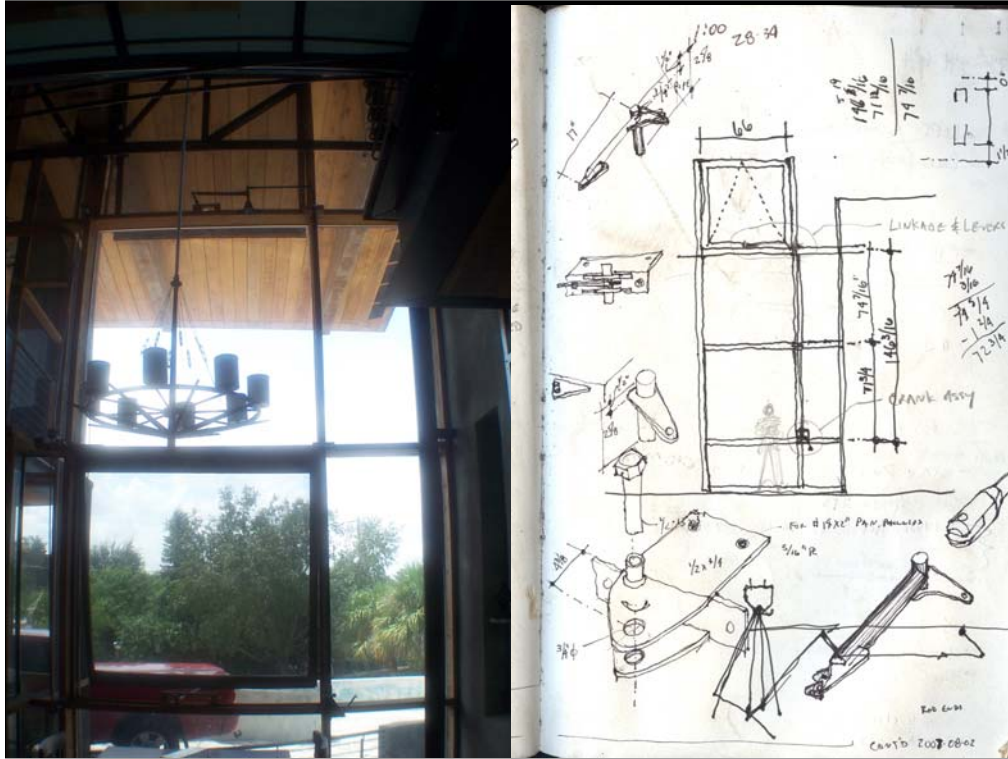
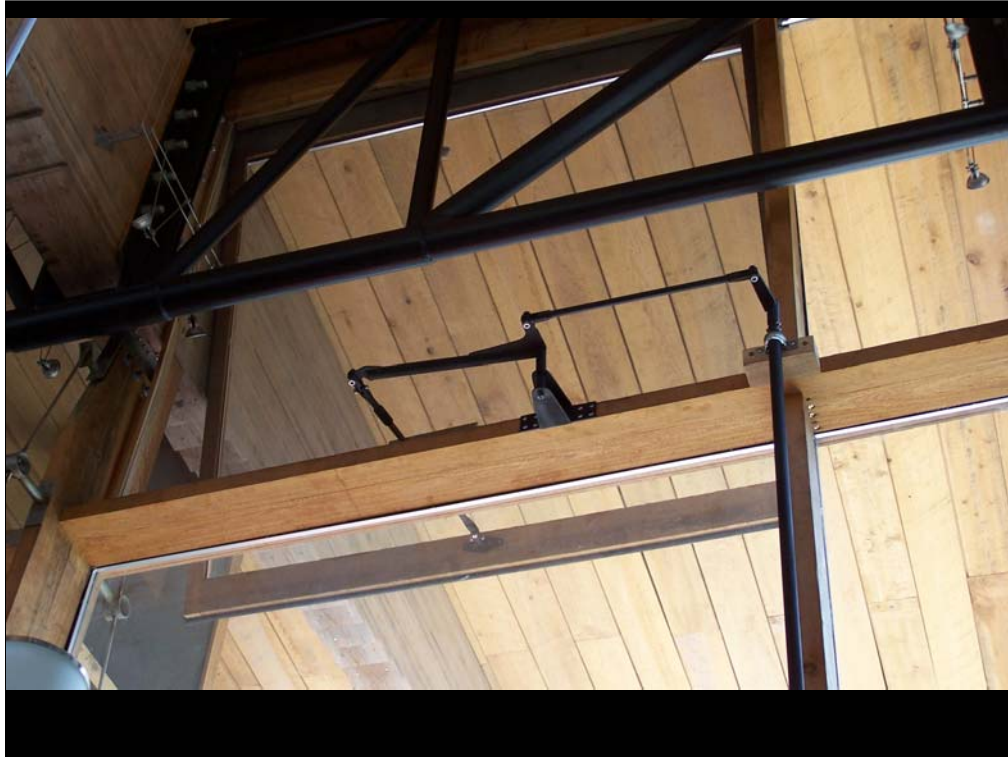


Operable panels design and fabrication

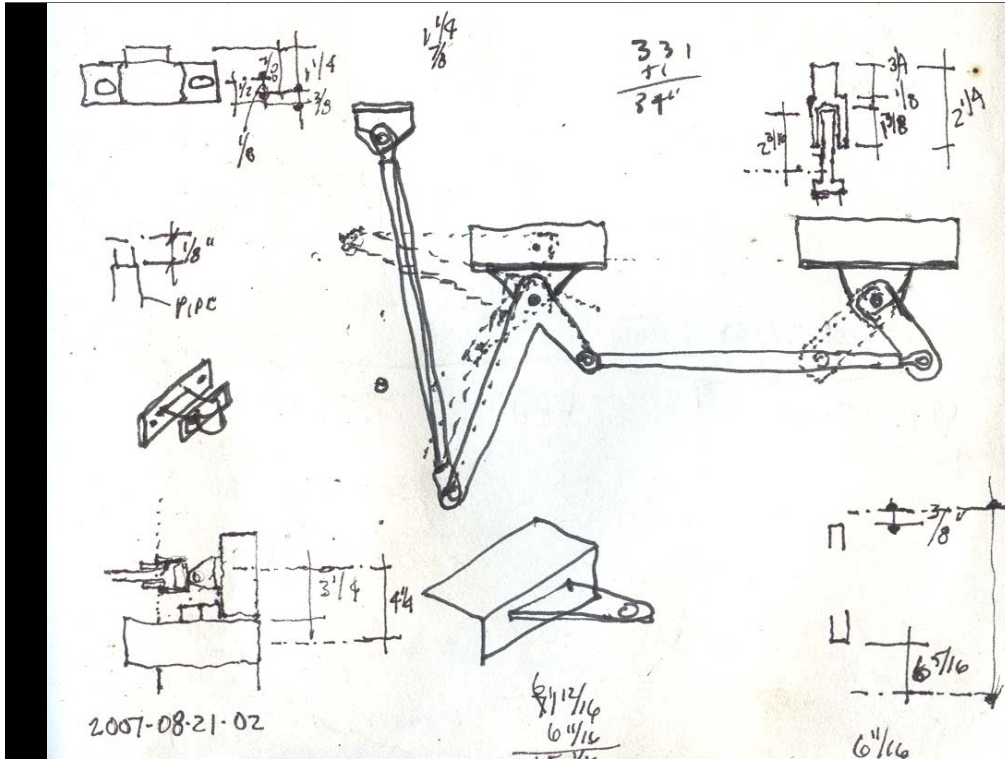




Window Hardware. Open a 200# awning window, 6'x6' 10" open at bottom. Sketch at right shows overall elevation and concept for using a simple worm gear & sprocket crank like a boat winch and linkage to open the panel.



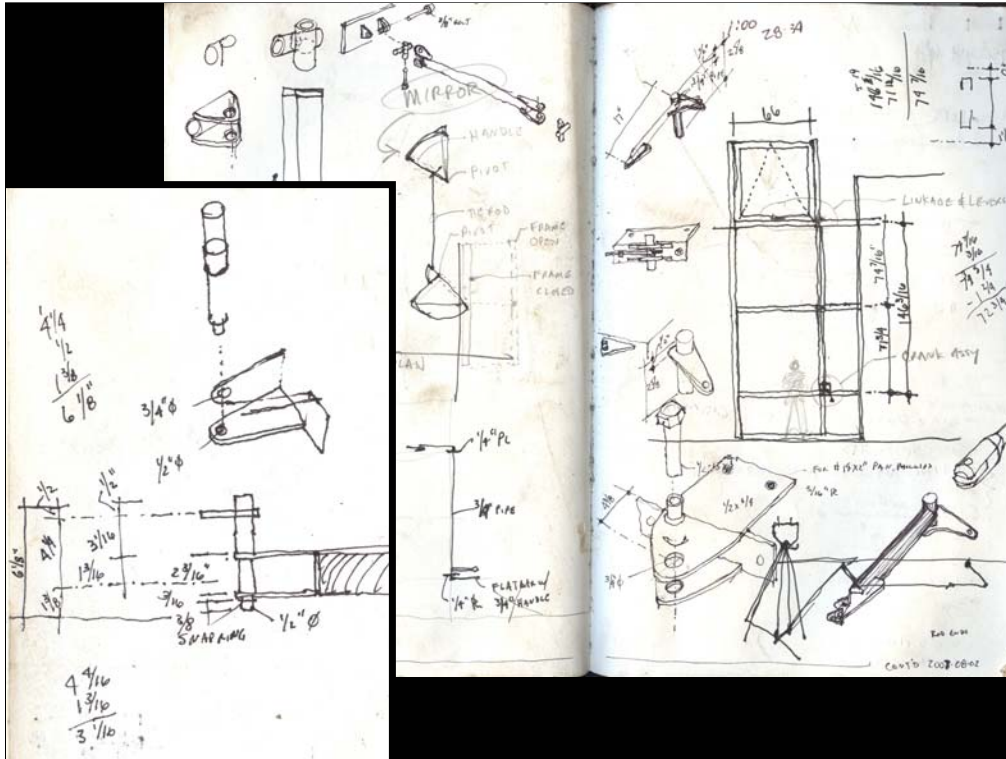
Use of simple materials, steel with brackets fabricated from plain sections: flat bar, pipe, solid round bar.



Concept is to use rotary motion to pivot a set of levers and pushrods to amplify the throw and open the 200# panel a distance of 10". At center are the two levers, right comes from the shaft turned by the boat winch, rotates a total of 90deg. And pushes a second bracket which has a lever arm designed to turn the 90deg rotation into a 10" throw. Lower left is the connection detail to the window frame through the screen (vertical dotted line). A steel 't' shaped bracket would be screwed to the window frame allowing the pushrod to be connected with a vertical bolt to allow for slight rotation as the levers cause it to change geometry. The pushrod also is allowed to slip through a small flap in the screen to maintain the insect protection.



Slide shows the bracket placement on the horizontal mullion plus the ends of the pushrods. Note the connection at left, it is a 'universal joint' allowing pivot movement in two directions. This is to account for geometry changes as the lever rotates and the glass panel also rotated on its hinges. The joint pieces are made from sections of $\frac{3}{4}$ " dia. Steel round bar turned on a metal lathe and cut/notched with a metal cutting bandsaw. The flat plate at the center is a reinforcing plate resolving the moment forces caused by the lever action and allowing the pushrod ends a flat connection point. The vertical pivot pin is held in place with a 'c-clip' and has a 'shoulder' at the top horizontal plate to keep it from riding out of its seat. The (8) screws into the horizontal mullion must be calculated to resist the moment from the 200# glass panel pushing on the lever arm. These specs can be found in the Wood Design Manual by the American Forest Products Association (link on class website – www.calivnodesign.com/70050/).



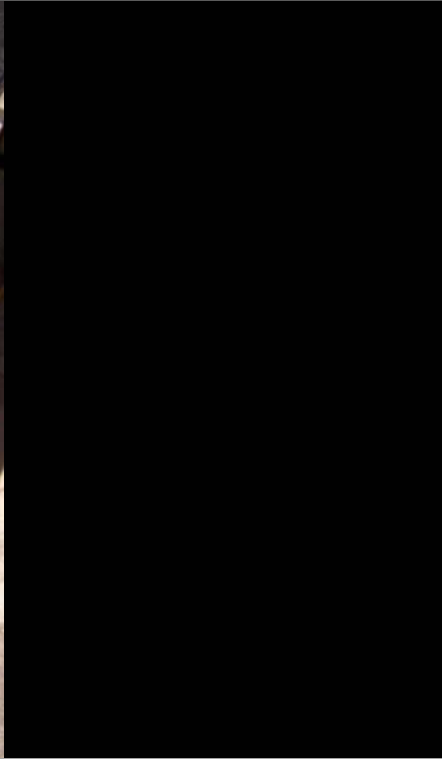
More sketches of the hardware development: the lower left is the center pivot bracket seen on previous slide. The pin configuration with its 'shoulder' can be seen here. This pin can be made on a metal lathe using a solid round steel bar of the larger diameter and turning the lower portion down to the smaller dia.



Opener made from worm drive cable winch.

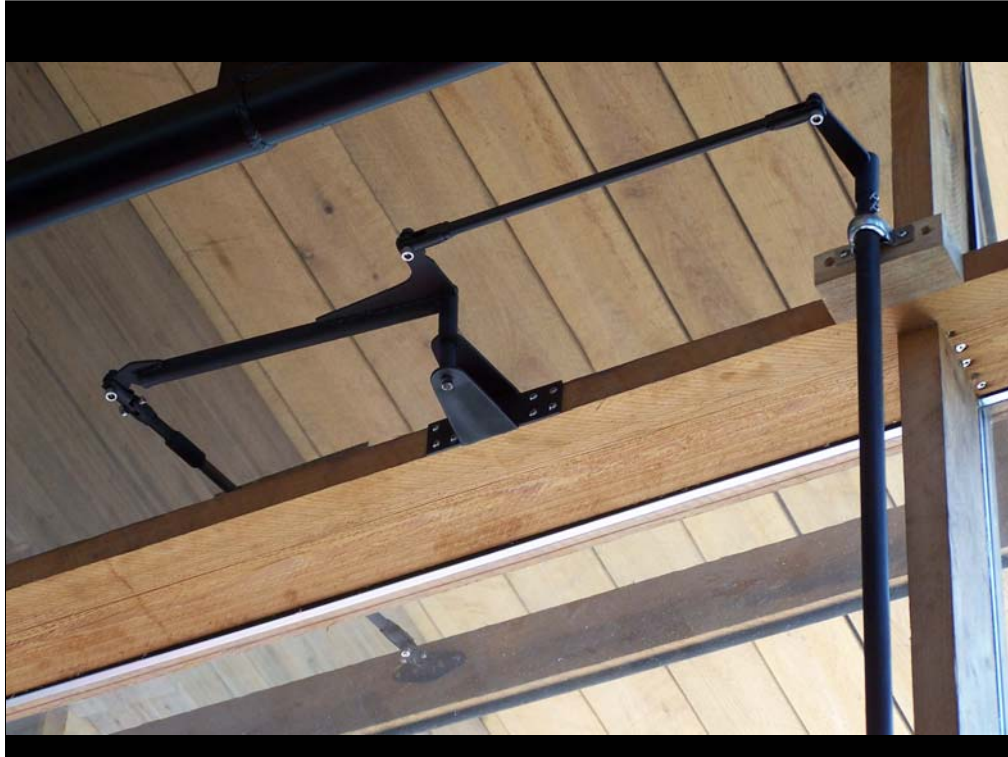


Process photos, before, during. The small angles are the stops which regulate how far the opener can turn.





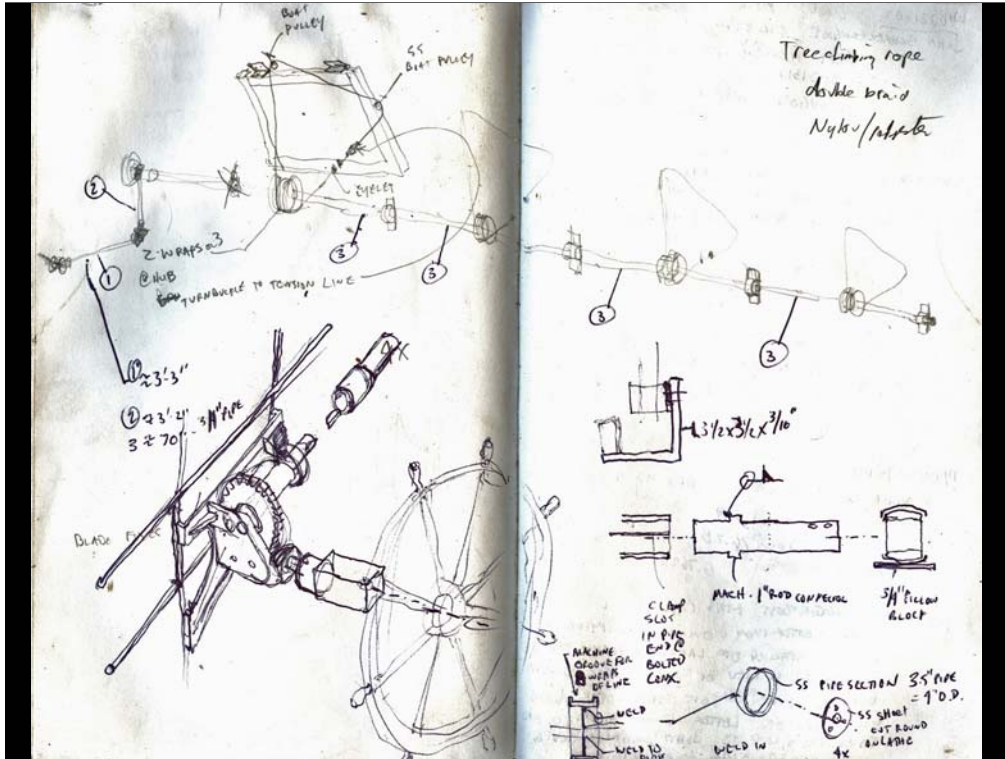
The parts being mocked up in the shop. The linkage rods can be seen at right with the end connections.



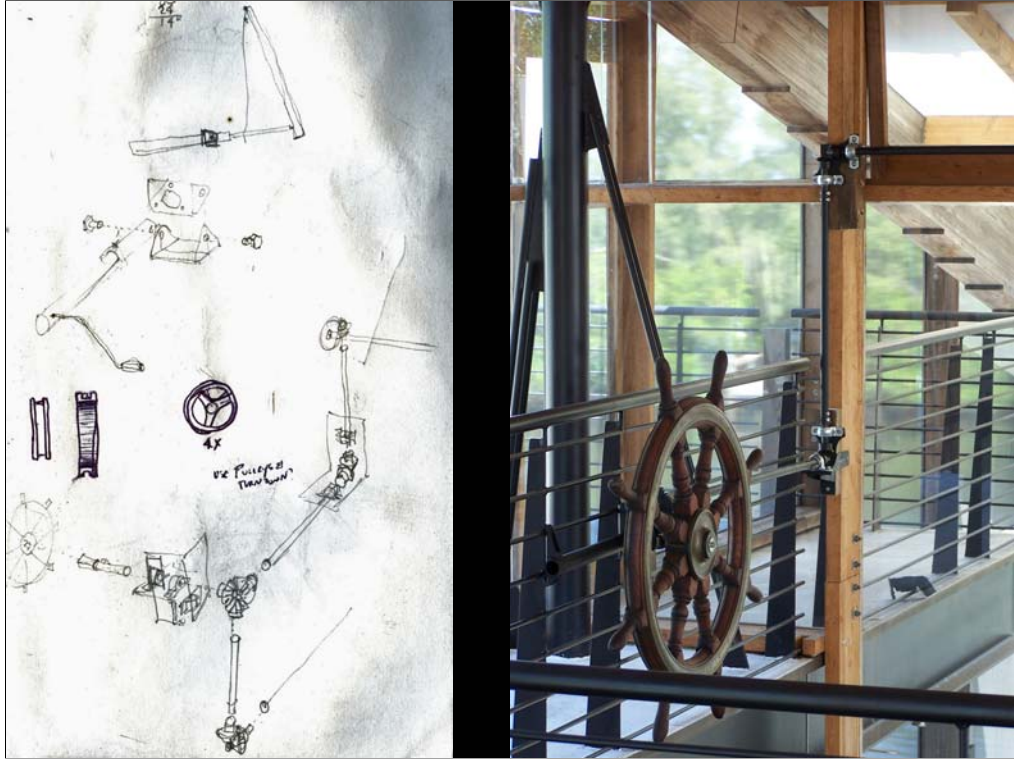
Close up of the linkage arms. Note the pushrod on the far left, there is a threaded coupling to control and adjust the length of the rod to ensure complete closure.

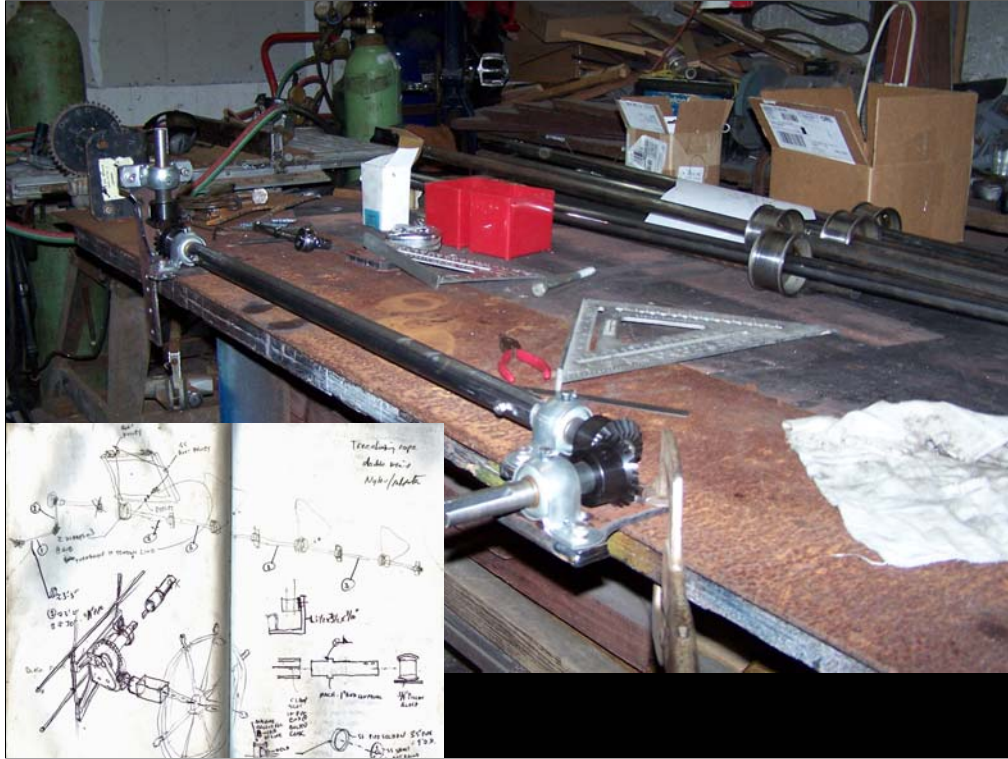


Second example, 4 clerestory panels, 3'x6' at 15' above finished floor, controlled by a ship's steering wheel made of solid brass and mahogany. The wheel came from a ferry that used to run between the Jersey shore and Manhattan.

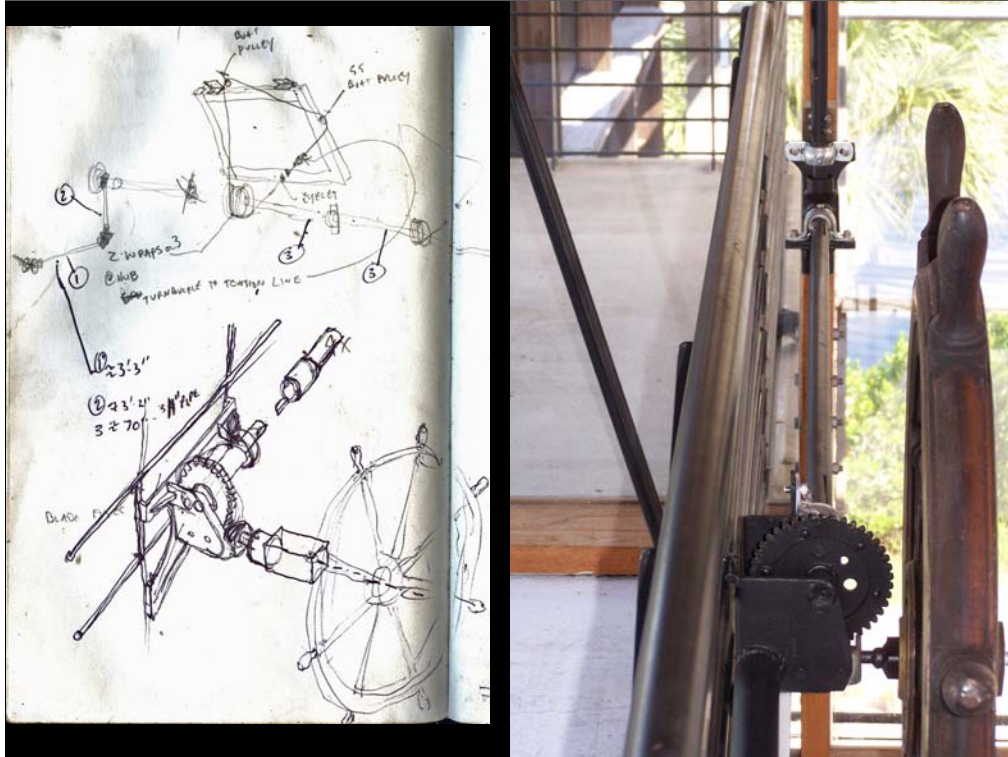


The wheel is mounted on an adapter block that is made to attached the wheel to the cable winch. Also a worm drive cable winch. The pieces are the wheel, the cable winch, solid steel drive rods with 2 sets of miter gears to change directions twice, and the long drive rod with stainless steel hubs scrolling a stainless steel cable at each opening panel.

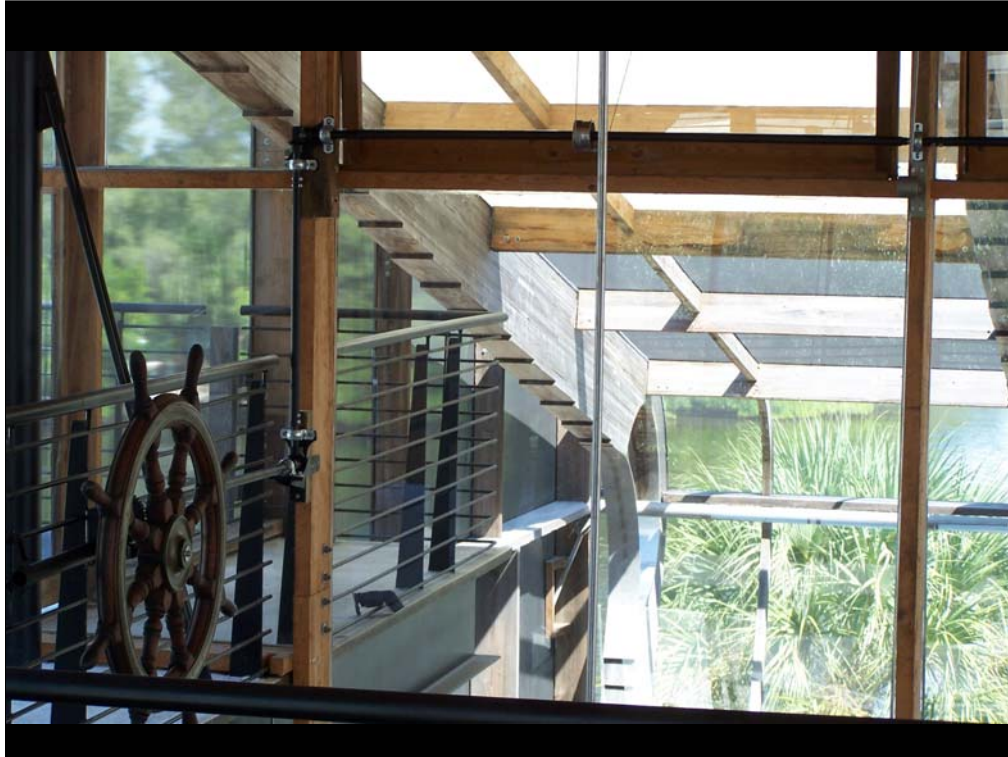




View of one of the miter gear sets used to change directions. The miter gears can be purchased through McMaster Carr Company, an industrial supply company (www.mcmaster.com) and the rods are held in place using what's called pillow block bearings. These are simply a bearing with a mounting bracket to bolt it down to something. These come in many sizes based on bearing size.



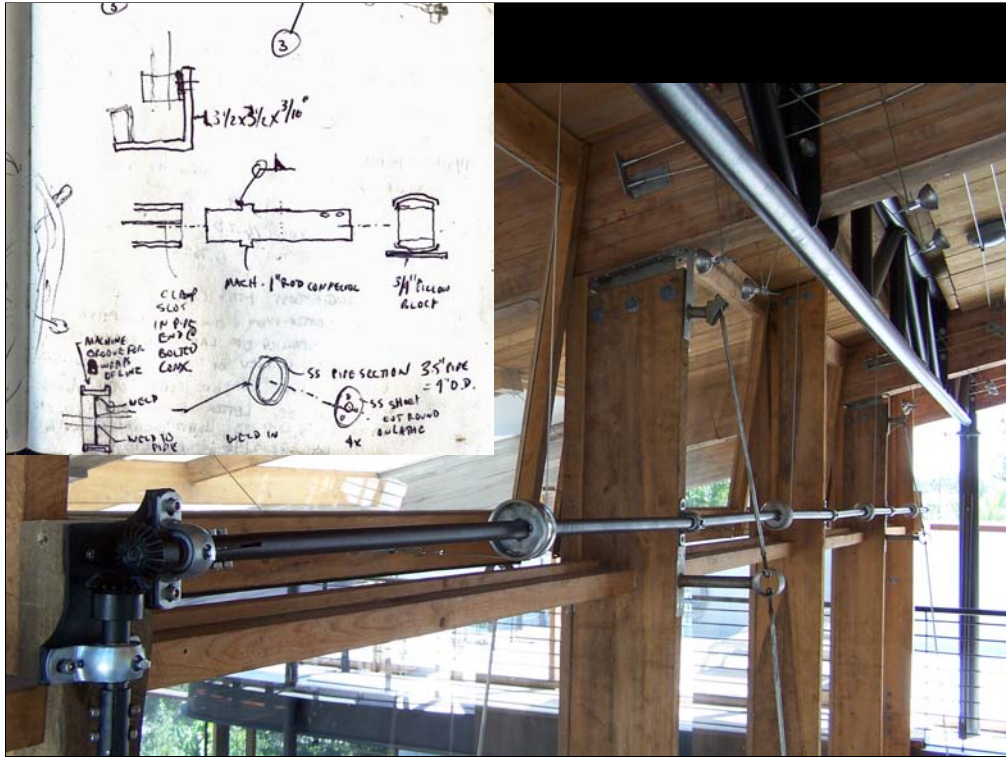
A closer view of the wheel and its attachment to the cable winch. The miter gear set can be seen in the background.



This photo shows the two miter gear sets and how they change the direction of the shaft rotation so that we are turning the shaft across the bottom edge of the panels to be opened.



One of the shafts with its stainless hub for scrolling the stainless cable to open the panel.



Here is the shaft with its hub and cable in place. The hub is made from a 2" wide slice of a 3" schedule 40 stainless steel pipe that has been turned on a lathe to provide a lip at each face to keep the cable from slipping off the edge of the hub. The width of the hub is determined by the diameter of the cable (1/8" in this case) times the number of wraps to develop enough friction to prevent slippage (2 or in this case) and the number of turns it will take to open the panel fully. The sketch shows the hub and the connection between shaft lengths. The shafts are coupled by turning a rod on a lathe to fit inside of one section of pipe and welding it, this will have a lip which fits into one of the pillow block bearings and the other end will extend through another pillow block bearing and into the next shaft section where it is secured with (2) 1/4-20 (1/4" dia x 20threads per inch) stainless steel, allen head cap machine screws. The second shaft is slotted so that when the screws are tightened, they clamp the end of the pipe around the extending shaft and secure it mechanically as well as with a friction force.



Note the cable that runs up to a pulley at the head of the window, through the gap between the head of the panel and the ceiling boards, to another pulley outside, and down to the sill of the panel outside.



One issue that was not foreseen initially is that the length of the cable must change during the opening process because of the nature of the triangle/square. When the panel is closed, the cable is at its shortest length and forms a triangle. As the panel opens, the cable triangle becomes a polygon with 4 sides and as it opens, the sum of the 4 sides increases as a 4th vertex is made. This was overcome by placing a spring of known tension coefficient on the outside of the panel at the end of the cable so that it can stretch while maintaining constant pressure pulling from the outside between the 4 separate panels. The spring is on the outside so that there will be a positive force (not spring loaded) pulling the panels closed while in the closed position ensuring a positive seal.



The 4 clerestory panels can be seen in the background just below the far pipe truss.





Tom Kundig, find more info at <http://www.olsonkundigarchitects.com/>



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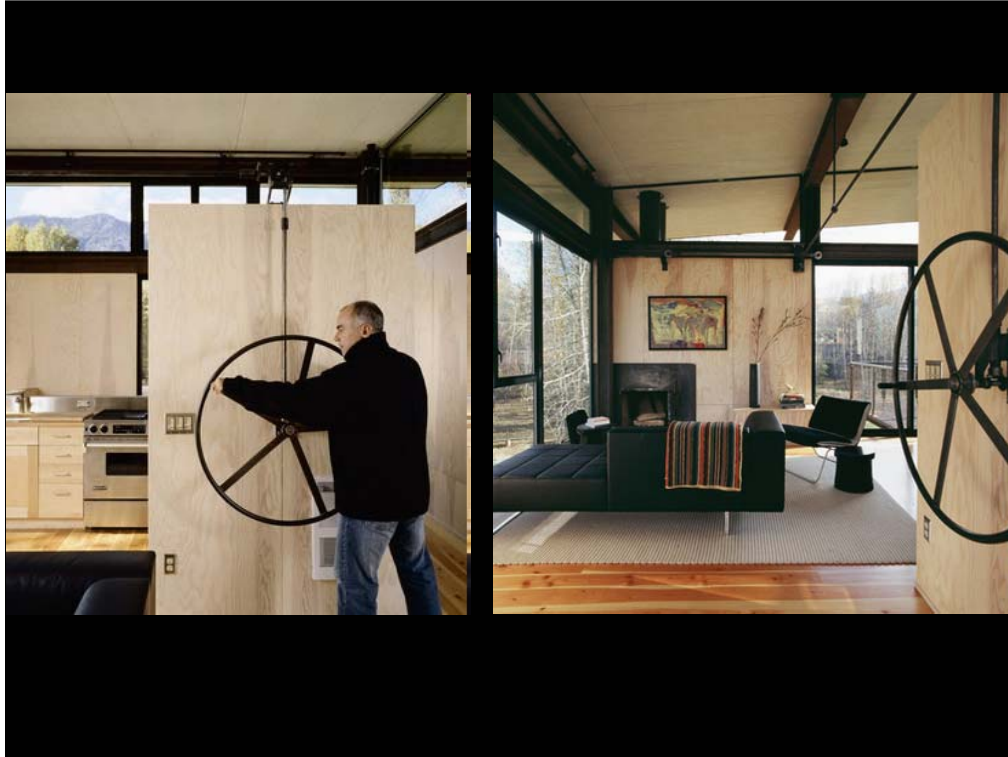
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Delta Shelter

PROJECT ROLES
Tom Kundig, Design Principal

LOCATION & YEAR
Mazama, WA, 2005

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PROJECT DETAILS RECOGNITION RELATED WORKS INTERIORS

This 1,000 square-foot weekend cabin, basically a steel box on stilts, can be completely shuttered when the owner is away. Situated near a river in a floodplain, the 20' x 20' square footprint rises three stories and is topped by the living room. Kitchen. Large, 10' x 18' steel shutters can be closed simultaneously using a hand crank.

Interiors by Olson Kundig Architects.

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