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LM-4541-1	0	2006-03-24	
Prepared by:	**Approved by:**	**Classification:**	**Page:**
Bård Brandåstrø Jørgen Ramdal	Ole G. Dahlhaug	Open	1 of 2

Measurement of atmospheric pressure in the Francis Turbine Test Rig.

1 General

This procedure describes the measurement of the atmospheric pressure in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

$p_{amb.}$ - Atmospheric pressure

2 The system

2.1 Description

The barometer is a Vaisala PTB220 Digital Barometer, which is located inside the control room at the Water Power Laboratory. The barometer communicates directly to the data acquisition system through a serial port.

2.2 Equipment used in measurement

- Barometer
  - Vaisala PTB220 Digital Barometer (Reg nr. 4541-1)
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.

3 Computations

This is an absolute measurement.

4 Figures

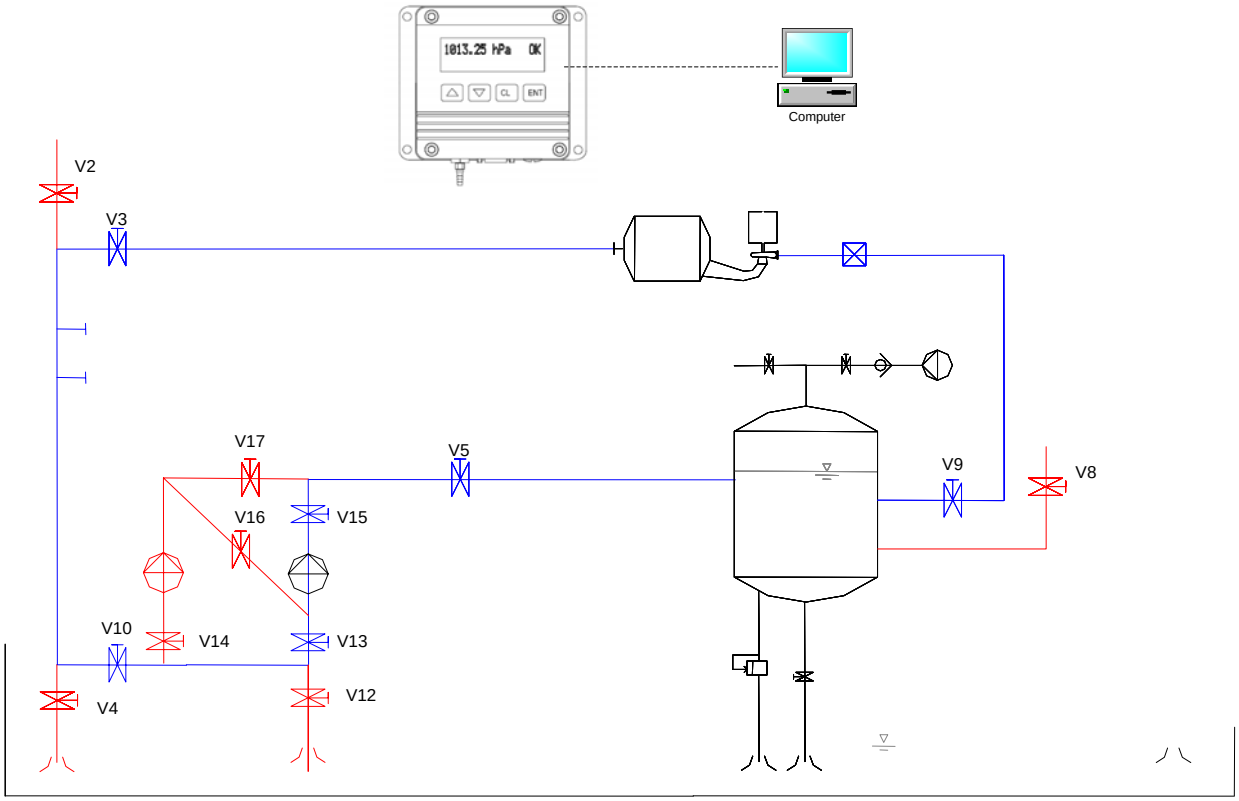

Figure 1: Arrangement and position of oxygen probe.

5 References

– Specification for Vaisala PTB220 Digital Barometer. (doc IA-4541-1)

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Measurement of dissolved oxygen content on the Francis Turbine Test Rig.

1 General

This procedure describes the measurement of the dissolved oxygen content in water in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

D.O.	-	Dissolved oxygen [mg/l]
m.v	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection in calibration equation

2 The system

2.1 Description

The oxygen probe in use is a TriOxmatic 700 IQ, which is located in the main pump inlet. The probe is connected to an IQ Sensor Net 182 universal digital signal converter/amplifier system. The amplifier presents the D.O. value in mg/l within a range from 0.0 to 60.0 mg/l. An output signal from 4 to 20 mA from the IQ Sensor Net 182 system is fed to the data acquisition system. The signal is transformed into a 2-10 V signal via a 500 ohm resistance before the data acquisition system.

2.2 Equipment used in calibration

- Oxygen probe
  - Trioxmatic 700 IQ (Reg. no. 4551-1)
- Signal converter/amplifier
  - IQ Sensor Net 182 (Reg. no. 4551-1)
  - Drop resistance type Econsistor 8E16 500 ohm
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.

3 Computations

This is an absolute measurement, but in order to get the correct values displayed and recorded on the data acquisition unit, the output signal from the amplifier has to be correlated with the value displayed on the amplifier.

$$D.O = a \cdot (m.v) + b \qquad \text{[mg/l]} \qquad (1)$$

The parameters a, and b are found using linear interpolation for the amplifier reading and the measured volt signal.

4 Figures

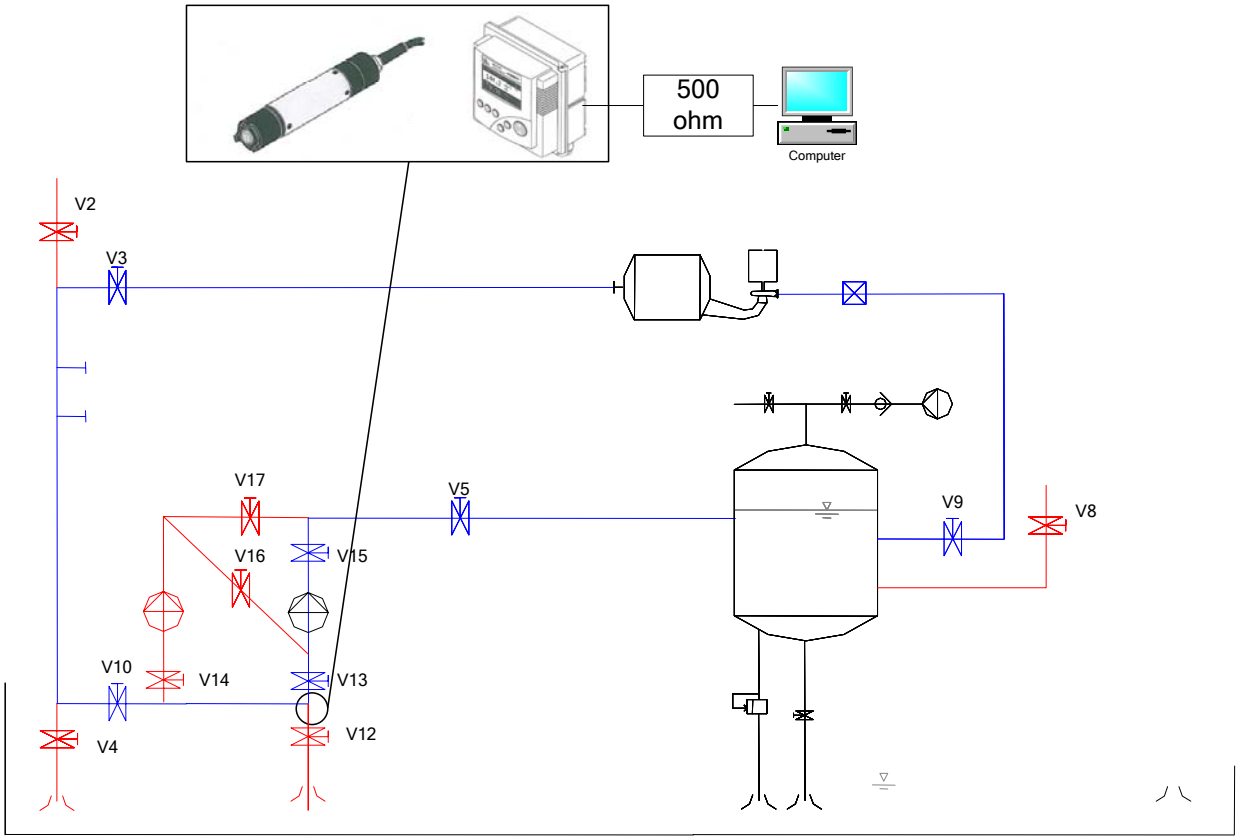

Figure 1: Arrangement and position of oxygen probe.

5 References

– Specification for Trioxmatic 700 and DIQ/S 182 signal converter/amplifier. (doc IA-4551-1)
– Calibration Document for dissolved oxygen measurement system. (LCd-4551-1)

Measuring procedure of rotational speed in the Francis Turbine Test Rig

1 General

This procedure describes measurment of rotational speed in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

2 The system

2.1 Description

The measuring system contains of a photocell and a circular disc with one cut fixed to the generator shaft. The photocell is a OPB 960T51 optical fork supplied by 5 VDC. The photocell is sending infrared light towards the disc, and a signal is sent to the logging computer every time the cut on the disk is passing. The pulse frequency is recorded. The rotational speed is calculated from the number of times the is passing per unit time.

2.2 Equipment used in measuring

- Photo cell with disc
  - OPB 960T51 optical fork (reg nr. 4431-1)
  - 300 ohm resistance
  - 1000 ohm resistance
  - 5 V power supply
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.

3 Computations

60 divided on the time between each pulse gives directly the rotational speed in [rpm]
This is an absolute measurement, and is checked using a tachometer, or a high accuracy stroboscope.

4 Figures

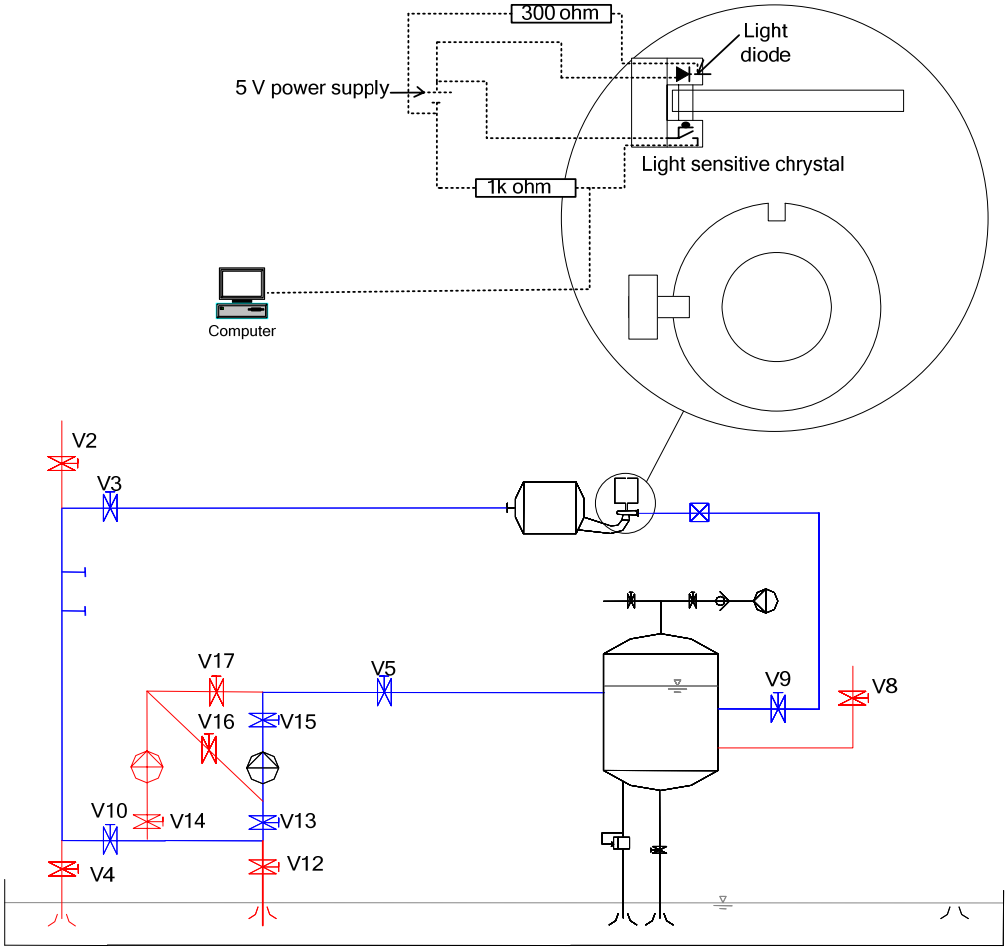

Figure 1: Arrangement

5 References

–

Measuring procedure of guide vane angle in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the guide vane angle in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

2 The system

2.1 Description

The measuring system consists of a Stegman AG612 angle transducer, and a signal converter with a 12 V power supply. The angle transducer has a 13 bit resolution, which gives 0.044^{o}/step. The signal converter is sending a binary signal to the data acquisition unit through RS232 port.

2.2 Equipment used in measuring

- Stegman AG612 angle transducer
  - (Reg. no. 4228-1)
- Signal Converter with 12 V external power supply
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.

3 Computations

The angle transducer gives an absolute signal.

4 Figures

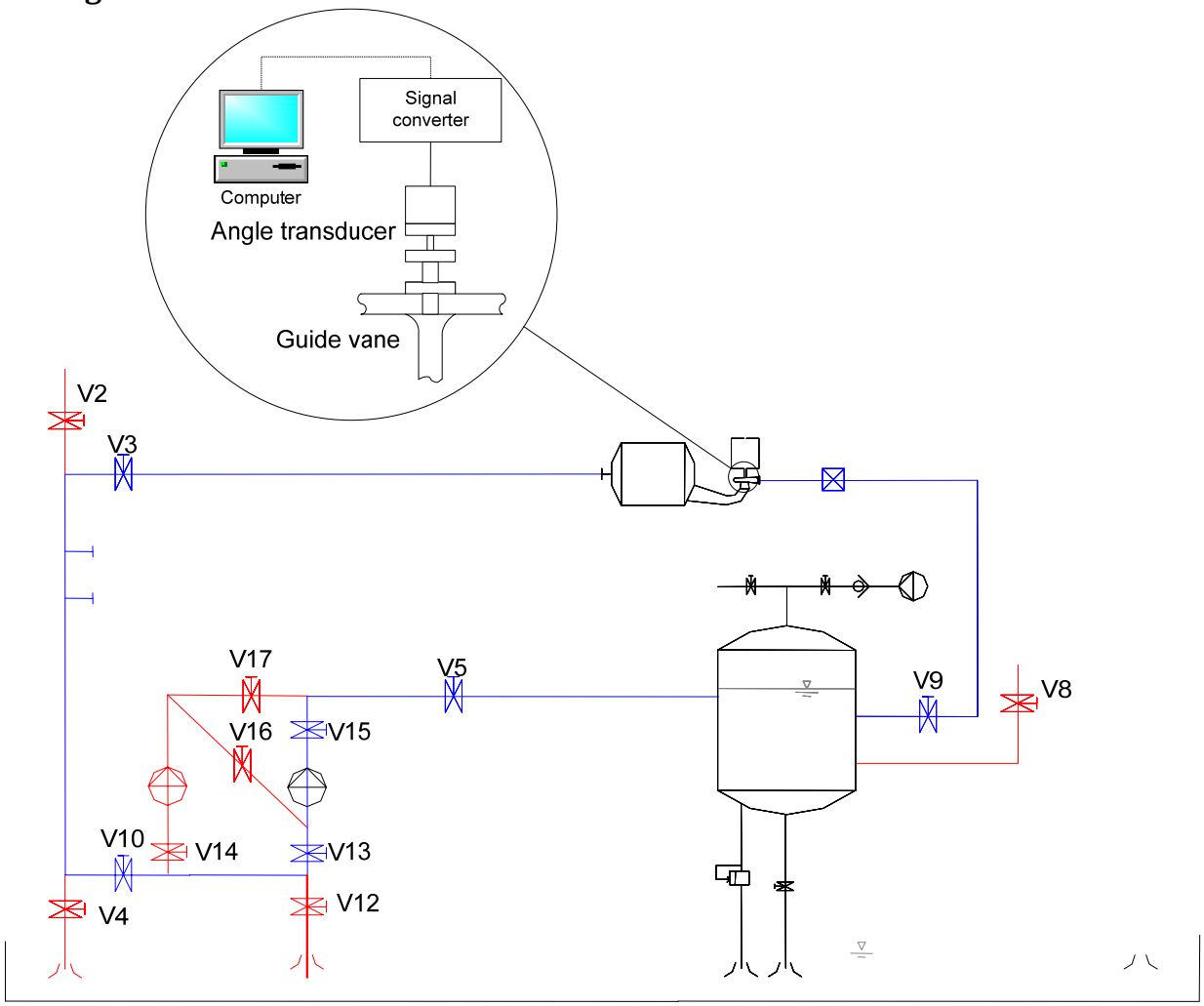

Figure 1: Arrangement

5 References

– Documentation for Stegman AG612 angle transducer (Doc IA 4228-1)

Measuring procedure for discharge in the Francis Turbine Test Rig

1 General

This procedure describes measuring of discharge in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
Q	-	Discharge [m^3/s]

2 The system

2.1 Description

The measuring system consists of an electromagnetic flow meter, Krohne Aquaflux ifs 4000.

When a conductive fluid moves across a magnetic field a voltage is induced in the conductor. The magnitude of the voltage is directly proportional to the speed of the moving fluid.

The flow range for the unit is from approximately 0.15 to 500 l/s.

2.2 Equipment used in measuring

- Flow meter
  - Krohne Aquaflux ifs 4000 (Reg. no. 4624-4)
- Internal amplifier and power supply
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.

3 Computations

The relationship between the measured volt signal and the flow is a linear equation

$$Q = a \cdot (m.v) + b \qquad [\mathrm{m}^3/\mathrm{s}] \tag{1}$$

The parameters a, and b are determined in the calibration.

4 Figures

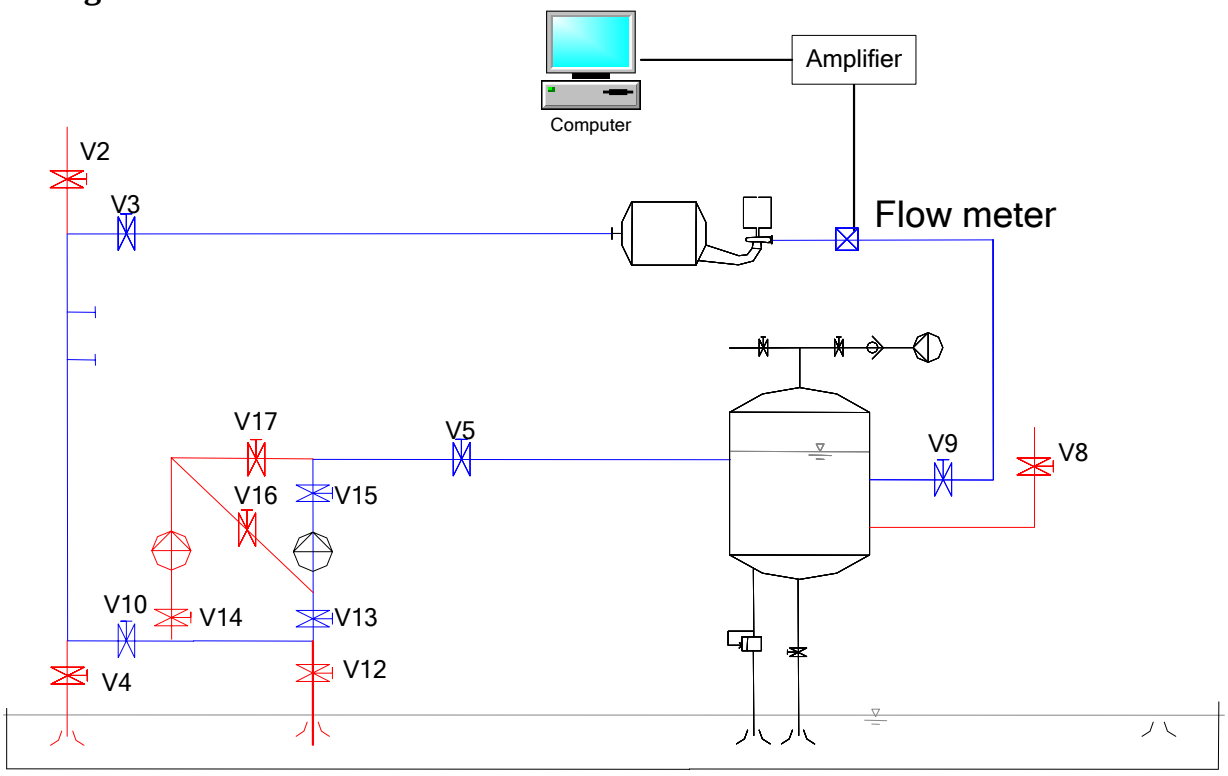

Figure 1: Arrangement

5 References

– Specification for Krohne Aquaflux IFS 4000. (doc IA-4624-4)
– Calibration document for turbine flow measurement system. (FCd-4624-4)

Measuring procedure of differential pressure in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the differential pressures in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
p	-	Pressure [kPa]

2 The system

2.1 Description

The measuring system consists of a differential pressure transducer connected to the inlet pipe and draft tube of the model turbine.

The output signal from the pressure transducer is 4 – 20 mA. The signal is being transformed into 2-10 VDC using a drop resistor before the data acquisition system.

The maximum pressure range for the transducer is 0 to 1000 kPa, and the output can be adjusted to give a more accurate output for a smaller range.

2.2 Equipment used in measuring

- Differential pressure transducer
  - Fuji Electric FHCW36WI (Reg. no. 4536-2)
- Drop resistance
  - Type Econsistor 8E16 500 ohm
- Data acquisition unit
  - National Instruments data acquisition unit

- LabView for computation and presentation of data.
- External 24 V power supply

3 Computations

The relationship between the measured volt signal and the pressure is a linear equation

$$p = a \cdot (m.v) + b \qquad \text{[Pa]} \tag{1}$$

The parameters a, and b are found in calibration, and inserted into the LabView program for calculation.

4 Figures

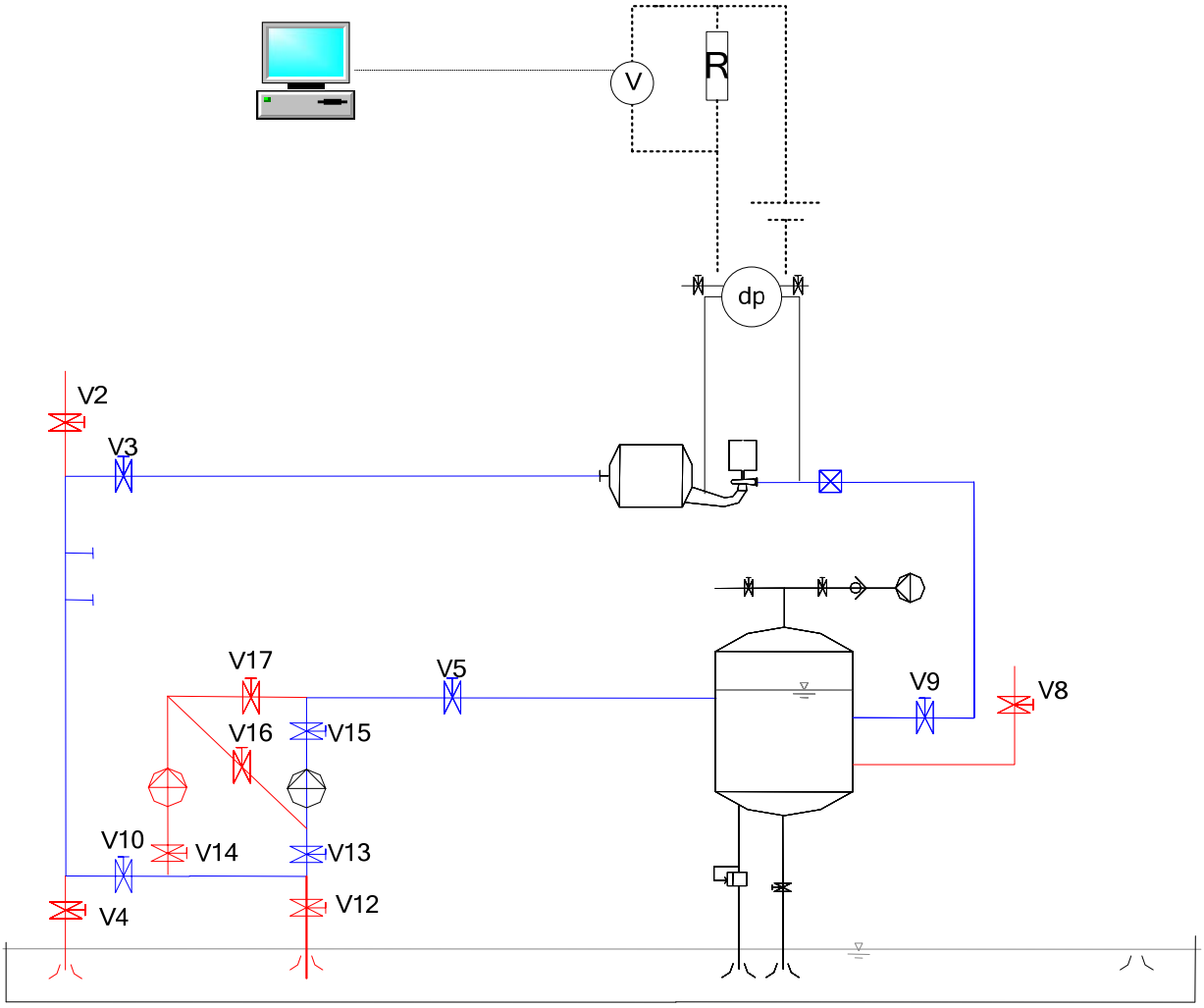

Figure 1: Arrangement

5 References

– Specification for Fuji Electric FKCW38V4A differential pressure transducer. (doc IA-4536-1/2/4/5/8)
– Calibration document for turbine differential pressure measurement system (FCd-4536-2)

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Measuring procedure of inlet pressure in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the inlet pressures in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
p_1		Inlet pressure
ρ	-	Water density [kg/m^3]
g	-	Gravity [m^3/s]
Z	-	Difference in height between inlet and pressure transmitter [m]

2 The system

2.1 Description

The measuring system consists of a differential pressure transducer.

Water pressure is fed to the high pressure side of the differential pressure transducer, and the low pressure side is open to atmosphere.

The output signal from the pressure transducer is 4 – 20 mA. The signal is being transformed into 2-10 VDC using a drop resistor before the data acquisition system.

The pressure range for the transducer is 0 to 1000 kPa, but the output can be adjusted to give a more accurate output for a smaller range.

2.2 Equipment used in measuring

- Differential pressure transducer
  - Fuji Electric FHCW36WI-AKCAY (Reg. no. 4536-4)
- Drop resistance
  - Econsistor 8E16 500 ohm
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.
  - External 24 V power supply

3 Computations

The relationship between the measured volt signal and the pressure is a linear equation. The parameters a, and b are found in calibration, and inserted into the LabView program for calculation.

Z is the height difference between the pressure transducer and the inlet level. This height is found during calibration and is to be checked as one of the routines during running of tests. The total inlet pressure is

$$p_1 = a \cdot (m.v) + b - \rho \cdot g \cdot Z \tag{1}$$

4 Figures

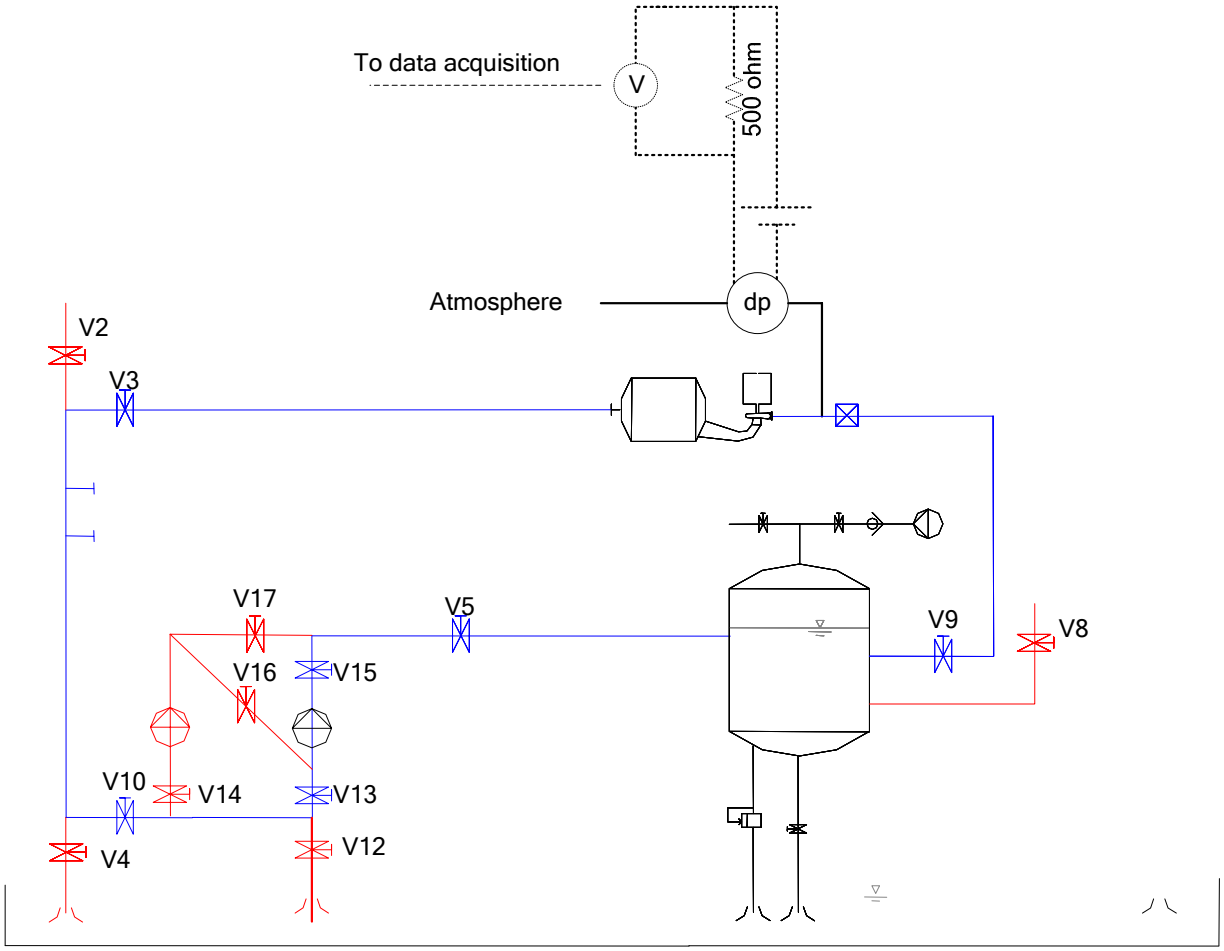

Figure 1: Arrangement

5 References

- Specification for Fuji Electric FHCW36WI-AKCAY differential pressure transducer. (doc IA-4536-1/2/4/5/8)
- Calibration document for turbine inlet pressure measurement system. (FCd-4536-4)

Measuring procedure of turbine runner axial force in the Francis Turbine Test Rig.

1 General

This procedure describes the measurement of the axial force in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

W	-	Mass	[kg]
m.v.	-	Measured value	
a	-	Slope in calibration equation	
b	-	Intersection constant in calibration equation	
g	-	Gravity	[m/s^2]
F	-	Force	[N]
p	-	Pressure	[kPa]
A	-	Area	[m^2]

2 The system

2.1 Description

The measuring system consists of a hydraulic thrust bearing and a differential pressure transducer.

Oil pressure is fed to the differential pressure transducer from the two sections of the axial thrust bearing, and the differential pressure is directly dependent on the hydraulic axial thrust.

The output signal from the pressure transducer is 4 – 20 mA. The signal is being transformed into 2-10 VDC using a drop resistor before the data acquisition system.

The pressure range for the transducer is 0 to 6000 kPa which gives a weight range from 0 to approximate 2500 kg.

2.2 Equipment used in measuring

- Differential pressure transducer
  - Fuji Electric FKCW38V4A (Reg. no. 4536-8)
- Drop resistance
  - Type Econsistor 8E16 500 ohm
- Hydraulic axial thrust bearing
- Oil hydraulic pump unit for feeding oil to bearing
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.
  - External 24 V power supply

3 Computations

The relation between the force and the pressure measured by the differential pressure transducer is

$$F = W \cdot g = \frac{p}{A} \quad [\mathrm{N}] \tag{1}$$

Since A is constant in the hydraulic axial thrust bearing, the force is determined directly by using the voltage signal from the pressure transducer.

The calibration equation is a linear equation

$$F = (a \cdot (m.v) + b) \cdot g \quad [\mathrm{N}] \tag{2}$$

and the parameters a and b are found in the calibration.

4 Figures

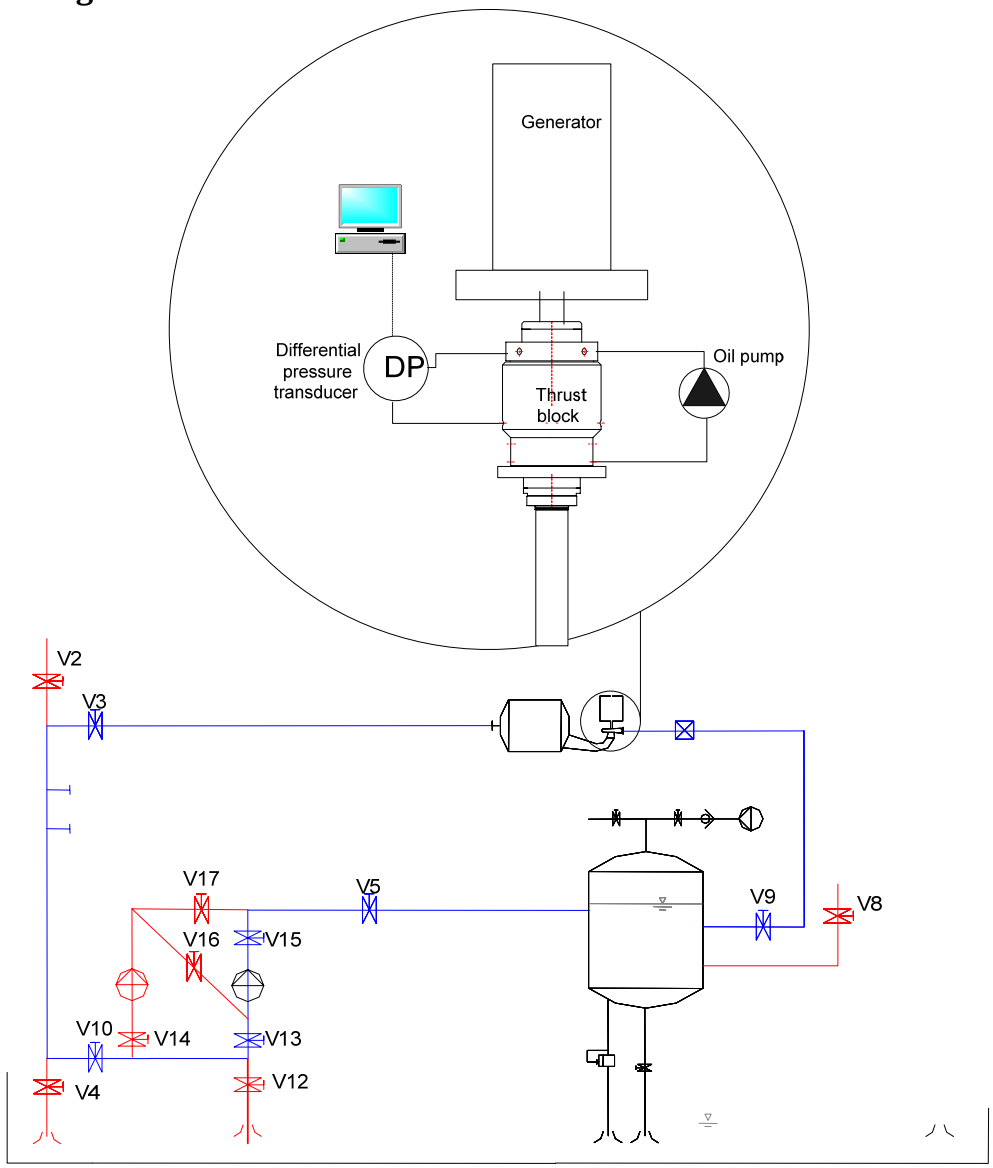

Figure 1: Arrangement

5 References

– Specification for Fuji Electric FKCW38V4A differential pressure transducer. (doc IA-4536-1/2/4/5/8)
– Calibration document for turbine runner axial force measurement system. (FCd-4536-8)

Measuring procedure of generator torque in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the generator torque in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
T	-	Torque [Nm]

2 The system

2.1 Description

The measuring system consists of a weighing cell of type Hottinger Z6FC3 with external amplifier, and a hydraulic bearing. The generator is resting on an approximately friction free hydrostatic bearing, and the generator arrangement makes sure the load cell, connected to an arm, is absorbing all radial force acting on the generator. The weight range for the weighing cell is 500 kg and an external amplifier in connection with the weighing cell gives an output signal from 0-10 V that is sent to the data acquisition unit for post processing.

2.2 Equipment used in measuring

- Load cell
  - Hottinger Z6FC3 (Reg. no. 4331-5)
- Measuring amplifier
  - Hottinger MVD2630A (Reg. no. 2763-27)
- Hydraulic bearing
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.
  - External 24 V power supply

3 Computations

The relationship between the measured volt signal and the torque is a linear equation

$$T = a \cdot (m.v) + b \qquad \text{[Nm]} \qquad (1)$$

The parameters a, and b are found in calibration.

4 Figures

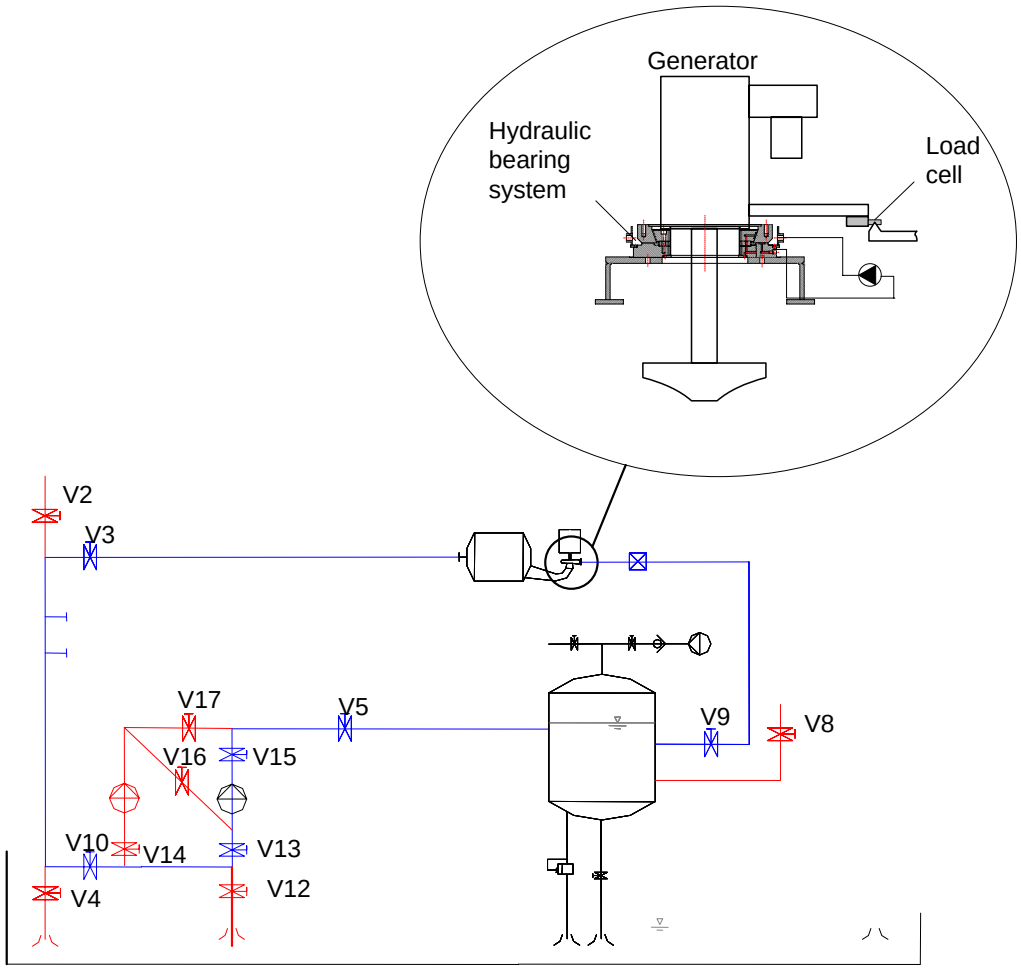

Figure 1: Arrangement

5 References

– Specification for Hottinger load cell. (doc IA-4331-5)
– Specification for Hottinger MVD2630A amplifier. (doc IA-2763-27 in the instrument archive)
– Calibration document for generator torque measurement system. (FCd-4331-5)
– Calibration document for measurement of torque arm. (FCd-4331-5 Supplement)

Measuring procedure of friction torque in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the generator friction torque in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
T	-	Torque [Nm]

2 The system

2.1 Description

The measuring system consists of a hydraulic bearing, and a weighing cell of type Hottinger Z6FC3 with external amplifier. Two mechanical bearings connected to the generator shaft are absorbing all radial and axial movement in the turbine. These two bearings are inserted into a hydraulic bearing/thrust block that makes it possible to measure axial thrust and radial friction. The load cell, connected to the hydraulic bearing unit and a mechanical stop, is absorbing all friction in the two bearings connected to the generator axle. The weight range for the weighing cell is 0-10 kg and an external amplifier in connection with the weighing cell gives an output signal from 0-10 V that is sent to the data acquisition unit for post processing.

2.2 Equipment used in measuring

- Load cell
  - Hottinger Z6FC3 (Reg. no. 4331-2)
- Measuring amplifier
  - Hottinger ME30 (Reg. no.
- Hydraulic thrust block
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.
  - External 24 V power supply

3 Computations

The relationship between the measured volt signal and the torque is a linear equation

$$T = a \cdot (m.v) + b \text{ [Nm]} \quad (1)$$

The parameters a, and b are found in calibration.

4 Figures

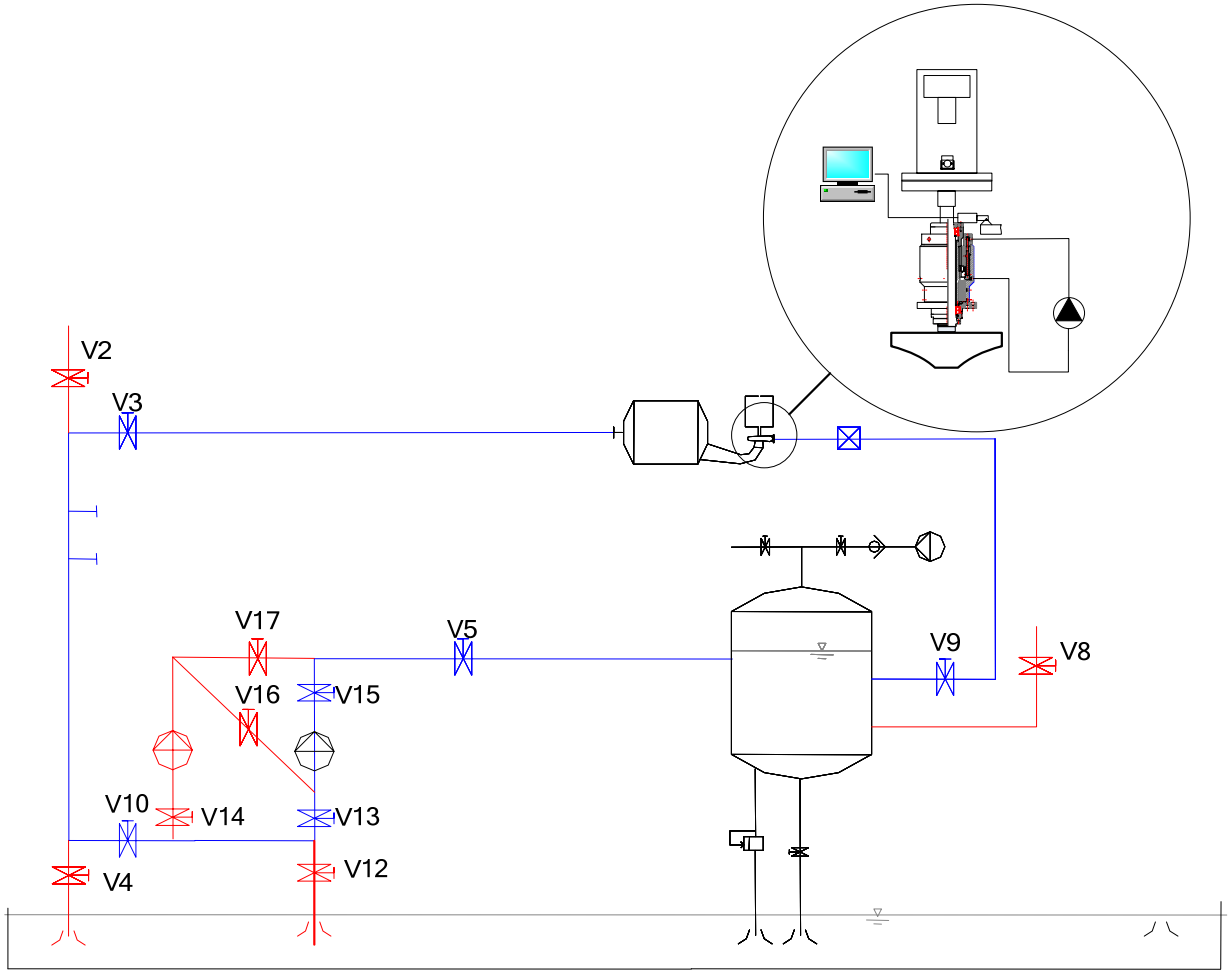

Figure 1: Arrangement

5 References

– Specification for Hottinger load cell. (doc IA-4331-2 in the instrument archive)
– Calibration document for friction torque measurement system.(FCd-4331-2)
– Calibration document for measurement of torque arm. (FCd-4331-2 Supplement)
– Specification for Hottinger ME30 amplifier. (doc IA-2763-28)

Measuring procedure of water temperature in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the water temperature in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
θ	-	Temperature [^{o}C]

2 The system

2.1 Description

The measuring system consists of a temperature probe, with internal amplifier/signal converter. The temperature probe is a PT 100 element. The signal converter gives an output signal that varies from 4-20 mA, which is converted into a 2-10 V signal via a 500 ohm resistance before the data acquisition system. The temperature range is from 0 to 100 ^{o}C.

2.2 Equipment used in measuring

- Temperature probe
  - (Reg. no. 4514-3)
- 500 ohm resistance
  - Type Econsistor 8E16
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.

3 Computations

The relationship between the measured volt signal and the temperature is a linear equation

$$\theta = a \cdot (m.v) + b \qquad [^{o}C] \tag{1}$$

The parameters a, and b are found in calibration.

4 Figures

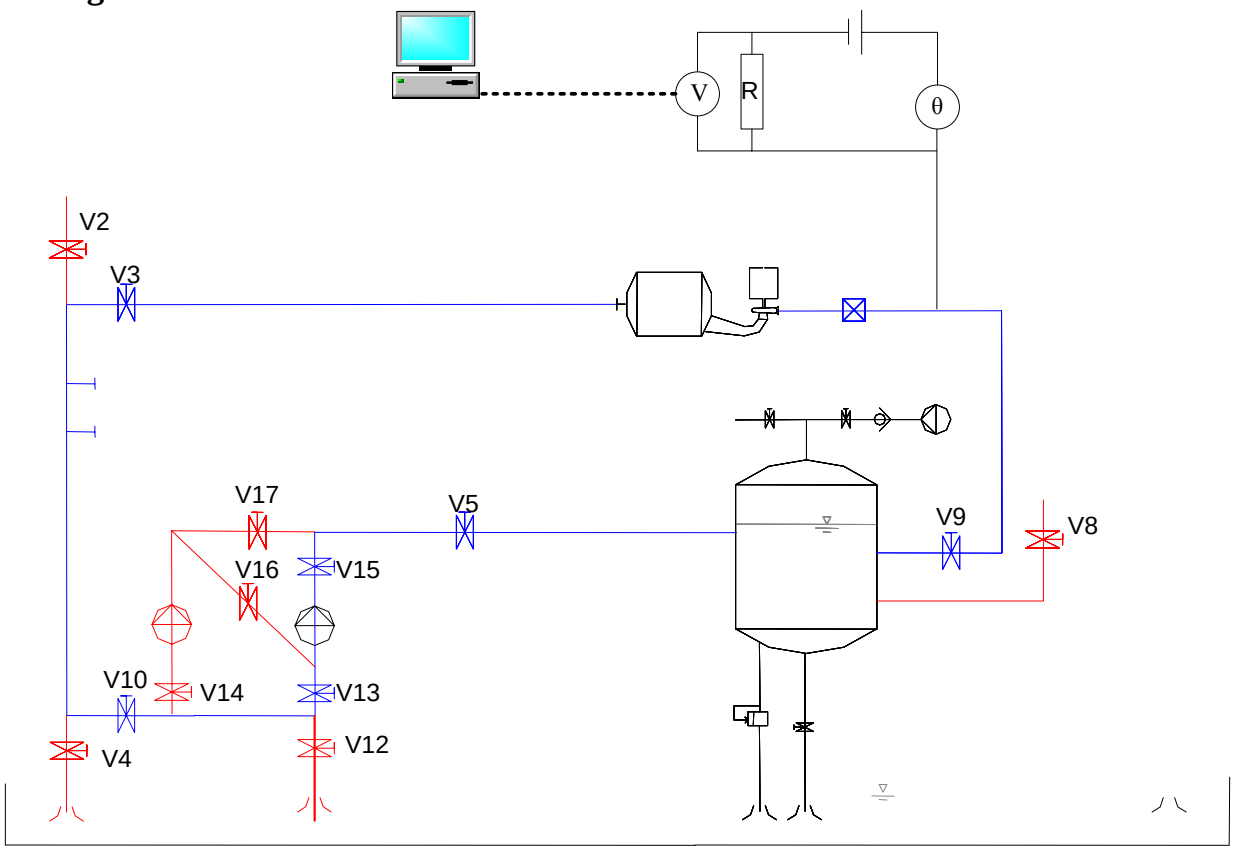

Figure 1: Arrangement

5 References

– Specification for temperature probe. (doc IA-4514-3)
– Calibration document for temperature probe.
– Documentation for 500 ohm drop resistance.

Measuring procedure of pressure pulsations in the Francis Turbine Test Rig

1 General

This procedure describes measuring of pressure pulsations in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
p	-	Pressure [kPa]
D	-	Runner outlet diameter
Rotational Cavity	-	The annular volume between outlet of guide vanes and inlet of runner blades
$f_{logging}$	-	Logging frequency
f_n	-	Runner rotational frequency
n_b	-	Number of blades

2 The system

2.1 Description

The measuring system consists of a number of pressure transducer connected to different parts of the model turbine. The IEC 60193 states how pressure transducers are to be placed in relationship with the model turbine and each other. (See figure.)

The pressure transducers are connected either to the test rig logging computer or to a separate logging computer depending on the number of transducers in use.

During each test, the logging frequency should be set to at least ten times the highest frequency that is expected to be found. This will be the blade passing frequency.

The logging period for each operational point should preferably be two minutes or longer.

2.2 Equipment used in measuring

- Pressure transducers
  - (Reg. no. 453…)
- Data acquisition unit
  - National Instruments data acquisition unit
  - LabView for computation and presentation of data.
  -

3 Computations

The relationship between the measured volt signal and the pressure is a linear equation

$$p = a \cdot (m.v) + b \qquad \text{[Pa]} \tag{1}$$

The parameters a, and b are found in calibration, and inserted into the LabView program for calculation.

The minimum logging frequency can be calculated by

$$f_{logging} = 10 \cdot f_n \cdot n_b \tag{2}$$

4 Figures

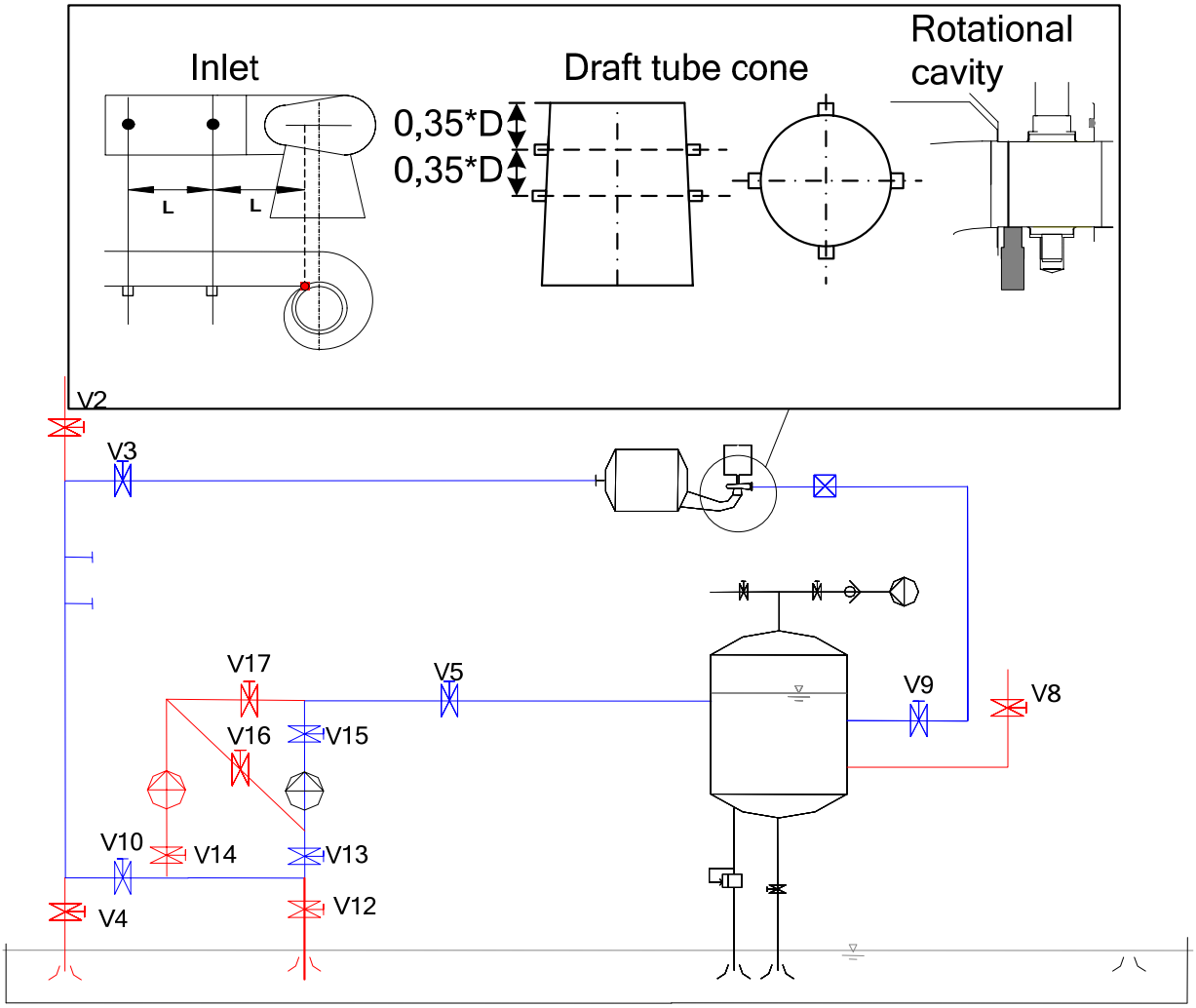

Figure 1: Arrangement and placing of pressure transducers.

5 References

- Specification for pressure transducer. (doc IA-453…)
- Calibration document for pressure measurement system (FCd-453…)

Measuring procedure of guide vane torque in the Francis Turbine Test Rig

1 General

This procedure describes measuring of the guide vane torque in the Francis Turbine Test Rig.

1.1 Definitions and abbreviations

m.v.	-	Measured value
a	-	Slope in calibration equation
b	-	Intersection constant in calibration equation
T	-	Torque [Nm]

2 The system

2.1 Description

The measuring system consists of four especially made guide vanes located in each quadrant of the turbine. The guide vanes have strain gauges attached to them, and a voltage signal that is sent from an external amplifier and through the strain gauges, is varied as the guide vane shafts are stressed due to influence from the water on the guide vanes. The voltage signal is recorded by the data acquisition unit.

2.2 Equipment used in measuring

- Strain gauges (type HBM XY41-3/350)
- Measuring amplifier (Spider 8 Reg. no 2768-…)
- Data acquisition unit
    - Spider / Catman
    - National Instruments data acquisition unit
    - LabView for computation and presentation of data.

3 Computations

The relationship between the measured volt signal and the torque is a linear equation

$$T = a \cdot (m.v) + b \text{ [Nm]} \quad (1)$$

The parameters a, and b are found in calibration.

4 Figures

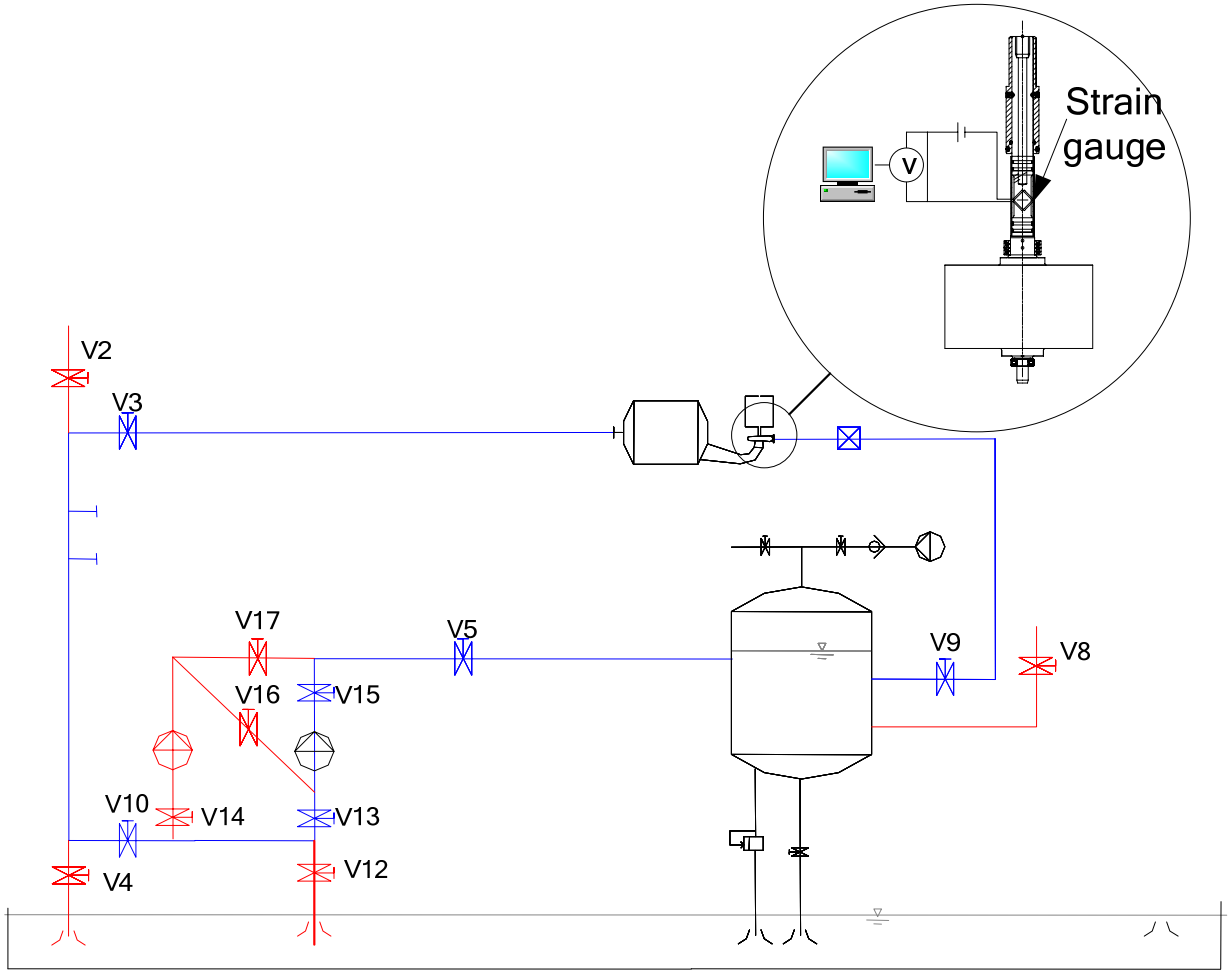

Figure 1: Arrangement

5 References

- Specification for strain gauges
- Calibration document for guide vane torque measurement system.(FCd-001)
- Specification for amplifier. (doc IA-2768-1/2)