Ramgen Power Systems

NETL CO2 Carbon Capture Technology Review

Pittsburgh, PA

August 24, 2011

Forward Looking Statement

Some of the information contained in this document contains “forward-looking statements”. In many cases you can identify forward-looking statements by terminology such as “may,” “will,” “should,” “expects,” “plans,” “anticipates,” “estimates,” “predicts,” “potential,” or “continue,” or the negative of such terms and other comparable terminology. Forward-looking statements are only predictions and as such inherently include risks and uncertainties. Actual events or results may differ materially as a result of risks facing Ramgen Power Systems, LLC (“Ramgen”) or actual results differing from the assumptions underlying such statements. These forward-looking statements are made only as of the date of this presentation, and Ramgen undertakes no obligation to update or revise the forward-looking statements, whether as a result of new information, future events or otherwise. Your decision to remain and receive the information about to be presented to you shall constitute your unconditional acceptance to the foregoing.

Company

- Privately-held R&D company founded in 1992
- Focused on unique applications of proven supersonic aircraft technology
- Primary technology innovations
  - Supersonic stationary air & gas compressors
  - High velocity combustor
  - Supersonic expander
- Product embodiments
  - Two-stage 100:1 Pr CO2 Compressor
  - 40+% ISC Engine

US Army Corps of Engineers

Project Overview

Test Advanced Compression

- Development of high-efficiency, low-cost CO_2 compression
- Significantly reduced CCS capital and operating costs

Integrate advanced compression within a gas turbine engine

- Achieve 40+% net electric efficiency
- Achieve system efficiencies of 80%
- Lower capital and operating costs
- Achieve power/heat ratio > 1:1
- Utilize and/or enable opportunity fuel use

Support CCS deployment in the 2013 – 2015 timeframe

- Commercial size high pressure CO_2 compressor stage ~10MW
- Subscale low pressure CO_2 compressor stage ~1MW
- Demo completion in 2012
- Optimization of compressor performance through synergies achieved with engine development activities

Project goals and objectives will demonstrate benefits of compression technology in time for CCS demonstrations around the world ~ 2013-2015

Project Overview Scope of Work

Task 2.0 - CO2 Compressor Preliminary Design and Test Facility Prep September 30, 2011

- Change compressor size from 3,000hp to commercial scale 13,000hp
- Design & build a closed loop CO2 test facility
- Task 2.7 - Aero Tool Development - Improve understanding of supersonic aerodynamics
- Task 2.8 - Product Traceability - Minimize gap between Demo Unit design and CCS ready product

Task 3.0 - Demo of CO2 Compressor – December 30, 2012

- Test two rotors sized to produce supercritical CO2 at 1,000,000 Mt/CO2/year

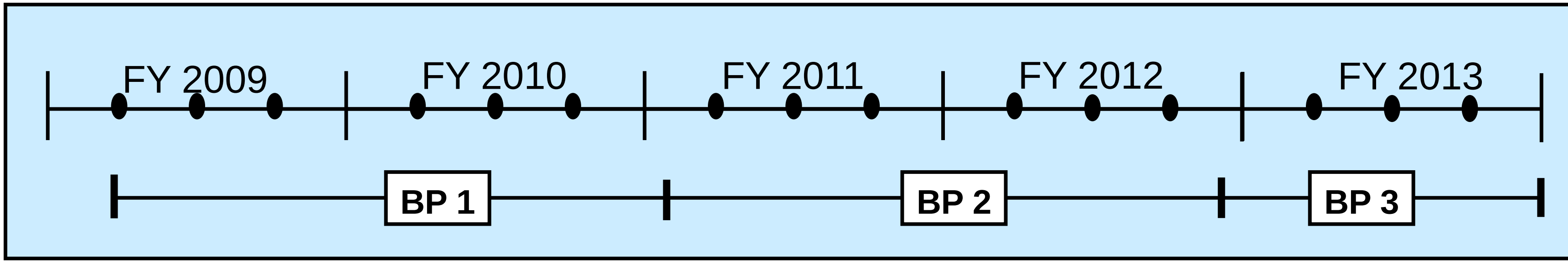
Task 4.0 - Design and Testing of Prototype ~1.5MW ISC Engine March 30, 2012

- Task 4.1/4.2 Design and test shock wave compressor configurations in an engine embodiment to understand system performance potential
- Task 4.3 - ISC Subcomponent Tests - Isolate, test, analyze & optimize the major engine components; compressor, AVC combustor, expander

Task 5.0 - Scale ISC Engine to 5.0MW September 30, 2013

- Task 5.1 – 1.5MW Integrated Engine for Performance Optimization
- Optimize the performance and design of the engine using Ramgen technology compression, combustion, expansion
- Task 5.2 - 5MW Commercial Scale Prototype and Field Test
- Conduct a fueled operational test in a suitable field test site located at a working coal mine with suitable ventilation air and drainage methane collection capability

Program Funding & Cost Share



	BP1	BP2	BP3	Total DOE Program
	$22.70	$32.50	$24.60	$79.70
DOE Support	$13.30 70%	$17.00 70%	$19.70 50%	$50.00
Ramgen Cost Share	$9.4 41%	$15.5 48%	$4.9 20%	$29.7 37%

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Project Participants

Dresser-Rand invests in Ramgen's "game-changing technology"

- Support on-going CO2 compressor development
- Satisfy DOE matching funds requirement
- Consistent with strategy to be technology leader in our industry
- Extend served market into Electric Utility industry
- Invest up to $49 million
  - Fund development & demonstration
  - Obtain an option to purchase assets

Dresser-Rand is consistently ranked among top three manufacturers in its served markets

- Turbomachinery
- Reciprocating compressors
- Steam turbines

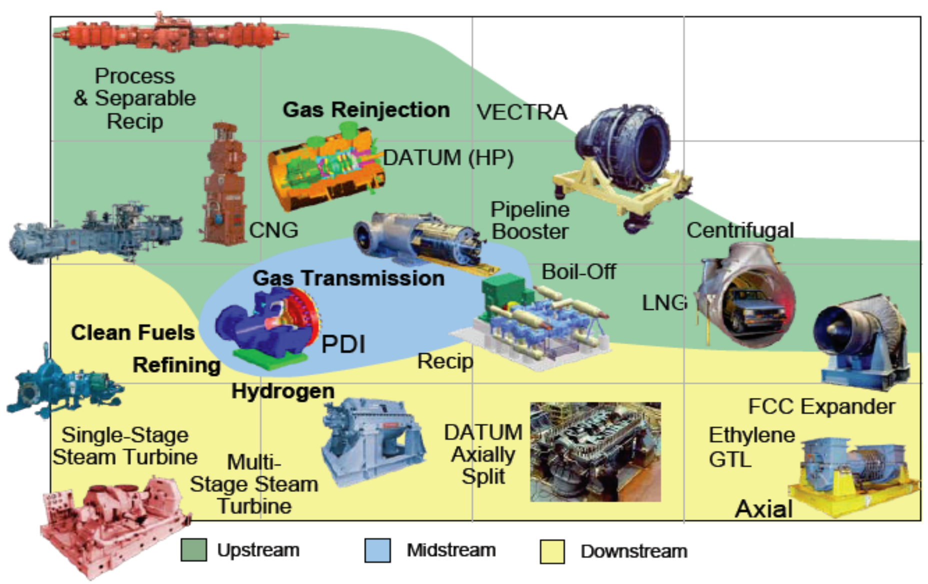
#1 in North America

Global sales & service presence

Strong products & brands

Established customer base

Leading supplier of CO2 compressors



DRESSER-RAND.

Benefits to the CCS Program – CO_2 Compressor

Lowers installed capital costs of CCS technology
- 40-50% of conventional depending on type of CCS
- Simplifies installation
- Smaller footprint
- Reduces cooling water load

Improves the power plant cycle efficiency through cost effective heat integration of high quality heat of compression
- Re-boiler
- Boiler feed water heating
- Coal drying
- Organic Rankine Cycle

Lowers the costs associated with retrofitting existing PC plants with
- 18% improvement in COE with conventional capture technology
- 23% improvement in COE with advanced capture technology

Increases onsite steam and/or power generation to offset CCS parasitic power requirements

Benefits to Reducing GHG – ISC Engine

Improves Distributed Generation efficiency

- 40+% electric efficiency
- 80% cogeneration efficiency
- >1:1 power to heat ratio

Extracts power from Opportunity Fuels

- Ventilation Air Methane
- Landfill gas
- Eliminates methane emissions
- Improves mine safety
- Compelling return on investment

Enable intermittent renewable resource as a Fuel-fired Flywheel

- "Instant-on" capability supports intermittent/unpredictable renewable resources
- Supports a variety of dual use applications

Enables advanced heat recovery cycles

- Alternative working fluids
- Alternative power cycles

Anticipated Benefits, when Successful

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Economic Security

- U.S. equipment & technology equipment exports
- U.S. job creation
- Keeping U.S. businesses competitive

Energy Security

- Use of coal, our nation's most abundant fossil fuel
- Economic re-powering of older fossil plants
- Unique Capability to use dilute fuels to generate electricity
- Potential distributed generation engine
  - 40+% net electric efficiency
  - 80% CHP
  - >1:1 Power to heat ratio
- Enables renewables
- Enables EOR

Environmental Security

- Reduced cost to implement CCS
  - Reduced capital and reduced operating costs
  - Lower energy consumption
- CO_2 and Methane emissions reduction
- Applies equally to NGCC power plants

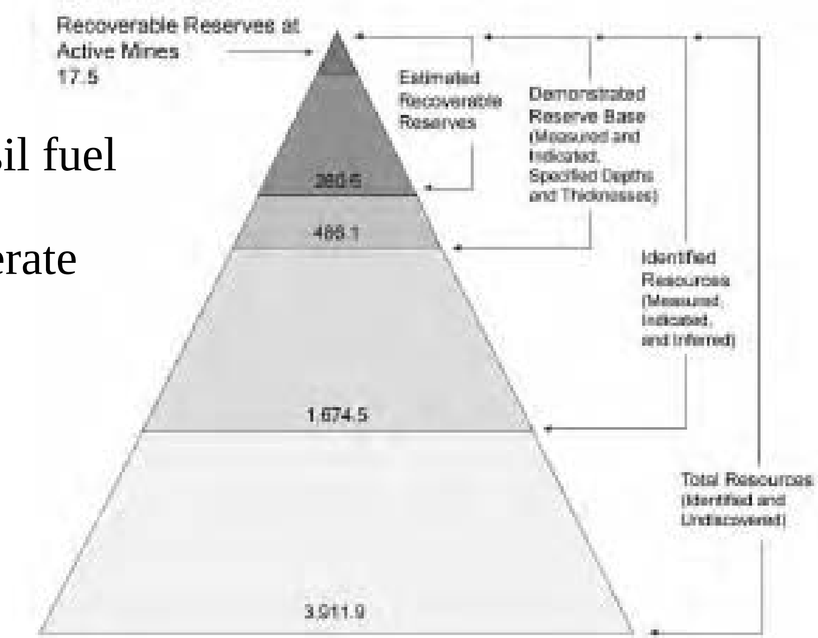
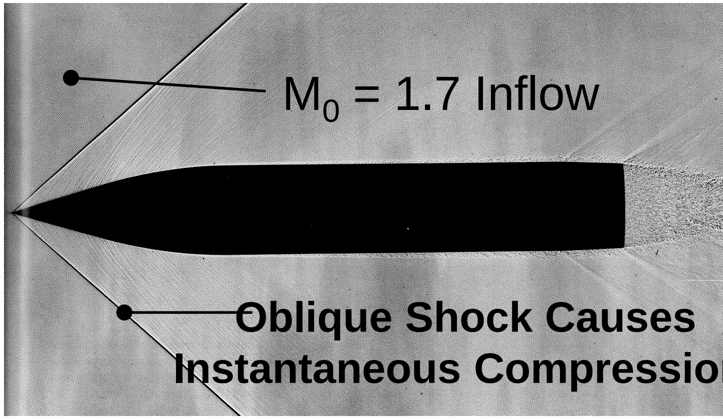


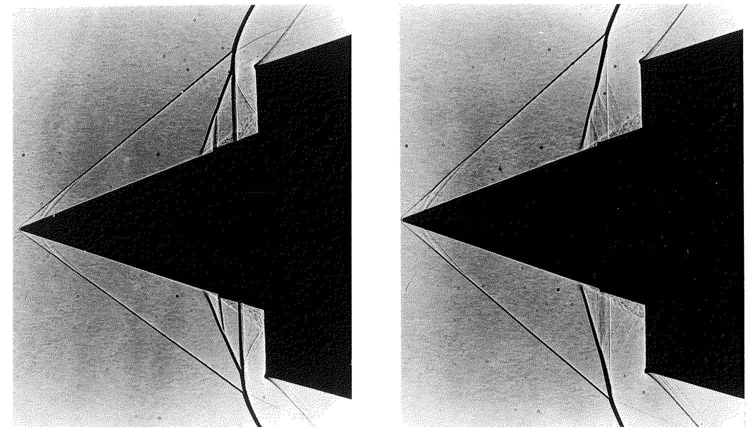
Figure 2-1
U.S. Coal Resources and Reserves (Billion short tons as of January 1, 2009) [7]

EPRI – Integrated Generation Technology Options July 2011

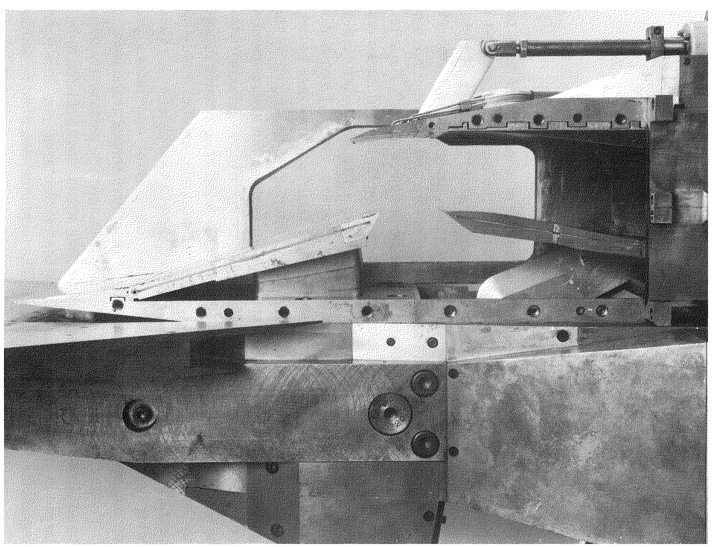
Technology Fundamentals/Background



Schlieren Photo of Projectile with Shocks



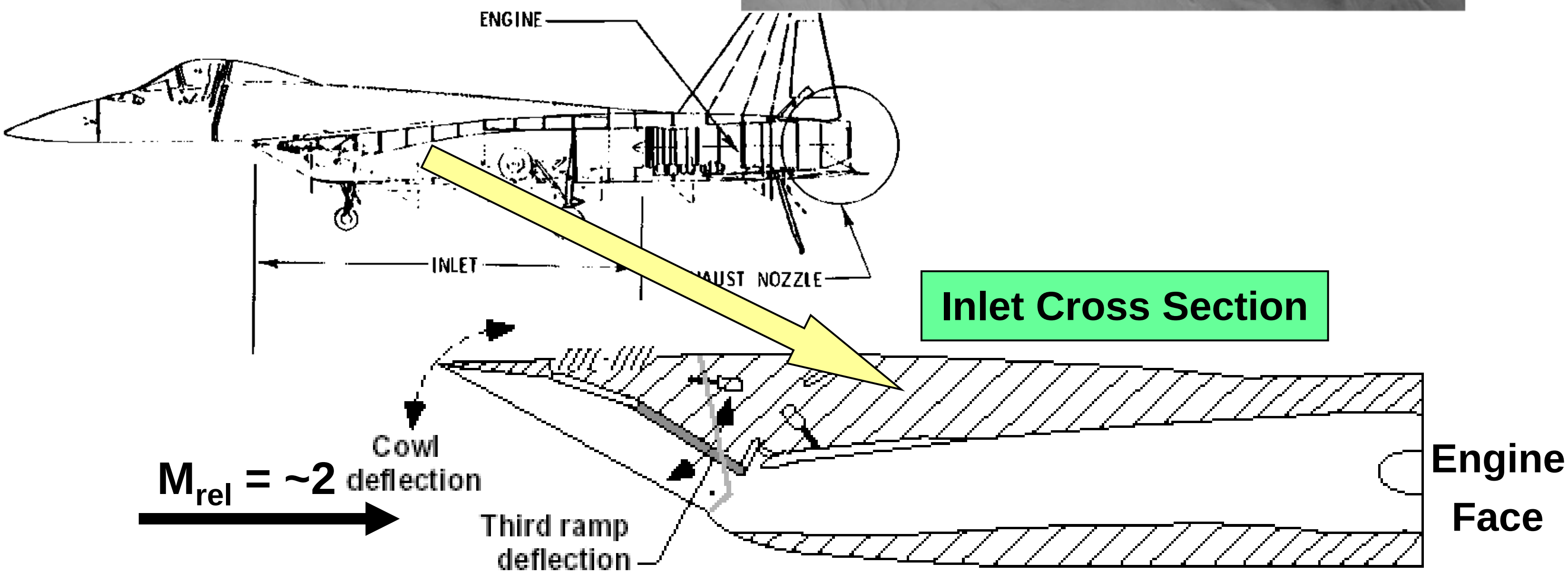
Schlieren Photo of Inlet Center-body and Cowl with Shocks



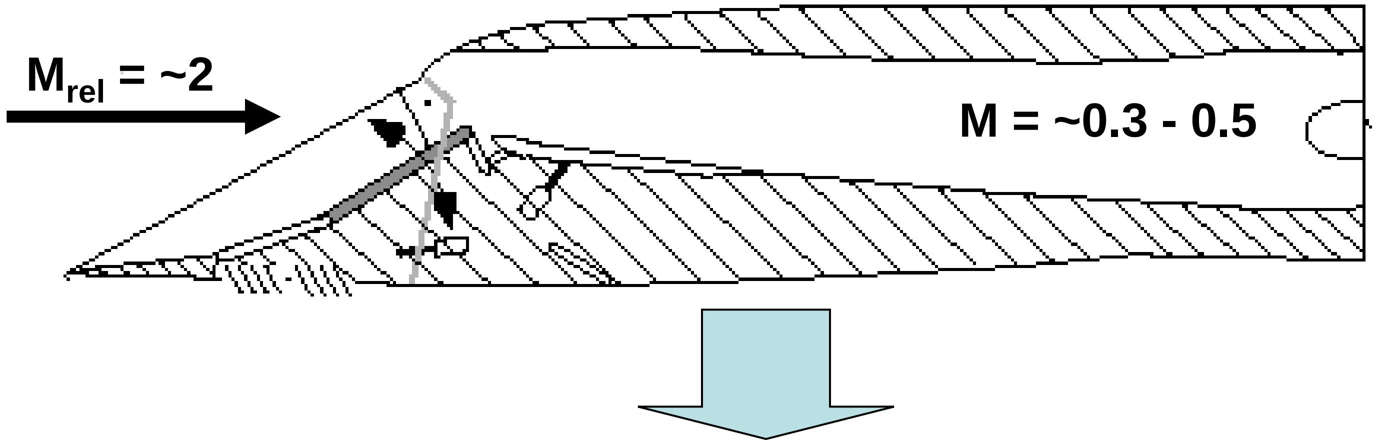
2-D Mixed Compression Inlet Model

- Initial External Shock System Followed by Internal Shock System
- Throat Bleed Slot For Inlet Starting
- Side Window For Schlieren Photography

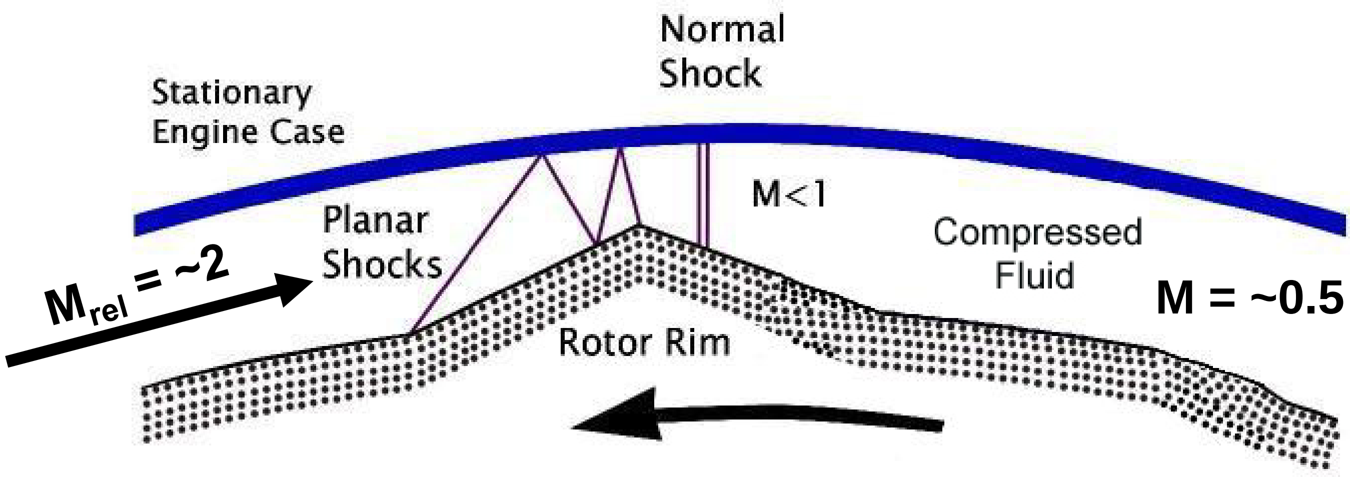
F-15 2-D Planar Supersonic Inlet



Rampressor Rotor Development

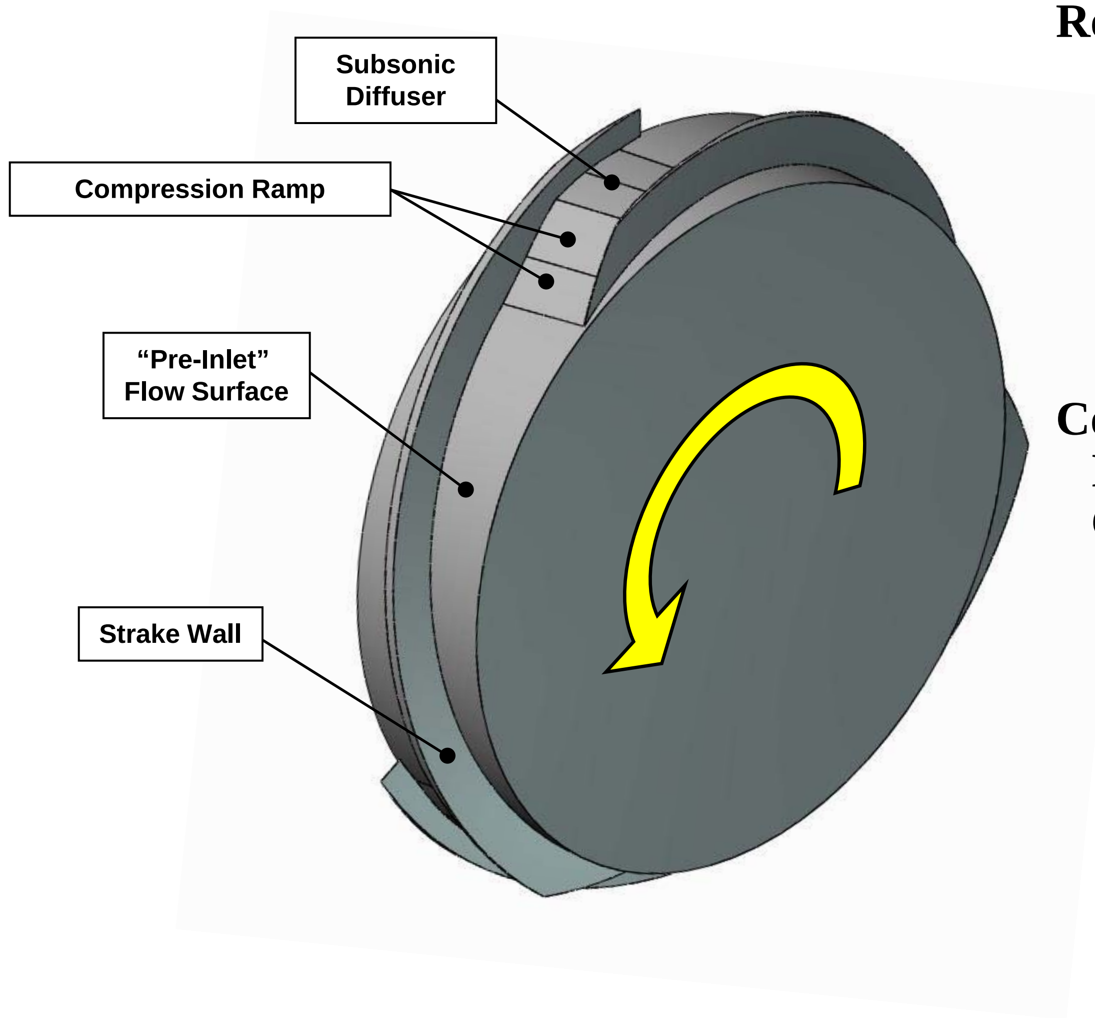


Supersonic F-15 Inlet



Rampressor Rotor

Typical Rotating Supersonic Flow Path



Rotor Flow Path:

- 3 Supersonic Compression Inlet Flow Paths On Disk Rim
- High Efficiency, Compact Compression
- Minimal Number of Leading Edges
- Flow Path Geometry Similar For Different Pressure Ratios

Combination of Supersonic Flight Inlet & Conventional Axial Flow Compressor Aerodynamics:

- Rotor Rim Radius Change Produces Compression
- 3 "Blades" (Strakes) Do Minimal Flow Work
- Axial Inflow/Outflow

Fundamental Science Driving Technology

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can be handled with sufficient accuracy for most purposes when the unit is a typical single-stage air compressor. A little more discretion must be used on multistage compressors handling heavy gases, however, because fan-law deviation can become quite significant for speed changes as small as 10 per cent.

Choke Effect

The basic slope of the head flow curve has been discussed at some length, but the choke or stonewall effect that occurs at flows higher than design flow and which must be superimposed upon the basic slope (Fig. 11.19) has not yet been discussed.

Just as basic slope is controlled by impeller-tip vector geometry, the stonewall effect is normally controlled by impeller-inlet vector geometry. In Fig. 11.24, vector U_1 may be drawn to represent the tangential velocity of the leading edge of the blade similar to ... of the inl... radially (... relative to ... V. At des... shown.

…it is conventional practice to limit the Mach# to 0.85 or 0.90 at design flow.

Mach Number Considerations

The magnitude of V_{rel} compared to the speed of sound at the inlet pressure and temperature is called the relative inlet Mach number. It is the magnitude of this ratio that indicates stonewall effect in a conventional stage. While true stonewall effect should theoretically not be reached until the relative inlet Mach number is unity, it is conventional practice to limit the Mach number to 0.85 or 0.90 at design flow.

It is evident from Fig. 11.24 that, for a given rpm, the magnitude of V_{rel} will diminish with decreasing flow, since V is proportional to flow. If V_{rel} decreases, then relative inlet Mach number decreases, so the stonewall effect is normally not a factor at flows below design flow. It is also evident that at low flows the direction of V_{rel} is such that the gas impinges on the leading side of the blade, resulting in positive

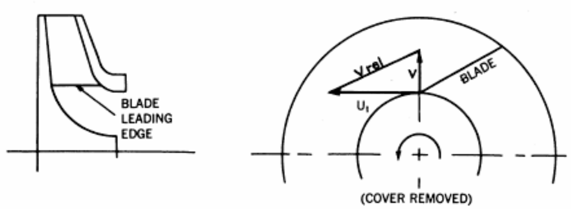


Figure 11.24 Impeller inlet geometry and velocity diagram.

$$c = \sqrt{kg\bar{R}T / MW}$$

incidence, a factor ... gh values of positive incide...

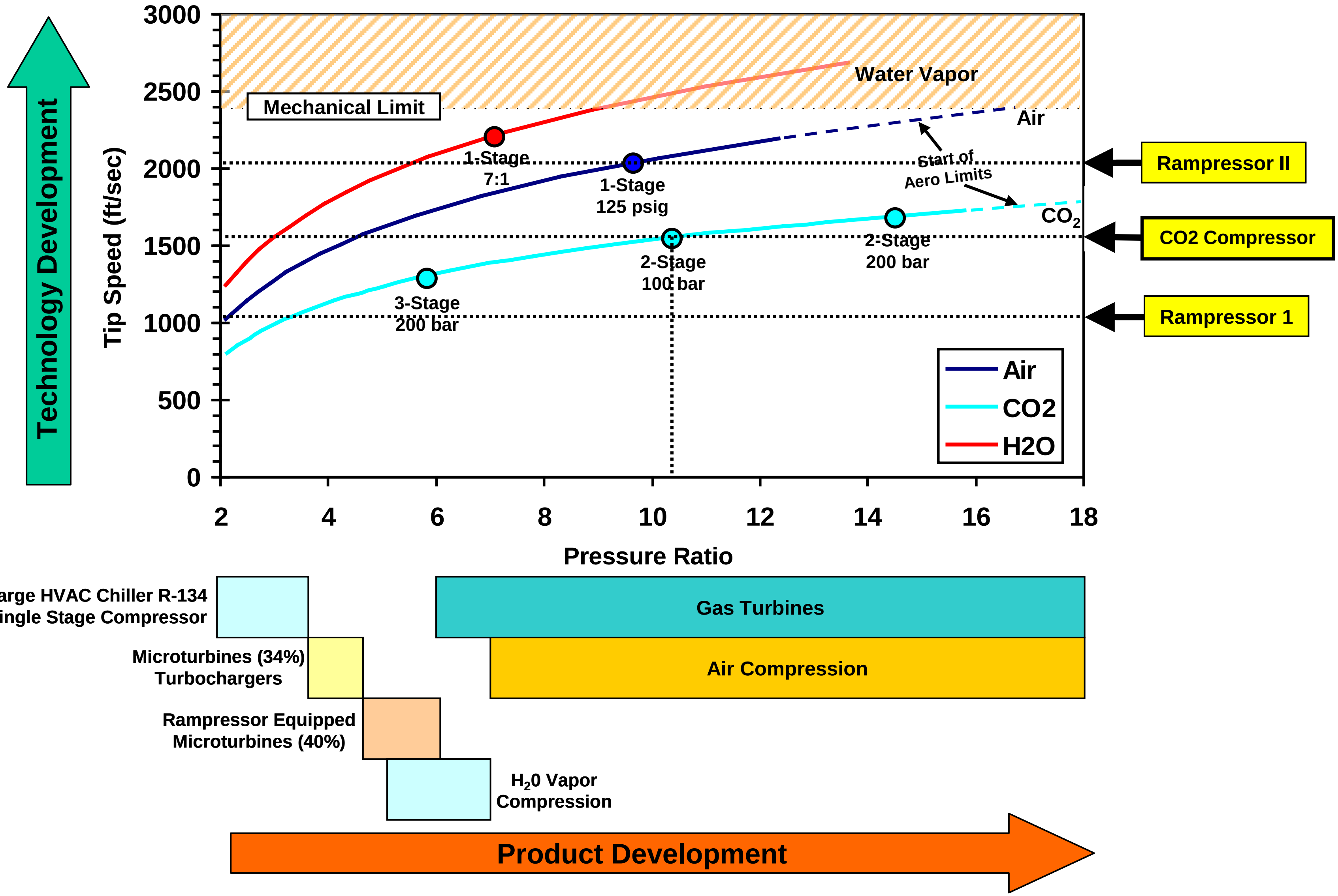
Let us now ... , so also does V_{rel} and relati... e trailing side of the blade, ... rved that high degrees of negative incidence tend to contribute to the stonewall problem as Mach number 1.00 is approached, presumably because of boundary layer separation and reduction of effective flow area in the blade pack.

Significance of Gas Weight

Since values of U_1 are typically in the 500-fps (152.4-m/second) range and values of V in the 250-fps (76.2 m/second) range, it is obvious that, since the speed of sound for air at 80 deg. F (26.7 deg. C) is 1140 fps (348 m/second), lighter gases suffer no true impeller stonewall problems as described, even at high overloads. Some head loss below the basic slope will be observed, however, in even the lightest gases, due in part to increased frictional losses throughout the entire stage and in part to the extreme negative incidence at high overloads.

The lightest common gas handled by conventional centrifugal compressors for which stonewall effect can be a definite factor is propylene with a sonic speed of 740 fps (225.7 m/second) at −40 deg. F (−40 deg. C). In order of increasing severity are propane at 718 fps (219 m/second) at −40 deg. F (−40 deg. C), butane at 630 fps (192.1 m/second) at −20 deg. F (−29 deg. C), chlorine, and the various Freons. The traditional method of handling such gases is to use an impeller of larger than normal flow area to reduce V, and run it at lower than normal rpm to reduce U_1, thus keeping the value of V_{rel} abnormally low. This procedure requires the use of more than the usual number of stages for a given head requirement and sometimes even requires the use of an abnormally large frame for the flow handled.

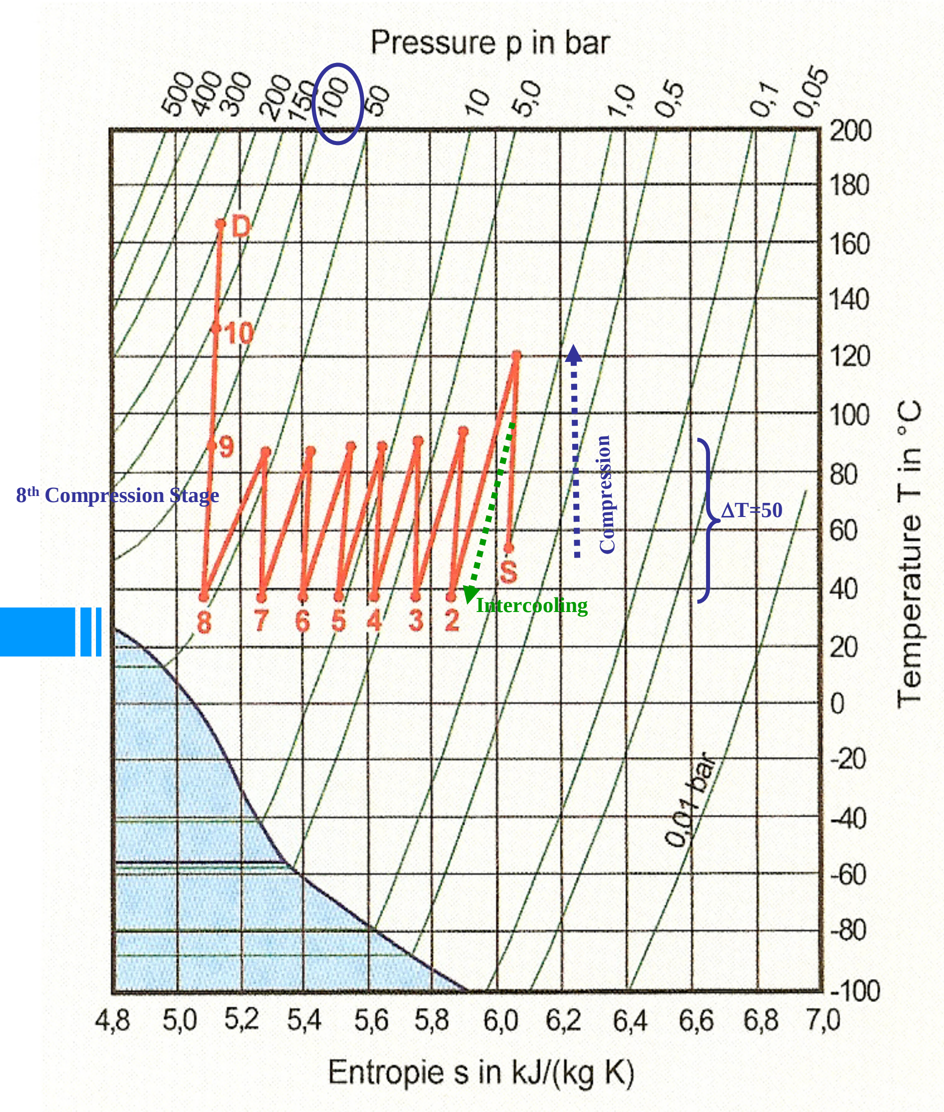
Compression Applications vs. Pr/Tip Speed



Technical & Economic Advantages New/Existing PC Plants

“State of the Art” is Expensive

- 10-stage 6000 hp
  - $8.0 million ➩$1350/hp
  - Pr 200:1 ➩1.70 per stage



- 8-stage 20,000 hp
  - $15.0 million ➩$750/hp
  - $23.0 million installed ➩$1150/hp
  - Pr 143:1 ➩1.86 per stage

Ramgen CO_2 Compressor Product

100+:1 CO_2 compressor ⇨ 2-casings/2-stages/Intercooled

- No aero Mach# limit
- 10+:1 pressure ratio; 400°F temperature rise
- 1400 fps tip speeds; Shrouded rotor design

Single-stage, discrete-drive

- Single stage per drive optimizes specific speed match
- Simple single-step external gearbox or high speed direct drive
- Lower mechanical losses

Variable speed option

- Match MW and temperature changes with speed changes

Configuration adapts easily to match process requirements

- Mismatched thru-flow/Side stream additions

Active IGV Flow control on each stage

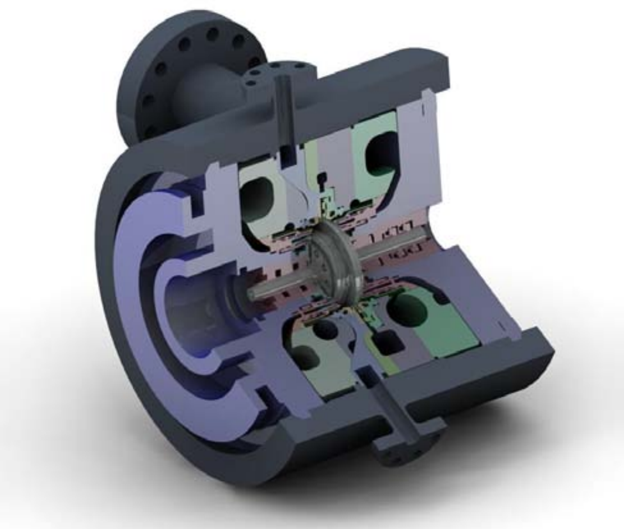
- Match CO2 capture system constant pressure requirement

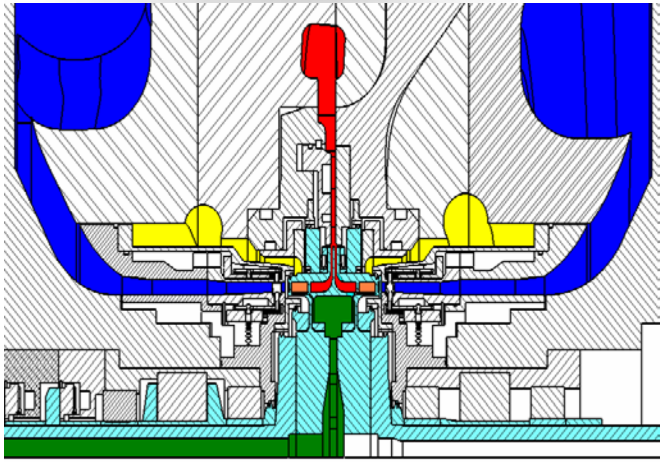
Heat exchangers

- Inter/aftercooler can be the CCS or power plant
- “Compressor” heat exchanger cost can be eliminated
- Eliminate or substantially reduce cooling tower requirement
- Eliminate or substantially reduce cooling tower make-up water
- 3x LMTD ⇨ heat exchangers with 1/3 the surface area

1/10th the physical size -1/2 the installation cost

- Facilitate space constrained retrofits





Challenges in applying it to existing PC Plants

Compressor Conditions Change w/CCS Type

Amine systems
- Suction pressures – 15; 22; 25; 30 psia
- Regeneration heat required
  - Conventional amines – 1550 Btu/lb-CO2
  - Advanced amines – 1200 Btu/lb-CO2
  - Unidentified really advanced amines – 800 Btu/lb-CO2
- 8% parasitic power
- Post combustion - New & Retrofit

Chilled Ammonia
- Elevated Suction pressures – ~ 200-300 psia
- Regeneration heat required
  - Chilled ammonia – 860 Btu/lb-CO2
  - Future – 700 Btu/lb-CO2???
- 4% parasitic power
- Post combustion - New & Retrofit

Chemical Looping
- Suction pressure atmospheric

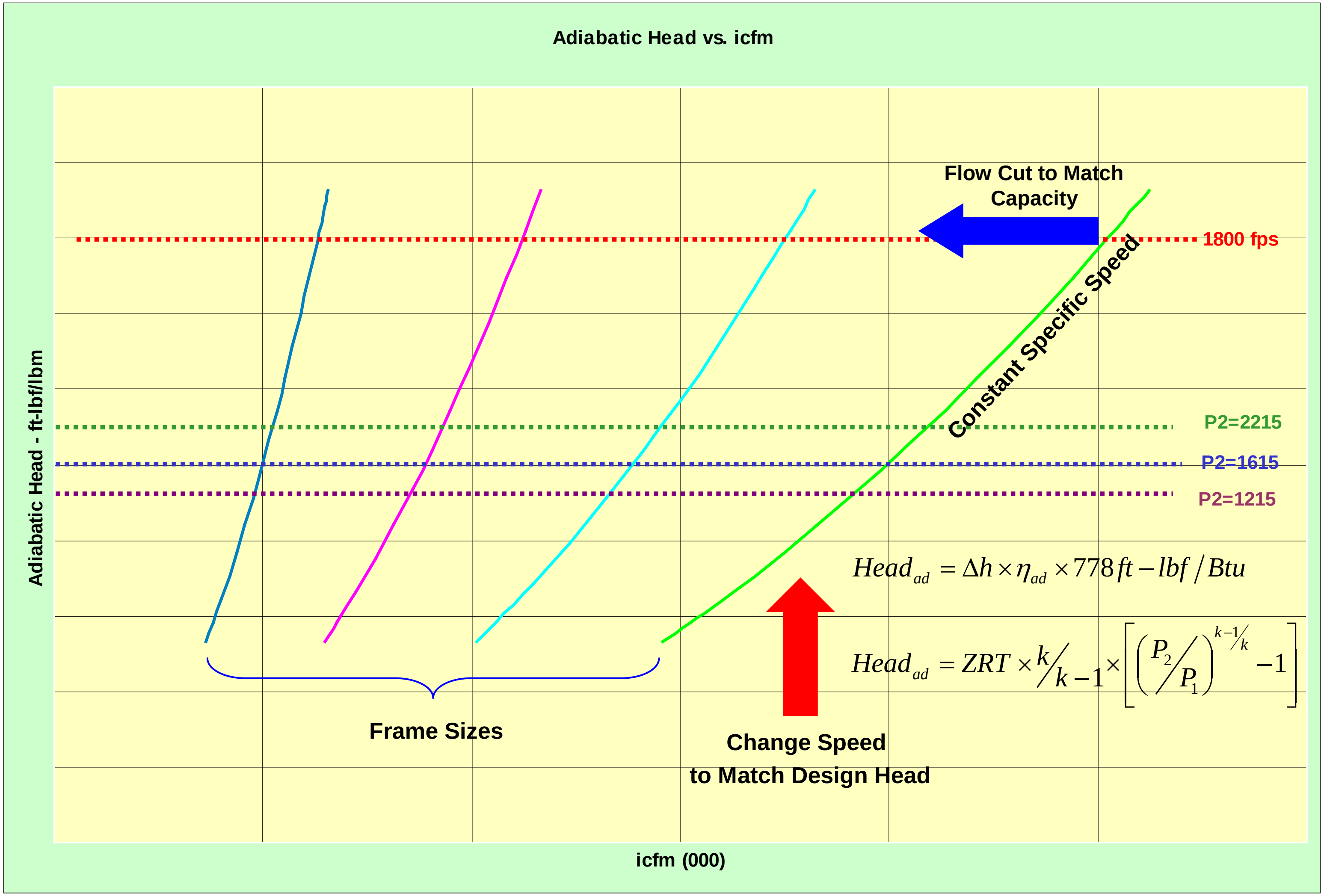
Selexol/Rectisol
- Selexol suction pressures 50, 150 & 300 psia with sidestreams
- Selexol for IGCC power gen
- Rectisol suction pressures 15-25 & 45 psia
- Rectisol for chemical processes & polygen
- 5% parasitic power

Oxy-fuel systems
- Raw gas feed – 15 to 500 psia
- Twin purified suction streams – ~150 & 300 psia
- 12-13% parasitic power
- New plants only

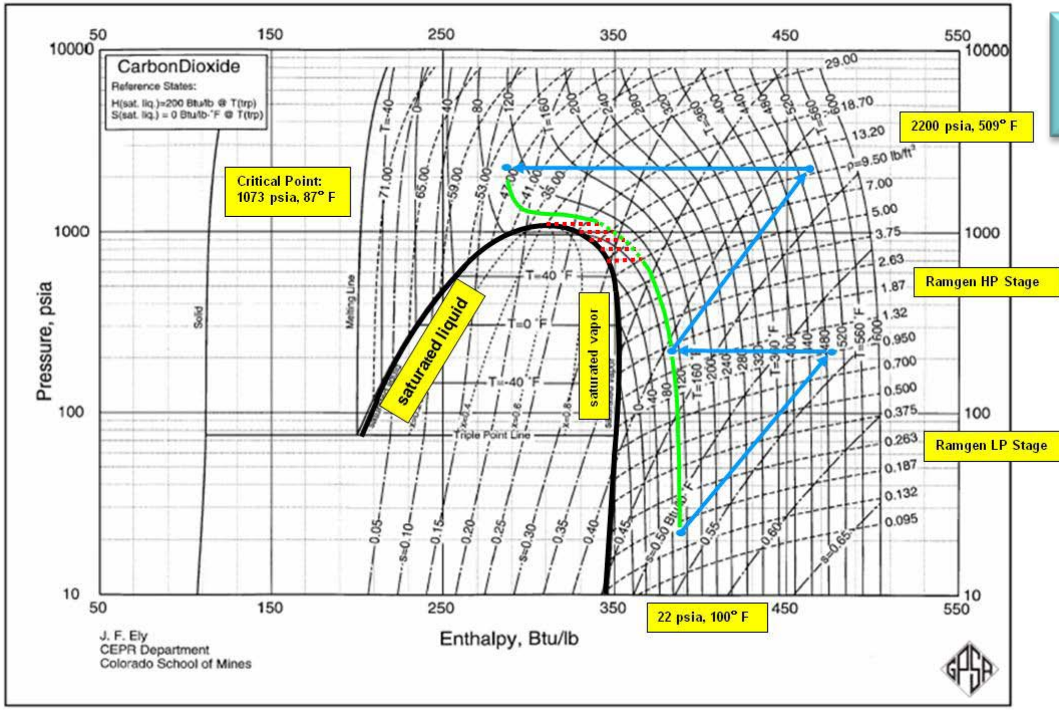
Membrane Separation & Enzyme Processes
- Suction pressures from <3.0-14.7 psia

Discharge pressures
- 1200;1600
- 2000; 2215
- 2500; 2700; 2900 psia

Optimizing Compressor Selection



Heat Integration – Essential to Lower CCS Costs

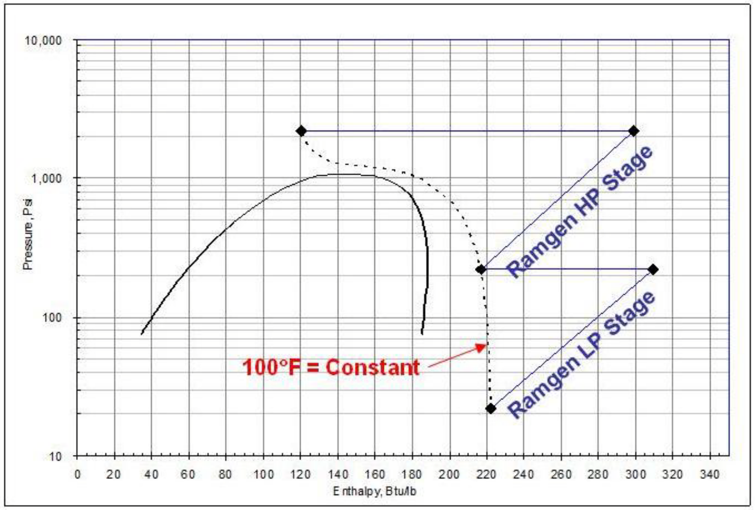


Two-stage Compression avoids two-phase zone

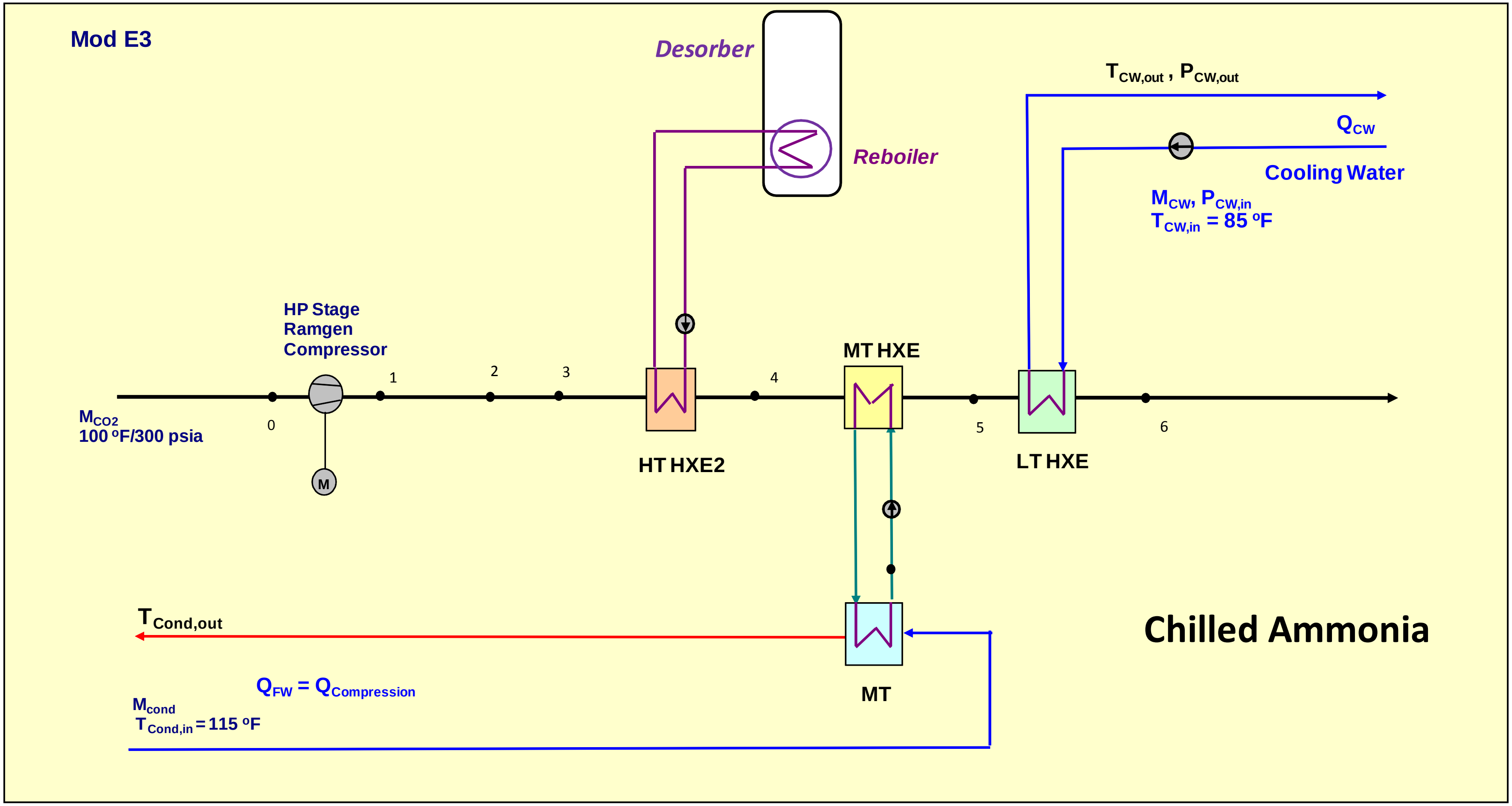
	Low Pressure Stage 22-220 psia	High Pressure Stage 220-2200 psia
Compressor Shaft Work	90.6 Btu/lb	87.0 Btu/lb
Compressor Discharge Temperature	489°F	509°F
Recovery Temperature	100°F	100°F
Recoverable Heat	92.4 Btu/lb	178.8 Btu/lb
Recoverable Heat/Compression Work	102%	205%

Heat available in the HP hot discharge CO_2 is more than double the compressor shaft work

153% of the combined LP + HP shaft work is available as heat in the discharge CO_2



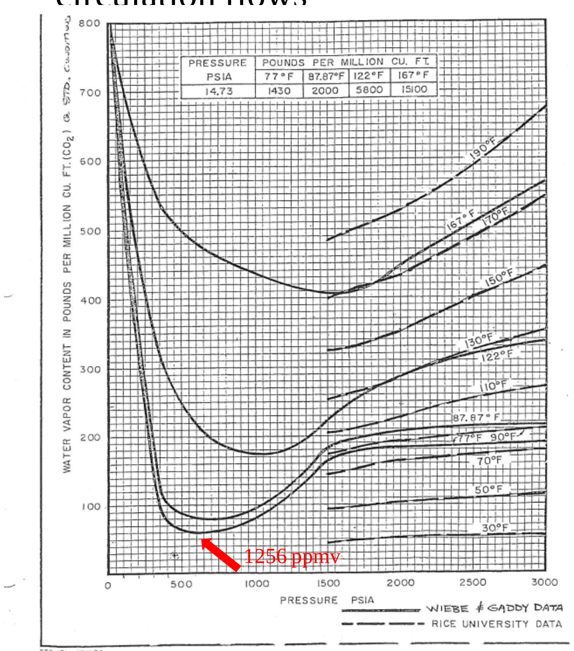
Utility CCS Compression w/Heat Integration



No Consensus on H_2O Content

- **Moisture content specified varies considerably among potential users**
  - Most "over-specify" moisture level required or "just don't know"
  - Has direct impact of where and how drying is achieved
  - Can add significant capital cost and complexity
  - Can increase operating cost with ~10% re-circulation flows

	Design Condition 1	Design Condition 2	Design Condition 3	Design Condition 4
	Remote EOR	Adjacent EOR	Remote Geological	Adjacent Gelogical
Pipeline material	carbon steel	carbon steel	carbon steel	304/316 SS
Compression pressure (psia)	2200	1600	2200	1600
CO_2	>95 vol%	>95 vol%	not limited[1]	not limited[1]
150 ppmv **Water**	dehydration[2] (0.015 vol%)	dehydration[2] (0.015 vol%)	dehydration[2] (0.015 vol%)	no dehydration[3] no free water
N_2	<4 vol%	<4 vol%	not limited[1]	not limited[1]
O_2	<40 ppmv	<40 ppmv	<100 ppmv	<100 ppmv
Ar	< 10 ppmv	< 10 ppmv	not limited	not limited
NH_3	<10 ppmv	<10 ppmv	not limited	not limited
CO	< 10 ppmv	< 10 ppmv	not limited	not limited
Hydrocarbons	<5 vol%	<5 vol%	<5 vol%	<5 vol%
H_2S	<1.3 vol%	<1.3 vol%	<1.3 vol%	<75 vol%
CH_4	<0.8 vol%	<0.8 vol%	<0.8 vol%	<4.0 vol%
H_2	uncertain	uncertain	uncertain	uncertain
SO_2	<40 ppmv	<40 ppmv	<3 vol%	<3 vol%
NOx	uncertain	uncertain	uncertain	uncertain

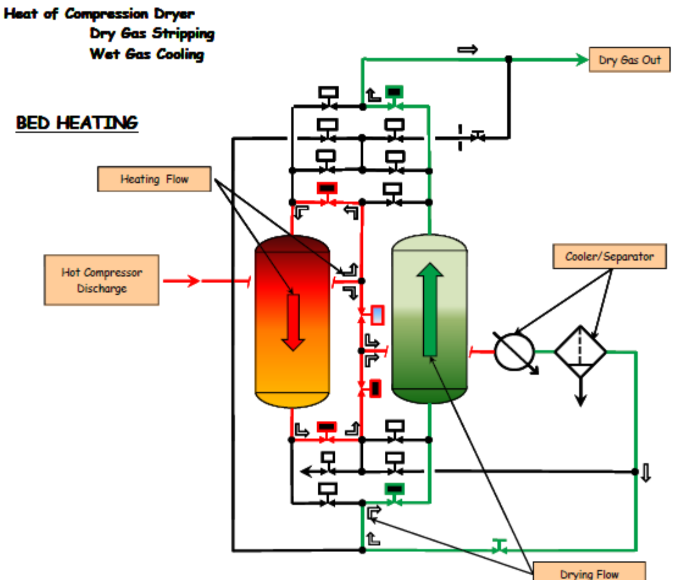


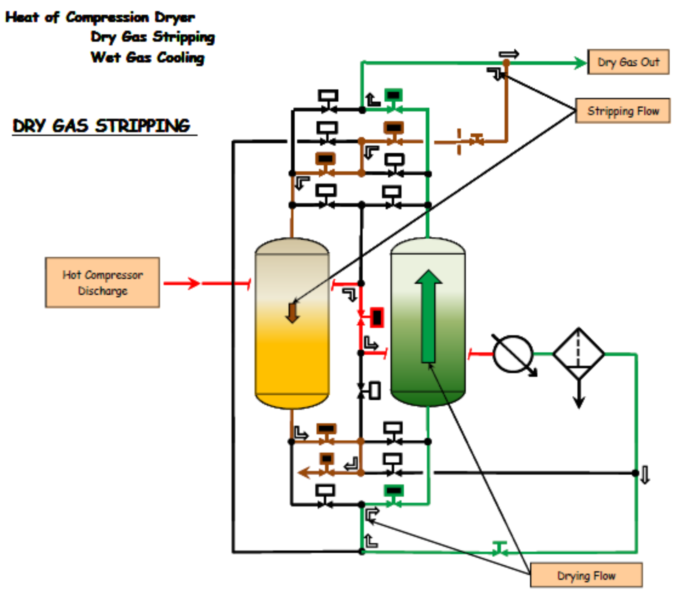
	Current Systems Analysis Guidelines CO_2 Specification	Typical Food Grade CO_2 Specification (Toromont Process Systems)	Kinder Morgan Pipeline Specification For EOR (Kinder Morgan CO_2 Company, 2003)	CO_2 Norway Compressor Specification (CO_2 Norway)	Canyon Reef Project Specification (Doctor and Palmer)	Dakota Gasification Company CO_2 experience (Perry and Eliason, 2005)	Acid Gas Injection experience (Carrol and Maddocks, 1999)
CO_2	----	99.95 vol%	>95 vol%	99.5 wt%	>95.0 vol%	96 wt%	22-90 vol% (water-free basis)
Water	233°K (-40°F) dew point	8 ppmv 8 ppmv	<30 lb/MMcf 628 ppmv	Dew point <-5°C 2697 ppmv	No free water, dew point <-29°C 325 ppmv	0.006 wt% 325 ppmv	No free water
N_2	<300 ppmv	40 ppmv	<4 vol%	0.48 wt%	<4 vol%	0.6 wt%	
O_2	<40 ppmv	9 ppmv	<10 ppmv	<10 ppmv	<10 ppmw	0.03 wt%	
Ar	<10 ppmv	20 ppmv					
NH_3		2 ppmv					
CO		2 ppmv		<10 ppmv			
Hydrocarbons		1 ppmv	<5 vol%	<100 ppmv	<5 vol%	2 wt%	
H_2S		0.5 ppmv	<10 - 200 ppmv		<1500 ppmw	1 wt%	10-77 vol% (water-free basis)
CH_4		30 ppmv				0.3 wt%	0-4 vol% (water-free basis)
NO		2.5 ppmv		<50 ppmv			
NO_2		2.5 ppmv					
SO_2		2 ppmv		<10 ppmv			
volatile hydrocarbons		20 ppmv					Some ethane and propane
Benzene		20 ppbv					
Glycol			<0.3 gal/MMcf				

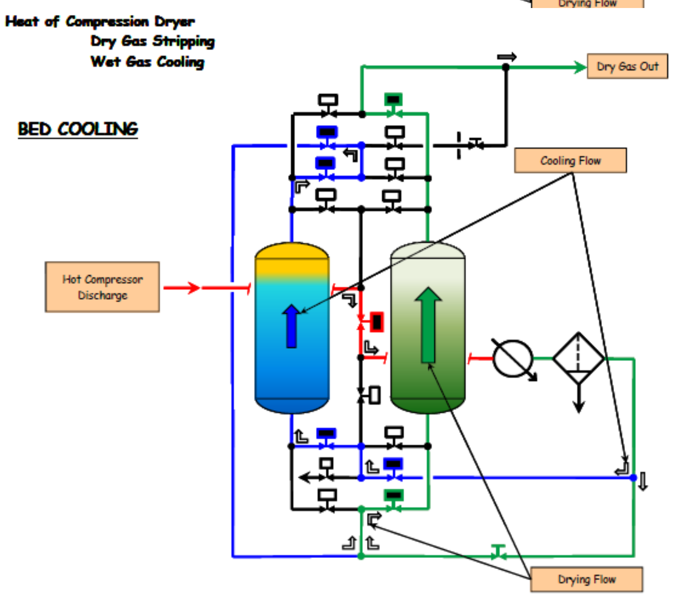
Heat of Compression CO_2 Dryer

SPX Heat of Compression Dryer

- The heat of compression is adequate to provide the desired outlet dew point with no need for addition external regeneration heaters.
- Total gas "consumed" for DGS is less than 4% of the inlet flow and lasts for no more than 1-1/2 hours out of an 18 to 24 hour drying period
- Average CO2 consumption will be less than 0.33% of the process flow.







Reduce CC(C)&S COE Penalty

MAN Turbo CO_2 Compressor

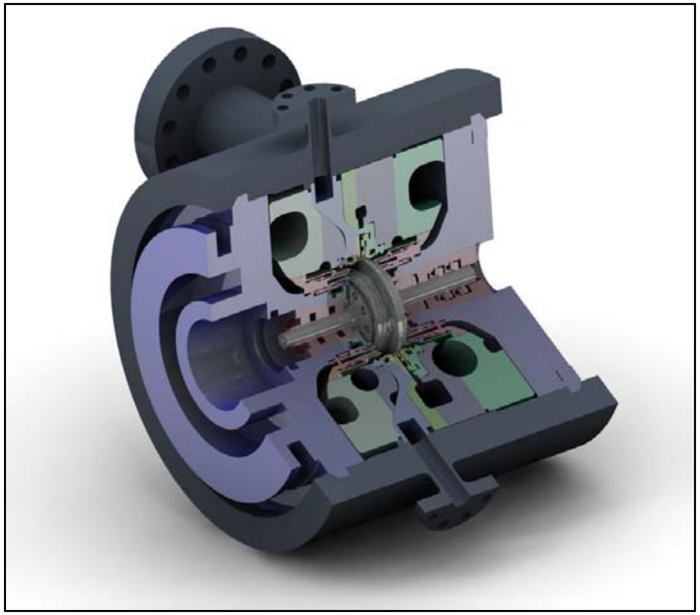
10-stage 6000 hp

- $8.0 million ⇨$1350/hp
- Pr 200:1 ⇨1.70 per stage

8-stage 20,000 hp

- $15.0 million ⇨$750/hp
- $23.0 million installed⇨$1150/hp
- Pr 143:1 ⇨1.86 per stage

Ramgen CO_2 Compressor



Pr 12+:1 per stage; intercooled

1/10th the physical size

40-50% of the installed capital cost

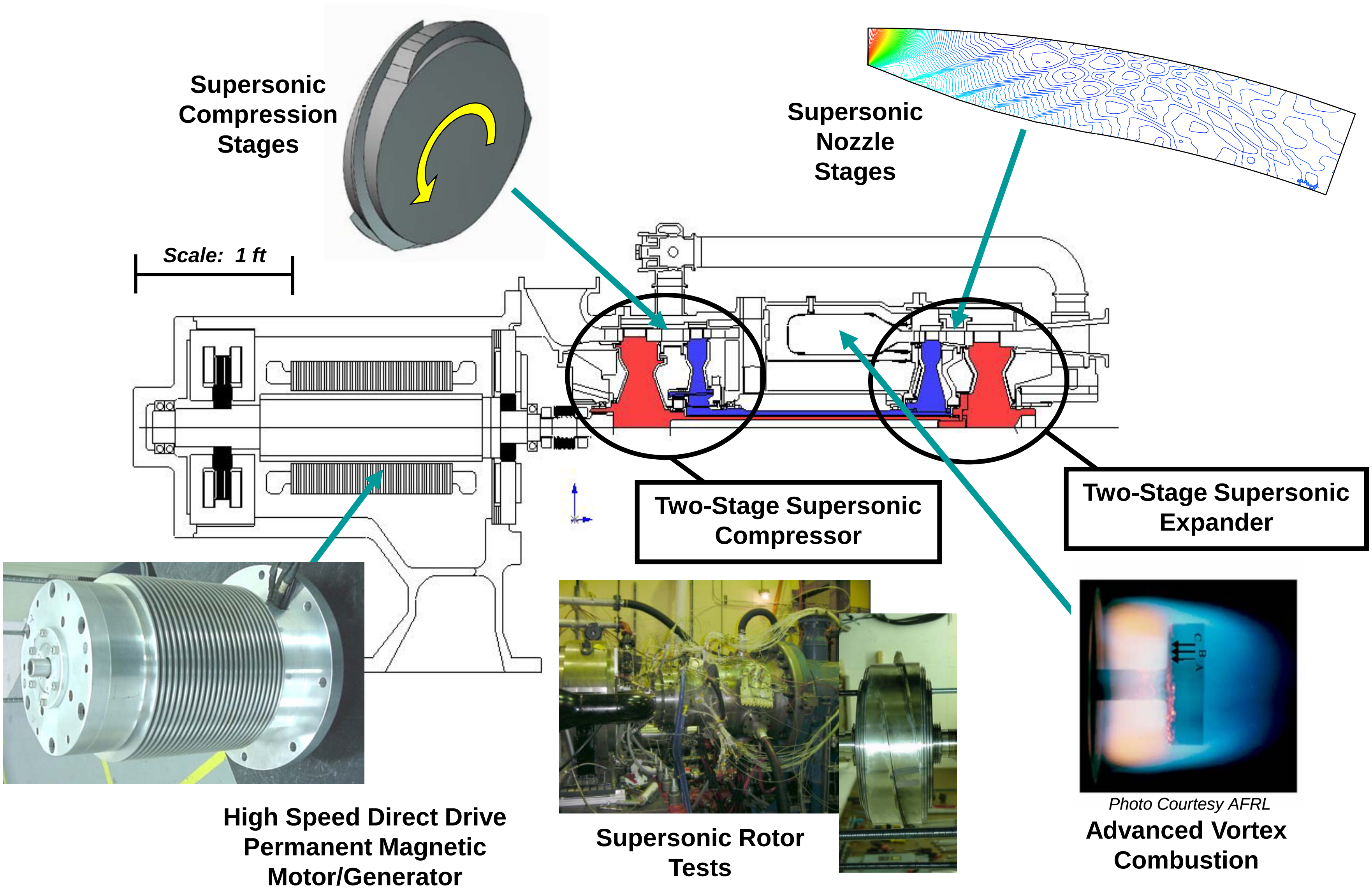
~Same shaft input power requirements

Recover of 80+% of the input Btu at 500°F

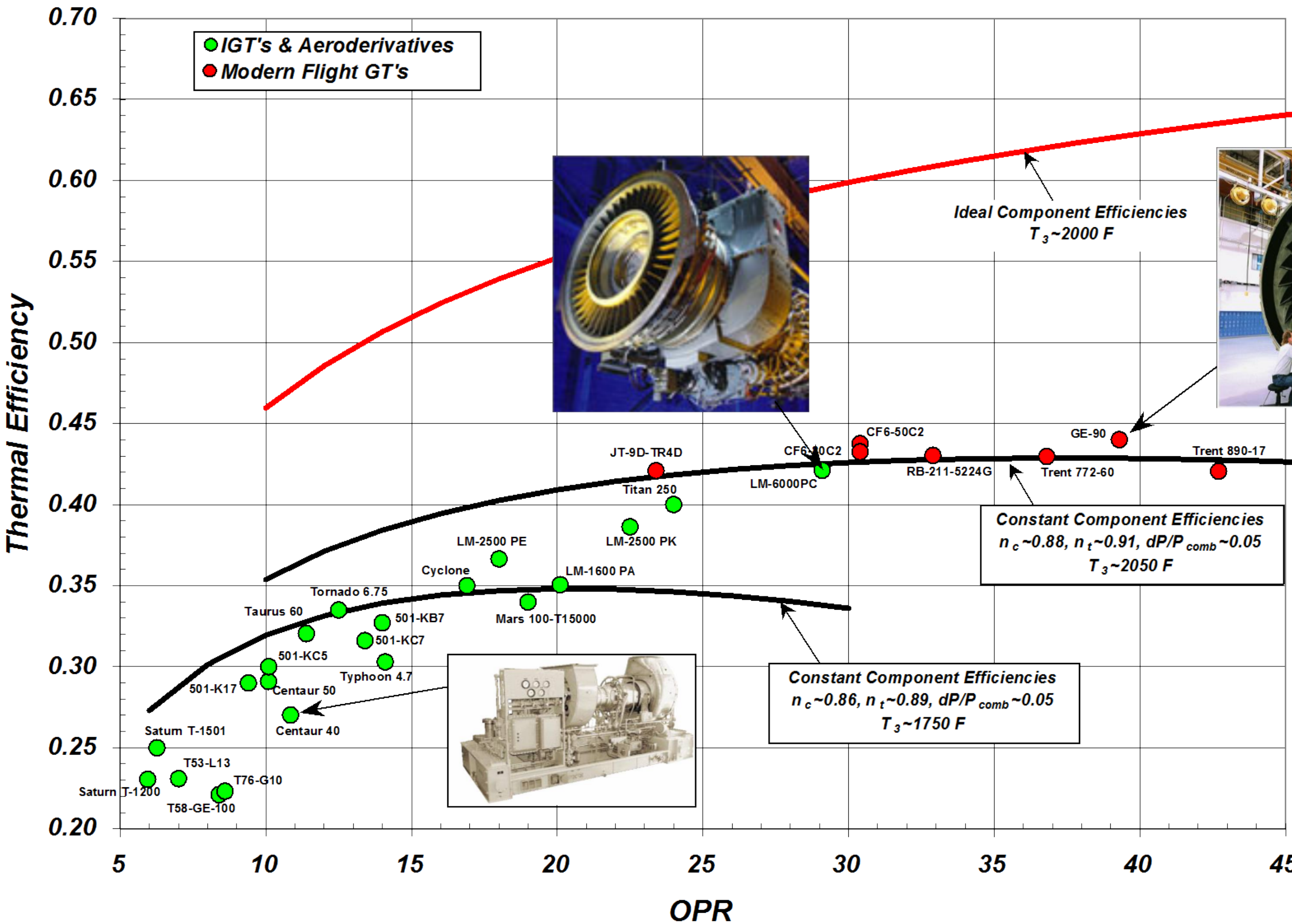
Improve CCS efficiency

Reduce power plant de-rate

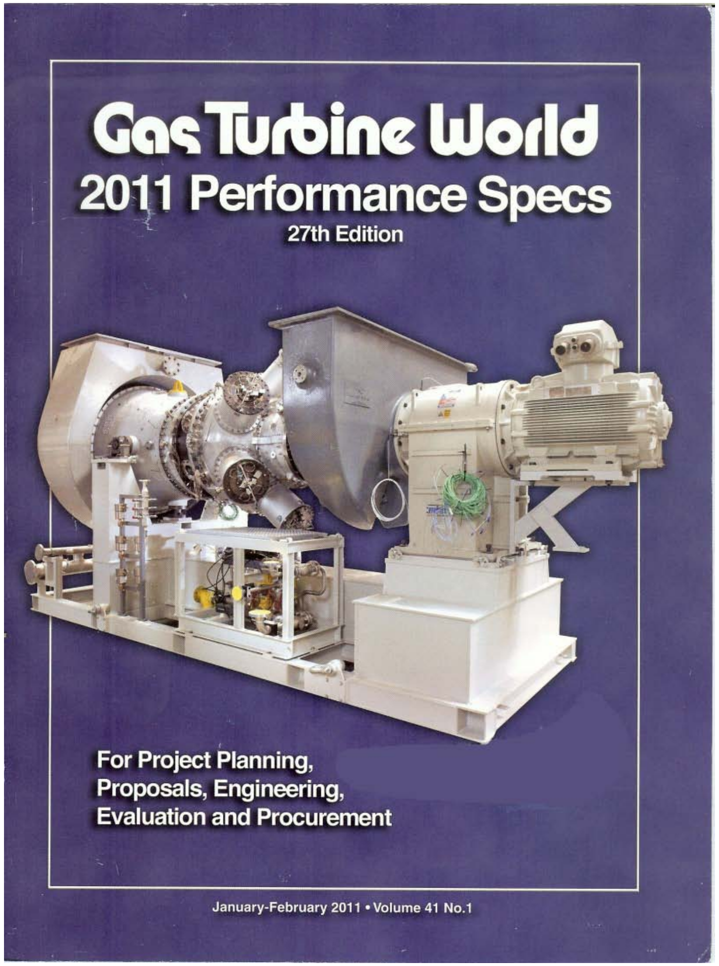
ISCE Technologies



Impact of Component Efficiencies



Recent Industrial GT Product Introductions



MAN Turbo GT6

– 6.9MW - 33.4% shaft

– 6.6MW - 32.0% net electric

Kawasaki GPB17D

– 1.7MW - 26.0% net electric

Ramgen ISC Engine

Improves Distributed Generation efficiency

- 40+% net electric efficiency
- 80% cogeneration efficiency
- >1:1 power to heat ratio

Extracts power from Opportunity Fuels

- Ventilation Air Methane
- Landfill gas
- Eliminates methane emissions
- Improves mine safety
- Compelling return on investment

Enable intermittent renewable resource as a Fuel-fired Flywheel

- “Instant-on” capability supports intermittent/unpredictable renewable resources
- Supports a variety of dual use applications

Enables advanced heat recovery cycles

- Alternative working fluids
- Alternative power cycles

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"Instant-on" Renewables Support

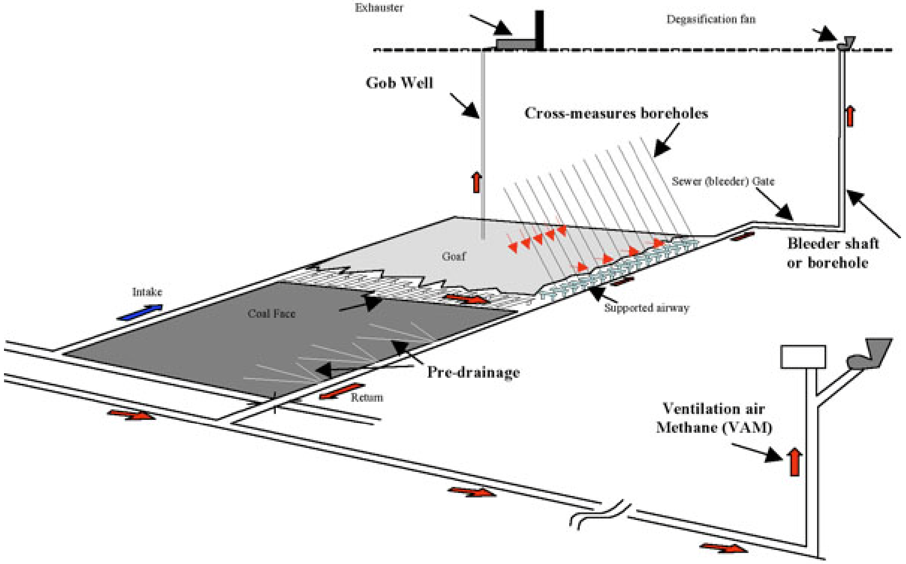
- Conventional GT engines change power output by increasing speed thru fuel addition/subtraction
- There is a 3-7 second "turbo lag" associated with engine spool-up or down
- Secondary, UPS-like, systems are sometimes used to manage these load transitions
- The Ramgen ISC Engine output power changes at constant speed by changing the location of the shock structure in the throat

NO SPEED CHANGE

- Fuel addition/subtraction changes the location of the shock structure
- Changes in power can be accomplished as quickly as fuel can added/subtracted
- The AVC combustion can achieve stable 100% load swings in milliseconds
- The Ramgen ISC Engine can be deployed as a "fuel fired flywheel" in support of renewables for short AND long duration load support, replacing capacitor, battery and flywheel systems.
- The engine also has the potential to provide VAR support when idling

Coal Bed Methane

- Coal bed methane (CBM) is a low methane concentration mixture that can detonate when compressed
- Current practice is to vent CBM to the atmosphere to improve mine safety
- Methane is 23x more potent as a GHG than CO_2



- Shock compression is an instantaneous phenomenon
- The ISC Engine has the potential to ingest this dilute methane/air mixture and compress it BEFORE it detonates, allowing…
- Detonation to occur in the combustor to extract power in the gas turbine

Program Technical Risk Reduction

Utilizing existing Industrial GT combustor and turbine

- Compressor will be retrofit onto existing Industrial GT with power output consistent with testing at Ramgen facility in Redmond
- Avoids design and check-out of these proven components
- Accelerates demonstration and validation of compressor performance
- Program risk and cost reduction

Saturn T1200 selected

- PR = 6:1
- Airflow = 13 pps
- Power Output = 1,141 hp (850 kW)

Potential Performance

- for 1,500 kW at PR~12:1 with Proven AVC Combustor Characteristics in 40+% thermal efficiency Range

System Retains All Capabilities Originally Proposed

- Rapid Load Following
- Ability to Burn Low Pressure Dilute Fuels

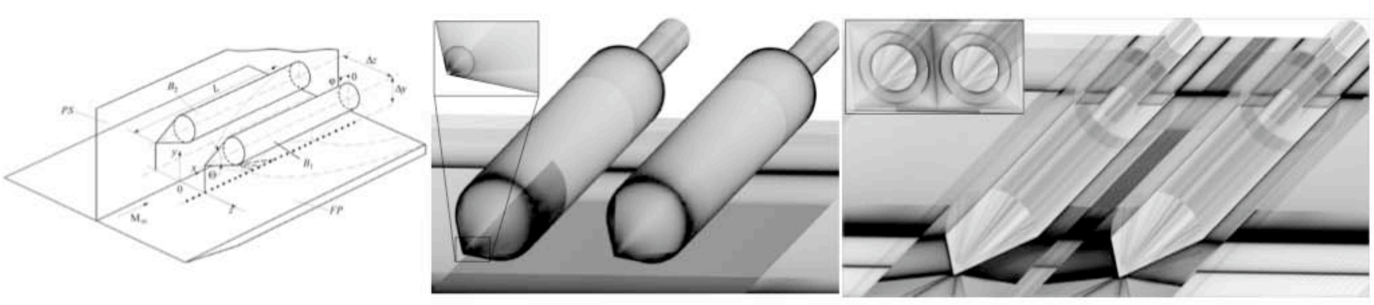
Goal to be demonstrating in October 2011

Manufacturing Development

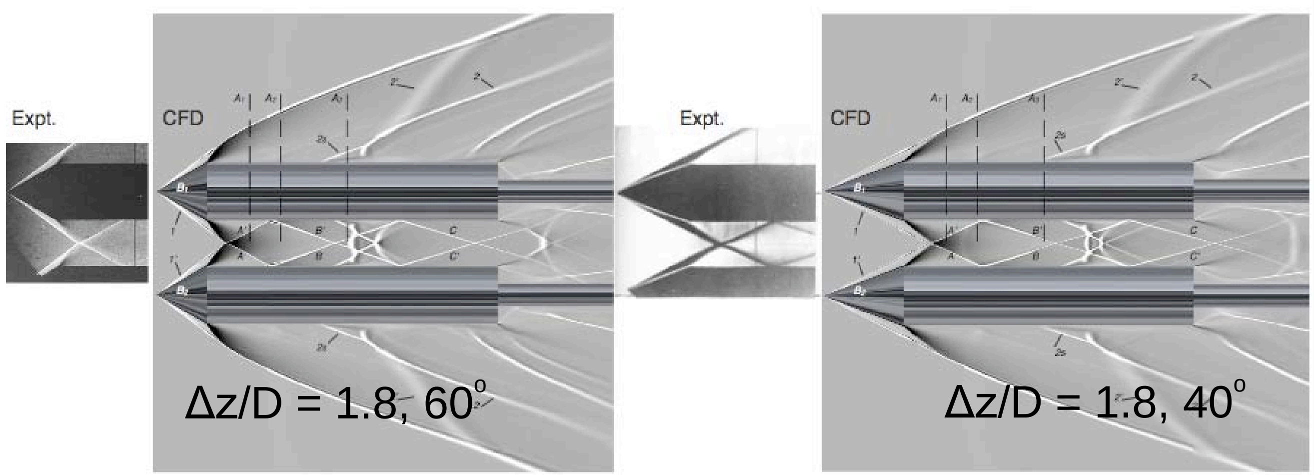
Design for Manufacturing activities to reduce cost and improve quality

- Powdered Metal HIP formation of rotors with small structures and passages
- Over the horizon machining techniques for long narrow passages
- High temperature composite ring manufacturing and performance in the presence of high temperature CO_2
- High stress e-beam welding
- ECM techniques for long narrow passages

CFD Development at Oak Ridge National Labs

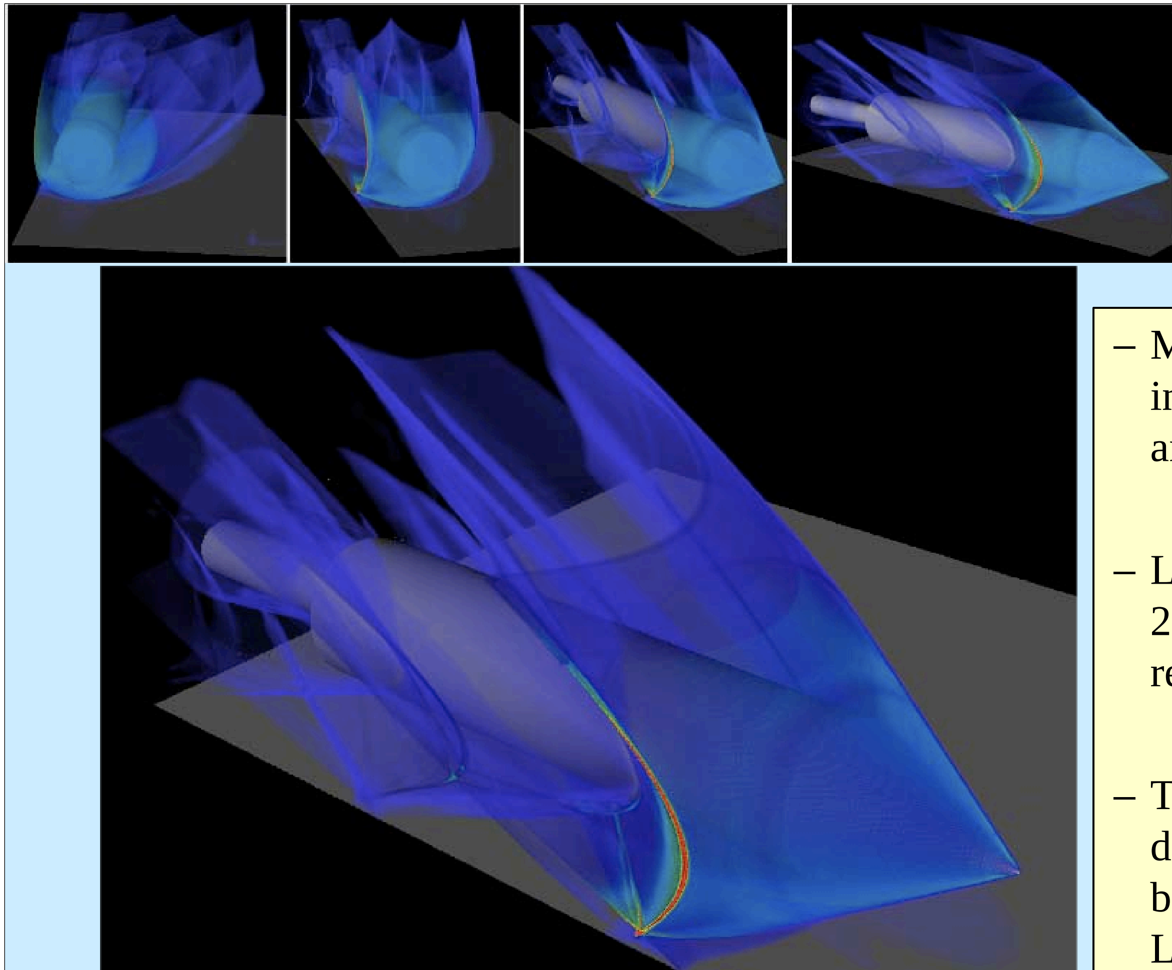


Aero CFD Tool development has benefitted greatly from Oak Ridge National Laboratory Supercomputer work to optimize the codes Ramgen depends on to generate and analyze shock wave structures and interactions



Geometry, Grid & Predicted Shock Comparisons

One Billion Grid Cell Crossing Shock Structures



- Major improvements have been made in parallel performance in the last year and a half.

  32-64 ⇒ 1000 processors

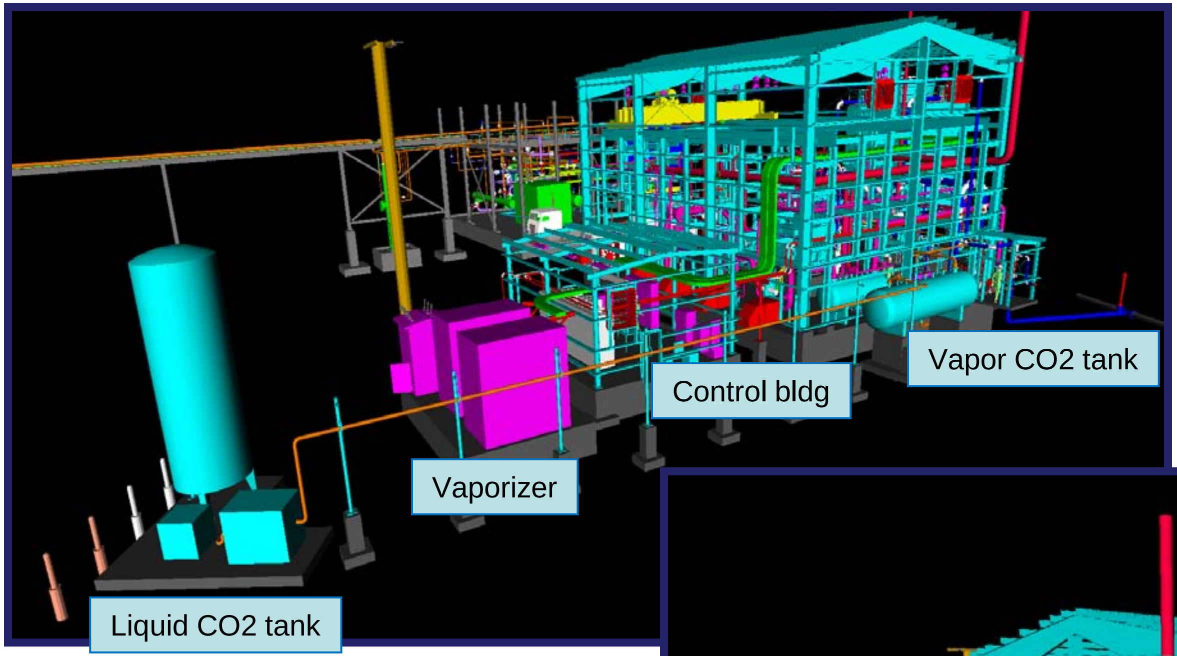
- Latest improvements as of summer 2011 have been a speed up in read/write file I/O performance

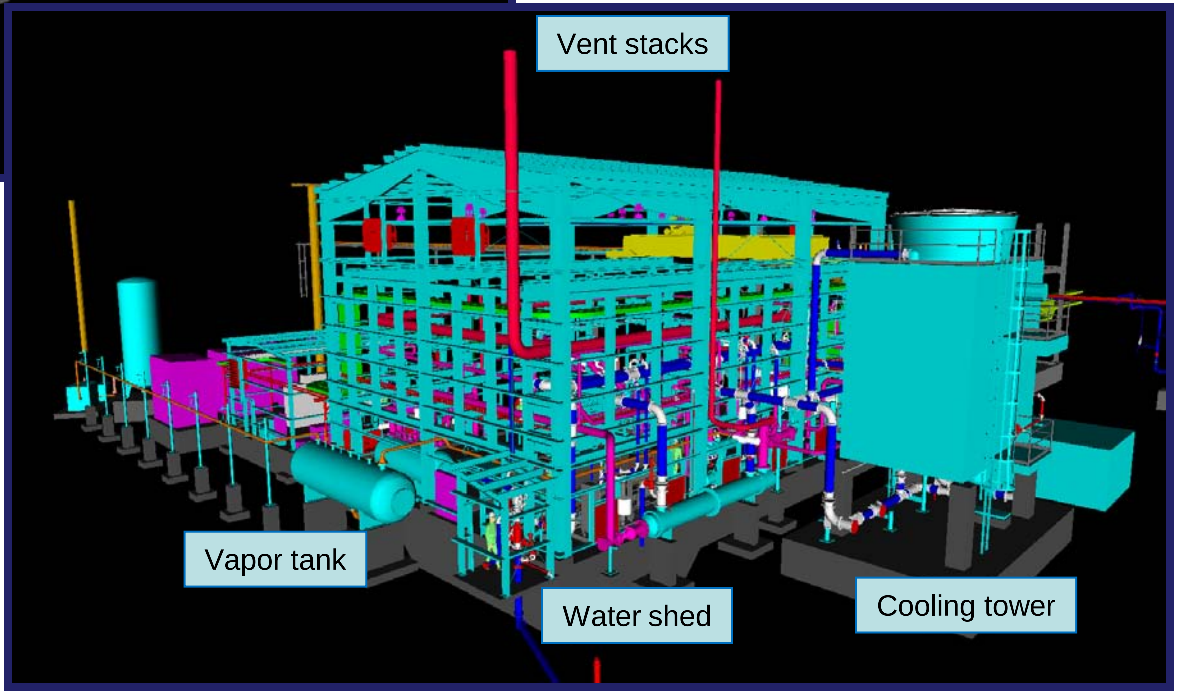
  5x to 7x faster

- These performance improvements have directly accelerated our computations both in-house, as well as on Oak Ridge Leadership Computing Facility system.

3D Volume rendering of shock systems is a technique we have gained expertise in, as a direct result of the HPC project at Oak Ridge National Laboratory.

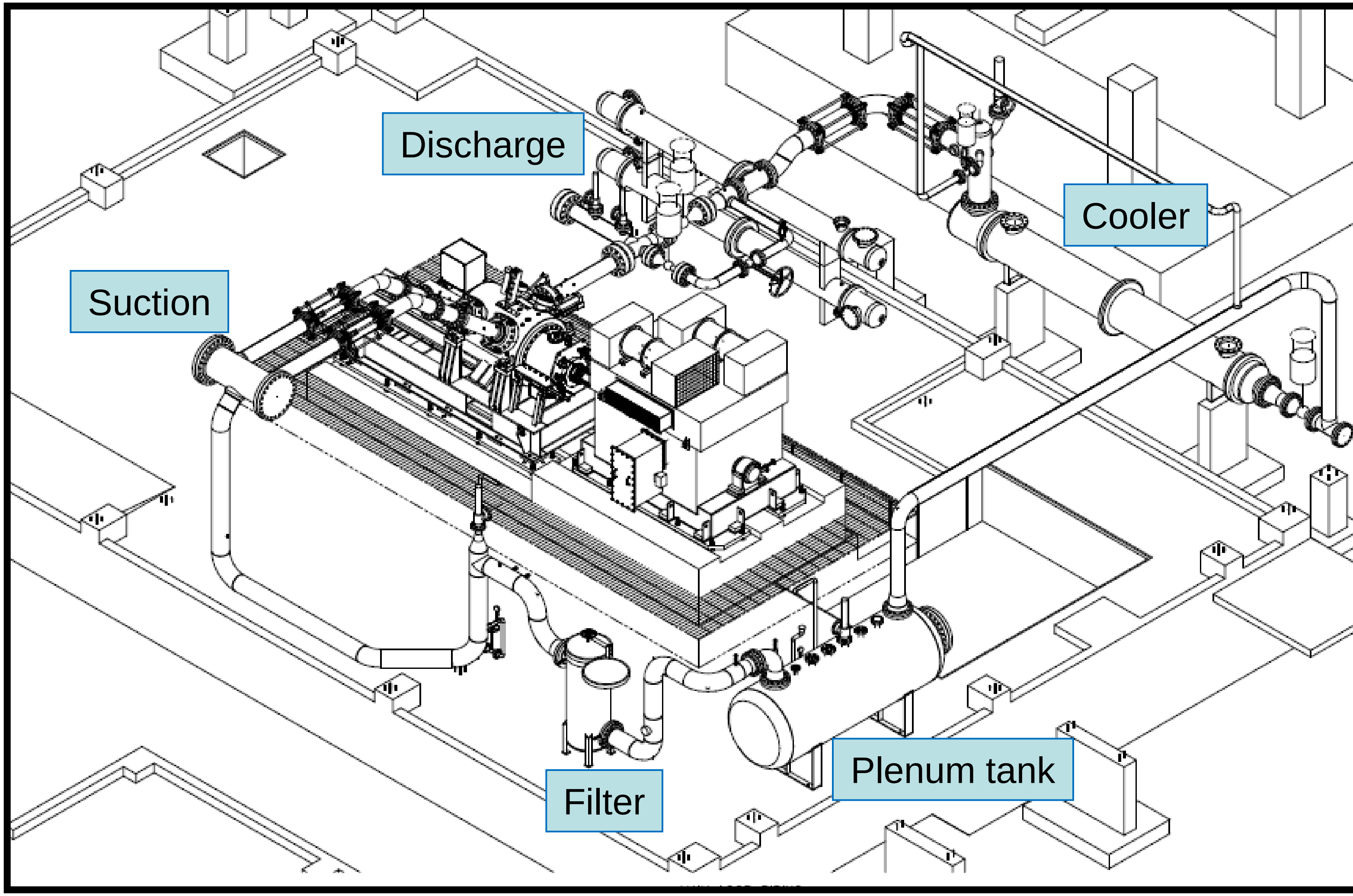
High Pressure CO2 Compressor Facility



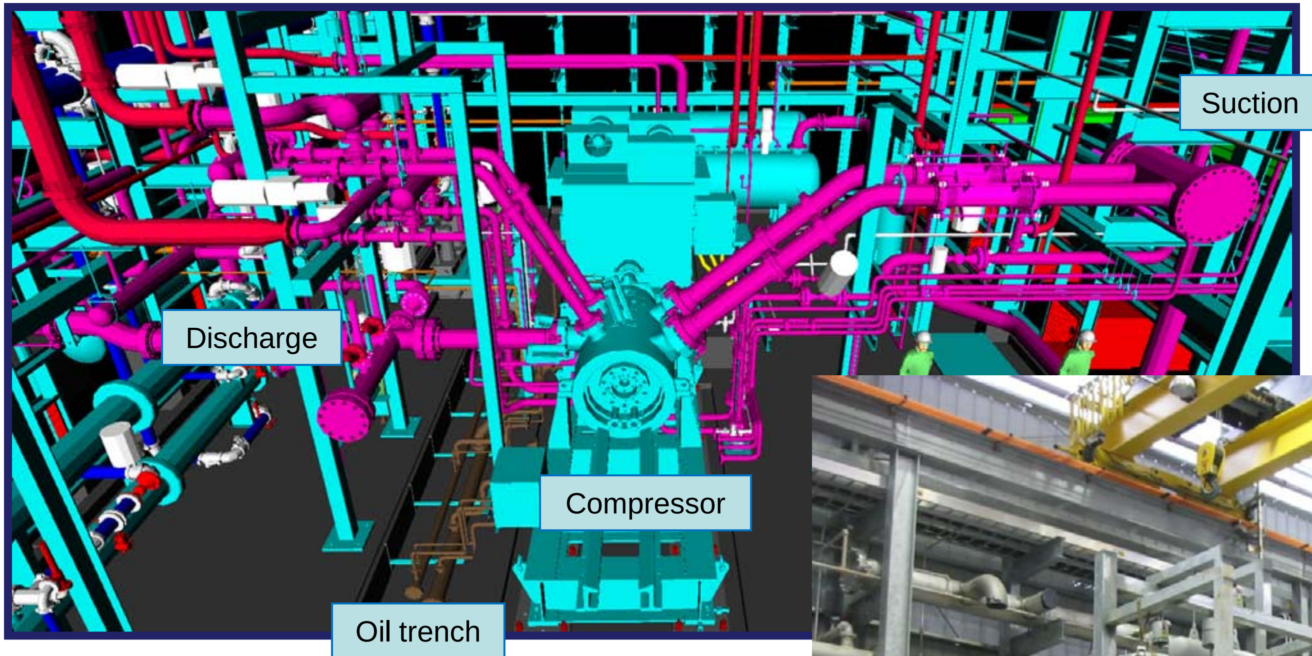


High Pressure CO2 Compressor Facility

High Pressure CO_2 Compressor Facility



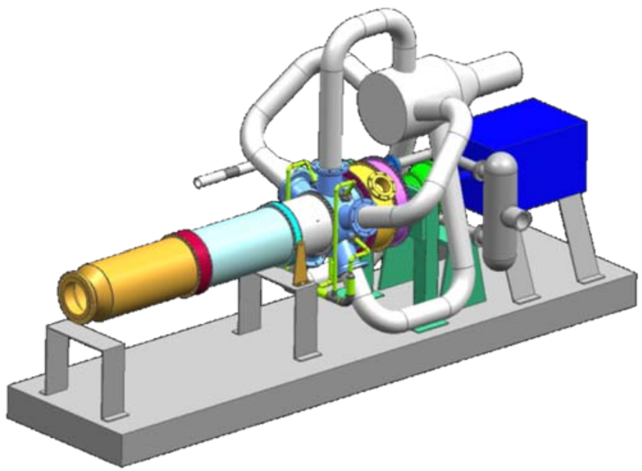
10MW HP CO_2 Compressor Test Stand

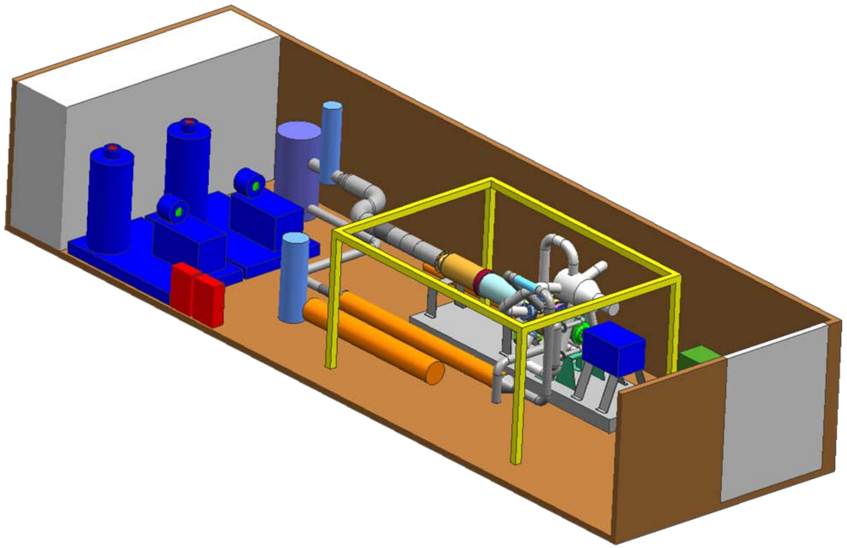


- –Dresser-Rand Facility, Olean, NY
- –10MW
- –Closed loop CO2
- –Variable speed drive
- –P1 = 220 psia
- –P2 = 2200 psia

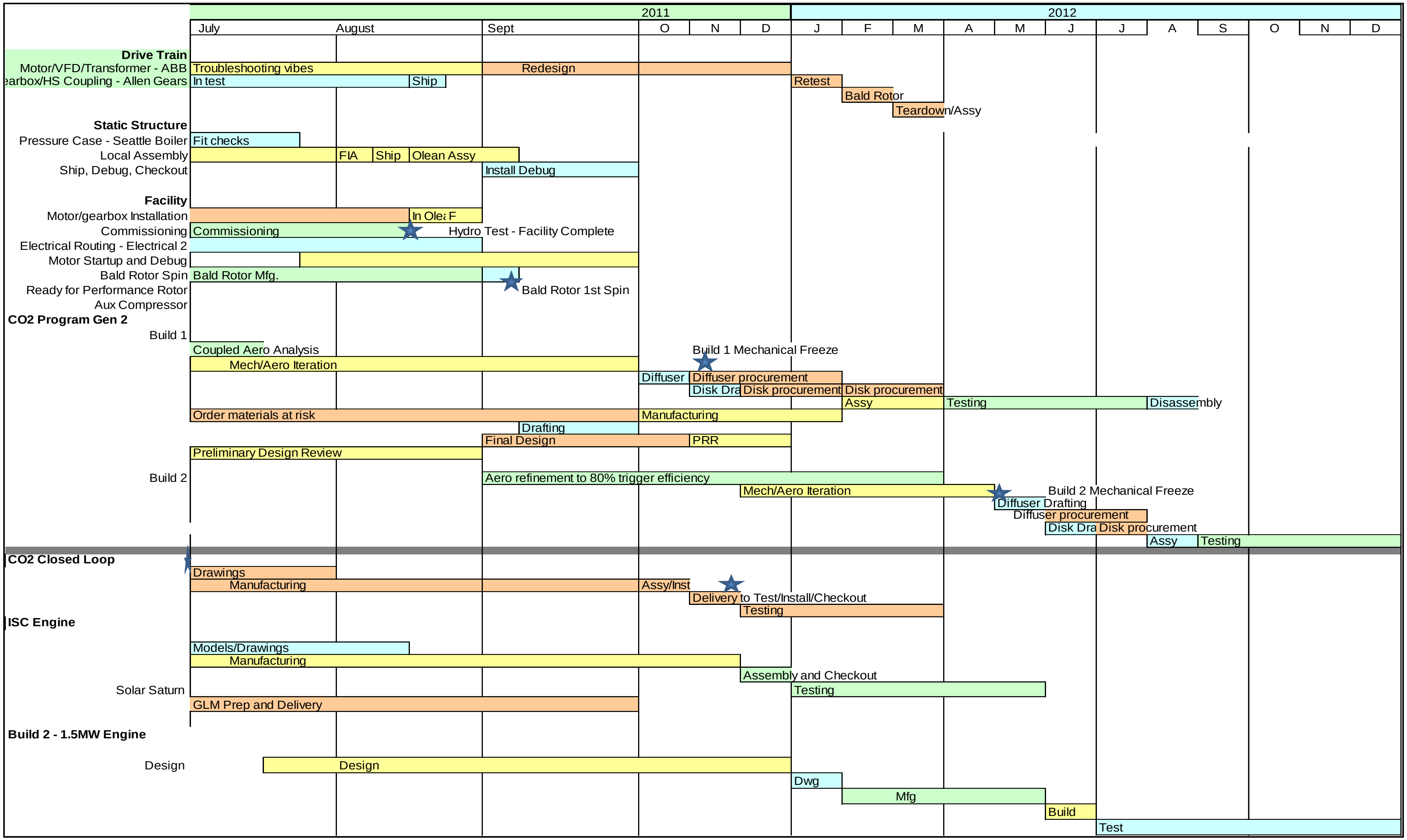
Multi-Gas Compressor Test Cell

- **Ramgen Facility – Redmond, WA**
- **1.0 MW closed loop CO_2 Compressor test rig**
  - LP Stage
  - Pr 10:1
  - Variable speed electric drive
- **1.0 MW Air Compressor stage test rig**
  - Saturn power turbine drive
- **Initial testing scheduled for Nov 2011**
- **Modular aero design configured for rapid configuration changes**
  - CFD validation
  - Product scaling studies





Progress & Current Status



Test Schedule

Demo of CO2 Compressor

- Bald Rotor – September 30, 2011
- Build 1 - April 1, 2012 to July 31, 2012
- Build 2 – September 1, 2012 to December 31, 2012
- Test schedule being affected by motor/bearing vibration problems
- Suppliers are pushing deliveries out on critical path components
- Ramgen using schedule slippage to continue aero improvement efforts
- CO2 Demo is 12 months behind schedule

Closed Loop LP CO2 Compressor

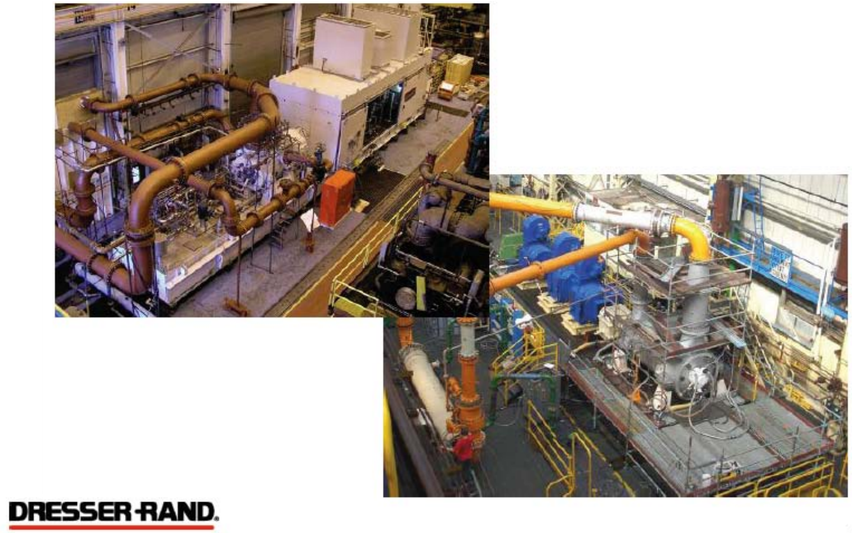
- December 1, 2011 to March 31, 2012

ISC Engine

- 1.5 MW Build 1 – January 1, 2012 to May 31, 2012
- 1.5MW Build 2 – July 1, 2012 to December 31, 2012
- 5.0MW Build 3 – 2013
- ISC Engine is 9 months ahead of schedule

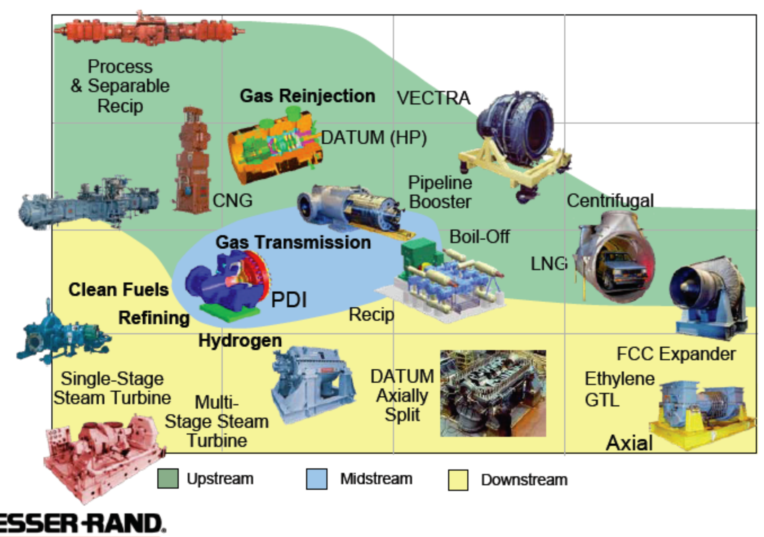
Commercialization w/by Dresser-Rand

RAMGEN POWER SYSTEMS™



DRESSER-RAND.

Note: Partial list as of December 2007.

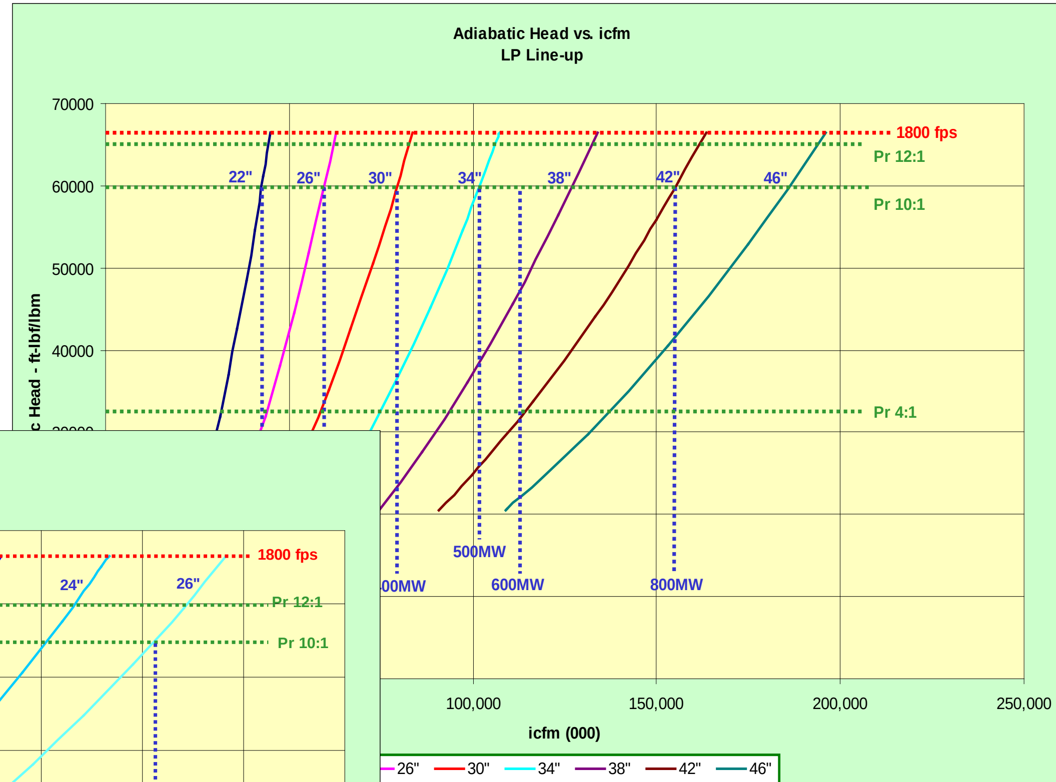


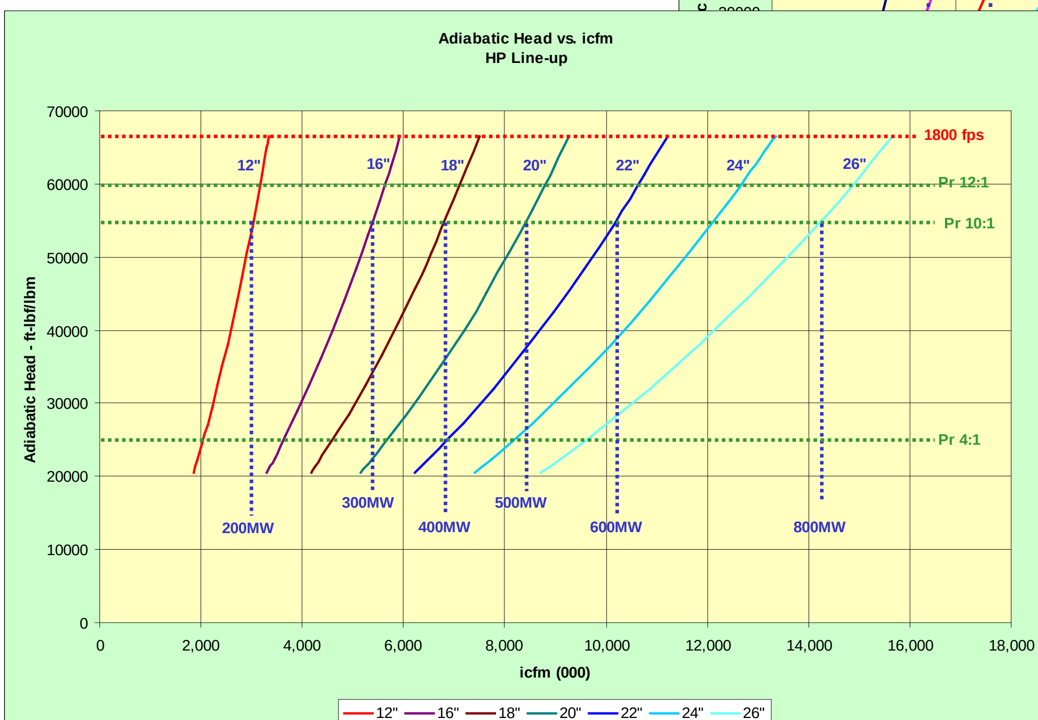
Compressor Commercial Scale-up

RAMGEN POWER SYSTEMS™

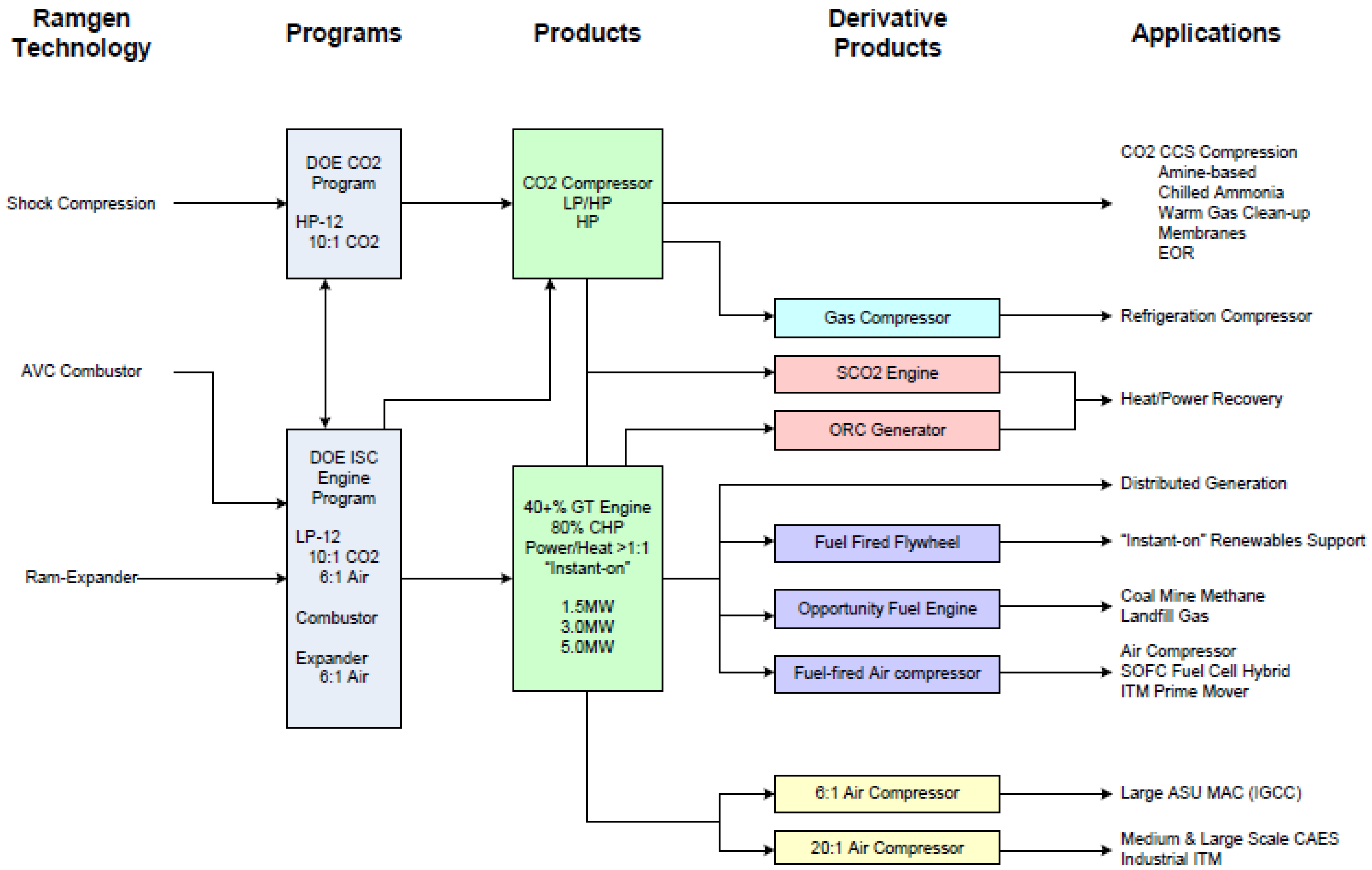
Productization

- Aero scaling & prediction
- Design for manufacturing
- Design for cost
- Packaging
- Materials & option list





Technology Development Roadmap



Ramgen Power Systems

Pete Baldwin

President

pete_baldwin@ramgen.com

+1-425-736-7272