Welcome to

# Energy Production Systems Engineering

**Thomas Blair, P.E.**
USF Polytechnic – Engineering
tom@thomasblairpe.com

UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC

**Session 1: Introduction & Electrical Safety**

**Spring 2012**

---

## Session 1: Introduction & Electrical Safety

- **Introduction to Energy Production Systems Engineering**
- **Electrical Installation Safety Requirements**
- **Electrical Safe Work Practices**



---

## Introduction to Energy Production Systems Engineering



---

## Welcome

Syllabus
Contact Information
Schedule
Homework
Tours
Project
Exams
Questions?



---

## EPE will cover…

Safety related issues
Energy conversion processes
Systems needed
Equipment utilized
Engineering documentation & calculations
Instrumentation and controls
Thermodynamic processes
Combustion process
Efficiency & heat rate calculations



---

## Electrical Network

"Raw Energy Resource Recovery"
"Resource Delivery"
"Generation (energy production/conversion)"
"Transmission"
"Distribution"
"Utilization"

## Raw Energy Resources

Coal
Oil
Natural Gas
Hydroelectric
Biofuels
Geothermal
Solar
Wind
Other?



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Coal

Various Types
Anthracite, Bituminous, Subbituminous, Lignite -
BTU/lb varies from 14K – 6K

Contains Ash, Sulfur, and other components



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Coal Analysis

Grindability Index,
Heating value,
Ultimate analysis,
Sulfur forms,
Ash composition,
Ash fusion temperatures



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Coal Processing

Coal Storage
Coal Cleaning (Separation)
Coal Crushing/Pulverizing
Coal Drying
Coal Delivery



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

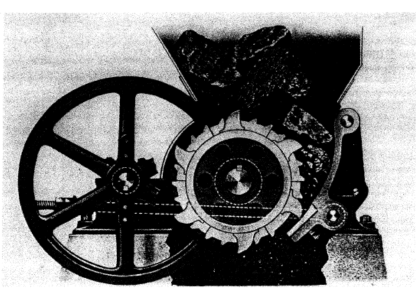


**FIGURE 1.2.1** Roll crusher used to reduce coal top size. (*Source: Coal Preparation, 5th ed., Society for Mining, Metallurgy, and Exploration, Inc., 1991.*)

UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

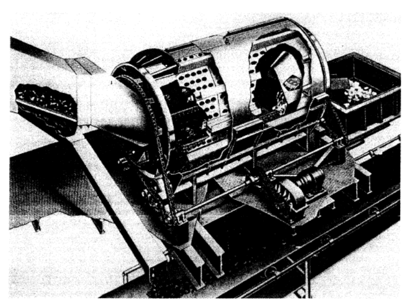


**FIGURE 1.2.2** Rotary breaker. (*Source: Coal Preparation, 5th ed., Society for Mining, Metallurgy, and Exploration, Inc., 1991.*)

UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

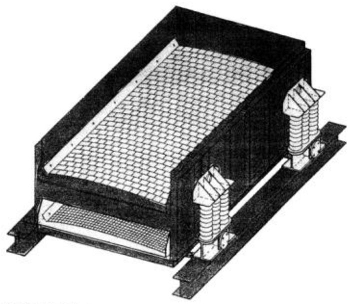


FIGURE 1.2.3 Vibrating screen.



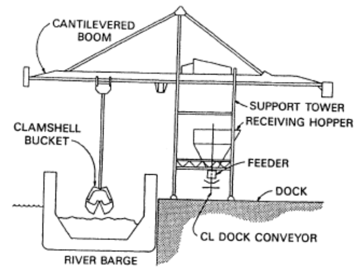



Fig. 5-12. River barge unloading system with clamshell bucket unloader.



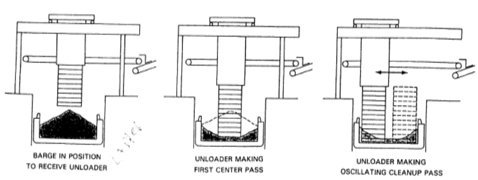



Fig. 5-14. Continuous bucket ladder unloader—unloading procedure. (From McNally Wellman. Used with permission.)



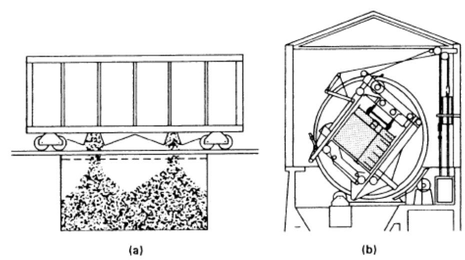



FIGURE 1.2.14 Railcar unloading featuring bottom-dump (*a*) and rotary-dump (*b*) cars.



## Coal Handling

- Weighing and sampling
  - Cross stream sampling
- Dust Control
  - Collection / Suppression
- Freeze control
  - Mechanical / Chemical
- Storage and Handling
  - Active / Reserve Storage
  - Combustion prevention



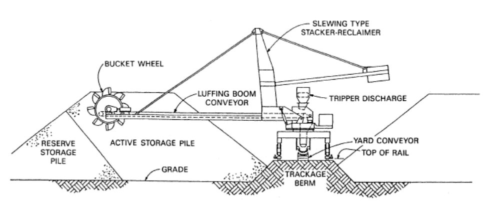



Fig. 5-25. Stockout/reclaim system with slewing type bucket wheel stacker–reclaimer.

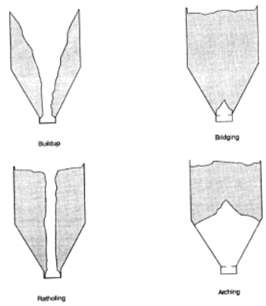
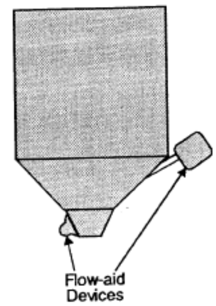



FIGURE 1.2.18 Typical flow problems in bins.

USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)




USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

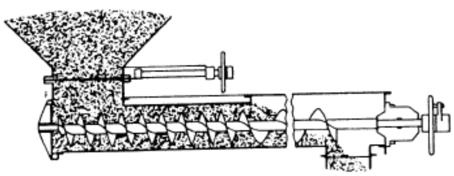


FIGURE 1.2.20 Screw feeder.

USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

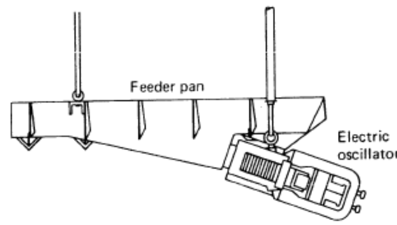



FIGURE 1.2.21 Vibratory feeder.

USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

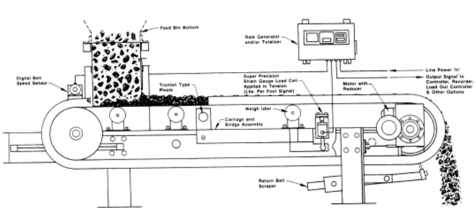
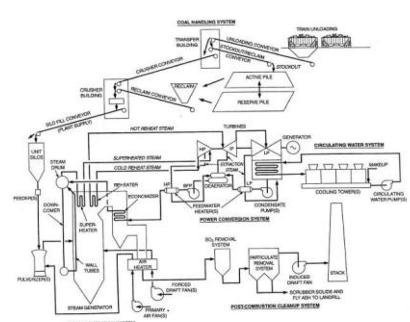


FIGURE 1.2.22 Belt feeder.

USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)



USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Oil & Natural Gas

Oil Storable / Gas used on delivery
Combined cycle
Rankine = steam cycle
Brayton = combustion cycle
Efficiency about 50%
    Brayton & Rankine cycle alone efficiency about 30%
Multiple fuel design for varying availability / cost



## Nuclear Energy

Fission, Breeder (fertile), Fusion
Uranium & Plutonium primary elements
Fuel assembled in ceramic pellets & inserted in fuel rods with helium in gap



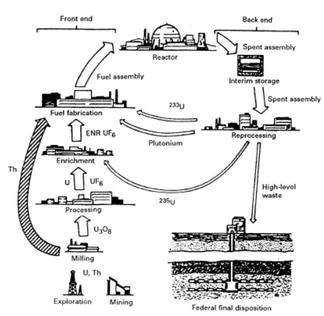



FIGURE 1.4.1 Overview of nuclear fuel cycle.



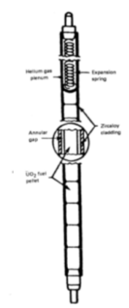


FIGURE 1.4.5 Ceramic fuel element design (Courtesy of Chapman and Hall Pub.).

## Nuclear Energy

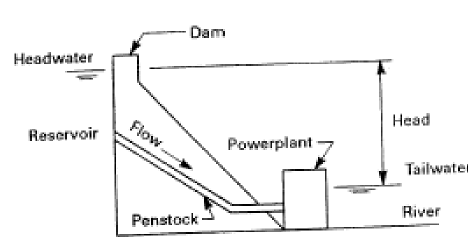
Helium Gas improve Thermal conductivity
Expansion Spring, thermal expansion
Zircaloy Tube cladding
UO2 Fuel Pellet



## Hydro-Electric

Oldest & renewable
High capitol cost
Convert Potential Energy to Electric Energy
Falling Water / Tides / Pumped Storage





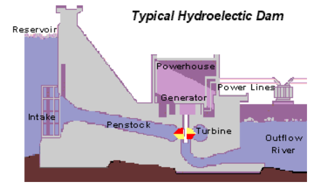
## Hydro-Electric

Falling Water Design –
Headwater is stored behind Dam
Flow is controlled through water turbine.
Turns generator at typically slower RPM
Slower rotation = more poles in generator
Generator typically larger in diameter and shorter in length – typically salient pole design.



## Hydro-Electric

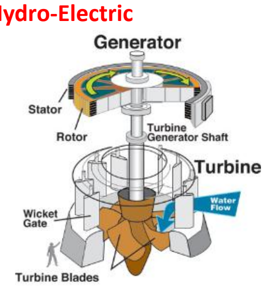
Flow Path






## Hydro-Electric

Turbine Generator



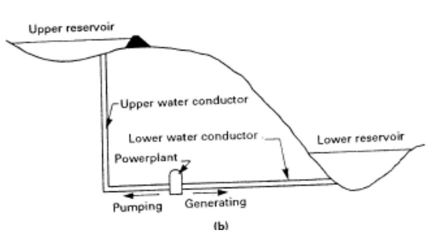



## Hydro-Electric

Pumped Storage is used to provide energy during peaks.
During low load, water is pumps to reservoir.

During high load, water from reservoir turn turbine.

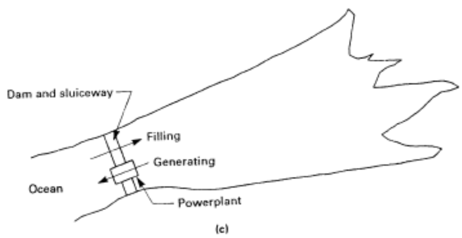







## Hydro-Electric

Tidal – During tide level changes, water enters/leaves reservoir and drives turbine generator.






## Solar Energy

Photovoltaic cell & Thermal Energy
Solar Cells – Flat Plate & Concentrated Solar Power
Solar Cells – direct conversion to DC



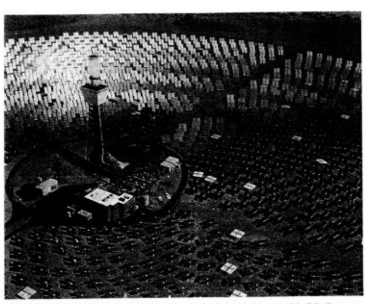


**FIGURE 1.6.11** The heliostat field focuses sunlight onto the central power tower of the Solar One project. Solar Two will refurbish this 10-MW system. (*Credit: Sandia/PIX00036.*)



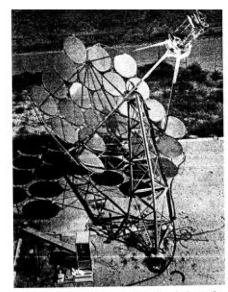


**FIGURE 1.6.12** One potential application for silvered polymer reflectors is for solar concentrators such as this 5-kW, parabolic dish/Stirling system made by Cummins Power Generation, Inc. (*Credit: Cummins Power Generation, Inc./PIX01730.*)



## Solar Energy



## Solar Energy

11 MW Serpa solar power plant in Portugal

## Solar Energy

| Type Of System | Solar Concentration {suns} | Operating Temperature {C} | Efficiency {%} |
|---|---|---|---|
| Trough Electric | 80 | 350 | 10 - 14 |
| Power Tower | 800 | 560 | 15 - 20 |
| Dish Stirling | 3000 | 800 | 24 - 28 |

43

Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Geothermal

65 Geothermal plants in operation
Three factors needed

1. Heat conducts laterally or from below
2. There is interconnected facture shallow enough to be drilled
3. Water/Steam fills the network

44

Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Geothermal

Steam rising from the Nesjavellir Geothermal Power Station in Iceland.

45

Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

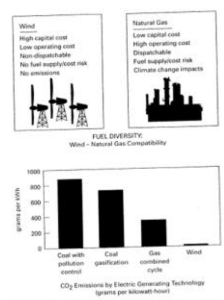



FIGURE 1.8.1 Wind benefits, fuel diversity, and emissions. (Source: Worldwatch Institute, 1994.)

## Wind Energy

Location important
Surveys
Development cost

46

Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

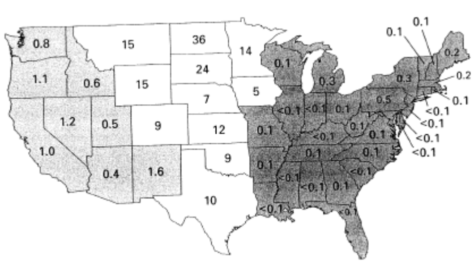


FIGURE 1.8.3 State-by-state distribution of these resources (as a percentage of 1990 electrical consumption of the lower 48 states). (Source: Pacific Northwest Laboratory, 1992.)

Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Biomass Energy

Absorbs $CO_2$ during growth to offset $CO_2$ during combustion
Minimal Sulfur
Ash used as fertilizer
Renewable

48

Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Renewable

**TABLE 1.10.1** Ranges of Weight and Moisture Percentages

| Refuse item | Composition, percent | Moisture, percent |
|---|---|---|
| Corrugated boxboard | 1.32–6.81 | 8.59–50.23 |
| Newspaper | 8.88–21.35 | 9.60–34.87 |
| Magazines, books | 2.05–3.74 | 7.23–26.27 |
| All other paper | 19.78–24.77 | 18.60–33.53 |
| Plastics | 2.00–6.82 | 3.62–19.65 |
| Rubber, leather | 1.22–2.60 | 3.57–18.42 |
| Wood | 1.18–6.58 | 8.09–24.98 |
| Textiles | 2.24–8.92 | 9.14–36.64 |
| Yard trimmings | 0.26–33.33 | 21.08–62.20 |
| Food waste | 7.23–16.45 | 52.35–73.45 |
| Fines, −1 in (−25 mm) | 2.83–11.75 | 10.10–43.00 |
| Metallic | 6.81–11.08 | 2.57–10.83 |
| Glass, ceramics, etc. | 7.13–23.06 | 0.59–6.00 |
| Composite | | 16.77–42.10 |

*Source:* Elmer R. Kaiser, "Physical-Chemical Character of Municipal Refuse," *Combustion*, February 1977.

49



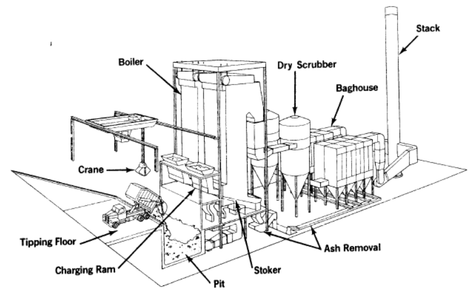



**FIGURE 1.10.1** Typical mass-burning refuse-to-energy system.



## End of Introduction to Energy Production Engineering



## Electrical Safety

## Installation Safety Requirements



## Where is the Hazard?


53

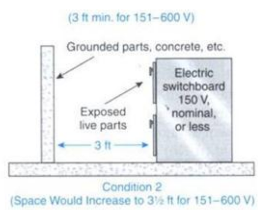


## Aisle Working Space < 600V

| Volts Line - Gnd | Live to Insulated | Live to Gnd | Live to Live |
|---|---|---|---|
| 0 – 150 | 900mm 3ft | 900mm 3ft | 900mm 3ft |
| 151 – 600 | 900mm 3ft | 1.1 m 3.5 ft | 1.2 m 4 ft |

54

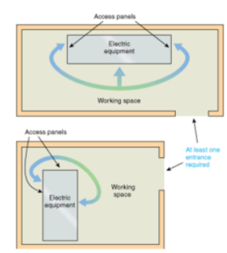
## Aisle Working Space < 600V






## Access to working space < 600V

<1200 A svc – at least one entrance
- 2 personnel doors 24in x 6 ft
- With panic hardware






## Access to working space < 600V

If >1200A or >1.8m (6 ft)
- 2 personnel doors 24in x 6 ft
- With panic hardware

Exception
- One door if unobstructed
- Or if double working space depth (aisle)



## Access to working space < 600V

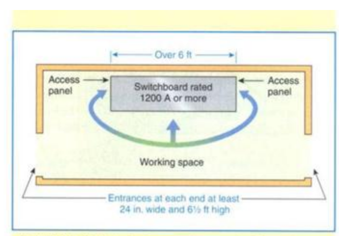



**Exhibit 110.13** Basic Rule, second paragraph. For equipment



## Minimum Clear Working Space > 600V

| Voltage ph-gnd | Live vs Insulated | Live vs gnd | Live vs live |
|---|---|---|---|
| 601-2500v | 900mm 3ft | 1.2m 4ft | 1.5m 5ft |
| 2501-9000v | 1.2m 4ft | 1.5m 5ft | 1.8m 6ft |
| 9001-25kV | 1.5m 5ft | 1.8m 6ft | 2.8m 9ft |
| 25001-75kV | 1.8m 6ft | 2.5m 8ft | 3.0m 10ft |
| Above 75kV | 2.5m 8ft | 3m 10ft | 3.7m 12ft |



## Fence Requirements

ANSI C2, National Electrical Safety Code

**Table 110-1**
**Values for Use with Fig 110-1**

| Nominal Voltage Between Phases | Typical BIL | Dimension "R" | |
|---|---|---|---|
| | | m | ft |
| 151–7200 | 95 | 3.0 | 10.0 |
| 13 800 | 110 | 3.1 | 10.1 |
| 23 000 | 150 | 3.1 | 10.3 |
| 34 500 | 200 | 3.2 | 10.6 |
| 46 000 | 250 | 3.3 | 10.9 |
| 69 000 | 350 | 3.5 | 11.6 |
| 115 000 | 550 | 4.0 | 13.0 |
| 138 000 | 650 | 4.2 | 13.7 |
| 161 000 | 750 | 4.4 | 14.3 |
| 230 000 | 825 | 4.5 | 14.9 |
| 230 000 | 900 | 4.7 | 15.4 |
| 345 000 | 1050 | 5.0 | 16.4 |
| 345 000 | 1175 | 5.3 | 17.3 |
| 345 000 | 1300 | 5.5 | 18.3 |
| 500 000 | 1550 | 6.0 | 19.8 |
| 500 000 | 1800 | 6.6 | 21.5 |
| 765 000 | 2050 | 7.1 | 23.4 |

## Fence Requirements

ANSI C2, National Electrical Safety Code

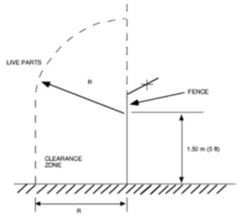



Fig 110-1
Safety Clearance to Electric Supply Station Fences



## Clearance from Gnd

3m (10 ft) – sidewalks & areas accessible to pedestrians only

3.7m (12ft) – driveways and residential property (< 300Vlg)

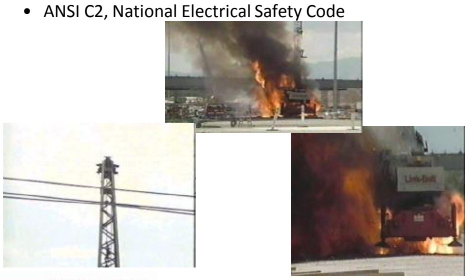
4.5m (15ft) - driveways and residential property (> 300Vlg)

5.5m (18ft) – streets, alleys, and areas exposed to truck traffic



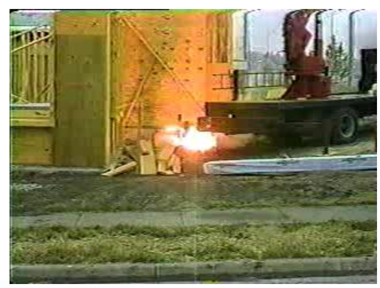
## Clearance from Gnd

- ANSI C2, National Electrical Safety Code





## Clearance from Gnd





## Hazardous (Classified Locations)

- Equipment labeled class, gas classification group, and operating temperature. Class I equipment temp < auto ignition temp
- Threaded conduit wrench tight
- Equipment selection under supervision of PE
- Documentation required
- Flexible conduit must have parallel bonding jumper.



## Definitions

- Class I location where flammable gasses or vapors may be present in air to at explosive level
  - Div1 – exist under normal operations or frequently or faulty equipment operation may cause simultaneous failure of elect. Equipment.
  - Div2 – liquids / gasses used, but not normally in explosive concentrations or concentration prevented by positive mechanical ventilation or is adjacent to class I, div 1

## Definitions

Class II location where combustible dust may be present
- Div1 – exist under normal operations or faulty equipment operation may cause simultaneous failure of elect equipment or where combustible dusts are eclectically conductive
- div2 – combustible dusts not normally in explosive concentrations or concentration may prevent cooling of electrical equipment



## Definitions

Class III location where easily ignitable fibers may be present
- Div1 – where fibers are produced handled, or used
- Div2 – areas where stored or handled other than manufacturing process



## Area Classification

NFPA 497 – Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Area

NFPA 499 – Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Area



## Area Classification

NFPA 497

| Chemical | CAS No. | Class I Division Group | Type[a] | Flash Point (°C) | AIT (°C) | %LFL | %UFL | Vapor Density (Air = 1) |
|---|---|---|---|---|---|---|---|---|
| Hydrogen | 1333-74-0 | B[d] | GAS | | 520 | 4.0 | 75.0 | 0.1 |
| Hydrogen Cyanide | 74-90-8 | C[d] | GAS | −18 | 538 | 5.6 | 40.0 | 0.9 |
| Hydrogen Selenide | 7783-07-5 | C | I | | | | | |
| Hydrogen Sulfide | 7783-06-4 | C[d] | GAS | | 260 | 4.0 | 44.0 | 1.2 |
| Isoamyl Acetate | 123-92-2 | D | I | 25 | 360 | 1.0 | 7.5 | 4.5 |
| Isoamyl Alcohol | 123-51-3 | D | II | 43 | 350 | 1.2 | 9.0 | 3.0 |
| Isobutane | 75-28-5 | D[g] | GAS | | 460 | 1.8 | 8.4 | 2.0 |
| Isobutyl Acetate | 110-19-0 | D[d] | I | 18 | 421 | 2.4 | 10.5 | 4.0 |
| Isobutyl Acrylate | 106-63-8 | D | I | | 427 | | | 4.4 |
| Isobutyl Alcohol | 78-83-1 | D[d] | I | −40 | 416 | 1.2 | 10.9 | 2.5 |



## Burner Management (Combustion Control)

## Boiler Control

NFPA 85 – Boiler and Combustion Systems Hazards Code

Startup / Shutdown sequence

Trip Sequence



## What are Electrical Hazards?

Fire Ignition
Electric Shock
Arc Flash
Arc Blast
Fall
Projectile
Other?

## Electric Shock

To eliminate this hazard, we need to know
The source of the hazard
How the exposure could occur
How the human body would react
What action is necessary to reduce / eliminate hazard



## Reducing Shock Hazard

Can the circuit be de-energized
If not, how can exposure occur
What action would minimize the hazard
What PPE would minimize the exposure



## Recent Electrician Survey

97% had experienced a shock at work sometime in the past
26% witnessed an injury
58% were exposed to a possible injury every day.



## Electrocutions by Age

<20 = 10%
20-24 = 18%
25-34 = 34% (IKE)
35-44 = 22%
45 – 54 = 10%
>55 = 6%



## Electrical Shock

Average of 30,000 electrical contact injuries annual in US
Average of 3 electrocutions every day
>50% of these occurred on less than 600v
4th leading cause of industrial death
7 ½ watts @ 120v is more that enough to kill



## Shock Hazard Analysis Determines

Voltages
Limited, restricted, and prohibited boundary requirements
PPE

| Effect of Current | AC Current in Amps – Men | AC Current in Amps - Women |
|---|---|---|
| Perception threshold (tingling) | 0.0010 | 0.0007 |
| Slight shock-not painful (no loss of ctrl) | 0.0018 | 0.0012 |
| Shock-Painful (no loss of ctrl) | 0.0090 | 0.0060 |
| Shock-severe (muscle ctrl loss, breathing difficulty) | 0.0230 | 0.0150 |
| Possible Ventricular Feb. (3 sec shock, "let go" threshold) | 0.1000 | 0.1000 |
| Possible Ventricular Feb. (1 sec shock) | 0.2000 | 0.2000 |
| Heart muscle activity ceases | 0.5000 | 0.5000 |
| Tissue and organs burn | 1.5000 | 1.5000 |



## Arc Flash

DIFFERENT FROM SHOCK PROTECTION



## Arc Flash

Temperature > 35,000F
This is 4 times hotter than the surface of the sun.
More hospital admissions for electrical burns than shocks
More than 2,000 admissions to burn centers annually
Arc flashes can and DO kill at distances of 10 feet!!!



## Arc Flash

Exposure Energy is Expressed in cal/cm2

1 cal/cm2 Equals the Exposure on the tip of a finger by a Cigarette Lighter in One Second

An Exposure Energy of Only 1.2 cal/cm2 Will Cause a 2nd Degree Burn on Human Skin



## Arc Blast

Cu expands by 67,000 times it solid volume during arc event
Pressure hazard cause fall injuries
Sound can exceed 160dB, rupturing ear drum
Shrapnel leaves arc blast area at speeds exceeding 700 MPH (fast enough to completely penetrate human body
Pressure wave can damage lungs, brain, and central nervous system.



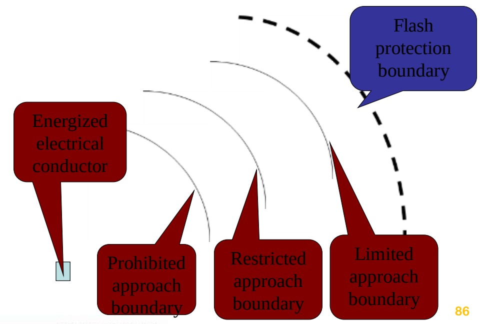
## Definitions

Arc Rating –(ATPV)- max incident energy of a PPE system prior to break open
Flame Resistant (FR)– combustion is prevented, terminated, or inhibited with or without the removal of the ignition source
Flash Hazard – condition cause by the release of energy caused by an electric arc
Flash Protection Boundary – distance from live parts where 2nd degree burns would result if an arc flash occurred

## Definitions

Limited Approach Boundary – distance from live parts where shock hazard exists
Prohibited Approach boundary – distance from exposed live parts where work is considered the same as making contact
Restricted Approach Boundary – a distance beyond which only qualified persons may enter because it requires shock protection equipment or techniques

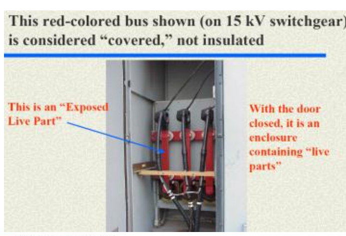







## Definitions

Exposed live part – not suitably guarded, isolated, or insulated






## Definitions

Working Near (live parts) – Any activity inside a limited approach boundary
Working On (live parts) – coming in contact with live parts with body or equipment regardless of PPE. (inside restricted approach boundary)



## Establishing an Electrically Safe Work condition

The main objective of an electrically safe work condition is to reduce the risks of electric shock, flash, and arc blast by removing the energy source



## Establishing an Electrically Safe Work condition

Determine all possible sources (include stored or induced energy)
Interrupt Load
Open disconnect device
Visually Verify
Apply LO/TO
Use proper voltage detector to verify absence of voltage
If possible induced/stored energy sources, ground conductors

## Simple LO/TO Procedures

Involves one set of circuit conductors or circuit parts
Is not required to be written for each application
Each worker is responsible for his/her own LO/TO
(note – in 2012 eliminated the line of sight lockout allowed previously.)



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Complex LO/TO Procedures

Is allowed under certain conditions
Requires a qualified person to be in charge of the procedure
Requires a written plan of execution that identifies the person in charge
Shall identify the method to account for all affected persons



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Electrically Safe Condition

Check drawings and identify all possible sources of hazardous energy
Interrupt load current and open disconnects
Visually verify opening of contacts where possible
Apply Lockout/tagout devices according to policy
Test voltage and verify operation of tester
Apply grounds where necessary



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Electric Safe Work Permit

Used when can not de-energize
(1) A description of the circuit
(2) Justification
(3) A description of the safe work practices
(4) Results of the shock hazard analysis
(5) Determination of shock protection boundaries
(6) Results of the flash hazard analysis
(7) The Flash Protection Boundary
(8) The necessary personal protective equipment
(9) Means employed to restrict access
(10) Evidence of job briefing
(11) Energized work approval



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Test for Voltage

Determine what voltage detector will be suited for application
Who will use detector
Verify voltage testing equipment is working before and after voltage check
Define work area
Test before touching every exposed conductor in work area
Retest when conditions change or location unattended



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Lock And Tagout

A circuit part is not considered in an electrically safe condition until it is;
Disconnected
Under lockout/tagout
Tested to verify absence of voltage
If required, the circuit is grounded
Each exposed person is involved
Training on procedure
Plan developed with up-to-date drawings
Control of all sources
Unique lockout/tagout devices



UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## LO/TO Procedures

Remember, the LO/TO procedure may, in itself, be hazardous

97



## Lock And Tagout

Voltage verification
Coordination and auditing yearly
Responsibility of employer
Establish procedure
Provide training
Provide hardware
Audit execution
Audit the procedure

98



## Job Briefing

Required before every job covering
Hazards
Work procedures
Special precautions
Energy source control
PPE requirements
Addition job briefing required if scope of work changes

99



## Shock Hazard Boundaries

Limited, restricted, and prohibited approach boundary

| Phase to phase voltage | Exposed Movable Conductor | Exposed fixed circuit part | Restricted approach boundary | Prohibited approach boundary |
|---|---|---|---|---|
| <50 | Not specified | Not specified | Not specified | Not specified |
| 50-300 | 10’ | 3’ - 6” | Avoid contact | Avoid contact |
| 301-750 | 10’ | 3’ - 6” | 1’ | 1” |
| 751-15kV | 10’ | 5’ | 2’ - 2” | 7” |
| 15.1-36kV | 10’ | 6’ | 2’ - 7” | 10” |

100



| DEFINITION OF LINEMAN INSULATED GLOVE CLASSES | | |
|---|---|---|
| CLASS NUMBER | TEST VOLTAGE | AC MAXIMUM USE VOLTAGE |
| 00 | 2,500 VAC | 500 VAC |
| 0 | 5,000 VAC | 1,000 VAC |
| 1 | 10,000 VAC | 7,500 VAC |
| 2 | 20,000 VAC | 17,000 VAC |
| 3 | 30,000 VAC | 26,500 VAC |
| 4 | 40,000 VAC | 36,000 VAC |

101



## Flash Protection Boundary

Provide protection from Burns due to arc event
Limit to 1.2 cal/cm^2 (2nd degree burn)
Curable burn, but still painful and can cause injury!!!

102

## Bolted Fault vs. Arcing Fault in Medium-Voltage Switchgear

- Bolted Faults
  - **Current $I^2t$**
  - **Mechanical forces**
- Testing
  - **Interrupting capability**
  - **Thermal capacity of bus**
  - **Mechanical bracing of bus**

Typical UL test setup



USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Bolted Fault vs. Arcing Fault in Medium-Voltage Switchgear

- Arc Faults
  - **Mechanical forces and Current $I^2t$**
  - **Heating and burning of conductors and enclosure**
  - **Radiation**
  - **Rapid overpressure of equipment and surroundings**

ANSI/IEEE C37.20.7 test



USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Arcing Fault in Medium-Voltage Switchgear



USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

## Electrical Safety

**To be continued …**

USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC
Energy Production Engineering
Thomas Blair, P.E.
(tom@thomasblairpe.com)

# Energy Production Systems Engineering

**Thomas Blair, P.E.**
USF Polytechnic – Engineering
tom@thomasblairpe.com
USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC

**End of Session 1: Introduction & Electrical Safety**

**Spring 2012**