ARCHERFIELD AIRPORT MASTER PLAN

TECHNICAL PAPER
TP 01/10
(Revision 3)

RUNWAY SYSTEM DESIGN
WIND USABILITY ANALYSIS

Estimating the Usability Factor
and
Determining the Number and Orientation of Runways

FEBRUARY 2010

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1. INTRODUCTION

The objective of this Technical Paper is to estimate the usability factor for the existing runway system at Archerfield Airport, and to examine if an increase in usability is possible with alternative secondary runway directions.

The latter examination will be conducted in two stages, firstly by determining which secondary runway orientation maximises the overall usability factor and, secondly, by establishing if alternative directions provide a usability factor equivalent to or greater than the value estimated for the existing runway system

The runway usability factors are estimated by detailed analysis of wind distribution as recorded by the Bureau of Meteorology (BOM).

For airport planning purposes 5 years of wind data is normally regarded as a reliable statistical base for selection of runway direction(s). In this instance the analysis utilises BOM data for 16 years from 1992 to 2008.

The results of these analyses will be used in support of the runway system geometry proposed in the *Archerfield Airport Master Plan*.

2. ICAO AND CASA REQUIREMENTS

The Civil Aviation Safety Authority (CASA) Manual of Standards (MOS) Part 139[1] adopts the view that "…runway useability and number and orientation of runways…[are]…matters relating to economics, efficiency and the environment…[and are]…not within the scope of…[airport]…standards." In other words, safety concerns related to runway availability are dealt with by provisions for pilots to carry sufficient fuel reserves to access an alternative airport should weather conditions preclude a landing at the preferred destination.

This contrasts with the approach adopted by the International Civil Aviation Organisation (ICAO) which recommends that the number and orientation of runways should provide at least 95% usability when considering the range of weather conditions experienced at the site.[2]

Annex 14 states[3] that in assessing runway usability *…" it should be assumed that landing and take-off of aeroplanes is, in normal circumstances, precluded when the cross-wind component exceeds:*

- *37km/h (20kt) in the case of aeroplanes whose reference field length…*[ARFL]*…is 1500m or over, except that when poor runway braking action owing to a insufficient longitudinal coefficient of friction is experienced with some frequency, a cross-wind component not exceeding 24km/h (13kt) should be assumed;*
- *24km/h (13kt) in the case of aeroplanes whose reference field length…*[ARFL]*…is 1200m or up to but not including 1500m; and*
- *19km/h (10kt) in the case of aeroplanes whose reference field length…*[ARFL]*…is less than 1200m.*

A runway is usable by an aircraft until the actual crosswind exceeds the limit nominated for its class. In general terms this methodology provides a conservative estimate of runway usability as specific aircraft are often certified with crosswind limits in excess of the generic values adopted for planning purposes. For example, the Dash 8-300 series has a certified crosswind limit of 30 knots (kt) yet ICAO requires a planning limit of only 10kt.

Some reduction for planning purposes is clearly justified, as airlines or passenger charter operators may specify lower crosswind limits for First Officer handling and also when the runway surface is wet, but a 50% reduction – from 30kt to 15kt - is arguably the maximum likely to be considered in actual operations.

Regardless of aircraft classification or handling capabilities, the aviation safety regulator will typically specify the lowest (10kt) crosswind limit for inexperienced or "ab-initio" student pilots.

[1] MOS Part 139, Chapter 6, Section 6.1, Paragraph 6.1.1.3.
[2] Annex 14, Volume 1, Chapter 3, Section 3.1, Paragraph 3.1.1.
[3] Annex 14, Volume 1, Chapter 3, Section 3.1.2.

On the other hand meteorological analysis is typically based on 3-hourly meteorological observations which may exclude significant short-term weather events which would make actual usability marginally less than the percentage of time otherwise calculated.

Experience has shown that these factors tend to compensate for each other and that estimates of usability derived using the ICAO methodology and available meteorological data provide a reliable guide for airport planning purposes. ICAO reports that the format in which wind data is normally available "…generally results in a slightly conservative [estimate] for the usability factor."[4]

[4] Annex 14 – Volume 1, Attachment A-1, Section 1, Para 1.1.2(a).

3. METEOROLOGICAL DATA ANALYSIS

Wind strength and direction data recorded by BOM in the 16 years 1992 - 2008 has been analysed in producing this Technical Paper. While earlier records are available these are not in the format required by software utilised to undertake this analysis. As readings are taken at 3 hourly intervals the 16 year data set provides a statistically significant sample of 44,293 observations.

This greatly exceeds the minimum ICAO recommendation that not less than 5 years of wind data "…with observations made at least 8 times daily…" be used for airport planning purposes.[5]

For the purpose of the analysis day hours incorporate observations made from 9am to 6pm and night hours observations from 9pm to 6am. Wet runway conditions have been assumed where the rainfall recorded within a three hour observation period is greater than 0.1mm. Only 2.7% of observations meet this criteria - an equivalent of around 10 days a year. As a consequence dry runway conditions can be anticipated 97.3% of the time - an equivalent of around 355 days a year.

The analysis commences with an "all hours, all conditions" assessment using the full data set. Sample data sets were then extracted to allow assessments of usability in all hours, day hours and night hours respectively when the runway condition is dry or wet i.e. during and/or immediately following rain periods.

For completeness, the subsequent analysis considers each class of aircraft defined by ICAO. In practice, the decision concerning secondary runway orientation will be based on a 10kt crosswind limitation, given the significance of ab-initio pilot training at Archerfield and the dominance of light single or twin engine aircraft representative of this class.

Graphs showing results of meteorological data analysis are included as Attachments 1-18 at the end of this Technical Paper.

[5] Annex 14, Volume 1, Chapter 3, Section 3.1.3.

4. EXISTING RUNWAY USABILITY

This analysis estimates the usability factor of the 10/28 paved and asphalt surfaced parallel runways, to establish if there are weather conditions in which additional runways should be provided to meet the ICAO 95% usability target.

In circumstances where additional runways are recommended, the analysis is extended to provide estimates of the additional usability provided by the existing 04/22 parallel grassed runways.

ALL HOURS – ALL CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.92
13	97.31
10	92.82

This satisfies the recommended ICAO usability for all aircraft other than those with ARFL less than 1200m.

In combination with the existing 04/22 secondary runways the following usabilities are attained:

Limiting Crosswind (kt)	Airport Usability (%)
20	100.00
13	99.90
10	99.01

This satisfies the ICAO usability requirements for all classes of aircraft.

These tables show that for aircraft with limiting crosswind capability of 10kt the grassed runways provide an additional usability of 6.19%. This equates to around 22.6 days on average each year.

ALL HOURS – DRY CONDITIONS

When runway surface conditions are expected to be dry, runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.92
13	97.29
10	92.77

This satisfies the recommended ICAO usability for all aircraft other than those with ARFL less than 1200m.

In combination with the existing 04/22 secondary runways the following usabilities are attained:

Limiting Crosswind (kt)	Airport Usability (%)
20	100.00
13	99.90
10	99.02

This satisfies the ICAO usability requirements for all classes of aircraft.

These tables show that for aircraft with limiting crosswind capability of 10kt the grassed runways provide an additional usability of 6.25% of the time when the runways are dry. This equates to around 22.2 "dry" days on average each year.

ALL HOURS – WET CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.79
13	97.90
10	93.92

This satisfies the recommended ICAO usability for all aircraft other than those with ARFL less than 1200m.

In combination with the existing 04/22 secondary runways the following usabilities are attained:

Limiting Crosswind (kt)	Airport Usability (%)
20	100.00
13	99.78
10	98.37

This satisfies the ICAO usability requirements for all classes of aircraft.

These tables show that for aircraft with limiting crosswind capability of 10kt the grassed runways provide an additional usability of 4.45% of the time when the runways are wet. This equates to around 0.4 "wet" days on average each year.

DAY HOURS – ALL CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.84
13	95.19
10	87.63

This satisfies the recommended ICAO usability for all aircraft other than those with ARFL less than 1200m.

In combination with the existing 04/22 secondary runways the following usabilities are attained:

Limiting Crosswind (kt)	Airport Usability (%)
20	100.00
13	99.93
10	99.34

This satisfies the ICAO usability requirements for all classes of aircraft.

These tables show that for aircraft with limiting crosswind capability of 10kt the grassed runways provide an additional usability of 11.71% of the time in daylight hours. This equates to around 42.7 days on average each year.

DAY HOURS – DRY CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.83
13	95.13
10	87.50

This satisfies the recommended ICAO usability for all aircraft other than those with ARFL less than 1200m.

In combination with the existing 04/22 secondary runways the following usabilities are attained:

Limiting Crosswind (kt)	Airport Usability (%)
20	100.00
13	99.93
10	99.34

This satisfies the ICAO usability requirements for all classes of aircraft.

These tables show that for aircraft with limiting crosswind capability of 10kt the grassed runways provide an additional usability of 11.84% of the time in daylight hours when the runways are dry. This equates to around 42.1 "dry" days on average each year.

DAY HOURS – WET CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.81
13	97.31
10	91.58

This satisfies the recommended ICAO usability for all aircraft other than those with ARFL less than 1200m.

In combination with the existing 04/22 secondary runways the following usabilities are attained:

Limiting Crosswind (kt)	Airport Usability (%)
20	100.00
13	99.50
10	97.61

This satisfies the ICAO usability requirements for all classes of aircraft.

These tables show that for aircraft with limiting crosswind capability of 10kt the grassed runways provide an additional usability of 6.03% of the time in daylight hours when the runways are wet. This equates to around 0.6 "wet" days on average each year.

NIGHT HOURS – ALL CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.99
13	99.42
10	97.92

This satisfies the recommended ICAO usability for all aircraft classes of aircraft. This supports the current situation where the existing 04/22 secondary runways are not available for operations at night

NIGHT HOURS – DRY CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	100.00
13	99.44
10	97.98

This satisfies the recommended ICAO usability for all classes of aircraft.

NIGHT HOURS – WET CONDITIONS

Runways 10/28 provide the following usability for the aircraft classes under consideration:

Limiting Crosswind (kt)	Runway Usability (%)
20	99.77
13	98.38
10	95.97

This satisfies the recommended ICAO usability for all classes of aircraft.

OBSERVATIONS AND RECOMMENDATIONS

This analysis indicates that for planning purposes the 10/28 parallel runways satisfy the ICAO 95% usability factor for all aircraft operating at night and, in daylight hours, for all aircraft other than those with a 10kt crosswind limitation.

As these paved/asphalt surfaced runways represent a significant investment in key infrastructure this finding lends support to the proposition that they be regarded as a fixed asset for the purposes of airport planning.

ICAO recommends that additional runways be provided for daytime use to increase the overall usability for this class of aircraft. This confirms that only runways 10/28 need to be lit for aircraft operations at night.

The 04/22 secondary runways increase daytime usability for 10kt crosswind limited aircraft by nearly 43 days on average each year. Even so, as the runways accommodate only 10% of total traffic on average, it is reasonable for them to be retained as natural surfaced, or grassed for the current numbers of aircraft movements.

5. OPTIMAL RUNWAY USABILITY

This analysis assumes retention of the 10/28 parallel runways and determines the optimal alignment of secondary runways i.e. the secondary runway orientation which provides the maximum estimate of usability for 10kt crosswind limited aircraft in the range of wind conditions experienced at the site.

The optimal secondary runway direction is expressed as degrees relative to Magnetic North, i.e. degrees Magnetic (ºM).

This estimate of usability factor is confined to the use of day hours wind speed and direction data as the previous analysis has shown that the secondary runways are required only for daytime use.

DAY HOURS – DRY CONDITIONS

When runway surface conditions are expected to be dry the optimal runway direction is:

Runway Direction (ºM)	Runway Designation	Runway Usability (%)
022/202	02/20	99.68

This provides a marginal increase in usability of 0.34% compared with the existing 04/22 secondary runways. This equates to around 1.2 days on average each year.

DAY HOURS – WET CONDITIONS

When runway surface conditions are expected to be wet the optimal runway direction is:

Runway Direction (ºM)	Runway Designation	Runway Usability (%)
180/360	18/36	99.07

This provides an increase in usability of 1.46% compared with the existing 04/22 secondary runways. This equates to around 0.1 day on average each year.

OBSERVATIONS AND RECOMMENDATIONS

This analysis indicates that for planning purposes the estimated usability factor is maximised for secondary runways aligned north-south, and designated 180/360, at times when the runway surface is expected to be wet.

Wet runway surface conditions are an important consideration as this is when;

- the availability of natural surface runways is most threatened; and
- pilots are likely to have increased difficulty in controlling their aircraft in limiting crosswind conditions.

Where the runway surface is expected to be dry the estimated usability factor is maximised for secondary runways aligned 022/202°M, and designated 02/20.

6. SECONDARY RUNWAY OPTIONS

This analysis also assumes retention of the 10/28 parallel runways and determines if, for 10kt crosswind limited aircraft, alternative secondary runways orientations will provide an estimated usability factor equivalent to or greater than the estimated usability of the existing runway system.

This usability estimate is also confined to the use of day hours wind speed and direction data as the previous analysis has shown that the secondary runways are required only for daytime use.

This criteria is satisfied where the estimated usability is 99.34% or greater in conditions where the runway surface is likely to be dry, and 97.61% or greater where the runway surface is likely to be wet.

DAY HOURS – DRY CONDITIONS

When runway surface conditions are expected to be dry, the usability criteria are satisfied for the following range of runway directions:

Runway Direction (ºM)	Runway Designation	Runway Usability (%)
180/360	18/36	99.61
010/190	01/19	99.64
020/200	02/20	99.68
030/210	03/21	99.63
040/220	04/22	99.34

This shows that any secondary runway direction between a north-south orientation – designated 18/36 – and 039/219ºM will provide a greater estimate of overall usability than the existing 04/22 parallels. Near optimal usability is achieved if the secondary runways are oriented between 010/190 and 030/210ºM. Even a runway oriented 180/360ºM provides a marginal increase in estimated usability of 0.27% compared with the existing 04/22 secondary runways. This equates to around 1.0 "dry" day on average each year.

DAY HOURS – WET CONDITIONS

When runway surface conditions are expected to be wet, the usability criteria are satisfied for the following range of runway directions:

Runway Direction (ºM)	Runway Designation	Runway Usability (%)
180/360	18/36	99.07
010/190	01/19	99.03
020/200	02/20	98.99
030/210	03/21	98.63
040/220	04/22	97.61

This shows that a secondary runway direction oriented north-south – designated 18/36 –will provide an increase in estimated usability of 1.46% compared with the existing 04/22 secondary runways. This equates to around 0.1 "wet" day on average each year.

OBSERVATIONS AND RECOMMENDATIONS

The secondary runways could be re-oriented to provide some marginal improvement in estimated usability in the range of wind conditions experienced at the site. Runways oriented in the range 010/190 to 030/210ºM will provide optimal usability when the runway surface conditions are expected to be dry. On the other hand an orientation in the range 180/360 to 010/190ºM will optimise usability when the runway surface conditions are wet.

7. CONCLUSIONS

The existing 10/28 paved and asphalt surfaced runway system represent a significant financial investment and should desirably be retained. This is justified by reference to wind data for the site recorded by BOM.

A detailed analysis of 16 years climate data has shown that these runways satisfy the ICAO 95% usability factors for all aircraft operating at night and, in daylight hours, for all aircraft other than those with a 10kt crosswind limitation.

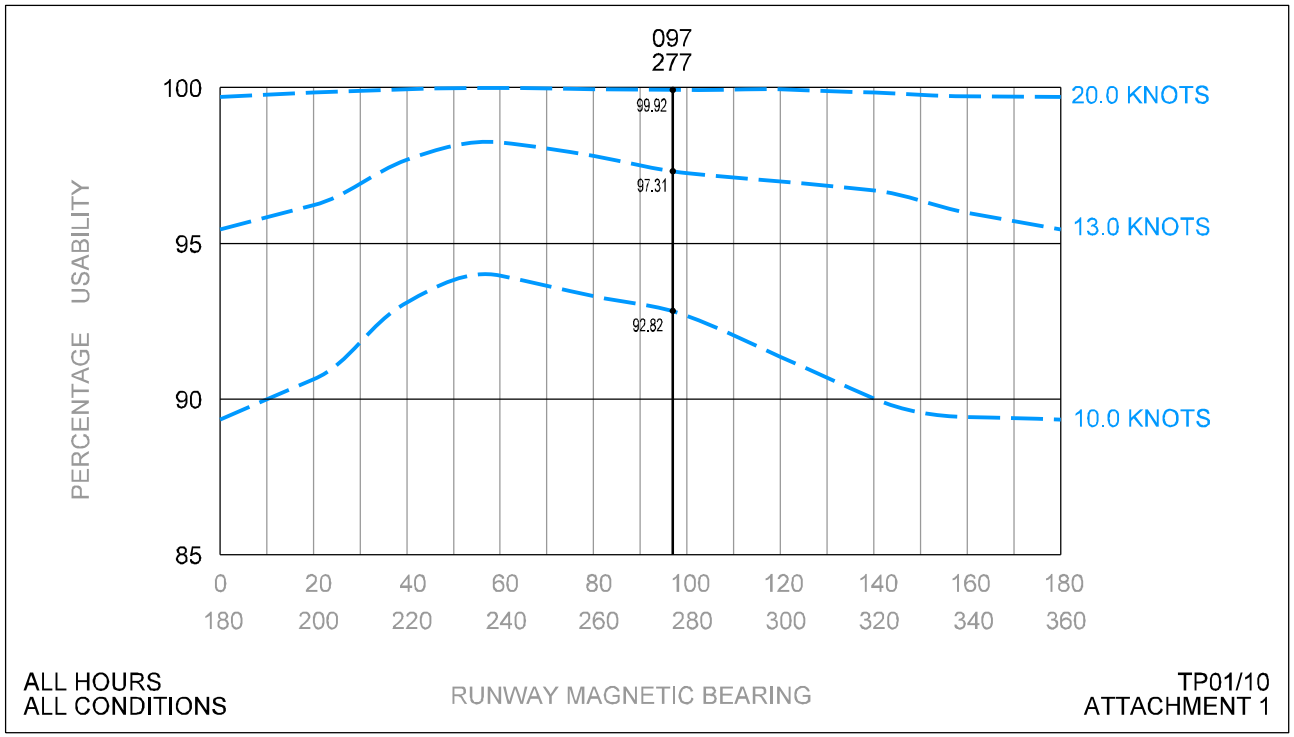
ICAO recommends that additional runways should be provided for daytime use to increase the estimated usability factor for this class – the smaller aircraft typically used at Archerfield, either privately or in flying training.

By day, the existing 04/22 parallels are estimated to increase overall usability for these aircraft by 11.8% of the time when the runway surface is expected to be dry, and 6.0% of the time when the runway surface is expected to be wet.

Alternative secondary runway directions in the range 180/360 to 030/210°M will provide near to optimal usability, with the range 010/190 to 130/210°M preferable in dry runway conditions and 180/360 to 010/190°M in wet runway conditions.

The latter may be preferable as pilots are likely to experience greater difficulty in landing with a crosswind on wet runways.

For planning purposes practical alternatives to the existing secondary runways are available which retain or increase the estimated usability factor of the runway system. While the estimated gains are marginal, an alternative secondary runway direction may nevertheless be justified by broader planning considerations.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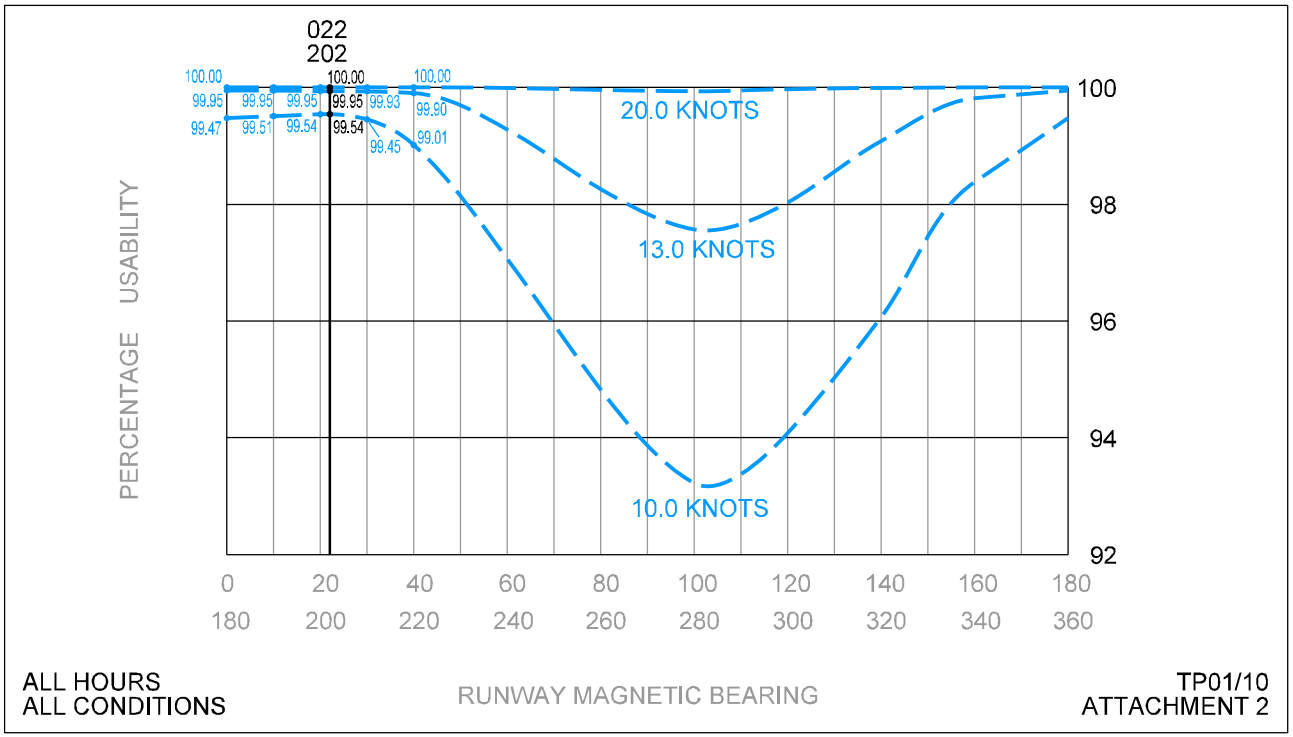
ALL HOURS
ALL CONDITIONS
RUNWAY MAGNETIC BEARING
TP01/10
ATTACHMENT 1



ALL HOURS
ALL CONDITIONS

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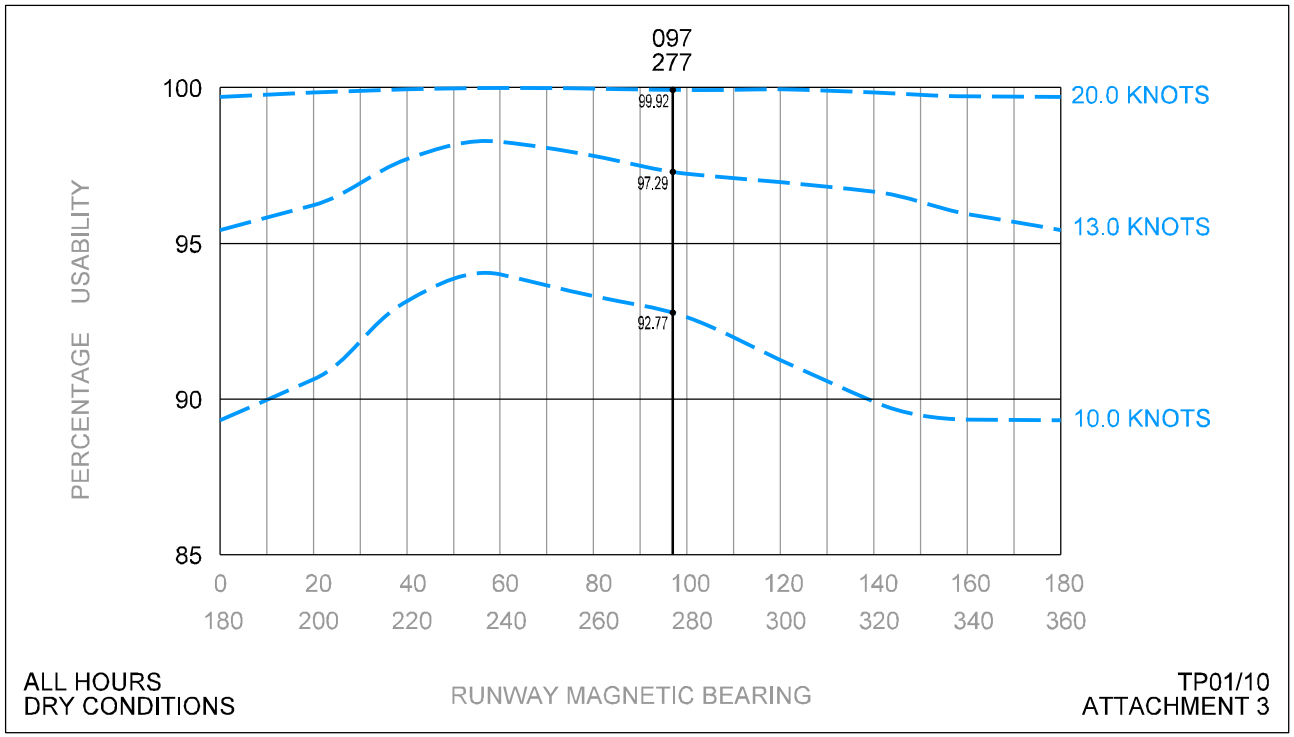
ATTACHMENT 2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ALL HOURS
DRY CONDITIONS
RUNWAY MAGNETIC BEARING
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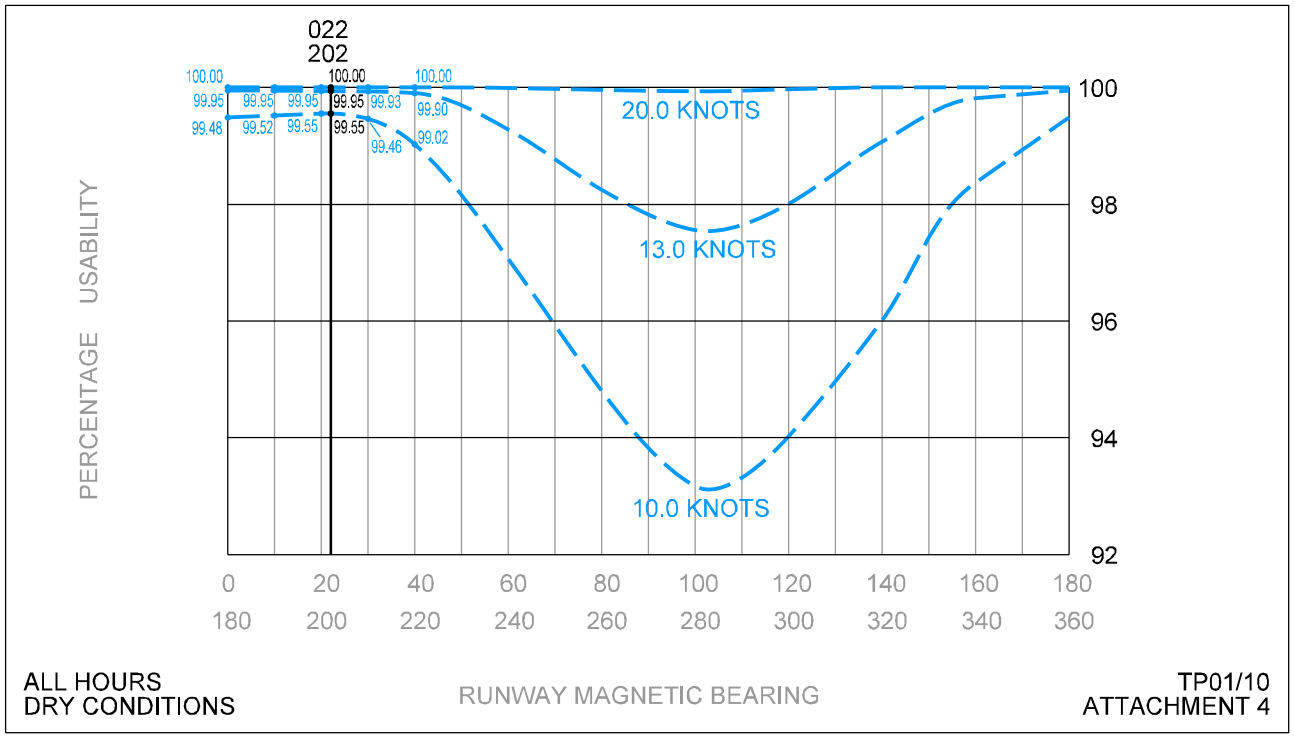
ATTACHMENT 3



ALL HOURS
DRY CONDITIONS

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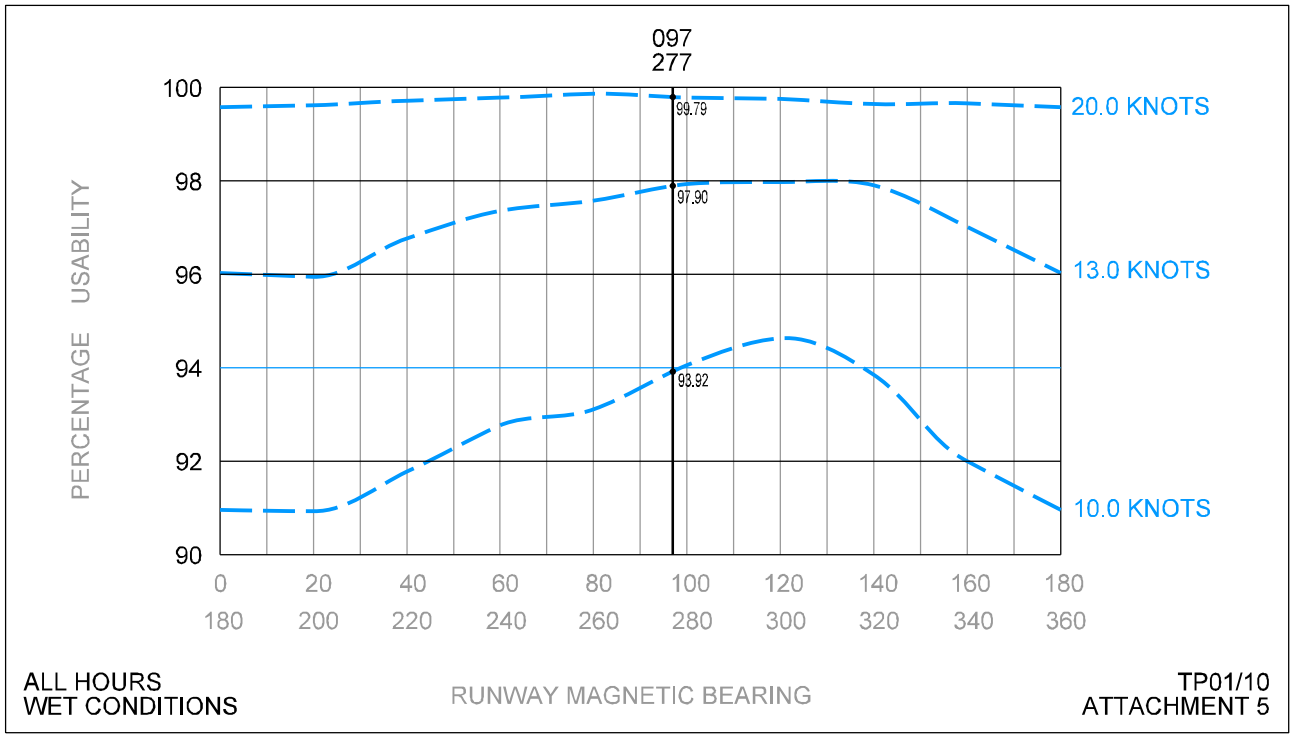
ATTACHMENT 4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PERCENTAGE USABILITY
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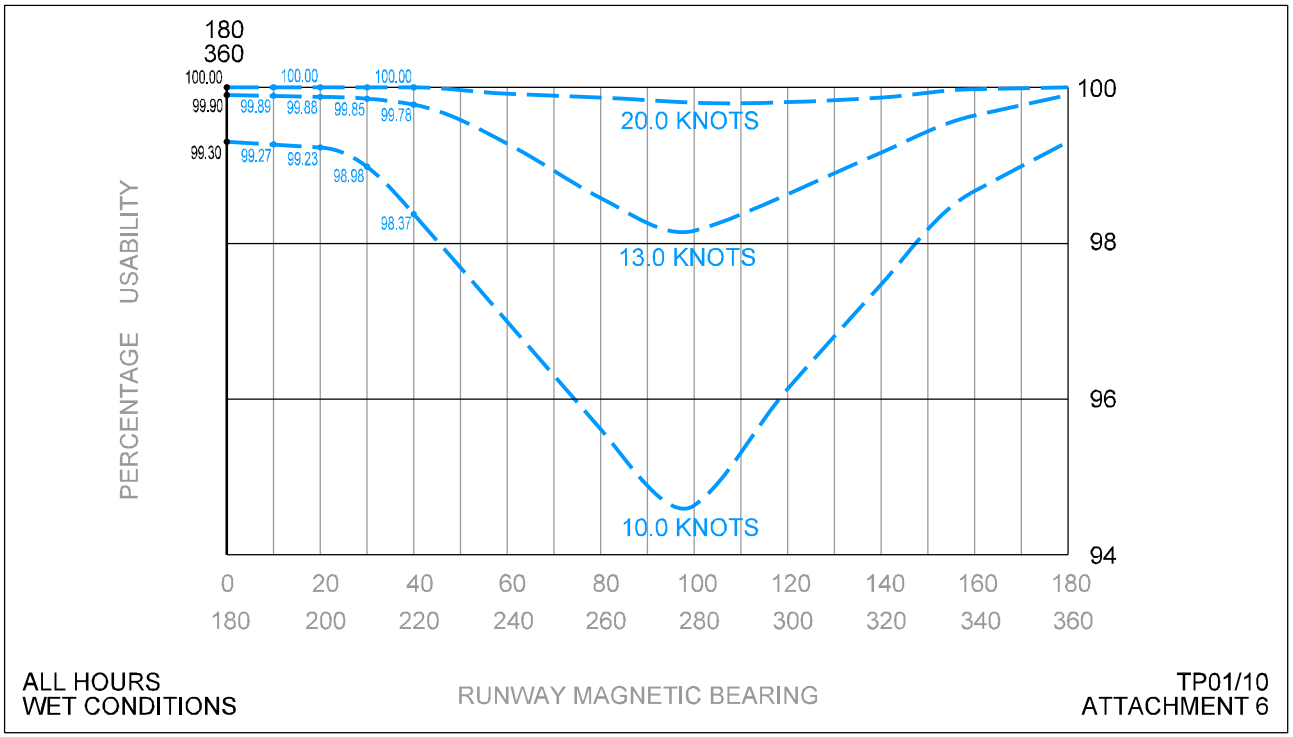
RUNWAY MAGNETIC BEARING
ALL HOURS
WET CONDITIONS
TP01/10
ATTACHMENT 5



ALL HOURS
WET CONDITIONS

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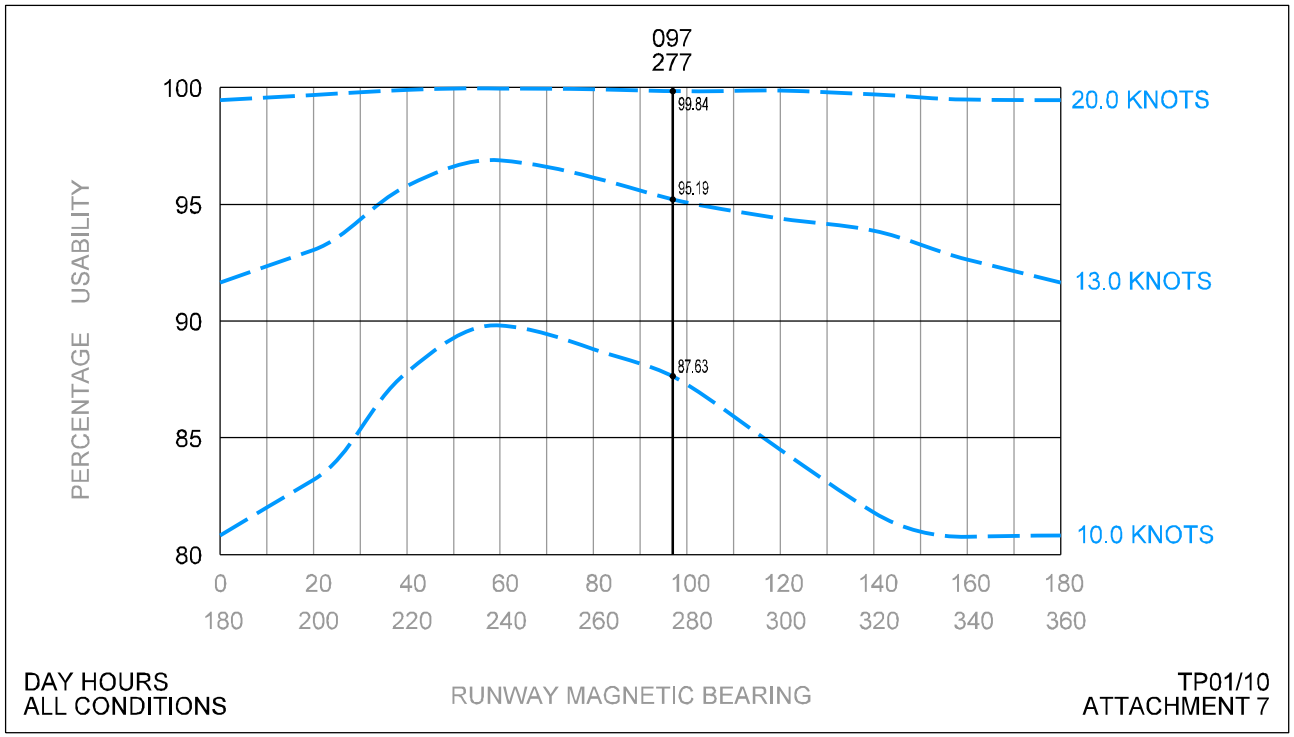
ATTACHMENT 6



DAY HOURS
ALL CONDITIONS

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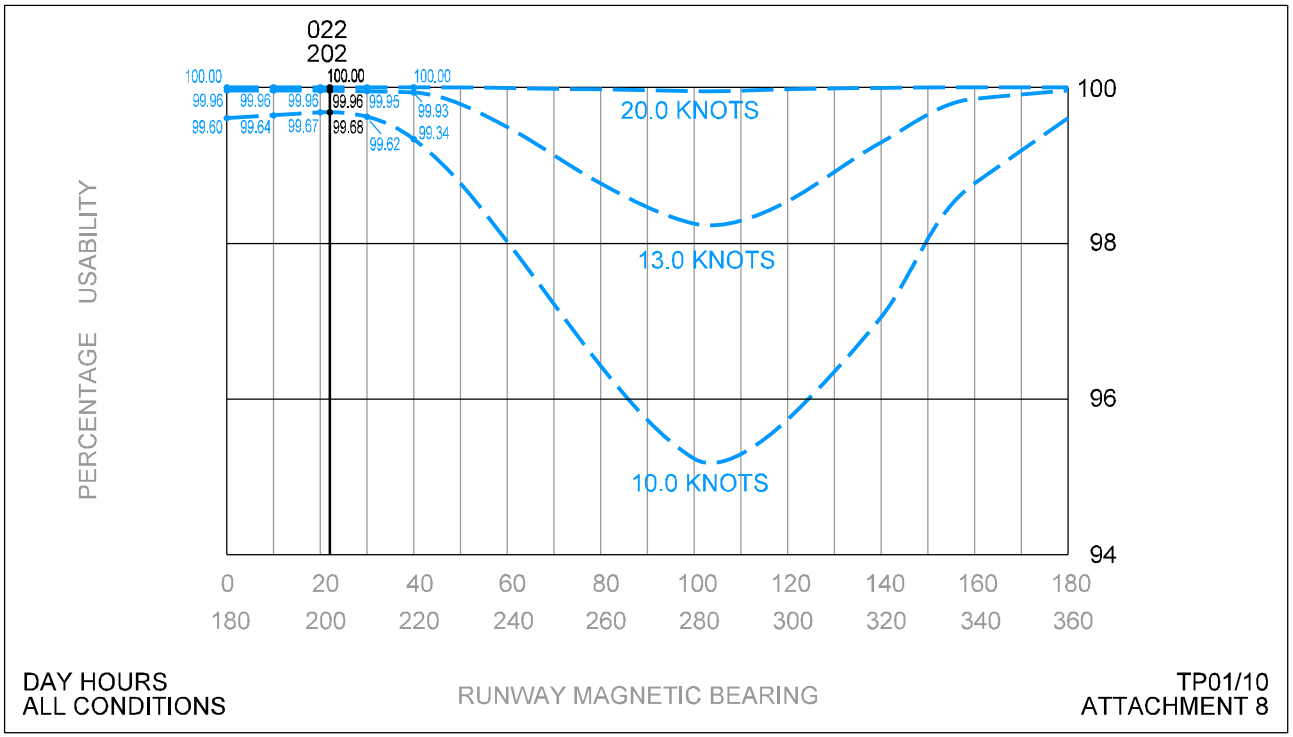
ATTACHMENT 7



DAY HOURS
ALL CONDITIONS

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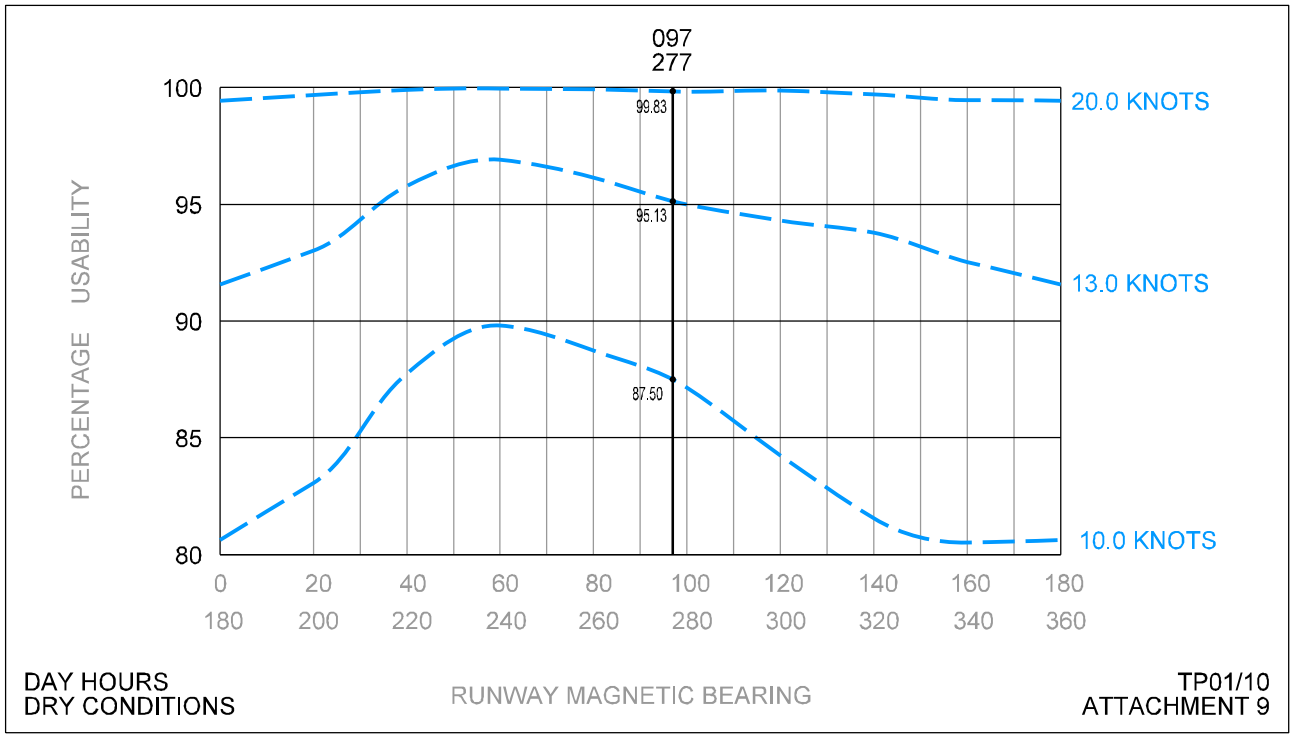
ATTACHMENT 8



DAY HOURS
DRY CONDITIONS

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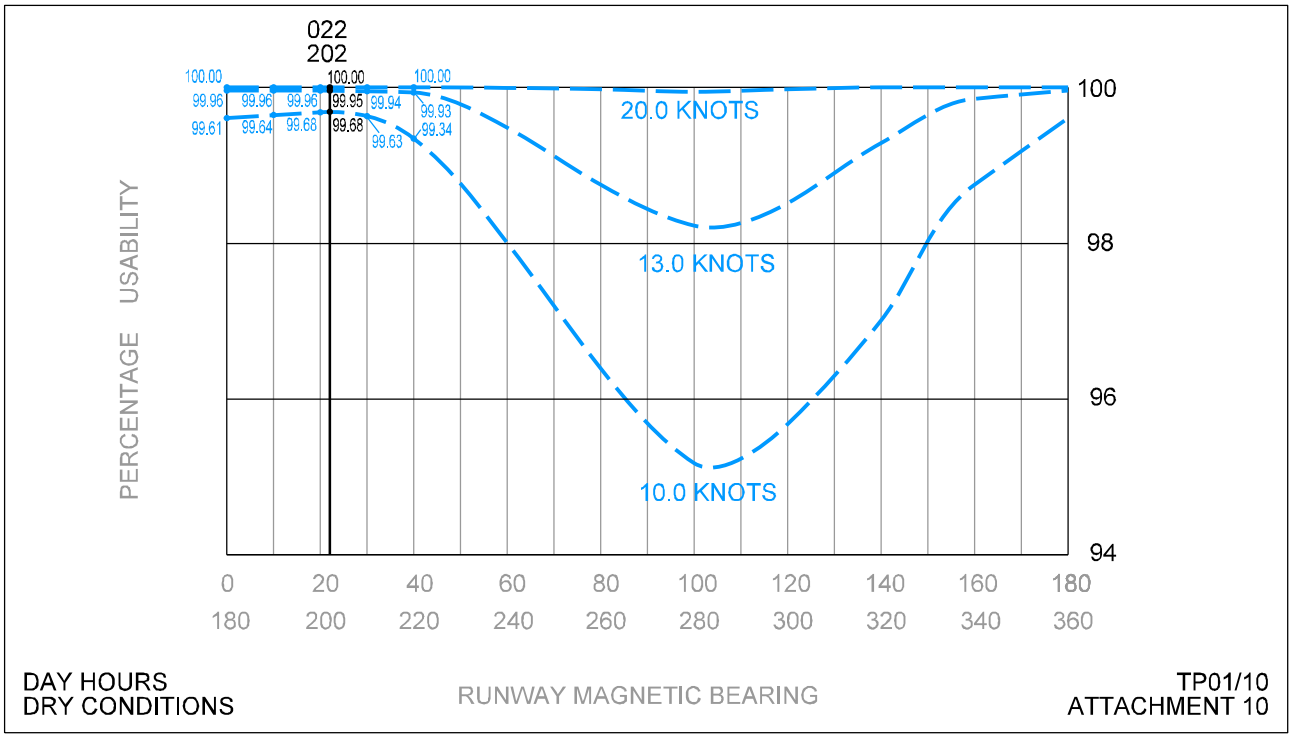
ATTACHMENT 9



DAY HOURS
DRY CONDITIONS

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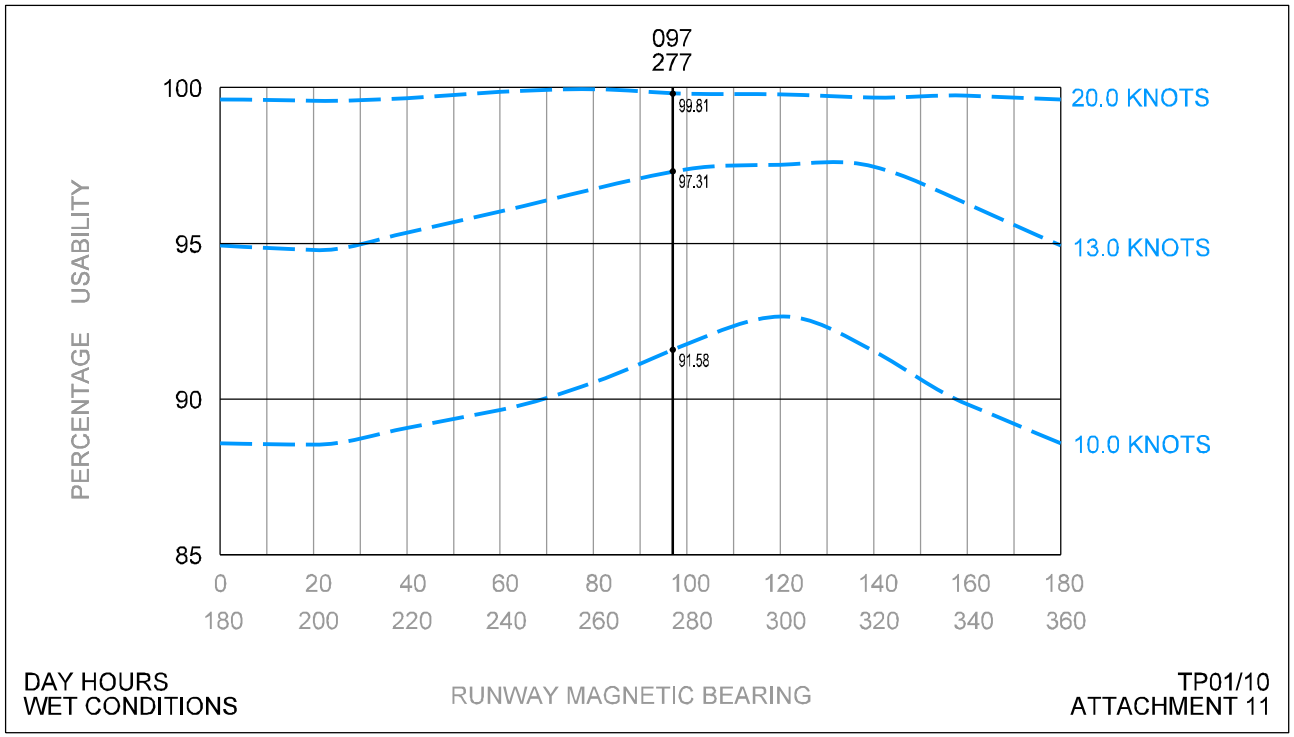
ATTACHMENT 10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PERCENTAGE USABILITY
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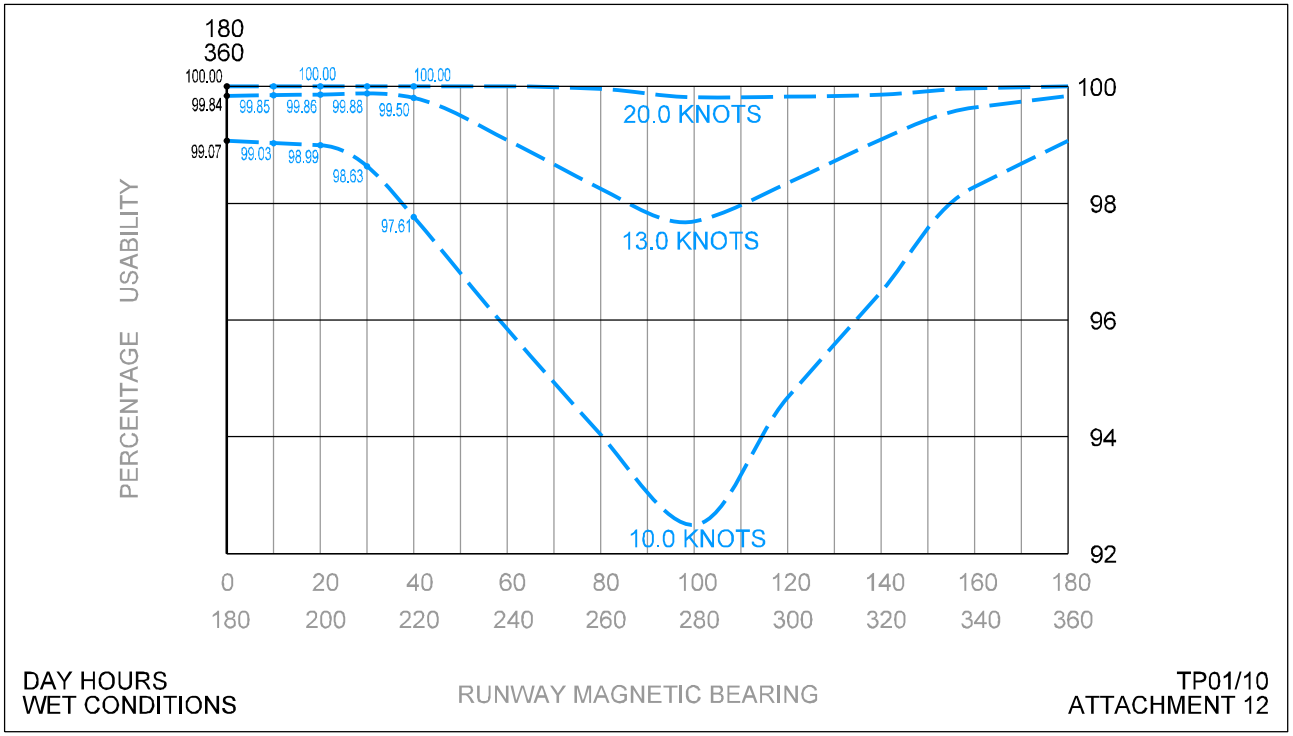
RUNWAY MAGNETIC BEARING
DAY HOURS
WET CONDITIONS
TP01/10
ATTACHMENT 11



DAY HOURS
WET CONDITIONS

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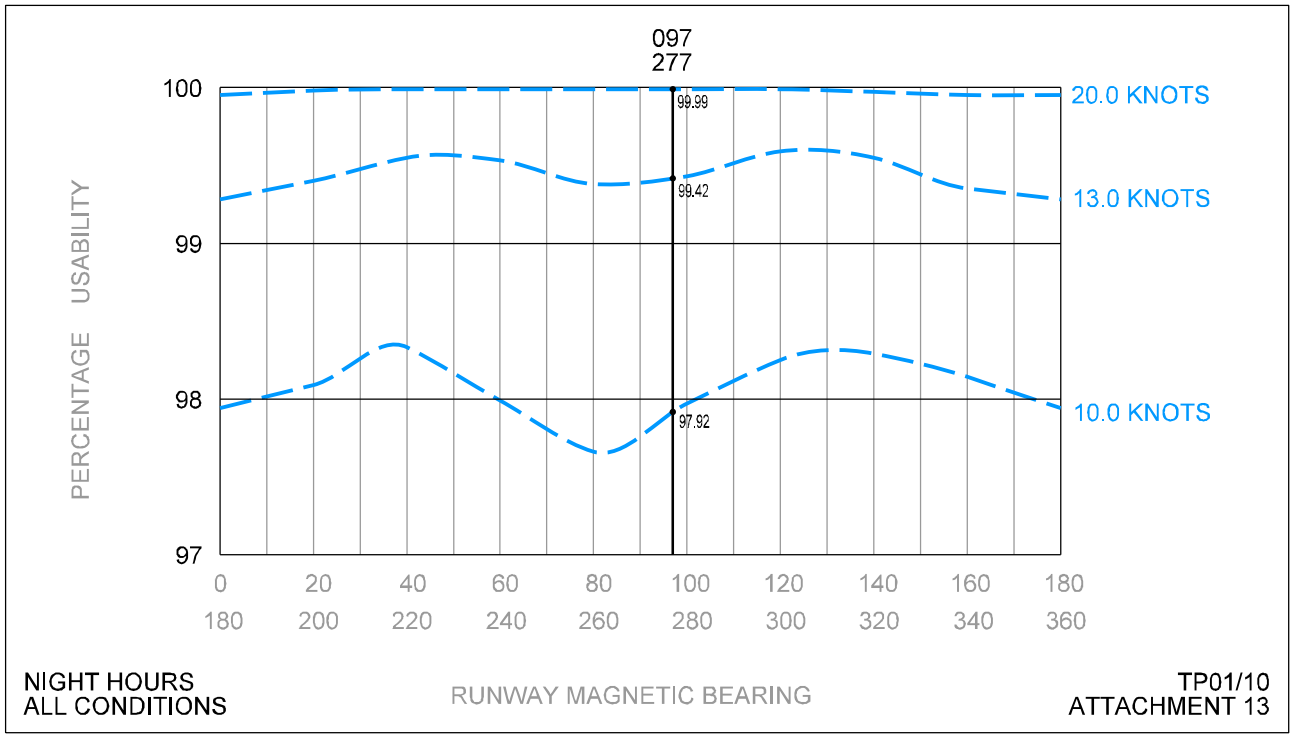
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RUNWAY MAGNETIC BEARING
NIGHT HOURS
ALL CONDITIONS
TP01/10
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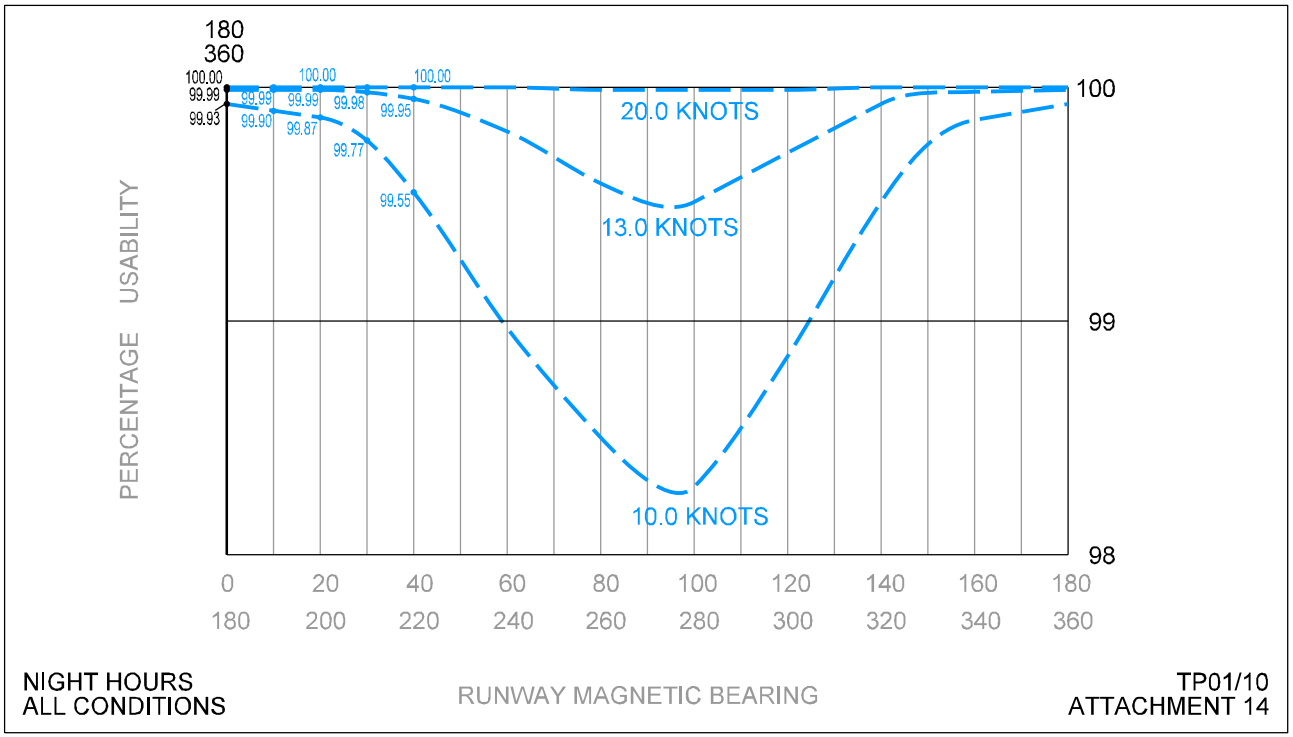
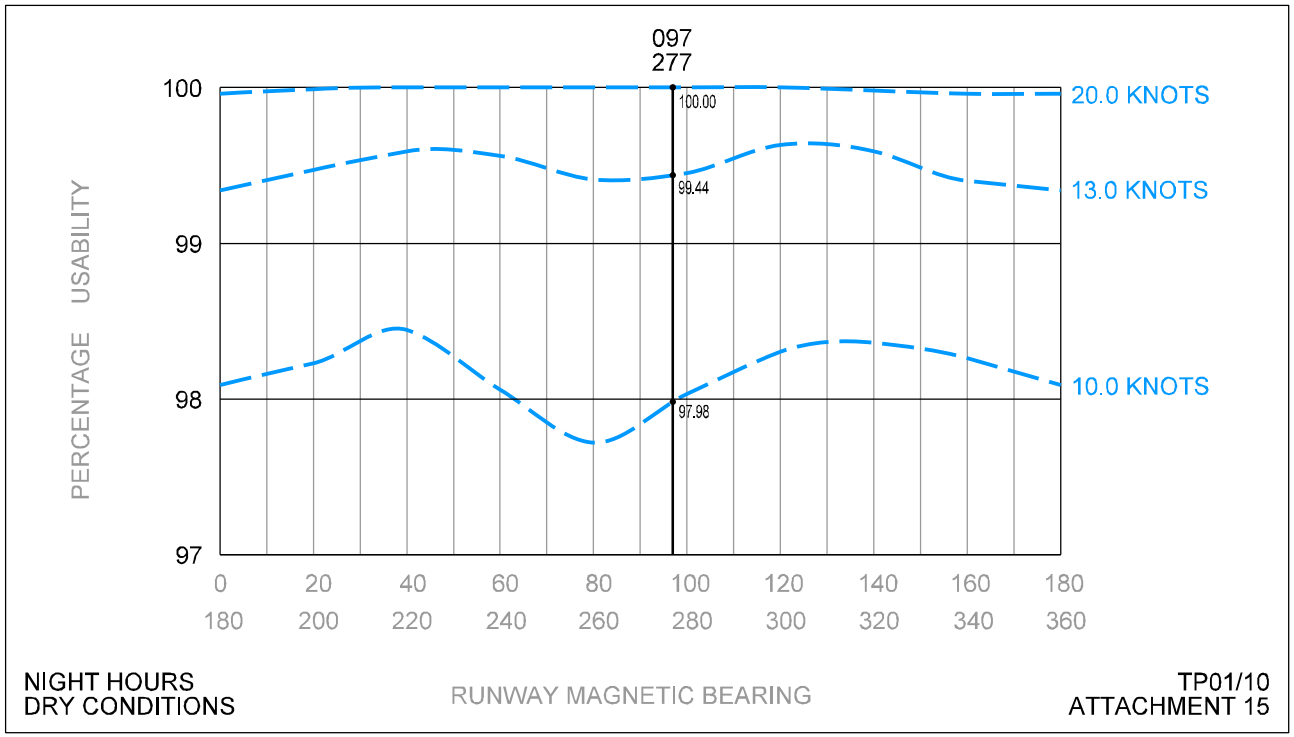


NIGHT HOURS
ALL CONDITIONS

TP01/10
ATTACHMENT 14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PERCENTAGE USABILITY
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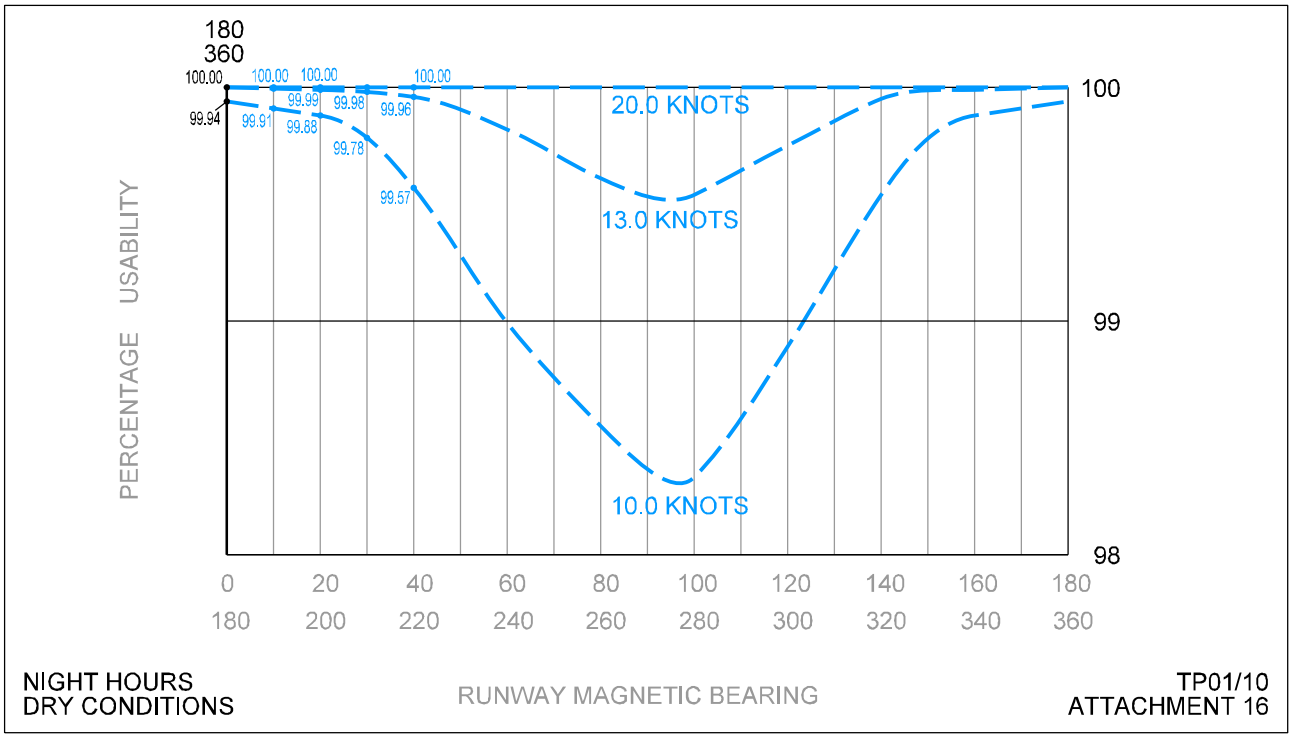
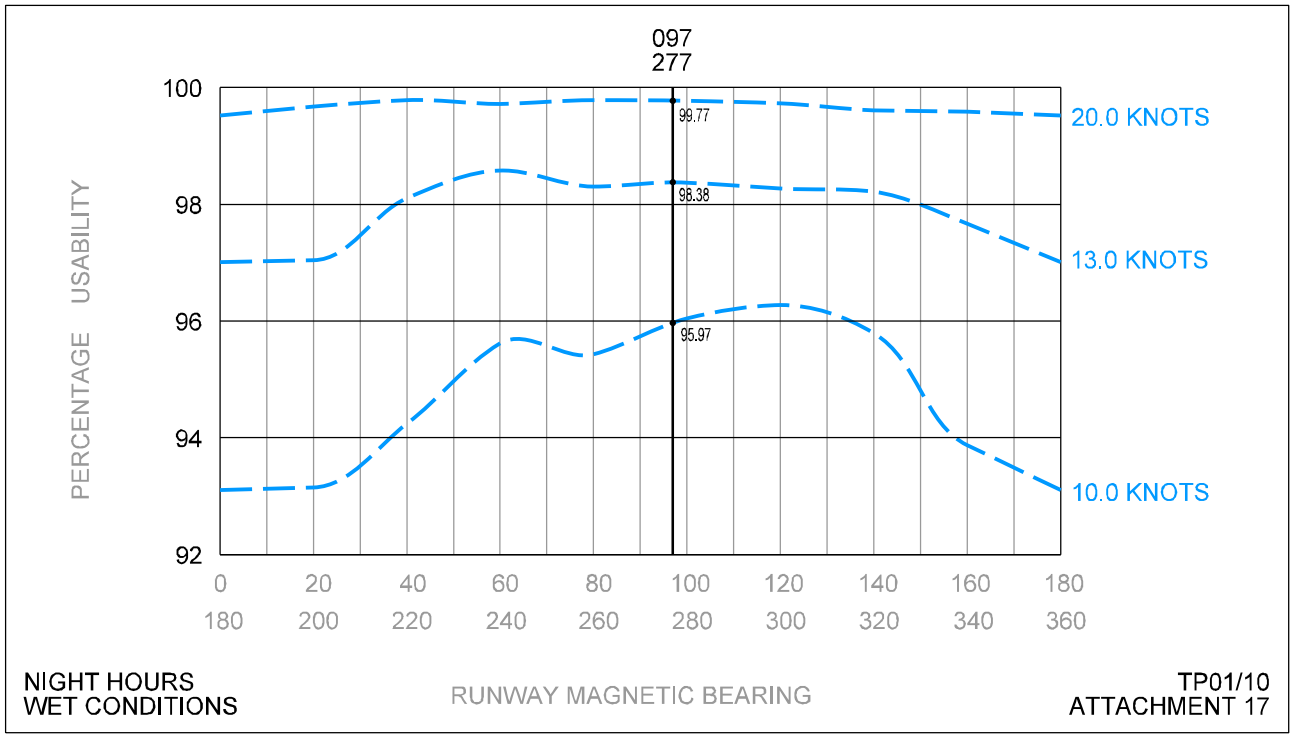
180 200 220 240 260 280 300 320 340 360
RUNWAY MAGNETIC BEARING
NIGHT HOURS
DRY CONDITIONS
TP01/10
ATTACHMENT 15



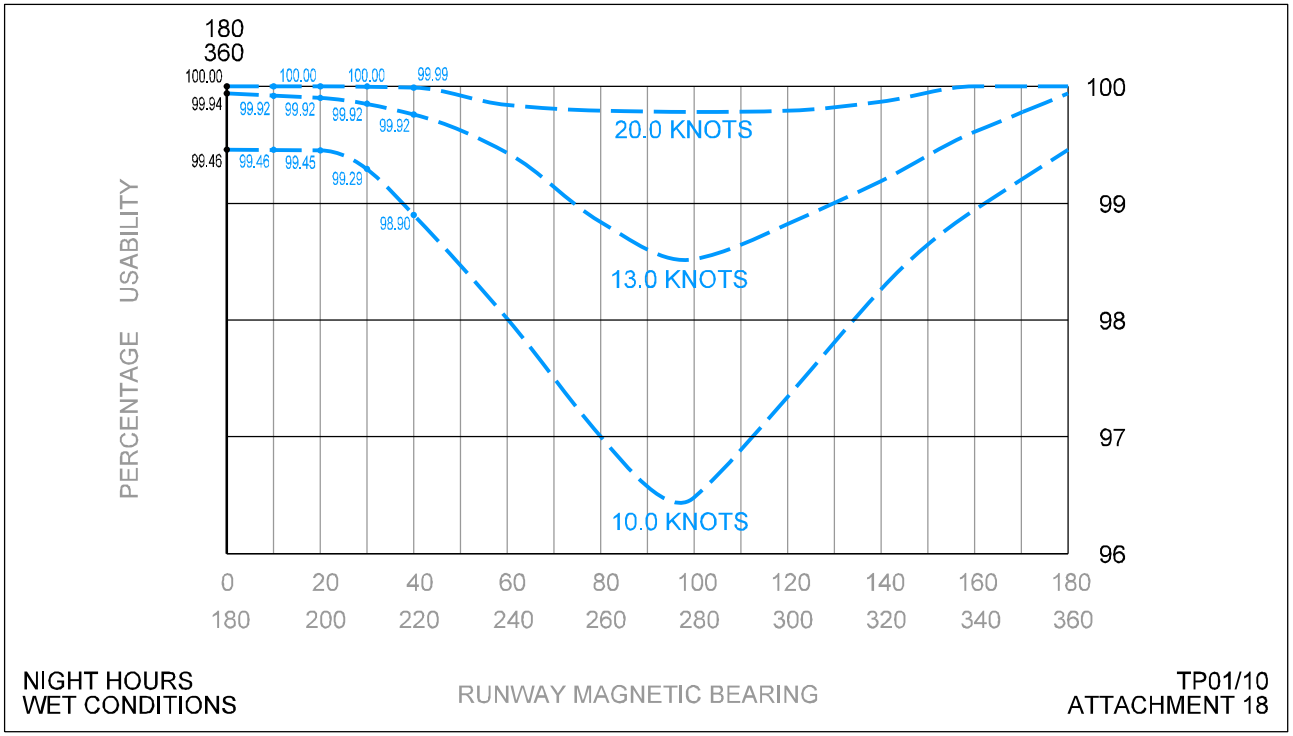
NIGHT HOURS
DRY CONDITIONS

TP01/10
ATTACHMENT 16



NIGHT HOURS
WET CONDITIONS

TP01/10
ATTACHMENT 17


180
360
100.00
99.94
99.46
100.00
100.00
99.99
99.92
99.92
99.92
99.92
99.46
99.45
99.29
98.90
20.0 KNOTS
13.0 KNOTS
10.0 KNOTS
100
99
98
97
96
PERCENTAGE USABILITY
0
20
40
60
80
100
120
140
160
180
180
200
220
240
260
280
300
320
340
360
NIGHT HOURS
WET CONDITIONS
RUNWAY MAGNETIC BEARING
TP01/10
ATTACHMENT 18