In the mid 1970's, AiResearch Manufacturing Company of Arizona initiated a study to create an Auxiliary Power Unit (APU) utilizing the basic power section of the production turboprop engine (TPE331). The concept was to direct drive a load compressor and gearbox to provide improved economical capabilities for future commercial aircraft.

Upon receipt of a Request for Proposal form both Boeing and MBB Airbus, Garrett prepared and submitted documents to both companies. The Model GTCP331-250 was proposed to meet the requirements of the Airbus A300/A310 aircraft. Garrett was the successful bidder and was awarded a contract in October, 1978. The Model GTCP331-200 was proposed to meet the requirements of the Boeing 757/767 aircraft. Garrett was the successful bidder and was awarded a contract in January, 1979. The following chart was presented in supporting documents displaying Program Management of the GTCP331 Project within the Garrett Corporation. Unfortunately, this is the only organization chart I was able to find during my research. I will attempt of recognize all personnel who contributed to the program. Hopefully, anyone, whom I missed due to poor memory, will be understanding and forgiving.
After Bob Wells, Skip Stohlgren and I settled in, the first order of business was to complete the design and release all drawings. This was my first time to work with Buzz Norr and his group. I had many meetings with Buzz and soon learned that he was a P-47 pilot during World War II and an ardent aviation history buff. We hit it off great and shared many war tales. He brought his A-2 Jacket in one day; his Squadron and Aircraft art work were still in good condition, but the goat skin leather was displaying its age. He proudly showed that it still fit! My envy of an ex-JUG jockey was very evident.

Buzz assigned Dave Edmonds as the lead man of the draftsmen and checkers who created, checked and released all drawings defining the new auxiliary power units. Dave created L3622102, a two-sheet cross-sectional layout drawing that defined the arrangement, features and materials of the GTCP331. This became a very useful item during future design reviews.

Figure 1, a reduction of the cross-section, displays the materials used in and the features of the GTCP331 units.

Figure 1-GTCP331 Features

The completely new elements for the GTCP331 configuration are gearbox, load compressor and accessories (fuel control, lubrication pump, starter motor, cooling fan). New features required to adapt the TPE engine to meet the requirements of an auxiliary power unit are:

1-A compressor inlet housing to mate with the load compressor.
2-A cool skin turbine shroud which provides the means discharging air from the load compressor surge control valve into the APU exhaust system.
3-Turbine wheel containment.
4-Acoustic treatment of the compressor inlet and turbine exhaust.
Improvement changes made to the TPE power section were inserted blade first and second stage turbine wheels, material changes and method of manufacture of all three turbine wheels, oil scavenging and seal improvements, including dual seals with drain cavities which are vented overboard via a manifold.

The gearbox assembly is mounted on the forward face of the load compressor and provides the drive pads for GTCP331 accessories (starter motor, oil pump, fuel control and cooling air fan) and the customer-furnished electrical generator. The different electrical philosophy (8000 rpm, 90/120 kva air cooled generator utilized by Airbus aircraft and 12000rpm, 75/90 kva, oil cooled generator utilized by Boeing aircraft) required two versions of this module.

The cast aluminum gearbox housing also provides four equally spaced forward mounting pads, provisions for oil servicing/draining, ports for contamination detection and pressure sensing. Figures 2 and 3 display the arrangement of the wet sump gearbox and gear train.

Figure 2-Accessory Gearbox

Figure 3-Gear Arrangement
The load compressor is attached directly to the power section and is driven at power section rotor speed by a free floating and positive lubricated quill shaft. All features of the load compressor are displayed in Figures 4 through 8. A key element of the load compressor and its control is the inlet guide vane assembly (IGV) shown in Figures 5, 6, and 8. This assembly consists of 28 individual vanes with a gear segment on the forward end of each vane. A master gear attached to the actuator bellcrank and a ring gear completes the IGV assembly. The guide vanes modulate, based on aircraft demand, to regulate load compressor inflow.
Another important feature incorporated into the load compressor design is the utilization of a primary carbon face seal with a secondary air blown labyrinth seal on both sides of the impeller. Venting of this cavity between the two seals overboard via a manifold prevent ingestion of oil into the passenger cabin. If you ever traveled on a Lockheed L-1011 and were subjected to the MIL-L-7808 oil fumes from the APU (not a Garrett unit!), you will understand the value of this arrangement.

The adaptation of the TPE power section for APU applications is shown in Figure 9.
Noise reduction was a requirement. This was attained by the using honeycomb panels covered with perforated metal of the surfaces in the flow passages of the compressor inlets and the turbine exhaust. The Acoustic treatment is shown in Figure 10.

Figure 10-Acoustics Treatments
Figure 11-GTCP331 APU External Features

Figure 12-GTCP331 APU External Features
During detail design of the basic APU, specifications for the full authority microprocessor APU Electronic Controller were released to our Tucson facility. Specifications for other parts and units that were to be defined and fabricated by outside sources were also issued. I spent much time with Dave Edmonds reviewing, approving and signing detail drawings. Dave’s drafting table was very close to Director of Engineering Frank Roberts office. I had never had much contact with Roberts, just participating in the early morning stand-up reports of the previous days activities. These meetings occurred in Eddie Butler’s Development Assembly Department and always included department heads and some management people. Since I was in the Air Turbine Motors and Constant Speed Drive Project and Roberts was in Prime Propulsion Project, we only listened to each other’s problems. But I soon learned, that he was a hard man and you had better be prepared when you went to his office. I observed grown men dash from his office with a very worried look and apparent wondering what they would do for an answer to problems. I stored this information, for I knew that my day would arrive!

In 1979 the fabrication of our development units, qualification units and the first flight test systems for the two customers was initiated, under the supervision of Herb Johnson’s Development Fabrication Department. Herb assigned Bill Stockton and John McKweon to handle this task. Most of everything progressed well except, for a mistake I made in the adaptation of the TPE to our APU needs. I had always insisted on maintaining common parts between units. This became a bad mistake due to Quality Control and disposition of discrepant parts. It soon became evident that APU personnel were not FAA approved to disposition propulsion engine parts, even though the parts were to be utilized by the APU Project. This impacted our program when several hundred second stage compressor diffuser vanes from the casting vendor were rejected with minor discrepancies. The TPE Engineer had no requirement for the castings so he reject the lot. Unfortunately, we did not find out about this until it impacted our schedule. I had to quickly create new drawings/part numbers for identical parts! It remains an item that I will never understand, but that’s government work.

Our first design review, with airline and aircraft manufacture representatives in attendance, was held within in this period. After Bob Wells and Skip Stohlgren presented the program status and reviewed future plans, I had the task of presenting all of the features of the GTCP331 APU. The presentation was held in the 301 building second floor conference room. Each participant was provided a table with a complete set of half-size drawing and I utilized full size drawings on a portable bulletin board to present our design concepts. I am sure that the participants appreciated having the drawing to refer to and make notes as the presentation progressed. But it became a serious distraction, for every time I progressed to another drawing there was much shuffling of paper, noise and loss of attention. I gained a valuable lesson and learned the value of a View Graph presentation. Some of the participants are in the following photograph.
John Boppart became the Director of Engineering and Frank Roberts moved up to Vice President of Engineering. It you recall John was the Project Engineer in charge of the CSDS inlet valve back in my ATM and CSDS Project Engineer days. He and I had many confrontations in those days and now he was my boss! I learned to appreciate him, for he was sharp, fair and a very good engineer. His weekly progress meetings were prompt, to the point and useful. I soon learned that everything you presented in the meetings had better be correct. If there were a mistake, he would point it out before you could finish your sentence. Maurine Lecky kept participants aware of meeting status, and if John had a conflict she cancelled the meetings in a timely manner.

My cubical/office was located just across the hall from the double door entrance from the stairs. This proved to be a bad location because the hallway facing the door became a stopping place for people to “shoot the bull.” Besides the disturbing chatter, they always seemed to be on their way from the coffee machine. Coffee cups were often placed on top of the panel which was very detrimental for my book selves, for much coffee was spilled. To this day many of my books continue to show stains from this ill mannered activity. In fact, the stained books still bare witness to this after the many years.

That panel was also involved in an embarrassing “foot-in-mouth” event. After a long meeting with John Boppart, Bob Wells and Skip, it was late in the day. I was putting things away and preparing to leave for home when a voice, which I did not immediately recognize said “I am sure pleased that you are on the GTCP331 program.” Without looking up I responded “I am damned glad to hear that. There sure as hell not many who are!” Then I looked up and there was John Boppart peeking over the panel. Bad location of my foot again!

Roger DeRudder, Tim Kjellberg, Roger Payne and John Zimmerer worked with Lou Smith, Ez Baumer and Earl Reynolds designing and preparing the required test equipment and test cells. They also worked with Eddie Butler’s assemble men to prepare the first development units for test. In
June, development testing was initiated. The following photograph shows some of the crew monitoring the first development unit during its assembly.

The first problem occurred with the failure of the power section compressor inlet housing. This housing is composed of two aluminum castings welded to a perforated aluminum sheet metal cylinder. The weld joint at the front casting failed. Our investigation revealed that the vendor had machined this area for cosmetic purposes. This was not observed due to the part being painted. Corrective action was completed and testing continued.

The next problem was a horrible screeching noise emitted from the load compressor under some operational conditions. It would have sounded as if we had a bunch of screech owls in the cabin. Chuck Linder was assigned the task of resolving this problem by use of the load compressor component test rig. This became a very long and costly program. Just as Goodyear is known for the accidental solution of rubber vulcanizing, Linder became the solver of compressor noise. After many tests and much data without success, he was monitoring the inlet guide vanes visually. It was thought that this was the area of instability. As he induced a thin screw driver into the vane area to feel if there was vibration, the noise stopped! So the master inlet guide vane was modified to incorporate a flat plate in the compressor inlet and no more screech owls! This modification is displayed in Figure 13.

![Figure 13-Master Inlet Guide Vane Modification](image-url)
Something of interest occurred during this test program. During lunch period Chuck Linder was across the table from Dave Edmonds and me when he begin gasping for air and choking. Dave leaped up, dashed around the table and lifted Linder up into the proper position and delivered several rapid compressions of Linder’s belly. The lodged material ejected with great velocity. Dave received a very nice article in the AiReporter for having saved a life!

Our Torrance facility was having trouble manufacturing some of our subcontracted parts, so I was assigned the task of helping solve the problem. When I arrived on the Phoenix Flight Line, I found that Frank Roberts and his wife were on the same flight. After introductions, we boarded the ATF3 powered Falcon 200. My first flight aboard this aircraft. I was in for a surprise, for the airplane was a hotrod! Takeoff and climb out at an angle that would be suitable for a F-15 and then we settled in for a very fast trip to LA. The landing was even more exciting, for thrust reverses were not installed! After a long roll and heavy braking, we departed the runway just before going into the ocean, at least that is the way it felt. I can say one thing, Tony DuPont may have created a fabrication and maintenance nightmare for AiResearch, but it is one hot engine.

Since this was my first visit to Torrance since the opening day tour, I was quite surprised at the external changes in the facility. The complete area was enclosed by an eight foot chain link fence with razor wire loops on top. Guard houses and electrical controlled gates at the entry where it was necessary to show identifications badges. Even with this, our fellow employees reported that they still had much vandalism and stealing in the parking lot. After finishing my task, the return flight home was equally as exciting with the landing almost ending on 24th Street. I ended the trip very pleased that I had left LA many years ago.

We received a complete tail section of the Airbus aircraft from MBB. This aircraft section was to be utilized to demonstrate various installation and maintenance tasks and as an APU operational test stand. Arrangement in the tail cone is shown in Figure 14 and the personnel who conducted these activities are in the following photograph.

![Figure 14-The General Arrangement of the APU Tail Cone Installation](image-url)
1- Kjellberg, 2-John Teas, 3-Harold Whitton, 4-MBB Wolfer, 5-MBB Schultz, 6-Vince Corcoran, 7-Larry Wallace, 8-MBB Werner Hoose, 9, __, 10-Walter Kitty Rep., 11-Barney Turner, 12-Roger DeRudder, 13-Ez Baumer and 14-MBB Horst Warnecke.

The development testing progressed very well and by June 1980 over 1000 hours of operation had been accumulated. Also the tail section, with a complete GTCP331-250 APU installation, was shipped to Alaska and successfully demonstrated low temperature and adverse weather operation under realistic conditions.
We were having fabrication difficulties and it appeared that the qualification and flight test units would not make the required delivery. So Frank Roberts required Bill Stockton, John McKeon and me to review fabrication status in weekly meetings in his office in the 301 Building. At first, I felt some queasiness due to my prior observations outside of his old office in the 501 Building. But I soon learned that he was reasonable man who required an honest evaluation, i.e., no BS and assurance that corrections were being made. At following meetings, you had better have made the progress promised or you were in for one of his dressings down. The three of us were able to avoid that and soon gained his praise as the required FAA and customer qualification testing was initiated in December 1980. As a result of the increased work load Rick Dorsey, Wayne Ruby and Steve Woodard joined the project and became very active in the test programs.

Four engines were committed to qualification testing. Test requirements are grouped into FAA required and customer required tests as shown in Figure 15. The FAA and qualification testing progressed very well, but I do recall one thing that occurred that is of interest. It happened just prior to turbine wheel containment test. Lee Matsch dashed into my office and said that I must stop the test. His stress man had reevaluated the containment ring and recommended the thickness be increased by 0.060". The test unit was in the test cell and ready, the old Test Engineer’s philosophy (build ‘em, run ‘em, bust ‘em and fix ‘em) kicked in. I told Lee that the test was on and if it failed we would fix it. The test was a beautiful success as shown the following Figure 16. Later Lee came by and agreed that sometimes a test is worth more than an analysis.

Figure 15-Qualification Test Matrix

![Figure 15-Qualification Test Matrix](image)

Figure 16-Successful Power Turbine Wheel Containment

![Figure 16-Successful Power Turbine Wheel Containment](image)
The first units were shipped to Boeing and Airbus in April 1981 as the Qualification test continued. This event rated an article in Engineering News which included this photograph.

June 1981 John Boppart become the Vice President of Engineering and Bob Von Flue replaced him as Director of Engineering. Bob Von Flue and I were friends from our Air Turbine Starter and Air Turbine Motor days.

August 4 the rollout of Boeing 767 was accomplished, many of our people were in attendance and the first flight of the 767 occurred in September 1981. The qualification testing was completed. The reports were issued and approved in October. The GTCP200/250 received FAA Certification December 4, 1981.

The Boeing 757 rollout occurred January 13, 1982 and first flight was in February. MBB A310 first flight occurred in March.

In May, I learned of the ill-treatment of my good friend Perry Sebring. I contacted Bob Orr who was on a one year consulting contract prior to his retirement. Bob knew Perry very well, for they were long time employees, both starting in the Los Angeles AiResearch facilities. He was also of the old Garrett school of “employee treatment.” I spent much time in his office on the second floor of the 301 Building talking about the many projects to which Perry had contributed. I expressed my opinion that he was one of our best development engineers and deserved much better treatment. Bob promised to look into the situation, but cautioned me that he no longer had any influence in these matters. Sometime later, I was called to his office and he told me that there was nothing he could do. To this day I do not know...
why Perry was treated this way. I entered this information into “things that will influence my retirement” log.

In July, the FAA Certification of the 767 was received, and things became so calm that Bob Wells left the program for a similar position with F109 propulsion engine project. 1982 was a very busy and successful year, in which the GTCP331 APU entered airline service with all three aircraft as a Category I-Essential APU meaning that the APU was legally qualified to supply electrical or pneumatic power necessary for maintaining safe operation of the aircraft on the ground or in flight. This classification/requirement permitted twin engine aircraft to operate over long oceanic routes. I continued working the GTCP331 Program as Production Engineering gradually assumed responsibility for the program and Skip Stohlgren transferred to the Israeli LAVI (Young Lion) fighter program.

The GTCP331 APU attained several significant advancements for Garrett gas turbine technology, namely:

1-First use at Garrett of a full authority digital electronic engine control. The ECU, manufactured by AiResearch-Torrance, controls all engine functions, provided automatic engine self-protection and contains a broad range of integrated built-in-test.

2-First use at Garrett of powdered metal turbine disk technology. The first stage turbine disk is fabricated from powdered metal Astroloy.

3-The first use in the gas turbine industry of a dual alloy turbine disk. The third stage turbine is fabricated from a powdered metal disk which is diffusion bonded bonded to a cast blade ring.

4- The first at Garrett of extensive internal acoustic treatment, both on the inlet and exhaust

In September, the Boeing 767 entered airline service. After which I picked up a few additional tasks from Bob Von Flue. One was to join with Bill Shoup and try to secure the Northrup F-20 Secondary Power System. Bill had been working on this activity for some time. I joined in and found that the OEM had once again presented us with a “Blivet” (ten pounds of crap in a five pound bag)! A very limited and odd shaped cavity for the system. A wood and metal mockup was fabricated and furnished for Northrop’s aircraft mockup. The installation was very crowded. It was obvious that it would be a difficult task and the system would have maintenance and life problems.

The F-20 was beautiful single engine airplane with F-5/T-38 features. It was being proposed for the Air Force/Navy Advanced Tactical Fighter/Aircraft (ATF) program. Bill and I spent much time trying to solve the design and installation problems. Our problem was finally solved when Northrop lost the contract because the Air Force decided to modify existing F-16 aircraft to meet the ATF requirements. Also the potential foreign (export) customers would not contract for the F-20 aircraft because the aircraft would not be in the US military inventory.
The Boeing 757 entered airline service in January 1983 and I continued doing odd jobs for Bob von Flue. Some of these tasks were not pleasant because of “the big talkers/little doers” in charge, but I will not go into that. Late in 1983 I joined the LAVI program and that will be the next story.

BIBLIOGRAPHY

1-GTCP331-200(A) Auxiliary Power unit for the BOEING 767-757 Airplane
   EXECUTIVE SUMMARY DECEMBER 1978
2-Various articles from many AiReporters and other company publications
3-Drawing-L3622102 LAYOUT-MATERIALS GTCP331-200 by Edmonds
4-SAE Paper 801147, The GTCP331 Auxiliary Power Unit for the Next
   Generation Commercial Transports by Robert E. Wells and Aldo L. Romanin
5-ASME Paper 83-GT-188 THE GTCP331, 600 hp AUXILIARY POWER UNIT PROGRAM
   by L. M. Stohlgren

I wish to thank Bob Wells, Dave Edmonds and John Zimmerer for the data from their files and once again Bill Spragins for editing and correcting my writing.
TO: R.J. Von Flue
FROM: E.L. Gammill

SUBJECT: Engineering Stores

DATE: October 30, 1979

REFERENCE: E:ELG:1081:0727-79

The GTCP331 Project has placed additional orders for qualification units. This hardware will increase the inventory value to approximately 4.5 million by April of 1980.

In addition to the problems and suggested solutions of the referenced memo, the following has been brought to Project's attention:

1. Since environmental conditioning is non-existent, damp weather and/or evaporative cooling will cause a serious corrosion problem.

2. Lighting needs to be improved.

3. Security appears to be a real problem.

4. Transportation continues to be a problem resulting in Engineering personnel utilizing personal cars.

The latest complaint, but by no means the least, (Bob, I really hate to sling this one at you) is the cat excrement problem. Yes, our stores area is a haven for the neighborhood cats.

Once again a clean, orderly, controlled and secure Engineering store in the laboratory area would ultimately pay for itself via more efficient use of Engineering manpower and fewer lost and/or damaged parts.

E.L. Gammill
GTCP331 APU Project
Power Systems Applications Development

cp
TO: Distribution

SUBJECT: GTCP 331 APU North American Operators Conference 21-23 February in Phoenix

DATE: February 27, 1984

The 757/767 operators had requested subject conference last fall when they were having many frequent problems with this APU. However, it was February before all of the key airline personnel were available at the same time.

In the meantime, the GTEC fixes were incorporated and the problems diminished to a manageable number and frequency. The result was unanimous praise by the operators for the aggressive approach that GTEC has taken to solve the problems. One of them said "the introduction of this APU into service was a dream compared to earlier APUs, especially the L1011 ST6. However, lest we feel complacent, he went on to say that the ST6 is now a fine APU with excellent performance and good reliability.

Problems do remain and the airlines asked GTEC to continue the same aggressive approach towards their solution. They set some priorities and established a troubleshooting committee to include each airline, Boeing, and GTEC.

All attendees had a very positive attitude. They like the APU. "It provides plenty of air and good, 'clean', electric power needed for an electronic aircraft." The flight crews feel the APU is essential and are most unhappy when it is not available. United said "...the 331 will eventually outshine the 85."

Larry Aycock, GASD Customer Service Engineer, did an excellent job as the moderator. This was reflected in the numerous airline comments such as "This is the best technical coordination meeting I have ever attended."

Larry, GASD, and GTEC are all to be complimented on this excellent session.

Jack Campbell

JC: ba