The LIST, to be used to pre-populate worksheet causes via the PFFM Methodology
(ref. “Assess Hazards with Process Flow Failure Modes Analysis”, CEP March 2013)

Entering scope of review drawing:
- Pressure increases in incoming stream
- Pressure decreases in incoming stream
- Temperature increases in incoming stream
- Temperature decreases in incoming stream
- Incoming stream is contaminated (light ends, heavy ends, salts, chemical additives, pH, etc., etc.)
- Incoming stream contains unwanted phases (solids, liquid HC or aqueous, vapour)

Control Valves (similar logic & questions can be applied to steam traps & other automatic draining or venting devices):
- fail open
- fail open, with or without bypass open
- fail closed—or partially closed¹ (bypass assumed closed)

Manual block valves:
- Normally closed block valve left open, or opened during normal operation
- Normally open block valve left closed, or closed during normal operation (or partially closed¹)

Vent, Drain & Bleed valves:
- Vent, drain, or bleed valve opened during normal operation
- Vent, drain, or bleed valve left open at start-up

Emergency (or remotely operated) isolation, depressuring, venting, purging valves:
- Emergency isolation valve fails to close when required
- Emergency isolation valve fails closed during normal operation
- Emergency depressuring, venting or purge valve fails to open when required
- Emergency depressuring, venting or purge valve fails open during normal operation

Heat Exchangers (S&T):
- Tube(s) become plugged
- Tube rupture occurs
- Tube leak occurs
- Shell side blocked in (inlet & outlet) while tube side flowing
- Shell side blocked in (inlet & outlet) while exchanger is shut down
- Tube side blocked in (inlet & outlet) while shell side flowing
- Tube side blocked in (inlet & outlet) while exchanger is shut down
- Inadequate heat exchange (if shell and tube sides are both process streams, this question may be asked for both streams individually)
- Excessive heat exchange (if shell and tube sides are both process streams, this question may be asked for both streams individually)

Heat Exchangers (aerial coolers):
- Tube(s) become plugged
- Tube rupture occurs
- Tube leak occurs

¹ Partially closed valves can present a hazard if there is not enough flow to sustain an effective purge, sweep, or to keep a flame lit (flare, furnace, boiler, etc.)
• Excessive cooling of tube side fluid occurs in exchanger
• Inadequate cooling of tube side fluid occurs in exchanger
• Fan stops due to mechanical or electrical failure
• Exchanger blocked in (inlet & outlet) during shutdown

Heat Exchangers (plate & frame, spirals, etc.):
• Hot side plugs off
• Cold side plugs off
• Leak occurs between hot & cold sides
• Rupture occurs between hot & cold sides
• Inadequate heat exchange (if hot and cold sides are both process streams, this question may be asked for both streams individually)
• Excessive heat exchange (if hot and cold sides are both process streams, this question may be asked for both streams individually)
• Hot side blocked in (inlet & outlet) while cold side flowing
• Hot side blocked in (inlet & outlet) while exchanger is shut down
• Cold side blocked in (inlet & outlet) while hot side flowing
• Cold side blocked in (inlet & outlet) while exchanger is shut down

Piping segments, miscellaneous fittings:
• Piping segment left blocked in with heat tracing on (or off)
• Piping segment left blocked in and ambient temperature changes
• Any dead legs in this section/node?
• Check valve sticks open and forward flow stops
• Atmospheric vent line becomes plugged from atmospheric sump, vessel, drum, etc.
• Hose rupture occurs or hose becomes disconnected
• Expansion joint failure occurs
• Restriction orifice plugs
• Restriction orifice erodes/corrodes away

Pipelines:
• Pipeline leak or rupture occurs

Pumps:
• Suction block valve closed on pump (while pump running, or during pump start-up)
• Suction strainer becomes plugged
• Suction vibration dampener fails on PD pump
• Online pump stops due to mechanical or electrical failure
• For batch service pumps: pump running when not required
• For batch service pumps: pump not running when required
• Pump seal (packing, etc.) failure occurs
• VFD fails and speeds up (or slows down) the pump
• More pumps in parallel service operating than required
• Check valve sticks open on pump discharge (and pump stops)
• Discharge block valve closed on pump (while pump running, or during pump start-up)
• Check valve sticks open on discharge of standby pump with suction and discharge block valves both left open
• Check valve sticks open on discharge of standby pump with suction block valve closed and discharge block valve left open
• Discharge vibration dampener fails on PD pump
• For chemical injection pumps specifically: Injection rate set too low
• For chemical injection pumps specifically: Injection rate set too high

Compressors:
• Suction block valve closed (while compressor running, or during start-up)
• Suction strainer becomes plugged
• Suction vibration dampener fails on PD compressor
• Online compressor stops due to mechanical or electrical failure
• VFD fails and speeds up (or slows down) the compressor
• More compressors in parallel service operating than required
• Compressor seal (packing, etc.) failure occurs
• Discharge block valve closed (while compressor running, or during start-up)
• Check valve sticks open on compressor discharge (and compressor stops)
• Check valve sticks open on discharge of standby compressor with suction and discharge block valves both left open
• Check valve sticks open on discharge of standby compressor with suction block valve closed and discharge block valve left open
• Discharge vibration dampener fails on PD compressor

Vessels/Tanks:
• Rate of inflow to vessel exceeds rate of outflow (consider for each liquid phase)
• Rate of outflow from vessel exceeds rate of inflow (consider for each liquid phase)
• Failure of individual internals (depends on nature of internals—i.e. demister mat plugs, internals collapse and block outlet nozzle, weirs collapse, etc.)
• Failure of heating coils or cooling coils
• Failure of mixers/agitators
• Packing failure of mixers/agitators
• Solids accumulate in vessel
• Material in vessel ages/decomposes or otherwise changes composition over time (shelf life of chemical in storage; biological growth in diesel fuel, stratification of chemical mixture in storage, other)—generally relevant only for chemical injection tote tanks or storage tanks, but ask the question if unsure—team can always answer “not applicable” or “not credible”

Pressure relief devices:
• Pressure relief device sticks closed in dirty/sticky service
• Pressure relief device freezes closed (if credible)
• Pressure relief device opens and fails to reseat (when discharge is to another part of the process, i.e. pump suction, process vessel, etc., and not easily detected)
• Pressure/vacuum device fails to close after operation restored to normal pressure
• Rupture disc fails to rupture when required
• Rupture disc ruptures during normal operation (or during upset)

Distillation Columns:
• Tray collapse occurs
• Trays become fouled

Reactors:
• Catalyst deactivated/fouled, or reaction stops
• Catalyst bed plugs off
• Excessive reaction rate, or runaway reaction
• Internals failure
• Catalyst residue left in piping during catalyst change-out (watch out for offgasing while vessel is open, presenting personnel hazards due to toxic gases)

Dryers, molecular sieve units, etc.
• Media becomes plugged
• Media is deactivated
• Switching valve failure occurs (consider all modes of operation, consider individual valve failures)
• Media is too active (or absorbs/adsorbs unwanted components)
• Media must be changed or partially removed (bed exposed to atmosphere/vessel entry concerns)
• Media residue left in piping during change-out (watch out for offgasing while vessel is open, presenting personnel hazards due to toxic gases)

Fired Heaters
• Tubes (or other heat transfer surface) fouled
• Tube leak or tube rupture occurs
• Combustion air supply filter plugs off
• ID or FD fan stops
• ND, ID or FD damper wide open
• ND, ID or FD damper closed
• Flame arrestor plugs off or is otherwise damaged
• Excessive heat transferred to process fluid
• Insufficient heat transferred to process fluid
• If a bath is used, bath leaks and liquid level lost
• If a heating bath is used, medium deteriorates or is contaminated
• For fuel supply issues, see valve failure types
• Refractory failure occurs

Filters/strainers
• Filter/strainer becomes plugged
• Media not replaced in filter/strainer after maintenance
• Backflow into filter/strainer during cleaning/change-out

Operational:
• Normal operating mode
• Start-up mode—consider all of the above as required, including cold s/u
• Planned Shutdown mode—consider all of the above as required
• Emergency Shutdown mode—consider all of the above as required
• Unusual operating modes—vessels bypassed, equipment out for maintenance, etc.
• Equipment spacing
• Sampling
• Ease of accomplishing required tasks (human factors)
• etc. etc. etc.

Trucks at loading/offloading stations:
• Hose rupture occurs or coupling becomes disconnected during loading/offloading
• Truck moves during loading/offloading
• Static charge accumulates during loading/offloading
• Vehicle collides with truck during loading/offloading
• Loading not stopped when truck full (or suction vessel empty)
• Offloading not stopped when truck empty (or destination vessel full)
• Incorrect or contaminated material offloaded
- Material loaded to contaminated or wrong truck
- Loading/offloading rate too high
- Loading/offloading rate too low

Maintenance:
- Equipment with lower-than-desired reliability (especially any identified as SG devices)
- Equipment isolation concerns with respect to preparing equipment for maintenance

Dust or other fine solids:
- Static electrical build-up occurs in area where dust is present
- Heat accumulation occurs in area where dust is present (friction, other)
- Dust explosion hazards in area

Streams leaving scope of the review drawing
- Flow is blocked downstream
- Backflow into leaving stream occurs from downstream equipment
System Failures (considered only for last stream associated with a given vessel, pump, etc., or group thereof—must be considered for every piece of equipment in the review)
- Pool Fire—consider equipment spacing as well as overpressure, etc. concerns
- Jet Fire—consider equipment spacing as well as fireproofing aspects
- Power failure (sometimes local power failure and total failure present different consequences, so the team may list more than one unmitigated consequence for this cause, or may want to consider more than one cause)
- Instrument air failure (sometimes local instrument air failure and total failure present different consequences, so the team may list more than one unmitigated consequence for this cause, or may want to consider more than one cause)
- Steam failure
- Cooling medium failure
- Heating medium failure
- Heat tracing failure
- Other utility failure, as applicable (nitrogen, refrigeration, utility air, etc.)
- Blocked in liquid thermal expansion concerns (in cased any were missed when asked per the piping segment or heat exchanger question sets above)
- Dead leg concerns in the area
- Low temperature brittle fracture concerns (carbon steel becomes brittle at temperatures < -29°C, which can occur in cold climates or if auto-refrigeration is a factor for the process during normal or process upset conditions)
- Start-up/shutdown issues in the area
- Equipment spacing/location concerns in the area
- Emergency isolation (and depressurization) concerns
- Maintenance isolation concerns in the area
- Failure of control signal from remote DCS/PLC (if and as appropriate)
- Commissioning issues (new equipment)

NOTE TO THE USER: This list is based on over 20 years of use for process hazards analysis in operating facilities and in facilities at the design stage. Every attempt has been made to make the list comprehensive and complete. However, due to human frailties, new technologies, and other factors, the list may not be complete. The user should make every effort to improve and add to the list as new failure modes are identified. Sharing these additions with the author would be much appreciated (sesco@xplomet.com), in the interest of identifying all significant process hazards during every review exercise.