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SUBJECT: A Flow Visualization Loop For Flow Pattern Studies in Reactor Models.

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FROM: W. R. Nixon and H. A. MacColl

SUMMARY

The installation of a milling yellow flow visualization loop has been completed. Milling yellow is an organic dye which when dissolved in water exhibits flow double refracting properties that permit visual observations of flow patterns. The equipment is to be used in qualitative studies of flow patterns in various models of reactor vessels and components.

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INTRODUCTION

The flow visualization loop was constructed for use as an additional tool in qualitative studies of flow patterns in various models of reactor vessels and components. The loop utilizes a milling-yellow solution as the working fluid. Milling yellow is an organic dye which when dissolved in water exhibits an optical property known as flow double refraction; this phenomenon depends on the interference of visible light frequencies and occurs because of viscous stresses in a moving liquid (analogous to the photoelastic behavior by many solids). When the solution is flowing through a transparent vessel located between two polarizing plates (set at 90° polarizing angle to each other), the light interference patterns permit clear visual observation of turbulent patterns, regions of flow separation, and, in some cases, lines that correspond to constant values of maximum shearing stress.

LOOP DESIGN

The milling-yellow flow visualization loop was installed in the new slurry area located in the southwest corner of building 9204-1 on the first floor.

In general, the loop has three major components: the mixing facility, the constant temperature bath, and the model analysis section. A photograph of the equipment with a model in place is shown in Figure 1. The constant temperature bath and pump are not shown.

Milling yellow is a yellow organic dye and was purchased in powder form from the Allied Chemical and Dye Company. The commercial powder is insoluble in water at room temperature, but if the water is heated to boiling, enough milling yellow will dissolve to give a solution of about one per cent by weight.^{1,2,3,4} The desired concentration may then be obtained by holding the solution at approximately 210°F until enough water has evaporated. The concentration was determined by evaporating a weighed sample to dryness in an oven held at 210°F and weighing the residue.

Heat was supplied by a steam coil of 1/2-inch stainless steel tubing inside the drum. The temperature of the solution was held at approximately 210°F by use of a brass Fulton-Sylphon thermal-control valve installed in the steam line. The outlet at the bottom of the drum was connected to the suction side of the main circulating pump so that the milling-yellow solution could be pumped into the constant temperature bath.

A thirty-gallon stainless steel drum was used for the mixing tank.

The optical sensitivity and the viscous properties of aqueous milling yellow solutions have been found to change markedly with small changes in concentration and temperature.^{2,3} Because of this the supply tank was equipped with a cooling coil, heater, and necessary temperature sensing and control equipment in order to maintain a solution temperature at 25°C. The accuracy within which the temperature can be maintained has not yet been determined.

The constant temperature bath was made from a 25-gallon stainless steel tank with a cooling coil of 3/8-inch stainless steel tubing. Cooling water was obtained by recirculating water through a water cooler. A mercury-to-mercury thermoregulator was used as the temperature sensing element which activated the necessary solenoid valves through electronic relays. Two solenoid valves are wired so that when one valve is open, the other will be closed. When the solution in the tank is too cool, solenoid valve number one is closed, causing the water to circulate in the external loop (including the cooler). When the solution is too warm, solenoid valve number one will open, causing cooling water to circulate through the coils in the tank and through the cooler. The parallel valve arrangement in which solenoid valve number one is located provides a high degree of flexibility as to the amount of cooling water which will flow through the coil at any time. A 500-watt heater, fabricated from stainless-steel calrod welded into a two-inch pipe plug, was installed in the side of the tank. A 5-amp Variac was used to control the heat input of the heater. Figure 2 shows the electrical schematic diagram for the constant temperature bath.

Flow double refraction may be observed in the lucite models by placing the model between two polarizing plates set at ninety degrees to each other. Light passes through a white translucent plastic sheet (which served as a light diffuser), a glass polarizing plate (the polarizer), the lucite model with milling yellow flowing through it, and another glass polarizing plate (the analyser) in that order. The polarizer and the analyser were made by laminating a plastic polarizer sheet between two pieces of strain-free glass. They were purchased from the Polaroid Corporation. The 18-inch square polarizer was set in a wooden frame which held it in a fixed position, but the 12-inch diameter round analyser was clamped in an aluminum frame which allowed the glass to rotate to any angle with respect to the polarizer. A wooden micarta-top table was used to hold the light source and the polarizer plate. Another larger wooden table was used to hold the lucite model and the analyser plate. The flow rotameters and a surge tank made of three-inch glass pipe were also mounted on the larger table. The surge tank also served as an air trap and a settling-chamber for foreign matter. A thermometer with 1/10-degree graduations was mounted at one end of the surge tank.

All the system which was in contact with the milling yellow solution was stainless steel or glass except for two teflon gaskets used with the glass pipe flanges. Stainless steel was used because of the dezincification which occurs when milling yellow is used with brass or bronze. The main circulating pump was a stainless steel centrifugal Durco pump with a mechanical seal and a closed impeller. The pump used to circulate the cooling water was a model D-11 Eastern centrifugal pump.

When the stress patterns in the flowing milling yellow solution are viewed with white light, they appear vividly as regions of different colors; the pattern depends on the maximum rate of deformation of the fluid. Two G. E. 500-watt reflector photoflood lamps mounted on a ring stand were used as the constant white light source. Stroboscopic illumination is useful, when turbulence is present in the flowing fluid, for bringing out the motion of individual eddies and discrete liquid masses. The stroboscopic equipment is composed of a Strobolume, to give a high intensity light source, connected to a Strobotac, to give variable flashing speeds. Both of these items were manufactured by General Radio Company.

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Figure 1. Model Analysis Section of Flow Visualization Loop.

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Fig. 2. Electrical Schematic Diagram for Constant Temperature Bath

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