ACCIDENT

Aircraft Type and Registration:	Cessna 402C, N603AB
No & Type of Engines:	2 Continental TSIO-520-VB piston engines
Year of Manufacture:	1997 (Serial no: 402C0603)
Date & Time (UTC):	11 February 2017 at 2004 hrs
Location:	Virgin Gorda Airport, British Virgin Islands (BVI)
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 8
Injuries:	Crew - None Passengers - None
Nature of Damage:	Extensive damage to the landing gear and aircraft structure
Commander's Licence:	Commercial pilot's licence (FAA)
Commander's Age:	29 years
Commander's Flying Experience:	5,458 hours (of which 809 were on type) Last 90 days - 225 hours Last 28 days - 80 hours
Information Source:	AAIB Field Investigation

Synopsis

After landing on Runway 03 at Virgin Gorda Airport, the pilot was unable to stop the aircraft on the runway and it came to rest on a bank at the edge of the ramp. The aircraft was extensively damaged but none of the nine occupants, including the pilot, were injured. The investigation generated a number of concerns both in the maintenance and operation of this aircraft, which was engaged in international public transport.

Two Safety Recommendations are made to the Federal Aviation Administration.

History of the flight

The aircraft was flying from St Thomas in the US Virgin Islands to Virgin Gorda (VIJ) in the British Virgin Islands. There were eight passengers on board, together with the pilot. It was the pilot's eleventh flight of the day, and his fourth flight to Virgin Gorda. All these flights were short, with the longest flight being about 40 minutes duration and the shortest just a few minutes. The flight from St Thomas to Virgin Gorda took 35 minutes.

The weather in Virgin Gorda was excellent with a light easterly wind and little cloud. The pilot commenced his approach to Virgin Gorda using his usual turning and configuration points. The aircraft touched down normally and the pilot retracted the flaps before applying the brakes. The brakes responded, although the pilot commented that the right brake did not seem to respond as positively as he expected. The pilot reapplied the brakes but the

left brake pedal “flopped to the floor”. Judging he had insufficient room to abort the landing, the pilot continued to pump the brakes which he did not consider to be responding. He shut down the engines before the aircraft left the paved surface, struck signage and then a low wall before coming to rest on a bank.

The pilot vacated the aircraft through the side window and then opened the main door to allow the passengers to exit the aircraft. None of the occupants was injured. The aircraft was extensively damaged.

Aircraft information

General

The Cessna 402C is a low-wing, twin-engine aircraft equipped with a retractable, tricycle landing gear. The structure is of an all-metal semi-monocoque construction and, in its passenger carrying configuration, the aircraft can accommodate a maximum of ten people. The aircraft is certified for single-crew operation.

Maximum takeoff mass is 6,850 lb but, with the addition of vortex generators, this can be increased to 7,210 lb. Landing performance in terms of weight and distance can be improved by ‘short-field operations’ modifications to the flaps and landing gear. Modifications that have been approved by the Federal Aviation Administration (FAA) have an individual Supplemental Type Certificate (STC).

Brakes

The aircraft has an independent hydraulically-actuated brake system for each mainwheel and the brakes can be operated from either the pilot’s or the co-pilot’s rudder pedals. A parking brake consists of a manually-operated handle. When brake pressure is applied and the handle is pulled, the brakes remain pressurised until the parking brake is released.

There are two hydraulic master cylinders, one for each brake, connected to the pilot’s rudder pedals. The master cylinders have integral oil reservoirs and depressing the top of a rudder pedal causes the corresponding piston rod to push the piston into the cylinder, thereby pressurising the brakes (Figure 1).

N603AB (manufacturer’s serial number 402C0603)

The aircraft had accrued approximately 20,200 flying hours. It was equipped with an Aircraft Payload Extender/Short Takeoff and Landing (APE STOL) modification, which is approved under STC SA02208SE. The modification increases the maximum landing weight to 7,210 lb and, according to the manufacturer, *‘provides landing field length reductions up to 25%’.*

The operator had recently completed an extensive programme of maintenance over a period of approximately three years. When the accident occurred, the aircraft had accrued 41 hours and 95 flight cycles since it was returned into service in January 2017.

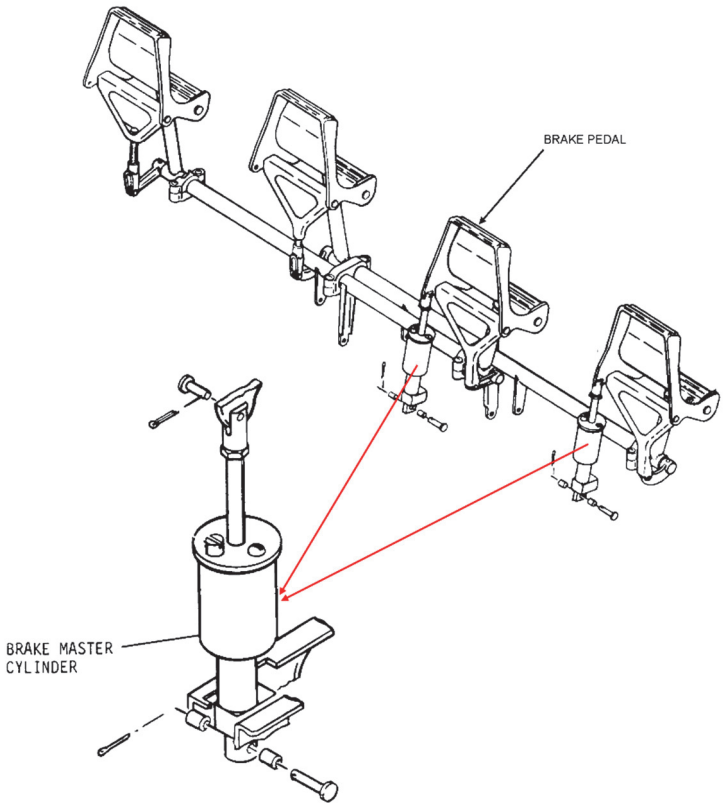


Figure 1

Schematic of the brake master cylinder installation

The aircraft had been involved in a previous accident at Virgin Gorda in March 2008. The official narrative of the event states:

> *'The pilot attempted to stop the aircraft but the left brake failed during the second application. In an effort to avoid running off the end of the runway and into the ocean the pilot applied left rudder and made a turn in the direction of the apron. The aircraft crossed the apron and struck the terminal building with the right wing, the tail of a parked Aztec with the left wing and came to rest after hitting the security gate at the end of the terminal building. The aircraft sustained substantial damage to the nose as well as the right wing. The Aztec, terminal building, and security gate were also damaged.'*

The AAIB was asked to assist with the examination of the brake units and records indicate that they were extensively corroded. The operator advised that they *'serviced the brake and repaired the minor damage to the wing'* before the aircraft was returned into service.

On-site examination

In the accident of 11 February 2017 the aircraft came to rest on a grassy slope within the airport perimeter and adjacent to the northern edge of the tarmac apron (Figure 2).

Figure 2
General view of the accident site

Distinct tyre marks from all three wheels were visible across the apron and grass and this indicated heavy sideward loading as the pilot tried to turn to avoid over-running into the sea. There was no evidence of locked brakes, such as pronounced skid marks or marks caused by loose stones dragged across the surface.

As the aircraft traversed the grass it struck a frangible runway sign before passing through a low retaining wall. The nose landing gear collapsed and the right main landing gear was broken off. After encountering rising ground and colliding with a group of substantial rocks, the aircraft slewed to rest through about 45°.

Damage sustained by the left propeller indicated that it was not rotating when the accident occurred, that engine having already been shut down by the pilot. The right propeller had been rotating with very little energy, shortly after its engine was shut down.

Brake system test following aircraft recovery

The left brake worked when tested and the brake pedal action was considered normal.

The right brake could not be tested because the right main landing gear had detached and the hydraulic pipes were broken. The brake unit and disc appeared to be in satisfactory visual condition and fluid had leaked from the broken pipes.

The brake master cylinders, brake units and parking brake control valve were removed and taken to the AAIB facility for further examination and testing.

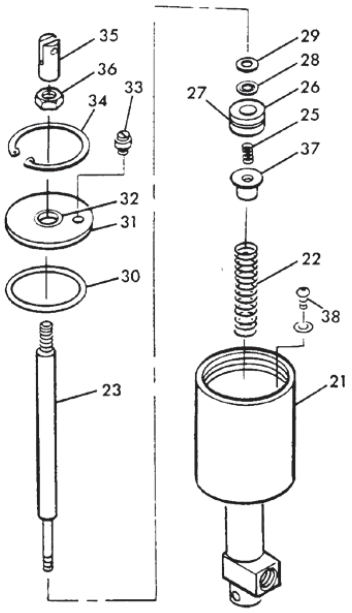
Equipment investigation

Brake master cylinders

The operator stated that both master cylinders were overhauled when the aircraft underwent its most recent maintenance. This was reported to have involved cleaning the units and installing new seals and springs. The Federal Aviation Administration requires (FAR 91.417) that maintenance records are retained for a period of one year. The operator advised that the aircraft had been in maintenance for approximately three years and records for the master cylinders were not available.

Left master cylinder

Damage on the identification plate obscured most of the details but the unit was manufactured by Cleveland in August 1994. Figure 3 is a schematic depicting the internal construction of a Cleveland master cylinder.



21	Housing
22	Piston return spring
23	Piston rod
25	Piston spring
26	Piston
27	O-ring
28	Stat-O-seal
29	Washer
30	Rubber ring
31	Cover plate
32	Bronze bushing
33	Filler plug
34	Snap ring
35	Clevis
36	Check nut
37	Spring guide
38	Screw and washer assembly

Figure 3

Schematic of the Cleveland brake master cylinder

The filler plug was missing and the cover plate could be rotated using finger pressure. When the snap ring and cover plate were removed, it was apparent that the rubber ring was missing.

Debris and contamination inside the oil reservoir was analysed and identified to be general environmental dirt and aluminium flakes (Figure 4).

Figure 4

Debris in the left master cylinder oil reservoir

A basic functional test established that the master cylinder could generate and hold pressure.

The piston rod and return spring were removed, revealing two pieces of a broken return spring in the lowest section of the housing bore. The broken pieces, when placed end to end, had a combined length that was approximately half a complete spring (Figure 5). The coil was wound in the opposite direction to the intact spring.

Figure 5

The intact piston return spring and the remains of the broken spring

Examination of the piston rod revealed debris trapped between the stat-o-seal and the washer (Figure 6a). This was subsequently identified to be part of the stat-o-seal, which was in poor condition (Figure 6b).

The piston rod spring guide was found to be secured to the piston rod by means of a roll pin. This is contrary to the Cleveland design, but conformed to units manufactured by Gerdes Product Co, which was the predecessor to Cleveland.

Figures 6a and 6b

Trapped seal debris and general condition of the stat-o-seal

Right master cylinder

The right master cylinder was manufactured by Gerdes Product Co in December 1979.

The filler plug was missing and a tooth-lock washer had been fitted to secure the bronze bushing, which was otherwise loose in the cover plate; the bush is supposed to be an interference fit. Debris and contaminants found inside the oil reservoir were identified to be general environmental dirt and aluminium flakes.

A basic functional test of the master cylinder showed no anomalies and the unit could generate and hold pressure. Disassembly revealed stat-o-seal degradation, but to a lesser extent than the left master cylinder.

The joint between the piston rod guide and the piston rod was found to be threaded, which was contrary to the Gerdes Product Co, but conformed to the Cleveland design.

Master cylinder servicing requirements

The Cessna maintenance schedule requires a visual inspection of the brake system and a functional test every 200 hours of operation or 12 months, whichever occurs first. The master cylinders should be serviced at the same time; this requires removal of the filler plugs, replenishing the oil reservoir with hydraulic oil, and refitting the filler plugs.

There are no scheduled requirements to change the brake fluid or to periodically overhaul the brake system components.

Weight and balance

The aircraft was under the maximum landing weight and within the approved centre of gravity. The loading sheet had been completed incorrectly but the aircraft was in balance and this had no bearing on the accident.

Regulatory oversight of the operator

The operator was registered in the state of Florida, USA and was regulated by the US Federal Aviation Administration (FAA). The operator's headquarters was in Fort Lauderdale, Florida but its operating base was in San Juan, Puerto Rico, an unincorporated territory of the USA. The FAA regulates airlines through various Flight Standards District Offices (FSDO) which are spread geographically around the USA. The operator was regulated by the San Juan FSDO. The FSDO is responsible for certification and operations of an air carrier and performs a variety of compliance actions in regards to procedures, pilot certification, aircraft maintenance and certification.

The British Virgin Islands Airports Authority set the rules for operations into Virgin Gorda Airport which are published in the Air Navigation (Overseas Territories) Order 2007. This sets out the requirements for aircraft performance, pilot qualification and operating limitations. It is the responsibility of the operator to ensure that these requirements are met and ultimately the regulator (in this case the FAA) to ensure the operator is complying with the instructions.

Airfield information

Due to issues of topography, length and surface conditions, Virgin Gorda Airport is restricted by the instructions issued under the Air Navigation (Overseas Territories) Order, 2007. This means the pilot in command must have:

- A commercial licence
- Minimum total flying hours of 1,500
- Minimum of 100 hours multi-engine piston aircraft, including at least 50 hours of the type being flown
- Made at least 10 previous landings at the aerodrome
- Made at least 3 landings at the aerodrome in the previous 90 days

Due to the terrain in the approach, an offset right base approach is flown meaning the aircraft is aligned with the runway centreline at around 700 ft aal. The runway itself is made of compacted fine gravel, with a tarmac turning area at each end and there is a small tarmac ramp off to the side. The landing distance available (LDA) on Runway 03 is 795 m (2,608 feet).

Aircraft performance

To meet the requirements of the approval to operate into Virgin Gorda, the operator had to ensure that the aircraft could stop in 70% of the LDA. The only figures provided by the operator for the Cessna 402C were from the Pilots Operating Handbook (POH). These figures were based on a level, hard-surface runway using maximum effective braking. They were also based on the Cessna 402C before it was modified with wing vortex generators to allow for higher weights as well as a further modification to improve the short takeoff and landing performance of the aircraft. The figures available were therefore not valid for the aircraft.

The figures also did not account for the gravel surface at Virgin Gorda. The surface conditions of a gravel runway may have an adverse effect on stopping distance as the loose unbounded material of the runway may degrade braking performance compared to a hard surface. Very little guidance could be found on the use of gravel runways, with the exception of Canada which has a number of gravel runways. Transport Canada specifies a factor of 10% for propeller driven aircraft with a MTOW less than 5,700 kg (AC 700-011).

Using the figures in the Flight Manual Supplement for the Aircraft Payload Extender STOL System (STC SA02208SE), the Cessna 402C could not meet the 70% requirement as laid down in the Virgin Gorda approval even before the distance was factored for the gravel runway performance. Whilst the aircraft could stop in the distance available, the safety margin which should have been applied was being used on normal landings.

On the accident flight the flaps were retracted after touchdown, which is contrary to the guidance in the Flight Manual Supplement. Retraction is only suggested for light weights, with this aircraft touching down only 170 lbs below MLW. This retraction would have compromised the landing performance as set out in the performance tables. This was a common company procedure.

No guidance was provided to the pilots on how to calculate the landing distance required (LDR), how to factor for the gravel surface, or any guidance that a LDR was to be calculated.

Meteorology

There was no weather reporting station at Virgin Gorda and no ATC service. The weather at Beef Island Airport which is 6 nm to the west of Virgin Gorda reported excellent conditions with the wind easterly, less than 10 kt. The temperature was 30°C.

Pilot information

The pilot had completed over 800 landings at Virgin Gorda over the preceding twelve months. He was appropriately qualified, and met all the experience limitations. He had received no training on how to calculate a landing performance figure for the gravel runway.

Analysis

Engineering

The pilot reported that the left brake pedal "flopped to the floor" on his second brake application. The symptoms are similar to those reported by another pilot who was involved in an accident to the same aircraft at the same airport in 2008. The cause of this previous occurrence is not recorded but records cite extensive corrosion and the operator reported that they serviced the brakes when the aircraft was repaired.

A 'troubleshooting chart' in the Cessna 402C maintenance manual outlines the recommended diagnostics if the '*brake pedal bottoms*'. The initial action is to check the fluid content in the brake system and, if this is satisfactory, the condition of the stat-o-seal should be checked. If both features are satisfactory, the chart recommends checking the brake disc for warping.

The left brake system was found to work after the aircraft was recovered, thereby eliminating insufficient fluid as the cause. Examination of the brake disc showed no evidence of distortion or warping.

A basic functional test of the master cylinders established they could generate and hold pressure but subsequent strip examination identified several anomalies, some of which could have a significant detrimental effect on braking performance. The omission of the filler plugs created an entry point for debris and contaminants that were found in the oil reservoirs of both master cylinders. Analysis established that the debris was a combination of general environmental dirt and aluminium flakes; the latter most likely originating from the internal wall of the oil reservoir. The aircraft manufacturer considered that the presence of debris, if trapped between the sealing faces, could compromise the quality of the seal. This would have an adverse effect on braking performance but the symptoms would only be apparent whilst the debris remained trapped.

The omission of the rubber ring seal from the left master cylinder would have had no effect on braking performance but was indicative of a shortfall during maintenance. The remains of a broken spring in the left master cylinder was unlikely to have interfered with system operation but they also were indicative of a shortfall during maintenance. The operator did not know when the spring failure occurred and considered the omission to remove the broken parts to be an error on their part.

In the case of both cylinders, the method used to attach the spring guides to the piston rods was contrary to that expected by the manufacturer. The evidence indicated that the internal components from one manufacturer's cylinder had been transposed with those of the other, that is, that the Cleveland parts had been installed in the Gerdes Product Co unit and vice versa. Whilst not influencing the performance of the master cylinders, the error was indicative of a shortfall during maintenance.

The stat-o-seal in the left master cylinder was degraded to the extent that it was breaking apart and its ability to create a reliable, effective seal would be compromised. A leak past

the stat-o-seal will have an adverse effect on brake performance and, in the worst-case scenario, will result in the brake pedal bottoming and total brake failure on the affected system.

The master cylinders were reported to have been dismantled, cleaned and rebuilt when the aircraft was last on maintenance. This included cleaning the units and installing new springs and seals. Records of the work were not available but regulations only require such to be retained for a period of 12 months and the aircraft was on maintenance for approximately three years. However, the contamination in the oil reservoir and the condition of the stat-o-seal is not considered typical of a master cylinder that has only accrued 41 hours since overhaul.

Operations

The pilot was experienced and suitably qualified for the flight. He had completed over 800 landings at the airport without incident. There is no evidence to suggest that the landing was long, or beyond the normal touchdown position.

He had no opportunity to calculate or assess the landing performance of the aircraft as there were no valid performance charts in the aircraft or the operations manual. There was also no guidance on what factor to use for a gravel runway.

Once the aircraft landed and it became apparent there was an issue with the brakes, the pilot attempted to steer the aircraft to avoid departing the end into the sea. He shut down both engines before the impact. There was no emergency procedure for loss of braking or brake failure for the Cessna 402C.

In view of the shortfalls noted both in the maintenance and the operation of this aircraft, the following two Safety Recommendations are made:

Safety Recommendation 2018-002

It is recommended that the Federal Aviation Administration review the maintenance capability, processes and planning of Air Sunshine to ensure that they are sufficiently robust for conducting international passenger charter services.

Safety Recommendation 2018-003

It is recommended that the Federal Aviation Administration review the operations data management and operating procedures of Air Sunshine to ensure that they are sufficiently robust for conducting international passenger charter services.

Conclusions

The aircraft landed at Virgin Gorda in conditions (of weight, altitude, temperature and surface condition) where the landing distance required was very close to the landing distance available and without the required safety margin. Hence, when the performance of the brakes was not as expected, probably due to debris in the braking system, the aircraft could not be stopped on the runway.

Analysis of the maintenance state of the aircraft involved in this accident indicated that the maintenance capability, processes and planning of its operator were not consistent with the standards expected in conducting international passenger charter services. This appeared also to be the case for the operational procedures and data management.