

SUMMARY

**Persistence of Horizontal-Pipe Thermal-
Transient-Induced Flow Stratification***

by

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MASTER

In a related previous paper [1], the test geometry, test methodology and the scope of the Phase III of the thermal-transient-induced pipe stratification studies at Argonne National Laboratory (ANL) were explained. In this paper focus is on Phase III simulated pipe stratification persistence resulting from a thermal transient passing through a horizontal pipe of the reactor system. Results presented here involve only the upstream leg of the two-pipe, horizontal elbow system used in the Phase III studies [1]. Note that the orientation of the elbow at the end of a horizontal pipe (up, down, or in the horizontal plane) has an influence on the pipe stratification "persistence time," t_p . This matter is currently under investigation. For the purposes of this paper, only the horizontally disposed elbow data has been considered.

When a flow is stratified under transient thermal conditions imposed at the pipe inlet (ΔT_{IN} signifying the inlet temperature ramp imposed at constant flow and over transient time, t_t), t_p of the stratified layer can be expressed as the time duration of the top-to-bottom temperature difference, ΔT_{TB} , at a given section of the pipe. Under turbulent downramp conditions, which have been the case in all the tests in Phase III studies, the stratified flow becomes a retarded or stagnated and even reversed top layer of fluid persisting upon a fast moving cold bottom layer (the bottom layer accelerates on account of conservation of mass). Therefore, between the bottom and the top layers a shear layer (interface) forms which varies from turbulent at its bottom edge to laminar at its top edge. Reduced turbulence in the interface retards convective energy exchange between the two layers, whereby the stratified top layer becomes very persistent. The resulting t_p will be, inevitably, a function of the identifiable test parameters Richardson number (Ri), Reynolds number (Re), and ϕ [1]. Dimensionless thermal transient time ϕ

makes the present studies very complex and unique. All pertinent work in open literature [2, 3, and 4] treats only the steady-state stratified pipe flows and therefore useful only in one limiting situation when $\phi \gg 1.0$ (quasi-steady-state stratified flows). Two sample test data from the large number of tests available are presented in Figs. 1 and 2, respectively, for $\phi > 1.0$ and $\phi < 1.0$ to illustrate certain aspects of the persistent stratified flows.

The following table is a listing of the principal test parameters in the sample cases.

Test Parameter	P32818	P3P286
ΔT_{IN} ($^{\circ}C$)	67.	67.6
Re	31,700	33,900
Ri	4.96	4.38
t_t (s)	250.	7.5
ϕ	4.7	0.13

Shown in Figs. 1 and 2 are the top and bottom thermocouple differences at various cross-sections along the upstream pipe [1]. The difference (70-60) is taken at the last measurement location along the pipe, just before the flow passes through a 90-degree sweep elbow. This location is some 41 hydraulic diameter away from the inlet.

The three stages of thermal stratification in a pipe—namely, build-up, persistence and wash-out—are clearly evident in the ΔT_{TB} curves presented in Figs. 1 and 2. t_p is the sum of the three stages. Thermal-hydraulically, the tests shown are rather similar, except for the duration of the thermal transient time, t_t . Therefore, the observed persistence time, t_p , and the strength of stratification, ΔT_{TB} , differences in these two tests are due to

the difference in ϕ only.

For P32818, for which $\phi > 1.0$, the dimensionless persistence time (t_p/t_c) is order of 1; whereas, for P3P286, for which $\phi < 1.0$, it is order of 40 or better. Everything else being the same, this marked difference in the value of the dimensionless persistence time in these two tests shows the significant role ϕ exerts. In the laboratory tests, dimensionless persistence times up to 90 have been measured.

The dimensionless top-bottom temperature differences, $\Delta T_{TB}/\Delta T_{IN}$, for test P32818 is about 38 percent; for test P3P286 the same is about 96 percent. The propensity to build-up such significant stratification with long persistence times in reactor piping systems highlights the need to understand overall reactor systems operation under such adverse conditions as well as the concern for potential thermal stresses in the system components. Particularly during the washing-out of the stratified layer, the stratification interface becomes unstable and give rise to significant thermal oscillations which subject the pipe walls to thermal striping conditions. It is because of such concerns that it is desirable to understand the thermal stratification persistence phenomenon in reactor piping and be able to correlate it with the pertinent thermal-hydraulic parameters as identified in the foregoing. The present ANL effort is progressing in this direction.

References:

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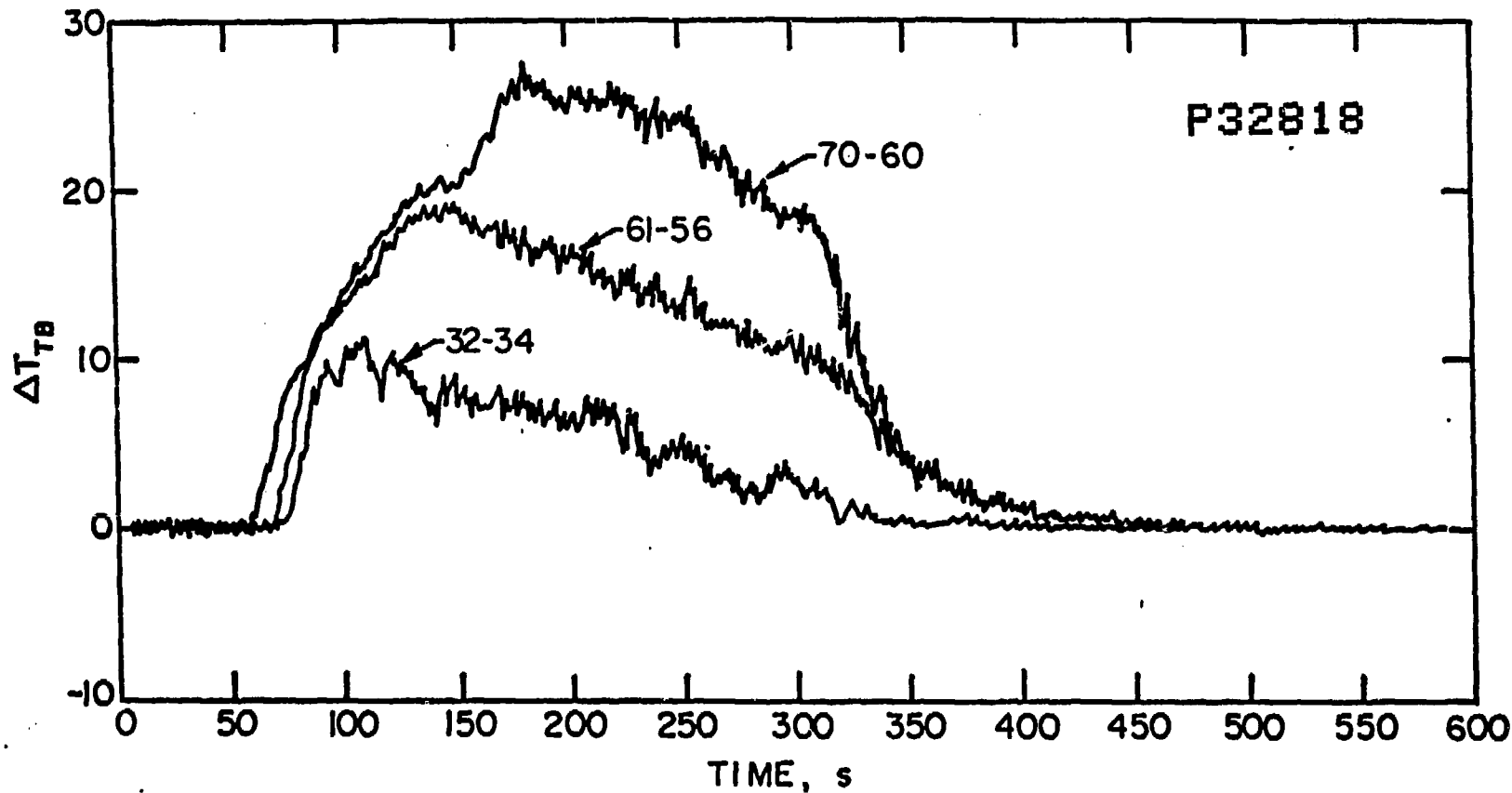


Fig. 1. Top-to-bottom Temperature Differences at Various Sections Along the Pipe, Which Quantifies Local Persistence of Stratification.

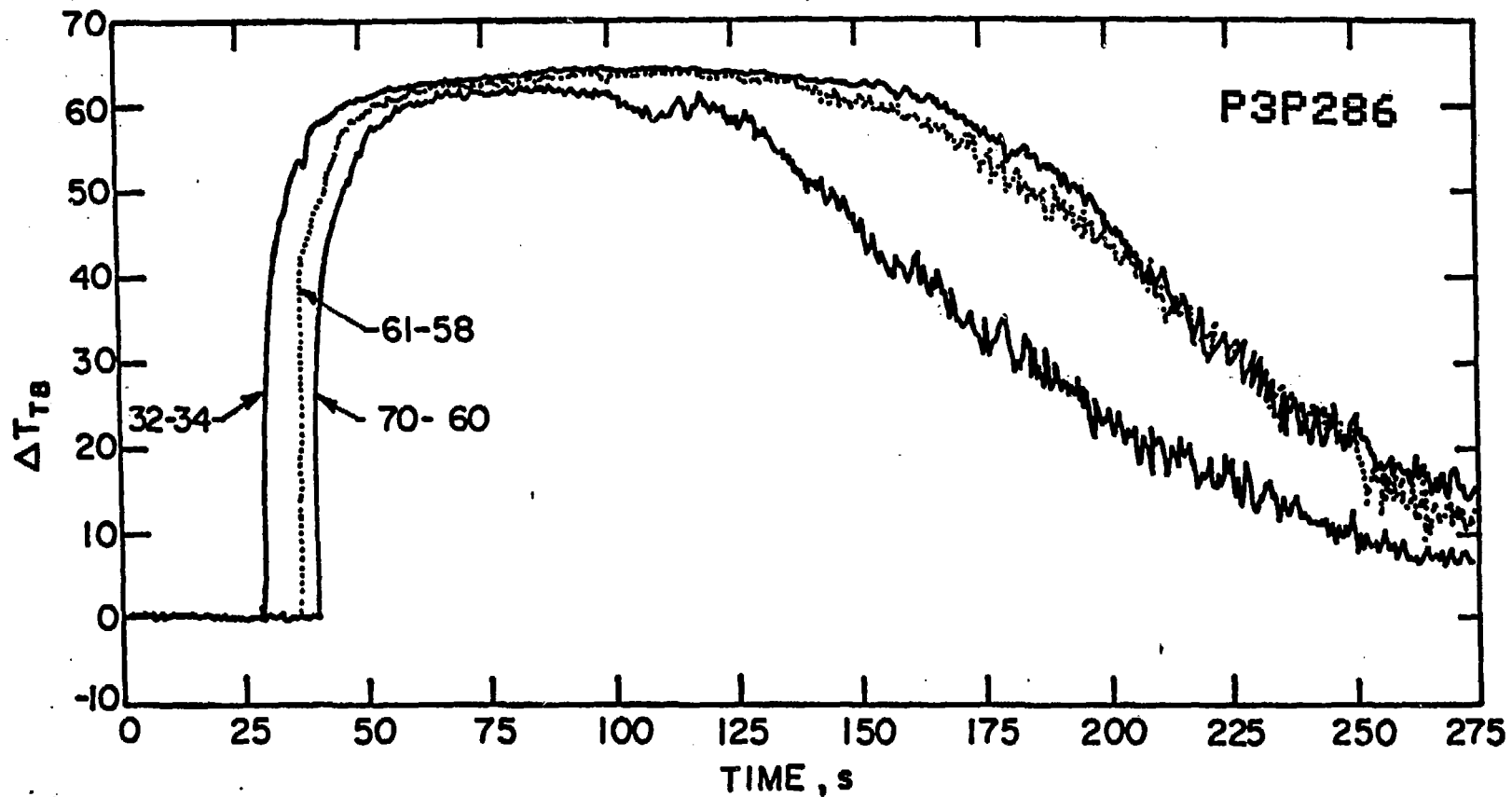


Fig. 2. Top-to-bottom Temperature Differences at Various Sections Along the Pipe Which Quantifies Local Persistence of Stratification