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Test of MDU nitrous oxide from Medclair

Efficiency and comfortability test

Commissioned by Medclair

Kåre Tjus

ivl

Author: Kåre Tjus
Commissioned by: Medclair
Photographer: Medclair
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IVL Swedish Environmental Research Institute Ltd.,
P.O Box 210 60, S-100 31 Stockholm, Sweden
Phone +46-(0)10-788 65 00 // www.ivl.se

This report has been reviewed and approved in accordance with IVL's audited and approved management system.

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Summary

For three days, the performance of MDU, a mobile destruction unit for nitrous oxide was tested at IVL.

Nitrous oxide, with chemical formula N_2O, is widely used as pain relief in medical applications. However, it has also a severe effect on the environment as a greenhouse gas, therefore it is important to minimize its use and when it is possible, destruct it. Medclair has constructed a catalytic unit, MDU, that can decompose nitrous oxide to oxygen and nitrogen gases. IVL has measured N_2O destruction efficiency, energy consumption and noise and temperature changes in the room when simulating the conditions during childbirth and for dental patients

It was found that the destruction of nitrous oxide always was higher than 99,9 %. The noise level was below 35 decibels. The energy consumption was estimated to be in the range between 3,1 kWh and 14,2 kWh per kg N_2O, dependent on how many patients and childbirths that take place. No noticeable temperature increase in the room was noticed during the test period.

1 Test of Medclair MDU

1.1 Introduction.

IVL has, on behalf of Medclair, carried out an investigation of the function for a catalytic nitrous oxide destruction-unit , MDU, during 25 to 27 August 2020.

1.2 Experimental setup

The MDU (August 2020) equipment from Medclair was operated in IVL facilities for three days, evaluating nitrous oxide destruction efficiency and nitrous oxide emissions, energy consumption, noise and temperature increase in room during simulated nitrous oxide supply simulating the conditions for dental patients and during childbirth.

Nitrous oxide emissions from the MDU was measured directly in the outlet gas using two individual measurement instruments IR Sick Sidor and Geotech G200 in the off gas from the MDU. The nitrous oxide destruction efficiency was calculated from emission measurement and a known feed to the unit. The unit was fed with a constant gas flow of 25-30 L/min of ambient air. To simulate conditions for dental care use and childbirth conditions pure nitrous oxide was fed to the feed stream. Nitrous oxide feed was controlled through “regulator” and measured with an Alicat mass flow meter (accuracy 0,2% of rate). Nitrous oxide addition was kept between 2 and 10 gram/minute and are described closer under the different chapters. Figure 1 describes the experimental set up.

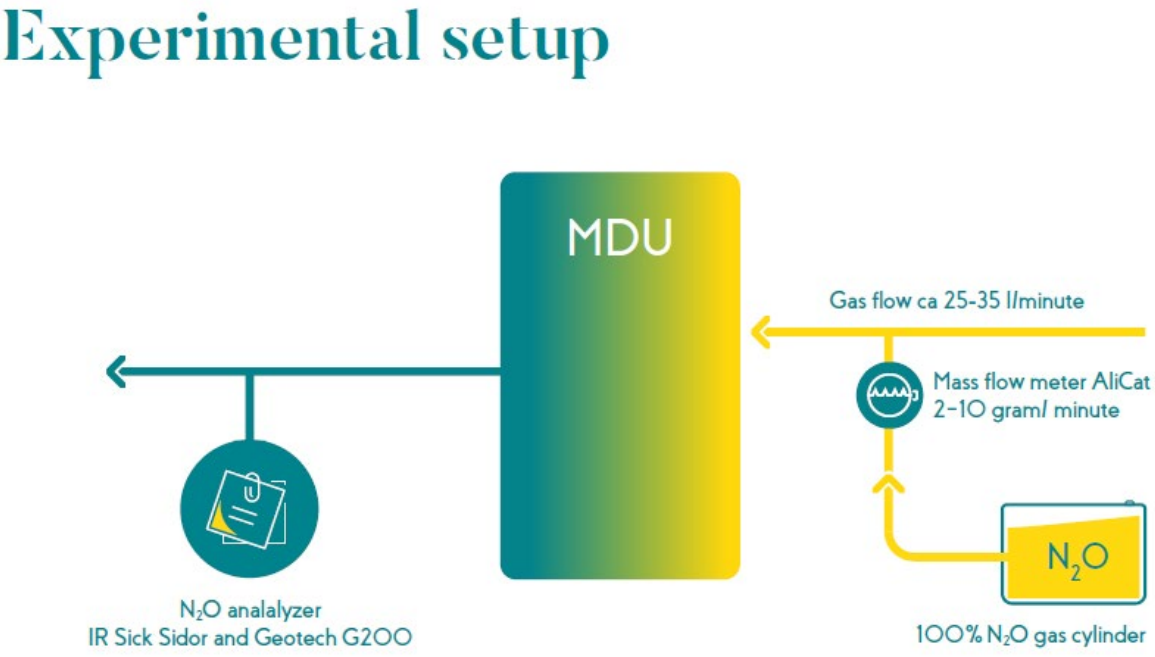

Figure 1. Experimental setup and operation of the MDU.

1.3 The energy measurement

Energy is required to heat the catalyst to a temperature between 400–600 °C and to maintain the temperature during standby mode and during operation. The catalytic decomposition of nitrous oxide is an exothermic reaction reducing the energy consumption for heating during operation up to 100% depending of inlet concentration. During operation, energy from the decomposition of nitrous oxide adds energy so the operating energy is lower than the standby energy, the higher the nitrous oxide content the lower the energy consumption. When the heater is completely switched off, some energy is still needed to maintain electronics control etc.

To cover different operational variations some operational modes was identified and are briefly described below:

Dental treatment

Two typical conditions during dental treatment were identified and mimicked, a lower concentration of 5 g N_2O/minute and a higher concentration of 8 g N_2O/minute. During dental practice the typical procedure averages about 30 minutes and the N_2O loading is rather constant.

Childbirth

Typical use of N_2O for childbirth includes both high concentrations and periods of paus. To simulate this a concentration of 8,5 g N_2O was fed to the machine in 3 minutes intervals followed with 3 minutes paus for a period of a total 1,5 hours.

Standby mode

Between childbirths and between dental procedures the machine needs to keep the catalyst heated to be ready for the next procedure. This mode was calculated on an hourly basis.

Sleep mode

For longer time without operation (during nights and weekends) it is beneficial to enter the sleep mode from an energy consumption perspective. The power consumption during sleep mode was measured and calculated on an hourly basis.

Start up

When sleep mode is entered a startup is needed to heat the catalyst to operational temperature. The startup requires about 45 minutes for the machine to be operational.

The energy consumption was measured using a standard energy meter that was placed between MDU socket and 220-volt wall socket. The table below shows the measured energy consumption for different operational modes and cases based on the energy measurements as shown in Appendix.1. The average power consumption was calculated from the energy consumption during the typical operational time.

In table 1 below is the energy consumption for the operational modes calculated based on our measurements, see appendix 1.

Table 1 Power consumption for the different operationally modes

Operationally mode	Typical operation time [hours]	Power consumption [Watt]	Measured Energy use per typical operational time [Watthour]
Dental Treatment 5g N_2O /minute for 30 minutes	0,5	82	41
Dental treatment 8g N_2O /minute 30 minutes	0,5	44	22
Childbirth 8.5 g N_2O /minute 45 minutes +45 minutes paus	1,5	149	223
Standby mode 1hour	1	240	240
Sleep mode 1hour	1	29	29
Startup 45 minutes	0,75	436	233

2 Measurement of outgoing nitrous oxide after destruction in MDU

For the operational modes when nitrous oxide was added the nitrous oxide reduction was always above 99,9% during the three days evaluation.

Table 2 Outlet concentrations of nitrous oxide

		N_2O added per minute [gram]	**Flow into MDU, [l/minute]**	**Estimated concentration [ppm]**	**Outlet concentration N_2O measured with SICK * [ppm]**	**Outlet concentration N_2O measured with Geotech G200*[ppm]**
Standby mode 1	**13:10 to 13:46 25 August**	0	19,5	0	No measurement	No measurement
Simulated dental treatment 1	**14:14 to 14:46 25 August**	5	19,5	141 000	<100	No measurement
Simulated dental treatment 2	**10:39 to 11:07 26 August**	8,30	24,25	188 000	<100	No measurement
Simulated childbirth	**13:35 to 15:16 26 August**	8,81	28,67	169 000	<100	<15
Standby mode 2	**9:30 to 10:39 26 August**	0	No measurement	0	No measurement	No measurement

- Note that the detection limit for the SICK Sidor analyzer is 100 ppm, measure range is 0-20 000 ppm and Geotech G200 has range 0-1000 ppm and limit 10 ppm.

The values above are average values for the three days run.

3 Noise and temperature measurement

The MDU unit was placed in a quiet room with a volume of 60 m^3 (20 m^2 floor space), the ventilation in the room was about 70 m^3 / h. The noise was measured before and after the MDU was switched on and with the fully heated machine switched on; at one meter around the machine.

Table 3 Measured noise from the MDU

	Meter away from the machine	Decibel measured
MDU switched off	1	29,4
MDU on	1	33,5
MDU on	1	33,4
MDU on	1	33,3
MDU on	1	33,5
MDU on	1	32,8
MDU on	1	33,3
MDU on	1	32,7
MDU on	1	32,4
MDU on	1	32,8
MDU on	0,5	32,5
MDU switched off		29,5

3.1 Temperature measurement in the room

To a completely heated MDU, 3.5g nitrous oxide per minute was supplied for just over two hours (room volume of 60 m^3 and ventilation in the room 70 m^3 / h.). The air flow through the MDU was constant 30 liters per minute. The temperature in the room was monitored before and during the supply of nitrous oxide to the MDU. No substantial temperature increase was observed.

Table 4 Measured temperature in the room

Time	Added N_2O g/minute	Temperature in the room °C
10:30	0	20,5
10:37	0	20,6
11:29	3,5	21,2
12:12	3,5	20,9
13:47	3,5	20,7

3.2 Discussion of the results

N_2O, nitrous oxide, in the room was monitored for a shorter period with G200 and was found to be below the detection limit of 10 ppm. Nitrous oxide was also measured direct out from the MDU and was always lower than 100 ppm (below the detection limit) with Sick and lower than 15 ppm with Geotech G200. This means that the purification is better than 99.9%.

From the experiments, the energy requirement per kg of nitrous oxide destroyed can be calculated for different operating cases. In the calculations it is assumed that 65% of all nitrous oxide is collected by the ventilation mask used by dental patients and during childbirth and that 35 % emerges in the room.

1) It is assumed that two dental treatments take place per day five days a week and that MDU starts automatically at 7 am in the morning and shuts off at 4pm and that it is in sleep mode during the night and on weekends.

2) It is assumed that five dental treatments take place per day five days a week and that MDU starts automatically at 7 am in the morning and shuts off at 4pm and that it is in sleep mode during the night and on weekends.

3) It is assumed that MDU is used for child deliveries with periodic supply of nitrous oxide four times a day with a total time of 90 minutes (45 minutes on and 45 minutes off) each time. The equipment is available 24 hours a day, 7 days a week.

Table 5 Assumption of energy consumption for different cases

Estimated case	Amount of N_2O [kg/week]	Collected N_2O 65 % of supplied [kg/week]	Energy consumption [kWh/week]	destructed N_2O [kWh/ kg]
2 dental-treatments per day (30 minutes each) 5 days a week, 5 g N_2O/minute	**1,50**	**0,98**	**13,82**	**14,18**
5 dental-treatments per day (30 minutes)5 days a week, 8 g N_2O/minute	**6,00**	**3,90**	**12,17**	**3,12**
Child deliveries 4 periods per day (45 minutes active per period), 7 days a week, 8g N_2O /minute	**10,08**	**6,55**	**36,48**	**5,57**

4 General judgment

The equipment is small and handy and easy to move with good wheels, no disturbing noise and no noticeable temperature increase during the experiments. The nitrous oxide purification is very high and stable during the experiments. The energy consumption per kg of nitrous oxide is between 1.5 and 7 kWh / kg, per kg of carbon dioxide equivalent corresponds to between 5 and 24 kWh / ton of separated carbon dioxide equivalent, when N_2O is equal to 298 kg carbon dioxide in a 100 time perspective.

MDU has previously been tested in a real environment, at that time 5 years ago, there were complaints about temperature increase and noise, it seems that these problems have been corrected now.

5 Appendix1 Protocol for energy measurements

Table 6 Measurements of energy consumption

Moment	Time-period for measured energy consumption [Minutes]	Calculated average power consumption [Watt]	Energy for specified moment [Wh]	Time when measured
Startup+ Standby (45+52minutes)	**97**		**550**	**11:33 to 13:10 25 August**
Stand by	**36**	**267**	**160**	**13:10 to13:46 25 August**
Simulated dental treatment 5g/minute, measured for 24 of total 30 minutes	**22**	**82**	**30**	**14:14 to 14:46 25 August**
Sleeping mode+ Startup+ Standby mode	**1123**	**46**	**869**	**14:46 25 August to 9:30 26 August**
Standby	**69**	**226**	**260**	**9:30 to 10:39 26 August**
Simulated dental treatment 8g /minute, measured for 28 of total 30 minutes	**28**	**44**	**21**	**10:39 to 11:07 26 August**

Simulated birth delivery app 8g/minute 15 times each 3 minutes and 15 times with 3 minutes rest	**101**	**149**	**250**	**13:35 to 15:16 26 August**
Sleeping mode	**1039**	**29**	**500**	**15:26 26 August to 8:45 27 August**
Start-up 45 minutes	**32**	**436**	**233**	**8:46 to 9:18 27 August**

IVL Swedish Environmental Research Institute Ltd.
P.O. Box 210 60 // S-100 31 Stockholm // Sweden
Phone +46-(0)10-7886500 // www.ivl.se