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A DESCRIPTION OF THE CROSSFLOW SYSTEM TO SUPPORT 1.4% POWER UPRATE AT SONGS

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F-1

determine if the process signals are rapidly changing, for instance due to fouling or defouling of the main feedwater or main steam venturies. The installation and commissioning were reasonably trouble-free and the system has been operating successfully for approximately one year.

INTRODUCTION

CROSSFLOW (UFM) & CORRTEMP (UTM) SYSTEMS SETUP

CROSSFLOW (UFM) SYSTEM

General Description

CROSSFLOW system consists of four ultrasonic transducers mounted on a metal support frame that attaches, externally, to the pipe (see Figure 1). Transmitter (a transducer, that propagates an ultrasonic signal), placed at cross-section A, propagates ultrasonic signal in a perpendicular direction to the pipe axis. Receiver (a transducer, that receives an ultrasonic signal) is placed in the same cross-section on the opposite side of the pipe. Similar pair of transducers (transmitter and receiver) is placed in a pipe's cross-section B with a certain distance L downstream of the cross-section A. Turbulent flow in the pipe forms a spatial random pattern of eddies moving with the flow. In cross-section A the ultrasonic signal are affected by the eddies, causing modulation of ultrasonic signal, respectively [Ref. 1]. Demodulation of the ultrasonic signal results in a random signal $X_a(t)$. An ultrasonic beam in the cross-section B, a distance L downstream of the first beam, produces another random signal $X_b(t)$. Turbulent pattern of eddies moving along the pipe, remains almost the same over a certain distance L_t. If the distance L between cross-sections A and B is smaller then L_t, the signal $X_b(t)$ is similar to signal $X_a(t)$ with a certain time delay, τ^*:

$$X_a(t) = X_b(t+\tau^*) \qquad (1)$$

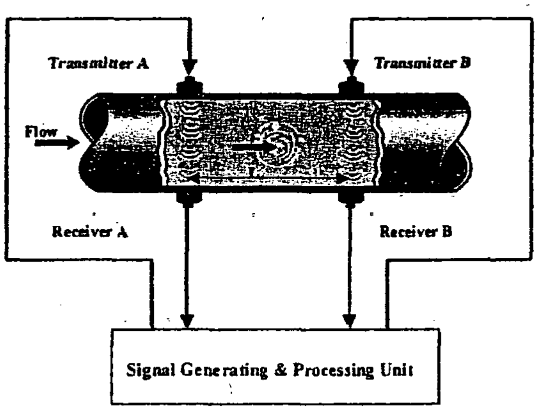


Figure 1: CROSSFLOW system (ultrasonic cross-correlation flow meter)

Cross-correlation function could be used to calculate τ^*. Figure 2 shows a typical cross-correlation result. Function $R(\tau)$ has well defined maximum at $\tau=\tau^*$.

$$R(\tau) = \int_0^T X_a(t) X_b(t+\tau)dt \qquad (2)$$

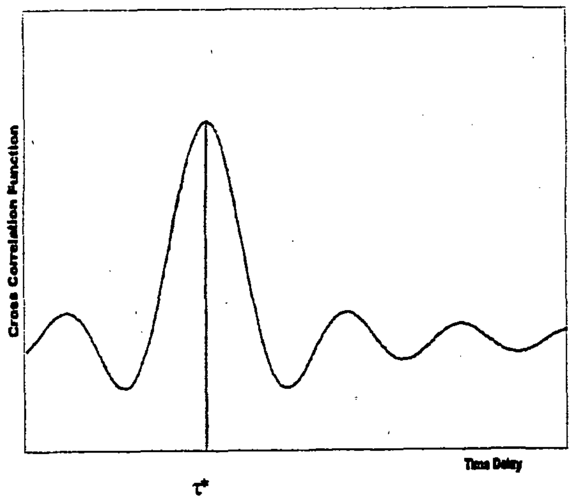


Figure 2: Typical cross-correlation function

Measured flow velocity, which is a transport velocity of the turbulent pattern along the pipe, is calculated as follows:

$$V_m = \frac{L}{\tau^*} \qquad (3)$$

This velocity, V_m, is not the average velocity, V_a, of the fluid. Hence, the measured velocity V_m must be multiplied by a velocity profile correction factor, C_0, to obtain the average velocity of the fluid in the pipe.

$$V_a = C_0 V_m \qquad (4)$$

and the flow rate in the pipe is calculated by the following equation by substituting Equations 3 and 4:

$$W = \rho A Va = C_0 \rho A \frac{L}{\tau} \qquad (5)$$

Where: A is the cross-sectional flow area
ρ is the density of the fluid.

CORRTEMP (UTM) SYSTEM

General Description

The *UTM* system uses clamp-on ultrasonic transducers by definition. Figure 3 is a schematic representation of the ultrasonic arrangement using a transducer pair. The two transducers are installed perpendicular to the pipe surface on diametrically opposing positions. These are used to measure the speed of sound in water. Once the pressure is known, the water temperature is calculated from NIST water and steam properties table.

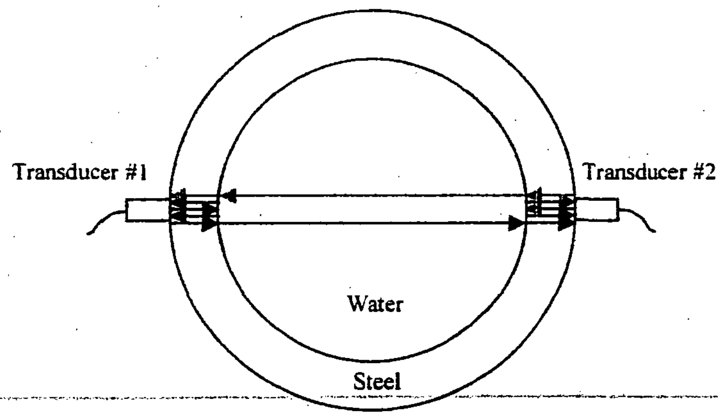


Figure 3: Schematic ultrasonic arrangements

One of the transducers generates an ultrasonic pulse that reverberates in the pipe wall thickness at least two times and is received by the same transducer on each reverberation. The time difference between the two received back wall echoes, in combination with the speed of sound in steel, is used to calculate the pipe wall thickness. This is repeated with the second transducer in order to determine the pipe wall thickness at the second position. The inside diameter *ID* is calculated by subtracting the two thickness values from the pipe outside diameter *OD*. The pipe outside diameter is measured accurately once during system installation. In general, the system could be operated in two modes: 1) Through Transmission (TT mode); In the TT mode the opposing transducer receives the ultrasonic pulse that has passed through pipe walls and pipe diameter once. This waveform is processed to determine the time of flight of sound wave along one pipe inside diameter. 2) Pulse Echo (PE mode); In the PE mode the ultrasonic pulse is reflected from the opposing point on the inside diameter of pipe with respect to transmitter. The transmitter is used as a receiver after sending the ultrasonic pulse and receives the pulse after it has traveled one round trip along the pipe diameter. The round trip transit time of the reflected ultrasonic signal from the opposing pipe wall's inner surface is divided by two to determine the time of flight of sound wave along one pipe inside diameter. Details of this cancellation process are proprietary and are out of the scope of this document [Ref. 2].

CROSSFLOW SYSTEM / PLANT COMPUTER INTERFACE

A serial communication (RS232/RS485) was used to implement an on-line flow and temperature correction software layer to interface the AMAG CROSSFLOW ultrasonic flow measurement system and AMAG CROSSTEMP ultrasonic temperature measurement system with the South California Edison SONGS Plant Process Computers (Plant Monitoring System "PMS" & Colss Backup Computer System "CBCS"). The software ACL (Algorithm and Communication Layer) is composed of three different modules. These modules are OVCC.DLL (Online Venturi Correction Coefficient) and COMPRO residing on UFM unit, and OTCC.DLL (Online Temperature Correction Coefficient) residing on the UTM unit (Figure 4).

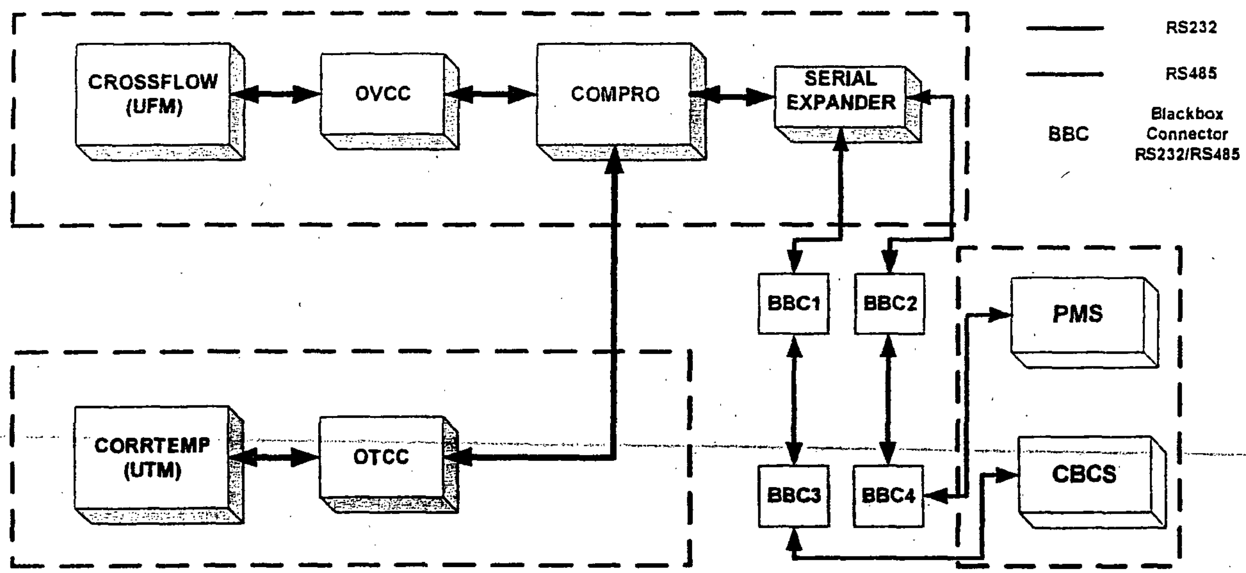


Figure 4: CROSSFLOW / Plant Computer Interface

Algorithm & Communication Layer "ACL" Configuration

The CROSSFLOW & CORRTEMP systems are supplied as digital measurement devices that uses the outputs from Plant Process Computers (PMS and CBCS) to calculate the required Venturi flow correction, to calculate the required temperature compensation and sends the results back to the Plant Process Computers for flow and temperature corrections.

As a result, the ACL software layer is required to act as an interface between the CROSSFLOW (UFM) and the CORRTEMP (UTM) systems on one side and the Plant Process Computers on the other side. The ACL software layer acquires field input data from the Plant Process Computer, CROSSFLOW and CROSSTEMP systems, calculate the Venturi calibration correction factors and temperature correction factor in accordance with the SCE requirements, and provide output data to the Plant Process Computers. The ACL inputs/outputs provided/required by Plant Process Computers is transmitted through serial port communication.

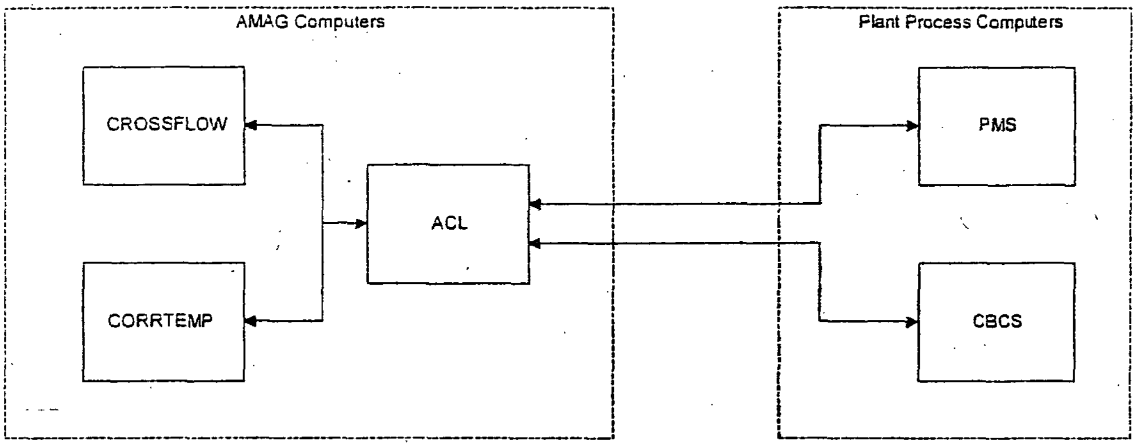


Figure 5: Product Prospective

In summary, the ACL software layer will perform the following functions:

- Acquire field input data for the CROSSFLOW flow calculation and Venturi and temperature correction calculations
- Calculate flow adjustment correction factors
- Calculate temperature adjustment correction factors
- Detect and handle rapid defouling events
- Detect and handle communication error events
- Send output data to the Plant Process Computers through serial port communication

By starting the CROSSFLOW the ACL reads database constants listed in the table below from *"startup.ini"* file. These values are user configurable and are read once at the start of each of CROSSFLOW and CORRTEMP. Each of the two systems will have its exclusive *"startup.ini"* file (*"otcc.ini","ovcc.ini", respectively).*

Table 1: Some of the ACL Database Constant Input Data

Variable Name	Description
100%FF	100% power loop feedwater
kFv_min	(100%FF*kFv_min)/100 gives the minimal feed water power used in calculations
CfFWUpperLimitConst	The upper limit value for FW Cf
CfFWLowLimitConst	The lower limit value for FW Cf
CfBDUpperLimitConst	The upper limit value for BD Cf
CfBDLowLimitConst	The lower limit value for BD Cf

Table 1: Some of the ACL Database Constant Input Data (cont.)

	Variable Name	Description
	CfMSUpperLimitConst	The upper limit value for MS Cf
	CfMSLowLimitConst	The lower limit value for MS Cf
	DF	Detection limit for rapid defouling
	Nf	Size of Cf long buffer
	Kf	Size of Cf short buffer
	CfPercentGoodFW	Minimum Buffer Limit for Good Cf, FW
	CfPercentGoodMS	Minimum Buffer Limit for Good Cf, MS
	CfPercentGoodBD	Minimum Buffer Limit for Good Cf, BD
	CfBDUncertaintyLongConst	Uncertainty limit for BD Cf long buffer
	CfFWUncertaintyLongConst	Uncertainty limit for FW Cf long buffer
	CfMSUncertaintyLongConst	Uncertainty limit for MS Cf long buffer
	CfUncertaintyShortConst[1]	Uncertainty limit, Cf short buffer, FW, MS
	ObjectFactory	Plant's name determines Online Operation, "Stand Alone" sets offline mode.

In general, CROSSFLOW UFM and CORRTEMP configuration parameters are divided into different categories. There are a few key parameters, which are important to the quality and performance of the system. These parameters are the values that will be used in on line calculation mode for verifying the quality assured uncertainty calculation for the transmitted data to plant computers. For example feedwater maximum allowable uncertainty "UncertaintyLongFw" is the value based on the quality assured calculation. The same type parameter limits the uncertainty verification for blow down and steam flow calculation. However, there are parameters that could be set and modified by utility Licensee (trained utility personnel). Those parameters are plant specific parameters such as correction factor upper and lower limits, the short and long buffer size, etc. Finally, the system is designed in a format that could be used as an offline mode "Stand Alone". This feature gives flexibility to the user in case of experiencing any problem to use the system in the offline mode for calculating the flow and temperature correction factors.

ALGORITHM & COMMUNICATION LAYER (ACL)

The CROSSFLOW system is supplied as a digital measurement device that uses the outputs from Plant Process Computers (PMS and CBCS) to calculate the required Venturi flow correction and sends the results back to the Plant Process Computers for flow correction. The CROSSTEMP system is supplied as a digital measurement device that uses the Plant Process Computers outputs to calculate the required temperature compensation and sends the results back to the Plant Process Computers for temperature correction. As a result, the ACL software layer is required to act as an interface between the CROSSFLOW (UFM) and the CROSSTEMP (UTM) systems on one side and the Plant Process Computers on the other side. The ACL software layer acquires field input data from the Plant Process Computer, CROSSFLOW and CROSSTEMP systems, calculate the Venturi calibration correction factors and temperature correction factor in accordance with the SCE requirements, and provide output data to the Plant Process Computers. The ACL inputs/outputs provided/required by Plant Process Computers be transmitted through serial port communication (RS232 / RS485) (Figure 6). In summary, the ACL software layer will perform the following functions:

- Acquire field input data for the CROSSFLOW flow calculation and Venturi and temperature correction calculations
- Calculate flow adjustment correction factors
- Calculate temperature adjustment correction factors
- Detect and handle rapid defouling events
- Detect and handle communication error events
- Send output data to the Plant Process Computers through serial port communication

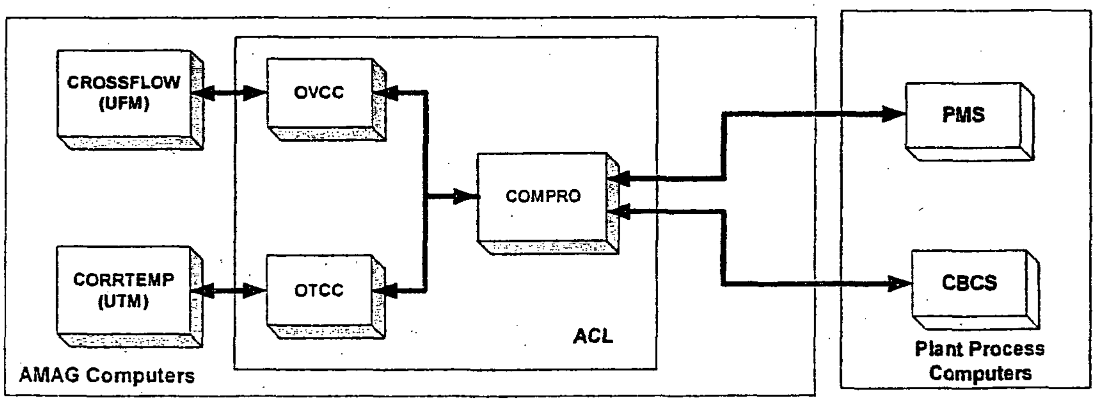


Figure 6: System Architecture

In general, ACL consists of OVCC, OTCC, and COMPRO. COMPRO is the communication module between UTM/UFM system and Plant Process Computers (PPC) [Ref. 3]. It collects the input data from PPC (pressure, temperature, and venturi flow data) and makes it available to OVCC and OTCC. Also, collecting output data and delivering it to PMS and CBCS. The OVCC is the correction factor algorithm (C_f) module. It delivers pressure and temperature to CROSSFLOW and collects F_u (CROSSFLOW measured flow) for buffering and generating C_f and other outputs/alarms/errors for the system. Also the OTCC performing the same type of calculation as OVCC module. It delivers pressure to CORRTEMP and collects T (CORRTEMP measured temperature) for buffering and generating C_t and other outputs/alarms/errors for the system. Figure 7 and Figure 8 show the input/output/alarms/errors screens for both UFM and UTM systems.

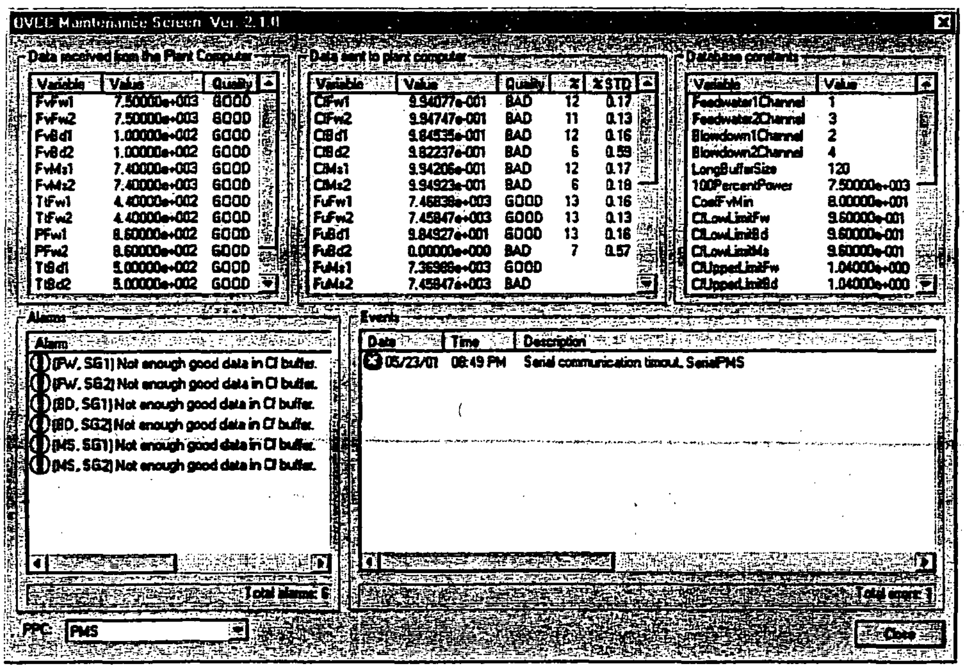


Figure 7: OVCC Maintenance Screen

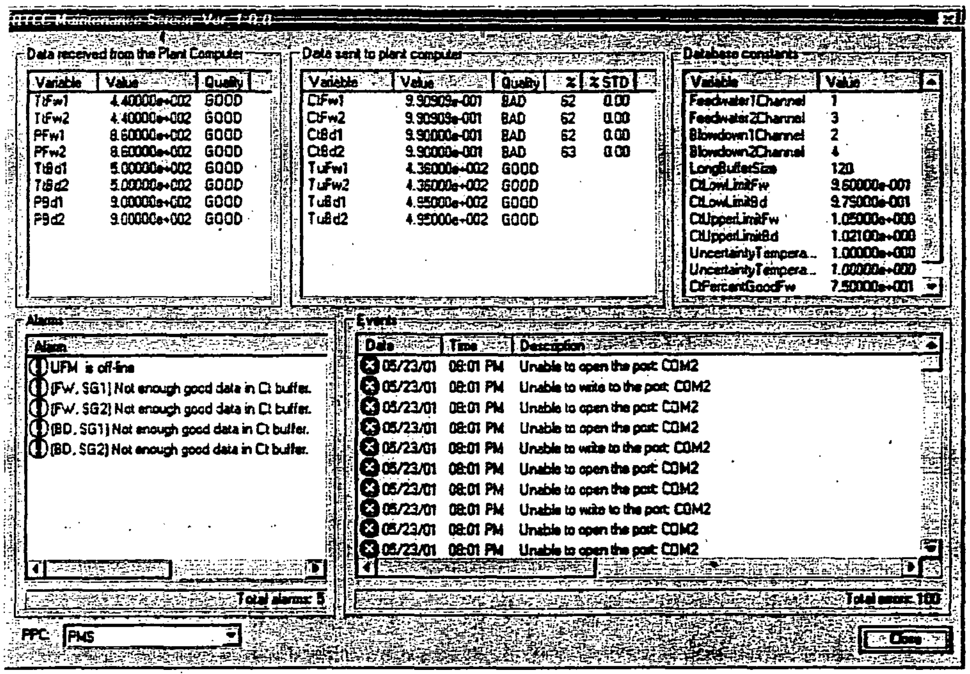


Figure 8: OTCC Maintenance Screen

CROSSFLOW (UFM) & CORRTEMP (UTM) FIELD INSTALLATIONS

The combined CROSSFLOW (UFM) / CORRTEMP (UTM) systems is shown in Figure 9. The following describes the hardware for one unit and each unit is identical. In general in each unit, main feedwater flow rate & temperature for each of two main feed lines are measured by permanently installed ultrasonic detector assemblies consisting of brackets (UFM & UTM brackets) and permanently installed sensors that are strapped on the main feedwater lines (20 inches line). Also, blowdown flow rate & temperature for each of two blowdown lines are measured by permanently installed ultrasonic detector assemblies consisting of brackets (UFM & UTM brackets) and permanently installed sensors that are strapped on the blowdown lines (4 inches line). Figure 10 to Figure 15 show the installed bracket for main feedwater and blowdown lines. A total length of 600 feet of cables was used for connecting the installed hardware transmitter and receiver probes to the electronics that was setup in demineralization control room.

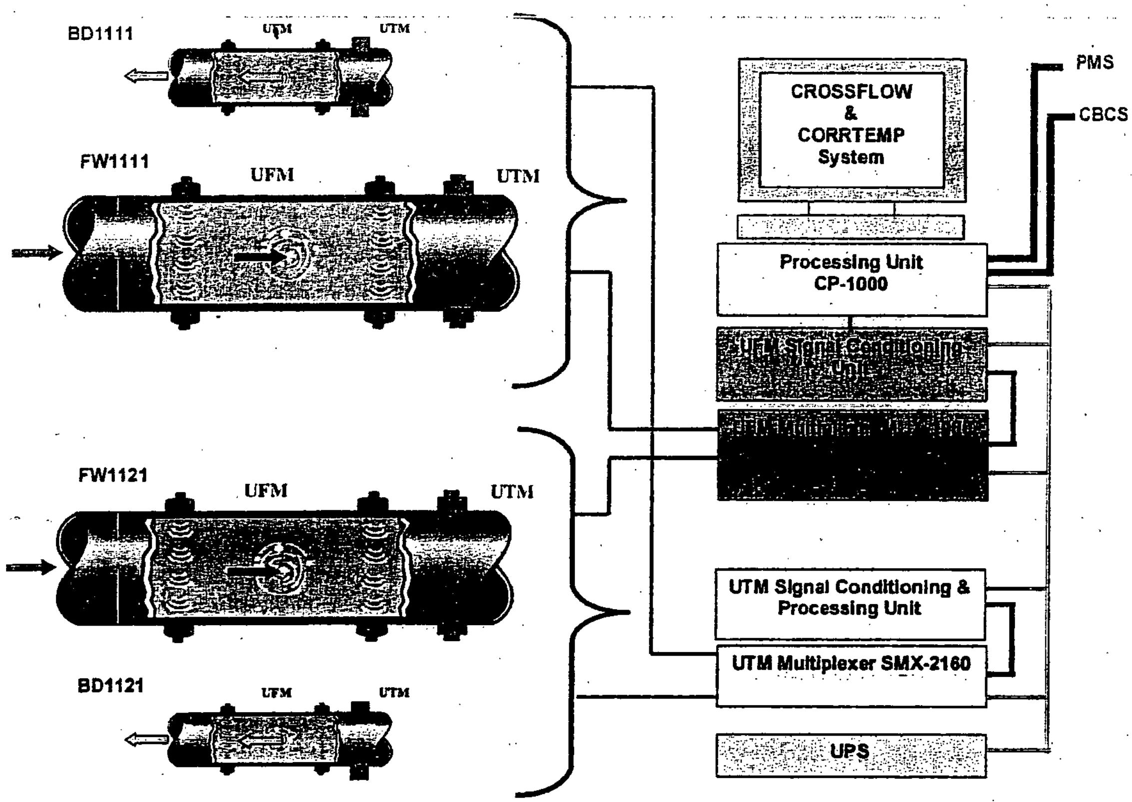


Figure 9: CROSSFLOW & CORRTEMP combined hardware for SONGS Unit 2 and 3

Figure 10: UFM & UTM installation on blowdown lines

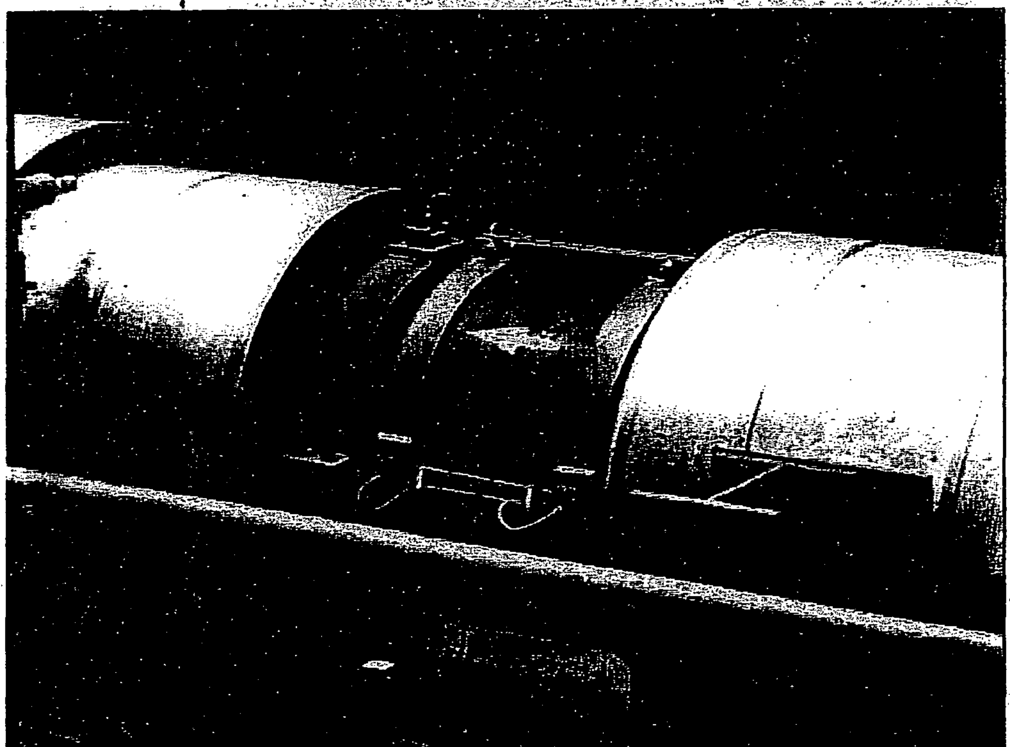


Figure 11: UFM & UTM installation on main feedwater lines

Figure 12: Insulated UFM & UTM brackets on blowdown lines

Figure 13: Insulated UFM & UTM brackets on main feedwater lines

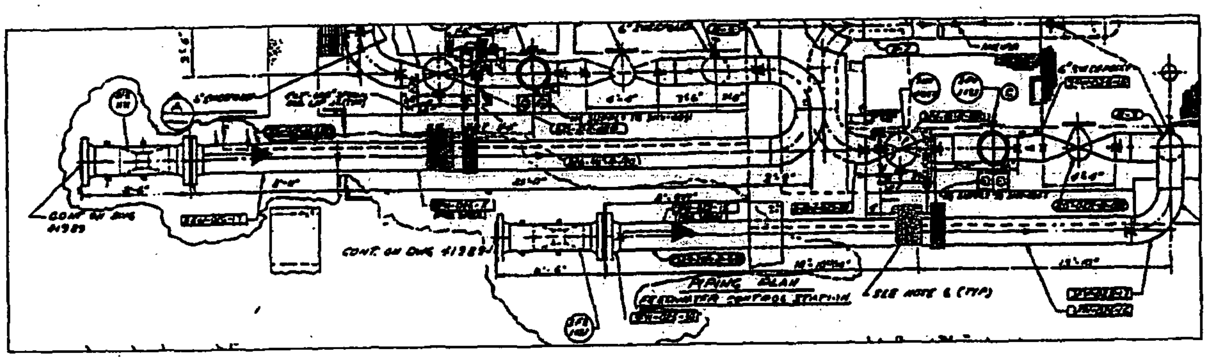


Figure 14: SONGS typical feedwater line UFM and UTM installation plan view

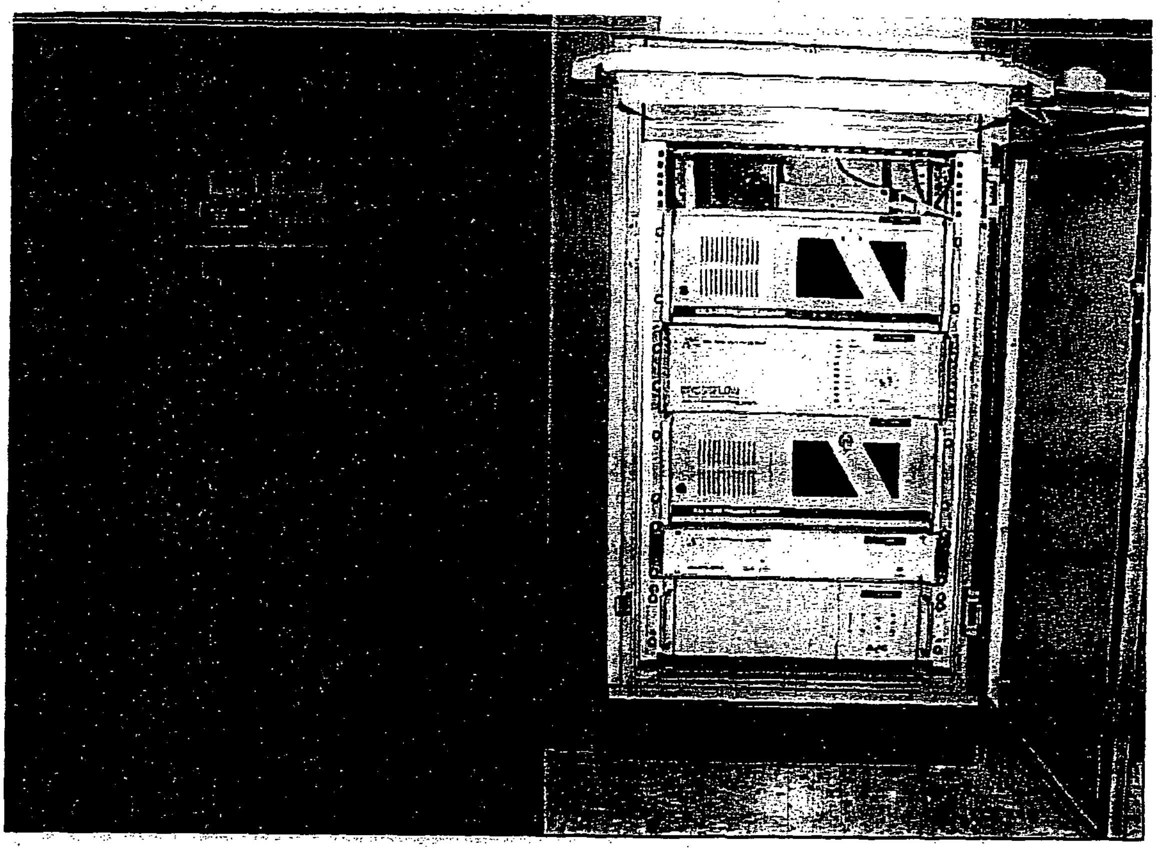


Figure 15: CROSSFLOW/CORRTEMP electronics system cabinet

CALCULATION OF REACTOR POWER

Reactor power is based on a secondary calorimetric which uses steam flow rates, can be calculated using raw plant

SYSTEM COMMISSIONING AND OPERATING EXPERIENCES

The system commissioning and operating experiences are discussed in Reference 4.

References

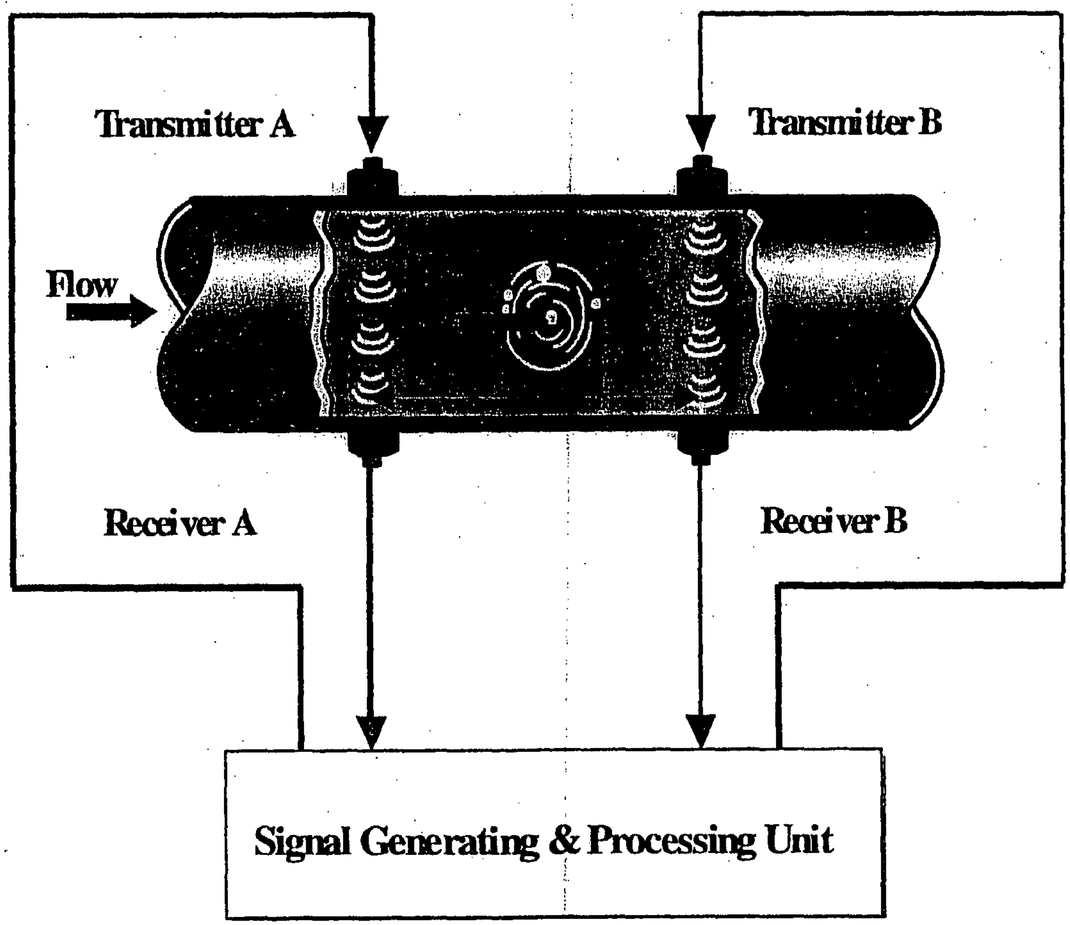
1. Westinghouse-CE Topical Report CENPD-397-P-A, Revision 01, "Improved Flow Measurement Accuracy Using Crossflow Ultrasonic Flow Measurement Technology," May 2000.

2. Advanced Measurement & Analysis Group (AMAG), "AMAG-MAN-EN-006-00 Users Manual for CORRTEMP 1.0.x UTM System," Revision 0, August 2001.

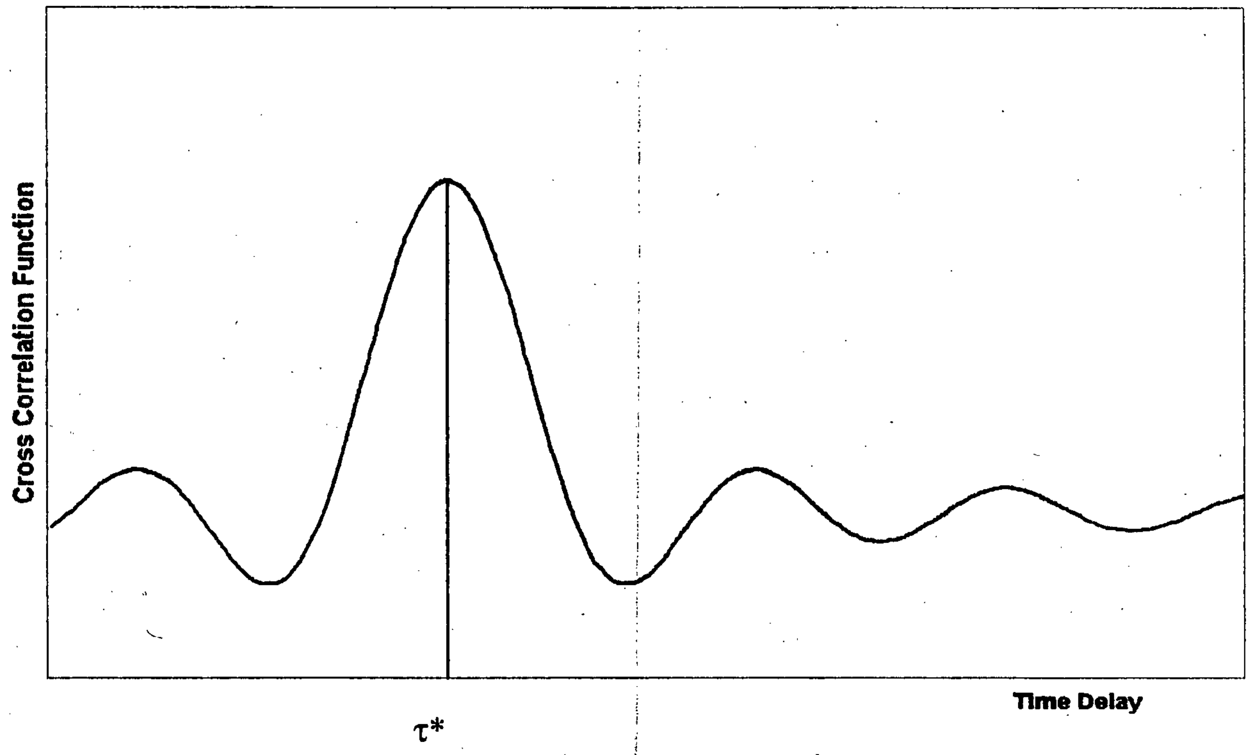
3. Advanced Measurement & Analysis Group (AMAG), "Software Requirements Specifications SRS-7137-06-Rev02," January 2002.

4. "A Description of the CROSSFLOW System to Support 1.4% Power Uprate at SONGS," Vahid Askari, AMAG, Inc, Joseph G. Murray, SONGS/SCE, and Michael J. Schwaebe, SONGS/SCE, presented to EPRI NPPI Conference July 2002.

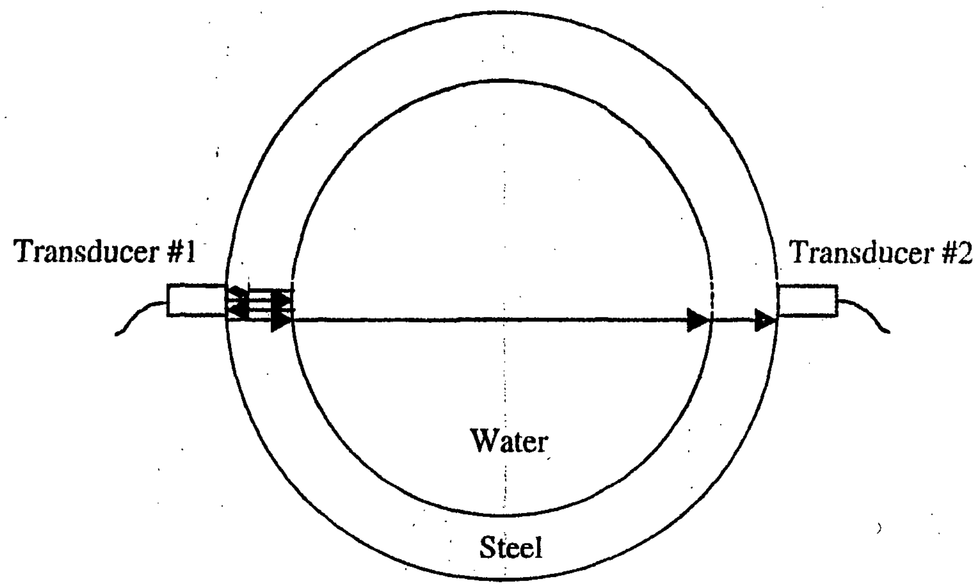
CROSSFLOW System

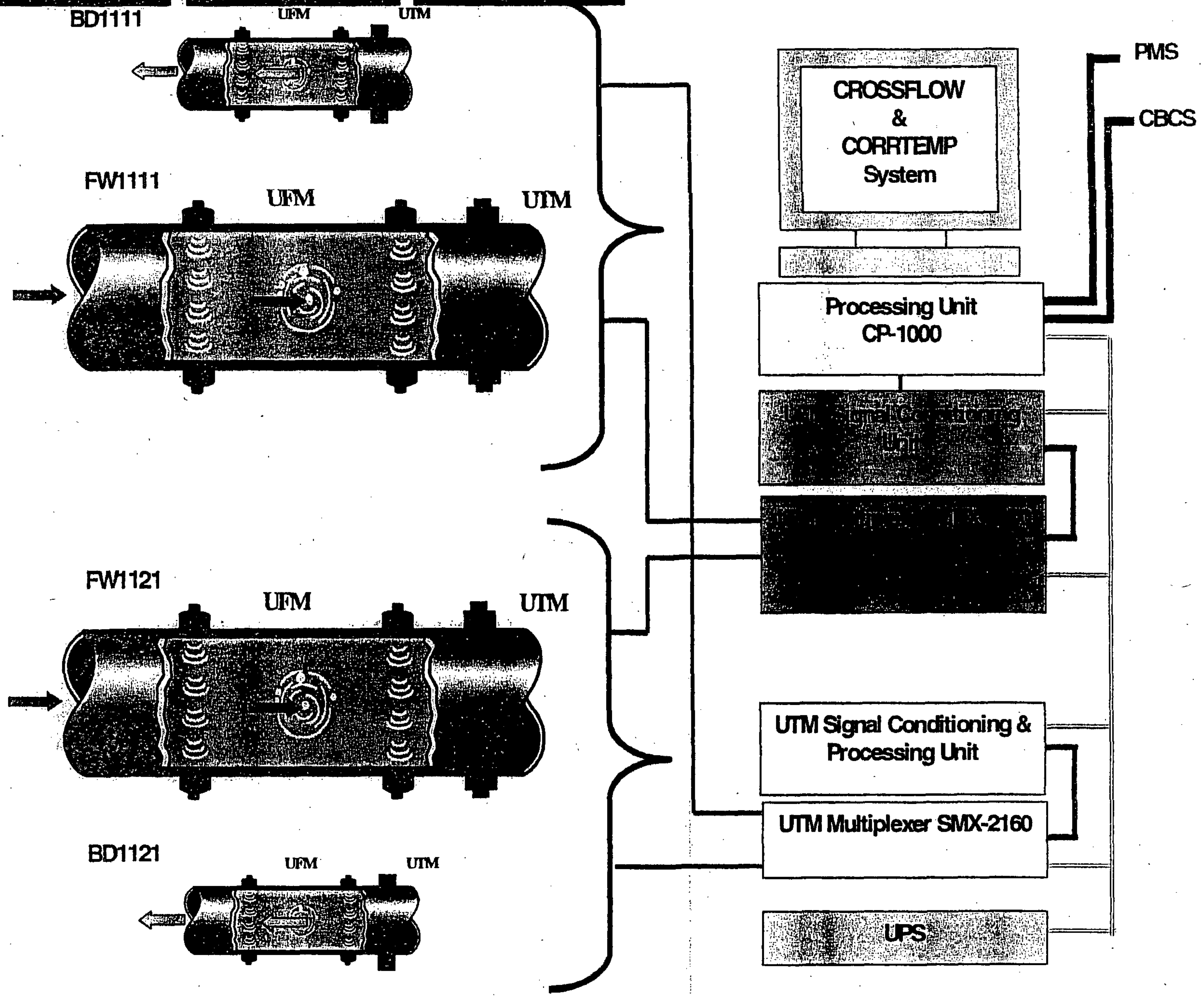


Typical Cross Correlation Function

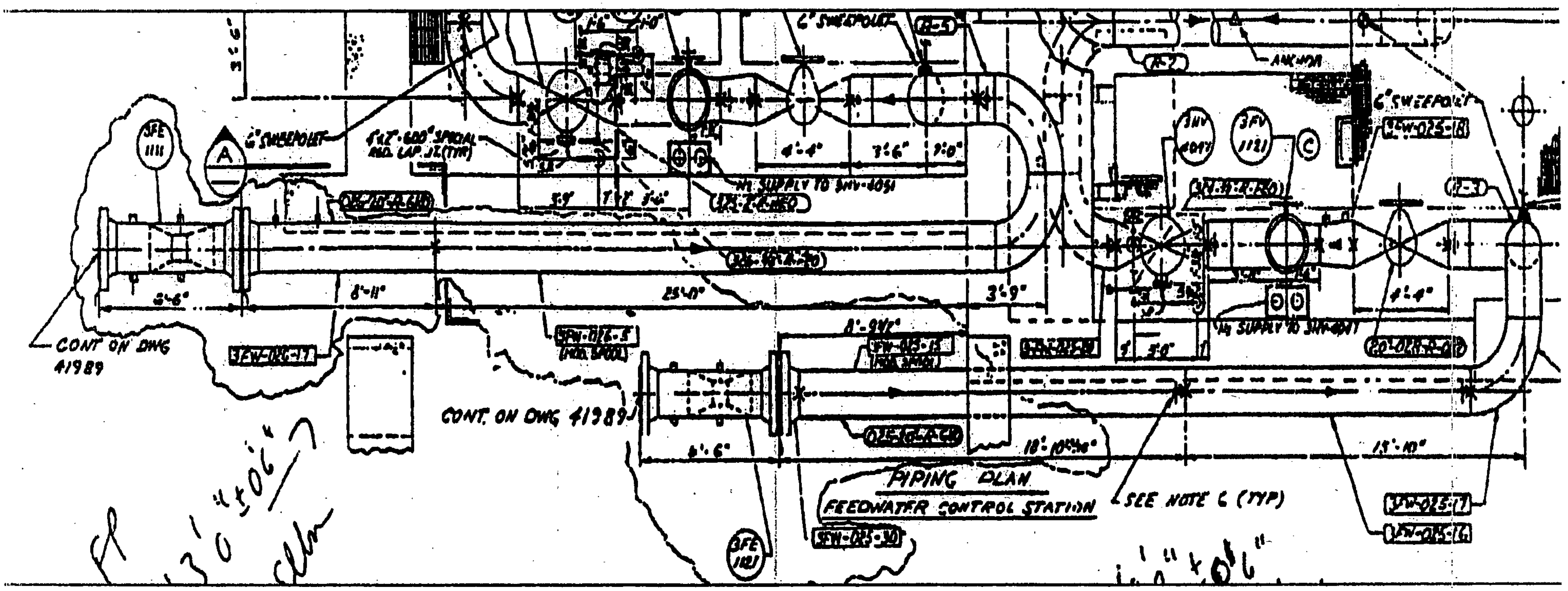


CORRTEMP UTM

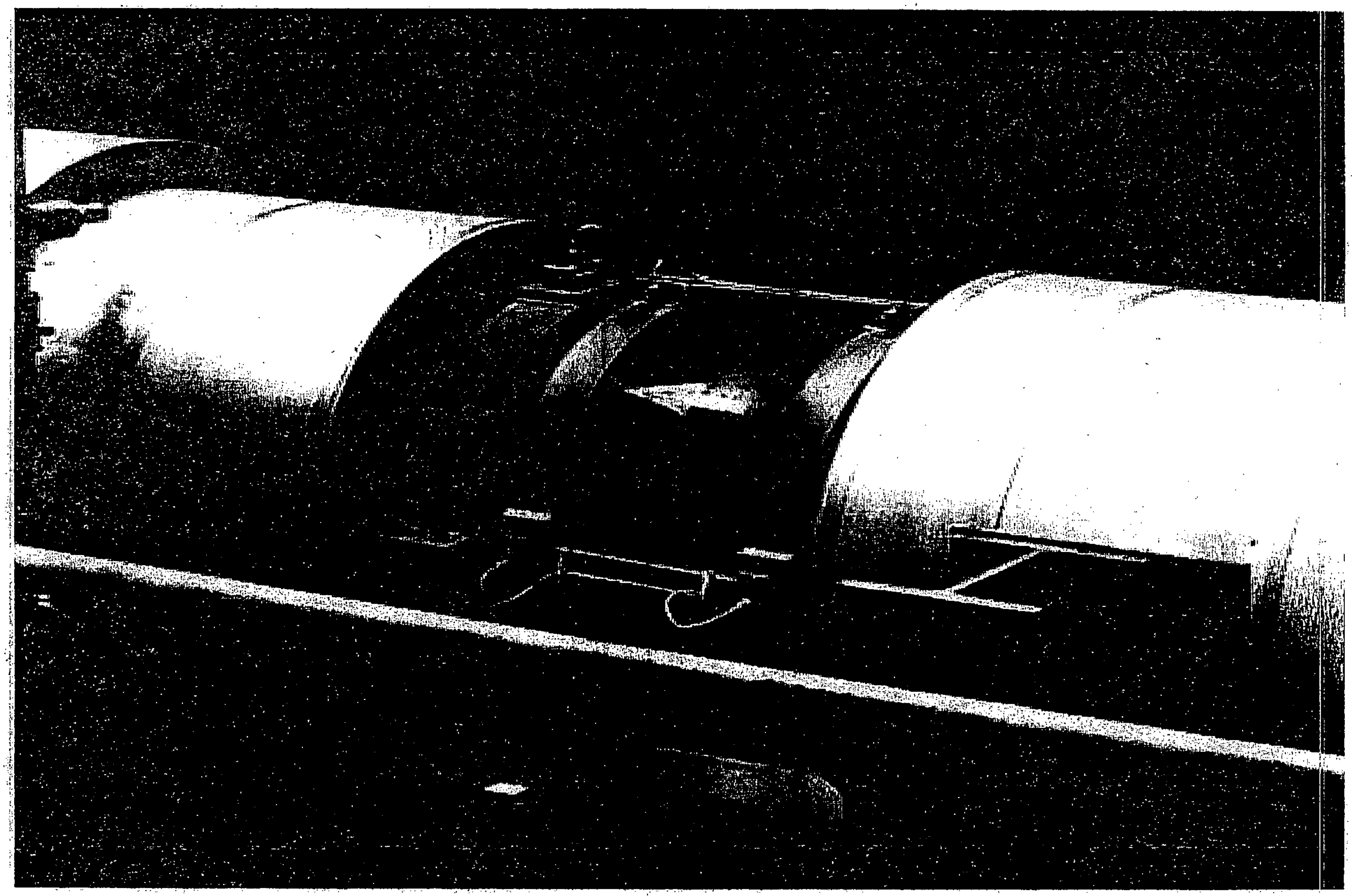



BD1111
UFM
UTM
FW1111
UFM
UTM
FW1121
UFM
UTM
BD1121
UFM
UTM
CROSSFLOW
&
CORRTEMP
System
PMS
CBCS
Processing Unit
CP-1000
UTM Signal Conditioning &
Processing Unit
UTM Multiplexer SMX-2160
UPS

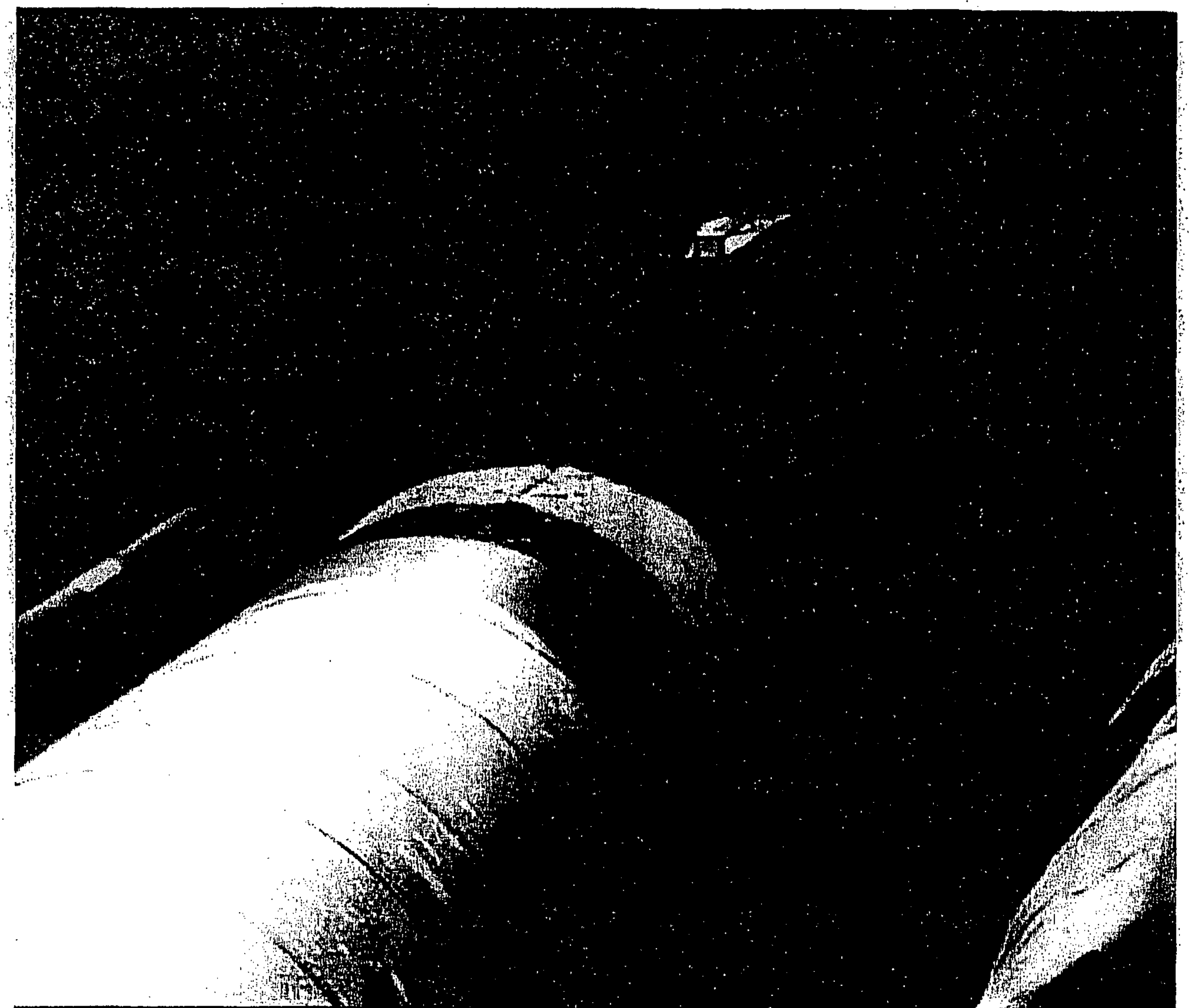
Feedwater Plan View



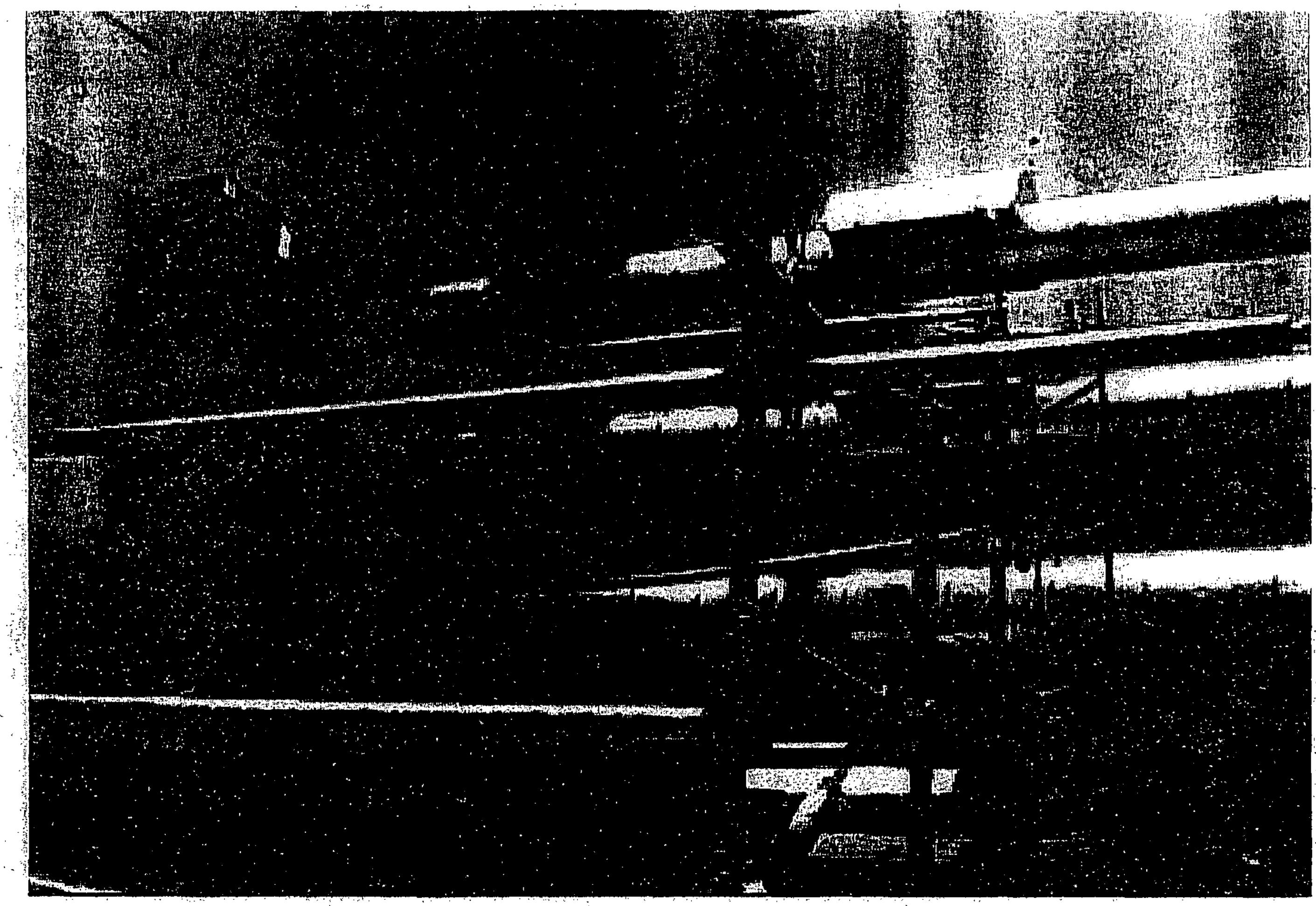
Feedwater UFM and UTM



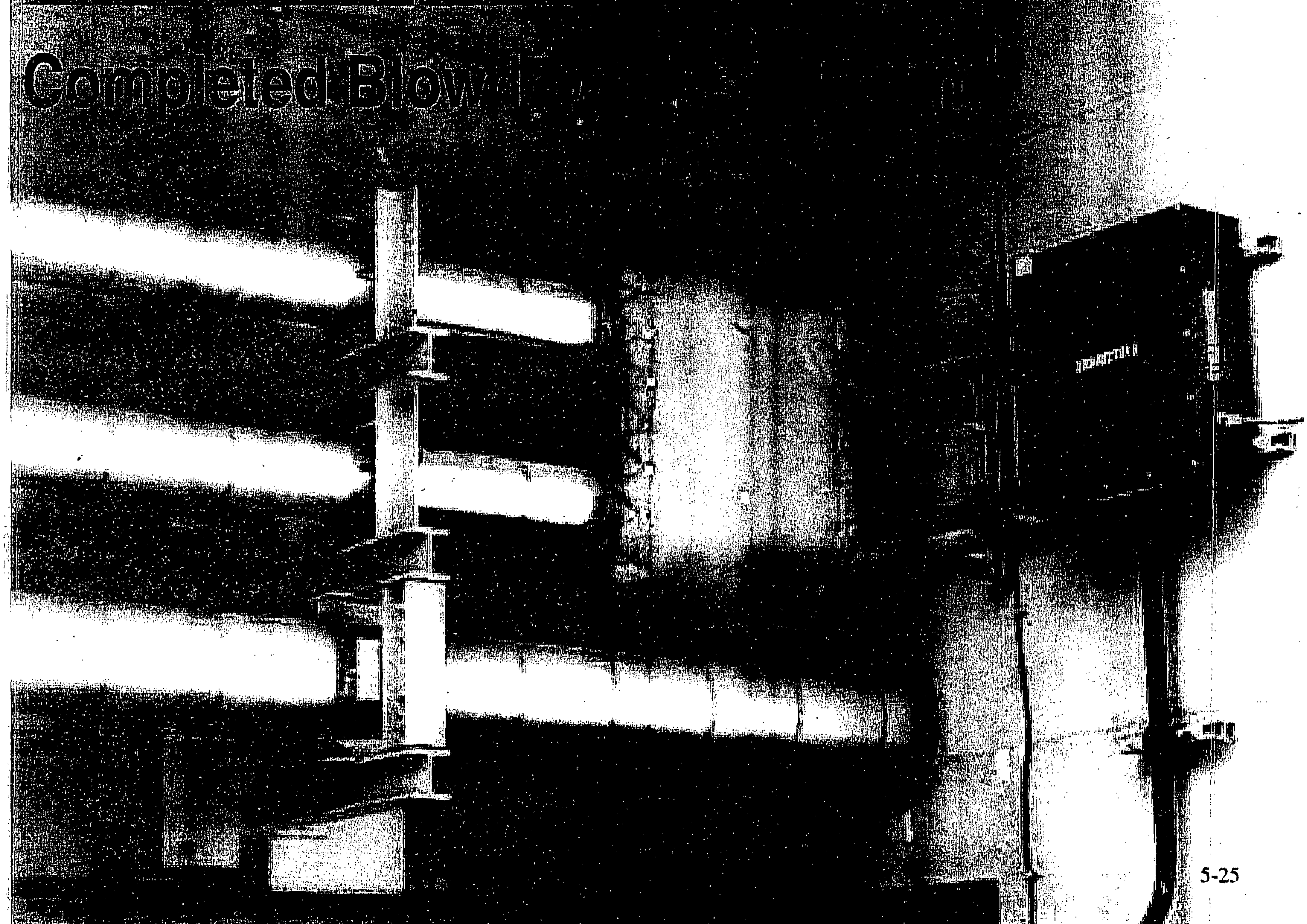
UFM and UTM after Insulation



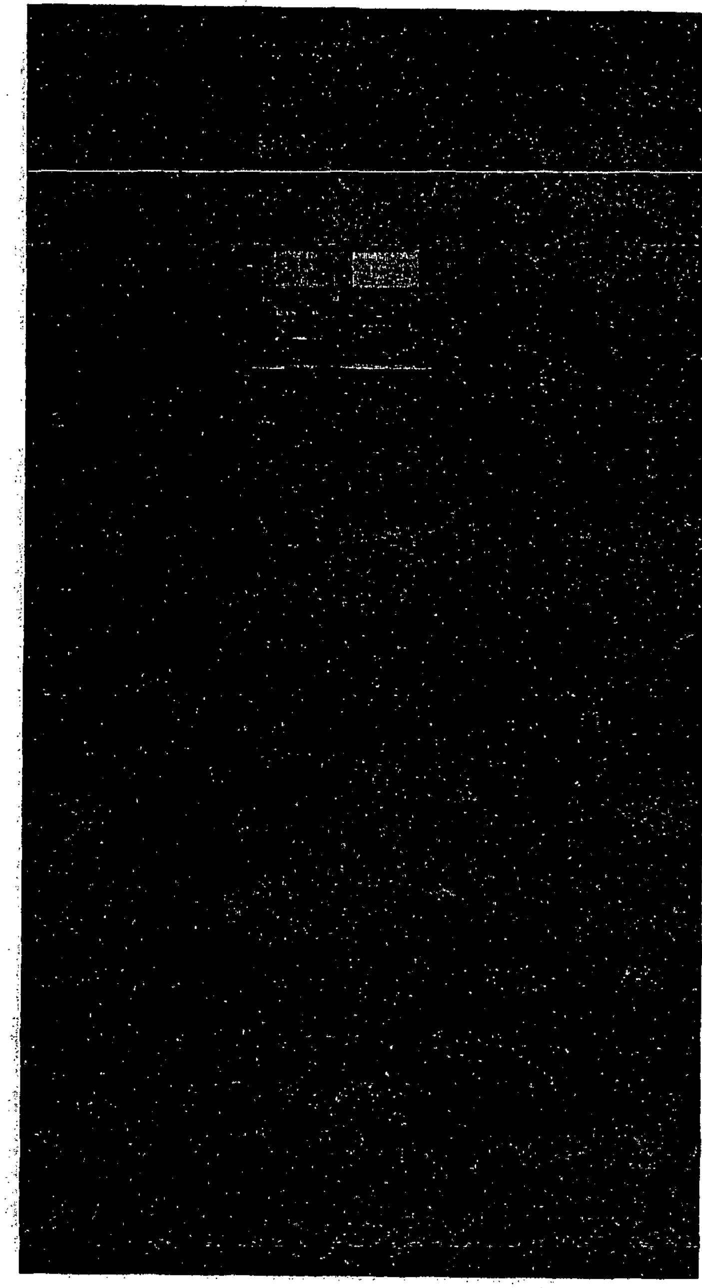
Blowdown UFM and UTM



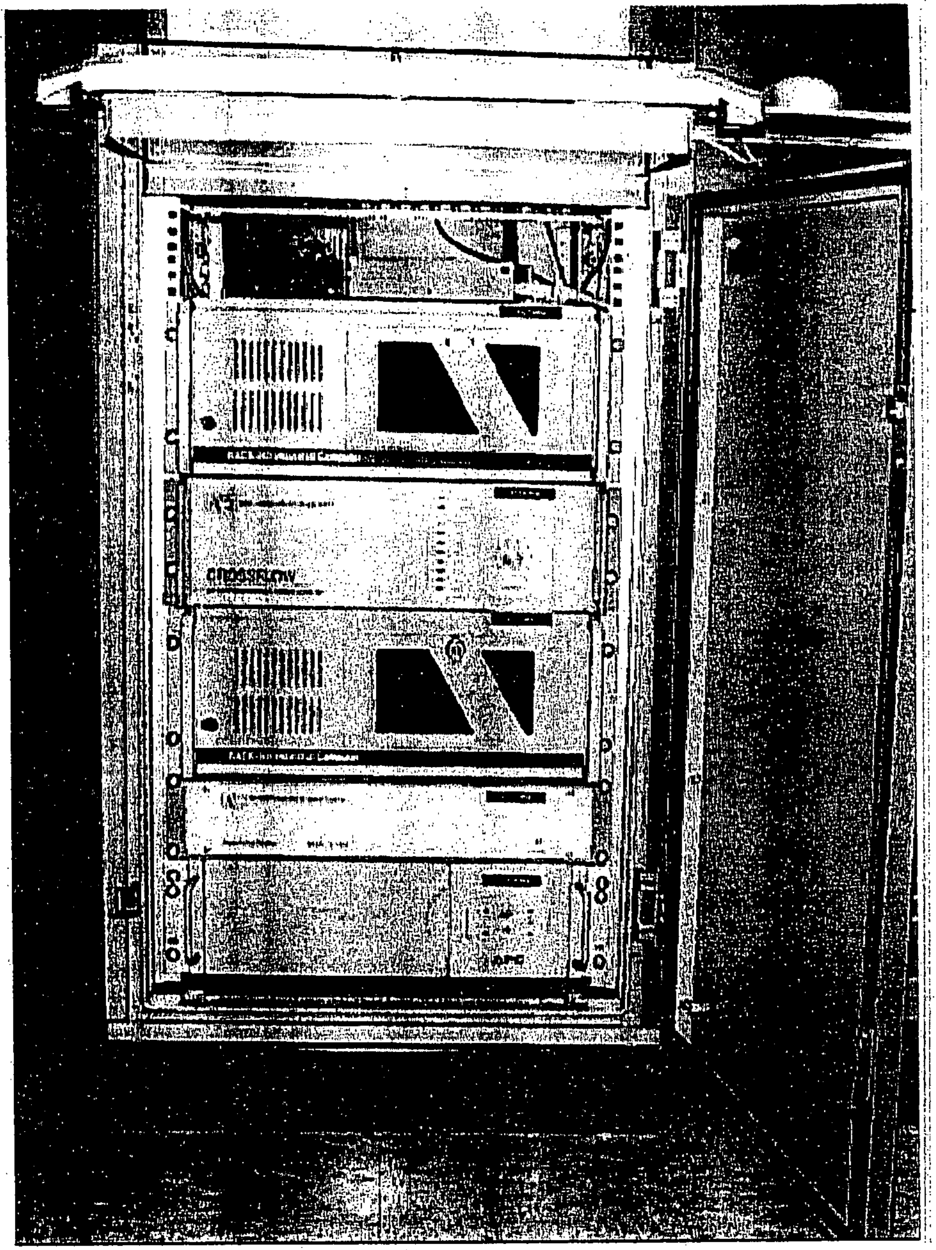
Completed Blow



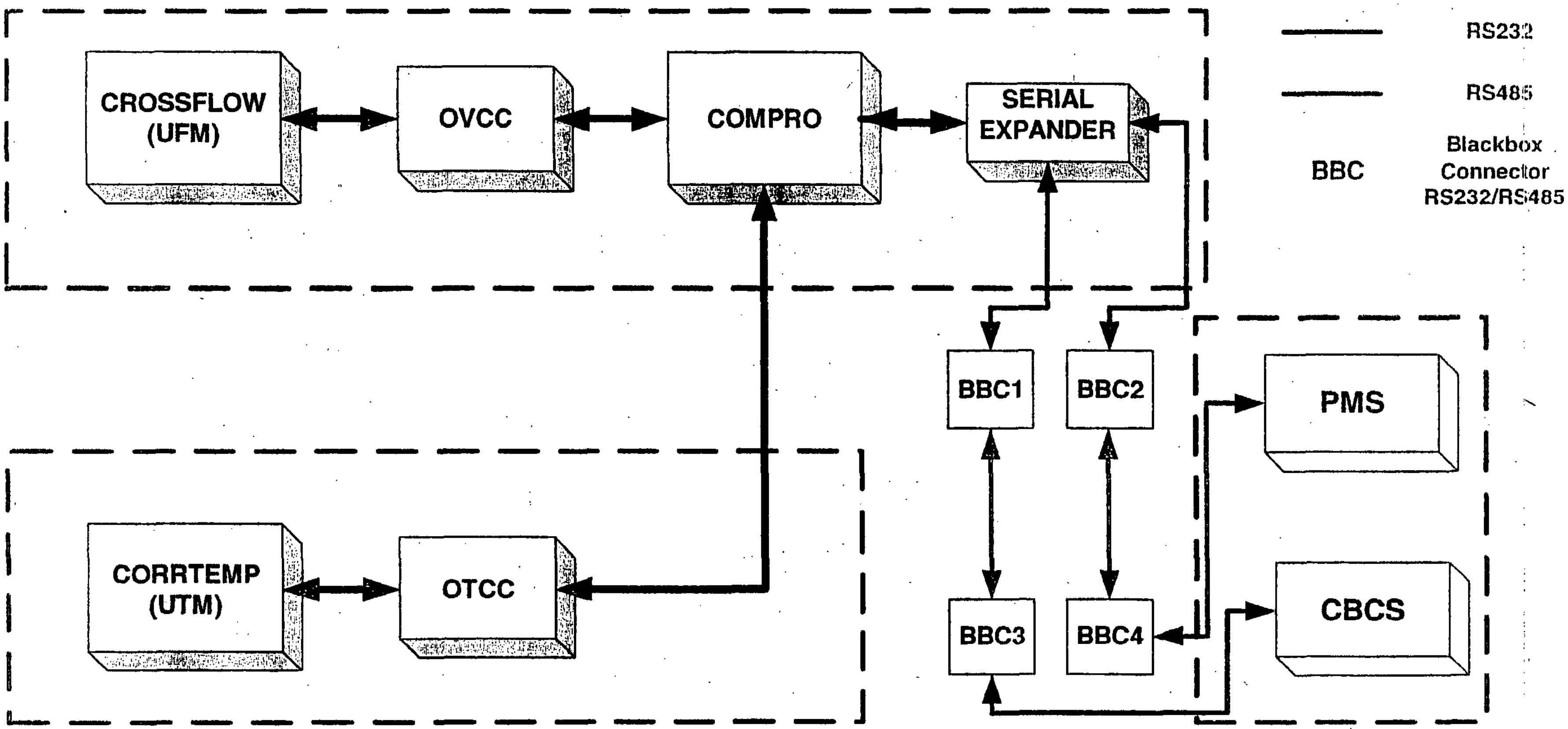
CROSSFLOW Panel



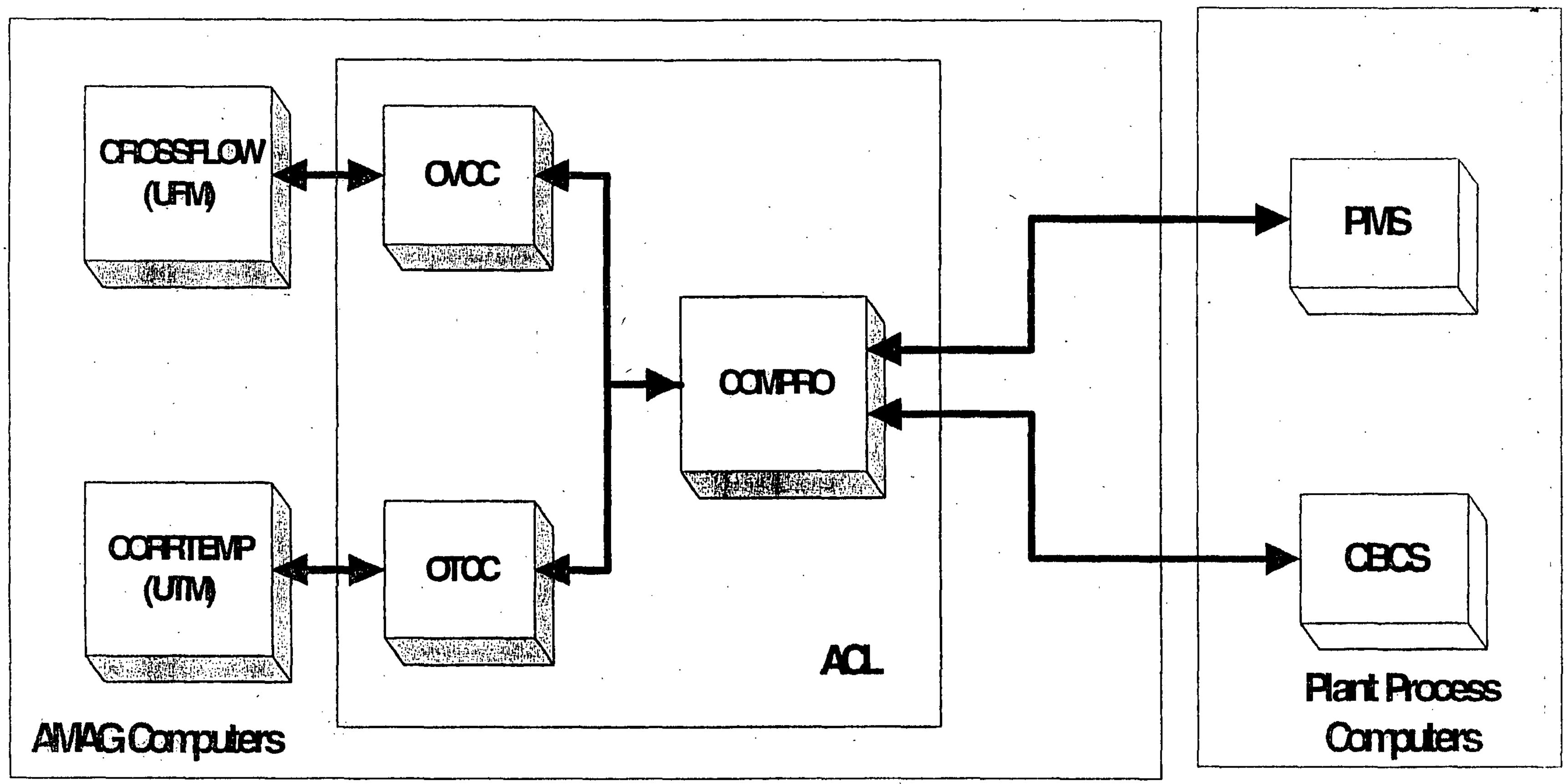
CROSSFLOW Panel



Plant Computer Interface



System Architecture



ACL Database

Home
Sessions
Session I

	Variable Name	Description
	100%FF	100% power loop feedwater
	kFv_min	(100%FF* kFv_min)/100 gives the minimal feed water power used in calculations
	CfFWUpperLimitConst	The upper limit value for FW Cf
	CfFWLowLimitConst	The lower limit value for FW Cf
	CfBDUpperLimitConst	The upper limit value for BD Cf
	CfBDLowLimitConst	The lower limit value for BD Cf
	CfMSUpperLimitConst	The upper limit value for MS Cf
	CfMSLowLimitConst	The lower limit value for MS Cf
	DF	Detection limit for rapid defouling
	Nf	Size of Cf long buffer
	Kf	Size of Cf short buffer
	CfPercentGoodFW	Minimum Buffer Limit for Good Cf, FW
	CfPercentGoodMS	Minimum Buffer Limit for Good Cf, MS
	CfPercentGoodBD	Minimum Buffer Limit for Good Cf, BD
	CfBDUncertaintyLongConst	Uncertainty limit for BD Cf long buffer
	CfFWUncertaintyLongConst	Uncertainty limit for FW Cf long buffer
	CfMSUncertaintyLongConst	Uncertainty limit for MS Cf long buffer
	CfUncertaintyShortConst[1]	Uncertainty limit, Cf short buffer, FW, MS
	ObjectFactory	Plant's name determines Online Operation, "Stand Alone" sets offline mode.

Home | Sessions | Session I

QVCC Maintenance Screen Ver. 2.1.0

Data received from the Plant Computer

Variable	Value	Quality
FvFw1	7.50000e+003	GOOD
FvFw2	7.50000e+003	GOOD
FvBd1	1.00000e+002	GOOD
FvBd2	1.00000e+002	GOOD
FvMs1	7.40000e+003	GOOD
FvMs2	7.40000e+003	GOOD
TtFw1	4.40000e+002	GOOD
TtFw2	4.40000e+002	GOOD
PFw1	8.60000e+002	GOOD
PFw2	8.60000e+002	GOOD
TtBd1	5.00000e+002	GOOD
TtBd2	5.00000e+002	GOOD

Data sent to plant computer

Variable	Value	Quality	%	% STD
CfFw1	9.94077e-001	BAD	12	0.17
CfFw2	9.94747e-001	BAD	11	0.13
CfBd1	9.84535e-001	BAD	12	0.16
CfBd2	9.82237e-001	BAD	6	0.59
CfMs1	9.94206e-001	BAD	12	0.17
CfMs2	9.94923e-001	BAD	6	0.18
FuFw1	7.46838e+003	GOOD	13	0.16
FuFw2	7.45847e+003	GOOD	13	0.13
FuBd1	9.84927e+001	GOOD	13	0.16
FuBd2	0.00000e+000	BAD	7	0.57
FuMs1	7.36988e+003	GOOD		
FuMs2	7.45847e+003	BAD		

Database constants

Variable	Value
Feedwater1Channel	1
Feedwater2Channel	3
Blowdown1Channel	2
Blowdown2Channel	4
LongBufferSize	120
100PercentPower	7.50000e+003
CoefFvMin	8.00000e+001
CfLowLimitFw	9.60000e-001
CfLowLimitBd	9.60000e-001
CfLowLimitMs	9.60000e-001
CfUpperLimitFw	1.04000e+000
CfUpperLimitBd	1.04000e+000

Alarms

Alarm
(FW, SG1) Not enough good data in Cf buffer.
(FW, SG2) Not enough good data in Cf buffer.
(BD, SG1) Not enough good data in Cf buffer.
(BD, SG2) Not enough good data in Cf buffer.
(MS, SG1) Not enough good data in Cf buffer.
(MS, SG2) Not enough good data in Cf buffer.

Total alarms: 6

Events

Date	Time	Description
05/23/01	08:49 PM	Serial communication timout, SerialPMS

Total errors: 1

PPC: PMS

Close

Home | Sessions | Session I

OTCC Maintenance Screen Ver. 1.0.0

Data received from the Plant Computer

Variable	Value	Quality
TtFw1	4.40000e+002	GOOD
TtFw2	4.40000e+002	GOOD
PFw1	8.60000e+002	GOOD
PFw2	8.60000e+002	GOOD
TtBd1	5.00000e+002	GOOD
TtBd2	5.00000e+002	GOOD
PBd1	9.00000e+002	GOOD
PBd2	9.00000e+002	GOOD

Data sent to plant computer

Variable	Value	Quality	%	% STD
CtFw1	9.90909e-001	BAD	62	0.00
CtFw2	9.90909e-001	BAD	62	0.00
CtBd1	9.90000e-001	BAD	62	0.00
CtBd2	9.90000e-001	BAD	63	0.00
TuFw1	4.36000e+002	GOOD		
TuFw2	4.36000e+002	GOOD		
TuBd1	4.95000e+002	GOOD		
TuBd2	4.95000e+002	GOOD		

Database constants

Variable	Value
Feedwater1Channel	1
Feedwater2Channel	3
Blowdown1Channel	2
Blowdown2Channel	4
LongBufferSize	120
CtLowLimitFw	9.60000e-001
CtLowLimitBd	9.79000e-001
CtUpperLimitFw	1.05000e+000
CtUpperLimitBd	1.02100e+000
UncertaintyTempera...	1.00000e+000
UncertaintyTempera...	1.00000e+000
CtPercentGoodFw	7.50000e+001

Alarms

Alarm
UFM is off-line
(FW, SG1) Not enough good data in Ct buffer.
(FW, SG2) Not enough good data in Ct buffer.
(BD, SG1) Not enough good data in Ct buffer.
(BD, SG2) Not enough good data in Ct buffer.

Total alarms: 5

Events

Date	Time	Description
05/23/01	08:01 PM	Unable to open the port: COM2
05/23/01	08:01 PM	Unable to write to the port: COM2
05/23/01	08:01 PM	Unable to open the port: COM2
05/23/01	08:01 PM	Unable to open the port: COM2
05/23/01	08:01 PM	Unable to write to the port: COM2
05/23/01	08:01 PM	Unable to open the port: COM2
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05/23/01	08:01 PM	Unable to write to the port: COM2
05/23/01	08:01 PM	Unable to open the port: COM2
05/23/01	08:01 PM	Unable to open the port: COM2

Total errors: 100

PPC: PMS

Close

SONGS Power Uprate Configuration

- AMAG UFM and UTM on feedwater and blowdown
- CROSSFLOW ACL software calculates FW, BD and steam flow CFs and FW temperature CFs, determines quality, and provides alarms.
- CROSSFLOW ACL interface between both the primary and backup process computers, with independent calculation of CFs.
- Two reactor power calorimetrics, FW and main steam
- Main steam calorimetric reactor power is preferred. The steam venturis are not subject to rapid fouling and de-fouling like the FW.
- Plant process computer de-fouling alarm based upon FW and main steam calorimetrics.