Single Parameter Control: Does It Impact Safety?

J.J. Lichtenwalter, ***B&W Y-12 Technical Services, L.L.C.***
Jeff Castor, ***Bechtel Jacobs Company L.L.C.***
Clinton Gross, ***Paschal Solutions Inc.***

National Nuclear Security Administration

Y-12 National Security Complex

Importance

Reaffirmation/revision of
ANSI/ANS-8.1-1998

Process Analysis (PA) Requirement

- NCS practitioners utilize the PA requirement to reduce the probability of a criticality accident.

- "Before a new operation with fissionable material is begun, or before an existing operation is changed, it shall be determined that the entire process will be subcritical under both normal and credible abnormal conditions." [ANSI/ANS-8.1]

Double Contingency Principle (DCP)

- "Process designs should/shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible."
  [ANSI/ANS-8.1/DOE-STD-3007-2007 (indirectly)]

- NCS practitioners utilize the DCP to:
  - analyze abnormal events,
  - reduce the probability of a criticality accident, and
  - satisfy part of the PA requirement.

DOE-STD-3007-2007

- The DCP is indirectly a “shall”.
- “It is not always possible to control two independent parameters for every process, thus ANSI/ANS-8.1-1998 does not make the Double-Contingency Principle a requirement.” [DOE-STD-3007-2007]
- True?

DOE-STD-3007-2007 (cont.)

- "Therefore, in the case where a criticality accident is credible and only one parameter is controlled, the process does not meet the Double-Contingency Principle." [DOE-STD-3007-2007]

- The Standard implies that the probability of a criticality accident has increased with single parameter control.

- True?

ANSI/ANS-8.1 Claim

- Why is the DCP a “should”?

- “First, it governs the attitude toward criticality safety evaluation by suggesting good judgment but not specifying it uniquely, as its application is difficult to confirm.” [TID-7016]

- “Second, under certain conditions where personnel are protected by shielding, single-contingent control may be acceptable.” [TID-7016]

ANS/ANSI-8.1 Claim (cont.)

- "Clearly, there are single contingencies that are so unlikely that they are acceptable." [Nuclear Criticality: Heritage Conference 2000 DVD Set]

- "You can't satisfy the Double Contingency Principle for all operations." [Nuclear Criticality: Heritage Conference 2000 DVD Set]

Nuclear Regulatory Commission

- The DCP is a “should”.
  - “Therefore, the standard recognizes that adherence to the DCP can be one means, but is not necessarily the only means of meeting the underlying subcriticality [PA] requirement”. [Interim Staff Guidance-03, Rev. 0]

Acceptability of Single Parameter Control

- "Nuclear criticality safety is achieved by controlling one or more parameters of the system…" [ANSI/ANS-8.1]

- ANSI/ANS-8.22 provides guidance on limiting and controlling a single parameter: moderation.

- "The DCP does not necessarily require two controls; it requires 'at least two…changes in process conditions' be needed before criticality is possible. Meeting this may necessitate one, two, or more than two controls depending on the possible conditions that can lead to criticality."
  [Interim Staff Guidance-03, Rev. 0]

Acceptability of Single Parameter Control (cont.)

- "As few control parameters as feasible should be used, preferably only one. Of those available, considerations of geometry and mass, in their respective types of systems, are probably the simplest to apply." [K-1380]

- "Combinations of parameters are sometimes feasible but should be used with care, especially where administrative controls are required for each." [K-1380]

H. Henry, et. al, *Studies in Nuclear Safety*, K-1380, 1957

Acceptability of Single Parameter Control (cont.)

- "Where safety based on geometry alone is precluded, designs may be predicated on batch sizes and/or chemical concentrations…" [ORNL-2087/LA-2063]

A.D. Callihan, *Critical Experiments and Nuclear Safety at Oak Ridge National Laboratory,* ORNL-2087, 1956.
A.D. Callihan, et. al, *Nuclear Safety Guide,* LA-2063, 1956.

Single Parameter Control Alone

Changes in process conditions may only equate to a single parameter affected and that one parameter is all that can be controlled.

Example: improper loading of solids / requirement on loading (mass); however, some overload leads to a criticality accident

Single Parameter Control Alone (cont.)

Changes in process conditions usually only equate to a single parameter affected and it is possible that control on another parameter is not needed to ensure subcriticality.

- Other controls may be excluded based on limiting natural physiochemical processes

Example: overload of solids (mass) / bulk density of solid does not support a criticality accident at overload mass (density)

Single Parameter Affected

Changes in process conditions usually only equate to a single parameter affected but the control on another parameter is needed to ensure subcriticality.

Example: water intrusion (moderation) / requirement on container dimensions (volume)

Multiple Parameter Affected

- Changes in process conditions rarely may involve multiple parameters requiring multiple controls on multiple parameters

Example: forklift wrecks into an array (interaction, geometry) / control on container loading (mass), container diameter (geometry), fixed spacers (interaction)

Single Parameter Control

"The number of controls required upon a single controlled process parameter shall be based upon control reliability and any features that mitigate the consequences of control failure." [Interim Staff Guidance-03, Rev. 0]

"The DCP does not necessarily require two controls; it requires 'at least two…changes in process conditions' be needed before criticality is possible. Meeting this may necessitate one, two, or more than two controls depending on the possible conditions that can lead to criticality." [Interim Staff Guidance-03, Rev. 0]

Single Parameter Control (cont.)

- Historical evidence supports
- There are a large number of changes in process conditions that only equate to a single parameter affected
- Single parameter control can result in just as safe a process as multiple parameter control because it is the controls that are important to safety, not the number of parameters controlled.

Consequences

- Without the allowance for multiple controls on a single parameter:
  - NCS practitioners may use:
    - less reliable or less robust administrative controls on multiple parameters in place of engineered controls on one parameter, reducing safety
    - try to “fit to” multiple parameter control

      Example: claim mass in addition to concentration control for waste disposal

  - This conflicts with the DOE 420.1b and ANSI/ANS-8.1 preferred order of controls.

Consequences (cont.)

Example: a geometry controlled solution tank leaks to a geometry controlled dike

- A DOE deviation required
  - Implies reduction in safety
- ANSI/ANS-8.1, Section 4.2.3 prefers geometry control. Inference: safest
- Historical references (e.g., TID-7016) prefer geometry control. Inference: safest

Conclusions

- NCS depends upon:
  - the correct identification of real-world changes in process conditions
  - the appropriate selection of independent, robust, reliable controls
  - no common-mode failures whether single or multiple parameter control
    - in either case, a common-mode failure that defeats multiple controls will likely have the same negative consequence.

Conclusions (cont.)

Historical evidence supports the DCP being a “should” in ANSI/ANS-8.1, Section 4.2.2 and single parameter control in Section 4.2.

Conclusions (cont.)

Does single parameter control negatively impact safety?

The impact is no different than multiple parameter control because the question is misplaced.

The level of safety is determined by the nature of the controls, not the number of parameters on which the controls are placed.