Thermal Integration of a Catalytic Burner and a Carbon Dioxide Removal Unit

Patent #10,156,373 (A) and Patent #10,458,681 (B)

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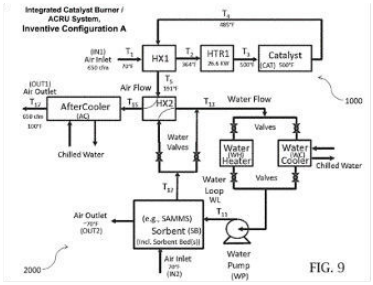
Technology Overview

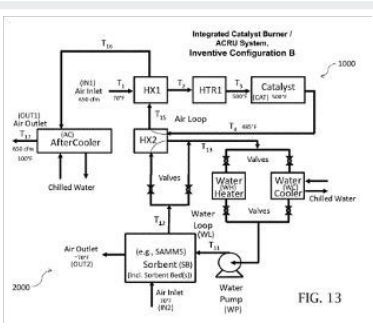
Thermal Integration of a Catalytic Burner and a Carbon Dioxide Removal Unit – Patent #10,156,373 (A) and Patent #10,458,681 (B)

The present invention provides a methodology of reducing total power consumption and waste-heat generation. The catalytic burner and Advanced Carbon Dioxide Removal Unit (e.g., ACRU) can be inventively integrated in various ways.

In inventive configuration A, the temperature of the sorbent beds is controlled with a water loop, and the second heat exchanger acts as a heat reservoir in the sorbent water loop to transfer heat from the catalytic apparatus to the inventive system's adsorption-desorption apparatus.

The inventive integration according to configuration B is beneficial if improvement is desired in the carbon dioxide (CO_2) sorbent regeneration temperature profile of the standalone ACRU. Configuration B offers reduced waste heat and an improved electrical load profile with a rapid sorbent heating rate. In both inventive configuration A and configuration B, a second heat exchanger (HX2) acts as a thermal reservoir, with the configurations differentiated by how the burner and ACRU are connected. Overall, there is a new transfer of heat from the catalytic burner to the ACRU.





Capabilities

- Integrates a catalyst and sorbent systems to use—within the sorbent system—the waste heat from the catalyst.
- Combines a contaminant-removing, catalytic heat-producing, oxidizing subsystem and a heat-producing, contaminant-removing, temperature-swing-desorption subsystem to significantly reduce the total amount of heat produced and energy consumed, thereby increasing overall thermal efficiency.
- Inventive configuration A reduces the total amount of waste heat generated in an enclosed space (e.g., onboard a submarine), and produces the optimum electrical load profile for the combined burner and ACRU systems without significantly changing the sorbent regeneration temperature profile.
- Inventive configuration B offers reduced waste heat and an improved electrical load profile with a rapid sorbent heating rate.

Benefits

- According to inventive configuration A, the net transfer of heat results most notably in a lower total amount of heat generated for the integrated systems.
- According to inventive configuration B, the net transfer of heat results most notably in a faster heating profile for the sorbent.

Benchmarks

Benchmarks are unique qualities that are used to compare against existing patents, patent filings, and commercially available products in this assessment tool.

Index Number	Title	Description
1	**Reduction of Total Energy Consumption**	**Reduction of Total Energy Consumption:** To achieve reduction of total energy consumption, the waste heat generated by the catalytic system is transferred into the adsorption system during the sorbent heat-up portion of the sorbent regeneration cycle.
2	**Reduction of Generated Waste Heat**	**Reduction of Generated Waste Heat:** To reduce generated waste heat, the heat is transferred using a thermal reservoir, which accumulates heat from the catalytic apparatus and transfers it to the adsorption apparatus at a later time, and is repeatedly cycled as the sorbent is cycled.
3	**Faster Heating Profile**	**Faster Heating Profile:** To achieve a faster heating profile, configuration B heats the sorbent faster, therefore shortening regeneration time.

Market Research

Executive Summary

This section provides insights into market size, trends, and barriers to entry for the commercial applications of the technology, as well as recommendations for deeper market research.

Potential Markets

Oil Refineries
Refers to post-extraction treatment that is used to obtain high-quality oil for various uses.

Market Insights

Market Size

- The global Oil Refining market was valued at $1,345.0 billion in 2020 and is projected to reach $3,751.5 billion by 2030, growing at a Compound Annual Growth Rate (CAGR) of 5.3% from 2021 to 2030.

Market Trends

- The global demand for oil refining is primarily driven by increasing investment toward construction, as well as expansion and upgrading of refineries to fulfill petroleum product demand and reduce dependence on imported, refined petroleum products.
- Government regulations pertaining to carbon emissions, and a positive outlook toward aviation and road transportation sector are some of the factors augmenting demand for refined products.
- With the growing numbers of vehicles, the demand for gasoline and gas oil has increased significantly, resulting in construction of new oil refineries to meet the growing demand.

Barriers to Entry – High

- Growing adoption of clean fuel is expected to hamper the growth of the oil refining market during the forecast period.

Key Players

- Bharat Petroleum Corporation Limited, Bp Plc, Chevron Corporation, China National Petroleum Corporation, ExxonMobil Corporation

Market Research (cont.)

Potential Markets	Market Insights
Catalytic Converters These devices are designed to convert toxic gases such as carbon monoxide, nitrogen oxide, and hydrocarbons into less dangerous substances through a redox reaction	**Market Size** • The global Catalytic Converter market is projected to reach $28.5 billion by 2030 at a CAGR of 8% from 2023-2030. **Market Trends** • Significant growth can be attributed to the surge in automobile sales, one of the largest consumers of catalytic converters. • Increasing awareness of air pollution and the growing application of catalytic converters in non-automotive industries. • Increasing strategic growth measures will likely create new opportunities for future growth. **Barriers to Entry – High** • The Catalytic Converter market has seen a surge in competition and constant evolution, with numerous companies striving to capture a larger market share. **Key Players** • Yutaka Giken Company Limited (Japan), Faurecia SA (France), Futaba Industrial Co. Ltd. (Japan), Eberspächer Group (Germany), Calsonic Kansei Corporation (Japan).
Air Pollution Control Systems eliminate volatile substances that are harmful to human health	**Market Size** • The global Air Pollution Control Systems market is estimated to have been worth $96,670 million in 2022 and is forecast to reach $119,520 million by 2028 (a CAGR of 3.6%). • The growing use of air pollution control systems, rising environmental awareness, and ongoing government initiatives to promote the use of renewable energy over fossil fuels are key factors anticipated to increase the global market for air pollution control systems. • The development of the Metal Processing, Oil and Gas Exploration, and Cement Manufacturing industries—all of which use air pollution control systems—will propel the market for these systems throughout the forecast period. **Market Trends** • Escalating demand from the Pharmaceutical and Medical industries, global decline in air quality, and a quickening pace of industrialization and urbanization. **Barriers to Entry – High** • Environmental regulations inhibit new firms' entry in a variety of manufacturing industries. **Key Players** • Babcock and Wilcox Enterprises, Mutares, Elex, FLSmidth, Feida Group Company, KC Cottrell.

Market Research (cont.)

Potential Markets	Market Insights
Heat Exchanger manufacturers Systems used to transfer heat between a source and a working fluid	**Market Size** • The global Heat Exchanger market was estimated at $17.5 billion in 2022 and is expected to expand at a CAGR of 5.1% from 2023 to 2030. **Market Trends** • A growing focus on efficient thermal management in various industries—including Oil and Gas, Power Generation, Chemical and Petrochemical, Food and Beverage, and HVAC and Refrigeration—is expected to drive demand for heat exchangers over the forecast period. • Oil and gas companies' rising investments in exploration and production activities in the U.S. are expected to boost demand for these products in the Oil and Gas industry. • Significant power markets such as China, the U.S., India, Russia, and Japan are restructuring their operating models to adopt the structure of renewable energy and efficient energy utilization by installing heat exchangers and shifting from traditional energy use. **Barriers to Entry – Low** • Barriers to entry remain relatively low in this market, despite the need for highly skilled manufacturers. **Key Players** • Alfa Laval, Kelvion Holding GmbH, Danfoss, API Heat Transfer, Xylem Inc.

Market Research (cont.)

Conclusions

- The Oil Refinery market remains viable for this invention, as there is an established use case; the invention must add value to a market in order to gain traction.
- Catalytic Converters could be a potential market for the invention, but it would pose challenges to newcomers; the automotive segment of this market is substantial, and the implementation of this device might not be feasible, since automotive manufacturers already integrate design features to resolve the same issue(s) this technology seeks to address.
- The Air Pollution Control market could be promising in large-scale plants where the devices needed are being used. This invention can add value and efficiency to existing processes.
- The Heat Exchanger Manufacturing market remains viable for this product; it is the exact device this invention interacts with.

Recommendations

Priority Key:

- **Must:** A critical and time sensitive recommendation to advance technology with respect to the area of focus.
- **Should:** An important recommendation to advance technology but is dependent upon predecessor recommendations or is not time sensitive.
- **Could:** A recommendation that will have insignificant impact on advancing the technology but could be a beneficial consideration.

Recommendations	Priority	ROM Cost	ROM Timeline
Advance TRL and MRL Plan	2	$15,000	4 months
Market Planning and Scouting	3	$35,000	6 months
License technology	1	$15,000	2 months
ROM Total:		**$65,000**	

Level of Market Opportunity

Low----------Moderate----------High

Analyst: DVIRC

Competitor Analysis

Competitor Analysis Intent

The intent of this section is to identify potential commercially available, competing technologies and provide conclusions and recommendations based on the information provided at the time of assessment. The resulting information may be used to identify technology strengths or weaknesses in features or claims, as well as potential licensing partners.

Research Methods

Various resources to uncover information about different companies that perform similar functions

Markets	Competitors
Oil Refineries	• **Bharat Petroleum Corporation Limited:** Large oil refineries in Mumbai, Kochi, and Bina push performance and efficiency to its highest level with many different distillation processes. • **BP Plc:** Oil refinery capacity of 1.64 million barrels per day in 2022. In the period of consideration, BP sold interests in refineries and reduced its daily capacity by 1 million barrels per day. • **Chevron Corporation:** Chevron had a crude oil refining capacity amounting to 1.8 million barrels per day worldwide at the end of 2022. Refining capacity was highest in 2013 and 2014, at 2.0 million barrels per day, with a low of 1.6 million barrels in daily capacity in 2018.
Catalytic Converters	• **Yutaka Giken Company Limited:** Products include those for drive systems, exhaust systems, and braking systems, e.g., torque converters, catalytic converters, mufflers, exhaust manifolds, silencers, heat collectors, and exhaust manifolds. • **Faurecia SA:** Developer and manufacturer of complete exhaust systems, including components reducing emissions and components for exhaust system acoustics. In 2017, value-added sales reached $4,493.2 million (26.5% of corporate total). • **Futaba Industrial Co. Ltd:** Diesel particulate filter (DPF) – apparatus that removes particulate matter (PM) contained in exhaust gas from diesel engines. Urea selective catalytic reduction (SCR) devices are catalytic devices that remove nitrogen oxides (NOx) contained in exhaust gas.
Air Pollution Control	• **Babcock and Wilcox Enterprises:** Waste-to-energy processes that avoid landfilling, reduce harmful methane emissions, and provide electricity and/or heat for industrial processing and district heating systems. • **Mutares:** Operates projects according to the rules of the Clean Development Mechanism (CDM) anchored in the Kyoto Protocol, as well as the “Gold Standard” established by international environmental organizations. • **Elex:** Flue gas cleaning with over 7000 units installed worldwide.

Competitor Analysis (cont.)

Markets	Competitors
Heat Exchanger Manufacturers	• **Alfa Laval:** Copper brazed-plate heat exchangers provide efficient heat transfer with a small footprint, are maintenance free, provide a long service lifetime, and can withstand high temperatures and extremely high design pressures. • **Kelvion Holding GmbH:** Plate-, shell-and-tube-, refrigeration, and finned-tube heat exchangers, as well as modular cooling towers used in global markets for power generation, oil and gas, chemistry, marine applications, climate and environment, food and beverages, and transportation. • **Danfoss:** Micro channel heat exchanger (MCHE) is designed for residential and commercial air conditioning systems, as well as refrigeration equipment driven by energy efficiency and reduction of the refrigerant charge.

Technology Readiness Level – Hardware

Technology Readiness Level Intent	Current TRL
The intent of this document is to determine the level of effort required to advance the technology from its current state to a desired future state. Project tasks may be proposed to assist in technology advancement. The *Technology Readiness Level (TRL) Deskbook* version July 2009 served as the reference document for the TRL assessment. TRLs run from 1 to 9.	**3**

Research Methods

TRL determination has been conducted on applicable levels as seen below. The assessment was conducted by reviewing the following materials:

- Technology Overview
- Patent # 10,458,681
- Q&A call with inventor

Findings

The patent for Thermal Integration of a Catalytic Burner and a Carbon Dioxide Removal Unit provides a methodology of reducing total power consumption and waste heat generated through recovery of waste heat from a catalyst system for use in sorbent system through configuration B. Configuration B offers reduced waste-heat and an improved electrical load profile with a rapid sorbent heating rate, resulting in a notably faster heating profile for the sorbent. The status of this invention is currently TRL 3, as a characteristic proof of concept and software model have been established. A prototype has not been developed, and a Technical Data Package (TDP) has not been created. There has not been any advancement in the development of the technology since granting of the patent. Although the technology is not ready for manufacturing—since a prototype has not been built or tested in any laboratory or real-world environments—all necessary components are available.

Conclusions

For the Thermal Integration of a Catalytic Burner and a Carbon Dioxide Removal Unit to advance to reach TRL 9, a prototype must be developed and validated in a software model through operational environment. The design must be finalized, and a TDP developed. Upon finalization of the design, building a prototype and validating the same in relevant environments would be essential. Lastly, the resulting technology would need to be integrated into existing systems.

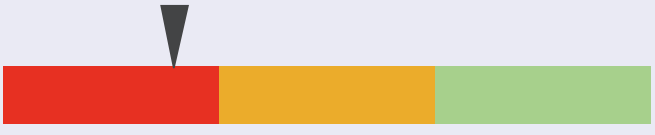
Technology Readiness Level – Hardware (cont.)

Recommendations

Priority Key:

- **Must:** A critical and time sensitive recommendation to advance technology with respect to the area of focus.
- **Should:** An important recommendation to advance technology but is dependent upon predecessor recommendations or is not time sensitive.
- **Could:** A recommendation that will have insignificant impact on advancing the technology but could be a beneficial consideration.

Recommendations to advance TRL to 9	Priority	ROM Cost	ROM Timeline
Develop TDP	Must	$1,000	1 month
Develop Proof of Concept	Must	$2,000	2 months
Develop Cost Model	Must	$1,000	1 month
Develop prototype	Must	$5,000	3 months
Validate prototype in operational setting	Must	$3,500	2 months
Complete Design for Manufacturing	Should	$2,500	2 months
Discuss potential to license technology to OEMs	Could	$2,000	2 months
Finalize Cost Model	Should	$1,000	1 month
Third party TRL revision	Could	$3,500	2 months
Finalize TDP	Should	$1,000	1 month
ROM Total		**$22,500**	**15-17 mos.**



Analyst: DVIRC

TECHNOLOGY VIABILITY ASSESSMENT POWERED BY MILTECH

Manufacturing Readiness Level

Manufacturing Readiness Level Intent	Current MRL
The intent of this assessment is to determine the level of effort required to advance the technology from its current state to desired future state. Project tasks may be proposed to assist in the advancement of the technology. The *Manufacturing Readiness Level (MRL) Deskbook* version 2.0 served as the reference document for the MRL assessment. MRLs run from 1 to 10.	**2**

Research Methods

Although a contractor has not been identified, an MRL determination has been conducted on applicable levels as seen below. The assessment was conducted with the following events and materials:

- Q&A interview with the inventor
- Patent # 10,458,681

Findings

The MRL will generally track with the TRL but be slightly lower. The following is an assessment of the technology's current MRL and reasoning for the rating.

The patent for Thermal Integration of a Catalytic Burner and a Carbon Dioxide Removal Unit has not been prototyped, although manufacturing concepts have been identified, categorizing the technology as a MRL 2. The components and equipment needed for constructing the technology already exist, but the patent focuses on using the existing equipment in a novel way. Welding ducts would be the most likely method of manufacturing the system. The system will be operated by microcontrollers to allow the user to sequence the valves, but that process is not a complicated addition and the inventor could develop it. Although potential suppliers have not been identified, most components are readily available, and there are no special skills needed to manufacture the system beyond welding. There are no foreseen approvals or certifications, since the current configurations of the system already exist.

Conclusions

Until the TRL process (TDP, testing) is advanced, the MRL will remain low. Most parts are COTS, and no specialized or complex manufacturing is required beyond the addition of the heat exchanger and welding of ducts. The system can be advanced through the remaining MRL levels without excessive expense. Further prototype development is a crucial next step, followed by system validation.

Suppliers will need to be identified and confirmed, including backup suppliers to widen sourcing options for COTS parts and limit supply chain issues. A more thorough MRL assessment should be completed when these suppliers have been identified and an evaluation can be made in a production environment.

Manufacturing Readiness Level (cont.)

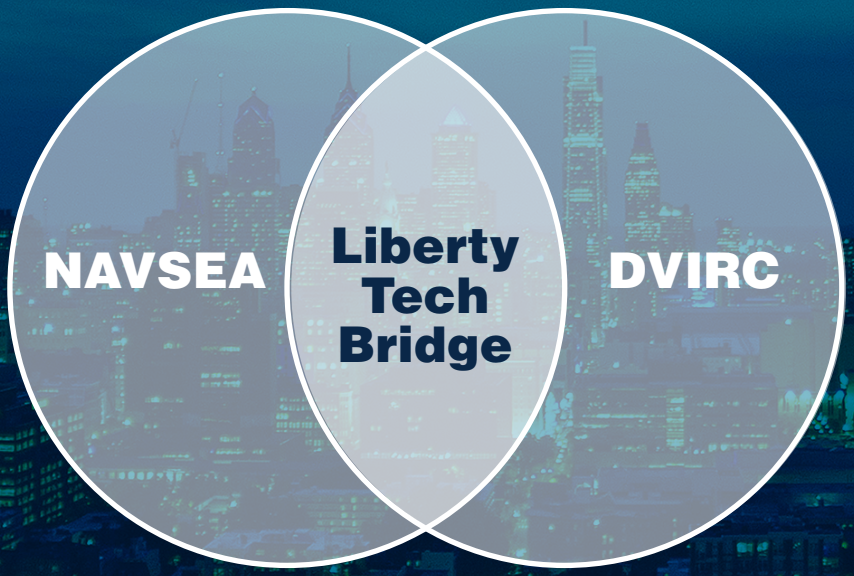
Recommendations

Priority Key:

- **Must:** A critical and time sensitive recommendation to advance technology with respect to the area of focus.
- **Should:** An important recommendation to advance technology but is dependent upon predecessor recommendations or is not time sensitive.
- **Could:** A recommendation that will have insignificant impact on advancing the technology but could be a beneficial consideration.

Recommendations to advance MLR	Priority	ROM Cost	ROM Timeline
DDevelop BoM	Must	$1,500	2 months
Develop Cost Model	Should	$1,000	1 month
Scout assembly/COTS suppliers	Must	$2,000	2 months
Perform Critical Design Review	Must	$2,000	1 month
Complete Design for Manufacturing	Should	$2,500	2 months
Discuss potential to license technology to OEMs	Could	$2,500	2 months
Finalize Cost Model	Should	$1,000	1 month
Finalize BoM	Should	$1,500	1 month
Third party MRL revision	Should	$3,500	2 months
Finalize/Select COTS suppliers	Must	$1,000	1 month
Pilot Production Run	Must	$3,500	1 month
Evaluation and Design Modification	Must	$2,000	1 month
Full-Rate Production Run	Must	TBD	TBD
ROM Total:			

Analyst: DVIRC



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