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THE NASA LANGLEY BUILDING SOLAR PROJECT AND THE SUPPORTING LEWIS SOLAR TECHNOLOGY PROGRAM

by Robert G. Ragsdale and David Namkoong
ewis Research Center
leveland, Ohio 44135

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Lewis Research Center

ABSTRACT

The NASA will use solar energy to heat and cool a new office building that is now under construction at its Langley Research Center in Hampton, Virginia. Planned for completion in December 1975, the 53,000 square foot, single story building will utilize 15,000 square feet of various types of solar collectors in a test bed to provide nearly all of the heating demand and over half of the air conditioning demand. This is a cooperative project involving joint participation between Langley and NASA's Lewis Research Center in Cleveland, Ohio.

Drawing on its space-program-developed skills and resources in heat transfer, materials, and systems studies, NASA-Lewis will provide technology support for the Langley building project. A solar energy technology program underway at Lewis includes solar collector testing in an indoor solar simulator facility and in an outdoor test facility, property measurements of solar panel coatings, and operation of a laboratory-scale solar model system test facility. Based on results obtained in this program, NASA-Lewis will select and procure the solar cellectors for the Langley test bed. The selection will be made in late 1974 or early 1975.

Early results from simulator tests indicate that non-selective coatings behave more nearly in accord with predicted performance than do selective coatings. Initial experiments on the decay rate of thermally stratified

hot water in a storage tank have been run. Results suggest that where high temperature water is required, excess solar energy collected by a building solar system should be stored overnight in the form of chilled water rather than hot water.

INTRODUCTION

There are a number of ways that solar energy can be utilized to supply a significant portion of the nation's energy needs. These ways were identified and assessed as to their potential in a study carried out by the NASA and the National Science Foundation (ref. 1). One important way is to use solar energy to heat and cool buildings. Three initial, or "phase-zero", studies have just been completed under NSF sponsorship to determine what kind of R and D program makes the most sense in this area (refs. 2-4). The results of these studies will assist in determining program goals and the approaches to be taken to achieve them.

Regardless of the specifics that result from such a program definition, it is clear that a significant technology effort will be required to learn more about how solar heating and cooling components, sub-systems, and total systems work in the real environments where they will find eventual application. Because of this fact, and as a part of its efforts to apply its space-program-developed technology and skills to significant national needs here on Earth, the NASA has decided to use solar energy to heat and cool a new office building that it is to construct at its Langley Research Center in Hampton, Virginia. A solar energy R and D program underway at the Lewis Research Center in Cleveland, Ohio will provide the technology base for this NASA project. This solar "test bed" facility will enable us to find out how various kinds of solar collectors behave in a total system operating in conjunction with a real building. We will also discover how the complete system works, or fails to work, in a real situation that includes such things as year-round weather variations, possible local power failures, unexpected maintenance requirements, and the actual experience and resultant attitudes of the building occupants.

It is the purpose of this paper to describe the status of this project. This description will be presented in two general categories. First, the status of the Langley Building Solar Project will be described. This will be done primarily in terms of project parameters such as objectives, approaches, schedules, and milestones. It will also include, however, a technical description of the system we plan to build, and a description of the technology information that will be required for project success. The second discussion category will be solar energy technology program currently underway at the Lewis Research Center. This discussion will be primarily technical in nature, and will summarize what we are doing at Lewis in the area of solar heating and cooling, what we have learned to date, and what we see for the near-future. This discussion will be slanted toward defining how the output of the technology program is aimed at providing the input information necessary for success of the Langley Building Solar Project. It should also become apparent that the output of the Lewis solar technology program will have much broader application and value than just to the Langley building project.

LANGLEY BUILDING SOLAR PROJECT

NASA plans to utilize a new Systems Engineering Building, called the SEB, at its Langley Research Center in Hampton, Virginia, as a test bed for solar heating and cooling systems investigations. The SEB is an approved FY'74 "construction of facilities" project. Ground breaking for the building occurred recently, and building occupancy is presently scheduled for late 1975.

This solar energy project is a joint activity that involves both NASA-Langley and NASA's Lewis Research Center in Cleveland, Ohio. The overall project responsibility is in the NASA Headquarters Office of Energy Programs. The Center's major responsibilities are as follows:

NASA-Lewis:

- Initial project definition
- Preliminary engineering design of solar system
- Selection and procurement of solar collectors
- Preparation of test plan
- Data interpretation

NASA-Langley:

- Detailed final design of solar system, exclusive of collectors
- Procurement and installation of solar system, exclusive of solar collectors
- Installation of solar collectors
- System operation and data acquisition

The success of this project will depend heavily on joint participation and cooperative endeavors of both NASA centers involved.

The objective of this project is to determine the technical and operating characteristics of various kinds of solar collectors in a complete solar system being used to supply a significant part of the heating and cooling needs of a real building. This will enable us to find out how various kinds of components and subsystems work, and which ones work best. Ultimately, this kind of information will be used to achieve solar heating and cooling systems that are economically competitive, long-life, and reliable.

The approach being used to achieve this project objective is as follows:

1. Design a system to utilize solar energy to heat and cool the SEB.
2. Design the system so that up to 16 types of collectors can be tested and compared simultaneously.
3. Design the complete system so that the building heating and cooling does not depend on success of the solar system.
4. Emphasize minimum project cost.
5. The building construction schedule paces the project--have the solar system operational at building occupancy.
6. Utilize the NASA-Lewis solar technology program to support the project.

With this information as a background, let us now discuss the building, the solar system, the current project status, and the future plans.

The Building. The SEB is to be a single-story office building. The basic data on the building and its energy demand are summarized in Table 1. The building is to have 53, 000 square feet of floor area, and will provide office space for 350 people. It will be located in Hampton, Virginia, where typical mid-eastern seaboard weather conditions prevail.

The building was designed with energy conservation in mind. Preliminary design calculations were carried out to determine the most cost-effective energy conservation features, e.g., thickness of insulation to use on the roof. A charcoal filter will be used in the building ventilation system to reduce the amount of outside air that will have to be air conditioned and/or heated. The room ventilation air will be ducted through the light fixtures to utilize this heat source most efficiently.

The yearly energy demand of the building is approximately 4300 million BTU's. This demand is primarily air conditioning (80%) rather than heating (20%), as is generally typical of office buildings. The only significant change in the building design that was made to accommodate the solar system was to use an absorption chiller for the air conditioning rather than a conventional - and more cost-effective - compression machine. Thus the building will utilize a commercial 150 ton lithium bromide chiller that is driven by hot water. Hot water will also be the energy source used for space heating.

The building heating and cooling system will receive its hot water from the solar system (when it is available) or from a steam-water converter driven from the Langley central steam supply system. Thus, whenever the solar system can supply all or part of the energy demand of the building, it will be used. Whenever auxiliary energy is needed, it will be supplied by the central steam system. This steam system utilizes an oil-fired boiler.

The Solar System. The solar collector test bed will be located on the ground in an area adjacent to the building. In some ultimate application, the collectors would most likely be on the roof, be the roof, or be integrated into the building structure including perhaps the south wall. However, the ground location was selected for this project for the following reasons:

- Provides ready accessibility required for test bed operation
- Minimizes project cost
- Land space was available

As depicted in Figure 1, the solar system will contain a hot water storage tank and a cold water storage tank, each of approximately 30,000 gallons capacity. The collector field will contain twelve separate rows of collectors, with each row individually instrumented and flow controlled. Each row can have a preset outlet temperature controller that will vary the flow - as the solar input varies - to provide a constant temperature water supply. If desired, the field, or any one row, can also be operated at a preset, fixed water flow. In that mode, the outlet water temperature will vary as the solar input varies.

Up to 16 different kinds of solar collectors can be tested at one time, although this will not necessarily be what is done with the first generation of collectors to be tested. For example, 2 or 3 rows may be used to test the same collectors installed at 3 different tilt angles, such as horizontal (roof), vertical (wall), and 32° (optimum for Hampton, Virginia). The point to be made here is that the system is flexible so that it can operate as a test bed, as opposed to a fixed design, frozen-in-place system. Thus it is neither necessary, nor even sensible, to define in detail at this time exactly what the first set of collectors and experiments will be.

Regardless of the collector types to be first used, the solar field size had to be selected. This was done by comparing how much energy the building needs with how much solar energy is available, along with some estimate of collection efficiency. The results of this comparison are summarized in Figure 2, for 15,000 square feet of solar collectors facing due south, and tilted up 30° from the horizontal. The building energy demand shown for each month was actually determined by carrying out detailed, computer calculations of the hourly variations of the various heating and cooling loads of the building. The building cooling energy requirements were calculated using a chiller coefficient-of-performance (COP) of 0.6, which is typical of absorption machines.

The two solar system supply curves show how much of the building energy demand can be met if either 30% or 50% of the solar insulation can be utilized for this purpose. The results summarized in Figure 2 were the basis for selecting 15,000 square feet as the size of the collector field. This field size should provide most of the heating needs, half or more of the cooling needs, and will require us to deal with overcapacity in spring and fall. Thus we will be able to study all significant operational aspects of solar heating and cooling of buildings except, of course, those associated uniquely with building integration of the solar system.

As a matter of interest, we show in Figure 3 how a particular kind of collector might behave in our Langley solar system. The basis for the calculated results was actual insolation measurements made at Langley on February 4, 1974. This was a clear, sunny day, and as such is not representative of an average winter day at Langley. The measured, horizontal flux was corrected to that corresponding to a tilt angle of 30°, and this is shown in the upper curve in Figure 3.

The lower curve shows the results of a computer calculation of how much energy would have been collected by a 2-glass, selective coating (absorptively of 0.9 and emissivity of 0.1), flat plate solar collector. The calculations were carried out for 170° F inlet water temperature and 210° F outlet water temperature. These temperatures correspond to values dictated by the heating and cooling subsystem needs of the building for that day. Figure 3 shows that the collector efficiency varies from zero at 7 AM up to a maximum of 41.5% at noon, and back down to zero at 5:30 PM.

For that day and that kind of collector performance, 29% of the insolation falling on the collector would have been collected. This corresponds to 8 million BTU for 15,000 square feet of collector surface. This would have exceeded the total building demand of 7 million BTU for that day. This is a thermal excess could have been stored for use on the following day.

Of course, this is an ideal calculation. It was a particularly sunny day. And collectors undoubtedly perform better in our computer "world" than they will in the real one. However, the results depicted in Figure 3 do show the general nature of what we expect to happen.

Project Status and Future Plans. The major milestones of the Langley Building solar project are shown in Table 2. The detailed design of the solar system, exclusive of the collectors themselves, has just been completed by Langley, and is in the process of final review and approval. A collector test program is underway at Lewis, and will be the basis for collector selection later this year. The solar system components (but not the collectors) will be procured by Langley and installed over a period running from this fall to next summer. Collector procurement by Lewis will be timed to provide for their delivery to Langley for installation in the fall of 1975. The entire system with collectors in place will be checked out and operational by the time of building occupancy, which is now scheduled for December, 1975.

This is an exciting project. There are a number of unknown and uncertainties. We are bound to encounter problems due to the myriad of differences that exist between the computer/laboratory world and the real one. The challence is great, but so is the potential payoff. There are, of course, a number of questions that must be answered before proceeding into a major experimental project such as this one. Some of these questions are:

1. How well do collectors work, even under ideal conditions?
2. How do they work in less-than-ideal, outdoor conditions?
3. What kind of coatings are best for flat plate collectors?
4. What are the dynamic interactions between the various components and subsystems of an entire solar system?

5. Do we know enough about the foregoing to expect success with a real system, in real weather, connected to a real building?

It is the purpose of the solar energy technology program at NASA-Lewis to answer these questions. Let us now discuss that program.

NASA-LEWIS SOLAR TECHNOLOGY

A solar technology program currently underway at NASA-Lewis will provide the research and technology base to support the Langley Building solar project. The various outputs of the Lewis program will also contribute to advancing the general status of solar heating and cooling technology, as will the Langley Building project itself.

The solar technology program consists of efforts in four major areas:

- Collector testing in a solar simulator facility
- Collector testing in an outdoor test facility
- Coatings and Materials Studies
- Operations of a solar model systems test facility

A highlight summary of the present status and future plans of each of these projects will be presented in the following sections of this paper. More detailed information on work is available in past publications (references 5 and 6), and in companion papers presented at the International Solar Energy Society Meeting, Fort Collins, Colarado, August 19-21, 1974 (references 7 and 8).

The Solar Simulator. The solar simulator test facility was constructed so that solar collectors could be tested under known, controllable, and variable conditions. A photograph of the simulator is shown in Figure 4. Pertinent data on the simulator is given in Tables 3 and 4.

Basically, the simulator delivers simulated "sunshine" (air-mass 2 spectral distribution) uniformly over a 4-foot by 4-foot area. The intensity can be varied from a maximum value of 350 BTU/ft^2/hr (typical "high-noon at Tuscon" intensity) down to as low as desired. Any lesser value is attainable, but 150 BTU/ft^2/hr is the usual cut-off that we observe because below this value the spectral distribution is beginning to depart significantly from that corresponding to air-mass 2. This is not a serious limitation, however, since solar collectors collect little energy at fluxes less than 150 BTU/ft^2/hr.

Ordinarily a test series consists of measuring collector efficiency at 3 or 4 fluxes (between 150 and 350 BTU/ft^2/hr), for a number of inlet coolant temperatures ranging from 100° F up to 210° F. These tests are carried out at a fixed water flow rate of approximately 10 lb/hr/ft^2 of collector surface. This flow rate is typical of that to be encountered in usual applications. In this range, collector efficiency is essentially independent of coolant flow rate. The collector efficiency is higher at higher test fluxes for a given outlet temperature. This is illustrated in Figure 5 by data obtained from a 2-glass, flat copper plate collector that utilized ordinary flat black paint hand-sprayed onto the plate surface. This data illustrates two general characteristics common to all collectors - efficiency drops off as operating temperature increased, but increased as heat flux increases. This leads to a different "operating line" for each flux. Although Figure 5 doesn't show it, there is also a different operating line for each ambient temperature.

These operating lines can be brought together - approximately - by plotting efficiency versus one parameter. That parameter is obtained by dividing the temperature difference between the inlet coolant and the ambient air by the incident heat flux. Calculated curves of collector efficiency versus this parameter are shown in Figure 6. These curves were calculated by Honeywell, Inc., as a part of effort they are carrying out under Contract NAS-3-17862. The use of this parameter represents an approximation - primarily the assumption that the inlet coolant temperature is a good representation of "collector" temperature. However, the approximation appears to be good for the ranges of conditions we care about, and its use is quite convenient. Figure 7 shows the data from Figure 5 replotted using this parameter.

So far we have completed testing of four collectors. The performance of these collectors is summarized in Table 5. We have 3 other collectors that are nearing completion the testing stage. We are still in the early stages of simulator testing. We are learning about collectors, and also about how to operate the facility in the most useful and productive manner. This is a useful facility that we feel will contribute greatly to understanding and improving collector performance.

We plan to test all collectors that appear to be of reasonably valid design in this facility. This includes collectors that we design and build, collectors we buy, and collectors whose ownership remains with the original owner. To provide cost-free test of a collector in this facility requires only that the owner give NASA the right to publish the data collected.

Outdoor Test Facility. Collectors will be tested outdoors as well as in the indoor facility. One unit of this facility is shown in Figure 8. This unit can test 5 different collectors side-by-side. The facility can handle sizes up to 4-foot by 8-foot. Thus, this one unit can test 160 square feet of collectors in total. A second, identical unit is nearing completion. The schedule for bringing these two units into operation is shown in Figure 9.

This outdoor test should augment information learned in the simulator. In the outdoor facility, tests will be carried out to determine the effects on performance of such factors as wind, rain, dust, humidity, clouds, and long term thermal cycling over many day-night periods. One of our first interesting tasks will be to compare actual collector outdoor behavior with that anticipated from our simulator testing of the same collector. The simulator will also be used as a controlled calibration check on deteriorating performance by returning an outdoor collector to the simulator from time to time. In combination, the simulator and the outdoor facility should provide a powerful tool for collector development, short of operation in an entire system.

Coatings and Materials Studies. The coating and materials work is aimed primarily at determining what combinations of collector plate materials (such as steel, aluminum, and copper) and coatings yield the best collector in terms of initial performance, life, and low cost. In general, we are trying to identify as many coating candidates as possible, measure these properties (primarily absorptivity and emissivity), and then prepare collector panels of the promising ones for test in the simulator.

Figure 10 summarizes some measurements made to date. Absorptivity is the important property in the wavelength range of "sunshine", which is approximately 0.2 to 2 microns.

The "ideal" dashed line in the figure shows what is desired - high absorptivity say .9 or greater, and low emissivity, say 0.1 or less. Measured values are shown for ordinary flat black plant, two commonly utilized "selective" coatings (CuO and black-nickel), and a relatively new candidate for a solar selective coating, black-chrome (BL-CR). All of the selective coatings exhibit relatively high ratios of absorptivity-to-emissivity in the range 8 to 12. Ordinary black paint has a very high emissivity. However, it also has a higher absorptivity than the selective coatings. Interestingly, the best collector performance we have measured so far had a black paint coating on the copper panel. However, these were early results, and there is no reason yet to doubt that eventually selective coatings will deliver the higher performance that theory predicts. Whether this will provide a cost-effective justification for their use is another matter that remains to be resolved.

Our primary interest to data in black-chrome is that it provides an alternative to black-nickel and may give better performance, be lower cost to apply, be more reliable or longer life, or perhaps be more appropriate chemically with some plate materials than black-nickel. Obviously, it may not deliver all, or perhaps any, of these advantages. We intend to investigate these and other coating candidate materials so that comparative evaluations can be made.

Model Systems Test Facility - Purpose. A solar model systems test facility has been constructed, and is currently undergoing check-out testing at NASA-Lewis.

The purpose of our model systems tests will be:

- To simulate the dynamics of a solar heating-cooling system
- To determine the ratio of the total heating-cooling demand of a building that can be supplied by solar energy
- To provide an experimental verification for computer heating-cooling simulation programs.

Elements of the System. - Functionally, the system provides for solar heat input, auxiliary heating, heat storage, and heat delivery as shown in Figure 11. Solar heat input is provided by a steam-water heat exchanger when heat simulation is required or a solar collector field when the actual component is needed. Auxiliary heating is also provided by a steam-water heat exchanger. A cylindrical water tank is used for heat storage. Cold water flowing through a heat exchanger serves as the heat sink simulating the heat demand required from the solar loop. If heat energy is to be used for cooling, a subsystem is used. This subsystem consists of a water-chiller, a chilled water storage tank, and a heater to simulate the heat load of a building. Figure 12 is a photograph of the major components of the system.

The components have been sized according to the first application of the model system facility -- the Langley solar building. The heating, cooling, and flow rates, are 1/50th of the Langley values, and the components have been sized accordingly. The thermal storage tanks, therefore, have a 600 gallon capacity for the hot water system, and a 400 gallon capacity for the chilled water. The water chiller is a lithium bromide absorption unit rated at 3 tons of refrigeration.

An essential feature of the system is the provision for programming the solar heat input to and the heating demand from the system. This is accomplished by translating the heating rates into a curve scribed onto a rotating drum. The curve functions as a cam, and the "cam" follower in turn controls the heat or cold load to and from the system. If solar insolation data is available at a location where a building design is contemplated, the model system can simulate the dynamics on a realistic operating basis.

The system is designed for a flexible arrangement of its component parts. When completed, it will have the capability to operate with either solar heat or auxiliary heat supplying the total load, or with the auxiliary heat topping the solar heat; heat input to the system can be a programmed simulation of solar heat, or it can be the heat that is absorbed by actual solar collectors; heating and cooling energy consumption can be programmed as a single energy demand, or the cooling subsystem can be operated separately from the building heating requirements.

Test Schedule. - System build-up and testing has been scheduled in three phases as shown in Figure 13. The first includes the solar simulating heat exchanger and the single, load simulating heat exchanger as the heat input and output components respectively. Weather and building design data for the Langley building application will be programmed into these components initially. The second phase will be the building up of the cooling subsystem and incorporating it into the system. The subsystem as shown in Figure 14, is designed, as in the Langley building application, for a number of paths for chilled water flow, depending upon energy availability. The water can flow from the chiller directly to the load, or to the storage tank. Chilled water to the load can be tapped from the storage tank directly; or there can be flow partly from the storage and partly from the chiller to the load. The energy load in this subsystem would be programmable for "cold" demand only.

The third phase replaces the solar input heat exchanger with an actual solar collector field. For this purpose, we have completed final design, and will soon begin installation of a field of 600 ft^2 of solar collectors. These will be placed on the ground just outside of the building housing the model system test facility. There is no attempt here to <u>simulate</u> absorbed solar heat, but rather to study the dynamics of an <u>actual</u> collector field operating in a total system.

Currently, the system is being checked out prior to Phase 1 testing. As part of the check-out, and also to obtain useful information, hot water was delivered to and from the storage tank to study stratification. Further details are described in the Thermal Stratification Test section that follows.

<u>Thermal Stratification Test.</u> The most common method mentioned for storage of heat absorbed by solar collectors has been by use of water. Water is relatively plentiful and cheap and, with its density inversely proportional to temperature, can be temperature stratified. Stratification permits a measure of isolation of the high temperature water from the cold regions of storage.

In conjunction with the system check out procedure, a thermal stratification test was performed. Water heated by the solar simulating heat exchanger was pumped into the top of the heat storage tank and recirculated through the bottom of the tank. The tank itself is a nominal 600-gallon cylindrical tank, 4 feet in diameter and its vertical axis 8 feet in length. Thermocouples supported along a central vertical tube and along horizontal tubes, were designed to give a clear indication of temperature distribution throughout the test. The entire tank was wrapped with one-inch nitrile rubber insulation. Its thermal conductivity is in the same range as that of Fibreglas (approximately 0.26 BTU/hr-ft^2 - ^{o}F/in.).

The system was pressurized to 10 psig to prevent pump cavitation. The flow rate of water was adjusted so that the temperature entering the top of the tank was between 200^o and 205^o F. Flow rate ranged from 0.3 to 0.4 gpm depending upon the water inlet temperature to the heat exchanger.

Results show that a sharp gradient of stratification is possible, as is shown in Figure 15. After $5\frac{1}{2}$ hours of heating, approximately 8 cu. ft. of water has been raised to over 190^o F, while the remaining volume is virtually unaffected. The sharp degree of stratification has the main disadvantage in that it creates a high driving force for heat conduction. Thus, after 16 hours with no further heating, the temperature dropped in the heated region and increased in the adjacent cooler region. The shaded portion is the temperature drop due to heat loss to ambient conditions. Further heating and storing resulted in further penetration of heat into the lower depths of the tank and less sharp temperature gradients. Reduction in the maximum temperature was always evident, however, after an overnight period of no heat addition.

There are a couple of implications arising from these observations. If the system is designed to operate at a high temperature level, the hot water should be used at the end of the heating period and not allowed to dissipate overnight. Where a water chiller is driven by the hot water, for instance, it would be better to operate the chiller by the end of the heating day and to store any excess chilled water. The dissipation of chilled water would be much less than that of the high temperature water. Another implication is that high temperature dissipation in storage should receive consideration in the design of a Thermal storage tank. From this viewpoint, the tank design should be such as to minimize the area across which heat is transferred from the high temperature region to the cold. A large L/D, vertically oriented cylinder, for instance, would be a desirable configuration.

Tests were also conducted whereby the stored hot water was pumped out of the storage tank. The water was circulated from the top of the tank, through the cold water heat exchanger, and then pumped into the bottom of the storage tank. The upper part of the tank, intended to include the upper 4 thermocouples, was initially filled with water at 195° to 200° F. These thermocouples, spaced vertically approximately 12 inches apart, were attached to pen recorders. The results of one test where the flow rate was 3 gpm is shown in Figure 16. The temperature history shown is that of the lowest of the 4 thermocouples. Prior to time

"0 minutes", the pen trace showed no slope or perturbation. Time "0" was chosen arbitrarily during the "no change" period. The perturbations are seen to occur at about the time that a temperature drop-off is incipient. The oscillations become more regular and more severe as the temperature level begins and continues to decrease. At about 160°, the oscillation reaches down to the cold region temperature and back up again -- an amplitude of 50° in this case. The other three thermocouples also respond similarly though the oscillations are not as severe.

Another run was made under identical conditions except that the discharge flow rate was $\frac{1}{2}$ of the previous case. No such oscillations occurred.

Further investigation will attempt to define the problem and the conditions under which these temperature variations occur. As far as our system is concerned, however, the oscillations can present a problem. Presumably there would be a temperature sensor immersed in the water to indicate whether the temperature is high enough to be used. If this sensor is located where the oscillations occur, it could be indicating "go" and "no-go" in repeating and rapid succession. This instability, especially if aggravated by valve responses to the oscillations, can be detrimental to system operation and component life. These are initial results, of course, and we have yet to determine the extent to which they may be related to the specific component designs of our system. These stratification tests will be continued, and results reported at some future date.

CONCLUDING REMARKS

The NASA is planning to construct and operate a solar test bed system in conjunction with a new 53,000 square foot, single-story office that is being built at its Langley Research Center at Hampton, Virginia. The technology support for this project will be provided by a solar energy program underway at NASA's Lewis Research Center at Cleveland, Ohio.

The Langley Building Solar Project status is as follows:

- 15,000 square feet of collector's will be used.
- This will provide nearly all the heating needs and half of the cooling needs.
- Up to 16 different kinds of collectors can be tested simultaneously.
- Initial operation is scheduled for December, 1975.
- Collectors for this project will be selected by Lewis late in 1974 or early 1975.

The status of the supporting solar energy technology program at NASA-Lewis is as follows:

- A solar simulator facility is being used to test solar collectors under known, controllable, and variable conditions.
- An outdoor collector test facility is nearing completion.
- Property measurements are being made of non-selective and selective solar coatings.
- A complete laboratory-scale solar model system test facility is operational, and thermal storage tests are underway.

The overall goal of all of this work is to learn how solar heating and cooling components and systems work, and to make technology advancements necessary to achieve cost-competitive, reliable, long-life systems.

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TABLE 1. - NASA - LANGLEY BUILDING DATA

TYPE	• SINGLE STORY OFFICE
	• 53 000 FT^2
	• 350 PEOPLE
	• HAMPTON, VA.
ENERGY DEMAND	• 850 MBTU/YR HEATING
	• 3500 MBTU/YR COOLING
	• 150 TON ABSORPTION COOLER
	• HOT WATER HEATING

TABLE 2. - LANGLEY BUILDING PROJECT SCHEDULE

ACTIVITY	COMPLETION DATE
SOLAR SYSTEM DESIGN	JUNE 1974
SELECT COLLECTORS	SEPT-DEC 1974
INSTALL SYSTEM	AUG 1974 - JULY 1975
INSTALL COLLECTORS	JULY-SEPT 1975
BUILDING OCCUPANCY	DEC 1975

TABLE 3. - NASA-LEWIS SOLAR SIMULATOR

RADIATION SOURCE

143 LAMPS, 300 WATTS EACH
GE TYPE ELH, TUNGSTEN-HALOGEN, DICHROIC
9° TOTAL DIVERGENCE ANGLE

TEST AREA

4 FT. BY 4 FT., MAXIMUM

TEST CONDITIONS

FLUX: 150 TO 350 BTU/HR-FT^2
FLOW: UP TO 1 GAL/MIN
INLET TEMP: 75 TO 210°F
WIND: 0 OR 15 MPH @ 75°F

TABLE 4. - SOLAR SIMULATION - HOW GOOD?

		AIR-MASS-2 SUNLIGHT	SIMULATOR
ENERGY OUTPUT PERCENT	UV	2.7	.3
	VISIBLE	44.4	48.4
	IR	52.9	51.3
ENERGY USES	ABSORPTIVITY (SEL)	.898	.897
	ABSORPTIVITY (NON-SEL)	.969	.969
	GLASS TRANS.	.854	.859
	AL MIRROR REFL.	.864	.875
	SOLAR CELL EFF.	12.6	13.4

TABLE 5. - COLLECTOR PERFORMANCE COMPARISON

[HEAT FLUX = 250 BTU/HR-FT^2; COOLANT FLOW = 10 LB/HR-FT^2; AMBIENT TEMPERATURE = 75° F.]

COLLECTOR	EFFICIENCY		
	T_{IN} = 75° F	150° F	210° F
2-GLASS, BLACK PAINT	76	50	29
1-GLASS, SEL. COATING	79	45	17
2-GLASS, CuO COATING	58	38	16
1-GLASS, SEL. COATING + HONEYCOMBS	79	43	13

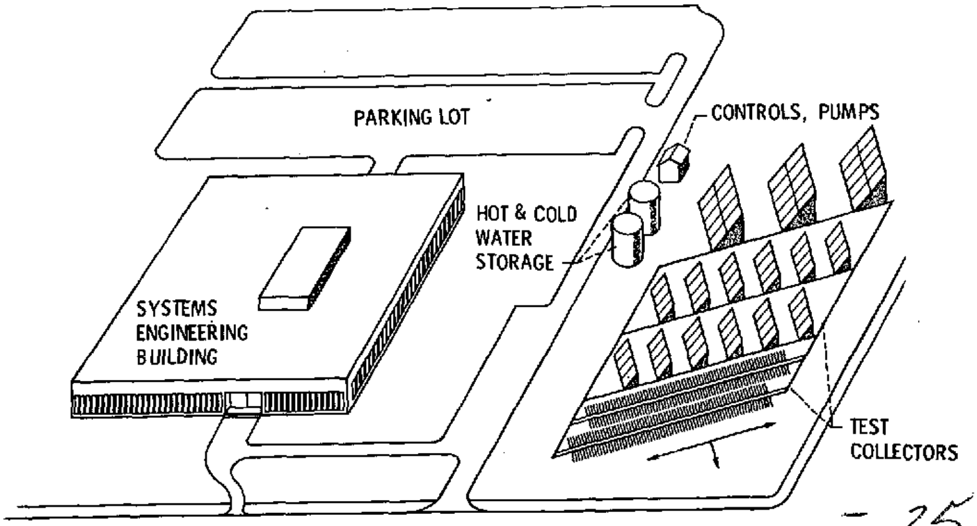

Figure 1. - Solar collector test bed - Langley Research Center.

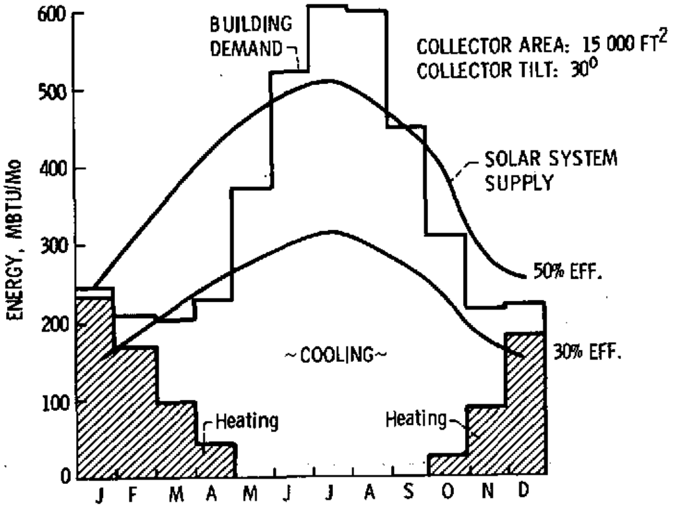

Figure 2. - Langley SEB. Energy match.

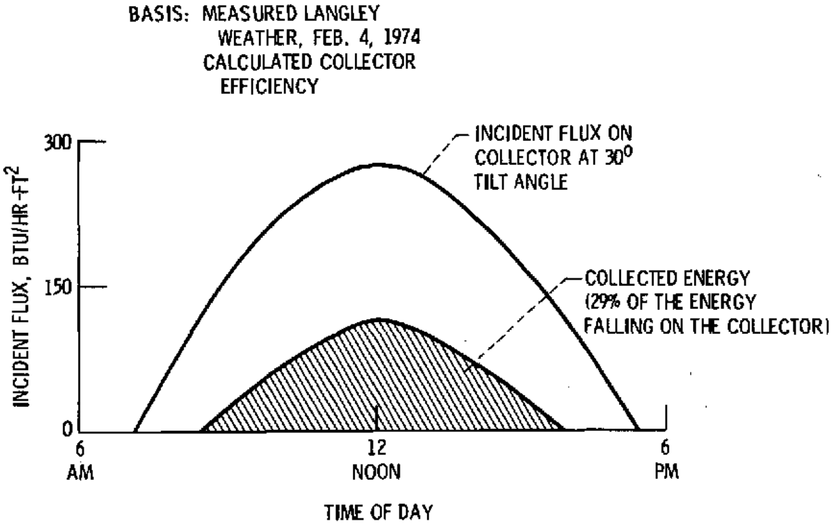

Figure 3. - Flat-plate, selective surface type collector used on Langley building. Note: This means that on this day, approximately 8 million Btu would have been collected by a 15 000 ft^2 collector field. This would exceed 100% of the building need (approx. 7 million Btu needed).

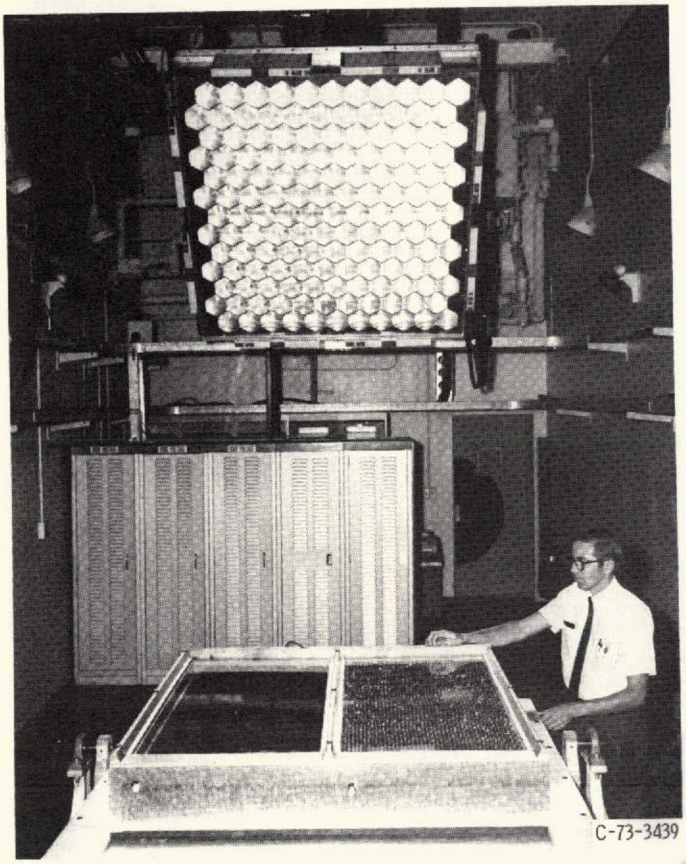

Figure 4. - NASA-Lewis solar simulator.

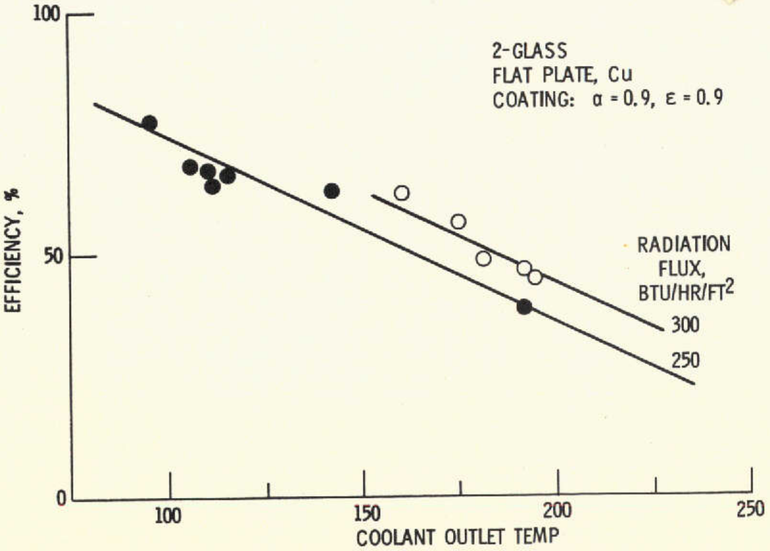

Figure 5. - Illustrative simulator test data.

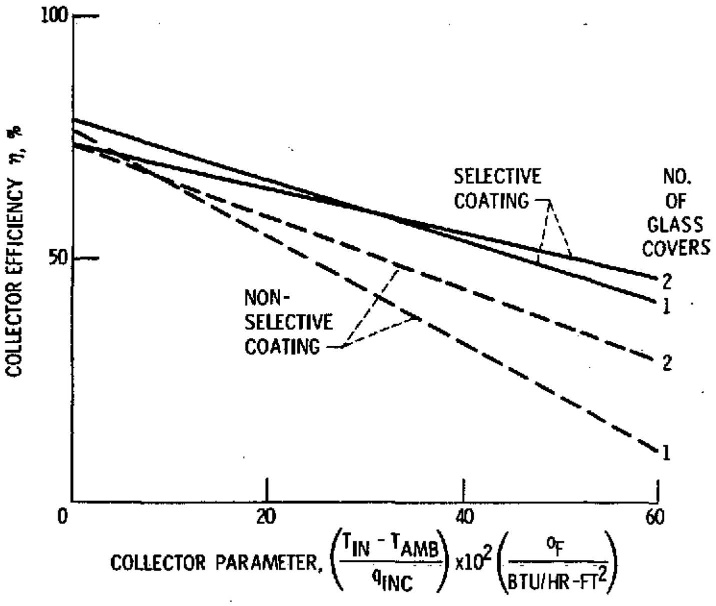

Figure 6. - Collector efficiency - theory.

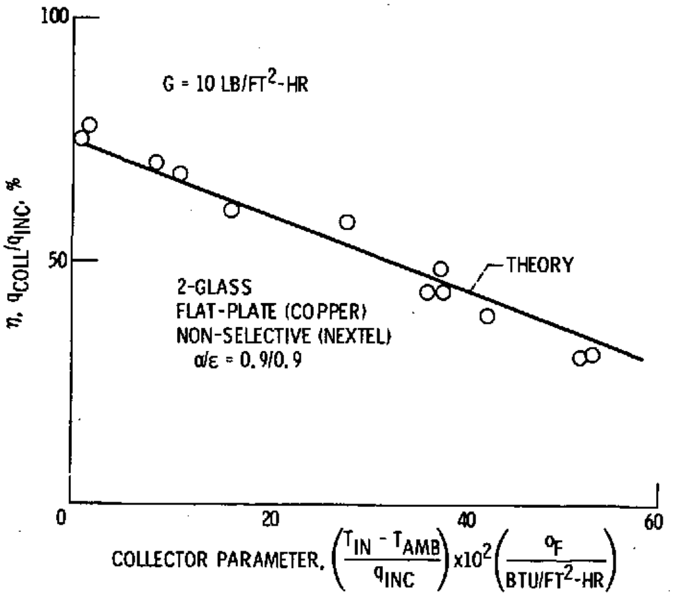

Figure 7. - Simulator test data - collector no. 1.

Figure 8. - Outdoor collector test facility.

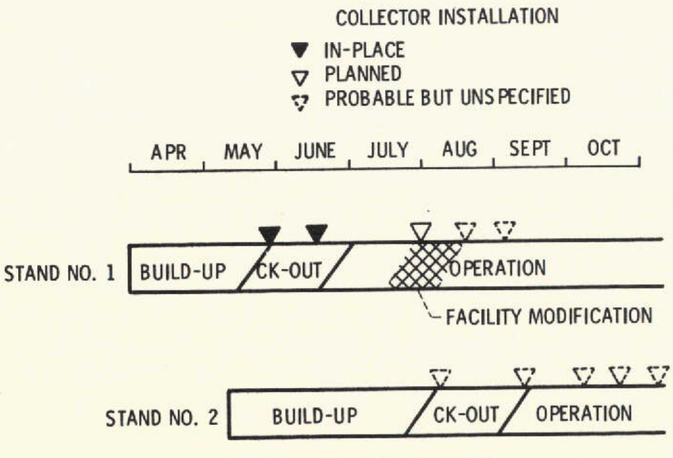

Figure 9. - Outdoor collector facility.

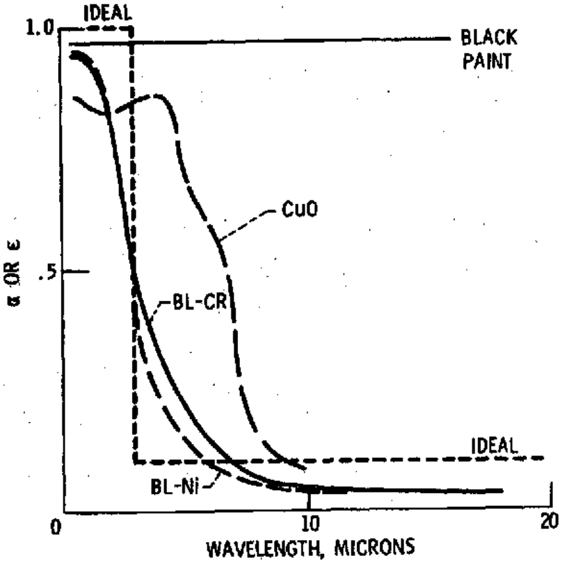

Figure 10. - Solar coatings.

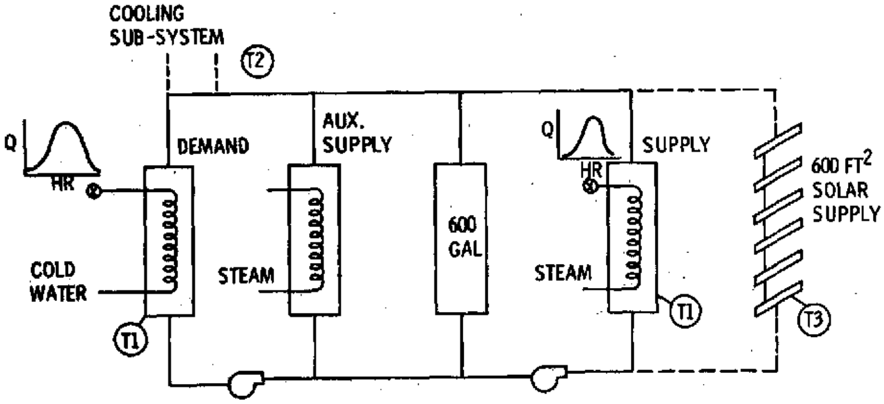

Figure 11. - Model systems facility.

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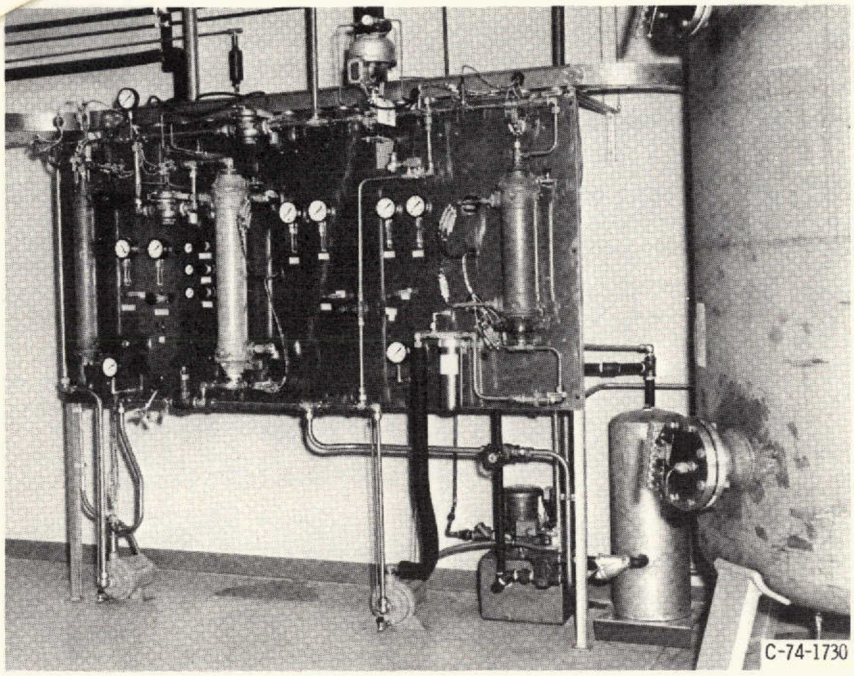

Figure 12. - Solar model systems facility.

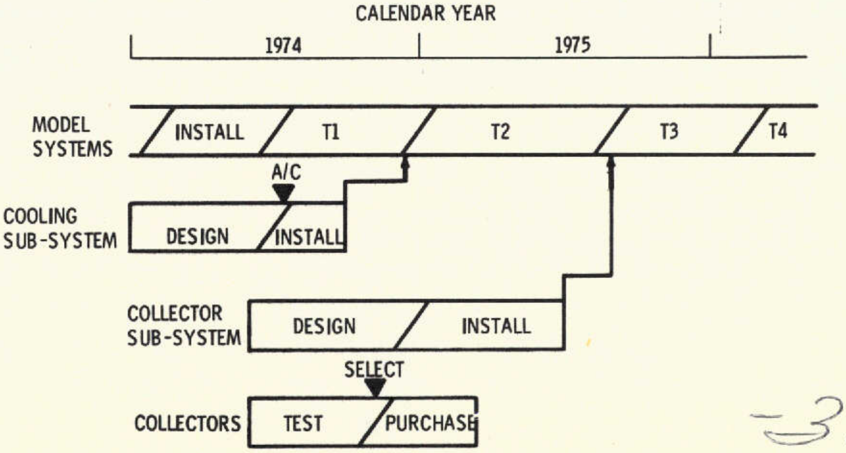

Figure 13. - Model systems test schedule.

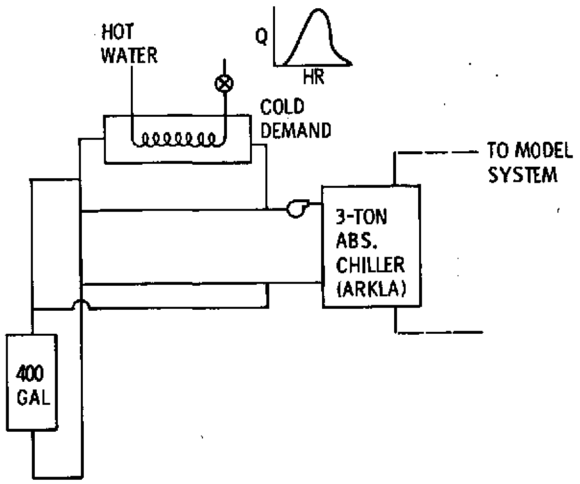

Figure 14. - Cooling sub-system.

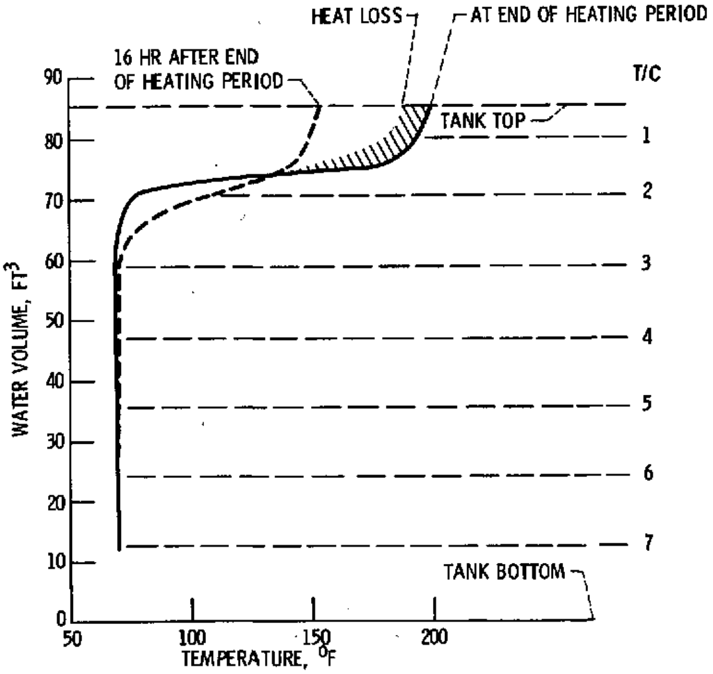

Figure 15. - Temperature distribution within tank after heating.

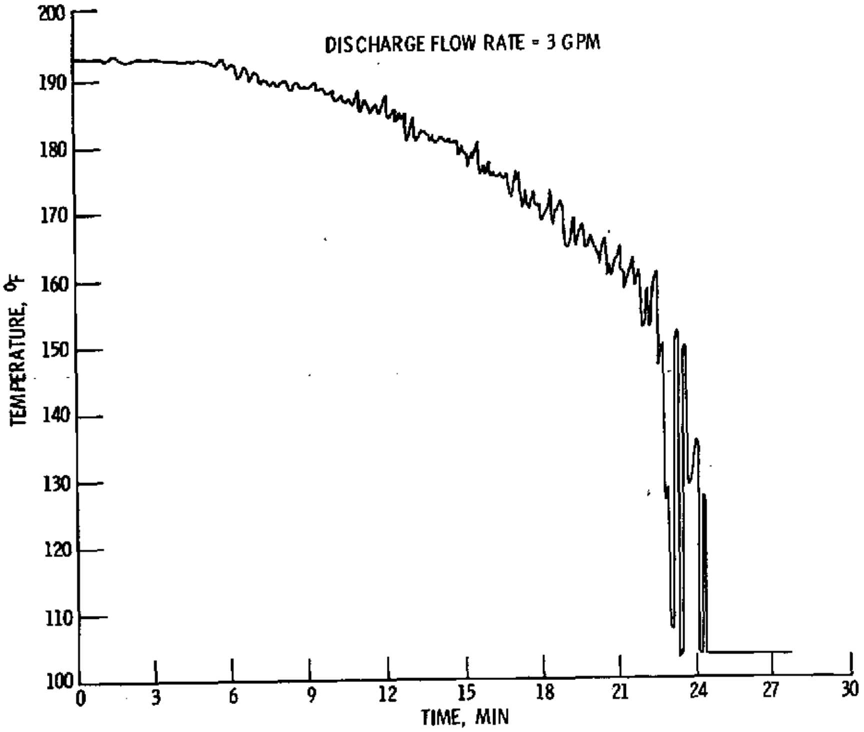

Figure 16. - Temperature history of a station within hot water storage tank upon discharge.