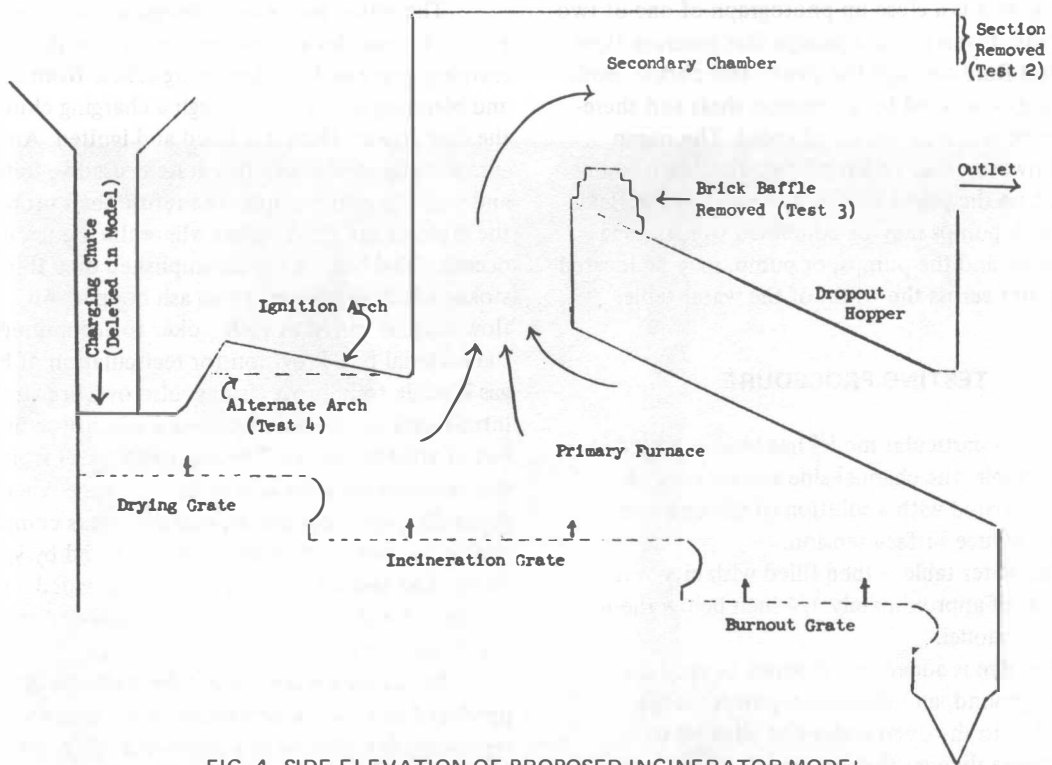


FIG. 4. SIDE ELEVATION OF PROPOSED INCINERATOR MODEL

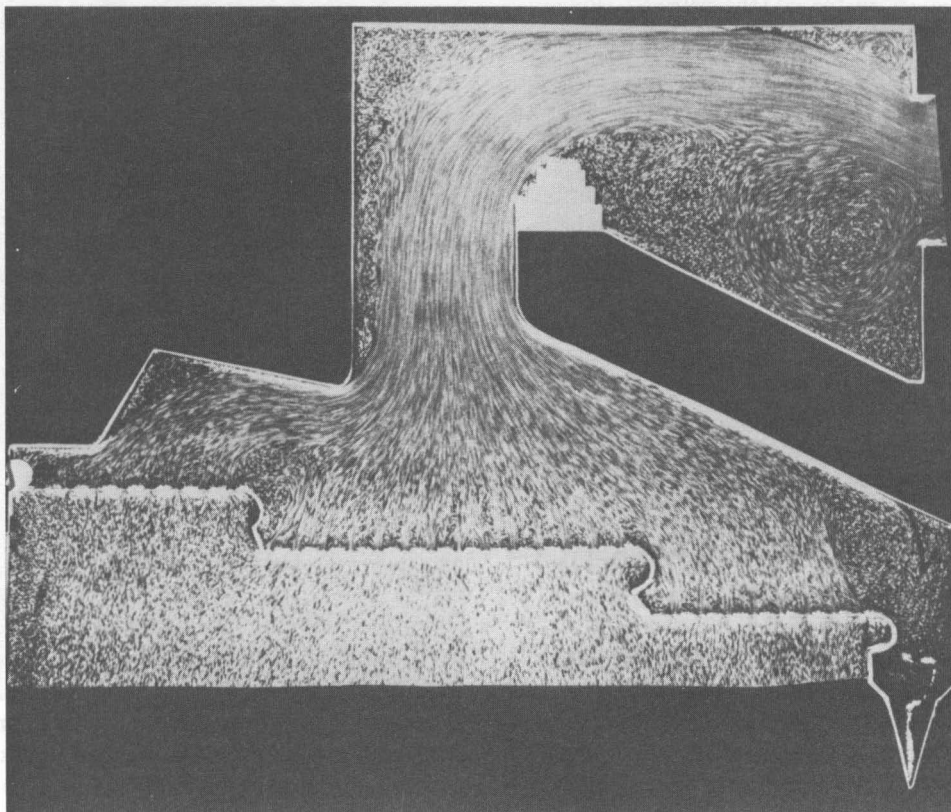


FIG. 5. FLOW DISTRIBUTION FOR TEST 1

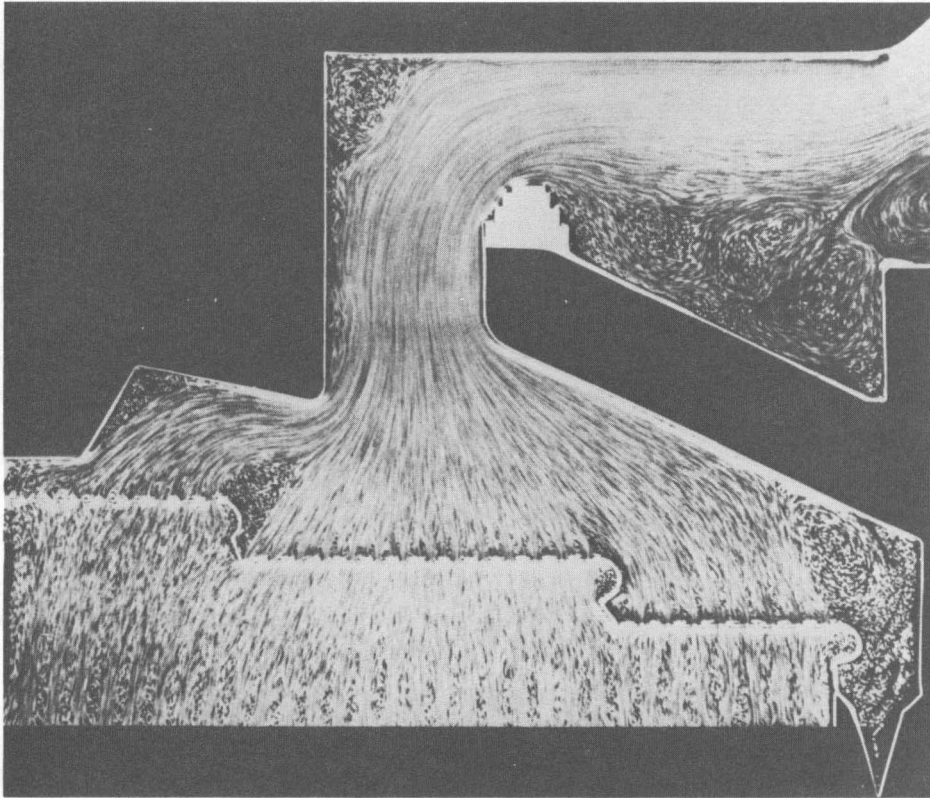


FIG. 6. FLOW DISTRIBUTION FOR TEST 2

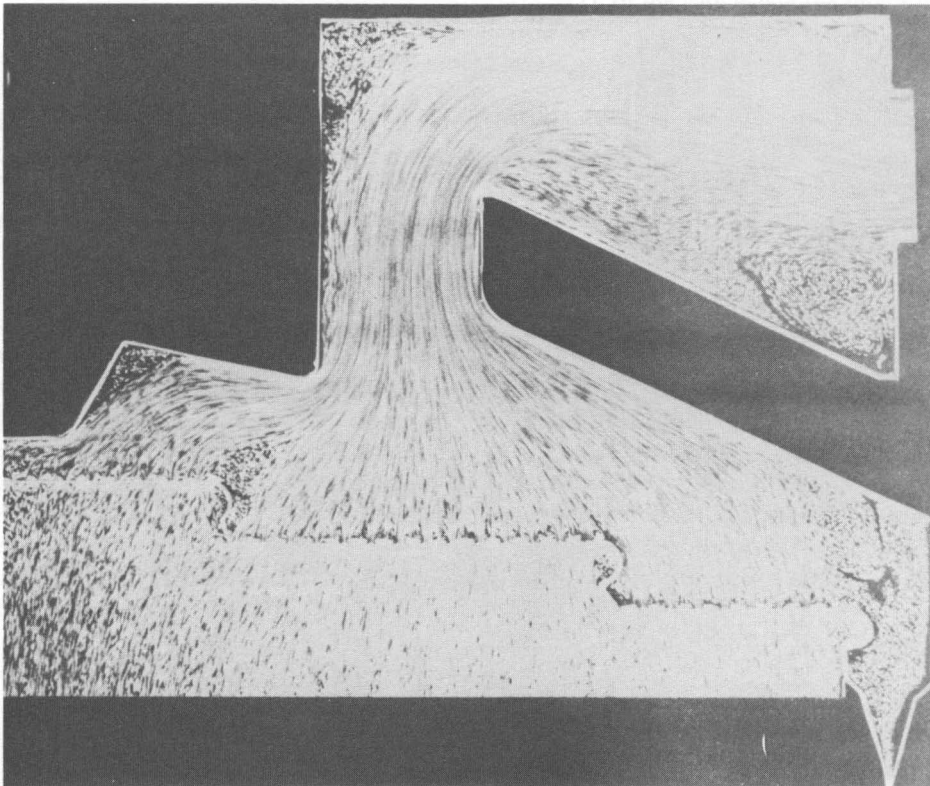


FIG. 7. FLOW DISTRIBUTION FOR TEST 3

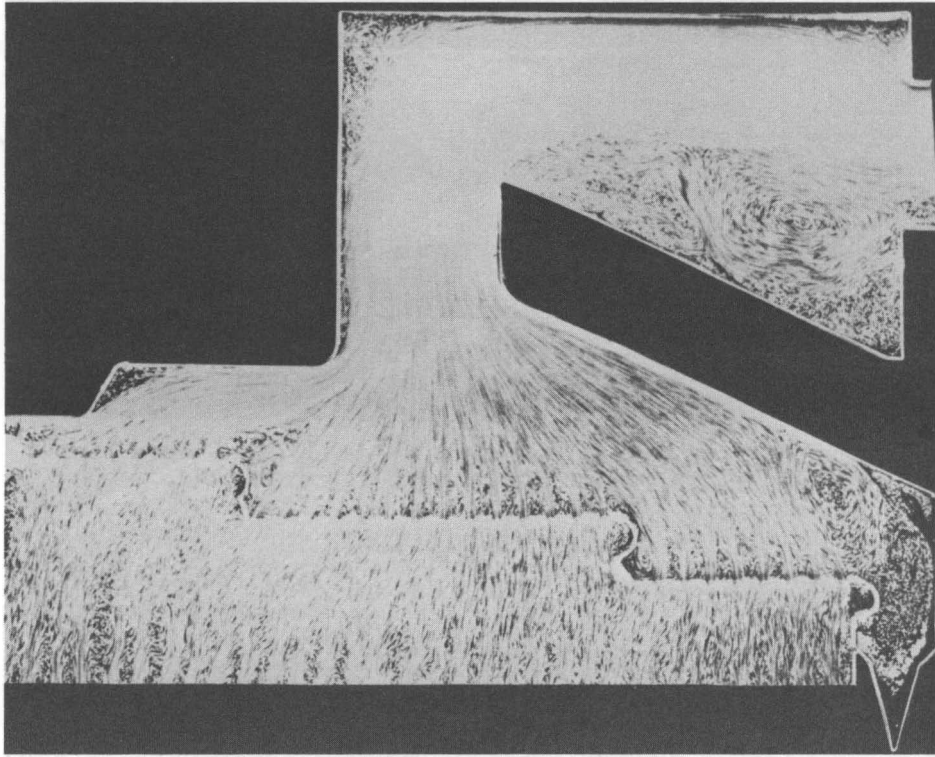


FIG. 8. FLOW DISTRIBUTION FOR TEST 4

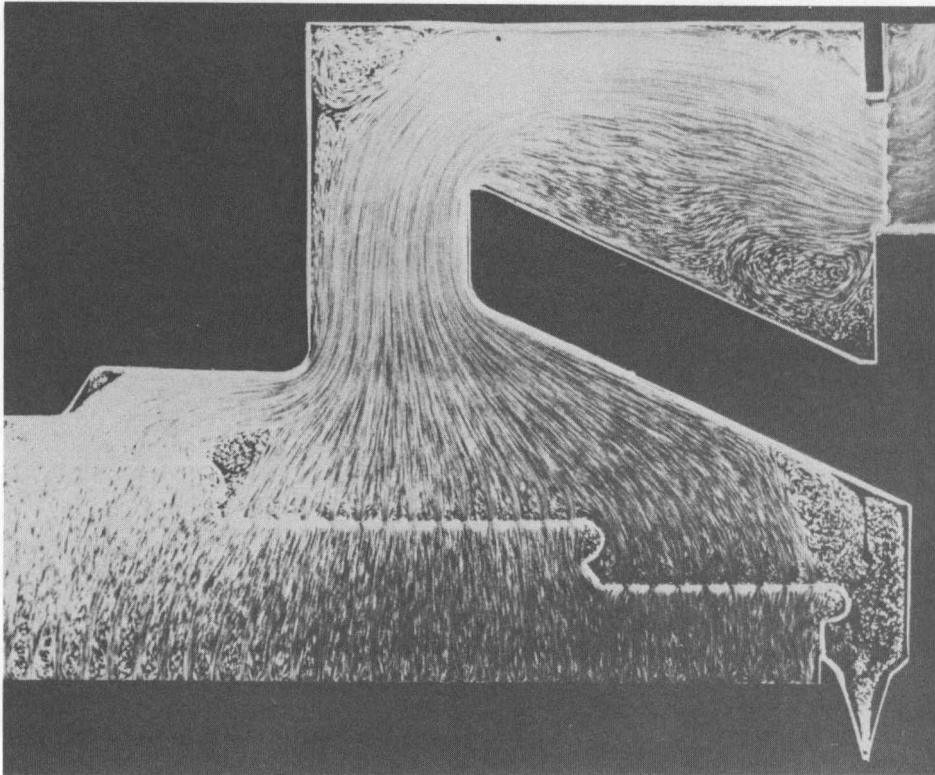


FIG. 9. FLOW DISTRIBUTION FOR TEST 5



velocity gradient with the highest velocities near the roof. High velocities here would tend to prevent dropout of cinders and ash and possibly transport entrained materials out of the chamber before burn-out is completed. Low velocities were noted at the bottom of the outlet plane. The dropout hopper area of the secondary chamber indicated very low velocity eddies which was a desirable feature.

Test 2. A test was run with an enlarged outlet plane on the secondary chamber. This enlargement was accomplished by removing the upper portion of the existing outlet. The purpose of this test was to demonstrate that this arrangement would not improve flow distribution or reduce the velocities along the roof of the secondary chamber. As indicated on Figure 6 no improvement was noted so the outlet plane was restored to its' original state for subsequent tests.

Test 3. A test was made with the brick baffle at the inside of the turn into the secondary chamber removed and the outlet plane restored. Removing this baffle increased the area of the flow channel entering the secondary chamber, hence reducing the average velocity at this point. As may be seen in Figure 7 this also reduced the velocity gradient noted in the previous test. Flow distribution was judged to be satisfactory in this configuration.

Test 4. Sloped ignition arch modified to a horizontal arch. Due to construction details it was felt that a horizontal arch would be more practical than a sloped arch. As shown in Figure 8 this did not influence the flow distribution except directly under the arch. There was no adverse effect noted, therefore this arrangement was also judged to be acceptable.

Test 5. Resistance added at the outlet plane. A weir was placed in the model at the secondary chamber outlet plane to simulate the resistance to flow that the system would sense due to dampers, flow distributors, mechanical dust collectors, etc., downstream from this outlet. It is felt that performance of an actual operating unit will approach the flow distribution shown in Figure 9. The addition of resistance at the outlet plane produced a general smoothing of velocity distribution in the secondary chamber. A greater portion of the chamber receives through flow

and peak local velocities have been reduced which should improve cinder dropout.

## STUDY CONCLUSIONS

Based on the flow distribution demonstrated in the water table model the flow envelope tested in Tests 3, 4 or 5 were judged to be acceptable. Either a sloped or horizontal ignition arch can be used. The decision therefore becomes a matter of design economics. The brick baffle should be eliminated to insure more uniform flow velocities in the secondary chamber.

The above conclusions do not consider absolute velocities through the system and their effect on ash and dust entrainment, erosion, and/or gas residence time for completion of combustion.

## SUMMARY

1) The use of cold flow models to study flow distribution in prototype furnaces is justifiable and practical when the controlling similarity criteria for a given problem are recognized and provided for in the model work.

2) In the case where the interest is solely in flow distribution, it is necessary only to maintain exact geometric similarity of the flow envelope.

3) The modeling techniques presented have proved to be a direct approach to the solution of flow distribution problems which do not lend themselves to analytical solution. They provide means by which complex flow patterns may be studied and understood. They are not considered a panacea. They can be misapplied, as have other techniques, and provide erroneous results. This is particularly true of 2-D smoke table and water table. They should not be used for the solution of three-dimensional work.

4) Visual observation of flow phenomena, either by direct observation or study of still photographs and movies, is a tremendous aid to the understanding of flow distribution patterns. Any comprehensive flow modeling program should consider visual techniques.