Dear Chair Henderson, Commissioner DeBone, Commissioner Adair,

Thank you for giving me an opportunity to provide feedback on the current regulations and Ordinance Number 2019-012, more specifically the reconsideration of text amendments to the Deschutes County Code refining the regulation and enforcement of marijuana production on rural lands, which were originally adopted as Ordinance No. 2018-012. Those proposed amendments to the Deschutes County Code were discussed during eight work sessions starting on Aug 2, 2018. During the first public hearing process it was stated in the record multiple times that the proposed changes to the code will make programmatic changes to the regulation and enforcement of marijuana production on rural lands. In addition, the Planning Commission work session that reviewed these rules can be found at the following address: http://deschutescountyor.iqm2.com/Citizens/SplitView.aspx?Mode=Video&MeetingID=2047&Format=Agenda There was certainly a tone of apprehension in addition to discussion that these rules overstep what is reasonable in specific cases. I am still concerned about the proposed text amendments because they will impact the workability for farmers in Deschutes County and continue to set precedence that farming rights and farmland will not be preserved. The proposed text amendments are not reasonable additions to the code and should not be adopted.

I would like to get on the record again, that the Deschutes County Comprehensive Plan specifically calls for Deschutes County to preserve farmland and protect both current and future agricultural opportunities via the Exclusive Farm Use Zone by supporting stakeholders in studying and promoting economically viable agricultural opportunities and practices (DCCP, Policy 2.2.10) and encouraging small farming enterprises, including, but not limited to, niche markets, organic farming, farm stands or value added products (DCCP, Policy 2.2.11). I do not believe that the proposed amended changed meet these guidelines as they do not encourage small farms or the other goals mentioned above.

In my reading of the proposed code I wanted to highlight just a few of my many concerns specific to the proposed code changes:

Increases in setbacks, and separation distances will eliminate compatibility for small farming enterprises and niche markets. The increase in neighbor notification is concerning, and would likely trigger even more public input, making this process on the country even more financially burdensome. This is especially burdensome when “hemp” farms do not follow any of these code requirements and yet from a taxonomy and genetics perspective, “hemp” and “marijuana” are the same cannabis plants, expressing different traits in the same way a black tailed deer and a white tailed deer are related to one another.

The changes to odor and noise will continue to add more burden the application process put on the applicant. More specifically on the noise and odor letter, I am increasingly concerned that licensed engineer letters (roughly $2000-$3000 cost to the applicant) are being dismissed by Commissioners during review. This occurs after highly qualified planning staff and hearings officers have approved the letters. I would like to put in the record to review the odor and noise letters for 247-18-000887-AD and 247-18-000890-AD, these two applications were submitted on the same day. In both of these cases the same engineer from ColeBreit Engineering created odor and noise letters. The noise and odor letter for 247-18-000887-AD, which is my family's application, was approved without question. The noise and odor letter for 247-18-000890-AD was held under scrutiny by both Commissioner Henderson and Commissioner Adair during deliberations. Furthermore, if you look at both the production (247-17-000040-AD) and processing (247-18-000887-AD) from my family's farm, both which were approved without question, we proposed to use the same odor technology solutions as the application for 247-18-000890-AD. There must be fair standards by which my cannabis community is held to and I fear that the changes being proposed in the code Ordinance No. 2018-012 / Ordinance Number 2019-012 will continue to isolate and stifle one group of farmers.

This leads me to a big picture issue and perhaps the most concerning one; the recent conditions upon which we, as a county, are denying cannabis land use has become a moving target. Recently many subjective qualifiers for denial that are not in the code to begin with are becoming grounds for an application to get denied. This is made more concerning when you consider that these denials are occuring after highly qualified planning staff and/or code officers have found the application to meet code. It is the duty of the County to make clear standards from which an applicant should base their burden of proof from and daniels cannot be a moving target. This is absolutely unworkable and on its face, it is not treating all farmers in rural Deschutes County with fair consideration.

Lastly, I would like you to consider the specific experience that my family has had navigating this process starting in 2015. We purchased 15 acres of Exclusive Farm Use zoned land in early 2015 and we only just started building out facilities a few months ago. The County “opted out” of cannabis businesses by the end of 2015 which made fundraising and maintaining ownership of our company, Glass House Grown, impossible as it was unclear if the 15 acre parcel we owned would be allowable for an OLCC farm. The opt out and the subsequent land use application process to follow would also cause our family to have significant delays associated with entering the OLCC market. As a family owned and operated business that was bootstrapping every dollar, we did not have the luxury of hiring lawyers or consultants to help with the land use process, so every step took so much longer. To date we have spent roughly $25,000 on both applications with the County. By the time we got our approval for cannabis production in early 2017, we had lost any legal ability to make sales in the regulated medical market due to rule changes from OLCC and OHA that forced the market to shift to recreational facilities. As a family and business that puts intergy above all, we accepted that our livelihood of generating revenue from growing cannabis had been cut off and we survived off debt as we worked towards our vision for the farmland. Its challenging to estimate how much profit we lost as a result of the events that followed the “opt out” in 2015, but arguably we lost 1-2 years of revenues depending on how

quickly we would have executed the build out. By our projections, that's roughly $700,000 to $1,400,000 in profits that we lost. Beyond losing profits, our craft cannabis company lost out on vital branding and marketing opportunities as the industry was coming on board to OLCC driven markets, and to that we can never put a value to.

Thank you for considering my comments and as you know I look forward to seeing workable regulations for Deschutes County farmers.

Lindsey Pate
CEO and Co-Founder, Glass House Grown
Rural Resident of the Terrebonne EFU Zone
Mailing Address: L.Pate, 2660 NE Hwy 20, Ste 610-443, Bend OR, 97701

S2O Dynamics

Cannabis Odor and Noise Report

To: **Cameron Yee**

From: **Laura Breit, PE**

Date: **November 21, 2018**

QUALIFICATIONS

I am a mechanical engineer licensed in Oregon #79874PE. Our company has provided several dozen of these reports since 2016. While not a qualification by itself, this has involved extensive research, development of our own techniques, and a deeper understanding of the factors at play, including:

-Common practices and requirements from other jurisdictions, and the effects of these as the cannabis industry matures

-Efficacy and required maintenance of various methods, such as carbon filtration and fogging

-Demonstration of odor & noise compliance at not-yet-constructed sites

SUMMARY

This report addresses noise and odor mitigation for a growing facility located at 25606 Alfalfa Market Road, Bend, OR 97701, owned and operated by S2O Dynamics. S2O Dynamics is a partner of Lunchbox Alchemy, a well-known cannabis producer headquartered in Bend.

The growing facility consists of five greenhouses, two of which are currently existing, although they are not yet being used for cannabis cultivation. These two greenhouses are 30’ x 96’, and the planned greenhouses are 30’ x 132’. All greenhouses will use pass-through ventilation with two 50” J&D Typhoon wall-mounted exhaust fans. ColeBreit engineering conducted a site visit on November 19th, 2018, to record noise levels during operation of the two existing greenhouses. This information will be used to demonstrate current noise levels, and will be used to extrapolate expected noise levels for future operation of all 5 proposed greenhouses. All ten exhaust fans will be on automatic controls, preventing nighttime operation of outdoor equipment between the hours of 10:00 pm and 7:00 am.

Odor in each greenhouse will be neutralized with a Fogco fogging system, designed to spray odor neutralizer into the airstream of any greenhouse exhaust fans any time they activate. A system specific to this site has been designed and provided by Fogco. CAD schematics of this design are included in this report.

The site also includes a 10’ x 10’ x 7’ prefabricated composting shed of solid construction, which will require odor mitigation separate from the fogging system.

Further considerations of odor and noise from grow spaces and all exterior equipment will be discussed within this report.

Fig. 1: Satellite image of existing greenhouses, future greenhouse locations marked

See *Appendix A* for additional building plans.

Specification sheets on all HVAC and outdoor equipment, and odor control products, can be found in *Appendix B.*

Site layout, equipment and structure positioning, and geography will impact the propagation of noise from this equipment. This will be discussed further, and photographs taken by ColeBreit Engineering during the November 19th site visit can be found in *Appendix C.*

CANNABIS ODOR ANALYSIS AND CALCULATION

Applicable Standard

The Deschutes County code DCC 18.116.330(B)(10) reads:

Odor. As used in DCC 18.116.330(B)(10), building means the building, including greenhouses, hoop houses, and other similar structures, used for marijuana production or marijuana processing.

> a. The building shall be equipped with an effective odor control system which must at all times prevent unreasonable interference of neighbors' use and enjoyment of their property.

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b. An odor control system is deemed permitted only after the applicant submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the system will control odor so as not to unreasonably interfere with neighbors' use and enjoyment of their property.

c. Private actions alleging nuisance or trespass associated with odor impacts are authorized, if at all, as provided in applicable state statute.

d. The odor control system shall:

i. Consist of one or more fans. The fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the required CFM or

ii. Utilize an alternative method or technology to achieve equal to or greater odor mitigation than provided by (i) above.

e. The system shall be maintained in working order and shall be in use.

Odor Mitigation Technology Review

Activated Carbon Filtration has been utilized in many industries for many years, and is considered a proven technology. Due its relatively low first cost, it is a common odor control method for cannabis facilities.

Vapor-phase odor neutralization has seen several years of successful usage in wastewater treatment and agriculture. Many neutralizer solutions have been developed, with an increase of biodegradable solutions. Recently, this technology has been applied to cannabis cultivation as an odor mitigation technique. It is less common than activated carbon, but has been used widely enough to be considered as a standard form of odor control.

See *Appendix D* for information gathered, including:

A. Technology Overview
B. Activated Carbon as a recognized odor control method in cannabis
C. Activated Carbon as a recognized odor control method in other industries
D. Activated Carbon has lowest first cost
E. Vapor-phase odor neutralization in wastewater treatment
F. Vapor-phase odor neutralization in agriculture

See *Appendix E* for requirements of other jurisdictions.

Proposed Odor Mitigation Design

Odor mitigation systems at this site consist primarily of a system professionally designed by Fogco. The system will use fogging rings attached to the outlet of both exhaust fans on each greenhouse to spray an odor-neutralizing solution called "Odor Armor 420" directly into the exhaust airstream. Fan and fogger controls will be wired so that fans can only operate between the hours of 10:00 pm and 7:00 am, and fogging equipment will activate any time a fan activates. Refer to *Appendix B* for images of typical fog ring system installations and statements regarding the efficacy and safety of Odor Armor 420. Fogco has additionally provided a complete submittal for all system components, which can be provided upon request.

Additionally, the composting shed will require a carbon filter attached to an inline fan to adsorb odors within the shed, sized in accordance with Deschutes County code, at no less than one third of the structure volume. Given a size of 10’ x 10’ x 7’, the shed volume is 700 cubic feet. One third of this is 234 cubic feet. We recommend usage of 8” Max-Fan with an attached Can 100 carbon filter, capable of 580 CFM. Any alternative fan and filter combination capable of similar CFM will be suitable as well. Our recommended CFM is oversized to further decrease the chances of odors leaving the structure beyond the minimum code requirement.

Can-Filters

Can 100 SKU: 358710

Recommended Exhaust CFM: 840 CFM / 1400m3h @ 0.1 sec contact time
Prefilter: Yes
Flange: 8" - 10" - 12"
Dimensions: *(with pre-filter)*
- Outside Diameter: 42 cm / 16.5"
- Height: 100 cm / 39.4”

Weight: 47 kg / 103 lbs.
Carbon Weight: 37 kg / 81.5 lbs.
Carbon Bed Depth: 6.5 cm / 2.56"
Max Operating Temp: 80˚C / 176˚F
Pressure drop at max CFM: 180pa / .75"wg

Recommended Fan:

FAN	Filtered Air CFM	Watts
14" Max-Fan™	958	240
12" Max-Fan™	1260	488
12" Can-Fan® HO	825	310
10" Max-Fan™	834	228
10" Can-Fan® HO	641	267
8" Max-Fan™	580	165
8" Can-Fan® HO	600	278

Can 75 SKU: 358715

Recommended Exhaust CFM: 600 CFM / 1000m3h @ 0.1 sec contact time
Prefilter: Yes
Flange: 6" - 8" - 10" - 12"
Dimensions: *(with pre-filter)*
- Outside Diameter: 42 cm / 16.5"
- Height: 75 cm / 29.5"

Total Weight: 36 kg / 79 lbs.
Carbon Weight: 28 kg / 61.6 lbs.
Carbon Bed Depth: 6.5 cm / 2.56"
Max Operating Temp: 80˚C / 176˚F
Pressure drop at max CFM: 180pa / .75"wg

Recommended Fan:

FAN	Filtered Air CFM	Watts
12" Max-Fan™	1080	475
10" Max-Fan™	747	225
10" Can-Fan® HO	595	270
8" Max-Fan™	550	162
8" Can-Fan® HO	550	280
8" Can-Fan®	407	130
6" Can-Fan® HO	338	136

Fig. 2: Can-Filters’ Can 100 Filter

8" Max-Fan™

SKU: 340420

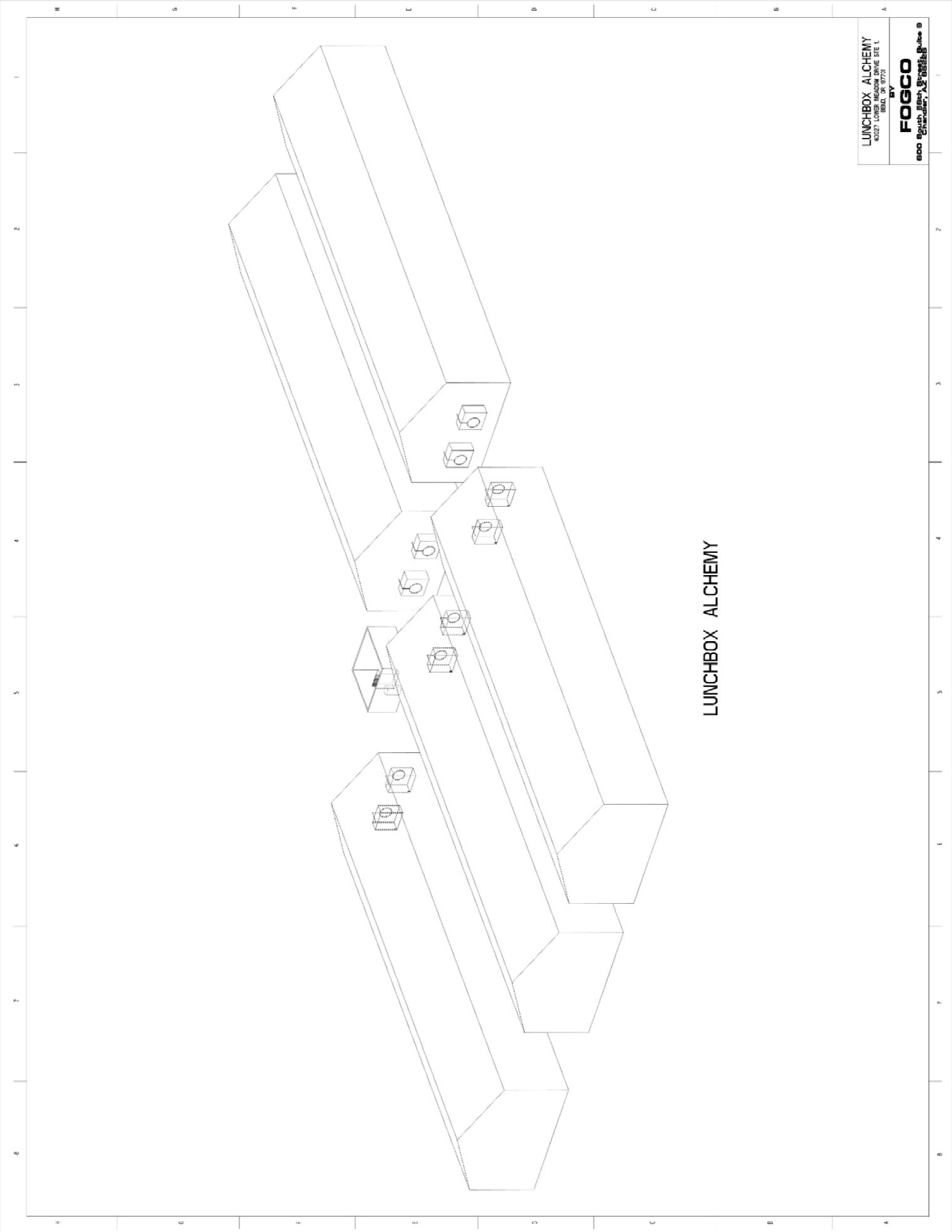
CFM	667 at 0wg
RPM	3250
Max Watts	179
Amps	1.5 @ 120 VAC 60 Hz
Sones	
Diameter	8"
Length	8 7/8"
Blade Design	Mixed Flow
Housing	Plastic
Inlet/Outlet	8"

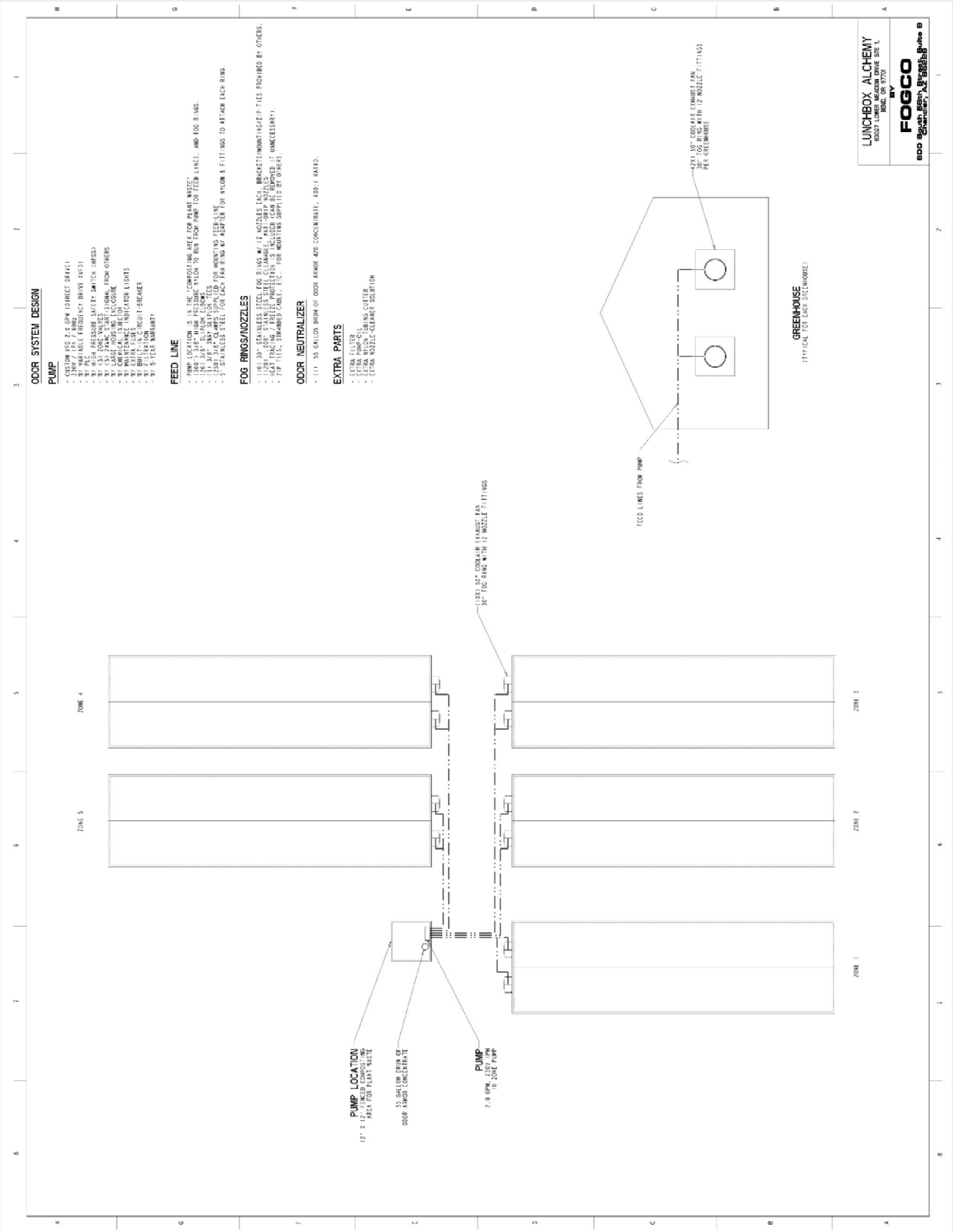
PERFORMANCE AT PRESSURE

						Free Air				Fan Attached to Filter						
FAN MODEL	SPEED	RPM	VOLTS	MAX WATTS	MAX AMPS	0"	.125"	.25"	.375"	.5"	.75"	1.0"	1.25"	1.5"	MAX in. wg	DUCT DIA.
6" Max-Fan™	High	3303	115	75	0.65	334	322	309	296	283	255	225	187	13	1.546	6?
	Med./High	2944	115	66	0.58	264	253	238	221	205	175	143	93	N/A	1.405	
	Medium	2351	115	53	0.49	201	176	153	131	116	82	24	N/A	N/A	1.132	
8" Max-Fan™ *667 CFM*	-	3250	120	179	1.5	667	650	630	610	585	520	420	150	100	1.84	8"
8" HO Max-Fan™	High	2935	115	213	1.87	932	899	869	840	803	723	638	340	208	2.064	8?
	Med./High	2705	115	188	1.71	849	802	770	729	687	600	465	270	110	1.803	
	Medium	2460	115	178	1.62	749	703	660	613	568	477	316	140	N/A	1.469	
10" Max-Fan™ *1019 CFM*	-	2990	120	228	1.9	1019	985	950	920	885	815	705	535	155	1.78	10"
12" Max-Fan™ *1708 CFM*	-	3374	120	489	4.1	1708	1680	1655	1630	1595	1530	1460	1380	1300	3.34	12"
14" Max-Fan™ *1700 CFM*	-	1700	120	253	2.1	1700	1630	1560	1490	1400	1150	240	N/A	N/A	1.19	14"

Performance certified is for installation type D - Ducted inlet, Ducted outlet.
Performance ratings do not include the effects of appurtenances (accessories). * Static Pressure at 0 W.G.

Fig. 3: Max-Fan CFM ratings and electrical data


LUNCHBOX ALCHEMY
63127 LOWER ALLOUNE DRIVE STE L
BEND, OR 97701
BY
FOGCO
800 South 58th Street, Suite B
Lincoln, NE 68510
LUNCHBOX ALCHEMY


ODOR SYSTEM DESIGN
PUMP
- CUSTOM VFD 2.6 GPM (DIRECT DRIVE)
- 1/2 HP 1800 RPM 115/230V
- 1/2 HP VARIABLE FREQUENCY DRIVE (VFD)
- W/ PLC
- W/ (1) PRESSURE SAFETY SWITCH (HPSS)
- W/ (3) ZONE VALVES
- W/ (3) 24VAC START SIGNAL FROM OTHERS
- W/ (1) LARGE VOLTS FREE CLOSURE
- W/ CHEMICAL TANK LOCK
- W/ MAINTENANCE INDICATOR LIGHTS
- W/ 115VAC 15A PLUG
- W/ BUILT-IN CIRCUIT BREAKER
- W/ FILTRATION
- W/ 5 YEAR WARRANTY
FEED LINE
- PUMP LOCATION IS IN THE COMPOSTING AREA FOR PLANT WASTE
- (300) 3/8" HIGH PRESSURE NYLON TO RUN FROM PUMP FOR FEED LINES, AND FOG RINGS.
- (30) 3/8" BRASS ELBOWS
- (31) 3/8" BRASS SELF LOCK TEES
- (250) 3/8" BRASS SELF LOCK TEES
- (2) 3/8" BRASS CAPS SUPPLIED FOR MOUNTING FEED LINE
- (2) STAINLESS STEEL FOR EACH FAN RING W/ ADAPTER FOR NYLON & FITTINGS TO ATTACH EACH RINGS.
FOG RINGS/NOZZLES
- (10) 30' STAINLESS STEEL FOG RINGS W/ 12 NOZZLES EACH, BRACKETS/MOUNTING/ZIP TIES PROVIDED BY OTHERS.
- (300) 3/8" BRASS ROTATING CLEANER NOZZLES, 1 GPM @ 80 PSI
- (4) TRACING 3/8" BRASS ROTATING NOZZLES (IF UNNECESSARY).
- ZIP TIES, STRANDED CABLE, ETC. FOR MOUNTING SUPPLIED BY OTHERS
ODOR NEUTRALIZER
- (1) 55 GALLON DRUM OF ODOR ARMOR 400 CONCENTRATE, 400:1 RATIO.
EXTRA PARTS
- EXTRA FILTER
- EXTRA PUMP-OIL
- EXTRA NOZZLE-CLEANING CUTTER
- EXTRA NOZZLE-CLEANER SOLUTION
ZONE 4
ZONE 5
ZONE 3
ZONE 2
ZONE 1
(1X) 36" COOLAIR EXHAUST FAN
30' FOG RING WITH 12 NOZZLE FITTINGS
(2X) 36" COOLAIR EXHAUST FAN
30' FOG RING WITH 12 NOZZLE FITTINGS
PER GREENHOUSE
FEED LINES FROM PUMP
GREENHOUSE
(TYPICAL FOR EACH GREENHOUSE)
PUMP LOCATION
12' X 12' FENCED COMPOSTING
AREA FOR PLANT WASTE
55 GALLON DRUM OF
ODOR ARMOR CONCENTRATE
PUMP
2.9 GPM, 2300 RPM
TO ZONE PUMP
LUNCHBOX ALCHEMY
60027 LINES MEADOW DRIVE SITE 1
BEND, OR 97701
BY
FOGCO
800 South Broadway, Suite B
Coldwater, KS 67029

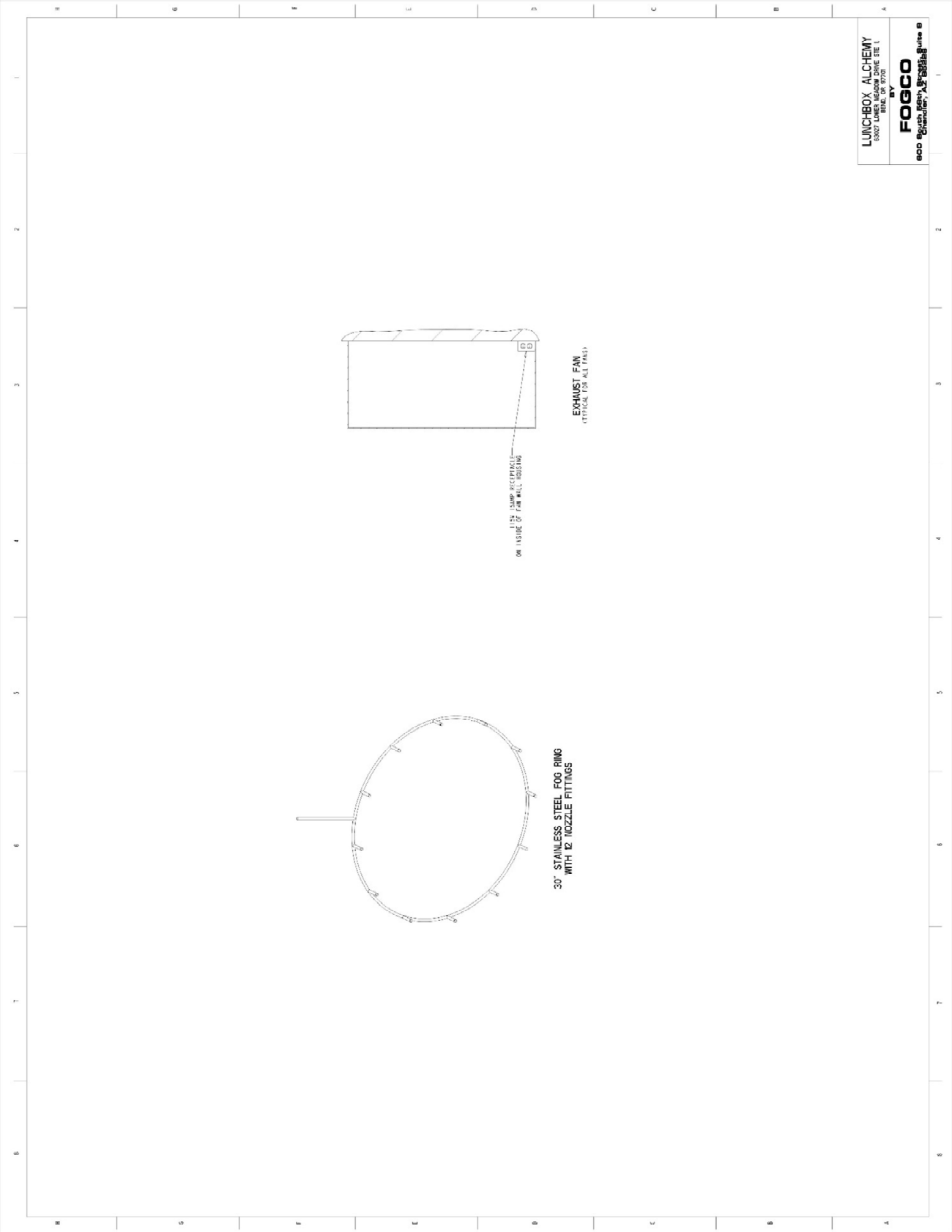


Fig. 4: CAD-generated plan set for this facility, designed and provided by Fogco

Please note that the address provided on these plans is for Lunchbox Alchemy's Bend office, although the plans directly pertain to the facility described in this report. Equipment selections and technical aspects of these documents are accurate and specific to this site, and satisfy the intent of showing a functional, multi-zone, ring fogger system.

Odor Mitigation System Maintenance

From the American Society of Heating, Refrigeration and Air Conditioning (ASHRAE), "the life of activated carbon in odor control systems ranges from a few weeks to a year or more, depending on the concentration of the odorous emission". [2016 ASHRAE Handbook – HVAC Systems and Equipment, see *Appendix F*] This is in-line with the information we have received from the filter manufacturer, "The life of a filter is determined by the concentration of the contaminant, the relative humidity and the volume of air being cleaned. Unfortunately, there is no indicator light on the filter that tells you when it is ready to be replaced. Typically 12-18 months is expected of the Original Can-Filter, although many of them have lasted much longer."

Our recommendation is to change the pre-filter every three months along with the activated carbon filter every six months. Per ASHRAE, depending on the concentration of the contaminants, the filter life could be much shorter or longer than six months, so it is imperative that the facility manager keep a close eye on the "breakdown" of the carbon filter and change more frequently if required. Odor is the evidence of breakdown.

The most important aspect of maintaining a fogging system for odor mitigation is providing a reliable supply of fogging solution. We recommend that when solution drums are 1/2 full, they are to be refilled, or new drums are to be purchased and stored in such a manner that the old drums can be quickly replaced. The drums and pumping system must also be in an interior space to prevent freezing damage, and neutralizer lines will be heat-traced. Exhaust fans are not to be operated without a fog ring attached and functioning. It will be the responsibility of the site owner to ensure this, to promptly replace damaged equipment, and to not exhaust air if the fogging system is not functional.

Replacement of carbon filters and prefilters, annual maintenance and cleaning of fogging equipment, supplying odor neutralizer solution, and 6-month testing of controls will be the responsibility of the site owner.

Odor Mitigation Conclusion

This odor control system will satisfy the requirements of DCC 18.116.330(B)(10)(d)(i), and prevent unreasonable interference of neighbors' use and enjoyment of their property.

NOISE ANALYSIS AND CALCULATION

Applicable Standard

The Deschutes County code DCC 18.116.330(B)(11)(a) reads:

Noise. Noise produced by marijuana production and marijuana processing shall comply with the following:

a. Sustained noise from mechanical equipment used for heating, ventilation, air condition, odor control, fans and similar functions shall not exceed 30 dB(A) measured at any property line between 10:00 p.m. and 7:00 a.m. the following day.

Noise Calculation and Analysis

Equipment noise generated from cannabis-related activities will mostly be generated by the pair of exhaust fans serving each greenhouse. In November of 2018, these fans were manually adjusted for lower speed, reducing them from 651 RPM to 420 RPM. This was done by the site owner in an effort to reduce noise levels on each fan, although data regarding the exact effect is not available. Future exhaust fans on the additional proposed greenhouses will receive the same modifications. Other noise-generating equipment will include a pump for the fogging system which will operate in tandem with exhaust fans, and circulation fans and heaters located within the greenhouses. The pumping system will be located within the composting structure, which is solid-walled and insulated, and will mute pump noise. The circulation fans and heaters are taken into account with the noise calculation methods presented herein, and both sources of noise will be muted by greenhouse walls.

ColeBreit Engineering performed a site visit on November 19th, 2018, to assess equipment noise and site conditions. First, ambient noise levels were recorded before 7:00 am at the approximate center of each property line.

Since no noise data is available for these exhaust fans at a modified RPM, a noise level of 74.3 dBA will be used to represent the total "point source" of noise at the exhaust end of each greenhouse. This will be used for estimating future noise levels with the addition of the other three greenhouses. The technique used to find this noise level follows:

Both exhaust fans and all interior mechanical equipment in only the south greenhouse were activated. Noise levels were recorded from the exterior at a point centered in front of both exhaust fans, at a distance of approximately 5 feet, typical to HVAC equipment noise ratings. This resulted in a noise level of 74.3 dBA.

Finally, noise levels were recorded at the same locations as before with both greenhouses operating all exhaust fans and interior equipment. Results from noise recording with and without equipment running are shown in Table 1 below. These results show the difference in noise at property lines with all HVAC equipment activated, however, it should also be noted that ambient noise levels were also slightly increasing due to distant activity and traffic, as these readings were taken later that morning. The engineer could only distinguish fan noise from ambient noise at the east property line, and then only faintly. DBA levels listed here were averaged between approximately 10 seconds of noise measurement, each taken during a period of minimal traffic noise.

Property line	Distance to property line	Recorded ambient dBA, no equipment running	Time of recording	Recorded dBA, all equipment running	Time of recording
West	562'	39.9	6:40 am	41.3	7:21 am
South	537'	41.6	6:46 am	41.7	7:15 am
East	193'	43.2	6:52 am	44.5	7:10 am
North	537'	40.1	6:58 am	40.2	7:04 am

Table 1: Recorded noise levels at property lines

In order to predict noise levels from operation of all five greenhouses, ColeBreit conducted virtual noise modeling of the site. Measured noise from both exhaust fans and all interior circulation fans for each greenhouse is represented as a single source of 74.3 dBA, labelled EF, and placed at the

end of each greenhouse at a height of 2 meters. Greenhouses are modeled as 8’ tall buildings, given that they have a sidewall height of 8’. An enlarged view of the equipment locations used in the noise model is shown in Figure 5.

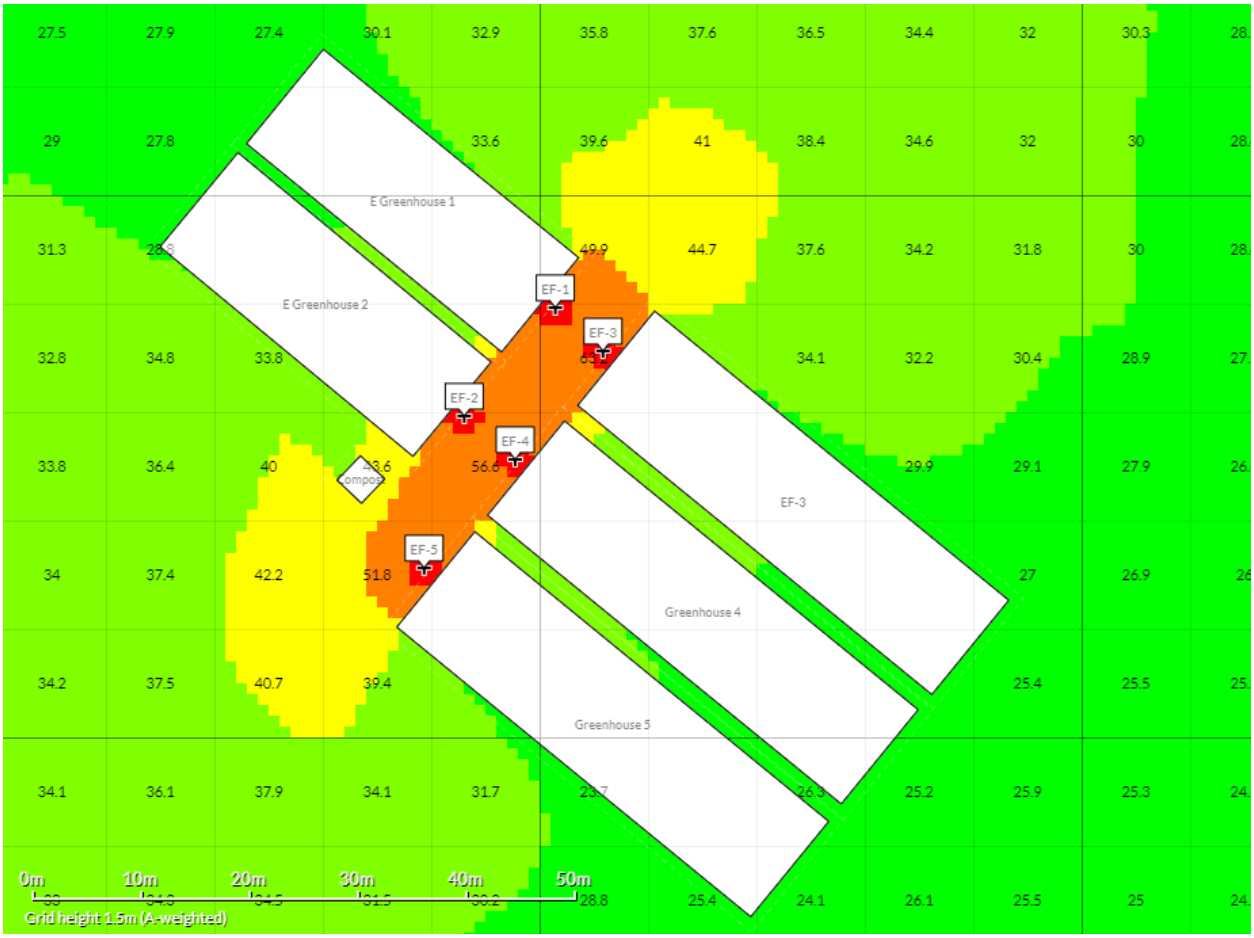


Fig. 5: Greenhouse and equipment layout, and noise propagation pattern, enlarged

Greenhouses and equipment locations have been chosen so that all fans face into an open space between all five greenhouses. This allows for the greenhouses themselves to act as a partial barrier, interfering with noise levels before they begin propagating towards property lines. As the sound waves travel further from these sources, they become increasingly dispersed and less powerful at any given point. As this occurs, sound is also partially absorbed and partially deflected by ground, trees, vegetation, and structures, and is affected by atmospheric conditions. There are many factors that affect this manner of propagation across an outdoor space, far exceeding what could be presented with simple equations in this report. Due to this complexity, rather than being calculated by hand, noise is simulated with computer software called “DBmap”. This software automates all of these calculations in accordance with ISO 9613, Parts 1 & 2. ISO 9613 has been in place since 1996, and is an international standard for calculating outdoor sound propagation. Please refer to *Appendix G* to review the equations and general calculation process described by ISO 9613 Part 2 in detail. ISO 9613 Part 1 further details atmospheric effects on propagation, and can be provided upon request.

These equations are an internationally accepted set of calculation methods that can be applied to any typical outdoor space. By manually inputting data into this software, placing buildings and equipment, manually placing receivers at chosen points along each property line, and adjusting site condition settings to match the site in question, this simulation gives an accurate approximation of noise levels, with all factors considered, at this specific site.

Ground hardness factor is a scale of noise absorption from flat pavement at 0.0 to a soft, densely vegetated field at 1.0. A ground hardness factor of 0.6 was assumed to reflect:

-Soft, uneven ground consisting of sand and rocks. Ground immediately near the greenhouses is mostly soft, flat sand.

-Moderate grass, brush, and tree coverage surrounding where the greenhouses are to be located

Please refer to *Appendix C* for photos of the site demonstrating these conditions.

Noise receivers were modeled at the nearest, loudest, or otherwise most significant points along each property line at a height of 1.5 meters, the approximate height of a human listener. The model includes full, simultaneous operation of all equipment in approximate locations respective to the building. Equipment was modeled slightly outside of the dotted line surrounding each building; this line is called the “facade level” and placing equipment slightly outside of it will additionally model the reflection of noise off of the structure wall. A diagram of the whole site and receiver locations, and a table of final noise levels are on the following page.

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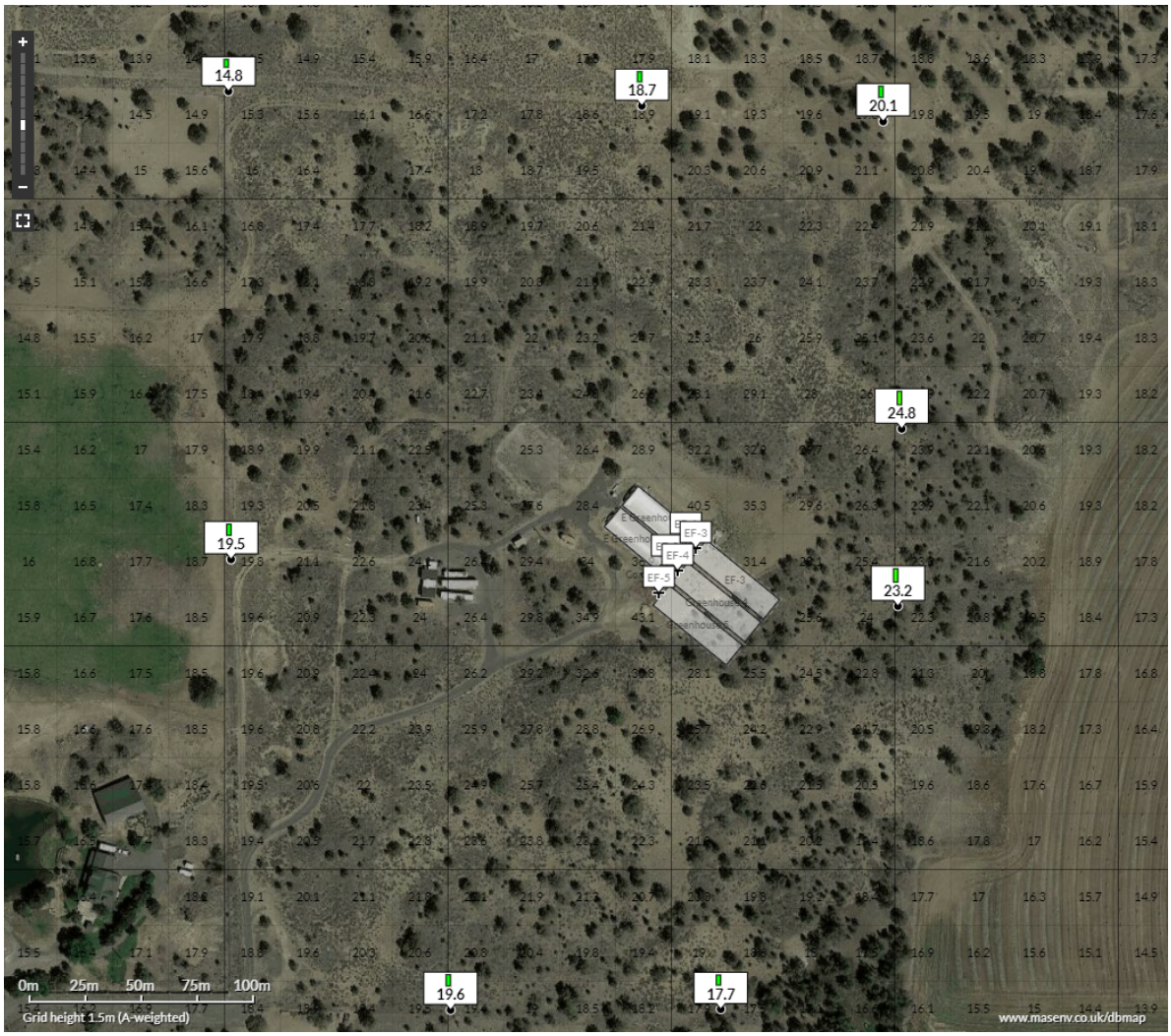


Fig. 6: Simulated sound levels at property lines with all equipment operating simultaneously

Final predicted noise levels with simultaneous operation of all exhaust fans and mechanical equipment are tabulated below.

Property line	Simulated peak noise level along property line, dBA
West	19.5
South	19.6
East	24.8
North	20.1

Table 2: Predicted future noise levels at property lines

Noise Mitigation Conclusion

Given the simulations and considerations shown above, the facility will comply with DCC 18.116.330(B)(11)(a).

Appendix A – Building Plans

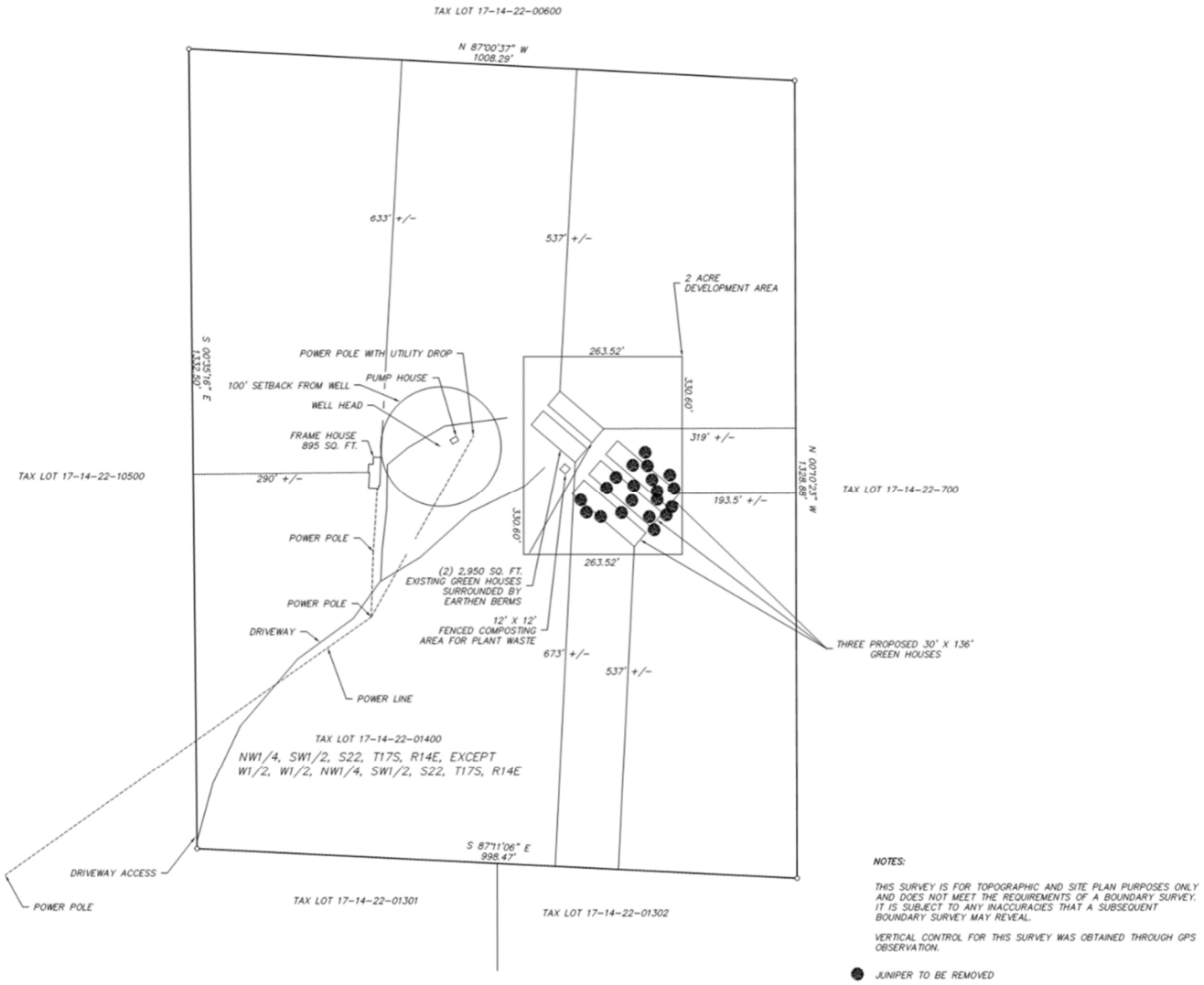


Fig. A1: Site plan, property lines shown

HANDY HOME PRODUCTS
A Backyard Products Company

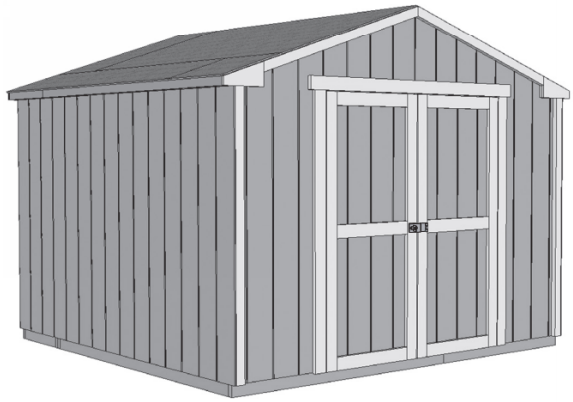
16757-CR7	08/24/2015

ASSEMBLY MANUAL

MARCO SERIES
PRINCETON 10' x 10' (305 x 305 cm)

ACTUAL FLOOR SIZE IS 120 x 116-5/8" (305 x 296 cm)

KEEP THIS MANUAL FOR FUTURE REFERENCE



Figs. A2: Image of prefabricated composting shed

Appendix B – System Equipment & Specifications

Fig. B1: Image of typical Fogco pumping station and odor neutralizer drums

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Fig. B2: Image of typical Fogco rings positioned on greenhouse exhaust fans

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Fig. B3: J&D Typhoon Slant Wall Exhaust Fan, typical installation

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St. Croix Sensory, Inc.

1150 Stillwater Boulevard North
Stillwater, MN 55082

1-800-879-9231
T: 651-439-0177
F: 651-439-1065

www.fivesenses.com

15 May 2017

Dana Pack
Fogco Systems, Inc.
600 S 56th St.
Chandler, AZ 85226

Re: Fogco-Benzaco Odor Management of Marijuana Grow Facility Air Emissions

On April 6, 2017, St. Croix Sensory evaluated the efficacy of a high-pressure, hose-and-nozzle, water fogging odor management system at CW Nevada medical marijuana grow facility in Pahrump, Nevada.

For more than 35 years, St. Croix Sensory staff has been assisting facility owners, consulting engineering firms, and regulatory agencies quantify odors from a variety of industrial, agricultural, and municipal operations, including wastewater treatment, landfills, composting, and manufacturing in both field and laboratory settings. St. Croix Sensory manufactures and markets state-of-the-art odor sampling and measurement equipment. Our "ODOR SCHOOL"® is an internationally recognized program to prepare inspectors to conduct field evaluations of ambient odors. We are dedicated to providing and maintaining the highest standard of quality for all laboratory services and manufactured products. St. Croix Sensory maintains a professional practice that continually reviews ASTM International, CEN (European), and ISO Methods. Our quality control practices ensure quality is met from receiving of materials and sample to the finished products and final reports delivered to our customers.

The purpose of this study was to evaluate the efficacy of an odor management system provided by Fogco Systems, Inc. (of Chandler, AZ) utilizing an odor counteractant specifically formulated for cannabis growing operations by Benzaco Scientific, Inc. (ODOR-ARMOR 420®). Three screened and trained assessors performed as an odor judge tribunal to evaluate at the fence line the untreated and treated air emissions from the grow facility. The evaluation protocol accommodated the guidelines of ASTM E1593 Standard Guide for Assessing the Efficacy of Air Care Products in Reducing the Perception of Indoor Malodor. The growing facility's almost continuous exhaust fans created the desirable "actual" conditions downwind at the facility fence line to be compliant with the ASTM 1593 scope for quantitative odor assessment in determining efficacy.

The odor tribunal unanimously agreed the treated air emissions with the Fogco System utilizing the Benzaco ODOR-ARMOR 420® odor counteractant product demonstrated "no discernible odor" at the fence line downwind of the facility continuous exhausts. Prior to the Fogco/Benzaco treatment, the ambient air at the fence line downwind of the CW Nevada facility presented as pungent, earthy, and marijuana-weed-like. The odor tribunal reported a consensus, "the marijuana odor disappeared when the fogging system was operating".

St. Croix Sensory is ISO/IEC 17025:2005 Accredited

St. Croix Sensory, Inc. Page **2** of **2**

Downwind of the CW facility, from 1/8 to 1-mile on public access roadways, the ambient air was without a discernible odor. On the day of the evaluations, 4/6/2017, the weather conditions were dry (20% relative humidity), mostly sunny (60-deg F) with wind direction at the CW facility in Pahrump, NV was from the south at moderate wind speeds of 10-mph.

The Fogco System appeared to create a uniform evaporating fog-mist with no free-water droplets observed in the air, nor upon the immediate ground area. The Benzaco Scientific odor counteractant, when observed close to the immediate fog-mist, did not appear to have a strong, specific top-note fragrance, other than slightly floral and/or sweet.

The evaluation of the Fogco high-pressure fogging system, treating the exhaust air with Benzaco's ODOR-ARMOR 420® at the Pahrump, Nevada, CW Nevada marijuana grow facility demonstrated efficacy-effectiveness in treating the facilities air emissions, yielding "no discernible marijuana odor".

Respectively submitted,

Charles McGinley
Technical Director
St. Croix Sensory, Inc.

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Fig. B3: Statement regarding efficacy of a Fogco system using Odor Armor 420

Benzaco Scientific
Engineered Dust and Odor Control

SAFETY DATA SHEET

1.0 IDENTIFICATION

GHS Product Identifier

Product Name	Odor-Armor 420®
Other Means of Identification	Not available
Product Type	Liquid
Recommended Use of the chemical	Cannabis Odor Counteractant (not meant for direct contact with food or plants)
Supplier Details	Benzaco Scientific, Inc. 5024 Garfield Street NW Washington, DC 20016
Emergency Telephone Information	888-413-5800

2.0 HAZARD INFORMATION

GHS Classification of the substance / mixture

Physical Hazards	Not classified.
Health Hazards	Not classified.
Environmental Hazards	Not classified.
OSHA Defined Hazards	Not classified.

OSHA Hazard Communication Standard

This product is not a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

GHS Label Elements

Hazard Symbol	None
Signal Word	None
Hazard Statement	This mixture does not meet the criteria for classification.

Precautionary Statement

Prevention	Observe good industrial hygiene practices.
Response	Wash hands after handling.
Storage	Store away from incompatible materials.
Disposal	Dispose of waste and residues in accordance with local authority requirements.

Hazards not otherwise classified (HNOC) None known.

Supplemental Information

Eye Contact	May cause irritation in sensitive individuals.
Skin Contact	May cause irritation in sensitive individuals.
Skin Absorption	Prolonged skin contact is unlikely to result in absorption of harmful amounts.
Inhalation	At room temperature, exposure to vapor is minimal due to low volatility. Mist may cause irritation of upper respiratory tract (nose and throat).
Ingestion	May cause stomach distress or vomiting if ingested in great quantity.
Effects of Repeated Exposure	None known.

3.0 COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	Common Name and Synonyms	CAS#	Weight %
Essential Oils	No information available	Mixture	1-50
Surfactant NP-9	No information available	Mixture	1-50
Poly (Oxy-1,2-Ethanediyl), Alpha-Hydro-Omega-Hydroxy	No information available	25322-68-3	.0079

*This product is non-toxic, non-corrosive, non-flammable and bio-degradable.

*The specific chemical identities of the ingredients in this mixture are considered to be trade secrets and are withheld in accordance with the provisions of 1910.1200 of the Code of Federal Regulations.

4.0 FIRST-AID MEASURES

First aid measures for different exposure routes

Eye Contact Flush eyes thoroughly with water for several minutes. Remove contact lenses after the initial 1-2 minutes and continue flushing for several additional minutes. If effects occur, consult a physician, preferably an ophthalmologist.

Skin Contact Wash skin with soap and plenty of water.

Inhalation Not a normal route of exposure. If symptoms develop, move person to fresh air, if they persist, obtain medical attention.

Ingestion Do not induce vomiting. Rinse mouth with water and then drink one glass of water. Obtain medical attention immediately. Never give anything by mouth if victim is unconscious, is rapidly losing consciousness or is convulsing.

Most important symptoms/effects, acute and delayed

Long Term Effects None known.

Indication of immediate medical attention and special treatment needed, if necessary

Notes to Physician No specific antidote. Treatment of exposure should be directed at the control of symptoms and the clinical condition of the patient.

5.0 FIRE-FIGHTING MEASURES

Extinguishing Media This product is non-flammable, however, treat for surrounding material.

Fire Fighting Procedures Non-flammable. This product is water based and water soluble.

Special Protective Equipment for Firefighters As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

Hazardous Combustion Products Combustion products may include and are not limited to: Oxides of Carbon.

6.0 ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Personal Precautions Use appropriate safety equipment. For additional information, refer to Section 8, Exposure Controls and Personal Protection. Keep unnecessary and unprotected personnel from entering the area. Spilled material may cause a slipping hazard.

Methods and materials for containment and cleaning up

Before attempting to clean up, refer to hazard data within this document. Contain spilled material if possible.

Small spills	Absorb with non-reactive, non-flammable absorbent and place in suitable covered and properly labeled containers. Wash the spill site with large quantities of water.
Large spills	Prevent large spills from entering sewers or waterways. Contact emergency services and supplier for advice. For larger quantities, review Federal, State / Provincial and Local Governments prior to disposal. Product is highly biodegradable.
Environmental Precautions	Prevent from entering into soil, ditches, sewers, waterways and/or groundwater. See Section 12, Ecological Information.

7.0 HANDLING AND STORAGE

Precautions for safe handling

Advice on safe handling	Safety glasses and gloves recommended.

Conditions for safe storage, including any incompatibilities

Technical measures / Storage conditions:	Keep out of reach of children. Store away from direct sunlight or ultraviolet light. Keep container tightly closed when not in use and store in a dry place away from incompatible materials, heat and sources of ignition.
Shelf life:	Use within 12 months.
Maximum Storage Temperature:	40 - 95 °F *May get cloudy at higher temperatures.

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

Control parameters

Biological Limit Values	No biological exposure limits noted for the ingredient(s).

Appropriate Engineering Controls

Ventilation	Provide general and/or local exhaust ventilation to control airborne levels below the exposure guidelines.

Individual Protection Measures

Eye/Face Protection	Safety glasses should be sufficient for most operations; however, for misty operations wear chemical goggles. This product is non-toxic and non-corrosive.
Skin Protection	No precautions other than clean body-covering clothing should be needed.
Hand protection	Wear appropriate chemical resistant gloves when handling this material for prolonged or repeated contact. Consistent with general hygienic practice for any material, skin contact should be minimized. This product is non-toxic and non-corrosive.
Respiratory Protection	Not normally required if good ventilation is maintained.
Ingestion	Use good personal hygiene. Do not consume or store food in the work area. Wash hands before smoking or eating.

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Physical State	Liquid
Color	Clear, Colorless, Opaque
Odor	Fragrant
Odor Threshold	No test data available
pH (100%)	6.5
Freezing Point	No test data available
Melting Point	No test data available
Boiling Point	>100 °C (212 °F)
Flash Point - Closed Cup	>200 °C
Evaporation Rate (H_2O = 1):	No test data available
Flammability Solid	Not flammable
Flammability Gas	Not flammable
Flammable Limits In Air Lower:	Not flammable
Upper	Not flammable
Vapor Pressure	No test data available
Vapor Density (air = 1)	No test data available
Specific Gravity (H2O = 1)	0.999
Solubility in Water (by weight)	100 %
Auto Ignition Temperature	No test data available
Decomposition Temperature	No test data available
Viscosity	Water thin
Pour Point	No test data available

10.0 STABILITY AND REACTIVITY

Stability/Instability	Stable under recommended storage conditions.
Conditions to Avoid	Exposure to elevated temperatures can cause product to decompose. Generation of gas during decomposition can cause pressure in closed systems. Avoid direct sunlight or ultraviolet sources.
Incompatible Materials	To avoid losing product integrity; mix this product only with water.
Hazardous Polymerization	Will not occur.
Thermal Decomposition	Decomposition products depend upon temperature, air supply and the presence of other materials. Decomposition products may include but are not limited to oxides of carbon when heated to decomposition.

11.0 TOXICOLOGICAL INFORMATION

Information on likely routes of exposure

Ingestion	LD50, Rat 3,000 mg/kg.
Skin Absorption	May cause irritation in sensitive individuals.

Information on toxicological effects

Repeated Dose Toxicity	None known.
Chronic Toxicity and Carcinogenicity	No ingredients listed by IARC, ACGIH, NTP or OSHA.
Developmental Toxicity	No known significant effects or critical hazards.
Reproductive Toxicity	No known significant effects or critical hazards.
Genetic Toxicology	No known significant effects or critical hazards.

12.0 ECOLOGICAL INFORMATION

Ecotoxicity The product is not classified as environmentally hazardous. However, this does not exclude the possibility that large or frequent spills can have a harmful or damaging effect on the environment.

Components
Poly (Oxy-1,2-Ethanediyl), Alpha-Hydro-Omega-Hydroxy (CAS 25322-68-3)

Aquatic	Species	Test Results
Fish LC50	Atlantic Salmon (Salmo salar)	>1,000 mg/l, 96 hours

Persistence / degradability No data is available on the degradability of this product.
Bioaccumulative potential No data available.
Mobility in Soil No data available.
Other adverse effects No other adverse environmental effects (e.g. ozone depletion, photochemical ozone creation potential, endocrine disruption, global warming potential) are expected from this product.

13.0 DISPOSAL CONSIDERATION

Waste Treatment

Waste disposal Methods DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. All disposal practices must be in compliance with all Federal, State/Provincial and local laws and regulations. Regulations may vary in different locations. Waste characterizations and compliance with applicable laws are the responsibility solely of the waste generator.

Contaminated Packaging Composition Information. FOR UNUSED & UNCONTAMINATED PRODUCT, the preferred options include sending to a licensed, permitted recycler, sending to an incinerator or other thermal destruction device.

14.0 TRANSPORT INFORMATION

DOT Non-Bulk NOT REGULATED
DOT Bulk NOT REGULATED
IMDG Non-Combustible Liquid. Not regulated as dangerous goods for transport under IMDG.
ICAO/IATA Non-Combustible Liquid. Not regulated as dangerous goods for transport under ICAO and IATA.

This information is not intended to convey all specific regulatory or operational requirements/information relating to this product. Additional transportation system information can be obtained through an authorized sales or customer service representative. It is the responsibility of the transporting organization to follow all applicable laws, regulations and rules relating to the transportation of the material.

15.0 REGULATORY INFORMATION

US Federal Regulations This product is not a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

Toxic Substance Control Act (TSCA) 12(b) Export Notification (40 CFR 707, Subpoint D)
Not regulated.
CERCLA Hazardous Substance List (40 CFR 302.4)
Not listed.
SARA 304 Emergency Release Notification
Not regulated.
OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)
Not listed.

Odor-Armor 420® pg 6

Superfund Amendments and Reauthorization Act of 1986 Title III (SARA)

Hazard Categories	Immediate Hazard	NO
	Delayed Hazard	NO
	Fire Hazard	NO
	Pressure Hazard	NO
	Reactivity Hazard	NO

To the best of our knowledge, this product does not contain chemicals at levels which require reporting under this statute.

SARA 302 Extremely hazardous substance
Not listed.
SARA 311/312 Hazardous Chemical
No
SARA 313 (TRI reporting)
Not regulated.

Other Federal Regulations

Clean Air Act (CAA) Section 112 Hazardous Air Pollutants (HAPs) List
Not regulated.
Clean Air Act (CAA) Section 112 (r) Accidental Release Prevention (40 CFR 68.130)
Not regulated.
SARA 313 (TRI reporting)
Not regulated.
Safe Drinking Water Act (SDWA)
Not regulated.

US State Regulations

US California Controlled Substances. CA Dept of Justice California Health and Safety Code Section 11100
Not listed.
US Massachusetts RTK – Substance List
Not regulated.
US New Jersey Worker and Community Right-to-Know Act
Not listed.
US Pennsylvania Worker and Community Right-to-Know Law
Not listed.
US Rhode Island RTK
Not regulated.
US California Proposition 65
This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins.

Canadian Domestic Substance List (DSL)

All ingredients are register on the DSL.

Canadian WHMIS regulations

SDS prepared pursuant to Canadian WHMIS regulations (Controlled Products Regulations under the Hazardous Product Act).

16.0 OTHER INFORMATION, INCLUDING DATE OF PREPARATION OR LAST REVISION

Date:	May 12, 2017	**SDS prepared by:**	Benzaco Scientific, Inc.
Revision:	May 12, 2017	**Telephone:**	888-413-5800

Disclaimer
The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Fig. B4: Odor Armor 420 Material Safety Data Sheet

DELL TECH
Laboratories Ltd

October 5, 2002

Mr. John Ablon, President
Benzaco Scientific Inc.
5024 Garfield St. NW
Washington, DC
USA 20016

Dear Mr. Ablon:

You have requested that Dell Tech Laboratories provide additional information to that on the Material Safety Data Sheet (MSDS) that we prepared for your product, Odor Armor. Specifically, you are asking about the toxicology of the ingredients in your formulation beyond what is stated on the MSDS.

Our information is based on a search on the toxicology of the component materials. One important element of our search is the presence or absence of any ingredient on lists provided by United States Federal and State regulators. When chemical materials have demonstrated sufficient toxicology or environmental concerns, regulators will place them on these lists. The lists serve to warn consumers about the use, shipping, handling and disposal requirements of the chemical.

In our search, we have used a reference known as "the List of Lists" of regulated chemical materials in the USA. After comparing these lists to the components in Odor Armor, Odor Armor does not contain any components of concern that are listed on the following regulatory lists:

1. List of Hazardous Air Pollutants from Section 112 of the Clean Air Act Amendments of 1990
2. List of Priority Pollutants of the National Permit Discharge Elimination System (NPDES) Permit Regulations (40 CFR 122) from the EPA Office of Water
3. Resource Conservation and Recovery Act materials List (includes F, K, P, U and D listings)
4. List of Extremely Hazardous Substances from Section 302 of the Superfund Amendments and Reauthorization Act of 1986 (SARA)
5. List of Toxic Chemicals from Section 313 of SARA
6. List of Hazardous Substances from the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
7. List of Ozone Depleting Substances from Section 602 of the Clean Air Act
8. List of Hazardous Substances under part 116 of the Federal Water Pollution Control Act (FWPCA)
9. No component at a level subject to disclosure on the Hazardous Substance List of the Pennsylvania Right-To-Know List

Together with the Material Safety Data Sheet that we previously provided, we feel that we have completely covered the information that you requested. Should the regulatory agencies in the United States add any of the components in your product to any list of toxicology or environmental concern, we will notify you immediately.

Yours very truly,

Dell Tech Laboratories Ltd.
Robert J. Dell
President

UWO Research Park, 100 Collip Circle, London, ON N6G 4X8 Tel: 519.858.5021 Fax: 519.858.5026 www.delltech.com

Fig. B5: Statement regarding Odor Armor 420 toxicity

Appendix C – Site Photos

Fig. C1: Ground conditions typical to rougher areas

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Fig. C2: Ground conditions typical to flatter areas

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Appendix D – Odor Technology Review

A. From "BiOdor Project Proposal Feasibility Study"

Gingrich et al., Calvin College, 2015.

Carbon Adsorption:

In a carbon adsorber unit, the air stream passes over a bed of activated carbon and the contaminants adhere to the surface of the carbon, thus removed from the air stream. This is a relatively simple form of odor-control and the only real [operating] cost comes from purchasing new activated carbon after the old carbon has been spent. Moisture is a large limiting factor for carbon adsorption. It is imperative that the carbon be kept dry, lest the adsorptive capacity is greatly reduced. The disposal and replacement costs associated with carbon adsorption are also high compared to alternative technologies.

Activated carbon removes hydrogen sulfide and other odor-producing compounds by catalyzing the oxidation of hydrogen sulfide, resulting in elemental sulfur and water according to the following reaction.

$$2H_2S\ (g) + O_2\ (g) \xrightarrow{yields} \frac{1}{4}\ S_8\ (s) + 2H_2O\ (g)$$

Most of the water produced from this process is lost to the air stream as it passes through the system, while the sulfur is adsorbed into the porous surface of the activated carbon. The adsorption continues until the pores can no longer take in sulfur. As the pores reach their capacity for sulfur uptake, the odor compounds begin to break through the media, meaning noticeable odors are released from the unit indicating the media needs to be replaced.

B. From "Final Environmental Impact Report for the Cannabis Land Use Ordinance and Licensing Program"

County of Santa Barbara, California. December 2017. Appendix F: Cannabis Odor Control: Supplemental Odor Control Technology Research Summary.

Introduction and Overview

Effective technologies exist to suppress cannabis malodors. Activated carbon filtration systems have been proved to be effective for indoor cannabis facilities by Denver's Department of Environmental Health. Vapor-phase systems have been proven to be effective for outdoor odor mitigation by the City

of San Diego's Department of Environmental Services, Air Pollution Control District, and Solid Waste Local Enforcement Agency, as well as greenhouse cultivation by established greenhouse growers in Carpinteria. These technologies could be implemented to effectively reduce cannabis malodors in Santa Barbara County.

Additionally, counties have implemented agriculture buffer requirements which serve in part to reduce land use conflicts which arise from odors. Buffer requirements may be a useful strategy for cannabis odor mitigation within the County where neighboring land uses are far apart. Anecdotal evidence suggests that strong cannabis odors can still be detected large distances away from the source. Thus, buffers may be utilized but are likely to be more effective remote areas of the County where larger buffer distances could be implemented. In more urban areas, odor mitigation technologies would be more appropriate as they would significantly reduce odors over a shorter distance.

Activated Carbon Filtration

Ventilation System

In this system, odor causing agents are adsorbed and filtered through activated carbon (Pennsylvania State University 2002). Odorous gas from the operation facility is collected via a ventilation system. Blowers then direct the gasses to the distribution system which uniformly delivers the gas to the filter. The filter sorbs and degrades the odors resulting in relatively odor-free exhaust.

Supporting information and Current Usage

The City of Denver's Department of Environmental Health regulates nuisance odors under Denver Revised Municipal Code, Chapter 4 – Air Pollution Control, Section 4-10. Under this rule, an odor control plan must be submitted 1) describing any odors anticipated to originate from the premises of marijuana growing, processing, and manufacturing facilities and 2) describing control technologies that will be used to prevent odors from leaving the premises (City and County of Denver 2017). The Department of Environmental Health states the, "rule recognizes carbon filtration as the current best control technology for marijuana cultivation and marijuana infused product facilities" (Denver Department of Environmental Health 2017). However, other odor control technologies are permitted so long as it can be demonstrated that the technology can effectively mitigate odors.

The Director of the Environmental Quality Division of Denver's Department of Environmental Health (Denver Director) was contacted by phone on November 30, 2017 to discuss how effective carbon filtration is, where it has been applied, and if it had the potential to impact product quality. The Denver Director stated that approximately 60 percent of indoor grow operations in Denver had installed odor mitigation control prior to the rule, and that 98 percent of those who installed odor mitigation had utilized carbon filtration. In creating the rule, input from indoor grow operators and HVAC control technicians was included to ensure the regulations would reflect technical and economic feasibility. City officials toured the cultivation facilities to determine the effectiveness of the carbon filtration technology. City officials determined that carbon filtration was effective in removing odors. However, the Denver Director stated that carbon filtration is only effective for processing facilities and indoor grows, which was the only type of cultivation facility in Denver at the time of the ruling. The Denver

Director noted that the initial cost of investment for a carbon filtration system is $10,000-$15,000 for a medium-sized 10,000 square foot indoor facility with an additional $2,000-$3,000 per year in operation and management costs. The Denver Director also stated that the carbon filtration technology would not impact the quality of the cannabis. Finally, the Denver Director stated that the quality of cannabis would only be impacted if the HVAC system, not the carbon filtration system, malfunctioned and humidity was not properly controlled.

A grower in Carpinteria was contacted by phone on November 19, 2017. The grower utilizes vaporphase technology (discussed below) to mitigate cannabis odors from his greenhouse in Carpinteria. He had considered carbon filtration, but stated that he did not use it because he would not have been able to control the internal environment of his greenhouse. The grower noted that carbon filtration would be appropriate for manufacturing, indoor grows, drying rooms, and packaging.

A Code Compliance Officer for the Portland Cannabis Program (Portland Officer), stated that there is no specific odor requirement for the City of Portland. If odor complaints are made, then an action plan is required to reduce odors. Portland's Zoning Code Section 33.262.070 simply states that "continuous, frequent, or repetitive odors may not be produced" (City of Portland 2017a). Portland's code guide for cannabis businesses states that "all exhaust and relief air should be filtered or scrubbed" in order to comply with the zoning code (Portland Bureau of Development Services 2017). The Portland Officer stated that retailers, wholesalers, and processors use countertop carbon systems in order to mitigate odors. Large ventilation systems with activated carbon filters are used for indoor cultivation. These systems are scaled proportionately to the size of the facility. However, Portland does not currently have any greenhouses and the Portland Officer does not know of any odor mitigation strategies for greenhouses.

<u>Canisters</u>

Activated carbon ventilation systems which are supported by activated carbon gas canisters.

Supporting Information and Current Usage

The Director of the Planning and Development Department of the City/County of Pueblo, Colorado (Pueblo Director), was contacted by phone on December 1, 2017. The Pueblo Director stated that Pueblo only regulates odor for cannabis in industrial zones and that agricultural zones is exempt from cannabis odor mitigation. Pueblo County Code Title 17 Chapter 17.120.190 requires that all cannabis establishments in the central business zoning district (B-4) have odor mitigation. "The building (term includes buildings, greenhouses, and hoop houses) shall be equipped with a ventilation system with carbon filters sufficient in type and capacity to eliminate marijuana odors emanating from the interior to the exterior discernable by a reasonable person…" (County of Pueblo 2017). The Pueblo Director stated that mitigate odors in greenhouses, some growers are using canisters with activated carbon inside to filter the air. This works similarly to the ventilation activated carbon systems used in indoor grows but can be used for greenhouses. The Pueblo Director and officials from the Department of Public Health and Environment plan to use an olfactometer to test the effectiveness of this technology in greenhouses on December 21st.

Vapor-Phase System

A manufacturer of this technology as it specifically applies to cannabis was contacted. As described, a deodorizing liquid comprised of essential oils in the citrus and pine family are placed inside a vaporizing mechanism. The vapor travels through a distribution pipe that is suspended high up in the greenhouse and runs along its entire perimeter. The vapor escapes from holes in the distribution pipe and a curtain a vapor along the perimeter is produced. The vapor interacts with and changes the chemistry of cannabis malodors. Because of this chemistry change, the olfactory receptors in the human nose no longer interprets the smell as a malodor. The result is an odor-neutralizing, not an odor-masking technology. The interviewed manufacturer had a third-party consultant perform a public health and safety assessment for their specific cannabis deodorizer. Acute inhalation studies were performed and the product was evaluated against health criteria developed by regulatory agencies such as the USEPA. This particular manufacturer's cannabis deodorizer met all applicable health criteria thresholds (CPF Associates, Inc. 2017).

In Pueblo Colorado, some growers are using this technology to mitigate the cannabis odor emitted from greenhouse fan exhaust. The Pueblo Director and officials from the Department of Public Health and Environment plan to use an olfactometer to test the effectiveness of this technology in neutralizing the odors from greenhouse fan exhaust on December 21st.

The Landfill Operations Program Manager for the City of San Diego's Department of Environmental Services (San Diego Manager), was contacted by phone on November 30, 2017. The San Diego Manager stated that the City of San Diego uses the technology produced by the interviewed manufacturer, but uses a different blend of the same essential oils that is specific to the malodors resulting from landfills. The San Diego Manger, along with the San Diego Air Pollution Control District (APCD) and the Solid Waste Local Enforcement Agency (LEA), performed a pilot study of the technology's effectiveness at the Miramar landfill. The San Diego Manger noted that he, along with the officials from APCD and LEA, could not smell the landfill within 25-30 feet of the device and that the technology was effective in reducing odor in nearby communities. These communities are the nearest sensitive receptor and are located one mile away from the landfill on the other side of a highway. The San Diego Manager stated that the odor mitigation technology is only effective when the device was downwind of the source of the malodors and between the source of the malodor and sensitive receptors. Because wind direction changes during the day, the landfill uses other odor mitigation strategies (e.g., covers) in addition to the vapor-phase technology. The San Diego Manager mentioned that the technology would be more effective in an enclosed area (e.g., greenhouse), because wind direction would not have to be considered and the vapor would be closer to the odor source, and therefore, would have a greater likelihood of interacting with and neutralizing the malodors. Like the grower in Carpinteria, the San Diego Manager stated that the vapor had a pine scent, but that this scent was only noticeable when too much vapor is being produced. He stated that reducing the amount of vapor leaving the system was effective in reducing the pine scent.

A grower in Carpinteria was contacted by phone on November 29, 2017, and stated that the scent of cannabis is no longer noticeable at a distance of 50 feet from the greenhouse when this technology is used. However, the grower stated that the liquid and resulting vapor has a pine/citrus scent, which can

be noticeable if too much vapor is being produced. If this occurs, it was stated that the amount of vapor produced by the system can be reduced.

C. From "Odor in Commercial Scale Compost: Literature Review and Critical Analysis

Washington State University & State of Washington Department of Ecology. October 17, 2013.

The fourth major odor-control strategy includes incorporation of carbon-based materials to piles, including activated carbon, high carbon wood ash, and biochar. Among these, activated carbon is generally understood to be technically effective but too expensive for widespread use in compost odor control.

D. From "Evaluating Odour Control Technologies Using Reliability and Sustainability Criteria: Odour control technology at wastewater treatment or water recycling plants.

NJR Kraakman, J Cesca. November 2012.

Activated Carbon Filter (AC): A granular impregnated AC bed (density 450kg/m^3), including a pre-filter operated at an EBRT of 2.5 sec, a system pressure drop of 900 Pa (excluding the pressure drop of an upfront pre-filter of 250 Pa) and a cost of $6 per kg was used as a model adsorption filter. The most common practice in AC filtration involves two filters (one filter in operation and one in standby to allow bed replacement). Bed replacement is based on empirical experience because carbon manufacturers typically do not guarantee carbon life in wastewater treatment plant (WWTP) applications. A standard carbon life of 12 months was used for stand-alone applications and the inlet concentrations of 10 ppm. No regeneration of the AC was considered. Disposal costs as a hazardous waste of $500 per kL were used for landfill.

E. From "Wastewater Odor Control: An Evaluation of Technologies"

Vaughan Harshman & Tony Barnette

December 28th, 2000

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Odor control on the backburner.
In the modern world of wastewater treatment, control of odors has moved from an afterthought to a primary design consideration for most collection and treatment facilities. As development encroaches on our facilities and our new neighbors become less tolerant of nuisance odors, wastewater professionals have found the need to address odor as a primary concern in the design and operation of collection and treatment facilities. As the attention paid to odor control has increased, so has the number of odor control technologies that are available in the marketplace.

This paper consists of an evaluation of the qualitative characteristics and the economic properties of the various technologies available for wastewater odor control. The goal of this paper is simply to compile and summarize this information. There are a virtually limitless number of unique odor control problems and challenges and it would be impossible to identify one technology as the most applicable for all situations. It is hoped that this paper could be used as a guide to select the most appropriate technology or technologies based on the unique characteristics of a given application.

Background

Any place or process in which wastewater is collected, conveyed or treated has the potential to generate and release nuisance odors to the surrounding area. However, most odor problems occur in the collection system, in primary treatment facilities and in solids handling facilities. In most instances, the odors associated with collection systems and primary treatment facilities are generated as a result of an anaerobic or "septic" condition. This condition occurs when oxygen transfer to the wastewater is limited such as in a force main. In the anaerobic state, the microbes present in the wastewater have no dissolved oxygen available for respiration. This allows microbes known as "sulfate-reducing bacteria" to thrive. These bacteria utilize the sulfate ion (SO4-) that is naturally abundant in most waters as an oxygen source for respiration. The byproduct of this activity is hydrogen sulfide (H2S). This byproduct has a low solubility in the wastewater and a strong, offensive, rotten-egg odor. In addition to its odor, H2S can cause severe corrosion problems as well. Due to its low solubility in the wastewater, it is released to the atmosphere in areas such as wet wells, headworks, grit chambers and primary clarifiers. There are typically other "organic" odorous compounds, such as mercaptans and amines, present in these areas, but H2S is the most prevalent compound.

Solids handling facilities are another significant odor problem area. In biosolids dewatering and treatment processes, the biosolids commonly undergo extreme turbulence, pH adjustment and/or thermal treatment. Depending on the nature of the biosolids stream and the treatment used, the odor compounds released can

consist of any combination of the following compounds in a wide range of concentrations: ammonia, amines, hydrogen sulfide, organic sulfides and mercaptans. Additionally, anaerobic digestion of sludge creates the anaerobic conditions in which sulfate-reducing bacteria thrive, causing the formation of hydrogen sulfide that is vented with the digester "biogas" formed from the digestion of sludge.

There are many different technologies that can be applied to control odors from wastewater collection and treatment systems. These technologies can be split into two main groups: vapor-phase technologies, used to control odorous compounds in the air or gas; and liquid-phase technologies, used to control odorous compounds in the liquid wastewater itself. Vapor-phase technologies typically are used in point-source applications such as wastewater treatment plants and pump stations or for the treatment of biogas. Liquid-phase technologies typically are used in collection systems where control of both odors and corrosion are concerns and/or where multiple point odor control is an objective.

Discussion

This article breaks the technologies into vapor-phase and liquid-phase groups for comparison. The technologies are compared easily within the same group, but generalized comparisons across groups are not possible. Vapor-phase designs are driven by the ventilation rate for headspace to be treated and the mass loading of the contaminant volatilized from the wastewater to the vapor phase. Liquid-phase designs are driven by the wastewater flow rate and/or the total mass loading of the contaminants within the liquid phase. The ventilation and volatilization rates corresponding to liquid flow and mass loading vary widely for individual applications, making generalized comparisons of vapor- vs. liquid-phase treatment impossible. Often the general objectives and the logistics of an application will dictate one approach being desired over the other. If that is not the case, it is suggested that the designer evaluate vapor phase and liquid phase technologies independently to determine the most appropriate technology for each group, then make an application-specific analysis to choose the ultimate technology or combination of technologies.

Vapor-Phase Technologies

Vapor-phase technologies ventilate the point sources of odor problems (wet wells, headworks, etc.). For air treatment, the ventilation system is designed to maintain a negative pressure on the area at all times. This

prevents the "leakage" of odorous air from vents, manways, access hatches or other areas. The discharge from the ventilation system is the only route for the odorous air to escape, therefore it must be treated. Vapor-phase systems are very effective at preventing fugitive emissions from the ventilated sources and preventing odor problems associated with those sources.

If large amounts of air are ventilated, vapor-phase systems also can be effective at providing adequate ventilation for occupancy and/or reducing the contaminant concentration to levels that do not pose safety or corrosion hazards. Biogas treatment systems are concerned primarily with the removal of hydrogen sulfide to prevent the formation of sulfur dioxide (SO2), a product of the combustion of gas containing hydrogen sulfide. Most plants that have anaerobic treatment burn the methane-rich biogas produced from the anaerobic sludge digestion (either as waste gas in a flare or in engines, turbines or boilers for the production of power or steam). Because of this practice, the removal of hydrogen sulfide many times is required to meet emissions standards or to prevent corrosion in the combustion equipment. The technologies evaluated in this paper for use in treating the ventilation air or biogas are wet air scrubbing, liquid redox technology, biofiltration, solid scavengers and carbon adsorption.

Wet Air Scrubbing

Wet air scrubbing is the most flexible and reliable technology for vapor-phase wastewater odor control. This technology can be used to treat virtually any water-soluble contaminant. In addition to hydrogen sulfide and "organic" odors, wet scrubbing is very effective for ammonia removal. In a wet air scrubber the odor contaminants are solubilized from the vapor phase into an aqueous chemical solution. The removal mechanism is purely chemical and is not subject to upsets as are biological processes. The chemical balance in the system is automatically and continuously maintained, even under changing loading conditions, minimizing the chance for odor break-through. The application of a multi-stage scrubber allows the utilization of a different chemical solution in each of the stages to efficiently use chemicals and target a wide range of contaminants for treatment.

One major advantage of wet scrubbing systems is the reliability and flexibility provided by the use of chemicals and chemical reactions. A major challenge in the design and operation of wet air scrubbers is the minimization of chemical use and cost while maintaining complete, flexible and reliable treatment. One design used to reduce chemical use is the multi-stage scrubbing system. As mentioned above, in raw wastewater odor control applications the most prevalent contaminant is hydrogen sulfide, but other organic odorous compounds typically are present as well. Hydrogen sulfide can be solubilized with a solution of

sodium hydroxide. However, the other odor-causing compounds are best treated by sodium hypochlorite. In a single-stage scrubber system, sodium hydroxide and sodium hypochlorite are used in a recirculating chemical solution. Since sodium hypochlorite is a strong oxidizer, it readily reacts with the sulfide that is solubilized by the sodium hydroxide. Therefore, in a single-stage system sodium hypochlorite must be added in sufficient quantities to oxidize the hydrogen sulfide and maintain a residual to treat the other odor compounds. In a multi-stage system, sodium hydroxide is used alone in the first stage to solubilze hydrogen sulfide. Sodium hypochlorite is added to the last stage only. By eliminating the sodium hypochlorite from the sulfide removal process, the consumption rate for this chemical is greatly reduced.

Liquid Redox Technology

Liquid redox technology has a relatively long history, but is not widely used in the odor control market. Most liquid redox processes are used in the petrochemical and natural gas industries and generally are considered too complicated and costly for odor control applications. Liquid redox units use a chelated metal dissolved in a water solution to remove hydrogen sulfide from a gas stream and convert it catalytically to solid, elemental sulfur. The metal, held in solution by organic chelating agents, acts as a catalyst, speeding up the naturally occuring reaction.

The metal ion in the solution removes electrons (negative charges) from a sulfide ion (S-) to form sulfur and in turn can transfer the electrons to oxygen (O2) in the regeneration process. Although there are many metals that can perform these functions, iron (Fe) is the most commercially used because it is inexpensive and non-toxic. Liquid redox processes have limited applications in wastewater treatment facilities compared to wet scrubbers, as they generally have higher capital costs. Where these processes have seen greater demand is in the treatment of anaerobic biogas, where higher levels of hydrogen sulfide and the presence of carbon dioxide cause the lower capital costs of wet scrubbers to be offset by their much higher operating chemical costs. Generally speaking, liquid redox units have operating costs that can be less than 10 percent of other vapor phase treatment options because of the regeneration of the active catalyst, the iron solution. However, because of their higher capital costs, the lower operating costs are enough to justify the use of liquid redox systems only when the requirement for the removal of hydrogen sulfide reaches 200 to 300 lbs./day. Above this level, the low operational cost of a liquid redox system easily can achieve less than a 2—3 year payback on the initial capital investment. Comparisons to conventional wet scrubbers are not productive. The two technologies really do not overlap. Liquid redox units focus on digester gas treatment and ventilation air applications with extremely high loadings of hydrogen sulfide. Additionally, because they

remove only hydrogen sulfide, liquid redox units used for ventilation air odor control in wastewater facilities often will require polishing with hypochlorite or carbon to remove other odor compounds present.

[Sections removed for abbreviation]

Carbon Adsorption

In a carbon adsorption system, the air stream is passed over a bed of adsorbent (carbon) and the odor-causing compounds are attracted to and adhere to the surface of the adsorbent. This is the simplest of the three wastewater odor control technologies. There is no on-going chemical supply to the system, and there are no biological processes to be upset. Adsorption is applicable to a wide range of compounds. Hydrogen sulfide and related sulfur-based compounds are removed effectively by carbon adsorption systems, but ammonia and other nitrogen-based compounds are not effectively treated. Various carbon type systems including activated and impregnated can be used independently or in combinations to remove many different contaminants.

Conclusion

As expected, this review and analysis does not provide a conclusive determination of "the best" odor control technology. Rather, it supports the contention that the existing conditions, treatment objectives and economic restraints must be considered in selection and design of any odor control strategy.

This article was originally published on Dec. 28, 2000. It has been revised for clarity.

F. From “Managing Milk Plant Odors

by Nicholas J. Pinto, PE, Richard A. Straut, PE, and Eric A. Pond, PE

H.P. Hood pasteurizes, processes, and packages milk and nondairy products at its plant in Oneida, New York. The operation discharges wastes from processing, cleaning, and sanitizing operations. Wastewater is treated at the Plant's pretreatment facilities and then discharged to the city's sanitary sewer. Pretreatment facilities comprise two covered and aerated 149,000-gal flow equalization tanks (FETs), pH adjustment, flow control, spill recovery system, and a submersible effluent pump station. Air is released through a vent located atop each FET and from the spill tank and pump station adjacent to the FETs.

The FETs at Hood

Shortly after the FETs were put in service, neighbors began to complain about odors. The plant's operators responded by adding chlorine and increasing aeration, but their actions resulted only in minimal odor reduction. It became clear that an odor control system was necessary. Barton & Loguidice Engineers was asked to find an odor control system. Working closely with Jim Sylvester of H.P. Hood, B&L developed a plan.

Source of odors

Organic compounds, primarily, were responsible for the odors, and they were mostly generated by the accelerated chemical decomposition of lactose in the caustic/acid high-temperature sanitizing processes. Since the FETs were aerated to maintain dissolved oxygen, hydrogen sulfide odors were essentially absent. Complaints about odor coincided with elevated tank pH and late summer afternoons when neighbors were likely to be outdoors.

Control technologies and complications

B&L investigated technologies that were proven to remove organic-based odors. Although the pretreatment facilities were originally designed to accommodate odor control systems (generally considered to be accomplished by scrubbing or adsorption), available space was limited. Any solution would have to fit in an existing small control room along a small strip of land adjacent to the existing building. Two added complications were the known build-up of a gelatin-like material that would plug the vent screens and the formation of milkstone (milk-product minerals) on surfaces exposed to the wastewater or wastewater aerosols. Four odor control technologies were evaluated for treating the air released from the pretreatment system:

- Biofilters
- Adsorption and activated media
- Packed bed scrubbers with oxidizers
- Vapor-phase neutralization.

Biofiltration

With biofiltration, media adsorption and biological oxidation remove air-borne odorous compounds. The air passes through porous organic media, and microbes in the media metabolize the odor-producing

compounds adsorbed on the moist filter particles. The media typically is a combination of compost, wood chips, and nutrients. To maintain the biological process, temperature, pH, and moisture content must be carefully controlled.

Prepackaged biofiltration odor-control technology systems consist of shallow media trays that are stacked to promote uniform air distribution through the media. Prepackaged biofilter systems generally include several parallel-connected biofilters, a blower, humidifier/scrubber (particulate and mist eliminator), control panel, and piping.

A site-built conventional earthen biofilter system was also considered. Such an approach requires two large subsurface biofilter beds containing drainage piping, air distribution piping, media, and a wood chip or mulch cover. As with a packaged system, moisture, pH, and temperature must be accurately maintained. Because earthen biofilters are exposed, they would require additional maintenance such as weed removal and watering. Conventional biofilters use one deep layer of media (4 ft) which is susceptible to compaction and short-circuiting over time.

Packaged biofilters rather than conventional biofilters were focused on for the Hood pretreatment system because they are compact, require less installation effort, and are less prone to media short-circuiting. Moisture level and temperature are generally automatically adjusted by the system. Biofilter media would likely have to be replaced every 3-5 yr, and the scrubber/humidifier and ductwork would have to be cleaned periodically to remove the gelatinous organic substance and milkstone deposits.

Adsorption and activated media

Activated media adsorption technologies such as activated carbon air treatment vessels were evaluated for potential applicability to odor control. These technologies are generally effective in removing air-borne organic gasses and odors, but we were concerned that the gelatinous substance in the FET and pumping station would build-up in the activated media and cause plugging. Additionally, the malodorous constituents represent only a fraction of the total organic compounds that would be adsorbed by the activated media. Because of the large loading of organic substances, media such as activated carbon would have to be regenerated or replaced frequently. We, therefore, judged media adsorption technologies to be incompatible with this application.

Scrubber

A packed bed scrubber uses a physical-chemical process by which odorous gas is transferred to the scrubbing fluid and oxidized. Such a system consists of a blower, scrubbing vessel packed with randomly dispersed plastic media, oxidizing solution, solution pump, and spray manifold. During operation, odorous gas is pulled through the scrubber and contacts the solution-saturated scrubber media. The oxidizing agents, such as sodium hypochlorite or hydrogen peroxide solution, oxidize odorous organic compounds. Typical decomposition by-products are carbon dioxide and water.

Prepackaged scrubber systems are available and generally include a low profile packed bed scrubbing vessel with packing, spray manifold, recirculating pump, blower, control panel, and chemical feed system. Systems are typically automated and require little labor. Scrubber solution level and concentration is automatically maintained by the system. Oxidizing agent inventory must be maintained, however, and the system must be routinely inspected for proper performance and component function. The scrubber and related ductwork must be cleaned to remove gelatinous substances and milkstone deposits.

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Neutralization

With vapor-phase odor neutralization, gaseous odor-neutralizing compounds react or interfere with odor molecules to change their structure and render them inodorous. Since this technology works in a vapor phase, the need to transfer gaseous odors into a liquid phase, such as with the scrubber or biofilter, is eliminated. Vapor-phase reactions are nearly instantaneous; therefore, the residence time is short.

Internal vapor-phase neutralization uses the existing covered tank headspace as a "reaction vessel," thus eliminating need for construction of an external contact vessel. For applications with insufficient headspace, an external contact vessel can be constructed. External contact vessels are similar to traditional scrubber systems but are typically smaller because of the faster reaction rates.

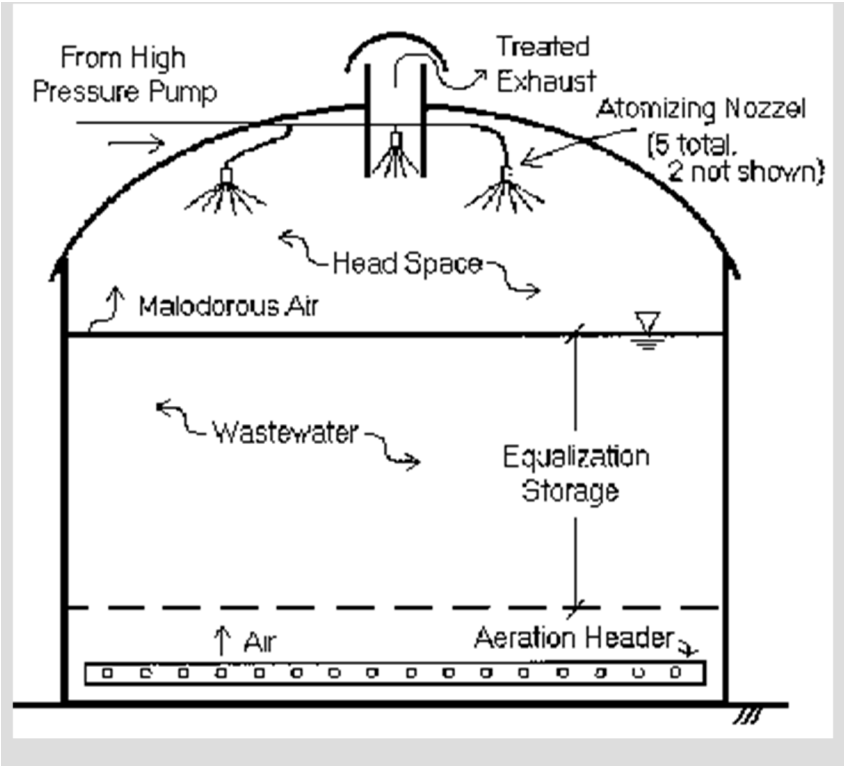
Odor neutralizing compounds vary depending on the application; many operators prefer products from essential plant oils not only for their effectiveness but also because they are generally nonhazardous and benign to the environment.

High-pressure chemical feed system

Decision-making

Although packed bed scrubber systems and biofiltration systems would remove odorous compounds from the air stream, their high cost and the probable build-up of organic material and milkstone in air handling equipment and treatment vessels made them less desirable for this application. We similarly dismissed media adsorption; adsorption would have had the added liability of costly media regeneration or replacement.

The technology that satisfied our criteria was the internal vapor-phase misting system. It provided effective odor treatment, limited construction, low operating expense, and low maintenance. This is the system that H.P. Hood installed. A single high-pressure pump (500 psi) and misting nozzles and piping at the flow equalization system made up the installed system. An inverted 3-ft diameter by 5-ft high vent stack was installed beneath the existing vent of each FET.



Odor control system

Two misting nozzles were installed in each tank's headspace under the existing dome-style covers, and a third nozzle was installed in the stack. The stack minimizes short-circuiting of untreated air and provides redundant treatment by channeling exhausted air through the mist created by the center-mounted conical-spray pattern nozzle. We recommended an essential oil based odor neutralizing solution because it is neither hazardous nor corrosive.

To date, the system has proven to be effective and reliable. Odors released by the facility have been eliminated.

_____

At Barton & Loguidice, PC in Syracuse, *Nicholas J. Pinto, PE* is a senior vice president, *Richard A. Straut, PE* is a senior managing engineer, and *Eric A. Pond, PE* is a project engineer. Jim Sylvester was H.P. Hood's Project Engineer and oversaw installation.

Appendix E – Odor Control Requirements of Other Jurisdictions

A. From Happy Valley Municipal Code 16.49.030

Happy Valley Municipal Code 16.49.030 (D & E):

D. Odor. As used in Section 16.49.030, building means the building, or portion thereof, used for marijuana production or processing and shall be regulated as follows:

1. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter;

2. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM;

3. The filtration system shall be maintained in working order and shall be in use. The filters shall be changed a minimum of once every three hundred sixty-five (365) days;

4. Negative air pressure shall be maintained inside the building;

5. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building;

6. The filtration system shall be designed by a mechanical engineer licensed tin the State of Oregon. The engineer shall stamp the design and certify that it complies with this subsection (D); and

7. An alternative odor control system is permitted if the applicants submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required.

E. Noise. The applicant shall submit a noise study by an acoustic engineer licensed in the State of Oregon. The study shall demonstrate that generators as well as mechanical equipment used for heating, ventilating, air conditioning, or odor control will not produce sound that, when measured at any lot line of the subject property, exceeds fifty (50) dB(A).

B. From Estacada Ordinance Series of 2016, No. 005, 16.07.010 (C)

C. Odor. As used in subsection 16.65.020 (C), building means the building, or portion thereof, used for marijuana retailing.

1. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter.

2. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM.

3. The filtration system shall be maintained in good working order and shall be in use. The filters shall be changed a minimum of once every 365 days.

4. Negative air pressure shall be maintained inside the building.

5. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building.

6. The filtration system shall be designed by a mechanical engineer licensed in the State of Oregon. The engineer shall stamp the design and certify that it complies with subsection 16.65.020 (C).

7. An alternative odor control system is permitted if the applicant submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required.

C. From Kalamazoo County, Michigan, Ordinance N. 595

d. Odor. It is the intent of this ordinance that no odor shall be detectable outside of any building where marijuana is present. As used in this subsection, building means the building, or portion thereof, used for marijuana production or marijuana processing.

i. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter.

ii. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM.

iii. The filtration system shall be maintained in working order and shall be in use. The filters shall be changed a minimum of once every six (6) months or as manufacturer recommended.

iv. Negative air pressure shall be maintained inside the building.

v. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building.

vi. An alternative odor control system is permitted if the special use permit applicant submits and municipality accepts a report by a mechanical engineer licensed in the state of Michigan demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required. The municipality may hire an outside expert at the applicant's expense, to review the alternative system design and advise as to its comparability and whether in the opinion of the expert it should be accepted.

D. From Regulatory Guidance for Licensed I-502 Operations in Spokane County

Air Quality and Odor Controls:

Odor – All businesses must comply with Spokane Clean Air's odor regulation. Odor control measures may include, but are not limited to: use of carbon adsorption media or other controls at all exhaust air discharge points, use of vertical exhaust vents or stacks, and/or completely enclosing the operation and recirculating ventilation air within the enclosure.

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Appendix F – ASHRAE Statement Regarding Carbon Filter Life

A. From 2016 ASHRAE Handbook – HVAC Systems and Equipment

"Incineration and scrubbing are usually the most economical methods of controlling high concentrations of odorous compounds from equipment such as cookers in rendering plants. However, many odors that arise from harmlessly low concentrations of vapors are still offensive. The odor threshold (for 100% response) of acrolein in air, for example, is only 0.21 ppm, whereas that for ethyl mercaptan is 0.001 ppm and that for hydrogen sulfide is 0.0005 ppm (AIHA 1989; MCA 1968). Activated carbon beds effectively overcome many odor emission problems. Activated carbon is used to control odors from chemical and pharmaceutical manufacturing operations, foundries, sewage treating plants, oil and chemical storage tanks, lacquer drying ovens, food processing plants, and rendering plants. In some of these applications, activated carbon is the sole odor control method; in others, the carbon adsorber is applied to the exhaust from a scrubber."

"The life of activated carbon in odor control systems ranges from a few weeks to a year or more, depending on the concentration of the odorous emission.

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Appendix G – ISO 9613, Part 2: General Method of Calculation

INTERNATIONAL STANDARD

ISO 9613-2

First edition
1996-12-15

Reviewed and confirmed in 2017

Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

Acoustique — Atténuation du son lors de sa propagation à l'air libre —
Partie 2: Méthode générale de calcul

Reference number
ISO 9613-2:1996(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9613-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 9613 consists of the following parts, under the general title *Acoustics — Attenuation of sound during propagation outdoors:*

— *Part 1: Calculation of the absorption of sound by the atmosphere*

— *Part 2: General method of calculation*

Part 1 is a detailed treatment restricted to the attenuation by atmospheric absorption processes. Part 2 is a more approximate and empirical treatment of a wider subject — the attenuation by all physical mechanisms.

Annexes A and B of this part of ISO 9613 are for information only.

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Introduction

The ISO 1996 series of standards specifies methods for the description of noise outdoors in community environments. Other standards, on the other hand, specify methods for determining the sound power levels emitted by various noise sources, such as machinery and specified equipment (ISO 3740 series), or industrial plants (ISO 8297). This part of ISO 9613 is intended to bridge the gap between these two types of standard, to enable noise levels in the community to be predicted from sources of known sound emission. The method described in this part of ISO 9613 is general in the sense that it may be applied to a wide variety of noise sources, and covers most of the major mechanisms of attenuation. There are, however, constraints on its use, which arise principally from the description of environmental noise in the ISO 1996 series of standards.

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Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

1 Scope

This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in parts 1 to 3 of ISO 1996) under meteorological conditions favourable to propagation from sources of known sound emission.

These conditions are for downwind propagation, as specified in 5.4.3.3 of ISO 1996-2:1987 or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted from this part of ISO 9613.

The method also predicts a long-term average A-weighted sound pressure level as specified in ISO 1996-1 and ISO 1996-2. The long-term average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions.

The method specified in this part of ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects:

— geometrical divergence;
— atmospheric absorption;
— ground effect;
— reflection from surfaces;
— screening by obstacles.

Additional information concerning propagation through housing, foliage and industrial sites is given in annex A.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. It does not apply to sound from aircraft in flight, or to blast waves from mining, military or similar operations.

To apply the method of this part of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

NOTE 1 If only A-weighted sound power levels of the sources are known, the attenuation terms for 500 Hz may be used to estimate the resulting attenuation.

The accuracy of the method and the limitations to its use in practice are described in clause 9.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9613. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9613 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1996-1:1982, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures.*

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ISO 1996-2:1987, *Acoustics — Description and measurement of environmental noise — Part 2: Acquisition of data pertinent to land use.*

ISO 1996-3:1987, *Acoustics — Description and measurement of environmental noise — Part 3: Application to noise limits.*

ISO 9613-1:1993, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere.*

IEC 651:1979, *Sound level meters,* and Amendment 1:1993.

3 Definitions

For the purposes of this part of ISO 9613, the definitions given in ISO 1996-1 and the following definitions apply. (See table 1 for symbols and units.)

3.1 equivalent continuous A-weighted sound pressure level, L_{AT}: Sound pressure level, in decibels, defined by equation (1):

$$L_{AT} = 10 \lg \left\{ \left[(1/T) \int_0^T p_A{}^2(t)\, dt \right] \Big/ p_0{}^2 \right\} \text{ dB} \quad \ldots (1)$$

where

$p_A(t)$ is the instantaneous A-weighted sound pressure, in pascals;

p_0 is the reference sound pressure (= 20 × 10⁻⁶ Pa);

T is a specified time interval, in seconds.

The A-frequency weighting is that specified for sound level meters in IEC 651.

NOTE 2 The time interval T should be long enough to average the effects of varying meteorological parameters. Two different situations are considered in this part of ISO 9613, namely short-term downwind and long-term overall averages.

Table 1 — Symbols and units

Symbol	Definition	Unit
A	octave-band attenuation	dB
C_{met}	meteorological correction	dB
d	distance from point source to receiver (see figure 3)	m
d_p	distance from point source to receiver projected onto the ground plane (see figure 1)	m
$d_{s,o}$	distance between source and point of reflection on the reflecting obstacle (see figure 8)	m
$d_{o,r}$	distance between point of reflection on the reflecting obstacle and receiver (see figure 8)	m
d_{ss}	distance from source to (first) diffraction edge (see figures 6 and 7)	m
d_{sr}	distance from (second) diffraction edge to receiver (see figures 6 and 7)	m
D_I	directivity index of the point sound source	—
D_z	screening attenuation	—
e	distance between the first and second diffraction edge (see figure 7)	m
G	ground factor	—
h	mean height of source and receiver	m
h_s	height of point source above ground (see figure 1)	m
h_r	height of receiver above ground (see figure 1)	m
h_m	mean height of the propagation path above the ground (see figure 3)	m
H_{max}	largest dimension of the sources	m
l_{min}	minimum dimension (length or height) of the reflecting plane (see figure 8)	m
L	sound pressure level	dB
α	atmospheric attenuation coefficient	dB/km
β	angle of incidence	rad
ρ	sound reflection coefficient	—

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3.2 equivalent continuous downwind octave-band sound pressure level, L_{fT}(DW): Sound pressure level, in decibels, defined by equation (2):

$$L_{fT}(\mathrm{DW}) = 10 \lg \left\{ \left[(1/T) \int_0^T p_f{}^2(t)\, \mathrm{d}t \right] \Big/ p_0{}^2 \right\} \quad \mathrm{dB} \qquad \ldots (2)$$

where $p_f(t)$ is the instantaneous octave-band sound pressure downwind, in pascals, and the subscript f represents a nominal midband frequency of an octave-band filter.

NOTE 3 The electrical characteristics of the octave-band filters should comply at least with the class 2 requirements of IEC 1260.

3.3 insertion loss (of a barrier): Difference, in decibels, between the sound pressure levels at a receiver in a specified position under two conditions:

a) with the barrier removed, and

b) with the barrier present (inserted),

and no other significant changes that affect the propagation of sound.

4 Source description

The equations to be used are for the attenuation of sound from point sources. Extended noise sources, therefore, such as road and rail traffic or an industrial site (which may include several installations or plants, together with traffic moving on the site) shall be represented by a set of sections (cells), each having a certain sound power and directivity. Attenuation calculated for sound from a representative point within a section is used to represent the attenuation of sound from the entire section. A line source may be divided into line sections, an area source into area sections, each represented by a point source at its centre.

However, a group of point sources may be described by an equivalent point sound source situated in the middle of the group, in particular if

a) the sources have approximately the same strength and height above the local ground plane,

b) the same propagation conditions exist from the sources to the point of reception, and

c) the distance d from the single equivalent point source to the receiver exceeds twice the largest dimension H_{max} of the sources ($d > 2H_{max}$).

If the distance d is smaller ($d \leq 2H_{max}$), or if the propagation conditions for the component point sources are different (e.g. due to screening), the total sound source shall be divided into its component point sources.

NOTE 4 In addition to the real sources described above, image sources will be introduced to describe the reflection of sound from walls and ceilings (but not by the ground), as described in 7.5.

5 Meteorological conditions

Downwind propagation conditions for the method specified in this part of ISO 9613 are as specified in 5.4.3.3 of ISO 1996-2:1987, namely

— wind direction within an angle of ± 45° of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and

— wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.

The equations for calculating the average downwind sound pressure level L_{Af}(DW) in this part of ISO 9613, including the equations for attenuation given in clause 7, are the average for meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.

These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights.

6 Basic equations

The equivalent continuous downwind octave-band sound pressure level at a receiver location, L_{fT}(DW), shall be calculated for each point source, and its image sources, and for the eight octave bands with nominal midband frequencies from 63 Hz to 8 kHz, from equation (3):

$$L_{fT}(\mathrm{DW}) = L_W + D_c - A \qquad \ldots (3)$$

where

L_W is the octave-band sound power level, in decibels, produced by the point sound source relative to a reference sound power of one picowatt (1 pW);

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D_c is the directivity correction, in decibels, that describes the extent by which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omnidirectional point sound source producing sound power level L_W; D_c equals the directivity index D_I of the point sound source plus an index D_Ω that accounts for sound propagation into solid angles less than 4π steradians; for an omnidirectional point sound source radiating into free space, D_c = 0 dB;

A is the octave-band attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

NOTES

5 The letter symbol A (in italic type) signifies attenuation in this part of ISO 9613 except in subscripts, where it designates the A-frequency weighting (in roman type).

6 Sound power levels in equation (3) may be determined from measurements, for example as described in the ISO 3740 series (for machinery) or in ISO 8297 (for industrial plants).

The attenuation term A in equation (3) is given by equation (4):

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \quad \ldots (4)$$

where

A_{div} is the attenuation due to geometrical divergence (see 7.1);

A_{atm} is the attenuation due to atmospheric absorption (see 7.2);

A_{gr} is the attenuation due to the ground effect (see 7.3);

A_{bar} is the attenuation due to a barrier (see 7.4);

A_{misc} is the attenuation due to miscellaneous other effects (see annex A).

General methods for calculating the first four terms in equation (4) are specified in this part of ISO 9613. Information on three contributions to the last term, A_{misc} (the attenuation due to propagation through foliage, industrial sites and areas of houses), is given in annex A.

The equivalent continuous A-weighted downwind sound pressure level shall be obtained by summing the contributing time-mean-square sound pressures calculated according to equations (3) and (4) for each point sound source, for each of their image sources, and for each octave band, as specified by equation (5):

$$L_{AT}(\mathrm{DW}) = 10 \lg \left\{ \sum_{i=1}^{n} \left[\sum_{j=1}^{8} 10^{0,1\left[L_{fT}(ij) + A_f(j)\right]} \right] \right\} \ \mathrm{dB} \quad \ldots (5)$$

where

n is the number of contributions i (sources and paths);

j is an index indicating the eight standard octave-band midband frequencies from 63 Hz to 8 kHz;

A_f denotes the standard A-weighting (see IEC 651).

The long-term average A-weighted sound pressure level L_{AT}(LT) shall be calculated according to

$$L_{AT}(\mathrm{LT}) = L_{AT}(\mathrm{DW}) - C_{met} \quad \ldots (6)$$

where C_{met} is the meteorological correction described in clause 8.

The calculation and significance of the various terms in equations (1) to (6) are explained in the following clauses. For a more detailed treatment of the attenuation terms, see the literature references given in annex B.

7 Calculation of the attenuation terms

7.1 Geometrical divergence (A_{div})

The geometrical divergence accounts for spherical spreading in the free field from a point sound source, making the attenuation, in decibels, equal to

$$A_{div} = \left[20 \lg(d/d_0) + 11\right] \ \mathrm{dB} \quad \ldots (7)$$

where

d is the distance from the source to receiver, in metres;

d_0 is the reference distance (= 1 m).

NOTE 7 The constant in equation (7) relates the sound power level to the sound pressure level at a reference distance d_0 which is 1 m from an omnidirectional point sound source.

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7.2 Atmospheric absorption (A_{atm})

The attenuation due to atmospheric absorption A_{atm}, in decibels, during propagation through a distance d, in metres, is given by equation (8):

$$A_{atm} = \alpha d/1\,000 \qquad \ldots (8)$$

where α is the atmospheric attenuation coefficient, in decibels per kilometre, for each octave band at the midband frequency (see table 2).

For values of α at atmospheric conditions not covered in table 2, see ISO 9613-1.

NOTES

8 The atmospheric attenuation coefficient depends strongly on the frequency of the sound, the ambient temperature and relative humidity of the air, but only weakly on the ambient pressure.

9 For calculation of environmental noise levels, the atmospheric attenuation coefficient should be based on average values determined by the range of ambient weather which is relevant to the locality.

7.3 Ground effect (A_{gr})

7.3.1 General method of calculation

Ground attenuation, A_{gr}, is mainly the result of sound reflected by the ground surface interfering with the sound propagating directly from source to receiver. The downward-curving propagation path (downwind) ensures that this attenuation is determined primarily by the ground surfaces near the source and near the receiver. This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope. Three distinct regions for ground attenuation are specified (see figure 1):

a) the source region, stretching over a distance from the source towards the receiver of $30h_s$, with a maximum distance of d_p (h_s is the source height, and d_p the distance from source to receiver, as projected on the ground plane);

b) the receiver region, stretching over a distance from the receiver back towards the source of $30h_r$, with a maximum distance of d_p (h_r is the receiver height);

c) a middle region, stretching over the distance between the source and receiver regions. If $d_p < (30h_s + 30h_r)$, the source and receiver regions will overlap, and there is no middle region.

According to this scheme, the ground attenuation does not increase with the size of the middle region, but is mostly dependent on the properties of source and receiver regions.

The acoustical properties of each ground region are taken into account through a ground factor G. Three categories of reflecting surface are specified as follows.

Table 2 — Atmospheric attenuation coefficient α for octave bands of noise

Temperature	Relative humidity	Atmospheric attenuation coefficient α, dB/km							
		Nominal midband frequency, Hz							
°C	%	63	125	250	500	1 000	2 000	4 000	8 000
10	70	0,1	0,4	1,0	1,9	3,7	9,7	32,8	117
20	70	0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6
30	70	0,1	0,3	1,0	3,1	7,4	12,7	23,1	59,3
15	20	0,3	0,6	1,2	2,7	8,2	28,2	88,8	202
15	50	0,1	0,5	1,2	2,2	4,2	10,8	36,2	129
15	80	0,1	0,3	1,1	2,4	4,1	8,3	23,7	82,8

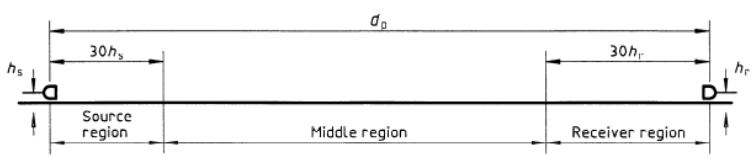

Figure 1 — Three distinct regions for determination of ground attenuation

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a) **Hard ground,** which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground $G = 0$.

NOTE 10 It should be recalled that inversion conditions over water are not covered by this part of ISO 9613.

b) **Porous ground,** which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground $G = 1$.

c) **Mixed ground:** if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

To calculate the ground attenuation for a specific octave band, first calculate the component attenuations A_s for the source region specified by the ground factor G_s (for that region), A_r for the receiver region specified by the ground factor G_r, and A_m for the middle region specified by the ground factor G_m, using the expressions in table 3. (Alternatively, the functions a', b', c' and d' in table 3 may be obtained directly from the curves in figure 2.) The total ground attenuation for that octave band shall be obtained from equation (9):

$$A_{gr} = A_s + A_r + A_m \qquad \ldots (9)$$

NOTE 11 In regions with buildings, the influence of the ground on sound propagation may be changed (see A.3).

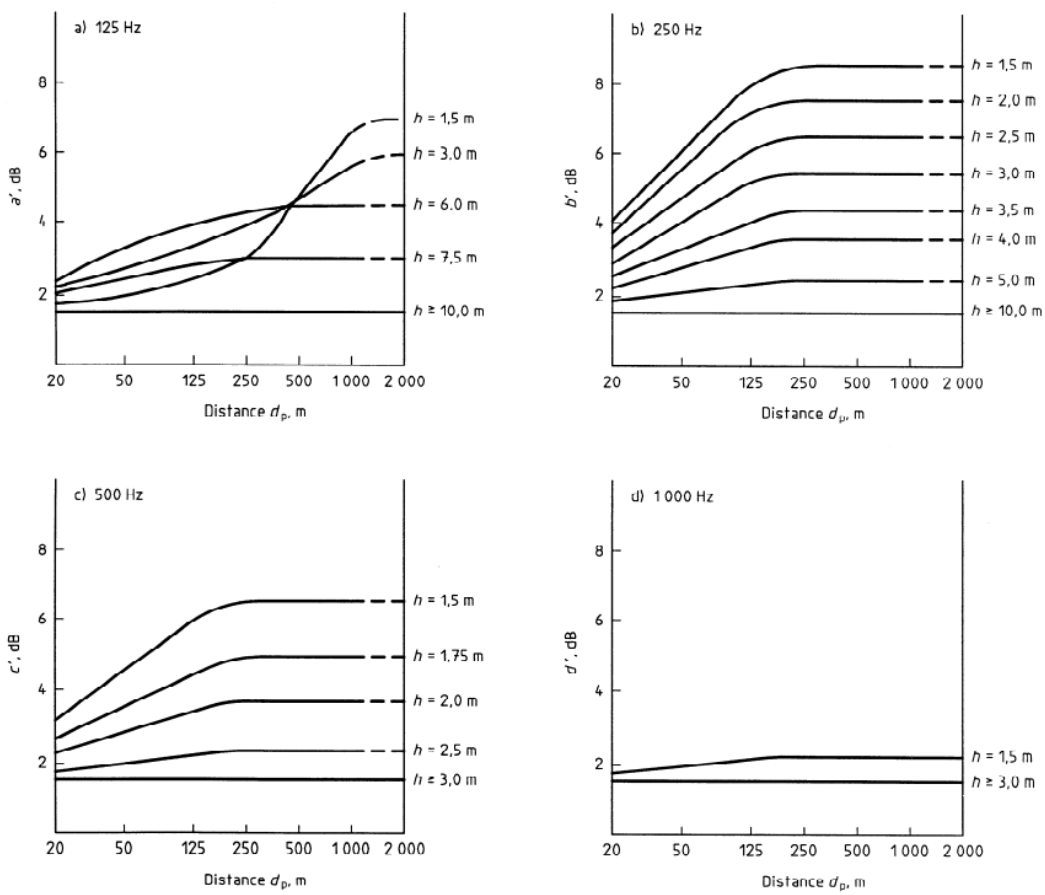

Figure 2 — Functions a', b', c' and d' representing the influence of the source-to-receiver distance d_p and the source or receiver height h, respectively, on the ground attenuation A_{gr} (computed from equations in table 3)

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Table 3 — Expressions to be used for calculating ground attenuation contributions A_s, A_r and A_m in octave bands

Nominal midband frequency Hz	A_s or A_r [1] dB	A_m dB
63	$-1{,}5$	$-3q$ [2]
125	$-1{,}5 + G \times a'(h)$	$-3q(1-G_m)$
250	$-1{,}5 + G \times b'(h)$	
500	$-1{,}5 + G \times c'(h)$	
1 000	$-1{,}5 + G \times d(h)$	
2 000	$-1{,}5(1-G)$	
4 000	$-1{,}5(1-G)$	
8 000	$-1{,}5(1-G)$	

NOTES

$$a'(h) = 1{,}5 + 3{,}0 \times e^{-0{,}12(h-5)^2}\left(1 - e^{-d_p/50}\right) + 5{,}7 \times e^{-0{,}09h^2}\left(1 - e^{-2{,}8 \times 10^{-6} \times d_p^2}\right)$$

$$b'(h) = 1{,}5 + 8{,}6 \times e^{-0{,}09h^2}\left(1 - e^{-d_p/50}\right)$$

$$c'(h) = 1{,}5 + 14{,}0 \times e^{-0{,}46h^2}\left(1 - e^{-d_p/50}\right)$$

$$d'(h) = 1{,}5 + 5{,}0 \times e^{-0{,}9h^2}\left(1 - e^{-d_p/50}\right)$$

1) For calculating A_s, take $G = G_s$ and $h = h_s$. For calculating A_r, take $G = G_r$ and $h = h_r$. See 7.3.1 for values of G for various ground surfaces.

2) $q = 0$ when $d_p \leqslant 30(h_s + h_r)$

$$q = 1 - \frac{30(h_s + h_r)}{d_p} \quad \text{when } d_p > 30(h_s + h_r)$$

where d_p is the source-to-receiver distance, in metres, projected onto the ground planes.

7.3.2 Alternative method of calculation for A-weighted sound pressure levels

Under the following specific conditions

— only the A-weighted sound pressure level at the receiver position is of interest,

— the sound propagation occurs over porous ground or mixed ground most of which is porous (see 7.3.1),

— the sound is not a pure tone,

and for ground surfaces of any shape, the ground attenuation may be calculated from equation (10):

$$A_{gr} = 4{,}8 - (2h_m/d)\left[17 + (300/d)\right] \geqslant 0 \text{ dB} \quad \ldots (10)$$

where

h_m is the mean height of the propagation path above the ground, in metres;

d is the distance from the source to receiver, in metres.

The mean height h_m may be evaluated by the method shown in figure 3. Negative values for A_{gr} from equation (10) shall be replaced by zeros.

NOTE 12 For short distances d, equation (10) predicts no attenuation and equation (9) may be more accurate.

When the ground attenuation is calculated using equation (10), the directivity correction D_c in equation (3) shall include a term D_Ω, in decibels, to account for the apparent increase in sound power level of the source due to reflections from the ground near the source.

$$D_\Omega = 10 \lg \left\{1 + \left[d_p^2 + (h_s - h_r)^2\right] \Big/ \left[d_p^2 + (h_s + h_r)^2\right]\right\} \text{ dB} \quad \ldots (11)$$

where

h_s is the height of the source above the ground, in metres;

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h_r is the height of the receiver above the ground, in metres;

d_p is the source-to-receiver distance projected onto the ground plane, in metres.

7.4 Screening (A_{bar})

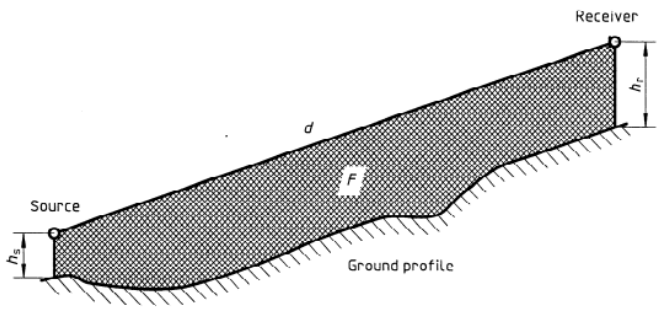
An object shall be taken into account as a screening obstacle (often called a barrier) if it meets the following requirements:

— the surface density is at least 10 kg/m^2;

— the object has a closed surface without large cracks or gaps (consequently process installations in chemical plants, for example, are ignored);

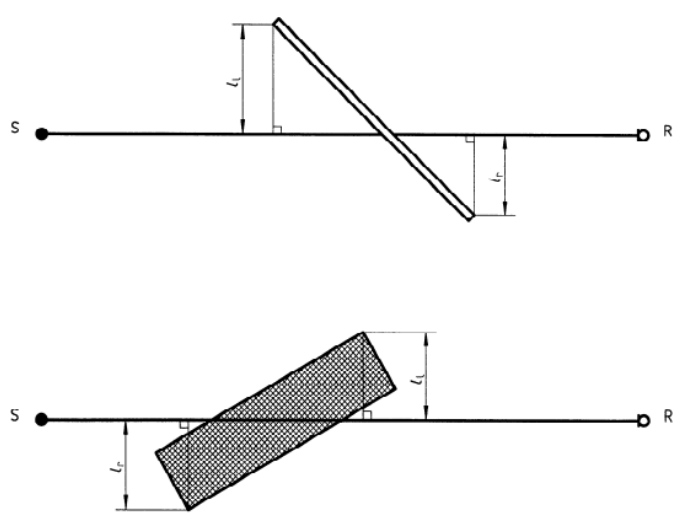
— the horizontal dimension of the object normal to the source-receiver line is larger than the acoustic wavelength λ at the nominal midband frequency for the octave band of interest; in other words $l_l + l_r > \lambda$ (see figure 4).

Each object that fulfils these requirements shall be represented by a barrier with vertical edges. The top edge of the barrier is a straight line that may be sloping.



$h_m = F/d$, where F is the area

Figure 3 — Method for evaluating the mean height h_m



NOTE — An object is only considered to be a screening obstacle when its horizontal dimension perpendicular to the source-receiver line SR is larger than the wavelength: $(l_l + l_r) > \lambda$

Figure 4 — Plan view of two obstacles between the source (S) and the receiver (R)

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For the purposes of this part of ISO 9613, the attenuation by a barrier, A_{bar}, shall be given by the insertion loss. Diffraction over the top edge and around a vertical edge of a barrier may both be important. (See figure 5.) For downwind sound propagation, the effect of diffraction (in decibels) over the top edge shall be calculated by

$$A_{bar} = D_z - A_{gr} > 0 \quad \ldots (12)$$

and for diffraction around a vertical edge by

$$A_{bar} = D_z > 0 \quad \ldots (13)$$

where

D_z is the barrier attenuation for each octave band [see equation (14)];

A_{gr} is the ground attenuation **in the absence of the barrier** (i.e. with the screening obstacle removed) (see 7.3).

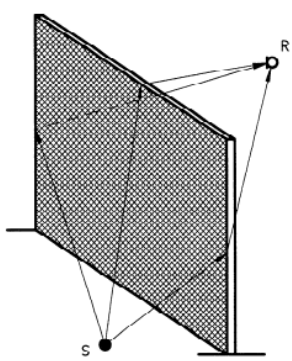

Figure 5 — Different sound propagation paths at a barrier

NOTES

13 When A_{bar} as defined by equation (12) is substituted in equation (4) to find the total attenuation A, the two A_{gr} terms in equation (4) will cancel. The barrier attenuation D_z in equation (12) then includes the effect of the ground in the presence of the barrier.

14 For large distances and high barriers, the insertion loss calculated by equation (12) is not sufficiently confirmed by measurements.

15 In calculation of the insertion loss for multisource industrial plants by high buildings (more than 10 m above the ground), and also for high-noise sources within the plant, equation (13) should be used in both cases for determining the long-term average sound pressure level [using equation (6)].

16 For sound from a depressed highway, there may be attenuation in addition to that indicated by equation (12) along a ground surface outside the depression, due to that ground surface.

To calculate the barrier attenuation D_z, assume that only one significant sound-propagation path exists from the sound source to the receiver. If this assumption is not valid, separate calculations are required for other propagation paths (as illustrated in figure 5) and the contributions from the various paths to the squared sound pressure at the receiver are summed.

The barrier attenuation D_z, in decibels, shall be calculated for this path by equation (14):

$$D_z = 10 \lg \left[3 + \left(C_2/\lambda\right) C_3 z K_{met}\right] \text{ dB} \quad \ldots (14)$$

where

C_2 is equal to 20, and includes the effect of ground reflections; if in special cases ground reflections are taken into account separately by image sources, $C_2 = 40$;

C_3 is equal to 1 for single diffraction (see figure 6);

$$C_3 = \left[1 + \left(5\lambda/e\right)^2\right] \Big/ \left[\left(1/3\right) + \left(5\lambda/e\right)^2\right] \quad \ldots (15)$$

for double diffraction (see figure 7);

λ is the wavelength of sound at the nominal midband frequency of the octave band, in metres;

z is the difference between the pathlengths of diffracted and direct sound, as calculated by equations (16) and (17), in metres;

K_{met} is the correction factor for meteorological effects, given by equation (18);

e is the distance between the two diffraction edges in the case of double diffraction (see figure 7).

For single diffraction, as shown in figure 6, the pathlength difference z shall be calculated by means of equation (16):

$$z = \left[\left(d_{ss} + d_{sr}\right)^2 + a^2\right]^{1/2} - d \quad \ldots (16)$$

where

d_{ss} is the distance from the source to the (first) diffraction edge, in metres;

d_{sr} is the distance from the (second) diffraction edge to the receiver, in metres;

a is the component distance parallel to the barrier edge between source and receiver, in metres.

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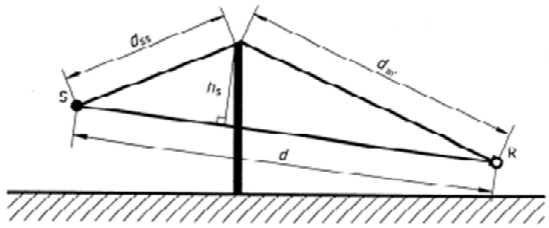
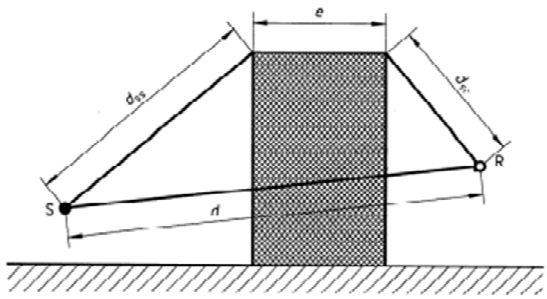


Figure 6 — Geometrical quantities for determining the pathlength difference for single diffraction



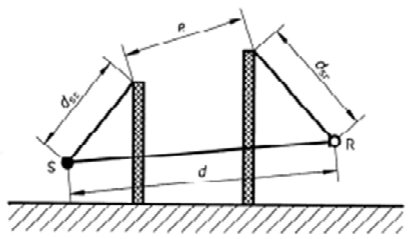


Figure 7 — Geometrical quantities for determining the pathlength difference for double diffraction

If the line of sight between the source S and receiver R passes above the top edge of the barrier, z is given a negative sign.

For double diffraction, as shown in figure 7, the pathlength difference z shall be calculated by

$$z = \left[\left(d_{ss} + d_{sr} + e \right)^2 + a^2 \right]^{1/2} - d \qquad \ldots (17)$$

The correction factor K_{met} for meteorological conditions in equation (14) shall be calculated using equation (18):

$$K_{met} = \exp\left[-(1/2000)\sqrt{d_{ss} d_{sr} d/(2z)} \right] \quad \text{for } z > 0$$

$$K_{met} = 1 \quad \text{for } z \leq 0 \qquad \ldots (18)$$

For lateral diffraction around obstacles, it shall be assumed that $K_{met} = 1$ (see figure 5).

NOTES

17 For source-to-receiver distances less than 100 m, the calculation using equation (14) shows that K_{met} may be assumed equal to 1, to an accuracy of 1 dB.

18 Equation (15) provides a continuous transition from the case of single diffraction ($e = 0$) where $C_3 = 1$, to that of a well-separated double diffraction ($e \gg \lambda$) where $C_3 = 3$.

19 A barrier may be less effective than calculated by equations (12) to (18) as a result of reflections from other acoustically hard surfaces near the sound path from the source to the receiver or by multiple reflections between an acoustically hard barrier and the source.

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The barrier attenuation D_z, in any octave band, should not be taken to be greater than 20 dB in the case of single diffraction (i.e. thin barriers) and 25 dB in the case of double diffraction (i.e. thick barriers).

The barrier attenuation for two barriers is calculated using equation (14) for double diffraction, as indicated in the lower part of figure 7. The barrier attenuation for more than two barriers may also be calculated approximately using equation (14), by choosing the two most effective barriers, neglecting the effects of the others.

7.5 Reflections

Reflections are considered here in terms of image sources. These reflections are from outdoor ceilings and more or less vertical surfaces, such as the façades of buildings, which can increase the sound pressure levels at the receiver. The effect of reflections from the ground are not included because they enter into the calculation of A_{gr}.

The reflections from an obstacle shall be calculated for all octave bands for which all the following requirements are met:

— a specular reflection can be constructed, as shown in figure 8;

— the magnitude of the sound reflection coefficient for the surface of the obstacle is greater than 0,2;

— the surface is large enough for the nominal midband wavelength λ (in metres) for the octave band under consideration to obey the relationship

$$1/\lambda > \left[2/\left(l_{\min}\cos\beta\right)^2\right]\left[d_{s,o}d_{o,r}/\left(d_{s,o}+d_{o,r}\right)\right] \quad \ldots (19)$$

where

λ is the wavelength of sound (in metres) at the nominal midband frequency f (in hertz) of the octave band $\left(\lambda = \frac{340\ \text{m/s}}{f}\right)$;

$d_{s,o}$ is the distance between the source and the point of reflection on the obstacle;

$d_{o,r}$ is the distance between the point of reflection on the obstacle and the receiver;

β is the angle of incidence, in radians (see figure 8);

$l_{\min}$ is the minimum dimension (length or height) of the reflecting surface (see figure 8).

If any of these conditions is not met for a given octave band, then reflections shall be neglected.

The real source and source image are handled separately. The sound power level of the source image $L_{W,\text{im}}$ shall be calculated from

$$L_{W,\text{im}} = L_W + 10\lg(\rho)\,\text{dB} + D_{\text{Ir}} \quad \ldots (20)$$

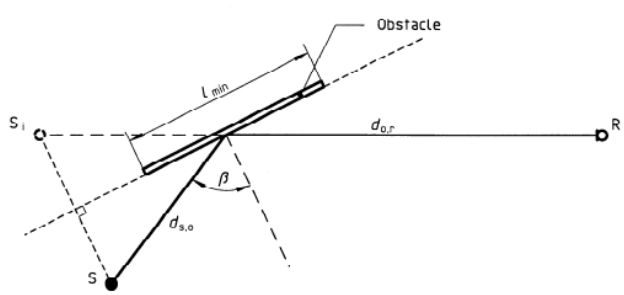
where

ρ is the sound reflection coefficient at angle β on the surface of the obstacle ($\geq 0{,}2$) (see figure 8);

D_{Ir} is the directivity index of the source in the direction of the receiver image.

If specific data for the sound reflection coefficient are not available, the value may be estimated using table 4.

For the sound source image, the attenuation terms of equation (4), as well as ρ and D_{Ir} in equation (20), shall be determined according to the propagation path of the reflected sound.



NOTE — A path $d_{s,o} + d_{o,r}$ connecting the source S and receiver R by reflection from the obstacle exists in which β, the angle of incidence, is equal to the angle of reflection. The reflected sound appears to come from the source image S_i.

Figure 8 — Specular reflection from an obstacle

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Table 4 — Estimates of the sound reflection coefficient ρ

Object	ρ
Flat hard walls	1
Walls of building with windows and small additions or bay	0,8
Factory walls with 50 % of the surface consisting of openings, installations or pipes	0,4
Cylinders with hard surfaces (tanks, silos)	$\frac{D \sin(\phi/2)}{2d_{sc}}$ *) where D is the diameter of the cylinder; d_{sc} is the distance from the source to the centre C of the cylinder; ϕ is the supplement of the angle between lines SC and CR.
Open installations (pipes, towers, etc.)	0

*) This expression applies only if the distance d_{sc} from the source S to cylinder C is much smaller than the distance d_{cr} from the cylinder to receiver; see figure 9.

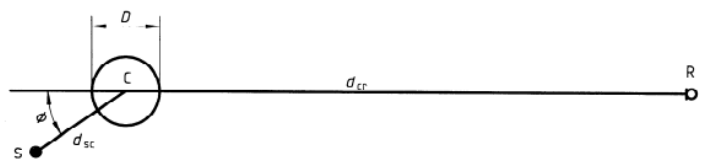

Figure 9 — Estimation of sound reflection coefficient for a cylinder

8 Meteorological correction (C_{met})

Use of equation (3) leads directly to an equivalent continuous A-weighted sound pressure level L_{AT} at the receiver for meteorological conditions which are favourable for propagation from the sound source to that receiver, as described in clause 5. This may be the appropriate condition for meeting a specific community noise limit, i.e. a level which is seldom exceeded (see ISO 1996-3). Often, however, a long term average A-weighted sound pressure level L_{AT}(LT) is required, where the time interval T is several months or a year. Such a period will normally include a variety of meteorological conditions, both favourable and unfavourable to propagation. A value for L_{AT}(LT) may be obtained in this situation from that calculated for L_{AT}(DW) via equation (3), by using the meteorological correction C_{met} in equation (6).

A value (in decibels) for C_{met} in equation (6) may be calculated using equations (21) and (22) for the case of a point sound source with an output which is effectively constant with time:

$$C_{met} = 0 \qquad \text{if } d_p \leqslant 10(h_s + h_r) \qquad \ldots (21)$$

$$C_{met} = C_0 \left[1 - 10(h_s + h_r)/d_p\right] \qquad \text{if } d_p > 10(h_s + h_r) \qquad \ldots (22)$$

where

h_s is the source height, in metres;

h_r is the receiver height, in metres;

d_p is the distance between the source and receiver projected to the horizontal ground plane, in metres;

C_0 is a factor, in decibels, which depends on local meteorological statistics for wind speed and direction, and temperature gradients.

The effects of meteorological conditions on sound propagation are small for short distances d_p, and for longer distances at greater source and receiver heights. Equations (21) and (22) account approximately for these factors, as shown in figure 10.

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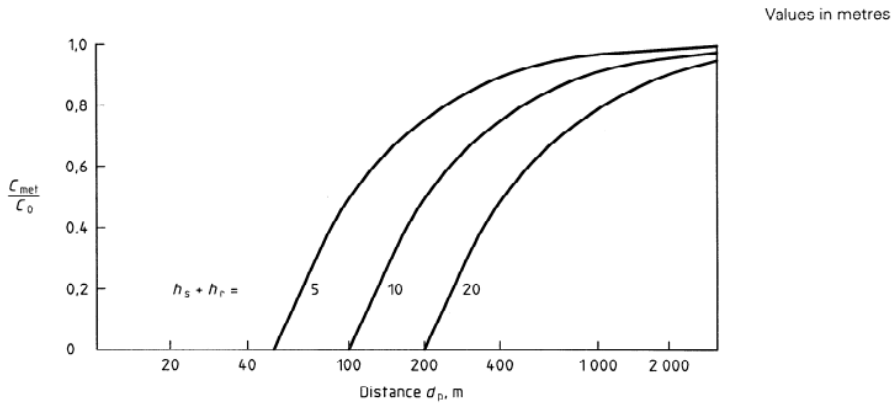

Figure 10 — Meteorological correction C_{met}

NOTES

20 A value for C_0 in equations (21) and (22) may be estimated from an elementary analysis of the local meteorological statistics. For example, if the meteorological conditions favourable to propagation described in clause 5 are found to occur for 50 % of the time period of interest, and the attenuation during the other 50 % is higher by 10 dB or more, then the sound energy which arrives for meteorological conditions unfavourable to propagation may be neglected, and C_0 will be approximately + 3 dB.

21 The meteorological conditions for evaluating C_0 may be established by the local authorities.

22 Experience indicates that values of C_0 in practice are limited to the range from zero to approximately + 5 dB, and values in excess of 2 dB are exceptional. Thus only very elementary statistics of the local meteorology are needed for a ± 1 dB accuracy in C_0.

For a source that is composed of several component point sources, h_s in equations (21) and (22) represents the predominant source height, and d_p the distance from the centre of that source to the receiver.

9 Accuracy and limitations of the method

The attenuation of sound propagating outdoors between a fixed source and receiver fluctuates due to variations in the meteorological conditions along the propagation path. Restricting attention to moderate downwind conditions of propagation, as specified in clause 5, limits the effect of variable meteorological conditions on attenuation to reasonable values.

There is information to support the method of calculation given in clauses 4 to 8 (see annex B) for broad-band noise sources. The agreement between calculated and measured values of the average A-weighted sound pressure level for downwind propagation, L_{AT}(DW), supports the estimated accuracy of calculation shown in table 5. These estimates of accuracy are restricted to the range of conditions specified for the validity of the equations in clauses 3 to 8 and are independent of uncertainties in sound power determination.

NOTE 24 The estimates of accuracy in table 5 are for downwind conditions averaged over independent situations (as specified in clause 5). They should not necessarily be expected to agree with the variation in measurements made at a given site on a given day. The latter can be expected to be considerably larger than the values in table 5.

The estimated errors in calculating the average downwind octave-band sound pressure levels, as well as pure-tone sound pressure levels, under the same conditions, may be somewhat larger than the estimated errors given for A-weighted sound pressure levels of broad-band sources in table 5.

In table 5, an estimate of accuracy is not provided in this part of ISO 9613 for distances d greater than the 1 000 m upper limit.

Throughout this part of ISO 9613 the meteorological conditions under consideration are limited to only two cases:

a) moderate downwind conditions of propagation, or their equivalent, as defined in clause 5;

b) a variety of meteorological conditions as they exist over months or years.

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The use of equations (1) to (5) and (7) to (20) (and therefore also table 5) is limited to case a): meteorological conditions only. Case b) is relevant only to the use of equations (6), (21) and (22). There are also a substantial number of limitations (non-meteorological) in the use of individual equations. Equation (9) is, for example, limited to approximately flat terrain. These specific limitations are described in the text accompanying the relevant equation.

Table 5 — Estimated accuracy for broadband noise of L_{AT}(DW) calculated using equations (1) to (10)

Height, h *)	**Distance,** d *)	
	$0 < d < 100$ m	100 m $< d < 1\,000$ m
$0 < h < 5$ m	± 3 dB	± 3 dB
5 m $< h < 30$ m	± 1 dB	± 3 dB

*) h is the mean height of the source and receiver.
d is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

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Annex A
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Additional types of attenuation (A_{misc})

The term A_{misc} in equation (4) covers contributions to the attenuation from miscellaneous effects not accessible by the general methods of calculating the attenuation specified in clause 7. These contributions include

— A_{fol}, the attenuation of sound during propagation through foliage,

— A_{site}, the attenuation during propagation through an industrial site, and

— A_{hous}, the attenuation during propagation through a built-up region of houses,

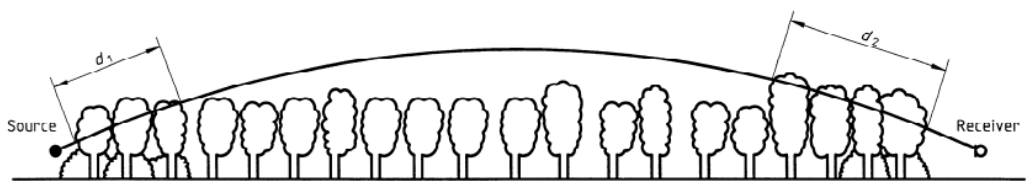
which are all considered in this annex.

For calculating these additional contributions to the attenuation, the curved downwind propagation path may be approximated by an arc of a circle of radius 5 km, as shown in figure A.1.

A.1 Foliage (A_{fol})

The foliage of trees and shrubs provides a small amount of attenuation, but only if it is sufficiently dense to completely block the view along the propagation path, i.e. when it is impossible to see a short distance through the foliage. The attenuation may be by vegetation close to the source, or close to the receiver, or by both situations, as illustrated in figure A.1. Alternatively, the path for the distances d_1 and d_2 may be taken as falling along lines at propagation angles of 15° to the ground.

The first line in table A.1 gives the attenuation to be expected from dense foliage if the total path length through the foliage is between 10 m and 20 m, and the second line if it is between 20 m and 200 m. For path lengths greater than 200 m through dense foliage, the attenuation for 200 m should be used.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f	Nominal midband frequency Hz							
m	63	125	250	500	1 000	2 000	4 000	8 000
	Attenuation, dB:							
$10 \leq d_f \leq 20$	0	0	1	1	1	1	2	3
	Attenuation, dB/m:							
$20 \leq d_f \leq 200$	0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

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A.2 Industrial sites (A_{site})

At industrial sites, an attenuation can occur due to scattering from installations (and other objects), which may be described as A_{site}, unless accounted for under A_{bar}, or the sound source radiation specification. The term installations includes miscellaneous pipes, valves, boxes, structural elements, etc.

As the value of A_{site} depends strongly on the type of site, it is recommended that it is determined by measurements. However, for an estimate of this attenuation, the values in table A.2 may be used. The attenuation increases linearly with the length of the curved path d_s through the installations (see figure A.2), with a maximum of 10 dB.

A.3 Housing (A_{hous})

A.3.1 When either the source or receiver, or both are situated in a built-up region of houses, an attenuation will occur due to screening by the houses. However, this effect may largely be compensated by propagation between houses and by reflections from other houses in the vicinity. This combined effect of screening and reflections that constitutes A_{hous} can be calculated for a specific situation, at least in principle, by applying the procedures for both A_{bar} and reflections described in 7.4 and 7.5. Because the value of A_{hous} is very situation-dependent, such a calculation may be justified in practice. A more useful alternative, particularly for the case of multiple reflections where the accuracy of calculation suffers, may be to measure the effect, either in the field or by modelling.

A.3.2 An approximate value for the A-weighted attenuation A_{hous}, which should not exceed 10 dB, may also be estimated as follows. There are two separate contributions

$$A_{hous} = A_{hous,1} + A_{hous,2} \quad \text{. . . (A.1)}$$

A.3.3 An average value for $A_{hous,1}$ (in decibels) may be calculated using the equation

$$A_{hous,1} = 0{,}1 B d_b \quad \text{dB} \quad \text{. . . (A.2)}$$

where

B is the density of the buildings along that path, given by the total plan area of the houses divided by the total ground area (including that covered by the houses);

d_b is the length of the sound path, in metres, through the built-up region of houses, determined by a procedure analogous to that shown in figure A.1.

The path length d_b may include a portion d_1 near the source and a portion d_2 near the receiver, as indicated in figure A.1.

The value of A_{hous} shall be set equal to zero in the case of a small source with a direct, unobstructed line of sight to the receiver down a corridor gap between housing structures.

NOTE 25 The A-weighted sound pressure level at specific individual positions in a region of houses may differ by up to 10 dB from the average value predicted using equations (A.1) and (A.2).

Table A.2 — Attenuation coefficient of an octave band of noise during propagation through installations at industrial plants

Nominal midband frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
A_{site}, dB/m	0	0,015	0,025	0,025	0,02	0,02	0,015	0,015

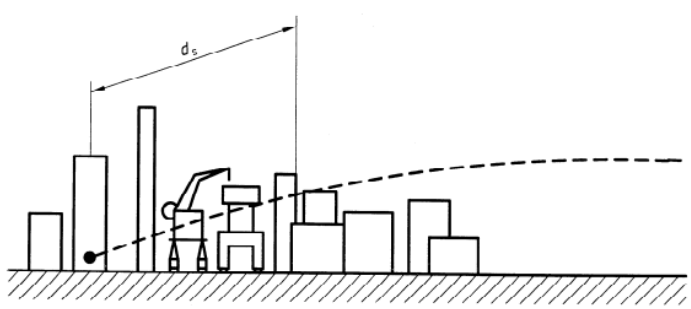

Figure A.2 — The attenuation A_{site} increases linearly with the propagation distance d_s through the installations at industrial plants

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A.3.4 If there are well-defined rows of buildings near a road, a railway, or a similar corridor, an additional term $A_{hous,2}$ may be included (provided this term is less than the insertion loss of a barrier at the same position with the mean height of the buildings):

$$A_{hous,2} = -10 \lg[1 - (p/100)] \text{ dB} \quad \ldots (A.3)$$

where p (the percentage of the length of the façades relative to the total length of the road or railway in the vicinity) is $\leqslant$ 90 %.

A.3.5 In a built-up region of houses, the value of $A_{hous,1}$ [as calculated by equation (A.2)] interacts as follows with the value for A_{gr}, the attenuation due to the ground [as calculated by equation (9) or equation (10)].

Let $A_{gr,b}$ be the ground attenuation in the built up region, and $A_{gr,0}$ be the ground attenuation if the houses were removed [i.e. as calculated by equation (9) or equation (10)]. For propagation through the built-up region in general, $A_{gr,b}$ is assumed to be zero in equation (4). If, however, the value of $A_{gr,0}$ is greater than that of A_{hous}, then the influence of A_{hous} is ignored and only the value of $A_{gr,0}$ is included in equation (4).

The interaction above is essentially to allow for a range of housing density B. For low-density housing, the value of A_{gr} is dominant, while for high-density housing A_{hous} dominates.

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Annex B
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May 23rd Staff Memorandum Response

To: **Deschutes County Board of Commissioners**

From: **Rob James, PE**

Date: **June 7, 2019**

Dear Deschutes County Board of Commissioners,

I am writing in regards to contention around the cannabis odor control system for the greenhouses at 25606 Alfalfa Market Road. It is our understanding that you accept the efficacy of a similar system described in the Nevada case study we provided in our report, but denied this applicant on the grounds that the case study was unclear on the distance between the production facility and their points of measurement. What we do know is multiple measurements were taken between 1/8th of a mile and 1 mile, and also along their fence line, all downwind. We wanted to communicate to you directly to clarify why we see this evidence as a valid demonstration that this system will function effectively at the site in question.

This Fogco system relies on dispensing vapor into exhaust air by surrounding the fan outlets with a ring of nozzles. Vapor systems fundamentally depend on maximizing interaction between vapor and odors (literally how many particles of each will touch each other), and a central piece of this is treating air tightly to where odors are most densely gathered. Our independent research has led us to believe that these nozzle rings are the most effective way to meet these goals in a greenhouse application, as no significant amount of air can physically avoid this vapor as it exhausts. Both the air and vapor quickly disperse as they get further from the building, losing interaction as distance between particles increases. This implies that if no odors are detectable downwind, then the entirety of odor neutralization in this system must be happening very quickly, and very close to where air is leaving the greenhouses.

The Nevada case study describes that their odor tribunal could detect pungent cannabis odors with the system off, and then unanimously agreed that there was no discernible odor with the system on. As such, we do not expect a substantial difference in odor detection whether measuring a mile away, 1/8th of a mile away, or a few feet away. **Regardless of this distance, detectable odors are neutralized at the point that they leave the structure.** This is not a masking solution, and would not prevent the tribunal from detecting odors if they were present. This is why we see their consensus as strong evidence that this system will prevent detectable odors at any fence line on the property.

Sincerely,

Rob James

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Glass House Grown

Cannabis Odor and Noise Report

To: **Lindsey & Christopher Pate**

From: **Laura Breit, PE**

Date: **November 21, 2018**

QUALIFICATIONS

I am a mechanical engineer licensed in Oregon, #79874PE. Our company has provided several dozen of these reports since 2016. While not a qualification by itself, this has involved extensive research, development of our own techniques, and a deeper understanding of the factors at play, including:

-Common practices and requirements from other jurisdictions, and the effects of these as the cannabis industry matures

-Efficacy and required maintenance of various methods, such as carbon filtration and fogging

-Increasingly sophisticated simulation software, and continued research on alternative standards

SUMMARY

This report addresses odor & noise mitigation for a processing facility located at 4859 N Highway 97, Redmond, OR 97756. The purpose of the facility is agricultural support for a permitted cannabis cultivation greenhouse in Deschutes County. This facility will be used for cannabis processing, including production of three forms of solventless cannabis concentrates: rosin, ice water extract (IWE), and dry sift hash. No volatile substances, CO_2, or harmful chemicals are used in these processes. Rosin and dry sift hash will be processed in the main structure, and IWE will be processed in a separate 10’ x 20’ building housing a walk-in freezer. Other rooms may be subject to cannabis odors as well, and will be used for drying, trimming, packaging, and storage. These aforementioned rooms will be referred to as “processing rooms” in this report. The support structure also includes employee spaces not used for cannabis processing or storage.

The support structure is of solid, insulated construction, and the IWE building is a modified shipping container. Support structure peak roof height is 11’ 7”, although ceilings are 7’ 11”. Average roof height of 9’ 9” will be used in volume calculations for the sake of conservative calculation. The IWE building has a 8’ 6” ceiling.

Odor in both structures will be neutralized with carbon filters attached to inline fans placed throughout the facility. The HVAC system will use mini-split heat pumps to condition both structures without needing to exhaust air to outside. Additionally, a compressor may be located outside the IWE structure to operate the walk-in freezer. No noise mitigation measures will be required, and the facility will only be staffed during normal working hours.

Further considerations of odor and noise from grow spaces, facility operation, and all exterior equipment will be discussed within this report.

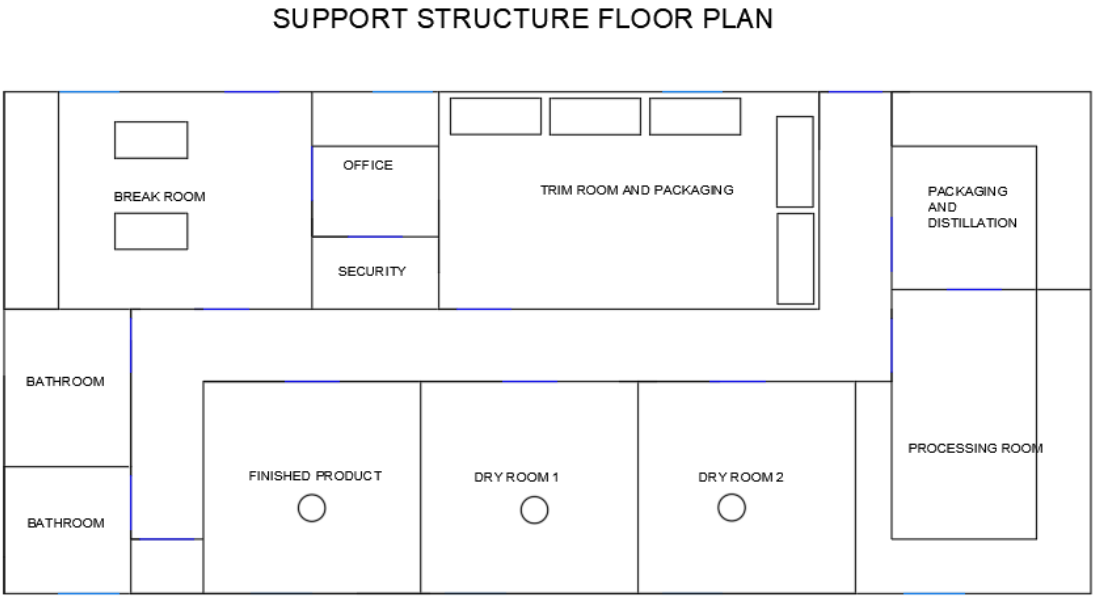

Fig. 1: Simple Floor Plan

See *Appendix A* for further information about the site layout and location.

Specification sheets on all HVAC and outdoor equipment can be found in *Appendix B.*

Site geography and equipment positioning will impact the propagation of noise from this equipment. This will be discussed further, and photographs taken by ColeBreit Engineering during a site visit on November 15th, 2018 can be found in *Appendix C.*

CANNABIS ODOR ANALYSIS AND CALCULATION

Applicable Standard

The Deschutes County code DCC 18.116.330(B)(10) reads:

Odor. As used in DCC 18.116.330(B)(10), building means the building, including greenhouses, hoop houses, and other similar structures, used for marijuana production or marijuana processing.

> a. The building shall be equipped with an effective odor control system which must at all times prevent unreasonable interference of neighbors' use and enjoyment of their property.
>
> b. An odor control system is deemed permitted only after the applicant submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the system will control odor so as not to unreasonably interfere with neighbors' use and enjoyment of their property.

c. Private actions alleging nuisance or trespass associated with odor impacts are authorized, if at all, as provided in applicable state statute.

d. The odor control system shall:

i. Consist of one or more fans. The fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the required CFM or

ii. Utilize an alternative method or technology to achieve equal to or greater odor mitigation than provided by (i) above.

e. The system shall be maintained in working order and shall be in use.

Odor Mitigation Technology Review

Activated Carbon Filtration has been utilized in many industries for many years, and is considered a proven technology. Due its relatively low first cost, it is a common odor control choice for cannabis facilities.

See *Appendix D* for information gathered, including:

A. Technology Overview
B. Activated Carbon as a recognized odor control method in cannabis
C. Activated Carbon as a recognized odor control method in other industries
D. Activated Carbon has lowest first cost

See *Appendix E* for odor control requirements of other jurisdictions.

Proposed Odor Mitigation Design

No air will be exhausted from processing rooms, and exchange of “smelly” air with non-production spaces will be minimal. Two carbon filters with inline fans will circulate and scrub air at either end of the hallway near the exits to improve the likelihood that fugitive odors will be neutralized before they are able to leave the structure. Suggested carbon filter and fan products, placement, and sizing is shown on the following pages. The IWE Building should use a single carbon filter with inline fan within the walk-in freezer. ColeBreit does not anticipate any functionality issues with operating a carbon filter and inline fan within a cold space.

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Room name	Room Notes	Width	Length	Square Footage	Height	Room Volume (rounded up)
PROCESSING ROOM	Production of cannabis concentrates	13’	16’ 10”	219 SF	9’ 9”	2136 CF
PACKAGING ROOM	Packaging of processed cannabis concentrates	11’	10’ 11”	120 SF	9’ 9”	1170 CF
TRIM ROOM	Trimming of cannabis	21’	12’	252 SF	9’ 9”	2457 CF
DRY ROOM 1	Drying of cannabis	12’	11’ 9”	141 SF	9’ 9”	1375 CF
DRY ROOM 2	Drying of cannabis	12’	11’ 9”	141 SF	9’ 9”	1375 CF
FINISHED PRODUCT	Storage of finished cannabis concentrates	12’	11’ 9”	141 SF	9’ 9”	1375 CF
HALLWAY	Irregular dimensions, see site plan	4’	65’ 9”	263 SF	9’ 9”	2565 CF
WALK-IN FREEZER	Separate structure for IWE processing, see site plan	10’	10’	100 SF	8’ 6”	850 CF

Table 1: Room information

Room name	1/3rd of Room Volume	Suggested Carbon Filter & Fan	Supplied Carbon Filtration	Excess Filtration
PROCESSING ROOM	712 CF	10” Max-Fan w/ Can 100 Filter	834 CFM	122 CFM
PACKAGING ROOM	390 CF	8” Max-Fan w/ Can 75 Filter	550 CFM	160 CFM
TRIM ROOM	819 CF	10” Max-Fan w/ Can 100 Filter	834 CFM	15 CFM
DRY ROOM 1	459 CF	8” Max-Fan w/ Can 75 Filter	550 CFM	91 CFM
DRY ROOM 2	459 CF	8” Max-Fan w/ Can 75 Filter	550 CFM	91 CFM
FINISHED PRODUCT	459 CF	8” Max-Fan w/ Can 75 Filter	550 CFM	91 CFM
HALLWAY	855 CF	(2) 8” Max-Fan w/ Can 75 Filter	1100 CFM	245 CFM
WALK-IN FREEZER	284 CF	8” Max-Fan w/ Can 75 Filter	550 CFM	266 CFM

Table 2: Carbon filtration by room

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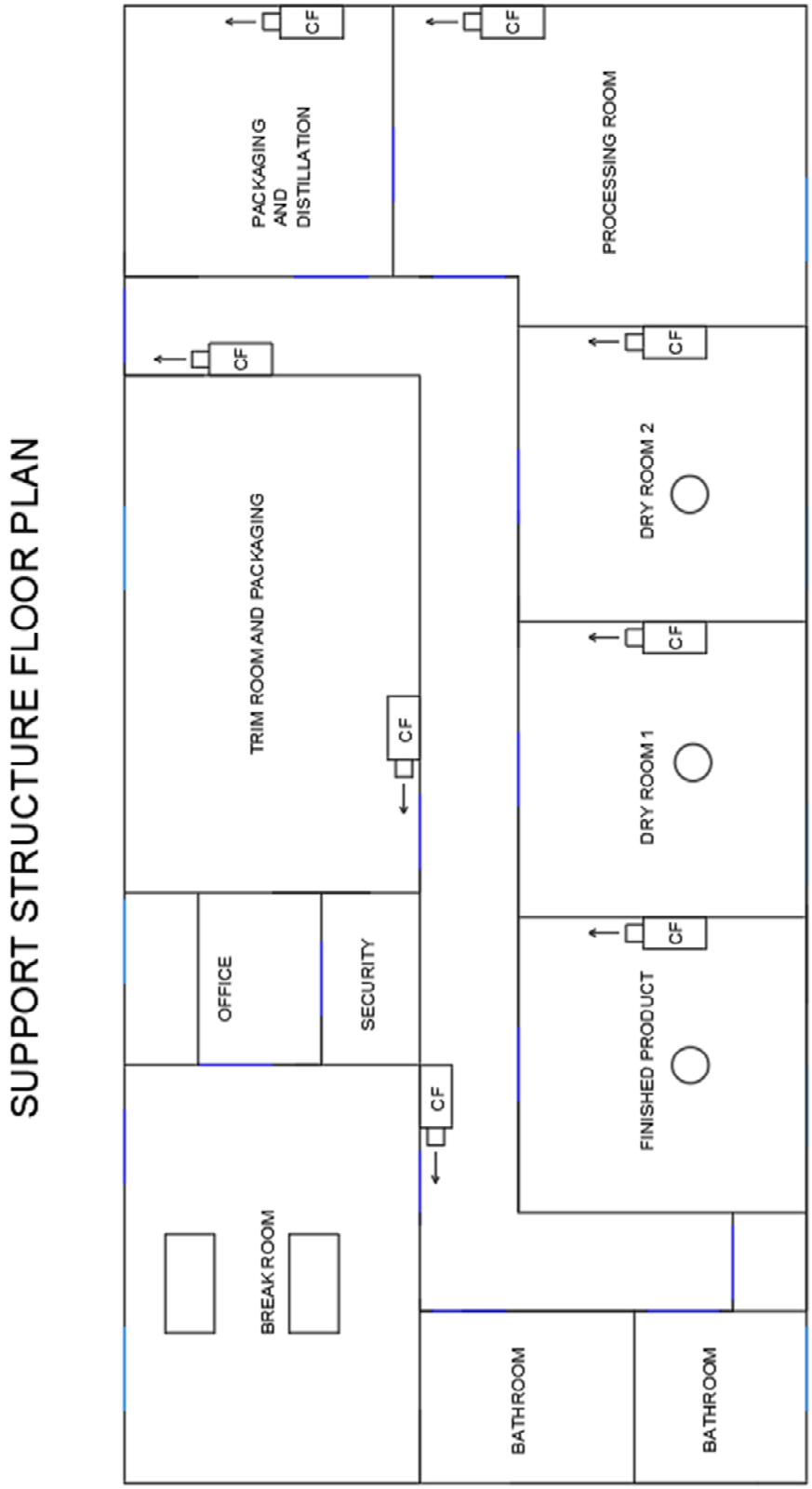

Fig. 2: Recommended carbon filter (CF) locations

Can-Filters

Can 100 SKU: 358710

Recommended Exhaust CFM: 840 CFM / 1400m3h @ 0.1 sec contact time
Prefilter: Yes
Flange: 8" - 10" - 12"
Dimensions: *(with pre-filter)*
- Outside Diameter: 42 cm / 16.5"
- Height: 100 cm / 39.4"

Weight: 47 kg / 103 lbs.
Carbon Weight: 37 kg / 81.5 lbs.
Carbon Bed Depth: 6.5 cm / 2.56"
Max Operating Temp: 80˚C / 176˚F
Pressure drop at max CFM: 180pa / .75"wg

Recommended Fan:

FAN	Filtered Air CFM	Watts
14" Max-Fan™	958	240
12" Max-Fan™	1260	488
12" Can-Fan® HO	825	310
10" Max-Fan™	834	228
10" Can-Fan® HO	641	267
8" Max-Fan™	580	165
8" Can-Fan® HO	600	278

Can 75 SKU: 358715

Recommended Exhaust CFM: 600 CFM / 1000m3h @ 0.1 sec contact time
Prefilter: Yes
Flange: 6" - 8" - 10" - 12"
Dimensions: *(with pre-filter)*
- Outside Diameter: 42 cm / 16.5"
- Height: 75 cm / 29.5"

Total Weight: 36 kg / 79 lbs.
Carbon Weight: 28 kg / 61.6 lbs.
Carbon Bed Depth: 6.5 cm / 2.56"
Max Operating Temp: 80˚C / 176˚F
Pressure drop at max CFM: 180pa / .75"wg

Recommended Fan:

FAN	Filtered Air CFM	Watts
12" Max-Fan™	1080	475
10" Max-Fan™	747	225
10" Can-Fan® HO	595	270
8" Max-Fan™	550	162
8" Can-Fan® HO	550	280
8" Can-Fan®	407	130
6" Can-Fan® HO	338	136

Fig. 3: Can-Filters' Can 75 & Can 100 Filter

8" Max-Fan™

SKU: 340420

CFM	667 at 0wg
RPM	3250
Max Watts	179
Amps	1.5 @ 120 VAC 60 Hz
Sones	
Diameter	8"
Length	8 7/8"
Blade Design	Mixed Flow
Housing	Plastic
Inlet/Outlet	8"

10" Max-Fan™

SKU: 340430

CFM	1019 at 0wg
RPM	2990
Max Watts	228
Amps	1.9 @ 120 VAC 60 Hz
Sones	11.5 at 0.10wg
Diameter	10"
Length	8 1/2"
Blade Design	Mixed Flow
Housing	Galvanized
Inlet/Outlet	10"

PERFORMANCE AT PRESSURE

FAN MODEL	SPEED	RPM	VOLTS	MAX WATTS	MAX AMPS	Free Air 0"	.125"	.25"	.375"	Fan Attached to Filter .5"	.75"	1.0"	1.25"	1.5"	MAX in. wg	DUCT DIA.
6" Max-Fan™	High	3303	115	75	0.65	334	322	309	296	283	255	225	187	13	1.546	6?
	Med./High	2944	115	66	0.58	264	253	238	221	205	175	143	93	N/A	1.405	
	Medium	2351	115	53	0.49	201	176	153	131	116	82	24	N/A	N/A	1.132	
8" Max-Fan™ *667 CFM*	-	3250	120	179	1.5	667	650	630	610	585	520	420	150	100	1.84	8"
8" HO Max-Fan™	High	2935	115	213	1.87	932	899	869	840	803	723	638	340	208	2.064	8?
	Med./High	2705	115	188	1.71	849	802	770	729	687	600	465	270	110	1.803	
	Medium	2460	115	178	1.62	749	703	660	613	568	477	316	140	N/A	1.469	
10" Max-Fan™ *1019 CFM*	-	2990	120	228	1.9	1019	985	950	920	885	815	705	535	155	1.78	10"
12" Max-Fan™ *1708 CFM*	-	3374	120	489	4.1	1708	1680	1655	1630	1595	1530	1460	1380	1300	3.34	12"
14" Max-Fan™ *1700 CFM*	-	1700	120	253	2.1	1700	1630	1560	1490	1400	1150	240	N/A	N/A	1.19	14"

Performance certified is for installation type D - Ducted inlet, Ducted outlet.
Performance ratings do not include the effects of appurtenances (accessories). * Static Pressure at 0 W.G.

Fig. 4: Can-Filters' 8" & 10" Max-Fan

Odor Mitigation System Maintenance

From the American Society of Heating, Refrigeration and Air Conditioning (ASHRAE), "the life of activated carbon in odor control systems ranges from a few weeks to a year or more, depending on the concentration of the odorous emission". [2016 ASHRAE Handbook – HVAC Systems and Equipment, see *Appendix F*] This is in-line with the information we have received from the filter manufacturer, "The life of a filter is determined by the concentration of the contaminant, the relative humidity and the volume of air being cleaned. Unfortunately, there is no indicator light on the filter that tells you when it is ready to be replaced. Typically 12-18 months is expected of the Original Can-Filter, although many of them have lasted much longer."

Our recommendation is to change the pre-filter every three months along with the activated carbon filter every six months. Per ASHRAE, depending on the concentration of the contaminants, the filter life could be much shorter or longer than six months, so it is imperative that the facility manager keep a close eye on the "breakdown" of the carbon filter and change more frequently if required. Detectable odor is the evidence of breakdown.

Replacement of carbon filters and prefilters and maintenance of fans will be the responsibility of the site owner.

Odor Mitigation Conclusion

This odor control system will satisfy the requirements of DCC 18.116.330(B)(10)(d)(i), and prevent unreasonable interference of neighbors' use and enjoyment of their property.

NOISE ANALYSIS AND CALCULATION

Applicable Standard

The Deschutes County code DCC 18.116.330(B)(11)(a) reads:

Noise. Noise produced by marijuana production and marijuana processing shall comply with the following:

a. Sustained noise from mechanical equipment used for heating, ventilation, air condition, odor control, fans and similar functions shall not exceed 30 dB(A) measured at any property line between 10:00 p.m. and 7:00 a.m. the following day.

Noise Calculation and Analysis

At the time of this report, the buildings described herein are not yet constructed, and no equipment was available for on-site testing. Instead, three ambient noise readings were taken during a morning site visit on November 15th, 2018 at approximately 7 am, and a virtual noise model was performed to estimate noise levels contributed by future HVAC equipment. Comparing these two analyses, with results shown in Figure 5 below, demonstrates how this site complies with the language and intent of Deschutes County code, and will not present a nuisance to neighboring properties. Due to the irregular shape of the property, tabulated results from the noise model will refer to the receiver points marked on Figures 5 & 7, rather than by the typical cardinal directions.

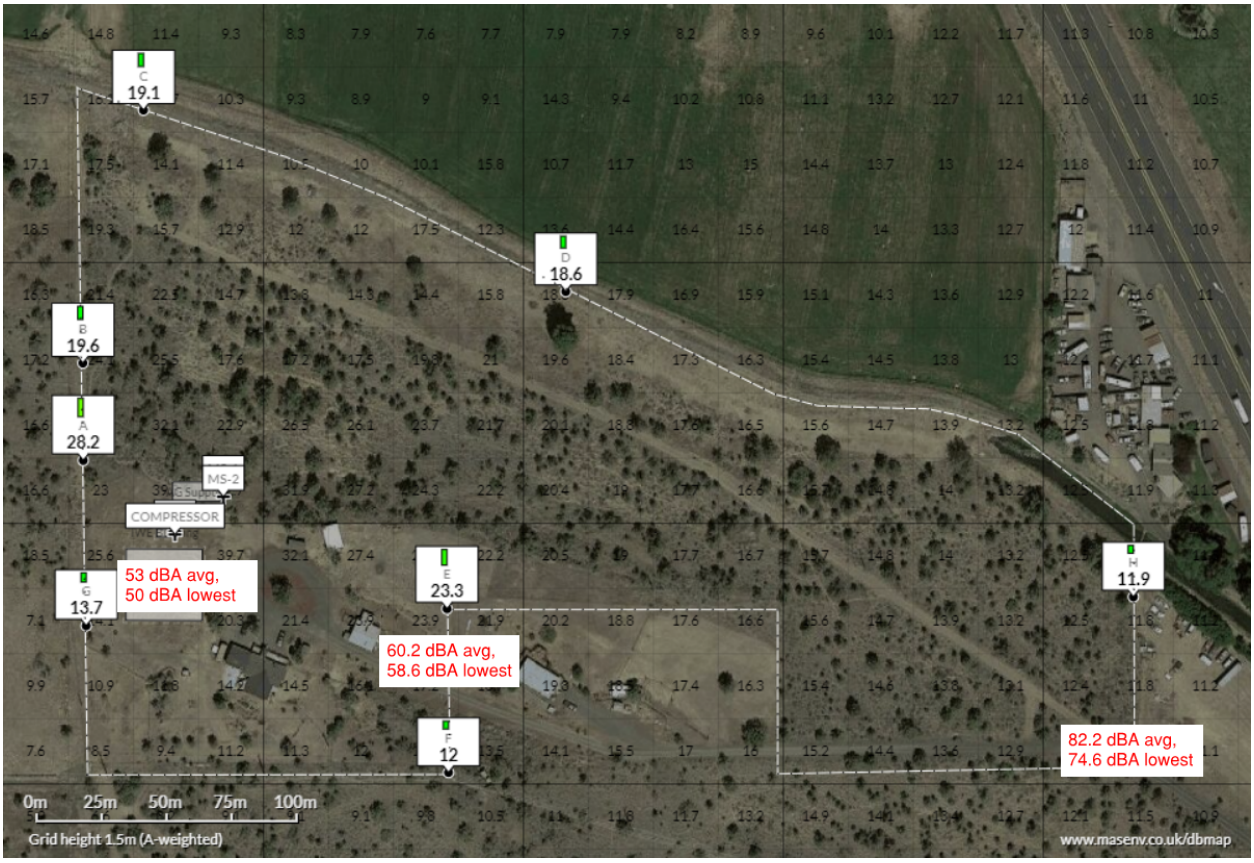

Fig. 5: Existing ambient noise levels and expected equipment noise contributions at property lines (no equipment or cannabis-related structures installed).

Ambient noise levels are marked on Figure 5 at the approximate location that each recording was taken, with the approximate average and the lowest level detected during each recording period. These are much higher ambient noise levels than most properties ColeBreit has reported on, due to the proximity to Highway 97. It can be expected that highway noise will significantly reduce perceptible noise from this site at all property lines, especially so on the eastern half. As an approximate demonstration of this effect, adding the western peak level of 28.2 dBA to the nearby ambient low of 50.0 dBA, resulting noise levels are still 50.0 dBA. This is due to the logarithmic nature of combining noise levels. In other words, equipment noise will be completely "washed out" by typical highway noise across the site. See below for the method of simple decibel arithmetic:

Decibel Addition and Subtraction

Sound levels are generally expressed in decibels, which are logarithmic and so cannot be manipulated without being converted back to a linear scale. You must first antilog each number, add or subtract and then log them again in the following way:

$$L = 10 \, \mathrm{Log}_{10} \left(\sum_{i=1}^{n} 10^{(L_i / 10)} \right)$$

For example, adding three levels 94.0 + 96.0 + 98.0:

$$L = 10 \, \mathrm{Log}_{10} \left(10^{9.4} + 10^{9.6} + 10^{9.8} \right) = 101.1 \text{ dB}$$

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Equipment information and sound ratings have been tabulated below. The compressor serving the IWE Building was chosen to represent the loud end of typical compressors for walk-in freezers, refer to Appendix B for more information. Any model of compressor may be installed, provided the sound rating does not exceed the 76 dBA shown here.

Equipment	Tag	Serves	dBA Rating	Quantity
Mini Split A	MS-1	AG Support Structure	58	1
Mini Split A	MS-2	AG Support Structure	58	1
Mini Split B	MS-3	IWE Building	63	1
Compressor	COMP	IWE Building	76	1

Table 3: HVAC Equipment and Noise Ratings

Sound will propagate from the levels provided by each piece of equipment out towards each property line. As the sound waves travel further from these sources, they become increasingly dispersed and less powerful at any given point. As this occurs, sound is also partially absorbed and partially deflected by ground, trees, vegetations, and structures, and is affected by atmospheric conditions. There are many factors that affect this manner of propagation across an outdoor space, far exceeding what could be presented with simple equations in this report. Due to this complexity, rather than being calculated by hand, noise is simulated with computer software called “DBmap”. This software automates all of these calculations in accordance with ISO 9613, Parts 1 & 2. ISO 9613 has been in place since 1996, and is an international standard for calculating outdoor sound propagation. Please refer to *Appendix G* to review the equations and general calculation process described by ISO 9613 Part 2 in detail. ISO 9613 Part 1 further details atmospheric effects on propagation, and can be provided upon request.

These equations are an internationally accepted set of calculation methods that can be applied to any typical outdoor space. By manually inputting data into this software, placing buildings and equipment, manually placing receivers at chosen points along each property line, and adjusting settings to match the site in question, this simulation gives an accurate approximation of noise levels, with all factors considered, at this specific site.

Ground hardness factor is a scale of noise absorption from flat pavement at 0.0 to a soft, densely vegetated field at 1.0. A ground hardness factor of 0.5 was assumed to reflect:

-Flat, sandy ground with some grass coverage surrounding where the structures will be located

-Dispersed tree coverage and areas of uneven ground throughout the property

Noise receivers were modeled at the nearest, loudest, or otherwise most significant points along each property line at a height of 1.5 meters, the approximate height of a human listener. The model includes full, simultaneous operation of all equipment in approximate locations respective to the building. Equipment was modeled slightly outside of the dotted line surrounding each building; this line is called the “facade level” and placing equipment slightly outside of it will additionally model the reflection of noise off of the structure wall. A closeup of the building with noise propagation, a diagram of the whole site and receiver locations, and a table of final noise levels are on the following pages.

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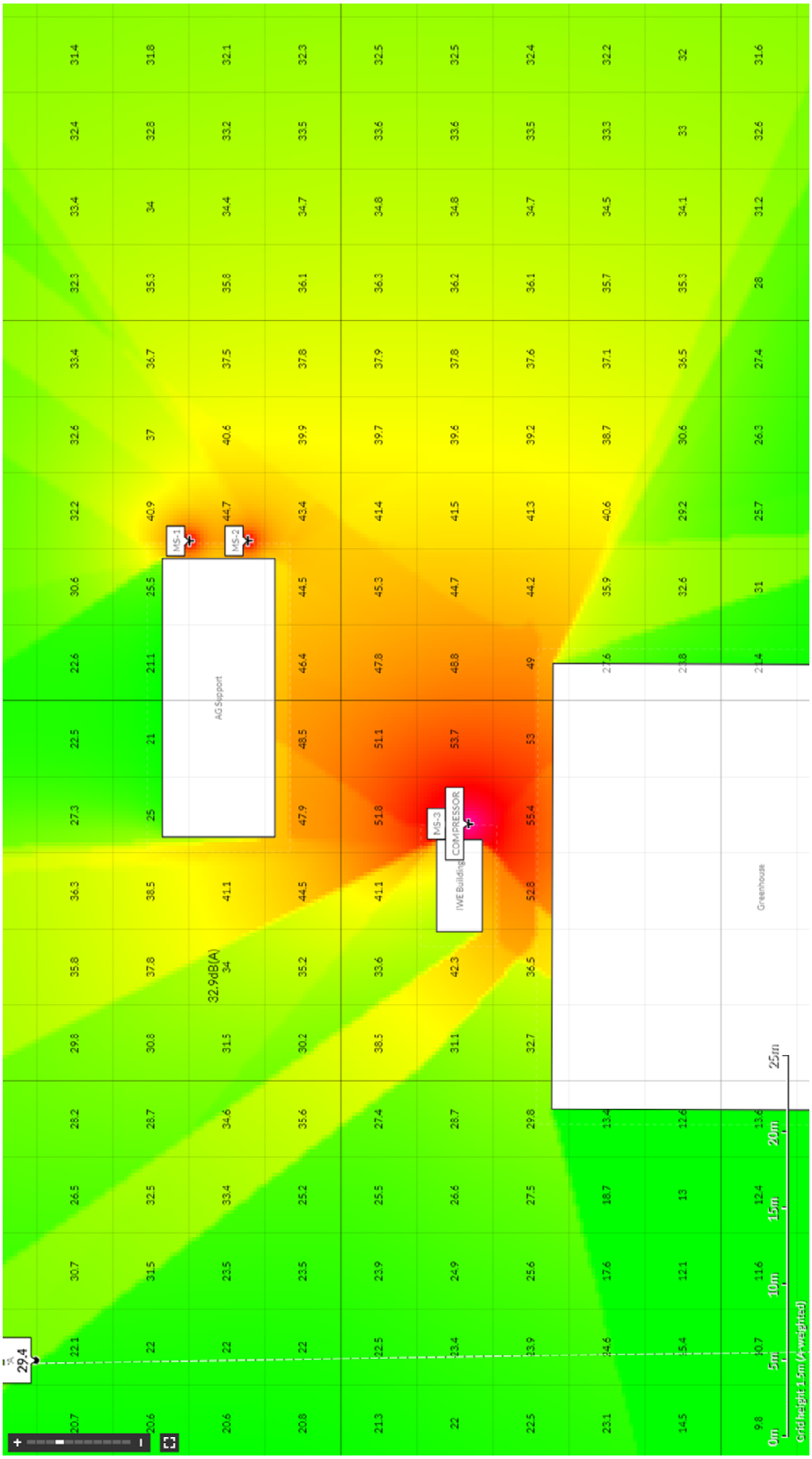

Fig. 6: Equipment placement in relation to structures, and color-coded noise propagation, enlarged view

Fig. 7: Expected peak noise levels (calculated) at property lines with all future equipment operating. Note location of callout for Figure 6.

Receiver mark	Final simulated dBA contributed by equipment	Final predicted dBA levels from combined simulated equipment and 50 dBA, the lowest recorded ambient noise level
A	28.2	50.0
B	19.6	50.0
C	19.1	50.0
D	18.6	50.0
E	23.3	50.0
F	12	50.0
G	13.7	50.0
H	11.9	50.0

Table 4: Final predicted noise levels at modeled receivers

Equipment noise is not expected to exceed a 30 dBA contribution at any property line, regardless of ambience or operating schedule. This simulation does not account for uneven, hilly ground, or tree coverage in areas around the site, which could further dampen noise.

Noise Mitigation Conclusion

Given the simulations and considerations shown above, the facility will comply with DCC 18.116.330(B)(11)(a).

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Appendix A – Site Plans

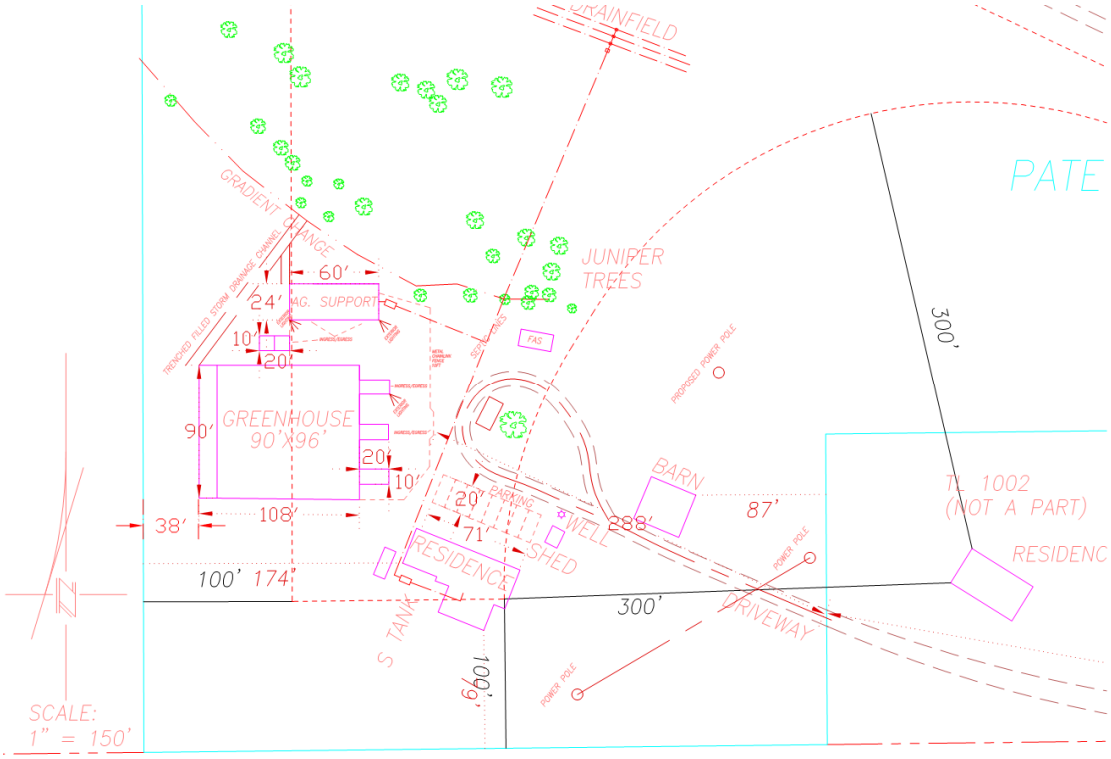
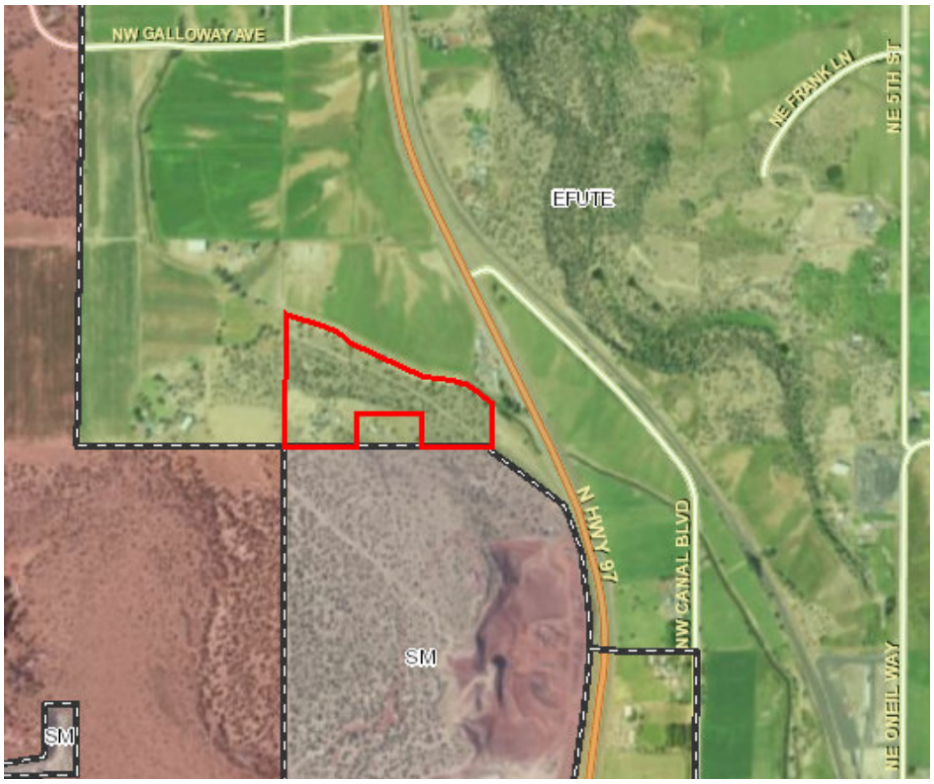


Fig. A1: Southwest section of site plan, showing locations of structures described in this report



Figs. A2: Satellite image showing location of property and surrounding area

Appendix B – System Specifications

Job Name:	
Tag#	

DAIKIN

Submittal Data Sheet	FTXS12LVJU / RXS12LVJU
1-Ton Wall Mounted Heat Pump System	

Complete warranty details available from your local dealer or at www.daikincomfort.com. To receive the 12-Year Parts Limited Warranty, online registration must be completed within 60 days of installation. Online registration is not required in California or Quebec. *If product is installed in a commercial application, limited warranty period is 5 years.*

Indoor Specifications

	Cooling		Heating	
Airflow Rate (cfm)	H	M	H	M
	403	307	438	335
	L	SL	L	SL
	205	155	240	212
Sound (dBA) H / M / L / SL	45 / 37 / 29 / 23		45 / 39 / 29 / 26	
Dimensions (H × W × D) (in)	11-5/8 × 31-1/2 × 8-7/16			
Weight (Lbs)	22			

Outdoor Specifications

Compressor	Hermetically Sealed Swing Type			
Refrigerant	R-410A			
Refrigerant Oil	PVE (FVC50K)			
Airflow Rate (cfm)	Cooling		Heating	
	H	1,183	H	992
	L	989	L	840
Sound Power Level (dBA)	63			
Dimensions (H × W × D) (in)	21-5/8 × 30-1/8 × 11-1/4			
Weight (Lbs)	75			

Efficiency

Cooling		Heating	
SEER	23	HSPF	12.5
EER	12.8	COP	4.35

Performance

Cooling (Btu/hr)	
Rated (Min/Max)	12,000 (4,800 / 12,000)
Sensible @ AHRI	9,250
Moisture Removal gal/h	.5
Standard Operating Range	50°F – 115°F
Extended Operating Range*	0°F – 115°F

Rated Cooling Conditions: Indoor: 80°F DB/67°F WB
Outdoor: 95°F DB/75°F WB

***With field settings and wind baffle**

Heating (Btu/hr)	
1:@ 47° Rated (Min/Max)	14,400 (4,400 / 14,400)
2: @ 17° Rated	9,200
3: @ 5° Max	6,430
Operating Range	5°F – 65°F

1: Rated Heating Conditions: Indoor: 70°F DB/60°F WB
Outdoor: 47°F DB/43°F WB
2: Rated Heating Conditions: Indoor: 70°F DB/60°F WB
Outdoor: 17°F DB/15°F WB
3: Rated Heating Conditions: Indoor: 70°F DB/60°F WB
Outdoor: 5°F DB/5°F WB

Electrical

	208/60/1	230/60/1
System MCA	8.75	8.75
System MFA	15	15
Compressor RLA	4.4	3.9
Outdoor fan motor FLA	.22	.22
Outdoor fan motor W	23	23
Indoor fan motor FLA	.15	.15
Indoor fan motor W	23	23

MFA: Max. fuse amps **MCA**: Min. circuit amps (A) **FLA**: Full load amps (A)
RLA: Rated load amps (A) **W**: Fan motor rated output (W)

Piping

Liquid (in)	1/4
Gas (in)	3/8
Drain (in)	5/8
Max. Interunit Piping Length (ft)	65.6
Max. Interunit Height Difference (ft)	49.2
Chargeless (ft)	32.8
Additional Charge of Refrigerant (oz/ft)	.21

Daikin North America LLC 5151 San Felipe, Suite 500 Houston, TX 77056
(Daikin's products are subject to continuous improvements. Daikin reserves the right to modify product design, specifications and information in this data sheet without notice and without incurring any obligations)

Submittal Creation Date: July 2017

Page **1** of **4**

Fig. B1: Mini Split A

Submittal Data Sheet
4-Ton Multi-Split Outdoor Unit
RMXS48LVJU

FEATURES

- Connect from 2 up to 8 indoor units from a single outdoor unit
- Long piping lengths, up to 440 ft
- Use with ductless wall mount, cassette or slim duct indoor units
- 12 year limited parts and compressor warranty with online registration

BENEFITS

- Quiet operation

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Submittal Data Sheet
4-Ton Multi-Split Outdoor Unit
RMXS48LVJU

PERFORMANCE			
Outdoor Unit Model No.	RMXS48LVJU	Outdoor Unit Name:	4-Ton Multi-Split Outdoor Unit
Type:	Heat Pump	Rated Cooling Conditions:	Indoor (°F DB/DB): 80 / 67 Ambient (°F DB/WB): 95 / 75
Rated Cooling Capacity (Btu/hr):	48,000	Rated Heating Conditions:	Indoor (°F DB/WB): 70 / 70 Ambient (°F DB/WB): 47 / 43
Max/Min Cooling Capacity (Btu/hr):	54,000 /	Rated Piping Length(ft):	
Cooling Input Power (kW):	4.73	Rated Height Difference (ft):	98.00
Rated Heating Capacity (Btu/hr):	54,000	SEER (Non-Ducted/Ducted):	18.80 / 14.10
Max/Min Heating Capacity (Btu/hr):	61,000 /	HSPF (Non-Ducted/Ducted):	11.3 / 9.6
Heating Input Power (kW):	4.26	Heating COP (Non-Ducted/Ducted):	3.0 / 2.7

OUTDOOR UNIT DETAILS			
Power Supply (V/Hz/Ph):	208-230 / 60 / 1	Compressor Type:	Inverter
Power Supply Connections:	L1, L2, Ground	Capacity Control Range (%):	29 - 100
Min. Circuit Amps MCA (A):	27.00	Airflow Rate (H) (CFM):	3,740
Max Overcurrent Protection (MOP) (A):	30.00	Gas Pipe Connection (inch):	3/4
Max Starting Current MSC(A):		Liquid Pipe Connection (inch):	3/8
Rated Load Amps RLA(A):	23.3	Sound Pressure (H) (dBA):	58
Dimensions (HxWxD) (in):	52-15/16 x 35-7/16 x 12-5/8	Sound Power Level (dBA):	57
Net Weight (lb):	283		

Daikin City Generated Submittal Data

Daikin North America LLC, 5151 San Felipe, Suite 500, Houston, TX, 77056

www.daikinac.com www.daikincomfort.com

(Daikin's products are subject to continuous improvements. Daikin reserves the right to modify product design, specifications and information in this data sheet without notice and without incurring any obligations)

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Fig. B2: Mini Split B

BOHN

SCROLL COMPRESSORS
Unit Specifications

Model	Fig. ++	Compressor	Connections (ID)		Receiver 90% Full Lbs.	Fan(s)	Dimensions			Net Wt. Lbs.	Sound Data dBA†
			Liquid	Suction			D (In.)	W (In.)	H (In.)		
BZ*020M6	C	ZS15K4E	1/2	7/8	14	2	28-1/4	37-3/4	19-3/4	209	71
BZ*025M6	C	ZS19K4E	1/2	7/8	14	2	28-1/4	37-3/4	19-3/4	218	73
BZ*030M6	D	ZS21K4E	1/2	7/8	20	1	30-1/4	42-1/2	29-3/4	287	72
BZ*035M6	D	ZS26K4E	1/2	7/8	20	1	30-1/4	42-1/2	29-3/4	290	74
BZ*045M6	D	ZS30K4E	1/2	1-1/8	20	1	30-1/4	42-1/2	29-3/4	317	73
BZ*055M6	D	ZS38K4E	1/2	1-1/8	20	1	30-1/4	42-1/2	29-3/4	317	74
BZ*060M6	D	ZS45K43	1/2	1-1/8	20	1	30-1/4	42-1/2	29-3/4	317	76
BZ*020L6	C	ZF06K4E	1/2	7/8	14	2	28-1/4	37-3/4	19-3/4	209	71
BZ*025L6	C	ZF08K4E	1/2	7/8	14	2	28-1/4	37-3/4	19-3/4	218	73
BZ*030L6	C	ZF09K4E	1/2	7/8	14	2	28-1/4	37-3/4	19-3/4	218	71
BZ*035L6	C	ZF11K4E	1/2	7/8	14	2	28-1/4	37-3/4	19-3/4	217	73
BZ*045L6	D	ZF13K4E	1/2	1-1/8	20	1	30-1/4	42-1/2	29-3/4	307	73
BZ*055L6	D	ZF15K4E	1/2	1-1/8	20	1	30-1/4	42-1/2	29-3/4	313	74
BZ*060L6	D	ZF18K4E	1/2	1-1/8	20	1	30-1/4	42-1/2	29-3/4	317	76

Fig. B3: Typical walk-in freezer compressors

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Appendix C – Site Photos

Fig. C1: Ground conditions looking northeast from future greenhouse location

Fig. C2: Ground conditions looking west from greenhouse location, typical to flat areas of site

Appendix D – Odor Technology Review

A. From "BiOdor Project Proposal Feasibility Study"

Gingrich et al., Calvin College, 2015.

Carbon Adsorption:

In a carbon adsorber unit, the air stream passes over a bed of activated carbon and the contaminants adhere to the surface of the carbon, thus removed from the air stream. This is a relatively simple form of odor-control and the only real [operating] cost comes from purchasing new activated carbon after the old carbon has been spent. Moisture is a large limiting factor for carbon adsorption. It is imperative that the carbon be kept dry, lest the adsorptive capacity is greatly reduced. The disposal and replacement costs associated with carbon adsorption are also high compared to alternative technologies.

Activated carbon removes hydrogen sulfide and other odor-producing compounds by catalyzing the oxidation of hydrogen sulfide, resulting in elemental sulfur and water according to the following reaction.

$$2H_2S\ (g) + O_2\ (g) \xrightarrow{yields} \frac{1}{4}\ S_8\ (s) + 2H_2O\ (g)$$

Most of the water produced from this process is lost to the air stream as it passes through the system, while the sulfur is adsorbed into the porous surface of the activated carbon. The adsorption continues until the pores can no longer take in sulfur. As the pores reach their capacity for sulfur uptake, the odor compounds begin to break through the media, meaning noticeable odors are released from the unit indicating the media needs to be replaced.

B. From "Final Environmental Impact Report for the Cannabis Land Use Ordinance and Licensing Program"

County of Santa Barbara, California. December 2017. Appendix F: Cannabis Odor Control: Supplemental Odor Control Technology Research Summary.

Introduction and Overview

Effective technologies exist to suppress cannabis malodors. Activated carbon filtration systems have been proved to be effective for indoor cannabis facilities by Denver's Department of Environmental Health. Vapor-phase systems have been proven to be effective for outdoor odor mitigation by the City

of San Diego's Department of Environmental Services, Air Pollution Control District, and Solid Waste Local Enforcement Agency, as well as greenhouse cultivation by established greenhouse growers in Carpinteria. These technologies could be implemented to effectively reduce cannabis malodors in Santa Barbara County.

Additionally, counties have implemented agriculture buffer requirements which serve in part to reduce land use conflicts which arise from odors. Buffer requirements may be a useful strategy for cannabis odor mitigation within the County where neighboring land uses are far apart. Anecdotal evidence suggests that strong cannabis odors can still be detected large distances away from the source. Thus, buffers may be utilized but are likely to be more effective remote areas of the County where larger buffer distances could be implemented. In more urban areas, odor mitigation technologies would be more appropriate as they would significantly reduce odors over a shorter distance.

Activated Carbon Filtration

Ventilation System

In this system, odor causing agents are adsorbed and filtered through activated carbon (Pennsylvania State University 2002). Odorous gas from the operation facility is collected via a ventilation system. Blowers then direct the gasses to the distribution system which uniformly delivers the gas to the filter. The filter sorbs and degrades the odors resulting in relatively odor-free exhaust.

Supporting information and Current Usage

The City of Denver's Department of Environmental Health regulates nuisance odors under Denver Revised Municipal Code, Chapter 4 – Air Pollution Control, Section 4-10. Under this rule, an odor control plan must be submitted 1) describing any odors anticipated to originate from the premises of marijuana growing, processing, and manufacturing facilities and 2) describing control technologies that will be used to prevent odors from leaving the premises (City and County of Denver 2017). The Department of Environmental Health states the, "rule recognizes carbon filtration as the current best control technology for marijuana cultivation and marijuana infused product facilities" (Denver Department of Environmental Health 2017). However, other odor control technologies are permitted so long as it can be demonstrated that the technology can effectively mitigate odors.

The Director of the Environmental Quality Division of Denver's Department of Environmental Health (Denver Director) was contacted by phone on November 30, 2017 to discuss how effective carbon filtration is, where it has been applied, and if it had the potential to impact product quality. The Denver Director stated that approximately 60 percent of indoor grow operations in Denver had installed odor mitigation control prior to the rule, and that 98 percent of those who installed odor mitigation had utilized carbon filtration. In creating the rule, input from indoor grow operators and HVAC control technicians was included to ensure the regulations would reflect technical and economic feasibility. City officials toured the cultivation facilities to determine the effectiveness of the carbon filtration technology. City officials determined that carbon filtration was effective in removing odors. However, the Denver Director stated that carbon filtration is only effective for processing facilities and indoor grows, which was the only type of cultivation facility in Denver at the time of the ruling. The Denver

Director noted that the initial cost of investment for a carbon filtration system is $10,000-$15,000 for a medium-sized 10,000 square foot indoor facility with an additional $2,000-$3,000 per year in operation and management costs. The Denver Director also stated that the carbon filtration technology would not impact the quality of the cannabis. Finally, the Denver Director stated that the quality of cannabis would only be impacted if the HVAC system, not the carbon filtration system, malfunctioned and humidity was not properly controlled.

A grower in Carpinteria was contacted by phone on November 19, 2017. The grower utilizes vaporphase technology (discussed below) to mitigate cannabis odors from his greenhouse in Carpinteria. He had considered carbon filtration, but stated that he did not use it because he would not have been able to control the internal environment of his greenhouse. The grower noted that carbon filtration would be appropriate for manufacturing, indoor grows, drying rooms, and packaging.

A Code Compliance Officer for the Portland Cannabis Program (Portland Officer), stated that there is no specific odor requirement for the City of Portland. If odor complaints are made, then an action plan is required to reduce odors. Portland's Zoning Code Section 33.262.070 simply states that "continuous, frequent, or repetitive odors may not be produced" (City of Portland 2017a). Portland's code guide for cannabis businesses states that "all exhaust and relief air should be filtered or scrubbed" in order to comply with the zoning code (Portland Bureau of Development Services 2017). The Portland Officer stated that retailers, wholesalers, and processors use countertop carbon systems in order to mitigate odors. Large ventilation systems with activated carbon filters are used for indoor cultivation. These systems are scaled proportionately to the size of the facility. However, Portland does not currently have any greenhouses and the Portland Officer does not know of any odor mitigation strategies for greenhouses.

<u>Canisters</u>

Activated carbon ventilation systems which are supported by activated carbon gas canisters.

Supporting Information and Current Usage

The Director of the Planning and Development Department of the City/County of Pueblo, Colorado (Pueblo Director), was contacted by phone on December 1, 2017. The Pueblo Director stated that Pueblo only regulates odor for cannabis in industrial zones and that agricultural zones is exempt from cannabis odor mitigation. Pueblo County Code Title 17 Chapter 17.120.190 requires that all cannabis establishments in the central business zoning district (B-4) have odor mitigation. "The building (term includes buildings, greenhouses, and hoop houses) shall be equipped with a ventilation system with carbon filters sufficient in type and capacity to eliminate marijuana odors emanating from the interior to the exterior discernable by a reasonable person…" (County of Pueblo 2017). The Pueblo Director stated that mitigate odors in greenhouses, some growers are using canisters with activated carbon inside to filter the air. This works similarly to the ventilation activated carbon systems used in indoor grows but can be used for greenhouses. The Pueblo Director and officials from the Department of Public Health and Environment plan to use an olfactometer to test the effectiveness of this technology in greenhouses on December 21st.

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C. From "Odor in Commercial Scale Compost: Literature Review and Critical Analysis

Washington State University & State of Washington Department of Ecology. October 17, 2013.

The fourth major odor-control strategy includes incorporation of carbon-based materials to piles, including activated carbon, high carbon wood ash, and biochar. Among these, activated carbon is generally understood to be technically effective but too expensive for widespread use in compost odor control.

D. From "Evaluating Odour Control Technologies Using Reliability and Sustainability Criteria: Odour control technology at wastewater treatment or water recycling plants.

NJR Kraakman, J Cesca. November 2012.

Activated Carbon Filter (AC): A granular impregnated AC bed (density 450kg/m^3), including a pre-filter operated at an EBRT of 2.5 sec, a system pressure drop of 900 Pa (excluding the pressure drop of an upfront pre-filter of 250 Pa) and a cost of $6 per kg was used as a model adsorption filter. The most common practice in AC filtration involves two filters (one filter in operation and one in standby to allow bed replacement). Bed replacement is based on empirical experience because carbon manufacturers typically do not guarantee carbon life in wastewater treatment plant (WWTP) applications. A standard carbon life of 12 months was used for stand-alone applications and the inlet concentrations of 10 ppm. No regeneration of the AC was considered. Disposal costs as a hazardous waste of $500 per kL were used for landfill.

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Appendix E – Odor Control Requirements of Other Jurisdictions

A. From Happy Valley Municipal Code 16.49.030

Happy Valley Municipal Code 16.49.030 (D & E):

D. Odor. As used in Section 16.49.030, building means the building, or portion thereof, used for marijuana production or processing and shall be regulated as follows:

1. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter;

2. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM;

3. The filtration system shall be maintained in working order and shall be in use. The filters shall be changed a minimum of once every three hundred sixty-five (365) days;

4. Negative air pressure shall be maintained inside the building;

5. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building;

6. The filtration system shall be designed by a mechanical engineer licensed tin the State of Oregon. The engineer shall stamp the design and certify that it complies with this subsection (D); and

7. An alternative odor control system is permitted if the applicants submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required.

E. Noise. The applicant shall submit a noise study by an acoustic engineer licensed in the State of Oregon. The study shall demonstrate that generators as well as mechanical equipment used for heating, ventilating, air conditioning, or odor control will not produce sound that, when measured at any lot line of the subject property, exceeds fifty (50) dB(A).

B. From Estacada Ordinance Series of 2016, No. 005, 16.07.010 (C)

C. Odor. As used in subsection 16.65.020 (C), building means the building, or portion thereof, used for marijuana retailing.

1. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter.

2. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM.

3. The filtration system shall be maintained in good working order and shall be in use. The filters shall be changed a minimum of once every 365 days.

4. Negative air pressure shall be maintained inside the building.

5. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building.

6. The filtration system shall be designed by a mechanical engineer licensed in the State of Oregon. The engineer shall stamp the design and certify that it complies with subsection 16.65.020 (C).

7. An alternative odor control system is permitted if the applicant submits a report by a mechanical engineer licensed in the State of Oregon demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required.

C. From Kalamazoo County, Michigan, Ordinance N. 595

d. Odor. It is the intent of this ordinance that no odor shall be detectable outside of any building where marijuana is present. As used in this subsection, building means the building, or portion thereof, used for marijuana production or marijuana processing.

i. The building shall be equipped with an activated carbon filtration system for odor control to ensure that air leaving the building through an exhaust vent first passes through an activated carbon filter.

ii. The filtration system shall consist of one or more fans and activated carbon filters. At a minimum, the fan(s) shall be sized for cubic feet per minute (CFM) equivalent to the volume of the building (length multiplied by width multiplied by height) divided by three. The filter(s) shall be rated for the applicable CFM.

iii. The filtration system shall be maintained in working order and shall be in use. The filters shall be changed a minimum of once every six (6) months or as manufacturer recommended.

iv. Negative air pressure shall be maintained inside the building.

v. Doors and windows shall remain closed, except for the minimum length of time needed to allow people to ingress or egress the building.

vi. An alternative odor control system is permitted if the special use permit applicant submits and municipality accepts a report by a mechanical engineer licensed in the state of Michigan demonstrating that the alternative system will control odor as well or better than the activated carbon filtration system otherwise required. The municipality may hire an outside expert at the applicant's expense, to review the alternative system design and advise as to its comparability and whether in the opinion of the expert it should be accepted.

D. From Regulatory Guidance for Licensed I-502 Operations in Spokane County

Air Quality and Odor Controls:

Odor – All businesses must comply with Spokane Clean Air's odor regulation. Odor control measures may include, but are not limited to: use of carbon adsorption media or other controls at all exhaust air discharge points, use of vertical exhaust vents or stacks, and/or completely enclosing the operation and recirculating ventilation air within the enclosure.

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Appendix F – ASHRAE Statement Regarding Carbon Filter Life

A. From 2016 ASHRAE Handbook – HVAC Systems and Equipment

"Incineration and scrubbing are usually the most economical methods of controlling high concentrations of odorous compounds from equipment such as cookers in rendering plants. However, many odors that arise from harmlessly low concentrations of vapors are still offensive. The odor threshold (for 100% response) of acrolein in air, for example, is only 0.21 ppm, whereas that for ethyl mercaptan is 0.001 ppm and that for hydrogen sulfide is 0.0005 ppm (AIHA 1989; MCA 1968). Activated carbon beds effectively overcome many odor emission problems. Activated carbon is used to control odors from chemical and pharmaceutical manufacturing operations, foundries, sewage treating plants, oil and chemical storage tanks, lacquer drying ovens, food processing plants, and rendering plants. In some of these applications, activated carbon is the sole odor control method; in others, the carbon adsorber is applied to the exhaust from a scrubber."

"The life of activated carbon in odor control systems ranges from a few weeks to a year or more, depending on the concentration of the odorous emission.

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Appendix G – ISO 9613, Part 2: General Method of Calculation

INTERNATIONAL STANDARD

ISO 9613-2

First edition
1996-12-15

Reviewed and confirmed in 2017

Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

Acoustique — Atténuation du son lors de sa propagation à l'air libre —
Partie 2: Méthode générale de calcul

Reference number
ISO 9613-2:1996(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9613-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 9613 consists of the following parts, under the general title *Acoustics — Attenuation of sound during propagation outdoors:*

— *Part 1: Calculation of the absorption of sound by the atmosphere*

— *Part 2: General method of calculation*

Part 1 is a detailed treatment restricted to the attenuation by atmospheric absorption processes. Part 2 is a more approximate and empirical treatment of a wider subject — the attenuation by all physical mechanisms.

Annexes A and B of this part of ISO 9613 are for information only.

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Introduction

The ISO 1996 series of standards specifies methods for the description of noise outdoors in community environments. Other standards, on the other hand, specify methods for determining the sound power levels emitted by various noise sources, such as machinery and specified equipment (ISO 3740 series), or industrial plants (ISO 8297). This part of ISO 9613 is intended to bridge the gap between these two types of standard, to enable noise levels in the community to be predicted from sources of known sound emission. The method described in this part of ISO 9613 is general in the sense that it may be applied to a wide variety of noise sources, and covers most of the major mechanisms of attenuation. There are, however, constraints on its use, which arise principally from the description of environmental noise in the ISO 1996 series of standards.

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Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

1 Scope

This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in parts 1 to 3 of ISO 1996) under meteorological conditions favourable to propagation from sources of known sound emission.

These conditions are for downwind propagation, as specified in 5.4.3.3 of ISO 1996-2:1987 or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted from this part of ISO 9613.

The method also predicts a long-term average A-weighted sound pressure level as specified in ISO 1996-1 and ISO 1996-2. The long-term average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions.

The method specified in this part of ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects:

— geometrical divergence;
— atmospheric absorption;
— ground effect;
— reflection from surfaces;
— screening by obstacles.

Additional information concerning propagation through housing, foliage and industrial sites is given in annex A.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. It does not apply to sound from aircraft in flight, or to blast waves from mining, military or similar operations.

To apply the method of this part of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

NOTE 1 If only A-weighted sound power levels of the sources are known, the attenuation terms for 500 Hz may be used to estimate the resulting attenuation.

The accuracy of the method and the limitations to its use in practice are described in clause 9.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9613. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9613 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1996-1:1982, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures.*

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ISO 1996-2:1987, *Acoustics — Description and measurement of environmental noise — Part 2: Acquisition of data pertinent to land use.*

ISO 1996-3:1987, *Acoustics — Description and measurement of environmental noise — Part 3: Application to noise limits.*

ISO 9613-1:1993, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere.*

IEC 651:1979, *Sound level meters,* and Amendment 1:1993.

3 Definitions

For the purposes of this part of ISO 9613, the definitions given in ISO 1996-1 and the following definitions apply. (See table 1 for symbols and units.)

3.1 equivalent continuous A-weighted sound pressure level, L_{AT}: Sound pressure level, in decibels, defined by equation (1):

$$L_{AT} = 10 \lg \left\{ \left[(1/T) \int_0^T p_A{}^2(t)\, dt \right] \Big/ p_0{}^2 \right\} \quad \text{dB} \qquad \ldots (1)$$

where

$p_A(t)$ is the instantaneous A-weighted sound pressure, in pascals;

p_0 is the reference sound pressure (= 20 × 10⁻⁶ Pa);

T is a specified time interval, in seconds.

The A-frequency weighting is that specified for sound level meters in IEC 651.

NOTE 2 The time interval T should be long enough to average the effects of varying meteorological parameters. Two different situations are considered in this part of ISO 9613, namely short-term downwind and long-term overall averages.

Table 1 — Symbols and units

Symbol	Definition	Unit
A	octave-band attenuation	dB
C_{met}	meteorological correction	dB
d	distance from point source to receiver (see figure 3)	m
d_p	distance from point source to receiver projected onto the ground plane (see figure 1)	m
$d_{s,o}$	distance between source and point of reflection on the reflecting obstacle (see figure 8)	m
$d_{o,r}$	distance between point of reflection on the reflecting obstacle and receiver (see figure 8)	m
d_{ss}	distance from source to (first) diffraction edge (see figures 6 and 7)	m
d_{sr}	distance from (second) diffraction edge to receiver (see figures 6 and 7)	m
D_I	directivity index of the point sound source	—
D_z	screening attenuation	—
e	distance between the first and second diffraction edge (see figure 7)	m
G	ground factor	—
h	mean height of source and receiver	m
h_s	height of point source above ground (see figure 1)	m
h_r	height of receiver above ground (see figure 1)	m
h_m	mean height of the propagation path above the ground (see figure 3)	m
H_{max}	largest dimension of the sources	m
l_{min}	minimum dimension (length or height) of the reflecting plane (see figure 8)	m
L	sound pressure level	dB
α	atmospheric attenuation coefficient	dB/km
β	angle of incidence	rad
ρ	sound reflection coefficient	—

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3.2 equivalent continuous downwind octave-band sound pressure level, L_{fT}(DW): Sound pressure level, in decibels, defined by equation (2):

$$L_{fT}(\mathrm{DW}) = 10 \lg \left\{ \left[(1/T) \int_0^T p_f{}^2(t)\, \mathrm{d}t \right] \Big/ p_0{}^2 \right\} \quad \mathrm{dB} \qquad \ldots (2)$$

where $p_f(t)$ is the instantaneous octave-band sound pressure downwind, in pascals, and the subscript f represents a nominal midband frequency of an octave-band filter.

NOTE 3 The electrical characteristics of the octave-band filters should comply at least with the class 2 requirements of IEC 1260.

3.3 insertion loss (of a barrier): Difference, in decibels, between the sound pressure levels at a receiver in a specified position under two conditions:

a) with the barrier removed, and

b) with the barrier present (inserted),

and no other significant changes that affect the propagation of sound.

4 Source description

The equations to be used are for the attenuation of sound from point sources. Extended noise sources, therefore, such as road and rail traffic or an industrial site (which may include several installations or plants, together with traffic moving on the site) shall be represented by a set of sections (cells), each having a certain sound power and directivity. Attenuation calculated for sound from a representative point within a section is used to represent the attenuation of sound from the entire section. A line source may be divided into line sections, an area source into area sections, each represented by a point source at its centre.

However, a group of point sources may be described by an equivalent point sound source situated in the middle of the group, in particular if

a) the sources have approximately the same strength and height above the local ground plane,

b) the same propagation conditions exist from the sources to the point of reception, and

c) the distance d from the single equivalent point source to the receiver exceeds twice the largest dimension H_{max} of the sources ($d > 2H_{max}$).

If the distance d is smaller ($d \leq 2H_{max}$), or if the propagation conditions for the component point sources are different (e.g. due to screening), the total sound source shall be divided into its component point sources.

NOTE 4 In addition to the real sources described above, image sources will be introduced to describe the reflection of sound from walls and ceilings (but not by the ground), as described in 7.5.

5 Meteorological conditions

Downwind propagation conditions for the method specified in this part of ISO 9613 are as specified in 5.4.3.3 of ISO 1996-2:1987, namely

— wind direction within an angle of ± 45° of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and

— wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.

The equations for calculating the average downwind sound pressure level L_{AT}(DW) in this part of ISO 9613, including the equations for attenuation given in clause 7, are the average for meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.

These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights.

6 Basic equations

The equivalent continuous downwind octave-band sound pressure level at a receiver location, L_{fT}(DW), shall be calculated for each point source, and its image sources, and for the eight octave bands with nominal midband frequencies from 63 Hz to 8 kHz, from equation (3):

$$L_{fT}(\mathrm{DW}) = L_W + D_c - A \qquad \ldots (3)$$

where

L_W is the octave-band sound power level, in decibels, produced by the point sound source relative to a reference sound power of one picowatt (1 pW);

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D_c is the directivity correction, in decibels, that describes the extent by which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omnidirectional point sound source producing sound power level L_W; D_c equals the directivity index D_I of the point sound source plus an index D_Ω that accounts for sound propagation into solid angles less than 4π steradians; for an omnidirectional point sound source radiating into free space, D_c = 0 dB;

A is the octave-band attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

NOTES

5 The letter symbol A (in italic type) signifies attenuation in this part of ISO 9613 except in subscripts, where it designates the A-frequency weighting (in roman type).

6 Sound power levels in equation (3) may be determined from measurements, for example as described in the ISO 3740 series (for machinery) or in ISO 8297 (for industrial plants).

The attenuation term A in equation (3) is given by equation (4):

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \quad \ldots (4)$$

where

A_{div} is the attenuation due to geometrical divergence (see 7.1);

A_{atm} is the attenuation due to atmospheric absorption (see 7.2);

A_{gr} is the attenuation due to the ground effect (see 7.3);

A_{bar} is the attenuation due to a barrier (see 7.4);

A_{misc} is the attenuation due to miscellaneous other effects (see annex A).

General methods for calculating the first four terms in equation (4) are specified in this part of ISO 9613. Information on three contributions to the last term, A_{misc} (the attenuation due to propagation through foliage, industrial sites and areas of houses), is given in annex A.

The equivalent continuous A-weighted downwind sound pressure level shall be obtained by summing the contributing time-mean-square sound pressures calculated according to equations (3) and (4) for each point sound source, for each of their image sources, and for each octave band, as specified by equation (5):

$$L_{AT}(\mathrm{DW}) = 10 \lg \left\{ \sum_{i=1}^{n} \left[\sum_{j=1}^{8} 10^{0,1\left[L_{fT}(ij) + A_f(j)\right]} \right] \right\} \ \mathrm{dB} \quad \ldots (5)$$

where

n is the number of contributions i (sources and paths);

j is an index indicating the eight standard octave-band midband frequencies from 63 Hz to 8 kHz;

A_f denotes the standard A-weighting (see IEC 651).

The long-term average A-weighted sound pressure level L_{AT}(LT) shall be calculated according to

$$L_{AT}(\mathrm{LT}) = L_{AT}(\mathrm{DW}) - C_{met} \quad \ldots (6)$$

where C_{met} is the meteorological correction described in clause 8.

The calculation and significance of the various terms in equations (1) to (6) are explained in the following clauses. For a more detailed treatment of the attenuation terms, see the literature references given in annex B.

7 Calculation of the attenuation terms

7.1 Geometrical divergence (A_{div})

The geometrical divergence accounts for spherical spreading in the free field from a point sound source, making the attenuation, in decibels, equal to

$$A_{div} = \left[20 \lg(d/d_0) + 11\right] \ \mathrm{dB} \quad \ldots (7)$$

where

d is the distance from the source to receiver, in metres;

d_0 is the reference distance (= 1 m).

NOTE 7 The constant in equation (7) relates the sound power level to the sound pressure level at a reference distance d_0 which is 1 m from an omnidirectional point sound source.

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7.2 Atmospheric absorption (A_{atm})

The attenuation due to atmospheric absorption A_{atm}, in decibels, during propagation through a distance d, in metres, is given by equation (8):

$$A_{atm} = \alpha d/1\,000 \qquad \ldots (8)$$

where α is the atmospheric attenuation coefficient, in decibels per kilometre, for each octave band at the midband frequency (see table 2).

For values of α at atmospheric conditions not covered in table 2, see ISO 9613-1.

NOTES

8 The atmospheric attenuation coefficient depends strongly on the frequency of the sound, the ambient temperature and relative humidity of the air, but only weakly on the ambient pressure.

9 For calculation of environmental noise levels, the atmospheric attenuation coefficient should be based on average values determined by the range of ambient weather which is relevant to the locality.

7.3 Ground effect (A_{gr})

7.3.1 General method of calculation

Ground attenuation, A_{gr}, is mainly the result of sound reflected by the ground surface interfering with the sound propagating directly from source to receiver. The downward-curving propagation path (downwind) ensures that this attenuation is determined primarily by the ground surfaces near the source and near the receiver. This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope. Three distinct regions for ground attenuation are specified (see figure 1):

a) the source region, stretching over a distance from the source towards the receiver of $30h_s$, with a maximum distance of d_p (h_s is the source height, and d_p the distance from source to receiver, as projected on the ground plane);

b) the receiver region, stretching over a distance from the receiver back towards the source of $30h_r$, with a maximum distance of d_p (h_r is the receiver height);

c) a middle region, stretching over the distance between the source and receiver regions. If $d_p < (30h_s + 30h_r)$, the source and receiver regions will overlap, and there is no middle region.

According to this scheme, the ground attenuation does not increase with the size of the middle region, but is mostly dependent on the properties of source and receiver regions.

The acoustical properties of each ground region are taken into account through a ground factor G. Three categories of reflecting surface are specified as follows.

Table 2 — Atmospheric attenuation coefficient α for octave bands of noise

Temperature	Relative humidity	Atmospheric attenuation coefficient α, dB/km							
		Nominal midband frequency, Hz							
°C	%	63	125	250	500	1 000	2 000	4 000	8 000
10	70	0,1	0,4	1,0	1,9	3,7	9,7	32,8	117
20	70	0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6
30	70	0,1	0,3	1,0	3,1	7,4	12,7	23,1	59,3
15	20	0,3	0,6	1,2	2,7	8,2	28,2	88,8	202
15	50	0,1	0,5	1,2	2,2	4,2	10,8	36,2	129
15	80	0,1	0,3	1,1	2,4	4,1	8,3	23,7	82,8

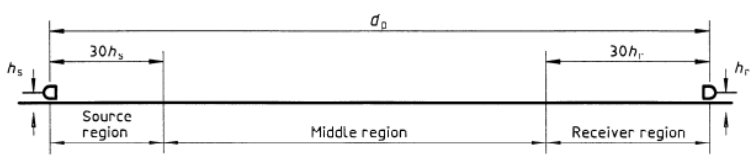

Figure 1 — Three distinct regions for determination of ground attenuation

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a) **Hard ground,** which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground $G = 0$.

NOTE 10 It should be recalled that inversion conditions over water are not covered by this part of ISO 9613.

b) **Porous ground,** which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground $G = 1$.

c) **Mixed ground:** if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

To calculate the ground attenuation for a specific octave band, first calculate the component attenuations A_s for the source region specified by the ground factor G_s (for that region), A_r for the receiver region specified by the ground factor G_r, and A_m for the middle region specified by the ground factor G_m, using the expressions in table 3. (Alternatively, the functions a', b', c' and d' in table 3 may be obtained directly from the curves in figure 2.) The total ground attenuation for that octave band shall be obtained from equation (9):

$$A_{gr} = A_s + A_r + A_m \qquad \ldots (9)$$

NOTE 11 In regions with buildings, the influence of the ground on sound propagation may be changed (see A.3).

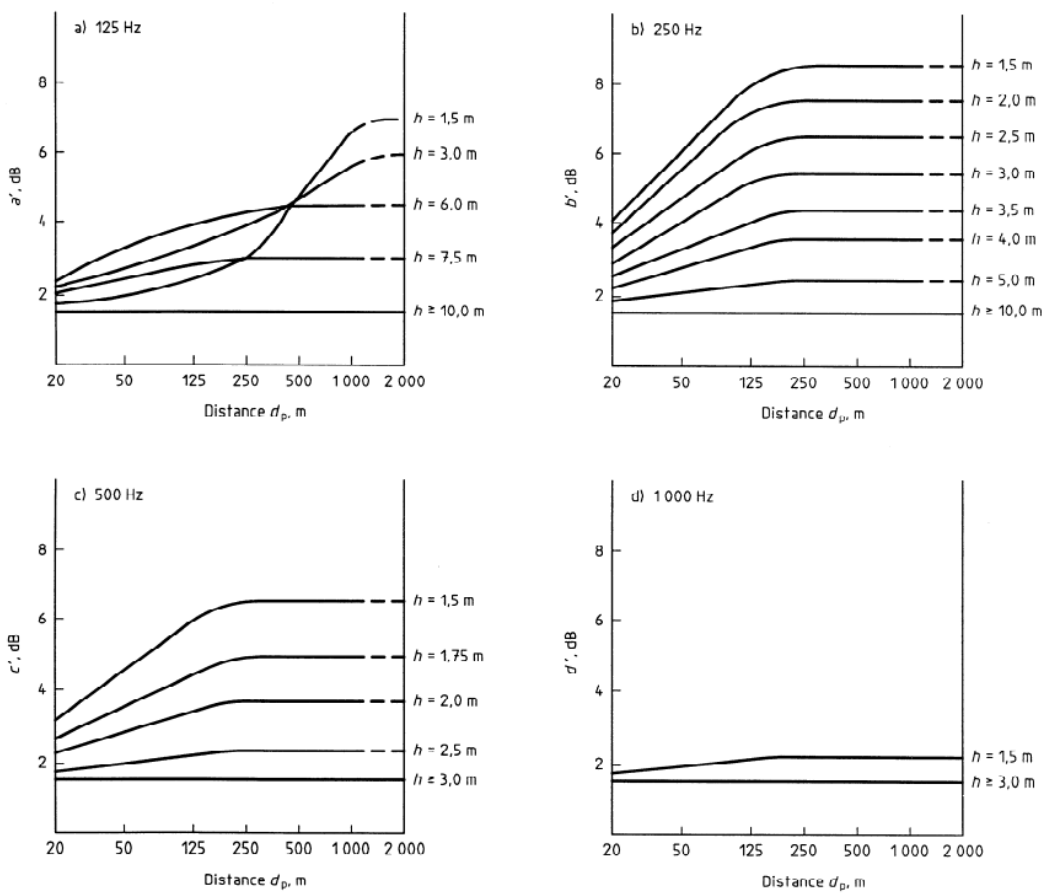

Figure 2 — Functions a', b', c' and d' representing the influence of the source-to-receiver distance d_p and the source or receiver height h, respectively, on the ground attenuation A_{gr} (computed from equations in table 3)

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Table 3 — Expressions to be used for calculating ground attenuation contributions A_s, A_r and A_m in octave bands

Nominal midband frequency Hz	A_s or A_r [1] dB	A_m dB
63	$-1{,}5$	$-3q$ [2]
125	$-1{,}5 + G \times a'(h)$	$-3q(1-G_m)$
250	$-1{,}5 + G \times b'(h)$	
500	$-1{,}5 + G \times c'(h)$	
1 000	$-1{,}5 + G \times d(h)$	
2 000	$-1{,}5(1-G)$	
4 000	$-1{,}5(1-G)$	
8 000	$-1{,}5(1-G)$	

NOTES

$$a'(h) = 1{,}5 + 3{,}0 \times e^{-0{,}12(h-5)^2}\left(1 - e^{-d_p/50}\right) + 5{,}7 \times e^{-0{,}09h^2}\left(1 - e^{-2{,}8 \times 10^{-6} \times d_p^2}\right)$$

$$b'(h) = 1{,}5 + 8{,}6 \times e^{-0{,}09h^2}\left(1 - e^{-d_p/50}\right)$$

$$c'(h) = 1{,}5 + 14{,}0 \times e^{-0{,}46h^2}\left(1 - e^{-d_p/50}\right)$$

$$d'(h) = 1{,}5 + 5{,}0 \times e^{-0{,}9h^2}\left(1 - e^{-d_p/50}\right)$$

1) For calculating A_s, take $G = G_s$ and $h = h_s$. For calculating A_r, take $G = G_r$ and $h = h_r$. See 7.3.1 for values of G for various ground surfaces.

2) $q = 0$ when $d_p \leqslant 30(h_s + h_r)$

$$q = 1 - \frac{30(h_s + h_r)}{d_p} \quad \text{when } d_p > 30(h_s + h_r)$$

where d_p is the source-to-receiver distance, in metres, projected onto the ground planes.

7.3.2 Alternative method of calculation for A-weighted sound pressure levels

Under the following specific conditions

— only the A-weighted sound pressure level at the receiver position is of interest,

— the sound propagation occurs over porous ground or mixed ground most of which is porous (see 7.3.1),

— the sound is not a pure tone,

and for ground surfaces of any shape, the ground attenuation may be calculated from equation (10):

$$A_{gr} = 4{,}8 - (2h_m/d)\left[17 + (300/d)\right] \geqslant 0 \text{ dB} \quad \ldots (10)$$

where

h_m is the mean height of the propagation path above the ground, in metres;

d is the distance from the source to receiver, in metres.

The mean height h_m may be evaluated by the method shown in figure 3. Negative values for A_{gr} from equation (10) shall be replaced by zeros.

NOTE 12 For short distances d, equation (10) predicts no attenuation and equation (9) may be more accurate.

When the ground attenuation is calculated using equation (10), the directivity correction D_c in equation (3) shall include a term D_Ω, in decibels, to account for the apparent increase in sound power level of the source due to reflections from the ground near the source.

$$D_\Omega = 10 \lg \left\{1 + \left[d_p^2 + (h_s - h_r)^2\right] \Big/ \left[d_p^2 + (h_s + h_r)^2\right]\right\} \text{ dB} \quad \ldots (11)$$

where

h_s is the height of the source above the ground, in metres;

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h_r is the height of the receiver above the ground, in metres;

d_p is the source-to-receiver distance projected onto the ground plane, in metres.

7.4 Screening (A_{bar})

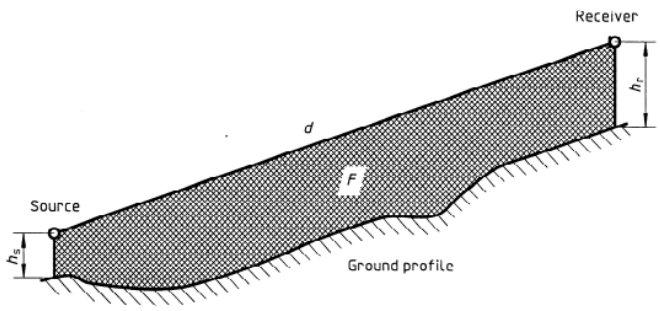
An object shall be taken into account as a screening obstacle (often called a barrier) if it meets the following requirements:

— the surface density is at least 10 kg/m^2;

— the object has a closed surface without large cracks or gaps (consequently process installations in chemical plants, for example, are ignored);

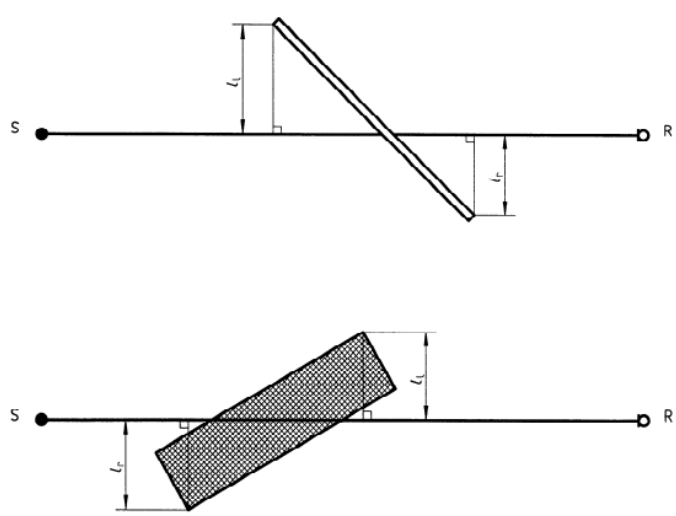
— the horizontal dimension of the object normal to the source-receiver line is larger than the acoustic wavelength λ at the nominal midband frequency for the octave band of interest; in other words $l_l + l_r > \lambda$ (see figure 4).

Each object that fulfils these requirements shall be represented by a barrier with vertical edges. The top edge of the barrier is a straight line that may be sloping.



$h_m = F/d$, where F is the area

Figure 3 — Method for evaluating the mean height h_m



NOTE — An object is only considered to be a screening obstacle when its horizontal dimension perpendicular to the source-receiver line SR is larger than the wavelength: $(l_l + l_r) > \lambda$

Figure 4 — Plan view of two obstacles between the source (S) and the receiver (R)

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For the purposes of this part of ISO 9613, the attenuation by a barrier, A_{bar}, shall be given by the insertion loss. Diffraction over the top edge and around a vertical edge of a barrier may both be important. (See figure 5.) For downwind sound propagation, the effect of diffraction (in decibels) over the top edge shall be calculated by

$$A_{bar} = D_z - A_{gr} > 0 \quad \ldots (12)$$

and for diffraction around a vertical edge by

$$A_{bar} = D_z > 0 \quad \ldots (13)$$

where

D_z is the barrier attenuation for each octave band [see equation (14)];

A_{gr} is the ground attenuation **in the absence of the barrier** (i.e. with the screening obstacle removed) (see 7.3).

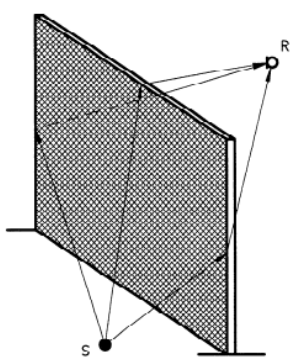

Figure 5 — Different sound propagation paths at a barrier

NOTES

13 When A_{bar} as defined by equation (12) is substituted in equation (4) to find the total attenuation A, the two A_{gr} terms in equation (4) will cancel. The barrier attenuation D_z in equation (12) then includes the effect of the ground in the presence of the barrier.

14 For large distances and high barriers, the insertion loss calculated by equation (12) is not sufficiently confirmed by measurements.

15 In calculation of the insertion loss for multisource industrial plants by high buildings (more than 10 m above the ground), and also for high-noise sources within the plant, equation (13) should be used in both cases for determining the long-term average sound pressure level [using equation (6)].

16 For sound from a depressed highway, there may be attenuation in addition to that indicated by equation (12) along a ground surface outside the depression, due to that ground surface.

To calculate the barrier attenuation D_z, assume that only one significant sound-propagation path exists from the sound source to the receiver. If this assumption is not valid, separate calculations are required for other propagation paths (as illustrated in figure 5) and the contributions from the various paths to the squared sound pressure at the receiver are summed.

The barrier attenuation D_z, in decibels, shall be calculated for this path by equation (14):

$$D_z = 10 \lg \left[3 + \left(C_2/\lambda\right) C_3 z K_{met}\right] \text{ dB} \quad \ldots (14)$$

where

C_2 is equal to 20, and includes the effect of ground reflections; if in special cases ground reflections are taken into account separately by image sources, $C_2 = 40$;

C_3 is equal to 1 for single diffraction (see figure 6);

$$C_3 = \left[1 + \left(5\lambda/e\right)^2\right] \Big/ \left[\left(1/3\right) + \left(5\lambda/e\right)^2\right] \quad \ldots (15)$$

for double diffraction (see figure 7);

λ is the wavelength of sound at the nominal midband frequency of the octave band, in metres;

z is the difference between the pathlengths of diffracted and direct sound, as calculated by equations (16) and (17), in metres;

K_{met} is the correction factor for meteorological effects, given by equation (18);

e is the distance between the two diffraction edges in the case of double diffraction (see figure 7).

For single diffraction, as shown in figure 6, the pathlength difference z shall be calculated by means of equation (16):

$$z = \left[\left(d_{ss} + d_{sr}\right)^2 + a^2\right]^{1/2} - d \quad \ldots (16)$$

where

d_{ss} is the distance from the source to the (first) diffraction edge, in metres;

d_{sr} is the distance from the (second) diffraction edge to the receiver, in metres;

a is the component distance parallel to the barrier edge between source and receiver, in metres.

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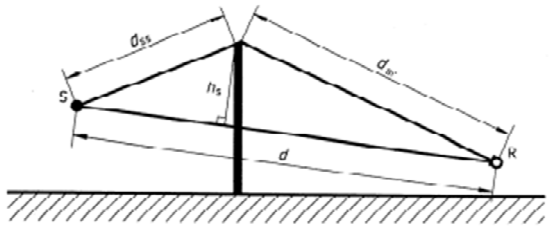
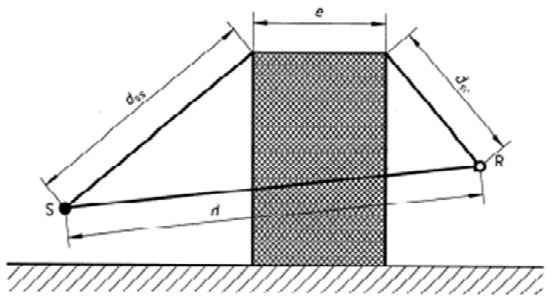


Figure 6 — Geometrical quantities for determining the pathlength difference for single diffraction



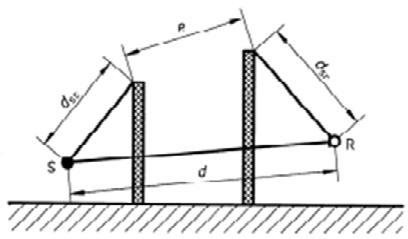


Figure 7 — Geometrical quantities for determining the pathlength difference for double diffraction

If the line of sight between the source S and receiver R passes above the top edge of the barrier, z is given a negative sign.

For double diffraction, as shown in figure 7, the pathlength difference z shall be calculated by

$$z = \left[\left(d_{ss} + d_{sr} + e \right)^2 + a^2 \right]^{1/2} - d \qquad \ldots (17)$$

The correction factor K_{met} for meteorological conditions in equation (14) shall be calculated using equation (18):

$$K_{met} = \exp\left[-(1/2000)\sqrt{d_{ss} d_{sr} d/(2z)} \right] \quad \text{for } z > 0$$

$$K_{met} = 1 \quad \text{for } z < 0 \qquad \ldots (18)$$

For lateral diffraction around obstacles, it shall be assumed that $K_{met} = 1$ (see figure 5).

NOTES

17 For source-to-receiver distances less than 100 m, the calculation using equation (14) shows that K_{met} may be assumed equal to 1, to an accuracy of 1 dB.

18 Equation (15) provides a continuous transition from the case of single diffraction ($e = 0$) where $C_3 = 1$, to that of a well-separated double diffraction ($e \gg \lambda$) where $C_3 = 3$.

19 A barrier may be less effective than calculated by equations (12) to (18) as a result of reflections from other acoustically hard surfaces near the sound path from the source to the receiver or by multiple reflections between an acoustically hard barrier and the source.

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The barrier attenuation D_z, in any octave band, should not be taken to be greater than 20 dB in the case of single diffraction (i.e. thin barriers) and 25 dB in the case of double diffraction (i.e. thick barriers).

The barrier attenuation for two barriers is calculated using equation (14) for double diffraction, as indicated in the lower part of figure 7. The barrier attenuation for more than two barriers may also be calculated approximately using equation (14), by choosing the two most effective barriers, neglecting the effects of the others.

7.5 Reflections

Reflections are considered here in terms of image sources. These reflections are from outdoor ceilings and more or less vertical surfaces, such as the façades of buildings, which can increase the sound pressure levels at the receiver. The effect of reflections from the ground are not included because they enter into the calculation of A_{gr}.

The reflections from an obstacle shall be calculated for all octave bands for which all the following requirements are met:

— a specular reflection can be constructed, as shown in figure 8;

— the magnitude of the sound reflection coefficient for the surface of the obstacle is greater than 0,2;

— the surface is large enough for the nominal midband wavelength λ (in metres) for the octave band under consideration to obey the relationship

$$1/\lambda > \left[2/\left(l_{\min}\cos\beta\right)^2\right]\left[d_{s,o}d_{o,r}/\left(d_{s,o}+d_{o,r}\right)\right] \quad \ldots (19)$$

where

λ is the wavelength of sound (in metres) at the nominal midband frequency f (in hertz) of the octave band $\left(\lambda = \frac{340\ \text{m/s}}{f}\right)$;

$d_{s,o}$ is the distance between the source and the point of reflection on the obstacle;

$d_{o,r}$ is the distance between the point of reflection on the obstacle and the receiver;

β is the angle of incidence, in radians (see figure 8);

$l_{\min}$ is the minimum dimension (length or height) of the reflecting surface (see figure 8).

If any of these conditions is not met for a given octave band, then reflections shall be neglected.

The real source and source image are handled separately. The sound power level of the source image $L_{W,\text{im}}$ shall be calculated from

$$L_{W,\text{im}} = L_W + 10\lg(\rho)\,\text{dB} + D_{\text{Ir}} \quad \ldots (20)$$

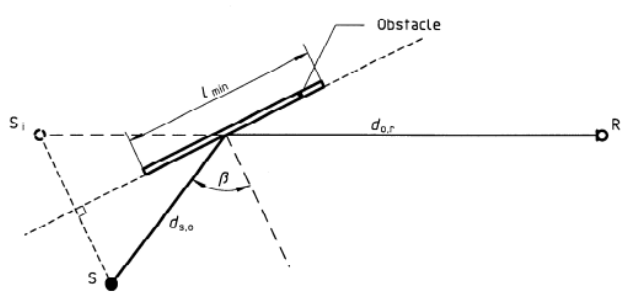
where

ρ is the sound reflection coefficient at angle β on the surface of the obstacle ($\geq 0{,}2$) (see figure 8);

D_{Ir} is the directivity index of the source in the direction of the receiver image.

If specific data for the sound reflection coefficient are not available, the value may be estimated using table 4.

For the sound source image, the attenuation terms of equation (4), as well as ρ and D_{Ir} in equation (20), shall be determined according to the propagation path of the reflected sound.



NOTE — A path $d_{s,o} + d_{o,r}$ connecting the source S and receiver R by reflection from the obstacle exists in which β, the angle of incidence, is equal to the angle of reflection. The reflected sound appears to come from the source image S_i.

Figure 8 — Specular reflection from an obstacle

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Table 4 — Estimates of the sound reflection coefficient ρ

Object	ρ
Flat hard walls	1
Walls of building with windows and small additions or bay	0,8
Factory walls with 50 % of the surface consisting of openings, installations or pipes	0,4
Cylinders with hard surfaces (tanks, silos)	$\frac{D \sin(\phi/2)}{2d_{sc}}$ *) where D is the diameter of the cylinder; d_{sc} is the distance from the source to the centre C of the cylinder; ϕ is the supplement of the angle between lines SC and CR.
Open installations (pipes, towers, etc.)	0

*) This expression applies only if the distance d_{sc} from the source S to cylinder C is much smaller than the distance d_{cr} from the cylinder to receiver; see figure 9.

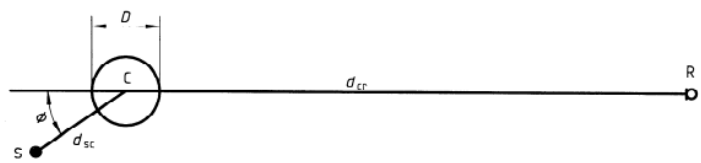

Figure 9 — Estimation of sound reflection coefficient for a cylinder

8 Meteorological correction (C_{met})

Use of equation (3) leads directly to an equivalent continuous A-weighted sound pressure level L_{AT} at the receiver for meteorological conditions which are favourable for propagation from the sound source to that receiver, as described in clause 5. This may be the appropriate condition for meeting a specific community noise limit, i.e. a level which is seldom exceeded (see ISO 1996-3). Often, however, a long term average A-weighted sound pressure level L_{AT}(LT) is required, where the time interval T is several months or a year. Such a period will normally include a variety of meteorological conditions, both favourable and unfavourable to propagation. A value for L_{AT}(LT) may be obtained in this situation from that calculated for L_{AT}(DW) via equation (3), by using the meteorological correction C_{met} in equation (6).

A value (in decibels) for C_{met} in equation (6) may be calculated using equations (21) and (22) for the case of a point sound source with an output which is effectively constant with time:

$$C_{met} = 0 \qquad \text{if } d_p \leqslant 10(h_s + h_r) \qquad \ldots (21)$$

$$C_{met} = C_0 \left[1 - 10(h_s + h_r)/d_p\right] \qquad \text{if } d_p > 10(h_s + h_r) \qquad \ldots (22)$$

where

h_s is the source height, in metres;

h_r is the receiver height, in metres;

d_p is the distance between the source and receiver projected to the horizontal ground plane, in metres;

C_0 is a factor, in decibels, which depends on local meteorological statistics for wind speed and direction, and temperature gradients.

The effects of meteorological conditions on sound propagation are small for short distances d_p, and for longer distances at greater source and receiver heights. Equations (21) and (22) account approximately for these factors, as shown in figure 10.

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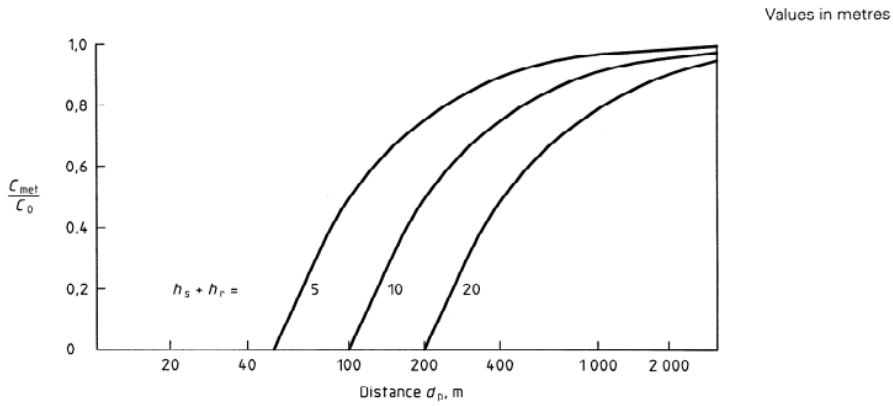

Figure 10 — Meteorological correction C_{met}

NOTES

20 A value for C_0 in equations (21) and (22) may be estimated from an elementary analysis of the local meteorological statistics. For example, if the meteorological conditions favourable to propagation described in clause 5 are found to occur for 50 % of the time period of interest, and the attenuation during the other 50 % is higher by 10 dB or more, then the sound energy which arrives for meteorological conditions unfavourable to propagation may be neglected, and C_0 will be approximately + 3 dB.

21 The meteorological conditions for evaluating C_0 may be established by the local authorities.

22 Experience indicates that values of C_0 in practice are limited to the range from zero to approximately + 5 dB, and values in excess of 2 dB are exceptional. Thus only very elementary statistics of the local meteorology are needed for a ± 1 dB accuracy in C_0.

For a source that is composed of several component point sources, h_s in equations (21) and (22) represents the predominant source height, and d_p the distance from the centre of that source to the receiver.

9 Accuracy and limitations of the method

The attenuation of sound propagating outdoors between a fixed source and receiver fluctuates due to variations in the meteorological conditions along the propagation path. Restricting attention to moderate downwind conditions of propagation, as specified in clause 5, limits the effect of variable meteorological conditions on attenuation to reasonable values.

There is information to support the method of calculation given in clauses 4 to 8 (see annex B) for broad-band noise sources. The agreement between calculated and measured values of the average A-weighted sound pressure level for downwind propagation, L_{AT}(DW), supports the estimated accuracy of calculation shown in table 5. These estimates of accuracy are restricted to the range of conditions specified for the validity of the equations in clauses 3 to 8 and are independent of uncertainties in sound power determination.

NOTE 24 The estimates of accuracy in table 5 are for downwind conditions averaged over independent situations (as specified in clause 5). They should not necessarily be expected to agree with the variation in measurements made at a given site on a given day. The latter can be expected to be considerably larger than the values in table 5.

The estimated errors in calculating the average downwind octave-band sound pressure levels, as well as pure-tone sound pressure levels, under the same conditions, may be somewhat larger than the estimated errors given for A-weighted sound pressure levels of broad-band sources in table 5.

In table 5, an estimate of accuracy is not provided in this part of ISO 9613 for distances d greater than the 1 000 m upper limit.

Throughout this part of ISO 9613 the meteorological conditions under consideration are limited to only two cases:

a) moderate downwind conditions of propagation, or their equivalent, as defined in clause 5;

b) a variety of meteorological conditions as they exist over months or years.

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The use of equations (1) to (5) and (7) to (20) (and therefore also table 5) is limited to case a): meteorological conditions only. Case b) is relevant only to the use of equations (6), (21) and (22). There are also a substantial number of limitations (non-meteorological) in the use of individual equations. Equation (9) is, for example, limited to approximately flat terrain. These specific limitations are described in the text accompanying the relevant equation.

Table 5 — Estimated accuracy for broadband noise of L_{AT}(DW) calculated using equations (1) to (10)

Height, h *)	**Distance,** d *)	
	$0 < d < 100$ m	$100 \text{ m} < d < 1\,000$ m
$0 < h < 5$ m	± 3 dB	± 3 dB
$5 \text{ m} < h < 30$ m	± 1 dB	± 3 dB

*) h is the mean height of the source and receiver.
d is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

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Annex A
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Additional types of attenuation (A_{misc})

The term A_{misc} in equation (4) covers contributions to the attenuation from miscellaneous effects not accessible by the general methods of calculating the attenuation specified in clause 7. These contributions include

— A_{fol}, the attenuation of sound during propagation through foliage,

— A_{site}, the attenuation during propagation through an industrial site, and

— A_{hous}, the attenuation during propagation through a built-up region of houses,

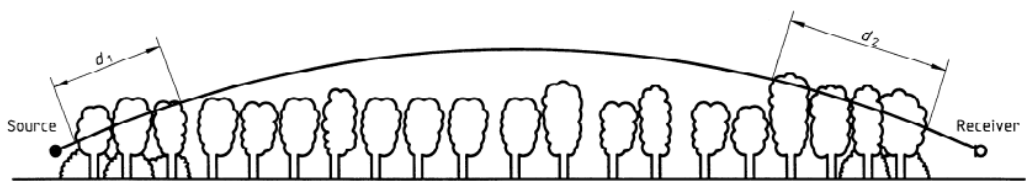
which are all considered in this annex.

For calculating these additional contributions to the attenuation, the curved downwind propagation path may be approximated by an arc of a circle of radius 5 km, as shown in figure A.1.

A.1 Foliage (A_{fol})

The foliage of trees and shrubs provides a small amount of attenuation, but only if it is sufficiently dense to completely block the view along the propagation path, i.e. when it is impossible to see a short distance through the foliage. The attenuation may be by vegetation close to the source, or close to the receiver, or by both situations, as illustrated in figure A.1. Alternatively, the path for the distances d_1 and d_2 may be taken as falling along lines at propagation angles of 15° to the ground.

The first line in table A.1 gives the attenuation to be expected from dense foliage if the total path length through the foliage is between 10 m and 20 m, and the second line if it is between 20 m and 200 m. For path lengths greater than 200 m through dense foliage, the attenuation for 200 m should be used.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f	Nominal midband frequency Hz							
m	63	125	250	500	1 000	2 000	4 000	8 000
	Attenuation, dB:							
$10 \leq d_f \leq 20$	0	0	1	1	1	1	2	3
	Attenuation, dB/m:							
$20 \leq d_f \leq 200$	0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

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A.2 Industrial sites (A_{site})

At industrial sites, an attenuation can occur due to scattering from installations (and other objects), which may be described as A_{site}, unless accounted for under A_{bar}, or the sound source radiation specification. The term installations includes miscellaneous pipes, valves, boxes, structural elements, etc.

As the value of A_{site} depends strongly on the type of site, it is recommended that it is determined by measurements. However, for an estimate of this attenuation, the values in table A.2 may be used. The attenuation increases linearly with the length of the curved path d_s through the installations (see figure A.2), with a maximum of 10 dB.

A.3 Housing (A_{hous})

A.3.1 When either the source or receiver, or both are situated in a built-up region of houses, an attenuation will occur due to screening by the houses. However, this effect may largely be compensated by propagation between houses and by reflections from other houses in the vicinity. This combined effect of screening and reflections that constitutes A_{hous} can be calculated for a specific situation, at least in principle, by applying the procedures for both A_{bar} and reflections described in 7.4 and 7.5. Because the value of A_{hous} is very situation-dependent, such a calculation may be justified in practice. A more useful alternative, particularly for the case of multiple reflections where the accuracy of calculation suffers, may be to measure the effect, either in the field or by modelling.

A.3.2 An approximate value for the A-weighted attenuation A_{hous}, which should not exceed 10 dB, may also be estimated as follows. There are two separate contributions

$$A_{hous} = A_{hous,1} + A_{hous,2} \quad \text{. . . (A.1)}$$

A.3.3 An average value for $A_{hous,1}$ (in decibels) may be calculated using the equation

$$A_{hous,1} = 0{,}1 B d_b \quad \text{dB} \quad \text{. . . (A.2)}$$

where

B is the density of the buildings along that path, given by the total plan area of the houses divided by the total ground area (including that covered by the houses);

d_b is the length of the sound path, in metres, through the built-up region of houses, determined by a procedure analogous to that shown in figure A.1.

The path length d_b may include a portion d_1 near the source and a portion d_2 near the receiver, as indicated in figure A.1.

The value of A_{hous} shall be set equal to zero in the case of a small source with a direct, unobstructed line of sight to the receiver down a corridor gap between housing structures.

NOTE 25 The A-weighted sound pressure level at specific individual positions in a region of houses may differ by up to 10 dB from the average value predicted using equations (A.1) and (A.2).

Table A.2 — Attenuation coefficient of an octave band of noise during propagation through installations at industrial plants

Nominal midband frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
A_{site}, dB/m	0	0,015	0,025	0,025	0,02	0,02	0,015	0,015

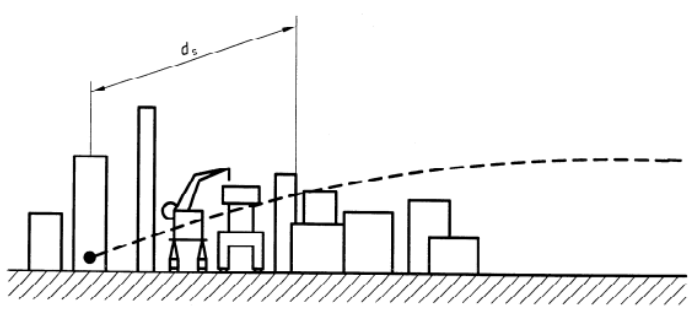

Figure A.2 — The attenuation A_{site} increases linearly with the propagation distance d_s through the installations at industrial plants

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A.3.4 If there are well-defined rows of buildings near a road, a railway, or a similar corridor, an additional term $A_{hous,2}$ may be included (provided this term is less than the insertion loss of a barrier at the same position with the mean height of the buildings):

$$A_{hous,2} = -10 \lg[1 - (p/100)] \text{ dB} \quad \ldots (A.3)$$

where p (the percentage of the length of the façades relative to the total length of the road or railway in the vicinity) is $\leqslant 90$ %.

A.3.5 In a built-up region of houses, the value of $A_{hous,1}$ [as calculated by equation (A.2)] interacts as follows with the value for A_{gr}, the attenuation due to the ground [as calculated by equation (9) or equation (10)].

Let $A_{gr,b}$ be the ground attenuation in the built up region, and $A_{gr,0}$ be the ground attenuation if the houses were removed [i.e. as calculated by equation (9) or equation (10)]. For propagation through the built-up region in general, $A_{gr,b}$ is assumed to be zero in equation (4). If, however, the value of $A_{gr,0}$ is greater than that of A_{hous}, then the influence of A_{hous} is ignored and only the value of $A_{gr,0}$ is included in equation (4).

The interaction above is essentially to allow for a range of housing density B. For low-density housing, the value of A_{gr} is dominant, while for high-density housing A_{hous} dominates.

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Annex B
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