ACCIDENT

Aircraft Type and Registration:	Pegasus Quantum 15-912, G-BYNO
No & Type of Engines:	1 Rotax 912 piston engine
Year of Manufacture:	1999
Date & Time (UTC):	5 April 2006 at 1225 hrs
Location:	Clench Common Airfield, near Marlborough, Wiltshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Aircraft destroyed; damage to other aircraft and barn roof
Commander's Licence:	Private Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	14,000 hours approximately (of which about 600 were on type) Last 90 days - 22 hours Last 28 days - 8 hours
Information Source:	AAIB Field Investigation, with the participation of the British Microlight Aircraft Association

Synopsis

After an uneventful flight and while on the approach to land, the wing pitched up and the aircraft turned to the right. It subsequently crashed into the roof of a barn close to the landing threshold of the airstrip. Ferrules[1] had failed in four rigging cable assemblies causing structural failure of the aircraft. These four cable assemblies had been recently fitted. The cable assemblies were made locally; they were not approved by the manufacturer, nor were they approved by the BMAA.

Footnote

[1] Ferrule – a sleeve of metal which is crimped onto the wire rope to allow a loop in the rope to be formed.

History of the flight

The flight was an air experience lesson bought for the passenger as a gift. The flight progressed uneventfully until the aircraft returned to the airstrip. Runway 34 was in use and the surface wind was estimated to be from approximately 350º at 10 to 15 kt. The aircraft joined the circuit and all appeared normal until it was at approximately 80 ft agl on its approach to land. At this point the aircraft encountered some turbulence. This is a known phenomenon with the wind from this direction due to the presence of a wood situated very close to the eastern edge of Runway 34. The pilot was seen to make appropriate control inputs to correct the disturbance. Shortly afterwards an unusual noise was heard by the passenger and also by several eyewitnesses. One eyewitness saw a cable trailing to the rear of the aircraft. The wing then pitched up and the aircraft turned to the right, before descending towards a barn that was close to the landing threshold of the airstrip. The aircraft struck and penetrated the roof of the barn; the pilot and the passenger sustained serious injuries.

Three flights earlier, about two weeks previously, the aircraft had been fitted with four replacement rigging cable assemblies, which had been locally made. Soon after the accident the AAIB published Special Bulletin S4/2006 which gave preliminary details of the accident and drew attention to the requirement to use approved parts in critical applications. No safety recommendations were made in the Special Bulletin.

Pilot's comments

The pilot suffered very serious injuries to his legs and back. When he regained consciousness three weeks later he had no recollection of the accident flight. He had completed a flight in G-BYNO on the morning of the accident but his recollection of this flight was patchy. He did recall that he did a thorough pre-flight inspection of G-BYNO, during which he noticed nothing untoward. He stated he was not aware that cables had been replaced on G-BYNO two weeks previously.

Passenger's comments

The passenger suffered serious injuries to his legs and left arm. He stated that before the flight the pilot of G-BYNO gave him a general description of the air experience lesson. It was emphasised that all items of clothing were to be secure and his camera, which he took on the flight, was to be around his neck on a lanyard. When not being used it was to be stowed in a pocket on the front of the flying suit that was secured with Velcro. He was subsequently given a flying helmet with an intercom, a thermal flying suit and gloves; these all fitted correctly.

After being securely strapped into the aircraft the pilot started the aircraft's engine and then taxied out to the runway. After a check of the intercom the pilot proceeded to line up on the runway and take off. Once airborne the pilot said to the passenger that if he felt uneasy at any time then they would return to Clench Common "without delay".

The flight progressed uneventfully until the aircraft was on final approach to land. At this stage the passenger could feel the aircraft being buffeted by the wind. As they came abeam the farm buildings on the right, he heard a 'twang'. The passenger did not say anything and he did not hear the pilot say anything. The wing then suddenly pitched up and the aircraft turned to the right. He became aware that the aircraft was descending rapidly towards the roof of a barn and he then heard two loud bangs. He believed these were the aircraft hitting the barn roof and then the ground.

Witnesses' comments

There were numerous witnesses to the accident. The majority were outside the flying club house which was situated to the north of the barn. They observed G-BYNO on final approach, and all reported that the aircraft was disturbed by some turbulence; shortly afterwards there was a loud bang. Then they saw the wing pitch up and the aircraft turn right. They subsequently lost sight of the aircraft just before it impacted the barn roof.

One eyewitness was standing by the signals square on the edge of the airstrip on the north-western side of the barn. He stated that he was preparing his aircraft to go flying, and was interested in observing G-BYNO as it made its approach to land as he wanted to get an idea of the flying conditions. All appeared normal until the aircraft was at approximately 80 ft agl when it was disturbed by a gust of wind. He saw the pilot putting large inputs into the control frame as he corrected this disturbance. He subsequently heard "something peculiar" and thought something had hit the propeller but he did not see any loose article come out of the cockpit and felt everything was still normal at this point. G-BYNO then pitched up slightly.

He then heard a second noise similar to the first, followed by an unusual noise from the engine. He subsequently saw a wire trailing from the aircraft's control frame, to the right side of the aircraft, beneath the propeller; this wire then went into the propeller. The wing then pitched up and the aircraft turned right towards the barn. It crashed into the roof of the barn in a nose down and right wing down attitude.

Aircraft information

The Pegasus Quantum 15 is a two-seat, weight-shift controlled, flexwing microlight which consists of a tricycle unit or 'trike' suspended beneath a flexible wing assembly. The trike incorporates the engine, landing gear, seats and cockpit, and has a front strut and monopole. The latter provides an attachment point for the wing. Attached to the wing is the control frame which is triangular and consists of a left frame, a right frame and a base bar; this is commonly called the 'A' frame.

Four rigging cables brace the control frame relative to the wing. Two cables run from the bottom of the left control frame, one forward and one rearwards, and similarly, two cables run from the bottom of the right control frame, one forward and one rearwards (see Figures 1a and 1b). These cable assemblies consist of

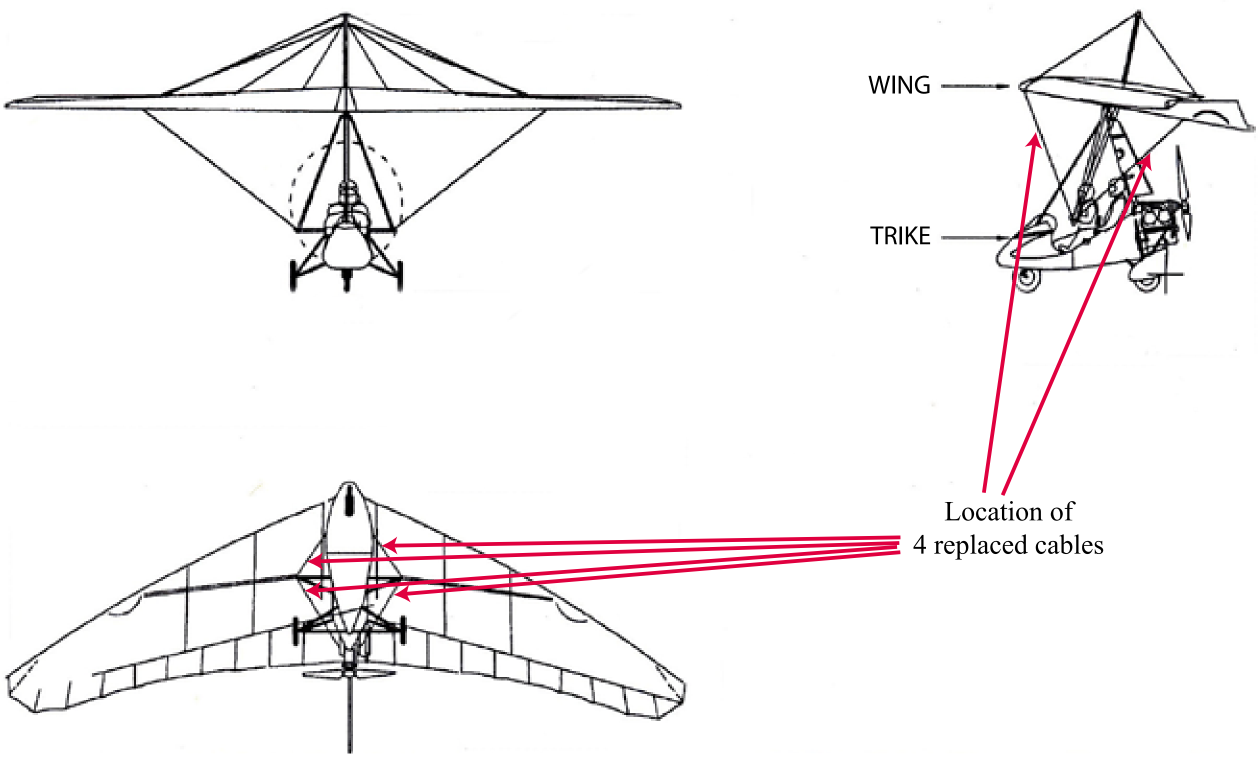


Figure 1a

Aircraft layout and location of replaced cables

Figure 1b

Location of the failures in the cable assemblies
(Note: generic microlight model shown)

a length of 3mm diameter, 7 x 7 strand wire rope, with a loop at each end. The loops are formed by the cable passing around a teardrop shaped eyelet, often called a thimble, through which bolts are fitted. The loop is held in place by two ferrules which are crimped onto the wire rope using a crimping tool. Each ferrule is crimped in two places forming two 'necks' in each ferrule. As part of the manufacturing process a simple gauge is used to test that the dimensions of the necks are sufficiently small to ensure that the cables are adequately gripped. It is common practice for protective plastic shrouds to be fitted to cover the ferrules.

On the Pegasus Quantum there are also flying wires that extend from the base of the control frame outboard to the wing spar, rather like a bracing strut found on many high wing light aircraft. These flying wires are swept slightly aft, which has the effect that the maximum loads in the forward pair of rigging cables are higher than those in the rear rigging cables.

G-BYNO was built in 1999 and had logged over 1,700 hours. The aircraft operated on a Permit-to-Fly, for which its last inspection and check flight were on 25 August 2005.

Meteorological information

The Met Office provided an aftercast for the time of the accident. The synoptic situation at 1200 hrs indicated that there was a ridge of high pressure covering the British Isles with a light northerly flow affecting the Marlborough area.

The METARs for RAF Lyneham, 11 nm north-west of Clench Common, issued 30 minutes before and after the accident, showed that the wind was from 350º at 10 kt and there were FEW clouds at 4,500 ft agl. Although RAF Lyneham is 138 ft below Clench Common in elevation, it is believed that the wind at the airstrip would have been comparable.

Airstrip information

Clench Common is an airstrip two nautical miles south of Marlborough, Wiltshire, which is predominately used by microlight aircraft. It is 650 ft amsl and consists of two grass runways, orientated 34/16 and 05/23. Runway 34/16 is 390 m in length and Runway 05/23 is 330 m in length. There is an Air-Ground radio frequency for aircraft operations.

To the east of the threshold of Runway 34 there is a barn and a collection of small buildings. The barn is used for aircraft storage and the buildings are used as offices and a club house. Behind these buildings is a small wood of 60 ft high trees.

Wreckage information

The aircraft had penetrated the roof of the barn. As a result the internal wing structure had failed causing both the wings to fold upwards, and most of the aircraft wreckage was contained within the barn.

During the initial examination, failure of the ferrules to grip the wire rope at one end of each of the four rigging cable assemblies was evident. See Figure 2 for an example of failed ferrules (note the wire rope has pulled through the ferrules) and Figures 1a and 1b for a diagram showing the location of the four cables. No ferrules or plastic shrouds were found on the rear ends of the two

Figure 2

rear cables and these cable ends had damage consistent with having been struck by the propeller.

A search of the ground under the aircraft's likely final approach path revealed several pieces of propeller and two blue plastic shrouds. These two shrouds had damage consistent with having been struck by the propeller, and ferrules were present inside both of them. Photographs of the aircraft taken as it was taxiing prior to the accident flight confirmed that blue plastic shrouds were present on the rear end of both the rear cables. The wreckage trail was therefore consistent with the cable ends pulling through the ferrules of the two rear rigging cable assemblies, whilst in flight.

The ferrules on G-BYNO were compared with those on another aircraft of a similar type at the site and the G-BYNO ferrules were found to have a substantially smaller wall thickness.

Previous maintenance activity

The owner of the aircraft was a qualified microlight instructor with over 7,000 flying hours. He had noticed that there were signs of corrosion in all four rigging cables and on 22 March 2006 all four rigging cable assemblies were replaced. The owner of the aircraft stated that, due to many days of poor weather, there was a lot of flying training planned. He was also concerned that new cable assemblies supplied from the manufacturer might take over a week to arrive since a recent order of parts had been lost in transit. He therefore asked an acquaintance, known to have significant experience in cable making, to make a set of cable assemblies for the aircraft using tools and parts available at the airfield workshop.

The acquaintance was retired but had over 35 years experience with hang-gliders and microlights, including working for an organisation that manufactured microlight aircraft. He was also interviewed and he recalled agreeing with the owner that the cables needed replacing. He felt comfortable with assisting since he was experienced in making cables, and he was confident that he had the correct wire rope (material type and size), the correct tools and the correct gauge with which to check the compression of the ferrules.

A representative from the aircraft manufacturer attended the accident site. He confirmed that the replacement rigging cables assemblies had been made using a correct type of wire rope and the correct tools; however, the ferrules used were of a different type from those used by the manufacturer.

The aircraft had flown for a total of 1 hour and 50 minutes on three flights, not including the accident flight, since the cables were replaced.

British Microlight Aircraft Association (BMAA) Guide to Airworthiness Procedures

The BMAA Guide to Airworthiness Procedures covers a wide range of aircraft types and includes sections covering both modifications and maintenance.

The Modifications section starts with the following words:

> *'It is not legal to fly any modified aircraft, including a microlight, without first obtaining appropriate approval for the modification.…'.*

Modifications are classified as Major or Minor, and both need to be approved by the BMAA. The definition of a Major modification is as follows:

'A major modification is a change to the state of the aircraft that affects the primary aircraft structure, flying controls, aerodynamic surfaces, powerplant design and operation, flight or ground handling. It may also sometimes comprise a collection of minor modifications that in combination are of sufficient complexity to justify this definition. Minor modifications are those that do not meet the above classification.'

It is noted that repairs are classified and treated in the same way as modifications.

The Maintenance section starts with the following words:

'General maintenance tasks, such as replacing hoses, engine components and other such consumable items need not be submitted to the BMAA for approval. In general, this holds true where 'form, fit and function' is not altered and components are replaced with fully interchangeable parts approved by the manufacturer'.

There is no explicit warning in the maintenance section that the fitting of non-manufacturer-approved parts in safety-critical areas requires a major modification application form to be submitted to the BMAA for approval.

The BMAA were contacted and confirmed that had a major modification application form been submitted for the cables in G-BYNO the application would have been rejected on the grounds that only parts approved by the manufacturer should be used.

Operator's Manual

The Operator's Manual contains a section on the maintenance of rigging cables as follows:

'WARNING. Kinked, corroded or damaged cables should be changed at once with new factory supplied items. Flying with damaged cables could cause structural failure, resulting in injury or death.'

Comparison of the G-BYNO cables with factory supplied items

A comparison was made between the cable assemblies fitted to G-BYNO and a new set supplied from the manufacturers. The only discernable difference was the type of ferrule used; see Figure 3 for a comparison of uncrimped ferrules, and Figures 4a and 4b for a comparison of the end of cable assemblies. The following comparisons were made:

Physical properties of the ferrules

The mass, wall thickness, internal diameter, hardness and chemical composition were determined using metallurgists where appropriate. One end of each of the

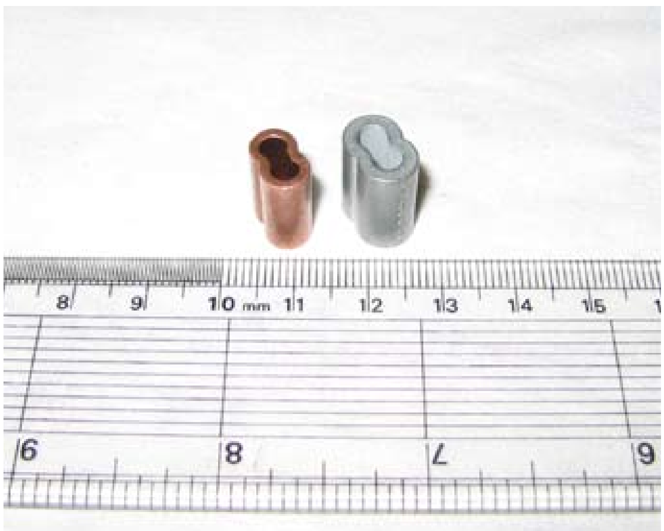


Figure 3

Photo: QinetiQ

Figure 4a

End of cable assembly (factory-supplied)

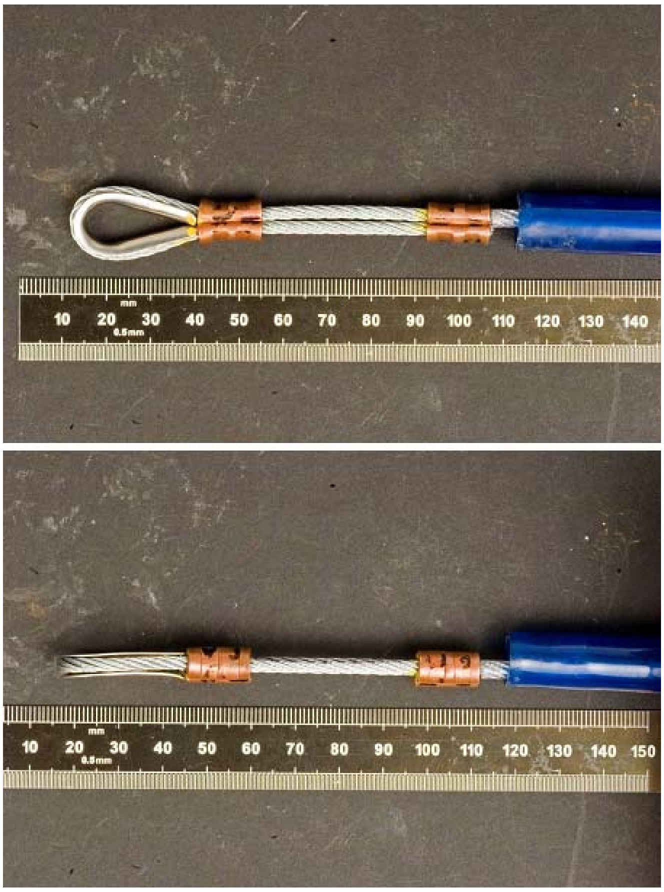


Photo: QinetiQ

Figure 4b

End of cable assembly (G-BYNO)

four cables had failed and the physical properties of all the ferrules from G-BYNO's cable assemblies that had failed are tabulated below. Two ferrules are used at each end of the four cables, making a total of eight ferrules. However, only seven ferrules were recovered from the accident site as one of the ferrules from the rear end of the rear cables was not found.

Two unused ferrules, one of the type used on G-BYNO and one of the type used in factory-supplied cables, were obtained. The widths, before crimping, were 11.0 mm and 13.2 mm respectively. Thus the effect of crimping the ferrules in G-BYNO was to reduce the width of the ferrule, ie produce a neck, in two places, typically from 11.0 mm to 8.5 mm; a compression of 2.5 mm. For the

	Ferrules from G-BYNO cables (mean value of seven ferrules that failed)	Ferrules from factory-supplied cables
Mass (g)	4.7	7.4
Diameter of hole for wire rope (mm) before crimping	3.7	4.0
Wall Thickness (mm)	1.5	2.2
Width (mm) – dimension of "neck" in ferrule after crimping	8.5	9.2

manufacturer's supplied cables the reduction was from 13.2 to 9.2 mm; a compression of 4.0 mm.

The chemical composition of the seven ferrules that failed on G-BYNO and a ferrule from a factory-supplied cable were determined using Energy Dispersive X-ray (EDX) analysis in a scanning electron microscope. The analysis concluded that all seven ferrules from G-BYNO that failed were pure copper. The ferrule from a factory-supplied cable was also determined to be, apart from the thin anti-corrosion coating, pure copper. There remains the possibility that beryllium, which cannot be detected using EDX analysis, could be present in the ferrules tested although this is considered unlikely.

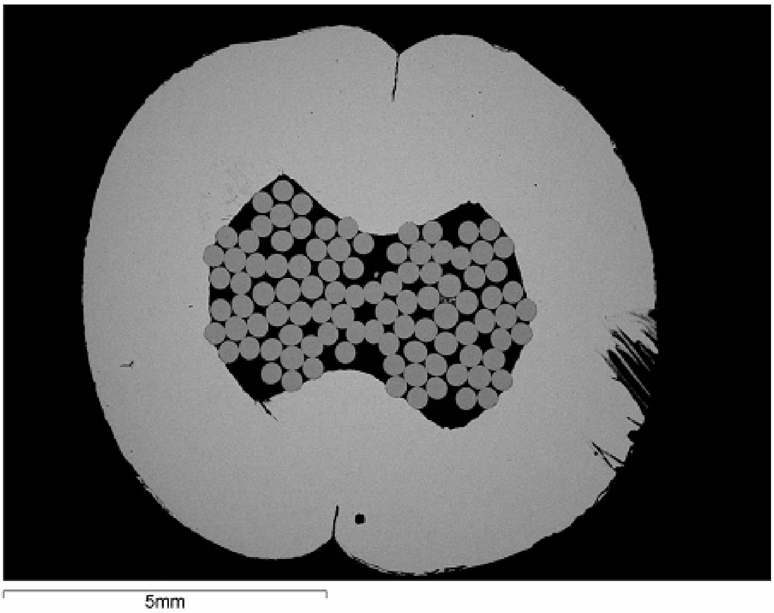
Vickers hardness tests were also carried out on crimped and uncrimped ferrules for both G-BYNO and factory-supplied parts. Such is the size of the ferrules that the crimping process has the effect of significantly hardening the material. The tests concluded that the copper used in the G-BYNO ferrules was significantly harder than that used for factory-supplied parts. This probably resulted in the G-BYNO ferrules having inherently less friction between the internal ferrule surfaces and the wire rope compared to the factory-supplied ferrules.

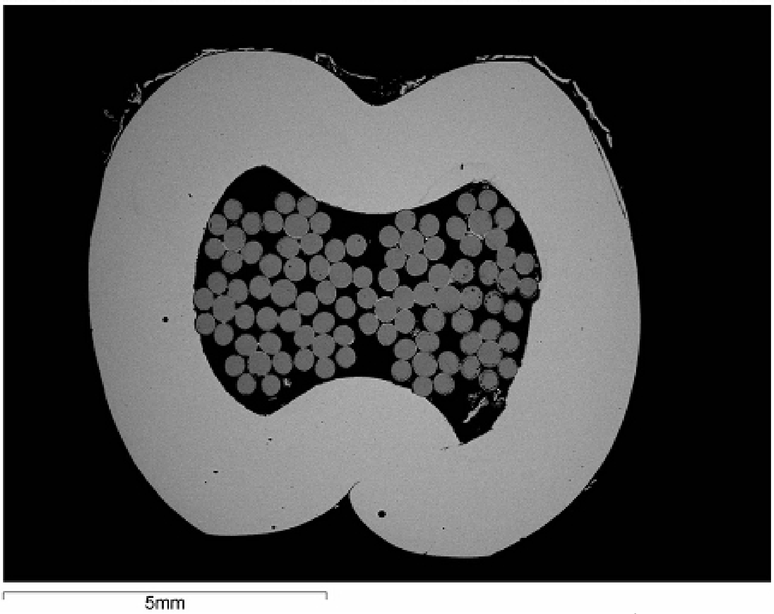
The end of one cable assembly from G-BYNO that did not fail, and a comparable factory-supplied item were sectioned and polished. The sections were made through the ferrules and wire rope in the region of the neck produced by crimping. Figure 5a and Figure 5b show the sections from the factory-supplied cables and G-BYNO respectively. Comparing the two sections it is evident that for the factory-supplied items there is:

a) more contact between strands of the wire rope and the ferrule;

b) more contact between the strands and other strands of wire rope;

c) less void space.





Photos: QinetiQ

Figures 5a (top) and 5b (bottom)

Sections through crimped ferrules

Length of cable assemblies

Cables that are over-length can be subject to 'snatching' and therefore become more highly loaded. Therefore the cable assemblies fitted to G-BYNO were measured and compared to the dimensions on the manufacturer's drawings. The accuracy of the measurements was compromised since one end of each of the four cables had failed causing the thimble (the key component that defines the length) to become detached, and both the rear cables were damaged by the propeller. As a result of the measurements it was concluded that it was likely that the G-BYNO cable assemblies were of the correct length.

Cable loading

For this aircraft, at an all-up weight of 409 kg, the load in these cables at the +4g design case is 1.66 kN. The manufacturer estimated that during the approach to land +2g loads could be expected and, with control forces added the loads in the cables would be about 1.0 kN.

The manufacturer estimated that the minimum load required to cause these cables to fail is 5.4 kN.

Destructive testing

One end of each of the four cable assemblies on G-BYNO had failed. Such cables carry tensile loads only and therefore the magnitude of the load at the end that did not fail was the same as that at the end that did fail. Therefore destructive testing of the cable ends that did not fail indicates the likely upper maximum of the load of the failed end of the cable; the load at failure may well have been much less. Two cables from G-BYNO, namely the forward end of the left forward cable and the forward end of the left rear cable, were tested using tensile load testing equipment. The applied strain rate was 5 mm/minute, until failure. Three ends of manufacturer supplied cables were similarly tested. The results are contained in the table below.

The cables supplied by the manufacturer failed in overload at the base of the ferrule, as was expected. It is usual in such tests to achieve a maximum load in excess of the nominal load for the wire rope alone. As noted above the manufacturer uses a minimum failure load for this stainless steel wire rope of 5.4 kN.

The G-BYNO cables pulled through the ferrules, indicative of insufficient purchase by the ferrules, without the wire rope failing. The two results for G-BYNO cables show significant variation and, importantly, it should be noted that the other ends of the cables tested must have failed on the aircraft at lower loads than those achieved during the tests. The destructive tests on the G-BYNO cables resulted in the appearance of the cable ends being similar to that found on the failed cables ends at the wreckage site - see Figure 2.

Cable	**Maximum load (kN)**
Manufacturer's cable – A	6.98
Manufacturer's cable – B	7.03
Manufacturer's cable – C	6.69
G-BYNO - forward end of left forward cable	3.45
G-BYNO - forward end of left rear cable	2.39

Analysis

All four rigging cable assemblies were found failed at the wreckage site. All four had been fabricated using a correct type of wire rope, the correct tools and of lengths which appeared to be correct. However, all four cable assemblies were made using incorrect ferrules and therefore did not conform to either the BMAA's Guide to Airworthiness Procedures or the Operator's Manual.

The two test results for cables from G-BYNO (2.39 kN and 3.45 kN) showed significant variation and were most probably higher than the loads which caused the cables to fail in the accident. It is possible that the lowest load to fail the cables at the other end was considerably less than these values. However the tested loads are higher than the loads that the manufacturer estimated for the aircraft on approach and thus it cannot be stated with certainty that the cables failed because they could not sustain the normal in-flight load conditions. It remains possible that some load case was experienced which was outside the +4g design case. There is, however, no direct evidence for this. Also there might have been some slippage and progressive failure of the cables during flight prior to the final failure of the cables at the time of the accident.

These tests also confirmed that the tested cables from G-BYNO failed as a result of the wire rope pulling through the ferrules. This resulted in the cable ends having a similar appearance to those found at the wreckage site. The lower wall thickness of the ferrules used for the G-BYNO rigging cables appears to have resulted in reduced grip on the wire rope and this conclusion is supported by the comparative photographs of the sections through the cable assemblies. The copper used in the ferrules for G-BYNO was harder than that used for factory-supplied cable assemblies and this is also likely to have reduced the grip inside the ferrule.

The eyewitness evidence indicated that at least two cables failed with the aircraft on approach and that at least one cable struck the propeller. The two blue shrouds from the rear two rigging cables were found on the airfield under the likely flight path of the aircraft and these provided very strong evidence that the two rear rigging cables failed prior to impact with the barn. It was not possible to be certain if the front cables, which typically carry higher loads than the rear cables, failed before the rear cables, or indeed failed before impact with the barn. However, the description of the aircraft's trajectory from the eyewitnesses would suggest that the front left cable failed first, causing the wing to pitch up and the aircraft to turn right, followed very shortly afterwards by the front right cable failing. The fact that the two forward cables carry higher loads than the rear two cables makes it more likely that the forward cables failed first. This would have allowed the rear cables to be struck by the propeller.

Whilst the decision to replace the four rigging cable assemblies appears to have been correct and timely, an important link in the chain of causes of this accident was the decision not to purchase factory-supplied parts. The Operator's Manual clearly states that factory-supplied cables should be used as replacements. The section entitled 'Maintenance' in the BMAA Guide to Airworthiness Procedures could be more explicit in stating that when replacing safety-critical items, either fully interchangeable parts approved by the manufacturer must be used, or a modification needs to be submitted for BMAA approval. Therefore the following safety recommendation is made aimed at ensuring that approved parts are used for safety-critical items:

Safety Recommendation 2007-007

It is recommended that the BMAA update their Guide to Airworthiness to state clearly that only parts approved either by the manufacturer or in a BMAA approved modification, should be used for the replacement of all safety critical items.