DOCUMENT RESUME

ED 035 173 EF 000 961

TITLE	Research Study in the Cost of Housing, Volume 3.
PUB DATE	Oct 62
NOTE	33p.
AVAILABLE FROM	New York State Division of Housing and Community Renewal, Albany, New York
EDRS PRICE	EDRS Price MF-$0.25 HC Not Available from EDRS.
DESCRIPTORS	*Building Materials, *Construction Costs, *Environmental Research, *Facility Case Studies, *Housing, Maintenance, Structural Building Systems

ABSTRACT

The results of a study based on experiments conducted in multistory fireproof structures of public housing projects, and in a mock-up simulating all conditions of a fireproof structure, are reported. The findings are based on tests conducted during several winter seasons, none of which deviated markedly from the norm in New York City. The following conclusions are drawn--(1) a structure with conventional cavity walls with single glazed sash requires 2.3 per cent times as much energy to heat as a structure with polystyrene insulated cavity walls and double glazed sash with thermo-barrier frames, (2) savings in the initial construction of the better insulated buildings are estimated at $10,150, and (3) the savings in the cost of maintenance are indicated at $15,531 per annum. A history of the experiment is given along with drawings and charts. (RK)

RESEARCH STUDY IN THE COST OF HOUSING

NELSON A. ROCKEFELLER, GOVERNOR
STATE OF NEW YORK

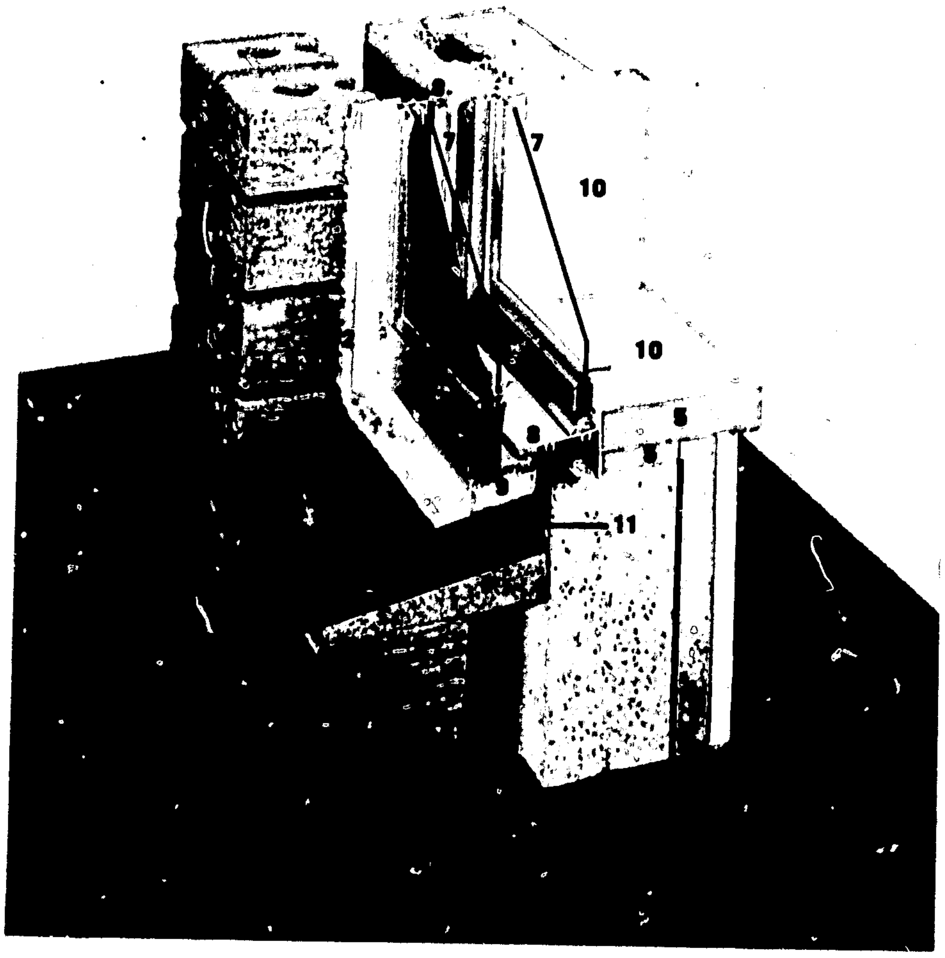
JAMES WM. GAYNOR, COMMISSIONER
DIVISION OF HOUSING AND COMMUNITY RENEWAL

JOHN T. HAUGAARD, JR., P.E., C.E.
ASSISTANT COMMISSIONER, DEVELOPMENT

JOSHUA D. LOWENFISH, AIA., R.A., B.ARCH., B.A.I.D.
CHIEF OF ARCHITECTURAL RESEARCH

VOL. III OCTOBER NINETEEN HUNDRED AND SIXTY-TWO

TABLE · OF · CONTENTS



SECTION THROUGH INSULATED CAVITY WALL WITH DUAL GLAZED SASH 1. FACING BRICK = OUTER WITHE 2. AIR SPACE = CAVITY 3. CINDER-CONCRETE BLOCK + 4. PARGING + 5. EXTRUDED POLYSTYRENE INSULATION + 6. TWO COATS OF PLASTER = INNER WITHE 7. DOUBLE HUNG SASH + DOUBLE HUNG STORM SASH = DUAL GLAZING 8. EXTRUDED THERMOPLASTIC VINYL BARRIER IN ALUMINUM FRAME 9. FIBERGLASS INSULATION 10. ALUMINUM SURROUND 11. SLATE SILL & 12. CAULKING

PREAMBLE

With the cost of construction still on the rise, the problem of obtaining more housing per dollar—without affecting desirable amenities—is becoming ever so much more difficult.

To the busy world of public officials, real-estate owners and/or operators, architects and engineers, building material producers and constructors, the following "RESULTS IN A CAPSULE FORM" will pinpoint the accomplishments of a five year long study in heat transfer characteristics through insulated exterior masonry walls with dual glazed sash and thermo-barrier frames. It will show at a glance substantial economies contained therein.

To those in the building industry, however, whose interest in quality and economy of construction and of maintenance is of paramount importance, the subsequent chapters of documentation in research and development will prove, it is hoped, revealing as well as rewarding.

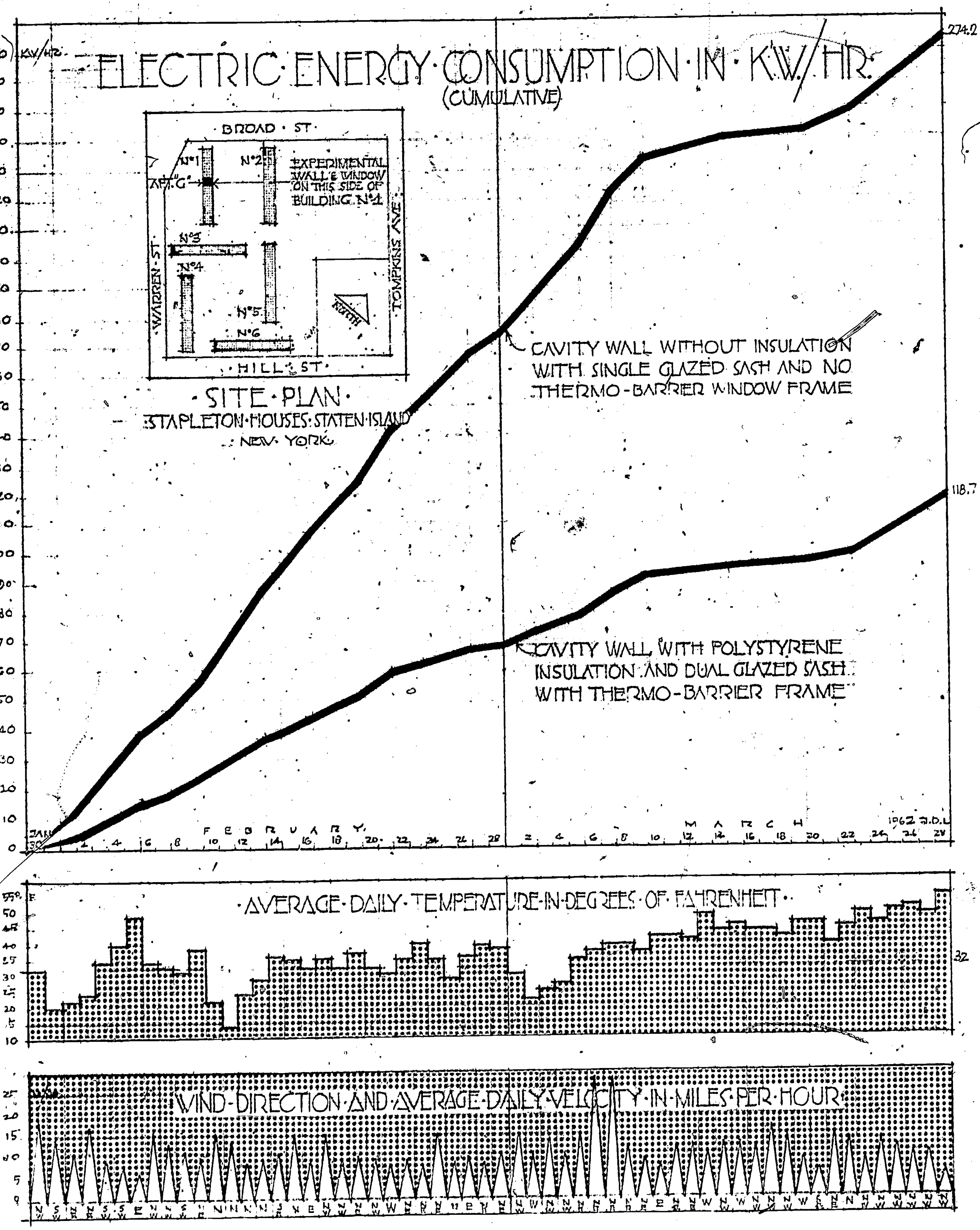
The results of this study are based on experiments conducted in multi-story fireproof structures of public housing projects and in a mock-up simulating all conditions of a fireproof structure. The final results pertain to structures built of cavity walls and dual glazed sash with thermo-barrier frames, in projects heated by low pressure steam, derived from a central plant within a project of a thousand apartments. In projects of lesser scope, the savings per apartment would be smaller and in larger ones, greater. Other factors being equal, the size of material and equipment orders would account for the difference.

The findings are based on tests conducted during several winter seasons, none of which deviated markedly from a norm in New York City.

In large operations—private or public in character—the results obtained to-date, if implemented, may cause a total saving of millions of dollars annually in the cost of heating; may produce better livability the year round; may be an accessory to a substantial modification of the method of heating such structures and significantly, may be instrumental in a large scale preservation of this country's natural resources—the supply of oil.

It would be presumptuous to assume that these results are the ultimate in insulation of structures or that they are the last word in quality or economy; nevertheless they do represent a long stride in the direction where greater economies lie.

The achievement of this study, it is believed, can be assigned the coveted characterization of a BREAKTHROUGH.


ELECTRIC·ENERGY·CONSUMPTION·IN·KW/HR
(CUMULATIVE)
KW/HR
274.2
118.7
BROAD · ST
Nº1
Nº2
APT."G"
EXPERIMENTAL WALL & WINDOW ON THIS SIDE OF BUILDING Nº1
Nº3
Nº4
Nº5
Nº6
WARREN ST
TOMPKINS AVE
HILL ST
NORTH
·SITE·PLAN·
STAPLETON·HOUSES·STATEN·ISLAND
NEW YORK
CAVITY WALL WITHOUT INSULATION WITH SINGLE GLAZED SASH AND NO THERMO-BARRIER WINDOW FRAME
CAVITY WALL WITH POLYSTYRENE INSULATION AND DUAL GLAZED SASH WITH THERMO-BARRIER FRAME
JAN
FEBRUARY
MARCH
1962
·AVERAGE·DAILY·TEMPERATURE·IN·DEGREES·OF·FAHRENHEIT·
32
WIND·DIRECTION·AND·AVERAGE·DAILY·VELOCITY·IN·MILES·PER·HOUR

RESULTS IN A CAPSULE FORM

ENERGY

A STRUCTURE WITH CONVENTIONAL CAVITY WALLS WITH SINGLE GLAZED SASH REQUIRES 2.3 TIMES AS MUCH ENERGY TO HEAT AS A STRUCTURE WITH POLYSTYRENE INSULATED CAVITY WALLS AND DOUBLE GLAZED SASH WITH THERMO-BARRIER FRAMES.

MONEY

In a public housing project of a thousand apartments* with 4.74 rental rooms in each, the savings in the initial construction are estimated at $10,150.00**, and the savings in the cost of maintenance are indicated at $15,531.00 per annum.

In middle and high income projects, savings would be greater because of a considerably larger cubical content of structures.

Considering the life of a structure in public housing at 50 years, the accrued operational saving for each apartment therein would be $777.00 and in a project of a thousand apartments $776,550.00; in ten such projects—$7,765,500.00; in twenty—$15,531,000.00 etc.

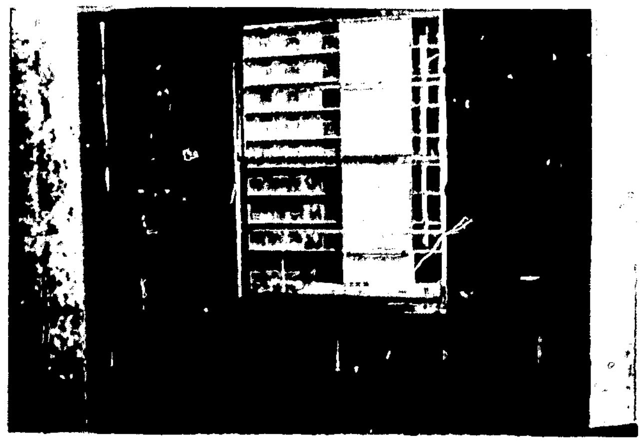
•

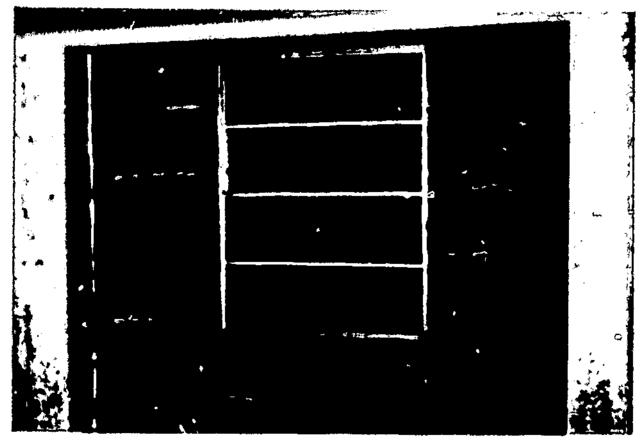
If Governor Rockefeller's proposed AIR RIGHTS program of 250,000 apartments for middle income occupants, to be built in the next 10 years, incorporated the better insulated walls and windows, the savings in construction would exceed $2,500,000.00 and the reduced fuel for heat, during the life of these structures, would produce an annual saving of over $3,882,000.00 or in 50 years, a saving of over $194,000,000.00

Nationally, in public and private construction such savings could easily reach many millions of dollars every year.

---

* An average size project in large urban areas.
** Although the savings may seem puny in a multi-million dollar contract, it is important to note that an improvement in construction and in livability plus a large reduction in the cost of maintenance aver the life of the project was achieved at a reduction rather than an increase in the initial cost.





1. STAPLETON HOUSING PROJECT, WHERE INSULATED CAVITY WALL AND DUAL GLAZED SASH EXPERIMENTS WERE CONDUCTED 2. DUAL GLAZED SASH WITH THERMO-BARRIER FRAME REPLACED CONVENTIONAL SINGLE GLAZED SASH 3. EXTRUDED TYPE EXPANDED POLYSTYRENE APPLIED ON ROOM SIDE OF INNER WITHE OF CAVITY WALL 4. POLYSTYRENE COVERED WITH A BROWN COAT OF PLASTER 5. WHITE COAT OF PLASTER 6. ONE OF THE TEST CHAMBERS UNDER CONSTRUCTION—EXPANDED POLYSTYRENE BEING APPLIED TO THE CHAMBER'S CEILING

RESOURCES

In a public housing project of a thousand apartments, the annual saving in fuel* is indicated at 225,000 gallons; during the life of a project—11,250,000 gallons; in ten such projects—112,500,000 gallons; in twenty—225,000,000 etc.

It requires but little imagination to project such economy to both public and private housing on a national scale in order to realize the staggering amount of fuel potentially saved from this country's fast dwindling oil reserves.

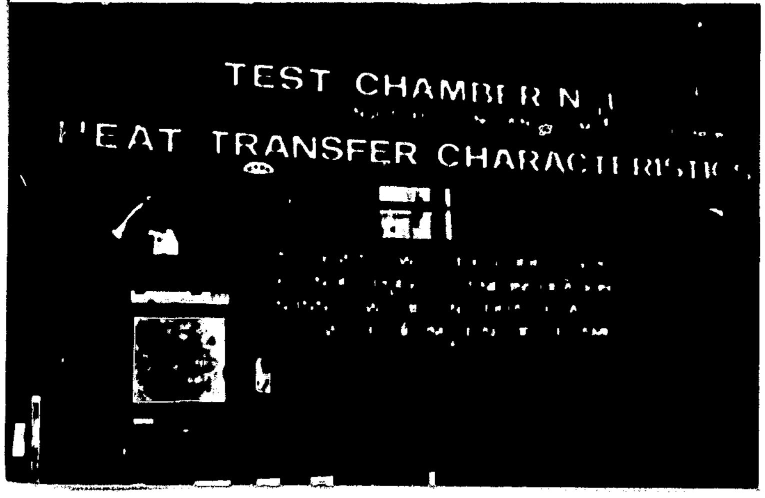
●

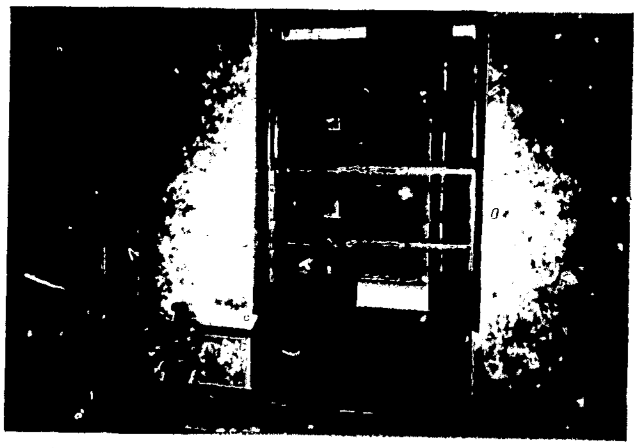
AMENITIES

In public housing the additional wall insulation would retard external heat transmission during the summer months, thus creating a more comfortable temperature within the apartments. The extent of such temperature drop has not been actually tested but our calculated guess is that it may not be inconsequential.

In middle income and high income housing, the additional wall insulation would reduce the amount of electric output required to operate the various air cooling apparatus.

* No. 6 oil.




7. TEST CHAMBER No. 1 WITH VISION PANEL IN CENTER, MICROMAX UNIT ON THE LEFT FOR AUTOMATIC RECORDING OF TEMPERATURE OF BOTH CHAMBERS AND BOTH PLENUMS THROUGHOUT THE TEST PERIOD. ABOVE AND TO THE RIGHT OF MICROMAX IS KILOWATT-HOUR METER. THERMOMETER, THERMISTOR AND J TUBE CAN BE SEEN THROUGH THE VISION PANEL 8. TEST CHAMBER No. 2 WITH DUAL KILOWATT-HOUR METERS ON THE LEFT SIDE OF CHAMBER ENCLOSURE. THERMISTOR, J TUBE AND THERMOMETER IN PLENUM ON THE LEFT OF TEST CHAMBER.

Of somewhat lesser importance, yet definitely constituting an amenity, is the fact that the dual glazing and polystyrene on masonry would also afford better protection against excessive street and/or yard noises.

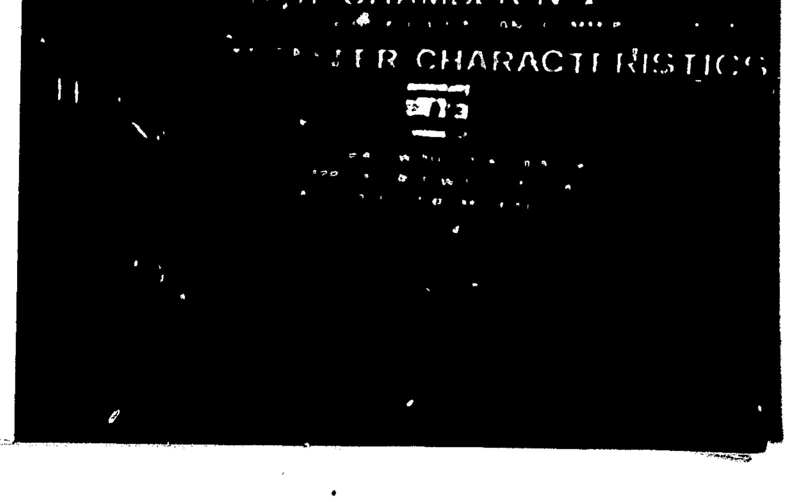
The dual operable sash would also afford indirect ventilation during the warm weather by keeping the outer sash opened at the bottom and the inner sash at the top, thus minimizing considerably objectionable drafts and soot infiltration.

BY-PRODUCT

Although not directly related to heat transfer characteristics, the easily removable operable sash by DeVAC lends itself to the replacement of broken glass in the shop rather than on site.* Based on records of replacement of broken glass in New York City housing projects alone, it appears that savings of over $272,000.00 could be effected annually if readily removable sash were to be used (See page 24).

For an historical background leading to the Stapleton research and for complete facts and substantiation of figures turn to pages that follow.

* Where sash cannot be readily removed for replacement of glass in the shop, twice as much time is consumed in such operation and labor accounts for 75% of the overall cost.



HISTORY OF THE EXPERIMENT

APPROPRIATIONS

In the 1957-58 fiscal budget, the New York State Legislature appropriated a $30,000.00 grant for a comprehensive research study in the cost of housing. This initiated the research work at the Division of Housing and Community Renewal under the direction of Joshua D. Lowenfish, A.I.A.*

EXPERT ADVICE

On December 9, 1957, during the Research Bureau's sponsored conference with thirty-three mechanical engineers and educators, several experts, among whom was Charles F. Neergaard—a consultant in planning and management—advocated better insulation of walls and windows as a means of attaining a substantial economy in the cost and maintenance of housing. Their many years of successful experience in planning and construction in this country and abroad added weight to the proposal.

COLLEGE RESEARCH 1957-58

In 1957-58, the Research Institute of Syracuse University and the School of Architecture of Pratt Institute were commissioned to study exterior masonry walls with an emphasis among others on insulation values, wind load resistance and water and vapor permeability.

The Syracuse study revealed a heat loss U factor of .25 for solid masonry walls (3¾" brick, ¼" parging, 6" cinder-concrete block and plastered free standing furring on the inside) and a U factor of .285 for cavity walls (3¾" brick, 2¼' air space, 4" cinder-concrete block with ½" plaster on the inside).

Among the 17 different types of walls tested, a variation of a cavity wall with 3" cement impregnated wood-fiber slabs in lieu of 4" cinder-concrete block for the inner withe, produced a U factor of .102. The cost of this wall was estimated to be equal to that of the conventional cavity type.

Pratt Institute, in search of better insulation materials, analyzed 12 different exterior walls. Among materials recommended were 3" thick cement impregnated wood-fiber slabs in place of 4" cinder-concrete block on the inner withe of cavity walls and 1" thick Styrofoam sheets in the cavity abutting the outside surface of the inner withe.

Since heat loss through a square foot of single glazed window is considerably greater than that of a square foot of wall, the Pratt study recommended double glazing as a means of reducing the required heat output to maintain the interior at a desired temperature of 70°F.

* The Interim Report of June 1958, "RESEARCH STUDY IN THE COST OF HOUSING" (Vol. I), contains the proposed outline of activities in research of nearly 100 avenues of approach. Broadly speaking the plan was to cover concepts in planning, new materials and new methods of construction. The actual research was conducted in cooperation with the building industry, architects and engineers and several universities.
The Report of February 1962, "RESEARCH STUDY IN THE COST OF HOUSING" (Vol. II), fully describes the results of college participation and the aid rendered by the architects and engineers, several manufacturers of building materials and by a number of applicators. The subjects ranged from site and unit planning; from structural and mechanical design to maintenance problems of completed projects. Heat Transfer Characteristics was only a part of the total picture.

EXPERIMENTAL SHED 1958-59

In 1958-59, endowed with another legislative grant of $30,000., the Division's research work continued apace, with an emphasis on heat transfer characteristics through exterior walls.*
Pratt Institute and Polytechnic Institute of Brooklyn were entrusted with the task of pursuing this endeavor.

Pratt planned and supervised construction of the experimental shed on the grounds of its campus; Polytechnic Institute instrumented the shed, performed field tests and supplied the analysis of the effect of two winter seasons on an insulated cavity wall having 3¾" brick on the outer withe, 2" air space and 1" polystyrene with 3" cement impregnated wood-fiber slabs on the inner withe plus ½" plaster on the room side vs. a conventional solid masonry wall consisting of 3¾" brick, ¼" parging, 6" cinder-concrete block, ½" free space and ¾" furring channels with ¾" metal lath and plaster.

The shed was essentially a guarded hot box, one face of which contained the two types of masonry walls. The shed contained two Test Cells abutting the two experimental walls and a plenum on three sides of the shed and its top and bottom. Inner and outer faces of walls and windows were instrumented with copper-constanton thermocouples. The low temperature functions of the couples were immersed in ice baths to maintain 32°F reference point. The thermocouples were connected to potentiometers through switching arrangements that reduced the time required to take readings. Manual procedures were used for taking data. Test Cells temperatures were maintained by means of mercury pool gas thermometers actuating relay circuits which controlled the current to electric heaters. Test Cells temperatures were kept at constant value and wattmeters measured the total electrical energy supplied to each test room. Readings of corresponding thermocouples were taken simultaneously in both Test Cells and were made as rapidly as possible to reduce any error because of change in outside conditions. Readings were taken at various times of the day and night so as to test the walls under a variety of atmospheric conditions. Openings in the wall for internal probes to detect transient conditions were made.

After the first winter's tests, Professor Wojan and Dr. Imber (both of Polytechnic Institute of Brooklyn) concluded that:

1. The experimental cavity wall did not give appreciably more resistance to heat transfer than the conventional solid wall.

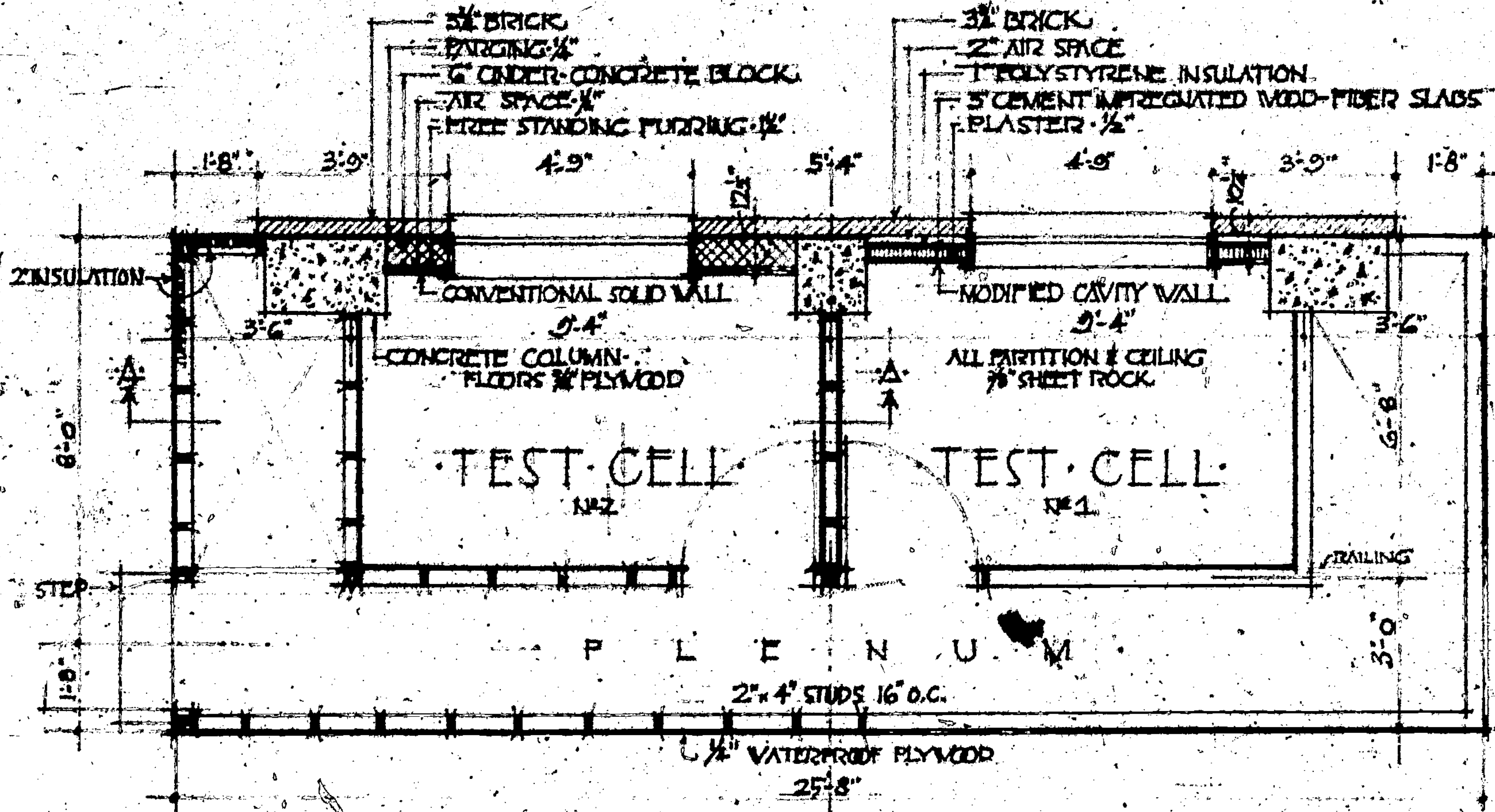
2. The dew point appeared in a highly undesirable position in the cavity wall both from its location within the cement impregnated wood slabs and the placement of polystyrene sheets which tended to retain condensed vapor.

3. Half of the total loss through the entire wall appeared through the single glazed windows.

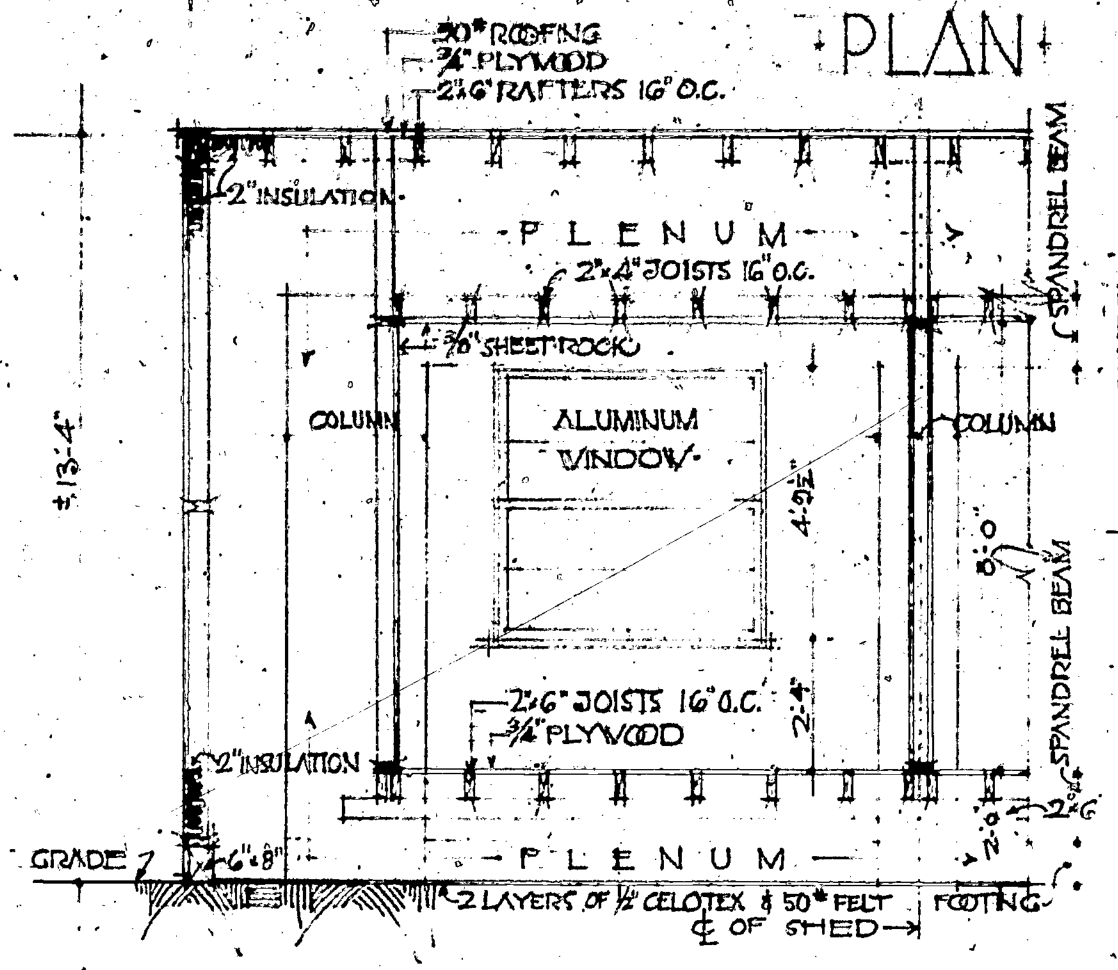
4. Heat losses through concrete columns and spandrels (which were incorporated in the shed walls to simulate multi-story skeleton frame) constituted a minor portion of heat losses because of the relatively small area occupied by same.

5. Two or three dimensional heat flow in wall sections of large thermal capacity had a greater effect on heat transfer than could be expected from standard handbook methods of calculating heat losses.

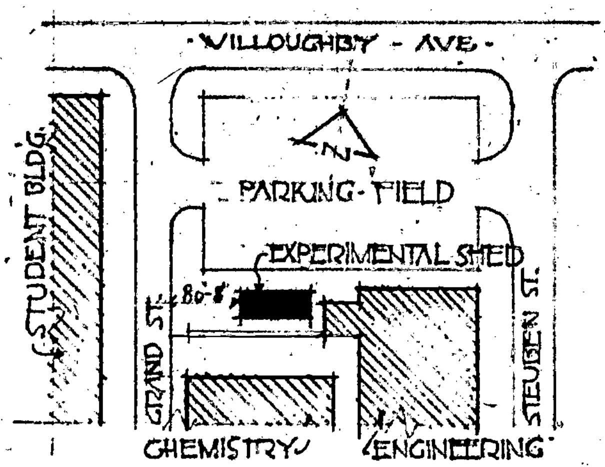
* The $30,000 grant was divided among four universities. Besides Pratt and Polytechnic Institute, New York University conducted a study in plumbing and Alfred University's College of Ceramics explored the possibility of new wall materials for public halls and bathrooms.



PLAN



SECTION AA



SITE PLAN

NO SCALE

NEW YORK STATE DIVISION OF HOUSING & COMMUNITY RENEWAL

POLYTECHNIC INSTITUTE OF BROOKLYN

SCHOOL OF ARCHITECTURE PRATT INSTITUTE

EXPERIMENTAL TESTING SHED

AT THE CAMPUS OF PRATT INSTITUTE IN BROOKLYN NY

NOVEMBER 1958 J.D.L.

Because of these findings and subject to confirmation through additional tests, Polytechnic Institute's recommendations were:

1. Against the use of the cavity wall as constituted in the tests.

2. For further study of cavity wall components keeping in mind not only heat transfer characteristics, but dew point conditions, vapor barrier locations, transients, thermal capacity of materials, construction problems and costs.

3. For improvement in window design as a potential means of appreciably reducing total heat losses.

Polytechnic's conclusion 2, was supported by the following analysis: "One of the most critical problems that appear to be present in the experimental cavity wall is the location of the dew point. It can be noted that for a large range of room humidities, the dew point falls within the inner withe of cement impregnated wood slabs. During previous tests of relative humidities within apartments, it was found that they range in the fifty to sixty percent area. It is apparent, therefore, that such humidities would cause condensation within the inner withe slabs. Condensation, because of dew point conditions within a wall section, will lower its thermal resistance and may cause damage to its components." In this particular design the placement of the polystyrene vapor barrier was such, that water would tend to be retained within the inner withe, where the damage would be most severe.

EXPERIMENTAL SHED 1959-60

Between the two winter seasons several refinements were made in construction and controls. The inner wall sections of the plenum were insulated with 2" glass-wool bats, so as to reduce heat exchanges between the inner wall sections and the test rooms. Additional electric heating units and thermostatic controls were added to the plenum so as to maintain its temperature as close as possible to that of the test rooms. Additional thermocouples were added to monitor the plenum temperatures.

In the winter, tests continued at various times during the day and at night and the readings included the coldest spells of the season. Relative heat losses were determined by temperature-resistance graphs and by electrical power input.

Data obtained from the tests of both seasons indicated no appreciable difference in the performance of the two walls. The handbook calculations for the experimental cavity wall indicated a 200 percent increase in heat resistance as compared with the standard solid masonry wall, yet when instrument accuracy and losses through window leakage were accounted for, the performance of the two walls was approximately the same.

The difference between handbook data listing the thermal properties of the various wall components on an "as dry basis" and that obtained in the field was partially due to moisture migration and water penetration, which altered drastically the thermal conductivities.

The handbook procedure for calculating heat losses, by assuming steady state heat transfer conditions, likewise appeared in error because it neglected the thermal capacity or storage effect of the wall structure. Dense materials may offset poor insulation properties by high thermal capacity.

Recalculation of dew point conditions confirmed previous findings. The dew point fell within the inner withe of cement impregnated wood slabs with resultant diminution of insulation value and damage to the wall components.

The final recommendations:

1. Reiterated previous conclusion against the use of the experimental wall on the ground that it was more expensive to build without an appreciable benefit of lesser thermal conductivity and with dew point falling within the inner withe.

2. To insulate concrete columns and spandrels, primarily for the purpose of reducing condensation on the inside surfaces and secondarily, for fuel saving potential.

3. To conduct additional study in depth of basic wall components and their thermal resistance, so as to increase insulating values.

4. To conduct additional study of window frames and glazing, to improve both their construction and insulation values.

Because of lack of funds (there was no legislative appropriation for research in 1959-60) the components of the experimental cavity wall were not modified to obviate the possible deterioration of the inner withe, and windows with better insulation were not installed to test their heat transfer characteristics.

TESTS OF GLASS AND OF RIGID PLASTIC WALL INSULATION 1960-61

Without specific appropriations for research in planning and construction since 1958-59, the scope of work was limited to the extent of private industries' willingness to participate and to limited expenditures via "change orders" to the major contracts during construction of several public housing projects.

It is thus that the test of glazing and of rigid wall insulation was conducted in 1960-61 at Manhattanville Houses and the subsequent tests, leading to a breakthrough in heat transfer characteristics through walls and windows, were conducted at Stapleton Houses the following year.

•

From previous tests it was fairly well established that the main culprit in heat losses was the window frame and glazing and that a cavity wall has a greater resistance to moisture permeability than a solid wall. The Manhattanville tests were intended to pinpoint the best method of glazing and the most effective barrier for heat losses through a wall.

METHOD OF PROCEDURE

The Manhattanville tests in Building No. 6, apartments 2B and 2C, and in the Perambulator Room, conducted by Konstandt Laboratories, consisted of three window glazing variations and two cavity wall variations —one conventional and the other with polystyrene insulation on the inside face of the inner withe.

Guarded hot-boxes (as outlined by ASTM C 236-54T) were built around each testing area. The inside and outside wall surfaces on all sides of the guarded hot-boxes consisted of ¾" plywood, laminated to 2" fiberglass board of 12 lb. density in the center. The thermal conductance of each box was less than 0.03 BTU/HR per S.F./°F. The open end of each box was hermetically fitted around the windows and the insulated wall sections with sponge rubber and fiberglass.

The heat in the guarded boxes was supplied by electric heating coils (1000 watts each) and regulated by means of thermostats. The heat consumption was measured by means of watt-hour meters, calibrated to read within 0.05 KW. The rooms surrounding the boxes served as plenums and the temperature therein was maintained by means of thermostatically controlled electric heaters.

All temperatures of tested surfaces were measured with thermocouple probes, calibrated to give an accuracy of 0.1°F. During the testing periods, temperatures were read at 15 minute intervals. Windows were subject to 3 separate testing periods with a total of 11 hours and 15 minutes each; walls were subject to 3 separate testing periods with a total of 13 hours each.

MATERIALS TESTED

All windows in the experiment were of aluminum projected type with 2" frames and 3" mullions, manufactured by Lupton. Windows were fabricated of 6063-T5 extruded aluminum alloy. Frame sections were 1¼" deep and ⅛" thick. Metal surrounds on the inside of all windows were of hot rolled, smooth, blue annealed steel—jambs No. 18, stools No. 16 and closure plates No. 14 U.S.S. gauge.

Window No. 1 equalled 11.048 s.f. in area of which 8.178 s.f. was glass of double strength quality.

Window No. 2 equalled 11.048 s.f. in area of which 8.178 s.f. was ¾" thick "THERMOPANE" commercial type as manufactured by Libby-Owens-Ford.

Window No. 3 equalled 13.284 s.f. in area of which 10.791 s.f. was glass of double strength quality reinforced with a storm sash consisting of a sheet of double strength quality glass in a wooden frame 1¾" wide. Storm sash abutted aluminum frame and was caulked tightly to masonry. All windows subject to this experiment faced due east.

•

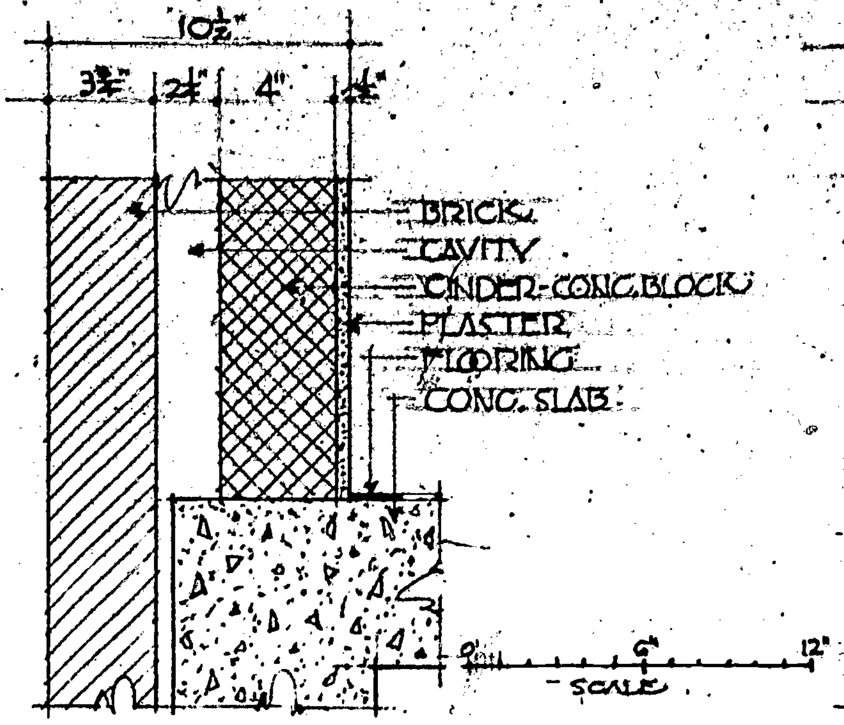
Wall Panel No. 1 equalled 13.425 s.f. in area—a standard cavity wall with an outer withe of 3¾" brick, 2¼" cavity and an inner withe of 4" cinder-concrete block finished with 2 coats of plaster ½" thick.

Wall Panel No. 2 equalled 13.425 s.f. in area—a modified cavity wall with outer withe of 3¾" brick, 2¼" cavity and an inner withe of 4" cinder-concrete block, ¼" parging, 1" Styrofoam insulation and 2 coats of plaster ½" thick.

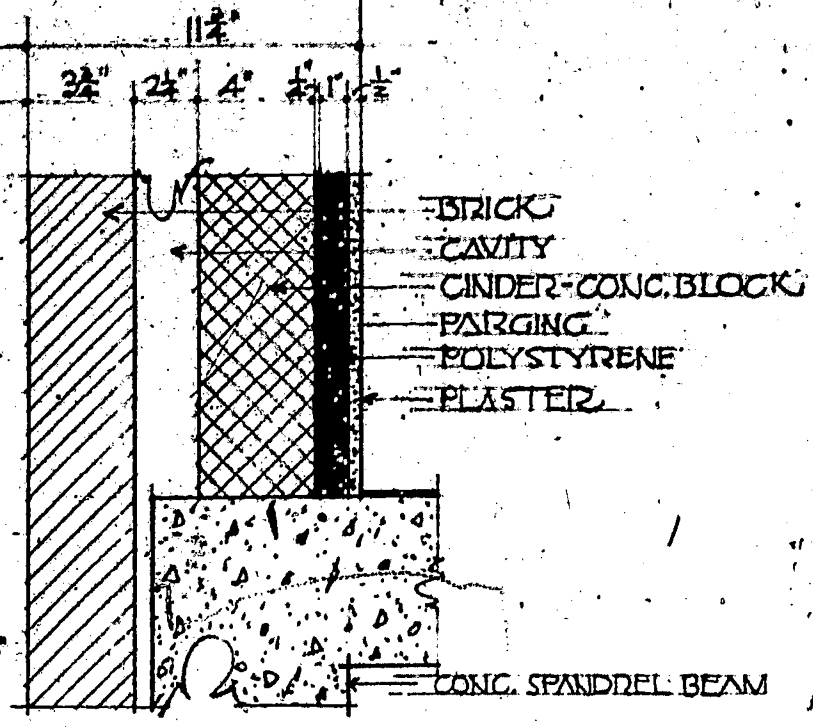
Both wall panels faced due west.

HEAT TRANSFER CHARACTERISTICS OF GLASS AND RIGID PLASTIC WALL INSULATION

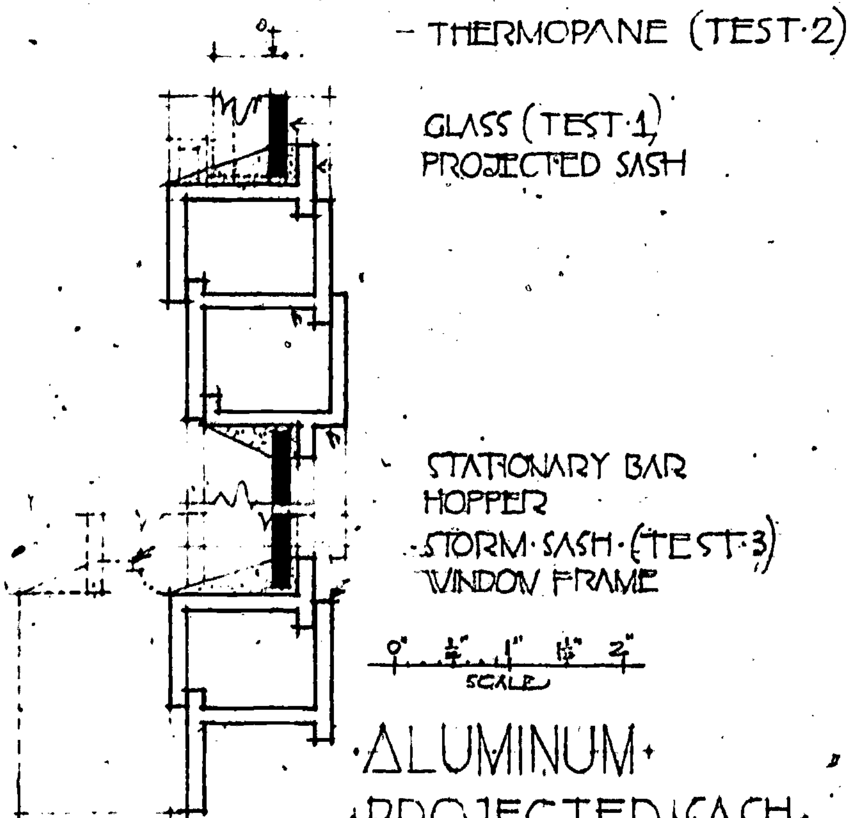
TESTS AT MANHATTANVILLE PROJECT NYS-74 IN MANHATTAN NY



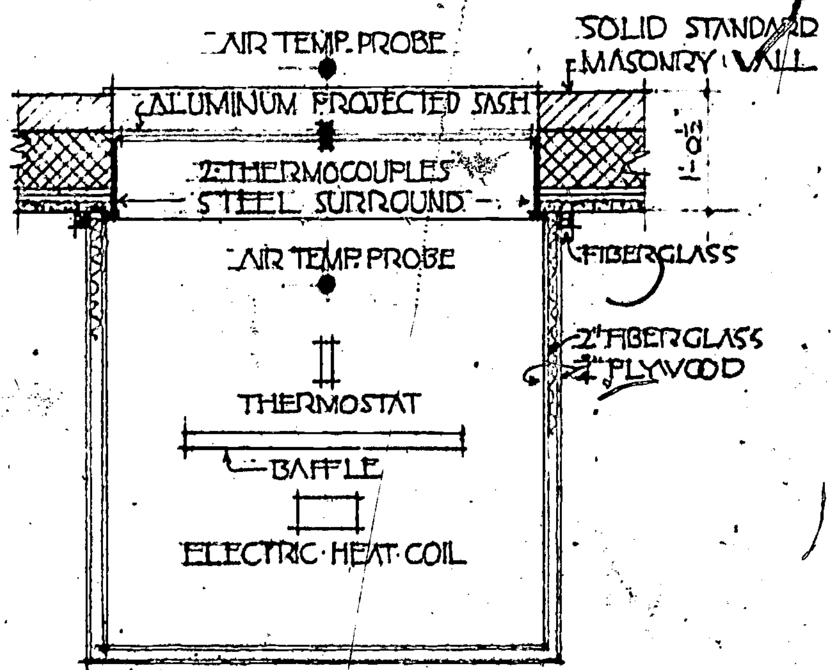
STANDARD CAVITY WALL



INSULATED CAVITY WALL



ALUMINUM PROJECTED SASH



PLAN OF GUARD BOX

0 1 2 3 4

SCALE

NEW YORK STATE DIVISION OF HOUSING AND COMMUNITY RENEWAL

JANUARY 1961 J.D.L.

RESULTS OF TESTS

At the time the windows were tested, outside temperature varied from 26.2 to 35.45°F and wind velocity ranged from 6 to 35 miles per hour.

During wind condition blowing in a direction away from the windows, "THERMOPANE" window indicated resistance nearly twice as large as that of the window with ordinary glass. On the other hand, a 35 mile per hour wind blowing perpendicularly at the windows resulted in the "THERMOPANE" window performing no better than the one with ordinary glass. This no doubt was due to leaks between the frame and the operable sash and/or the several components within the sash.

The storm sash during the high wind showed resistance 2.4 times better than that of the conventional window and with no wind in its path a resistance 3.3 times as good.

The results of these tests pointed out clearly that effectiveness of insulation in windows is as much dependent on their components (frames, glass, putty, etc.) as on the fit within masonry openings and the precision of assembly of the components themselves. They also indicated that storm sash with 2" deep air space between the two glass surfaces was most effective in resistance to thermal conductance.

•

The two wall sections were tested with outside temperature varying from 21.02 to 32.20°F.

The results of these tests revealed that 1" Styrofoam insulation on the inside face (room side) of the inner withe when added to 4" cinder-concrete block reduced thermal transmittance of the wall approximately thirty percent.

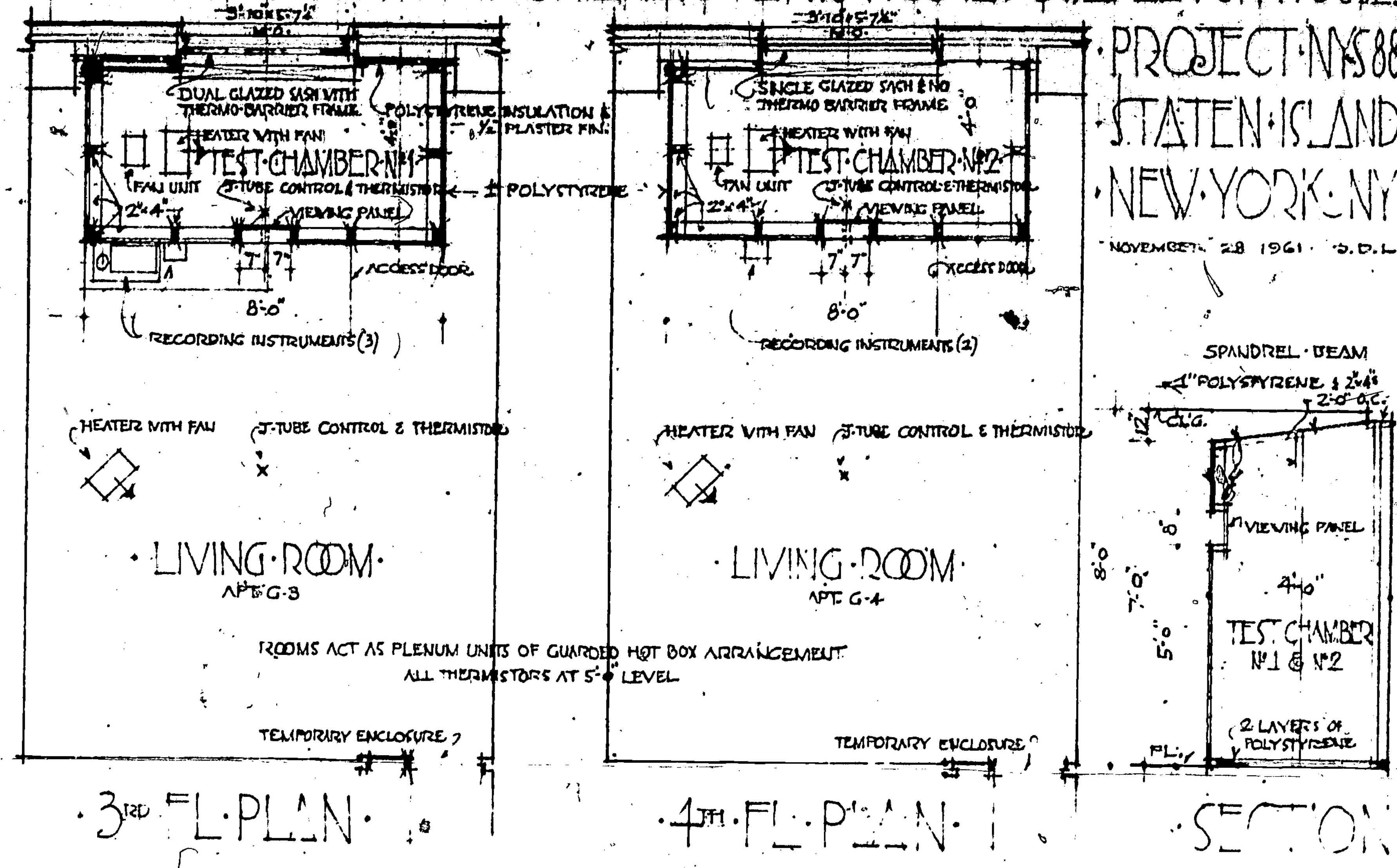
•

Because of the relatively short duration of these tests and limited calibration of the instruments, the Manhattanville experiments were not deemed sufficiently definitive to warrant a clear cut recommendation in redesign of walls and windows in the State's public and middle income housing program. Consequently, additional tests of both walls and windows were scheduled for the following winter season.

DIAGRAMS & OUTLINE SPEC. FOR PROPOSED EXPERIMENT OF HEAT TRANSFER CHARACTERISTICS AT STAPLETON HOUSES

PROJECT NY-5-88
STATEN ISLAND
NEW YORK, NY.

NOVEMBER 28 1961 · S.D.L.



TESTS SHALL BE CONDUCTED IN BLD'G. Nº1 IN APT. "G" ON THE THIRD AND FOURTH FLOOR

ON THE THIRD FLOOR IN THE LIVING ROOM OF APT. "G" THE RADIATOR AND BRANCHES SHALL BE REMOVED, THE WINDOW WITH ITS SURROUND AND PLASTER ON THE CAVITY SHALL LIKEWISE BE REMOVED.

A NEW DUAL GLAZED SASH WITH THERMO-BARRIER FRAME AND A SURROUND WILL BE SUPPLIED BY DE-VAC ALUMINUM WINDOW PRODUCTS.

½" CEMENT MORTAR, 1" STYROFOAM BY DOW CHEMICAL AND ½" PLASTER FINISH (BROWN AND WHITE) SHALL BE APPLIED TO THE CAVITY WALL.

A STYROFOAM ENCLOSURE (TEST CHAMBER) SHALL BE CONSTRUCTED IN ACCORDANCE WITH PLAN & SECTION SHOWN ABOVE. 2"x4" STUDS SHALL BE WEDGED BETWEEN FLOOR & CEILING. STYROFOAM SHEETS SHALL BE NAILED TO STUDS & TOP AND BOTTOM PLATES. VERTICAL JOINTS SHALL BE SEALED WITH ADHESIVE TAPE. 8"x14" GLAZED VIEWING PANEL SHALL BE INSTALLED IN ACCORDANCE WITH PLAN AND SECTION. ACCESS DOOR TO TEST CHAMBER TO BE HELD IN PLACE BY MEANS OF ADHESIVE TAPE.

UPON COMPLETION OF PLASTERING INSTALL RADIATOR & BRANCHES. HEAT SHALL BE SHUT OFF UNTIL THE END OF EXPERIMENT.

OPENING BETWEEN THE LIVING ROOM & CORRIDOR SHALL BE ENCLOSED WITH STYROFOAM BOARDS HELD TOGETHER & FASTENED TO FRAME BY MEANS OF ADHESIVE TAPE. ONE PART OF ENCLOSURE SHALL BE OPENABLE.

ON THE FOURTH FLOOR IN THE LIVING ROOM OF APT. "G" THE RADIATOR AND BRANCHES SHALL BE SHUT OFF. EXISTING WINDOW AND PLASTER ON CAVITY WALL SHALL BE LEFT IN PLACE.

A STYROFOAM ENCLOSURE (TEST CHAMBER) SHALL BE CONSTRUCTED IN AN IDENTICAL MANNER TO THE ENCLOSURE ON THE THIRD FLOOR. SAME APPLIES TO ENCLOSURE BETWEEN LIVING ROOM AND CORRIDOR.

APARTMENTS "G-3" & "G-4" SHALL BE PROVIDED WITH TWO TEMPORARY ELECTRIC CABLES OF 30 AMPERES EACH FOR HEATERS IN THE LIVING ROOMS AND IN TEST CHAMBERS

INSTRUMENTATION, FANS AND HEATERS WILL BE INSTALLED BY PROF. CLIFFORD A. WOJAN AND HIS STAFF

UPON COMPLETION OF TESTS WHICH WILL TAKE PLACE DURING JANUARY, FEBRUARY, MARCH & APRIL OF 1962, THE DOUBLE GLAZED NEW WINDOW AND THE POLYSTYRENE INSULATION SHALL BE LEFT IN PLACE. THE TEST CHAMBERS AND THE ENCLOSURES BETWEEN LIVING ROOMS AND CORRIDORS SHALL BE REMOVED.

ACCESS TO APTS. "G3" & "G4" WILL BE RESTRICTED DURING THE PERIOD OF THE TESTS TO PROF. WOJAN & HIS STAFF & TO JOSHUA D. LOWENFISH, CHIEF OF RESEARCH DIVISION OF HSG. & COMMUNITY RENEWAL

0' 2' 4' SCALE 6' 8' 10'

STAPLETON TESTS 1961-62

Shortly after the results of Manhattanville tests were digested, Mr. Andrew Forgatch, the eastern sales representative of DeVAC Aluminum Window Products, submitted to the Division a double hung dual glazed sash with thermo-barrier frame for thorough scrutiny.

This window, fully described in Appendix I of this study, appeared to have been ideally suited to the next stage of the Divisions research and development program. Mr. F. W. Hetman, President of DeVAC Inc., offered, to manufacture free of charge, a window to fit the size of the masonry opening in the living room of apartment G3 at the Stapleton Housing project—then under construction.

Mr. Henry Weisl, in charge of Building Products Sales of the Dow Chemical Company, was approached concerning the possibility of the use of Styrofoam in connection with the forthcoming experiment. He agreed to supply free of charge the entire Styrofoam wall insulation together with an additional quantity of same for the construction of Test Chambers No. 1 and No. 2, as demonstrated on accompanying drawing and photographs (See pages 8, 9 and 18).

For full description of Styrofoam see Appendix II of this study.

•

The proposed Stapleton experiment in Staten Island, N. Y., was rounded off with the appointment of Professor Clifford A. Wojan of Polytechnic Institute of Brooklyn, to help plan the basic design of the Test Chambers; instrument and monitor the operation of the tests; collate and analyze the results and submit recommendations thereon.

Dr. Murray Imber and Dr. Robert Corry, both faculty members of Polytechnic Institute, assisted Prof. Wojan in the pursuit of this task.

•

With the location of the project determined; with the materials to be tested on order; with the staff of experts on hand and the "change order" procedure of payment for construction and technical supervision agreed upon, the actual work of erecting the two Test Chambers began on January 2, 1962. Instrumentation was completed January 26, and readings of temperature and electric meters began on January 30.

TEST CHAMBERS

The Stapleton experiment was conducted in apartments G3 and G4 of Building No. 1. The living rooms of each apartment serving as plenums for Test Chambers No. 1 and No. 2 were isolated from adjacent corridors by means of hinged Styrofoam panels. The two identical Test Chambers were basically guarded hot boxes, 4′ x 8′ x 7′ high, each built of 2″ x 4″ studs and plates and sheathed on three sides, top and bottom with 1″ Styrofoam boards. The floors of the Chambers had a double layer of insulation, the ceilings sloped down from spandrel beams of the outside walls. A viewing glass panel within each Chamber facilitated instrument readings. (See illustration on page 18).

Test Chamber No. 1 in a 'artment G3 enclosed a modified cavity wall consisting of an outer withe of 3¾" "facing" brick (ASTM C-216 Grade S.W.), 2¼" air space, an inner withe of 4" solid load-bearing cinder-concrete block (ASTM C-145), ¼" parging, 1" extruded polystyrene (Styrofoam) and two coats of plaster ½" thick.

Mortar for parging was composed by volume of 1 part Portland Cement, 1½ parts lime putty and 6 parts sand; brown coat of plaster was in proportions of one part "neat" gypsum plaster to not more than three parts of sand by weight; white finish coat was mixed in proportions of three parts lime putty to one part white calcined gypsum gauging plaster by volume.

The cavity wall contained a DeVAC aluminum double hung dual glazed sash with thermo-barrier frame. The window surround by DeVAC, likewise of aluminum, was filled with Styrofoam and a part of the window frame, additionally insulated with fiberglas. (See illustration on page 4).

Test Chamber No. 2 in apartment G4 enclosed a standard cavity wall consisting of an outer withe of 3¾" "facing" brick, 2¼" air space, an inner withe of 4" solid load-bearing cinder-concrete block and two coats of plaster ½" thick.

The cavity wall contained a Fenestra strengthened aluminum double hung window, with a steel trim surround. The window complied with Aluminum Window Manufacturers Association DH-A2 requirements. Frame and sash was of 6063-T5 extruded aluminum alloy having a minimum thickness of .062" for all members except sill which was .078" thick. The window specification called for air infiltration not to exceed .50 cubic foot per minute, per lineal foot of sash perimeter, during a wind velocity of 25 miles per hour.*

Window masonry openings in both Test Chambers were 3'-10" x 5'-7¼". All physical characteristics within the two Test Chambers were identical.

THEORY OF TESTING

The basic heat transfer equations through walls and windows are listed in various heating and ventilating manuals. In general, these manuals describe the heat losses through the wall sections from inside the room to the outside air by the equation:

$$Q = UA\Delta t$$

where Q is the total heat loss in BTU/unit time, U is the overall of heat transfer coefficient, A is the surface area of the room whence heat is being lost and Δt is the temperature difference between the inside room and the outside atmosphere.

The heat transfer lost through the window section of the wall is described by most publications as the heat loss by conduction (i.e., using the equation $Q = UA\Delta t$) plus an additional heat loss due to air leakage from wall, frame and sash with its several components.

These methods of calculating heat losses assume steady state conditions. The assumption is that inside and outside temperatures remain constant and that wind velocity remains constant throughout the time data is taken. For example, conditions for heat losses through walls and windows in the New York metropolitan area are frequently assumed as 70°F inside, 0°F outside, 15 mile per hour wind outside and still air inside.

* The DeVAC prime sash has air infiltration of .283 cubic feet per minute, per lineal foot of sash perimeter, during a wind velocity of 25 miles per hour and .095 when storm sash is added.

In actual field performance, building walls are subject to a continuously varying state of atmospheric conditions. In addition, walls have thermal capacity and can store some thermal energy within their various components. As a result such walls have radiation effects on both inner and outer surfaces that vary with wall temperature, conditions of atmosphere and other circumstances.

These factors usually are neglected when the conventional handbook method of calculating heat losses is used. Field tests in the experimental shed, referred to before, indicated variations up to 100% from results obtained via the conventional calculation methods.

TEST PROCEDURE

Test Chambers No. 1 and No. 2 were maintained at a temperature of 70°F throughout the operating period (January 30 to March 28, 1962 incl.) by means of mercury filled J tubes which operated electric heating units. Steam radiators were disconnected, so as to maintain independent control. The energy input to the heating units was measured by means of dual kilowatt-hour meters.

Temperature of the Test Chambers and plenums was recorded on a Micromax recording unit throughout the test period. The signals sent to the recorder were supplied by means of thermistors mounted within the Test Chambers and in plenums.

Similarly, the plenums (living rooms) were maintained at 70°F by J tube controlled electric heating units.

Since no temperature differential existed between the plenums and the Test Chambers, no heat flow occurred between these areas. It can therefore be assumed that all electrical energy supplied to the Test Chambers was dissipated in heat losses through the exterior walls and windows.

Conversion of this electrical energy into thermal units of BTU gave the heat losses of the conventional wall and window vs. the polystyrene insulated wall with dual glazed sash and thermo-barrier frame.

TEST RESULTS

The test interval during which data was collected, covered the period from January 26 to April 4, 1962. However, for comparative data of performance of the two walls and windows, an interval from January 30 to March 28 was selected. Prior to January 30, adjustments were required in instrumentation and after March 28, the atmospheric temperature was so high that performance of instruments became erratic and validity of results doubtful.

Final results of data gathered during the two winter months indicate that the average heat loss through the standard cavity wall and single glazed sash was 2.3 times as much as the heat dissipated through the polystyrene insulated cavity wall and the dual glazed sash with thermo-barrier frame. In other words, the standard wall and window required 130% more heat than the insulated one.

Test results also indicated that the ratio of heat losses varied widely with atmospheric conditions. The more severe the weather condition, the greater was the ratio. For example, during periods of rain, strong north-east wind and other adverse weather conditions, the ratio exceeded 4. In terms of fuel, its consumption would be 400% greater. Under unusually mild conditions the ratio approached 1.

During the summer, it is assumed that the ratio of heat gain from the outside would be retarded in the case of the insulated wall. However the extent of such retardation has not been tested.

From January 30 to March 28, the energy consumption in Test Chamber No. 1 was 118.7 kilowatt-hours and the consumption in Test Chamber No. 2 was 274.2 kilowatt-hours. From these figures the thermal ratio value of 2.3 was obtained. The equivalent thermal losses were 406,000 BTU and 932,000 BTU respectively.

No condensation formed on the inner surface of either the conventional or the modified cavity wall during the tests.

Since heat losses through the conventional walls are 2.3 times as much as through the modified ones, it follows that the fuel requirements for the former are 2.3 times that of the latter. However, the ratio must be somewhat reduced to compensate for uninsulated concrete columns and spandrels.

FUEL REDUCTION AND SAVINGS IN DOLLARS AND CENTS

Most recent records* of fuel consumption for heat and hot water in State subsidized public housing projects in the City of New York, reveal a figure of 795 gallons of No. 6 oil per apartment per year, of which 287.5 gal. was consumed in producing hot water and 507.5 gal. for generating heat. At 6.16 cents per gallon of fuel, annual cost of fuel supply per apartment equals $31.26

Since uninsulated concrete columns and spandrel beams account for 21.5%** of the outside walls and since uninsulated walls proved 2.3 times less effective, the percentage of heating required for composite walls equals

$$\frac{21.5 + \frac{1}{(2.3 \times 78.5)}}{100} = 55.63$$

or a gain of 44.37%. In terms of fuel it represents a saving of 225 gal. per apartment per year and in terms of money—an annual saving of $14.00 per apartment.

In an average project of one thousand apartments annual savings in the cost of maintenance are indicated at:

Fuel	$14,000.00
Boiler servicing & replacement†	1,100.00
Interest & subsidy (4.25%) on initial savings of $10,150.00††	431.38
Total	$15,531.38 or $15,531.00

INITIAL SAVINGS • REDUCTION IN THE COST OF HEATING EQUIPMENT

For the purpose of obtaining current heating contract costs, the following four projects under construction were considered: Section I of Alexander Hamilton Houses, NYS-81, 478 apartments; Section I of Borgia Butler Houses, NYS-84, 990 apartments; Chelsea Houses, NYS-102, 425 apartments and Arthur H. Murphy Houses, NYS-108, 280 apartments. The heating contracts for the four projects (2173 apartments) cost $1,979,984.00 or $911.00 for an average apartment of 4.74 rental

* Calendar year of 1961.
** Average of 4 projects—Marlboro, Castle Hill, Manhattanville and Rutgers.
† Replacement every 20 years.
†† For breakdown on initial savings, see page 24.

rooms each. The physical plant accommodating boilers, hot water tanks, etc., including a chimney stack is estimated at $69.00 per apartment, thus the physical plant with stack, mechanical equipment, mains, risers, returns, branches and radiators equal $980.00 per apartment.

Based on the above, in a project of a thousand apartments the cost of heating is estimated at $980,000. With a 44.37% reduction in heat required in projects insulated with polystyrene sheets on inner withe of cavity walls and dual glazed sash, and based on four boilers and 35MBh required for heating, the anticipated savings in plant equipment etc., are:

One Boiler	$ 50,000
Radiators (15,530 MBh × $5.00)	77,650
Piping (15,530 MBh × $2.50)	38,825
Physical plant & chimney	17,000
Total Initial Savings	$183,475 ($183.47 per apt.)

ADDITIONAL INSULATION COST

Predicated on most recent available information, it has been established that the cost of Styrofoam insulation (in truck load quantities) is 9 cents a square foot and the cost of installation including contractor's overhead and profit is 21 cents a square foot, or a total of 30 cents a square foot in place.

Including installation and contractor's overhead and profit, the cost of DeVAC dual glazed sash with thermo-barrier frame and aluminum surround on the inside (in quantities of 5,000 units) is reliably estimated at $4.20 a square foot and that of a standard aluminum window with a steel surround (single glazing and frame without thermo-barrier) is $3.30 a square foot, thus the difference between the two windows is 90 cents a square foot.

These unit cost differentials—30 cents (Styrofoam) and 90 cents (dual glazed sash) per square foot will now be applied to wall and window areas of 4.5 rental room apartments in four typical public housing projects in order to arrive at the additional cost entailed.

Thus in Manhattanville Houses, if exterior walls and windows were insulated in a 4.5 rental room apartment, the additional cost would be:

266 s.f. of wall insulation	@ 30 cents =	$ 79.80
88.8 s.f. of windows	@ 90 cents =	79.92
	Total	$159.72

Castle Hill Houses:

191 s.f. of wall insulation	@ 30 cents =	$ 57.30
126.72 s.f. of windows	@ 90 cents =	114.05
	Total	$171.35

Marlboro Houses:

195.23 s.f. of wall insulation	@ 30 cents =	$ 58.57
120.61 s.f. of windows	@ 90 cents =	108.55
	Total	$167.12

Rutgers Houses:

225 s.f. of wall insulation	@ 30 cents =	$ 67.50
102.78 s.f. of windows	@ 90 cents =	92.50
	Total	$160.00

Hence average additional cost of a 4.5 rental room apartment =

$$\frac{159.72 + 171.35 + 167.12 + 160.00}{4} = \frac{658.19}{4} = \$164.55$$

and in terms of an average 4.74 rental room apartment*=

$$\frac{164.55}{4.5} = \frac{X}{4.74} \text{ or } X = \frac{164.55 \times 4.74}{4.5} = \$173.326 \text{ or } \$173.33$$

From the above figures the following conclusions can be drawn:
The savings due to reduction in heating equipment and physical plant equal $183.48 per apartment; the additional cost due to insulation is $173.33. The creation of a more efficiently and more comfortably operated project can be accomplished therefore, at a reduction in initial investment of $10.15 per apartment or $10,150.00 in a project of one thousand apartments.

RECAPITULATION

It has been established from these experiments and other sources mentioned hereafter, that better insulation of walls and windows in housing as well as other structures, could save in construction cost initially and save in maintenance cost during the period of operation.

For every 1,000 apartments a minimum saving of $10,150.00 could be attained in the first cost and of $15,531.00 in fuel for every year during the life of the structures.

Considering the tens of thousands of housing units, for both low and middle income occupants, to be built in this country every year, the potential in economy could be most significant indeed.

Aside from monetary considerations, better insulated walls and windows enhance the amenities through cooler temperature within apartments during the oppressive summer heat and muffle street and yard noises as well.

The indicated preservation of this country's natural resources—the supply of oil—when applied on a nation-wide scale, must also be considered as one of the more important accomplishments of this study.

•

This may seem paradoxical, yet it does prove the contention of singularly few voices asserting over and over again that it does not necessarily entail additional expenditures of money to produce better functioning structures. To attain these ends, it does entail, however, the exercise of initiative, imagination, resourcefulness, knowledge, and perseverence.

BY-PRODUCT OF STAPLETON STUDY

Replacement of broken glass in New York City Housing Authority's maintenance program is a continuous nuisance and a costly one to boot. A replacement of a broken pane of glass is estimated presently at $3.20, of which 75% constitutes the cost of labor. Spare parts ready for replacement, in windows with operable parts easily removable, could save at least one half of its total cost.

The extent of such saving can be readily perceived from the Authority's most recent report (Jan. 1, 1961 to Sept. 30, 1961) accounting for

* 4.74 rental room apartment is the common denominator for initial and subsequent savings and for additional costs.

127,868 replacements. Thus, on an annual basis, in New York City subsidized housing projects alone a saving of $272,785.00 could be effected.

The New York Times of July 19, 1962, reported that last year 163,736 panes of glass were smashed in New York City's schools and that replacement cost was $818,680.00 or $5.00 per pane. If the type of sash were modified to accommodate "in shop" repair, this expense likewise could be halved.

The use of PLEXIGLAS (by Rohm and Haas), though considerably more expensive than standard glass, may prove a worthy substitute in minimizing the extent of the damage.

FUTURE IMPROVEMENTS

Although the results of these tests are most gratifying, they do not by any means represent the acme of perfection nor are they intended to be considered the last word in the art of wall and window insulation.

An additional improvement of 12.13% can be attained simply by insulating the outside wall columns and spandrel beams. The latter could be so designed that its thickness would fit within the depth of the cavity wall, thus simplifiying the application of polystyrene insulation.

Since the heat transfer through windows is considerably greater than that through the walls*, it may be advisable to provide glass area of adequate dimensions and pleasing proportions, but not in the glass-wall fashion, which unfortunately and erroneously is considered by some architects a prerequisite in modern design.

In case of glass vulnerability to heat transmittance, Rohm and Haas, producers of PLEXIGLAS, claim resistance of its product to be 11% greater than that of glass in equivalent thickness. If ordinary glass were replaced with ¼" PLEXIGLAS, the resistance would be 25% greater. The additional cost would no doubt be more than offset during the operating period of projects through conservation of fuel.

PLEXIGLAS should be tested to verify its potential.

Heat absorbing glass should also be tested in connection with increased comfort within apartments during oppressively high temperature of summer months.

EXPERIMENTS BY OTHERS

In the latter part of 1961, Dividend Engineering of Owens-Corning Fiberglas Corporation estimated that an air conditioned junior high school in Kansas City, Mo., could save $13,950 on equipment and $1,836 in yearly operating costs through the substitution of 2" for ¾" Fiberglas Roof Insulation, addition of 3½" Fiberglas Building Insulation in walls and substitution of "heat reducing plate glass" for standard plate glass.

Although the function and design of schools differs widely from multi-

* Because of limited funds, the Stapleton experimental tests did not attempt to evaluate separately the window and wall heat losses. Some indications of the efficacy of each have been obtained from the Manhattanville tests.

story fireproof housing, it nevertheless confirms our findings that savings of both, in initial construction and subsequent operation, can be attained through judicious application of insulating materials.

•

Progressive Architecture of April 1962, in an article entitled "ADVANCES IN CAVITY WALL" points out among other advantages of "foamed-in-place polyurethane" filled in the 2¼" cavity, as creating high thermal resistance ($K = 0.16$) and an excellent moisture barrier. The cost is estimated at 35 cents per square foot but it is more than compensated by a lower U factor of the wall resulting in reduced heating expense and elimination of vapor barriers.

In a June 1962 circular letter, the Pittsburgh Corning Corporation recommends FOAMTHANE, a rigid polyurethane foam insulation with a K factor of 0.15, as a better way to insulate cavity walls. "There are no voids such as can occur with foamed-in-place materials" says P.C. "because the controlled conditions under which FOAMTHANE is manufactured, assures a uniform density and therefore more consistent insulation value."

Here we discern a conflict of urethanes—liquid vs. rigid. The quality of the application of either would no doubt, affect materially the end result.

•

Professor McGuinness of Pratt Institute in a recent contribution to Progressive Architecture stressed the vital relation between glass and "opaque areas" (walls and roofs) and heat-flow out of buildings in cold weather and into buildings in warm weather.

Glass with its high transmission factor and roofs and walls with low thermal conductivity require careful consideration when related to comfort and economies.

If sufficient insulation is provided for, to create an overall U factor of 0.10 BTU/hr/sq.ft./°F the beneficial effects among others are, a decrease in cost and size of heating and cooling equipment and a reduction in operating costs.

Professor McGuinness cites an analysis by Dividend Engineering of a Singer Distribution Center Building in Syosset, New York, wherein $38,000 of additional insulation would reflect a $91,000 savings in reduced heating and cooling equipment and an annual operating cost saving of $8,930.

•

On July 22, 1962, The New York Times reported that a shopping center in New Orleans, originally designed without insulation, showed that by adding roof insulation at a cost of $22,500, air conditioning savings would amount to $30,500 and annual operating costs would show a decrease of $2,250.

•

All these corroborate our findings of initial and subsequent savings via better insulation.

ALTERNATE METHODS OF HEATING

SEVERAL ALTERNATES

With a considerable reduction in the output of heating made possible through improved insulation in walls and windows, a vast opportunity presents itself in the design of more efficient heating systems and in more economical use of fuel to generate same.

Presently, a two pipe, ten pound pressure steam system with convector radiators is commonly used in a preponderant majority of public housing projects in large metropolitan areas. Within apartments, the exposed risers, returns, branches and convector boxes are rather unsightly and destroy a goodly part of a wall space. The risers and branches also present somewhat of a hazard to the youngsters not yet understanding parental advice to "keep away from fire."

In the middle and high income housing, where risers and branches are concealed, the appearance, utility of wall space and safety problems are not present.

•

With considerably lesser heat transmittance, possibilities loom large for a modified steam or hot water baseboard radiation (a finless horizontal branch) or hot water radiant heat in floors, or perhaps even electric baseboard heating, sill line convectors or radiant wall heaters. In the case of the last three mentioned, the cost of boiler room, chimney and boiler room equipment can be entirely omitted.

Greatly reduced heat requirements may also be conducive to exposed vertical heating riser system at both ends of exterior wall within each room and with three risers in corner rooms, thus obviating the need for branches and radiators. Additional heat efficiency in this system may be attained through the introduction of fins on the risers not unlike that in convector radiation. If developed, this system has enormous potential for cutting initial cost. The hazard to crawling tots and skipping youngsters can be eliminated by provision of perforated asbestos screens from the floor up to sill height.

ELECTRIC HEATING

The suggestion of electric heating is predicated on an extremely effective insulation with a total U factor of perhaps 0.5 and on relatively cheap electric power supply. On large projects it is not entirely beyond the realm of possibility to generate own electric power for that purpose.

At this juncture it may be of interest to note that Chicago's Marine City, a huge complex with two 60-story round towers with 900 luxury apartments, offices, garages, etc. will be electrically heated and air conditioned, with each apartment and office having its own controls.

HIGH-TEMPERATURE-HOT-WATER-SYSTEM

On large scale projects High Temperature Hot Water System (HTHW) may be a good substitute for low pressure steam because of an indicated economy in initial installation. HTHW has been successfully operated on the continent where skilled and unskilled labor is comparatively less expensive than here. However, advocates of this system claim that the economies derived from its efficiency can more than balance the labor cost factor.

AS TO THE FUTURE

The list of possibilities for more modern materials, equipment and methods of construction at a reduced cost, if you please, can be literally expanded ad infinitum. Fairly convincing tests can be brought to light even though they may sometime seem slow in arriving. But the measure of real success will depend on how persuasive and attractive the suggested improvements are and how open minded to their implementation will the construction industry be.

Changes are inevitable—of that one can be sure—however, the big question still remains, HOW SOON.

AND IN THE PAST

From "RESEARCH STUDY IN THE COST OF HOUSING," Vol. I, June 1958, after the research program was outlined on a broad scale:

"The tools for greater economy in construction are about to be attained. Henceforth, it is the courage, wisdom and speed in the application of these tools that will make the effort count."

•

From "RESEARCH STUDY IN THE COST OF HOUSING" Vol. II, February 1960:

"Whether any of the many potentials will be tapped, followed up and implemented depends upon how vigorously this program is pursued. The size of the challenge, though large, should not be impossible to resolve, if it is so willed."

ACKNOWLEDGMENTS

The writer, whose task it has been to follow these experimental studies from inception to completion, wishes to acknowledge the many good minds and more willing hands that have assisted unstintingly in the problems encountered.

Sincere thanks are owed to:

Commissioner James Wm. Gaynor, whose dynamic administration of the Division of Housing and Community Renewal has been characterized by a constant search for better and less costly ways of producing housing and whose drive to increase the rate of housing construction has not dimmed his recognition of the need for research;

Assistant Commissioner John T. Haugaard, Jr. for his support and steadfast encouragement throughout these experiments;

My colleagues of the Division's staff, George Cherr, Peter Angelos and Henry Bernhardt for their engineering advice and John J. O'Rourke for his assistance in supplying fuel consumption data;

Professor Clifford Wojan, Dr. Murray Imber and Dr. Robert Corry, all of Polytechnic Institute of Brooklyn for their expert collaboration;

Messrs. William Brostek and Robert H. Gulliver of the New York City Housing Authority for their help in arranging "change orders" with the several contractors;

Mr. James Burke, the General Contractor's Superintendent of Construction, for his help in building the Test Chambers;

Messrs. Henry Weisl, R. E. Polson, Russell G. Lind and Paul Harsha, all of the Dow Chemical Company, for their ever ready help to supply free Styrofoam for the wall insulation and the Test Chambers;

DeVAC's Messrs. F. W. Hetman, Rodger Bartlett, R. L. Peterson and Andrew T. Forgatch for their unstinting aid and knowledge in producing and donating a window that contributed so much to the success of the last phase of the experiment.

To Andrew T. Forgatch, a selflessly dedicated man, an extra "thank you" for the frequent companionship on the many long trips across the bay and during the writer's instrument readings at the site.

Lastly, most sincere thanks to Mrs. Joshua D. Lowenfish for being willing to put up with her husband's 5 A.M. schedules during the construction period, and with late home comings for dinner during the rush hour jams of the ferries.

REFLECTIONS

If the trips across the windy bay to and from Staten Island seemed rugged at times, the magnificent view of lower Manhattan with its myriad of flickering lights at dusk, more than compensated for the writer's occasional discomfort. Research or not, it is a sight one must not miss.

APPENDIX I

The sash used in the Stapleton experiment was tested with the knowledge that there are other window manufacturers whose product can closely approximate the insulating values of DeVAC and that the sash cost is competitive.

DeVAC MODEL No. 419 PRIME DOUBLE-HUNG

DeVAC double hung dual glazed units contain the prime sash, storm sash and/or screen with a THERMO-BARRIER in the central portion of the frame. The frames and the barrier interlock securely. There is no metal to metal contact between the inner and outer frame—heat or cold transmittance is thus considerably reduced. All joints of the main frames are milled to exact tolerances and are fastened together in an interlocking butt type joint with non-magnetic screws.

Although aluminum extrusions of 6063-T5 meet the requirements of the door and window industry, DeVAC uses 6063-T6 extrusions, which have greater tensile, yield and sheer strength.

The use of 6063-T6 extrusions in frames, mullion and sash minimize field problems and repairs. All horizontal members of the prime sash are of tubular construction.

Through the use of THERMO-BARRIER, condensation problems on inner surfaces of glass and metal have been overcome. With the ingenious design of the split frame and the use of extruded Geon thermoplastic, high impact dry vinyl for the barrier, the U factor on the interior frame does not exceed .400. A special sealant between metal and vinyl enhances its efficiency.

Good materials and fine tolerances resist infiltration of cold air and create economy in heating operation and in maximum comfort of tenants. Silicone treated Schlegel wool-pile are used on the prime sash around the perimeter and a double seal of wool pile at the meeting rails. All prime sash operate on spring loaded nylon cushion blocks, with a pin lock locking device which engages in predetermined ventilating positions provided in the main frames. The cushion nylon hardware allows the sash to be easily removed from the inside for cleaning and maintenance. Lift handles are provided for easy operation.

All sash is factory glazed with glass set in vinyl glazing channels. There is no glass to metal contact and close tolerances do not permit air or water leakage around the perimeter. Vinyl channels eliminate glass breakage through expansion and contraction. In multiple housing, reglazing costs are minimized since immediate replacement is possible with a spare sash—glazing becomes a shop project. Glazing beads are reusable.

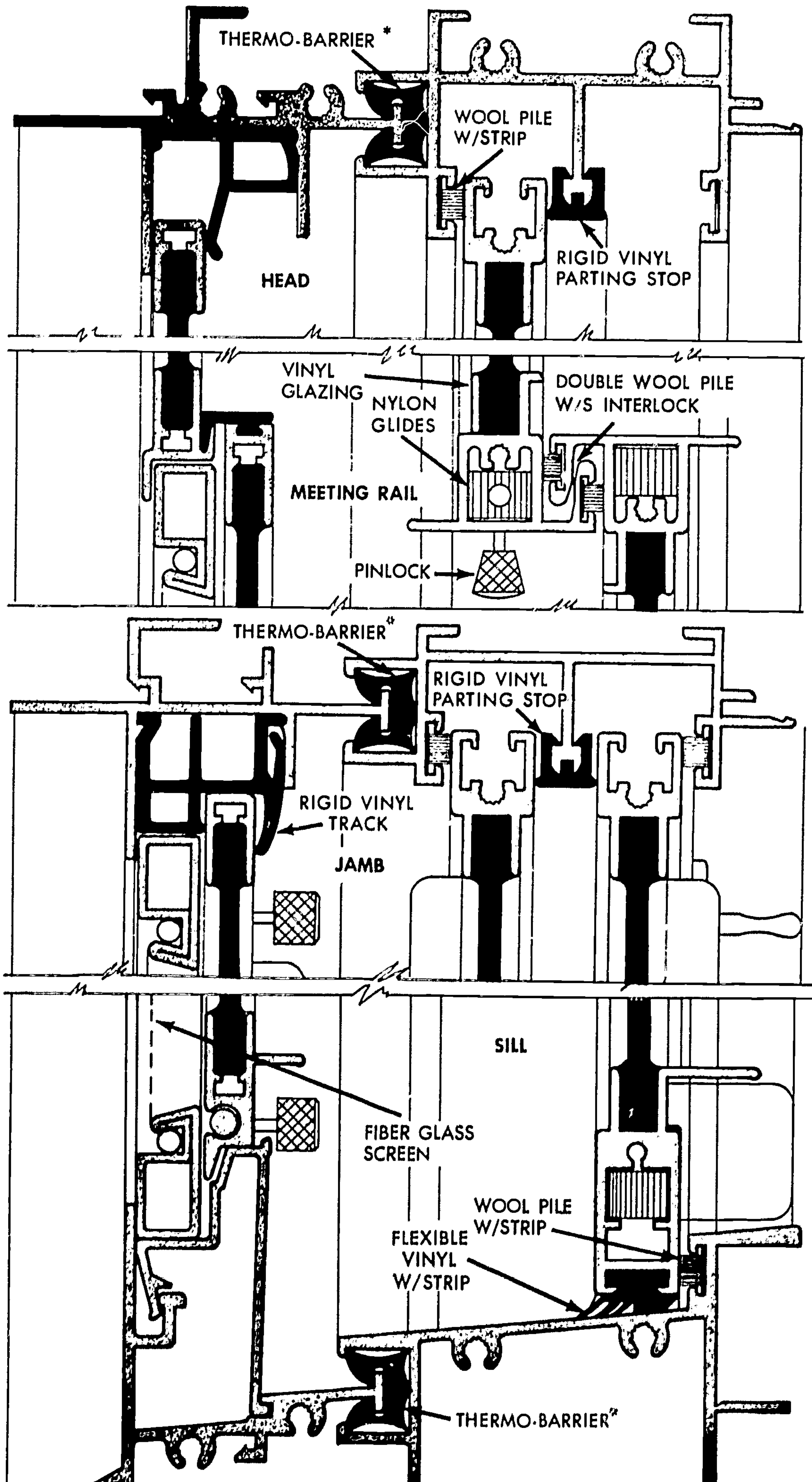
Although all sash is shipped with the units, sash can be removed to a storage area and reinserted at a later date.

The DeVAC #419 double hung prime sash has infiltration of no more than .283 cubic feet of air per minute per foot of perimeter sash when subjected to wind velocity of 25 miles per hour and the dual glazed sash—.095.

Although, for comparative window prices in this study, unanodized

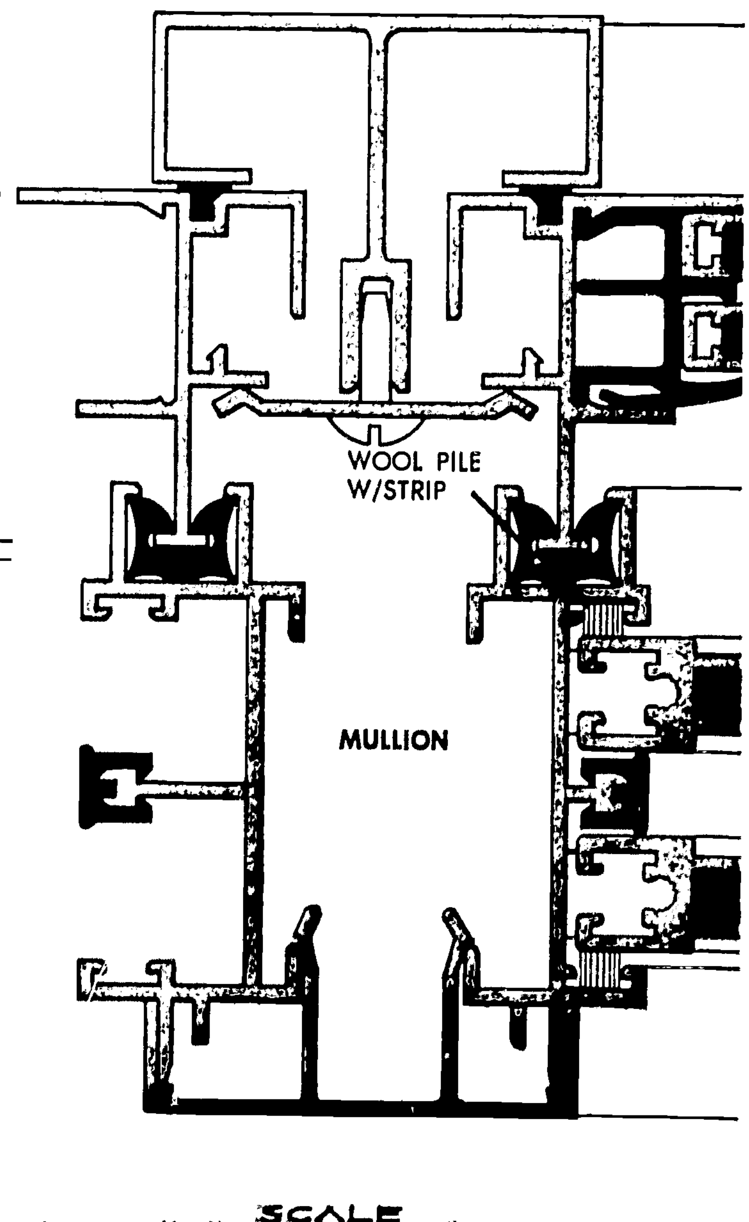
DeVAC

MODEL NO. 419
PRIME DOUBLE-HUNG
(WITH CUSHIONED-BLOCK BALANCE)



DOUBLE-HUNG SIZES AND STOCK NUMBERS

HEIGHT (Rough Opening / Unit Size / Glass)	WIDTH: Rough Opening 23 Unit Size 22 9/16 Glass 20	27 26 9/16 24	31 30 9/16 28	33 32 9/16 30	35 34 9/16 32	39 38 9/16 36
32 7/8 / 32 3/8 / 14	2014	2414	2814	3014	3214	3614
36 7/8 / 36 3/8 / 16	2016	2416	2816	3016	3216	3616
44 7/8 / 44 3/8 / 20	2020	2420	2820	3020	3220	3620
52 7/8 / 52 3/8 / 24	2024	2424	2824	3024	3224	3624
60 7/8 / 60 3/8 / 28	2028	2428	2828	3028	3228	3628



aluminum was considered, DeVAC adopted anodizing as a standard at a slight increase in price. There should be specific emphasis on this refinement depending on the nearness of salty air or the exposure of industrial smoke and fumes, thus in areas in and near Denver, 202R1 anodizing will prove adequate; in Pittsburgh, 204R1 is recommended and in Atlantic City, 215R1 should be applied.

The following advantages are listed as a result of anodization: neater and more durable surface; easier and smoother operation; resistance to oxidization, pitting or corrosion; is not abrasive and therefore will not deteriorate weatherstripping; does not absorb grease and dust; it is easier to clean; helps minimize maintenance cost.

•

The window manufacturing firm of DeVAC, Inc. is located at 10130 State Highway 55, Minneapolis 27, Minnesota.

The development of THERMO-BARRIER frame dates back to 1953 when the firm decided to solve the problems of condensation and other related factors resulting from high conductivity of aluminum. In 1957, thermal plastic materials as separators between interlocking aluminum frame members were first started.

In 1960, Professor C. E. Lund of University of Minnesota conducted a study entitled "Evaluation of Frame Surface Temperatures Covering DeVAC Aluminum Window Frame with Thermal Barrier," wherein some interesting facts were revealed.

The study indicated that heat loss through a solid aluminum window is nearly four times greater than it is through an aluminum frame with THERMO-BARRIER.

"As the net heat flow for a material is dependent also upon the distance it has to travel, both thermal conductivity and distance must be considered. The relative heat flowing through the aluminum frame is 42.5 greater than that through the vinyl thermo-barrier. Thus it may be seen that installing a thermal barrier in the aluminum frame in order to break the high rate of heat flow through the solid aluminum will retard the flow of heat from the warm to the cold side surfaces of the frame.

"At 0°F outside still air temperatures, the insulated frame shows no condensation for humidities approaching 40% (sufficient protection for normal humidities maintained) whereas the maximum humidity for a solid frame is 30% (not sufficient protection for normal humidities maintained). At 15 mph outside wind velocities and 0°F temperature, the maximum relative humidities are 30% for the insulated frame and 15% for the solid frame. Increased outside wind velocities increases the rate of air infiltration into a building which in turn reduces the relative humidity when such velocities prevail over long term intervals. This assists in reducing the inside surface condensation. The insulated aluminum frame is a definite improvement over the solid aluminum frame due to the increase in inside surface temperatures above the critical temperatures found in the solid aluminum frame."

•

Weatherometer tests were conducted recently in southern Florida to determine the effect of extreme weather conditions on 8750 Geon thermoplastic vinyl extrusions. The findings were that physical properties had not changed as a result of the exposure. The vinyl had increased in tensile strength and there was no decrease in the amount of deflection. Freezing temperatures of northern climates have likewise no adverse effect on the Geon vinyl.

APPENDIX II

The polystyrene insulation used in the Stapleton experiment was tested with the knowledge that there are several manufacturers whose product closely approximates the insulating values of Styrofoam and that it is competitive with others.

HISTORY AND THE USE OF STYROFOAM

Styrofoam was developed during World War II as a flotation medium for the military.

After the war, intensive development program diversified its uses. Today, large quantities of this material are being used for insulation, for decorative purposes and for flotation.

By far the largest quantities of Styrofoam go into insulation. It comes in several varieties and serves many uses. Thus, "SCORBORD" is used for perimeter insulation; "ROOFMATE" and "ROOFMATE FR" is used in built-up roofs.

Styrofoam FR has a flame-retardant element added at no price premium. Styrofoam CB is used in curtain wall laminated sandwich construction.

During the past few months, "the MILLER SYSTEM" was developed for use of Styrofoam as a base for wall board. A high initial tack adhesive, called "STYROTAC," makes this adaptation possible.

As a plaster base and for comfort insulation, Styrofoam has been used in wall construction for the past seven years. Styrofoam acts as its own vapor barrier and provides high, permanent insulating values.

Concrete keys positively to the cellular surface of Styrofoam insulation. When forms are removed Styrofoam is ready for two coat plaster finish.

Styrofoam, an inorganic material, will not rot nor mildew. Because of the tiny non-interconnecting air cells, Styrofoam resists passage of heat or cold or moisture vapor. Its high compressive strength permits pouring of concrete over Styrofoam in floor construction and its light weight makes it easy to handle and install.

•

ENGINEERING DATA

PHYSICAL PROPERTIES

Density: 1.6 to 2.0 lbs/cu. ft.
Compressive yield strength: 16 to 32 psi (ASTM D 1621-59T)
Tensile strength: 45 to 61 psi
Sheer strength: 27 to 36 psi

THERMAL PROPERTIES

Burning characteristics: Self extinguishing (ASTM D 1692-59T)

Linear thermal coefficient of expansion between 0° and 80°F: <0.00004 in./in./°F

Average thermal conductivity (mean temp. 70°F): <0.26 BTU-in/sq. ft.-hr.-°F

Heat distortion temperature: 170°F

•

WATER RESISTANCE PROPERTIES

Capillarity—none

Water absorption (ASTM C-272-53): <0.25% by volume

Water adsorption: 0.15 lb./sq. ft. of surface area when submerged for 48 hours under a 10' head of water.

Water vapor transmission (ASTM E 96-53 T, procedure E): 1.0 to 2.0 perm. inch.

•

METHOD OF APPLICATION ON WALLS

In the case where Styrofoam is applied to 4" cinder-concrete block on the room side of an inner withe of a cavity wall, the wall surface shall be parged with mortar approximately ¼" thick. The thickness should be uniform throughout.

Styrofoam boards shall be pressed hard against parging to assure complete adhesion.

Two coats of finish plaster shall be applied not sooner than 24 hours after application of Styrofoam to cinder-concrete block. Total thickness of plaster need not exceed ½".

Brown base coat of plaster should be scratched thoroughly and allowed to dry but not fully set when additional brown is added to bring plaster to grounds. To improve working qualities and help minimize cracking of white coat, an addition of 25 lbs. of fine silica sand per 100 lbs. of gauging plaster is recommended.

Insufficient troweling may result in cracks in the finish coat.

For composition of mortar and plaster see p. 20 of the text.

When the outdoor temperature is less than 55°F, a uniform temperature of not less than 55°F shall be continuously maintained through the building for a period of not less than one week prior to the application of plaster, while plastering is applied and after the plaster is dry. Adequate ventilation shall be provided during and subsequent to application of plaster.