PALO VERDE
NUCLEAR GENERATING STATION

I&C Program

Classroom Lesson

I&C Program	**Date: 2/25/2011 1:44:37 PM**
LP Number: NIA97C000603	**Rev Author: DANIEL R. REED**
Title: Pneumatic Instruments	**Technical Review:** De Dea, Thomas J(Z31735) Digitally signed by De Dea, Thomas J(Z31735) DN: cn=De Dea, Thomas J(Z31735) Date: 2012.04.19 09:33:11 -07'00'
Duration : 30 HOURS	
	Teaching Approval:

INITIATING DOCUMENTS

None

REQUIRED TOPICS

None

CONTENT REFERENCES

Instrument Engineer's Handbook, Liptak 1969

Instrumentation for Process Measurement and Control, Anderson 1980

Process Instruments and Controls Handbook, Considine 1974

SOER 88-01 "Instrument Air Failures"

REVISION COMMENTS

Feb 25, 2011	Jeff De Dea	changed evaluation from aLPE to a written Exam .

Tasks and Topics Covered

The following tasks are covered in Pneumatic Instruments :

Task or Topic Number*	**Task Statement**
Lesson:	Pneumatic Instruments
PRO22	Maintain pneumatic relay
PRO21	Maintain flapper/nozzle assembly
PRO20	Maintain instrument bellows
PRO25	Maintain analog pneumatic recorder
PRO26	Maintain pressure to pressure converter
PRO33	Maintain current to pressure converter
PRO24	Maintain pneumatic square root extractor

Total task or topics: 7

TERMINAL OBJECTIVE:

1 Given the appropriate equipment and procedures, the I&C Technician will calibrate and maintain pneumatic instruments. Mastery will be demonstrated by successful completion of a written Exam with a score of 80% or better.

1.1 Describe how performing a Two Minute Drill applies to calibration of pneumatic instruments

1.2 Describe the operation of a flapper/nozzle detector

1.3 Describe the operation of a pressure switch

1.4 Describe the operation of a pneumatic relay

1.5 Describe the operation of a link-lever assembly

1.6 Describe the characteristics of a Force Balance pneumatic instrument

1.7 Describe the operation of a Current to Pressure converter

1.8 Describe the operation of a Pressure to Pressure converter

1.9 Describe the theory of operation of a Pneumatic Recorder

1.10 Describe the theory of operation of a Temperature to Pressure converter

1.11 Describe the theory of operation of a Pneumatic Square Root Extractor

1.12 Describe the characteristics of a Motion Balance pneumatic instrument

1.13 Calibrate a pressure switch in accordance with lab standards

1.14 Calibrate a Current to Pressure converter

1.15 Calibrate a Pressure to Pressure converter

1.16 Calibrate a Pneumatic Recorder

1.17 Calibrate a Temperature to Pressure converter

1.18 Calibrate a Pneumatic Square Root Extractor

TO: 1	**Given the appropriate equipment and procedures, the I&C Technician will calibrate and maintain pneumatic instruments. Mastery will be demonstrated by successful completion of a written Exam with a score of 80% or better.**

EO: 1.1 Describe how performing a Two Minute Drill applies to calibration of pneumatic instruments

Main Idea

Two-Minute Drill

When working with compressed air, always know your air source and how to shut it off.

Be aware of local hazards including the hazard of working with pressurized air and moving equipment.

Optional Methods & Activities:

Expectation: Every task utilizes a two-minute drill to verify conditions, job hazards and assumptions discussed during the pre-job brief.

Standards

When: Prior to starting the task and after breaks and distractions.

How:

Take two minutes to evaluate the task or job site.

- Look up and down, look all around.
- Ask yourself or each other:
- "What are the hazards?"
- "How can I or others around me get hurt?"
- "Am I practicing a questioning attitude?"
- Take action to control or eliminate hazards.
- Need help? Contact your leader.
- Are Required Personal Protective Equipment (PPE) and tools ready for use?
- Perform a walk down or observation of the area upon

return from absences from the job site. Verify that conditions are as expected and make adjustments as required.

- If more than one worker, discussion of hazards occurs. Answers are provided to all questions; to all workers.

Many pneumatic instruments are located in dark, dirty, hot or out of the way locations not frequently occupied. Many are located over grating which creates a drop hazard.

Why: An “at the workplace” assessment of the hazards and conditions present for performance and to validate any assumptions made during the pre-job brief. Assure barriers are correct to prevent undesirable events.

EO: 1.2 Describe the operation of a flapper/nozzle detector

Introduction

Pneumatic instruments are used extensively at Palo Verde. Pneumatics is an old technology with a long history. Many of the great scientists in history experimented with pneumatics including Archemides, Galileo, Torricelli, Pascal, Boyle, Charles and Avagadro.

While there are historical records of pneumatic devices back to the days of the ancient Greeks, usually powered by bellows operated by a person or persons, pneumatic instrumentation and controls became popular during the industrial revolution when steam driven compressors made compressed air cheaply, and controls were needed for industry.

Some advantages of pneumatics are that there is no electricity to cause an arc, spark or electrical hazard. This can be important in industries that deal with many flammable chemicals such as refineries. Pneumatic instruments have constant air flow, and so are self cooling. They are reliable and rugged, widely available and have the capacity to exert large forces to operate actuators for various uses.

The natural gas industry historically used high pressure natural gas rather than air to power some of their pneumatic instruments, with a corresponding constant bleed of natural gas and sometimes a 'flare' for each instrument. This was how you ensured the instrument was working; the flare was lit.

Disadvantages of pneumatics are the requirement for a clean dry steady air supply, signal delays on long runs (since air is compressible, the signal only travels at sonic velocities of about 300 meters/second), limited signal transmission length, and runs of tubing are generally more bulky than wiring to carry the same information electronically.

Pneumatic instruments can be divided into Motion Balance and Force Balance instruments. Force balance instruments "Instruments which operate by force-balance between the detected variable and the generated output, require no motion and therefore tend to be more maintenance free than are motion-balance devices." From the omega instrument dictionary

Motion balance instruments require a motion feedback, such as a valve motion in order to re-balance the flapper nozzle clearance.

With the advent of solid state devices and electronic controllers, PLCs and digital PC based controllers, pneumatics are becoming less popular. However here at Palo Verde, the I&C technician must have a

working knowledge of pneumatic instruments since we will have many legacy pneumatic instruments around for a long time to come.

Main Idea

I. Flapper/Nozzle

Optional Methods & Activities: Prevent Events, Hazard Assessment: Pre-job Brief, Two Minute Drill – *Be aware of potential hazards involved in working around pressurized air.*

A. Definition

1. Flapper – a restriction to the air flow produced by the nozzle

   Discuss implications of dirty or wet air supply in pneumatic instruments

2. Nozzle - Small tube with restriction designed to direct air flow toward flapper

   Nozzle opening is usually less than 1/100 inch

3. Some form or flapper-nozzle is used in most pneumatic instruments to convert motion to air pressure

B. Description

1. There are two air restriction devices, the nozzle and another restriction, the supply line restriction, which must be smaller than the nozzle

   Otherwise the backpressure in the nozzle created by the flapper would be always at supply pressure.

2. Output is taken from the nozzle back pressure compartment

3. Nozzle back pressure determined by baffle/nozzle clearance

4. Because the supply restriction is smaller than the nozzle, the nozzle back pressure compartment has a pressure proportional to the flapper position

   Point out that range of flapper motion is very small (2/1000 inch for example) (Usually less than 1/4 diameter of nozzle).

5.	3-15 psig is used for most pneumatic signals because of the linear relationship of the nozzle/flapper over the range	
6.	The major limitation of this detector is the small volume of output air due to the small size of the supply air restriction	Ask how we get around this limitation: answer - air booster relays

EO: 1.3 Describe the operation of a pressure switch

Main Idea

II. Pressure to Motion Converter

Optional Methods & Activities:

Nearly all our instruments convert the signal into some kind of motion. Diaphragms and bellows are the two most popular ways we do this..

A. Diaphragm

PPT slides on pneumatics

1. Thin membrane
    a. Separates two pressures
    b. Limited in degree of motion
    c. Can be stacked to extend range of motion (pressure capsule- Ashcroft Pressure switch)
2. United Electric Model 555 pressure switch

Show slide

    a. Input pressure inflate diaphragm
    b. Diaphragm moves stem
    c. Stem actuates adjustable switch

B. Bellows
1. Corrugated cylinder
2. Made of phosphor bronze, brass, beryllium, etc.
3. Not unlike series of stacked diaphragms
4. Range of motion
    a. Considerably larger than diaphragm
    b. 50-90% of bellows length
        1) Overange will "set" the bellows

2) Installed mechanical stop

C. Feedback

All pneumatic instruments must have a feedback mechanism to rebalance the flapper nozzle relationship to the new position.

1. Bellows coupled to Flapper Nozzle
2. Acts to provide negative feedback
3. Causes instrument response to be repeatable and stable

EO: 1.4 Describe the operation of a pneumatic relay

Main Idea

	Optional Methods & Activities:
III. Pneumatic Relays	
A. Pilot Valve	Ask students why we need pneumatic relays
1. Pressure-to-pressure converter that supplies large volume of air	Talk about how nearly all pneumatic instruments have some sort of relay built in.
2. Two variable restrictions are used	PPT slides on pneumatic relays
3. Output pressure signal taken from point between the two restrictions	
4. Incorporated in a loop to overcome air supply limitations of a flapper-nozzle	
B. Direct-acting relay	
1. Input pressure increase produces an output pressure increase	Mark airflow on projected image, show input-output relationship
C. Reverse-acting relay	
1. Can be used for self-balancing instrument	Mark airflow on projected image, show input-output relationship
2. Pilot actuator attached to beam	
D. Non-bleed pilot	
1. Normal pilot disadvantage -consumes large quantity of air, instrument air is quite expensive to produce	Walk through operation showing airflows on projected image
2. Non-bleed pilot reduces air usage	
3. The key to the non-bleed pilot is the movable exhaust port	

4. Disadvantage of a non-bleed pilot: flat spot in its' operation

   a. Cause: Once the pilot is balanced, a small input motion will have no effect on the output

   b. Elimination: Slight bleed from relay back pressure compartment

Illustrate the limited bleed of the device

How much bleed is too much?

EO: 1.5 Describe the operation of a link-lever assembly

Main Idea

IV. Links and Levers

Optional Methods & Activities:

Note lever, link and pivot should be discussed together

A. Description

PPT slides on links & levers

1. Links

   a. Connect levers in same plane

   b. Adjustable in length

   c. Connection points are usually operator changeable

2. Levers

   a. A single pivot rigid component

      1) 1:1

      2) Multiply

      3) Divide

      4) Change direction

B. Mechanics

1. Physical lever - the lever as actually seen within the instrument

2. Actual lever - Identified as the length of the lever between the pivot point and the link connection point

3. Effective lever

a. Identified as the length or distance between the pivot point and the link such that the angle formed is perpendicular to the link

b. Effective lever length changes as the actual lever rotates

c. Effective lever length equals actual length only when link-lever forms a 90^{o} angle at the connection point

Illustrate this point using a pointer as a lever on board

d. Multiplying factor decreases as lever moves away from 90^{o} position

C. Configurations

1. "Z"

a. As one lever moves (rotates), the other moves (rotates) in the opposite direction

b. Gain adjustment made by differing the relative lengths while maintaining the 90^{o} relationship

1) Makes effective lever and actual lever essentially the same

2) Reduces excessive gain variations

c. Incorrect link lever arrangement may cause output to move in the opposite direction from desired

2. "U"

a. As one lever rotates, the other rotates in the same direction

b. No gain adjustment since the effective levers remain proportional (assuming 90^{o} relationship is maintained)

D. Angularity Error

1. Caused by unequal input and output lever lengths

2.	Output lever travels through different angle than input lever	Example of 2:1 lengths in U configuration to show effect
3.	Minimized by placing input lever and output lever at midtravel position and adjusting link for 90^{o} angle with levers	Can also show how minimizing travel to small arc limits error
4.	Angularity compensator - compensates for angularity error	Always maintains right angle
	a. Gears in mesh	
	b. Rack and pinion	
	c. Motion multiplier/divider	
5.	Anti-arcing mechanism - produces linear pen movement as pen arm swings through arc	

EO: 1.6 Describe the characteristics of a Force Balance pneumatic instrument

Main Idea

V. Pneumatic Feedback Instruments	Optional Methods & Activities: Explain that there are two categories of feedback movements
A. Force Balance Instruments - general description	Minimal motion
1. Moment Balance - utilizes balance beam	Example: I2P converter, Foxboro pneumatic pressure transmitter
2. True force balance - utilizes force rod	
B. Motion Balance	Something moves
1. Linear motion	Example: Valve positioner
a. Utilizes input rod	
b. Lined up on one axis	
2. Angle motion	
a. Utilizes dual pivot type lever	
b. Angular input motion	
VI. Force Balance Instruments	
A. Moment Balance Instruments	
1. Moment: Defined as the measure of tendency to cause rotation about a point or axis	
2. Calculated by force x distance to fulcrum	Draw lever on board and show the relationship of two forces applied. (F_1 x L_1) = (F_2 * L_2) = equilibrium
3. DOES NOT EQUATE TO MOVEMENT!!	
4. Example	

a. Change of input pressure causes input bellows to expand

b. Input bellows expansion converted to force by opposing force of input spring

c. Increased moment of left side causes lever to pivot about fulcrum

d. Increased moment of left side pivots right hand side of beam closer to flapper

e. Output pressure increases

f. Balancing bellows expands and balances beam

5. Gain

a. Ratio of output to input

b. Left side is input

c. Right side is output

d. Gain is varied through changing length of moments of sides — Mechanical gain

e. Changed by repositioning fulcrum

6. Instrument characteristics

a. Balancing beam

b. Two moments applied to beam

1) Input moment

2) Output moment

EO: 1.7 Describe the operation of a Current to Pressure converter

Main Idea

B. Moment Balance

1. Foxboro E69R Current to Pressure Converter

a. Components

1) Flapper

2) Precision galvanometric motor

3) Floating Nozzle

4) Relay

5) Feedback bellows

b. Operation

1) Input current moves motor and Flapper

2) As Flapper moves air pressure within nozzle varies

3) Air pressure variation sensed by relay

4) Output pressure varies coupled back to feedback bellows

5) Rebalances Flapper nozzle combination

6) Identified as force balance by use of moment arm and extremely small motion of arm. (.002")

Optional Methods & Activities:

PPT slide series I2P converter

EO: 1.8 Describe the operation of a Pressure to Pressure converter

Main Idea

	Optional Methods & Activities:
2. Foxboro Model 13A	
a. Components	PPT slide on Foxboro Model 13A
1) Range Rod acts as balance beam	
2) Has both input moment and balancing moment	
b. Operation	
1) Force bar, flexure connector, range rod form "U" connected beam	
2) Range acts as variable fulcrum	
a) Adjust mechanical advantage	
b) Gain	
c) Zero set by adjusting balancing mechanism spring	Point out the coarse adjustments only accessible by removing the plugs in the bottom of the instrument

EO: 1.9 Describe the theory of operation of a Pneumatic Recorder

Main Idea

3. Moore 5329 M Pneumatic Record
    a. Components
        1) Force beam
        2) Input bellows
        3) Range spring
        4) Flapper/Nozzle
        5) Motion are
        6) Actuator
        7) Zero spring
    b. Operation
        1) Input pressure variation alters bellows expansion
        2) Opposed by Range Spring
        3) Causes nozzle to be blocked
        4) Nozzle pressure variation coupled to actuator
        5) Actuator moves causing range spring to move
        6) Force beam is back to original position

Optional Methods & Activities:

PPT slides on Pneumatic recorder

Mention that this recorder does require electricity to drive paper.

Radwaste control room still has 2 of these in use as of 2007.

Much small diameter 1/8" tubing inside this recorder. Tubing leaks are a problem we've had many times.

7) Output is coupled from motion arm to Pen through the drag link

C. True Force Balance

1. Components

a. All components lined up in straight line

b. No levers involved

2. Operations

a. Increase in input pressure moves input diaphragm to right

b. Force rod moves toward nozzle

c. Output pressure rises

d. Output pressure causes balance bellows to expand and move force rod back to equilibrium

EO: 1.10 Describe the theory of operation of a Temperature to Pressure converter

Main Idea

D. True Force Balance

1. Moore Series 33 temperature transmitter

   a. Classification: True force balance transmitter

   b. output: 3-15 psi proportional to temperature

   c. Operation - increase in temperature

      1) Helium pressure rises

      2) Thermal system bellows expands (input)

      3) Force rod moves down moving flapper closer to nozzle

      4) Back pressure rises

      5) Output pressure rises via direct acting non bleed relay

      6) Balancing force exerted by balancing bellows force rod

   d. Adjustments

      1) Zero- spring pressure acting on force red

      2) Span - fixed, is function of pressure of fill gas in bulb

Optional Methods & Activities:

PPT slides on pneumatic temp transmitter

We still have these on the Boric Acic Concentrator

EO: 1.11 Describe the theory of operation of a Pneumatic Square Root Extractor

Main Idea

2. Moore Model 65 Square Root Extractor

   a. Components

      1) Booster Pilot Assembly

      2) Floating link

      3) Movable nozzle

      4) Bellows

         a) Input

         b) Feedback

      5) Input diaphragm

   b. Operation

      1) Supply pressure admitted to bellows through restriction and to nozzle through center stem

      2) Bellows pressure also acts on Pilot booster diaphragm

      3) Increase in input pressure moves floating link closer to nozzle in effect closing the nozzle

      4) Closing the nozzle increases bellows pressure and hence output pressure

Optional Methods & Activities

Uses the cosine function of a small angle to convert square root related input signals to linear output signals.

We have several of these in each unit located in the radwaste control room in the back of a panel.

PPT slide on pneumatic square root extractor

5) Output pressure is ported back to the feedback bellows which causes the feedback bellows to reposition the nozzle

EO: 1.12 Describe the characteristics of a Motion Balance pneumatic instrument

Main Idea

VII. Motion Balance Instruments

Optional Methods & Activities:

A. Linear Motion balance Instruments

PPT slides on motion balance instruments

1. Similar to true force balance
2. Key differences
   a. Input balancing spring converts force of input into motion of flapper
   b. Repositioning balance bellows does **not** affect input
3. Main Similarity - all motions are in line
4. Balancing effect occurs when balancing bellows moves nozzle as a result of output pressure changes

Draw simple floating lever link nozzle balancing link arrangement

B. Examples of Linear Force Balance Instruments at PVNGS - None

C. Angle motion Balance Instruments

1. Characterized by floating lever
   a. Two pivots
   b. Neither pivot fixed to case
2. Increase in input pressure
   a. Left side moves up
   b. Pivot on opposite end initially motionless

c. Floating lever position relative to nozzle changes

d. Output pressure decreases

e. Air pressure to balance bellows decreases

f. Right side pivots down restoring position of floating beam in relation to nozzle

3. Feedback does not oppose or alter input signal

a. Moving balance link does not affect input link (no leverage)

b. Key characteristic of angle motion balance

4. Gain varied by altering input lever arm in relation to output lever arm

a. Toward input link = motion gain greater than one

b. toward balance link = motion gain less than 1

5. Simplified example (assume pressure increase)

a. Left side of floating lever moves down

b. Nozzle backpressure and output pressure increase

c. Balancing bellows expands moves right side floating lever up

d. Nozzle backpressure drops slightly until equilibrium is attained

6. Example - Fisher model 3582 Valve Positioner

This instrument will be covered in the Flow control valves lesson plan

VIII. Industry Events

Prevent Events: Use Operating Events – *Read SOER 88-01*

A. SOER 88-01 Instrument Air Failures

1. Air System Failures responsible for 73 reactor trips and 163 LERS over 4 year period (1984-7)
2. Areas to control are:
    a. Dew point
    b. Particulate
    c. Oil content
3. Methods
    a. Alarms
    b. Dryer maintenance
    c. Low point blowdown
    d. Preventive maintenance

EO: 1.13 Calibrate a pressure switch in accordance with lab standards

Main Idea

Using Laboratory Practical Exercise NIA97L001211, calibrate a pressure switch.

Observe the precautions and general conditions on the LPE

During initial instructor lab demonstration and pre job brief PPE is not required as long as there are no actual safety hazards. During training, practice and evaluations simulating work in the field, personal protective equipment and electrical protective equipment are required in designated areas of the lab. PPE may be required in non-designated areas as deemed necessary by the instructor.

All requirements of the LPE must be met to satisfy this objective.

EO: 1.14 Calibrate a Current to Pressure converter

Main Idea

Using Laboratory Practical Exercise NIA97L001311, calibrate a current to pressure.

Observe the precautions and general conditions on the LPE

During initial instructor lab demonstration and pre job brief PPE is not required as long as there are no actual safety hazards. During training, practice and evaluations simulating work in the field, personal protective equipment and electrical protective equipment are required in designated areas of the lab. PPE may be required in non-designated areas as deemed necessary by the instructor.

All requirements of the LPE must be met to satisfy this objective.

EO: 1.15 Calibrate a Pressure to Pressure converter

Main Idea

Using Laboratory Practical Exercise NIA97L001411, calibrate a pressure to pressure converter

Observe the precautions and general conditions on the LPE

During initial instructor lab demonstration and pre job brief PPE is not required as long as there are no actual safety hazards. During training, practice and evaluations simulating work in the field, personal protective equipment and electrical protective equipment are required in designated areas of the lab. PPE may be required in non-designated areas as deemed necessary by the instructor.

All requirements of the LPE must be met to satisfy this objective.

EO: 1.16 Calibrate a Pneumatic Recorder

Main Idea

Using Laboratory Practical Exercise NIA97L001511, calibrate a pneumatic recorder.

Observe the precautions and general conditions on the LPE

During initial instructor lab demonstration and pre job brief PPE is not required as long as there are no actual safety hazards. During training, practice and evaluations simulating work in the field, personal protective equipment and electrical protective equipment are required in designated areas of the lab. PPE may be required in non-designated areas as deemed necessary by the instructor.

All requirements of the LPE must be met to satisfy this objective.

EO: 1.17 Calibrate a Temperature to Pressure converter

Main Idea

Using Laboratory Practical Exercise NIA97L001611, calibrate a temperature to pressure converter.

Observe the precautions and general conditions on the LPE.

During initial instructor lab demonstration and pre job brief PPE is not required as long as there are no actual safety hazards. During training, practice and evaluations simulating work in the field, personal protective equipment and electrical protective equipment are required in designated areas of the lab. PPE may be required in non-designated areas as deemed necessary by the instructor.

All requirements of the LPE must be met to satisfy this objective.

EO: 1.18 Calibrate a Pneumatic Square Root Extractor

Main Idea

Using Laboratory Practical Exercise NIA97L001711, calibrate a pneumatic square root converter.

Observe the precautions and general conditions on the LPE.

During initial instructor lab demonstration and pre job brief PPE is not required as long as there are no actual safety hazards. During training, practice and evaluations simulating work in the field, personal protective equipment and electrical protective equipment are required in designated areas of the lab. PPE may be required in non-designated areas as deemed necessary by the instructor.

All requirements of the LPE must be met to satisfy this objective.

SUMMARY OF MAIN PRINCIPLES

The following items are things to consider in your lesson summary. They are not mandatory. You should develop your own summary.,

Objectives Review

Review the Lesson Objectives

Topic Review

Restate the main principles or ideas covered in the lesson. Relate key points to the objectives. Use a question and answer session with the objectives.

Questions and Answers

Oral questioning

Ask questions that implement the objectives. Discuss students answers as needed to ensure the objectives are being met.

Problem Areas

Review any problem areas discovered during the oral questioning, quiz, or previous tests, if applicable. Use this opportunity to solicit final questions from the students (last chance).

Concluding Statement

If not done in the previous step, review the motivational points that apply this lesson to students needs. If applicable, end with a statement leading to the next lesson.

You may also use this opportunity to address an impending exam or practical exercise.

Should be used as a transitional function to tie the relationship of this lesson to the next lesson. Should provide a note of finality.