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GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

DATE
April 2, 1962

A METHOD TO DETERMINE OPTIMUM VENTURI SIZE

W. H. Radtke

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A METHOD TO DETERMINE OPTIMUM VENTURI SIZE

INTRODUCTION

The Hanford reactors have undergone numerous hydraulic changes which have increased production output either directly, as in the case of raising bulk limited power levels, or indirectly, such as reorificing⁽¹⁾ to accommodate major advances in pile flattening efficiencies. Unfortunately, whenever major hydraulic changes occur, Panellit pressures that had been prevalent also change, sometimes to the extent that efficient pile operation is affected. Therefore, when hydraulic changes occur, an investigation is generally made to seek a new orifice and/or venturi design that will not only alleviate the Panellit problem but also utilize the available reactor process water in the best possible fashion.

The method presented in this document discusses the approach made at DR reactor. This method should, with few changes (mainly in limit requirements), apply to determining the optimum orifice size at any reactor.

SUMMARY

Each reactor flow system has individual peculiarities which necessitate a separate analysis to determine the optimum venturi size. There is some probability that one venturi size may represent an optimum selection for groups of reactors, notably the old reactors, K reactors, and C reactor. To some extent this has already been done in the form of the .283 venturi, .310 venturi, etc.

DISCUSSION

The first step in the solution of the problem is to determine the limiting pressure requirements for the Panellit system. Within the venturi, or central, zone the primary limit considerations are the maximum high trip pressure limit⁽²⁾ and the trip-after-instability, or TAI limit⁽³⁾. Both requirements are dependent upon Panellit base pressures and corresponding dial indications for their computation. However, the former will represent an upper limit, with respect to Panellit base value, while the latter represents a lower limit. A "bracketing" condition is thus formed. The numerical values for the minimum and maximum Panellit pressure is then calculated in such a way that, within practical limitations, the reading of the Panellit dial will have no effect on the resulting limit.

- (1) Reorificing is used here as a general term meaning a change in the flow indicating device, either orifice or venturi.
- (2) HW-46000, Process Standards - Reactor, A-050 (50.03).
- (3) HW-46000, Process Standards - Reactor, A-020 (20.03).

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In the case of the maximum pressure limit, the minimum front header pressure (FHP) dial reading at high trip and an arbitrary low dial reading for normal operation are needed for the high trip limit calculation. The maximum high trip limit (HTP_{max}) is then calculated using the relationship:

$$HTP_{max} = FHP - 80(2)$$

This gives the highest Panellit pressure allowable. In terms of base pressure (if the dial reading is 90 at high trip), the maximum allowable base pressure is $FHP - 80 - 90$ or $FHP - 170$. Normally the central zone dial is not tolerated below 30; therefore, the maximum allowable Panellit pressure that will meet the high trip requirement is:

$$FHP - 170 + 30 \text{ or } FHP - 140.$$

To determine the minimum Panellit pressure based on a TAI limit of 130 C, the curves in Process Standard A-020 (20.03) were used. An average front header pressure (FHP), the highest maximum rear header pressure (P_{MRH}), and a low seasonal inlet temperature were used for the calculation of a minimum base pressure. To this was added the normal high dial reading of 70 to yield a minimum Panellit pressure.

The next step is to determine the extremes in tube flows and front header pressures to be used in the final analysis. For these, a current, representative "Reactor Operating Limits" may be used. Foreseeable adjustments of these extremes due to reactor changes (the charging of bumper fuel for example) can augment this information.

The results of the data and calculations thus far may be tabulated for the DR reactor case as follows:

Front Header Pressures

Minimum - 515 psi

Maximum - 528 psi (affecting central zone tubes only)

Limiting Panellit Pressures

Minimum - 246 psi

Maximum - 375 psi

Tube Flows

Minimum - 42.0 gpm (natural metal)

Maximum - 54.0 gpm (enriched metal)

Minimum - 41.0 gpm (calculated change due to bumpers)

Maximum - 56.6 gpm (calculated change due to .634 reaming of rear Parker fitting)

Combinations Used For "Worst Case" Computations

Low flow-high Panellit pressure - 41.0 gpm - 528 psi (FHP)

High flow-low Panellit pressure - 56.6 gpm - 515 psi (FHP)

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Construction of Figure I

The calibration curves for the .283, .310, and .320 venturis were used for the plot of changing venturi throat diameter versus ΔP (front header pressure minus Panellit pressure) with parameters of tube flow. The flows chosen should include the extremes tabulated above plus any other possible future flow that is to be included in the study.

For the low flow, high Panellit pressure case, a ΔP using the maximum FHP and maximum Panellit pressure is calculated. On Figure I, the intersection of this ΔP and the low flow curve can be read out in terms of a venturi size on the abscissa scale. Similarly, a high flow, low Panellit pressure case can be calculated using the minimum FHP and minimum Panellit pressure. The resulting ΔP is projected to intersect with the high flow curve and again a venturi size may be obtained.

For DR reactor, the low flow, high pressure calculation yielded a ΔP of 528-375 or 153 psi. This yielded an approximate venturi size of .340-.345. The high flow, low pressure calculation gave a ΔP of 515-246 or 269 psi. This gave an approximate venturi size of .345-.350. To depict this relationship more clearly, Figure II was constructed. It consists of a flow versus ΔP (FHP minus Panellit pressure) for the .335, .340, .345, .350, and the .355 inch diameter venturis. The minimum and maximum Panellit pressure points are then plotted as to their corresponding flow rates. It would appear that a .350 venturi is needed to assure strict compliance to the low Panellit pressure limit. However, the highest apparent venturi size that may be used without exceeding the low flow extreme, which would result in more tubes approaching the maximum high trip limit, is the .345 venturi. Therefore, the .345 venturi is the choice for further study.

Investigating the .345 Venturi

After selecting the correct, theoretically, venturi size, the next step is to duplicate the characteristics which have dictated the choice by testing prototypical reamed venturis. Fortunately, in the DR case, the first venturi tested by Thermal Hydraulics Operation was a .344 reamed venturi which almost exactly duplicated the theoretical .345 venturi characteristics, thus, further testing was unnecessary. Figure III shows the comparison of the theoretical to the actual.

The Case for the .344 Venturi at DR Reactor

In addition to the Panellit characteristics, Figure III also shows the total pressure drop across the venturi, pigtail assembly, and the nozzle inlet port. When incorporated into a tube demand curve calculation, this pressure drop indicates that the average central zone tube will experience approximately a 0.9 gpm flow increase. Since this flow gain roughly cancels the detrimental flow effects from the addition of bumper fuel, it may be used as a selling point for the .344 venturi at DR reactor.

On a full-pile basis, studies were conducted which explored the effects by which our extreme tube flows were derived, i.e., full-pile bumper loading and rear

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Parker fitting reaming. This was done primarily to insure that drastic changes in riser pressure, hence front header pressure that would occur would not lessen the desirability of the .344 venturi. A case which would possibly be of interest is that of the pile demand with full-pile usage of the new venturi in the present central zone and no bumper loading. The resulting demand curve is shown in Figure IV along with the seven and eight pump supply curves. If no fringe throttling for water plant limitations is required, the pile will attain, roughly, a flow of 87,600 gpm (based on 12 C inlet water). This means, with the 1300 gpm of shield cooling water factored in, a total flow of 88,900 gpm.

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FIGURE I
THEORETICAL CALIBRATION CURVES
FOR VARYING VENTURI DIAMETERS

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FIGURE II

THEORETICAL VENTURI CALIBRATION CURVES

Basis: Figure I

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THEORETICAL & ACTUAL
VENTURI CHARACTERISTICS

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FIGURE IV

REACTOR FLOW WITH .344 VENTURI
Inlet Temp. 12 °C

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