MACH 3

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GENERAL ELECTRIC

**UDF —
Designs on the future**

The ATO connection

CF6 — The international American

"This business is on a 'full court press' to meet its commitments . . . "

The ATO connection

PRODUCTION

Growing Pains.

In a high-tech business they're called bottlenecks, production delays, producibility problems. But whatever they're called — they hurt.

They hurt schedule. They hurt delivery. And unless they are cured immediately, they hurt customer satisfaction and ultimately employee jobs.

The Aircraft Engine Business Group's growing pains are a result of the largest production schedule build-up of new engine products in the Group's history.

Everyone feels these pains and everyone is challenged to make things better. Statistical Process Control teams, Producibility teams and literally thousands of individuals across AEBG are working on these problems every day. Among those helping are a number of employees in Advanced Technology Operations (ATO).

"This business is on a 'full court press' to meet its commitments to ENCORE, the Group's master schedule," says C.M. (Sonny) Pierce, manager of Manufacturing and Quality Technology. Pierce was recently assigned the responsibility of focusing ATO's tremendous resources directly on schedule problems in the shops and Materials Purchasing.

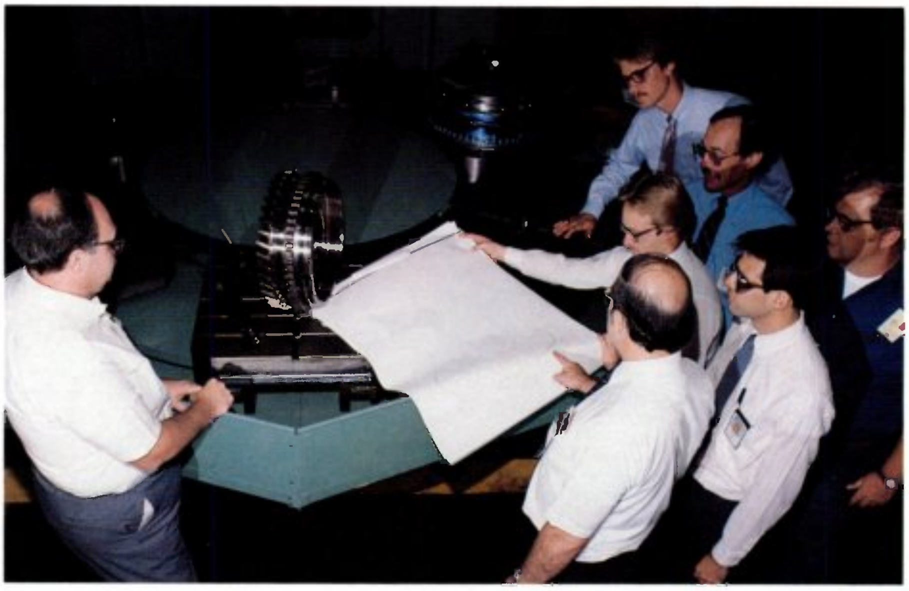
He points out that this ATO commitment to the solution of production problems is not new.

"There were a whole host of activities already in place to help get on ENCORE including many that involve ATO," Pierce says. "We are simply adding to that already increased emphasis."

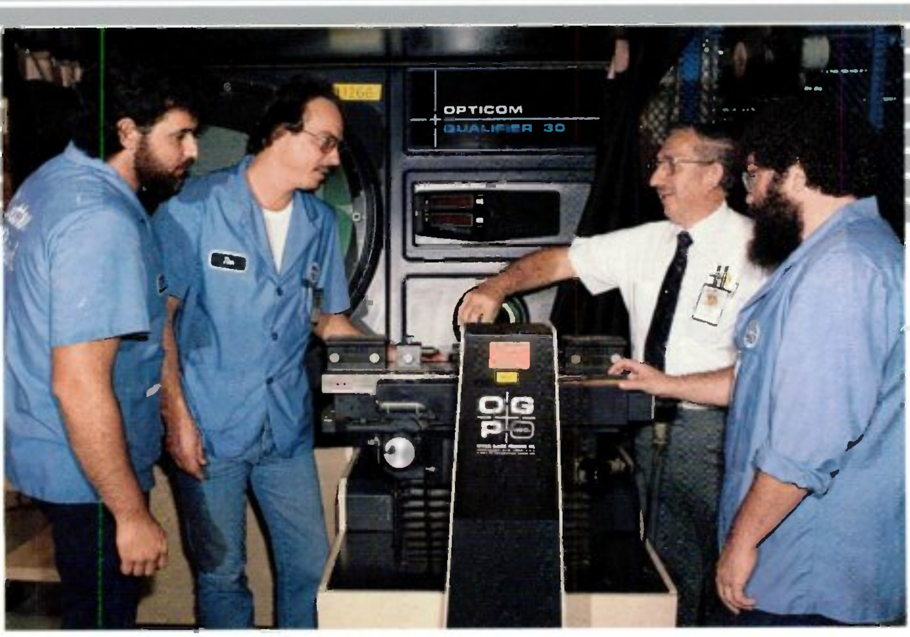
The current ATO effort focuses on technical bottlenecks at locations throughout AEBG. The range of technical assistance is enormous — from people to inventions.

"We have provided Methods Specialist support 12 hours a day, six days a week. We have invented and implemented new tools for inspection and production," Pierce explains.

"Our technical people come from all over. Will Hansen, who works for ATO in Hookset, is now solving problems with an electro-chemical machining vendor in Cincinnati. Earl Helder, who works in Evendale ATO, is supporting Everett and its electron-beam welding.



Project team members (left to right), Herb Fry, Factory Automation; Gerry Geverdt, Machining Technology Lab; Scott Ernest, Rotating Parts Quality; Rick Fallon (inside), Design Engineering; Jim Haverland, Machining Technology Lab; Chuck Donaldson, Quality Technology Lab, and Steve Lotz, Rotating Parts Quality.



Cutter-Grind team members (left to right), Greg Conner, Tim Kirkendall, Leon Hughes and Gary Allen.

"The same people who were giving speeches and writing papers on the latest UDF technology last weekend are working around the clock this weekend to inspect Rene' 95 parts in a vendor's shop."

Every one of the more than 60 bottlenecks currently being worked on with support from ATO involves people and a program plan. A program leader is responsible for the effort and reports directly to Pierce. The program plan is often twofold: it involves an immediate fix and a long-term solution so the problem won't recur as the schedule continues to build.

"Calling priorities is one of the most important parts of the job," says Pierce. "But properly using the talents of the people in the organization is even more important."

Pierce realizes that focusing all these ATO resources on meeting production schedules puts people on important assignments at the expense of other important work.

Top management also understands the dilemma. Brian Rowe said recently he shares concern that ATO and other engineering forces must focus heavily on production to get us back on schedule. But he adds that he feels the conflict will balance out in time.

On the positive side, Pierce says ATO's credibility with production people increases when those who designed a new technology are out there in the shops implementing it. That involvement allows for easier transfer from development to production. It shows that technology development people are ready and willing to go the ▶

Continued of Page 8

Success!

The call came at about two in the afternoon.

Al Gude, manager of Rotating Parts and Casings, wanted to talk to someone in ATO about the repair of more than 30 Stage 1 and 2 compressor spools for CFM56 engines.

"These parts cost $12,000 apiece, but most people think we should scrap them," Gude told Rich Vertz, manager of Metalworking Technology. "You have the technical expertise. We'll support you with anything you need. What do you say?"

"What could I say?" Vertz smiles. "The shop manager had complete confidence in us. He offered all his resources to help. ATO management gave us number-one priority to get the job done. There was just no way we could fail."

And so the teamwork began. After a dozen meetings and hundreds of phone conversations, the pieces of the puzzle were fitting together. ATO's Gerry Geverdt led the effort which involved a new closed-loop machining technology. Design Engineering calculated an allowance to remove additional material from the dovetail slot and designed the slot contour configuration.

The Cutter Grind Operation designed a special numerical control (NC) end-mill using dovetail-slot geometry. Factory Automation developed touch-probe cycles to locate each dovetail slot and define NC tool off-sets for precision machining. This software was then integrated into the NC part machining program by the Machinability Lab. Quality Technology provided a new Zyglo inspection process.

Repair of the compressor spools was accomplished to quality specifications with a closed-loop machining process just one week after implementation began. The project eased critical flow of quality parts to engine production, verified a new technology ready for manufacturing and saved $400,000 as well.

"What's especially exciting about this story is the teamwork of all the organizations involved," says Gerry Geverdt.

"Because of that cooperation, bits and pieces of many technologies developed over the last few years came together in a successful application for our engine hardware manufacturing business." ■

UDF™

— Designs on the future

Full-scale UDF model running in test at Peebles.

ENGINEERING

Listen carefully. The first rumblings of a technology revolution are in the wind.

General Electric is heading "back to the future" with a new breed of propeller. It's a propeller with an unusual twist which may well power 150-passenger aircraft by the early 1990's.

The unusual twist combines the best features of modern turbofans with propellers-of-old. Counter-rotating, knife-like fan blade rows are attached to a turbine drive system at the back of an aircraft engine to form what is called a "propulsor."

They certainly look different. *Forbes* has reported, "...they look like the curved blades of an over-grown Cuisinart."

But don't be fooled by appearances. Those fan blades are shaped for flight speeds of Mach .8. They replace the familiar forward fan/nacelle, fan shaft and low-pressure turbine with a direct-drive unit at what is projected to be a 30 percent fuel savings.

This direct-drive unit eliminates the need for a heavy gearbox to send power to the blades. Instead the UDF™ (Unducted Fan) engine uses hot gases produced by the core jet engine gas generator to power two multi-stage, counter-rotating turbines directly attached to the fan blades.

This concept was born in 1983 when a group of GE engineers and technicians began their search for a more fuel-efficient engine. Knowing that the most fuel-efficient engines are those which discharge large amounts of air at relatively low jet velocity, these innovators set about designing an engine like no one had ever seen before.

Dave Chi (left) and Dan Kavanagh make last minute adjustments to the scale model UDF rig before test in the anechoic chamber at Evendale.

They called their creation the GE36, Unducted Fan Engine or UDF. And history was made — almost.

First, critical performance data needed to be gathered. The initial phase of that program drew on an already established GE technology: scale-model testing with engine simulators.

Since the mid-sixties, AEBG mechanical and installed performance engineers had been working to design a family of high-technology "mini-engine" test vehicles or rigs in scale-model sizes from a three-inch to two-foot blade tip diameter. Installed in wind tunnels, the largest of these sophisticated model engines permits powered testing of the UDF concept.

The UDF scale model test rig went from concept to hardware in just 12 months. Today, three rigs are being tested for overall performance and sound levels generated by a UDF propulsor. Those tests are taking place at Boeing's wind tunnel in Seattle, at NASA's wind tunnel in Cleveland and at GE's acoustic test facility (Cell 41) in Evendale.

During the simulated tests at Evendale, a free jet of air blows upwards into the huge anechoic (sound deadening and measuring) chamber. The inside of the chamber

On the cover. *Laser drilling of UDF mixer frame.*

is treated with foam wedges to absorb sound reflections. Technicians then measure the various components of sound generated by the two spinning fans.

Before the full-scale UDF can be certified to power a commerical aircraft, engineers must bring noise characteristics to well below FAA specifications. In July, General Electric demonstrated through acoustic testing of powered scale models that the UDF engine will meet federal aviation noise requirements.

"Low and high speed overall performance was even better than expected," said Tom Donohue, manager of the Advanced Engineering Technologies Department, Evendale. "Technicians continue to test different UDF propulsor blade numbers, shapes, angles and row-to-row spacing in our vertical wind tunnel for the quietest UDF possible.

"Our predictions are that we can design a configuration to meet special local community requirements as well as federal noise standards."

The second phase of the UDF performance program involves large-scale engine demonstrator tests for performance and noise as well as checks on blades, pitch control and general operation of the entire propulsor unit. Those tests are now going on at GE's Peebles, Ohio, test facility and will continue through November.

After completion of tests at Peebles, the engine will be torn down and parts examined to see if further testing is required.

Meanwhile, Boeing has already delivered a 727 aircraft which is now being modified at the GE test facility in Mojave, California, as a flying test bed for the first in-air UDF test. The engine will be installed on that plane in the spring, with the flight test scheduled for next summer.

"It's a good feeling to be involved with a concept that holds as much promise as this does," says Tom Donohue. "We've had a tightly knit group of super people do a great job of pulling this project together. There's still a lot to learn about how the engine is going to behave, but all of our testing so far says the engine will meet the goals we have set."

Call the UDF what you will — a trend setter, a new thrust in aviation, a flying Cuisinart — this engine is changing the course of aircraft propulsion history. UDF's high fuel efficiency offers the promise of a continued trend toward more affordable air transportation for the next two decades. ■

Leaman Houston assembles blades into the inner rotor of the UDF power turbine.

Source:
Har West
8-332-6194

. . . 13 percent of all direct-hourly jobs across the Aircraft Engine Business Group are a result of revenue-sharing participation.

CF6 — The international American

REVENUE-SHARING

When you build *the* world-class engines, demand for your products just naturally extends to every corner of that world. Markets for General Electric aircraft engines cover the globe.

One way GE enhances its leadership in worldwide markets is through revenue-sharing participation with other engine producers. The international marketplace is an important driver to AEBG sales and requires well-thought-out business strategies.

Countries including England, France, Germany, Italy and Sweden have government-supported aircraft engine industries of their own. International realities dictate that, in some cases, these industries will participate in production of components for engines that are sold by GE for use in their countries.

That's where revenue-sharing participation comes in.

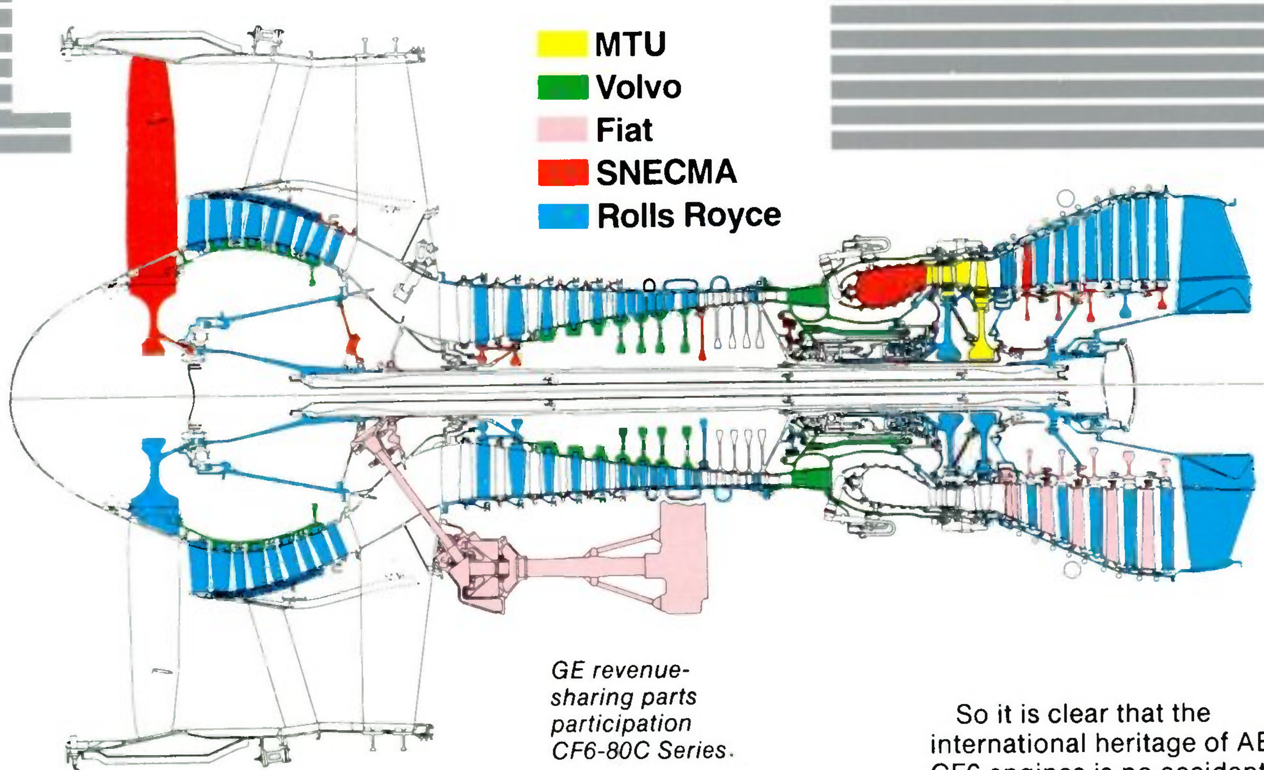
Revenue-sharing means GE agrees to a mutually beneficial production assignment with a foreign engine manufacturer. The participating company may assist not only in manufacture, but in product support and in the provision of technical expertise.

GE has long recognized the marketing, economic and technical benefits of revenue-sharing. The history of joint assignments in AEBG goes back further than is generally realized. It began with military engine license agreements reached just after World War II. In the early 70's, as GE became a producer of high-bypass engines for commercial airliners, the company began consciously seeking international participation in commercial engine programs as well.

Revenue-sharing works by matching the engineering or manufacturing expertise of each international participant to the specific needs of the engine program. That combined effort must meet or exceed product requirements on quality, producibility and timing.

In programs like the CF6 series, General Electric is project manager. GE oversees and has ultimate responsibility for design, manufacture, production and marketing.

Fiat, MTU, Rolls Royce, SNECMA and Volvo join GE by contributing the parts listed in the chart above. These companies are actively involved in such engine aspects as design and analysis, engine endurance testing, component testing, manufacturing of engine components, metallurgical/



GE revenue-sharing parts participation CF6-80C Series.

laboratory testing, advanced manufacturing processes and repair development. Revenues are shared on a participation basis.

General Electric decision-makers have an excellent track record of revenue-sharing programs which benefit GE, the United States and our international revenue-sharing participants as well.

"We've created several thousand jobs in our own factories, in the factories of our suppliers in the U.S., and in factories throughout the world that wouldn't be there without revenue-sharing participation," says Bob Garvin, manager of Marketing Development and International Planning.

A recent survey shows that 13 percent of all direct-hourly jobs across the Aircraft Engine Business Group are a result of revenue-sharing participation.

Today the United States is the largest single market anywhere for aircraft engines — civilian and military. But according to Garvin, 10 or 15 years from now instead of being 50 percent of the world's market for commercial engines, the U.S. will be 30 percent to 35 percent. The importance of other large industrial countries as markets for engines will grow proportionately.

So it is clear that the international heritage of AEBG's CF6 engines is no accident. Shared participation in that program and others is a part of a long-term plan for future business success around the Aircraft Engine Business Group and around the world. ■

Source:
Harry Kent
8-332-4842

Modules/Components	FIAT	MTU	Rolls Royce	SNECMA	VOLVO
Fan Blades/Rotor/ Stator			■	■	■
High Pressure Compressor			■	■	■
Compressor Rear Frame					■
Combustor				■	
High Pressure Turbine		■	■		
Low Pressure Turbine	■		■	■	
Accessory Drive System	■				


Pickering


Krall

▶ Production (Continued)

extra mile to help solve problems on the shop floor.

For technology development people, their involvement means a strengthened awareness of production.

"It's a broadening experience for people who are used to working on projects that often last two or three years to aim for immediate results," Pierce says. "Everyone loves a challenge and there's real excitement in solving important problems."

"ATO has always been available to support production," Pierce continues. "Only now, considering the rapid increase in production rate we're determined to meet by year's end, we've intensified that commitment.

"We are bringing all the talent of ATO to bear so that next year and the year after we will continue to develop cost superiority and quality excellence for the future." ■

AFTERBURNER

The heat is on.

As we move into the last quarter of 1985, the challenges we face in the Aircraft Engine Business Group are no secret.

Our customers expect to receive high-quality engines on time. And we intend to ship them.

We will pull ourselves back on schedule. We will keep our promises.

Commitment to schedule is a very personal challenge for every one of us in AEBG. *Your* job, no matter what it is — is critical to success. When you are a great business and moving fast, *every* player on the team must hold his or her position like never before.

In this issue of MACH3 we see teamwork played out in several different but equally effective ways. We report on revenue-sharing. We cover the UDF. We talk about "the ATO connection" helping us meet schedule.

- Revenue-sharing participation is built on teamwork. Our international joint ventures have increased business and jobs worldwide.
- The story of the UDF is a study in teamwork. Great cooperation was needed across the aerospace industry to make this exciting concept a reality.
- Advanced Technology Operations' commitment to teamwork is obvious as it channels considerable resources onto the manufacturing floor.

The dedication described in these stories is typical of cooperation from everyone — hourly workers, salaried employees and managers — working hard to help us get back on schedule.

Winning in the aircraft engine business across the world, across the Group or across the plant hinges on each of us individually dedicating ourselves to keep this business running smoothly so that we can ship product.

Success is within our reach. We will win, but we need *you* to do it.

We're in the world series.

It's the bottom of the ninth inning. We're down by one, but the bases are loaded and you're up to bat.

Step up and take a swing. Take a big swing. ■

George Krall
Frank Pickering

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MACH 3

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GENERAL ELECTRIC

Statistical Process Control — the problem solver

Jet Pac takes off

SPC's profitable past

Computers that forecast the future

Lorraine Hail (front) and Audrey Endres inspect parts as they come into Jet Pac. Sonny Blackwell inputs paperwork to let the computer know that the parts have arrived.

Jet Pac takes off

ASSEMBLY

Walking through the Product Support Shop's Jet Pac facility in the Evendale Plant is like walking through a department store warehouse during the holiday season. Brown paper packages fill more than 120,000 square feet (equal to about a mile of a two-lane highway) in the new spare parts packing center.

But the thousands of packages in this state-of-the-art computer-aided operation aren't tied with ribbon and put under Christmas trees. They're placed in bar-coded packaging trays, scanned by laser readers and guided to an automated carrousel stacker in the $2.2 million facility.

Employees in Jet Pac's high-tech operation began packaging parts in January. They ship an average of one million pieces of engine hardware every month.

The bottomline at the Jet Pac facility is customer satisfaction and employees are well aware that they are the final link between the company and the customer.

"Our employees know we put the company's reputation into the box right along with the parts," explains Tracy Smith, manager of Product Support Shop Operations.

Eva Carpenter carefully counts and packs parts for delivery to the customer.

"Quality heads our list of packaging materials," says Smith. "We wrap quality, we pack it, and we send it to our customers."

At Jet Pac there is a deliberate and concentrated emphasis on quality and communication. An electronic communications board in the center of the area constantly broadcasts unit measurement status and employee information. There are also dozens of training sessions, quarterly business reviews and numerous roundtable meetings.

The computerized packaging area is designed to reduce packing time from two weeks to one week. Total packing costs, including all overhead, averages less than three percent of the dollar value of the part to be packed – three cents on the dollar.

Jet Pac sends out some 40,000 spare parts each work day. These parts include everything from expensive rotor assemblies to simple nuts and bolts.

After material is received from Lynn, Evendale Manufacturing, the satellites or outside vendors, it is verified for quality and quantity, then loaded into bar-coded packaging trays. The bar-coding process enters information into a data entry system.

Next, parts are sent along a conveyor where a robot manipulation transfers them to the main carrousel for storage. When parts are needed they are called out by the "brains" of the operation, a tandem computer

A view from the top of the 38-foot-high "Engine Care Everywhere" Warehouse, where packaged parts are stored until needed by customers.

which prioritizes customer orders. Parts are automatically retrieved from the storage stacker and routed along the half-mile of conveyors which wind around the packing area for delivery to an employee packaging station.

At his or her individual workstation, an employee gives the parts one final visual inspection, then packs them according to computer-generated dispatch order card instructions and returns them to the conveyer. Finally, packages are moved to an "overpack" or short-term storage station where they are placed in accumulating pallets until bulk distribution is made to specific customer destinations.

One major advantage of this high technology system is on-line, real-time control: a simple wanding process immediately records the movement of "Class III" (smaller) parts.

Larger parts are packaged using a foam-in-place method for securing the item in its container. This method results in lighter weight containers while still providing maximum protection during shipping.

Jet Pac operates from a 40-year-old building that received a facelift. Lighting was improved, the area was painted and new workstations were built. More than 3,000 holes were drilled in the solid concrete floor for installation of new equipment.

"The list of customers who have toured Jet Pac reads like a Who's Who of the aerospace industry," says Al DesMarais, Pack Design specialist. "This operation's unique computer system and extensive bar-coding technology are among the most modern anywhere." ■

Source:
Rich Weis
8-332-1144

Al DesMarais verifies bar-coded labels on material handling trays as the robot in the background loads incoming parts onto the carrousel for storage.

SPC Statistical Process Control — the problem solver

"I'm sick and tired of putting out fires. With SPC we solve the problem once and for all."
Ed Pyle, senior production engineer
Component Engineering, Everett

QUALITY

It's early morning, 6:48, first shift.

Tony Rox sits down at his workstation in the Rotating Parts Operation. His task, until 3:18 in the afternoon, will be to cut precise radii and carefully deburr high pressure turbine disc slots.

He uses hand tools. His work is precise, demanding and tedious.

That same morning, Process Control Engineer Jennifer Wallace, and the Statistical Process Control (SPC) Team of which she is a part, are devising a plan to make Tony Rox's job easier and more efficient.

Rework and re-inspection costs in the Evendale Rotors Finish Unit where Rox works could amount to one-half million dollars by year's end. The SPC team, made up of Design, Manufacturing, Quality and support organizations, is determined to improve quality and lower those costs.

Using statistical techniques learned in a 13-week class taught throughout Lynn, Evendale and the satellites since January, the team identifies normal variation in the bench operators' process. They then use control charts to define problem areas and monitor performance. The team holds roundtable discussions with bench hands and inspectors to explain what they've found and to ask for support in solving problems.

Soon inspectors begin plotting visual nonconformances on statistical attribute charts. Summary charts are displayed on the shop floor and bench hands monitor their own progress.

"I think it's great! The charts help us improve quality right at our worksta-

On the Cover Process Control Engineer Jennifer Wallace and Diversified Inspector Lee Schwiejohann examine the quality contour on a high pressure turbine disc.

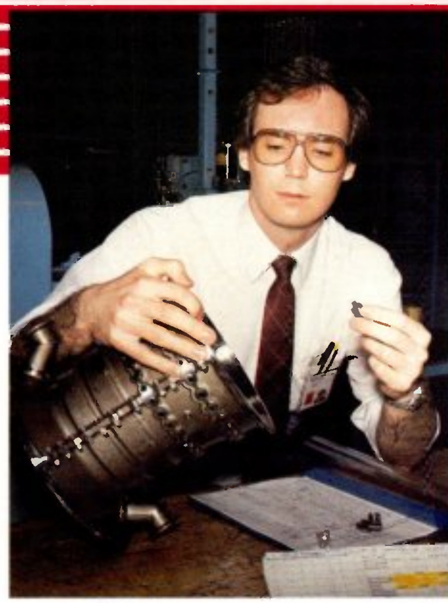
tion," says Hand Operator Tony Rox. "It's good for us and it's good for the business to improve the quality of our parts."

Ninety-thousand dollars a year is the savings projected through application of statistical techniques in the Rotors Finish Unit. The case is typical of dozens of SPC teams throughout AEBG. Savings in tens of thousands of dollars are the norm when teams apply SPC to catch and correct imperfections on-line instead of relying on inspection and rework to find and correct mistakes.

"Nothing in our business is as unproductive as nonconforming hardware," says Jim Cole, manager of Advanced Quality Planning at Evendale. "SPC helps us to understand our industrial processes. It tells us what's normal and what's not before the process starts producing parts that are nonconforming. By making improvements in the process before we suffer losses, we improve the quality of our product and our productivity."

"SPC helps avoid costly problems and makes us more competitive."
Jeri Gates Griffith
sample layout inspector
Shroud Inspection, Albuquerque

"SPC is a natural for use with operator control plans. Operators receive instant feedback and processes are under tightest possible control."
Phil Crosby, quality engineer
Purchase Materials Quality, Lynn



"SPC tells us that a process can perform within a specified tolerence range. It assures that we're making only conforming hardware."
Bruce Kirch, quality control engineer
Casing Manufacturing Operation, Lynn

Times are changing in American industry. Until 1970, the United States was the undisputed leader in manufacturing technology and quality. Today American manufacturing feels the heat of foreign competition on its heels.

"The Japanese understand and use statistical process control – we taught it to them. Now it's time that we begin taking statistical process control seriously," says Cole.

The surest way to beat the competition and reduce costs is by improving quality, improving first-run yields. That's what SPC is all about – controlling the process and making only conforming hardware.

"SPC is a powerful, simple tool that determines the normal variation of production processes, then monitors the process so the operator can recognize non-random changes when they start to creep in," says Wally Mielcarz, manager of Quality and Technical Planning at Lynn.

"Control charts plot process data and reflect statistical control limits," Mielcarz continues. "When these limits are exceeded, the statistics are saying that something in the process is changing that requires attention."

Often these warnings can be seen *before* engineering specification limits are exceeded. That allows critical time needed to take action before producing nonconforming material.

SPC's emphasis is to understand and control the process rather than rely on end-of-line inspection. This emphasis demands a radical change in the way everyone thinks about the product.

Statistical process control demands ownership of the process. It results in higher quality products, higher productivity, better customer satisfaction and job security.

With SPC, quality is here and now. "Quality is Me." ■

Source:
Dave Newell
8-263-3148

Quality Analyst Linda Jackson examines a large titanium rotating part forging. SPC helps insure the continuing quality of such parts.

SPC's profitable past

MATERIALS

Although GE's aircraft engine business recently undertook a massive training effort in statistical process control (SPC), the concept of SPC is not new.

Statistical analysis has been used in quality control for decades, and statistical process control has been used with excellent results in many operations throughout the Group for years.

One of AEBG's first SPC success stories began in 1970 when Raw Materials Quality engineers recognized that statistical tools were available to develop a new approach to the control of mechanical properties of critical rotating part forgings.

The first step was to cut-up several parts to determine how the mechanical properties varied throughout the material which would be machined into the finished part, and how these results compared with test ring results. Test rings are extra material added to each forging, from which test specimens can be taken.

Until statistical analysis of the test data predicted that the process by which the parts were made was capable of continuously producing properties which met drawing requirements, the process could not be fully approved. Frequently changes were required either in the process or the drawing.

After the process was approved, the second step was to test 100 percent of test rings for at least 35 forgings, and statistically analyze the results to verify that the process was producing consistent mechanical properties. This analysis also provided the control limits that test ring properties would be expected to meet in the future.

At this point, the Quality Engineer could introduce a 10 percent sampling plan, under which the supplier would test each tenth test ring and plot the data on charts using control limits established by AEBG. Any downward trends in properties could then be detected and corrected long before drawing limits were violated.

This approach to process control became AEBG's first Purchased Materials Quality specification, PMQC-1.

Now, fifteen years later, more than 50,000 critical part forgings have been produced under statistical control. Drawing property nonconformances have been virtually eliminated on parts with SPC, and millions of dollars in testing and material costs have been saved as a result.

"In 1970 we had to work hard to convince the first supplier, as well as many AEBG skeptics, that sampling would not compromise product quality," says Jim Sliger, senior design liason engineer in Co-Production Programs. "Today, suppliers of critical forgings are total supporters of SPC as the *best* method of material control.

"SPC is a time-proven, cost-proven method of increasing quality and productivity."

Today there is renewed emphasis on SPC throughout the Group. Because of computerization, it is an idea whose time has come *again*. Some 1200 employees and 160 vendors will be trained in SPC by year's end.

Source:
Carl Schmidt
8-332-0143

Plant III tool staging design team (from left) Roland Richards, Keith Therrien, John Rizzo and (seated) Hans Bukow, look into the plant's future with the help of computer simulation.

Computers that forecast the future

SYSTEMS

Have you ever wanted to gaze into a crystal ball and see the future?

That technology isn't available yet, but Lynn's Plant III design team now has the next best thing. Computer Integrated Manufacturing is developing computer simulation models which represent the Factory of the Future as it will operate in the late 1980's.

Plant III simulation checks out factory design concepts and tests various "what if's" of factory production and layout. It also projects equipment, tooling and support system requirements for the factory.

Plant III activity is broken into three parts for computer modeling: overall factory production, tool staging and tool flow.

The factory production segment centers on machine tools including lathes, vertical machining centers (VMC's), and grinders as well as support automation such as an automatic guided vehicle system, coordinate measuring machines and parts staging. This segment includes 24 engine parts currently slated for Plant III production and represents every phase of the manufacturing cycle.

The tool staging model simulates the entire staging area, which is probably the factory's most complex subsystem. In tool staging, tools are loaded into magazines which are then delivered to lathes and VMC's. Tools returning from the machines are refurbished and stored. This computer model takes its requirements from the overall factory model, which records its demands for refurbished tool magazines. The simulation determines whether tool staging will perform as required.

The tool flow element of the simulation project estimates how many tools of each kind will be needed in Plant III. It tracks the flow of about 70 different tool types (up to several hundred of each) from staging to the machines and back.

Plant III simulation uncovers problems before they occur in the real factory. One potential trouble spot the model has already identified is the Parts Staging Area, where parts are fixtured before each machining operation.

Problems there included layout and modes of operation within the area, quantities of fixtures required and the load on precision staging facilities. Changes have now been made in the design of the area. Without simulation, these pitfalls would not have been known until the equipment was installed and operating, when changes would be costly and difficult to make.

"Plant III simulation is extremely effective in helping us identify bottleneck resources and in redesigning or designing around problem sources where appropriate," says Plant III Manager Dick Segalini.

Simulation engineers have now run the computer models many times to include revised data and new "what if's" supplied by Plant III people. The next step is to simplify the process of changing and rerunning the models so that Plant III people can run programs themselves.

This interface will allow factory ▶


Mattheson


Nelson

▶ Computers (continued)

management team members to juggle the production mix and fine tune other areas of the factory as they complete the design process and begin actual part production later this year.

Although the crystal ball of computer simulation has its limits, it is a cost-effective way to reduce risks in major projects like the Factory of the Future. The simulation has allowed Plant III designers to learn a lot about the factory even before it is built and to provide security in important development decisions.

Source:
Kit Hendricks
8-263-0816

AFTERBURNER

We in the Aircraft Engine Business Group have been very successful recently in gaining sales of both military and commercial engines. Each of us should take pride in these products. They are the best turbine engines in the world.

However we have been less successful recently in convincing our customers that we can deliver large numbers of these excellent engines on time, and then provide the required field support.

The excellent records compiled by GE engines are evidence that we have done this in the past. Our customers expect top engine performance from GE. In order to convince them that we can meet our commitments, all of us, individually, must dedicate ourselves to personal excellence — to the concept that "Quality is Me."

This is not a Quality Operations Program. It's bigger than that.

"Quality is Me" is the realization that we are each responsible for housekeeping; we are each responsible for safety; we are each responsible for delivering quality in the best possible product — be it an airfoil, a fabricated or rotating part, a purchase order, a contract, a design drawing, a tech order, a program management plan, an investment strategy, or whatever our speciality — to the customer.

For many of us, that "customer" is the next person or group in GE. We need to be just as conscientious and dedicated to delivering a quality product to our *internal* customers as we are to our ultimate military or commercial customers.

This issue of MACH 3 describes our expanding activities in statistical process control at Lynn, Evendale and the satellites. We are rededicating ourselves to SPC because it will result in improved quality of our products, which will then result in improved efficiency of our operations.

Through personal and group initiative in "up front" planning, SPC avoids generating nonconformances in the product rather than relying so heavily on successive inspections to find these problems which must then be corrected.

Although tremendous investments are being made in improved facilities, tools and training across AEBG, there will be areas where tools, procedures and training are not yet available. Communicate that fact. Help develop the best approaches until all that's needed can be provided. Help yourself. Help each other. Let's all be the best we can be.

Quality Operations at Lynn and Evendale are dedicated to improving our performance in the classic Quality functions – inspection, audit and test. Those functions alone cannot assure total product quality. You are responsible. We are responsible. "Quality is Me." ■

Bob Mattheson,
manager, Lynn Quality Operation

Jim Nelson,
manager, Evendale Quality Operation

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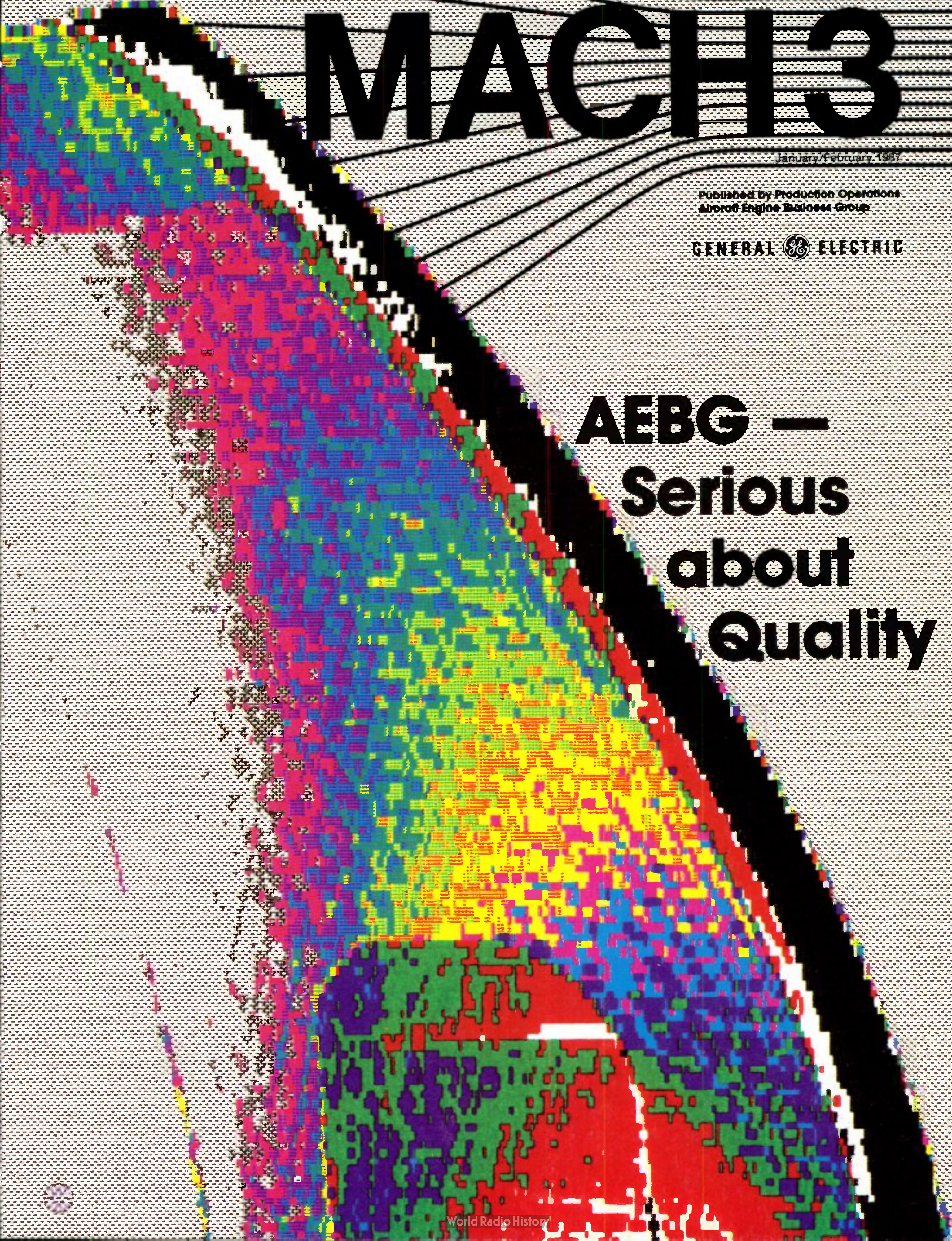
GENERAL ELECTRIC



AEBG — Serious about Quality

Supplier Excellence:

Helping AEBG keep its

MATERIALS

The Aircraft Engine Business Group is more dependent than ever on suppliers. Outside sources now produce over sixty-five percent of GE's jet engine parts.

The job is tough. Some suppliers have had difficulty keeping up with these growing demands. Problems ranging from nonconformances to missed shipments have increased dramatically with the growth of engine sales. To try to solve these problems, GE has channeled its own resources into supplier production.

Two years ago, Dick Mountel and his team in Purchased Materials Fabricated and Machined Parts saw a need to cut back GE's costly direct involvement in the management of suppliers' production work. They wanted to encourage supplier self-sufficiency, while still assuring consistently high-quality products and on-time delivery. After extensive team research and development, they initiated the Supplier Excellence Program.

Supplier Excellence identifies requirements for supplier performance in the areas of quality, engineering, cost and pricing, and production control. The program also defines what's needed in the areas of management, materials, methods, manpower and machinery to produce the product involved. Supplier Excellence also provides an extensive audit check list for better supplier self-evaluation.

"The Supplier Excellence Program has enhanced our ability to work with our GE customer," says Jack Rouse, Vice President and General Manager of General Tool Company (GTC), one of the suppliers who participates in the program. "We still have disagreements, but now we can sit down and come to a resolution. The bottom line is we're working better together."

The Supplier Excellence Program pairs GE people with supplier counterparts — buyers with sales estimators, contract administrators with production control people, quality representatives with quality assurance managers, and value and design engineers with manufacturing engineers. These teams identify operational problems early and solve them before they impact delivery schedules.

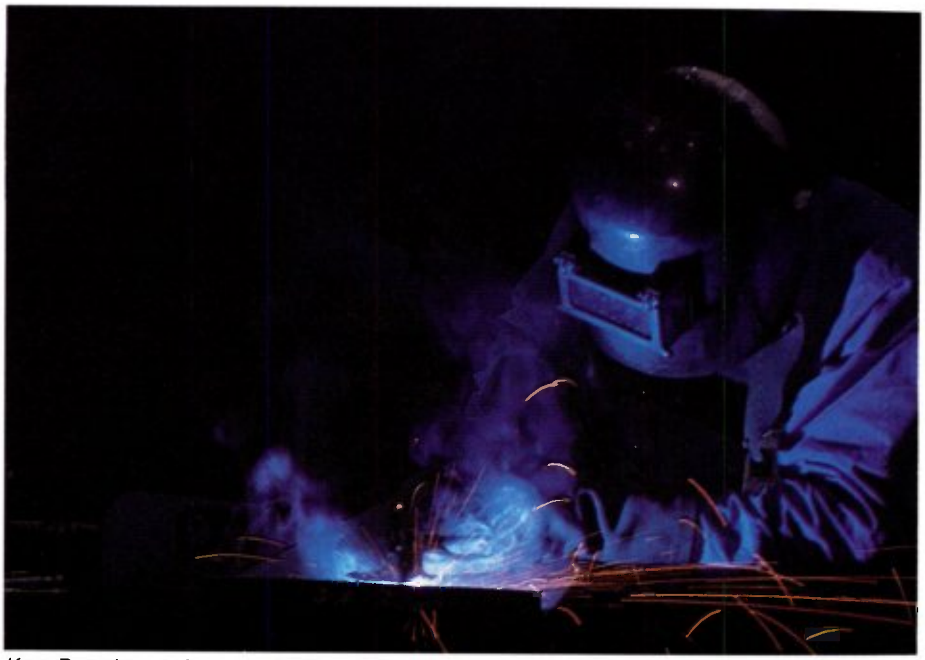
Although the Supplier Excellence Program is relatively new, suppliers have already felt its impact. GTC is just one of many suppliers already chosen to participate.

GTC produces casings and shafts, and refurbishes liner parts for a number of GE engines. In the past, GTC had in-house problems with nonconforming material. The Supplier Excellence Program enhanced GTC's own corrective action program by assisting them in getting to the root causes of the problems.

"Because of internal quality discrepancies," says Cindy Moore, AEBG Contract Administrator, "GTC sometimes fell behind schedule. Since they've become a part of the Supplier Excellence Program, GTC is aware of their own requirements."

Cindy Moore's counterpart at GTC is Project Manager Dave Grouse. It's his job to make sure parts are shipped to GE on time and without nonconformances.

"As a result of Supplier Excellence, now we program parts to be com-



Ken Brooks performs a MIG welding operation on an assembly fabrication.

promises

pleted 30 days in advance of the ship date," says Grouse. "A new computer program helps me know where the bottlenecks are. With 30 days' lead time, I can shift workloads to get parts out on schedule. And I can also identify and fix quality problems and keep nonconforming parts from going out the door."

Both AEBG and its suppliers believe the program has helped.

"The Supplier Excellence Guide asks specific questions that helped us make our people more aware of problems," says Frank Schulz, Quality Assurance Manager at GTC. "Now we post a monthly report of each department's discrepant material. When people started seeing their mistakes on public display, incidents dropped dramatically. Supplier Excellence makes it easier to get to the root cause of a problem."

Since the program began, GTC's Quality Rating has risen appreciably. A recent report indicated zero percent delinquencies on scheduled shipments.

Early statistics confirm positive results. The Supplier Excellence Program offers an opportunity for improved communication and improved quality work for GE's engine customers. That's a very good beginning. ■

Source:
Dick Ruff
8-332-9181

(Photos top to bottom)

General Tool Company welder Ken Brooks uses a disc grinder to make a preparation for a weld joint.

Quality technician Cliff Lane of GTC records a dimension from an AEBG low-pressure turbine rotor shaft.

GTC Project Manager Dave Grouse checks parts shipment schedule.

Higher, Faster, Farther — Accepting the quality challenge

It's 1 a.m. in Cincinnati and high noon in Singapore when the telephone rings.

Pulling himself out of a deep sleep, Doug Vance wakens quickly to news of an aircraft grounded by engine trouble halfway around the world. Within minutes, Vance and GE's rep in China begin making plans to get that airplane back into the sky —fast.

"If a customer has an engine problem, our people grab a suitcase and go anywhere in the free world to solve it," says Vance, the Aircraft Engine Business Group's NDE Applications manager. "We work with the airlines and the military as well as AEBG's own shops and suppliers to keep the fleet flying."

On the cover. *Ultrasonic C-scan of UDF™ blade.*

NDF Technician Joel Schraan performs field ultrasonic inspection of UDF™ blade.

The aircraft engine industry in which Vance and his people use nondestructive quality evaluations to save precious time getting costly grounded aircraft back into the air, is brutally competitive. Engines today are operated at higher speeds, stresses and temperatures than ever before. And the marketplace is changing as rapidly as engine technology.

To meet both the technology and the competition, GE's Aircraft Engine Business Group recently opened a new Quality Technology Center (QTC) in Evendale. Vance's operation is part of it.

"Customers demand the best, and our job is to provide it," says David Hampson, manager of the Quality Technology Center. "Our charter is to offer the best in quality and the best in overall cost of ownership for all our customers."

The Quality Technology Center works to meet customer needs in three ways — through support of engines in the field, through development of advanced nondestructive evaluation (NDE) technologies and through inspection automation.

The QTC's goal is to continually devise new ways to assure higher quality engines at lower cost. They make such improvements by advancing visual inspection automation, infrared technology, composite quality technology and metallic quality technology beyond the state of the art.

"We're a technically driven business, but advanced technology originates in the minds of men and women," Hampson says. "That's why the more than 100 scientists, engineers and technicians who work at the center are key to our continued AEBG success."

Field quality support experts at the Quality Technology Center use evaluation techniques like automated eddy current and ultrasonics at remote sites around the world to examine engines through movable probes. The inspections are performed in the shop and in the field as required by military or commercial customers.

"We provide on-wing, nondestructive inspection. That way tests can be performed without tearing the engine apart and losing valuable flight time," says John Dierdorf, NDE technician.

"When there's a problem, we begin to devise a test to solve it right away. We also build an inspection kit so that our customer can check for similar kinds of problems in the future."

While the Manufacturing and Field Quality Technology group is designing inspections for today's engines, QTC's Materials and Process Quality (M&PQT) development group is designing inspections for the engines of the future. Current technology development projects include inspections for UDF™ and Advanced Tactical Fighter components.

"The Manufacturing and Field people are fire fighters, solving problems on engines already in service," says NDE Engineer Kory Rogus. "In M&PQT, we're tomorrow-oriented. We work closely on engines still being designed to develop NDE inspections for engine materials and parts which have never been inspected before.

"Our impact on the business is to assure that we have the finest inspection techniques in the 1990's and beyond."

Advanced technologies in NDE development include acoustic

Engineering co-op Doug Beitch positions a light fixture on an optical bench for thickness measurement of a CFM-56 blade.

microscopy, precision robots, microfocus radiography, computerized ultrasonic testing, acoustic emission and holography plus eddy current and laser metrology.

The third area of expertise offered by the Quality Technology Center is inspection automation. Engineers and technicians in inspection automation develop computer-aided inspection systems which provide the manufacturing community a consistently high level of quality in production and, through economical, innovative and precise automated NDE, give the design community new latitude for performance without sacrificing reliability.

Visual inspection automation at the center is breaking new ground every day, and infrared technology is being used for in-process as well as final inspection of engine hardware.

The related functions of QTC's three technology groups make teamwork easy. By combining the critical quality processes of field ▶

NDE Technician John Dierdorf proof-tests what will soon be an on-wing ultrasonic inspection technique.

(Continued on page 8)

Automated SPC —

Key to a better blisk

"SPC tolerancing provides us with a comprehensive data base for our DNC milling operation and allows for on-line statistical analysis of the milling process."

Rick Paul, manager
Hooksett Blisk Manufacturing

Rick Tower inspects airfoil
entered into the SPC data

MANUFACTURING

Hooksett's blisk production presented a challenge. But one thing was certain — there could be no compromise in quality.

Hooksett is the manufacturing source for compressor rotors used on the T700 and CT7 helicopter engine programs. Blisk and impeller components for those rotors are more complex than rotors on most engines because T700 and CT7 blades are an integral part of the rotor disk.

Blisk and impeller blades are milled into the forging instead of being assembled as individual parts into dovetail slots on the machined engine disk. That manufacturing complexity makes the blisk a difficult production and quality challenge.

In early 1986, management was reviewing blisk production at the Hooksett plant. More than 6,700 discrepant blisk characteristics had been presented to the Material Review Board (MRB) in the prior year. The board had accepted 85 percent of the deviations "as is."

Hooksett's Manufacturing Quality team met with T700 design engineers to discuss drawing changes which would reduce the number of MRB's without compromising the quality of blisk hardware.

"Design engineers felt that increasing the drawing limits could result in an engine performance problem," said Joe Minihane, quality control engineer who was a member of the original team. "After investigating all possible options, we selected process control tolerancing."

Statistical process control (SPC) tolerancing allows increased drawing limits to be applied to manufactured parts when the process generating the hardware is statistically in control — or within certain limits. To be acceptable, the process must be continually monitored according to SPC guidelines.

If the manufacturing process is not monitored, or if it is determined to be outside of SPC guidelines, then tighter conventional drawing limits are applied. The challenge for Hooksett was to design a system that would satisfy SPC requirements and be manageable in everyday production.

Employees at Hooksett make blisks four at a time on multi-axis, DNC milling machines. The blisks have six different part numbers, each with five characteristics to be monitored. The parts are produced on 18 different machines.

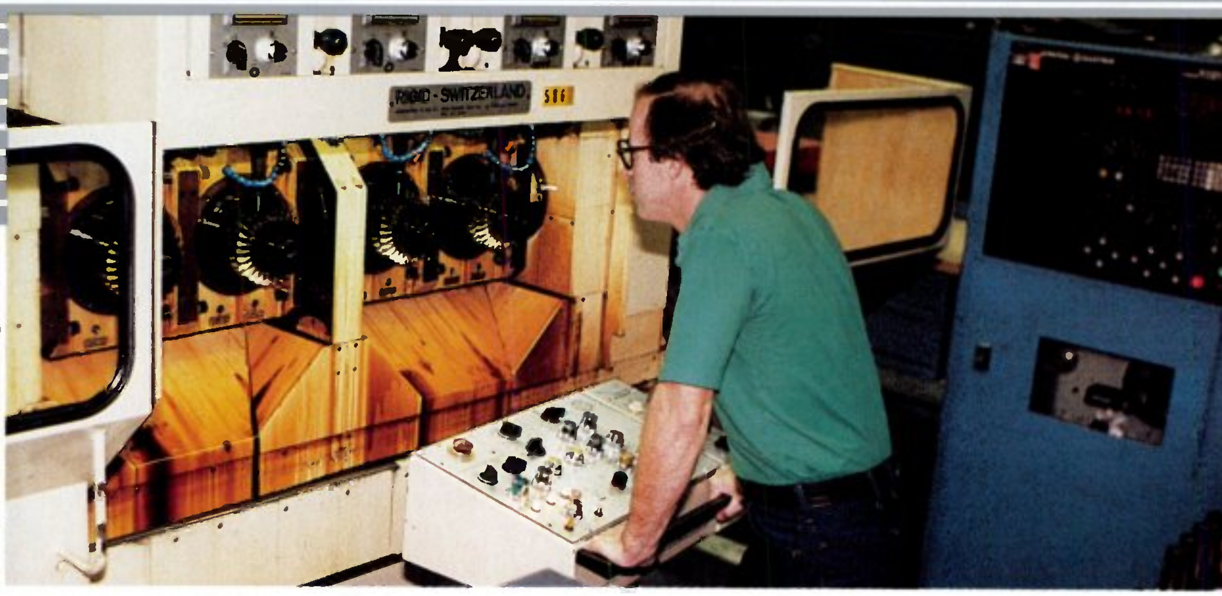
"Five hundred and forty control charts must be generated and monitored to make the system work," says process control engineer Sally Hoosick. "Tracking the process manually would be a paperwork nightmare. So we developed an on-line computer-aided statistical process control system — CASPER — which performs the functions automatically."

CASPER software builds a file by work station, drawing number, characteristic and date milled. The system then calculates critical data for the process control tolerancing.

If any of four critical conditions are not met, the data sheet requests "PCE sign-off required." Then the process control engineer reviews the part history for common irregularities that might have caused a nonconformance. If an assignable cause is determined, the data is pulled from the statistical database and processed by conventional drawing limits.

If the process is determined to

characteristics which are then base.



"Process control helps me mill a better blisk by giving immediate results about how well my process is running."

Rick Bouchard,
Machine Operator

be out of control, the work station is shut down and a corrective action program is begun.

"The greatest feature of the system is that it will allow us to closely monitor the milling process, focus on problem areas and implement immediate corrective action," says Hoosick.

"Even with the increased drawing limits, engine performance variation will be minimized because only a small percentage of the parts are permitted to be at the extremes of their tolerance band."

The Hooksett manufacturing team chose stage 3/4 blisks to begin the program because those parts had the worst MRB performance record. Prior to SPC analysis, the manufacturing process itself was reviewed to be sure any defects generated by the NC program were removed.

A data base is currently being gathered for all airfoil dimensions through the CASPER system. That information is also being analyzed to be sure it meets SPC guidelines. Progress is reviewed monthly by Design Engineering and the customer. Upon completion of this program, all of Hooksett's blisks will be processed by SPC.

"SPC tolerancing provides us with a comprehensive characteristic data base for our DNC milling operation, as well as allowing for continual on-line statistical analysis of the milling process," says Rick Paul, manager of Blisk Manufacturing.

Automated process control tolerancing will reduce dimensional variation which in turn improves quality and throughput rates. Automated SPC has also reduced scrap and rework.

And there's money to be saved. Once this system is fully operational, it has the potential of eliminating one thousand MRB hold tickets annually. With a cost of $250 each to process, that's a possible savings of a quarter of a million dollars.

Photos by L.W. Wagner

Sally Hoosick reviews SPC control chart data with the help of CASPER software.

Source:
John Wilbur
8-265-8149

COR Feb. 18 through Feb. 27

▶ (Continued from page 5)

support, development and automation at one facility instead of in multiple labs, the entire organization benefits.

"A technology center that houses all those groups makes a statement to our customers and our employees," Dave Hampson says.

"When anyone asks, 'What is AEBG doing about quality?' we can point to the Quality Technology Center. It's a whole building filled with state-of-the-art equipment and personnel dedicated to a flawless engine today and tomorrow." ■

Source:
Vince Polimeni
8-732-4685

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MACH 3 is written for GE Aircraft Engine Business Group employees. Its purpose is to reflect production operations achievement, inspire innovation, inform readers, and share production technology throughout the Group.

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AFTERBURNER

Another Contractor Operations Review (COR) will be held Wednesday, February 18 through Friday, February 27. And it's important to think like a customer.

Although the Air Force COR will take place primarily at Evendale, its outcome will impact the entire Aircraft Engine Business Group.

Sixty-five percent of AEBG's current business is military.

The government is working hard to get the best quality engines for our country's defense at the lowest possible cost. As taxpayers ourselves, we can appreciate that perspective.

Our customers expect engines that are reliable, maintainable and mission-ready. They expect a quality product at a reasonable cost, shipped on time.

Our military customers also expect us to live up to our agreements with them. These agreements are defined in the flowdown of our contract requirements through engineering drawings to manufacturing instructions. They include test procedures, quality criteria and instructions, control of government hardware and property, instructions to and control of our suppliers.

Our military customer is satisfied when we fully comply with what the contract says and when our workmanship produces hardware, software and documentation that result in a quality product delivered on time.

In the 1984 COR, we were found unsatisfactory in several areas surveyed. After 18 months of hard work and millions of dollars of investment, the 1986 COR team found no areas unsatisfactory, although several areas were still marginal including quality and product integrity — the measured conformance of our engine hardware to contract requirements.

The Air Force is now withholding 11 percent of AEBG's progress payments as a result of those COR's and late deliveries to contract schedule through most of 1986. That's between $18 million and $23 million each month, depending on the number of engines delivered.

Soon we'll have a chance to change our customer's mind.

Every employee has a part in showing our best capability and how we have worked to correct past deficiencies. For those employees who are actually contacted by a member of the COR team, certain attitudes can make an important difference.

When you meet a member of the COR team, remember that our customer has contracted for GE engines because they are a superior product. Be proud of that. Be professional and courteous. Have your procedures available. Be certain your procedures are current and follow them! Show the Air Force you believe "the stakes are high" by assuring Quality in every part of our product.

Know your job. If our customer asks a question, answer it. If problems are brought to your attention and you can fix them, do so immediately. If you can't, ask your supervisor for help.

Additional attention must be given to safety and housekeeping, material handling, accuracy of labor vouchering, productivity and wearing badges.

Competition in the great engine war is fierce. And we are about to face a major battle: the battle for our customer's confidence.

Think about it. Think like a customer.

DICK BURKE

GEORGE KRALL