Westinghouse
Electric Corporation

Power Systems
Company

PWR Systems Division

Box 355
Pittsburgh Pennsylvania 15230

June 22, 1976
AW-76-23

Mr. T. A. Ippolito, Chief
Electrical Instrumentation and Control
Systems Branch
U. S. Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, Maryland 20014

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Response to NRC Request for Additional Information Re: Westinghouse New Integrated Protection System Presentation

REF: Westinghouse Letter No. NS-CE-1110 Eicheldinger to Ippolito Dated June 22, 1976

Dear Mr. Ippolito:

This application for withholding is submitted by Westinghouse Electric Corporation ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. Withholding from public disclosure is requested with respect to the subject information which is further identified in the affidavit accompanying this application.

The undersigned has reviewed the information sought to be withheld and is authorized to apply for its withholding on behalf of Westinghouse, WRD, notification of which was sent to the Secretary of the Commission on April 19, 1976.

The affidavit accompanying this application sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.790 of the Commission's regulations.

Accordingly it is respectfully requested that the subject information which is proprietary to Westinghouse and which is further identified in the affidavit be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should be addressed to the undersigned.

Very truly yours,

Robert A. Wiesemann, Manager
Licensing Programs

/smh

Enclosure

cc: J. W. Maynard, Esq.
Office of the Executive Legal Director, NRC

AW-76-23

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Robert A. Wiesemann, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Robert A. Wiesemann

Robert A. Wiesemann, Manager
Licensing Programs

Sworn to and subscribed before me this 7th day of June 1976.

[signature]

Notary Public

MY COMMISSION EXPIRES ... 15, 1978

(1) I am Manager, Licensing Programs, in the Pressurized Water Reactor Systems Division, of Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing or rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Water Reactor Divisions.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse Nuclear Energy Systems in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(g) It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition in those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information is not available in public sources to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in the attachment to Westinghouse letter No. NS-CE-1110, Eicheldinger to Ippolito dated June 22, 1976 concerning slides that are part of a presentation on the Westinghouse New Integrated Protection System. The letter and attachment are being submitted in response to the NRC's request for additional information as a result of the NRC/Westinghouse meeting on May 26, 1976.

This information is part of that which will enable Westinghouse to:

(a) Apply for patent protection.

(b) Optimize protection system and breaker and channel bypass designs.

(c) Assist its customers to obtain licenses.

(d) Justify the design basis for integrated protection system.

(e) Optimize on-line testing reliability.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the equipment described in part by the information.

(b) Westinghouse plans to sell the use of the information to its customers for purposes of meeting NRC requirements for licensing documentation.

Public disclosure of this information is likely to cause substantial harm to the competitive position of Westinghoue because (1) it would result in the loss of valuable patent rights, and (2) it would enable others to use the information for commercial purposes and also to meet NRC requirements for licensing documentation, each without purchasing the right from Westinghouse to use the information.

The technology is in the evolving state in applications using large numbers of microprocessors. A microprocessor-based protection system will allow a significant commercial advantage to any Nuclear Steam Systems Supplier in terms of performance and cost. The schedule and scope of prototype testing is aimed at verifying the design so that Westinghouse can market the system at the earliest practical time. Premature release of information on the testing could destroy the competitive position of Westinghouse. Building and testing the prototype will cost Westinghouse over $500,000. Westinghouse will expend 15 man years of preparation time this year in planning and coordinating details of the testing before starting to build the prototype. Being an innovative concept, this information might never be discovered by the competitors of Westinghouse independently. To duplicate this information, competitors would first have to be similarly inspired and would then have to expend an effort similar to that of Westinghouse to develop the design.

Further the deponent sayeth not.

QUESTION #1

1. "By means of quantitative analysis establish that flow stratification/assymmetries in the vicinity of the TTFM detectors are either negligible or can be dealt with effectively."

RESPONSE

The recommended installation of detectors for the N-16 Transit Time Flowmeter (TTFM) is [ ] With one pair of detectors on a,c
one side of the pipe, Figure 3-5 of WCAP 9172 (attached as Figure 1) shows a strong weighting towards the detector location and a relatively weak weighting for the opposite side of the pipe. With [ ] the sensitivity to N-16 distribution in a,c
the pipe is considerably more uniform. Figure 3-6 of WCAP 9172 (attached as Figure 2) shows the function [ ] a,c

Experimentally, peak to peak differences in single pair flow velocity up to [ ] have been observed at Prairie Island Unit b,c
2, as reported in the attached response to question 2. Other measurements reported in WCAP 9172 show smaller differences.

With observed differences up to [ ] between pairs of detectors located at different azimuthal positions, a series of calculations has been performed to evaluate the ratio between observed peak to peak single detector pair velocity differences and the maximum error in the flow measured by [b,c

] a,c

The azimuthal dependence of the flow velocity in the hot leg coolant pipe is not expected to be large as the coolant enters the hot leg from a large plenum and there are no bends upstream of the detector locations. A slight azimuthal dependence could be expected due to effects of the upwards coolant flow from the reactor core in the plenum and from the control rod guide tube structure in the plenum. If the N-16 detectors are located in the wake of an RTD scoop, a local, lower than normal velocity perturbation is expected.

In order to evaluate the effects of azimuthal flow variations on the coolant flow measured by both one detector pair and [ ] N-16 detector geometries, a series of test profiles were generated and their effects on TTFM observed flows calculated. Figures 3 through 13 show the results of these calculations. a,c

Figure 3 gives the results for the first test case where the
coolant velocity varies [ ] from the a,c
detector pair 1 location. Thus, the coolant velocity
increases [

] At [a,c

] This pattern, in this orientation, a,c
produces [ ] for the one detector pair N-16 TTFM a,c
measurements. The relative flow is [
] on the plot which corresponds to the described a,c
flow pattern orientation. As this flow pattern is rotated
[ ] the peak coolant velocity is at the [a,c

] At [a,c
] to a,c
the detector location. As the flow pattern is shifted [

] Again, [a,c
] As the pattern is [a,c

] In this case, the a,c
relative flow measured by one detector pair is [
] Note that the flow along the line connecting the a,c
[ ] Thus, the a,c
one detector pair flow error is only about [ ] a,c
flow deviation.

For this flow pattern, [ ]measured flow a,c
has[
] Thus, for this a,c
test azimuthal flow distribution, [
] a,c
for all azimuthal flow variation orientations. This simple
flow pattern is [
]of the pipe. a,c
The ratio of single detector pair peak to peak deviation to
[ ] a,c

Figure 4 shows the results for a similar flow pattern where
the [
]of the pipe. At the[a,c

] This flow variation can be visualized as a a,c
[ ] For this a,c
flow profile, Figure 4 shows that the single detector pair
error[ ] a,c
with somewhat smaller magnitude than for the Figure 3 flow
distribution. The[

] The ratio of single detector pair peak to a,c
peak deviation to[ ] a,c

Figure 5 gives the one[ ] for a a,c
flow distribution that is the same as for Figure 4, [
]as a,c
shown in the sketch in the upper left of Figure 5.

In this case, the one detector pair error is not [
]of the pipe. At [a,c
] rotation, there is a pronounced peak as the [a,c
] Note a,c
that the true average flow is at a relative flow of[ ]as a,c
there is a positive flow deviation up to[ ]in one half of a,c
the pipe while the opposite side is constant at[ ] a,c

In this case, [
] There is a maximum[a,c
]and a maximum[a,c
.] These repeat at [a,c
] The maximum peak to peak one detector pair a,c
difference is[ ]orientation a,c
of the flow pattern to the one detector pair location at the top of the pipe. The ratio of observed peak to peak one detector pair flow difference to maximum[
] a,c

Thus, the two detector pair error is [ ] a,c
of the peak to peak deviation seen with a single detector pair moved to different orientations around the pipe.

Figure 6 shows the one [ ] results for a a,c
shape of flow disturbance that might be expected [
] of the N- a,c
16 detectors. This flow disturbance is simplified in that the [ ] has a flow velocity [a,c
] than the remainder of the pipe. The true average flow a,c
velocity in the pipe is [
] in the remainder of the pipe. The single detector a,c
pair measured flow velocity has a peak to peak deviation of [
] The maximum a,c
[ ] a,c
disturbance rotation where the disturbance area is [
] The ratio of peak to peak single a,c
detector pair measured flow [
] a,c

Figures 7 through 13 give the one and two detector responses for several shapes of disturbance where the flow velocity in the shaded area is [ ] than the a,c
remainder of the pipe. Table I summarizes the results for all test cases (Figures 3 to 13).

Typically, the ratio of one detector pair peak to peak
difference to [ ] maximum error to true a,c
velocity is [
] represented by Figures 7, 8 and 12 a,c
(note that 7 and 8 are identical except for 8 having twice
the magnitude of flow perturbation). In the physically
reasonable cases of Figures 4, 5 and 6, the ratio is
significantly greater than [ ] for a,c
Figure 4. The maximum observed difference between [
] at Prairie Island Unit 2 is [ ] as reported in the a,c b,c
test results documented in the attached response to question
#2. Lower differences were reported in WCAP 9172, which
describe earlier measurements at Prairie Island Unit 2.
These measurements and the results of the calculations
reported here, support the choice of [ ] as the upper bound of a,c
the error due to azimuthal velocity profile for two pairs of
N-16 detectors placed on opposite sides of the reactor
coolant hot leg pipe.

At Commanche Peak Unit 1, [
] It is expected that the a,c
azimuthal coolant velocity profile is likely to be [ ] a,c
for the four loops when the [ ] of hot leg a,c
orientation with respect to the core is considered [

] Thus, this a,c
flow symmetry between loops can be demonstrated or shown not to exist by looking at the results of the N-16 flow measurements for each of the three symmetric loops at Commanche Peak Unit 1. Note that the N-16 TTFM reports coolant velocities measured for[ ]of N-16 detectors a,c
as well as the loop flow calculated from [ ] of a,c
detector on each loop.

If symmetry is demonstrated, the results for the[
]installation can be used to obtain a [a,c

] and thus significantly reduce this source of a,c
error.

If symmetry is not demonstrated and the[

] a,c

In conclusion, the[ ]error term applied to the N-16 TTFM a,c
accuracy is a conservative upper limit which can be significantly reduced with more plant data. During the startup of Commanche Peak Unit 1, the data obtained will likely allow a significant reduction of this number when applied to the total flow through the reactor core.

The radial velocity profile has been covered in WCAP 9172.
Figure 3-8 (attached as Figure 14) shows that this error is
bounded by [ ] for the [ ] of obtaining the a,c a,c
transit time from the cross correlation function. In fact, a
smaller error band of [ ] is demonstrated for a a,c
nearly four decade range of Reynolds numbers. The actual
radial flow profile may be somewhat flatter than expected for
a well developed radial flow profile at a Reynolds number of
[ ] as the detector location is only a few pipe diameters a,c
downstream from a large plenum in a straight section. Thus,
the effective profile is expected to be representative of a
somewhat larger Reynolds number where the N-16 TTFM error is
smaller.

TABLE I

FIGURE #	ONE DETECTOR PAIR PEAK TO PEAK MEASURED VELOCITY DIFFERENCE	TWO DETECTOR MAXIMUM ERROR POSITIVE	NEGATIVE	RATIO *
3	[			] a,c
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				

* Ratio of one detector pair peak to peak measured velocity difference to [ ] maximum a,c
error (greater of positive or negative error).

b.c

N-16 Detector Sensitivity in Main Coolant Pipe - One Detector

Figure 1

11,907-12

b.c

N-16 Detector Sensitivity in Main Coolant Pipe - Two Detectors Spaced 180°

Figure 2

a,c

Figure 3

a,c

Figure 4

a,c

Figure 5

a,c

Figure 6

a,c

Figure 7

a,c

Figure 8

a,c

Figure 9

a,c

Figure 10

a,c

Figure 11

a,c

Figure 12

a,c

Figure 13

11,307-14

b,c

Figure 14

Calculated Error for 30-inch Detector Spacing in Standard Geometry

QUESTION #2

2. "The most desirable and convincing evidence of the level of TTFM uncertainty would be a direct comparison to a meter of known accuracy. However, lacking such calibration the proposed TTFM design should be presented in sufficient detail that when supplemented by careful analysis of the individual potential sources of error the level of accuracy can be established. In particular, clarification is needed to show that the observed differences in flow measurement pairs are consistent with the claimed accuracy for the proposed measuring technique."

RESPONSE:

The N-16 TTFM has been compared with a highly accurate sonic flow measuring device, the leading edge flowmeter, in tests at Prairie Island Unit 2. The most recent and accurate tests were conducted in January 1979 and are documented in the attached summary report. The leading edge flowmeter accuracy for the reactor coolant flowmeter system installed at Prairie Island Unit 2 has been established as [ ] and has a,c been verified by weigh tank measurements at Alden Laboratories.

The results which are documented in the attached report for prototype detectors, collimators, alignment hardware, and data analysis electronics show agreement between the N-16 TTFM and LEFM of [ ] sequence with a a,c maximum single deviation of [ ] This close agreement a,c demonstrates that the accuracy analysis for the N-16 TTFM is realistic and probably conservative.

The observed coolant velocity measurement differences for differently positioned N-16 detector pairs has been discussed in the response to question #1 and results in the previously discussed [ ] of N-16 detectors a,c mounted on [ ] a,c

The TTFM measures volumetric flow in the reactor hot leg while the LEFM measures volumetric flow in the cold leg. At 100% reactor power, there is about a [ ] difference in flow a,c volumetric rates due to the T across the steam generator. This coolant density difference must be corrected for in order to compare the two measurement techniques. This calculation is performed by using two equations:

1. Heat Balance (Primary calorimetric):

$$\text{Power} = m\,(h_h - h_c)$$

where

Power = BTU/min = Secondary Calorimetric Power ± heat losses

m = reactor coolant mass flow rate $\left(\frac{\text{lb}}{\text{min}}\right)$

h_h = Hot leg enthalpy (BTU/lb)

h_c = Cold leg enthalpy (BTU/lb)

2. Volumetric-Mass Flow Relationship:

$$m = V_h\,\rho_h = V_c\,\rho_c$$

where: V_h = Hot leg volumetric flow rate (ft^3/min)

V_c = Cold leg volume time flow rate (ft^3/min)

ρ_h = Hot leg coolant density (lb/ft^3)

ρ_c = Cold leg coolant density (lb/ft^3)

With these two equations, the mass flow rate and the cold leg volumetric flow rate can be determined by measuring:

a) The hot leg volumetric flow rate from the TTFM
b) Secondary calorimetric power with adjustment for heat losses
c) The cold leg coolant temperature. Note that either the hot or cold leg temperature is needed, but usually the cold leg temperature is more accurate. If both hot and cold leg temperatures are available with high accuracy, the calorimetric power is not needed.
d) Compressed water tables to give h_h, h_c, ρ_h, and ρ_c as a function of coolant temperature and pressure. As these functions are only slightly a function of pressure, an accurate measure of pressure is not required.

As the enthalpy and density functions are non-linear, an iterative solution using the hot leg temperature as a parameter must be used.

The accuracy of this technique adds a small uncertainty in the overall measurement. If the calorimetric accuracy is [ ] a,c
and the cold leg temperature accuracy is [ ] the hot leg to a,c
cold leg volumetric flow conversion accuracy is [ ] if the a,c
calorimetric and temperature errors are added statistically
and [ ] if they are added linearly. These numbers are for a,c
a reactor where nominal $T_h = 591^{\circ}F$ and nominal $T_c = 532^{\circ}F$. In a higher temperature plant, where $T_h = 620^{\circ}F$ and $T_c =$

555^{o}F, the results would be[ ](statistical) and [ ] a,c a,c (linear). In a four loop plant, statistical analysis would reduce this to[ ] a,c

SUMMARY OF TEST OF PROTOTYPE TRANSIT TIME FLOWMETER AT PRAIRIE ISLAND UNIT 2

1.0 SUMMARY AND CONCLUSIONS

1.1 Test of Prototype Equipment on Loop A

The prototype Transit Time Flowmeter (TTFM) electronics and production detectors and collimators were tested on Loop A of Prairie Island Unit 2 and compared with the Leading Edge Flowmeter (LEFM). These measurements
demonstrate that the TTFM meets or exceeds the [ ] a,c
accuracy claimed for this instrument. The comparison between the two units is summarized in Table 1. The
TTFM flow averaged [ ] than the LEFM flow and a,c
the maximum single deviation was [ ] in test number a,c
2.

1.2 Test of Developmental Equipment on Loop B

On Loop B there is only one pair of detectors located on the bottom of the hot leg main coolant pipe. The detectors and collimators are developmental units and have a mechanical accuracy of about 1-1/2%. The
average TTFM flow was [ ] than for the LEFM. a,c
This [ ] flow in the bottom of Loop B is a,c
consistent with the fact that the bottom detectors on
Loop A showed a [ ] velocity than the average a,c
velocity measured in Loop A and the limited mechanical accuracy for the Loop B installation.

TABLE 1 - SUMMARY OF COMPARISON BETWEEN TRANSIT TIME LOWMETER AND LEADING EDGE FLOWMETER

Loop A (with full set or production detectors and shields)

	Leading Edge Flowmeter GPM	Transit Time Flowmeter GPM	% Difference
Test 1			
Test 2			
Test 3			
Test 4			
Average			

a,c

Loop B (only one pair of developmental detectors on bottom of pipe; 1-1/2% mechanical accuracy

	Leading Edge Flowmeter GPM	Transit Time Flowmeter GPM	% Difference
Test 1			
Test 2			
Test 3			
Test 4			
Average			

a,c

2.0 STATISTICAL ANALYSIS OF LOOP A MEASUREMENTS

Table 2 gives the results of a statistical analysis of eleven TTFM flow measurements in Loop A at NRP. During seven of these tests, no LEFM flow measurements were made. These seven tests when combined with the four tests in Table 1 allow some statistical analysis of the TTFM reproducibility. These eleven tests span two days and, therefore, may contain real flow differences. However, the plant was operating in a steady state as records of various plant parameters indicate and there is no reason to expect any real flow variations. In any case, the reproducibility of the TTFM measurements can be no worse than obtained from the data from these tests.

The measured standard deviations for the individual four transit time measurements are for Loop A:

TABLE 2

	Eleven Measurement Statistics			
Measurement	Average (m sec)	(m sec)	(%)	
Top Detectors - Forward Connection				a,c
Top Detectors - Reverse Connection				
Bottom Detectors - Forward Connection				

Bottom Detectors - Reverse Connection [ ] a,c

RMS Average = [ ] a,c

Note that each transit time measurement is the result of cross correlation of approximately [ ] of detector signal. a,c

The standard deviation of individual transit time measurements averages [ ] The standard deviation for the top detector pair appears to be [ ] than for the bottom detector pair although with only eleven measurements, this difference may not be real. a,c a,c

When the forward and reverse connection measurements are averaged for each detector pair, and the top and bottom measured velocities are combined, the percentage standard deviations become smaller as each of the measurements is nearly statistically independent:

TABLE 3

	Eleven Measurement Statistics		
Loop A Detectors	Average (ft/sec)	(ft/sec)	(%)
Average Top Detector Coolant Velocity	[		] a,c
Average Bottom Detector Coolant Velocity			
Average Coolant Velocity			

The [ ] observed standard deviation is slightly [a,c
] observed for individual transit a,c
time measurements. This is based on four measurements and a reduction of $\sqrt{4} = 2$ is expected when the result is based on four statistically independent measurements. This
[ ] obtained in WCAP 9172 from the a,c
1975 tests.

The errors due to this run to run reproducibility can be significantly reduced by performing repeated flow measurements and averaging the result. The reproducibility can be measured for a given series of measurements and used to determine whether the TTFM has degraded. The analysis time of the TTFM can be increased which inherently averages the equivalent of several measurements. This would not, however, allow the reproducibility to be determined. It would be possible to modify the TTFM software to automatically perform a sequence of flow measurements and provide the average measured flow and the measurement reproducibility.

3.0 COMPARISON OF TOP AND BOTTOM DETECTOR MEASURED COOLANT VELOCITIES

Table 3 shows that the top detector pair measured a
velocity of [ ] while the bottom detector pair a,c
measured [ ] The difference is [ ] with the a,c a,c
top detectors measuring a velocity [ ] than the a,c

average while the bottom detectors measured a velocity
[ ] than the average. The average velocity in loop a,c
A gives a coolant flow very close to that measured by the
leading edge flowmeter. In loop B, Table 1 shows that the
single pair of detectors on loop B measured a flow [
] that measured by the leading edge flowmeter. Thus, a,c
the results show a [ ] is measured by a,c
detector pairs located on the bottom of the reactor coolant
pipe. This is consistent with the results reported in WCAP
9172 except that the maximum magnitude of individual
detector measured coolant velocity differences [
] than observed in the measurements reported a,c
in WCAP 9172.

4.0 <u>ACCURACY ANALYSIS OF TEST</u>

The results of this comparison of the Transit Time
Flowmeter and the Leading Edge Flowmeter must be judged
with the error sources in this test. The average deviation
between the two instruments over four runs is [ ] with a,c
the Transit Time Flowmeter giving the [ ] flow a,c
as seen in Table 1.1. The overall mechanical accuracy of
the TTFM installation at Prairie Island is [ ] on the a,c
effective distance between the two regions of coolant seen
by the upstream and downstream detectors. The main coolant
pipe diameter tolerance is [ ] based on the acceptance a,c
limits for the piping. This dominant error source is large
because the as-built pipe inside diameter for Prairie

Island Unit 2 hot leg is unavailable. In future installation, this pipe ID should be measured prior to plant operation.

The Leading Edge Flowmeter accuracy is [ ] a,c
Adding these error sources statistically gives a comparison error of [ ] With the measured difference of [ ] the a,c a,c
accuracy of the TTFM is demonstrated to be less than the 1.5% claimed for the instrument on a per loop basis.

QUESTION #3

"Establish, by means of careful review of machining and assembly drawings for the TTFM, that the close tolerances that have been shown to be required on detector/collimator spacing and angle can, in fact, be maintained in the proposed service environment, including protential thermal cycles."

RESPONSE:

Utilizing information concerning the location of the gamma chamber sensitive volume, "as-built" dimensions of the N-16 TTFM support structures for Comanche Peak Units 1 & 2 and an evaluation of thermal effects, it has been confirmed that the required accuracy for detector alignment and spacing will be maintained in an operating condition. The sensitive volume centerline between a pair of detectors must be held within [ ] nominal spacing in order to a,c achieve the desired accurate flow measurement. A check of the actual alignment tube machining and assembly of the collimator boxes has shown that the close tolerances specified have been met. In addition, it should be noted that the original detector alignment method was revised from the use of set screws to the use of custom machine "VESPEL" alignment rings. These rings are machined to match each detector's marked centerline, thereby permitting each detector to be precisely positioned within the respective collimator box. The surfaces of the collimator boxes and each alignment bracket are machined to maintain the position of the centerline of the detectors with respect to the hot leg piping.

Using the in-process and final inspection data from sixteen (16) support structures fabricated for Comanche Peak, the worst case misalignment of any detector pair in the cold installed condition projected [ ] from the collimator a,c
box openings into a hot leg pipe would result in a variance of [ ] from the desired 30 inch nominal spacing. a,c
Considering operating conditions, the thermal effects on the support structure in conjunction with the fabrication variances will result in a total worst case variance of [ ] a,c
from the nominal spacing. Based on this evaluation, the required accuracy can be obtained with the present design. This flow measurement system does have the capability of having a length dimension other than the nominal 30 inch spacing to be entered into its data base. Therefore, known fabrication variations and/or predicted thermal effects could be accounted for by entering a specific spacing number into the system for each separate assembly. For the units presently being installed at the Comanche Peak site, this action is not deemed to be necessary.

QUESTION #4

"Establish that the pipe internal cross sectional area can be measured to the required accuracy, especially for plants in which the hot leg pipe is clad internally with an overlay which may be nonumiform in thickness. Specify intervals of such measurements and discuss the possibility of crud formation or pipe corrosion which may affect pipe cross sectional stability."

RESPONSE

The best method to establish the hot leg pipe cross sectional area is by direct measurement (see table below for Comanche Peak Unit 1 & 2 actual data).

UNIT	PIPEHEAT NO.	INSIDE DIAMETER MAXIMUM	INSIDE DIAMETER MINIMUM	
1	[		]	b,c
2				

These "cold" measurements are then converted to inside diameters for hot leg operating temperatures. The TTFM electronics incorporate an appropriate thermal expansion correction to account for the actual T_{HOT} temperature as referenced to a selected base hot leg temperature (for which the pipe diameter has been established by measurement and for which corrections have been made to the initial measurement conditions).

The hot leg pipes are centrifugally cast and machined to specified inside and outside dimensions and thus are very uniform and have a very circular cross section. They are solid stainless steel with no inside clad and thus have no non-uniformities as does the interior of the reactor vessel. There are no joints between pipe sections in the region where the N-16 detectors are installed. The specification requirement for the hot leg pipe inside diameter at Prairie
Island Unit 2 is[ ]which results in an b,c
uncertainty of[ ]flow if no as-built measurements are a,c
available and no direct (or indirect) measurements of higher accuracy are available. Since the hot leg pipe is cast stainless steel, has a machined smooth inside surface and the reactor coolant velocity is 50 ft./sec. at the N-16 detector location, changes in pipe diameter due to crud disposition and/or corrosion are negligible. The maximum expected
changes are less than[ ]and changes of this amount b,c
would have a[ ]change on flow accuracy. a,c

QUESTION #5

5. "Establish, preferably by means of detector signal simulation codes that correctly model all pertinent phenomena (including the addition of uncorrelated noise as detector separation is increased), that the detector spacing to be employed in the TTFM is optimum and that the fitting procedure by which a transit time is to be extracted from the imperfect, randomly varying detector data is capable of providing the required accuracy."

RESPONSE:

Experimental measurements have shown that the reproducibility of the TTFM is excellent. The TTFM combines the results of four cross correlation measurements into each flow measurement on one coolant loop. Each cross correlation takes [ ] of data is used in the flow measurement on each loop. The cross correlation for detector pairs on opposite sides of the pipe may be performed at the same time, but, the signals are nearly statistically independant. In a four loop plant, flow measurement in all loops involves 16 cross correlations or [ ] of data.

a,c

a,c

The single loop, single flow measurement reproducibility has been found experimentally to be [ ] This can be confirmed for each implementation by repeated measurements and can also be significantly reduced by averaging repeated measurements. In a four loop plant, this error source is almost negligible and can be reduced and confirmed by performing repeated measurements. a,c

WCAP 9172 reported tests have a repeatability [ ] (reported on page 5-17) which agrees closely with the more recent measurements. a,c

This excellent repeatability demonstrates that the flow can be accurately measured using the random pattern of N-16 concentrations in the hot leg. If rapid response were required, this could be a significant source of error. The N-16 TTFM is used to periodically verify the absolute coolant flow and to calibrate the elbow tap class 1E flow measurement system that remains the rapid-response reactor protection flow measurement system. Currently, absolute flow measurements are required at 18 month intervals for which rapid response measurements are not required.

Detector Spacing

The performance of the system has been tested using spacings from [ ] Shorter spacings require tighter mechanical accuracy, especially those causing "toe in" or "toe out" angular errors in the detector-collimator mounting. Longer spacings could result in loss of correlation, but are usually mechanically infeasible. The nominal spacing is [ ] which results in good performance as demonstrated in WCAP 9172 and verified in the prototype system measurements reported in the response to question #2.

b,c

b,c

Random Noise Effects

Random noise that is incoherent between upstream and downstream detector pairs will cross correlate to zero over the average and will flatten the peak observed in the cross-correlation function (Figure 2.2 of WCAP 9172). There is a test of peakedness of this function by the microprocessor analyzing the cross correlation function in the TTFM.

If the cross correlation function is excessively flat, a warning message will be printed. Also, there will be an excessive difference between the four separate cross correlation peak locations that comprise the flow measurement on one loop. This error condition is also tested for by the microprocessor software.

Systematic noise can cause errors. The main source of this is 60 Hz pickup by the detector cables. 60 Hz (or 50 Hz as appropriate) is heavily filtered in the analog electronics prior to signal digitization and is also digitally filtered with an algorithm that averages data over a multiple of the line frequency period and thus acts as a notch filter for the line frequency and multiples thereof.

With extensive reproducibility data that can be verified by doing repeated measurements, simulating or analytical analysis of the effects of random detector noise is not considered necessary.