JIMCO KPC

Device for reduction of grease and oil deposits in hoods and ducts and for reductions of the emission of particles and odour in ventilation air from commercial kitchen cooking hoods

Document	**Test Report**
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Document Responsible	Arne Oxbøl

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1. INTRODUCTION

This test report is the implementation of a test design developed for verification of a UV-C[1] technology used in hoods and ducts in ventilation air from commercial kitchen cooking hoods. following the DANETV method.

1.1. NAME AND CONTACT OF PROPOSER

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1.3. REFERENCE TO THE TEST PLAN AND SPECIFIC VERIFICATION PROTOCOL

JIMCO VERIFICATION PROTOCOL NOVEMBER 2012

JIMCO TEST PLAN, NOVEMBER 2012.

1.4. SUMMARY OF AMENDMENT AND DEVIATIONS TO TEST PLAN

Amendment	Effect on the test
Time schedule is changed.	The test started app. four weeks later than scheduled. This has no effect on the test.
Change of one test person	No effect on the test
No ozone test	Critical for the evaluation of odour concentrations
No weekly test of system odour – only two days test of system odour	No effect on the conclusion
No weekly test of deposit – test of deposit in two long periods with and without UV	More conclusive results

[1] UV-C: UV radiations in the C band

2. TEST DESIGN

Table 1 Overview of the test design

Parameter	Unit	Method	Number of test
Odour	OU/m³	Olfactometry	9 sets with and without UV
Oil mist	mg/m³	Collection on filters - weighing	2 sets with and without UV
Oil mist	mg/m³	Collection on filters – analysis of oil components	2 sets with and without UV
Inspection	-	Visual inspection of grease deposit Pictures	Inspection of all the hoods in the kitchen after each period (with and without UV)
Inspection	Weight/area/time	Removal of deposit from duct wall - weighing	After each period (with and without UV)

3. TEST RESULTS

3.1. TEST DATA SUMMARY

On three consecutive days nine sets of odour were measured (one set is without and with JIMCO KPC switched on). When JIMCO KPC was switched on, ozone was measured immediately after the odour sampling.

On each of the first two consecutive days one set of particles/oil mist was collected. 15 minutes sampling with JIMCO KPC switched on alternated with 15 minutes sampling with JIMCO KPC switched off until a total sampling of one hour for each mode was accomplished. The filters were weighed giving the total weight of particles, followed by analysis for fatty acids giving the total weight of fatty acids.

The activity in the restaurant was collected from the cashier system as number of transactions per 15 minute. A transaction can be anything from a cup of coffee to a number of burger menus. Assuming that almost all transactions comprise some food (burger, pommes frites, nuggets etc.) the number of transactions is taken as a satisfying measure of the activity. We also assume, that the transactions take place regularly over time, and that the cashier clock corresponds with the sampling clock.

The results are seen below.

Table 2 Test results as average values for each day

Parameter	Unit	Without UV	With UV	Without UV	With UV	Without UV	With UV
Date	dd-mm-yy	03-12-2012	03-12-2012	04-12-2012	04-12-2012	05-12-2012	05-12-2012
Measuring period	hh:mm	17:18 - 18:37	17:00 - 18:20	17:14 - 19:05	16:57 - 18:50	12:24 - 13:30	12:11 - 13:14
Operating parameters							
Temperature	°C	26	26	27	28	26	26
Moisture (stated or calculated)	Vol %	1,10	1,10	1,38	1,09	1,10	1,10
Flowrate	m³(s,d)/h	2.500	2.500	2.600	2.700	2.500	2.500
Concentrations							
Ozone	mg/m³(s,d)	-	1,2	-	1,6	-	1,7
Odour	OU/m³(20°,w)	8.600	3.400	6.200	3.300	5.100	2.600
Particles	mg/m³(s,d)	6,1	6,6	3,9	4,2	-	-
Oil mist	mg/m³(s,d)	3,3	1,8	1,5	0,75	-	-
Emissions							
Ozone	g/h	-	3,0	-	4,2	-	4,3
Odour	OU/s	6.500	2.600	4.800	2.700	3.800	2.000
Odour for dispersion modelling (OML) (*SQRT(60))	mio OU/s	0,051	0,020	0,037	0,021	0,030	0,015
Particles	kg/h	0,015	0,017	0,010	0,011	-	-
Oil mist	kg/h	0,0085	0,0045	0,0039	0,0020	-	-

(s,d) indicates dry gas at standard conditions (0°C, 101,3 kPa)
(20°,w) indicates humid gas at standard condition (20°C and 101,3 kPa)
Average value for odour is calculated as gemetric average value

It can readily be seen from the results that the odour concentrations are lower when JIMCO KPC is switched on. This is outlined in details in the following.

3.1.1. Ozone

Some ozone is present in the exhaust of the system. We have estimated the amount of ozone reacted relative to the amount of ozone generated.

The initial installation comprised 10 single 89 kW lamps (four at the grill and three at each deep fry)[2]. Extra lamps were installed at the grill (200 kW[2]). We are informed that one 79 kW lamp generates 0,7 g ozone/hour. Assuming that 89 kW lamps generate ozone proportionally the following generation takes place – see Table 3:

Table 3 Ozone generation in the installed lamps

Lamps	Effect per lamp	Effect, total	Ozone generation
number	kW	kW	g/hour
10	89	890	7,9
8	25	200	1,8
-	-	1090	9,7

The emission of ozone varies on the three days between 3,0 g/h and 4,3 g/h – 31% to 43% did not react. This amount is still present in the sample bags and has time to react further before analysis. On the opposite the figures show that from 57% to 69% of the ozone reacts.

[2] Information from Martin Bendix, JIMCO A/S

At the time of odour analysis ozone is still present in some samples – app. 5% of the total generated ozone. It indicates that the ozone reaction has continued in the sample bags but also that the ozone reaction is slow.

3.1.2. Odour

From the observed odour concentrations the efficiency of the JIMCO KPC is calculated by means of the instructions in EN 13.725[3], annex H - see Table 4 .

Table 4 Calculated efficiency of the JIMCO KPC

Date	Start	End	$C_{raw\ gas}$	$C_{clean\ gas}$
03-12-12	17:36	18:02	8.400	3.500
03-12-12	18:11	18:37	8.700	5.300
04-12-12	16:58	17:24	4.900	2.800
04-12-12	17:32	17:58	6.900	3.000
04-12-12	18:07	18:32	6.800	3.900
04-12-12	18:41	19:05	6.400	3.700
05-12-12	12:11	12:33	4.500	2.000
05-12-12	12:37	13:00	5.000	3.300
05-12-12	13:05	13:30	5.700	2.800
Odour reduction in average			48%	
95% confidence interval (%)			34% to 58%	

Table 5 shows the odour character of the samples. The samples with UV (clean gas) have characters like “chemical, sweet, earthy, citrus” together with the character of kitchen. The samples without ozone have kitchen characters “deep fry oil, warm oil, food”. The reaction might have continued and at least some masking takes place by the rest ozone. Consequently the results are not fully representative for the real concentration leaving the duct.

Table 5 Odour characters of the samples and ozone in clean gas samples

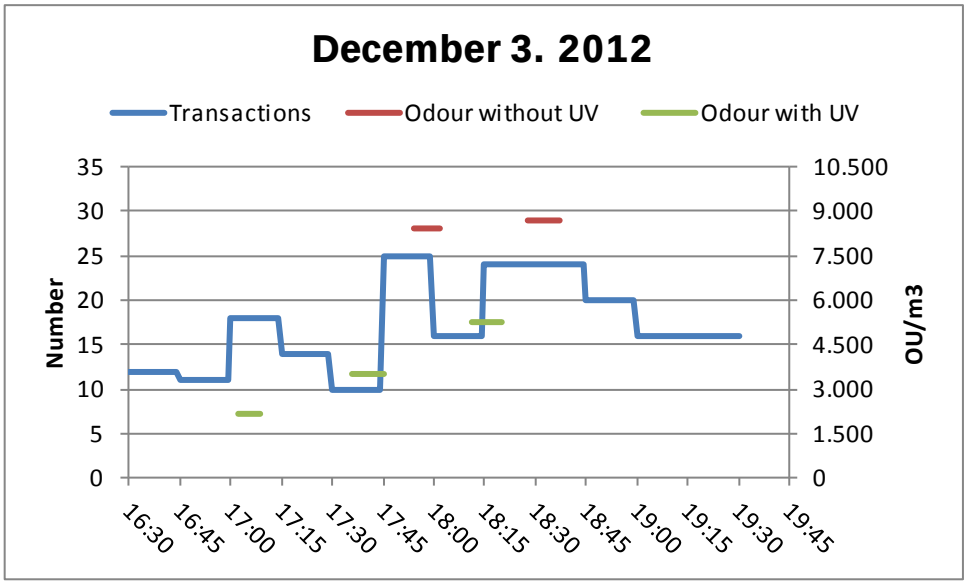
Date	Start	End	Raw gas	Clean gas	Ozone (ppm)
03-12-2012	17:36	18:02	hot iron, cake, deep fry oil, hot oil	lemon, citric acid, chemical, wet grass, coffee	0,6
03-12-2012	18:11	18:37	deep fry oil, hot oil, baking	sour, hot oil, cake, deep fry oil, coffee	0,7
04-12-2012	16:58	17:24	deep fry oil, hot oil	lemon, chemical, deep fry oil, paraffin	>0,8
04-12-2012	17:32	17:58	deep fry oil, chemical, hot oil	lemon, chemical, deep fry oil	0,9
04-12-2012	18:07	18:32	deep fry oil, grease, stearic, paraffin	deep fry oil, chemical	0,75
04-12-2012	18:41	19:05	deep fry oil, grease, chemical	deep fry oil, hot grease, nuts	0,9
05-12-2012	12:11	12:33	earthy, pork rinds, deep fry oil, cooking	resin, chemical, sweetish, lemon	1
05-12-2012	12:37	13:00	deep fry oil, grease	deep fry oil, chemical, lemon	0,9
05-12-2012	13:05	13:30	deep fry oil, grease	deep fry oil, chemical, lemon	0,9

The efficiency measured app. 12 hours after sampling is app. 50%. Taking above mentioned information about ozone and the odour character into consideration, we can not be sure that the real efficiency when leaving the exhaust is 50%. It is, however, our experience that pure ozone without the UV effect reacts to a much poorer extent before leaving the exhaust from kitchens like the one in question.

[3] EN 13.725, Air quality, odour concentrations, 2003.

Figure 1 shows the relationship between the activity in the restaurant and the odour concentrations (with and without the JIMCO KPC switched on) on December 3rd. The blue line shows the number of transactions per 15 minute. The red lines show the odour concentration without JIMCO KPC switched on, and the green lines show the odour concentrations with JIMCO KPC switched on. There is only two measurements without JIMCO KPC switched on due to a defective sample bag. The loss of samples was compensated on December 4th. by taking four sample sets.

Figure 1The relationship between the activity in the restaurant and the odour concentrations (December 3rd)



The picture is not quite clear but indicates, however, no direct relationship between activity and odour concentration. It is likely that the JIMCO KPC contribute to the lower concentrations when the system is switched on.

The next Figure 2 shows the relationship between the activity in the restaurant and the odour concentrations (with and without the JIMCO KPC switched on) on December 4th.

Figure 2 The relationship between the activity in the restaurant and the odour concentrations on (December 4th)

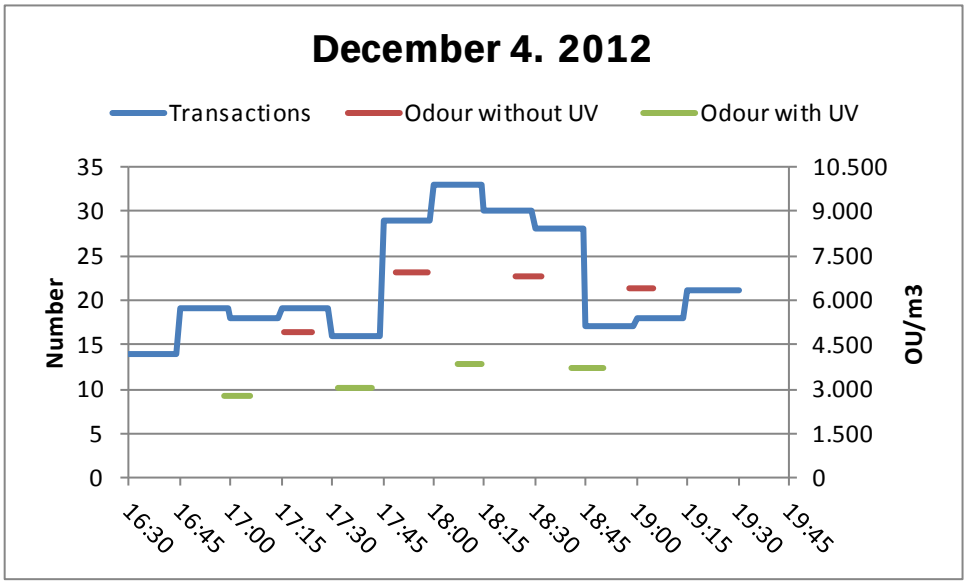
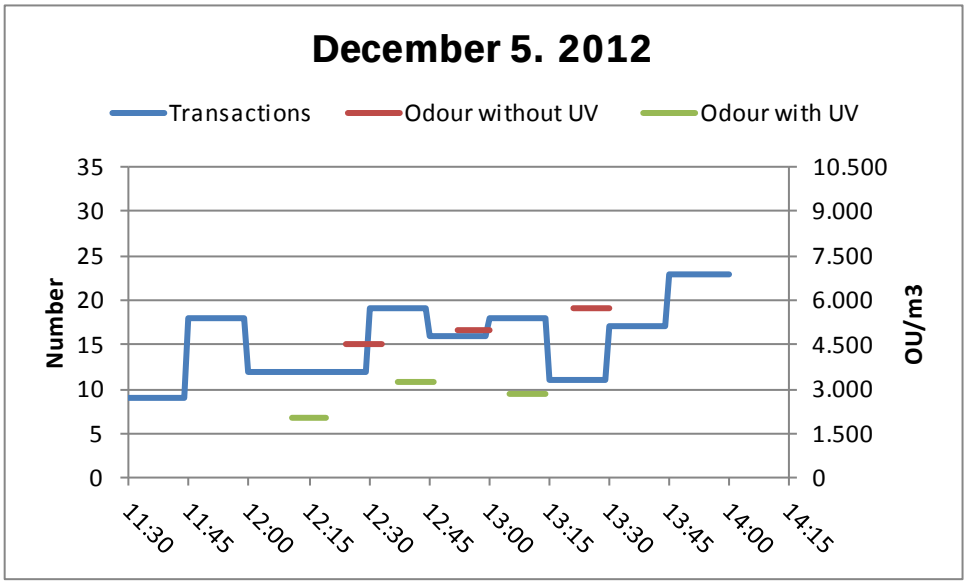


Figure 2 indicates clearly the effect of JIMCO KPC. Except for sample set two the activity levels are comparable in each set of samples or even higher when JIMCO KPC is switched on – and the odour concentrations are always lower when the JIMCO KPC is switched on.

Figure 3 shows the relationship between the activity in the restaurant and the odour concentrations (with and without the JIMCO KPC switched on) on December 5th.

Figure 3 The relationship between the activity in the restaurant and the odour concentrations on (December 5th)



Also this Figure 3 supports the effect of JIMCO KPC.

Table 6 below shows the average number of transactions per hour in periods with and without JIMCO KPC switched on. The samples from December 5th were drawn at lunch time, where the activity traditionally is lower than at dinner time.

Table 6 The average number of transactions per hour in periods with and without JIMCO KPC switched on

Date	Without JIMCO KPC	With JIMCO KPC
03-12-2012	80	70
04-12-2012	95	95
05-12-2012	57	65

The number of transactions support the assumption that period without and with JIMCO KPC switched on is comparable.

3.1.3. Effect of reacted ozone in the sample bags

The test plan comprises a test of the long term effect of ozone present in the sample bags compared to the overall effect of the JIMCO KPC system. An initial experiment was done: a sample of raw gas was split into three sample bags. To one sample bag was added app. 1 ppm ozone, to another sample bag was added app. 5 ppm ozone and the last sample bag remained untreated. All three samples were analyzed for odour after app. 16 hours. The results are shown in Table 7.

Table 7 Results of odour samples

Sample	Ozone (ppm)	Odour (OU/m^3)	Odour character
Untreated	0	6.400	baking, chemical, hot oil, ironing
Treatment 1	1	2.700	sweetish, chemical, synthetic flowers
Treatment 2	5	3.900	chemical, laundry, washing powder

The odour characters indicate that ozone is what the panelists primarily perceive from the samples with ozone. The higher odour concentration in the sample with more ozone supports this indication. The ozone has apparently not disappeared from the samples, and masking of the original kitchen odour is consequently significant. The test is consequently not feasible.

The JIMCO KPC treatment comprises the reaction of the UV radiation and ozone. Our ozone treatment is only a treatment with ozone, and in this context the ozone reaction might not be completely comparable.

The odour characters in the treated samples from the restaurant (Table 5) show that the original kitchen odour is still present in most of the samples along with some contribution from the ozone.

3.1.4. System odour

Before the test was initiated work was done to clean the ventilation hoods and ducts as much as possible, and low concentrations of system odour was achieved (300 – 500 OU/m^3). Low concentrations were also dependent of the deep fry oil quality, and consequently several factors influence the odour.

It was assumed that the JIMCO KPC treatment would keep the exhaust system clean and free of deposits of grease and oil. It was consequently assumed that the system odour (without production) would be a good parameter for documentation of the cleaning effect of the JIMCO KPC system. It was intended to follow the system odour with weekly samples from the exhaust system drawn in the morning before opening time. The results of morning samples from the first test week are shown below in Table 8. The samples are drawn on two mornings the day after the test sampling.

Table 8 Results of system odour (morning)

Date	Sample 1 (OU/m^3)	Sample 2 (OU/m^3)
04-12-12, morning	5.400	6.000
05-12-12, morning	5.500	4.000

The results show that the system odour is much higher than the initial level of the clean system. The cleaning effect was consequently not satisfying. Therefore the weekly testing was not implemented.

3.1.5. Particles/ oil mist

The results of the measurement of particles and fatty acids are shown in the Table 9 below.

Table 9 Results of the measurement of particles and fatty acids

Date	Treatment	Particles (mg/m^3)	Fatty acids (mg/m^3)
03-12-2012	Without JIMCO KPC	6,1	3,3
	With JIMCO KPC	6,6	1,8
04-12-2012	Without JIMCO KPC	3,9	1,5
	With JIMCO KPC	4,2	0,75

The level of particles and fatty acids decreases significantly from December 3rd to December 4th. An explanation might be that the deep fry oil was discarded in the night between the two days and replaced with new oil. This is not investigated further but is in good agreement with our experience that old oil have a tendency to emit smoke when heated.

While the amount of particles does not decrease as an effect of the JIMCO KPC (on the contrary it increases), the amount of fatty acids is reduced app. 40% on both days. This is an important finding because this effect is not influenced by further reaction with ozone from sampling to analysis. Once sampled on the filter the particles are no longer in contact with the gaseous ozone.

Despite the relatively low number of results they seem to significantly show a reaction between UV radiation, ozone and fatty acids. This significant effect also supports to some extent the findings of 50% odour reduction.

Further analysis of the fatty acid fraction shows the composition of fatty acids. This is shown in the following Table 10. C14:0 indicate a fatty acid with 14 carbon atoms and no double bonds (saturated). C16:1 indicate a fatty acid with 16 carbon atoms and one double bond (unsaturated).

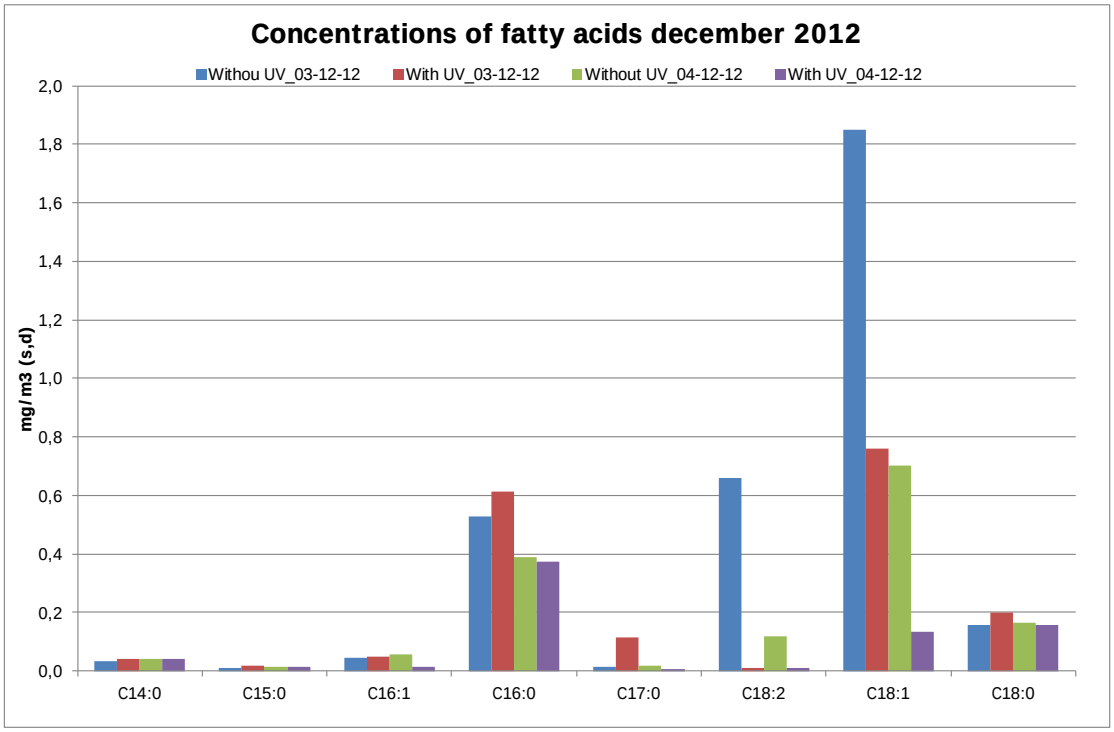
Table 10 Fatty acid fraction

Fatty acid		Without UV	With UV	Change	Without UV	With UV	Change
No. of C	Common name	mg/m^3 (s,d)		%	mg/m^3 (s,d)		%
C14:0	Myristic acid	0,033	0,040	20	0,042	0,040	-5
C15:0	Pentadecylic acid	0,010	0,016	64	0,013	0,013	-5
C16:1	Palmitoleic acid	0,046	0,049	5	0,055	0,013	-77
C16:0	Palmitic acid	0,529	0,614	16	0,388	0,374	-3
C17:0	Margaric acid	0,013	0,116	774	0,018	0,007	-58
C18:2	Linoleic acid	0,661	0,009	-99	0,119	0,011	-91
C18:1	Oleic acid	1,850	0,758	-59	0,701	0,135	-81
C18:0	Stearic acid	0,159	0,199	25	0,164	0,157	-4
Sum		3,300	1,800	-45	1,500	0,750	-50

The picture is not quite clear, e.g. margaric acid is significantly increased on the first day and reduced on the second day. Palmitoleic acid is significantly reduces on the second day while unchanged on the first day. The concentrations are, however, very low and random production variations might be part of the explanation. For the actual investigation it is important that the sum of fatty acids is reduced with app. 50% on both days.

Figure 4 shows the concentrations in bars.

Figure 4 Graphic illustration of the fatty acid concentrations



These results show that two major unsaturated fatty acids react and are significantly reduced. Linoleic acid with its two double bonds is reduced to almost nothing on both days.

3.2. TEST PERFORMANCE OBSERVATION

3.2.1. Deposition of grease in the exhaust system

It was quite early realised that the JIMCO KPC system could not totally prevent deposition of grease on the inspection doors and the inside of the exhaust system. Though not overwhelming the deposition was significant and we assessed that weekly description of the deposit would not give the best picture of effect of JIMCO KPC. Consequently we selected another method.

After a period with the JIMCO KPC system switched on day and night (except for the short sampling periods with the system switched off) the inspection doors were removed and replaced by new ones. The JIMCO KPC was switched off. The inspection doors were weighed followed by removing the grease mechanically and by means of organic solvents. The inspection doors were weighed again, and the removed grease was weighed.

After a period with the JIMCO KPC system switched off the procedure was repeated with the replaced inspection doors.

All the weight differences are recalculated into deposition per m^2 per day. The results are shown in the following Table 11.

Table 11 Weight differences of grease depositions

Inspection door	With UV		Without UV	
	Days	g/m^2/day	Days	g/m^2/day
Deep fry, pommes frites	53	0,31	28	0,30
Deep fry, other	53	0,90	28	0,59
Grill, west door	53	7,9	28	8,0
Grill, east door	53	3,7	28	2,9

The restaurant has informed that there were 45.288 transactions during the 53 days with UV (854 per day) and 24.936 during the 28 days without UV (890 per day). This indicates that the two periods are comparable.

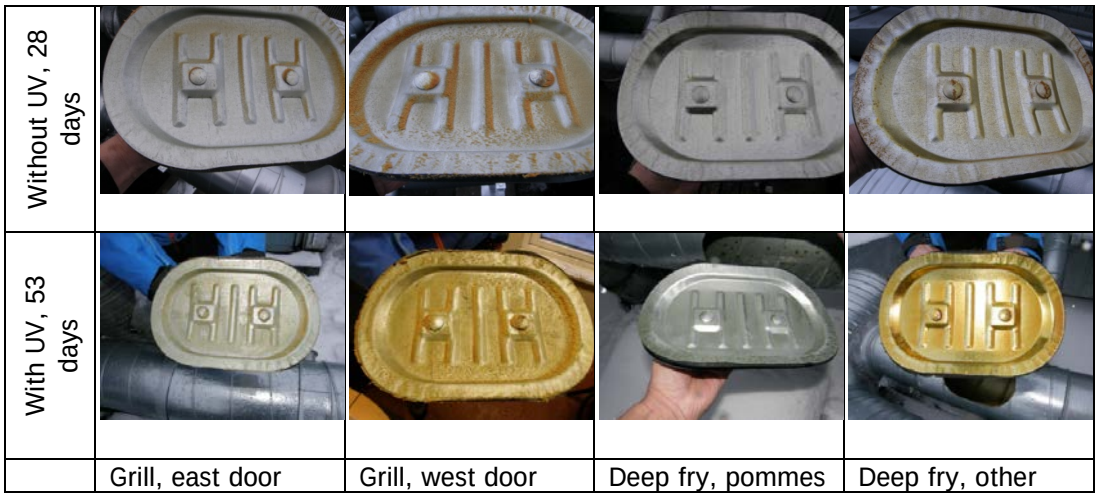
The results show that the total amount of deposit on each inspection door is not reduced by the Jimco KPC system. The levels of deposit are with UV are in the same range or even a little higher than with no UV.

The deposit might, however, have another composition when the Jimco KPC system is applied as with the composition of the collected particles/oil mist, see 3.1.5.

3.2.2. Pictures of the exhaust system

Below pictures show the inspection doors after periods with and without the JIMCO KPC system switched on. It is worth to notice that the period without the system switched off was only 28 days while the system was switched on for 53 days.

Figure 5 Inspection doors – with and without JIMCO KPC system switched on



It is worth to notice that the west door in the grill exhaust is placed in the side where the flow hits the door directly. The east door is on the opposite side and is not hit directly.

The pictures show a significant yellow coloured deposit on two of the inspection doors when UV is switched on. For the inspection door on “deep fry, other” it is worth to notice that the material was very difficult to remove, neither with pentane nor with dichloromethane. The material seems to have polymerized.

The material on all the inspection doors was easy to remove, when the UV was not switched on. The reaction with ozone and UV seems to alter the grease, and this is in good agreement with findings in Table 10 and Figure 4 showing significant changes of the fatty acid composition.

It is an interesting finding that the deposition on the door in the exhaust from the deep fry, pommes frites, is significantly different from the deposition on the door in the exhaust from the deep fry, other, when the JIMCO KPC system is switched on. We have no verified explanation, but we exclude the possibility of significantly more production in the deep fry, other. Normally pommes frites are included in all menu and we assume that the activity in the deep fry, pommes frites, more likely is the highest deep fry activity.

The apparently different effect must have something to do with the lamps or the conditions in the exhaust from the deep fry, pommes frites. The installed effect of the lamps is identical in the two deep fry exhaust and as far as we have observed when sampling, both systems have worked satisfying. The restaurant has informed that the oils in the two deep fry systems are identical. The temperature in the pommes frites section is 168°C but 182°C in the other section. In the other system fish and chicken is cooked – all breaded. The temperature and the breading might have an effect on the emission.

3.2.3. Evaluation of the hoods in the kitchen

On the day where the inspection doors were replaced (after 60 days with the JIMCO KPC switched on) we also inspected the hoods in the kitchen. The major finding is that walls in the hoods were dry and not sticky from grease.

In the hood over the grill only two of three sections were provided with a set of JIMCO KPC lamps. Figure 6 shows a possible effect of the lamps.

Figure 6 The interior of the grill hood with the JIMCO KPC system switched on – after 53 days

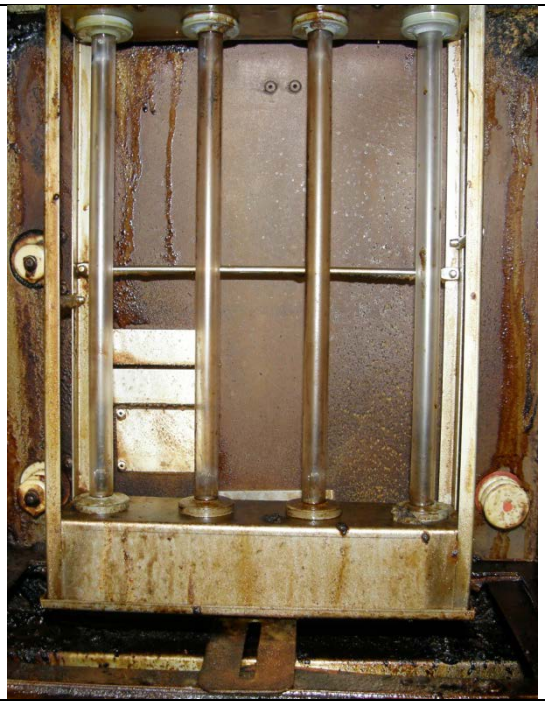
Three sections in the grill hood	Section in the grill hood with no lamps	Sections in the grill hood with lamps

The back walls of the sections with lamps are significantly cleaner than the back wall of the section without lamps.

On the day where the inspection doors were replaced again (after 28 days with the JIMCO KPC switched off) we also inspected the hoods in the kitchen again. There was not a significant change – the surfaces were still not sticky. Figure 7 compare the deposit on the

wall behind one set of lamps with and without the JIMCO KPC system switched on. This comparison indicates more deposit after 28 days without the JIMCO KPC system switched off.

Figure 7 Deposit on one wall section.

	
With UV – 53 days	Without UV – 28 days

3.3. TEST QUALITY ASSURANCE SUMMARY, INCL. AUDIT RESULT

All calculations are controlled by FORCE Technology's normal procedure for quality assurance and the procedures for internal audits are followed /1/.

3.4. AMENDMENTS TO AND DEVIATIONS FROM TEST PLAN

One test person, Thue Grønhøj Frederiksen, was replaced with Steen Meldorf for employment reasons. This change has no effect on the performance of the test.

Due to the findings in section 3.1.3 it was not possible to perform the ozone test according to the Test Plan, November 2012.

It was intended to follow the system odour with weekly samples from the exhaust system drawn in the morning before opening time. The results of morning samples from the first test week showed, however, that the system odour is much higher than the initial, low level of the clean system. The cleaning effect was consequently not satisfying though not totally absent. Therefore the weekly testing was not implemented.

When it was realised that the JIMCO KPC system could not totally prevent deposition of grease on the inspection doors and the inside of the exhaust system it was assessed that weekly description of the deposit would not give the best picture of effect of JIMCO KPC. Consequently the test method was replaced by determination of the deposits (g grease/m^2/day) in periods without and with the JIMCO KPC system switched on.

See appendix B for more information.

4. REFERENCES

/1/	ETV Test Centre and Test Organisation. Centre Quality Manual – Air and Energy Technology. FORCE Technology Document version 3. March 2012.
/2/	FORCE Technology DANAK accreditation no. 51. Accreditation to testing Environmental samples: Air, water, soil, waste. Etc
/3/	FORCE Technology DANAK accreditation no. 65. Accreditation to analyse Environmental samples: Air, water, soil, waste. Etc.

Appendix A

Terms and definition

ETV	Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and adequate quality assurance.
Evaluation	Evaluation of test data for a technology product for performance and data quality
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance
QA	Quality assurance
Standard	Generic document established by consensus and approved by a re-cognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Test/testing	Determination of the performance of a product for parameters defined for the application
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

Appendix B

Amendment and deviation information

JIMCO VERIFICATION PROTOCOL NOVEMBER 2012 - JIMCO TEST PLAN, NOVEMBER 2012

No.	Date of action	Amendment content	Deviation	Reason for change	Corrective active action	Impact of change	Originated by
1	13/11 2012	Time schedule is changed.		Proposer considered whether to continue with the test after the pretest	New test period starts 3/12 2013-02-01	The test started app. four weeks later than scheduled. This has no effect on the test.	MKO
2	30/11 2012	Change of one test person		Due to illness the first appointed technician was replaced	Another technician was appointed	No effect on the test	AOX
3	17/1 2013		No ozone test	The test was not feasible within the time frame and due to unforeseen difficulties with identification of ozone odour.		Critical for the evaluation of odour concentrations	AOX
4	4/12 2012		No weekly test of system odour – only two days test of system odour	The system odour showed to be significant early in the test period. Not relevant.		No effect on the conclusion	AOX
5	4/12 2012		No weekly test of deposit – test of deposit in two long periods with and without UV	The increase of deposit was not possible to register per week by visual inspection.	The deposits were determined quantitatively for longer periods	More conclusive results	AOX

Date 01/01 2013
Test responsible
Approved by

Arne Oxbøl (AOX)
Signature

Date 01/01 2013
Test center manager
Approved by

Marianne Kyed Ørbæk (MKO)
Signature