REPORT
Wearable for Jalaai(brick firing) workers for thermal protection

Industrial Design Project -II

Submitted by Arjun Prasanth-156130011
Guide- Prof. G G Ray

IDC- School Of Design
Indian Institute of Technology
2017

Declaration

I declare that this written submission represents my own ideas and where other's ideas or words have been used, I have adequately cited and referenced the original sources. I also declare that I have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any ideas/source/fact in my submission. I understand any violation of the above will be the cause for a disciplinary action by the institute and can also issue penal action from the sources which has been thus not been properly cited or from whom proper permission has not been taken where required.

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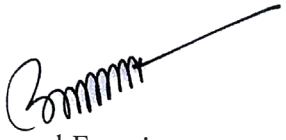
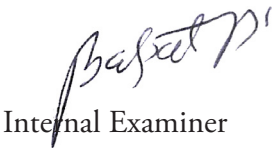
Approval

This project titled “Wearable For Jalaai (brick firing) workers for thermal protection” is prepared and submitted by Arjun Prasanth in partial fulfilment of the requirement for the degree of ‘Masters in Design’ in Industrial Design. It has been examined and is recommend for approval and acceptance.

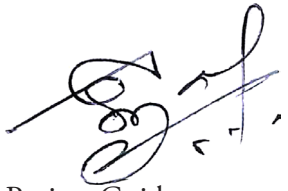


External Examiner

Mr. Ashok Panwalkar



Internal Examiner



Project Guide

Chairman

Prof. Manoj Neergat

(Energy Sci; & Engg.)

Acknowledgement

This project is a result of lots of constructive feedback and inspiration from my project guide Prof G G Ray and his method of understanding a situation to the core level with deep insights. I would also thank Lavanya and Amar who contributed to the development of the project and constant support mentally and intellectually. I would like to express my sincere gratitude to all my PD faculuties who gave useful suggestions that helped me throughout the design process. A big thanks to all my classmates who were there with me, analyzing the project , providing interesting ideas and valuable suggestions.

Abstract

Brick making is labour intensive mostly unskilled work and requires different level of skill in different parts of brick making. Each worker has a specific function and has to be highly skilled and specialised in that work. Brick kilns in India are mostly manually operated.
The process of jalaai is the baking of green bricks and strengthening the bricks for a specified time. The workers who perform this task are known as Jalaai workers. Jalaai workers have to endure high heat stresses while working on the kiln top on the background of general environmental heat.

This study was focussed on the Jalaai workers and the challenges that they face while working, their occupational health hazards and their possible solutions.

This project, in particular, was aimed at reducing the radiant heat being experienced by the workers with special reference to their face and neck region.

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JAAAI WORKERS

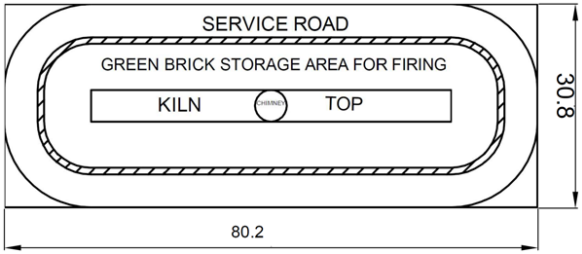
Jalaai workers

Introduction

Brick kilns in India are mostly manually operated. The brick kilns operate from September to June and remain closed from July to September. The workers are, therefore, seasonal workers who come to the brick kilns during the dry period of the year and goes back during monsoon for cultivation of their own small farm land.
Brick making is labour intensive mostly unskilled work and requires different level of skill in different parts of brick making. Each worker has a specific function and has to be highly skilled and specialised in that work. Most of the workers are illiterate or semiliterate and migratory in nature. The various types of workers working in the brick kilns are

- Pathera(Molding of raw bricks) workers
- Bharai (Transfer of raw bricks to kiln) workers
- Khadkan(Arrangement of raw bricks in Kiln for baking) workers
- Jalaai(Fireman)workers
- Nikashi(Removal of baked bricks) workers

Fig 1



Layout of a Kiln Top of Bull Trench Type with dimensions in meters

Jalaai workers

Introduction

The process of baking and strengthening of green bricks by baking at 900-1000˚C for a specified time is called jalaai. The workers who perform this task are known as Jalaai workers.

The work done by jalaai workers is

- To maintain the right temperature inside the kiln by charging coal
- To Open and close of air vent as required
- To determine the time for baking the bricks they need to look through the holes by checking the colour of the chute
- To charge the coal, they break large chunks of coal to smaller pieces
- A typical work-rest cycle of a Jalaai worker is to work for 15-20 min followed by a rest pause for 45/60 minute.

Fig 2

Jalaai workers

Challenges and issues

Central Pollution Control Board (CPCB) has recognised the brick production industry as a highly resource and energy intensive and polluting industry owing to prevalence of obsolete production technologies. While, the clusters are the source of local air pollution affecting local population, agriculture and vegetation; at a global scale they also contribute to climate change. With an average consumption of 18 tonnes of coal per 100,000 bricks, the brick sector consumes about 24 million tonnes of coal per year which is about 8 % of the total coal consumption of the country (third largest consumer after power and steel sector). In addition, it also consumes several million tonnes of biomass fuels. The share of energy in total cost of brick production is 50-35 %.

Fig 3

Continual kilns like this can operate without stopping for months and even years as workers steadily fire fresh batches of bricks.

Fig 4

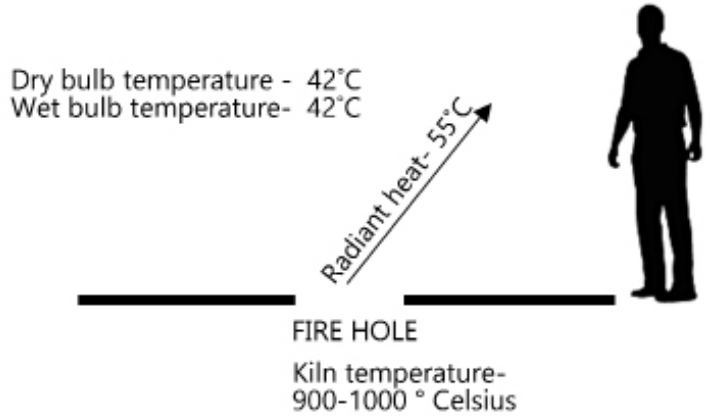
Brick kilns dot the landscape at the back-ground

Jalaai workers

Challenges and issues

Occupational hazards faced by Jalaai workers:

Jalaai workers have to endure high heat stresses while working on the kiln top on the background of general environmental heat. While inside the kiln the temperature is between 900 to 1000˚C. On the surface it is mostly the radiant heat of around 27.4˚C (average CET for summer in a place like Gujarat). The DB/WB ranges from 20 to 26˚C (WB) and 25 to 36˚C during the summer months of April, May in a place like Gujarat. They have to peep holes where the air coming and striking their faces are at a temperature of about 100˚C. This is only a part of the heat stress that they have to face. Apart from High radiant heat the workers also faces high Environmental heat (Dry Bulb Temp upto 36˚C) and the humidity level goes to % (RH). As a result the workers can be subjected to continuous heat load specially the radiant heat.



Jalaai workers

Challenges and issues

Fig 5
Worker Using Long Rod to Stir Wood Shavings into the Underground Brick Furnace

Associated Socio-Economic Issues

The workers in the brick industry are subjected to extreme working conditions and poor remuneration. Currently in India, brick manufacturing is a labour-intensive sector, with crude techniques causing considerable worker drudgery. They are also exposed to high concentrations of Respirable Suspended Particulate Matter (RSPM), during monitoring and regulating the fire, as the furnace chamber is covered with ash (ash acts as insulator)
The nature of the work requires skilled labour especially for moulding and firing. There is large scale migration towards the major brick production clusters every season due to this.

Fig 6

HEAT & HUMAN BODY

HEAT & HUMAN BODY

Heat loss mechanism

The human body regulates temperature by keeping a tight balance between heat gain and heat loss. Your temperature regulation system is more analogous to the operation of a home furnace, as opposed to the function of an air conditioner. Humans regulate heat generation and preservation to maintain internal body temperature or core temperature. Normal core temperature at rest varies between 36.5 and 37.5 °Celsius (°C), which is 97.7 to 99.5 °Fahrenheit (°F). Core temperature is regulated by the hypothalamus (in the brain), which is often called the body's thermostat. The hypothalamus responds to various temperature receptors located throughout the body and makes physiological adjustments to maintain a constant core temperature. For example, on a hot day, temperature receptors located in the skin send signals to the hypothalamus to cool the body by increasing the sweat rate.

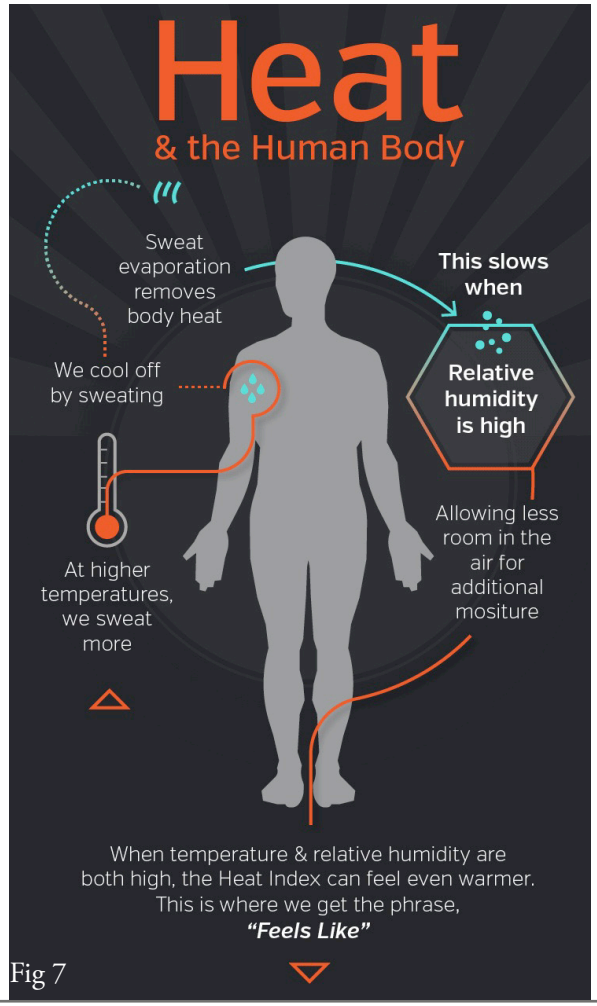


Fig 7

Ref- https://goo.gl/YQzs8Y

Exercise
↓
Muscle activity
↓
Temperature generation by muscle
↓
Body water gets heated up
↓
Body temperature sensed by brain
↓
Brain stimulates sweat glands for release of sweat
↓
Body temperature drops down due to sweat evaporation

HEAT & HUMAN BODY

Thermal control mechanism of body

Thermoregulation is the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different. A thermoconforming organism, by contrast, simply adopts the surrounding temperature as its own body temperature, thus avoiding the need for internal thermoregulation. The internal thermoregulation process is one aspect of homeostasis: a state of dynamic stability in an organism›s internal conditions, maintained far from thermal equilibrium with its environment (the study of such processes in zoology has been called physiological ecology). If the body is unable to maintain a normal temperature and it increases significantly above normal, a condition known as hyperthermia occurs. For humans, this occurs when the body is exposed to constant temperatures of approximately 55 °C (131 °F), and with prolonged exposure (longer than a few hours) at this temperature and up to around 75 °C (167 °F) death is almost inevitable
There are three avenues of heat loss: convection, conduction, and radiation. If skin temperature is greater than that of the surroundings, the body can lose heat by radiation and conduction. But, if the temperature of the surroundings is greater than that of the skin, the body actually gains heat by radiation and conduction. In such conditions, the only means by which the body can rid itself of heat is by evaporation. So, when the surrounding temperature is higher than the skin temperature, anything that prevents adequate evaporation will cause the internal body temperature to rise. During intense physical activity (e.g. sports), evaporation becomes the main avenue of heat loss. Humidity affects thermoregulation by limiting sweat evaporation and thus heat loss

Constant body temperature

External source

- Temperature gradient(Difference between air temperature and skin temperature)
- Airflow
- Humidity (Humidity directly proportional to thermal heat load in body because sweat will not get evaporated

Internal source

- Muscle contraction due to work

Ref- https://goo.gl/FQmjB5

HEAT & HUMAN BODY

Heat stress

Heat stress is the condition in which the body exposed to high temperatures is unable to control its core temperature by sweating or other natural cooling methods and is prone to several heat induced illnesses.

The types of heat induced illnesses that can occur are the following:

i) Heat Stroke:

Heat Stroke is the most serious of thve heat related illnesses that can occur. Heat strokes occur when the body is unable to control its core temperature by sweating and usually in combination with dehydration and the body temperature rises rapidly. According to the National Institute for Occupational Safety and Health (USA), when the core body temperature rises above 41.2˚C, it is considered as a heat stroke.

ii) Heat Exhaustion:

Heat Exhaustion is a condition of the body in which is caused by excessive loss of water and salt from the body usually through sweating.

iii) Heat Cramps:

Heat cramps occur in people who sweat a lot during work in a hot environment. Sweating leads to the loss of electrolytes from the body. This leads to cramps in the muscles of the human body.

iv) Heat Rash:

Heat rashes occur due to excessive sweating in hot environments.v)

v) Rhabdomyolysis:

Rhabdomyolysis is a condition associated with prolonged heat stress and physical exertion which results in the rupture of muscle. When this happens, electrolytes and large proteins are released into the bloodstream that can cause irregular heat rythms and seizures.

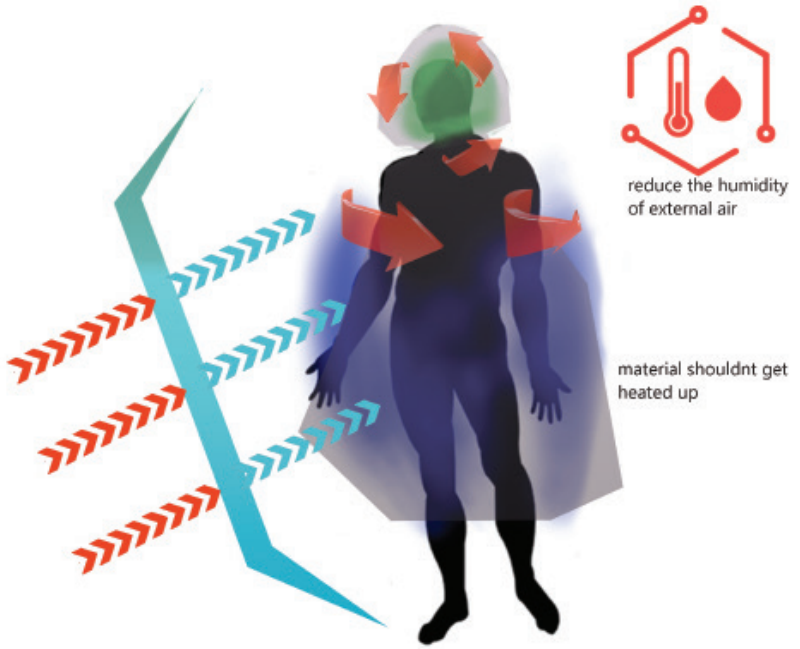
vi) Heat Syncope:

Heat Syncope is the episode of dizziness felt after prolonged standing or sudden rising from a prolonged sitting or lying position. This is usually a result of dehydration.

HEAT & HUMAN BODY

Methods to protect from external load of heat

- Reduce the temperature gradient between the surface of the skin and external air. This can be done by putting heat reflective external jacket around the body
- External heat to be reached mostly by the process of radiation, so material shouldn't gets heated up (not increases its own temperature)
- Reduce the temperature before in contact with outer skin.
- Increase the airflow in the body to increase sweat evaporation which will give cooling effect to the body.
- Reduce the humidity of the external air.



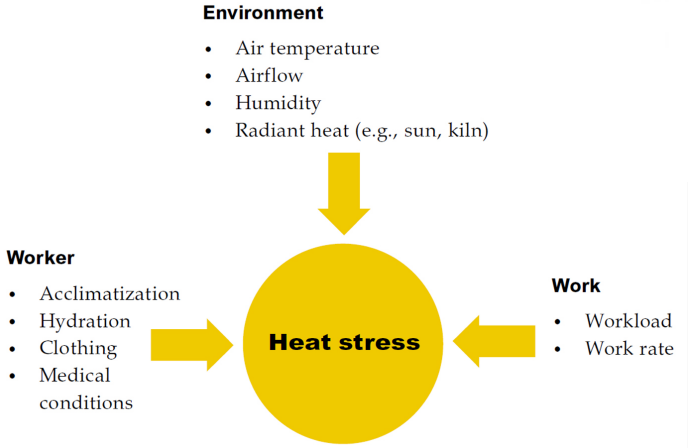
HEAT & HUMAN BODY

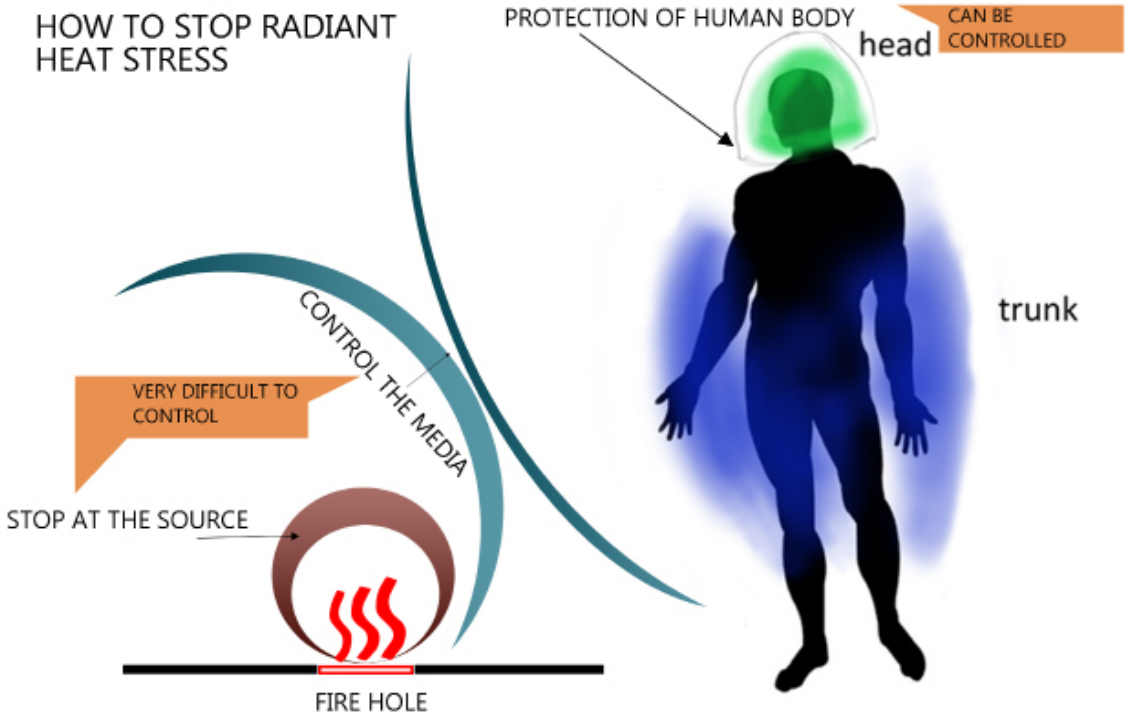
Methods to stop radiant heat stress

Working in the heat and doing physical activity can affect the body›s cooling system. If the body is unable to cool itself, a worker can experience heat stress. If heat stress is not recognized and treated in the earky stages, more serious and fatal conditions may quickly develop.

Heat stress can result in a range of problems from skin rashes and light headedness to convolusions and unconsciousness. Early symptoms of heat stress- such as excessive fatigue, lethargy, irritability, irritability- can result in serious accident.

Primary factors contributing to heat stress





Three methos to stop radiant heat stress for Jalaai workers

- Control the media
- Stop the radiant heat at the source
- Protection of human body

As to stop the radiant heat at the source and controlling the media is difficult, personal protection of human body to taken into consideration aa a viable method

LITERATURE STUDY

LITERATURE STUDY

EXISTING HEAD COOLING TECHNIQUES

Solar Powered Safety Helmet Hard Ventilate Hat with Cooling Fan

Fig 8

Product specifications

1 sun hat, 1 solar fan No batteries required Solar Power: 0.3W Fan Diameter: Approx. 65mm / 2.56” Helmet Size: Approx. 285 x 225 x 120mm. The solar panels collect the sunshine, convert it into electricity and drive the fan, thus generating a cool breeze.
Price- Rs 3000

Kuchofuku Air-Conditioned Helmet

Fig 9

Product specifications

Your neck and back will be cooled by the fan air. It will decrease your head temperature by 6.9°C (44.4°F) and humidity by 32%. Battery-powered and connected by simple cables, this is a minimal solution to a timeless problem for the working man.
Price-US$ 115

Miracool Hard Hat Pad

Fig 10

Product specifications

They’re designed to sit in the top part of your hard hat’s suspension and attach to the suspension using hooks and loops. To activate the pads and benefit from all-day comfort, all that you have to do is soak the pads in cold water. Powerful cooling crystals activate and keep you cool
Price- $56

LITERATURE STUDY

HEAD BAND & NECK PROTECTION

Frugal methods

Fig 11

Fig 12

Fig 13

To bring in positive values of usage of frugal head and neck protection turban which is being used all over the world, has been looked through to incorporate in the design.

Key features

- Cost effective
- Easy to fit
- Easily removable
- Easy connection to the rest of the suit
- Easy to maintain and easy to clean

LITERATURE STUDY

Personal protective equipment

Personal protective equipment refers to protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter. Protective equipment may be worn for job-related occupational safety and health purposes, as well as for sports and other recreational activities. "Protective clothing" is applied to traditional categories of clothing, and "protective gear" applies to items such as pads, guards, shields, or masks, and others.
The purpose of personal protective equipment is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels. PPE has the serious limitation that it does not eliminate the hazard at source and may result in employees being exposed to the hazard if the equipment fails. Any item of PPE imposes a barrier between the wearer/user and the working environment. This can create additional strains on the wearer; impair their ability to carry out their work and create significant levels of discomfort. Any of these can discourage wearers from using PPE correctly, therefore placing them at risk of injury, ill-health or, under extreme circumstances, death

LITERATURE STUDY

Personal protective equipment

Bee keepers suit

Fig 14

Are worn by the beekeepers. The face and neck are the most important areas to protect, so most beekeepers wear at least a veil.

Fire fighter suits

Fig 15

Are the most importantequipment for a firefighter. Firefighters are equipped with a heavy duty protective suit, loaded with features to help keep them safe. It goes without saying that the main feature of a firefighter suit is its fire resistant material made of Kelvar and Nomex.

Hazmat suits

Fig 16

Are worn for protection against hazardous materials, as well as dangerous chemicals and toxins. They are generally worn by people who work in environments that are dangerously contaminated, but are also worn by several law enforcement agencies such as the DEA,whenever necessary.

Wet suits

Fig 17

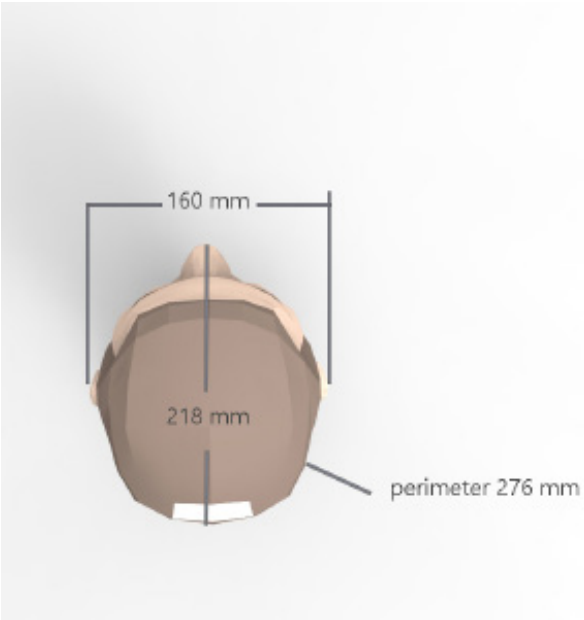
Are worn by watersport enthusiast and career divers, wetsuits while seemingly simple, provide lots of protection. The neoprene material provides quality insulation allowing users to maintain their normal body temperature even in dangerously cold water conditions.

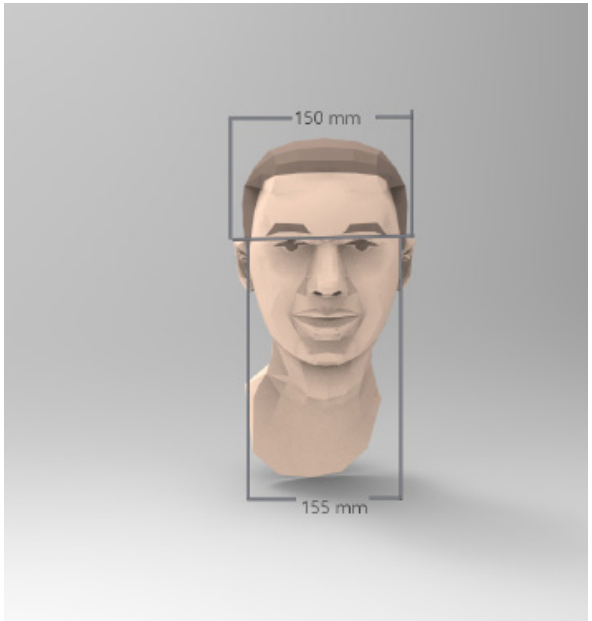
DESIGN DIRECTION

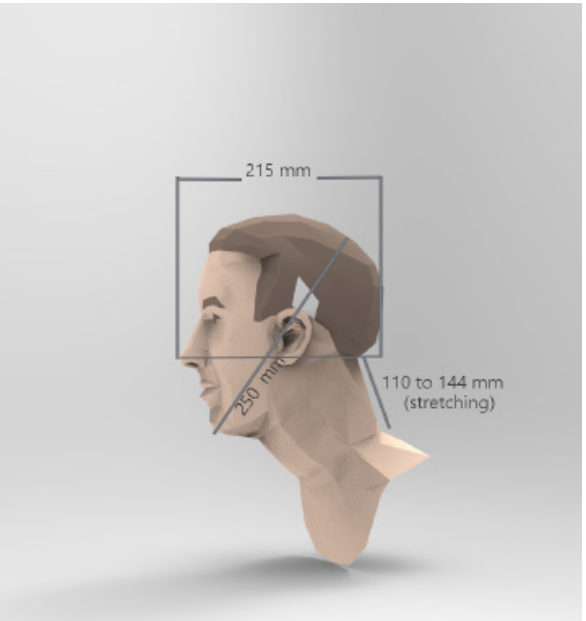
Project brief

- Design of a system for the Jalaai (brick firing) workers to sustain them while working under high radiant heat temperature(55-60 ° Celsius).
- This project, in particular, is aimed at reducing the radiant heat being experienced by the workers with special reference to their face and neck region.
- Addition of cooling effect and sweat control in helmet.

Basic human head anthropometric data







- The basic anthropometric data of human head considered for the design of head wearable.

Keywords for concept generation

Materials selection

Visor

The material with which the visor had to be made had to be highly heat resistant with a low thermal conductivity coefficient, high transmission of visible light (400-700 nm), lightweight, durable and not very expensive.

Transparent ceramics

- Highly heat resistant
- Expensive to manufacture
- Not very lightweight
-

PVC

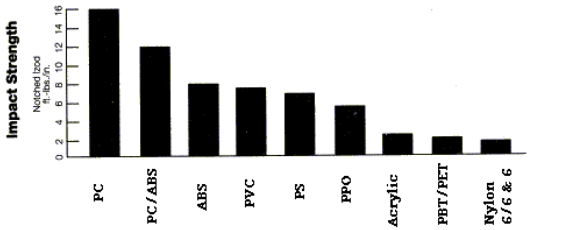
- Lightweight (1.4 g/cm3
- Transparent
- Durable
- It has melting temperature of 160˚C and a glass transition temperature of 81˚C
- Cracks on exposure to UV radiation from the Sun

Aerogels

- Low thermal conductivity (usually about 0.017 W/mK
- Highly efficient in preventing conduction and convection
- Lightweight
- Do not transmit visible light very well
- Expensive to manufacture

Acrylic

- The melting point is 160˚C
- The glass transition temperature is 105˚C



The impact strength compared to other plastics

Polycarbonate ☑

- It has a glass transition temperature of about 147 °C (297 °F)
- Offers very high impact strength
- Good low frequency and high voltage insulating characteristics
- Unlike most thermoplastics, polycarbonate can undergo large plastic deformations without cracking or breaking. As a result, it can be processed and formed at room temperature using sheet metal techniques, such as bending on a brake. Even for sharp angle bends with a tight radius, heating may not be necessary. This makes it valuable in prototyping applications where transparent or electrically non-conductive parts are needed, which cannot be made from sheet metal. PMMA/Acrylic

Polycarbonate was chosen as the material for the visor

http://www.ptsllc.com/intro/polycarb_intro.aspx

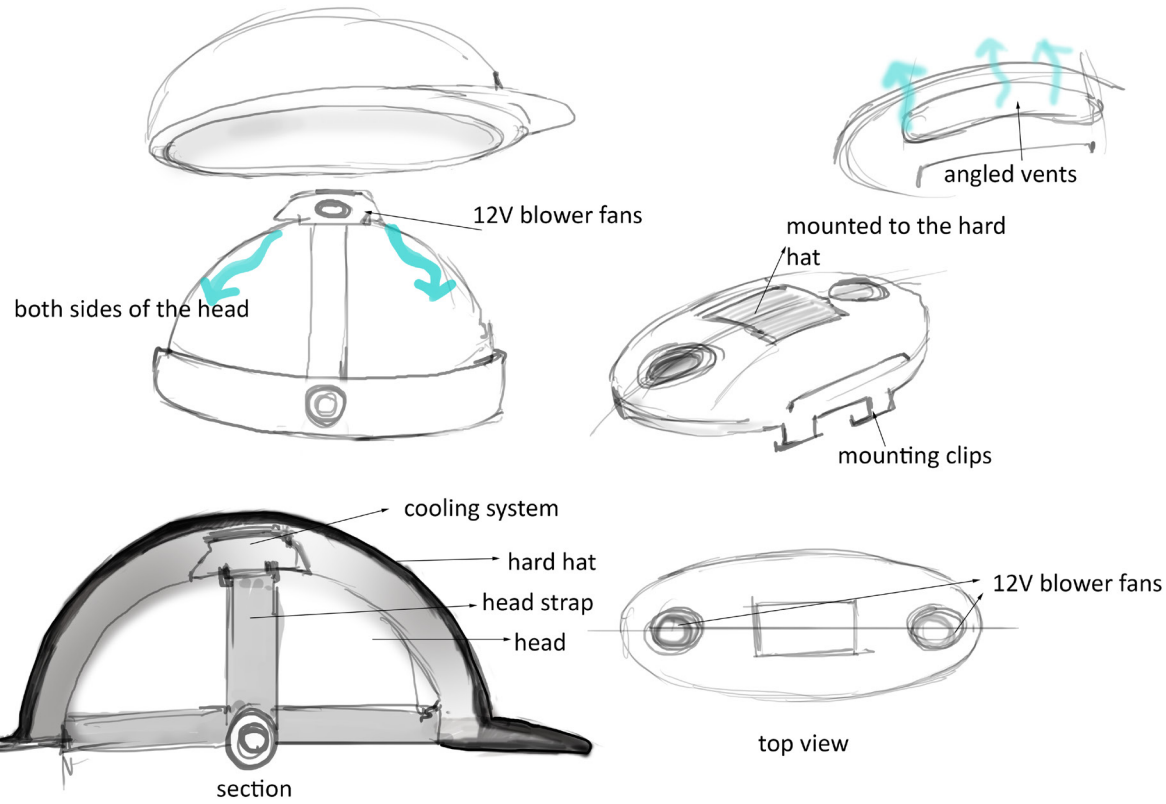
DESIGN IDEATIONS

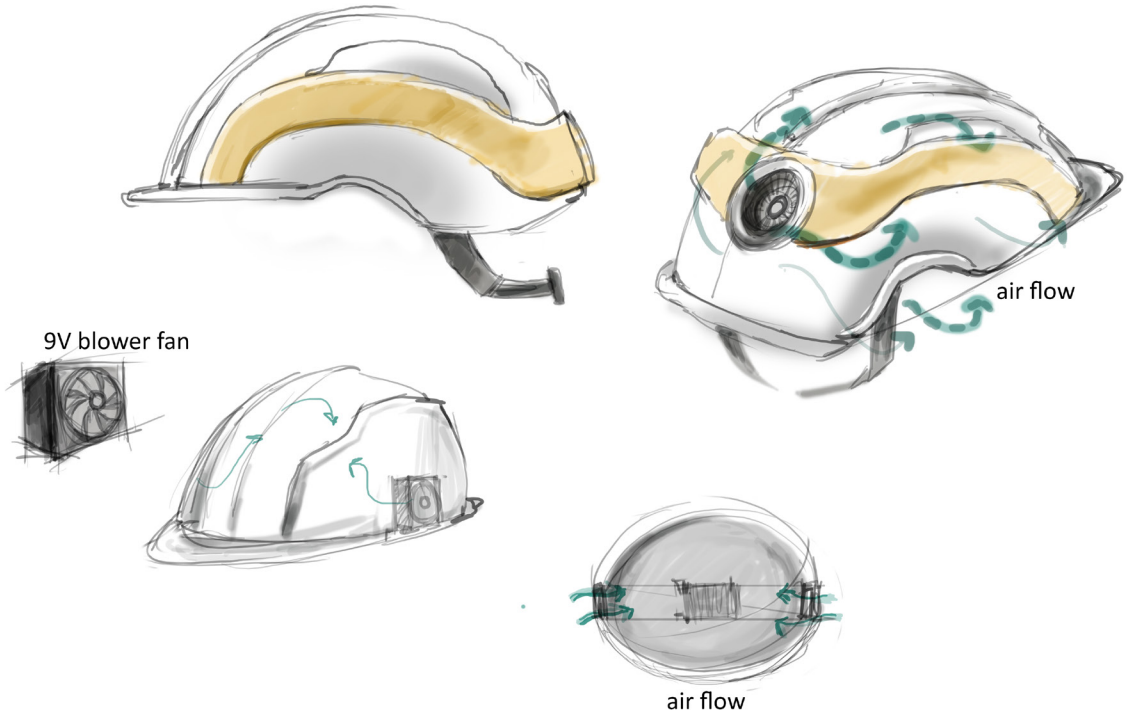
Design ideations | Head cooling system

Ideation 1

Disadvantages

- Fan runs battery operated, not cost effective



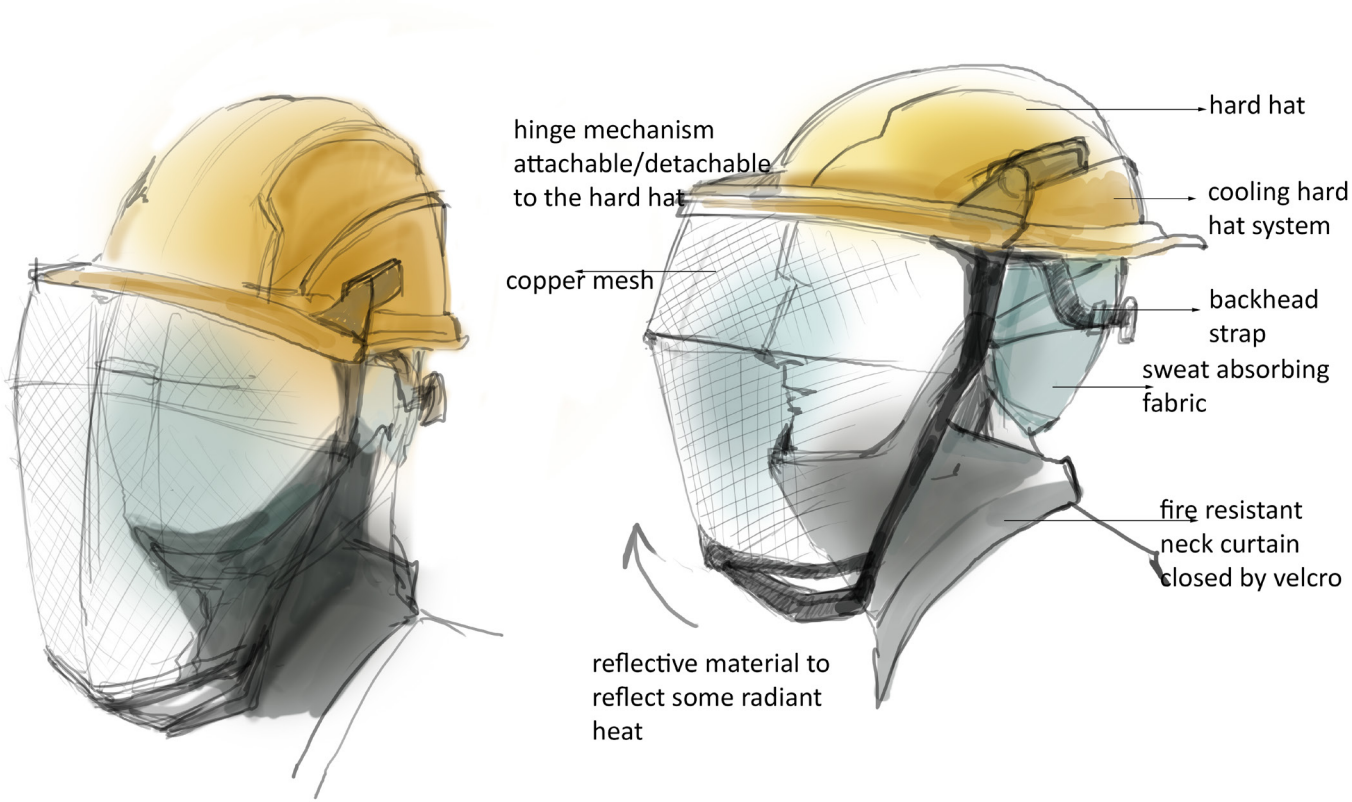


Disadvantages

- Fan runs battery operated, not cost effective

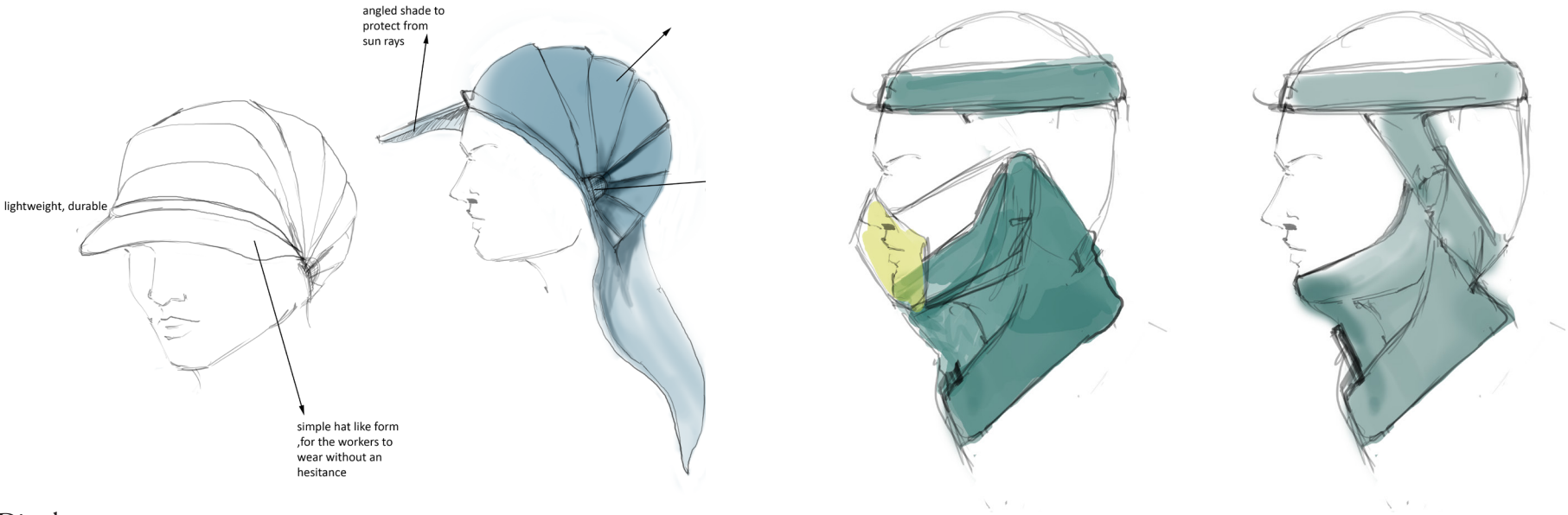
Design ideations | Neck & head protection system

Ideation 1



Design ideations | Neck & head protection system

Ideation 2

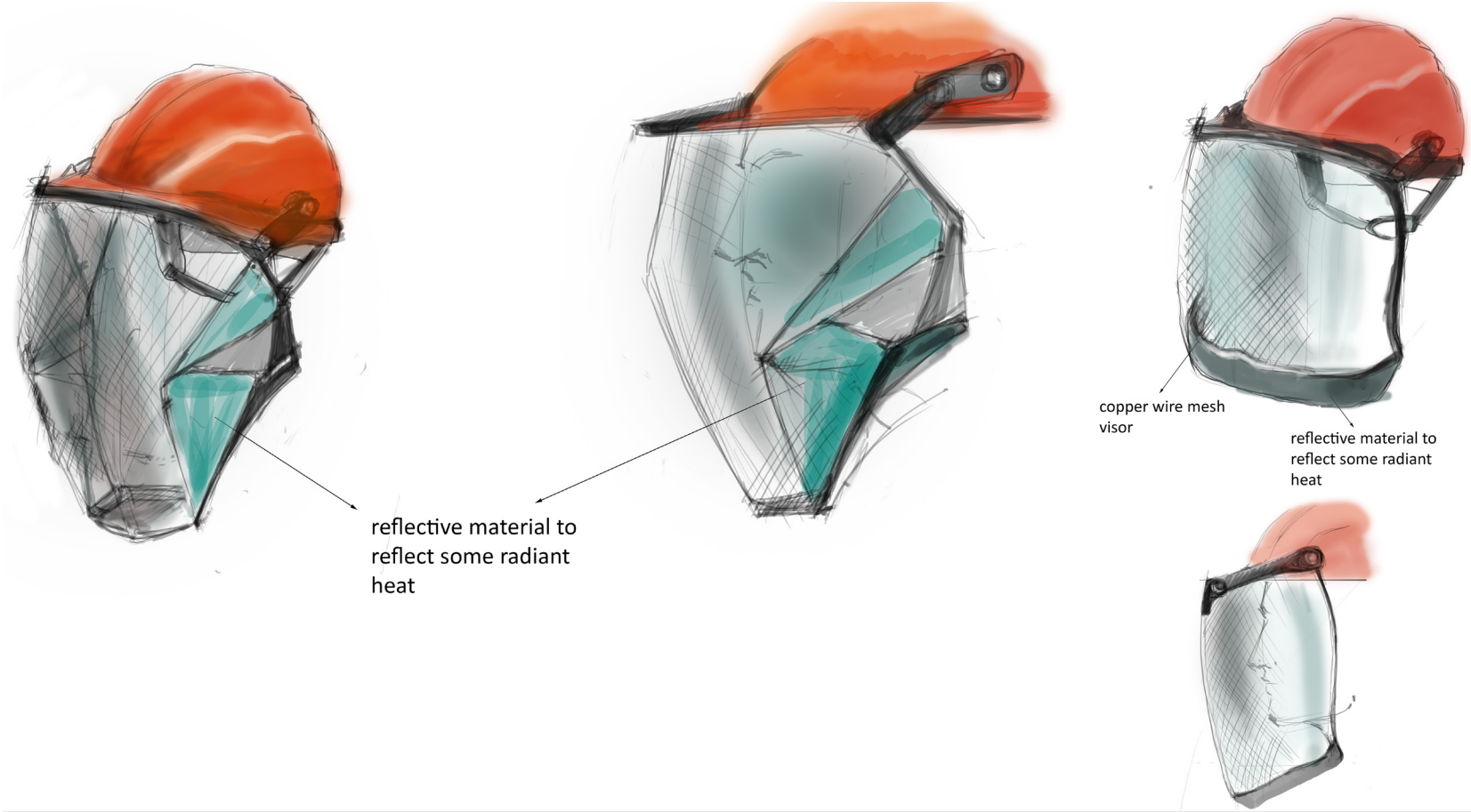


Disadvantages

- A sense of congestion at the neck and chin portion when subjected to longer duration of work at extreme conditions of temperature, as it is closely in contact with the larger part of the body.

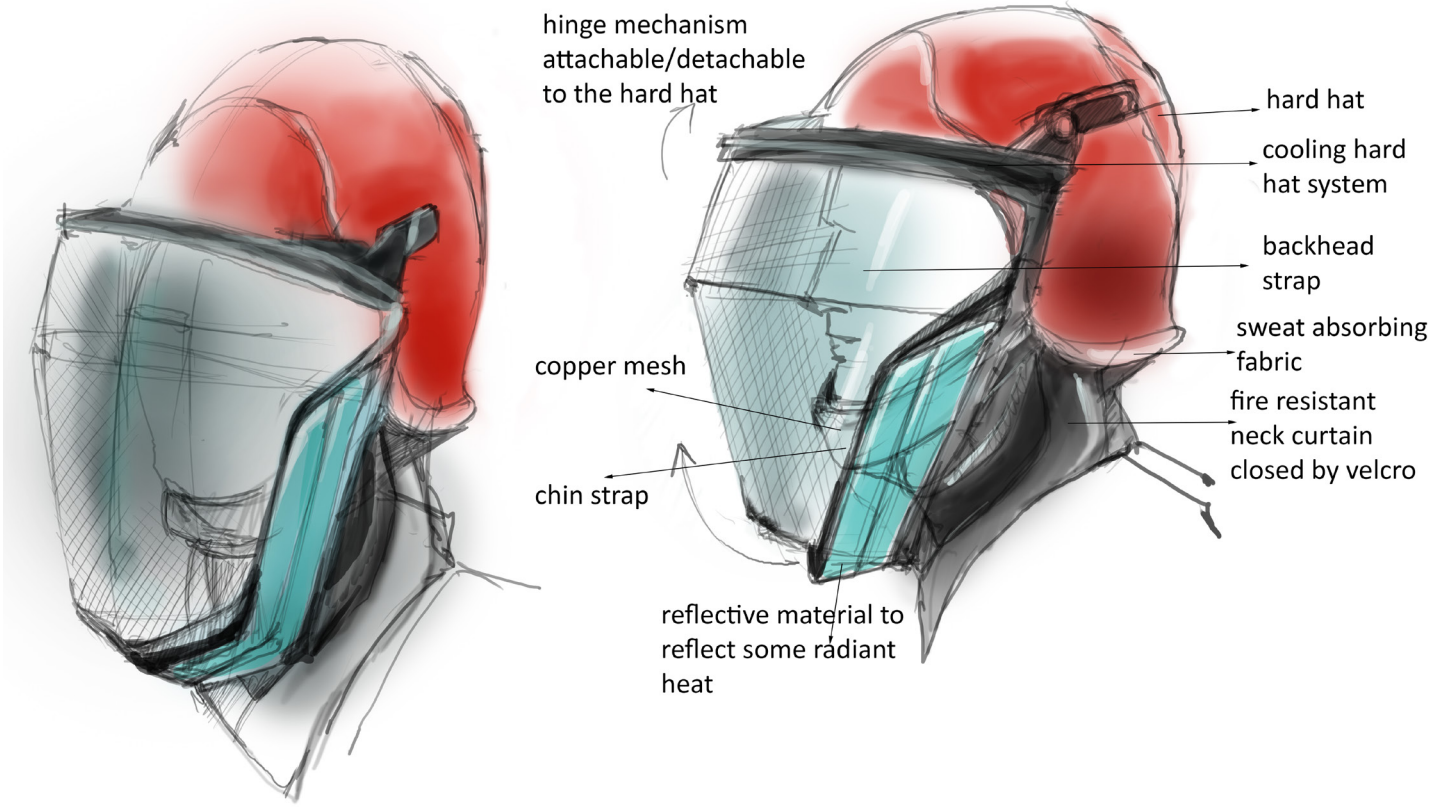
Design ideations | Neck & head protection system

Ideation 3



Design ideations | Neck & head protection system

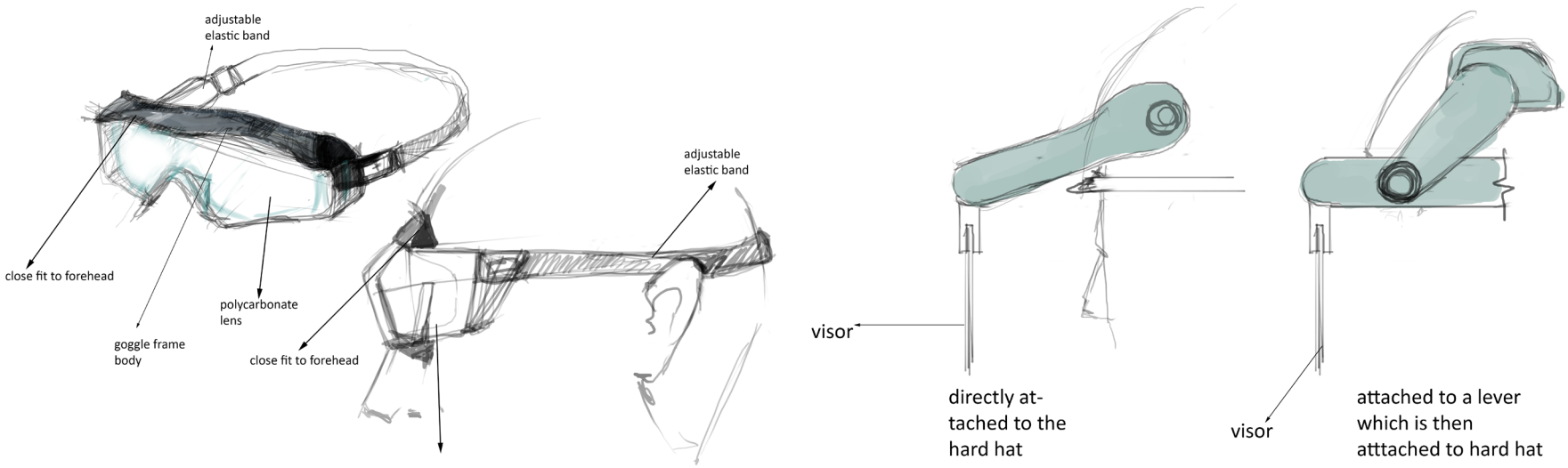
Ideation 3



Design ideations | Neck & head protection system

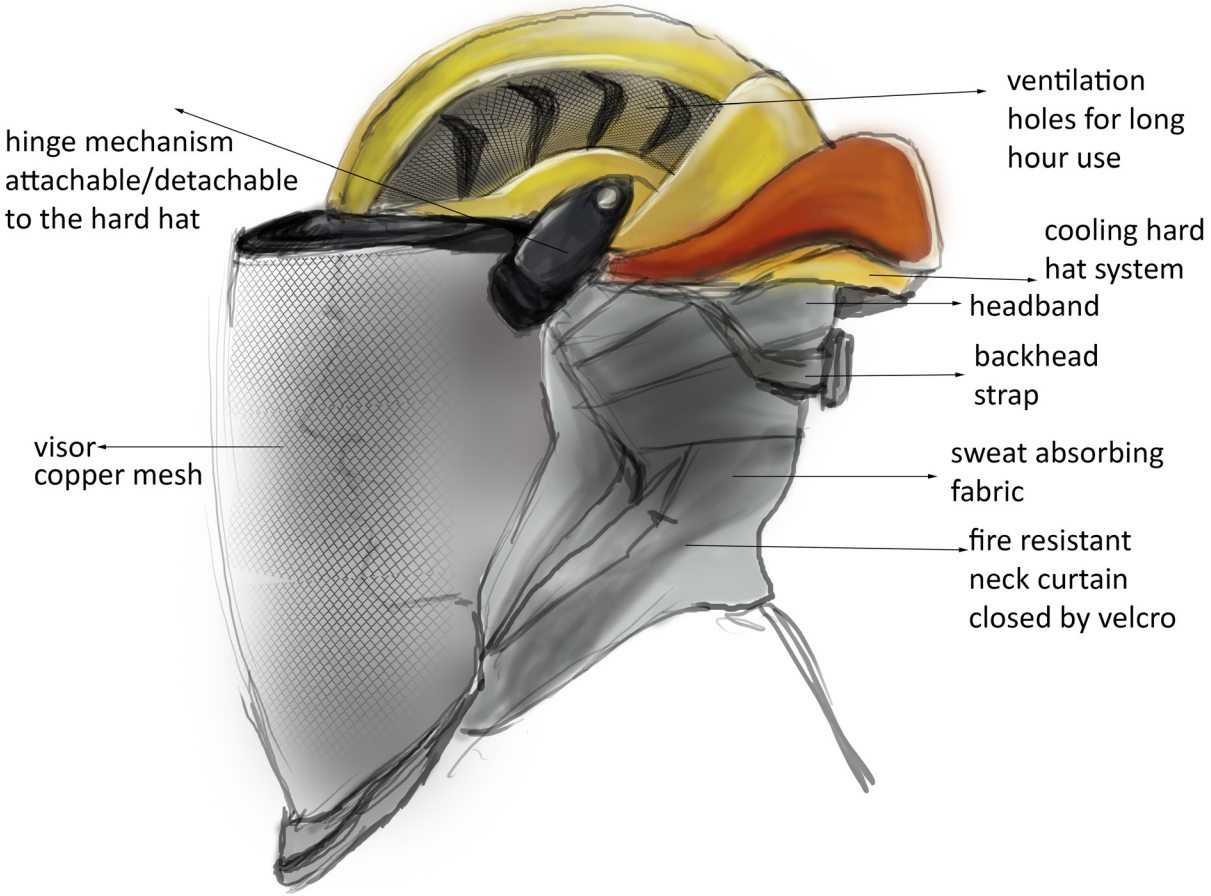
Ideation 4

Separate eye protective wear concept



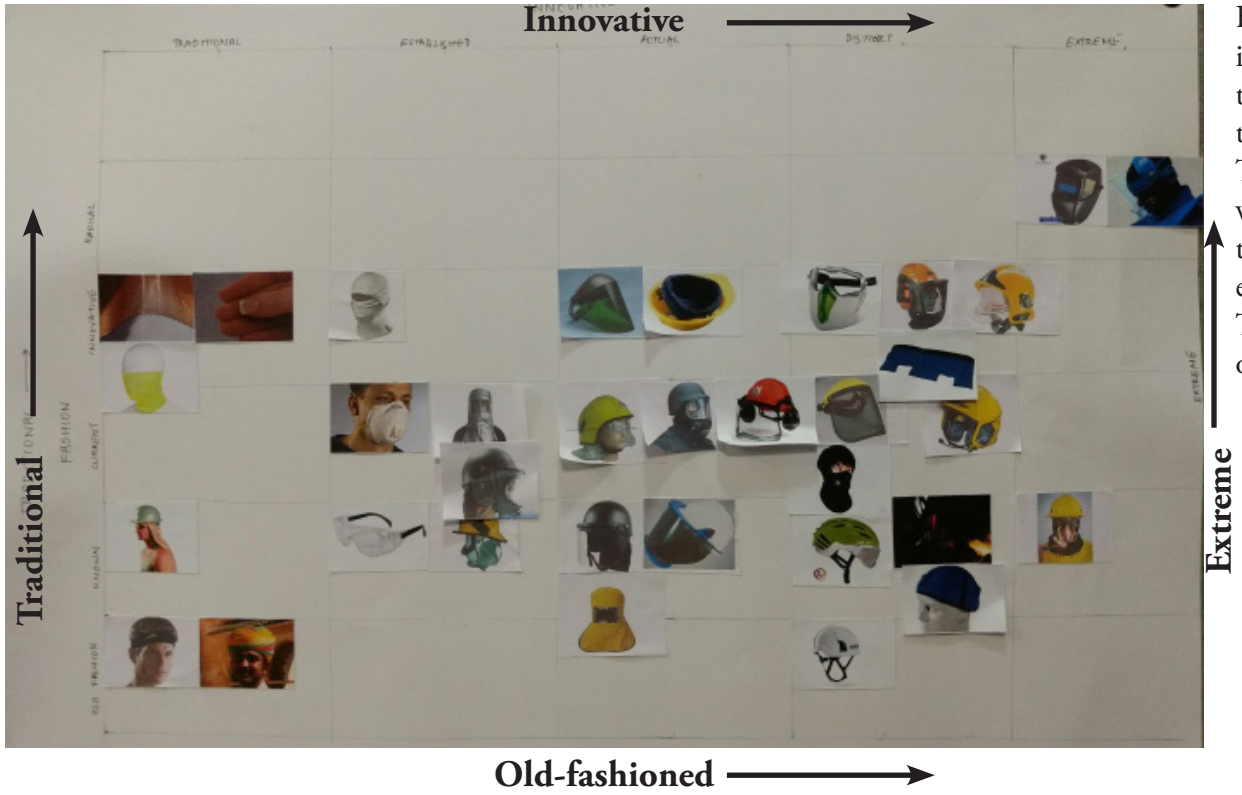
Design ideations | Neck & head protection system

Ideation 5



CONCEPT DEVELOPMENT

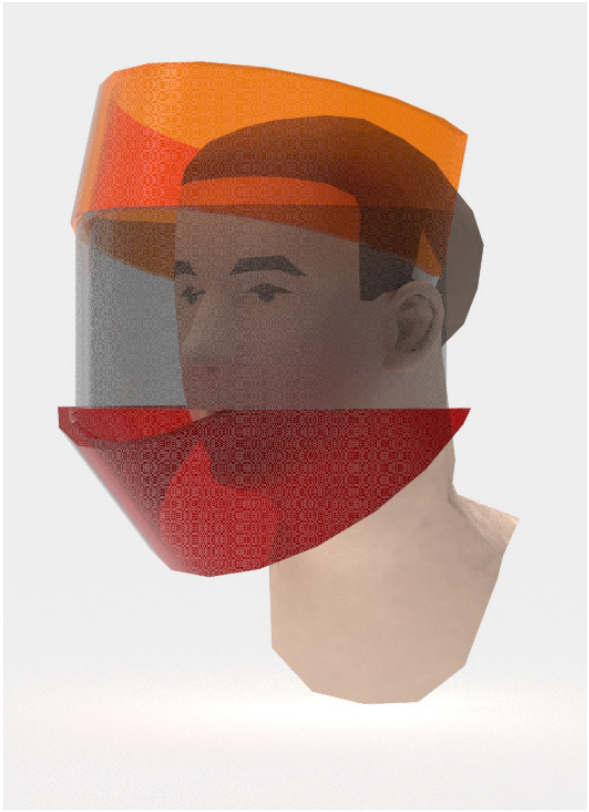
Concept development | Visual perception matrix



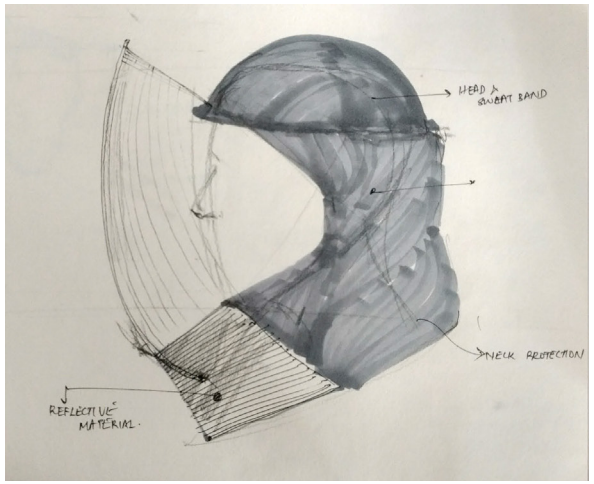
By perceiving the characteceristics of the existing products in the market helps in a great deal towards the concept generation and apprehend the design logic behind it.
The similar images related to the product were collected and arranged in a matrix with the axis tradional, innovative, old fashioned, extreme.
Then you can determine the zone and jonour of product you want to design.

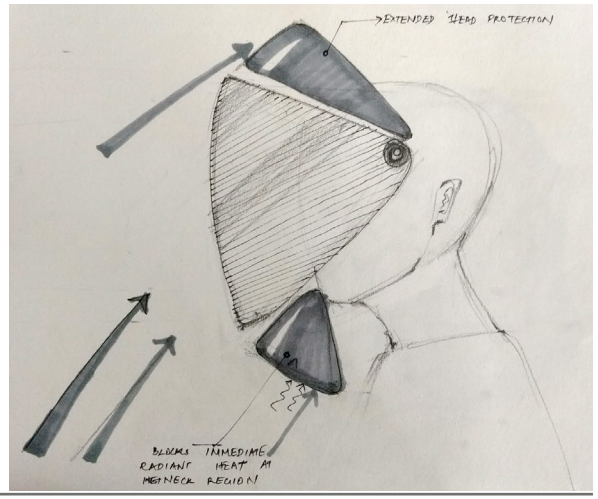
Concept development | Basic concept

Top part of head and neck to be covered. Visor extended



According to the profile of head and reducing the area of vision

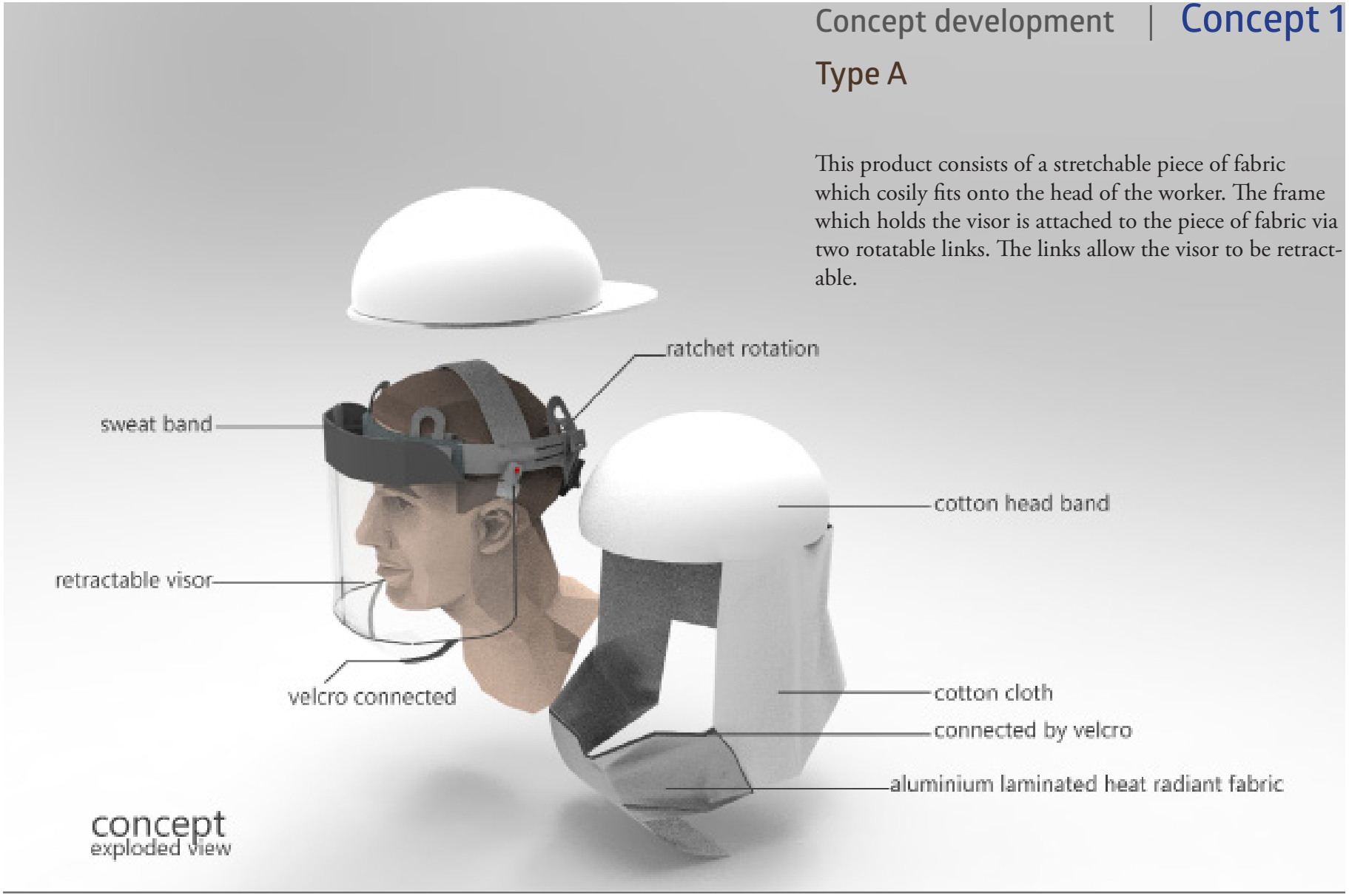




Concept development | Concept 1

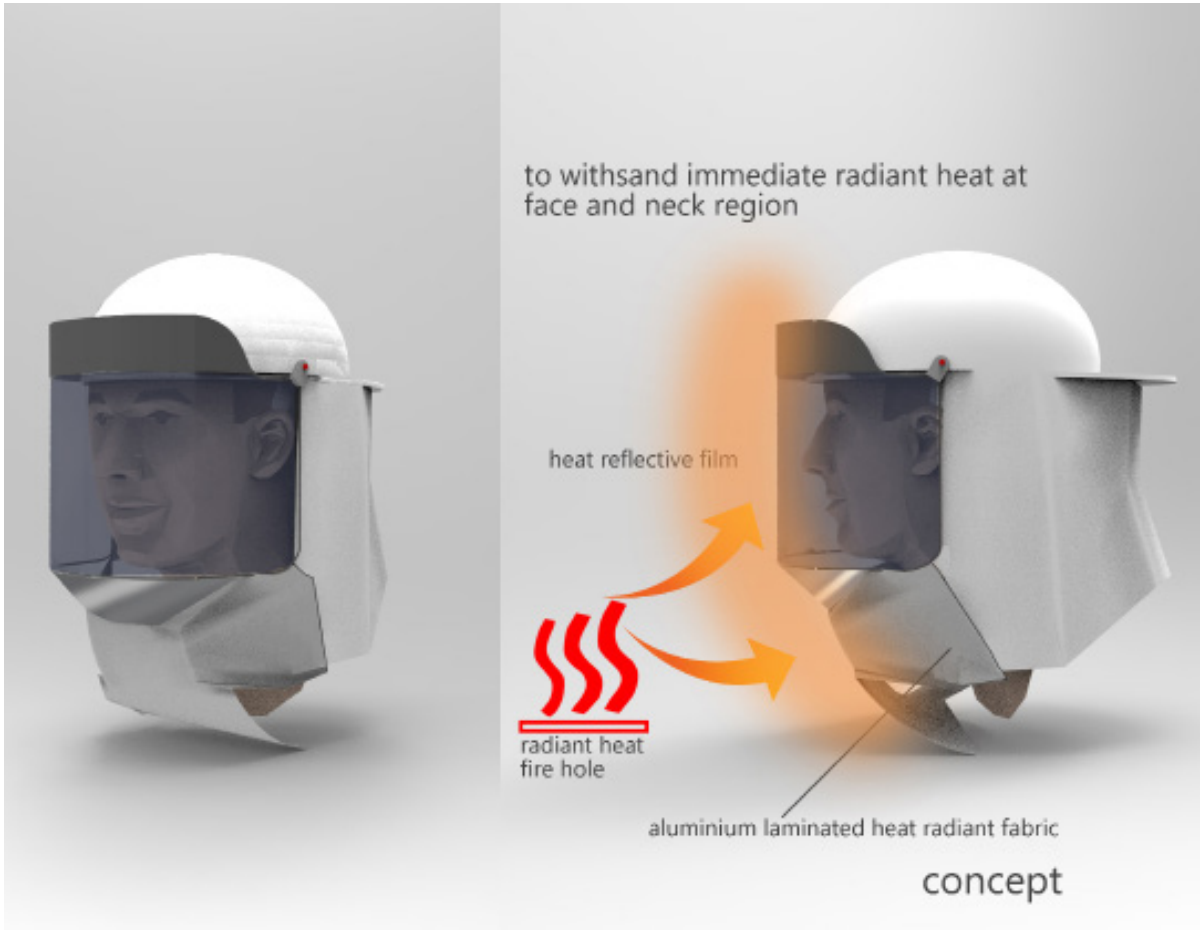
Type A

This product consists of a stretchable piece of fabric which cosily fits onto the head of the worker. The frame which holds the visor is attached to the piece of fabric via two rotatable links. The links allow the visor to be retractable.



Concept development | Concept 1

Type A



- The heat from the peep holes mainly affect the frontal portion of the face and the hot air rises upwards and does not affect the back of the head as much. Aluminium laminated heat radiant fabric to withstand immideate radiant heat at face and neck region is provided. So, this product provides adequate thermal protection to the worker.
- The product has a retractable visor which is highly adjustable. This allows the workers to lift up the visor to talk with their fellow workers and spit tobacco which are essential parts of their normal way of work
- Fabric is riveted at the visor part and runs through the entire length of the head providing protection of all parts from heat
- The product is very easy to use.
- The product requires very little maintenance

Issues

- The visor can become dusty and may require cleaning on the part of the worker.

Concept development | Concept 1

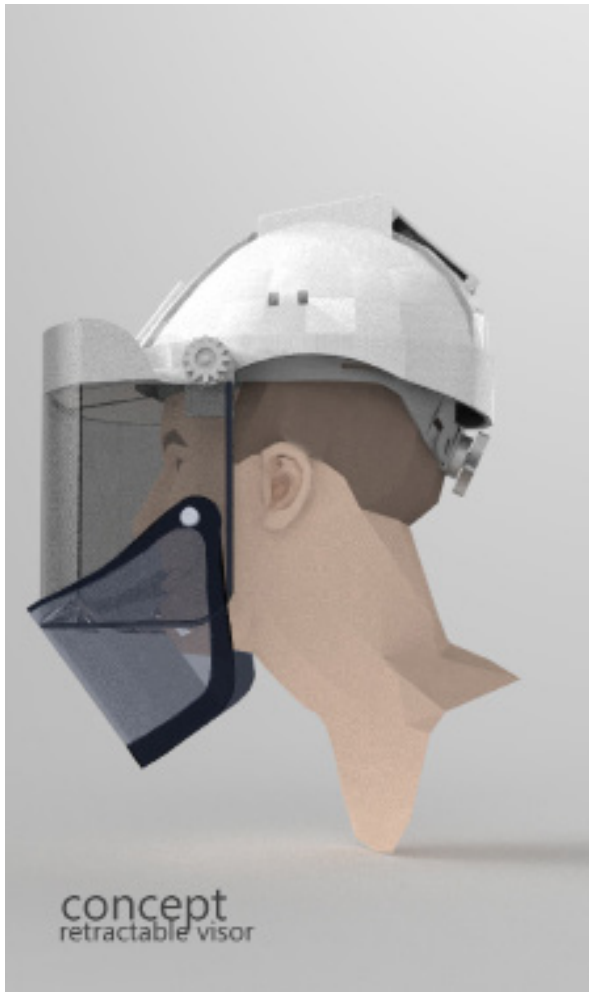
Type B

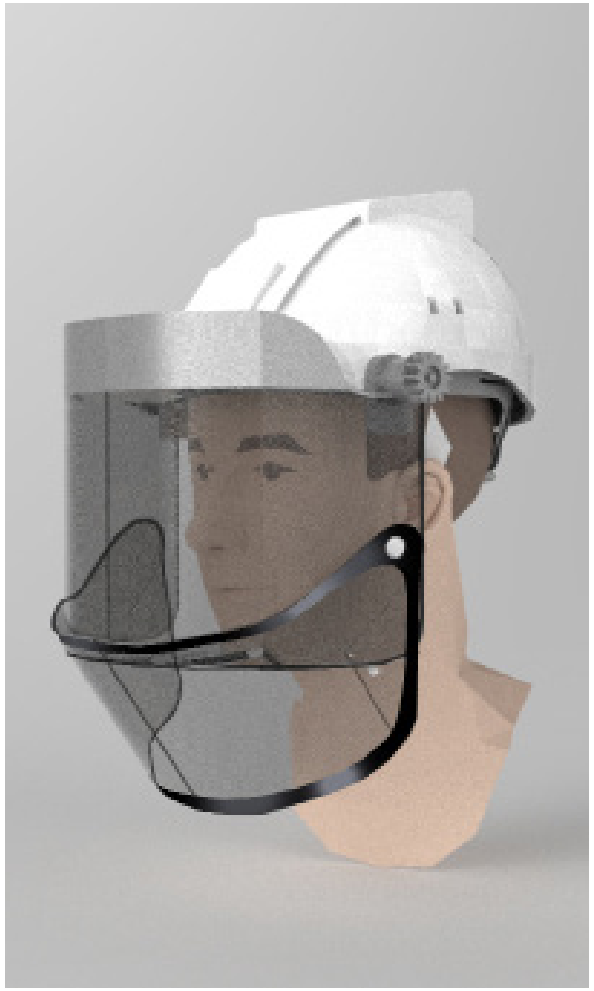
- The visor part is divided into two so that the worker can pull up only the bottom part when needed

Issues

- The junction of the two parts of the visor is prone to entrance of dust
- Maintenance will be an issue
- Manufacturing cost will be high

Mock up

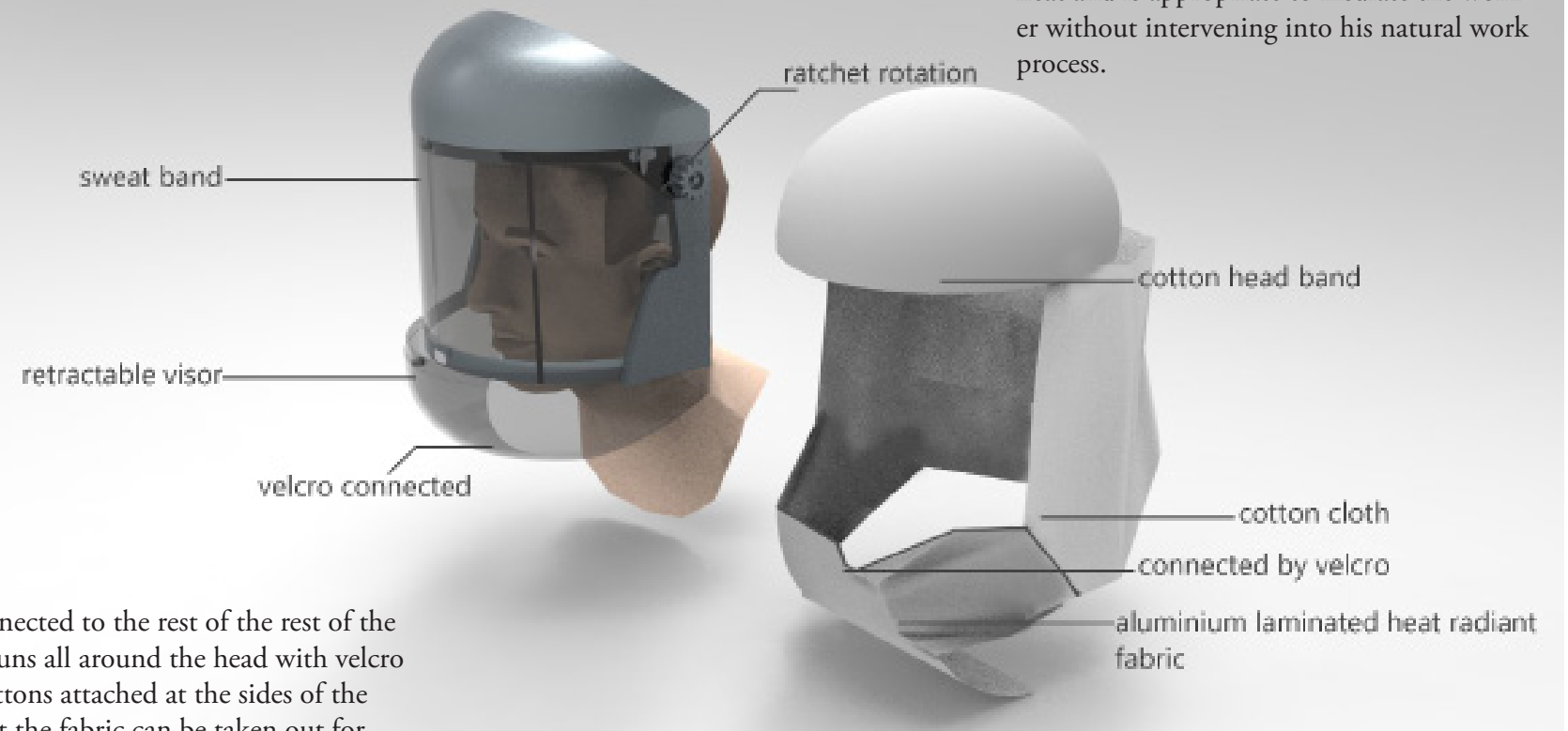




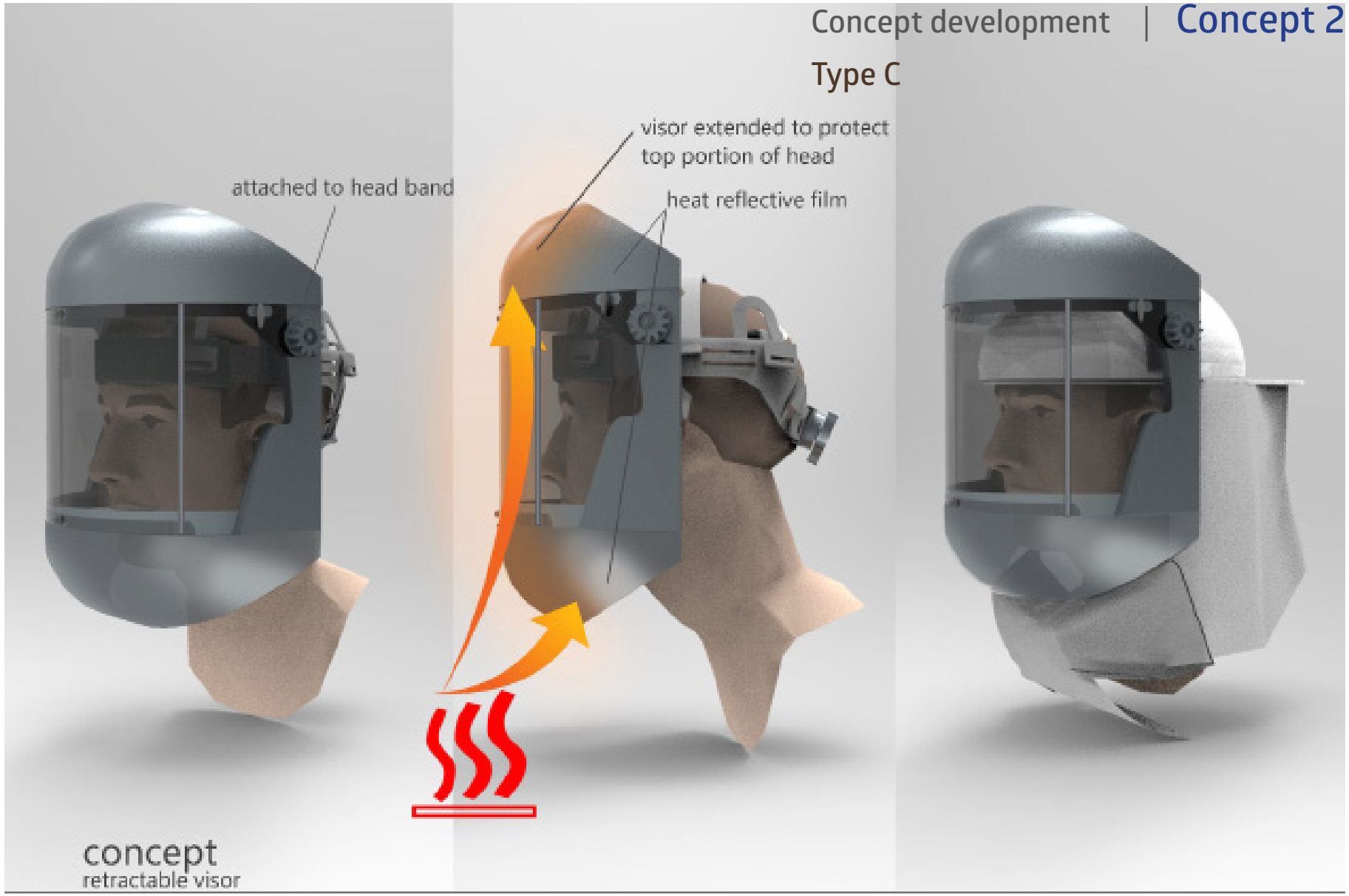
Concept development | Concept 1

Type C

Visor extended to the top and bottom part to protect the worker from immidiate radiant heat and is appropriate to insulate the worker without intervening into his natural work process.



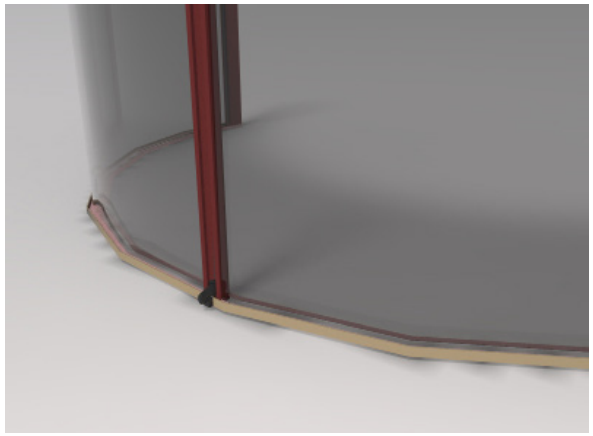
Visor is connected to the rest of the rest of the fabris that runs all around the head with velcro and tich buttons attached at the sides of the visor, so that the fabric can be taken out for washing


Concept development | Concept 2
Type C
attached to head band
visor extended to protect
top portion of head
heat reflective film
concept
retractable visor

Concept development | Concept 1

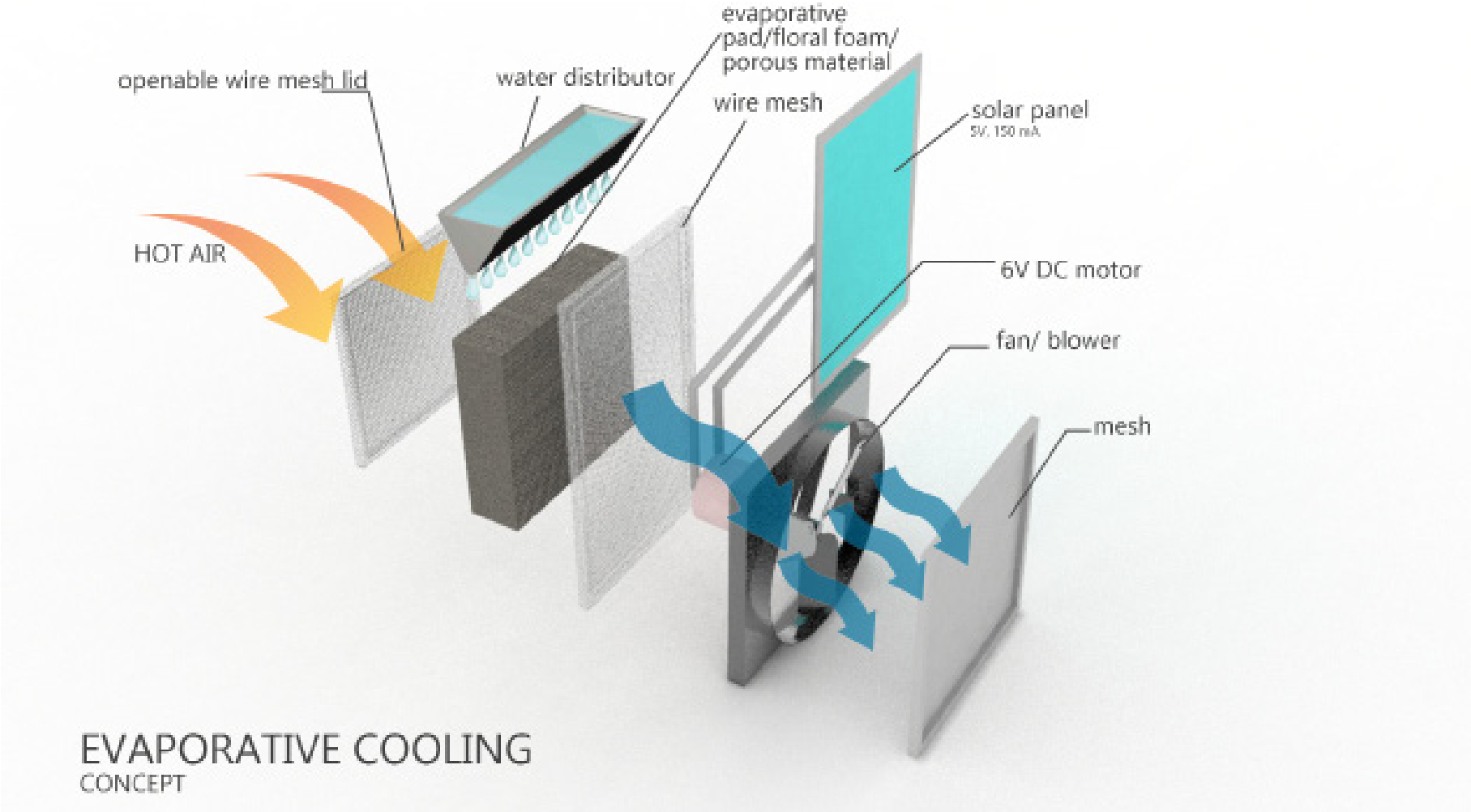
Type C

- The total weight of the helmet is comfortable for the worker working for 8-10 hours under radiant heat temperature of 55-60 degree Celsius
- The retractable visor enables the worker to talk to their fellow workers without taking their helmet off and spit both of which are very essential to their natural way of work.
- The ventilation also prevents the visor from becoming foggy.
- The cleaning wiper is slid through the channel in the middle so that the visor cannot be dusty as the environment is dusty.
- Heat reflective aluminized polyester film which is capable of reflecting 97 % of radiant heat.
- The helmet also contains ventilation holes with has a filter which filters the dust from the environment and makes the air that the workers are breathing cleaner and healthier.
- The ventilation also prevents the visor from becoming foggy



Concept development | Helmet

Basic concept

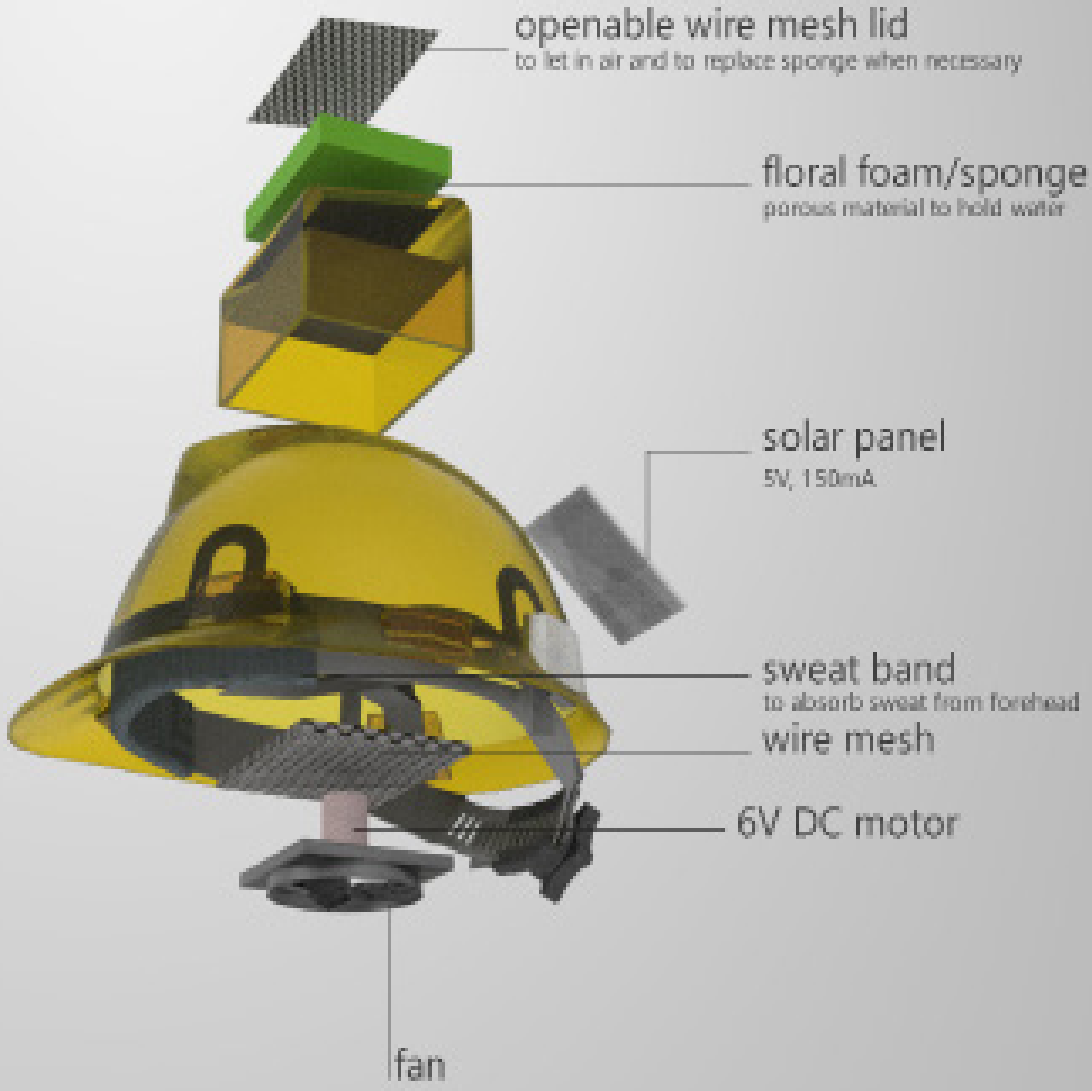


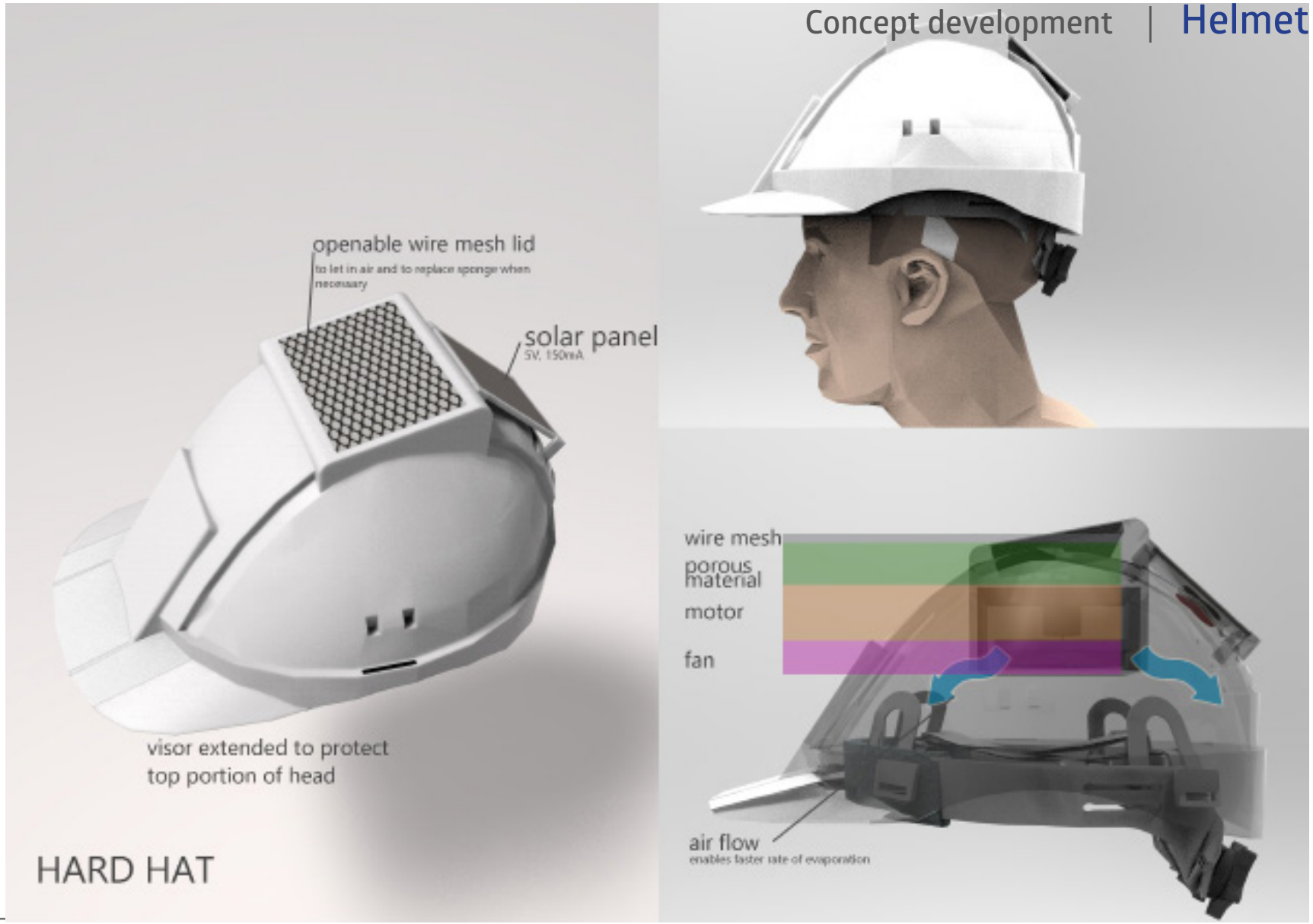
Concept development | Helmet

Exploded view

Solar powered fan and affordable cooling system for head

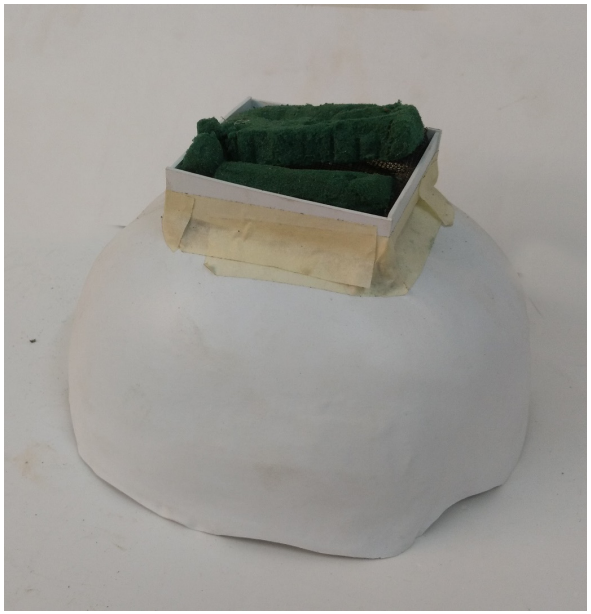
- Taking the concept of evaporative cooling, to enable body temperature drop by sweat evaporation, helmet is designed. This enables faster rate of evaporation of sweat from the surface of the head.
- The process of pouring water over the porous material at regular intervals of time and its level of easiness for the evaporative cooling technology




Concept development | Helmet
openable wire mesh lid
to let in air and to replace sponge when necessary
solar panel
5V, 150mA
visor extended to protect top portion of head
HARD HAT
wire mesh
porous material
motor
fan
air flow
enables faster rate of evaporation

How the value is added?

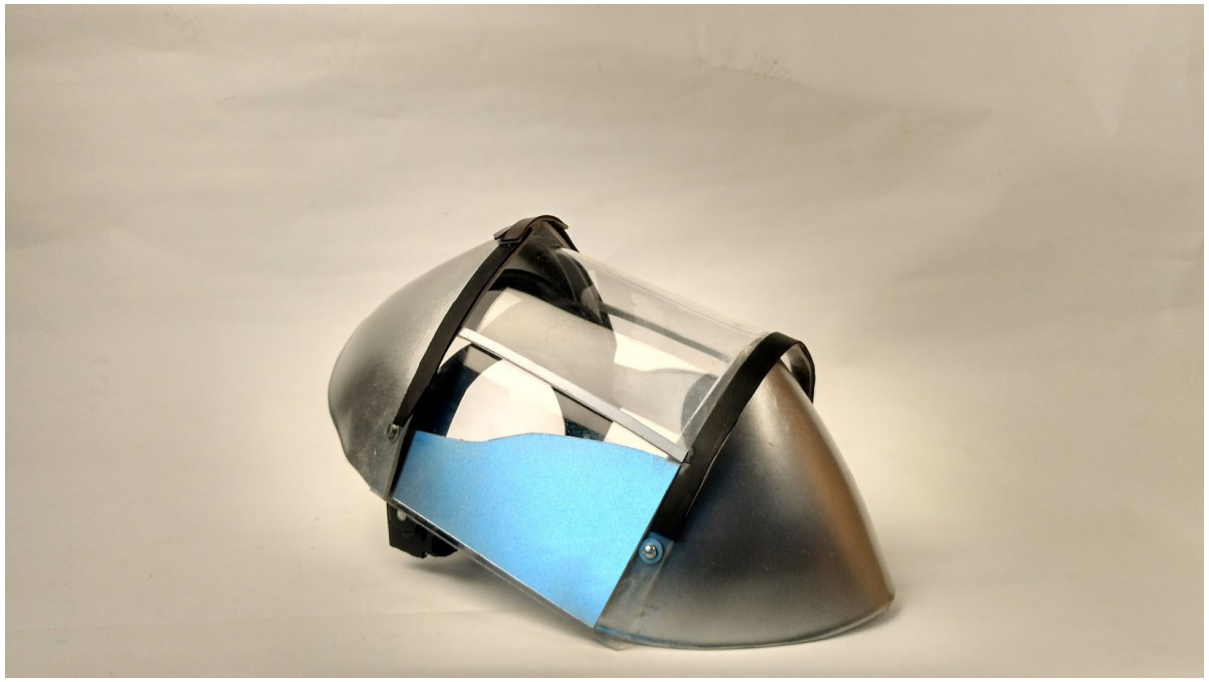
- This wearable solves the issue of heat stress experienced by the body when exposed to high temperatures when the body is unable to control its core temperatures by sweating or other natural cooling methods and when it is prone to different heat induced illness like heat stroke, heat exhaution, heat cramps, heat rash, rhabdomylosis, heat syncope.
- The fan helps to blow air and thereby increase the comfort level of the worker. The flow of air helps reduce the heat felt by the worker as a result of convection. Despite the head being fully covered, the worker will not feel as uncomfortable as the fan circulates air.
- The value spent by the organisation is totally worth it in the longer run when considering the health factor of the workers.
- An awareness of personal care, hygiene etc is evoked through this initiative




Working scenario
WEARABLE FOR JALAAI WORKERS

Prototypes

Helmet



Visor

SWOT Analysis

Strengths

- Completely caters to the Indian climatic conditions .
- Frugal design
- Easy to maintain
- Relation to the current head wearable, inspired from traditional turban style design which covers head and neck region
- Easily to manufacture
- Cost effective innovative product
- Abrasion resistant
- Cloth acts as a radiator, absorbs more sweat after the water is dried out, and dissipates on the surface.
- Durable
- Sustainable technology
- Easily fit to head
- Portable
- Non harmful to the body parts

Weaknesses

The workers are not aware of the health issues while working under the high radiant heat temperature(55-60 Celsius)
The jalaai workers cant buy their own set of wearable as they cant afford it, so the contractors should assist for the purchase of the wearable .
The NGO's should come up to spirit up with their own business model.

Opportunities

Solar powered evaporative cooling technology technique is not feasible in most of the occasions as the water has to be refilled . But this can be done in this scenario as the process of refilling can be done during the resting time after 15-20 minutes of work

Threats

As the product is easy to manufacture and sold there is a chance of emergence of another company with the same technology
Dying out of the technology of brick firing in Indian scenario will result in threat to the business
There is a chance of economic downturn as the health awareness is not prevailing in most parts of India
Services could be changed over time

References

Image reference

- Fig 1 .....https://goo.gl/9qqcgM
- Fig 2 .....https://goo.gl/t1jvn1
- Fig 3 .....https://goo.gl/Ka8bxh
- Fig 4 .....https://goo.gl/6dTDYo
- Fig 5 .....https://goo.gl/HfP1XM
- Fig 6 .....https://goo.gl/jzTN6P
- Fig 7 .....https://goo.gl/THfRDt
- Fig 8 .....https://goo.gl/T7ykkW
- Fig 9 .....https://goo.gl/uR4ES2X
- Fig 10.....https://goo.gl/iFTZ9K
- Fig 11.....https://goo.gl/D9W3oc
- Fig 12.....https://goo.gl/wTJHZc
- Fig 13.....https://goo.gl/H2ubmJ
- Fig 14.....https://goo.gl/v6hfFM
- Fig 15.....https://goo.gl/9seoid
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Online journals

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