IATA Guidance on Airport Fuel Storage Capacity - EDITION 1

May 2008

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Acknowledgements

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IATA Guidance on Airport Fuel Storage Capacity

1 Introduction

The aim of this Guidance is to suggest a thought process and provide a general reference for assessing airport fuel storage capacity.

Fuel supply reliability has a major impact on financial and operational viability of flights. Airport fuel infrastructure forms a vital part of the fuel supply chain. While at most airports the fuel facility appears to be adequate, some airports are perceived to have insufficient or excessive facilities. In case of supply disruptions, insufficient capacity could result in non-availability of jet fuel. Insufficient storage capacity may also add pressure on ensuring fuel quality. The need to ensure fuel quality and safety could result in restrictions in fuel availability or even non-availability of jet fuel when storage capacity is insufficient. The knock-on effect of non-availability of jet fuel or even restrictions in availability is huge: consequential damages may arise from cancelled flights, diversions, payload limitations, tankering, and techstops for refuelling. On the other hand, excessive capacity could result in higher charges. There is always a trade-off, and it is essential to strike the right balance between storage capacity, operational reliability and cost.

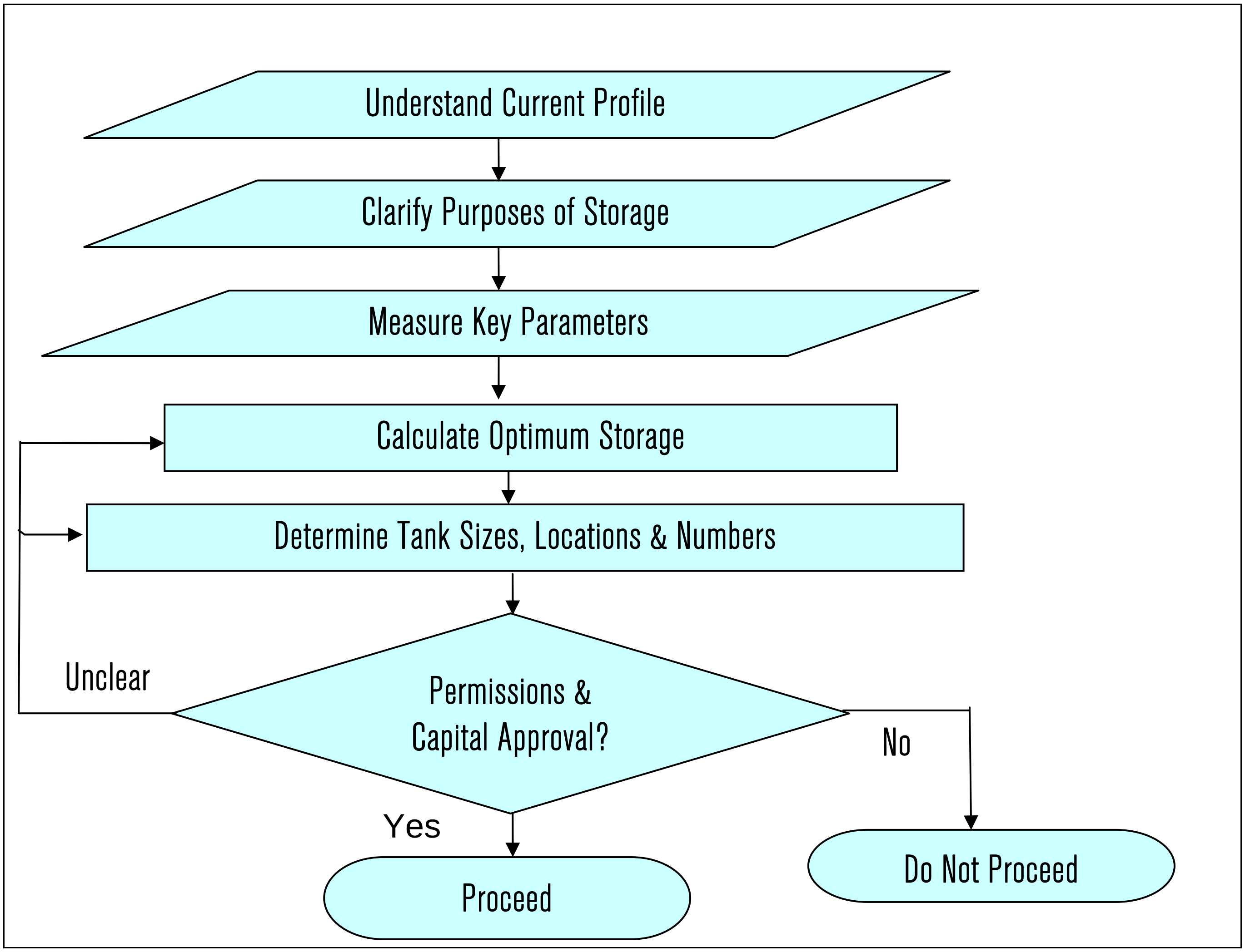
In reality, determining the adequate level of storage capacity is a complex task. Each airport has unique fuel supply and demand situations. Constraints not quantifiable may defy optimisation by mathematical models. Stakeholders have different priorities, often difficult to reconcile. Yet it is worthwhile to define a framework of thought process for better communication among stakeholders and regulators, and for informed opinions by them. Although this Guidance cannot guarantee an optimal solution, certainly it will give perspective, add dimension, and offer checklists for a better solution.

Sections 2 – 8 of this document provide a “long list” of many of the issues that may be relevant at any airport. The worked examples that are given at appendix 2, 3 and 4 aim to help readers identify the main purposes and hence the priorities at their specific airports.

Users of this guidance material should note that this material focuses on capacity only. It will also be essential that the final plan takes full account of safety, quality control and engineering considerations. Once the optimum capacity has been determined, it will therefore be essential to seek expert safety, quality control and engineering advice to develop specific projects.

2 The Process

Shown below is a schematic process of facility size determination:



3 Understand Airport's Current Profile

Before embarking on the quantification exercise, it is important to fully understand each of the following:

1. Demand forecast (current average daily/monthly, peak daily/monthly and demand profile during the day.
2. The supply modes (road tank trucks (bridgers), pipeline, rail cars, barges, etc) and capacities.
3. Fuel receipt operating hours of the supply modes for fuel delivery to the airport depot
4. Operating hours of the Airport Depot
5. Airport Depot Offloading facilities, restrictions, etc (e.g. number of off-loading islands in place, size of pipeline receiving station, etc)

6. Specific operational needs in the said Depot, e.g. if fuel receipt mode is dedicated to Jet A-1, then you need at least 3 tanks (one for aircraft refuelling, one for receiving and one for settling/maintenance, etc). If the fuel receipt mode is NOT dedicated to Jet A-1, then you need extra tank(s) and additional time for fuel recertification (it takes more time and you cannot use the fuel in the tank under test), etc.

4 Purposes of airport storage

Having understood the current profile, the next step is to clarify the purpose of airport storage. A draft "Checklist" of potential purposes grouped by key areas is as follows. It is suggested that users of this guidance material use this checklist to determine which are the key purposes for their specific airport and focus their attention on ensuring their storage is adequate for those purposes. It is very unlikely that every one of the following possible purposes will apply at any single airport.

Demand

- To accommodate current demand
- To accommodate future demand growth
- Ullage for unexpected demand reductions

Supply

- To accommodate normal current supply
- Buffer for supply schedule
- Cover against significant supply interruptions
- To accommodate future supply developments

Stock management

- To allow for day-to-day stock fluctuations
- To allow for seasonal variations in stock
- To provide a facility to re-blend unbatched (untested or uncertified) fuel (if relevant at the airport in question)
- To provide an appropriate level of redundancy in case part of the infrastructure fails.

Quality Control

- To allow for settling time & quality control checks for recertification
- Maintenance requirements (preventive and breakdown)
- To allow for recirculation and filtering of product from any tank

Regulatory Requirements

- Compulsory stocks, if imposed by the State
- Time allowed for Customs requirements

5 Key Measurable Parameters when determining the level of stockholding capacity

The next step is to quantify key measurable parameters for each of the purposes that were identified for the airport in question. It is not necessary to quantify measurable parameters for purposes that are not relevant to the airport in question.

Table 1 below provides an example of a potential purpose and the measurable parameters relevant to it. A more detailed draft "Checklist" of the measurable parameters that are relevant to each of the potential purposes defined in section 3 above is attached at Appendix 1 to this document.

Issue	Potential Purpose	Measurable Parameter (Do not quantify if purpose not relevant at this airport)
1. Demand	1.1 To accommodate future demand growth	1.1.1 Planning horizon and the airports growth potential
		1.1.2 Average day/month demand, peak day/month demand
		1.1.3 Opportunities for incremental expansion of storage capacity
		1.1.4 Confidence in obtaining suitable locations and land for future expansion

Table 1

6 Calculate Optimum Storage

It is recommended that users of this guidance material adopt a two-stage approach to determining the amount of storage quantity that is required in their location.

The first stage is a high-level review. In the event that this indicates that the current storage quantity is approximately correct, it may be appropriate to take no further action. If, however, the high-level review indicates that the current quantity may not be correct, users may wish to invest time, money and effort in conducting an optimisation study, as outlined in section 6.2 below.

6.1 Stage 1 - High-Level Review of Necessary Amount of Storage

To conduct the high-level review, users of this material should identify the most important of the measurable parameters from the answers that they have entered in the "Checklist" at Appendix 1. In this context, the most important parameters will be those that have the largest impact on the amount of storage quantity required. It will be important to select a relatively small number of items – typically two-to-four parameters.

It is recommended that users assess the number of days of useable storage capacity that could be required to accommodate reasonably common levels for each of these parameters. (As an example, if Customs normally take one day to release a fresh batch of fuel, but extend this to two days several times each year and three days once every few years, then it would be reasonable to include two days in the calculation).

It will then be necessary to add up the number of days of storage assessed as being reasonably required for each of the factors under consideration. In assessing the total amount of storage required, it is recommended that users take account of the fact that it is unlikely that the worst case will be encountered on every parameter at the same time. As an example, consider the case just described in which Customs usually take one day and two days have been allowed in the calculation. Suppose further that supply is by ship and on average requires one day's stock be held at the airport, with three days being included in the calculation to allow for extreme weather events that occur a few times a year. Suppose as well that quality control requirements typically take a day, with two days being included in the calculation to allow for occasional batches of off-spec fuel. The sum of the extreme cases for all three parameters would be two days for Customs plus three days for supply plus two days for quality control, making seven days, but users are advised to think about how likely it is that maximum stock would need to be held for all three parameters at the same time. As a "rule of thumb", if there are three or more parameters, the total difference is unlikely to need to be more than 85 % of the sum of each of the individual differences. In this case, the user might therefore be satisfied that, for instance, six-and-a-half days stock would in practice be sufficient. This example is summarised in the table below.

	Parameter	Average Stock Required for this Parameter	Max Stock Required for Worst Reasonably Foreseeable Occurrence for this Parameter	Difference between Average and Maximum
	A	B	C	D
1	Parameter 1	1	2	1
2	Parameter 2	1	3	2
3	Parameter 3	1	2	1
4	Total (Average) [B1+B2+B3]	3		
5	Total (Difference) [D1+D2+D3]			4
6	85% of Total (Difference) [D5x0.85]			3.4
7	Overall Total (B4+D6)			6.4

Table 2

Note: As a "rule of thumb", if there are three or more parameters, the total difference is unlikely to need to be more than 85 % of the sum of each of the individual differences

In the event that users of this guidance material are satisfied that the current storage capacity is sufficiently similar to the indicative level suggested by this calculation, it may be appropriate to take no further action. If, however, the high-level review indicates that the current storage capacity is inadequate, it is recommended that an optimisation study be conducted, as outlined in the section below.

6.2 Stage 2 – Detailed Modelling

In order to determine the optimum amount of storage, it will be necessary to develop an optimisation model. Each airport is different, so it is not possible to provide a generic model. All models will need to concentrate on the defined key purposes for the airport in question and should avoid analysing purposes that are not relevant to that airport. Depending on the complexity of the airport in question, it may be possible to do this as a straightforward spreadsheet or more complex models such as simulation exercises and/or statistical analysis may be required.

The optimum position in any model is likely to be the one that minimises the total cost of:

(a) building and operating tanks and keeping fuel in them; plus
(b) disruption costs caused by any inadequacies in tankage capacity.

More details on modelling are given in the worked examples that are attached.

7 Operational Considerations, Finance & Permissions

Operational, financial considerations & necessary permissions that have been identified are listed below. It is advised that input be obtained from your technical and financial specialists in addressing these issues.

7.1 Operational Considerations

- Determine number of separate tank farms
- Determine location(s) of tanks.
- Determine number of tanks (For continuous operation, need at least 3 tanks. If fuel unbatched, need at least 1 additional tank).
- Determine optimum size of each tank
- Compliance with codes & standards, such as Separation distances, emergency fire water & bund capacity.
- Determine logistics for storage to aircraft transportation
- Determine availability of workforce
- Determine customs requirements
- Determine maintenance requirements

7.2 Finance & Contractual Considerations

- Fuel owner obligation for minimum daily stock
- Quantify costs, including cost of capital
- Determine lowest cost funding options
- Confirm project meets financial criteria
- Ensure project is financially viable taking account of lease length, depreciation period, funding structure etc.
- Confirm funding.
- Compulsory stock obligations

7.3 Permissions

- Land availability
- Planning permission
- Regulatory approval (e.g. Seveso)
- Environmental requirements
- Other Relevant Legislation

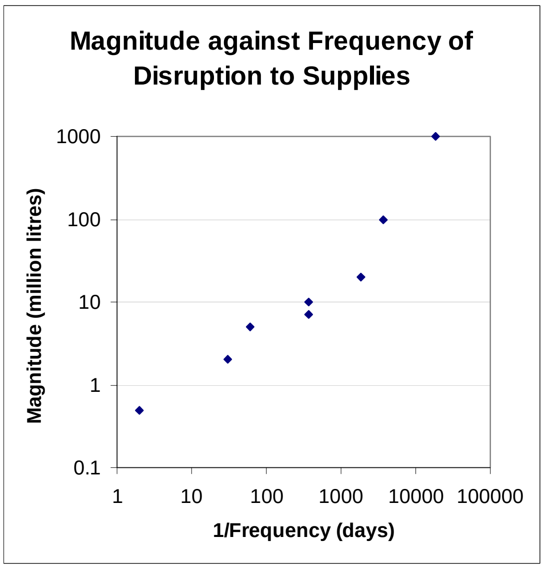
8 Consultations & Transparency

It is clear that airlines have more confidence in the adequacy of fuel infrastructure at their home base airports than at foreign airports. One of the reasons for such a view could be that the airlines are more engaged with the home base fuel infrastructure provider and hence receive more information than from fuel infrastructure providers at other locations.

To improve the situation, IATA strongly recommends that the fuel infrastructure manager conduct regular meetings with airline stakeholders and provide information on supply reliability, demand fluctuations, and storage capacity - current and in the mid-term. Agreement with the airlines is particularly important when plans are being developed for expansion of the facilities.

9 Disruption to Supply and Contingency Planning

It is not feasible to build facilities that would withstand all disruptions. Raising design limits (safety factors and margins) could lower the chance of events above such limits, but construction and operating costs would inevitably increase, often by exponential order. The chart below shows the risk to supply assessed at London Heathrow Airport.



The chart demonstrates that while the probability of a 100 million litre disruption is limited to once every 10 years, a 5 million litre disruption could occur 6 times a year. Similar relations between the magnitude and the probability may apply to any airport worldwide. Risk assessment and cost/benefit trade-off analysis are essential in striking a balance unique to individual airports. Different parameters yield strikingly different solutions.

It is also physically infeasible and economically inefficient to protect airport fuel storage against all conceivable forms of supply disruptions. Hence it is prudent to determine a risk threshold that is reasonable and agreeable to all stakeholders in determining storage capacity and to put in place a fuel contingency plan to mitigate the risk of stock out.

10 Suggested approach and next steps

The suggested approach for anyone seeking to determine the optimum storage for their airport is to:

- Understand the airport's current profile
- Clarify the purposes of storage relevant to that airport
- Quantify the measurable parameters that are applicable to those purposes
- Calculate Optimum Storage
- Review Operational Considerations, Finance & Permissions

Finally communication with all stakeholders during the process and when final results are known is strongly encouraged.

Appendix 1: Draft checklist of the measurable parameters that are relevant to each of the potential purposes defined in section 3

Issue	Potential Purpose	Is potential purpose relevant at this airport?	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
1. Demand	1.1 To accommodate current demand	Yes / No	1.1.1 Average day / month demand, peak day/month demand	
	1.2 To accommodate future demand growth	Yes / No	1.2.1 Planning horizon and the airports growth potential	
			1.2.2 Average day/month demand, peak day/month demand	
			1.2.3 Opportunities for incremental expansion of storage capacity	
			1.2.4 Confidence in obtaining suitable locations and land for future expansion	
	1.3 Ullage for unexpected demand reductions	Yes / No	1.3.1. Frequency and impact of weather considerations (e.g. hurricanes / typhoons)	
			1.3.2 Frequency & scale of major changes in demand	
2. Supply	2.1 To accommodate normal supply schedule	Yes / No	2.1.1 Standard quantity of a batch by delivery method used (i.e. pipeline batch, ship cargo size, block train, truck size)	
	2.2 Buffer for supply schedule	Yes / No	2.2.1 Understand Supply Infrastructure (including off-airport storage)	
			2.2.2 Understand pipeline schedules	
			2.2.3 Understand size of tankers, railcars, etc	
			2.2.4 Understand off airport storage	
	2.3 Cover against significant supply interruptions	Yes / No	2.3.1 Supply Infrastructure (including off-airport storage)	
			2.3.2 Security of supply (i.e. how many supply routes, highest % of total airport supply from any one route, what % of lost supply can be made up by spare capacity on alternate routes, how long to restore 'lost' supply?)	
			2.3.3 Frequency & scale of major supply interruptions	
			2.3.4 Availability of fuel contingency plan for airport community	
			2.3.5 Scope & impact of contingency plan (known at Heathrow as the "allocation system")	
3. Stock management	3.1 To allow for day-to-day stock fluctuations	Yes / No	3.1.1 Quantify normal variability in supply and demand.	
	3.2 To allow for normal stock fluctuations within a day	Yes / No	3.2.1 Quantify normal variability in stock levels within each day	
	3.3 To allow for normal airport operations	Yes / No	3.3.1 Quantify any individual stock holdings by Suppliers	
			3.3.2 Quantify the need for a strategic reserve, if any	
			3.3.3 Hydrant/non hydrant operation	

Issue	Potential Purpose	Is potential purpose relevant at this airport?	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
	3.4 To allow for seasonal variations in stock	Yes / No	3.4.1 Quantify normal seasonal variations in supply, demand and stock levels	
	3.5 To provide a facility to re-blend unbatched fuel at the location (if relevant)	Yes / No	3.5.1 Does this location receive unbatched fuel?	
			3.5.2 What quantities of unbatched fuel are received and in what frequencies?	
			3.5.3 What is the expected frequency of needing to re-blend and in what quantities?	
			3.5.4 Need to determine how many additional tanks will be required.	
			3.5.5 Expected frequency and impact of receiving off spec cargos?	
	3.6 To provide a level of duplication in case part of the facility fails	Yes / No	3.6.1 Understand current facility	
			3.6.2 Understand risk of failure of part of the existing facility.	
			3.6.3 Understand security risks.	
4. Quality Control	4.1 To allow for settling time & quality control checks	Yes / No	4.1.1 How many tanks are there currently?	
			4.1.2 Required settling time.	
			4.1.3 Time taken to perform quality control checks.	
			4.1.4 Any limitation on when own staff / lab can perform quality control checks (i.e. is this 24 hours, 7 days a week?)	
			4.1.5 Is fuel receipt continuous?	
	4.2 Maintenance requirements	Yes / No	4.2.1 Types of maintenance performed at airport (e.g. tank cleaning)	
			4.2.2 Frequency & duration of each type of maintenance.	
			4.2.3 Understand legal obligations in this area	
			4.2.4 Impact on storage of each type of maintenance (e.g. 1 tank out of service at a time)	
5. Regulatory Requirements	5.1 Compulsory stocks, if imposed by the State	Yes / No	5.1.1 Understand legal obligations in this area	
			5.1.2 Quantity of stock that the State requires to be held at the airport.	
	5.2 To provide sufficient time to meet Customs requirements	Yes / No	5.2.1Understand legal obligations in this area	

Annex 2

Worked Example – London Heathrow Airport

1. Airport's Current Profile

Heathrow is currently limited to 480,000 ATM's per Annum. At present the airport caters to around 670 flights per day on average.

1.1. **Fuel Demand:** In 2008 the fuel demand is forecast to be 8 billion litres. The bulk of demand comes from medium, long and ultra-long haul flights - in 2007, only 8% of the demand came from short-haul flights. There is relatively little seasonal variation – demand in the busiest and quietest weeks is typically 10% above or below the annual average. Growth is strong and BAA and British Airways demand forecasts show fuel demand doubling by 2030.

1.2. **Supply & Offloading Facilities:** There are three pipeline supply routes into the airport, plus deliveries by train. Heathrow had a facility for receiving deliveries by road from late January 2006 until the end of September 2007 and is aiming to relocate it by the end of 2008.

1.3. **Current Storage:** There are two fuel tank farms at the airport, the Perry Oaks installation which serves terminals 1, 2, 3 and 5 and the Sandringham Road Depot, which serves terminal 4 and the Cargo Area. Following completion of the HAFCO tank farm in 2005, useable storage capacity at Heathrow is currently 56 million litres. This will drop to 52 million litres when two tanks known as the "interim storage tanks" are removed from service. Target midnight stock is 34 million litres.

1.4. **Fuel Distribution:** Fuel is delivered to aircraft at Heathrow via hydrant systems. There is one that serves terminals 1, 2 & 3 (also known as the Central Terminal Area or CTA Hydrant). Another serves Terminal 4 and the Cargo Area. A third system delivers fuel to the Terminal Five stands.

1.5. **Product diversity:** Following the loss of Buncefield in December 2005, supply into Heathrow in the summers of 2006 and 2007 was not adequate to meet unconstrained demand and some of the steps taken to increase supply resulted in Heathrow receiving "unbatched" or "uncertified" fuel. The planning assumption for the Heathrow study, however, was that supply will be adequate to meet demand by the time additional storage is built at Heathrow so no allowance has been made in the calculations for receipt of "unbatched" or "uncertified" fuel.

1.6. **Fuel Contingency Plan:** An airline industry agreed voluntary fuel contingency plan is available. The main objective of the plan is to minimize disruptions to passengers and flights.

2. Purposes of Fuel Storage at LHR

Four main purposes were identified for having fuel storage at Heathrow.

- **Purpose 1**: The first was to **enable appropriate quality control checks to be carried out on the fuel.** Specifically, fuel is received at the airport on a continuous basis, but each time the fuel "parcel" changes (which happens several times per day), the fuel needs to be allowed to settle in a tank for a defined period of time before it can be sampled, tested and released for use. In addition, quality control procedures require fuel to be sampled and tested and retention samples taken at various other times. The result is that the storage needed to be adequate to allow each tank farm at all times to have at least one tank receiving fuel, one tank containing fuel being settled and one tank available to deliver into the fuel hydrant.

- Purpose 2: The second very important reason for having tanks at Heathrow was **to allow for normal fluctuations in stock levels**, both within a day and between one day and the next. In uneventful periods, stocks in 2007 typically fluctuated by 8 million litres within a day and the midnight stock level typically fluctuated by 14 million litres within a month. Heathrow needs to have adequate fuel in its storage tanks and sufficient additional capacity in the tanks to be able to cope with current and future fluctuations of this nature.

- Purpose 3: The third purpose of fuel storage at the airport is **to provide a level of buffer stock to be able to deal with operational hiccoughs.** A study conducted for HHOpCo in April 2006 identified the typical spread of different sizes of supply interruptions, ranging from relatively small one (with impacts of around 0.5 million litres each) that typically occur once every couple of days through to massive events such as the loss of Buncefield that can be described as "once in 50 year events". One of the main aims of the Heathrow study was to provide a rational basis for determining the sizes and frequencies of events that it is worth providing for and, by association, the ones for which no provision should be made.

- Purpose 4: The final aim of storage at Heathrow was that it should be built at an appropriate rate **to accommodate future demand growth**.

3. Key Measurable Parameters

Potential Purpose	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
1.1 To accommodate current demand	1.1.1 Average day / month demand, peak day/month demand	Average throughput in 2007 was 20.2 million litres per day. Average throughput over the summer period was 21.2 million litres per day.
1.2 To accommodate future demand growth	1.2.1 Planning horizon and the airports growth potential	Planning horizon is through to year 2030. For growth potential, see item 1.2.2.
	1.2.2 Average day/month demand, peak day/month demand	BAA's jet fuel forecast shows average day demand in 2030 as 40.7 million litres, with a summer peak of 43.3 million litres. British airways have produced an independent forecast of 43.1 million litres per day.
	1.2.3 Opportunities for incremental expansion of existing storage capacity	None.
	1.2.4 Confidence in obtaining suitable locations and land for future expansion	There are significant constraints in land availability at Heathrow.
2.1 To accommodate normal supply schedule	2.1.1 Standard quantity of a batch by delivery method used (i.e. pipeline batch, ship cargo size, block train, truck size)	Supply changes are expected to have taken place by the time that additional tanks are built, but exact details are not known, so the modelling assumptions are that each pipeline supply route will deliver a third of the airport's demand and all routes will deliver batched fuel.
2.2 Buffer for supply schedule	2.2.1 Understand Supply Infrastructure (including off-airport storage)	Heathrow currently receives fuel via three pipeline supply routes, plus trains. It is aiming to be able to receive road deliveries again from the end of 2008.
	2.3.3 Frequency & scale of major supply	"Supply events" included in the modelling were "once every

Potential Purpose	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
	interruptions	ten year", "once every five year" and two types of "once a year" events, with current impacts of 100 million litres, 20 million litres 10 million litres and 7 million litres respectively. The sizes of each event (but not their frequencies) are assumed to increase in proportion to fuel demand.
	2.3.4 Availability of fuel contingency plan for airport community	An industry agreed voluntary fuel contingency plan is available.
	2.3.5 Scope & impact of contingency plan (known at Heathrow as the "allocation system")	When a "supply event" occurs, the maximum daily stock loss is 1/3 of total supply and the "allocation system" is expected to reduce demand down to match available supply in 14 days
3.1 To allow for day-to-day stock fluctuations	3.1.1 Quantify normal variability in supply and demand.	Supply is normally distributed with a standard deviation that is 0.07 times throughput. Demand is normally distributed with a standard deviation that is 0.19 times throughput.
3.2 To allow for normal stock fluctuations within a day	3.2.1 Quantify normal variability in stock levels within each day	Currently typically 8 million litres.
3.3 To allow for normal airport operations	3.3.3 Hydrant/non hydrant operation	Hydrant operation.
3.4 To allow for seasonal variations in stock	3.4.1 Quantify normal seasonal variations in supply, demand and stock levels	Summer / winter demand are typically 10% above / below the annual average. Stock levels vary on a daily basis rather than seasonally.
3.5 To provide a facility to re-blend unbatched fuel at the location (if relevant)	3.5.1 Does this location receive unbatched fuel?	Planning assumption is that Heathrow will be receiving only batched fuel by the time new tanks are built.
3.6 To provide a level of duplication in case part of the facility fails	3.6.1 Understand current facility	Heathrow has two tank farms and three hydrant systems.
4.1 To allow for settling time & quality control checks	4.1.1 How many tanks are there currently?	Six at Perry Oaks (excluding the Interim Storage tanks). Nine in the Cargo Depot.
4.2 Maintenance Requirements	4.2.2 Frequency & duration of each type of maintenance.	Each tank is visually inspected every year and cleaned every three years.

4. Optimum Storage Calculation

Current requirement for additional useable jet fuel storage

The oil industry typically works to a benchmark of seeking sufficient storage capacity at a pipeline-supplied airport depot to be able to hold approximately three days' demand. The airline industry has confirmed that they were comfortable with a similar benchmark. The Heathrow study team, aware of these benchmarks, but also recognising that there were serious space constraints at Heathrow, decided to conduct its own analysis in order to be confident of the results.

In practice, HAFCO and British Airways each developed separate optimisation models and then compared conclusions.

Each of the models calculated firstly the expected frequencies of small scale disruptions and the resulting expected tankering costs and secondly the frequencies of stock-outs and the disruption costs that would be expected to follow and then compared these numbers against the expected cost of building and operating additional tankage. In general terms, the greater the useable capacity of the tankage at the airport, the lower are the expected costs of stock-outs and operational tankering, but the higher are the costs of building and operating the tanks. The optimum position is the one at which the total expected cost is minimised.

The British Airways model was based on simulation techniques and looked in particular at two variables - the time that the airline community would have to be able to prepare for an impending stock-out and at the ongoing cost of tactical tankering required to deal with small-scale disruptions. In this model, the optimum position is the point at which the expected frequency of stock-outs multiplied by the expected cost of each stock-out (which is itself a function of the amount of time available to the airline community to react to an impending stock-out) plus the expected reduction in tactical tankering costs are equal to the cost of building and maintaining the tanks plus costs of holding additional stock. The BA model took as an input that additional capacity would be added in pairs of tanks, with each tank having a useable capacity of eight million litres.

HAFCO's model used statistical analysis. As with the BA model, this one also assessed the tankering costs that arise from small-scale disruptions. The HAFCO model took as a given that the allocation system would reduce demand down to meet available supply within 14 days and used inputs from two UK-based airlines to estimate the expected cost of a stock-out. It calculated the optimum position as being the one at which the marginal cost of building and operating additional tankage is just equal to expected marginal costs of the stock-outs plus tankering. The HAFCO model calculated the required useable capacity to the nearest million litres.

British Airway's analysis shows that the airport currently needs four additional tanks, each with a useable capacity of 8 million litres (i.e. 32 million litres in total). HAFCO's analysis shows that the current requirement is 28 million litres, rising to 33 million litres by the summer of 2010. (Hence, at an average peak day demand of 24 million litres the total storage required at LHR is 3.5 days.)

Through a similar analysis it has been determined that the future useable storage capacity requirement at LHR is 97 million litres by 2030.

5. Location Analysis

A detailed study was undertaken to determine the locations for the future fuel tanks. As a first step a list of 16 locations were identified based on input from various stakeholders including the airport. The initial long-list was then reduced to a short list using ten selection criteria which included the estimated cost of constructing and operating additional tanks and a consideration of whether aircraft stands would be impacted. The short list was then analysed in more detail with input from specialists in areas such as COMAH, engineering and planning law.

The final conclusion of the study is that a bund and two additional fuel tanks of 13 million litre useable capacity each need to constructed as soon as possible on the current stand 596 to support terminals 1, 2, 3 & 5 and that provision needs to be made in the airport's plans for staged construction through to 2030 of six further tanks of the same size in the same area of the airport, plus three smaller tanks for the proposed third runway and two smaller tanks near the Sandringham Road depot.

6. Consultations & Transparency

HHOpCo and HAFCo the fuel facility provider meets the airlines on a regular basis to discuss matters related to costs, investments, throughput and charges. This particular exercise to determine the current and future storage requirement was carried out by a task group comprised of HHOpCo, HAFCo, BAA, two airline representatives, the AOC and IATA in a totally transparent manner. The details of the study and the outcomes are being shared with the airline community and all other stakeholders. It should be noted, however, that current land constraints at Heathrow mean that there may be challenges in gaining support from airline operational personnel for additional fuel tanks.

Appendix 3

Worked Example in OFC (at Athens International Airport)

Olympic Fuel Company S.A. (OFC) after international tender has been awarded by Athens International Airport (AIA) as the Fuelling Concessionaire, so to design, finance, build and operate the Airport Depot and the Hydrant Refuelling System for 23 years, starting in 2001.

This Guideline is used for the calculation of the OFC optimum storage. For simplification reasons and maximizing the benefits to the Guideline's users, the worked example is based on the following assumptions:

- Commencement of OFC operations: 2001
- Peak month/day: of 2001
- Fuel Supply mode: Pipeline (100%), though during 2001 and early 2004 fuel has been transported to OFC by road tank trucks (bridgers).

Step 1: Understand Airport's Current Profile (see Guideline/Article 3)

1. Demand Forecast

Fuel Volumes at AIA are affected by seasonality (see Figure 1: Average Daily Demand per Month in 2002 and 2007). OFC has to cover this fuel demand. Daily Volume to be used in the storage calculation is determined as 2000 m^3.

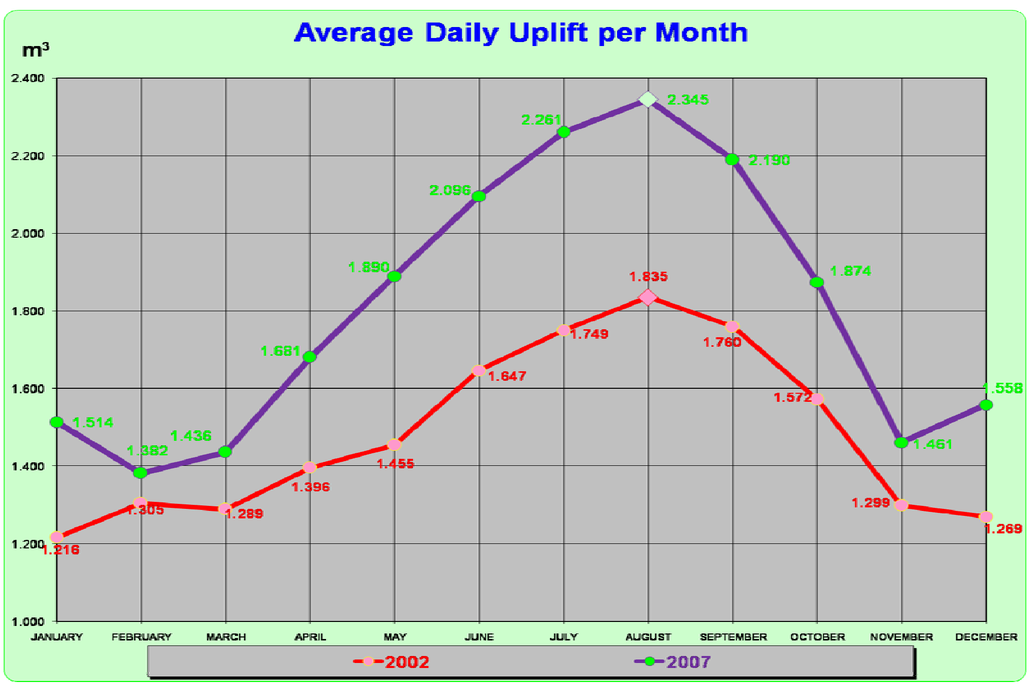


Figure 1: Average Daily Demand per Month in 2002 and 2007

As far as future demand evolution is concerned, this has been determined as 3 % annual increase.

2. Supply Modes

The fuel supply is provided by Jet A-1 dedicated pipeline interconnecting OFC with Hellenic Petroleum Refinery at Aspropyrgos, of a distance of 53km. The Refinery tanks are also dedicated to Jet A-1 and positively segregated from other fuel grades.

3. Operating Hours

Operating hours of AIA: 24 hours/day, 7 day/week. Consequently, OFC's operating hours are the same. Fuel supply can also performed in the same operating framework as above.

Customs and other Related Offices operating hours: Monday to Friday.

4. Fuel Receipt Technical / Operational Data

- Pipeline flow rate is 200m^3/hr with the capability to increase up to 300 m^3/hr.
- OFC inlet filters (FWS) can operate at least at 500 m^3/hr.
- OFC is also equipped with 6 Bridger offloading islands (used before pipeline construction), which are maintained operational, so to be used in case of Pipeline major shut down.

Step 2: Purposes of Airport Storage (see Guideline / Article 4)

a) To accommodate current and future demand (during the concession period).
b) To accommodate current and future supply schedule and interruptions.
c) To allow for day – to – day stock fluctuations.
d) To allow for all required Fuel Quality Controls (JIG, etc).
e) To allow for Maintenance (preventive and breakdown).
f) To satisfy Customs requirement to check/register the fuel quantities received before these quantities are released for aircraft refuelling.

Step 3: Identification of Key Measurable Parameters in Determining the Storage Capacity (See Guideline / Article 5)

Based on the above, the Key Measurable Parameters for OFC are the following:

1. Operational Stock to accommodate peak with daily demand: 3 days.
2. Emergency Stock to accommodate Pipeline interruption, without the need to activate bridger (truck) offloading: 3 days. This is the minimum number of days that are required either for the Pipeline for small repair works as for switching to bridger supply mode.
3. In addition to fuel quality control, there are also Customs related requirements. The receipt quantity is checked by Customs, to assure that volume departed from the Refinery tanks was received at OFC tanks. So, each pipeline transportation is checked by Customs. Since weekends are involved, then 2 days are envisioned.

Step 4: Checklist of the measurable parameters.

Potential Purpose	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
1.1 To accommodate current demand	1.1.1 Average day / month demand, peak day/month demand	Average throughput in 2001 was 2000 m3 per day
		Average throughput over the summer season (July - August) was 2350 m3 (30% higher).
1.2 To accommodate future demand growth	1.2.1 Planning horizon and the airports growth potential	Till 2021 (end of concession)
	1.2.2 Average day/month demand, peak day/month demand	About 4000m3 per peak day 124000 m3 per peak month in 2021
	1.2.3 Opportunities for incremental expansion of storage capacity	Yes
	1.2.4 Confidence in obtaining suitable locations and land for future expansion	Available land for 4 additional tanks
1.3 Ullage for unexpected demand reductions	1.3.1. Frequency and impact of weather considerations (e.g. hurricanes / typhoons)	No
	1.3.2 Frequency & scale of major changes in demand	N/A
2.1 To accommodate normal supply schedule	2.1.1 Standard quantity of a batch by delivery method used (i.e. pipeline batch, ship cargo size, block train, truck size)	Pipelines receipts between 5000 to 9000 m3 per parcel
2.2 Buffer for supply schedule	2.2.1 Understand Supply Infrastructure (including off-airport storage)	1. Jet A-1 dedicated Pipeline.
		2. Possibility for trucks
	2.2.2 Understand pipeline schedules	Twice a week
	2.2.3 Understand size of tankers, railcars, etc	N/A
	2.2.4 Understand off airport storage	Two Refinery Jet A-1 dedicated Tanks -total capacity 17000 m3
2.3 Cover against significant supply interruptions	2.3.1 Supply Infrastructure (including off-airport storage)	Jet A-1 dedicated pipeline, Jet A-1 dedicated tanks at Refinery, alternative supply with bridger (truck)
	2.3.2 Security of supply	If Pipeline is interrupted, then trucks can be utilised within 3 days
	2.3.3 Frequency & scale of major supply interruptions	None up to now
	2.3.4 Availability of fuel contingency plan for airport community	No
3.1 To allow for day-to-day stock fluctuations	3.1.1 Quantify normal variability in supply and demand.	Current typical demand on peak season is 2500m3 on Fridays, Saturdays and Mondays. Supply is 4800m3 per day by pipeline.
3.2 To allow for normal stock fluctuations within a day	3.2.1 Quantify normal variability in stock levels within each day	600 m3
3.3 To allow for normal airport operations	3.3.1 Quantify any individual stock holdings by Suppliers	N/A
	3.3.2 Quantify the need for a strategic reserve, if any	N/A
	3.3.3 Hydrant/non hydrant operation	Hydrant operation

Potential Purpose	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
3.4 To allow for seasonal variations in stock	3.4.1 Quantify normal seasonal variations in supply, demand and stock levels	July and August demand is typically 25-30% above the annual average
3.6 To provide a level of duplication in case part of the facility fails	3.6.1 Understand current facility	OFC has one tank farm and one hydrant system.
4.1 To allow for settling time & quality control checks	4.1.1 How many tanks are there currently?	4 tanks
	4.1.2 Required settling time.	2hours minimum
	4.1.3 Time taken to perform quality control checks.	1 hour
	4.1.4 Any limitation on when own staff / lab can perform quality control checks (i.e. is this 24 hours, 7 days a week?)	No
	4.1.5 Is fuel receipt continuous?	No
4.2 Maintenance requirements	4.2.1 Types of maintenance performed at airport	Tank cleaning (one tank at a time)
	4.2.2 Frequency & duration of each type of maintenance.	Each tank visually inspected annually. Cleaned every 3 years
	4.2.4 Impact on storage of each type of maintenance (e.g. 1 tank out of service at a time)	None. Still 3 Tanks in Operation
5.1 Compulsory stocks, if imposed by the State	5.1.1 Understand legal obligations in this area	N/A
	5.1.2 Quantity of stock that the State requires to be held at the AP	N/A
5.2 To provide sufficient time to meet Customs requirements	5.2.1Understand legal obligations in this area	2 business days for Customs clearance.

Step 5: Tabulation of OFC Worked Example

All the aforementioned calculations are input in the table below, in which size and number of tanks are shown. Additionally, Pipeline requirements are linked to fuel demand evolution. It is worthy to note that, based on worked example assumptions on volume future evolution, number of tanks are shown to require increase during the concession period, while the Pipeline flow rate has also to be increased.

OFC Case Study
for Optimum Tankage Sizing
And Pipeline Operational Requirements

Estimated Storage Capacity (3% Annual Increase)												Pipeline operational Requirements Per Week			
Year	Max daily demand	Emergency Stock (1)		Operational Stock		Required Stock	Pipeline Receipt		Total Quantity	Required Tanks (3)	Quantity (4)	Pumping Flowrate	Operating Hours	Operating Days (5)
	m^3	*Numbers of Days*	*m^3*	*Numbers of Days*	*m^3*	*m^3*	*Numbers of Days (2)*	*m^3*	*m^3*	*No*	*m^3*	*m^3/hour*	*hours*	*days*
2001	2.000	3	6.000	3	6.000	12.000	2	4.000	16.000	4	14.000	200	70	2,9
2002	2.060	3	6.180	3	6.180	12.360	2	4.120	16.480	4	14.420	200	72	3,0
2003	2.122	3	6.365	3	6.365	12.731	2	4.244	16.974	4	14.853	200	74	3,1
2004	2.185	3	6.556	3	6.556	13.113	2	4.371	17.484	4	15.298	200	76	3,2
2005	2.251	3	6.753	3	6.753	13.506	2	4.502	18.008	4	15.757	200	79	3,3
2006	2.319	3	6.956	3	6.956	13.911	2	4.637	18.548	4	16.230	200	81	3,4
2007	2.388	3	7.164	3	7.164	14.329	2	4.776	19.105	4	16.717	200	84	3,5
2008	2.460	3	7.379	3	7.379	14.758	2	4.919	19.678	4	17.218	200	86	3,6
2009	2.534	3	7.601	3	7.601	15.201	2	5.067	20.268	4	17.735	200	89	3,7
2010	2.610	3	7.829	3	7.829	15.657	2	5.219	20.876	5	18.267	200	91	3,8
2011	2.688	3	8.063	3	8.063	16.127	2	5.376	21.503	5	18.815	200	94	3,9
2012	2.768	3	8.305	3	8.305	16.611	2	5.537	22.148	5	19.379	200	97	4,0
2013	2.852	3	8.555	3	8.555	17.109	2	5.703	22.812	5	19.961	300	67	2,8
2014	2.937	3	8.811	3	8.811	17.622	2	5.874	23.497	5	20.559	300	69	2,9
2015	3.025	3	9.076	3	9.076	18.151	2	6.050	24.201	5	21.176	300	71	2,9
2016	3.116	3	9.348	3	9.348	18.696	2	6.232	24.927	5	21.812	300	73	3,0
2017	3.209	3	9.628	3	9.628	19.256	2	6.419	25.675	5	22.466	300	75	3,1
2018	3.306	3	9.917	3	9.917	19.834	2	6.611	26.446	6	23.140	300	77	3,2
2019	3.405	3	10.215	3	10.215	20.429	2	6.810	27.239	6	23.834	300	79	3,3
2020	3.507	3	10.521	3	10.521	21.042	2	7.014	28.056	6	24.549	300	82	3,4
2021	3.612	3	10.837	3	10.837	21.673	2	7.224	28.898	6	25.286	300	84	3,5

(1) Minimum 3 days to switch from Pipeline to trucks in case Pipeline is interrupted
(2) Max days for Customs Clearance
(3) Of 6000 m^3 each
(4) To be transferred every week
(5) Max allowed 5 days. 2 days for maintenance requirements

Note: Tank Volume
Total = 6000 m^3
Unpumpable (1,1) m = 600 m^3
Ullage = 200 m^3
So, Working Volume = 5200 m^3

Appendix 4

Worked Example – Hong Kong International Airport

1. Airport's Current Profile

The Hong Kong International Airport (HKIA) currently caters for 295,600 aircraft movements per annum, which translates into around 400 departing flights per day on average.

Fuel Demand: The bulk of the 2007 demand came from long and ultra-long haul flights. There is some variation in demand with the busiest day being Friday and busiest months being October and November due to flying out of Christmas cargo. Growth is continuing to be strong. In 2009 the fuel demand at HKIA is forecast to be about 7 million m^3.

Appropriate Quality Control Checks: All of the fuel is imported into Hong Kong with most coming from Singapore and other Asian countries. It is off loaded at Tsing Yi (in Hong Kong) for settlement, quality control and re-certification, then barged to Sha Chau aviation fuel receiving facility (AFRF), located 6 kilometres north of the HKIA. The remaining fuel coming from the refineries in China is directly barged to the AFRF. After quality testing at the AFRF, the fuel is pumped to the tank farm at the airport by subsea pipelines.

Reserve Requirements: The Hong Kong Government requires an aviation fuel reserve of 11 days of the projected demand to be maintained at HKIA.

Current Storage: There were 9 tanks (6 x 22,500 m^3 and 3 x 11,000 m^3). With an addition of 3 tanks of 17,000 m^3 in 2007, there are now 12 tanks.

Sustainable Capacity: The sustainable capacity of Sha Chau is about 16,800 m^3 per day. With the addition of a small receiving facility on the airport in 2006, the total sustainable capacity has been increased to 19,800 m^3 per day.

Fuel Distribution: Fuel is delivered to aircraft at HKIA via hydrant system and dispensers.

PAFF: It was anticipated that a Permanent Aviation Fuel Facility (PAFF) would be in place from day one of new HKIA opening but this was not possible at that time due to site selection issues, so a temporary AFRF at Sha Chau was built. PAFF is now anticipated to be in operation by end-2009.

Fuel Contingency Plan: An industry agreed fuel contingency plan is in place. The main objective of the plan is to minimize disruptions to passengers and flights.

2. Purposes of Fuel Storage at HKIA

Three main purposes were identified for having fuel storage at HKIA.

Purpose 1: The first purpose of fuel storage at the airport is to provide an appropriate level of reserve. Because Hong Kong does not have refineries nor direct feed by pipelines, it is dependent on fuel from overseas. The marine operations could be affected by weather condition and may cause supply interruption.

Purpose 2: The second purpose for having tanks at HKIA is to allow for normal fluctuations in stock levels, within the day, week and months. In uneventful periods, demand in 2007 typically fluctuated by almost 2,000 m^3 per day within a week. The average demand in October and November 2007 was around 17,500 to 18,000 m^3 per day respectively compared to the low months of January and February 2007 when the average was around 16,000 to 16,300 m^3 per day respectively. HKIA needs to have adequate fuel in its storage tanks and sufficient additional capacity to be able to cope with current and future fluctuations of this nature.

Purpose 3: The final aim of storage at HKIA was that it should be built at an appropriate rate **to accommodate future demand growth** considering that the PAFF would be operational by end-2009. The average annual growth rate is about 6% for the last 7 years, and 8% over the last 3 years.

3. Key Measurable Parameters

Potential Purpose	Measurable Parameter (Do not quantify if purpose not relevant at this airport)	Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport)
1.1 To accommodate current demand	1.1.1 Average day/month demand, peak day/month demand	Average throughput in 2007 was 16,800 m^3 per day. Average throughput over the autumn period was 5-6% higher.
1.2 To accommodate future demand growth	1.2.1 Planning horizon and the airports growth potential	Planning horizon is through to year 2047 including provision of PAFF.
	1.2.2 Average day/month demand, peak day/month demand	About 35,000 m^3 per day in 2030.
	1.2.3 Opportunities for incremental expansion of existing storage capacity	None required as the PAFF outside of the airport would cater for the future demand.
2.1 Buffer for supply schedule	2.1.1 Frequency & scale of major supply interruptions	In the last 50 years, there have been some cases of 2 successive tropical cyclones each of which could incur a supply outage of 3 days, (i.e. in which Tropical Cyclone Signal no.3 (T3) or above is hoisted), with a period of five clear days between one T3 down and the next T3 up. Reserve equivalent of 11 days uplift demand caters for that. Besides, ocean tankers will need to take shelter when a tropical cyclone is nearby.
	2.1.2 Availability of fuel contingency plan for airport community	An industry agreed voluntary fuel contingency plan is in place.
3.1 To allow for day-to-day stock fluctuations	3.1.1 Quantify normal variability in demand.	Current typical demand is 18,400 m^3 on Fridays compared to 16,500 m^3 on Tuesdays. Supply may vary from 12,500 m^3 per day to 25,000 m^3 per day depending on shipment schedule. Thus stock can vary as much as 14,400 m^3 per day.
3.2 To allow for normal stock fluctuations within a day	3.2.1 Quantify normal variability in stock levels within each day	See above
3.3 To allow for normal airport operations	3.3.3 Hydrant/non hydrant operation	Hydrant operation.
3.4 To allow for seasonal variations in stock	3.4.1 Quantify normal seasonal variations in supply, demand and stock levels	October and November demand is typically 5-6% above the annual average.
3.5 To provide a facility to re-blend unbatched fuel at the location (if relevant)	3.5.1 Does this location receive unbatched fuel?	Only batched fuel
3.6 To provide a level of duplication in case part of the facility fails	3.6.1 Understand current facility	HKIA has one tank farm and one hydrant system. The 11 days reserve requirement and equipment redundancy cover any unusual events.
4.1 To allow for settling time & quality control checks	4.1.1 How many tanks are there currently?	12 tanks
4.2 Maintenance Requirements	4.2.2 Frequency & duration of each type of maintenance.	Each tank is visually inspected every day, externally surveyed every year, cleaned every three years, and internally surveyed every 10 years.

4. Storage Capacity

The storage capacity of the aviation fuel at HKIA is determined by the inherent ability within the delivery system to replenish stock at a reasonable rate, following draw down during outages (when deliveries by vessels cannot take place, for example during the passage of tropical cyclones but the aircraft continue to uplift fuel for departures).

The unique situation applicable to HKIA aviation fuel system is based on:

(a) There is no oil refinery in Hong Kong.
(b) HKIA is not directly fed by aviation fuel pipelines, thus being dependent on aviation fuel from overseas, all of which is brought by ocean tankers and majority discharged at oil companies' depots at Tsing Yi, settled and re-certified before being barged to the AFRF at Sha Chau.
(c) There are two 6,000 dwt berths at the AFRF at Sha Chau due to limitations of water depth. This was supplemented in 2006 by a very small receiving facility at the airport to a total capacity of about 19,800 m^3 per day.
(d) Hong Kong is prone to tropical cyclones from end-April to early-November. In the last 50 years, there have been some cases of 2 successive tropical cyclones each incurring a supply outage of 3 days, (i.e. in which Tropical Cyclone Signal no.3 (T3) or above is hoisted), with a period of five clear days between one T3 down and the next T3 up. Barging operation will cease when T3 or above is hoisted.

The Hong Kong Government decided during the planning stage of the new airport in June 1993 that the aviation fuel reserve to be maintained at HKIA should be equivalent of 11 days projected demand.

With the Hong Kong Government decision and the open access arrangement at HKIA, it was decided to have 6 tanks of 22,500 m^3 and 3 tanks of 11,000 m^3 capacity, giving a total operational capacity of 168,000 m^3, in order to meet the large and small quantities of aviation fuel to be brought by over 10 suppliers,

As an average of 3 days of uplift demand is needed for operation, it is obligatory on each supplier to maintain 8 days minimum reserve at HKIA.

In 2005, the fuel suppliers, the operator, the airlines (even though they bear the additional cost of the new tanks) and the Airport Authority agreed on the need for the 3 additional tanks at the airport. Accordingly, 3 tanks of 17,000 m^3 each have been built and put into operation, giving a total capacity of about 219,000 m^3.

The attached Table gives the summary of just-in-time additions of infrastructure built at HKIA, based on the demand and supply.

From end-2009, the PAFF will come into operation. The PAFF would be able to accommodate up to 80,000 dwt tankers from overseas, thus the distribution terminal at Tsing Yi would not be needed. The PAFF would have 8 tanks with a total of 264,000 m^3 capacity and ultimately 12 tanks with a total of 388,000 m^3 capacity. HKIA will be fed directly by pipelines from the PAFF.

Table

Year	2003	2004	2005	2006	2007	2008	2009
Operational capacity of on-airport tanks (m^3)	168,000	168,000	168,000	168,000	168,000	219,000	219,000
Replenishment rate per sustainable capacity (m^3 per day)	16,800	16,800	16,800	16,800	19,800	19,800	19,800
Daily uplift demand (m^3)	10,809	13,405	14,778	15,682	16,824	18,000**	18,900**
Original reserve level (days)	11	11	11	10.7	10.0	11	11
Level of fuel stock after the passage of the 1st tropical cyclone (days)	8	8	8	7.7	7.0	8	8
No. of days required to replenish the tanks to 11 days reserve level	5.4	11.8	21.9	42.1	17.0	30.0	63.0
Level of fuel stock after the passage of the 2nd tropical cyclone which is 5 days apart (days)	7.8	6.3	5.7	5.1	4.9	5.5	5.2
No. of days required to replenish the tanks to 11 days reserve level	5.8	18.7	38.9	79.1	28.9	55.0	121.0

**Forecast figures

IATA welcomes your comments and feedback on this publication at:

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