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In the last two years, the chemical process industries (CPI) have been spending a lot of time and money to comply with new process safety regulations.* To a great extent, these efforts center on reducing hazards to people and the environment by ensuring the mechanical integrity of equipment.

In actual practice, these compliance efforts yield very little, if any, return on investment. Simply put, money spent on safety does not directly translate into increased profits.

In contrast, time and money expended on process-related – as opposed to safety – issues have a definite payback. For example, programs to ensure the mechanical integrity of equipment critical to a plant's operation do increase a plant's output, yield and product quality and, thus, earnings. Therefore, it is worthwhile for plants that are addressing the safety hazards of process equipment to also address the question of how critical such equipment is to the smooth running of the processes themselves.

In starting up a program, the logical step is to first evaluate the most critical equipment. To do so, however, it is necessary to rank the equipment based on some criteria, such as their relative importance to a process.

A technique for making such rankings of process equipment is based on hazard and process criteria. The rankings should be performed by teams that are thoroughly familiar with the process being evaluated – a good choice being a plant's Process Hazard Analysis (PHA) group. Since the team's familiarity with a process is highest at the end of a PHA study, the best time for ranking the criticality of equipment is toward the tail end of such safety evaluations.

Six easy steps

The procedure for ranking equipment criticality ranking system consists of:

1. Determining the Hazard Criticality Rating (HCR) of various process equipment using Table 1 (Continues)

* The new process safety laws and the techniques for addressing them are covered in CE, March 1993, pp. 90-100.

RANKING EQUIPMENT CRITICALITY

The payoff is in
Improved production,
yield and quality

HAZARD CRITICALITY RATING

1. ASSESS THE PROCESS CHEMICAL HAZARD (PCH) BY:

- Determining the NFPA ratings (N) of process chemicals for: Health, Fire, Reactivity hazards
- Selecting the highest value of N
- Evaluating the potential for an emissions release (0 to 4):
High (RF=0): Possible serious health, safety or environmental effects
Low (RF=1): Minimal effects
None (RF=4): No effects
- Then, $PCH = N - RF$. (Round off negative values to zero.)

2. RATE OTHER HAZARDS (O) WITH AN ARBITRARY NUMBER (0 TO 4) IF THEY ARE:

- Deadly (4), if:
Temperatures > 1,000°F
Pressures are extreme
Potential for release of regulated chemicals is high
Release causes possible serious health safety or environmental effects
Plant requires steam turbine trip mechanisms, fired-equipment shutdown systems, or toxic- or combustible-gas detectors
Failure of pollution control system results in environmental damage*
- Extremely dangerous (3), if:
Equipment rotates at > 5,000 rpm
Temperatures > 600°F
Plant requires process venting devices
Potential for release of regulated chemicals is low
Failure of pollution control system may result in environmental damage*
- Hazardous (2), if:
Temperatures > 300°F;
Extended failure of pollution control system may cause damage*
- Slightly hazardous (1), if:
Equipment rotates at > 3,600 rpm
Temperatures > 140°F or pressures > 20 psig
- Not hazardous (0), if:
No hazards exist

3. SELECT THE HIGHER VALUE OF PCH AND O AS THE HAZARD CRITICALITY RATING

* Equipment with spare drop one category rating. A spare is an inline unit that can be immediately serviced or be substituted by an alternative process option during the repair period.

TABLE 1. The Hazard Criticality Rating (HCR) is determined in three steps

OPERATIONS & MAINTENANCE

- Determining the Process Criticality Rating (PCR) using Table 2
- Determining the Process and Hazard Criticality Ranking (PHCR) of equipment using Table 3
- Generating a criticality list by ranking equipment using their alphanumeric PHCR values
- Determining priorities for developing maintenance programs. The alphabetic part of the PHCR value determines the priority:

Category A	Highest priority
Category B	High priority
Category C	Medium priority
Category D	Low priority
- Correlating critical parameters to PHC rankings to determine inspection frequencies. Tables 4 and 5 illustrate the procedure for rotating equipment

The proof of the pudding

Once all the equipment is ranked by criticality, the teams involved can generate priority lists. These lists can then be used to ensure the mechanical integrity of critical equipment by prioritizing predictive and preventive maintenance programs, inventories of critical spare parts, and maintenance work orders in case of plants upsets.

The PHCR system has been incorporated into a mechanical-integrity program at Lubrizol's Deer Park, Tex., plant. At present, all equipment - fixed, rotating and instrumentation - are evaluated using the method.

At first, the hazards posed by the plant's different operating units are ranked and prioritized based on a PHA. These rankings are then used to determine the order in which the hazards need to be addressed. When these PHA approach completion, team members evaluate the equipment in each operating unit using the PHCR system.

In preparation for the PHCR evaluation, a spreadsheet containing all equipment and associated information is assembled. Typically, this information is compiled from historical data in the maintenance computer and downloaded into a spreadsheet (Table 7).

The PHA team determines a risk reduction factor (RF), "other" hazards (O), and a process criticality ranking (PCR). The length of time for completing the studies varies from two to six hours, depending on the size of the operating

PROCESS CRITICALITY RATING	
Essential (4)	The equipment is essential if failure will result in shutdown of the unit, unacceptable product quality, or severely reduced process yield
Critical (3)	The equipment is critical if failure will result in greatly reduced capacity, poor product quality, or moderately reduced process yield
Helpful (2)	The equipment is helpful if failure will result in slightly reduced capacity, product quality or reduce process yield
Not critical (1)	The equipment is not critical if failure will have little or no process consequences

TABLE 2 (above). The Process Criticality Rating (PCR) ranks how important equipment is to the smooth operation of the plant on a scale of 1 to 4

PHC RANKINGS					
Process Criticality Rating	Hazard Criticality Rating				
	4	3	2	1	0
4	A44	A34	A24	A14	A04
3	A43	B33	B23	B13	B03
2	A42	A32	C22	C12	C02
1	A41	B31	C21	CD11	D01

Note: The alphanumeric PHC value is represented first by the alphabetic character for the category (for example, category A is the most critical while D is the least critical). The first numeric portion represents the Hazard Criticality Rating, and the second numeric part the Process Criticality Rating.

TABLE 3 (above). The Process and Hazard Criticality Ranking is got from the process and hazard criticality ratings

TABLE 6 (below). A typical spreadsheet for ranking equipment criticality

SPREADSHEET FOR CALCULATING EQUIPMENT PHCRS							
Equipment Number	Equipment Description	NFPA rating	PCH	Other	HCR	PCR	PHCR
		H F R RF					
TKO	Tank	4 4 0 0	4	0	4	4	A44
TKO	Tank	4 4 0 1	3	3	3	4	A34
PU1BFW	Pump	2 0 0 0	2	1	2	3	B23

unit. The following example illustrates the technique for ranking the criticality of a boiler feedwater pump (PU1BFW in Table 6).

1. From Table 1, $N = 2$, the highest of the NFPA ratings of 2, 0, 0, and the risk reduction factor (RF) = 0, since there is the potential for serious burn from hot water. The value for the Process Chemical Hazard (PCH) = 2, because $N - RF = 2$. The rating of Other Hazards (O) = 1, because of the high temperature. Thus, the Hazard Criticality Rating (HCR) = 2, the higher numerical value of PCH and O

2. From Table 2, the Process Criticality Rating (PCR) = 3, since the pump is essential for plant operation

CRE VALUES				
PHCR	Mean time between failures, months			
	0-6	6-12	12-24	>24
A	a1	a2	a3	a4
B	a2	b1	b2	b3
C	a3	b2	c1	c2
D	a4	b3	c2	d1

TABLE 4 (above). The Criticality and Repetitive Equipment (CRE) values for rotating equipment with various MTBFs

MAINTENANCE CYCLES				
Frequency, days				
CRE	7	30	90	360
a1, a2	VM	LT		
a3, a4		VM	LT	
b1, b3			VM	
c1, d1				VM

VM: Vibration monitoring
LT: Lubrication sampling and testing

TABLE 5 (above). Predictive maintenance frequencies for rotating equipment based on their CRE values

- (but an inline spare is available)
- From Table 3, the Process and Hazard Criticality Ranking (PHCR) = B23
 - Since the pump is in Category B, it is "high priority" equipment
 - Assume the pump has a mean time between failure (MTBF) of 10 months. From Table 4, CRE = b1
 - From Table 5, the unit requires vibration monitoring every 90 days

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