Hindawi Publishing Corporation
Science and Technology of Nuclear Installations
Volume 2011, Article ID 175492, 13 pages
doi:10.1155/2011/175492

Research Article

Transparent Inflatable Column Film Dome for Nuclear Stations, Stadiums, and Cities

Alexander Bolonkin,[1] Shmuel Neumann,[2] and Joseph Friedlander[3]

[1] *New York City University (NYCU), 1310 Avenue R, Brooklyn, NY 11229, USA*
[2] *Department of Education, Michlala College of Jerusalem, 11 Sarei Yisroel Street, Suite 14, P.O. Box 34217, Jerusalem 94390, Israel*
[3] *Strategic Solutions Technology Group, P.O. Box 15, Shavei Shomron 44858, Israel*

Correspondence should be addressed to Alexander Bolonkin, abolonkin@juno.com

Received 16 May 2011; Accepted 3 July 2011

Academic Editor: Arkady Serikov

Copyright © 2011 Alexander Bolonkin et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

In a series of previous articles, one of the authors published designs of the AB Dome which can cover a city, important large installations or subregions by a transparent thin film supported by a small additional air overpressure. The AB Dome keeps the outside atmospheric conditions from the interior protecting a city from chemical, bacterial, and radioactive weapons (wastes). The design in this article differs from previous one as this design employs an inflatable columns which does not need an additional pressure (overpressure) inside the dome and is cheaper in construction (no powered air pumping station) and in operation (no special entrance airlock and permanent pumping expense). When dome is supported by columns, no overpressure is required inside the dome which is important when the dome covers a damaged nuclear reactor. The nuclear reactor may produce radioactive gases and dust, and, as inflatable domes are not typically hermetically sealed, the increased pressure inside the dome can leak out gas and dust into the atmosphere. The suggested design does not have this drawback. Positive pressure gradients expel dust particles—neutral pressure gradients will not. (Negative pressure gradients may even be possible in certain configurations.)

1. Introduction

1.1. Idea. The inflatable transparent thin film AB Dome offered and developed in [1–15], is a good means for protective isolation of a damaged nuclear station, converting a stadium, city, or region into a subtropical garden with excellent weather, obtainable clean water from condensation (and avoided evaporation), passively confining solar-heated air for heating houses (in cold regions), passively reflecting solar energy for cooling houses (in hot regions), protection of city from chemical, bacterial, radioactive weapons in war time, even the provision of electricity, and so forth.

However, for protection of damaged nuclear stations, the inflatable dome has a lack: the overpressure inside the dome. The increased positive pressure in the dome will force leaked radioactive gas and dust into the atmosphere. A conventional dome illustrated in Figure 1 would require filters to clean the air inside the dome to minimize the leak, but the problems with changing these filters in a highly radioactive site and the prohibitive cost render conventional inflatable domes practically and financially unfeasible for this application. While the geodesic or other rigid dome structures (Figure 2), may not overpressuer in the dome, the construction of these on site make this impractical as well.

The suggested Inflatable Column Film Dome Design does not have this drawback. In offered design of the film, cover of dome is supported by special inflatable columns and not necessary in overpressure incite of dome. The other advantages: the entrance and exit in/off dome open from any side no special cells (double doors) for entrance and exit. This dome is more comfortable for stadiums, storages, and nuclear stations. They have a good protection from the hot sun and rain and at any time you can move the plastic wrap and gain access to the dome from the outside world (for large cargoes, good weather) without progressive pressure loss.

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 pumps air under the film cover and

Figure 1: An example of current rigid structures: garden under rigid dome.

Figure 2: Stadium under inflatable dome.

lifts the new dome into place (inflation takes many hours). However, if we want to cover a city, garden, forest, or other obstacle course (as opposed to an empty, mowed field), we cannot easily deploy the thin film over building or trees without risking damage to it by snagging and other complications. In an early article [1] was suggested a new method which solves this problem. The idea is to install the inflatable columns pull cables and film. A double film blanket is filled by light gas (e.g., methane, hydrogen, or helium, although, of these, methane will be the most practical and, least leaky). Sections of this AB Blanket are lighter than the air and fly 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 and chemical, biological, and radioactive fallout or particulates. After finishing dome building, the light gas can be changed by air.

The building of the offered Inflatable Column Film Dome is easier still. It does not require the dirigible or helicopter. You install the inflatable columns. You set the inflatable columns, pull the cables between the columns, and put a single or double film between the cables.

We can cover a city, forest, or other obstacle-laden region, thus, easily by thin film.

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

This paper 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 the outer environment, Earth's atmospheric instabilities, cold winter, strong wind, rain, hot weather, and so on.

The offered inflatable column-supported structure is cheaper by many times than known rigid domes.

1.2. Information about Earth's Megacities. A megacity is usually defined as a metropolitan area with a total population in excess of 10 million people. Some definitions also set a minimum level for population density (at least 2,000 persons/square km). Megacities can be distinguished from global cities by their rapid growth, new forms of spatial density of population and formal and informal economics. A megacity can be a single metropolitan area or two or more metropolitan areas that converge upon one another. The terms *megapolis* and *megalopolis* are sometimes used synonymously with *megacity*.

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, as researchers say. 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.

The increase will be most dramatic in the poorest and the least urbanised continents, Asia and Africa. Surveys and projections indicate that all urban growth over the next 25 years will be in developing countries. One billion people, one-sixth of the world's population, now live in shanty towns.

By 2030, over 2 billion people in the world will be living in slums. Already over 90% of the urban population of Ethiopia, Malawi, and Uganda, three of the world's most rural countries, live in slums.

In 2000, there were 18 megacities conurbations such as Tokyo, New York City, Los Angeles, Mexico City, Buenos Aires, Mumbai (then Bombay), São Paulo, and 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 1950, New York was the only urban area with a population of over 10 million. Geographers have identified 25 such areas as of October 2005, as compared with 19 megacities in 2004 and only nine in 1985. This increase has happened as the world's population moves towards the high (75–85%) urbanization levels of North America and Western

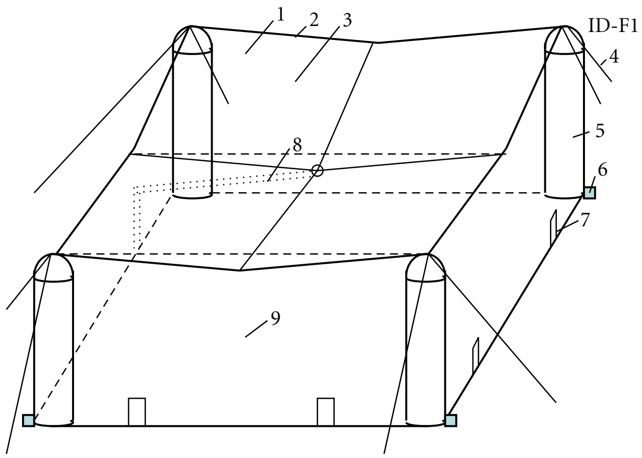


Figure 3: Column film dome. Notations: (1) film dome; (2) strong cable; (3) film; (4) bracing; (5) support inflatable column; (6) pumping station; (7) door; (8) pipe for rainwater; (9) film side wall.

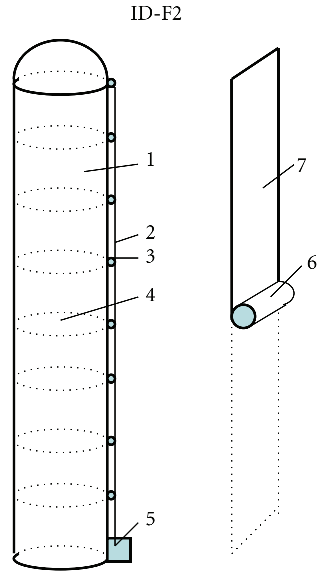


Figure 4: Inflatable column and design of film side wall (left). Film side wall (right). Notations: (1) inflatable column; (2) air tube and control wire; (3) control air valves; (4) internal partition; (5) air pump and control; (6) roll of film; (7) side of wall.

Europe. The 1990 census marked the first time the majority of US citizens lived in cities with over 1 million inhabitants.

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.

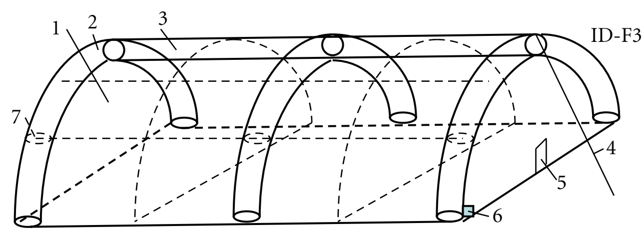


Figure 5: Semicircle film dome. Notations: (1) film dome; (2) semitoroid tube; (3) connection inflatable tube; (4) bracing; (5) door; (6) air pumping, control station; (7) internal partition.

2. Description of Innovations

Our design of the offered Inflatable Column Film Dome is presented in Figure 3. One has support inflatable columns (5), main strong cables (2), film (3), bracings (4), small pumps (6), door (7), pipe for rainwater (8), and film side wall (9).

The innovations are listed here: (1) the columns are gas-inflatable (only); (2) the root and walls are fabricated with very thin, transparent film (thickness is 0.05 to 0.2 mm) having controlled clarity (option); (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: it may be conventional ordinary film); (4) the space between double film is filled with air. The air pressure inside the dome may make more than the external atmosphere also for protection from outer wind, snow and ice.

The city covering Inflatable Column Film Dome 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). This water collected at high altitude (the roof of the Inflatable Column Film Dome is conventionally located at 100–300–500 m) may produce electric energy by hydroelectric generators located at Earth's surface. Wind generators located at high altitude (at roof surface) can produce electric energy. Such an AB Dome saves a lot of energy (fuel) for house heating in winter time and cooling in summer time.

The inflatable dome column is shown in Figure 4 (left). The film side wall is shown in Figure 4 (right).

Note: considerable savings in operating costs is obtained removing the necessity of continual working of inflation ventilators (fans) 5. We need the air pump for an initial pumping and additional pumping in case of a column damage to the inflatable columns.

The semicylindrical column dome is shown in Figure 5.

In this design the support columns have the semitoroid form. This form is more stable against wind, snow, ice.

Our design of the column dome from levitated AB Blanket sections for big area or city that includes the thin inflated

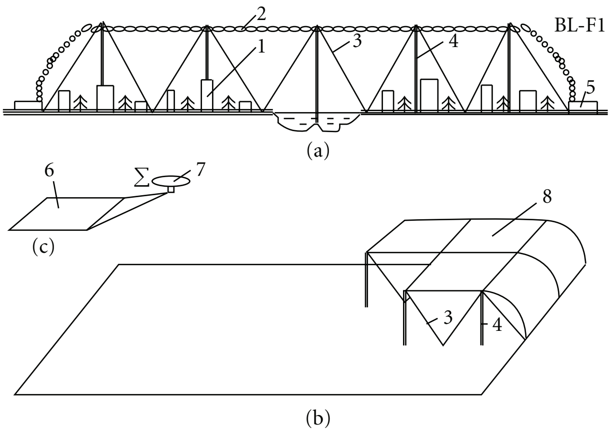


Figure 6: (a) Design of AB Blanket from the transparent film over city and (b) building the AB Dome from parts of the AB Blanket. Notations: (1) city; (2) AB Blanket; (3) bracing wire (support cable); (4) supported inflatable columns and tubes for rain water, for lifting gas, signalization, and control;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

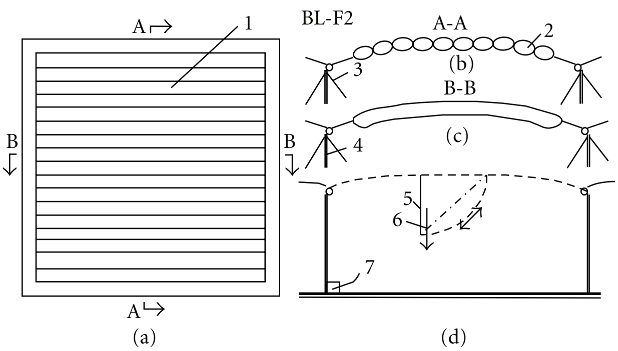


Figure 7: Design of AB Blanket section. (a) Typical section of blanket (top view); (b) cross section A-A of blanket; (c) cross-section B-B of blanket; (d) typical section of AB blanket (side view). Notations: (1) part of Blanket; (2) light lifting gas (for example: methane, hydrogen, or helium); (3)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

film plate parts is presented in Figure 6. The innovations are as follows: (1) the construction is partially 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 (e.g., methane, hydrogen, or helium). The air pressure inside the dome equals the atmospheric pressure. That may be more than the external atmosphere for protection from outer wind, snow, and ice (during ice build-up periods in winter).

Detail design of AB Blanket section is shown in Figure 7. Every section contains cylindrical tubes filled a light gas, has

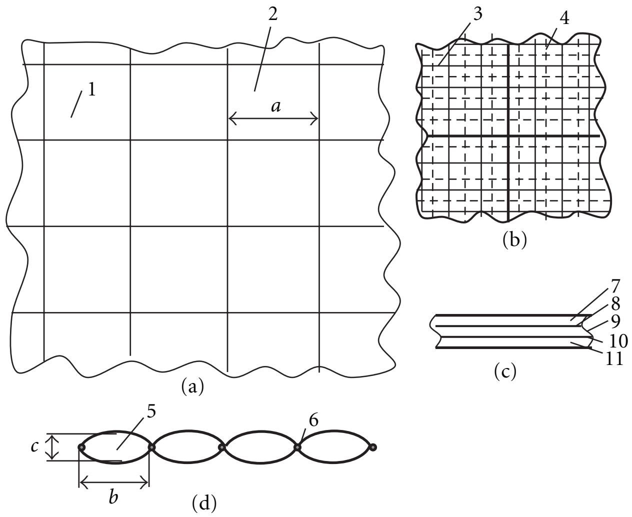


Figure 8: Design of advanced covering membrane. Notations: (a) Big fragment of cover with controlled clarity (reflectivity, carrying capacity) and heat conductivity; (b) small fragment of cover; (c) cross section of cover (film) having 5 layers; (d) longitudinal cross section of cover; (1) cover; (2) 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; (11) transparent dielectric layer. Common thickness is 0.1–0.5 mm. Control voltage is 5–10 V.

margins (explained later in Section 5), 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 cables, and signal and control wires.

Figure 8 illustrates the advanced thin transparent control AB Blanket cover we envision. The inflated textile shell—technical "textiles" can be woven or nonwoven (films)—embodies the innovations listed. (1) the film is thin, approximately 0.05 to 0.3 mm. A film this thin has never before been used in a major building. (2) The film has two strong nets, with a mesh of about 0.1×0.1 m and $a = 1 \times 1$ m; the threads are about 0.3–1 mm for a small mesh and about 1-2 mm for a big mesh. 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, a line width of about $100\,\mu$, and a thickness near $10\,\mu$. The wire net is electric (voltage) 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 multilayered covering is the main means for heat isolation, and puncture of one of the layers will not 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. (6) Part of the covering can have a very thin shiny aluminum coating that is about $1\,\mu$ (micron) for reflection of unnecessary solar radiation in the 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 nighttime. In the case of Manhattan, this alone might pay for it!

2.1. Brief Information about Advanced Cover Film. Our advanced blanket cover (film) has 5 layers (Figure 6(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). Liquid crystals are They 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 the film has solar cells, it may convert 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 wave length 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 transparency about 95% of light (visible) radiation. The transparency depends upon thickness and may be very high for thin film.

(3) Electrochromism. 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 rearview 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.

3. Theory and Computation of the Column Dome, AB Blanket, and Inflatable Dome

3.1. Lift Force of Support Inflatable Column. The maximal lift force of the dome column is

$$L_c = (p_c - p_a)S, \tag{1}$$

where L_c is lift force of the column, N; p_c is air pressure into column, N/m^2; p_a is atmospheric pressure, N/m^2. This pressure is variable, and average value equals about 10^5 N/m^2.

3.1.1. Lift Force of Blanket. The specific lift force of blanket is computed by the following equation:

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

where L is lift force, N; $g = 9.81\,\text{m/s}^2$ is gravity; $q_a = 1.225\,\text{kg/m}^3$ is an air density for standard condition ($T = 15°\text{C}$); $q_g < q_a$ is density of lift light gas. For methane $q_g = 0.72\,\text{kg/m}^3$, hydrogen $q_g = 0.09\,\text{kg/m}^3$, helium $q_g = 0.18\,\text{kg/m}^3$; 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 a lifting force 15 N/m^2 or 150,000 N = 15 tons.

3.1.2. The Weight (Mass) of Film. It may be computed by the equation

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

where W is weight of film, kg; γ is specific density of film (usually about $\gamma = 1500 \div 1800\,\text{kg/m}^3$); δ is thickness, m; S is area, m^2. For example, the double film of thickness $\delta = 0.05$ mm has weight $W = 0.15\,\text{kg/m}^2$. The section 100×100 m of the blanket has weight of 1500 kg = 1.5 tons.

3.1.3. Weight (Mass) of Support Cable. Weight of Support Cable (bracing wire) is computed by the following 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 $\gamma_c = 1800\,\mathrm{kg/m^3}$); σ is safety density of cable, $\mathrm{N/m^2}$. For cable from artificial fiber, $\sigma = 100 \div 150\,\mathrm{kg/mm^2} = (1 \div 1.5) \times 10^9\,\mathrm{N/m^2}$. For example, for $\sigma = 100\,\mathrm{kg/mm^2}$, $h = 500\,\mathrm{m}$, $L = 10\,\mathrm{N/m^2}$, $W_c = 0.009\,\mathrm{kg/m^2}$. However, if additional air pressure into dome is high; for example, lift force $L = 1000\,\mathrm{N/m^2}$ (air pressure $P = 0.01$ atm—0.01 bar), the cable weight may reach $0.9\,\mathrm{kg/m^2}$. That may be requested in a storm 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 the greatest during the coldest weather when the dome is heated and the temperature difference between its interior and exterior are the greatest. In extremely cold climates, such as the Arctic and Antarctica, the buoyancy effect tends to dominate dome pressurization, causing the AB Blanket to require reliable anchoring.

3.1.4. The Wind Dynamic Pressure. It is computed by the equation

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

where p_d is wind dynamic pressure, $\mathrm{N/m^2}$; ρ is air density; for altitude $H = 0$, the $\rho = 1.225\,\mathrm{kg/m^3}$; 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 $p = 1000\,\mathrm{N/m^2}$. That is greater than the dynamic pressure ($740\,\mathrm{N/m^2}$) of very strong wind $V = 35\,\mathrm{m/s}$ (126 km/hour). If it is necessary, we can increase the internal pressure by some times if needed for very exceptional storms.

3.1.5. The Thickness of the Dome Envelope. Its sheltering shell of film, is computed by formulas (from equation for tensile strength)

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

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, $\mathrm{N/m^2}$; σ is safety tensile stress of film, $\mathrm{N/m^2}$.

For example, compute the film thickness for dome having radius $R = 50$ m, additional internal air pressure $p = 0.01$ atm

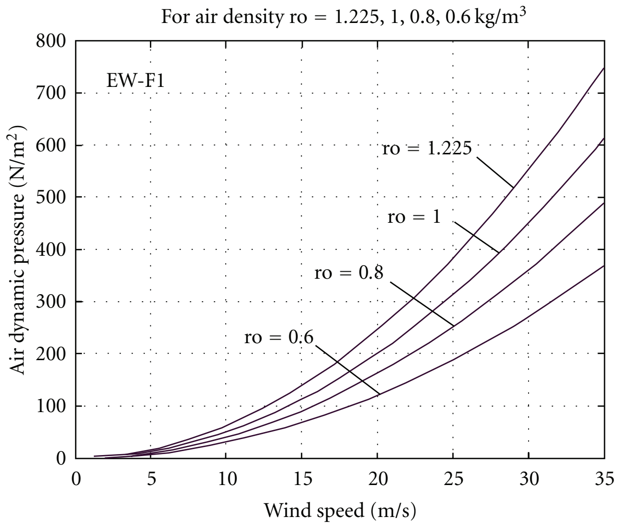


FIGURE 9: Wind dynamic pressure versus wind speed and air density ρ. The ro = 0.6 is for $H \approx 6$ km.

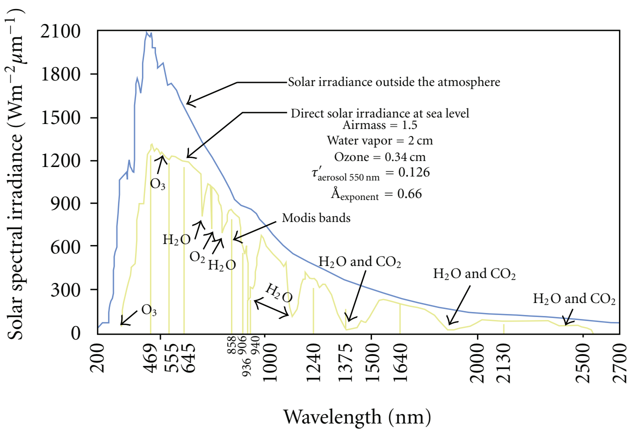


FIGURE 10: Spectrum of solar irradiance outside the atmosphere and at the sea level with absorption of electromagnetic waves by atmospheric gases. Visible light is 0.4–0.8 μ (400–800 nm).

($p = 1000\,\mathrm{N/m^2}$), safety tensile stress $\sigma = 50\,\mathrm{kg/mm^2}$ ($\sigma = 5 \times 10^8\,\mathrm{N/m^2}$), cylindrical dome

$$\delta = \frac{50 \times 1000}{5 \times 10^8} = 0.0001\,\mathrm{m} = 0.1\,\mathrm{mm}. \tag{5$'$}$$

3.1.6. Solar Radiation. Our basic computed equations, below, are derived from a Russian-language textbook [16]. Solar radiation impinging the orbiting Earth is approximately $1400\,\mathrm{W/m^2}$. The average Earth reflection by the clouds and the subaerial surfaces (water, ice, and land) is about 0.3. The Earth's atmosphere adsorbs about 0.2 of the sun's radiation. That means about $q_0 = 700\,\mathrm{W/m^2}$s of solar energy (heat) reaches our planet's surface at the Equator. The solar spectrum is graphed in Figure 10.

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):

$$\lambda_m = \frac{2.9}{T} \quad (\text{mm}), \tag{6}$$

where T is body temperature, °K. For example, if a body has an ideal temperature of 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.

$$E = \varepsilon\sigma_S T^4, \quad (\text{W/m}^2), \tag{7}$$

where ε is coefficient of body blackness ($\varepsilon = 0.03 \div 0.99$ for real bodies), $\sigma_S = 5.67 \times 10^{-8}$ [W/m$^2\cdot$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's surface is

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

where φ is the Earth longevity, θ is angle between projection of Earth's 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, $q_o \approx 700$ W/m^2 is the annual average solar heat flow to the Earth at the Equator corrected for Earth's reflectance.

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

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

where θ_m is maximum θ, $|\theta_m| = 23.5° = 0.41$ 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 the equation

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

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 the equation

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

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

The computation for relative daily illumination 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 [16])

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

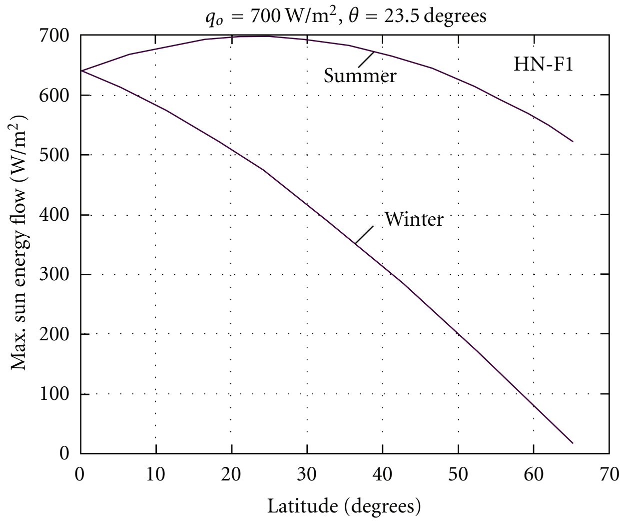


FIGURE 11: Maximum solar radiation flow at Earth's surface as function of the Earth latitude and season.

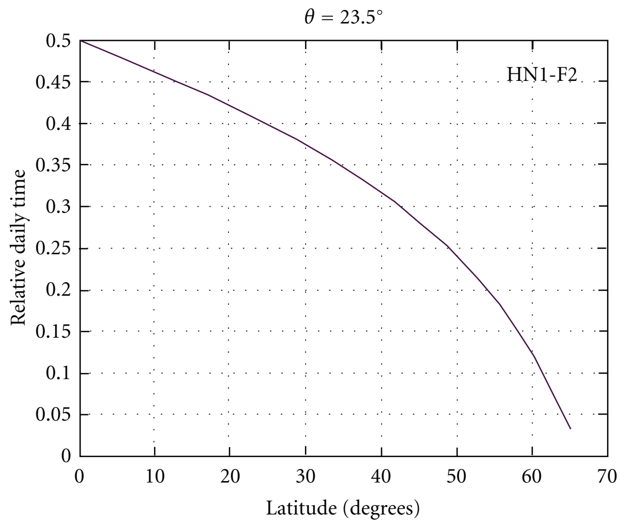


FIGURE 12: Relative daily light time relative to the Earth latitude.

where k is heat transfer coefficient, W/m$^2\cdot$K; $t_{1,2}$ are temperatures of the inter and outer multilayers of the heat insulators, °C; $\alpha_{1,2}$ are convention coefficients of the inter and outer multilayers of heat insulators ($\alpha = 30 \div 100$), W/m^2 K; δ_i are thicknesses of insulator layers; λ_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 (7)

$$q = C_r\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right], \quad \text{where } C_r = \frac{c_s}{1/\varepsilon_1 + 1/\varepsilon_2 - 1}, \quad c_s = 5.67\ \left(\text{W/m}^2\text{K}^4\right), \tag{13}$$

Table 1: (See [16], page 331.) Heat transfer.

Material	Density, kg/m^3	Thermal conductivity, λ, W/m·°C	Heat capacity, kJ/kg·°C
Concrete	2300	1.279	1.13
Baked 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: Naschekin [17, page 331], 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

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

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

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

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

The data of some construction materials is found in Tables 1 and 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 serves against radiation losses from the dome.

The general radiation heat Q computes by (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

$$Q = \frac{c_t m}{\eta}, \tag{15}$$

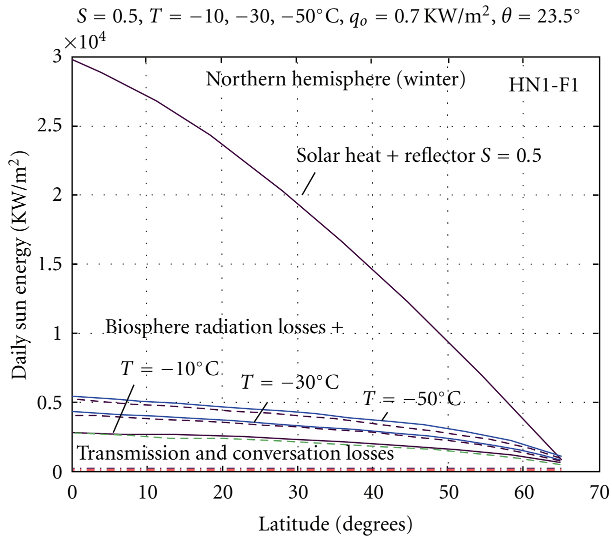


Figure 13: Daily heat balance through 1 m^2 of dome during the coldest winter day versus Earth's latitude (Northern hemisphere example). Data used for computations (see (6)–(14)): temperature inside the dome is $t_1 = +20$°C, outside are $t_2 = -10, -30, -50$°C; reflectivity coefficient of mirror is $c_2 = 0.9$; 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 $\delta = 1$ m; coefficient of film heat transfer is $\lambda_1 = \lambda_3 = 0.75$, for air $\lambda_2 = 0.0244$; ratio of cover blackness $\varepsilon_1 = \varepsilon_3 = 0.9$; for louvers, $\varepsilon_2 = 0.05$.

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, $\eta = 0.5$–0.8.

In Figure 13, the alert reader has noticed that 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.

3.1.7. Properties and Cost of Material. The costs of some materials are presented in Table 3 (2005–2007). Properties are in Table 4. Some difference in the tensile stress and density are result of difference sources, models, and trademarks.

3.1.8. 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 nighttime. A reader can derive the equations below from well-known physical laws Naschekin [17]. Therefore, the author does not give detailed explanations of these.

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 the equation

$$m_W = 0.00625[p(t_2)h - p(t_1)], \tag{16}$$

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 (16) is presented in Figure 14. Typical relative humidity of atmosphere air is 0.5–1.

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

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 the double layers of the film cover. That protects the inner 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 the equations

$$q(t) = q_0 \sin\left(\frac{\pi t}{t_d}\right), \qquad dQ = q(t)dt,$$

$$Q = \int_0^{t_d} dQ, \qquad Q(0) = 0, \qquad M_w = \int_0^{t_d} a\,dT,$$

$$dT = \frac{dQ}{C_{p1}\rho_1\delta_1 + C_{p2}\rho_2 H + rHa},$$

$$a = 10^{-5}(5.28T + 2), \qquad T = \int_0^{t_d} dT, \qquad T(0) = T_{\min}, \tag{17}$$

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), $^\circ$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 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, $^\circ$C.

Table 4: Material properties.

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

Source: [18].

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

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

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 (12). We take $\delta = 0$ in nighttime (through active control of the film).

$$t_1 = 0^\circ\text{C}. \tag{19}$$

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

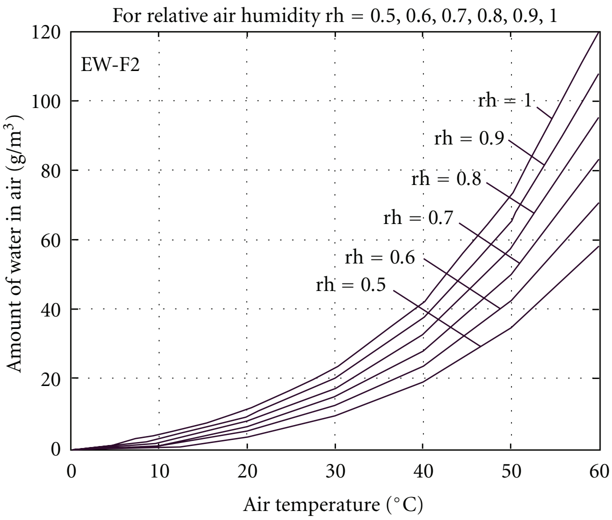


Figure 14: Amount of water in 1 m^3 of air versus air temperature and relative humidity (rh).

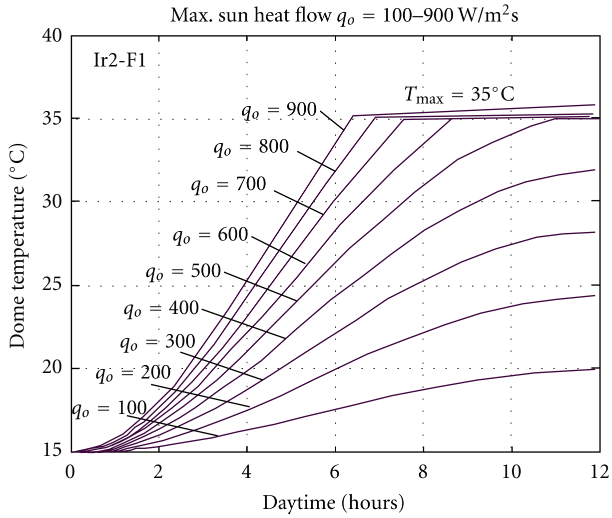


Figure 15: Heating of the dome by solar radiation from the night temperature of 15°C to 35°C via daily maximal solar radiation (W/m^2) for varying daily time. Height of dome film cover equals H = 135 m. The control temperature system limits the maximum internal dome temperature to 35°C.

The radiation heat flow q_r (from dome to night sky, radiation cooling) may be estimated by (10) as follows:

$$q_r = C_r\left[\left(\frac{T_{\min}}{100}\right)^4 - \left(\frac{T(t)}{100}\right)^4\right], \tag{20}$$

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

where 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 (10). We take $\varepsilon = 1$ in nighttime (through active control of the film).

The other equations are the same as (17)

$$dQ = [q_t(t) + q_r(t)]dt, \quad Q = \int_0^{t_d} dQ, \qquad Q(0) = 0,$$
$$M_w = \int_0^{t_d} a\,dT, \quad dT = \frac{dQ}{C_{p1}\rho_1\delta_1 + C_{p2}\rho_2 H + rHa},$$
$$a = 10^{-5}(5,28T + 2), \quad T = \int_0^{t_d} dT, \qquad T(0) = T_{\min}. \tag{21}$$

Let us take the following parameters: H = 135 m, α = 70, δ = 1 m between cover layers, λ = 0.0244 for air. Result of computation for given parameter are presented in Figures 15 and 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 the Earth.

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

4. Projects

4.1. Project 1. Tokyo. "Eastern Capital", officially Tokyo Metropolis is one of the 47 prefectures of Japan. It is located on the eastern side of the main island Honshū and includes the Izu Islands and Ogasawara Islands. Tokyo Metropolis was formed in 1943 from the merger of the former Tokyo Prefecture and the city of Tokyo. Tokyo is the capital of Japan, the center of the Greater Tokyo Area, and the largest metropolitan area of Japan. It is the seat of the Japanese government and the Imperial Palace and the home of the Japanese Imperial Family.

The Tokyo Metropolitan Government administers the twenty-three special wards of Tokyo, each governed as a city, which cover the area that was the city of Tokyo as well as 39 municipalities in the western part of the prefecture and the two outlying island chains. The population of the special wards is over 8 million people, with the total population of

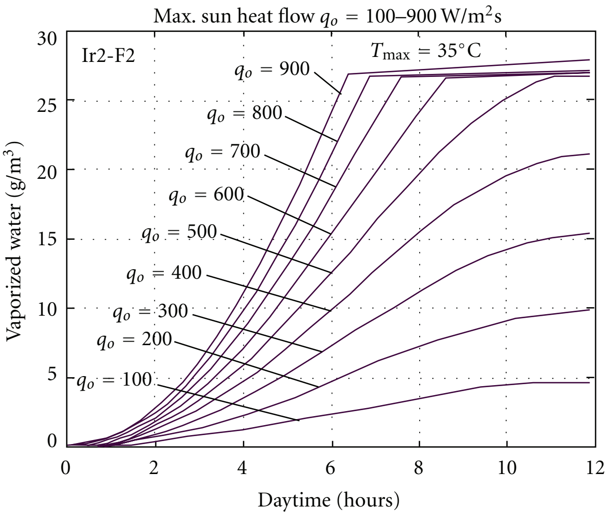


Figure 16: Water vaporization for 100% humidity of the air for different maximal solar radiation (W/m^2) levels delivered over varying daily time. Height of dome film cover equals H = 135 m. The temperature control system limits the maximum internal dome temperature to 35°C.

Figure 17: Project to cover the damaged Fukushima's nuclear station by inflatable dome.

the prefecture exceeding 13 million. The prefecture is part of the world's most populous metropolitan area with 35 to 39 million people (depending on definition) and the world's largest metropolitan economy with a GDP of US \$1.479 trillion at purchasing power parity in 2008, ahead of New York City, which ranks second on the list.

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.

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°F), and the coolest month being January, averaging 6.0°C (42.8°F). 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.

In our project, we take only the most important central part of the Tokyo having area of 60 km^2 and population of about 2 millions. The reader may easy recalculate the results for larger domes that would service over 8 millions of population.

Computation and Estimation of Dome Cost. Film. Requested area of double film is $A_f = 3 \times 60\,\text{km}^2 = 180\,\text{km}^2$. If the thickness of film is $\delta = 0.1$ mm, specific density $\gamma = 1800\,\text{kg/m}^3$, the mass of film is $M = \gamma\delta A_f$ = 32,500 tons or $m = 0.54\,\text{kg/m}^2$. If the cost of film is c—\$2/kg, the total cost of film is $C_f = cM$ = \$65 millions or c_a = \$1.08/m^2.

If average thickness of a gas layer inside the AB Blanket is $\delta = 3$ m, the total volume of gas is $V = \delta A = 1.8 \times 10^8\,\text{m}^3$. One m^3 of methane ($CH_4$) has lift force $l = 0.525\,\text{kg/m}^3$ or blanket of thickness $\delta = 3$ m has lift force $l = 1.575\,\text{kg/m}^2$, or the total blanket lift force is $L = 94.5 \times 10^3$ tons. Cost of methane is $c = \$0.4/\text{m}^3$; volume is $V = \delta A = 1.8 \times 10^8\,\text{m}^3$. But we did not take that in to 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.). The dome required to contain radioactivity form the damaged Fukushima's nuclear station is illustrated in Figure 17.

Support Cables. Let us take an additional air pressure as p = 0.01 atm = 1000 N/m^2, safety tensile stress of artificial fiber $\sigma = 100\,\text{kG/mm}^2$, specific density $\gamma = 1800\,\text{kg/m}^3$, $s = 1\,\text{m}^2$, 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 $m = \gamma p h/\sigma = 0.9$ 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 as c_t = \$0.5/m^2. The total cost of 1 m^2 material is $C = c_a + c_c + c_t = 1.08 + 0.9 + 0.5 = \$2.48/\text{m}^2 \approx \$2.5/\text{m}^2$ or \$150 millions of the USA dollars for the given area. The work will cost about \$100 million. *The total cost of blanket construction for the central part of Tokyo is a minimum of \$250 million US dollars. However, governmental rules and restrictions may increase this by any amount.*

The clean (rain) water is received from 1 m^2 of covered area is 1.1 kL/year (tons/year). That is enough for the city population. The possible energy (if we install at extra expense hydroelectric 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 would receive 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.

4.2. Project 2. Protection of Fukushima. A small cheap dome (300×700 m, cost about $20 mln) will be useful for every current nuclear station because radioactive leakage may be at any station at any time. Dome stops the spread of isotopes over a large area.

5. Discussion

As with any innovative macroproject 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 7), and every piece has special antifire margins (Figure 7). If one cylindrical section will be damaged, the gas flows up (it is lighter than air) and burns down only from this section (if film cannot easy burn), and the 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 in the 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 opening the special windows in dome (see Figure 1) and turn on the ventilators as 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 2).

(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 semispherical and semicylindrical 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 relevant part of the cover may be reeled down by control cable and repaired. The dome has independent sections.

6. Conclusion

Isolation of the damaged nuclear station from the atmosphere by the film is the easiest and the 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, forest, we cannot easily spread the thin film over building or trees. This paper 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 the 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 exchanged for air. Enveloping the city protects it from inclement weather, chemical and biological weapons, and radioactive fallout as well as other harmful particulate falls.

References

[1] A. A. Bolonkin, "Transparent inflatable blanket for cities," 2009, http://www.scribd.com/doc/24050198/.

[2] A. A. Bolonkin and R. B. Cathcart, "Inflatable "evergreen" polar zone dome (EPZD) settlements," 2006, http://arxiv.org/ftp/physics/papers/0701/0701098.pdf.

[3] A. A. Bolonkin, "Control of regional and global weather," 2006, http://arxiv.org/ftp/physics/papers/0701/0701097.pdf.

[4] A. A. Bolonkin, "Cheap textile dam protection of seaport cities against hurricane storm surge waves, tsunamis, and other weather-related floods," 2006, http://arxiv.org/ftp/physics/papers/0701/0701059.pdf.

[5] R. B. Cathcart and A. A. Bolonkin, "Ocean terracing," 2006, http://arxiv.org/ftp/physics/papers/0701/0701100.pdf.

[6] A. A. Bolonkin, *Non-Rocket Space Launch and Flight*, Elsevier, London, UK, 2006, http://www.scribd.com/doc/24056182.

[7] A. A. Bolonkin and R. B. Cathcart, "Inflatable "evergreen" dome settlements for Earth's polar regions," *Clean Technologies and Environmental Policy*, vol. 9, no. 2, pp. 125–132, 2007.

[8] A. A. Bolonkin, “Space towers,” in *Macro-Engineering: A Challenge for the Future*, V. Badescu, R. B. Cathcart, and R. D. Schuiling, Eds., chapter 8, pp. 121–150, Springer, 2006.

[9] A. A. Bolonkin, *New Concepts, Ideas, and Innovations in Aerospace, Technology and Human Life*, NOVA, Huntington, NY, USA, 2007, http://www.scribd.com/doc/24057071/.

[10] A. A. Bolonkin, “AB method of irrigation without water (closed-loop water cycle),” 2007, http://arxiv.org/ftp/arxiv/papers/0712/0712.3935.pdf.

[11] A. A. Bolonkin, “Inflatable dome for Moon, Mars, asteroids and satellites,” in *Proceedings of the American Institute of Aeronautics and Astronautics Conference*, no. AIAA-2007-6262, Long Beach, Calif, USA, September 2007, http://arxiv.org/ftp/arxiv/papers/0707/0707.3990.pdf.

[12] A. A. Bolonkin, “Cheap artificial AB-mountains, extraction of water and energy from atmosphere and change of country climate,” 2007, http://arxiv.org/ftp/arxiv/papers/0801/0801.4820.pdf.

[13] A. A. Bolonkin, “Optimal inflatable space towers with 3–100 km height,” *Journal of the British Interplanetary Society*, vol. 56, no. 3-4, pp. 87–97, 2003.

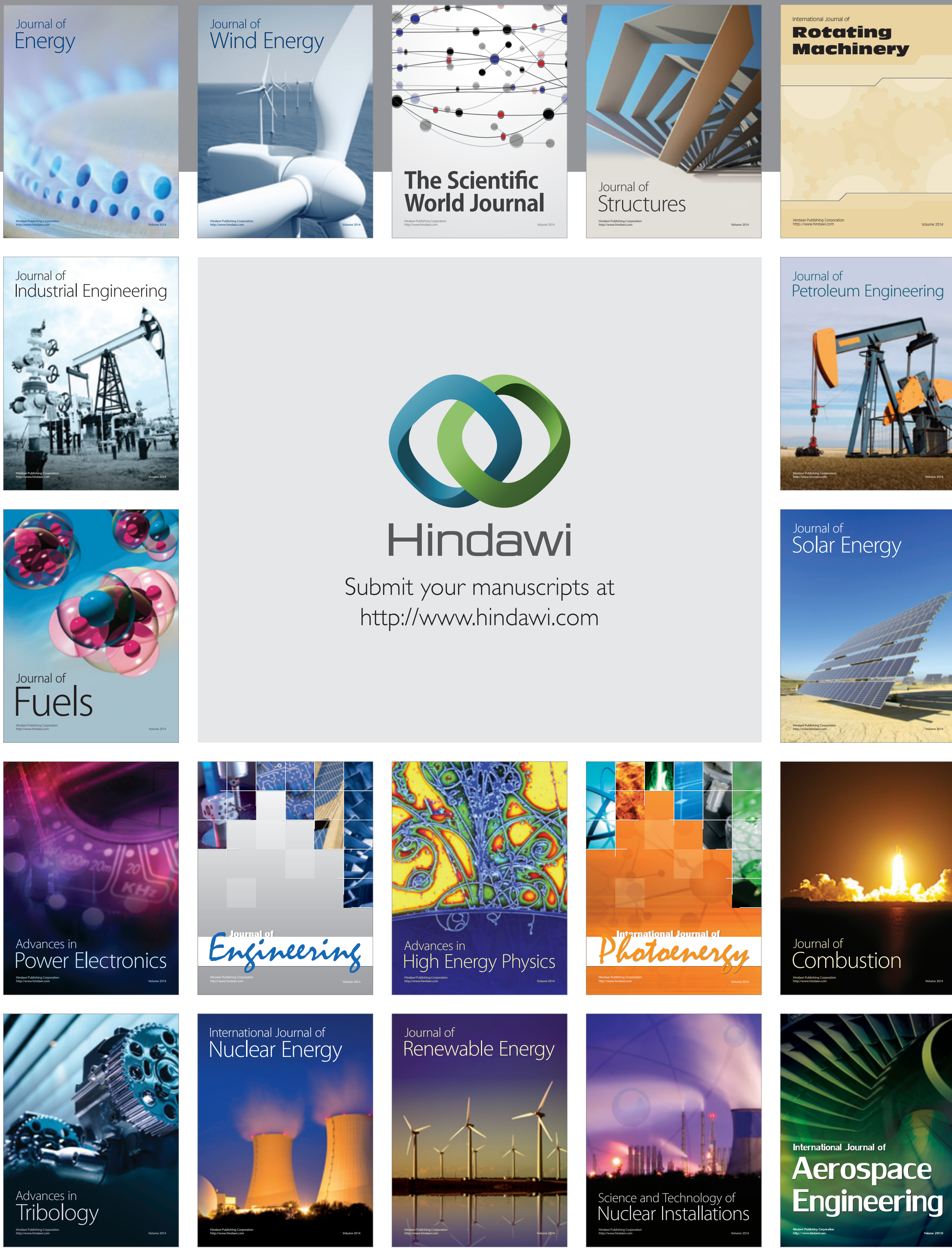
[14] A. A. Bolonkin and R. B. Cathcart, *Macro-Projects: Environment and Technology*, NOVA, Huntington, NY, USA, 2008, http://www.scribd.com/doc/24057930/.

[15] A. A. Bolonkin, “Cheap method of city protection from rockets and nuclear warheads,” 2007, http://arxiv.org/ftp/arxiv/papers/0801/0801.1694.pdf.

[16] P. Gleick, “Water resources,” in *Encyclopedia of Climate and Weather*, S. H. Schneider, Ed., pp. 817–823, Oxford University Press, New York, NY, USA, 1996.

[17] V. V. Naschekin, *Technical Thermodynamic and Heat Transmission*, Public House High University, Moscow, Russia, 1969.

[18] A. M. Howatson, P. G. Lund, and J. D. Todd, *Engineering Tables and Data*, Kluwer Academic, Boston, Mass, USA, 1991.


Journal of
Energy
Journal of
Wind Energy
The Scientific
World Journal
Journal of
Structures
International Journal of
Rotating
Machinery
Journal of
Industrial Engineering
Hindawi
Submit your manuscripts at
http://www.hindawi.com
Journal of
Petroleum Engineering
Journal of
Fuels
Journal of
Solar Energy
Advances in
Power Electronics
Journal of
Engineering
Advances in
High Energy Physics
International Journal of
Photoenergy
Journal of
Combustion
Advances in
Tribology
International Journal of
Nuclear Energy
Journal of
Renewable Energy
Science and Technology of
Nuclear Installations
International Journal of
Aerospace
Engineering