INSTRUMENT
for
NON INSTRUMENT ENGINEER

Makasar, November 2017

Agenda

- Dasar Instrumentasi dan Kontrol
- Teori *Control Loop*
- Pengenalan Transmitter (Sensor dan Transducer)
- **Control System (DCS dan PLC)**
- Dasar Control Valve
- Instrumen Proteksi Mesin

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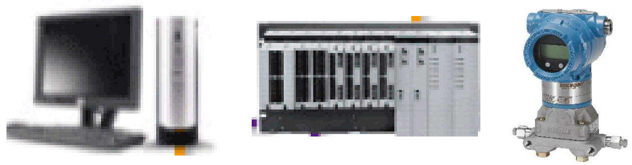
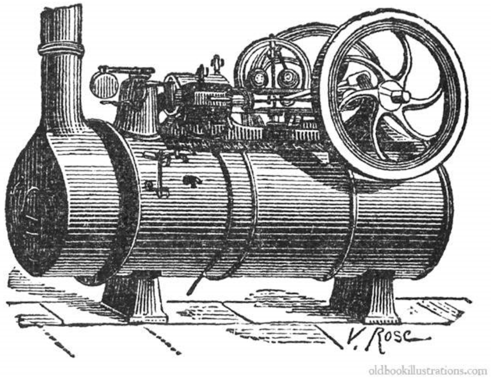
DASAR INSTRUMENTASI DAN KONTROL

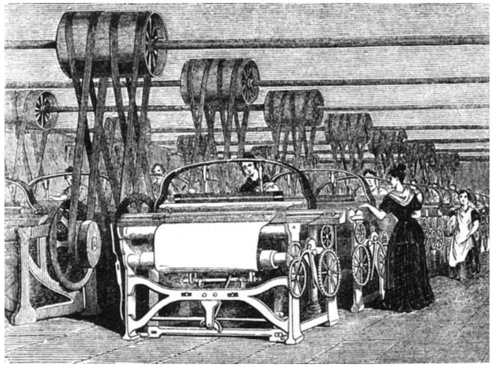


Background

1760

1st Industrial Revolution



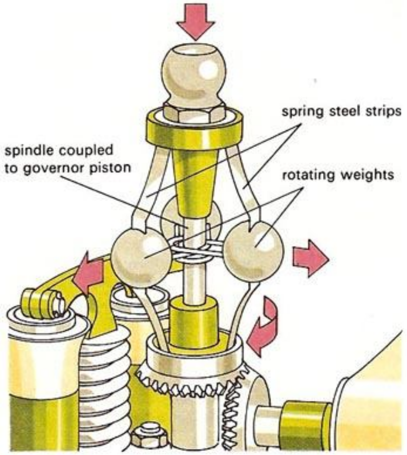


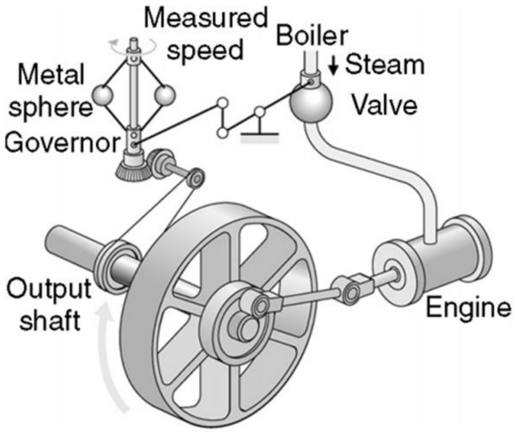
Handtool and Power Driven

Steam Engine Driven

1868

2nd Industrial Revolution





Fly Ball Governor

Background

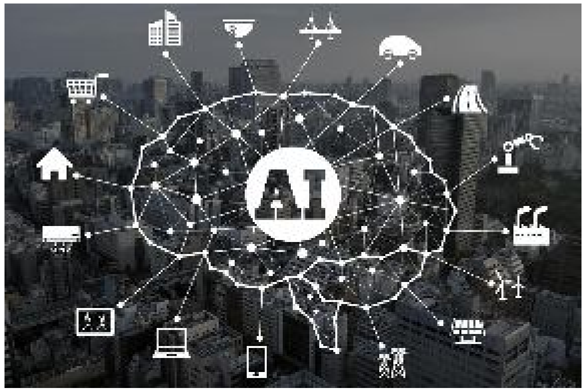
Early 1900’s

3rd Industrial Revolution

Process Automation

2017

4th Industrial Revolution : Cyber Physical System



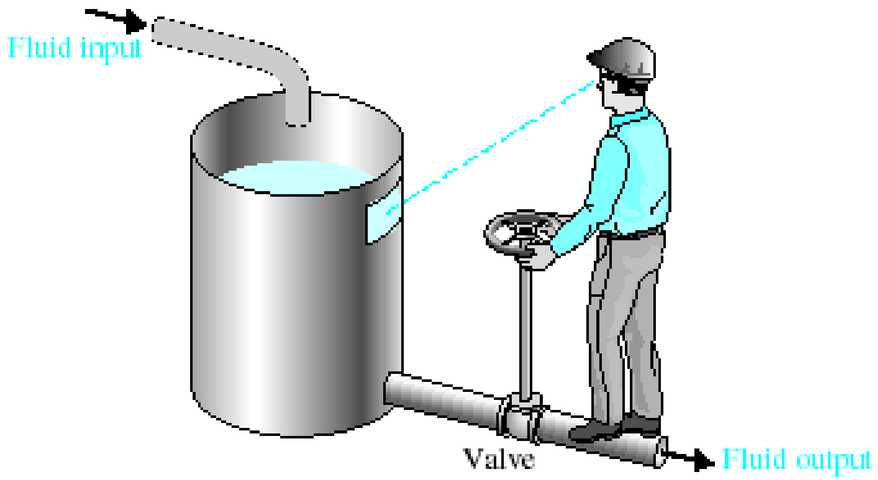
Background

Instrumentation & Control World

Instrumentasi

- Instrumentasi dapat digambarkan sebagai "*the art of science of measurement and process control.*"

- Instrumentasi adalah seni atau ilmu pengetahuan dalam penerapan alat ukur dan system pengendalian pada suatu obyek sesuai dalam batas daerah tertentu (set point)



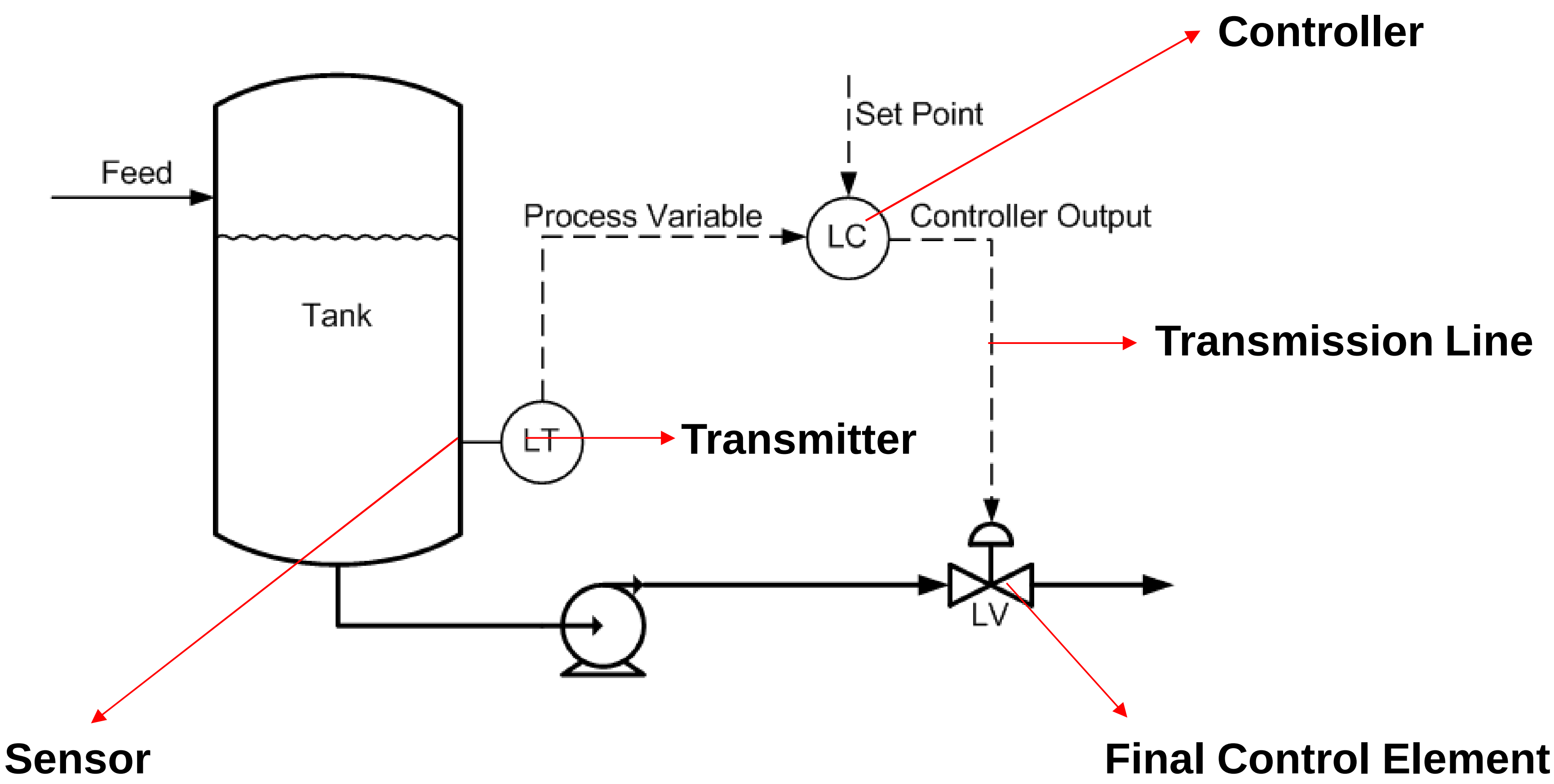
"Imagine the world without instrumentation and control…"

Instrumentasi

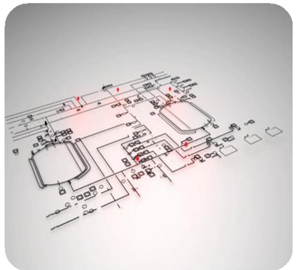
- Komponen Instrumentasi pada Kontrol Proses :

- **Sensors (Orifice, Thermocouple, dll)**
- **Transmitter (signal converter, amplifier, conditioner)**
- **Transmission line (electronic/electrical, instrument air, data line, dll)**
- **Controller (PLC, DCS, Computer)**
- Final Control Element (Control Valve, Motor, Lamp, dll

Instrumentasi



P&ID



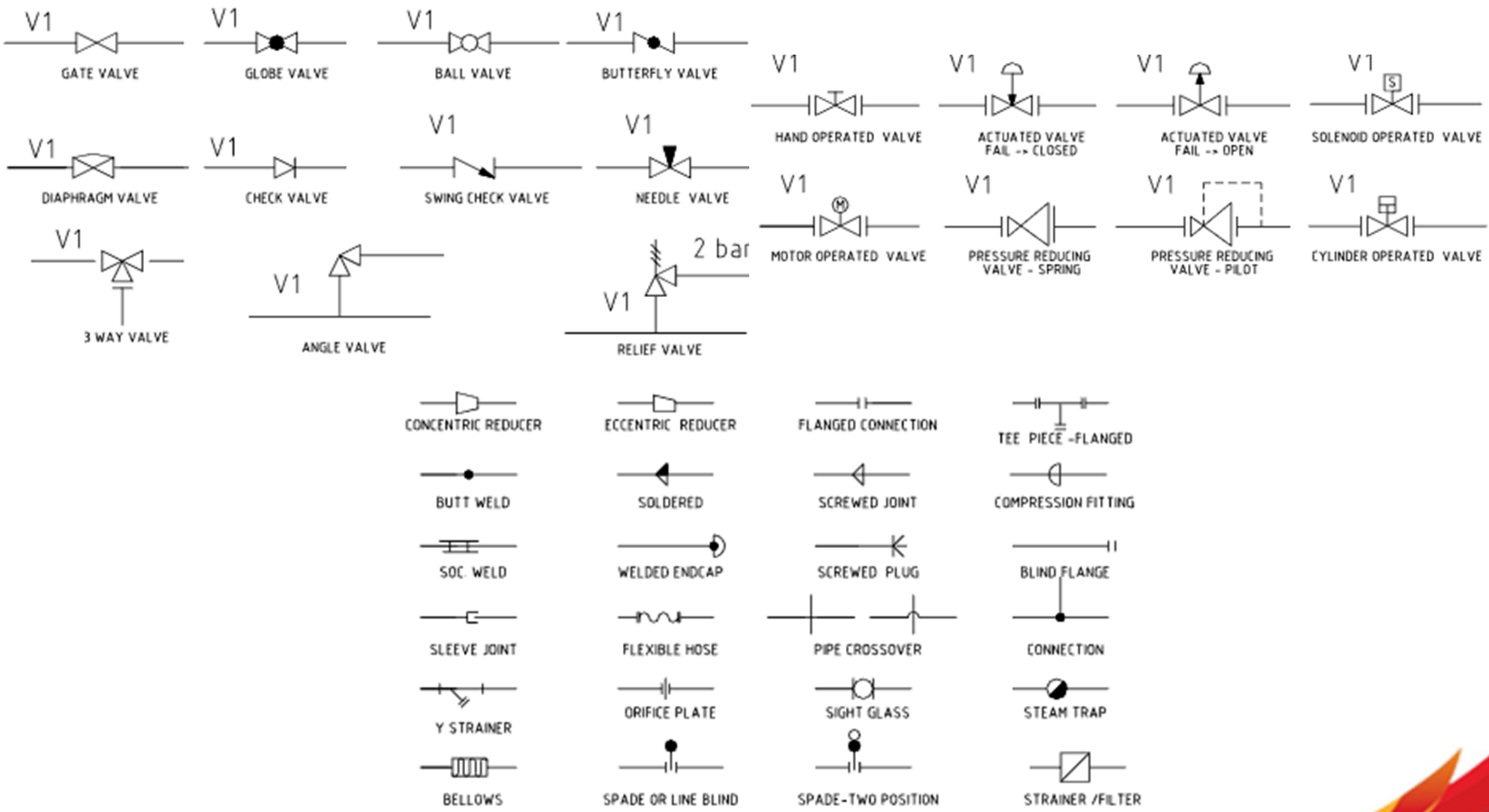
P&ID is a diagram in the process industry which shows the piping of the process flow together with the installed equipments and instrumentations

An ideal P&ID should include:

- Instrumentations and designations
- Mechanical equipments with name and numbers
- All valves and their identifications
- Flow directions
- Control inputs and outputs
- Interconnections and references
- Computer control system input
- Equipments rating or capacity
- Identification of components and subsystem delivered by others
- Vendor and contractor interfaces
- etc

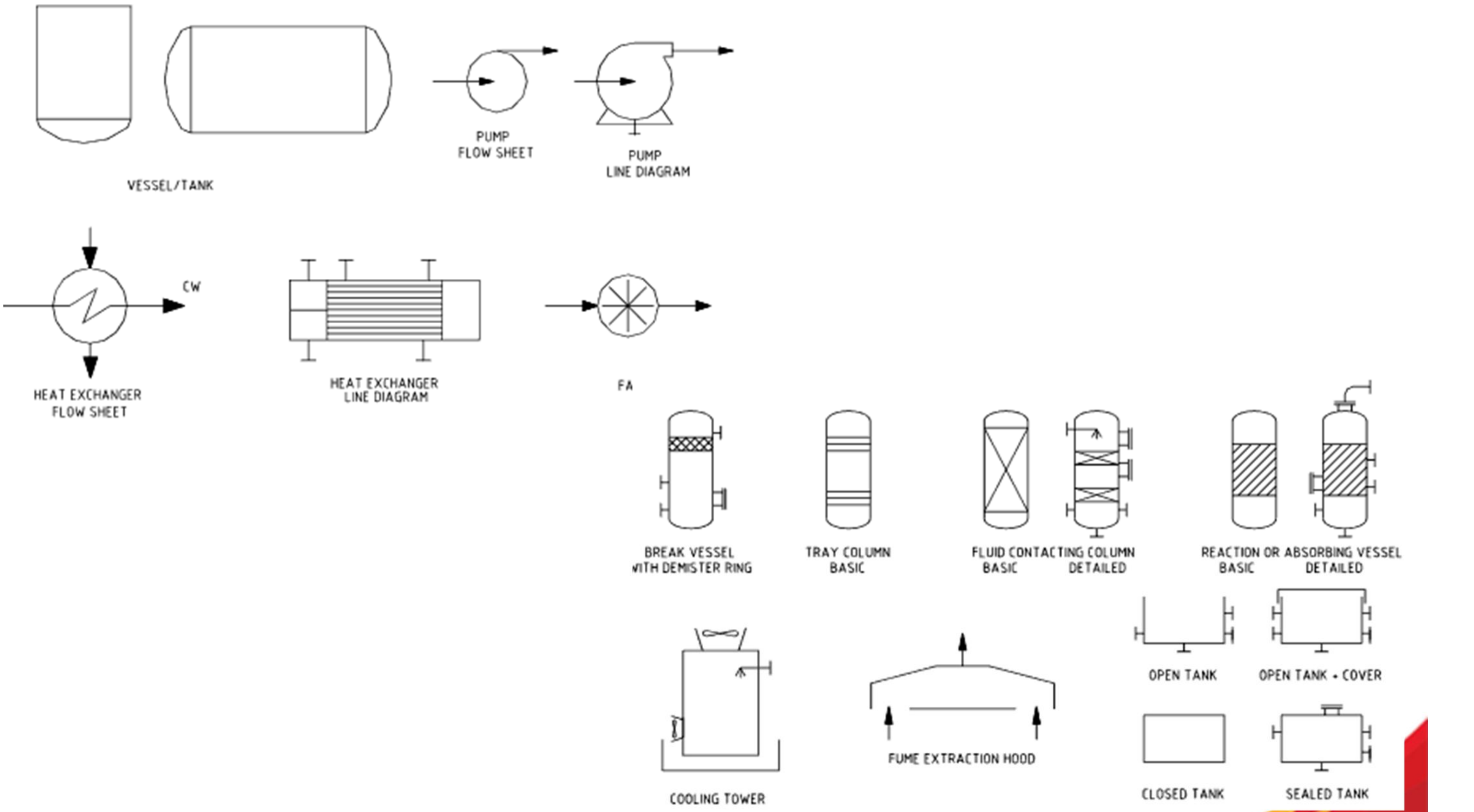
P&ID

Symbol, Abbreviation and Legends



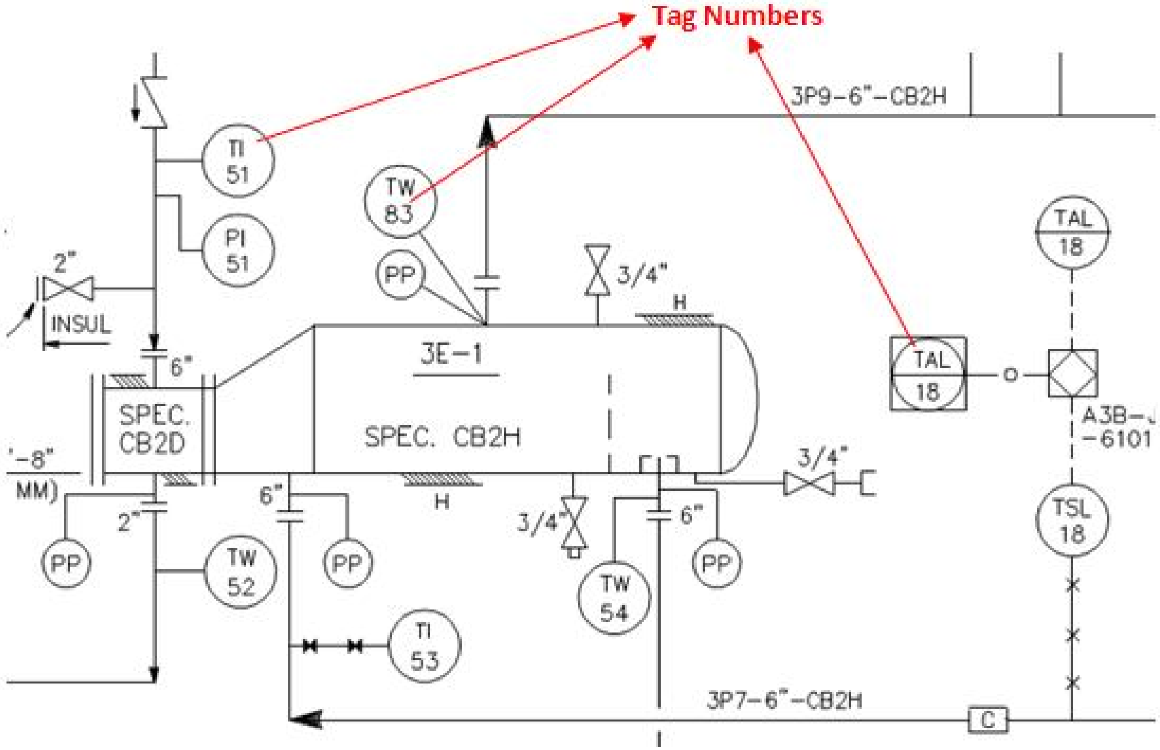
P&ID

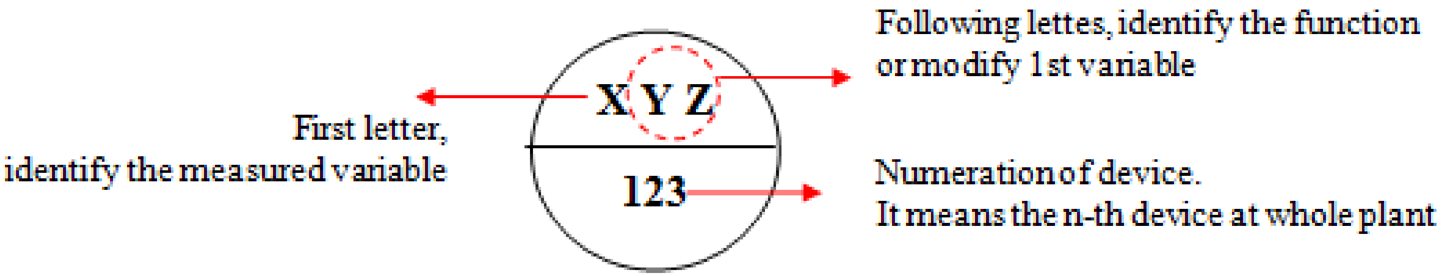
Symbol, Abbreviation and Legends



P&ID

Tag Numbers and Identification Letters





P&ID

Identification Letters

	First letter		Succeeding letters		
	Measured or initiating variable	Modifier	Readout or passive function	Output function	Modifier
A	Analysis		Alarm		
B	Burner, combustion		User's choice	User's choice	User's choice
C	User's choice			Control	
D	User's choice	Differential			
E	Voltage		Sensor (primary element)		
F	Flow rate	Ration (fraction)			
G	User's choice		Glass, viewing device		
H	Hand				High
I	Current (electrical)		Indication		
J	Power	Scan			
K	Time, time schedule	Time rate of change		Control station	
L	Level		Light		Low
M	User's choice	Momentary			Middle, intermediate
N	User's choice		User's choice	User's choice	User's choice
O	User's choice		Orifice, restriction		
P	Pressure, vacuum		Point (test connection)		

P&ID

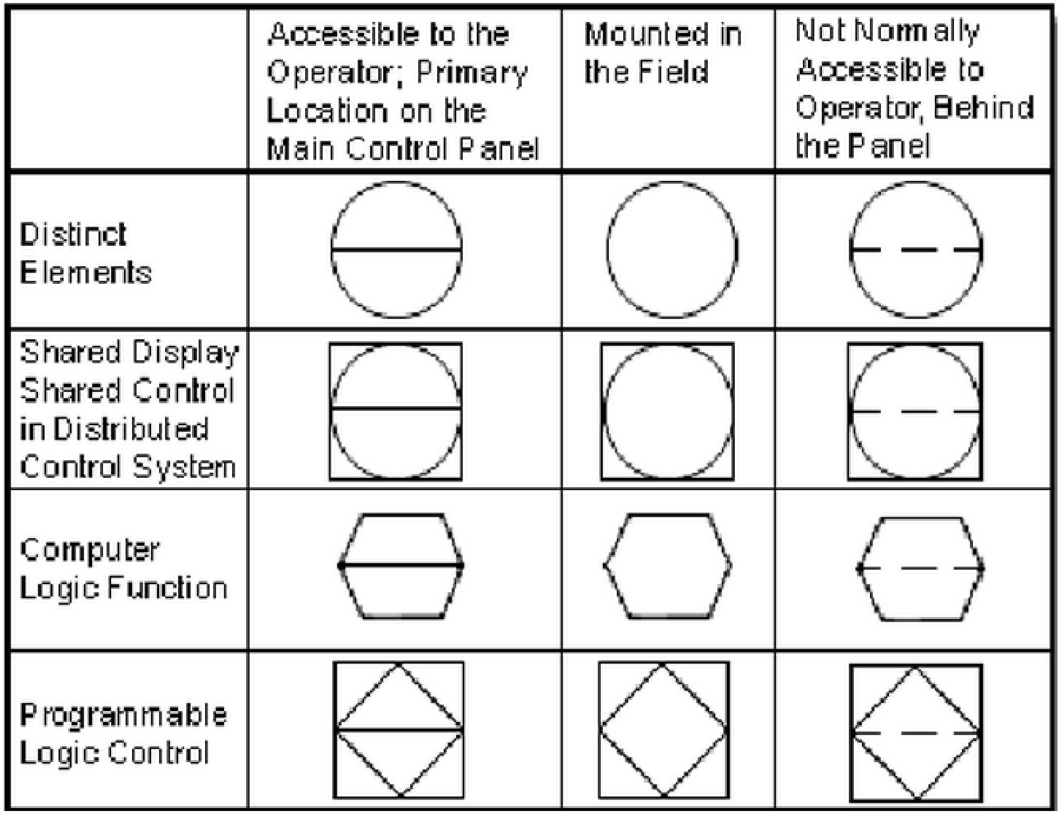
Identification Letters (contd.)

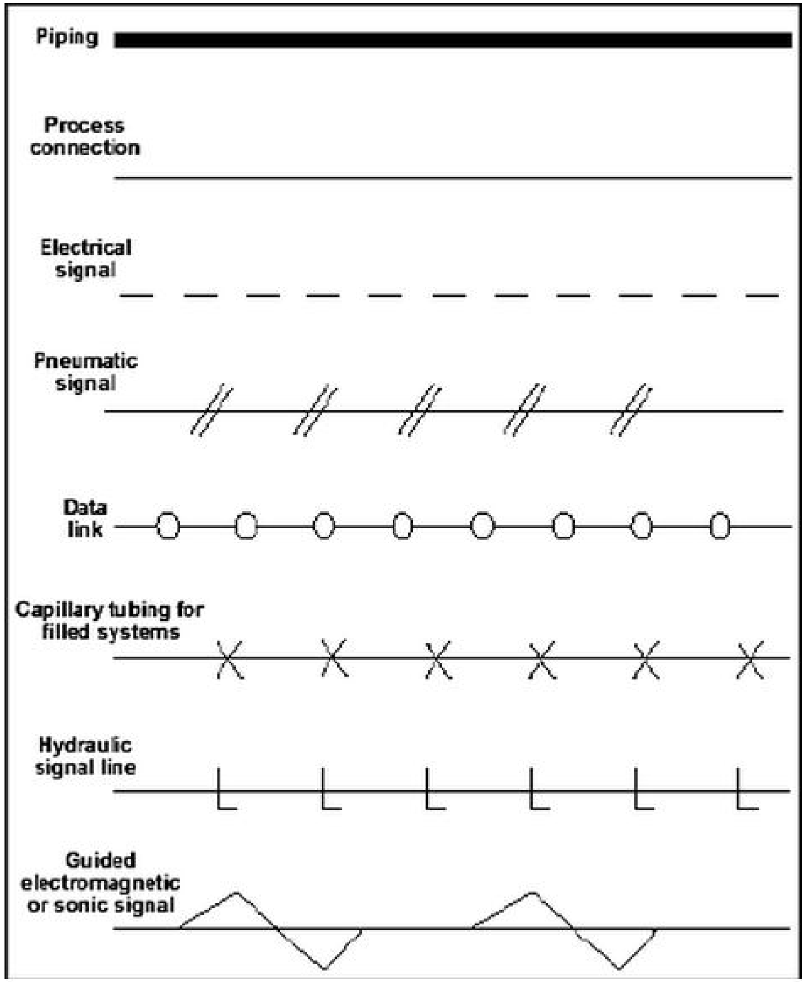
Q	Quantity	Integrate, totalizer			
R	Radiation		Record		
S	Speed, frequency	Safety		Switch	
T	Temperature			Transmit	
U	Multivariable		Multifunction	Multifunction	Multifunction
V	Vibration, mechanical analysis			Valve, damper, louver	
W	Weight, force		Well		
X	Unclassified	X axis	Unclassified	Unclassified	Unclassified
Y	Event, state, or presence	Y axis		Relay, compute, convert	
Z	Position, dimension	Z axis		Driver, actuator	

Source: Control Engineering with data from ISA S5.1 standard

P&ID

Instrument Location and Piping & Connection Symbol

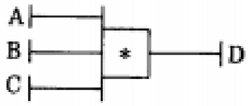
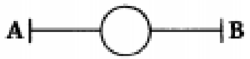




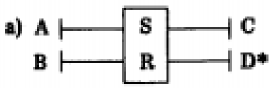
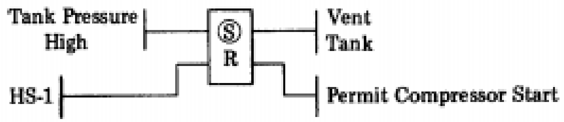
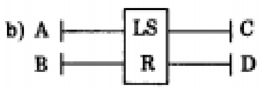
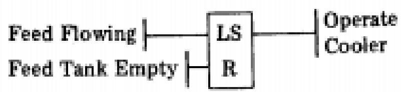
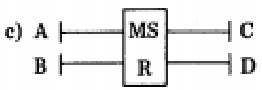
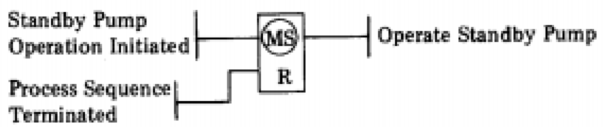
Logic Diagram

FUNCTION	SYMBOL	DEFINITION	EXAMPLE
4.1 INPUT	Statement of Input Alternatively: Statement of Input Initiating instrument or device number, if known	An input to the logic sequence	The start position of a hand switch *HS-1*, is actuated to pro input to start a conveyor. Alternative diagrams: a) HS-1 Start Conveyor Manually b) HS 1 Start Conveyor Manually
4.2 OUTPUT	Statement of Output Alternatively: Statement of Output Operated instrument or device number, if known	An output from the logic sequence.	An output from the logic sequence commands valve *HV-2* t Alternative diagrams: a) Open Valve HV-2 b) Open Valve HV 2
4.3 AND	BASIC A, B, C → A → D	Logic output *D* exists if and only if all logic inputs *A*, *B*, and *C* exist.	Operate pump if suction tank level is high and discharge val is open. Tank Level High, Valve Open → A → Operate Pump
4.4 OR	BASIC A, B, C → OR → D	Logic output *D* exists if and only if one or more of logic inputs *A*, *B*, and *C* exist.	Stop compressor if cooling water pressure is low or bearing temperature is high. Water Pressure Low, Bearing Temperature High → OR → Stop Compressor

Logic Diagram

FUNCTION	SYMBOL	DEFINITION	EXAMPLE
4.5 QUALIFIED OR	 *Internal details represent numerical quantities (see "Definition").	Logic output *D* exists if and only if a specified number of logic inputs *A*, *B*, and *C* exist. Mathematical symbols, including the following, shall be used, as appropriate, in specifying the number: a. $=$ equal to b. $\neq$ not equal to c. $<$ less than d. $>$ greater than e. $\nless$ not less than f. $\ngtr$ not greater than g. $\leq$ less than or equal to [equivalent to *f*] h. $\geq$ greater than or equal to [equivalent to *e*]	a) Operate mixer if two, and only two, bins are in service. Red Bin In Service Blue Bin In Service White Bin In Service Yellow Bin In Service $= 2$ Operate Mixer b) Stop reaction if at least two safety devices call for stop. Device #1 Actuated Device #2 Actuated Device #3 Actuated Device #4 Actuated Device #5 Actuated $\nless 2$ Stop Reaction c) Operate materials feeder if at least one and no more than two mills are in service. Mill #1 In Service Mill #2 In Service Mill #3 In Service ≥ 1 $\ngtr 2$ Operate Feeder
4.6 NOT BASIC	 **The *NOT* symbol may be drawn tangent to an adjacent logic symbol.**	**Logic output *B* exists if and only if logic input *A* does not exist.**	Shut off fuel gas if burners no. 1 and no. 2 are not on. Burner No. 1 On Burner No. 2 On A Shut Off Fuel Gas Some Alternatives: Burner No. 1 On Burner No. 2 On A Shut Off Fuel Gas Burner No. 1 On Burner No. 2 On OR Shut Off Fuel Gas

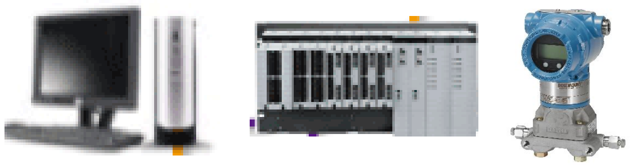
Logic Diagram

FUNCTION	SYMBOL	DEFINITION	EXAMPLE
4.7 MEMORY (Flip-Flop) BASIC	 *Output *D* shall not be shown if it is not used.	S represents *set memory* and R represents *reset memory*. Logic output *C* exists as soon as logic input *A* exists. *C* continues to exist, regardless of the subsequent state of *A*, until the memory is reset, i.e., terminated by logic input *B* existing. *C* remains terminated regardless of the subsequent state of *B*, until *A* causes the memory to be set. Logic output *D*, if used, exists when *C* does not exist, and *D* does not exist when *C* exists.	If tank pressure becomes high, vent tank and continue venting, regardless of pressure, until venting is stopped by manual actuation of hand switch, HS-1, provided that the pressure is not high. If the venting is stopped, a compressor may be started. 
		Input-Override Option If inputs *A* and *B* exist simultaneously, and if it is desired to have *A* override *B*, then *S* should be encircled, i.e., Ⓢ ; if *B* is to override *A*, then *R* should be encircled, i.e., Ⓡ *Loss-Of-Power-Supply Option* The unmodified letter *S* denotes that *no consideration* has been given to the action of the memory on loss of the logic power supply. See paragraphs 4.7 b, c, and d, below, and 3.8.	
	 (See Appendix C)	Similar to definition of symbol (a) except that the memory shall be *lost* in the event of loss of the logic power supply.	If feed begins to flow, the cooler shall operate until the feed tank is empty. In the event of loss of the logic power supply, the cooler shall not operate 
(cont'd)		Similar to definition of symbol (a) except that the memory shall be *maintained* in the event of loss of the logic power supply.	If standby pump operation is initiated, the pump shall operate, even on loss of the logic power supply, until the process sequence is terminated. The pump shall operate if start and stop commands exist simultaneously. 

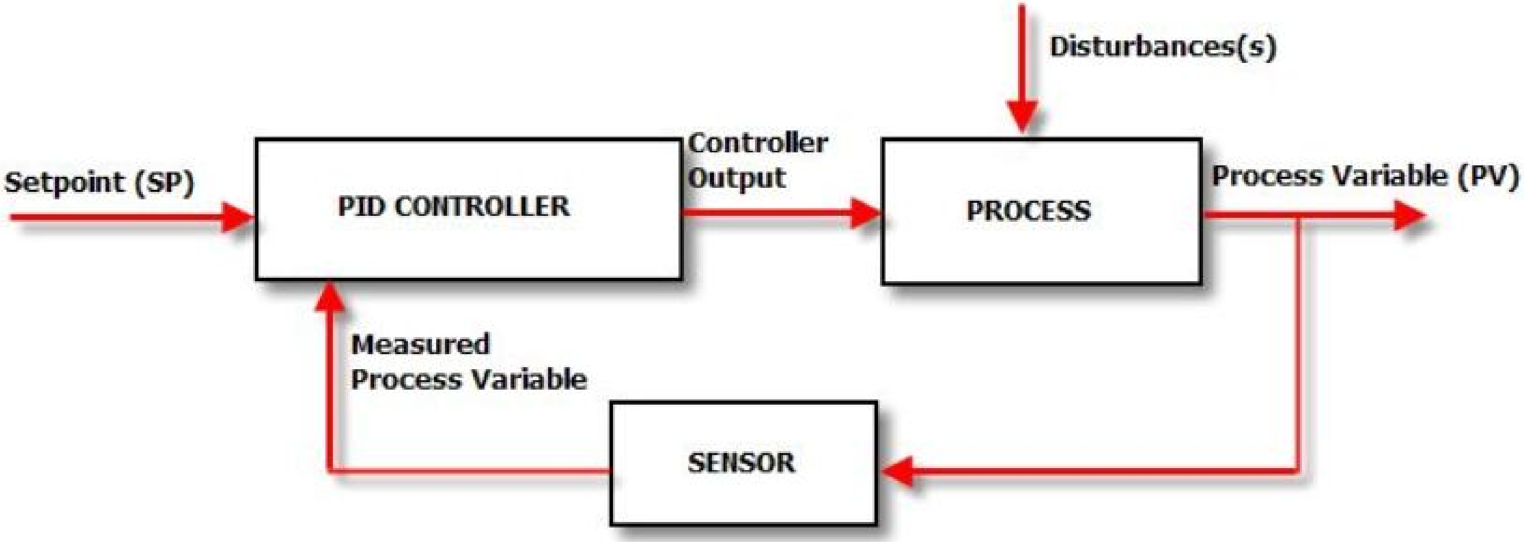
Logic Diagram

FUNCTION	SYMBOL	DEFINITION	EXAMPLE
4.7 (cont'd)	d) A ├─ NS / R ─┤ C; B ├─ ─┤ D	Similar to definition of symbol (a) except that *after consideration* it is deemed *not significant*, so far as the process is concerned, whether the memory is maintained or lost in the event of loss of power supply.	If reservoir level is low, operate fill pump until either level is high or water quality is unsatisfactory. It is not significant to the process what happens to the pump on loss of the logic supply. If start and stop commands are simultaneous, the pump shall stop. Reservoir Level Low ├─ NS / Ⓡ ─┤ Operate Fill Pump Reservoir Level High, Water Quality Unsatisfactory ─ OR
4.8 TIME ELEMENT	a) A ├─ * ─┤ B *For functional details, see the following (also see Section 3.9):	Logic output *B* exists with a time relationship to logic input *A* as specified.	
BASIC	b) A ├─ DI t ─┤ B (<u>D</u>elay <u>I</u>nitiation of output)	The continuous existence of logic input *A* for time *t* causes logic output *B* to exist when *t* expires. *B* terminates when *A* terminates.	If reactor temperature exceeds a high limit continuously for 10 seconds, block catalyst flow. Resume flow when temperature does not exceed the limit. Reactor Temp. High ├─ DI 10 s ─┤ Block Catalyst Flow
BASIC	c) A ├─ DT t ─┤ B (<u>D</u>elay <u>T</u>ermination of output)	The existence of logic input *A* causes logic output *B* to exist immediately. *B* terminates when *A* has terminated and has not again existed for time *t*.	If system pressure falls below a low limit, operate compressor at once. Stop the compressor when pressure is not low continuously for one minute. System Press. Low ├─ DT 1 min. ─┤ Operate Compressor
BASIC (cont'd)	d) A ├─ PO t ─┤ B (<u>P</u>ulse <u>O</u>utput)	The existence of logic input *A*, regardless of its subsequent state, causes logic output *B* to exist immediately. *B* exists for time *t* and then terminates.	If vessel purge fails for any period of time, operate evacuation pump for 3 minutes and then stop the pump. Vessel Purge Fails ├─ PO 3 min. ─┤ Operate Evacuation Pump

TEORI CONTROL LOOP



Pendahuluan



Control Loop

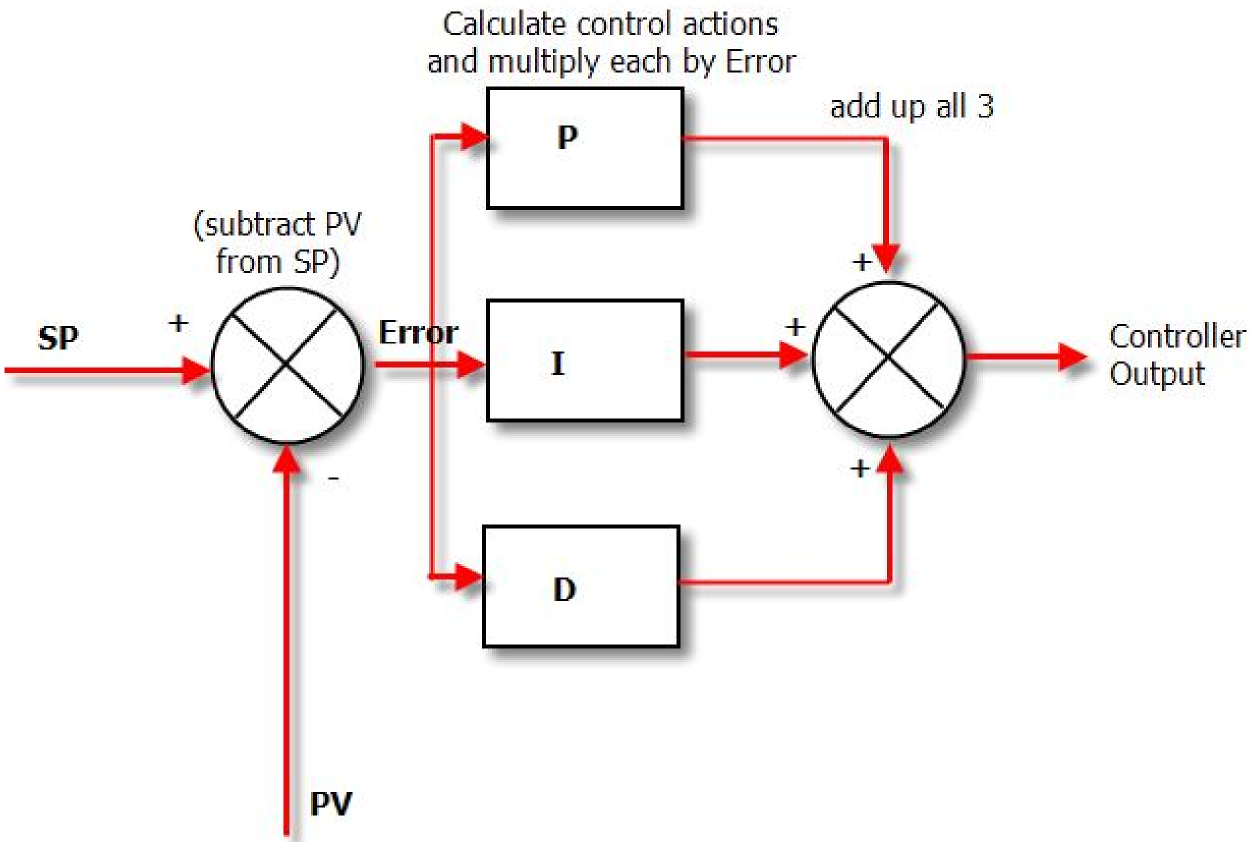
A control loop is a process management system designed to maintain a process variable at a desired set point. Each step in the loop works in conjunction with the others to manage the system. Once the set point has been established, the control loop operates using a four-step process.

1. **Sense**
   Measure the current condition of the process using a sensor, which can be an electronic (thermocouple, RTD or transmitter) or a mechanical device (thermal system).
2. **Compare**
   Evaluate the measurement of the current condition against the set point using an electronic or electric contact controller.
3. **Respond**
   React to any error that may exist by generating a corrective pneumatic or electric control signal.
4. **Affect**
   Actuate a final control element (valve, heater or other device) that will produce a change in the process variable.

The loop continually cycles through the steps, affecting the process variable in order to maintain the desired set point. Trerice is unique in its ability to provide all of the necessary components to create a complete control loop.

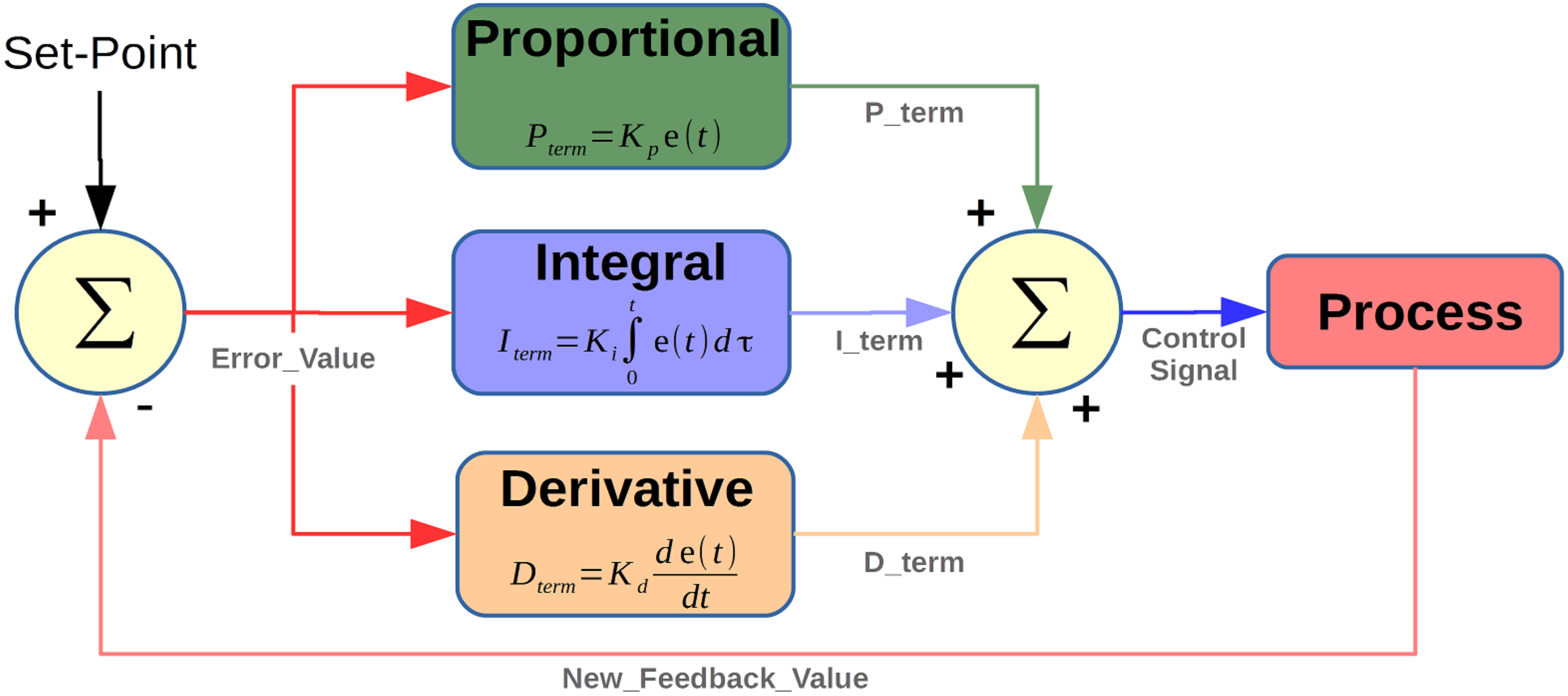
PID

- Dalam menjaga agar process variable (PV) selalu berada dalam rentang Set Point (SP), maka dibutuhkan suatu algoritma control. Salah satu yang paling umum digunakan adalah PID Control



PID

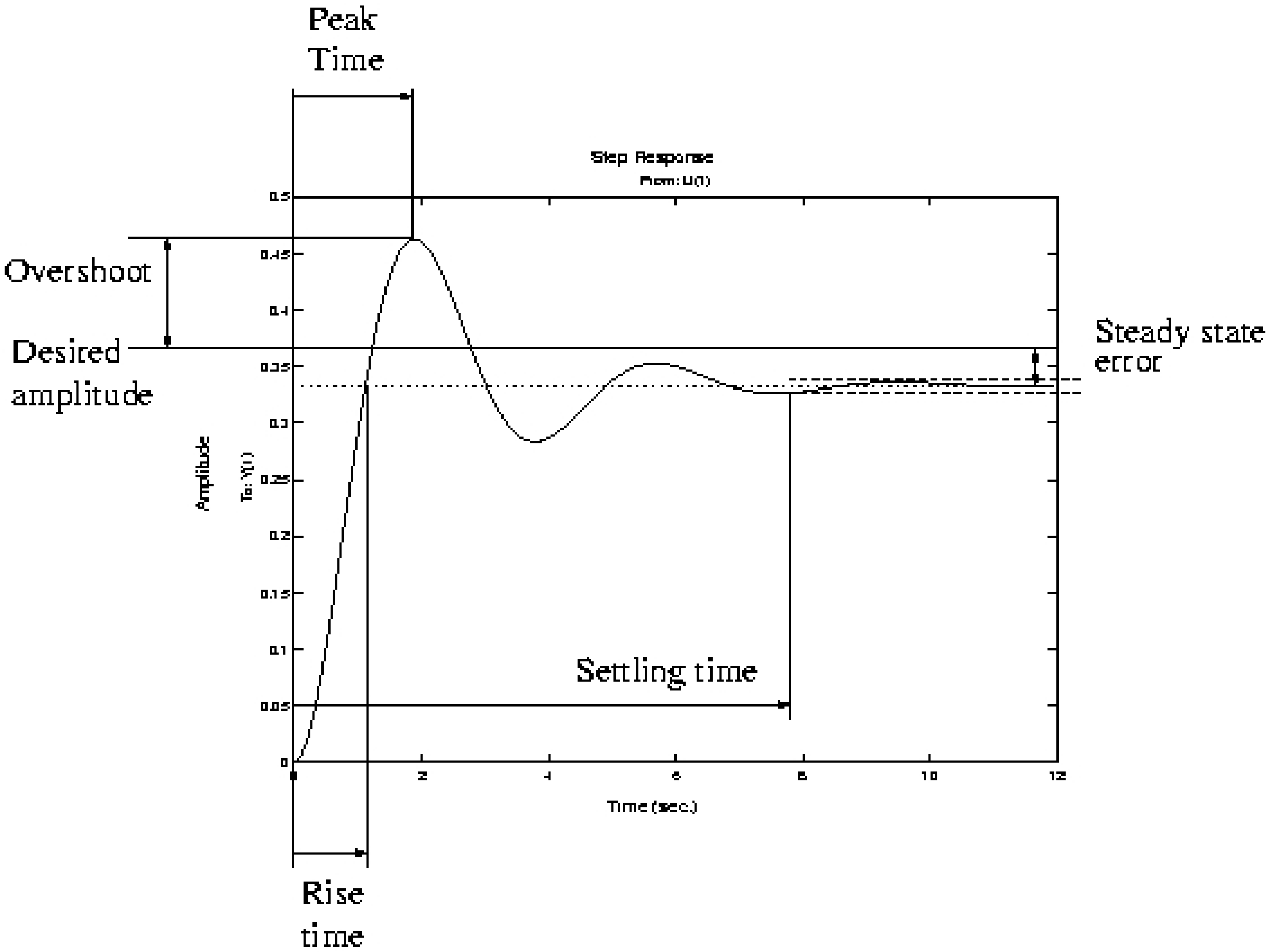
Formula



Set-Point
+
-
Σ
Error_Value
Proportional
$P_{term} = K_p e(t)$
Integral
$I_{term} = K_i \int_0^t e(t)\,d\tau$
Derivative
$D_{term} = K_d \frac{d\,e(t)}{dt}$
P_term
I_term
D_term
+
+
+
Σ
Control Signal
Process
New_Feedback_Value

PID

- Response Control Terminology



Proportional Control (P)

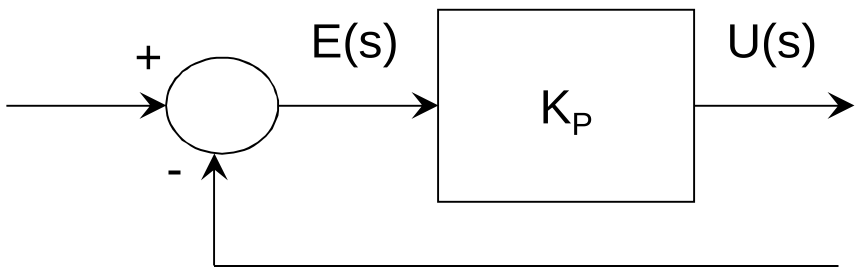
- Persamaan matematis :

$$u(t) = K_P \,.\, e(t)$$

dimana K_P : konstanta proporsional
dalam Laplace

$$U(s)/E(s) = K_P$$

Diagram Blok



- Dikenal juga sebagai : *gain*/penguatan

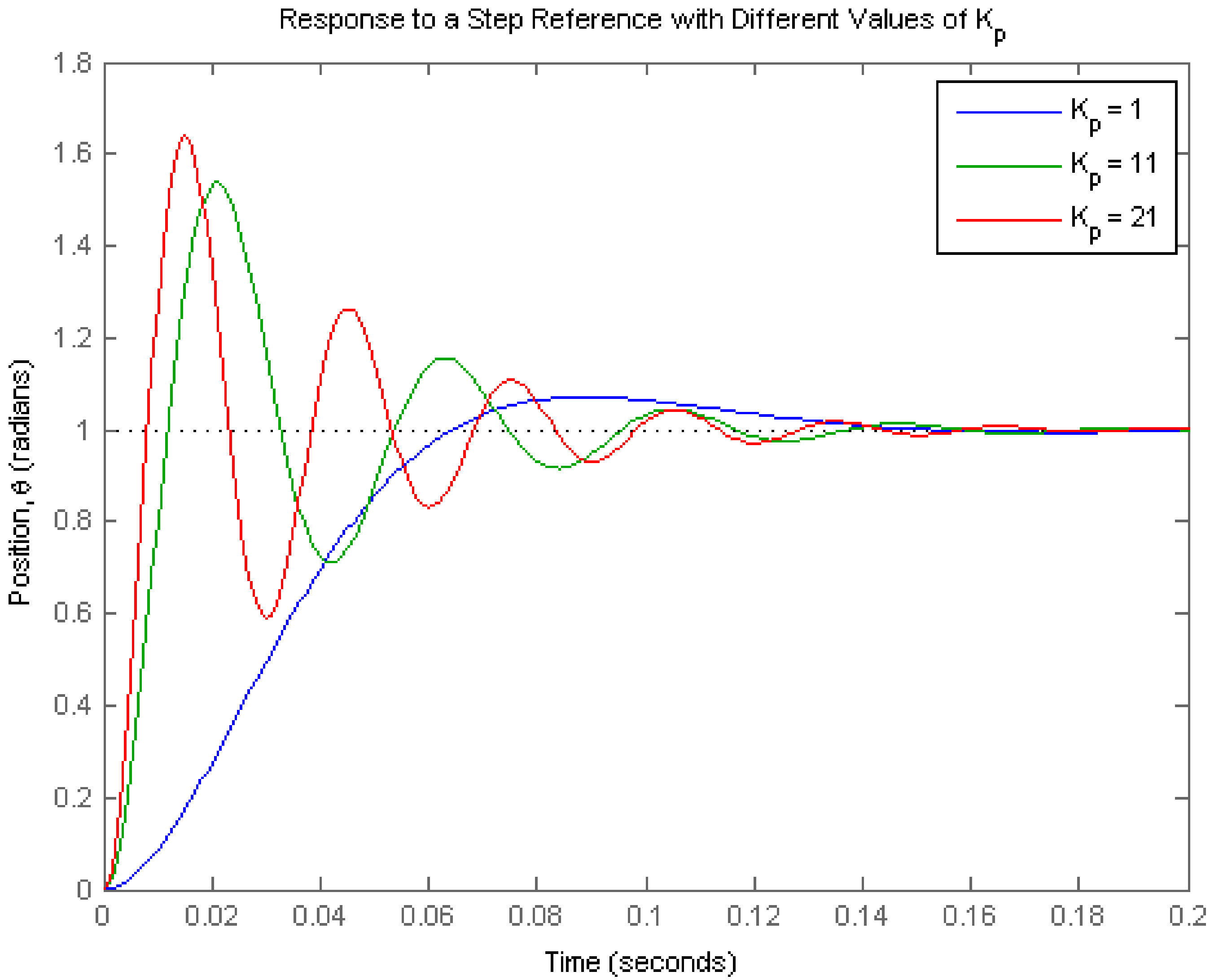
PID

Proportional Control (P)

- Pengaruh pada sistem :
  - Menambah atau mengurangi kestabilan
  - Dapat memperbaiki respon transien khususnya : rise time, settling time
  - Mengurangi (bukan menghilangkan) Error steady state
    - Catatan : untuk menghilangkan E_{SS}, dibutuhkan K_P besar, yang akan membuat sistem lebih tidak stabil
- Kontroler Proporsional memberi pengaruh langsung (sebanding) pada error
  - Semakin besar error, semakin besar sinyal kendali yang dihasilkan kontroleR

PID

Proportional Control (P)



PID

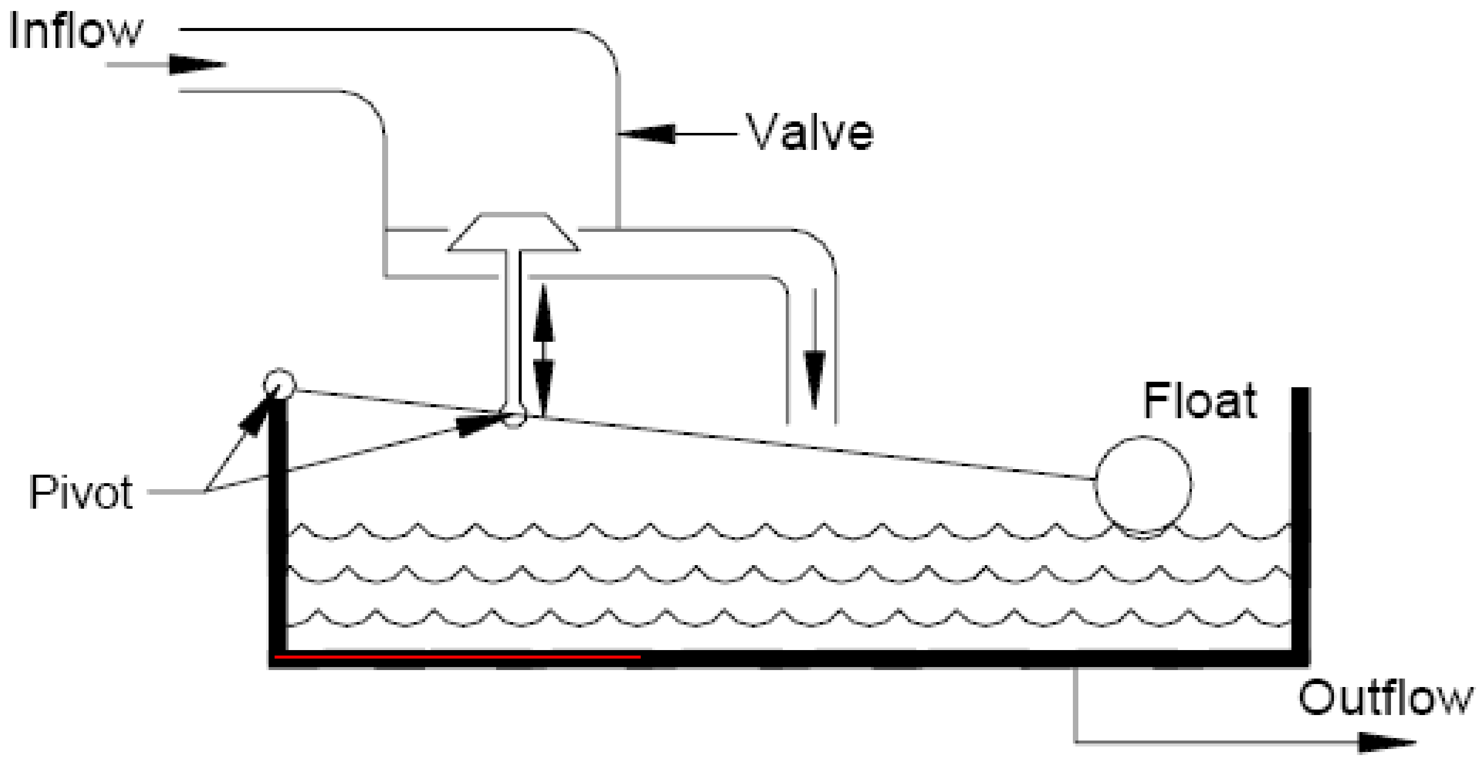


Figure 6
Simple Proportional Control

PID

Integral Control (I)

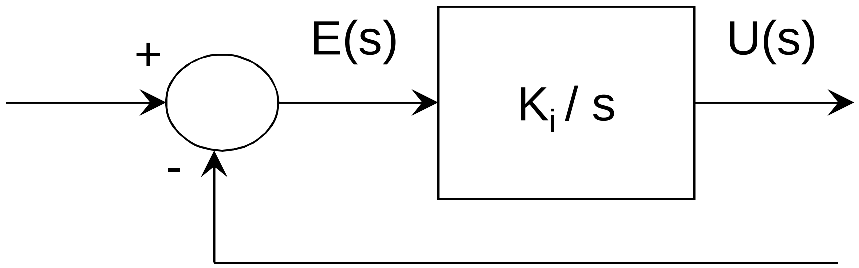
- Persamaan matematis :

$$u(t) = K_i \int_0^t e(t)dt$$

dimana K_i : konstanta integral
dalam Laplace

$$\frac{U(s)}{E(s)} = \frac{K_i}{s}$$

- Diagram Blok



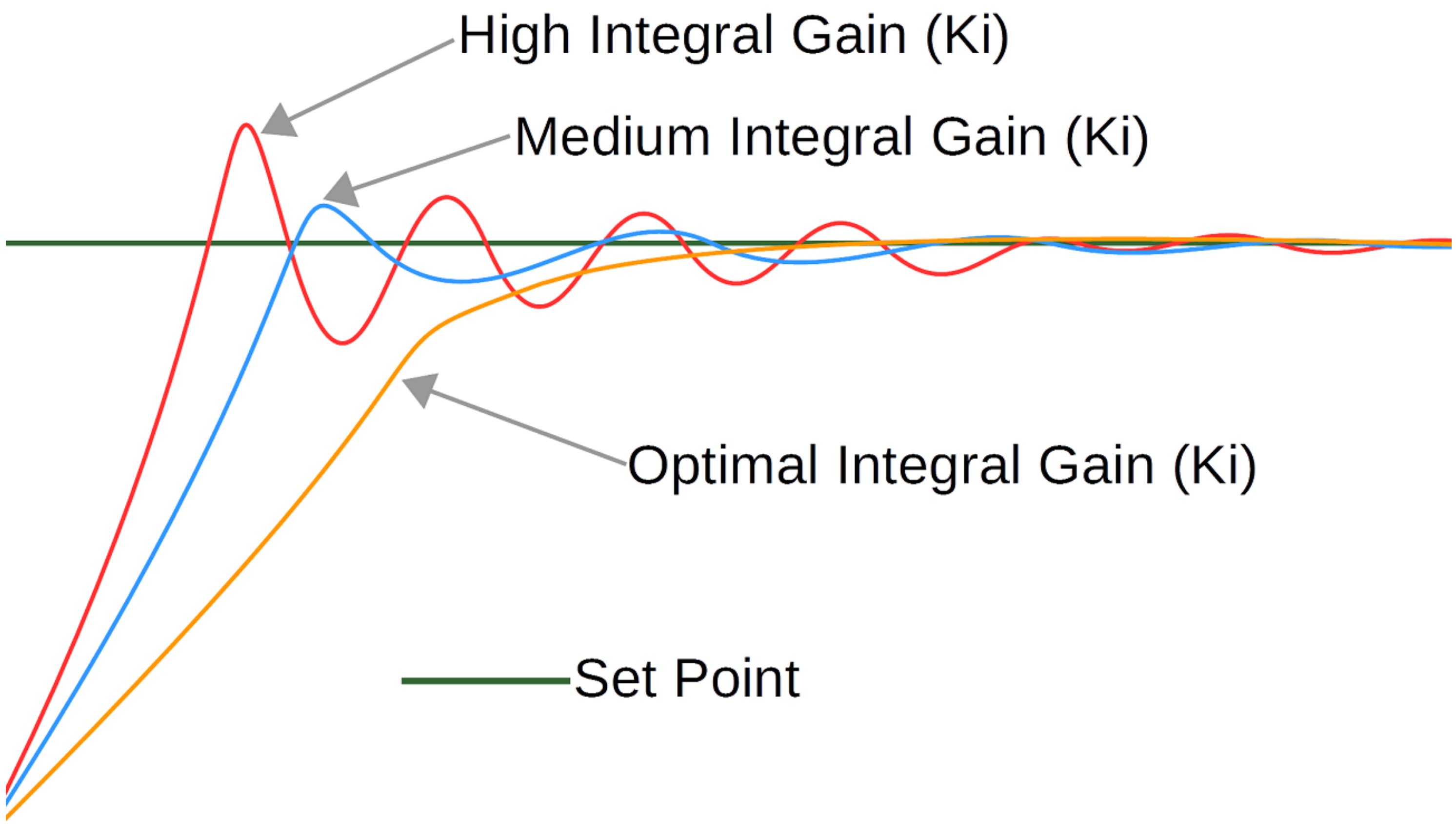
PID

Integral Control (I)

- Pengaruh pada sistem :
  - Menghilangkan Error Steady State
  - Respon lebih lambat (dibanding P)
  - Dapat menimbulkan ketidakstabilan (karena menambah orde sistem)
- Perubahan sinyal kontrol sebanding dengan perubahan error
  - Semakin besar error, semakin cepat sinyal kontrol bertambah/berubah

PID

Integral Control (I)



PID

Derivative Control (D)

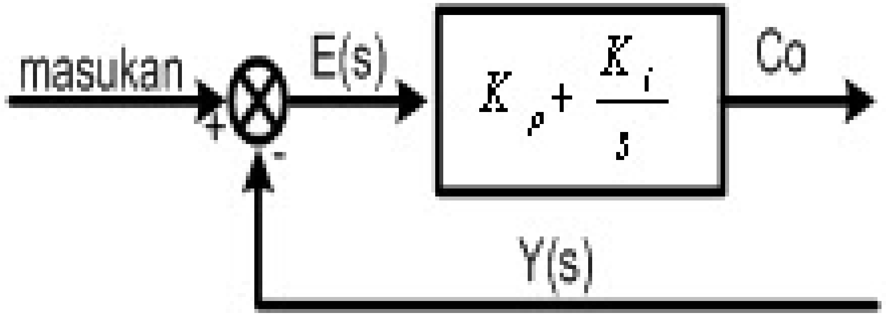
- Pengaruh pada sistem :
  - Memberikan efek redaman pada sistem yang berosilasi
    - sehingga bisa memperbesar pemberian nilai **Kp**
  - Memperbaiki respon transien, karena memberikan aksi saat ada perubahan error
  - D hanya berubah saat ada perubahan error, sehingga saat ada error statis D tidak beraksi
    - **Sehingga D tidak boleh digunakan sendiri**

- Besarnya sinyal kontrol sebanding dengan perubahan error (Δe)
  - Semakin cepat error berubah, semakin besar aksi kontrol yang ditimbulkan

PID

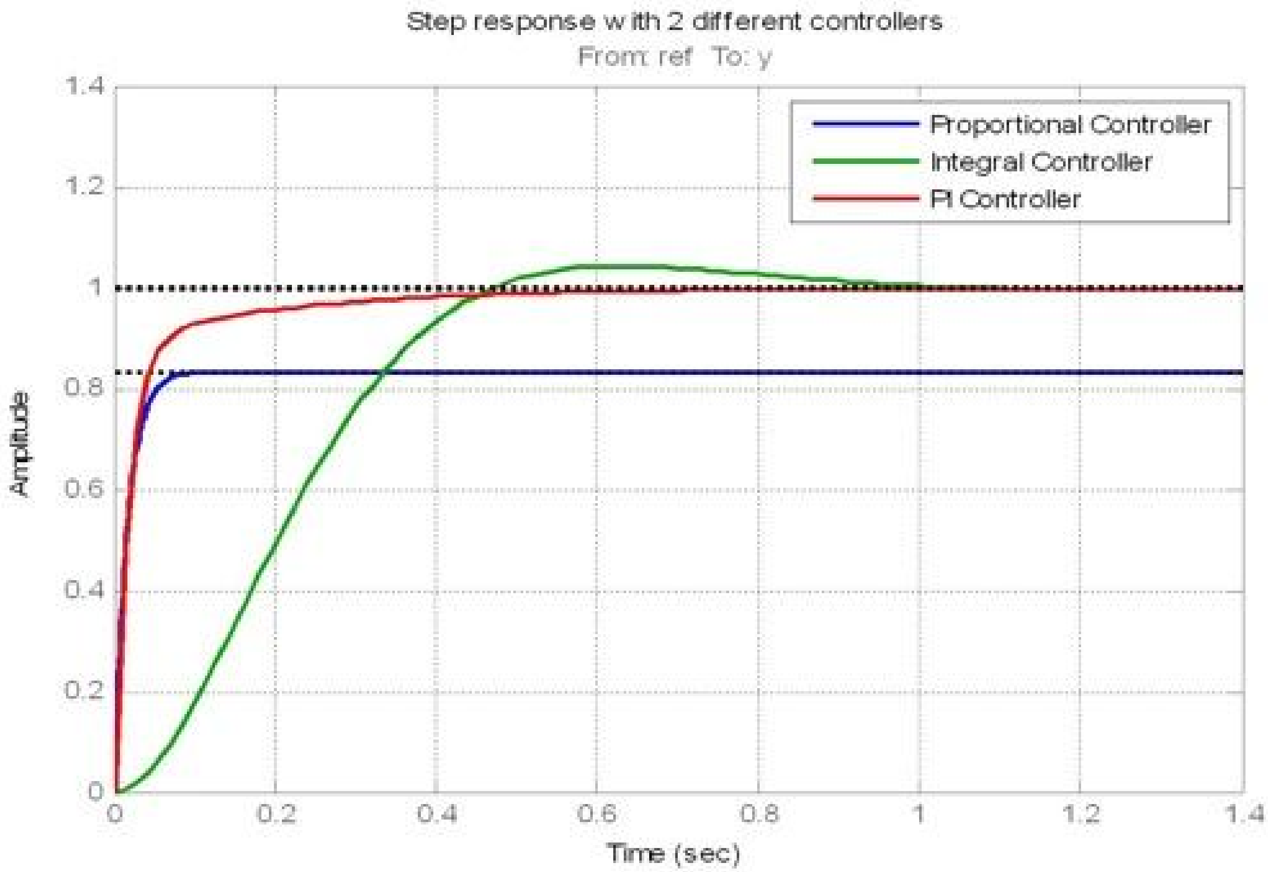
Proportional Integral Control (PI)

- Gabungan aksi kontrol proporsional dan aksi kontrol integral membentuk aksi kontrol proporsional plus integral (controller PI). Gabungan aksi ini mempunyai keunggulan dibandingkan dengan masing-masing penyusunnya.
- Keunggulan utamanya adalah diperolehnya keuntungan dari masing-masing aksi kontrol dan kekurangan aksi kontrol yang satu dapat diatasi. Dengan kata lain elemen-elemen controller P dan I secara keseluruhan bertujuan untuk mempercepat reaksi sebuah sistem dan menghilangkan offset.



PID

Proportional Integral Control (PI)



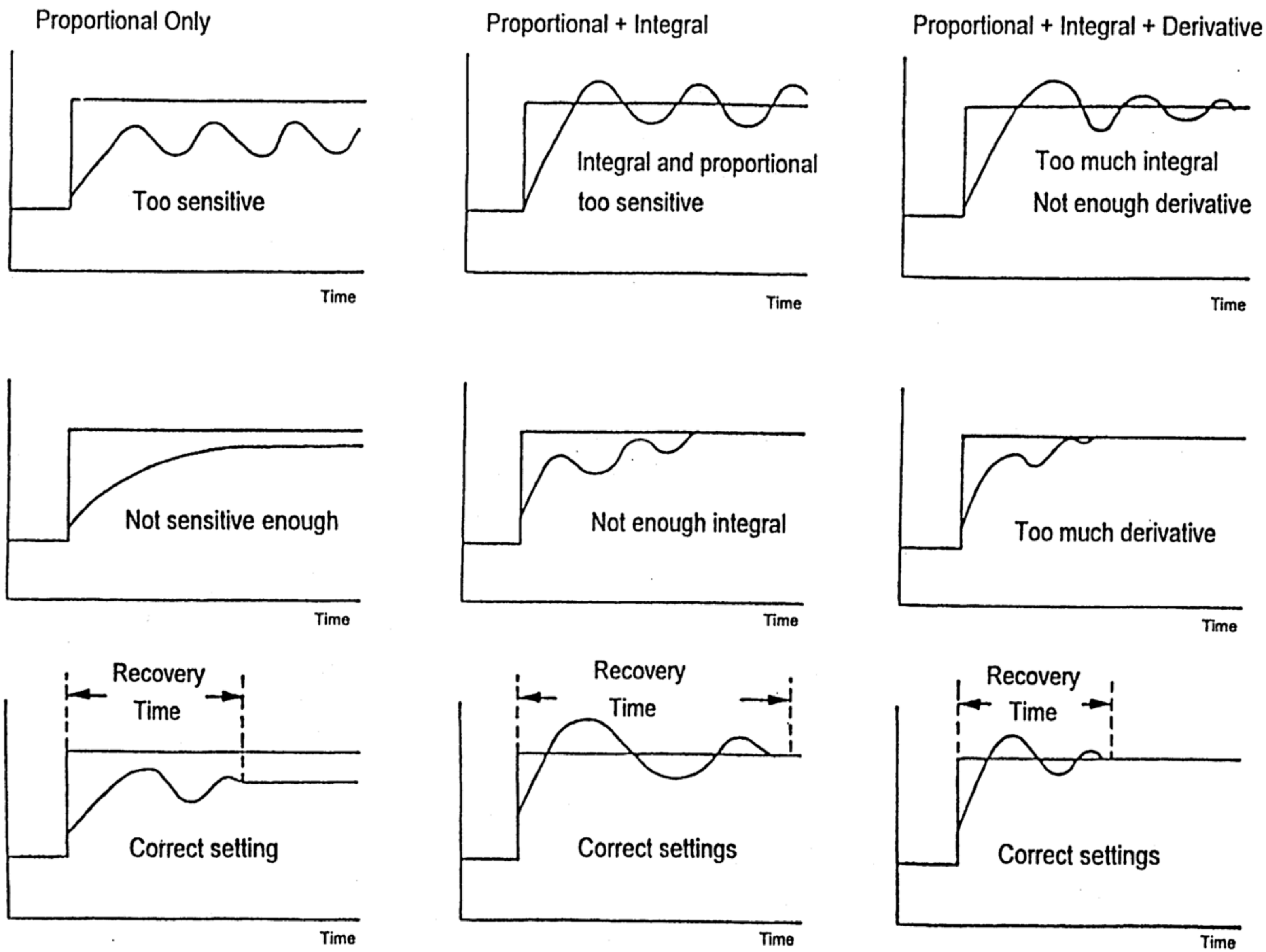
Respon	Rise Time	Overshoot	Settling Time	S-S Error
Kp	Turun	Naik	-	Turun
Ki	Turun	Naik	Naik	Hilang

PID

Proportional Integral Derivative Control (PID)

- PID digunakan pada proses yang butuh performa kontrol tinggi, contoh : temperature system
- Terbaik dari segi : stabilitas, settling time, dan offset removal
- Kendalanya : kompleksitas pada set up dan tuning parameter
- Derivative action digunakan pada proses:
  - Mengandung lags yang besar
  - Deviasi akibat perubahan beban proses minimum
- Keuntungan kontroler PID:
  - Menggabungkan kelebihan kontroler P, I, dan D
    - P : memperbaiki respon transien
    - I : menghilangkan error steady state
    - D : memberikan efek redaman

PID

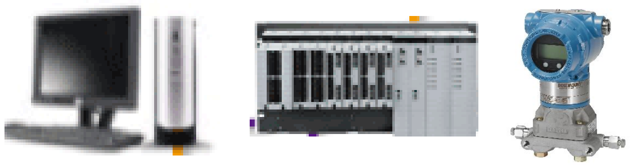

Proportional Only
Proportional + Integral
Proportional + Integral + Derivative
Too sensitive
Integral and proportional too sensitive
Too much integral
Not enough derivative
Not sensitive enough
Not enough integral
Too much derivative
Recovery Time
Correct setting
Recovery Time
Correct settings
Recovery Time
Correct settings
Time

PID

- Permasalahan terbesar dalam desain kontroler PID
  - Tuning : menentukan nilai Ki, Kp, dan Kd
- Metode – metode *tuning* dilakukan berdasar
  - Model matematika plant/sistem
  - Jika model tidak diketahui, dilakukan eksperimen terhadap sistem
- Cara *tuning* kontroler PID yang paling populer :
  - Ziegler-Nichols metode 1 dan 2
  - Metode tuning Ziegler-Nichols dilakukan dengan eksperimen (asumsi model belum diketahui)
  - Metode ini bertujuan untuk pencapaian maximum overshoot (MO) : 25 % terhadap masukan *step*

Badak LNG
A World Class Energy Company

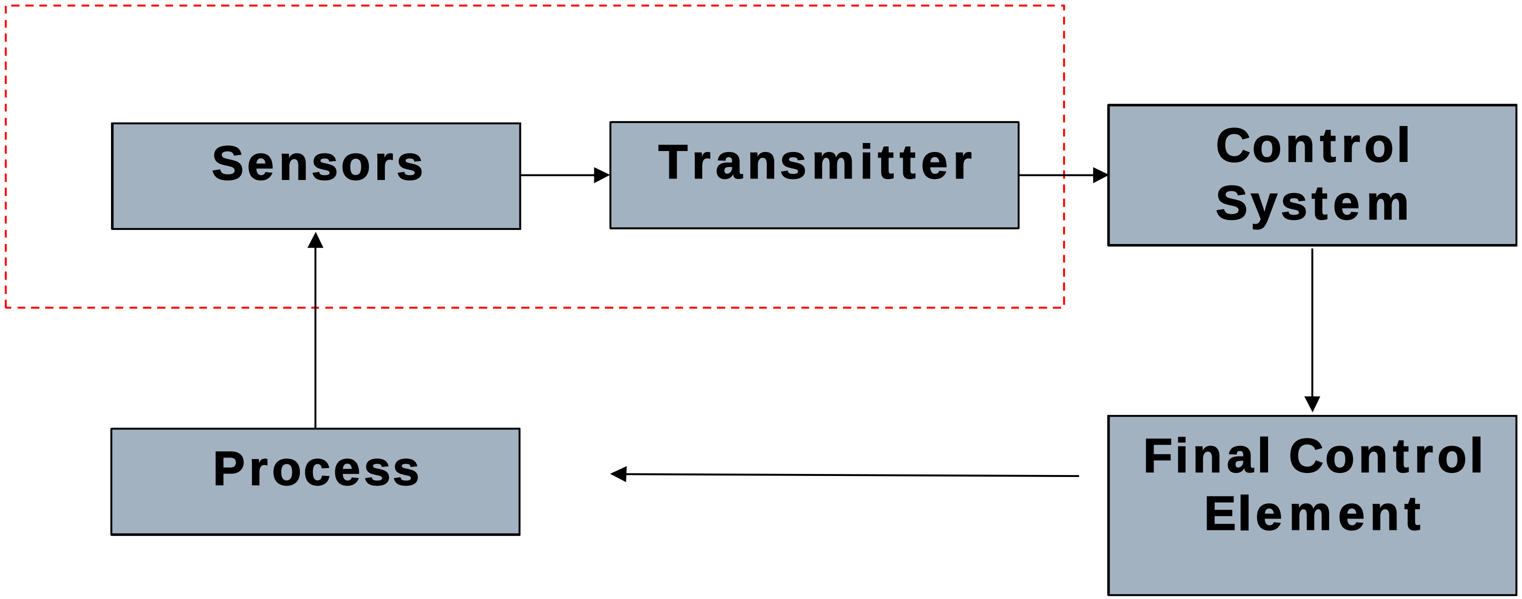
PENGENALAN TRANSMITTER (SENSOR-TRANSDUCER)



Pendahuluan

- Dalam dunia proses control, parameter fisis yang biasanya secara langsung diukur dan dikendalikan adalah :
  - Pressure
  - Temperature
  - Level
  - Flow
- Selain keempat besaran di atas, diukur pula beberapa parameter lain seperti speed, getaran, komposisi, kandungan material, dll.

Pendahuluan



Sensor adalah alat untuk merasakan perubahan proses parameter/besaran fisis yang ada.
Sensor dilengkapi dengan transducer untuk mengubah besaran fisis tersebut menjadi sesuatu yang bisa “diukur” seperti ohm atau mV

Transmitter “menerjemahkan” yang dikirimkan oleh transducer ke dalam suatu protocol standar (dalam bentuk 4-20 mA)

Transmitter

- Transmitter digunakan ketika pengontrol, indikator/display, atau recorder diperlukan di control room atau panel
- Di dalam transmitter terjadi perubahan sinyal dari besaran fisis (mV/ohm/degC) ke analog (biasanya dalam 4-20 mA)
- Sinyal sensor (umumnya dalam mV) perlu dikonversi menjadi sinyal standar (4-20mA)
- Contoh :
  - $50^oC – 150^oC$ → 4 mA – 20 mA
  - **Gain** transmitter → $16mA/100^oC = 0,16mA/^oC$
  - **Zero** transmitter → 50^oC

Transmitter

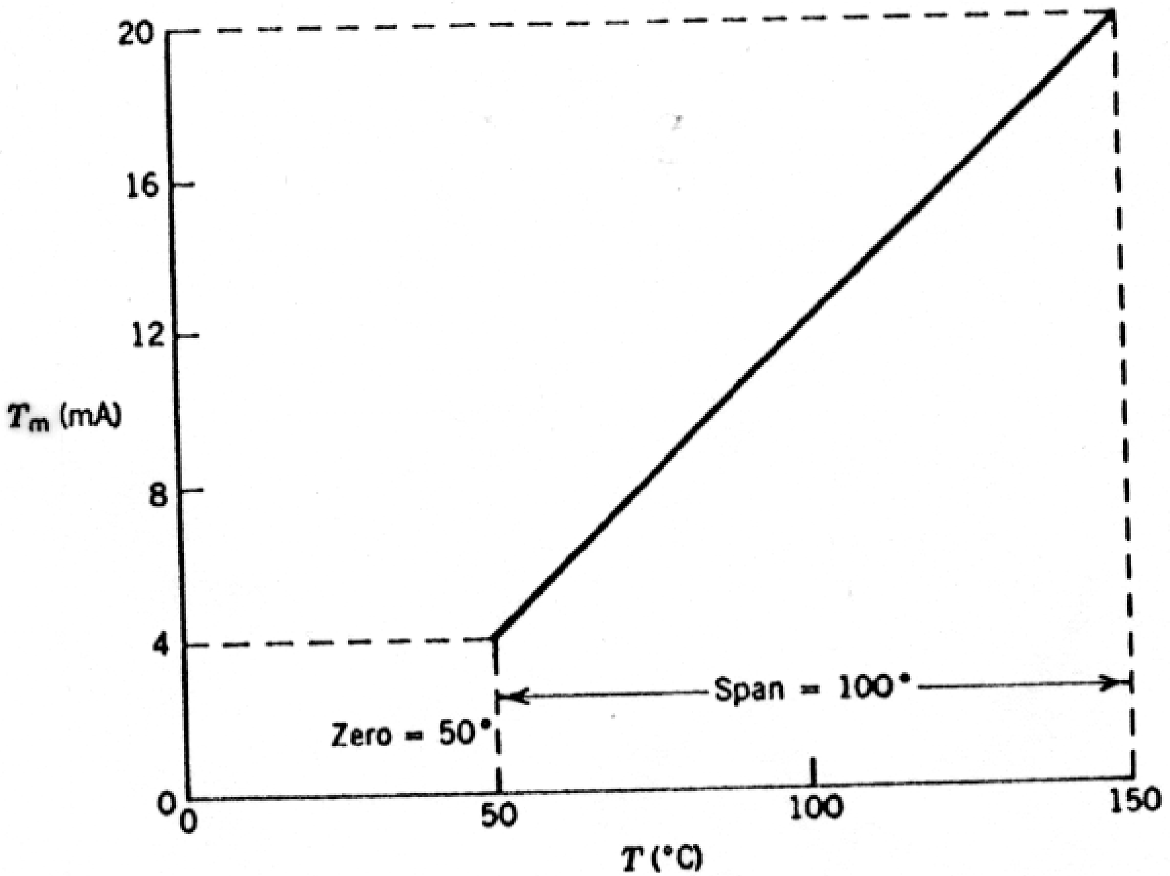


Figure 9.4. A linear instrument calibration showing its zero and span.

Transmitter

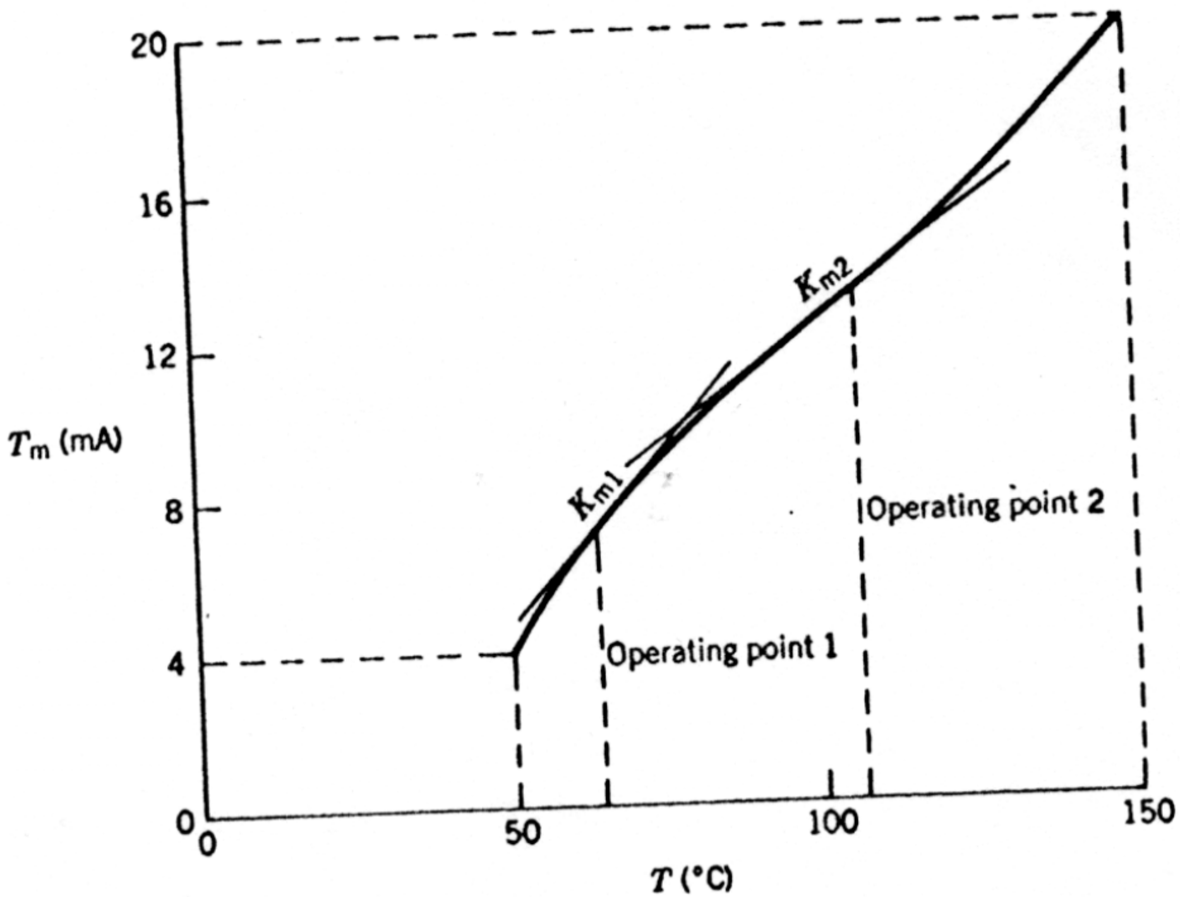


Figure 9.5. Gain of a nonlinear transducer as a function of operating point.

Transmitter

- Error = Bias + Variance
  - Bias : Sistematik error = true value – mean
  - Variance : Random error = Repeatability / kepresisian

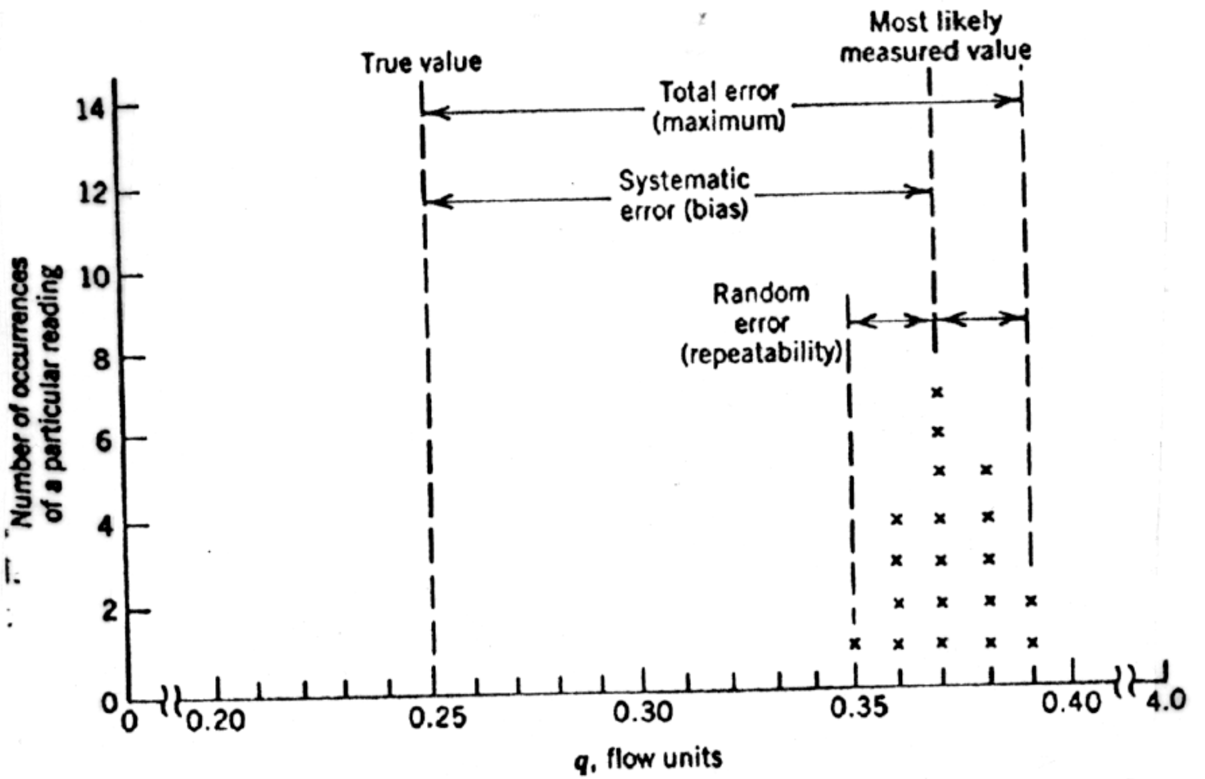


Figure 9.14. Analysis of types of error for a flow instrument whose range is 0 to 4 flow units.

Transmitter

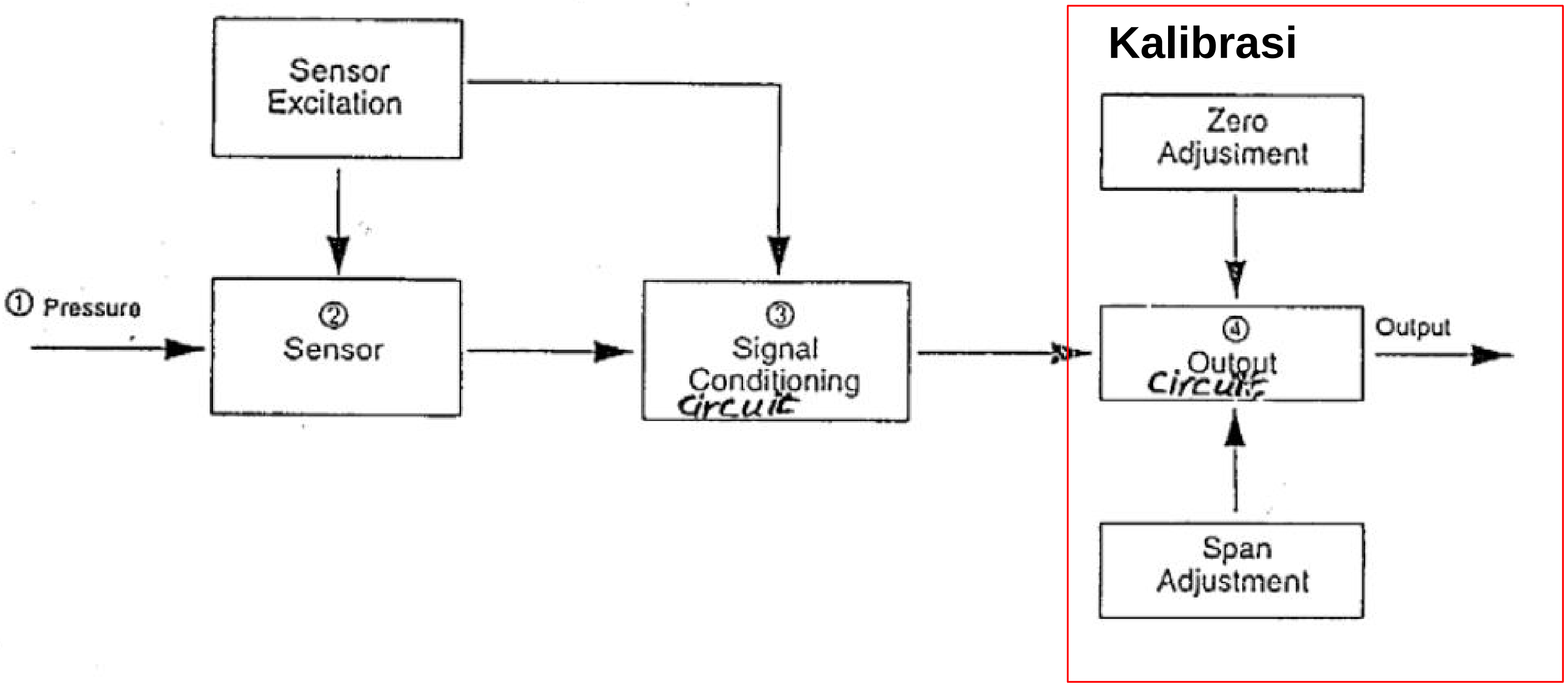
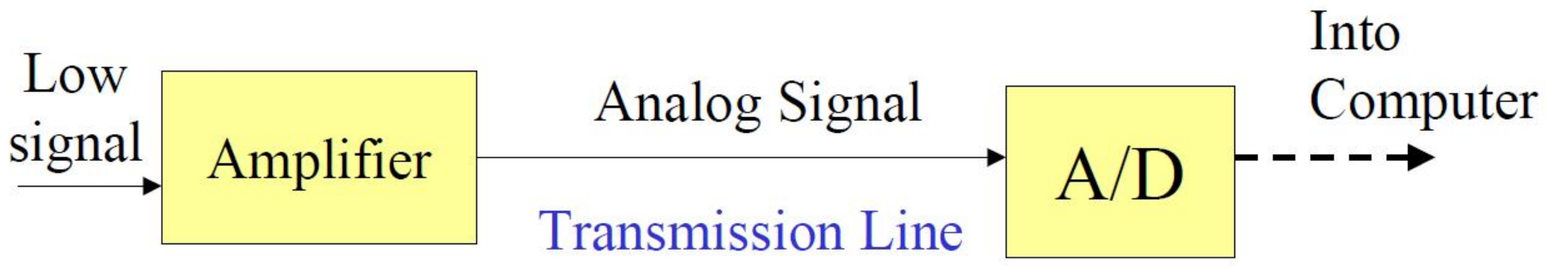


Figure 23, Electronic Pressure Transmitter

Transmitter

- Amplifikasi, transmit kemudian didigitalisasi



- Transmit, kemudian didigitalisasi

Transmitter

Pengukuran Tekanan

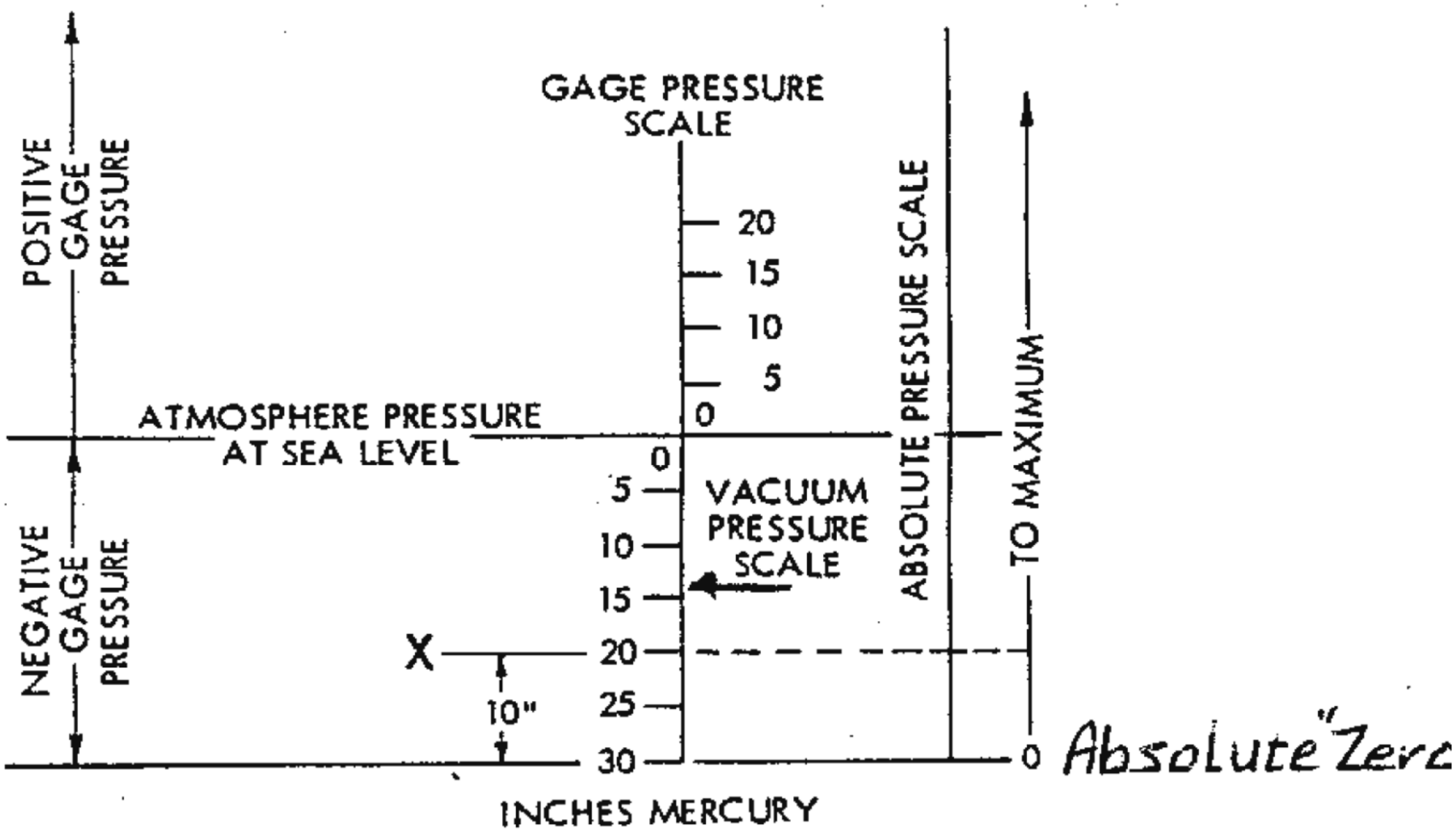
- Tujuan utama pengukuran tekanan di Industri:
  - Pemantauan dan pengontrolan tekanan proses agar proses berjalan sesuai rancangan
  - Pengamanan tekanan proses agar tidak melebihi batas ‘aman’

Pengukuran Tekanan

- Titik Referensi Tekanan :
  - Tekanan 0 absolut
  - Tekanan 1 atmosfer (Gauge)

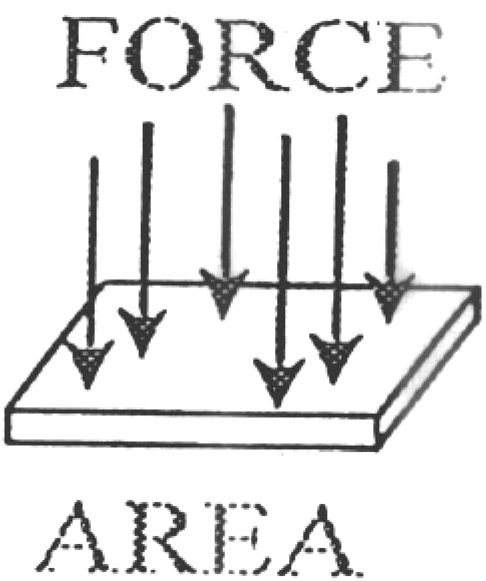
- Tekanan 0 absolut
  = perfect vacum
- Tekanan absolut
  = Tekanan diatas 0 absolut
- Gauge pressure
  = Tekanan absolut – tekanan atmosfer
- Vacum gauge pressure (tekanan minus)
  = tekanan atmosfer – tekanan fluida yg terukur

Pengukuran Tekanan



✱ The pressure at point X can be expressed as 10 inches of mercury absolute, or as 20 inches of mercury vacuum, or as —20 inches of mercury gage.

Pengukuran Tekanan



- Imperial Unit (british & american unit)
  - Satuan gaya : pound force (lbf)
  - Satuan luas : inch square (in^2)
  - Satuan tekanan :
    - pounds per square inch (lbf/in^2) atau PSI
    - Inch water column (in Wc)
- S.I. (System International)
  - Satuan tekanan :
    - Newton per meter persegi (N/m^2) atau Pascal (Pa)
    - Karena besaran ini terlalu kecil, maka yg sering digunakan di industri adalah bar. (1 bar = 100.000 Pa)
    - Millimeter water column (mm Wc)

Pengukuran Tekanan

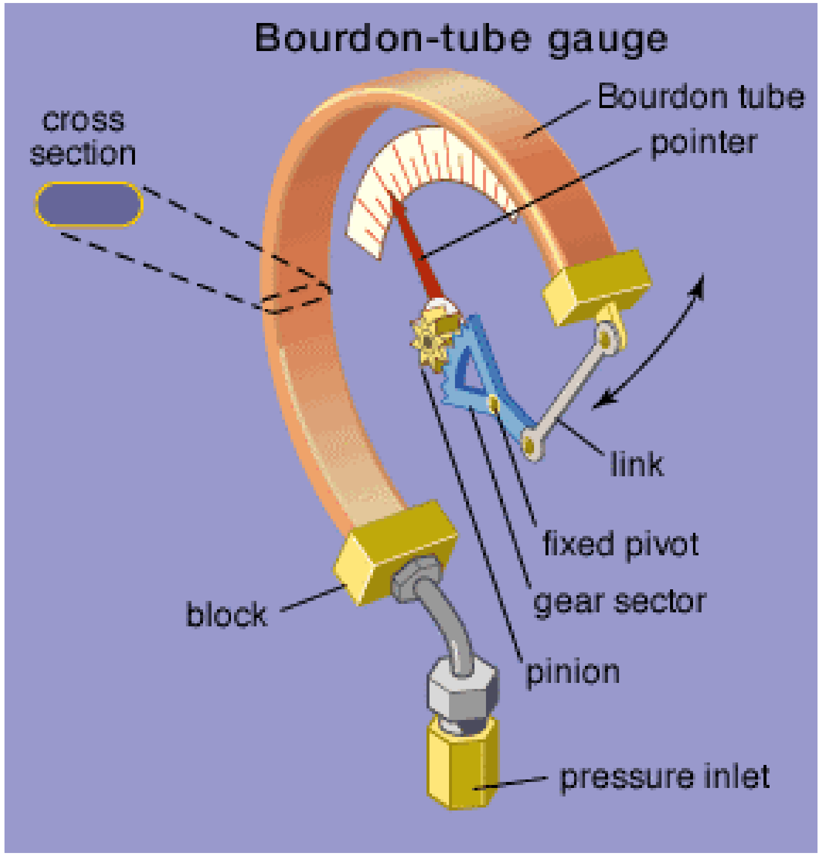
Elemen Pengukur Tekanan

- Burdon Tube
- Bellows Sensor
- Diaphragm Sensor
- Resonant Wire Sensor
- Strain Gauge Sensor
- Capacitance Pressure Sensor

Pengukuran Tekanan

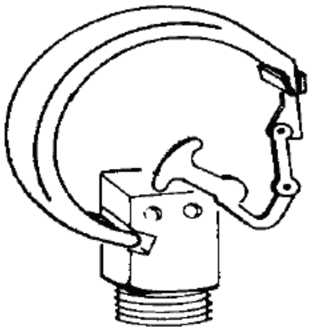
Bourdon Tube

- Merupakan tabung/selang logam yang diratakan (digepengkan)
- Bentuknya : C , spiral, dan helix
- Salah satu ujung terbuka, dan ujung lainnya tertutup
- Ketika tekanan fluida pada ujung terbuka bertambah, bentuk tabung ‘gepeng’ tadi akan menjadi bulat kembali. Hal ini akan membuat ujung yg tertutup bergerak

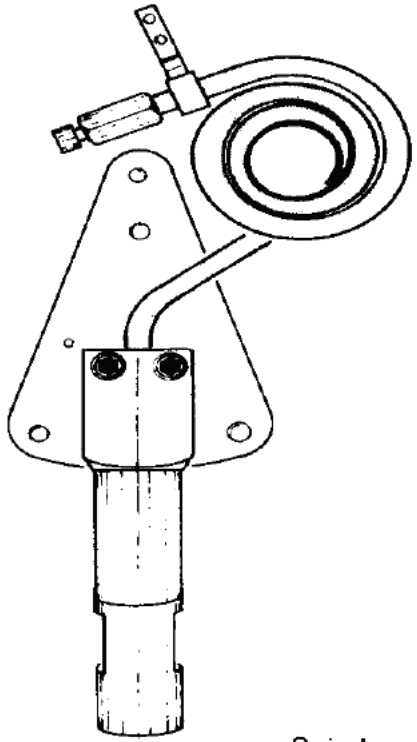


Pengukuran Tekanan

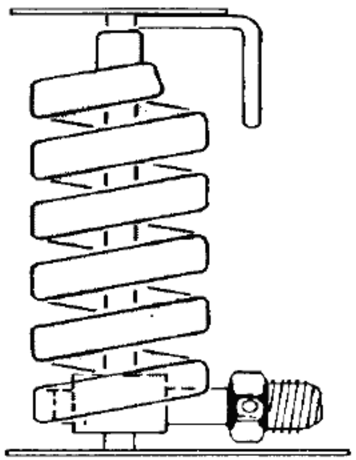
Bourdon Tube



C-Type



Spiral



Helical

COMMON TYPES OF BOURDON SPRINGS:

(a.) 'C' Type
(b.) Spiral
(c.) Helical

Pengukuran Tekanan

- C-type Burdon
  - Digunakan pada range pengukuran
    - 0-15 psig (0-100 kPa), hingga 0-1500 psig (0-10.000 kPa)
  - Sederhana, akurat dan memiliki tingkat presisi yg tinggi
  - Umumnya berukuran besar dan rentan terhadap overpressure (dibandingkan jenis burdon lainnya)
- Helical Burdon
  - Digunakan pada range pengukuran
    - 0-200 psig (0-1.300 kPa), hingga 0-6000 psig (0-40.000 kPa)
  - Heavy duty helical burdon tahan overpressure hingga 10 kali tekanan maksimum pada range pengukurannya
- Spiral Burdon
  - Sensitivitas sangat tinggi
  - Digunakan pada range pengukuran yg sangat rendah dan sangat tinggi
    - 0-10 psig (0-65 kPa), hingga 0-100.000 psig (0-700.000 kPa)

Pengukuran Tekanan

Bellows

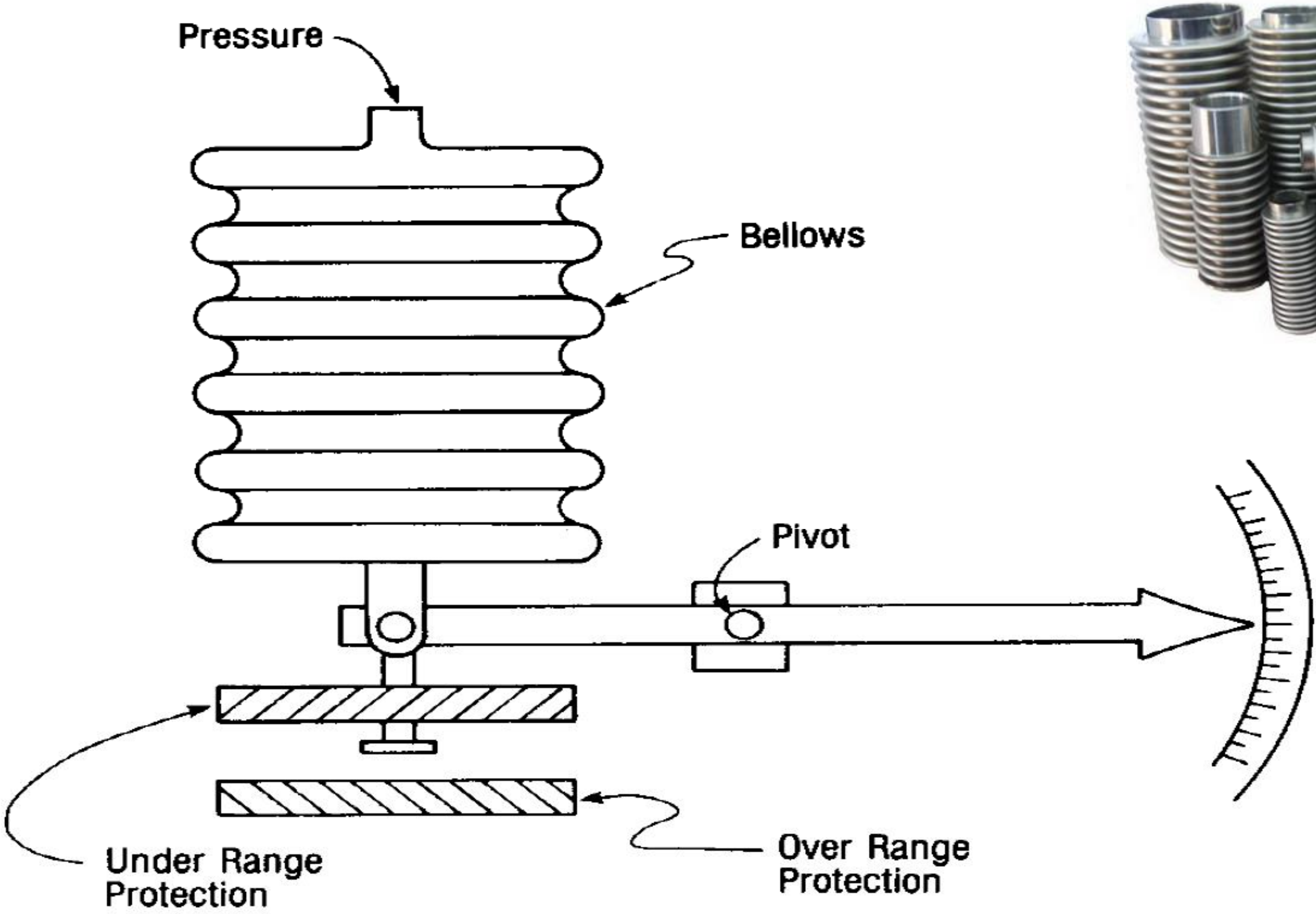
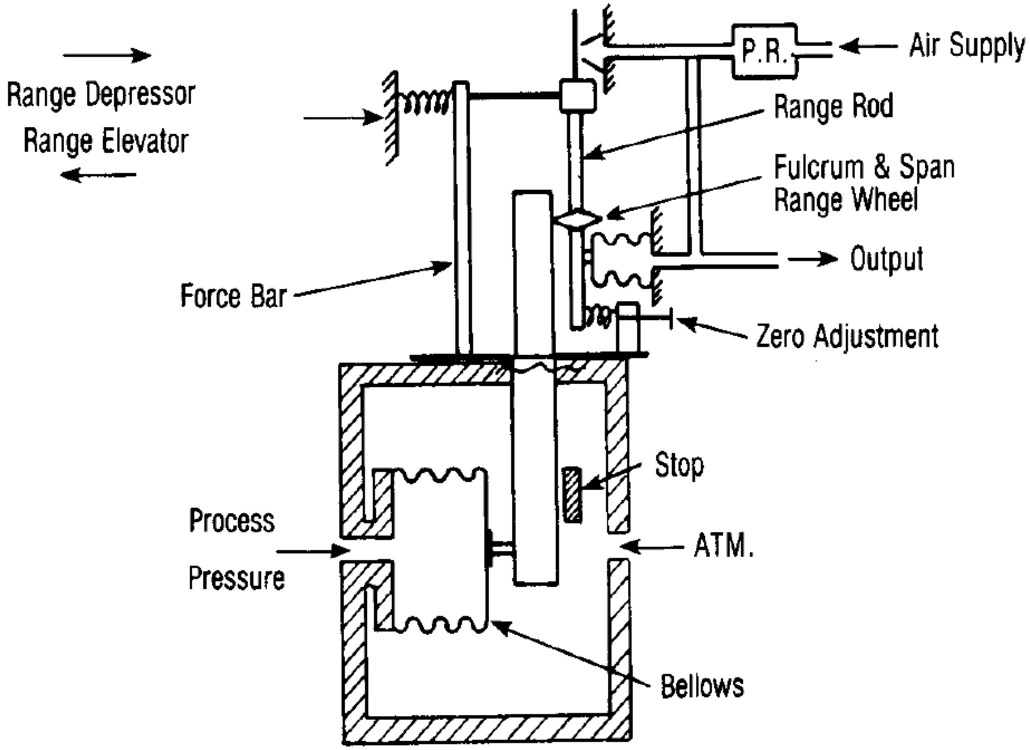


Figure 3, Bellows Gauge with under/over range protection

Pengukuran Tekanan

- Bellows sensor dapat mengukur dengan akurat pada nilai tekanan yg sangat kecil
  - Tekanan absolut 0-100 mm Hg
  - Tekanan gauge 0-5 inch H_2O (0-125 mm H_2O)



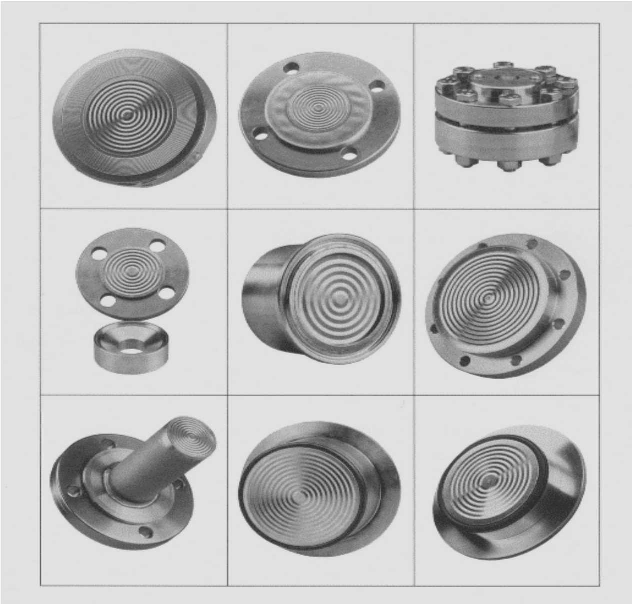
Pengukuran Tekanan

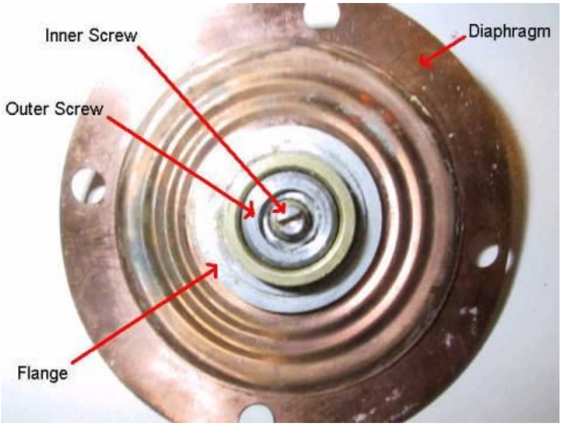
Diaphragm

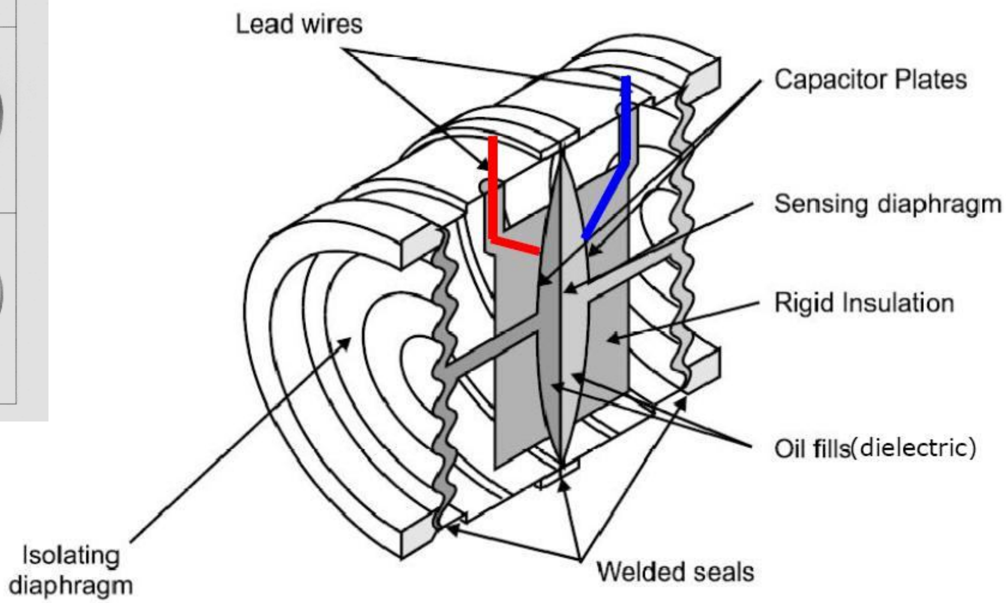
- Diafragma → disk (pelat bundar) tipis, datar, fleksible (pada arah sumbunya) dan bergelombang
- Defleksi diafragma proporsional dengan tekanan
- Sensitivitas diafragma meningkat seiring bertambahnya diameter
- Gerakan axial dari diafragma dihubungkan dengan sistem mekanis untuk mengukur tekanan

Pengukuran Tekanan

Diaphragm







Pengukuran Tekanan

- Diafragma merupakan element yang paling banyak dipakai sebagai pressure transmitter maupun DP Cell
- Ada 2 jenis diafragma :
  - Capsular diaphragm
    - Terdiri dari dua diafragma yang disatukan
    - Digunakan untuk referensi tekanan absolut
  - Single diaphargm
    - Tediri dari satu diafragma
    - Digunakan untuk pengukuran yg sangat sensitive

Pengukuran Tekanan

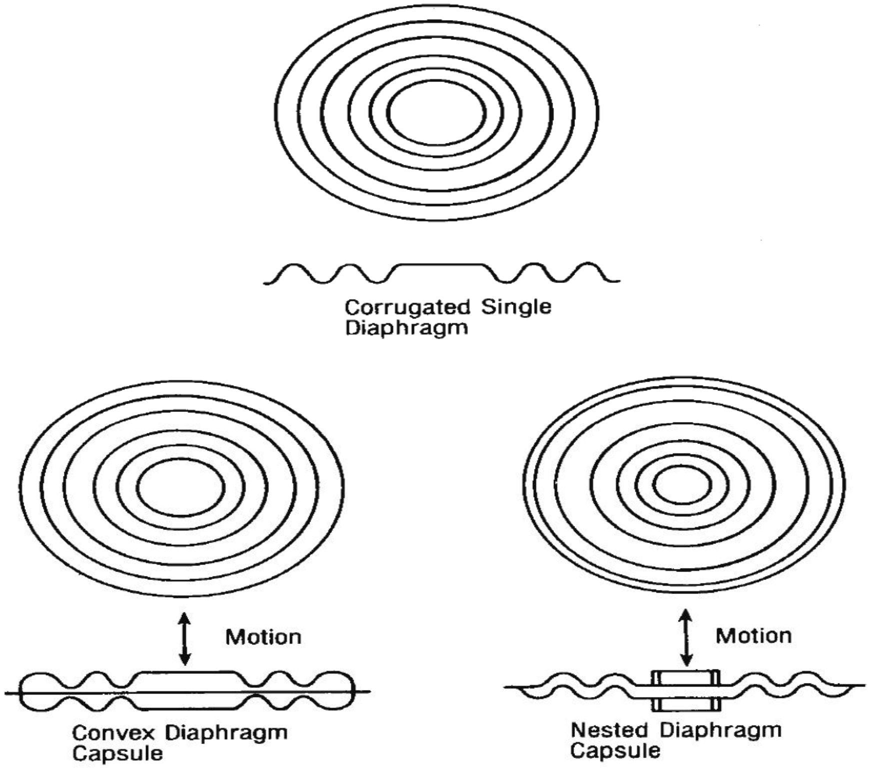


Figure 8, Typical Diaphragm Elements

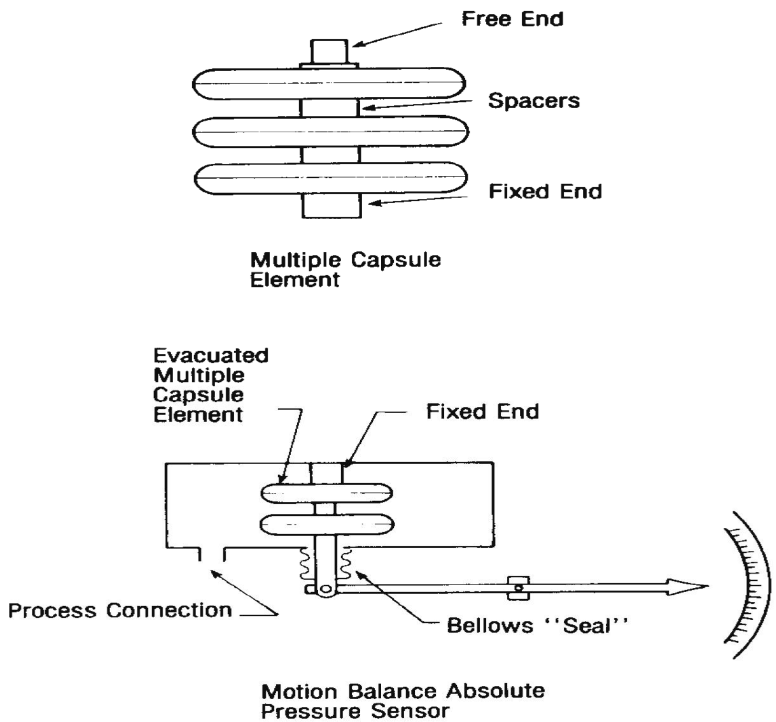


Figure 9, Examples of Capsule-Type Pressure Sensors

Pengukuran Tekanan

Strain Gage Sensor

- Saat ini merupakan elemen yg paling banyak digunakan untuk electronic pressure transmitter
- Prinsip kerja : perubahan strain → perubahan resistansi listrik → perubahan sinyal standar (4-20 mA)
- Desain strain gauge pressure sensor yg paling umum :
  - menggunakan **diafragma** untuk mensensing tekanan proses, kemudian meneruskan defleksi diafragma tsb ke sistem strain gauge
  - Diafragma → force bar → rangkaian strain gauge
- Strain gauge yg banyak dipakai saat ini adalah jenis semikonduktor.
- Ukurannya kecil, response pengukurannya tinggi (konstanta waktu rendah)
- Strain gauge accuracy : 0,2 – 0,5 % dari Span

Pengukuran Tekanan

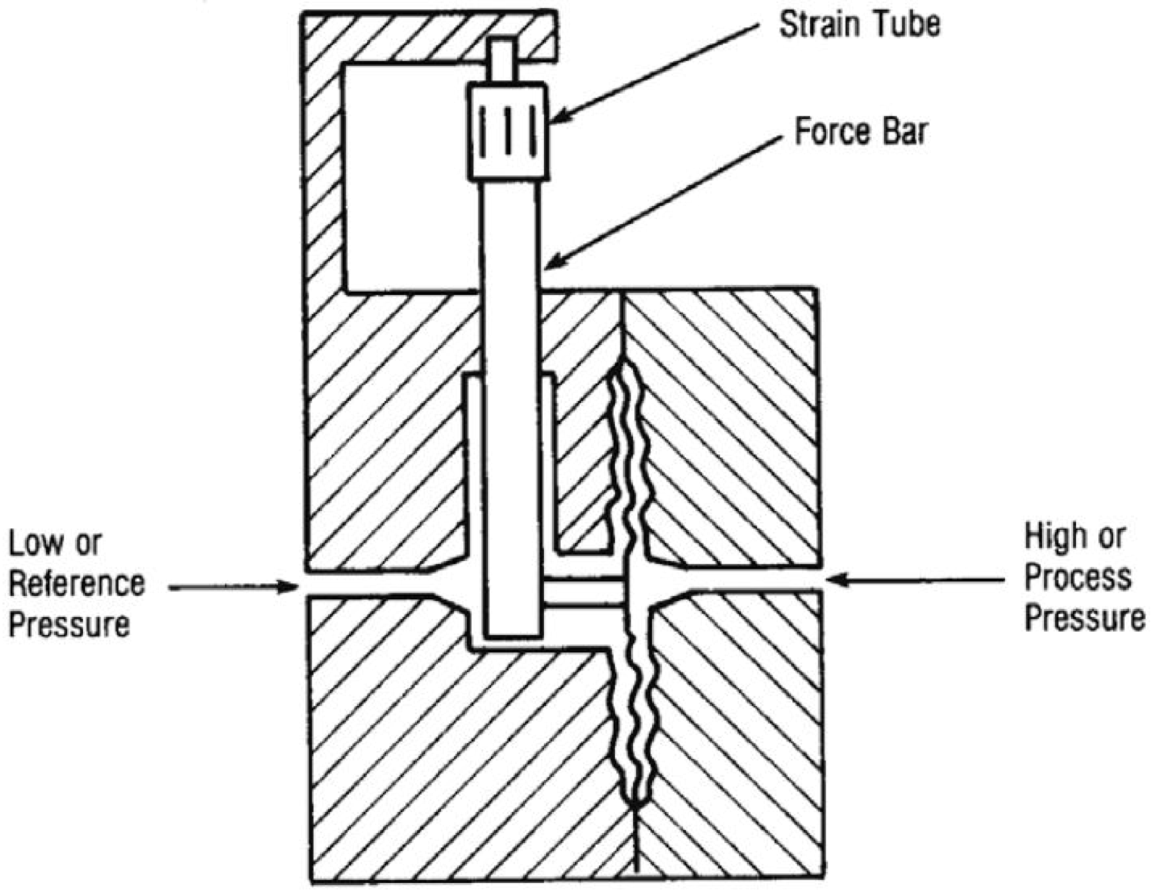


Figure 12, Force Balance D/P Cell with Strain Gauge Elements

Pengukuran Tekanan

Capacitance Pressure Sensor

- Digunakan pada electronic pressure transmitter
- Prinsip kerja :
  - perubahan tekanan → defleksi elemen elastis → perubahan kapasitansi → perubahan sinyal standar
- Elemen elastis yg biasanya digunakan adalah stainless steel diaphragm

Pengukuran Tekanan

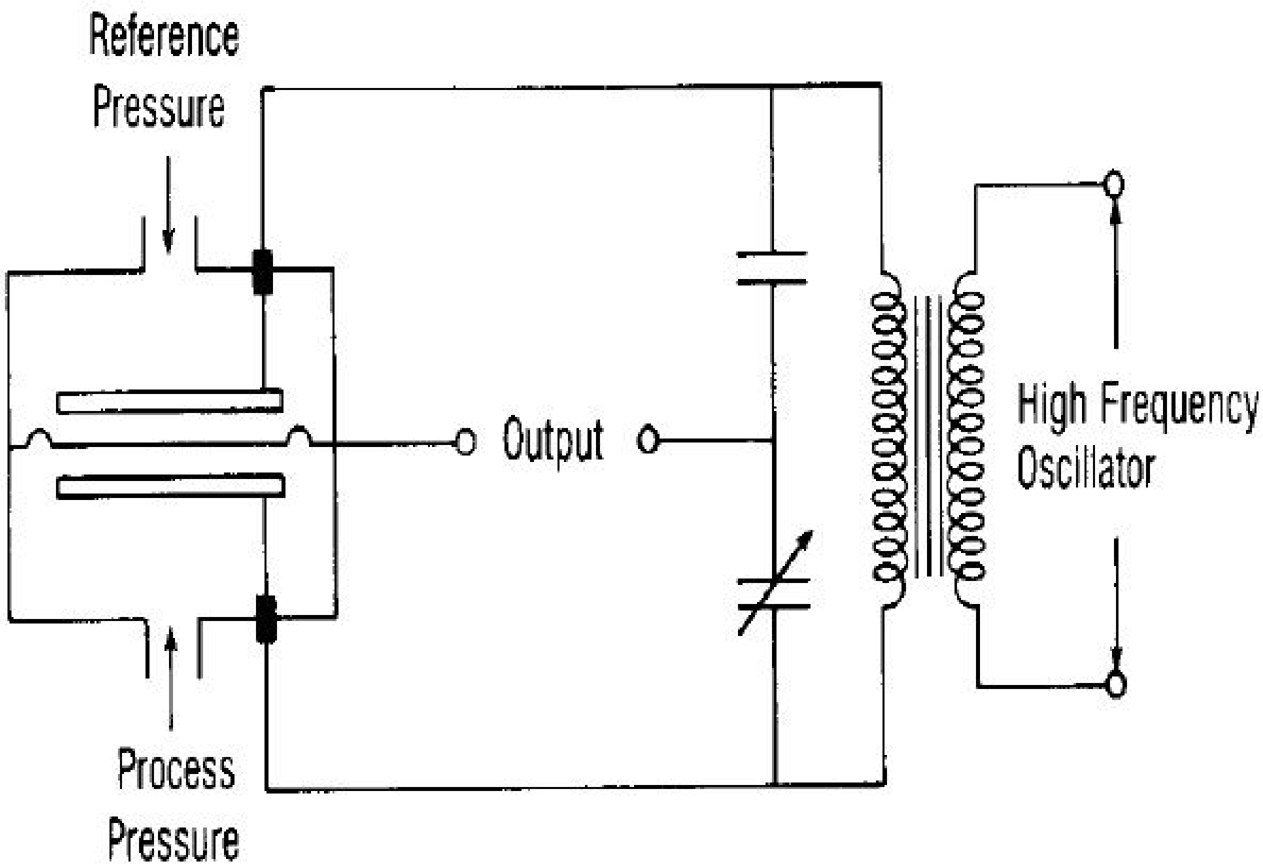
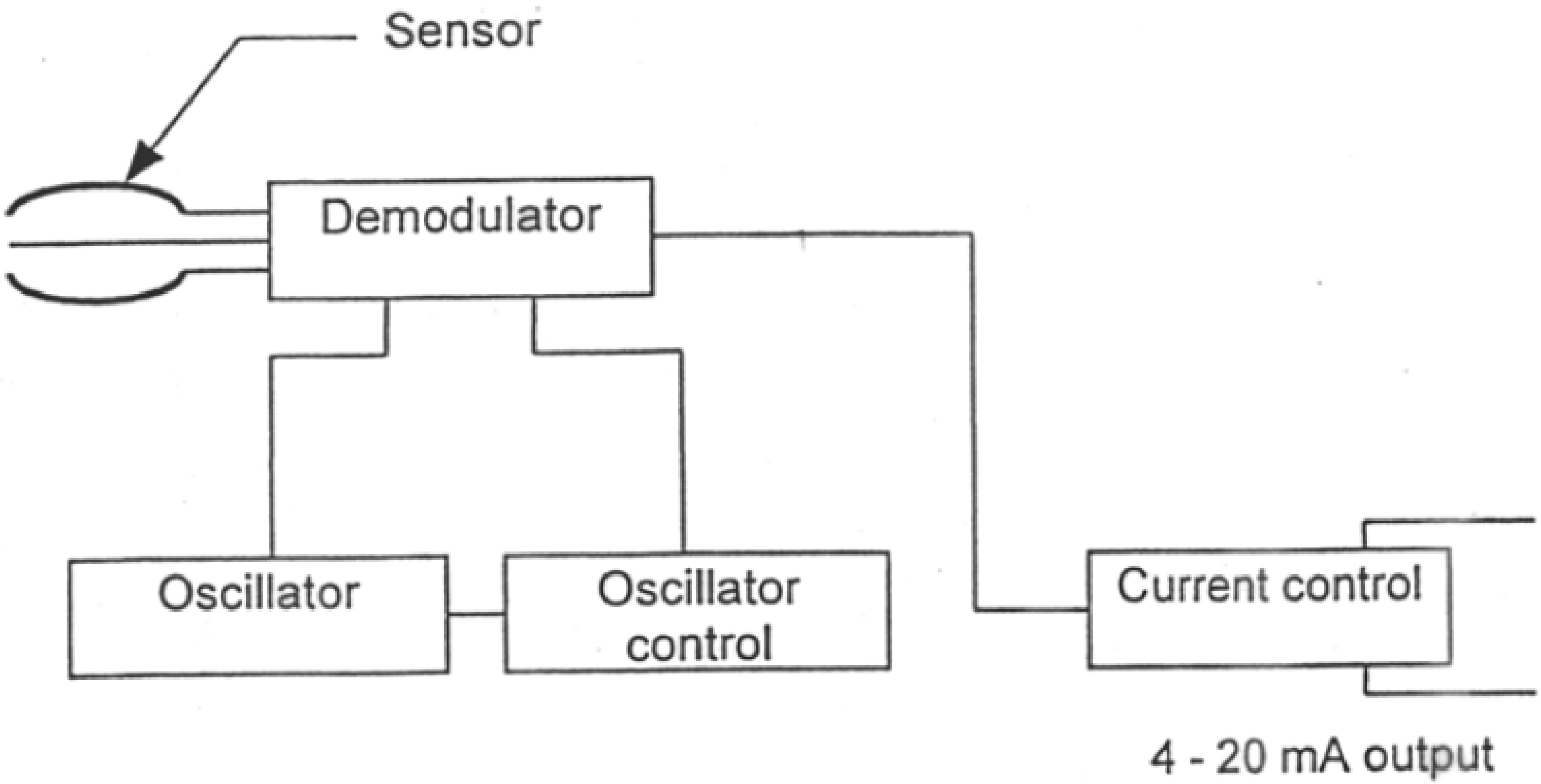


Figure 14, Capacitance Pressure Sensor

Pengukuran Tekanan



II. SISTEM PENGUKURAN - FLOW

METODE

- BEDA TEKANAN / DIFFERENTIAL PRESSURE (*)
- ELECTROMAGNETIC
- TURBINE METER (*)
- VORTEX METER
- VARIABLE AREA METER
- POSITIVE DISPLACEMENT METER
- ULTRASONIC METER
- CROSS-CORRELATION
- SONIC VENTURI

TABLE PEMILIHAN FLOW METER VS KONDISI PROSES

FLUID DUTY SELECTION TABLE

	Section	2.4	2.5	2.8	2.9	2.10	2.11	2.12	2.13	2.14	2.15	2.17	2.18	2.19	2.20	2.20	2.21	2.21	2.22	2.23	2.24	2.24	2.24
	Fluid Details \\ *Meter Type*	*Correlation*	*Elbow Taps*	*Laminar*	*Electro-Magnetic*	*Angular Momentum*	*Metering Pumps*	*Orifice*	*Pitot*	*Gas Displacement*	*Liquid Displacement*	*Solids flowmeter*	*Target*	*Thermal*	*Liquid Turbine*	*Gas Turbine*	*Doppler U-Sonic*	*Transit U-Sonic*	*V.A.*	*Venturi*	*Vortex Shedding*	*Vortex Precision*	*Fluidic Oscillation*
Liquid	Clean	X	√	√	*√	√	√	√	√	X	√	X	√	√	√	X	X	√	√	√	√	X	√
Liquid	Dirty	√	?	√	*√	√	√	?	?	X	X	?	√	√	?	X	√	?	√	√	?	X	?
Liquid	Slurries	√	X	?	*√	?	√	X	X	X	X	SD	?	?	X	X	?	X	X	?	X	X	X
Liquid	Low Viscosity	√	√	√	*√	√	√	√	√	X	?	X	√	√	√	X	√	√	√	√	√	X	√
Liquid	High Viscosity	√	?	?	*√	?	√	?	X	X	√	SD	?	?	X	X	?	?	?	?	X	X	X
Liquid	Corrosive	√	√	?	*√	√	?	√	√	X	?	X	?	?	?	X	√	√	√	?	?	X	?
Liquid	Very Corrosive	√	?	X	*√	X	X	?	?	X	X	X	X	?	X	X	√	√	√	X	X	X	X
Gas	Low Pressure	X	√	√	X	√	X	√	√	√	X	X	√	√	X	√	X	X	√	√	√	√	X
Gas	High Pressure	X	√	√	X	√	X	√	√	√	X	X	√	√	X	√	X	X	X	√	√	√	X
	Steam	X	X	?	X	X	X	√	X	X	X	X	√		X	SD	X	X	√	√	SD	X	X
	Reverse Flow	X	√	X	√	X	X	SD	X	X	X	X	X		SD	SD	√	√	X	X	X	X	X
	Pulsating Flow	?	X	√	√	X	X	?	X	X	X	X	X		X	X	√	√	?	?	X	X	X

* = Must Be Electrically Conductive
√ = Generally Suitable
? = Worth Consideration
X = Not Suitable
SD = Some Designs

BEDA TEKANAN / DIFFERENTIAL PRESSURE

TYPES OF METERS

- **ORIFICE PLATE**
- **VENTURI**
- **PITOT TUBE**
- **ELBOW TAPS**

KONSEP

BEDA TEKANAN YANG DISEBABKAN ADANYA HAMBATAN PADA ALIRAN FLUIDA

TEORI : HUKUM BERNOULLI

BEDA TEKANAN / DIFFERENTIAL PRESSURE

FLOW / ALIRAN AKAN BERBANDING DENGAN AKAR PANGKAT DUA DARI BEDA TEKANAN

Q = K * [H] **2

Q = FLOW / ALIRAN AKAN BERBANDING DENGAN AKAR PANGKAT DUA DARI BEDA TEKANAN

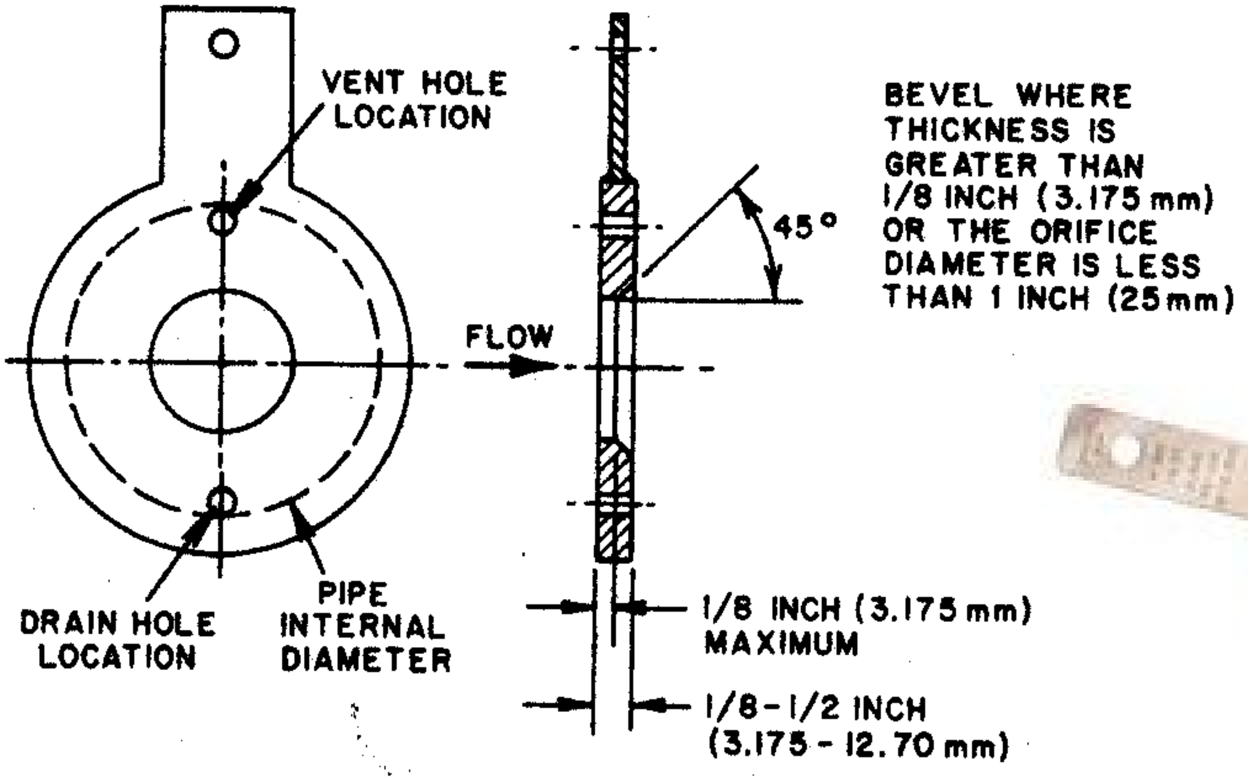
BEDA TEKANAN / DIFFERENTIAL PRESSURE

NILAI "K" DIPENGARUHI OLEH

- **PERBANDINGAN DIAMETER PIPA DAN LUBANG / BORE DARI METER**
- **JENIS PIPA, MATERIAL PIPA DAN MATERIAL METER**
- **PROSES KONDISI SAAT MENENTUKAN BORE (PRESSURE, TEMPERATURE, DENSITY DAN VISCOSITY)**

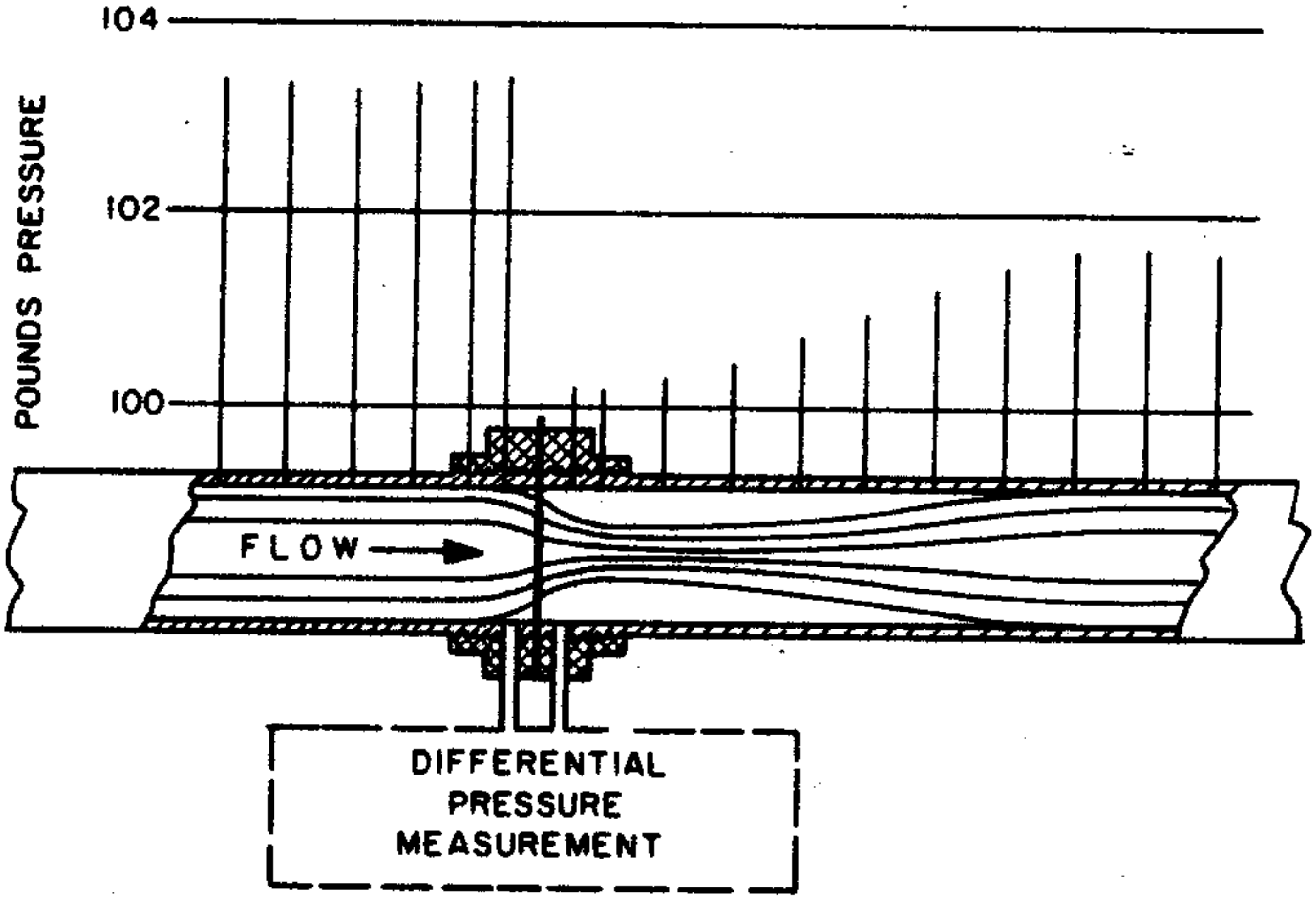
JIKA PROSES KONDISI AKTUAL BERFLUKTUASI TERHADAP PROSES KONDISI DESIGN, DIGUNAKAN "KOMPENSASI" DENGAN PRESSURE DAN TEMPERATURE

ORIFICE

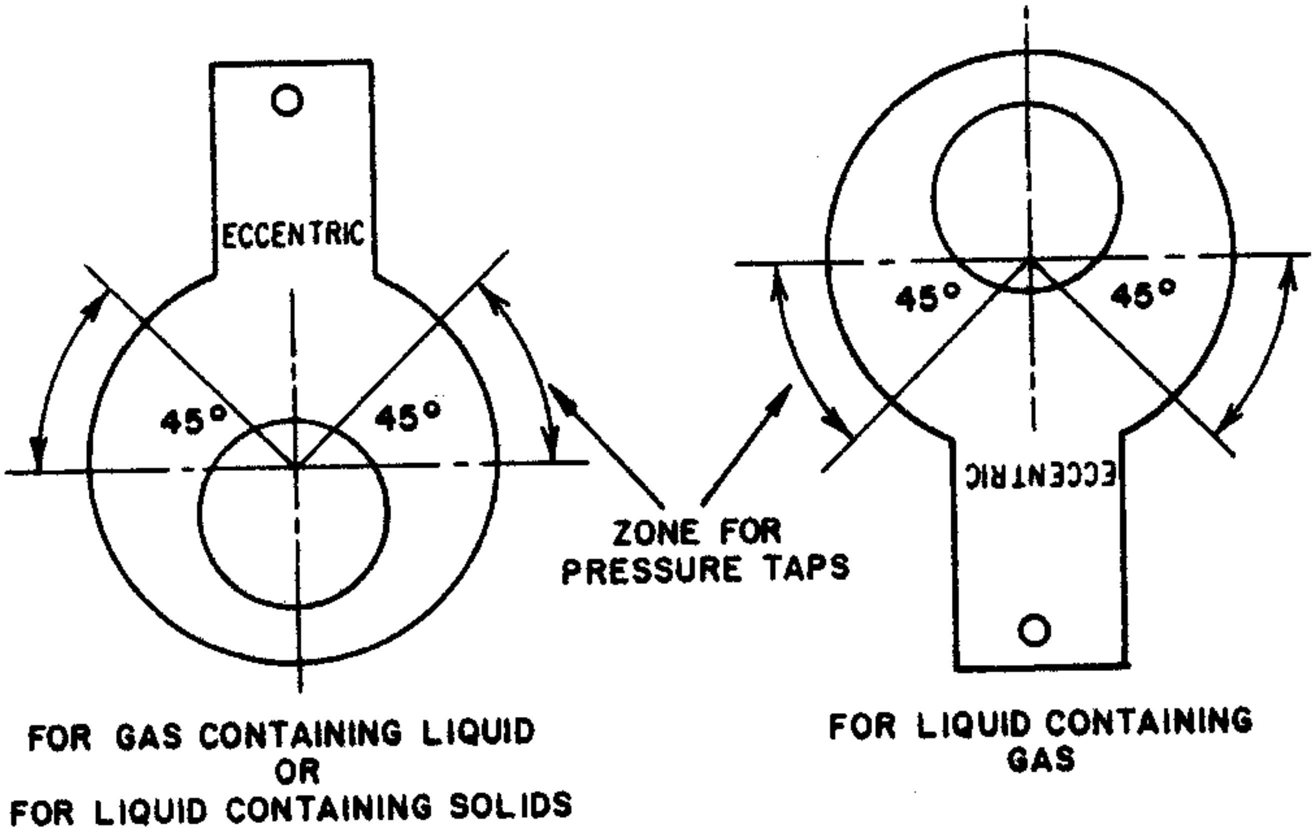


METER YANG BANYAK DIPAKAI, SEDERHANA , DAN RELATIF MURAH.

ORIFICE

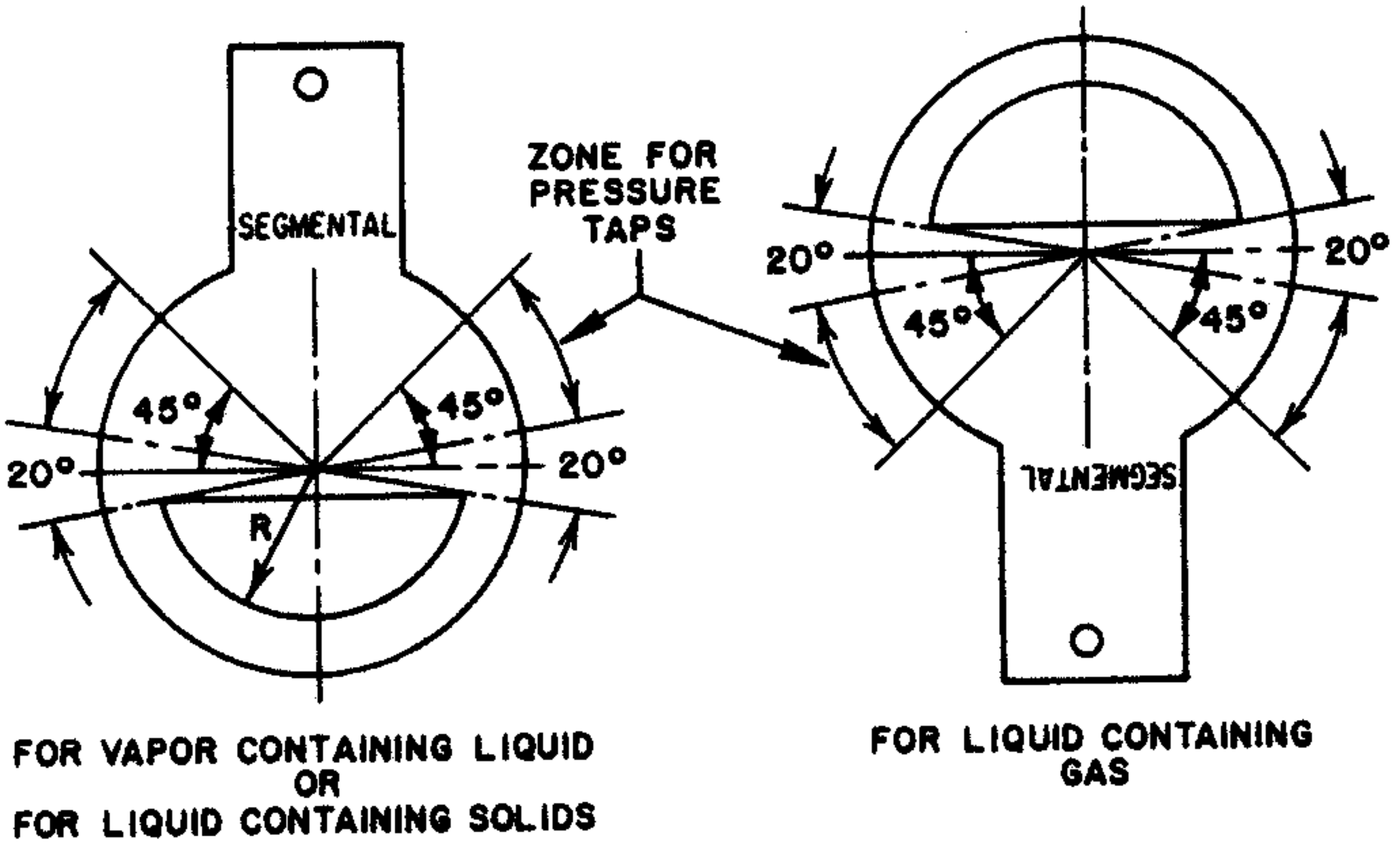

104
102
100
POUNDS PRESSURE
FLOW
DIFFERENTIAL
PRESSURE
MEASUREMENT

JENIS ORIFICE



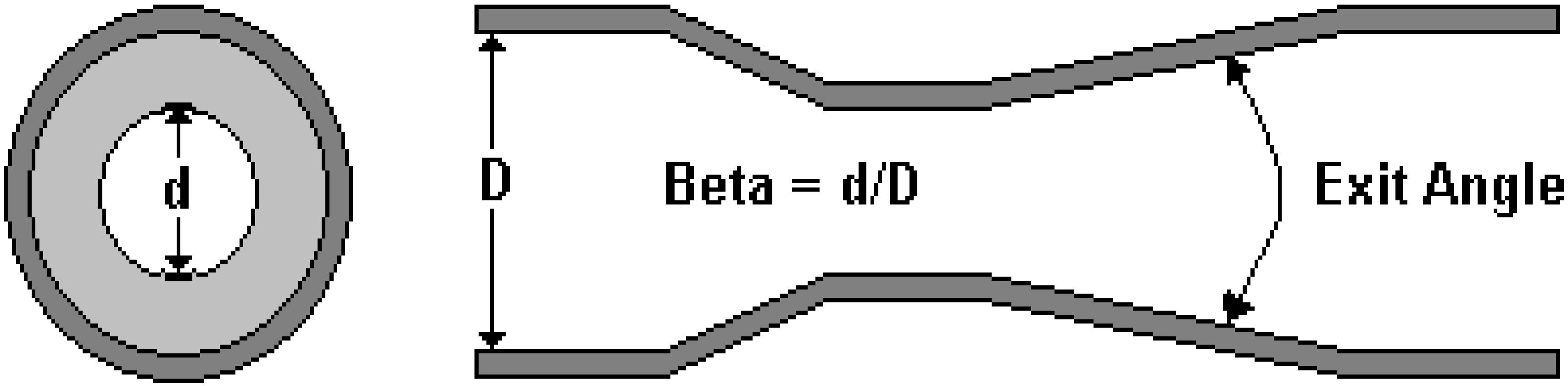
ECCENTRIC ORIFICE PLATE

JENIS ORIFICE



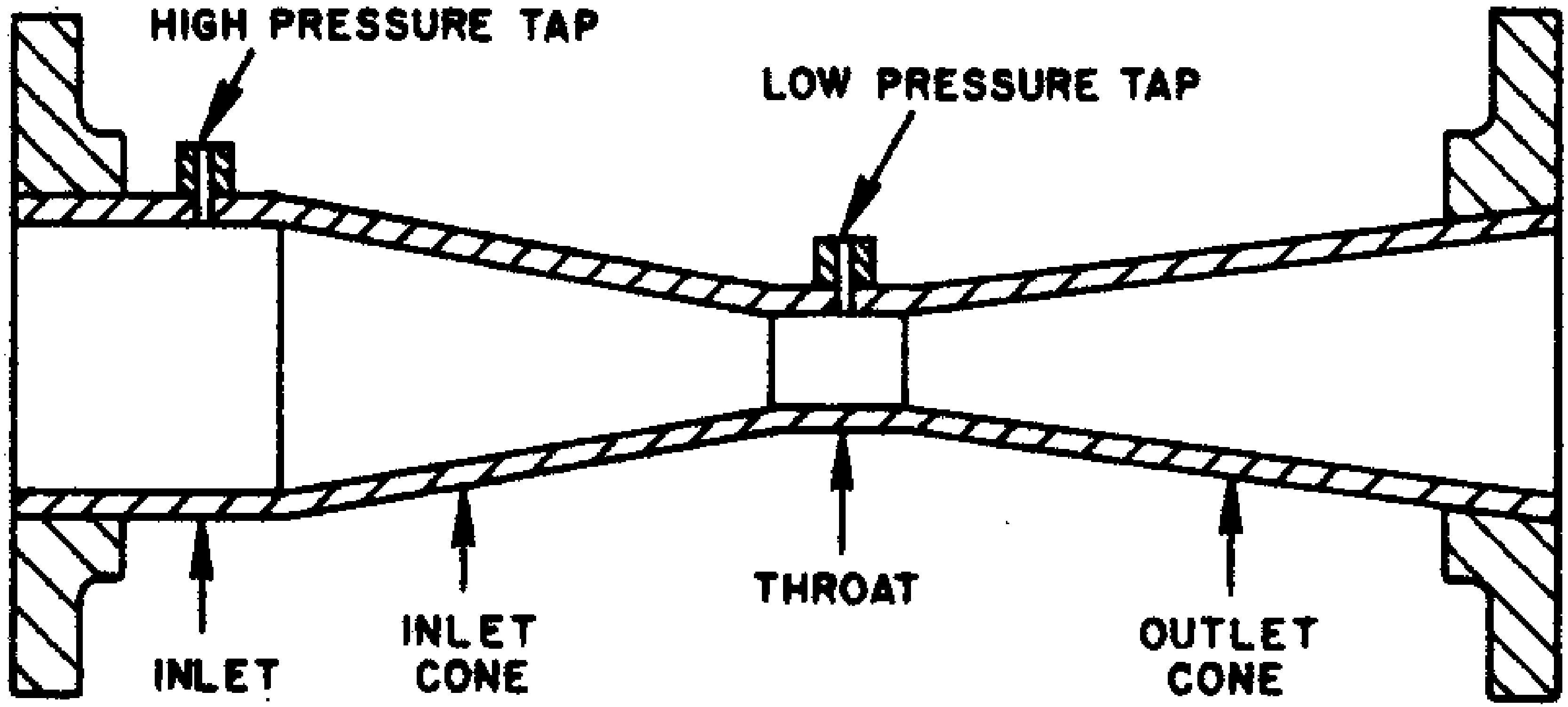
SEGMENTAL ORIFICE PLATE

VENTURI

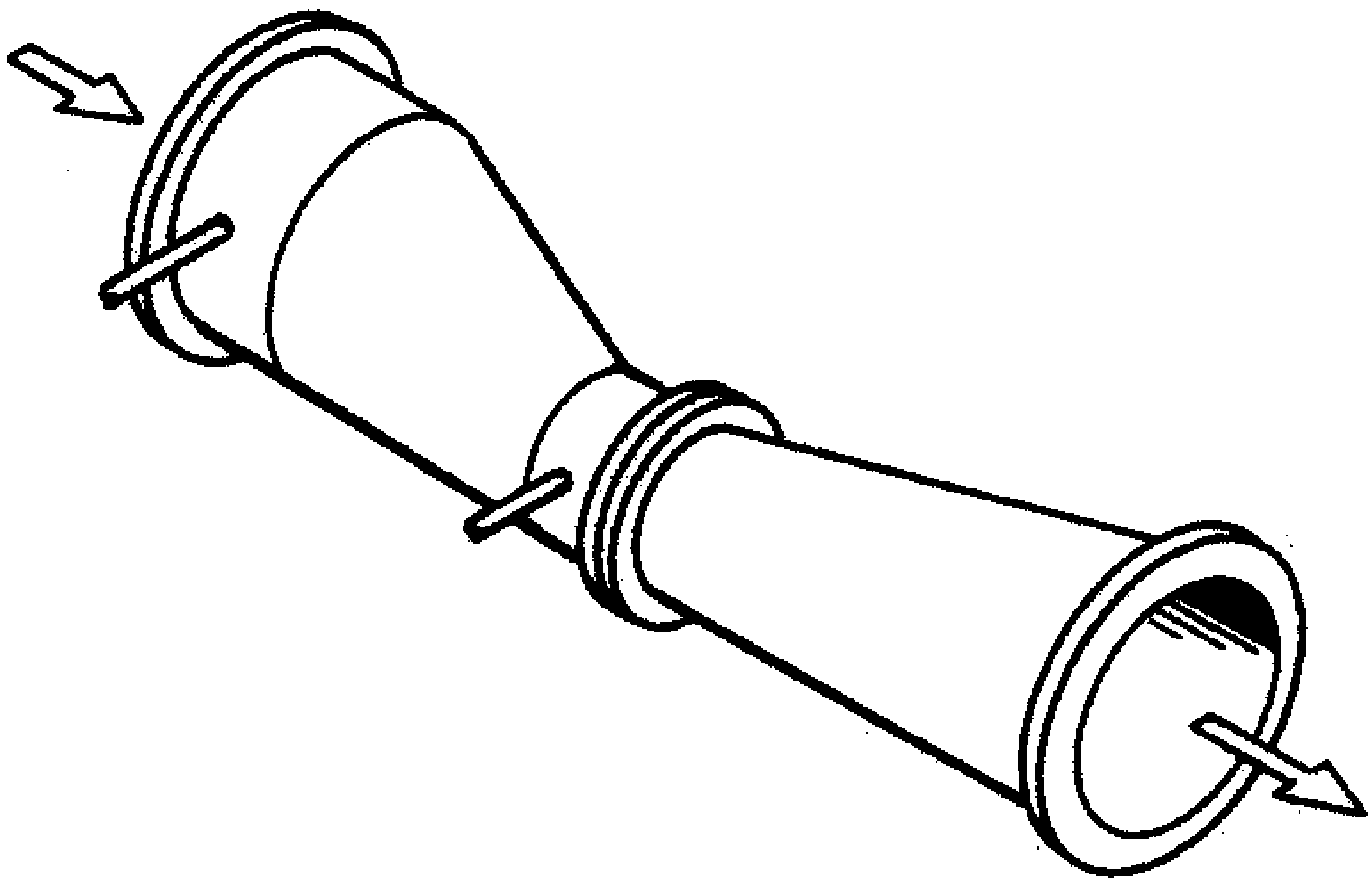


- DIPAKAI UNTUK MENGURANGI KEHILANGAN TEKANAN
- UMUM NYA DIGUNAKAN DI COMPRESSOR
- DIGUNAKAN PADA PROSES YANG BERTEKANAN RENDAH

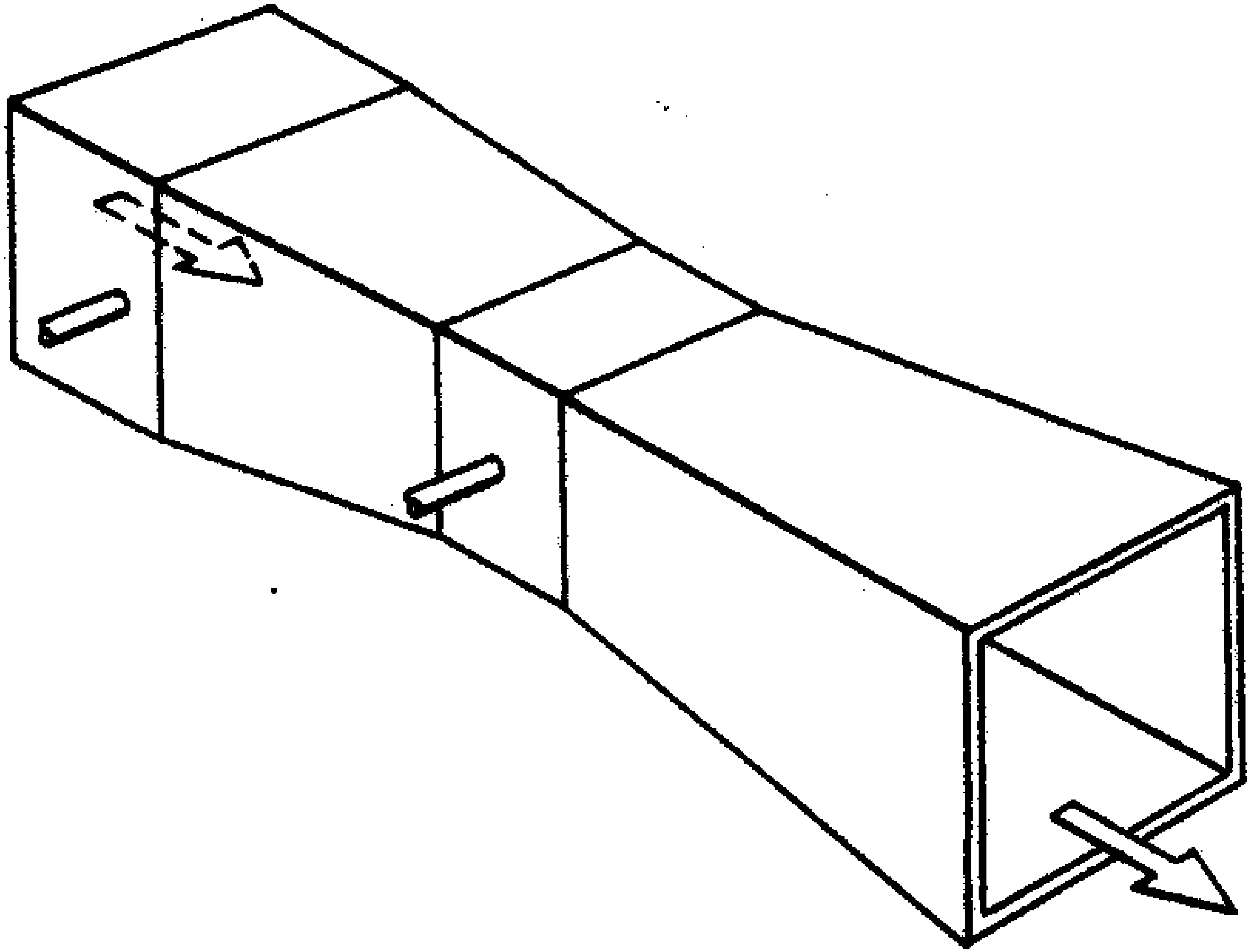
VENTURI


HIGH PRESSURE TAP
LOW PRESSURE TAP
THROAT
INLET
INLET CONE
OUTLET CONE

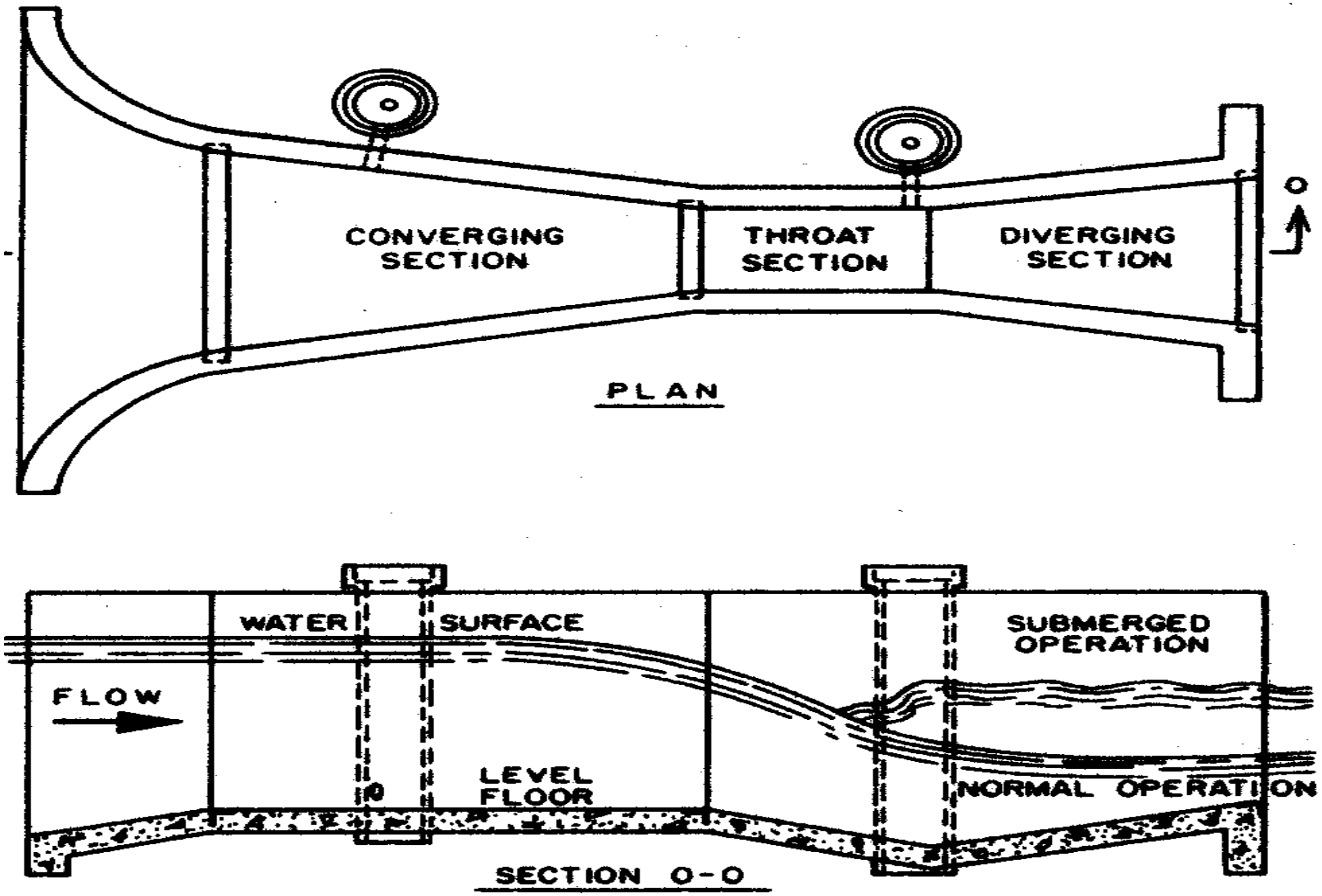
VENTURI



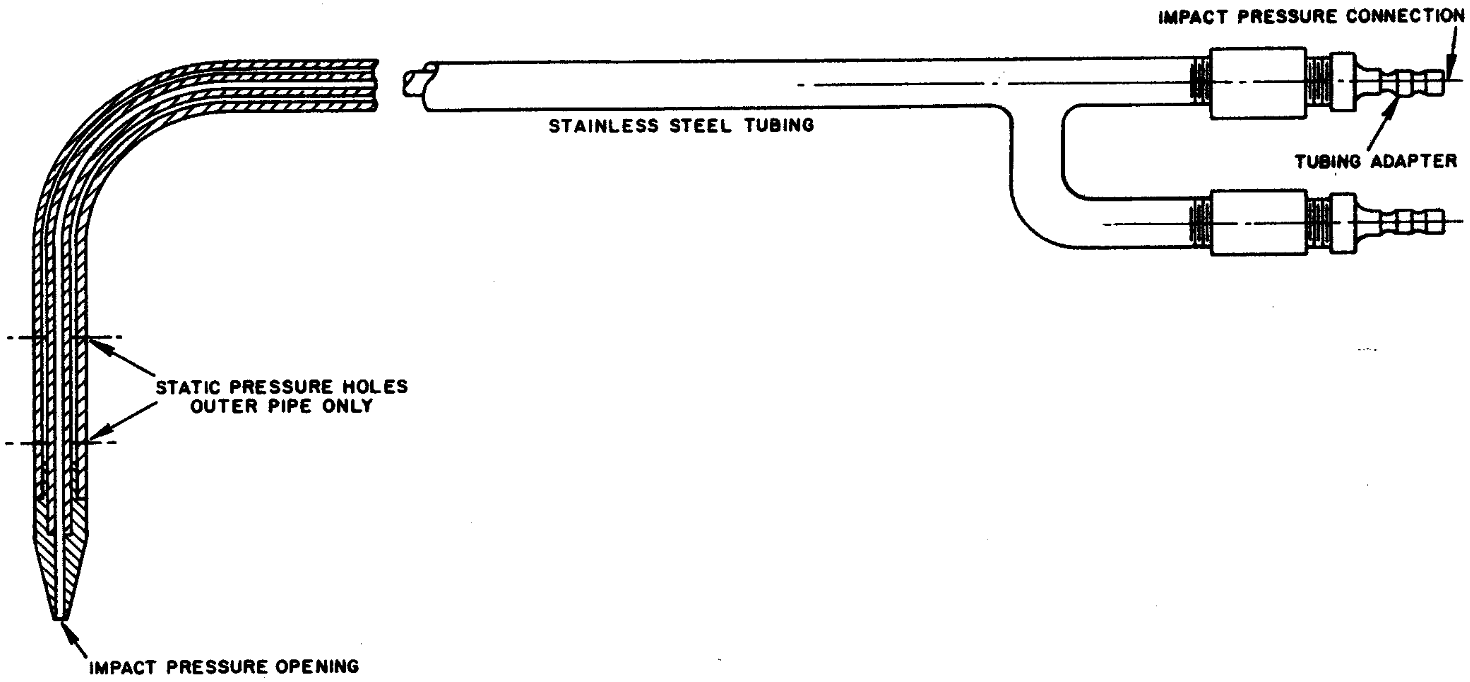
VENTURI



OPEN CHANNEL METER

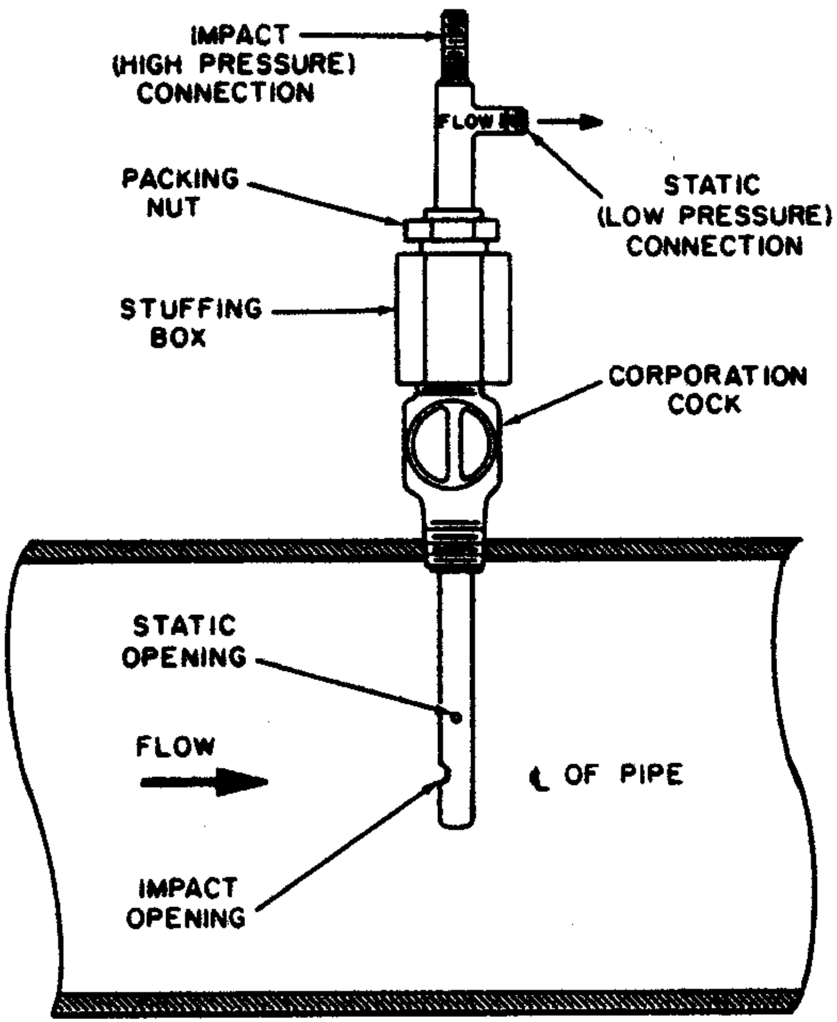


PITOT TUBE



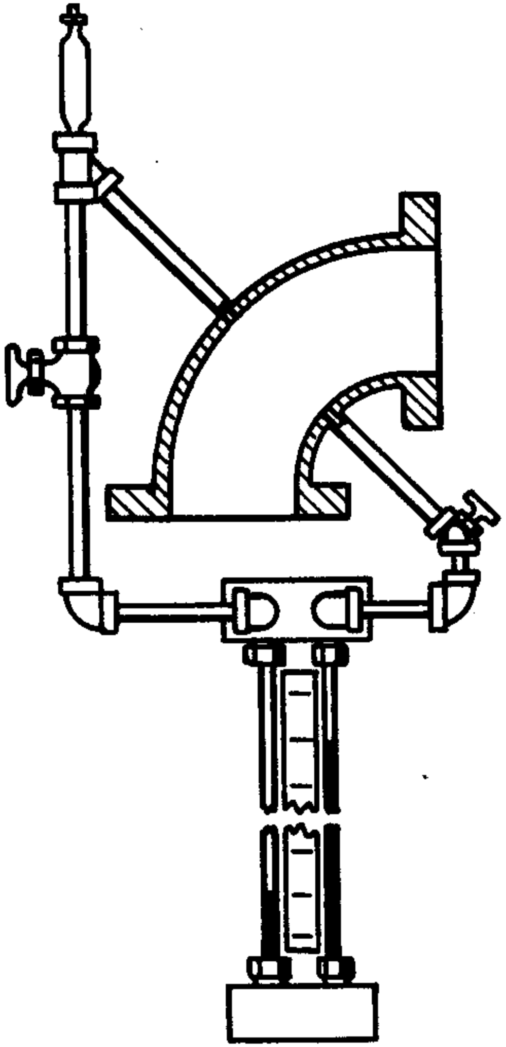
- DIGUNAKAN PADA PROSES YANG BERTEKANAN RENDAH
- UNTUK CLEAN SERVICE
- LOKASI YANG TERBATAS

PITOT TUBE



IMPACT
(HIGH PRESSURE)
CONNECTION
FLOW
PACKING
NUT
STATIC
(LOW PRESSURE)
CONNECTION
STUFFING
BOX
CORPORATION
COCK
STATIC
OPENING
FLOW
℄ OF PIPE
IMPACT
OPENING

ELBOW TYPE



- LOKASI YANG TERBATAS

Pengukuran Flow

- Pengukuran aliran dalam industri proses digunakan dalam transaksi jual beli, pengontrolan proses, dll.
- Banyak jenis instrumen pengukuran aliran. Akurasinya bervariasi, dan penggunaannya tergantung pada kondisi penerapannya
- Tidak ada satu flow meter pun yg dapat meng-cover semua jenis pengukuran aliran

Pengukuran Flow

- Pada pengukuran aliran, physical properties dari fluida yg diukur sangat penting (menentukan akurasi pengukuran)
- Faktor utama yang mempengaruhi aliran fluida dalam pipa adalah :
  - Ukuran pipa
    - Semakin besar ukuran pipa, semakin besar flowrate.
  - Friksi dengan dinding pipa (tingkat kekasaran dinding pipa)
    - Gesekan antara fluida dengan pipa memperlambat laju aliran fluida.
  - Viskositas fluida
    - Viskositas fluida menggambarkan resistansi fisik dari fluida untuk mengalir. Semakin tinggi viskositas fluida, laju alirannya semakin lambat
  - Specific gravity dari fluida
    - Specific gravity liquid = densitas liquid/densitas air.
    - Specific gravity gas = densitas gas/densitas udara.
    - Semakin besar specific gravity fluida, laju alirannya semakin lambat

Pengukuran Flow

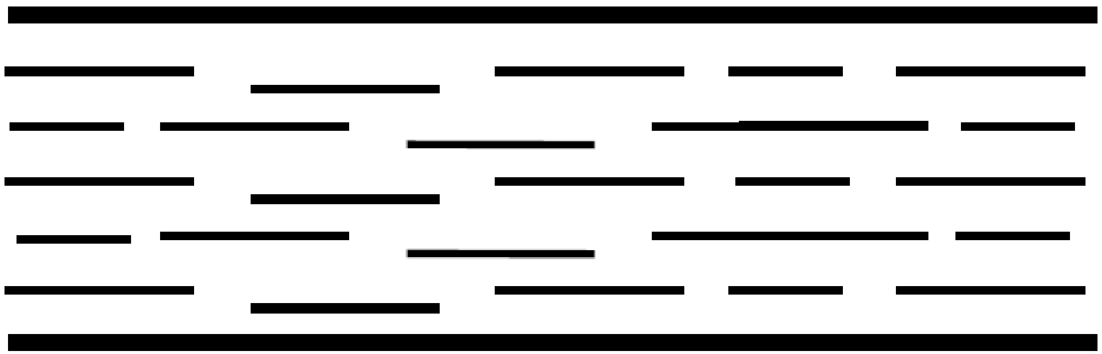
- Kondisi fluida
  - Kondisi fluida (bersih atau kotor) juga menjadi keterbatasan dalam pengukuran aliran
  - Beberapa alat ukur aliran tidak dapat bekerja pada fluida yg kotor
- Profil kecepatan aliran
  - Profil aliran berpengaruh pada akurasi dan performa pengukuran aliran. Bentuk profil aliran didalam pipa bergantung pada :
    - Momentum atau gaya internal dari fluida, yg menggerakan fluida melalui pipa
    - Gaya viskos dari fluida, yg cenderung memperlambat aliran, terutama pada bagian yg dekat dengan dinding pipa

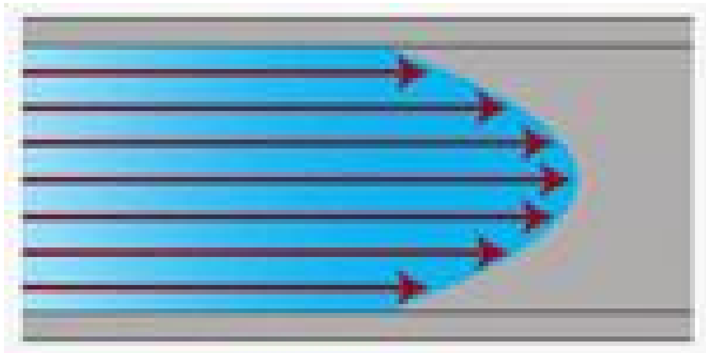
Pengukuran Flow

- Terdapat 3 jenis profil aliran fluida :
  - Laminar / streamlined
  - Transisi laminar-turbulent
  - Turbulent

Pengukuran Flow

- Aliran laminar atau streamlined didefinisikan sebagai aliran pada pipa yg dapat dibagi-bagi menjadi lapisan-lapisan yg bergerak paralel satu sama lain
- Re < 2300

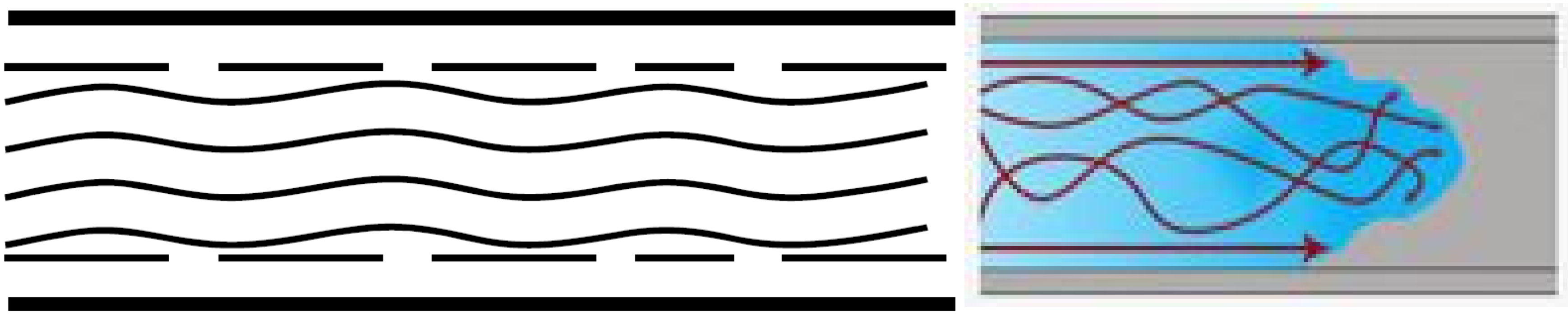




Laminar Flow pattern

Pengukuran Flow

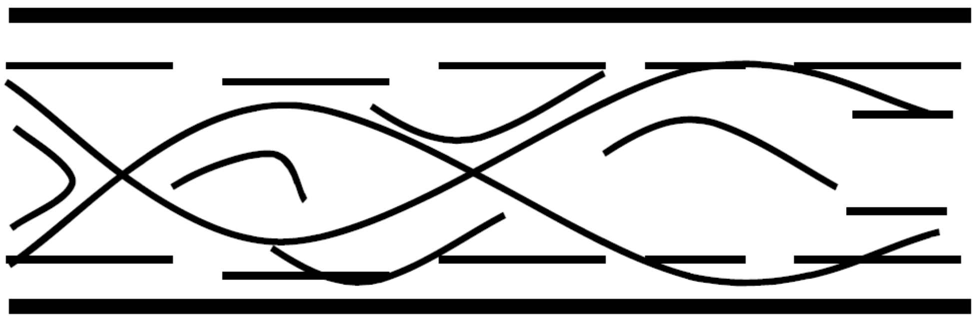
- Pola aliran transisi sulit diprediksi, dan dimungkinkan terjadi osilasi perubahan profil aliran, antara laminer dan turbulent
- $2300 < Re < 4000$

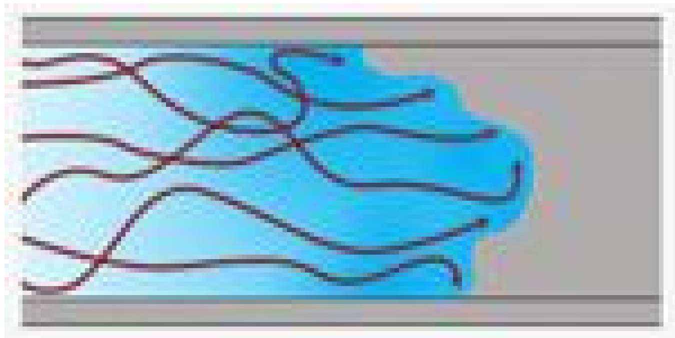


Transition Flow pattern

Pengukuran Flow

- Aliran turbulen adalah jenis aliran yg paling banyak ditemukan di dalam pipa. Aliran turbulen merupakan pola aliran yg memiliki kecepatan arah melintang (swirls, eddy current)
- Re > 4000

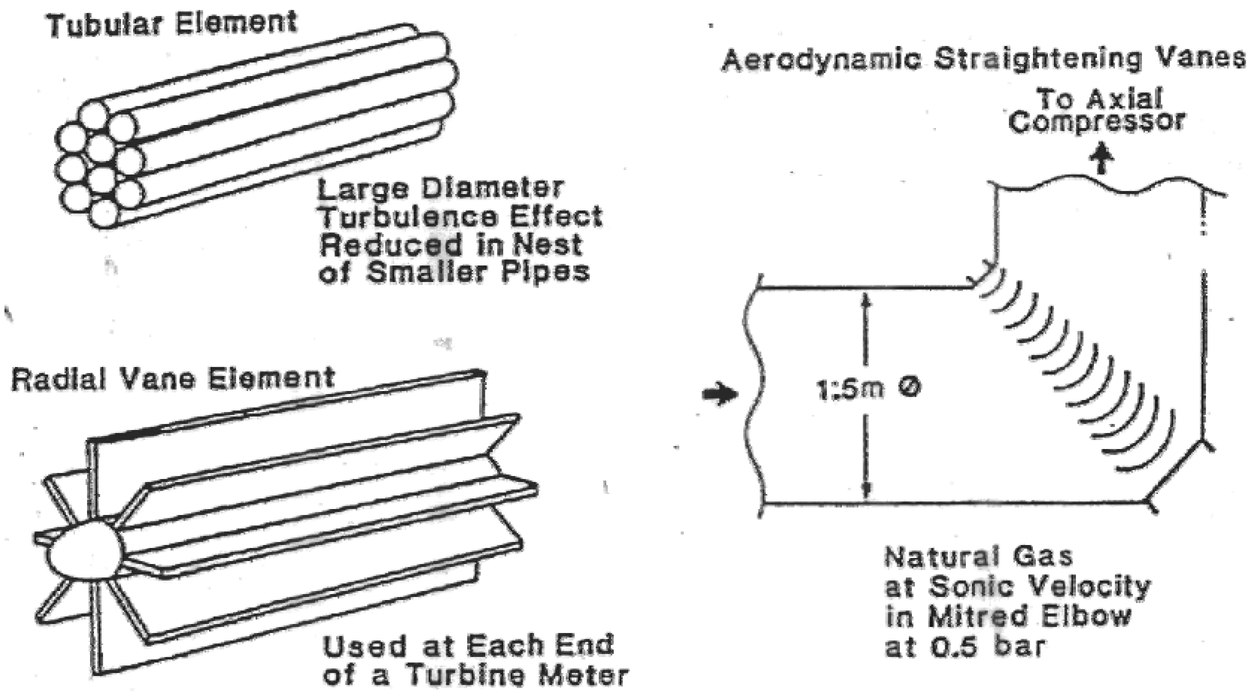




Turbulent Flow pattern

Pengukuran Flow

- Terdapat alat yg digunakan untuk memperbaiki pola aliran, dari turbulen ke transisi, atau bahkan ke laminer.
- Tujuannya untuk mendapatkan hasil pengukuran aliran yg akurat



Pengukuran Flow

- Pengukuran aliran dapat digolongkan menjadi 3 macam pengukuran :
  - laju aliran [m/s]
  - Debit (volume flowrate) [m3/s, gal/s, L/s]
  - Mass flow rate [kg/s, g/s, lb/s]

Pengukuran Flow

- Alat ukur aliran dapat dikelompokan menjadi 4 jenis :
  - Volumetric flow meter
    - Mengukur volume secara langsung. Contoh : positive displacement meters
  - Velocity flow meter
    - Contoh : Magnetic flow meter, turbine flow meter, ultrasonic flow meter
  - Inferential flow meter
    - Contoh : Differential pressure, target dan variable area flow meter
  - Mass flow meter
    - Mengukur aliran massa secara langsung. Contoh : Coriolis flow meter.

DP Flow Meter

- DP Flow meter paling banyak digunakan di industry saat ini
- Alat ukur dengan DP flow meter umumnya tidak memiliki ‘moving parts’.
- Namun, biasanya terjadi masalah pengikisan elemen ukur oleh aliran fluida (terutama pada fluida yg kotor)
- Terdapat 4 jenis DP flow meter :
  - Orifice plate
  - Tabung venturi
  - Elbow
  - Pitot tube

DP Flow Meter

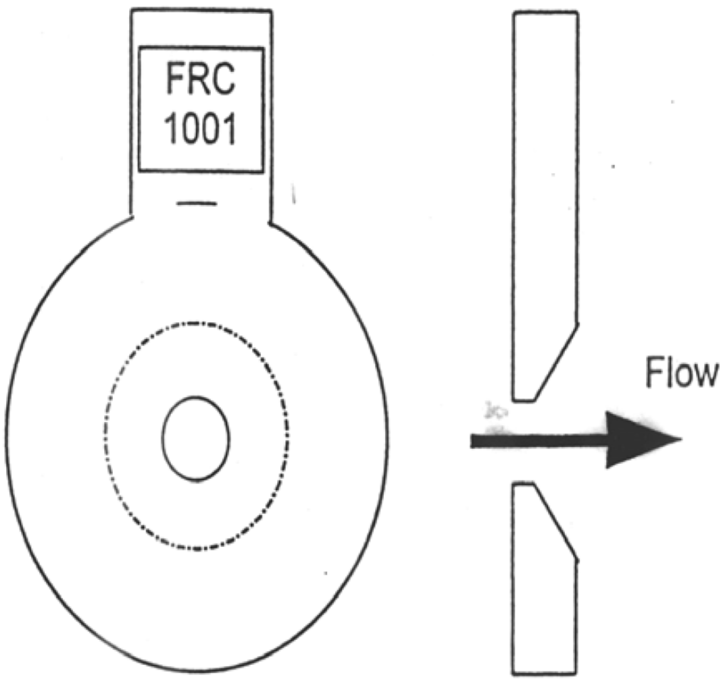
- Aplikasi pengukuran aliran : Clean liquids, gases steam, (no slurries or corrosive)
- Scale : Square Root
- Accuracy : 1% Full scale
- Permanent pressure loss : High
- Cost : low

DP Flow Meter - Orifice

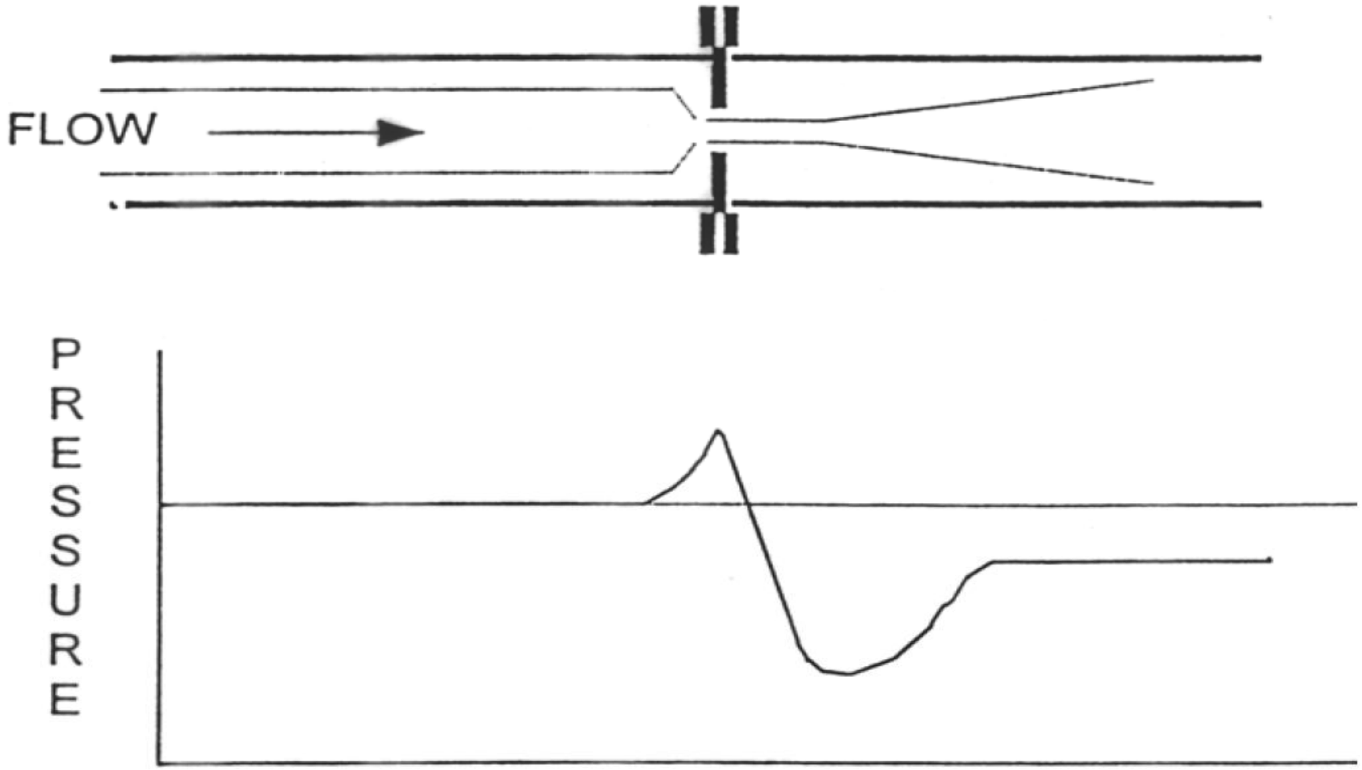
- Pada alat ukur aliran yg menggunakan elemen orifice, terdapat 4 komponen utama :
  - Orifice plate and holder
  - Orifice taps
  - Differential pressure transmitter
  - Flow indicator/recorder/controller

DP Flow Meter - Orifice

- Orifice Plate
  - Orifice plate merupakan pelat datar logam yg memiliki lubang berukuran tertentu di tengahnya
  - Fungsi dari orifice plate adalah untuk menghasilkan pressure drop, sehingga laju aliran dapat diukur (dg persamaan Bernoulli)
  - Ketika fluida mengalir melewati orifice plate, terjadi peningkatan kecepatan dan turbulensi, disertai dengan penurunan tekanan aliran (pressure drop).
  - Setelah fluida melewati orifice, kecepatannya akan berkurang kembali dan terjadi peningkatan tekanan
  - Dalam peningkatan tekanan ini (**pressure recovery**), tekanan fluida tidak kembali 100% seperti semula (**pressure loss**). Biasanya pressure recovery yg terjadi tidak lebih dari 50% dari total pressure drop orifice
  - Semakin cepat fluida mengalir, semakin besar pressure drop yg dihasilkan pelat orifice

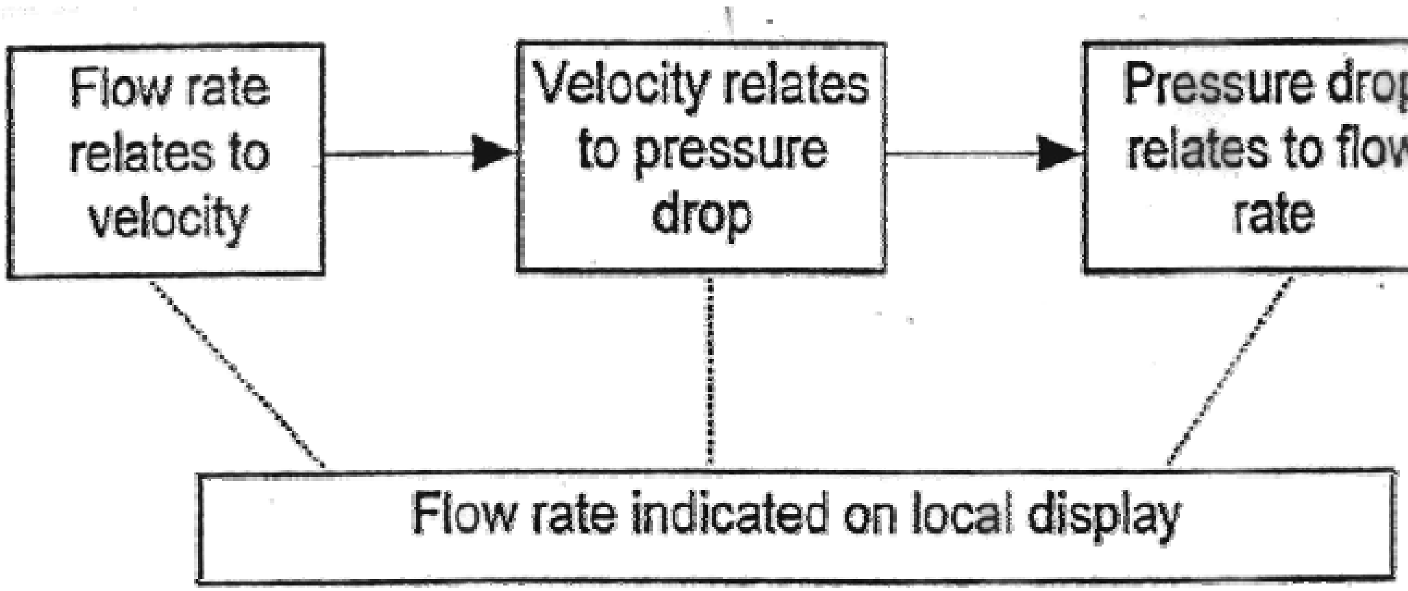


DP Flow Meter - Orifice



Pressure Profile Through the Orifice Plate

DP Flow Meter - Orifice



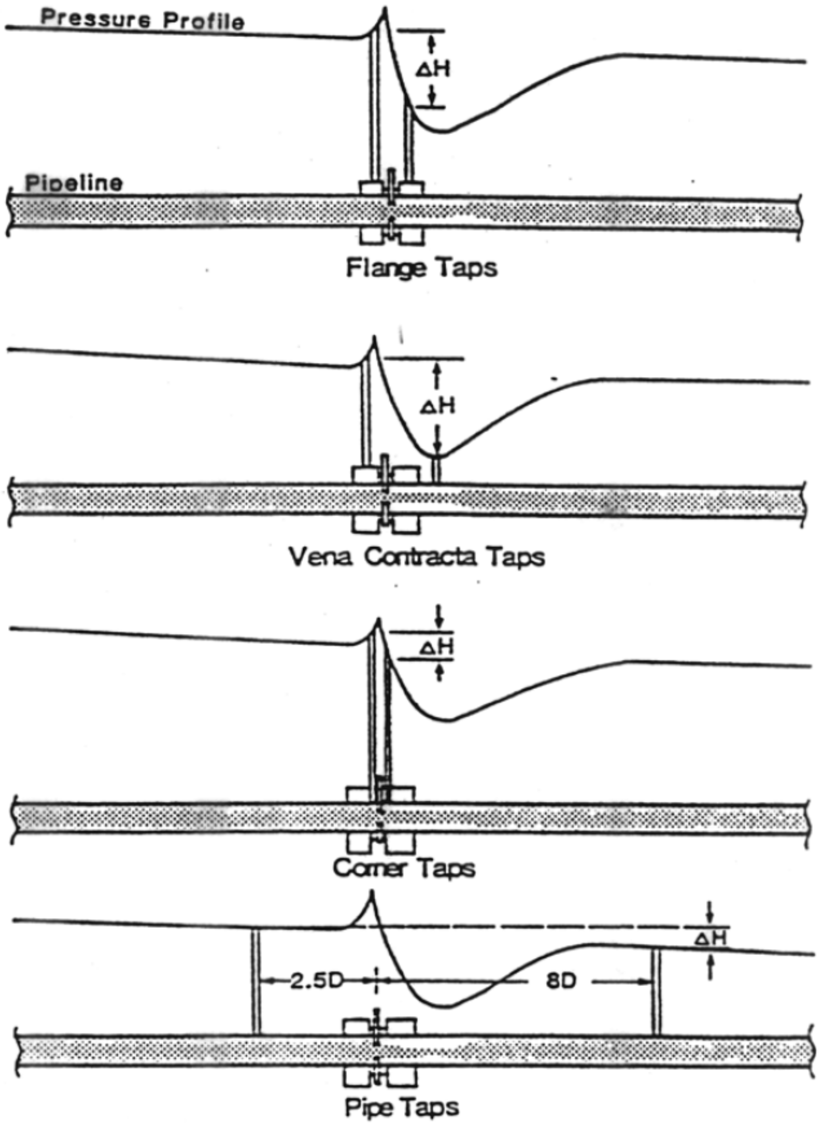
DP Flow Meter - Orifice

- Orifice Plate & Holder
  - Pelat orifice umumnya dipasang pada mounting (flanges) khusus di pipa horizontal
  - Pada bagian upstream dan downstream dari orifice plate terdapat lubang (taps) yang digunakan untuk memasang elemen ukur DP (differential pressure).
  - DP yg terukur digunakan untuk kalkulasi laju aliran pada transmitter.

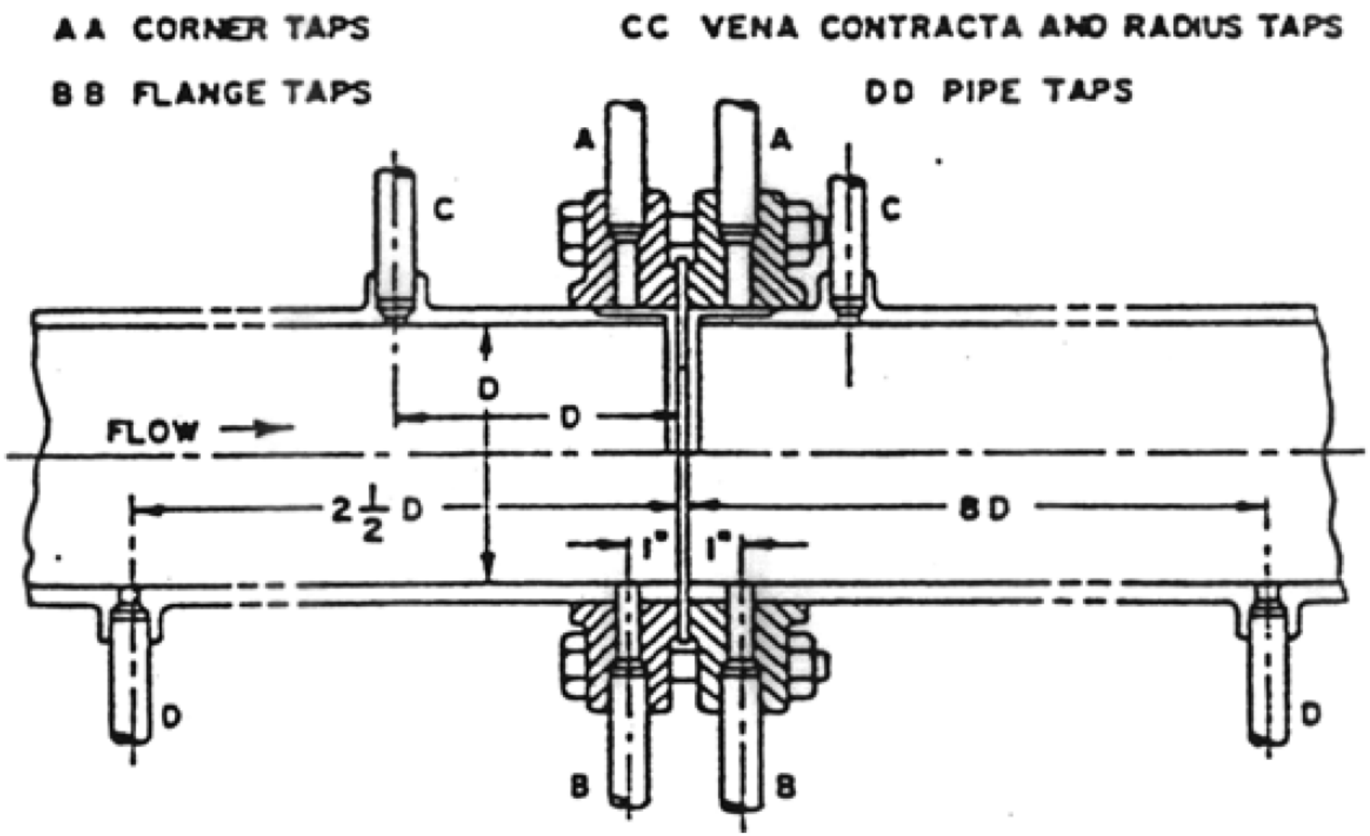
DP Flow Meter - Orifice

- Terdapat 4 jenis orifice taps yg umum digunakan :
  - Flange taps
    - Taps terletak pada flange
    - Paling banyak digunakan karena jarak tap dari orifice plate terkontrol dengan teliti
  - Vena contracta
    - Downstream tap terletak pada bagian vena contracta aliran (titik terjadinya maximum pressure drop)
    - Tujuan peletakan pada vena contracta adalah untuk mendapatkan nilai pengukuran DP yg maksimal (across the orifice)
  - Corner taps
    - Taps diletakan didekat orifice plate (baik upstream maupun downstream)
    - Baik untuk pengukuran DP (DP flow meter) pada pipa berdiameter kurang dari 50 mm
  - Pipe taps
    - Taps terletak di pipa aliran. Digunakan untuk mengukur **permanent loss of pressure** dari orifice (loss pressure setelah fluida melewati orifice)

DP Flow Meter - Orifice

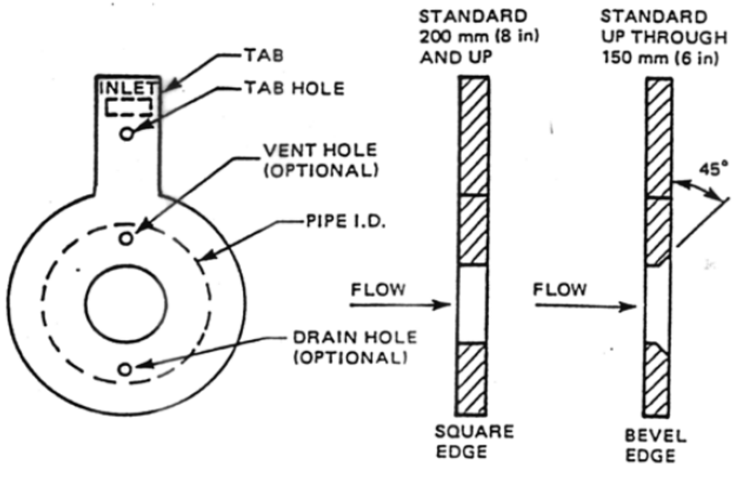


DP Flow Meter - Orifice

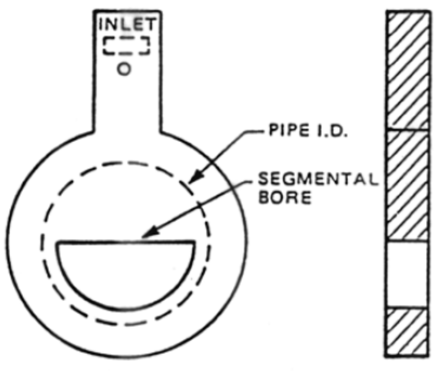


DP Flow Meter - Orifice

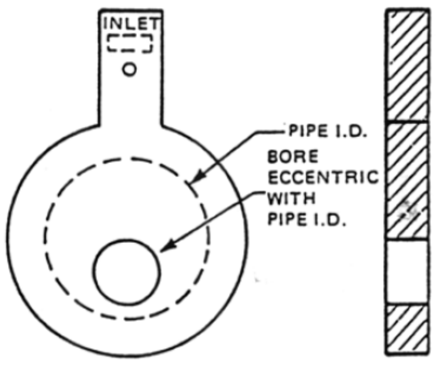
- Jenis-jenis Orifice



CONCENTRIC BORE ORIFICE PLATES



SEGMENTAL BORE ORIFICE PLATE (OPTIONAL)



ECCENTRIC BORE ORIFICE PLATE (OPTIONAL)

DP Flow Meter - Orifice

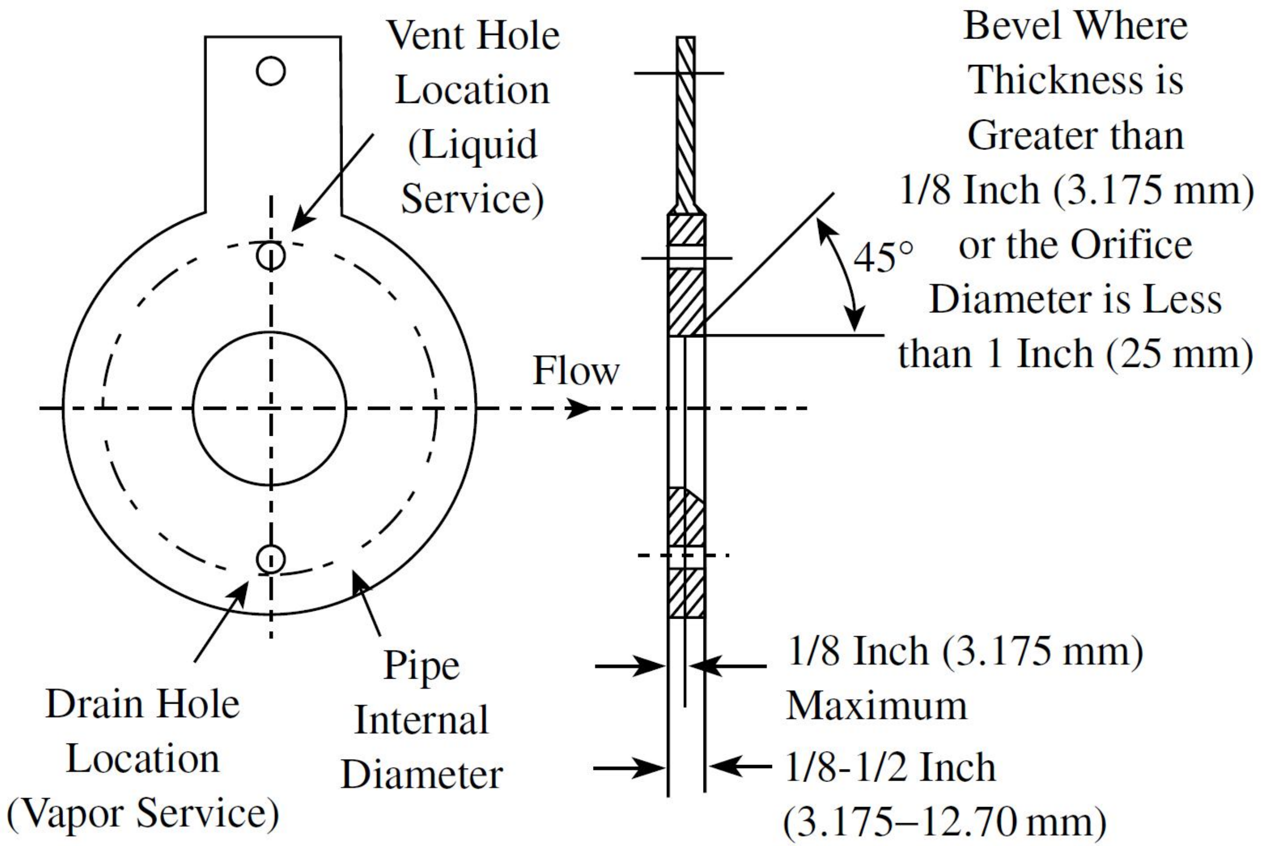


FIG. 2.15c
Concentric orifice plate.

DP Flow Meter - Orifice

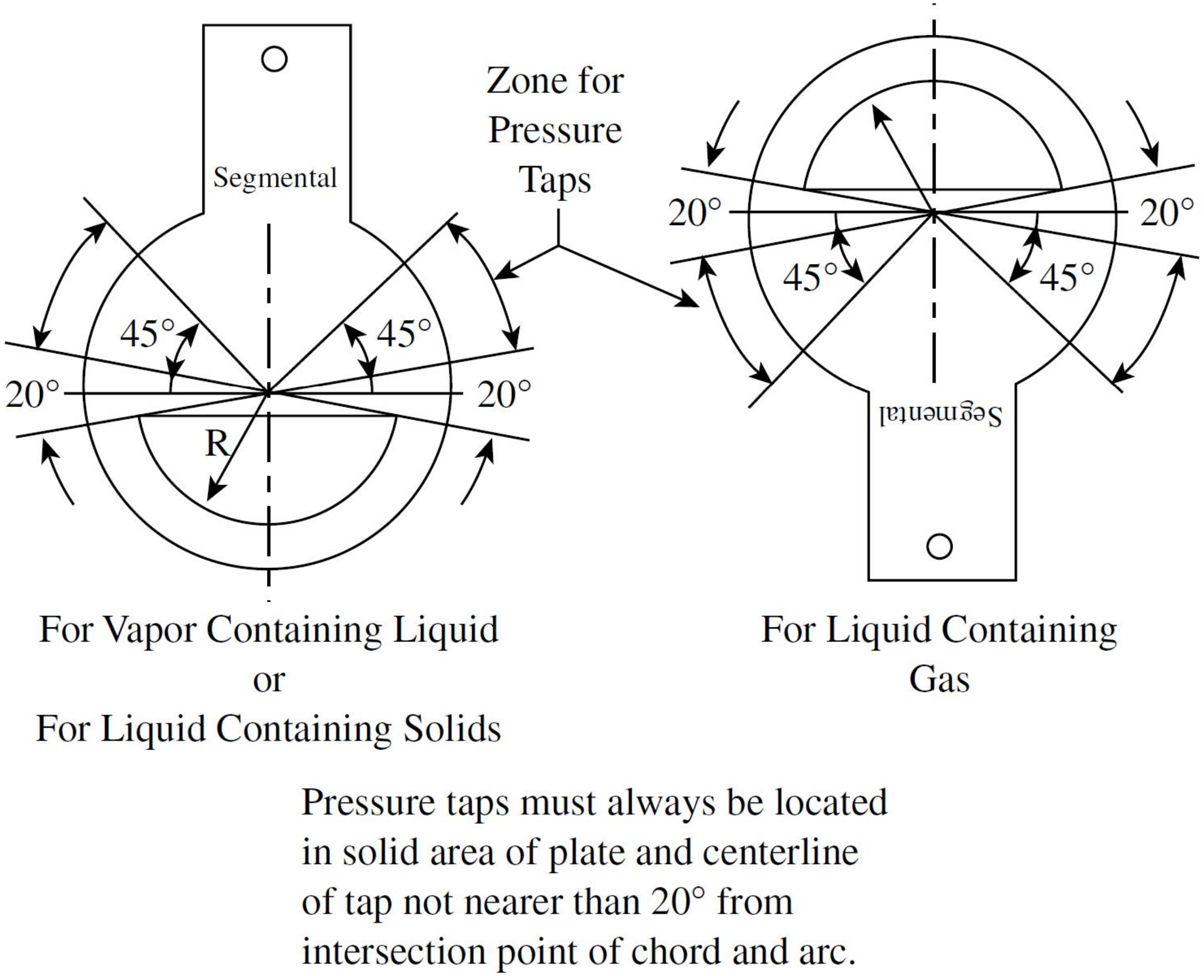


FIG. 2.15i

Segmental orifice plate.

DP Flow Meter - Orifice

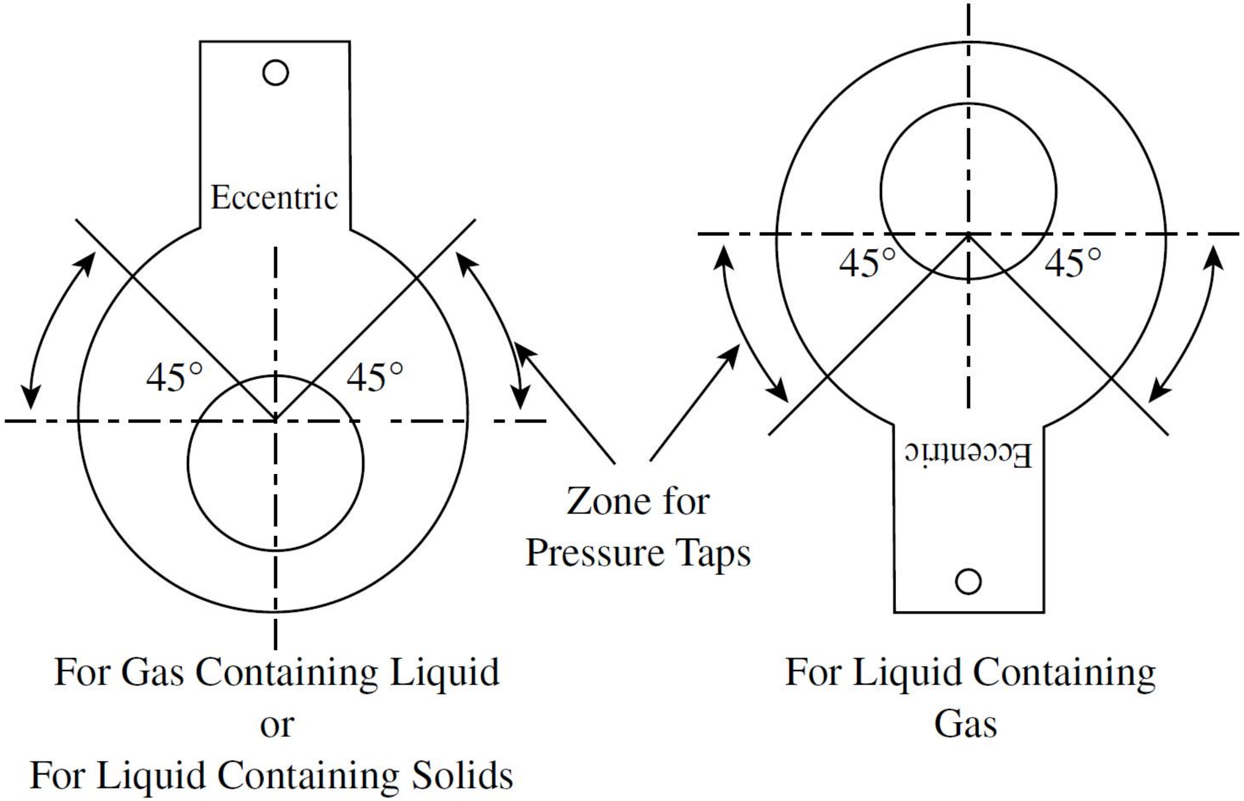
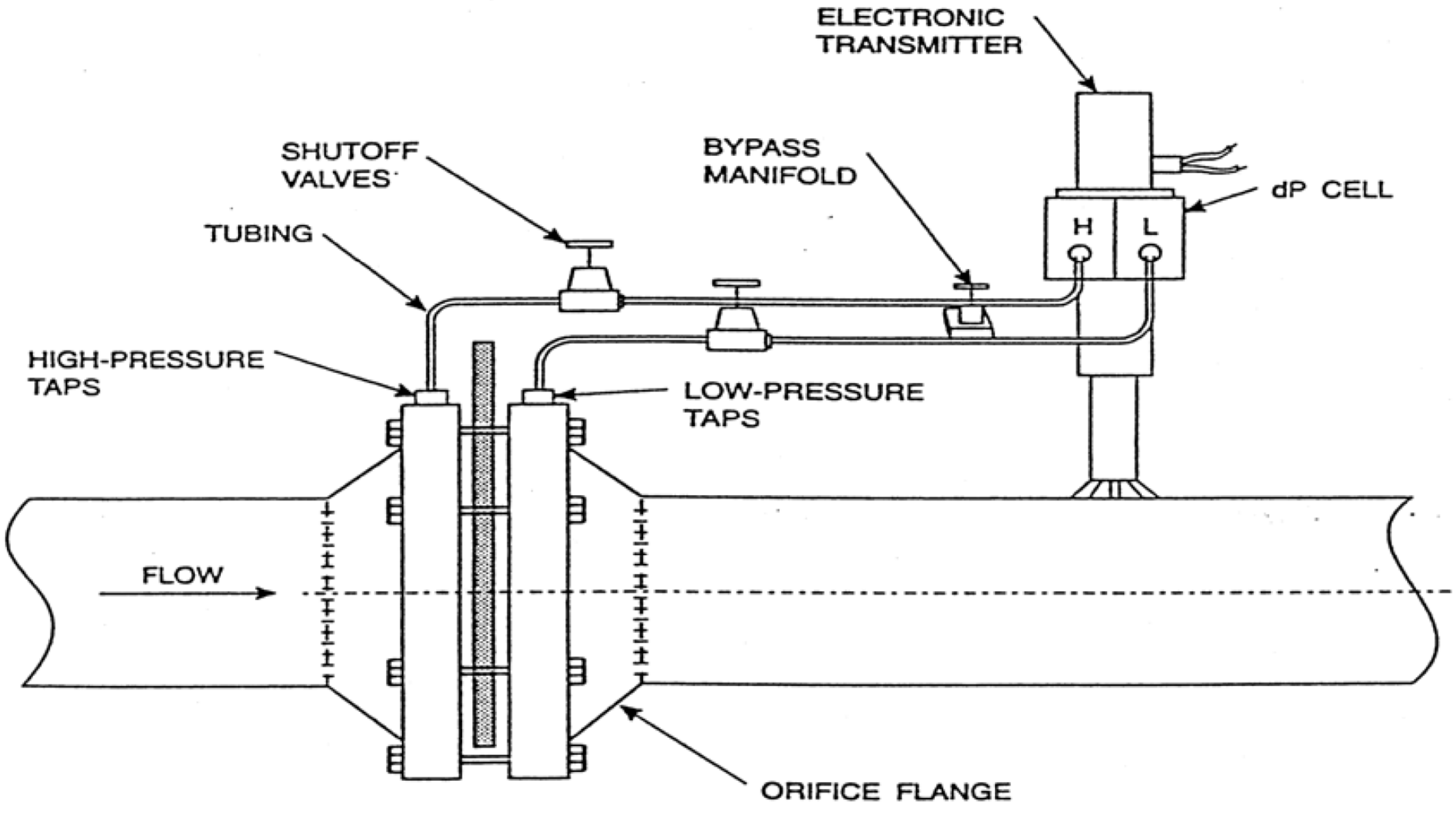


FIG. 2.15h
Eccentric orifice plate.

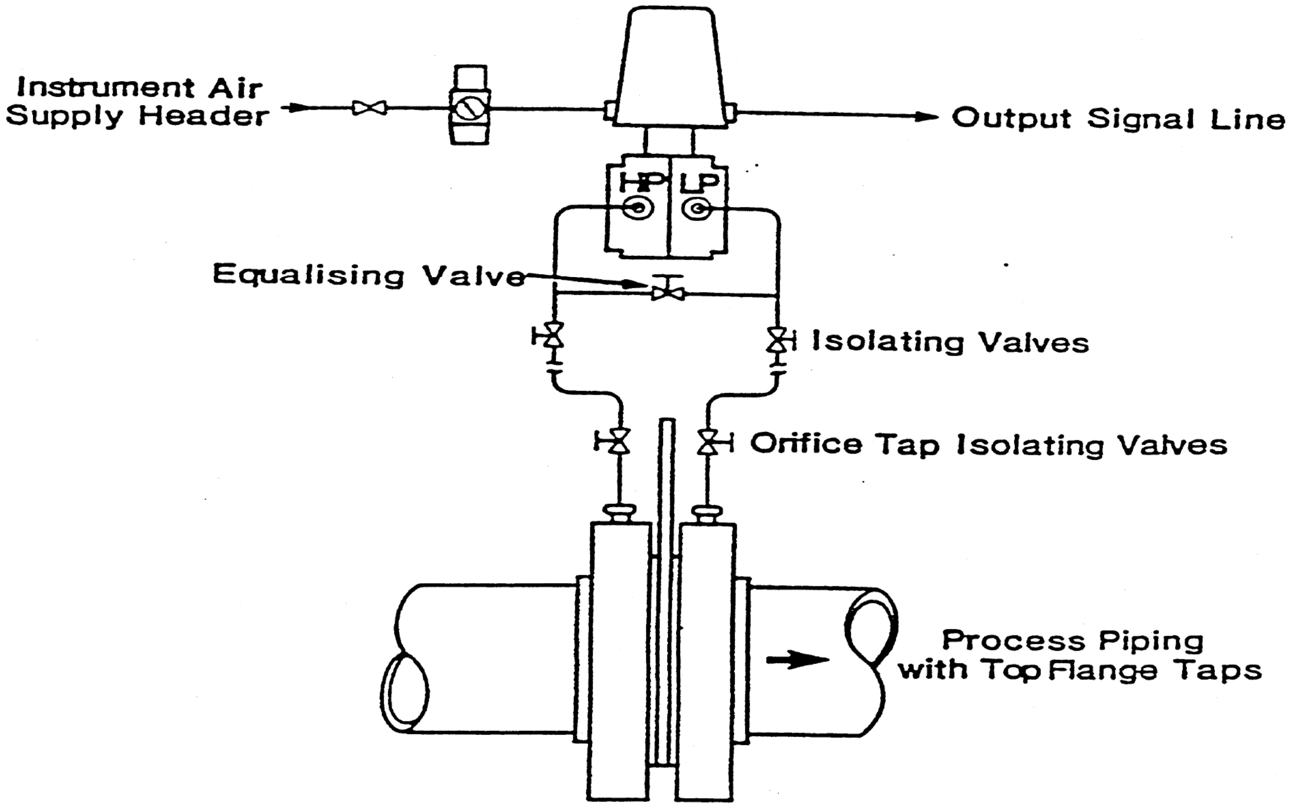
DP Flow Meter - Orifice

- Electronic DP Transmitter Line Connection



DP Flow Meter - Orifice

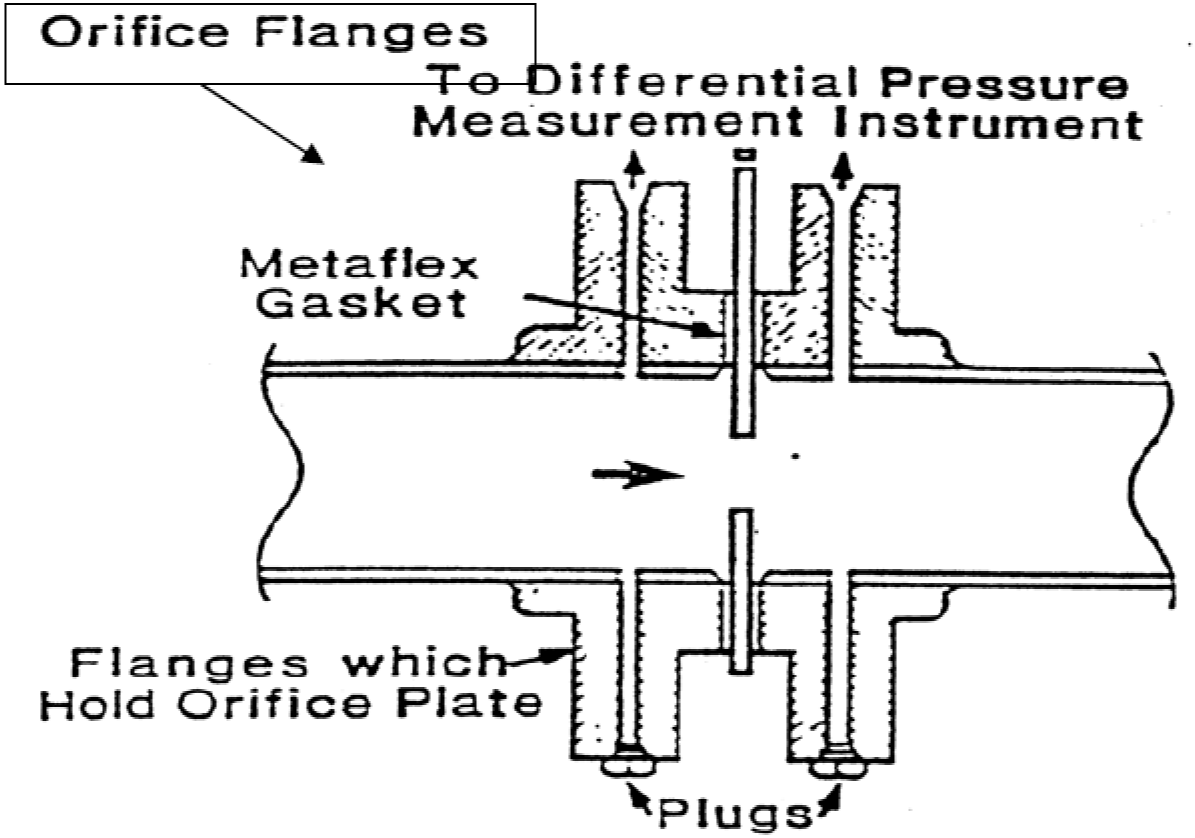
- Pneumatic DP Transmitter Line Connection

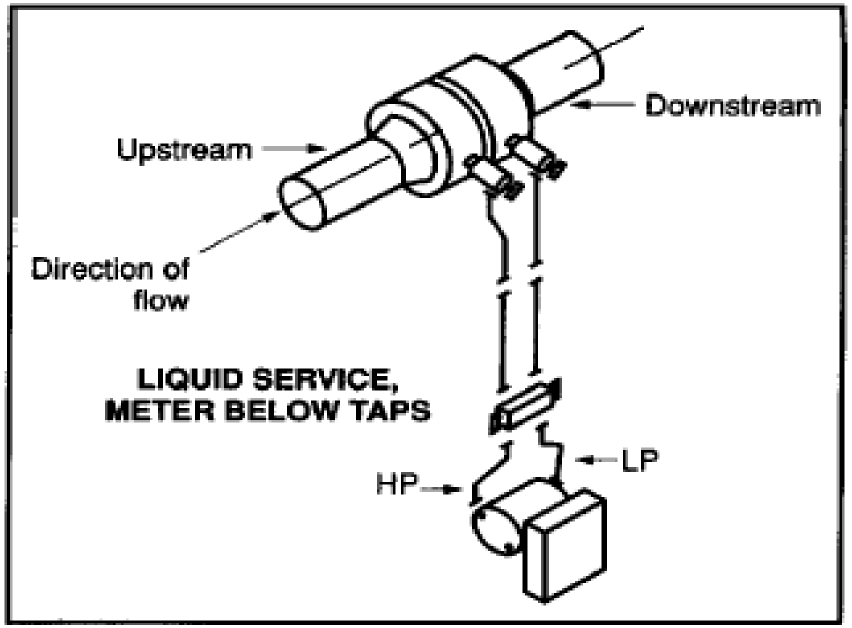


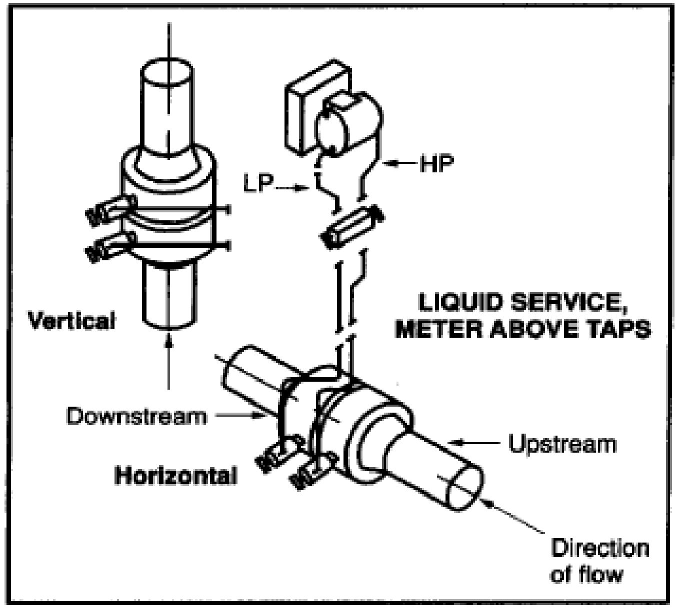
Differential Pressure Transmitter Line Connections

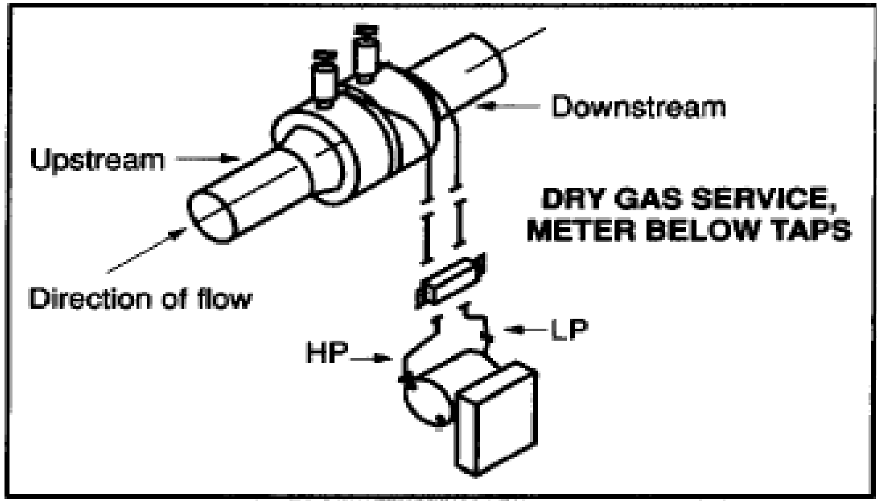
DP Flow Meter - Orifice

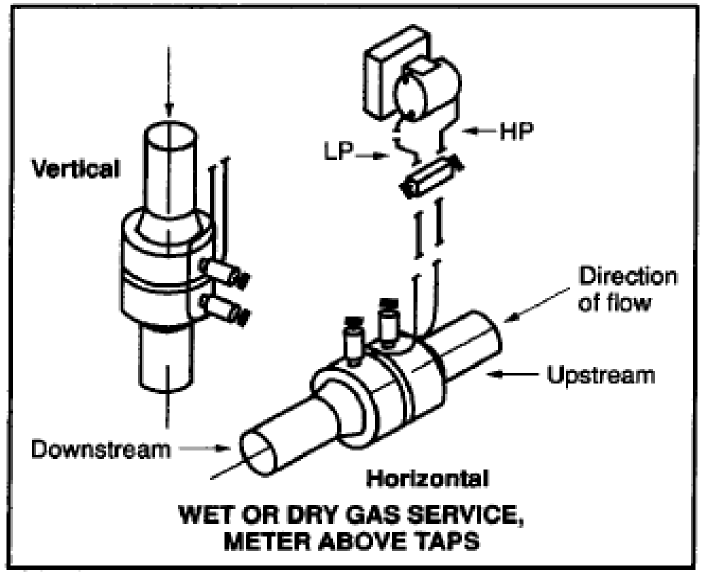
- Flange Connection untuk DP Transmitter

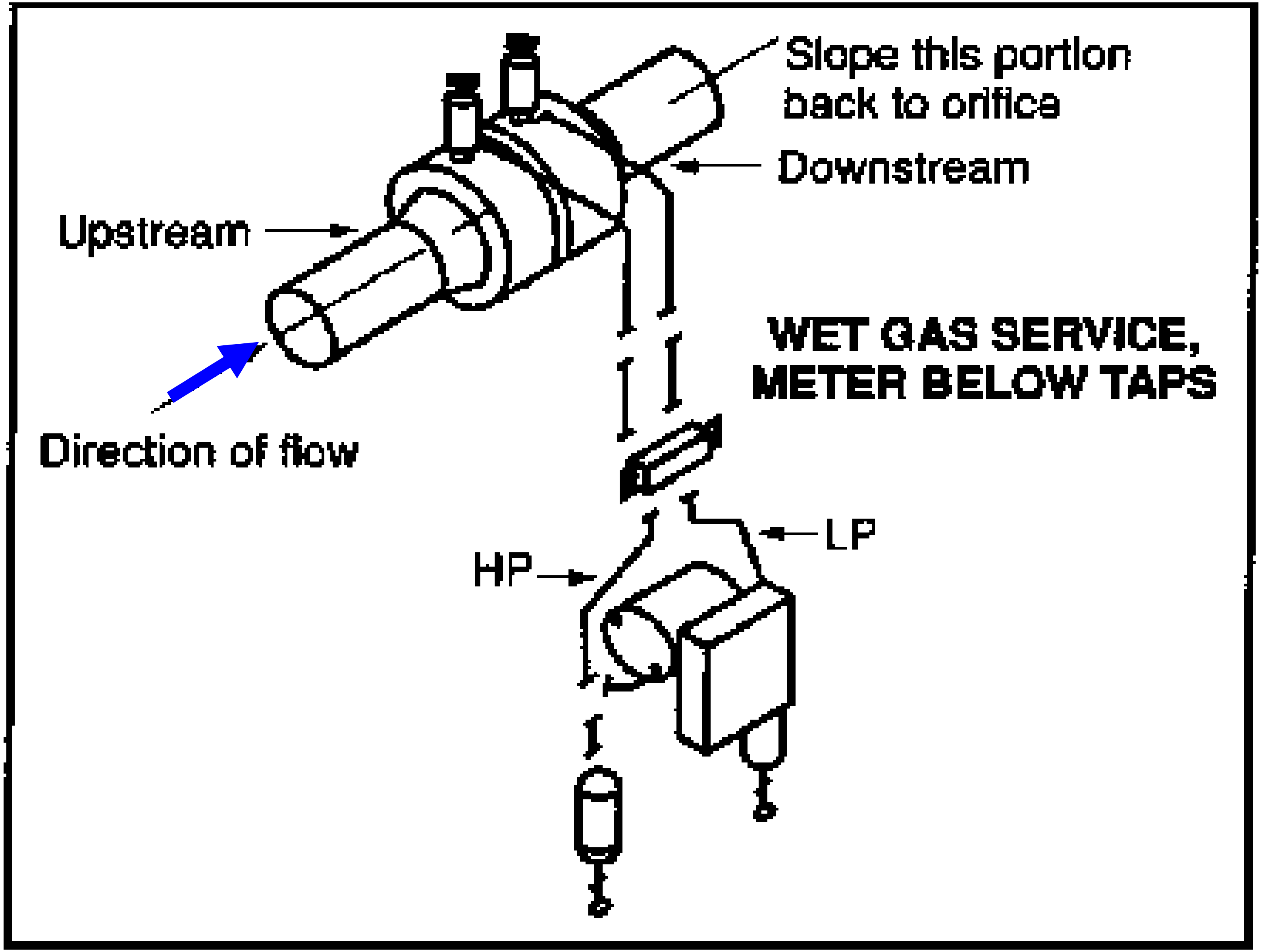


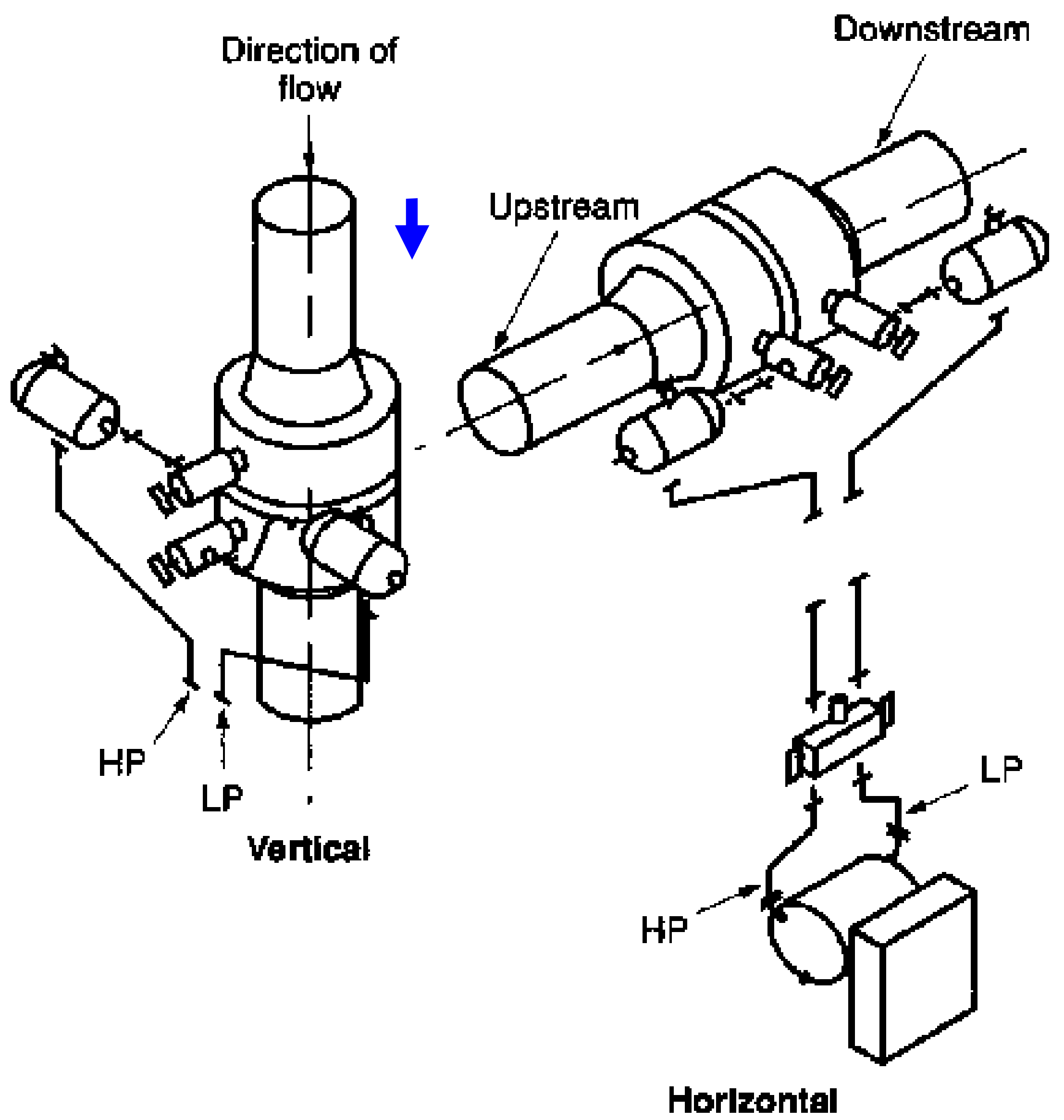

Upstream
Downstream
Direction of flow
LIQUID SERVICE, METER BELOW TAPS
HP
LP


LP
HP
Vertical
LIQUID SERVICE, METER ABOVE TAPS
Downstream
Upstream
Horizontal
Direction of flow

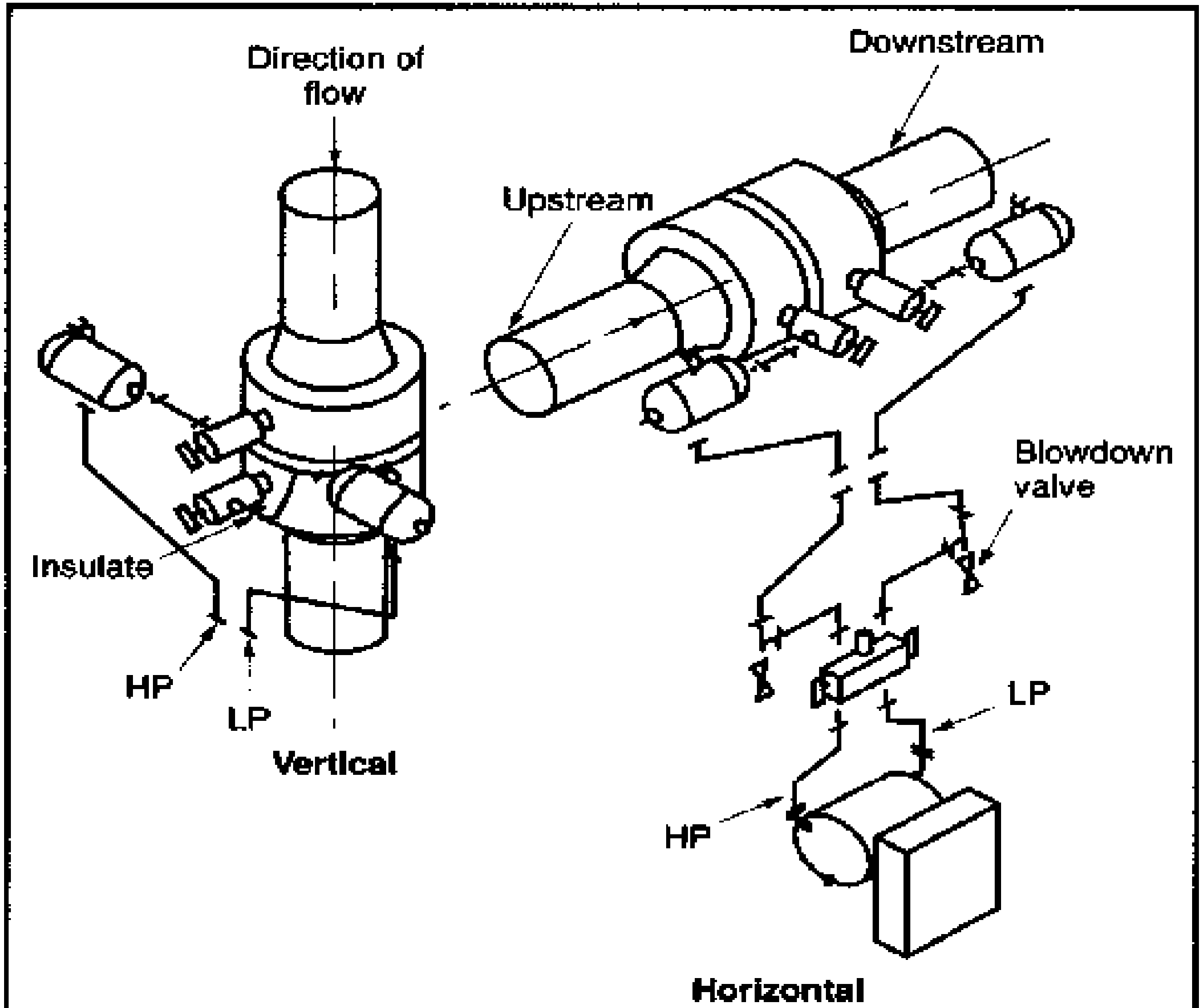

Downstream
Upstream
DRY GAS SERVICE, METER BELOW TAPS
Direction of flow
LP
HP


HP
LP
Vertical
Direction of flow
Upstream
Downstream
Horizontal
WET OR DRY GAS SERVICE, METER ABOVE TAPS


Slope this portion back to orifice
Downstream
Upstream
Direction of flow
WET GAS SERVICE,
METER BELOW TAPS
LP
HP



STEAM OR VAPOR SERVICE, METER BELOW TAPS
(WITH CONDENSATE POTS AND NO BLOWDOWN)



Gambar 17

STEAM SERVICE, METER BELOW TAPS
(WITH CONDENSATE POTS AND BLOWDOWN)

DP Flow Meter - Orifice

- Hubungan antara laju aliran (Q) dengan Δp

$$Q_m = \frac{Cd.A_{throat}.\sqrt{2.\rho.\Delta p}}{\sqrt{1-\beta^4}}$$

$$Q_m = K\sqrt{\Delta p}$$

C = Coefficient Discharge

A_{pipa}= Luas pipa dengan diameter d

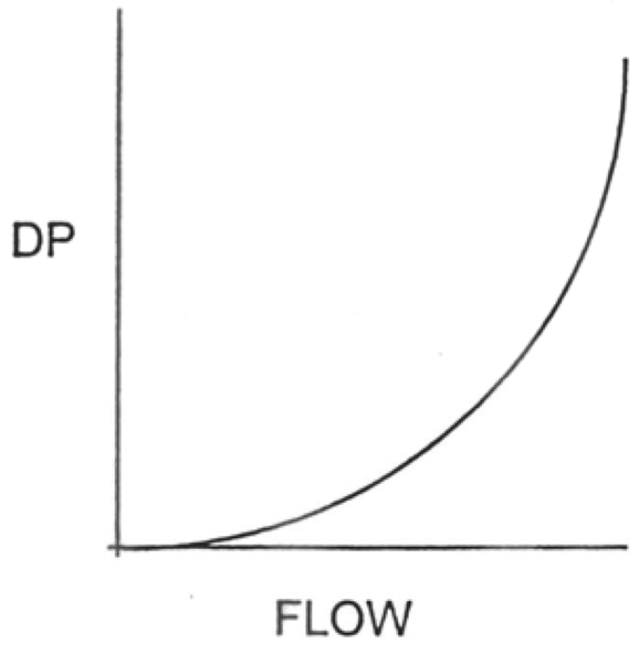
$$A_{throat} = \frac{\pi}{4}d^2$$

ρ = density

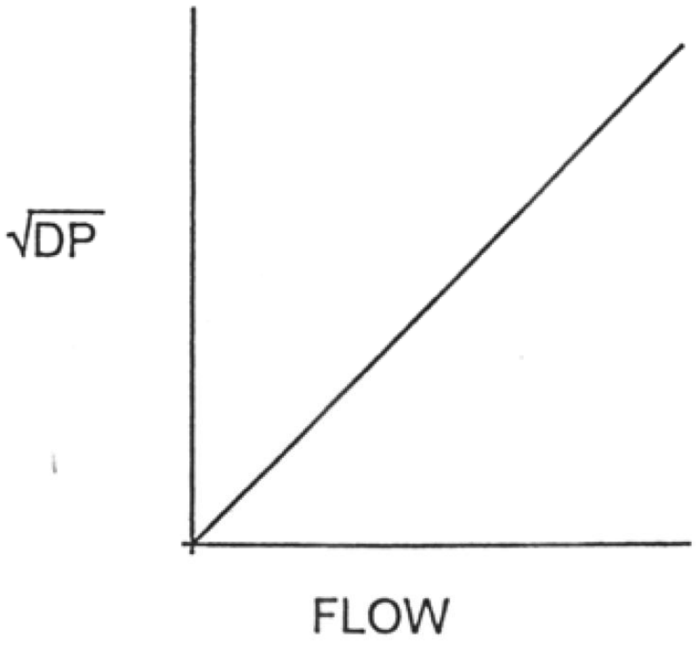
Δp = diferential pressure

β = perbandingan diameter = d / D = $(a/A)^{1/2}$

DP Flow Meter - Orifice



Transmitter output curve



Square root extractor output curve

DP Flow Meter - Orifice

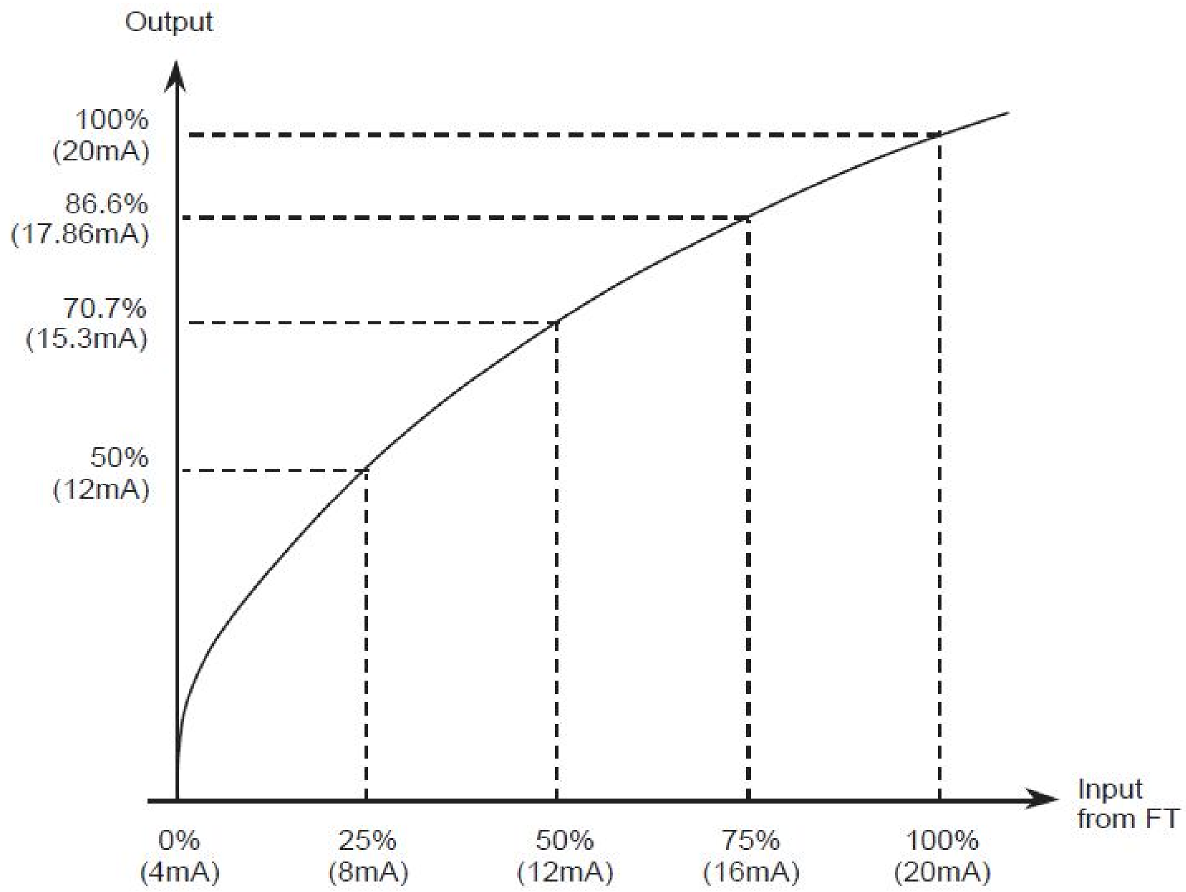


Figure 12
Square Root Extractor Input and Output

DP Flow Meter - Orifice

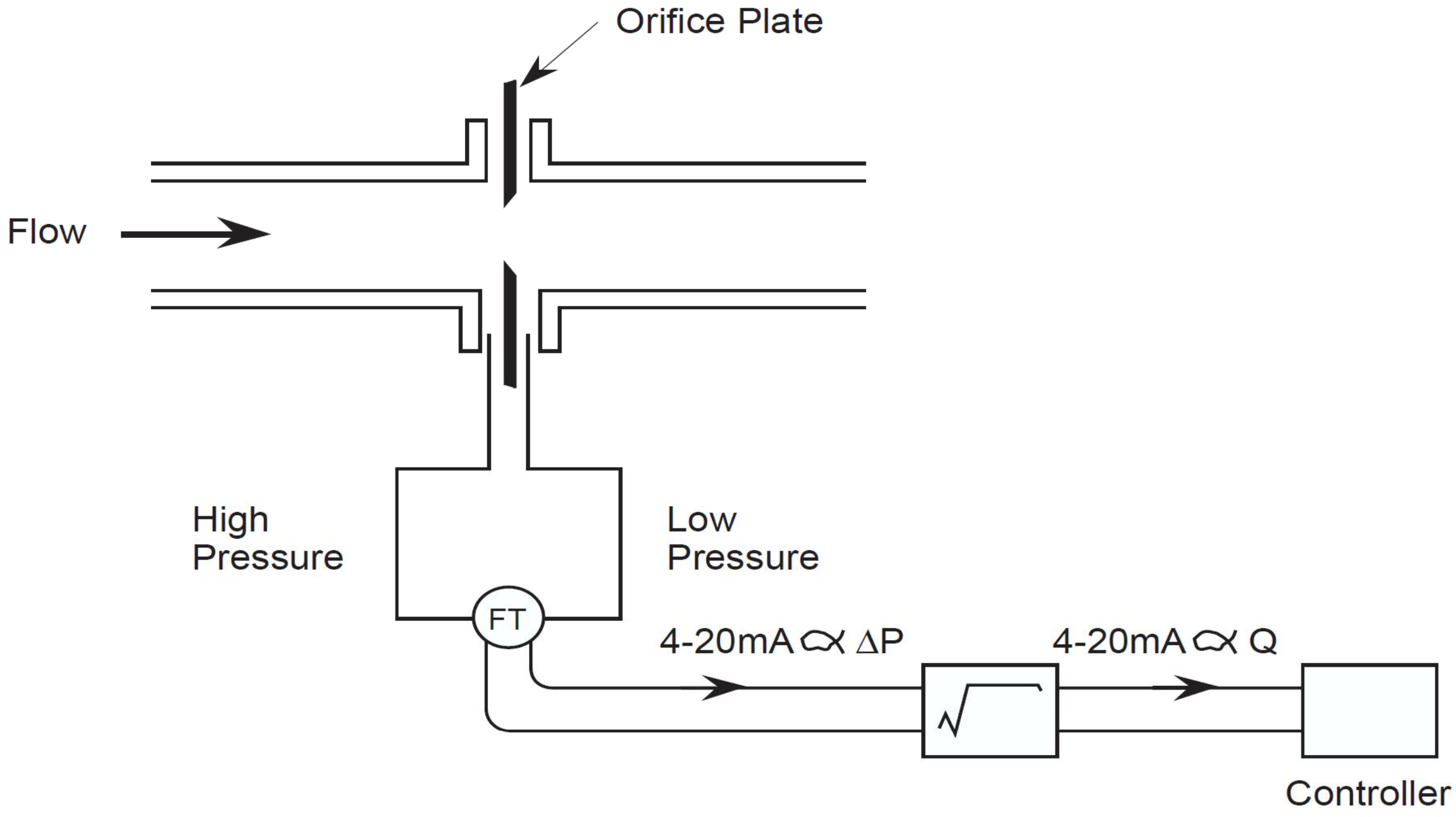


Figure 13

A Typical Square Root Extractor Installation

DP Flow Meter - Orifice

$$\text{Transmitter Output}$$

$$= \frac{\text{Flow Input}}{\text{Span Flow}} \text{Span Transmitter} + \text{Bias}$$

$$= \frac{\sqrt{\text{DP Input}}}{\sqrt{\text{Span DP}}} \text{Span Transmitter} + \text{Bias}$$

DP Flow Meter - Orifice

- Kelebihan Pengukuran dengan Orifice
  - Instalasi mudah
  - Dapat digunakan untuk sebagian besar ukuran pipa
  - Tidak memiliki moving parts
  - Dapat menghasilkan DP yg tinggi
  - Telah lama digunakan dan dikembangkan, sehingga data tentang aplikasinya lengkap
  - Harganya relatif lebih murah dibandingkan jenis pengukuran lainnya

DP Flow Meter - Orifice

- Kekurangan Pengukuran dengan Orifice
  - High permanent pressure loss (kerugian pemompaan tinggi)
  - Keakuratanya dipengaruhi oleh densitas, viskositas dan temperatur
  - Perlu sering dikalibrasi

DP Flow Meter - Venturi

- Tabung Venturi cocok untuk aplikasi pengukuran yg membutuhkan low permanent pressure loss

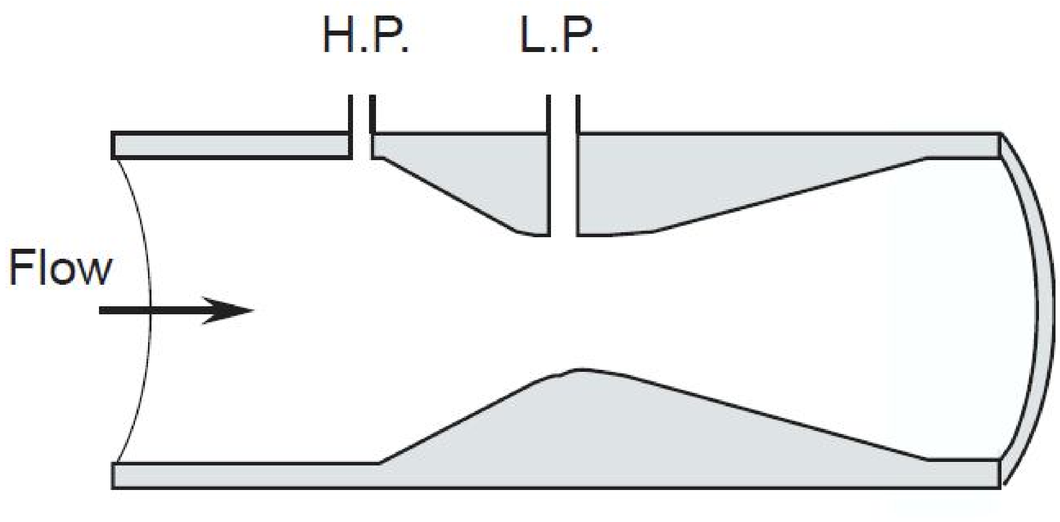


Figure 6
Venturi Tube Installation

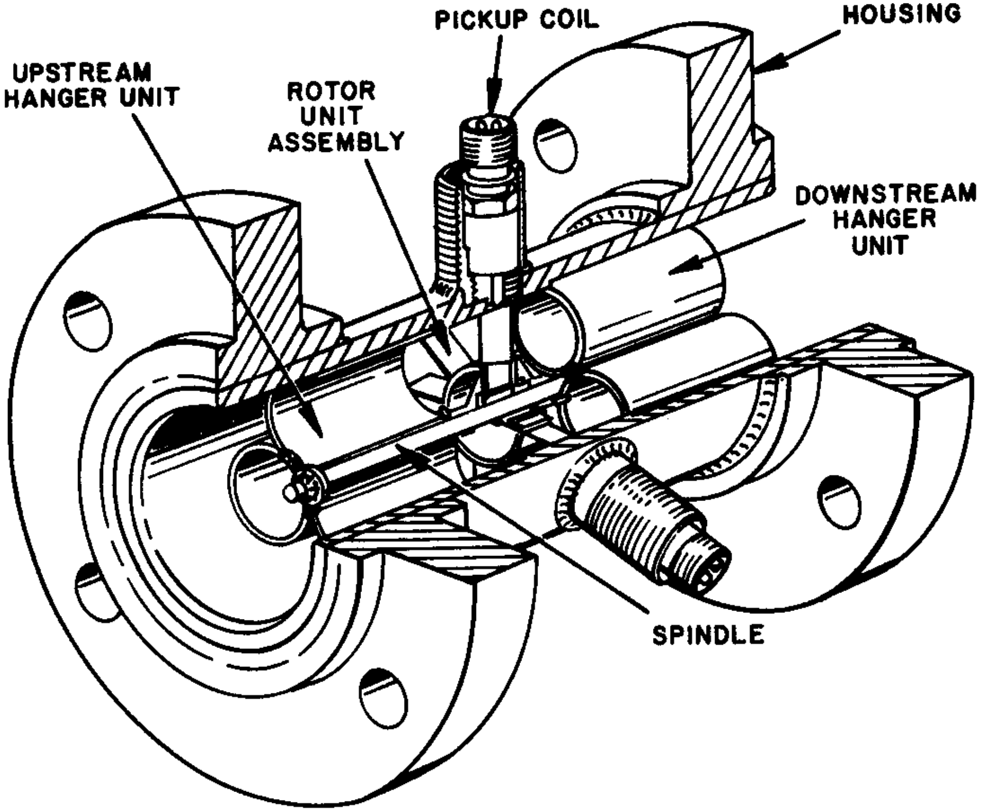
DP Flow Meter - Venturi

- Kelebihan :
  - Mampu mengukur laju aliran bertekanan rendah
  - Peluang terjadinya wear dan korosi lebih kecil dibanding orifice
  - Cocok untuk pengukuran aliran di pipa berdiameter besar
  - Untuk fluida bercampur solid, performa pengukuran yg didapat lebih baik dibanding orifice

DP Flow Meter - Venturi

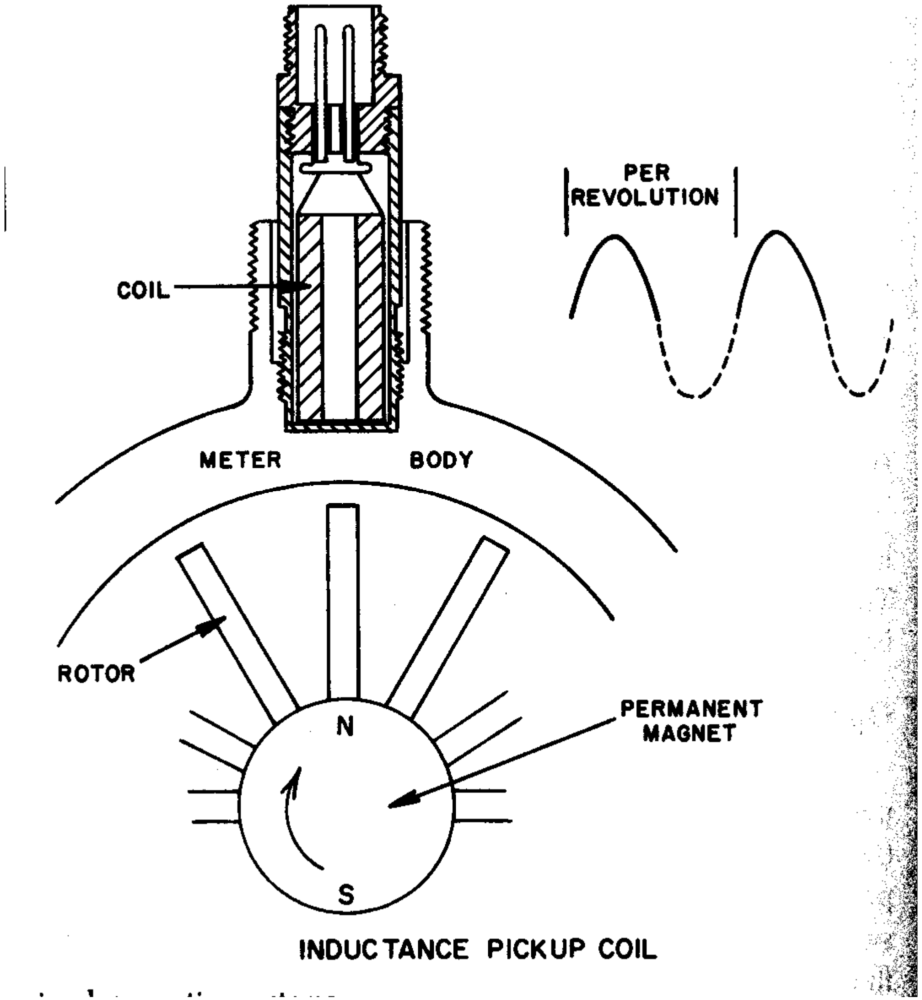
- Kekurangan :
  - Dimensinya lebih besar dibanding orifice
  - Harganya lebih mahal dari orifice (tergolong elemen DP yang mahal)
  - DP yang dihasilkan venturi lebih kecil dibandingkan orifice (sensitivitas pengukurannya lebih kecil daripada orifice)

TURBINE METER



- UMUMNYA LIQUID
- UNTUK CUSTODY

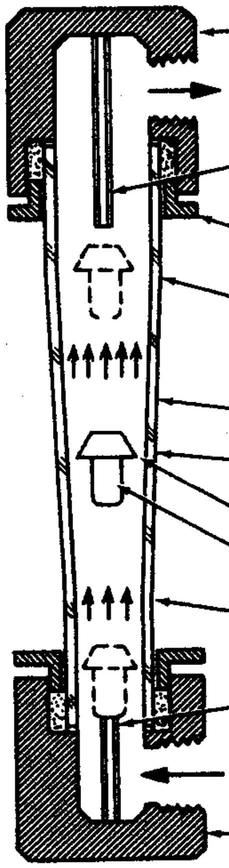
TURBINE METER



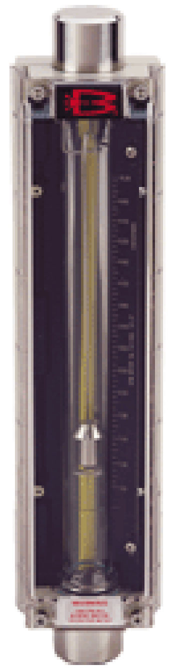
KONSEP

- FLOW MEMUTAR TURBINE
- KECEPATAN PUTARAN SEBANDING HARGA FLOW

AREA VARIABLE / ROTAMETER



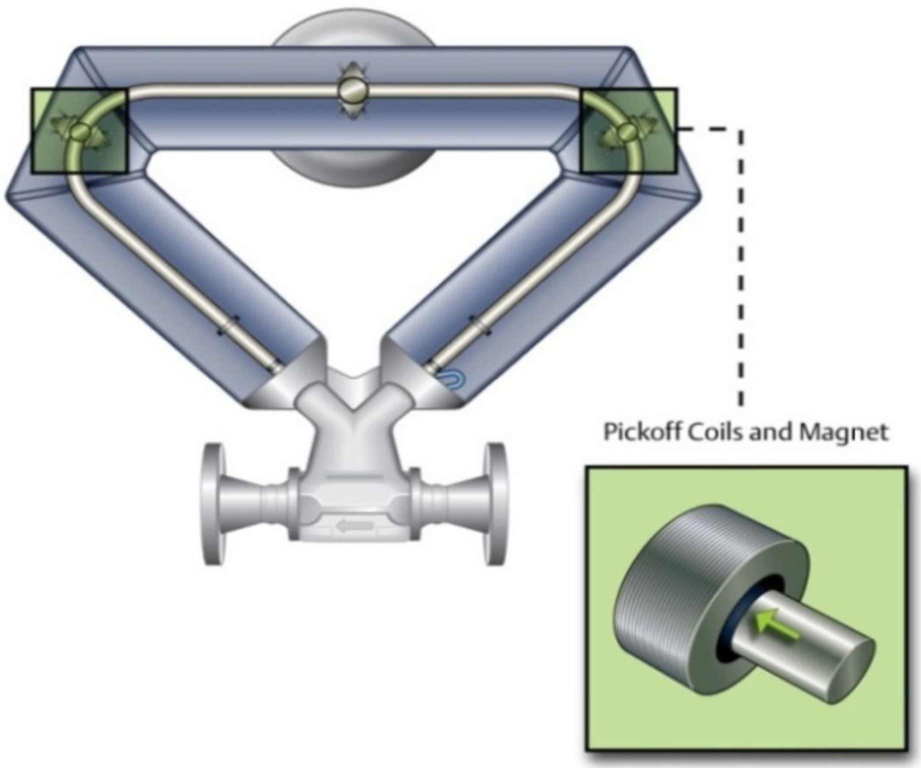
- **UNTUK FLOW / PRESSURE RENDAH**
- **BANYAK DIPAKAI UNTUK PURGING FLOW METER**

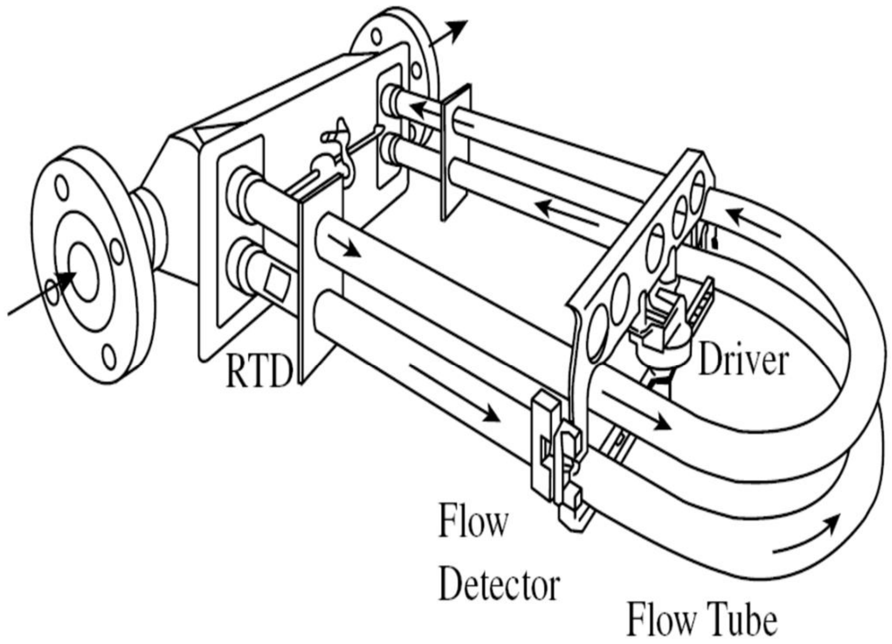


Model GT1000

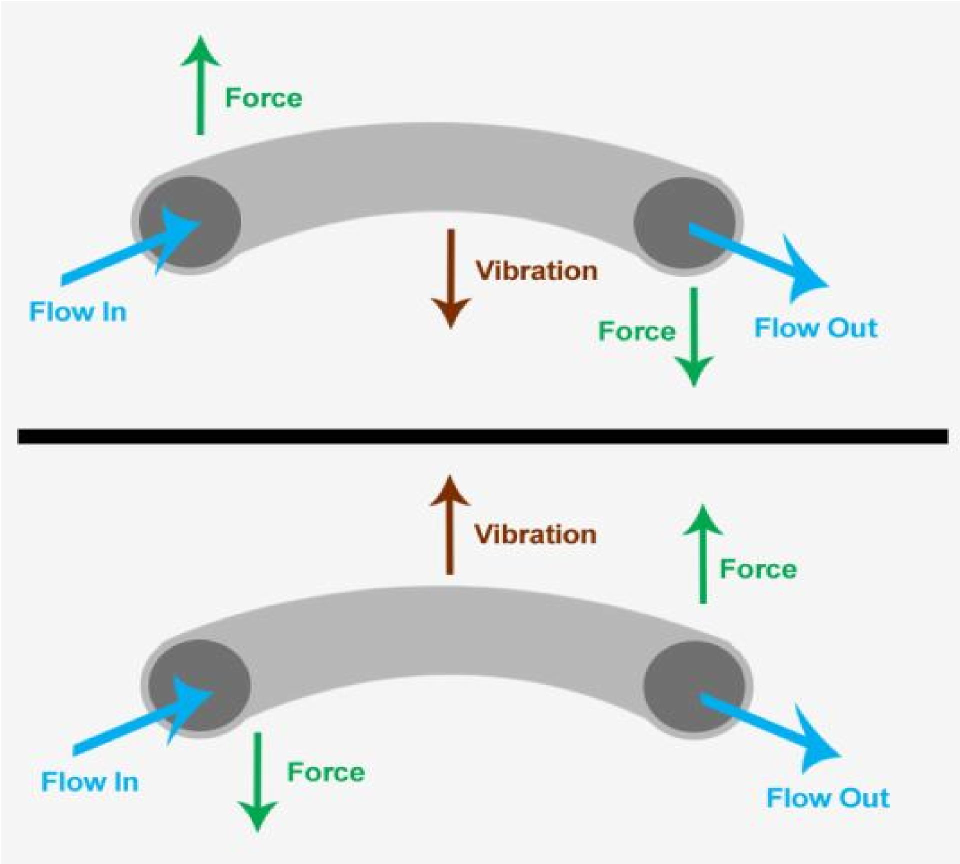
Coriolis Flow Meter

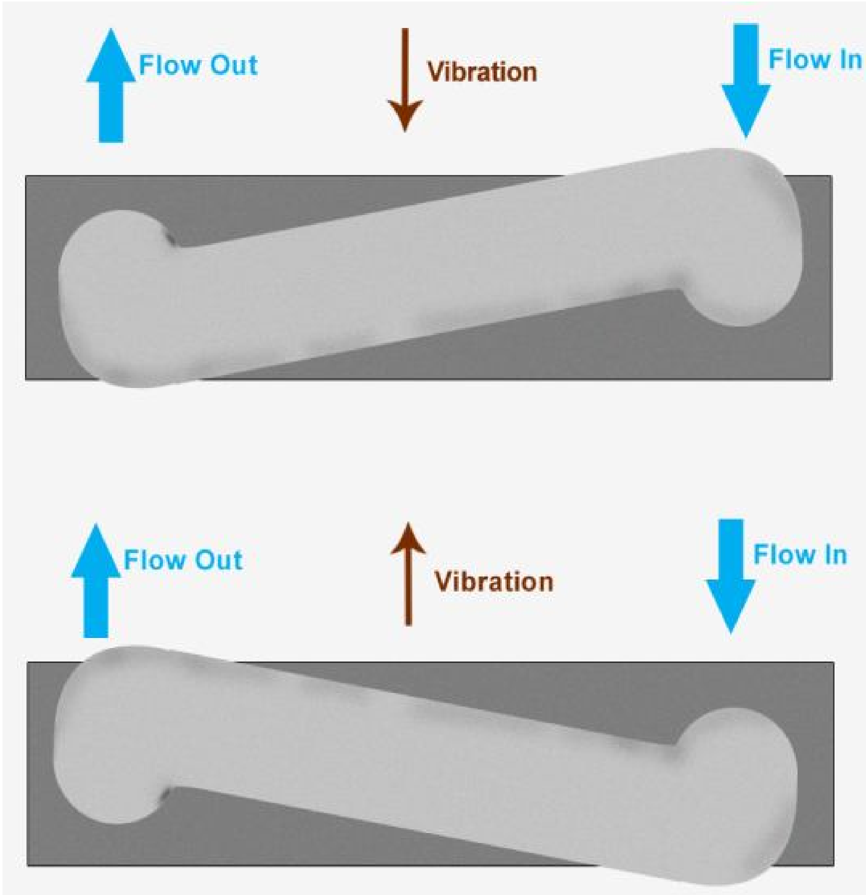
- Coriolis merupakan gabungan flowmeter dan densitometer





Coriolis Flow Meter



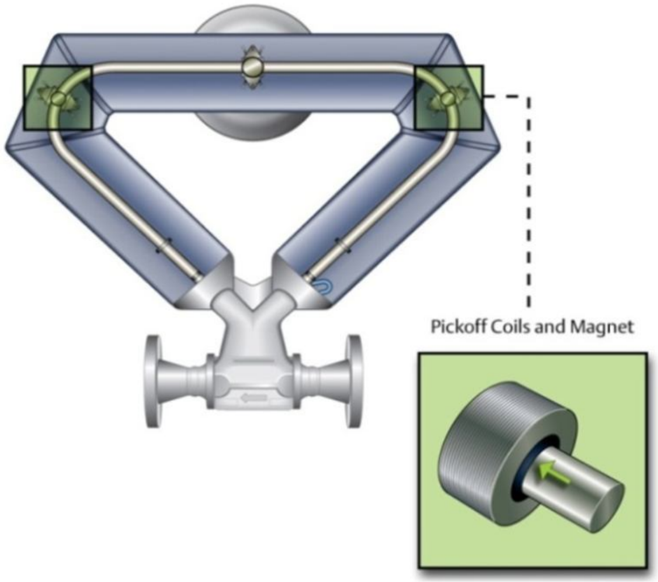


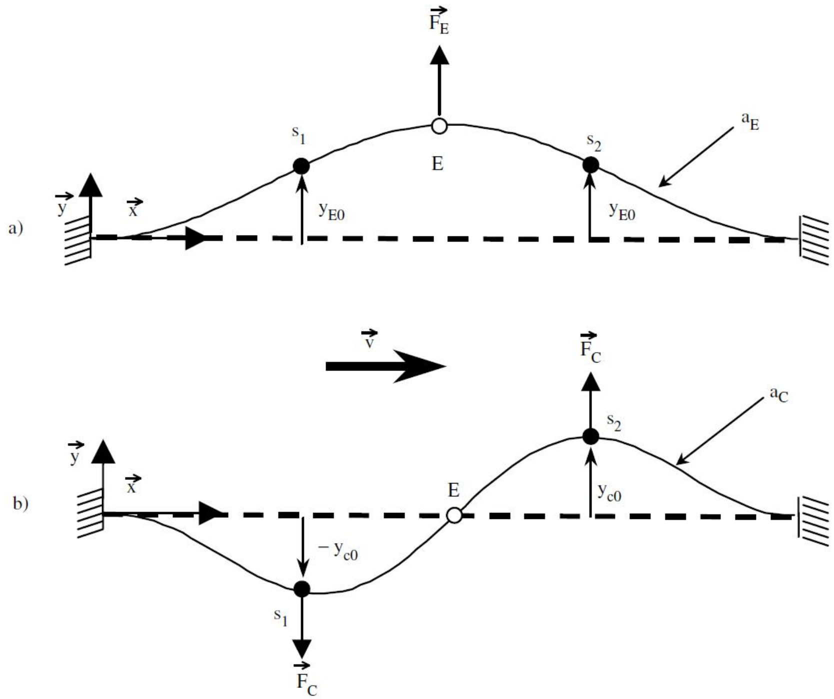
Coriolis Flow Meter

- Mass Flow sebanding dg time delay antara 2 flow detector (δt)
- Density sebanding dg frekuensi natural dari osilasi sistem
- Pada coriolis flowmeter amplituda osilasi dijaga konstan

Coriolis Flow Meter

- Flow Meter (δt)





$$\dot{m} = \frac{MEI}{l_t^3}\delta t$$

M = modal constant

E = modulus of elasticity, pound-force/in.^{2} (kPa)

I = moment of inertia, in.^{4} (cm^4)

Coriolis Flow Meter

- Densitometer ($T \sim f^{-1}$)

$$\omega_n = \sqrt{\frac{k}{m}} \qquad k = \frac{MEI}{I_t^3} \qquad m = \rho_f A_f l_t + \rho_t A_t l_t$$

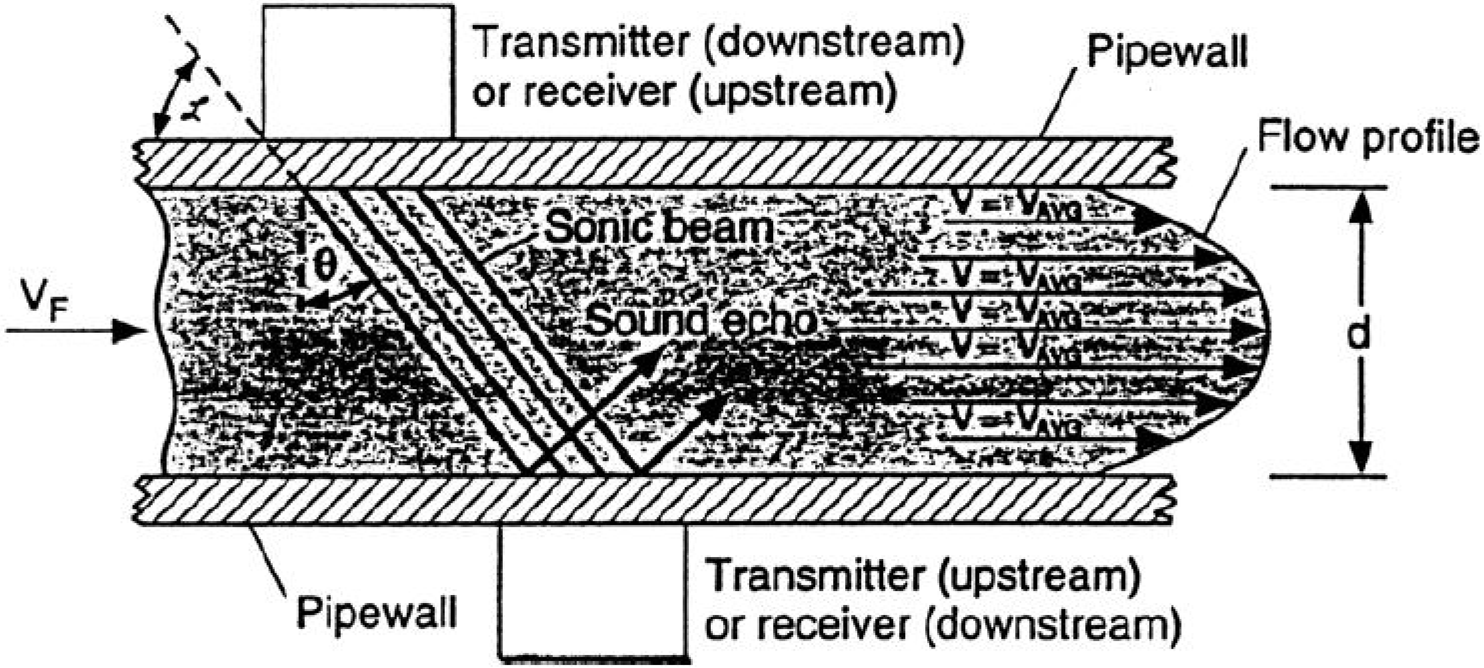
M = modal constant
E = modulus of elasticity, pound-force/in.^{2} (kPa)
I = moment of inertia, in.^{4} (cm^4)

$$\rho_f = \left(\frac{MEI}{4\pi^2 l_t^4 A_f}\right) T^2 - \frac{\rho_t A_t}{A_f} \qquad \rho_f = K_1 C_T T^2 - K_2$$

Ultrasonic Flow Meter

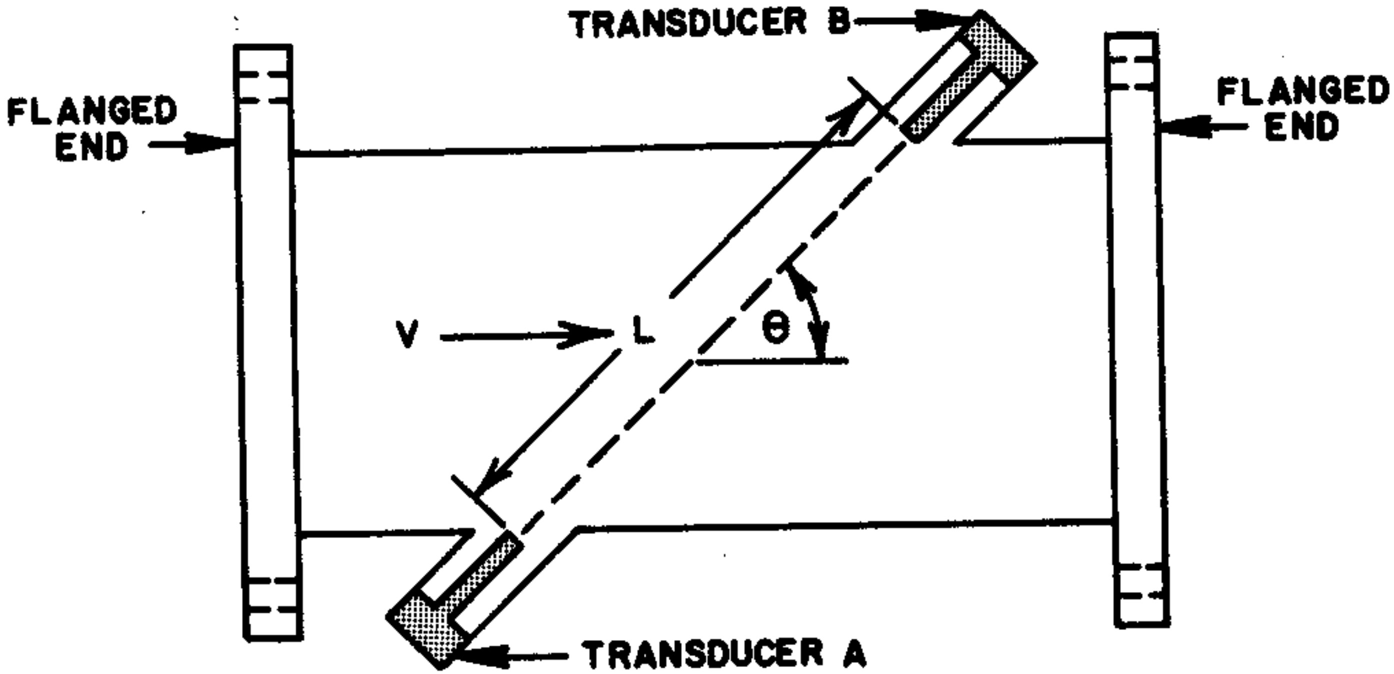
- Metode transit time
  - Pada ultrasonic flowmeter terdapat dua transducer (dari bahan piezoelectric) yg dipasang pada pipa secara bersebrangan.
  - Setiap transducer mengirim dan menerima gelombang ultrasonic (sekitar 1 MHz)
  - Perbedaan waktu transit dua gelombang ini digunakan untuk menghitung rata-rata kecepatan fluida.
  - Gelombang yg merambat searah dg aliran fluida, akan lebih cepat sampai ke receiver.

Ultrasonic Flow Meter



Ultrasonic Flow Meter

ULTRASONIC FLOW METER



- NON CONTACT FLOW METER
- MENGGUNAKAN KONSEP PENGARUH LAJU ALIRAN TERHADAP KECEPATAN GELOMBANG

ULTRASONIC FLOW METER

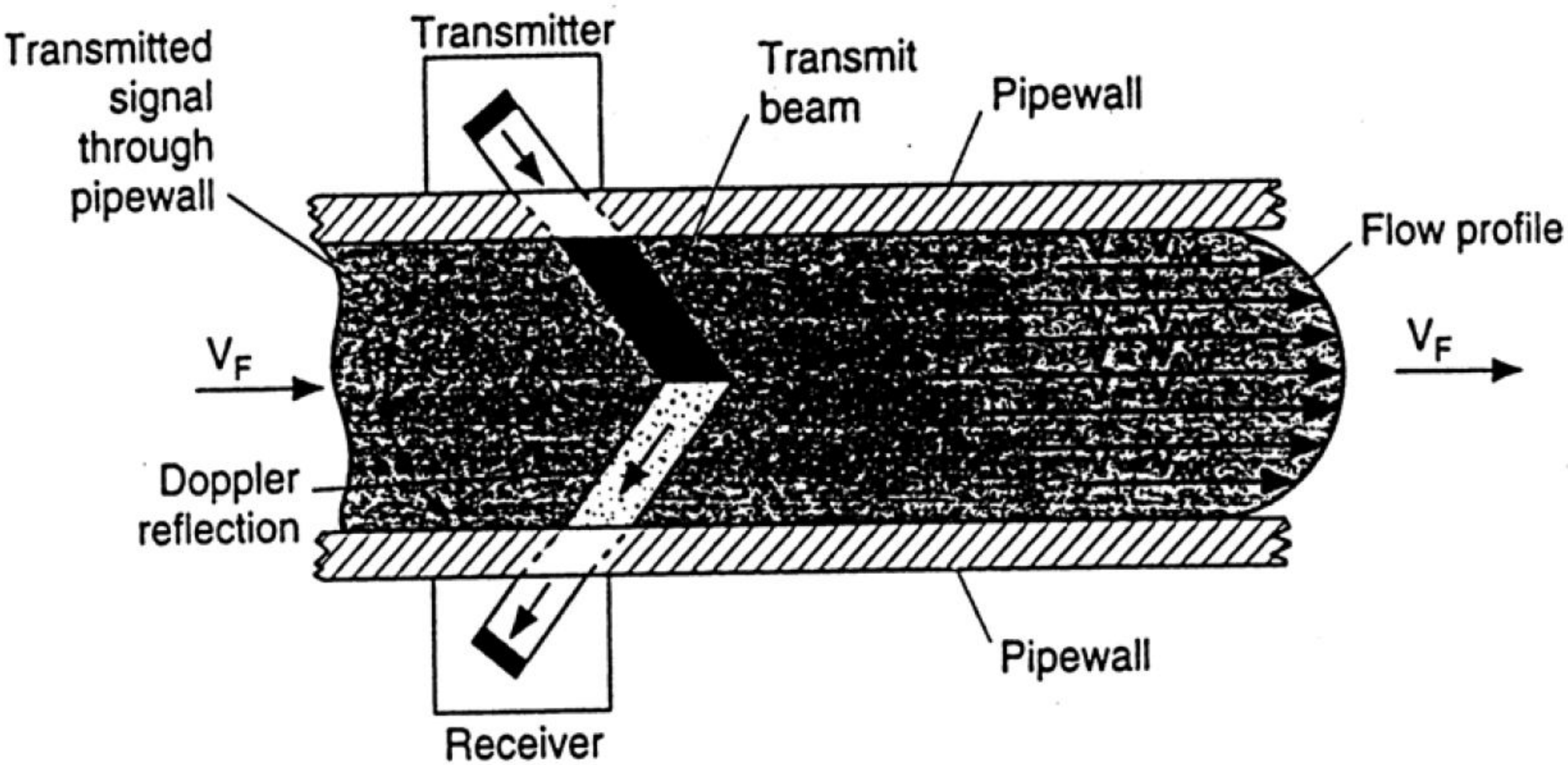
Ultrasonic Flow Meter

- Kelebihan
  - Pengukuran tidak mengganggu aliran didalam pipa
  - Dapat mengukur dua arah aliran dengan satu jenis instalasi
  - Tidak terpengaruh dengan perubahan temperatur proses
  - Cocok untuk fluida korosif dan pulsating flow (fluktuatif yg periodik)
  - Dapat dipasang dengan penjepitan pada pipa dan cocok untuk pengukuran aliran di pipa yg besar
- Kekurangan
  - Sangat bergantung pada Reynolds number (profil aliran)
  - Membutuhkan material pipa yg tidak berpori (hindari cast iron, cement dan fibreglass)
  - Perlu kalibrasi ulang secara periodik
  - Umumnya digunakan pada aplikasi dimana metode pengukuran aliran lain tidak applicable

Ultrasonic Flow Meter

- Metode doppler effect
  - Pada metode ini, aliran fluida mengandung reflective material, seperti partikel padat atau gelembung udara
  - Kebalikan dengan transit time ultrasonic, doppler effect flowmeter tidak dapat bekerja tanpa material reflektor. Transit time ultrasonic tidak bergantung pada ada tidaknya reflektor

Ultrasonic Flow Meter



Doppler-effect Ultrasonic Flow Meter

Ultrasonic Flow Meter

- Metode doppler effect
  - Kelebihan
    - Mudah dipasang, tanpa perlu melakukan shut down proses
    - Dapat digunakan untuk mengukur dua arah aliran
    - Tidak terpengaruh pada perubahan viskositas fluida
    - Cocok untuk pengukuran di pipa besar
    - Tidak menghambat aliran fluida
    - Harganya tidak tergantung dari ukuran pipa
  - Kekurangan
    - Energi suara yg merambat di pipa dapat menyebabkan error
    - Akurasinya bergantung apada perbedaan kecepatan antar partikel, fluida, dan juga ukuran partikel, konsentrasi dan distribusinya
    - Diperlukan kalibrasi ulang secara periodik

Pengukuran Level

- Pengukuran level didefinisikan sebagai pengukuran posisi permukaan batas dua media (misal : air dan udara)
- Satuan ukuran level dapat berupa unit panjang atau persentase. Dalam beberapa kasus level langsung dikonversi menjadi volume

II. SISTEM PENGUKURAN - LEVEL

METODE

- BEDA TEKANAN / DIFFERENTIAL PRESSURE
- BUBBLERS
- CAPACITANCE
- DISPLACER
- FLOAT LEVEL
- LEVEL GAUGE
- RADAR

PERBEDAAN TYPE PENGUKURAN LEVEL

Section	Instrument Type	LIQUIDS: Switches — Clean Fluid	LIQUIDS: Switches — Foam	LIQUIDS: Local Indicators — Accounting	LIQUIDS: Local Indicators — Standard	LIQUIDS: Self-Contained Local Controller — Clean	LIQUIDS: Self-Contained Local Controller — Hard-to-Handle	LIQUIDS: Transmitters — Clean	LIQUIDS: Transmitters — Hard-to-Handle	SOLIDS: Switches	SOLIDS: Transmitters
3.2	Antenna Level Sensors	G	—	—	—	—	—	P	P	G	P
3.3	Bubblers *	P–F	—	P–F	P–F	P–F	P–F	P–F	P–F	—	—
3.4	Capacitance Probes *	G	P–F	P–F	F	—	—	F	P–F	F	P–F
3.5	Conductivity Probes	F	P	—	—	—	—	—	—	P–F	—
3.6	Diaphragm Level Detectors	F	—	P	F	F	F	P–F	P	G	—
3.7	Differential Pressure Level Detectors *	G	—	F	G	G	F	G	F	—	—
3.8	Displacer Level Detectors *	E	—	F	G	E	P–F	E	P–F	—	—
3.9	Float Level Devices *	G	—	F	F	—	—	P–F	P	—	—
3.10	Impedance Probes	G	P–F	P–F	F	—	—	G	G	F	F
3.11	Level Gauges	—	—	F	G	—	—	—	—	—	—
3.12	Optical Level Switches	G	—	—	—	—	—	—	—	—	—
3.13	Radiation Level Sensors	G	—	G	—	—	—	G	E	E	G
3.14	Resistance Tapes	—	—	P	F	—	—	P	P	—	F
3.15	Rotating Paddle Switches	—	—	—	—	—	—	—	—	G	—
3.16	Slip Tubes	—	—	P–F	P–F	—	—	—	—	—	—
3.17	Tape Level Devices	G	—	E	G	—	—	G	P–F	—	F–G
3.18	Thermal Level Sensors *	G	—	—	—	—	—	—	—	—	—
3.19	Time Domain Reflectometry	—	—	—	—	—	—	—	—	—	—
3.20	Ultrasonic Level Detectors *	G	P–F	F	G	—	—	F	G	G	F
3.21	Vibrating Reed or Tuning Fork Switches	G	F	—	—	—	—	—	—	G	—

E—Excellent G—Good F—Fair P—Poor

BEDA TEKANAN

KONSEP

- **TEKANAN DI BAWAH CAIRAN SEBANDING DENGAN KETINGGIAN CAIRAN**

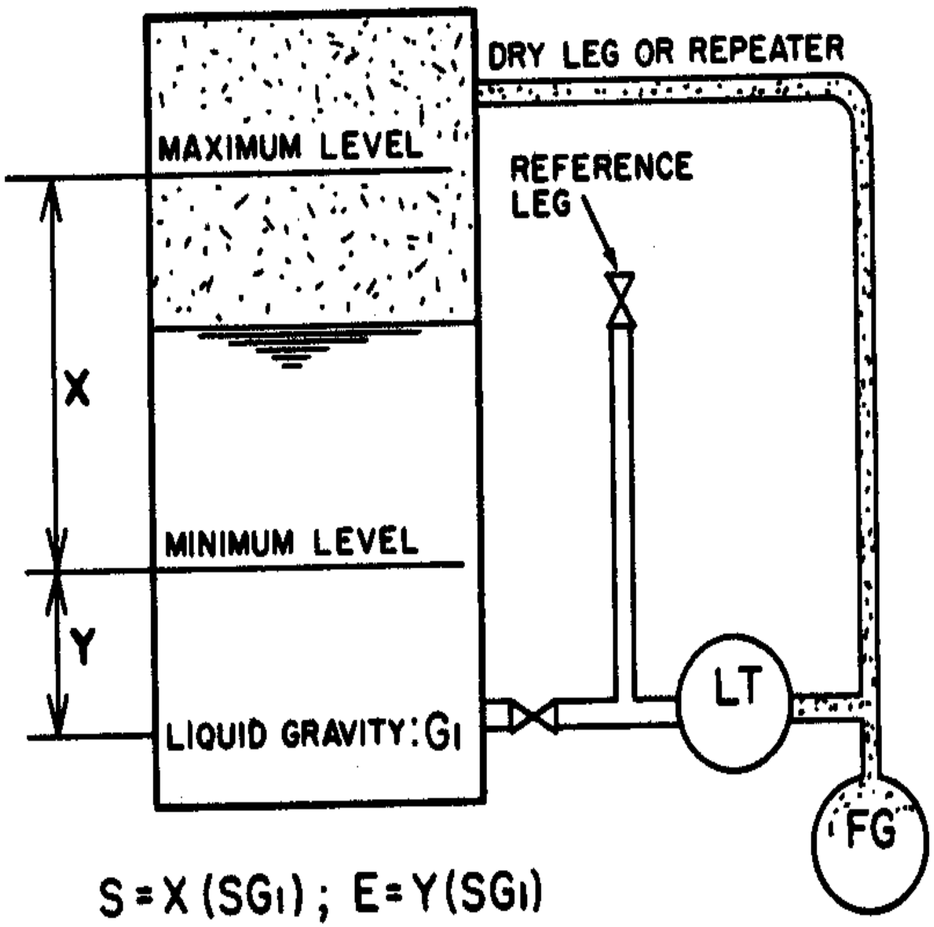
$$\triangle P\ (P2-P1) = K\ (H)$$

$\triangle$P (P2-P1) : BEDA TEKANAN

K : KONSTANTA SEBAGAI FUNGSI DARI DENSITY

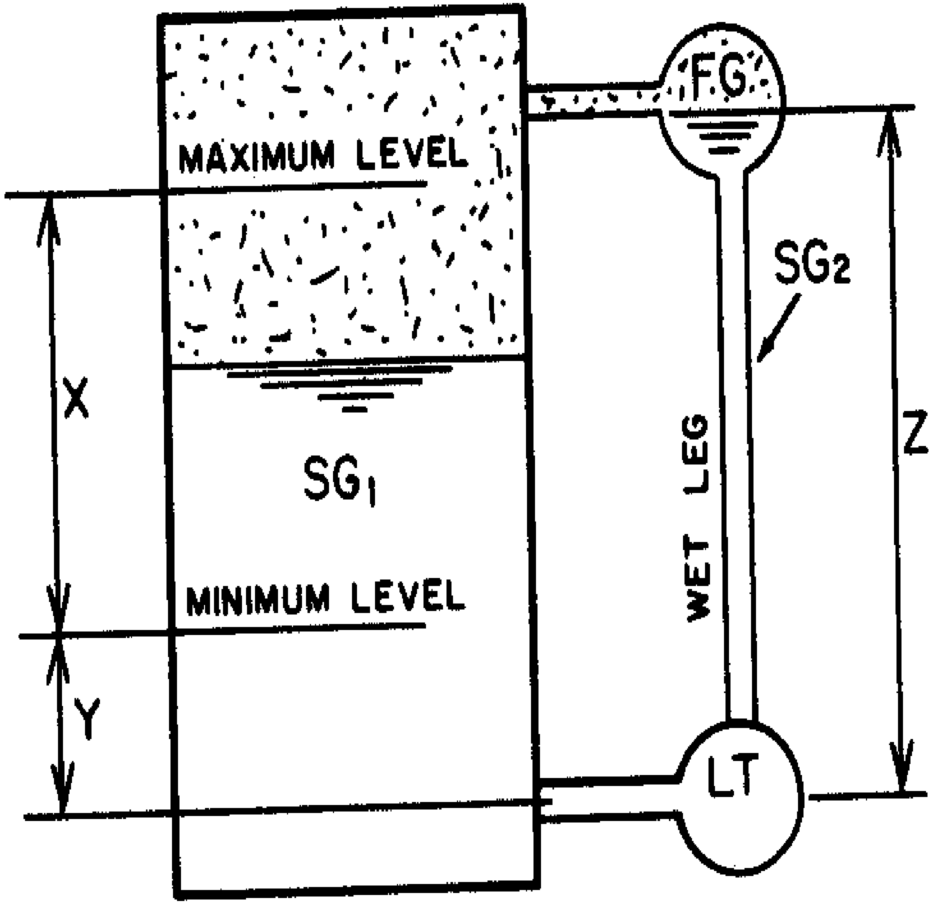
H : TINGGI PERMUKAAN CAIRAN

BEDA TEKANAN



SPAN : X * SG1
ZERO : Y * SG1

BEDA TEKANAN



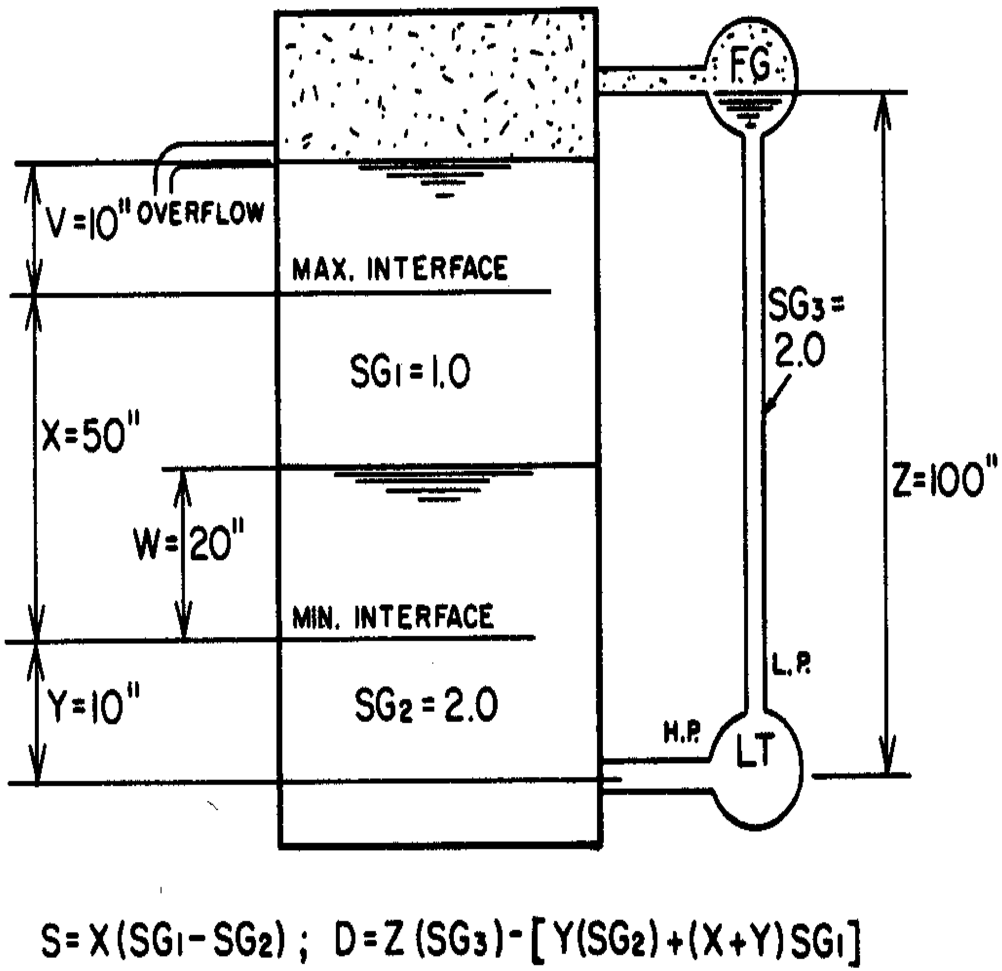
WET LEG : TAPPING ATAS BERISI CAIRAN

- **UNTUK MENGHINDARI KESALAHAN PENUNJUKAN AKIBAT OVER FLOW**

SPAN : X* (SG1)

ZERO : Y*SG1 – Z*SG2

BEDA TEKANAN

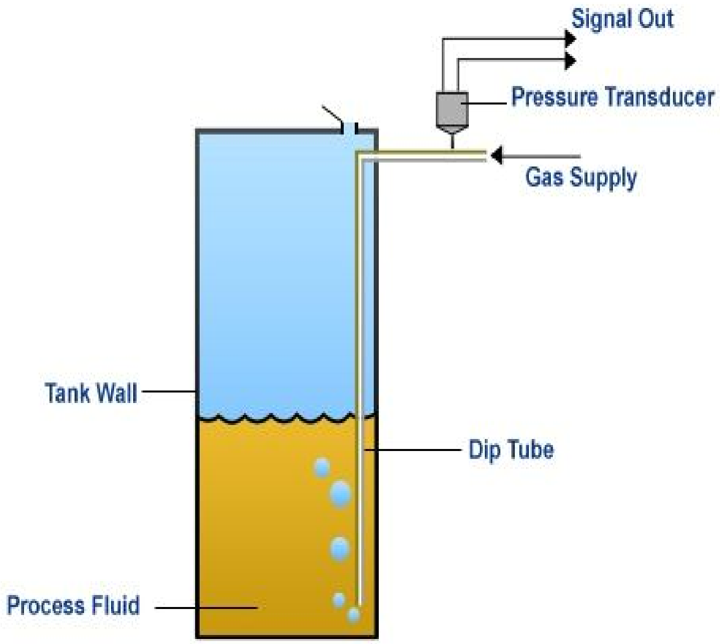


SPAN : X*(SG1-SG2)

ZERO (DEPRRESSION):

Z*SG3 - [(Y*SG2) + (X+Y)*SG1)]

BUBBLER



Bubbler Type Level Measurement Device

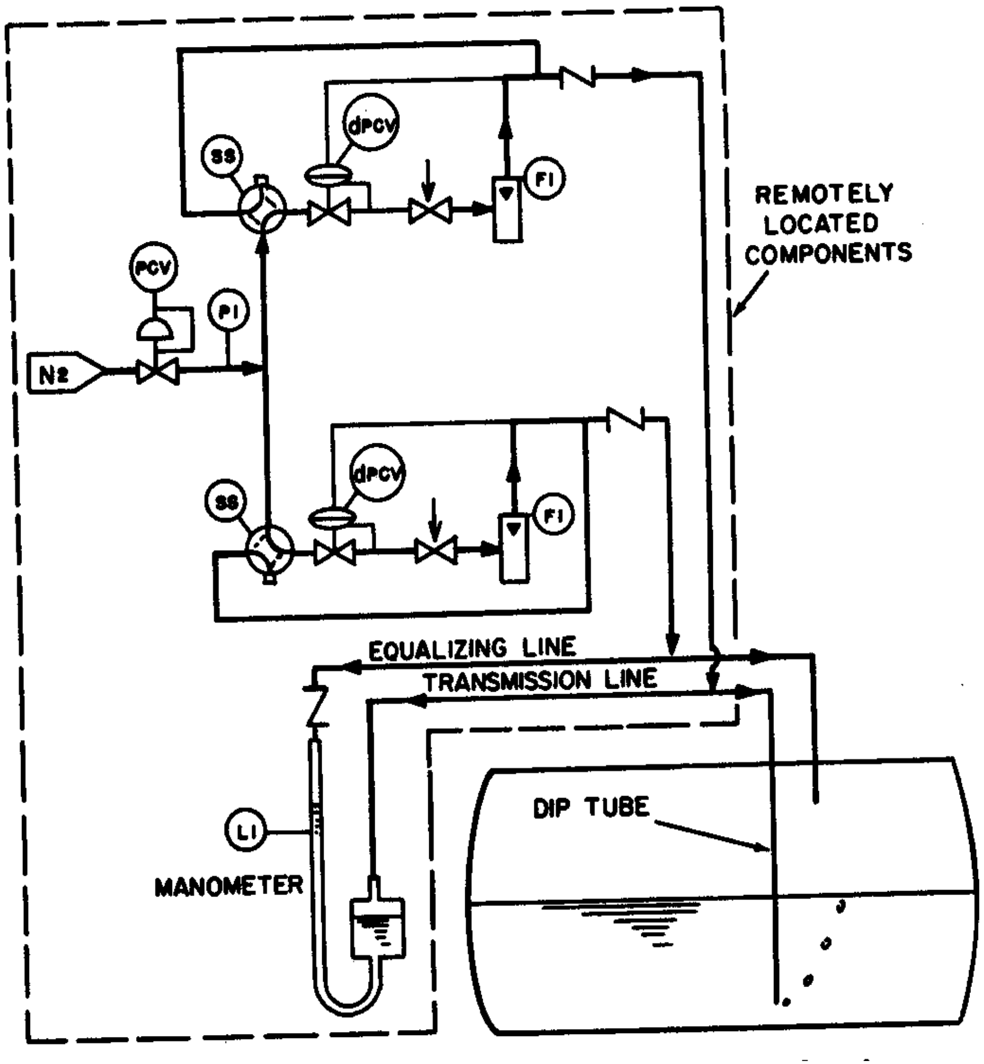
DIGUNAKAN DI

- **LNG TANK**
- **SUMP**

KONSEP :

- **BEDA TEKANAN**

BUBBLER



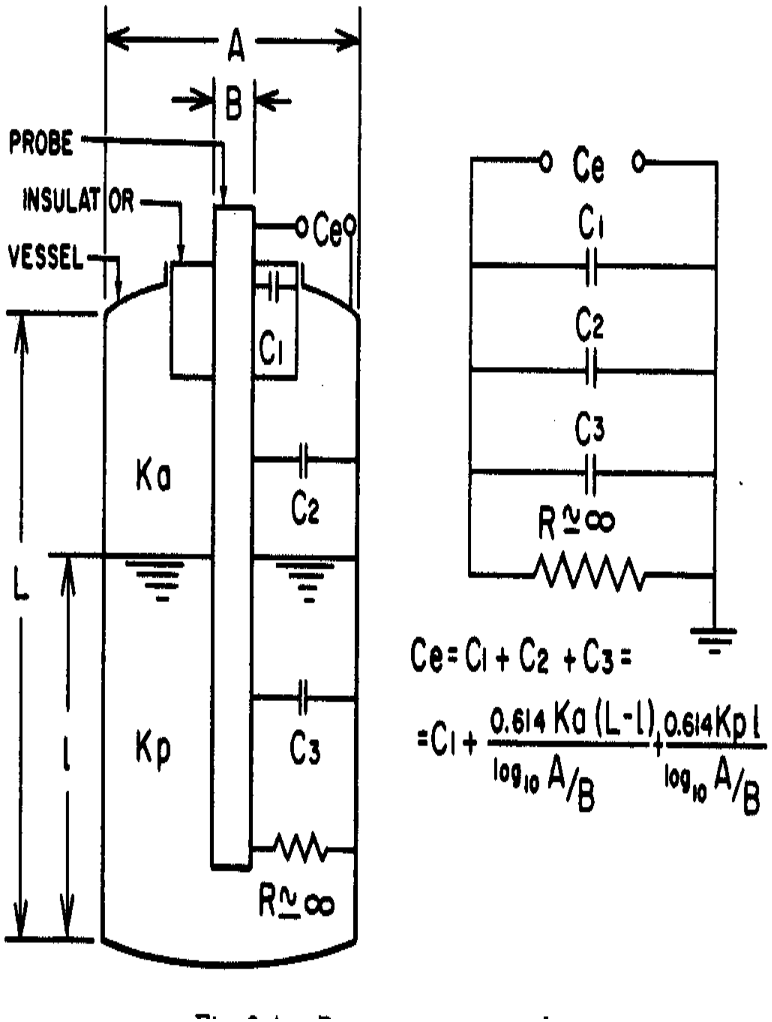
DIGUNAKAN DI

- LNG TANK
- SUMP

KONSEP :

- BEDA TEKANAN

CAPACITANCE



DIGUNAKAN DI

- TANKI KAPAL LNG

KONSEP :

- HARGA KAPASITANSI BERGANTUNG PADA CAPACITANCE PLATE PADA CAIRAN DI-ELECTRIC

C = FUNGSI DARI K, A, B, X

K : KONSTANTA DI-ELECTRIC

A : DIAMETER SILINDER LUAR

B : DIAMETER SILINDER DALAM

X : PANJANG SILINDER

DISPLACER

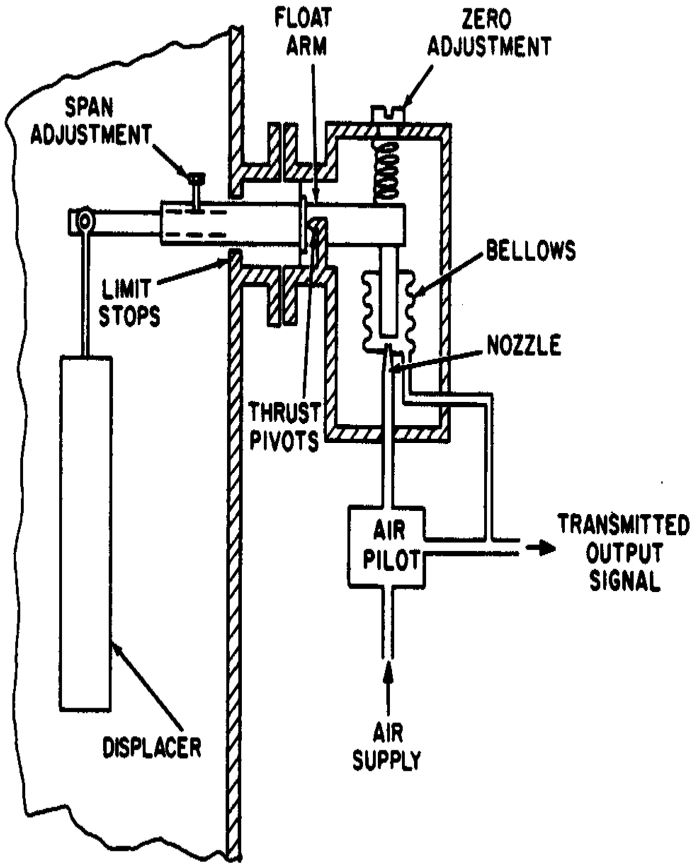


Fig. 3.8h Flexible disc sealed displacement transmitter

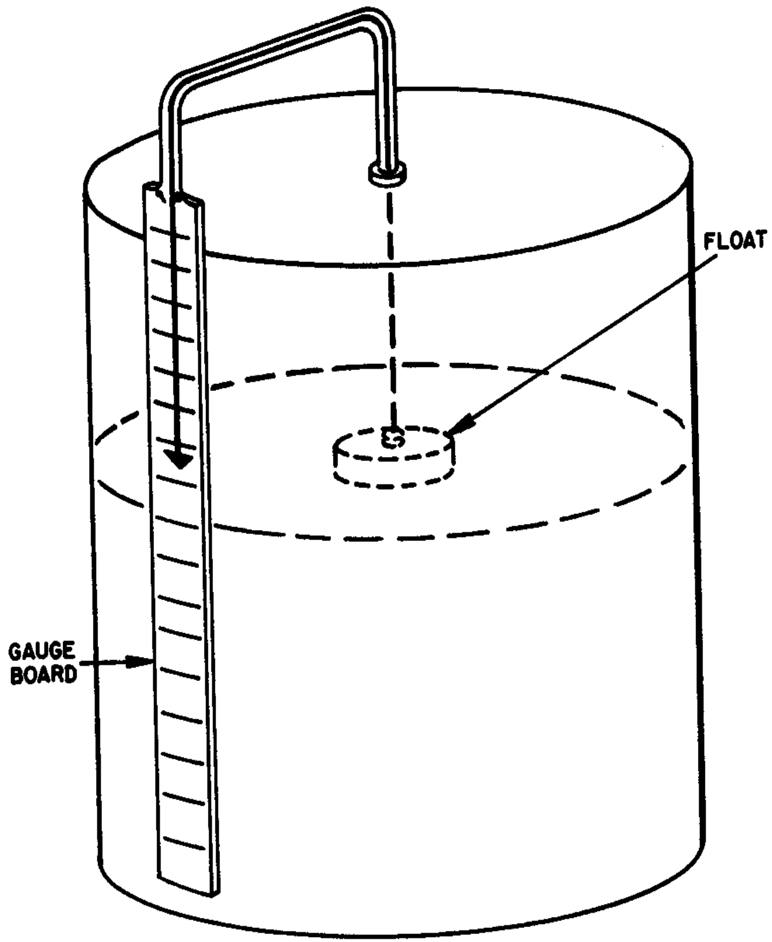
DIGUNAKAN DI

- **UNTUK LEVEL SWITCH**

KONSEP :

- **GAYA ANGKAT CAIRAN**

FLOAT LEVEL



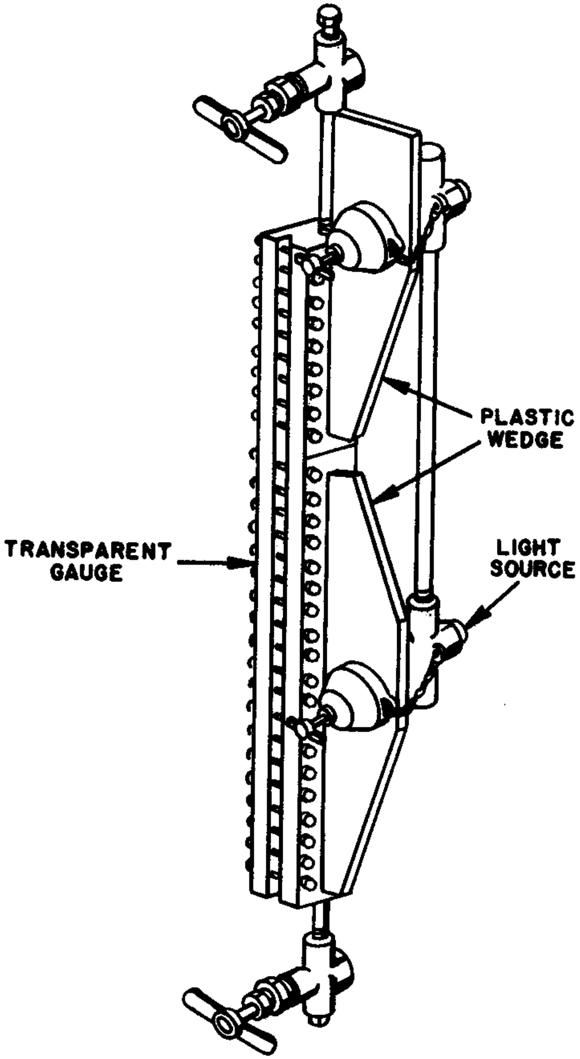
DIGUNAKAN DI

- **UNTUK TANKI BESAR**

KONSEP :

- **GAYA ANGKAT CAIRAN**

LEVEL GAUGE



DIGUNAKAN DI

- **UNTUK VISUAL INDIKASI**
- **HANYA FIELD MONITOR**

Pengukuran Level

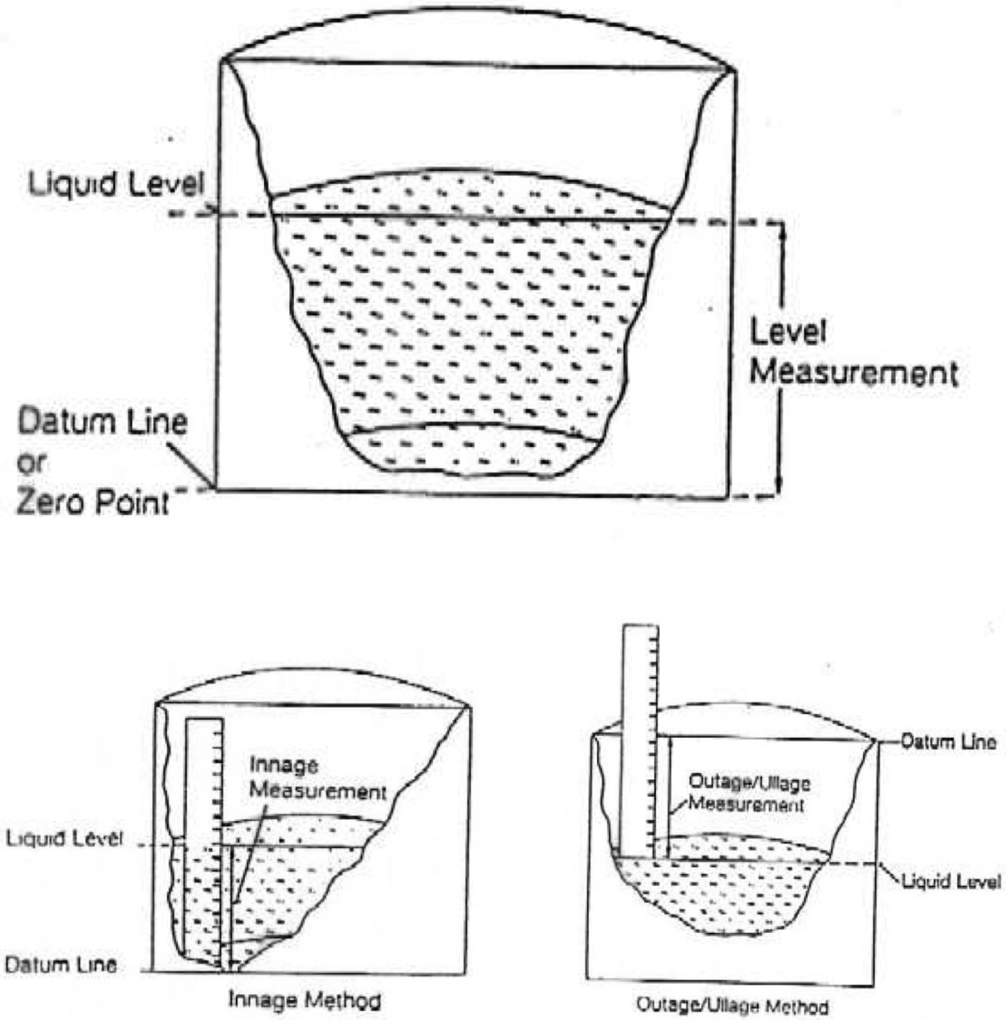


Figure 1

Pengukuran Level

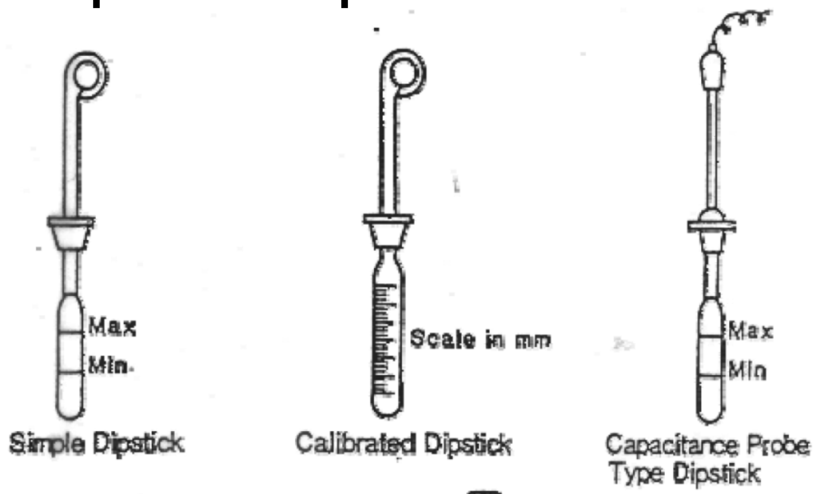
- Pengukuran level dapat dilakukan dengan 3 cara :
  - Mengukur posisi (ketinggian) permukaan zat cair
  - Mengukur pressure head (tekanan fluida)
  - Mengukur berat
- Cara ukur ini dapat dikelompokan lagi menjadi:
  - Metode langsung
  - Metode tidak langsung

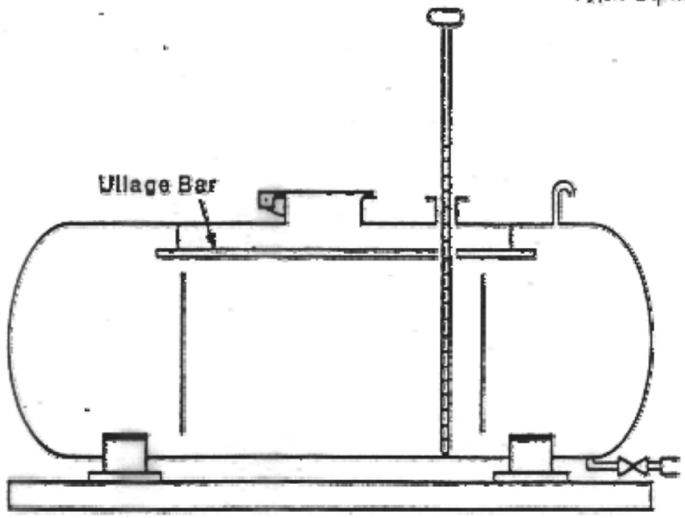
Pengukuran Level

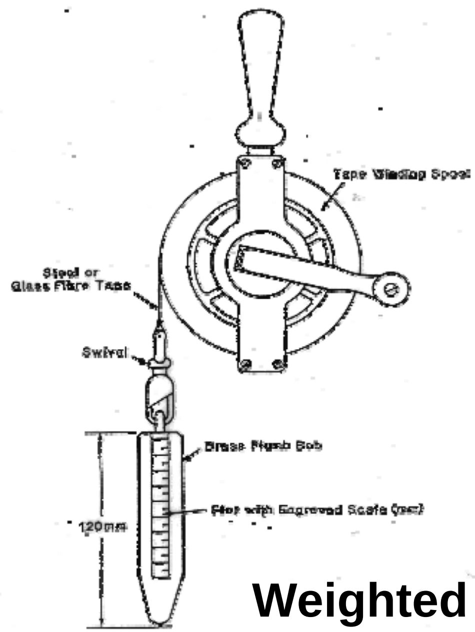
- Metode langsung banyak digunakan pada aplikasi yg perubahan levelnya lambat (tanki2 besar)
- Metode ini sederhana, reliable, low cost dan cocok untuk hazardous area.
- Terdapat empat jenis pengukuran level yg menggunakan metode langsung :
  - Dip-stick & Dip-rods
  - Weighted gauge tape (pita dengan bandul)
  - Sight glasses
  - Float (pelampung)

Pengukuran Level

Dipstick & Diprod



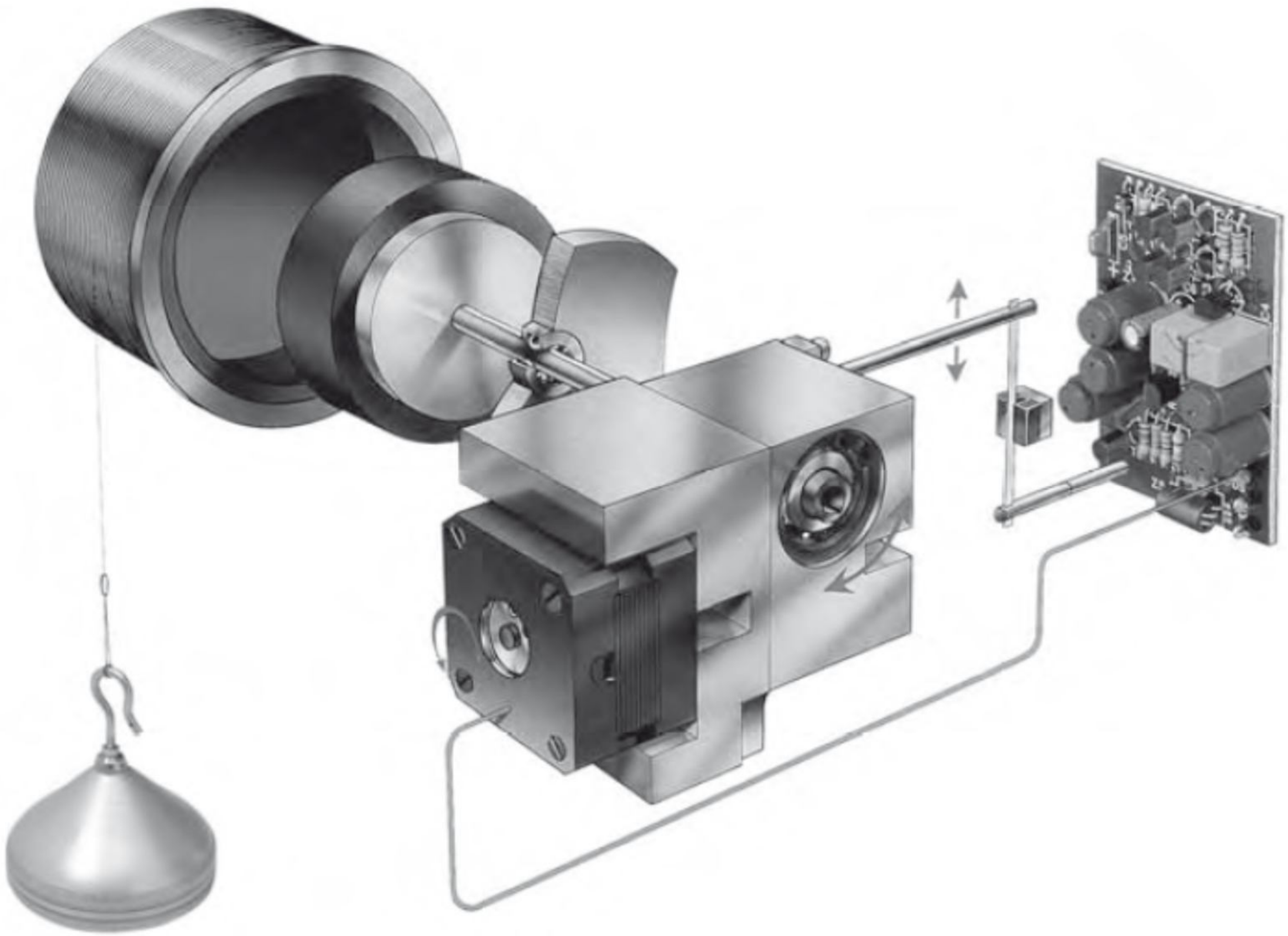




Weighted Gage Tape

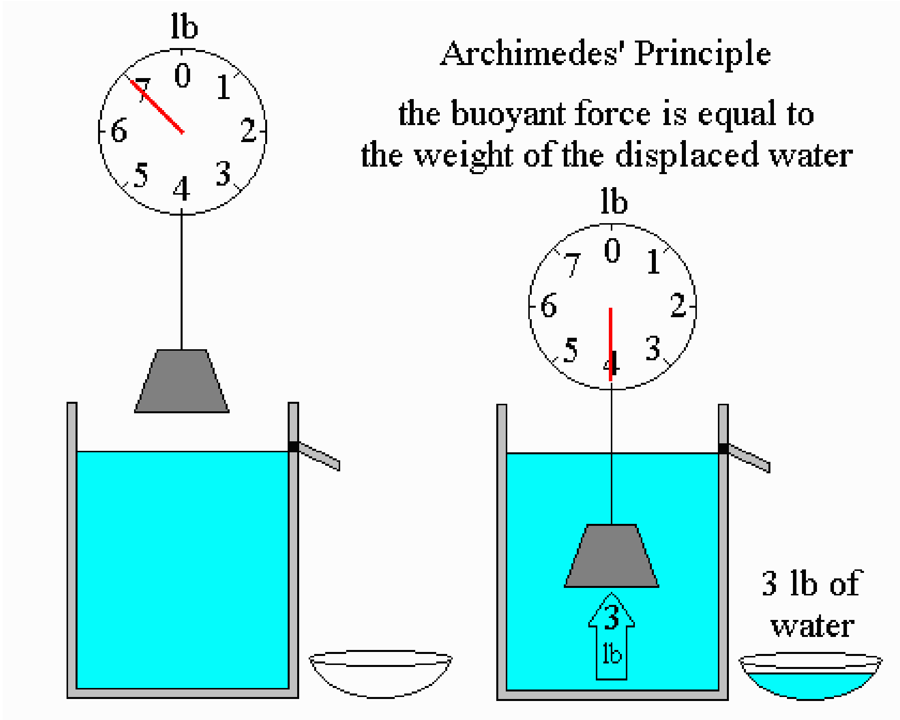
Pengukuran Level

Automatic Tank Gauging



Pengukuran Level

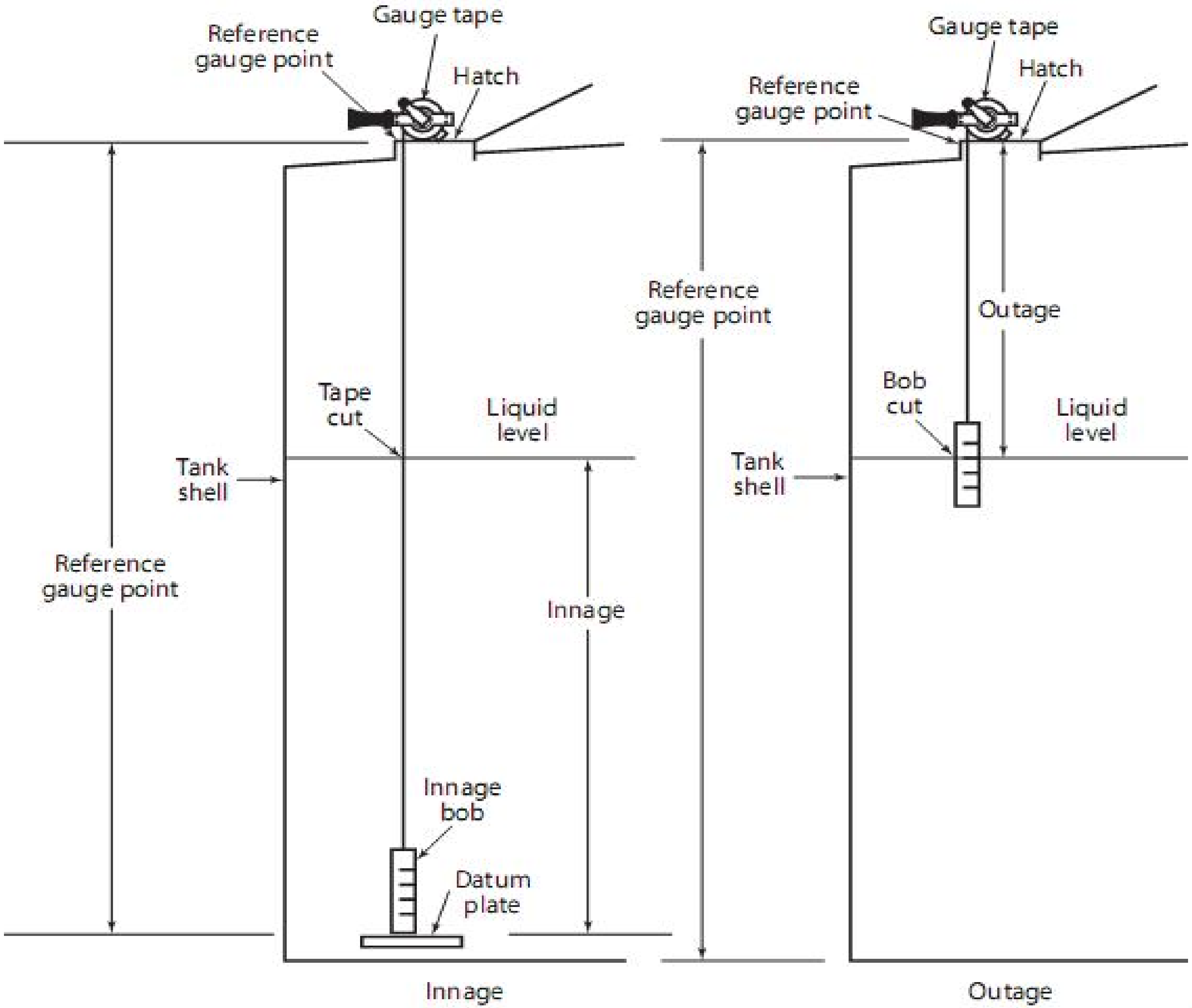
Automatic Tank Gauging



KETIKA SEBUAH BENDA DICELUPKAN KE DALAM SUATU CAIRAN, MAKA BENDA ITU AKAN MENDAPAT TEKANAN KEATAS YANG SAMA BESARNYA DENGAN BERATNYA CAIRAN YANG TERDESAK OLEH BENDA TERSEBUT

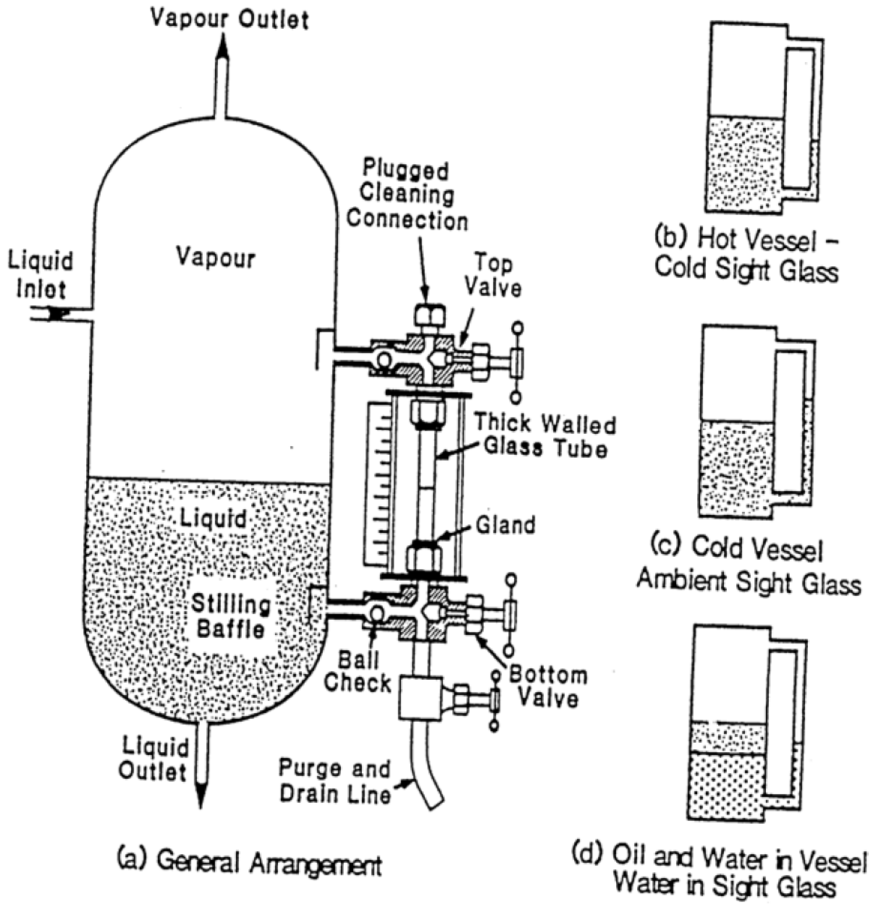
Pengukuran Level

Automatic Tank Gauging



Pengukuran Level

Sight Glass



Pengukuran Level

Sight Glass

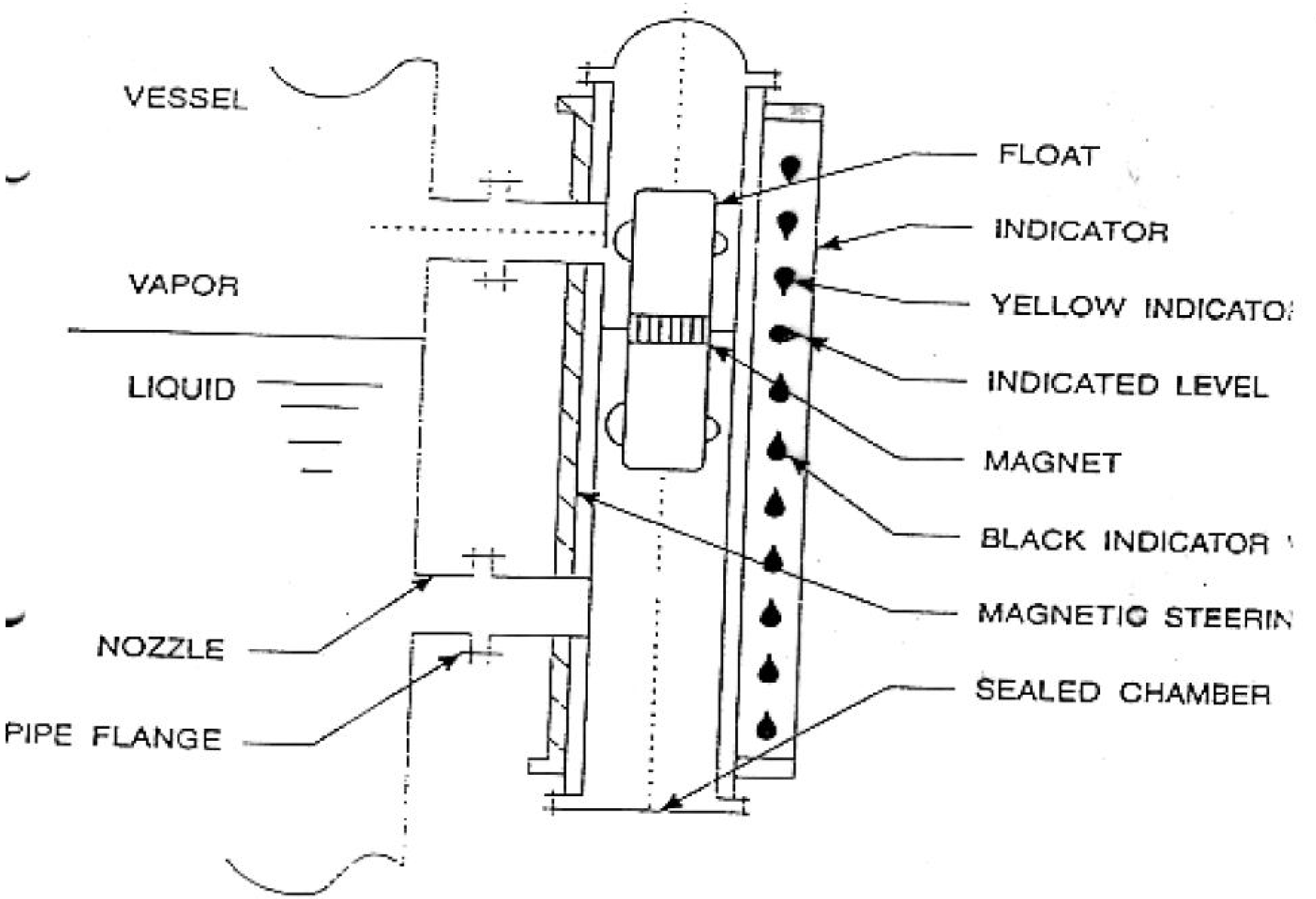


Figure 7. Magnetic type Sight gauges

Pengukuran Level

Float

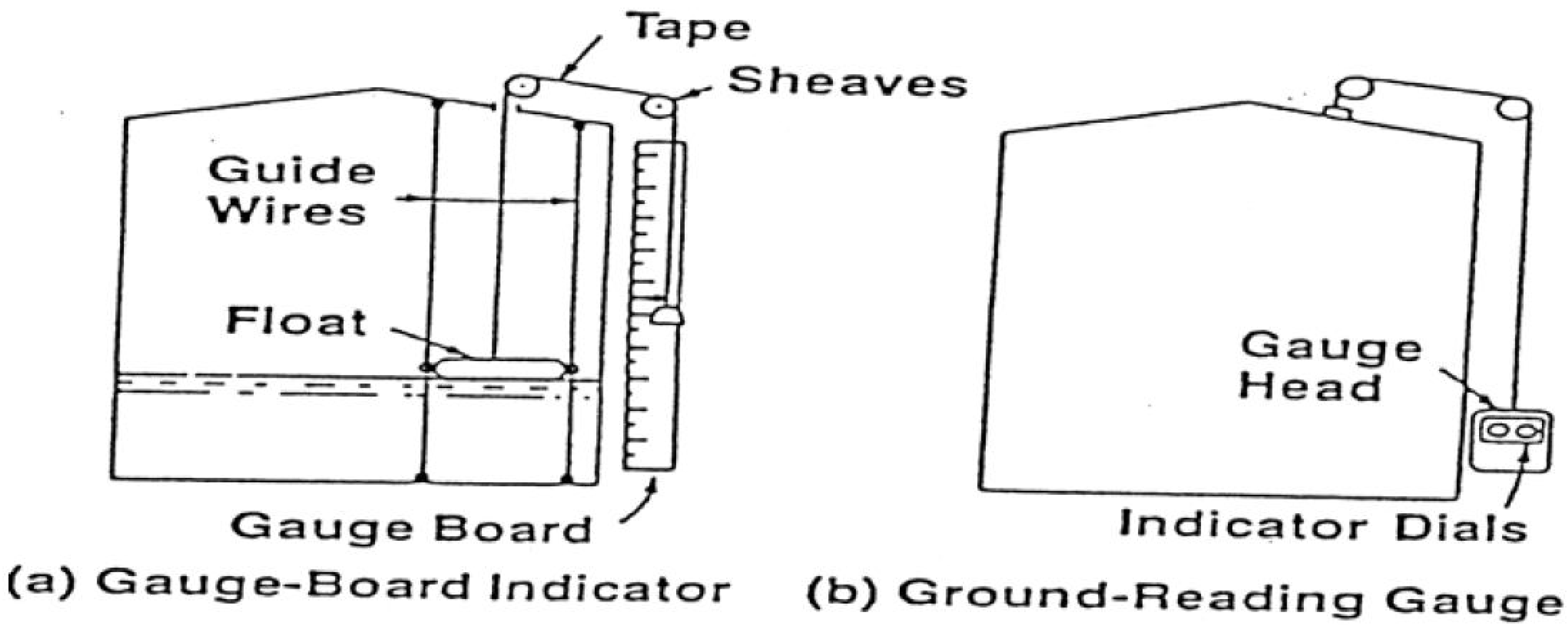


Figure 8. Weighted Tank Gauge using Float Type

Pengukuran Level

Float

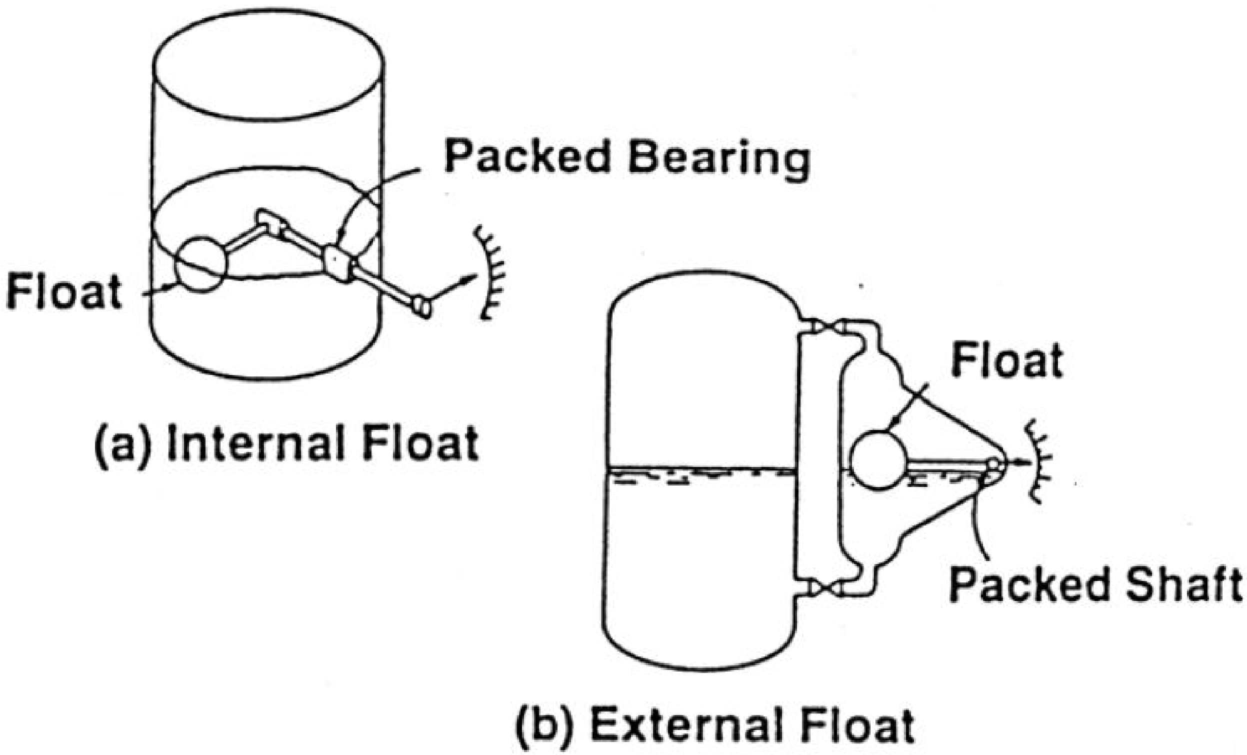
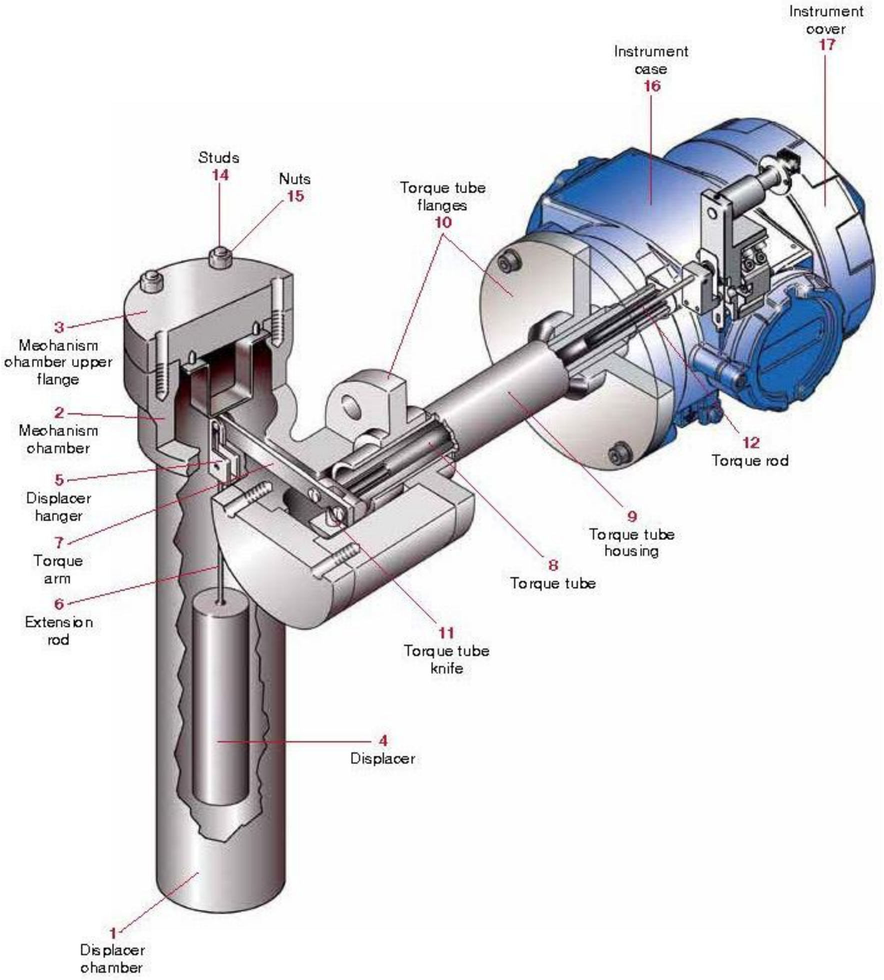
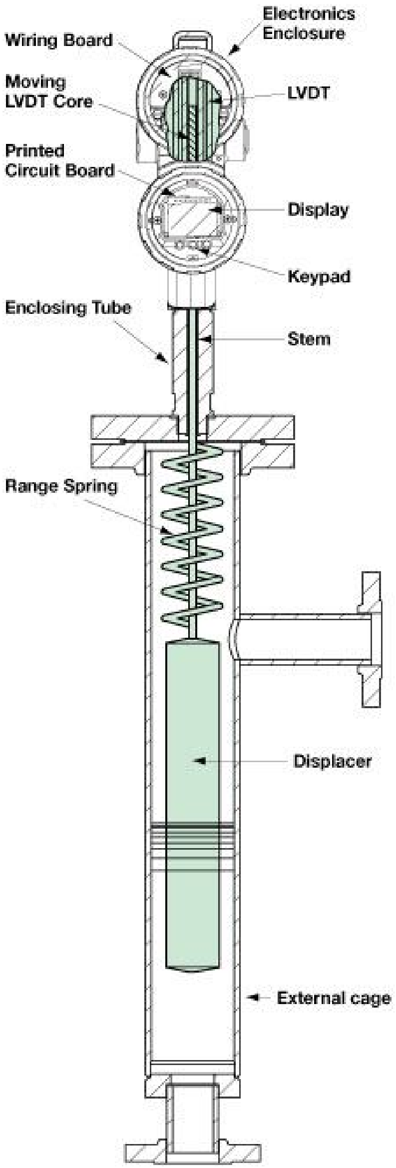


Figure 9. Floats for Level Indication

Pengukuran Level

Displacer





Pengukuran Level

Indirect Method

$P = \rho g h$

P is the static head pressure,

ρ is the density of the liquid,

G is the specific gravity of the liquid,

H is the height of the liquid

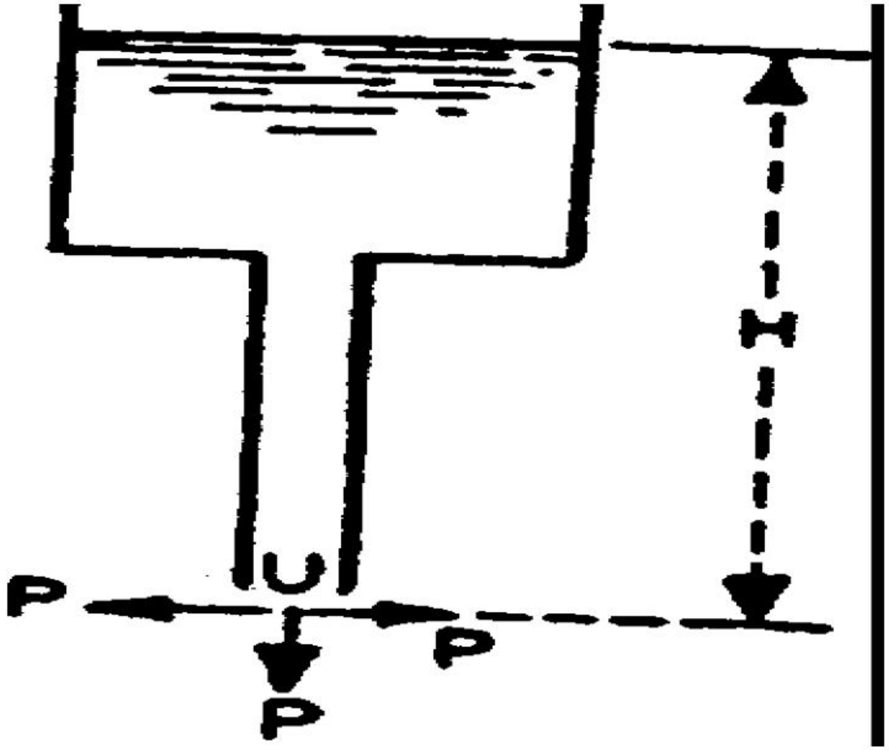


Figure 10. Basic elements of hydrostatic head

Pengukuran Level

Hydrostatic Head Open Vessel

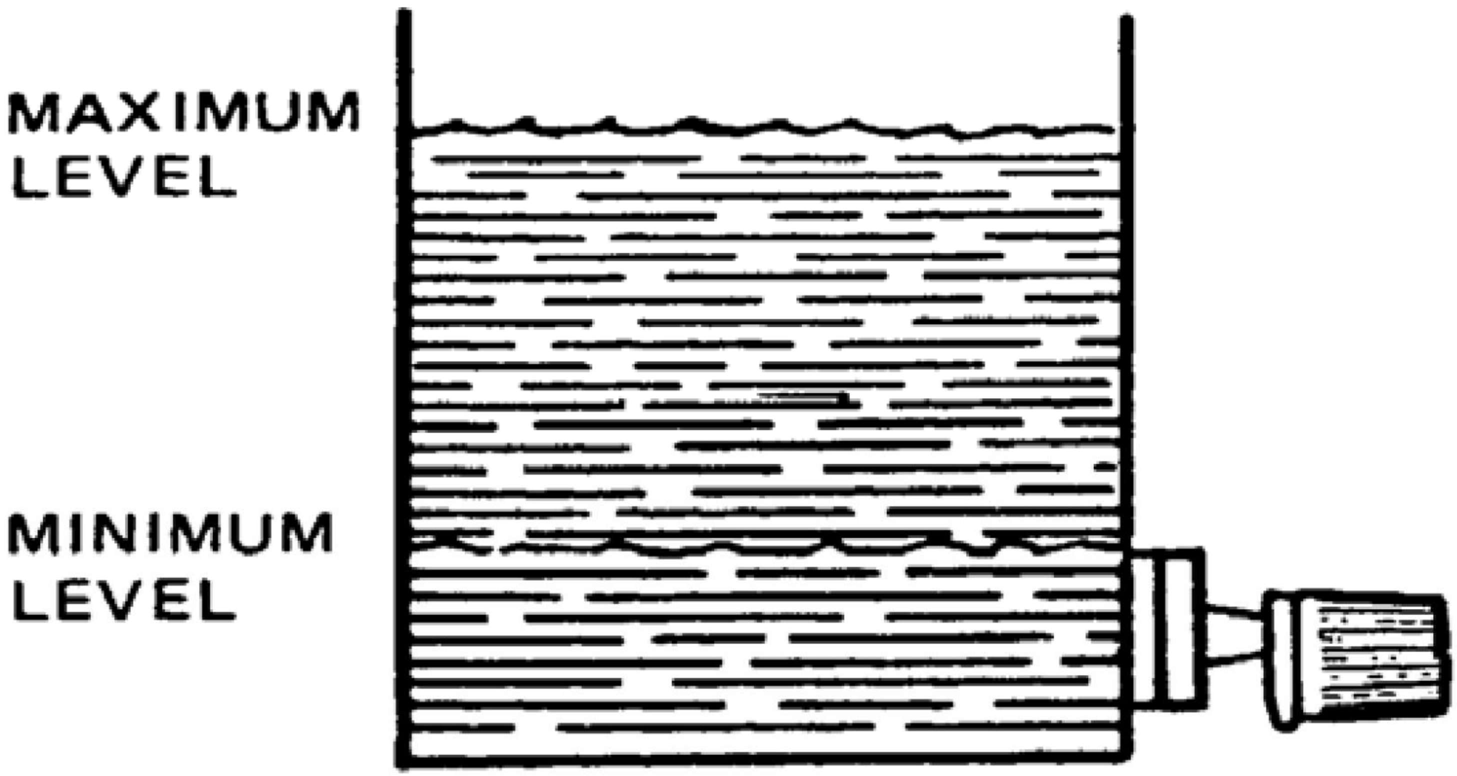
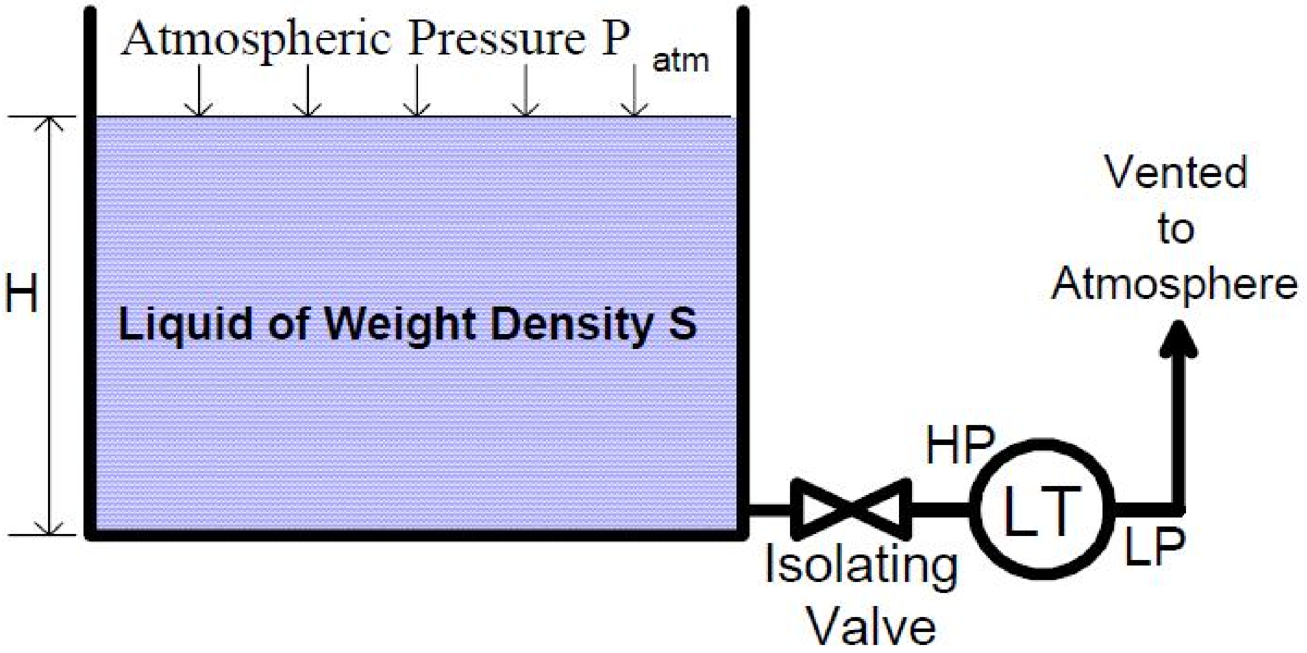


Figure 11. Diaphragm-box Transmitter

Pengukuran Level

Hydrostatic Head Open Vessel



$P_{high} = P_{atm} + S \cdot H$

$P_{low} = P_{atm}$

Differential pressure $\Delta P = P_{high} - P_{low} = S \cdot H$

Pengukuran Level

Hydrostatic Head Open Vessel

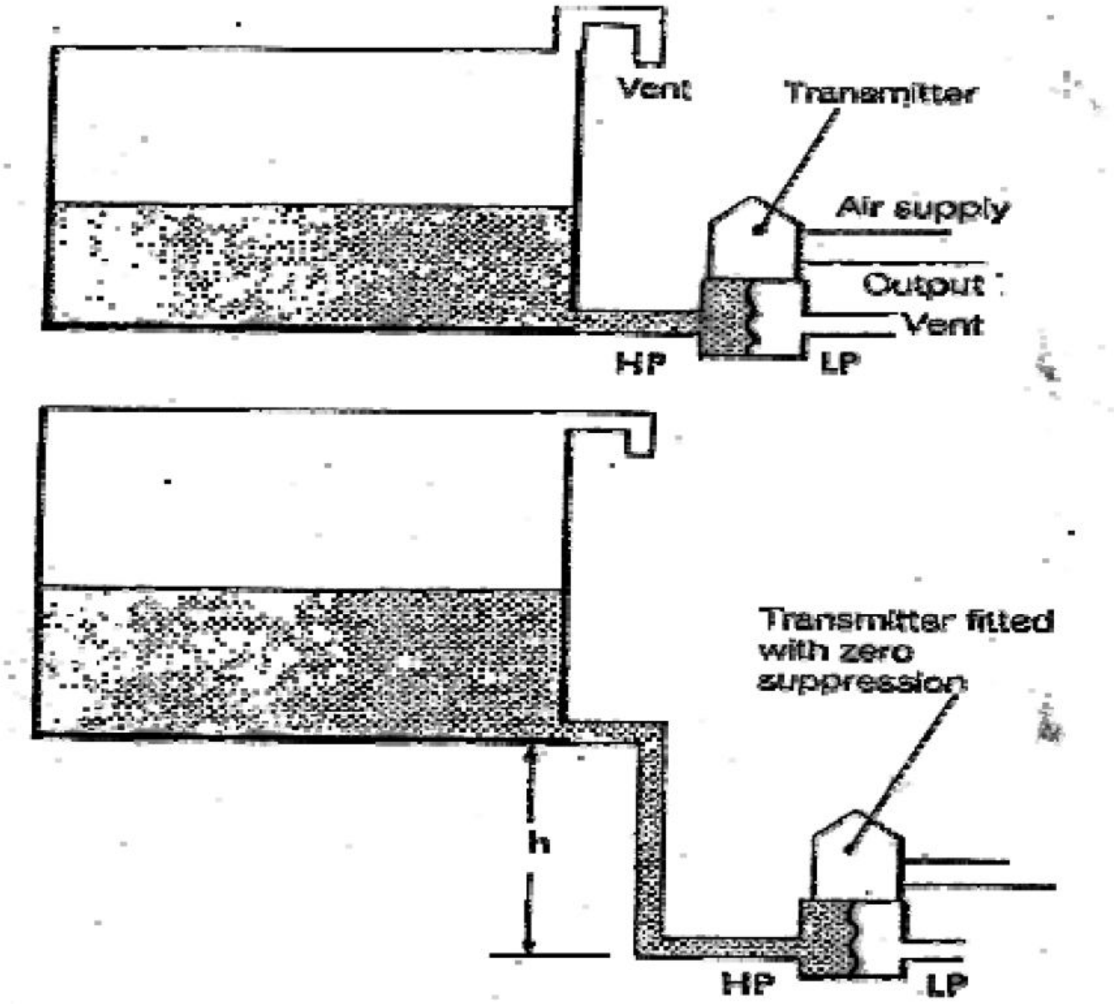


Figure 13. DP Transmitter installed for an Open Tank

Pengukuran Level

Hydrostatic Head Open Vessel

- Zero Suppression & Zero Elevation
  - Jika DP Cell dipasang **dibawah** / **diatas** dasar tanki, maka diperlukan zero **suppression** / zero **elevation** adjustment pada transmitter.

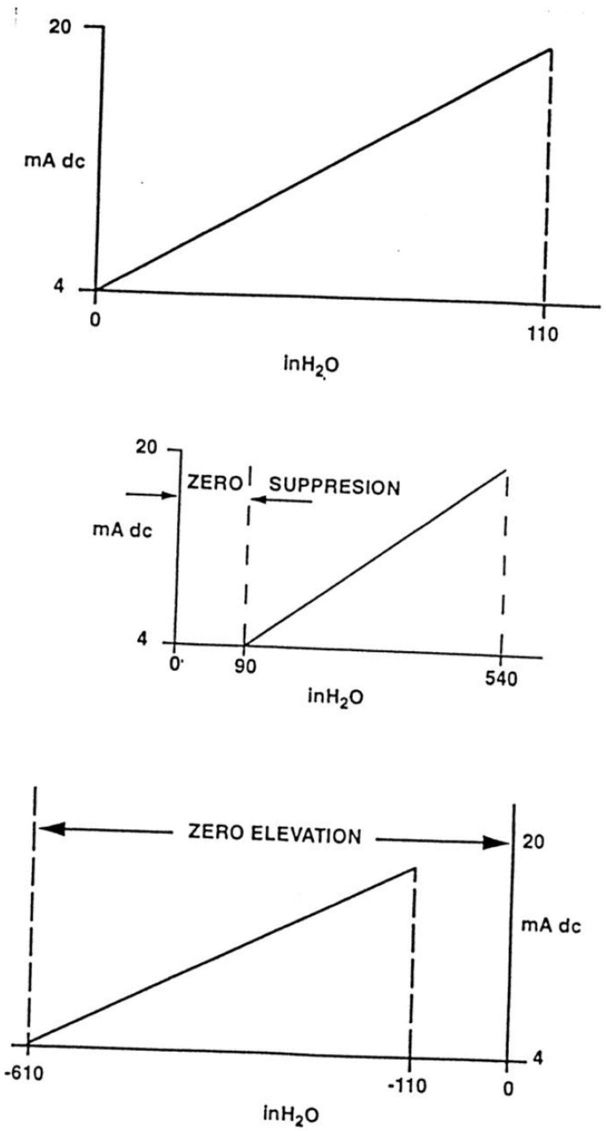


Figure 14. Zero Suppression & Zero Elevation

Pengukuran Level

Hydrostatic Head Closed Vessel

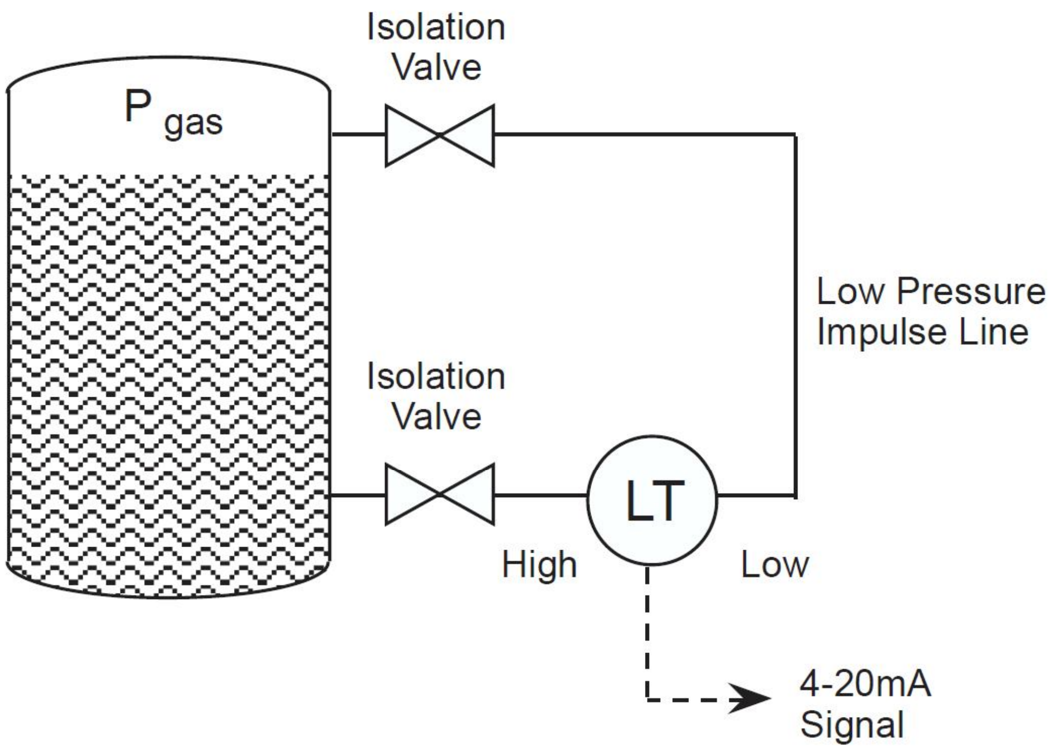


Figure 3
Typical Closed Tank Level Measurement System

Pengukuran Level

Hydrostatic Head Closed Vessel

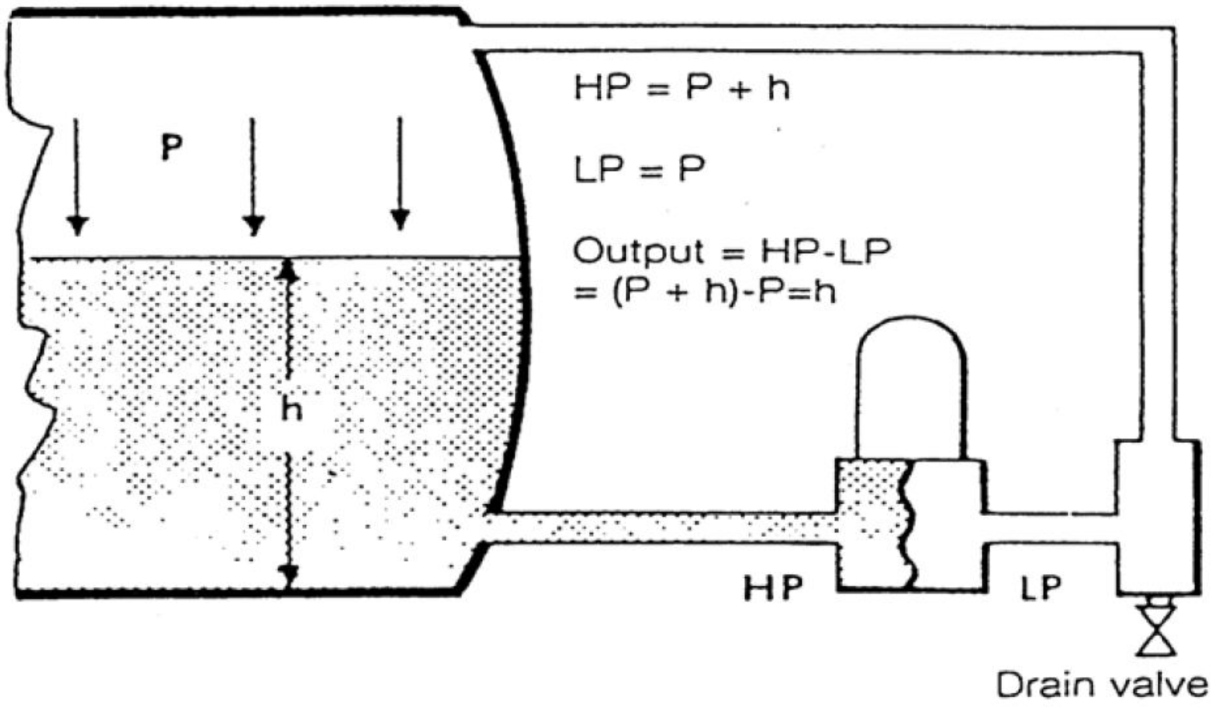


Figure 15. Dry leg, DP cell installed at the datum line

Pengukuran Level

Hydrostatic Head Closed Vessel

$$\text{Output} = [P\ (Sg_{\text{vapour}}) + h\ (Sg_{\text{liquid}})] - [P\ (Sg_{\text{vapour}}) + Z\ (Sg_{\text{leg}})]$$

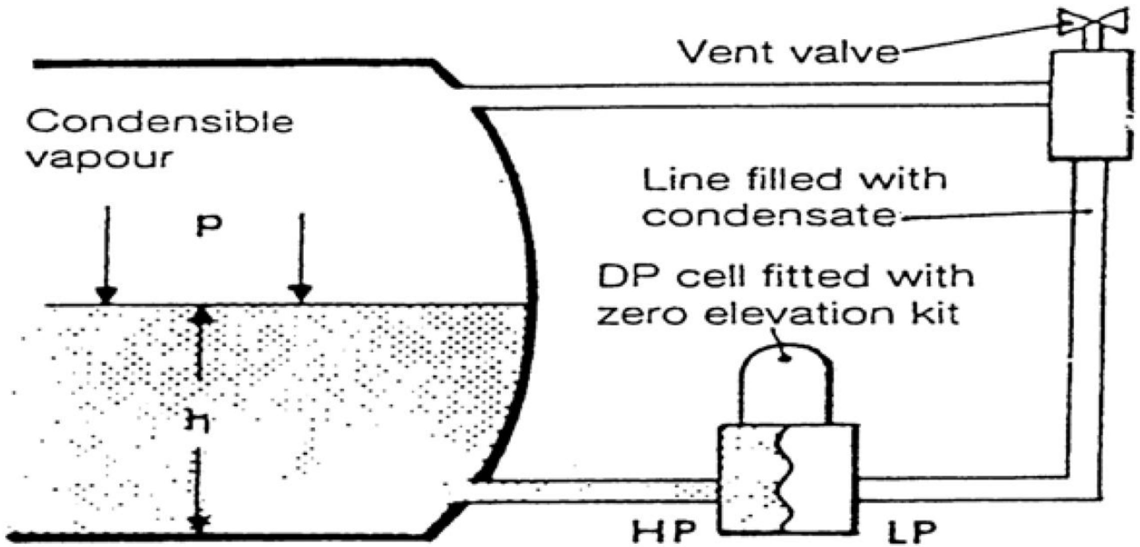


Figure 17. Wet leg, DP cell is installed at the datum line.

Pengukuran Level

Hydrostatic Head Closed Vessel

- Calibration Formula

$$\text{Span} = (x)(Gl)$$

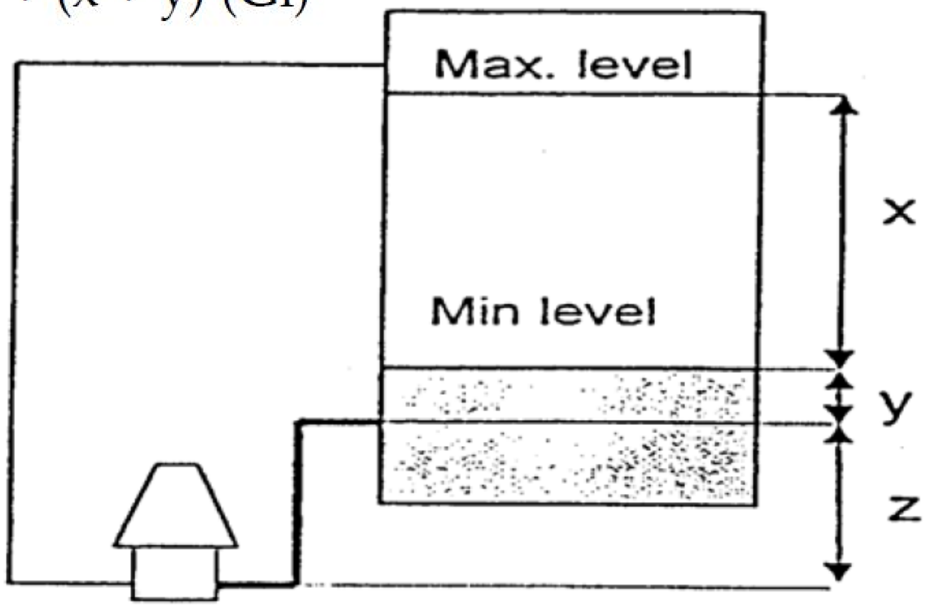
$$\text{LRV at minimum level} = (z)(Gs) + (y)(Gl)$$

$$\text{URV at maximum level} = (z)(Gs) + (x + y)(Gl)$$

Gl = Specific gravity of tank liquid

Gs = Specific gravity of seal liquid

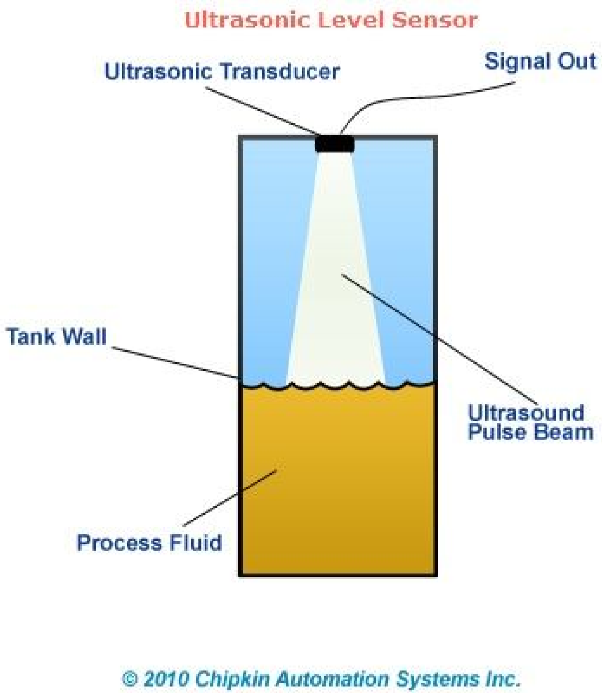
x, y and z are shown In figure 16.

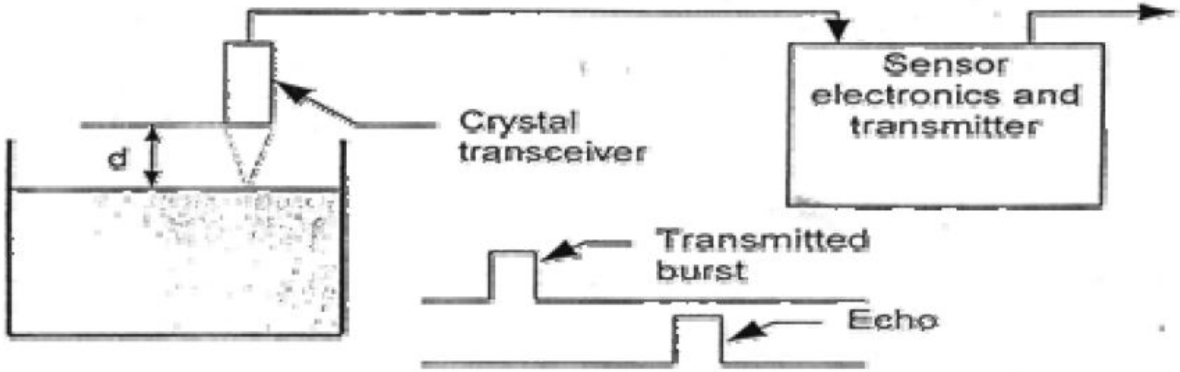


Dry Leg
Requires zero suppression

Pengukuran Level

Ultrasonic



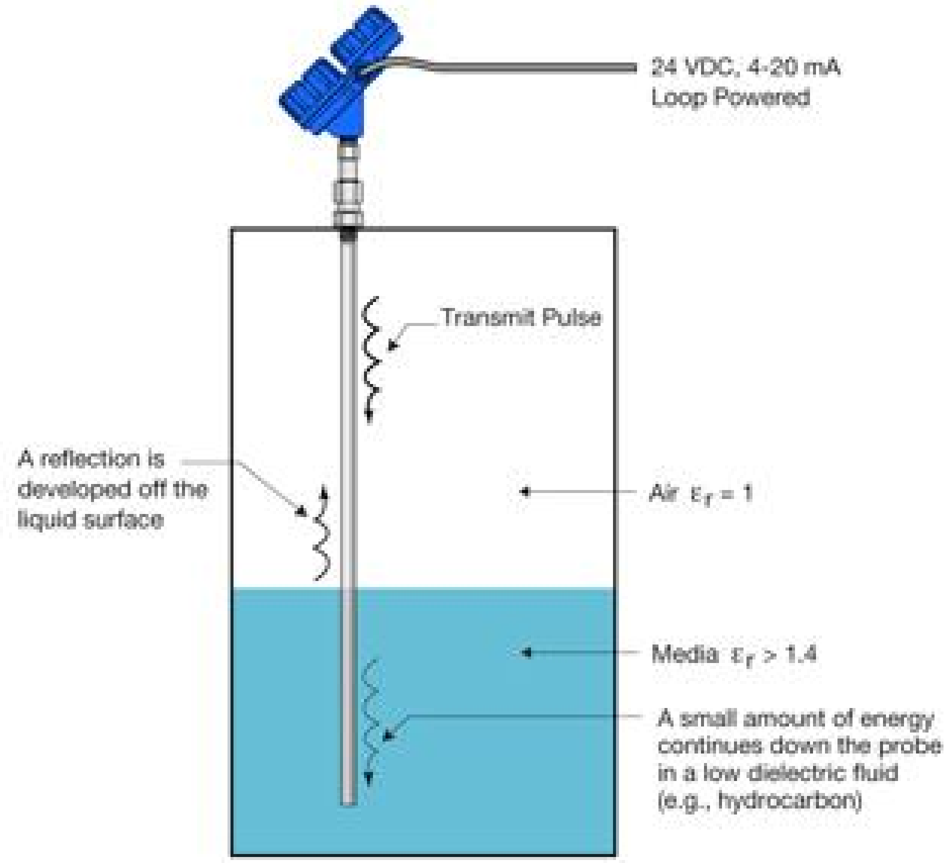


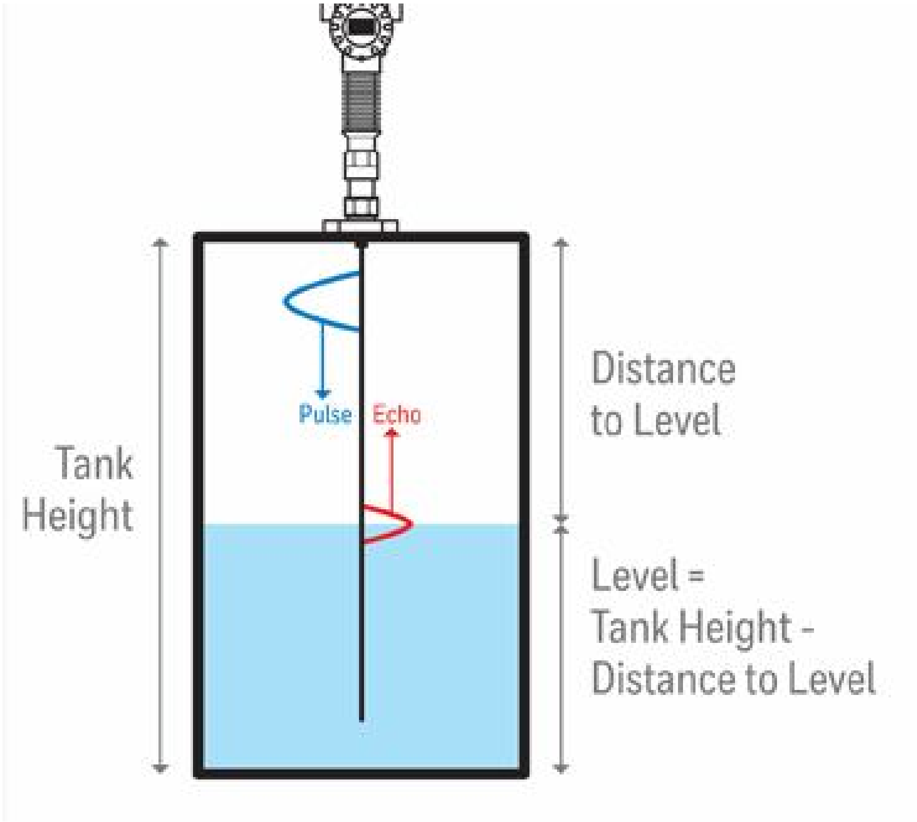
Distance d is the ullage

Figure 28. Ultrasonic level sensors principle

Pengukuran Level

GWR (Guide Wave Radar)

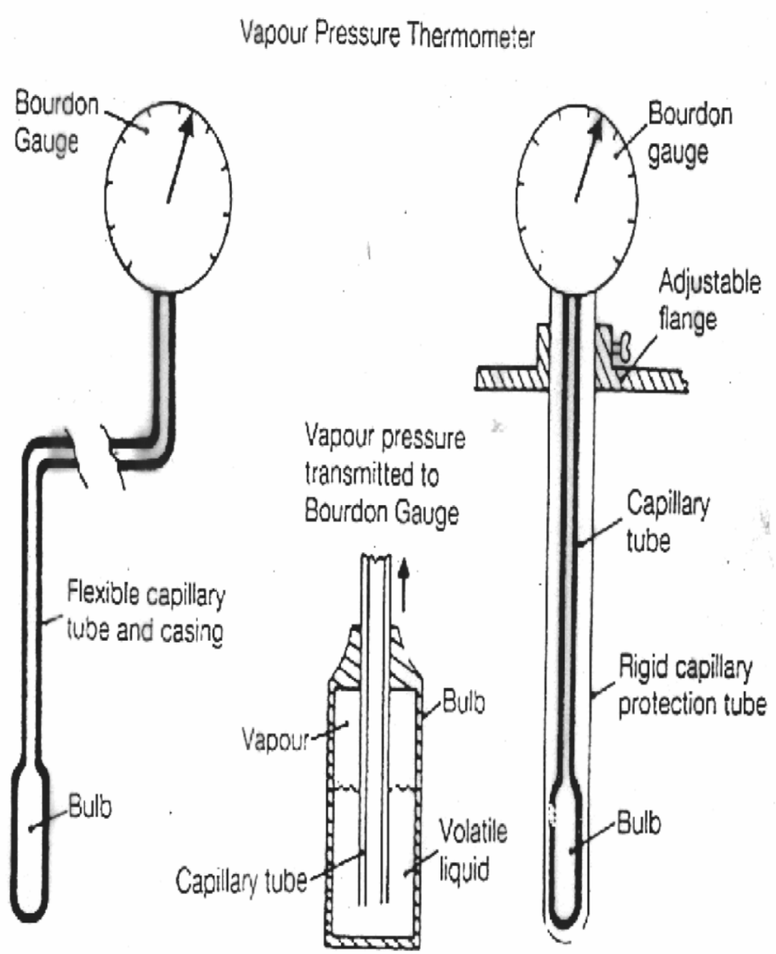


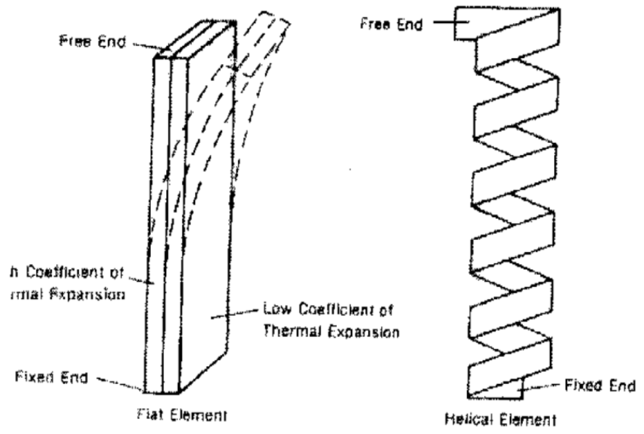


Pengukuran Temperatur

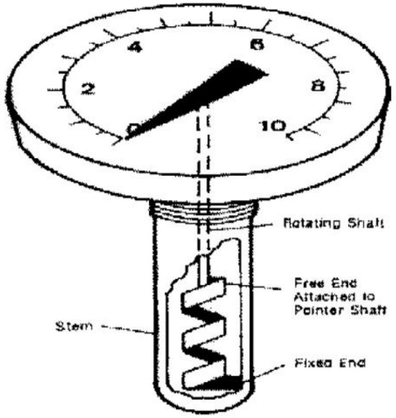
- Ada 2 jenis termometer :
  - Filled Thermometers
    - Terdiri dari bulb, kapiler, dan tabung burdon
    - Jenis bulb yg digunakan dikelompokan berdasarkan fluida kerja (thermometric liquid) yg mengisinya : mercury, zat cair lain dan gas.
    - Bulb, kapiler dan burdon terisi penuh dengan thermometric liquid dan tertutup rapat.
  - Bimetallic Thermometers
    - Prinsip kerja :
      - dua logam dengan koefisien muai berbeda direkatkan menjadi satu batang bimetal.
      - Ketika mengalami kenaikan temperatur, batang bimetal akan membengkok ke arah koefisien muai yg lebih kecil

Pengukuran Temperatur





Schematic Illustrating Concept of Bimetallic Temperature Elements



Schematic of a Typical Bimetallic Dial Thremometer

Figure 4.9

Pengukuran Temperatur

Thermocouple

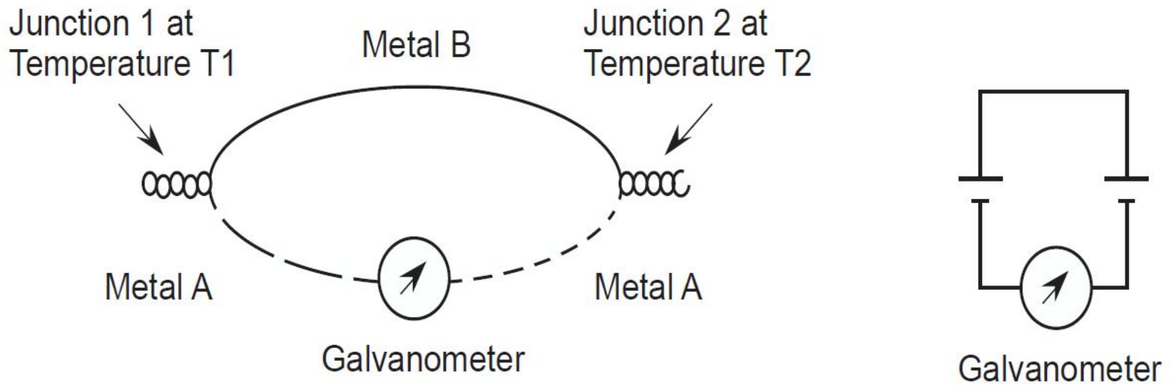
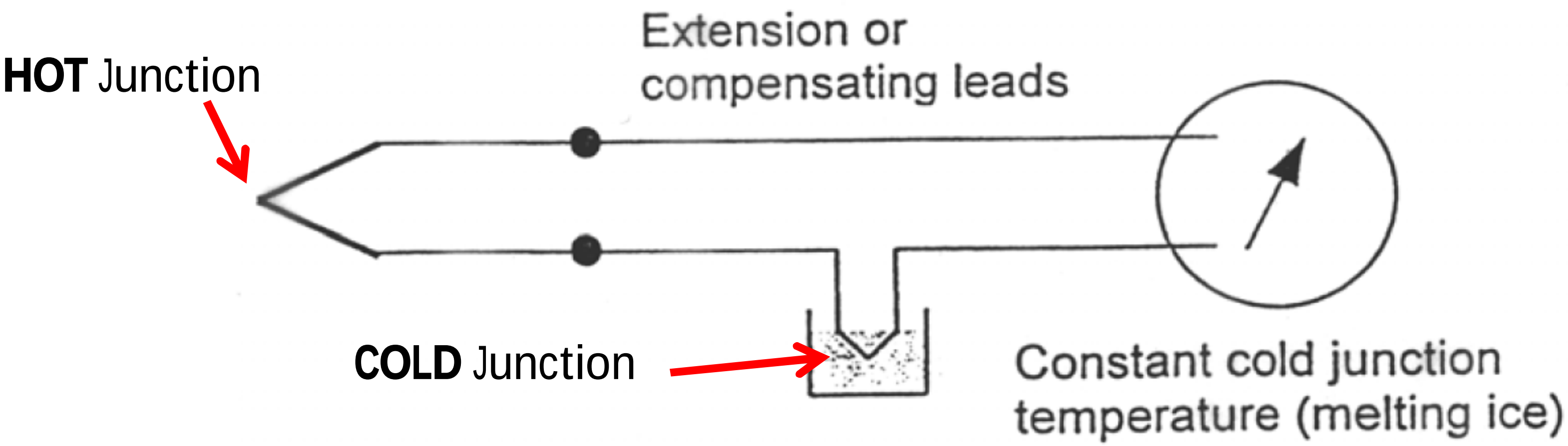


Figure 3
A Thermocouple Circuit



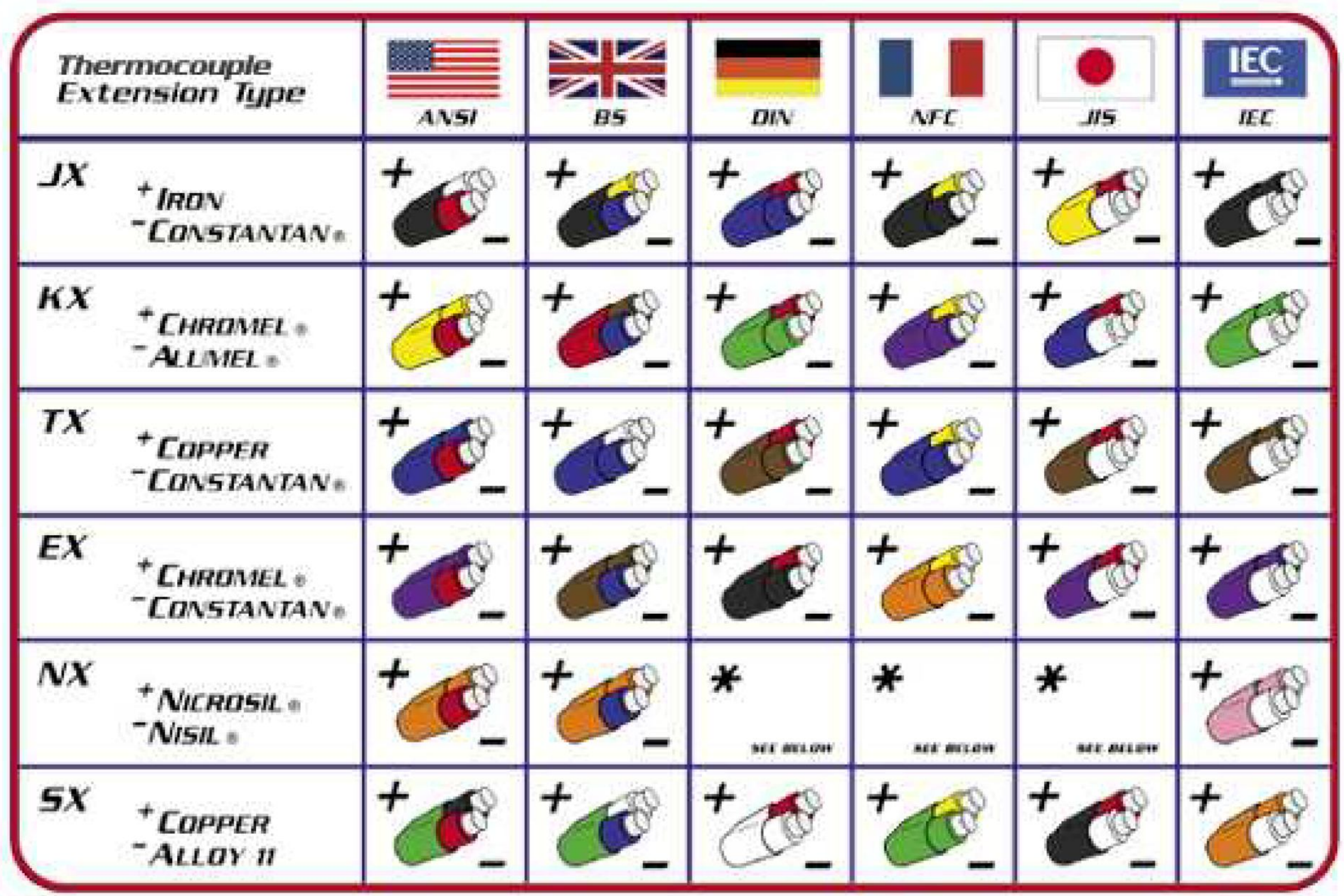
Pengukuran Temperatur

Thermocouple

- Jenis-jenis termokopel (Base metal thermocouple):
  - Tipe J
    - Termokopel paling umum. Terdiri dari Iron(besi) vs Constant.
  - Tipe K
    - Chromal vs Alumal. Memiliki daya tahan korosi yg lebih baik daripada tipe J
  - Tipe T
    - Copper vs Constantine. Biasanya digunakan untuk temperatur dibawah 0^o. Karakteristiknya lebih mudah diprediksi pada temperatur rendah dibandingkan tipe J dan K
  - Tipe E
    - Chromal vs Constantine. Memiliki sensitivitas terbesar untuk termokopel standar. 40 mV pada 1000^oF (dibandingkan tipe J 30 mV dan tipe K 22 mV). Karakteristiknya cenderung berubah seiring waktu. (kecenderungan perubahan karakteristik tipe E lebih besar dibandingkan tipe J, K dan T)

Pengukuran Temperatur

Thermocouple



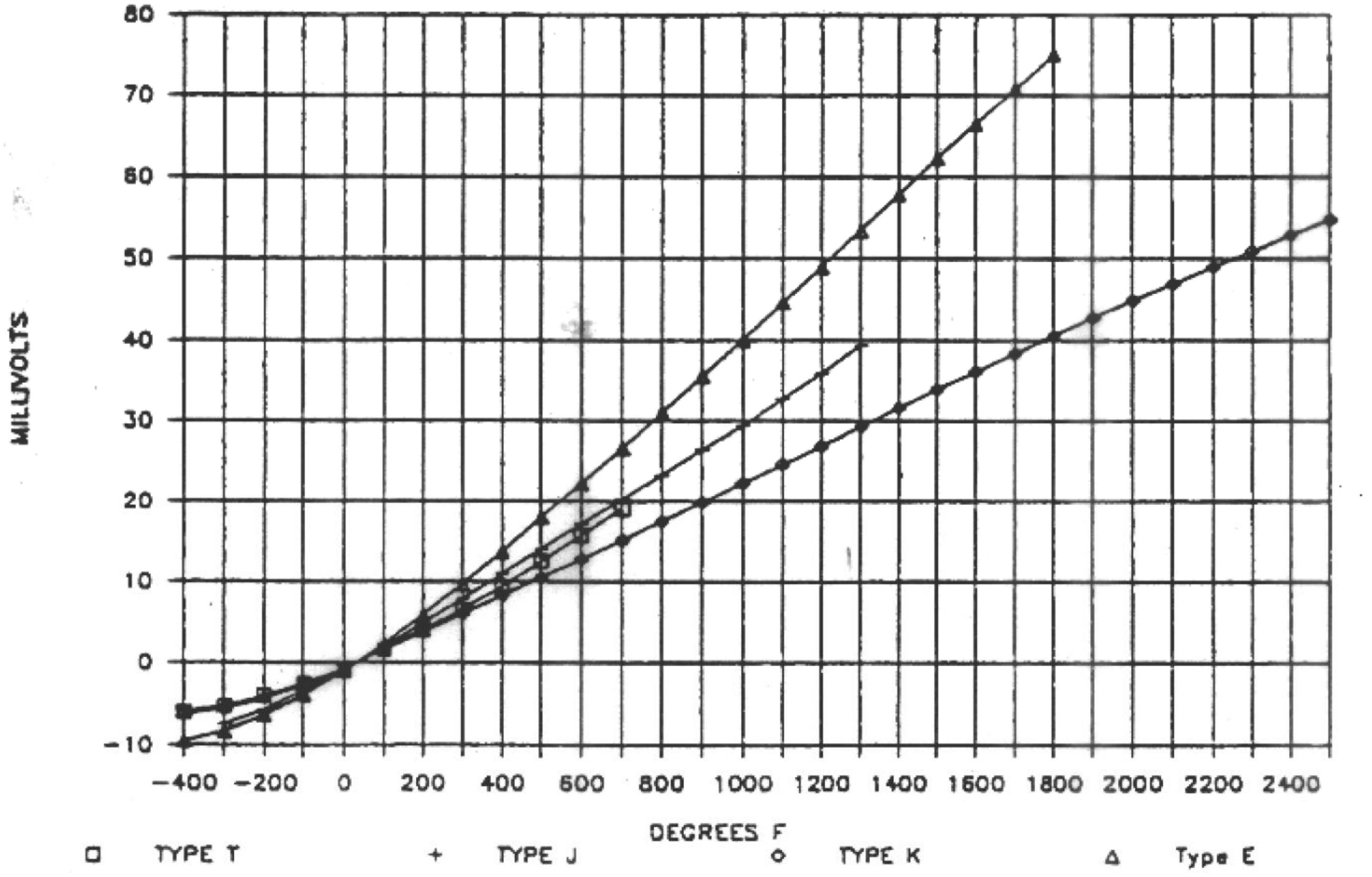
Pengukuran Temperatur

Thermocouple

Type	Temperature Range	British coloursystem		Inrernational colour system	
		+ve	**-ve**	**+ve**	**- ve**
K	0° to 1100 °C	Brown	blue	Green	White
T	- 185° to 300 °C	White	blue	Brown	White
J	20° to 700 °C	Yellow	blue	Black	white
E	-150° to 1000 °C	White	blue	Orange white	

Pengukuran Temperatur

Thermocouple



Output Versus Temperature Curves for the Four Types of Base Metal Thermocouples. (Types J, K, T and E)

Pengukuran Temperatur

Thermocouple

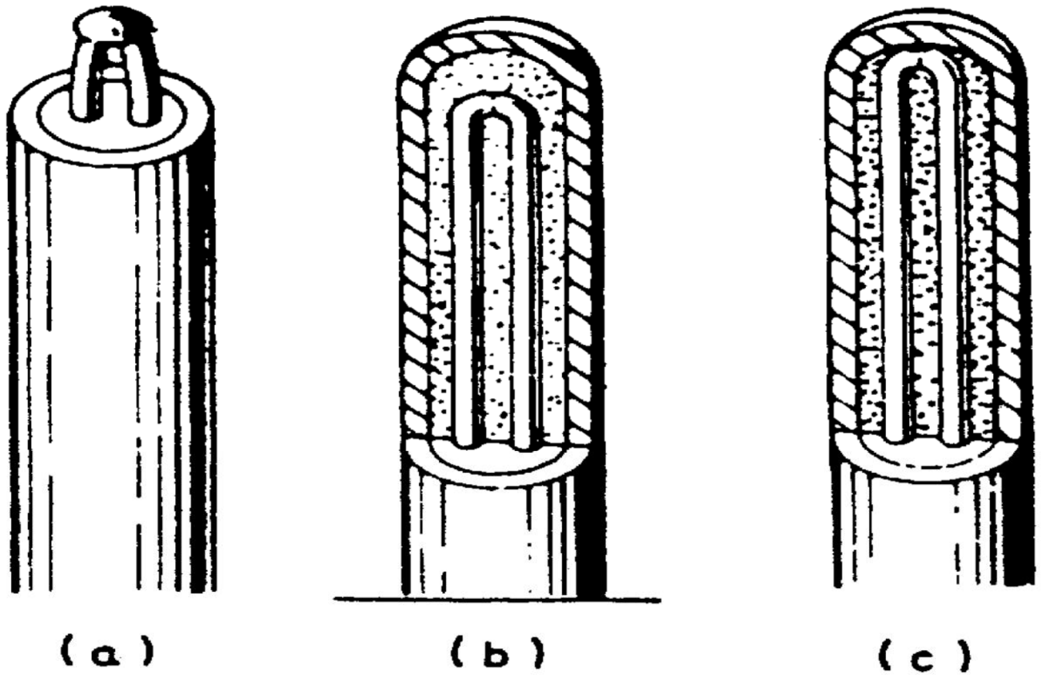
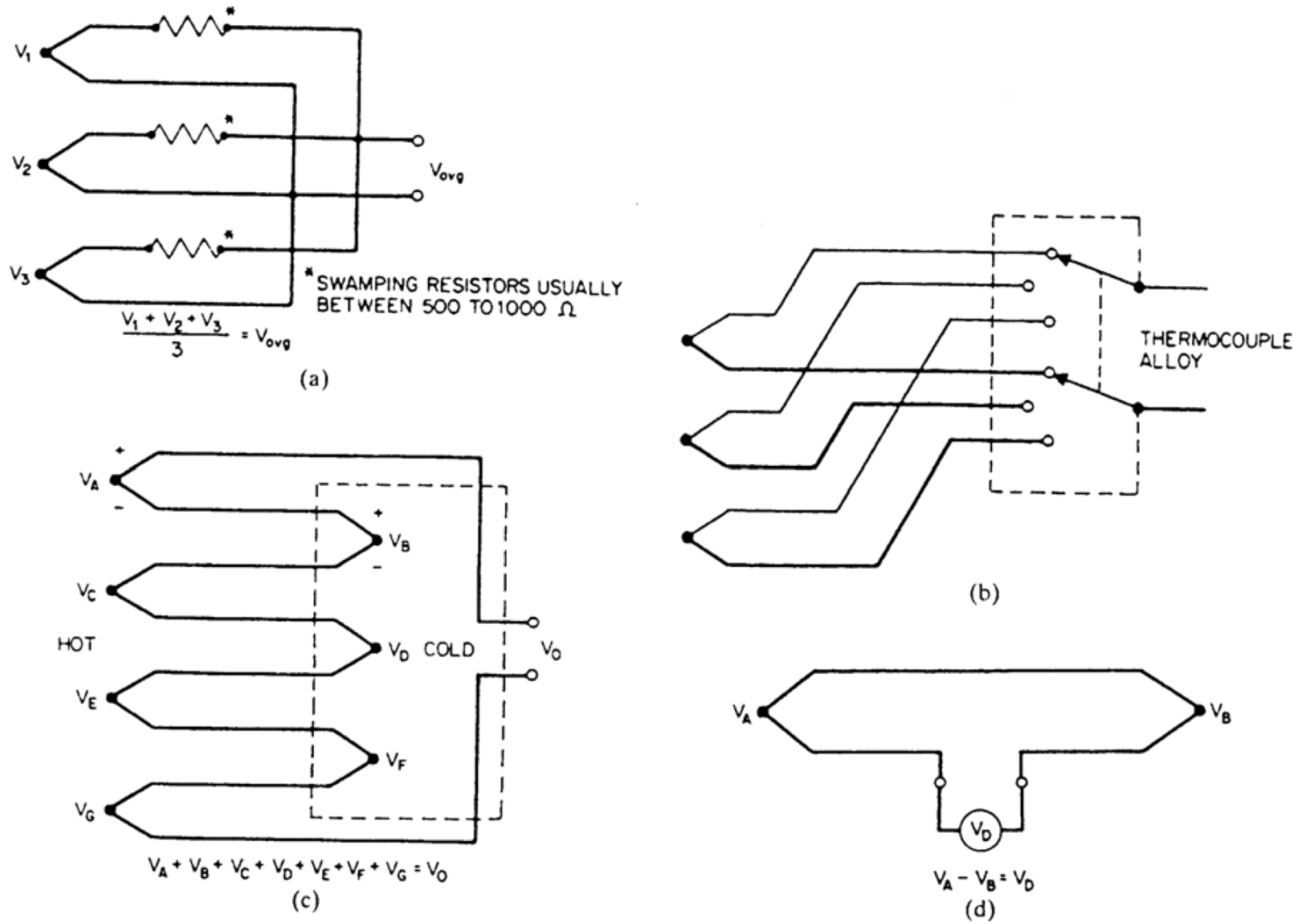


FIGURE 7 Thermocouple measuring junctions, (a) Exposed junction, (b) Ungrounded junction, (c) Grounded junction.

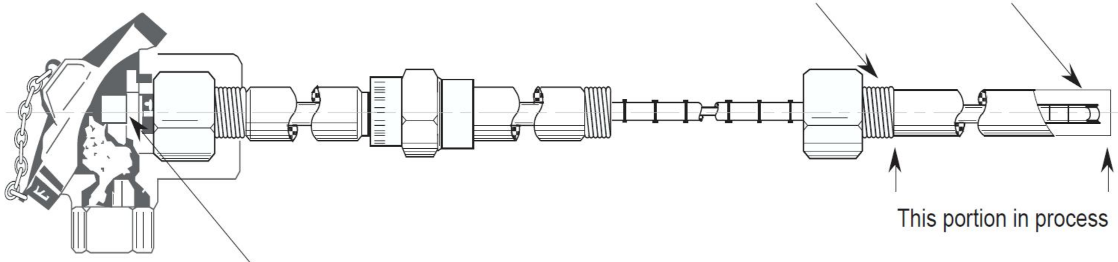
Pengukuran Temperatur

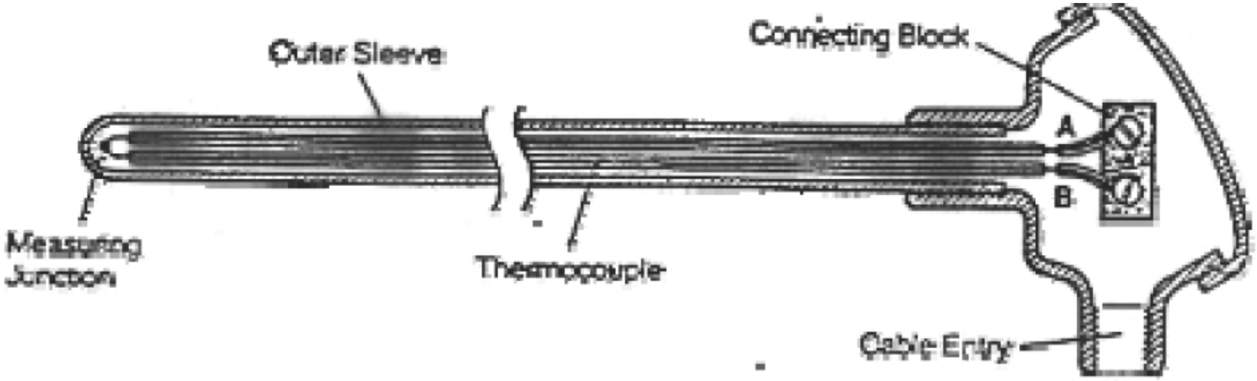
Thermocouple



Pengukuran Temperatur

Thermocouple





Types of measuring junction configuration

INSULATED: Hot junction insulated from sheath.
Gives floating output with typical insulation resistance in excess of 100 megohms.

GROUNDED: Hot junction welded to sheath tip giving earthed output and faster response to temperature changes.

EXPOSED. Fastest response mainly for the measurement of air temperature in ducts and continuous ovens. Restricted to a maximum operating temperature of 500°C.

Pengukuran Temperatur

RTD (Resistance Temperature Detector)

- Resistansi konduktor umumnya bertambah ketika terjadi peningkatan temperatur.
- RTD adalah konduktor yg karakteristik resistansinya diketahui, dan konstruksinya dirancang untuk pengukuran temperatur
- Pada dasarnya setiap konduktor dapat digunakan untuk membuat RTD, namun hanya sedikit yg karakteristiknya sudah teridentifikasi dengan baik.

Pengukuran Temperatur

RTD (Resistance Temperature Detector)

- Karakteristik konduktor yg dimaksud :
  - Stability
    - Pada range pengukuran temperatur, material harus tahan leleh, tahan korosi atau karakteristik elektriknya tidak berubah.
  - Linearity
    - Pada range temperatur kerja, perubahan resistansi terhadap perubahan temperaturnya harus selinear mungkin
  - High Resistively
    - Semakin besar resistansi bahan material, semakin sedikit material yg diperlukan untuk menghasilkan RTD dengan nilai resistansi tertentu
  - Workability
    - Material harus cocok untuk dimasukan ke dalam media kerja

Pengukuran Temperatur

RTD (Resistance Temperature Detector)

- Material yg teridentifikasi memiliki karakteristik yg ‘Baik’ :
  - Tembaga
    - good linearity&workability dan tahan hingga 250^{o}F (120^{o}C)
    - Low resistively (resistansinya rendah), sehingga perlu konduktor yg panjang atau luas penampang yg sangat kecil untuk mendapatkan resistansi yg diperlukan RTD
  - Nikel dan Nikel Aloy
    - High resistively, good stability, dan good workability
    - Poor linearity
  - Tungsten
    - Bersifat rapuh/getas (brittle) atau poor workability
  - Platinum/platina
    - Semua karakteristiknya memenuhi syarat untuk pengukuran temperatur di industri, mulai dari -300 sampai 1200^{o}F (-150 sampai 650^{o}C). RTD berbahan platina yg dijual dipasaran, memiliki sensitivitas 0,385 Ohm per ^{o}C, dengan resistansi mulai dari 50 Ohm sampai 1000 Ohm.
    - Harganya mahal

$$^{\circ}C = (\text{Ohms reading} - 100) / 0.385$$

Pengukuran Temperatur

RTD (Resistance Temperature Detector)

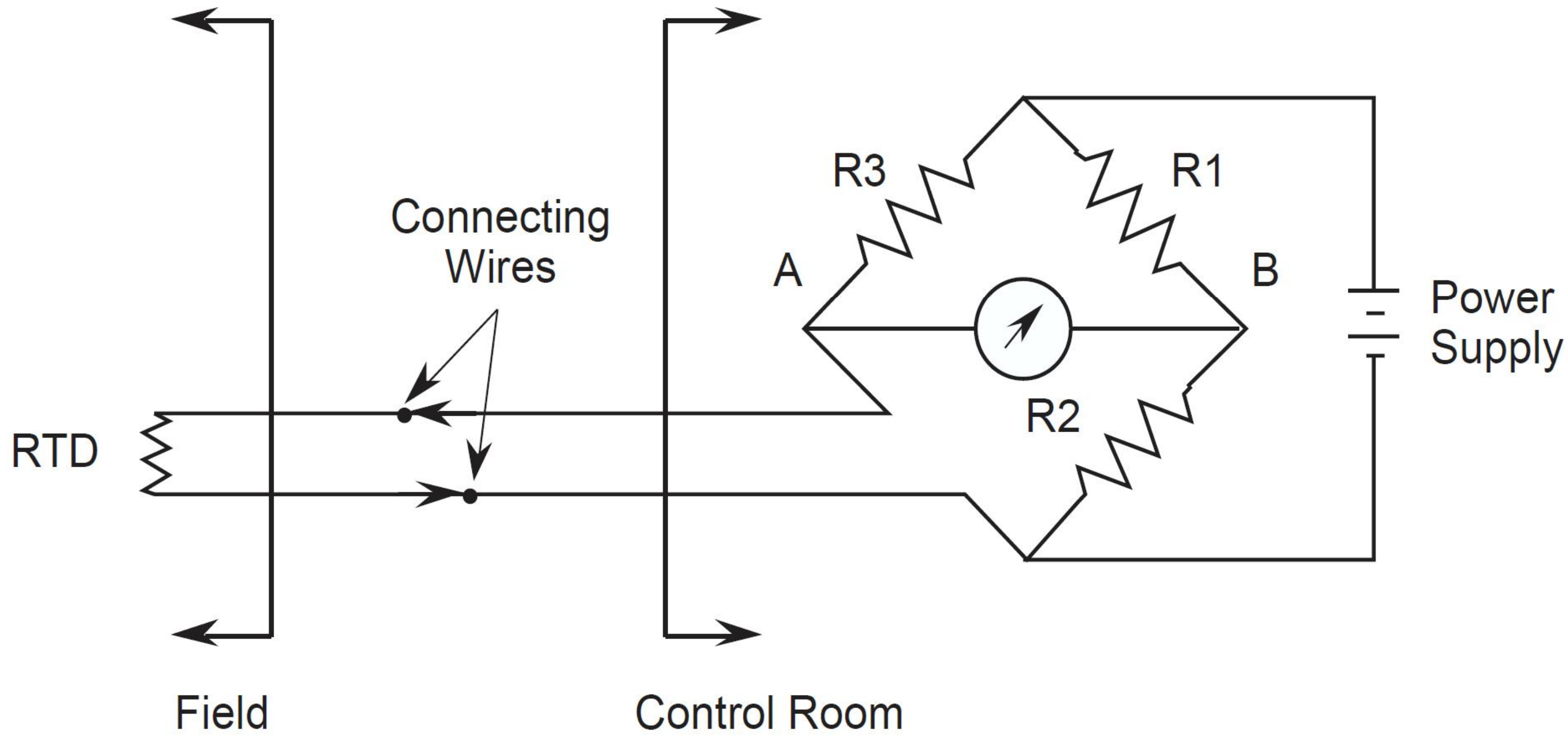


Figure 1
RTD using a Wheatstone Bridge

Pengukuran Temperatur

RTD (Resistance Temperature Detector)

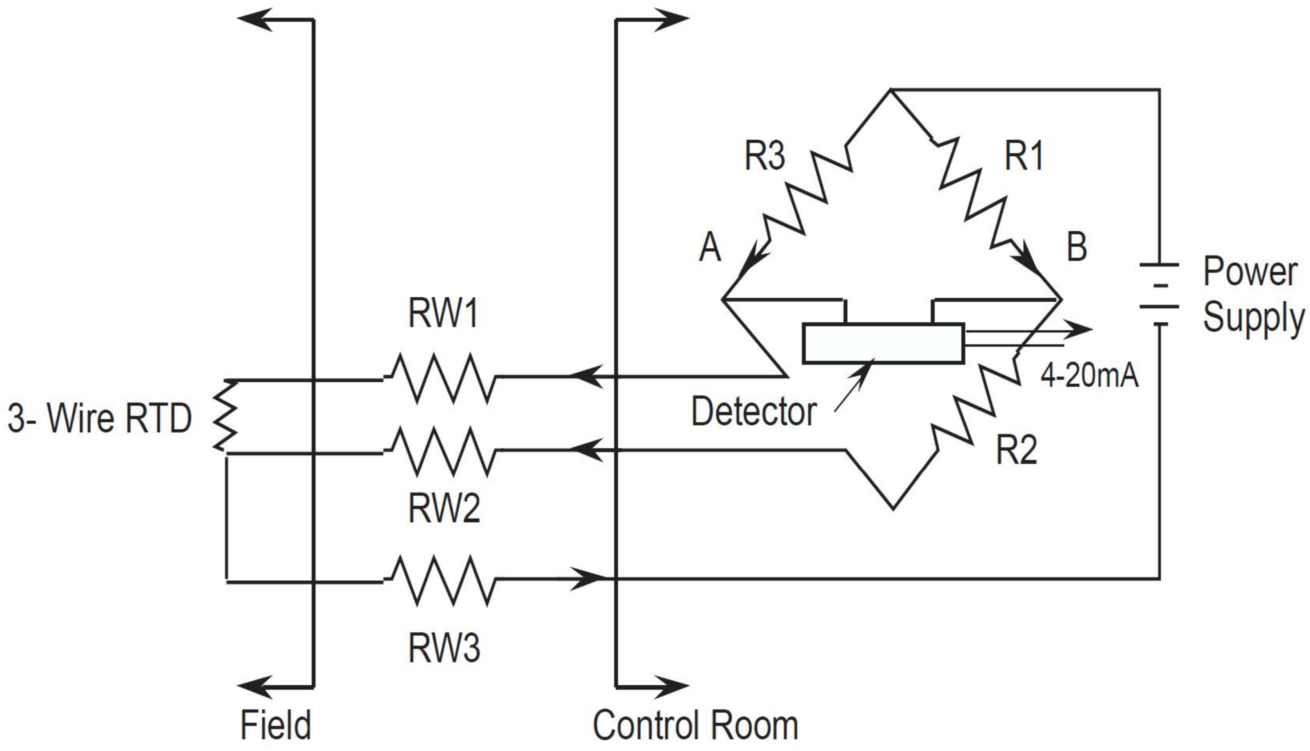
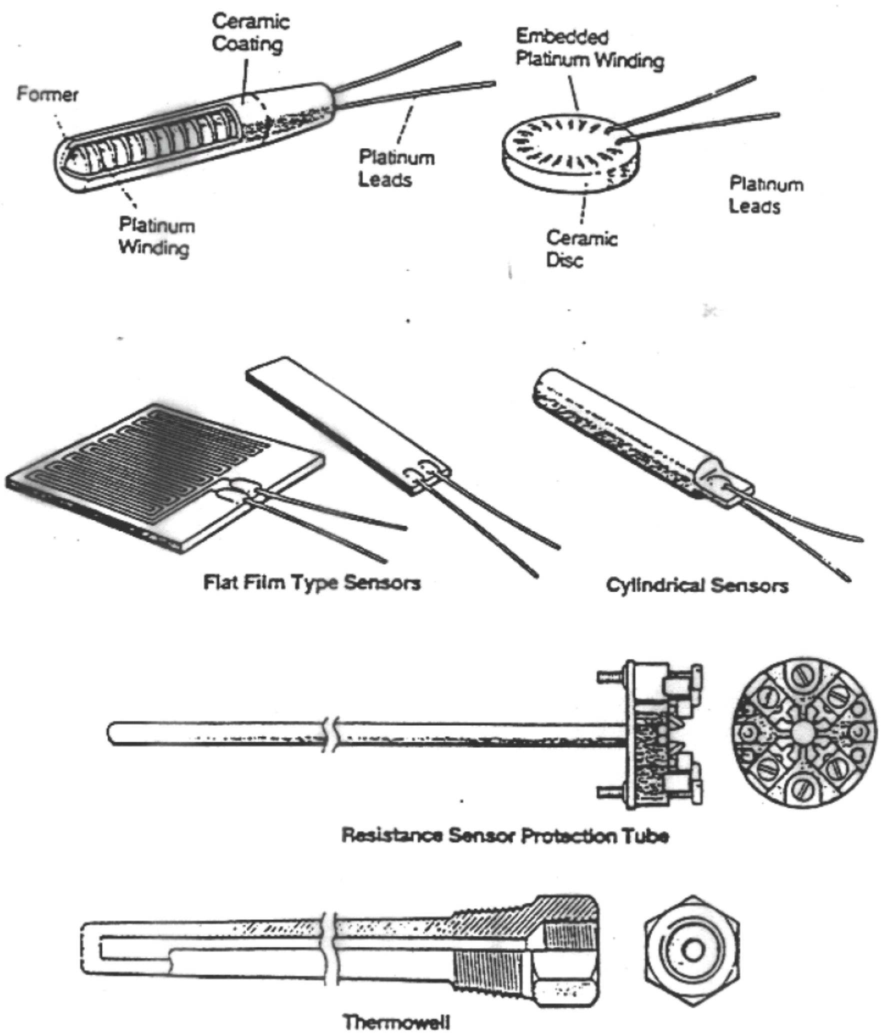


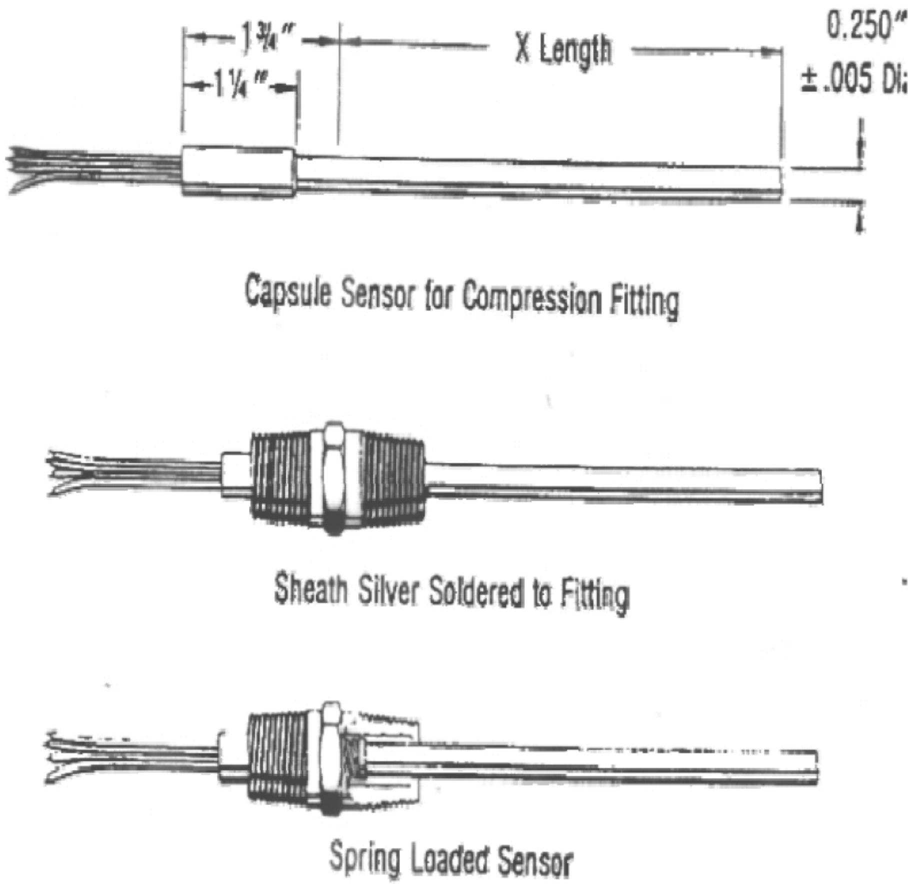
Figure 2
Three-Wired RTD

Figure 2 illustrates a three-wire RTD installation.

Pengukuran Temperatur

RTD (Resistance Temperature Detector)





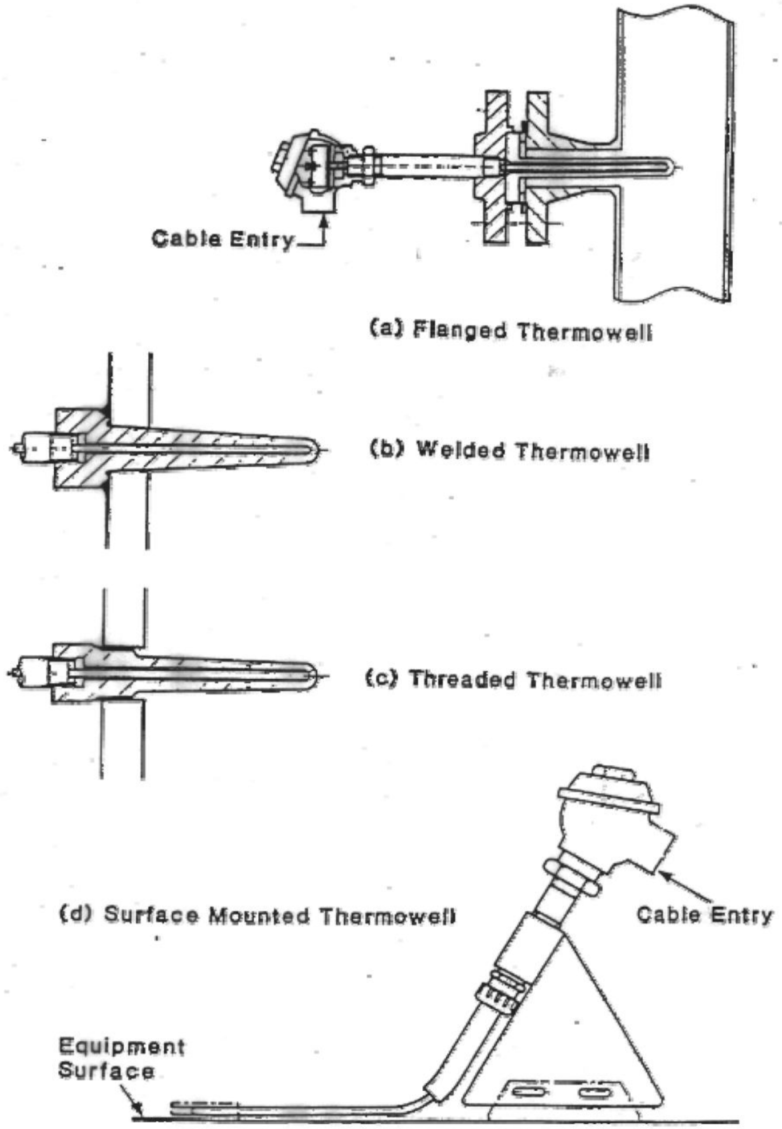
Pengukuran Temperatur

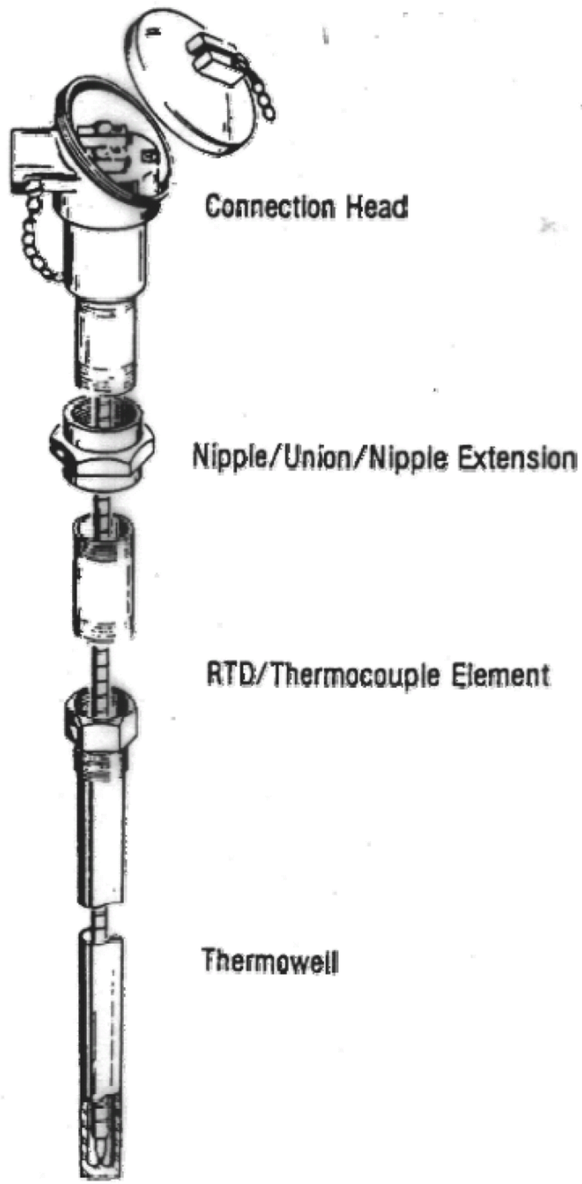
RTD/Thermocouple Comparison

	RTD	Thermocouple
Advantage	• Potentially the most accurate method. • Simple installation. • Needs only copper cables for long runs.	• Wide temperature range. • Versatile. • Simple application, just the tip needs to take up the required temperature.
Disadvantage	• Needs energising current. • Sensor types limited.	• Needs a temperature reference. • Needs extension cables for long runs.

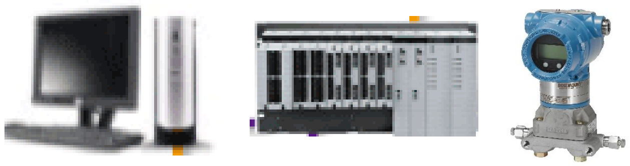
Pengukuran Temperatur

Thermowell

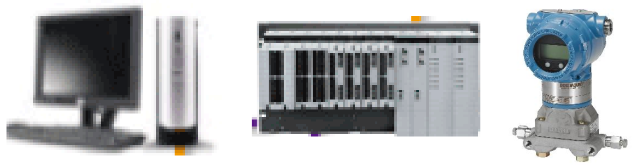




CONTROL SYSTEM (PLC + DCS)



CONTROL VALVE



INSTRUMEN PROTEKSI MESIN



Bently Nevada

- Bently Nevada is a global company providing products and services that is helping to protect and manage rotating and reciprocating machinery.

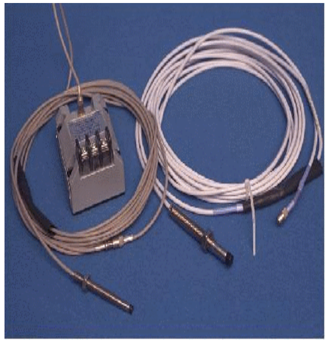
3500 MONIToRING SYsTEM

3500 monitoring system main components

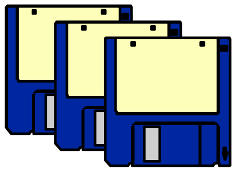
- Transducers.
- 3500 Monitor Racks.
- Software.
- Computer.

- Transducers.
- 3500 Monitor Racks.
- Software.
- Computer.

3500 Monitor Racks



Transducers



Software

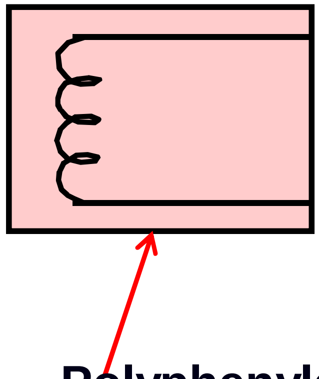
Computer

3500 MONITORING SYSTEM

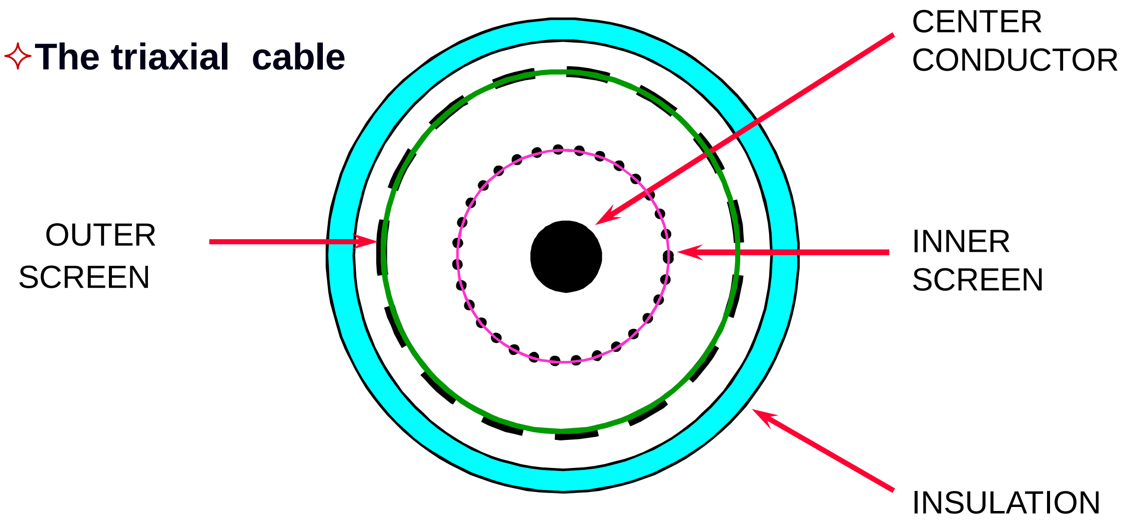
- **PROBE.**
- **Extension cable.**
- **Proximitor.**

✧The PROBE

✧**The tip assembly** ✧**The triaxial cable**



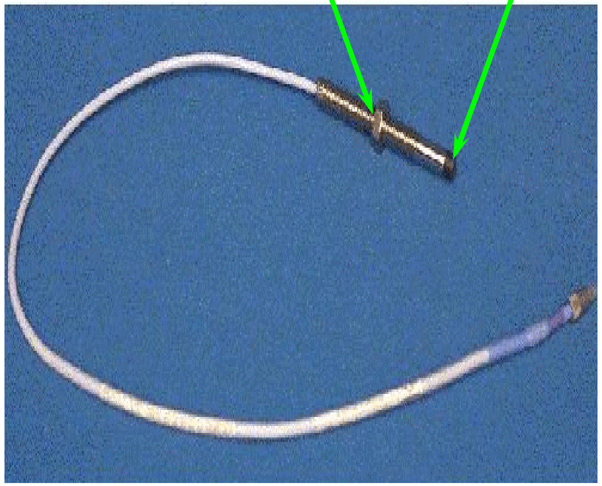
Polyphenylene sulfide



3500 MONIToRING SYsTEM

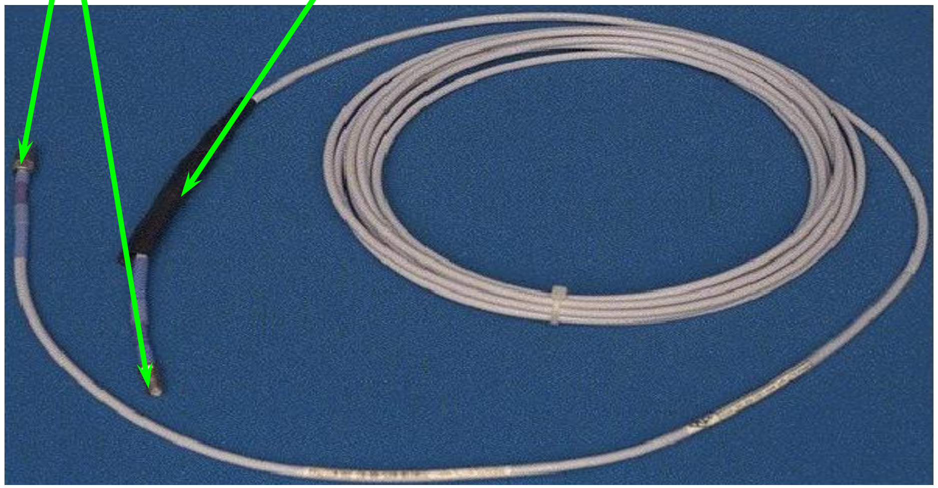
Probe Numbering

Probe Numbering



P/N 330106-05-30-10-02-00

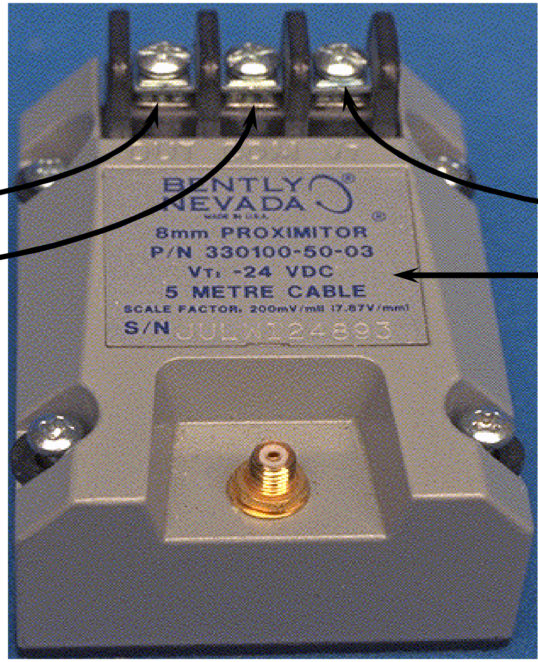
The extension cable



P/N 330130-080-00-00

Probe and extension cables are manufactured in standard lengths

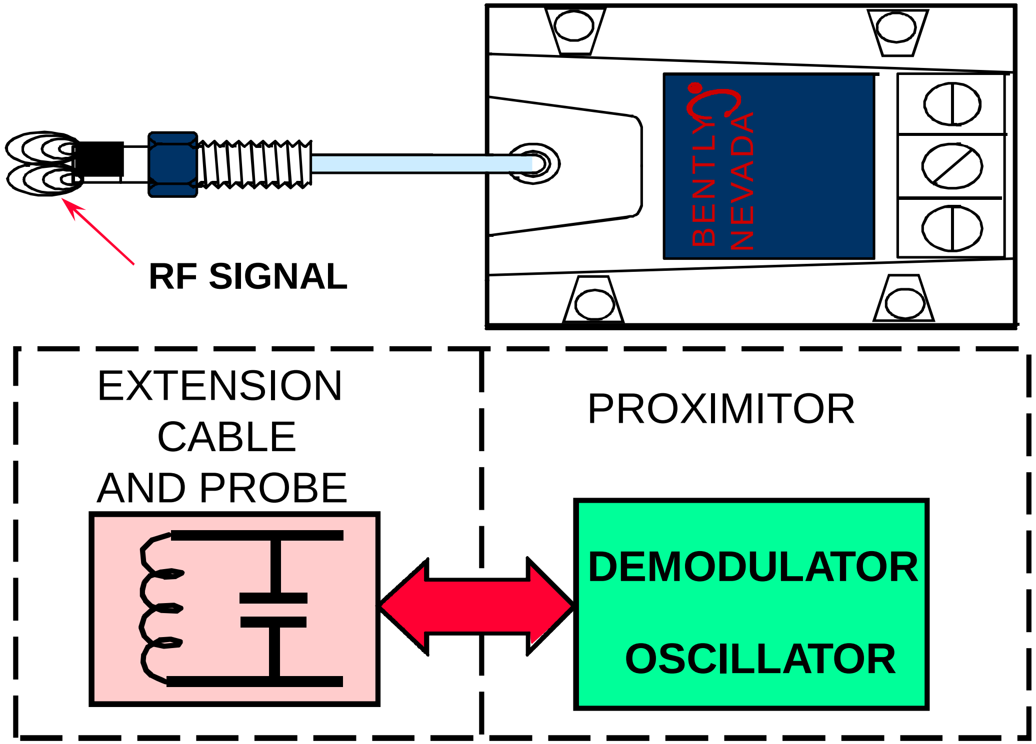
The proximitor



P/N 330100-90-00

- It is usually mounted in a junction box.
- A 75 Ώ miniature coaxial female connector for connection to the extension cable.
- A terminal strip is case mounted for supplying voltage to and taking signals from the proximetor.

Proximitor operation

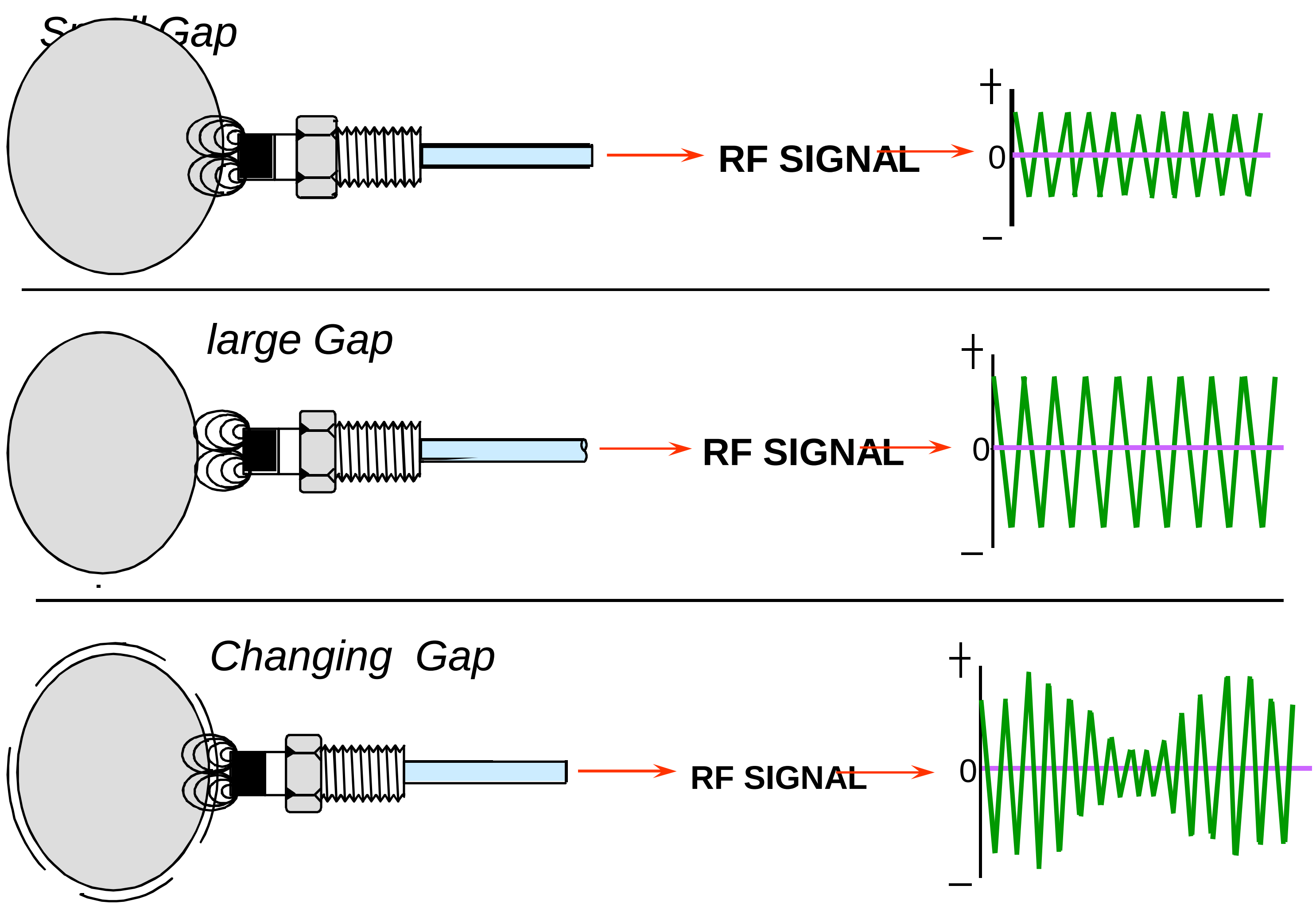


The proximitor is an electronic device that has two basic functions:

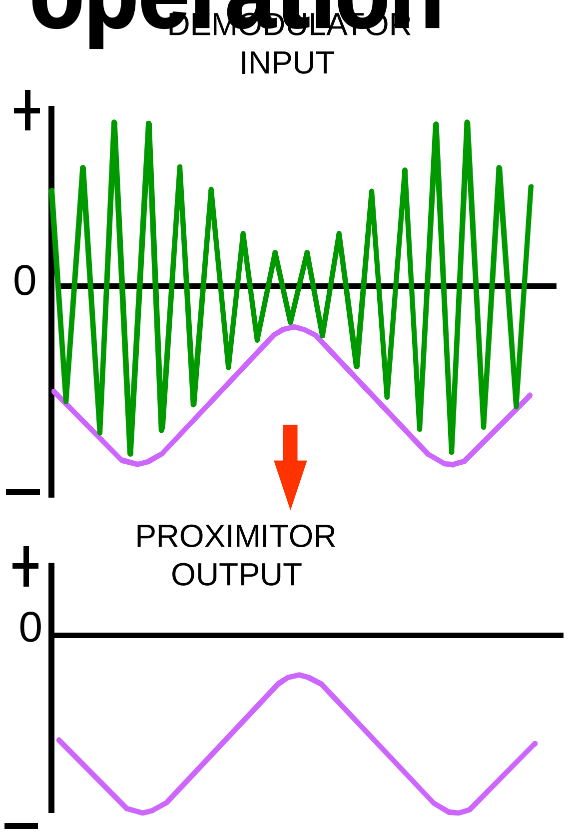
1) Generates a radio frequency (RF) signal using an oscillator circuit.

2) Conditions the RF signal to extract usable data using a demodulator circuit.

Amplitude and Eddy current

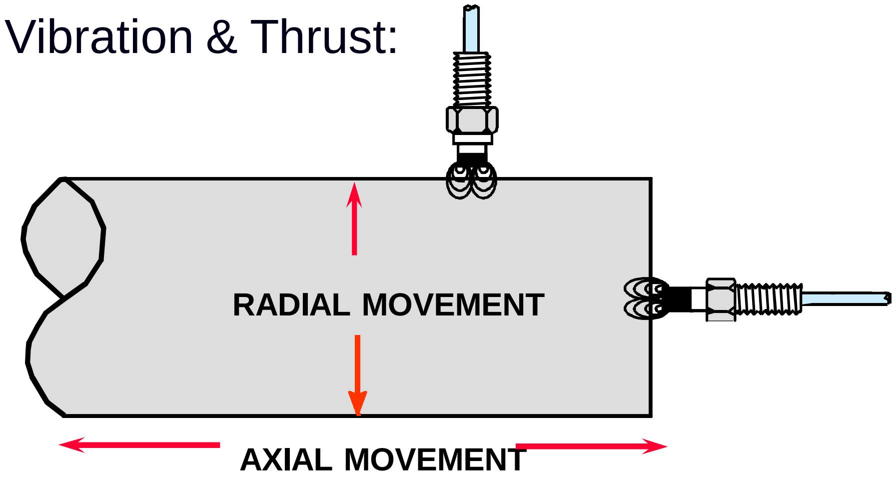


Demodulator operation



Applications:

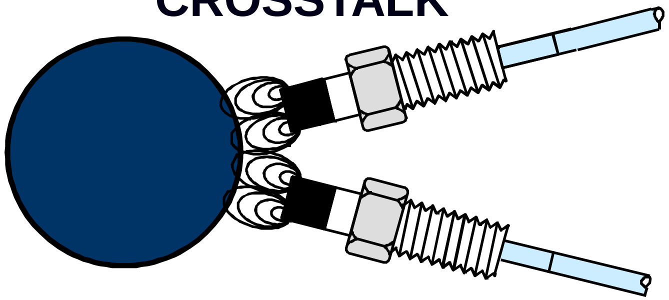
a) Vibration & Thrust:



b) The keyphasor that is used to measure machine speed.

Improper installation for the probes

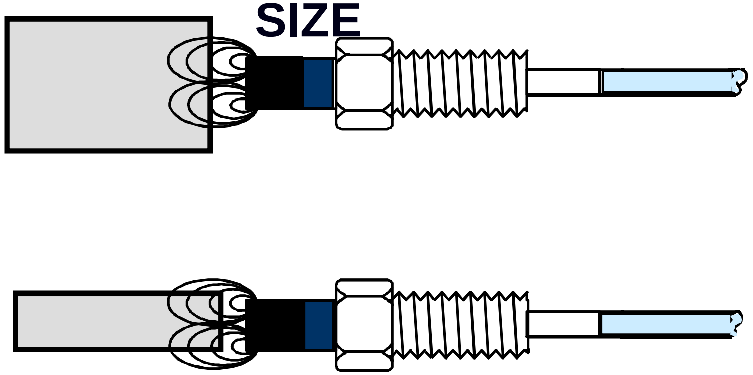
CROSSTALK



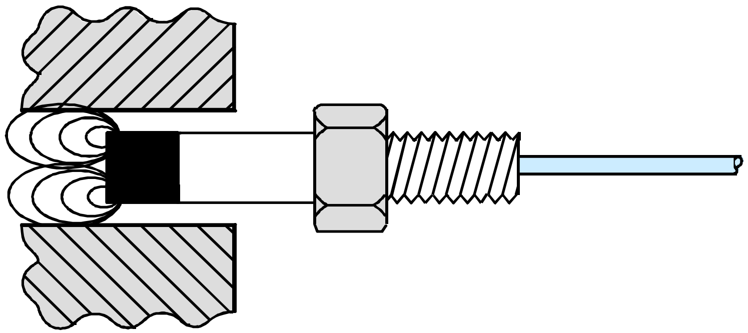
TARGET SIZE

YES

NO

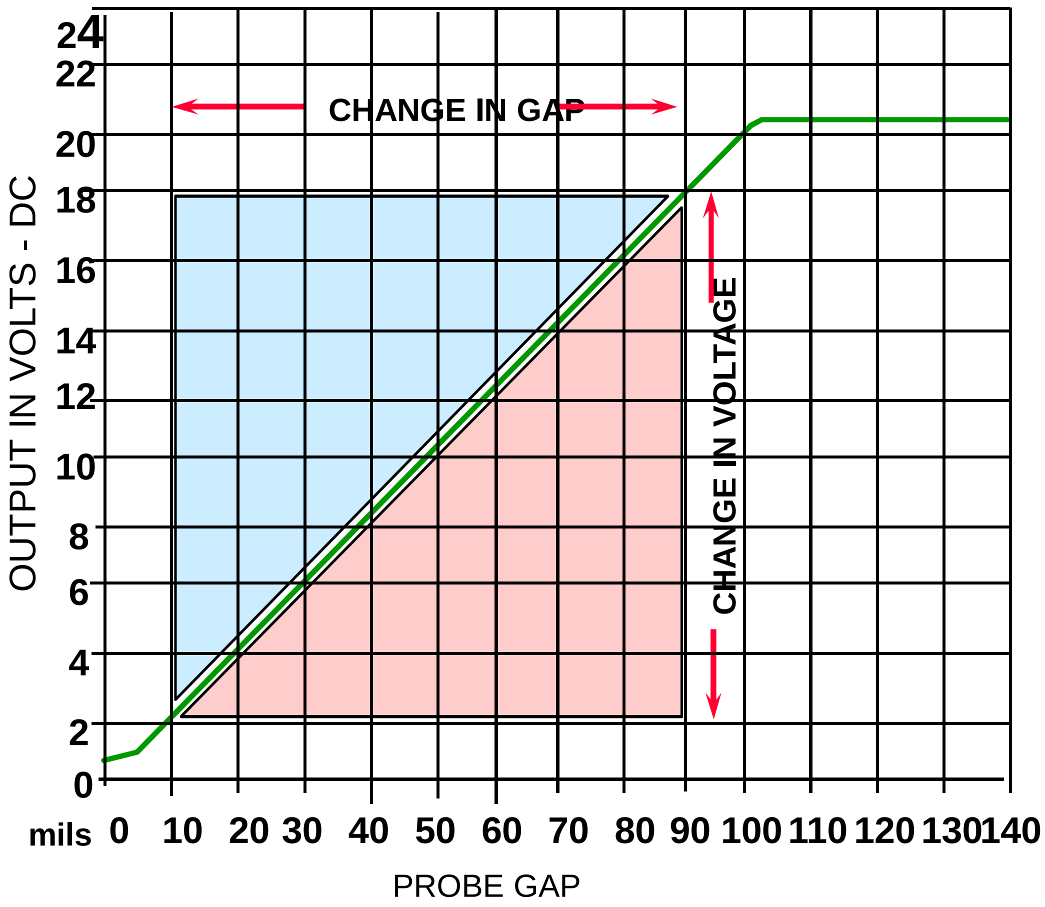


SIDEVIEW



Standard Scale Factor

$$\text{Average Scale Factor (ASF)} = \frac{\text{change in gap voltage}}{\text{change in gap}}$$



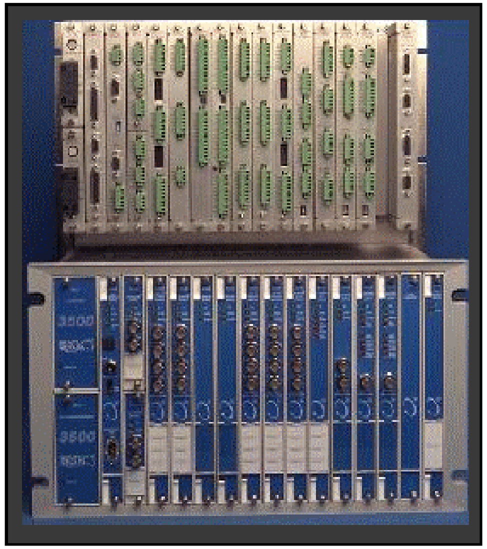
$$= \frac{18 - 2 \text{ VDC}}{80 \text{ mils}}$$

$$= 200 \text{ mV/mil}$$

3500 Monitor Racks configuration

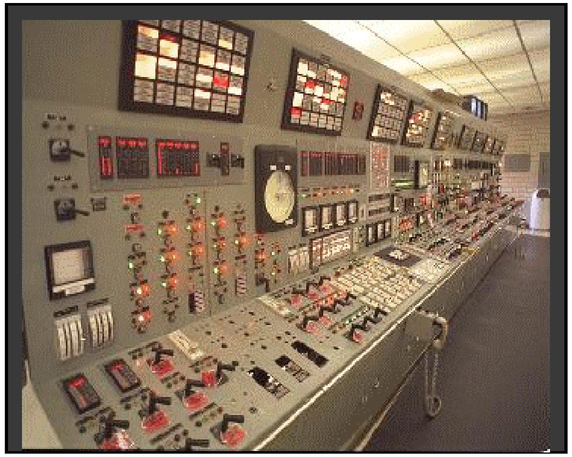
The 3500 monitoring system is available in one of three different rack configuration:

Bulkhead , Cabinet , Panel.



Bulkhead

Panel

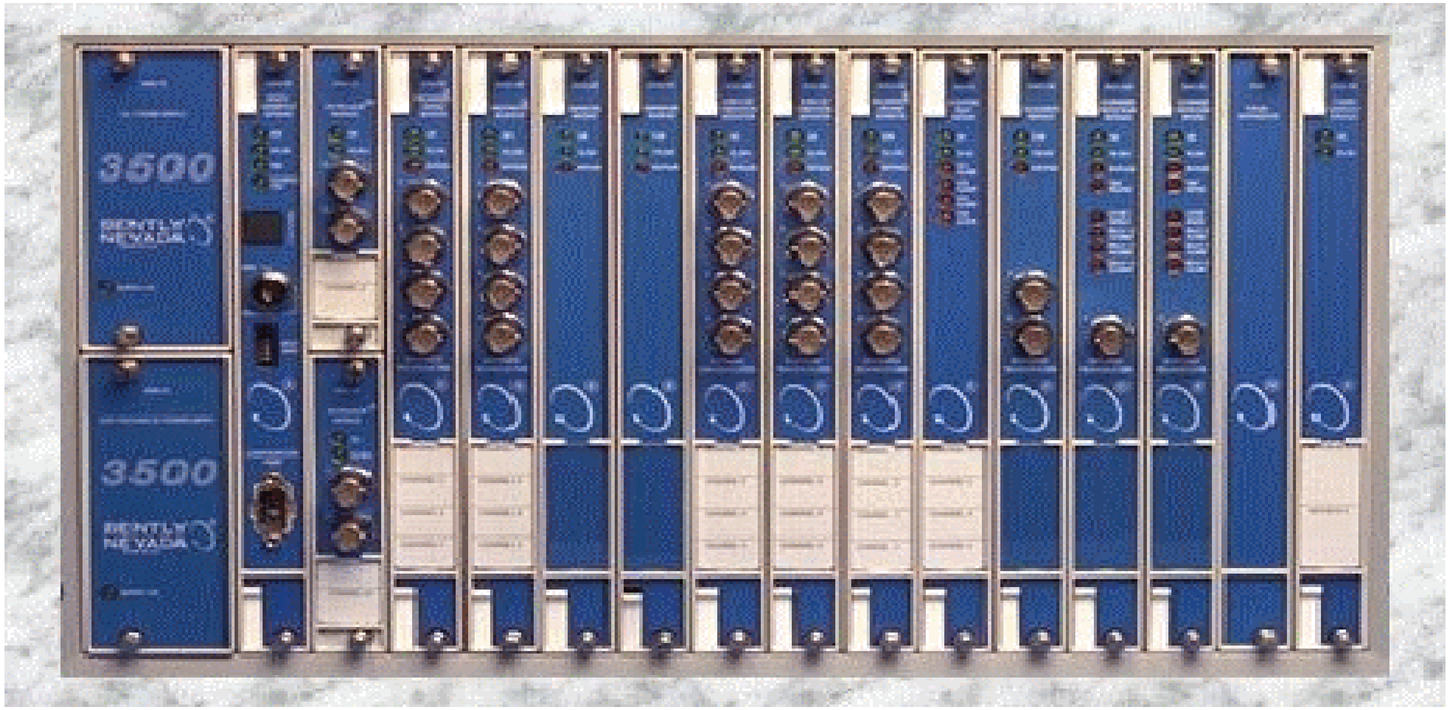


Cabinet

3500 Rack system

3500 rack system main components :

- **Rack Interface Module (RIM).**
- **Power supply modules.**
- **The modules.**
- **Display unit.**



3500/20 Rack Interface Module (RIM)

RS422

RS-232 serial communication

➢ It supports a Bently Nevada developed protocol used to configure the rack and retrieve machinery information.

➢ The Rack Interface Module (RIM) Contains:

- configuration for the 3500 Rack.
- Alarm Event list for the Rack.
- The System Event list for the Rack.

➢ It makes the 3500 Monitor Rack a ‘self-contained’ unit.

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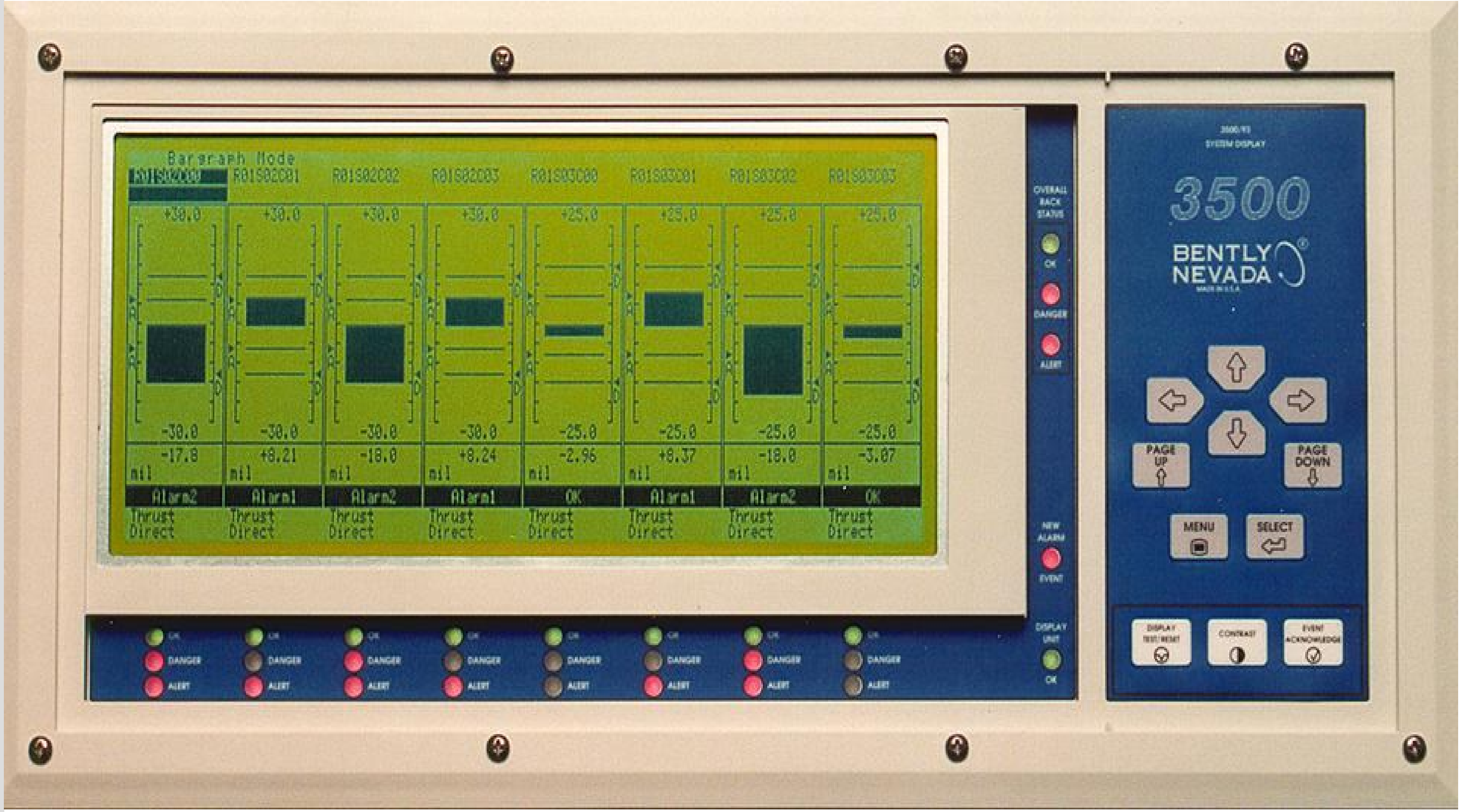
3500/15 Power supply

- ✧ Provides 20 to 30 VDC input voltage.
- ✧ Becomes fourth power module available Lo and High AC, and Lo and High DC.
- ✧ Powers an entire rack or may be mixed with any other modules to supply redundant power.

3500 MONITORING SYSTEM

3500/93 Display



3500/93 Display

- Bently Nevada has designed a display for the 3500 rack Uses one slot in 3500 Monitor Rack.
- It requires an external power supply if it is mounted more than 100 feet from the 3500 Monitor Rack.
- The data displays in one of three modes:
  8 Bar Graph, 16 Text (digital current values) or Group.
- Can also display the alarms and system events.

The Modules

- KeyPhasor module 3500/25
- Relay module 3500/32
- Proximitor module 3500/40
- Temperature module 3500/60 or 3500/61
- Communication gateway module 3500/92
- Tachometer module 3500/50
- Display interface module 3500/93
- Process Variable module 3500/62

3500/40 Proximitor module

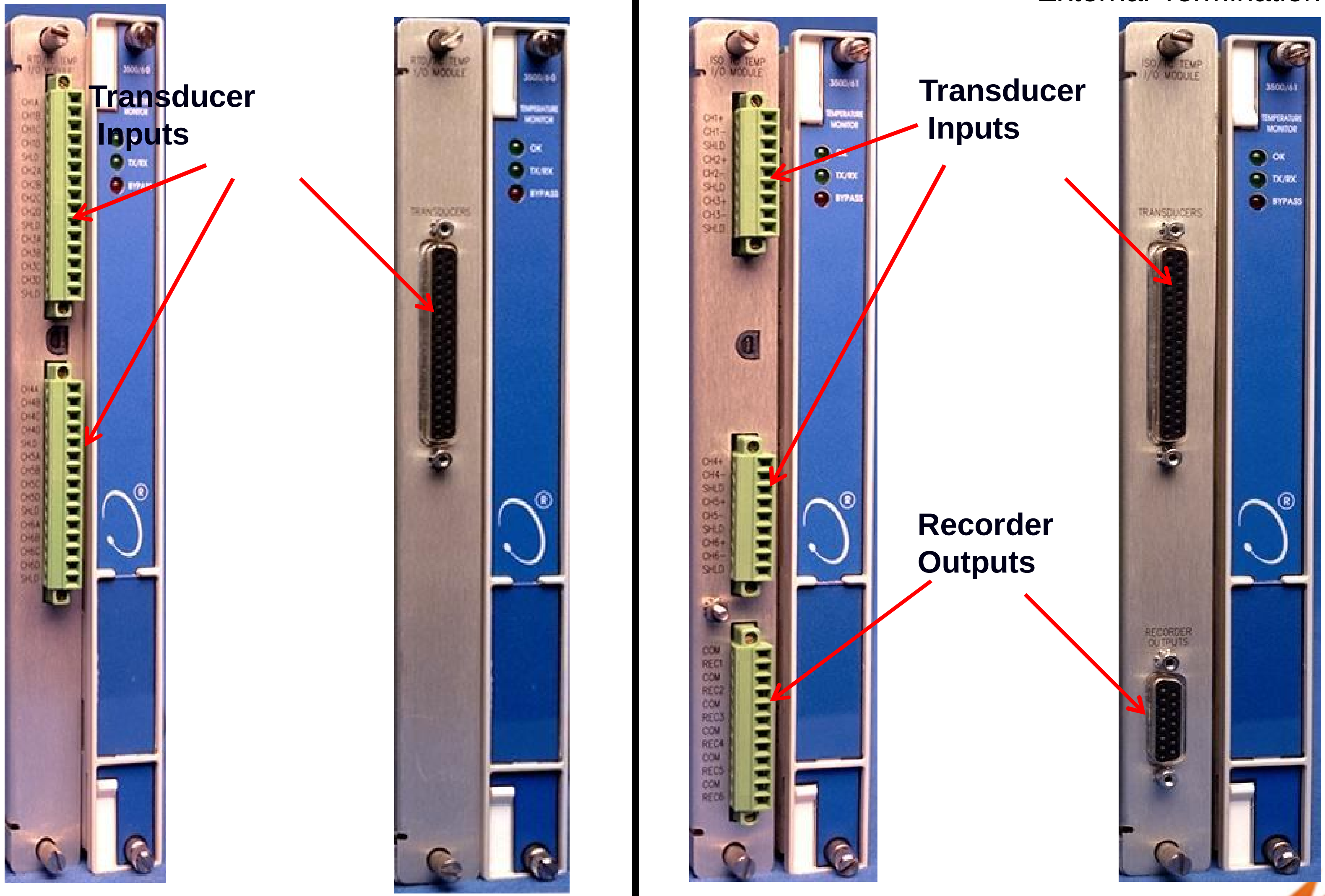
- The 3500/40 Proximitor® Monitor is a four channel monitor that accepts input from proximity transducers and uses this input to drive alarms.

- The 3500/40 can be programmed by using the 3500 Rack Configuration Software to perform any of these functions: Radial Vibration, Thrust Position.

3500 MONIToRING SYsTEM

3500/60 and 3500/61 Temperature module

Internal Termination | External Termination | Internal Termination | External Termination



- Six channel temperature monitors that accept both Thermocouple and RTD inputs and use these inputs to drive alarms.

- Software configurable for:
  - RTD or TC Inputs.
  - 1 to 6 Temperature Inputs.
  - Alarm1 and Alarm2 set points for each channel.
  - Adjustable upper and lower temperature scales, including negative and high temperature readings.

3500/32 Relay module

- The 4 Channel Relay Module is a full-height module that provides four relay outputs.

  Each output of the 4 Channel Relay Module can be independently programmed to perform needed voting logic.

- Each relay, utilized on the 4 Channel Relay Module, includes "Alarm Drive Logic".

- The Alarm Drive Logic is programmed using AND and OR logic, and can utilize alarming inputs (alerts and dangers) from any monitor channel or any combination of monitor channels in the rack.

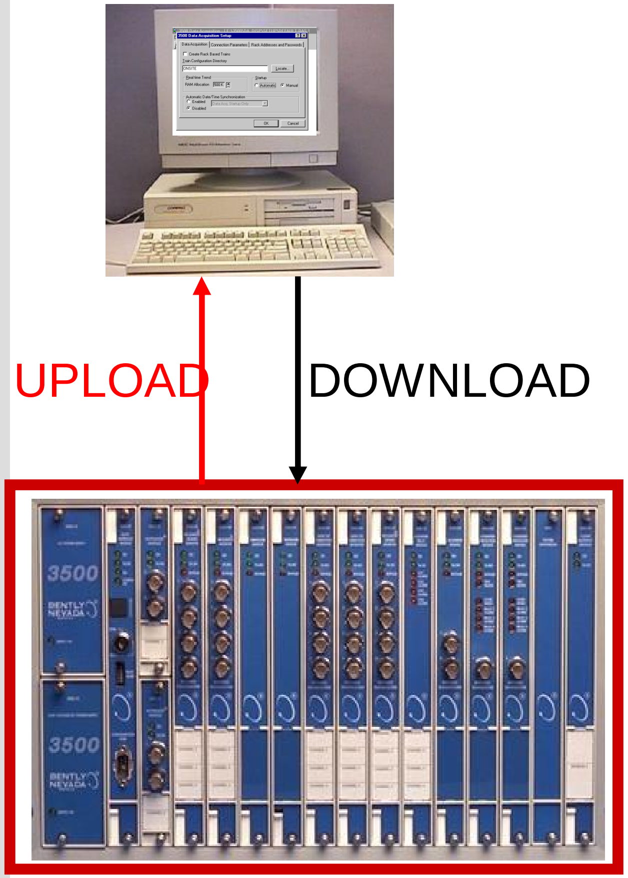
- This Alarm Drive Logic is programmed using the Rack Configuration Software to meet the specific needs for the application.

3500/92 Communication gateway module

- Provides serial communications between the 3500 Monitor Rack and control or automation systems using the Modbus serial protocol, such as:
  - Distributed Control System (DCS).
  - Programmable Logic Controllers (PLC).

- Provides two sets of ports on I/O module that operate independently and supply data to separate external systems:
  - RS232 compatible.
  - RS422 compatible.
  - RS485 compatible.

Rack Configuration Software



- 3500 Rack Configuration Software is the basic software used to communicate with the 3500 rack.
- It is used to set the parameters for ordering a rack, also to configure a 3500 Monitor Rack.
- The configuration data is recorded in the *.RAK file in the computer that is running the configuration software, then it needs to download to the 3500 Monitor Rack.

Computer Requirements

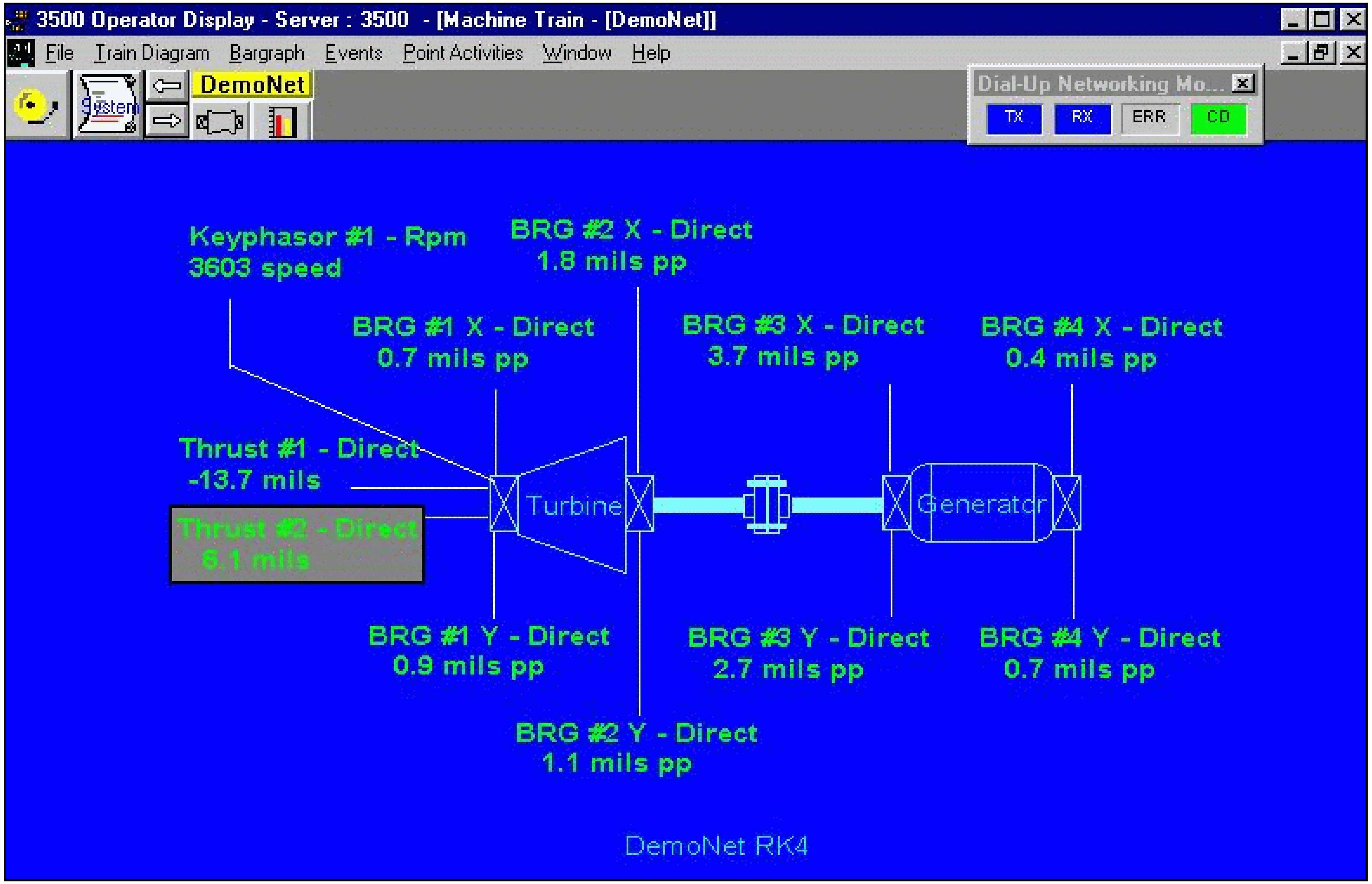
Rack Configuration:

- 386/33 with 3.5” HD floppy and VGA monitor.
- 4-8 MB RAM and 35 MB hard disk capacity (minimum).
- RS232 serial com port or 485 serial interface card.
- Microsoft Windows with DOS 6.0+, WFWG, Win NT, Win 95.

3500 monitoring system benefits and features

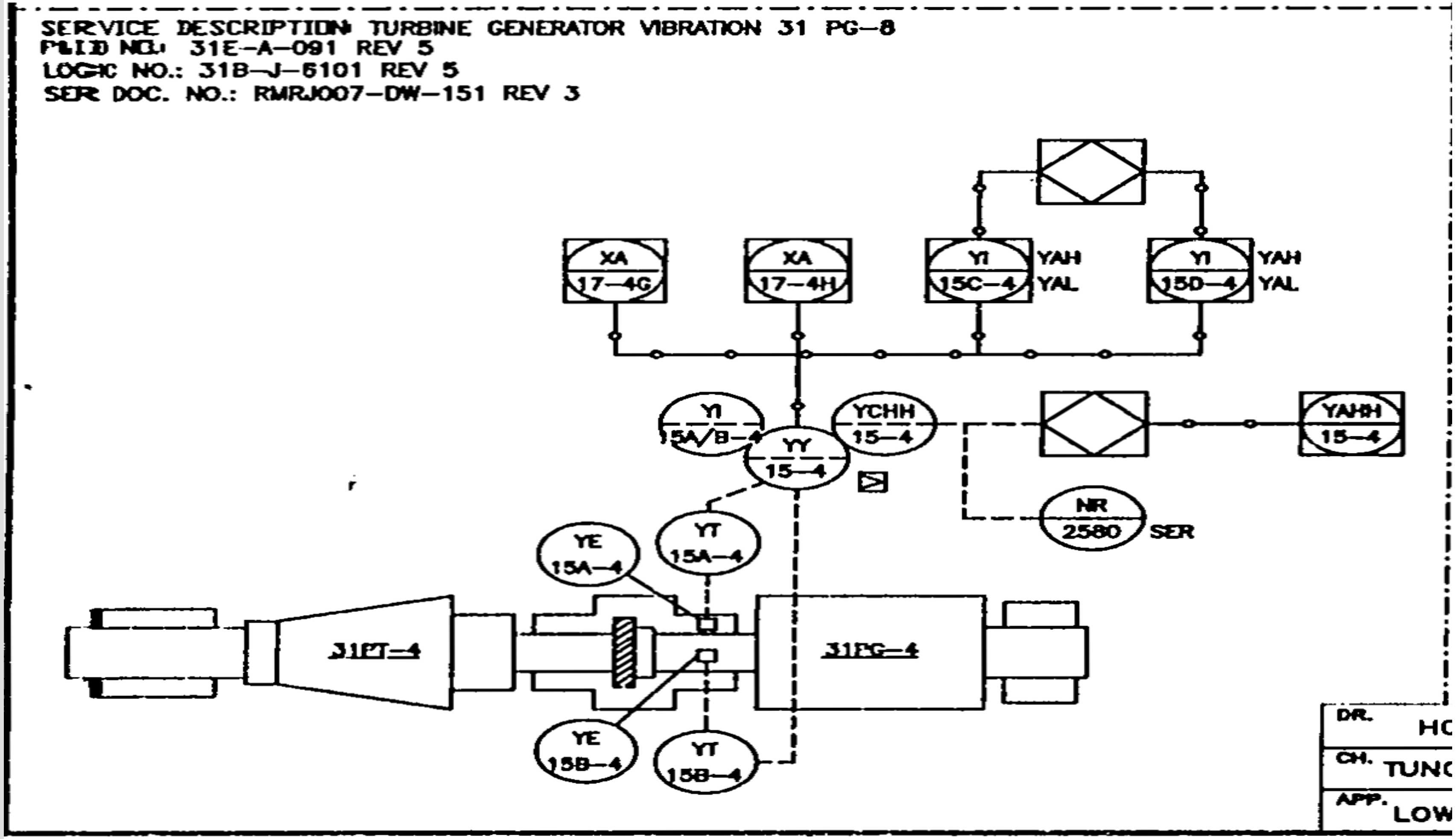
- Serial Data transfers using Communication Gateways.
- X Windows.
- DDE, NetDDE.
- Networking.
- Remote Communications.
  - host to host.
  - host to rack.
- High Flexibility.
- Machine Train Diagram Displays.
- Real-time and Historical Trend Data Collection and Reporting.

3500 Machine Train Display



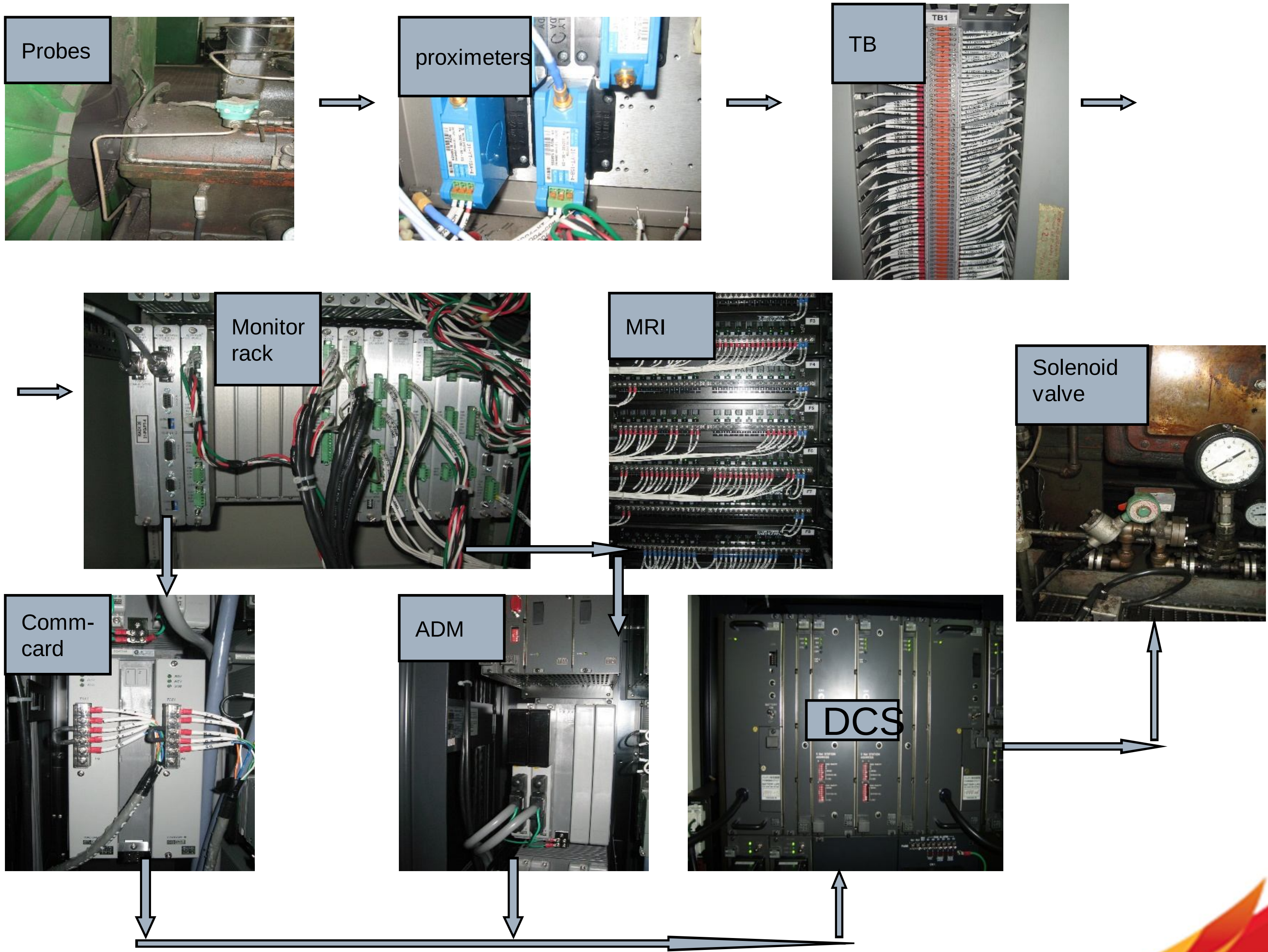
3500 MONIToRING SYsTEM

31PG-4 Inboard Radial vibration(YE-15A/B-4)



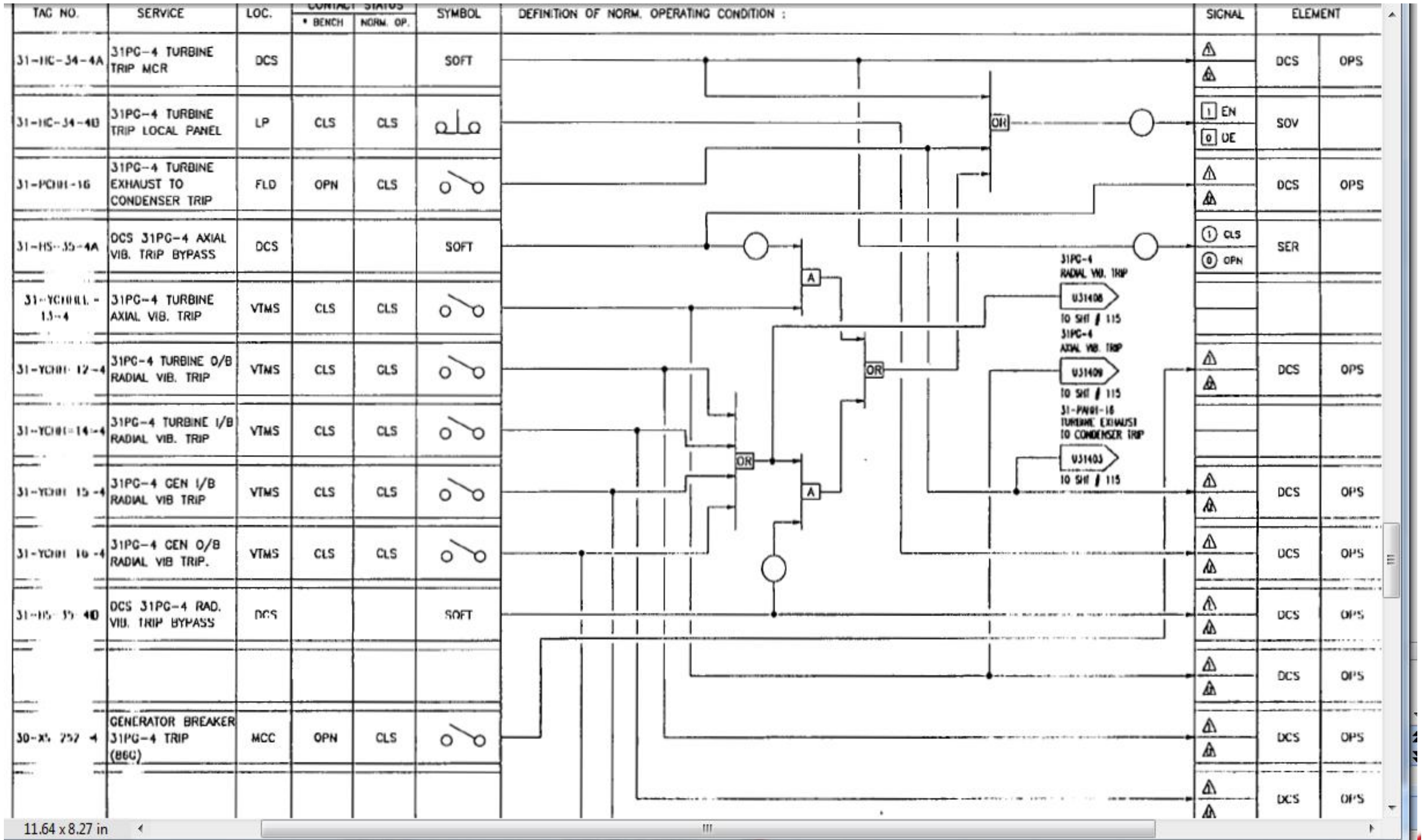
3500 MONITORING SYSTEM

VTMS loop overview



3500 MONITORING SYSTEM

31PG-4 Turbine trip solenoid valve (31-YCHH-15-4)



Thank you

Badak LNG
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