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UMR-MEC Conference on Energy

09 Oct 1975

Efficiency in the Use of Energy Has Been Effected Through Industrial Use of Subsurface Space

Truman Stauffer Sr.

EFFICIENCY IN THE USE OF ENERGY HAS BEEN EFFECTED THROUGH INDUSTRIAL USE OF SUBSURFACE SPACE

Dr. Truman Stauffer, Sr.
Department of Geosciences
University of Missouri - Kansas City

Our Nation, with its high standard of living made possible by industrialization, draws heavily on energy producing natural resources. Self reliance mandates the use of every measure of conservation in order to extend the yet finite supply of energy to meet our national needs. Efficiency in the use of energy has been and can increasingly be effected through industrial use of subsurface space. The use of mined rooms for industry and warehousing utilizes the natural stable underground temperature and the low coefficient of heat transfer existing naturally in the lithosperic materials of the subsurface environment. The small amount of energy usage required to adapt and maintain an underground site at temperatures compatible to industrial use as compared to the energy usage required to maintain identical temperatures in a surface structure results in a considerable net savings in energy. Missouri leads the nation in the variety and number of uses being made of the subsurface mined areas and is contributing modestly but significantly to self-reliance in our nation's use of energy.

The further study of subsurface space usage as an energy saving measure is indicated.

The industrial use of subsurface space within the natural climate and physical properties of in situ rock material is significantly contributing to the efficient conservation of energy. This method of saving energy has an even greater potential if applied to a wider array of subsurface uses and extended to other areas having compatible geology and geographic market situations. This paper draws on the Kansas City leadership in this field where for two decades the use of subsurface space has been successfully practised. Though not as extensive in their range of uses of the subsurface, other localities have also made supporting contributions to subsurface uses. Among these are Carthage and Springfield, Missouri, Boyers, Butler, and Wampum, Pennsylvania, as well as sites in Norway and Sweden.

The Kansas City area is a model in good conservation practises in that once abandoned limestone mines have been converted to a secondary and continuing use. It is a natural laboratory in its conservation of energy through use of the mined rooms for refrigerated and dry storage, factories and offices. Some 2,000 people work daily from 50 to 200 feet below the surface. The subsurface rooms converted to these uses are a byproduct left from the room and pillar mining of limestone. These rooms are interspaced with supporting pillars of limestone which are 25-30 feet in diameter and spaced 50-65 feet apart on center (Figure 1). Floors are paved with asphalt or concrete and partition walls where desired are usually of building

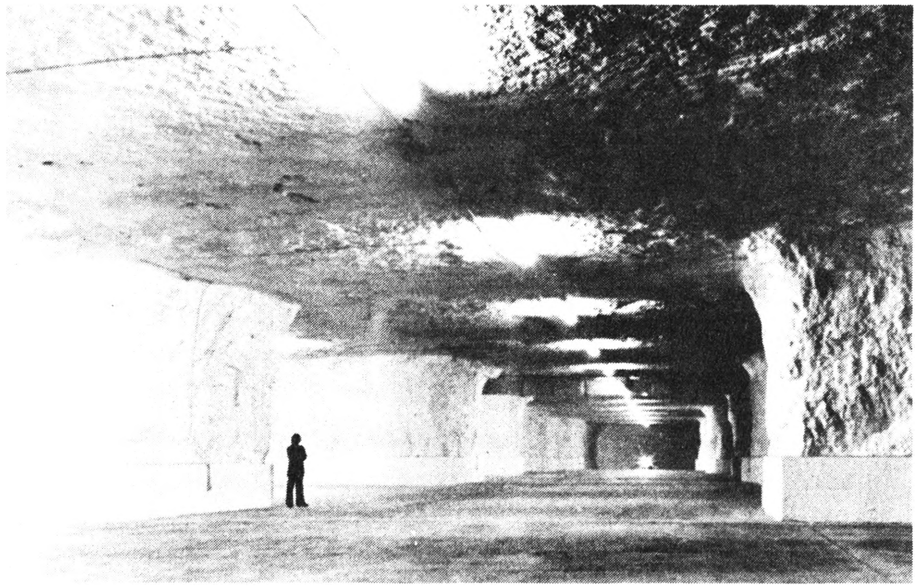

Figure 1. Mined Area Ready for Occupancy at Great Midwest Corporation in Kansas City

block construction. Large storage rooms, offices, and industrial space are easily arranged. The temperature and humidity is controlled by conventional heating and refrigeration methods.

Whereas the use of these underground rooms was motivated by the demand for economically attractive space, the economic benefits of low energy consumption was discovered as an added savings. The savings gained in low energy use are very important in our current national concern for independence during our energy crisis. Its greatest contribution may yet be achieved as it points the way for national acceptance of our underground space as a natural resource and its wise and careful use by compatible industries as an energy conserving factor on a national scale.

The rock strata commonly mined and later converted to space use in the Kansas City area is a Pennsylvanian limestone, about 24 feet thick, having a natural temperature in its mined rooms of 45 to $54^{O}F$ with less than 5^{O} variation between seasons. The surface temperatures, by comparison, dip below $0^{O}F$ and rise above $100^{O}F$. One can quickly see the economy of energy consumption gained by the use of the subsurface. The natural untreated subsurface temperature is closer to the temperature desired for industrial use and therefore requires less modification, and hence, less energy consumption (Figure 2). The very low range of subsurface temperatures, their natural proximity to desirable temperatures, and their constant predictability allows less capital outlay for equipment as capacity to modify the wide range of surface temperature extremes is not necessary. The savings in reduced equipment installation also conserves the energy which would have been expended in its production.

Kansas City, largely because of its underground resources, has the largest storage capacity for frozen foods in the world and nearly all of this freezer space is underground. Its ability to effectively compete for a lion's share of the frozen food industry lies to a great extent in making optimal use of natural subsurface space temperatures and the insular qualities of the surrounding rock.

There are many variables operating in freezer storage such as the amount of unfrozen food brought in that must be initially frozen and stored, the turnover of products allowing cold loss through

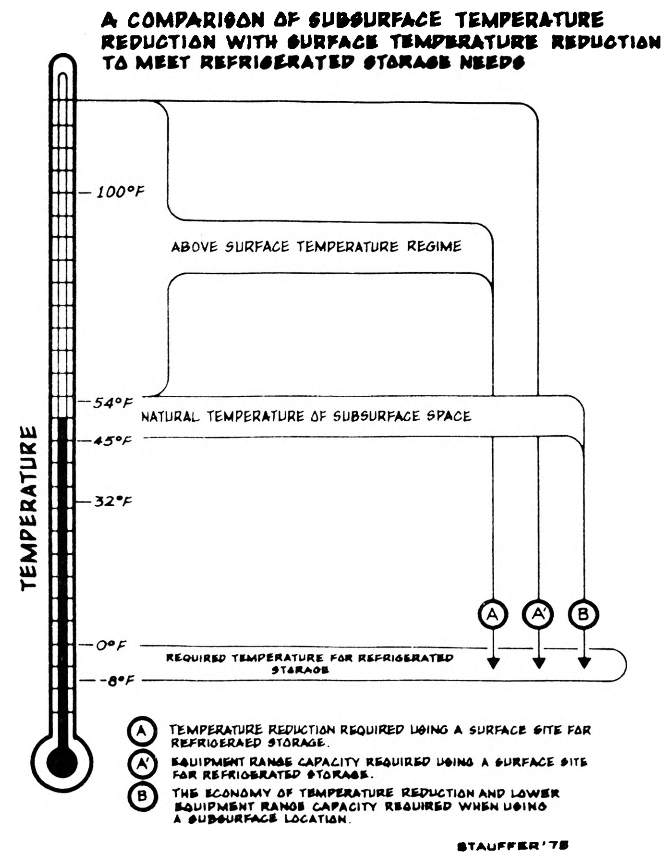

Figure 2.

opening of doors for loading, the character of the products, their dimensions, and mechanical and human activities within the storage area. All of these affect the efficient use of energy. For this study we will assume that the frequency and intensity of these variables happen to the same degree in both a surface and a subsurface freezer site or that they cancel each other. An example of such cancellation may be cited as the possible loss of space efficiency in the use of a mined site may be cancelled by its door traffic never admitting higher than 54°F air whereas the surface door may frequently admit air with very high temperatures. A monitored study with control of these variables is certainly indicated for greater accuracy.

The Kansas City experience, gained mainly by trial and error methods, has shown that the initial outlay for equipment in an underground refrigerated warehouse may successfully be reduced to 70% of that required for a conventional surface refrigerated warehouse. Research has shown that for a surface refrigerated warehouse of 1,600,000 cu. ft. to be kept at 0 to -8°F, 200 tons of refrigeration with 633 total connected horse power are required. For the same size plant located in a subsurface limestone mined area, the requirement for initial equipment is reduced to 448 horse power. To this initial reduction in energy use by virtue of smaller equipment may be added the additional savings gained by freezing down the rock walls.

Lorentzen (1959) reports on an underground freezer installation in Norway and cites definite advantages in using the natural rock for walls and freezing the rock walls, ceilings, floors, and pillars instead of using insulation. He found an initial savings by eliminating the cost of insulation and secondly, the cold stored deeply in the rocks could be tapped when large quantities of products to be frozen were brought in or in case of breakdown of machinery. These periods of peak loading, by the advent of fresh unfrozen commodities, tax the capacity of the conventional surface plant in that the compressor alone must compensate for increased cooling demand whereas the frozen rock of the underground serves in this capacity. The limestone rock of the Kansas City area has been found to be frozen to a depth of 22 feet and the pillars within the refrigerated rooms are solidly frozen. A temporary shutdown of the freezer within such a rock chamber will result in a temperature rise of about 1/2 of a degree per day whereas a breakdown in a surface location may raise 3-4 degrees daily. The risk of food quality loss is thus greatly reduced in the underground site.

Once the freezing of the rock surrounding the subsurface freezer plant has been achieved, the savings is even greater. The freezing of the rock walls to the optimum depth reportedly takes up to three years and gradual reduction of refrigeration may be achieved during this time so that eventual operation of refrigerator units in an underground site may be reduced to 40-50% of a comparable surface plant. Figure 3 shows the initial savings in

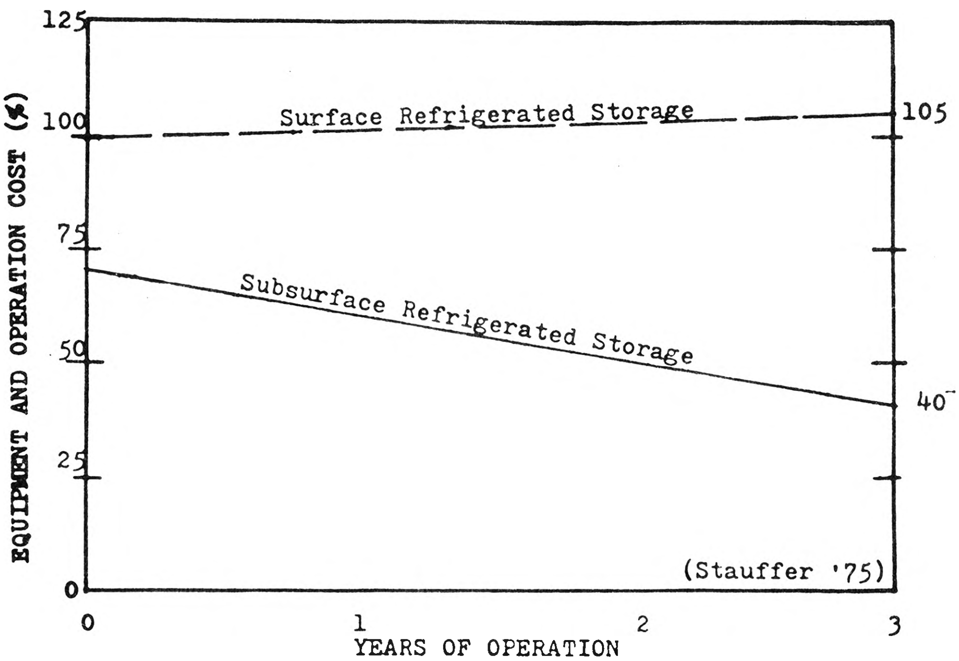

Figure 3. Comparison of energy savings effected by subsurface location based on equipment need and operation.

equipment outlay and the gradual reduction of equipment operation over time as compared to a surface operation which actually loses efficiency on a small scale.

Echo (April, 1975), an organ of Inland Storage Facilities, reports that their refrigeration equipment, by being underground, can cool twice as much as a comparable surface site. Muller (1975) also confirms the ability to withdraw up to 50% of the original equipment once the rock is frozen in depth but cites the problems of occasional low ceilings forcing short stacking of products, and pillars which spread outward toward the top prohibiting close storage, as taking a toll out of the savings. These areas which are not efficiently used have to be cooled regardless. His figure of net savings as compared to conventional freezer space approximates 30% which is yet a respectable savings in energy. One must also note that Muller is referring to an abandoned mine which has been converted to a freezer area. Current mining practises in the Kansas City area plan for the use of the mined space reducing if not eliminating low space use efficiency.

Warnock (1975) in his studies of initial equipment outlay found underground installation for refrigerated space to be only 50-60% of that required for a surface site and the heat loss in the underground installation in a full 24-hour day to be about equal to the heat loss above ground in a single hour.

Freezer storage in the Kansas City area ranges from sites which are in their initial months of operation to those sites with years of constant freezing wherein the rock has been frozen to its maximum. Assuming an average and conservative estimate of 40% in energy savings through use of the subsurface for refrigerated storage, as an attempt to evaluate the Kansas City experience, some interesting figures begin to emerge. In the Kansas City area alone the underground refrigerated warehouses are saving the electric energy used by 7,601 homes. When this is projected on a national scale the energy savings that could be realized if just one industry, the refrigerated warehousing industry, took advantage of the thermal qualities of the subsurface is quite impressive. A savings in energy could be achieved which would be sufficient to supply the electric energy needs of 110,019 homes or the residential needs for electric energy of a city of over a quarter million. The Kansas City figures are based on the 12,900 connected horse power currently installed in the Kansas City area for purposes of refrigerated storage being 60% of that required if the storage were on the surface and that in both cases the annual service use of the equipment is 75%. The rate of home use of electricity is based on the average non-business use of electricity in the Kansas City area. National projections are based on U. S. data of refrigerated warehousing.

Aside from the 3,320,000 square feet of refrigerated storage space located underground in the Kansas City area there is an additional 13,000,000 square feet which is currently used as space for cool and dry storage, factories, and offices. These uses require very minor modifications in the natural subsurface temperature. For most of these uses the heat gained by dehumidification is more than ample to make the adjacent office space comfortable. The ratio currently used for estimating the installation of equipment for these uses is .0825 of that for a comparable surface location. A five-ton unit of equipment is an accepted estimate of the needs for a home having 2,000 square feet. A five-ton unit underground efficiently serves 28,000-30,000 square feet in the Kansas City area. A few kinds of uses will require slightly more treatment, as in the case of tobacco storage, but to compensate for those requiring more treatment, there are other uses where no treatment whatsoever is required. On this basis, one can safely assume there is a 90% reduction in energy use when similar temperature and humidity conditions are attempted below the surface as compared to a conventional surface for such uses as general warehousing and factories. One cannot assume, however, that ideal temperatures and humidity are always maintained in warehouses on the surface. Subsurface space is easily maintained at the temperature and humidity desired whereas surface warehouse temperatures often go untreated and reflect the highs and lows of the existing weather. However, when and if similar conditions are attempted in both the surface and subsurface, the 90% savings in energy is conservatively realistic for a combination of non-freezer warehousing, factories, and offices.

It is my considerate opinion that the industries located underground in the Kansas City area have contributed significantly to the conservation of energy in both freezer and non-freezer uses and that a general figure of 70% reduction in energy usage for a combination of all subsurface uses in the Kansas City area is a conservative and reasonable estimate. Careful monitoring of controlled situations where all variables are compensated in both a surface and a subsurface experiment over a period of a minimum of three years is necessary to obtain absolute comparative data.

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