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E-PiPEline: Face Shields and Face Coverings Using Commonly Available Materials

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ABSTRACT

The Center for Disease Control has recommended that the public should wear cloth face coverings in public settings. Face coverings and face shields can be made by using Commonly Available Materials (CAMs). As part of the Sandia COVID-19 LDRD effort (funded under the Materials Science Investment Area), the Sandia E-PiPEline task evaluated design options for face coverings and face shields considering their effectiveness, durability, build difficulty, build cost, and comfort. Observations from this investigation are presented here to provide guidelines for home construction of face coverings and face shields.

ACKNOWLEDGEMENTS

This research is funded under COVID-19 LDRD Materials Science Investment Area. The Sandia E-PiPEline team would like to thank the folks in the LDRD office for supporting this work and would also like to thank Michael Grant for helping to sharpen the ideas behind the original E-PiPEline proposal.

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EXECUTIVE SUMMARY

The Center for Disease Control has recommended that the public should wear cloth face coverings in public settings. Face coverings and face shields can be made by using Commonly Available Materials (CAMs). As part of the Sandia COVID-19 LDRD effort (funded under the Materials Science Investment Area), the Sandia E-PiPEline task evaluated design options for face coverings and face shields considering their effectiveness, durability, build difficulty, build cost, and comfort. Observations from this investigation are presented here to provide guidelines for home construction of face coverings and face shields.

Analysis methodology techniques that are transparent and defensible were used to provide an analytic framework that articulates the design options, enumerates the assumptions, and provides a semi-quantitative assessment of alternatives while providing a clear linkage between analysis steps. The methodology employed followed the following steps:

1. Understand Design Alternatives in the Literature
2. Define the Design Space Identifying Design Characteristics and Options
3. Enumerate Alternative Designs
4. Develop Evaluation Metrics and Scoring Rubrics
5. Score Alternative Designs
6. Analyze Design Space for Trends and Develop Recommendations

The face shield design space (900 design combinations) using a systematic process includes the following CAM design options

Shield Material: Cellulose Acetate, Polypropylene & Vinyl, Polyethylene Terephthalate, Polypropylene, or Polyester
Structure: Foam, Safety Glasses, Velcro Straps, Cardboard, Tongue Depressor, or Rolled Paper
Strap Attachment Material: Rubber Band, Cotton Fabric, Velcro Straps, Cohesive Bandage, Elastic Band, or Latex Gloves
Strap Attachment Mechanism: Staple, Glue, Sew, Tape, or Compression

A large design space was examined for the face coverings (over 200,000 design combinations) using a systematic process. This design space using CAMs includes the following design options

Number of Layers: 1, 2, or 3
Material in Each Layer: (1) Tight Non-Woven Hydrophilic Coated Polypropylene Based, (2), Non-Woven Polypropylene Based, (3) Non-Woven Polypropylene/Polyester Blend Based, (4) Lignocellulosic Based; (5) Non-Woven Cohesive Polyester/Elastomer Blend Based; (6) Woven Cotton Based <600 Thread Count Based; or (7) Tight-Woven Cotton Based >600 Thread Count Based
Layer Connection Location: Around Edge, Around Edges and Center, or None
Layer Connection Mechanism: Staple, Glue, Sew, Friction, or None
Strap Attachment Material: Same as Layer 1, Same as Layer 2, Same as Layer 3, Elastic Band, Tourniquet Band, Velcro Straps, Rubber Band, Cohesive Bandage, or Latex Gloves
Strap Attachment Mechanism: Staple, Glue, Sew, Tape, Compression, or Integrated

The following observations were made from the analysis of the data regarding materials for the face shield.

- The most highly scored options used a foam as the primary frame/face interface material to provide the most effective liquid splash protection
- For reuse of the face shield, choosing materials that are compatible with solvents like polypropylene is crucial.

The following observations were made from the data regarding the design for the face shield.

- Minimizing the gap between the face shield and the forehead will help reduce the chance of liquid splash to the eyes
- It is important that the face shield extends down below the chin and stretch around the full-face area
- Designs that use compression to attach the face shield to the face were observed to be promising

From a design perspective, for the skin to frame interface, it is desired to maximize frame/skin interface surface area to provide enhanced splash protection along with a foam interface for a comfortable seal. For the location of the window, it is desirable for full face protection with extended facepiece length to provide protection from both front and side splash events. Design for multiple reuse options by leveraging material properties for improved compatibility with known disinfects and solvents.

The following observations from the data in the E-PiPEline study were made for the face covering:

- Leverage cotton and paper-based materials to capture aerosolized water droplets within the fiber matrix.
- The placement of natural-based materials sandwiched between two water repelling synthetic based materials decreases liquid movement towards the face
- Using materials with high fabric density to improve particle filtration while maintaining user breathability
- More layers increase effectiveness
- Full coverage over mouth and nose reduces chances of particles reaching the face
- Face covering conformability improves filtration effectiveness.

It was observed that the more layers the better. Assuming a three-layer face covering the following observations were made regarding the selection of materials for each layer:

For the *layer furthest from the mouth*, one should increase inertial impaction factor by maximizing fabric fiber density. This will likely increase the probability of blocking aerosolized viral particles. Selecting first layer materials that have a **low water absorption** may also reduce water saturation and increase face covering durability and breathability.

The *middle layer* should be designed for material interchangeability. Using **non-woven fabrics with high fiber density** will likely increase filtration effectiveness by providing a tortuous path for particles resulting in increased particle collision and entrapment in the middle layer. Materials with increased water absorbance provide a matrix for aerosolized liquid water capture. Additionally, the middle layer should have design features that allow for material interchange after high particle loading and water saturation which can reduce filtration effectiveness and user breathability.

The *layer closest to the mouth* should be designed for mouth and nose interface compatibility and with **high water repelling properties**. Select materials with a **high fiber density**. Do not select loose materials or weaves to prevent inhalation of material borne particles. By choosing these materials the user can reduce the chance of viral transmission via water wicking to the mouth and nose.

ACRONYMS AND DEFINITIONS

Abbreviation	Definition
CAM	Commonly Available Materials
HCP	Health Care Providers
OEC	Overall Evaluation Criterion
SME	Subject Matter Expert

1. INTRODUCTION AND MOTIVATION

The COVID-19 pandemic has caused the United States' Center for Disease Control and Prevention (CDC) to recommend that the general public wear face coverings in public settings to supplement social distancing measures [1]. As part of the Sandia COVID-19 LDRD effort (funded under the Materials Science Investment Area), a two-week task, the Sandia E-PiPEline, evaluated commonly available materials (CAMs) and design options for face coverings and face shields considering their effectiveness, durability, build difficulty, build cost, and comfort. This effort also provides representative option spaces, evaluation metrics, a process, and insights into the general desirable characteristics of the materials and designs for face shields and face coverings.

The motivation behind this work shifted from that which was originally proposed to the final deliverable. When the study was originally proposed, there was no nationwide guidance to wear face coverings or face shields. However, there was a shortage in supplies necessary for health care providers (HCPs) [2, 3, 4, 5, 6, 7]. As such, the original focus was on providing HCPs access to an emergency pipeline of face coverings and face shieldsusing Commonly Available Materials (CAMs) with a fast time to market. The study is akin to when NASA engineers effectively fit a "square peg in a round hole" to reduce the climbing carbon-dioxide within the Apollo 13 Lunar Module and saved 3 astronaut's lives [8]. Approximately halfway through the execution of this work, on April 3, the White House Coronavirus Task Force and CDC announced a new recommendation to help slow the spread of COVID-19 by encouraging the use of a cloth face covering when out in public [1]. While still evaluating CAMs for use in face shields and face coverings, with concurrence from stakeholders, this study's focus shifted to evaluating materials and designs for the general public as opposed to HCPs and making more tangible observations with the constraints imposed by the public rather than the health care sector.

In order to facilitate this new direction, CAMS for face shields and face coverings were identified through a literature search [9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. The characteristics of these CAMS were then generalized, so that other related materials could be considered. As an example, CAMs such as sheets and coffee filters were categorized as woven cotton based <600 thread count based fabrics or lignocellulosic based fabrics. The design space was then enumerated and metrics identified. The enumerated design space was then evaluated in a multi-objective algorithm to provide a notional ranking of their suitability relative to the identified metrics. While the absolute rankings are less important, the general characteristics of high performing and low performing designs provide meaningful insights.

In total 4 products were generated as a result of this LDRD effort:

1. One-page handout summarizing observations for face shields
2. One-page handout summarizing observations for face coverings
3. Executive summary providing more detail into the CAMs and observations
4. SAND report providing more complete documentation of the design space, process, metrics, and observations

It should be noted that given the limited scope of this work, it is recommended that additional, detailed study into the efficacy of the materials and designs identified in this work be undertaken before constructing the identified face shields and face coverings.

2. REPORT STRUCTURE

This report will take the form of annotating the two one-page handouts geared to be distributed to the public at large—one for face shields and one for face coverings both made from CAMs. This report also provides additional details into the problem motivation and analysis methodology. In addition, the design space explored for each of these designs is described, the metrics developed to evaluate the designs are given, and observations regarding the potential solutions for face shields and face coverings are provided.

3. ONE-PAGE HANDOUTS

3.1. Face Shields Made from Commonly Available Materials

See Page 15 for the one-page handout developed describing Observations Regarding Face Shield Designs Using Commonly Available Materials.

3.2. Face Coverings Made from Commonly Available Materials

See Page 16 for the one-page handout developed describing Observations Regarding Face Covering Designs Using Commonly Available Materials.

Observations Regarding Face Shield Designs Using Commonly Available Materials

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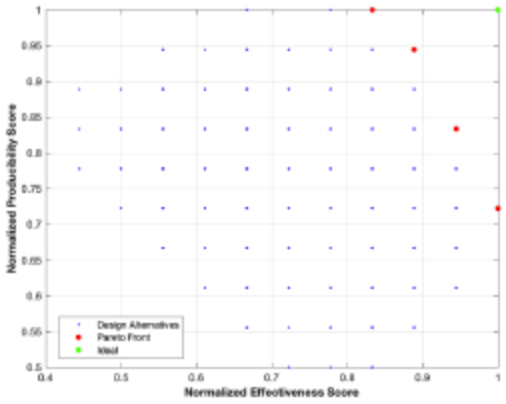
A Sandia COVID-19 LDRD effort, the Sandia E-PiPEline Team, systematically evaluated design options for face shields constructed from commonly available materials (CAMs). This study is not focused on face shields for medical applications, and as such, has excluded labeling and flammability considerations suggested by the FDA. Design options for face shields were analyzed with subject matter expert input considering the design's **effectiveness** (seal around face), **reusability** (compatibility with solvents, degree of inertness), **producibility** (ability to obtain materials, build time), **cost**, and **comfort** (fit around head, contact surface interface). Observations for the design of face shields using CAMS are provided here.



DESIGN SPACE

The principle design variables considered for the construction of a face shield were:

- **Primary shield material**: polyethylene, polypropylene, cellulose acetate
- **Structural material**: foams, safety glasses, cardboard, wood
- **Attachment methods**: sewn, glued, stapled

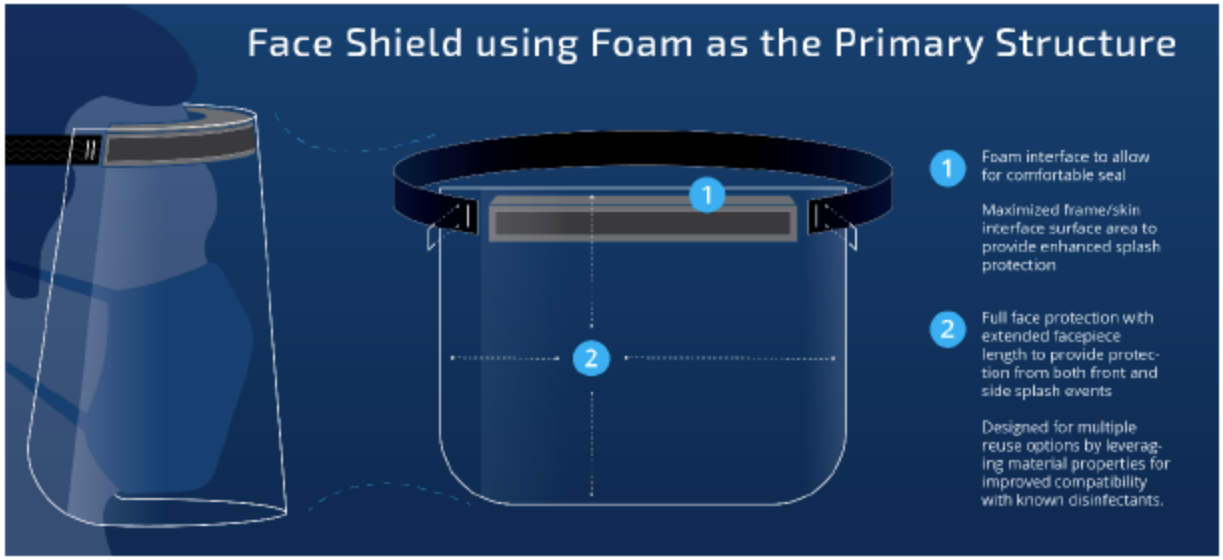
The graphic at top illustrates the results of scoring more than 900 designs evaluated for face shields using CAMs. The normalized design scores are shown in blue, with the best options shown in red. The scores are normalized relative to the highest score in the **effectiveness** and **producibility** metrics.

DESIGN OBSERVATIONS

- Minimizing the gap between the face shield and the forehead will help reduce the chance of liquid splash to the eyes
- It is important that the face shield extends down below the chin and stretch around the full-face area
- Designs that use compression to attach the face shield to the face were observed to be promising

MATERIAL OBSERVATIONS

- Using foam as the primary frame/face interface material provides splash protection
- For reuse of the face shield, choosing materials that are compatible with common solvents, like polypropylene



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Observations Regarding Face Covering Designs Using Commonly Available Materials

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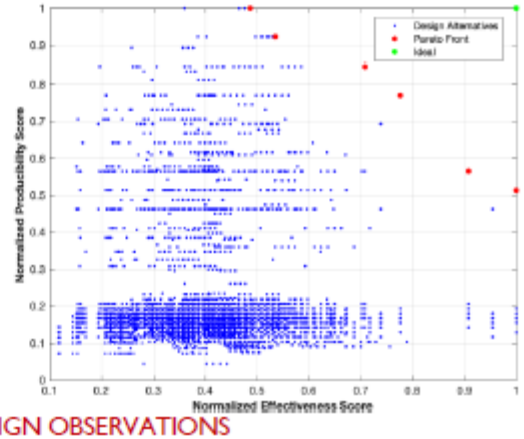
The Center for Disease Control has recommended that the public should wear cloth face coverings in public settings[1]. A Sandia COVID-19 LDRD effort, the Sandia E-PiPEline Team, systematically evaluated design options for face coverings constructed from commonly available materials (CAMs). The design options were analyzed with subject matter expert input considering the design's effectiveness (metric fiber density, material construction, and water saturation), reusability (degree of inertness), producibility (ability to obtain materials, build time), cost, and comfort (fit on face, breathability). Observations for the design of face coverings using CAMs are provided here.

DESIGN SPACE

The principle design characteristics and alternatives considered for the construction of a face covering are listed below.

- Number and materials of layers: 1-3 layers; woven cotton materials, paper-based materials, synthetic fabrics
- Connection method and location between layers: sewn, glued, stapled; around edge or center and edges
- Treatments of the top layer: machine wash, bake in oven, iron, machine dry, none
- Attachment methods: integrated designs, compression straps, Velcro straps

The graphic at top illustrates the results of scoring more than 200,000 designs evaluated for face coverings using CAMs. The normalized design scores are shown in blue, with the best options shown in red. The scores are normalized relative to the highest score in the effectiveness and producibility metrics.

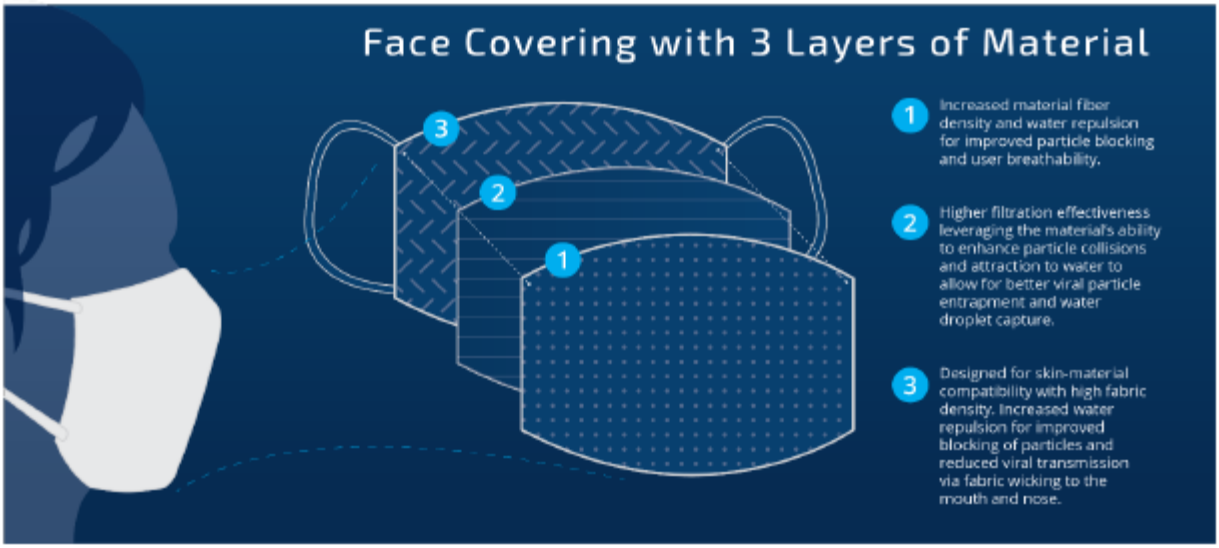


DESIGN OBSERVATIONS

- More layers increase effectiveness
- Full coverage over mouth and nose reduces chances of particles reaching the face
- Mask conformability improves effectiveness

MATERIAL OBSERVATIONS

- Leverage cotton and paper-based materials to capture aerosolized water droplets within the fiber matrix
- The placement of natural-based materials sandwiched between two water repelling synthetic based materials decreases liquid movement towards the face
- Using materials with high fabric density to improve particle filtration while maintaining user breathability
- Prioritize user safety by selecting materials that reduce loose material particle inhalation hazards



[1] https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover.html

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4. ANALYSIS METHODOLOGY

This section will describe the methods implemented in the analysis. Specifics into the exact design space, metrics, and the results of the analysis performed for the E-PiPEline LDRD to evaluate CAM face shields and face coverings are discussed elsewhere in this report.

To provide a transparent and defensible analysis, tools and techniques developed within the Systems Analysis and Engineering Group, were employed. These methods provide an analytic framework that articulates the design options, enumerates the assumptions, and provides a semi-quantitative assessment of the alternatives while providing a clear linkage between analysis steps. The methodology employed followed the following steps:

1. Understand Design Alternatives in the Literature
2. Define the Design Space Identifying Design Characteristics and Options
3. Enumerate the Alternative Designs
4. Develop Evaluation Metrics and Scoring Rubrics
5. Score Alternative Designs
6. Analyze Design Space for Trends and Develop Recommendations

4.1. Understand Design Alternatives in the Literature

The first step undertaken was to understand the design alternatives that are related and relevant to the E-PiPEline project. In particular, a broad swath of open-source literature found in journals, conference proceedings, textbooks, and the media was surveyed and examined for design options, distinguishing characteristics, evaluation criterion, and other relevant features pertinent to face shields and face coverings. Notes regarding these elements were taken and used to define the analysis.

4.2. Define the Design Space Identifying Design Characteristics and Options

For each CAM device, face shields and face coverings, identification of the major design characteristics and different design options were defined. To help describe the design space, a Morphological Matrix, first used by F. Zwicky to enumerate astronomical observations was employed [19, 20]. A sample Morphological Matrix is shown in Figure 1.

	Option 1	Option 2	Option 3
Characteristic 1	C1, O1	C1, O2	C1, O3
Characteristic 2	C2, O1	C2, O2	C2, O3
Characteristic 3	C3, O1	C3, O2	C3, O3

FIGURE 1. SAMPLE MORPHOLOGICAL MATRIX.

The rows in the Morphological Matrix describe different design characteristics. For example, if one were to consider the design of a pen, the characteristics might be the material of the pen casing, the writing tip of the pen, and the color of the pen's ink. The columns are different alternatives or options for the design characteristics. For example, for the color of the pen's ink, the alternatives may be black, blue, or red. A design is comprised of selecting one alternative for each of the characteristics. For example, for the Morphological Matrix in Figure 1, a design might be {C1, O1; C2, O3; C3, O2}.

There may be unallowable combinations of design options in the Morphological Matrix. While this table can take multiple forms, a sample compatibility table showing incompatibilities for the Morphological Matrix in Figure 1 is shown in Figure 2.

	C1, O1	C1, O2	C1, O3	C2, O1	C2, O2	C2, O3	C3, O1	C3, O2	C3, O3
C1, O1				1	1	1	1	1	1
C1, O2				1	1	0	1	1	1
C1, O3				1	1	1	1	0	0
C2, O1							1	1	1
C2, O2							0	0	1
C2, O3							1	1	1
C3, O1									
C3, O2									
C3, O3									

FIGURE 2. SAMPLE COMPATIBILITY MATRIX.

In Figure 2, the 0s indicate incompatibilities in the design options whereas 1s indicate compatibilities in the design options. For example, the 0 at the intersection of C1, O2 with C2, O3 indicates that C1, O2 is not compatible with C2, O3.

Similar to the unallowable combinations in design options, there may be required combinations. This can be identified in the Compatibility Matrix. For example, in Figure 2, designs containing C2, O2 are required to have C3, O3.

Based on the literature in the previous steps, categories of distinguishing design characteristics and design alternatives within each of these characteristic categories were identified. Then incompatibilities and required combinations identified.

4.3. Enumerate the Alternative Designs

Using the Morphological Matrix and the Compatibility Matrix, one can then enumerate all possible designs consisting of design alternatives for each design characteristic. As previously described, for the Morphological Matrix in Figure 1, a design might be {C1, O1; C2, O3; C3, O2}. Note that fully enumerating the Morphological Matrix in Figure 1 results in 27 designs (3 x 3 x 3) while enforcing the Compatibility Matrix shown in Figure 2 results in 13 possible designs. The enumerated compatible designs are:

{C1, O1; C2, O1; C3, O1}
{C1, O1; C2, O1; C3, O2}
{C1, O1; C2, O1; C3, O3}
{C1, O1; C2, O2; C3, O3}
{C1, O1; C2, O3; C3, O1}
{C1, O1; C2, O3; C3, O2}
{C1, O1; C2, O3; C3, O3}
{C1, O2; C2, O1; C3, O1}
{C1, O2; C2, O1; C3, O2}
{C1, O2; C2, O1; C3, O3}
{C1, O2; C2, O2; C3, O3}
{C1, O3; C2, O1; C3, O1}
{C1, O3; C2, O3; C3, O1}

For E-PiPEline, a tool written in Matlab was used to enumerate the design space accounting for the compatibility constraints.

4.4. Develop Evaluation Metrics and Scoring Rubrics

Metrics are attributes of the design alternative that can be measured (i.e., they have a measure of "goodness"). Metrics are quantitative or semi-quantitative (i.e., qualitative attributes that map to a quantitative scale) and are designed to be as orthogonal to other metrics as possible, although competing metrics are likely (e.g., range and weight of an aircraft).

Metrics were derived based on the problem objectives as well as from literature. For this analysis, all of the metrics were qualitative. Therefore, in order to make the metrics semi-quantitative, a scoring rubric was derived based on Subject Matter Expert (SME) knowledge. Ideally, a large number of SMEs would provide input on the scores or quantitative engineering assessments could be used for scoring. However, in the E-PiPEline study, team members were used to provide information. For each qualitative metric, a mapping between the low and high range and integer bins ranging from 1 to 5 were used. It was developed where the bin corresponding to 5 is the best. In addition, each characteristic was fully described. The interval for each bin is designed to be approximately the same (i.e., the range from 1-5 is designed to be linear and consistent between metrics).

The metrics and scores were applied to each element in the Morphological Matrix. If the element in Morphological Matrix did not contribute to the metric, a score of 0 was assigned. For example, if there are three metrics defined for the Morphological Matrix shown in Figure 1, weight, range, and speed, a total of 27 metrics need to be scored (9 elements x 3 metrics).

In addition, broader categories of metrics were formed. The overall scores for the broader categories were simply the average of the constituent metrics. Continuing with the previous example, a broader category of metrics may be performance which would be a combination of the range and speed. For the E-PiPEline study, metrics were evaluated at this broader level.

In addition to assigning scores directly to elements of the morphological matrix, rules-based evaluation augmentation scores were also developed. These are used primarily to handle non-linear, difficult to quantify cases of design combinations. These scores augmented the scored metric for the affected elements. These augmentations took one of three forms:

1. `DESIGN ELEMENT #1` **`WITH`** `DESIGN ELEMENT #2` causes `SCORE` to be `VALUE` or `ALTERED BY X%`
2. `DESIGN ELEMENT #1` **`WITHOUT`** `DESIGN ELEMENT #2` causes `SCORE` to be `VALUE` or `ALTERED BY X%`
3. `DESIGN ELEMENT` **`EQUALS`** `VALUE` causes `SCORE` to be `VALUE` or `ALTERED BY X%`

In the first case, **`WITH`**, matches elements in a given design and if they are both found it changes the value of the metric to that desired or alters the score by a given percentage. In the second case, **`WITHOUT`**, if `DESIGN ELEMENT #1` is found in a given design without `DESIGN ELEMENT #2`, the value of the score is augmented to the desired value or alters the score by a given percentage. Finally, the third case looks for a design element in the design and if found the score is augmented to the desired value or alters the score by a given percentage. Again, these values are found through SME elicitation. In this study's case, the SMEs consisted of the team members.

4.5. Score Alternative Designs

Using the evaluation metric scores and augmentation developed through the metric development process, each enumerated alternative is scored by linearly aggregating the scores across the design characteristics for each design. For metric *i* of the p^{th} design alternative this is given by

$$\gamma_{p,i} = \sum_{j=1}^{n} \gamma_{p,i,j} \ , i \in [1, q] \tag{1}$$

where $\gamma_{p,i,j}$ is the score of metric *i* for the j^{th} characteristic in the Morphological Matrix used in the design of the p^{th} design alternative, *n* is the number of characteristics in the Morphological Matrix, and *q* is the number of metrics. The resulting score for the i^{th} metric is then normalized by the number of non-zero scores summed, to result in $\bar{\gamma}_{p,i}$. This results in a vector of scores for the p^{th} design alternative

$$\Gamma_p = \{\bar{\gamma}_{p,1} \quad \cdots \quad \bar{\gamma}_{p,q}\} \tag{2}$$

For the individual metrics, scores are augmented before aggregation. Whereas for the broader category of metrics, augmentation is performed after aggregation.

4.6. Analyze Design Space for Trends and Develop Recommendations

The design alternatives are analyzed using several different methods. The first is understanding the Pareto Frontier of the scores for the broader categories of metrics.

In mathematical terms, the Pareto Frontier, *P*(*Y*), is defined as follows. For the function $f: \mathbb{R}^n \rightarrow \mathbb{R}^m$, let *X* be the compact set of decisions in $\mathbb{R}^n$ and *Y* be the feasible set of metric vectors in $\mathbb{R}^m$ such that $Y = \{y \in \mathbb{R}^m : y = f(x), x \in X\}$. Let a point $y'' \in \mathbb{R}^m$ strictly dominate another point $y' \in \mathbb{R}^m$ and be denoted by $y'' \succ y'$. Then, the Pareto Frontier is given by

$$P(Y) = \{y' \in Y : \{y'' \in Y : y'' \succ y', y' \neq y''\} = \emptyset\} \tag{3}$$

In other words, the Pareto Frontier is the set of designs in the design metric space such that for a fixed set of *q*-1 metrics there are no alternatives that score better in the remaining metric. Designs that perform worse are referred to as Pareto Dominated solutions. Whereas the designs on the Pareto Frontier are referred to as Pareto Optimal. The Pareto Frontier shows the tradeoff costs between metrics. In other words, it shows the incremental cost in one or more metrics in order to achieve an improvement in another metric. It can also help identify where there are diminishing returns in this tradeoff.

A sample Pareto Frontier is provided in Figure 3, where it is desired to minimize both Metric 1 and Metric 2.

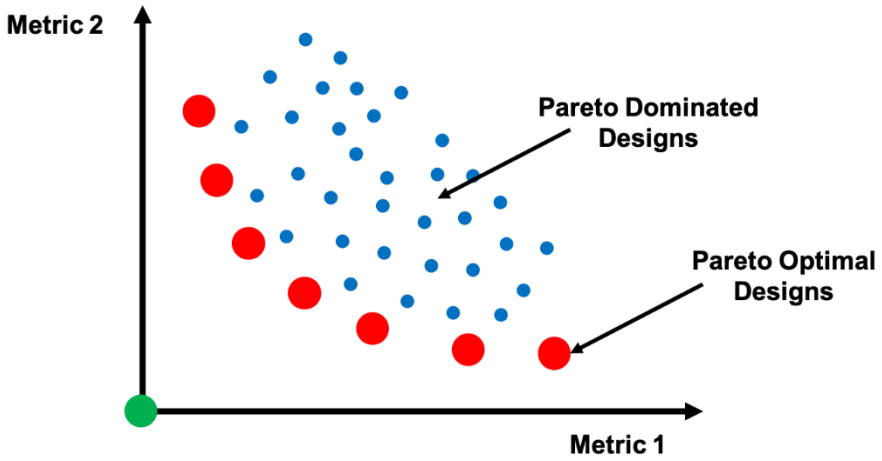


FIGURE 3. EXAMPLE PARETO FRONTIER.

In Figure 3, the blue dots are design alternatives that are dominated. The bigger, red dots represent the Pareto Optimal designs comprising the Pareto Frontier. Finally, the green dot at the origin is the ideal, where the minimum is desired.

The other analysis method invoked in this study is the concept of an Overall Evaluation Criterion (OEC). The OEC combines individual metrics into a single objective which can be minimized. For this study, a weighted approach to arrive at the OEC was used. For the p^{th} design alternative, this is given by

$$\xi_p = \sum_{j=1}^{q} \alpha_{p,j} \bar{\gamma}_{p,j} \tag{4}$$

where ξ_p is the OEC, $\alpha_{p,j}$ is the weight applied to $\bar{\gamma}_{p,j}$, the normalized score for the j^{th} metric. Additionally, the weights, $\alpha_{p,j}$ must abide by the constraint

$$\sum_{j=1}^{q} \alpha_{p,j} = 1 \tag{5}$$

A multitude of methods can be used to arrive at the weights, for example Analytic Hierarchy Process, Quality Function Deployment utilizing the Pugh Matrix, and direct elicitation from stakeholders [21, 22, 23]. For E-PiPEline, two sets of weights were used, one that evenly weighted all design metrics and one which examined only the effectiveness design alternative.

Once an aggregated OEC is obtained for each design alternative, the optimal combination of design alternatives for the design characteristics can be obtained. For E-PiPEline, the optimal design alternative is the one that maximizes the OEC.

The combination of the Pareto Frontier and the OEC produced an ordered list of design alternatives. Trends can be derived from the high performing design alternatives and the low performing design alternatives. These were then assessed and turned into observations regarding the investigation leading to recommendations for the design of face shields and face coverings.

5. SOLUTION SPACE

As described previously, the solution space was described compactly using a morphological matrix. The morphological matrices for the face shields and face coverings are provided in this section.

5.1. Morphological Matrix for Face Shields

The design characteristics and option space examined for face shields using CAMs is shown in Table 2. It should be noted that no compatibility constraints were considered in this analysis.

5.2. Morphological Matrix for Face Coverings

5.2.1. Characteristics Considered for Face Coverings

Table 1 provides a detailed description of the characteristics considered for the face coverings. The characteristics are given a legend, which is subsequently used in the morphological matrix.

Table 1. Descriptions of Characteristics Considered for the Face Coverings.

	Characteristic
Number of Layers	Number of Layers
Bulk Material	Material of Layer 1 - Outward Facing (**Layer 1**) Material of Layer 2 (**Layer 2**) Material of Layer 3 - Mouth Facing (**Layer 3**)
Layer Connection	Layer Connection Location (**Location**) Layer Connection Mechanism (**Mechanism**)
Treatment	Treatment of Layer 1 - Outward Facing (**Treatment Layer 1**)
Strap Attachment	Strap Material (**Material**) Strap Attachment Method (**Method**)

5.2.2. Material Families in the Morphological Matrices

To help condense and effectively communicate different options, families of materials were developed. These families of materials have similar characteristics and perform similarly to one another. The families of materials are shown in Table 3.

5.2.3. Morphological Matrix

The morphological matrix considered for face coverings is provided in Table 4 and Table 5.

Table 2. Face Shield Morphological Matrix.

Characteristic		*Option 1*	*Option 2*	*Option 3*	*Option 4*	*Option 5*	*Option 6*
Shield	**Material**	Transparency (Cellulose Acetate)	Sheet Protector (Polypropylene & Vinyl)	Lamination Material (Polyethylene Terephthalate)	Clear Plastic Folder (Polypropylene)	Clear Film (Polyester)	
Structure	**Structure**	Foam	Safety Glasses	Velcro Strips	Cardboard	Tongue Depressor	Rolled Paper
Upper Strap	**Material**	Rubber Band	Cotton Fabric	Velcro Straps	Cohesive Bandage	Elastic Band/Tourniquet	Latex Gloves
Attachment	**Method**	Staple	Glue	Sew	Tape	Compression	

Table 3. Face Covering Families of Materials.

Face Covering Material Family Description	Family Alias in Morph Matrix	Examples
Tight (T) Non-Woven (NW), Hydrophilic Coated (HC), Polypropylene (PolyP) Based	T NW HC PolyP Based	N95 Masks
Non-Woven (NW), Polypropylene (PolyP) Based	NW PolyP Based	Polypropylene Professional/Shop Towels, Halyard Surgical Wraps
Non-Woven (NW) Polypropylene (PolyP)/Polyester (PolyE) Blend Based	NW PolyP/PolyE Blend Based	Surgical Masks, Polyester Professional/Shop Towels, Non-Woven Gauze
Lignocellulosic (LC Paper) Based	LC Paper Based	Coffee Filters, Paper Towels, Stretcher Tissue Sheets
Non Woven (NW) Cohesive Polyester (CoPolyE)/Elastomer (Elast) Blend Based	NW CoPolyE/Elast Blend Based	Compression Wraps, Pre-Wrap (Underwrap), Coben Cohesive Wrap
Woven Cotton (WC) Based <600 Thread Count (TC) Based	WC <600 TC Cotton Based	Cotten Woven Fabrics (T-Shirt/Scarf), Woven Gauze
Tight (T) Woven Cotton (WC) Based >600 Thread Count (TC) Based	WC >600 TC Cotton Based	Pillow Cases, Flannel, Hospital Sheets

Table 4. Face Covering Morphological Matrix, Part 1 of 2.

Characteristic		*Option 1*	*Option 2*	*Option 3*	*Option 4*
Number of Layers	**Number of Layers**	Number of Layers : 1	Number of Layers : 2	Number of Layers : 3	
Face Covering Material	**Layer 1**	NW PolyP/PolyE Blend Based	NW PolyP Based	T WC >600 TC Cotton Based	WC <600 TC Cotton Based
	Layer 2	NW PolyP/PolyE Blend Based	NW PolyP Based	T WC >600 TC Cotton Based	WC <600 TC Cotton Based
	Layer 3	NW PolyP/PolyE Blend Based	NW PolyP Based	WC >600 TC Cotton Based	NW CoPolyE/Elast Blend Based
Layer Connection	**Location**	Around Edge	Center and Edges	None	
	Mechanism	Staple	Glue	Sew	Friction
Treatment	**Treatment Layer 1**	Machine Wash	Bake in Oven	Iron	Machine Dry on Hot
Strap Attachment	**Material**	Same as Bulk Material Layer 1	Same as Bulk Material Layer 2	Same as Bulk Material Layer 3	Elastic Band
	Method	Staple	Glue	Sew	Tape

Table 5. Face Covering Morphological Matrix, Part 2 of 2.

Characteristic		*Option 5*	*Option 6*	*Option 7*	*Option 8*	*Option 9*
Number of Layers	**Number of Layers**					
Face Covering Material	**Layer 1**	LC Paper Based	T NW HC PolyP Based	NW CoPolyE/Elast Blend Based		
	Layer 2	LC Paper Based				
	Layer 3	None				
Layer Connection	**Location**					
	Mechanism	None				
Treatment	**Treatment Layer 1**					
Strap Attachment	**Material**	Tourniquet Band	Velcro Straps	Rubber Band	Cohesive Bandage	Latex Gloves
	Method	Compression	Integrated			

5.2.4. Compatibility Conditions

In order to ensure different designs were compatible with one another when enumerated, compatibility conditions were enforced as described in Section 4.3, considered for the face coverings are provided in Table 6.

Table 6. Compatibility Conditions.

Design Variable #1	Compatibility Type	Design Variable #2
Number of Layers : 1	CANNOT HAVE	Layer 2 Material : Lignocellulosic Based
Number of Layers : 1	CANNOT HAVE	Layer 2 Material : Woven Cotton Based
Number of Layers : 1	CANNOT HAVE	Strap Material : Same as Bulk Material Layer 2
Number of Layers : 1	CANNOT HAVE	Strap Material : Same as Bulk Material Layer 3
Number of Layers : 2	CANNOT HAVE	Layer 2 Material : None
Number of Layers : 2	CANNOT HAVE	Layer 2 Material : Woven Cotton Based
Number of Layers : 2	CANNOT HAVE	Layer Connection Location : None
Number of Layers : 2	CANNOT HAVE	Strap Material : Same as Bulk Material Layer 3
Number of Layers : 3	CANNOT HAVE	Layer 2 Material : None
Number of Layers : 3	CANNOT HAVE	Layer 3 Material : None
Number of Layers : 3	CANNOT HAVE	Layer Connection Location : None
Strap Attachment : Integrated	CANNOT HAVE	Strap Material : Compression Fit from Cohesive Bandage
Strap Attachment : Integrated	CANNOT HAVE	Strap Material : Elastic Band
Strap Attachment : Integrated	CANNOT HAVE	Strap Material : Latex Gloves
Strap Attachment : Integrated	CANNOT HAVE	Strap Material : Rubber Band
Strap Attachment : Integrated	CANNOT HAVE	Strap Material : Tourniquet Band
Strap Attachment : Integrated	CANNOT HAVE	Strap Material : Universal Velcro Straps
Treatment : Machine Dry on Hot	CANNOT HAVE	Layer 1 Material : Lignocellulosic Based
Treatment : Machine Dry on Hot	CANNOT HAVE	Layer 1 Material : Non-Woven Cohesive Polyester Based
Treatment : Machine Wash	CANNOT HAVE	Layer 1 Material : Lignocellulosic Based
Treatment : Machine Wash	CANNOT HAVE	Layer 1 Material : Non-Woven Cohesive Polyester Based
Number of Layers : 1	MUST HAVE	Layer 2 Material : None
Number of Layers : 1	MUST HAVE	Layer 3 Material : None
Number of Layers : 1	MUST HAVE	Layer Connection Location : None
Number of Layers : 1	MUST HAVE	Layer Connection Mechanism : None
Number of Layers : 2	MUST HAVE	Layer 3 Material : None
Strap Material : Same as Bulk Material Layer 1	MUST HAVE	Strap Attachment : Integrated
Strap Material : Same as Bulk Material Layer 2	MUST HAVE	Strap Attachment : Integrated
Strap Material : Same as Bulk Material Layer 3	MUST HAVE	Strap Attachment : Integrated

6. METRICS AND SCORING RUBRICS

As described in Section 4, Analysis Methodology, the metrics for evaluating the face shields and face coverings were developed using SME knowledge, open source literature on face shields and face coverings, and the objectives of this project. The metrics and scoring rubrics used are provided in this section.

6.1.1. Face Shield Metrics and Scoring Rubrics

Descriptions of the metrics used for the face shields and their associated scoring rubrics can be found in Table 7.

6.1.1.1. Face Shield Scoring Augmentation

For the face shields, no scoring augmentations were performed. This means that the scores for each option was linearly added together as described in Section 4.

Table 7. Face Shield Metrics and Scoring Rubrics.

Category	*Metric*	*Definition*	*Goal*	*Scoring*				
				Low	**Low-Medium**	**Medium**	**Medium-High**	**High**
Effectiveness								
	Seal Around Face	Air flow resistance and degree of fiber wicking.	Maximize	Structure/skin interface provides minimal liquid blocking with no air flow resistance	Structure/skin interface provides some liquid blocking with no air flow resistance	Structure/skin interface provides liquid blocking with minimal air flow resistance	Structure/skin interface provides liquid blocking, some wicking protection, and some air flow resistance	Structure/skin interface filters aerosolized particles at (200nm) maximum and air flow is non-existent
	Resistance to Solvation	Resistance of shield to solvation.	Maximize	Solvation occurs with water and other common solvents	Resistance to solvation by: water Solvation occurs with: other solvents	Some Resistance to solvation by: Water, Ethyl Alcohol 70%, Isopropyl Alcohol Solvation occurs with: Acetone	Maintains transparency resistance to solvation by: Water, Ethyl Alcohol 70%, Isopropyl Alcohol Solvation occurs with: Acetone	Maintains transparency resistance to solvation by: Water, Ethyl Alcohol 70%, Isopropyl Alcohol, Acetone
Reusability								
	Degree of Chemical Inertness	Chemical inertness describes the degree of non-reactiveness, or inertness, of a material after 5 uses.	Maximize	One-Time Use Only	Severe Degradation	Moderate Degradation	Slight Degradation	Full Function and Performance
Producibility								
	Ability to Obtain Materials	Are these truly Commonly Available Materials (CAMs) that can be readily collected?	Minimize	Special Order, Very Constrained Supply	Special Order, Multiple Suppliers Limited Supply	Off the Shelf, Order, Abundant Supply	Off the shelf, Available On-Site by Special Request, Limited On-Site Supply	Off the shelf, Readily Available, Abundant On-Site Supply
	Build Time	Relative Construction Time Per Shield.	Minimize	Longest	Long	Medium	Short	Shortest
Cost								
	Material Cost	Relative Cost Per Shield Including All Items.	Minimize	Most Expensive	Expensive	Medium	Cheap	Cheapest
Comfort								
	Fit Around Head	How close is the face shield structure to the forehead? How flush is Face Shield structure's contact with the skin?	Maximize	No Contact	Limited Contact	Some Contact	Majority Contact	Perfect Contact
	Contact Surface Interface	Skin contact or hair irritation potential.	Minimize	Irritating, Uncomfortable, Limited Use	Frequent Irritation, Frequent Breaks Required	Some Irritation, Usable with Some Breaks	Limited-Irritation, Mostly Comfortable, Long Use	Non-Irritating, Comfortable, Extended Use

6.1.2. Face Covering Metrics and Scoring Rubrics

Descriptions of the metrics used for the face covering and their associated scoring rubrics can be found in Table 8 and Table 9.

6.1.2.1. Face Covering Scoring Rationale

The scores for the face coverings followed principles which take into account the mechanisms by which aerosolized particles may interact with the covering. Additionally, by determining that the face covering will need to at some degree trap aerosolized particles and inhibit the overall displacement of the particles to the environment the principle of inertial impaction, gravity sedimentation, electrostatic attraction, particle interception and basic Brownian diffusion were taken into account during the development of the scoring rubrics.

Inertial impaction and interference are two mechanism which we relied on for the determination of certain metrics like fiber density and structure. Inertial impaction of particles occur when the inertia of a particle is large enough that the particle will not follow the air stream around a fiber and will instead collide with the fiber matrix. Particle interference occurs when the fiber matrix disrupt the primary streamline of particles independent of particle inertia. Fiber matrices with densities that allow for a high degree of interference of particles, like spun bond, melt blown non-woven like fabrics or those with a tight structural weave, will in turn reduce particle inertia and velocity as the particles collide with the fibers in the face covering. Therefore, exhaled water vapor directional flow is inhibited by the face covering and a pressure differential is created approximating the fluid dynamics governed by the Bernoulli equations where pressure and velocity are inversely proportional. Consequently, unidirectional airflow from the covering proceeds as pressure increases within the covering in relation to external ambient pressure. This results in a uni-directional exhalation and overall reduction of exhaled water droplet displacement from the person to their external surroundings [28].

In order to reduce the exposure to the face covering wearer, the rubrics have taken into account the mechanism which govern water absorbency within the covering. This is an important factor as a trade off with water adherence to the fibers occurs as water droplet collision frequency increases due to the up scoring of covering materials that increases particle interference. However, prevention of water saturation at the interface of the mouth and face was deemed to be critical in reducing wicking/capillary action of liquid movement towards the mouth and nose which might pose a risk as the concentration of viral particles on the outside of face covering increase along with water saturation of face covering over time also increasing. This may present an inherent problem as the water accumulation within the covering may act as medium for external particle movement toward the mouth and nose. Therefore, a face covering layer with hydrophobic like qualities that can reduce the overall electrostatic attraction for water in the layer closest to the face scored higher during the development of the rubrics as they may reduce environmental exposure events to the mouth and nose. Materials that would serve this propose will include those like non-woven polypropylene which allow for a high degree of inertial impaction and particle interference and therein water droplet velocity reduction while minimizing the electrostatic attraction for water. Materials having oxygen or oxy-hydrogen groups are very susceptible to water absorption, whereas polymers containing only hydrogen and carbon, such as polyethylene, polystyrene and polypropylene are extremely water resistant [29].

In order to provide an active water diffusion gradient away from face an introduction of a moisture capture mode within the interchangeable middle layer of the face covering was postulated to increase

the effectiveness of the face covering and was captured in effectiveness parameter in the scoring rubric. This was also observed in literature to have positive benefits by capturing the liquid droplets exhaled from the covering wearer that could then be interchanged after water saturation occurs. Materials that would do well in this intermediate layer include more naturally derived fibers that are cellulosic in structure and composition which by nature will perform capillary action within the plant tissues. Additional resources can be found in [30-38].

6.1.2.2. Face Covering Scoring Augmentation

For the face shields, the scoring augmentations shown in Table 10 were used.

Table 8. Face Covering Metrics and Scoring Rubrics, Part 1 of 2.

Category	*Metric*	*Definition*	*Goal*
Effectiveness			
Inertial Impaction	Particle inertia restricts movement around respirator fibers which encourages particle collision with fibers. Effective for aerosol particles > 1 μm.		
	Metric Fiber Density	Density of Fibers.	Maximize
Diffusion	Diffusion filtering for small particles (< 0.1 μm) is aided by Brownian motion, resulting in a wandering particle path that increases particle collision with fibers.		
	Material Construction	Fabric structure extensibility is correlated with air permeability.	
	Water Saturation Potential	Degree hydrophilicity associated with material properties.	Minimize
Reusability			
	Durability Degree of Inertness	Chemical inertness describes the degree of non-reactiveness, or inertness, of a material	Maximize
Producibility			
	Ability to Obtain Materials	Are these truly Commonly Available Materials (CAMs) that can be readily collected?	Minimize
	Build Time	Relative construction time per face covering.	Minimize
Cost			
	Material Cost	Relative cost per face covering including all items.	Minimize
Comfort			
	Fit on Face	Ability for face covering to conform to face including material flexibility and ability to hold tension.	Maximize
	Breathability	The ease of breathing while wearing the face covering depends on the fiber density and water saturation of the aggregate face covering material.	Maximize

Table 9. Face Covering Metrics and Scoring Rubrics, Part 2 of 2.

Category	*Metric*	*Scoring*				
		Low	**Low-Medium**	**Medium**	**Medium-High**	**High**
Effectiveness						
Inertial Impaction						
	Metric Fiber Density	WC <600 TC Cotton Based	LC Paper Based	WC >600 TC Cotton Based	NW PolyP Based Melt Blown Fabrics	T NW HC PolyP Based
Diffusion						
	Material Construction	High Porosity Fabrics (Gauze)	Loose Knitted Fabric	Tight Knitted Fabric	Woven	Non-Woven Meltblown
	Water Saturation Potential	LC Paper Based	Cotton/Natural Fiber Based	Hydrophobic Coated Fiber	Hydrophilic Coated Synthetic Coated	Uncoated Synthetic Polymers
Reusability						
	Durability Degree of Inertness	LC Paper Based	Cotton/Natural Fiber Based	Hydrophilic Coated Synthetic Coated	Uncoated Synthetic Polymers	Hydrophobic Coated Fiber
Producibility						
	Ability to Obtain Materials	Special Order, Very Constrained Supply	Special Order, Multiple Suppliers Limited Supply	Off the Shelf, Order, Abundant Supply	Off the shelf, Available On-Site by Special Request, Limited On-Site Supply	Off the shelf, Readily Available, Abundant On-Site Supply
	Build Time	Longest	Long	Medium	Short	Shortest
Cost						
	Material Cost	Most Expensive	Expensive	Medium	Cheap	Cheapest
Comfort						
	Fit on Face	Rigid, Incomplete Fit Around Nose and Mouth	Semi-Conformable Around Mouth, Poor Fit Around Nose	Semi-Conformable Around Mouth And Nose	Flexible, Full Mouth Coverage, Partial Nose Coverage	Flexible, Full Coverage of Mouth and Nose
	Breathability	Highest Fiber Density Highest Water Saturation	High Fiber Density High Water Saturation	Medium Fiber Density Medium Water Saturation	Low Fiber Density Low Water Saturation	Lowest Fiber Density Lowest Water Saturation

Table 10. Scoring Augmentation for Face Coverings.

Design Option 1	Type	Design Option 2/Value	Metric	Modification
Number of Layers : 2	EQUALS	Number of Layers : 2	Effectiveness	10%
Number of Layers : 2	EQUALS	Number of Layers : 2	Reusability	5%
Number of Layers : 2	EQUALS	Number of Layers : 2	Producibility	-10%
Number of Layers : 2	EQUALS	Number of Layers : 2	Cost	-5%
Number of Layers : 2	EQUALS	Number of Layers : 2	Comfort	-5%
Number of Layers : 3	EQUALS	Number of Layers : 3	Effectiveness	20%
Number of Layers : 3	EQUALS	Number of Layers : 3	Reusability	10%
Number of Layers : 3	EQUALS	Number of Layers : 3	Producibility	-20%
Number of Layers : 3	EQUALS	Number of Layers : 3	Cost	-10%
Number of Layers : 3	EQUALS	Number of Layers : 3	Comfort	-10%
Tight Woven Cotton Based >600 Thread Count	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Effectiveness	10%
Tight Woven Cotton Based >600 Thread Count	WITH	Layer 2 Material : Polypropylene Non woven	Effectiveness	15%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Effectiveness	10%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Fit on Face	25%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Comfort	5%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Effectiveness	10%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Fit on Face	20%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Fit on Face	-10%
Number of Layers : 3	WITH	Layer 1 Material : Lignocellulosic Based	Effectiveness	-40%

Number of Layers : 3	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Effectiveness	-30%
Number of Layers : 3	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Effectiveness	-25%
Number of Layers : 3	WITH	Layer 2 Material : Lignocellulosic Based	Effectiveness	15%
Number of Layers : 3	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	20%
Number of Layers : 3	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Effectiveness	10%
Number of Layers : 3	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Effectiveness	-10%
Number of Layers : 3	WITH	Layer 2 Material : Polypropylene Non woven	Effectiveness	-10%
Number of Layers : 3	WITH	Layer 3 Material : Polypropylene Non woven	Effectiveness	30%
Number of Layers : 3	WITH	Layer 3 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	-15%
Number of Layers : 3	WITH	Layer 1 Material : Lignocellulosic Based	Degree of Inertness	-30%
Number of Layers : 3	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Number of Layers : 3	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Number of Layers : 3	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Degree of Inertness	10%
Number of Layers : 3	WITH	Layer 2 Material : Polypropylene Non woven	Degree of Inertness	10%
Number of Layers : 3	WITH	Layer 3 Material : Polypropylene Non woven	Degree of Inertness	20%

Number of Layers : 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Effectiveness	-15%
Number of Layers : 2	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	-5%
Number of Layers : 2	WITH	Layer 2 Material : Polypropylene Non woven	Effectiveness	30%
Number of Layers : 2	WITH	Layer 2 Material : Layer 2 Material : Non woven Polypropylene/Polyester Blend	Effectiveness	30%
Number of Layers : 2	WITH	Layer 1 Material : Lignocellulosic Based	Degree of Inertness	-25%
Number of Layers : 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-25%
Number of Layers : 2	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-5%
Number of Layers : 2	WITH	Layer 2 Material : Polypropylene Non woven	Degree of Inertness	20%
Number of Layers : 2	WITH	Layer 2 Material : Layer 2 Material : Non woven Polypropylene/Polyester Blend	Degree of Inertness	20%
Number of Layers : 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Effectiveness	35%
Number of Layers : 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Effectiveness	30%
Number of Layers : 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Effectiveness	20%
Number of Layers : 1	WITH	Layer 1 Material : Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	-10%
Number of Layers : 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Degree of Inertness	20%

Number of Layers : 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Degree of Inertness	20%
Number of Layers : 1	WITH	Layer 1 Material : Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Material of Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Effectiveness	-20%
Material of Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Degree of Inertness	-20%
Material of Layer 2	WITH	Layer 1 Material : Lignocellulosic Based	Degree of Inertness	-20%
Material of Layer 2	WITH	Layer 1 Material : Lignocellulosic Based	Degree of Inertness	-20%
Treatment : Machine Dry on Hot	WITH	Layer 3 Material : Woven Cotton Based <600 Thread Count	Effectiveness	20%
Treatment : Machine Dry on Hot	WITH	Layer 3 Material : Woven Cotton Based <600 Thread Count	Breathability	-10%
Treatment : Machine Dry on Hot	WITH	Layer 3 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	20%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Breathability	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	20%
Treatment : Machine Dry on Hot	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Breathability	-10%

Treatment : Machine Dry on Hot	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Dry on Hot	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	20%
Treatment : Machine Dry on Hot	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Breathability	-10%
Treatment : Machine Dry on Hot	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	20%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Breathability	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based <600 Thread Count	Effectiveness	20%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based <600 Thread Count	Breathability	-10%
Treatment : Machine Dry on Hot	WITH	Layer 1 Material : Tight Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Wash	WITH	Layer 3 Material : Woven Cotton Based <600 Thread Count	Effectiveness	15%
Treatment : Machine Wash	WITH	Layer 3 Material : Woven Cotton Based <600 Thread Count	Breathability	-10%
Treatment : Machine Wash	WITH	Layer 3 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%

Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	15%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Breathability	-10%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	15%
Treatment : Machine Wash	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Breathability	-10%
Treatment : Machine Wash	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Wash	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	15%
Treatment : Machine Wash	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Breathability	-10%
Treatment : Machine Wash	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Effectiveness	15%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Breathability	-10%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	-10%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based <600 Thread Count	Effectiveness	15%

Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based <600 Thread Count	Breathability	-10%
Treatment : Machine Wash	WITH	Layer 1 Material : Tight Woven Cotton Based <600 Thread Count	Degree of Inertness	-10%
Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Ability to Obtain Materials	-25%
Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Build Time	-15%
Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Material Cost	-25%
Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Fit on Face	25%
Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Breathability	-5%
Layer 1 Material : Woven Cotton Based <600 Thread Count	WITH	Layer 2 Material : Lignocellulosic Based	Ability to Obtain Materials	25%
Layer 1 Material : Woven Cotton Based <600 Thread Count	WITH	Layer 2 Material : Lignocellulosic Based	Build Time	15%
Layer 1 Material : Woven Cotton Based <600 Thread Count	WITH	Layer 2 Material : Lignocellulosic Based	Material Cost	25%
Layer 1 Material : Woven Cotton Based <600 Thread Count	WITH	Layer 2 Material : Lignocellulosic Based	Material Cost	5%
Layer 1 Material : Woven Cotton Based <600 Thread Count	WITH	Layer 2 Material : Lignocellulosic Based	Breathability	5%
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Degree of Inertness	3

Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Degree of Inertness	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Degree of Inertness	1
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Degree of Inertness	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Degree of Inertness	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Ability to Obtain Materials	1
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Ability to Obtain Materials	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Ability to Obtain Materials	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Ability to Obtain Materials	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Ability to Obtain Materials	4
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Ability to Obtain Materials	2
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Ability to Obtain Materials	5

Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Build Time	1
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Build Time	2
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Build Time	1
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Build Time	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Build Time	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Build Time	2
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Build Time	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Material Cost	1
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Material Cost	4
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Material Cost	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Material Cost	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Material Cost	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Material Cost	2
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Material Cost	4

Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Non-woven, Hydrophilic-coated Polypropylene Based	Fit on Face	2
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Polypropylene Non-woven Based	Fit on Face	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Lignocellulosic Based	Fit on Face	1
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non-Woven Cohesive Polyester Based	Fit on Face	3
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Tight Woven Cotton Based >600 Thread Count	Fit on Face	5
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Non woven Polypropylene/Polyester Blend	Fit on Face	2
Strap Material : Same as Bulk Material Layer 1	WITH	Layer 1 Material : Woven Cotton Based <600 Thread Count	Fit on Face	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Lignocellulosic Based	Degree of Inertness	1
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Degree of Inertness	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Degree of Inertness	3
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Polypropylene Non woven	Degree of Inertness	3
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : None	Degree of Inertness	0
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Lignocellulosic Based	Ability to Obtain Materials	5

Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Ability to Obtain Materials	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Ability to Obtain Materials	4
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Ability to Obtain Materials	2
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Polypropylene Non woven	Ability to Obtain Materials	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : None	Ability to Obtain Materials	0
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Lignocellulosic Based	Build Time	1
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Build Time	3
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Build Time	3
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Build Time	2
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Polypropylene Non woven	Build Time	2
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : None	Build Time	0
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Lignocellulosic Based	Material Cost	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Material Cost	4
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Material Cost	3
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Material Cost	2
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Polypropylene Non woven	Material Cost	4

Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : None	Material Cost	0
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Lignocellulosic Based	Fit on Face	1
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Woven Cotton Based <600 Thread Count	Fit on Face	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Tight Woven Cotton Based >600 Thread Count	Fit on Face	5
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Non woven Polypropylene/Polyester Blend	Fit on Face	2
Strap Material : Same as Bulk Material Layer 2	WITH	Layer 2 Material : Polypropylene Non woven	Fit on Face	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material :Polypropylene/Polyester Blend	Degree of Inertness	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Non Woven Cohesive Polyester Based	Degree of Inertness	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Tight Woven Cotton Based >600 Thread Count	Degree of Inertness	5
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : None	Degree of Inertness	0
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material :Polypropylene/Polyester Blend	Ability to Obtain Materials	2
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Non Woven Cohesive Polyester Based	Ability to Obtain Materials	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Tight Woven Cotton Based >600 Thread Count	Ability to Obtain Materials	4
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : None	Ability to Obtain Materials	0
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material :Polypropylene/Polyester Blend	Build Time	2

Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Non Woven Cohesive Polyester Based	Build Time	5
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Tight Woven Cotton Based >600 Thread Count	Build Time	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : None	Build Time	0
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material :Polypropylene/Polyester Blend	Material Cost	2
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Non Woven Cohesive Polyester Based	Material Cost	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Tight Woven Cotton Based >600 Thread Count	Material Cost	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : None	Material Cost	0
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Polypropylene/Polyester Blend	Fit on Face	2
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Non Woven Cohesive Polyester Based	Fit on Face	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : Tight Woven Cotton Based >600 Thread Count	Fit on Face	3
Strap Material : Same as Bulk Material Layer 3	WITH	Layer 3 Material : None	Fit on Face	0

7. ANALYSIS

The solution space for the face shield and face coverings were enumerated and scored according to the metrics described in Section 6. As described in Section 4, two analysis approaches were used, one which uses a multi-objective Pareto Frontier to determine tradeoffs in the solution space with various metrics and characteristics of the metrics that perform well and one which uses an OEC. This section provides the results of that analysis for both the face shields and the face coverings.

7.1. Face Shields

7.1.1. Pareto Frontier

Figure 4 and Figure 5 show two Pareto Frontiers from the analysis performed on the face shields. Each was generated using the scores found from the evaluations following the methodology described in Section 4. Note that these are three-dimensional Pareto Frontiers, holding the effectiveness metric constant. It should be noted that it is desired to maximize each of the broader categories and that the Pareto Frontier is denoted with larger red dots.

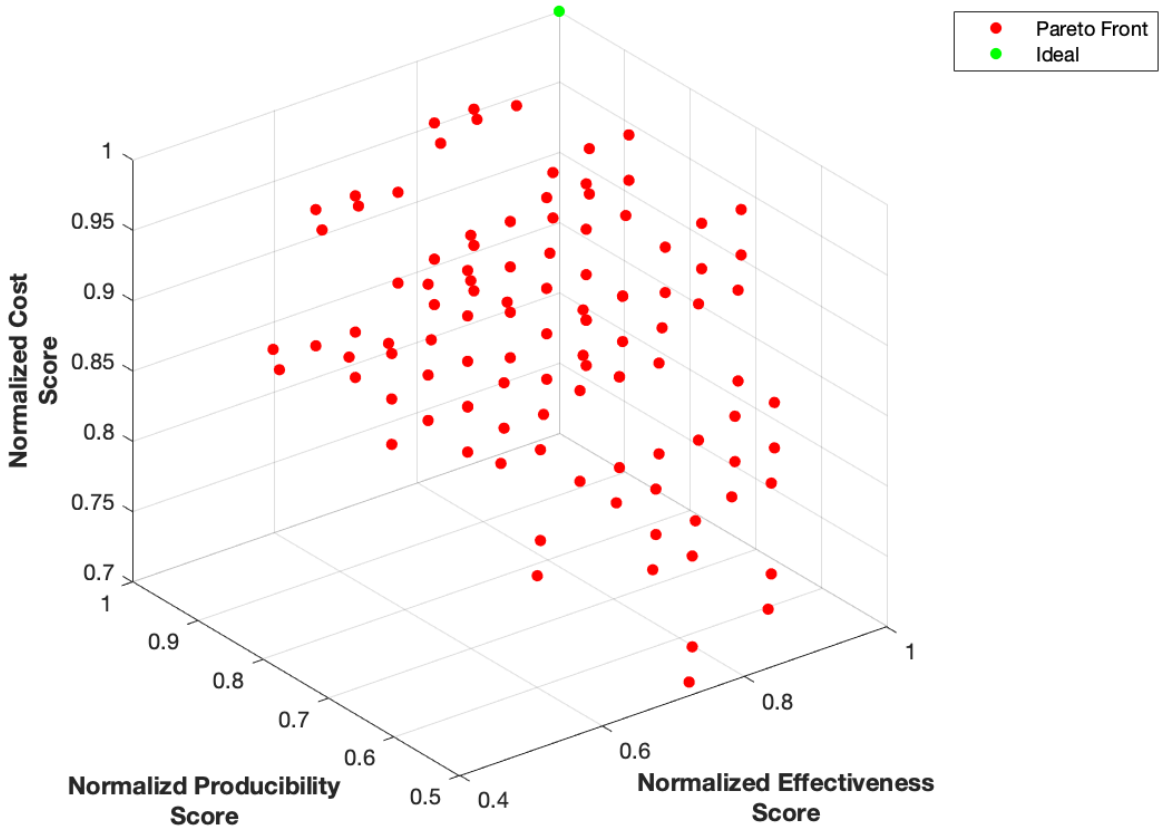


Figure 4. Face Shield Pareto Frontier (Effectiveness-Producibility-Cost)

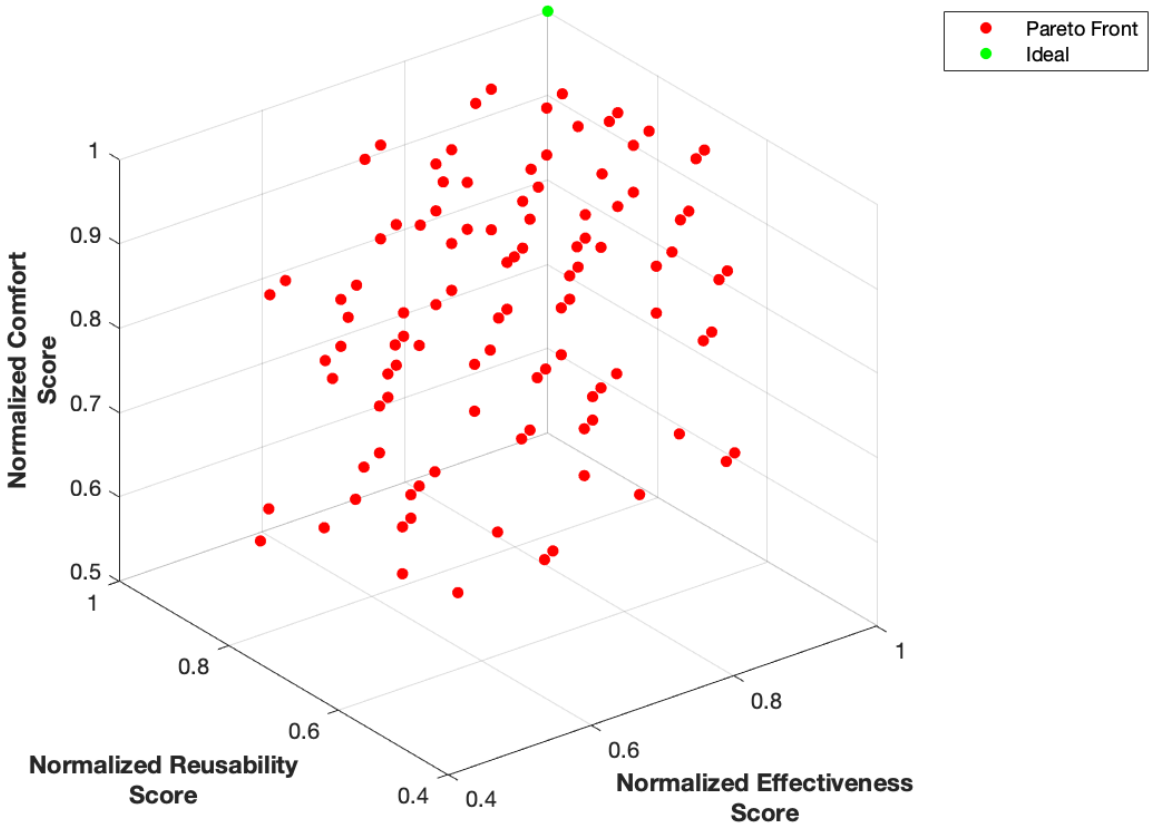


Figure 5. Face Shield Pareto Frontier (Effectiveness-Reusability-Comfort)

In addition, a further analysis examined the space with respect to only the effectiveness and producibility categories. This is shown in Figure 6.

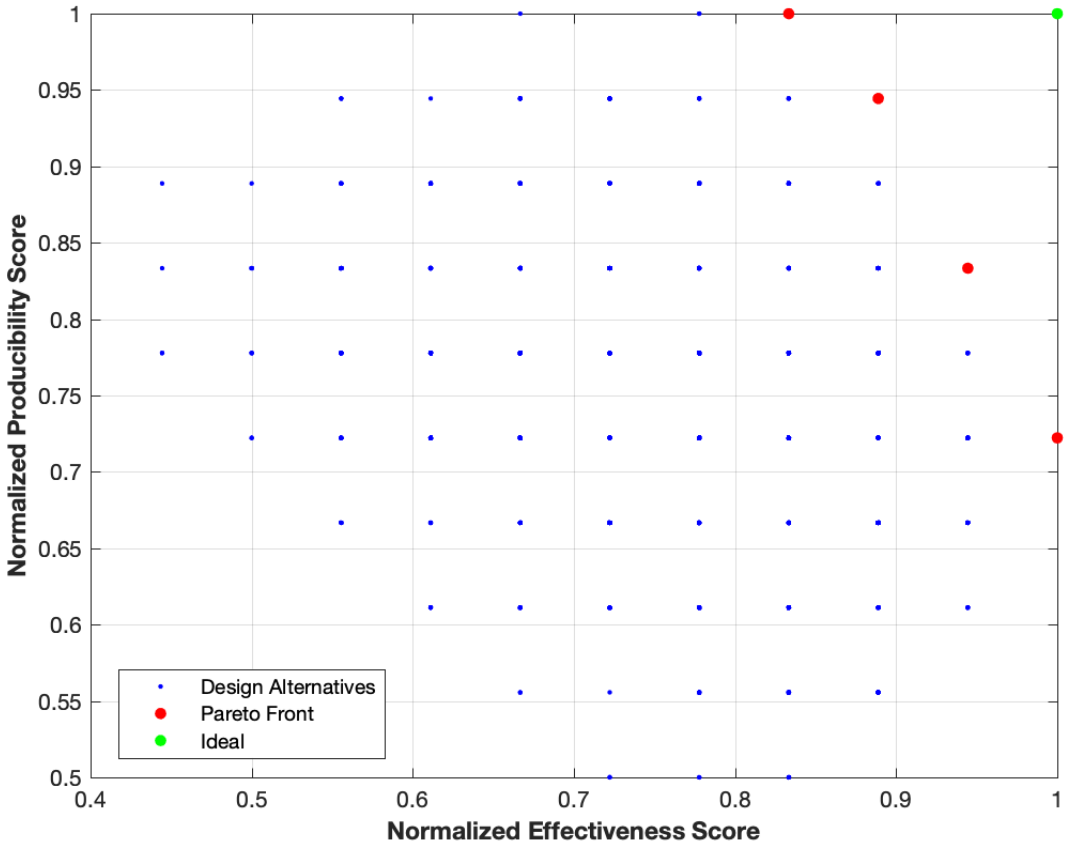


Figure 6. Face Shield Pareto Frontier (Effectiveness-Producibility).

7.1.2. Effectiveness

The performance of the face shield material was done by examining their effectiveness. Table 12 shows the most effective design solutions, while Table 13 shows the least effective design solutions. In the Appendix, a more exhaustive listing of this design space is provided, showing the most effective design solutions in Table A - 1 and the least effective design solutions in Table A - 2. In interpreting this data, observe the general trends from the scoring and not the absolute order within the broad categories as the absolute rankings may be insignificant due to the uncertainties in the analysis.

7.1.3. Overall Evaluation Criterion

An equal weighting was provided to each of the broader categories of metrics—effectiveness, producibility, reusability, comfort, and cost. Since there were five metrics, each metric contributed 20% to the OEC. Table 11 describes the mapping between the lower level metrics and the broader categories and shows these weights. This analysis provides a table of design options that performed well and poorly. These are provided in Table 14 and Table 15. A more extensive listing of the highest OEC scoring designs and the lowest OEC scoring designs are provided in the Appendix in Table A - 3 and Table A - 4. In interpreting this data, observe the general trends from the data and not the

absolute order within the broad categories as the absolute rankings may be insignificant due to the uncertainties in the analysis.

7.2. Face Coverings

7.2.1. Pareto Frontier

Figure 7 and Figure 8 show two Pareto Frontiers from the analysis performed on the face coverings. As before, each was generated using the scores found from the evaluations following the methodology described in Section 4.

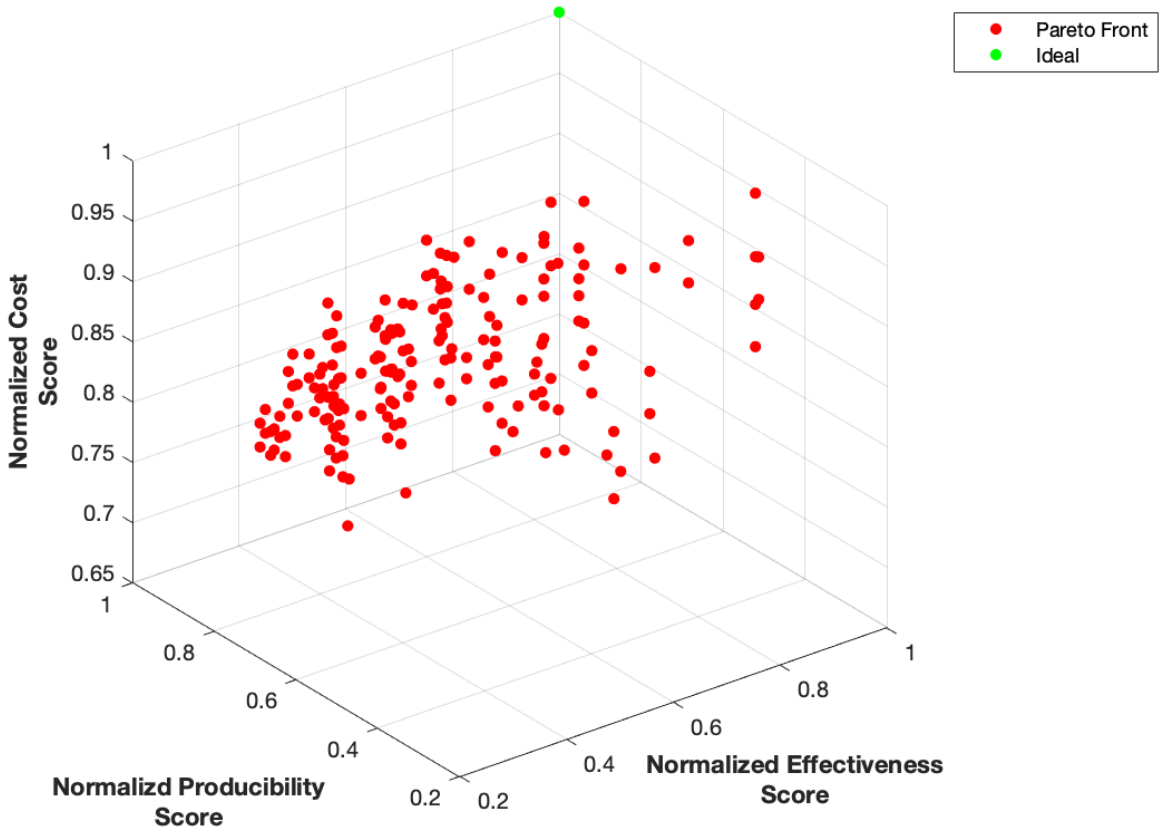


Figure 7. Face Covering Pareto Frontier (Effectiveness-Producibility-Cost)

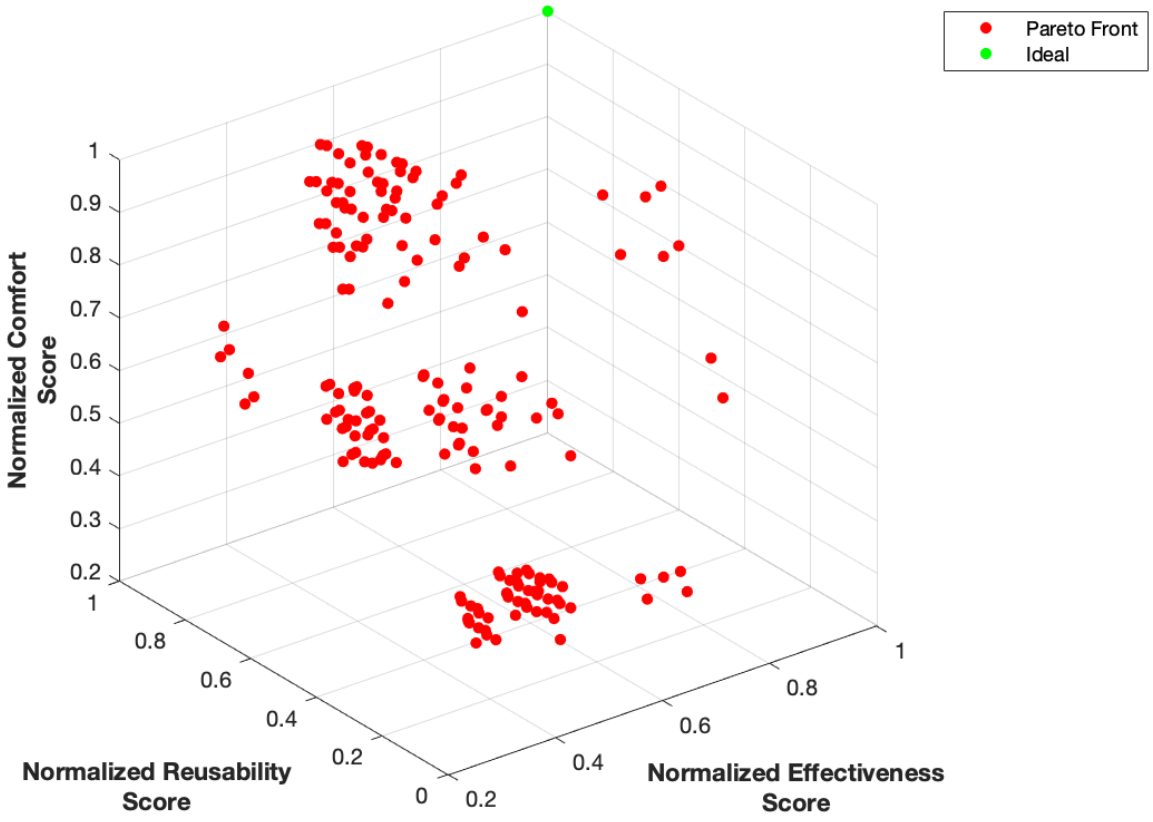


Figure 8. Face Covering Pareto Frontier (Effectiveness-Reusability-Comfort)

In addition, a further analysis examined the space with respect to only the effectiveness and producibility categories. This is shown in Figure 9.

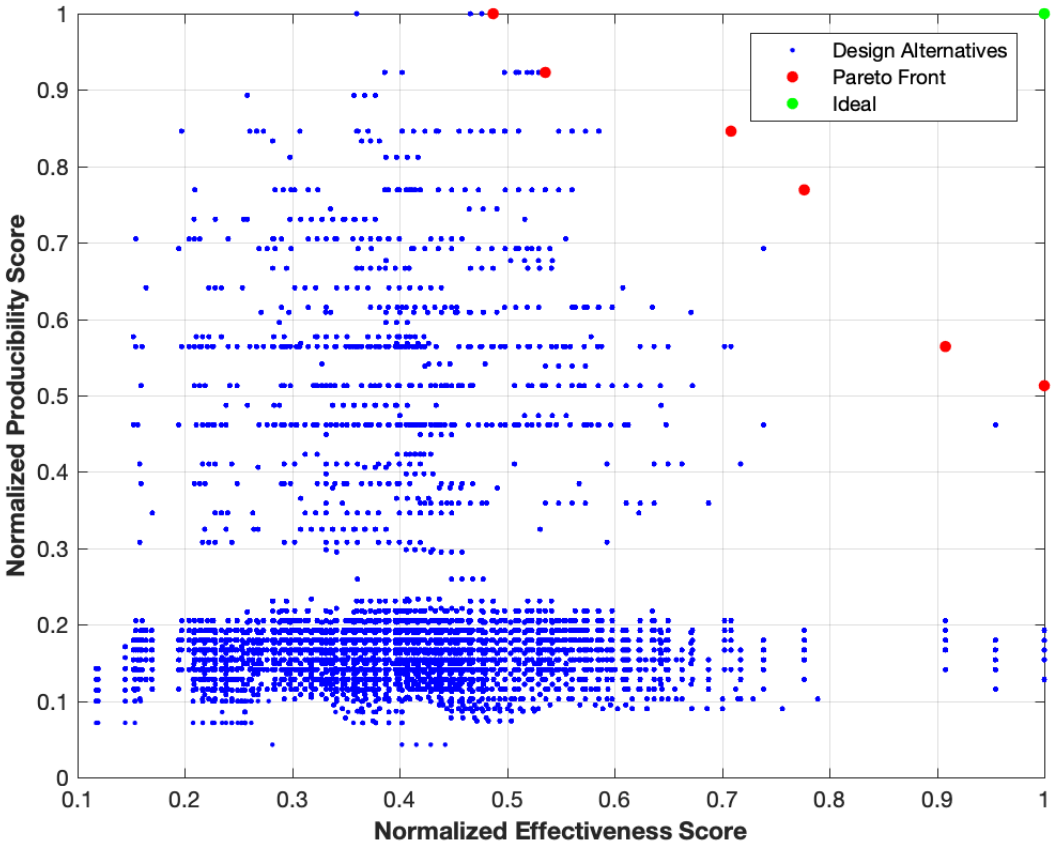


Figure 9. Face Covering Pareto Frontier (Effectiveness-Producibility).

7.2.2. Effectiveness

An examination of the performance of the face coverings was performed. Table 17 shows the most effective design solutions, while Table 18 shows the least effective design solutions. Larger listings of the most and least effective face covering solutions are provided in Table A - 5 and Table A - 6. In interpreting these data, observe the general trends from the scoring not the absolute ranking within the broad categories as the absolute rankings may be insignificant due to the uncertainties in the analysis.

7.2.3. Overall Evaluation Criterion

To understand the overall performance of a design, an equal weighting was provided to each of the broader categories of metrics—effectiveness, producibility, reusability, comfort, and cost. Since there were five metrics, each metric contributed 20% to the OEC. Table 16 describes the mapping between the lower level metrics and the broader categories and shows these weights. This analysis provides a table of design options that performed well and poorly. The best and worst performers are provided in Table 19 and Table 20. More extensive listings of the best and worst face covering designs with respect to the OEC are provided in Table A - 7 and Table A - 8. In interpreting these data, observe the general trends from the scoring and not the absolute order within the broad categories as the absolute order may be insignificant due to the uncertainties in the analysis.

Table 11. Face Shield Metric Mapping to Broad Categories.

Effectiveness	*Reusability/Durability*		*Producibility*		*Cost*	*Comfort*	
Weighting: (0.2)	**Weighting: (0.2)**		**Weighting: (0.2)**		**Weighting: (0.2)**	**Weighting: (0.2)**	
Seal Around Face	Compatibility with Cleaning Solvents	Degree of Inertness	Ability to Obtain Materials	Build Time	Material Cost	Fit Around Head	Contact Surface Interface
Weighting: (0.2)	**Weighting: (0.1)**	**Weighting: (0.1)**	**Weighting: (0.1)**	**Weighting: (0.1)**	**Weighting: (0.2)**	**Weighting: (0.1)**	**Weighting: (0.1)**

Table 12. Most Effective Face Shield Solutions.

Material	Structure	Strap Material	Strap Attachment Method
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Elastic Band	Compression
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Universal Velcro Strips	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Plastic Folder Polypropylene	Foam	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Elastic Band	Compression
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Glued
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched

Table 13. Least Effective Face Shield Solutions.

Material	Structure	Strap Material	Strap Attachment Method
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled

Table 14. Best Performing OEC Face Shields.

Material	Structure	Strap Material	Strap Attachment Method
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Elastic Band	Compression
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Compression Fit from Cohesive Bandage	Compression

Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Compression

Table 15. Worst Performing OEC Face Shields.

Material	Structure	Strap Material	Strap Attachment Method
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Cardboard	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Tongue Depressor	Latex Gloves (Nitrile)	Glued
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued

Table 16. Face Covering Metric Mapping to Broad Categories.

Effectiveness			*Reusability*	*Producibility*		*Cost*	*Comfort*	
Weighting: (0.2)			**Weighting: (0.2)**	**Weighting: (0.2)**		**Weighting: (0.2)**	**Weighting: (0.2)**	
Inertial Impaction	**Diffusion**		**Durability**	**Producibility**		**Cost**	**Comfort**	
Metric Fiber Density	Material Construction	Water Saturation	Degree of Inertness	Ability to Obtain Materials	Build Time	Material Cost	Fit on Face	Breathability

Weighting: (0.067)	Weighting (0.067)	Weighting: (0.067)	Weighting: (0.2)	Weighting: (0.1)	Weighting (0.1)	Weighting: (0.2)	Weighting: (0.1)	Weighting: (0.1)

Table 17. Most Effective Face Covering Solutions.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Staple

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Staple

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Taped

Table 18. Least Effective Face Covering Solutions.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Compression
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Glue
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Sew
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Staple
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Taped
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Compression
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Glue

1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Sew
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Staple
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Taped

Table 19. Best Performing OEC Face Coverings.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated

Table 20. Worst Performing OEC Face Coverings.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Compression
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Taped
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Sew

1	Woven Cotton Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Glue
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Lignocellulosic Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated

7.3. Observations

Observations from the analysis are provided below. Note that these observations are derived from the data from the analysis as well as the literature cited previously.

7.3.1. Face Shields

7.3.1.1. Material Observations

The following observations were made from the analysis of the data regarding materials for the face shield.

- The most highly scored options used a foam as the primary frame/face interface material to provide the most effective liquid splash protection
- For reuse of the face shield, choosing materials that are compatible with solvents like polypropylene is crucial.

7.3.1.2. Design Observations

The following observations were made from the data regarding the design for the face shield.

- Minimizing the gap between the face shield and the forehead will help reduce the chance of liquid splash to the eyes
- It is important that the face shield extends down below the chin and stretch around the full-face area
- Designs that use compression to attach the face shield to the face were observed to be promising

From a design perspective, for the skin to frame interface, it is desired to maximize frame/skin interface surface area to provide enhanced splash protection along with a foam interface for a comfortable seal. For the location of the window, it is desirable for full face protection with extended facepiece length to provide protection from both front and side splash events. Design for multiple reuse options by leveraging material properties for improved compatibility with known disinfects and solvents.

7.3.2. Face Coverings

7.3.2.1. Material Observations

The following observations from the data in the E-PiPEline study were made for the face covering:

- Leverage cotton and paper-based materials to capture aerosolized water droplets within the fiber matrix.
- The placement of natural-based materials sandwiched between two water repelling synthetic based materials decreases liquid movement towards the face
- Using materials with high fabric density to improve particle filtration while maintaining user breathability

It was observed that the more layers the better. Assuming a three-layer face covering the following observations were made regarding the selection of materials for each layer:

For the *layer furthest from the mouth*, one should increase inertial impaction factor by maximizing fabric fiber density. This will likely increase the probability of blocking aerosolized viral particles.

Selecting first layer materials that have a **low water absorption** may also reduce water saturation and increase face covering durability and breathability.

The *middle layer* should be designed for material interchangeability. Using **non-woven fabrics with high fiber density** will likely increase filtration effectiveness by providing a tortuous path for particles resulting in increased particle collision and entrapment in the middle layer [35]. Materials with increased water absorbance provide a matrix for aerosolized liquid water capture. Additionally, the middle layer should have design features that allow for material interchange after high particle loading and water saturation which can reduce filtration effectiveness and user breathability.

The *layer closest to the mouth* should be designed for mouth and nose interface compatibility and with **high water repelling properties**. Select materials with a **high fiber density**. Do not select loose materials or weaves to prevent inhalation of material borne particles. By choosing these materials the user can reduce the chance of viral transmission via water wicking to the mouth and nose.

7.3.2.2. Design Observations

The following observations were made from the data regarding the design for the face covering.

- More layers increase effectiveness
- Full coverage over mouth and nose reduces chances of particles reaching the face
- Face covering conformability improves filtration effectiveness.

7.3.2.3. Using the Observations for Practical Steps to Materials Selection for Face Coverings

The following are steps to interpret, evaluate, and use the observations provided in the design and creation of a face covering.

1. Understand the material's fiber parameters. Categorize your materials based on whether base fibers are synthetic or natural and if the fibers are small or large in diameter. Synthetic fibers are usually stronger and more durable for longer use situations as well as usually maintain a low water absorption while small fibers usually indicate a high fiber density.
2. Determine if the material stretches when pulled indicating a knitted or loose weave structure or if conversely the fabric is very stable under tension indicating an increase in fiber density with a non-woven or tight weave structure. Choose materials with a high fiber density that will maintain their shape when put under tension.
3. Determine if the fabric has any coatings, ink, or other surface treatment. A quick way of determining this is simply testing the fabric under water and check if water is repelled or absorbed by the material. Additionally, check if the treatment is applied to one or both sides of the material. With the understanding that the water absorbing material faces should point away and from the mouth or nose and placed further away from the mouth. This will minimize water wicking towards the mouth and nose interface of the face covering.

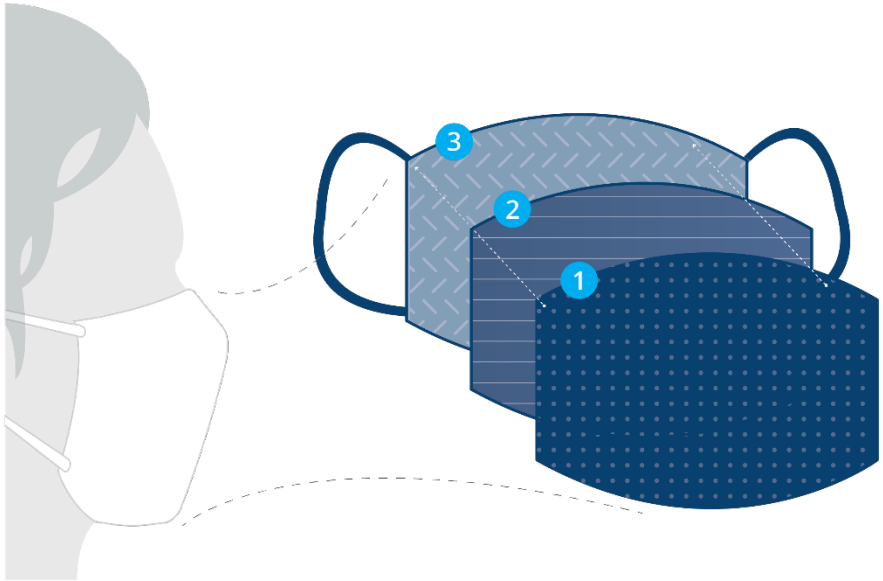
Table 21 provides an assortment of the materials examined in this study for the face coverings, some observations regarding these materials, and some observations regarding the location in the design of a face covering.

Table 21. Practical Description of Materials, Observations, and Locations.

Material Types	Examples	Water Saturation Potential	Face Coverings Observations	Highest Scored Face Covering Layer
Cotton with High Fiber Density	Pillowcases, flannel, high tread count clothing	Medium	Easy to wash, absorbent, fairly durable, high fabric density.	Layer closest and furthest from the mouth
Cotton with Medium to Low Fiber Density	Shirts, bandanas, woven gauze, scarfs	Medium	Easy to wash, absorbent, fairly durable, low fabric density	Middle Layer
Polypropylene	Professional/shop towels, Haylard surgical wraps, medical grade fabrics.	Very Low	Low water absorption, high fabric density, very durable	Layer closest and furthest from the mouth
Polyester Blends	Surgical masks, general shop towels, non-woven gauze, sports and performance apparel	Low	Low water absorption, high fabric density, dries quickly, durable	Layer closest and furthest from the mouth
Paper Based	Coffee filters, paper towels, stretcher tissue paper	High	High water absorption, varying degree of fabric density	Middle Layer

8. BUILD INSTRUCTIONS

Attractive CAM Face Covering Design Concept



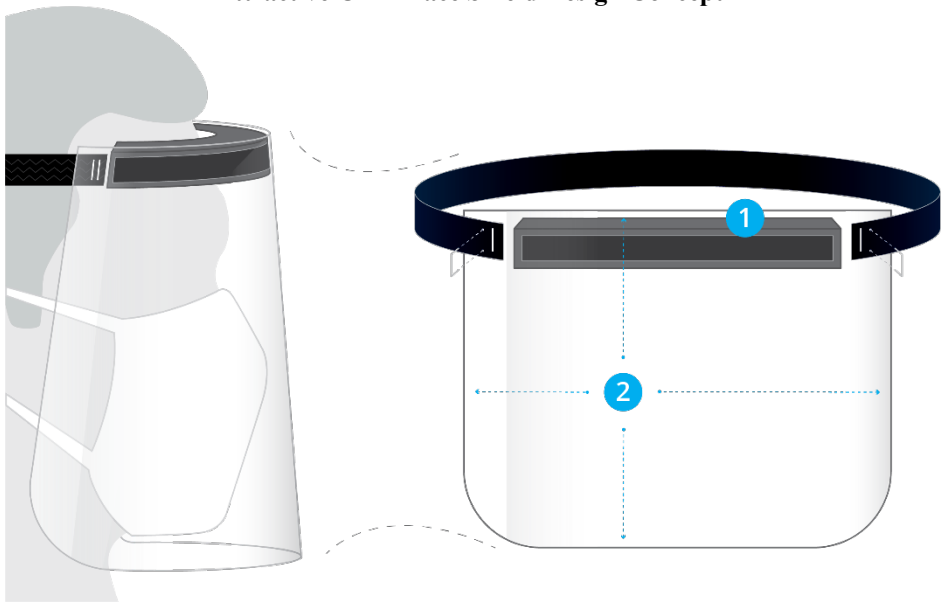
Material List for Attractive CAM Face Covering Design Concept

Number of Layers: 3
Layer 1: NW PolyP Based (Example: Halyard 600 Sterilization Wrap)
Layer 2: NW PolyP Based (Example: Polypropelene Professional Shop Towel)
Layer 2 Alternative: T WC >600 TC Cotton (Example: Flannel)
Layer 3: NW PolyP/PolyE Blend Based (Example: Surgical Mask)
Connection Location: Center and Edges
Connection Mechanism: Staple
Strap Material: Elastic Band
Strap Attachment: Staple
Treatment (If Appropriate): Machine Dry

Conceptual Written Build Instructions for Above CAM Face Covering

Step 1: Obtain materials listed above
Step 2: Cut out Layer 1 and Layer 2 from respective bulk materials and template
Step 3: If Layer 1 increases fiber density with heat, treat Layer 1 with Machine Dry
Step 4: Collect Layers 1 – 3, arrange in overlapping configuration order shown above
Step 5: Secure Layers 1 – 3 with staples in center and around edges of face covering
Step 6: Cut the correct length of elastic band to fit around each ear with strong tension
Step 7: Secure elastic bands with staples at each corner of face covering as shown
Step 8: Adjust face covering fit as needed to ensure best personalized fit possible

Attractive CAM Face Shield Design Concept



Material List for Attractive CAM Face Shield Design Concept

Material: Clear Polyester Film
Structure: Foam

Upper Strap Material: Elastic Band
Upper Strap Attachment Method: Staple

Conceptual Written Build Instructions for Above CAM Face Shield

Step 1: Obtain materials listed above
Step 2: Cut out face shield from bulk clear polyester film template
Step 3: Cut piece of foam to personalized length to fit around forehead
Step 4: Peel off adhesive strip from foam and affix to the top of clear polyester film
Step 5: Cut the correct length of elastic band to fit around head with strong tension
Step 6: Secure elastic band to upper corners of clear polyester film with staples
Step 7: Adjust face shield fit as needed to ensure best personalized fit possible

9. SUMMARY AND CONCLUSIONS

The CDC has recommended that the public should wear cloth face coverings in public settings. Face shields and face coverings can be made using CAMs. As part of the Sandia COVID-19 LDRD effort (funded under the Materials Science Investment Area), the Sandia E-PiPEline task evaluated design options for face coverings and face shields considering their effectiveness, durability, build difficulty, build cost, and comfort.

For the face shield, it was observed that:

- The most highly scored options used a foam as the primary frame/face interface material to provide the most effective liquid splash protection
- For reuse of the face shield, choosing materials that are compatible with solvents like polypropylene is crucial.
- Minimizing the gap between the face shield and the forehead will help reduce the chance of liquid splash to the eyes
- It is important that the face shield extends down below the chin and stretch around the full-face area
- Designs that use compression to attach the face shield to the face were observed to be promising

For the face covering, it was observed that:

- Leverage cotton and paper-based materials to capture aerosolized water droplets within the fiber matrix.
- The placement of natural-based materials sandwiched between two water repelling synthetic based materials decreases liquid movement towards the face
- Using materials with high fabric density to improve particle filtration while maintaining user breathability
- More layers increase effectiveness
- Full coverage over mouth and nose reduces chances of particles reaching the face
- Face covering conformability improves filtration effectiveness.

In addition, the study was conducted in a highly dynamic environment and subsequent studies have been published (e.g., [38]) Finally, while enumerating the design space for face shields and face coverings using CAMs, metrics, and process are strong contributions, this study was limited in scope and time. As such, further engineering analysis should be conducted in order to identify an optimal design and to verify efficacy of the design solution.

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APPENDIX A. BEST AND WORSE PERFORMING DESIGN SOLUTIONS

This appendix provides a more complete listing of the best and worst performing design solutions. The combination of design alternatives comprising the top and bottom designs for the face shields and face coverings are provided for both the OEC as well as for the metrics comprising the effectiveness metric. In interpreting this data, trends should be observed as opposed to their rankings of the solutions.

A.1. Face Shields

A.1.1.1. Most Effective Face Shield Solutions

The design solutions that had the highest effectiveness score are provided in Table A - 1.

A.1.1.2. Least Effective Face Shield Solutions

The design solutions that had the lowest effectiveness score are provided in Table A - 2.

A.1.1.3. Highest Scoring OEC Face Shield Solutions

The design solutions that had the highest OEC score are provided in Table A - 3.

A.1.1.4. Lowest Scoring OEC Face Shield Solutions

The design solutions that had the highest OEC score are provided in Table A - 4.

A.2. Face Coverings

A.2.1.1. Most Effective Face Covering Solutions

The design solutions that had the highest OEC score are provided in Table A - 5.

A.2.1.2. Least Effective Face Covering Solutions

The design solutions that had the lowest OEC score are provided in Table A - 6.

A.2.1.3. Highest Scoring OEC Face Covering Solutions

The design solutions that had the highest effectiveness score are provided in Table A - 7.

A.2.1.4. Lowest Scoring OEC Face Covering Solutions

The design solutions that had the lowest effectiveness score are provided in Table A - 8.

Table A - 1. Most Effective Face Shields.

Material	Structure	Strap Material	Strap Attachment Method
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Elastic Band	Compression
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Universal Velcro Strips	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Plastic Folder Polypropylene	Foam	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Elastic Band	Compression
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Glued
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Taped
Clear Polyester Film	Foam	Elastic Band	Glued
Clear Polyester Film	Foam	Elastic Band	Sewn/Stitched
Clear Polyester Film	Foam	Elastic Band	Taped
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Foam	Rubber Band	Compression
Clear Polyester Film	Rolled Paper	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Rolled Paper	Elastic Band	Compression
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Safety Glasses	Elastic Band	Compression
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Glued
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Taped
Clear Polyester Film	Universal Velcro Strips	Elastic Band	Glued
Clear Polyester Film	Universal Velcro Strips	Elastic Band	Sewn/Stitched

Clear Polyester Film	Universal Velcro Strips	Elastic Band	Taped
Clear Polyester Film	Universal Velcro Strips	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Universal Velcro Strips	Rubber Band	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Compression
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Elastic Band	Compression
Transparency (cellulose acetate)	Foam	Compression Fit from Cohesive Bandage	Compression
Transparency (cellulose acetate)	Foam	Elastic Band	Compression
Transparency (cellulose acetate)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Transparency (cellulose acetate)	Universal Velcro Strips	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Glued
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Taped
Clear Plastic Folder Polypropylene	Foam	Elastic Band	Glued
Clear Plastic Folder Polypropylene	Foam	Elastic Band	Sewn/Stitched
Clear Plastic Folder Polypropylene	Foam	Elastic Band	Taped
Clear Plastic Folder Polypropylene	Foam	Latex Gloves (Nitrile)	Compression
Clear Plastic Folder Polypropylene	Foam	Rubber Band	Compression
Clear Plastic Folder Polypropylene	Rolled Paper	Compression Fit from Cohesive Bandage	Compression
Clear Plastic Folder Polypropylene	Rolled Paper	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Safety Glasses	Compression Fit from Cohesive Bandage	Compression
Clear Plastic Folder Polypropylene	Safety Glasses	Elastic Band	Compression

Clear Plastic Folder Polypropylene	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Glued
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Taped
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Elastic Band	Glued
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Elastic Band	Sewn/Stitched
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Elastic Band	Taped
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Latex Gloves (Nitrile)	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Rubber Band	Compression
Clear Polyester Film	Cardboard	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Cardboard	Elastic Band	Compression
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Glued
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Sewn/Stitched
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Taped
Clear Polyester Film	Foam	Rubber Band	Glued
Clear Polyester Film	Foam	Rubber Band	Sewn/Stitched
Clear Polyester Film	Foam	Rubber Band	Taped
Clear Polyester Film	Foam	Universal Velcro Straps	Compression
Clear Polyester Film	Rolled Paper	Compression Fit from Cohesive Bandage	Glued
Clear Polyester Film	Rolled Paper	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Rolled Paper	Compression Fit from Cohesive Bandage	Taped
Clear Polyester Film	Rolled Paper	Elastic Band	Glued
Clear Polyester Film	Rolled Paper	Elastic Band	Sewn/Stitched
Clear Polyester Film	Rolled Paper	Elastic Band	Taped
Clear Polyester Film	Rolled Paper	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Rolled Paper	Rubber Band	Compression
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Glued
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Taped
Clear Polyester Film	Safety Glasses	Elastic Band	Glued

Clear Polyester Film	Safety Glasses	Elastic Band	Sewn/Stitched
Clear Polyester Film	Safety Glasses	Elastic Band	Taped
Clear Polyester Film	Safety Glasses	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Safety Glasses	Rubber Band	Compression
Clear Polyester Film	Universal Velcro Strips	Latex Gloves (Nitrile)	Glued
Clear Polyester Film	Universal Velcro Strips	Latex Gloves (Nitrile)	Sewn/Stitched
Clear Polyester Film	Universal Velcro Strips	Latex Gloves (Nitrile)	Taped
Clear Polyester Film	Universal Velcro Strips	Rubber Band	Glued
Clear Polyester Film	Universal Velcro Strips	Rubber Band	Sewn/Stitched
Clear Polyester Film	Universal Velcro Strips	Rubber Band	Taped
Clear Polyester Film	Universal Velcro Strips	Universal Velcro Straps	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Glued
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Taped
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Glued
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Sewn/Stitched
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Taped
Lamination Material (Polyethylene Terephthalate)	Foam	Latex Gloves (Nitrile)	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Rubber Band	Compression

Table A - 2. 100 Least Effective Face Shields.

Material	Structure	Strap Material	Strap Attachment Method
Clear Plastic Folder Polypropylene	Universal Velcro Strips	T-Shirt/Cotton Fabric	Stapled
Clear Polyester Film	Cardboard	Universal Velcro Straps	Stapled
Clear Polyester Film	Rolled Paper	T-Shirt/Cotton Fabric	Stapled
Clear Polyester Film	Safety Glasses	T-Shirt/Cotton Fabric	Stapled
Clear Polyester Film	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Clear Polyester Film	Tongue Depressor	Rubber Band	Stapled
Clear Polyester Film	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Clear Polyester Film	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Clear Polyester Film	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Lamination Material (Polyethylene Terephthalate)	Cardboard	Latex Gloves (Nitrile)	Stapled
Lamination Material (Polyethylene Terephthalate)	Cardboard	Rubber Band	Stapled
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Glued
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Sewn/Stitched
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Taped
Lamination Material (Polyethylene Terephthalate)	Foam	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Rolled Paper	Universal Velcro Straps	Stapled
Lamination Material (Polyethylene Terephthalate)	Safety Glasses	Universal Velcro Straps	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Compression Fit from Cohesive Bandage	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Elastic Band	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Compression
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Glued
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Sewn/Stitched

Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Taped
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	Latex Gloves (Nitrile)	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	Rubber Band	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	T-Shirt/Cotton Fabric	Glued
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	T-Shirt/Cotton Fabric	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	T-Shirt/Cotton Fabric	Taped
Sheet Protector (polypropylene (PP) and vinyl)	Foam	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Rolled Paper	Universal Velcro Straps	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Universal Velcro Straps	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Compression Fit from Cohesive Bandage	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Elastic Band	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Universal Velcro Straps	Glued
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Universal Velcro Straps	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Universal Velcro Straps	Taped
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Cardboard	Latex Gloves (Nitrile)	Stapled
Transparency (cellulose acetate)	Cardboard	Rubber Band	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Sewn/Stitched
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Foam	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Rolled Paper	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Safety Glasses	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Compression Fit from Cohesive Bandage	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Elastic Band	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Compression
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Sewn/Stitched
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Taped
Transparency (cellulose acetate)	Universal Velcro Strips	T-Shirt/Cotton Fabric	Stapled

Clear Plastic Folder Polypropylene	Cardboard	Universal Velcro Straps	Stapled
Clear Plastic Folder Polypropylene	Rolled Paper	T-Shirt/Cotton Fabric	Stapled
Clear Plastic Folder Polypropylene	Safety Glasses	T-Shirt/Cotton Fabric	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	Rubber Band	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Clear Polyester Film	Cardboard	T-Shirt/Cotton Fabric	Stapled
Clear Polyester Film	Tongue Depressor	Universal Velcro Straps	Stapled
Lamination Material (Polyethylene Terephthalate)	Cardboard	Universal Velcro Straps	Stapled
Lamination Material (Polyethylene Terephthalate)	Rolled Paper	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Safety Glasses	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Rubber Band	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	Universal Velcro Straps	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Rolled Paper	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Rubber Band	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Cardboard	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Rolled Paper	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Safety Glasses	T-Shirt/Cotton Fabric	Stapled

Transparency (cellulose acetate)	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Rubber Band	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Clear Plastic Folder Polypropylene	Cardboard	T-Shirt/Cotton Fabric	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	Universal Velcro Straps	Stapled
Clear Polyester Film	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled

Table A - 3. Best 100 Performing OEC Face Shields.

Material	Structure	Strap Material	Strap Attachment Method
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Elastic Band	Compression
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Compression Fit from Cohesive Bandage	Compression

Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Rubber Band	Compression
Clear Polyester Film	Foam	Rubber Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Safety Glasses	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Universal Velcro Straps	Compression
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Foam	Universal Velcro Straps	Compression
Clear Polyester Film	Universal Velcro Strips	Elastic Band	Compression
Lamination Material (Polyethylene Terephthalate)	Safety Glasses	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Foam	Elastic Band	Compression
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Taped
Lamination Material (Polyethylene Terephthalate)	Foam	Latex Gloves (Nitrile)	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Taped
Lamination Material (Polyethylene Terephthalate)	Foam	Rubber Band	Compression

Clear Plastic Folder Polypropylene	Safety Glasses	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Elastic Band	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Foam	T-Shirt/Cotton Fabric	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Stapled
Clear Polyester Film	Foam	T-Shirt/Cotton Fabric	Compression
Clear Polyester Film	Rolled Paper	Compression Fit from Cohesive Bandage	Compression
Clear Polyester Film	Safety Glasses	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Safety Glasses	Rubber Band	Compression
Clear Polyester Film	Universal Velcro Strips	Rubber Band	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Lamination Material (Polyethylene Terephthalate)	Foam	Universal Velcro Straps	Compression
Lamination Material (Polyethylene Terephthalate)	Safety Glasses	Elastic Band	Compression
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Elastic Band	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Rolled Paper	Compression Fit from Cohesive Bandage	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Latex Gloves (Nitrile)	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Rubber Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Latex Gloves (Nitrile)	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Rubber Band	Compression
Transparency (cellulose acetate)	Foam	Compression Fit from Cohesive Bandage	Compression

Clear Polyester Film	Universal Velcro Strips	Latex Gloves (Nitrile)	Compression
Clear Polyester Film	Safety Glasses	Universal Velcro Straps	Compression
Clear Plastic Folder Polypropylene	Foam	Latex Gloves (Nitrile)	Compression
Clear Plastic Folder Polypropylene	Foam	Rubber Band	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Taped
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Compression Fit from Cohesive Bandage	Glued
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Elastic Band	Taped
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Universal Velcro Straps	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Universal Velcro Straps	Compression
Clear Polyester Film	Foam	Compression Fit from Cohesive Bandage	Glued
Clear Polyester Film	Foam	Elastic Band	Taped
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Polyester Film	Universal Velcro Strips	Universal Velcro Straps	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Compression Fit from Cohesive Bandage	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Sewn/Stitched
Clear Plastic Folder Polypropylene	Foam	Universal Velcro Straps	Compression
Clear Plastic Folder Polypropylene	Safety Glasses	Elastic Band	Compression
Clear Plastic Folder Polypropylene	Universal Velcro Strips	Elastic Band	Compression
Clear Polyester Film	Foam	Elastic Band	Stapled
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Sewn/Stitched
Clear Polyester Film	Foam	Rubber Band	Sewn/Stitched
Clear Polyester Film	Rolled Paper	Elastic Band	Compression

Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Taped
Clear Polyester Film	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Taped
Lamination Material (Polyethylene Terephthalate)	Foam	Elastic Band	Sewn/Stitched
Lamination Material (Polyethylene Terephthalate)	Foam	T-Shirt/Cotton Fabric	Compression
Lamination Material (Polyethylene Terephthalate)	Safety Glasses	Rubber Band	Compression
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	Latex Gloves (Nitrile)	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Rolled Paper	Elastic Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Safety Glasses	Compression Fit from Cohesive Bandage	Taped
Transparency (cellulose acetate)	Foam	Elastic Band	Compression
Lamination Material (Polyethylene Terephthalate)	Foam	Compression Fit from Cohesive Bandage	Stapled
Lamination Material (Polyethylene Terephthalate)	Rolled Paper	Compression Fit from Cohesive Bandage	Compression
Lamination Material (Polyethylene Terephthalate)	Safety Glasses	Latex Gloves (Nitrile)	Compression
Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips	Rubber Band	Compression
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Elastic Band	Stapled
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Latex Gloves (Nitrile)	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Foam	Rubber Band	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Universal Velcro Strips	Compression Fit from Cohesive Bandage	Taped
Clear Plastic Folder Polypropylene	Foam	Compression Fit from Cohesive Bandage	Taped
Clear Polyester Film	Foam	Latex Gloves (Nitrile)	Taped
Clear Polyester Film	Safety Glasses	Compression Fit from Cohesive Bandage	Stapled
Clear Polyester Film	Safety Glasses	Elastic Band	Sewn/Stitched
Clear Polyester Film	Universal Velcro Strips	Elastic Band	Sewn/Stitched

Clear Polyester Film Lamination Material (Polyethylene Terephthalate)	Universal Velcro Strips Foam	T-Shirt/Cotton Fabric Compression Fit from Cohesive Bandage	Compression Glued

Table A - 4. Worst 100 Performing OEC Face Shields.

Material	Structure	Strap Material	Strap Attachment Method
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Compression
Transparency (cellulose acetate)	Rolled Paper	Rubber Band	Stapled
Transparency (cellulose acetate)	Safety Glasses	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Tongue Depressor	Compression Fit from Cohesive Bandage	Taped
Transparency (cellulose acetate)	Universal Velcro Strips	T-Shirt/Cotton Fabric	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	Rubber Band	Taped
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Rubber Band	Glued
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Cardboard	Compression Fit from Cohesive Bandage	Glued
Transparency (cellulose acetate)	Cardboard	Elastic Band	Taped
Transparency (cellulose acetate)	Rolled Paper	Latex Gloves (Nitrile)	Glued
Transparency (cellulose acetate)	Rolled Paper	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Elastic Band	Sewn/Stitched
Clear Plastic Folder Polypropylene	Cardboard	Latex Gloves (Nitrile)	Stapled
Clear Plastic Folder Polypropylene	Cardboard	Rubber Band	Stapled
Clear Plastic Folder Polypropylene	Cardboard	Universal Velcro Straps	Taped
Clear Plastic Folder Polypropylene	Rolled Paper	T-Shirt/Cotton Fabric	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	Elastic Band	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	Latex Gloves (Nitrile)	Taped
Clear Plastic Folder Polypropylene	Tongue Depressor	Universal Velcro Straps	Sewn/Stitched

Clear Polyester Film	Cardboard	T-Shirt/Cotton Fabric	Glued
Clear Polyester Film	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Taped
Lamination Material (Polyethylene Terephthalate)	Cardboard	Universal Velcro Straps	Glued
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Latex Gloves (Nitrile)	Glued
Sheet Protector (polypropylene (PP) and vinyl)	Cardboard	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Rolled Paper	Rubber Band	Glued
Transparency (cellulose acetate)	Rolled Paper	T-Shirt/Cotton Fabric	Sewn/Stitched
Transparency (cellulose acetate)	Tongue Depressor	Compression Fit from Cohesive Bandage	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Compression
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Stapled
Clear Plastic Folder Polypropylene	Cardboard	Latex Gloves (Nitrile)	Glued
Clear Plastic Folder Polypropylene	Cardboard	Rubber Band	Glued
Clear Plastic Folder Polypropylene	Cardboard	T-Shirt/Cotton Fabric	Sewn/Stitched
Clear Plastic Folder Polypropylene	Cardboard	Universal Velcro Straps	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	Rubber Band	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	Universal Velcro Straps	Taped
Clear Polyester Film	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	Universal Velcro Straps	Glued
Sheet Protector (polypropylene (PP) and vinyl)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Cardboard	Elastic Band	Stapled
Transparency (cellulose acetate)	Cardboard	Latex Gloves (Nitrile)	Sewn/Stitched
Transparency (cellulose acetate)	Cardboard	Rubber Band	Sewn/Stitched

Transparency (cellulose acetate)	Rolled Paper	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Rolled Paper	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Tongue Depressor	Compression Fit from Cohesive Bandage	Glued
Transparency (cellulose acetate)	Tongue Depressor	Elastic Band	Taped
Transparency (cellulose acetate)	Cardboard	Universal Velcro Straps	Sewn/Stitched
Clear Plastic Folder Polypropylene	Cardboard	T-Shirt/Cotton Fabric	Taped
Clear Plastic Folder Polypropylene	Cardboard	Universal Velcro Straps	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	Latex Gloves (Nitrile)	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Transparency (cellulose acetate)	Cardboard	Elastic Band	Glued
Transparency (cellulose acetate)	Cardboard	Latex Gloves (Nitrile)	Taped
Transparency (cellulose acetate)	Rolled Paper	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Elastic Band	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Latex Gloves (Nitrile)	Sewn/Stitched
Clear Plastic Folder Polypropylene	Tongue Depressor	Rubber Band	Glued
Clear Plastic Folder Polypropylene	Tongue Depressor	Universal Velcro Straps	Stapled
Lamination Material (Polyethylene Terephthalate)	Cardboard	T-Shirt/Cotton Fabric	Glued
Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Cardboard	Rubber Band	Taped
Transparency (cellulose acetate)	Tongue Depressor	Rubber Band	Sewn/Stitched
Clear Plastic Folder Polypropylene	Cardboard	T-Shirt/Cotton Fabric	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Clear Plastic Folder Polypropylene	Tongue Depressor	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Cardboard	Rubber Band	Stapled
Transparency (cellulose acetate)	Rolled Paper	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Tongue Depressor	Latex Gloves (Nitrile)	Taped
Transparency (cellulose acetate)	Tongue Depressor	Rubber Band	Taped
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Sewn/Stitched

Lamination Material (Polyethylene Terephthalate)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Cardboard	Latex Gloves (Nitrile)	Stapled
Transparency (cellulose acetate)	Cardboard	Universal Velcro Straps	Taped
Transparency (cellulose acetate)	Tongue Depressor	Elastic Band	Glued
Clear Plastic Folder Polypropylene	Cardboard	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Cardboard	Rubber Band	Glued
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Sewn/Stitched
Transparency (cellulose acetate)	Cardboard	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Latex Gloves (Nitrile)	Stapled
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Cardboard	Latex Gloves (Nitrile)	Glued
Transparency (cellulose acetate)	Tongue Depressor	Rubber Band	Stapled
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Taped
Clear Plastic Folder Polypropylene	Tongue Depressor	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Tongue Depressor	Rubber Band	Glued
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Sewn/Stitched
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Cardboard	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Tongue Depressor	Latex Gloves (Nitrile)	Glued
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Taped
Transparency (cellulose acetate)	Tongue Depressor	Universal Velcro Straps	Glued
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Stapled
Transparency (cellulose acetate)	Cardboard	T-Shirt/Cotton Fabric	Glued
Transparency (cellulose acetate)	Tongue Depressor	T-Shirt/Cotton Fabric	Glued

Table A - 5. 100 Most Effective Face Coverings.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Staple

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Compression Fit from Cohesive Bandage	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Staple

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Elastic Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Latex Gloves	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Latex Gloves	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Latex Gloves	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Latex Gloves	Staple

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Latex Gloves	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Rubber Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Rubber Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Rubber Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Rubber Band	Staple

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Rubber Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Same as Bulk Material Layer 1	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Same as Bulk Material Layer 3	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Tourniquet Band	Compression

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Tourniquet Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Tourniquet Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Tourniquet Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Tourniquet Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Universal Velcro Straps	Compression

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Universal Velcro Straps	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Universal Velcro Straps	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Universal Velcro Straps	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Wash	Universal Velcro Straps	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Compression Fit from Cohesive Bandage	Compression

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Compression Fit from Cohesive Bandage	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Compression Fit from Cohesive Bandage	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Compression Fit from Cohesive Bandage	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Compression Fit from Cohesive Bandage	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Elastic Band	Compression

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Elastic Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Elastic Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Elastic Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Elastic Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Latex Gloves	Compression

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Latex Gloves	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Latex Gloves	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Latex Gloves	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Latex Gloves	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Rubber Band	Compression

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Rubber Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Rubber Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Rubber Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Rubber Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Same as Bulk Material Layer 1	Integrated

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Same as Bulk Material Layer 3	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Tourniquet Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Tourniquet Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Tourniquet Band	Sew

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Tourniquet Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Tourniquet Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Universal Velcro Straps	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Universal Velcro Straps	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Universal Velcro Straps	Sew

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Universal Velcro Straps	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Glue Based	Machine Wash	Universal Velcro Straps	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Compression Fit from Cohesive Bandage	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Compression Fit from Cohesive Bandage	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Compression Fit from Cohesive Bandage	Sew

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Compression Fit from Cohesive Bandage	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Compression Fit from Cohesive Bandage	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Elastic Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Elastic Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Elastic Band	Sew

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Elastic Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Elastic Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Latex Gloves	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Latex Gloves	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Latex Gloves	Sew

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Latex Gloves	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Latex Gloves	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Rubber Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Rubber Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Rubber Band	Sew

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Rubber Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Rubber Band	Taped
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Same as Bulk Material Layer 1	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Same as Bulk Material Layer 3	Integrated

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Tourniquet Band	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Tourniquet Band	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Tourniquet Band	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Tourniquet Band	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Tourniquet Band	Taped

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Universal Velcro Straps	Compression
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Universal Velcro Straps	Glue
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Universal Velcro Straps	Sew
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Universal Velcro Straps	Staple
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	None	Machine Wash	Universal Velcro Straps	Taped

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Sew Based	Machine Wash	Compression Fit from Cohesive Bandage	Compression

Table A - 6. 100 Least Effective Face Coverings.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Tourniquet Band	Sew
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Tourniquet Band	Staple
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Tourniquet Band	Taped
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Universal Velcro Straps	Compression
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Universal Velcro Straps	Glue
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Universal Velcro Straps	Sew
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Universal Velcro Straps	Staple

1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Universal Velcro Straps	Taped
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped

1	Woven Cotton Based	None	None	None	None	None	Elastic Band	Compression
1	Woven Cotton Based	None	None	None	None	None	Elastic Band	Glue
1	Woven Cotton Based	None	None	None	None	None	Elastic Band	Sew
1	Woven Cotton Based	None	None	None	None	None	Elastic Band	Staple
1	Woven Cotton Based	None	None	None	None	None	Elastic Band	Taped
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Compression
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Glue
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Sew
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Staple
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Taped
1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Compression

1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Glue
1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Sew
1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Staple
1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Taped
1	Woven Cotton Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Compression
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Glue
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Sew
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Staple
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Taped

1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Compression
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Glue
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Sew
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Staple
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Sew

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Staple

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Taped
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue

1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Compression
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Glue
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Sew
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Staple
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Taped

1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Compression
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Glue
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Sew
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Staple
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Taped
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Compression
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Glue
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Sew
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Staple
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Taped

1	Lignocellulosic Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Compression
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Glue
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Sew
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Staple
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Taped
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Compression
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Glue
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Sew
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Staple

1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Taped

Table A - 7. Best 100 Performing OEC Face Coverings.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated

3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Iron	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Sew Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Non Woven Cohesive Polyester Based	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Iron	Same as Bulk Material Layer 2	Integrated

3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Iron	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 3	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 3	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 3	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated

3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Sew Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Non Woven Cohesive Polyester Based	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Non Woven Cohesive Polyester Based	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Sew Based	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Sew Based	Iron	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Staple	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Sew Based	Machine Wash	Same as Bulk Material Layer 2	Integrated

3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Iron	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Sew Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Glue Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Bake In Oven	Same as Bulk Material Layer 3	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Non Woven Cohesive Polyester Based	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Sew Based	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Non Woven Cohesive Polyester Based	Center and Edges	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Non Woven Cohesive Polyester Based	Center and Edges	Staple	Machine Wash	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Iron	Same as Bulk Material Layer 3	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 3	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Around Edge	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Tight Non-woven, Hydrophilic-coated Polypropylene Based	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Friction	Machine Dry	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Friction	Machine Wash	Same as Bulk Material Layer 3	Integrated
3	Polypropylene Non-woven Based	Polypropylene Non woven	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Machine Dry	Same as Bulk Material Layer 3	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Center and Edges	Staple	Iron	Same as Bulk Material Layer 3	Integrated
3	Non-Woven Cohesive Polyester Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Staple	Iron	Same as Bulk Material Layer 2	Integrated
3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Friction	Machine Wash	Same as Bulk Material Layer 2	Integrated

3	Polypropylene Non-woven Based	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Around Edge	Friction	Bake In Oven	Same as Bulk Material Layer 2	Integrated
3	Tight Woven Cotton Based >600 Thread Count	Tight Woven Cotton Based >600 Thread Count	Polypropylene/Polyester Blend	Center and Edges	Staple	Bake In Oven	Same as Bulk Material Layer 2	Integrated

Table A - 8. Worst 100 Performing OEC Face Coverings.

Number of Layers	Layer 1 Material	Layer 2 Material	Layer 3 Material	Layer Connection Location	Layer Connection Mechanism	Treatment	Strap Material	Strap Attachment
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Staple
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Latex Gloves	Glue
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped

1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Staple
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Latex Gloves	Staple
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Universal Velcro Straps	Compression
1	Woven Cotton Based	None	None	None	None	None	Elastic Band	Compression
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Glue

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Taped
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Staple
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Staple
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Latex Gloves	Compression
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Latex Gloves	Taped
1	Woven Cotton Based	None	None	None	None	None	Rubber Band	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Sew

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Taped
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Woven Cotton Based	None	None	None	None	None	Tourniquet Band	Compression
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Taped
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Latex Gloves	Sew
1	Non-Woven Cohesive Polyester Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Sew
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Glue

1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Staple
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Latex Gloves	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Elastic Band	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Glue
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Taped
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Staple
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Rubber Band	Compression

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Staple
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Sew
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Taped
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Staple
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Latex Gloves	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Tourniquet Band	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Taped
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Sew

1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Taped
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Staple
1	Woven Cotton Based	None	None	None	None	None	Universal Velcro Straps	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Sew
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Sew
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Taped
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Glue
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Glue

1	Woven Cotton Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Glue
1	Lignocellulosic Based	None	None	None	None	None	Elastic Band	Compression
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped
1	Woven Cotton Based	None	None	None	None	None	Compression Fit from	Compression

							Cohesive Bandage	
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Glue
1	Lignocellulosic Based	None	None	None	None	None	Rubber Band	Compression
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Staple
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Universal Velcro Straps	Compression
1	Lignocellulosic Based	None	None	None	None	None	Tourniquet Band	Compression
1	Tight Woven Cotton Based >600 Thread Count	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Taped

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Taped
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Sew
1	Woven Cotton Based	None	None	None	None	None	Latex Gloves	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Sew
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Glue
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Staple

1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Glue
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Taped
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Sew
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Staple
1	Lignocellulosic Based	None	None	None	None	None	Universal Velcro Straps	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Latex Gloves	Compression
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Taped
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Sew

1	Woven Cotton Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Glue
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Glue
1	Lignocellulosic Based	None	None	None	None	None	Compression Fit from Cohesive Bandage	Compression
1	Lignocellulosic Based	None	None	None	None	None	Latex Gloves	Compression
1	Non woven Polypropylene/Polyester Blend	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated
1	Lignocellulosic Based	None	None	None	None	None	Same as Bulk Material Layer 1	Integrated

APPENDIX B. COMMON HOSPITAL MATERIALS

This appendix provides a listing of some common hospital materials. These can be found in Table B - 1.

Table B - 1. Commonly Available Hospital Materials.

Items	Features	Specs	Cost	Reference
Steriliazation Wraps	Patterned High Surface Area	Tri Lamainate	$120/(300 [30"x30"])	
	Strong Tensil Strength	Spunbond PE-Meltblown PE-Spunbond PE		https://www.alimed.com/gemini-sterilization-wraps.html
	Anti Static Coating			
	Steril			
Drape/Stretcher Sheets				
	High Surface Area	Tissue Composition?	$30/100[40"x48"]	
	Lots of material to work with			https://www.alimed.com/drape-stretcher-sheets.html?refSrc=936008&nosto=productpage-nosto-1
	Possible Moisture Barrier			

Professional Towels	Embossing High Surface Area	Tissue?	$40/500[13"x18"]	
				https://tidiproducts.com/product/towels/
Paraffin Bars	Hydrophobic Properties	Paraffin	$30/6[1lb bar]	
				https://www.alimed.com/paraffin-bath-bars.html?pid=143967
Compression Wraps	Breathablity Two Directional Strech Moisture-Wick? Washable	Nylon/Lycra Blend/Foam	$16/3(2.5"x18")	
				https://www.alimed.com/nustim-wrap.html?pid=149478

Zinc Impregnated Gauze	Contains Zinc Oxide Highly Permeable		$140/(3"x10yd)	
				https://www.alimed.com/unna-boot-zinc-impregnated-gauze.html?pid=98415
Elastic Wrap/Edema Control	Self adhering/Hydrogen bonding	Latex	$55/(1"x5yd)	
				https://www.alimed.com/coban-elastic-wrap.html?refSrc=52000&nosto=productpage-nosto-1

Cohesive Bandage	Self adhesive Lightweight High Porosity Retains Tensile Strength Conformability Water Vapor Permeable	Non woven polyester fabric containing longitudinal polyester urethane (elastane) coated with self adherent	$52/36[2"x5yd]	https://www.alimed.com/co-flex-nl-cohesive-flexible-bandages.html?pid=116455
Underwrap	High Porosity Stretchable		$30/12[2.75"x30yd]	https://www.alimed.com/mueller-m-wrap-natural-underwrap.html?pid=98502

Universal Straps	Elastic Low porosity		$25/(3"x72')

https://www.alimed.com/universal-econo-strap.html?refSrc=930382&nosto=productpage-nosto-1

Janitorial Paper Towel	Highly Adsorbant Embossed High Surface Area	Processed Hemicellulose	$25.00/800ft

https://www.webstaurantstore.com/lavex-janitorial-800-white-hardwound-roll-paper-towel-case/5001RT800B.html

Coffee Filters	High Porosity	Processed Hemicellulose	$9/1000	
	High wettability Pore approx. 2micron		9.75" Top D 4.25" Bottom D	https://www.webstaurantstore.com/9-3-4-x-4-1-4-12-cup-coffee-filter-bunn-20115-0000-case/121CF12.html

APPENDIX C. DESIGN REFERENCE UPDATES

Between the initial proposal of this study (March 23, 2020) and its completion (April 12, 2020), there were several significant developments in the United States regarding CAM face coverings and face shields that are noted below. On April 4th, 2020, the Center for Disease Control and Prevention (CDC) recommended that the American public should wear cloth face coverings when entering public places to slow the spread of COVID-19 [24]. This was a significant change in CDC attributed to accumulating more knowledge about how the coronavirus is transmitted. On April 13th, the CDC issued more detailed recommendations about wearing and constructing cloth face coverings [25]. Outside the CDC, there were many developments with regards to new designs of CAM face shields, including the next few examples. Members of the Engineering Design Innovation Lab at the University of Wisconsin-Madison released open-source instructions about how to make their Badger Shield CAM face shield on March 26, 2020 using clear polyester film, foam and an elastic band [26]. HCP's at Unity Point Health of Cedar Rapids issued instructions about building CAM face shields on March 25, 2020 using transparency film, foam, and an elastic band [27]. While many more ideas have been proposed than mentioned in this appendix, it is important to note that new ideas for developing CAM face coverings and face shields will continue to evolve, and this study aims to contribute to that effort.

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