Emergency: Rotor discs replaced

Quick repairs keep 16T tests on track

Crews recently completed a fast-track maintenance and repair project to replace three rotor discs in the C1 compressor, and ensure uninterrupted use of the sole compressor for AEDC's 16-foot transonic wind tunnel,

The large, three-stage axial flow compressor drives air around the Propulsion Wind Tunnel's 16T-test circuit. Air Force Project Manager Simon Choi said, since 16T is used primarily to test the aerodynamic performance of large-scale aircraft models and full- and large-scale missiles, the condition of the facility's infrastructure directly impacts AEDC financially and our national test capability.

"The loss of 16T operational capabilities would seriously impact current and potential test programs and reimbursable budget authority income at AEDC," Choi said.

According to Ted Myers, Sverdrup investment project manager, fatigue-related cracking in the blade attachment point of the C1 compressor prompted the rotor discs replacement. The Air Force funded the project at an estimated $3.7 million and a two-year execution schedule, including 106 days of tunnel downtime.

The Sverdrup Investment Project Group executed the effort that involved fabricating three new rotor discs and 20 rotor thru-bolts, removing the old rotor, disassembling and inspecting all rotor components and then assembling and reinstalling the rotor assembly by a Sept. 20 operational deadline.

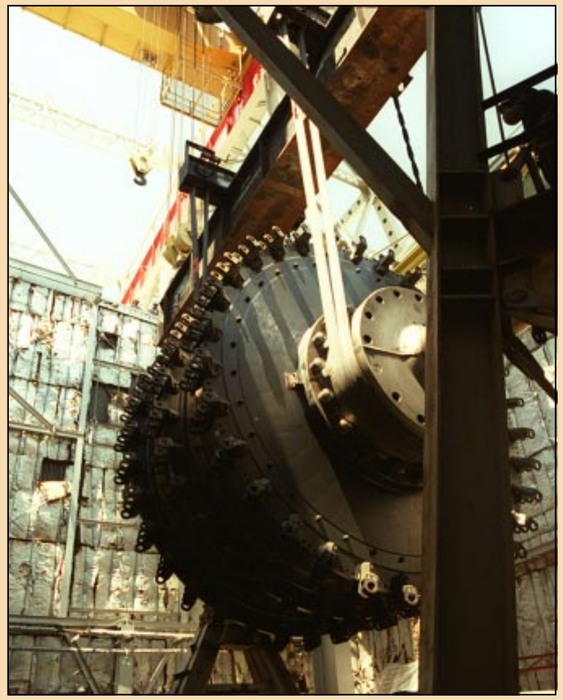
1961 photo of rotor blade damage after compressor failed during test on Aug. 3, 1961.

A $1.8 million contract for the major procurement items (the rotor discs and thru-bolts) was established in July 1998 with scheduled delivery in April 1999. A 40-week lead-time was essential to fabricate, machine and deliver the discs. Subcontractors supplied the large forgings, manufactured by the Hanjung Company in Korea, and the final machined components. These arrived by truck at AEDC in May 1999.

Planning for the compressor tear down began in February 1998. Input from the craftsmen, retired engineers and managers familiar with the original C1 overhaul in 1961 allowed the team to estimate the required manhours to accomplish the project in the most effective way.

"The magnitude of the work involved in the C1 rotor disc replacement project is difficult to convey without presenting scores of information concerning the planning, preparatory and actual installation stages of the project," Rick Meyer, the C1 compressor system engineer, said. "The extent of the preparatory work was especially important since only two retired engineers who had performed the task earlier in their careers were available for consultation."

Operational since 1956, the C1 compressor developed fatigue cracks between the blade-pin holes on its rotor discs. During a test, Aug. 3, 1961, the compressor failed when one of the rotor discs lost a steel blade inside the compressor. Severe damage prompted major repairs and a redesign effort. During this period, Westinghouse and AEDC engineers replaced the solid-steel blades with hollow composite fiberglass blades and devised a hinged joint to connect the new blades to the redesigned disc. These two changes reduced the rotor weight causing a reduction in the stress levels in the rotor components. They also reduced the disc's diameter to cut out cracks and machined a "T" head into the outer circumference of the discs to create a load path to support the new blades.



Iron workers use crane to lift C1 rotor to compressor.

The major tasks—shipping large compressor parts off base for repair, and designing a lighter weight hollow blade—required extensive development and time-consuming testing. As a result, C1 was not returned to service until April 1965.

So, in February 1992 when the compressor's annual rotor inspection revealed fatigue cracks on several of the discs' "T" heads, urgent analysis began with an extensive inspection of all the C1 rotor discs. This inspection exposed 26 crack indications in the "T" head area at 16 blade attachment locations. Using small hand-held carbide burr-grinders to grind out the cracks and produce a smooth radius, AEDC maintenance crews provided a temporary solution while proactive measures were taken to minimize the operational impact of a "T" head failure until the discs could be replaced. These measures included establishing an annual, semi-annual and weekly preventive maintenance inspection schedule to monitor the "T" heads and redundant load path adaptor-to-disc pin condition.

Another C1 rotor inspection in December 1997 revealed cracks had returned. An effort to grind out these cracks resulted in unacceptable stress levels and increased fatigue crack formation probability. Myers said analysis findings determined the discs would have to be replaced because continued use would cause the cracks to grow until the discs were beyond repair or failed catastrophically.

The rotor discs replacement began June 1, 1999, and involved a two, 10-hour shift operation working six days a week for 15 weeks.

Weighing approximately 130 tons, the rotor assembly had nine stacked components assembled and held by 18 thru-bolts.

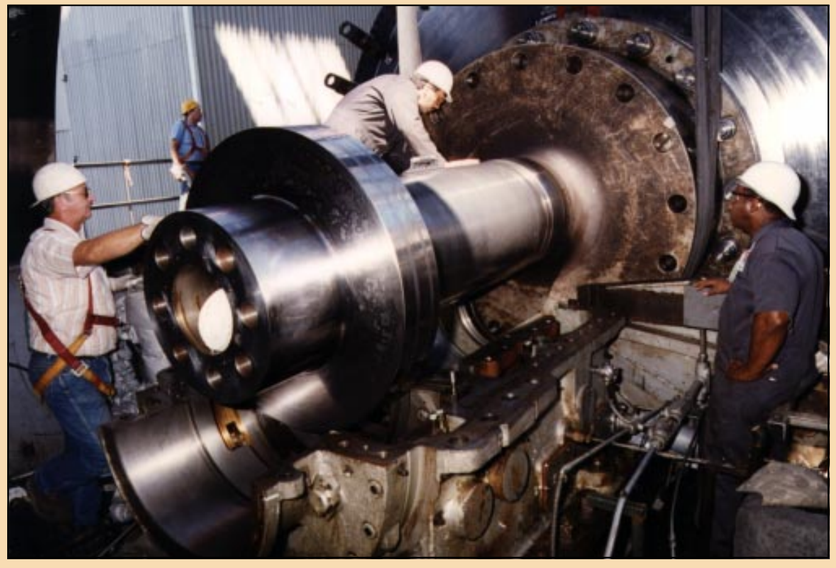
"The real technical challenge was in the build-up of the rotor assembly," Myers said. "The tight tolerances of the thru-bolts made this effort very difficult, but through machinist finesse, the rotor was successfully assembled."

Many AEDC personnel were involved in the effort's success.

"We received vital help from the AEDC transportation group, metallurgical lab, nondestructive testing lab and model shop," Meyer said. "Support personnel kept the cranes working with critical and timely repairs, and the warehouse personnel assisted when needed."

Demonstrating teamwork among the Air Force, AEDC contractors and outside vendors, the project was completed on schedule, on budget and met all the technical requirements.

"A dedicated work force from AEDC personnel and the outside vendors, excellent planning efforts and a success-oriented attitude contributed to the success of the C1 rotor discs replacement project," Myers said.



Wayne Brown (front left), Roy Jones, Brian Bergmann and Joe Sanders set the C1 rotor into bearings.

Riggers, Wayne Brown (left), Van Davidson and Larry Brown, prepare to pull 18, 10-foot long rotor through-bolts from the C1 rotor to unstack the rotor components.

By: Danette Duncan
Photos By: Butch Brooks

Model Shop contributes to rotor replacement project success

Quick Model Shop support during the C1 compressor rotor discs replacement installation phase made an on-schedule, on-budget completion possible.

"Their immediate action prevented the project from being delayed at least a month, saving AEDC time and money," said Simon Choi, AEDC Air Force project manager. "In the bigger picture, a delay could impact both the Joint Strike Fighter and the F-16 aircraft tests scheduled in 16T. This would have cost AEDC approximately $3 million in reimbursable budget authority income."

According to Rick Meyer, the C1 compressor system engineer, the challenge occurred when the crew disassembled the solid coupling between the C1 rotor and the motor drive shaft in AEDC's 16-foot transonic wind tunnel.

"In the C1 compressor's case, the solid coupling joining its rotor and the drive shaft from the motor drive building was bolted together by 14 bolts using 7-inch-diameter nuts," he said. "During removal, some of the nuts turning against the coupling face galled, which is the tearing of metal when two elements rub against each other without lubrication, making gouges up to a quarter inch deep in the face of the flange."

A flatbed trailer transported the shaft, which weighs about 30 tons, to the Model Shop so craftsmen could machine the flange to provide the necessary spot faces for each nut. To repair the flange's galled surfaces, 14, 8-inch circles, concentric to the boltholes, were cut one-quarter inch deep into the flange.

The Model Shop's tasks were to counterbore the 14 holes and fabricate the washers. "We did not realize the challenge until we actually saw the configuration of the coupling as to which side of the flange needed machining," said R.L. Kraft, a Model Shop coach.

The work began with a 3-inch arbor to get through the boltholes, then a 6-inch cutter was fastened to the arbor, and Numerical Controlled Programming was used to orbit the counterbore to an 8-inch diameter by one-quarter inch deep.

Then, the model shop fabricated 14, quarter-inch thick steel washers and hardened the material through a heat treatment process to better resist the galling forces produced during installation and future disassembly.

According to Steve Ary, an AEDC metallurgist, the Precision Inspection Lab performed a dimensional inspection, and the Metallurgical Lab conducted some extensive mechanical property tests to ensure that the rotor components met specification requirements. A laser tracking system, along with more conventional instruments, was used to verify the location and sizes of holes and other critical features, most within a few thousandths of an inch. Samples from each quadrant of the discs were tested for cleanliness, microstructure, strength, ductility and toughness using a variety of techniques. Existing components, such as the bolts and nuts, were also analyzed with the scanning electron microscope to determine material type for replacements.

"The materials used to manufacture many of the older components at AEDC are not well documented," Ary said. "The ability to determine the type of material and how it was processed allows us to repair existing parts or fabricate suitable replacements with very fast turnaround."

Outside machinists, Tommy Bush (left) and Brian Bergmann, remove the bolt fastening the C1 rotor to the turning trunion in the rotor erection frame before lifting the rotor from the stacking building.

Outside machinist Brian Bergmann positions the C1 rotor as it settles into bearings while holding a jug of lubricating oil to pour over the journal bearing before final placement.

No lost-time injuries during labor-intensive project

Extensive safety planning and training coordination during the 106-day C1 compressor rotor replacement project installation phase in AEDC's 16-foot transonic wind tunnel resulted in zero lost time due to injuries.

"We began examining the project from a safety perspective almost two years ago," said Tom Powell, senior engineer. "We conducted a safety hazard analysis that detailed what the project would include and how it would be accomplished."

Beforehand, 57 personnel who formed the rotor replacement team received mandatory safety training specific to the project including heat exhaustion, working around scaffolds and overhead cranes and the use of fall restraint equipment. This eliminated work stoppages for training.

During the course of this project, David Reep, a Sverdrup coach, brought the crew together daily at the beginning of each shift to review the effort's daily tasks and emphasize safety.

Accomplishing the project by Sept. 20, the team worked 30,000 manhours. Although recordable injuries occurred, no work time was lost due to those injuries.

"From the beginning the craftsmen, engineers, coaches and managers working on this project made safety awareness a priority," Lt. Col. Don Swallom said. "It would have become easy for everyone to have become complacent especially in a project of this magnitude. In the end the team proved safety is an important part of their job."