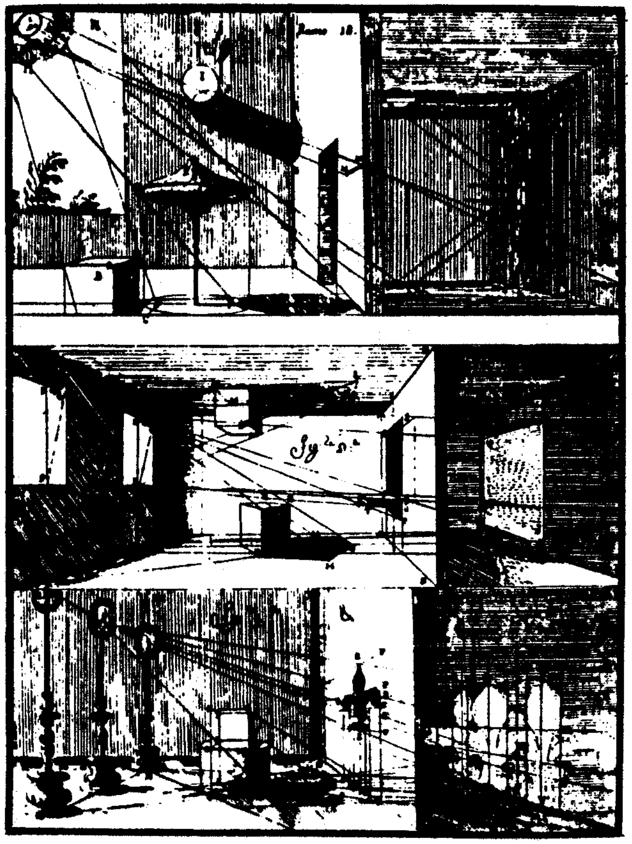
1975

Buildings in Use Study

Harvey Z. Rabinowitz
University of Wisconsin - Milwaukee

BUILDINGS IN USE STUDY



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buildings in use study

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BUILDINGS IN USE SURVEY

Harvey Z. Rabinowitz

Abstract

Results of a two-year post-occupancy evaluation of four elementary schools in Columbus, Indiana, all designed by nationally prominent architects. Two of the schools contained traditional classrooms and two utilized open plan concepts. The report evaluates a wide range of technical and functional factors.

2 Parts, plus Appendix. Pp. v + 258; drawings.

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PROJECT DESCRIPTION

The 'Buildings In Use' study is an attempt to examine, in the field, the performance of buildings which have been 'in use' for some time. We believe that such examination is the primary method through which better buildings can be designed. Three major factors are examined: technical performance, functional performance, and the relationship between environment and behavior.

This study has investigated four elementary schools in Columbus, Indiana. These schools, designed by nationally prominent architects, were completed in 1962, 1966, 1969 and 1972. The two older schools contain traditional classrooms; the two more recent buildings utilize semi-open (1969) and open (1972) educational and design concepts. The schools are similar in size (500-600 students) and in the social characteristics of their students.

Technical studies have been carried out in the following areas: exterior walls, roofs, interior walls, floors, ceilings, acoustics, lighting and H.V.A.C.. A "Field Test Manual" has been developed which was actually the basis for testing the technical performance of the buildings. The results of these field tests, as well as discussion of these results and relevant technical specifications and details are documented in the "Technical Factors Report". Over 100 tests and the results of these tests are included in the two reports.

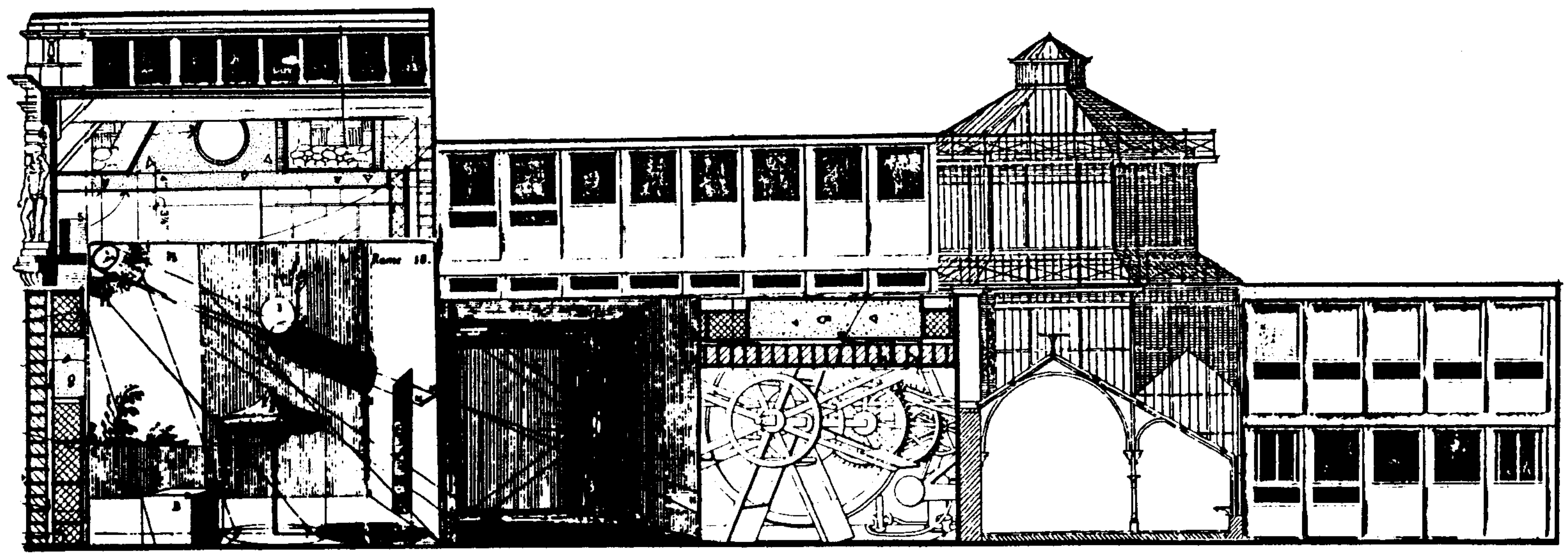
Functional studies include areas of 'activity support' exclusive of furniture. This includes studies of specialized areas and functions within the school as well as storage, classroom display, window usage and some activity support equipment. Measures in this area include capacity, anthropometric fit and amount of usage. Results will be reported in the "Functional Factors Report".

Behavioral studies have been carried out using observation supplemented by questionnaires and interviews. This aspect of the study was aided by participation of faculty from UWM's School of Education. Research questions concerning differences between schools in terms of groups size, type of activity, seating, student posture and spatial usage are addressed as well as studies within schools such as the effect of proximity and territoriality.

This information is directed to architects and clients in order to help them make the consequences of programming and design decisions more predictable. Researchers in this area will be interested in the concepts and methods of this study as part of the larger effort to accumulate experience and findings which have the goal of deve'oping a body of theory and procedure in this field.

buildings in use study

technical factors



INTRODUCTION

Those responsible for building design rarely examine, in a formal and comprehensive manner, the environment they have helped create. We believe such examination is, however, the primary method through which better buildings can be created. Thus, what we learn from this study can be used, by clients and architects, in the design of future buildings.

This report is one product of the 'Buildings In Use' Study. The overall study examines architectural attributes of existing buildings (in this case 4 elementary schools) in order to determine how they have performed technically and functionally, and the relationship between the environment of the building and the behavior of its user population. This particular document addresses only the technical factors aspect of the study.

The technical factors evaluation is based on another document produced as part of this overall study: the Field Tests Manual. This report includes detailed descriptions of the tests used in the examination of the buildings. These tests are, for the most part, field test equivalents of National Bureau of Standards, A.S.T.M., and Federal Specification Laboratory Tests and procedures.

There has been very little research performed in the comprehensive and formal evaluation of technical performance, much less of functional and behavioral factors, in existing buildings. The most notable work in this area is that of the Building Performance Research Unit at the University of Stratchclyde and the Pilkington Research Unit, University of Liverpool, both of whose efforts and reports were the precursors of the present 'Buildings In Use' Study.

In this 'hard' area of technical factors evaluation (in contrast to the 'softer' area of functional factors, and the even softer behavioral factors) we have adopted a formal and methodological approach. The procedural framework used in the Field Tests Manual is followed and test results are rated numerically wherever possible.

CRITERIA

Criteria used in judging technical performance were based on the premise that each subsystem of the building should perform as unobtrusively and reliably as possible. These subsystems, we feel, comprise the 'background' environment which should allow, but neither hinder nor stimulate, natural and typical activities to occur.

Highly reliable subsystems performance is expected, given routine maintenance and accounting for typical wear and tear. School administrators, teachers and students should be concerned with learning and not with building associated problems and repairs.

The following scale is used to indicate performance levels based on the stated assumptions:

○ 95% performance level, implying very satisfactory performance;

⊙ 85% performance level, implying minor performance problems which do not affect the activities within, or the image of, the building. Correctable by routine maintenance and/or repair;

Unacceptable is a:

● 75% performance level, implying major problems having some detrimental effects on the activities within, or the image of, the building. Correctable only by means of major repair or replacement procedures.

CONTEXT OF TECHNICAL FACTORS

Technical factors comprise the background environment which contains the very basic attributes: protection from the elements; suitable interior surfaces for the use of furnishings and equipment; thermal comfort and satisfactory auditory and visual conditions. They do not directly support activities, such as a blackboard, for instance, does. Flexibility, manipulation of environment (e.g. windowshades), storage and equipment are classified as direct activity support and are treated in another aspect of our study (functional factors).

Today's state of the art in design and construction produces a sound building with one or two or three major problems (below the 75% performance level) during its useful life. The elementary schools studied are not inconsistent with this performance. Though expected, major problems are unnecessary, unwanted and costly to resolve. Such problems also can be the basis for legal actions against the architect and/or contractor.

From the architect's viewpoint as a professional, the decisions he makes should have predictable and appropriate consequences in terms of performance, notwithstanding whether this desired performance is in the realm of technical factors, behavioral factors, perception or imagery. As a professional and a businessman, he must inform his client when client decisions, such as budget, will compromise appropriate performance. This 'service' to the client and the eventual user can protect the architect from future recrimination and legal action. Furthermore, the architect should, when given supervisory responsibility, not allow appropriate performance to be compromised through the construction process, notwithstanding the 'give and take' in that process.

To the architectural profession, many of whose members are wondering where their next project is coming from, such concepts as performance, technical analysis of existing buildings, much less behavioral studies, may not be particularly relevant. This type of study, however, seems to bridge the gap between research and practice. The results can be immediately applied as additional useful input into technical design decisions as well as providing a useful base and direction for continuing research. We believe that technical evaluation adequately documented and disseminated, serves both the needs of the professional today and is part of a new tradition in the practice of architecture.

COMMENT ON THE TECHNICAL DATA AND FINDINGS

1) Wherever possible information on the existing building is based on the original working drawings and specifications. The reader should note that changes in design and construction are often made subsequent to these original documents. Since 'as built' drawings are not available and changes have occurred, it is possible that some of our findings, especially in the area of 'probable cause' may be erroneous.

2) Many potential causal factors and combinations of such factors effect the problem situations noted in this report. We have drawn on as many sources to help aid in our analysis of each performance characteristic. In some cases a number of probable causes are mentioned because of the complexity of the situation. However, we do not in any way guarantee our findings or the performance of the buildings or their subsystems in the future.

3) The severity of the findings is documented for all results. The reader should be cautioned to read this carefully and retain perspective on particular items. Some lengthy discussions may, in fact, pertain to less significant defects of only academic interest. The summary of performance indicator at the beginning of each chapter quickly indicates the overall level of performance and levels for specific tests.

NOTES AND REFERENCES

- "Building Performance", Building Performance Research Unit. Applied Science Publishers, Essex, England, 1972.
- "Office Design: A Study of Environment", Pilkington Research Unit. University of Liverpool, England, May, 1965.
- "The Primary School: An Environment for Education", Pilkington Research Unit. University of Liverpool, England 1967.

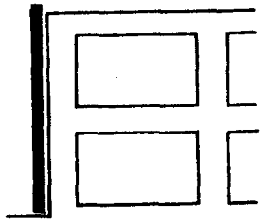
These reports are by two of the pioneering groups in the building evaluation field which who include technical factors in their evaluation.

- "Economics of Carpeting and Resilient Flooring", Geo. M. Parks. Wharton School, University of Pennsylvania Press, 1966.

The 95%; 85% 75% performance criteria and methodology are based on the system developed in this important study.

EXTERIOR WALLS

INTRODUCTION



The exterior wall performs several diverse functions simultaneously: when load-bearing, it provides physical support for the structure; it exists as the principal barrier between interior and exterior space and their frequently widely-differing environments; and its exterior surface and configuaration constitute much of the public image of the building it encloses.

Subject to various structurally-induced stresses and strains, constantly exposed to the elements and to public scrutiny, the exterior wall subsystem is one of the most difficult to design for continuing, satisfactory performance over the life of the building. Exterior windows and doors further complicate design, detailing and construction. Despite these complications, failures of this subsystem are infrequent.

The examination of the exterior wall, in the context of the 'Buildings In Use' Study, is confined to the investigation of performance in the areas of durability, weathertightness and appearance, and to attributes which affect performance in those areas. There are numerous generic materials commonly used in this subsystem, and the findings are discussed separately under the following materials-oriented categories: brick and concrete masonry; in-situ concrete; and curtain walls and other openings.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Their exterior walls were examined to determine what, if any, movement had occurred since completion of the structures, and how well the materials and systems used had weathered. The 'fit' between individual components within the various wall systems was also examined quite closely.

Equipment used in examining and testing of the exterior walls included: a plumb line, to check for wall deflection; a small rule calibrated to 1/64 inch, to measure the width and depth of cracks; a measuring tape, to determine the length of walls and cracks in them; and a camera, to record instances of deterioration.

For a more detailed description of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974.

A comparison of the measures and observations was made with existing standards to determine the quality of performance.

SUMMARY OF PERFORMANCE

	P	R	S	M
EXTERIOR MASONRY				
Structural Stability	O	⊙	NA	O
Thermal Stability	O	⊙	NA	O
Other Stabilities	O	⊙	NA	O
Air-Moisture Penetration	O	O	NA	⊙
Stain/Discoloration	⊙	O	NA	O
Deterioration	O	O	NA	O

EXTERIOR CONCRETE				
Stability	NA	NA	O	NA
Air-Moisture Penetration	NA	NA	O	NA
Stain/Discoloration	NA	NA	O	NA
Deterioration/Delamination	NA	NA	O	NA
CURTAIN WALLS				
Structural-Thermal Stability	O	O	O	O
Air-Moisture Penetration	O	O	⊙	⊙
Stain/Discoloration	O	O	O	O
Deterioration/Delamination	O	O	O	O

SUMMARY OF FINDINGS

Brick masonry exterior walls with block back-up were used extensively in three of the four schools studied. The difference in the specifications of these similar products, their storage conditions and their detailing and construction all influence performance during the useful life of the subsystem. Problems (below 85% performance level) were found at the Richards School. Conditions which bear watching wre found at Mt. Healthy. The Parkside School was generally satisfactory (85-95%).

Movement and attendant minor cracking due to a number of factors--structural loading, thermal expansion/contraction and shrinkage--were found at numberous locations at the Richards School. However, only a few of these cracks due to movement cause more than aesthetic problems. Some minor movement due to thermal expansion is also taking place at one or two locations at

Mt. Healthy. At certain locations at Mt. Healthy School the brickwork is very badly fitted. Future deterioration is probable at these locations and only time will tell, in this relatively new facility, whether real problems will emerge. The Parkside School, aside from minor areas of efflorescence, is in excellent condition.

The concrete exterior walls of the Smith School perform satisfactorily in all respects. Though extensive staining and discoloration is present and would, under normal circumstances, affect aesthetics, the intention of the architect was to allow, possibly even encourage, such occurrences. Thus, what in a normal context would be judged unsatisfactory is acceptable, even desirable, under these circumstances.

Performance of the Cor-ten curtain wall at the Smith School is satisfactory based on the same criteria used in judging the concrete exterior wall at that school.

The performance of door and window openings of the exterior wall in all schools is generally good. The doors at the Richards School are ill-fitted and do allow some air and moisture infiltration.

In all buildings studied children have dug caulking out of window framing. Caulking is rubbery and fun to throw.

Routine maintenance is necessary on the ramps of the Smith School. After some 5 years of exposure the paint is chalking and in some cases flaking (this has just been repainted!). Polyurethane insulation, sprayed on the undersides of exposed slabs is undergoing deterioration and is flaking and falling off in places.

DETAILS OF FINDINGS

EXTERIOR MASONRY

EXTERIOR MASONRY WALLS/STABILITY, STRUCTURAL LOADS (Fig. A.5)

Results: Performance was satisfactory at the Parkside and Mt. Healthy Schools. Performance at the Richards School was at the 75-85% level due to cracking evident under major roof truss supports in the multipurpose room.
Probable cause: Richards School. Probably due to actually higher loads than allowable under original design conditions or to expansion of restrained truss.
Discussion: There is a long vertical stepcrack emanating from each of the lowest spanning trusses of the multipurpose room. The cracking is long (over 10' is typical), visible but minor (1/16" or less). Due to the age of the building one can assume that this structural adaptation has been completed and that further consequences will not occur. There are no problems other than aesthetic directly related to this phenomonon, however, there are more serious indirect effects (see roofs). The probable cause of this phenomenon is an excessive loading on this lowest truss due to water trapped in the drainage valley directly above it. Other possible causes are: bearing seat improperly specified or installed; transfer of some loading from upper trusses to this one and; high stresses caused by thermal expansion and the restrained nature of these trusses (see Roof P. B-5).

EXTERIOR MASONRY WALLS/THERMAL STABILITY (Fig. A.6)

Results: Performance was satisfactory at the Parkside School. Some minor accommodation in the exterior wall at Mt. Healthy has taken place. The performance was below the 75% level at the Richards School. Expansion of roof truss over the multipurpose room causes wall movement which, in turn, causes moisture infiltration.
Probable cause: Lack of provision for the expansion of a long span truss.

Discussion: Mt. Healthy. At two locations the exterior wall is continued out of the building for some distance and that portion is exposed to the elements on both sides. The varying rates of expansion of the two portions of wall which are continuous implies some accommodation, since there is no expansion joint between the two portions. Some hairline cracking has occurred, however, this should be the extent of accommodation due to the use of horizontal reenforcement in the walls. This reenforcement should adequately absorb all thermal stress and minimize movement of the wall which otherwise would have caused major problems.

At the Richards School, a number of problems due to thermal movement have occurred. The first concerns the roof trusses spanning the multipurpose room. These 54 foot trusses are restrained at their ends causing wall movement and real leakage problems as described in the 'Roof' section of this report (See P. B-7).

Two other minor, but easily visible effects have occurred due to thermal expansion/contraction. These are primarily of academic interest because they are primarily aesthetic problems and visible primarily to researchers.

The long (78 feet) north-south wall forming the eastern end of the school has expanded and cracked the two perpendicular walls at their common T-joint. This cracking, while easily visible is minor and is only an aesthetic problem. This long wall, while designed without an expansion joint is broken up by entrance doors and an air intake grill. Notwithstanding these potiential places which could have provided relief from expansion the wall did expand (fig. A.6)

At the west end of the school there are two wings with 84 foot masonry walls perpendicular to the main body of the building. Though an expansion joint is provided at this juncture there is easily visible, though functionally harmless, cracking at this T-joint. Though we have not dissected this area we believe a logical explanation is an incorrectly constructed joint which allows a rigid connection at the point and in essence not allowing proper expansion.

EXTERIOR MASONRY WALL/STABILITY (OTHER) (Fig. A.8)

Results: In certain classrooms adjacent to 'stub' corridors there is a consistant, though minor, cracking at the caulked joint of the two walls.
Probable cause: The two walls are probably 'tied' at this T juncture and since no expansion joint is provided the exterior wall has moved causing a slight separation.
Discussion: Though visible (1/16"-1/64") these cracks are not functionally detrimental. Properly recaulked and painted they would probably not reoccur.

EXTERIOR MASONRY WALL/AIR-MOISTURE PENETRATION

Results: The varied phenomena noted in the previous sections have not resulted in air and moisture infiltration.
Probable cause: Not applicable.
Discussion: Not applicable.

EXTERIOR MASONRY WALL/STAIN AND DISCOLORATION

Results: Performance levels of exterior masonry walls were satisfactory in this regard at all schools except Parkside where some efflorescence has occurred.
Probable cause: Dissolved salts in the brick (or sometimes mortar) leaching out on to the surface.
Discussion: This is not an infrequently found condition. Though correctly specified and installed, efflorescence of masonry exterior wall may still occur. Knowledge of the quality control of the manufacturer and the use of a 'hard' brick which is more resistant to moisture penetration would

help to reduce the probability occurrence of this white staining on the brick's surface, but not necessarily prevent it.

EXTERIOR MASONRY WALL/DETERIORATION

Results: Performance was satisfactory at all schools.
Probable cause: Not applicable
Discussion: Not applicable

EXTERIOR CONCRETE

EXTERIOR CONCRETE: STABILITY (ALL ASPECTS)

Results: Performance was satisfactory.
Probable cause: Not applicable
Discussion: Not applicable

EXTERIOR CONCRETE: AIR AND MOISTURE PENETRATION

Results: Performance was satisfactory.
Probable cause: Not applicable
Discussion: Not applicable

EXTERIOR CONCRETE: STAIN AND DISCOLORATION

Results: Performance was satisfactory.
Probable cause: Not applicable
Discussion: Smith School. As mentioned in the Summary of Performance staining of the in situ concrete would not hinder performance--not even aesthetic performance, and indeed staining of the concrete is extensive due to the initial rusting of the Cor-ten steel.

EXTERIOR CONCRETE: DETERIORATION/DELAMINATION

Results: At the Smith School there are one or two individual instances of serious deterioration of the exterior concrete surfaces which should be corrected.
Probable cause: The overall low, or 'brutal' quality of the finish as specified by the architect has resulted in a few places in which performance is affected.
Discussion: A low quality of finish for the in situ concrete is acceptable, even encouraged, in this building for reasons mentioned previously. Thus, patches, spalling, honeycombing and formwork markings are plentiful and acceptable. However, at the exit ramp leading from the 3rd and 4th grade levels the concrete supports have 'lost' enough material to cause exposure of the reinforcement, perceptable movement of the bearing plate and some displacement in the ramp itself. Over time this will become serious and we recommend correction as soon as possible.

CURTAIN WALLS

CURTAIN WALLS: STABILITY (STRUCTURAL/THERMAL)

Results: Performance levels were satisfactory in this regard at all schools.
Probable cause: Not applicable
Discussion: Not applicable

CURTAIN WALLS: AIR/MOISTURE PENETRATION (Fig. A.9)

Results: Performance levels were marginally acceptable at most facilities studied (85%). Severe weather and windblown rain does cause instances of water infiltration but these occurrences are infrequent. The fit of the exterior doors at Richards is not tight enough to prevent air infiltration--this is correctable. At the Smith School water flowing down grooves in the metal wrapped sloping ramps has penetrated through the seal at the lower ends

of the ramps and has entered the building. This has been corrected. Probable cause: The original detailing, weathering and the removal of caulking by students have all contributed to deteriorated performance.
Discussion: The level of performance required of this subsystem does not permit air and water infiltration even during severe weather. Thus even the minimal occurrences of problems which were found constitute a lower level of performance. At the Richards School this is a problem in a few classrooms. The original exterior doors were 'hollow core' type, failed, and were replaced with solid core exterior doors, some of which may need refitting and weather protection.

At the Smith School the detail at the lower end of the sloped ramps is extremely difficult to solve with the use of the corrugated steel exteriors. The water races down the valleys of the corrugated metal exterior and is directed with some force at the joint with the curtain wall which could not perform adequately. The original detail has been modified with silicone caulk which seems to be performing adequately. It should be noted that the working drawings examined used the corrugated steel wound around the ramp which would have simplified the detail. The ramps were built with the metal corrugations running longitudinally.

At Mount Healthy recaulking is now taking place. The original material used on the industrial sash is dry and coming loose allowing water to enter.

CURTAIN WALLS: STAINING/DISCOLORATION

Results: Performance levels were satisfactory at all buildings examined except at Smith where extensive chalking of the painted steel ramp siding is evident.

Probable cause: Weathering.
Discussion: Chalking is a normal result of weathering of a painted surface. The ramps need repainting.
NOTE: They have just been repainted (1974).

CURTAIN WALLS: DETERIORATION/DELAMINATION

Results: The removal of caulking from window frames is present at the Smith, Parkside and Mount Healthy Schools. Normal deterioration of the wooden window frames is present at Richards. The original exterior hollow core doors at the Richards School deteriorated within one year of occupancy and were replaced with solid core doors. With these exceptions, performance levels were satisfactory. The galvanized industrial sash glazing at Mount Healthy is beginning to rust in spots. This is being repainted as a preventive measure.
Probable cause: Kids dig out caulking from around windows. Weathering has caused deterioration of Richards frames.
Discussion: The removal of caulking by kids at three of the facilities is surprising. Subsequently we noted similar situations at elementary schools in other localities. We are no longer surprised by this phenomenon. Covering the caulking with a metal strip, which has been used at the Smith School is effective in preventing occurrences, as is the use of hard or preformed gasketing such as a neoprene gasket or an elastomeric sealant such as polysulfide or silicone. Caulking materials which are easily removed and fun to throw or which have 'play' potential should not be used.

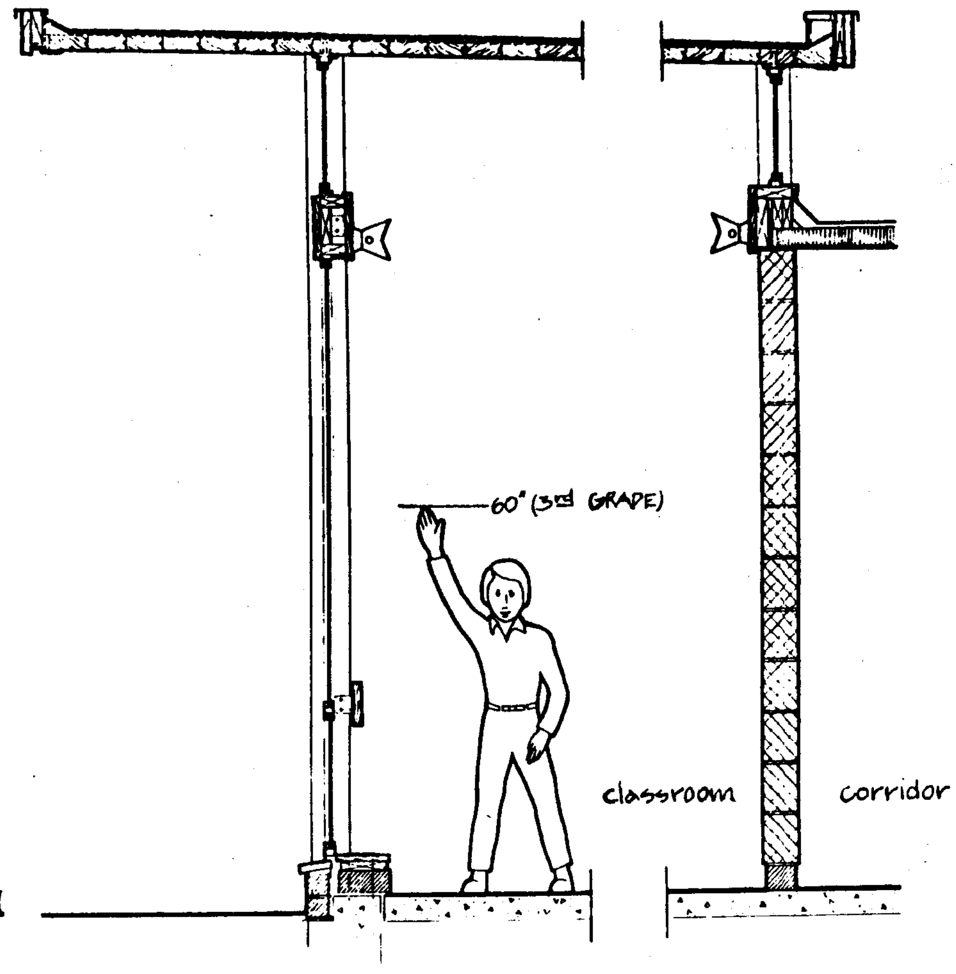


fig. A.1
PARKSIDE SCHOOL/SECTION

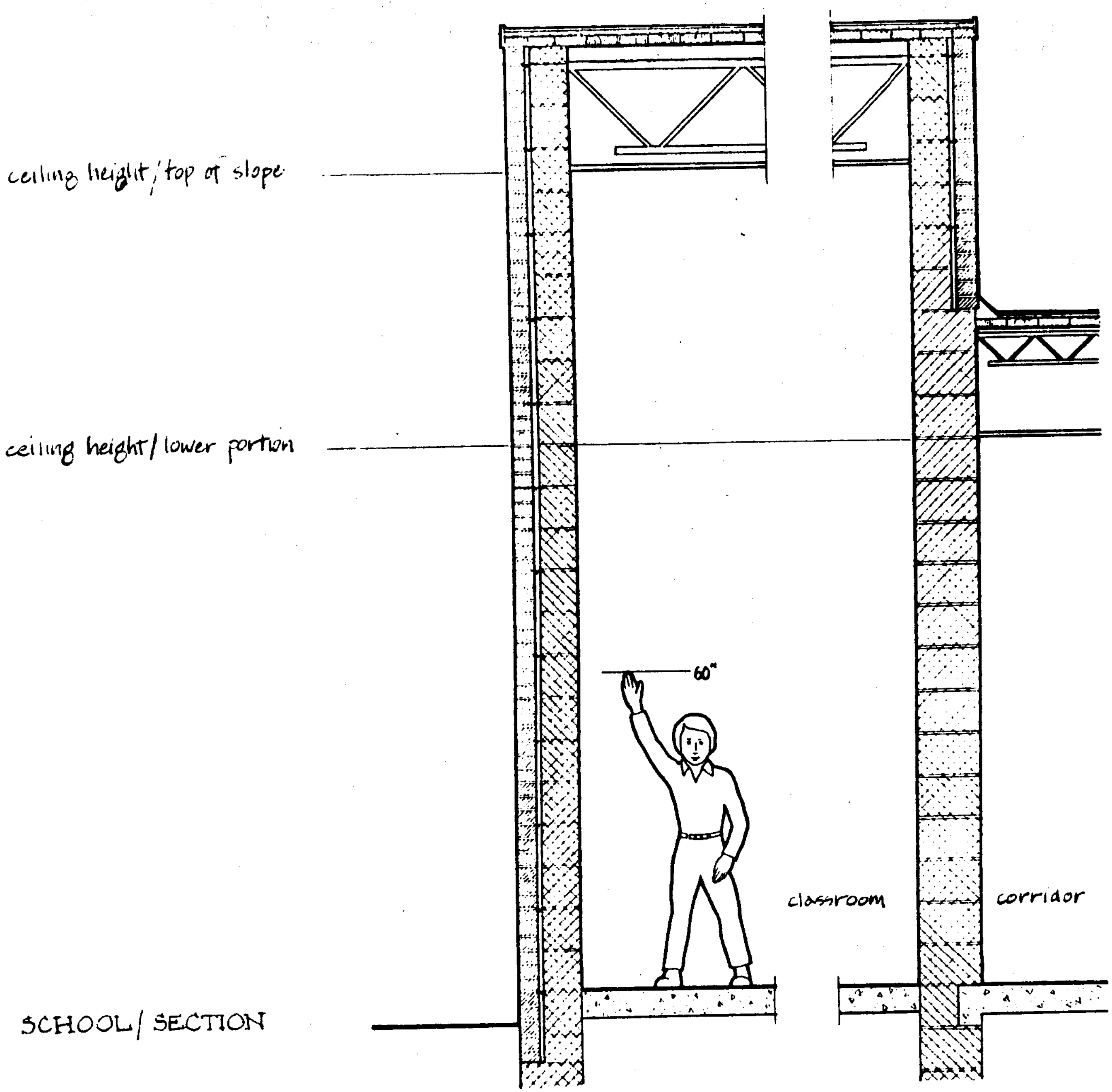


fig. A.2
RICHARDS SCHOOL/SECTION

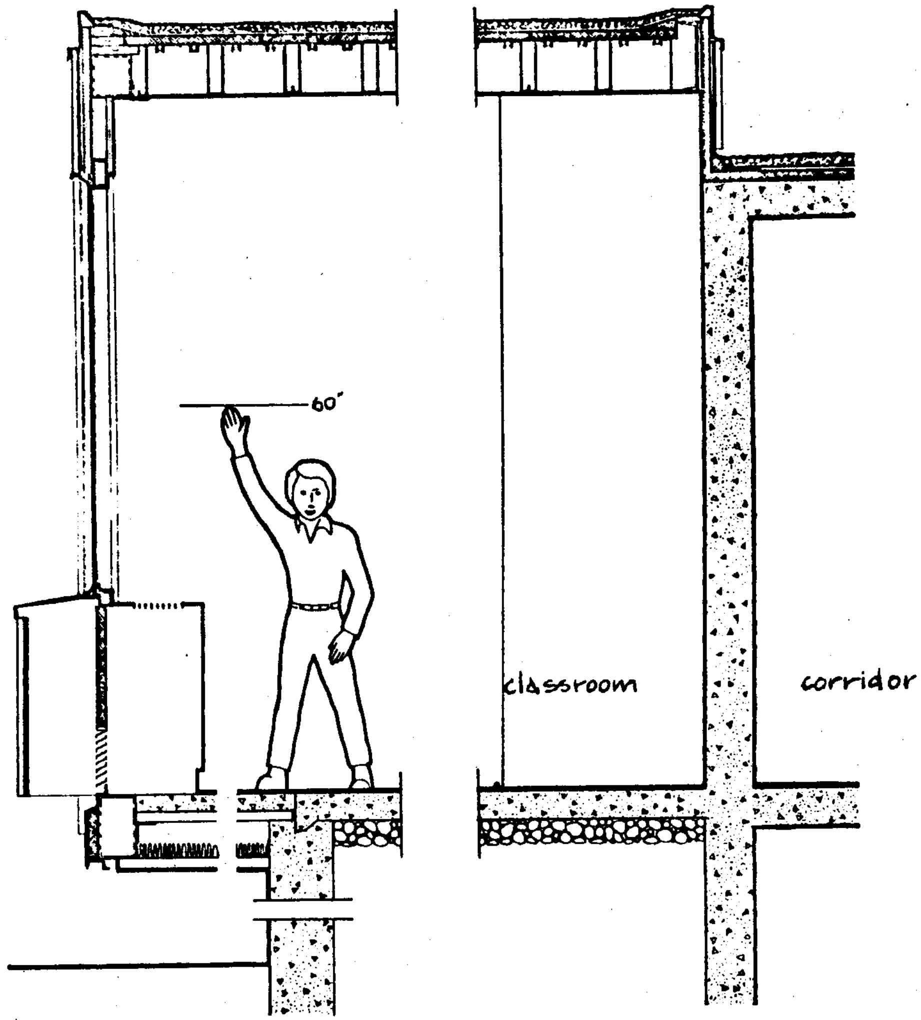


fig. A.3
SMITH SCHOOL/ SECTION

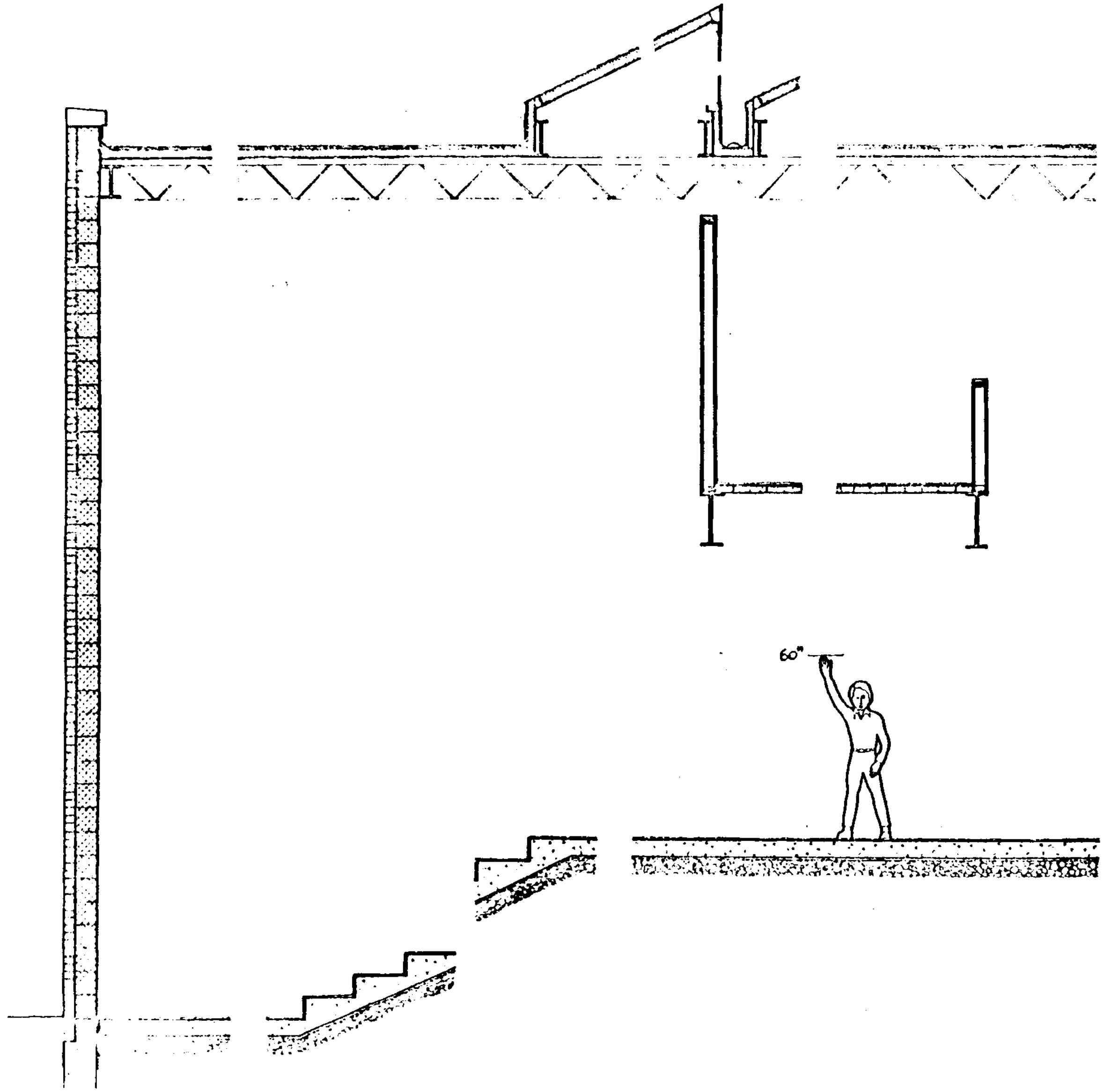


fig. A.4
MT. HEALTHY/SECTION

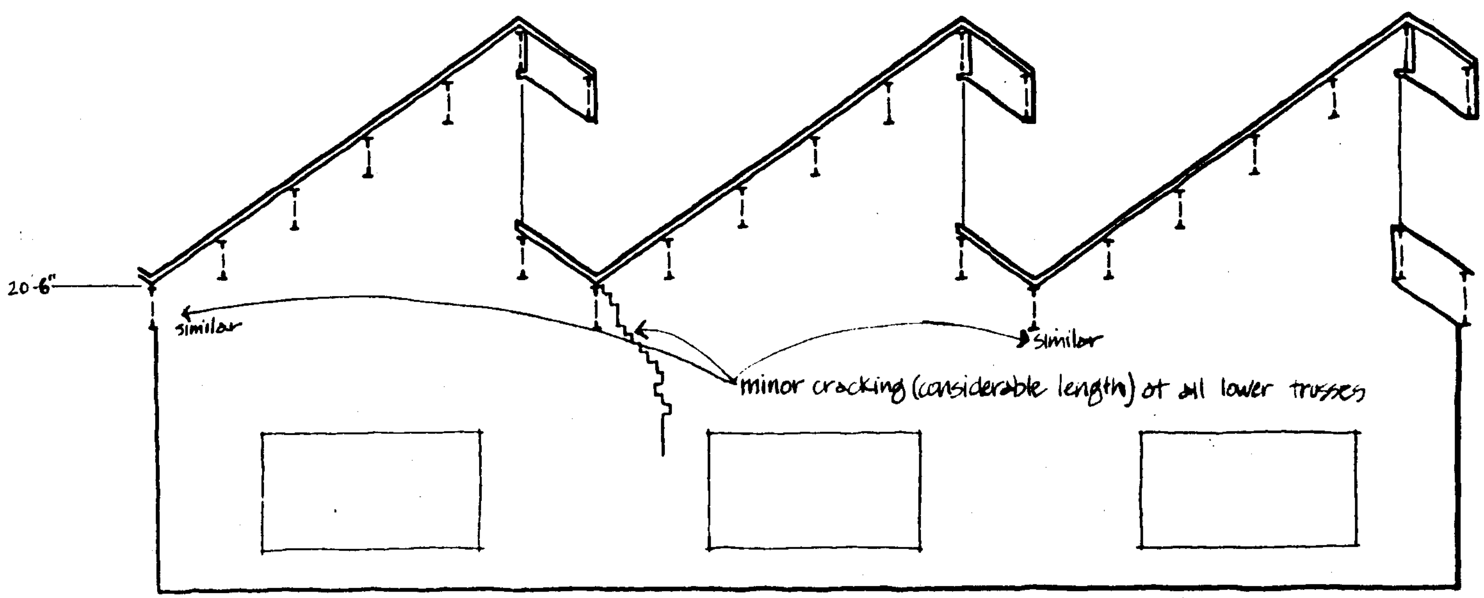


fig. A.5
RICHARDS SCHOOL / SECTION - MULTIPURPOSE ROOM

fig. A.6
RICHARDS SCHOOL / EAST END

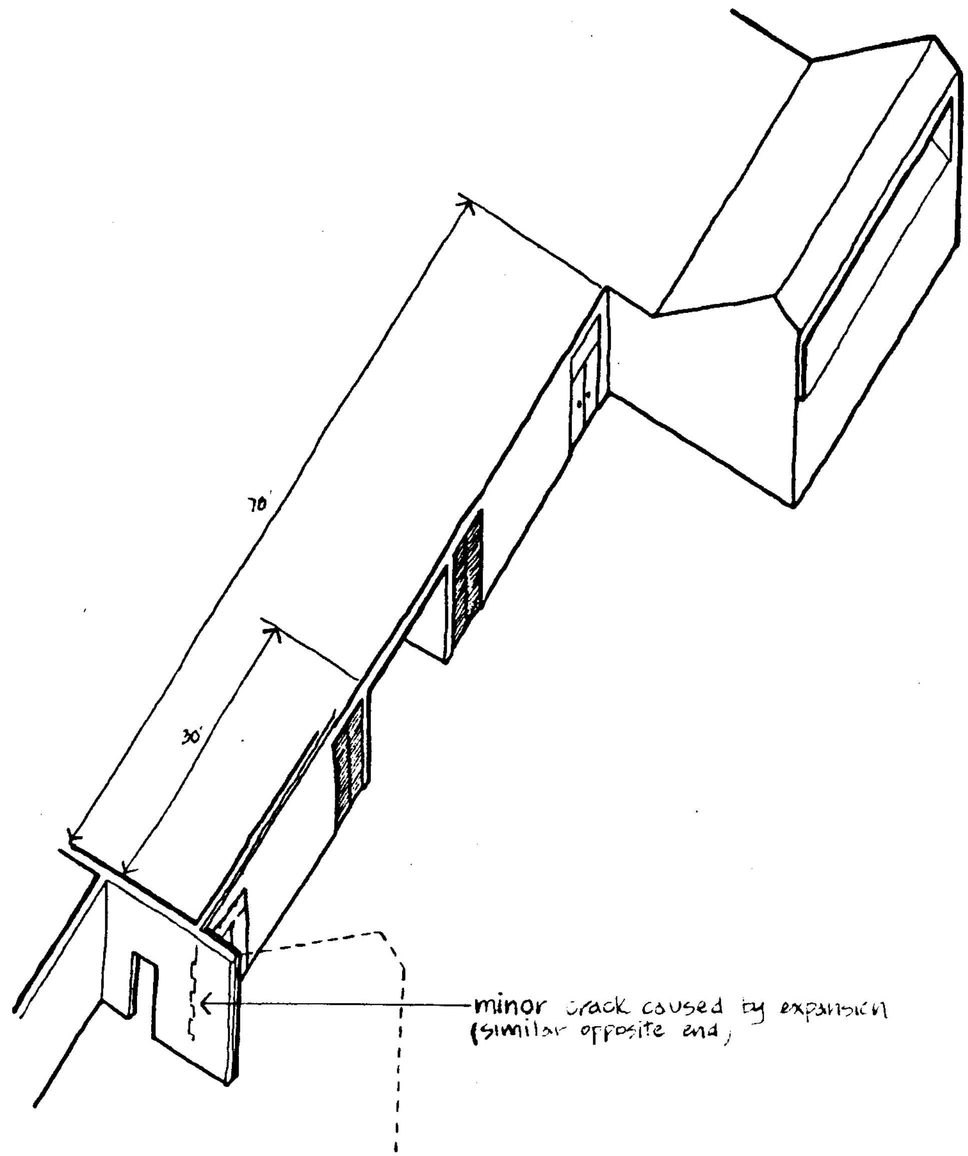
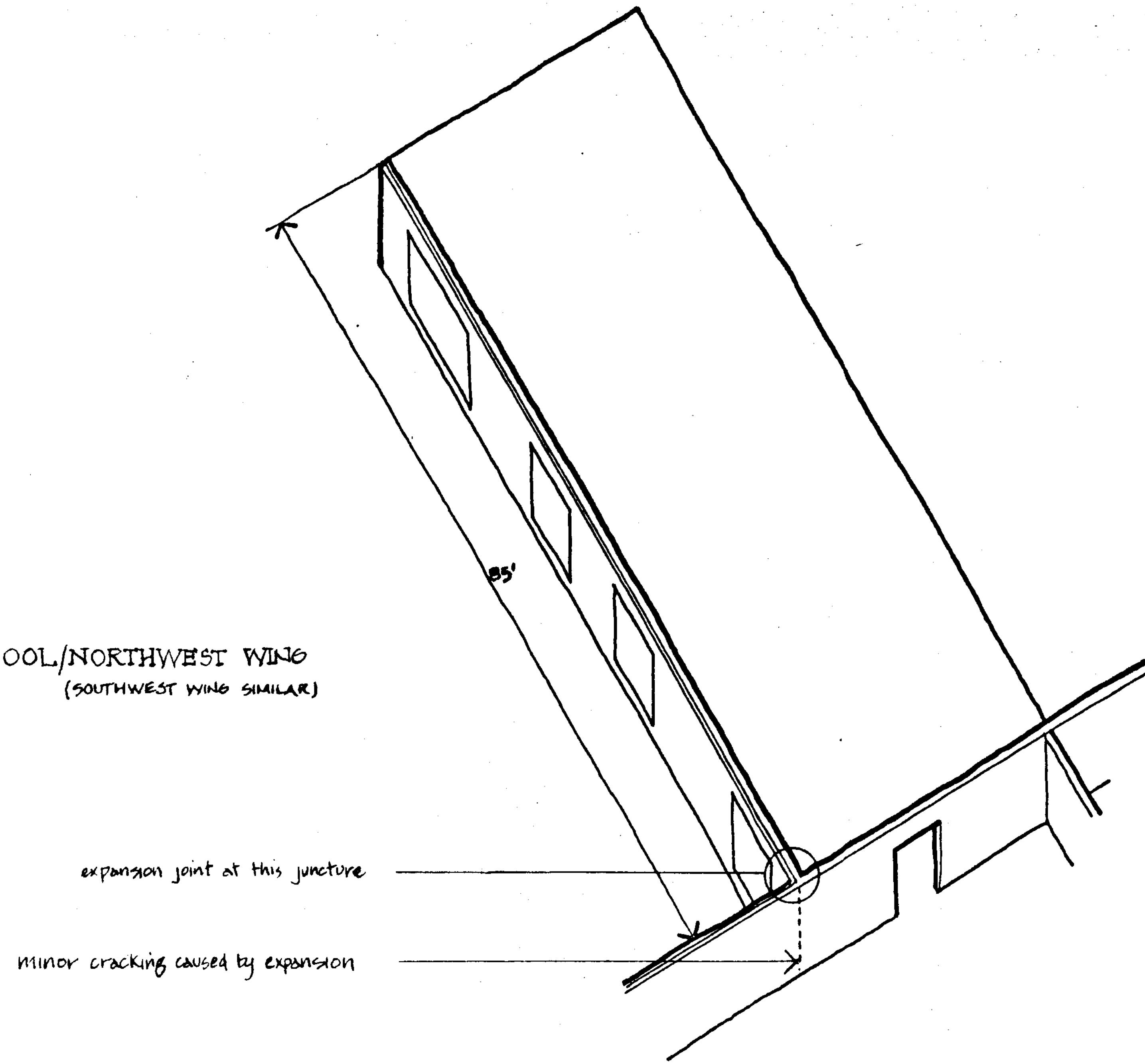


fig. A.7
RICHARDS SCHOOL/NORTHWEST WING
(SOUTHWEST WING SIMILAR)



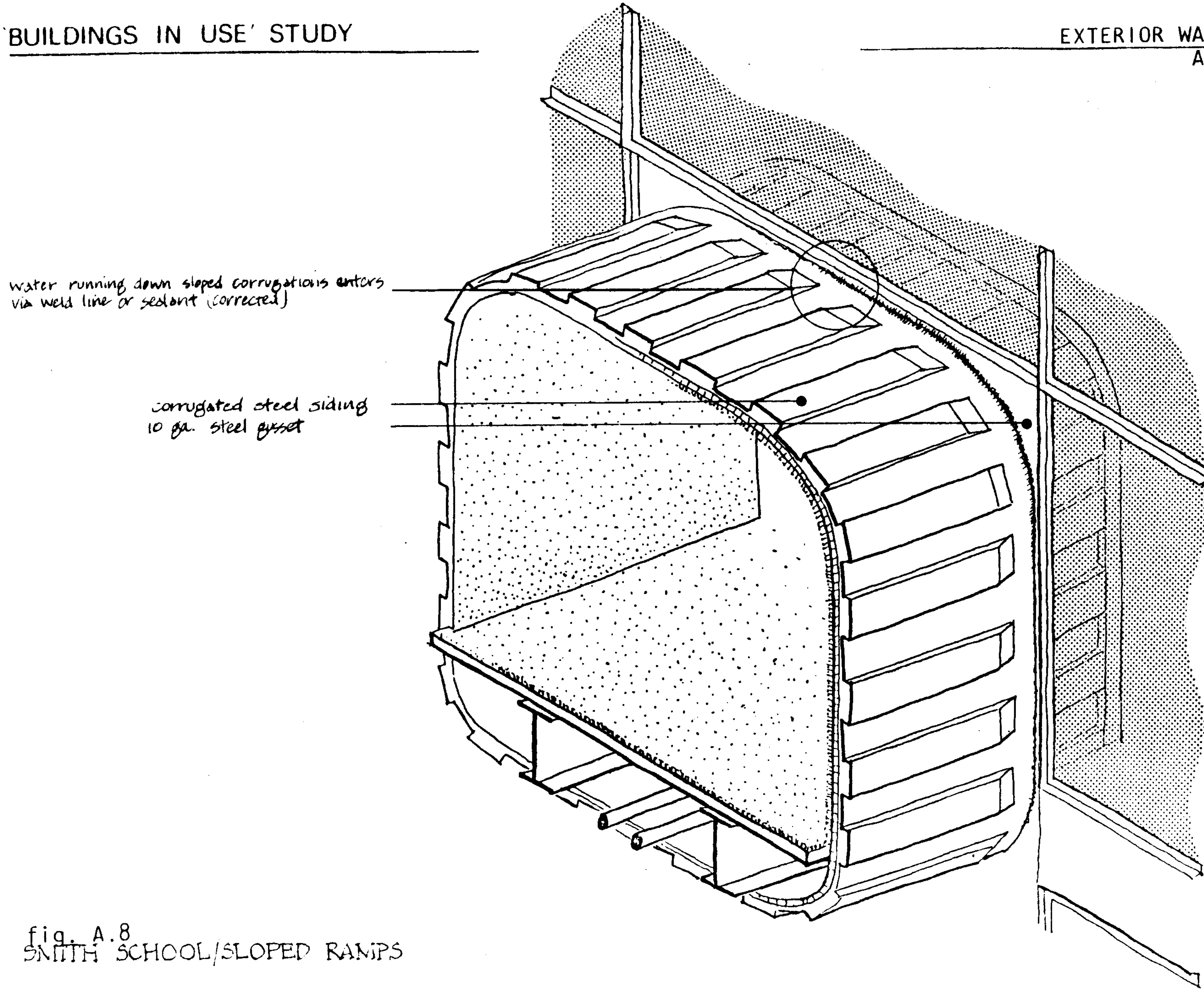
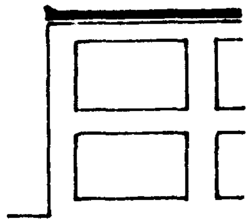


fig. A.8
SMITH SCHOOL/SLOPED RAMPS

ROOFS

INTRODUCTION



The primary objective of the roofing membrane is to absolutely keep out weather - primarily moisture. To satisfy this objective the most critical attribute of this system is to prevent any moisture penetration which may occur through improper design, faulty construction practices or through weathering action on this tenuous membrane.

The roofing membrane is the most 'sensitive' of all the building subsystems examined in this study. This is due to its having a constantly high exposure to the elements; the nature of water's insidious ability to infiltrate into a building and the numerous possibilities for error in design and construction.

Since this is so tenuous a membrane a reasonable course of action would be towards overdesign for moisture protection, very careful supervision of construction, and, getting the water off of the roof as quickly as possible.

METHOD OF EXAMINATION

Very rigorous measures and a detailed visual examination were made of this membrane. Evidence of moisture penetration was of prime importance as was evidence of weathering and entrapped air and moisture.

A 4' level, inclinometer and small rule calibrated to 1/32" were used to measure pitch, depth of standing water and deterioration. For a more detailed description of testing procedures used refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974. A comparison of these measures and observations with existing standards was used to determine the quality of performance.

SUMMARY OF PERFORMANCE

	P	R	S	M
DRAINAGE				
Ponding	○	●	○	○
Details	○	⊙	⊙	○
Roof Slopes	○	●	⊙	○
MOISTURE PENETRATION				
Details	○	○	○	●
Movement	○	●	○	○
DETERIORATION EROSION	○	●	○	⊙
IMPACT/INDENTATION/ BRITTLENESS	⊙	●	○	○

SUMMARY OF FINDINGS

The roofing membrane is one of the most tenous systems in any building. Roofing failure is a serious and frequent problem in any facility. Such failures are due to many causes: incorrect detailing, poor quality materials, improper construction practices, effects from other building subsystems, etc. None of these are without remedy in existing buildings nor unpreventable in future new construction.

The performance of the built-up roofing membranes of the four buildings studied was mixed. The Parkside roof is "the best in the district" (85% level) and the Mt. Healthy roof is generally satisfactory (75-85% level). The Smith School is rated at the 75%-85% level because of a potential for future problems though it is now performing satisfactorily. The Richards School is rated at below 75% becuase of numerous problems resulting from detailing, construction and deterioration during the life of this building.

No convergence of problem types is present. What exists is a cornucopia of causes, many of which are 'textbook cases'.

DETAILS OF FINDINGS

DRAINAGE

DRAINAGE/PONDING (Figure B.1 through B.4)

Results: Performance was generally satisfactory at the Parkside and Mt. Healthy Schools. Ponding due to inadequate drainage is a problem at the Richards (below 75%) and the Smith (85%) Schools. Within 1 year of occupancy all of the built up roofing at Richards had already been replaced when core samples revealed total saturation of the roof membrane and insulation. Richards Elementary School has the most extensive ponding closely followed by Smith. Roof construction at Smith is of such high quality, which is rare, that existing ponding does not now, and may not, cause future moisture penetration. The Richards School has a less well constructed roof and alligatoring, brittleness and membrane movement due to ponding caused many problems in the past and may well cause future problems.

Probable cause: No slope or inadequate slope specified in the original design is the major cuase of ponding.

Discussion: The main concern of the designer should be getting the water off of the roof. Ponding consists of substantial amounts of water which do not drain off of the roof surface. This can immediately cause leaks if the roof is not 'tight'. Even more insidious, however, is the deterioration of the membrane due to ponding. Freezing of this standing water, which is, of course, relatively shallow and easily frozen, can literally tear the roofing membranes. The more typical effect, however, is movement of the membrane caused by a temperature differential between the exposed roofing, which on a sunny day may be 180 degrees and the membrane under the pond which is substantially lower in temperature. Other effects of ponding are erosion of the protective gravel surface and alligatoring-minute cracking of the membrane. Moisture penetration is a cause of blistering, caused by expansion of the water vapor, and also a cause of roofing movement due to water vapor migration between the felts.

Specifying minimum slopes (1/8 inch/ft.) can be nullified by settling, construction tolerances, workmanship during construction or roof sag during the life of the building. In fact some roofs specified to slope towards the roof drain were found to actually slope away from the drain because of the above mentioned factors.

DRAINAGE/DETAILS (Figure B.6)

Results: Performance was adequate at all facilities examined. Drains can sometimes be higher than the roof surface due to additional flashing and therefore cause or exacerbate ponding conditions. Gutters between adjacent skylights at Mt. Healthy were found to be a trap for leaves and a potential source of blockage.
Probable cause: Architectural detailing and construction tolerences due to flashing, protection around drains.
Discussion: Typically all openings through the roof are protected by additional layers of roofing felt and flashing materials. This causes the roof to pitch up slightly at the drain. If a drain is chosen or installed in a manner which also raises it above roof level--the combination of the higher drain and the additional protection can actually be 2-3" above the roof level which will cause ponding in this location.

DRAINAGE/ROOF SLOPES (Figure B.1 through B.4)

Results: Performance was satisfactory (85%) at Mt. Healthy, at the 85% level at Parkside, but unsatisfactory (75% or below) at the Smith and Richards Schools where a lack of slope results in ponding.
Probable cause: Design did not specify sloped roofs.
Discussion: This, of course, is the primary couse of ponding. 'Dead' flat roofs were specified at the Smith and Richards Schools. At Richards the roof actually slopes away from the drain. This, we believe, is caused by some small amount of settlement in the exterior wall or poor construction which at

first caused minor ponding. The weight of this additional water gradually caused the roof membrane to sag in this area and increased its capacity to hold water, producing a cycle of increasing ponding.

The Smith School has two roof levels over each typical wing, the higher draining via scuppers to the lower on which are located the roof drains. Ponding is extensive on the upper roof levels. Extensive water protection raises the roof edges enough to prevent water from reaching the scuppers. This results in an extensive pond at the center of each upper roof area. The roof construction, though, is excellent and does not allow any moisture penetration.

MOISTURE PENETRATION

MOISTURE PENETRATION/DETAILS (Figure B.5)

Results: Performance was satisfactory (85%) at Parkside and Smith, unsatisfactory (below 75%) at Richards and Mt. Healthy. Detailing permitted water to penetrate the roof.
Probable cause: Inadequate detailing and/or unsatisfactory construction practices at locations of potential moisture penetration.
Discussion: In general all roof penetrations and changes in levels are well detailed in terms of tolerances and materials at all schools. A notable and inconsistant exception is the circular skylight details at the Richards School in which upstand flashing is omitted and the roofing felts are not carried up the edge of the raised skylight. These omissions provided a direct path for moisture and extensive leakage and water staining occured inside the building. This may have been the major factor which caused total saturation and replacement of the roof a year after occupancy. This has been corrected. The valley flashing over the multipurpose room was incorrectly installed--the flashing was improperly soldered--and this too caused leakage and was corrected.

At Mt. Healthy flashing was improperly installed at the junction of a lower roof that meets an exterior wall and around skylight monitors. This is in the process of being corrected. In the first case, the lower Roof/Exterior wall detail, the exterior wall material was changed from that specified on the working drawings-from diagonal wood siding to brick. We have not seen any revised drawings and there is a possibility that this change was made without the care of the original set or that because the original building form was unaltered, that this form was not sympathetic to the new and unanticipated materials, thus causing problems.

MOISTURE PENETRATION/MOVEMENT (Figure B.8)

<u>Results</u>: Performance is satisfactory (95%) at all schools with the exception of Richards (below 75%) where structural movement has resulted in moisture penetration through the roof membrane.
<u>Probable cause</u>: Thermal expansion and contraction of the 54 foot trusses over the multipurpose room causes openings in the roofing membrane.
<u>Discussion</u>: Unusual circumstances must be present for this phenomenon to occur for the roofing membrane is flexible. At the Richards School we believe these exceptional circumstances did occur as a result of some rather complex relationships.

The 54 foot long roof trusses over the multipurpose room are <u>not</u> free to move at their ends. Since the school is not air-conditioned and the trusses are at the top of this high space they are subject to considerable thermal expansion (and contraction). As they expand and contract they push the exterior walls in and out. This exterior wall is, in turn, restrained at its midheight by the adjacent corridor structure and this joint between the lower (corridor) roof and this moving wall is constantly opening and closing. This is beyond the capacity of the membranes and flashing to absorb this movement leads to water leaking in. This condition exists in the corridors at every point where the lowest roof truss abuts the corridor wall.

It should also be noted (see exterior walls) that extensive cracking occurs on the multipurpose room side emanating from this lowest truss. This may be due to the weight of water in the valley above or to this restrained movement as the lower portion of the wall cannot move outward while the upper portions can.

We believe thermal expansion and contraction of the brick exterior wall of some classrooms has 'popped' the rivets holding sections of aluminum flashing together. Wind-driven water has penetrated the flashing at these points and run into the classroom staining the ceiling. This, however, may also have been caused by expansion of the flashing itself.

DETERIORATION

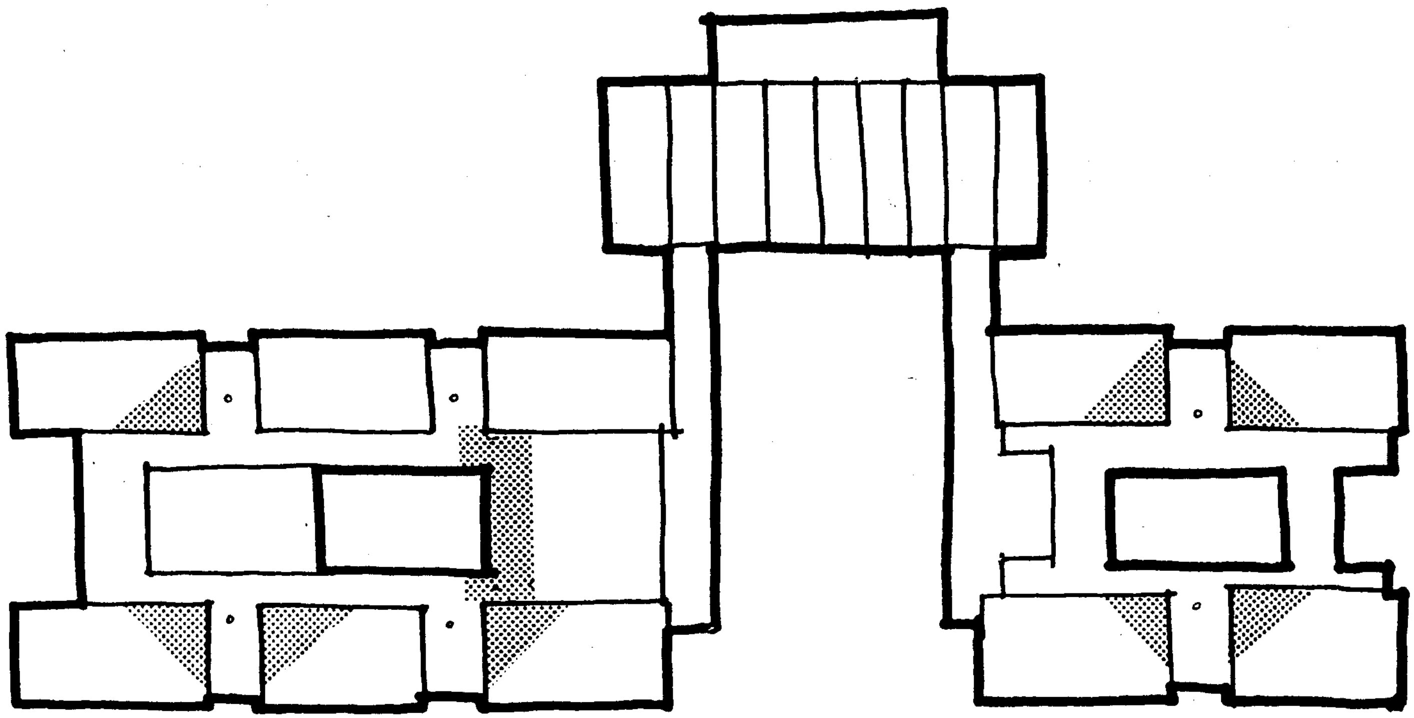
DETERIORATION/EROSION

Results: In general the roofs are weathering well with the exception of Mt. Healthy (85%) where erosion of aggregate is significant considering that the roof is only two years old. The Richards roof shows excessive deterioration (75-85%).
Probable cause: Unsatisfactory adhesion of the aggregate to bitumen roof membrane at Mt. Healthy. Poor construction seems to be a problem at Richards. A fire in one section of the school has also blistered the roof above it.
Discussion: The mineral aggregate on the roof surface is critical to the durability of the roofing system. It provides protection of the membrane from impact, infrared and ultraviolet light, to some extent minimized excess expansion and helps reduce blistering and alligatoring. The aggregate must be applied when the final layer of roofing bitumen is still hot so the aggregate is sufficiently bonded to this material.

IMPACT/INDENTATION BRITTLENESS

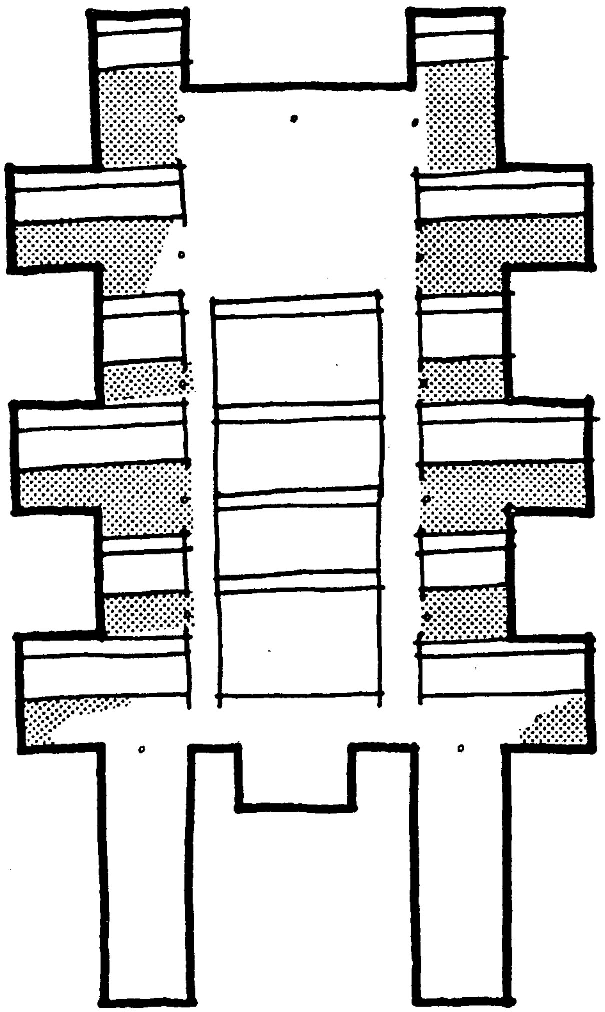
IMPACT/INDENTATION/BRITTLENESS

Results: Performance levels are satisfactory at all schools examined.
Probable cause: Not applicable
Discussion: The lack of impact and indentation problems to a large degree can be attributed to the fact that these roofs are only accessible to maintenance personnel. Most problems occur when roofs are used for activities or by hail impact. Brittleness is often caused by an inadequate final bitumen layer which by hastens the aging process of the bitumen. Neither impact or brittleness is a problem in these buildings.

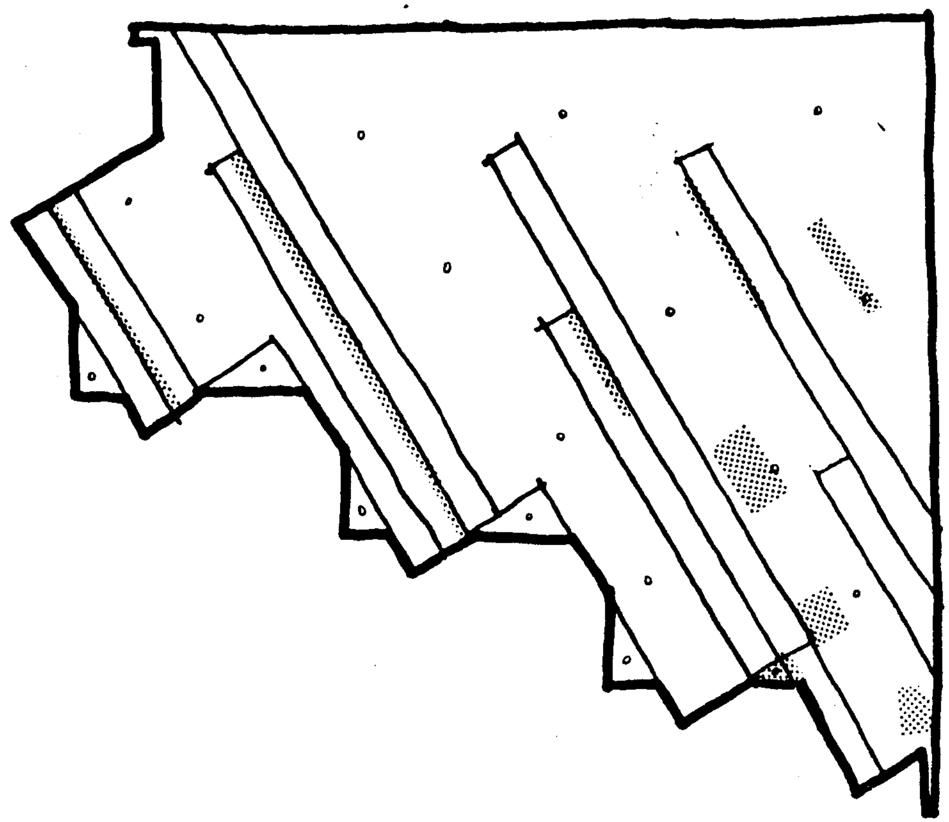


PARKSIDE SCHOOL: PONDING

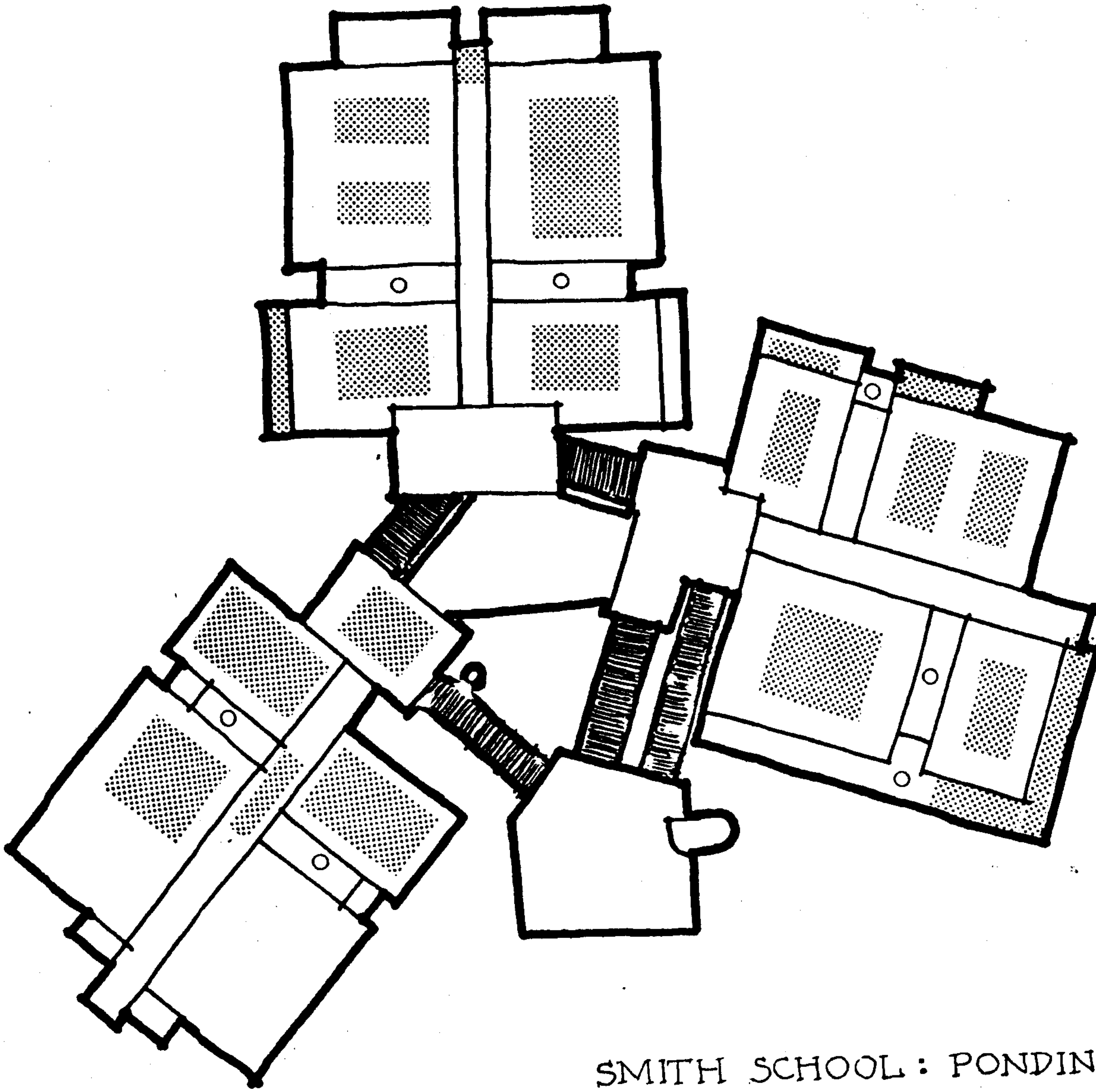
FIGURE B-1



RICHARDS SCHOOL: PONDING
FIGURE B.2

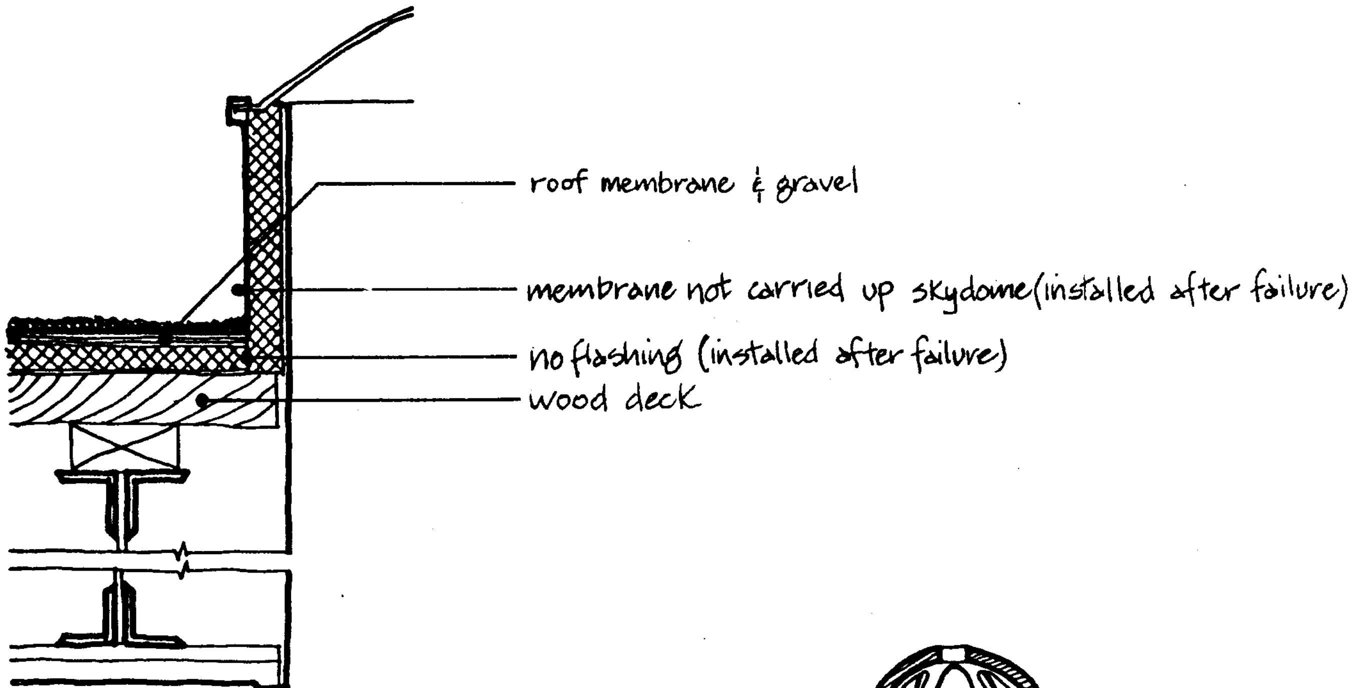


MT. HEALTHY SCHOOL: PONDING
FIGURE B.3

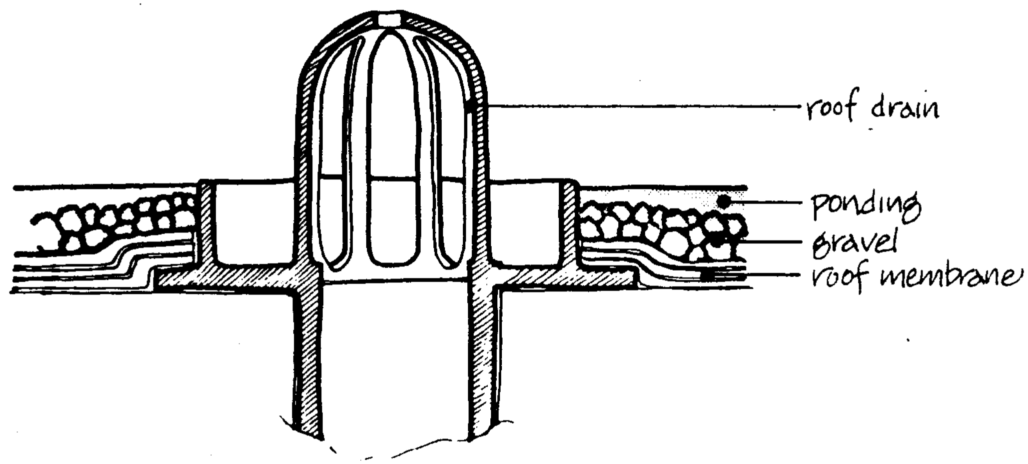


SMITH SCHOOL: PONDING

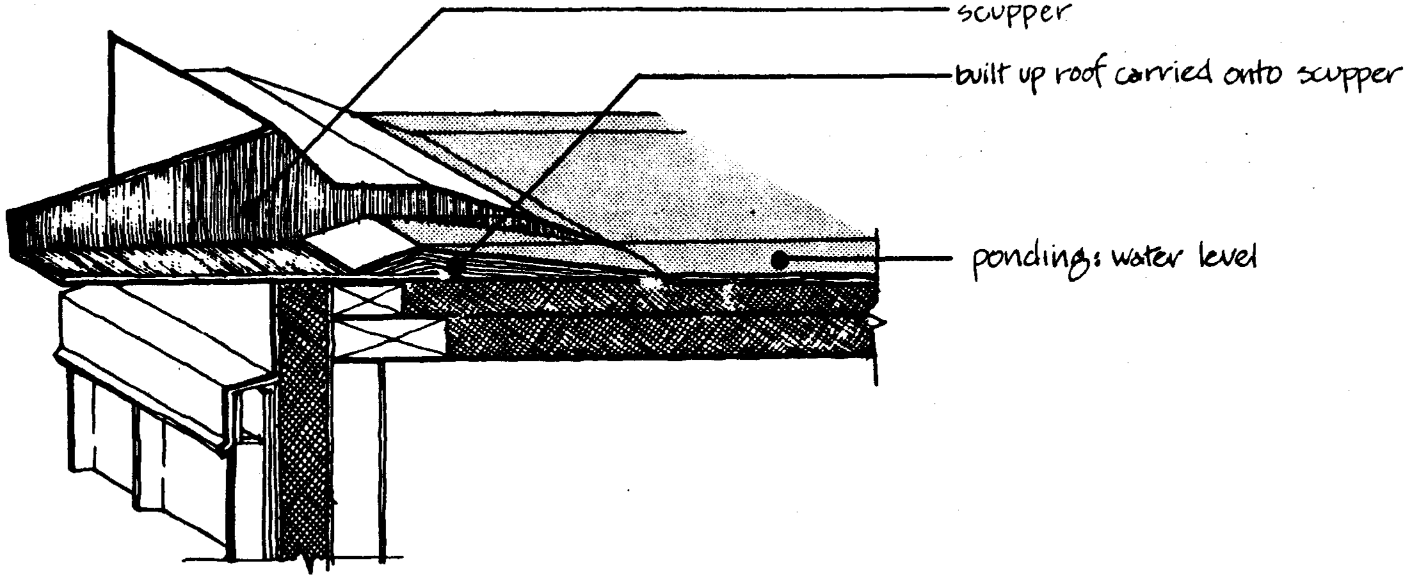
FIGURE B. 4



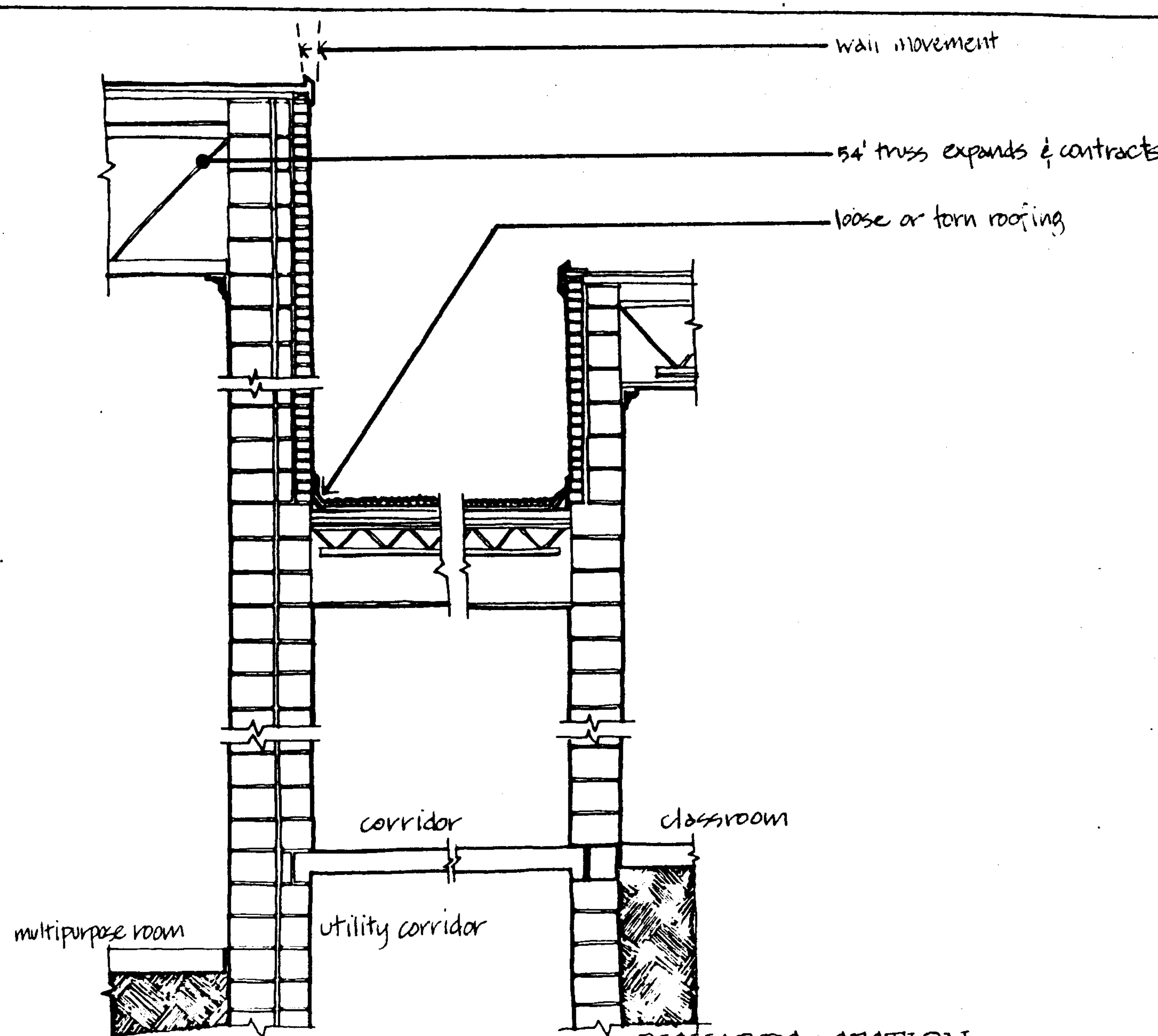
RICHARDS: SKYDOME
FIGURE B.5



RICHARDS: ROOF DRAIN
FIGURE B.6



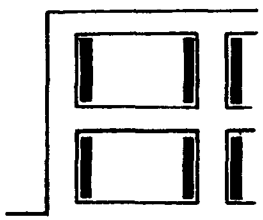
SMITH: SCUPPER
FIGURE B.7



RICHARDS: SECTION
FIGURE B.8

INTERIOR WALLS

INTRODUCTION



Many requirements affect the performance of the interior wall surface. Functional requirements of the enclosed space often require that equipment, furniture and other objects be attached to, hung from or abut the interior surface of the wall. As a membrane firmly attached to the load-bearing wall, it often displays tell-tale traces of undue movement before these are noticeable in any other part of the structure. Natural lighting and ventilation of the enclosed space, access to or egress from it, require openings of various dimensions and types, making its surface discontinuous. It must resist deterioration with age, and abuse as well as normal use. It must be maintainable and aesthetically pleasant. The extent to which these requirements are met will determine how well this subsystem performs. This subsystem, however, is not subject to the severe deterioration potential of exterior subsystems. Interior forces on the walls causing problems are rare and with routine maintenance this subsystem should perform well.

A variety of materials were used for the interior walls at the four schools studied, the most prevalant being painted concrete block. The exception is the Smith School in which gypsum wallboard mounted on metal studs was used.

This report concentrates on these predominant material types of such heavily-used areas as classrooms and corridors of each school. Limited application materials and less intensively-used areas of each school have been excluded, except where exceptional problems were encountered in their use.

METHOD OF EXAMINATION

A sample of classrooms, including more than 50% of each type and at least one from each grade level, was selected and studied in addition to the main common areas of the school and specialized areas such as the library, multi-purpose room, etc., thus ensuring a representative cross-section of room types.

Visual observation of the interior wall surface was the primary method of examination. Walls were examined for cracks, deflections and other indications of structural instability and attempts were made to correlate these findings with the location of expansion joints and known areas of exterior wall movement. The interior walls were also examined to determine if they provided sufficient support for attached loads.

Durability, water resistance, surface cohesion and general maintainability were checked by noting the type, extent and frequency of damage or change in the wall surface.

Equipment used to perform the tests: a four foot level to check for plumbness and deflection; a tape measure to determine the length of cracks; a small rule calibrated to 1/64 inch to measure the width and depth of cracks; various cleaning solutions to test staining and washability; and a camera used to record significant findings.

For a more detailed description of the testing procedures used refer to the Field Test Manual, 'Buildings In Use' Study, December, 1974

SUMMARY OF PERFORMANCE

	P	R	S	M
GYPSUM WALLBOARD				
Structural Stability	NA	NA	O	O
Wearability	NA	NA	O	O
Delamination/Cohesion	NA	NA	O	O
Water Absorption/Stain Resistance/Cleanability	NA	NA	O	O
Repair/Aesthetics	NA	NA	O	O
CONCRETE BLOCK WALLS				
Structural Stability	O	O	NA	NA
Wearability	O	O	NA	NA
Adhesion	⊙	⊙	NA	NA
Water Absorption/ Stain Resistance	O	O	NA	NA
Cleanability	O	O	NA	NA
INTERIOR WOOD TRIM				
Wear/Repair/Aesthetics	⊙	⊙	NA	NA

SUMMARY OF FINDINGS

In no school examined was there any serious technical problem with the interior wall. Some specific minor cracking was found but they are in no way detrimental.

The performance of white paint was found unsatisfactory (75%) in some locations. It quickly soils, stains and shows surface flaws requiring more frequent maintenance.

Wood trim around doors and windows at the Parkside and Richards Schools showed signs of wear, chipping and abrasion, indicating that wood does not perform satisfactorily in these instances. instances.

The interior walls at Smith Elementary School were generally in good condition. Interior wall surfaces at Parkside and Mount Healthy were found to be performing satisfactorily, at the 95% level.

DETAILS OF FINDINGS

GYPSUM WALLBOARD

GYPSUM WALLBOARD: STRUCTURAL STABILITY

Results: Performance was satisfactory at the Smith School--the only school which typically uses this material, though some hairline cracking does exist, these instances are insignificant from a performance standpoint.
Probable cause: Not applicable
Discussion: Not applicable. Of purely academic interest is a hairline crack, hardly noticeable, above the midpoint of the classroom. This seems to indicate a slight deflection at this point.

GYPSUM WALLBOARD: IMPACT RESISTANCE, SUPPORT FOR ATTACHED LOADS, INDENTATION, WEARABILITY

Results: Performance levels were acceptable at the Smith School
Probable cause: Not applicable
Discussion: Not applicable

INTERIOR GYPSUM WALLBOARD: DELAMINATION, COHESION

Results: Performance levels were generally satisfactoy (95%). However, instances of surface delamination of the gypsum wallboard occur in classroom walls.
Probable cause: The use of adhesive tape to hang wall displays, posters, etc. Removal of such tape often pulls paint off with it.
Discussion: No wall area is designed specifically for display and thus existing gypsum walls are used for this purpose. For further discussion of this issue, refer to the Display section of the Functional Factors Report, "Buildings In Use' Study, March, 1974.

INTERIOR GYPSUM WALLBOARD: WATER ABSORPTION, STAIN RESISTANCE, CLEANABILITY

Results: Performance levels at the Smith School were very satisfactory.
Probable cause: Not applicable
Discussion: Not applicable

INTERIOR GYPSUM WALLBOARD: REPLACEMENT/REPAIR, AESTHETICS

Results: Performance was acceptable at the Smith School.
Probable cause: Not applicable
Discussion: Not applicable

CONCRETE BLOCK WALLS

CONCRETE BLOCK WALLS: STRUCTURAL STABILITY

Results: Performance levels were satisfactory (95%) at Parkside and Mount Healthy. Performance levels of the interior walls were only adequate (85%) at Richards due to specific occurances of cracking.
Probable cause: Thermal expansion and contraction, shrinkage and construction are all possible causes.
Discussion: The concrete block wall interior at Parkside and Mount Healthy were found to perform satisfactorily. Discussion of extensive cracking in the Richards School can be found in the exterior walls section (A-6).

CONCRETE BLOCK WALLS: IMPACT RESISTANCE, COHESION, DELAMINATION, WEARABILITY, INDENTATION

Results: Performance levels were very satisfactory (95%) in all schools using this material.
Probable cause: Not applicable
Discussion: Not applicable

CONCRETE BLOCK WALLS: ADHESION

Results: Performance levels were generally satisfactory (95%), however, difficulty is experienced in mounting posters and displays on the concrete block walls.
Probable cause: Concrete block resists adhesive tape because of its surface texture and typically glossy painted surface.
Discussion: For further discussion, refer to the Display Section, Functional Factors Report, 'Buildings In Use' Study, March, 1974.

CONCRETE BLOCK INTERIOR WALLS: WATER ABSORPTION, STAIN RESISTANCE

Results: Performance levels were satisfactory (85%) at the Richards School. Some visible water staining has occurred at Mount Healthy (85%).
Probable cause: Interior of exterior wall was water stained, probably due to water infiltration.
Discussion: This seems to have been an isolated occurrence.

CONCRETE BLOCK INTERIOR WALLS: CLEANABILITY

Results: Performance was generally satisfactory (95%) at Parkside and Mount Healthy, but only adequate (85%) at Richards. A 'smudge' line between 2'-4' above floor level is easily

visible, especially in corridors. This line is lower in the lower grade corridor and higher in the upper grades.
Probable cause: Use of white paint on concrete block walls at Richards. Children's hands often run over this painted surface as they move through the halls.
Discussion: The use of white paint on both concrete block wall surfaces and wood trim, in that it soils and stains quickly and this requires more frequent cleaning and does not perform well in an elementary school. Brightly painted but darker colors between 1'-4' above the ground in the corridors would greatly improve this situation--reducing the frequency of cleaning and routine painting.

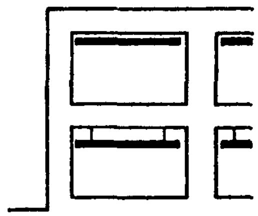
INTERIOR WOOD TRIM

INTERIOR WOOD TRIM: ABRASION, WEAR, REPAIRABILITY, AESTHETICS

Results: Performance of wood trim was only adequate (75-85%) at Parkside and Richards, showing signs of extensive wear, abrasion and chipping of paint. Performance was acceptable (95%) at Smith and Mount Healthy where metal trim was used.
Probable cause: Normal 'wear and tear' of an elementary school environment.
Discussion: The use of wood trim around classroom doors and windows (particularly on window sills as low as those at Parkside) was an inappropriate choice of material in such a high-intensity use facility as an elementary school. Parkside's oak trim is wearing better than Richards' white painted soft wood. The oak trim on the Parkside window sills is often stained because plants are placed upon them, leak, and oak stains readily when wetted. A clear plastic finish may prevent this occurrence.

CEILINGS

INTRODUCTION



Two generic types of exposed ceiling were examined in this study. The first is a relatively thin surface which is attached or hung from the structure. The second type forms the roof or floor deck besides acting as the finished ceiling.

While the ceiling has little direct relationship to classroom activities, it must be durable, maintainable and safe. Performance related to lighting and acoustics is included in sections F and G of this report. The extent to which the appropriate requirements are met determines how well this sybsystem performs. In general, this subsystem is less affected by outside forces than any other and its technical performance is usually high.

The ceiling of the Parkside School is primarily structural wood decking which is painted white. Richard's School on the other hand uses a finished white hung fiber acoustical ceiling which is not structural. The Smith School uses a thick aluminum pan ceiling finished on its exposed side which is also structural. This recently has had acoustical tile applied to it in many areas of the school. Mount Healthy uses an exposed structural fiber panel ceiling which acts as roof deck. It is unpainted on its exposed surface. Each type as described above is treated separately in the discussion of findings. Ceiling types with limited applications such as in kitchen and gymnasium areas are not included in this report.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Where further investigation was warranted, testing was performed. Equipment used was relatively simple: a level, tape measure and ruler graduated to 1/64 inch. A tension scale was used to test the stability and adhesion of the ceiling. A camera was used to record significant results. A more detailed description of testing procedures used can be found in the <u>Field Tests Manual</u>, 'Buildings In Use' Study. December, 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
WOOD DECK				
Replacement/Repair	O	NA	NA	NA
Out of System Hardware	O	NA	NA	NA
All other considerations	O	NA	NA	NA
ACOUSTICAL TILE				
Deflection/Displacement	NA	⊙	⊙	NA
Cohesion/Adhesion	NA	O	⊙	NA
Indent/Scratch/Stain	NA	⊙	O	NA
Color/Flaking/Fading	NA	⊙	O	NA
Replacement/Repair	NA	●	●	NA
RIGID FIBER PANELS				
Deflection/Displacement	O	NA	NA	O
Cohesion/Adhesion/ Indent/Scratch/Stain	O	NA	NA	⊙

SUMMARY OF FINDINGS

Performance levels of the various ceiling materials studied were very satisfactory (85-95% level). This subsystem is usually not affected by outside forces and thus its performance is typically at a high level.

The Parkside School ceiling had the best performance of any school examined. A close examination of the subsystem showed virtually no problems.

Serious problems occur at the Richards School and are caused by the leaking roof. Performance required by this subsystem does not include resistance to such undue causes and thus the lack of cohesion and the staining of this subsystem does not therefore constitute detrimental performance. However, while the aluminum pan ceiling at the Smith School performs well (85%), acoustical problems (see section G) have necessitated attachment of fiber acoustical tile to this aluminum ceiling in many areas.

At the Mount Healthy School, a relatively new facility, the ceiling has satisfactory performance (95%), though in some places it has been saturated by roof leakage it has retained stability and cohesiveness.

DETAILS OF FINDINGS

WOOD DECK

WOOD DECK/PARALLEL TO FLOOR, DEFLECTION AND DISPLACEMENT, COHESION, ADHESION, INDENTATION, SCRATCH, STAIN, COLOR HOMOGENITY, FLAKING, PEELING, DUST ACCUMULATION, CLEANABILITY

Results: Performance was satisfactory in all of the above attributes of the Parkside School ceiling.
Probable cause: Not applicable
Discussion: Not applicable

WOOD DECK/REPLACEMENT, REPAIR

Results: Some minor staining and deterioration is present (85%).
Probable cause: Rare incidents of water penetration through the roof.
Discussion: Previous incidents of leakage have occurred which have caused some problems with the ceiling which have not been repaired or repaired incorrectly. We feel these are not continuing problems and that performance is acceptable.

WOOD DECK/OUT OF SYSTEM HARDWARE

Results: Performance is satisfactory. Electrical conduit is exposed on the classroom ceilings.
Probable cause: No available plenum space
Discussion: The electrical conduit used to supply ceiling luminaries is exposed, however, this does not cause a reduced level of performance.

ACOUSTICAL TILE

ACOUSTICAL TILE/PARALLEL TO FLOOR, DEFLECTION, DISPLACEMENT

Results: Performance is unsatisfactory (75%) in a few areas of the Richards School. Ceiling tiles have become displaced.
Probable cause: The suspension system used makes replacing tile difficult.

Discussion: A 'Z' spline type of suspension system was used which does not allow the easy replacement of one or a few tiles because tiles and splines interlock on all sides. The ad hoc solution used-cutting the 'tongue groove' edge of a tile off and fitting in one tile-will usually loosen in time because of the tenuous fit and visibily 'tilt' in the ceiling. This is not judged harmful but usually is quite evident.

ACOUSTICAL TILE/COHESION, ADHESION

Results: Performance level marginally acceptable (75%) at the Smith School (replacement tiles) and acceptable at the Richards School (85%).
Probable Cause: Replacement tile is being adhesively applied to the ceiling of the Smith School to solve acoustical problems. In some instances the tiles are falling because the painted surface of the aluminum pan to which they are adhered is delaminating from the metal.

ACOUSTICAL TILE/INDENTATION, SCRATCH, STAIN

Results: Performance is satisfactory. Staining occurs at the Richards School.
Probable cause: The staining of the ceiling tile is due to extensive leakage through the roof carrying dirt and rust.
Discussion: The water penetration through the roof membrane, which is described in more detail in the roof section of this report, has caused extensive damage to the ceiling. Attributes of this subsystem do not include resistance to such undue incidents and thus have been rated satisfactory. Tiles have been replaced (11-'74).

ACOUSTICAL TILE/COLOR HOMGENEITY, FLAKING, FADING

Results: Performance was satisfactory (85-95%) for these attributes.
Probable cause: Not applicable
Discussion: Not applicable

ACOUSTICAL TILE/REPLACEMENT, REPAIR

Results: Performance in the attribute of replacement is unsatisfactory (below 75%) at the Richards School.
Probable cause: The suspension system creates problems in replacing ceiling tile and the future performance of that tile.
Discussion: A "Z" spline ceiling system which uses 'z' shaped splines 12" on center to which the ceiling tiles are attached and the spline system is not visible is used. Due to the nature of this system it is extremely difficult to replace a single ceiling tile.

RIGID FIBER PANELS

RIGID FIBER PANELS/DEFLECTION, DISPLACEMENT

Results: Performance was satisfactory at the Mt. Healthy School.
Probable cause: Not applicable
Discussion: Not applicable

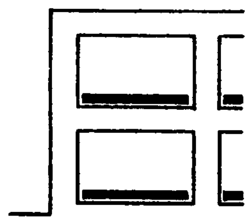
RIGID FIBER PANELS/COHESION, ADHESION, IDENTATION, SCRATCH, STAIN

Results: The performance at the Mount Healthy School was satisfactory. Cohesion performance of panels subject to water penetration through the roof membrane has been good.

Probable cause: Water penetration through the roof membrane has caused staining in some locations.
Discussion: The staining is only visible if the ceiling is inspected closely. The color of the panels (brown) and their textured pattern effectively camouflages existing staining.

FLOORS

INTRODUCTION



The finished floor is a membrane attached to the surface of the floor or subfloor which provides a surface suitable for use by the occupants of the facility. It is the only subsystem with which there is universal and continuous contact by user as well as by fixed and movable furnishings and equipment.

The primary concern of this subsystem is durability throughout its useful life: unattached objects naturally gravitate to it, often with considerable impact; it bears heavy static loads of long duration and it must resist the abrasive action of user circulation; it must withstand the effects of high strength chemical agents and possible deteriorating effects emanating from the structural subfloor on which it rests; in addition to these required qualities of durability it should not inhibit activities which occur on it while remaining easily maintainable and aesthetically pleasing. The extent to which these requirements are met determines how well this subsystem performs.

Three materials were primarily used on the four schools studied: finished concrete with a poured plastic composition flooring, resilient tile and carpeting. Limited use applications such as quarry tile in kitchen areas and wood gymnasium floors are not included in this study.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Appropriate field tests in the areas of staining, slip resistance and scratch resistance were used. The equipment used to perform field tests was simple: a level, tape measure and small ruler graduated in 65ths of an inch. Cleaning and staining soulutions were used where appropriate as was slip resistance apparatus. A camera was used to record examples of problems. For a more detailed description of the testing procedures used refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
RESILIENT TILE				
Indentation/Impact	O	⊙	NA	NA
Resiliency	O	O	NA	NA
Brittleness/Cohesion/ Adhesion	O	O	NA	NA
Scratch/Wear	O	O	NA	NA
Slip Resistance	O	O	NA	NA
Cleanability/Dust	O	O	NA	NA
Water Absorption/ Delamination	O	O	NA	NA
Replacement/Repair	⊙	O	NA	NA
Cigarette Burn/Color	O	O	NA	NA

	P	R	S	M
CARPETING				
Indentation/Impact/ Resiliency	NA	NA	○	○
Adhesion	NA	NA	○	●
Wear	NA	NA	⊙	⊙
Static Discharge	NA	NA	○	○
Cleanability/Dust	NA	NA	○	○
Water Absorption/Stain/ Color Fastness	NA	NA	○	○
COMPOSITION FLOORING				
All Attributes	NA	NA	○	NA

SUMMARY OF FINDINGS

Performance levels of the various flooring materials used in each of the four schools studied was generally satisfactory with most functioning at the 85% performance level in terms of the overall characteristics of durability, maintainability and appearance.

A few instances of minor deterioration of the resilient tile flooring were found. Replacement tiles at Parkside do not match the original color and pattern.

The performance of carpeting in the area of durability was satisfactory (85%) with the exception of specific highly-trafficked locations. Some instances of fading, staining and seam tearing occurred at the Smith School (75%). The carpeting at Mt. Healthy, a relatively new facility was in superior condition (95%) with some minor wear problems. Advances in carpeting materials in the last 10 years may make a significant difference in performance. Recently installed carpeting is very superior in performance to earlier products.

DETAILS OF FINDINGS

RESILIENT TILE

RESILIENT TILE/INDENTATION, IMPACT

Results: Performance levels were satisfactory at the Parkside School (85%). Some instances of minor permanent indentation is present in the Richards School classrooms, with the resilient tile performing at the 85% level.
Probable cause: Long term static loads (e.g., table legs) have caused depressions in the floor tile at the Richards School. Short term static loads cause no permanent set.
Discussion: Resistance to long term loading is a key performance specification for resilient floor tile. At Richards, the tile used did not perform to required levels although in other respects it is performing well. Indentations found were in the 1/32"-1/64" range and visible from 5'. While this is not detrimental to activities or safety, it will probably tend to shorten the useful life of this finished floor.

RESILIENT TILE/RESILIENCY

Results: Performance levels were satisfactory at all schools.
Probable cause: Not applicable.
Discussion: Not applicable.

RESILIENT TILE/BRITTLENESS, COHESION, ADHESION

Results: Performance, in regard to brittleness, was acceptable (85% level) at Parkside and at Richards with specific instances of very minor problems. Performance, in regard to cohesion and adhesion, was satisfactory (95% level) at all schools.
Probable cause: Cracking due to tile bending over openings in the subsurface.
Discussion: Resilient tile is brittle and must not be subjected to excess bending. At two locations in the Richards School the tile has been subjected to bending and, as a result, has

cracked. One such location is the lower end of a ramped surface; the other is at the exterior wall. This latter condition is due to a portion of the tile resting on packed exterior wall insulation which is not able to support it.

At Parkside, resilient tile has cracked at expansion joints in the concrete subfloor which occur at the entrances to the classrooms. All of the instances at both schools are minor, being either too small to affect safety or in locations which do not bear traffic. It should be noted that these minor conditions often occur because of constructional procedures and their effect on the subsurface.

RESILIENT TILE/SCRATCH, WEAR

Results: Performance was acceptable at Parkside. A somewhat lower level of performance was judged to be found at Richards.
Probable cause: Unknown
Discussion: This is difficult to measure and in fact may be due to the color and pattern and not to actual 'in use' performance. However, the indentation found at Richards and not at Parkside (though Parkside is 4 years older) makes the Richards tile suspect as being somewhat 'softer'.

RESILIENT TILE/SLIP RESISTANCE

Results: Performance levels are satisfactory (85%) at the schools examined.
Probable cause: Not applicable.
Discussion: Not applicable.

RESILIENT TILE/CLEANABILITY, DUST ACCUMULATION

Results: Performance was very satisfactory (95% level) at both schools examined.
Probable cause: Not applicable.

RESILIENT TILE/WATER ABSORPTION, DELAMINATION

Results: Performance was very satisfactory (95% level) at both schools studied in these areas.
Probable cause: Not applicable.
Discussion: No evidence of damage due to water absorption was discovered, even in areas most susceptable. A waxed surface is used, and most liquids cannot penetrate such a surface.

RESILIENT TILE/REPLACEMENT, REPAIR

Results: Performance was satisfactory at Richards (95% level) but unacceptable (75% level) at Parkside.
Probable cause: An adequate supply of the original tile was not furnished for replacement and repair.
Discussion: The original tile pattern and thickness is no longer available. Although the need for replacements has been limited, they are evident because of the pattern and color differences (2 thicknesses of tile are used to make up the difference in depth). This has only an aesthetic effect, however, and is in no way detrimental to technical performance. An adequate supply of replacement tile (5-10% extra) should be available for the useful life of the floor.

RESILIENT TILE/CIGARETTE BURN, COLOR FASTNESS, COLOR HOMOGENEITY

Results: Performance was at a very high level (95%) in both schools.
Probable cause: Not applicable.
Discussion: Smoking is not allowed in either school. The tiles used were homogeneous and do not show wear easily. Color fastness, even in areas exposed to direct sunlight, is satisfactory.

CARPETING

CARPETING/INDENTATION, IMPACT, RESILIENCY

Results: Performance levels were acceptable (95%) at the Smith and Mount Healthy Schools.
Probable cause: Not applicable.
Discussion: Not applicable.

CARPETING/ADHESION

Results: Performance was satisfactory at Mount Healthy (95%). At Smith, classroom carpeting is unravelling at its seams (75%) in a significant number of instances.
Probable cause: Result of improper installation.
Discussion: Carpet seams are taped, rather than sewn, and in a few locations have torn loose. Wide bands of tape have been used to cover the ravelling and prevent further damage and this is readily apparant. This condition should be corrected.

CARPETING/WEAR

Results: Performance levels are adequate at Mount Healthy and in the classrooms at Smith (85%). Carpeting on the ramps is wearing excessively at Smith (below 75%). Carpeting on the nosings in highly trafficked stairs is showing wear at Mount Healthy after only 2 years.
Probable cause: A type of carpeting (indoor-outdoor) was specified which does not withstand the intense usage in the corridors. Nosings of stairs get very high wear.
Discussion: After some 7 years of intensive use, the carpeting at the Smith School shows excessive wear and will soon need to be replaced. The wear on the nosings of the Mount Healthy stairs is considerable taking into account the short period of use (2 years) but not unexpected. This area carpeting will need to be replaced considerably before the rest of the building's carpeting. Whether any carpeting will wear well on the nosing should be investigated. Carpeting on the 'big steps' at Mount Healthy is wearing well; however, the nosings on the ends of the steps which attracts most traffic shows early signs of wear and will need to be replaced before the rest of the carpeting.

CARPETING/STATIC DISCHARGE

Results: Performance levels were satisfactory at Mount Health and unsatisfactory (below 75% performance) at Smith.
Prabable cause: Accumulation of static electricity through walking. Discharge to metal.
Discussion: Nylon, the material specified for the Smith School carpet is one of the worst in terms of static discharge performance. This may not be a problem if humidity control (above 60%) were present; however, the HVAC system does not provide this control.

CARPETING/CLEANABILITY, DUST ACCUMULATION

Results: Performance was satisfactory at all schools using carpeting.
Probable cause: Not appicable
Discussion: Minute particles retained by carpeting are a source of excessive wear. No evidence of such problem exists in the shcools studied probably due to the adequacy of the routine maintenance.

CARPETING/WATER ABSORBANCY, COLOR FASTNESS, STAIN

Results: Performance was generally satisfactory at the Smith and Mt. Healthy Schools. Any failures found are caused by undue outside forces. Some isolated fading is present at the Smith School.
Probable cause: Water penetration at the Mt. Healthy School has caused failure of the carpeting in one area. This carpeting has already been removed and was not examined in this project. Excessive staining of the ramp carpeting has occurred at the Smith School due to undue water penetration at the lower end of the sloped ramps. Color fading at the Smith School is very minor.
Discussion: The staining and the water absorbancy occurrences are the result of unusual and undue forces which this flooring is not made to resist. In terms of normally expected performance, especially in areas of potential problems (e.g., around classroom sinks) carpeting performed at quite satisfactory levels. For instance, carpeting below the cafeteria counter at Mount Healthy showed little staining. This most vulnerable spot indicates a high level of performance. The dark colors used and the presence of pattern also give positive effects in this area.

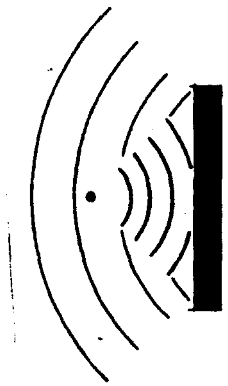
COMPOSITION FLOORING

COMPOSITION FLOORING/ALL ATTRIBUTES

Results: Performance was satisfactory for all characteristics of this material which was used in the heavily trafficked nodule areas of the Smith School. It is wearing very well and is well maintained. This is a clear finish and does show imperfections in the concrete structural floor.
Probable cause: Not applicable.
Discussion: The uneven coloring of the floor due to the finish of the structural floor below is consistant with the architect's intention in the design of a 'brutalist' building.

ACOUSTICS

INTRODUCTION



The acoustical environment of a space is a product of the physical geometry of that space, the acoustical properties of the materials of which it is constructed, and of the type and intensity of use.

At any time of day a typical elementary school contains areas which are quiet and areas of intense activity. In any area or room there is the potential to generate more noise than the activity, as well as, adjacent occupancies, can accept. It is important that classrooms and other areas be essentially sound absorptive, rather than sound reflective, so that diverse activities can occur simultaneously witout mutual interference.

An enclosed space has three primary characteristics which determine the quality of the acoustical environment. These are:

- Ambient sound level, which measures the amount of existing background noise;
- Reverberation time, which measures the tendency of sound to 'dwell' in the space (its decay time); and
- Attenuation, which indicates the loss of intensity of sound transmitted over distance or through a wall.

Determining, by direct measurement, the behavior of individual spaces within each of the schools in regard to these three criteria and comparison with accepted standards of acoustical performance results in an indication of the acoustical quality of the school environment.

METHOD OF EXAMINATION

Two methods of acoustical examination were used in this study. Ambient noise and attenuation tests were performed in the classrooms and corridors primarily using a Bruel & Kjaer Type 2203 precision sound level meter equiped with a Type 1613 octave band analyzer. White noise for determining sound transmission was provided on a pre-recorded casette tape. These measurements provided a basis for analytic comparisons of classroom acoustics and the transmission characteristics of the interior walls, both within and between the various schools, to accepted standards.

Bolt, Beranek and Newman, Inc., was retained to measure and analyze reverberation time, particularly of spaces in excess of 2000 square feet.

The results of these testing procedures are presented in graph form in the following section, Detailed Findings. For a more detailed descritpion of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study. December, 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
AMBIENT NOISE				
Unoccupied Classroom	○	○	○	○
Unoccupied Large Spaces	○	○	○	⊙
Occupied Classroom	○	○	○	○
Occupied Large Spaces	⊙	⊙	○	○
Lighting and Mechanical Equipment	⊙	○	○	⊙
TRANSMISSION				
Between Classrooms	⊙	○	○	NA
Hallway/Classrooms	⊙	⊙	⊙	NA
Multipurpose Room/ Classroom	NA	⊙	NA	NA
REVERBERATION				
Classroom	○	○	○	○
Large Spaces	●	●	⊙	○

SUMMARY OF FINDINGS

LEARNING AREAS (UNDER 2000 SQ.FT.)

Classroom acoustics in all the schools is almost entirely adequate. Ambient sound levels are loud enough to provide 'masking' of minor noises and low enough to prevent interference with learning activities. Room-to-room sound isolation is satisfactory, although one school does have a somewhat lower level of performance. Sound isolation between the hallway and classrooms was found to be only marginally adequate (75-85%), however.

At Richards school, a centralized multi-purpose room and the high sound levels generated there does interfere with adjacent classrooms which, because of their curricular needs, tend to leave their doors open. In the other schools the multi-purpose/gym is not adjacent to classrooms.

High reverberation times were found in the large, double (30 ft. x 60 ft.) Smith classrooms due to a 'hard' metal pan ceiling, the carpeting on the floor notwithstanding. That ceiling has since been replaced by acoustically-absorbant ceiling tiles which have reduced reverberation to within acceptable limits. Smith's smaller classrooms have the original metal pan ceilings and reverberation times there are somewhat higher than at the other schools, although still within acceptable limits. At the Parkside School the mechnical noise (ballasts) were judged too noisy in classroom areas.

LARGE AREAS (OVER 2000 SQ.FT.)

Room-to-room transmission is the only area of adequate performance for large activity areas.

High ambient noise and high reverberation times are present in almost all large spaces, primarily because of inadequate sound absorption. The Richards and Parkside multi-purpose rooms have the greatest problems because:

a) acoustical inadequacies, in terms of ambient noise and reverberation time, are much more pronounced than at the other schools; and

b) both spaces concerned being multi-purpose spaces, a variety of activities with a wide range of acoustical requirements are programmed to occur in them. Alternate spaces do not exist.

The above problem also exists at the Smith and Mount Healthy Schools. However, because the inadequacies of the acoustical environments are less pronounced and because other areas of these schools can be programmed for assemblies, meetings, drama, etc., the effects of these inadequacies are minimized and performance is more acceptable because the criteria are not so strict.

DETAILS OF FINDINGS

AMBIENT NOISE

AMBIENT NOISE/UNOCCUPIED CLASSROOM

Results: Ambient noise within acceptable limits (NC 35+ 5 db for traditional classrooms, NC 45+ 5 db for open classrooms).
Probable cause: Not applicable.
Discussion: Ambient noise levels should neither be too high, causing noise which interferes with clear hearing, not too quiet, an environment in which you can hear 'a pin drop'. Mechanical systems and lighting equipment provide most of this ambient 'background' noise level.

AMBIENT NOISE/UNOCCUPIED LARGE SPACES

Results: On the whole, large spaces fall within acceptable limits with the exception of the gymnasium at the Mount Healthy School where noise levels exceeded 62-63 DBA (75-85% performance).
Probable cause: Very loud ceiling mounted HVAC equipment within the space.
Discussion: Notwithstanding that this area is used only for gym-type activities, the background noise created by the mechanical equipment is above acceptable levels, making communication difficult even for such typically loud activities as gym classes.

AMBIENT NOISE/OCCUPIED CLASSROOM

Results: Within acceptable limits
Probable cause: Not applicable

Discussion: At the Mount Healthy School, the higher ambient noise levels reflect the children's activities added to the background ambient noise levels. An open classroom building, such as Mount Healthy, requires more 'masking' noise than a traditional school. The carpeting and exposed mineral fiber ceiling provides the absorption necessary to prevent unacceptable noise levels.

AMBIENT NOISE/OCCUPIED LARGE SPACES

Results: Satisfactory at Smith and Mount Healthy (85% performance). Occupied ambient noise levels at Parkside and Richards are much too high, especially during lunch-time and physical education activities (below 75% performance level).
Probable cause: Lack of absorptive surface materials.
Discussion: Originally built without absorptive materials, the gymnasium at the Smith School was extensively resurfaced with acoustical tile a year prior to this study, apparently with good results. The ambient noise levels reached at the unimproved older schools (Parkside and Richards) severely affect communication and other activities in the same area. The peak ambient noise levels found in the multi-purpose rooms of these two schools, 90-100+ dbA, are severe enough to cause severe discomfort, and even pain. Other problems also occur because of this lack of absorptive surface.

AMBIENT NOISE/LIGHTING AND MECHANICAL EQUIPMENT

Results: Satisfactory in all schools except Parkside where increases in ambient levels in a few classrooms (3-6 dbA resulting in approximately 40 dbA) do interfere with normal classroom communication (75-85% performance). Frequency of this distinct humming is in the normal speech range.

Probable cause: Loud humming lighting ballasts cause this increase in ambient levels.
Discussion: The flourescent ballasts were either specified incorrectly to begin with or have deteriorated in performance with age. The latter reason is most likely - the ballasts are 13 years old.

While the sound levels produced are not detrimental at these levels (approximately 40 dbA unoccupied) it is necessary to 'talk over' this background noise which is rather distinct. While it is an unconscious and easily made adaptation, is not the preferred condition.

TRANSMISSION

TRANSMISSION/BETWEEN CLASSROOMS

Results: Transmission of sounds between classrooms is within acceptable limits in all schools.
Probable cause: Not applicable.
Discussion: While attenuation between classrooms is lower at Parkside due to acoustical 'leaking' at the laminated beams, this transmission between spaces does not cause any difficulty in classroom situations. The transmitted sound is 'masked' by existing occupied ambient noise. Mount Healthy, with no walls between 'classrooms', was excluded from this test.

Note: The extension of the block partition above the hung ceiling at the Richards School was quite effective in reducing transmission through the ceiling cavity.

TRANSMISSION/HALLWAY/CLASSROOMS

Results: In the three schools studied which have partitions between hallway and classrooms, performance was found to be marginally adequate (75-85%). Sound is definitely transmitted to the classroom from the hallway (6-12 dbA at ambient level).
Probable cause: In each case an open grillwork is provided for return air from classrooms to centralized return grills in the corridors.
Discussion: Not an unexpected result under these design conditions. A direct path exists between source and receiver room. The traditional nature of the schools, where interference from the corridors is not expected adds to this problem. However, since corridors contain few or no 'activities' the situation is ameliorated.

TRANSMISSION/MULTIPURPOSE ROOM/CLASSROOM

Results: Richards School. Excessive transmission between the multi-purpose room and adjacent classrooms, notwithstanding the corridor between them.
Probable cause: Centralized location of the multi-purpose room proximate to the classrooms with intensive use generating high ambient noise levels in the multi-purpose room with little sound absorption. Curricular needs require doors between the multi-purpose room and the classrooms remain open to their mutual corridor.
Discussion: This problem is inherent in the concept of the centralized multi-purpose room used at Parkside. Careful acoustical treatment is necessary to prevent and correct this problem.

REVERBERATION

REVERBERATION/CLASSROOM

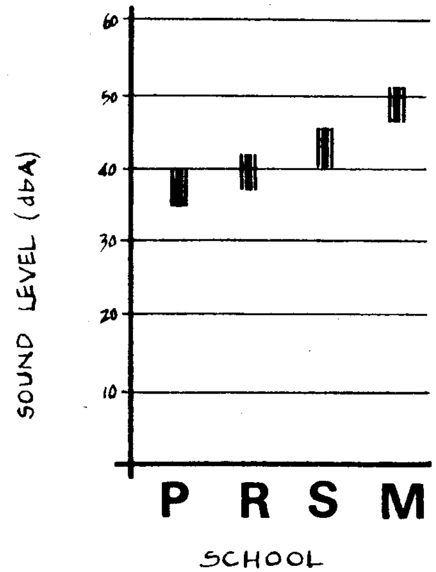
Results: Reverberation is within acceptable limits in all classrooms.
Probable cause: Not applicable.
Discussion: Just prior to the beginning of our study, the six double classrooms at the Smith School had their metal pan ceilings covered with acoustical tile. Based on the existing conditions and considering the previous ceiling finish--exposed metal pans--the original reverberation time would have been in excess of recommended standards. Significantly, in the single classroom at Richards which has not had such tile installed, the reverberation time borders on the limit of acceptability.

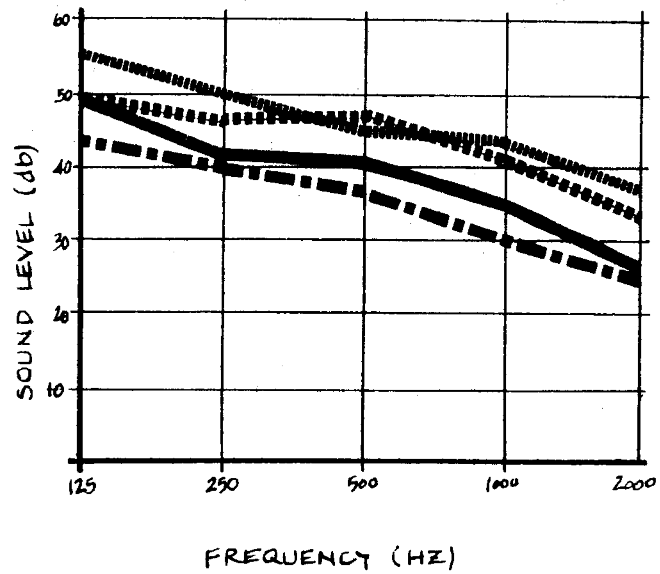
REVERBERATION/LARGE SPACES

Results: Severe problems in the Parkside and Richards multi-purpose rooms. Previously severe problem at Smith has been corrected. Acceptable conditions at Mount Healthy.
Probable cause: Large volume rooms (80,000 cubic feet) with hard surfaces and a lack of acoustically-absorptive materials.
Discussion: Reverberation time varies directly with the volume and indirectly with the amount of acoustically-absorptive material present. Therefore, large spaces with acoustically 'hard' surfaces have the greatest potential for problems in this area. The Parkside and Richards Schools have virtually no absorption in their large multi-purpose areas and, consequently, very severe reverberation problems. This is affirmed in the responses to a questionnaire given the teachers in both schools. Acoustical problems are so severe as to render these spaces useless for lectures, dramatics and other presentations.

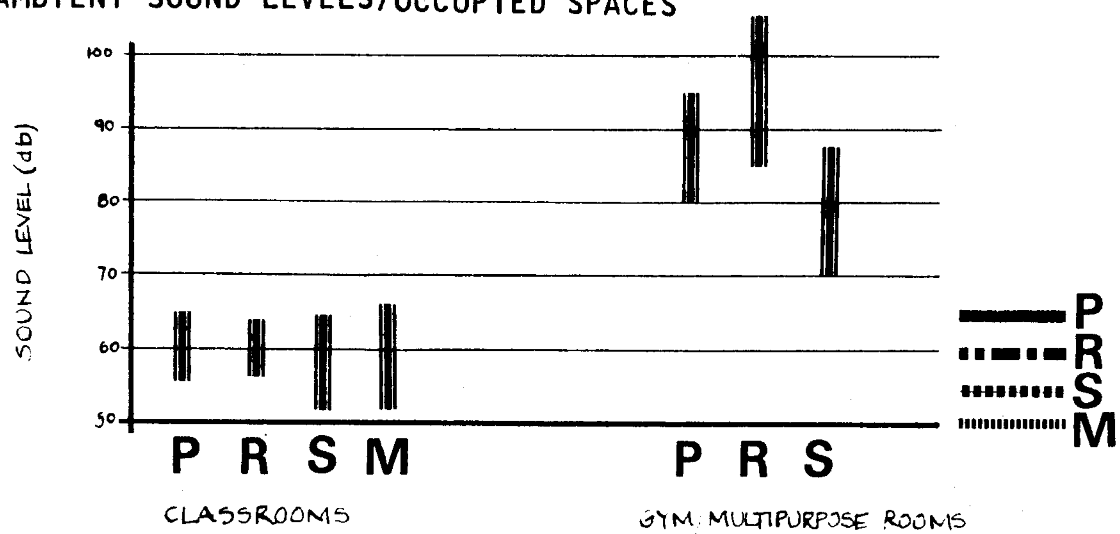
The multi-purpose room at Smith had extensive acoustical treatment prior to the beginning of this study, and present reverberation time is satisfactory although we are most certain this was not the case previously. Mount Healthy's gymnasium, with an exposed mineral tile ceiling, does have enough absorption to provide adequate performance.

F.1 AMBIENT SOUND LEVELS/UNOCCUPIED CLASSROOMS

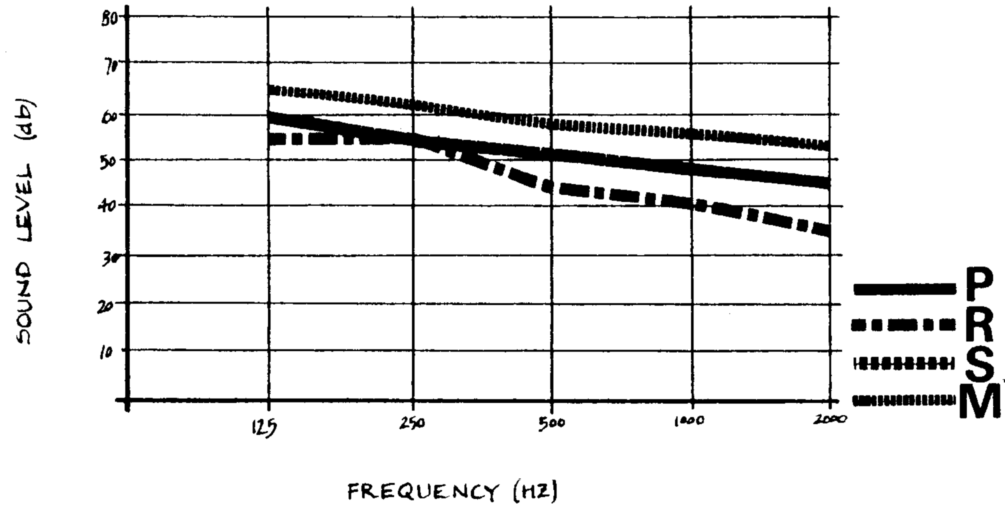




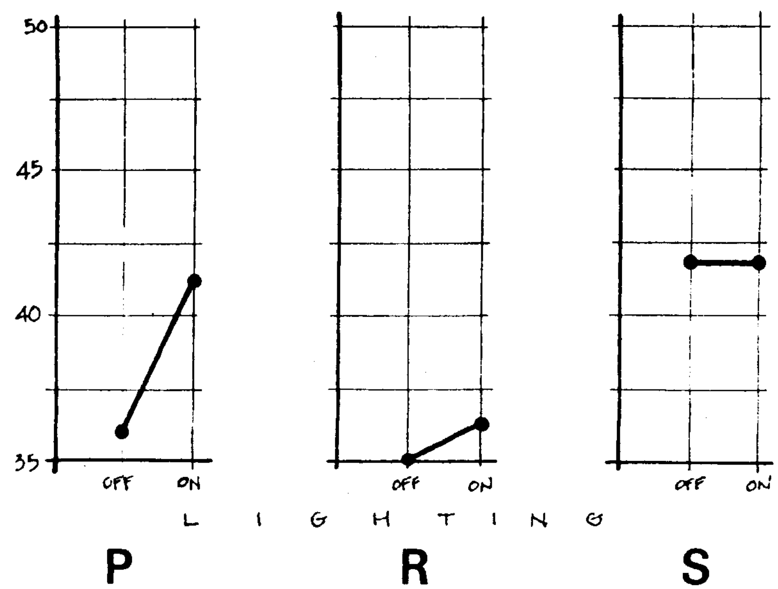
F.2 AMBIENT SOUND LEVELS/OCCUPIED SPACES



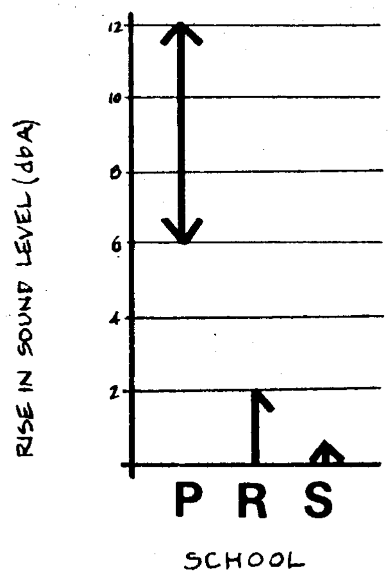
F.3 AMBIENT SOUND LEVELS/GYMS-MULTIPURPOSE ROOMS/UNOCCUPIED

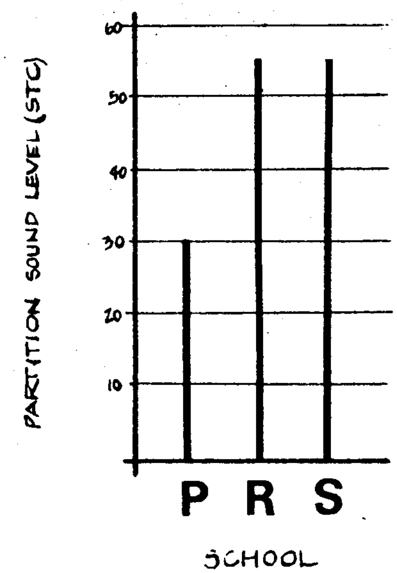


F.4 AMBIENT SOUND LEVELS/LIGHTING BALLAST

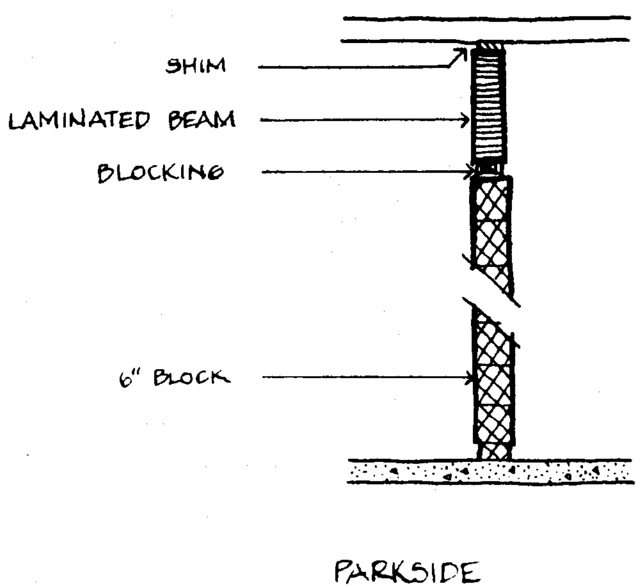


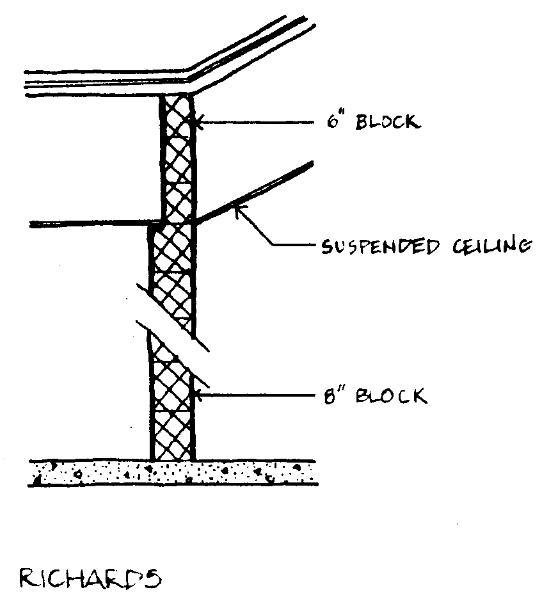
F.5 TRANSMISSION BETWEEN CLASSROOMS



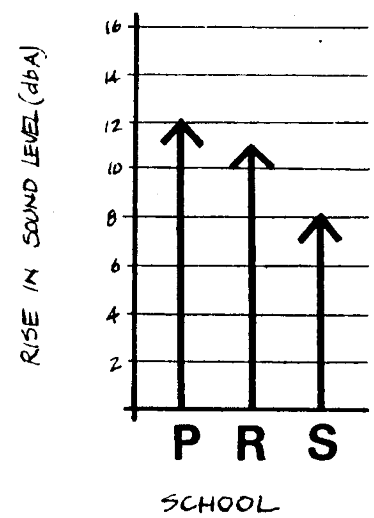


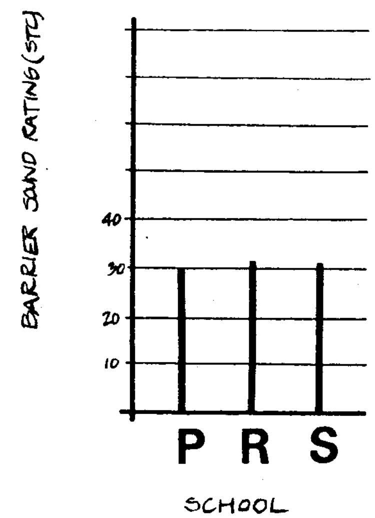
F.6 WALLS BETWEEN CLASSROOMS/SECTION



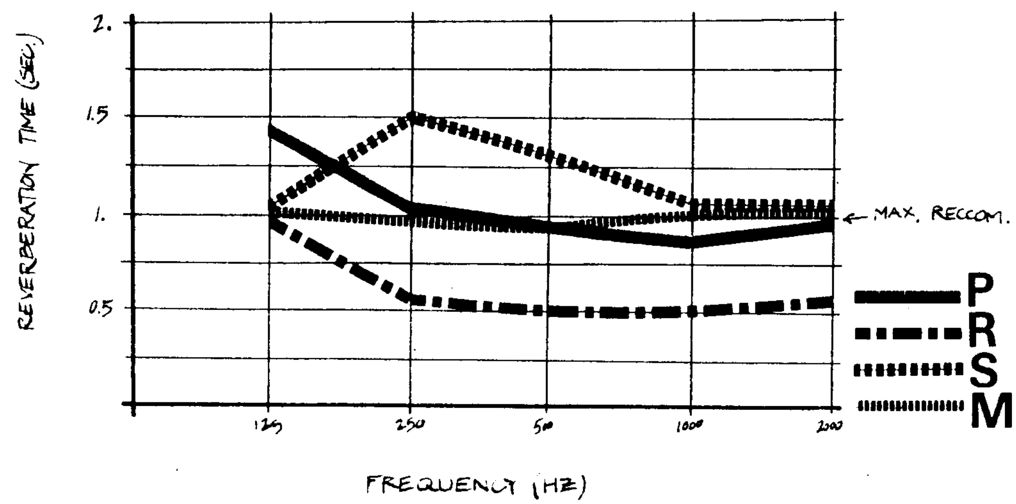


F.7 TRANSMISSION: HALLWAY/ CLASSROOM

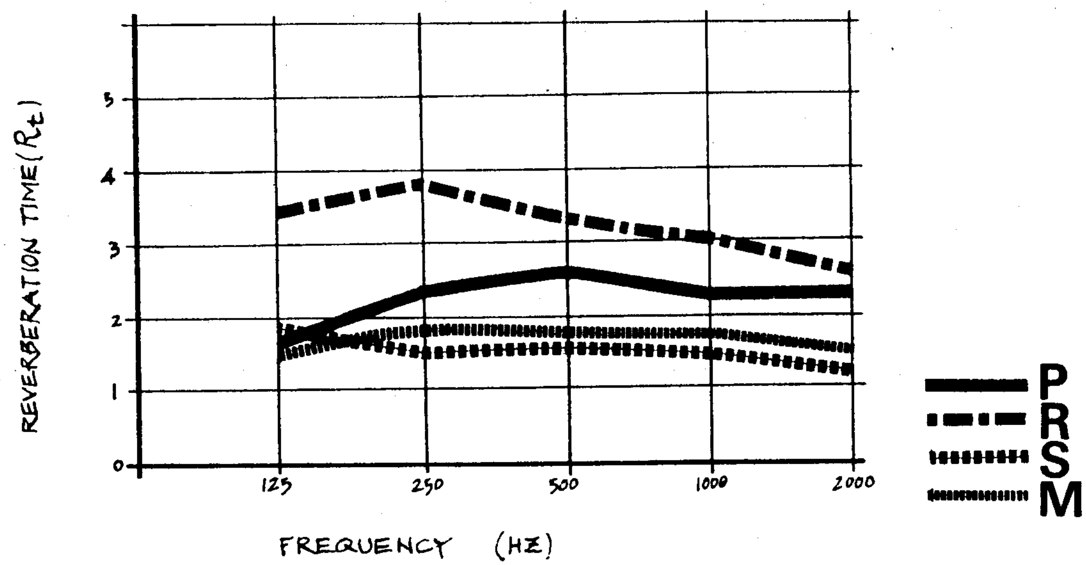




F.8 REVERBERATION/CLASSROOMS

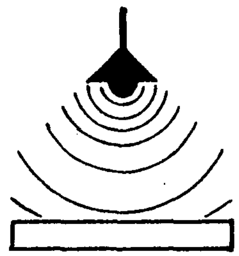


F.9 REVERBERATION : GYMS/MULTIPURPOSE ROOMS



LIGHTING

INTRODUCTION



Artificial and natural lighting provide the visual environment necessary for typical classroom activities. The performance of this visual environment is determined by a number of factors acting together: the quantity of light, the type of task, room brightness ratios, direct and reflected glare, and contrast rendition of the task surface. The quantity of illumination, which is the most common measure, alone is not a valid measure of lighting quality. In fact, improperly designed, a higher quantity of light can have a detrimental, rather than a beneficial, effect on occupants.

Unlike other technical factors included in our study which produce easily-recognizable and sometimes severe problems, improper lighting design produces eye strain, fatigue and discomfort which would be easily noticeable and attributable only under the most extreme conditions. The more subtle effects are difficult to pinpoint, but nonetheless affect the user.

Our criteria for good lighting design are taken from sources which include all the above mentioned factors and which should eliminate adverse physiological effects. Determining the performance of each of these characteristics and comparing these with recommended standards should produce a good indication of the quality, as well as the quantity, of lighting in the existing classrooms environments.

METHOD OF EXAMINATION

Measurements of the quantity of light (in classroom areas, only) were made with a General Electric Type 213 Light (foot-candle) Meter. Other measurements requiring luminance (foot-lamberts) readings were performed with Minolta and Honeywell (1°) spot meters. Measurements were made during different weather conditions and with the window shades in different positions. For a detailed description of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study, December, 1974.

SUMMARY OF PERFORMANCE

LIGHTING	P	R	S	M
Illumination	○	⊙	○	⊙
Room Contrast Ratios	●	⊙	●	○
Glare	●	⊙	●	○
Task/Immediate Surround Contrast Ratios	○	○	○	○
Darkened Room	●	○	○	○

SUMMARY OF FINDINGS

The visual environments of the classrooms in all schools were entirely satisfactory in terms of the quantity of light present. However, in those schools whose classrooms had large window areas, such as Parkside and Smith, performance in the areas of room contrast rations and direct glare was not acceptable, generally functioning at below the 75% level. The Mount Healthy School, depending heavily on artifical illumination with windows used primarily for visual relief and high lighting, had the most satisfactory lighting environment with performance generally at the 95% level. The Richards School, which had smaller windows in each classroom and used large skylights, was also acceptable, functioning at the 85% level.

DETAILS OF FINDINGS

LIGHTING/ILLUMINATION (FOOTCANDLES)

Results: Performance levels with regard to the quantity of illumination were satisfactory at all schools examined. Some exceptional conditions exist at the Mount Healthy School which make technical performance evaluation difficult. Richards had lower illumination than recommended standards (85% level).
Probable cause: Existing criteria in the technical literature are based on traditional classrooms, and Mount Healthy is a radical departure from that model. At the Richards School many bulbs are not producing maximum light output.
Disucssion: Illumination refers to the quantity of light incident on a work surface, and visual acuity generally increases with increased illumination. It is important to note that United States requirements in this regard are very high, in that they are based on performing difficult reading tasks with a high degree of acuity, and that lower standards, we believe. are quite acceptable. Mount Healthy has locations in 2 classroom areas which fall below the United States standard but which we believe are acceptab'e due to (a) the aforementioned 'luxurious' existing standards; (b) the tasks in the schools not approaching the criticalness of the task by which the standard was set; and (c) the openness of the school providing immediately adjacent areas where high level illumination exists. At the Richards School bulb replacement is necessary.

LIGHTING: ROOM CONTRAST RATIOS

Results: Performance levels at the Mount Healthy and Richards Schools were generally satisfactory, functioning at the 85% level. Parkside and Smith typically have poorer performance (75% or below) in this area.
Probable cause: Extensive window areas within the user's cone of vision result in high contrast ratios.
Discussion: The ratios of reflected light from larger surfaces

in a room determine the room contrast ratio. Adjacent surfaces with high contrast will produce eye muscle tension and visual fatigue. With the window shades open, room contrast ratios exceed those generally recommended. Only when the shades are fully drawn does the contrast ratio become acceptable (within 1:10 ratio). When the teacher closes the shade it is probably to eliminate direct glare, especially sky glare, and to reduce the size of the glare source.

The large windows at the Smith and Parkside Schools are the source of the very high room contrast ratios found. The Richards School windows, which are smaller (12 feet long) and in most classrooms are in the rear of the room, are most satisfactory, performing at the 95% level. They are large enough to create a 'space' for projects and activities while their location in the rear of the room and diminished size provide an adequate room contrast ratio.

LIGHTING: GLARE

Results: Performance levels at Parkside and Smith, are generally below the 75% level. Performance levels at Richards and Mount Healthy, 85% and 95% respectively, were satisfactory.
Probable cause: Intensity of the illumination created by the classroom windows.
Discussion: Room contrast ratios notwithstanding, the absolute amount of glare may be enough to provide the detrimental physiological effects described previously. An analogous, though exaggerrated, situation, disability glare, occurs when looking directly into the high beam headlights of on-coming automobiles. In a classroom situation, discomfort glare results in an elevated blinking rate, muscle tension and lessened visual efficiency. Classrooms with large southern windows at the Parkside and Smith Schools receive direct glare in excess of recommended levels. Large windows at Smith and Parkside produce from 300-2600 foot-lamberts with shades open when the upper limit is reasonably

400 foot-lamberts. Shades are often drawn only halfway to screen out sky glare which is in the 1000-3000 foot-lamberts range. Glare from lighting fixtures was not a problem in any of the schools due to the use of adequate diffusers and shielding of the bulbs. At Mt. Healthy, though, no diffuser is used on flourescent luminaires, they are above the normal cone of vision.

LIGHTING: TASK/IMMEDIATE SURROUND CONTRAST RATIOS

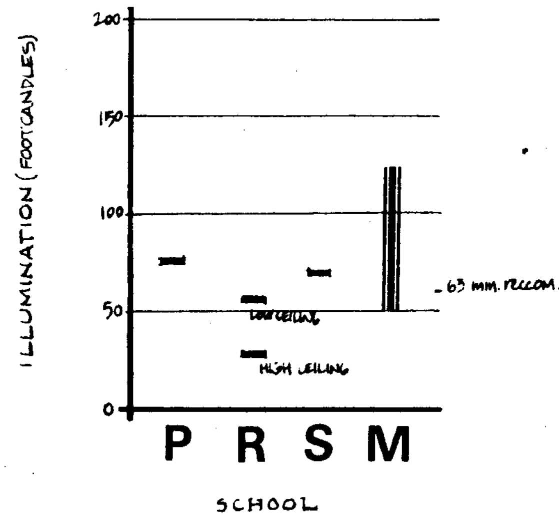
Results: Satisfactory in all schools.
Probable cause: Not applicable
Discussion: Due to the light colors chosen for desk tops and flooring materials.

LIGHTING: DARKENED ROOM

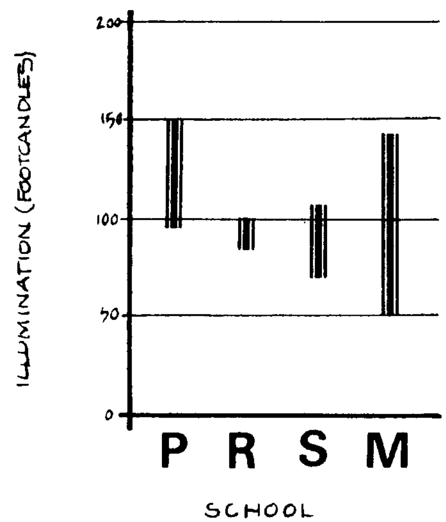
Results: Satisfactory at Smith, and Richards Schools.
Unsatisfactory (below 75% performance) at Parkside School.
Probable cause: Shades are semi-opaque
Discussion: Measurements in Parkside classrooms with south orientations produced readings over 300 foot-lamberts on the shades in bright sunlight which is detrimental to audio visual as insufficient contrast is produced in the image. Six footlamberts were read on the screen and from 4-11 footcandles in the classroom.

The Richards and Smith Schools produced 0 footcandles (almost complete darkness) which is satisfactory.

G.1 ILLUMINATION/ARTIFICIAL LIGHTING/CLASSROOMS



G.2 ILLUMINATION/ARTIFICIAL & NATURAL LIGHTING/CLASSROOMS



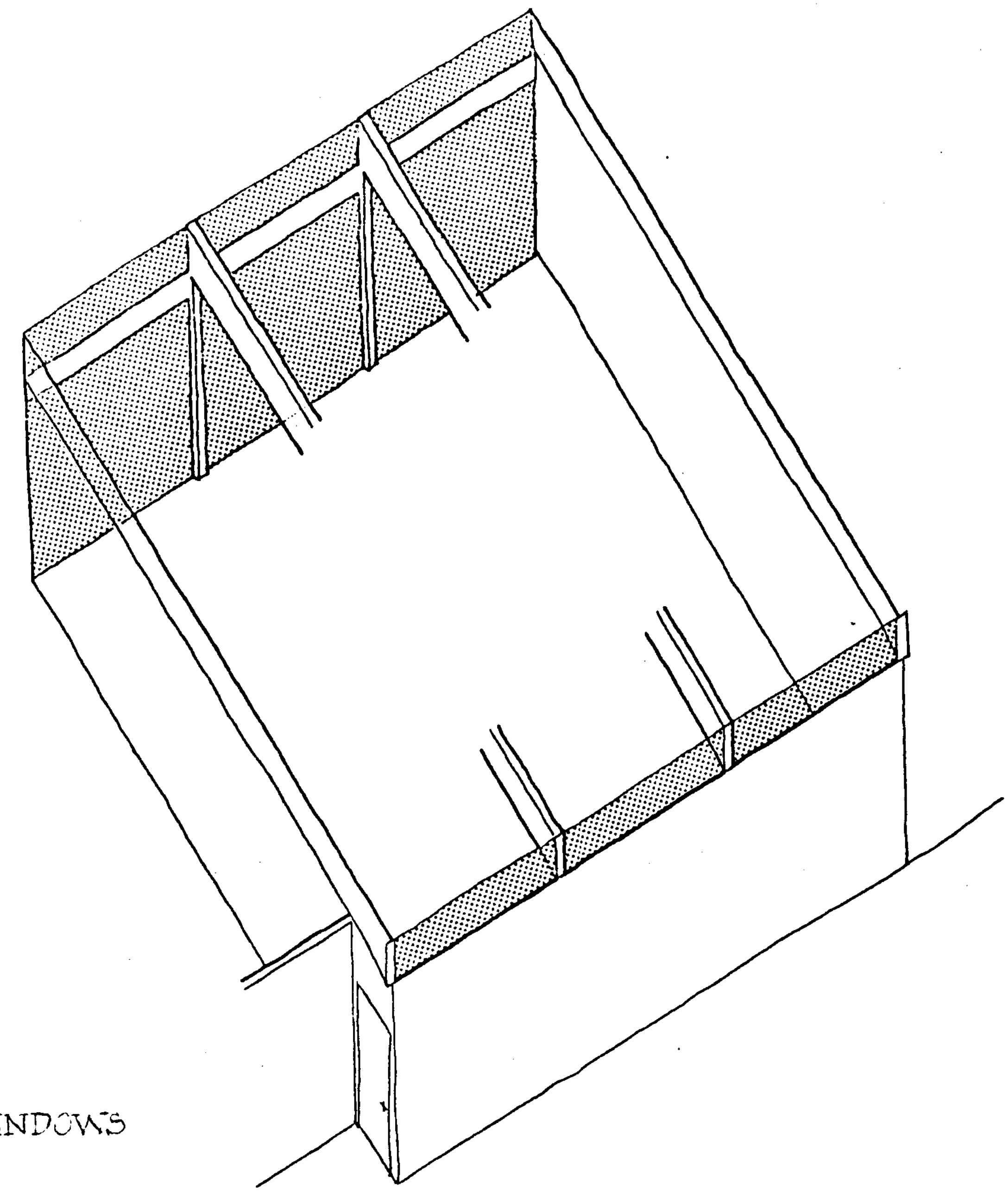


fig. G.3
PARKSITE SCHOOL/CLASSROOM/WINDOWS

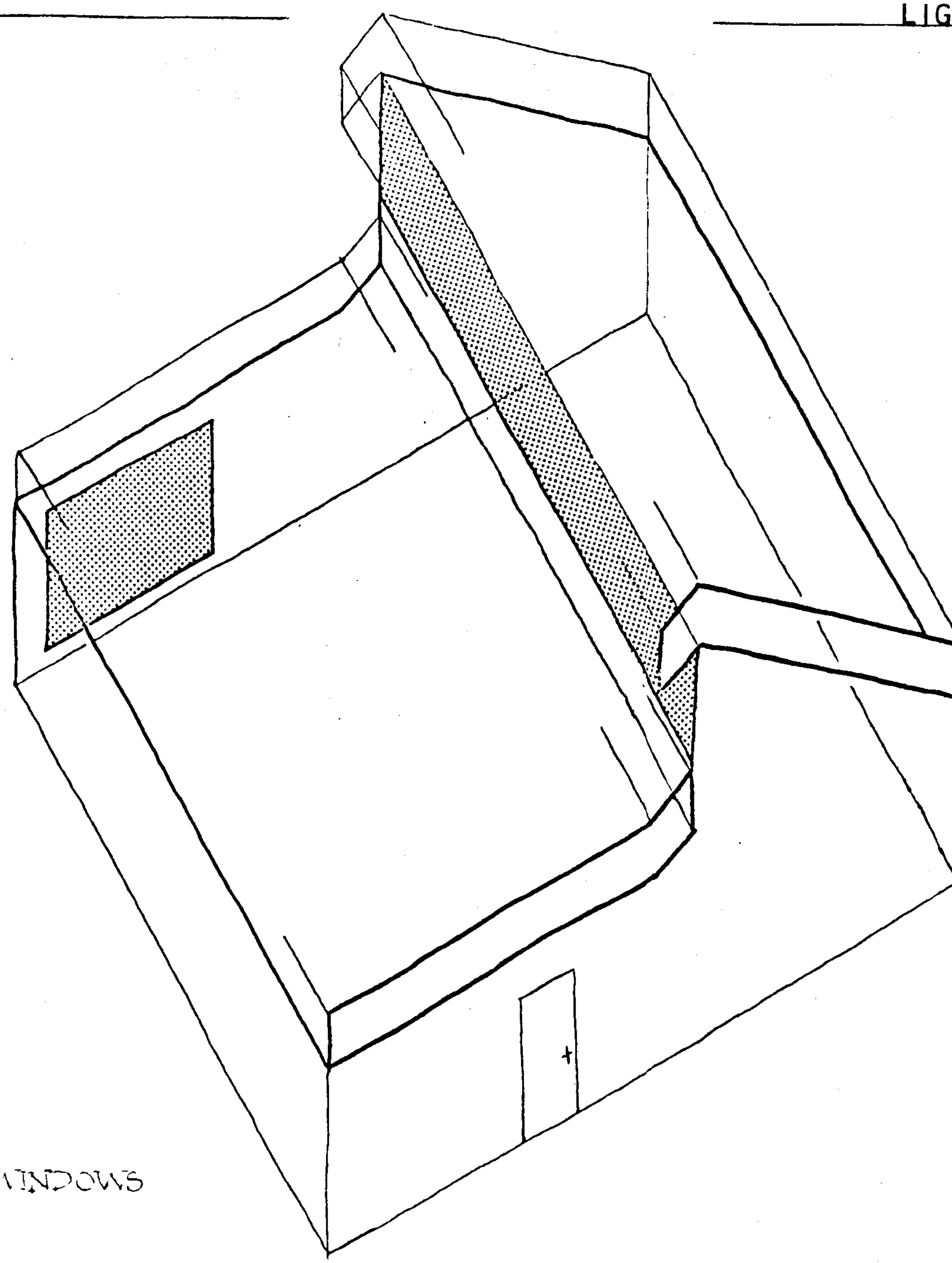


fig. G.4
RICHARDS SCHOOL/CLASSROOM/WINDOWS

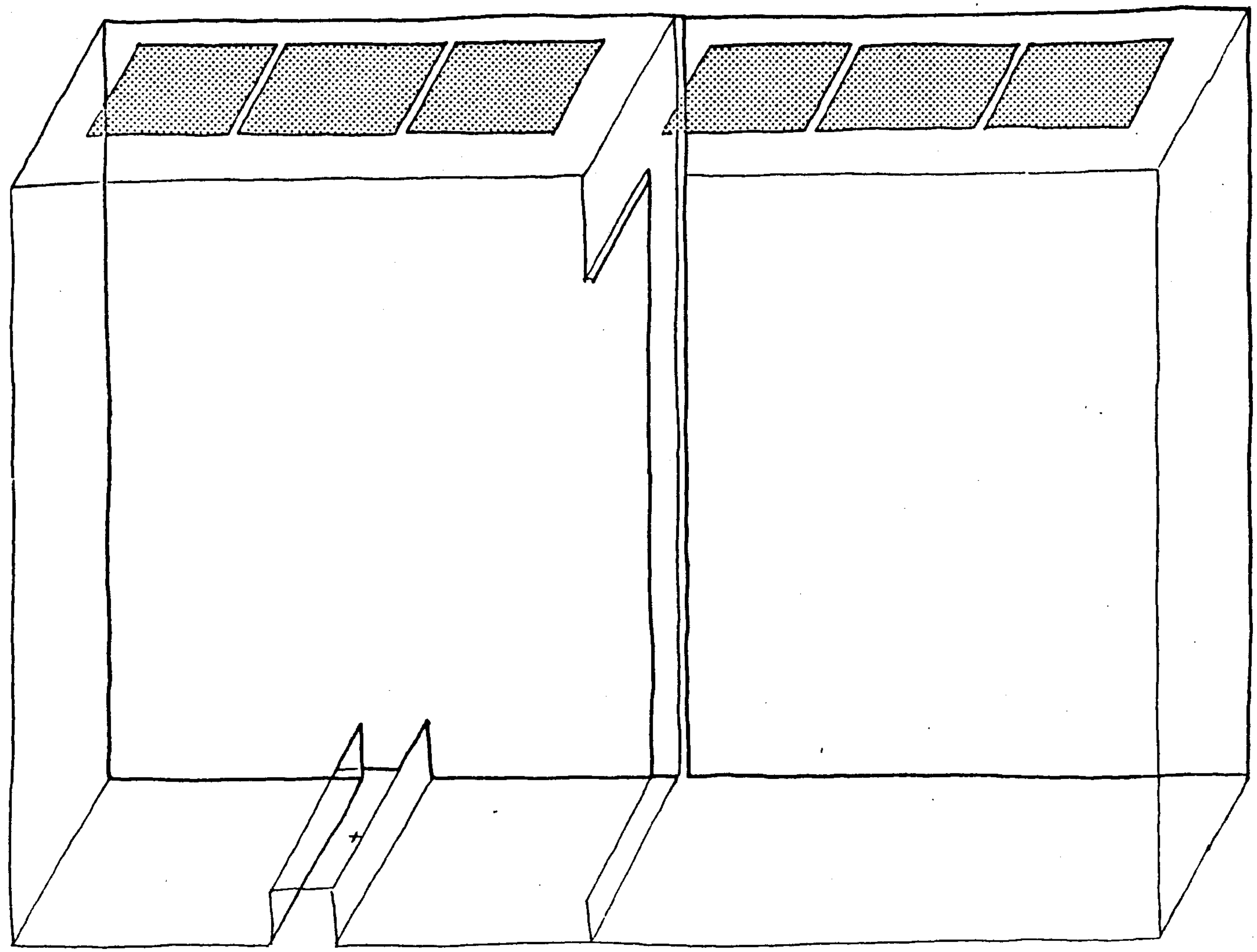
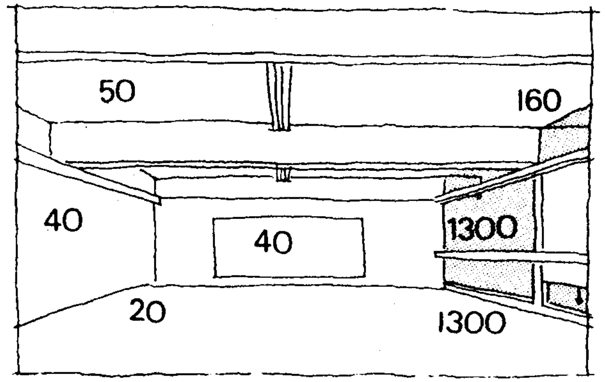
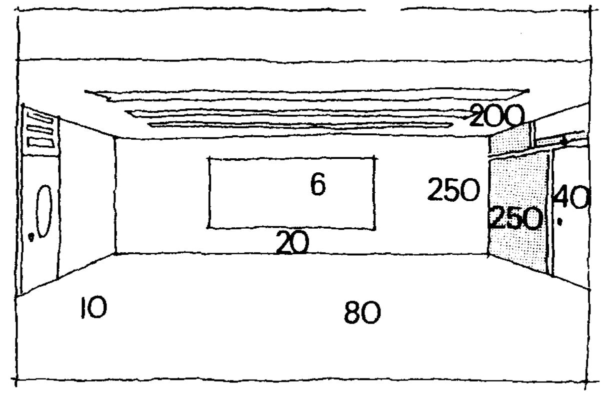


fig. G.5
SMITH SCHOOL/DOUBLE CLASSROOM/WINDOWS

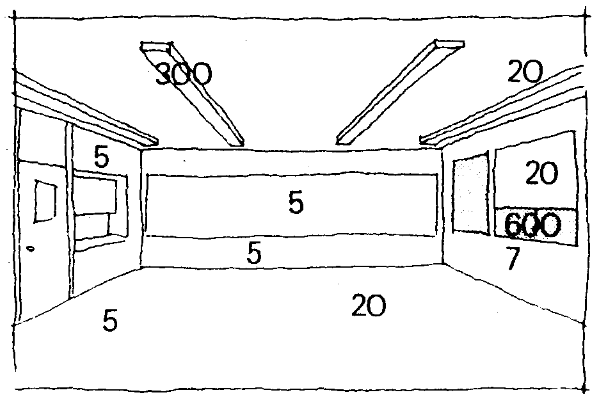
LUMINANCE/CLASSROOMS
figures are in footlamperts



G.6 PARKSIDE SOUTH - BRIGHT SUN



G.7 RICHARDS SOUTH - CLOUDY



G.8 SMITH SOUTH - CLOUDY BRIGHT

HVAC

INTRODUCTION

The proper design of the Heating, ventilating and air conditioning subsystem will determine the thermal comfort of a building's inhabitants. The comfort range is relatively small and deviations from it are easily perceived. The major determinant is the ambient temperature but drafts and radiative effects also have an influence on comfort, sometimes notwithstanding proper ambient temperature.

Added complexity in the design of HVAC subsystems is the variance in heating or cooling load needed throughout any one building - what is usually referred to as zoning. This requires the sub-system to deliver different temperatures of the heating cooling medium to many areas of the facility.

METHOD OF EXAMINATION

The quality of the thermal environment was measured by using a temperature recorder. Since cooling is not provided in the 3 older schools this was the factor most closely studied. Determining the performance of the following characteristic and comparing it with recommended standards results in an evaluation of the quality of the thermal environment. For a more detailed description refer to the Field Test Manual, December 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
Ambient Temperature	⊙	⊙	⊙	O

SUMMARY OF FINDINGS

Performance of HVAC systems is unsatisfactory during the beginning and end of the school year at the Parkside, Richards and Smith Schools. Mt. Healthy School has cooling capability and is satisfactory.

DETAILS OF FINDINGS

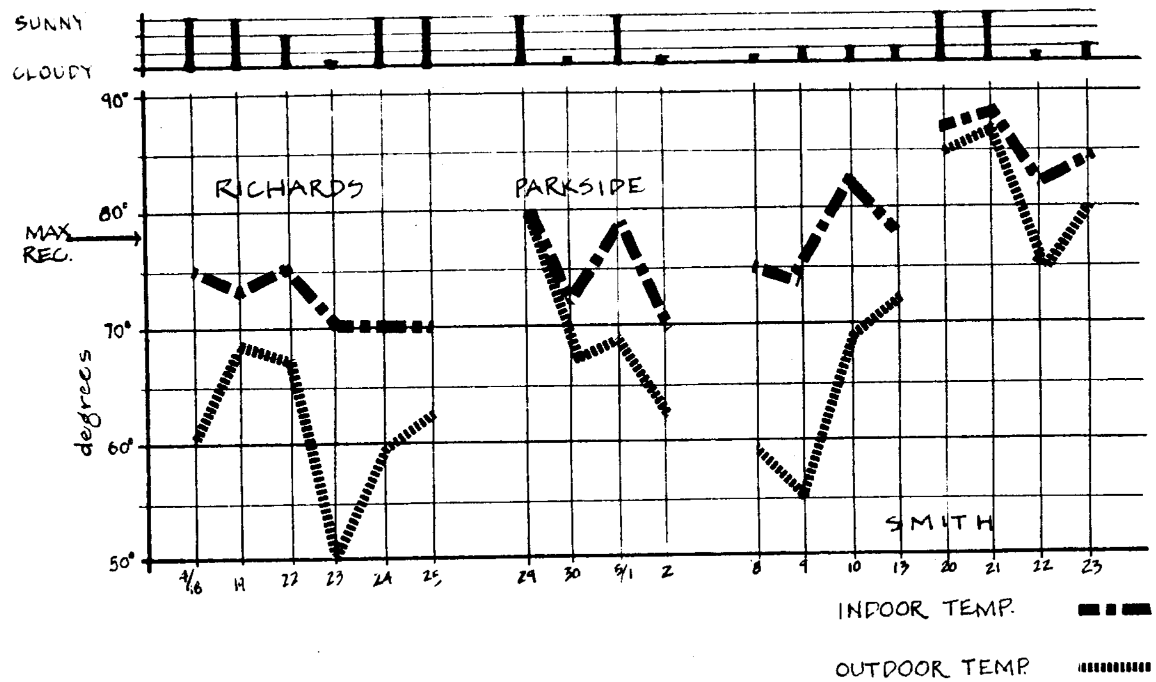
AMBIENT TEMPERATURE

Results: In the 3 schools without cooling systems the classroom temperatures exceed maximum recommended limits (78 degrees) from approximately mid-May through schools' closing date in early June. During the first 2-3 weeks of school in September this result can also be expected.
Probable cause: Lack of cooling capability.
Discussion: Since these schools are closed during the summer months the need for cooling capacity can be questioned. For about 6 weeks real discomfort will be experienced. It is possible in each school, we believe, to add on some cooling capacity without major alterations though this area needs more study. In the interim most teachers bring in their own fans to produce some cooling by convection during this period.

OTHER AREAS

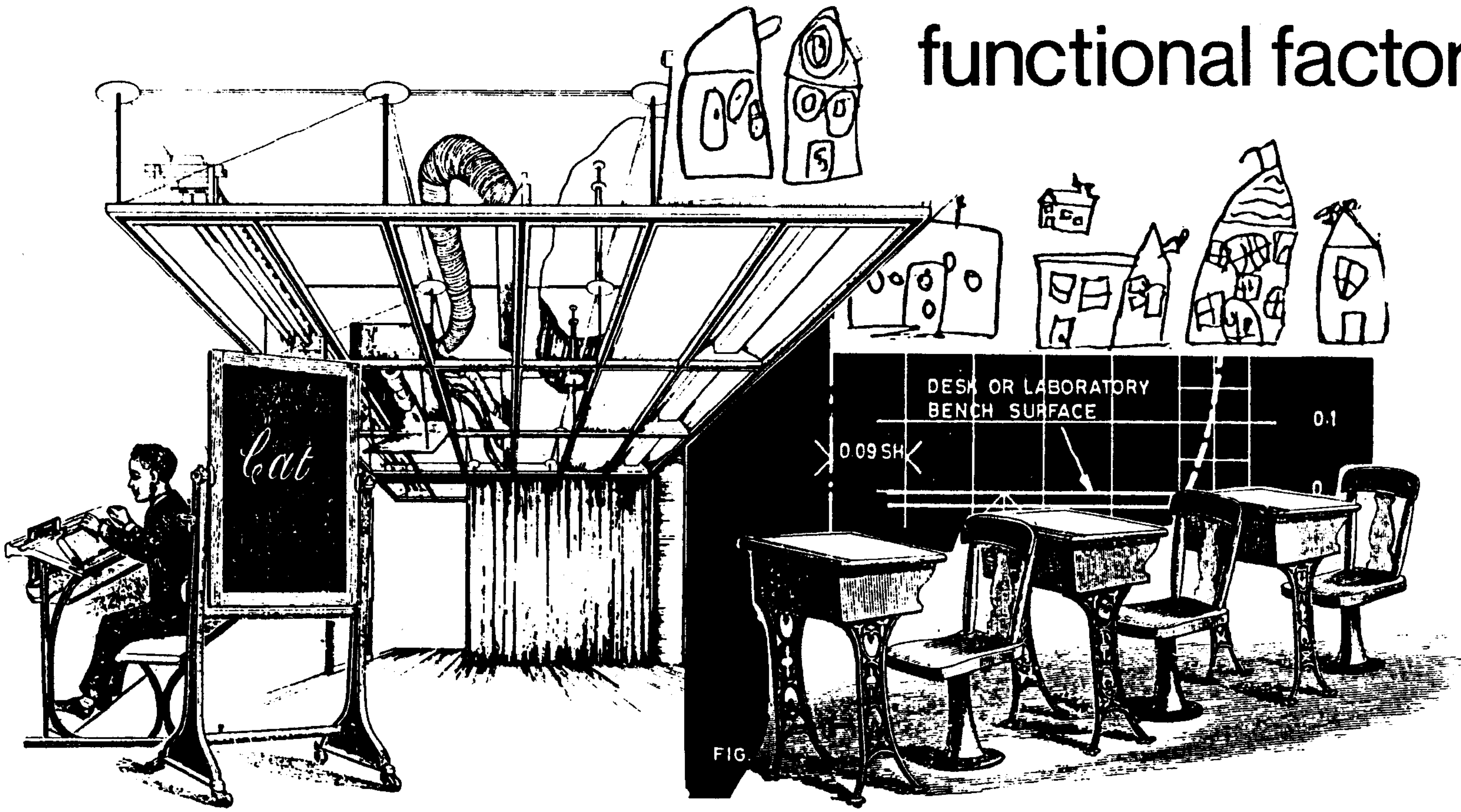
A warm weather ambient temperature study was our focus in the HVAC area. Further research needs to be done especially on the radiative effects of the uninsulated walls in the winter. Informal observations and a questionnaire given to teachers in two of the schools (without cooling) note virtually no problems with winter heating and unanimous dissatisfaction with hot weather.

INDOOR AMBIENT TEMPERATURE



buildings in use study

functional factors



INTRODUCTION

Those responsible for buidings rarely examine, in a formal and comprehensive manner, the environment they have helped create. We believe that such examination is, however, the primary method through which better buildings can be created. Thus, what we learn from this study can be used--by clients and architects--in the design of future buildings.

This report is one product of the "Buildings in Use" study. The overall study examines architectural characteristics of existing buildings to determine how they have performed technically and functionally and the relationship between the environment of the building and the behavior of its user population. This working document specifically addresses the functional aspect of the study. Other aspects--technical, field tests --are covered in other reports.

FUNCTIONAL FACTORS

Functional factors, as we define them, are those aspects of a building that DIRECTLY SUPPORT USER ACTIVITY. For instance, floors, ceilings, or acoustics do not directly support user activity--we consider these the 'background' environment. A blackboard, a closet and an electrical outlet do directly support user activities and performance in elementary schools. Furniture was not included as a part of this study though it is a part of the functional/activity support system.

Functional/activity support systems can be categorized by the scale of the support object. This report is generally organized from small scale items to rooms.

- small built-in components--coatracks, blackboards, bulletin boards
- storage--shelves, cabinets or closets
- entire areas specifically designed for special activities--music, art, library, reading, etc.

For various reasons the architect is primarily concerned with the latter two of the above mentioned areas. Architects' efforts are given to thinking about and shaping spaces to respond to intended usage and to 'servicing' these activities with storage. This effort is evident in the way these areas are configured, the way the 'background' environment--structure, lighting, acoustics--is detailed, the careful thinking about the connections between these areas and the location and design of storage and services for them.

The first category--component scale 'items' of activity support--is usually, though by no means universally handled by choosing catalog, or 'typical', items and 'attaching' them to the room surfaces in a routine manner. This attitude reduces the potential effect of this activity support scale at best and can even result in problems related to correct function. This report documents cases of quite conscientious manipulation of this small scale of activity support to produce behaviors very reinforcing of activity and a more routine attitude which results in potential deficiencies.

METHODS OF EVALUATION

For each factor discussed we have attempted to use objective measures in examining performance.

1) Anthropometric measures: relates to the measured dimensions of the element to the fit to a person's (or a child's) measure.

2) Measured use: regularly sampled observations of actual use.

3) Questionnaire data

4) Photographic documentation

5) Unobtrusive measures: ad hoc solutions, physical traces, records.

6) Room inventory

The criteria used in analyzing various functional elements are noted in the appropriate sections. If possible criteria are derived from standard sources; however, some criteria were developed from an analysis of observed phenomena.

HUMAN FACTORS

SUMMARY

Human factors is the study of human dimensions and attributes related to the design of objects which people use, primarily equipment. Included subjects of this section are chalkboards, cabinets, sinks, toilets, and drinking fountains. The performance of these items 'in use' is primarily measured by comparison with the standard dimensions of their users.

In addition to dimensional criteria the performance of chalkboards is also measured for performance related to glare affecting visibility. The provision of adequate display area from quantitative and qualitative performance standpoints is a part of the direct human factors 'interface' of person and environment and is also part of the component scale of activity support. Existing standards and actual use are contrasted to the design of display in all four schools.

ANTHROPOMETRICS

Performance Required: Provice components which are dimensionally compatible with the users of the schools.

Method: Comparison of dimensions of certain critical components of the school with existing standards. Sources include Time Saver Standards, Complete Guide to Planning New Schools, N. Englehardt, The Measure of Man, 2nd Edition, H. Dreyfuss.

Analysis:

ANTHROPOMETRICS

	STANDARDS GRADES		P		R		S		M	
	1-3	4-6	1-3	4-6	1-3	4-6	1-3	4-6	1-3	4-6
CHALKBOARD(bottom)	25"	29"	18"	24"	30"	30"	33"	33"	28"	32"
CAFETERIA COUNTER	31"	36"			35"		31"	36"	36"	
DRINKING FOUNTAIN	27"	32"	26"	32"	28"	28"	30"	32"	28"	34"
SINK	26"	29"	24"	30"	26"	26"	28"	30"	26"	32"
WATER CLOSET(seat)	11"	14"	16"		16"		16"		16"	

Findings: A comparison between existing standards and the actual dimensions indicates some discrepancies of which a few are critical. At the Richards and Smith School blackboard height is a real problem in the lower grades. A few teachers mentioned that 'platforms' were necessary to reach the chalkboard. Other items, though not standard, are within an acceptable range.

CHALKBOARD GLARE

Performance Required: Provide chalkboard with adequate contrast to read chalk writing.

Method: Comparison of performance with existing reflectance standards. Use of reflected and incident lighting measures. See Field Test Manual - Section G.

Analysis: Criteria: 'Black' chalkboards reflectance levels should not exceed 20%; it shall be free from visible 'ghost lines'; source: SCSD Performance Specifications.

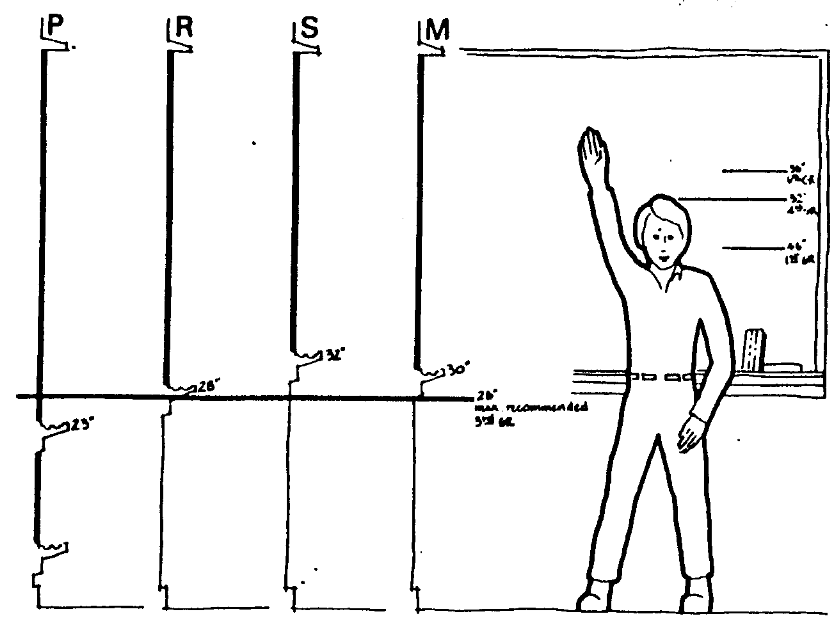
CHALKBOARD GLARE	RECOMMENDED STANDARDS	P	R I*	R O*	S
PERPENDICULAR POSITION	20% Max. Refl.	7%	10%	7%	10%
WORST SEAT POSITION	20% Max. Refl.	43%	10%	29%	45%

I* no window near board
o* window perp. to board

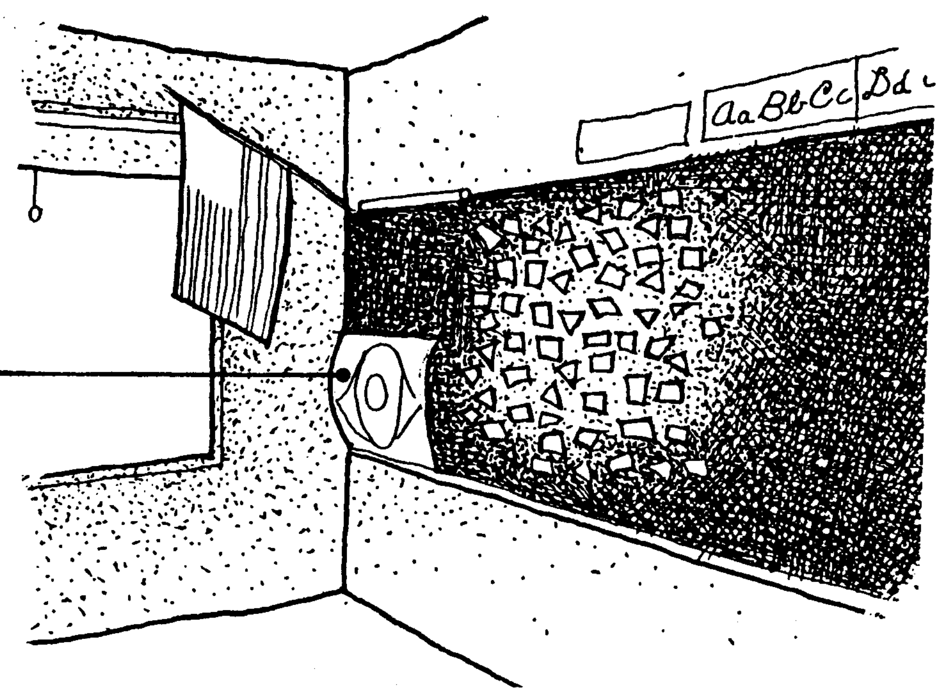
A combination of chalkboard placement and window size and location produce veiling reflections (inability to read writing on board) when window shades are not drawn at the Parkside and Smith School. Very serious glare (approx. 40%) is present. When shades are drawn performance is satisfactory. At the Richards School performance is generally satisfactory.

'BUILDINGS IN USE' STUDY

BLACKBOARD DIMENSIONS

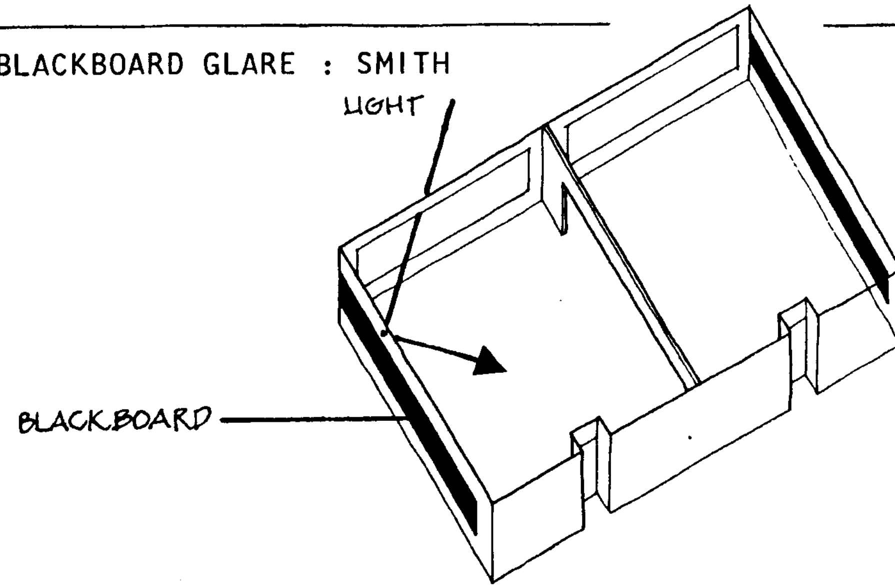


BLACKBOARD GLARE

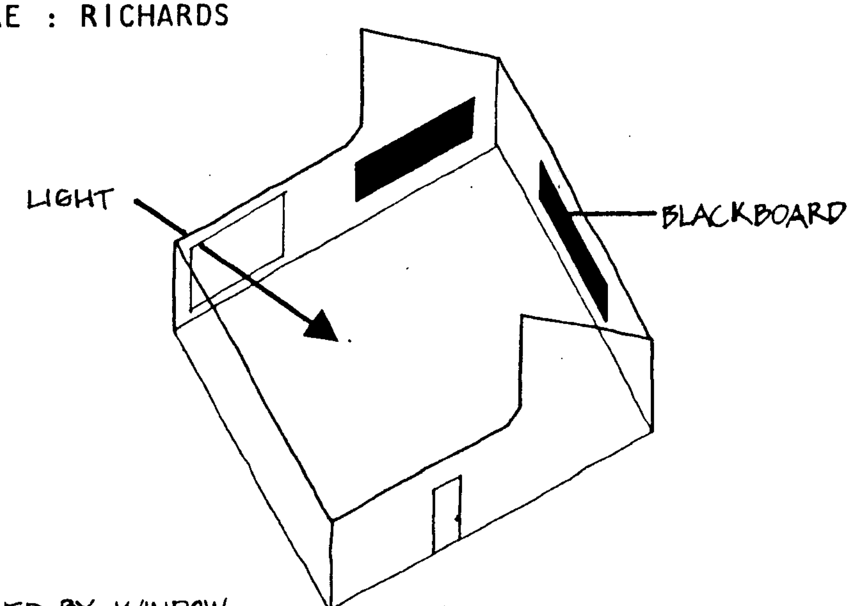


DISPLAY TAPED TO THE BLACKBOARD OFTEN OCCURS HERE, IN THE AREA OF WORST REFLECTIONS

BLACKBOARD GLARE : SMITH



BLACKBOARD GLARE : RICHARDS



GLARE IS MINIMIZED BY WINDOW LOCATION IN REAR OF CLASSROOM

DISPLAY

Performance required: Provide adequate area and attributes for displaying materials especially drawings, visuals, etc., in the school.

Method: Existing standards were found. A comparison of existing standards and actual quantity of display area is classrooms was made. Photographic sampling was used to measure the amount of display actually used. Ad hoc solutions to display were doccumented.

Analysis:

DISPLAY AREA

	RECOMMENDED STANDARDS	P	R	S	M
QUANTITY (linear feet)	30	20	20	30**	30
QUANTITY (square feet)	75*	80	80	60**	120

*this published standard was found to be low
**largely unusable due to placement

The quantity of display ranges from a less than usable 60 sq. ft. at Smith School to 120 sq. ft. at Mt. Healthy.

The findings have as their basis the assumption that maximizing opportunity for display usage within reasonable boundaries is called for. Many teachers will utilize these opportunities fully, some less and a few not at all - the latter emphasizing alternative media or methods.

Our observations found 'overflow' display in most classrooms except Mt. Healthy where display space was adequate. At Smith the overflow often occurred on the blackboard next to the window where glare is worst, this adaptation resolved the use of this problem area; on the window shades - they are often closed; in the hallway, although it is difficult to hang pictures on raw concrete; and in some case from the light-fixtures using paper clips and string. The displayed objects in this and the other schools were varied-primarily students drawings, educational charts and visuals, teacher cut outs, etc.

At the Parkside and Richards Schools the existing display area was well used with some overflow onto the walls. Richards School block walls are easily used for display compared to the brick back wall at Parkside where in some uses teachers have strung a 'clothesline' to hang pictures, cut outs, and constructions. At Mount Healthy display is rampant and most surfaces in classrooms and corridors are used.

Findings: We believe that approximately 25 linear feet (100 sq. ft.) of display space would be sufficient for most teachers. Most surfaces should be tackable and some provision should be made for ceiling attachment. Provision should also be made for display in corridors. Based on the above the Smith School needs quite a bit more useful display area and the Parkside and Richards Schools need only another increment, say 4-6 linear feet, of display. At Mount Healthy the display area is sufficient.

STORAGE/AUDIOVISUAL

SUMMARY

Both storage and the provision for using audiovisual equipment are crucial services for the well functioning elementary school. Expanding amounts of technical means for transmitting information and the use of sophisticated materials and other media have become conventional, even in elementary education.

Adequate storage is an important service in an elementary school. Very large amounts of material, of all sizes and shapes, are used throughout the school year. Access needs to storage also vary - some items are needed daily, some are used only once or twice a year. The performance requirements measured in our study were storage capacity, type and accessibility.

Supporting the use of audiovisual equipment is also critical in the schools studied. Performance requirements were storage and accessibility for audiovisual equipment, electrical connections and the ability to darken the room adequately for viewing projected images.

STORAGE CAPACITY

Performance required: Provide adequate storage for classroom and school needs.

Method: A comparison of the 'official' storage provided and the actual use of storage - both official and unofficial. A detialed storage 'inventory' of most classrooms was made, including photo documentation.

Analysis:

STORAGE CAPACITY

	STANDARD*	P	R	S	M
STORAGE CAPACITY PROVIDED PER CLASSROOM (cu.ft.)	250 (approx)	146	155	182	350

*standard developed through analysis of existing conditions

The originally specified storage capacity has increased for each new school. This wide range of alternatives is a good 'experiment' against which to test the performance of storage capacity.

'Overflow' storage was consistatnly and obviously evident at the Parkside, Richards and Smith Schools. Every cubic foot of storage space provided was brimfull as well as numerious other locations. Shelves in many cases were literally deflecting with the weight of their loads. Most shelf storage was multilayered - the objects being piled atop one another also creating problems in organization and disarray.

At the Parkside and Richards Schools overflow storage took place on the floor, in cardboard boxes and on folding tables. Occasionally a storage cabinet would be brought in from home by a teacher. At Smith most overflow storage occurred in the nodes in metal cabinets and steel shelving though the 3'x6' folding tables were again used in the classroom.

The Mt. Healthy School has sufficient built-in cabinetry and mobile cabinets, some of which went unused.

Findings: Based on these very consistant results we would recommend 250 cubic feet of storage area be provided for each classroom. Centralized storage needs would require an additional 50 cubic feet for each classroom.

SIZE OF STORAGE

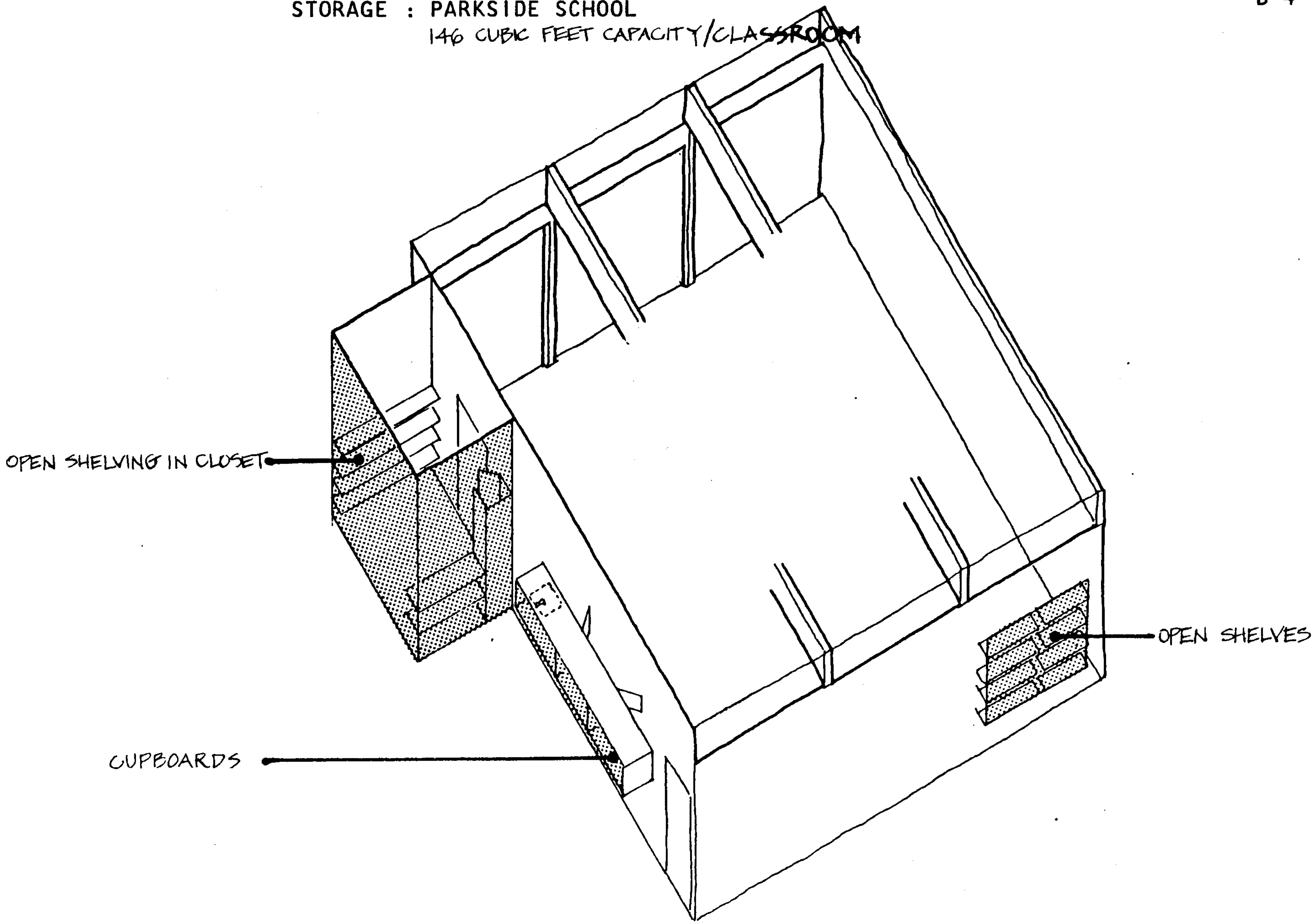
Performance required: Provide storage for objects of various sizes.

Method: See 'Storage Capacity".

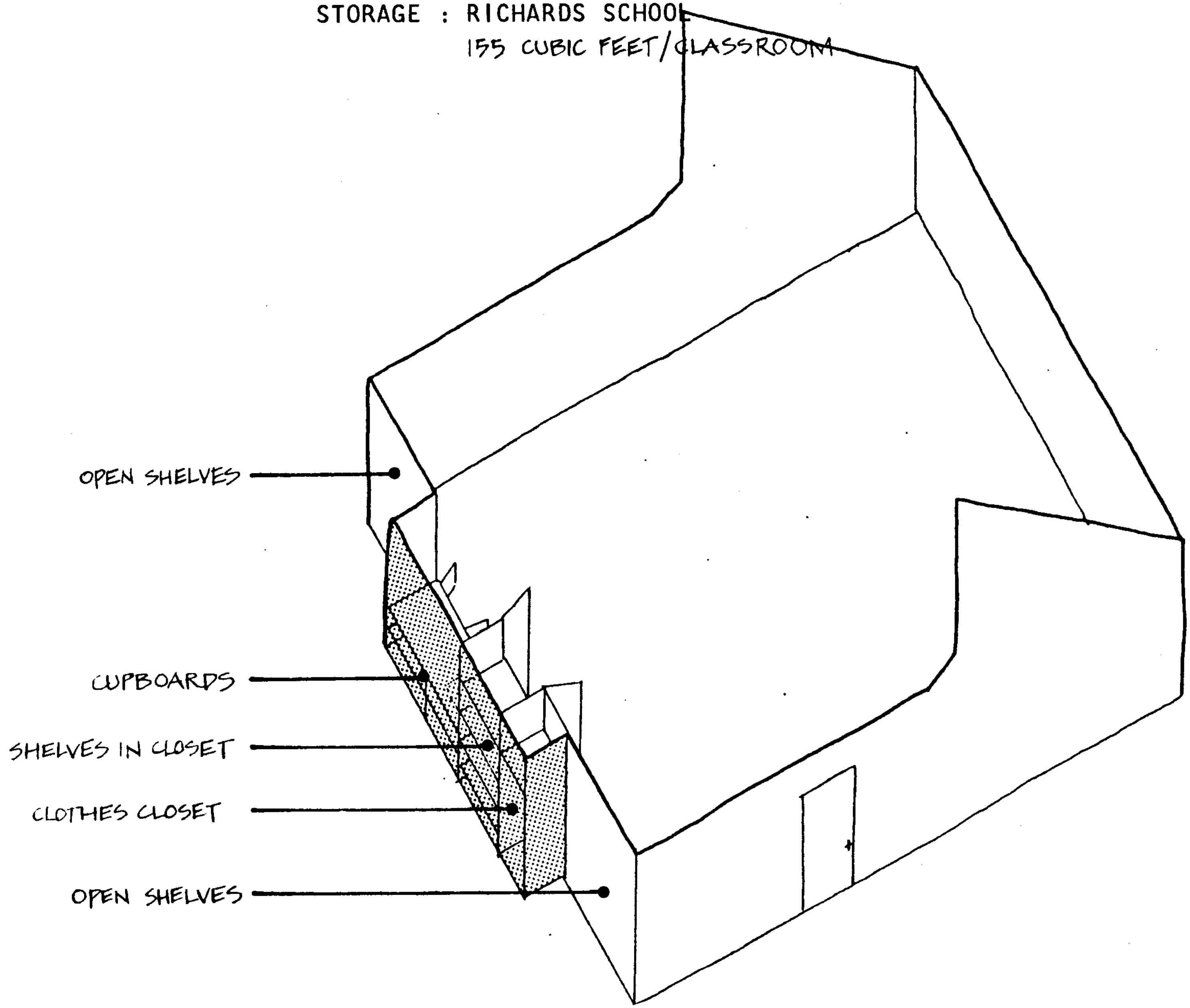
Analysis: There is a storage problem for all sizes of objects related to the lack of storage capacity. Universally displaced, however, are those large objects, say over 15 inches in all dimensions, for which the shelving systems and drawers make no provision. This includes:

- most audiovisual equipment
- screens and charts
- instructional media kits and sets
- globes
- recess equipment
- easels
- large models (eg. clockface, earth and moon)
- fish tanks
- plants
- fans
- cardboard boxes of miscellaneous objects

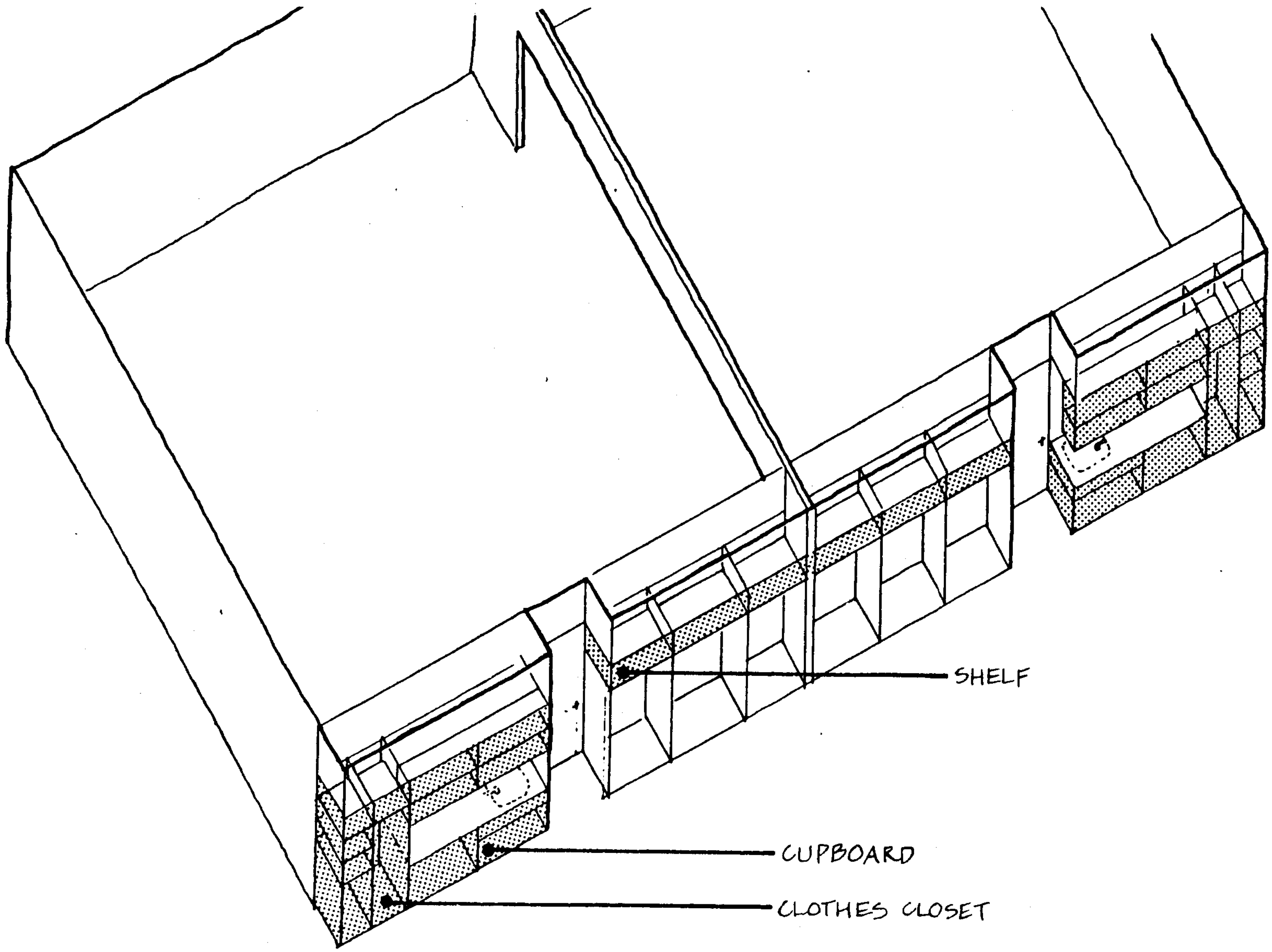
STORAGE : PARKSIDE SCHOOL
146 CUBIC FEET CAPACITY/CLASSROOM



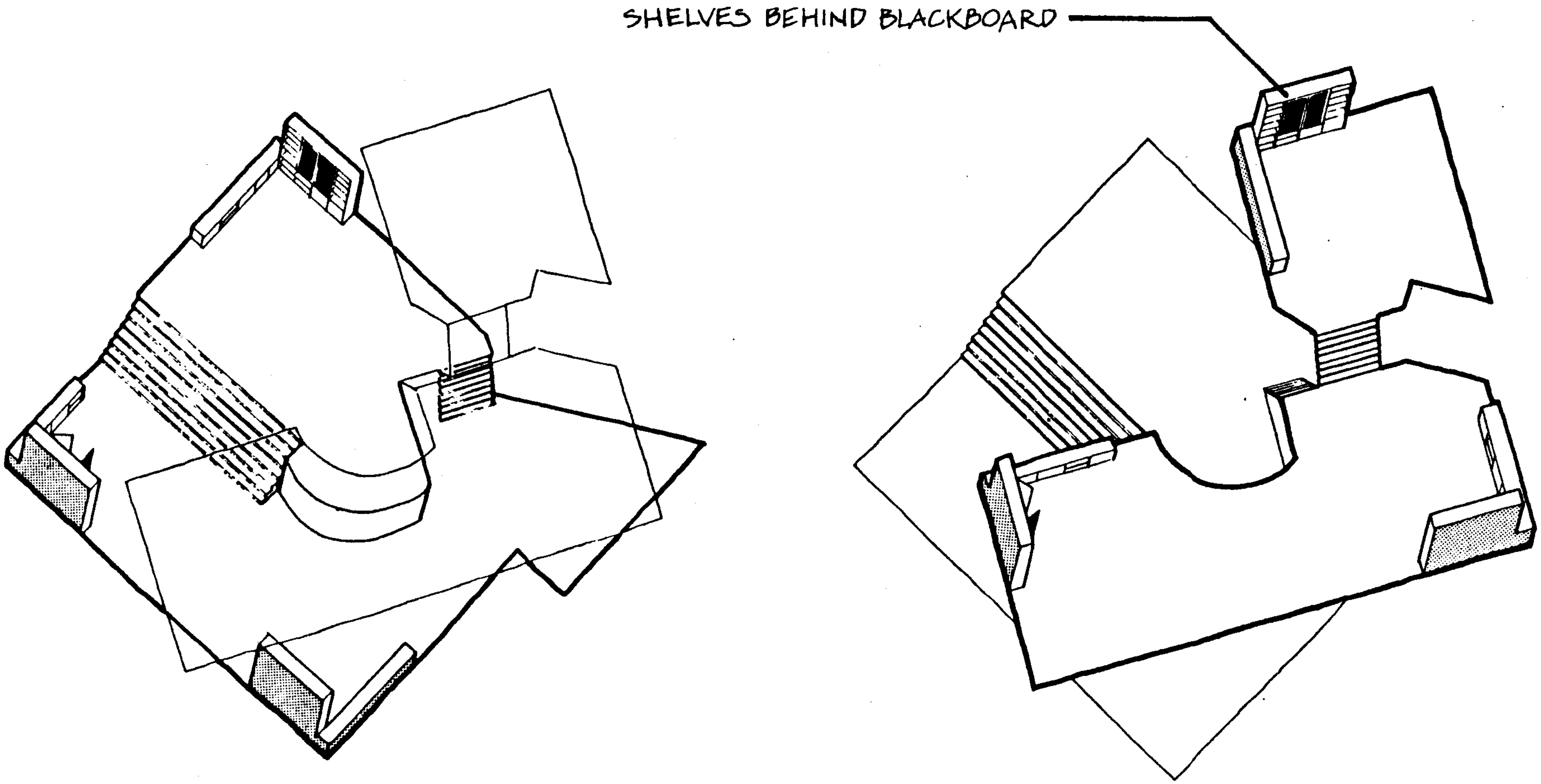
STORAGE : RICHARDS SCHOOL
155 CUBIC FEET/CLASSROOM



STORAGE : RICHARDS SCHOOL
182 CUBIC FEET/CLASSROOM (DOUBLE CLASSROOM SHOWN)



STORAGE : MT. HEALTHY SCHOOL
350 CUBIC FEET/CLASS AREA (6 SHOWN)



At the Parkside and Richards School these are found on the floor or on tables. At Smith approximately one-third of the built-in coat closets have been appropriated for large object storage. At Mt. Healthy there is adequate capacity for objects of all sizes.

Findings: The mix of storage needed should change to include the accommodation of large space objects.

LENGTH OF STORAGE

Performance required: Provide short term and long term storage.

Method: See 'Storage Capacity'

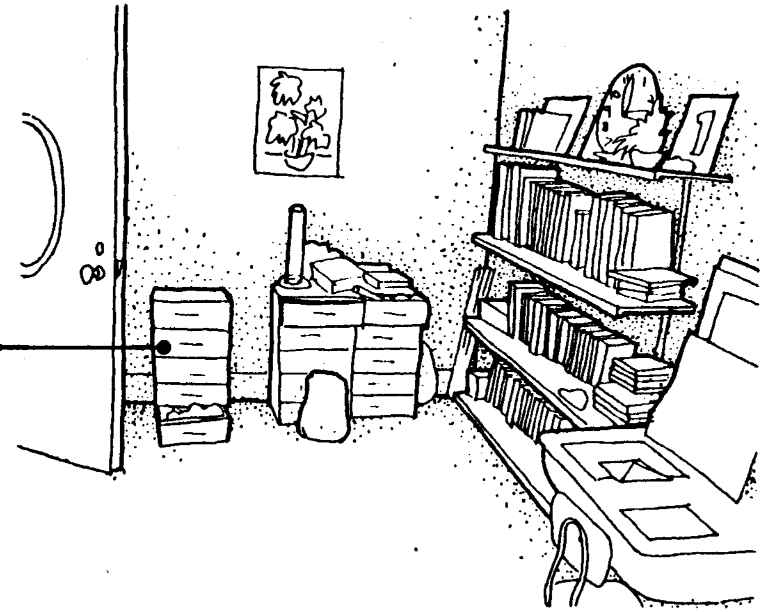
Analysis: The need for accessibility to storage can be categorized as follows:

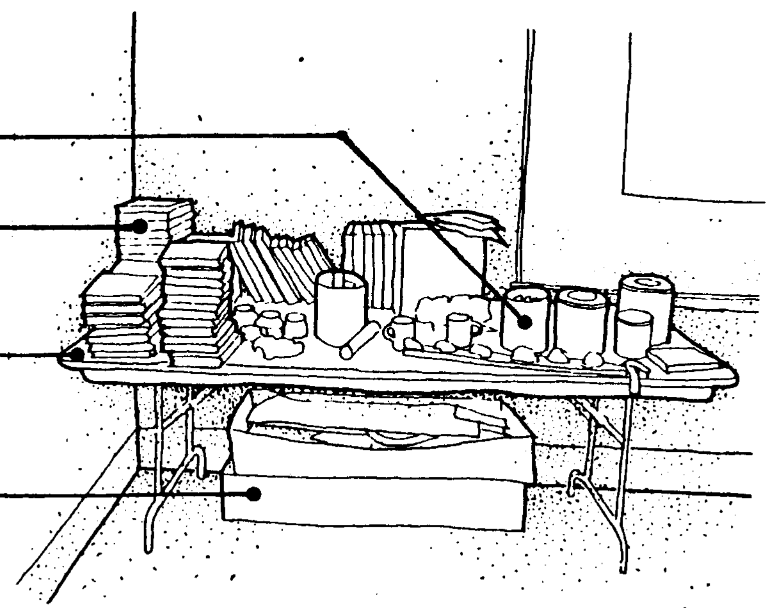
- immediately accessible storage. Items used almost daily includes crayons, chalk, paper or of all kinds, recess equipment, cleaning equipment books.
- short term storage. Items used regularly but not often. This category includes most audiovisual equipment, toys and games, educational media (flash cards, games), paints, books.
- long term storage. Infrequently used objects, included are Christmas decorations and equipment, globes, abacus, a fan, charts, decorations, textbooks.

In the Parkside, Richards and Smith Schools there has been adequate provision for immediate and some short term storage by the type and location of storage provided. Storage is virtually all within the classroom and consists principally of shelves and drawers. At Parkside and Richards long term storage and audio-visual equipment storage is present in the classroom and handled via various ad hoc solutions mentioned previously. At Smith the nodes have become 'opportunity spaces' where a variety of originally unprogrammed activities have occurred including area for a great amount of long term storage. Even at Mount Healthy there is some need for separate long term storage most of which is now stored in an ad hoc fashion in the team teaching room though there is still some capacity remaining in classroom storage.

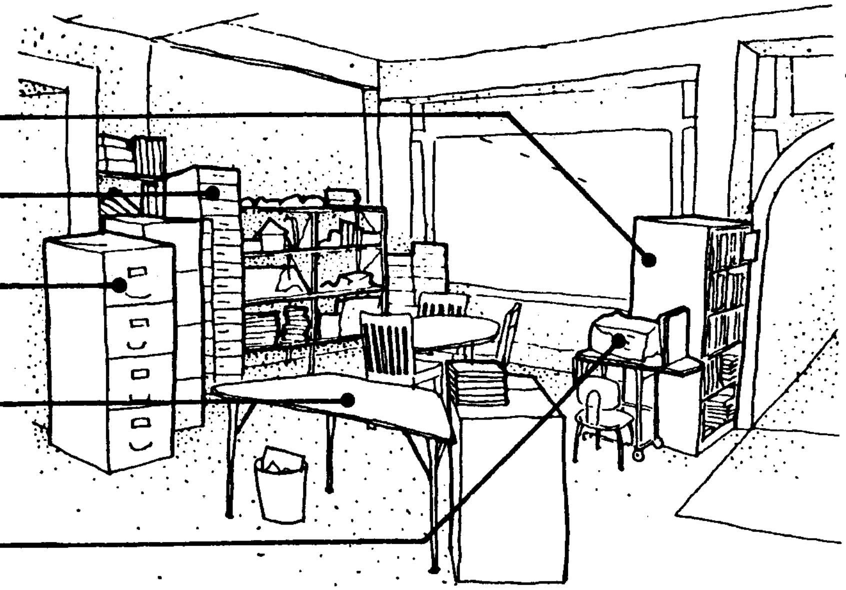
Another need for shared immediately accessible storage exists at some of these schools. At the Richards and Smith Schools programmed instruction materials are shared by a few classes and the storage and accessibility of these materials presents a problem. In both schools these materials are stored on metal shelving in corridor areas outside of the classroom proper. At Richards the constraining, enclosing walls of the classroom does not encourage free flow to these materials. The corridor is not a suitable environment for them. At Smith the node/corridor where they are stored does present problems but the environment is enhanced by the presence of teachers aides and additional resources, study carrels, etc.

TYPICAL STORAGE
Parkside and Richards Schools

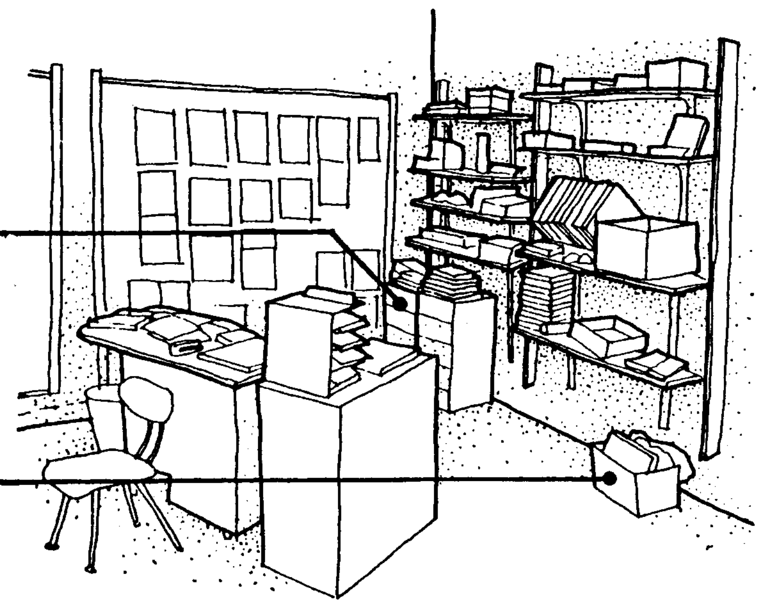




STORAGE : NODE AT SMITH SCHOOL



TYPICAL STORAGE



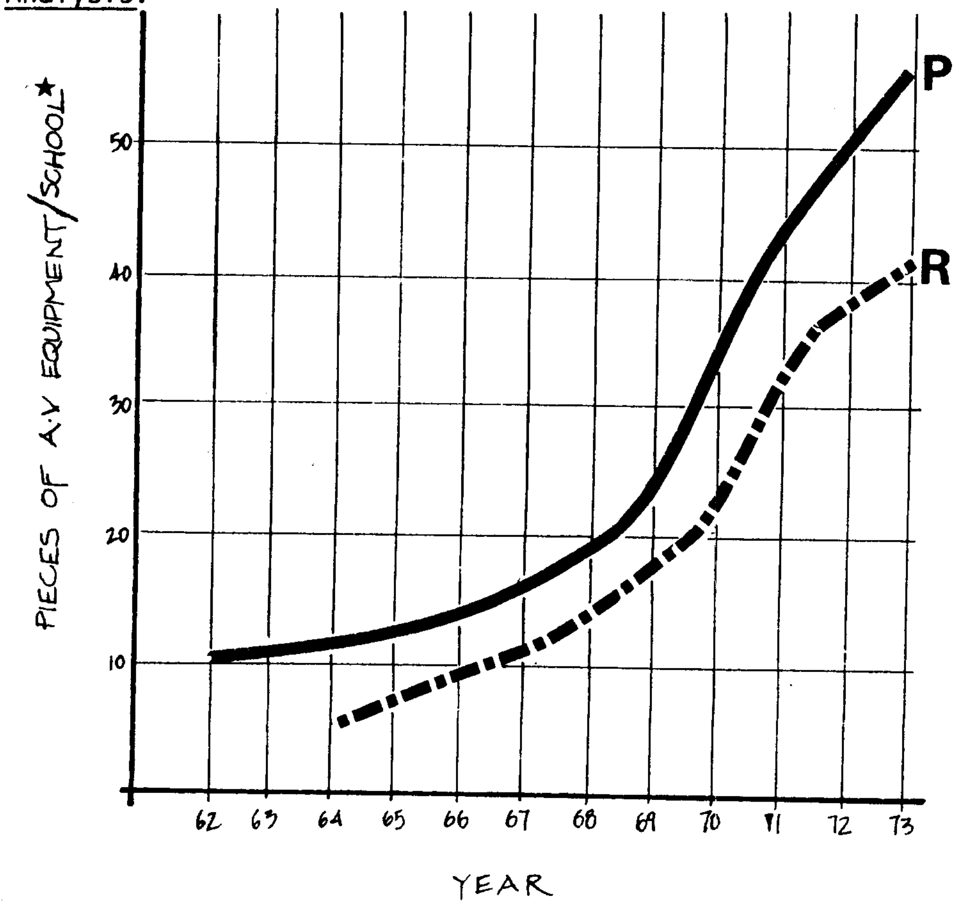
AUDIOVISUAL STORAGE

Performance required: Provide adequate storage for audiovisual equipment.

Method: See 'Storage Capacity'

Analysis:

A-V GROWTH



*INCLUDES: OVERHEAD, 16 MM. & FILMSTRIP PROJECTORS; RECORD PLAYERS, TAPE CASSETTE PLAYERS, CARTS

All the schools are fully equipped with a variety of audiovisual equipment; movie projectors, overhead projectors, filmstrip projectors, phonographs, tape and cassette recorders, etc. The school corporation has a central film library and TV studio and each school has videotape equpment for use by teachers and students. Students can even borrow cassette recorders and tape for home use.

The intensive use of audiovisual equipment is a recent phenomenon and schools planned a decade ago do not provide the activity support necessary. At the Parkside and Richards Schools this is evident in the lack of storage for such equipment. Equipment is in classrooms and in the library, taking up needed area in both places. Classroom storage of this equipment does make it immediately accessible thus encouraging its use; however, the way this accessibility is achieved is detrimental to other activities. Storage of this equipment in the library and conference rooms is a serious detriment in these schools.

At the Smith School, planned later than those just mentioned, storage is handled more adequately. The library is large and has sufficient area (about 300 sq.f.t) for central A-V storage. The nodes as unprogrammed 'opportunity areas' are used for A-V storage - a location close to the classroom providing immediate access.

Mt. Healthy School has a 'mini instructional media center' (I.M.C.) for each level (2 grades) in the school. This area, proximate to all classrooms and provided with adequate electrical outlets, is meant for the storage, accessibility and use of A-V equipment. In fact A-V equipment is found every place in the school including, but not especially in, the I.M.C. However, the open plan and large areas of this school do not hinder other activities while still providing for A-V requirements.

Findings: Approximately 60 cubic feet of storage per classroom for audiovisual equipment should be provided in elementary schools. 20 cubic feet in a central location for storage and access of unique pieces of equipment and 40 cubic feet within or easily accessible from the classroom.

ROOM DARKENING

Performance required: Provide adequate visual environment for images projected by audiovisual equipment.

Method: Comparison with existing standards. Measures of illumination and illummance were made in a sample of classrooms in each school. See section on lighting in the Field Test Manual for equipment and methods used.

Analysis: Recommendations (source: Time Saver Standards, I.E.S. Lighting Handbook, 4th ED.) are 0.1-0.2 footcandles. Task/sourround ratios were not considered significant because of the short duration of presentations (unlike cinemas).

The Parkside School had from 4-11 footcandles in typical classrooms - unsatisfactory conditions for viewing projected images due to lack of contrast. Smith and Richards had satisfactory performance (0 footcandles). Because Mt. Healthy's overhead skylights are not shaded conditions are unsatisfactory for viewing projected images.

For all-school and large group film or slide presentations the gyms are satisfactory at the Smith and Mt. Healthy School. Parkside and Richards gyms have many unshaded windows in their multipurpose rooms and performance is unsatisfactory.

Findings: Classroom and assembly rooms should be provided with means for darkening them to the 0-1 footcandle level. The shades at the Parkside School are not opaque to light and their replacement would eliminate this problem. Because of the teaching flexibility at Mount Healthy an area in each 2 grade levels can be modified to ensure proper conditions.

ELECTRICAL OUTLETS

Performance Required: Provide sufficient quantity and accessibility of outlets.

Method: Comparison of standards with electrical outlets in schools. Comparison of existing outlets with needs.

Analysis:

	P	R	S	M
# OUTLETS/CLASSROOM	2	2	2	4
LOCATION	F,R	F,R	F,R,S,	VARIES

F - front of room
R - rear of room
S - side of room

There is now a great deal of audio visual equipment available in all the schools studied (see p.b12). Outlets are also needed for other purposes - aquariums, Christmas lights, electric fans, incubators, etc.

The number and location of outlets at the Parkside, Richards and Smith School is inadequate. Mount Healthy has an adequate number of outlets in satisfactory locations. In a questionnaire given to teachers at the Parkside and Richards school only one teacher (of 24) did not express dissatisfaction of the existing number and/or location of outlets.

Findings: Well placed outlets are more basic to successful activity support than the quantity provided. The schools cited above provide neither atribute. Few student groups can use outlets simultaneously and more should be provided (4/classroom can supply 7-8 groups of 4 students each) with the ability to add even more in the future to accommodate possible changes in teaching. (See Chapter 4 Growth and Change). Outlets should be placed where groups can use them (towards the sides and rear of the rooms) with only I up front at the board. A centrally located floor outlet would be useful for class audiovisual usage but many building codes necessitate a raised (non-flush) receptable which would rule out this possibility. The use of a centrally located ceiling outlet or the newly developed 'power pole' are better solutions.

WINDOWS

The architect's intention for window usage is multifold. It is to provide a view outside and to allow natural light into the building. It may also provide a sense of place for activities and projects (e.g., plants).

What happened to the windows 'in use'? We noted in a previous report (Technical Factors) that certain schools had serious performance problems in lighting due to extensive window areas in and window placement in the classrooms. Do these findings affect use and performance? Measures were made of window shade manipulation to compare intended use with actual use and to analyze factors that reenforce or discourage the architect's intentions.

WINDOW USAGE

Performance required: The window should:

Provide a view and a link with the outside
Provide natural light
Possibly provide a place for activities

Method: A window shade study, done on a sampled basis at different times of day and different types of weather. This study indicates whether the windows are actually used as intended or whether technical problems such as glare and contrast ratio interfere with such use. The characteristics of the different window (size, location, orientation) will provide information on which windows were most 'successful'. Openness of the windowshade is used as the measure of 'usefulness'.

Analysis: The windows, on the average, were 48% open. There is great variance between the performance of different windows - some types were 88% open. That is, the shades were virtually always open reenforcing intended usage. Other types of window had their windowshades almost always closed - they were only 10% open.

- Smaller window areas, such as those at the Richards School, are found to be much more open (unshaded) than those schools with extensive window areas. 75% of the window area at the Richards School was left unshaded, only 43% of the large windows, at Parkside and Smith Schools, were unshaded.

- Smaller window areas with north orientation are nearly always unshaded (88% open). These windows, at the Richards School, are most 'successful' in terms of fulfilling intended use.

- <u>Skyglare is a real problem</u>: The brightness (illuminance) of the sky is in the range of 1000-5000 footlamberts while the interior of the classroom may have sarge surfaces with 20 footlamberts. This causes problems in contrast ration and discomfor/disability glare. In classrooms with extensive windows where the sky is visible, only 1% of all window area was fully unshaded. Shades were invariably drawn halfway down to eliminate this problem. At the Richards School smaller windows, (7'x12') for the most part located in the rear of the classroom, did not subject the users to sky glare. Fully 31% of the windows were fully open - the windowshades were unused.

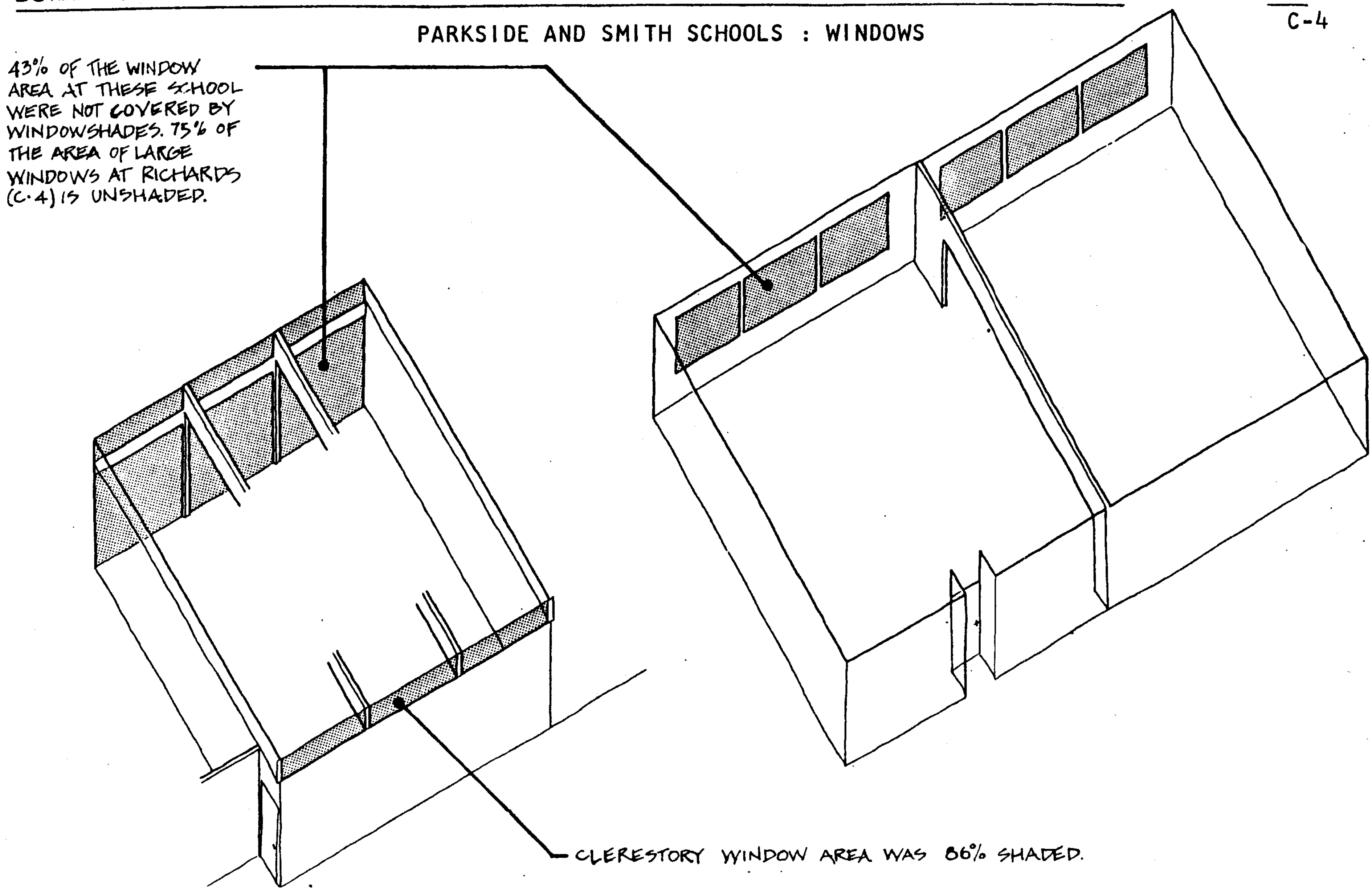
- <u>Clerestores</u>: Almost all the clerestories at the Parkside School are completely shaded (only 14% of this type of window area is unshaded). Sky glare is one reason here as is the 'bother' of constantly opening and closing those 6 small shades, as well as 3 large window shades for darkening the room, etc. The teachers prefer, for both reasons, to leave the shades closed.

  At the Richards School 3 large clerestories are oriented east - the users cannot see the sky. Here only these 3 shades plus a single windowshade must be manipulated for A.V. presentations. 75% of the area of the clerestory was unshaded.

- <u>Orientation</u>: This was less of a determinant than window space and location. North facing windows were only slightly more open (59%) than south facing ones (50%).

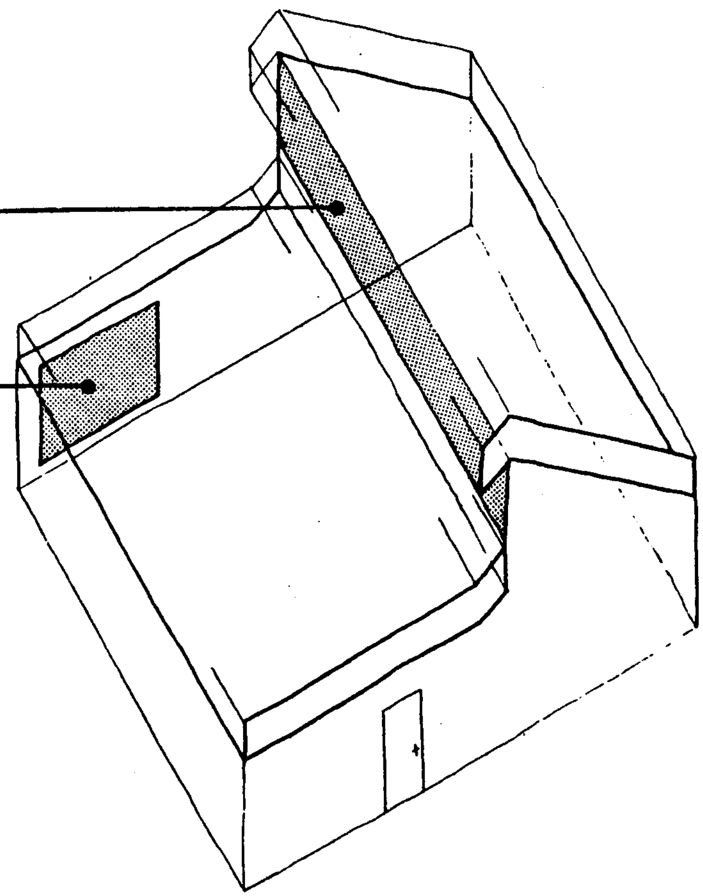
<u>Findings</u>: The actual usage of the windows is strongly determined by techical factors such as glare and room contrast ratios. Large glass areas with exposure of users to the sky glare should not be present (unless a low transmittance glass is used). Windows should be located in the 'rear' of the classrooms. The use of skylights and clerestories is a large expense and should be designed to minimize glare and for easy use.

PARKSIDE AND SMITH SCHOOLS : WINDOWS



WINDOWS : RICHARDS SCHOOL

WINDOWS AT THE RICHARDS SCHOOL ARE USUALLY OPEN (UNSHADED). THE LARGE WINDOW IS IN THE REAR OF THE ROOM; THE SKYLIGHT CANNOT BE DIRECTLY SEEN BY SEATED CHILDREN. DIRECT GLARE & CONTRAST RATIOS ARE THUS MINIMIZED.



FUNCTIONAL AREAS

SUMMARY

Each of the elementary schools studied, although similar in size and student population, is the product of different programs, different times and architectural designers. The results are dissimilar concepts, areas, sizes and functions for each school. This section of the Functional Factors report examines areas and attempts to measure their performance in supporting intended activities.

Measures of performance were made by analyzing photo documentation and noting behavior and activities over a two and a half month period from April through June 1974. Each area was randomly sampled 18 times on different days and at different times. Additional informal reconnaissance and photo documentation took place for a year before the formal sample began. Questionnaires, interviews and unobtrusive measures (records, traces) also were used when appropriate.

THE FORUM

The forum is a 20'x40' area in the center of the upper grade wing of the Parkside School.

> "It has no permanent furniture, so it is spacious; two or three classes can be assembled to share a lecture or demonstration here. Yet, owing to the several level floor (3 steps sourround a central area) a bare handful of students do not rattle around in the space; they can be consolidated on the lowest floor level for easy direction."
> Arch. Forum Nov. 1962.

Cushions were originally provided for the steps but the entire area has been carpeted within the last few years.

The area was examined to determine if it was used as intended and what attributes did cause the type of use it received.

Performance Required: Provide an area which can be used by classes, singly or together for group activities, presentations and events.

Method: See "Functional Areas-Methods". The weekly forum sign-up sheet used to reserve the space was another indicator of use.

Analysis: The forum is a well used and important space in the school. The teachers at the Parkside School evidentely agree. In a questionnaire given them they unanomously agreed that 'every school should have one'.

The forum is used formally (teachers sign up for it) by 3-4 classes each day and informally by small groups of students. It is occupied about 50% of the time based on our sampled observations. A variety of activities take place here: book fairs, play rehersals, physical play, studying, discussions, guest speakers, films and library story readings. The book fair may draw 50 people to this area and often only 2-3 students studying together may be found in the space. Proximity to the upper grade classrooms does affect its use - 7 of 8 upper grade teachers use it 'often', according to our questionnaire, while only 50% of lower grade teachers (3 of 6) mentioned using it 'often'.

Findings: Notwithstanding that this is a traditional elementary school there is indication that if given innovative teaching opportunities and amenities outside of the classroom that they will be well used. The 'Forum' seems to be successful, as intended, for a variety of activities and numbers of people. Its best atributes seem to be its proximate and easy accessibility, freedom from distractions and attractive design. The steps, especially, were used for sitting for a range of activities and numbers of users.

COURTYARDS

Each of the two wings of the school has an enclosed (20'x40') courtyard. Full height windows surround these areas and they are proximate to all classrooms. Access is via glass doors and amenities are provided - a reading circle for the lower grades and a work bench in the upper grade courtyard. Each is primarily paved with flagstones and has planting areas.

Performance required: Provide an outdoor space for group and class activities such as reading, planting, etc.

Method: See "Functional Areas-Methods". Interviews and a questionnaire also provided valuable information.

Analysis: The activity sampling was done at the most propitious time of year for outdoor activity - from April through June. Notwithstanding this, only one courtyard was used and only on one occasion. The lower grades' courtyard was not used once - the upper grade courtyard was used only once - by four boys standing around the workbench conferring about their textbook. In the year-long, informal 'reconnaissance' prior to the measured sample, we only found the courtyards used once.

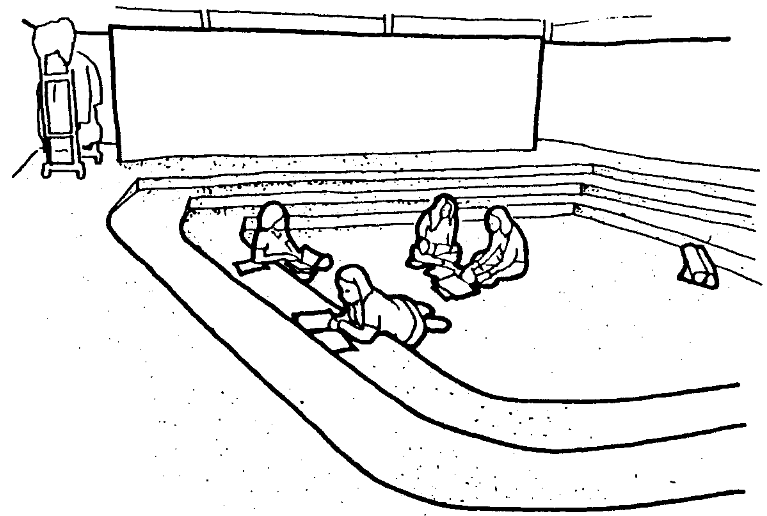
Interview and questionnaire data strongly indicates that weather is largely responsible according to the teachers. "It's too hot, sunny or breezy.", "Uncomfortable", "Glare is bad." are typical comments.

Findings: This area does not fulfill its intended use. It is not used and even with improved amenities its future usage is questionable. Weather, including the glare and heat from the surrounding windows and the flagstone pavement is the strongest hindrance. Other possible hindrances are, distractions in the surrounding corridor, the size and materials of the area limiting play activities and even acoustical problems because of the prevalence of 'hard' materials.

The teaching couryards at the Richards School, directly accessible from all classrooms, were even less used than those at Parkside. Here, again, a strong concept seems to be based on a faulty premise.

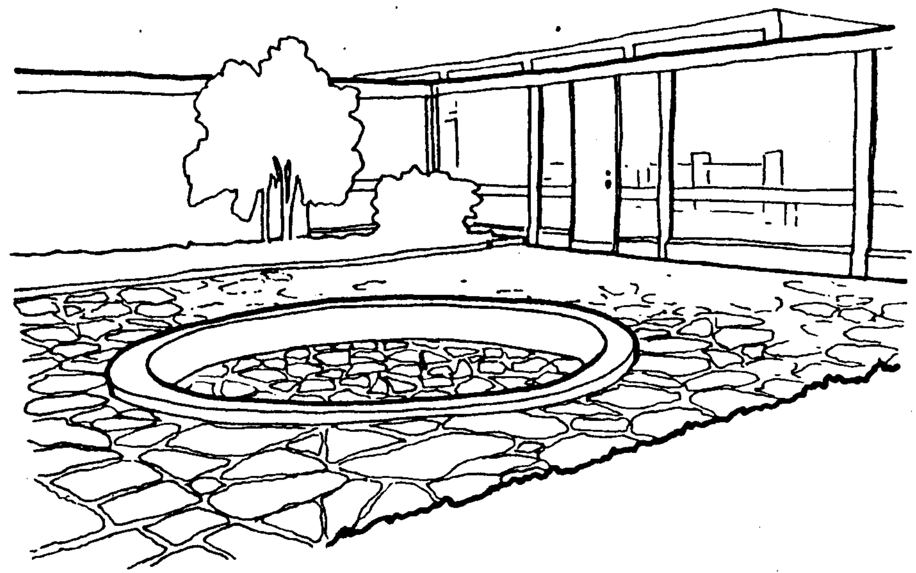
PARKSIDE : FORUM

THE FORUM IS OFTEN USED INFORMALLY BY STUDENTS FROM SOURROUNDING CLASSROOMS



PARKSIDE : COURTYARD

LOWER GRADES COURTYARD. THIS AREA WAS NEVER USED



MULTIPURPOSE ROOMS/GYMS

The two earlier schools (1962, 1966) have multipurpose rooms - a combination gym, cafeteria, assembly space, etc. The Smith and Mount Healthy Schools have separated the gym and cafeteria functions.

At the Parkside, Smith and Mount Healthy Schools the multipurpose room or gym is removed from the center of gravity of school activities; however, at Richards it is literally and figuratively (in size, location, accessability and form) the center for activities. We attempted to test if this powerful concept was viable. We also examined the multipurpose room concept vs. the separate gym and cafeteria.

Performance Required: Provide an area to be used for

Physical education
a cafeteria (multipurpose room)
events and assemblies

Method: See "Functional Areas-Methods". Only the Richards (central multipurpose room) and Smith Schools (remote gym) were observed on a regularly sampled basis. Questionaires and interviews were also used.

Analysis: Since the observational data was collected during April and May, months of mild weather in Columbus, Indiana, this would have an effect on the amount of physical education activities. However, the diminished activity should be equal in both facilities.

Both areas were being used during just over half of the observations. The uses, however, were very different. At the Smith School physical education activities were being held each time, with one exception.

At Richards only 2 of the activities observed (20%) were physical education - others were groups working with teacher aides (40%; 4 times), and rehersals and dramatic activities (30%; 3 times). The dedicated nature and removed location of the gyms at the Smith and Mount Healthy Schools both contribute to their single use as physical education facilities.

The Parkside and Richards Schools multipurpose rooms are neither dedicated nor as removed as the more recent schools. Each is used as a cafeteria and furthermore, Parkside uses the stage area, opening onto the major space, as a music classroom. The cafeteria function does inhibit physical education activities due to the set up of cafeteria tables during the morning and their removal and clean up during the afternoon. The acoustical quality of these multipurpose spaces (see Technical Factors - Acoustics) is another obstacle to the use of this room for gym activities.

Findings: The data does reflect these attributes. The Richards multipurpose room, while not supportive of gym activity is supportive of ad hoc small group activities. Its proximity to classrooms, the availability of the cafeteria tables during non-cafeteria hours and the relatively satisfactory acoustics for smaller, quieter activities does occasionally attract small groups of students. This, we believe, indicates the need for group activity spaces and not the particular success of the multipurpose room for this purpose.

The separate gym seems maore successful. To provide a minimum P.E. program for the eighteen classes in each school, a fulltime area is necessary. Our data seems to indicate that a separate gym is used for that purpose.

LIBRARIES

Each elementary school examined in this study has a school library - though the earliest, the Parkside school, originally didn't have one (see 'Growth and Change'). In each school the relationship between the classrooms and the library is different and this may have some effect on the way this area functions.

- At Parkside, the Library is located in the center of the upper grade wing and is easily accessible from all classrooms in that area.
- At the Richards school the Library is located in the administrative wing and is not easily accessible from any classroom.
- At Smith the Library is separated from the classrooms by two levels.
- At the Mt. Healthy school the Library is central to all classroom areas and accessibility is easy if not mandatory - the major corridor 'spine' in the school goes through the 'open' library.

In this school system four schools share a librarian - the librarian is in each school only 3 days every two weeks. At other times, library aides and parents staff this function.

Performance Required: provide access to books, sufficient book storage, seating and desk room and a librarian's area.

Method: see "Functional Areas - Methods".

Analysis: The first indicator explored was the amount of use the library received.

LIBRARY USAGE	P	R	S	M
TIMES OCCUPIED/TIMES OBSERVED	16/18	15/18	13/18	9/14
PERCENTAGE OCCUPANCY	89%	88%	72%	64%

The pattern above is not revealing in relating library usage to classroom proximity.

The following data indicates the type of group using the library. Independent groups were informal, small groups who were not part of a larger formal library use group. Large groups were part of teacher organized activity.

TYPE OF GROUP	P	R	S	M
INDEPENDENT GROUPS OBSERVED	22	9	7	5
ORGANIZED GROUPS OBSERVED	4	9	7	9

The libraries differ substantially in the type of group using this area.

Findings: The proximate location of the library at the Parkside school combined with the need to conduct small group activities outside of the classroom proper has made the library (and the Forum too!) actively used for this purpose. It's role, in terms of small groups meeting, is that of the multipurpose room at the Richards school though, of course, it physically supports these small group activities much better. In the lower grade wing at Parkside the corridor often contains these activities lacking alternatives (see "Functional Areas - Corridors").

At Richards and Smith schools the libraries are used in more traditional ways - the more remote location makes independent ventures by students more rare. At Mt. Healthy school the library is most used by class sized organized groups and least by independent groups. This may well be because of the open nature of the classroom areas where there are many areas where small groups can meet. However, the large amount of organized large groups seems at variance with the school's philosophy.

SCHOOL SECRETARY AREA

At the elementary school studied there is a school secretary. This individual's responsibilities include answering phone calls, school attendance, correspondence and reception.

At the Mt. Healthy and Parkside schools the secretary's area is at the entrance, easily visible and accessible. At Richards it is near the entrance but not visible from it; at the Smith school it is far removed (3 levels) from the entrance.

Two major patterns were examined - the role of this individual (and area), in the school and which environmental attributes affected behavior in this area.

Performance Required: The school secretary provides the following services:

- receptionist
- school correspondence
- school attendance
- phone answering

Method: See 'Functional Areas - Method'. Insufficient data was collected in this area at the Mt. Healthy school. In addition, at one of the schools, the secretary tabulated her tasks on two typical days.

Analysis: The school secretary's area is always occupied by the school secretary who, in addition to the above tasks, is involved in other activities:

- sells lunch tickets
- cares for sick students (nurse is shared with another school)
- sells school notebooks, pencils, etc.
- distributes mail
- handles public announcements
- duplicating

The location of this room and the amenities provided may even determine additional uses of this area:

Parkside: immediate proximity to classrooms and the need for activity space outside the classroom allows students to work in the school secretary/entrance area. In over half our observations groups of students - usually with a teaching aide - were working in this area on a folding table.

Richards: The school's duplicating machine, supplies and comfortable seating are located in the school secretary's area. A great deal of teacher activity takes place here! In 13 of 15 observations of behavior this area contained teachers either preparing material or having discussions. Note that Parkside had no teacher activity in this area.

Smith: Virtually no student or teacher activities in this area. It is separated vertically and horizontally from classroom areas and contains no seating or work areas for teachers.

Findings: The location of the room and the amenities provided determine the 'personality' of the school secretary area. Even minimally it is the 'hub' of the school containing mailroom, supplies and much of the student commerce in the school. This can be further reinforced however, as seen at the Parkside school where student work can occur at Richards where teachers prepare material and exchange ideas.

The entrance areas at the Richards and Smith schools - where the secretary is not located in the entrance - do not have amenities or the location to reinforce behaviors. Occasionally displays are present but we did not see but one activity in either of these spaces in any of our observations.

CIRCULATION AREAS

During our reconnaissance of the four schools we noted that their major circulation areas were liberally used for non-circulation activities. These areas, then, originally intended for only circulation, attracted our attention and were added to the previously designated 'functional areas'.

The layout of these circulation areas varies considerably between schools: (see diagrams, p. D-17).

At Parkside, circulation is split in two separate wings (upper and lower grades) and each wing is again split - into north and south corridors

At Richards, circulation is split in two, serving upper and lower grades. Because of the classroom layout 6 'stub' corridors are created each serving only one classroom.

At the Smith school the enclosed ramps form the major circulation path which is a rising spiral. At each leval the ramp opens onto a larger glass encased 'node' off of which branches a corridor serving 6 classrooms (2 grade levels).

At Mt. Healthy school a single corridor 'spine' serves the entire school. Most school activities are partially open to the spine or visible from it. The spine includes two large niches one of which is used as a portion of the library.

These circulation areas were examined to determine to what extent uses other than those originally intended occurred in them.

Performance required: Circulation area for the school

Method: See 'Functional areas - Methods'.

Analysis: Usage for non-circulation activities was quite high in all of the schools. Yet these are optional activities and these circulation areas do not contain supports - lighting, furnishings, finishes - for these activities.

CORRIDOR USAGE

	PERCENT OF OBSERVATIONS OCCUPIED (non-circulation activity)
PARKSIDE	
LOWER GRADES CORRIDOR	61%
UPPER GRADES CORRIDOR	45
RICHARDS	
LOWER GRADES CORRIDOR	27
UPPER GRADES CORRIDOR	0
STUB CORRIDOR	52
SMITH	
LOWER GRADES CORRIDOR	33
UPPER GRADES CORRIDOR	44
NODE - LOWER GRADES (1-2)	27
NODE - MIDDLE GRADES (3-4)	16
NODE - UPPER GRADES (5-6)	39
RAMPS	0
MT. HEALTHY	
SPINE	44

The number of groups using each corridor was small. In 83% of the observations a single group of children was present. The number of children per group was also quite small - of 83 groups observed 29 (31%) were of a single student; 30 (33%) consisted of 2 students in a group; and 11 (12%) consisted of a three student group.

In most of these groups the students were doing 'pencil and paper' activities (42%) or working together (34%). A further 16% were working with 'materials' - cutting, pasting, drawing. In other words, more passive class associated activities predominated.

Within each school specific circumstances determined differing frequencies and types of use.

Parkside: The lower grade corridors are more frequently used than those in the upper grade wing. As previously noted, the upper grade wing has the library and forum (p. D-8 and D-2) which are often used for small groups. The lower grade wing, lacking these facilities, uses the corridors more extensively. In the lower grade wing, only 3 classrooms share each corridor providing more seclusion than the corridors for the upper grades where 6 classes open onto this area.

Richards: Richards corridors are the least used. Each of the two major corridors is shared by 9 classrooms and is easily visible from the school's entrance area creating a 'public' quality. It also lacks the variegation which the niches at Parkside provide.

One particular 'stub' corridor is quite active. It serves a number of classes as central storage for programmed learning material which is heavily used.

Smith: The ramps are not used for non-circulation activity, however, the nodes and the branch corridors to the classrooms frequently contain small groups.

While the ramps are busy with circulation, the nodes create eddies and backwaters in this main circulation path which are not disturbed and do get some measure of activity. The upper grades 'node', by far is the largest, (approximately 441 square feet of usable space), gets the most activity - in 39% of our observations it was occupied by small groups of students. The other nodes (295 square feet and 233 square feet of usable space) are not large enough to become as removed from the major circulation.

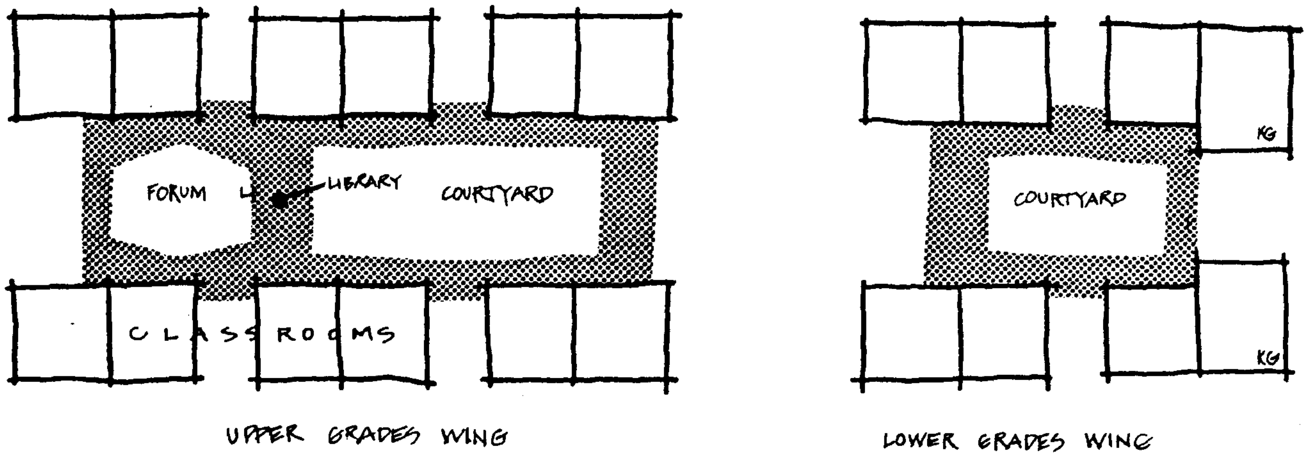
The classroom branch corridors are independent of the main spiral circulation. Shared by only 6 classes which are team taught, these areas are often used by small groups notwithstanding the inadequate lighting and small area (the corridor is only 8 feet wide).

Mt. Healthy: The spine at Mt. Healthy is used for non-circulation activities though not as much as in the other schools. As noted in 'Functional areas - Library' (p. D-8), this lesser use may be the result of the rather adequate areas, in quantity and type (places where small groups can exist independently while being proximate to teachers and class area) which exist in the teaching areas.

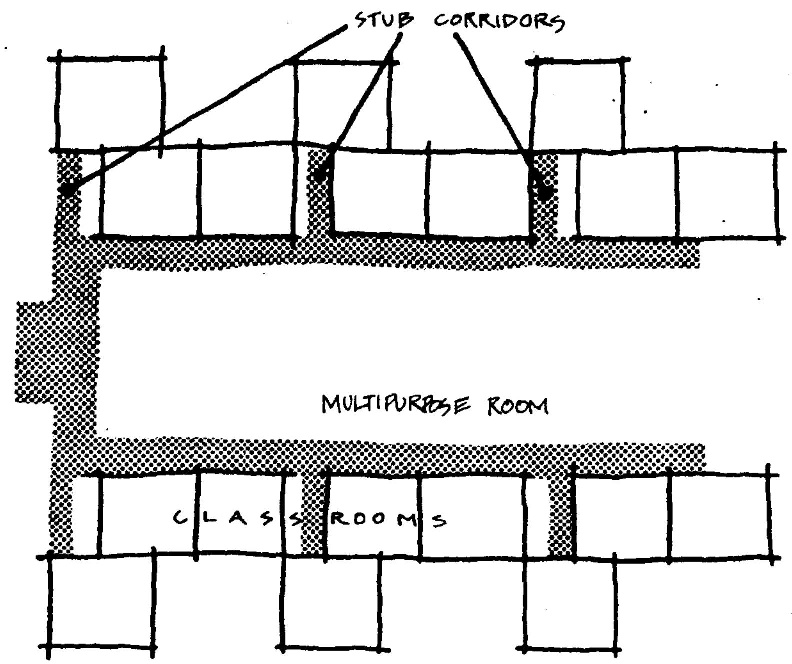
Findings: The extensive use, compared to the original intentions, of non-classroom areas, especially circulation areas with their attendant environmental difficulties, indicates a real need for attached ancilliary areas near the classroom.

The use of circulation areas seems to be determined by the proximate location of such areas to classrooms and by their privacy - or the number of classes which share it and its removal from public scrutiny. Unexpectedly, it's environmental conditions - these areas are not furnished, some are not carpeted, inadequate lighting and acoustical conditions prevail - seem no barrier to their use though the detrimental conditions may inhibit a greater frequency of usage.

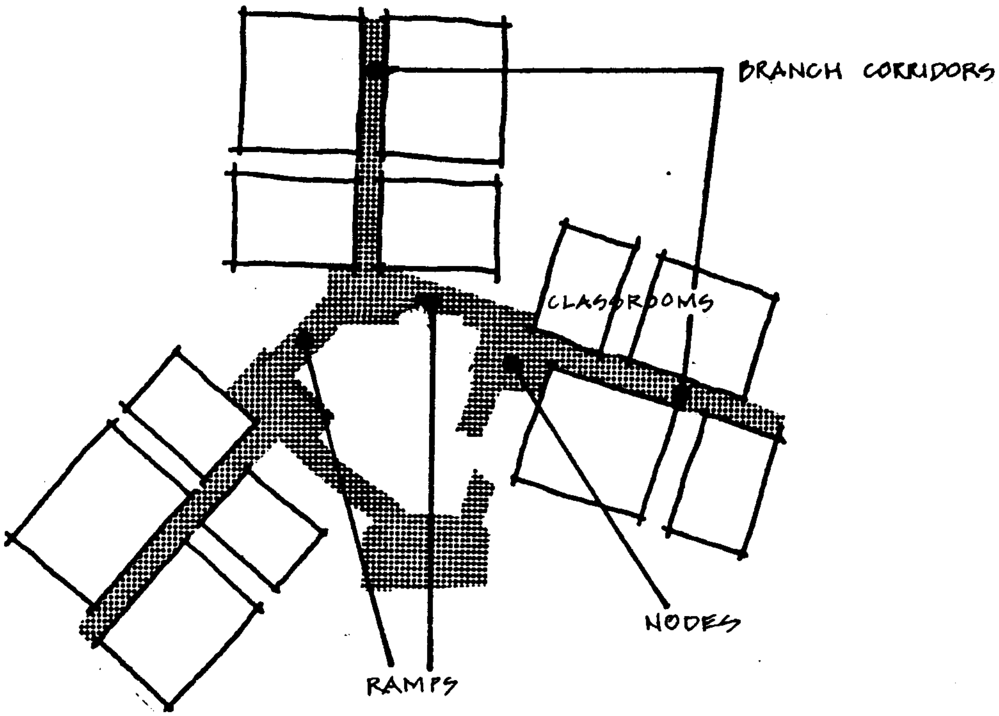
CIRCULATION DIAGRAM :
PARKSIDE SCHOOL



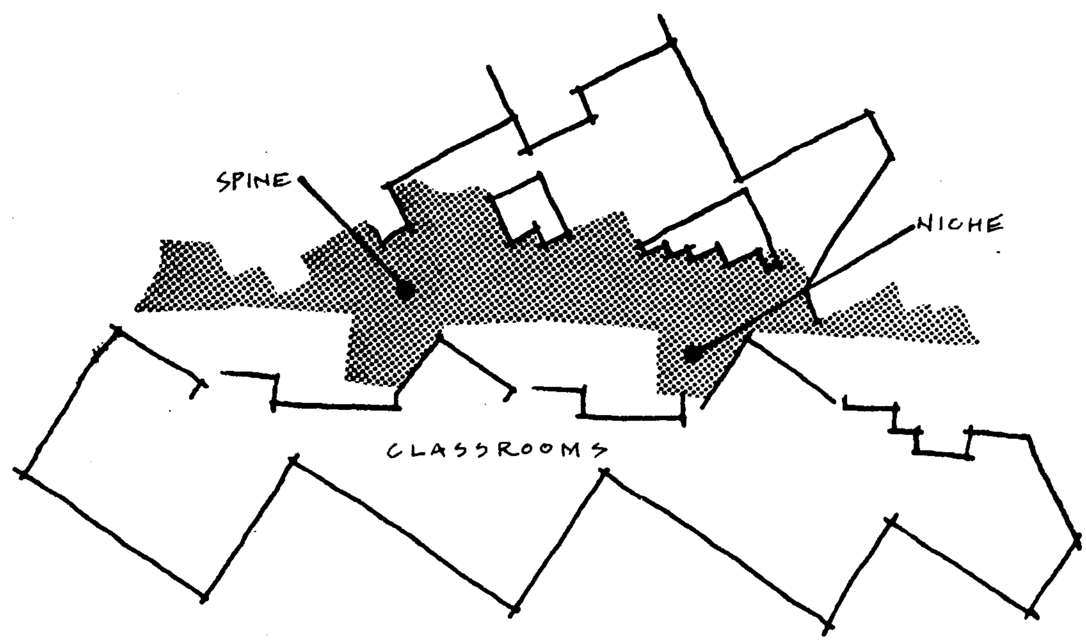
CIRCULATION DIAGRAM : RICHARDS SCHOOL



CIRCULATION DIAGRAM : SMITH SCHOOL

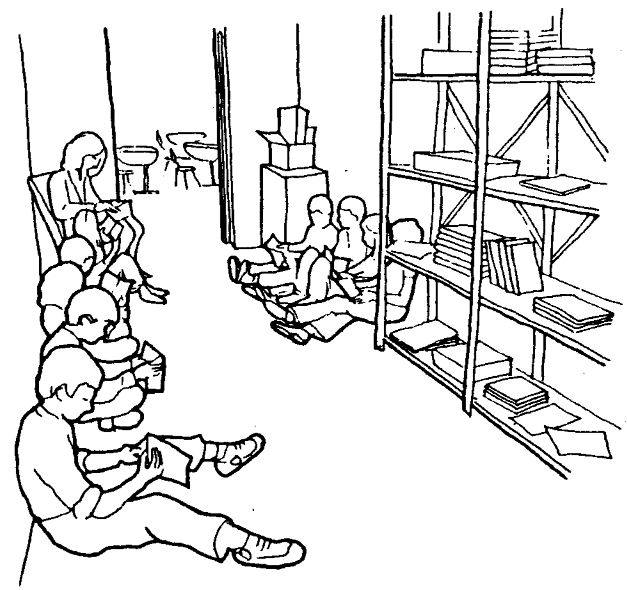


CIRCULATION DIAGRAM : MT HEALTHY SCHOOL



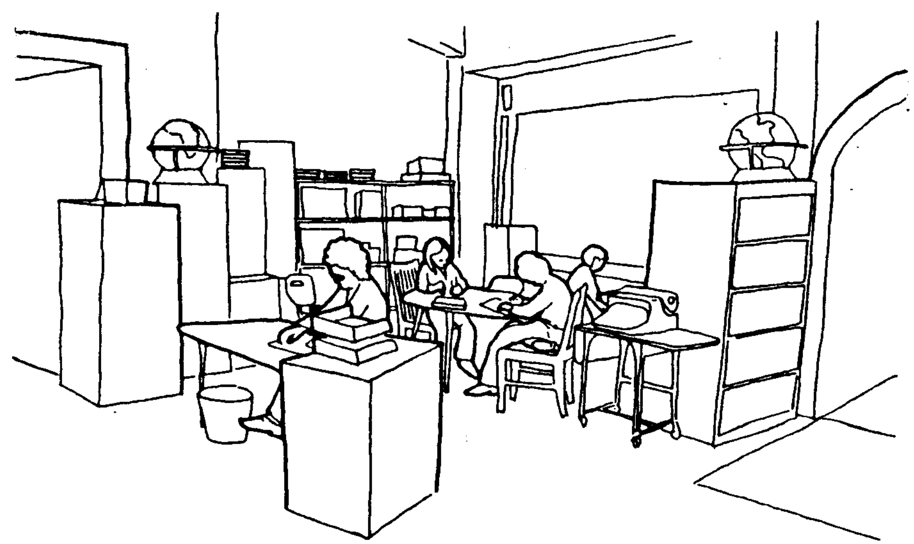
RICHARDS SCHOOL : STUB CORRIDOR

PRIMARILY USED FOR 'ACTIVE STORAGE' OF PROGRAMMED LEARNING MATERIALS. HERE A TEACHER'S AIDE USES IT TO DO READING WITH A GROUP OF 9 STUDENTS.



SMITH SCHOOL : NODE

A TEACHER'S AIDE IS USUALLY AT THE DESK AT THE UPPER GRADES NODE. STUDENTS IN THE REAR ARE INDEPENDENTLY DOING CLASSWORK. NOTE STORAGE.



GROWTH & CHANGE

SUMMARY

The four schools we examined, though their designs span only a period of 10 years (1960-1970), are a remarkable reflection of changes in education during that period. This section of the 'Functional Factors' report documents changes in the design of these schools.

Accommodation and facilitation of change is the time dimension of function. Four major types of functional change should be anticipated in design:

- increasing standards and criteria
- new philosophies and concepts
- changes in technology
- changes in legal opinion and legislation

The changes that are documented in this report should instill some respect for time in those responsible for designing and new facilities - both architects and their clients. Certain attributes of a building are especially critical in order to avoid functional and economic obsolescence.

- GENEROSITY. Optimally sizing a room, storage, and even services to exactly meet today's needs will hasten the onset of obsolescence in capacity and use.

- FLEXIBILITY. Allowing for the removal, alteration and relocation of walls and services

- EXPANSION. Accommodation for building additions with minimum disruption

- INTERCHANGEABILITY. Providing parts of the building which can be replaced with other components

Providing these attributes not only facilitates modification of a building's function but also responds to a change in function - for instance, if enrolment in a school declines, the building can be easily converted to another use, thus retaining economic value.

CHANGES IN STANDARDS

DISPLAY AND STORAGE

Display and storage needs increased greatly during the decade examined in this study (see p. A-6 and B-2). The growth in educational materials and equipment has been substantial and even the figure recommended for storage (p. B-3), adequate for today's needs, will be unsatisfactory in 5 years.

LIGHTING

Standards for the quality and quantity of natural and artificial light have been changing and based on work now in progress, will continue to change during the coming decade.

Older school buildings depended on large expanses of window for lighting and ventilation. With the common use of mechanical ventilation for heating and cooling and high output artificial lighting in schools, windows are literally no longer required. Window configurations should now be based on other criteria.

The large windows at the Parkside and Smith schools cause more problems (p. A-3; C-2) than they provide amenity. At Richards however, the window is generally used to create a place in a corner of the classroom and at Mt. Healthy only 2 of 6 class areas in a 'cluster' have large amounts of glass.

The quantity of artificial illumination in each school is now adequate. Parkside did not meet accepted quantity standards and the addition of a row of lighting remedied this problem. Recent thinking, however, which has not yet evolved into practice, emphasizes the quality of lighting - especially the importance of contrast. If this concept were applied to Parkside's original lighting configuration along two walls of the room - it could well be superior to the 'improvement' which was made.

CHANGES IN AREA

LIBRARY

The libraries in the schools studied are the best measure of change in areas for different activities.

The Parkside school design was based on the concept of the classroom library. As concepts in this area changed, a central activity area was easily converted into a well located, if small library (612 square feet).

SIZE OF LIBRARY

PARKSIDE	612 Sq. Ft.
RICHARDS	1050
SMITH	2000
MT. HEALTHY	1560

As shown in the accompanying figure the trend towards larger library areas is generally consistent. An elementary school in this district, completed in 1974, has a library substantially larger than any of the schools in this study.

PHILOSOPHICAL AND CONCEPTUAL CHANGES

TRADITIONAL & 'OPEN' SCHOOLS

The four schools clearly reflect the basic philosophical change from regimented to independent and 'open' education in elementary schools.

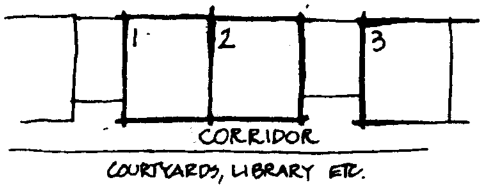
The Parkside school is in the tradition of the decades of earlier school buildings preceding it - typical 30 by 30 foot classrooms marching along corridors. This was the expected configuration at the time (1960) it was designed.

The Richards school reflects an abortive attempt to modify this concept and leans toward a 'team teaching' configuration. Originally, the two classrooms on the main corridor were to be combined into a double, team taught room, combined with the single 'outrigger' classroom to form a teaching cluster. While the concept was rejected, the original plan remains - with the double classroom sundered. Only the outdoor courtyard, which in fact is unused, is actually shared in plan. The wall separating the two classrooms is non-bearing and if the original concept was to be rejuvinated, this wall could be easily removed.

By 1969 the Smith school was able to incorporate the team teaching concept using the double and single classrooms originally proposed at Richards. The concept goes even further - 2 grades share a cluster which contains a pair of double and single classrooms.

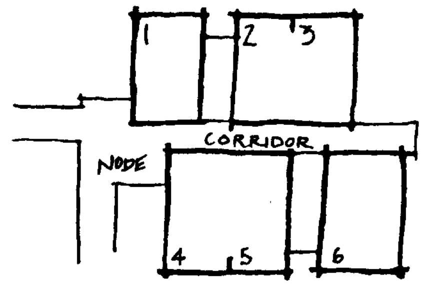
The most recent school, Mt. Healthy, is entirely 'open'. Each cluster of 2 grades has 6 potential class areas only one of which is clearly separated. Unlike any of the previous schools all students in a cluster, or any smaller number, can be com-

CHANGES IN EDUCATIONAL PHILOSOPHY REFLECTED IN BUILDING



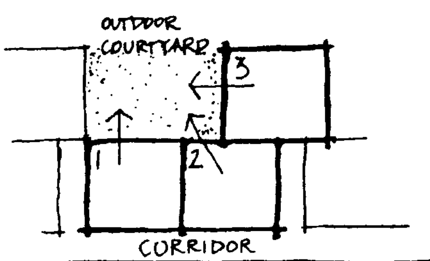
PARKSIDE SCHOOL 1962

TRADITIONAL CLASSROOMS ALONG A CORRIDOR.



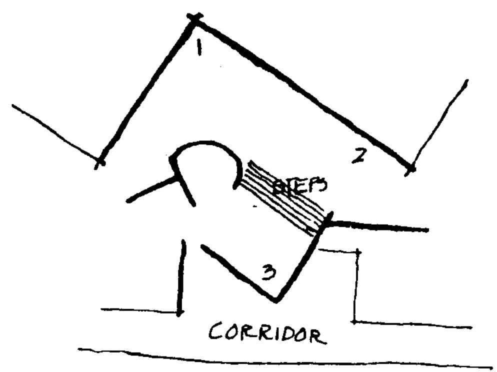
SMITH SCHOOL 1969

ROOMS 2/3 & 4/5 ARE DOUBLE CLASSROOMS. 6 CLASSES SHARE THIS 'CLUSTER'



RICHARDS SCHOOL 1966

IN THE ORIGINAL CONCEPTION CLASSROOMS 1 & 2 WERE TO BE COMBINED TO MAKE A DOUBLE ROOM.



MT HEALTHY 1972

AREAS 1, 2 & 3 ARE 'OPEN' TO EACH OTHER THOUGH 3 IS A HALF LEVEL ABOVE. OTHER CLASS AREAS ARE ALSO OPEN TO EACH OTHER.

bined in one area. Without walls around class areas, easily moveable furnishings and no assigned desks, freedom for independent action is reenforced by the design.

LIBRARY

Not only is the area of the library (p. E-4) increased but its importance and location has also undergone conceptual rethinking.

In the earlier schools, with the exception of Parkside where the library was located in the only available area, the location of the library vis a vis the classrooms is not critical. Both Richards and Smith have their libraries as far from the central locus of the classrooms as is possible. At Mt. Healthy the opposite is true - the 'resource center' (library) is centralized. The main corridor 'spine' passes directly through it and provides a maximum of contact for students with this function. In a subsequent facility - the Fodrea Elementary School - the resource center becomes the central focus of the school and the classrooms surround it, almost subserviently.

MUSIC AND ART

The Parkside school, the earliest, did not include these functions in program or design - all subsequent schools have dedicated areas for them. Presently at Parkside ad hoc measures are used. Art activities take place in classrooms - the art teacher moving materials to each room. Music takes place on the stage of the multipurpose room.

GYM/CAFETERIA

The concept of a multipurpose room for eating, recreation, meetings, presentations and dramatics evolved into the more satisfactory, if more expensive, separate gym and cafeteria. The earlier schools, Parkside and Richards, have the multipurpose room; the more recent schools separate these functions. Presentations and meetings can occur in either gymnasium or cafeteria; Smith school uses the gym while Mt. Healthy uses the cafeteria.

CHANGES IN TECHNOLOGY

EQUIPMENT

The quantity of audio-visual equipment has greatly increased in elementary schools during the past decade. Supports for the use of such equipment in the older schools - room darkening capability, outlets and storage, are not present. The more recent schools do support the present equipment but future technology may make these schools obsolete also.

While augury is not part of this study, enough prototypes and installed systems of television, individualized teaching mechanics, and computer terminals already exist to assure one that at least some of this technology will be used in elementary education. A major consideration in accommodating this change is the capacity to provide these services to many parts of the teaching areas via cables. Only Mt. Healthy, with an accessible ceiling and a most compact plan, seems to respond to this possibility.

LEGISLATIVE AND LEGAL CHANGES

This area is not a part of the 'Buildings in Use' examination per se, however, because it has become critical after many years of dormancy it is now an important consideration in growth and change and necessitates some commentary.

Three areas of legislation seem most relevant in terms of their ramifications on school facilities - provisions for access by the handicapped in public buildings; provisions for accommodating special education students in schools; and energy conservation provisions. We have not specifically examined the progress of this legislation in Indiana, however, very strong national trends in these areas are present and will soon be common. Often buildings must be retrofitted to include these changes.

FINDINGS

Findings in the area of growth and change must be based on the relatively short experience with this phenomenon in the schools studied and with some prediction of how these facilities can respond to the changes over the next 20-40 years. The criteria used are those identified earlier - generosity, flexibility, expansion and interchangeability. None of the schools are literally planned for growth and change. Notwithstanding this, however, their characteristics can inhibit or facilitate their functioning over time.

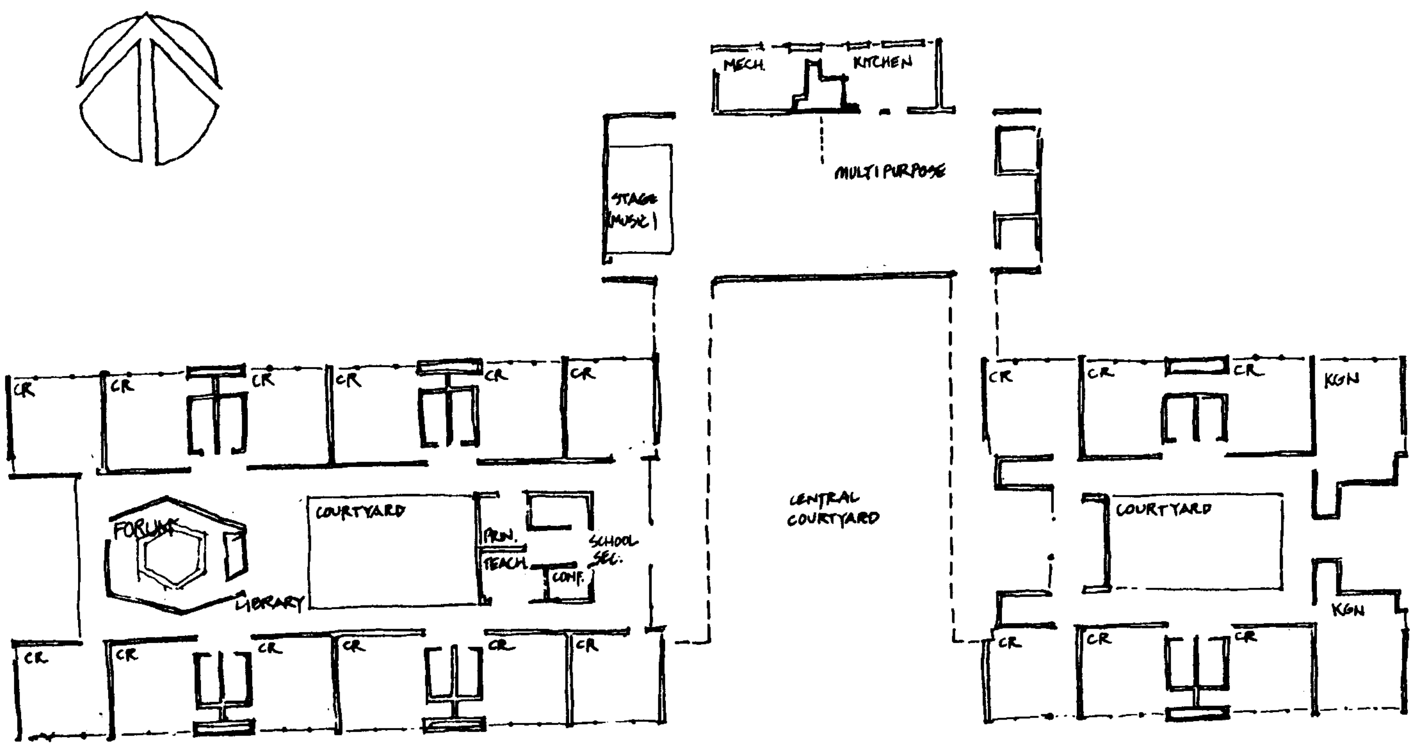
PARKSIDE. Parkside's design was originally generous enough in area to accommodate the addition of a library, the commonly seen small groups in circulation areas and a variety of activities in the Forum. Its lack of bearing walls and other encumberances can in the future, easily allow very open education. Even the courtyards can be utilized in the future with some provision for enclosure. Expansion, if necessary, can be clearly accommodated by extending existing corridors and adding areas. Interchangeable components are at a minimum - as they are in all the schools. Introducing additional utilities, teaching machines for example, may be difficult.

RICHARDS. Richards is presently the most 'taut' school examined. It has the least area to accommodate growth. East-west bearing walls restrict change but north-south walls can be easily removed opening classrooms as originally conceived. The courtyards, heretofore unused, have potential for additional area if covered. Utilities and services could be distributed by using the space between the hung ceiling and the roof.

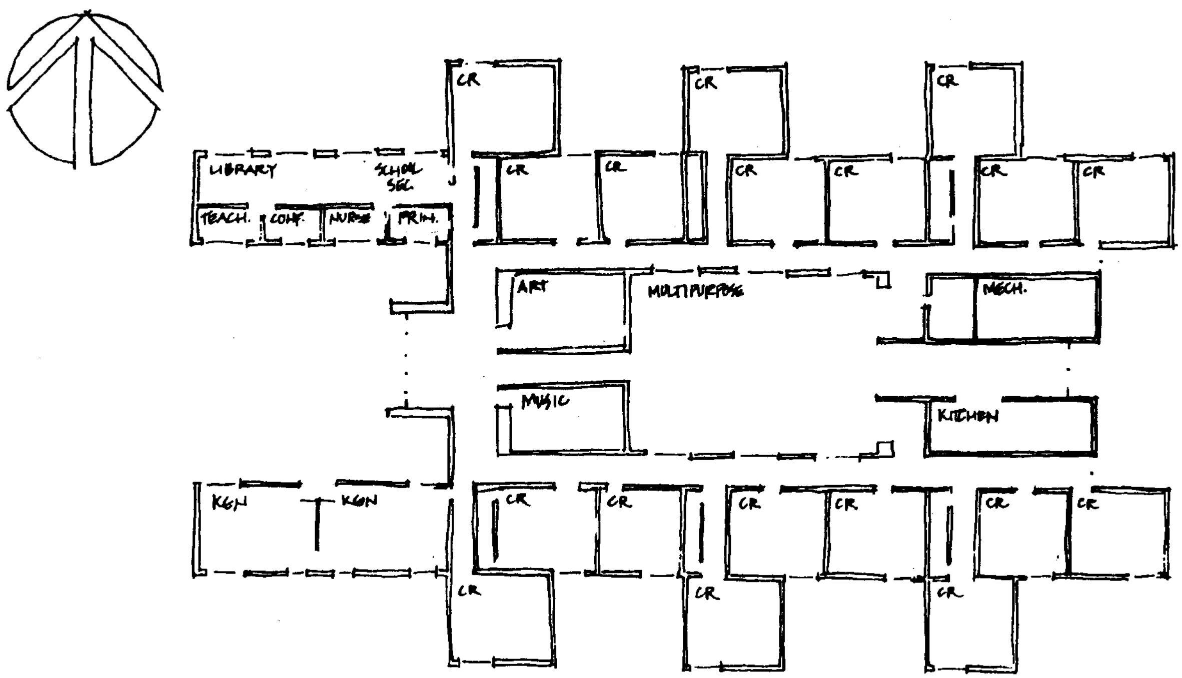
SMITH. The 'Nodes' and corridors at the Smith school have been used to supplement the existing teaching area. There is, however, no additional 'slack' area for future use and no easy way of providing this area at Smith. The existing columns can support additional floors, however the circulation to these floors - if the ramps continued upwards - would be cumbersome and not at all proximate to the classrooms. In terms of flexibility, some openness is provided by the double classroom but additional open areas are difficult to develop - the bathrooms divide the classrooms in one direction and solid concrete bearing walls in the other. The aesthetic of exposed pipes and utilities in this school makes the addition of services most easy.

MT. HEALTHY. This school is the most open and is the most responsive to change. Mobile bookshelves and storage units are already used frequently to respond to the differing area needs. Expansion can clearly be accomplished by extending the 'spine' if another cluster were appropriate. Like Smith the exposed utilities facilitates additional services or the relocation of existing ones.

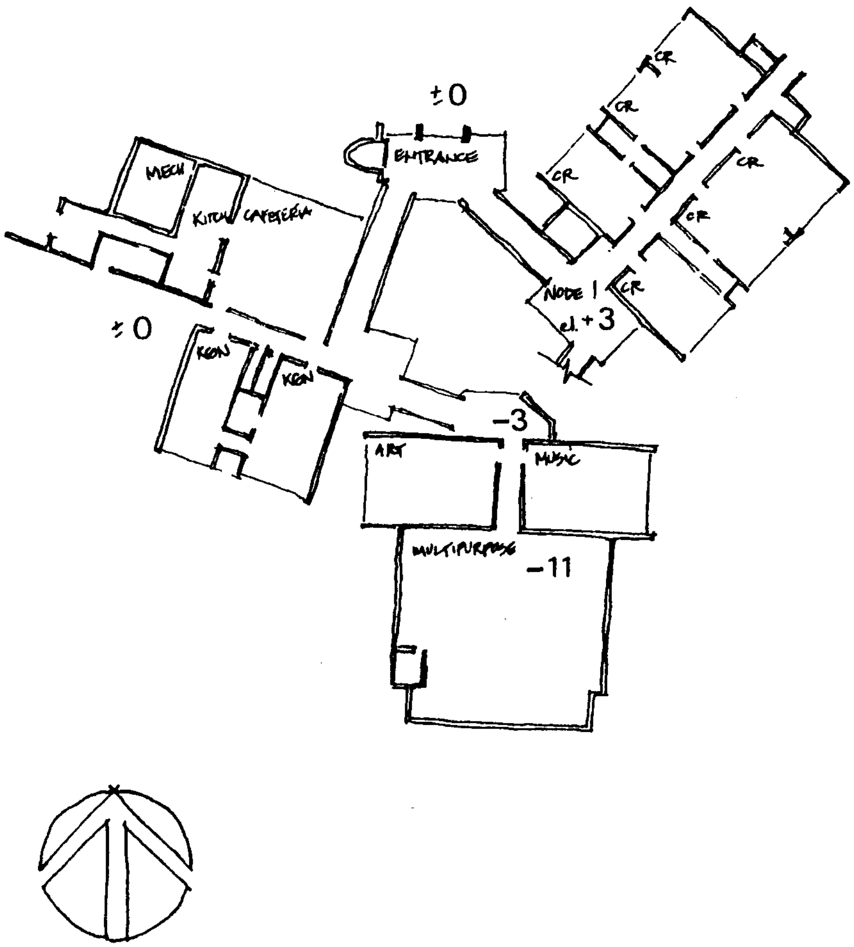
DIAGRAMMATIC PLAN OF PARKSIDE SCHOOL

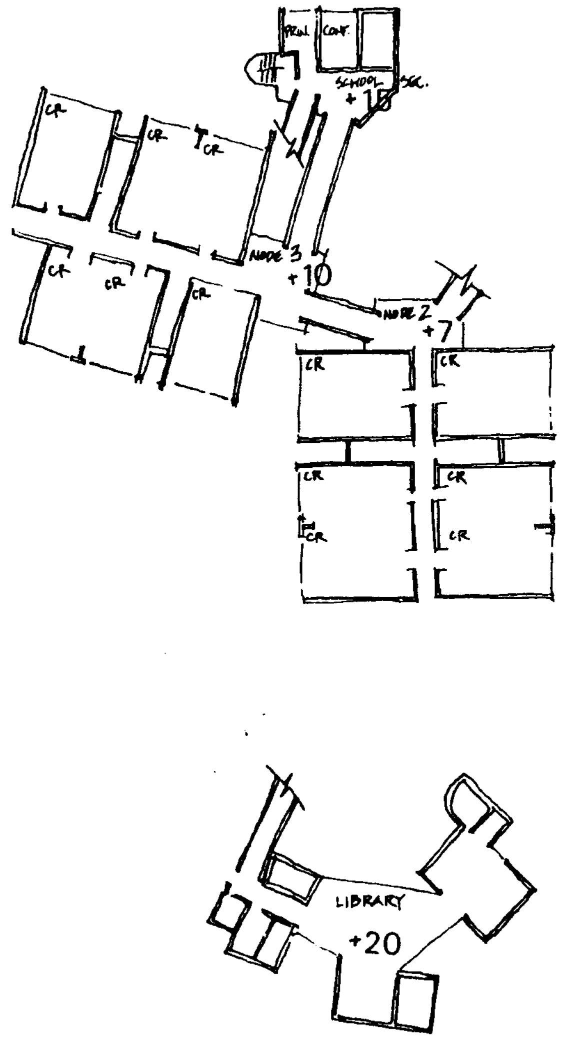


DIAGRAMMATIC PLAN OF RICHARDS SCHOOL

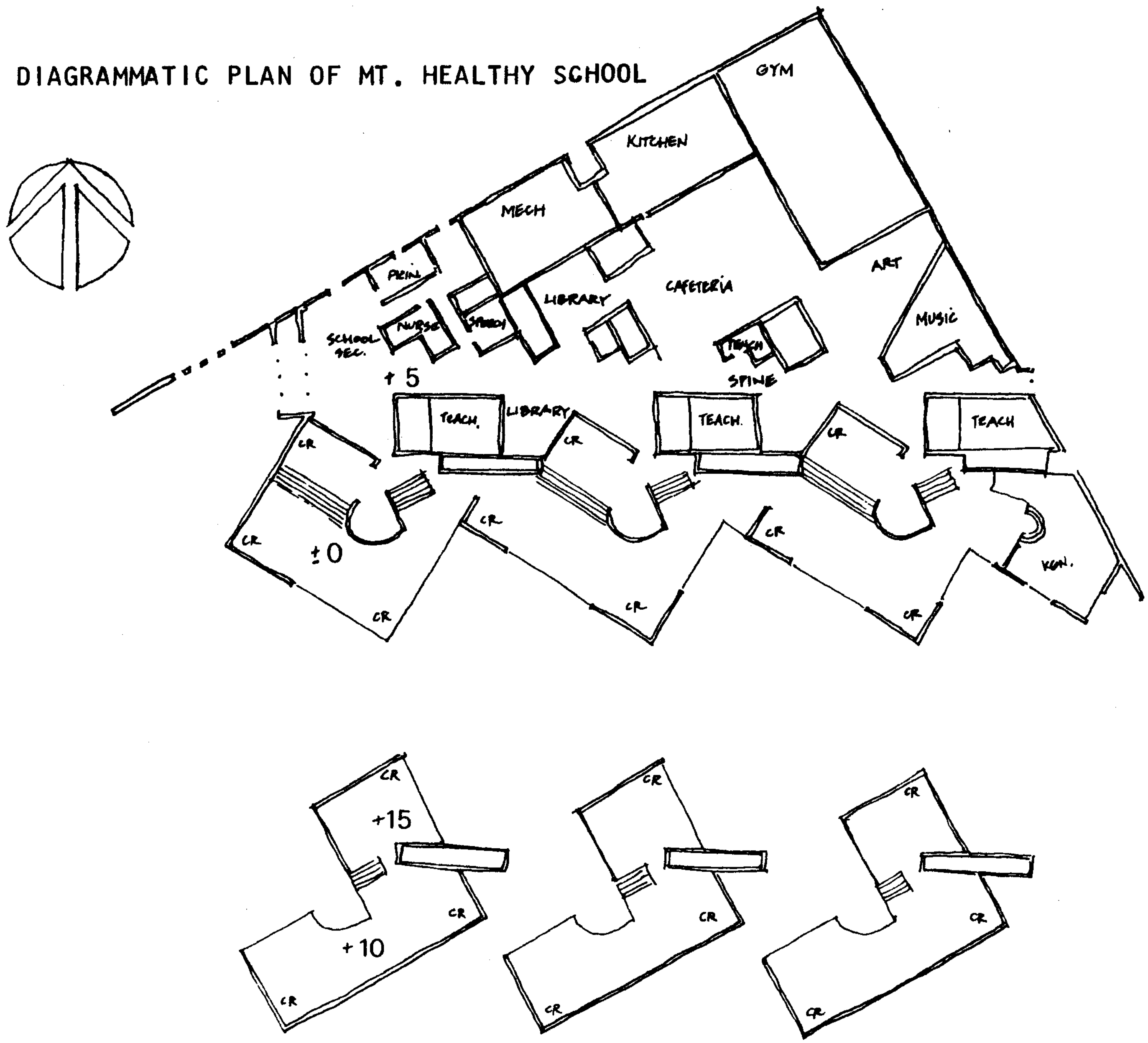


DIAGRAMMATIC PLAN OF SMITH SCHOOL

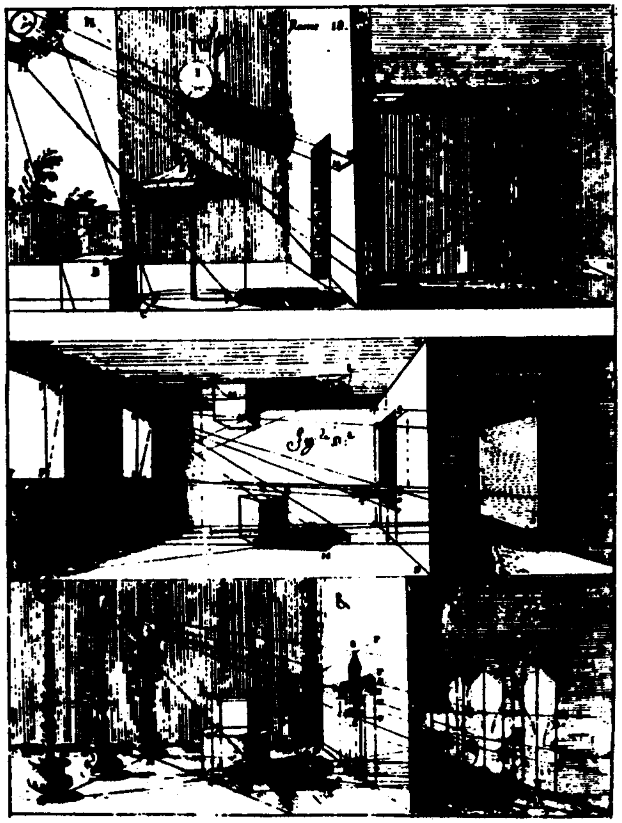




DIAGRAMMATIC PLAN OF MT. HEALTHY SCHOOL



buildings in use study



field tests manual

INTRODUCTION

Those responsible for building design rarely examine, in a formal and comprehensive manner, the environment they have helped create. We believe that such examination is, however, the primary method through which better buildings can be created. Thus, what we learn from this study can be used--by clients and architects--in the design of future buildings.

This report is one product of the "Buildings in Use" study. The overall study examines architectural characteristics of existing buildings in order to determine how they have performed technically and functionally and the relationship between the environment of the building and the behavior of its user population. This working document specifically addresses the technical aspect of the study. Later reports will include the other aspects.

TESTING AND MEASURING IN THE FIELD

Technical studies of buildings in use have been rare. Little information exists in this field and therefore, this manual should be of real use. It is truly meant to be a "working" document and suggested modifications will be welcomed - we are already making changes for the next 'edition'.

Although many laboratory tests exist for specific materials, there is a lack of field equivalents of laboratory tests which measure specific performance attributes of assembled components. Our field tests, derived primarily from existing A.S.T.M. and N.B.S. laboratory procedures, attempt to fill this need.

Laboratory procedures provide extreme accuracy by controlling test conditions through the use of apparatus which simulate real usage and actual building conditions. For instance, a standard abrading machine provides a simulation of the abrasion caused by the actions of shoes on a floor surface and the wear on this surface can be measured after a certain exposure to such a machine. Our tests, however, provide no such control and accuracy. For instance, in our field tests, the abrasion of floor surfaces has been provided by non-standard children wearing non-standard shoes carrying all sorts of grit, plus teaching and custodial staffs, over periods of time varying from two to twelve years, and the results must be reported in that context. What we lose in control of the agents of wear, we make up for in the very real nature of our testing situations.

EVALUATING TECHNICAL PERFORMANCE

Properly evaluating and reporting the results of many field tests is as critical as the effort involved in developing the tests.

After trying various methods, including detailed narrative, ratings, weightings, etc., we have developed a method which links the performance to the nature of the building. There are two assumptions which are the basis of this method.

> ...one generally cannot discuss an entire building, or even a subsystem, in such a technical investigation. There are too many performance characteristics in even the simplest situation. Each must be discussed separately.

> ...in terms of technical factors, the building must provide a satisfactory 'background' supportive of the activities in the building. A quite high performance standard for building subsystems is therefore expected so that technical factors will not at all hinder activities in the building.

The method of technical evaluation shown in the final chapter of this report presents many performance characteristics for each subsystem. Each characteristic is evaluated in the following way:

95% Performance Level: very satisfactory performance
85% Performance Level: minor performance problems which do not affect the activities within, or the image of, the building
75% Performance Level: major problems having some detrimental effects on the activities within, or on the iamge of, the building. These are correctable only by means of major repair or replacement procedures.

CRITERIA FOR EVALUATING PERFORMANCE

This manual does not contain criteria for evaluating the results of the field tests. Many factors outside the realm of this manual will affect the criteria used in individual cases of technical evaluation. Building type, age and the owner's own standards can alter the criteria for each subsystem. Our own study of elementary schools does contain criteria and an evaluation based on these tests but they are specific to our study, and some criteria even vary between the various school buildings.

USING THE FIELD TEST MANUAL

The tests in this manual exclude factors concerned with structure, fire safety and certain mechanical subsystems such as plumbing, electricity, etc. These were excluded because the standards in these areas are either so well defined in design, code, manufacture and installation and/or the measurement of these characteristics is beyond the scope of this study.

Interviews and discussions with maintenance personnel **are** invaluable in determining past performance and critical areas of performance for all subsystems. A careful examination of the working drawings and specifications can help determine areas of the building to be studied in detail and to clarify the reasons for the actual performance characteristics of certain subystems.

This manual should be used as a guide to testing. Good judgement should be used in modifying the tests to conform to the specific conditions encountered in different buildings. Although the manual is written generically, it certainly does not apply to many of the myriad of products and techniques available in construction.

Follow-up procedures for many of the tests can be very useful. The 'USE' part of each test has been performed, as mentioned earlier, by the actual users in uncontrolled circumstances. Because of this anonymous test, it is useful to use follow-up procedures in cases where findings indicate problems. The results of the follow-up tests should reveal a more exact level at which specific characteristics have failed.

The cause of problems revealed in the course of technical testing is also not a part of this manual because of the numerous circumstances which can affect performance. The technical evaluation aspect of our study will deal specifically with causal factors.

PREVIOUS STUDIES

Though a 'Field Test Manual', per se, was not found in our literature search, some significant examples of technical factors' evaluations were found.

A Study of the Performance of Buildings, K.W. Jaeggin and A.E. Brass, National Research Council of Canada 9352, May 1967.
An excellent outline for technical evaluation, very impressive and useful.

The studies of the Pilkington Research Unit of the Department of Building Science, University of Liverpool, on school, office buildings and factories. Significant research though criteria used are below U.S. levels.

Building Performance, Building Performance Research Unit, Applied Science Publishers, London, England 1972.

In addition:

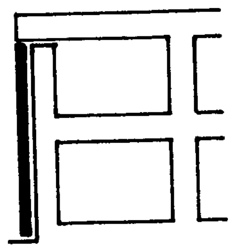
ASTM Standards in Building Codes 9th Edition, 1971.
American Society of Testing and Materials, Phila., Pa..
Contains a large number of laboratory test methods.

"Methodology for Development of Requirements for the Physical Elements of a Dwelling", H. Berger, National Bureau of Standards Report 10575. April, 1971.
Contains comprehensive lists of tests which are applicable to various activities.

Other documents which are specifically related to each subsystem are mentioned at the end of each chapter.

EXTERIOR WALLS

SUMMARY



The primary objective of the exterior wall is to keep out the weather - heat, cold, rain, snow and wind. In the process of achieving this goal, the wall is exposed to the brunt of these elements. The field tests in this area emphasize these primary objectives and are directed at conditions which impair this performance.

Undue movements of the exterior wall often create openings which will either now or in the future, cause problems. Ascribing the cause of these openings (cracks) is difficult and while they are categorized below in terms of the most likely cause, other factors can generate the same condition.

PERFORMANCE OBJECTIVE: PREVENT ELEMENTS FROM ENTERING BUILDING

TEST # 1: Control Undue Movement of Exterior Walls

Test Method: Determine past performance, if possible. Test by visually examining the complete exterior wall (outside and inside) from a distance of five feet with occasional examination from one foot in critical areas such as parapets, intersections and points of juncture with other subsystems. A vernier calipers, spark plug gapper or ruler calibrated to 1/32 inch should be used to measure separations. Depth of openings can be measured by a Depth Gauge employing a rod for probing (1/16 inch diameter and calibrated to 1/64 inch).

Oftentimes, problems not apparent on the exterior surface will be quite obvious inside because of the monolithic nature of interior materials, and their more uniform texture and color which should result in 'telltale' cracking.

A long level (at least 4 feet) and a simple venier inclinometer (Empire Corporation, Milwaukee, Wis.) reading to 1° is used to determine horizontal and vertical displacement. Data on the location and size of openings is recorded and photographs taken of these conditions.

Measures:

a. Due to thermal expansion and contraction of wall
- Cracking at intersection of walls
- Step cracking and buckling at parapets, especially corners
- Cracks in center of wall
- Cracking at intersection of low and high exterior wall
- Horizontal crack between foundation and exterior wall

b. Due to thermal expansion and contraction of structure
- Vertical or step cracks under points of structural support
- Horizontal crack at wall mid-section; lack of plumbness
- Horizontal crack or lack of plumbness where parapet meets roofline due to expansion of roofdeck
- Vertical cracks at parapet or exterior wall between column lines
- Vertical cracks at wall intersections (due to creep)

c. Due to structural loads
- Vertical crack over mid-section of lintel or step crack at upper ends of lintel
- Vertical cracks at column

d. Due to settlement
- Horizontal crack between wall and foundation
- Random vertical cracks in wall
- Step cracks at lower part of openings

TEST # 2: Resist Heat and Moisture Penetration At Openings

Test Method: Use test #1 with emphasis on the examination of caulking, gasketing and tolerances around all openings in wall.

Measures: Tolerance and seal of wall openings

- Missing or deteriorated caulking (caulking cracking, wrinkling, slump, adhesion, shrinkage, oil bleeding, brittleness, peeling)
- Gap between door and threshold (to 1/32 inch)
- Infiltration of air around door and windows
- Discoloration of openings around doors and windows

TEST # 3: Resistance to Moisture Penetration

Test Method: Same as test #2

Measures: Stains, discoloration due to moisture penetration

- Measure to 2 inches

TEST # 4: Control Condensation-Causing Heat Loss

Test Method: Same as test #3

Measures: Stains, discoloration

- Same as test #3

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST # 5: Resistance to Staining, Discoloration and Deterioration

Test Method: Same as test #1. Wall should be viewed from a distance of 5 feet.

Measures:

- Efflorescence from dissolved salts. Measure extent and severity to 1 inch
- Rust and dirt stains on surface. Measure to 6 inches. Spalling of surface (to 6 inches)
- Cracking, checking, blistering (to 1 inch)
- Fading, chalking
- Ink, pencil, marker paint damage

TEST # 6: Control Deterioration of Appearance

Test Method: Determine past performance if possible. Test by using routine maintenance procedures and commercially available cleaning materials to remove stains; discoloration; graffiti; etc., which is easily visible from 5 feet. The removal procedure should not exceed 15 minutes of application, scrubbing, etc.

Measures: Stain removal

- Completely removed (not visible from 2 feet)
- Trace remaining (just visible from 5 feet)
- Most removed (visible from 5 feet)
- Partially or not removed (easily visible from 5 feet)

REFERENCES

The most significant sources for development of these field tests were:

Performance Criteria for Exterior Wall Systems, National Bureau of Standards Report 9817. 4.25.68
This includes test descriptions in some detail and their background. Very comprehensive document on performance characteristics and the results of testing some typical specimans.

The Weathering and Performance of Building Materials, J.W. Simpson and P.J. Horrobin. Wiley, 1970.
Exterior materials emphasized. Excellent background for understanding performance required of various exterior wall materials.

The following were also helpful in test development:

The Contemporary Curtain Wall, W.H. Hunt, Jr., F.W. Dodge, N.Y., 1958

ASTM C509-66T, Cellular elastomeric, Performed Gasket and Sealing Material, Test #2,3

ASTM E283-65T & E331 Test for Air Leakage through Windows, Test for Water Resistance of Windows, Test #2,3

ASTM C67-66. Sampling and Testing Brick, Test #5

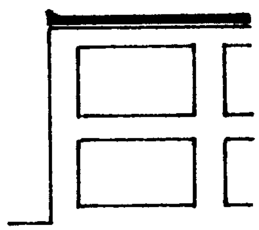
Fed. Standard #141a, method 6141. Gardner Washability Test, Test #6

SUMMARY OF EXTERIOR WALLS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE:	PREVENT ELEMENTS FROM ENTERING BUILDING
TEST # 1:	Control Undue Movement of Exterior Walls
TEST # 2:	Resist Heat and Moisture Penetrations at Openings
TEST # 3:	Resistance to Moisture Penetration
TEST # 4:	Control Condensation-Causing Heat Loss
PERFORMANCE OBJECTIVE:	PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY
TEST # 5:	Resistance to Staining, Discoloration and Deterioration
TEST # 6:	Control Deterioration of Appearance

ROOFS

SUMMARY

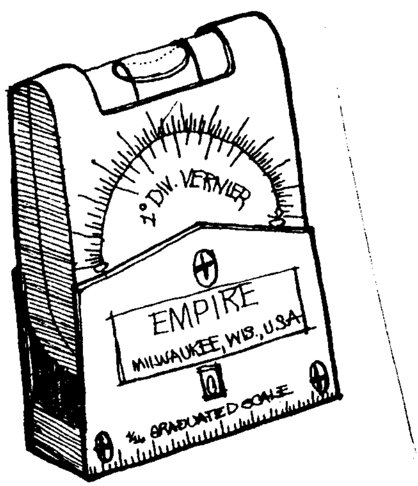


The primary objective of the roofing membrane is to absolutely keep out weather - principally moisture. In the process of achieving this goal, the roofing membrane is directly exposed to the brunt of the elements. The field tests in this area emphasize the primary objectives and are directed at conditions which impair this performance.

Small openings in the impervious roof surface cause leaks. Field tests in this area examine potential and actual openings and attempt to attribute their cause. The flat roofs are typical for the building type studied and are the only type examined by the B.I.U. Project.

PERFORMANCE OBJECTIVE: KEEP MOISTURE FROM ENTERING BUILDING

TEST # 1: Minimize Standing Water on Roof Surface



Test Method: Determine past performance, if possible. It is necessary that the field test should occur within four days of a moderate to heavy rain. Test by visually examining the entire roof to determine overall drainage patterns, standing water and obstacles to proper drainage. A long level (four feet or longer) used with a vernier inclinometer reading 1° accuracy should be used to determine slopes. Approximately five measures in each direction at equal intervals should be made for every 1000 sq. ft. of roof surface. A metal ruler can be used to measure the depth of standing water. Data is recorded and unusual conditions are photographed. Wear waterproof boots.

Measures: Ponding (standing water)

-Slopes of roof to 1° accuracy
-Extent (to two feet) and depth (to 1/4 inch) of standing water

measure with the ruler on membrane surface below aggregate level (on top of membrane).
- Obstacles in gutters and drains
- Comparison between the level of roof drain (lip) and roof three feet from drain (to 1/4 inch).

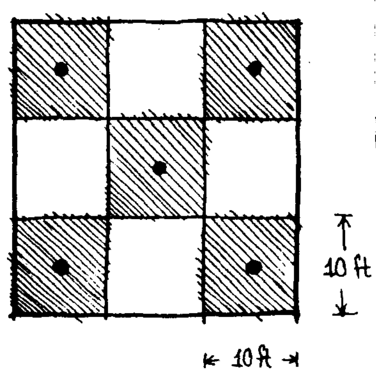
TEST # 2: Proper Detailing of Roof Penetrations

Test Method: Determine past performance if possible. Test by close examination of the working drawings and specifications to determine conditions which are not consistent with good practice and may cause potential leaks. These conditions bear careful examination in the field.

All penetrations through the roof membrane, including level changes, the roof edge, ducts, piping, skylights, etc., should be examined from a distance of one foot with a concentration on the interior of the building around these joints. Data is recorded and photographs are taken of unusual conditions.

Measures: Proper roof detailing

- Adequate flashing above roof level (to 1/2 inch)
- Membrane carried up around penetration (to 1/2 inch)
- Exposed flashing
- Evidence of leakage around penetrations



TEST # 3: Resistance to Movement

Test Method: Determine past performance if possible. Test by making a detailed visual examination of the roof from a few inches. Approximately five observations are made per 1000 sq. ft. on alternate ten foot squares. Data is recorded and unusual conditions are photographed.

Measures: Deterioration due to movement

- Tears and splits caused by moisture or temperature expansion and contraction (length to 1 inch: width and depth to 1/32 inch)
- Alligatoring around standing water due to temperature differentials or by enbrittlement (extent to 6 inches: width and depth to 1/32 inch)
- Blisters and buckles due to trapped air within membrane (to 1 inch)
- Holes (to 1/32 inch)
- Extent and quality of aggregate coverage

TEST # 4: Proper Installation of Roofing Membrane

Test Method: Same as Test #3

Measures: Roof construction

- Exposed laps of roofing membrane (to 1 inch)
- Fishmouthing (to 1 inch)

REFERENCES

Material on roofing performance which helped develop our field tests was plentiful. Manufacturers literature (Johns-Manville; Pittsburgh-Corning) and reports by institutions (National Research Council, Canada; Small Homes Council, University of Illinois; U.S. National Bureau of Standards) are all useful. The book, Manual of Built-Up Roof Systems, C.W. Griffin, McGraw Hill, 1970, was especially comprehensive. Though there is no lack of material in this area it remains, in general, an area of poor performance in practice. Reasons for this are discussed in detail in the Technical Factors Report.

In Addition:

ASTM D-1709 Impact Resistance for Film and Sheet-Type Materials

ASTM D-781 Sudden Application of Puncture

ASTM D-471 Absorption by hydroscopic Roof Covering Materials

"Flat Roof Failures" in Architects' Journal, 30 June 1971

A roofing contractor can be used to take a core sample of a roof which reveals problems in cross section. This is easily patched.

SUMMARY OF ROOFS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: KEEP MOISTURE FROM ENTERING BUILDING

TEST # 1: Minimize Standing Water on Roof Surface

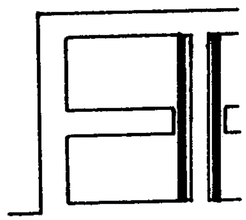
TEST # 2: Proper Detailing of Roof Penetrations

TEST # 3: Resistance to Movement

TEST # 4: Proper Installation of Roofing Membrane

INTERIOR WALLS

SUMMARY



Interior walls constitute the means for separating the various activities occurring simultaneously within the building. In fulfilling this principal separating function, such interior partitions must meet criteria of structural soundness, physical durablity and present an acceptable appearance. The field tests in this area emphasize these performance objectives and are directed at conditions which impair this performance.

PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY

TEST # 1: Resistance to Loads

Test Method: Determine past performance, if possible, Test by examining each interior wall from a distance of five feet. Cracks, splits or any other discrepancies should be carefully located and recorded in terms of position, length, depth, width, direction and described in detail in regard to special relationships, such as to beams, corners, wall openings, etc. Photograph any unusual conditions observed.

Deflections in any direction, as indicated by measurements taken with a plumb line and level, should also be noted, recorded and photographed.

Measures: Cracks, splits

- Record length, depth, width to 1/32 inch

Measures: Deflection

- Record to 1/32 inch

TEST # 2: Resistance to Impact

Test Methods: Determine past performance, if possible. Test by observing from a distance of one foot areas of high impact loads, such as around doorways, and note any instances of either cracking or splitting. Record and photograph.

Measures: Cracking, splitting, crushing, indentation
- Record to 1/32 inch

TEST # 3: Support for Attached Loads

Test Method: Determine past performance, if possible. Test by examining the wall at points of support for attached loads, from a distance of one foot, noting any damage to the wall, its surface or any other subsystems as a result of attached loads (e.g., clothes racks, blackboards, hung shelves, etc.). Record and photograph any instances of damage.

Measures: Cracking, splitting, deflection, permanent set
- Record to 1/32 inch

TEST # 4: Proper Installation of Nonsystem Elements

Test Methods: Determine past performance, if possible. Test by examining the interior walls, from a distance of one foot, at the interface with nonsystem elements. Door and window tolerances should be checked for loose fit or tight fit. Door jams and window frames should be checked for cracks and spaces where they meet the wall. Bulletin boards, blackboards and other fastened objects should be checked for looseness and broken surfaces around their fasteners. Any broken or loose hardware should be noted by location and type of damage, recorded and photographed.

Measures: Looseness, tightness

- Record according to the amount of or resistance to movement as extensive, moderate or slight

Measures: Cracks, splits

- Record to 1/32 inch

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

TEST # 5: Durability of Surfaces

Test Method: Determine past performance, if possible. Test by observing all wall surfaces from a distance of four feet. Cohesion/adhesion of surfaces can be checked by noting instances of buckling, peeling, delamination and the extent and location of each. Delamination of surface or residual adhesive which may occur due to removal of adhesive tape. Record and photograph.

Durability of the surfaces is tested by locating concentrations of dents, scratches, gouges and punctures. Such concentrations may be expected to occur around doors and the lower ten inches of doors. Observe from a distance of one foot. Measure the depth and width of these, if possible. Note their location, severity and photograph.

Test for color fastness to light, evenness of color and abrasion by visual comparison between an unused sample and a sample area of the material in use. Record and photograph any deterioration observed. Short descriptions of certain special instances where damage seems extreme or out of the ordinary should be written. Record and photograph.

Measures: Record the incidence, location, severity and extent of buckling, peeling, delamination, cracking, crazing, splitting, blistering (to 1/2 inch); indentation, punctures, scratching and gouging (to 1/32 inch).

TEST # 6: Resistance to Scratching and Abrasion

Test Method: Determine past performance, if possible. Test by locating, from a distance of four feet, concentrations of damage due to scratching or abrasion. Note any relationship to openings in the wall (e.g., windows, doors, etc.) and describe according to location, type, severity and extent of damage. Record and photograph.

Measures: Scratches, gouges, punctures, indentation, chipping

- Record to 1/32 inch

TEST # 7: Water Absorption and Retention

Test Method: Determine past performance, if possible. Test by comparing, from a distance of two feet, an unused sample with the material in use on the surface of the wall. Note instances of water-related deterioration, and such relationships to windows, doors, elements of the water system, the roof system and exterior walls as may exist. Record instances of damage by noting location, type, extent and severity of damage. Photograph.

Measures: Color change, staining, cracking, blistering, swelling

- Record by location, severity and extent of damage

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST # 8: Cleanability and Resistance to Stains

Test Method: Determine past performance, if possible. Test by visually locating, from a distance of five feet, stains and other areas which need cleaning. List the stains and note the locations. Attempt to remove the existing stains with cleansors and methods used by the maintenance staff. Record the results and any effects on wall materials.

Observe, from a distance of three feet, areas which have been cleaned and note any loss of gloss value in comparison to an unused sample of the same material, and any other cleaning-related deterioration.

Measures: Cleanability

- Record the change in the stain after cleaning as:
  - completely removed (not visible from two feet)
  - trace remaining (just visible from five feet)
  - mostly removed (visible from five feet)
  - partially or not removed (easily visible from five feet)

TEST # 9: Dust Accumulation

Test Method: Determine past performance, if possible. Test by visually comparing an unused sample with the material in use on the wall. Note any graying which might indicate dust retention on or within the surface of the material.

Measures: Color change (graying)

- Record color change as slight, moderate or severe.

In recent years some excellent work has been done in collecting performance data on interior finishes-interior walls, floors and ceilings. Two documents which contain excellent information are:

"The PBS Performance Specification for Office Buildings", by D. Hattis and T. Ware, et. al., National Bureau of Standards Report, 10 527, Jan. 1971

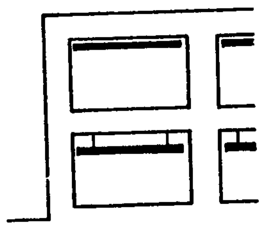
"The Performance Concept", V.I. by Staff, National Bureau of Standards Report, 9849, June 1968

SUMMARY OF INTERIOR WALLS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE:	PROVIDE STRUCTURAL STABILITY
TEST # 1:	Resistance to Loads
TEST # 2:	Resistance to Impact
TEST # 3:	Support for Attached Loads
TEST # 4:	Proper Installation of Nonsystem Elements
PERFORMANCE OBJECTIVE:	PROVIDE A PHYSICALLY DURABLE SURFACE
TEST # 5:	Durability of Surfaces
TEST # 6:	Resistance to Scratching and Abrasion
TEST # 7:	Water Absorption and Retention
PERFORMANCE OBJECTIVE:	PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY
TEST # 8:	Cleanability and Resistance to Stains
TEST # 9:	Dust Accumulation

CEILINGS

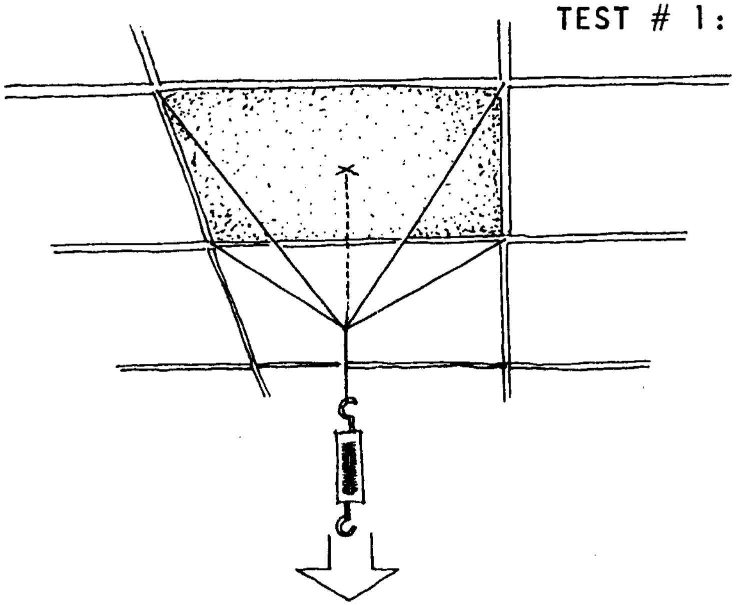
SUMMARY



The ceiling subsystem refers to the finished ceiling surface (i.e., that which is visible to the users of the building). As such, its satisfactory appearance is its primary function, and success or failure in this regard essentially derives from its initial design. This being the case, the principal concerns with the ceiling are that it retain its satisfactory appearance, that it be structurally sound, and that it not interfere with the normal activities of the space it encloses. The field tests in this area emphasize these primary objectives and are directed at conditions which cause deterioration in appearance and function.

PERFORMANCE OBJECTIVE: PROVIDE STABLE STRUCTURAL SUPPORT

TEST # 1: Resistance to Loads

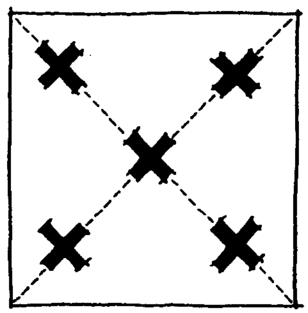


Test Method: Determine past performance, if possible. Test by constructing a simple apparatus consisting of a wire, run from each of the four corners of the ceiling grid, suspending a tension scale (see diagram). Apply downward pressure and observe any deflection which occurs as a result. The ceiling support system should be able to resist up to four pounds per square foot of ceiling area (see diagram). (Refers to suspended ceilings only.)

Measures: Deflection

- Record the pull in points, necessary to induce noticeable deflection (i.e., greater than 1/16 inch) in the ceiling grid.

TEST # 2: Parallel to Floor



Test Method: Determine past performance, if possible, Test, with a plumbline and a tape graduated to 1/16 inch, by measuring the floor to ceiling height at the one-fifth points of both room diagonals and at the crossing of the diagonals (see diagram). Record each height to 1/16 inch accuracy. Record and photograph.

Measures: Floor to ceiling distance

- Record differring in inches between the lowest and highest floor to ceiling distance
- Record inches deviation from the average floor to ceiling height

TEST # 3: Resistance to Ascending Forces

Test Method: Determine past performance, if possible. Test by slamming a door forcefully fifty times in succession, and observe, from a distance of two feet, any displacement or damage to the ceiling. Record and photograph.

Measures: Damage and displacement in ceiling

- Record type and extent of damage

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

TEST # 4: Cohesive Strength

Test Method: Determine past performance, if possible. Test by observing, from a distance of one foot, all coatings on exposed areas of the ceiling (one observation per 100 square feet of ceiling area). Locate and record areas of possible problems.

Measures: Crumbling, flaking, breaking, discoloration

TEST # 5: Adhesive Strength

Test Method: Determine past performance, if possible. Test by observing the entire ceiling from eye level to determine if any area has been sagging or pulling away from its support system. Check to see if any tiles have been replaced. Record and photograph problems and problem areas.

Measures: Delamination

- Record as severe, moderate or slight

TEST # 6: Resistance to Impact

Test Method: Determine past performance, if possible. Test by gently tapping the ceiling with the end of a broom handle, observing any damage from a distance of two feet. Tap again, harder, and observe. Finally, give it a very hard poke and observe, the indentation caused by even the hardest impact should not be greater than 1/16 inch deep. Record and photograph any damage. (This test should be run only once for each type of ceiling material in use.)

Measures: Indentation

- Record depth to 1/16 inch

TEST # 7: Resistance to Scratching

Test Method: Determine past performance, if possible. Test by obtaining samples of each type ot ceiling material in use. Using 6B, 2B, and 2H pencil leads of medium sharpness, make a scratch in the surface with each, using a force not quite sufficient to break the lead point. Note the apparent depth of the resulting scratches and record. (This need be done only once for each type of ceiling material in use.)

Observe the ceiling from eye level, noting any scratches and the areas in which they occur. Record and photograph, if possible.

Measures: Scratching

- Record depth as heavy, medium or trace
- Record areas of scratching by extent, severity and location of damage

TEST # 8: Resistance to Water

Test Method: Determine past performance, if possible. Test by observing the entire ceiling from eye level. Note any staining or discoloration from elements, such as rust, that may be present in water. Record and photograph any damage, and indicate the probable source of the leakage.

Measures: Staining

- Record areas of staining by extent, severity and location of damage.

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE

TEST # 9: Anthropometric Fit

Test Method: Determine past performance, if possible. Test by determining, through observation and from the results of Ceiling Test #2, that it is possible for the average person to walk under the ceiling without it or any other subsystem causing personal injury or presenting a potential danger. Record and photograph any potentially dangerous situations.

Measures: Ability to walk under the ceiling

- Minimum ceiling height: 6 feet, 8 inches

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST #10: Color Homogeneity

Test Method: Determine past performance, if possible. Test by scoring, on a sample of each type of material in use on the ceilings, a grid of 1/16 inch squares on an area of the surface 1/2 inch by 1/2 inch. Press and smooth on firmly a piece of 3M Company "Scotch" brand magic transparent tape over the scored lines and lift off sharply. Record the results, noting depth of color.

Observe the entire ceiling from eye level, noting any areas of flaking, peeling, any chips or dents, Record and photograph. Identify probable cause.

Measures: Depth of color on surface

- Linear depth to the nearest 1/32 inch, or as an approximate percentage of total thickness of ceiling material

Measures: Flaking and peeling

- Record the number of 1/16 inch squares that tear away during the testing procedure
- Record any damage observed by type, location, severity and extent

TEST #11: Resistance to Fading

Test Method: Determine past performance, if possible. Test by obtaining an unused sample of each material in use on the ceilings. Compare these samples with the installed ceiling for instances of fading. Record and photograph.

Measures: Fading

- Record as severe, moderate or slight

TEST #12: Resistance to Dust Accumulation

Test Method: Determine past performance, if possible. Test by examining the ceiling from eye level, noting any instances of trapped dirt or dust, especially around HVAC equipment and outlets, windows, doors, etc. Record and photograph.

Measures: Dust accumulation

- Record by location, extent and severity of damage

TEST #13: Cleanability

Test Method: Determine past performance, if possible. Test by washing a one foot square sample area of the ceiling surface with a mild detergent solution. Allow it to dry. From a distance of one foot, examine the cleaned surface for any cracking, splitting, spalling, blisters, delaminations or breaks in the surface. Record and photograph. Repeat test for each ceiling material.

Measures: Surface deterioration due to cleaning

- Record the type, extent and severity of damage

TEST #14: Access to Plenum

Test Method: Determine past performance, if possible. Test by removing the panels that provide access to the plenum. The opening provided must be large enough to permit access for servicing. Record the size of the panels and photograph.

Remove and replace the access panel twenty times. Examine from a distance of one foot, record and photograph any damage.

Measures: Accessibility

- Access panels should measure not less than 20 inches square.

Measures: Visual appearance

- Record any damage resulting from removing and replacing of the access panels by type, severity and extent of damage.

TEST #15: Accommodation for Out-of-System Hardware

Test Method: Determine past performance, if possible. Test by determining if the ceiling system is capable of accommodating other subsystems or out-of-system built elements in the typical enclosed space at all points where maintenance or adjustment of these built elements may be required. Record and photograph.

Measures: Adaptability to out-of-system hardware.

-Record as adequate or inadequate (and explain).

See interior wall notes P. C-6. The reports mentioned contain excellent documentation of performance and tests in the areas of interior walls, ceilings and floors.

SUMMARY OF CEILINGS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE STABLE STRUCTURAL SUPPORT
- TEST # 1: Resistance to Loads
- TEST # 2: Parallel to Floor
- TEST # 3: Resistance to Ascending Forces

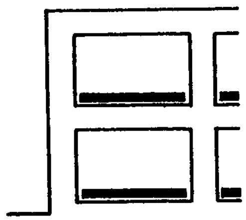
PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE
- TEST # 4: Cohesive Strength
- TEST # 5: Adhesive Strength
- TEST # 6: Resistance to Impact
- TEST # 7: Resistance to Scratching
- TEST # 8: Resistance to Water

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE
- TEST # 9: Anthropometric Fit

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY
- TEST #10: Color Homogeneity
- TEST #11: Resistance to Fading
- TEST #12: Resistance to Dust Accumulation
- TEST #13: Cleanability
- TEST #14: Access to Plenum
- TEST #15: Accommodation for Out-of-System Hardware

FLOORS

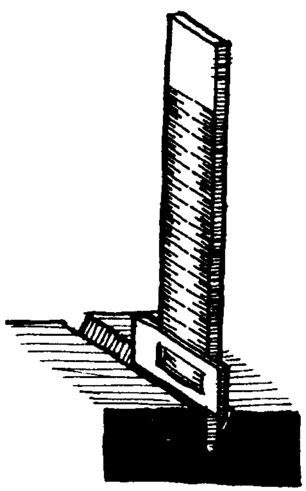
SUMMARY



The primary objective of the floor system is to provide a structurally stable plane for the activities occurring within the building and the equipment which supports these activities. The floor system should also be physically durable, maintainable, hygienic, safely usable and present a satisfactory appearance. The field tests in this area emphasize these primary objectives and are directed at conditions which impair this performance.

PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY

TEST # 1: Resistance to Static Loads



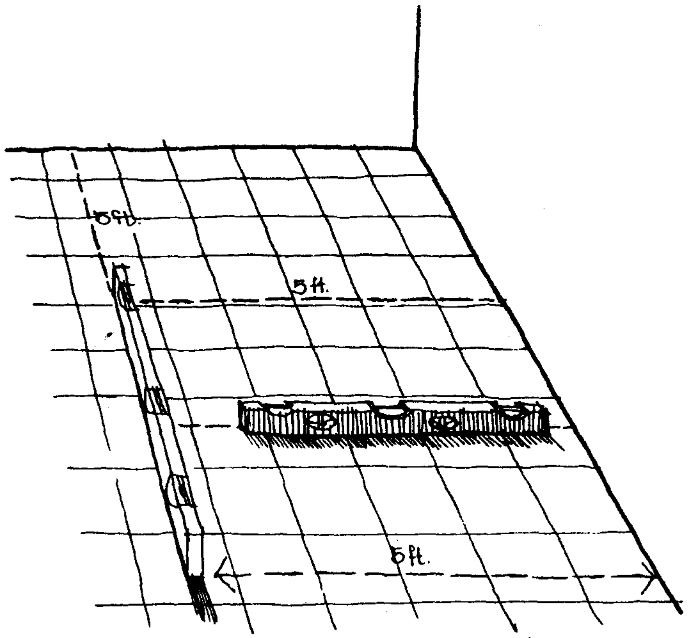
Test Method: Determine past performance, if possible. Test by locating at least one heavy load in the room (e.g. a desk, bookcase, file cabinet, etc.). Observe the floor around the legs from a distance of one foot noting any change in physical condition. If possible, shift the load and observe an indentation in the flooring. Measure this with a depth gauge.

Observe the floor from a distance of three feet, at any angle, with the floor illuminated. Record the number of indentations, and photograph.

Measure: Indentation, cracking, splitting
- -Based on depth, record as slight (less than 1/16 inch), moderate (1/16 to 1/8 inch), or severe (greater than 1/8 inch).
- -Based on width, record as slight (less than 1/32 inch), moderate (1/32 to 1/16 inch), or severe (greater than 1/16 inch).

Measure: Checking
- -Record as slight, moderate or severe based on areal extent and depth of cracking.

TEST # 2: Levelness of Surface



Test Method: Determine past performance, if possible. Test by sweeping the floor clean of all particulate matter which might interfere with the testing procedures. Rolling a spherical object such as a ball bearing to observe deviation from a straight line path, or observing flow or ponding of water during cleaning operations can be used as gross indicators of a general or localized non-level condition which can then be verified by more precise measurement using long levels.

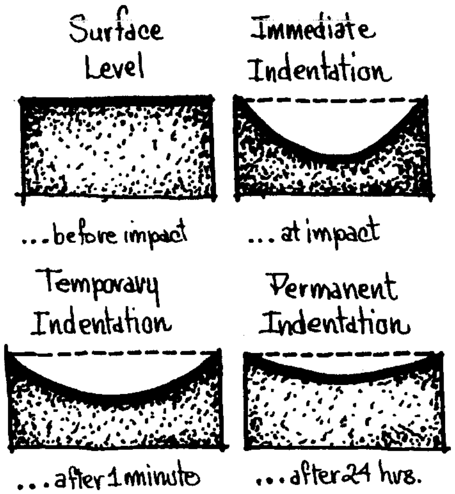
Place a four foot level on the floor parallel to, and within five feet of, a wall to determine whether or not the floor is indeed level. Determine if the level rests evenly on the surface along its entire length. Light penetration under the level from the opposite side will indicate deviations from a level condition. Repeat the test in the same location but with the level perpendicular to the wall. (Test should be conducted once for every 500 square feet of floor area.) Record the results.

Measure: Significant problems with an unlevel condition may be said to exist when such a floor is measurably and/or noticably sloped, either in general or in any small area such that it interferes with normal activities, routine maintenance, the stability of objects resting on it, or produces psychological discomfort for its occupants. Visually note and describe instances of cupping, bulging or slope as slight, moderate or severe.

PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE

TEST # 3: Resistance to Point Impact

Test Method: Determine past performance, if possible. Test by visually evaluating the result of impacting, with reasonable force, a conventional 3/4 inch diameter hammer head on the floor sur-



face. It should withstand any reasonable impact without damage. Record and photograph.

Measure: Determine the depth of any indentation, to the nearest 1/64 inch, with the aid of a level and any standard linear measuring device applicable to the situation. Note the occurrence of any splitting, cracking or crazing. Measures should be made at the time of the test and again after 24 hours. Note the permanence of the damage.

TEST # 4: Resistance to Abrasion and Scratching

Test Method: Determine past performance, if possible. Test by locating areas of heavy use (e.g. doorways, aisles between desks, under desks, in front of sinks, etc.). Place a four foot level over the area with each end of the level supported by an area of less hard use. Measure the depth of the wear with a ruler. If the test for color homogeneity (Floor Test #15) yields the fact that the surface color does not fully penetrate the material, observe and note any areas where the subsurface color of the material shows through.

For scratching, observe the flooring from a distance of three feet, at various angles, and note any areas of scratching or ground-in dirt. Clean a sample scratched area with a damp sponge passed vigorously over the area ten times. Rinse with one pass of a clean sponge. Observe the area again from a distance of one foot, recording the extent and severity of the damage from scratching and ground-in dirt. Photograph.

Measure: Abrasion
-For large area abrasion, note change in depth to 1/64 inch
-For abrasion with wear of the top surface color layer, note extent to 1 inch and depth to 1/16 inch.

Measure: Scratching
-Record depth of scratches to 1/64 inch and length to 1 inch

TEST # 5: Cohesive Strength

Test Method: Determine past performance, if possible. Test by visually locating areas of hard use (i.e. possible areas of crumbling or breaking) or areas subject to standing water. Observe from a distance of three feet. Record and photograph any deterioration.

For carpeting, test by running a common nail through a loop of the carpet. Holding the nail in the hand, exert a pressure increasing to about seven pounds. Record any yielding in the carpet, such as snagging or running, and photograph.

Measure: Crumbling, breaking
-Record as extensive, moderate or slight
Measure: Snagging, running
-Record the amount of pressure necessary to cause damage as heavy, moderate or light

TEST # 6: Adhesive Strength

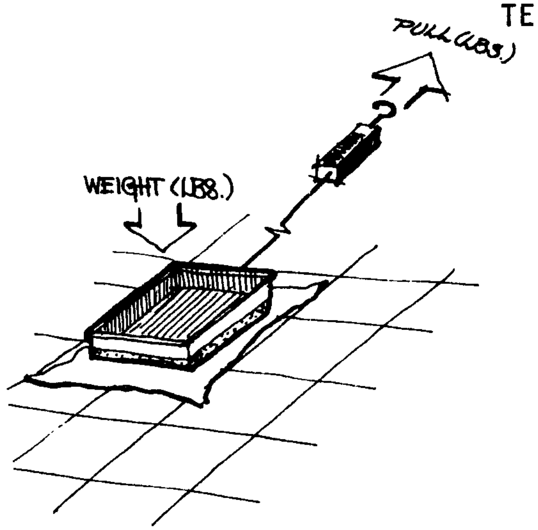
Test Method: Determine past performance, if possible. Test by visually examining the entire floor from eye level for bulges or loose tile. Test these areas by pulling upward on exposed edges to see if delamination has actually occurred.

For carpeting, test by running a common nail through about five loops and exerting a quick pull of about seven pounds to determine any yielding of the adhesive has occurred. Record and photograph.

Measure: Bulges, delamination
-Note existing bulges or delaminations to 1/32 inch
-Note any test-induced bulges or delaminations to 1/32 inch

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE

TEST # 7: Resistance to Slip



Test Method: Determine past performance, if possible. Test by using a slip meter to determine the coefficient of slip of hard, smooth surfaces (not to be used on carpeting or on heavily-textured surfaces). The slip meter is a weighted cloth bag which is pulled and the force necessary to cause the device to begin moving across a surface is noted on a tension scale. This test need be performed only once for each flooring material in use. Record the results for each surface, wet and dry.

Measure: Coefficient of slip
-Note the force necessary to move the testing equipment, under both wet and dry conditions, to the nearest pound. Determine the coefficient of slip.

TEST # 8: Control of Static Discharge

Test Method: Determine past performance, if possible. Test by walking several paces on the carpet or other flooring material. Touch a grounded conductor (e.g. another person or a light switch) noting the general force of any static discharge which occurs.

This test can also be performed using a voltmeter, by rubbing the surface of the floor and measuring the voltage at which a shock is received when turning on a piece of electrical equipment such as a light switch or electric typewriter. Use this measurement as a criterion for measuring other areas. (This test may not be reliable on days of high humidity.) Record.

Measure: Static discharge
-Record voltage generated during static discharge
-Indicate the severity of the discharge generally as severe, moderate or slight.

TEST # 9: Anthropometric Fit

Test Method: Determine past performance, if possible. Test by visually observing possible anthropometric problems in the course of performing other testing procedures. Record and photograph.

Measure: Anthropometric fit
-Measure to 1/2 inch

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY

TEST #10: Resistance to Chemical Cleansers

Test Method: Determine past performance, if possible. Test by exposing the floor surface, for sixty minutes, to each of the following: distilled water, a detergent solution, sodium hydroxide and a 1% soap solution. Compare the exposed surface to an unexposed sample of the same material. Record and photograph the results.

Measure: Changes in color, dimension, deterioration
-Record the type of damage and note its extent as either slight, moderate or severe.

TEST #11: Water Permeability

Test Method: Determine past performance, if possible. Test by submerging a flat sample of flooring (not to include carpeting) in water for a period of three hours. Test, by weighing, the amount of water absorbed during the test period. Absorption should not exceed 15%, by weight. Note any other deterioration of the sample as a result of the testing procedure. Record and photograph. (Test need be run only once for each type of material in use.)

Measure: Water absorption
-Record weight of the sample, before and immediately after the test, to the nearest gram. Difference should not exceed 15% of the pretest weight.
-Note any other test-related deterioration, recording its type and severity as either slight, moderate or severe.

TEST #12: Dust Accumulation

Test Method: Determine past performance, if possible. Test by collecting a sample of retained dust from a one foot square area of each type of flooring material in use by means of a baster (a tube device in which a rubber bulb is depressed to provide suction). The flooring surface (except carpeting) should not allow more than 1/4 gram of dust to be retained per square foot. Record the results.

The floor should also be checked by close visual observation, from a distance of three feet, to determine if there are any areas in which dust and other particulate matter can concentrate out of the reach of normal cleaning operations. Record and photograph any such areas.

Measure: Dust retention
-Record the weight of the retained dust sample to 1/2 gram
-Record the location of any uncleaned accumulations of dust or other particulate matter.

TEST #13: Economic Washability and Scrubability

Test Method: Determine past performance, if possible. Test by visually comparing an unused sample with each type of flooring material in use. Routine cleaning procedures should provide an 85% retention of the original appearance of the material. Record and photograph results.

Measure: Retention of original appearance
-For resilient floors, note the retention of marks and the level of gloss remaining
-For carpeting, observe pile height and record.

TEST #14: Convenient Repair and Replacement

Test Method: Determine past performance, if possible. Test by examining the entire floor, from eye level, noting areas where the flooring material has been repaired or replaced. New material should be of the same type as the original flooring. Record any significant discrepancies (other than those related to age and wear) and photograph.

Measure: Replaceability
-Record differences in material types

TEST #15: Color Homogeneity and Stability

Test Method: Determine past performance, if possible. Test by visually comparing the color of unused samples with each flooring material in use. Record and photograph any significant changes. Measure the depth of the surface color on an edge of each flooring sample. Such colored material should constitute not less than 50% of the thickness of the sample. Record the results.

Measure: Color stability
-Record any significant changes in color
Measure: Color homogeneity
- Measure depth of surface color to 1/32 inch

TEST #16: Resistance to Fading

Test Method: Determine past performance, if possible. Test by obtaining an unused sample of each type of flooring material in use. Locate possible areas of natural fading (e.g. areas near windows, areas subjected to standing water, etc.) and compare the flooring with the unused sample of the same material. Note any instances of fading. Record and photograph.

Measure: Fading
- Record as severe, moderate or slight

TEST #17: Resistance to Staining

Test Method: Determine past performance, if possible. Test by exposing each type of flooring material in use (except carpet) to the following stain-causing materials: pencil, orange juice, coffee, tea, milk, cold drinks, residue of cigarette snuffed out rapidly with the foot, chalk, grease, permanent inks, ball point, alcohol-based marker, lipstick, nail polish, heel marks, paint, etc. Exposure for 15 minutes and a subsequent use of a stain remover or cleansing agent tests the resistance to the material to each of these agents. Observe, from a distance of one foot, any change in the appearance of the tested areas. Record and photograph.

Measure: Stain resistance
-Record each agent tested as staining or non-staining

See interior wall notes P. C-6. The reports mentioned contain excellent documentation of performance and tests in the areas of interior walls, ceilings and floors.

SUMMARY OF FLOORS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE STRUCTURAL STABILITY
TEST # 1: Resistance to Static Loads
TEST # 2: Levelness of Surface

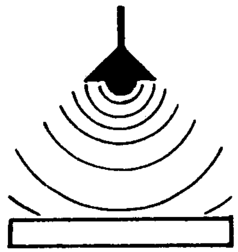
PERFORMANCE OBJECTIVE: PROVIDE A PHYSICALLY DURABLE SURFACE
TEST # 3: Resistance to Point Impact
TEST # 4: Resistance to Abrasion and Scratching
TEST # 5: Cohesive Strength
TEST # 6: Adhesive Strength

PERFORMANCE OBJECTIVE: PROVIDE A SAFE SURFACE
TEST # 7: Resistance to Slip
TEST # 8: Control of Static Discharge
TEST # 9: Anthropometric Fit

PERFORMANCE OBJECTIVE: PROVIDE SATISFACTORY APPEARANCE AND MAINTAINABILITY
TEST #10: Resistance to Chemical Cleansors
TEST #11: Water Permeability
TEST #12: Dust Accumulation
TEST #13: Economic Washability and Scrubability
TEST #14: Convenient Repair and Replacement
TEST #15: Color Homogeneity and Stability
TEST #16: Resistance to Fading
TEST #17: Resistance to Staining

LIGHTING

SUMMARY

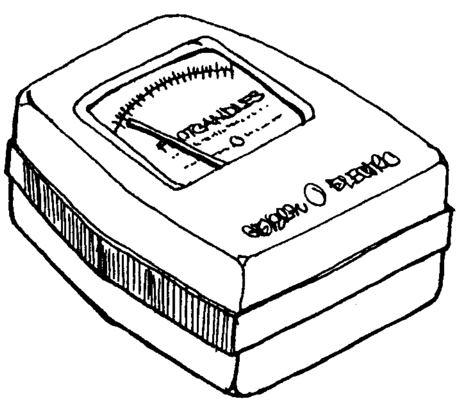


The primary objective of the lighting subsystem is to provide a satisfactory quantity and quality of illumination for the activities in the building.

Though specifying the quantity of illumination is now standard operating procedure in almost all environments, the quality of the illumination provided has not been considered in most cases. This includes direct and indirect glare, contrast rendition and contrast ratios.

PERFORMANCE OBJECTIVE: PROVIDE SUFFICIENT QUANTITY AND QUALITY OF LIGHT

TEST # 1: Provide Sufficient Quantity of Light

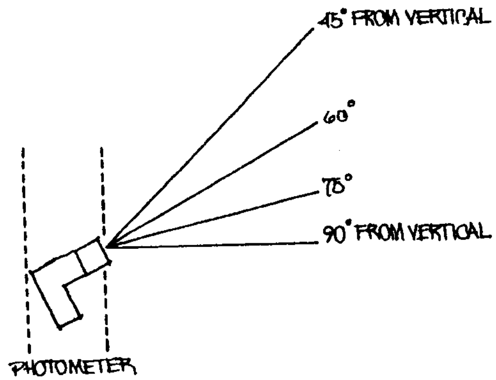


Test Method: Determine past performance, if possible. Use a footcandle meter which reads from 3-8000 footcandles. Multiple readings are taken in each room under luminaires, between luminaires, in the center of the room, at the edge of the room and at the windows. Readings are made under the following conditions - daylight only (between 9 a.m. & 3 p.m.), artificial illumination only (nighttime is best) and a combination of the two. All readings are taken 30 inches above the floor (table height).

Measures: Natural light, artificial light, combined natural and artificial light

- Artificial illumination only (nighttime) under luminaires, between luminaires, at walls
- Natural illumination only, at windows, at 5 feet intervals from windows to opposite wall
- Combination of artificial and natural illumination, at all of the above locations.

TEST # 2: Minimize Direct Glare



Test Method: Determine past performance, if possible. Use a spectra photometer reading in footlamberts or a (Minolta, Honeywell, etc.) lightmeter whose readings can be converted to footlamberts. Readings are taken with a 1° spot.

Readings are taken at eye level directly under and perpendicular to lighting fixtures in the viewing directions most frequently used. Readings are taken from 45 - 90° from the vertical. Use artificial lighting only.

Measures: Footlamberts of illumination

- Footlambert measurements parallel and percendicular to fixtures at the following angles - 45°, 60°, 75°, 90°, and graphed on a I.E.S. scissors curve.

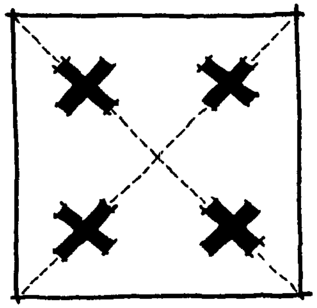
TEST # 3: Control Brightness Contrast Ratios

Test Method: Determine past performance, if possible. Use a photometer as in Test #2. This test is made under artificial light only, daylight only, and combinations of the two with window shades open and closed. Readings are taken from most of the work surfaces in the room.

Measures: Brightness contrast ratios

- Measures are taken on the ceiling on and between lighting fixtures, on upper wall(s), wall at eye level on various surfaces, on task, immediate task surround, window, wall adjacent to window, floor.
- Measures are taken under the following conditions: artificial light only, daylight only, combination artificial and daylight with shades open and closed.

TEST # 4: Eliminate Shadows on Task Surfaces



Test Method: The following test is made at the fourth points of both room diagonals. These are used as task locations and the footcandle level is read with and without a user at the task location to compare the possible effects of shadow on the task.

Measure: Task illumination

- The footcandles on the task with and without the seated user.

TEST # 5: Maintain Quantity and Quality of Illumination

Test Method: Using a photometer as described in Test #2, measure the luminaire brightness from seated eye level on the diffuser and/or bulb before and after cleaning a diffuser and bulb with a dry rag. Install a new bulb and again measure luminaire brightness.

Measure: Luminaire brightness

- Luminaire brightness, diffuser and/or lamp under three conditions - actual usage; bulb and diffuser cleaned; new bulb (diffuser cleaned).

REFERENCES

"I.E.S. Handbook", Illuminating Engineering Society, 1966. This contains almost all standard tests. A standard text.

"Contrast Rendition in School Lighting", Foster Sampson, Educational Facility Laboratories, N.Y., 1970. This is very significant and goes far beyond the I.E.S. Handbook.

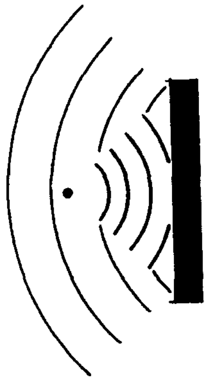
SUMMARY OF LIGHTING PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE SUFFICIENT QUANTITY AND QUALITY OF LIGHT

TEST # 1: Provide sufficient Quantity of Light
TEST # 2: Minimize Direct Glare
TEST # 3: Control Brightness Contrast Ratios
TEST # 4: Eliminate Shadows on Task Surfaces
TEST # 5: Maintain Quantity and Quality of Illumination

ACOUSTICS

SUMMARY

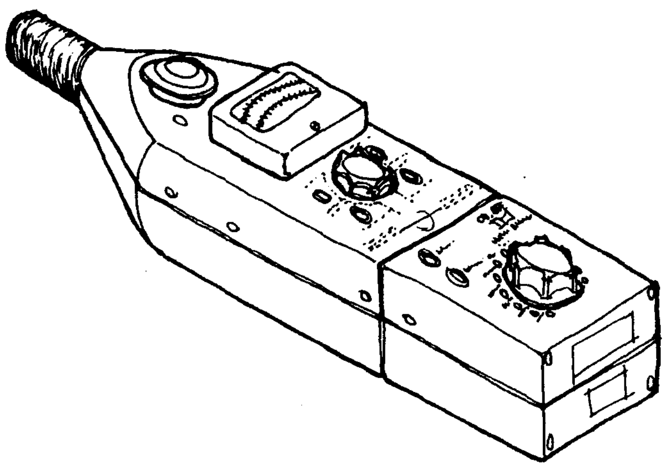


The primary objective of the acoustical environment is to be responsive to the activities within the building. To support clear communications and to provide privacy and a lack of acoustical interference. Field tests in this area emphasize these primary objectives and are directed at conditions which impair this performance.

The transmission of interfering sound between adjacent activities is a major characteristic to be tested although in large spaces the background or ambient sound level and the 'echo' effects can also be potential problems.

PERFORMANCE OBJECTIVE: PROVIDE AN ACCEPTABLE ACOUSTICAL ENVIRONMENT

TEST # 1: Correct Ambient Sound Level

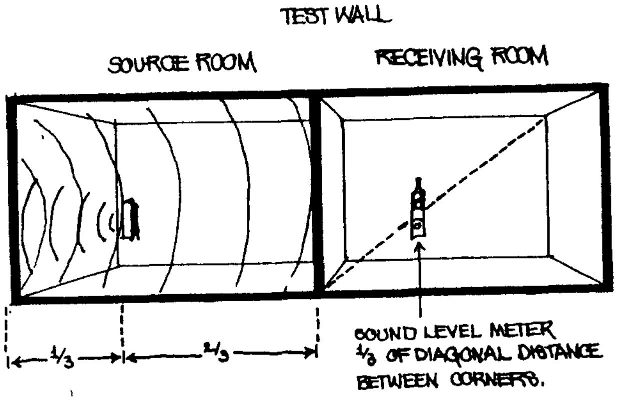


Test Method: Determine past performance if possible. Test by using a sound level meter with an 'A' scale and preferably a reading to 30 decibels. If possible, a meter with an octave band analyzer should be used. Sound level readings are taken within the area to be tested with and without normal activities present in the space. These readings should be taken on both the 'A' scale and at various frequencies. The meter should be used in an upright position and readings taken at the center of the room.

Measures: Ambient sound level

- In empty room: 'A' scale ± 1 db.
- Multiple readings with space in use: 'A' scale ± 3 db.
- Frequency distribution in empty room at 125, ± 50, 500, 1,000, and 2,000 HZ ± 1 db.

TEST # 2: Control Sound Transmission Between Spaces



Test Method: Determine past performance if possible. Test by using two rooms. One room contains a sound source and a sound level meter in the second room determines the amount of the transmitted sound. A good quality cassette recorder playing prerecorded 'white' noise at a level of 75 db. or more is a suitable source. A sound level meter with an 'A' scale is used as a receiver. Note #1

The cassette recorder is placed 2/3 of the distance from the wall being tested and facing away from the wall, The preferred placement of the sound level meter in the receiving room is 1/3 along one of the diagonals from the lowest corner of the room near the wall being tested to the far opposite upper corner of the room. Since there are four such diagonals, choose the one closest to non-sound absorbent surfaces. Measurements should be taken at least 30" from reflective surfaces.

A measurement is made in the source room with the source on and in the receiving room with the source off. A second reading in the receiving room with the source on will complete the test.

Note: The ambient sound level in the receiving room should be at least 10 dbA below the source level in the adjacent room. The test should simulate normal conditions. For example, if a door to the corridor connecting the two rooms if usually left open, the test should be done with the door open (and closed too!)

Measures: Ambient sound level

- Ambient sound level, ± 1 dbA, in receiving room without source on;

- Ambient sound level, ± dbA, in source room with source on;
- Ambient sound level, ± dbA, in receiving room with source on.

TEST # 3: Control Reverberation Within Spaces

Test Method: Determine past performance if possible. Test by using 18 inch diameter balloons to provide an instantaneous and loud sound source. A tape recorder specifically modified for the purpose records the reverberation test. Two trials are recorded in each space. The tape is analyzed in a laboratory to determine the reverberation time. Measurement is made at least 30 inches from any reflecting surface.

Since the equipment used in this test is quite expensive and sophisticated and since reverberation detrimental to normal speech should be heard using the balloons, it is possible to burst balloons and simply note the discernible reverberation if any.

Measures: Reverberation times

- Reverberation times for the following frequencies: 125, 250, 500, 1,000, and 2,000 HZ.

TEST # 4: Control Mechanical Systems' Noise

Test Method: Determine past performance if possible. Some as test #1. Readings are taken with lighting and mechanical systems turned off and turned on.

Measures: Mechanical systems noise

- Mechanical systems on dbA and 60, 125, 250, 500, 1,000, 2,000 HZ
- Mechanical systems off dbA and 60, 125, 250, 500, 1,000, 2,000 HZ
- Lighting on only dbA and 60, 125, 250, 500, 1,000, 2,000 HZ
- Mechanical on only dbA and 60, 125, 250, 500, 1,000, 2,000 HZ

TEST # 5: Control Impact-Generated Sound Transmission

Test Method: Test by using on typical sounds generated by impact such as footfalls or desk and chair movement. A 35 dbA white noise is used as background to determine if it masks the impact noises.

Measures: Impact noise

- Easily discernible noise from 20 feet
- Easily discernible noise from 15 feet
- Easily discernible noise from 10 feet
- Easily discernible noise from 5 feet

REFERENCES

ASTM E 90-66T, ASTM E 336-67T Transmission of sound through partitions

ASTM C423-66 Sound absorption of acoustical materials (reverberation)

"A Simplified Field Transmission Test", Siekman and Yerges, Sound and Vibration, V.5, #10

NOTE #1: White noise can be found in a telephone dial tone, T.V. station signal before programming begins, interstation hum on radios, etc.

SUMMARY OF ACOUSTICS PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE AN ACCEPTABLE ACOUSTICAL ENVIRONMENT

TEST # 1: Correct Ambient Sound Level

TEST # 2: Control Sound Transmission Between Spaces

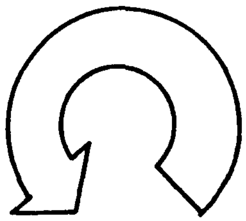
TEST # 3: Control Reverberation Within Spaces

TEST # 4: Control Mechanical Systems' Noise

TEST # 5: Control Impact-Generated Sound Transmission

HVAC

SUMMARY



The primary objective of the HVAC system is to provide an atmospheric environment including proper thermal conditions, air movement and humidity, responsive to the activities within the building.

Although excellent control of the above attributes is now standard practice in terms of design and installation, the actual operational effect of these attributes has been less studied especially in terms of relationships with other factors such as orientation, windows and performance over time.

PERFORMANCE OBJECTIVE: PROVIDE PROPER THERMAL ENVIRONMENT

TEST # 1: Control Dry Bulb Temperature

Test Method: Use a recording thermometer. Long term measurements are made during all seasons of the year in all space types and orientations of the building. Measurements are made at the 5 foot level in the center of the area.

Measures: Dry bulb temperature

- Dry bulb temperature in major spaces during all seasons
- Outside dry bulb temperature during the same period
- Inside dry bulb temperatures for different orientations
- Weather colorations, strong sun, partly cloudy, overcast, storm

TEST # 2: Control Dry Bulb Temperature

Test Method: Use Test Method #1.

Measure: Thermostat temperature.

-Record thermostat thermometer reading and thermostat setting at the time the dry bulb measurement is made with the recording thermometer.

TEST # 3: Provide Proper Dry Bulb Temperature in Occupied Zone

Test Method: Same as Test #1. Additional measurements are made five feet above floor level.

Measure: Dry bulb temperature

-Dry bulb temperature at one inch and six feet five inches above floor level.

TEST # 4: Control Radiant Temperature

Test Method: Use a surface thermometer (Pacific Transducer Corporation, Model 309F: about $10). Measurements are made directly on outside walls and windows.

Measure: Radiant temperature

-Mean radiant temperatures on room surfaces exposed to outdoor environment.

TEST # 5: Control Humidity

Test Method: Using a Whirling Psychrometer or equivalent gauges, record dry bulb and wet bulb temperatures. Use the same schedule as provided on Test #1.

Measures: Dry bulb, wet bulb temperatures

- Dry bulb and wet bulb temperatures
- Relative humidity using psychrometer chart
- Outdoor relative humidity

TEST # 6: Control Air Circulation

Test Method: Use either a deflecting air anemometer or smoke from titanium tetrachloride to measure air velocities in occupied zone. Measurements should be made at ankle and neck regions - 2 inches and 5 feet above floor at 1/3 points on both diagonals of the room.

Measure: Air velocity

- Record air velocity in feet per minute

PERFORMANCE OBJECTIVE: MAINTAIN HEALTH AND SAFETY STANDARDS IN HVAC SYSTEM

TEST # 7: Control Safety Hazards to Maintenance Staff and Users

Test Method: Interviews with maintenance staff and inspection of facilities and equipment.

Measure: Safety hazards

- Uninsulated 'hot' piping
- Unshielded moving equipment
- Adequate guards and barriers
- Adequate monitoring equipment

Test Method: Same as Test #6

Measure: Frequency of repairs

- Note quantity and quality of unusual maintenance and repairs

REFERENCES

ASHRAE Standard 55-66 Thermal Environment Standards were helpful as well as:

"The Performance Concept", VI., Staff of the National Bureau of Standards, Report 9849, June 1968

"Equipment Test Code 106ZR3", Air Diffusion Council, Chicago, 1972
Another excellent source of HVAC Test Procedures

SUMMARY OF HVAC PERFORMANCE TESTS

PERFORMANCE OBJECTIVE: PROVIDE PROPER THERMAL ENVIRONMENT

TEST # 1: Control Dry Bulb Temperature

TEST # 2: Control Dry Bulb Temperature

TEST # 3: Provide Proper Dry Bulb Temperature in Occupied Zone

TEST # 4: Control Radiant Temperature

TEST # 5: Control Humidity

TEST # 6: Control Air Circulation

PERFORMANCE OBJECTIVE: MAINTAIN HEALTH AND SAFETY STANDARDS IN HVAC SYSTEM

TEST # 7: Control Safety Hazards to Maintenance Staff and Users

TECHNICAL PERFORMANCE FACTORS

PERFORMANCE TEST				
stability				
movement.				
-structural loading				
-thermal movement				
-setting.				
impact.				
air infiltration.				
moisture infiltration				
thermal conductivity.				
staining.				
discoloration				
delamination.				
deterioration				
aesthetics				

PERFORMANCE TEST				
drainage (ponding)				
moisture penetration				
sag.				
movement				
deterioration.				
erosion.				
impact				
indentation.				
brittleness.				

PERFORMANCE TEST				
structural stability.				
impact.				
attached loads.				
cohesion.				
delamination.				
wearability				
indentation				
abrasion.				
scratch				
water absorption.				
stain				
cleanability.				
dust accumulation				
replacement/repair.				
aesthetics.				

PERFORMANCE TEST				
deflection.				
parallel to floor				
displacement.				
cohesion.				
adhesion.				
indentation (impact).				
scratch				
staining.				
anthropometric fit.				
color homogeneity				
flaking/peeling				
fading.				
dust accumulation				
cleanability.				
access to plenum.				
replacement/repair.				
out-of-system hardware.				
aesthetics.				

PERFORMANCE TEST				
indentation				
impact				
resiliency				
brittleness				
cohesion				
adhesion				
levelness				
abrasion				
scratch				
wear				
slip resistance				
static discharge				
cleanability				
dust accumulation				
water absorption				
delamination				
replacement/repair				
cigarette burn				
color fastness (fading)				

color homogeneity					
aesthetics.					

PERFORMANCE TEST				
illumination - natural. . . . . . (footcandles f_c)				
illumination - artificial . . . . (footcandles f_c)				
illumination - combined . . . . . (footcandles f_c)				
shade fully drawn . . . . (footcandles)				
luminaire luminance . . . . (footlamberts)				
room contrast . . . . ratio				
glare				
task/surround . . . . contrast ratio				
illumination.				
luminance gain (cleaning)				

PERFORMANCE TEST				
ambient, sound level: db. . . . . (w/children, lights)				
ambient, sound level: db. . . . . (w/o children)				
ambient, sound level: db. . . . . (w/o children, lights)				
attenuation, db . . . . (classroom-classroom)				
attenuation, db . . . . (classroom-hall)				
reverberation 500hz . . . . . . (seconds) 1000hz 2000hz				
mechanical systems noise: db. . .				
impact-generated noise: db . . .				

PERFORMANCE TEST				
ambient temp.				
temp. gradient.				
humidity.				
air movement.				
safety hazards.				

FUTURE TEST DEVELOPMENT

The next step in development of field testing will attempt to investigate and develop additional tests in the eight areas of subsystems and attributes.

This will include:

Exterior walls	Measurement of movement through the use of gauges Testing samples for compliance with specifications
Roofs	Core sampling
Floors	Testing samples for compliance with specifications
Lighting	Compatibility of existing tests with visual comfort index (VCI)
Acoustics	Articulation index test development for 'open' situations Use of recording long term ambient levels
HVAC	Room air velocity test Radiant effects measurement building

Surface/volume and operating costs

Economics

A study of the relations between architectural decisions, building costs and life cycle costs.