ADDENDUM TO LOG/105/13

ENVIRONMENTAL REQUIREMENTS FOR MOBILE GROUND POWER UNITS

July, 1957.

CONFIDENTIAL

CF-105

ENVIRONMENTAL REQUIREMENTS

FOR

MOBILE GROUND POWER UNITS

Report No. LOG/105/13

July 1955

AVRO AIRCRAFT LIMITED, MALTON, ONTARIO

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1. PURPOSE OF REPORT

In the General Requirements for the Mobile Ground Power Units for CF-105 aircraft, which was issued by Avro Aircraft Limited in March 1955, the following environmental conditions were specified:-

> "The ground power vehicles shall be capable of being started and satisfactorily operated by day and night under all weather conditions encountered in extreme cold climates at -65°F to humid, tropical, salty and hot, sandy desert climates of 130°F free air temperature and 160°F enclosed air temperature and at altitudes from sea level to 5,000 ft and in any plane within 15 degrees of horizontal".

This information was sufficient for the purpose of preliminary calculations but more specific details on the extremes of climatic conditions, under which the equipment is to operate satisfactorily and meet the general requirements laid down, should be made available to the prospective vendors as soon as possible in order that they might proceed with their design investigation and submit their Engineering Proposals by 31st August 1955.

With the requirements in their present form, the designer of the equipment may tend to err on the side of caution and make the units larger than necessary. The attendant results of overdesigning are likely to be (a) increased cost, this could be considerable if special equipment had to be developed to meet the requirements, (b) larger and heavier units with their associated problems of mobility and transportation, (c) a higher fuel consuption and (d) increased maintenance and overhaul cost.

The position was put before the Maintenance and Servicing Sub-Committee on 21st June 1955 and the CF-105 Development Co-ordinating Committee on 22nd June 1955 and to minimise delay it was agreed that Avro Aircraft Ltd. could proceed with their investigation on environmental conditions and circulate design data to the vendors of the mobile ground power equipment concurrently with the submission of this report to the Royal Canadian Air Force.

2. AIRCRAFT OPERATIONAL REQUIREMENTS

In order to determine the environmental requirements for the ground equipment due consideration must be given to the operational concept for the aircraft.

Operational Requirement ORI/1-63 states that "This fighter is to operate in the direct defence of Canadian Targets as a part of the North American Defence System" and the environmental requirements have therefore been investigated and drawn up on the basis that:

(a) The equipment shall comply with the requirements laid down in Specification AIR-7-4 at the extremes of climatic conditions to be experienced at operational bases which may be used in the defence of Canada.

(b) The equipment shall function satisfactorily under the extremes of climatic conditions likely to be experienced at any air base on the earth's surface.

Accordingly, the proposed requirements have been derived after studying climatic conditions in Canada and other countries in conjunction with the Meteorological Offices at 315 Bloor Street West, Toronto 5 and reference to the current requirements of the American and British military authorities.

3. CURRENT AMERICAN & BRITISH ENVIRONMENTAL REQUIREMENTS

The following passages are extracts from the current requirements of the American and British military authorities:

(1) ARDCM 80-1 - Handbook of Instructions for Aircraft Designers, Paragraph 0.150, on Temperature Operation (Ground):- "Although lower temperatures are encountered on the ground in the arctic, -65°F is considered as the lowest temperature that will normally be encountered as persistent for any appreciable time. Maximum free air temperatures on the earth's surface seldom exceed +130°F, solar radiation may raise the temperature of enclosed air to +160°F or higher. Therefore, aircraft and aircraft components shall be designed to function satisfactorily at sustained temperatures throughout the -65°F to +160°F range. In the design of cooling and induction systems, or similar systems utilising outside air, a free air temperature of +130°F may be considered as maximum. In those cases where location and/or operation of the equipment itself will subject it to higher temperatures than +160°F, the maximum operating temperature must be increased sufficiently to prevent maintenance and supply difficulties, as well as to insure ground and in-flight safety, or as required by other sections of the handbook."

(2) AP 970 Design requirements for aeroplanes for the Royal Air Force and Royal Navy Vol. 1 Chapter 105 Para. 1.2:- "The temperature limits to which individual items of instruments and equipment shall

be designed and tested will be laid down in the specification of the item. Unless otherwise laid down in this specification, all airborne and ground instruments and equipment are required to satisfy the general test requirements of Specifications No. D.T.D. 1085 to 1086 as appropriate; in particular:-

(1) all instruments and equipment shall function at +55°C (+131°F) and be undamaged at +70°C (+158°F).

(2) All ground instruments and equipment shall function at -26°C (-14.8°F) and be undamaged at -40°C (-40°F)."

4. CLIMATIC CONDITIONS IN CANADA

The climatic conditions in Canada are summarized below:-

Temperature: The temperature in a country the size of Canada is dependent not only on relative position to the equator but also on topographical features. The coastal regions, such as British Columbia and the St. Lawrence estuary, have a marine climate; in the hinterland, however, the climate is continental with large variations of temperatures between summer and winter.

The highest and lowest surface air temperatures recorded in Canada are 115°F, at Gleichen in Alberta, and -81°F at Snag in Yukon Territory.

Rainfall: The presence of warm ocean currents provides an abundant rainfall in the west and southeast of Canada. The rainfall in the St. Lawrence region is increased by the polar air masses sweeping down from the Hudson Bay area meeting the tropical air masses moving up from the Gulf of Mexico.

In general, Canada has three large dry areas, namely the interior valleys of Southern British Columbia, the extreme north, and the prairie southwest. Between Lake Winnipeg and western Alberta, the rainfall is in the order of 15 inches per annum.

Seasonal Rainfall: The rainfall in the continental area of Canada is influenced by the movement of warm moist air currents and is a maximum in the summer months. In the coastal area of British Columbia, however, the rainfall is heaviest during the winter months.

Snowfall: For the greater part of Canada the annual snowfall is less than 40 inches. The heaviest snowfall being experienced in the mountainuous area near the Alaskan border, whilst in Newfoundland and the northwest of Quebec it is over 120 inches per annum.

Further data on Canadian climatic conditions, together with those for Alaska, Greenland and Iceland, are recorded on Table I overleaf.

Representative Climatic Conditions for Canada

Location	Altitude (ft)	Temperature (°F)				Pressure (in. Hg)	Dew Point (°F)		Precipitation (in)
		Extremes On Record		Average Annual Extremes		Mean Annual Station Pressure	Maximum	Corresponding air temp.	Average Annual
		Max	Min	Max	Min				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ALASKA									
Anchorage	87	86	-38	77	-	-	-	-	14.3
Big Delta	1268	-	-	-	-	-	-	-	11.6
Ladd	462	91	-66	-	-	29.33	-	-	11.9
Nome	13	84	-47	73	-36	29.79	-	-	18.7
CANADA									
Bagotville	536	96	-41	-	-	29.37	76	85	38.8
Calgary	3540	97	-46	91	-31	26.25	66	88	17.5
Centralia	830	98	-18	-	-	29.08	78	86	31.3
Churchill	115	91	-50	84	-43	29.80	73	82	14.4
Dawson	1062	95	-73	86	-54	28.65	69	91	14.0
Edmonton	2219	94	-55	91	-39	27.55	70	91	17.8
Gander	482	91	-16	88	-10	29.32	71	76	39.5
Goose Bay	144	74	-19	90	-30	29.68	74	78	28.7
Halifax	136	94	-21	88	- 6	29.78	78	82	54.2
Montreal	98	97	-29	92	-20	29.86	75	86	41.8
North Bay	1210	99	-46	91	-33	28.58	77	77	41.2
Ottawa	339	102	-38	94	-26	29.60	76	91	34.8
Quebec	245	96	-32	89	-19	29.70	77	84	44.8
Regina	1884	111	-54	98	-39	27.93	76	87	15.1
Saskatoon	1645	104	-54	97	-41	28.17	72	92	14.4
Seven Is.	190	90	-43	-	-	29.70	69	68	42.4
Snag	1925	89	-81	82	-67	27.76	67	74	13.8
Toronto	578	105	-24	95	-13	29.40	80	88	30.9
Val D'or	1108	90	-43	-	-	-	-	-	-
Vancouver	22	92	0	87	13	29.96	73	77	56.8
Victoria	52	97	4	87	20	29.97	69	90	26.2
Watson	2248	93	-67	85	-58	28.47	72	77	16.8
Winnipeg	786	108	-44	96	-35	29.10	77	90	19.7

Cont'd .....

The information made available by the Meteorological Offices indicate that the consistently highest temperatures, together with high humidity, experienced in Canada are recorded in the southwest of Ontario. Accordingly, the maximum temperature requirements has been based upon a statistical analysis of air temperature and dew-point frequencies, which have been derived from meteorological records, for Centralia and Windsor in Ontario; this information is shown on Tables 2 and 3 overleaf together with similar records for Calgary (at 3,557 ft) in order to provide data on the effect of altitude. It will be noted that the maximum tarmac temperatures are shown to be 20°F above the ambient screen or shade temperature; this is an assumption which has been based on data made available by the U.S. Weather Bureau and information obtained from other sources of references. The interpretation of these facts is that the environmental requirements for extreme hot weather conditions in Canada should read:-

Place	Maximum Temperature (°F)		Dew Point Temperature (°F)
	Screen	Tarmac	
Calgary	80	100	60
Centralia	90	110	75

AIR TEMPERATURE CHART

Temp. Range °F		Calgary					Centralia				
Screen	Tarmac	1950	1951	1952	1953	1954	1950	1951	1952	1953	1954
70-74	90-94	261	169	210	244	167	481	538	551	578	482
75-79	95-99	136	82	106	122	82	312	372	359	339	335
80-84	100-104	34	22	32	38	21	158	207	255	187	154
85-89	105-109	13	5	2	7	7	26	49	166	86	59
90-94	110-114	12						4	41	45	7
95-99	115-119	3							7	3	
TOTAL		459	278	350	411	277	977	1170	1379	1238	1037

DEW POINT CHART

Temp. Range °F	Calgary					Centralia				
	1950	1951	1952	1953	1954	1950	1951	1952	1953	1954
50 - 54	658	466	541	569	446	841	1018	635	775	766
55 - 59	113	239	128	216	74	913	751	647	726	735
60 - 64	4	52	19	52	5	691	751	493	610	785
65 - 69	1	1		7		333	277	488	377	360
70 - 74	3					85	29	241	147	66
75 - 79	1					7	1	22	13	
80 - 84	2							5		
TOTAL	782	758	688	844	525	2870	2827	2531	2648	2732

TABLE 2 - TEMPERATURE & DEW POINT FREQUENCY CHARTS - Showing the number of hours between May and October when the temperature and dew point was within the ranges indicated.

Month	Temperature (°F)								
	Calgary (30)			Centralia (9)			Windsor (23)		
	Max.	Min.	Normal	Max.	Min.	Normal	Max.	Min.	Normal
January	61	-46	16	64	-18	25	64	- 9	26
February	66	-42	17	54	- 9	23	65	-10	26
March	69	-35	26	70	-10	30	79	- 3	35
April	85	-22	39	80	11	43	87	15	47
May	90	2	50	88	23	54	93	27	57
June	95	27	56	98	31	66	99	37	68
July	97	32	62	94	41	70	101	46	72
August	95	31	60	96	42	70	98	44	71
September	90	8	52	97	29	61	99	30	64
October	85	- 8	42	85	25	54	90	22	54
November	71	-26	28	75	7	38	79	7	40
December	67	-45	19	59	- 8	27	62	- 8	28
Over the Year	97	-46	39	98	-18	47	101	-10	49

TABLE 3 - EXTREMES OF TEMPERATURE DATA FOR CALGARY, CENTRALIA AND WINDSOR

Note: The number of years over which these observations have been recorded is indicated alongside the name of the station.

This provides for all but the extremes of temperature and the corresponding dew point which are experienced for only a very short time (i.e. less than 1%) each year.

In the same way, the cold weather requirements have been based on a statistical study of the weather observations at Snag, Watson, Churchill and Ottawa; these stations have been selected as being representative of the extremes likely to be experienced at existing aerodromes in Canada, Alaska, Greenland and Iceland from which the CF-105 might be operated. The results are recorded on Table 4 overleaf and the following is considered a reasonable interpretation for environmental requirements to provide for the extremes of cold weather:-

Place	Maximum Temperature (°F)		Dew Point Temperature (°F)
	Screen	Tarmac	
Churchill	-40	-40	-45
Ottawa	-15	-15	-25
Snag	-60	-60	-65
Watson	-50	-50	-55

Information has also been requested from the U.S. Weather Bureau on cold weather conditions at Eurika in Ellesmere Island.

Variations in barometric pressure have also been investigated and the mean monthly atmospheric pressures for Calgary, Centralia and Windsor extracted from meteorological records for 1950-54, are shown on Table 5 overleaf. These fluctuations of pressure have only a slight effect on the performance of the equipment and the conclusion reached is that the following table, derived from the current issue of ANA Bulletin No. 421, is representative of both Canadian and world climates:-

Altitude (ft)	Ambient Pressure (ins. Hg)	
	Standard Hot Atmosphere	Standard Cold Atmosphere
0	29.92	29.92
1,000	28.93	28.57
2,000	27.98	27.32
3,000	27.04	26.17
4,000	26.14	25.09
5,000	25.25	24.05

5. WORLD-WIDE CLIMATIC CONDITIONS

As already indicated, due consideration has been given to a world-wide concept for the ground power equipment and the requirements should call for the equipment to operate satisfactorily under the most adverse weather conditions likely to be experienced.

Accordingly, a study has been made of world climatic conditions and Table 6 overleaf has been drawn up to show a representative scatter of climatic conditions likely to be experienced in the various parts of the world. This information has been extracted from authoritative references.

The highest free air temperatures recorded are 136°F at Arizin, Tripoli, 138°F at Basra in the Lower Euphrates and 140°F at Musandam Peninsula in the Iranian Gulf. The lowest surface temperature which is generally accepted is -90°F at Verkhoyansk in Siberia, though temperatures of -108°F have been claimed.

It is considered that the current American requirements, published in ARDCM 80-1, are realistic and are in essence reproduced in the requirements which follow.

6. PROPOSED ENVIRONMENTAL REQUIREMENTS

The information derived from the climatological study, which has been summarised on the preceding pages, has been analysed and it is now possible to draw up the environmental requirements in greater detail then hitherto. Recommendations on the limits of climatic conditions within which the equipment should function satisfactorily and also meet the requirements are presented in the ensuring paragraphs.

All the units should be designed to be capable of being started and operated satisfactorily in all weather conditions which may be experienced in world-wide operations. Thus provision must be made for extreme cold conditions through to humid, tropical, salty, hot and sandy desert climates and also in any plane within 15 degrees of the horizontal.

The performance of the equipment will vary considerably with changes of climatic conditions. Some services should be designed to meet the requirements laid down under extreme climatic conditions whilst with other services some fall off in performance would appear justifiable. Upon this basis, it is recommended that the design requirements, laid down in paragraph 2.2 of Report No. LOG/105/8, shall be satisfied within the following two classes of temperature, pressure and humidity:-

Class 1 - Extreme Climatic Conditions

Applicable to the A.C. and D.C. electrical supplies and also to air for cooling the cockpit and electronic gear, voice intercommunication and distilled water.

Altitude (ft)	Temperature (°F)		Barometric Pressure (in. Hg)		Dew Point (°F)	
	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere
0	130	-65	29.92	29.92	75	-70
1,000	124	-65	28.93	28.57	73	-70
2,000	118	-65	27.98	27.32	70	-70
3,000	112	-65	27.04	26.17	67	-70
4,000	106	-65	26.14	25.09	64	-70
5,000	100	-65	25.25	24.05	61	-70

Note: Provision must also be made for enclosed air temperature, due to solar radiation, of up to 160°F.

The above climatic conditions represent the worst likely to be experienced on world-wide operations. To meet these contingencies the electrical supplies will have to be maintained together with the low pressure air supply for cooling the electronic gear and the cockpit at all times. The intercommunication equipment and distilled water supply should present no great problem.

At the maximum temperature conditions there will be an increase in engine starting time. The turbo-driven generators, however, will continue to function satisfactorily as under extremely high temperatures there will be no demand for hot air for cockpit temperature control.

Class 2 - Normal Operational Climatic Conditions

Applicable to medium pressure air supply for starting the engines and for energising the turbo-driven generators.

Altitude (ft)	Temperature (°F)		Barometric Pressure (in. Hg)		Dew Point (°F)	
	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere
0	110	-60	29.92	29.92	75	-65
1,000	108	-60	28.93	28.57	72	-65
2,000	104	-60	27.98	27.32	68	-65
3,000	100	-60	27.04	26.17	64	-65
4,000	97.5	-60	26.14	25.09	61	-65
5,000	95	-60	25.25	24.05	58	-65
Note: In the event of an ambient temperature of -65°F being experienced the delivery temperature of the air supply for engine starting should not fall below 200°F.						

The above table is representative of the extremes of climatic conditions likely to be experienced on the apron of existing air bases in Canada, Alaska, Greeland and Iceland from which the CF-105 aircraft may be operated in defence of the North American continent. As indicated earlier in this report, there will be the rare occasion when local climatic conditions may fall outside the range indicated above; in this event the operational penalty will only be a slight increase in engine starting times.

Having regard to the extremes of conditions within which the equipment is to function satisfactorily, due consideration should be given to the following factors when designing the equipment:-

(a) The ingress of driving snow, moisture and sand on to switchgear, control panels and other items of equipment.

(b) The possibility of snow and freezing rain striking exhaust pipes and other hot spots, melting and subsequently freezing.

(c) That the fasteners on panels which have to be removed in service and the controls can be operated by personnel wearing heavy arctic clothing.

(d) The effect of extremes of temperature on certain materials, such as plastic and certain types of weather stripping.

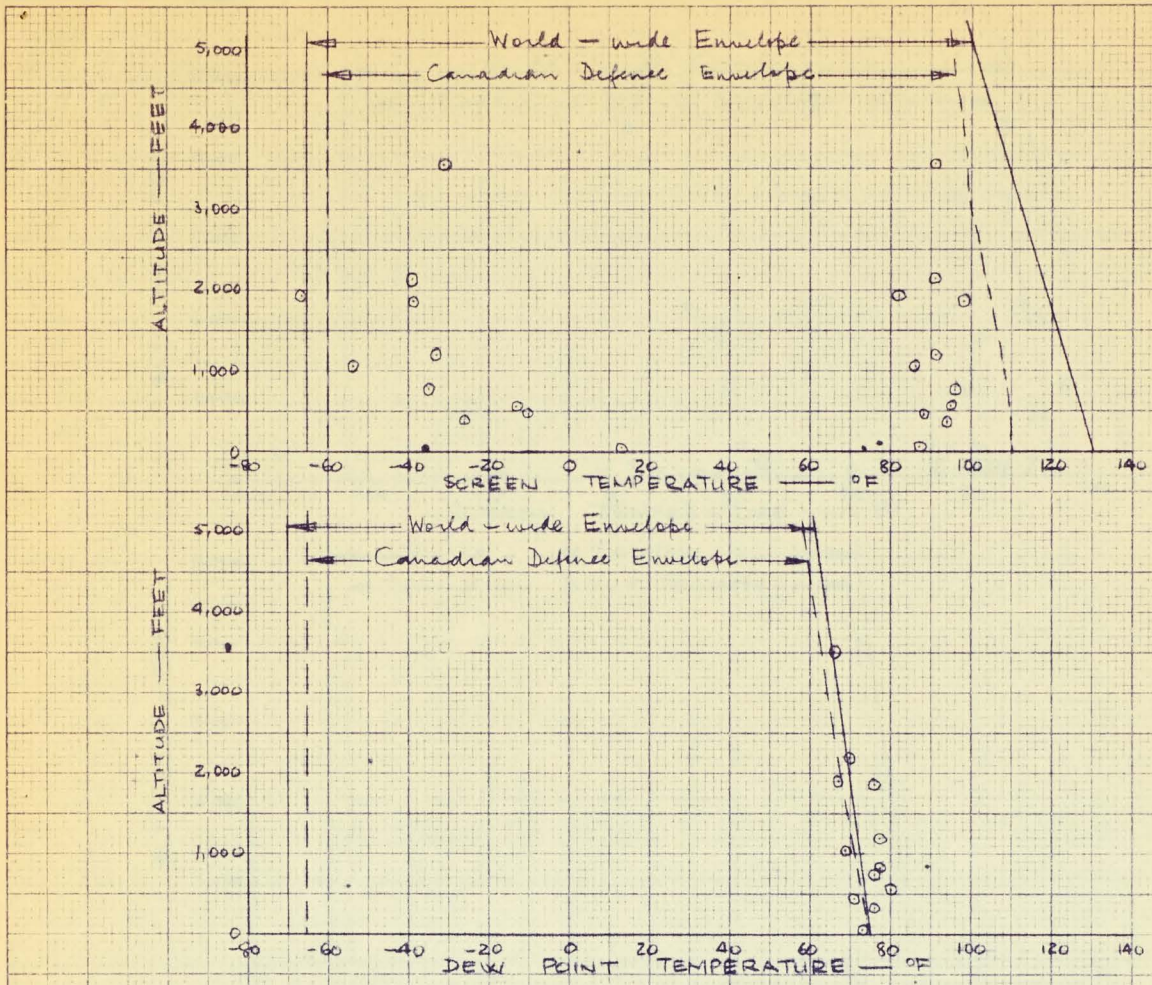
(e) Routing fuel lines so as to avoid vapour locks in extremely hot weather.

(f) The effect of climatic extremes on lubrication and cooling systems.

7. SUMMARY

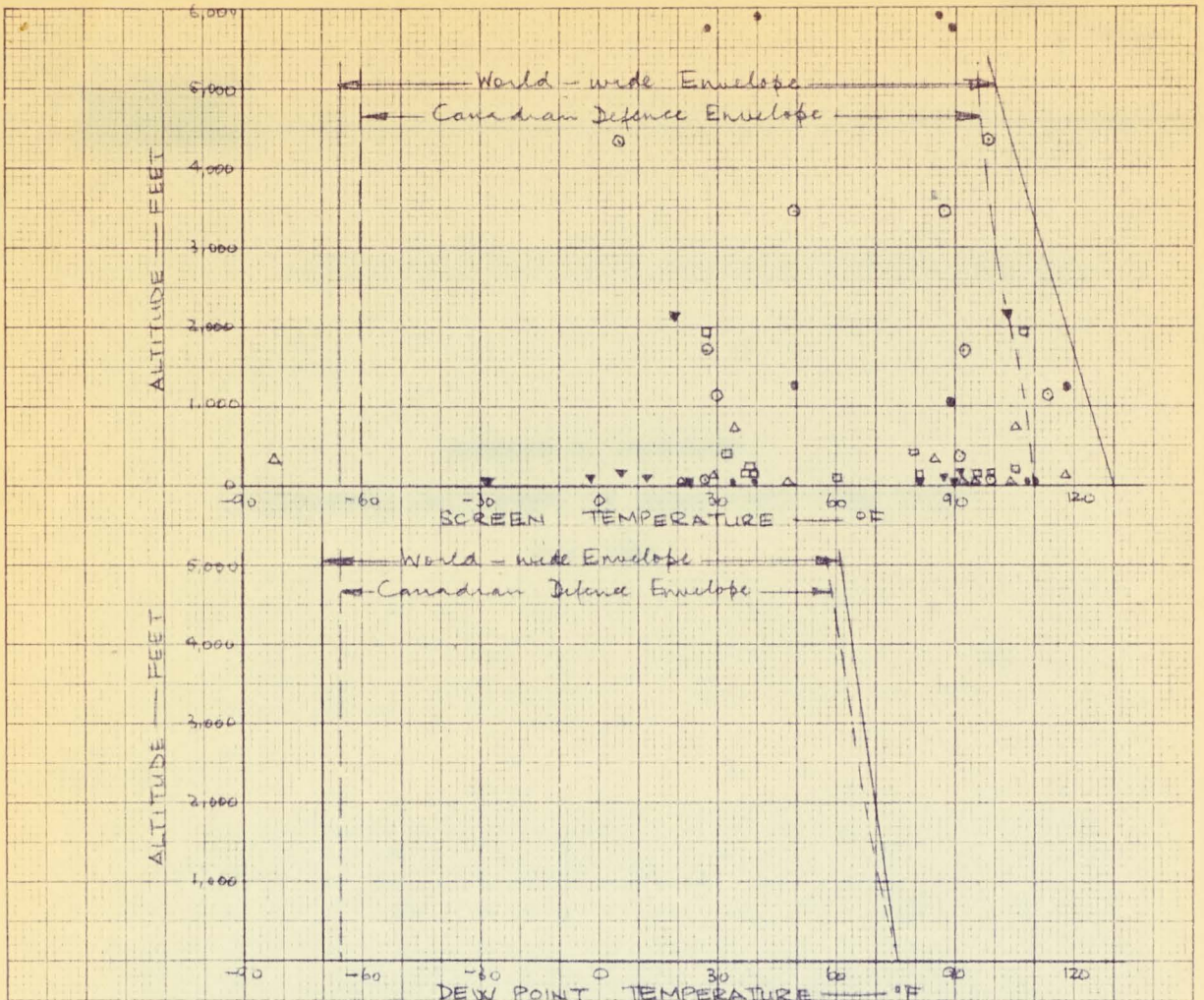
Figures 1 and 2 overleaf illustrate the recommended environmental requirements for temperature and humidity in both the Canadian and World-wide operational concepts for the mobile ground support equipment to be designed for the CF-105 aircraft. The superimposed points on Figure 1 represent the average annual maximum and minimum screen temperatures and dew point temperature for the various parts of Alaska, Canada, Greenland and Iceland; it will be appreciated that, as a general rule, the maximum dew point will not be experienced at maximum temperature conditions. The points on Figure 2 show the average annual maximum and minimum temperature for various parts of the world.

The environmental conditions for the design of the mobile ground power equipment has been discussed at some length with representatives of the Royal Canadian Air Force. The proposals recommended in this report are considered to be a reasonable interpretation of the climatic conditions upon which the design of the various items of equipment should be based.



KEY TO WEATHER STATIONS IN ALASKA, CANADA, GREENLAND AND ICELAND				
ALASKA Symbol •	CANADA Symbol ○		GREENLAND Symbol △	ICELAND Symbol □
Anchorage	Bagotville	Ottawa	Narsarssuak	Keflavik
Big Delta	Calgary	Regina	Sondestrom	
Ladd	Dawson	Shaq	Thule	
Nome	Edmonton	Toronto		
	Gander	Vancouver		
	North Bay	Winnipeg		

FIGURE 1 — TEMPERATURE AND DEW POINT ENVELOPES OF THE PROPOSED ENVIRONMENTAL REQUIREMENTS (Superimposed are the annual maximum and minimum screen temperatures and dew points recorded in various parts of Alaska, Canada, Greenland and Iceland)



KEY TO WORLD - WIDE WEATHER STATIONS

AFRICA Symbol •	AMERICA Symbol ○	ASIA Symbol △	AUSTRALASIA Symbol □	EUROPE Symbol ▼
Cairo	Buenos Aires	Baghdad	Alice Springs	Archangel
Johannesburg	Caracas	Calcutta	Auckland	Baku
Khartoum	Los Angeles	Chungking	Perth	Berlin
Leopoldville	Phoenix	Delhi	Port Darwin	Madrid
Nairobi	Salt Lake City	Singapore	Sydney	Oslo
Tunis	Santiago	Verkhoyansk	Townsville	Sevastopol

FIGURE 2 — TEMPERATURE AND DEW POINT ENVELOPES OF THE PROPOSED ENVIRONMENTAL REQUIREMENTS (Superimposed are the average annual maximum and minimum screen temperatures recorded in various parts of the world).

AMC/SACO

AVRO AIRCRAFT

ADDENDUM TO LOG/105/13.

ENVIRONMENTAL REQUIREMENTS FOR MOBILE GROUND POWER UNITS

July, 1957.

Prepared By: Ian H. Mitchell

Approved By: R. Watts
Chief of Equipment Design

Authorized for Release By: Jack Craig
P.P. Project Designer

FURTHER CONSIDERATIONS OF ENVIRONMENTAL REQUIREMENTS FOR GROUND AIR CONDITIONING

PURPOSE OF THE ADDENDUM

To re-examine the hot weather environmental requirements of the mobile ground air conditioner for the Arrow 2, and to re-define as necessary the ambient air characteristics for which the unit is to be ~~defined~~. designed.

PREFACE

The recommendations of this Addendum are intended to supplant some of those made in Report No. LOG/105/13 "Environmental Requirements for Mobile Ground Power Units" dated July, 1955, by Avro Aircraft Limited. This Addendum does not completely replace Report No. LOG/105/13. On subjects treated in Report No. LOG/105/13 but not mentioned in this Addendum, the former report is to be considered the authority.

INTRODUCTION

In Report No. LOG/105/13 it was recommended that the ground air conditioner be designed to be capable of cooling ambient air at a dry bulb temperature of 130°F and a dew point of 75°F, at sea level. The corresponding conditions suggested at 5,000 ft altitude were 100° dry bulb and 61° dew point.

Using these values in various design calculations carried out by Avro evaluating some possible configurations of air conditioning apparatus, it was possible to determine the approximate sizes and capacities of equipment required. When consulted, some vendors and manufacturers of this class of air conditioning equipment felt that the ambient conditions were unusually high compared with those imposed by the USAF. Avro then felt that the situation warranted a further investigation of ambient conditions in order to confirm the necessity of the severe conditions being imposed on the design, and to minimize the danger of a size, weight, and cost penalty associated with an overdesigned unit. Accordingly, Avro undertook a review of world wide conditions with the purpose of confirming or supplanting the suggested ambient air characteristics.

ACCOUNT OF THE INVESTIGATION

As a first step, Mr. C.C. Boughner, climatologist with the Air Services Branch of the Department of Transport, 260, Richmond Street West, Toronto, was consulted. Mr. Boughner had no recommendations for a readily available source of climatological data of the type needed, but was able to express some opinions based on personal experience that proved enlightening.

ACCOUNT OF THE INVESTIGATION Continued...

Mr. Boughner felt that while conditions of 130° dry bulb and 75° dew point were conceivable on some parts of the earth, they would be a most extraordinary combination of heat and humidity. He felt a more reasonable figure would be 115° dry bulb and 75° dew point.

In Report No. LOG/105/13 an apparently arbitrary but fairly representative list of weather stations is given to supply world wide climatic data. It was decided to review the list, taking the data given for each of the selected stations in Military Operational Research Report No. 65 "Collation of Climatic Data in Possible Theatres of War". This was done and the results tabulated and plotted. (See Fig. 1). This source has its shortcomings. It gives, for each month, the mean monthly vapour pressure (not the maximum) ~~vapour~~, and the mean daily maximum temperature of the month (not the maximum of the month). The technique used in the review was usually to select the month with the highest mean monthly vapour pressure (usually one of the hottest, if not the hottest month of the year) and record the vapour pressure and temperature data for that month as being the most critical. There is, in point of fact, no reason to suppose that the vapour pressure and the temperature ever reached their high levels simultaneously, but it is felt that this may be assumed without detracting greatly from the value of the technique. The assumption may balance the possibility of extremes of heat and moisture occurring separately.

To obtain a picture of Canadian conditions, data was selected from a number of stations tabulated in Report No. LOG/105/13 and was plotted in Fig. 2. The ten year maximums of dew point are given with their corresponding air temperature.

Mr. F. Ebersback, Head of the Thermal Servicing Equipment Section and of the Air Conditioning and Isolation Section of the Wright Air Development Centre, Dayton, Ohio, was consulted by telephone. He advised Avro that an American, British and Canadian ("A.B.C.") standard reference point for rating aircraft cooling air supply existed: 100° dry bulb, 85° wet bulb, with the air delivered at 50°F. He also said that a 90° "effective temperature" line was in use in the United States. This design line is an arbitrary straight line drawn on the psychrometric chart, joining 90° dry bulb, saturated to 137° dry bulb, zero moisture content.

It was learned later from the RCAF that the ABC point of reference (100° dry bulb, 85° wet bulb) is used only as a point for calculations comparing performances of air conditioners. It is not a standard or a design point as such.

It was noted that a Convair specification for a B-58 "Hustler" ground air conditioning unit gave 97° dry bulb, 87° wet bulb as a design point for its refrigeration system.

ACCOUNT OF THE INVESTIGATION Continued...

In USAF Exhibit No. WCL-876 for an Air Conditioner Pack - Air Cycle, sea level design conditions are:-

	Ambient	Flow	Supply Air
1.	130° DB, 76° WB	110 lb/min	50 psia 600°F
2.	100° DB, 76° WB	125 lb/min	53 psia 550°F

In Military Standard MIL-STD-210 "Climatic Extremes for Military Equipment", a probable hot thermal extreme of 125°F and probable high dew point of 85°, are quoted for world-wide operations. However, it is important to note that these two conditions are not specified as occurring concurrently. They are quoted as extremes of temperature and humidity individually for design purposes and may be expected to be exceeded on three days of the worst month in some parts of the world.

CHOICE OF A NEW DESIGN POINT

It can be shown that the maximum ambient dry bulb temperature is the important criterion in compressor sizing. It can also be shown that the enthalpy of the air-vapour mixture is the important criterion of refrigeration capacity. Since a line of constant wet bulb temperature is a line of constant enthalpy, a design point may be specified by a dry bulb and a wet bulb temperature to be catered to by the compressor sizing and the refrigeration capacity respectively.

It was felt that 130° was an acceptable maximum dry bulb temperature, in that temperatures of that order are occasionally attained in certain arid regions of the earth, notably the Near and Middle East, North Africa, and some parts of the Southwestern United States. As a maximum temperature, it affords a reasonable margin of safety. This margin of safety is felt to be especially desirable since the compressor could possibly be called upon to deliver a large volume of low-density air if a moderately high temperature were encountered at a high altitude airfield.

As for the wet bulb temperature, an examination of Figs. 1 and 2 shows that the 85° wet bulb line encloses most areas of the earth and virtually all of those worth considering from a practical point of view.

It is evident that the selection of 130° dry bulb, 85° wet bulb as a design point will be quite satisfactory from the point of view of world-wide conditions, without imposing a large penalty over a design based only on North American conditions.

CHOICE OF A NEW DESIGN POINT Continued...

The recommended design point is not, in fact, very far removed from the old one. The change represents a lowering of enthalpy of 3.6 BTU/lb of dry air, and a lowering of relative humidity from 16% to 15%. However, it is felt that the change is justified and necessary, and that 130° dry bulb, 85° wet bulb should be the ambient air conditions specified for sea level.

It is recommended that design conditions at altitude be determined by using the I.C.A.O. Standard atmospheric pressures and a constant dry bulb temperature lapse rate of 3.5°/1000ft. to 5000 ft. altitude, approximately the average I.C.A.O. lapse rate over that range. Since refrigeration capacity requirements would not increase with altitude, it is recommended that the wet bulb temperature be considered constant to 5000 ft. altitude.

CONCLUSIONS

Recommended ambient conditions are:-

Altitude (ft)	Pressure (lbs/ft^2 abs)	Dry Bulb Temp (°F)	Wet Bulb Temp (°F)	Specific Volume (ft^3/lb)
S.L.	2116	130	85	14.86
1000	2041	126.5	85	15.33
2000	1968	123	85	15.80
3000	1897	119.5	85	16.30
4000	1828	116	85	16.80
5000	1761	112.5	85	17.32

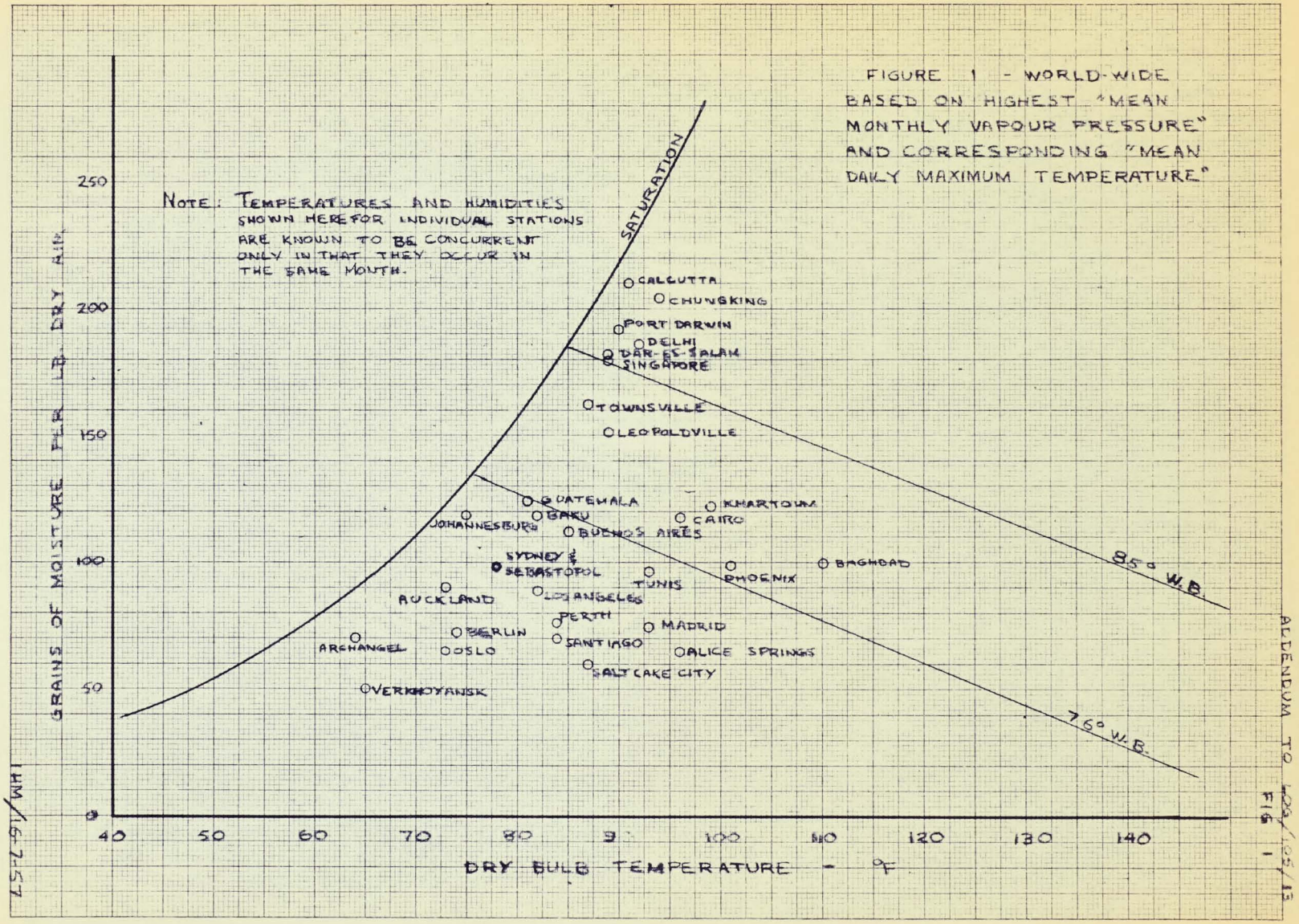
CONCLUSION Continued...

Thus if the compressor is sized to deliver 150 lbs/min at 5000 ft. altitude, 112.5° dry bulb, it will be able to deliver:-

$$150 \times \frac{17.32 \times 2116}{53.3 \times (130 + 460)} = 175 \text{ lbs/min at sea level, } 130^\circ \text{ DB}$$

or

184 " " " " 100° "
199 " " " " 59° "
261 " " " " -65° "



ADDENDUM TO 103/105/13
FIG 1

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