

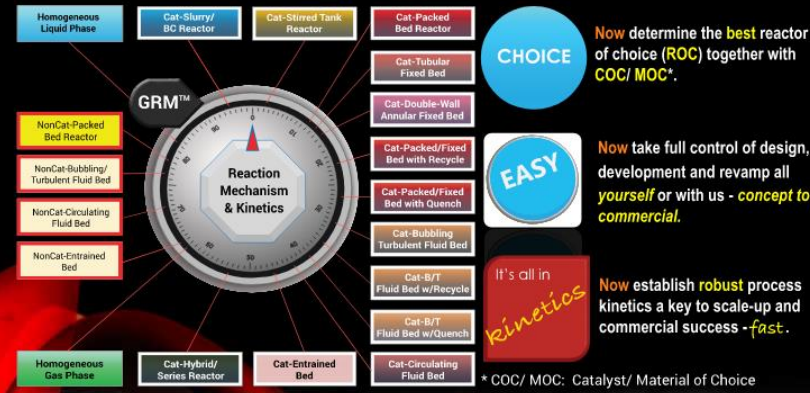
# FAST ASSURED REACTOR & TECHNOLOGY SOLUTIONS

● ENVIRONMENT ● ENERGY ● CHEMICAL ● PETROCHEMICAL ● CATALYST ● SYNGAS/COAL/BIO MASS/MINERAL CONVERSIONS ● CO<sub>2</sub> / POLLUTANTS CAPTURE

<b>your Reactor</b>	Revamp, upgrade or revive for profit, new market/ feed/ product
<b>your Technology</b>	Develop, model, design, scale-up, optimize, innovate
<b>your Plant</b>	Achieve true optimization with reactor as another unit operation



**DIFREX**<sup>®</sup>  
for reactors



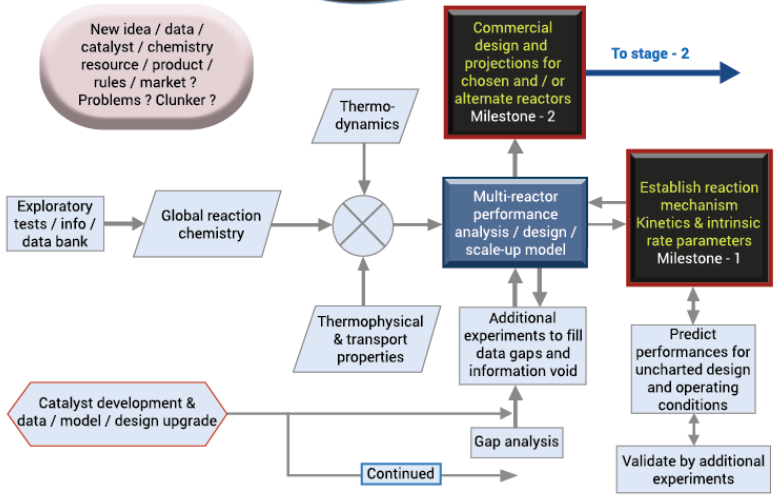
difrex.com

...reactor is life - rest is details

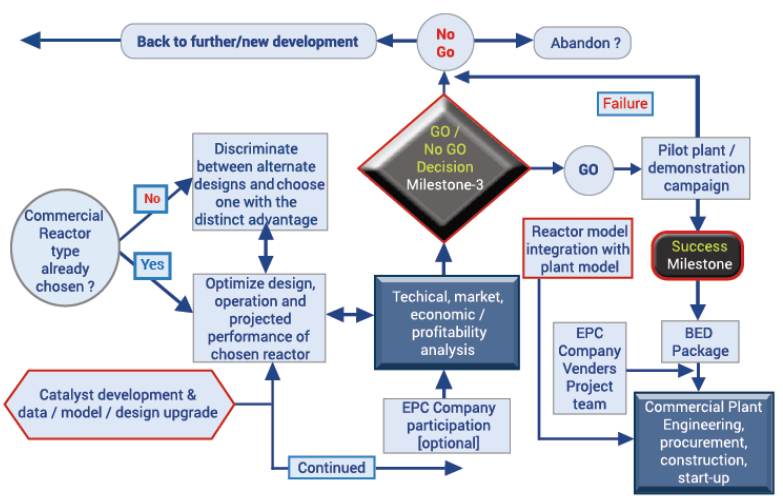
**Mission:** Our business is *reactors*. Our mission is to serve clients worldwide with the fastest, assured and most comprehensive reactor services and solutions in industry; to minimize risk and cost of process development; and to provide help in head start and confident decision on new reactor/ technology or change/ revamp of existing one.

**Vision:** Our vision is for our clients to see reactor as a *black box* no more and reap its fullest potentials for their process plants.

**Total solution**  
Concept to commercial



A recommended path for stage-1: concept to commercialization of a catalytic process

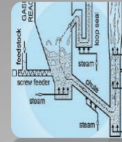


A recommended path for stage-2: concept to commercialization of a catalytic process

Reactor is **the heart** of process technology – new or old. It defines the *technological edge* of a Company.



Debottleneck, retrofit/ revamp, optimize, service, monitor, control your **current** reactor/ technology.



Analyze, model, develop, scale-up, design, optimize, catalyze, **innovate** a **new** reactor/ technology/ **idea**.



Make reactor **another unit operation** to achieve true optimization of your plant and operation.

....and powered by a friendly smartpack (GRM™)\* and standardized procedure take **full control** of it all **yourself** or with us.

\* to be released.

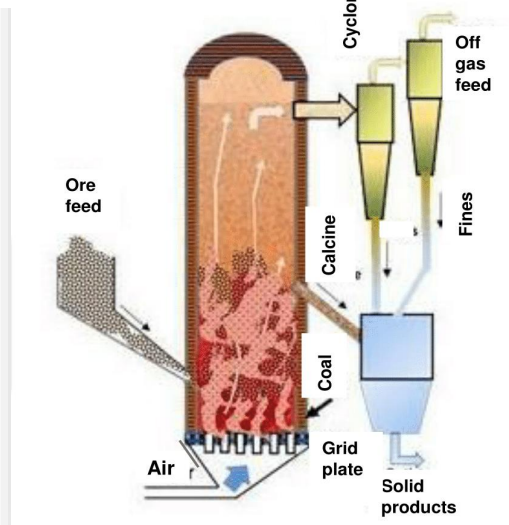
- 'No-Oops' **A2Z solutions** NOW cover a **vista of reactors** – **reactors of virtually any kind** involving **reactions of any kind or complexity** and **even non-stoichiometric** reactions as in refineries, coal and biomass conversions.
- Tasks are **now** completed at a **fraction of time and cost** to reach the **Decision (Go-No Go) Gate**.
- Evaluate **alternate reactor concepts** at about same time to make **the right decision** on **ROC (Reactor of Choice)**.
- **Head start** and **total CTC (concept-to-commercial)** services to **minimize failure**, and **improved reactor safety**.
- Aided by a **unique, friendly, secured and stand-alone GRM™** software package (**smartpack**) that can hide in a wallet, and **standardized procedures**, tasks **now** become **far easier** than ever before.
- Building a **robust kinetic model** from **raw data** and minimum information that may be **key to commercial success and safe operation** is **now** made **easy**.
- Performance **guarantee** can be offered due to our **'zero-failure'** track record of **multiple commercial successes** with **fixed and fluidized and quenched bed reactors** - backed by our **edge and insight** and advance 'oops' analysis.
- **Enterprise solutions** for sustained growth and edge.

Our reactor design, development and services are guided by five focal points

- **Easy**
- **Choice**
- **Agility**
- **Safety**
- **Assurance**

**Non-Catalytic Reactors/ Processors/ Converters too**

**Catalytic OR Non-Catalytic**



Broad-based, balanced expertise in **reaction engineering and applications**, and extensive experience of **Difrex** that includes **process engineering, modeling & simulation, catalyst/material development, hands-on experimentation, scale-up and commercialization, plant start-ups, operations and trouble-shooting world-wide**, and in **all aspects** of reactors, should serve diverse needs of clients in their labs, production plants and processing units.

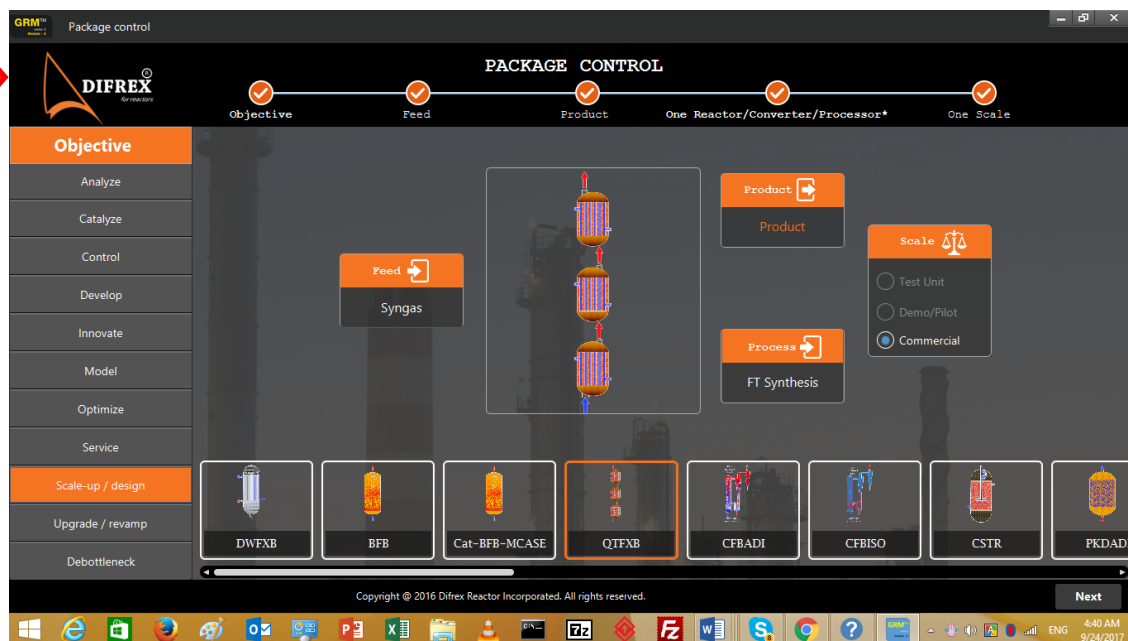


Utilize the GRM™ SmartPack\*. Follow Steps 1-3\*\* prompt and easy.  
 [Current version (series-G) contains ready-to-use modules for G-S systems only. These can be customized to G-S-L (series-L) and others (series-X) versions that will be available later.]

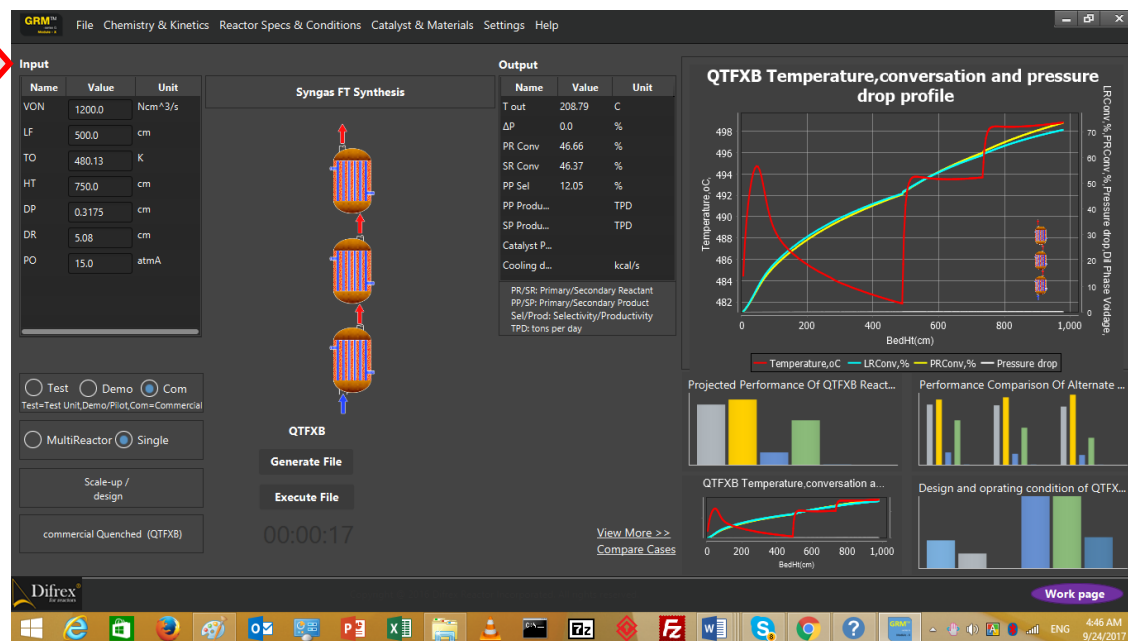
\* to be released; \*\* for Scale-up/ design

**Step 1** Collect system performance data on COC/MOC (Catalyst/ Material of Choice). Establish process mechanism and kinetics following the guideline provided. If full information on process mechanism and kinetics not available, the SmartPack built-in database should help you to fill in most of it for many systems. Preliminary design based on it should be adequate for most applications.

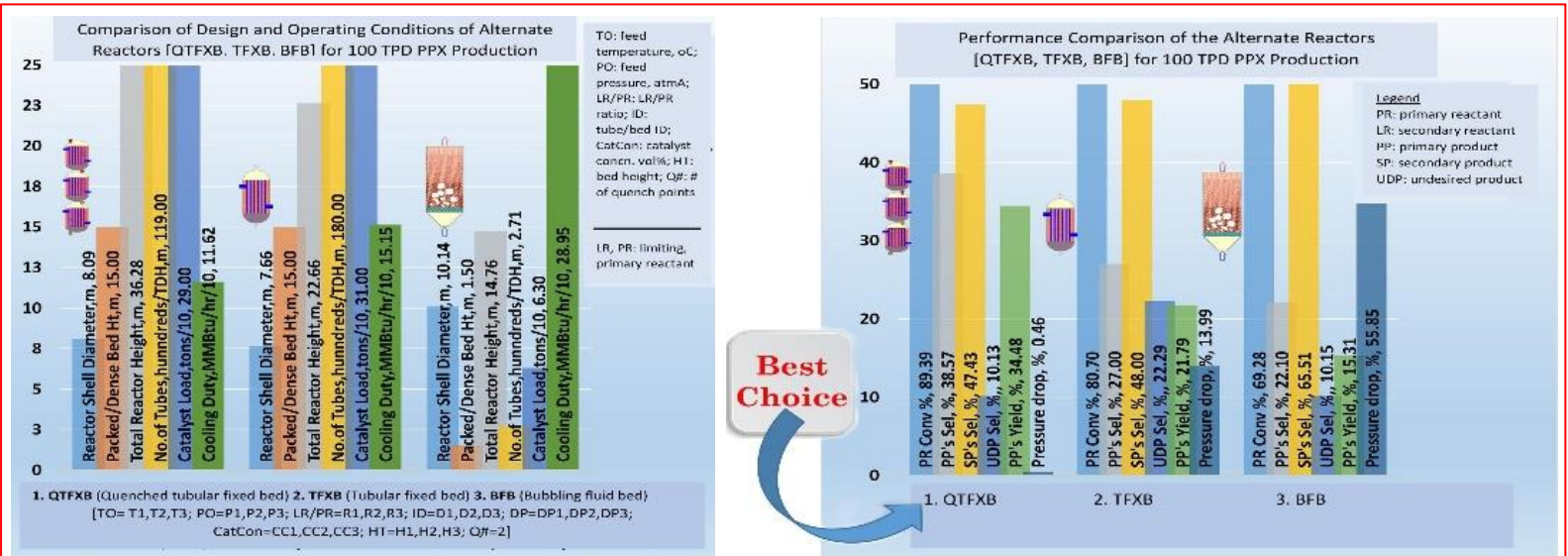
**Step 2** Define your process by answering five (5) questions on this page:  
 1. Objective  
 2. Feed  
 3. Key Product/ Product Group or Process  
 4. Reactor of Choice from the list below  
 5. Scale – Bench, Pilot/Demo or Commercial



**Step 3** Input# process mechanism/ kinetics, design/ operating conditions and catalyst/ material specs per top menu bar. Then:  
 1. Generate Input File  
 2. Execute  
 See input summary and results, showing complete design and performance summary in tabular and graphical forms and complete details@ in 'more >>' sheets.  
 - Complete case studies for the chosen Reactor by changing one or more variables on on-screen Input table.  
 - Compare cases on-screen.  
 - Repeat for another Reactor.  
 - Pick the Best or RIGHT reactor.



#Quick, friendly, easy and error-checked entries  
 @Complete temperature, pressure, composition, productivity, conversion and selectivity profiles, catalyst productivity and effectiveness factors, deactivation, equilibrium constants, reaction rates, cooling loads, thermo-chemical and transport property changes, heat and mass transfer modes, hydrodynamic behaviors like bubble growth, coalescence, slugging, grid, splash zone and free-board reactions, voidage profiles, TDH, solids loadings, flow regimes, entrainment rates, gas solid slip and more ....



Typical comparison of complete design and operating specs and projected performances of three reactors: QTFXB (quenched tubular fixed bed), TFXB (tubular fixed bed) and BFB (bubbling/turbulent fluid bed).

**Choice**

What's your choice?  
Is it the best?



Requirements

**AGILE**

Design

**Time** is everything. **Now** you can move faster from A to Z or concept to commercial with confidence.

Compare complete design and performance projections of your chosen reactors. You see your ROC (Reactor of Choice) and reach the decision gate (Go/No-Go). Much sooner. No trial and errors. No regret.

Develop, design and commercialize reactor of virtually any kind

Test, Model, Demonstrate

Scale-up, Optimize, Design

Determine ROC and design with confidence

Mega reactor

Micro-channel reactor

**Decision**



Safety measures need to be an integral part of reactor design. Case in point is the *POX* (*partial oxidation*) reactor class that can be *inherently* unsafe but enjoys the widest applications in industry. Hot spots, temperature runaway, pressure build-up and formation of explosive mixtures are among the potential causes that are now duly addressed for improved safety.

Reactor multiplicity is a key cause of reactor instability making it difficult to operate and/or control.

Reactor temperature runaway is a possible cause of some catastrophic accidents in commercial plants

Design, development and **prompt** commercialization of **POX** reactor-based technologies is one of our core strengths

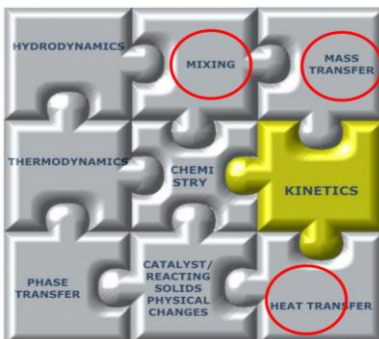
Current Difrex team members were instrumental in successful commercialization of two **POX** technologies, a **Fluidized Bed** and a **Fixed Bed**.

The **Fluidized Bed Technology** (ALMA Process) received the Kirkpatrick honorary award for new Technology in 1991.



New Reactor/ Technology or Revamp: Fear of cost runaway, missed expectations or failure prevails in process industry. Better development and design practice should reduce the fear and risk. In Difrex this practice is built on Reaction Engineering expertise, numerous applications and field experience, repeated and cross-validations of model projections, advance 'oops' analysis and learning from other failed ventures.

## It's all in *kinetics*



Kinetics masked/influenced by other phenomena

Move from *hypergolic reactions* (*spontaneous*) of gel/ liquid propellants in a rocket engine to *coal combustion/ gasification* (*fast*) in a circulating fluid bed reactor to *catalytic reactions* (*moderate to fast*) in a tubular reactor to *hydrocracking of heavy oil* (*moderate*) in a slurry reactor. Process rate/ kinetics moves from purely *mixing rate* to predominantly *heat transfer rate* to *chemical reaction rate* influenced by mass/ heat transfer rate to *chemical reaction rate* influenced by gas-liquid mass transfer rate. A robust reactor model accounts for such differences.

Our expertise in reaction kinetics extends beyond the area of conventional catalytic processes for bulk chemicals production to coal pyrolysis-gasification-combustion to hypergolic reactions of gel-gel propellants in rocket engines.

Fluidization and fluo-solids system design is a **core area of our expertise**.

Building **robust** kinetic model is a difficult and time-consuming task. **Difrex** makes it easy even with minimum information in hand.

We strive to minimize, if not eliminate, the need for extensive **pilot plant campaigns**.

**Bench/ Pilot Units & Scale-up:** Let us design, build and/or operate your bench and/or pilot-scale unit. Our design and operating strategies for these units are to **mimic** the dominating **features** (like kinetic, heat/ mass transfer and hydrodynamic behaviors) **and expected operating windows of a commercial unit**, to the extent possible. **Any gap between the two is filled by our expert scale-up model projections**. This minimizes uncertainties, cost and delays that are often associated with successive scale-up steps: **bench** → **pilot** → **demo** → **commercial unit**.

Our work is backed by experience, applications, coverage and track record unmatched in the field.

# Experimental Program

Misguided, lengthy and/or redundant data generation often results from an experimental campaign for a new process development. We help you prioritize the areas of focus in your experimental program by recommending a test matrix that is conducive to a collection of data most useful for promptly establishing reliable reaction mechanism and kinetics, catalyst screening, developing the reactor model and successful scale-up and optimization of the commercial reactor design.

## A2Z

Due to our *combined background and experience* in concept validation, reaction engineering, detailed design of reactors and auxiliary systems, modeling and simulation and process engineering we can help you in your next venture. And, we can do it with our services during *the entire process* from the Concept to Commercial.

## Go ahead

- Put that *sulfur guard/* device for *emission control* or for *feed gas treatment*
- Put it at *well mouth* or along *distribution lines*
- Put out a flare/ waste streams converter for *profit and environment*
- Install a *Mercury emission control* to your sludge/ waste incinerator
- Install a *Trace/ carcinogen controls* to meet *environmental regulation*
- Install a *GTL unit* at *well mouth, remote island/location* or on *ship-board*
- Carry out *retrofit, revamp or upgrade* you have postponed
- Revive *troubled/ idled* units
- Minimize *over- or under-designs*.



It should cost less than you think and Difrex can help.

## Debottlenecking, retrofit/ revamp

We provide both on- and off-site plant unit debottlenecking on short notice – worldwide. In-depth assessment of estimated benefits, cost and return on our recommendations on optimization of your running unit or retrofit or revamp is provided at a nominal charge. Most often the benefits and quick returns strongly justify the move. We provide prompt diagnosis and solutions to your troubled and idled units.

**Cause?**

- \* Feed-stock changed
- lighter to heavier crude?
- \* Gaps in original design?
- \* Operation not optimized?
- \* Catalyst decayed/ fouled?
- \* Channelling due to plugging/ agglomeration/slumping?
- \* Soot/ gunk build-up on walls/ internals?
- \* Ht-transfer surface fouled/blocked?
- \* Fines/ pressure build-up?
- \* Nozzle/line/ distributor blocked?
- \* Probes plugged/ misreading?

Productivity declined or was never achieved to start with?

200 Tons/day → 169 Tons/day

Push

**Estimated LOSS for Productivity Decline**

**1.2 MM\$/Year**

for 200 tpd Unit & 0.05\$/# profit

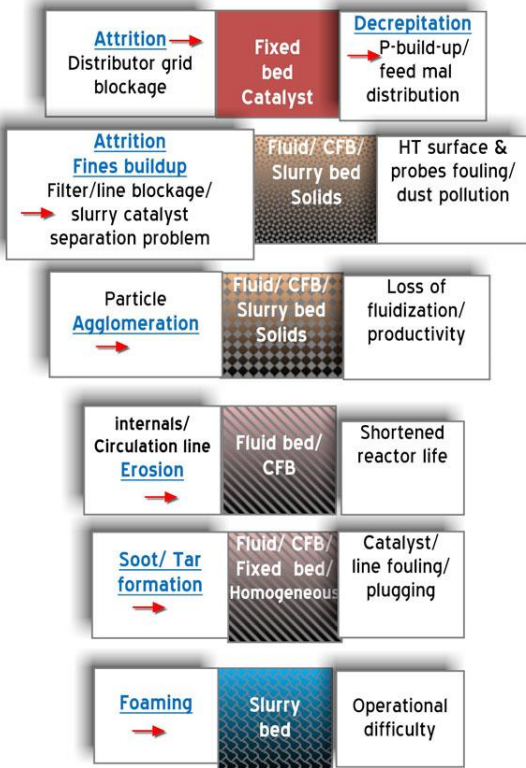
**Solution?\***

→ Bring back to Design Capacity →

**Estimated cost(max)?**

**\$400,000**

\* (If not due to fundamental design flaw)



## One-stop solutions

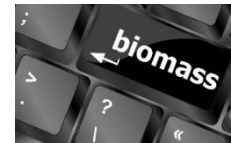
Although many final details beyond the key design specs and operating conditions are to be filled in by process engineers, there are aspects that still fall under the primary responsibility of the reactor designer. These aspects are usually not addressed by most computer models. Ignoring these aspects, inadequate or wrong solutions to *these issues* may lead not only to project failure but also to disastrous consequences *later* in a running plant.

Under-performing, uncontrollable, unpredictable, problem-ridden or dying reactor?  
Or one sitting in the sideline/ off-line? Call Difrex!

## Non-Catalytic G-S reactors

Our added strength is also in the design of non-catalytic (and mixed - catalytic and non-catalytic) reactors, wherein solids take part in both chemical and physical transformations. Areas covered include *Combustor/ Incinerator/ Gasifier/ Pyrolyzer* of biomass/sludge/coal/solid fuels, *minerals Roaster/Calciner*, and *Desulfurizer* and *Hg removal*.

Fuel ↔	Green wood crop	Verge Grass	Organic domestic waste
Moisture, wt%	50	60	54
Ash, dry wt%	1.3	8.4	18.9
LHV, MJ/kg	7.7	5.4	6.4
<b>Dry Wt% ash free</b>			
Carbon	49.1	48.7	51.9
Hydrogen	6.0	6.4	6.7
Oxygen	44.3	42.5	38.7
Nitrogen	0.48	1.90	2.20
Sulfur	0.01	0.14	0.50
Chlorine	0.10	0.39	0.30
Syngas, kg/kg fuel	2.37	2.40	2.42
Temperature, oC	900	900	900



**Roaster/Calciner/Extractor:**  
Our *non-catalytic fluidized bed* (NC-BFB) model can be readily customized to design your fluidized bed mineral calciner/ roaster unit, metals/ precious metals/ silicon or pigments production.

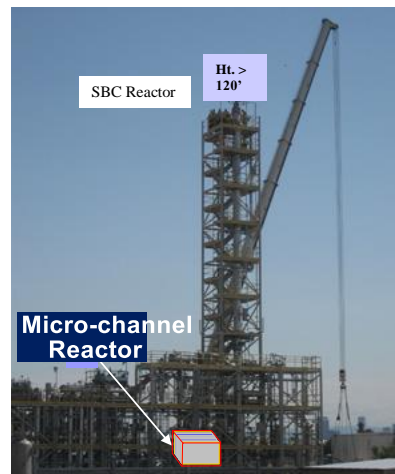
## CO<sub>2</sub> Capture, Desulfurizer, Hg Removal

We offer reliable design tools and guidance to promptly and *inexpensively build, install or upgrade* pollutant absorber/ desulfurizer - catalytic, non-catalytic or mixed using a packed, moving, fluidized bed (BFB or CFB) or a dual-bed (reactor-regenerator pair). We also offer a fluidized bed hot gas desulfurizer design. We are keen to join CO<sub>2</sub> capture and recycle ventures and PTF and PTC projects to realize economic success.

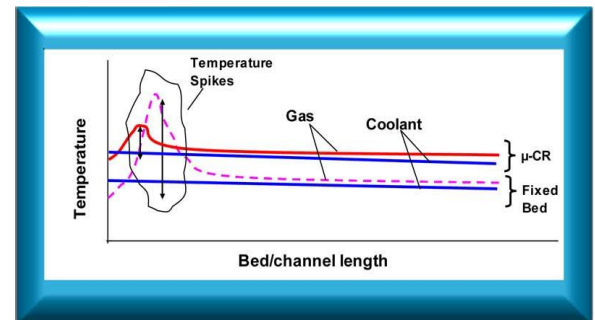
We designed, tested and commissioned mercury (Hg) capture system for a large **operating fluid bed sludge incinerator** in an Indiana refinery **within a week**

## Micro-channel Reactor [Process Intensification]

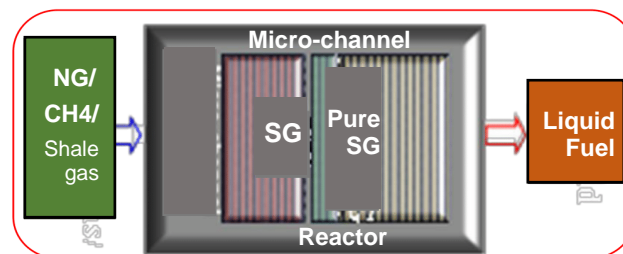
For small to medium scale plants a micro-channel reactor offers an attractive alternative due to a) negligible heat and mass transfer resistance, b) compact, minimal foot-print and size, c) modularity, d) shop fabrication, easy transportability and installation, e) minimum catalyst need and easy regeneration, and f) distributed applications, among other attributes.



Size comparison of a conventional SBC reactor with a microchannel reactor



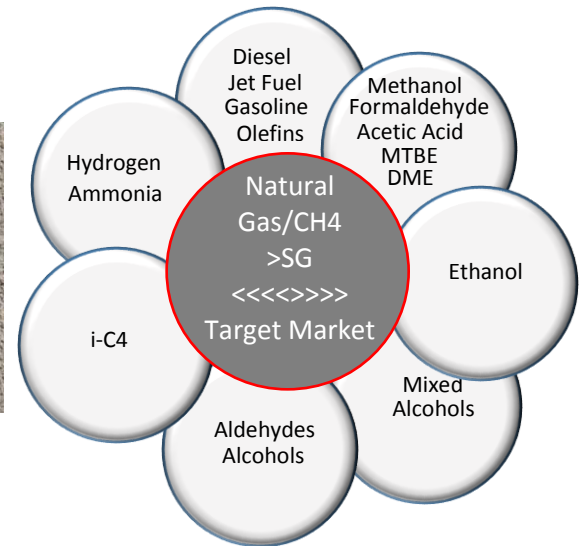
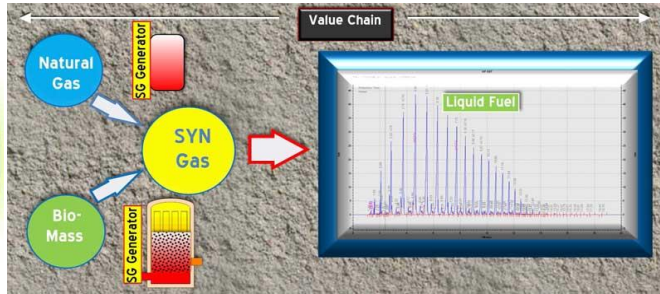
We have a strong position in microchannel reactor technology



We are open to work with you to build *distributed energy* network for liquid fuel generation and supply using microchannel reactors and *renewable* resources.

# Value Chain

We are strongly positioned to be a part of your **Entire Value Chain**  
 NG/Biomass → SYNGAS → Fuels/Chemicals



We were instrumental in **successful commercialization of Two POX technologies** - Fluidized Bed and Fixed Bed. We like to be a part of your next venture with another POX reactor including **SG Generator** using **abundant Natural Gas** and **Gasifier** using many **Renewable Resources**.

## Why Us

Our **culture** drives our desire and engagement for *your* best **value**. We go that extra mile.

## Retainer Services

We are willing to work with you and your team as consultant/ advisor under retainer agreement for your development/ design needs and strategic planning.

## Partner/ Sponsor

We seek partners/ sponsors particularly in software development.

## Enterprise solution

*Disruptive change* is the *new norm* that makes *sustained growth* challenging. Reactors in your plant face the brunt of this challenge as feeds and product demands and market can *change suddenly*. **Difrex** can help in your strategy to be pro-active not only to minimize losses due to such disruptions but also to capitalize on it. We can talk how. We help you *identify strategic niche* and make your strategic decision possible by our in-depth and unbiased analysis of both market potentials and *true technical positions* of competing/ emerging technologies.

Helping fast-track technology development & commercialization is one of our core strengths

Expertise built on members' past teaching and PI positions and *design, development, modeling, consulting, advisory and debottlenecking* services to companies and institutes including...



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