Fuel Efficiency Stocktake of Tourist Flight Operators

Report compiled by Francis Aviation (NZ) Ltd.
General Report

tourism INDUSTRY ASSOCIATION NEW ZEALAND

EXECUTIVE SUMMARY

The Tourism Energy Efficiency Programme (TEEP) is a partnership project between Energy Efficiency and Conservation Authority (EECA) and Tourism Industry Association (TIA) providing practical assistance for tourism businesses in the accommodation and transport sectors to reduce their electricity consumption, fuel consumption and carbon emissions.

TEEP 2009 follows on from the highly successful TEEP 2008 pilot programme where 12 tourism businesses from around New Zealand took part in the energy audit programme identifying potential energy savings of 2.6 gigawatt hours (9,698 gigajoules). More than 420 tourism businesses also took part in the programme's research and educational campaign last year.

Learnings from the audits and other activities are being turned into practical action, advice and guides, which will be used to help all members identify and achieve savings.

A stocktake of seven Tourist Flight Operators (TFO), representing a variety of operations, was carried out during 2009 in order to identify opportunities to improve fuel efficiency. Each stocktake was based on a questionnaire developed by a TFO workshop in Queenstown during April 2009.

To the best of our knowledge this stocktake is the first of its kind in the world. Fuel efficiency analysis is addressed at the airline level but not for general aviation. Credit is due to the Tourist Flight Operators who have participated in the survey and to the Tourism Industry Association and Energy Efficiency and Conservation Authority (EECA) for providing the resources to undertake the individual stocktakes.

This stocktake is a reflection of the increased awareness within the tourism sector that more action is needed for fuel efficiency.

Scenic flights by their very nature are about the visitor experience, not how quickly or directly the aircraft can reach its destination. Safety and passenger enjoyment may in some cases take priority over fuel efficiency. That said, savings can be made by having a 'culture of fuel efficiency' within an organisation and adopting a fuel consumption measuring and monitoring system.

One company with such a system in place has found a 2% fuel saving in the second year of implementation. This system has been adapted and sent to the participating Tourist Flight Operators to trial. Feedback from the operators has so far been positive. To date there has been little research into quantifying the specific fuel savings appropriate to any modification or technique changes (the industry often relying on anecdotal evidence). An additional benefit of adopting the proposed system is that it would provide a baseline and pool of data from which future modifications and technique changes can be compared, to ascertain the nature and quantity of any fuel efficiency benefits.

It is recognised that a 'fuel efficiency culture' starts with training. Almost all participating TFOs comment that recently graduated pilots have little awareness of fuel efficiency from either a commercial or environmental perspective. Communicating the findings of this report to the flight training community, through a medium such as the Aviation Industry Association (AIA) Flight Training Committee, will promote discussion between the General Aviation and Flight Training communities to find mutually acceptable opportunities to address this issue.

Findings from this stocktake indicate that the majority of fuel saving opportunities arise from modifications to existing aircraft and changes to operating techniques. There are very limited opportunities to invest in brand new replacement aircraft for a number of reasons:

- the current economic climate,
- low utilisation of aircraft by TFOs (the nature of scenic Visual Flight Rules (VFR) charter flying particularly),
- the lack of technological development by aircraft and engine manufacturers in the last 30 plus years
- little research into quantifying the specific fuel savings appropriate to each modification or technique.

For some TFOs, aerodynamic modifications, modern technology propellers and Global Positioning System (GPS) are available now or will be shortly, for their aircraft types. The expected benefits versus costs will need to be examined on a case by case basis by the individual TFOs.

For the piston-engined aircraft, improved instrumentation and General Aviation Modifications, Inc. (GAMI) Injectors (only apply to fuel injected piston engines) are available to enable more accurate fuel management techniques.

It is recognised that aviation is a very safety conscious industry and has a strong 'safety culture'. It is important that individual operators examine any suggested modifications or techniques in the context of their own safety and regulatory requirements. It is not within the scope of this stocktake to investigate the specific opportunities for every airframe/ engine/ operation combination.

Some of the fuel efficiency techniques proposed are contentious, partly due to lack of scientifically robust research, with a number of myths emerging. It is not the purpose of this document to endorse such techniques, but to raise awareness of their existence, promote discussion and where possible attempt to distinguish fact from fiction.

One area of discussion is leaning the fuel mix for piston engines. Good instrumentation is required to lean accurately.

With helicopters there are limited opportunities to improve fuel efficiency. As with fixed wing aircraft they have an airspeed which corresponds to best fuel economy; however in the case of helicopters this is much lower than their normal operating range, thus making it commercially non-viable to fly at this airspeed.

Another characteristic of helicopter operations is that start-up and shutdown cycles are more costly than the fuel required to keep the engine running during turnarounds of approximately less than 10 to 20 minutes. Minimising these turnaround times will assist with fuel efficiency. As with fixed wing aircraft keeping helicopters clean and polished will reduce drag and consequently fuel burn.

Key recommendations:

1. Instilling a culture of fuel efficiency into organisations and raising awareness of fuel usage and efficiency.

2. Fuel consumption measuring and monitoring system for all aircraft types – fixed and rotary wing. This will serve to:
    - raise awareness - fuel efficient culture in organisation (starts with training)
    - add to data bank – reliable information for the future to calculate fuel savings and payback times for different technologies
    - condition monitoring – early indication of defects - aircraft performance

3. Training – engage with the flight training sector to discuss the findings of this TEEP Tourist Flight Operators stocktake project, promoting discussion between themselves and the wider General Aviation (GA) community.

4. Ensuring aircraft are regularly washed and polished will also improve fuel efficiency and applies to all TFOs.

5. Fuel injected piston engines can be modified to retrofit advanced fuel injector technology (where available), digital fuel flow and EGT gauges for more accurate fuel measurement. Investigate the availability of the Energy Efficiency Conservation Authority (EECA) energy intensive business technology grants for operators.

6. The information from the fuel consumption measuring and monitoring system is collated after the first 6 months and subsequently annually by an independent third party such as the Tourism Industry Association.

All TFOs have contributed to the pool of knowledge and found some scope for fuel efficiency improvements within their own organisation.

As part of this stocktake participating companies have been sent a separate report which provides the tools and information on finding the Supplemental Type Certificates (STC) for equipment that will improve fuel efficiency. In the future fuel price increases or the requirement for aviation to meet greenhouse gas emission standards or limits could make these technologies more financially viable.

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GLOSSARY

AIA	Aviation Industry Association
ASTM	American Society of Testing and Materials
ATC	Air Traffic Control
C of G	Centre of Gravity
EGT	Exhaust Gas Temperature
FAA	Federal Aviation Authority
FADEC	Full Authority Digital Engine Control
GA	General Aviation
GAMI	General Aviation Modifications, Incorporated
GPS	Global Positioning System
“Hg	Inches of Mercury (unit of Pressure measurement)
IFR	Instrument Flight Rules
LOP	Lean of Peak
NZCAA	Civil Aviation Authority of New Zealand
POH	Pilot Operating Handbook
ROP	Rich of Peak
RPM	Revolutions per minute
STC	Supplemental Type Certificate
TCM	Teledyne Continental Motors (engine manufacturer)
TEEP	Tourism Energy Efficiency Programme
TFO	Tourist Flight Operator
TIANZ	Tourism Industry Association New Zealand
TXNZ	Tourism Exchange New Zealand
VFR	Visual Flight Rules

1 INTRODUCTION

Fuel represents a significant cost to TFOs and recent high prices, coupled with the volatility of fuel prices has lead to a number of initiatives being adopted to improve fuel efficiency. In most cases these are mainly cost driven, however customer expectations of the need for more environmental awareness has also been a factor. Most of the TFOs involved in the stocktakes have had some involvement with noise issues to varying degrees, and measures taken to reduce their noise imprint in some cases complement fuel efficiency, but can also compromise it.

The purpose of this study is to collate and distribute fuel efficiency opportunities among TFOs.

It is recognised that aviation is a very safety conscious industry and has a strong ‘safety culture’. It is important that individual operators examine any suggested modifications or techniques in the context of their own safety and regulatory requirements. It is not within the scope of this study to investigate the specific opportunities for every airframe/ engine/ operation combination.

2 PROCESS

As Part of the Tourism Energy Efficiency Programme (TEEP) a number of stocktakes of TFOs were carried out between April and May 2009. As with other tourism sectors involved in TEEP, the objective was to reduce fuel consumption and carbon emissions, improve their environmental performance and energy efficiency and achieve cost savings for the businesses involved. Unlike other tourism sectors, due to the wide variation in both aircraft fleets and types of operation, the scope to define specific savings has been limited; however a number of opportunities to save fuel were identified.

Initially a workshop was held in Queenstown. This was attended by TFOs (not all of whom eventually participated) representatives from the Civil Aviation Authority (CAA) and Airways Corporation of NZ. The object of this meeting was to brainstorm ideas for fuel efficiency savings and finalise the questionnaire that was to be used in the subsequent stocktake process.

Once it had been determined which TFOs were participating, these organisations were requested to provide information regarding their fleets and operations via the 'Tourism Flight Operators Fuel Efficiency Questionnaire' (see Appendix 1). This questionnaire is broken down into a number of sub-headings which represent different areas of the TFO's operation.

A follow-up meeting with the participating TFO was then carried out, where certain aspects of their operation were discussed in more detail and any potential opportunities presented.

Finally a report confidential to the participating TFO and TIANZ was produced, to be read in conjunction with this report which gives more detail of the opportunities and techniques highlighted.

3 PARTICIPATING TFOs

Seven TFOs have taken part in the stocktake. They operate a total of 48 aircraft with a variety of different types. These can be roughly categorised for fixed wing aircraft into:

- Piston, carburettored
- Piston, fuel injected
- Turbine

For helicopters the categories are:

- Rotary Piston, fuel injected
- Rotary Turbine.

Types and categories are detailed in the table below:

Figure 1 TFO aircraft types

AIRCRAFT	PASSENGER CAPACITY	ENGINE
Fixed Wing - Piston, carburettored		
BN2A-26	9	2x Lycoming O-540
BN2B-26	9	2x Lycoming O-540
Cessna 180C	3	1x Continental O-470L
Fixed Wing - Piston, fuel injected		
Cessna 172S	3	1x Lycoming IO-380
Cessna 185A	5	1x Continental IO-520D
Cessna A185F	5	1x Continental IO-520D
PA32 -300	6	1x Lycoming IO-540
Cessna 206	5	1x Continental IO520
Cessna 206 float	5	1x Continental IO 520F
Cessna T207A	6-7	1x Continental TSIO 520
GA8	7	1x Lycoming IO-540
DHC-3	10	1x P & W 1340
Fixed Wing - Turbine		
Cessna 208	12	1x PT6A-114A
Cessna 208B Grand Caravan	13	1xPT6-112
Cessna 208B	12	1xPT6-114A
P6/B2-H4	9	1x P & W PT6-27
Nomad N24A	15	2x RR250
Rotary - Piston, fuel injected		
R44 Raven II	3	1x Lycoming H60DIA
Rotary - Turbine		
AS350BA	6	1x Turbomeca Arriel 1B
AS350B2	6	1x Turbomeca Arriel 1D1

AS350 SuperD	6	1x LTS101
AS350B	5	1x Turbomeca Arriel 1B
AS 355F1	6	2xRR(Allison)C-20F

The ages of the aircraft are as follows:

Figure 2 Aircraft age

AGE RANGE (years)	NUMBER OF AIRCRAFT
<10	9
10 to 20	14
20 to 30	14
30 to 40	7
>40	4

The majority of operations centred on scenic flights, although one operator did provide a number of scheduled services.

One operator specialised in float-plane operations and one in ski-planes.

Two TFOs operated helicopters, one solely.

Six operators were located on the South Island and one on the North Island.

4 OPPORTUNITIES FOR FUEL EFFICIENCY SAVINGS

4.1 FUEL CONSUMPTION MEASURING AND MONITORING SYSTEM

The TFOs varied in whether or not they measured and monitored the fuel consumption of the individual aircraft, and to what level of detail. One operator in particular has put together a comprehensive system of analysing their fuel consumption for each aircraft. This operator has found the system advantageous in providing a baseline for measuring the benefits of any newly applied modifications and techniques. It also provides a source of condition monitoring; a sudden increase in fuel consumption could indicate a defect. One unexpected benefit they found was that by simply posting the monthly report on the company notice board, fuel consumptions have decrease by approximately 2%. It is important to note that the report only supplies fuel consumption figures for specific aircraft registrations and does not report on an individual pilot basis; however it would appear that the exercise of measuring and monitoring alone has increased awareness and vigilance in the pilots, which has resulted in a fuel saving.

The system used by this operator has thus been adapted, simplified and distributed via a template to the other TFOs (see Appendix 2). It is proposed that this system is adopted by all the participating TFOs. It has been pointed out that this 'measuring and monitoring' system can be run by a junior pilot (not requiring senior management input other than overview).

In addition to the advantages outlined above, the system could help add to a pool of knowledge (which is currently lacking) to quantify specific fuel savings to be made from particular modifications or change in techniques, should a similar study be carried out in the future.

4.2 EQUIPMENT

4.2.1 Aircraft

As can be seen from Figure 1, out of a total of 48 aircraft, comprising of 23 different types, only 9 aircraft are less than 10 years old. The majority are 10 to 30 years old. Discussion at the original TEEP workshop in Queenstown revealed that there is a reluctance to invest in new aircraft for a number of reasons. Cost is paramount and the nature of scenic flight operations is that they have relatively low aircraft utilisation compared to other types of flight operations. This is partly due to the fact that they operate VFR, therefore being dependent on weather conditions, but also the tourism market tends to be seasonal. There was also comment that, unlike the automotive industry, there has been minimal technological improvements available in new GA aircraft and engines, to justify the expense of buying new. Speculative reasons include the litigation culture in the USA (where most aircraft manufacturers are based) which has stifled aircraft design. A number of new technologies are available for sports/ recreational aircraft, but have not been approved for public transport use. It should be noted that this perception doesn't apply as much to helicopters which have a wider number of applications and uses (e.g. military, police etc), attracting technical development and investment.

One notable exception to the above is the GA8 Airvan. This aircraft is manufactured in Australia by Gippsland and seems particularly well suited to the GA sector, such that two of the participating TFOs have made the investment to buy new. They burn approximately 60 litre/hour carrying 7 passengers (**8.6** litres/pass/hour) compared to a Cessna 206 which would burn approximately the same amount of fuel to carry 5 passengers (**12** litres/pass/hour). This represents a **28%** fuel saving. The cost of a new GA8 Airvan is $690,000 AUD (approx $870,000 NZD).

Another reason for not investing in new aircraft and engines is the stringent inspection and overhaul requirements. Due to these requirements a number of components are thoroughly overhauled or replaced at regular intervals, resulting in an almost re-conditioned aircraft. For example a 35 year old aircraft will have very few original engine components still in place. This process ensures that what seem like very old aircraft and engines are kept in 'near new' condition.

Other aircraft that the TFO's have indicated may potentially be worth investing in when financial conditions permit are; Cessna 208B Caravan, Vulcanair (formerly Partenavia) P68C, Bush Hawk and for helicopters R44 and AS350 Super D. While fuel efficiency is a consideration, other factors which affect new aircraft selection are; safety record, structural strength, passenger comfort and suitability to the operation.

It is worthy of note that some operators have consciously made the decision to operate a number of different aircraft types, with varying capacity in their fleets. The advantage of this is that it allows flexibility to accommodate parties of different sizes, thus maximising the load factor (ratio of seats filled to seats available) and hence fuel efficiency. Other operators have consciously decided to operate one aircraft type only. This reduces training costs with pilots only needing one type rating and other overheads such as maintenance costs; however this does restrict flexibility with loading. One operator has made the decision to only operate twins, on the grounds of safety and that they appeal to a particular market who can't obtain travel insurance for single engine aircraft.

4.2.2 Engines

Similar philosophies apply to engines as do aircraft. There is a reluctance to invest in new technologies which provide minimal improvements when existing engines are overhauled to high specifications.

One notable new entrant into the engine market is the diesel engine. The diesel engine market is dominated by two manufacturers, Centurion (formerly Thielert) (Austrian) and SMA (French) who have engines certified to be retrofitted to Cessna 172, Cessna 182 and Piper Cherokees. One of the drivers behind the design of the diesel engine is that they can run on conventional Jet A1 fuel and potentially Jet A1 alternatives (an issue to be discussed in section 5.1). As this is fairly new technology and a retrofit would also involve the replacement of a number of other systems, including instrumentation changes, the cost of retrofitting a diesel engine to one of the above types is approximately 2.5 times that of a like-for-like engine replacement. This coupled with the fact that Thielert have recently just been declared bankrupt, has not made the diesel engine a popular replacement yet. With further technological advancement and proven results it may become a more attractive alternative in the future. Austro Engine are the relative newcomers to this scene and are working closely with Diamond Aircraft to power their line of singles and twins that have appeared on the flight lines of several flight training organisations in NZ.

The preferred engine for the AS350 squirrel helicopter would seem to be the LTS 101 which can now be retrofitted to the AS350B. If it were financially viable for a helicopter operation to replace their engines, anecdotal evidence suggests that a LTS101 engine retrofit could produce up to **10%** fuel efficiency savings.

4.2.3 Propellers

Propellers are an area where some operators consider there has been sufficient technological advancement to warrant investment. Most of the participating TFOs have been involved with and hence are very conscious of noise issues, both operating in the Department of Conservation estate and in their day-to-day operations. A great deal of the development of propellers has gone into reducing their noise footprint. Generally speaking 3 blade propellers are quieter than 2 blade propellers (2 blades being longer and thus having higher tip speeds); however conventional 2 blade propellers are more fuel efficient. Modern composite materials and other developments such as blended airfoil design and tip sweep have improved the latest 3 blade propellers to comparable fuel efficiencies of these conventional 2 blade propellers.

Some operations such as float plane and ski-planes require 3 blade propellers for ground clearance regardless of fuel efficiency.

A number of TFOs aircraft types have STCs (the process of certification for replacement aircraft parts) for new technology propellers.

> STC is the process of approving and certifying modifications to aircraft types or engines. This is a comprehensive and costly process for the initial applicant. Once a modification has been granted an STC, the costs involved are minimal (although the holder of the STC may still apply a charge). The NZCAA does not publish lists of STCs, however the FAA (USA authority) do. Generally speaking if something is approved by the FAA, NZCAA would also approve this modification. FAA STCs are listed at http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgSTC.nsf/MainFrame?OpenFrameSet

4.2.4 Aerodynamic Modifications

A number of aerodynamic modifications are available for the TFOs aircraft types. Examples of aerodynamic modifications are:

Fairings – These are exterior structures intended to produce a smooth outline and reduce drag. There are fairings to fit wheels/landing gear, exhausts, wing tips, wing roots, wing hinges, tails, aircraft body, and even to fit such as fuel drains. A variety of claims are made by different manufacturers regarding increased efficiency.

Flap and Aileron Gap seals – These create a pressure barrier between the high pressure air on the bottom of the wing and the low pressure air on the top of the wing. One manufacturer claims that these can improve performance by up to 4mph (any speed improvement can be translated to a fuel saving).

Vortelator Kits – These work by causing the boundary layer to stay attached to flying surfaces for a greater distance and to keep the boundary layer thinner. The result of this is that the drag (profile and skin friction) is reduced. They are designed for most piston Cessnas. The manufacturers claim an 'up to 6mph' (5 knots) gain and would cost approximately $700 USD (excluding fitting).

It is difficult to verify the manufacturers' claims of performance improvements. At the initial TEEP workshop in Queenstown, the general feeling was that aerodynamic modifications deliver minimal fuel savings. A recent article in "Aviation Consumer" magazine suggested that as a rule of thumb it costs approx $1,000USD per knot gained (based on one knot gained is roughly equivalent to 0.4 litres/hour fuel saving).

4.2.5 Fuel Management Instrumentation

These can vary in complexity from Full Authority Digital Engine Control (FADEC) to digital gauges.

FADEC is currently only available for 2 piston engine types (neither of which are operated by the participating TFOs); however TCM are developing it further with a view to fitting it to other engine types. Although a number of cars have equally sophisticated fuel management systems, an aircraft system must have reliability and durability standards well in excess of automotive systems. With FADEC each cylinder of an engine is independently optimised continuously. Fuel savings and costs are uncertain at this stage, however projected figures are approximately **10 - 15%** fuel savings and $4,000USD (excluding installation).

Currently available are engine analysers. These allow the pilot to look at a variety of digital engine data e.g. fuel flows, RPMs, manifold pressures etc. and set upper and lower limits to these parameters. There are a number on the market which vary in complexity and price (normally between $1,200USD and $5,000USD excluding installation). Operators would need to check their aircraft/ engine types for STCs, to find appropriate modifications.

Aircraft purchased more that 10 years ago would probably come standard with analogue gauges. There are now a number of digital replacement gauges available for most aircraft types. These give more accurate data and are usually priced less than $1,000USD (excluding installation). A number of participating TFOs have invested in digital fuel flow and EGT gauges.

Both engine analysers and digital instrumentation allow the pilot to manage the engine more effectively. Details of such techniques will be discussed further in section 4.3.

4.2.6 General Aviation Modifications, Inc. (GAMI) Injectors

The fuel/ air distribution in aircraft piston engines is often non-uniform and less than optimal, depending on the age and design of the engine.

GAMI have developed a fuel injector nozzle system to deliver specific amounts of fuel to each individual cylinder compensating for any fuel/ air imbalance. In other words the nozzle matches the fuel going into a particular cylinder to the air available through the induction system. This leads to smoother operation and the ability to lean an engine more accurately and consistently (see section 4.3.1).

Anecdotal evidence suggests that by fitting GAMI Injectors enabling accurate leaning, fuel savings of approximately 4 litres/hr can be achieved. They cost approximately $1,200USD (excluding installation).

One participating TFO has fitted GAMI Injectors but is unable to quantify the precise fuel savings.

4.2.7 Global positioning Systems (GPS)

GPS is not essential for Visual Flight Rules (VFR) operations; however it can assist the pilot in two ways. It can give wind information allowing the pilot to select optimum altitudes (see section 4.3.3) and it can assist the pilot in more accurate navigation and potentially more direct routings.

There are a number of systems on the market of varying complexity. Most modern aircraft (less than 10 years old) would have the option of GPS fitted, however to hard-wire a GPS into an older aircraft requires an STC. Operators should check STCs to determine which makes/ models are appropriate to their aircraft types. Some of the participating TFOs who only operate VFR have found that a hand-held GPS such as the Garmin 296 (costing approximately $1,200USD) are sufficient for their requirements. Other TFOs argue that GPSs are of limited value to them as sectors are relatively short (few opportunities to search for favourable winds) and riding in a tailwind leads to a less comfortable ride for the passengers.

4.3 TECHNIQUES

4.3.1 Engine leaning

As a piston engine aircraft gains altitude, the air becomes less dense and therefore the fuel flow needs to be reduced in order to maintain the required fuel/ air mixture. This process is called 'leaning the mixture'. If the mixture is not leaned enough, a rich mixture will result providing an excess of fuel, and if the mixture is leaned too much then the engine is starved of fuel, which in the extreme would cause engine failure. The required fuel/ air ratio varies depending on what the pilot wishes to achieve e.g. to save fuel or reduce time.

Leaning techniques have been a source of controversy for a number of years and due to the lack of impartial scientifically robust research are likely to continue to be for some time. It is not the intention of this document to endorse any particular technique. It will simply present some of the arguments for and against each technique. It is the responsibility of individual operators to research the optimum technique that suits their particular operation.

There is little argument that leaning is essential for both sensible fuel management and engine longevity. To accurately lean (regardless of technique used) it helps to have precise, preferably digital fuel flow and/ or Exhaust Gas Temperature (EGT) instrumentation. Balancing the cylinders with such as GAMI Injectors will also help.

Essentially there are two main leaning techniques; Rich of Peak (ROP) and Lean of Peak (LOP).

The technique endorsed by engine manufacturers is ROP. Here the mixture is progressively leaned, noting the rise in EGT. When the EGT is seen to 'peak' the mixture is returned back towards the rich position until a predetermined decrease in EGT is observed.

The controversial technique is known as LOP. Here the same process applies until 'peak' EGT, but then the mixture is further pulled towards the lean position until a pre-determined decrease in EGT is observed. This is represented graphically in Figure 3 below.

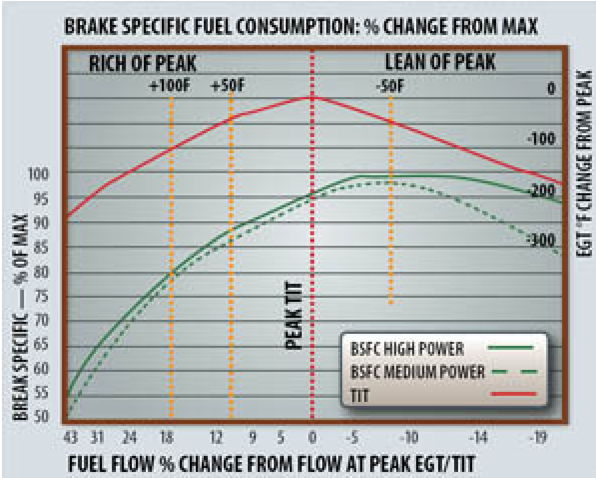


Figure 3 Leaning Techniques
Aviation Consumer Magazine Nov 2005

Advocates of LOP claim they can achieve fuel savings of up to 25% (with a corresponding time penalty of 10%); however representatives of Lycoming (engine manufacturers) dispute this and claim ROP is likely to be more fuel efficient. Those who oppose LOP argue that valve and cylinder head damage can result, impacting engine longevity; a point disputed by proponents of LOP. It is possible to find a number of ‘expert’ opinions to support each of the arguments outlined, but few (if any) are backed up by transparent robust scientific evidence.

Caution must certainly be exercised with LOP if instrumentation is not accurate enough and/ or pilot technique not refined, as relatively small movement of the mixture lever to the lean side can result in fuel starvation and small movement to the rich side could result in the engine being operated at its peak temperatures. Additionally relatively small changes in air density may adversely affect accurate mixture control. If LOP is to be applied, consideration of pilot experience and capacity to closely manage the mixture must be taken into account, along with the installation of precise instrumentation. Details of any engine warranties should also be examined as operating using techniques other than those the engine manufacturer endorses may invalidate such warranties.

4.3.2 “Over Square”

This technique only applies to piston engines with constant speed propellers which can vary the inlet manifold pressure. The term ‘square’ relates to a convenient relationship between inlet manifold pressure (in “Hg) and RPM (in 100’s) e.g. 23”Hg manifold pressure and 2300 rpm. In the past some pilots have been taught to never fly ‘over square’ in order to not over-stress the engine. This has lead to some misinformation. Most aircraft can safely be flown with higher manifold pressures and lower RPMs to produce a given power setting. Details and tables of these are given in the Pilot Operating Handbooks (POHs).

Flying with a higher manifold pressure and lower RPM reduces fuel consumption but has the added advantage of reducing noise; however it is essential that the POH is consulted and the aircraft flown within the permitted ranges.

4.3.3 Optimising Altitudes

One factor that can affect the efficiency of a flight is the prevailing wind. If an aircraft is able to take advantage of tailwinds and minimise its exposure to headwinds, then fuel efficiency can be greatly improved. Detailed weather reports are available to pilots with forecast winds at different levels, however GPS (see Section 4.2.7) can give instantaneous and more accurate wind information. This allows the pilot to fly at the optimum level for the winds at that particular time.

Should a pilot be faced with no alternative but to fly with a headwind, it can be beneficial to use a higher power setting, fly at a lower altitude and descend early to minimise time into the headwind. Conversely if in a tailwind, it pays to take advantage of the tailwind as long as possible. Consideration could be given to cruising higher at a lower power setting and initiating descent as late as possible.

4.3.4 Direct Routings

Another feature of GPS is that it is an extremely accurate navigation system with most modern models providing a moving map display showing terrain. This allows the pilot to more accurately fly direct routings. Whether or not an aircraft is equipped with GPS, direct routings will help with fuel efficiency, but mainly for schedule services. As a number of TFOs pointed out though, the purpose of a scenic flight is not to get from A to B by the shortest possible route but to offer a quality sight-seeing experience.

4.3.5 Helicopter turnarounds

Helicopters usually keep their engine(s) running during a turnaround or ‘running change’ as starting and shutdown cycles are more costly than the fuel required to keep the engine(s) running. Taking steps to reduce these turnaround times will keep the associated fuel burn to a minimum.

4.4 LOAD AND BALANCE

4.4.1 Aft Centre of Gravity (C of G)

Aircraft have limits on the forward and aft range of C of G in order to ensure longitudinal stability of the aircraft. Loading with an aft C of G (but within limits) is more fuel efficient, due to less induced drag of the tailplane. Most TFOs are aware of this and aim to seat passengers accordingly.

4.4.2 Fuel Load

If an excess fuel load is carried, surplus to the requirements of a particular flight, the additional weight will reduce fuel efficiency. Most TFOs carry a pre-determine fuel load (derived from experience) applicable to their regular routes. Also the majority of TFOs carry out detailed calculations of fuel load, taking into account required reserves, for non-standard flights.

4.5 AIR TRAFFIC CONTROL (ATC) AND ROUTING ISSUES

Holding, whether on the ground or in the air, is detrimental to fuel efficiency. This can be an issue at some of the busier controlled airports. Generally speaking TFOs are happy with the service they receive from Airways (ATC provider) and feel that ATC try where possible to minimise delays. Some TFOs actively plan their own departures and arrivals at times not to coincide with scheduled airline services, whilst others are of the opinion that the scheduled services are too unreliable to make this realistic. Queenstown Airport is shortly to trial a new radar system. The GA community in this area is currently in discussions with Airways to ensure the interests of this user group are protected under the new system.

All TFOs reported that when they requested direct routings, they are usually granted by ATC wherever possible.

When an airport has several runways, fuel efficiency can be improved by using a runway more in-line with the direction of the routing (subject to head/ tail and crosswind constraints of the aircraft). Most TFOs reported that they sometimes request such runways and are generally happy that ATC grant these requests if possible.

Some TFOs feel that the published departure and arrival procedures which are to be carried out at controlled airports, do not always offer best fuel efficiency (possibly due to noise abatement procedures) for their regular routings. On occasions recognised regular operators are offered expeditious approaches.

All of the TFOs surveyed believe they have a good working relationship with ATC and where applicable have mechanisms in place to discuss appropriate issues with local ATC.

4.6 SCHEDULING AND EFFICIENCY OF USE

Different TFOs have differing approaches to scheduling and efficiency of their fleet. Some operators have established fleets with a mix of aircraft of varying size, so that passenger group size can be matched to aircraft capacity. Others have made the decision to operate only one aircraft type, hence offering only one capacity. With the exception of the TFO that offers schedule services, where the flights generally depart regardless of number of passengers, most TFOs attempt to delay departures to varying degrees in order to fill the aircraft.

Some TFOs have access to collective booking systems; some have less formal agreements with other companies, whilst others stand alone. All the TFOs were informed of new booking systems such as TXNZ which potentially could help advanced bookings and optimise planning. One operator however did point out that the drawback of such systems is that pre-booked customers often have an expectation to fly on a particular type of aircraft and are unhappy at switching types or modifying times at a later stage, reducing flexibility for the TFO.

A number of operators need to fly empty sectors to link up with other tourism services. As the TFOs factor the cost of this into their overall price, these sectors are not seen as non-revenue; however they do have a detrimental effect on overall fuel efficiency .

4.7 STAFF TRAINING

Some of the participating TFOs employ relatively inexperienced pilots. There is a general consensus that pilots recently out of initial training have very little awareness of the need for fuel efficiency, from either a commercial or environmental perspective. They comment that inexperienced pilots are often afraid to lean the mixture by any technique.

All TFOs carry out training to compensate for the above according to their own requirements and procedures. It is generally acknowledged that fuel efficiency awareness is something that is built on with a pilot’s increasing experience and capacity. Discussion between the GA and Flight Training communities should be promoted to find mutual opportunities to address this issue.

Taking up the Fuel Consumption Measuring and Monitoring System could raise awareness of fuel efficiency to all pilots within the TFOs.

Some TFOs train their ground staff specifically in procedures for scheduling and loading.

4.8 MAINTENANCE

Most of the major engineering and maintenance work is out-sourced to specialist companies, some of which the TFOs have a stake in. It is not within the scope of this report to examine in detail the efficiency of major maintenance, but to focus on the routine day to day up-keep of the aircraft.

4.8.1 Washing and polishing aircraft

Washing and then polishing aircraft is an area where fuel efficiency savings can be made. All but one operator says they wash their aircraft regularly, while only four of the participating TFOs polish them regularly. Anecdotally it is claimed that washing and polishing can improve performance by 3 to 4kts of airspeed (which could translate to **1** to **1.5**litres/hr of fuel savings).

4.8.2 Multi-grade Oil

Some operators believe that multi-grade oils provide better fuel consumption. This is based on the fact that the long chain polymers which provide a higher viscosity, allowing the engine to spin over more easily at ambient temperatures. Multi-grade oils however do not always provide the same corrosion protection and cleaning qualities as other oils and for this reason some operators prefer to stick with the engine manufacturers recommended oil.

4.9 INFRASTRUCTURE

The offices and facilities from which the TFOs operated varied considerably. They ranged from small offices within airport terminal buildings to some operators owning or leasing several buildings and hangars. Those who simply leased offices in terminal buildings have very little control of lighting and heating while those who had independent premise had a variety of efficiencies of heating and lighting. Suggestions were made to some TFOs regarding the use of energy efficient lighting, lighting controls and sensors, hot water temperature (where applicable) and heating options.

All the TFOs were vigilant about switching off office equipment (except the server) at night.

5 DISCUSSION ON FUTURE DEVELOPMENTS

5.1 ALTERNATIVE FUELS

The use of sustainably renewable fuels represents aviation's best opportunity to minimise its carbon footprint.

Alternative fuels fall broadly into two categories:

- 1^{st} generation - competes with food crops
- 2^{nd} generation - utilises waste products or feedstocks that grow where conventional food crops can't.

Examples of 2^{nd} generation feedstock are forestry waste, jatropha, and algae. There is consensus within the industry that only 2^{nd} generation alternative fuel development should be pursued.

Jet A1 (turbine fuel) alternatives, have already been trialled e.g. Air New Zealand's flight of December 2008. The focus is to provide a 'drop-in' fuel which can be blended with conventional fuel regardless of the original feedstock. This allows any alternative to be gradually introduced as production is stepped up. Jet A1 alternatives are currently undergoing the rigorous American Society of Testing and Materials (ASTM) approval process and production is yet to be scaled up to industrial levels. Time frames of 5 to 10 years are currently being predicted, to grow the feedstock and produce enough fuel for a 10% blend of alternative to conventional fuel. 15 to 20 years for a 20 to 30% blend.

Sustainably renewable alternatives to avgas (petroleum) are also being pursued; however there is less investment in this area due to it being a much smaller market relative to the Jet A1 market. To compound the issue the most commonly used type of avgas, 100LL contains lead. Environmentalists are lobbying strongly for the removal of this. Some ethanol based alternatives have been explored, however the hygroscopic (readily taking up and retaining moisture) properties of these fuels make them inappropriate for aviation purposes. Some small pistons with low compression engines have been converted to take mogas (motor gasoline), however this is being increasingly blended with ethanol.

There is one promising prospect emerging, a fuel marketed as "Swift fuel". This is derived from cellulosic feedstock such as switchgrass or sorghum. Swift Enterprises claim their fuel will be cheaper than avgas and some 15 to 20% more efficient. It too is currently undergoing the ASTM approval process. One drawback of Swift fuel and in fact all avgas replacements that have been investigated, is that they require different fuel nozzles. This precludes the 'drop-in' blending of fuels such as is possible with Jet A1. Potentially this could lead to complications as production is scaled up; getting a wide enough distribution network in place for converted aircraft, in the early stages. Figures of 5 to 7 years are being projected in terms of any sizable introduction into the market although some speculate longer.

5.2 FUTURE TECHNOLOGIES

A number of advancements in aircraft and engine design have been adopted into the sports and recreational aircraft sector. However due to a number of factors including regulatory restrictions, costs and potential liability issues, on the whole these have not transferred onto the General Aviation (GA) sector. Some of these advancements are; refined aerodynamic and control systems, radical redesign of airframes and location of propellers, composite structures and advanced avionics. Engines are another area of development not yet fully realised by GA operators. In addition to the diesel engines described in section 4.2.2, small turbofan and turbojet engines are being developed. NASA is researching these opportunities through its ‘General Aviation Propulsion Program’.

Some of these technologies (if or when they become available) will provide direct fuel savings, while some (such as engine design) will open up other alternative fuel options.

6 CONCLUSIONS

The aviation industry has always had a fundamental awareness of fuel conservation.

The importance of fuel awareness and its inherent relationship to flight safety is something every student pilot learns from an early stage of their training.
With this in mind, improving fuel efficiency for the participating TFOs is always going to be challenging, the current economic climate just makes it more so, as major re-investment in hardware is not a priority. Opportunities for fuel savings arise from modifications to existing aircraft, small but important changes to operating techniques and attitudes within the community towards fuel efficiency.

One opportunity that is relevant to all TFOs is to apply a Fuel Consumption Monitoring and Measuring System. Raising awareness of fuel consumption within an organisation may in itself lead to savings, but it will also provide condition monitoring, a baseline from which to measure any modifications or technique changes and add to a pool of information regarding the effectiveness of certain fuel efficiency initiatives.

For some TFOs, aerodynamic modifications, modern technology propellers and GPS are available now or will be shortly, for their aircraft types. The expected benefits versus costs, will need to be examined on a case by case basis by the individual TFOs.

For the piston-engined aircraft, improved instrumentation and GAMI Injectors (only apply to fuel injected piston engines) are available to enable more accurate fuel management techniques.

Ensuring aircraft are regularly washed and polished will also improve fuel efficiency and applies to all TFOs.

Future opportunities for fuel efficiency savings centre around the development and certification of airframe and engine technology, some of which already exists within the sports and recreational flying sector. Development and implementation of alternative fuels will significantly reduce the carbon footprint of aviation in general, but these are some years away.

Appendix 1

Tourist Flight Operators Fuel Efficiency Questionnaire

16 March 2009

Equipment

1. Please complete the table below (approx figures):

Aircraft (specify type and variant)	No. of pax seats	Age of aircraft	Total hours of individual aircraft	Hours in last 6 months	Mods applicable to fuel efficiency (include when embodied)	Engine(s)	Age of engine(s)	Total hours of engine(s)	Hours /time to next major overhaul	Age of prop(s)/ blade system	Hours/time to next prop overhaul	Type of fuel used	Additional avionics e.g. GPS/ Fuel management system (please give details of makes/ models)

2. Please give your main reasons for selecting your aircraft types.

3. Please give your main reasons for selecting your engine types (if appropriate).

4. Are you aware of any additional fuel saving technologies/ initiatives available for your type of aircraft e.g. wheel fairings?

5. What equipment do you use to monitor fuel usage in flight? Did this equipment come as standard with the aircraft or was it retrofitted?

6. Are you aware of any fuel efficiency technologies used by other TFOs for your aircraft/ engine type?

7. What aircraft types/ engines are you considering within the next 5 years? Would you buy new or used aircraft?

8. What is your policy on engine replacement?

9. What is your policy on propeller/ blade system replacement?

10. What other equipment have you considered investing in in the next 5 years to improve fuel efficiency?

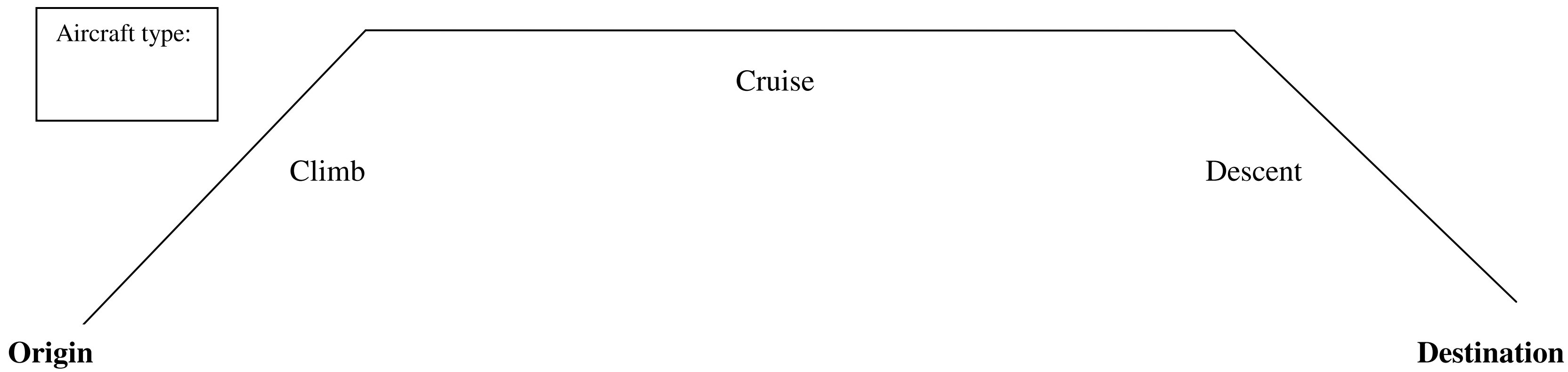
Personnel

11. Please indicate number of pilots, their total hours and type ratings as applied to your aircraft types.

12. Please list any other operational personnel and give a brief description of their role.

Operations

13. Please sketch your ideal flight profile (terrain/ weather/ ATC permitting) showing power settings, flap settings, speeds, altitudes and any fuel saving techniques (such as leaning the mixture). Please cut and paste or copy for different aircraft types.



14. How do you determine how much fuel to be carried i.e. detailed calculations or rule-of-thumb?

15. What operational procedures for fuel efficiency do you have in place?

16. How do you measure fuel usage and in what units?

17. Do you have a clearly defined ‘Fuel Policy’?

18. Do you monitor and analyse fuel usage for each aircraft? If so please supply historical figures for each type.

19. Do you regularly tanker fuel (e.g. due to unavailability of specific fuel types)?

20. Multi-engines aircraft – do you have an engine-out taxi policy if appropriate?

21. Do you consider fuel efficiency in your load and balance calculations?

22. Do you have a means for en-route pilots to feedback factors e.g. adverse weather which may affect subsequent flights?

23. Are you aware of any procedure used by other TFO's that may be useful and could be adopted into your operation?

24. Do you have any material or information you feel would be useful to share with the TFO community regarding fuel efficiency?

Staff training

25. What knowledge of fuel efficiency do you expect your pilots to know from their basic training?

26. What additional training do you provide in fuel efficiency techniques?

27. Do you monitor pilots' fuel efficiency performance and offer feedback? (please indicate if this is on an individual or collective basis)

28. How often do you review/ refresh fuel efficiency training?

29. Do you have any training appropriate to fuel efficiency for non flying operational staff?

ATC/ routings

Please answer the following 5 questions using the scale: *never, sometimes, frequently, always*

30. Do you experience delays on the ground prior to takeoff? If so please give approx delay times.

31. Fixed wing aircraft - do you request appropriate runways subject to head and crosswind constraints? How often are these requests granted?

32. Are you held in holding/ circling patterns on arrival? If so please give approx delay times.

33. Do you ask for direct routings? If so are they granted?

34. Are you offered direct routings by ATC?

35. Do you consider airline schedules when planning your departure/ arrivals?

36. Do the VFR departure and arrival procedures offer best fuel efficiency for the routes you fly?

37. What constraints apply to your regular routes? e.g. within DOC estates, noise abatement constraints, curfews

38. Do you have a good working relationship/ familiarisation visits with local ATC?

39. Do you have a mechanism to discuss issues with local ATC?

Scheduling/ efficiency of use

40. What is your average load factor over the last year? Please indicate if you don’t measure this.

41. What percentage of flights are non-revenue? E.g. positioning of aircraft

42. What measures do you take to ensure efficient use of your fleet?

43. Do you have access to any collective booking systems?

Maintenance

44. How often do you wash your aircraft?

45. Do you polish your aircraft?

46. Do you have a system to regularly review manufacturer's Service Bulletins that affect fuel consumption?

47. Is your organisation vigilant about non-airworthiness defects which may affect drag? E.g. door closing, seals, damage to fairings.

Infrastructure - facilities

48. Lighting – do you use energy efficient light bulbs?

49. Lighting controls – do you use daylight sensors, occupancy sensors, manual switching off?

50. Building insulation – do you have floor, wall and ceiling?

51. Window insulation – do you have double glazed, blinds and curtains, none?

52. Water heating – what is your hot water temperature [55°C - 60°C, 60°C - 65°C or 65°C - 70°C], how is it heated by solar, gas, electric, other?

53. Water heating - do you insulate cylinder, lag pipes, have flow restrictors on showers and/or low flow shower heads?

54. Equipment – standby for television/s and kitchen equipment, settings for fridge/s and chiller/s?

55. Office equipment – are computers turned off at night except for server?

56. HVAC system and space heating – what fuel is used - electric, gas, other? What settings are used for heat pumps and heaters -

57. Workshop/maintenance equipment – how are outside lights controlled – manual, sensor – how are compressors, pumps etc managed

General questions

58. Have you looked into any current or future alternative fuel options for your aircraft type? If your engine manufacturer/ CAA approved any such fuels, what would be the drivers to make you use them?

59. What would be on your fuel efficiency technology wish list?