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Protection of Environment from Damaged Nuclear Station and Transparent Inflatable Blanket for Cities

—Protection from Radioactive Dust and Chemical, Biological Weapons

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ABSTRACT

The author, in a series of previous articles, designed the "AB Dome" made of transparent thin film supported by a small additional air overpressure for the purpose of covering a city or other important large installations or sub-regions. In present article the author offers a variation in which a damaged nuclear station can be quickly covered by such a cheap inflatable dome. By containing the radioactive dust from the damaged nuclear station, the danger zone is reduced to about 2 km^2 rather than large regions which requires the resettlement of huge masses of people and which stops industry in large areas. If there is a big city (as Tokyo) near the nuclear disaster or there is already a dangerous amount of radioactive dust near a city, the city may also be covered by a large inflatable transparent Dome. The building of a gigantic inflatable AB Dome over an empty flat surface is not difficult. The cover is spread on a flat surface and a ventilator (fan system) pumps air under the film cover and lifts the new dome into place but inflation takes many hours. However, to cover a city, garden, forest or other obstacle course in contrast to an empty, mowed field, the thin film cannot be easily deployed over building or trees without risking damage to it by snagging and other complications. This article proposes a new method which solves this problem. The design is a double film blanket filled by light gas such as, methane, hydrogen, or helium-although of these, methane will be the most practical and least likely to leak. Sections of this AB Blanket are lighter than air and will rise in the atmosphere. They can be made on a flat area serving as an assembly area and delivered by dirigible or helicopter to station at altitude over the city. Here they connect to the already assembled AB Blanket subassemblies, cover the city in an AB Dome and protect it from bad weather, chemical, biological and radioactive fallout or particulates. After assembly of the dome is completed, the light gas can be replaced by (heavier but cheaper) air. Two projects for Tokyo (Japan) and Moscow (Russia) are used in this paper for sample computation.

Keywords: *Radiation Shield, Protection of Environment from Damaged Nuclear Station, Dome for City, Blanket for City, Protection of Cities from Chemical, Biological and Radioactive Weapons, Encapsulating Nuclear Sites*

1. Introduction

1.1. Brief History of Nuclear Accidents

1) Chernobyl disaster: The Chernobyl disaster was a nuclear accident that is considered the worst nuclear power plant accident in history, and is the only one classified (until recently) as a level 7 event on the International Nuclear Event Scale. Large areas in Ukraine, Belarus, and Russia were evacuated, and over 336,000 people were resettled. According to official post-Soviet data, about 60% of the fallout landed in Belarus. Russia, Ukraine, and Belarus have been burdened with the continuing and substantial decontamination and health care costs of the Chernobyl accident. More than fifty deaths are directly attributed to the accident, all among the reactor staff and emergency workers. Estimates of the total number of deaths attributable to the accident vary enormously, from possibly 4,000 to close to a million.

2) The Fukushima I nuclear accidents are a series of ongoing equipment failures which released radioactive materials at the Fukushima I Nuclear Power Plant, following the 2011 Tōhoku earthquake and tsunami on March 11, 2011. Fears of radiation leaks led to a 20 km (12 mile) radius evacuation around the plant. On March 18, Japanese officials designated the magnitude of the danger at reactors 1, 2 and 3 at level 5 on the 7 point International Nuclear Event Scale (INES). On March 19, Japan banned the sale of food raised in the Fukushima area up to 100 km (65 miles) from the damaged facility due to contamination above safe limits. Traces of radioactive iodine were found in drinking water in Tokyo, 210 km (135 miles) from the reactors.(see **Figure 1**)

3) Vulnerable megacities: In 1800 only 3% of the world's population lived in cities. 47% did by the end of the twentieth century. In 1950, there were 83 cities with populations exceeding one million; but by 2007, this had risen to 468 agglomerations of more than one million. If the trend continues, the world's urban population will double every 38 years, say researchers. The UN forecasts that today's urban population of 3.2 billion will rise to nearly 5 billion by 2030, when three out of five people will live in cities.

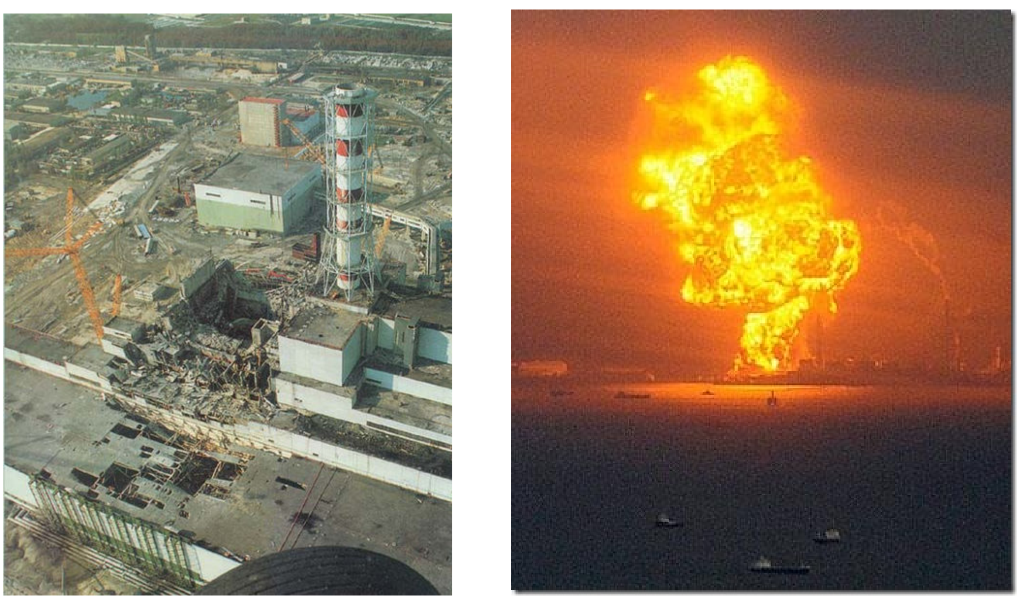
In 2000, there were 18 megacities–conurbations such as Tokyo, New York City, Los Angeles, Mexico City, Buenos Aires, Mumbai (then Bombay), São Paulo, Karachi that have populations in excess of 10 million inhabitants. Greater Tokyo already has 35 million, which is greater than the entire population of Canada.

By 2025, according to the *Far Eastern Economic Review*, Asia alone will have at least 10 megacities, including Jakarta, Indonesia (24.9 million people), Dhaka, Bangladesh (26 million), Karachi, Pakistan (26.5 million), Shanghai (27 million) and Mumbai (33 million). Lagos, Nigeria has grown from 300,000 in 1950 to an estimated 15 million today, and the Nigerian government estimates that the city will have expanded to 25 million residents by 2015. Chinese experts forecast that Chinese cities will contain 800 million people by 2020.

In the 2000s, the largest megacity is the Greater Tokyo Area. The population of this urban agglomeration includes areas such as Yokohama and Kawasaki, and is estimated to be between 35 and 36 million. This variation in estimates can be accounted for by different definitions of what the area encompasses. While the prefectures of Tokyo, Chiba, Kanagawa, and Saitama are commonly included in statistical information, the Japan Statistics Bureau only includes the area within 50 kilometers of the Tokyo Metropolitan Government Offices in Shinjuku, thus arriving at a smaller population estimate. A characteristic issue of megacities is the difficulty in defining their outer limits and accurately estimating the population. It is these concentrations of populations densities that the present inventions is designed to protect.

2. Proffered Ideas

Idea 1: Quickly cover the damage nuclear station by a cheap inflatable AB-Dome made of thin film to stop the spreading the radioactive dust. Enveloping the entire nuclear station will require a dome less than 1 km^2. By way of example, Fukushima I Nuclear Power Plant is



(a) (b)

Figure 1. (a). Chernobyl nuclear station after explosion. (b). Fukushima nuclear station explosion.

enveloped by an initial dome which is quickly erected over the radioactive site. A more permanent dome is lowered over the initial dome encapsulating the radioactive dust. (see **Figure 2 and 3**)

The radiation of isotopes decreases in time. And in the duration of some years the radiation may be reduced to acceptable levels. Impermeable film covering the damaged station does not allow isotopes to spread across the planet. In the normal case the wind and atmospheric flows, streams will distribute them throughout the world. The radiation near the Chernobyl vs. time is shown in **Figure 4**.

Idea 2: To protect the nearest big city (Tokyo) from radioactive dust by the inflatable transparent AB-Dome from a thin film. Area is about 60 - 100 km^2.

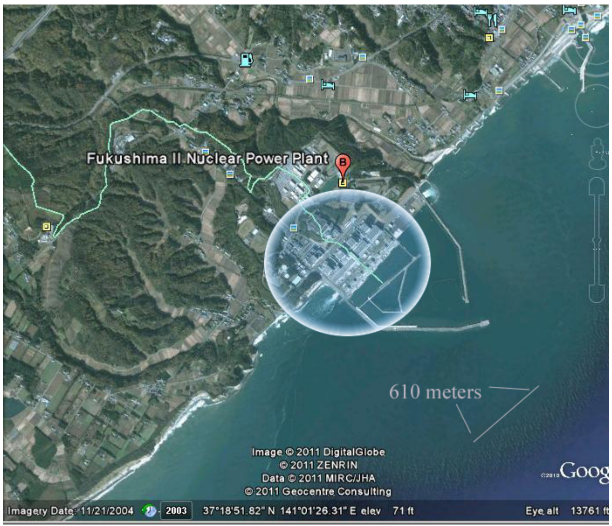


Figure 2. Initial dome over fukushima nuclear power plant.

Figure 3. Permanent containment dome over initial fukushima nuclear power plant.

To protect Tokyo from radioactive fallout, Tokyo may be covered by AB-Dome made from an inflatable transparent thin film designed and developed by author in [1-12]. The additional benefits are that this is a good means for converting a city or region into a subtropical garden with excellent weather, which also provides for clean water from the atmosphere by condensation and avoided evaporation and saves energy for heating houses in cold regions, reflecting energy for cooling houses in hot regions, protects a city from radioactive dust, chemical, bacterial weapons in war time, and even can produce net electricity etc. (**Figure 5**)

However, the author did not describe the method—by which we can cover a city, forest or other obstacle-laden region by thin film. This article suggests a method for covering the city and any surface which is neither flat nor obstruction free by thin film which insulates the city from outer environment, Earth's atmospheric instabilities, cold winter, strong wind, rain, hot weather and so on.

This new subassembly method of building an inflatable dome is named by the author 'AB-Blanket'. This idea is to design from a transparent double film a blanket, with the internal pockets or space filled by light gas Blanket are lighter than air and fly in atmosphere. They

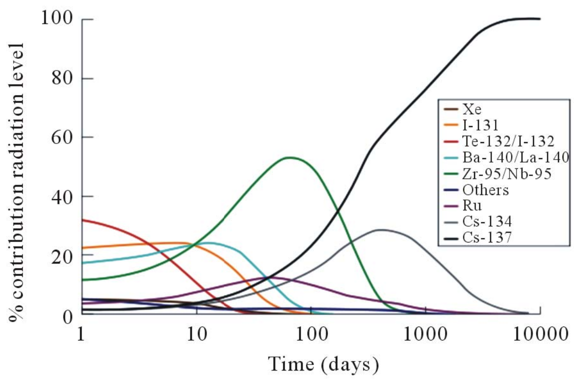


Figure 4. Contributions of the various isotopes to the (atmospheric) dose in the contaminated area soon after the accident.

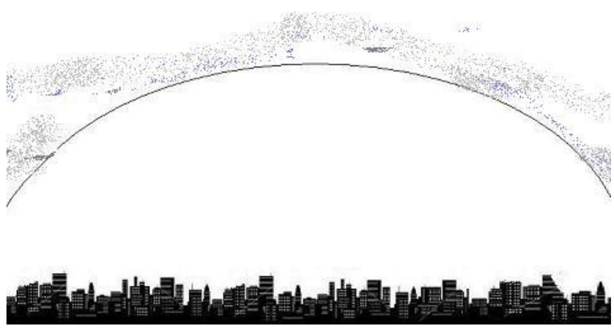


Figure 5. Dome Blanket over City to protect from the contaminated area soon after the accident.

(methane, hydrogen, helium). Subassemblies of the AB can be made in a factory, spread on a flat area, filled by gas to float upwards, and delivered by dirigible or helicopter to a sky over the city. Here they are connected to the AB Dome in building and as additional AB Blankets are brought into place, they cover the city and are sealed together. After building the dome is finished, the light gas can be changed to air. The film will be supported by small additional air pressure into Dome.

3. Description of Innovations

One design of the dome from levitated AB Blanket sections that includes the thin inflated film plate parts is presented in **Figure 6**. The innovations are: 1) the construction is gas-inflatable; 2) each part is fabricated with very thin, transparent film (thickness is 0.05 to 0.2 mm) having the option for controlled clarity; 3) the enclosing film has two conductivity layers plus a liquid crystal layer between them which changes its clarity, color and reflectivity under an electric voltage (option); 4) The space between double film is filled with a light gas (for example: methane, hydrogen or helium). The air pressure inside the dome is more than the external atmosphere also for protection from outer wind, snow and ice.

The film (textile) may be conventional (and very cheap) or advanced with real time controlled clarity for cold and hot regions.

The city AB Dome, constructed by means of these AB Blankets, allows getting clean water from rain for drinking, washing and watering which will often be enough for a city population except in case of extreme density. We shall see this for our calculations in the case of Manhattan, below. The water collected at high altitude (Blanket conventionally located at 100 - 500 m) may produce electric energy by hydro-electric generators located at Earth's surface. Wind generators located at high altitude (at Blanket surface) can produce electric energy. Such an AB Dome saves a great deal of energy (fuel) for house heating in winter time and cooling in summer time.

Detailed design of Blanket section is shown in **Figures 7**, **8**. Every section contains cylindrical tubes filled a light gas, has margins (explained later in Discussion), has windows which can be open and closed (a full section may be window), connected to Earth's surface by water tube, tube for pumping gas, bracing gables and signal and control wires.

The net prevents the watertight and airtight film covering from being damaged by vibration; (3) the film incorporates a tiny electrically conductive wire net with a mesh about 0.1 × 0.1 m and a line width of about 100 μ and a thickness near 10 μ. The wire net is electric (voltage)

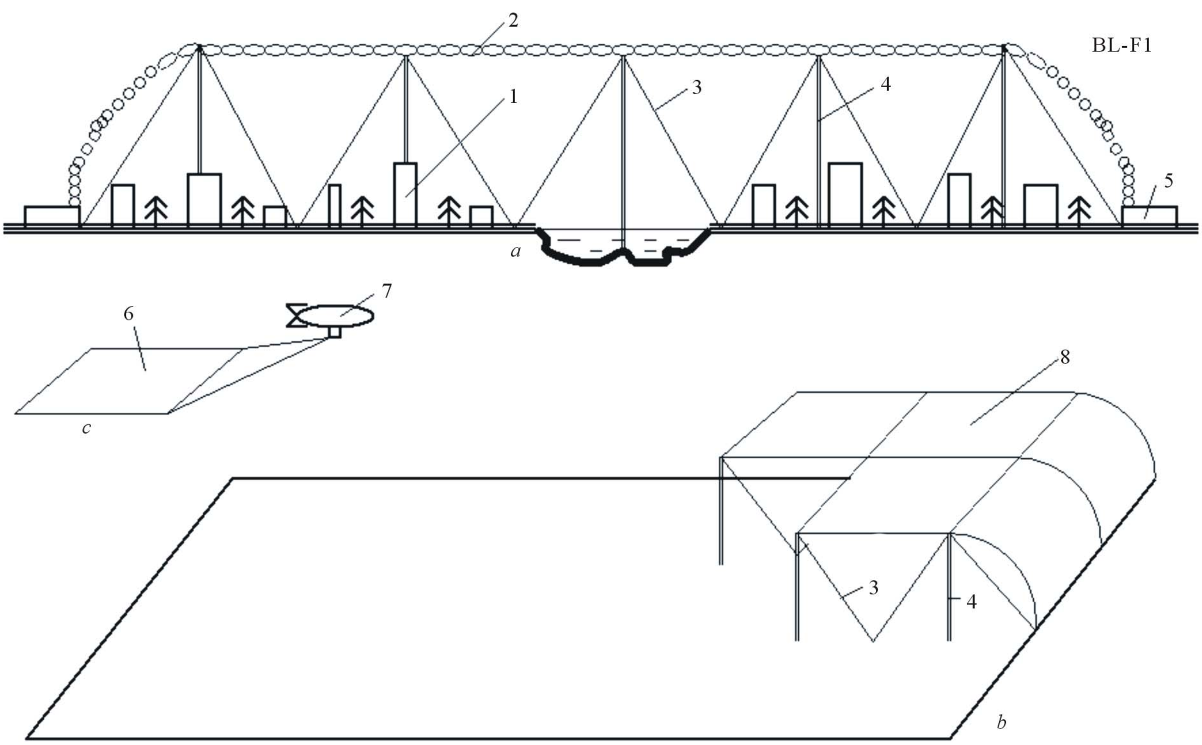


Figure 6. (*a*) Design of AB Blanket from the transparent film over city and (*b*) building the AB Dome from parts of Blanket. ***Notations:*** **1–city; 2–AB-Blanket; 3–bracing wire (support cable); 4–tubes for rain water, for lifting gas, signalization and control; 5–enter. Exit and ventilator; 6–part of Blanket; 7–dirigible; 8–building the Blanket.**

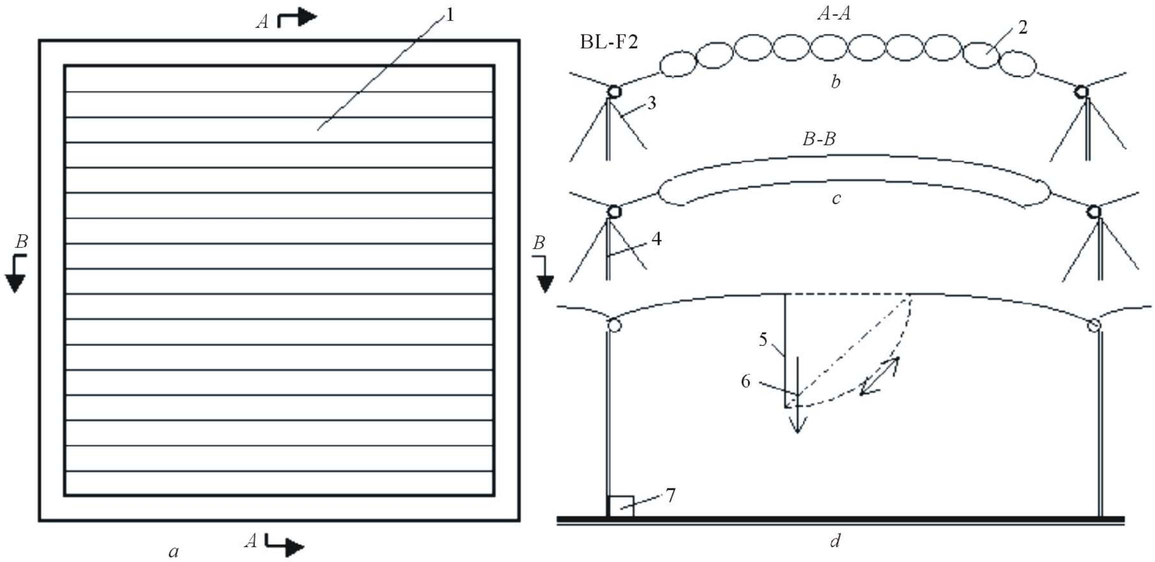


Figure 7. Design of AB Blanket section. (*a*) Typical section of Blanket (top view); (*b*) Cross-section A-A of Blanket; (*c*) Cross-section B-B of Blanket; (*d*) Typical section of Blanket (side view). *Notations:* 1–part of Blanket; 2–light lift gas (for example: methane, hydrogen or helium); 3–bracing wire (support cable); 4–tubes for rain water, for lifting gas, signalization and control; 5–cover of windows; 6–snow, ice; 7–hydro-electric generator, air pump.

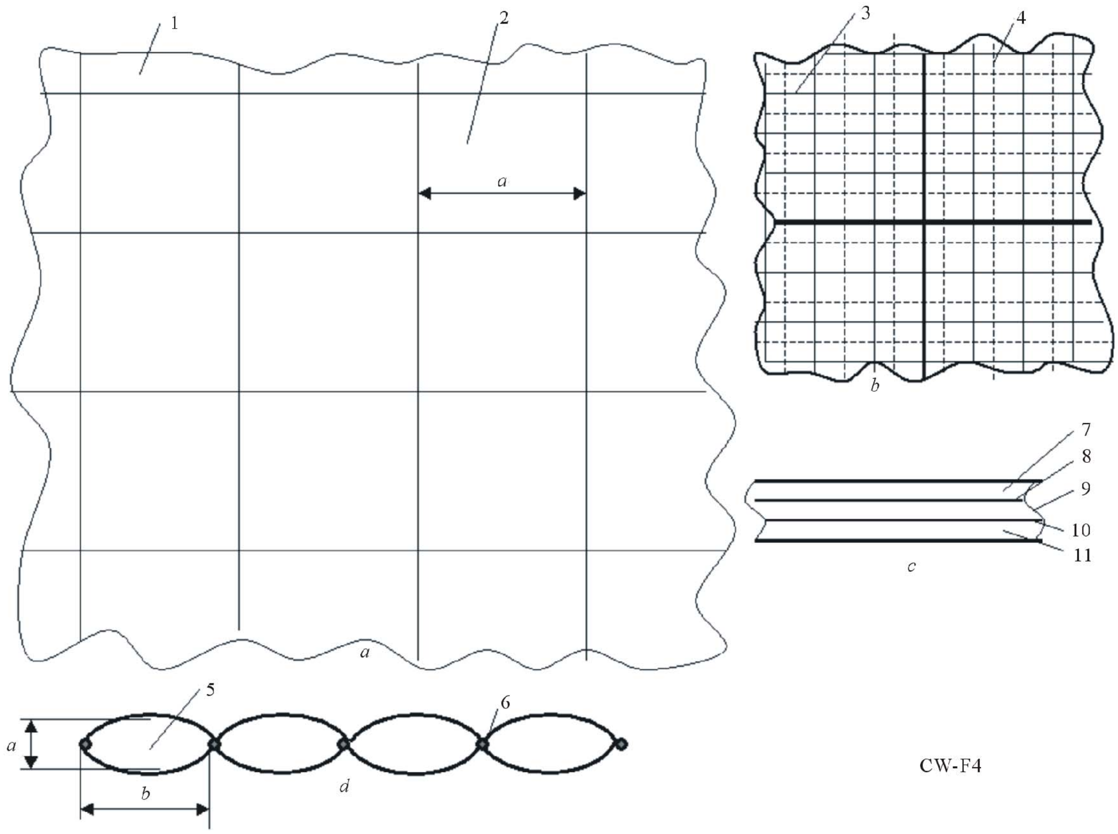


Figure 8. Design of advanced covering membrane. *Notations*: (*a*) Big fragment of cover with controlled clarity (reflectivity, carrying capacity) and heat conductivity; (*b*) Small fragment of cover; (*c*) Cross-section of cover (film) having 5 layers; (*d*) Longitudinal cross-section of cover; 1–cover; 2–mesh; 3–small mesh; 4–thin electric net; 5–cell of cover; 6–margins and wires; 7–transparent dielectric layer; 8–conducting layer (about 1 - 3 μ); 9–liquid crystal layer (about 10 - 100 μ); 10–conducting layer; and 11–transparent dielectric layer. Common thickness is 0.1 - 0.5 mm. Control voltage is 5 - 10 V.

control conductor. It can inform the dome maintenance engineers concerning the place and size of film damage (tears, rips, etc.); (4) the film has twin-layered with the gap—*c* = 1 - 3 m and *b* = 3 - 6 m—between film layers for heat insulation. In polar (and hot) regions this multi-layered covering is the main means for heat isolation and puncture of one of the layers won't cause a loss of shape because the second film layer is unaffected by holing; (5) the airspace in the dome's covering can be partitioned, either hermetically or not; and (6) part of the covering can have a very thin shiny aluminum coating that is about 1 μ (micron) for reflection of unnecessary solar radiation in equatorial or collect additional solar radiation in the polar regions [2].

The town cover may be used as a screen for projection of pictures, films and advertising on the cover at night time. In the case of Manhattan this alone might pay for it!

3.1. Brief Information about Advanced Cover Film

Our advanced Blanket cover (film) has 5 layers (**Figure 8(c)**): transparent dielectric layer, conducting layer (about 1 - 3 μ), liquid crystal layer (about 10 - 100 μ), conducting layer (for example, SnO_2), and transparent dielectric layer. Common thickness is 0.3 - 1 mm. Control voltage is 5 - 10 V. This film may be produced by industry relatively cheaply.

1) Liquid crystals (LC) are substances that exhibit a phase of matter that has properties between those of a conventional liquid, and those of a solid crystal. Liquid crystals find wide use in liquid crystal displays (LCD), which rely on the optical properties of certain liquid crystalline molecules in the presence or absence of an electric field. The electric field can be used to make a pixel switch between clear or dark on command. Color LCD systems use the same technique, with color filters used to generate red, green, and blue pixels. Similar principles can be used to make other liquid crystal based optical devices. Liquid crystal in fluid form is used to detect electrically generated hot spots for failure analysis in the semiconductor industry. Liquid crystal memory units with extensive capacity were used in Space Shuttle navigation equipment. It is also worth noting that many common fluids are in fact liquid crystals. Soap, for instance, is a liquid crystal, and forms a variety of LC phases depending on its concentration in water. The conventional controlled clarity (transparency) film reflects superfluous energy back to space if too much. If film has solar cells it may converts part of the superfluous solar energy into electricity.

2) Transparency. In optics, transparency is the material property of allowing light to pass through. Though transparency usually refers to visible light in common usage, it may correctly be used to refer to any type of radiation. Examples of transparent materials are air and some other gases, liquids such as water, most glasses, and plastics such as Perspex and Pyrex. Where the degree of transparency varies according to the wavelength of the light. From electrodynamics it results that only a vacuum is really transparent in the strict meaning, any matter has a certain absorption for electromagnetic waves. There are transparent glass walls that can be made opaque by the application of an electric charge, a technology known as electrochromics. Certain crystals are transparent because there are straight lines through the crystal structure. Light passes unobstructed along these lines. There is a complicated theory "predicting" (calculating) absorption and its spectral dependence of different materials. The optic glass has transparence about 95% of light (visible) radiation. The transparency depends upon thickness and may be very high for thin film.

3) Electrochromism is the phenomenon displayed by some chemical species of reversibly changing color when a burst of charge is applied. One good example of an electrochromic material is polyaniline which can be formed either by the electrochemical or chemical oxidation of aniline. If an electrode is immersed in hydrochloric acid which contains a small concentration of aniline, then a film of polyaniline can be grown on the electrode. Depending on the redox state, polyaniline can either be pale yellow or dark green/black. Other electrochromic materials that have found technological application include the viologens and polyoxotungstates. Other electrochromic materials include tungsten oxide (WO_3), which is the main chemical used in the production of electrochromic windows or smart windows.

As the color change is persistent and energy need only be applied to effect a change, electrochromic materials are used to control the amount of light and heat allowed to pass through windows ("smart windows"), and has also been applied in the automobile industry to automatically tint rear-view mirrors in various lighting conditions. Viologen is used in conjunction with titanium dioxide (TiO_2) in the creation of small digital displays. It is hoped that these will replace LCDs as the viologen (which is typically dark blue) has a high contrast to the bright color of the titanium white, therefore providing a high visibility of the display.

4. Theory and Computations of the Ab Blanket

1) Lift force of Blanket. The specific lift force of Blanket is computed by the equation:

$$L = g\left(q_a - q_g\right)V \tag{1}$$

where L is lift force, N; g = 9.81 m/s^2 is gravity; q_a= 1.225 kg/m^3 is an air density for standard condition (T = 15˚C); $q_g < q_a$ is density of lift light gas. For methane q_g = 0.72 kg/m^3, hydrogen q_g = 0.09 kg/m^3, helium q_g = 0.18 kg/m^3; V is volume of Blanket, m^3. For example, the section 100 × 100 m of the Blanket filled by methane (the cheapest light gas) having the average thickness 3 m has the lift force 15 N/m^2 or 150,000 N = 15 tons.

2) **The weight (mass) of film** may be computed by equation

$$W = \gamma \delta S \tag{2}$$

where W is weight of film, kg; γ is specific density of film (usually about γ = 1500 ÷ 1800 kg/m^3); δ is thickness, m; S is area, m^2. For example, the double film of thickness δ = 0.05 mm has weight W = 0.15 kg/m^2. The section 100 × 100 m of the Blanket has weight 1500 kg = 1.5 tons.

3) Weight (mass) of support cable (bracing wire) is computed by equation:

$$W_c = \gamma_c \frac{hLS}{\sigma} \tag{3}$$

where W_c is weight of support cable, kg; γ_c is specific density of film (usually about γ_c = 1800 kg/m^3), σ is safety density of cable, N/m^2. For cable from artificial fiber σ = 100 ÷ 150 kg/mm^2 = (1 ÷ 1.5)×10^9 N/m^2. For example, for σ = 100 kg/mm^2, h =500 m, L = 10 N/m^2, W_c = 0.009 kg/m^2. However, if additional air pressure into dome is high, for example, lift force L = 1000 N/m^2 (air pressure P = 0.01 atm - 0.01 bar), the cable weight may reach 0.9 kg/m^2. That may be requested in a storm weather when outer wind and wind dynamic pressure is high.

As wind flows over and around a fully exposed, nearly completely sealed inflated dome, the weather affecting the external film on the windward side must endure positive air pressures as the wind stagnates. Simultaneously, low air pressure eddies will be present on the leeward side of the dome. In other words, air pressure gradients caused by air density differences on different parts of the sheltering dome's envelope is characterized as the "buoyancy effect". The buoyancy effect will be greatest during the coldest weather when the dome is heated and the temperature difference between its interior and exterior are greatest. In extremely cold climates, such as the Arctic and Antarctica, the buoyancy effect tends to dominate dome pressurization, causing the Blanket to require reliable anchoring.

4) The wind dynamic pressure is computed by equation

$$p_d = \frac{\rho V^2}{2} \tag{4}$$

where p_d is wind dynamic pressure, N/m^2; ρ is air density, for altitude H = 0 the ρ= 1.225 kg/m^3; V is wind speed, m/s. The computation is presented in **Figure 9**.

The small overpressure of 0.01 atm forced into the AB-Dome to inflate it produces force p = 1000 N/m^2. That is greater than the dynamic pressure (740 N/m^2) of very strong wind V = 35 m/s (126 km/hour). If it is necessary we can increase the internal pressure by some times if needed for very exceptional storms.

5) The thickness of the dome envelope, its sheltering shell of film, is computed by formulas (from equation for tensile strength):

$$\delta_1 = \frac{Rp}{2\sigma}, \quad \delta_2 = \frac{Rp}{\sigma} \tag{5}$$

where δ_1 is the film thickness for a spherical dome, m; δ_2 is the film thickness for a cylindrical dome, m; R is radius of dome, m; p is additional pressure into the dome, N/m^2; σ is safety tensile stress of film, N/m^2.

For example, compute the film thickness for dome having radius R = 50 m, additional internal air pressure p = 0.01 atm (p = 1000 N/m^2), safety tensile stress σ= 50 kg/mm^2 (σ = 5 σ 10^8 N/m^2), cylindrical dome.

$$\delta = \frac{50 \times 1000}{5 \times 10^8} = 0.0001\ \text{m} = 0.1\ \text{mm} \tag{6}$$

6) Solar radiation. Our basic computed equations, below, are derived from a Russian-language textbook [19]. Solar radiation impinging the orbiting Earth is approximately 1400 W/m^2. The average Earth reflection by clouds and the sub-aerial surfaces (water, ice and land) is about 0.3. The Earth-atmosphere adsorbs about 0.2 of the Sun's radiation. That means about q_0 = 700 W/m^{2}s of solar energy (heat) reaches our planet's surface at the Equator. The solar spectrum is graphed in **Figure 10**.

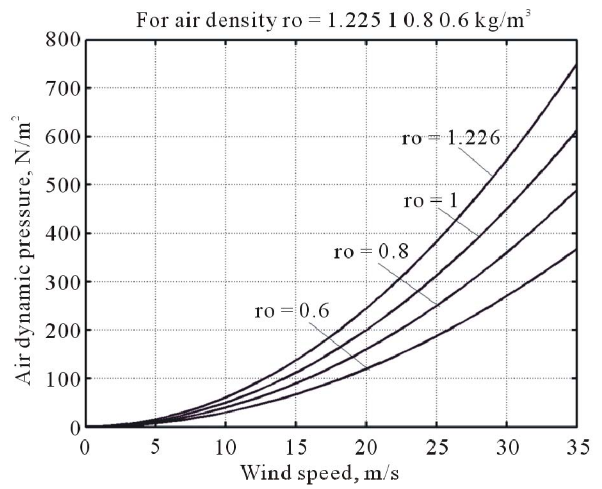


Figure 9. Wind dynamic pressure versus wind speed and air density *ρ*. The *ro* = 0.6 is for *H* ≈ 6 km.

The visible part of the Sun's spectrum is only $\lambda = 0.4$ to $0.8\ \mu$. Any warm body emits radiation. The emission wavelength depends on the body's temperature. The wavelength of the maximum intensity (see **Figure 10**) is governed by the black-body law originated by Max Planck (1858-1947):

$$\lambda_m = \frac{2.9}{T},\ [\text{mm}] \tag{6}$$

where T is body temperature, ˚K. For example, if a body has an ideal temperature 20˚C (T = 293 ˚K), the wavelength is $\lambda_m = 9.9\mu$.

The energy emitted by a body may be computed by employment of the Josef Stefan-Ludwig Boltzmann law.

$$E = \varepsilon\sigma_S T^4,\ [W/m] \tag{7}$$

where ε is coefficient of body blackness (ε = 0.03 ÷ 0.99 for real bodies), $\sigma_s = 5.67 \times 10^{-8}$ [W/m^{2}K] Stefan-Boltzmann constant. For example, the absolute black-body ($\varepsilon = 1$) emits (at T = 293˚C) the energy E = 418 W/m^2.

Amount of the maximum solar heat flow at 1 m^2 per 1 second of Earth surface is

$$q = q_0\cos(\varphi \pm \theta)\quad [\text{W}/m^2] \tag{8}$$

where φ is Earth longevity, θ is angle between projection of Earth polar axis to the plate which is perpendicular to the ecliptic plate and contains the line Sun-Earth and the perpendicular to ecliptic plate. The sign "+" signifies Summer and the "-" signifies Winter, $q_0 \approx 700$ W/m^2 is the annual average solar heat flow to Earth at equator corrected for Earth reflectance.

This angle is changed during a year and may be estimated for the Arctic by the following the first approximation equation:

$$\theta = \theta_m \cos\omega, \quad \text{where} \quad \omega = 2\pi\frac{N}{364} \tag{9}$$

where θ_m is maximum θ, $|\theta_m| = 23.5^\circ = 0.41$ radian; N is number of day in a year. The computations for Summer and Winter are presented in **Figure 11**.

The heat flow for a hemisphere having reflector (**Figure 6**) at noon may be computed by equation

$$q = c_1 q_0\left[\cos(\varphi - \theta) + S\sin(\varphi + \theta)\right] \tag{10}$$

where S is fraction (relative) area of reflector to service area of "Evergreen" dome. Usually S = 0.5; c_1 is film transparency coefficient ($c_1 \approx$ 0.9 - 0.95).

The daily average solar irradiation (energy) is calculated by equation

$$Q = 86400\,c\,qt, \quad \text{where} \quad t = 0.5(1 + \tan\varphi\tan\theta),\ |\tan\phi\tan\theta| \le 1 \tag{11}$$

where c is daily average heat flow coefficient, $c \approx 0.5$; t is relative daylight time, 86400 = 24 × 60 × 60 is number of seconds in a day.

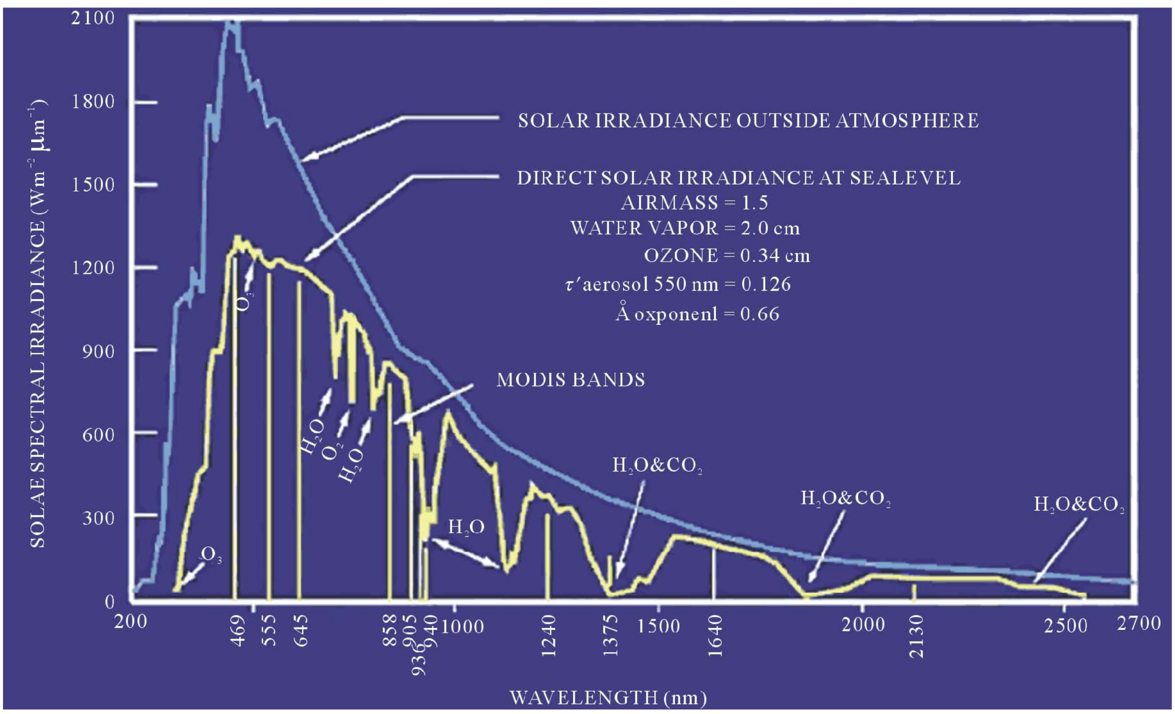


Figure 10. Spectrum of solar irradiance outside atmosphere and at sea level with absorption of electromagnetic waves by atmospheric gases. Visible light is 0.4 - 0.8 μ (400 - 800 nm).

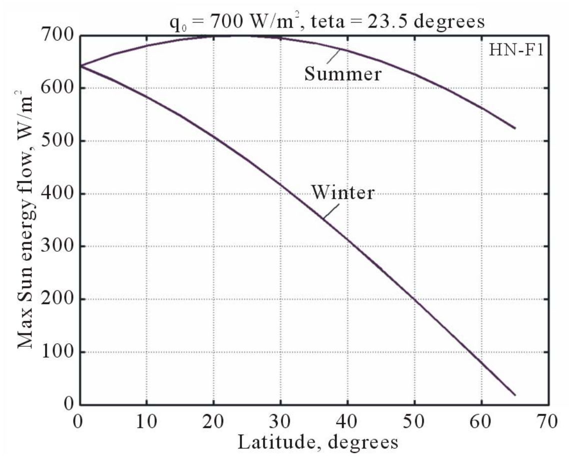


Figure 11. Maximum sun radiation flow at Earth surface as function of Earth latitude and season.

The computation for relative daily light period is presented in **Figure 12**.

The heat loss flow per 1 m^2 of dome film cover by convection and heat conduction is (see [19]):

$$q = k\left(t_1 - t_2\right), \quad \text{where} \quad k = \frac{1}{1/\alpha_1 + \sum_i \delta_i/\lambda_i + 1/\alpha_2} \tag{12}$$

where k is heat transfer coefficient, W/m^{2}K; $t_{1,2}$ are temperatures of the inter and outer multi-layers of the heat insulators, C$^\circ$, $\alpha_{1,2}$ are convention coefficients of the inter and outer multi-layers of heat insulators (α = 30 ÷ 100), W/m^{2}K; δ_i are thickness of insulator layers; δ_i are coefficients of heat transfer of insulator layers (see **Table 1**), m; $t_{1,2}$ are temperatures of initial and final layers ˚C.

The radiation heat flow per 1 m^{2}s of the service area computed by Equations (7):

$$q = C_r\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right], \tag{13}$$

$$\text{where} \quad C_r = \frac{c_s}{1/\varepsilon_1 + 1/\varepsilon_2 - 1}, \quad c_s = 5.67 \ \left[\mathrm{W/m^2K^4}\right]$$

where C_r is general radiation coefficient, ε are black body rate (Emittance) of plates (see **Table 2**); T is temperatures of plates, K^o.

The radiation flow across a set of the heat reflector plates is computed by equation

$$q = 0.5\frac{C_r'}{C_r}q_r \tag{14}$$

where C_r' is computed by Equation (8) between plate and reflector.

The data of sme construction materials is found in **Table 1, 2**.

As the reader will see, the air layer is the best heat insulator. We do not limit its thickness δ.

As the reader will notice, the shiny aluminum louver coating is an excellent mean jalousie (louvered window, providing a similar service to a Venetian blind) which

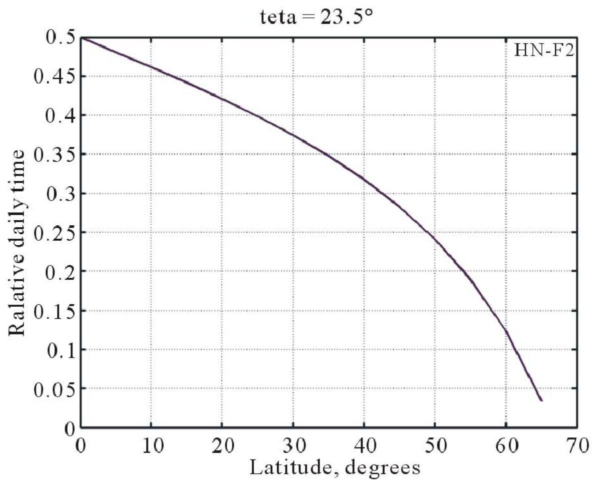


Figure 12. Relative daily light time relative to Earth latitude.

Table 1. [14], p. 331. Heat transfer.

	Material kg/m^3	Density, Thermal conductivity, W/m ˚C	Heat capacity, kJ/kg ˚C
Concrete	2300	1.279	1.13
Bake brick	1800	0.758	0.879
Ice	920	2.25	2.26
Snow	560	0.465	2.09
Glass	2500	0.744	0.67
Steel	7900	45	0.461
Air	1.225	0.0244	1

Table 2. Nacshekin [14], p. 465. Emittance, ε (Emissivity).

Material	Temperature, *T*˚C	Emittance, ε
Bright Aluminum	(50 ÷ 500)˚C	0.04 - 0.06
Bright copper	(20 ÷ 350)˚C	0.02
Steel	50˚C	0.56
Asbestos board	20˚C	0.96
Glass	(20 ÷ 100)˚C	0.91 - 0.94
Baked brick	20˚C	0.88 - 0.93
Tree	20˚C	0.8 - 0.9
Black vanish	(40 ÷ 100)˚C	0.96 - 0.98
Tin	20˚C	0.28

serves against radiation losses from the dome.

The general radiation heat Q computes by Equation (11). Equations (6)-(14) allow computation of the heat balance and comparison of incoming heat (gain) and outgoing heat (loss).

The computations of heat balance of a dome of any size in the coldest wintertime of the Polar Regions are presented in **Figure 13**.

The heat from combusted fuel is found by equation

$$Q = c_t m/\eta \quad (15)$$

where c_t is heat rate of fuel [J/kg]; c_t = 40 MJ/kg for liquid oil fuel; m is fuel mass, kg; η is efficiency of heater, η = 0.5 - 0.8.

In **Figure 8** the alert reader has noticed: the daily heat loss is about the solar heat in the very coldest Winter day when a dome located above 60° North or South Latitude and the outside air temperature is –50˚C.

7) Properties and cost of material. The cost some material are presented in **Table 3** (2005-2007). Properties are in **Table 4**. Some difference in the tensile stress and density are result the difference sources, models and trademarks.

8) Closed-loop water cycle. The closed Dome allows creating a closed loop cycle, when vapor water in the day time will returns as condensation or dripping rain in the night time. A reader can derive the equations below from well-known physical laws Nacshekin [14] (1969). Therefore, the author does not give detailed explanations of these.

9) Amount of water in atmosphere. Amount of water in atmosphere depends upon temperature and humidity. For relative humidity 100%, the maximum partial pressure of water vapor for pressure 1 atm is shown in **Table 5.**

The amount of water in 1 m^3 of air may be computed by equation

$$m_W = 0.00625\left[p(t_2)h - p(t_1)\right] \quad (16)$$

where m_W is mass of water, kg in 1 m^3 of air; $p(t)$ is vapor(steam) pressure from **Table 4**, relative $h = 0 \div 1$ is relative humidity. The computation of Equation (16) is

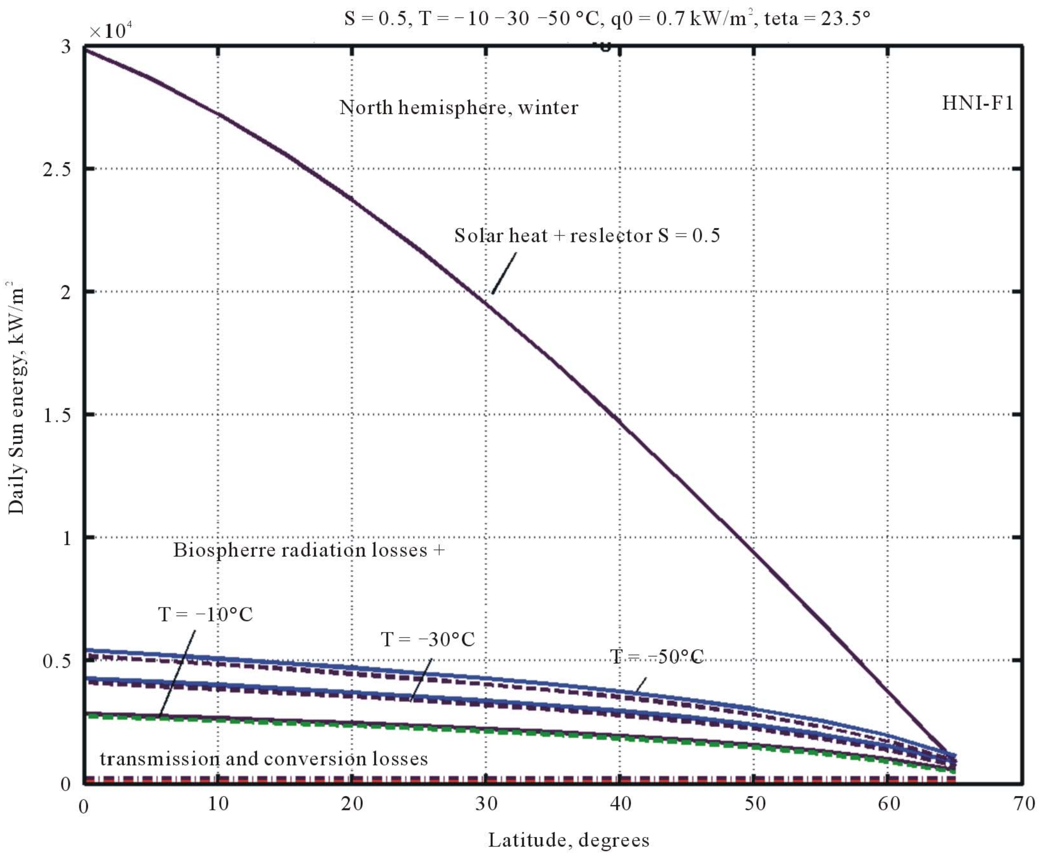


Figure 13. Daily heat balance through 1 m^2 of dome during coldest winter day versus Earth's latitude (North hemisphere example). Data used for computations (see Equation (6)-(14)): temperature inside of dome is t_1 = +20°C, outside are t_2 = –10, –30, –50°C; reflectivity coefficient of mirror is c_2 = 0.9; coefficient transparency of film is c_1 = 0.9; convectively coefficients are $\alpha_1 = \alpha_2$ = 30; thickness of film layers are $\delta_1 = \delta_2$ =0.0001 m; thickness of air layer is δ = 1 m; coefficient of film heat transfer is $\lambda_1 = \lambda_3$ = 0.75, for air λ_2 = 0.0244; ratio of cover blackness $\varepsilon_1 = \varepsilon_3$ = 0.9, for louvers ε_2 = 0.05.

Table 3. Average cost of material (2005-2007).

Material	Tensile stress, MPa	Density, g/cm^3	Cost USD$/kg
Fibers:			
Glass	3500	2.45	0.7
Kevlar 49, 29	2800	1.47	4.5
PBO Zylon AS	5800	1.54	15
PBO Zylon HM	5800	1.56	15
Boron	3500	2.45	54
SIC	3395	3.2	75
Saffil (5% iO_2+Al_2O_3)	1500	3.3	2.5
Matrices:			
Polyester	35	1,38	2
Polyvinyl	65	1.5	3
Aluminum	74-550	2.71	2
Titanum	238-1500	4.51	18
Borosilicate glass	90	2.23	0.5
Plastic	40 - 200	1.5-3	2 - 6
Materials:			
Steel	500 - 2500	7.9	0.7 - 1
Concrete	-	2.5	0.05
Cement (2000)	-	2.5	0.06 - 0.07
Melted Basalt	35	2.93	0.005

Table 4. Material properties.

Material	Tensile strength	Densityg/cm^3		Tensile strength	Densityg/cm^3
Whiskers	kg/mm^2		Fibers	kg/mm^2	
AlB_{12}	2650	2.6	QC-8805	620	1.95
B	2500	2.3	TM9	600	1.79
B_4C	2800	2.5	Allien 1	580	1.56
TiB_2	3370	4.5	Allien 2	300	0.97
SiC	1380 - 4140	3.22	Kevlar or Twaron	362	1.44
Material			Dynecta or Spectra	230-350	0.97
Steel prestressing strands	186	7.8	Vectran	283-334	0.97
Steel Piano wire	220 - 248		E-Glass	347	2.57
Steel A514	76	7.8	S-Glass	471	2.48
Aluminum alloy	45.5	2.7	Basalt fiber	484	2.7
Titanium alloy	90	4.51	Carbon fiber	565	1,75
Polypropylene	2-8	0.91	Carbon nanotubes	6200	1.34

Source: Howatsom A.N., Engineering Tables and Data, p. 41.

Table 5. Maximum partial pressure of water vapor in atmosphere for given air temperature (pressure is 1 atm).

t, C	–10	0	10	20	30	40	50	60	70	80	90	100
p,kPa	0.287	0.611	1.22	2.33	4.27	7.33	12.3	19.9	30.9	49.7	70.1	101

presented in **Figure 14**. Typical relative humidity of atmosphere air is 0.5 - 1.

10) Computation of closed-loop water cycle. Assume the maximum safe temperature is achieved in the daytime. When dome reaches the maximum (or given) temperature, the control system fills with air the space 5 (**Figure 13**) between double-layers of the film cover. That protects the inside part of the dome from further heating by outer (atmospheric) hot air. The control system decreases also the solar radiation input, increasing reflectivity of the liquid crystal layer of the film cover. That way, we can support a constant temperature inside the dome.

The heating of the dome in the daytime may be computed by equations:

$$q(t) = q_0 \sin(\pi t/t_d), \quad dQ = q(t)dt,$$
$$Q = \int_0^{t_d} dQ, \quad Q(0) = 0, \quad M_w = \int_0^{t_d} a dT,$$
$$dT = \frac{dQ}{C_{p1}\rho_1\delta_1 + C_{p2}\rho_2 H + rHa}, \tag{17}$$
$$a = 10^{-5}(5.28T + 2),$$
$$T = \int_0^{t_d} dT, \quad T(0) = T_{\min},$$

where q is heat flow, J/m^2 s; q_o is maximal Sun heat flow in daily time, $q_o \approx 100 \div 900$, J/m^{2}s; t is time, s; t_d is daily (Sun) time, s; Q is heat, J; T is temperature in dome (air, soil), ˚C; C_{p1} is heat capacity of soil, $C_{p1} \approx 1000$ J/kg; $C_{p2} \approx 1000$ J/kg is heat capacity of air; $\delta_1 \approx 0.1$ m is thickness of heating soil; $\rho_1 \approx 1000$ kg/m^3 is density of

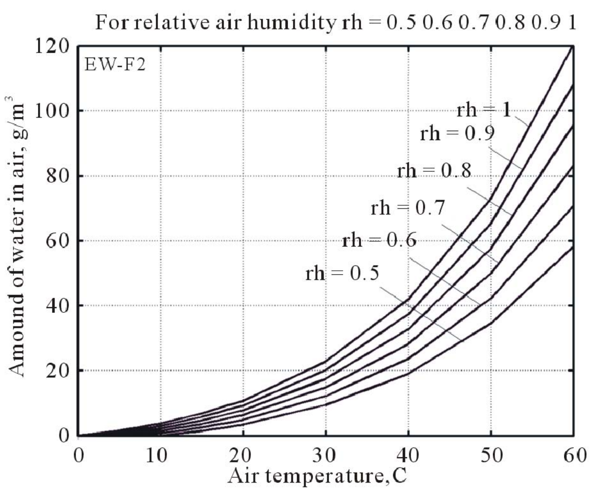


Figure 14. Amount of water in 1 m^3 of air versus air temperature and relative humidity (rh). $t_1 = 0$˚C.

the soil; $\rho_2 \approx 1.225$ kg/m^3 is density of the air; H is thickness of air (height of cover), $H \approx 5 \div 300$ m; $r = 2{,}260{,}000$ J/kg is evaporation heat, a is coefficient of evaporation; M_w is mass of evaporation water, kg/m^3; T_{min} is minimal temperature into dome after night, ˚C.

The convective (conductive) cooling of dome at night time may be computed as below

$$q_t = k(T_{\min} - T(t)),$$
$$\text{where} \quad k = \frac{1}{1/\alpha_1 + \sum_i \delta_i/\lambda_i + 1/\alpha_2} \tag{18}$$

where q_t is heat flow through the dome cover by convective heat transfer, J/m^{2}s or W/m^2; see the other notation in Equation (12). We take $\delta = 0$ in night time (through active control of the film).

The radiation heat flow q_r (from dome to night sky, radiation cooling) may be estimated by equations (10).

$$q_r = C_r\left[\left(\frac{T_{\min}}{100}\right)^4 - \left(\frac{T(t)}{100}\right)^4\right],$$
$$\text{where} \quad C_r = \frac{c_s}{1/\varepsilon_1 + 1/\varepsilon_2 - 1}, \quad c_s = 5.67 \quad [\mathrm{W/m^2\,K^4}] \tag{19}$$

where q_r is heat flow through dome cover by radiation heat transfer, J/m^{2}s or W/m^2; see the other notation in Equation (10). We take $\varepsilon = 1$ in night time (through active control of the film).

The other equations are same (17)

$$dQ = [q_t(t) + q_r(t)]dt, \quad Q = \int_0^{t_d} dQ,$$
$$Q(0) = 0, \quad M_w = \int_0^{t_d} a dT,$$
$$dT = \frac{dQ}{C_{p1}\rho_1\delta_1 + C_{p2}\rho_2 H + rHa}, \tag{20}$$
$$a = 10^{-5}(5{,}28T + 2), \quad T = \int_0^{t_d} dT, \quad T(0) = T_{\min},$$

Let us take the following parameters: $H = 135$ m, $\alpha = 70$, $\delta = 1$ m between cover layers, $\lambda = 0.0244$ for air. Result of computation for given parameter are presented in **Figures 15-16**.

For dome cover height $H = 135$ m the night precipitation (maximum) is 0.027 × 135 = 3.67 kg (liter) or 3.67 mm/day. The AB Dome's internal annual precipitation under these conditions is 1336.6 mm (maximum). If it is not enough, we can increase the height of dome cover. The globally-averaged annual precipitation is about 1000 mm on Earth.

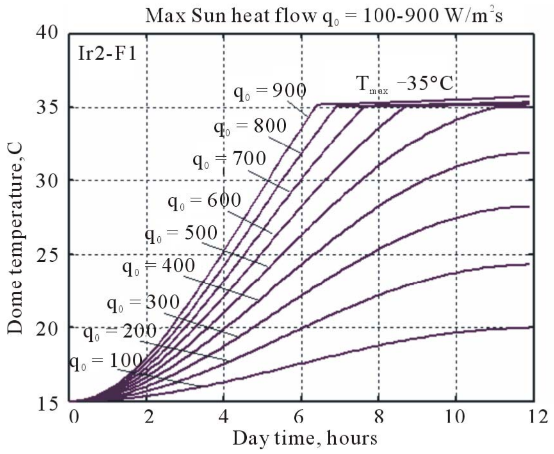


Figure 15. Heating of the dome by solar radiation from the night temperature of 15˚C to 35˚C via daily maximal solar radiation (W/m²) for varying daily time. Height of dome film cover equals H = 135 m. The control temperature system limits the maximum internal dome temperature to 35˚C.

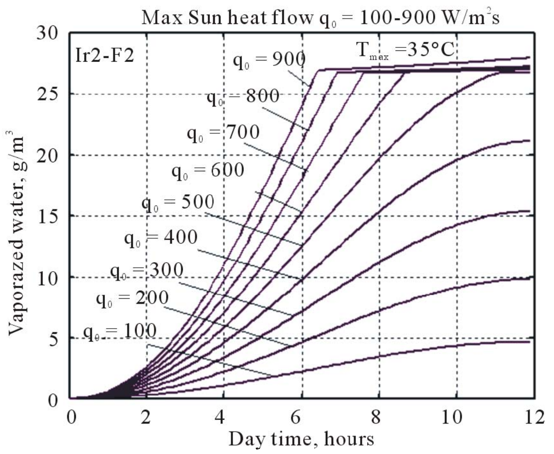


Figure 16. Water vaporization for 100% humidity of the air for different maximal solar radiation (W/m²) levels delivered over varying daily time. Height of dome film cover equals H = 135 m. The temperature control system limits the maximum internal dome temperature to 35˚C.

As you see, we can support the same needed temperature in a wide range of latitudes at summer and winter time. That means the covered regions are not hostage to their location upon the Earth's surface (up to latitude 20˚ - 30˚), nor Earth's seasons, nor it is dependent upon outside weather. Our design of Dome is not optimal, but rather selected for realistic parameters.

5. Projects

5.1. Project 1. Tokyo

As of October 2007, the official intercensal estimate showed 12.79 million people in Tokyo with 8.653 million living within Tokyo's 23 wards. During the daytime, the population swells by over 2.5 million as workers and students commute from adjacent areas. This effect is even more pronounced in the three central wards of Chiyoda, Chūō, and Minato, whose collective population as of the 2005 National Census was 326,000 at night, but 2.4 million during the day.

1) Climate. The former city of Tokyo and the majority of mainland Tokyo lie in the humid subtropical climate zone (Koppen climate classification Cfa), with hot humid summers and generally mild winters with cool spells. The region, like much of Japan, experiences a one-month seasonal lag, with the warmest month being August, which averages 27.5˚C (81.5℉), and the coolest month being January, averaging 6.0˚C (42.8℉). Annual rainfall averages nearly 1,470 millimetres (57.9 in), with a wetter summer and a drier winter. Snowfall is sporadic, but does occur almost annually. Tokyo also often sees typhoons each year, though few are strong. The last one to hit was Fitow in 2007.

Considerable data on the urban area of Greater Tokyo is in http://en.wikipedia.org/wiki/Greater_Tokyo_Area.

In our project we take only the most important central part of the Tokyo having area of 60 km² and population about 2 millions. About 10 times this area contains 8 million people and 600 times the area contains 42 million people. The reader may easily recalculate the effort required for 8 millions of population.

2) Computation and estimation of Dome cost:

a) Film. Requested area of double film is $A_f = 3 \times 60$ km² = 180 km². If thickness of film is δ = 0.1 mm, specific density γ = 1800 kg/m³, the mass of film is $M = \gamma\delta A_f$ = 32,500 tons or m = 0.54 kg/m². If cost of film is c-$2/kg, the total cost of film is $C_f = cM$ = $65 millions or c_a = $1.08/m².

If average thickness of a gas layer inside the AB-Blanket is δ = 3 m, the total volume of gas is $V = \delta A$ = 1.8×10^8 m³. One m³ of methane (CH_4) has lift force l = 0.525 kg/m³ or Blanket of thickness δ = 3 m has lift force l = 1.575 kg/m² or the total Blanket lift force is $L = 94.5 \times 10^3$ tons. Cost of methane is c = $0.4/m³, volume is $V = \delta A$ = 1.8×10^8 m³. But we did not take in account because after finishing building the AB Dome the methane will be changed for overpressured air. (Thus $72 million in methane would not be kept in inventory, but if the AB-Blankets were each 1% of the final area, neglecting leaks only $720,000 worth of methane would be in play at any one time. With some designs step by step methane replacement with air will be possible (if overpressure support is introduced another way, etc.)

b) Support cables. Let us take an additional air pressure as p = 0.01 atm = 1000 N/m², safety tensile stress of artificial fiber σ = 100 kG/mm², specific density γ = 1800 kg/m³, s = 1 m², and altitude of the Blanket h = 500 m. Then needed cross-section of cable is 1 mm^2 per 1 m^2 of Blanket and mass of the support cable is $m = \gamma ph/\sigma = 0.9$ kg per 1 m^2 of Blanket. If cost of fiber is \$1/kg, the cost of support cable is c_c = \$0.9/m^2. Total mass of the support cables is 54,000 tons.

The average cost of air and water tubes and control system we take c_t = \$0.5/m^2.

The total cost of 1 m^2 material is $C = c_a + c_c + c_t = 1.08 + 0.9 + 0.5$ = \$2.48/m^2 ≈ \$2.5/m^2 or \$150 millions of the USA dollars for taken area. The work will cost about \$100 million. The total barebones cost of Blanket construction for central part of Tokyo is about \$250 million US dollars. Note that this figure can easily increase by any amount based on overhead added by governmental regulation as well as local custom and rules.

The clean (rain) water is received from 1 m^2 of covered area is 1.1 kL/year. That is enough for the city population. The possible energy (if we install at extra expense hydro-electric generators and utilize pressure (50 atm) of the rain water) is about 4000 kJ/m^2 in year. That covers about 15% of city consumption.

Tokyo receives a permanent warm climate and saves a lot of fuel for home heating (decreased pollution of atmosphere) in winter time and save a lot of electric energy for home cooling in the summer time.

5.2. Project 2. Moscow (Russia)

1) Area (land) of Moscow is 1,081 km² (417.4 sq mi), population (as of the 2002 Census) 10,470,318 inhabitants, density 9,685.8/km² (25,086.1/sq mi). Average annual high temperature is 9.1C, average annual low temperature is 2.6˚C. The average high monthly temperature is 24˚C (July) (Record is 36.5˚C), the average low monthly temperature is -8^{o}C (January)(Record low is –42.2˚C). Annual rainfall is 705 mm.

2) Estimation. The full Moscow area is significantly larger than the central Tokyo area (by 18 times) and has less population density (by 3 times). We can cover only the most important central part of Moscow, the place where the Government and business offices, tourist hotels, theaters and museums are located.

If this area equals 60 km^2 the cost of construction will be cheaper than \$250 million US because the labor cost less (by 3 - 5 times) then the USA. But profit from Moscow Blanket may be more then from the Manhattan cover because the weather is colder in Moscow than in New York.

6. Discussion

As with any innovative macro-project proposal, the reader will naturally have many questions. We offer brief answers to the most obvious questions our readers are likely to ponder.

1) *The methane gas is fuel. How about fire protection*?

The danger is minimized as AB Blanket is only temporarily filled by methane gas for air delivery and for period of Dome construction. After dome construction is complete, the methane is replaced with air and the Blanket will then be supported at altitude by small additional air pressure into AB-Dome.

The second precaution to prevent danger of fire is that the Blanket contains methane in small separated cylindrical sections (in piece 100 × 100 m has about 30 these sections, see **Figure 8**) and every piece has special anti-fire margins (**Figure 8**). If one cylindrical section will be damaged, the gas flows up (it is lighter than air), burns down only from this section (if film cannot easy burn) and piece get only hole. In any case the special margins do not allow the fire to set fire to next pieces.

2) *Carbonic acid* (*smoke,* CO_2) *from industry and cars will pollute air into dome.*

The smoke from industry can be deleted out from dome by film tubes acting as feedthroughs (chimneys) to the outer air. The cars (exhaust pipes) can be provided by a carbonic acid absorber. The evergreen plants into Dome will intensely absorb CO_2 especially if concentration of CO_2 will be over the regular values in conventional atmosphere (but safe for people). We can also periodically ventilate the Dome in good weather by open the special windows in Dome (see **Figure 7**) and turn on the ventilators like we ventilate the apartment. We can install heat exchangers and permanently change the air in the dome (periodically wise to do anyway because of trace contaminant buildups).

3) *How can snow be removed from Dome cover?*

We can pump warm air between the Blanket layers and melt show and pass the water by rain tubes. We can drop the snow by opening the Blanket windows (**Figure** 7(**d**)).

4) *How can dust be removed from the Dome cover?*

The Blanket is located at high altitude (about 200 - 500 m). Air at this altitude has very little dust. The dust that does infill and stick may be removed by rain, wash down tubes or air flow from blowers or even a helicopter close pass.

5) *Storm wind overpressures*?

The storm wind can only be on the bounding (outside) sections of dome. Dome has special semi-spherical and semi-cylindrical form factor. We can increase the internal pressure in storm time to add robustness.

6) *Cover damage.*

The envelope contains a rip-stop cable mesh so that the film cannot be damaged greatly. Electronic signals alert supervising personnel of any rupture problems. The needed part of cover may be reeled down by control cable and repaired. Dome has independent sections.

7. Conclusions

Isolation of the damaged nuclear station from the atmosphere by the film is the easiest and cheapest way to stop the spread of radioactive isotopes on the planet.

Additionally, towns and cities in close proximity of the reactor can be protected by transparent film domes. The building of gigantic inflatable AB-Dome over an empty flat surface is not difficult. The cover spreads on said flat surface and a ventilator pumps air under the cover (the edges being joined and secured gas-tight) and the overpressure, over many hours, lifts the dome. However, if we want to cover a city, garden, or forest we cannot easily spread the thin film over building or trees. This article suggests a new method which solves this problem. The innovation is the design of the double film Blanket filled by light gas (methane, hydrogen, helium). Subassemblies of the AB Dome, known as AB Blankets, are lighter than air and fly in atmosphere. They can be made on a flat area and delivered by dirigible or helicopter to the sky over the city. Here they are connected to the AB Dome under construction. After building is finished, the light gas can be changed by air. Enveloping the city protects it from inclement weather, chemical and biological weapons and radioactive fallout as well as other harmful particulate falls.

Considering the danger to the Japanese national economy, which can be damaged by loss of investor confidence at even the possibility of fallout plumes hitting real estate investments, which has already begun to happen in the wake of the Fukushima I nuclear incidents, see for example, http://www.efinancialnews.com/story/ 2011 -03-18/union-investments-nuclear-fund-suspension as well as export losses from supply chain interruptions caused by evacuation disorders, the losses avoided might well finance the AB domes construction itself.

It may be that with emergency conditions the covering of a city is too much for the immediate governmental finance and management capacity, but certainly the Fukushima I Nuclear complex itself should have an AB Dome put on it in the weeks to come for simple insurance against further disaster compounding past events. (In logic, it would make sense to put domes around all reactors before, not after, they are damaged. In this case, even 99% containment could make the difference between a bad few weeks and a bad few decades.). Plainly put, the first AB Dome around the Fukushima I Nuclear complex might be much cruder than the final version which could be erected at leisure—but if a worst case event happens right when the wind is toward Tokyo, there would be no offsite damage. If another event chain damages the already damaged reactors, or something of equal seriousness-comes up—the equivalent of an outer enclosure dome would exist as a new ditch of last resort around the complex. Given the estimated total of 4,277 tons of spent fuel at a plant wracked intermittently with explosions and fire, it would be prudent to move quickly.

The works of a given field are presented in [1-12], reference materials in [13-15].

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