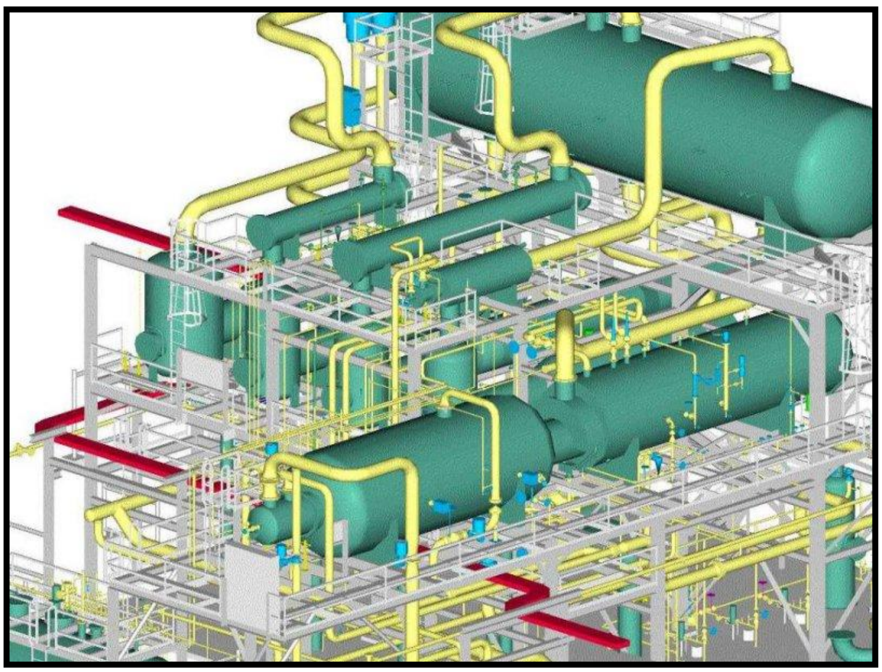
pakarab FERTILIZERS LIMITED MULTAN

# Basic Instrumentation

## Instrument Unit



## PAKARAB FERTILIZERS LIMITED MULTAN

**GEN-01 (Rev 0)**


Prepared by : Rashid Saud
Reviewed by : Ali Raza Soomro
Approved by: Pervaiz Iqbal

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# 1. Piping and Instrumentation Diagram [P&ID] Study

It is recommended that learners review the different types of instrument and line symbols used in P&ID on **Annexure A**

**Learning objectives:**

- ✓ To remember line symbols used in P&ID
- ✓ To remember instrument symbols used in P&ID
- ✓ To understand how inst & line symbol used in P&ID
- ✓ To study single loop DWG and discuss each symbols

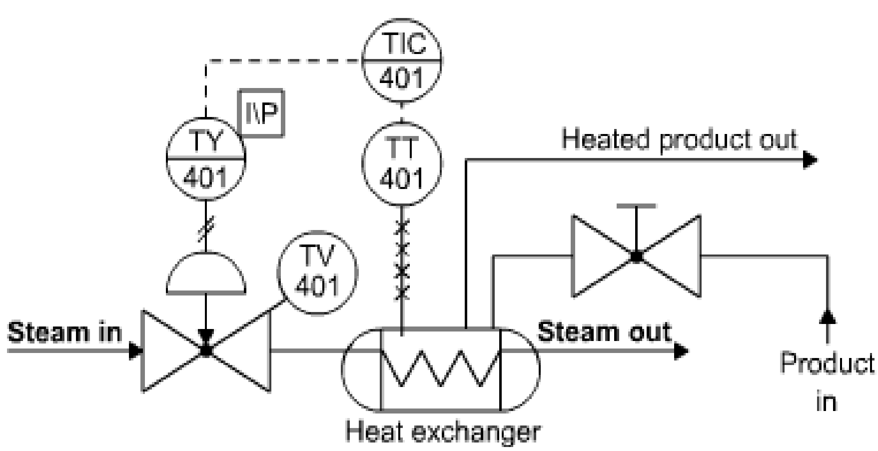
P&ID (Piping and Instrument Diagram) drawings provide various types of information, such as:

- Which components are in circuit,
- How instruments are connected,
- Where instruments are located,
- What functions the instruments perform.

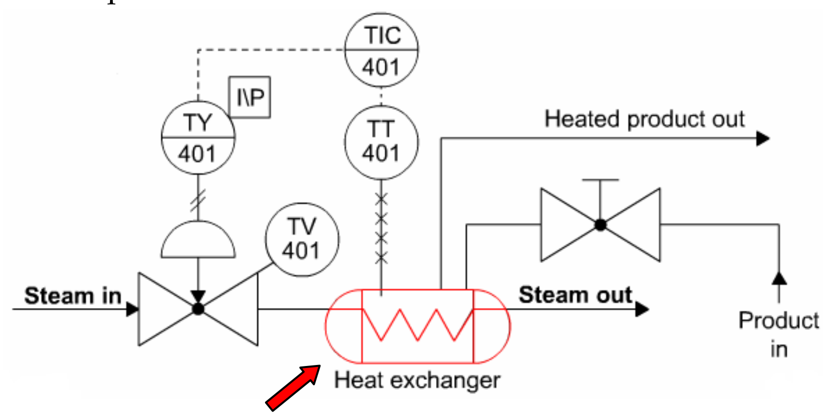
A thorough understanding of these diagrams helps the operator or technician to do three things:

- Monitor a processor,
- Work more efficiently,
- Troubleshoot.

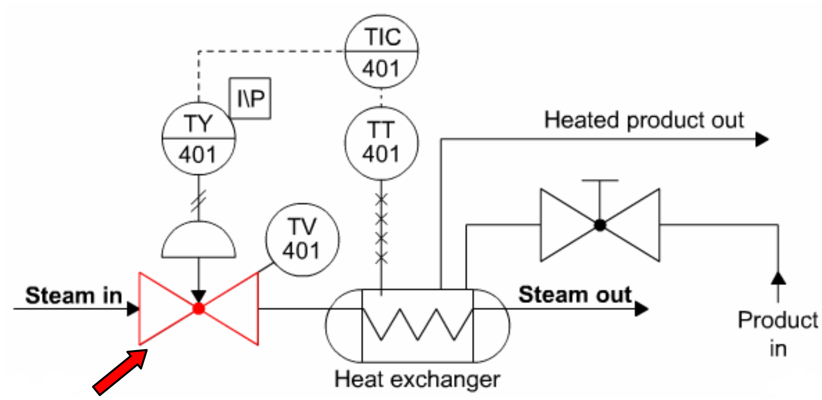
To illustrate how to read a P&ID diagram, a single loop that controls a heat exchanger is used.



In this system, steam is fed by a pipe into a sealed enclosure (called a heat exchanger) through which water flows.
As the water passes through the enclosure and makes contact with the pipe, the water is heated to a higher temperature.

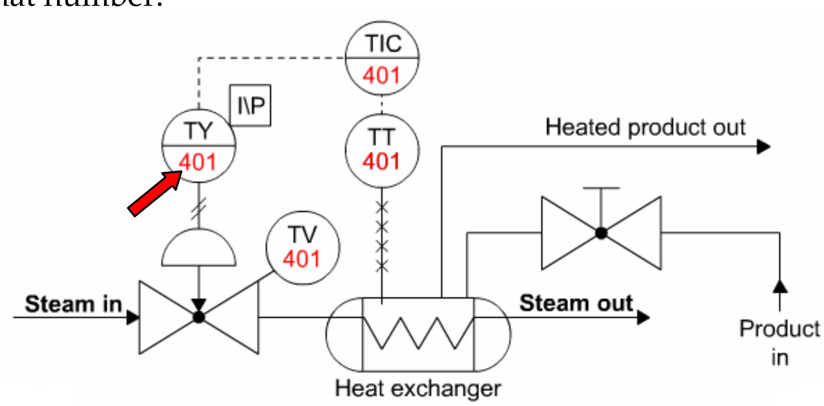



The symbol look like a bow tie represents a valve that passes fluid.



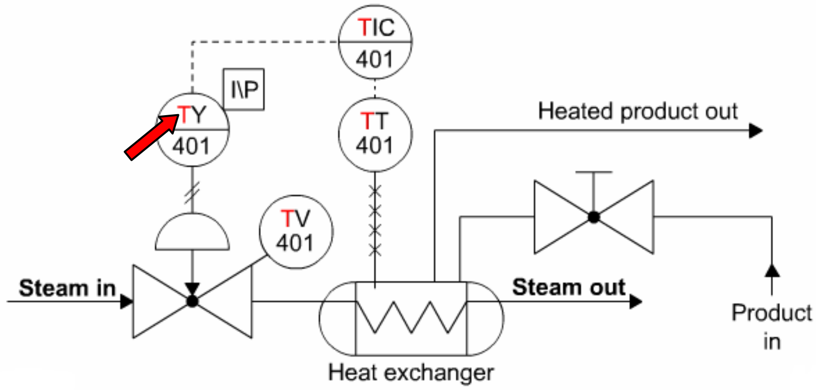

The steps for reading the control loop portion of the P&ID diagram are listed on the following sequence.

**Step 1**
The tag number 401 on the components indicates they are located on the control loop identified by that number.



**Step 2**

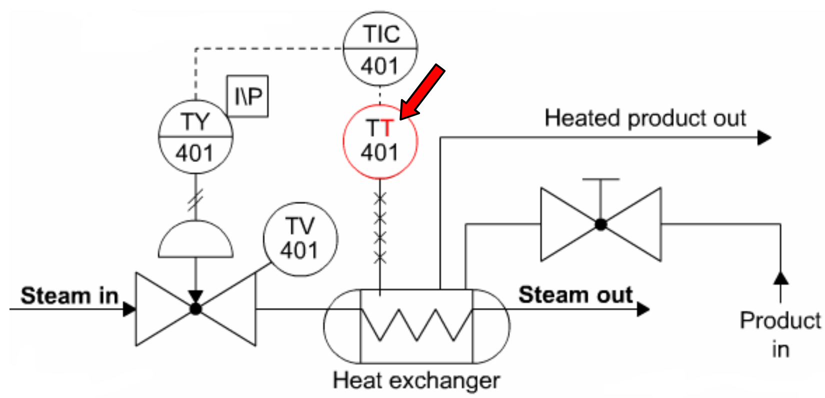
The first letter of each functional identifier is a “T,” which means temperature is being controlled.




**Step 3**

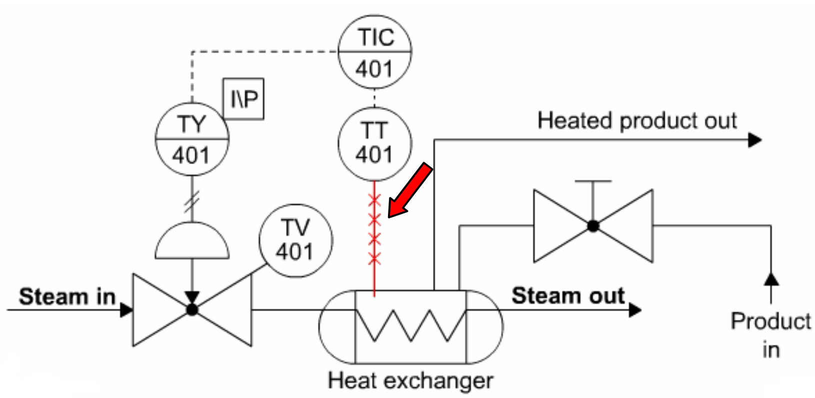
The instrument connected to the heat exchanger provides two different types of information.

- The second letter in the functional identifier indicates it is a transmitter.
- The ballon has no line inside its symbol, which means it is field mounted.



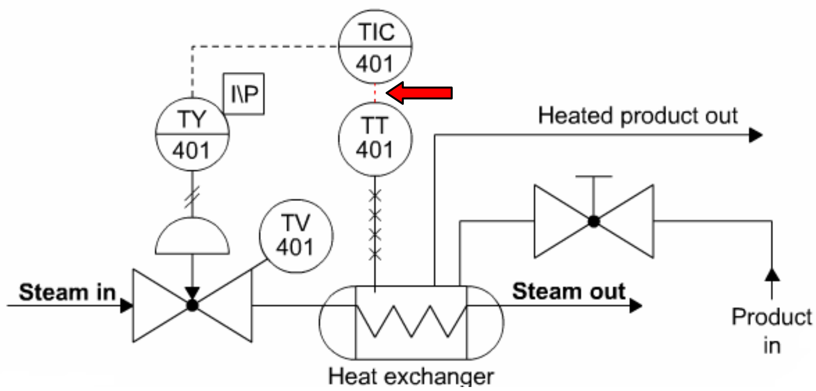

**Step 4**

The line with Xs indicates a capillary tube sends a signal from the exchanger to the transmitter.



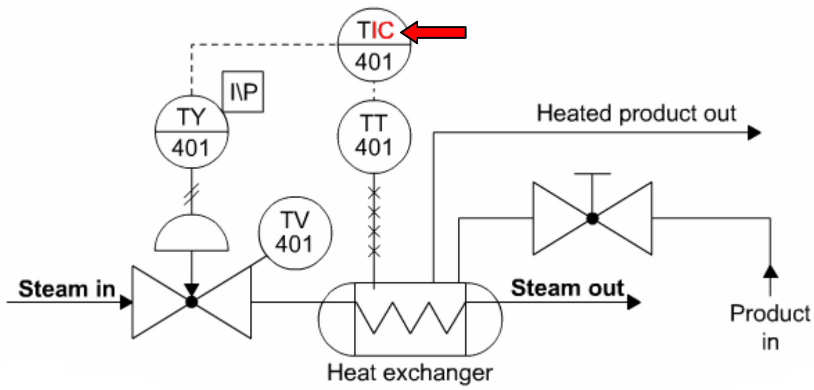
**Step 5**

The dashed line from the transmitter indicates it produces an electronic signal.



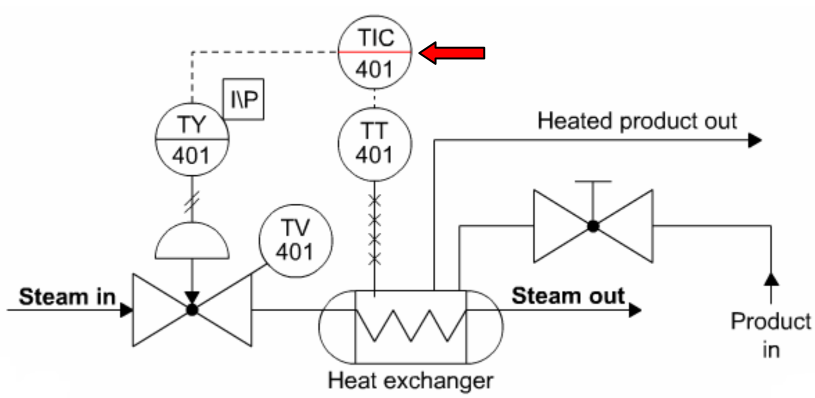

**Step 6**

The instrument to which the transmitter sends an electronic signal is a controller and indicator, specified by the second and third letters, "IC," of the functional identifier.



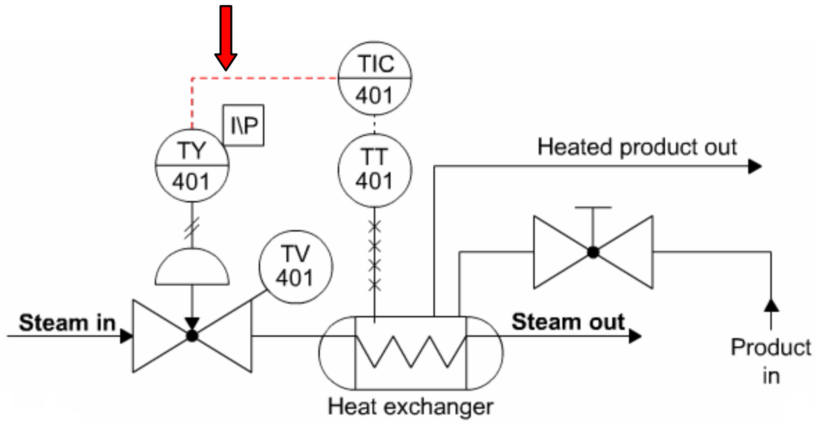

**Step 7**

The solid line inside the balloon indicates it is board mounted.



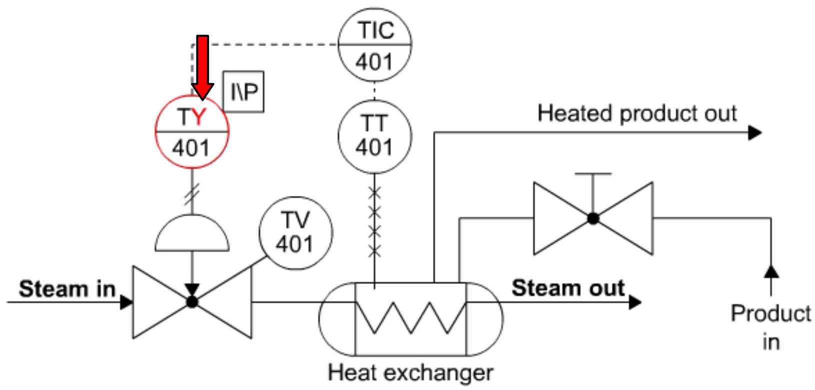
### Step 8

The dashed line to the left of the controller indicates it sends an electronic signal.



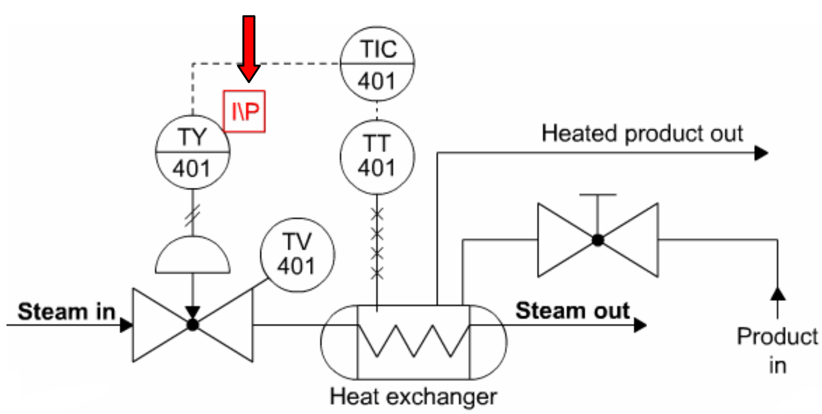

### Step 9

The instrument to which the controller output is connected is a transducer, as indicated by the second letter, "Y," of the functional identifier inside the balloon.



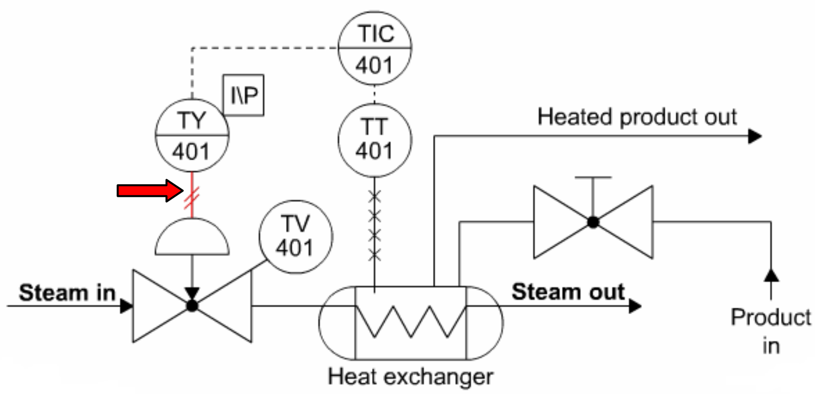

### Step 10

The function of the transducer is to convert an electronic signal to a pressure signal, as specified by the square containing the letters "IP."



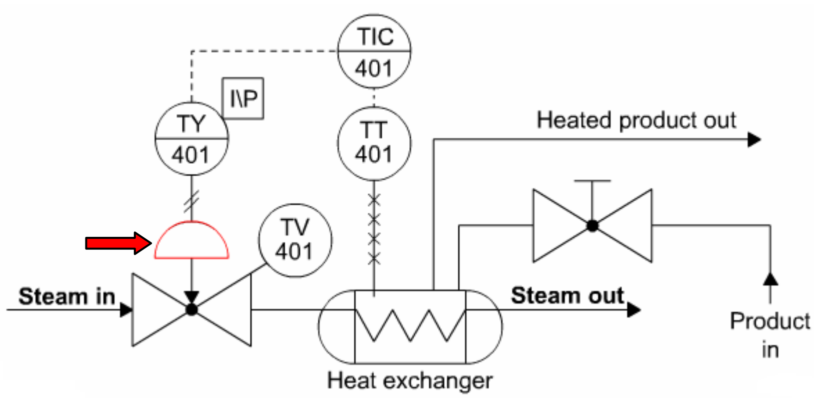
**Step 11**

The fine line with diagonal markings that extends from the bottom of the transducer symbol is a pneumatic line.



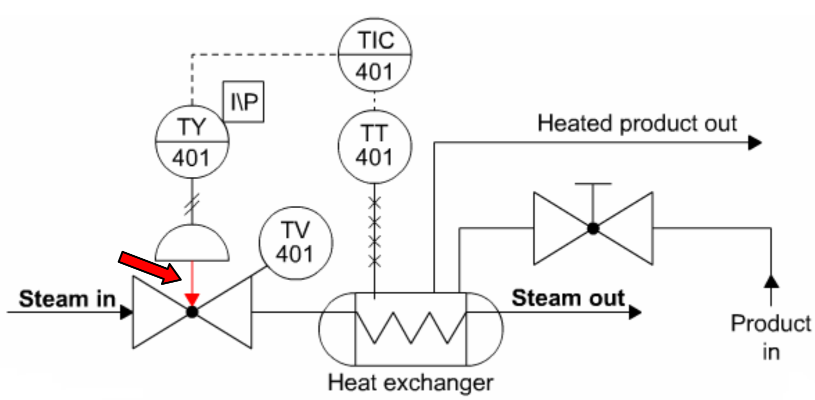

**Step 12**

The half circle symbol represents a pneumatic-controlled (diaphragm) actuator. Its function is to open and close the globe valve that regulates the steam that flows to the heat exchanger.




**Step 13**

The arrow that points downward from the actuator indicates it is a "fail-to-close" type of valve.



## 1.1 Annexure A

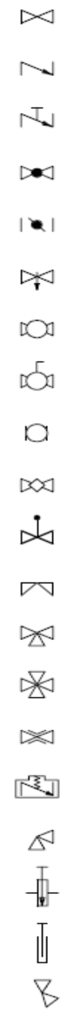
### ABBREVIATIONS

| | |
|---|---|
| AG | ABOVE GROUND |
| ATM | ATMOSPHERE |
| BB | BLOWBACK |
| BL | BATTERY LIMIT |
| BTL | BOTTOM TANGENT LINE |
| BYP | BYPASS |
| C | CLOUD |
| CC | CHEMICAL CLEANOUT |
| CL | CENTERLINE |
| CO | CLEANOUT |
| CONN | CONNECTION |
| CSC | CAR SEAL CLOSED |
| CSO | CAR SEAL OPEN |
| CTR | CENTER |
| DCS | DISTRIBUTED CONTROL SYSTEM |
| DE | DE-ENERGIZED |
| DES | DESIGN |
| DIA | DIAMETER |
| DSP | DISPLACE TYPE LEVEL TRANSMITTER |
| DP | DESIGN PRESSURE |
| D/P | DIFFERENTIAL PRESSURE |
| DRN | DRAIN |
| DT | DESIGN TEMPERATURE |
| DWG | DRAWING |
| (E) | EXISTING |
| E | ENERGIZED |
| EIV | EMERGENCY ISOLATION VALVE |
| EL | ELEVATION |
| ESD | EMERGENCY SHUTDOWN |
| FOF | FACE OF FLANGE |
| (F) | FURNISHED |
| FC | FAIL CLOSED |
| FI | FAIL INDETERMINATE |
| FL | FAIL LOCKED (LAST POSITION) |
| FLG | FLANGE |
| FO | FAIL OPEN |
| FP | FULL PORT |
| FV | FULL VACUUM |
| GC | GAS CHROMATIGRAPH |
| GO | GEAR OPERATED |
| GR | GRADE |
| H | HIGH |
| HDR | HEADER |
| HH | HAND HOLE |
| HLL | HIGH LIQUID LEVEL |
| HIL | HIGH INTERFACE LEVEL |
| HHIL | HIGH HIGH INTERFACE |
| HHLL | HIGH HIGH LIQUID LEVEL |
| HOA | HAND/OFF/AUTO |
| HP | HIGH PRESSURE |
| HPT | HIGH POINT |
| IAS | INSTRUMENT AIR SUPPLY |
| ID | INTERNAL DIAMETER |
| ISBL | INSIDE BATTERY LIMITS |
| L | LOW |
| LC | LOCKED CLOSED |
| LIL | LOW INTERFACE LEVEL |
| LLIL | LOW LOW INTERFACE LEVEL |
| LLL | LOW LIQUID LEVEL |
| LLLL | LOW LOW LIQUID LEVEL |
| LO | LOCKED OPEN |
| LP | LOW PRESSURE |
| LPT | LOW POINT |
| MAX | MAXIMUM |
| MIN | MINIMUM |
| MOV | MOTOR OPERATED VALVE |
| MTL | MATERIAL |
| MW | MANWAY |
| NC | NORMALLY CLOSED |
| NIL | NORMAL INTERFACE LEVEL |
| NLL | NORMAL LIQUID LEVEL |
| NNF | NORMALLY NO FLOW |
| NO | NORMALLY OPEN |
| NOZ | NOZZLE |
| O/C | OPEN/CLOSE |
| O/O | ON/OFF |
| OP | OUTPUT |
| OSBL | OUTSIDE BATTERY LIMITS |
| OVHD | OVERHEAD |
| PES | PROGRAMMABLE ELECTRONIC SYSTEM (FOR SAFETY INSTRUMENTED SYSTEM) |
| PLC | PROGRAMMABLE LOGIC CONTROLLER |
| PRESS | PRESSURE |
| PV | PROCESS VARIABLE |
| (R) | RELOCATED |
| REQD | REQUIRED |
| ROC | RATE OF CHANGE |
| RTD | RESISTANCE TEMPERATURE DETECTOR |
| SC | SAMPLE CONNECTION |
| SCH | SCHEDULE |
| SD | SHUTDOWN |
| SDA | SETPOINT DEVIATION ALARM |
| SEQ | SEQUENCE CONTROL PROGRAM |
| SG | SPECIFIC GRAVITY |
| SIS | SAFETY INSTRUMENTED SYSTEM |
| SO | STEAM OUT |
| SP | SET POINT |
| SS | STAINLESS STEEL |
| S/S | START/STOP |
| STD | STANDARD |
| T/C | THERMOCOUPLE |
| TDH | TOTAL DIFFERENTIAL HEAD |
| TEMP | TEMPERATURE |
| THRD | THREADED |
| TL | TANGENT LINE |
| TSO | TIGHT SHUT-OFF |
| T/T | TANGENT TO TANGENT |
| TYP | TYPICAL |
| UG | UNDERGROUND |
| (V) | VENDOR |
| VAC | VACUUM |
| VB | VORTEX BREAKER |
| VHP | VERY HIGH PRESSURE |
| VNT | VENT |
| W/ | WIDTH |
| W/O | WITHOUT |

### INSULATION TYPE CODES

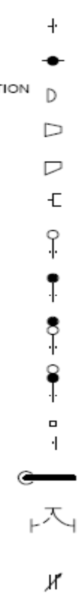
| | |
|---|---|
| CF | COLD INSULATION WITH FIRE PROTECTION |
| CH | COLD AND HOT INSULATION |
| CJ | CHILLED FLUID JACKETED |
| CP | CONDENSATION CONTROL |
| CS | COLD INSULATION WITH SOUND ATTENUATION |
| CT | CHILLED FLUID TRACED |
| ET | ELECTRIC TRACED |
| FP | FIRE PROTECTION INSULATION |
| HJ | HOT FLUID JACKETING |
| HT | HOT FLUID TRACED |
| IA | ACOUSTIC CONTROL INSULATION |
| IC | COLD SERVICE INSULATION |
| IH | HEAT CONSERVATION INSULATION |
| IS | PERSONAL PROTECTION INSULATION |
| PF | PREVENTION FROM FREEZING INSULATION |
| PS | PROCESS STABILITY INSULATION |
| SJ | STEAM JACKETED |
| ST | STEAM TRACED |

### VALVE SYMBOLS



- GATE (OR GENERIC)
- CHECK
- STOP CHECK
- GLOBE
- BUTTERFLY
- NEEDLE
- BALL
- ORBIT
- GENERIC ROTARY (1/4 TURN)
- PLUG
- POST INDICATOR
- DIAPHRAGM
- 3-WAY
- 4-WAY
- PINCH
- MINIMUM FLOW/BYPASS
- ANGLE
- KNIFE
- SLIDE
- RAM

### PIPING FITTINGS



- FLANGE
- WELDED CONNECTION
- CAP
- CONCENTRIC (OR GENERIC) REDUCER
- ECCENTRIC REDUCER
- HOSE CONNECTION
- SPACER
- BLANK
- OPEN FIGURE 8 BLIND
- CLOSED FIGURE 8 BLIND
- VALVE PLUG
- BLIND FLANGE
- TANGENTIAL ENTRY
- SWING ELBOW
- ISOLATING FLANGE

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## PIPING SPECIALITY ITEMS

- Y-TYPE STRAINER
- CONE STRAINER
- T-TYPE STRAINER
- DUPLEX STRAINER
- BASKET STRAINER
- TEMPORARY STRAINER
- FILTER
- DETONATION ARRESTOR
- FLAME ARRESTOR
- STEAM TRAP
- EJECTOR/EDUCTOR
- PULSATION DAMPENER
- IN-LINE SILENCER
- VENT SILENCER
- REMOVABLE SPOOL
- FLEXIBLE HOSE
- EXPANSION JOINT
- DAMPER
- BREATHER
- SPRAY NOZZLE
- VENT COVER
- VENT COVER W/ SCREEN
- IN-LINE MIXER
- EXCESS FLOW VALVE
- EXHAUST HEAD
- SAFETY/SHOWER EYEWASH
- TRUCK GROUNDING

## PIPING LINE SYMBOLS

- PRIMARY (AG AND UG)
- SECONDARY / UTILITY (AG AND UG)
- FUTURE ON NEW P&IDs
- JACKETED OR DOUBLE CONTAINMENT
- SLOPE REQUIREMENT

## LINE DATA IDENTIFICATION

WBS - SERVICE - SEQUENCE - LINE CLASS - SIZE - INSUL

XX - XXX - XXXX - XXXX - XXXX - XX

## OFF-PAGE AND DRAIN CONNECTORS

### OFF-PLOT CONNECTOR

CONNECTOR NUMBER — XXXXX | P&ID NO

SERVICE DESCRIPTION

ORIGIN/DESTINATION

### PRIMARY / SECONDARY AND INSTRUMENT SIGNAL CONNECTOR

CONNECTOR NUMBER — XXXXX | P&ID NO

SERVICE DESCRIPTION

ORGIN/DESTINATION

### UTILITY CONNECTOR

CONNECTOR NUMBER — XXX

SERVICE DESCRIPTION — YYY

DESTINATION — PID NO

### CLOSED DRAIN

CONNECTOR NUMBER — XXXXX

LINE SERVICE CODE — YYY

DESTINATION — PID NO

### OPEN DRAIN

CONNECTOR NUMBER — XXXXX

LINE SERVICE CODE — YYY

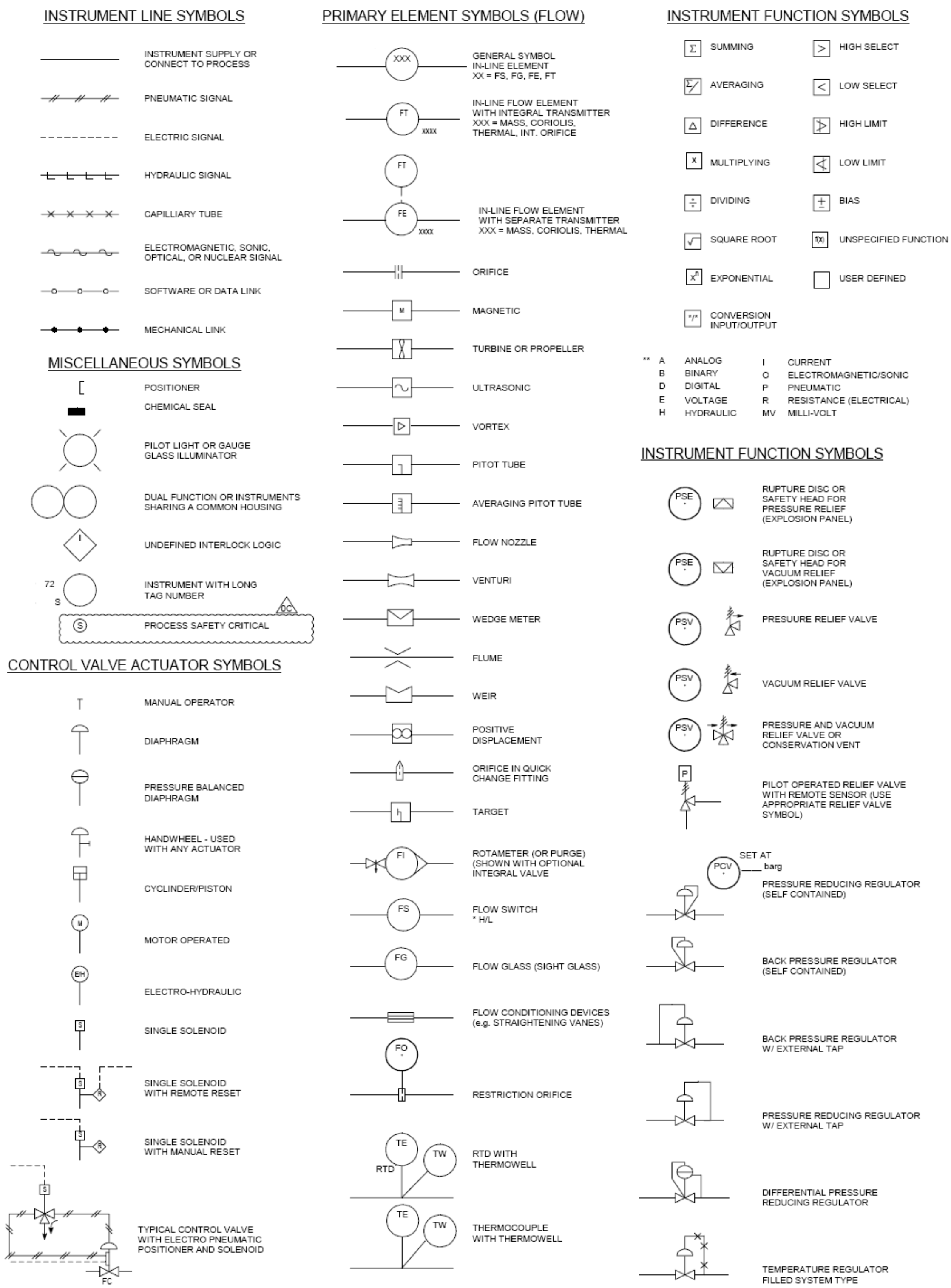
DESTINATION — PID NO

## MISCELLANEOUS

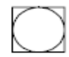
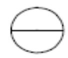
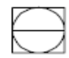
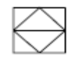
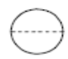
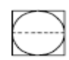
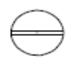
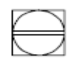
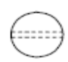
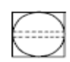
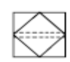
- PURGE CONNECTION (XXXX = PURGE PRESSURE AND MEDIUM)
- SAMPLE CONNECTION (XX/YY = TYPE/NUMBER)
- NOTE REFERENCE SYMBOL (XX = NOTE NUMBER, ROTATE ARROW AS REQUIRED)
- TIE-IN SYMBOL (XXXX = IDENTIFICATION NUMBER)
- POINT OF CHANGE IN LINE CLASS OR INSULATION REQUIREMENT OR VENDOR BREAK
- SP - XXXX — PIPING SPECIALTY ITEM
- PACKAGED EQUIPMENT LINES
- BATTERY LIMITS (OR MATCH LINE)
- GRADE SYMBOL

## LINE SERVICE CODES

| | |
|---|---|
| AB | BREATHING AIR |
| AC | COMBUSTION AIR |
| AD | DRYING AIR |
| AI | INSTRUMENT AIR |
| AP | REGENERATION AIR |
| AR | PLANT AIR (UNITED REQUEST) |
| BC | COLD BLOWDOWN |
| BH | HOT BLOWDOWN |
| BL | LOW PRESSURE BLOWDOWN |
| BO | BOILER BLOWOFF |
| CA | CATALYST |
| CL | CHLORINE |
| CPS | PHOSPHATE SOLUTION |
| DA | ACID SEWER |
| DB | BENZENE SEWER |
| DC | CAUSTIC SEWER |
| DCH | CHEMICAL SEWER |
| DM | DMDS DRAIN |
| DO | OILY WATER SEWER |
| DP | PROCESS SEWER |
| DR | STORM WATER SEWER |
| DS | SANITARY SEWER |
| DW | POTENTENIALLY BENZENE CONTAMINATED WASTEWATER SEWER |
| EF | POND EFFLUENT |
| GCD | CARBON DIOXIDE |
| GCM | CARBON MONOXIDE |
| GF | FUEL GAS |
| GH | HYDROGEN |
| GI | INERT GAS (NITROGEN) |
| GLR | GLYCOL RETURN |
| GLS | GLYCOL SUPPLY |
| GN | NATURAL GAS |
| HCL | HYDROCHLORIC ACID |
| HS | SULFURIC ACID |
| HOR | HOT OIL RETURN |
| HOS | HOT OIL SUPPLY |
| IN | INHIBITOR |
| KC | CAUSTIC |
| KCS | SPENT CAUSTIC |
| KO | OXYGEN |
| KP | CHEMICALS |
| ME | METHANOL |
| NH | HIGH PRESSURE PURIFIED NITROGEN |
| NL | LOW PRESSURE PURIFIED NITROGEN |
| OC | COOLING OIL |
| OF | FUEL OIL |
| OH | HYDRAULIC OIL |
| OL | LUBE OIL |
| OS | SEAL OIL |
| OW | WASH OIL |
| OX | SLOP OIL |
| P | PROCESS PIPING |
| PC | PROCESS CONDENSATE |
| PE | PE WASTEWATER |
| RE | ETHYLENE REFRIGERATION |
| RP | PROPYLENE REFRIGERATION |
| SA | SERVICE AIR |
| SC | SUBCOOLED CONDENSATE |
| SCD | PROCESS CONDENSATE DIRTY |
| SCH | HIGH PRESSURE STEAM CONDENSATE |
| SCL | LOW PRESSURE STEAM CONDENSATE |
| SCM | MEDIUM PRESSURE STEAM CONDENSATE |
| SCS | SUSPECT CONDENSATE |
| SCR | MEDIUM PRESSURE REDUCED CONDENSATE |
| SH | HIGH PRESSURE STEAM |
| SL | LOW PRESSURE STEAM |
| SM | MEDIUM PRESSURE STEAM |
| SMR | MEDIUM PRESSURE REDUCED STEAM |
| SPD | PROCESS STEAM DIRTY |
| SV | VERY HIGH PRESSURE STEAM |
| VA | ATMOSPHERIC VENT |
| WA | POTABLE WATER |
| WB | BOILER FEED WATER |
| WBV | VERY HIGH PRESSURE BOILER FEEDWATER |
| WBZ | BENZENE CONTAMINATED OILY WATER |
| WC | COOLING WATER SUPPLY |
| WD | DRINKING WATER |
| WF | FIRE WATER |
| WI | DEMINERALIZED WATER |
| WJ | JACKET WATER |
| WL | CHILLED WATER SUPPLY |
| WM | CHILLED WATER RETURN |
| WPE | PELLET WATER |
| WQ | QUENCH WATER |
| WR | COOLING WATER RETURN |
| WRC | RECOVERY WATER |
| WS | WASTE SLUDGE |
| WSE | SERVICE WATER |
| WSR | SEAWATER RETURN |
| WSS | SEAWATER SUPPLY |
| WW | POTENTIALLY BENZENE CONTAMINATED WASTEWATER |
| WWN | NEUTRALIZED WASTEWATER |
| WWT | TREATED WASTEWATER |


INSTRUMENT LINE SYMBOLS
INSTRUMENT SUPPLY OR CONNECT TO PROCESS
PNEUMATIC SIGNAL
ELECTRIC SIGNAL
HYDRAULIC SIGNAL
CAPILLIARY TUBE
ELECTROMAGNETIC, SONIC, OPTICAL, OR NUCLEAR SIGNAL
SOFTWARE OR DATA LINK
MECHANICAL LINK
MISCELLANEOUS SYMBOLS
POSITIONER
CHEMICAL SEAL
PILOT LIGHT OR GAUGE GLASS ILLUMINATOR
DUAL FUNCTION OR INSTRUMENTS SHARING A COMMON HOUSING
I
UNDEFINED INTERLOCK LOGIC
72
S
INSTRUMENT WITH LONG TAG NUMBER
PC
S
PROCESS SAFETY CRITICAL
CONTROL VALVE ACTUATOR SYMBOLS
MANUAL OPERATOR
DIAPHRAGM
PRESSURE BALANCED DIAPHRAGM
HANDWHEEL - USED WITH ANY ACTUATOR
CYCLINDER/PISTON
M
MOTOR OPERATED
E/H
ELECTRO-HYDRAULIC
S
SINGLE SOLENOID
S
R
SINGLE SOLENOID WITH REMOTE RESET
S
R
SINGLE SOLENOID WITH MANUAL RESET
S
FC
TYPICAL CONTROL VALVE WITH ELECTRO PNEUMATIC POSITIONER AND SOLENOID
PRIMARY ELEMENT SYMBOLS (FLOW)
XXX
GENERAL SYMBOL IN-LINE ELEMENT XX = FS, FG, FE, FT
FT
xxxx
IN-LINE FLOW ELEMENT WITH INTEGRAL TRANSMITTER XXX = MASS, CORIOLIS, THERMAL, INT. ORIFICE
FT
FE
xxxx
IN-LINE FLOW ELEMENT WITH SEPARATE TRANSMITTER XXX = MASS, CORIOLIS, THERMAL
ORIFICE
M
MAGNETIC
TURBINE OR PROPELLER
ULTRASONIC
VORTEX
PITOT TUBE
AVERAGING PITOT TUBE
FLOW NOZZLE
VENTURI
WEDGE METER
FLUME
WEIR
POSITIVE DISPLACEMENT
ORIFICE IN QUICK CHANGE FITTING
TARGET
FI
ROTAMETER (OR PURGE) (SHOWN WITH OPTIONAL INTEGRAL VALVE
FS
FLOW SWITCH * H/L
FG
FLOW GLASS (SIGHT GLASS)
FLOW CONDITIONING DEVICES (e.g. STRAIGHTENING VANES)
FO
RESTRICTION ORIFICE
TE
TW
RTD
RTD WITH THERMOWELL
TE
TW
THERMOCOUPLE WITH THERMOWELL
INSTRUMENT FUNCTION SYMBOLS
Σ SUMMING
> HIGH SELECT
Σ/ AVERAGING
< LOW SELECT
Δ DIFFERENCE
HIGH LIMIT
X MULTIPLYING
LOW LIMIT
÷ DIVIDING
± BIAS
√ SQUARE ROOT
f(x) UNSPECIFIED FUNCTION
xⁿ EXPONENTIAL
USER DEFINED
*/* CONVERSION INPUT/OUTPUT
** A ANALOG
B BINARY
D DIGITAL
E VOLTAGE
H HYDRAULIC
I CURRENT
O ELECTROMAGNETIC/SONIC
P PNEUMATIC
R RESISTANCE (ELECTRICAL)
MV MILLI-VOLT
INSTRUMENT FUNCTION SYMBOLS
PSE
RUPTURE DISC OR SAFETY HEAD FOR PRESSURE RELIEF (EXPLOSION PANEL)
PSE
RUPTURE DISC OR SAFETY HEAD FOR VACUUM RELIEF (EXPLOSION PANEL)
PSV
PRESUURE RELIEF VALVE
PSV
VACUUM RELIEF VALVE
PSV
PRESSURE AND VACUUM RELIEF VALVE OR CONSERVATION VENT
P
PILOT OPERATED RELIEF VALVE WITH REMOTE SENSOR (USE APPROPRIATE RELIEF VALVE SYMBOL)
PCV
SET AT ___ barg
PRESSURE REDUCING REGULATOR (SELF CONTAINED)
BACK PRESSURE REGULATOR (SELF CONTAINED)
BACK PRESSURE REGULATOR W/ EXTERNAL TAP
PRESSURE REDUCING REGULATOR W/ EXTERNAL TAP
DIFFERENTIAL PRESSURE REDUCING REGULATOR
TEMPERATURE REGULATOR FILLED SYSTEM TYPE

## GENERAL INSTRUMENT SYMBOLS

| LOCATION/ACCESSIBLITY | DISCRETE INSTRUMENTS | SHARED DISPLAY AND CONTROL (DCS) | PLC | DISCRETE HARDWARE INTERLOCK |
|---|---|---|---|---|
| 1. FIELD LOCALLY MOUNTED<br>2. ACCESSABLE TO AN OPERATOR AT DEVICE |  |  |  |  |
| PRIMARY LOCATION NORMALLY ACCESSIBLE TO AN OPERATOR<br>1. CENTRAL OR MAIN CONTROL ROOM<br>2. FRONT OF MAIN PANEL OR CONSOLE MOUNTED.<br>3. VISIBLE ON VIDEO DISPLAY<br>4. ACCESSIBLE TO AN OPERATOR AT DEVICE OR CONSOLE |  |  |  | |
| PRIMARY LOCATION NORMALLY INACCESSIBLE TO AN OPERATOR<br>1. CENTRAL OR MAIN CONTROL ROOM<br>2. REAR OF MAIN PANEL OR CABINET MOUNTED.<br>3. NOT VISIBLE ON VIDEO DISPLAY<br>4. NOT NORMALLY ACCESSIBLE TO AN OPERATOR AT DEVICE OR CONSOLE |  |  |  | |
| AUXILIARY LOCATION NORMALLY ACCESSIBLE TO AN OPERATOR<br>1. SECONDARY OR MAIN CONTROL ROOM<br>2. FIELD OR LOCAL CONTROL PANEL<br>3. FRONT OF SECONDARY OR LOCAL PANEL MOUNTED<br>4. VISIBLE ON VIDEO DISPLAY<br>5. ACCESSIBLE TO AN OPERATOR AT DEVICE OR CONSOLE. |  |  |  | |
| AUXILIARY LOCATION NORMALLY INACCESSIBLE TO AN OPERATOR<br>1. SECONDARY OR MAIN CONTROL ROOM<br>2. FIELD OR LOCAL CONTROL PANEL<br>3. REAR OF SECONDARY OR LOCAL PANEL MOUNTED<br>4. NOT VISIBLE ON VIDEO DISPLAY<br>5. NOT NORMALLY ACCESSIBLE TO AN OPERATOR AT DEVICE OR CONSOLE. |  |  |  | |

## INSTRUMENT IDENTIFICATION LETTERS

| | FIRST LETTER | | SUCEEDING LETTERS | | |
|---|---|---|---|---|---|
| | MEASURED OR INITIATING VARIABLE | MODIFIER | READOUT OR PASSIVE FUCTION | OUTPUT FUNCTION | MODIFIER |
| A | ANALYSIS | | ALARM | | |
| B | BURNER FLAME COMBUSTION | | USER'S CHOICE | USER'S CHOICE | USER'S CHOICE |
| C | USER'S CHOICE (TYPICALLY CONDUCTIVITY - ELECTRICAL) | | | CONTROL | CLOSED |
| D | USER'S CHOICE (TYPICALLY DENSITY OR SPECIFIC GRAVITY) | DIFFERENTIAL | | | DIVERT |
| E | VOLTAGE | | SENSOR (PRIMARY ELEMENT) | | |
| F | FLOW RATE | RATIO (FRACTION) | | | |
| G | USER'S CHOICE OR GAUGING (DIMENTIONAL) | | GLASS, VIEWING DEVICE | | |
| H | HAND | | | | HIGH |
| I | CURRENT (ELECTRICAL) | | INDICATE | | |
| J | POWER | SCAN | | | |
| K | TIME, TIME SCHEDULE | TIME RATE OF CHANGE | | CONTROL STATION | |
| L | LEVEL | | LIGHT | | LOW |
| M | USER'S CHOICE (TYPICALLY MOISTURE OR HUMIDITY | MOMENTARY | | | MIDDLE, INTERMEDIATE |
| N | USER'S CHOICE | | USER'S CHOICE | USER'S CHOICE | USER'S CHOICE |
| O | USER'S CHOICE | | ORIFICE, RESTRICTION | | OPEN |
| P | PRESSURE -VACUUM | | POINT (TEST) CONNECTION | | |
| Q | QUANTITY OR HEAT DUTY | INTEGRATE, TOTALIZE | | | |
| R | RADIATION | | RECORD | | |
| S | SPEED, FREQUENCY | SAFETY | | SWITCH | |
| T | TEMPERATURE | | | TRANSMIT | THROUGH |
| U | MULTIVARIABLE | | | MULTIFUNCTION | MULTIFUNCTION |
| V | VIBRATION, MECHANICAL ANALYSIS | | MULTIFUNCTION | 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, UNCLASSIFIED, FINAL CONTROL ELEMENT | |

# 2. TUBING AND FITTINGS SIZES

**Learning objectives:**

- ✓ To study characteristics Of Pipe And Tubing
- ✓ To study tube Run Installation
- ✓ To study tube Measuring And Cutting
- ✓ To study tube Bending Offsets
- ✓ To study removing Burrs And Ridges
- ✓ To study tube Bending Techniques
- ✓ To study compression Fittings
- ✓ To study compression Fittings Installation
- ✓ To study testing For Leaks
- ✓ To study general Guide Lines For Installing Tubing

## 2.1. INTRODUCTION

- Pipe and tubing are hollow cylinders that are used to transport fluids (liquid or gas) from one point to another.
- Generally, compressed air is used as the energy source for the operation of pneumatic instruments.
- Supply headers are used for connection of tubing to instruments and carry the control signals.

## 2.2. CHARACTERISTICS OF PIPE AND TUBING

Pipe and tubing are sometimes interchanged.
In most cases, pipe and tubing are labeled according to manufacturer's definition.
Pipe is assumed to be more rigid than tubing, to have larger outside diameter and to have thicker walls.
Fewer fittings are required for tubing installations than for piping.
A fitting is potential leak point, so fewer fittings means less chance of a leak.

**Pipe and tubing materials**

Two major factors must be considered

- Type of material the pipe or tubing is made of:
- The size dimension of the pipe or tubing:

Common material for pipe is brass, black iron, copper, or various types of steel
Common material for tubing is copper, stainless steel, or plastic

The type and size depend on the physical characteristics of the system, such as temperature, air pressure transported through it and corrosiveness of the environment

- Copper tubing is easily bent, and will hold up well in most environment.
- Stainless steel tubing is used for corrosive environment
- When tubing must be connected and disconnected frequently, plastic tubing is often used

**Pipe sizes**

Pipe is sized according to two factors

- Inside Diameter
- Wall thickness

Generally pipe sizes are given in terms of approximate inside diameter rather than actual inside diameter
Inside diameter varies as wall thickness varies
Usually expressed as NOMINAL PIPE SIZE (NPS)
Such as 1/4 inch NPS or 21 inch NPS
Inside diameter is slightly larger than the NPS
For example 1 inch NPS has actual inside diameter is 1.049 inches
Wall thickness is generally referred to in terms of a Schedule Number.
Schedule Number varies with the wall thickness.
For each NPS there can be more than one Schedule Number
For example,

| Nominal pipe size (Inches) | Identification steel Schedule No. | Wall thickness (Inches) | Inside diameter (Inches) |
|---|---|---|---|
| 1/8 | ….<br>40<br>80 | 0.049<br>0.068<br>0.093 | 0.307<br>0.269<br>0.215 |

In addition to Schedule Numbers, many other terms and methods are used by the manufacturers to express pipe wall thickness.

Tubing sizes

Tubing is sized according to its actual outside diameter.
Normally expressed in 1/4 inch, 3/8 inch, or 1/2 inch.
For each type of material used there are standard wall thicknesses.
Standard Copper wall thickness is 0.038 inches.
Stainless Steel tubing are 0.049 inches and 0.035 inches.

## 2.3. TUBE MEASURING AND CUTTING

### Measuring tubing

FOLLOW THESE STEPS

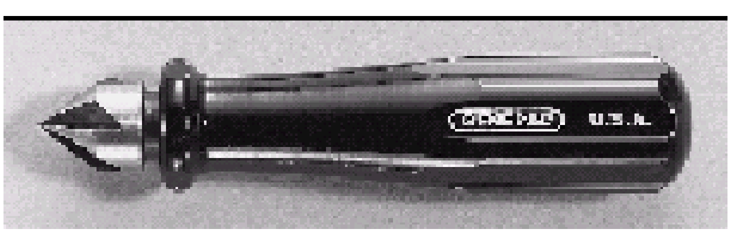
- Measure the distance between the components, where tubing is to be installed.
- Mark with pencil, the length of tubing slightly longer (about 1 or 2 inches) than the distance between the components is measured.

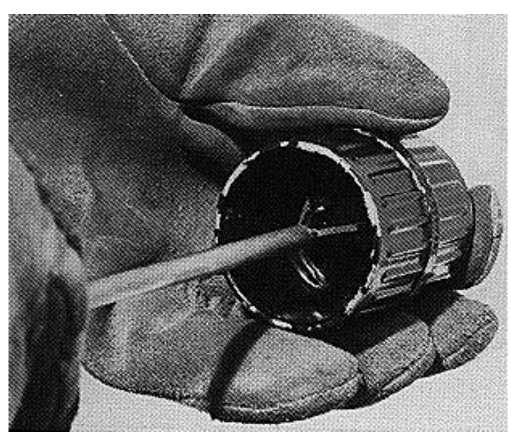
### Cutting tubing

- Tubing is usually cut with a device called a Tube Cutter
- A cutter consists of a cutting wheel, a handle and a roller.
- Tubing can also be cut with Hacksaw
- The blade of the hacksaw should be kept as perpendicular as possible to produce an even, squared-off cut.
- An uneven cut tube should be squared off with a file.

## 2.4. REMOVING BURS AND RIDGES

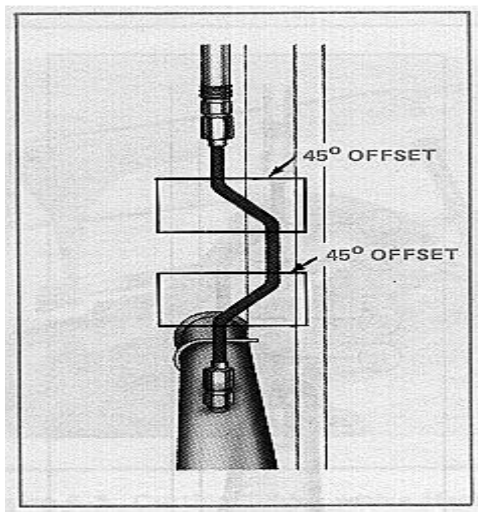
The best method for removing burrs and ridges is to use a "Deburring Tool".



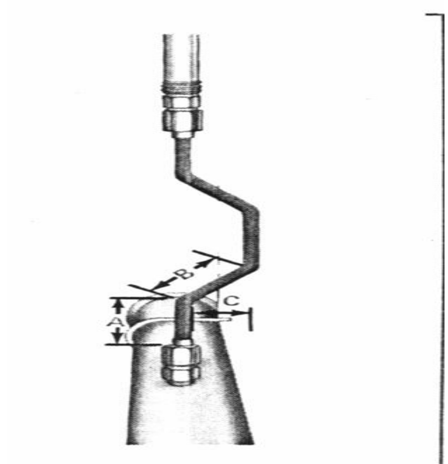
## 2.5. TUBE BENDING TECHNIQUES

A piece of tubing that is bent so that it deviates from a straight line but continues in the same direction is called an Offset.
Offsets are referred to by the angles of their bends.
For example 45$^o$ angle as shown in figure is called 45$^o$ Offsets.




**Measure for an offset**

- The amount of tubing required to make the offset must be calculated.
- Two lengths "A" and "C" must be calculated.
- "A" is the length of tubing from the end of the pipe to tube adapter to the first bend



- "C" is the distance from the centre of the adapter to the instrument panel.
- "B" is the distance from the first bend to the instrument panel.
- Therefore, the distance from the first bend to the second bend is the offset.

EXAMPLE:
Let,
A = 1 inches &	C = 1 inches
Now consider Offset Chart to know the length of "B"

## OFFSET CHART

| ANGLE OF OFFSET $45^0$ | |
|---|---|
| OFFSET DISTANCE | TUBE LENGTH |
| 1 | 1 – 13/32 |
| – 1/8 | 1 – 19/32 |
| – 1/4 | 1 – 25/32 |
| – 3/8 | 1 – 15/16 |
| – 1/2 | 2 – 1/8 |
| – 5/8 | 2 – 5/16 |
| – 3/4 | 2 – 15/32 |
| – 7/8 | 2 – 21/32 |

Therefore, B = 2 5/16 inches

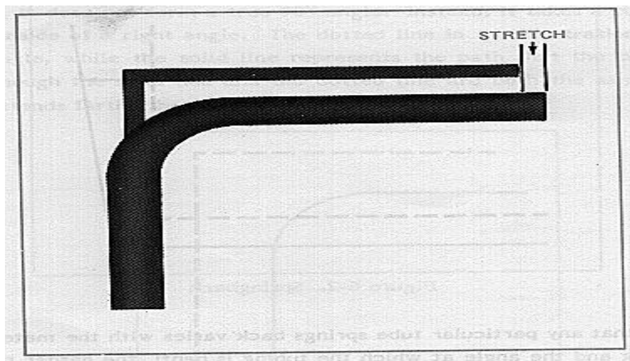
**Bending for offset**

- A device for tube bending is called "Tube Bender".
- Take the measurement for the entire run and then making all the bends.
- Always mark with pencil on the tube before bending.
- Parts of Tube Bender
  - Forming Wheel
  - Tube Clamp
  - Slide Block Handle
  - Forming Wheel Handle
- After all the bends have been made, trim off the excess length of tubing from one end.

**Characteristics of $90^{o}$ bend**

STRETCH:

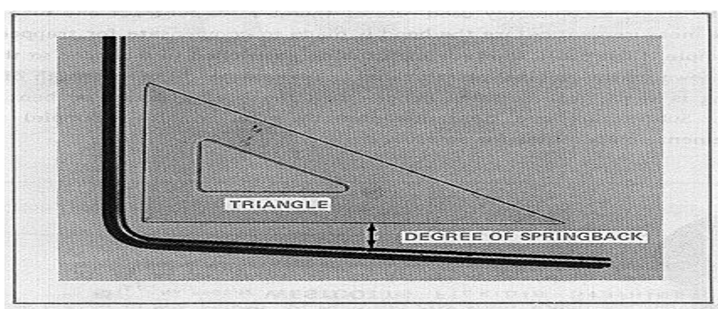
Apparent increase in tubing length when tubing is bent 90o. The length of tube stretches varies with the size of forming wheel or the size of the tubing.




**Characteristics of $90^{o}$ bend**

SPRING BACK:

The tendency of tubing to unbend after it has been released from a tube bender.
The degree that any particular tube springs back varies with the material and size of the tubing and the angle at which tubing is bent.




**Compensating for tube stretch**

The rule of thumb is to subtract one tube diameter from the measurement before the bend is made.
Example:1/4 inch Tubing
For Reverse bend, if a length of 5 inches of tubing to be bent Then, the tubing should be bent at 4 inches. i.e, subtract 1/4 inch from original length.

**Compensating for springback**

- Test a piece of scrap tubing for its tendency to unbend
- Measure the degrees of spring back with the help of Triangle
- For example, if a particular type of tubing springs back 3o
- For a 90o bend, that type of tubing should be bent 93o to get a 90o bend

**2.6. COMPRESSION FITTINGS**

Compression fittings might be used to make connection between tubing and pipe, or between tubing and instruments.
The two most common types of tube fittings used in pneumatic instrumentation are;

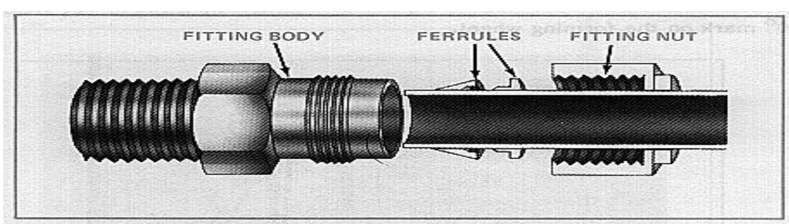
- Flared Fittings
- Compression Fittings

We shall discuss only Compression Fittings

**Compression fittings**

The four main parts of Compression Fitting are;

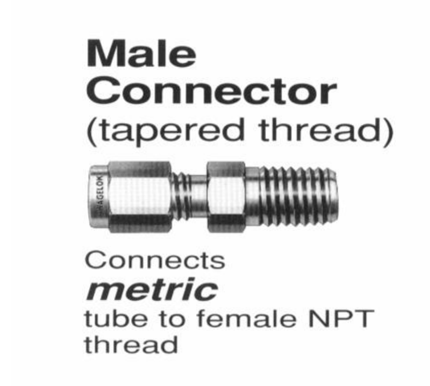
- Fitting Body
- Fitting Nut
- Two Ferrules




**Some commonly used tube fittings are**,

- Male Connector
- Union
- Union elbow
- Union Tee
- Union Cross
- Reducer
- Cap

**Male Connector**
**1/4 inch NPT x 6mm OD Tube**




**Male Straight**
**¼ inch straight x 6 mm OD tube**


**Male Elbow**


**Female Connector**


**Bulkhead Male Connector**

Bulkhead Union


Male Branch Tee


Union Cross


Cap


Back Ferrule

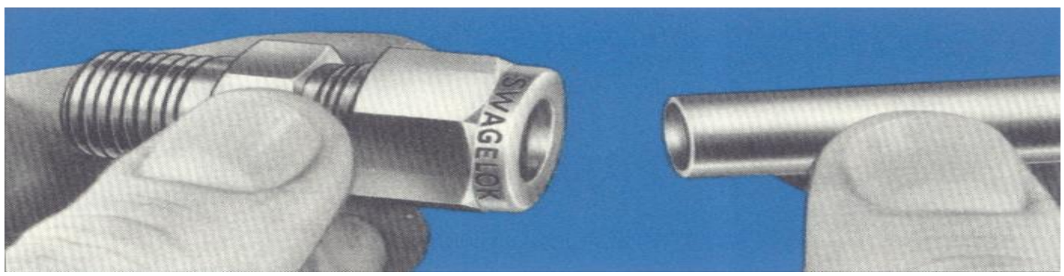
## 2.7. COMPRESSION FITTINGS INSTALLATION

Tube fittings are installed in following easy steps;

- Simply insert the tubing into the Tube Fitting. Make sure that the tubing rests firmly on the shoulder of the fitting and that the nut is finger-tight.
- Before tightening the nut, scribe the nut at the 6 O'clock position.
- Hold the fitting body steady with a backup wrench and tighten the nut 1 ¼ turns. Watch the scribe mark, make one complete revolution and continue to the 9 O' clock position.

**Tightening Procedure**

1-

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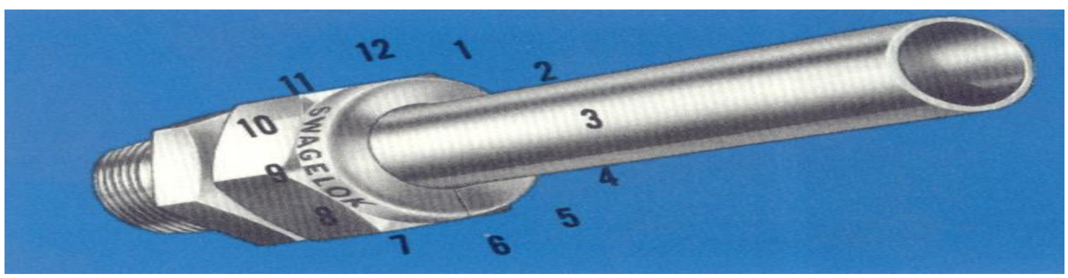


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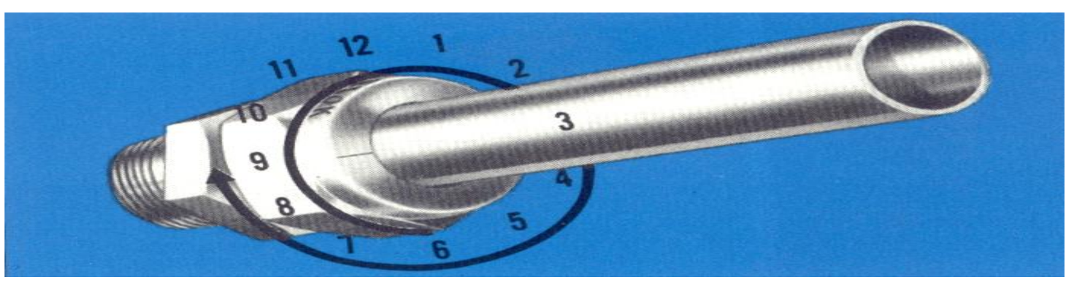



**Re-installation instruction**

The same reliable leak-proof seal can be obtained every time the connection is remade.

- Tighten nut by hand. Rotate nut to the original position with a wrench. An increase in resistance will be encountered at the original position. Then tighten slightly with the wrench.

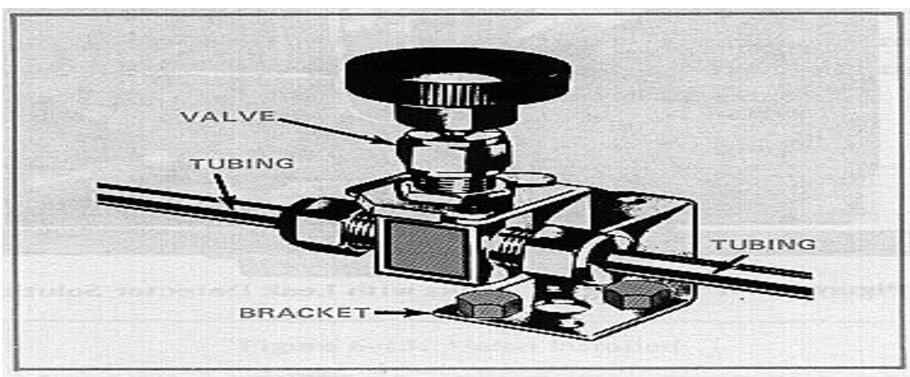
## 2.8. TESTING FOR LEAKS

STEPS FOR LEAK TEST:

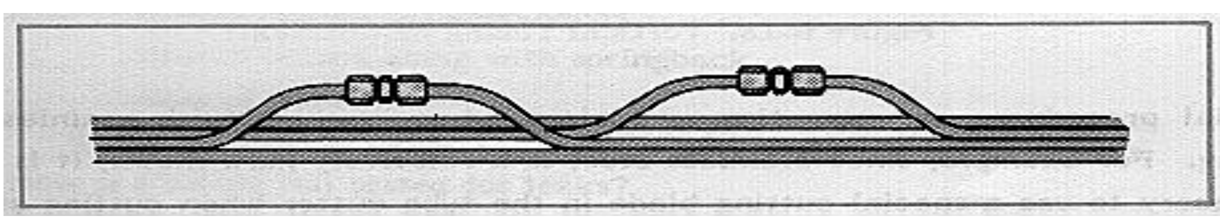
- Pressurized the system with Air
- Prepare a soapy water solution
- Spray it around all fittings
- Liquid will bubble if it contact with a leak
- If a leak is found, the fitting should be tightened
- Check the seal again
- If leak does not stop, the fitting or tubing connected to it may have to be replaced

## 2.9. GENERAL GUIDELINES FOR INSTALLING TUBING

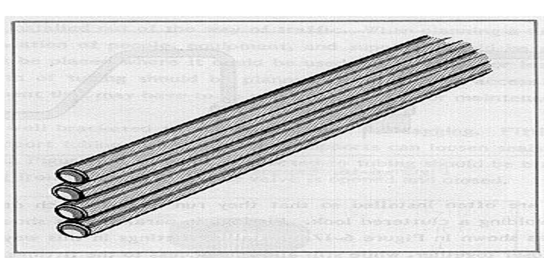
- Tubing should be installed out of the way of traffic
- Tubing should be well bracketed to avoid vibrations and sagging



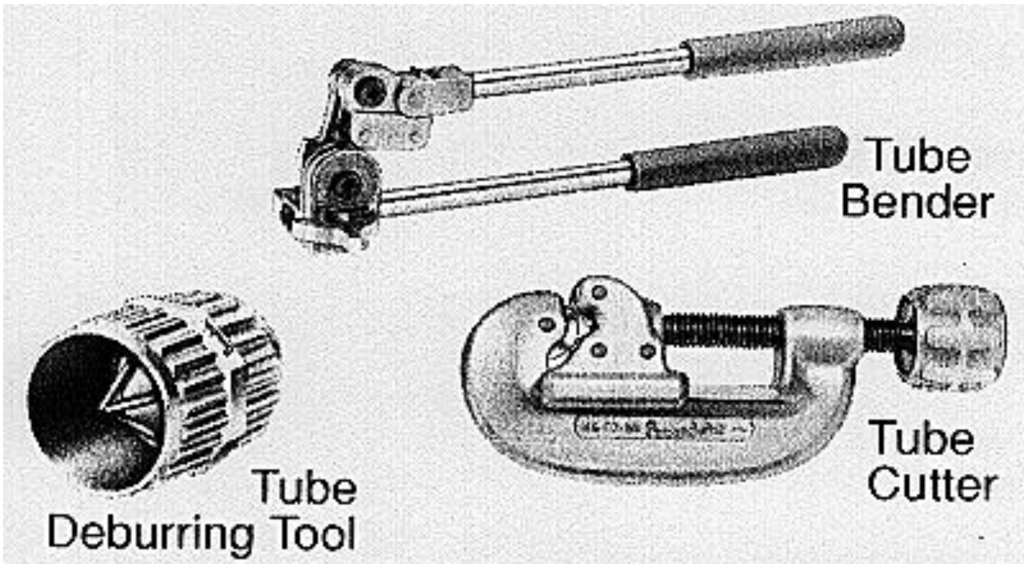

- A bend should be put in the run to act as an expansion loop
- Fittings in parallel runs should be staggered and offset



Tubing should be ganged or laid vertically



**Tools required for tubing exercise**



# 3. RELAY & GATE LOGIC

**Objectives:**

After this session participants are able to understand the Following points related to Relay & Digital Logic Gates:

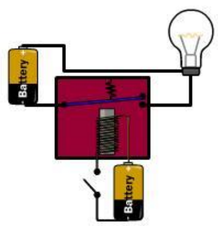
- ✓ Working Principle
- ✓ Types
- ✓ Technical Terms
- ✓ Logic Diagram (Reading)
- ✓ Function In Interlock

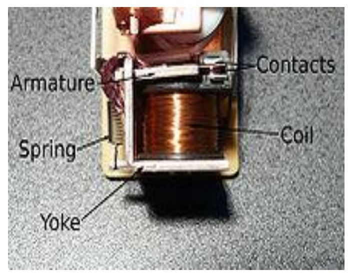
**Introduction**

INTERLOCKING or ESD is a method of preventing undesired states in a state machine, which in a general sense can include any electrical, electronic, or mechanical device or system.
In most applications an **interlock** is a device used to help prevent a machine from harming its operator or damaging itself by stopping the machine when tripped.
In Process industry we accomplished this by using several technique like RELAY, DIGITAL GATES, MICRO PROCESSOR,….etc
A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism, but other operating principles are also used. Relays find applications where it is necessary to control a circuit by a low-power signal, or where several circuits must be controlled by one signal.

### 3.1. BASIC DESIGN & OPERATION

A simple electromagnetic relay, such as in the picture, is an adaptation of an **ELECTROMAGNET**. It consists of a **COIL OF WIRE** surrounding a **SOFT IRON CORE**, an **IRON YOKE**, which provides a low reluctance path for magnetic flux, a movable iron **ARMATURE**, and a set, or sets, of **CONTACTS**; two in the relay pictured. The armature is hinged to the yoke and mechanically linked to a moving contact or contacts. It is held in place by a **SPRING** so that when the relay is de-energized there is an air gap in the magnetic circuit.




### 3.2. TYPES

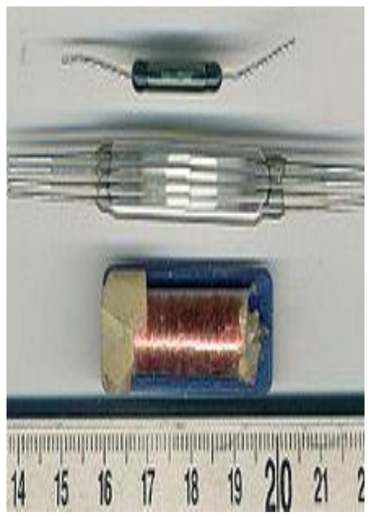
- LATCHING RELAY
- REED RELAY
- MERCURY – WETTED RELAY
- POLARIZED RELAY
- MACHINE TOOL RELAY
- CONTACTOR RELAY
- SOILD – STATE RELAY
- SOLID STATE CONTACTOR RELAY
- BUCHHOLZ RELAY
- FORCED – GUIDED CONTACTS RELAY
- OVERLOAD PROTECTION RELAY

**Latching relay**

Has two relaxed states (bistable). These are also called "impulse", "keep", or "stay" relays. When the current is switched off, the relay remains in its last state. This is achieved with a solenoid operating a ratchet and cam mechanism, or by having two opposing coils with an over-center spring or permanent magnet to hold the armature and contacts in position while the coil is relaxed, or with a remanent core. In the ratchet and cam example, the first pulse to the coil turns the relay on and the second pulse turns it off. In the two coil example, a pulse to one coil turns the relay on and a pulse to the opposite coil turns the relay off. This type of relay has the advantage that it consumes power only for an instant, while it is being switched, and it retains its last setting across a power outage. A remanent core latching relay requires a current pulse of opposite polarity to make it change state

**Reed relay**

Has a set of contacts inside a vacuum or inert gas filled glass tube, which protects the contacts against atmospheric corrosion. The contacts are closed by a magnetic field generated when current passes through a coil around the glass tube. Reed relays are capable of faster switching speeds than larger types of relays, but have low switch current and voltage ratings.

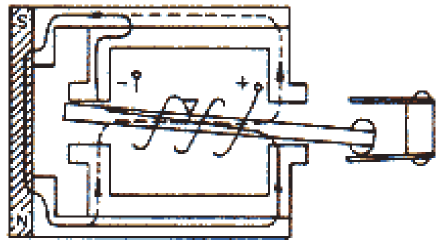



**Mercury – wetted relay**

is a form of reed relay in which the contacts are wetted with mercury. Such relays are used to switch low-voltage signals (one volt or less) because of their low contact resistance, or for high-speed counting and timing applications where the mercury eliminates contact bounce. Mercury wetted relays are position-sensitive and must be mounted vertically to work properly. Because of the toxicity and expense of liquid mercury, these relays are rarely specified for new equipment

**Polarized relay**

placed the armature between the poles of a permanent magnet to increase sensitivity. Polarized relays were used in middle 20th Century telephone exchanges to detect faint pulses and correct telegraphic distortion. The poles were on screws, so a technician could first adjust them for maximum sensitivity and then apply a bias spring to set the critical current that would operate the relay.




**Machine tool relay**

is a type standardized for industrial control of machine tools, transfer machines, and other sequential control. They are characterized by a large number of contacts

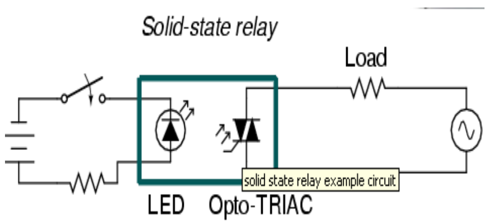
(sometimes extendable in the field) which are easily converted from normally-open to normally-closed status, easily replaceable coils, and a form factor that allows compactly installing many relays in a control panel. Although such relays once were the backbone of automation in such industries as automobile assembly, the programmable logic controller (PLC) mostly displaced the machine tool relay from sequential control applications.

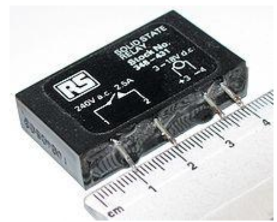
**Contactor relay**

is a very heavy-duty relay used for switching electric motors and lighting loads. Continuous current ratings for common contactors range from 10 amps to several hundred amps. High-current contacts are made with alloys containing silver. The unavoidable arcing causes the contacts to oxidize; however, silver oxide is still a good conductor Such devices are often used for motor starters. A motor starter is a contactor with overload protection devices attached. The overload sensing devices are a form of heat operated relay where a coil heats a bi-metal strip, or where a solder pot melts, releasing a spring to operate auxiliary contacts. These auxiliary contacts are in series with the coil. If the overload senses excess current in the load, the coil is de-energized. Contactor relays can be extremely loud to operate, making them unfit for use where noise is a chief concern.

**Soild – state relay**

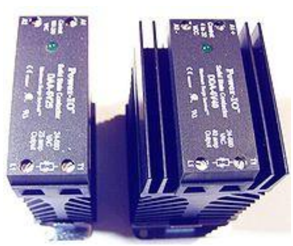
is a solid state electronic component that provides a similar function to an electromechanical relay but does not have any moving components, increasing long-term reliability. With early SSR's, the tradeoff came from the fact that every transistor has a small voltage drop across it. This voltage drop limited the amount of current a given SSR could handle. As transistors improved, higher current SSR's, able to handle 100 to 1,200 Amperes, have become commercially available. Compared to electromagnetic relays, they may be falsely triggered by transients.



**Solid state contactor relay**

is a very heavy-duty solid state relay, including the necessary heat sink, used for switching electric heaters, small electric motors and lighting loads; where frequent on/off cycles are required. There are no moving parts to wear out and there is no contact bounce due to vibration. They are activated by AC control signals or DC control signals from Programmable logic controller (PLCs), PCs, Transistor-transistor logic (TTL) sources, or other microprocessor and microcontroller controls



**Buchholz relay**

**Buchholz relay** is a safety device sensing the accumulation of gas in large oil-filled transformers, which will alarm on slow accumulation of gas or shut down the transformer if gas is produced rapidly in the transformer oil.

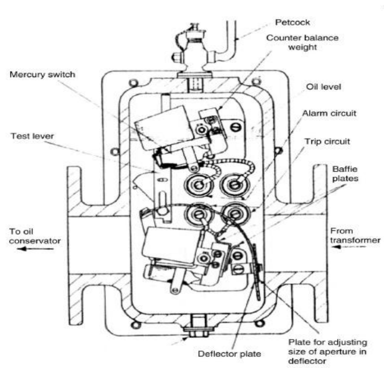



Figure 12
*Details of the Bucholtz relay construction*

**Forced – guided contacts relay**

**Forced-guided contacts relay** has relay contacts that are mechanically linked together, so that when the relay coil is energized or de-energized, all of the linked contacts move together. If one set of contacts in the relay becomes immobilized, no other contact of the same relay will be able to move. The function of forced-guided contacts is to enable the safety circuit to check the status of the relay. Forced-guided contacts are also known as "positive-guided contacts", "captive contacts", "locked contacts", or "safety relays".

**Overload protection relay**

Electric motors need over current protection to prevent damage from over-loading the motor, or to protect against short circuits in connecting cables or internal faults in the motor windings. One type of electric motor overload protection relay is operated by a heating element in series with the electric motor. The heat generated by the motor current heats a bimetallic strip or melts solder, releasing a spring to operate contacts. Where the overload relay is exposed to the same environment as the motor, a useful though crude compensation for motor ambient temperature is provided.


**3.3. POLE & THROW**

Since relays are switches, the terminology applied to switches is also applied to relays. A relay will switch one or more poles, each of whose contacts can be thrown by energizing the coil in one of three ways:

NORMALLY OPEN (**NO**)
Contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive. It is also called a **Form A** contact or "make" contact.

NORMALLY CLOSED (**NC**)
Contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive. It is also called a **Form B** contact or "break" contact.

CHANGE OVER (**CO**)
Or double-throw (**DT**), contacts control two circuits: one normally-open contact and one normally-closed contact with a common terminal. It is also called a **Form C** contact or "transfer" contact ("break before make"). If this type of contact utilizes a "make before break" functionality, then it is called a **Form D** contact
The following designations are commonly encountered:

**SPST**

Single Pole Single Throw. These have two terminals which can be connected or disconnected. Including two for the coil, such a relay has four terminals in total. It is confusing whether the pole is normally open or normally closed. The terminology "SPNO" and "SPNC" is sometimes used to resolve the confusion.

**SPDT**

Single Pole Double Throw. A common terminal connects to either of two others. Including two for the coil, such a relay has five terminals in total.
**DPST**

Double Pole Single Throw. These have two pairs of terminals. Equivalent to two SPST switches or relays actuated by a single coil. Including two for the coil, such a relay has six terminals in total. The poles may be Form A or Form B (or one of each).

**DPDT**

Double Pole Double Throw. These have two rows of change-over terminals. Equivalent to two SPDT switches or relays actuated by a single coil. Such a relay has eight terminals, including the coil.
The "S" or "D" may be replaced with a number, indicating multiple switches connected to a single actuator. For example 4PDT indicates a four pole double throw relay (with 14 terminals).

**Difference Between DC & AC Relays**

**DC Relay**

Direct current (DC) is steady and never reverses. A DC relay uses a single coil of wire wound around the iron core to make the electromagnet. When the DC coil is energized, the magnetism generated in the core is steady because the DC just keeps going. The steady magnetism keeps the lever attracted as long as the DC is flowing. Once the current is turned off and the iron core is no longer magnetized, the spring-loaded lever returns to a relaxed position and the electrical contacts are switched back.

**AC Chatter**

In a DC relay, when the current stops and the magnetism in the core falls to 0, the spring-loaded lever starts to pull back to the relaxed position. If AC is applied, the lever doesn't go very far because the core becomes magnetized and attracts the lever again. This cycle of releasing the lever and pulling it back is repeated each time the AC reverses and the relay sounds like it's buzzing, or chattering. Sometimes the electrical contacts may not even switch correctly.

**AC Relay**

To prevent this chatter, the AC relay has two coils to make a transformer to keep the core magnetized. The wire of the traditional coil is the transformer primary. The secondary of the transformer looks like a D-shaped copper washer or ring.
Some of the magnetism from the primary coil produces current inside the copper ring. The current in the ring, or transformer secondary, is actually delayed compared to the current in the primary coil to keep the core always partially magnetized. The lever won't chatter against the core because, while the AC is flowing, the continuously magnetized core never releases it.

**3.4. APPLICATIONS**

Relays are used to and for:

- ❖ Control a high-voltage circuit with a low-voltage signal, as in some types of modems or audio amplifiers
- ❖ Control a high-Current (electricity) current circuit with a low-current signal, as in the starter solenoid of an automobile
- ❖ Detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers (protection relays)
- ❖ Isolate the controlling circuit from the controlled circuit when the two are at different potentials, for example when controlling a mains-powered device from a low-voltage switch. The latter is often applied to control office lighting as the low voltage wires are easily installed in partitions, which may be often moved as needs change. They may also be controlled by room occupancy detectors in an effort to conserve energy

- Logic functions. For example, the Boolean AND function is realised by connecting normally open relay contacts in series, the OR function by connecting normally open contacts in parallel. The change-over or Form C contacts perform the XOR (exclusive or) function. Similar functions for NAND and NOR are accomplished using normally closed contacts. The Ladder programming language is often used for designing relay logic networks.
- Early computing. Before vacuum tubes and transistors, relays were used as logical elements in digital computers.
- Safety-critical logic. Because relays are much more resistant than semiconductors to nuclear radiation, they are widely used in safety-critical logic, such as the control panels of radioactive waste-handling machinery.

Time delay functions. Relays can be modified to delay opening or delay closing a set of contacts. A very short (a fraction of a second) delay would use a copper disk between the armature and moving blade assembly. Current flowing in the disk maintains magnetic field for a short time, lengthening release time. For a slightly longer (up to a minute) delay, a dashpot is used. A dashpot is a piston filled with fluid that is allowed to escape slowly. The time period can be varied by increasing or decreasing the flow rate. For longer time periods, a mechanical clockwork timer is installed.

**3.5. RELAY APPLICATION CONSIDRATIONS**

Selection of an appropriate relay for a particular application requires evaluation of many different factors:

**Number & type of contacts**

normally open, normally closed, (double-throw)

**Contact sequence**

"Make before Break" or "Break before Make". For example, the old style telephone exchanges required Make-before-break so that the connection didn't get dropped while dialing the number.

**Rating of contacts**

small relays switch a few amperes, large contactors are rated for up to 3000 amperes, alternating or direct current

**Voltage rating of contacts**

typical control relays rated 300 VAC or 600 VAC, automotive types to 50 VDC, special high-voltage relays to about 15 000 V

**Coil voltage**

machine-tool relays usually 24 VAC, 120 or 250 VAC, relays for switchgear may have 125 V or 250 VDC coils, "sensitive" relays operate on a few mill amperes Coil current

**Package / enclosure**

open, touch-safe, double-voltage for isolation between circuits, explosion proof, outdoor, oil and splash resistant, washable for printed circuit board assembly

**Assembly**

Some relays feature a sticker that keeps the enclosure sealed to allow PCB post soldering cleaning, which is removed once assembly is complete.

**Mounting**

sockets, plug board, rail mount, panel mount, through-panel mount, enclosure for mounting on walls or equipment

**Switching time**

where high speed is required

**“Dry" contact**

when switching very low level signals, special contact materials may be needed such as gold-plated contacts

**Contact protection**

suppress arcing in very inductive circuits

**Coil protection**

suppress the surge voltage produced when switching the coil current
Isolation between coil circuit and contacts
Accessories such as timers, auxiliary contacts, pilot lamps, test buttons
Regulatory approvals
Stray magnetic linkage between coils of adjacent relays on a printed circuit board.

### 3.6. PROTECTIVE RELAY

Over current relay
Induction disc over current relay
Distance relay
Current Differential Protection

### 3.7. LOGIC GATES

A **logic gate** performs a logical operation on one or more logic inputs and produces a single logic output. The logic normally performed is Boolean logic and is most commonly found in digital circuits. Logic gates are primarily implemented electronically using diodes or transistors, but can also be constructed using electromagnetic relays (relay logic), fluidic logic, pneumatic logic, optics, molecules, or even mechanical elements.
In electronic logic, a logic level is represented by a voltage or current, (which depends on the type of electronic logic in use). Each logic gate requires power so that it can source and sink currents to achieve the correct output voltage. In logic circuit diagrams the power is not shown, but in a full electronic schematic, power connections are required

### 3.8. TRUTH TABLE

A truth table is a table that describes the behavior of a logic gate or any combination of logic gates. It lists the value of the output for every possible combination of the inputs and can be used to simplify the number of logic gates and level of nesting in an electronic circuit. In general the truth table does not lead to an efficient implementation;

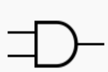
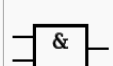
a minimization procedure, using Karnaugh maps, the Quine – McCluskey algorithm or an heuristic algorithm is required for reducing the circuit complexity.

**3.9. BACK GROUND**

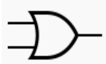
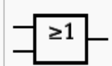
The simplest form of electronic logic is DIODE LOGIC. This allows AND & OR gates to be built, but not inverters, To build a functionally complete logic system, relays, valves (vacuum tubes), or transistors can be used. The simplest family of logic gates using BIPOLAR TRANSISTOR is called RESISTOR-TRANSISTOR LOGIC (RTL). These gates were used in early integrated circuits. For higher speed, DIODE-TRANSISTOR LOGIC (DTL). TRANSISTOT-TRANSISTOR LOGIC (TTL) then supplanted DTL with the observation that one transistor could do the job of two diodes even more quickly, using only half the space. In virtually every type of contemporary chip implementation of digital systems, the bipolar transistors have been replaced by COMPLEMENTARY FIELD-EFFECT TRANSISTORS (MOSFETs) to reduce size and power consumption still further, thereby resulting in complementary metal–oxide–semiconductor (CMOS) logic

**3.10 BASIC GATES**

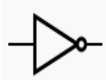
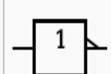
**AND GATE**

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | | *OUTPUT* |
|---|---|---|---|---|---|---|
| | | | | *A* | *B* | *A * B* |
| AND |  |  | A . B | 0 | 0 | 0 |
| | | | | 0 | 1 | 0 |
| | | | | 1 | 0 | 0 |
| | | | | 1 | 1 | 1 |

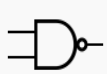
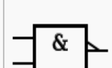
### OR GATE

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | | *OUTPUT* |
|---|---|---|---|---|---|---|
| | | | | *A* | *B* | *A + B* |
| OR |  |  | A + B | 0 | 0 | 0 |
| | | | | 0 | 1 | 1 |
| | | | | 1 | 0 | 1 |
| | | | | 1 | 1 | 1 |

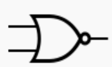
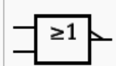
### NOT GATE

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | *OUTPUT* |
|---|---|---|---|---|---|
| | | | | *A* | $\overline{A}$ |
| NOT |  |  | A = $\overline{A}$ | 0 | 1 |
| | | | | 1 | 0 |

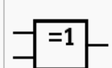
### NAND GATE

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | | *OUTPUT* |
|---|---|---|---|---|---|---|
| | | | | *A* | *B* | $\overline{A * B}$ |
| NAND |  |  | $\overline{A*B}$ | 0 | 0 | 1 |
| | | | | 0 | 1 | 1 |
| | | | | 1 | 0 | 1 |
| | | | | 1 | 1 | 0 |

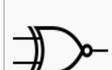
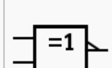
**NOR GATE**

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | | *OUTPUT* |
|---|---|---|---|---|---|---|
| | | | | *A* | *B* | $\overline{A+B}$ |
| NOR |  |  | $\overline{A + B}$ | 0 | 0 | 1 |
| | | | | 0 | 1 | 0 |
| | | | | 1 | 0 | 0 |
| | | | | 1 | 1 | 0 |

**XOR GATE**

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | | *OUTPUT* |
|---|---|---|---|---|---|---|
| | | | | *A* | *B* | $A \oplus B$ |
| XOR |  |  | $A \oplus B$ | 0 | 0 | 0 |
| | | | | 0 | 1 | 1 |
| | | | | 1 | 0 | 1 |
| | | | | 1 | 1 | 0 |

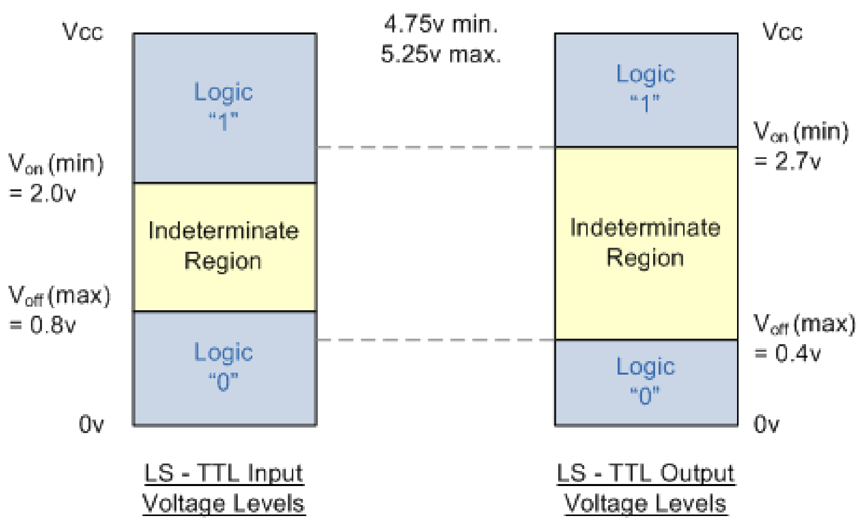
**XNOR GATE**

| *Type* | *Distinctive shape* | *Rectangular shape* | *Boolean algebra between A & B* | *INPUT* | | *OUT PUT* |
|---|---|---|---|---|---|---|
| | | | | *A* | *B* | *A + B* |
| XNOR |  |  | $\overline{A \oplus B}$ or $A \odot B$ | 0 | 0 | 1 |
| | | | | 0 | 1 | 0 |
| | | | | 1 | 0 | 0 |
| | | | | 1 | 1 | 1 |

**Logic level**

**Examples of binary logic levels:**

| Technology | L voltage | H voltage | Notes |
|---|---|---|---|
| CMOS | 0V to $V_{CC}/2$ | $V_{CC}/2$ to $V_{CC}$ | $V_{CC}$ = supply voltage |
| TTL | 0V to 0.8V | 2V to $V_{CC}$ | $V_{CC}$ = 5V ±10% |
| ECL | $V_{EE}$ to −1.4V | −1.2V to 0V | $V_{EE}$ is about −5.2V; $V_{CC}$=Ground |



# 4. PLC BASE LOGIC

## 4.1. INTRODUCTION

A **programmable logic controller**, **PLC**, or **programmable controller** is a small computer used for automation of real-world processes, such as control of machinery on factory assembly lines. The PLC usually uses a microprocessor. The program can often control complex sequencing and is often written by engineers. The program is stored in battery-backed memory and/or EEPROMs.
PLCs were invented as less expensive replacements for older automated systems that would use hundreds or thousands of relays and cam timers. Often, a single PLC can be programmed to replace thousands of relays. Programmable controllers were initially adopted by the automotive manufacturing industry, where software revision replaced the re-wiring of hard-wired control panels.

## 4.2. HISTORY

The PLC was invented in response to the needs of the American automotive industry. Before the PLC, control, sequencing, and safety interlock logic for manufacturing automobiles and trucks was accomplished using relays, timers and dedicated closed-loop controllers. The process for updating such facilities for the yearly model change-over was very time consuming and expensive, as the relay systems needed to be rewired by skilled electricians. In 1968 GM Hydramatic (the automatic transmission division of General Motors) issued a request for proposal for an electronic replacement for hard-wired relay systems.

## 4.3. BASIC PLC COMPONENTS

Programmable controllers have grown throughout industrial control applications because of the ease they bring to creating a controller: ease of programming, ease of wiring, ease of installation, and ease of changing. PLCs span a wide range of sizes, but all contain six basic components:

- Processor or central processing unit (CPU)
- Rack or mounting
- Input assembly
- Output assembly
- Power supply
- Programming unit, device, or PC/software

**Processor**

The process, central processing unit, or CPU is the "brain" of the PLC. The size and type of CPU will determine things like: the programming functions available, size of the application logic available, amount of memory available, and processing speed. Understanding the CPU can be a complex subject and we will tackle that in other articles.

**Rack Assembly**

Most medium to large PLC systems are assembled such that the individual components - CPU, Input/Output, Power Supply - are modules that are held together within a rack.

**Input/Output Assembly**

Inputs carry signals from the process into the controller, they can be input switches, pressure sensors, operator inputs, etc. These are like the senses and sensors of the PLC. Outputs are the devices that the PLC uses to send changes out to the world. These are the actuator the PLC can change to adjust or control the process - motors, lights, relays, pumps, etc.
Many types of inputs and outputs can be connected to a PLC, and they can all be divided into two large groups - analog and digital. Digital inputs and outputs are those that operate due to a discrete or binary change - on/off, yes/no. Analog inputs and outputs change continuously over a variable range - pressure, temperature, potentiometer.

**Power Supply**

The power supply provides power for the PLC system. The power supply provides internal DC current to operate the processor logic circuitry and input/output assemblies.

**4.4. BASICS OF PLC OPERATION**

The operation of the PLC system is simple and straightforward. The Process or CPU completes three processes:

- Scans, or reads, from the input devices
- Executes or "solves" the program logic, and
- Updates, or writes, to the output devices.

**Scan: Read, Execute, Write**

This process of reading inputs, executing logic, and writing outputs is called the PLC Scan, or just scan. When the Programmable Logic Controller is set to Run mode - the program is scanned in a cyclical manner - input, program execution, output. see also Input/Output Basics for a discussion of the role of the Input/Output modules)

**Input Scan**

During the input scan, the PLC reads the status of all inputs in order to update its input table. If there have been any changes in an input status - it will be updated to the system during the input scan.

**Program Logic**

Once all the inputs are updated, the CPU then solves the program logic. Based on the outcome of solving the logic there might need to be a change in the state of outputs.

**Output Scan**

During the output scan, the status of the outputs is updated to reflect the most recent program scan. Once the PLC has completed a full scan of input, logic, and outputs - it starts again at the input scan. The scan time is highly dependent upon the CPU's processing capability and the size of the program logic. Some PLCs allow the programmer to interrupt this scan sequence with interrupts

**4.5. INPUT & OUTPUT BASICS**

**Input Modules**

Input modules perform two primary functions

(1) receive the electrical signal from the input device and
(2) report that status to the CPU. In essence, an input module provides signal

termination, isolation, conditioning, and reporting. They do this for discrete and analog devices.

**Output Modules**

Output modules do the same as inputs but in reverse. The output modules transmit discrete or analog signals to activate various devices. The output module translates the status of the output (as determined by the CPU) into the appropriate real-world electrical signal required.

## 4.6. PLC PROGRAMMING BASICS

Programmable Logic Controllers are usually programmed using one of the following languages:

- Ladder Logic
- Instruction List
- Structured Text
- Function Block Diagrams

Although there are other possible ways to program PLCs, these are amongst the most widely used and are recognized by IEC 61131-3.
Since Ladder Logic is the most commonly encountered programming method we will explain programming using Ladder Logic.

**Ladder Logic**

A program written in a format similar to ladders like diagrams used in electrical drawings.

**Instructions**

A mnemonic and data address defining an operation to be performed by the controller.

**User Memory**

The memory that stores user program or ladder logic.

**Data Highway Plus (DH+)**

A local area network designed to provide simple communication between PLCs, and PC's.

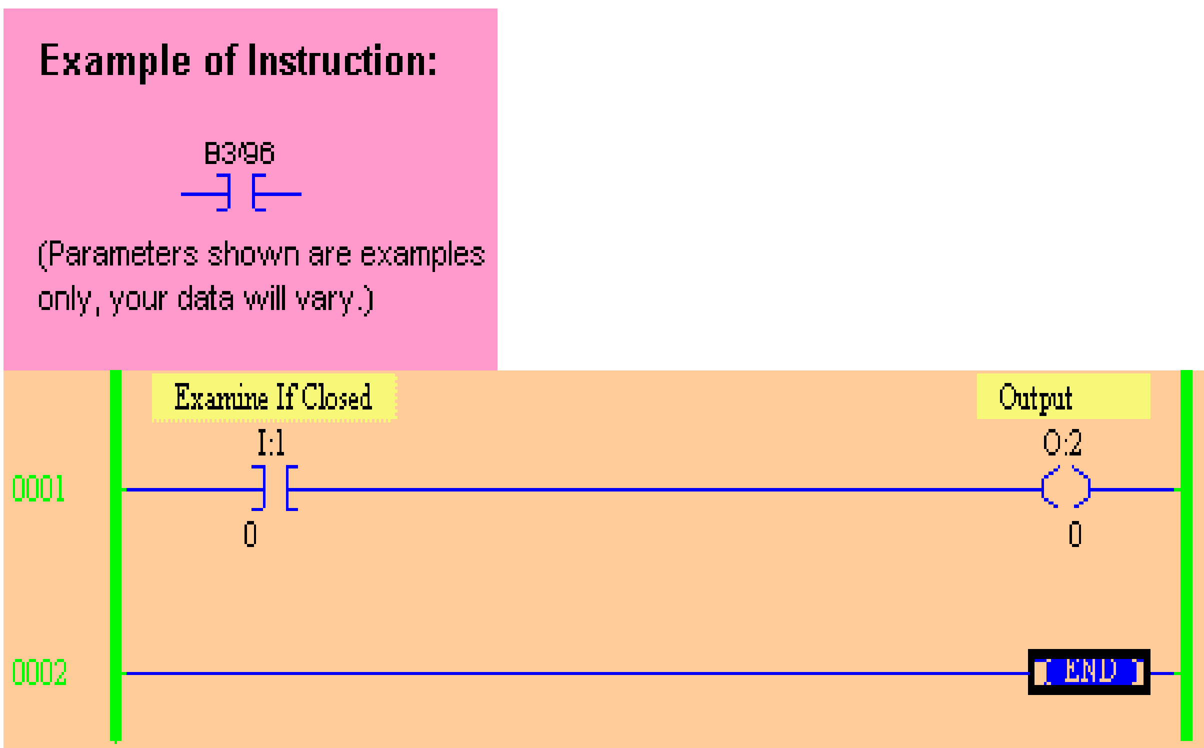
**Addressing**

A device that allows access to a PLC for troubleshooting and programming.

## 4.7. SOME BASIC INSTRUCTIONS

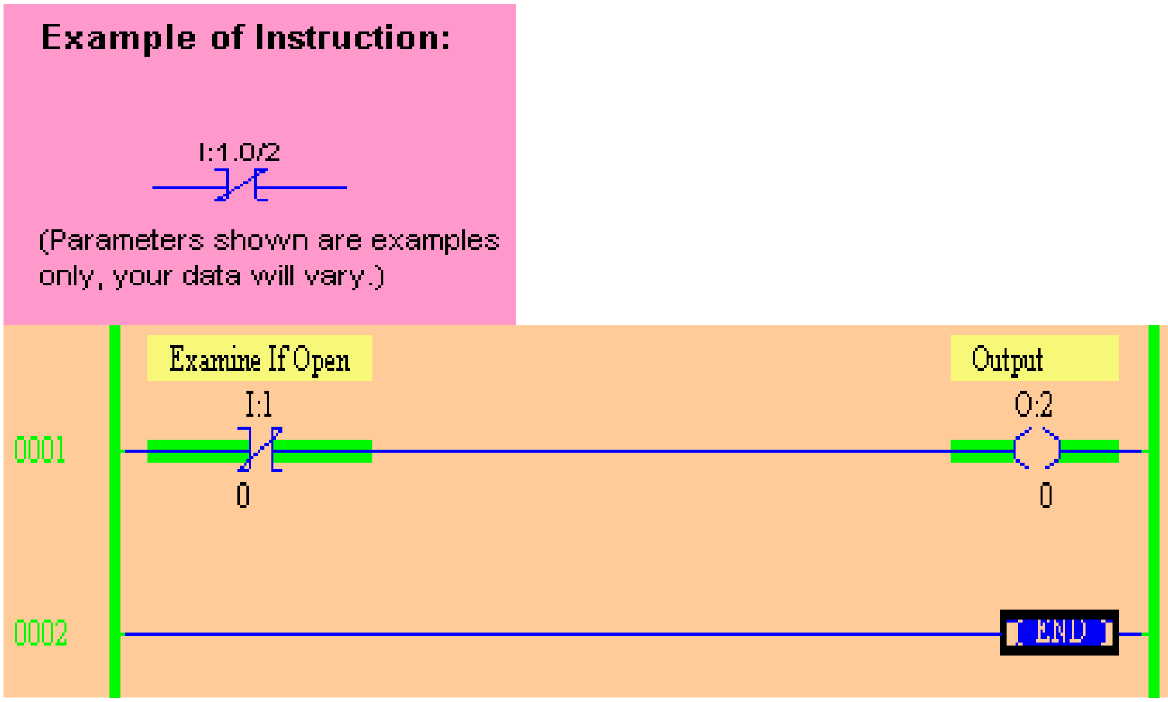
**Examine if Closed (XIC)**

Use the XIC instruction in your ladder program to determine if a bit is On. When the instruction is executed, if the bit addressed is on (1), then the instruction is evaluated as TRUE. When the instruction is executed, if the bit addressed is off (0), then the instruction is evaluated as FALSE



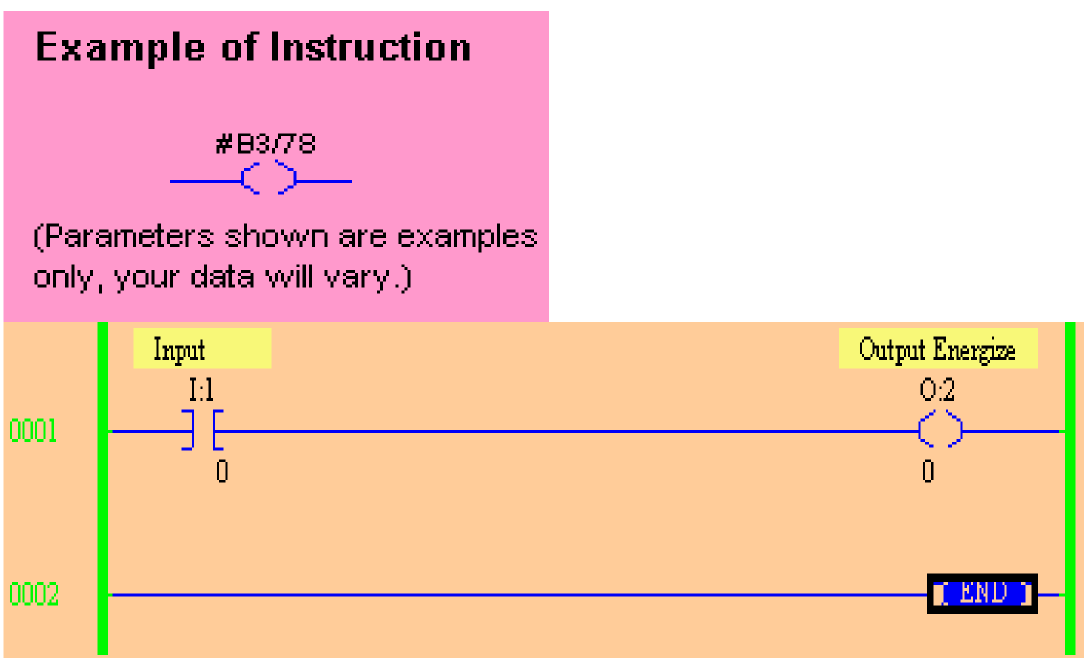

**Examine if Open (XIO)**

Use an XIO instruction in your ladder program to determine if a bit is Off. When the instruction is executed, if the bit address is off (0), then the instruction is evaluated as TRUE. When the instruction is executed, if the bit addressed is on (1), then the instruction is evaluated as FALSE.

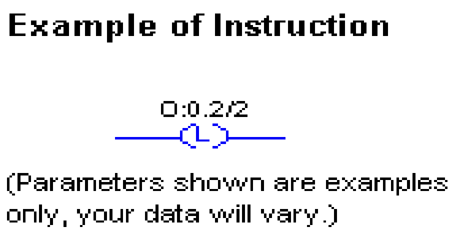


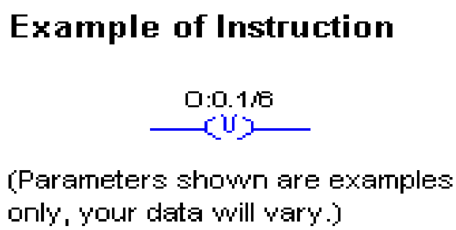

**Output Energize (OTE)**

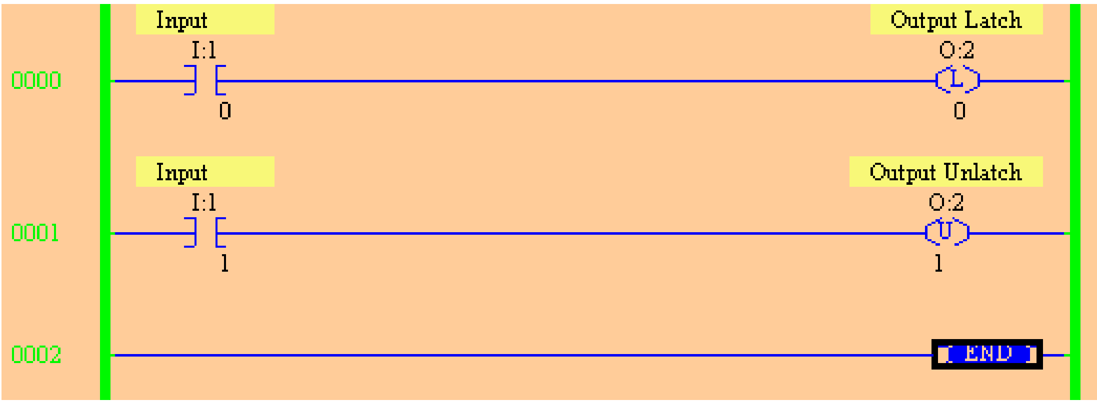
Use an OTE instruction in your ladder program to turn On a bit when rung conditions are evaluated as TRUE



## Output Latch and Output Unlatch

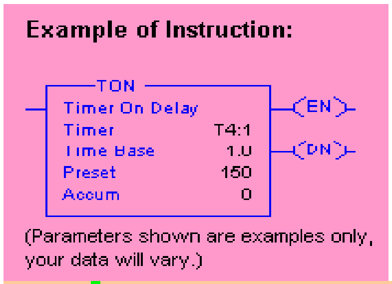


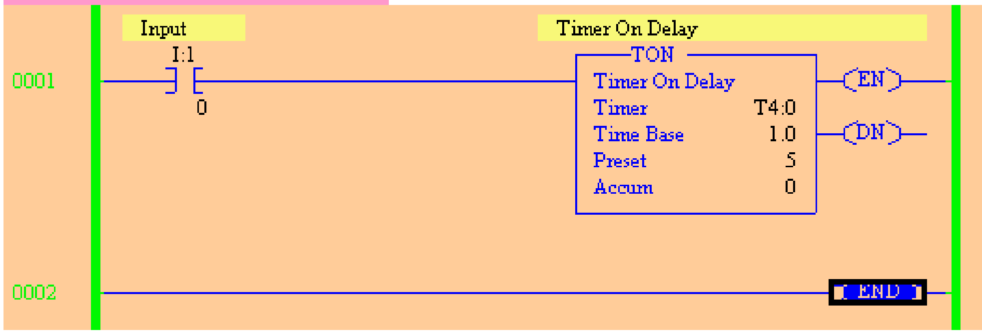




## Timer On-Delay (TON)

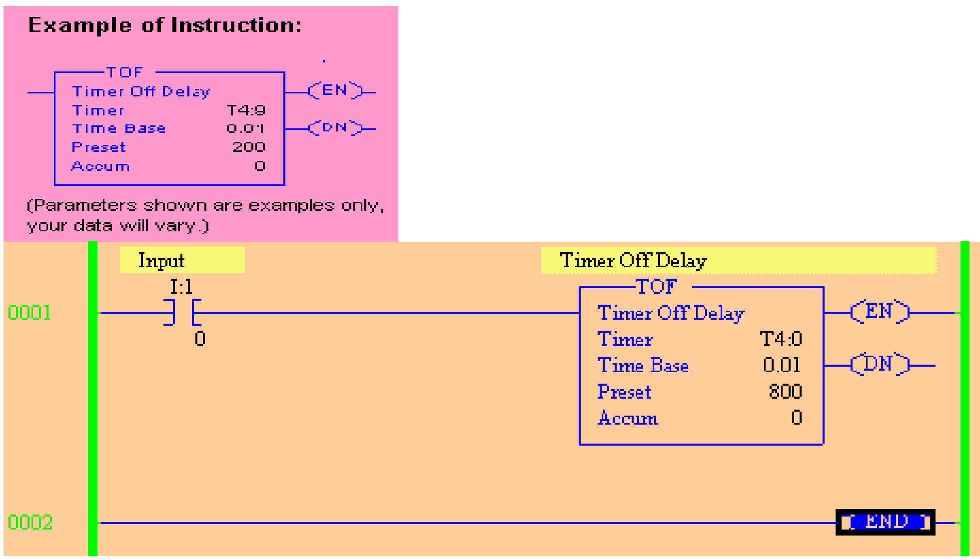
Use the TON instruction to turn an output on or off after the timer has been on for a preset time interval. The TON instruction begins to count time base intervals when the rung conditions become TRUE. As long as rung conditions remain true, the timer adjusts its accumulated value (ACC) each evaluation until it reaches the preset value (PRE). The accumulated value is reset when rung conditions go FALSE, regardless of whether the timer has timed out.



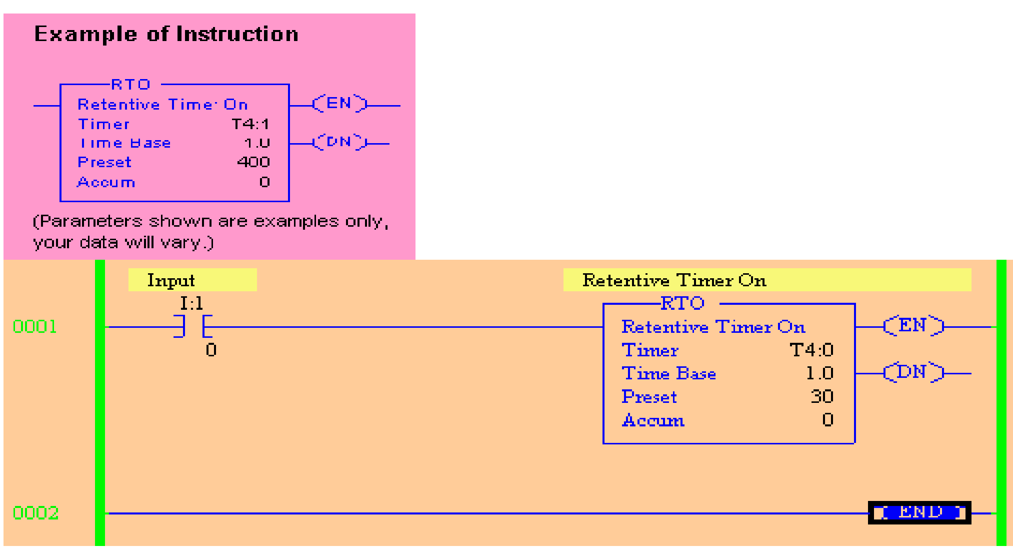
**Timer Off-Delay (TOF)**

Use the TOF instruction to turn an output on or off after its rung has been off for a preset time interval. The TOF instruction begins to count time base intervals when the rung makes a TRUE-to-FALSE transition. As long as rung conditions remain FALSE, the timer increments its accumulated value (ACC) each scan until it reaches the preset value (PRE). The accumulated value is reset when rung conditions go TRUE regardless of whether the timer has timed out.



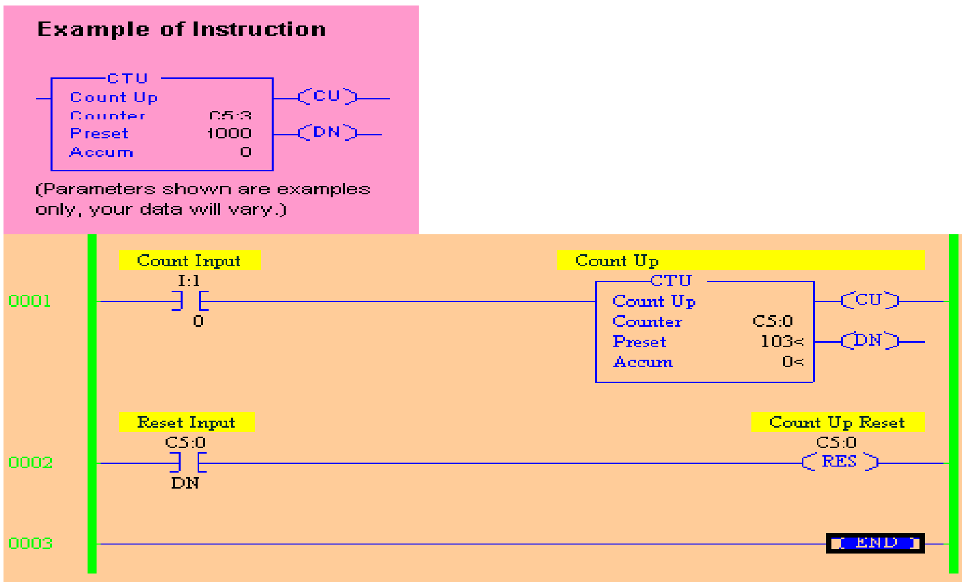

**Retentive Timer (RTO)**

Use the RTO instruction to turn an output on or off after its timer has been on for a preset time interval. The RTO instruction is a retentive instruction that begins to count time base intervals when rung conditions become TRUE.



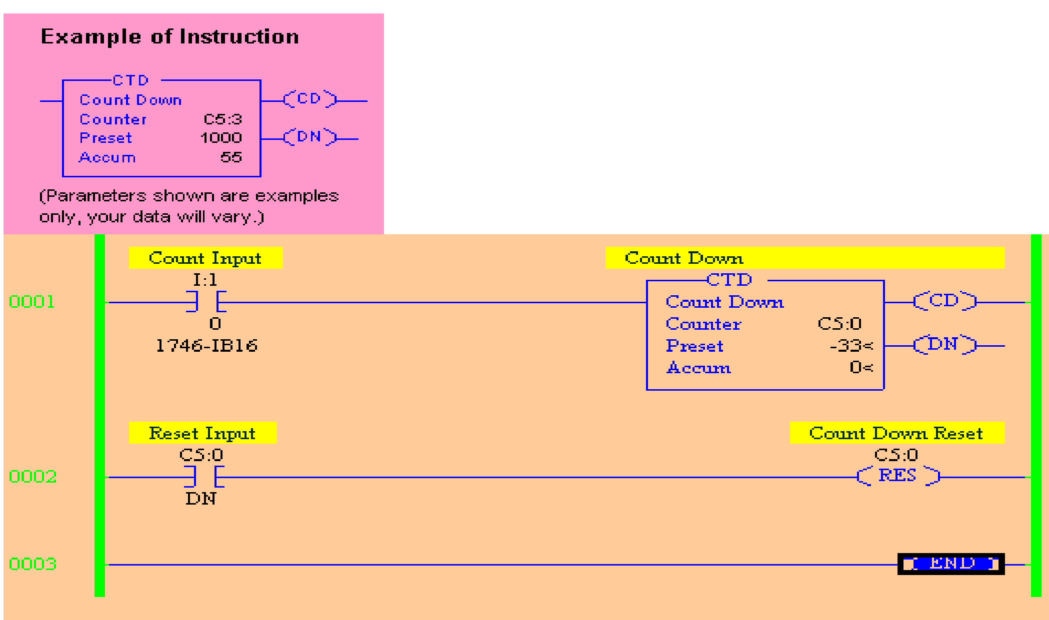
## Count Up Instructions

The CTU is an instruction that counts FALSE-to-TRUE rung transitions. Rung transitions can be caused by events occurring in the program (from internal logic or by external field devices) such as parts traveling past a detector or actuating a limit switch.



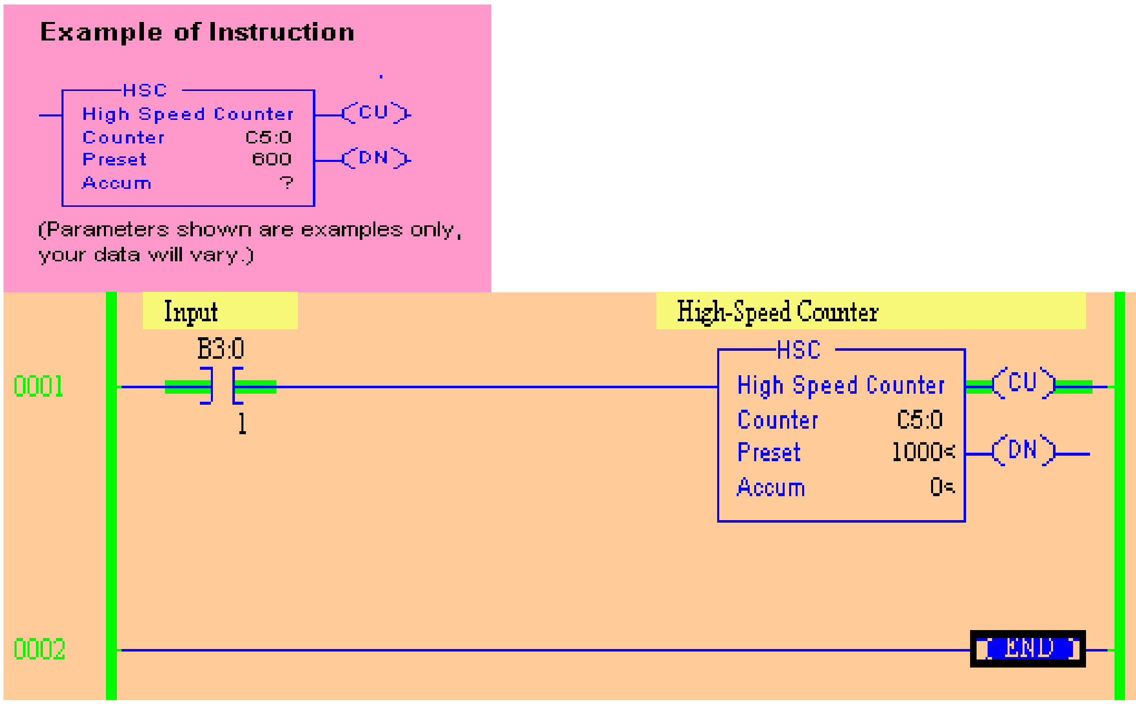

## Count Down (CTD)

The CTD is an instruction that counts FALSE-to-TRUE rung transitions. Rung transitions can be caused by events occurring in the program such as parts traveling past a detector or actuating a limit switch.



**High-Speed Counter (HSC)**

The High-Speed Counter is a variation of the CTU counter. The HSC instruction is enabled when the rung logic is TRUE and disabled when the rung logic is FALSE.




**Reset (RES)**

Use a RES instruction to reset a timer or counter. When the RES instruction is enabled, it resets the Timer On Delay (TON), Retentive Timer (RTO), Count Up (CTU), or Count Down (CTD) instruction having the same address as the RES instruction.