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PROCESS TEST MR-105-15
PRODUCTION INCREASES BY THE USE OF VENTURI ORIFICES

References:

1. HW-28335, "Process Test MR-105-14, Unit Cost Reduction by the Use of Supplemental Orifices."
2. HW-28083, "Pile Safety as Affected by Boiling Considerations".
3. HW-28153, "Tube Temperature Limits Based Upon Panellit Settings".
4. HW-27085, "PT-105-534-A, D Pile Operation With Maximum Panellit Pressure Monitor Protection".
5. HW-28008, "PT-105-534-A, Supplement A".

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OBJECT

Process Test MR-105-14(1) presented the basis for the use of supplemental and venturi orifices in certain regions of a reactor operating in accordance with the scram before boiling limit described in references 2 and 3 and provided for the reactor testing of the supplemental orifice. It is the purpose of this test to demonstrate the feasibility of using venturi orifices on a reactor so that maximum production gains may be achieved under this new limit.

BASIS

The elimination of the excess header pressure requirement through intensive maintenance of the Panellit gages will result in substantial reactor power increases. However, with limited water plant capacities, the magnitude of these power increases will be dependent upon both the efficiency of water distribution among the reactor process tubes and the mechanisms by which the water is distributed.

The reasons for the power level dependency upon the water distribution efficiency are quite obvious, but the power dependency upon the distribution devices arises from the necessity for maintaining high sensitivity to flow changes of the Panellit gages at all normal flow rates to comply with the requirements of the scram before boiling limit. This limit provides safety for two types of process tube flow restriction which could cause boiling: 1) plugging of the pigtail, cone screen or orifice, and 2) plugging of any component downstream of the Panellit pressure tap. The two equations for these limits as given in Process Specification 11.00 (approved but unpublished) are as follows:

1. Upstream Plugging: $\Delta T_w \text{ allow.} = (T_s - T_i) \left[\frac{LT - 10 - P_{rh}}{P_p - P_{rh}} \right]^{\frac{1}{1.8}}$
2. Downstream Plugging: $\Delta T_w \text{ allow.} = (T_s - T_i) \left[\frac{P_h - HT - 5}{P_h - P_p} \right]^{\frac{1}{2}}$

where: $\Delta T_w \text{ allow}$ = allowable water temperature rise ($^{\circ}\text{C}$)

LT = low trip on Panellit gage (psi)

HT = high trip on Panellit gage (psi)

P_h = front crossheader pressure (psi)

P_p = Panellit pressure (psi)

P_{rh} = rear crossheader pressure (psi)

T_s = saturation temperature in rear crossheader ($^{\circ}\text{C}$)

T_i = inlet water temperature ($^{\circ}\text{C}$)

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In examining these limit equations, it becomes apparent that neither limit is dependent upon the absolute rate of water flow within the tube. Furthermore, for any given set of conditions, the lower of the two limits as calculated from the equations must be considered to be the operational limit for the tube, and the maximum allowable water temperature rise would be effected at the point where these two equations are equal as shown in Figure I of the Appendix.

Examination of these exponential ratios will reveal that the Panellit pressure term appears either directly or indirectly in all components of the ratios. Since the front and rear header pressures are approximately fixed by the present water plant and piping design and since the possible variation of trip range is quite small with the present Panellit gages, it becomes apparent that equality of the two exponential ratios can best be attained through the adjustment of Panellit pressure.

From this discussion, it is apparent that an ideal Panellit pressure exists which is primarily dependent upon front crossheader supply pressure and which is completely independent of tube flow rate. The variation of this ideal Panellit pressure with the various parameters is shown in Figure II of the Appendix.

The device used at present for water distribution is a double orifice assembly which has an inherent flow characteristic such that alteration of the normal tube flow (by changing orifice diameter) results in an alteration of the normal Panellit pressure. It appears that this type of distribution device alone is obsolete for general use in tubes operating under scram before boiling provisions since the normal Panellit pressures for all tubes (completely irrespective of their water flow rates) should be maintained in the 200 to 230 psi range for maximum allowable temperature rise limits while maintaining an economical distribution of process water in the reactor. To accomplish this, devices are needed which will allow any flow rate to be maintained at the optimum Panellit pressure.

Such devices have been developed and tested in the flow laboratory. These are: 1) the supplemental orifice for use in the outer fringe zones of the reactors, 2) the single primary orifice for use in the inner fringe zones, and 3) the single venturi orifice for use in the central zone of the reactors. The double orifice mechanism is currently being tested in the D Reactor under PT-MR-105-14 (1), and the single primary orifice device is simply the present type of orifice now in general use.

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The venturi orifice is one which will allow maximum central zone tube flow while retaining the advantages of maintaining optimum Panellit pressure. The use of such orifices with the scram before boiling limit would allow reactor power increases of about 50 per cent at B and F Reactors instead of only approximately 35 per cent by the use of the present type orifices with existing water plant facilities. Furthermore, by the use of these orifices, wider Panellit trip ranges could be used safely. This would simplify the operation of the reactor, particularly with respect to gage recalibrations caused by film changes within the process tubes.

Therefore, the use of supplemental orifices in the outer fringes, single primary orifices in the inner fringes, and venturi orifices in the central zones of the reactors with existing instrumentation and water plant facilities will permit efficient water utilization and the attainment of maximum increases in reactor safety and power levels. These gains can be achieved in this manner at a relatively low initial cost.

It is the purpose of this process test to provide the necessary authorization for the experimental installation of venturi type orifices in a limited number of heavy metal process tubes in the central zones of the B, D, and F Reactors to demonstrate the feasibility of their installation and general use as standard reactor equipment.

DESCRIPTION

The venturi orifice for use in the B, D, and F Reactors is shown in Figure III of the Appendix. This orifice simply replaces the present type orifice in the central tubes and is held in the present orifice shells. The cone screen is placed in its normal position immediately upstream of the orifice.

Flow laboratory tests have shown that this orifice will deliver 30 gpm at 360 psi front header pressure in simulated average central zone tube of the D Reactor with the present type of cone screen. The efficiency of pressure recovery of this orifice is such that it will deliver 96 per cent of the maximum possible flow if no orifice were present. The Panellit pressure under these conditions would be at the ideal Panellit pressure for maximum permissible water temperature rise limits.

Four different materials will be used for this test: Type 303 stainless steel, 24-ST-6 aluminum, 61-ST-6 aluminum, and 63-ST-6 aluminum. Each of these different materials will be tested with and without an anodic layer of the Martin Hard Coat to establish their relative merits from the standpoints of strength, hardness, machinability, and corrosion.

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PROCEDURE

A collective total of 40 tubes in the B, D, and F Reactors which are charged with regular metal or poison will be equipped with experimental venturi type orifices during their next available outages, and will be operated on a trip-before-boiling basis. The tube film conditions will be analyzed prior to each outage and each tube will be provided with the proper orifice to give the optimum Panellit pressure at the maximum flow rate.

During succeeding outages, the nozzles and orifices will be examined for any detrimental effects. Panellit gages will be checked for trip settings as specified in the Process Standards, Document HW-28522.

SCHEDULE

A total of 40 tubes will be equipped with the experimental orifices during the next available outage at any of these three reactors. The test shall be in effect for a period of six months following installation.

EFFECTS ON PRODUCTION

There will be no reactivity effects. Front elevator time will be necessary for the inspection of the orifices and nozzles during each shutdown. This process test authorizes the extension of each reactor outage for a maximum of two hours for the nozzle inspections and a maximum of six hours to make the original installation.

COST

Charge Code - XXXX - 6141 - 628.

The total cost of fabrication and installation is estimated to be \$1500.

RESPONSIBILITIES

Operations Sub-Section - Record routine data.

Process Sub-Section - Supervise the installation of the orifices, interpret data, and issue all reports.

J. E. Robb

J. E. Robb, Area Engineer
Process Improvement
Process Sub-Section
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FIGURE III
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VENTURI ORIFICE

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