THE PRODUCT BRIEF

PHOENIX-MB72 UVC Decontamination chamber

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PROJECT BRIEF

To find a way to best decontaminate, within reasonable criteria, microphones that have been used by persons possibly infected with a respiratory virus.

The problem

Airborne viral droplets are known to be expelled through human speech, singing, and the use of wind instruments (https://www.pnas.org/content/early/2020/05/12/2006874117) and by its very nature a microphone required for intelligible and feedback free use must be placed well within the field of the spread of viral material. As carriers of Sars Cov-2 Virus can be asymptomatic (https://wwwnc.cdc.gov/eid/article/26/7/20-1595_article) it will not be possible through physical screening measures to ensure that someone performing or speaking is not distributing viral material in close vicinity through speech or singing alone. In the current circumstances, while artists or speakers can minimise the risk of transmission by physically distancing any equipment that is used in close oral proximity (within a few meters) should be treated as a potential biohazard. It is therefore essential that such equipment is handled and processed in a manner that ensures as best possible the prevention of transmission of viral particles to any further person.

Known solutions and issues

1) **Time**. It is known that over reasonable time (a few days) the virus particles of Sars Cov-2 will not survive. https://www.thelancet.com/journals/lanmic/article/PIIS2666-5247(20)30003-3/fulltext

- This is a highly impractical method, the logistics of taking a biohazard item, placing it safely in a storage unit and leaving it for in excess of a week before the subsequent use renders this method highly impractical. Methods to ensure the item is not interfered with or used prematurely along with maintaining perfect quarantine make this method vulnerable to failures.

2) **Chemical**. There are many known killers of virus particles products such as household bleach, disinfectants and alcohols are able to effectively kill a virus load given adequate and total exposure https://www.epa.gov/pesticide-registration/list-n-disinfectants-use-against-sars-cov-2.

- It has been noted that for a chemical disinfectant to work sufficiently it must be applied to the contaminated article in an even covering across all surfaces and must penetrate well into all small interstices and textured surfaces. While an effective planar surface treatment, if it can be maintained for the required time, will function the probability of it working in practice is limited, especially if done by untrained operatives. Differing compounds and concentrations of those compounds can require different exposure durations, sometimes up to five minutes. Such long exposures are extremely problematic without submersing the microphone, which would likely destroy it. How to maintain adequate exposure duration of a substance that is highly prone to evaporation is a complex issue, especially as high concentration of alcohol vapor can damage the internals of the item being sterilised. There is no way to ensure that operatives are not cutting corners or mistakenly applying the chemicals ineffectively.
  https://help.prusa3d.com/en/article/prusa-face-shielddisinfection_125457#_ga=2.191544232.385199637.1590002957-1410290373.1562521512

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3) **UVC Sterilization Exposure**. It is known that exposure to high concentration UV-C radiation can effectively kill the Sars Cov-2 virus. https://www.medrxiv.org/content/10.1101/2020.03.25.20043489v1.full.pdf

- Adequate exposure to high power UV-C radiation can very effectively kill many virus strains and is used as a sterilisation method in Hospitals and laboratories. It is problematic unless highly controlled as the light must expose the items upon all surfaces while never exposing human skin as it can cause severe skin burns. Also, high power UV-C can, over excessively prolonged periods of time, cause damage to certain plastics or paint finishes. Use of UV-C would require the existence of a proper handling and exposure unit where the items could be entirely exposed with no shadows, and for no longer than required to be effective.

4) **Shielding**. The se of a physical barrier between the infected person and the equipment can be a very effective way of preventing contamination.

- The use of an impervious physical barrier, such as a plastic bag can entirely prevent the virus from contaminating the equipment, however it very seriously impairs the performance of the microphone requiring excessive post processing of the signal. The plastic, if light enough in weight can also cause severe audible distortion and noises if the voice causes it to vibrate against the microphone. This plastic once used must be treated as a biohazard and great care must be taken in removing and disposing of it to not contaminate the microphone or other items it may contact. Plastic that is light enough is easy to damage or tear and if such an event happens there is a further problem of how to then decontaminate the equipment.

5) **Temperature**. Temperatures of above 70 deg C are known to kill the virus. https://www.thelancet.com/journals/lanmic/article/PIIS2666-5247(20)30003-3/fulltext

- The whole item would require to be in an environment where every part exposed to the virus would be raised above 70 degrees C for an adequate duration. This is a problem with sensitive materials such as micro-fine plastic membranes there are many plastics and esoteric materials used in communications equipment which have a glass-transition point very close to the temperatures required to kill some viruses. Without knowing what every single microphone is capable of enduring without suffering loss of performance we cannot expose them to such high temperatures safely, some plastic parts within microphones weigh milligrams and are micrometres thick precision shapes. In many cases in outdoor concerts technical teams avoid leaving high quality microphones in direct sunlight because of thermal issues. https://omnexus.specialchem.com/polymer-properties/properties/glass-transition-temperature

6) **Disposal**. Single use disposable items are a guaranteed method of ensuring contamination is not spread to the next user.

- It is possible with very reduced quality to use disposable very cheap equipment, however there will be a significant problem with e-waste, sourcing sufficient equipment and cost for a result that is significantly reduced quality.

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Possible solutions

Considering the above issues it is decided that the most viable, efficient method would be the minimum contact UV-C exposure.

Time related, shielding, and disposal decontamination options were immediately deemed to be wholly impractical due to severe logistical or quality of end result concerns.

Temperature and chemical methods were deemed to be far too aggressive on the equipment, would require excessive care if they could be made to work, and leave too much room for mistakes with general stage crew.

There are numerous issues to be resolved, but there could be a possible effective process to satisfy all the requirements without excessively damaging the equipment.

Issues to address:

- There needs to be a method to effectively expose as much contaminated surface as possible, shadows need to be avoided.
- Skin exposure must be avoided in all circumstances, whatever solution is employed there must be a safety interlock on the light source.
- There must be a safe transport system to get the contaminated objects to the unit in a safe manner.
- There must be a clear indication that the prescribed exposure time has been reached.
- There must be clear simple procedures to follow by operatives that ensure they avoid cross contamination.
- The process must cause minimal damage to the items being decontaminated.
- The unit must be simple to operate with minimum possibility for erroneous operation.

DESIGN BRIEF

The design brief

1) **Portability.** The unit must be usable in a fast flowing production environment and be deployable to any convenient location at short notice. The unit must have adequate facilities for handling and be able to withstand the rigours of environments in concert, theatre, film and broadcast use. The unit should be made of road-grade 18mm Baltic birch plywood with a polymer textured robust surface finish.

2) **Effectiveness**. The unit must deliver an effective exposure dose in a suitably short time as to not impact on workflow of the event at hand. The unit should have 72 watts of UVC tubes in a diffuse reflective chamber made from a highly UVC reflective surface.

3) **Versatility.** The unit must be able to accept a wide range of production items that are put before delegates and performers, this would range from small items like lapel microphones through to larger table top items like self-supporting gooseneck microphones. Communications equipment such as headsets, belt-packs and walkie talkie devices must also be able to be accommodated. The unit should have removable cassette format support systems made specifically to support the required items in the correct manner.

4) **Workflow.** The unit must fit into the fast moving production workflow and be able to accept all items required in a manner that allows for effective UVC exposure over the entire surface of the item in a manner that operatives with a high workload are able to perform securely and repetitively without mistakes or failures. The unit shall be delivered with the required cassette and full instructions on correct asset management.

5) **Safety**. The unit must protect operatives from unwanted exposure to UVC light that can cause severe skin and eye burns, the security must be failsafe, interlocks must be physical hardware functions, not software based. Exposure times must be carefully controlled and not be subject to operator error or misunderstanding of functions. The unit should use an automation-grade position switch to detect door opening which should perform a hard-kill on the drive electronics rendering the unit completely off-line when the door opens.

6) **Size**. The unit must be large enough to accept all common items used in close proximity to performers or delegates and be able to accept them in a manner that allows the complete UVC exposure of all operating surfaces. The unit shall be at least 50cm x 50cm x 50cm internally.

7) **Hygiene.** The unit must be internally self-sterilising, there should be no mechanisms inside that can allow a build up of contamination in a place where the UVC light cannot reach, all hinges, switches and latches that can be externally located must be externally located and any internally located devices must be exposed to the UVC light or easily wiped down with a disinfectant solution. The unit shall have external door hinges, control panels, and electronics, door latches shall be magnetic and easily wiped down.

8) **Robustness.** Internal items must be adequately robust to withstand portable use in a production environment all plastics must be UVC resistant or not quickly degraded by UVC light, lamp supports shall be made from UV resistant ASA plastics, all other internal items from impact resistant PET-G which is robust under UV exposure, all internal plastics shall be periodically replaceable service parts.

DESIGN PROCESS

The design process

The project origins came from a collaboration between Newell Acoustic Engineering and a local theatre technical department undertaking technical studies into effective methods of sterilising microphones that have been in close proximity with a performer's breath. We studied all of the above methods, with liquid chemical methods being the principle desirable option, after exhausting any safe reasonable process using chemical sterilisation and looking at all alternatives it was decided that UVC was the only safe reliable option for such a process.

Fortunately, there was a project underway in the engineering workshops to build a UV curing station for resin 3D printed parts, it was decided that this project could be modified and re-engineered on a larger scale to produce a perfectly designed solution for the events production industry, a solution that could help the industry recover from recent closure and assure performers and staff alike that they could work safely. This solution could also satisfy statutory legislative requirements to sterilise production equipment in a safe controllable manner and show governments that the industry can responsibly adapt to new challenging circumstances.

Great care was taken to ensure that the systems would be effective, organisations were approached with a view to actual testing but it was found that such a test would only apply to one single model of item, and every single possible item would require testing. In light of this a series of desktop studies were carried out using published data and machine specifications to find the required exposure times where it can be assumed that a safe amount of sterilisation has been achieved.
https://www.uv-technik.co.uk/assets/Uploads/product-documents/Disinfection-UV-C-Explained2.pdf

Surface decontamination was relatively quick and simple, deeper decontamination in switches and grilles was a more challenging problem to verify, following studies where PPE respirators with internal filters, valves and grilles it was deemed adequately similar (and indeed exceeded our risk requirements) to use the results of those studies as a baseline guide for our purposes. In all cases it was calculated that in a 1/8th cubic meter space with reflective walls over 60% reflectivity at 250nm wavelengths a 5 minute average exposure exceeded the times recommended by various scientific studies. Items heavily contaminated with secretions are recommended to undergo a dual exposure cycle, machines intended for such use regularly can be ordered with a longer exposure program.

Studies were made into internal wall materials, what was reflective to visible light was not necessarily reflective to UVC wavelengths, materials behind acrylic or glass were highly attenuating and therefore it could not be possible to place either the lamps or reflectors behind such materials, ePTFE was deemed to be the best reflective solution but was impractical from a production, price, and sourcing perspective, as a secondary material aluminum was deemed to have reflectivity in the 60% to 70% range as opposed to about 25% for stainless steel, commonly used in surgical machinery. It was eventually settled on using a matte aluminium surface for maximum diffusion rather than a highly polished surface that would maintain linear reflections.

DESIGN PROCESS

The light tubes were mounted in a manner to avoid flexing under shock loads, they are rigidly fixed to the structure of the case through semi-flexible plastic clips which also protect them from internal impact risk, it was studied that ASA (http://polymerdatabase.com/Polymer%20Brands/ASA.html) plastic was required as a UV resistant impact resistant support best suited to our needs, all close coupled internal items were made from UV resistant ASA. External components and cassette components are all manufactured from high stability impact and chemical resistant PET-G (https://www.acmeplastics.com/what-is-petg) Careful choice was considered when choosing which polymers to fabricate custom parts from.

All custom polymer parts are manufactured in house on our own 3D print farm enabling rapid time to market, minimal tooling costs, and easy real time problem solving.

System electronics and microprocessor controls are based on the industry standard ATMEGA microprocessor packaged in an easily accessible consumer format, the unit has no internal bespoke electronics ensuring it is 100% field serviceable by any basic trained electronics engineer. All parts are available from normal global component suppliers. The 8 bit ATMEGA code is published on our website and in product documentation.

User interface is designed to be as simple as possible, one button and a light to say the cycle is complete, additional lights are provided to confirm the door is closed with the processor ready and that the cycle in in progress. There is no further control so there can be no mistake. Opening of the door before the cycle is complete stops all processes, immediately cuts of the power to the lights and resets the timer to zero, once the door is closed the cycle must be run again, only after the factory pre-programmed exposure times have completed will the unit ever display a green “completed” indicator. The sequence can be run multiple times if required simply by pressing the start button again. In the event of damage or failure of one light source the second light source will continue to function, in such a circumstance the reflective nature of the internal space will allow the unit to continue to function at reduced power, in such a circumstance where maintenance is difficult it is recommended that the cassette be removed, rotated 180 degrees and re-inserted for a second exposure after the normal exposure process. This ensures that the unit will still have adequate, but slower, availability in the event of a lamp failure.

In conjunction with precise instruction and use of recommended gloves and zip-lock bags the unit can ensure a fully audited asset management process, careful following of the instructions can ensure that all processed items are exposed as required and not cross contaminated between the process and delivering to the performer. The unit is designed in such a way as to minimise possible exposure to the user, the interior is self-cleaning and the exterior is able to be easily wiped down or sprayed with disinfecting solutions. The outer coating is a hard waring water resistant cross-linked polymer coating intended for harsh environment use.