McIntosh Unit 4 PCFB Demonstration Project

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Introduction

The City of Lakeland, Foster Wheeler Corporation and Westinghouse Electric Corporation have embarked on a utility scale demonstration of Pressurized Circulating Fluidized Bed (PCFB) technology at Lakeland's McIntosh Power Station in Lakeland, Florida. The U.S. Department of Energy will be providing approximately $195 million of funding for the project through two Cooperative Agreements under the auspices of the Clean Coal Technology Program. The project will involve the commercial demonstration of FOSTER WHEELER PYROFLOW® PCFB technology integrated with Westinghouse's Hot Gas Filter (HGF) and power generation technologies.

The total project duration will be approximately eight years and will be structured into three separate phases; two years of design and permitting, followed by an initial period of two years of fabrication and construction and concluding with a four year demonstration (commercial operation) period. It is expected that the project will show that Foster Wheeler's Pyroflow PCFB technology coupled with Westinghouse's HGF and power generation technologies represents a cost effective, high efficiency, low emissions means of adding greenfield generation capacity and that this same technology is also well suited for repowering applications.

Background

The City of Lakeland, Department of Electric & Water Utilities (Lakeland) is a municipally owned and operated electric and water utility in Central Florida. Lakeland is conveniently located between Tampa and Orlando which has allowed Lakeland to grow and prosper over its 92 year history. Lakeland is the third largest municipal utility in the State of Florida serving more than 104,000 electric customers and also has residential rates that are currently the second lowest of all Florida utilities. Despite enjoying low electric rates and steady load growth, Lakeland is not immune to competition. Competition is driving all utilities to find ways not only to prevent cost growth but to also lower costs. A heightened awareness of the environment by the general public and Lakeland's customers is also maintaining the pressure for "clean" electric generation. Traditionally these two goals have not been complimentary in that environmental compliance normally has meant an increase in generation costs to achieve that compliance. This raises the question each utility must soon face: how to provide new generating capacity, needed for growth and replacement of retired capacity, at a competitive cost while meeting stringent environmental requirements.

Lakeland has experienced and is forecasting steady load growth within its municipal system of approximately 15 MW per year which will result in a capacity shortfall in the year 2000 of approximately 45 MW. In addition to the pending capacity shortfall, Lakeland wishes to retire 50 MW of very old and inefficient existing generating capacity. Considering both of these issues and future needs, Lakeland needs to bring on line at least 150 MW of additional generating capacity by the year 2000.

In today's competitive environment, the prospects of adding additional capacity in itself can bring many uncertainties. With the majority of Lakeland's capacity already tied to one fuel that has greater uncertainties in such areas as price and availability, the need to add more capacity led Lakeland to look closely once again at America's most abundant fuel source, coal. Lakeland's current mix of resources include approximately 200 MW of base load pulverized coal and 450 MW of intermediate/peaking gas capacity. This capacity is divided between two power stations that Lakeland owns which are located within the city limits on the shores of Lake Parker. The larger of the two power stations is the McIntosh station on the north side of Lake Parker with approximately 590 MW[1] of generating capacity while the smaller Larsen station on the south side of the lake has about 230 MW of generating capacity.

Lakeland was a pioneer of sorts when the 334 MW McIntosh 3 unit went on-line in 1982. The unit was one of the first "scrubbed", zero-discharge coal units in the nation. Today, Lakeland is looking to be a pioneer again by partnering with Foster Wheeler Corporation and Westinghouse Electric Corporation to build and operate a utility scale demonstration of PCFB technology (unit 4) at Lakeland's McIntosh Plant site. The addition of McIntosh unit 4 will provide Lakeland with new, cost competitive and environmentally clean coal based capacity for the 21st Century. The added capacity that this unit will provide will not only add to Lakeland's fuel diversity, but will provide energy at some of the lowest costs per megawatt hour of any generating source in the Southeast. These factors combined with the state of the art pollution controls provided by the Foster Wheeler PCFB process and the Westinghouse HGF technology will ensure that McIntosh unit 4 will keep Lakeland very competitive and environmentally acceptable well into the future. The successful construction and operation of this technology will provide utilities with a means of adding needed generating capacity in a manner that is consistent with the competitive and environmental challenges that all are facing.

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[1] McIntosh Unit 3 is a 334 MW pulverized coal unit that is jointly owned by Lakeland and the Orlando Utilities Commission.

Project Structure

The proposed McIntosh Unit 4 PCFB Demonstration Project would be constructed as two sequential demonstrations that would demonstrate both PCFB and Topped PCFB technology. There are two primary reasons for this proposed project structure:

(i) The DOE funding being provided for the project results from a combination of two previous Clean Coal awards: the DMEC-1 PCFB Repowering Project (DMEC-1) selected under Round III and the Four Rivers Energy Modernization Project (FREMP) selected under Round V. The DMEC-1 project was intended to demonstrate PCFB technology while the FREMP project was planning to demonstrate Topped PCFB technology. By utilizing a sequential approach with the McIntosh Unit 4 PCFB project, it will be possible to demonstrate both PCFB (1st Demonstraton) and Topped PCFB (2nd Demonstration) technology in the same project, thereby satisfying the objectives of both the DMEC and FREMP projects.

(ii) Additional development work is required on certain components of the Topped PCFB cycle prior to the construction of the same components at a commercial scale. Specifically, additional development is required for the Westinghouse topping combustor (multi-annular-swirl-burner or MASB) including the demonstration of MASB operation at low outlet oxygen levels. Important aspects of Westinghouse's MASB development work have been and will be conducted at the University of Tennessee Space Institute. Some additional development work may also be performed for other components of the carbonizer system. Development on the carbonizer system has been performed at Foster Wheeler's John Blizzard Research Center in Livingston, New Jersey. Both of these systems are incorporated in the Wilsonville Power Systems Development Facility (PSDF) facility at a Southern Company operated site in Wilsonville, Alabama that will shortly be starting operation. The combination of the above programs is expected to provide Westinghouse and Foster Wheeler with the necessary information required to finalize the design of the carbonizer and MASB's in time to support the demonstration of Topped PCFB technology.

The project schedule (discussed in more detail below) anticipates the start of commercial operation of the 1st Demonstration in the winter of the year 2000. In parallel with the first two years of operation of the 1st Demonstration will be the design, fabrication and construction of the 2nd Demonstration culminating in a planned start of operation of late 2002 for the combined facility.

Project Objectives

Through the sequential demonstration of both PCFB and Topped PCFB technology it has been possible to preserve the objectives of both the original Cooperative Agreements described in the preceding section. The objectives governing the agreement relating to PCFB technology include the demonstration of PCFB technology to provide for the potential commercialization of the technology in the 21st century and to provide the capability of achieving significant reductions in the emissions of sulfur oxide and nitrogen oxides from existing facilities when they are repowered with PCFB technology.

The objectives for the agreement relating to Topped PCFB technology call for the demonstration of the technology in a "fully commercial power generation setting" which is certainly the case at the McIntosh site as is further explained below. All the key components of the Topped PCFB technology will be demonstrated thereby paving the way for future plants that will operate at higher gas turbine inlet temperatures and that are expected to provide cycle efficiencies in excess of 45%. Additional objectives relating to the Topped PCFB technology that will be proven through a successful demonstration include reductions in sulfur oxide emissions of as much as 95% and nitrogen oxide emissions as low as 0.17 lb/MMBTU of heat input.

Process Description

PCFB technology is a combined cycle power generation system that is based on the pressurized combustion of solid fuel to generate steam in a conventional Rankine cycle combined with the expansion of hot pressurized flue gas through a gas turbine in a Brayton cycle. The technology can be subdivided into the basic PCFB cycle ("First Generation") and Topped PCFB cycle ("2nd Generation" or "Advanced PCFB"). In the PCFB cycle, hot pressurized flue gas is expanded through the gas turbine at a temperature of less than 1650°F. Topped PCFB cycles include a coal carbonizer (mild gasifier) to generate a low BTU fuel gas which is used to fire the inlet of the gas turbine (in a topping combustor or MASB) and increase the gas turbine inlet temperature from a less than 1650°F up to 1900° - 2300°F or higher. Both versions of PCFB technology offer high cycle efficiencies and ultra low emissions. More detailed descriptions of the PCFB and Topped PCFB cycles are provided below.

Figure 1 presents a simplified schematic of the 1st Demonstration of the McIntosh Unit 4 PCFB Demonstration Project incorporating a PCFB cycle. Combustion air is supplied from the compressor section of the gas turbine to the PCFB combustor located inside a pressure vessel. Coal and limestone are mixed with water into a paste which is pumped into the combustion chamber using piston pumps commonly used in the concrete industry. The same type of pumps have been successfully proven in a number of pressurized fluidized bed combustion (PFBC) coal projects around the world.

Combustion takes place at a temperature of approximately 1560° - 1600°F and at a pressure of about 200 psig. The resulting flue gas and fly ash leaving the cyclone enter the hot gas filters where dust removal takes place. The hot gas filters are a Westinghouse design based closely on the filter supplied to the Sierra Pacific Piñon Pine project in Tracy, Nevada. In addition to the Piñon Pine project, a Westinghouse filter has undergone approximately 6000 hours of testing at Ohio Power's Tidd PFBC Demonstration facility in Brilliant, Ohio (Round I project). A full scale commercial module of this type of ceramic candle filter has also undergone more than 6000 hours of extensive testing at Foster Wheeler's PCFB test facility in Karhula, Finland.

The hot clean gas leaving the filter is expanded through the gas turbine before passing through a heat recovery unit and entering the stack. Heat recovered from the cycle from both the combustor and the heat recovery unit is used to generate steam to power a reheat steam turbine. Approximately 15% of the gross power output is derived from the gas turbine with the steam turbine contributing the remaining 85%.

The gas turbine technology is based on a standard Westinghouse 251B12, single shaft, cold end drive industrial machine that has had the center section of the turbine modified. A scroll section has been added to allow for the removal of compressor discharge air from the casing for external firing in the PCFB combustor and to allow for the introduction of hot clean gas back through the casing into the expander section. This air outlet/gas inlet configuration has been previously applied in recuperative gas turbine cycles. The gas inlet temperature of less than 1650°F allows for a simplified turbine shaft and blade cooling system. This combined with low excess air operation in the PCFB combustor provides a maximum amount of steam generation per unit mass of air from the gas turbine and therefore maximizes power output from the cycle.

Figure 2 shows the process flow arrangement of the 2nd Demonstration of the McIntosh Unit 4 PCFB Demonstration Project. This involves the addition of a carbonizer island which includes a topping combustor (MASB) to convert the PCFB cycle to a Topped PCFB cycle. Through the addition of this equipment, the inlet temperature to the gas turbine is increased via the combustion of coal derived "syngas". This has the effect of increasing the cycle power output while simultaneously improving the net plant heat rate. Natural gas can also be used as the topping fuel thereby providing a backup to the operation of the carbonizer island.

In the top right hand corner of Figure 2, the carbonizer island is shown. Dried coal and limestone are fed via a lock hopper system to the carbonizer together with part of the gas turbine compressor discharge air. The coal is partially gasified or carbonized at about 1700°F to produce a syngas and char solids stream. The limestone is used to absorb sulfur compounds generated during the mild gasification process and to catalyze the gasification process. After cooling the syngas to about 1200°F, the char and limestone entrained with the syngas are removed by a Westinghouse hot gas filter. The char and limestone are transferred to the PCFB combustor for complete carbon combustion and limestone utilization. The hot clean filtered syngas is then fired in a topping combustor (MASB) to raise the turbine inlet temperature to almost 2000°F. The gas is expanded through the turbine, cooled in a heat recovery unit and exhausted to the stack. As in the case of the previous cycle, combustion air is supplied to the PCFB combustor from the compressor section of the gas turbine. Coal and limestone are again fed to the PCFB combustor in paste form but are supplemented by the char transferred from the carbonizer as discussed above.

Performance

The First Demonstration would involve a basic PCFB cycle that would come on line in the year 2000 and would provide approximately 157 MW of coal-fired generating capacity. The cycle would have a gas turbine inlet temperature of approximately 1550°F. Following the completion of some additional development work, the Second Demonstration of the project would be constructed and brought on line approximately two years later. This would entail the conversion of the 1st Demonstration PCFB system to a Topped PCFB system through the addition of a carbonizer island and a topping combustor. The addition of the carbonizer system would generate a coal derived, low BTU synthesis gas that would be fired at the inlet of the gas turbine to raise the turbine inlet temperature to approximately 1975°F. The net impact of this equipment addition would be an additional 12 MW of power output with an associated improvement in heat rate of about 600 BTU/kWhr for the entire plant.

The project would be constructed as McIntosh Unit 4 within the boundaries of existing station on land owned by the city. The new unit will be designed to burn a range of coals including both the current Eastern Kentucky coal burned in unit 3 and high ash, high sulfur coals that are expected to be available in the future at substantially lower prices than mid to low sulfur bituminous coals. Limestone would be sourced from a number of nearby Florida limestone quarries while ash would be disposed of in a landfill or marketed to others.

The majority of the project's water makeup requirements will be met using secondary treated sewage effluent for cooling tower makeup while the use of sewage "sludge" (3 - 4% solids) is being considered for preparation of the coal-water paste mixture that is pumped into the PCFB. Service water will be used only for boiler water makeup feed to the demineralizer system. Wastewater from the unit will be treated on site for neutralization and removal of heavy metals before being returned to the Glendale waste water treatment facility (owned by Lakeland) for discharge. Gaseous emissions from the plant will be controlled using state of the art technology and will be representative of recent best available control technology (BACT) determinations in Florida.

Project Schedule

The City of Lakeland wishes to have the 1st Demonstration plant enter commercial operation during the winter of the year 2000. Prior to commencing fabrication and construction (Phase 2) of the new facility, the permitting and licensing process required by the state of Florida must be completed. In addition, DOE requires that the National Environmental Policy Act (NEPA) process be completed prior to DOE providing any funds for the purpose of fabricating and constructing the facility.

The NEPA and permitting/licensing processes are each expected to take 20 months to complete and are parallel critical path activities dictating the duration of Phase 1 of the project. At the time of writing, Phase 1 was expected to begin around December 1, 1996 following the formal execution of the Cooperative Agreements by Lakeland and DOE. Phase 2 begins with the general release for fabrication and construction for the 1st Demonstration and lasts for a total of 53 months. Phase 3 has an overall duration of 48 months. The first 29 months of Phase 2 cover the period from the end of Phase 1 through to the start of Phase 3 during which the 1st Demonstration facility is fabricated and constructed. The second 24 months of Phase 2 overlap with Phase 3 and cover the time required to design, engineer, fabricate and construct the 2nd Demonstration equipment.

Phase 3 will be structured in two segments: an initial two year period while the PCFB technology of the 1st Demonstration is demonstrated, and a subsequent two year period during which the Topped PCFB technology of the 2nd Demonstration will be operated. The additional equipment required for the 2nd Demonstration will be engineered, procured and constructed in parallel with the operation of the 1st Demonstration during the first two years of Phase 3. All efforts will be made to minimize the amount of downtime of the facility required to connect the 2nd Demonstration equipment to the 1st Demonstration plant.

Figure 3 presents an overview of the anticipated project schedule.

Project Cost and Funding Summary

The total cost and funding summaries for McIntosh Unit 4 PCFB Demonstration Project in "as spent" dollars are shown below. The total project costs include the total cost to construct the facility, certain project related offsite costs, 4 years of operation and maintenance (O&M) costs, owner's costs and permitting costs.

		($1000)
COSTS	Total Project Costs	387,970
	Lakeland In-Kinds	2,030
	TOTAL COSTS	**390,000**
FUNDS	Lakeland In-Kinds	2,030
	Lakeland	192,970
	DOE	195,000
	TOTAL FUNDS	**390,000**

The total McIntosh Unit 4 PCFB Demonstration project costs have been divided between the two Cooperative Agreements.

Participant Project Financing

The City of Lakeland has a number of financing alternatives to use for the project. Lakeland has accumulated reserves for future expansion and system general purpose uses. These funds are available for use by the City's Department of Electric & Water Utilities and part of them have been earmarked for the McIntosh Unit 4 PCFB Demonstration Project.

Lakeland also enjoys very favorable bond ratings due to its long-standing financial health. Recently, the drop in interest rates was found to be financially favorable for Lakeland's financing team to issue tax exempt revenue bonds in order to provide funding for several projects listed in Lakeland's current capital forecast. As with any bond issue, this issue has been rated by the bond rating agencies. Lakeland had the bonds rated by Standard and Poor's Group (AA-) and Moody's Investors Service, Inc. (Aa). Lakeland has maintained these ratings since 1989 when the Moody's rating was upgraded to the current level.

The payments for operating costs of Lakeland's Department of Electric & Water Utilities are funded through revenue generated by the sale of electricity and water. The amount of revenue is in part determined by the rates charged for these products. The Department of Electric & Water Utilities, through its long range forecasts, identifies when rate increases are expected. These are identified years in advance of the actual need and are then implemented when, and at the level necessary to continue the financially sound operations of Lakeland. The City Commission for the City of Lakeland has the rate making authority for the Department of Electric & Water Utilities.

Detail revenue and expense budgets are prepared and reviewed each year. The approved budgets are then used to update the long range forecast to determine their impact on future years. This process has been very successful for Lakeland in avoiding unplanned rate increases. In fact, since 1989, Lakeland has been able to implement lower rate increases than originally forecast. Lakeland also believes that the Pressurized Circulating Fluidized Bed generator that this project will involve will operate more efficiently than any of its current generators, further strengthening Lakeland's financial position, and aiding it in providing cost effective power to its customers. The revenue anticipated from operating the new generator is based on the expected demand from existing customers and is not contingent on any future negotiations or sales to another utility.

Project Organization

The City of Lakeland is anticipating entering into an engineer, procure, construct (EPC) contract with a Foster Wheeler/Westinghouse consortium for the entire McIntosh Unit 4 PCFB project with the exception of certain specific items such as a 90 car unit train that would be handled by Lakeland's staff. Through the execution of a single EPC contract, Lakeland would have a single point of contact and single point of responsibility for all issues associated with the project. In order to assist Lakeland in reviewing and monitoring the performance of the EPC contractor, Lakeland is in the process of entering into an additional contract with a company who will act as the "Owner's Engineer". This company will safeguard Lakeland's interest on the project and conduct an ongoing prudency review.

In order to obtain the required permits and licenses for the construction and operation of McIntosh Unit 4, the City of Lakeland has retained the services of a qualified environmental consulting firm with particular expertise in the state of Florida. This same firm will be empowered to prepare the necessary information required by DOE to complete the NEPA process and is expected to liaise closely with DOE's chosen NEPA consultant or subcontractor.

Project Status

At the time this paper was written, DOE had recently announced approval of the project and efforts were underway to have all the Cooperative Agreements and related project agreements formally executed by the parties. Completion of this activity will trigger the formal start of Phase 1 of the McIntosh Unit 4 project. In parallel with this activity, the scope of work of each of the project participants, and their role within the project structure, is currently being fine tuned and finalized. The agreements necessary for each project participant to fulfil their project obligations are in the process of being negotiated. Two important project activities that will be initiated shortly are the permitting and NEPA activities.

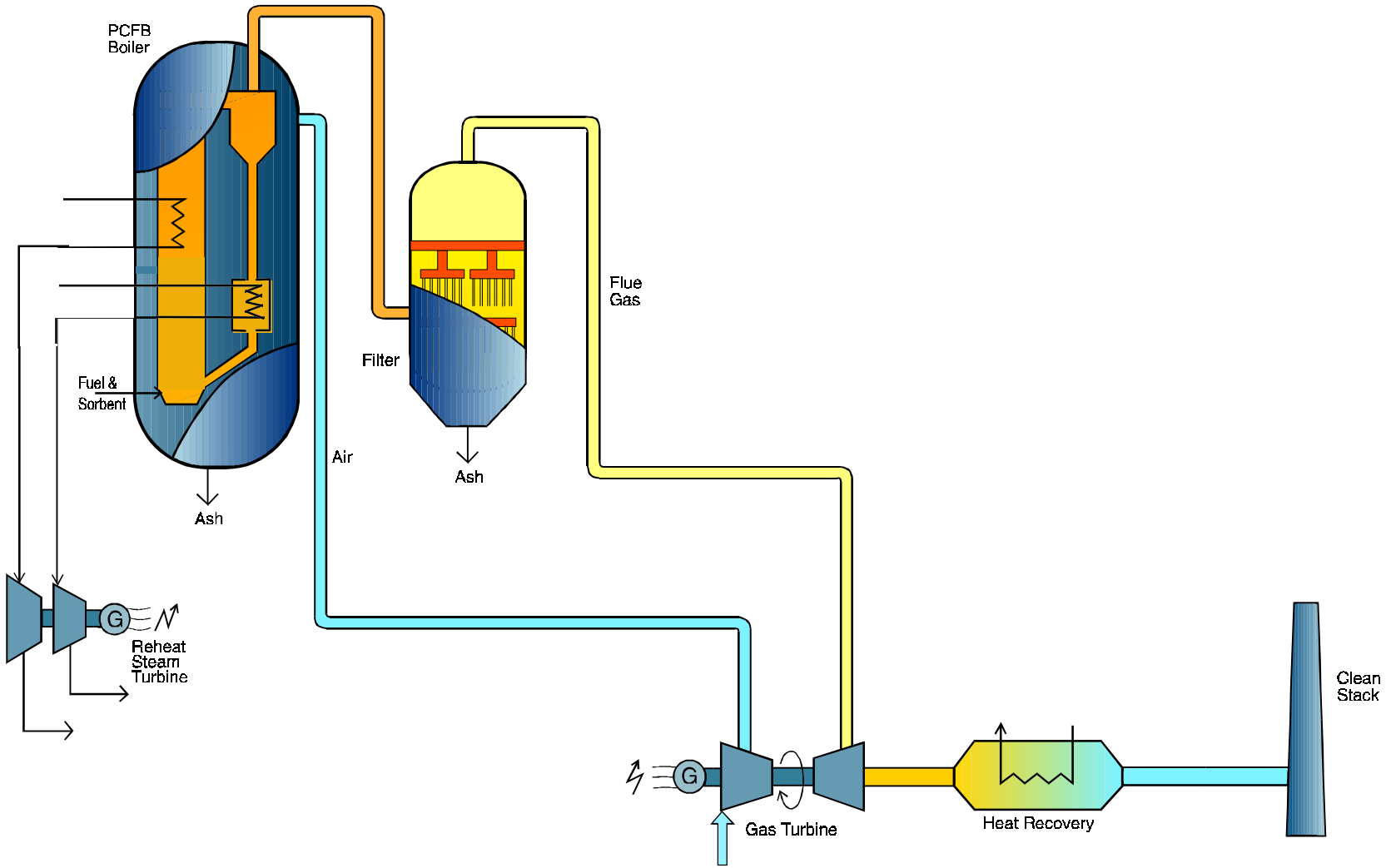


Figure 1.
PCFB Cycle - 1st Demonstration

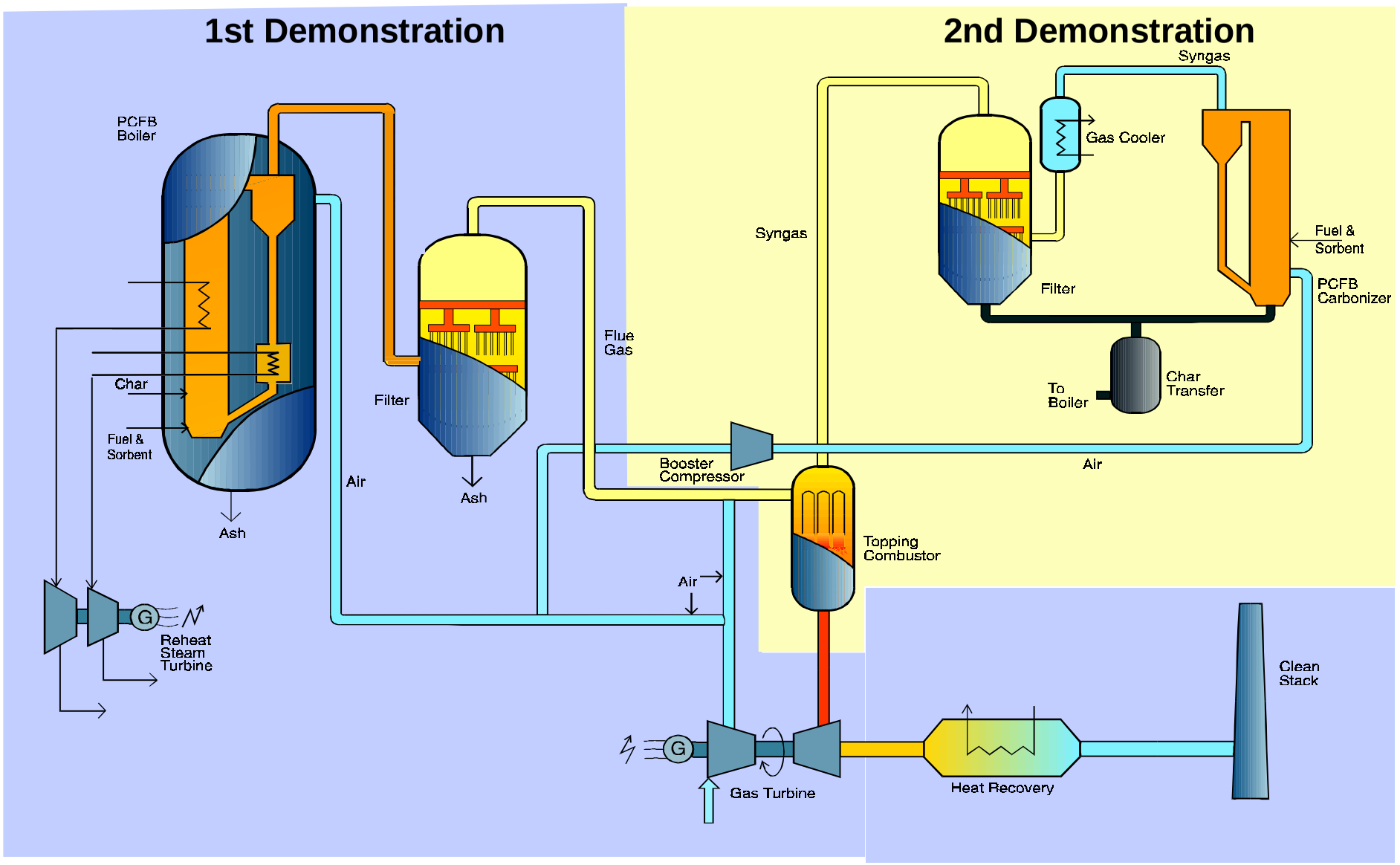
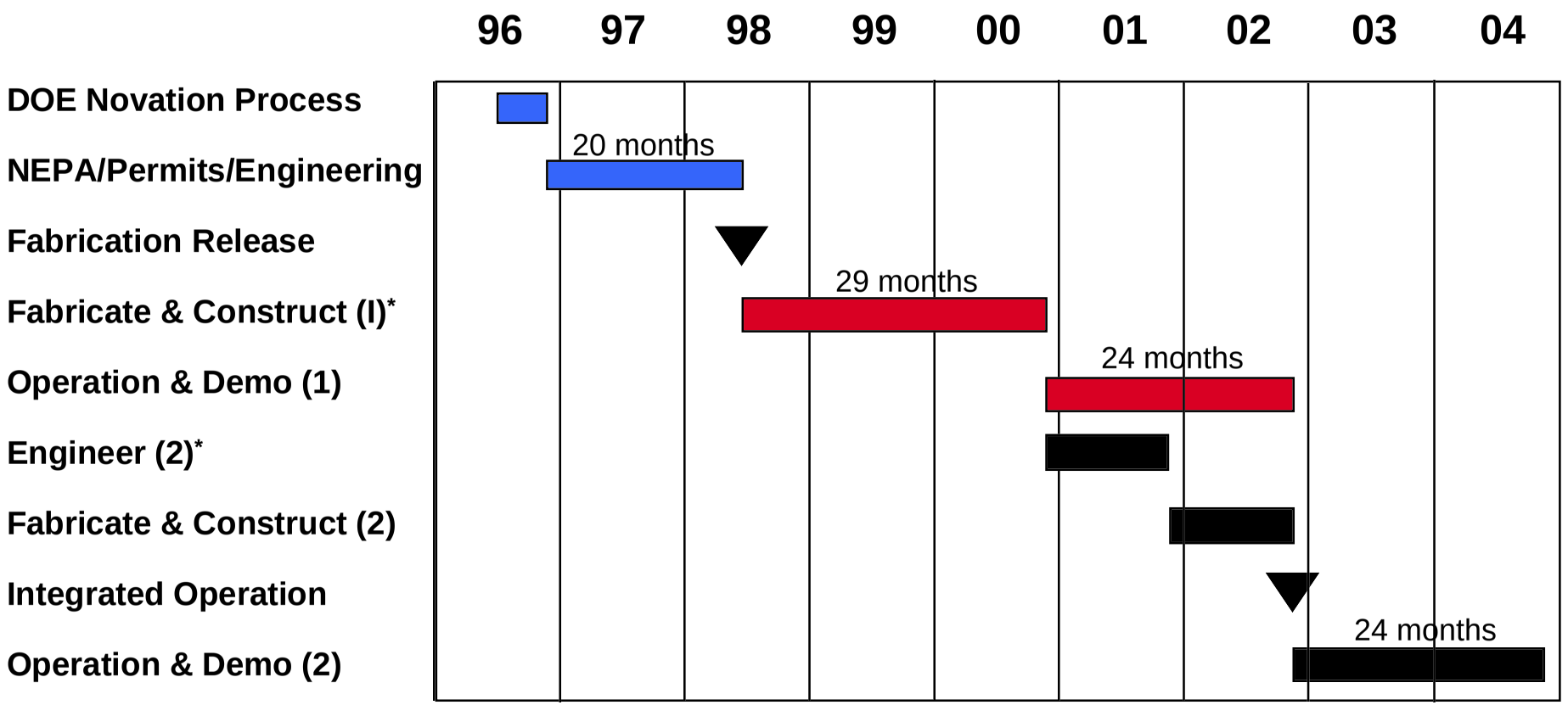


Figure 2
Topping PCFB Cycle - 2nd Demonstration

Figure 3
McIntosh Unit 4 Summary Schedule



*** (1) refers to 1st Demonstration and (2) to 2nd Demonstration**