Think preventive...
Hochschule Ostwestfalen-Lippe
University of Applied Sciences

IFDC

SS 2017

Master Thesis

Healthy Building

Design study of different facades for various zones of hospitals and rehabilitation resorts.

Scientific Work

In the master course

International Façade Design and Construction

At the Hochschule Ostwestfalen-Lippe

Presented by

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Mouhand Abobakr,

15- June-2017

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Chapter 1

Abstract

The scientists all over the world are in a race with diseases, they define the diseases and then start to develop a medicine for it, during the process between setting the disease definition and producing the medicine, there is time consumed and the risk of disease prevalence is increased.

Prevention is better than cure. The humans have a skin to protect them, and the buildings also have the façades to preserve them. The challenge is how to reach the point of healthy façade. Therefore, the scope of this research is to study the façade systems of diagnostic imaging and operation theatre rooms in case of bacteria, radiation and sterilization effects then comparing those factors with the façade of hospital and rehabilitation resorts. In addition, the starting point for this research will be from inside the hospital, search for different aspects that affect human body and environment, like addressing the problems of infection, artificial radiation, and hygienic materials in hospital rooms, then compare these problems with façade aspects to reach the successful healthy façade design. The definition of healthy façade depends on the areas of applying this façade. Therefore, the research at the end will specify the main factors that should consider it to make our façade healthy, whether it is used for hospitals or for rehabilitation resorts, or even in diagnostic imaging and operation theatre rooms inside hospital.

Introduction

Recently in the last two decades, the spreading of epidemic diseases getting increased and the numbers of infections expanded due to many reasons, one of them is the escalating curve of populations all over the world, and the domination of chemical items and products on our life style. Therefore, and according to the research published in 2007 by the Centre for Disease Control and Prevention in the United States, that 99,000 death cases in United States and 25,000 death cases in Europe each year are due to infections.

Besides the infection aspect, the radiation used in health examinations, diagnostic imaging and treatment conditions such as cancer, also poses risks following radiation exposure. According to the cancer registry analysis data in the United States, it is suspected that nearly 8% of all cancer cases are caused by radiation therapy While secondary cancer accounts for about 14% of all cancer cases, radiation therapy to treat primary cancer is thought to be a major cause of secondary cancer, which means that patients in hospitals are exposed to the radiation double or treble times than the people outside the hospital, in case they get the therapy or stay close to the diagnostic imaging department.

Therefore, the voices all over the world start raising up to face these phenomena, which influenced the recent development in building designs and construction. Therefore, those aspects need more consideration, investing knowledge, experience and time to improve the products and provide better healthy life style.

Identify the problems

There are notable demands from all over the world to improve our life style and make our buildings and surrounding environment greener, also increasing the number of diseases makes the way of thinking constricted in the bubble of healthy life. However, the word “healthy” has wide meanings that require a lot of investigations to cover small part of it. Up to the present, there is no 100% healthy building or healthy façade, because a lot of factors play a role in this topic. Therefore, to reach the closer point of healthy façade we must search in different fields and make a comparison at the end to get an output that could be helpful to improve our lives. Furthermore, there is a lot of important facts we should search about, in this scientific work, the main problems can be defined within the following questions:

Infections: what types of microorganisms that increase the ratio of nosocomial?

What is bacteria? How many types of bacteria? What is the difference between them? How could the bacteria affect the surfaces? What is the proper material to be used in façades to prevent bacteria prevalence? And, how could the healthy façade of hospitals and rehabilitation resorts look like?

Radiation: what is the artificial radiation? What is the true effect of the ionization radiation? How this type of radiation will affect the human body? What is the risk of this radiation? What will be the proper materials used to protect ourselves form artificial radiation? How these materials perform against radiation? And, how could the healthy façade of hospitals and rehabilitation resorts deals with special types of radiation?

Operation rooms: what is the hygienic requirements of operation rooms? How could we use these requirements to implement in different areas of façade? What is the cladding system that is used in operation rooms? How do these materials perform against infection and radiation? And, how could the optimal healthy façade of hospitals and rehabilitation resorts looks like?

Structure :

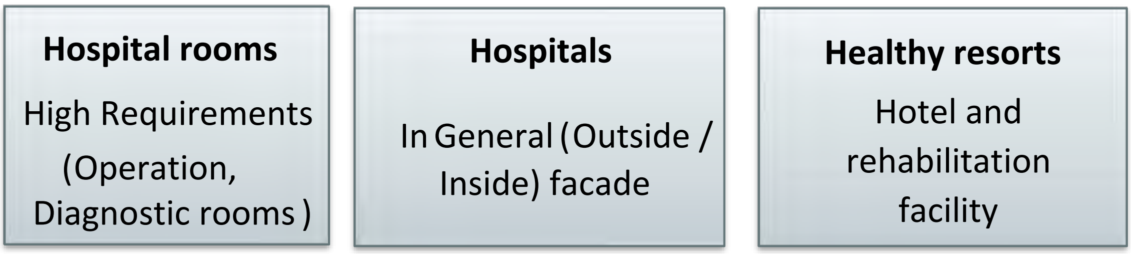
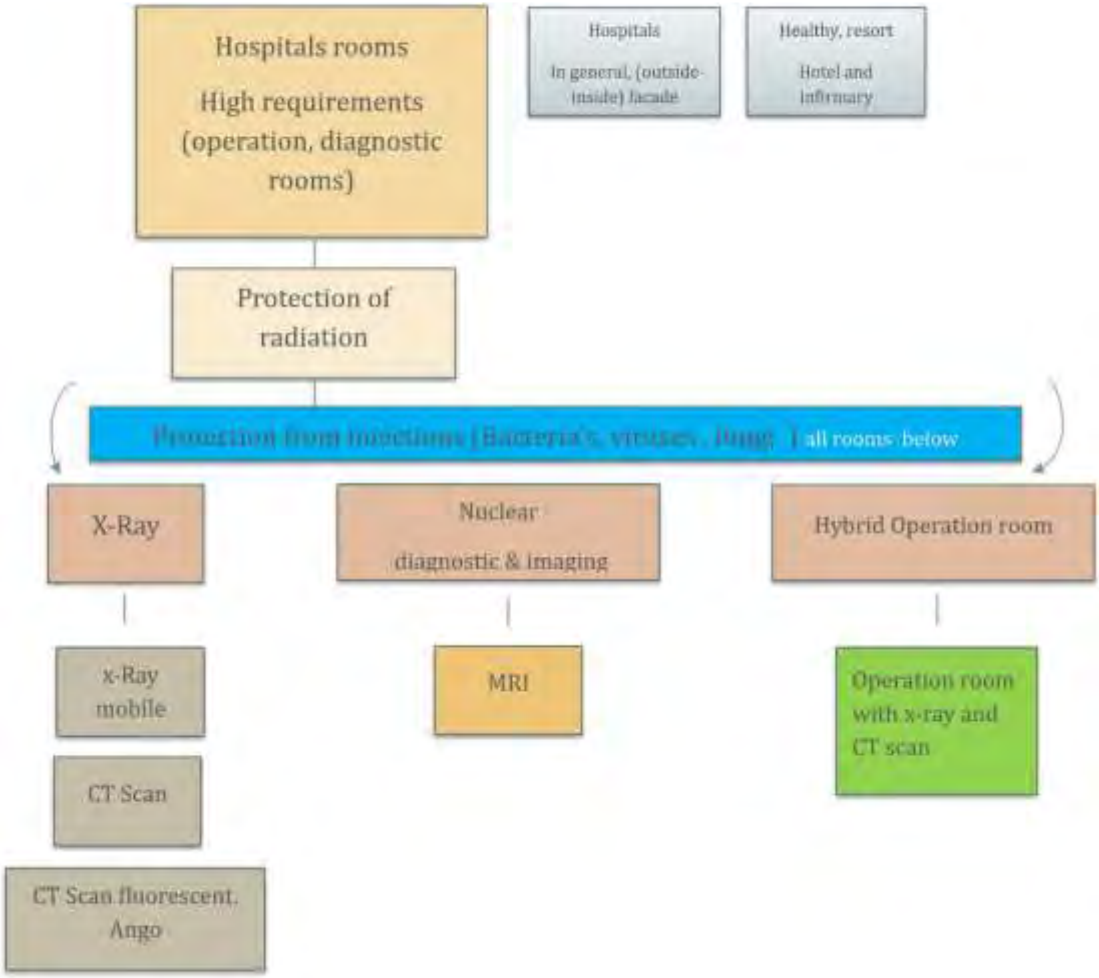


Figure I: the classification of healthy building



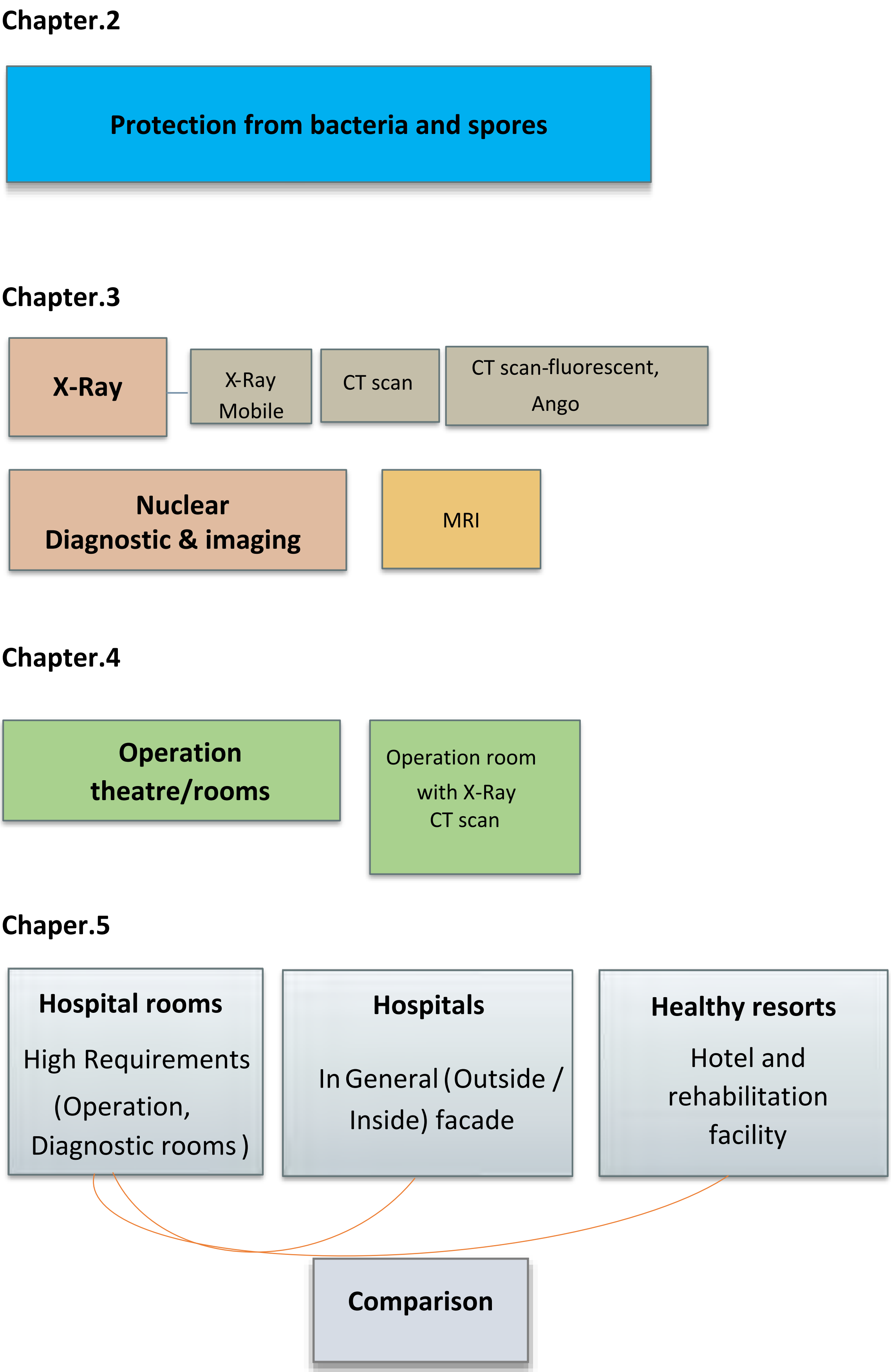


Figure II: structure of research

Chapter 2

1. Bacteria:

"Bacteria are microscopic single celled organisms that thrive in diverse environments. They can live within soil, in the ocean and inside the human gut". (1)

Human's relationship with bacteria is complex. Sometimes they lend a helping hand, by curdling milk into yogurt or helping with our digestion. At other times they are destructive, causing diseases like pneumonia and 'MRSA'.

There are typically 40 million bacterial cells in a gram of soil, and a million bacterial cells in a millilitre of fresh water. There are approximately $5x10^{30}$ bacteria on earth. (1)

1.1 Structure of Bacteria:

All the living organisms are classified as either prokaryotes or eukaryotes. In the case of bacteria is prokaryote, the entity structure of the bacteria consists of a single cell with the simple internal structure. Consider the free floating twisted DNA tread like mask called the "nucleoid".

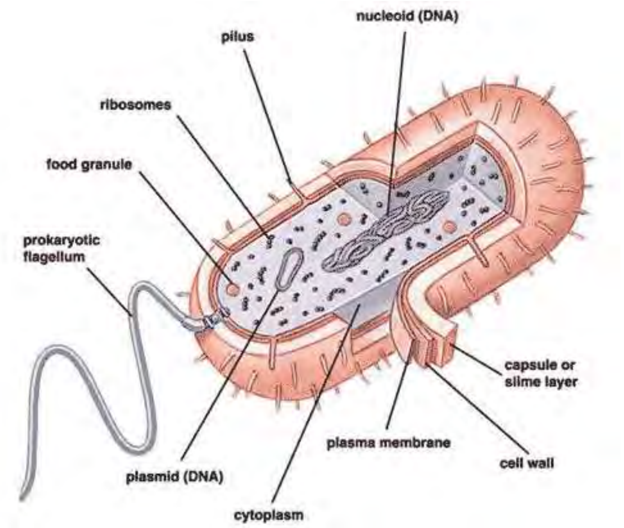


Figure 1: Structure of bacteria.

Bacteria rarely have a membrane bound organelles and contain a circular pieces of DNA called "plasmids", considering the specialized cellular structure that is designed to produce energy from proteins formation process. Inside the spherical units, the assembling of proteins from individual amino acids is processed using the information encoded in a stand of messenger RNA.

Usually the main core of bacteria is surrounded by two protective covers (outer cell wall –and inner cell membrane). In rare cases, they are bacteria without cell wall or bacteria with third wall protection, depends on the cell's developments and outmost protective layer called “capsule”. In addition, bacteria surfaces to be covered by whip like extensions, flagella or Pilli. (2)

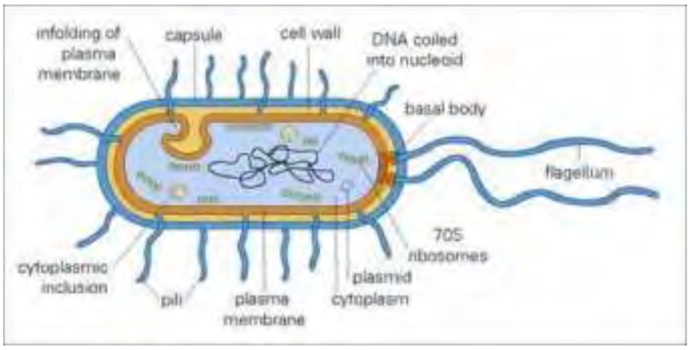
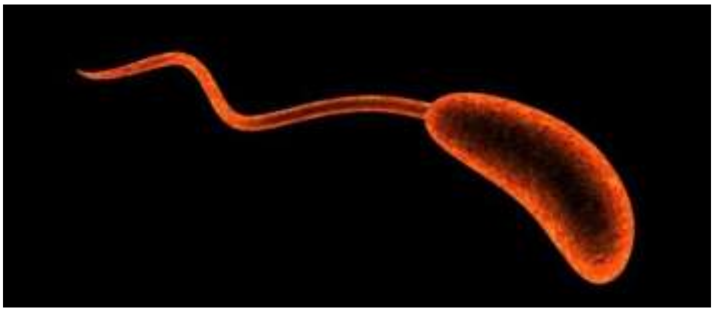


Figure 2: cell wall and bacteria Structure. /Figure 3: microscope capture for cell wall.



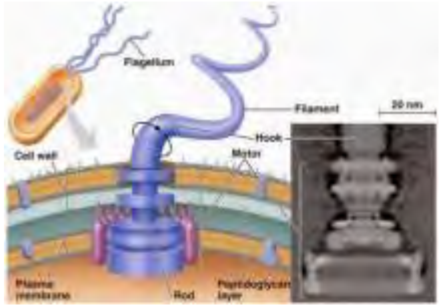


Figure 4: flagella microscope capture. /Figure 5: Flagella details Graph.

1.2 Classification systems of bacteria:

The classification of bacteria serves a variety of different functions, since a variety of bacteria can be grouped depends on different types. Usually it is grouped in three different ways depending on (Scientist, Clinician and Epidemiologist perspective) as well as O2 growth requirement of the species combined with the biomedical tests. However for clinicians, the vectors of transmission of the pathogen considered as an important aspect. (3)

1.3 Gram stain and Bacterial morphology:

According to all different tests that can expose the bacteria stain shapes and classifies it in groups, the Gram stain has withstood the test time. Therefore, this technique, which was discovered by Hans Gram in 1884, remains an important and useful technique till this day, which allows to classifying a huge number of bacteria preposition in the way of getting results of classification as “Gram positive” and “Gram negative”. Depending on this technique, they stain the bacteria with crystal violet and iodine, which leads to colored Gram positive bacteria in blue- purple stain and Gram negative bacteria in red. The difference between the two groups is believed to be due to the much large peptidoglycan (cell wall) in Gram positives. As a result, bacteria can be distinguished based on their morphology and staining properties. (3)

1.4 Growth requirements:-

Microorganisms can be grouped on the basis of bacteria needs for oxygen to grow. However, anaerobic bacteria are bacteria that do not live or grow when oxygen is present. According to that, the anaerobic bacteria considered to be of high speed proliferation rate in the world beside that strictly anaerobic bacteria grow only in conditions where there is minimal or no oxygen in environment. Bacteria such as bacteroides found in the gastrointestinal tract, which play an important role in the bowl, is an example of anaerobes. Strict aerobes only grow in significant quantities of oxygen. On the other hand, microaerophilic bacteria grow under conditions of reduced oxygen and sometimes also require increased levels of carbon dioxide. In some stressful environment conditions, such as limited availability of carbon and nitrogen. The spores given the capability to grow on the bacteria (gram positive structure) which leads to the survival of the bacteria and re-infection, beside that in (gram negative structure) the additional outer membrane layer creates permeability barrier for transport mechanisms needed which may allow the bacteria to survive. (3)

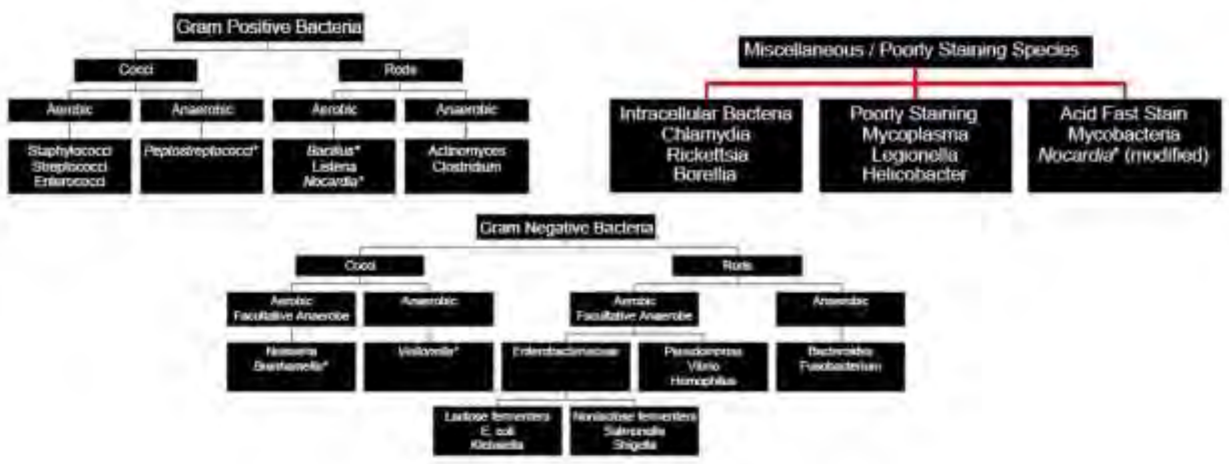


Figure 6: Classification of bacteria’s in groups.

S-Layer on bacteria:-

In (1953), Houwink demonstrated by electron microscopy a monolayer of macromolecules in a regular array, which we would now call an “S-layer”, on the external surface of the cell wall. Which is on the range of surface component of bacteria wall "also it is clear that S-layer is structural and even an integral component of the cell wall, which serves a complex of functions including being a chaperon to sensitive requirements of the periplasm and the plasma membrane."(4)

S-layer provides for some number of bacterial strategies utilizing wall components to reduce the impact of live environmental influences (5). Also some functions co-exist in many bacteria to form barrier against predators. Recently, and according to (Chart eta 1984) research (6), the S-layer considered generally to cover-up and protect a functional macromolecular mosaic that lie underneath, which is considering the S-layer until nowadays to be crystalline and it is working as protecting layer for the cell. Depending on that, the three dimensional structures of many crystalline (S-Layer) (Bacteria surface) have been studied by electron microscopy.

However, the protein molecules are composed of light elements (C, O, N and H) which made it so sensitive to radiation damage in the electron microscope (7). Therefore the protein molecules in S-layer are in link with two different environment, on the inner side with the bacteria membrane (or wall) and on the outer side with the exterior solution that will give the protein molecules a strong trend to orient with one specific surface towards the bacterium, with an opposite surface facing outwards, which give the S-layer the mechanism of orienting an axis perpendicular to the membrane.

Considering the influence of temperature on the way of forming the crystals (S-layer), the well-formed crystals are near the melting point which increases the growth of crystals. At higher temperature, the thermal motions of the molecules control the attractive force between molecules and make the components move in a liquid fashion.

On the other hand, if the temperature is much lower and the thermal motions are so slight, that a protein monomer which has come in contact with monomer in an orientation, which is not the optimal in terms of strong interaction, so the monomer will remain at the suboptimal position.(7)

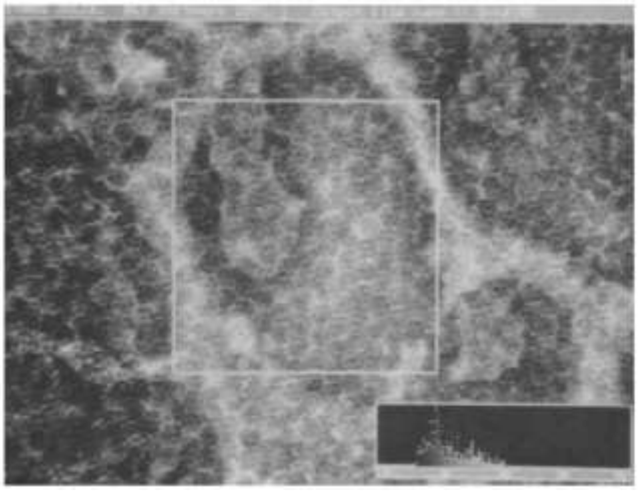


Figure7: An electron micrograph of a negatively stained S-layer from *Bacteroides buccae,* Scanned by a CCD camera.

Bacteria strain and Colony Growth:-

As an example for colony growth, type B subtilis strain 3610 is gram -positive bacterium with rod shaped body and multiple flagella, which generate a propelling force in the direction of its body (8)(9).

They swim with a mean speed about 40µ m/s in a thin liquid film on the substrate (10).In our experiments, the bacteria have mean dimensions of 0.72 µm x 7.4µm.

Colonies grow on soft (0.5%) l b agar substrate, L B: more commonly called Luria broth, agar plates are typically used as a growth substrate for the bacteria. For inoculation, 5µL of B subtilis overnight culture (OD 650=1) is placed on the Ager. The inoculated gel is stored in an incubator at 30°C and 90% humidity. After a lag time of two hours, a colony start to expand outward isotropically with speed 1.4 cm per hour. (11)

1.5.1 Bacteria in hospitals:

Nosocomial: this term means any disease contacted by patient while under medical care.

- Nosocomial infection: are infections that have been caught in a hospital.

The rapid dissemination of antimicrobial - resistant microorganisms in hospitals worldwide is a problem of era. The causes of this problem are multifactorial, considering the inappropriate use of antimicrobial agents in hospitals and application of basic infection control practices by hospitals personnel. Also, the inconvenient application in hospital rooms to cut down the infection dissemination. Therefore, Methicillin - resistant staphylococcus aureus strains are endemic in numerous hospitals. Since the majority of coagulase - negative staphylococcal isolates have been resistant to methicillin for several times. However, vancomycin:(Is an antibiotic used to treat a number of bacterial infections) is the effective therapeutic and prophylactic agents for staphylococcal infections in many patients which make the use of vancomycin increase in hospitals. On the other hand and after 1989, more than 10% of hospitals gained enterococci isolated from patients in (ICUs: intensive care units) which discovered afterwards that enterococci are resistant to Vancomycin. (12)

Therefore, the healthcare associated enterococcal infections in 1980s and 1990s decided to make studies of the transmission of pathogenic enterococci among patients in hospitals. According to that, Enterococci can persists for as long as 60 minutes after inoculation onto hand and as long as 4 months on inanimate surfaces, where they can serve as a reservoir of ongoing transmission in the absence of regular sterilization (14). That mean also in general, any kind of bacteria can develop itself during some special aspects to be antimicrobial resistant, which led to produce a new antimicrobial to cut off the epidemic dissemination. However, hospitals can work as reservoir of macrobiotic or as distributor to community in some special cases.

Footer:

Methicillin - resistant staphylococcus aureus (MRSA): is a bacterium responsible for several difficult to treat infections in humans. Coagulase - negative staphylococci (CONS): are part of the normal flora human skin, these organisms have relatively low virulence but are increasingly recognized as agents of clinically significant infection of bloodstream and other sites (13).

Enterococci have an intrinsic and acquired resistance to antibiotics (15)

1.5.1 Protection from infections:-

According to many different international associations worldwide, Like (INICC : International Nosocomial Infection Control Consortium) , (HAL: Healthcare Acquired Association) , (NNIS: National Nosocomial Infection Surveillance) and (DAI : Device Associated infections) all of this associations published a lot of researches and articles concerned about infections occurred due to bacteria, and we can sum and abstract the most influential bacteria's in hospitals to five categories:

1- Gram Positive

2-Gram Negative

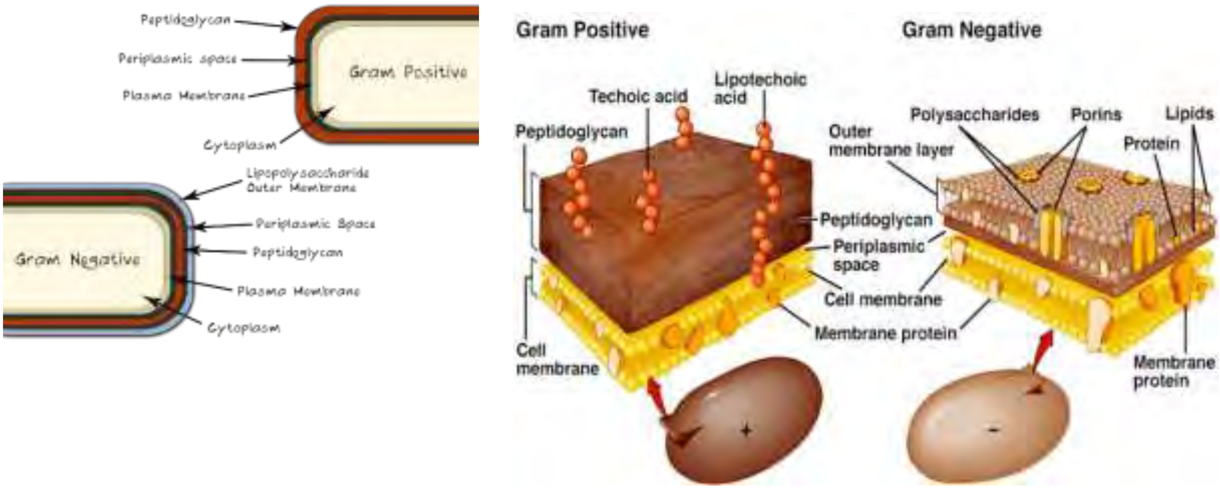


Figure 8, 9: Gram positive – Gram negative comparison.

3- Staphylococcus, Genus includes at least 40 species; most of species are harmless and reside normally on the skin and mucus membranes of humans and other organisms. Also (MRSA: Methicillin - Resistant Staphylococcus) considered as most epidemic bacteria prevalent in hospital worldwide.

4- Vibrio, is a genus of Gram negative bacteria, possessing a curved-rod shape, several species of which can cause food borne infection.

5- Pseudomonas, is genus of Grams - negative, aerobic Gammaproteobacteria and the family of Pseudomonas contain 191 species.

For example, consider the MRSA way of prevailing the infection. Most MRSA infections occur in people who've been in hospitals or in other health care settings. Therefore, when it occurs in these settings, it’s known as health care-associated MRSA (HA-MRSA). The HA-MRSA typically occur in surgeries, intravenous tubing or artificial joints. However HA-MRSA it's spread by skin to skin contact or touching objects that have the bacteria on them. MRSA infections are common among people who have weak immune systems and are in hospitals. (16)

On the other hand, whereas MRSA is formed because of using antibiotics, so if we do not use antibiotics, we would not have any problems with MRSA!

Therefore we have to point out some components that prevent bacterial infections prevalence.

Components:-

- Vancomiymicin, Vanomiymicin is an antibiotic, is used to treat bacterial infections.

- (CCCP): Carbonyl cyanide m-chlorophenyl hydrazone.

CCCP is a chemical inhibitor of oxidative phosphorylation and causes the gradual destruction of living cells and death of the organism.

-Medicinal fungi/Medicinal mushrooms

The fungi can be induced to produce such metabolisers using biotechnology to work as antibiotic against some bacteria's.

For example, some important medicinal mushrooms:

-Auricularia auricula, Flammulina velutripes,Grifola frondosa, Agaricus bluzei etc..(17)

1.5.2 Infection control practices:-

According to world health organization, "the practical guidelines for infection control in health care facilities".2004, Infection control practices can be divided in two categories:-

1. Standard precautions.

2. Additional (transmission -based) precautions.

<u>Standard precautions:-</u>

Treating all patients in the health care facility at all time with basic level "Standard" including patients and workers who involve in practicing, and this standard includes the following:-

-Hand washing and antisepsis "hand hygiene"

-Use of personal protective equipment, especially when handling blood, body substances, excretions and secretions.

-Appropriate handling of patient care equipment.

-Prevention of needle stick/ sharp injuries.

-Environmental cleaning and spills-management and appropriate handling of waste.

Additional (Transmission - Based) Precautions:-

The Additional (Transmission - Based) Precautions are implemented while ensuring the standard precautions are preserved, Therefore, the additional precautions divide to some branches, for example.

-Airborne precautions

-Contact precautions

Airborne precautions:-

Airborne precautions are designed to reduce the transmission of diseases spread by airborne way. Therefore, the application of airborne protections depends a lot on the function, the operation room, and the diseases are assumed to protect for. In case of operation rooms, it is supposed to implement HEPA filters (99% clean air) and the intake air goes directly to outside the building. Nevertheless, airborne transmission occurs when droplet nuclei (evaporated droplets) <5 micron in size are disseminated in the air. This droplet nuclei can be suspended in the air for some time. So droplet nuclei is the residuum of droplet and when it is suspended in the air, and dry, it produces particles in range size of 1-5 microns. These particles can be suspended in the air for long time, especially when bound with dust particles. (18)

So the following precautions must be taken

Under consideration:

- Implements standard precautions

- Place patient in a single room that has negative air flow pressure, the air should be discharged to the outdoors.

- Keep doors closed.

- Wear a special high filtration particulate respirator mask for anyone enters the room.

- Masking the patients with a surgical mask in case of transportation of the patient.

Contact Precautions:-

Are the diseases transmitted by the way including colonization or infection with the multiple antibiotic resistant organisms, eteric infection and skin infections? For that the following precautions need to be taken:

- Implement standard precautions.

- Place patient in a single room or in a room with another patient infected by the same pathogen.

- Implement hygienic and antibacterial surfaces, painting and equipment in the room and corridors.

- All horizontal surfaces and all toilets should be cleaned daily.

- Limit the movement and transport of the patient from the room. (18)

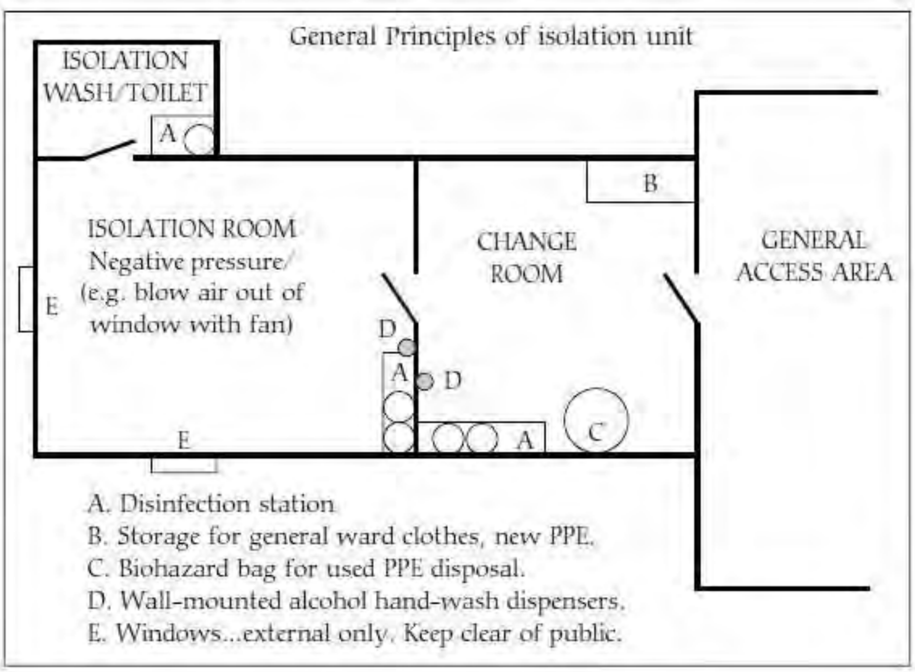


Figure 10: Example drawing of a typical SARS isolation facility.

Table 3. *Chemical Disinfectant – level of disinfection achieved*[3]

Level of Disinfection	Activity against microbes
High level chemical disinfectant	Inactivates all microbial pathogens except where there are large numbers of bacterial spores
Intermediate level disinfectant	Inactivates all microbial pathogens except bacterial spores
Low level disinfectant	Rapidly inactivate most vegetative bacteria as well as medium sized lipid-containing viruses, but may not destroy bacterial spores, mycobacteria, fungi or small non-lipid viruses

Environmental surfaces in the patient's room

Equipment	Standard procedure	Comments
Floor	Damp mop with detergent and water.	Clean twice in each shift and more often if needed.
Spillage – of blood, body fluids, secretions and excretions	Wipe with paper towel or reusable cloth to soak up the majority of the spill. Clean with detergent and water. Dry the area.	Discard paper towel into clinical (infectious) waste If using reusable cloth – separate into contaminated linen bag
Commode, toilet seats	Clean seat and arms with detergent and water and dry whenever used. Wipe with disinfectant for example 1-2% sodium hypochlorite and dry after cleaning	Whenever soiled, clean with detergent first and then wipe with disinfectant, for example. Sodium hypochlorite-1-2% and dry after cleaning.

Table 1, 2: Recommendations procedure, World health organizations, practical guidelines for infection control in healthcare facilities, 2004.

1.6 Implement protection in hospitals:-

1.6.1 Nano-antimicrobial Materials:-

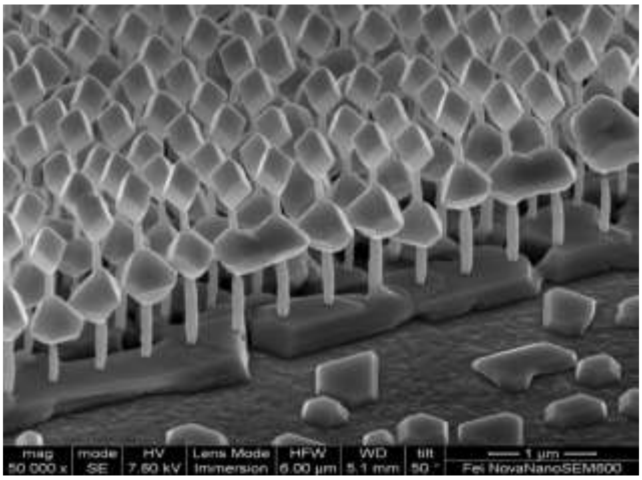


Figure 11: Nanomaterial microscope capture.

Since the infections of bacteria increase nowadays to be a major cause of morbidity and mortality, so attentions has been mostly devoted to new and emerging nanoparticle - based material in the field of antimicrobial chemotherapy. Moreover, most of the microbiological researches focus mainly on (free swimming) bacteria, where the most bacteria is found in the hospitals and in the industrial setting in association with surfaces. And generally, bacteria microbial communities, composed of multiple species that interact with each other and their environment. (19)

Therefore," First, the bacteria bind reversibly to the surface and then secrete binding molecules such as adhesion proteins that cause irreversible attachment. Once settled, the bacteria proliferate and form colonies inside peptidoglycan envelopes, which leads to the development of a mature biofilm". (19)

Consequently, nanotechnology nowadays provides an intact platform for adjusting the physicochemical properties of materials to generate effective antimicrobials. (20)

Nanomaterial's (NM) may be advantageous as active antibacterial groups, since their surface area is extremely large relative to their size and (NM) could serve to control bacterial infection. Also the mechanisms of (NM) work on the direct contact with the bacteria cell wall without the need to penetrate the cell. Nowadays (NM) is used for example :(metal, metal oxide and organic nanoparticles), which the environment factor also play a role and effect the lethality of NM to bacteria including aeration, PH and temperature.

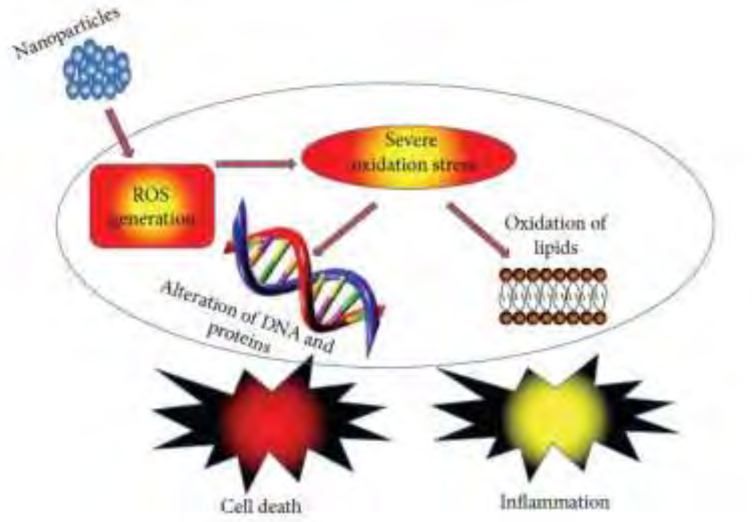


Figure 12: Mechanism of nanoparticles to attach bacteria cell.

Footer:

Biofilm are agglomerates of microorganisms that adhere to a substrate.

Furthermore, NM acts in a long five major lethal pathways, where the two factors related to each other and work in parallel way.

1. Disruption of membrane potential and integrity.

2. Production of reactive oxygen species(ROS or Oxygen free radicals)

Therefore, the damage of membrane occurs when NM bind electrostatically to the cell wall and membrane, which leads to alteration of (membrane potential, membrane depolarization) which in result make an interruption of energy transduction or cell lysis and imbalance of transport that leads to cell death.

ROS oxygen free radicals, considered as the most effective determinant in vitro and in vivo cytotoxicity NM, are induced indirectly/directly due to respiratory chain disruption by the NM where the blast of ROS is caused by severe oxidative stress and lead to RNA and DNA damage. However, in some cases where high concentration of ROS leads to cell death, and in low doses cause DNA damage. In some instances, where the ROS induced by visible or UV light, the toxicity of NM is photo catalytic.

For example, TiO_2 NM was induced by UV light leads to respiratory dysfunction and death of E.Coli cells. (20)

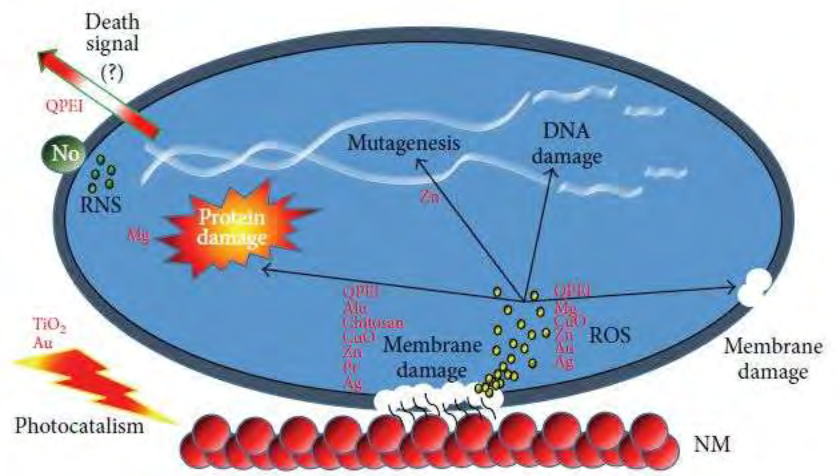


Figure 13: NM antibacterial mode of action.

1.6.2 Inorganic Nanoparticles:-

Metal and metal oxides had widely antimicrobial activities and high potent antibacterial effect through reactive oxygen species (ROS), or effective due to their physical structure and metal ion release.

For example, silver (Ag), iron oxide (Fe_3O_4), Titanium oxide (TiO_2), copper Oxide (CuO) and zinc oxide (ZnO).

Silver: - (Ag)

Silver nanoparticles have been widely used as antimicrobial agent against bacteria, viruses and fungi. Ag was recognized already from ancient times and used for the disinfection of medical devices .However, the mechanism of Ag nanoparticles is still not clear, small diameter of Ag nanoparticles have an excellent antimicrobial effect to those of a large diameter. Also, it has an efficient bactericidal antibacterial agent against various pathogens in vitro and in vivo. Nonetheless, still some questions about Ag and the way of effectiveness on humans! And, is the Ag really kills biofilm or just-planktonic cells?. Moreover, investigations showed that the Ag ion can inhibit and disrupt protein structure by binding to thiol and amino groups, also increasing the membrane permeability and inactivating the respiratory chain.

Finally, Ag-NM has antibacterial effects on both gram-positive and gram-negative bacteria and AG-NM is the most promising antibacterial metal.

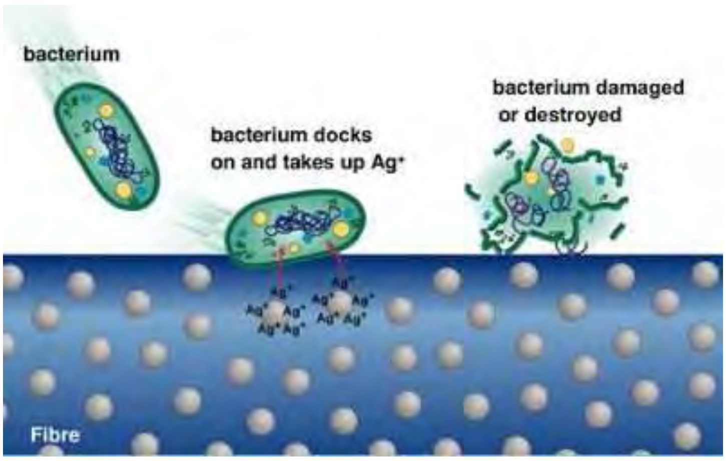


Figure 14: NM silver attacking the bacteria.

Titanium Oxide: - (TiO_2)

Titanium Oxide is another oxide metal with antimicrobial efficiency which known as high ability to kill both gram-positive and gram negative bacteria. More recent reports shown also high efficiency against various viral species and parasites. (TiO_2) is photocatalytic and its toxicity induced by visible light or UV. However TiO_2 is effective against spores of bacillus. On the other hand, the combination between TiO_2 and Ag could lead to better result.

Zinc Oxide: - (ZnO)

Zinc oxide has a wide range of antimicrobial activity against various microorganisms and it is chosen based on concentration of partial size. Also ZnO prevent the growth of (methicillin-sensitive S. aureus (MSSA), Methicillin-resistant S. epidermidis(MRSE). However, ZnO NM are relatively low cost and have low toxicity to human cells .ZnO comes with white colour, UV blocking and the formation make it suitable for fabric and glass industrial as coating materials for medical purpose. (21)

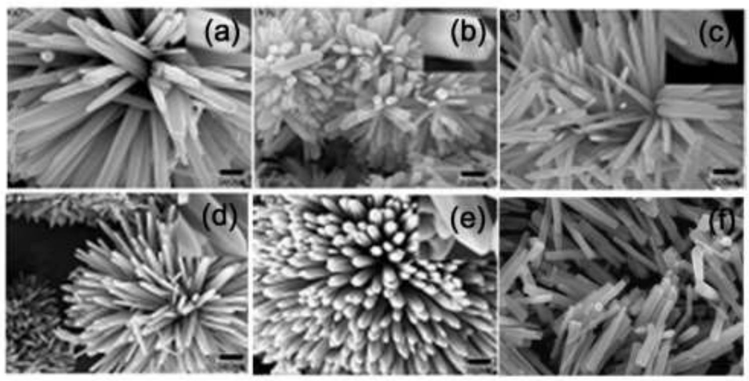


Figure 15: SEM images of the ZnO NRs prepared by using the hydrothermal method at different temperatures of (a) 100°C, (b) 120°C, (c) 140°C, (d) 160°C and (e) 180°C and the co-precipitation method at 180°C (f). The length of the scale bar is 0.5 µm.

Iron Oxide and Gold:-

Iron Oxide (Fe_3O_4) can be modified to introduce antimicrobial properties. Microbiological researches proved that surface modified used Fe_3O_4 nanoparticles prove anti-adherent properties and reduce of gram-positive and gram-negative bacteria colonization. On the other hand, Gold (Au) comparing with Silver (Ag) have less effect as antibacterial. However, Au-NM tied up to antibiotics such as (vancomysin, ampicillin etc.)will be bactericidal including penicillin and vancamysin resistant also Au-NM binding to nan-antibiotic induce ROS are used as therapy against cancer cells.

Copper Oxide (CuO):-

Although (CuO) nanoparticles have been effective against various bacterial pathogens where (CuO) is greatly active depends on bacteria species. Like comparing CuO with Ag, Ag NM have more efficiency against some kinds of bacteria species and vice versa with CuO. Moreover, CuO is much cheaper NM comparing with Ag and other nanomaterials. In general, CuO is much better with B. Subtilies and B. anthracis bacteria. (19)

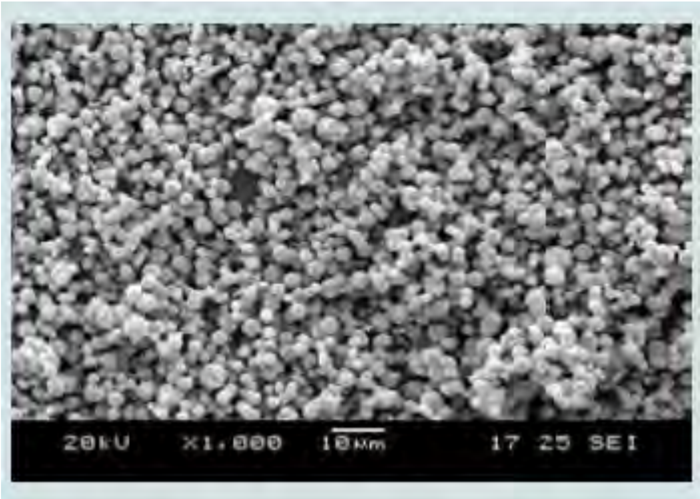


Figure 16: CuO Nanoparticles.

1.6.3 Organic Nanoparticles:-

Polymeric nanoparticles shoot microorganisms by releasing antibiotics, antimicrobial against or by contact, killing cationic surfaces such as quaternary ammonium compounds, alkyl pyridiniums or quaternary phosphonim.

The mechanism of action against bacteria depends on the surface charge, which the positive charge of surfaces is capable of conferring antimicrobial properties by an ion exchange between bacterial membrane and the charge surface, and the effect depends on the ability of multiple charges and the interact with the cell membrane.

However, in comparison between organic and inorganic materials, the organic is less stable in higher temperatures, which make it harsh withstand on process conditions and give the priority to inorganic materials to be more used in market. (19)

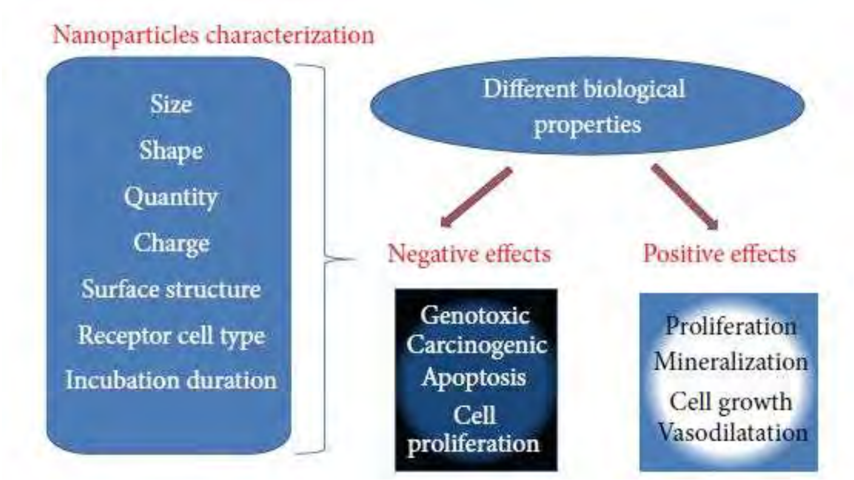


Figure 17: The biological activity of different organic and inorganic NM varies from negative To positive effects in different systems of *in vitro* cell lines.

<u>Quaternary ammonium compounds:-</u>

Quaternary ammonium compounds such as (benzalkonium chloride, stearaikonium chloride and cetrimonium chloride) are well known disinfections. Their antimicrobial activity is a function of N-alkyl chain length and hence lipophilicity. Compounds with alkyl chain length of 12-14 provide optimum antibacterial activity against gram-positive bacteria, also of 14-16 length groups with carbon chains shown better result. (19)

Footer:

Quaternary ammonium (quats), are positively charged polyatomic icons of structure $NR_4^{+.}$

Quaternary phosphonium: polyatomic cations with chemical formula PR_4^+, quaternary phosphonicm salts $(C_6H_5)_4P^+Cl^-$

Pyridiniums: is a basic heterocyclic organic compound with chemical formula C_5H_5N.

Chapter 3

2. Radiation

Since the beginning of life, radiation is naturally exists everywhere. Light and heat radiations, resulting from nuclear reactions in the sun, are essential to the existence of both human beings and other organisms. Also, radioactive materials exist naturally in the environment, and our bodies contain radioactive materials such as polonium and carbon. Radiations involve the presence of life.

Therefore, and since the discovery of X-ray and radioactivity in 1895, for the scientists had the opportunity to produce radiation and radioactive materials artificially. It is notable that the first usage of X-ray was in medical diagnosis, which also gave early opportunity to detect the potential dangers of radiation. However, we can classify radiation into “ionizing” and “non-ionizing” radiation. Ionizing radiation includes cosmic X-rays, X-rays and the radiation from radioactive materials. Non-ionizing radiation includes ultra-violate light, radiant heat, radio waves and microwaves. Also, the ionizing radiation and radioactive materials led to dramatic advances in medical diagnosis and treatment. Therefore, we have to make balance between the benefits and risks of the procedures that expose people to radiation, because of the greatest concern about ionizing radiation, that causes potential malignant diseases to people exposed to it, and might lead to inherited defects in later generations, depending on the amount of radiation that a person might expose to. (22)

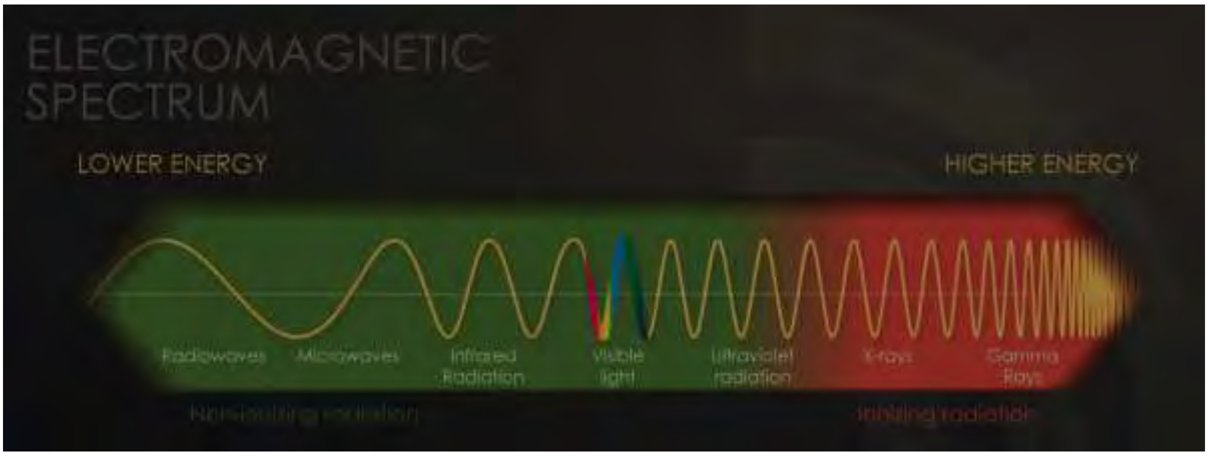


Figure 18: Electromagnetic spectrum

2.1 Structure of matter:-

Everything in the world consists of atoms. Looking deeply, each atom contains a positive and negative charge where the positive exists in nucleus and negative in electrons. The electrons carry negative electric charge moving around the nucleus in orbits, where the nucleus is ten thousand times smaller than electrons orbits, and electrons itself are smaller.

The nucleus of atom contains (protons: with positive charge equal to electrons negative charge) and (neutrons: "neutral" i.e. without any charge).Therefore, the number of electrons in the atom or the number of protons in the nucleus gives the atomic numbers, which give unique characteristics of element. Also, the mass number mean the total number of protons + neutrons with considering the (protons-neutrons) nucleus is heavier than electrons. Also, the nuclides of an element that have the same number of protons but different numbers of neutrons are called isotopes.

Example: - Iron has ten isotopes from iron -52 to iron-61 with the same number of protons and different number of neutrons. (22)

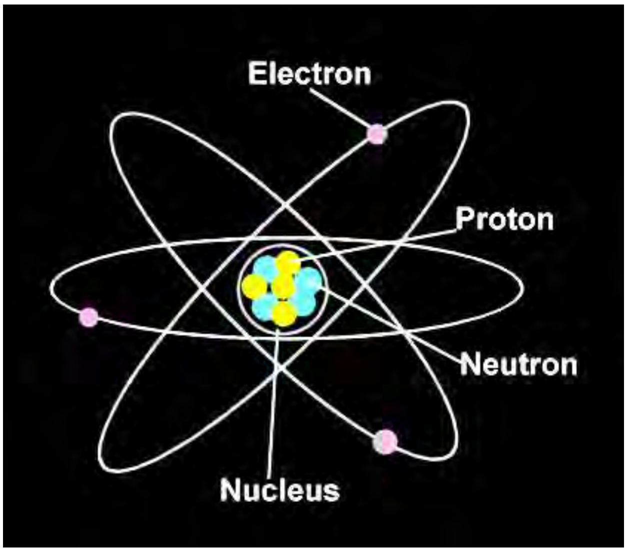


Figure 19: Structure of matter.

Radioactivity and radiation:-

Some nuclides are stable and some are not, depending on the balance between the number of neutrons and protons a nuclide contains. However, larger stable nuclei have more neutrons than protons. Therefore, when the nuclei have too many neutrons, it tries to be structurally stable by transforming the neutrons to protons which called beta decay, results in the emission of a negatively charged electron called a beta particle. On the other hand, nuclei with too many protons converts the spare protons to neutrons in different form of beta decay, results in the emission of a positron by losing positive charge and get plus electrons charge. This kind of transformations, leaving the nucleus with spare energy and lose it, leads to the gamma rays –high energy photons, which keep the parcels of energy without charge or mass. Therefore, the transformation of a nucleus is called radioactivity, and the spare energy emitted in the form of (ionizing) radiation, and the nuclide that changes and emits radiation is called radionuclide, although some nuclei producing alpha particle when the nuclei consists of two protons and two neutrons. In general, the alpha particle is much heavier than the beta particle and carries two units of positive charge. (22)

Radionuclides → unstable nuclides

Radioactivity → Emission of radiation

Radiation type → Alpha, beta, gamma, X-ray neutron

Activity → Decay rate of radionuclide

2.2 Types of Radiation:-

Alpha radiation (α):

Is a positive charged helium nucleus emitted by large unstable nucleus. It has short range in air (1-2 cm) and can be absorbed completely by paper or skin. Alpha can be dangerous if it enters the body, for example: - By inhalation or ingestion and it can affect the nearby tissues and stomach.

Beta radiation (β):

Is an electron emitted by an unstable nucleus .Beta particles can penetrate more than alpha because of its smaller size, and it can move through materials or tissue. Beta radiation can be absorbed by sheet of plastic, glass or metal where is beta radiation can’t penetrate the top of skin but the exposure to high-energy beta can cause skin burns.

Gamma Radiation (Y):

Is very high energy photon, and a form of electromagnetic radiation. Also, it is emitted from unstable nucleus with accompanied beta particle emitted in the same time. The gamma radiation penetration is very strong and need thick metal such as steel or lead as radiation protection materials. (22)

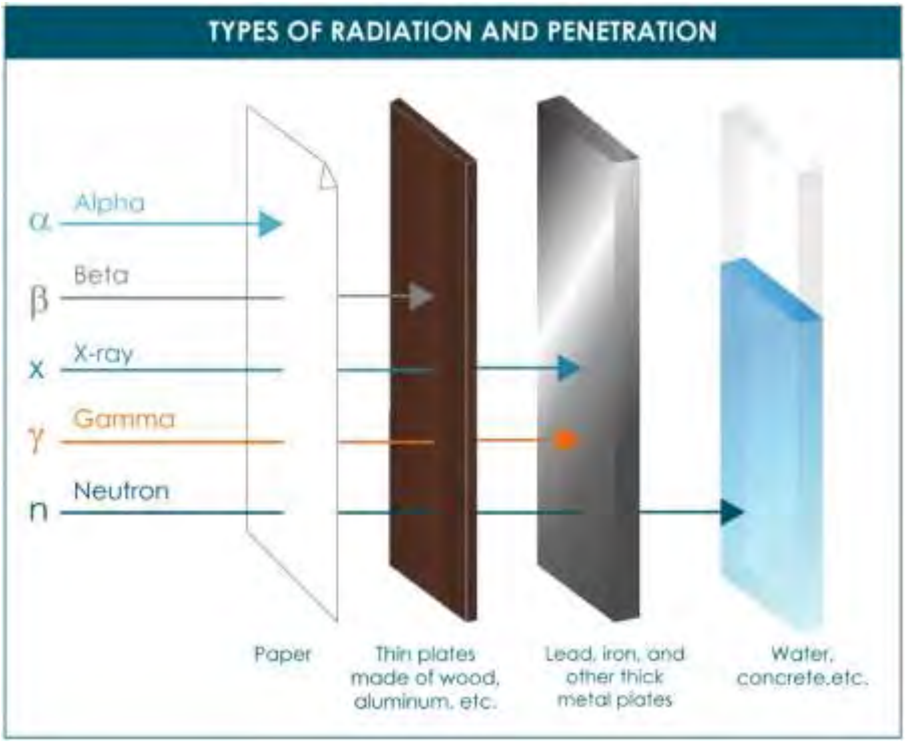


Figure 20: Type of radiation penetration.

X-Ray radiation:

Is a high energy photon like gamma radiation. It is artificial radiation produced by rapid slowing down of an electron beam. X-ray radiation has the same strong penetration of gamma radiation and it needs also a thick material to shielding.

Neutron Radiation:

It is the worth effective radiation, because of unstable nucleus during atomic fission and nuclear fusion. Neutron radiation have higher penetration and once interact with tissue, they cause beta and gamma emission. Therefore requires heavy shielding.

2.3 Ionizing radiation:

X-Rays and Gamma rays lose energy in different ways, but each involves liberating atomic (orbiting) electrons, which is depositing energy in interactions (layers) with other electrons. Also, neutrons lose energy in different ways specially through clashing with nuclei that contain protons. Therefore the protons being charged and again deposit energy through electrical interactions. In general, radiation produces electrical interaction in the material.

Finally, any radiation causes ionization. Ionization (is a process by which neutral atom or molecule becomes charged by removing an electron from the atom, and the electron removed ionizes other atoms or molecules). However, ionization can occur directly with alpha and Beta particles and indirectly with gamma, x-rays and neutrons, which is known as ionizing radiation. On the other hand, excitation comes with definition of passing charged particles through atoms, and gives energy to the atomic electrons without removing them. (22)

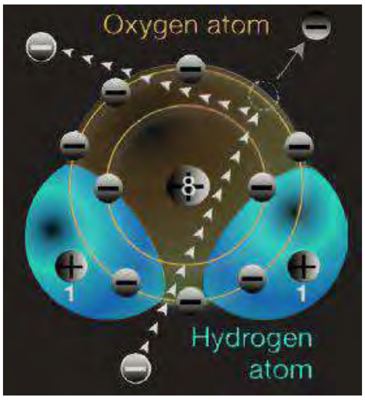


Figure 21: Ionization of a water molecule by a charged particle.

The radiation effects on the cells:

Each time the atom excites or ionizes by charged particle, energy loss will occur, the result of this energy loss is a minute rise in temperature of the atom part that excites or ionizes. So, the ionizing radiation is dissipated as heat through increased vibrations of the atomic and molecular structures, therefore, this process leads to chemical changes that causes harmful biological effects when occurs on the human tissues. As we know, everything in the world consists of molecules, so microscopically, the nucleus cell of biological tissue consists of approximately 80% of water and 20% of biological complex compounds. Therefore, when the ionizing radiation passing through cellular tissue, it produces charged water molecules, which are called free radicals.

Free radicals are highly chemical reactive molecules, and it can modify important molecules in the cell. So, is the ionizing radiation causes harmful effects? There are two kinds of effects, one affects directly to the DNA molecule by chemical change, another kind is producing free radicals through which affects the DNA by interacts. Notable the degree of penetration and effect of ionizing radiation, it depends on the amount of doses and the nature of interactions with tissue. (22)

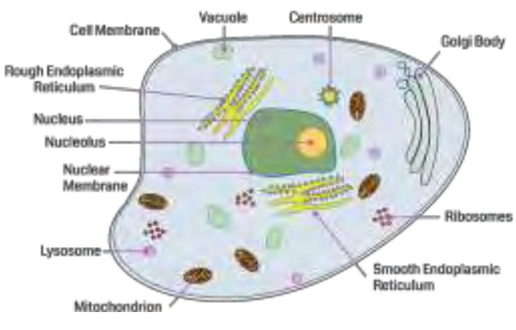


Figure 22: Diagram of a cell.

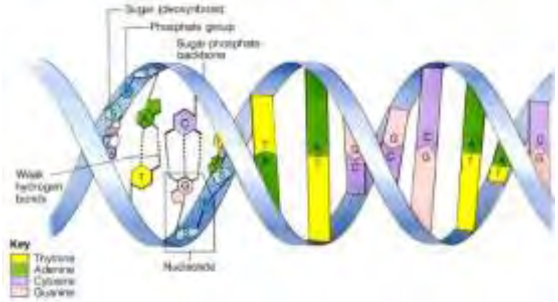


Figure 23: DNA structure.

Types of radiation exposure:-

Chronic radiation exposure: involves low level of radiation over long period of time , the effect of chronic exposure is the increased risk of developing delayed somatic effects such as cancer, cataracts and genetic effects passing along future generations.

Somatic effect: is the biological effect that occurs on the exposed individual.

Genetic effect: refer to biological changes on the descendants of the exposed individuals due to mutation of their genetic materials.

Hereditary effect is a genetic effect that is inherited or passed onto an offspring.

Accurate radiation exposure: is delivered in a short period of time and larger acute exposure lead to deterministic effects. (23)

25 - 100 rads	*Minor blood changes, some illness anticipated*
100 - 300 rads	*Illness (lowering of the white blood cell count, nausea, bacterial infections, vomiting, loss of appetite, diarrhea, fatigue, hair loss, and possible sterility), at the end of this range death may occur but this is infrequent and would be associated with those individuals undergoing simultaneous physiological stress. These are the classic signs and symptoms of the radiation sickness syndromes.*
300 - 450 rads	*Anticipated death of 50% of population within 30 days, if medical assistance is not provided. Death caused by complications associated with radiation sickness syndromes.*

Figure 24: Radiation exposure effects.

2.4 X-Ray:-

In general, X-Ray is produced by firing beam of electrons at a metal target (tungsten), the electrons in the metal absorb energy from electron beam, and then the metal atoms become excited and release the energy in the form of X-Rays.

Figure 25: X-ray machine.

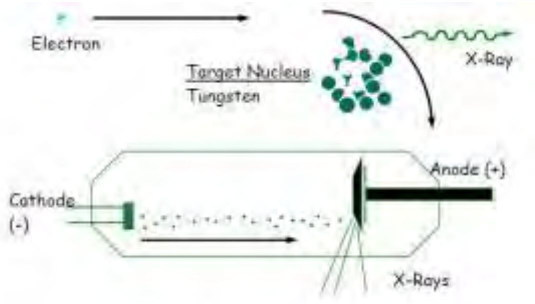


Figure 26: X-ray mechanical concept.

X-Ray tube

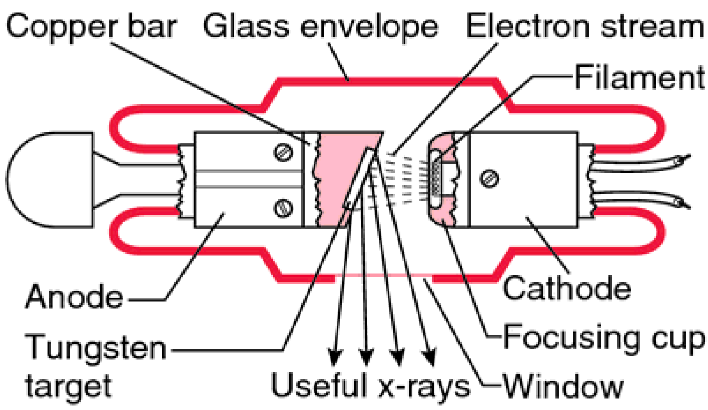


Figure 27: X-ray tube.

The diagram shows the basic X-Ray tube where the X-Ray radiation comes from. The tube has three basic components:

1. The glass envelope, which is made of low-thermal-expansion borosilicate glass or any kind of glass that can tolerate very high level of heat. Also, the envelope supposed to

be thick and must be able to hold a very low pressure vacuum to ensure that the electrons and X-Rays that are produced cannot collide with air molecules.

2. Cathode (the focusing cup): which contain a small filament and supplied with a low voltage to create (thermionic emission) which mean to liberate the electrons from tungsten filament when it is energized in the direction of target (anode).

3. Anode (the target): it consists of an anode disc, and the disc is attached with small neck to a (rotor). A rotor is a device made to rotate in very high speed where it is consists of (stator: is a series of electrical coils).

X-Ray tube Housing

The tube housing of X-Ray has a lot of functions; one of them is to tolerate very high level of heat when X-Ray generates the most energy, that is converted to heat. Another thing is filled with oil, which is cooling the hot glass envelope, and the oil has a little filtering effect. In addition to that, some housing have fan that helps to cool the air around the housing tube.

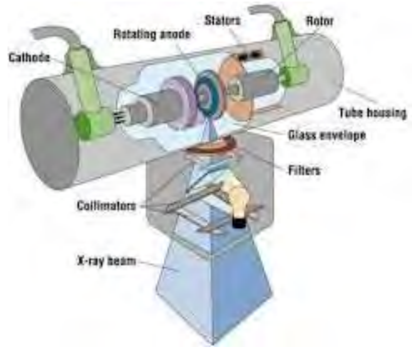


Figure 28: X-ray tube housing.

The diagram shows how the electrons impact the target surface and then interact with target material (Tungsten).

2.4.1 CT-scan:-

CT or computed tomography refers to a computerized X-ray imaging, a procedure in which a beam of X-ray is pointed at a patient and quick rotated around the patient body to create cross-sectional images or slices by producing signals that are processed by the machine's computer. The slices called topographic images and it contain more details comparing with normal X-ray. Nevertheless, the CT worked different than X-ray mechanism where is X-ray using a fixed X-ray tube. The CT scanner uses a motorized X-ray source that rotates around open circle (donut-shape structure called a gantry). The patient lies on a bed that slowly moves through the gantry when the X-ray tube rotates around the patient. Therefore, every time the X-ray tube completed 360 degree rotation, the produced image is transmitted to the computer, then the bed moves further to continue scanning process. The thickness of the tissue represented in each image slice is usually in ranges of 1-10 millimetres. (24)

Figure 29: CT-scan.

2.4.2 CT Scan (IV) and nuclear medicine:

All X-rays can easily imaging the dense structure such as bone but with soft tissues, and according to the doctors, diagnostic sometimes requires a (IV CT, IV- intravenous) or nuclear medicine for diagnostic. That means, the patient is given a radionuclide in a carrying substance by injection, ingestion or inhalation. Then the radionuclide emits gamma rays. This kind of technique makes the diagnosis such as blood vessels, blood stream and stomach much better. However, these kinds of medicines or compounds considered as radiant materials, where most of the diagnostic procedure use the radionuclide gives of gamma rays with energy of 0.14 Mev. That means, the risk to effects can vanish within few hours. (24)

Figure 30: IV CT-scan image.

Risks of CT-Scan:

CT scan use x-rays, and all x-rays produce ionizing radiation, and the ionizing radiation has the potential to cause biological effects. However, the risk increases with the number of exposures and in general, the risk of developing cancer from radiation exposure is little, but is possible according to the test below, where it shows the results of exposing to CT Scan radiation comparing with natural radiation. (24)(See appendix)

Study	Gender	Age	# of exams	Dose (mSv)	Additional Cancer Risk(%)
CT-Brain CT (Standard)	Male	27	1	2	0.019037%
Plain Film-Chest x-ray (2 views)	Male	27	1	0.1	0.000952%
Brain Scan	Male	27	1	6.9	0.065677%
Upper GI (Barium Swallow)	Male	27	1	6	0.057111%
					0.142777%

Based on your radiation exposure from these studies, your additional risk of getting cancer is 0.142777%

An Additional Cancer Risk of 0.142777% is equal to 1 in 700 chances.

Or said another way, a 99.857223% chance of having no effect of the above studies.

Figure 31: Radiation exposure test.

2.5 (MRI) Magnetic Resonance Imaging:-

The human body is mostly water, where 70% of the human body consists of water. The water molecules (H_2O) contain O_2-oxygen and hydrogen nuclei (protons). However, the main concept of MRI works in the mechanism of hydrogen nuclei, in which these nuclei become aligned in magnetic field. Consequently, the MRI scanner applies a strong magnetic field in range of 0.5 ~ 4 Tesla compared with 0.5 Tesla for earth, which leads to aligning the protons spins. Afterwards, the scanner produce a (RF) radio frequency current to create a ranging magnetic field, which make the protons absorb the energy from the variable field and flip their spins. Gradually, the protons return to their normal spin when the field is turned off. Rightly, this return process leads to produce a radio signal, this signal can be measured by receivers in the scanner and made into an image. However, protons return to their spins at different rate so the scanner can recognize it among tissues. (26)

Figure 32: MRI machine.

2.5.1 Physics behind the Scenes:

When we look at ourselves, the human body consists of billions of atoms, and when we make a short comparison between atoms and earth, will have the same physics principles. Each of them have electrical charge, rotates (spins) around its own axis, rotation produce magnetic field and each of them consists of 70% of Water. Therefore, water consists of 2 hydrogen atoms and 1 oxygen atom. So, the hydrogen atom has nucleus with one proton on it, electrically charged and it rotates around its axis. Nevertheless, take the hydrogen atoms as the main productive item to generate MR image, it come from two reasons: firstly, we have a lot of them in our body, secondly, the Gyro magnetic ration is different for each protons, and hydrogen have a largest ration of 42.57 MHz/Tesla. Therefore, each hydrogen protons spinning around their own axes and the magnet have North Pole and South Pole, where is an opposite pole attracts each other. In our body the magnets are ordered in such way that the forces equalize. (27)

In regards to that, when we put a patient in MRI device under magnetic range of 1~ 4 Tesla, the mechanism will change. The hydrogen protons will align with magnetic field in two ways (parallel and anti-parallel) or (low and high energy). That leads to get a net magnetization, which all tiny magnetic fields of protons point in the same direction. (27)

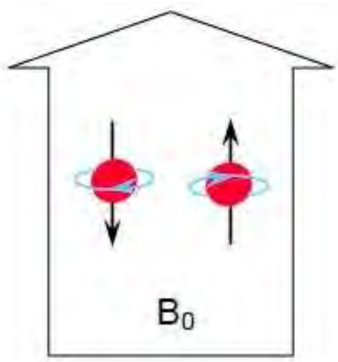


Figure 33: Hydrogen protons aligned with magnetic field.

To see what happens in net magnetization, will simply rotate the proton field direction to 3 vectors, x-y-z, as the figure below.

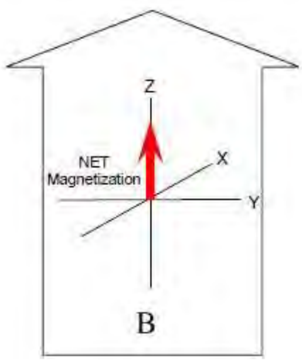


Figure 34: Net magnetization analysis.

Afterwards will send (RF) at the center frequency with a certain strength and certain period to test it at which frequency the protons are spinning. That leads to rotate the net magnetization plane (90°).

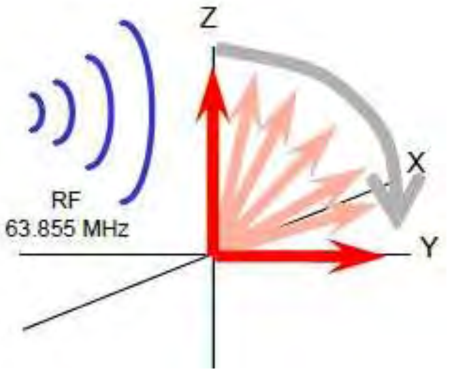


Figure 35: Rotation of protons.

Furthermore, when raised the protons to high energy because of energy absorption from (RF), the protons get extra energy, which leads to discharge this energy in way of (RF) pulse. (27)

Risks of MRI:-

MRI considered safer comparing with x-ray and CT scan, because MRI do not work in concept of radiation ionizing like in X-Ray and CT scan, but it works on concept of magnetic fields and radio frequency. However, there are some points must be taken under consideration: first, the effects of static magnetic fields, where several accidents occurred and have been reported as a result of magnetic fields, like for example: oxygen tanks, furniture, needles and keys become projectiles when they interact with magnetic fields. Also, there is a lot of reports shows the biological effects of static magnetic field on humans, once effected by magnetic fields, such as the retina, pineal gland and some cells in the paranasal sinuses. (28)

Figure 36: Accident example.

Second, time-varying magnetic fields gradients. As the gradient coils are switched ON/OFF during imaging, a significant amount of acoustic noise will be generated in the bore of the magnet. This noise is manifested as chirping sound or loud tapping.

Finally, the effects of radio frequency fields: "Radio frequency (RF) pulses are used in MRI imaging for the excitation of the nuclei." The RF power is transformed in the form of heat within patients' tissue. Therefore, the absorption of energy from RF generates ohmic heat within tissue, and it's greatest at the surface and minimal at the center of the patient's body. (28)

2.6 Implement protection in rooms:-

2.6.1 X-RAY and CT scan rooms:

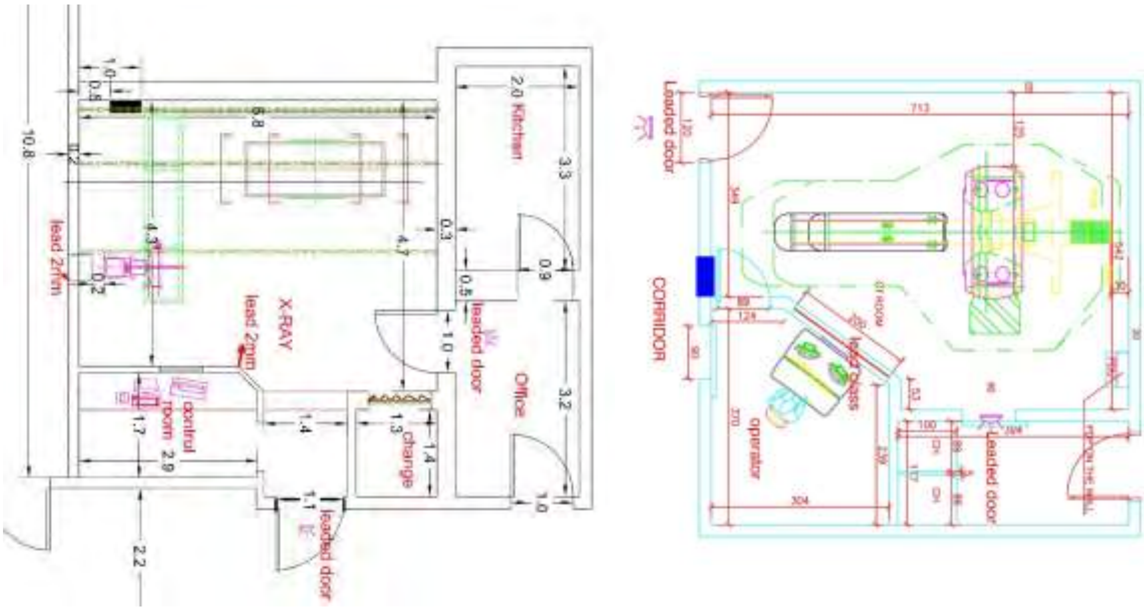


Figure 37: Left, X-ray room – Right , CT room.

Characteristics of shielding:

There are two general classifications of radiation shielding defined as; Thermal shielding and biological shielding.

Thermal shielding is used to dissipate excessive heat from high absorption of radiation energy. Where, biological shielding is needed to reduce radiation, to a safe level for humans and animal. Therefore, the danger of exposure to radiation in biological shielding classified into two categories (Internal and external). The internal include a medical problem and do not involve shielding, where external radiation comes from outside human source such as X-Ray tubes, nuclear reactor or radioactive materials, like radium. Furthermore, protection against external radiation depends on the distance from radiation source, time of exposure to the radiation and imposing a protective shield between the source and the body to be protected, in addition to radiation source, type of installation, and the properties of shield material. (29)

Selection of a shield material:

In general, any material of sufficient thickness could work as a shield of radiation. But, due to certain characteristics, lead and concrete are common used materials in this field. However, the choice of materials depends on some factors such as, final desired attenuated radiation level, ease of heat dissipation resistance to radiation damage, and required thickness and weight. Therefore, the following are important criteria of the shield material:

Attenuation:

The attenuation of radiation depends on the effective cross section of the shield. Also, it is important to recognize the second radiation that is produced by an irradiated shield material. For example, Gamma rays produced within shield materials by neutron absorption and then by source of second radiation.

Gamma Rays and X-Rays:

The attenuation in such case, depends on the density of the shield materials, where it is supposed to have higher atomic number to attenuator X-Rays.

Thermal Heat:

It is necessary to remove heat from the inner layer of the shield materials. For that the material should have good heat conductivity.

Radiation damage resistance:

It is important requirement of shield material that it does not have deleterious effect on the mechanical or physical properties. In addition to this, the designer supposed to look for availability of the material, cost, shield size, weight, material fabrication, transportation cost and flexibility of the material. Therefore, the value of lead material in this field is rising. (29)

Properties of lead:

The properties of lead that make it more common material used in healthy building are: the density, high atomic number, high level of stability, ease of fabrication, high degree of flexibility in application, and the availability. In addition to that, lead has low level of neutron absorption and that means no secondary Gamma radiation, since the material that has high rate neutron capture will become radioactive. For that reason, and after long periods of exposure to neutron, lead emits a little amount of radiation. However, the most effective fact the shield materials supposed to have is density, that prevents the radiation to pass through, lead is not the highest density material comparing with (Tantalum, Tungsten and Thorium) but, lead is most available and cheapest. Another advantage that, lead is a metal, which can exhibit a smooth surface and be less exposed to dirt and contaminants. Also, the ability to reuse the lead, since the price of lead scrap could be high as 80% pure lead. Therefore, the table below shows the usages of lead in applications, where normal sheet lead thickness is available from 0.002 inches/ 0.005 cm up to many inches, and any thickness under 1/32 inches/ 0.07 cm is referred as foil, and above 1/2 inch /1.27 cm as lead plate. (29)

Table I   FORMS OF LEAD USED FOR RADIATION SHIELDING

FORM	USE
Lead Sheet, Slab and Plate	Permanent shield installations
Lead Shot	Where solid lead *is* impractical, due to location, shape, and accessibility
Lead Wool	Filling deep cracks in a radiation barrier
Lead Epoxy	In-the-field crack filling patching
Lead Putty	Non-hardening, temporary seal or patch
Lead Brick	Convenient, easily handled; may be moved and re-used
Lead Pipe	Shielding of radioactive liquids
Lead-clad Tubing	Shielding of radioactive liquids
Lead-lined/Lead-clad Pipe	Shielding of radioactive liquids
Lead sleeves	Shielding of duct and pipes carrying radioactive materials
Lead Powder	Dispersed in rubber or plastic for flexible shielding; also mixed with concrete and asbestos cement
Lead Glass	Transparent Shielding
Lead-Polyethylene-Boron	Combined gamma, neutron, and thermal neutron barrier material

Table 2 - Commercial lead sheets

Thickness		Weight in Pounds for a 1 Square Foot Section	
Inches	Millimeter equivalent	Nominal Weight	Actual Weight
1/64	0.40	1	0.92
3/128	0.60	1 1/2	1.38
1/32	0.79	2	1.85
5/128	1.00	21/2	2.31
3/64	1.19	3	2.76
7/128	1.39	3 1/2	3.22
—	1.50	—	3.48
1/16	1.58	4	3.69
5/64	1.98	5	4.60
3/32	2.38	6	5.53
—	2.5	—	5.80
—	3.0	—	6.98
1/8	3.17	8	7.38
5/32	3.97	10	9.22
3/16	4.76	12	11.06
7/32	5.55	14	12.9
1/4	6.35	16	14.75
1/3	8.47	20	19.66
2/5	10.76	24	23.60
1/2	12.70	30	29.50
2/3	16.93	40	39.33
1	25.40	60	59.00

Notes:
1. The density of commercially rolled lead is 11.36 g/cm^3
2. The commercial tolerances are +-0.005 inches for lead up to 7/128 and +-1/32 for heavier sheets.

Figure 38: Forms of lead – Dimensions.

Lead bricks:

Lead bricks is interlocking system produced in a wide range and size and gives high performance to prevent radiation leakage and it's more resistant to damage than concrete.

Typical standard sizes of interlocking brick are (3 inch / 7.6 cm long X 3 inch /7.6 cm thick X 2 inch/ 5.08 cm high) and, for non-interlocking are (2 inch / 5.08 cm X 4 inch / 10.16 cm X 2 inch / 20.32 cm. (29)

Figure 39: Lead bricks.

Lead shielded door:

“The standard door is constructed by utilizing a single layer of lead sheet in the center with same thickness used in wall, and the lead sheet extends to the edges of the door. Solid wood cores on either side of the lead sheet are held together, utilizing poured lead dowels of 1.5 inches from all edges and 8 inches on center."(29)

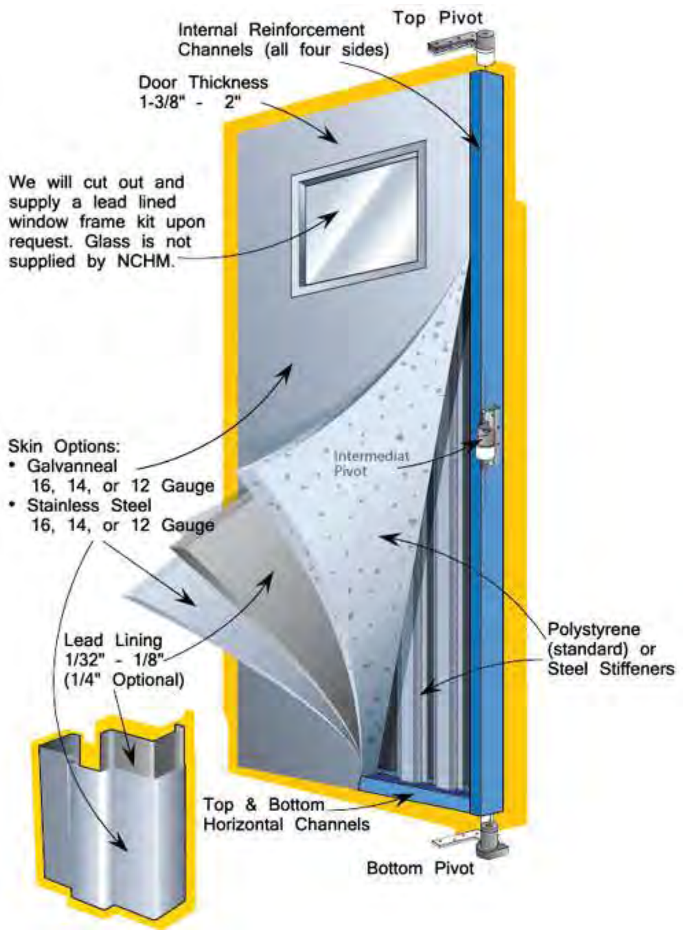
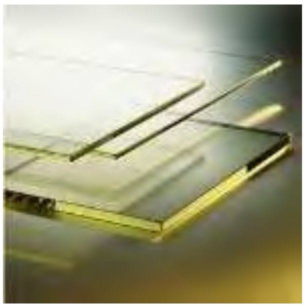


Figure 39: Lead door.

Lead glass:

In X-Ray rooms and CT scan rooms, it is supposed to install lead glass in area between the machine room and the operation room, where the staff can control the operation of the machine. Usually the lead glass window consists of lead sheet with thickness of 1.5 ~ 2 mm. Also, lead glass can be installed in multiple layers so it will equal to the lead thickness in the wall.

Figure 40: Lead glass.



Concrete or cinder block:

Another shielding material is concrete or cinder block with imperforated sheet of lead fixed in center, and the lead sheet extends to the outer edges of the block on all sides. Therefore, the lead sheet in each block overlaps, that in all adjoining block by 1inch providing a continuous lead lining. On the other hand, there is common solution used, that consists of 20 cm solid concrete blocks, which could work with same performance.

Design requirements:

The following factors should be taken into consideration in the design and construction of X-Ray protective space:

1. Energy of radiation source
2. Orientation of beam
3. Distance from source to point of protection
4. Size and location of openings barrier
5. Geometrical relationship between the source of radiation, opening and the position of the person.
6. Maximum allowable dose rate
7. Amount of leakage radiation of the machine.

Additional factor must be the height of radiation source below 7 feet. Also, any openings in the protective barrier such as nail, screw or bolt holes, ducts, pipes, doors, windows etc., must be protected not to impair the overall attenuation of the rays. (29)

Fixing the lead sheet:

The width of lead sheet should not exceed 48 inch for handling reasons, and the sheet supposed to be positioned against the wall surface. Also, all joints should be lap joints with an overlap of 0.5 inch or twice the sheet thickness. It is recommended that the sheet installed be continuous, by attaching along the upper edge. The top of the sheet supposed to turn out at least 2 inch over the horizontal support at each joint and at 16 inch.

There are three methods of fastening the lead sheet to a wall surface:-

1. The screw-capping method: It requires a lead-patch burned to the lead sheet over each fixative. Also, the patch should extend several inches in every direction to prevent the penetration inside the fastener hole, and the patches should be the same thickness of lead sheet.

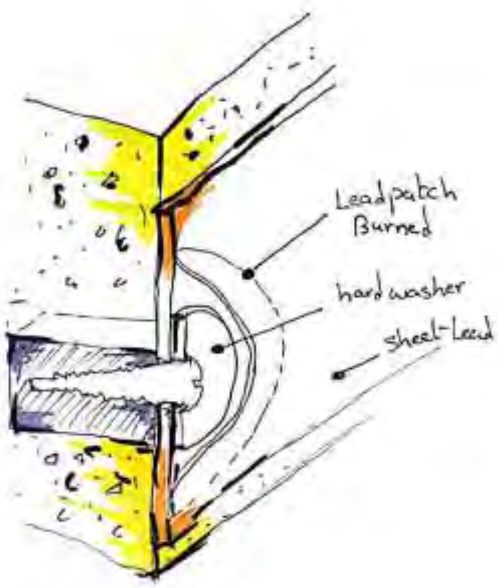


Figure 41: Screw-capping method.

2. The lead plug method: It does not require the addition of lead patches.

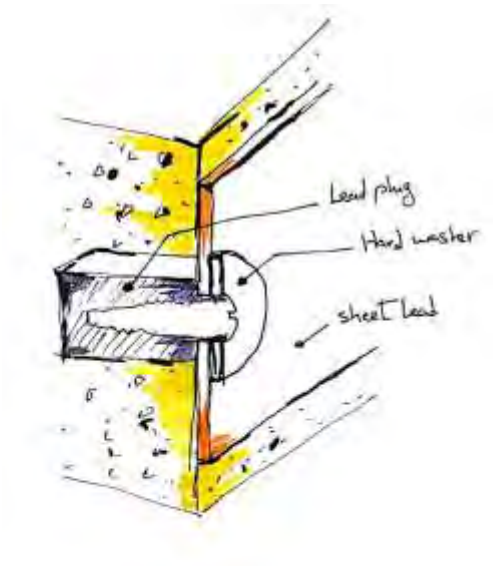


Figure 42: Lead plug method.

3. Horizontal boards attached: It is considered to employ boards attached horizontally across the studs. The lowest boards applied first with height about 18 inch and then covered with lead sheets, which is turned back over the upper edges of the top board and then turned upward about 1 inch and fix it with studs. Another sheet applied with same procedure, and the joints between the lead sheets are burned or soldered.

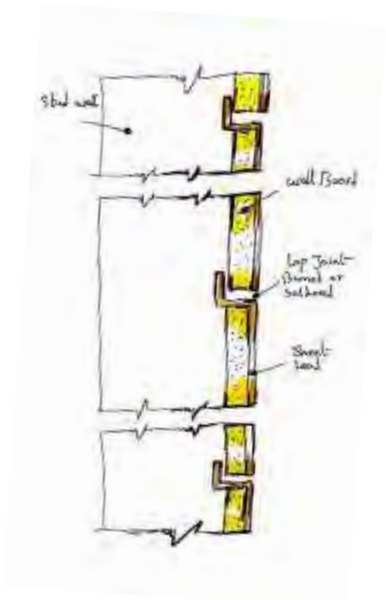


Figure 43: Horizontal boards Attach.

In addition to that, the sheet at the floors and ceiling supposed to extend around the corners and burned or soldered to the surface sheet. Also, the lead sheet should extend to the door frame to prevent the penetration (29).

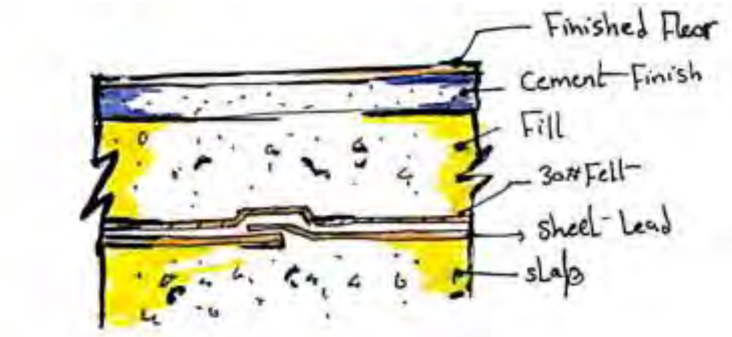


Figure 44: Floor details.

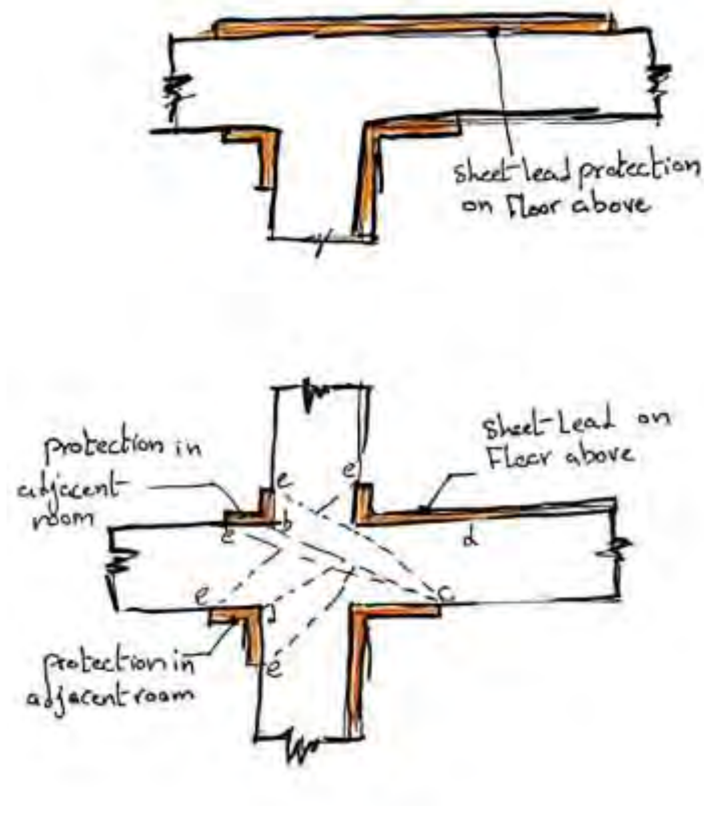


Figure 45: slabs/floors protection.

Important points in installation:

- The ceiling lining should be extended sufficiently to prevent passing rays through gaps between the lead on the wall and that applied for ceiling protection.

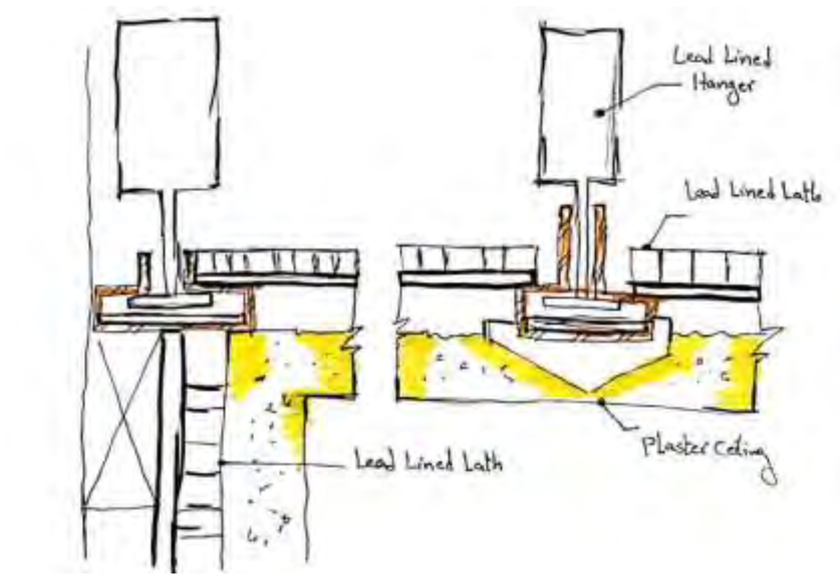


Figure 46: suspended ceiling with wall.

- Extend the lead sheet up in each wall for minimum 2 inch in case of covering floor with lead.

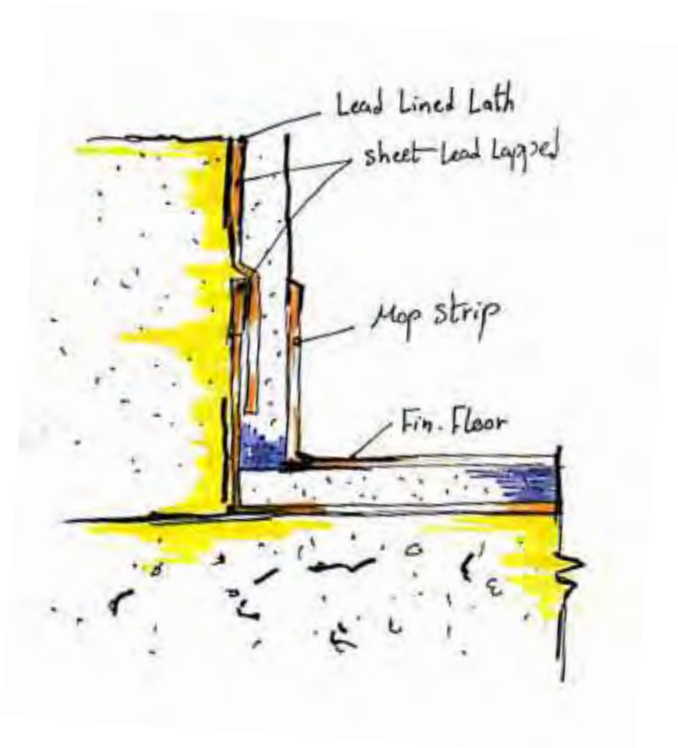


Figure 47: wall with floor details.

- Extend the lead sheet around the corner with minimum 2 inch.

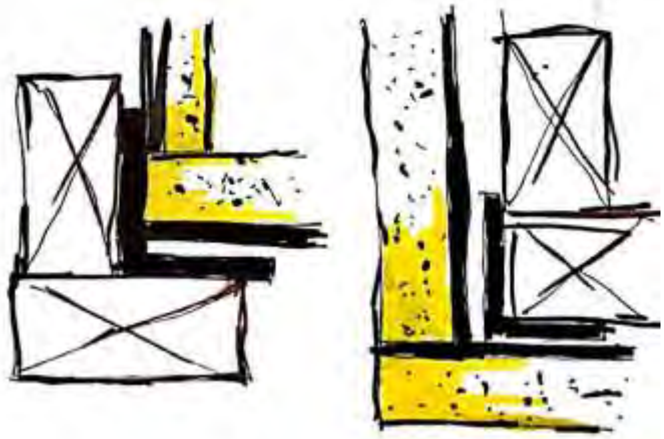


Figure 48: Corner covering.

- The amount of shielding in the door should be equal to the amount of shielding in the wall.

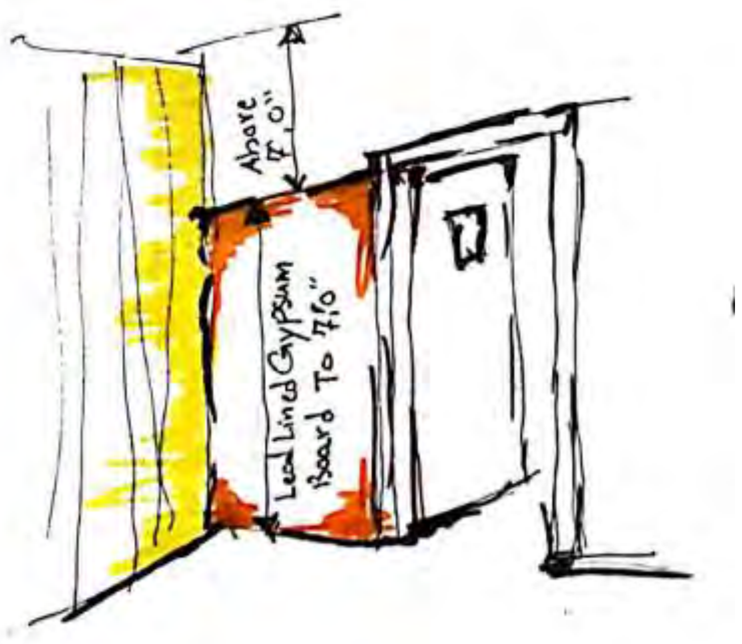


Figure 49: Lead height.

- Should make fit close with lead or lead laminate, apply it to the side of the door closest to the wall shielding in case of shielding door.
- When ventilation is required in either wall or doors, should use light proof louvers of solid lead and construct it in inter-locking lead channel with the same thickness of lead in surface.
- In case of applied duct work, should the duct enter the room well away from the direct rays of useful beam or enter near to ceiling or corners to minimize the shielding requirements. (29)
- There is three methods to lead laminated plywood :-

  1- In Figure 49, 'a batten is fastened on top of a lead strip, which is then turned up around the sides of the batten. The batten is fastened to plugs in the wall, at the minimum number of points to ensure secure fastening' (29).

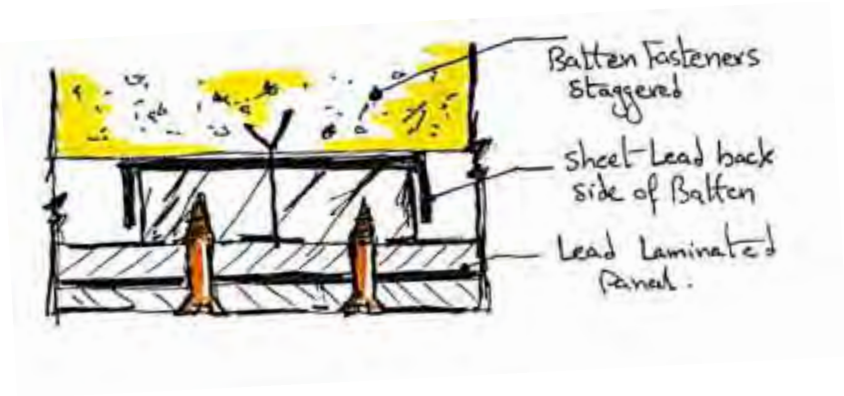


Figure 50: methods number 1.

2- In Figure 50, 'the laminated panels are directly fastened to plugs in the wall, with the joints and fasteners covered by a batten, made from the laminate material, which is glued into place' (29).

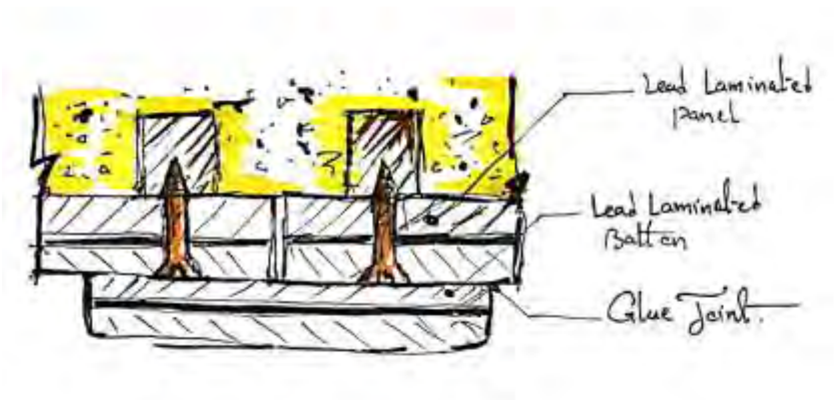


Figure 51: methods number 2.

3- Figure 52,' illustrates a third method where a wooden batten is placed over the joints and fasteners, and is then fastened through the laminated panels into plugs in the wall. The wooden batten is then covered with a strip of lead sheet, which is fastened along its edges to complete the shielding' (29).

Figure 52: methods number 3.

2.6.2 MRI rooms: -

Before the shielding:

Following points should be implemented before installation of the MRI machine and the room shield:-

- Every site should be evaluated for (EMI: Electromagnetic Interference) and vibration prior to finalization of the site.
- EMI usually occurred by elevators, electrical distribution within the building, car parking, roads and subways.
- Using Galvanized steel, Aluminium, Silicon steel or low carbon steel could be useful with considering a proper eddy current shielding effect by wielding or soldering.
- In case of (EMI) issues, the (MACS: Magnetic active compensation system) should be used, where this system measure EMI fluctuations and generate a balancing field, so the MRI does not notice the EMI.
- MRI is so sensitive to vibration, so the vibration test should be done in early step.
- As soon as decided which MRI system will be used, starts with the - 5 - gauss zone and implement it in plan. (30)

Figure 53: 5-gauss zones.

Shielding:

RF (Radio frequency) shielding is required for every MRI system. Therefore, should check out with manufacturer about the MRI system characteristics and confirm the specific requirements. For example:

9.8 MHz....0.23 T	63.9 MHz...... 1.5T
12.7 MHz.....0.3 T	127.8 MHz ... 3.0 T
15.0 MHz...0.35 T	200.2 MHz ... 4.7 T
42.6 MHz.....1.0 T	400.0 MHz.....9.4 T

However, most of manufacturers require 100 dB of RF shielding Attenuation. (30)

Types of shielding:-

There are three types of shielding in MRI rooms.

Following the three types:-

1- Monolithic copper, it is RF shielding made of copper sheeting wrapped around wood frames bolted together and form wall and ceiling. This is the common system, which is lighter and easy to modify, and provide permanent RF shielding.

2- Cell type, it is plywood laminated on both sides with copper, galvanized steel or aluminium. This system could create shimming problems and it is heavier than previous one.

3- Pan-form, it is entirely a metal system, where the metal is bolted together to form the walls, ceiling and floor. Therefore, this system can utilize galvanized steel, stainless steel or Aluminium. Also, this system cannot be modified on site (30).(see appendix)

Figure 54: Types of shielding MRI room, from left to right.

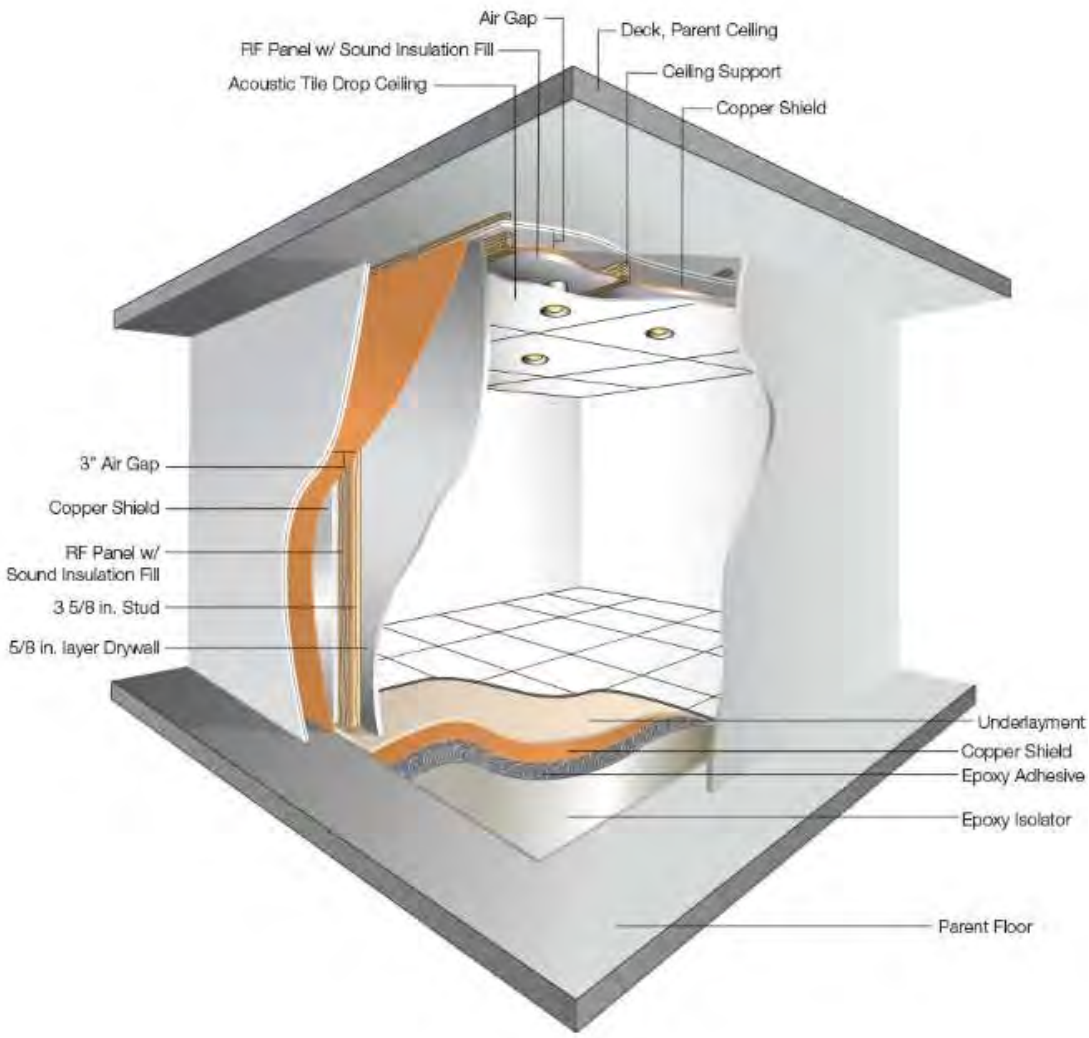


Figure 55: 3D MRI room shielding layer.

RF Flooring:

There are three types of RF flooring,

- Monolithic copper, this type requires a normal 1 inch build-up with moisture resistant, and it needs a cement underlayment finishing.

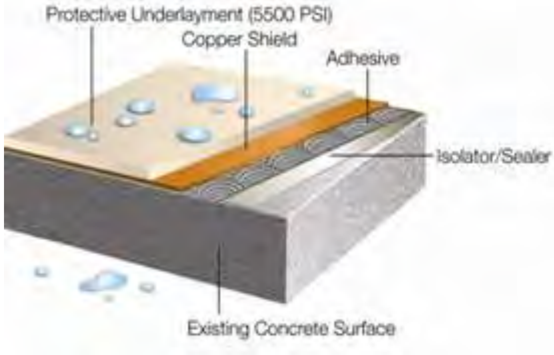


Figure 56: Monolithic copper floor type.

- Modular cell type floor, it is a panel system requiring build-up of 1 1/8 inch to 1 3/8 inch with identical construction like that in cell wall and ceiling panels. It consists of wood core with laminated metal on both sides of the woods. Therefore, the vapour barrier is placed on the floor to isolate the shield from the ground, also the finished flooring could be installed directly on top of the cell floor panels.

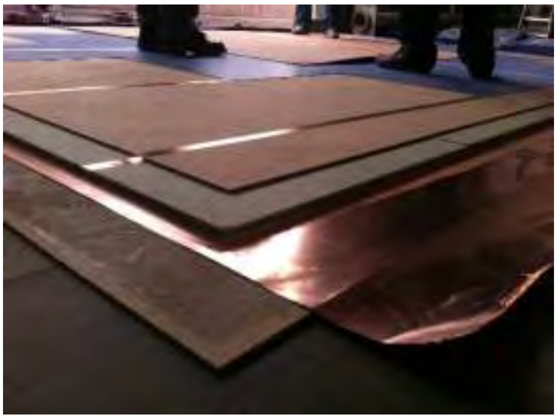


Figure 57: Modular cell type floor.

- The pan-form floor: is a construction consists of metal with pan-shaped panels bolted together. Usually, this system is done with a concrete underlayment, however, this system is not recommended if the MRI had trenches within (30).

RF Filters and wave guides:-

Usually there is a complex box closed to MRI system, this box is the first step for everything comes from outside the MRI room. Therefore, this box has two functions: -

- Create penetration points for electrical power for lighting and MRI system, and carrying the data cables.

- Wave guides allow a fluid flow into MRI room such as air-conditioning, water and medical gasses.

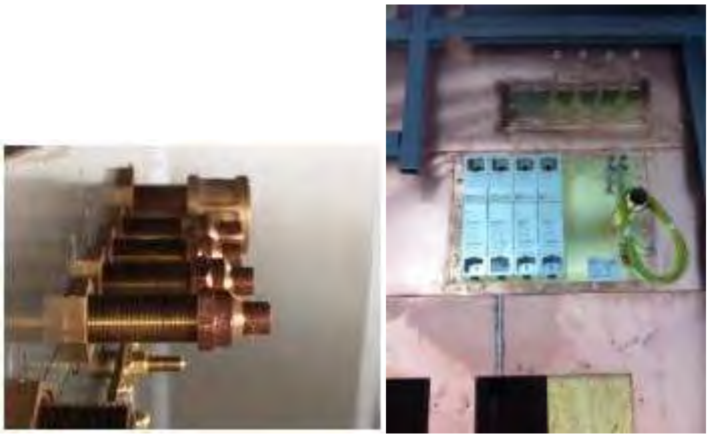


Figure 58: RF-Filter.

EMI windows - MRI rooms:-

In case of MRI room, glass windows are required, which can provide a good visibility and excellent shielding effectiveness. But in case of MRI it is different than X-Ray, where radiation and lead could not be the proper solution for the glass. Nevertheless, in case of MRI glass windows, it requires EMI glass windows or optical filters windows. (30)

Construction of the glass window:-

It consists of high quality woven wire mesh bonded between glass layers in full clean room conditions. However, the lamination process uses index matched adhesive providing a light transmission and reduce of electromagnetic interference. Also, the lamination will improve the thermal and the acoustic where MRI system produces sufficient noise. Therefore, two laminated windows are glared in units with optimal thermal, and then the extended mesh is folded into the frame and contacted between copper flange and the shielded wall. (31)

Figure 59: MRI glass window.

Chapter 4

3. Operation theatre/rooms

Figure 60: O.R operation room.

Operation rooms –hygienic requirements:-

Looking through the previous chapters, the hygienic requirements of operation rooms not that far away from previous requirements, but that it is Operation Theatre! That means the materials will be used supposed to be of higher requirements, grades, and the ratio of any infection or error should be closed to zero. Therefore, looking through all the newest facade-modular systems installed in operation rooms, we could recognize some basic materials used in each room such as; stainless steel ,silicon, Corian floor and impact or glass panels .For that reason, we will start this chapter by discussing stainless steel types, since usually is the primary structure for modular system.

3.1 Stainless steel:

Hygiene is the most important requirement in sanitation process and hospital constructions. Also, “easy to clean” considered as important requirement of the material that is used in hospitals, especially in the operation theatre, where stainless steel has a proven record of success in these areas.

The easy cleaning ability of stainless steel makes it the first choice for strict hygienic conditions. Also, corrosion resistance, formability and strength are important benefits to fabricators and users in the sector. The stainless steel properties of corrosion resistance, durability, economy and aesthetics made it accepted in various applications. In addition, it helps to minimize the damage and risk to the human health, where during sterilization process it is more active with water, soap or detergents to disinfection or prevent spores colonization. For example, in food service equipment, stainless steel resists aggressive fluids, abrasive materials and impacting utensils. Furthermore, stainless steel is basically inert to most of the acids/alkalis where these two materials usually attack the surface within some fluids or gases and lead to become a place of bacteria. For that reason, these characteristics are the worst chance for bacterial infection.

Besides the above, the following additional properties of stainless steel are:-

-Stainless steel is mechanically resistant.

-Stainless steel can be maintained for decades.

- It has self-healing surface (self-healing: the ability of materials to treat the light scratches).

-It is more formable comparing with other metallic materials.

-Stainless steel can withstand fire for a long time and does not buckle easily.

-Stainless steel is excellent cryogenic and has high temperature oxidation resistance.

- Stainless steels are generally corrosion resistance. (32)

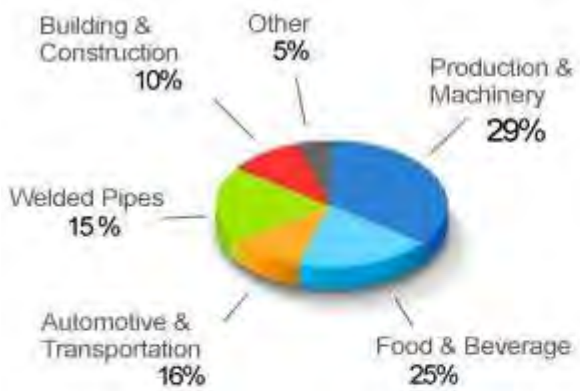


Figure 61: Applications categories of stainless steel.

Stainless steel groups:-

Over the years, and since the start of stainless steel development, the number of stainless steel grades has increased dramatically. Therefore, stainless steel has traditionally been divided into categories, depending on their micro structure at room temperature. Nevertheless, here we will divide stainless steel into four main groups:

Ferritic, Martensitic, Ferriticaustenitic, and Austenitic stainless steel. Later on, we will explain which stainless steel grade is used in hospitals, Operation Rooms and belongs to which home group.

	Type of stainless steel			
Property	Ferritic	Martensitic*	Duplex	Austenitic
Density (g/cm^3)	7.7	7.7	7.8	7.9–8.1
Elastic modulus (GPa or kN/mm^2)	220	215	200	190–200
Thermal expansion ($\times 10^{-6}$/°C) 200–400°C	11	12	15	17–18
Thermal conductivity (W/m°C) 20°C	30	30	12-15	15
Heat capacity (J/kg°C) 20°C	460	460	500	500
Resistivity (μΩm) 20°C	0.6	0.6	0.8	0.8
Ferromagnetism	Yes	Yes	Yes	No#

Figure 62: Typical physical properties for various stainless steel categories.

1. Ferritic Stainless Steel:-

The standard ferritic grade consists of chromium (11.2-19%) and a little percentage of nickel. Because of nickel, which is the most expensive alloying element, Ferritic grade stainless steel is more price stable compared to stainless steel with high nickel content. Sometimes molybdenum is added to improve corrosion resistance properties, Also, adding niobium or titanium improves the welding ability. However, the ferritic group referred to as Cr-steels, are magnetic due to ferritic micro structure.

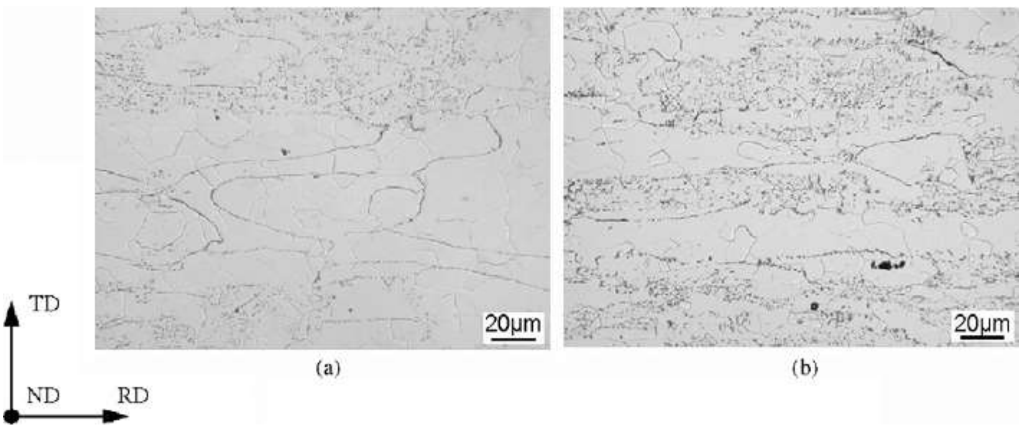


Figure 63: Microstructure of the ferritic stainless steel X6Cr17 in flat sections; (a) center layer (s = 0.0); (b) subsurface layer (s = 0.8).

2. Martensitic:-

The martensitic group has higher carbon content compared with other groups, which is required to increase the stainless steel hardenability and strength. Also, sometimes nitrogen is added to improve the strength. In addition, sulphur is added sometimes to improve the machinability. In general, martensitic group is magnetic and hard enable.

4.Ferritic – austenitic:-

Ferritic – austenitic is a group with balance of approximately 50% ferrite and 50% austenitic. This kind of combination contributes to the high strength and high resistance to stress and corrosion cracking. The components of this group are chromium (20.1-25.4%), Nickel (1.4-7.0%) , Molybdenum (0.3-4.0%) and nitrogen is added sometimes to improve the corrosion resistance and increase strength. The Ferritic – austenitic group is magnetic due to the ferrite content.

4. Austenitic:-

The austenitic is the largest group of stainless steel and can be divided into five sub- groups, (Cr-Mn grades, Cr- Ni grades, Cr-Ni-Mo grades, high performance austenitic grades and high temperature austenitic grades). In general, Austenitic group is excellent corrosion resistance, has good formability and welding ability. Also, Austenitic grades are non- magnetic and have good strength impact at low temperatures.

4.1 Cr- Ni grades:-

The Cr- Ni grades are mainly alloyed with chromium and nickel and no molybdenum. Some grades are alloyed with nitrogen to improve the strength, or alloyed with sulphur to improve machinability.

4.2 Cr-Mn Grades:-

In the Cr-Mn grades, the nickel content is decreased by replacing some of it with manganese and nitrogen, so the chemical composition will be around 17%Cr, 4%Ni and 7%Mn. This grade has almost the same characteristic but with high strength.

4.3 Cr-Ni-Mo grades:-

In this grade, the corrosion resistance is increased by alloying with molybdenum (2-3%) to be acid-proof stainless steel. Therefore, the composition of grades will nearly be: Chromium content 17% and nickel content 10-13%, plus the molybdenum content.

4.4 High Performance austenitics:-

The high performance austenitics were designed to be used in very demanding environments. They have higher alloying content with chromium 17-25%, nickel 14- 25% and molybdenum 3-7% with nitrogen content to improve corrosion resistance and strength. However, some grades alloyed with copper to improve the resistance to certain acids.

4.5 High temperature austenitics:-

The high temperature austenitic stainless steel is designed to be used at temperature exceeding 550°C. Furthermore, this steel designed to prove a long service life in dry gases at high temperature (800-1150°C).This kind of grades is good oxidation resistance rather than resistance to corrosion. The composition of high temperature austenitic grades is: chromium content (17-25%), nickel (8-20%), and no molybdenum, however, silicon is added sometimes to increase the oxidation resistance. (33)

Stainless Steel

Stainless Types	Typical Chemical Composition %				Characteristics	Typical Applications
	Cr	Ni	C	Other Significant Elements		
Austenitic Stainless Steels						
201	16	3.5-5.0	.06	Mn – 6-7.5	Low nickel, high work hardening	Hose clamps, cookware
NITRONIC® 30	16	2.5	.02	Mn – 8.5, N – .17	High strength, abrasion resistance, good formability	Hose clamps, truck and bus frames, bulk solids handling equipment, coal buckets and hopper cars
301	17	7	.10		High strength, high work hardening	Wheel covers, springs, hose clamps, food processing equipment
304	18	8	.06		Multipurpose	Food equipment, tubing, architectural trim
304L	18	9	.02		Low carbon minimizes carbide precipitation during welding	Welded parts and other 304 applications
309S	22	12.5	.05		Oxidation resistant	Heating elements, furnace parts
316	16.5	10.5	.05	Mo – 2	Pitting corrosion resistance	Heat exchangers, chemical equipment, marine applications
316L	16.5	10.8	.02	Mo – 2	Low carbon minimizes carbide precipitation during welding	Welded Type 316 applications
321	17	9.5	.02	Ti – 5XC min.	Titanium stabilized	Heat exchangers to intermediate temperatures, aircraft

Figure 64: Table of Austenitic stainless steels –examples applications.

3.1.2 Stainless steel 304 and 316:-

There are more than 250 different grades of stainless steel .These various grades of stainless are divided into five major families as explained before .However, in case of modular system in hospitals, and according to the health testing organization, there are two grades of stainless steel that are accepted, stainless steel 304 and 316 or (304L and 316L), where 304L or 316L means extra-low carbon version of type 304/316, which minimizes harmful carbide precipitation due to welding.

In principle, stainless steel 304 and 316 look very similar. Both of them are related to austenitic group, and both are non-magnetic. Also, each of these stainless steel grades will resist corrosion and are easily formed and fabricated. However, the difference between both of them is the addition of molybdenum to 316. Therefore, molybdenum increases the corrosion resistance of the material and making it ideal for more acidic environments. In addition, stainless steel 304 is less expensive and considered to be one of the most widely used austenitic stainless steel, where stainless steel 316 is the most required grade in applications within sea water environments, marine applications, surgical instrumentation and operation rooms, as modular system for all. (34)

304/316 Fabrication:

Grades 304 and 316 have very good formability, their combination of low- yield strength and high elongation permits successful forming of even complex shapes. In addition to that, the 304/316 stainless steel are common available in thickness range from 0.38 cm to 1.9 cm, and widths up to 121.9 cm depending on the thickness. (35)

Physical Properties		304/304L	316/316L
Density		0.29lb./in^3	0.29lb./in^3
		8.03g/cm^3	7.99g/cm^3
Electrical Resistivity, microhm-in (microhm-cm)	68°F (20°C)	28.4 (72)	29.4 (74)
	1200°F (659°C)	45.8 (116)	–
Specific Heat, BTU/lb./°F. (kJ/kg•K)	32 - 212°F (0-100°C)	0.12 (0.50)	0.12 (0.50)
Thermal Conductivity, BTU/hr/ft/°F (W/m•K)	at 212°F (100°C)	9.4 (16.2)	9.4 (16.2)
	at 932°F (500°C)	12.4 (21.4)	12.4 (21.4)
Mean Coefficient of Thermal Expansion, in/in/°F			
32 - 212°F (0 - 100°C)		9.4×10^{-6}(16.9)	8.9×10^{-6}(16.0)
32 - 600°F (0 - 315°C)		9.6×10^{-6}(17.3)	9.0×10^{-6}(16.2)
32 - 1000°F (0 - 538°C)		10.2×10^{-6}(18.4)	9.7×10^{-6}(17.5)
32 - 1200°F (0 - 649°C)		10.4×10^{-6}(18.7)	10.3×10^{-6}(18.5)
32 - 1500°F (0 - 871°C)		–	11.1×10^{-6}(19.9)

304/304L – 316/316L

Magnetic Permeability, H = 200
Oersteds, Annealed - 1.02 max

304/304L Modulus of Elasticity, ksi (MPa)
28.0×10^3 (193×10^3) in tension
11.2×10^3 (78×10^3) in torsion

316/316L Modulus of Elasticity, ksi (MPa
28.0×10^3 (193×10^3) in tension
11.2×10^3 (77×10^3) in torsion

304/304L Melting Range, °F (°C) – 2550 - 2650 (1399 - 1454)

316/316L Melting Range, °F (°C) – 2500 - 2550 (1371 - 1399)

Figure 65: Table of 304/304L-316/316L stainless steels –physical properties.

Chemical Composition	304	304L
Carbon	0.08 max.	0.03 max.
Manganese	2.0 max.	2.0 max.
Phosphorus	0.045 max.	0.045 max.
Sulfur	0.030 max.	0.03 max.
Silicon	0.75 max.	0.75 max.
Chromium	18.0 - 20.0	18.0 - 20.0
Nickel	8.0 - 12.00	8.0 - 12.0
Nitrogen	0.10 max.	0.10 max.
Iron	Balance	Balance
	316	**316L**
Carbon	0.08 max.	0.03 max.
Manganese	2.0 max.	2.0 max.
Phosphorus	0.045 max.	0.045 max.
Sulfur	0.03 max.	0.03 max.
Silicon	0.75 max.	0.75 max.
Chromium	16.0 - 18.0	16.0 - 18.0
Nickel	10.0 - 14.0	10.0 - 14.0
Molybdenum	2.0 - 3.0	2.0 - 3.0

Figure 66: Table of 304/304L-316/316L stainless steels –chemical composition.

3.2 Protection solution – Present:-

Figure 67: O.R operation room.

Recently, there are lots of companies in healthcare field who developed a various solutions to satisfy the Operation Room (O.R.) requirements, and make the solutions that fulfil the hygienic grades and requirements according to the healthcare organization and ministry of health, depending on the regulations of the countries. Therefore, in this chapter we will explain HT-Group system, beginning with substructure and the wall panel systems (metal – glass- impact).

3.2.1 Wall substructure:-

"The substructure of the wall system facing formwork is fitted in front of the brickwork as a non-load-bearing interior wall. Fitting is carried out using vertical C-profile supports which are screwed to the floor rails at the distance of the grid or according to the outline drawing. Standard height is 4 meters; grid spacing is up to 1.25 meters. The connection to the bare ceiling is seamless. Cross beams between the vertical profile supports are used for the fixing of additional installations. Openings for doors and windows are already taken into account during the planning and building phase."(37)

Figure 68: Wall substructure 3D-simulation.

Figure 69: Wall substructure.

According to the architecture design and hospital plan, there are two types of substructure, first the face formwork substructure fixed directly to the brickwork as we show in figure 74, second, in case of the area of hospital is divided into two operation rooms, or using the wall of room as barrier wall between two functions, then we need to use double wall panel system as we will mention later.

Face formwork substructure:

DIMENSIONS	
Building shell height	approx. 4000 mm
Profile supports	C-profile min. 40 x 60 x 2 mm
Floor and ceiling rail	C-profile min. 60 x 60 x 1.5 mm
Grid spacing	max. 1250 mm
Prefabricated wall thickness	min. 80 mm
Installation flexibility	approx. 60 mm

TECHNICAL DATA	
Floor and ceiling rail	galvanised sheet steel C-profile I the floor rail must be levelled to the screed/bare floor
Profile supports	galvanised sheet steel C-profile I the side and lower connections are rigid I the upper connection to the bare ceiling is sling

SPECIAL FITTINGS I SUPPLEMENTARY ITEMS	
Cross beams	galvanised sheet steel C-profile I for the fixing of additional installations to the building structure
Mineral wool	60 mm thick I for increased fire and noise protection regulations

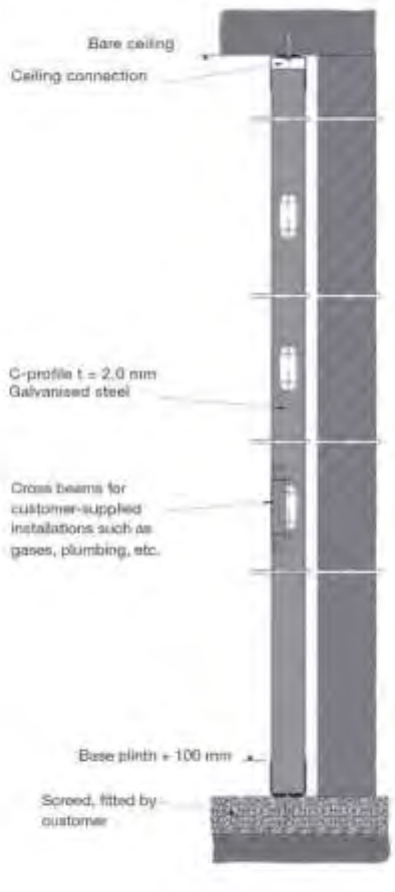


Figure 70: Wall substructure.

Double wall panel substructure:

It is used in case of adjusting the architecture design, for example, into two rooms, or to make a barrier between the operation room and corridor. Therefore, the double wall substructure could fit these requirements, with applying galvanized steel sheet C-profile as substructure wall to hang the panels on it later in dimensions of 40*60-210*2 mm.

DIMENSIONS	
Building shell height	approx. 4000 mm
Profile supports	C-profile 40 x 60–210 x 2 mm
Floor and ceiling rails	C-profile 60–250 x 60 x 1.5 mm
Grid spacing	max. 1250 mm
Prefabricated wall thickness	100–150 mm I 200–250 mm
Installation flexibility	60–110 mm I 160–210 mm

TECHNICAL DATA	
Floor and ceiling rail	galvanised sheet steel C-profile I the floor rail must be levelled to the screed/bare floor
Profile supports	galvanised sheet steel C-profile I the side and lower connections are rigid I the upper connection to the bare ceiling is sling

SPECIAL FITTINGS I SUPPLEMENTARY ITEMS	
Cross beams	galvanised sheet steel C-profile I for the fixing of additional installations to the building structure
Mineral wool	60 mm thick I for increased fire and noise protection regulations

Figure 71: system informations.

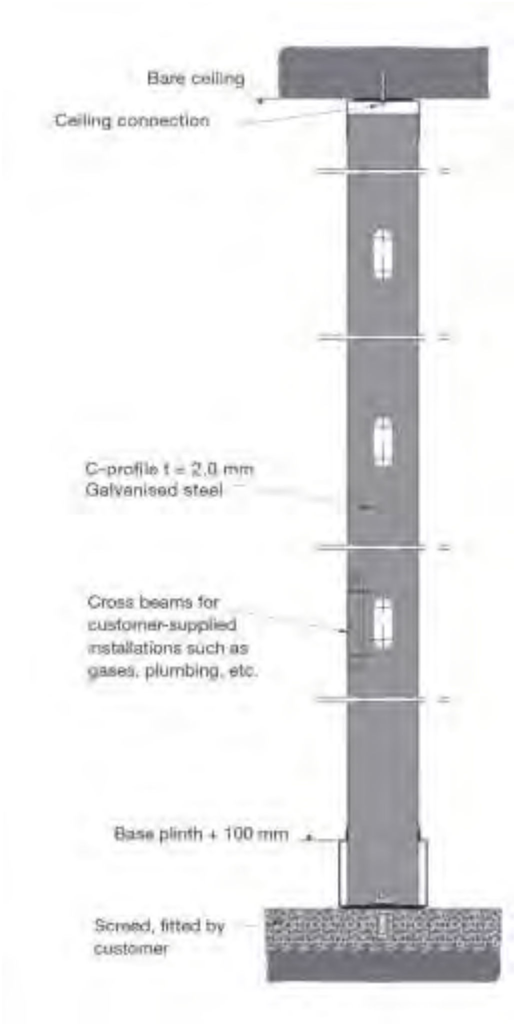


Figure 72: Wall substructure.

Wall panels:

Wall panels are divided into three kinds of panel systems (metal - glass- impact panels), where each of them had different grades of resistance and classification. Also, most of the time, choosing the system is affected by the price value. For example, the glass panels considered as expensive once compared with metal and impact panels. Also, the function of the room is another concern, where most of the time it is preferred to install the impact panels system in corridors because of its flammable resistance and damage resistance. (38)

3.2.2 Metal:

Figure 73: O.R metal panels covered.

The surface of metal wall panels is microscopically flat and free of pores, resistant against living organisms and chemical substances, as well as resistant against all general hospital detergents and disinfectants. Depending on hospital requirements and demanded quality, steel sheet or stainless steel is applied on the panels. Therefore, the wall panels are installed on to the substructure in modular construction with 6 mm joints. This allows for a subsequent removal and re-installation of each individual panel in order to enable later installation work, changes to the installations, or repair work without any great effort. Therefore, Operation Room (O.R.) downtime is reduced. Fire, noise, and x-ray protection are integrated according to hospital requirements and O.R. features. The 20 mm thick panels can be individually positioned, are room-high, and have a maximum panel width of 1.25 mm. (38)

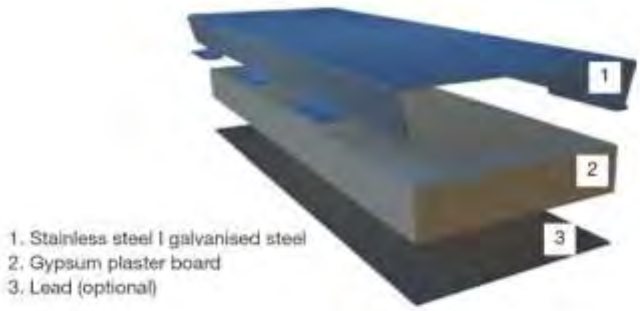


Figure 74: O.R metal panels components.

In point of fact, there are two kinds of materials used in metal panels system; stainless steel and galvanised steel. Therefore, the point of picking the materals depends on healthcare regulation in some places and the project cost as well .

DIMENSIONS	
Panel width	max. 1250 mm
Panel height	room-high
Panel thickness	approx. 20 mm

TECHNICAL DATA		
Material (formwork)	stainless steel (Mat. no. 1.4301)	galvanised steel
Material (core)	18 mm fire resistant gypsum plaster board	18 mm fire resistant gypsum plaster board
Surface		
standard	ground	white pre-coated RAL 9010
optional	powder-coated	powder-coated
Colour (powder-coated)		
standard	according to colour chart	white RAL 9010
optional		according to colour chart

STRUCTURE	
Wall covering	approx. 20 mm thick I comprising 1 mm of stainless/galvanised steel with fire resistant gypsum plaster board glued to the rear
Lead insert	1–2 mm of lead glued to the rear of the fire resistant gypsum plaster board
Weight force	without additional cross beams of up to 600 Nm (60 kg/m^2)

Figure 75: stainless steel & galvanized steel data.

Stainless steel wall panel:

The stainless steel wall facing formwork of the metal wall systems is fitted in front of the brickwork as a non-load-bearing interior wall. Fitting is carried out using individual panels in modular construction with a joint width of approx. 6 mm. The design of the partition system provides for the subsequent removal and re-installation of each individual panel in order to enable later installation work, changes to the installations, or repair work without any great effort. (38)

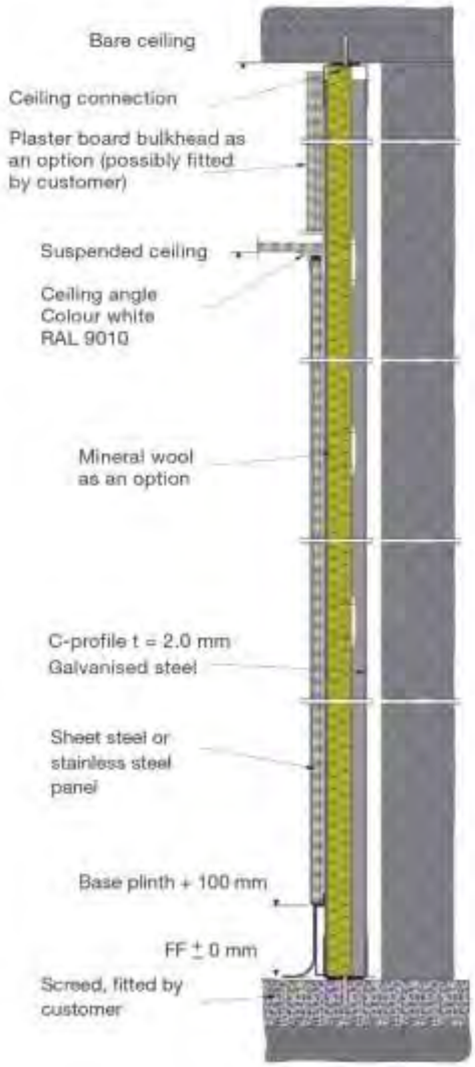


Figure 76: stainless steel wall panel.

DIMENSIONS	
Clear room height	approx. 3000 mm
Panel width	max. 1250 mm
Facing formwork	from 100 mm thickness
Joint width	approx. 6 mm
Panel height	to the suspended ceiling
Base plinth height	100 mm

WALL COVERING	
Wall panel	approx. 20 mm thick I comprising 1 mm of stainless steel (Mat. no. 1.4301) with fire resistant gypsum plaster board glued to the rear I weight force without any additional cross beams of up to 600 Nm (60 kg/m^2)
Surface (wall panel)	ground I powder-coated
Base plinth	galvanised sheet steel I 1.5 mm thick I with raised PVC floor covering
Ceiling edge angle	white RAL 9010 powder-coated extruded aluminium profile
Joint profile	silicone profile

SUBSTRUCTURE	
Floor and ceiling rail	min. 1.5 mm thick galvanised sheet steel C-profile 60 x 60 mm I the floor rail must be levelled to the screed/bare floor
Profile supports	2 mm thick galvanised sheet steel C-profile 40 x 60 mm
Cross beams	2 mm thick sheet steel I for the fixing of additional installations to the building structure

SPECIAL FITTINGS I SUPPLEMENTARY ITEMS	
Ceiling bulkhead	with gypsum plaster boards (fire protection)/with gypsum plaster boards (hygiene) I installation from top edge of the suspended ceiling to bottom edge of the bare ceiling
Fire protection	fitting in accordance with the demands of EI 30 and EI 60
X-ray protection	1–2 mm lead inserts glued to the rear of the fire resistant gypsum plaster board

Figure 77: stainless steel wall panel data.

Galvanized steel panel:

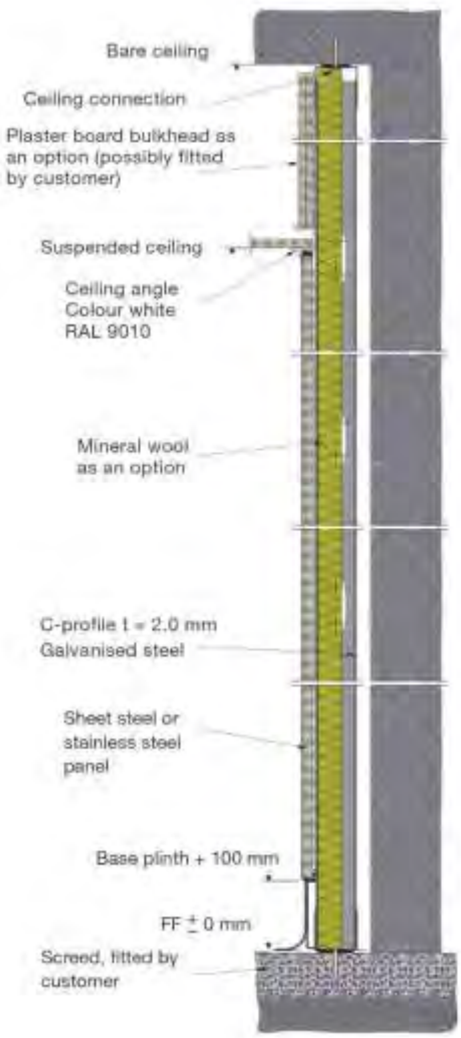


Figure 78: Galvanized steel wall panel.

DIMENSIONS	
Clear room height	approx. 3000 mm
Panel width	max. 1250 mm
Facing formwork	from 100 mm thickness
Joint width	approx. 6 mm
Panel height	to the suspended ceiling
Base plinth height	100 mm

WALL COVERING	
Wall panel	approx. 20 mm thick I comprising 1 mm of galvanised steel with gypsum plaster board glued to the rear I weight force without any additional cross-beams of up to 600 Nm (60 kg/m²)
Surface (wall panel)	powder-coated
Base plinth	galvanised sheet steel I 1.5 mm thick I with raised PVC floor covering
Ceiling edge angle	white RAL 9010 powder-coated extruded aluminium profile
Joint profile	silicone profile

SUBSTRUCTURE	
Floor and ceiling rail	min. 1.5 mm thick galvanised sheet steel C-profile 60 x 60 mm I the floor rail must be levelled to the screed/bare floor
Profile supports	2 mm thick galvanised sheet steel C-profile 40 x 60 mm
Cross beams	2 mm galvanised sheet steel I for the fixing of additional installations to the building structure

SPECIAL FITTINGS I SUPPLEMENTARY ITEMS	
Ceiling bulkhead	with gypsum plaster boards (fire protection)/with gypsum plaster boards (hygiene) I installation from top edge of the suspended ceiling to bottom edge of the bare ceiling
Fire protection	fitting in accordance with the demands of EI 30 and EI 60
X-ray protection	1–2 mm lead inserts glued to the rear of the gypsum plaster board

Figure 79: Galvanized steel wall panel data.

3.2.3 Glass panels:

Aesthetics and functionality are combined in the material of glass and set new standards of hygiene as well as generate a unique atmosphere in all types of clean rooms. The modular glass room system provides the highest hygiene standards. The surface of the glass wall is microscopically flat and free of pores, resistant against living organisms and chemical substances, resistant against all common hospital detergents and disinfectants. The material properties ensure a perfect environment for both the patients and staff. Fire, noise, and x-ray protection are integrated into the wall panels according to hospital requirements and O.R. features. Because a single-pane safety glass is applied onto a non-flammable support plate, the glass system is enormously shockproof and solid. (39)

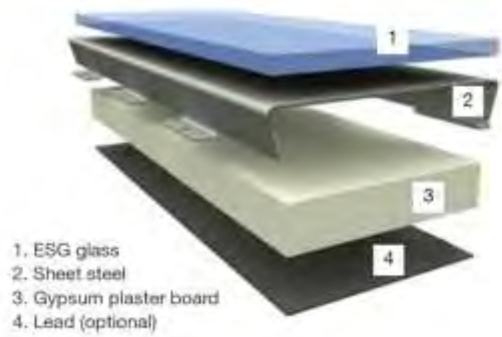


Figure 80: O.R glass panels covered.

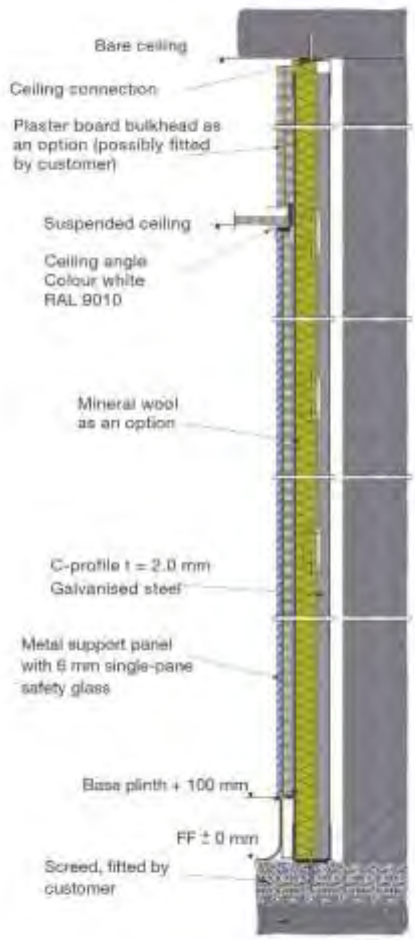


Figure 81: O.R glass wall panels.

DIMENSIONS	
Clear room height	approx. 3000 mm
Panel width	max. 1250 mm
Facing formwork	from 100 mm thickness
Joint width	approx. 7 mm
Panel height	to the suspended ceiling
Base plinth height	100 mm

WALL COVERING	
Wall panel	approx. 27 mm thick I comprising 6 mm single-pane safety glass + paint coating + sheet steel base panel
Colour design	single-pane safety glass with choice of colour according to colour chart
Ceiling edge angle	white RAL 9010 powder-coated extruded aluminium profile
Base plinth	stainless steel plinth I raised PVC floor covering
Joint profile	silicone profile

SUBSTRUCTURE	
Floor and ceiling rail	min. 1.5 mm thick galvanised sheet steel C-profile 60 x 60 mm I the floor rail must be levelled to the screed/bare floor
Profile supports	2 mm thick galvanised sheet steel C-profile 40 x 80 mm
Cross beams	2 mm thick sheet steel I for the fixing of additional installations to the building structure

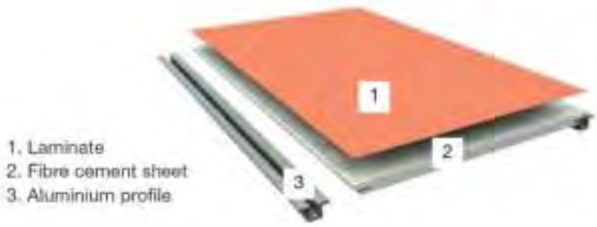
SPECIAL FITTINGS I SUPPLEMENTARY ITEMS	
Ceiling bulkhead	with gypsum plaster boards (fire protection)/with gypsum plaster boards (hygiene) I installation from top edge of the suspended ceiling to bottom edge of the bare ceiling
Fire protection	fitting in accordance with the demands of EI 30 and EI 60
X-ray protection	1-2 mm lead inserts glued to the rear of the fire resistant gypsum plaster board

Figure 82: O.R glass wall panel data.

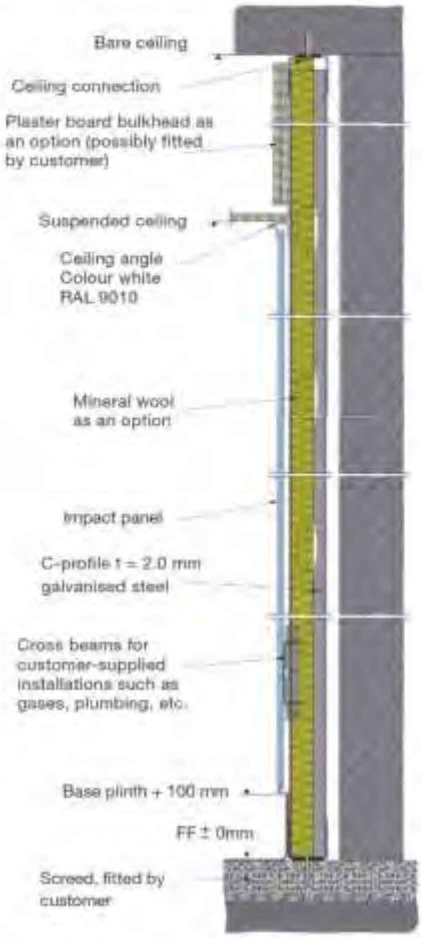
3.2.4 Impact panels:

Figure 83: O.R impact panels covered.

Impact wall panels are particularly suited for the designing of wall protection systems and room-high wall cladding. The panels comprise a non-flammable fibre cement sheet with a particularly resistant surface coating, e.g. a ceramic coating. Impact wall systems are frequently used in intensive care units (I.C.U.) or corridors, as well as in patient rooms, sanitary rooms, or staff rooms. Impact panels are screwed to the aluminium profiles. (40)



DIMENSIONS	
Clear room height	approx. 3000 mm
Panel width	max. 1200 mm
Facing formwork	from 100 mm thickness
Joint width	approx. 6 mm
Panel height	to the suspended ceiling
Base plinth height	100 mm



WALL COVERING	
Wall panel	approx. 12.5 mm thick shockproof fibre cement sheet
Coating	high-pressure laminate I ceramic coating I pure acrylate coating
Base plinth	Galvanised sheet steel I 1.5 mm thick I with raised PVC floor covering
Ceiling edge angle	white RAL 9010 powder-coated extruded aluminium profile
Joint profile	silicone profile

SUBSTRUCTURE	
Floor and ceiling rail	min. 1.5 mm thick galvanised sheet steel C-profile 60 x 60 mm I the floor rail must be levelled to the screed/bare floor
Profile supports	2 mm thick galvanised sheet steel C-profile 40 x 60–210 mm
Cross beams	2 mm thick sheet steel I for the fixing of additional installations to the building structure

TINGS I SUPPLEMENTARY ITEMS	
	with gypsum plaster boards (fire protection)/with gypsum plaster boards (hygiene) I installation from top edge of the suspended ceiling to bottom edge of the bare ceiling
	fitting in accordance with the demands of EI 30 and EI 60

Figure 84: Impact wall panel data.

3.3 Future Solution:-

<u>Black Silicon:</u>

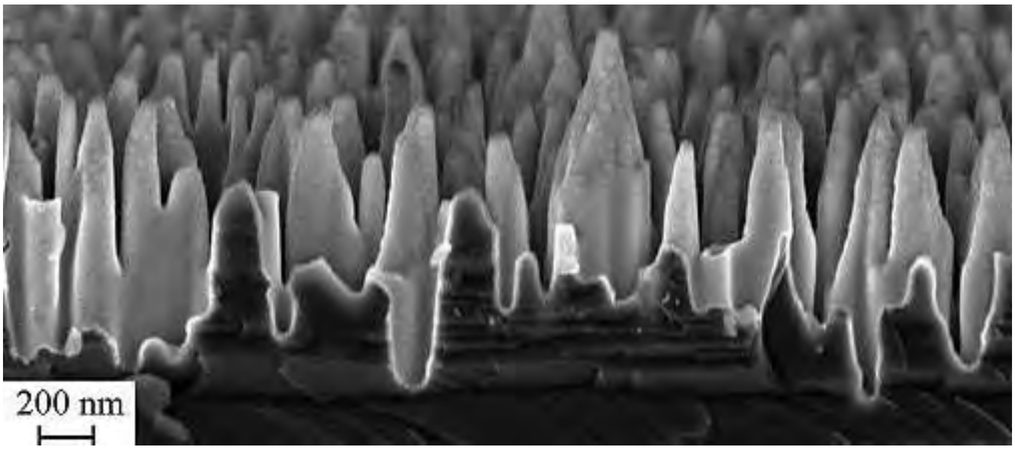


Figure 85: the spiky surface of black silicon- electron micrographs scan.

To keep up with the requirements of hospitals, black silicon could be a proper material for operation theatre application. “Black silicon (BSi) is silicon with a surface that has been modified to feature nano scale spike structures which give the material very low reflectivity.”(36)

According to the recent researches, it was found that spikes on black silicon surface can destroy a wide range of bacteria. Therefore, surface structures similar to black silicon can be found in nature. Researchers at Swinburne institute of technology, Australia, found that the wings of the cicada psaltoda claripennis could kill certain type of rod-shaped bacteria. Furthermore, the researchers were motivated to seek out other insects with similar spike-like surface architectures and they found that the wings of the diplacodes by bipunctata or (wandering percher dragonfly) where even more deadly, killing both rod- shaped and spherical bacteria.

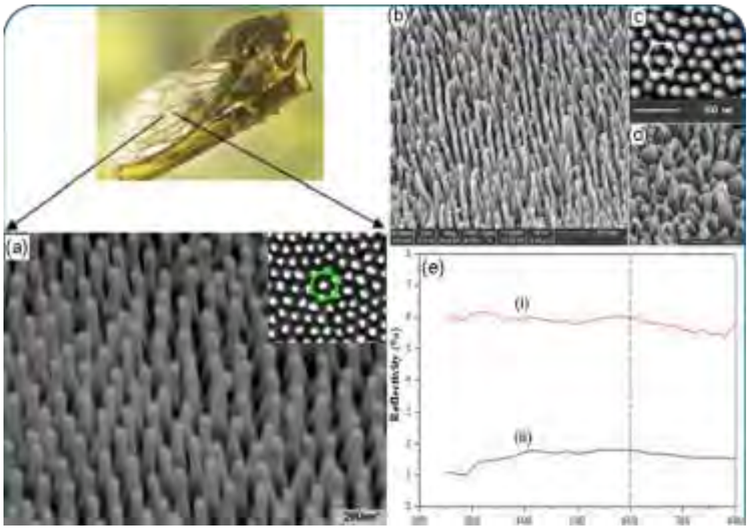


Figure 86: SEM images of a cicada wing.

Where (**a**) Large-scale perspective view. (**b**) Large-scale perspective view and (**c**) higher-magnification top view showing a hexagonal pattern. (**b**) and (**c**) were obtained after the PMMA film was heated at 90°C for 30 min. (**d**) Perspective view after the film was heated at 60°C for 30 min. (**e**) Wavelength dependence of the measured reflectivity of an un patterned flat PMMA film (**i**) and replicated PMMA film with nano-nipple arrays on the surface (**ii**).

Figure 87: The surface structure of black silicon is similar to the surface of the wings of the Wandering Dragonfly.

“This structure generates a mechanical bacteria killing effect which is unrelated to the chemical composition of the surface, say professor Crawford, who is Dean of the faculty of life and social sciences at Swinburne". (36)

In addition to that, the research endorsed that the black silicon have similar bacteria killing properties compared with wandering percher dragonfly wing, and both surfaces were found to be highly effective against bacteria. "Say proffessor crawford, they exhibited estimated average bacteria killing rates of up to 450,000 cells per minute of exposure for every square centimetre of available surface". (36)

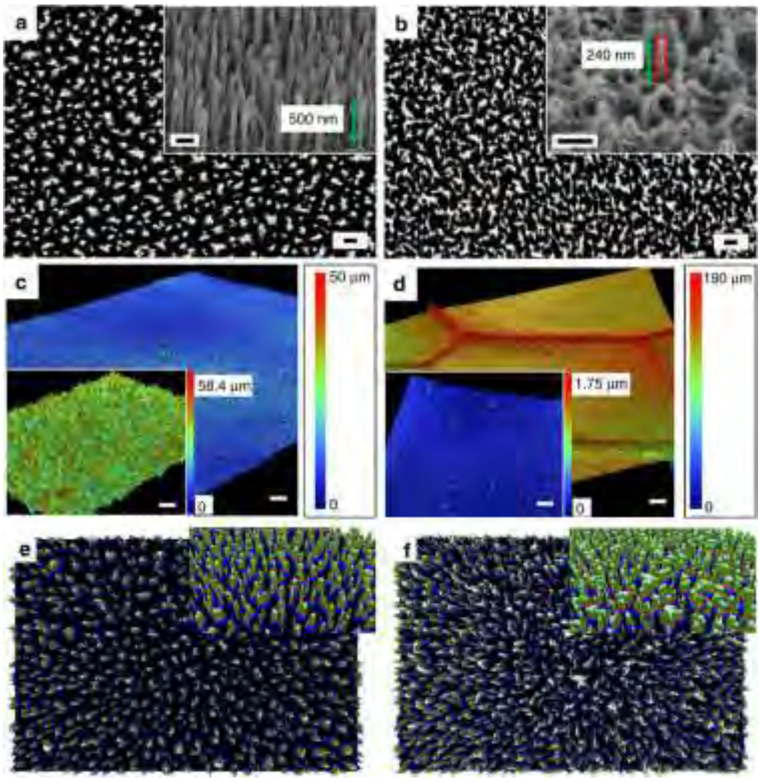


Figure 88: Scanning electron micrographs of the upper surface of BSi.

Where (**a**)BSi and (**b**) dragonfly forewings at × 35,000 magnification demonstrate the surface patterns of the two samples. Scale bars, 200 nm. Micrographs tilted at an angle of 53° (inset) show sharper nanopillars of black silicon distinct from one another and approximately twice the height of those of the dragonfly wing. Optical profilometry shows the nanoprotrusions of (**c**) bSi and (**d**) dragonfly forewings. Scale bars, 50 µm; inset, 2 µm. Three-dimensional reconstructions based on a displacement map technique further highlight the differences and similarities of (**e**) bSi and (**f**) dragonfly forewings.

Therefore, among the variety of bacteria, the BSi surfaces are active against Gram-positive, Gram-negative and spores.

Surface	Cicada wing (*P. claripennis*)*	Dragonfly wing (*D. bipunctata*)	Black silicon
Surface characteristics			
Water contact angle	159°	153°	80°
Chemical composition	Lipids/waxes	Lipids/waxes	Mostly SiO_2
Height of nanoprotrusions	200 nm	240 nm	500 nm
Bactericidal activity			
Effectiveness	Gram-negative	Gram-negative Gram-positive Spores	Gram-negative Gram-positive Spores
Efficiency†			
Versus P. *aeruginosa* ATCC 9027	2.0×10^5	3.0×10^5	4.3×10^5
Versus S. *aureus* CIP 65.8T	N/A	4.6×10^5	4.5×10^5
Versus B. *subtilis* NCIMB 3610T	N/A	1.4×10^5	1.4×10^5

*Cicada wing values are based on previously published data[7,8,9].
†Values represent the number of average killing rate (cells killed per cm^{-2} min^{-1}) over 3 h.

Figure 89: Table Feature comparison of insect wings and black silicon surfaces.

The development of BSi as antibacterial nano-material could be applied to the surfaces of medical implants in near future to make them far safer.

Chapter 5

4. Comparison hospitals rooms- Hospitals and Rehabilitation Resorts Façades

Depending on the information and data gathered from previous chapters, this section is dealing with the comparison between previous subjects (Bacteria – Radiation - Operation Rooms) and, Hospitals /Rehabilitation Resorts Façades, as a concluding chapter. Also, in this chapter, we will clarify the results of these comparisons, and will give practical suggestions for the façades design requirements.

4.1 Bacteria's Conditions– Hospital and Rehabilitation Resorts Facades

Growth Requirements & Temperature:

According to the explanation introduced in chapter 2 about Bacteria's growth requirements and S-layer, that explanation leads us to certain result: Growth of bacteria increase with temperature.

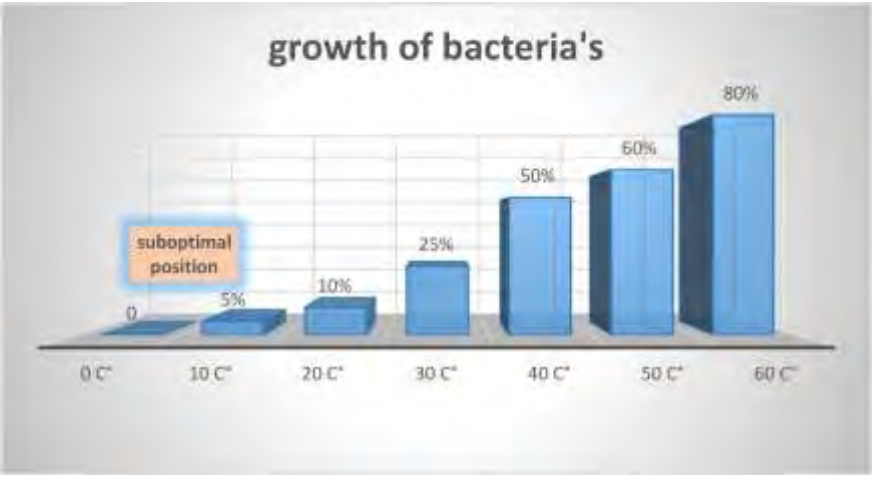


Figure 90: Bacteria's growth & temperature.

Therefore, the ratio of bacteria growth is parallel with increasing the temperature of the room. On the other hand, when temperature decreases to zero, the bacteria will enter the suboptimal position and will be in freeze grow state.

Looking to another factor in the same experiment in chapter 2, the humidity increase leads to increase in bacteria growth.

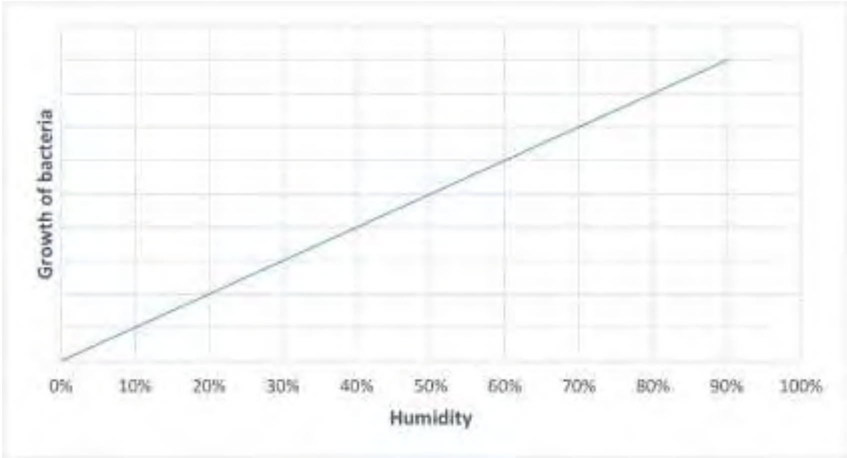


Figure 91: Bacteria’s growth & Humidity.

Also, growth requirements in the same chapter show that most of the bacteria needs sufficient amount of Oxygen to activate the growth procedures. In such a special case, sufficient amount of carbon and nitrogen could help to have spores growth on the surface of gram-positive bacteria.

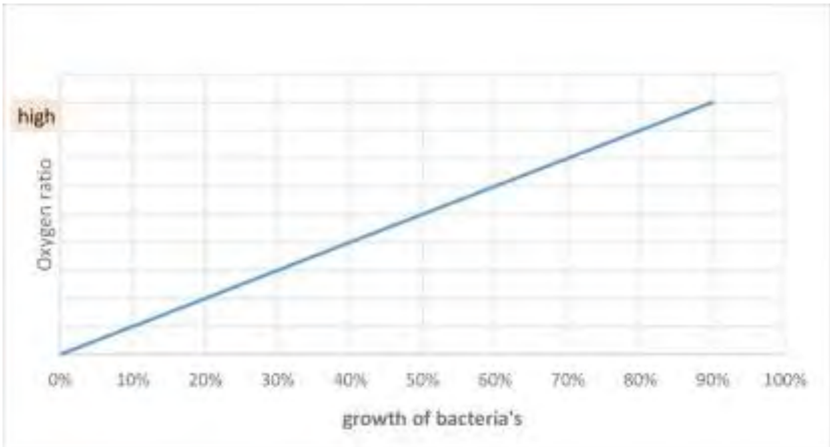


Figure 92: Bacteria’s growth & Oxygen amounts.

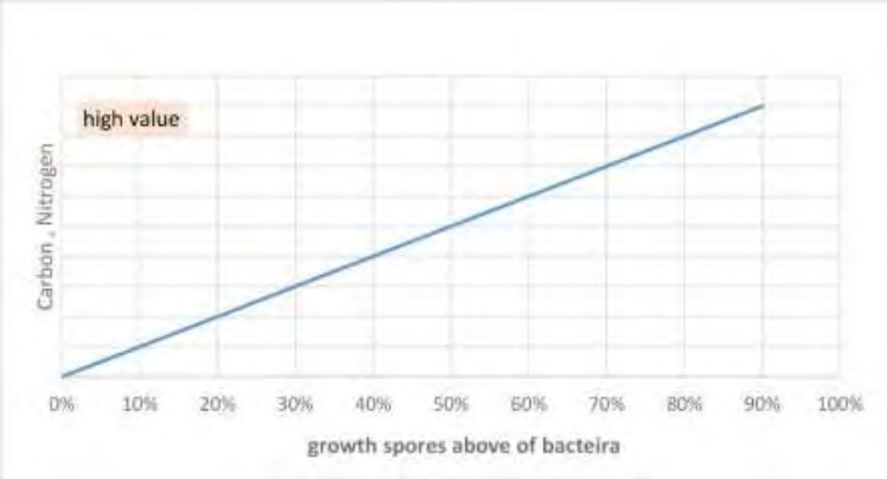


Figure 93: Spores growth & Carbon, Nitrogen amounts.

<u>Airborne Precautions:</u>

According to standard requirement of airborne precautions in hospitals, there is a theory of implementing different values of air pressure to prevent airborne infections. For example, the theory that is used in operation room could fit, as well, the façades of hospitals, because of implementing positive air pressure inside the operation room and negative air pressure outside, which means that positive values prevent air flowing from outside to inside and prevent bacteria spreading to inside as well.

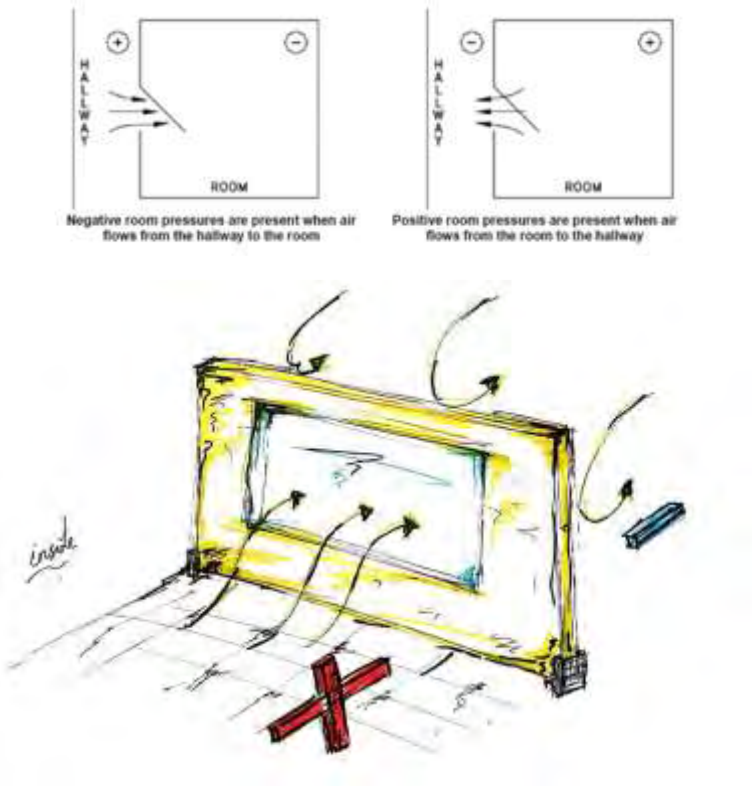


Figure 94: Air pressure values & bacteria prevalence.

So, considering the hospitals façade and rehabilitation resorts façade, we could implement the same concept, because the façade in this case will work as first defender line against the bacteria and spores coming from outside.

Isolation:

Considering the standard precaution instructions, the requirements to isolate the patients in Intensive Care Units (ICU) to prevent epidemics from spreading out all over the hospital, could fit well if we implement it in outer façade skin design, in a way of separating the façade units and totally closing the ventilation axis between the façade units. That could prevent any kind of spores/bacteria to move through all façade gabs especially if we consider the double skin façade.

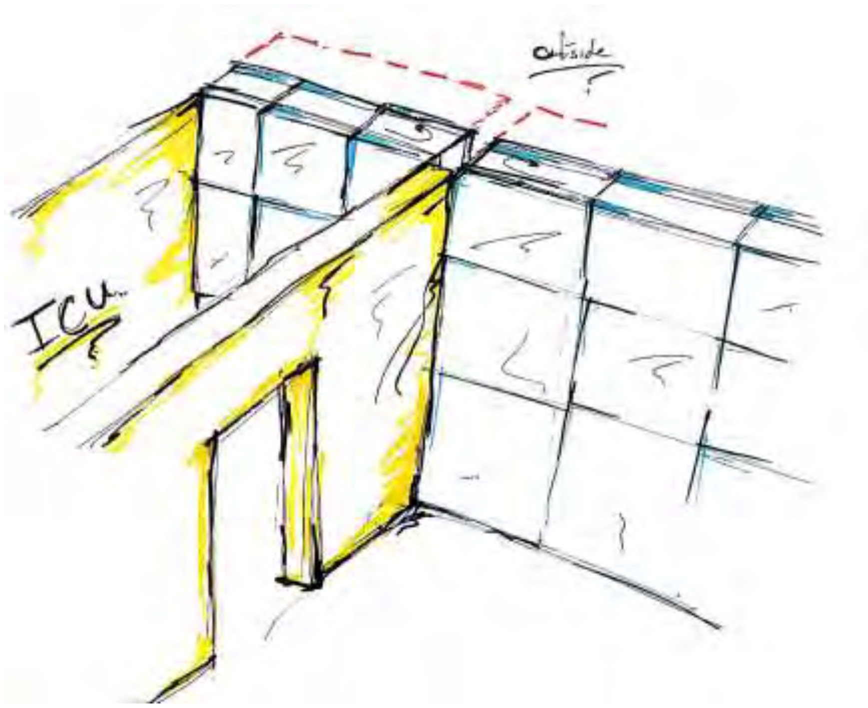


Figure 95: Isolating the rooms depends on the function.

Also, limiting the movement-transport of the patients in/out the room could be reflected in façade itself in direction of materials used. For example, if there are a certain active pathogen aspects in corridors, then we should implement materials in façade system that work against bacteria ratio prevalence.

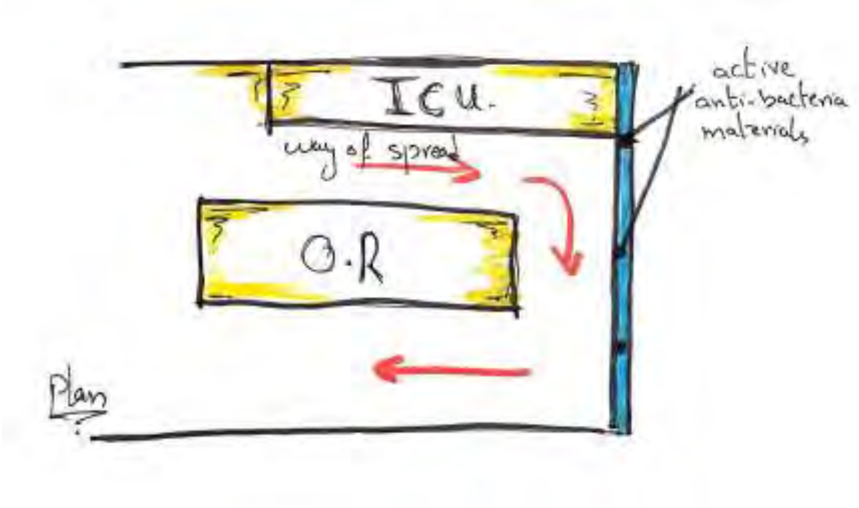


Figure 96: Rooms functions & façade effectiveness against bacteria spreading.

Nanomaterial's:

Silver (Ag) nanoparticles are widely used as antimicrobial agent against bacteria, viruses and fungi. However, there are some questions about Ag and the way of its effectiveness on humans. Nonetheless, Ag- iron can inhibit and disrupt protein structure of bacteria. It is not clear yet if it kills the cells of bacteria or disrupts the construction process of the cells. For that reason, if we talk about the hospital façade or rehabilitation resorts façade, Ag could fit as first line defender, especially that Ag is active against gram-positive and gram-negative bacteria, but it is supposed to take under consideration the diameter size of Ag nanoparticles, because small diameter size works effectively than big diameter size.

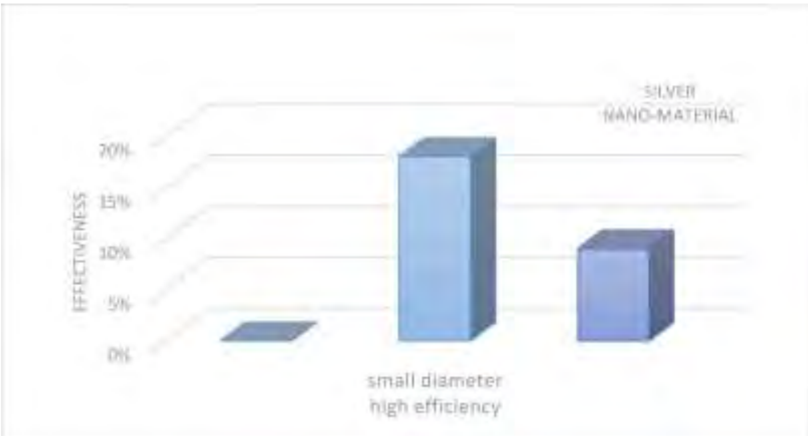


Figure 97: Effectiveness of material & diameter size.

Titanium oxide TiO_2:

Titanium oxide material also known with its high ability to kill both gram-positive and gram-negative bacteria and recent reports show the titanium oxide nanoparticles have high efficiency against viral species and parasites. However, titanium oxide nanoparticles are photocatalytic and their toxicity induced by visible light or UV. In addition to that, the combination between titanium oxide and silver nanoparticles leads to better results. For that reason, this solution could be helpful to be used in façades when a certain amount of daylight values consist to induce material to work effectively. However, this solution will be helpful for hospitals and rehabilitation resorts in preventing gram-positive and gram-negative bacteria.

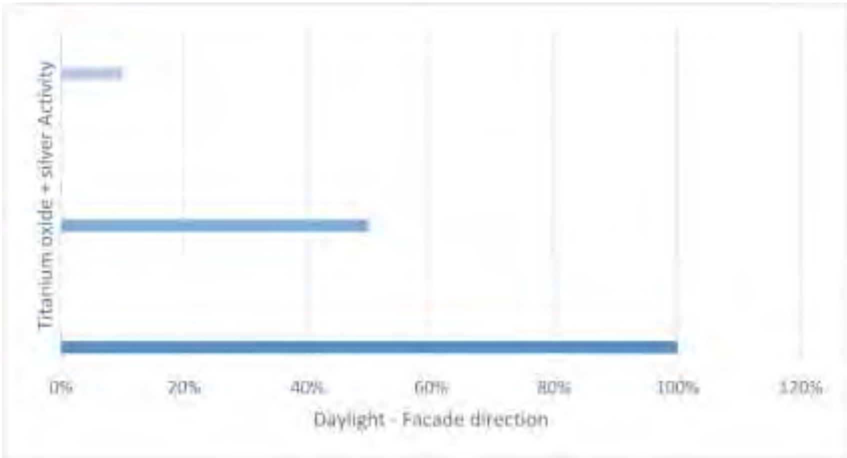


Figure 98: Effectiveness of materials related to daylight.

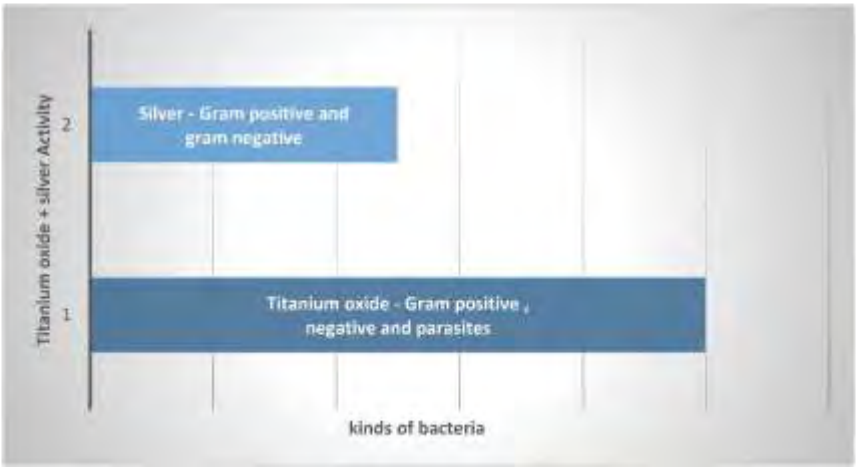


Figure 99: Effectiveness of materials related to bacteria stain.

Zinc oxide (ZnO):

Zinc oxide is antimicrobial material that kills various microorganisms and prevents growth of MRSE (Methicillin-resistant S. epidermis) and MSSA (Methicillin - Resistant Staphylococcus), but usually ZnO is chosen based on concentrate of partial size. Also, form point of hospital façades, ZnO is known as UV blocking material, and the formation characteristic makes it suitable for fabric and glass as coating material. Therefore, ZnO would be good coating material of glass in case of hospital façade to prevent especially MRSE and MSSA.

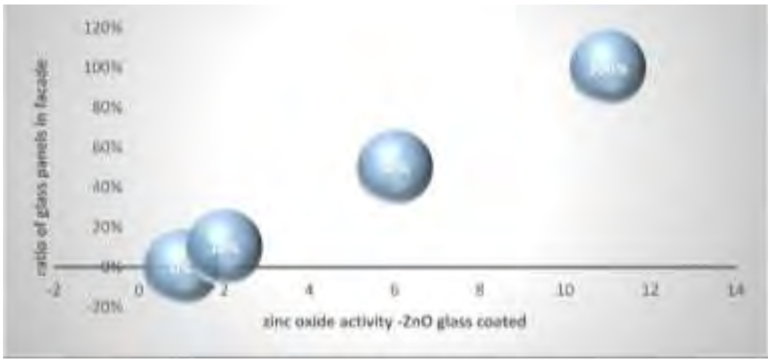


Figure 100: Effectiveness of glass panels & number of panels.

Iron oxide FeO_4 and copper oxide CuO :

Microbiological researchers found that surface modified by iron oxide nanoparticles prove anti-adherent properties and reduce gram-positive and gram-negative bacteria colonization. Therefore, iron oxide could be the proper solution material of rehabilitation resorts façades, whereas the mechanism of iron oxide nanoparticles is to reduce bacteria growth in a way of preventing the ability of bacteria's adhesion on surfaces.

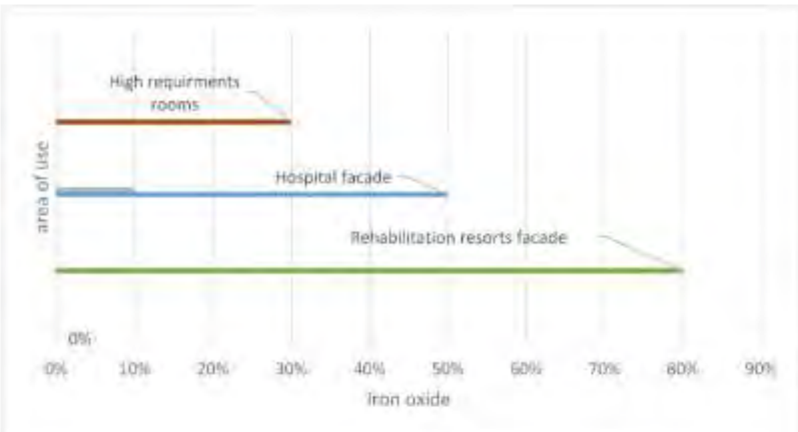


Figure 101: Iron oxide nano-material& area of use.

On the other hand, copper oxide nanoparticles have been effective against various bacteria and especially B.Subtilies and B.anthracis bacteria. Also, the combination of copper oxide with silver leads to better results, whereas, the silver is used to prevent Gram-positive and gram-negative bacteria colonization, so projecting this information on façade itself, that means CuO + Ag could be a good material for hospital façade, knowing that CuO price is cheap. However, we must consider the types of bacteria that need to be prevented.

Organic nanoparticles:

According to the explanation in chapter2, the mechanism of the organic nanoparticles consists of charging the surface of materials with positive charge, which leads to ion exchange between surface and bacteria membrane, and disrupt the bacteria growth. Therefore, the more efficiency the material has means the more multiple charge number needs. Also, the organic nanoparticles materials are less stable in high temperatures comparing with non-organic nanoparticles materials. For that reason, organic nanoparticles materials could not be the good solution to use in façade of hospitals or rehabilitation resorts. In general, it is also not proper option for hot climate zone.

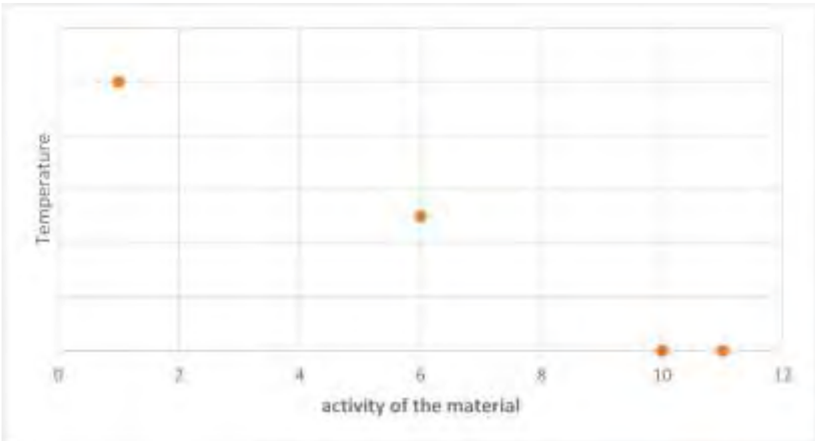


Figure 102: Effectiveness of organic nanoparticle's & temperature.

4.2 Radiation – Hospital and Rehabilitation Resorts Facades

Radiation Doses:

According to chapter3 and design requirements of shielding materials from x-Ray and CT-scan radiation (ionizing radiation), the amount of radiation doses considered as important factor to choose the shielding material and the thickness of the material as well. In principle, high amount of radiation doses mean thicker shielding material required.

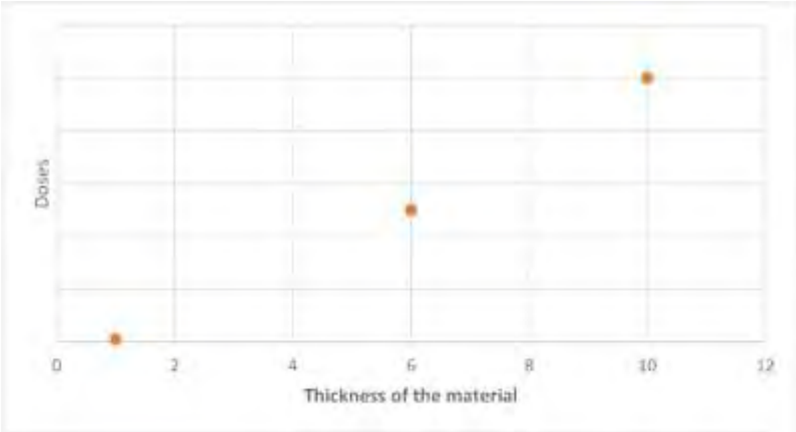


Figure 103: Thickness of material & ratio of doses.

Therefore, in case of x-Ray or CT-scan rooms, the radiation is generated by x-Ray machine, and the ratio of radiation fluctuates between 2-16 ≈ mSv depending on the number of diagnostic images and the type of image (brain, chest, etc.) required. For example, 2-4 mm thickness of lead is required form healthcare organization in general concept for x-Ray and CT-scan rooms, but each case or project is unique depending on various factors. However, projecting this point in the comparison between x-Ray, CT-scan rooms and hospital façade, we have to consider two factors affecting the hospital façade.

Frist, cosmic radiation or cosmic ray, which is a cosmic phenomenon and this kind of radiation, is non-ionizing radiation with amount of 0.4 ≈ mSv per year approximately, and 2 ≈ mSv per year as Terrestrial radiation. In additional to that, the amount of cosmic ray is increasing by altitude. Also, the amount of terrestrial radiation increased /decreased depending on surroundings (rocks, soil, water, air, animals, plants and food).

Second, in some especial cases the project or the orientation of façade is close to certain types of radiation sources like the radiation comes from control tower in airports or train stations. In this case, the amount of radiation and the types of radiant machines should be taken under consideration.

Therefore, in case of the first situation with 2.5-3 ≈ mSv per year (cosmic ray + terrestrial radiation) approximately, and compare it with 16 ≈ mSv per day/number of images from x-

Ray source ,then we will get a result of 0.007 mSv per day, which means that any type of absorption / dissipation materials could work well in this case.

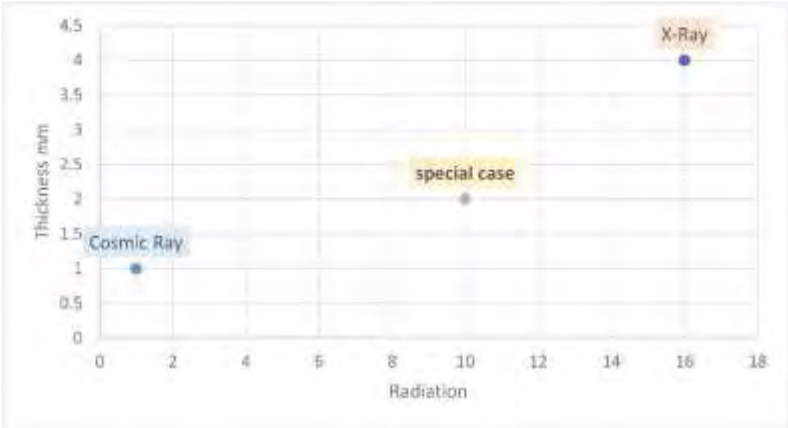


Figure 104: Thickness of material &types of radiation.

<u>Distance from radiation source, size of opening barrier and geometrical relationship:</u>

Related to x-ray and CT-scan rooms design and addition to the doses factor, the points of distance, size of opening barrier and geometrical relationship we should also consider it. For example, the distance between the radiation source and the shielding material, the size of opening barrier if it consist in x-Ray/CT-scan rooms or the geometric relationship between the radiation source and the room.

In term of distance, the healthcare requirement of x-ray room 6*5 meters, the minimum distances between x-Ray tube and the control partition should be 2 meters with 2 mm lead as radiation protection material inside the partition. Therefore, increasing the distances affects directly on the thickness of shielding materials. Linking that to the hospital and rehabilitation resorts façades, that means, in special cases of outdoor radiation, it should consist of thicker radiation protection materials, close to the Domain of source. For example, the height of protection material in x-ray room is 2.2 meters approximately, when the height of x-ray tube (source of radiation) is 1.9 meters, which means, if the outdoor source is in height range of 0-3 meter, the thicker material in façade panel should be in same domain.

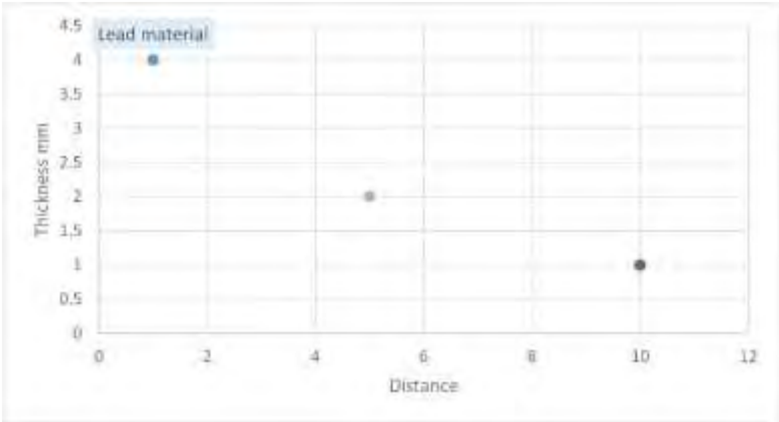


Figure 105: Thickness of material & distance from source.

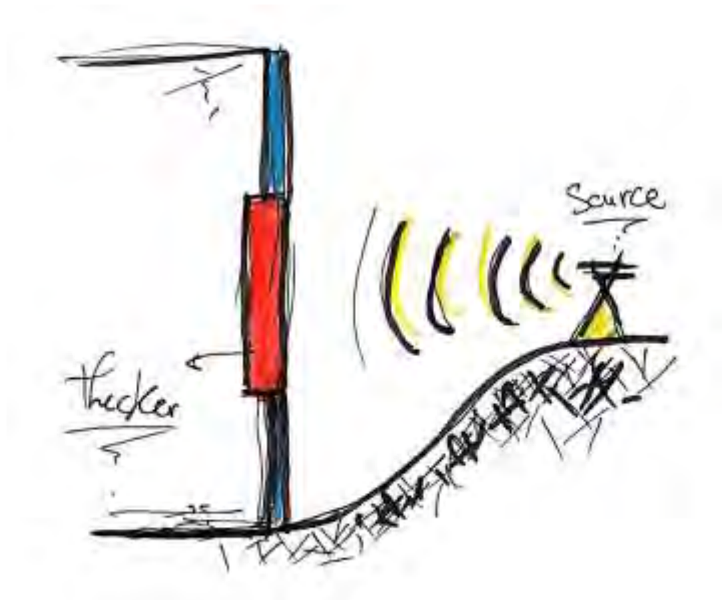


Figure 106: Thickness of material & axis of source.

Usually if there is any opening barrier in x-Ray/CT-scan rooms like (ventilation opening, ducts, and pipes holes), we should make a special solutions in this case to prevent radiation penetrating. On the other hand, and reflecting this concept in the façade itself in case of outside radiation, that means, the windows, doors, opening in walls and ventilations opening, all of them should have another protection materials behind this opening, like a second protection line. Also, we should consider the angle of the radiation sources, axis and domain of radiation. However, this point is the definition of geometric relationship between the source (sender) and receiver.

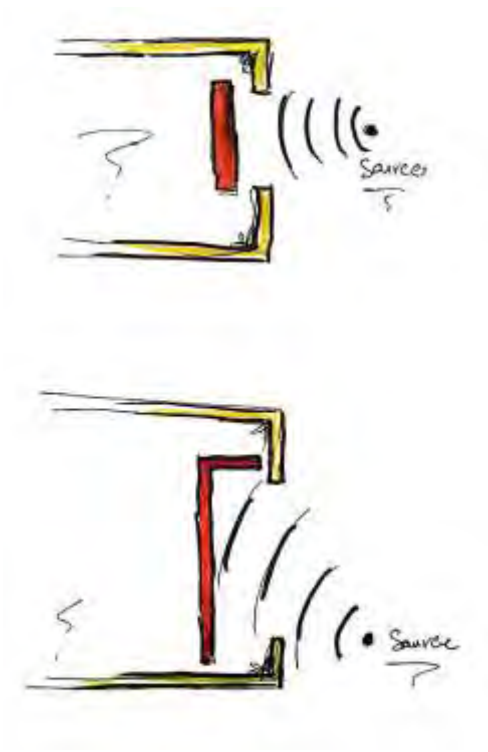


Figure 107: Protection material & geometric relationship.

<u>Materials and second radiation:</u>

In domain of radiation protection aspects (lead) material is playing a role in x-Ray and CT-Scan rooms as the most used material, because of certain features, like atomic number, whereas, material with high density and high atomic number considered as protection material.

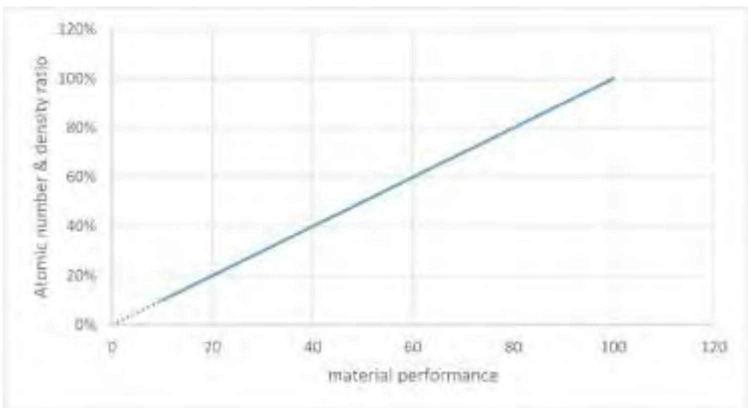


Figure 108: Density of material & material performance.

Besides that, the factors of ease heat dissipation, resistance to radiation damage, and good heat conductivity to reduce the heat in inner layer surface are the most important factors that protection materials supposed to contain.

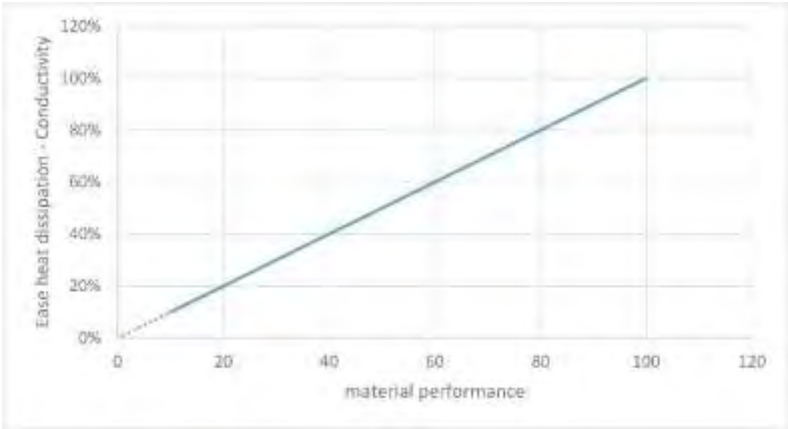


Figure 109: Conductivity value of material & material performance.

Figure 110: Dissipation the radiation inside the material.

Also, attenuation of radiation concerns the effective cross section of the shielding material, and neutron absorption. For example, lead material had low neutron absorption, which prevents the second radiation (Beta radiation) from the material itself. (See chapter3)

Looking through the big scale to hospital façade, implementing materials with the same features could be useful but in rare cases, because most of hospitals designs considered the zones functions, and usually the x-Ray room is not close to the façade skin. However, in some especial cases the x-ray or even CT-Scan rooms could be close to the façade like mobile dental X-Ray. That means, we could have invert effect from inside to outside. However, in case of rehabilitation resorts could not have any diagnostic imaging machines, which means there is no invert effect, and any type of materials that have the minimum protection requirements of cosmic radiation could work well.

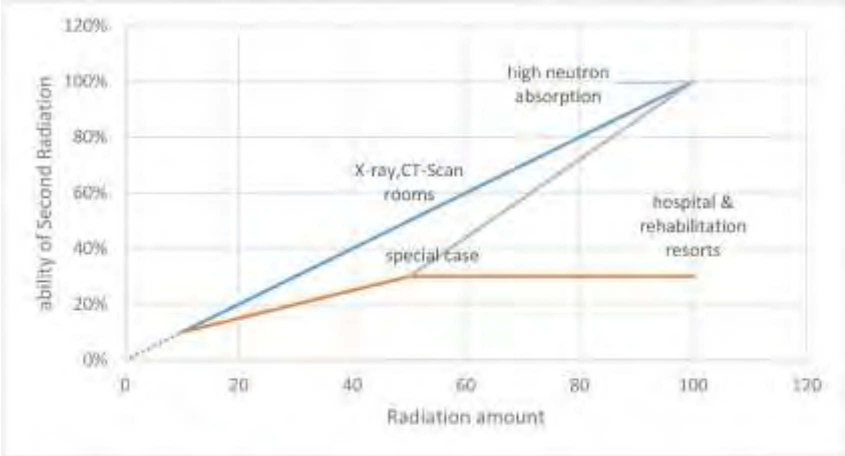


Figure 111: Second radiation & radiation emitting amount.

4.2.1 MRI: Magnetic Resonance Imaging:

EMI and vibration:

Depending on precaution points of EMI design for MRI room in chapter3, the site is supposed to have EMI and vibration test before installing MRI machine in room. So, usually EMI occurs by different factors such as electrical distribution, cars, parking, roads and subways. However, the MRI rooms usually should be close to the façade because of delivery issues. Therefore, there are EMI and vibration influence that could happen in case of cars movement, subway, etc. So in this case, the motive to apply protection materials in façade increases, whereas the proper material is copper. However, the MACS solution (MACS, see chapter3) is possible in high ratio of EMI and vibration influences!

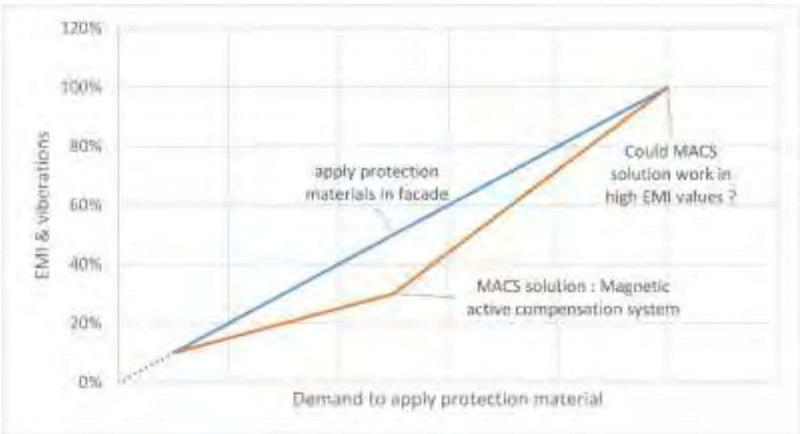


Figure 112: EMI, Vibrations & applying protection material.

Delivery plan:

MRI device in principle is huge; therefore, to deliver MRI to the room, we need a big opening in façade. Also, after few years, there is a possibility to change the MRI machine and bring a new one! However, there are two factors that should be considered; first the façade unit size in the level/floor where the MRI machine shall pass through, second, the ability to open this unit several times and preserve the same quality of protection tightness in the unit and in the connection line between the unit and the slab.

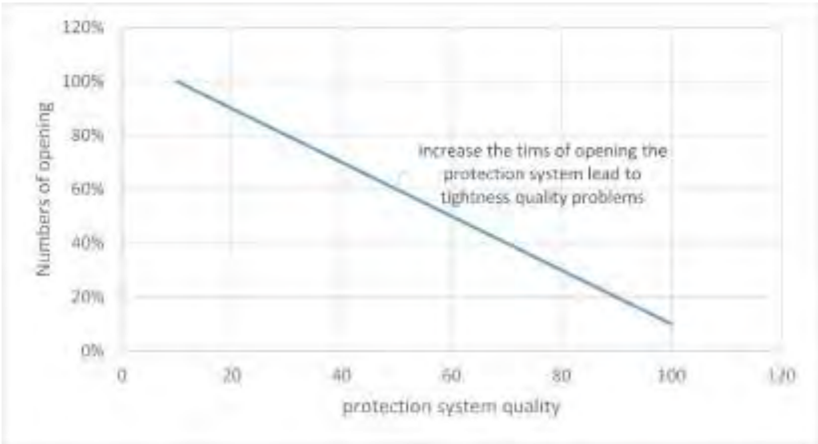


Figure 113: Number of delivery & system quality.

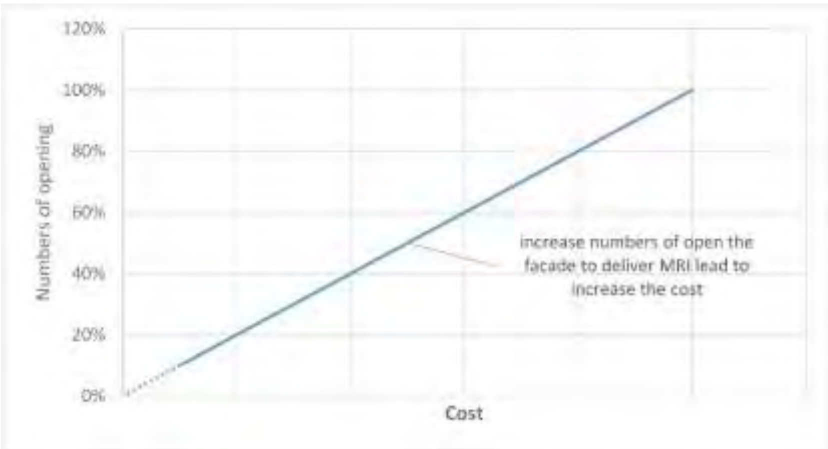


Figure 114: Number of delivery & cost.

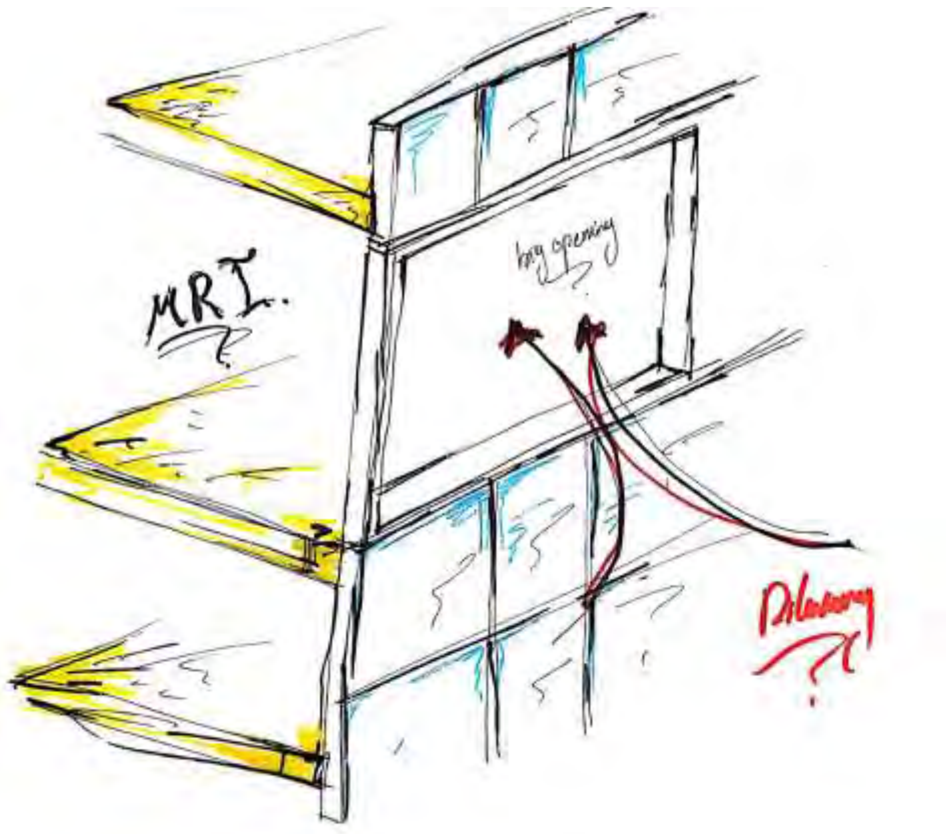


Figure 115: Size of opening in façade & room function.

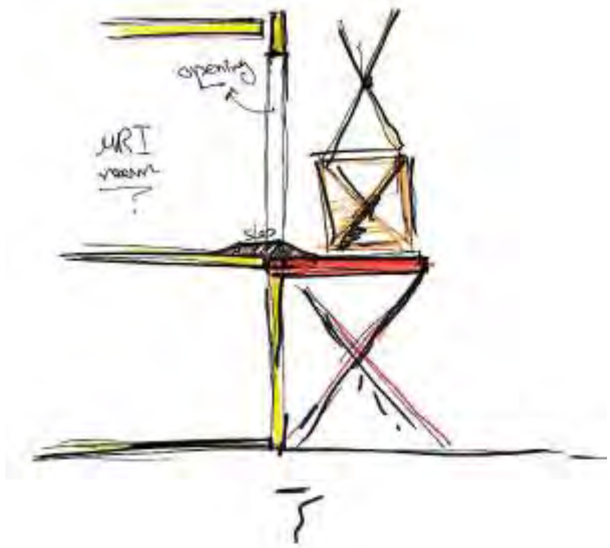


Figure 116: Delivery plan & flexibility of façade system.

4.3 Operation Rooms – Hospital and Rehabilitation Resorts Facades:

Acidic environments and detergents resistance:

According to stainless steel characteristics in chapter4, the materials used in hospitals should be suitable for acidic environments and detergents resistance; because places like hospitals have a daily sterilization process, and one of those places involved in this procedure are the surfaces of hospitals. In fact, the components that are used in the sterilization process like some detergents, that increase the acidic atmosphere in rooms, lead afterwards to the acidic corrosion in the surfaces and increase the growth ratio of molds as well. Therefore, comparing those requirements with rehabilitation resorts façade and inner face of hospital façade, both of these façades have the same materials characteristics in spite of resistance grade, because of the number of sterilization processes that are different between them. For example, the ratio is 5-3-1, where 5 means (five times per day) - sterilizing the operation room, and 3 (three times per day) -the inner façade of hospital and 1 (one time per day) is related to rehabilitation resorts façade. In addition to that, those materials that are not acidic and detergents resistance are susceptible to lose own characteristics during time, and leads afterwards to a lot of problems.

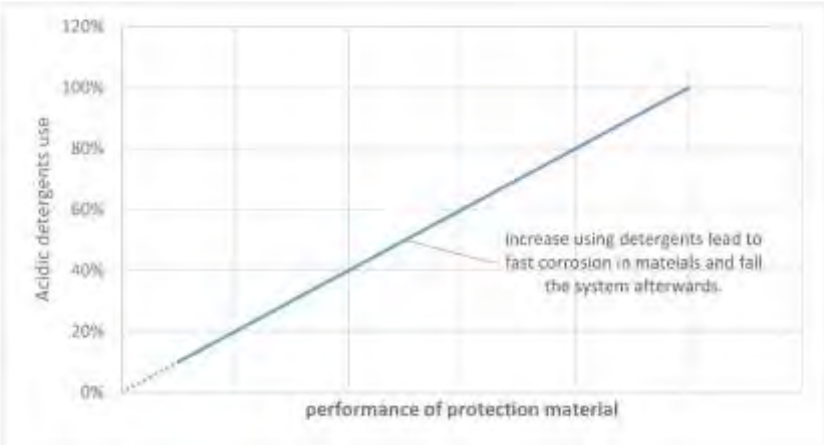


Figure 117: Detergent use & material performance.

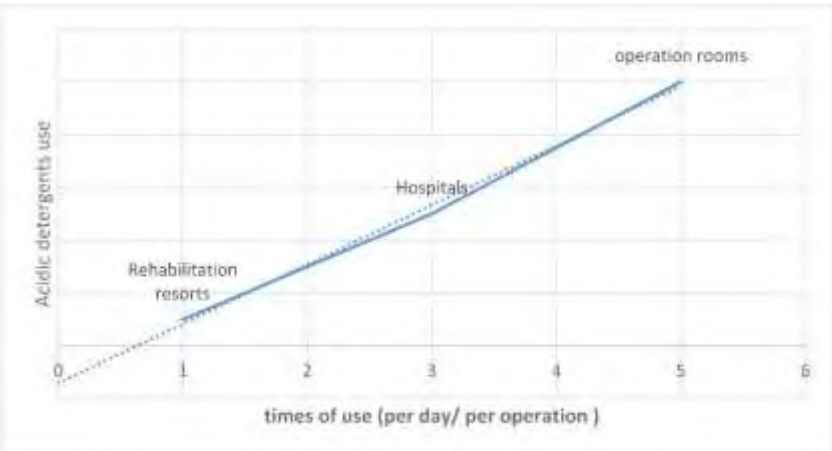


Figure 118: Number of times use per day& area of use.

Self-healing and high temperature oxidation resistance:

Self-healing is one of the most important performance characteristic of stainless steel. Stainless steel contains chromium, which makes stainless steel able to reacts with oxygen and water to treat light scratches. However, scratches could increase the ability of spores and bacteria colonization in the material.

On the other hand, stainless steel considered as high temperature oxidation resist and excellent cryogenic resistance. For that reason, stainless steel is used in areas where is high or low temperature could be good option, like for example, using it as modular system structure in genetics laboratory in low temperature environment, since stainless steel is excellent cryogenic resistance material.

Therefore, we should implement materials that have the self-healing and high temperature oxidation resistance in hospitals and rehabilitation resorts facades, especially in outer face of façade, where there is a possibility of facade to be corroded by oxidation processes. But why the high percentage of corrosion always occurs in the corners? Nevertheless, implement a 316L/304L stainless steel plate in corners could decrease the corrosion rate there.

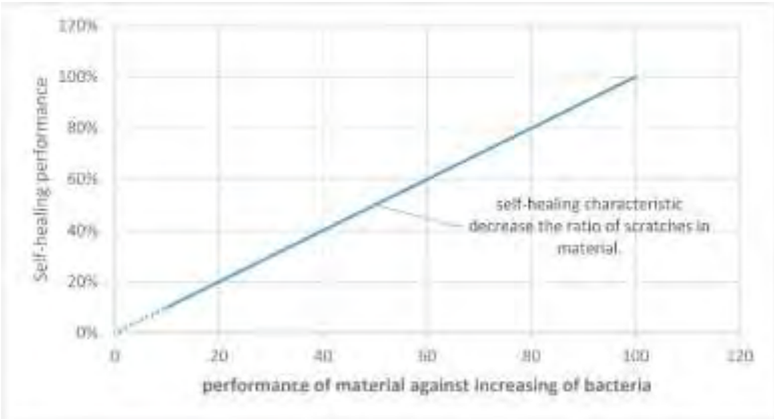


Figure 119: Self-healing & performance of material against bacteria.

Corrosion at certain time could help to increase the number of spores, and make a way for spores to move from outside to inside through the façade.

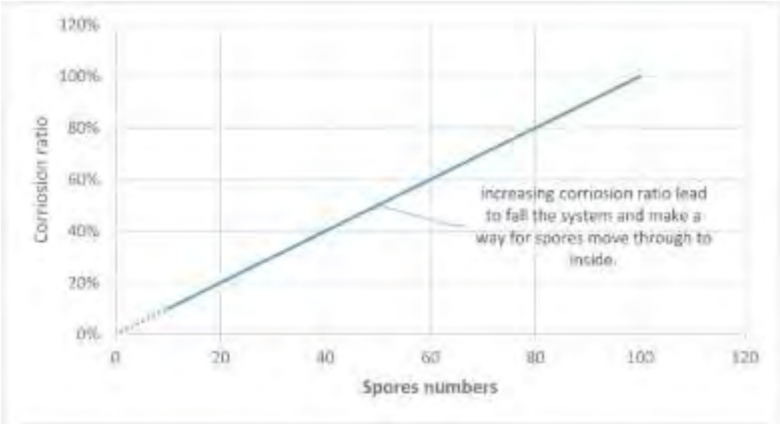


Figure 120: Corrosion values of material & number of spores.

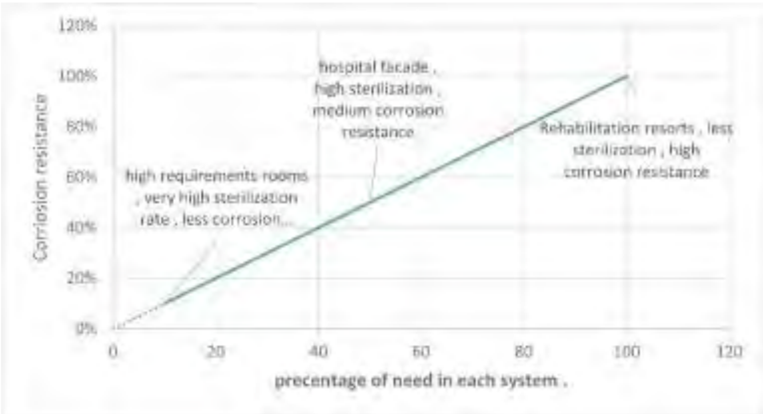


Figure 121: Corrosion resistance values & area of use.

Smooth Surface:

Looking through three different wall panels systems (metal, glass, impact) in chapter4, the h most smooth and dense surface is the most hygienic performance. Whereas, the smoothness factor plays a role in decrease the spores and bacteria's colonization in surfaces. In addition to that, using glass in wall panels improve the hygiene performance as explained previously in chapter4. Furthermore, most of the newest hospitals and rehabilitation resorts were built with certain numbers of glass panels in façade. But if the newest façades are almost from glass, what will be a good cover material to hide the appearance of slabs between floors? It is "Spandrel façade"! There is also a possibility to implement an impact wall panel with ceramic coating, the system that is used in hospitals corridors (see chapter4). In general, increasing the number of smooth surface panels leads to better results.

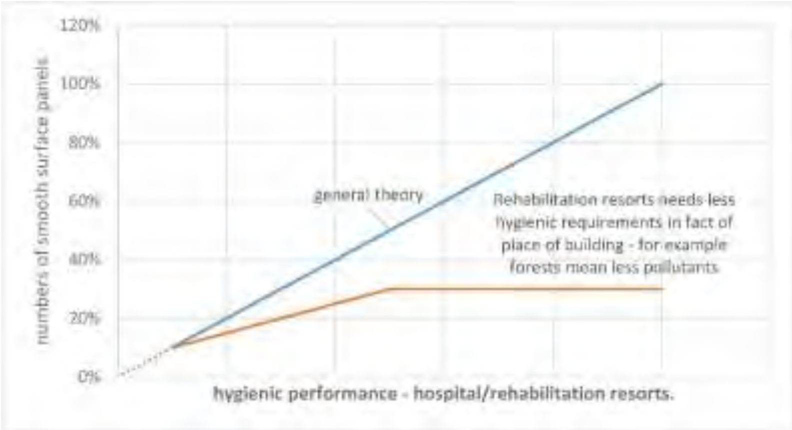


Figure 122: Number of smooth panels & hygienic performance.

Cleaning Plan:

According to chapter2, Enterococci bacteria can stay four months on surface. An enterococci bacterium is one of the nosocomial bacteria that we should implement a protection material against it in hospitals. In general, cleaning plan for modular system or façade has a different requirements and procedures than normal building façade; it concerns about cleaning, disinfection and sterilization. Therefore, the important factors are; how many times of cleaning per day, surface temperature, and water temperature in case of using water to clean.

In principle, three times to five times per day of cleaning is sufficient, depending on the room function. But also the surface temperature plays a role in disinfection process, where 90 c° of surface temperature needs minimum one minutes of cleaning process, 80 c° needs 10 minutes, 75 c° needs 30 minutes and 70 c° needs 100 minutes as thermal disinfection. Also, using water for cleaning and disinfection needs more time if the water is cold, and less time if the water is warm or reached boil temperature. Therefore, in case of hospital façade or rehabilitation resorts façade, the (cleaning plan, disinfection and sterilization plan) should be implement in inner face of the façade, in case of total close façade system (double skin – non ventilated). But what will happen in case of ventilated façade or opening windows in façade? The contaminates that are attached to the outer face could move inside the hospital through window's openings.

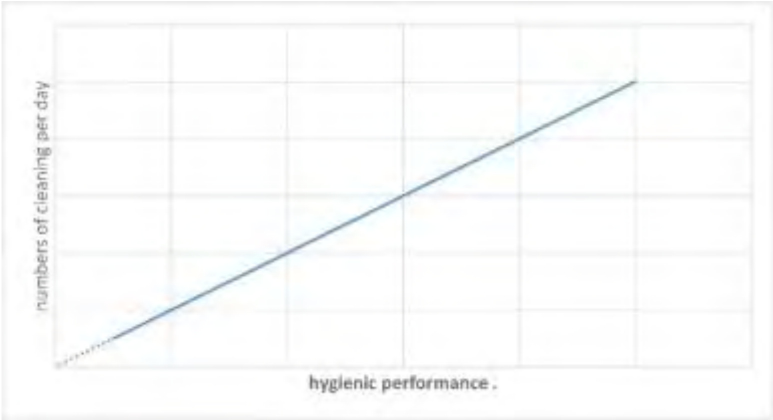


Figure 123: Number of cleaning-per day & hygienic performance.

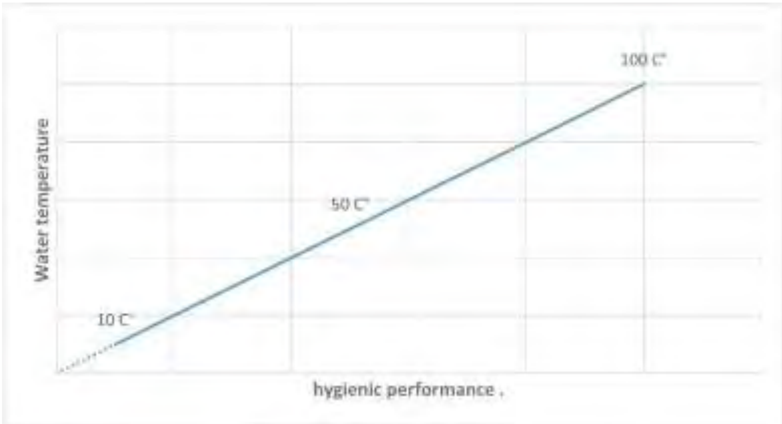


Figure 124: Water temperature &hygienic performance.

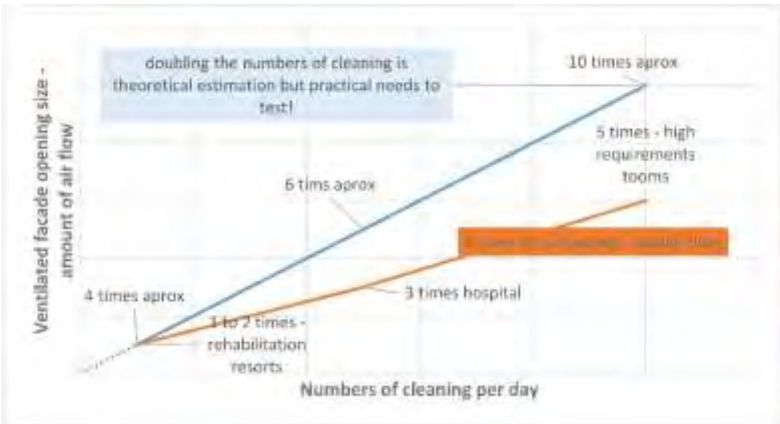


Figure 125: Façade system &number of cleaning –per day.

5. Discussion and Conclusion:

The objective of this research project is to investigate the health effects of three different cases: bacteria, radiation and hygienic materials used in the façade system on human occupants. The intended scope of the facade system implementation is targeted towards high requirement rooms, hospitals and rehabilitation resorts facade. This research has revealed that satisfying all design requirements for the three cases in hand in single façade system may be in theoretical in nature. It is rather practical to consider each case individually.

When addressing the façade design in the “bacteria” case, the following factors must be considered for various applications (hospital rooms – hospital façade – rehabilitation resorts façade): -

- Bacterial growth increases as the surface temperature increases.
- A rise in relative humidity fosters bacteria growth.
- Whilst most of bacteria types need sufficient amounts of oxygen to grow, in the lack of it, anaerobic bacteria can grow but requires the presence of carbon or nitrogen.
- Epidemics can vastly spread through airborne infection through the heat, ventilation and air conditioning systems. Therefore, it is essential to select and install the appropriate number of stages with their corresponding efficiencies to serve different zones. Manipulating the pressure values to maintain the hygiene level inside the concerned zones.
- Achieving optimum results lies in installing separate façade units to ensure no mixing of air occurs between the two adjacent rooms.
  for important point in the façade is the function behind it, so in term of isolation, the façade of a hospital could have a different design, because of the room function behind it, and in case if there are ICU rooms, then the façade should be designed in a way that separates the units and prevents any type of airborne connection.
- Simulating the infection path by analytical architectural plan identifies the areas of potential bacterial growth. Therefore, the inner face of facade materials should be equipped with disinfection features to enhance its performance. This can be facilitated by appropriate material selection
- The selection of nanomaterial’s in façade depends on several factors (bacteria stains, size of particles, amount of daylight, and areas of use). Consequently, caution should be exercised in selecting and employing such material in appropriate façade applications. Therefore, international standards should be used a selection tool to utilize nanomaterial’s while abiding by the local requirement of the project in hand.

In case of radiation in this research, the main focus was on the ionization radiation (artificial radiation), but the concept of non-ionizing radiation is similar to ionization radiation with less amount and ratio of doses. We can see that the most important factors in case of radiation are:-

- To encounter higher radiation levels, an increase in the absorption material thickness is required. However, higher radiation doses reduce the durability of the materials.

- As far as the hospital façade or rehabilitation resorts façade is concerned: it is recommended that prior to measuring the distances from the source to the façade, to identify the radiation types as they may affect the façade. It is also important to highlight that all radiation sources outside the building, incident angles, and the relationship between the radiation source and façade must be considered.
  To minimise or block radiation from passing through the walls/façade, the protection materials selection should involve characteristics such as; density of the material, atomic number, thickness, second radiation –neutron absorption and conductivity value.
  In case of MRI machine, the façade should prevent EMI & vibration to pass through. Furthermore, the quality of the façade units, particularly the units that covers the MRI room, should be of high quality and easy to open several times, preserving the tightness value and magnet control. In addition, the façade system should have the ability for extra fixing point installation in case of delivering the machines.

As far as the **operation theatre** façade requirements design, the following aspects should be addressed in comparison with hospital and rehabilitation resorts façade:

- Acidic environment resistance, which is the resistance to acids and detergents ratio fluctuates from system to another. Such resistance is application-sensitive. Therefore, shifting from rehabilitation resorts to operation room's façade, a gradual increase in the value of acids and detergents is required.
- Furthermore, corrosion resistance and self-healing performance of materials are important factors in case of decreasing the number of bacteria and spores. Therefore, rehabilitation resorts façades requires the highest corrosion resistance and self-healing material performance as they are subject to less cleaning daily frequency compared to the operation theatre. Therefore, the grade of corrosion resistance should decrease gradually from the façade of hospital to the high requirement rooms inside the hospitals in this case.
- Emphasis must be placed on smooth surface in area of façade at higher levels of spores ratio. Furthermore, the façade design plays a vital role to decrease the ratio of spores For example, increasing the number of glass panels leads to decreasing the number of spores that could adhere to the surface when the glass material considered as non-adhesive surface.
- The procedure of cleaning plan concept in hospitals differ from the conventional façade cleaning. In fact, cleaning in hospitals includes three procedures under the same definition (cleaning, disinfection and sterilization) with different individual requirement. Also, in terms of cleaning, the procedures should be done in inner and outer face, considering the number of daily cleaning and the façade system as well.

Recommended Future Work

Several areas of recommended future work were identified throughout this project. Such areas are listed below with the proposed investigation as an initial course of action:

1. **Bacterial development**: Bacteria develops against antibiotics and anti-microorganisms during with time. Would nanomaterial's develop and/or update their characteristics in order to cope with such factor?

2. **Bacterial Resistance**: Each nanomaterial could resist a specific type of bacteria or spores. Could a single material be developed to treat all types of bacteria/spores?

3. **Selective Solution:** An optimum solution is reached to kill bacteria, how can the system be selective in order keep beneficial bacteria? How can the façade position itself for optimum results?

4. **Disease Prevention**: Could the façade play a role in preventing diseases from spreading from inside out and outside in? What would the design implications be in case of hospital construction in urban location?

5. **Sensitivity to Geographic Location**: The performance of selected material should be assessed in terms of the geographic location. Climate conditions can make the performance of nanomaterial's at hand deviate from that described in their technical catalogue. A special emphasis should be placed on excessive temperature and relative humidity that seem to be rising every year due to global warming.

6. **Radiation Effects:** Testing the radiation and magnetic field effects are important to implement a protection material, but how can the façade performance be assessed in a presence of radiation and magnetic leakages?

7. **MRI Machines**: How openings/windows in façade of hospital would look like especially in case of delivering and installation MRI machines various times? Would the façade tightness efficiency be after each delivery?

8. **Life Time:** What is the expected lifetime for the protection materials? Is the façade flexible enough to accommodate new protection developments? Or is only specific to the original protection solution.

9. **Transparency vs. Protection**: A balance must be struck between protecting people from radiation and keeping certain ratio of transparency level by implementing leaded glass. However, further investigation is recommended to consider high radiation levels and whether or not the transparency level will be compromised.

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7. Appendix:-

Chapter 2

General Phenotypic Classification of Bacteria

Gram Positive Bacteria					
Name	**Morphology**	**O_2 Require-ments**	**Commens-al**	**Reservoirs / Sites of colonization, Transmission**	**Types of Infections**
Staphylococci	Cocci in grape-like clusters	facultative anaerobe	Yes	Skin, nares / endogenous, direct contact, aerosol	Soft tissue, bone, joint, endocarditis, food poisoning
Streptococci	Cocci in pairs, chains	facultative anaerobe	Some species	Oropharynx, skin / endogenous, direct contact, aerosol	Skin, pharyngitis, endocarditis, toxic shock
Pneumococci	Diplococci, lancet shaped	facultative anaerobe	±	Oropharynx, sinus / aerosol	Pneumonia, otitis, sinusitis, meningitis
Enterococci	Cocci in pairs, chains	facultative anaerobe	Yes	GI tract / endogenous, direct contact	UTI, GI, catheter-related infections
Bacilli	Rods, spore-forming	aerobic	±	Soil, air, water, animals / aerosol, contact	Anthrax, food poisoning, catheter-related infections
Clostridia	Rods, spore formers	anaerobic	Some species	GI tract, soil / Breach of skin, endogenous, ingestion	Tetanus, diarrhea, gas gangrene, botulism
Corynebac-terium	Rods, nonspore forming	facultative anaerobe	Some species	Skin	Catheter-related infections, diphtheria
Listeria	Rods, nonspore formers	facultative anaerobe	No	Animals, food products / Ingestion	Meningitis
Actinomyces	Irregular, filamentous, form sulfur granules	anaerobic	Yes	GI tract / endogenous	Skin, soft tissue

Table 3: Classification of gram positive bacteria, Frank lewg, Bacterial classification, structure and function, July 23. P6, 2015.

Gram Negative Bacteria					
Name	**Morphology**	**O_2 Requirements**	**Commensal**	**Reservoirs / Sites of colonization, Transmission**	**Types of Infections**
Enterobacteriaceae (*E. coli*, klebsiella, salmonella, shigella)	Rods	facultative anaerobe	Some species	GI tract, animals / Endogenous, fecal-oral	Diarrhea, urinary tract, food poisoning, sepsis
Bacteroides	Rods	anaerobic	Yes	GI tract / Endogenous	Abscesses, intraabdominal infections
Pseudomonas	Rods	aerobic	No	Water, soil / Endogenous, breach of skin barrier	Infections in immunocompromised hosts, Cystic Fibrosis
Vibrio (cholera)	Rods, curved shape	microaerophilic	No	Water / Contaminated food, water	Diarrhea
Campylobacter	Rods, curved shape	microaerophilic	No	Food / Ingestion of contaminated food	Diarrhea, Bacteremia
Legionella	Rods, poorly stained	microaerophilic	No	Water / Inhalation of aerosol	Pneumonia, febrile illness
Neisseria	Cocci, kidney-bean shaped	Microaerophilic	No (*N. meningitidis* sometimes)	Humans / Sexual , aerosol	Meningitis, pelvic inflammatory disease
Hemophilus	Coccobacillary - pleomorphic	facultative anaerobe	Some species	Respiratory tract / Endogenous, aerosol	Respiratory, sinusitis, otitis meningitis
Bartonella	Small, pleomorphic rods	aerobic / microaerophilic	No	Cats, fleas, lice / cat bites, lice or fleas?	Cat scratch disease, endocarditis, bacillary angiomatosis

Table 4: Classification of gram negative bacteria, Frank lewg, Bacterial classification, structure and function, July 23. P7, 2015.

Miscellaneous Bacteria					
Name	**Morphology**	**O_2 Require-ments**	**Commensa l**	**Reservoirs / Sites of Colonization, Transmission**	**Types of Infections**
Helicobacter	GN, but not visible on Gram stain - helical (corkscrew) shaped	microaero-philic	Yes	Stomach / Endogenous, Fecal-oral	peptic ulcer disease, gastric ulcer
Mycobacteria	Rods, Weakly Gram positive, Acid fast stain positive	aerobic	No	Lungs / Fomites	Tuberculosis
Treponemes	Not visible on Gram stain, spiral shaped on dark field exam	nonculturable on routine media	No	Humans / Sexual transmission	Syphilis
Borrelia	Not visible on Gram stain, spiral shaped on dark field exam	nonculturable on routine media	No	Rodents, Ticks / Tick bites	Lyme, Relapsing fever
Mycoplasma	Not visible on Gram stain, no cell wall, pleomorphic	Non-culturable on routine media	Some species	Humans / aerosol	Respiratory tract infections
Rickettsia/ Ehrlichia	Obligate intracellular (Gram negative but not visible on Gram Stain)	Non-culturable on routine media	No	Ticks, Mites/ transmitted from the feces of infected lice, fleas, ticks	Cause a variety of illnesses including systemic vasculitis (e.g. Rocky Mountain Spotted Fever), rash, pneumonia

Table 5: Classification of miscellaneous bacteria, Frank lewg, Bacterial classification, structure and function, July 23. P8, 2015.

Table 1: Representative synthesis/preparation method for selected antimicrobial nanomaterials.

Material	Nanomaterial/particles description	Representative synthesis/preparation method	Reference
Titanium oxide (TiO_2)	Nanosilver-decorated titanium dioxide (TiO_2) nanofibers with antimicrobial activity were synthesized which displayed a self-cleaning property and toxic decomposition potential	Titanium nanofibers were prepared by electrospinning. Briefly, pluronic and PVP were each dissolved in ethanol. A TiO_2 solution was prepared by adding titanium isopropoxide (TiP) in a mixture of ethanol and HCl. The solution was mixed with the PVP-pluronic solution followed by stirring at room temperature and the resulting precursor gel was heated at 50°C for 24 hrs. The gel was then electrospun and the formed fibers were calcined at 500°C for 4 hrs under air to form crystalline titanium dioxide nanofibers	[168]
Silver (Ag) compounds	In situ production of silver nanoparticles on cotton fabric is described and their antimicrobial potential is evaluated	Cotton fabric was introduced into a loading bath containing silver nitrate. To this solution CTAB and glucose were added and the mixture was shaken at 50°C. Subsequently, sodium hydroxide and water were added and the mixture was further shaken at 50°C. The coated samples were thoroughly rinsed with water and dried. The silver coated samples were washed with nonionic detergent (Triton X-100) and then the fabrics were dried	[169]
Copper oxide (CuO)	Copper oxide nanoparticles prepared by electrochemical reduction displayed excellent antibacterial activity against *Escherichia coli* and *Staphylococcus* strains	Copper oxide nanoparticles were prepared by electrochemical reduction, using an electrolysis cell in which a copper metal sheet served as a sacrificial anode and a platinum (inert) sheet acted as a cathode. For this process tetrabutylammonium bromide in an organic medium acted as a structure-directing agent which was used with acetonitrile (ACN) at a 4 : 1 ratio. The reduction process was allowed to takes place under an inert atmosphere of nitrogen for 2 hrs. Desired particle size was achieved by controlling parameters such as density, solvent polarity, distance between electrodes, and concentration of stabilizers	[170]
Iron oxide (Fe_3O_4) & zinc oxide (ZnO)	Zinc oxide was combined with iron oxide to produce magnetic composite nanoparticles with improved colloidal aqueous stability and adequate antibacterial activity	To prepare the Fe oxide nanoparticles, $FeCl_2 \cdot 4H_2O$ solution was added to a porcine gelatine aqueous solution, followed by addition of a $NaNO_3$ solution and allowed to react for 10 min. Then the pH was raised to 9.5 by adding a NaOH aqueous solution (1 N). The Zn/Fe oxide composite nanoparticles were prepared similarly except for substituting the Fe^{2+} ions for a mixture of Fe^{2+} and Zn^{2+} of different weight ratios. The mixtures containing weight ratios [Zn]/[Fe] of 1 : 9, 3 : 7, 1 : 1, 8 : 2, and 9 : 1 were prepared by mixing different volumes of $FeCl_2 \cdot 4H_2O$ solution with the appropriate volumes of $ZnCl_2$ solution. The procedure that followed was as described for the iron oxide nanoparticles	[171]
Magnesium oxide (MgO)	Magnesium oxide (MgO) nanowires (diameter, 6 nm; length, 10 μm) were synthesized. These nanowires showed bacteriostatic activity against *Escherichia coli* and *Bacillus* species	A microwave hydrothermal technique was used to prepare MgO nanowires. In brief, an aqueous solution of a fixed concentration of urea was added dropwise to an aqueous magnesium acetate solution. The solution was then loaded into a microwave furnace. The product obtained was collected, dried, and calcined to obtain a white-colored final material	[172]
Nitric oxide (NO) nanoparticles	Nitric oxide- (NO-) releasing nanoparticle technology was used for the treatment of methicillin-resistant *Staphylococcus aureus*	First a hydrogel/glass composite was synthesized by adding tetramethyl orthosilicate, polyethylene glycol, chitosan, glucose, and sodium nitrite in sodium phosphate buffer. In this glass composite, nitrite was reduced to NO due to redox reactions initiated with thermally generated electrons from glucose. After the redox reaction, the ingredients were combined and dried using a lyophilizer, resulting in a fine powder consisting of nanoparticles containing NO. The water channels inside the particles of the hydrogel/glass composite opened in an aqueous environment, facilitating the release of the trapped NO over extended periods of time	[105]
Polyethylenimine and quaternary ammonium compounds	Antibacterial activity of quaternary ammonium polyethylenimine (PEI) nanoparticles embedded at 1% w/w in hybrid dental composite resins was determined	An ethanol solution of PEI was cross-linked with 8.7 mmol dibromopentane (PEI monomer/dibromopentane). The generated HBr was neutralized by treatment with sodium hydroxide and the resulting residue was purified from NaBr by gravitational filtration and dried under reduced pressure. The cross-linked PEI was further alkylated with bromooctane, as described above, to produce octane alkylated PEI. Octane alkylated PEI dispersed in anhydrous THF was reacted with methyl iodide in the presence of 2% cross-linked 4-vinylpyridine. The product was filtered to remove 4-vinylpyridinium salt and the filtrate was evaporated to dryness under reduced pressure	[173]
Chitosan & polyguanidines	Guanidinylated chitosan derivatives of different molecular weights were synthesized. Guanidinylated chitosan exhibited a fourfold lower inhibitory concentration compared with chitosan	A chitosan solution was prepared in HCl and then adjusted to pH 8-9 by 5% w/v aqueous sodium carbonate. The precipitate was washed with water and the desired amount of aminoiminomethanesulfonic acid was added. The reaction was kept at 50°C for 15 min and then the mixture was cooled to room temperature. Once cooled it was poured into saturated aqueous sodium sulfate, and the precipitate was filtered off, washed thoroughly with water and ethanol, and then dried under vacuum to give guanidinylated chitosan	[174]

Table 6: Method for select antimicrobial nanomaterials , Hindawi Publishing Corporation, alternative antimicrobial approach, Nano- Antimicrobial materials, Article ID 246012, p4, 2015

Chapter 3

Radiation Exposure test.

3/16/2017 X-Ray Risk : Report - Printer-Friendly

Print

It is important for you to talk to your doctor about the tests you have had done or are considering having. This site is intended to provide information about your additional risk of cancer based on medical imaging, not to provide medical advice. We want patients to have accurate information when weighing the pros and cons of medical imaging. It is important to remember that in properly performed individual exams, the potential health benefits almost always outweigh the potential risks. Averages do not predict what is going to happen to you, but we provide this information to ensure patients and physicians are informed when making medical decisions.

Study	Gender	Age	# of exams	Dose (mSv)	Additional Cancer Risk(%)
CT-Brain CT (Standard)	Male	27	1	2	0.019037%
Plain Film-Chest x-ray (2 views)	Male	27	1	0.1	0.000952%
Brain Scan	Male	27	1	6.9	0.065677%
Upper GI (Barium Swallow)	Male	27	1	6	0.057111%
					0.142777%

Based on your radiation exposure from these studies, your additional risk of getting cancer is 0.142777%

An Additional Cancer Risk of 0.142777% is equal to 1 in 700 chances.

Or said another way, a 99.857223% chance of having no effect of the above studies.

Keep in mind, the overall lifetime risk of developing an invasive cancer is 37.5% (1 in 3) for women and 44.9% (1 in 2) for men regardless of imaging history. These statistics are averages and do not predict what is going to happen to you. They do not take into consideration individual risk factors including lifestyle (smoking, diet, exercise, etc), family history (genetics) or radiation exposure. The majority of cancers occur later in life and the average lifetime risk of dying from cancer is 25% (1 in 4).

Figure 1:X-ray risk, the truth about radiation and cancer, angio calc, LLc, 2009 Available: http://www.xrayrisk.com/calculator/calculator.php .

Figure 1-1: X-ray room door shielding. A guide to the use of lead for radiation shielding lead industries Association, Inc, 292 Madison Avenue, New York 1001.

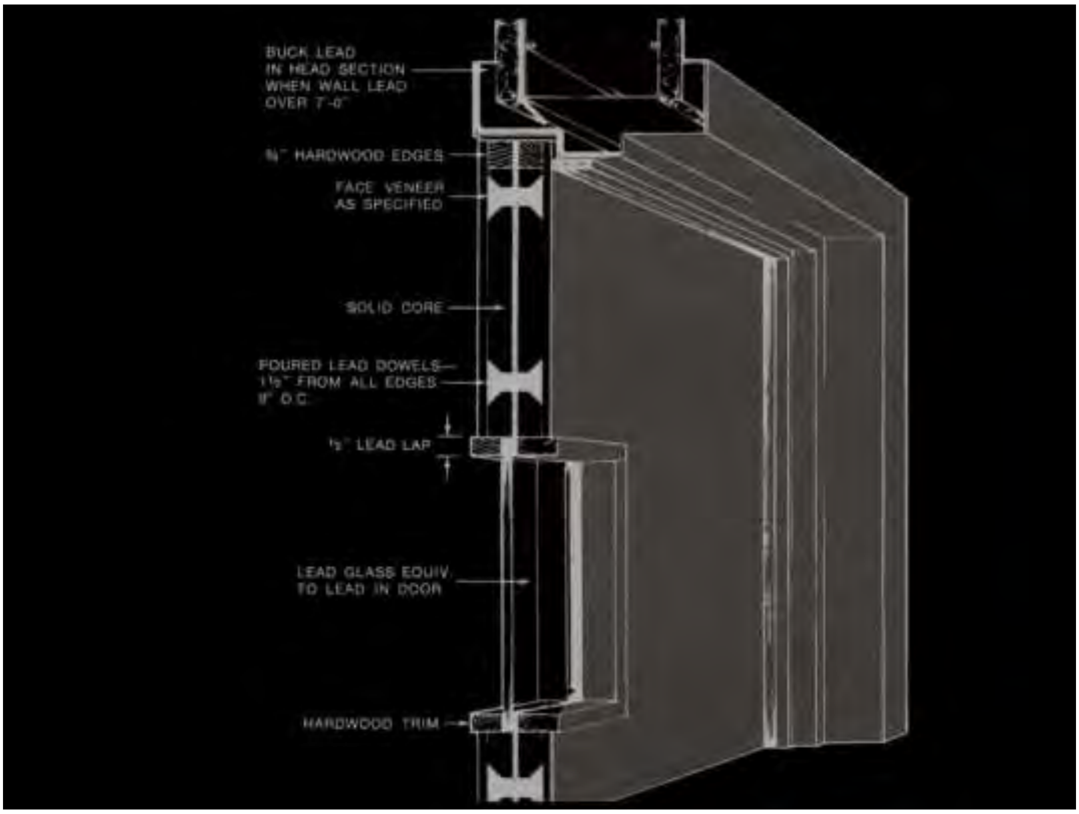
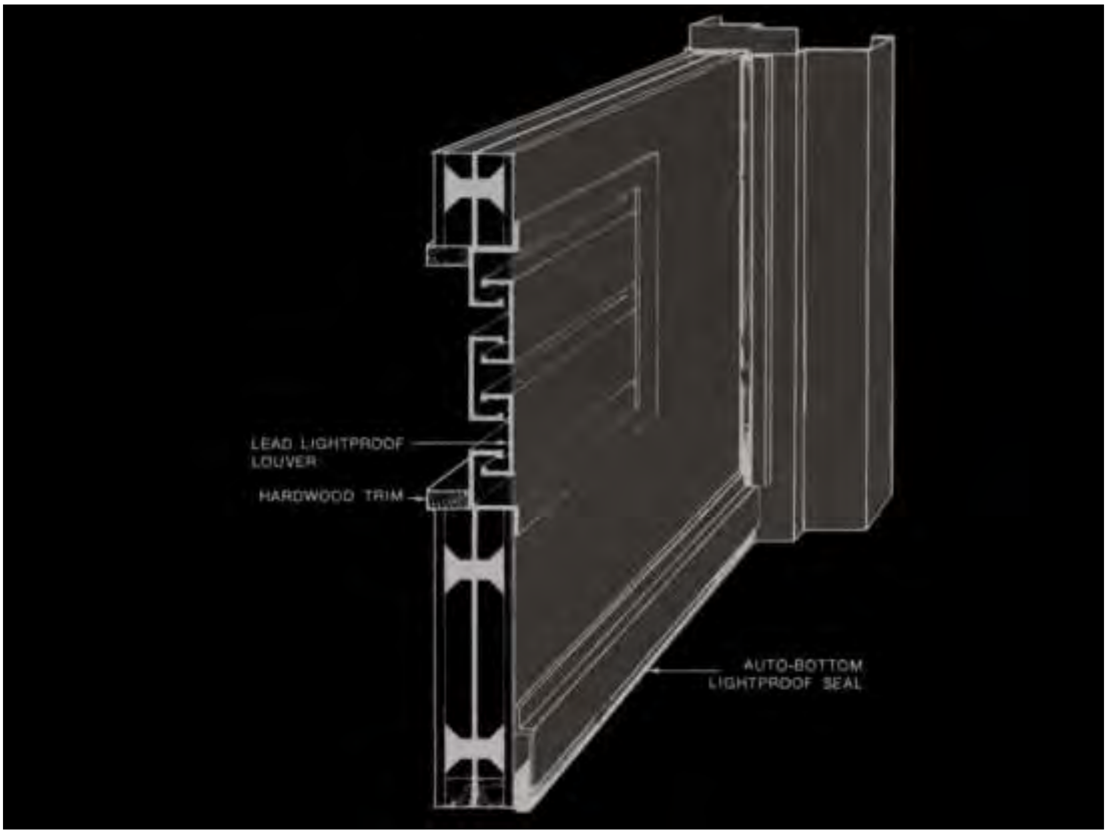


Figure 1-2: Frame door connection. A guide to the use of lead for radiation shielding lead industries Association, Inc, 292 Madison Avenue, New York 1001.



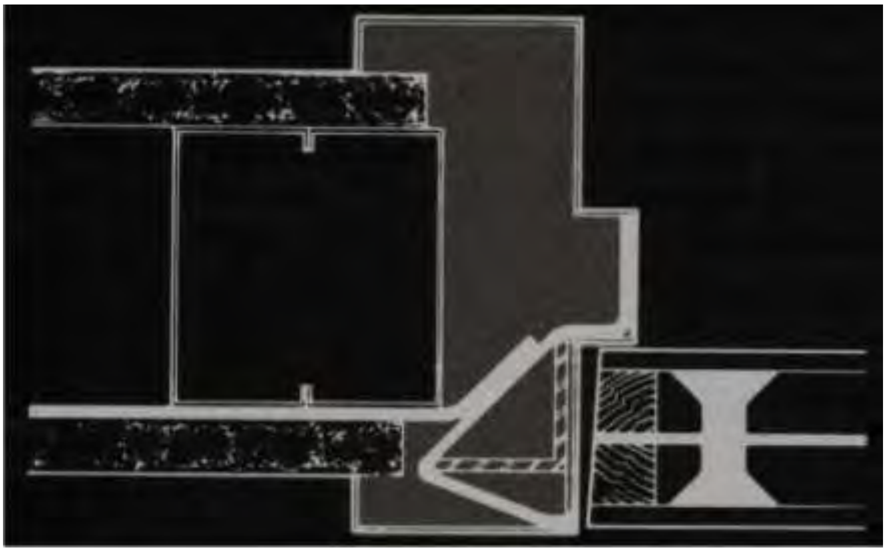


Figure 1-3: Ventilation opening case. Figure 1-4: Structure shielding. A guide to the use of lead for radiation shielding lead industries Association, Inc, 292 Madison Avenue, New York 1001.

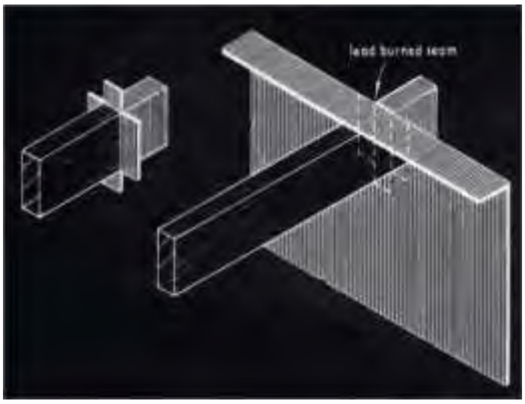


Figure1-5: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

CELL TYPE SHIELD CEILING TO WALL

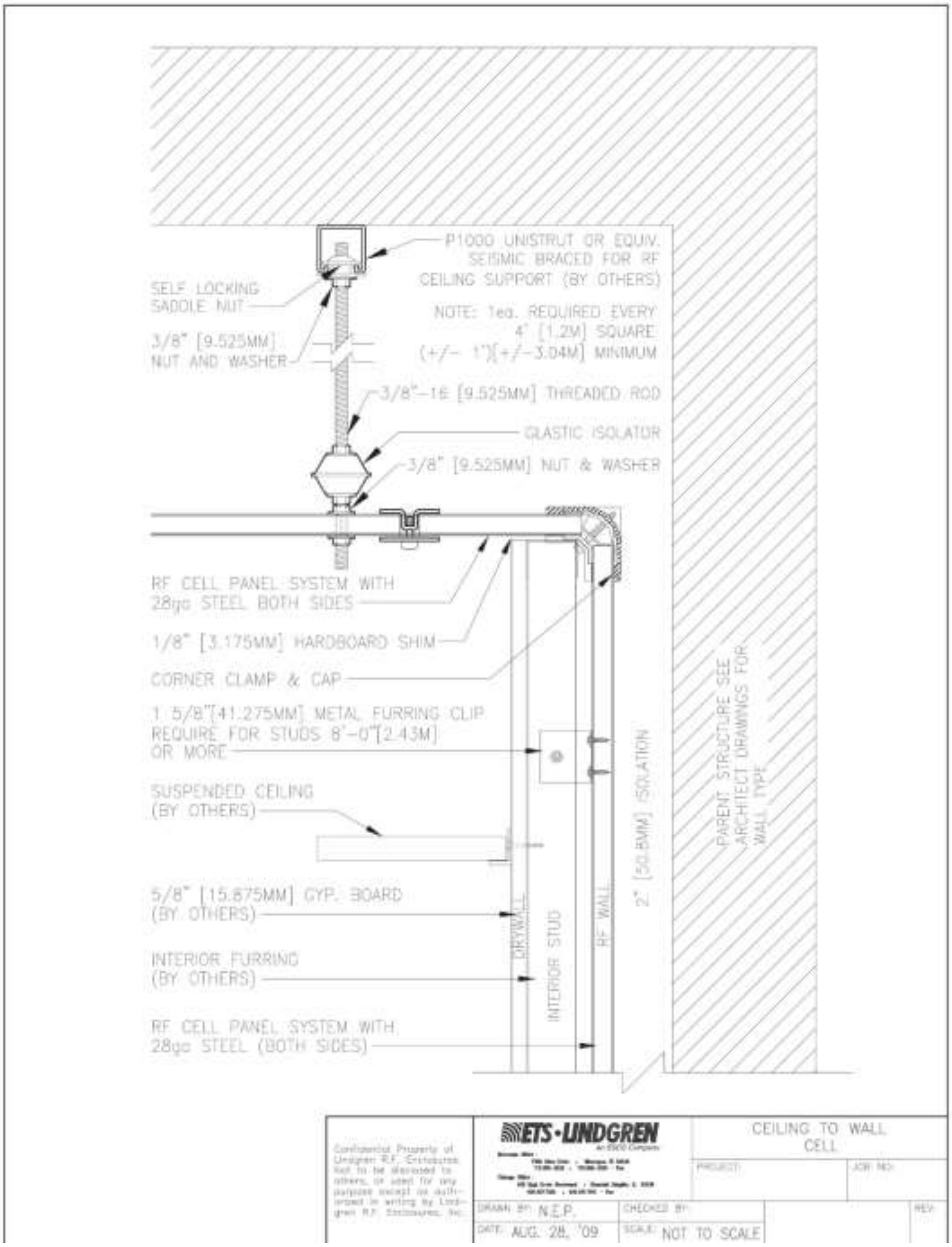


Figure1-6: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

COPPER SHIELD CEILING TO WALL

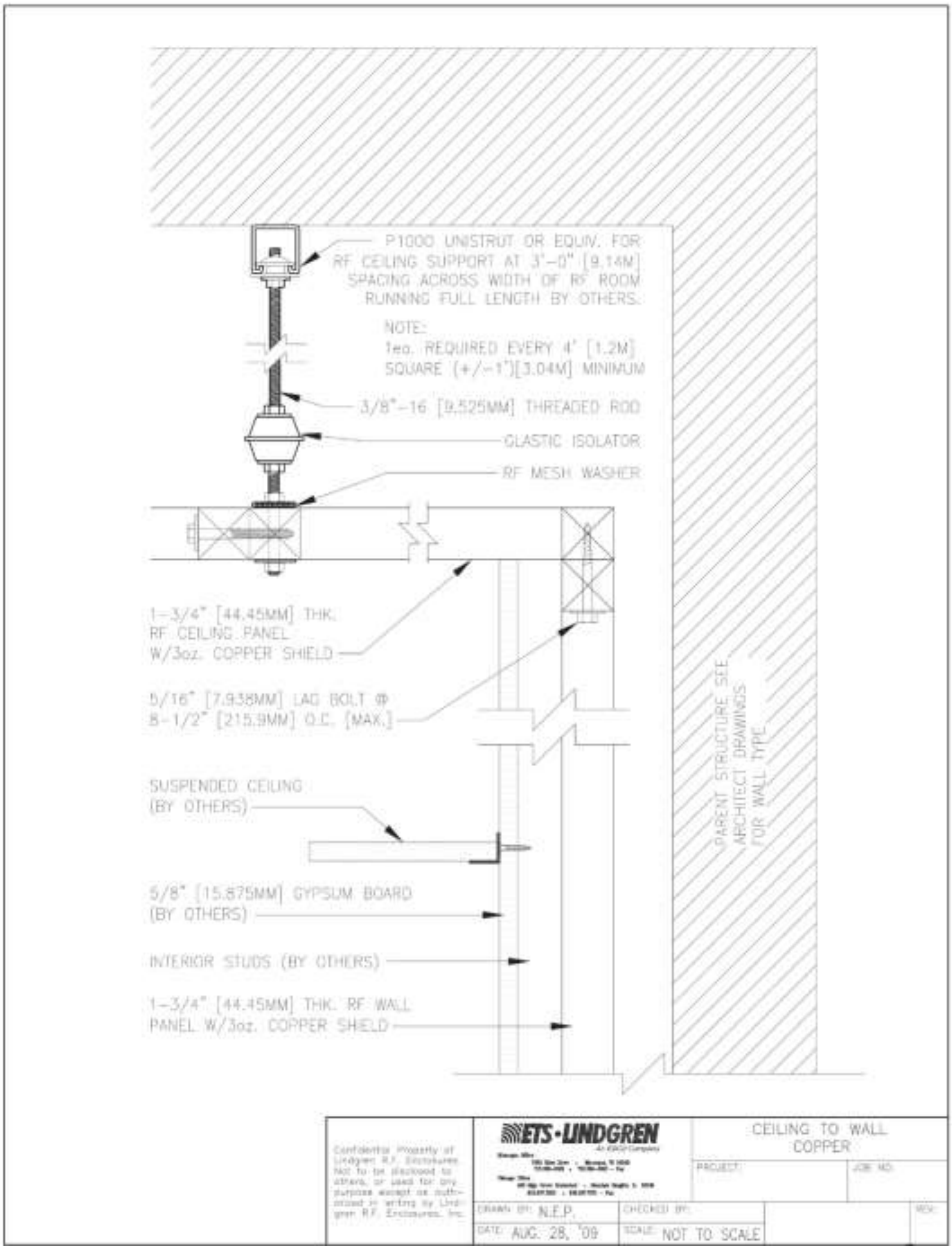


Figure1-7: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR ELEVATION- INSWING, COPPER SHIELD, MONOLITHIC FLOOR

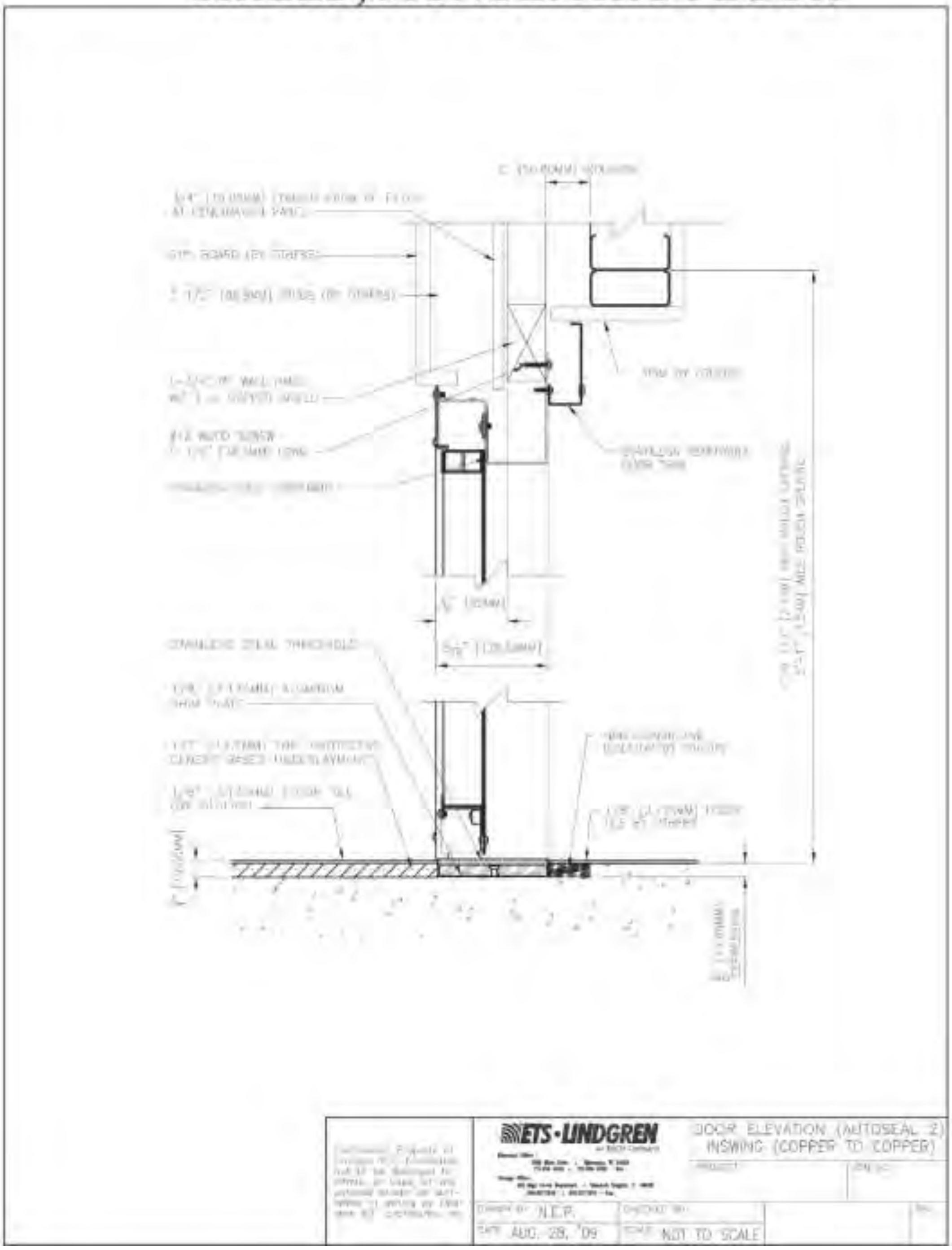


Figure1-8: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR ELEVATION- OUTSWING, COPPER SHIELD, CELL TYPE FLOOR

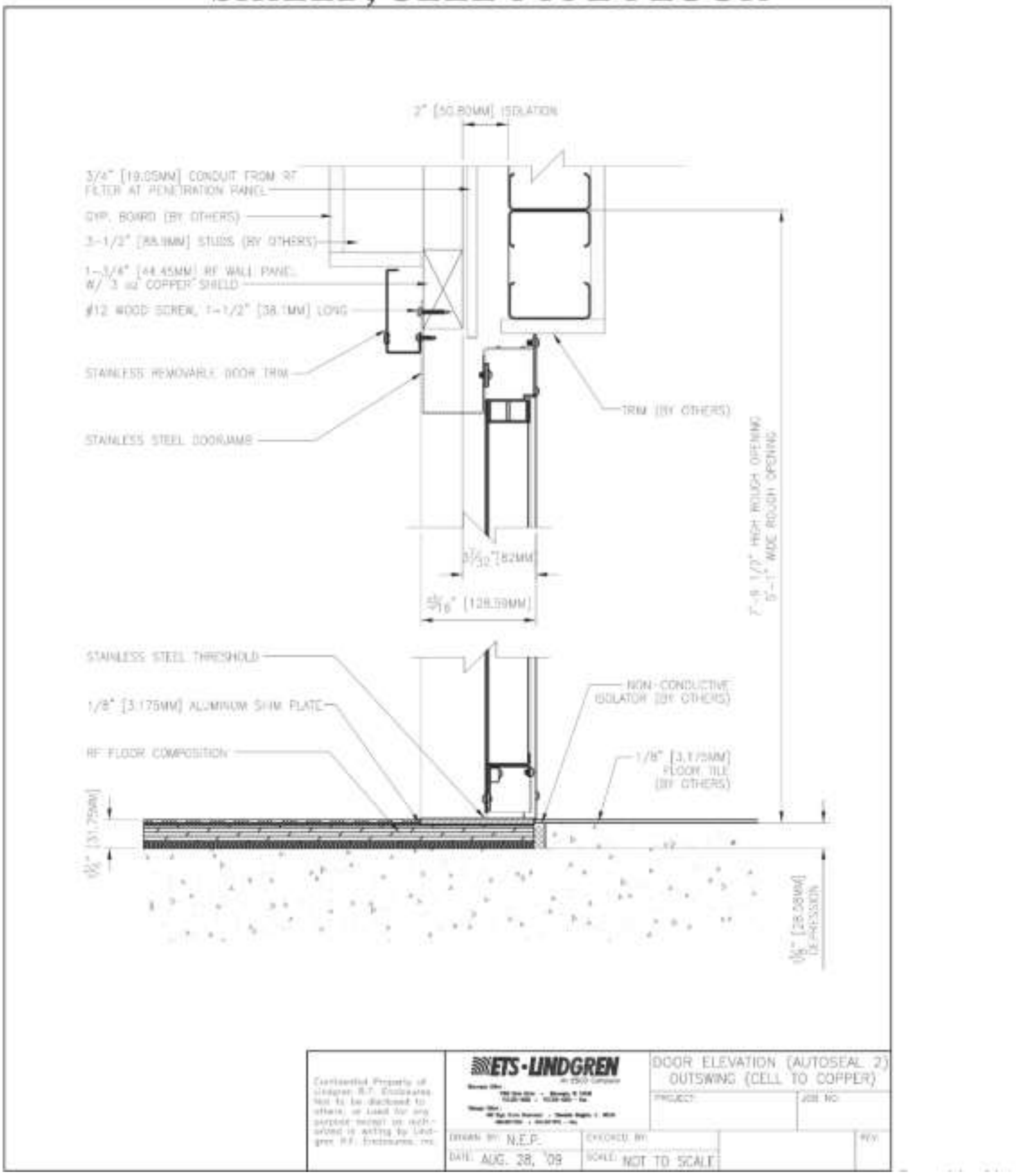


Figure1-9: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR ELEVATION- OUTSWING, COPPER SHIELD, MONOLITHIC FLOOR

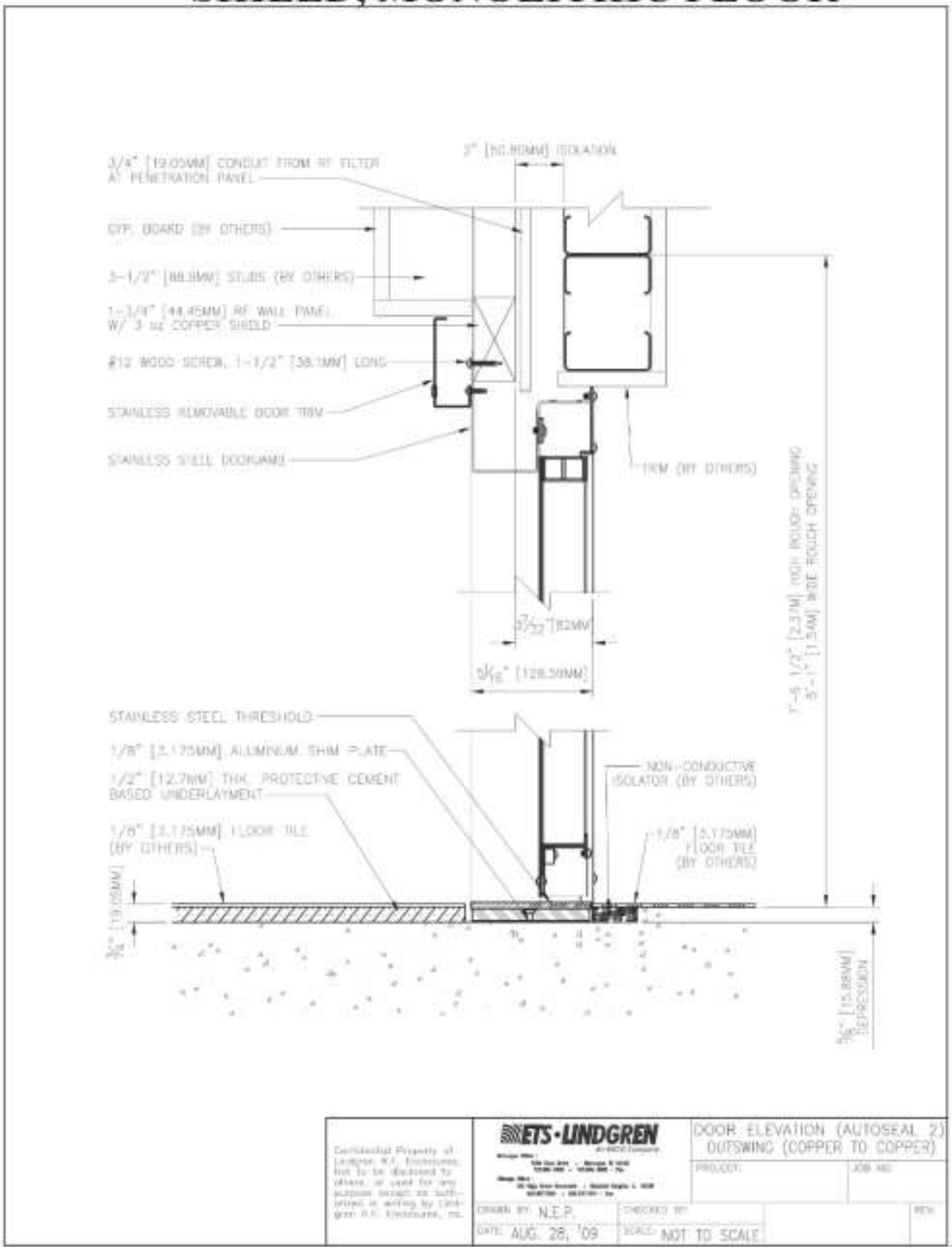


Figure1-10: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR ELEVATION- INSWING, COPPER SHIELD, CELL TYPE FLOOR

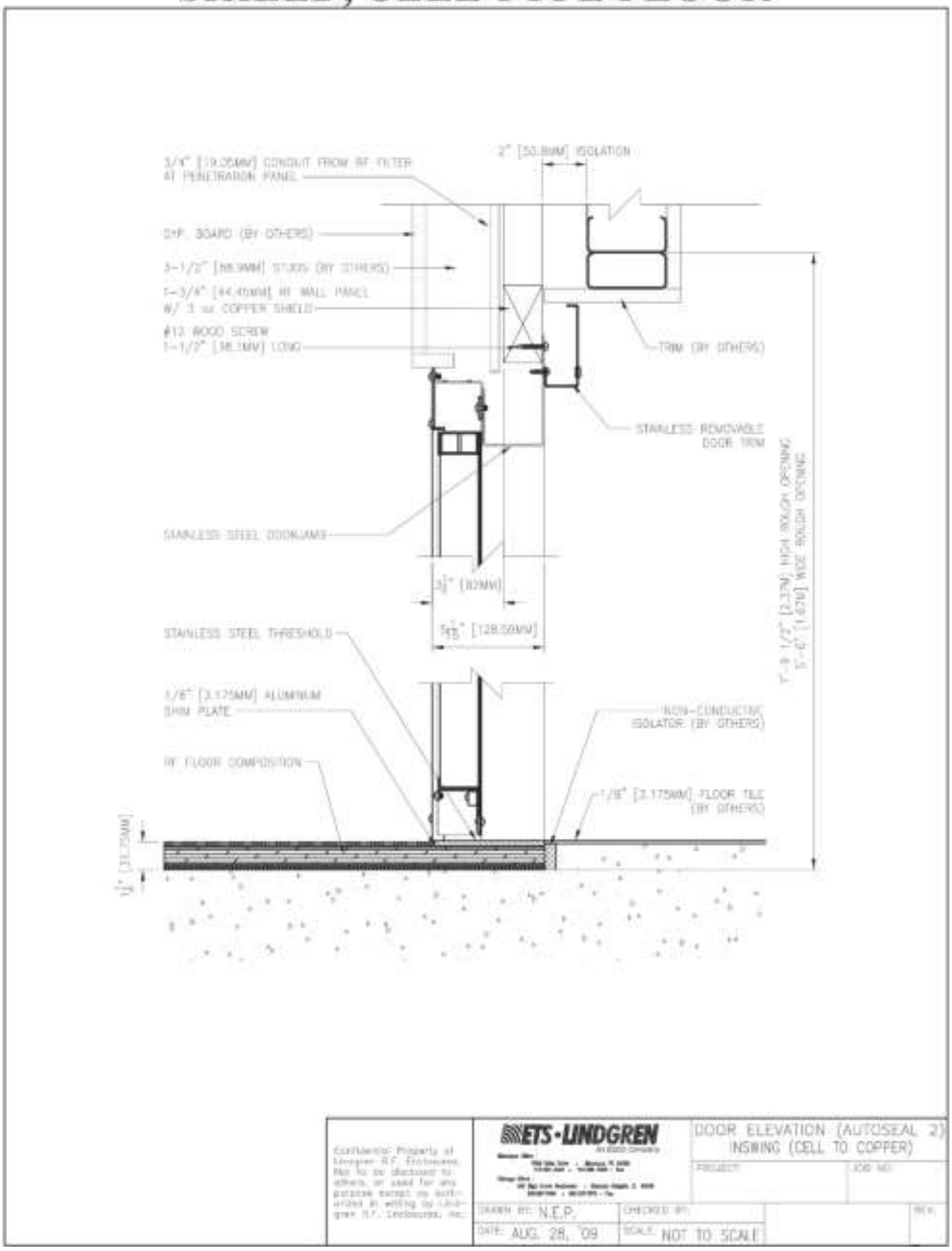


Figure1-11: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR PLAN- INSWING, CELL TYPE SHIELD

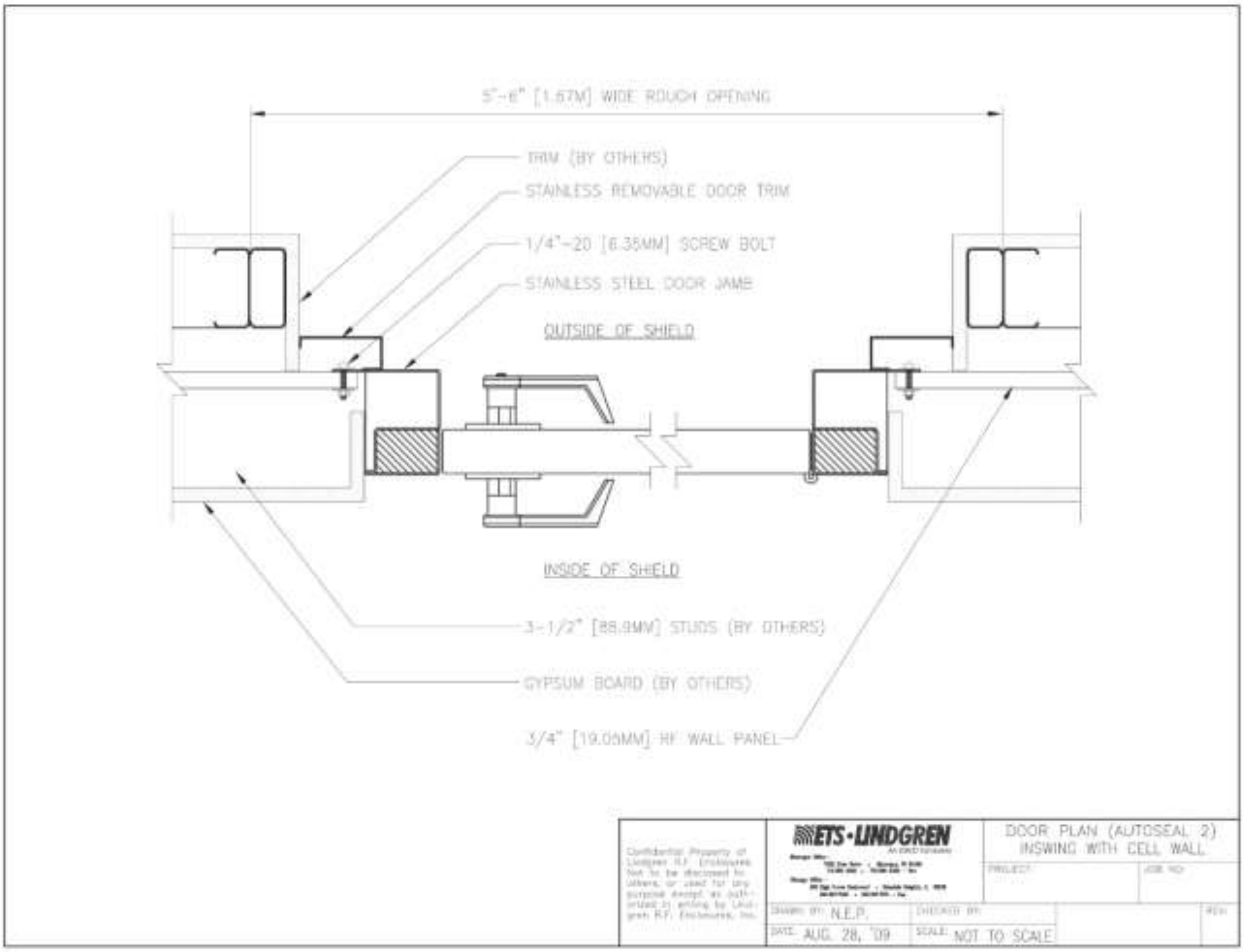


Figure1-12: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR ELEVATION- INSWING, COPPER SHIELD

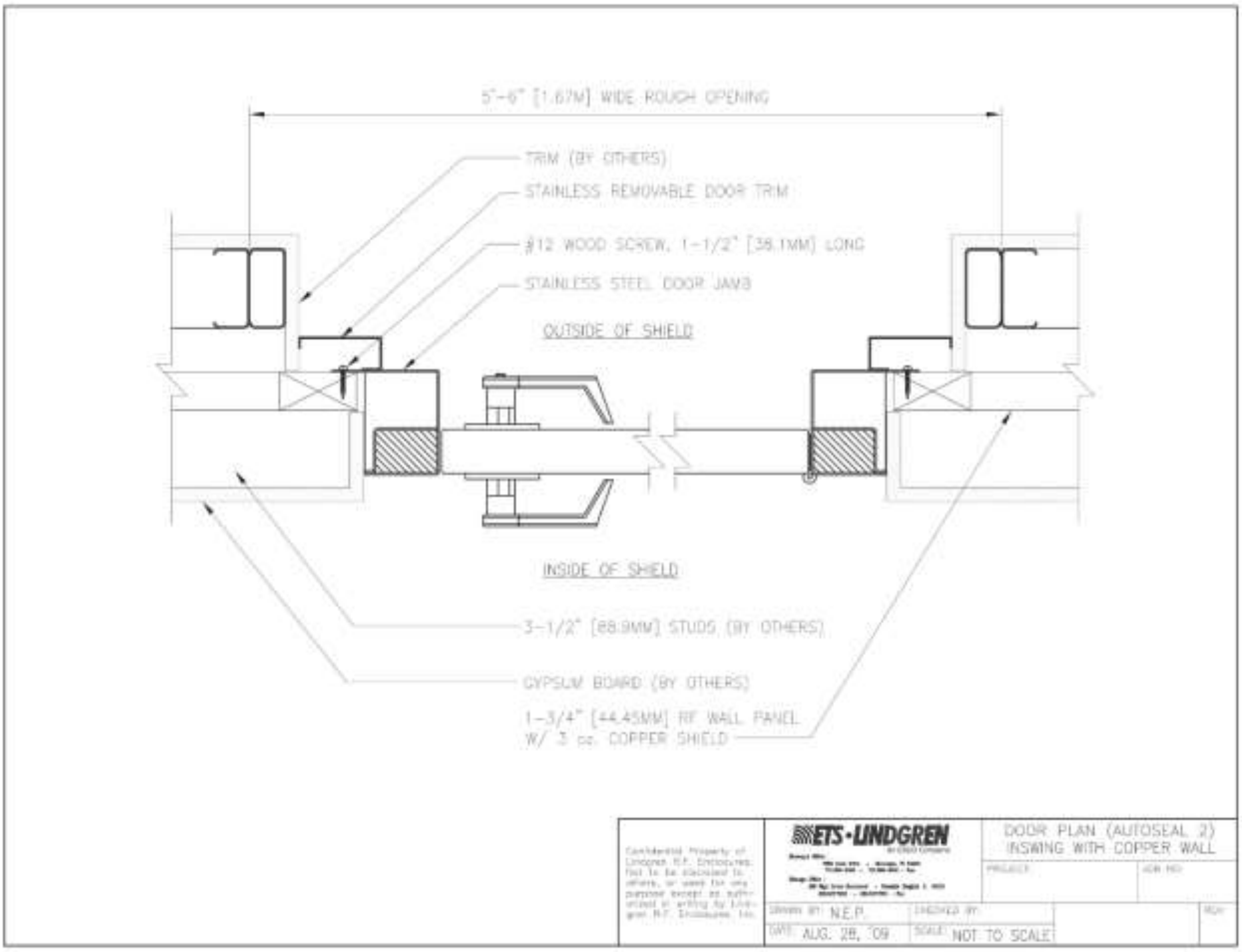


Figure1-13: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR PLAN- OUTSWING, CELL TYPE SHIELD

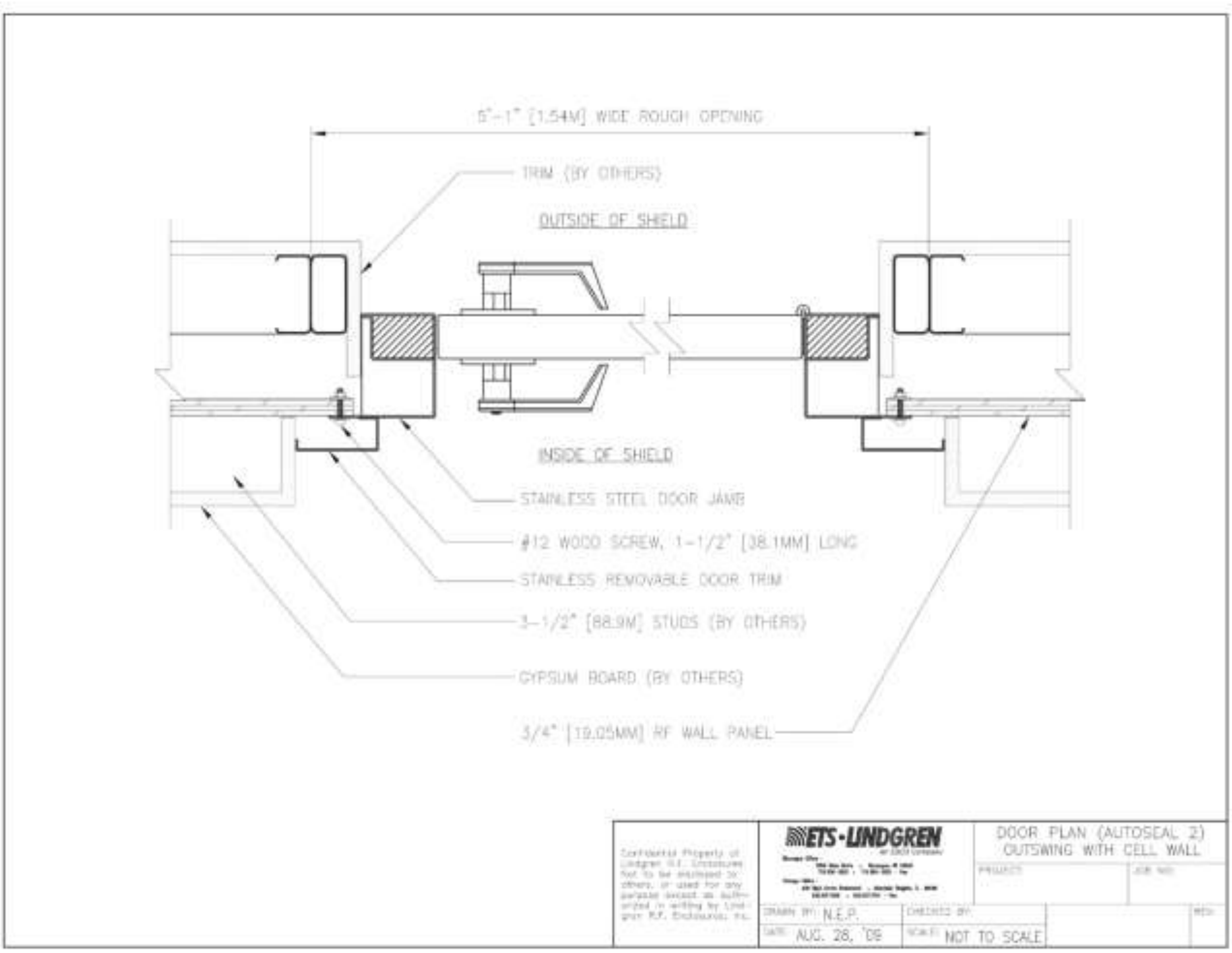


Figure1-14: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

AUTO-SEAL II DOOR PLAN- OUTSWING, COPPER TYPE SHIELD

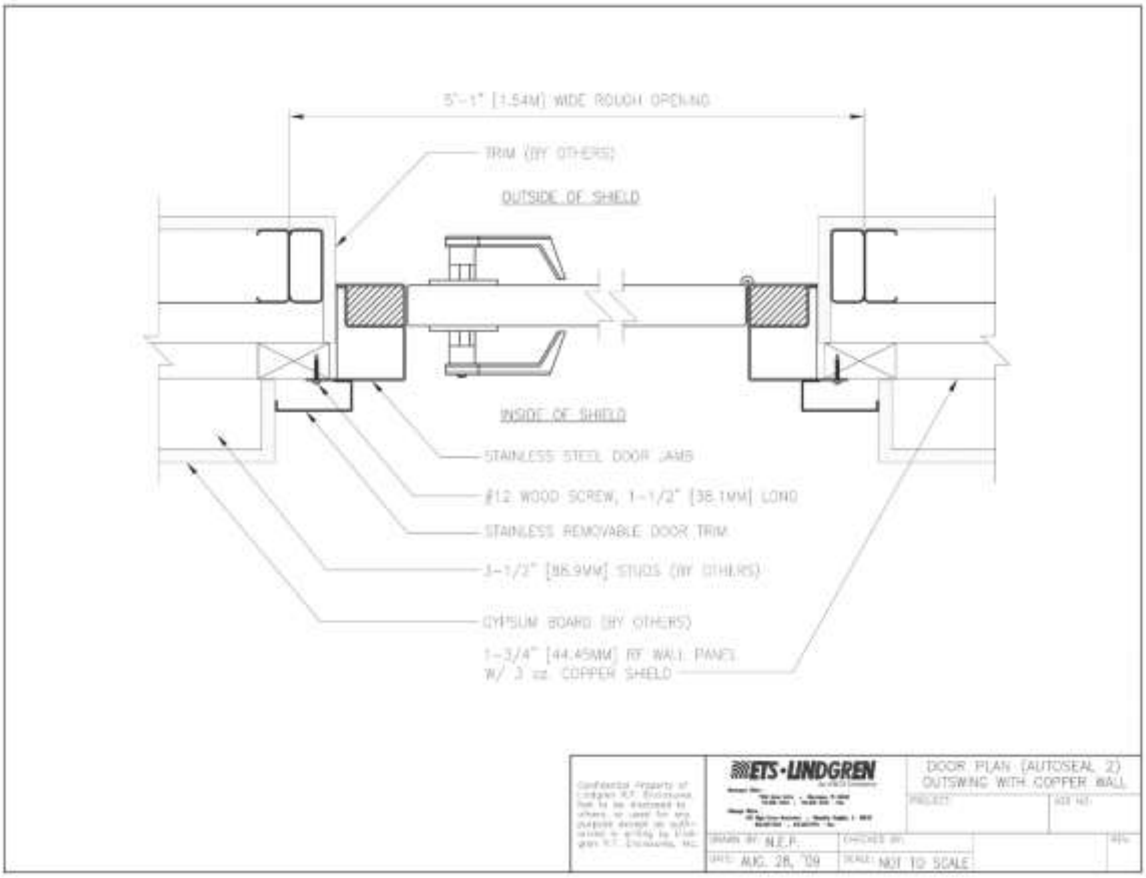


Figure1-15: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

FLOOR TO WALL- CELL TYPE SHIELD, CELL TYPE FLOOR

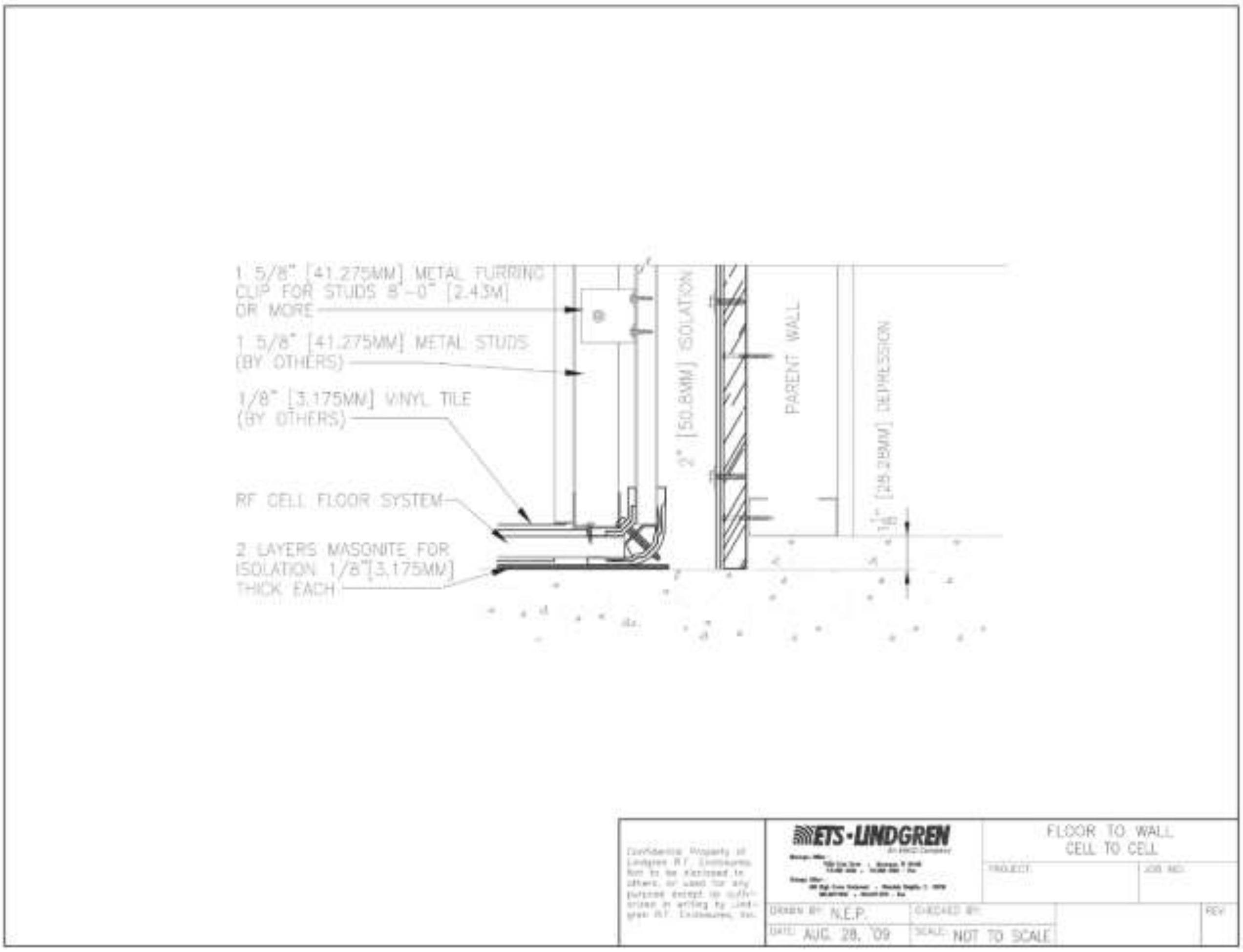


Figure1-16: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

FLOOR TO WALL- COPPER SHIELD, CELL TYPE FLOOR

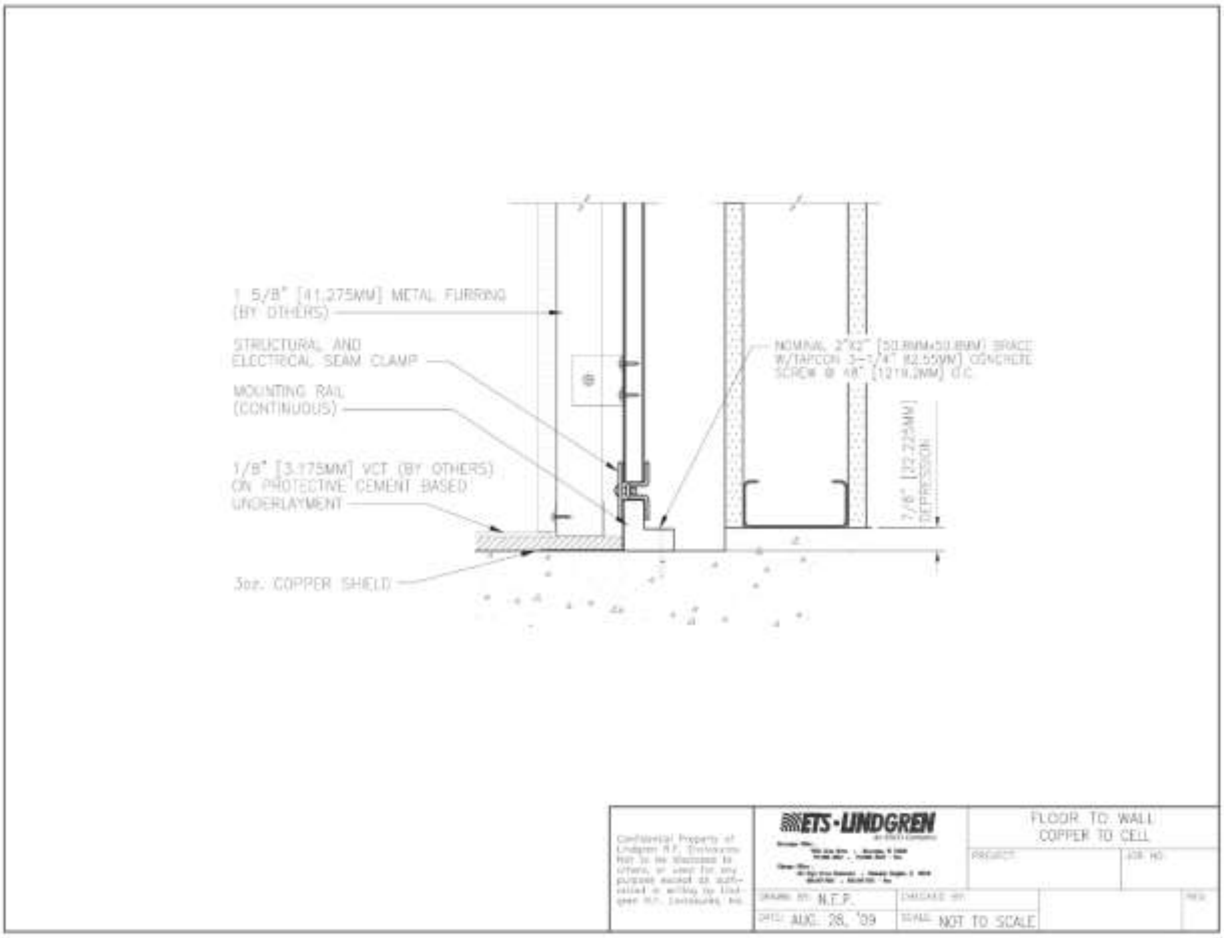


Figure1-17: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

FLOOR TO WALL- CELL TYPE SHIELD, MONOLITHIC FLOOR

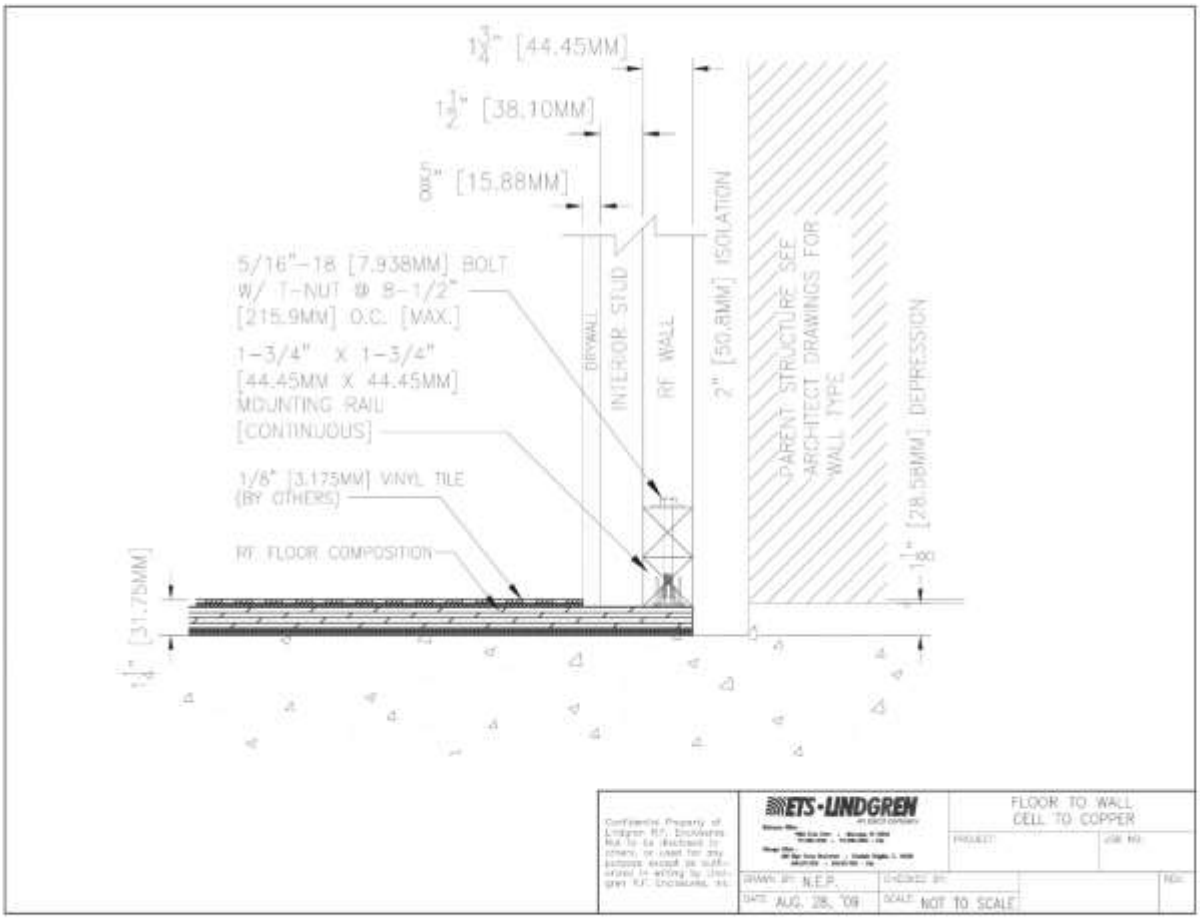


Figure1-18: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

FLOOR TO WALL- COPPER SHIELD, MONOLITHIC FLOOR

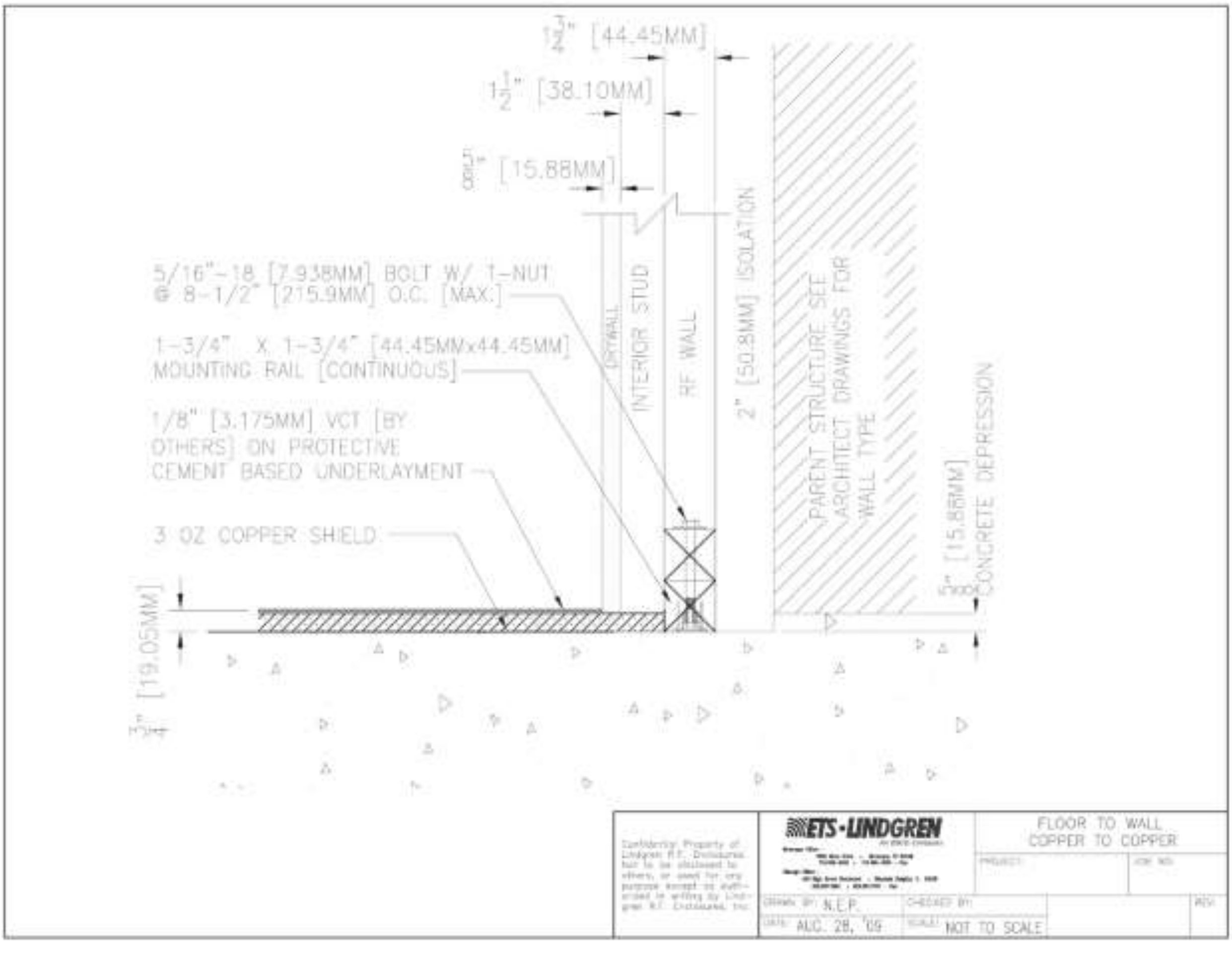


Figure1-19: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

MEDICAL GAS WAVEGUIDE

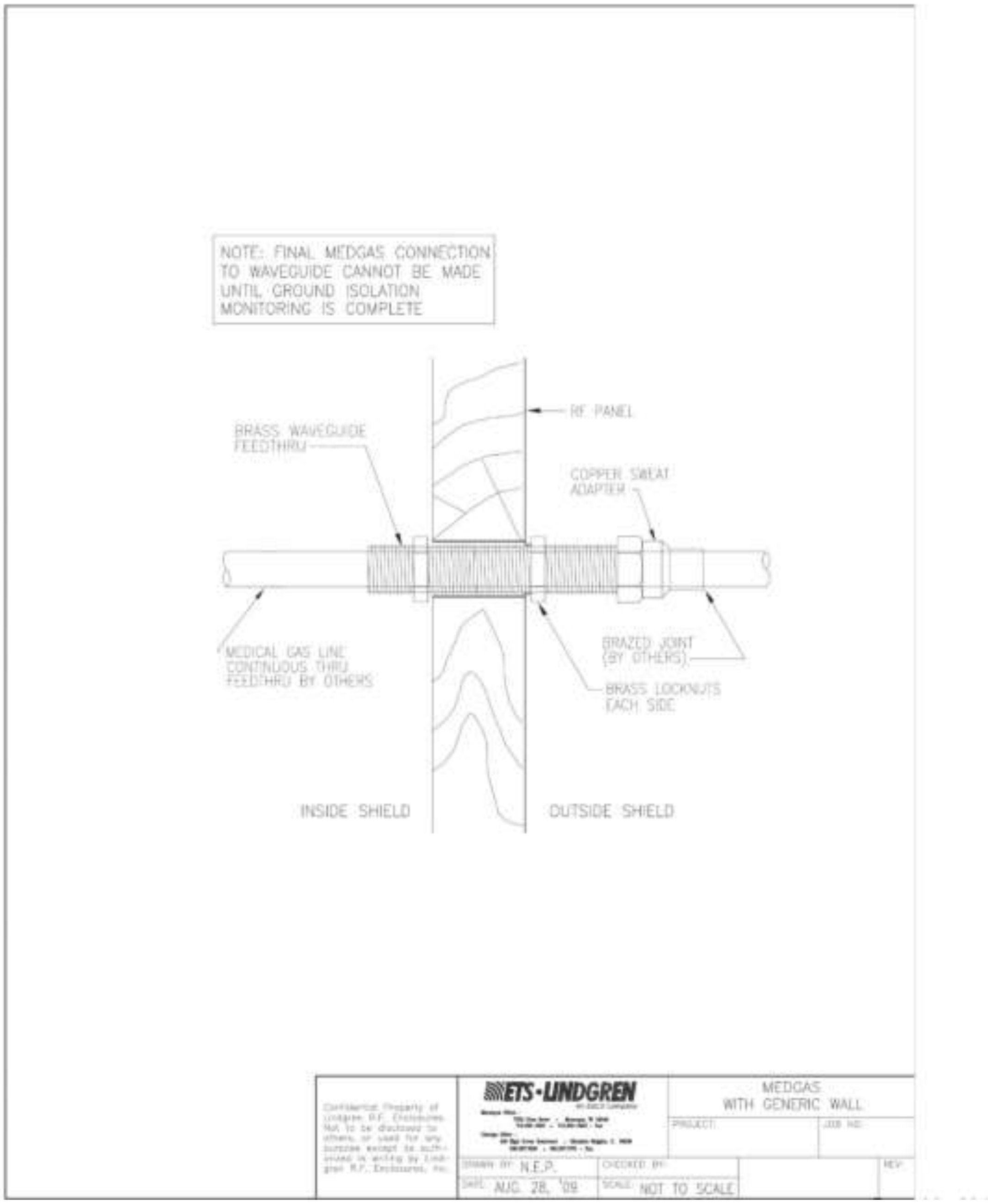
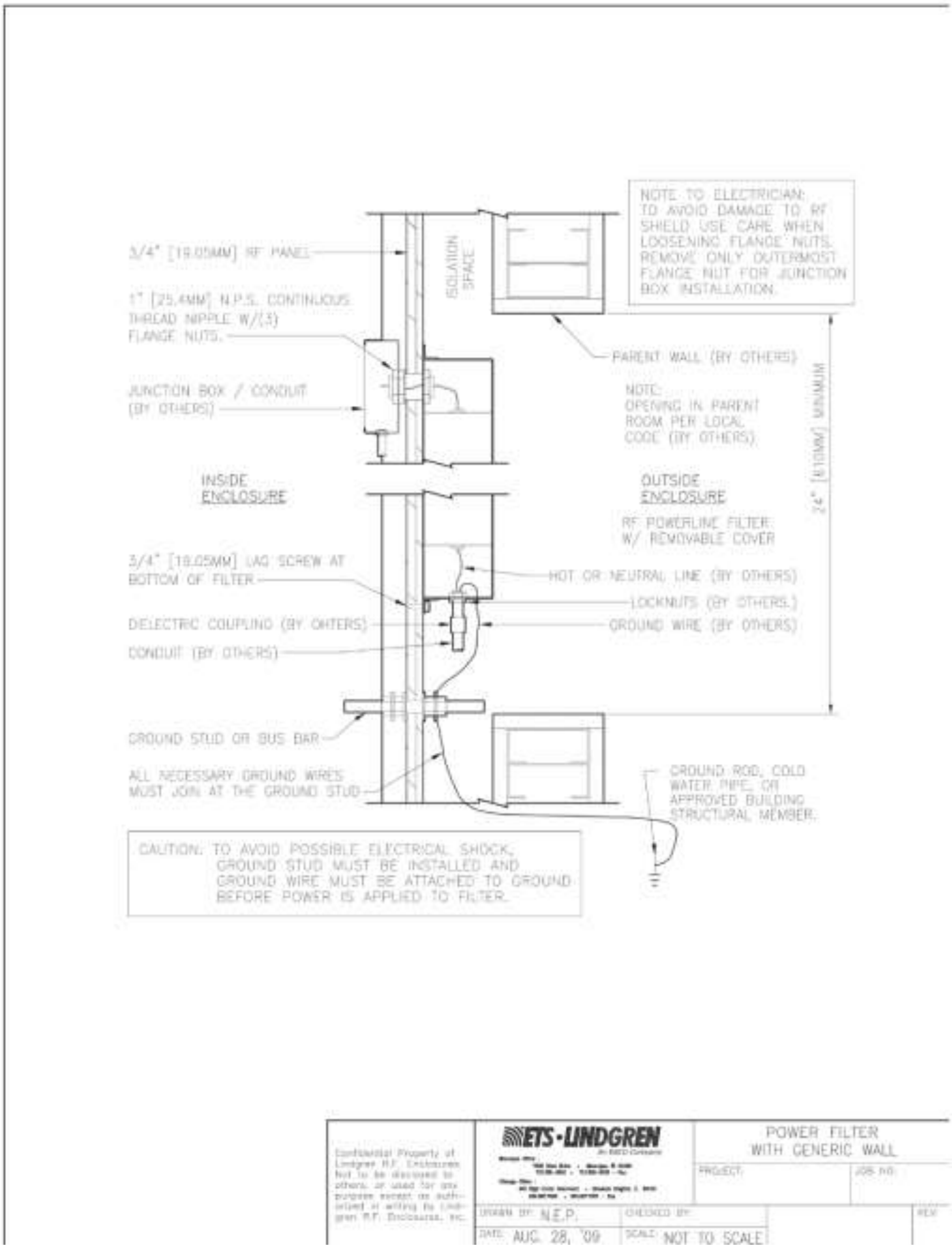


Figure1-20: MRI- room shielding details. ETS. LINDGREN an ESCO company, MRI Shielding, Glendale heights, IL 60139, Sep 2009, Available : http://www.ets-lindgren.com/ .

RF ELECTRICAL POWER FILTER



Affidavit

I hereby declare that the Master thesis with the title:

Healthy Building

'Design study of different facades for various zones of hospitals and rehabilitation resorts'.

Has been written only by the undersigned and without any assistance from third parties. Furthermore, I confirm that no sources have been used in the preparation of this paper other than those indicated in the Thesis itself.

Mouhand Abobakr,

Detmold, June 15th, 2017