THE IMPACT OF AIR POLLUTION AT SELECTED MAJOR CANADIAN AIRPORTS

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ABSTRACT

This study examines the present and future emissions impact of aircraft and airport operations at three major Canadian airports. Airport emission sources include aircraft traffic, ground traffic and stationary installations. Emission densities (tons of pollutants per year per square mile) are calculated at Toronto International Airport, Montreal International Airport (Dorval) and St-Hubert Airport, for 1976, 1984 and 1996. These emission densities of HC, CO and NO_x are compared to the emission densities of Toronto and Montreal. The results seem to indicate that there is or will be no significant air pollution problem at these airports, at least for the next 20 years, as long as aircraft engines in the future meet proposed U.S. emission standards.

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1 INTRODUCTION

This report examines the present and future emissions impact of aircraft and airport operations in Canada. Specifically an attempt will be made to:

a) determine airport emission densities at three major Canadian airports,
b) compare these with city emission densities.

Emission densities, i.e. tons of pollutants (HC, CO, NO_x) emitted per year per square mile, will be calculated for 1976 and projected for 1984 and 1996, at three Canadian airports: Toronto International Airport (TIA), Montreal International Airport (Dorval) and St-Hubert Airport (general aviation). Airport emission densities will be obtained by calculating total emissions in one year, from aircraft, access traffic, ground service vehicles, heating plants and fuel storage and by dividing these total emissions by the airport surface area. These emission densities will then be compared to the emission densities of metropolitan Toronto and Montreal to obtain some indication of the relative importance of aircraft-related emissions.

Aircraft emissions during cruising flight, the effect of cold weather on emissions, and high altitude emissions will not be considered in this report.

Emissions during cruise do not contribute significantly to air pollution at ground level, within the city confines. Emissions generated above approximately 3 500 feet are considered to be dispersed by wind and rain, and most often fall on little-populated rural areas. Secondly, gas turbine engines, the jets and turboprops, are remarkably efficient at high speed (i.e. cruise).

Aeroengines winter emissions are probably somewhat higher than summer emissions. Cold weather testing on automobiles has shown that, while HC and CO emissions are very much higher when the cold engine is first started, these emissions are virtually the same as in summer, once the engine has warmed up. Anyhow, differences in combustion technology suggests a relatively smaller effect on gas turbines.

Stratospheric air pollution is not a local or even a national problem; it is an international problem. Pollutants emitted during flight at high altitudes are dispersed around the world by air currents. Research on the problems and possible solutions must be international in scope.

2 AIRPORT EMISSION DENSITIES

2.1 Aircraft Emissions - General

Aircraft emissions at an airport are calculated by first multiplying "time-in-mode" by the modal emission factors of the different pollutants, to obtain aircraft emission factors, then by multiplying this result by the number of landing-takeoffs (LTO's) in the different aircraft classes. A landing-takeoff cycle includes all normal operation modes performed by an aircraft between the time it descends from an altitude of 3 500 feet (1 100 meters) on its approach and the time it subsequently reaches the 3 500 feet (1 100 meters) altitude after takeoff. The LTO cycle incorporates the ground operations of idle, taxi, landing run, and takeoff run and the flight operations of takeoff and climbout to 3 500 feet (1 100 meters) and approach from 3 500 feet (1 100 meters) to touchdown (1). Each class of aircraft has its own typical LTO cycle. Time-in-mode refers to the time, expressed in minutes, spent by an aircraft during one of the phases of its LTO cycle. Modal emission factors are emission factors, expressed in lbs/hour, during the different modes.

2.2 Aircraft Emissions - Scenario 1

This is a first approximation. Aircraft engine emission factors are readily obtained from publications of the U.S. Environmental Protection Agency (EPA) (1). In this first approximation, the emission factors are based on time-in-mode at a "typical metropolitan airport" (see Tables 1 and 2).

The numbers of LTO cycles (at the airports in question, in 1976) are obtained from a Statistics Canada publication (3) (see Table 3). This published information is divided into "Itinerant" and "Local" flights. A complete itinerant flight breakdown (i.e. number and type of various aircraft) can be obtained from Statistics Canada computer printouts (4). No such breakdown exists for local flights, so it will be assumed that local LTO's are performed by pilots operating small piston aircraft. Local flights are much more prevalent at general aviation (GA) airports. Itinerant flights, on the other hand, occur mostly at commercial, air carrier (AC) airports. They include domestic, trans-border and international unit toll or charter operations.

At Toronto International Airport there were 122 425 LTO's in 1976. The projected 1984 and 1996 LTO's are 170 171 and 265 662, respectively, corresponding to aircraft traffic 1.39 and 2.17 times the traffic of 1976 (5).

At Montreal International Airport there were 80 090 LTO's in 1976. The projected 1984 and 1996 LTO's are 104 117 and 55 262, respectively, corresponding to aircraft traffic 1.30 and 0.69 times the traffic of 1976 (5). The drop in traffic in 1996 is explained by the expected switch of much of the air carrier traffic from Dorval to Mirabel; for the purpose of this study, 1984 is projected to Dorval's busiest year.

At St-Hubert Airport there were 132 702 LTO's in 1976. Since no Department of Transport (DOT) projections exist for this airport the projected 1984 and 1996 LTO's are set at 179 148 and 285 309, respectively, corresponding to aircraft traffic 1.35 and 2.15 times the traffic of 1976. These were based on projections at other airports.

Aircraft emissions from Scenario 1 are given in Table 4.

2.3 Aircraft Emissions - Scenario 2

Scenario 2 is similar to Scenario 1, and applies only to TIA. It is felt that, by now, it is established that both Dorval and St-Hubert airports do not seem to be major pollution contributors. The number of LTO's is the same. However, aircraft engine emission factors are different; EPA's modal emission factors are applied with a different time-in-mode. A different fleet mix is assumed in 1996 (see Table 7).

It is felt that the taxi-idle time before takeoff of 19 minutes, for commercial aircraft (i.e. Jumbo - Long Range - Medium Range Jets, Turboprop Aircraft) is too long. The delays taken into account by EPA for emission calculations at American airports are shorter at Canadian airports. A more representative figure of 12 minutes is proposed, instead of 19 minutes. This is obtained by the addition of the taxi-idle time after landing of seven minutes (as given by EPA) plus an average before takeoff delay of five minutes. This is felt to be fairly representative of Canadian airports (6). The modified time-in-mode is given in Table 5.

Furthermore, this report compares emissions generated at an airport with emissions generated on a city-wide level. Thus, aircraft emissions should be calculated only within the airport perimeter. However, much of the climbout and approach happens outide the airport's boundaries. Correspondingly, some of the emissions are generated outside of the airport. The Los Angeles Airport Study presents the following information: 13.1% of the air contaminants emitted by jet aircraft on descent are within the airport boundary, while 17% of the air contaminants emitted by commercial four-engined and two-engined piston powered air-craft are within the airport boundary (7). No figure is presented for helicopters or single-engine piston aircraft. For the sake of simplicity, this reports uses a 15% figure, i.e. 15% of the "approach" emissions are within the airport perimeter. Climbout adjustment is somewhat more difficult to obtain and is estimated at 30%, i.e. 30% of the climbout emissions are within the airport perimeter. This number was obtained by comparing takeoff and climbout performance curves published by the Civil Aeronautics Board, and EPA's time-in-mode (1, 8). Both these perimeter modifications will be applied in all cases except for helicopters.

The fleet mix refers to the number of aircraft in each category, i.e. the number of jet aircraft, the number of piston aircraft, etc. The updated fleet mixes at TIA for 1984 and 1996 are based on private conversations with DOT and Air Canada personnel (5, 9).

Not enough information was known to adequately predict the new proposed types of aircraft and engines. The mix is therefore in terms of existing aircraft and engines. The modified emission factors are given in Table 6. Aircraft emissions from Scenario 2 are given in Table 4.

2.4 Aircraft Emissions - Scenario 3

Scenario 3 also applies only to TIA. The numer of LTO's, the aircraft emission factors for 1976 and 1984 and the 1996 fleet mix are the same as in Scenario 2. However there are different aircraft engine emission factors for 1996, reflecting proposed emission regulations on commercial aircraft engines.

There are no regulations or proposed regulations on emissions from aircraft engines, in Canada. It was assumed, however, that U.S. standards would be met by most aircraft operating in Canada. The proposed standards will be in force beginning in 1981 and 1985 depending on the type of engine, size, etc. It is felt that, (using conservative estimates), in 1996, in Canada, 75% of the regulated gas turbine engines will be built to newly manufactured engine (NME) specifications while 25% of the regulated gas turbine engines will be built to newly certified engine (NCE) specifications.

The modified 1996 emission factors resulting from these proposed U.S. regulations are presented in Table 8 (see Appendix C).

Aircraft emissions from Scenario 3 are given in Table 4.

2.5 Access Traffic Emissions

Access traffic emissions are obtained by multiplying the appropriate emission factors, by the average round trip mileage of vehicles travelling within the airport boundaries, by the number of vehicles per year.

The emission factors are obtained from the U.R.T.E.I. (Urban Road Transportation Emission Inventory) computer program (25). It is assumed that 97% of the access traffic vehicles at an airport will be gasoline engined and that 3% of the vehicles will be diesel engined. The average emissions factors are (grams/mile):

	HC*	CO	NO_x
1976	6.0	51	4.9
1984	3.5	30	3.5
1996	3.5	30	3.5

* Hydrocarbon emissions include exhaust, evaporation and blowby.

At TIA, the access traffic vehicles' average round trip mileage within the airport boundaries is 1.75 miles (11). The number of vehicles per year is 5 826 495 (11). Note that parking facilities at this airport are very congested. The number of vehicle trips, therefore, may not be representative of the airport's activity level, when compared to the number of vehicle trips at Dorval airport.

At Dorval, the access traffic vehicles' average round trip mileage within the airport boundaries is 1.5 miles (12). The number of vehicles per year is 5 146 500 (12).

At St-Hubert, the access traffic vehicles' average round trip mileage within the airport boundaries is .75 mile. The number of vehicles per year is 250 000 (24). Note that St-Hubert airport, being a general aviation airport, does not have big passenger volume. There is no terminal, and there are no regular airline scheduled flights.

2.6 Service Vehicles Emissions

Ground service vehicles emissions are obtained by multiplying the appropriate emission factors by the amount of fuel (gasoline or diesel) consumed (10). The emission factors are (lb/gal):

	HC	CO	NO_x
Gasoline Engine	.59	2.64	.15
Diesel Engine	.08	.39	.41

At TIA the amount of fuel consumed, in 1976, was 115 000 gallons (imperial) of gasoline and 20 000 gallons of diesel fuel (13). At Dorval the amount of fuel consumed, in 1976, was 120 000 gallons of gasoline and 75 000 gallons of diesel fuel (14). At St-Hubert the amount of fuel consumed per year is about 30 000 gallons of gasoline and 25 000 gallons of diesel fuel (24).

2.7 Fuel Distribution Emissions

It is difficult to obtain accurate data on the fuel distribution network's hydrocarbon emissions. Fuel evaporation's share of hydrocarbon emissions is set at 9%, 6% and 5% of aircraft hydrocarbons, in 1976, 1984 and 1996, respectively. This agrees with information from the Vancouver Airport environmental study (10).

2.8 Heating Plant Emissions

Heating Plant Emissions were obtained by multiplying the appropriate emission factors by the amount of fuel (natural gas or oil) consumed (10). The emission factors are:

	HC	CO	NO_x
Natural Gas	.00806 lb/MCF	.02014 lb/MCF	.10069 lb/MCF
Oil	.00320 lb/gal	.00480 lb/gal	.07220 lb/gal

At TIA, the amount of fuel consumed, in 1976, was 316 800 MCF (thousand cubic feet) of natural gas and 211 325 gallons (imperial) of oil (15). At Dorval, the amount of fuel consumed, in 1976, was 765 907 MCF of natural gas and 1 363 714 gallons of oil (16, 17). Montreal's relatively colder climate, compared to Toronto's, accounts for possible energy use discrepancies. At St-Hubert, the amount of fuel consumed per year is approximately 175 000 gallons of oil (24).

2.9 Airport Emission Densities

All yearly airport emissions are given in Table 4. "Non-Aircraft" emission sources include access traffic, service vehicles, fuel distribution and heating plants.

Yearly airport emission densities are obtained by dividing total yearly emissions by the airport surface area (see Table 10). The surface areas are 6.56, 5.94 and 1.97 square miles, respectively, for Toronto International Airport, Montreal International Airport and St-Hubert Airport.

3 AIR QUALITY

3.1 Urban Emission Densities

One of the objectives of this report is to compare airport emission densities with urban emission densities. Toronto and Montreal urban emission densities are obtained by dividing their respective total emissions by their respective metropolitan surface areas.

Toronto's 1974 (latest information available) HC, CO, and NO_x emissions are 83 156, 378 232 and 97 258 tons respectively (18). Metropolitan Toronto's surface area is 240 square miles.

Montreal's 1972 (latest information available) HC, CO, an NO_x emissions are 282 218, 680 178 and 95 083 tons respectively (19). Montreal Urban Community's surface area is 190 square miles.

The cities' emission densities are (tons/year/mile^2):

	HC	CO	NO_x
Toronto	346	1,576	405
Montreal	1,485	3,580	500

Toronto's figures are more recent and may be more accurate.

3.2 Urban Air Quality

Another objective of this report is to establish a link between the calculated emission densities (see Table 10 and Section 3.1) and the air quality meaurements obtainable from the National Air Pollution Surveillance, "NAPS", network (20).

Table 9 gives the average of the maximum air quality readings, the highest 99.9% air quality reading and the recommended national air quality limits for CO and NO_x, in Toronto and Montreal. (The air quality limits are established by a federal-provincial committee on air pollution).

Some of the "desirable" air quality limits in these cities were not met in 1976. Comparing urban air quality readings with urban emission densities, it is possible to develop, by a rollback technique, a set of urban emission densities which would meet all acceptable and desirable air quality limits.

Using rollback with the average of the maximum air quality readings, to insure "clean" air in these cities the emission densities should be less than or equal to (tons/year/mile^2):

	HC*	CO	NO_x
Toronto	N/A	985	405
Montreal	N/A	1,790	500

Using rollback with the highest 99.9% air quality reading, to insure "clean" air in these cities the emission densities should be less than or equal to (tons/year/mile^2):

	HC*	CO	NO_x
Toronto	N/A	1,126	297
Montreal	N/A	1,279	500

* There are no air quality limits for hydrocarbons in Canada.

Comparing urban emission densities and airport emission densities, it is possible to picture airport operations' relative importance (see Table 10).

4 DISCUSSION

4.1 Comparison between City and Airport Emission Densities

It seems legitimate to compare yearly emission densities of a city with those of its airport:

a) same climate (i.e. winds, precipitation, temperature);
b) same geography and altitude (approximately);
c) same periodicity of emissions.

Periodicity of emissions can adversely affect emission density comparisons between the city and its airport.

There seems to be no indication of unusual weekly or monthly periodicity; there are no really busy weeks or months to break the city/airport parallel. Indeed winter activity is lower and summer activity is higher in both the city and its airport.

Daily emission periodicity can affect the city/airport parallel two ways:

a) emissions during a typical <u>busy</u> day at the airport (referred to as "planning day") compared to emissions during an <u>average</u> day at the airport. The Transport Canada "Planning Day" is a typical busy day, based on an average of the seven busiest days in the three busiest months (23). The "average" day is a year divided by 365.
b) emission peak periods during the day at the airport, compared to emission peak periods during the day, in the city.

Emissions during a typcial busy day (i.e. planning day) are approximately 1.22, 1.12 and 1.02 times higher than emissions during an "average" day, for HC, CO and NO_x, respectively (see Table 11). On the average, then, emissions during a busy day are 1.12 times the emissions during an average day. This difference is not judged to be important enough to affect the conclusions.

Emission peaks occur at 0900 hours, 1200-1400 hours and 1800 hours, with periods of very low emissions during the night (see Figure 1). This corresponds fairly closely to emission peaks and dips in the city as given in various mean diurnal concentration charts.

Thus, emission densities in the city can be compared to emission densities at the airport.

4.2 Reduction of Emissions at Airports

The long term airport air pollution picture in Canada does not seem to present immediate problems. Even the large and busy airports seem to be low polluters. The total HC, CO and NO_x pollution burden caused by airports throughout the whole country is quite small: less than 0.5% for any one of these pollutants (21). In the event, however, that air pollution regulations become much more severe, or that political pressures force airports to further clean up their act, the following well-known methods for the reduction of emission might be applied.

(1) Aircraft Utilization Changes

Any procedure limiting taxiing and idling (t/i) will reduce hydrocarbons and carbon monoxide since emissions during t/i account for about 60 to 80% of total aircraft HC and CO emissions. Spreading out during the day of aircraft departures and arrivals will reduce traffic density and unnecessary delay. This can be accomplished by selective taxation and increased mid-day, night-time flights. Towing aircraft to the runway, carrying passenges to the aircraft (Planemates) and taxiing using fewer engines are also possible. There is still much controversy about benefits and safety for some of these proposed methods.

(2) Access Traffic Utilization Changes

Passenger cars in particular are important contributors to air pollution at airports. Access traffic accounts for 7%, 25% and 6% of total airport HC, CO and NO_x emissions respectively. Increased patronage of public transportation can reduce passenger car dependency and thus decrease overall access traffic emissions. This can be accomplished by making parking on the airport grounds more difficult (i.e. fewer parking spots available or more expensive parking fees); by improving public transportation price, convenience, frequency, speed and comfort.

(3) Aircraft Engine Regulations

Regulations are proposed in the U.S. to control emissions from aircraft engines (22). Canadian regulations could enforce the same standards, get the same air pollution reductions, in the same time frame.

4.3 Maximum Emission Densities Within the Airport Grounds

There are certain locations on the airport grounds where the emission densities are higher than average, at least for short periods of time. The HC and CO trouble spots occur on the aircraft apron - passenger terminal - parking lot area where there is a combination of aircraft idling and taxiing, heavy vehicle traffic, and non-aircraft activity. The NO_x trouble spots occur on the runways, reflecting aircraft takeoff and initial climbout.

A detailed and accurate calculation of the emission densities at these maximum effect locations is beyond the scope of this report. However, a crude approximation suggests that CO emission densities in the terminal area are in the order of 2 1/2 to 3 times the average airport emission densities (see Appendix A). These higher emission densities seem to meet acceptable air quality objectives (see Appendix B).

5 CONCLUSION

According to the assumptions and methods adopted in this report, the following conclusions can be arrived at. On a yearly basis, there seems to be no immediate air pollution problem at Toronto International Airport, Montreal International Airport and St-Hubert Airport, and it seems that there will be no significant future air pollution problem at these airports in 1984 or 1996 if aircraft engines in the future meet the proposed U.S. emission standards. The calculations are somewhat conservative since the 1984 and 1996 emission factors for heating plants, service vehicles and fuel evaporation are not updated to reflect replacement and modernization of equipment.

It cannot be concluded that there is no air pollution problem (immediate or future) at other Canadian airports. However, since the airports studied are among the busiest airports (i.e. highest traffic density) in Canada, it is probably correct to assume that they are also among the highest polluting airports in Canada. Thus at least most, if not all, other Canadian airports will be lesser air pollution offenders.

6 RECOMMENDATIONS

An update of this report should be done, perhaps every three to five years on account of the many assumptions made, the proposed nature of aircraft emission regulations and the projected level of NO_x which seems marginal when compared to the desirable air quality standard. Special attention should be spent on emission regulations, their severity, implementation and actual impact.

TABLE 1 "TIME-IN MODE"

	Time-in Mode, minutes				
Aircraft	Taxi-idle	Takeoff	Climbout	Approach	Taxi-idle
Jumbo jet	19.00	.70	2.20	4.00	7.00
Long range jet	19.00	.70	2.20	4.00	7.00
Medium range jet	19.00	.70	2.20	4.00	7.00
Air Carrier turboprop	19.00	.50	2.50	4.50	7.00
Business jet	6.50	.40	.50	1.60	6.50
General aviation turboprop	19.00	.50	2.50	4.50	7.00
General aviation piston	12.00	.30	4.98	6.00	4.00
Military piston	6.50	.60	5.00	4.60	6.50
Helicopter	3.50	0	6.50	6.50	3.50

TABLE 2 EMISSION FACTORS

Aircraft Type		Emission Factors, lbs/LTO HC	 CO	 NO_x
0-9000 (GA piston)	1P	.40	12.2	.05
0-19000 (H) (GA piston)	1P	.40	12.2	.05
0-19000 (H) (Helicopter)	1T	.52	5.70	.57
4001-19000 (GA piston)	2P	.80	24.4	.10
19001-79000 (military piston)	2P	40.8	304.0	.40
9001-39000 (GA turboprop)	2T	2.2	6.2	2.4
39001-79000 (AC turboprop)	2T	5.8	13.2	5.0
9001-39000 (H) (Helicopter)	2T	1.04	11.4	1.14
9001-39000 (business jet)	2J	7.2	31.6	3.2
39001-79000 (medium range jet) (estimated for Rolls Royce Spey)	2J	50.4	42.1	11.6
79001-159000 (medium range jet)	2J	9.8	34.0	20.4
159001-199000 (medium range jet)	3J	14.7	51.0	30.6
314001- (jumbo jet)	3J	36.6	140.4	94.2
39001-79000 (GA turboprop)	4T	4.4	12.4	4.8
79001-159000 (AC turboprop)	4T	11.6	26.4	10.0
39001-79000 (business jet)	4J	14.4	63.2	6.4
199001-314000 (long range jet)	4J	164.8	189.6	31.6
314001- (jumbo jet)	4J	48.8	187.2	125.6
314001- (long range jet)	4J	164.8	189.6	31.6

TABLE 3 AIRCRAFT LTO'S IN 1976

Aircraft Type		Toronto	% LTO(a)	Dorval	St-Hubert
0-9000	1P	19 482	16	10 989	100 103
0-19000 (H)(d)	1P	335	-	429	1 139
0-19000 (H)	1T	623	1	3 718	3 325
4001-19000	2P	14 002	11	7 359	26 202
19001-79000	2P	2 503	2	839	155
9001-39000	2T	3 491	3	3 607	199
39001-79000	2T	2 252	2	2 934	208
9001-39000 (H)	2T	11	-	21	319
9001-39000	2J	6 052	5	4 953	866
39001-79000	2J	845	1	283	1
79001-159000	2J	32 700	27	25 568	7
159001-199000	3J	14 683	12	11 564	2
314001-	3J	5 832	5	2 103	0
39001-79000	4T	82	-	186	37
79001-159000	4T	27	-	15	112
39001-79000	4J	526	-	592	22
199001-314000	4J	5 426	4	3 364	3
314001-	4J	3 430(b)	3	420	0
314001-	4J	10 123(c)	8	1 116	2
TOTAL		122 425	100	80 090	132 702

(a) The % LTO column applies only to Toronto International Airport

(b) JT9 engine

(c) JT3 engine

(d) Helicopter

(e) P, T, J refer to piston, turboprop and jet engines, repectively; 1, 2, 3, 4 refer to the number of engines.

E 4 EMISSIONS (TONS/YEAR)

		Aircraft Only			Non-Aircraft			Total Emissions		
	Year	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
	1976	1 872	4 103	1 435	272	732	91	2 144	4 835	1 526
	1984	2 602	5 703	1 995	262	690	104	2 864	6 393	2 099
rio 1	1996	4 062	8 904	3 114	368	1 078	164	4 430	9 982	3 278
	1976	1 316	2 712	640	272	732	91	1 588	3 444	731
	1984	1 829	3 770	890	262	690	104	2 091	4 460	994
rio 2	1996	1 525	6 271	2 796	368	1 078	164	1 893	7 349	2 960
	1976	1 316	2 712	640	272	732	91	1 588	3 444	731
	1984	1 829	3 770	890	262	690	104	2 091	4 460	994
rio 3	1996	761	3 030	2 282	368	1 078	164	1 129	4 108	2 446
l	1976	688	1 753	656	171	652	172	859	2 405	828
	1984	894	2 279	853	169	615	207	1 063	2 894	1 060
rio 1	1996	475	1 210	453	103	377	137	578	1 587	590
bert	1976	39	989	7	13	56	14	52	1 045	21
	1984	53	1 335	9	16	70	18	69	1 405	27
rio 1	1996	84	2 126	15	27	112	31	111	2 238	46

ronto International Airport

TABLE 5 MODIFIED TIME-IN-MODE

Aircraft	Time-in Mode, minutes Taxi-idle	Takeoff	Climbout	Approach	Taxi-idle
Jumbo jet	12.00	.70	.66	.60	7.00
Long range jet	12.00	.70	.66	.60	7.00
Medium range jet	12.00	.70	.66	.60	7.00
Air Carrier turboprop	12.00	.50	.75	.68	7.00
Business jet	6.50	.40	.15	.24	6.50
General aviation turboprop	12.00	.50	.75	.68	7.00
General aviation piston	12.00	.30	1.49	.90	4.00
Military piston	6.50	.60	1.50	.69	6.50
Helicopter	3.50	-	6.50	6.50	3.50

TABLE 6 MODIFIED EMISSION FACTORS

		Emission Factors, lbs/LTO		
Aircraft Type		HC	CO	NO_x
0-9000 (GA piston)*	1P	.14	5.31	.01
0-19000 (H) (GA Piston)	1P	.40	12.20	.05
0-19000 (H) (Helicopter)	1T	.52	5.70	.57
4001-19000 (GA piston)	2P	.28	10.62	.02
19001-79000 (military piston)	2P	25.00	182.00	.20
9001-39000 (GA turboprop)	2T	.56	2.28	.78
39001-79000 (AC turboprop)**	2T	4.12	9.98	2.46
9001-39000 (H) (Helicopter)	2T	1.04	11.40	1.14
9001-39000 (business jet)	2J	6.00	30.00	2.00
39001-79000 (medium range jet) (estimated for Rolls Royce Specy)	2J	41.96	39.58	7.25
79001-159000 (medium range jet)	2J	4.50	21.88	9.96
159001-199000 (medium range jet)	3J	6.75	32.82	14.94
314001- (jumbo jet)	3J	26.22	98.58	47.73
39001-79000 (GA turboprop)	4T	1.12	4.56	1.56
79001-159000 (AC turboprop)	4T	8.24	19.76	4.92
39001-79000 (business jet)	4J	12.00	60.00	4.00
199001-314000 (long range jet)	4J	125.64	140.92	13.82
314001- (jumbo jet)	4J	34.96	131.44	63.64
314001- (long range jet)	4J	125.64	140.92	13.82

* GA refers to general aviation

** AC refers to air carrier

TABLE 7 FLEET MIX (1996) AT TIA

Aircraft		% LTO	Number LTO
0-9000 (GA piston)	1P	9	23 910
0-19000 (H) (GA Piston)	1P	-	-
0-19000 (H) (Helicopter)	1T	1	2 657
4001-19000 (GA piston)	2P	5	13 283
19001-79000 (military piston)	2P	-	-
9001-39000 (GA turboprop)	2T	1	2 657
39001-79000 (AC turboprop)	2T	1	2 657
9001-39000 (H) (Helicopter)	2T	-	-
9001-39000 (business jet)	2J	8	21 253
39001-79000 (medium range jet) (estimated for Rolls Royce Spey)	2J	-	-
79001-159000 (medium range jet)	2J	20	53 132
159001-199000 (medium range jet)	3J	20	53 132
314001- (jumbo jet)	3J	20	53 132
39001-79000 (GA turboprop)	4T	2	5 313
79001-159000 (AC turboprop)	4T	1	2 657
39001-79000 (business jet)	4J	2	5 313
199001-314000 (long range jet)	4J	-	-
314001- (jumbo jet)	4J	10	26 566
314001- (long range jet)	4J	-	-
TOTAL		100	265 662

TABLE 8 MODIFIED EMISSION FACTORS (1996)

		Emission Factors, lbs/LTO		
Aircraft Type		HC	CO	NO_x
0-9000 (GA piston)	1P	.14	5.31	.01
0-19000 (H) (GA Piston)	1P	-	-	-
0-19000 (H) (Helicopter)	1T	.52	5.70	.57
4001-19000 (GA piston)	2P	.28	10.62	.02
19001-79000 (military piston)	2P	-	-	-
9001-39000 (GA turboprop)	2T	.56	2.28	.78
39001-79000 (AC turboprop)	2T	4.12	9.98	2.46
9001-39000 (H) (Helicopter)	2T	-	-	-
9001-39000 (business jet)	2J	6.00	30.00	2.00
39001-79000 (medium range jet) (estimated for Rolls Royce Spey)	2J	-	-	-
79001-159000 (medium range jet)	2J	3.90/1.70*	13.52/5.89	11.70/5.25
159001-199000 (medium range jet)	3J	5.85/2.55	20.28/8.84	17.55/7.88
314001- (jumbo jet)	3J	10.89/7.54	41.76/28.93	37.11/24.48
39001-79000 (GA turboprop)	4T	1.12	4.56	1.56
79001-159000 (AC turboprop)	4T	8.24	19.76	4.92
39001-79000 (business jet)	4J	12.00	60.00	4.00
199001-314000 (long range jet)	4J	-	-	-
314001- (jumbo jet)	4J	16.63/11.47	63.80/44.02	56.69/37.42
314001- (long range jet)	4J	-	-	-

* NME/NCE (newly manufactured engine/newly certified engine)

BLE 9 AIR QUALITY MEASUREMENTS

y	Pollutant	Measurement	Av. of Max. Readings (ppm)**	Highest 99.9% Readings (ppm)	Recommended Limit (ppm)
onto	CO	1-hour	12	10	30 (max. accep
onto	CO	8-hour	8	7	13 (max. accep
onto	CO	1-hour	12	10	13 (max. desir.
onto	CO	8-hour	8*	7*	5 (max. desir.)
onto	NO_x	1-hour	.17	.20	.21 (max. accep
onto	NO_x	24-hour	.09	.15*	.11 (max. accep
onto	NO_x	annual	.03	N/A	.05 (max. accep
onto	NO_x	annual	.03	N/A	.03 (max. desir.
ntreal	CO	1-hour	18	17	30 (max. accep
ntreal	CO	8-hour	10	14*	13 (max. accep
ntreal	CO	1-hour	18*	17*	13 (max. desir.
ntreal	CO	8-hour	10*	14*	5 (max. desir.)
ntreal	NO_x	1-hour	.18	.15	.21 (max. accep
ntreal	NO_x	24-hour	.08	.11	.11 (max. accep
ntreal	NO_x	annual	.03	N/A	.05 (max. accep
ntreal	NO_x	annual	.03	N/A	.03 (max. desir.

Does not meet maximum desirable limit

Parts per million

TABLE 10 EMISSION DENSITY COMPARISONS (tons/year/mile^2)

		HC	CO	NO_x
Metro Toronto	(1976)	346	1 576	405
Metro Toronto - desirable*	(1976)	N/A	985	405
Metro Toronto - desirable**	(1976)	N/A	1 126	297
Toronto Airport (Scenario 1)	(1976)	327	737	233
Toronto Airport (Scenario 1)	(1984)	437	975	320
Toronto Airport (Scenario 1)	(1996)	675	1 522	500
Toronto Airport (Scenario 2)	(1976)	242	525	111
Toronto Airport (Scenario 2)	(1984)	319	680	152
Toronto Airport (Scenario 2)	(1996)	289	1 120	451
Toronto Airport (Scenario 3)	(1976)	242	525	111
Toronto Airport (Scenario 3)	(1984)	319	680	152
Toronto Airport (Scenario 3)	(1996)	172	626	373
Metro Montreal	(1976)	1 485	3 580	500
Metro Montreal - desirable*	(1976)	N/A	1 790	500
Metro Montreal - desirable**	(1976)	N/A	1 279	500
Dorval Airport (Scenario 1)	(1976)	145	405	139
Dorval Airport (Scenario 1)	(1984)	179	487	178
Dorval Airport (Scenario 1)	(1996)	97	267	99
St-Hubert Airport (Scenario 1)	(1976)	26	530	11
St-Hubert Airport (Scenario 1)	(1984)	35	713	14
St-Hubert Airport (Scenario 1)	(1996)	56	1 136	23

* Rolled back, using the average of the maximum air quality readings.

** Rolled back, using the highest 99.9% air quality reading.

TABLE 11 PERIODICITY OF EMISSIONS

	Aircraft Emissions in 1976		
	HC	CO	NO_x
Total tons/year	1 292	2 830	753
Av. lbs/day*	7 075	15 496	4 123
Daily lbs/day**	8 614	17 346	4 212

* from report

** from planning day

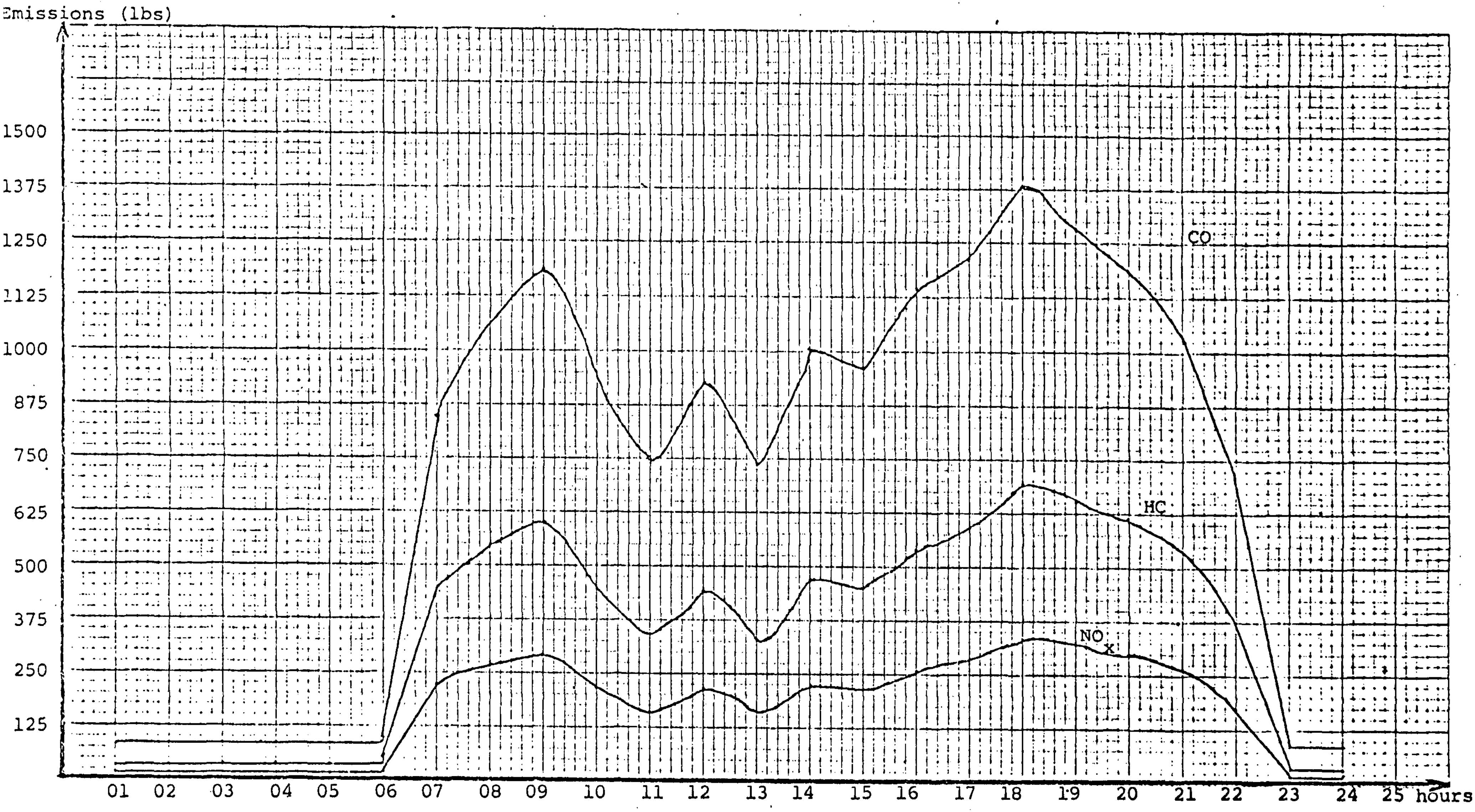

Figure ~~A8~~ Hourly Emissions Periodicity

1

FIGURE 1 HOURLY EMISSIONS PERIODICITY

APPENDIX A HIGHEST CO EMISSION DENSITY

The following substantiates Section 4.3 in the text and apply to Toronto International Airport for 1976 only.

The highest HC and CO emission densities occur at the aircraft apron - passenger terminal - parking lot complex where NO_x emissions are expected to be low. This is an area of approximately one square mile; (the boundaries are arbitrarily chosen).

Within this area, the CO attributable to aircraft operations is approximately one third of all CO produced by aircraft within the airport perimeter. Again, within this one square mile area, the CO attributable to non-aircraft operations is approximately two thirds of all CO produced by non-aircraft sources on the airport grounds. This "two thirds" includes most of the vehicle emissions.

Therefore, 934 tons per year of CO are produced by aircraft in the one square mile area, while 750 tons per year of CO are produced by non-aircraft in the one square mile area. The CO emission density in the one square mile complex is 1 684 tons/year/mile^2.

APPENDIX B ACCEPTABLE AIR QUALITY, TORONTO

Using the "One-Hour Acceptable" CO objective (since maximum emissions occur for short periods of time - see Figure 1), to insure acceptable clean air in Toronto, the CO emission densities should be less than or equal to 3 940 or 4 728 tons/year/mile^2 (based on average of maximum air quality readings and highest 99.9% air quality reading, respectively).

The following is a comparison of emission densities:

	CO (tons/year/mile^2)
Metro Toronto	1 576
Metro Toronto desirable *	985
Metro Toronto desirable **	1 126
Metro Toronto acceptable (1-hour) *	3 940
Metro Toronto acceptable (1-hour) **	4 728
Toronto Airport 1976	605
Toronto Airport 1976 (highest emission density)	1 684

* Based on average of maximum air quality readings.

** Based on highest 99.9% air quality reading.

APPENDIX C EPA PROPOSED REGULATIONS*

In the U.S., the Environmental Protection Agency has determined that aircraft engines cause sufficient emissions to warrant regulations. These EPA regulations will cover only commercial aircraft engines, the aircraft engines which have been determined to be the major cause of air pollution at high activity major air terminals. These rules will require only engines of 6 000 pounds thrust (or equivalent power) or greater, used in commercial applications, to comply with gaseous emission standards. There are no requirements for piston engines, small turboprop and small (6 000 pounds thrust) turbojet and turbofan engines, and auxiliary power units (APU's). These engines, with the exception of the APU's, are used on aircraft that operate mainly from general aviation airports. While general aviation aircraft contribute significantly to air pollution at those airports, the total general aviation airport pollution contribution to the surrounding region is small, and the pollution reduction obtainable is not sufficient to justify the cost of emission regulations. There are no APU standards for several reasons:

1) no NO_x control technology has been developed in spite of reasonable efforts,
2) only minimal CO control is obtainable, yet significant costs would be incurred, and
3) the HC emissions are already below the standard in the uncontrolled engine.

There are standards and implementation dates for three engine categories: newly-manufactured, newly-certified and in-use (retrofit). The standards apply to:

(a)	<u>newly-manufactured</u>		
	HC, CO	6 000 lbs and above	1981
	NO_x	20 000 lbs and above	1984
(b)	<u>newly-certified</u>		
	HC, CO, NO_x	6 000 lbs and above	1984
(c)	<u>in-Use (retrofit)</u>		
	HC, CO	12 000 lbs and above	1985

* Federal Register, March 24, 1978 (see Reference 22).

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