ENCLOSURE 2

MFN 06-160

TEPCO/GE UdFlow System for the Measurement of Nuclear Feedwater Flow Rate by Ultrasonic Doppler Technology

Non-Proprietary Version

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 06-160, which has the proprietary information removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]].

TEPCO/GE UdFlow System for the Measurement of Nuclear Feedwater Flow Rate by Ultrasonic Doppler Technology

June 2, 2006
U.S. Nuclear Regulatory Commission Headquarters
Rockville, Maryland

TEPCO

Tokyo Electric Power Company, Inc.
Research & Development Center
Thermal Hydraulics & Fluid Structure Dynamics Research Group

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Meeting Objectives

- Introduce NRC to the TEPCO/GE UdFlow System
- Present the reasons for the development of the System
- Describe the System hardware
- Develop the science behind the System
- Discuss the System accuracy Qualification Test results
- Detail the future activities and test plans
- Present LTR structure and content
- Solicit guidance from NRC

Introduction: The TEPCO / GE UdFlow System

- Feedwater pipe inner surfaces (piping and venturis) become rougher over time, which causes increased inaccuracy in the flow rate measurement.
- Existing ultrasonic flow meters assume a velocity flow profile to calculate feedwater flow rate. The assumed flow profile changes with pipe age.
- TEPCO Research & Development (R&D) has developed an Ultrasonic flow meter [[ ]].
- TEPCO R&D is collaborating with GE to evaluate, design, test, license, and manufacture this flow meter (the "TEPCO/GE UdFlow System") for application to BWRs and PWRs.
- [[ ]]
- GE will be submitting a Licensing Topical Report (LTR) for NRC approval to apply the TEPCO/GE UdFlow System to Measurement Uncertainty Recapture (MUR) power uprates.

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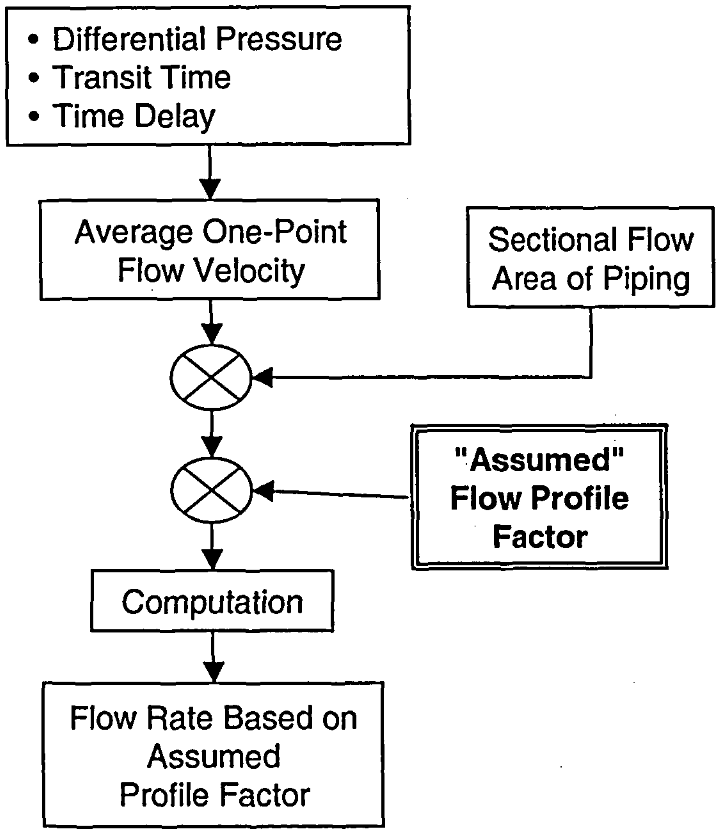
Existing Flow Meters

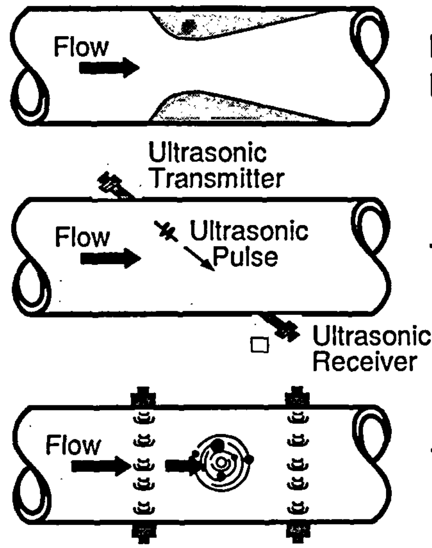
Flow Meter Algorithm



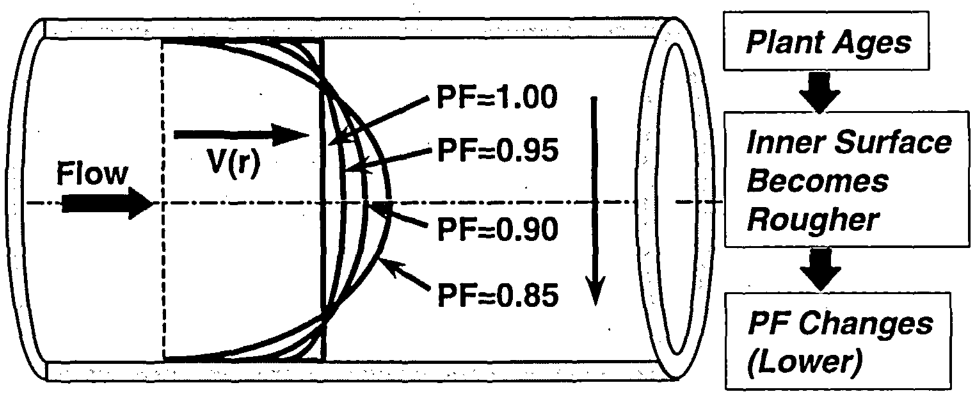
Flow Rate Based on "Assumed" Flow Profile

Existing Flow Meters

Existing Flow Meters	Parameter
• **Venturi**	**Differential Pressure**
• **Time of Flight**	**Transit Time**
• **Cross Correlation**	**Time Delay**



- Flow Profile Factors (PF) are determined by velocity profiles.
- Velocity profile is a function of Reynolds Number and pipe inner surface roughness.



Feedwater Flow Nozzle Inner Surface Degradation

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- Changes in inner surface roughness cause changes in flow velocity profile, which will affect flow meter accuracy (for flow meters that use a flow profile factor)

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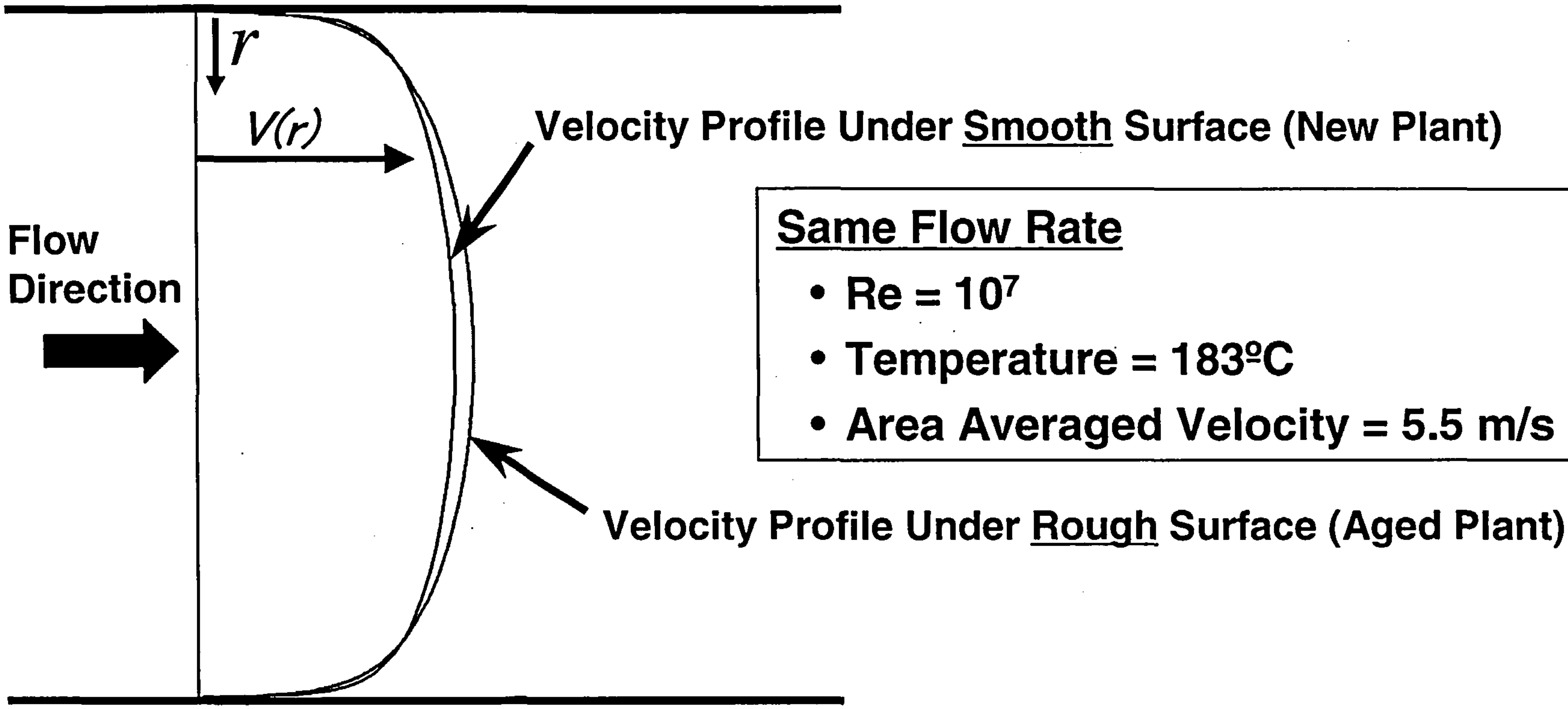
Profile Factor Effect on Existing Flow Meters



Same Flow Rate

- Re = 10^7
- Temperature = 183ºC
- Area Averaged Velocity = 5.5 m/s

- Different velocity profiles (New Plant and Aged Plant) for the same flow rate, require different profile factors for accurate flow meter measurement
- Impossible to simulate actual (changing) plant conditions during flow meter factory testing of existing flow meters
  - Surface roughness (corrosion)
  - Reynolds Number
  - Pipe configurations (flow disturbance, biased flow)

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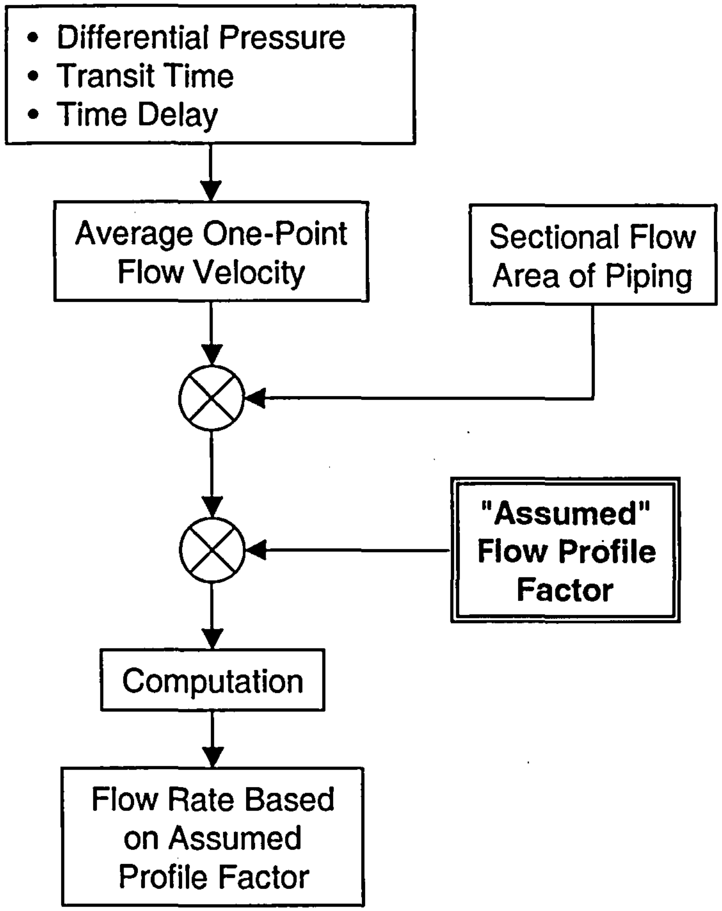
Flow Meter Methodology Comparison

Existing Methodology



Flow Rate Based on "Assumed" Flow Profile

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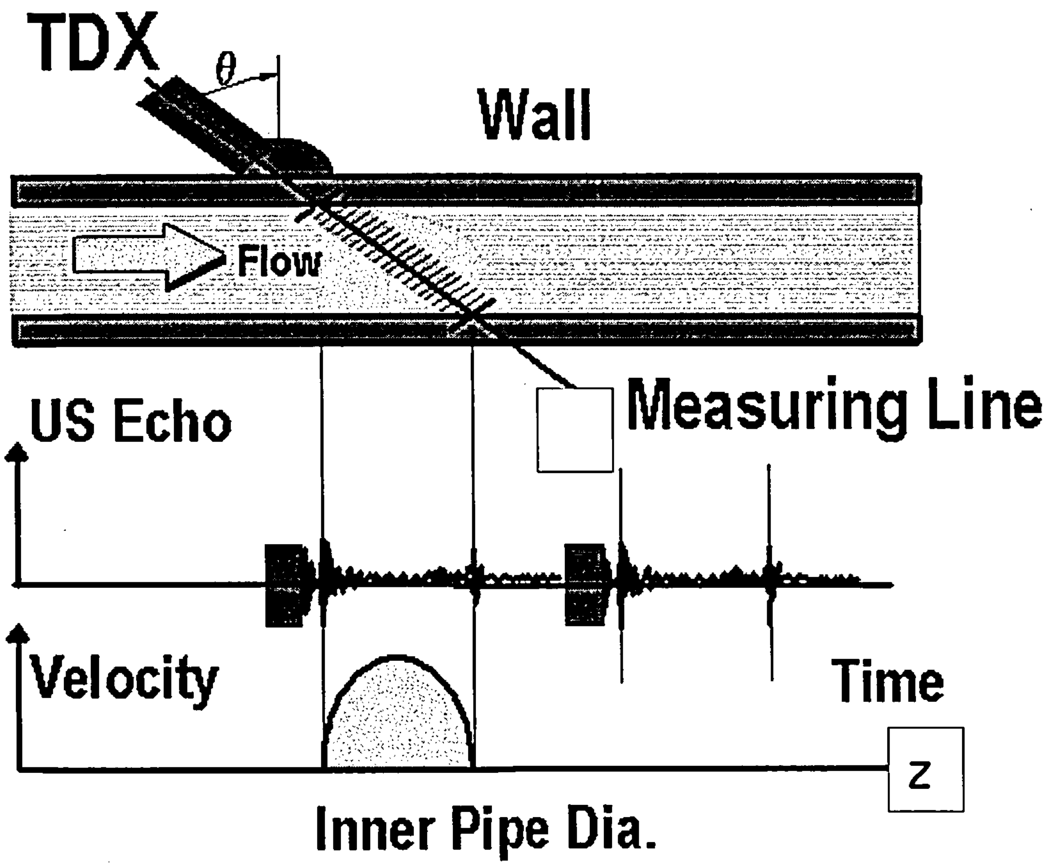
TEPCO/GE UdFlow System Science



- Pulsed Ultrasonic Echography
- Instantaneous Doppler Shift Frequency

$z = cT / 2$

$v = cf_D / 2f_0$

z - Distance Traveled

v - Flow Velocity

c - Sound Velocity

f_D - Doppler Frequency

T - Time Between Pulses

f_0 - Basic Frequency

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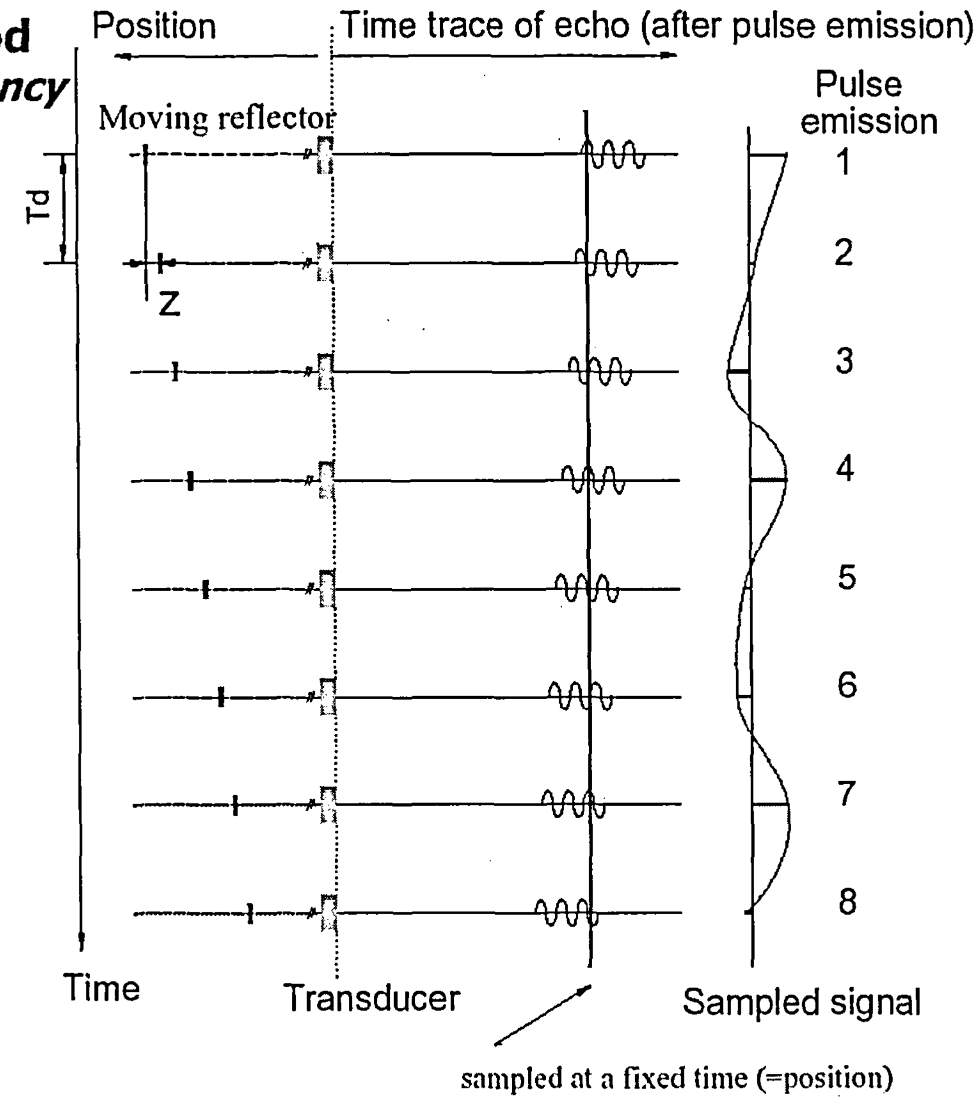
TEPCO/GE UdFlow System Science

Ultrasonic Doppler Method
Detection of Doppler frequency



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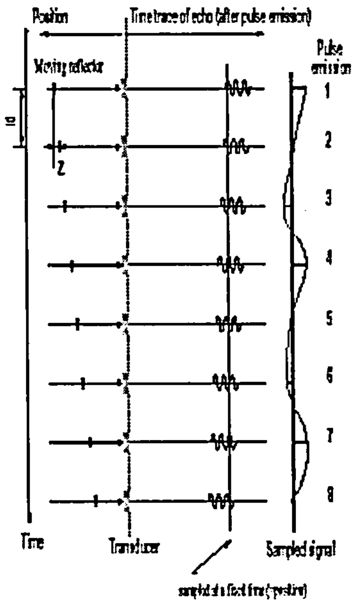
TEPCO/GE UdFlow System Science

Ultrasonic Doppler Method

Detection of Doppler frequency



$$\phi = f_0 T_d$$

$$d\phi/dt = f_0 dT_d/dt$$

$$T_d = 2z/c$$

$$dT_d/dt = (2/c)dz/dt = 2v/c$$

$$d\phi/dt = 2vf_0/c = f_D$$

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Ultrasonic Doppler Method

Measurement limitation

- From Nyquist sampling theorem

  $f_{D\,max} < f_{prf}/2 \Rightarrow V_{max} < c f_{prf}/4 f_0$

- Maximum depth

  $P_{max} = c/2 f_{prf}$

- Measurement constraint

  $V_{max} P_{max} < c^2/8 f_0$

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TEPCO/GE UdFlow System Science

Ultrasonic Doppler Method

Characteristics and specifications

- Spatial resolution
  $$dz = cT_d / 2$$
- Velocity resolution
  $$dv = c f_D / 2 f_o$$
- Maximum depth
  $$P_{max} = c/(2f_{prf})$$
- Maximum velocity
  $$V_{max} = cf_{prf}/(4f_0)$$

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Qualification Tests – NIST, Nmi, Nmi - J

- "Proof-of-Principle" testing was conducted at:
  - NIST – U.S. National Institute of Standards and Technology
  - Nmi – Nederlands Meetinstituut
  - Nmi-J – Japan National Institute of Advanced Industrial Science and Technology
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Qualification Tests - CENAM

- "Statistically significant" testing was conducted at CENAM, Centro Nacional de Metrología, in January 2006.
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Qualification Tests - Specifics

Facility	Liquid	Flow Condition	Pressure	Reynolds Number	Temperature
NIST	Water	Stable, Well-controlled	Atmospheric (pump head)	4.0E5 to 2.7E6	Ambient
Nmi-J	Water	Stable, Well-controlled	Atmospheric (pump head)	1.0E6 to 2.0E6	Ambient
Nmi	Water	Stable, Well-controlled	Atmospheric (pump head)	8.5E4 to 1.8E5	Ambient
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Flow Profile Measurement – Nuclear FW Conditions

Test Specification

Thermal-Hydraulic Conditions Similar to Actual BWR Plant

Type of Liquid: Water

Flow Condition: Stable, Controlled

Pressure: 7.6 MPa

Reynolds Number: 1.6×10^7

Temperature: 216 ºC

Flow Rate: 3200 t/h

Feedwater Piping

Inner Diameter: 500 mm

Wall Thickness: 28 mm

Material: Carbon Steel

Results

- **A velocity profile was obtained using a single transducer.**
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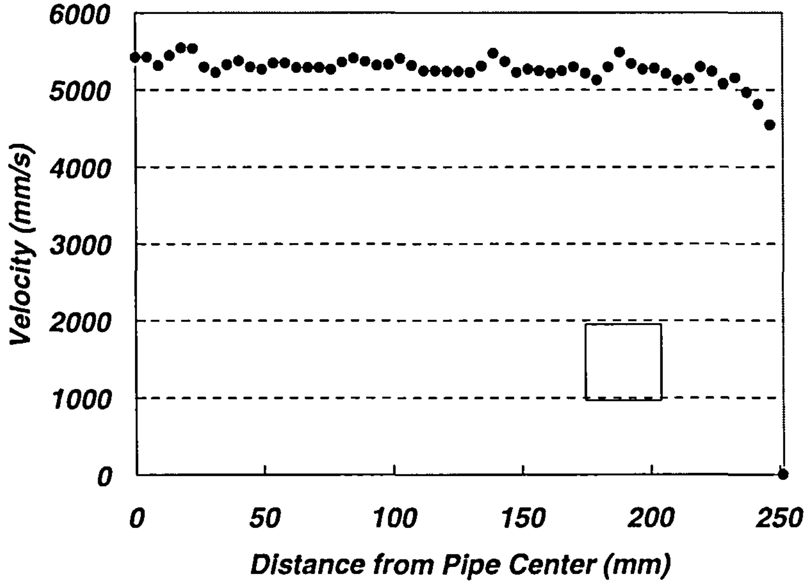
Instantaneous Velocity Profile Across the Pipe Cross-Section



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Conclusion

- A new type of ultrasonic Doppler flow meter has been developed that can [[ ]]

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- By improving feedwater flow rate measurement accuracy, an operating nuclear power plant can apply to NRC for an increase in power output.

- To allow the application of this flow meter to an operating nuclear power plant, GE requests US NRC review and approval of GE's LTR, to be submitted in September 2006.

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