Synergies between process energy efficiency and relief loads

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Recent moves to improve efficiency and reduce relief loads

1. Background & motivation

2. Design approach to address concurrently energy efficiency and required relief loads

3. Case studies of dual benefits:
   - Pump with excess discharge pressure
   - Cooling upstream of product separator
   - Three-product distillation column

4. Conclusions
1. Background and motivation
Recent moves to improve efficiency and reduce relief loads

- **Energy:**
  - Expand production without additional utilities
  - Reduce the largest variable cost of production
  - Reduce CO$_2$ emissions
Recent moves to improve efficiency and reduce relief loads

- **Energy:**
  - Expand production without additional utilities
  - Reduce the largest variable cost of production
  - Reduce CO$_2$ emissions

- **Relief Load:**
  - Expand production without additional flare capacity
  - Reduce risks
  - Eliminate relief to atmosphere
Similarities in work processes

The work process to reduce energy/utility consumption is similar to that used to reduce loads to the relief system:
Similarities in work processes

The work process to reduce energy/utility consumption is similar to that used to reduce loads to the relief system:

- Survey the entire system as a whole
- Identify major consumers (of energy or flare capacity)
- Eliminate unnecessary consumption
- Reduce demands of largest consumers
2. Efficiency and relief loads: Design approach to address both
Reducing the energy consumed in a process *may* also reduce the required relief load if:
Efficiency and relief loads: Design approach to address both

Reducing the energy consumed in a process *may* also reduce the required relief load if:

- The normal energy balance is changed
- The energy source responsible for the relief load is the one reduced
Efficiency and relief loads: Design approach to address both

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*As we will see, these are necessary but not sufficient*
3. Case Studies

These examples were developed to illustrate the synergies that can be discovered when applying this integrated approach.
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*Example 1: Pump with excess discharge pressure*

*Example 2: Cooling upstream of product separator*

*Example 3: Distillation column with upper reboiler added*
**Example 1:**
**Pump with excess discharge pressure**

**ENERGY**

Feed control valve is less than 50% open

Indicates pump power consumption could be reduced
Example 1: Pump with excess discharge pressure

ENERGY

Feed control valve is less than 50% open

Indicates pump power consumption could be reduced

RELIEF LOAD

Charge pump can develop head larger than exchanger MAWP

Blocked outlet at exchanger results in large liquid release through RV at pump discharge.
Example 1: Pump with excess discharge pressure

- **Pump curve**
- **System curve**
- **Excess pressure**
- **Normal flow rate**
Example 1: Pump with excess discharge pressure

POTENTIAL SOLUTION

Install variable-speed driver on charge pump

Flow controller adjusts pump speed
Example 1: Pump with excess discharge pressure

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Install variable-speed driver on charge pump
Flow controller adjusts pump speed

ENERGY BENEFITS
Pressure loss across feed control valve has been eliminated
Reduced normal electricity demand
Example 1: Pump with excess discharge pressure

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Install variable-speed driver on charge pump
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Reduced normal electricity demand

RELIEF LOAD BENEFITS
None: Blocked-outlet relief load is unchanged
Flow rate during relief

- **Flow, gpm**: 0, 100, 200, 300, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600
- **Head, ft**: 0, 50, 100, 150, 200, 250, 300, 350, 400, 450
- **Discharge pressure, psig**: 0, 50, 100, 150, 200, 250, 300, 350, 400, 450

- **Pump curve**
- **System curve**
- **Relieving flow rate**
- **Normal flow rate**
- **Exchanger relieving pressure**
Example 1: Pump with excess discharge pressure

ALTERNATE SOLUTION
Reduce pump impeller size
Pump with smaller impeller

- Large impeller
- Small impeller
- System curve
- Normal flow rate
- Exchanger relieving pressure
Example 1: Pump with excess discharge pressure

ALTERNATE SOLUTION
Reduce pump impeller size

ENERGY BENEFITS
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Example 1: Pump with excess discharge pressure

ALTERNATE SOLUTION

Reduce pump impeller size

ENERGY BENEFITS

Reduced normal electricity demand

RELIEF LOAD BENEFITS

Reduced pump head results in smaller relief load for blocked-in exchanger
Pump with smaller impeller

- Large impeller
- Small impeller
- System curve
- Normal flow rate
- Exchanger relieving pressure
- Relieving flow rate

Graph showing flow, head, and discharge pressure for different impeller sizes.
Example 1: Pump with excess discharge pressure

ALTERNATE SOLUTION
Reduce pump impeller size

ENERGY BENEFITS
Reduced normal electricity demand

RELIEF LOAD BENEFITS
Reduced pump head results in smaller relief load for blocked-in exchanger

PROCESS FLEXIBILITY LOST
Reduced maximum throughput
**Example 1: Conclusion**

Reducing the energy consumed in a process *may* also reduce the required relief load if:

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Example 1: Conclusion

Reducing the energy consumed in a process *may* also reduce the required relief load if:

- The normal energy balance is changed
- The energy source responsible for the relief load is the one reduced

*Example 1 showed that these are not sufficient. Investigation is still required to test relief benefits.*
Example 2: Cooling upstream of product separator

ENERGY
Intention is to reduce overall energy consumption in this process
- Cooling water
- Fuel gas
ENERGY
Intention is to reduce overall energy consumption in this process
- Cooling water
- Fuel gas

RELIEF LOAD
Separator has lowest MAWP in the circuit

Several scenarios result in large vapor load to flare, among them loss of cooling water

Flare maximum case is cooling water failure
Example 2:
Cooling upstream of product separator

POTENTIAL SOLUTION

Add air cooler upstream of water cooler
Example 2: Cooling upstream of product separator

POTENTIAL SOLUTION

Add air cooler upstream of water cooler

ENERGY BENEFITS

Reduced cooling water demand
Example 2: Cooling upstream of product separator

POTENTIAL SOLUTION
Add air cooler upstream of water cooler

ENERGY BENEFITS
Reduced cooling water demand

RELIEF LOAD BENEFITS
Reduced relief load upon cooling water failure
Example 2: Cooling upstream of product separator

ALTERNATE SOLUTION

Enhance feed/effluent heat exchange capacity
Example 2: Cooling upstream of product separator

ALTERNATE SOLUTION

Enhance feed/effluent heat exchange capacity

ENERGY BENEFITS

Reduced cooling water demand and reduced fuel gas demand
Example 2: Cooling upstream of product separator

ALTERNATE SOLUTION

Enhance feed/effluent heat exchange capacity

ENERGY BENEFITS

Reduced cooling water demand and reduced fuel gas demand

RELIEF LOAD BENEFITS

Reduction in relief load for cooling water failure case
Example 2 showed that benefits may vary among potential solutions.
Example 3: Three-product distillation column

**ENERGY**
Fuel gas short; make-up with purchased natural gas

Excess medium-pressure steam; let-down to LPS; LPS is vented
Example 3: Three-product distillation column

ENERGY
Fuel gas short; make-up with purchased natural gas

Excess medium-pressure steam; let-down to LPS; LPS is vented

RELIEF LOAD
Flare system loaded during power failure event

Large power failure relief load from this column
Example 3: Three-product distillation column

POTENTIAL SOLUTION
Convert bottoms pump driver to motor
Example 3: Three-product distillation column

**POTENTIAL SOLUTION**
Convert bottoms pump driver to motor

**RELIEF**
Reduces power-failure relief load since reboiler will trip off
Example 3: Three-product distillation column

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ENERGY
Reduces consumption of MPSteam, which means more is vented
Increases consumption of electricity
Example 3: Three-product distillation column

POTENTIAL SOLUTION
Convert bottoms pump driver to motor

RELIEF
Reduces power-failure relief load since reboiler will trip off

ENERGY
Reduces consumption of MPSteam -- which means more is vented

Increases consumption of electricity

This solution is rejected.
Example 3: Three-product distillation column

ALTERNATE SOLUTION
Add upper reboiler

MPSteam → condensate
**Example 3:** Three-product distillation column

**ALTERNATE SOLUTION**
Add upper reboiler

MPSteam $\rightarrow$ condensate

**ENERGY**
Reduces fuel gas consumption while increasing MPStream consumption

Reduces venting of MPStream
**Example 3:**
Three-product distillation column

**ALTERNATE SOLUTION**
Add upper reboiler

MPSteam → condensate

**ENERGY**
Reduces fuel gas consumption while increasing MPSteam consumption

Reduces venting of MPSteam

**RELIEF LOAD**
Upper reboiler pinches out during relief

Power failure relief load decreases
Example 3: Three-product distillation column

<table>
<thead>
<tr>
<th>Process parameter</th>
<th>Furnace reboiled only</th>
<th>Furnace and upper steam-reboiled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflux / Feed, mol/mol</td>
<td>0.48</td>
<td>0.57</td>
</tr>
<tr>
<td>Condenser duty, MMBtu/hr</td>
<td>30.2</td>
<td>33.8</td>
</tr>
<tr>
<td>Furnace reboiler duty, MMBtu/hr</td>
<td>36.6</td>
<td>31.0</td>
</tr>
<tr>
<td>Steam reboiler duty, MMBtu/hr</td>
<td>0</td>
<td>9.6</td>
</tr>
<tr>
<td>Total reboiler duty, MMBtu/hr</td>
<td>36.6</td>
<td>40.6</td>
</tr>
<tr>
<td>Fuel costs for the reboiler, k$/yr</td>
<td>3,840</td>
<td>3,260</td>
</tr>
</tbody>
</table>
### Example 3: Three-product distillation column

<table>
<thead>
<tr>
<th>Relief parameter</th>
<th>Furnace reboiled only</th>
<th>Furnace and upper steam-reboiled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power failure relief load, lb/hr</td>
<td>182,000</td>
<td>136,000</td>
</tr>
</tbody>
</table>
Example 3: Conclusion

Reducing the energy consumed in a process *may* also reduce the required relief load.

*Example 3 showed that the reverse formulation is also true:*

Reducing the required relief load in a process *may* also improve the energy efficiency.
Energy efficiency and required relief loads can be improved by the same changes to a process.
Energy efficiency and required relief loads can be improved by the same changes to a process.

The dual benefits are not automatic; good engineering investigation is required to identify and evaluate potential solutions.
Synergies between process energy efficiency

Q & (perhaps) A

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