EQUIPMENT SPECIFICATION APPROVAL/REVISION PAGE	SPECIFICATION NO. ORNL-CFTC-2010CFL01	REV. 0	ISSUE DATE 05-24-2010
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PROJECT TITLE: CARBON FIBER TECHNOLOGY CENTER	PLANT Offsite	DOE ARRA PROJECT NO. 2004140	
	W.O. OR E.S.O. K8098AAA		
SPECIFICATION FOR: HIGHLY FLEXIBLE CARBON FIBER SEMI-PRODUCTION LINE		SSC IDENTIFICATION NO.	

1. APPROVALS

SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY MG ABDALLAH	5/24/10	PRINCIPAL ENGINEER CC EBERLE	5/24/10
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2. REVISIONS/APPROVALS

REV. NO.	DESCRIPTION OF REVISION

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1. SCOPE

This specification defines the requirements for a highly flexible Carbon Fiber Semi-production Line (CFSL). It is intended to be capable of producing various carbon fiber grades including standard modulus commercial grades, intermediate modulus aerospace grades, and fiber grades that are currently in development at both ends of the cost and performance spectrum.

The CFSL will be highly instrumented and capable of processing any of several kinds of precursor fibers including those based on PAN, pitches, lignin, polyethylene, and rayon in tow, nonwoven mat, or discontinuous, loose fiber form. It shall accommodate polyacrylonitrile (PAN) tow sizes from 3k to 80k at 1.25 denier per filament (dpf). The line will be rated at >= 25,000 kg of annual production, based on 24k PAN tows with 1.25 dpf and 6,000 annual operating hours. The Seller will deliver a fully integrated line, including all ovens and furnaces; pre- and post-treatment modules; conveyance and packaging equipment; tensioning and drawing equipment; effluent treatment equipment; and data acquisition and control hardware and software. Data acquisition and control will be centralized in a dedicated control center. The CFSL will be installed in a new building that is currently in design. The Seller shall include equipment installation in its proposal, as an option that may be selected or declined by the Company.

2. APPLICABLE DOCUMENTS

The current revisions of the following documents are incorporated by reference:

American National Standards Institute, Inc (ANSI)/National Fire Protection Association (NFPA) 70, National Electrical Code

ANSI A 13.1, Scheme for Identification of Piping Systems

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code

ASME B31 Code for Pressure Piping

American Society for Testing and Materials (ASTM) C1055, Standard Guide for Heated System Surface Conditions That Produce Contact Burn Injuries

National Electrical Manufacturers Association (NEMA) 250, Enclosures for Electrical Equipment (1000 Volts Maximum)

Company Specification for Special Project 017144

Underwriters' Laboratories, Inc. (UL) 508, Standard for Industrial Control Equipment

UL 508A, Standard for Safety Industrial Control Panels

US 29 Code of Federal Regulations (CFR) 1910, Occupational Safety and Health Standards

3. REQUIREMENTS

3.1 SYSTEM REQUIREMENTS

The CFSL shall satisfy the following system requirements:

- >= 25,000 kg annual production capacity, based on 24k PAN tows with 1.25 dpf
- Maximum line speed >= 1.5 m/min
- Line width >= 300 mm
- Tow size from 3k – 80k at 1.25 dpf
- Tow band >= 24 tows for 24k or smaller tows, reduced tow count allowable for tow size > 24k
- Capability to process mat or loose fiber formats >= 300 mm wide
- Availability >= 6,000 hrs/yr
- The CFSL shall be designed to handle the worst case loads (e.g., gas evolution rate) from PAN, pitch, or rayon fibers. It shall additionally be designed for loads from lignin or polyethylene based on effluent estimates in Attachment ORNL-CFTC-2010CFL01-5.
- The CFSL shall operate as a fully integrated system with central computer control and data acquisition.
- The data acquisition and control system shall prevent unauthorized access to restricted information.
- The CFSL shall provide all required capabilities within the facility constraints described in Section 3.9.

The CFSL design, operation, and maintenance shall be fully documented as specified herein. All documentation shall be provided in English.

The Seller shall submit with its Proposal a summary of overall system design and performance parameters demonstrating that it satisfies the system requirements.

3.2 GENERAL EQUIPMENT CONFIGURATION AND LAYOUT

The general CFSL configuration is illustrated in Figure 1 and Figure 2 and shall include the following equipment modules:

1. Spooled precursor creel
2. Baled precursor feed station
3. Bulk material feed station
4. Pre-treatment system
5. Drive unit
6. Tow oxidation ovens, with drive units after each of the first three thermal zones
7. Drive unit after tow oxidation ovens
8. Parallel to the tow oxidation ovens will be a bulk materials oxidation oven
9. Low-temperature (LT) carbonization furnace
10. Drive unit
11. High-temperature (HT) carbonization furnace
12. Drive unit
13. Surface treatment unit including washing and drying
14. Drive unit
15. Tow band spreading unit
16. Size application unit including drying
17. Drive unit
18. Take-up winding station
19. Bulk packaging station

In addition to the above in-line equipment, other essential equipment includes a regenerative thermal oxidizer, thermal oxidizer, and control and data acquisition system. All equipment and software shall be fully integrated and optimized to function as a single system with single-point operational control.

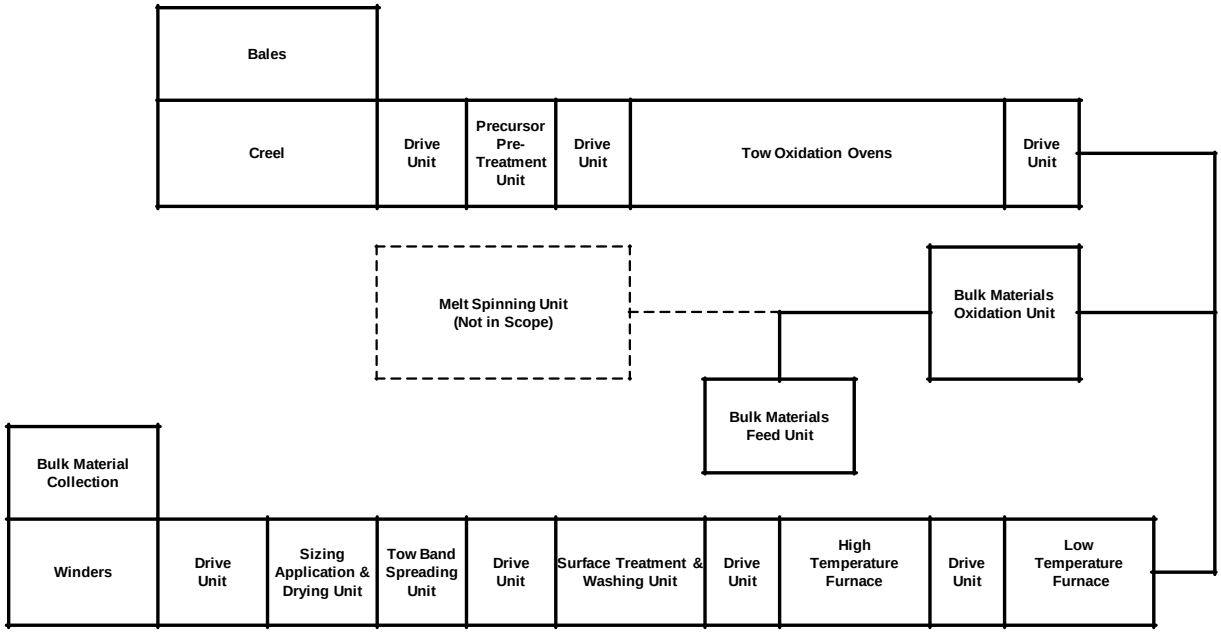

Figure 1. General CFSL equipment configuration.

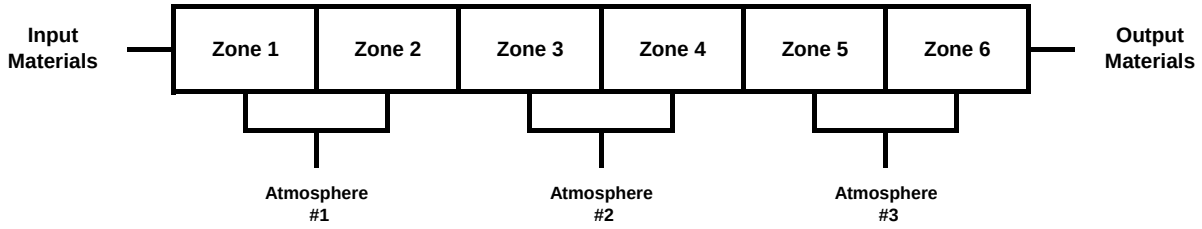

Figure 2. Bulk material oxidizer configuration.

The equipment layout shall include space for a portable creel (Section 3.3.1.1) or winder (Section 3.3.7.1) column to be positioned immediately after any of the oxidation ovens, carbonization furnace, or surface treatment unit. The Seller shall submit with its Proposal a description and footprint layout of the entire CFSL, including plan and elevation layout drawing(s), and the assembled equipment weight as well as the weight of each separate component. Updates shall be provided with the Design Approval Data**,** Advanced Engineering Data**,** and Certified Data submissions.

3.3 PROCESS EQUIPMENT

All major production line equipment is described in this section. The Seller shall submit with its Proposal a basic description and specification of all equipment. Updates shall be provided with the Design Approval Data and Certified Data submissions.

3.3.1 Fiber Feeding Stations

Continuous tows shall be fed from spools on a creel or boxes on a mezzanine. Mats or loose fibers shall be fed from a bulk material feed system.

3.3.1.1 Creel

The creel shall have fixed spindles to handle the maximum number of tows for spools of precursor fiber up to 25 kg/spool on large cores. It shall be arranged in vertical columns of four spools, e.g., for a 24-tow line the creel will have six columns of four spindles each. The creel shall be outfitted with adjustable "limiters" that are initially positioned to limit the maximum fiber spool size to that of a 20 kg spool. The creel shall also have spindles for at least 13 spools with 90 mm cores, arranged approximately horizontally (modest angle to horizontal is allowable to optimize tow payout) and positioned above the large-spool array. Additionally, there shall be a portable column of four spindles that can be positioned at the creel station or immediately before any of the oxidation ovens, carbonization furnaces, or surface treatment unit. Every creel spindle shall be equipped with a back-tension brake. Brakes, controls, and speeds shall be compatible with those of drive units and take-up winding equipment.

3.3.1.2 Baled Tow Feed Station

Large tow may be fed to the line from 500 – 1,000 kg bales on a mezzanine to be located above the creel. The feed mezzanine platform shall be 6 m wide x 7.5 m long, positioned with the long dimension parallel to the line's fiber flow direction. The mezzanine shall be accessible via standard stairs that shall be positioned parallel to the mezzanine's long dimension, on the side nearest the building exterior wall. Its height shall be sufficient to provide adequate space above the creel for creel loading and maintenance, as well as lighting, fire protection equipment, piping/tubing, wiring/cabling/conduit, and ductwork that may need to be supported from the mezzanine structure. The mezzanine floor level shall not exceed 6 m above the process floor. The mezzanine shall structurally support loads up to 12 kPa (250 psf). Railing and stairs shall conform to Occupational Safety & Health Administration (OSHA) standards. There shall be a gate at the bottom of the stairs, equipped with a locking mechanism that is interfaceable with the building's access control system.

3.3.1.3 Bulk Fiber Feed Station

The CFSL shall be equipped with a bulk fiber feed station that directly feeds the bulk material oxidation oven (Section 3.3.3.2). The feed station shall include means for feeding both non-woven mat and loose fibers to a moving mesh belt for conveyance through the oxidation oven. Non-woven mat dimensions shall be ~ 600 mm (2 feet) in width and ~12 mm (0.5 inch) in depth. The bulk material oxidizer shall be in-line with a melt spinning unit that has the capability to produce 600 mm wide spun-bond material. Therefore the mat and loose fiber feed systems shall be positioned so as to not interfere with direct feed from the melt spinner, or shall be readily moved or removed. The mesh belt shall extend at least 2 m out of the bulk oxidizer at the

upstream end, with at least one side of the belt readily accessible for manual loading and for observation of automatic fiber loading operations.

3.3.2 Pre-Treatment System

The pre-treatment system shall include appropriate thread guides (eyelet condenser boards), fiber guide system for bale feed, steam stretching station, precursor moistening unit, and tow band forming combs. The steam stretching station shall be operable with saturated steam at atmospheric pressure.

3.3.3 Oxidation Ovens

The CFSL shall be equipped with parallel oxidation oven systems for tows and bulk material forms. All oxidation ovens shall be equipped with deluge water systems for quenching process excursions, i.e., runaway exotherms. The deluge system shall not be part of the building fire protection system, rather it shall be a process system that receives commands from the line control system.

3.3.3.1 Tow Oxidation Ovens

Tow oxidation ovens shall be rated for >= 400ºC continuous operation, with six independently controllable thermal zones. The ovens shall be designed and configured to enable evaluation of the effects of various parameters including temperature, air velocity, and air flow direction. Temperature shall deviate from the set point by <= 5ºC throughout the heated volume of each thermal zone when a full-width tow band of standard modulus, commercial grade 24k PAN tows is running at standard line speed[1]. Target residence time shall be 90 minutes at standard line speed. Materials of construction and off-gas removal system shall be compatible with effluents from PAN, pitches, lignins, polyethylene, and rayon. The top thermal zone in the first oven stack shall be compatible with sulfur-containing exhaust from sulfonated polyethylene precursor fibers. Other thermal zones are not required to be compatible with sulfurous exhaust gases. Effluents from the conversion of lignin- and polyethylene-based precursors are estimated in Attachment ORNL-CFTC-2010CFL01-5.

3.3.3.2 Bulk Materials Oxidation Oven

The bulk materials oxidation oven shall be rated for >= 600ºC continuous operation, with six independently controllable thermal zones. It shall have three gas flow zones in which gas flows and atmospheric composition can be independently controlled. Each gas flow zone will comprise two thermal zones. The Seller shall recommend the gas flow configuration, providing the basis for its selection, in its Proposal. Conveyor width shall be >= 600 mm and heated length shall be ~ 6 m. Residence time shall range from <= 10 minutes to >= 4 hours. Temperature shall deviate from the set point by <= 5ºC throughout the heated volume of each thermal zone at standard gas flow conditions, with no material in the oven. Materials of construction and off-gas removal system shall be compatible with effluents from PAN, pitches, lignins, sulfonated polyethylene, and rayon. Effluents from the conversion of lignin- and polyethylene-based precursors are estimated in Attachment ORNL-CFTC-2010CFL01-5.

[1] Standard line speed is that which delivers rated throughput of baseline material

3.3.4 Carbonization Furnaces

The CFSL shall be equipped with LT and HT carbonization furnaces. Each of these furnaces will be capable of carbonizing materials in both tow and bulk material formats.

3.3.4.1 LT Furnace

The LT furnace shall be rated for >= 1,000ºC continuous operation, with four independently controllable thermal zones. Temperature shall deviate from the set point by <= 1% at standard gas flow conditions, with no material in the furnace. The controllers shall be synchronized in a master-slave configuration such that in zones 2 – 4, the temperature control is relative to the temperature of the preceding zone. Target residence time shall be 90 seconds at standard line speed. Materials of construction and off-gas removal system shall be compatible with effluents from PAN, pitches, lignins, polyethylene, and rayon. Effluents from the conversion of lignin- and polyethylene-based precursors are estimated in Attachment ORNL-CFTC-2010CFL01-5.

The LT furnace shall be designed to enable carbonization at 600ºC followed by steam or CO_2 treatment at 1,000ºC. Thus it requires appropriately located ports for steam and CO_2 injection, and materials of construction shall be compatible with steam and CO_2 at 1,000ºC. Estimated maximum steam and CO_2 injection rates are both <= 50 kg/hr at atmospheric pressure. The steam shall be saturated and the CO_2 will be at approximately room temperature.

3.3.4.2 HT Furnace

The HT furnace shall be rated for >= 2,000ºC continuous operation, with six independently controllable thermal zones. Temperature shall deviate from the set point by <= 1% at standard gas flow conditions, with no material in the furnace. The controllers shall be synchronized in a master-slave configuration such that in zones 2 – 6, the temperature control is relative to the temperature of the preceding zone. Target residence time shall be 90 seconds at standard line speed. Materials of construction and off-gas removal system shall be compatible with effluents from PAN, pitches, lignins, polyethylene, and rayon.

3.3.5 Post-Treatment System

The post-treatment system consists of surface treatment and size application units. Each unit shall be covered by a durable, transparent enclosure with ~100 mm diameter, 150 mm exhaust port in the top, for attachment to an exhaust system to create a negative pressure enclosure. All rolls shall be positioned inside the enclosures, which shall have sides extending below the bath liquid levels. Enclosures shall be easily removable or equipped with hinged doors to provide ready access to the enclosed units.

3.3.5.1 Surface Treatment Unit

Fiber surface treatment shall be conducted in a standard single-stage electrolytic surface treatment module that includes fiber washing and drying capabilities. It shall be designed to include a removable basin for containing spillage, overflow, and leakage, with capacity to contain the entire liquid volume of the surface treatment bath. A spare basin shall be provided.

The Seller shall detail in its Proposal the types and concentrations of electrolyte that can be used, the surface treatment residence time, and the fiber drying method.

3.3.5.2 Size Application Unit

Size application shall be conducted in a conventional submerged "kiss-roll" size application unit that includes drying capabilities. It shall be designed to include a removable basin for containing spillage, overflow, and leakage, with capacity to contain the entire liquid volume of the size application bath. A spare basin shall be provided. If they are designed to be interchangeable, the same basin can serve as the spare for both the surface treatment and size application units.

The Seller shall detail in its Proposal the size application residence time and the drying method.

3.3.6 Materials Handling and Conveyance

3.3.6.1 Tow Conveyance

The tow conveyance system shall be designed to minimize damage to the fibers, especially those in small tow formats. All rollers shall have hard surfaces and mirror finish. Tow or fiber abrasion and pinching shall be minimized.

A tow band spreading unit shall be located between the surface treatment and size application units. The oxidation ovens, carbonization furnaces, surface treatment unit, and size application unit shall all be equipped with a tow band bypass to enable bypassing selected unit operations without shutting them down.

3.3.6.2 Tow Tensioning and Drawing

The CFSL shall be equipped with drawing and/or tensioning capabilities with a wide range of tension and draw control. General drive unit arrangement for the line is shown in Figure 1. Exceptional draw control shall be provided in the oxidation system. Draw control hardware in oxidation is illustrated in Figure 3.

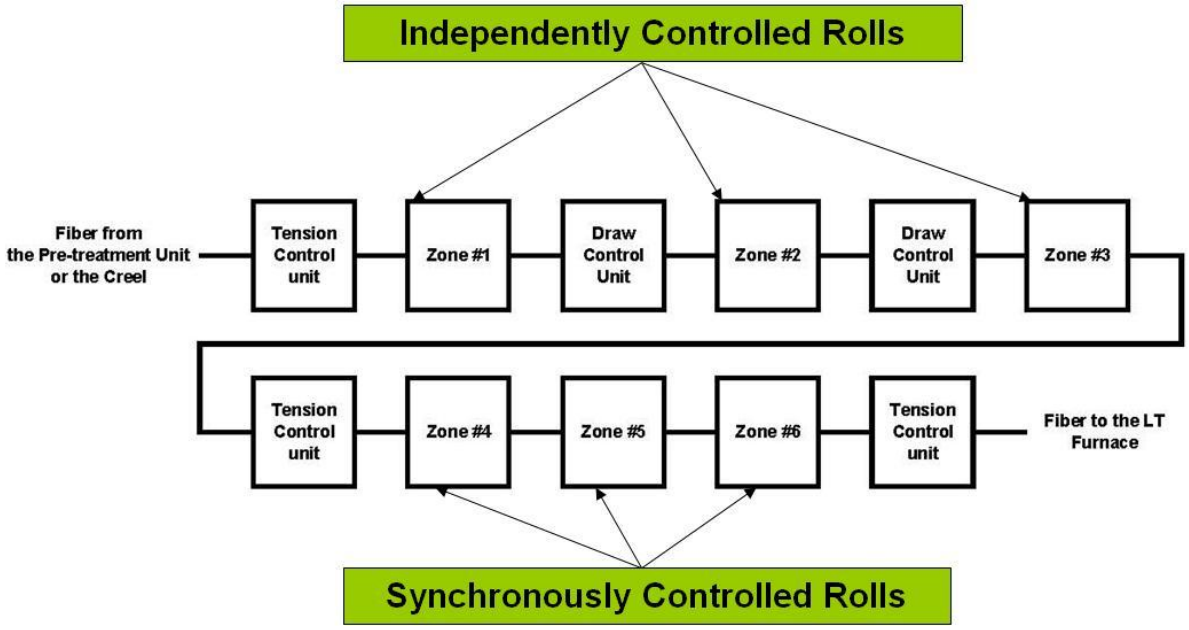

Figure 3. Draw control hardware layout in oxidation ovens

In Figure 3, drive units labeled as "tension control" shall be serpentine drives and drive units labeled as "draw control" shall be delta or omega drives. The Seller shall recommend the number of rolls for each unit to deliver the required drawing range and precision. Passback rolls at the entrant end of each oxidation zone shall be driven, with independent control in zones 1 – 3 and synchronous control in zones 4 – 6.

Tension and/or draw ranges required at the various production line positions are shown in Table 1. The Seller shall recommend in its Proposal the type of drive unit and its number of rolls at each position for which that information is not specified herein.

Table 1. Tow drawing and tensioning values

Location	Draw Ratio	Tension	Tolerance	Tow-to-Tow Variation
Pretreatment	1 - 5X			
Oxidation Zone #1	0.5 - 5X			
Oxidation Zone #2	0.5 - 5X		< 0.5% of the set value	
Oxidation Zone #3	0.5 - 5X			
Oxidation Zones #4 - 6	0.5 - 5X			< 1.0%
LT Furnace	0.5 - 2X			
HT Furnace	0.5 - 2X			
Surface Treatment		<= 80 N/tow	< 1.0% of full scale	
Size Application		<= 80 N/tow		

3.3.6.3 Bulk Materials Conveyance

The bulk materials conveyance system shall include means for feeding both mat and loose forms of discontinuous fibers to the conveyor at the entrance to the bulk oxidizer (Section 3.3.1.3) as well as to both carbonization furnaces. The bulk materials conveyance system shall also have a means of collecting those products at the exit of the bulk oxidizer and each carbonization furnace.

In the bulk material oxidizer, the conveyor shall be >= 600 mm wide. The stabilized mat will either be slit into two 300 mm (1 foot) wide mats or folded into a roughly 300 mm (25 mm deep) mat for further thermal processing through the conversion line, as a mat, using the bulk transport systems. The mat slitter or folder shall be furnished by the Company. The mat shall be slit or folded before collection for transport to the LT furnace. The Seller's Proposal shall be based on manual transport of mat and loose fibers between the oven and furnaces, but should include an option for automatic bulk material conveyance (no manual material transfer needed) through the entire production line.

The bulk material conveyor shall be approximately the same width as the maximum tow band width in the carbonization furnaces. There shall be means for feeding materials in both mat and loose fiber formats to the inlet and collecting them at the outlet of both carbonization furnaces.

The bulk material conveyor shall be removable from the carbonization furnaces. The furnaces shall be capable of properly carbonizing tows with the bulk conveyor either installed or removed. If the bulk materials conveyor temperature rating is below that of the HT furnace, then that

furnace shall be interlocked so that it can be operated at temperature above the conveyor's rated temperature only when the conveyor has been removed.

Bulk conveyance shall be provided through the post-treatment system. It is allowable to design the post-treatment system such that the bulk conveyor must be removed for tow operations, provided that the removal or installation of the bulk conveyor can reasonably be accomplished by a skilled two-person crew working one eight-hour shift. Bulk material conveyance shall be provided to the bulk packaging station.

3.3.7 Packaging Stations

Packaging stations will be provided for all types of fibers in all formats.

3.3.7.1 Take-Up Winders

A take-up winding station shall have one stationary, mechanical winder for each tow. Additionally, there shall be a portable column of four fully electronic winders that can be positioned at the winding station or immediately after any of the oxidation ovens, carbonization furnaces, or surface treatment unit. The winders shall be compatible with 10 kg spools with 89 mm hard paper core or soft paper pull-out cores (for center-pull packages).

The winder base speed range will be from <= 0.5 to >=2.5 m/min with automatic compensation for spool diameter growth. The winders shall be capable of delivering >= 5 m/min, however gear changeout is acceptable, if required, to reach the upper end of the required speed range. Speed control precision shall be <= 1% of the speed setting.

The winders shall be enclosed in a durable, transparent enclosure with hinged access doors and two ~100 mm diameter,150 mm exhaust ports in the top (one on each end), for attachment to an exhaust system to create a negative pressure enclosure.

3.3.7.2 Bulk Packaging Station

A bulk packaging station shall be provided on a mezzanine situated above the take-up winding station. The packaging mezzanine shall be 6 m wide x 6 m long. The mezzanine shall be accessible via standard stairs that shall be positioned parallel to the production line, on the side of the mezzanine nearest the building exterior wall. Its height shall be sufficient to provide adequate space above the creel for creel loading and maintenance, as well as lighting, fire protection equipment, piping/tubing, wiring/cabling/conduit, and ductwork that may need to be supported from the mezzanine structure. The mezzanine floor level shall not exceed 6 m above the process floor. The mezzanine shall structurally support loads up to 12 kPa (250 psf). Railing and stairs shall conform to OSHA standards. There shall be a gate at the bottom of the stairs that can be equipped with an electronic locking mechanism that is interfaceable with the building's access control system.

The bulk packaging station shall provide means for packaging mat products. Means for packaging loose fiber products and bulk packaging of tows shall be offered as optional items.

3.3.8 Effluent Treatment

The Seller shall supply equipment to treat all off-gases and other effluents requiring treatment before discharge into the environment. This shall include a regenerative thermal oxidizer and non-regenerative thermal oxidizer to treat off-gases from the conventional production of PAN-based carbon fibers, and stack(s) for exhausting gases to the atmosphere. The off-gas treatment

system shall also treat off-gas from the conversion of fibers based on pitches, rayon, lignin, and polyethylene. It shall include provisions for the future addition of scrubbers for treatment of sulfur-containing off-gases from polyethylene fibers. Estimated off-gas loads from the conversion of lignin- and polyethylene-based precursors are documented in Attachment ORNL-CFTC-2010CFL01-5.

The Seller shall provide estimates of the size and weight of effluent treatment devices in its Proposal, as well as structural loads associated with their support. It shall also provide that data as well as estimated effluent discharges from the treatment module with the Design Approval Data.

3.3.9 Interconnecting Hardware

The Seller shall design and/or specify all hardware for interconnecting utility distribution points, production line equipment, instrumentation, control and data acquisition system, effluent treatment equipment, and effluent discharge points. This includes all process exhaust ductwork; enclosure exhaust ductwork; process and utility piping; electrical wiring and cabling; and instrument wiring, cabling, and tubing. The Seller shall also design and/or specify all structures required to support the aforementioned interconnecting hardware. A summary list of interconnecting hardware and associated support structures shall be submitted in the Proposal. Preliminary design data shall be submitted with the Design Approval Data, and final design documentation with the Advanced Engineering Data and Certified Data.

The interconnecting hardware and associated structural support hardware shall be furnished and installed by the Installer.

3.3.10 Permanent Access Equipment

Permanent platforms, ladders, etc. needed for maintenance and operations access to the process equipment described in Section 3.3 shall be supplied by the Seller. A list of access equipment and the process equipment for which it provides access shall be submitted in the Proposal, and its preliminary design shall be submitted with the Design Approval Data.

3.4 INSTRUMENTATION

The CFSL shall be highly instrumented A general instrument list is provided in Table 2. Other instrumentation shall include a pH meter in the surface treatment bath, collected length measurement on all take-up winders, and weight scales at the bulk packaging station. All instruments shall be digital and interfaced to the data acquisition system. Where applicable, measurement error is included in the control tolerances specified in Section 3.3.

Table 2. General instrument listing

Unit Operation	Temp.	Tension (tow band mean)	Draw ratio	Conveyance speed	Residence time	Flow rate	Power demand
Creel	No	Out	No	Out	No	No	Yes
Bulk feed	No	No	No	Yes	No	No	Yes
Pre-treatment	In, out, ctr	In, out	Yes	In, out	Yes	Steam	Yes

Unit Operation	Temp.	Tension (tow band mean)	Draw ratio	Conveyance speed	Residence time	Flow rate	Power demand
Tow oxidation	5/zone	In, out every zone	Yes	In, out every zone	Every zone	Air, every zone	Every zone
Bulk oxidation	3/zone	No	No	Yes	Yes	Air, every zone	Every zone
LT furnace	2/zone	In, out	Yes	In, out	Yes	N2, all ports	Every zone
HT furnace	2/zone	In, out	Yes	In, out	Yes	N2, all ports	Every zone
ST bath	3	In	No	In	Yes	No	No
ST dryer	In, out, ctr	Out	No	Out	Yes	No	Yes
Size bath	3	In	No	In	Yes	No	No
Size dryer	In, out, ctr	Out	No	Out	Yes	No	Yes
Winder	No	In	No	In	No	No	Yes
Bulk packaging	No	No	No	Yes	No	No	Yes

Temperature monitors are assumed to be thermocouples unless otherwise specified by the Seller. All thermocouples shall be mounted in instrument ports or similar fixtures enabling quick and easy replacement by one person. Locations of temperature monitors are defined in Table 3.

Table 3. Locations of temperature monitors

		ID	Axial[2]	Height	Transverse[2]
Tow Oxidation	Every thermal zone	1	Inlet	Above top tow	Center
		2	L/4	Below bottom tow	Right edge
		3	Center	Center	Center
		4	3L/4	Above top tow	Left edge
		5	Exit	Below bottom tow	Center
Bulk Oxidation	Every thermal zone	1	Inlet	Above conveyor	Center
		2	L/4	Above conveyor	Right edge
		3	Center	Above conveyor	Center
		4	3L/4	Above conveyor	Left edge
		5	Exit	Above conveyor	Center
LT Furnace	Zone 1	1	Center of zone	Below tow	Center
		2		Above tow	W/4 right side

[2] L represents heated length of zone, so e.g., L/4 position is ¼ of heated length from inlet position. Likewise W represents heated width and W/4 is ¼ of heated width from reference edge.

		ID	Axial[2]	Height	Transverse[2]
	Zone 2	1		Below tow	Center
		2		Above tow	Left edge
	Zone 3	1		Above tow	Center
		2		Below tow	Right edge
	Zone 4	1		Above tow	Center
		2		Below tow	W/4 left side
HT Furnace	Zone 1	1	Center of zone	Above tow	Center
		2		Below tow	W/4 right side
	Zone 2	1		Below tow	Center
		2		Above tow	W/4 left side
	Zone 3	1		Above tow	Center
		2		Below tow	Right edge
	Zone 4	1		Below tow	Center
		2		Above tow	Left edge
	Zone 5	1		Above tow	Center
		2		Below tow	W/4 left side
	Zone 6	1		Below tow	Center
		2		Above tow	W/4 right side
ST, Size	Bath	1	Inlet	Same height as #2	Center
		2	Center	Above tow	Center
		3	Exit	Same height as #2	Center

Effluent monitoring ports shall be included in the exhaust ducts from all ovens, furnaces, and thermal oxidizers, to readily enable future addition of effluent monitoring.

The Seller shall include in its Proposal a complete list of instruments, including type and accuracy data for each instrument. Instrument specifications shall be included in the Design Approval Data. Piping and instrumentation diagrams (PIDs) shall be included in the Advanced Engineering Data, including the dimensioned interface locations in plan and elevation. All final instrument design information shall be documented in the Certified Data.

All ovens and furnaces shall be equipped on both sides with digital temperature displays that are easily readable from the floor, that are programmed to indicate deviation from the temperature setpoint at the center of each thermal zone. The control system shall be programmed to block display of absolute data on these temperature displays.

3.5 DATA ACQUISITION AND CONTROL SYSTEM

The Seller shall supply all data acquisition and control capabilities for the entire operation of the equipment. The Seller shall submit in its Proposal a description of data acquisition and control hardware, software, capabilities, features, operational modes, and options.

3.5.1 Operator Interface

The operator interface shall be a digital computing platform with user-friendly Graphical User Interface (GUI) and data acquisition/control software. A common GUI and code shall be used for every control station, enabling operators to control all hardware and access all data with knowledge of only one interface protocol. The operator interface shall require minimal training for operators that are moderately proficient users of Mac or IBM-compatible computers. The control and data acquisition system shall communicate with operators via English language and Arabic numerals.

3.5.1.1 Control Center Hardware

The control system shall utilize current state-of-the-art control hardware with large, flicker-free displays. It shall include sufficient data storage capacity to store at least a 30-day data log for the system, with capability to regularly backup the data to a secure, remote data storage center. It shall have Universal Serial Bus (USB) ports and Digital Video Disc-Read Only Memory (DVD-ROM) drives that are accessible only to authorized system administrators.

Input devices shall include keyboard, mouse, touchpad, and/or joystick, all of which shall be ergonomically designed.

Output devices shall include high resolution digital printers with photographic image quality.

All computer hardware shall be readily upgradeable.

The Seller shall provide a summary specification of the computer hardware in its Proposal and in the Design Approval Data.

3.5.1.2 Process Floor Consoles

Operator consoles shall be provided on the process floor in the creel, pre-treatment, oxidation, carbonization, post-treatment, and packaging areas. Authorized personnel shall be able to access all control functions and data, for which they are authorized, at any console on the process floor.

The Seller shall describe the process floor consoles and their locations in its Proposal and in the Design Approval Data.

3.5.1.3 Computer Software

Control software, together with the operating system, shall provide the following capabilities:

- Controlled access to control functions and data, limited to authorized personnel only, with different access levels for different personnel
- Fast entry to “sleep” mode upon operator command (rapidly terminates data display)
- Resume data display mode upon command by authorized personnel
- Automated start-up and shutdown of all equipment
- Programmable or manual control of all controlled process parameters in all CFSL equipment, including scram, constant rate of change, and defined time-parameter profiles
- Select displayed units (e.g., meters-kilograms-seconds, feet-pounds-seconds, etc.)
- Deluge water control

Data acquisition software, together with the operating system, shall provide the following capabilities:

- Store run ID, precursor data, etc.

- Store operator ID's
- Log operator inquiries and commands
- Log specific measured parameter data at specified time intervals
- Log all measured parameter data at specified time intervals >= 10 seconds
- File password protection
- Data compression
- Network connection with password-protected web interface for system monitoring by authorized personnel; NO ability to control via web interface
- System alarm remote notification (e.g. call one or more designated phone numbers)
- Backup of specified data at specified time intervals

The Seller shall include in its Proposal and in the Design Approval Data a tabulated description of data acquisition and control functions.

3.5.2 Data Security

See Section 3.6.

3.5.3 Diagnostics

The data acquisition and control system shall be furnished with maintenance test circuits that will assist in isolating any failure to a particular system function. The test circuits can be any combination of switches, diagnostic boards, visual indicators, and/or test programs. All test circuits and test programs shall be documented in the Certified Data.

3.5.4 Operator Messages

The data acquisition and control system shall display prompts and error messages at the operator's control panel. The system shall enable printing and electronic storage of displayed messages. A list of prompts and error messages with definitions shall be included in the operation and maintenance manuals.

3.5.5 Low-Power Mode

The facility will be equipped with uninterruptible power. The data acquisition and control system shall have a low-power mode that engages when it is on backup power. When on backup power, the system shall perform only the essential control and data acquisition functions that are necessary to conduct a safe shutdown, and to log and maintain critical data until the equipment is safely shut down.

3.6 SECURITY

The CFSL shall be designed to control access to all restricted data. This is primarily detailed equipment design data and process data.

There shall be no absolute data displays that are normally visible from the process floor, mezzanines, or elevated positions along the walls (in case of future addition of observation deck[s]). Visible displays that show deviation from a parameter set point (e.g., difference between measured temperature and target temperature in a furnace) are allowed, but they shall not be programmable or selectable to display absolute data.

The operator consoles on the process floor will be normally in "sleep mode" such that the screens are blank or display a "screen saver" but can be "awakened" in seconds by authorized

personnel via their Company-issued key cards. They can then access the console's operator interface by entering their Company-issued password. The consoles shall grant them the same level of access as they would have in the control center. The consoles shall be equipped with means to detect operator departure (e.g., motion sensor, pressure pad, or laser beam) and will return to "sleep mode" immediately upon operator departure. They shall further have a timeout function that also returns them to sleep mode after a specified time of inactivity, which shall serve as a backup in case the departure detector fails.

All control center displays shall be "normally on". In the control center, operator access to control functions and display controls shall also require a combination of Company-issued key card and password. Operator consoles shall be equipped with "scram" buttons by which operators can turn off the display of all control center data in the event of unauthorized personnel entry into the control center. The scram buttons shall not affect control settings, they shall only terminate data display. After scramming, data display shall be able to be restored at any time by a normal key card and password-authorized "awaken" command.

Process data shall be accessible over the internet only to authorized persons who are logged into the Company's secure web portal and who have been granted access by the Company's system administrator.

All tensioning and drawing units shall be situated inside opaque enclosures with hinged access doors and one ~100 mm diameter, 150 mm exhaust port in the top. The enclosures of all units downstream of the LT furnace shall be connected to the exhaust system to effect a negative pressure enclosure. The access doors shall be equipped with electronic locks that are interfaced to the control system and can be unlocked by local password entry on a keypad, from a control room console, or a floor console. The doors shall be equipped with motion sensors and hydraulic or electric actuators that automatically close and lock the door if no motion is detected for a specified time period. The time period shall be programmable with a default setting of one minute.

The Seller shall briefly describe the CFSL security features in its Proposal and submit summary specifications of the security equipment with the Design Approval Data.

The Seller shall include with its Proposal and in the Certified Data a list of major equipment components or subsystems with the Export Control Classification Number (ECCN) identified for each component or subsystem. This data may be combined with other tabular data that is delivered under this procurement.

3.7 OPERATING ENVIRONMENT

The CFSL will be installed in or near Oak Ridge, Tennessee between 200 - 300 m elevation. The equipment shall be qualified to operate at rated capacity within the following ranges of environmental conditions.

3.7.1 Process Floor Environment

Temperature: 10° – 45°C

Relative humidity: up to 100%

Dust and particulate: typical carbon fiber production process space

Electromagnetic and acoustic backgrounds are negligible.

3.7.2 Control Center and Motor Control Center Environment

Temperature: 20° – 27°C

Relative humidity: 30 - 55%

Electromagnetic and acoustic backgrounds are negligible.

3.8 HEALTH AND SAFETY

The equipment shall be furnished with safety devices and shall meet or exceed the applicable safety requirements in 29 CFR 1910. All equipment shall be guarded to prevent personnel injury during automatic operation.

The Seller shall provide a list of Hazardous Materials and associated Material Safety Data Sheets (MSDS) for any hazardous materials incorporated into the equipment, in compliance with the requirements of OSHA 29 CFR 1910.1200, Hazard Communication.

The equipment shall comply with the requirements of NFPA 70, Standard for Electrical Safety in the Workplace.

The equipment shall comply with the requirements of 29 CFR 1910, Subpart O – Machinery and Machine Guarding.

The equipment shall consist of components meeting the requirements of OSHA 29 CFR 1910 Subpart S, Electrical.

Maximum equipment surface temperature shall be limited in accordance with ASTM C1055. All hot (>= 45ºC) surfaces shall be labeled with warning signs.

The maximum equipment noise level shall not exceed 60 decibels adjusted (dBA) in the control center, 70 dBA measured at operators' floor consoles, and 80 dBA at one meter from equipment enclosures or external surfaces.

The Seller shall identify and describe any breathing hazards posed by the CFSL, including upgrades identified in Section 3.12, in the Design Approval Data.

All piping shall comply with ASME B31 Code for Pressure Piping as applicable and shall be labeled in accordance with ANSI A13.1.

Flow diagrams shall show system designations, line numbers, line sizes, and piping specification number. System designations shall be defined on the drawings and may be the Seller's standard designations. Valves shall be identified by a standard valve number and unique valve identifier. Valve identification numbers (VINs) will be provided by the Company. The following information shall be tabulated on the piping drawings:

- Service, designation, and specification subsection
- Service design pressure, design temperature, test pressure, test type, and test media
- Valve information including VIN, standard valve number, type, and (if applicable) instrument number
- Pressure reducing and relieving devices indicating type, size, pressure setting and capacity
- Insulation type and thickness
- Backflow protection devices including location and backflow preventer device type

All pressure containment structures that are addressed within the mandatory scope of the ASME Boiler and Pressure Vessel Code shall be ASME code-stamped pressure vessels, and shall be described in the Design Approval Data.

"The Company's Authority Having Jurisdiction (AHJ) is Mr. Richard M. Griffey, Email: griffeyrm@ornl.gov, Tel: (865) 574-8907. The AHJ is responsible for enforcing the National Electrical Code and determining the equipment to be acceptable based on the action by the NRTL."

3.9 INTERFACES

3.9.1 Facility Constraints

The CFSL will be installed in a new building that is specified in detail in Company Specification for Special Project 017144. (Note: Seller copies are available on request.)

The production line (excluding bulk materials oxidation oven, control and data acquisition, motor control center, regenerative thermal oxidizer, and thermal oxidizer) shall fit within an envelope not to exceed 118 m long x 7.5 m wide x 8 m high. No pipes, ducts, wires, or other structures may protrude vertically outside this envelope; all pass-throughs must be horizontal. The bulk materials oxidation oven shall be located adjacent and parallel to the tow oxidation ovens, with the centerlines of the two oven sets separated by 9 – 11 m. All of the equipment components and subassemblies shall be transportable through a 3.6 m wide x 4.8 m tall doorway during installation. The heaviest equipment lift shall not exceed 89 kN (10 tons). Floor loads shall not exceed 12 kPa (250 psf).

The control center shall fit within 50 m^2 of floor space. The motor control center, including access space to all hardware, shall fit within an envelope not to exceed 50 m long x 5 m wide x 4 m high.

The Seller shall submit in its Proposal a schedule of utility requirements and preliminary guidance on their interconnecting hardware. Maximum allowable utility demands by the CFSL are shown in Table 4. Piped utilities will be available from manifolds running parallel to the line along the nearest wall. The main electrical distribution point will be located in the motor control center. Details on utility provisions and distribution are detailed in Company Specification for Special Project 017144.

Table 4. Utility allowances

Utility	Specification	Maximum allowable demand
Electricity	480 V, 3-phase	1.5 MW
Natural gas	50 kPa gage	60 Nm^3/hr
Process water	Demineralized	100 kg/hr
Cooling water	33ºC maximum supply temperature	10,000 kg/hr
Deluge water[3]	700 kPa	4,000 kg in 10 min

[3] Provided to quench excursions in oxidation ovens

Nitrogen gas	-67ºC dewpoint, <= 10 ppm oxygen, 100 kPa gage	150 Nm^3/hr
Ventilation		120 kW in process space
Conditioned air		10 kW in main control and motor control centers
Steam	100 kPa gage, saturated	150 kg/hr

3.9.2 Power

3.9.2.1 Electrical Systems

Electrical equipment and wiring shall be standardized by the Seller to comply with NFPA 70-2008, the National Electrical Code. All electrical equipment, components, and assemblies shall be listed and labeled by a Nationally Recognized Testing Laboratory (NRTL). Control panels shall be UL 508A listed. Exceptions shall be indicated to the Company. After Subcontract award, shop drawings for non-listed control panels shall be provided to the Company for preliminary acceptance. Non-listed control panels shall be made available to the Company for factory inspection at no additional cost.

An insulated equipment grounding conductor shall be provided in all electrical raceways. The Seller shall furnish power conditioning and isolation equipment required to allow electromagnetic interference (EMI) sensitive electrical systems to operate correctly. All electrical enclosures for equipment located in a process area shall be rated NEMA 12. Conductor splices shall only be performed on terminal strips or at device terminals. All conductors entering or exiting enclosures shall be terminated on a terminal strip. All wiring shall be identified with wiring numbers.

3.9.2.2 Electrical Documentation

The Seller shall specify electrical requirements in its Proposal. The Seller shall submit electrical schematics, wiring diagrams, interconnection diagrams, and control panel layouts in the Design Approval Data. The Seller shall provide in the Advanced Engineering Data detailed drawings for electrical services required, including the dimensioned equipment supply entry location in plan and elevation and indicating the voltage, phases, and current kilovolt-ampere (KVA) load at the supply location. All of the aforementioned documentation shall be submitted as-built in the Certified Data package.

3.9.3 Natural Gas

The Seller shall specify natural gas requirements (demand rate, temperature, pressure, cleanliness, etc.) in its Proposal. The Seller shall provide in the Advanced Engineering Data detailed drawings for natural gas piping, including the dimensioned equipment supply entry locations in plan and elevation and indicating the pipe sizes and materials at all interface locations. The Seller shall provide schematics and piping diagrams with its Certified Data package.

3.9.4 Cooling Water

The Seller shall specify cooling water requirements (demand rate, temperature, pressure, cleanliness, etc.) in its Proposal. Cooling shall not require deionized water. The Seller shall

provide in the Advanced Engineering Data detailed drawings for coolant piping, including the dimensioned equipment supply entry and exit locations in plan and elevation and indicating the pipe sizes and materials at all interface locations. The Seller shall provide schematics and piping diagrams with its Certified Data package.

3.9.5 Deluge Water

The Seller shall specify deluge water (for quenching process excursions in the oxidation module) requirements (demand rate, temperature, pressure, cleanliness, etc.) in its Proposal. The Seller shall provide in the Advanced Engineering Data detailed drawings for deluge water piping, including the dimensioned equipment supply entry and exit locations in plan and elevation and indicating the pipe sizes and materials at all interface locations. The Seller shall provide schematics and piping diagrams with its Certified Data package.

3.9.6 Nitrogen Purge

The Seller shall specify nitrogen purge gas requirements (demand rate, temperature, pressure, cleanliness, etc.) in its Proposal. The Seller shall provide in the Advanced Engineering Data detailed drawings for nitrogen purge gas piping, including the dimensioned equipment supply entry locations in plan and elevation and indicating the pipe sizes and materials at all interface locations. The Seller shall provide schematics and piping diagrams with its Certified Data package.

3.9.7 Heating, Ventilation and Air Conditioning (HVAC)

The Seller shall specify HVAC requirements (composition, demand rate, temperature, pressure, cleanliness, etc.) in its Proposal. The Seller shall provide in the Advanced Engineering Data detailed drawings for concentrated HVAC requirements, if any, including the dimensioned equipment supply entry locations in plan and elevation. The Seller shall provide schematics and diagrams with its Certified Data package.

3.9.8 Structural

The Seller shall submit in its Proposal, confirmed in the Design Approval Data, a floor loading diagram and estimated loads imposed on building structures by equipment, piping, cable trays, etc; and the weights of all equipment components and assemblies. A schedule of floor penetrations required for equipment installation, indicating penetration location, size, and depth shall be submitted in the Advanced Engineering Data. All final structural data shall be delivered in the Certified Data package.

3.9.9 Miscellaneous Utilities

Requirements for compressed air or gas, CO_2, deionized water, vacuum, and any other miscellaneous utilities shall be described in the Seller's Proposal. The description shall include compositions, demand rates, temperatures, pressures, cleanliness, and all other relevant parameters. The Seller shall provide in the Advanced Engineering Data detailed drawings for piping or other means of conveyance, including the dimensioned equipment supply entry locations in plan and elevation and indicating the conveyance sizes and materials at all interface locations. The Seller shall provide schematics and conveyance diagrams with its Certified Data package.

3.10 SPARE PARTS

The Seller shall provide in the Certified Data a recommended spare parts list based on mean time between failure rates, in which each part is described, identified, and priced. The list shall identify the original equipment manufacturer (OEM) and part number. This listing shall include the recommended spare parts 10,000 hours of operation. The Company may, at its sole discretion, have the option to purchase any or all of these listed spare parts. Each OEM spare parts package shall be priced separately.

3.11 OPERATION AND MAINTENANCE MANUALS

The Seller shall submit in the Advanced Engineering Data manuals for operation and maintenance of all equipment supplied by the Seller, as well as a detailed replacement parts manual. The replacement parts manual shall include (an) exploded view(s) with each item identified such that it may be obtained from either the Seller or the original manufacturer. The part number and serial or lot control number shall be provided for each replacement part that may be necessary to maintain the system in a fully functioning condition. The operation manuals and replacement part manuals should also contain the following information for the major equipment assemblies:

- Equipment identification number, model number, etc.
- Equipment serial number
- Seller name
- Manufacturer name (if different from Seller)
- Manufacturing plant address
- Seller product designation
- Manufacturer product designation (if different from Seller)
- Date of manufacture (month and year)
- Materials safety data sheets (MSDS)

The Seller shall include in its Proposal a summary operations manual briefly describing key features and operational procedures, specifically including start-up and shutdown procedures and times. It shall also tabulate estimated annual maintenance costs for the first ten years of operations, based on 500 hours of continuous operation every month and shutdown for the remainder of each month.

3.12 OPTIONS AND UPGRADES

The Seller may offer certain equipment as options. Additionally, certain anticipated future upgrades shall be considered in the instant equipment design and configuration.

3.12.1 Optional Equipment

The Seller shall include in its Proposal equipment for packaging loose fiber products as well as equipment for bulk packaging of tow into boxes (e.g., “roping”). If the Company exercises any Option(s), the Seller shall submit preliminary equipment designs with the Design Approval Data and detailed designs with the Advanced Engineering Data.

3.12.2 Planned Upgrades

The CFSL shall be upgradeable by the anticipated future addition of the following equipment and/or features:

- Creel or similar equipment to temporarily store >= 20 spools (heat-resistant spools ~ 150 mm [6”] diameter x ~ 250 mm [10”] long) of fiber in the bulk materials feed area, and to load them onto the bulk oxidizer conveyor
- Creel to transfer oxidized (stabilized) fiber from spools of fiber exiting the bulk oxidizer to the LT furnace
- Ultra-high temperature furnace rated >= 2,800ºC
- Advanced surface treatment unit
- Additional sizing unit
- Scrubbers for treating off-gases from sulfonated polyethylene precursor fibers

The equipment structures shall be designed to provide structural support for this equipment so that it can be added in the future with little or no structural modification. The Seller may assume that equipment upgrades will conform to this baseline specification for line width, line speed, and rated capacity.

4. QUALITY ASSURANCE REQUIREMENTS

4.1 GENERAL QC REQUIREMENTS

All technical requirements in this specification are classified as acceptance requirements.

The Seller shall submit with its Proposal a copy of its general Quality Control Program (QCP) description, with documented evidence showing how the Seller intends to comply with all requirements of this specification. This QCP shall provide sufficient detail and scope to allow the Company to determine the quality control that can be expected from the Seller. This QCP shall describe quality control policies and practices that shall be used to ensure that the proposed equipment shall meet the requirements in this specification.

The Seller shall identify in its Proposal any requirement(s) of this specification that are not satisfied by its Proposal. Any deviation from specified requirements must be approved by the Company. A Company Request for Deviation form may be submitted to initiate this process.

The Certified Data package shall include the rated capacities and capabilities, accuracy, and uncertainty performance specifications of each component, device, or system. It shall also include the Seller’s certification that the products ordered by the Company based on the stated specifications have been supplied and conform to the requirements of this specification (Certificate of Conformity), with supporting test and inspection documentation.

Equipment and products not conforming to this specification and the applicable detail specifications, or to modifications authorized by the Company, are subject to rejection.

4.2 QUALITY CONTROL (QC) PLAN

The Seller shall submit in the Design Approval Data a detailed QC Plan that is specific for this equipment. It shall encompass the manufacturing process from raw materials receiving to final product shipment and shall specifically define the tests and inspections to be performed to verify

that the hardware and software meet the requirements. The Design Approval Data shall also include a detailed schedule of milestones for meeting delivery dates.

In its QC Plan, the Seller shall establish control factors, processes, and performance indices to meet this specification's technical and operational requirements.

The QC Plan shall include statistical process control (SPC). The Seller shall establish and maintain procedures and requirements for an SPC system based on key characteristics (KC) of each equipment unit and sub-unit. The Seller shall conduct SPC analysis of the KC's. If statistical analysis determines that a KC is out of control, the Seller shall:

- Investigate the cause(s),
- Eliminate special causes of variation and reestablish statistical control, and
- If a KC is not capable, the Seller shall take corrective action to reestablish capability.

The Seller shall document all corrective actions affecting the process and assure the effectiveness of the actions. The Company reserves the right to review the results of all SPC analyses, capability calculations, and corrective actions.

4.3 QUALIFICATION

4.3.1 Product Qualification

This specification requires qualified products, design, manufacturing installation, and operation procedures. The CFSL equipment design, fabrication, installation, and operation should be supported by design calculations, drawings, process control documents (PCD), material specifications, and MSDS. The CFSL design, manufacturing, installation and operations shall fully comply with government safety and health regulations.

4.3.2 Audits

The Company reserves the right to audit equipment manufacturing operations, process records, quality assurance and certification systems, raw material traceability, test procedures, and test data.

4.3.3 Approvals

The Company reserves the right for the final qualification approval of the CFSL design, manufacturing, installation, and operational procedures for successful completion of both base and detail specification requirements.

4.4 CHANGE CONTROL AND NONCONFORMANCE

Formal notification of design or manufacturing changes is required. Company approval is required for major changes and will be granted through Advance Change Notices (ACNs). Prior to implementing a major change, the Seller shall contact the Company with the following information:

a. A detailed description of the change and
b. A draft of the change

The Seller may proceed with the proposed change only after receipt of written authorization by the Company's subcontract administrator.

If it is necessary to make any change in the QC Plan's control factors, the Seller shall request an ACN to revise the PCDs and maintenance manual. The change shall not be incorporated prior to the receipt of a signed ACN.

All deviations from the technical specifications that were not approved prior to conducting activities associated with these deviating conditions shall be classified as nonconformance. All nonconformance documentation shall be provided to the Company's subcontract administrator two weeks prior to shipment of the system. Shipment shall not take place until all nonconformances have been approved by the Company's subcontract administrator.

Suspect/counterfeit products or materials are prohibited. The Seller's Proposal constitutes a certification by the Seller that no suspect/counterfeit items shall be supplied.

The Company's goods recipient will verify that the correct quantity meeting the stated specification, catalogue or related model number, and/or Seller quote is received. Subsequent determination that the incorrect product was provided or that any product fails to function as specified shall be documented as a nonconforming condition and shall be returned to the Seller for reimbursement.

4.5 INSPECTION AND TESTING

The Seller shall submit in its Proposal a Test Matrix listing the proposed performance acceptance tests, and national approved standards for which they apply, if applicable. The Test Matrix shall include an explanation of each test listed along with methods of inspection.

The Seller shall submit in the Design Approval Data a Test Plan outlining how testing and verification will be performed, and standards to be utilized in conducting measurements. This Test Plan shall demonstrate that the installed equipment satisfies requirements and shall include performance testing as described in Section 4.5.2. An Inspection and Test Report documenting the results of all inspection and testing shall be submitted with the Certified Data. The Test Plan shall be a part of the detailed QC Plan and shall at a minimum describe the tests listed in Table 5. All tests require Company approval.

Table 5. Minimum Required Acceptance Tests

Hardware or Function	Test	Specification Section
Creel	Operation, braking, and fiber guiding	3.3.1.1
Baled tow feed	Operation of tow guiding system	3.3.1.2
Bulk material feed	Operation of conveyor and material feed	3.3.1.3
Pre-treatment system	Temperature range, distributions and accuracy wrt set point	3.3.2
Tow oxidation ovens	Temperature range, distributions and accuracy wrt set point, air flow capacity and control	3.3.3.1
Bulk material oxidation ovens	Temperature range, distributions and accuracy wrt set point, gas flow and temperature control accuracy	3.3.3.2
Low temperature furnace	Temperature range, distributions and accuracy wrt set point, nitrogen flow capacity and leakage, exhaust gas leakage	3.3.4.1
High temperature furnace	Temperature range, distributions and accuracy wrt set point, nitrogen flow capacity and leakage, exhaust gas leakage, interlock and alarm function	3.3.4.2
Surface treatment	Electrolyte concentration, supply voltage and current, flow	3.3.5.1

Hardware or Function	Test	Specification Section
unit	circulation, bath temperature, fumed gases, dryer temperature, leakage	
Size application unit	Bath concentration, flow circulation, bath temperature, size content on the fiber, dryer temperature, leakage	3.3.5.2
Tow conveyance	Speed range and accuracy of drive system, operation of tow band spreader and tow band bypasses	3.3.6.1
Tow tensioning and drawing	Tension, speed range, and accuracy wrt set point; tow-to-tow variation in tension; operation of driven passback rolls in oxidation	3.3.6.2
Bulk materials conveyance	Operation and speed of bulk material conveyance system at all major unit operations	3.3.6.3
Winders	Winding speed, accuracy of accumulated tow length measurement	3.3.7.1
Bulk packaging	Conveyance speed, accuracy of accumulated product measurement	3.3.7.2
Thermal oxidizer	Natural gas flow capacity, oxidizing air flow capacity, temperature, alarm, and exhaust gases	3.3.8
Regenerative thermal oxidizer	Natural gas flow capacity, oxidizing air flow capacity, temperature, alarm, and exhaust gases, switching operation	3.3.8
Interconnect piping and ductwork	Damper/valve/vane operation, leakage	3.3.9
Instrumentation	Functionality and accuracy of all instruments	3.4
Data acquisition and control	Essential control functions, common control functions, data acquisition from all instruments, operation of all operator consoles, operation of all input and display devices	3.5
Security	Correct operation of all security interlocks	3.6

4.5.1 Factory Acceptance Testing

The equipment shall be pre-assembled and inspected at the Seller's facility. Inspection and tests to be performed at the Seller's facility shall be identified in the Test Plan. The Seller shall supply all tools and materials required to conduct inspection and testing at its facility. The Company may, at its discretion, witness any or all of the final performance verification inspection and testing performed at the Seller's facility. The Seller shall notify the Company's Technical Project Officer (TPO) at least 30 days in advance of such tests. Results of this testing shall comprise part of the equipment acceptance for shipment.

4.5.2 Equipment Commissioning

The equipment shall be inspected, tested, and commissioned, under the Seller's supervision, after installation to demonstrate full compliance with the specified requirements. These tests shall be conducted in accordance with the Test Plan, subject to Company approval of the Test Plan. The results of post-installation testing shall be documented in an Acceptance Document, fully endorsed by both the Company and the Seller, and shall be the basis for final acceptance.

The equipment shall be commissioned by at least 48 hours of continuous operation satisfying performance requirements for each of the following materials:

1. Maximum width tow band of 24k PAN tows;

2. Maximum width tow band of large (>= 48k) PAN tows;
3. Maximum number of small (3k, 6k, or 12k to be determined by Company) PAN tows;
4. Maximum width mat of PAN, lignin, or pitch-based fibers;
5. Maximum width pile of loose PAN< lignin, or pitch-based fibers.

The precursor fibers used for commissioning shall be selected and provided by the Company.

The Seller shall supervise commencement of operations.

4.5.3 Calibration

The Certified Data package shall indicate the equipment calibration status (calibrated or not calibrated) of each device and - if shipped in a calibrated condition - a description or reference to the method used to perform the calibrations at the time of shipment including the reference standard(s) used for this purpose.

Where applicable, the Certified Data package shall include instructions concerning the calibration of associated devices, instruments, or components to fully ensure the stated operating capabilities based on methods traceable to the US National Institutes for Standards and Technology.

4.6 INSTALLATION

The Seller shall separately price equipment installation in its Proposal. The Company shall have sole discretion and option to select either Seller installation or of contracting installation by others. If the Company contracts installation by others, the Seller shall supervise the equipment installation.

The Seller shall provide an installation plan including preliminary installation procedures in the Design Approval Data. A final installation plan with detailed installation procedures shall be provided with the Advanced Engineering Data package. The Seller shall provide a list of tools and equipment required for installation and alignment, as well as material handling instructions including recommended rigging or lift points for heavy components or assemblies, in the Advanced Engineering Data.

For installation planning purposes, the Seller may assume that utility manifolds will be provided along the nearest wall of the building, at elevations to be provided by the Company during preliminary engineering. The motor control center and CFSL control center will be adjacent to the equipment high-bay. All interconnecting piping, ductwork, wiring, cabling, and their associated structural supports, from the main distribution points to the equipment, between the equipment components, and to/from the control center, shall be designed by the Seller and furnished by the Installer.

4.7 TRAINING

The Seller shall provide operator training for four (4) complete shifts of operators during equipment installation, testing and commissioning. Operator instruction shall include an in-depth classroom lecture and actual operational demonstration of start-up, turn-down, and maintenance procedures.

The Seller shall submit a written training program with its Proposal to include the following elements:

- Equipment included in each training session;
- Trainer's names, qualifications and contact information;
- Anticipated duration of each training session; and,
- Topics and learning objectives, such as:
    - Equipment function;
    - Safe and effective operation of the equipment;
    - Manual and automatic modes of operation for the overall system and each major component; and,
    - Operator cleaning and maintenance tasks.

The Seller shall describe how training will be accomplished so as to safely train the operators during testing and commissioning, without incurring excessive schedule delays. The Seller shall professionally video tape and edit the training sessions. Prior to recording the first training session, the Seller shall submit samples of video/audio quality for approval by the TPO. Video Tape or Digital Video Disc (DVDs) shall be cataloged and added to the O&M Manual deliverables.

4.8 SOFTWARE SUPPORT AND BACK-UP

The Seller shall submit in its Proposal an itemized list of all software included with this equipment. This list shall include a description of the software, what feature(s) this software will enable, a statement addressing who will be responsible for supporting this software, and the software support provider's qualifications. This information shall be updated in the Design Approval Data.

The software shall be validated and verified for correctness prior to release to the Company. The Seller shall include, with the Certified Data shipment, one complete system software backup copy (with offline media capabilities) on Company approved media. The backup software media and backup procedures shall be described in the Design Approval Data. The Seller shall also provide with the Certified Data one complete set of software documentation.

4.9 WARRANTY

The Seller shall submit a detailed warranty description with its Proposal and in the Certified Data Package. It shall also describe any optional Service and Maintenance programs in its Proposal.

4.9.1 Extended Warranty Option

The Seller shall propose, and the Company may exercise at its sole discretion, an Extended Warranty for a total of 2-years after commissioning, and shall assign one (1) fully-qualified person on-site as a full-time operations and maintenance director for the duration of the Extended Warranty period. During the Extended Warranty period, the Seller shall provide, without charge, covered replacement hardware. The Company shall then have 2-years after final acceptance to identify any software defects by testing against the Seller's documentation and the Company's test programs for the control system. The Seller shall repair any defects discovered during the Extended Warranty period.

4.10 RECORD-KEEPING

The manufacturer shall keep the following records on file for a period of at least 5 years from the date of manufacture, unless otherwise specified on the purchase order.

- Traceability
- All records pertaining to raw material receiving inspection and certification, in-process records, and product testing specified in the manufacturer's Quality System and this specification
- All records pertaining to the SPC requirements specified in the manufacturer's Quality System

5. SCOPE OF SUPPLY

The Seller shall provide preliminary engineering, detailed engineering, equipment manufacturing, standard operational procedures, and initial operator training. The Seller will also provide a quote for installation, which the Company may exercise at its option. The Seller shall supervise the equipment installation (if by others), commissioning, and commencement of operations. A detailed tabulation of roles and responsibilities is shown in Table 6. For each subsystem in Table 6, the table entry includes all hardware, software, and structures associated with that subsystem unless otherwise noted.

Table 6. Scope of Supply

Equipment*	Design	Mfr	Install	Test	Accept	Specification Section
Creel	Seller	Seller	Installer	Seller	Company	3.3.1.1
Baled tow feed						3.3.1.2
Tow guiding system	Seller	Seller	Installer	Seller	Company	
Mezzanine	Seller	Seller	Installer	Seller	Company	
Under-mezzanine fire protection system	Company	Company	Company	Company	Company	
Under-mezzanine lighting	Seller	Installer	Installer	Company	Company	
Stairs and gate	Seller	Seller	Installer	Seller	Company	
Gate lock	Seller	Seller	Installer	Seller	Company	
Key card reader	Company	Company	Company	Company	Company	
Crane	Company	Company	Company	Company	Company	N/A
Bulk material feed	Seller	Seller	Installer	Seller	Company	3.3.1.3
Pre-treatment system	Seller	Seller	Installer	Seller	Company	0
Tow oxidation ovens	Seller	Seller	Installer	Seller	Company	3.3.3.1
Bulk material oxidation ovens	Seller	Seller	Installer	Seller	Company	3.3.3.2
Low temperature furnace	Seller	Seller	Installer	Seller	Company	3.3.4.1
High temperature furnace	Seller	Seller	Installer	Seller	Company	3.3.4.2
Surface treatment unit	Seller	Seller	Installer	Seller	Company	3.3.5.1

Equipment*	Design	Mfr	Install	Test	Accept	Specification Section
Size application unit	Seller	Seller	Installer	Seller	Company	3.3.5.2
Tow conveyance	Seller	Seller	Installer	Seller	Company	3.3.6.1
Tow tensioning and drawing	Seller	Seller	Installer	Seller	Company	3.3.6.2
Bulk materials conveyance						3.3.6.3
All equipment except slitter/folder	Seller	Seller	Installer	Seller	Company	
Mat slitter or folder	Company	Company	Company	Company	Company	
Winders	Seller	Seller	Installer	Seller	Company	3.3.7.1
Bulk packaging						3.3.7.2
Fiber guiding systems	Seller	Seller	Installer	Seller	Company	
Mezzanine	Seller	Seller	Installer	Seller	Company	
Under-mezzanine fire protection system	Company	Company	Company	Company	Company	
Under-mezzanine lighting	Seller	Installer	Installer	Company	Company	
Stairs and gate	Seller	Seller	Installer	Seller	Company	
Gate lock	Seller	Seller	Installer	Seller	Company	
Key card reader	Company	Company	Company	Company	Company	
Crane	Company	Company	Company	Company	Company	N/A
Thermal oxidizer	Seller	Seller	Installer	Seller	Company	3.3.8
Regenerative thermal oxidizer	Seller	Seller	Installer	Seller	Company	3.3.8
Exhaust stacks	Seller	Seller	Installer	Seller	Company	3.3.8
Interconnecting hardware						3.3.9
Process exhaust ducts/pipes	Seller	Installer	Installer	Installer	Company	
Enclosure exhaust ducts/pipes	Seller	Installer	Installer	Installer	Company	
Utility piping	Seller	Installer	Installer	Installer	Company	
Process piping (includes deluge water)	Seller	Installer	Installer	Installer	Company	
Electrical wiring	Seller	Installer	Installer	Installer	Company	
Instrument wiring	Seller	Installer	Installer	Installer	Company	
Instrument tubing	Seller	Installer	Installer	Installer	Company	
Seals and gaskets	Seller	Installer	Installer	Installer	Company	
Exhaust – thermal oxidizers to stacks	Seller	Installer	Installer	Installer	Company	
Structural supports	Seller	Installer	Installer	Installer	Company	
Fasteners	Seller	Installer	Installer	Installer	Company	
Permanent access equipment	Seller	Seller	Installer	Seller	Company	3.3.10
Instrumentation	Seller	Seller	Installer	Seller	Company	3.4
Data acquisition and	Seller	Seller	Installer	Seller	Company	3.5

Equipment*	Design	Mfr	Install	Test	Accept	Specification Section
control						
Security						3.6
Software	Seller	Seller	Installer	Seller	Company	
Key card readers	Company	Company	Company	Company	Company	
Card reader interfaces	Seller	Seller	Installer	Seller	Company	
Console departure detectors	Seller	Seller	Installer	Seller	Company	
"Scram" hardware	Seller	Seller	Installer	Seller	Company	
Tension/draw unit enclosures	Seller	Seller	Installer	Seller	Company	
Enclosure door position sensors	Seller	Seller	Installer	Seller	Company	
Enclosure inactivity sensors	Seller	Seller	Installer	Seller	Company	
Enclosure door closing system	Seller	Seller	Installer	Seller	Company	

* All equipment shall include associated fittings, valves, junctions, switches, meters, seals, clamps. fasteners, etc. unless otherwise noted. Installer shall furnish fasteners, gaskets, etc. at interfaces with hardware furnished by Seller or Company.

5.1 PRELIMINARY ENGINEERING

The primary focus of preliminary engineering will be defining the process and project parameters while also moving the project and equipment integration to an advanced stage to develop project details. During this phase, efforts will concentrate on the selection of sub-suppliers and the refinement of the schedule for project execution, based on detailed input from material and technology sub-suppliers. Long lead-time purchases that may impact final delivery are identified and accelerated for early release if necessary to meet the project schedule. Key technical milestones such as PIDs, bills of materials, hazardous operations analysis (HAZOP), risk assessment, and operational review of the design, etc. are developed to finalize the required scope of supply and ensure a successful project.

Completion of this phase of the project allows the Company and the Seller to review the proposed scope of supply and associated costs, to ensure equitable and complete definition of the requirements, and to ensure project success. Each party is given the opportunity to ensure that their responsibilities are clearly understood. The Seller will perform engineering to design, identify, evaluate, select candidate materials and equipment, and perform process integration required to deliver a successful project.

The deliverables of this phase shall include the following, with all resulting documentation submitted with the Design Approval Data:

- Definition of the project team and issuance of subcontracts, if necessary, to ensure proper development by discipline
- Kick-off meeting with the Company's key representatives
- Development of preliminary process flow diagrams
- Development of PID's

- Development of system general assembly and layout diagrams, with recommended design loads
- Confirmation of a detailed equipment list by unit operation
- First revision of basic electrical engineering, including:
  - Single line power and control diagrams
  - Termination drawings
  - Instrumentation list
  - Wiring schematics
- First revision of the conceptual layout of interconnecting vent pipes
- Development of equipment drawings and design details for core technologies
- Identification and qualification of sub-suppliers
- Refinement of technical specifications for the major sub-assemblies and materials packages, preparation for the release of sub-supplier purchase orders
- Definition of battery limits, calculation of utilities and definition of connected loads
- Refinement of the project schedule with critical path analysis
- Identification of potential long lead-time purchases that could negatively impact the project schedule, and preliminary negotiations with suppliers of those items
- Completion of HAZOP and risk assessment for the equipment operation
- Revision of the major engineering documents (PIDs, layout, etc.) to include the incorporation of the results from the HAZOP
- Revision of the scope of supply and the generation of a scope of responsibilities
- Seismic and civil review, if required

5.2 DETAILED ENGINEERING

After the Company's subcontract administrator issues written approval of the Design Approval Data, the Seller shall conduct detailed engineering to finalize all aspects of the preliminary engineering and release design documents for manufacture. The detailed design shall in every respect conform to the requirements of this specification, except if an exception has been granted in writing by the Company's authorized contract representative. Detailed engineering documents, after final revisions, shall be delivered in the Certified Data package. The Seller shall provide in its Proposal a list of all engineering documentation to be provided in the Design Approval Data and Certified Data packages.

5.3 EQUIPMENT MANUFACTURING

The Seller shall fabricate and assemble the equipment in accordance with its detailed design, and deliver the equipment to the Oak Ridge, Tennessee site designated by the Company.

5.4 INSTALLATION

If the Company opts for Seller installation, the Seller shall install the equipment at the site.

If the Company opts for installation by others, the Seller shall provide technically competent staff to supervise the installation.

5.5 COMMISSIONING

The Seller shall provide technically competent staff to supervise the equipment start-up, acceptance testing, commissioning, and commencement of operations. Equipment testing, commissioning, and operator training shall be conducted as described in Sections 4.5 and 4.7.

5.5.1 Commissioning Acceptance Criteria

The Seller's Test Plan and final acceptance criteria shall be developed from the plans, specifications, and equipment manufacturer's operating criteria. The Seller is responsible for meeting contractual requirements found in the plans and specifications. The Seller is responsible for furnishing a working system. All items logged as deficient shall be corrected per the plans and specifications.

5.5.2 Final Commissioning Report Requirements

The Company will utilize a disinterested 3rd party Commissioning Agent (CA), skilled in carbon fiber manufacturing and operation, to assure that the Seller's test plan and commissioning acceptance criteria are achieved. Along with Seller input and coordination, the Company's CA shall submit a final report to the Company which includes a statement that the project meets the Company's performance requirements, and includes a narrative of the results of the completed inspections, operational and functional testing. The final report shall include an outline of the deficiency list and dates identifying items found and dates items corrected. All open items will be identified in the report. Technical data from the equipment shall be included as well as all test results, manufacturer's start-up sheets, and testing adjusting & balancing (TAB) reports when possible. The Company's CA shall also furnish an electronic copy of the final report on Compact Disc (CD) to the Company and Seller; and the CD shall be menu-driven and include all documentation possible from the final report.

At the conclusion of the commissioning process and after the final summary has been completed, the Company's CA shall formally recommend system and equipment performance acceptance to the Company's TPO. The final commissioning report shall include:

1. Summary
2. Commissioning plan
3. Commissioning site visit reports
4. Submittal reviews
5. O&M data reviews

6. PREPARATION AND DELIVERY

6.1 LABELING

A corrosion resistant, metal nameplate shall be attached to each major equipment item. This nameplate shall be plainly and permanently marked with the following information:

Equipment identification number, model number, etc.
Equipment serial number
Seller name
Manufacturer name (if different from Seller)
Manufacturing plant address
Seller product designation
Manufacturer product designation (if different from Seller)
Date of manufacture (month and year)

Separately packaged equipment subassemblies and/or components shall be marked to provide positive identification to the equipment. When such markings impair proper functioning of the equipment, a metal tag shall be used.

6.2 PACKING AND SKIDDING

All the components shall be packaged and skidded to provide protection against deterioration and damage during shipment.

6.3 SHIPPING PLAN

The Seller shall submit in the Design Approval Data, with an update in the Advanced Engineering Data, a shipping plan that shall include a description of methods to be used to preserve, package, skid, and identify equipment. Ground transport shall be by air-ride equipped vehicle(s). After the equipment is loaded at the Seller's facility, unloading and reloading operations shall be limited to those required at terminals where the transport mode is changed (e.g., from ground transport to marine transport). The Seller shall contact the Company ten business days prior to shipment of the equipment to confirm shipping method and route.

6.4 MARKING

Each shipping skid shall be marked with the Seller's name; Company name; Company purchase order number; Seller's model number; equipment, sub-assembly or component identification; and gross weight. Boxes containing loose parts, attachments, and accessories shall be marked for identification with the equipment to which they belong, and where possible, boxes are to be secured to the skid of the basic unit.

6.5 SHIPPING

The Seller shall provide for transport of the equipment from the Seller's facility to the designated site in Oak Ridge, Tennessee, USA. The Seller shall be liable for any damages to the equipment until it is received at the designated site.

6.6 DOCUMENTATION

The Seller shall submit the following Certified Data under a separate cover upon shipment of the equipment:

Complete Bills of Material for all components
Copies of the packing list

7. MANUFACTURERS DATA

Manufacturer's data itemized on attachments ORNL-CFTC-2010CFL01-1, -2, -3, and -4 shall be furnished and transmitted by the Seller to the Company by the dates specified. These data sheets list the information required for the Company to adequately evaluate the Seller's Proposal, approve preliminary engineering and commencement of detailed engineering, obtain engineering requirements for equipment installation, and obtain Certified Data for operating and maintaining the instrument in the Company's facility. The Seller shall mark transmitted data as "Proposal Data", "Design Approval Data", "Advanced Engineering", or "Certified Data". The Seller shall grant the Company unlimited rights to copy and internally distribute data (excluding executable code) that is provided on electronic media.

7.1 PROPOSAL DATA

Proposal data is information considered sufficient to allow a technical evaluation of a manufacturer's proposal and/or product. The proposal should address the requirements in each section of this specification. The Seller shall submit with its proposal copies of data as noted in attachment ORNL-CFTC-2010CFL01-1.

7.2 DESIGN APPROVAL DATA

Design approval data is information required to ensure that the manufacturer has an adequate understanding of specified requirements. Design approval data are generally in the form of preliminary or conceptual drawings, sketches, block diagrams, and/or flow charts. The Seller shall submit design approval data for Company approval within 90 days after award, as noted in attachment ORNL-CFTC-2010CFL01-2.

7.3 ADVANCED ENGINEERING DATA

Advanced engineering data is design information that is sufficient to enable installation engineers to complete the equipment installation design or initiate preliminary material processing. The Seller shall submit advanced engineering data at least 180 days before shipment, as noted in attachment ORNL-CFTC-2010CFL01-3.

7.4 CERTIFIED DATA

Certified data is detailed information that allows for complete installation, alignment, operation, maintenance, and repair of equipment or certification of materials for their intended use. The Seller shall submit certified data upon shipment as noted in attachment ORNL-CFTC-2010CFL01-4.

APPENDIX A. PROCESS DESCRIPTION

Figure A-1 shows a flowchart of the process steps to convert PAN precursor fiber to carbon fiber. These steps are required to produce commercial grade, standard and intermediate modulus carbon fibers. The key steps of the continuous conversion of acrylic precursors to carbon fibers are described in this section.

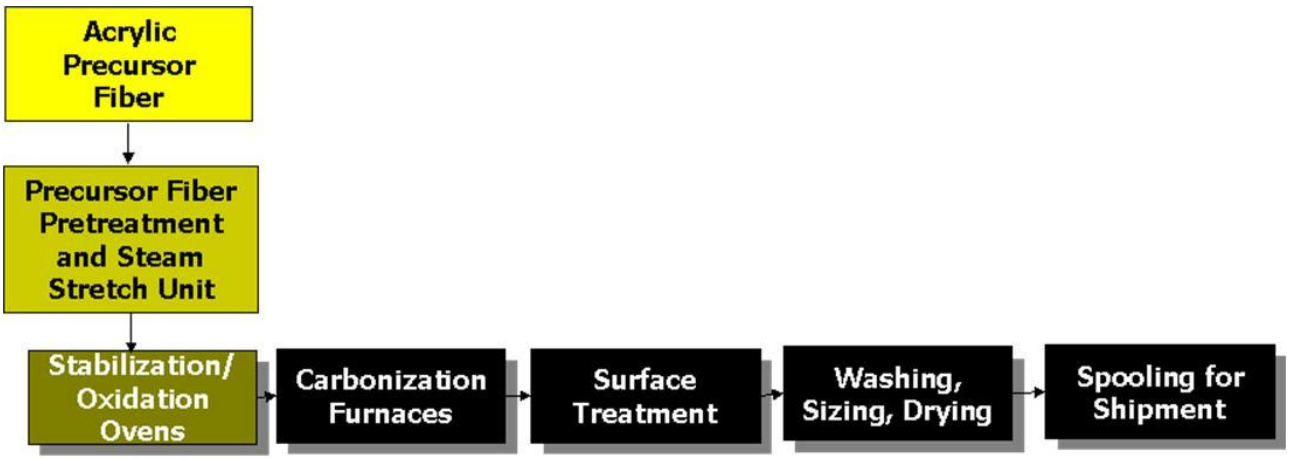

Figure A-1. Conventional PAN Acrylic Fiber Conversion Process Steps.

A.1 PAN Precursor Fiber Conversion Process Summary

Fiber Feed: Precursor fibers are fed from standard packages into the carbon fiber line.

Pre-treatment: The precursor fibers usually undergo pre-treatments such as steam heating and stretching to align the polymer chains.

Oxidation: Acrylic fibers are thermoplastic and must be thermally modified prior to high temperature treatment and conversion to carbon fibers. This modification is achieved by heating the acrylic fibers in air for cross-linking and transformation into thermoset materials. The oxidized acrylic fibers will not melt on subsequent heating. This property makes them suitable for inclusion in flame protective fabrics. Oxidation most commonly occurs between 200º – 300ºC, rarely up to 400°C, with residence time typically well over an hour.

Carbonization: The oxidized acrylic fibers are carbonized in an inert atmosphere at high temperature. During carbonization, non-carbon elements are eliminated to produce fibers with composition approaching 100% carbon. Additionally, crystalline morphology is involved in this step such that the fibers develop their final mechanical properties of tensile strength, modulus, and elongation at break. Carbonization most commonly occurs between 500º – 1,500ºC with a residence time between 2 – 5 minutes. About half of the original mass of the input precursor fibers evolves as gaseous effluents during oxidation and carbonization.

Graphitization: For some specialty applications, carbonized fibers are further graphitized at higher temperature, typically between 2,000º – 3,000ºC with residence time on the order of one minute. This very high temperature treatment is conducted to develop graphitic morphology, thus increasing tensile modulus.

Surface Treatment: Carbonized or graphitized fibers have inert surfaces that do not readily bond to polymer matrices. To promote bonding with the resin in the final composite, the fibers are chemically activated in a surface treatment process.

Sizing: The surface treated fibers are normally coated with finish materials called sizing. This sizing both protects the fibers during subsequent handling and promotes wetting when impregnating the fibers with resins during composite manufacture.

Collection: The finished carbon fiber is collected into a standard package.

A.2 Brief Description of the major equipment and operation

A creel is used to mount acrylic precursor fibers which are wound on large spools. Alternatively, acrylic fibers may be fed from bale or box type packaging in a large tow format. Typically the fibers are initially drawn from the creel or boxes through a pre-treatment system that includes a thread guide, pre-stretching station, precursor moistening unit, and tow band forming combs.

After pre-treatment, the fibers are oxidized. The oxidation equipment is comprised of a series of ovens, each with multiple independently controlled heating zones. Hot air circulates and progressively oxidizes the acrylic fiber. The tow band is drawn through the ovens by drives. Proper material handling within the ovens is achieved by varying the speed of the intermediate drives. The exiting process gas is passed through a thermal oxidizer to oxidize the effluent prior to discharging it to the atmosphere.

After oxidation, the oxidized acrylic tows are carbonized. Typically there are two nitrogen-purged carbonization furnaces. In the first ("low-temperature" or LT) furnace the temperature is typically between 500º – 1,000ºC, most of the non-carbon mass is eliminated, and crystalline morphology begins to form. In the second ("high-temperature" or HT) furnace, the temperature is typically between 1,000º – 1,500ºC and the remaining non-carbon mass is eliminated such that the fiber's composition approaches 100% carbon.

Graphitization, if conducted, typically occurs in a third ("ultra-high temperature" or UHT) furnace. The UHT furnace may operate at up to 3,000ºC may and may require an inert cover gas other than nitrogen for health and safety reasons.

The tow band typically makes multiple passes through the oxidation ovens, followed by a single pass through each carbonization and graphitization furnace. The effluent, including tars, from the off gassing in the oxidation ovens, carbonization furnaces, and graphitization furnace (if used) is fed into a thermal oxidizer where it is oxidized prior to discharge to the atmosphere. All process gas effluent streams are sucked through the thermal oxidizer and the heat exchangers by a purified air fan. This allows the incinerator combustion chamber to have negative pressure, and prevents untreated air from being released to the atmosphere.

The thermal treatment units (oxidation ovens, LT furnace, and HT furnace) are the heart of a carbon fiber line and represent a significant proportion of the total line cost. The physical size of the oxidation ovens and carbonization furnaces is largely a function of the line speed rather than the mass throughput.

The carbonized or graphitized fibers are delivered to a surface treatment unit, to improve the adherence of the fiber to the resin matrix and improve the final properties of the composite. The most common surface treatment method is immersion in an electrolytic bath, followed by washing and drying. An alternative surface treatment method that is growing in popularity is exposure to an ozone-rich environment. Typical surface treatment residence times are tens of seconds for both methods.

Finally, the fibers are passed through a water-based sizing bath for a few seconds. The roller formation in the bath provides an even impregnation throughout the fibers on the individual strands. The fibers are then dried.

The most common collection method is precision winding onto cylindrical spools, followed by shrink wrapping. Instead of spooling, the fibers may be draped in a box as required for some end user applications.

Throughout the conversion process, fiber tensioning and stretching are very important. Therefore tension stands and stretch roll stands are strategically located along the tow band. A central, computerized control and data acquisition system is interfaced to all process and mechanical equipment to ensure that the equipment components and modules are working properly as a system and to log the process data.

ATTACHMENT 1. ORNL-CFTC-2010CFL01-1 PROPOSAL DATA

EQUIPMENT SPECIFICATION HIGHLY FLEXIBLE CARBON FIBER SEMI-PRODUCTION LINE	Specification Number ORNL-CFTC-2010CFL01-1	Revision 0
	Issue Date	Revision Date
	Plant: Offsite	Page 1 of 2

MANUFACTURER'S DATA REQUIREMENTS

Item No.	DATA SUBMITTAL—PURPOSE AND DESCRIPTION	Specification or Reference	Number of Copies	Form[a]	Date[b]
	Proposal Data The Seller shall submit the following information with its Proposal				
1	Summary of overall system design and performance parameters	3.1	6	E	
2	Description and footprint layout of entire CFSL	3.2	6	E	
3	Basic description and specification of all process equipment	3.3	6	E	
4	Bulk oxidizer gas flow configuration recommendation and basis	3.3.3.2	6	E	
5	Types and concentrations of electrolyte that can be used, residence time, and fiber drying method in surface treatment unit	3.3.5.1	6	E	
6	Size application residence time and drying method	3.3.5.2	6	E	
7	Type of drive unit and number of rolls at each drive unit position	3.3.6.2	6	E	
8	Effluent treatment device(s) size, weight, and structural loads	3.3.8	6	E	
9	Summary list of interconnecting hardware and associated support structures	3.3.9	6	E	
10	List of permanent access equipment and the process equipment for which it provides access	3.3.10	6	E	
11	List of instruments, including type and accuracy data for each instrument	3.4	6	E	
12	Description of data acquisition and control hardware, software, capabilities, features, operational modes, and options	3.5	6	E	
13	Data acquisition and control system computer hardware specification	3.5.1.1	6	E	
14	Description of process floor consoles and their locations	3.5.1.2	6	E	
15	Description of data acquisition and control functions	3.5.1.3	6	E	
16	Brief description of CFSL security features	3.6	6	E	
17	List of major equipment components or subsystems with the associated ECCNs	3.6	6	E	
18	Utility requirements (electricity, natural gas, cooling water, process water, deluge water, nitrogen, HVAC, miscellaneous) and preliminary guidance on interconnection hardware	3.9	6	E	
19	Floor loading diagram, estimated loads on building structures, weights of all equipment components and assemblies.	3.9.8	6	E	

ATTACHMENT 1. ORNL-CFTC-2010CFL01-1 PROPOSAL DATA (CONTINUED)

EQUIPMENT SPECIFICATION	Specification Number ORNL-CFTC-2010CFL01-1		Revision 0
	Issue Date	Revision Date	
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MANUFACTURER'S DATA REQUIREMENTS

Item No.	DATA SUBMITTAL—PURPOSE AND DESCRIPTION	Specification or Reference	Number of Copies	Form[a]	Date[b]
	Proposal Data (Continued)				
20	Summary operations manuals	3.11	6	E	
21	Prices for optional packaging equipment	3.12.1	6	E	
22	Description of general quality assurance program	4.1	6	E	
23	Specified requirement(s) that are not satisfied by the proposal	4.1	6	E	
24	Test matrix	4.5	6	E	
25	Price for equipment installation	4.6	6	E	
26	Description of training program	4.7	6	E	
27	Itemized list of software with software support information	4.8	6	E	
28	Warranty description, including optional service and maintenance programs	4.9	6	E	

[a]Indicate the following:
A—Full size prints
B—Full size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Seller's standard form
F—Other (Specify) Standard AWS or ASME forms
G- Other (Specify) Electronic media

[b]To be completed by the contract administrator at the time of award.

ATTACHMENT 2. ORNL-CFTC-2010CFL01-2 DESIGN APPROVAL DATA

EQUIPMENT SPECIFICATION	Specification Number ORNL-CFTC-2010CFL01-2	Revision 0
	Issue Date	Revision Date
HIGHLY FLEXIBLE CARBON FIBER SEMI-PRODUCTION LINE	Plant: Offsite	Page 1 of 2

MANUFACTURER'S DATA REQUIREMENTS

Item No.	DATA SUBMITTAL—PURPOSE AND DESCRIPTION	Specification or Reference	Number of Copies	Form[a]	Date[b]
	Design Approval Data The Seller shall submit Design Approval Data within 90 days after award of contract unless otherwise noted. This data will be used as part of Company Acceptance.				
1	Description and footprint layout of entire CFSL	3.2	6	E	
2	Basic description and specification of all process equipment	3.3	6	E	
3	Effluent treatment device(s) size, weight, and structural loads; effluent discharge estimates	3.3.8	6	E	
4	Preliminary design data for interconnecting hardware and associated support structures	3.3.9	6	E	
5	Preliminary design of permanent access equipment	3.3.10	6	E	
6	Instrument specifications	3.4	6	E	
7	Data acquisition and control system computer hardware specification	3.5.1.1	6	E	
8	Description of process floor consoles and their locations	3.5.1.2	6	E	
9	Description of data acquisition and control functions	3.5.1.3	6	E	
10	Specifications of security equipment	3.6	6	E	
11	Identification of any breathing hazards	3.8	6	E	
12	Pressure containment structures requiring ASME code stamp	3.8	6	E	
13	Electrical schematics, wiring diagrams, interconnection diagrams, and control panel layouts	3.9.2	6	E	
14	Floor loading diagram, loads on building structures, weights of all equipment components and assemblies	3.9.8	6	E	
21	Preliminary design of optional equipment (if purchased)	3.12.1	6	E	
22	Detailed QC plan	4.2	6	E	
23	Detailed milestone schedule	4.2	6	E	
24	Test plan	4.5	6	E	
25	Preliminary installation plan	4.6	6	E	

ATTACHMENT 2. ORNL-CFTC-2010CFL01-2 DESIGN APPROVAL DATA (CONTINUED)

EQUIPMENT SPECIFICATION	Specification Number ORNL-CFTC-2010CFL01-2	Revision 0
	Issue Date	Revision Date
HIGHLY FLEXIBLE CARBON FIBER SEMI-PRODUCTION LINE	Plant: Offsite	Page 2 of 2

MANUFACTURER'S DATA REQUIREMENTS

Item No.	DATA SUBMITTAL—PURPOSE AND DESCRIPTION	Specification or Reference	Number of Copies	Form[a]	Date[b]
	DESIGN APPROVAL DATA (CONTINUED)				
26	Itemized list of software with software support information and description of backup software media and procedures	4.8	6	E	
27	Preliminary engineering documents	5.1	6	E	
28	Shipping Plan	6.3	6	E	

[a]Indicate the following:
A—Full size prints
B—Full size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Seller's standard form
F—Other (Specify) Standard AWS or ASME forms
G- Other (Specify) Electronic media

[b]To be completed by the contract administrator at the time of award.

ATTACHMENT 3. ORNL-CFTC-2010CFL01-3 ADVANCED ENGINEERING DATA

EQUIPMENT SPECIFICATION	Specification Number ORNL-CFTC-2010CFL01-3	Revision 0
	Issue Date	Revision Date
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MANUFACTURER'S DATA REQUIREMENTS

Item No.	DATA SUBMITTAL—PURPOSE AND DESCRIPTION	Specification or Reference	Number of Copies	Form[a]	Date[b]
	Advanced Engineering Data The Seller shall submit Advanced Engineering Data 180 days before shipment. The Company will use this data to perform the installation engineering.				
1	Description and footprint layout of the entire CFSL	3.2	6	A	
2	Design data for interconnecting hardware and associated support structures	3.3.9	6	E	
3	Piping and instrumentation diagrams	3.4	6	A	
4	Detailed drawings for utility connections (electricity, natural gas, cooling water, process water, deluge water, nitrogen, HVAC, miscellaneous)	3.9	6	A	
5	Schedule of floor penetrations	3.9.8	6	E	
6	Operation and maintenance manuals	3.11	6	E	
7	Detailed design of optional packaging equipment, if purchased	3.12.1	6	E	
8	Final installation plan	4.6	6	E	
9	List of tools and equipment required for equipment installation, handling procedures for heavy components or assemblies	4.6	6	E	
10	Shipping Plan	6.3	6	E	

[a]Indicate the following:
A—Full size prints
B—Full size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Seller's standard form
F—Other (Specify) Standard AWS or ASME forms
G- Other (Specify) Electronic media

[b]To be completed by the contract administrator at the time of award.

ATTACHMENT 4. ORNL-CFTC-2010CFL01-4 CERTIFIED DATA

EQUIPMENT SPECIFICATION	Specification Number ORNL-CFTC-2010CFL01-4		Revision 0
	Issue Date	Revision Date	
HIGHLY FLEXIBLE CARBON FIBER SEMI-PRODUCTION LINE	Plant: Offsite	Page 1 of 1	

MANUFACTURER'S DATA REQUIREMENTS

Item No.	DATA SUBMITTAL—PURPOSE AND DESCRIPTION	Specification or Reference	Number of Copies	Form[a]	Date[b]
	Certified Data				
	The Seller shall submit the following Certified Data under a separate cover upon shipment of the equipment				
1	Certified correct copies of all Proposal Data items		4 1	E G*	
2	Certified correct copies of all Design Approval Data items		4 1	E G*	
3	Certified correct copies of all Advanced Engineering Data items		4 1	E G*	
4	Documentation of all diagnostic test circuits and test programs for data acquisition and control system	3.5.3	4 1	E G*	
5	Spare parts list	3.10	4 1	E G	
6	Rated capacities and capabilities, accuracy, and uncertainty performance specifications	4.1	4 1	E G	
7	Certificate of conformity	4.1	4 1	E G	
8	Inspection and test report	4.5	4 1	E G	
9	Equipment calibration status and procedures	4.5.3	4 1	E G	
10	Backup software with documentation	4.8	4 1	E G	
11	Final design documentation	5.2	4 1	E G	
12	Bills of materials and packing lists	6.6	4 1	E G	

[a]Indicate the following:
A—Full size prints
B—Full size reproducibles
C—Microfilm aperture card
D—Manual (booklet, brochure, report, etc.)
E—Other (Specify) Seller's standard form
F—Other (Specify) Standard AWS or ASME forms
G- Other (Specify) Electronic media

[b]To be completed by the contract administrator at the time of award.

ATTACHMENT 5. ORNL-CFTC-2010CFL01-5 EFFLUENTS FROM LIGNIN AND POLYETHYLENE

EQUIPMENT SPECIFICATION	Specification Number ORNL-CFTC-2010CFL01-5	Revision 0
	Issue Date	Revision Date
HIGHLY FLEXIBLE CARBON FIBER SEMI-PRODUCTION LINE	Plant: Offsite	Page 1 of 1

ESTIMATED EFFLUENTS FROM LIGNIN AND POLYETHYLENE FIBERS

All effluent data expressed as mass percentage of precursor fibers fed to the semi-production line

Lignin (Kraft)

Gases evolved in oxidation oven or equivalent (air/oxygen) <400°C

Negligible

Gases in LT furnace

Volatiles: 40-45% of lignin (dry basis)

H_2 7-9% (of volatiles)

CO 24-28%

CO_2 14-16%

H_2O 5-10%

O_2 1-3%

VOCs 38-44% (mainly comprising coniferaldehyde, coniferyl alcohol, syringaldehyde, and sinapyl alcohol

Tar: 3-5% of lignin (dry basis)

Polyethylene

Gases evolved in oxidation oven or equivalent (air/oxygen) <400°C

SOx vapor	~ 190%
Water vapor	~ 43%

Gases evolved in LT furnace (400-800°C)

Sulfur-containing volatile gas	~ 2%
Hydrocarbon and other vapors	~ 30%
Tars	~ 2%

ATTACHMENT 6. ORNL-CFTC-2010CFL01-6 ABBREVIATIONS AND ACRONYMS

AC	Alternating current
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CA	Commissioning agent
CD	Compact disc
CD-RW	Compact disc read and write
CFR	Code of Federal Regulations
CFSL	Carbon Fiber Semi-production Line
dBA	Decibels adjusted
DVD	Digital video disc
DVD-ROM	Digital video disc – read only memory
EMI	Electromagnetic interference
FTIR	Fourier transform infrared
GB	Gigabyte
IBM	International Business Machines
KVA	Kilovolt-Amperes
Na	Sodium
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association; also National Fluid Power Association
NRTL	Nationally Recognized Testing Laboratory
pA	Picoamp
PAN	Polyacrylonitrile
PC	Personal computer
QC	Quality control
QCP	Quality control program
RAM	Random access memory
TAB	Testing adjusting and balancing
TPO	Technical project officer
UL	Underwriters' Laboratories
USB	Universal serial bus
VIN	Valve identification number