NINESIGMA

INNOVATION CONTEST

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REQUEST # 4180134

Waste Heat Recovery from the Top of a Crude Oil Distillation Column

Opportunity

Total opportunity for this Challenge consists of up to €30,000 in cash plus a possible supplier contract for up to seven installations. Successful proposals may also have the opportunity to negotiate a R&D grant to further develop their technology. Furthermore, there could be the opportunity to market and demonstrate successful pilots together with PKN ORLEN.

Timeline

Opening Challenge:	October 1, 2015
Submission deadline:	December 9, 2015
Announcement of finalists:	February 29, 2016
Finals:	March 2016
Announcement of winners:	March 31, 2016

Financials

- A maximum of three respondents will be awarded cash prizes up to €10,000 each.
- Prize winning respondents can be invited to negotiate pilot projects with PKN ORLEN.
- Successful pilots can result in supplier negotiations with PKN ORLEN for installation of up to seven systems. Capex for each system is different, and for the K1 Plock refinery Capex can be up to € 10 mln or more for solutions proven in petrochemical industry
- Further R&D funding opportunities may be available at the discretion of PKN ORLEN (for example a PhD student or postdoctoral researcher grant)

For questions and comments, you are welcome to contact us at the SOLUTION PROVIDER HELP DESK:

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REQUEST DESCRIPTION

NineSigma, representing **PKN ORLEN**, seeks submissions for **waste heat recovery technologies that can operate with low-grade heat of about 115 to 120°C**. The successful solution will address specifically the heat lost from the top of the K1 distillation column located in Orlen's Plock refinery (Poland).

ABOUT THIS CHALLENGE

Participants in this challenge will submit proposals for the PKN ORLEN Waste Heat Recovery Challenge on the Challenge website.

Participants in this competition vie for up to three €10,000 cash prizes. Award winners might have the opportunity to negotiate with PKN ORLEN to engage with pilot projects (the objective of these pilot projects is to demonstrate proof of concept of the proposed solutions).

Participants must complete the proposal and submit by December 9, 2015. The proposal submission will serve as the official entry in this Challenge. The submission should contain a non-confidential introduction to the respondent's handling concept, background and expertise.

Finalists will be selected by February 29, 2016, and be invited for in depth evaluation Finals in March, 2016. Remote conferencing facilities will be used for these Finals. Award winners will be announced by March 31, 2016.

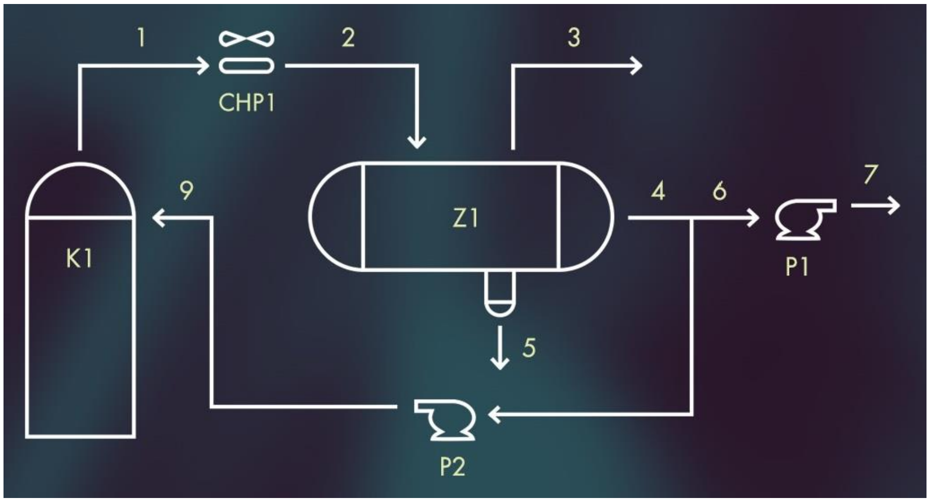
BACKGROUND

Conserving energy is an absolute necessity for all industries. It is no longer economically viable for manufacturing or processing plants to emit heat-laden exhaust into the atmosphere without first reclaiming a significant portion of that energy.

PKN ORLEN has made optimal use of the high-grade waste heat sources in their refinery in Plock (Poland) to preheat combustion air, crude oil, and boiler feed water. However, the heat lost through the air coolers at the top of the K1 atmospheric crude distillation column still needs a solution. Pinch analysis has shown that with conventional technology no economic use of this low-grade heat (e.g. for further preheating the crude oil by heat from the process streams) is achievable within the refinery. A novel mean to usefully capture a portion of this heat is required.

SPECIFICATION OF THE PROCESS

The following figure gives a graphical overview of the system in question:



During distillation of crude oil in column K1, vapors leaving the column (stream 1) are cooled in the air cooler CHP1. The cooled mixture of gas and liquid (stream 2) goes to the reflux drum Z1, where separation into the following phases occurs: gas phase (stream 3), liquid hydrocarbon phase (stream 4), and liquid water phase (stream 5). The hydrocarbon fraction is divided into two parts. The first part (stream 6) is transported by pump P1 for further processing (stream 7). The second part (stream 8) is returned by pump P2 to the column as top reflux (stream 9).

The following table summarizes the thermodynamic properties of the most important streams:

Stream	1	2	3*	4	5	6	7	8	9
Stream Temperature [°C]	116.8	61.0	61.0	61.0	61.0	61.0	61.9	61.0	61.4
Stream Pressure [kPag]	89	89	79	79	79	79	1850	79	750
Density at stream temperature (kg/m³)	4.526	697.6		683.2	979.7	683.2	685.7	683.2	684.2
Flow rate [t/h]	186.2	186.2		173.5	12.7	41.9	41.9	192.5	131.5
Volumetric flow [m3/h]	41,130	266.9		254.0	13.0	61.3	61.1	-206.3	192.2
Enthalpy [kJ/mol]	-185.3	-227.8		-206.3	-282.8	-206.3	-206.0	-206.0	-206.2
Entropy [kJ/kmol°C]	249.2	129.9		174.7	15.2	174.7	175.0	174.7	174.8
Heat flux [GJ/h]	-465.1	-571.7		-372.4	-199.3	-90.0	-89.9	-282.4	-282.2
Specific heat capacity [kJ/kg°C]	2.001	2.425		2.296	4.186	2.296	2.295	2.296	2.295
Heat of vaporization [kJ/kg]	554.2	554.2		440.2	2211.6	440.2	251.6	440.2	347.8

(*) stream 3 is normally not flowing (excess to flare)

Notes:

- The crude distillation unit works continuous throughout the whole year (24 hrs. for 365 days).
- Design capacity of column K1 is 17,000 tpd
- Stream 1 contains, apart from light hydrocarbons, water (~6,86%) and small amounts of H_2S (~0.45 %).
- The overhead system (see picture 1) of the atmospheric column is the most critical section in terms of corrosion rates. Under deposit corrosion ('pitting corrosion') is predominantly on the inlet of the aircoolers (mainly due to ammonium chlorides and iron sulfides deposits).
- The diameter of the stream 1 line is 900 mm and this is splitted in two 700 mm lines to divide the stream over the air cooler units (see picture 2).
- The overhead line, air coolers and reflux drum are not on ground level (situated at 40m height)
- The amount of waste heat managed by the air coolers CHP1 from stream 1 is ~106,6 GJ/h. The cost of 1 GJ is about 10$ (expressed as fuel gas savings).
- CHP1 has 20 separate air cooler units and covers a total area of about 30 by 8 meters (see picture 3).
- The volumetric flow rate of cooling air going over the cooler is about 216,000 m³/h.

Picture 1 (left): overhead system of the K1 unit showing the stream 1 line

Picture 2 (top): view of stream 1 line coming from the top and splitted in 2 700 mm lines

Picture 3 (bottom): alternate view of the split of stream 1 and the air cooling units

KEY SUCCESS CRITERIA

PKN ORLEN invites proposals with the following properties for the process described above:

Performance:

- Optimize the recovery and management of heat from stream 1, while maintaining the physical and chemical parameters of stream 2
    - Not alter the flow of stream 1 or stream 2 (at most ~1% impact on flow)
    - Not cool stream 2 below 61°C
    - If cooling to 61°C is not achieved, part of the CHP1 cooler can be included to reach the target temperature
- Be reversible: CHP1 must remain fully available as a fallback option in case of maintenance or failure of the proposed technology
- Be scalable and able to function properly when the flow is at 70% or 110% of the design capacity
- Be able to recuperate at least 10% of the wasted heat in a useful form (e.g. electricity, chemicals..) preferably more
- Able to operate in a hazardous environment (meet refinery safety standards)
- Be limited in size and weight as there are restrictions on the construction of new trestles

    Note: if the solution is to be erected above the existing air coolers platform, additional calculations for support structures will have to be performed
- Able to be implemented during a scheduled plant maintenance shutdown
    - Typically 30 days time window
    - Most preparation can however be done prior to maintenance shutdown
- Have reasonable maintenance cost and a long lifetime

Financials will be in line with the anticipated savings to be realized on the distillation units, but the following maxima apply for the K1 Plock refinery case:

- Capex < € 10 mln unless the technology has proven its performance in the petrochemical industry
- Expected investment return rate (IRR) around 12% (for calculations purpose please assume a period of 10 years)
- OPEX calculations should be based on average prices of utilities in EU

POSSIBLE APPROACHES

Proposed approaches for energy recovery from the waste heat stream should be compelling in terms of performance and economics. They should also take into account the physical and operational constraints described above. PKN ORLEN is open to new approaches and these can use the available heat for example to produce electricity, to provide direct drive to compressors, or to convert into chemical products.

Proposals might include, but are not limited to:

- High efficiency heat pumps
- Organic Rankine cycle
- Stirling technology
- Thermoacoustic, thermogalvanic, thermal-photovoltaic technologies that can operate at low temperatures
- Novel organic and/or inorganic thermoelectric elements
- Creation of low pressure steam that is suitable for use in the available pressure net
- Other innovative approaches (new methods, new materials, and hybrids of existing technologies…)

APPROACHES NOT OF INTEREST

The following approaches are not of interest:

- Approaches to re-use the waste heat for pre-heating crude oil, process water..
- Approaches assuming the possibility of using waste heat for air to furnaces preheating (projects already launched)

- Approaches that are unsafe or use toxic ingredients
- Approaches that require constant monitoring by professionals
- Approaches that can not be applied in hazardous areas

RESPONDING TO THIS CHALLENGE

All entries must be submitted online at NineSights, the NineSigma open innovation community, according to the online instructions. Supplemental files may be submitted as well. All that is submitted is part of the entry.

Entries from companies (small to large), research institutes, consultants, venture capitalists, entrepreneurs, or inventors are welcome.

Appropriate entries will respond online based on the template provided for this Challenge, and must address the following points:

- Non-confidential description of proposed heat recuperation technology
    - Abstract
    - Key principle
    - Unique selling points
    - Current or expected performance (efficiency, size, cost)
    - Remaining technical challenges and remediation plans
- Business model, including overview on how the system is run
- Team experience and background

When available include also information on the following:

- Time estimated to implement the technology on site
- Supporting data, for example:
    - Examples of similar installations
    - Results from industrial or laboratory tests
    - Calculations illustrating the efficiency of the proposed technology
    - Videos and/or pictures

By submitting a response, respondents agree to Terms and Conditions and all of the following submission requirements, including confidentiality, selection, and the review processes:

Respondents agree to the submission terms described in the response form.

Confidentiality
Respondents confirm that their submissions do not contain any confidential information.

Selection / Review Process
Respondents acknowledge that PKN ORLEN reserves the sole and absolute right and discretion to award prizes as stated in the challenge, including awarding three respondents. The entry evaluation and award determination will be made by an internal PKN ORLEN team.

See Terms and Conditions for details. Challenge opens on October 1, 2015. Must submit at least one entry by December 9, 2015 to be eligible.

Presented photographs, documents and diagrams are the intellectual property of PKN ORLEN S.A., unless otherwise registered, and they may not be used or reproduced, without PKN ORLEN S.A. permission, for any other purpose than to participate in the competition