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METAL CURTAIN WALLS

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CONTENTS

WELCOME TO CONFERENCE

By Charles H. Topping
Senior Architectural and Civil Consultant
E. I. du Pont de Nemours and Company, Inc.
Member of the Board of Governors and
Chairman of the Membership Committee of the
Building Research Institute

I welcome you to this conference and on behalf of the officers and members of the Building Research Institute, I extend a special welcome to the guests who are non-members. We hope you will find the conference interesting and well worth your while. The members know how the Institute operates but for you guests I should explain that this type of conference is only one of the Institute's several methods of assisting the members in the solution of their problems. Discussion and exchange of information on both research and experience are the tools that the Institute gives its members to help improve building design and construction.

The conference chairman is Edward X. Tuttle, Vice President of Giffels and Vallet, Inc. He is a member of the Building Research Institute, a member of the Building Research Advisory Board, and a member of the American Institute of Architects. He has long been interested in the subject of metal curtain walls and two years ago he initiated an informal study group devoted to the subject. This conference is the culmination of that effort. It is not the last event but it is an important milestone.

INTRODUCTION TO THE CONFERENCE

By Edward X. Tuttle
Vice President
Giffels & Vallet, Inc., L. Rossetti
Conference Chairman

We are here to discuss progress to date in the development of metal curtain wall construction -- its potential and its limitations, if any.

BRAB and its working partner, Building Research Institute, have for several years fostered the development of a building science, and I sincerely believe they have succeeded in establishing the concept.

"All our research data on curtain walls can be made available to all of you; we want this subject explored and exploited for the building industry." This remark was made about two years ago by an official of one of the great companies who sent representatives to an informal meeting which had as its purpose the exploration of benefits to be had by engaging in cooperative research in the field of metal curtain walls. This is the kind of objective statement that might well have come from the director of a medical research foundation. Such an attitude is a major characteristic of scientific programs.

This conference was conceived as an interim report and discussion regarding metal curtain wall development. Architects, engineers, researchers, and manufacturers of basic materials, wall units, and unit elements will report on their requirements, their findings, their hopes and their unsolved problems.

I believe that it has become rather generally recognized in recent years that the cost of buildings, in terms of human effort, has not been reduced at anything like the rate of reduction in cost of food, clothing, toys, and adult luxuries. The need for maintaining a high standard of shelter is about as great as it is for maintaining high standards for food and clothing. Our rapidly increasing population is making necessary a vast increase in housing and educational and production facilities. Meeting increased space requirements alone is straining our capacity, but, if we add to that the increased quality and reduction in cost and construction time which we have learned to demand, new building units and production methods must be devised.

Mass-producing a building wall unit under factory controlled conditions of speed and quality for later assembly at the site appears to offer extremely interesting possibilities for improving the quality, reducing cost, and speeding building construction.

Previous Institute conferences have included discussion of other materials used in curtain walls. This conference will be limited to consideration of metal as the primary material. Another limitation will be the omission, except for incidental reference, of discussion of fireproofing problems.

The props here are as simple as those for a Japanese drama, and we can rely with confidence upon the performers to maintain what is obviously an eager, almost explosive interest.

I doubt if a more distinguished panel of speakers has ever been assembled to discuss any other subject in the building industry.

It is my privilege to present the first of the three speakers of this session on "Recent Studies of Metal Curtain Walls," Mr. Walter A. Taylor. He will be followed immediately by Mr. William H. Scheick and then by Mr. John O. Blair.

PART I

RECENT STUDIES OF METAL CURTAIN WALLS

SURVEY OF ARCHITECTS - A Reprint

Presented at the conference by
Walter A. Taylor,
Director of Education and Research Department,
American Institute of Architects

(This is a reprint of "Architects' Use of Metal Wall Panels," a summary of a survey conducted by the Research Advisory Service of the American Institute of Architects, published in the Bulletin of the AIA. It was presented by Walter A. Taylor, Director of Research and Education Department of the AIA and a member of the Building Research Institute, at the Metal Curtain Wall Conference held by the Building Research Institute on Sept. 28 and 29, 1955.)

ARCHITECTS' USE OF

METAL WALL PANELS

summary of a survey conducted by the research advisory service of the american institute of architects

reprinted from the bulletin of the american institute of architects, july-august 1955

EXTERIOR METAL BUILDING PANELS

Statements made by respondents & quoted in this report are opinions of individual respondents only & do not represent opinions of The American Institute of Architects. Similarly, summaries of check-off responses, whether favorable or unfavorable to subject products, are to be taken only as representative opinions of a sample of practicing architects & do not signify either endorsement or disapproval by The American Institute of Architects.

In accordance with conditions printed in announcement of The AIA Research Advisory Service, if any findings are used in advertising, if such advertising includes reference to survey & advisory services by The American Institute of Architects, advertisement must include a statement summarizing above conditions.

In 1954, a small group of executives of leading manufacturers* of basic curtain wall materials proposed to collaborate in study & development of exterior metal building panels for benefit of secondary manufacturers & fabricators, & building industry generally. This study was initiated by a survey conducted by the Research Advisory Service of The American Institute of Architects.**

711 architects were quizzed in this survey. Included were:

- **architects of major "metal panel" buildings erected in the US in 1953 & 1954**
- **members of several AIA national technical committees**
- **state AIA chapter technical representatives**
- **representative architects known for contemporary & progressive practice**

Each state was represented in proportion to its number of practicing architects compared to national total with a minimum of 2 correspondents/state. Unusually high % of returns from questionnaire (57%) indicates very active interest in this field. Geographic distribution of responses was very closely proportionate to architect population.

To ensure that findings were representative of profession in general, each office was questioned as to frequency & order of volume of various building types & if office specialized in only one field. Figure 1 shows comparison of offices having done work in each principal field & relative number questioned that specialized in only that field.

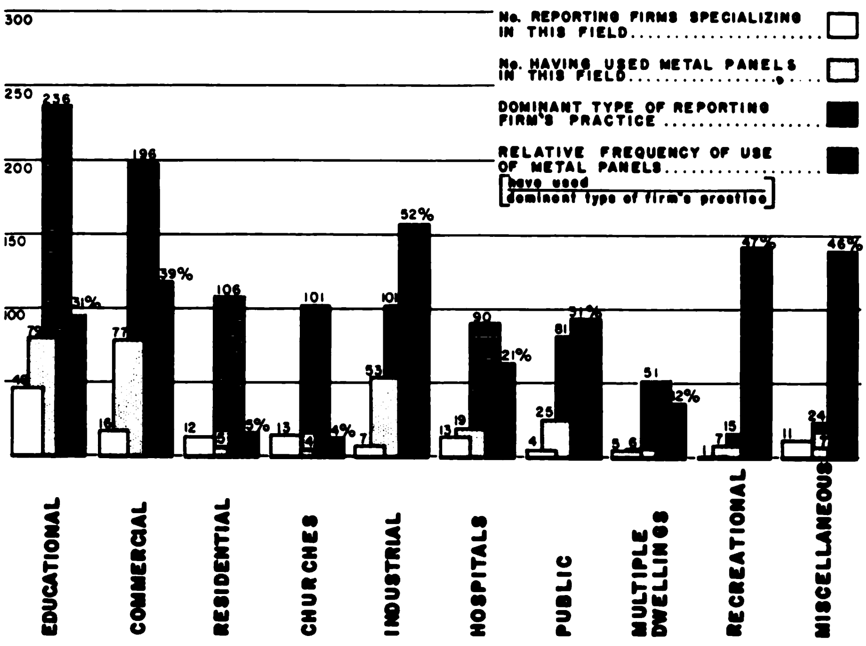
Architects were questioned as to type of buildings in which metal panels would be desirable if existing codes & fire-ratings were not involved, with results shown Fig 2.

Architects were asked if they had ever specifically considered use of metal panels for a particular job & had decided on another material. The 4 principal reasons for failure to use panels were:

reason not used	% of cases
economic	44.8%
esthetic	19.1%
code restrictions	18.3%
technical	17.8%
	100.0%

Higher cost than conventional construction for particular job was barrier in nearly half of cases. Esthetic consideration of panels presently produced at competitive costs proved restrictive in about 1/5 of cases. Technical reasons, for the particular application, such as physical abuse, acoustics, sizes, etc, kept architect from selecting metal panels in a similar number of cases. Code restrictions also prevented consideration of panels in about 1/5 of these cases.

A high % of architects indicated that at one time or another they had used



all charts by Bloomfield

FIGURE 1 — types of buildings in respondents' practice & percent using metal building panels

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* *Aluminum Company of America*
Ferro Enamel Corporation
Owens-Corning Fiberglas Company
Reynolds Metal Company
United States Steel Corporation
(Note: professional advisor — Edward X Tuttle, AIA)

** *A parallel but less extensive survey of building owners & building contractors was conducted by the Building Research Advisory Board*

AIA File No. Q2.5

EXTERIOR METAL BUILDING PANELS

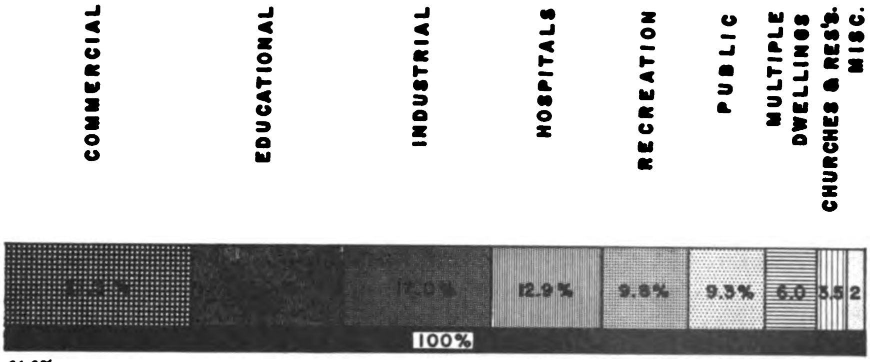

FIGURE 2 — **preferences indicated for use of metal building panels for various building types**

metal panels in one or more building types. More reporting architects have used metal building panels on educational & commercial buildings than any other types.

When frequency of use is compared to dominant practice of offices reporting — ranking of use of panels in lieu of other construction would be:

ranking of building types

1. **industrial buildings**
2. **recreation buildings**
3. **miscellaneous**
4. **commercial buildings**
5. **educational buildings**
6. **public buildings**
7. **hospitals**
8. **multiple dwellings**
9. **residential buildings**
10. **churches**

Comments from architects further indicated that under these conditions, metal panels could be advantageously used on any type building excepting in cases where esthetics are dictated by existing group design.

Although some architects maintain that stock sizes cannot adequately meet varying needs of different building types, Fig 3 indicates most desirable sizes as summarized from opinions of reporting architects.

Opinions indicate most needed panel would be a 4′ x 8′ module with additional sizes to satisfy more specific needs. Inquiry as to most reasonable number of panel sizes to meet all but special needs indicates that 4, 6, 3, or 10 would satisfy most of architects' requirements.

If first choice of 4 panel sizes (from Fig 4) is accepted, density graph of panel sizes (Fig 3) indicates that these panels should be:

- 4′ x 8′
- 4′ x 4′
- 2′ x 8′
- 2′ x 4′

89% of architects responding agreed that same module could be used on inside that had been selected for outside. 75% agreed that panels should be delivered to site completely assembled (ext & int metal surfaces enclosing required insulation) ready for installation.

Discrepancies in panel sizes are encountered when wall is used *between* structural columns as opposed to *by-passing* columns on inside or outside.

Provisions must be made in panel dimensions for jointing & supports. Appearance, weather-tightness, & ease of assembly are equally important to success of this type of construction. Architects were questioned as to their opinions of 3 types of panel jointing with preferences as shown in Fig 5.

Many respondents further classified method of jointing by writing-in their favorite method. In order of number of write-in entries, following types of jointing were noted:

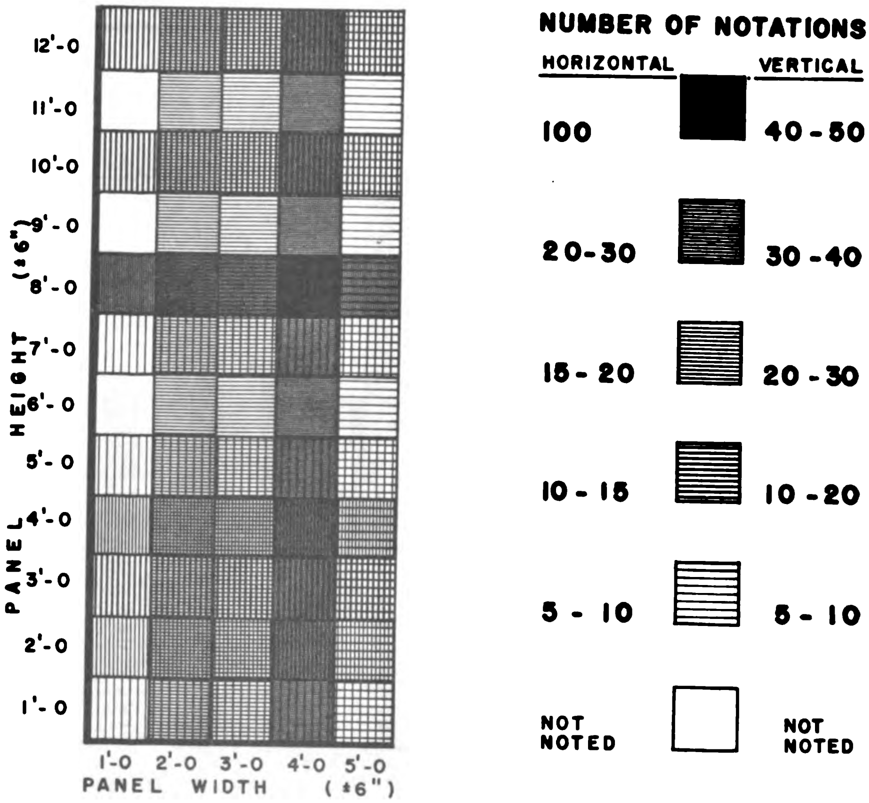

FIGURE 3 — **demand for standard dimensions for stock exterior metal building panels**

AIA File No. Q2.5

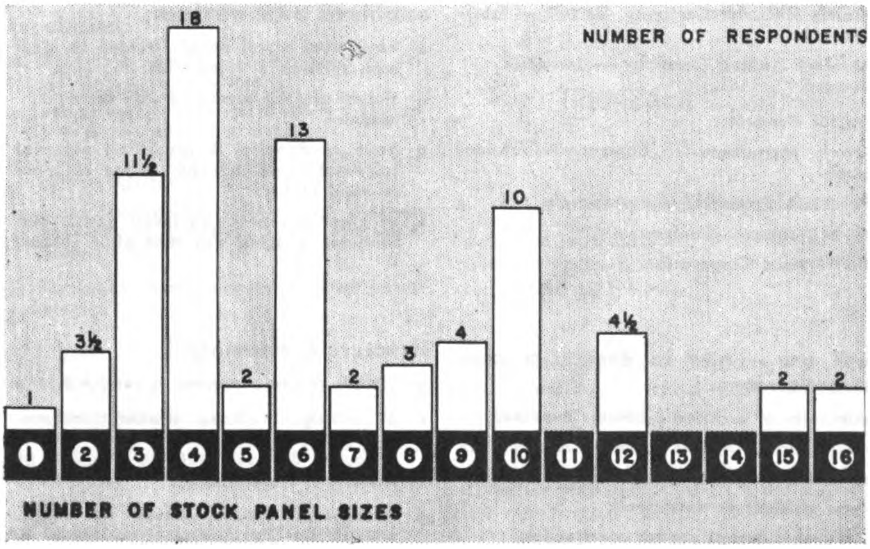

FIGURE 4 — **reasonable minimum number of stock panel sizes (circled figures)**

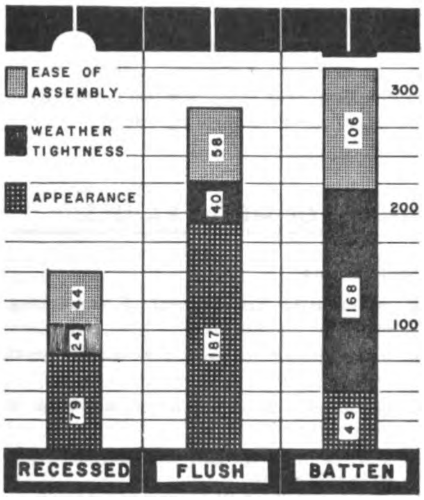

FIGURE 5 — **joint type preference**

total entries — jointing methods

see p 100

22 t & g

20 interlocking

8 overlap

6 shiplap

5 mullions

4 gasket

3 undercut

3 recessed battens

3 in sash

3 accented tee

2 exterior window

2 concealed

2 skin frame

2 lap 4"

1 keyed

1 v-joint

Comments indicate desirability of at least 3 types of jointing & possibly others for specific purposes dependent upon:

esthetics (scale & effect)
weather-tightness
ease of assembly
geographic location
physical characteristics of metal *(more)*
inside finish
expansion, contraction & vapor barrier
maintenance costs (caulking vs gaskets)
replacement (ease of)
deflections

Specific panel texture & finish desired by architects for particular application is dependent upon application. However, general preference for different kinds of finishes is indicated in Fig 6.

In general, finish should be:

dictated by design application
not an imitation
indicative of properties of sheet metal.

Use of colored panels was considered desirable by practically all architects reporting — even at extra cost.

Many architects noted that:

- **present selection of colors is limited & not completely satisfactory**
- **must keep in competitive price range**
- **greater uniformity between panels of same color must be achieved**
- **dark anodized, warm bronze & gold & other anodized metallic finishes are desirable**
- **must be permanent color**

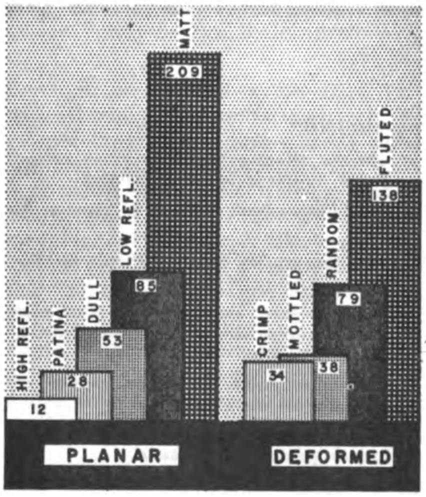

FIGURE 6 — **panel finish preference**

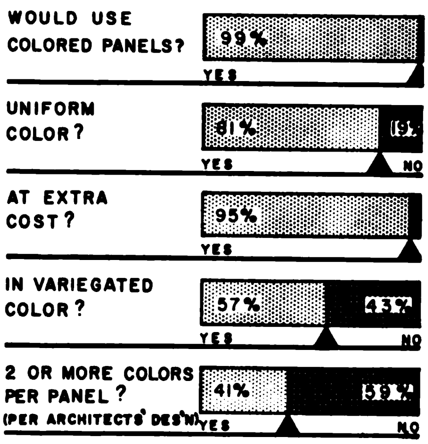

FIGURE 7 — **use of color**

GENERAL COMMENTS—METAL PANELS

Respondents were invited & urged to comment freely & frankly about their experience with metal wall panels. Numerous comments have been summarized & classified under following topics:

FUTURE OF METAL PANELS:

optimistic:

- enthusiastic about great & expanding uses
- need for well designed, inexpensive panel system for housing
- appearance of some current buildings is very admirable
- still in infancy but will develop into widespread use
- client conservatism & conventionalism are temporary stumbling blocks
- cost will be reduced
- semi-prefabrication will become more common

pessimistic:

- esthetic effect achieved in many present panel buildings is unsatisfactory
- prejudice against material by some architects
- job inaccuracies create difficult installation
- speed & short erection time economical only in severe climates — then technical difficulties arise
- inferior products will retard general acceptance of metal panels
- current installations must be time-tested before general acceptance
- special conditions of use limits standardization

USE OF PANELS:

have used — brand names:

Albro Company
American Steel Band Company
Bettinger Corporation — porcelain enameled steel
Davidson Company — fabricators
Erie Enameling Works
Fenestra (Detroit Steel) "C" Panels — steel & aluminum
Fleur City Ornamental
General Bronze
Hope's Windows, Inc — Windowall — metal panels by Seapercel Pacific
Knapp Brothers Company System
Lupton
Mahon Company
Martin Hoffman Company, Detroit — fabricators
McMath Axilrod Company — porcelain enamel
Milcor Products
Overly Manufacturing Company — fabricators
Porcelain Enamel Faced Armorply
H. H. Robertson Company
US Plywood Corporation

will use — now in design or construction stage:

minimum of erection problems expected
using colored & matt finish on one building
sandwich panel being contemplated
very satisfactory esthetically
6 panel-buildings under construction
considering for church project

willing to use — building types:

airports	industrial
banks	laboratories
churches	offices
commercial buildings	public buildings
hospitals	schools
hotels	service stations
housing	shopping centers

have used — specific jobs:

Allegheny County Home & Hospital
American Locomotive Company Parts — warehouse
Carnegie Institute of Technology — dormitory
Charleston Navy Yard — electronic shop building
Hillside High School, San Mateo, Calif.
hydro-electric & steam power plants
Manufacturing Plant, Hendersonville, NC
Memorial Hospital Association hospital chain
12-story office building

DESIGN CONSIDERATIONS:

design principles:

maximum prefabrication
inside setting
inside glazing
absence of exposed screw heads
maximum flexibility

combined with windows:

- have used metal panels welded to steel sash sections & filled with fiberglass
- should also be combined with door module
- have used metal & insulating material sandwiches set in same frame as glass in steel sash
- of great advantage to insert panels into mullions in same way that glass is used

structure & assembly:

- pitfalls can be overcome by correct details
- all fittings, anchors, flashings, expansion joints, caps, inside & outside corners & special devices should be furnished by panel manufacturers
- installation details should be simple enough for inexperienced tradesmen to install
- strong support is needed at as few points as possible — possibly 12' oc minimum, horizontally
- caulking should not be totally relied upon
- distortion can be minimized by deformed shapes — difficult to obtain absolutely flat surfaces.
- simple details at roof & floors
- adequate erection tolerances must be provided
- maximum flexibility necessary
- factory-assembled as complete & large as possible
- stock structural mullions should be available
- concealed exterior fasteners are desirable if properly detailed
- room for adequate thermal expansion is mandatory
- difficult to assemble with perfect vapor seal & inconspicuous joints
- must be resistant to corrosion
- wiring & piping may be obstacles for some applications
- details should permit uniform alignment & uniform jointing

replacement:

- transit damage & defects often not found until rust spots appear after installation
- difficult to repair panels — must be replaced
- unexplained damage & vandalism require that panels at lower levels be replaceable
- finish can be resistant to damage even when misused

insulation:

- insulation should not be subject to deterioration by moisture
- panels may be more satisfactory if insulation is not used structurally
- fibered or foam glass insulation has proven satisfactory
- paper honeycomb light-weight concrete backing has not been completely satisfactory
- insulation must be waterproof or waterproofed

condensation & conductivity:

- metal-to-metal contact should be avoided
- sweating & condensation prevalent in south
- rubber glazing helps solve thru-conductivity problem
- breathing sandwiches appear to be better solution than sealed sandwich
- disposition of condensate in air conditioned buildings may be a problem

air leakage:

- discomfort & added heating & cooling load at 100°F to -50°F temperatures if not completely air-tight
- need more laboratory testing of new materials before they are placed on market
- wind velocities need consideration for air leakage

economics:

- presently high initial cost for good quality panels
- panels are competitive in price in places where masonry must be supported (ie above strip windows)
- built-in equipment offers opportunity to use inexpensive finish on inside panel
- production & delivery dates need more coordination with project schedule
- light-weight makes for ease of handling
- insurance rating may be adversely affected
- replacement may be necessary if panels are in exposed location
- large & repetitive installations are most economical
- "sandwich" panels may hold best future for solving cost problem
- chemical reactions may require maintenance
- acoustical panels can be integral & provide high degree of sound absorption

TRENDS & COMMENT — the architect says • • •

• • • about building codes:

Suggested amendment to a section of city ordinances (of the City of Buffalo) would read as follows:

"Load bearing walls including exterior walls, penthouse walls, court & shaft walls of bay windows shall be of noncombustible construction & shall have 4-hr fire-resistive rating. Non-load-bearing panel walls shall be of non-combustible construction & shall be constructed & attached to structural frame so they will maintain their place in structure under interior fire exposure equivalent to severity of fire hazard represented by contents & occupancy of building. Such non-load-bearing exterior panel walls shall have not less than 1-hr fire-resistive rating, except that in exposed locations where protection of window openings is a requirement of this code (Sec 64) such panel walls shall have 2-hr fire-resistive rating against outside fire exposure."

• • • about industrial uses:

"We started using prefabricated aluminum & steel wall panels in 1949 on our Watauga project, a small hydro plant in upper east Tennessee. This type of construction was fairly new then & although it was necessary to work with manufacturer in developing special details & extrusions, results were gratifying from standpoint of low cost, ease, & speed of erection, & appearance. Panels consisted of 16-ga fluted sheets of striated aluminum backed with 18-ga zinc-coated flat steel sheets, & 1½" space between filled with fiberglass insulation.

"These panels fabricated & assembled at factory were shipped in varying lengths up to 16' & were welded directly to adjustable steel girts attached to structural steel framing. Inside wall surfaces were made of single fluted sheets of striated aluminum & were set inward far enough to cover structural steel in walls.

"A short time later, we built our South Holston hydro plant using same general type of construction but with significant changes — we used steel back-up sheets as our interior wall finish & we introduced flat nondeformed aluminum sheets on a subordinate wing. Use of regular steel back-up sheets for interior wall finish required careful design of exposed structural steel but proved very satisfactory. Exterior flat sheets proved unfortunate as difference in light reflection from imperfections in these panels turned out to be very unpleasant.

"In spite of this experience, we used flat, nondeformed aluminum exterior sheets in connection with factory-assembled, insulated wall panels on main shop section of our Power Service Building in 1950.

For some unexplained reason, these 16" wide striated aluminum facing panels developed large indentations shortly after erection which gave impression that wall surface had been severely damaged. After considerable study & experimentation, manufacturer discovered that by striking surface of panels with a rubber hammer, this "oil-canning" disappeared entirely.

Panels were otherwise satisfactory except for deficiency in overlap of male & female connecting lips & inadequacy of caulking in joints.

"In 1949, we adopted insulated metal wall panel construction for boiler room section of first of our 7 new steam plants & are now using this construction on remaining 6. 5 will have fluted exterior panels of striated aluminum with flat steel interior sheets & 1½" to 2" fiberglass insulation. Two will have fluted exterior panels of maroon asphalt- & asbestos-protected steel. Office wing on 5 of these plants will have porcelain enameled steel panels set in aluminum frames. One plant is built with factory-assembled panels but on other 6 panels are assembled during erection."

• • • about sandwich panels:

"Panel systems & units we have used may be roughly divided into two general categories:

concealed supporting frame
exposed supporting frame

METAL PANEL SURVEY (concluded)

concealod supporting frame:

"This category would include such units as manufactured by H H Robertson Company (*Q-Panel*), Mahon, & Detroit Steel Products (*Fenestra*).

"Panels of these manufacturers are applied to outside of structural steel framing system. General characteristic of panels is such that it is most adaptable to, & appropriate for, industrial application.

"Bright metallic appearance, in our opinion, limits its use to a large degree. It is difficult to combine with fenestration. Structural framing system when exposed on interior presents problems which do not permit wide-spread architectural use — more industrial in character. To clean up structural frame imposes high cost for refining connections & welding. Panel we have used most is one which is manufactured by H H Robertson & Company & presents a bold corrugated exterior surface. We have found that by using striated aluminum sheet, halations attendant to slight buckling in surface metal are reduced to minimum. Scale of corrugation being very large, again limits its application to industrial or very large scale structures. Corrugation, however, is essential to rigidizing panel — flat panel is most difficult to handle. Economics are reasonable, especially where there is a premium on speedy erection & completion time for project.

exposed supporting frame:

"This category would include porcelain enameled panels as devised by US Plywood & used at GM Technical Center & Ing-Rich panels devised by this office & used at RCA — Cherry Hill project. These panels are designed primarily for architectural use & have application in all building types. Principal advantage is possibility of use of wide range of color. This office has used panels of 2 types in this category.

- **insulated sandwich panel, exterior, interior finish**
- **non-insulated, exterior weathering surface & finish only**

"In all instances we have set panels in exposed stainless steel grid which is applied to structure of building. Panel used in RCA project has proven most satisfactory & was developed according to our specifications with following requirements:

- **insulating "U" factor of 0.14 to 0.19**
- **panel must be constructed entirely of inert materials which will not be adversely affected by moisture & heat**
- **panels must be "vented" & "weeped" to permit condensed moisture to be dissipated & to permit expansion & contraction due to temperature change**
- **assembly of panel accomplished by mechanical means rather than reliance on adhesive**

  to our knowledge & experience there has been no system developed that will accomplish an adhesive bond between porcelain & an insulating core material without eventual delamination due to effects of moisture & stresses of temperature change & subsequent shearing of insulation material

  reliance upon this method of assembly for purposes of rigidizing porcelain enameled panel is worthless
- **for architectural reasons, panel must present a flat appearance, flat both in finish & in dimensional surface**

  any buckling of glazed material is most objectionable architecturally

  to overcome this, RCA panels are rigidized by small scale deforming (corrugating) surface prior to porcelainizing
- **as an insulating core we have found foam glass to be most satisfactory**

"Supporting grid frame has proven a most difficult aspect of panel-wall construction. We have used maintenance-free stainless steel on several projects but cost is extremely high. We look to possibility of some type of extruded aluminum frame which might possibly be porcelainized (possibly by low temperature frit process) for added protection against pitting & oxidization. Mild steel framing presents a never-ending maintenance problem since it requires regular painting. Although we have been able to devise a panel which is reasonable in cost we have not been able to lick high cost of frame. When this latter is accomplished, we feel sure that panel-wall construction can be universally used.

"A word about other panels used prior to developing RCA panel. We have used paper core, porcelain-enameled sandwich panels — plywood backed porcelain-enameled facing panels — aluminum-honey-comb-backed facing panels. We found that paper-core panel was completely unsatisfactory. Water entered panel & decomposed paper core, adhesive bond between paper & porcelain failed, trapped air in core expanded from solar heat & blew out caulking at joints & entire panel delaminated. We have had no failures to date on other 2 panel types although our experience with paper-core laminated panel leads us to be concerned for durability of these types. Fortunately, in these latter types we are not relying on panel as a total wall but only as an exterior weather surface."

CONCLUSIONS

Active response by correspondents in this survey indicates widespread interest in metal wall construction. Presently, building types most frequently employing panel construction are industrial plants, recreation facilities, commercial & educational buildings, although most architects questioned indicated desire to use metal panels on practically any building type.

For most architectural needs, these panels could be standardized into a minimum number of stock units with variations of jointing to allow for flexibility of exterior appearance. Actual dimensions of panels must accommodate joint detail & structural mullions or columns dependent upon method of installation. Windows & possibly doors should fit into completed network as a module — facilitating ease of installation & helping to make entire unit competitive in price. Standardization of sizes & number of jointing details could also reduce cost of these units while helping to maintain high quality thru manufacturing techniques, testing & records of durability.

Condensation & infiltration are both factors of considerable concern affecting all climatic regions & should be fully solved before a new panel is placed on market. Most architects believe methods of jointing & details of construction can be satisfactorily solved & thorough testing by manufacturers will help assure high quality, long lasting, & maintenance-free walls of uniform, varigated, or multicolored panels.

Opinions as to color & finish are varied but indicate that specific application would dictate these considerations. In general, deformation & finish should be appropriate to basic properties of sheet metal.

Current problems of labor jurisdiction, color uniformity, corrosion, transit damage, etc, are considered obstacles that time, technology, & the economy will ultimately eliminate.

BRAB SURVEY

Presented at the conference by
William H. Scheick,
Executive Director of the
Building Research Institute and the
Building Research Advisory Board

The BRAB Survey of Metal Curtain Walls is a companion to the AIA Survey of Architects, presented by Walter Taylor. The sponsors were the same:

Aluminum Company of America
Ferro Corporation
Owens-Corning Fiberglas Corporation
Reynolds Metals Company
United States Steel Corporation

The purpose was also the same, to reveal facts for product research and development. However, the BRAB questionnaires were addressed to the owners of buildings with metal curtain walls and to the contractors who had erected them. The manufacturers of metal panels gave us the names of contractors and owners of 639 buildings widely distributed throughout the United States.

In order to be clear on what we were asking questions about, we gave them our definition of metal curtain walls, as follows:

"Metal curtain walls are exterior walls of non-load-bearing metal panels attached to a structural frame. These panels span between floors, girts, or studs and are designed to carry wind loads but not vertical loads."

"The definition includes:

a. Panels consisting only of a metal skin.

b. Composite or sandwich panels consisting of a metal skin, plus an insulating material and an interior facing or liner.

c. Panels with windows as integral components and those without integral windows.

d. Continuous metal spandrels where masonry back-up, if any, has been applied for reasons (e.g., code requirements, insulation, interior finish) other than its contribution to the strength required for the curtain wall.

"It does not include:

a. Metal panels used as a decorative facing material for masonry-bearing walls.

b. Individual or unit metal spandrels applied to masonry walls."

As a result of our broad definition, the inquiry was broadened in scope, and we have data from owners and contractors of many types of buildings.

We received useable information on 220 of the 639 buildings. We found that some of the remaining 419 buildings were still in the planning stage, some were under construction, and some were so recently built that the owners did not care to comment on them. So, the 220 buildings included in the survey have been in use for some time. Over 80 owners told us that their buildings were either in a planning or construction stage. We wound up with 157 owners' questionnaires and 78 contractors' questionnaires, representing responses from 44% of the owners and 34% of the contractors. This is an exceptionally good response for a mail survey. The survey ran from October 1954 through February 1955. Owners and contractors were asked to check questions. The tables here reproduce the questions as they appeared on the questionnaire. The figures in the tables represent number of replies received. Each reply, except in rare cases, refers to one building.

We believe there are definite limitations to this survey. In the case of the contractors, we were talking with technical people, but with the owners we were not. The survey, I believe, at best was introductory and exploratory. There were quite a number of things that perhaps could have been more specific, and when we started to analyze our figures we realized that they had to be examined closely and studied pretty hard to determine precisely what they mean. For example, if you ask about air infiltration or leakage of water and you get 90% replies saying that things are O.K. then how bad is the 10% involved? Therefore, this is not the place where simple majority figures can be interpreted rather glibly. In our building industry, as you know, a failure can be spectacular. I believe we all know of a famous building that a lot of criticism because it leaks easily. If it leaks, it can be serious. If 99 out of 100 replied no leakage, that one exception - for all we know - might have been pretty bad.

We also found that we couldn't really tie our figures to types of buildings, and in some cases we didn't have to tie them to types of panels. Anyone pursuing this study further might find that one particular batch of panels came through with flying colors and that the failures or troubles that were recorded might have been due to somebody else's product. Our own reports didn't separate such things, but, generally speaking, we believe that this information will give designers, inventors, and producers much to think about and is a good supplement to the AIA "Study of Architects," presented by Walter Taylor. Included here are comments on some of the tables.

Types of Buildings. As you can see from Table 1, the survey covered a wide variety of buildings. "Service stations and repair shops" may not be accurately represented in this table because one questionnaire may have covered hundreds of identical buildings. We believe that in many cases reported under this heading it was not the number of buildings but a whole series, or chain, of buildings. The figures for other types of buildings mean number of buildings.

Years of Experience. The experience that is represented in the reports, as shown in Table 2, suggests that we are really talking about something pretty new. Sixty-eight percent of the owners who reported have had less than 4 years' experience. That is not very long for a building. Of course, some of the things that they talked about could be expected to show up quickly. One thing that it definitely proves is how new the product is.

Much of our data on the reported performance of the metal curtain walls must be judged in the light of the limited experience of many owners with these buildings. In this tabulation you will note that 51 (or 38%) of the 132 owners replying to the questions had occupied the building less than 2 years. The date of enclosing buildings, as reported by the contractors, also confirms the recent growth of metal curtain wall construction.

Infiltration. In Table 3 the replies on infiltration relate to all the various types and sizes of buildings and classes of metal curtain walls covered by the survey. The figures lack special significance if you are interested in only one material or one panel type or one type of building.

Also, in evaluating these figures, ask yourself what degree of perfection is required. Should we be content with a fairly high percentage of perfection or is even one case of infiltration by air, water, snow, or dust unacceptable? I feel that the infiltration of air and water is rather high; that this is an indication that here is something designers need to give more attention to, particularly with respect to horizontal joints and the inclusion of windows in the panels.

Appearance. On the appearance, as you can see by Table 5, the feeling is generally quite favorable, and this seems to concur with what Walter Taylor found among the architects. I would say that if there is anything they seem to pick on as the weakest point, it is the joint design. I don't know whether they are thinking about the appearance or something else. Perhaps some of them are thinking of performance.

Performance. On the owners' report of performance (Table 6), I think there are just enough adverse reports, although the figures given seem to be preponderantly favorable. Also, there are just enough adverse reports here to make designers sit up and take notice, and perhaps say, "If this is a new thing we are trying to promote, here are some of the bugs we had better design out."

Assembly Methods. On the matter of assembly methods (Table 8), when we understand what the contractors believe, we find that the difficulty seems most frequently to be with working tolerances, with preparation of framing, and with calking and water-proofing. Some of these things apply to the handling of other building products as well, so they are not new.

Contractor's Opinions of Metal Curtain Wall Features. As might be expected, the height, width, thickness and weight of the panels vary considerably (Table 9). Yet this apparently makes no difference to contractors. One very interesting thing--and I think it is typical of our building contractors today--they have very little to say about it being too heavy, too light, too large, or too small. I believe the attitude of the American contractor is pretty much, "You design it and we will build it; we are not too fussy about things like weight and size."

Contractors' Opinions of Erecting Metal Curtain Walls. The contractors had a chance to report on the manufacturers' service. The first part of Table 10 shows how they reported. In a time when it was hard to get a lot of things in the building industry the service suffered as a consequence. I don't know whether we can attach importance to these figures. It does show that when the figures in the "not satisfactory" column are large, presumably something should be done to improve those services.

Of course, it could be very touchy in our industry to make comparisons between one type of construction and another, as the information in the second part of Table 10 does. I must say that I doubt very much the value of these figures, because in studying what we asked for, I come to the conclusion that there was an insufficient breakdown and inclusion of pertinent information. It does show some opinions, however, that people on both sides of the industry, in competitive products, might compare and interpret as they see fit.

General Conclusions. In Table 12 we have the general conclusions of both the building owners and the contractors based on their actual experience with metal curtain walls. The general conclusions were simply a question of "would use" or "would not use again." The replies were generally favorable, perhaps more so on the part of the owners than the contractors.

Other Information. Other interesting information provided by the questionnaire, covering such subjects as condensation, maintenance, contractors' problems, and design details, are presented in Tables 4, 11, 13 and 14.

TABLE 1

METAL CURTAIN WALL STUDY

Type of Building	Number of Buildings for which Usable Replies were Received
Power Generating Plants for Public Service and Industrial Companies, including Water and Sewage Treatment Facilities	48
Manufacturing Buildings	47
Office Buildings for Professional and Business Firms, Banks and Insurance Companies, Including Industrial Administration Buildings	37
Research Laboratories	16
Schools & University Buildings	15
Storage Buildings such as Warehouses and Parking garages	13
Residential Buildings such as Dormitories Barracks and Apartment Houses	9
Service Stations and Repair Shops	9
Commercial Buildings such as Stores, Restaurants, Hotels and Shopping Centers	8
Airport Buildings such as Passenger Terminals, Hangars and Maintenance Buildings	7
Public Buildings such as Armories, Bus Depots, and Recreational Centers	6
Medical Buildings such as Hospitals and Clinics	5
Total:	220

TABLE 2

OWNERS' YEARS OF EXPERIENCE WITH THEIR METAL CURTAIN WALL BUILDINGS

Occupancy	Buildings	Percentage
Less than 6 months	13	10
6 months to 1 year's	18	13
1 to 2 year's	20	15
2 to 3 year's	17	13
3 to 4 year's	22	17
4 to 5 year's	14	11
5 to 6 year's	11	8
6 to 7 year's	7	5
7 to 8 year's	6	5
Over 8 years'	4	3
	132	100

DATE OF ENCLOSING BUILDINGS WITH METAL CURTAIN WALLS AS REPORTED BY CONTRACTORS

Year	Buildings	Percentage
1955	1	1
1954	29	40
1953	12	16
1952	11	15
1951	9	12
1950	6	9
1949	2	3
1948	2	3
1946	1	1
	73	100

TABLE 3

OWNERS' REPORT ON PERFORMANCE OF METAL CURTAIN WALL BUILDINGS

INFILTRATION BY AIR, WATER, SNOW, OR DUST

	Air	Water	Snow	Dust
No infiltration	100	110	110	107
Noticeable infiltration at vertical joints	15	9	4	11
Noticeable infiltration at horizontal joints	18	9	5	11
Noticeable infiltration at joints around windows	29	16	4	14
	162	144	123	143

TABLE 4

OWNERS' REPORT ON PERFORMANCE OF METAL CURTAIN WALL BUILDINGS

WINTER COMFORT CONDITIONS

No complaints about drafts near walls	111
Drafts have been noticeable near walls	18
	129

Surface of wall comfortable to the touch	52
Surface of wall cold to the touch	34
	86

VAPOR CONDENSATION ON INTERIOR WALL SURFACES

None ever observed	134
Some condensation when outside temperatures are below (average about 0° F.) degrees	11
	145

VAPOR CONDENSATION ON WINDOWS

No noticeable condensation	94
Some condensation when outside temperatures are below (average about 9° F.)	35
	129

VAPOR CONDENSATION ON THE INSIDE OF WALL PANELS

No evidence of any such condensation	83
No means of observing conditions inside panels	70
Some evidence that condensation has taken place	14
	167

TABLE 5

OWNERS' OPINIONS OF METAL CURTAIN WALL BUILDINGS

OWNERS' OPINION OF THE APPEARANCE OF THE METAL CURTAIN WALLS

Respecting	Good	Satisfactory	Could be Improved	Total
Material	114	27	7	148
Surface pattern or	100	34	6	140
Joint design	93	29	25	147
Color	89	44	4	137
Finish	87	41	9	137

THE OPINIONS OF OTHERS ON THE GENERAL APPEARANCE OF THE WALLS

Expressed by	Strong Approval	Mild Approval	Mild Disapproval	Strong Disapproval	Total
The public	68	42	3	0	113
Our employees	78	41	4	3	126
Our tenants	36	21	1	0	58

TABLE 6

OWNERS' REPORT ON PERFORMANCE OF METAL CURTAIN WALL BUILDINGS

EFFECT OF WEATHER ON EXTERIOR APPEARANCE

No noticeable effect	113
Some corrosion or rust spots	22
Some pitted or etched panel surfaces	6
	141

EXTERIOR FINISH OF PANELS

Dull (non-reflective)	70
Shiny (reflective)	48
Matt	32
	150

DISTORTION OF PANEL SURFACES

None apparent	128
Some waviness	19
Some buckling or oil can effect	5
	152

EFFECT OF AIRBORNE DIRT OR SOOT ON EXTERIOR WALLS

Rain keeps the panels clean	113
Horizontal surfaces accumulate grime	19
Dirt forms noticeable streaks down panels	14
Panels permanently darkened	11
	157

EFFECT OF AIRBORNE DUST ON INTERIOR WALL SURFACES

No dust patterns observed	125
Interior walls show a pattern formed by uneven deposit of dust from interior of building on the curtain walls (framing inside wall shows up in dust pattern on wall).	16
	141

RETENTION OF COLOR VALUES IN PANELS

Original color values retained	87
Some fading noticeable	37
	124

TABLE 7

OWNERS' MAINTENANCE RECORD OF METAL CURTAIN WALL BUILDINGS

PANEL JOINTS RE-CAULKED

Never	113
Every six months	2
Every year	3
Every two years	5
	123

WALLS CLEANED

Never	107
Every six months	4
Every year	6
Every two years	10
	127

REPLACEMENT OF PANELS

No panels have needed replacement	133
Some defective panels replaced	8
	141

ACCIDENTAL DAMAGE

None since completion of building	106
Some, but easily repaired	35
Some, difficult or impossible to repair	14
	155

RE-USE OF PANELS

No change in panels since completion of building	112
Panels have have been dis-assembled and re-used when changes were made in the building	38
	150

TABLE 8

CONTRACTORS' OPINIONS OF THE ASSEMBLY METHODS

Operation	Good	Satisfactory	Difficult	Total
Preliminary handling and storing of panels on site	45	25	4	74
Preparation of framing to receive panels	41	26	7	74
Site preparation of panels (e.g., drilling bolt holes)	40	18	4	62
Bolting (47), riveting (4), or welding (27) panels to framing	39	21	2	62
Joining panels vertically	43	27	3	73
Joining panels horizontally	34	22	3	59
Aligning panels	37	32	6	75
Adjustability of attachment devices	28	36	5	69
Working to tolerances and provisions for expansion and contraction	27	35	10	72
Caulking, waterproofing, flashing panels	28	36	8	72
Installation of windows	26	25	2	53
Insulating the wall	37	19	2	58
Installing back-up material	28	13	2	43
Finishing interior surfaces	36	17	2	55

TABLE 9

CONTRACTORS' OPINIONS OF METAL CURTAIN WALL FEATURES

THE WEIGHT AND SIZE OF THE PANELS

Respecting	WEIGHT OF PANELS: Too Heavy	WEIGHT OF PANELS: Too Light	WEIGHT OF PANELS: Satisfactory	SIZE OF PANELS: Too Large	SIZE OF PANELS: Too Small	SIZE OF PANELS: Satisfactory
Handling panels on the ground	0	0	71	3	0	64
Assembly of panels on the building	0	0	68	0	0	60
On-site storage	0	0	66	0	0	59

OUR PREFERENCES IN PANEL CONSTRUCTION

(Considering over-all erection time, handling panels, and the possibility of damage during erection and in transit.)

Panels without windows	38	Factory-insulated panels	42	Separate interior finish	35
Panels with integral windows	13	Insulation applied separately	55	Panels with interior finish	16
	51				51

THE VARIETY OF PANELS NEEDED

The number of different types of panels needed for the job (e.g., corner panels, window panels, straight wall panels, etc.) were:

Reasonable under the conditions of the job	66
Too much variety for ease of erection	2
Too much variety for easy identification of parts	1
Too much variety for storage and handling	0
	69

TABLE 10

CONTRACTORS' OPINIONS OF ERECTING METAL CURTAIN WALLS

THE PANEL MANUFACTURER'S SERVICE

Respecting	Good	Satisfactory	Not Satisfactory	Total
Timing of deliveries	38	23	21	82
Identification of panels by number	41	25	3	69
Completeness of shipments (no missing parts)	32	26	13	71
Protection of panels for shipping and handling (particularly the edges and joints)	31	26	11	68
Availability of spare parts	23	27	15	65

COMPARISON OF ERECTION TIME OF WALLS WITH COMPARABLE MASONRY WALL CONSTRUCTION

Time shorter by (average 50%)	39
Time about equal	11
Time longer by (average 31%)	4
	54

OUR COMPARISON OF METAL CURTAIN WALLS WITH ALTERNATE WALL CONSTRUCTIONS

Respecting	Metal Curtain Walls Better	Alternate Wall Constructions Better	No Answer	Total
Construction time only	51	7	14	72
Construction costs only	36	15	21	72
Construction costs and other factors such as the possibilities of better appearance, better performance, easier maintenance, earlier completion and occupancy, and increased floor space	52	6	14	72

TABLE 11

CONTRACTORS' INFORMATION ABOUT METAL CURTAIN WALL JOBS

PANELS APPLIED FROM

Outside building	55
Inside building	15
Both inside and outside	8
	78

ALTERNATIVE BIDS FOR DIFFERENT WALL CONSTRUCTIONS

Not required	65
Required	3
	68

BUILDING TRADES

Trade which erected the metal curtain walls:

Ironworkers	32
Sheet metal workers	21
Both sheet metal and ironworkers	8
Carpenters	5
Others	5
	71

ERECTION EQUIPMENT USED

Hand tools only	45
Swinging scaffolds	32
Block and tackle	31
Welding equipment	31
Crane	9
Other	20
	168

No jurisdictional questions raised	49
A jurisdictional question was raised	10
	59

BUILDING PERMITS

Special problems, if any, in obtaining permits because of the metal curtain walls:

No problem	47
No answer	25
A problem	6
	78

NUMBER OF STORIES

1 story	25
2 stories	10
3 to 6 stories	13
7 to 20 stories	12
Over 20 stories	4
	64

TABLE 12

GENERAL CONCLUSIONS
OF OWNERS AND CONTRACTORS

QUESTION TO OWNERS:

We would use___ not use___ metal curtain wall again for this type of building.

OWNERS' REPLIES

Would use	143
Would not use	4
No answer	10
	157

QUESTION TO CONTRACTORS:

We would___would not___recommend using metal curtain walls again for this type of building.

CONTRACTORS' REPLIES

Would recommend	61
Would not recommend	10
No answer	7
	78

TABLE 13

COMBINED REPLIES OF OWNERS AND CONTRACTORS ON DETAILS OF METAL CURTAIN WALL BUILDINGS

PANEL MATERIAL

Aluminum Sheet	83
Galvanized Steel	63
Porcelain Enameled Steel	32
Aluminum Extrusions	25
Stainless Steel	19
Aluminum outside - steel inside	15
Painted Steel	12
Aluminum Castings	5
Other	26
	280

SURFACE PATTERN

Large corrugations	96
Flat	85
Embossed, pebbly	19
Crimped	18
Small corrugations	16
Embossed, checkered	2
	236

PANEL COATING

None	99
Paint (applied at site)	79
Porcelain Enamel	27
Baked-on Enamel	13
	218

STYLE OF PANEL JOINT

Male and Female Flanges	136
Flush	36
Batten type	24
Recessed	23
	219

TABLE 14

MORE DETAILS ON METAL CURTAIN WALL BUILDINGS SURVEYED

BACK-UP WALL

None	169
Cinder block	11
Brick	7
Lightweight concrete	5
Other	37
	229

INTERIOR FINISH OF CURTAIN WALL

Metal	116
Plaster	19
Insulating boards	13
Asbestos-cement boards	12
	180

WINDOWS IN PANELS

Windows are separate from panels	180
Panels have windows as integral components	12
	192

TYPE OF WINDOWS

Pivoted	112
Sealed	43
Casement	32
Vertical sliding	9
Horizontal sliding	2
	198

THERMAL INSULATION

Part of composite panel	147
Separately installed	54
	201

* * * *

Thickness of insulation: 83% - 1-1/2 inches or more

Over-all U-factor of panels: range 0.13 to 0.25

TYPE OF INSULATION

Glass fiber	152
Rock wool	18
Lightweight concrete	8
Other	28
	206

VENTING OF THE WALL

Walls not vented	79
Vented to exterior	66
Totally sealed panels	50
Vented to interior	16
	211

SEALING OR CAULKING MATERIAL

Caulking compound	172
None	29
Plastic extrusions	19
	220

DATE: December 31, 1952
MASONRY CURTAIN WALLS
COST STUDY

Wall Tkns.	Exterior	Backup	Interior	Cost Sq. Ft.
12	Brick	Hol. Bk.	Tile Ceramic Glaze Any Color	$7.69
"	"	" "	" Clear Glaze	7.47
"	"	" "	" Salt Glaze	7.02
"	"	" "	" Clear Glaze (C)	6.60
"	"	None	Speed Tile Salt Glaze	6.39
"	"	"	Tile Unglazed	6.32
"	Speed Tile Unglazed Buff	"	" Ceramic Any Color	5.87
"	" " " "	"	" Clear Glaze	5.80
"	" " " Red	"	" Ceramic Glaze Any Color	5.74
"	Brick	"	Speed Tile Unglazed Buff	5.72
"	Speed Tile Unglazed Red	"	Tile Clear Glaze	5.67
"	" " " Buff	"	Speed Tile Unglazed Buff	5.63
"	" " " "	"	Tile Salt Glazed	5.63
"	" " " "	"	" Clear Glaze (C)	5.63
"	Brick	"	Speed Tile Unglazed Mag. Spot	5.62
"	Speed Tile Unglazed Buff	"	" " Salt Glaze	5.58
"	" " " Red	"	" " " "	5.54
"	" " " "	"	Tile Clear Glaze (C)	5.54
"	Brick	"	Speed Tile Unglazed Red	5.51
"	Speed Tile Unglazed Red	"	Tile Salt Glaze	5.50
"	" " " "	"	Speed Tile Unglazed	5.41
8	Brick	"	Brick	4.33
"	Claycraft Unglazed Buff	"	Claycraft Clear Glaze	3.86
"	Speed Tile Unglazed "	"	Speed Tile Unglazed Mag. Spot	3.67
"	" " " "	"	" " " Buff	3.65
"	Claycraft " "	"	Claycraft " "	3.43
"	Speed Tile " Red	"	Speed Tile " Red	3.39

NOTE: Cost per sq. ft. includes, foundations structural steel, heat loss, fabrication and erection of Curtain Walls

Figure 1.1

DATE: December 31, 1952
METAL CURTAIN WALL
COST STUDY

Exterior Panel		Insulation	Interior Panel		Cost Sq. Ft.
Gauge	Material		Gauge	Material	
16	Aluminum	1-1/2" Fiberglass	18	Galvanized Steel	$2.75
20	Stainless Steel	"	18	" "	3.85

NOTE: Cost per sq. ft. includes, foundations, structural steel, heat loss, fabrication and erection of panels

Figure 1.2

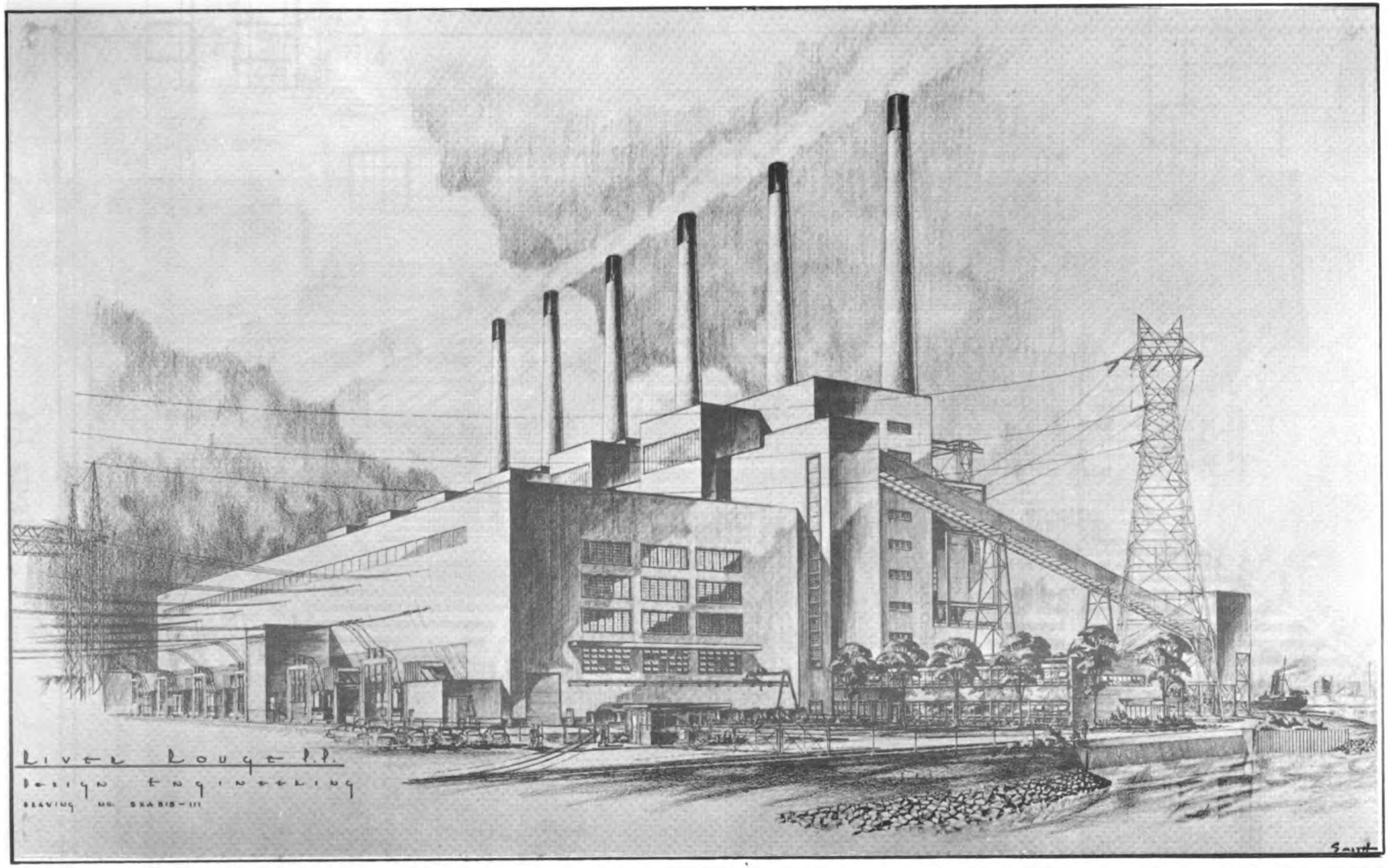
River Rouge P.P.
Design Engineering
Drawing No. SXA 815-111
Smith

Figure 1.3

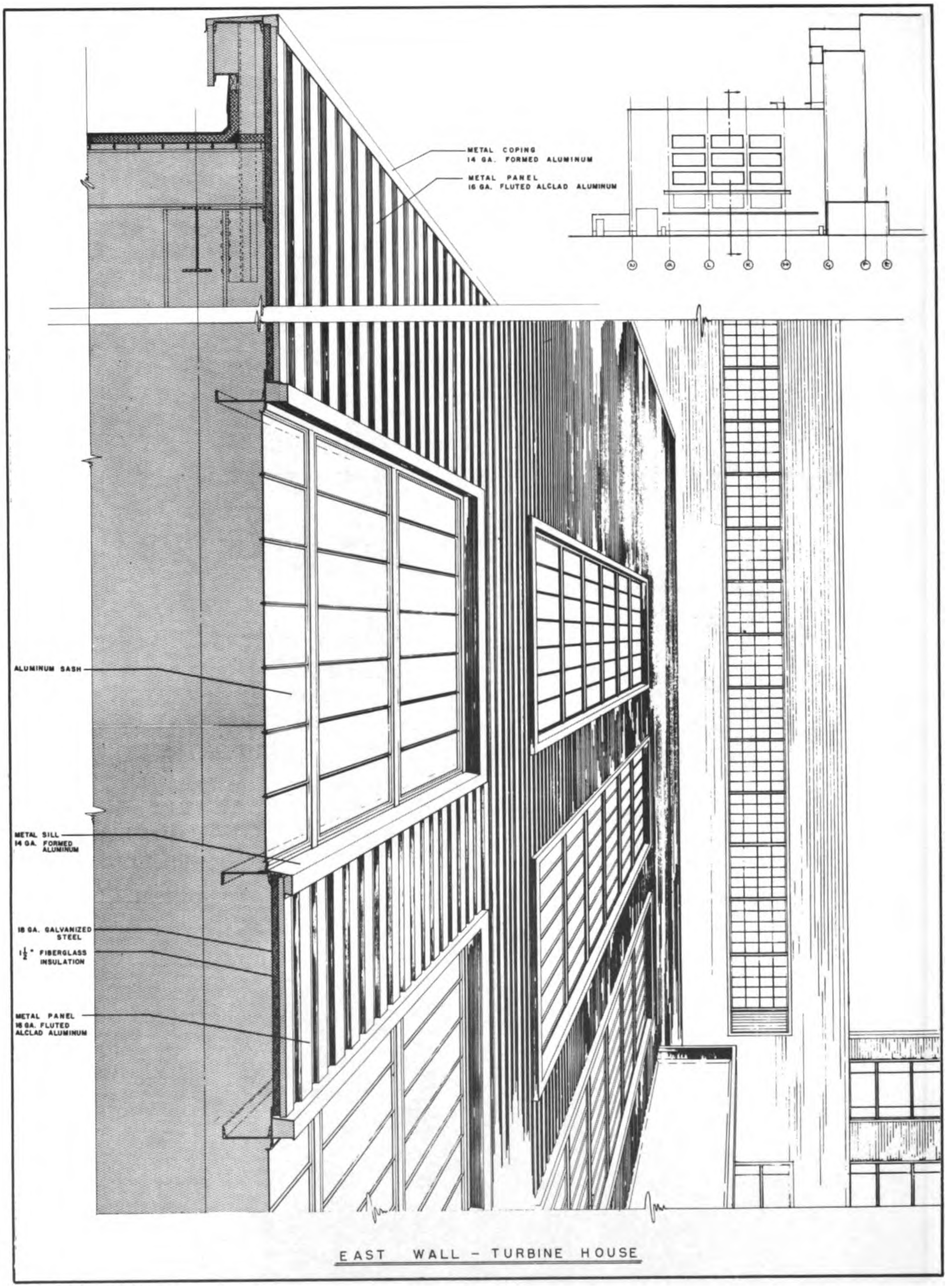
METAL COPING
14 GA. FORMED ALUMINUM
METAL PANEL
16 GA. FLUTED ALCLAD ALUMINUM
ALUMINUM SASH
METAL SILL
14 GA. FORMED ALUMINUM
18 GA. GALVANIZED STEEL
1½" FIBERGLASS INSULATION
METAL PANEL
16 GA. FLUTED ALCLAD ALUMINUM
EAST WALL - TURBINE HOUSE

Figure 1.4

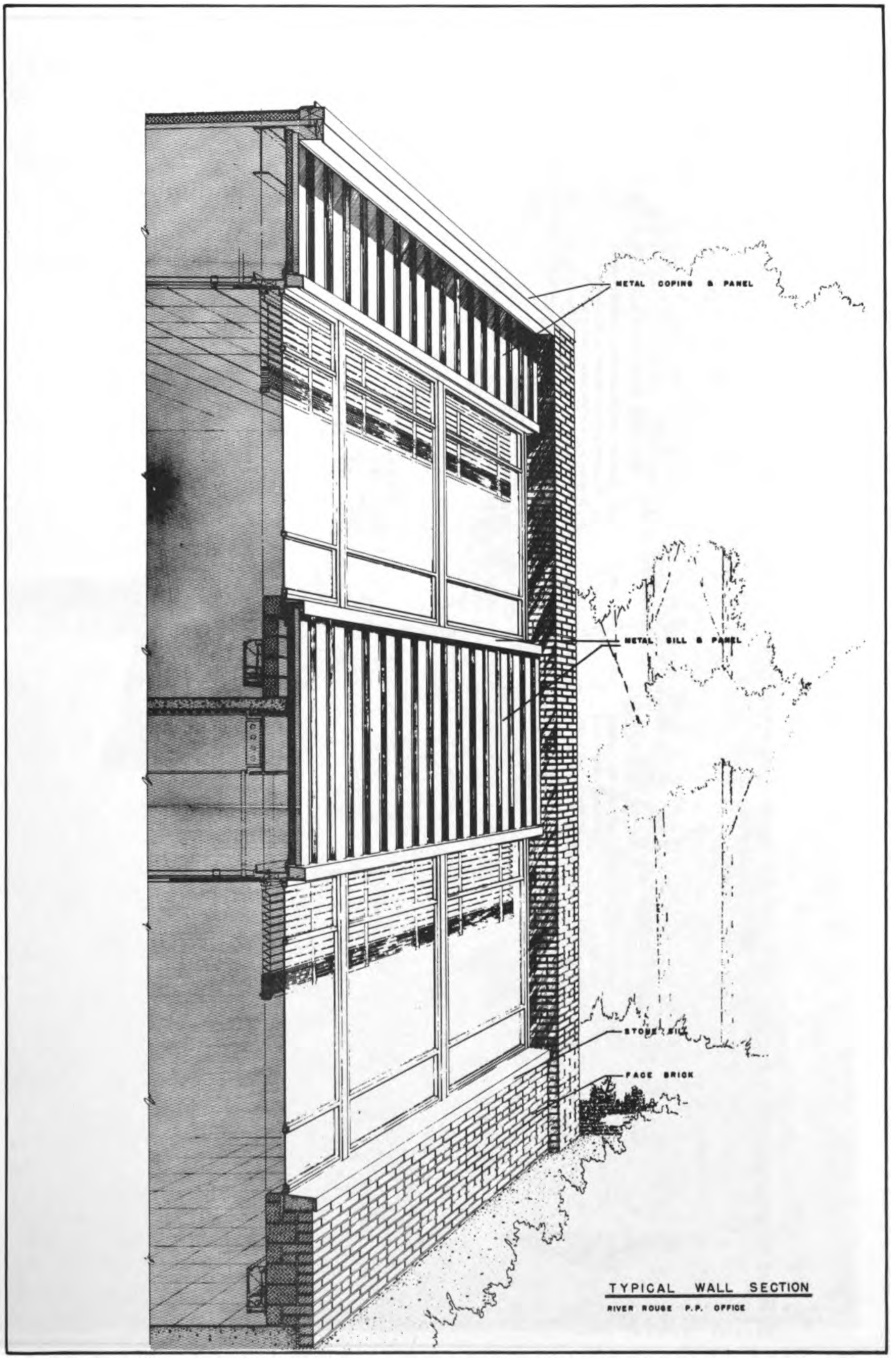
METAL COPING & PANEL
METAL SILL & PANEL
FACE BRICK
TYPICAL WALL SECTION
RIVER ROUGE P.P. OFFICE

Figure 1.5

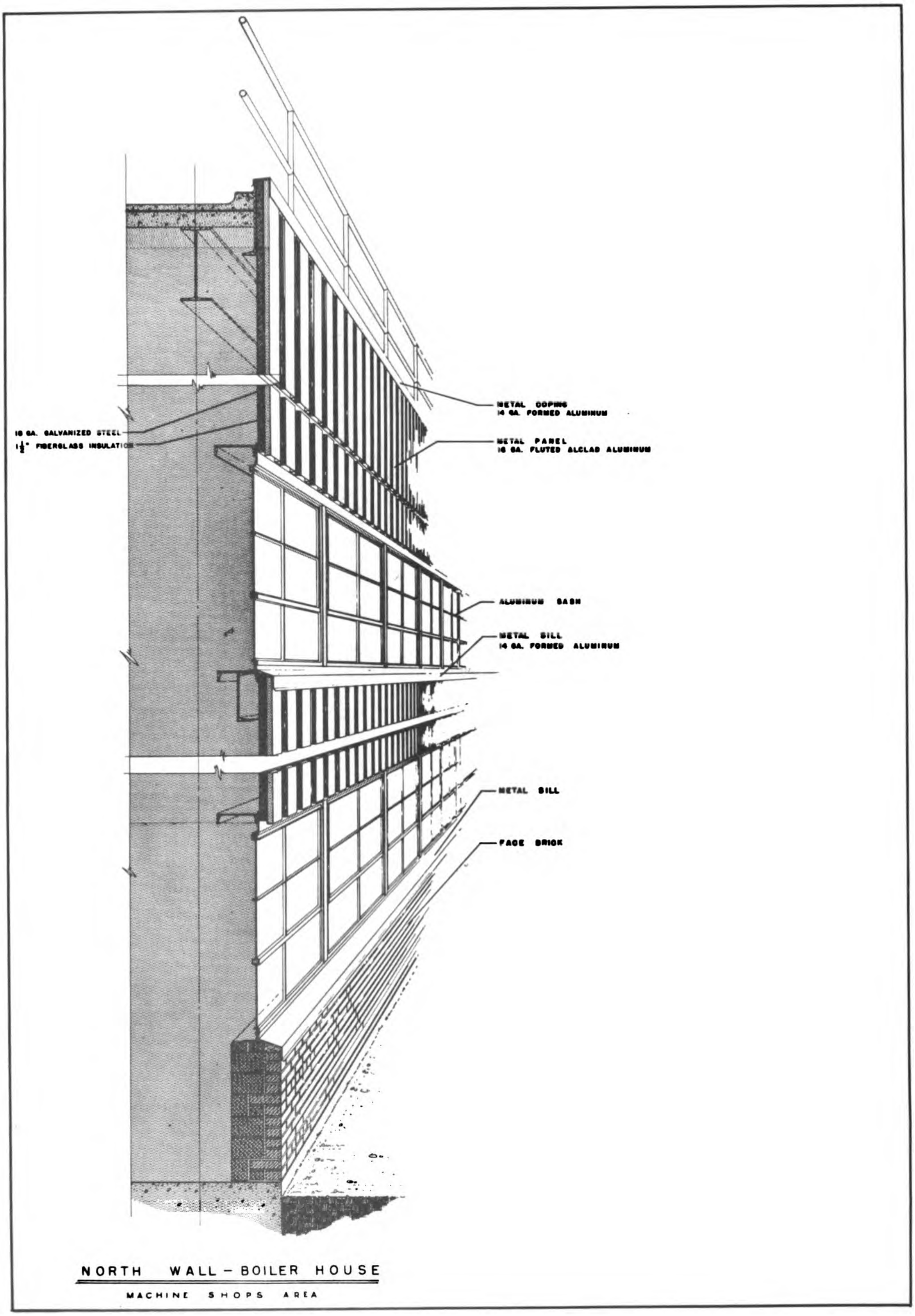
METAL COPING
14 GA. FORMED ALUMINUM
16 GA. GALVANIZED STEEL
1½" FIBERGLASS INSULATION
METAL PANEL
16 GA. FLUTED ALCLAD ALUMINUM
ALUMINUM SASH
METAL SILL
14 GA. FORMED ALUMINUM
METAL SILL
FACE BRICK
NORTH WALL – BOILER HOUSE
MACHINE SHOPS AREA

Figure 1.6

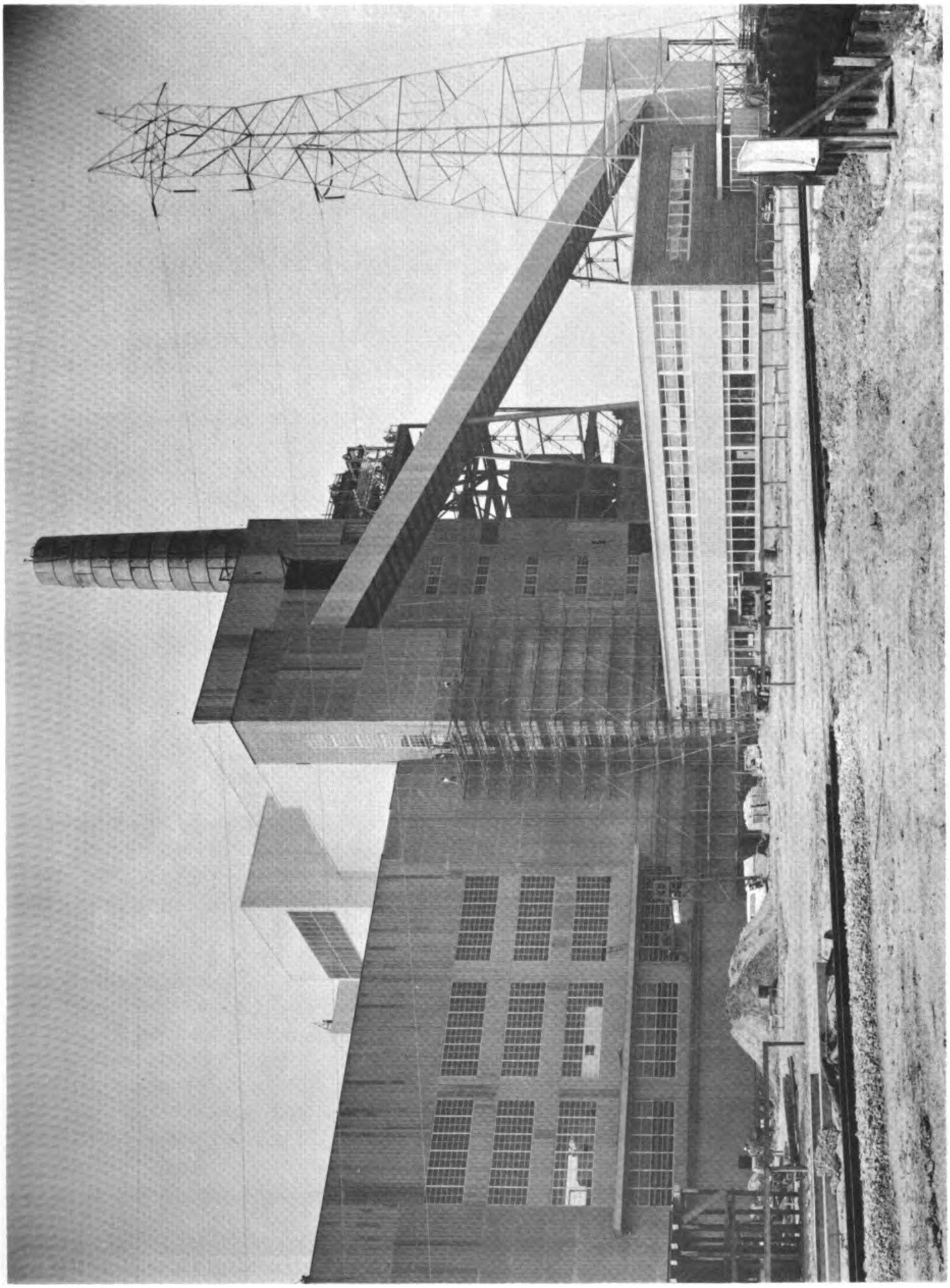

Figure 1.7

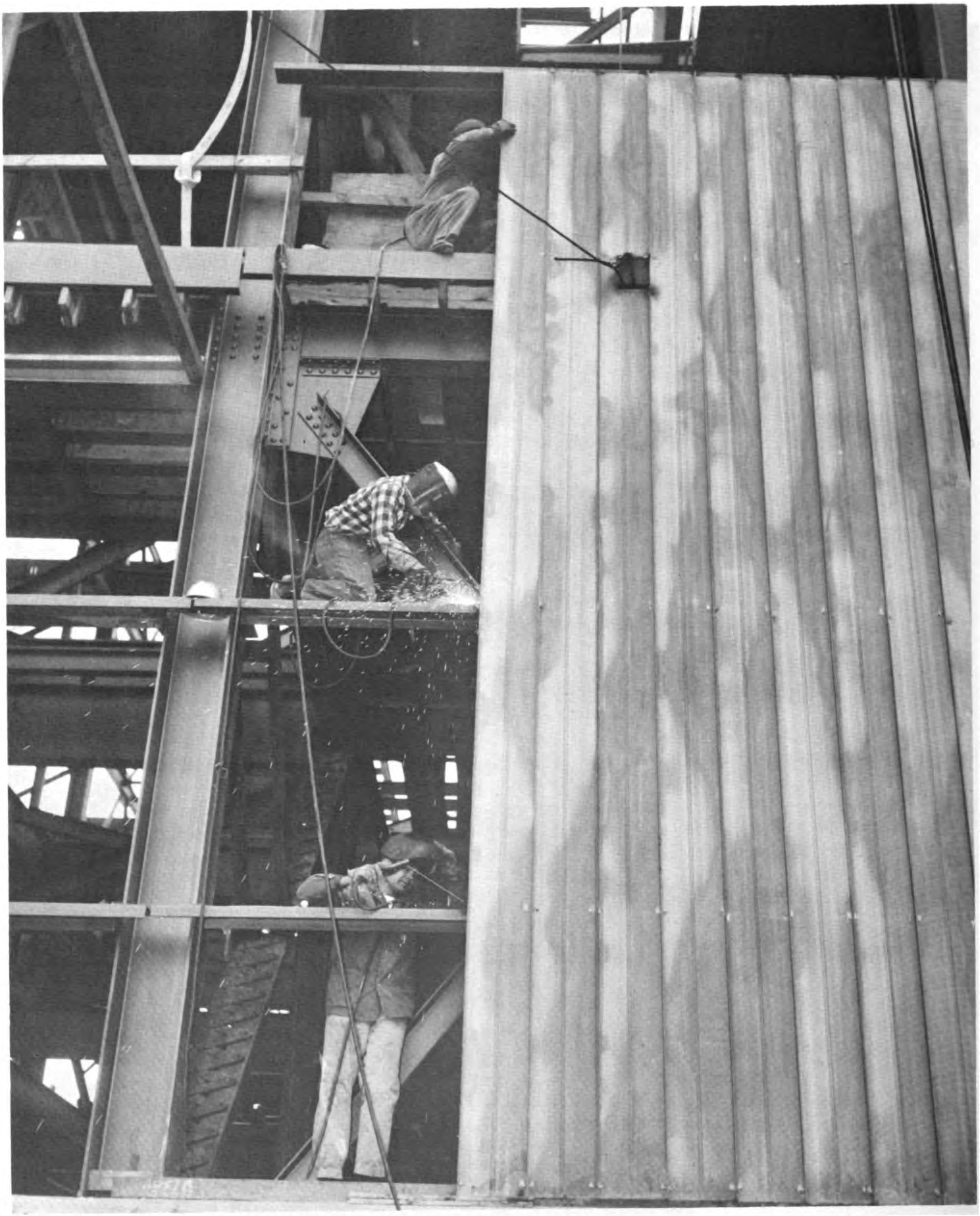

Figure 1.8

DETROIT EDISON SURVEY

Presented at the conference by
John O. Blair,
Division Architect of the
Detroit Edison Company

Mr. TUTTLE (Chairman): Our next speaker, Mr. John O. Blair, is Division Architect for the Detroit Edison Company. He is a graduate of the School of Architecture of the University of California, and has had many years of experience in different fields of architecture. As a member of the American Institute of Architects, he has served as Director and Treasurer of its Detroit Chapter for several years.

Mr. BLAIR: At the end of World War II The Detroit Edison Company, like many other electrical utilities, was faced with the big task of increasing its power plant capacities to accommodate the increased demand for electricity in the anticipated post-war expansion programs. To speed this program it was decided to enlarge two existing plants where water facilities were adequate and land was available to accommodate the storage of coal, which was used in this area as a source of heat to produce steam.

Existing buildings were of masonry construction and for aesthetic reasons it was decided to match the two power plant extensions with the masonry of the existing buildings. New coal handling systems were designed for the existing plants, and it was on these structures that we in Edison first used metal curtain walls to house mechanical equipment. Panels were factory fabricated in widths of 24" and of lengths to meet the building design. Insulation was 1-1/2" fiberglass, and protected metal and electro-galvanized steel were used in various structures. Panels in all structures were welded or bolted to steel girts and the joints caulked and die-clinched to produce weather-tight joints. These small structures so treated proved to us that the curtain walls were good, low cost building materials that could be installed quickly in all kinds of weather to afford protection for mechanical and electrical tradesmen installing equipment through the cold winter months.

Based on the experience gained on these small structures using insulated panels, we decided to thoroughly explore the cost of aluminum and stainless steel for use on our new River Rouge power plant project, now that there are no government restrictions on the use of these metals in building structures. The Architect and the Corrosion Committee of the company made a study of various types of metal panels offered by fabricators for industrial and commercial use, using aluminum and stainless steel. The Corrosion Committee investigated the metals for their ability to withstand the moderately corrosive industrial atmosphere at the River Rouge power plant site. The Architect studied fabrication and erection details, metal gauges, textures, finishes, joints, flashing details, and costs.

To assure our management that considerable savings could be realized by using metal curtain walls, 30 types of 8" and 12" masonry curtain wall sections were developed, using various types of brick, glazed and unglazed tile, and salt glazed and ceramic glazed tile in various sizes and bonding combinations. Two types of field or shop fabricated metal panel units were investigated, each having 18 gauge electro-galvanized steel for the inside face, 1-1/2" of fiber glass insulation and aluminum for the outside face finish for one type and stainless steel for the other.

Because the weight of the materials and their coefficients of heat transmission are important in analyzing total costs, unit costs were determined on the basis of the cost of the structural framework and foundations being chargeable to the walls because of variable weights. Unit costs were also determined for heating due to different coefficients of heat transmission on the many wall sections considered. The total unit costs per sq. ft. of wall surface based on these analyses for masonry curtain walls varied from $3.39 to $7.69, depending on wall thickness and the weight and quality of masonry unit used (Figure 1.1). The total unit cost for metal panel construction using electro-galvanized steel for the inside face, 1-1/2" fiberglass insulation, and fluted aluminum for the outside face was estimated at $2.75 per sq. ft. of wall surface (Figure 1.2). Using stainless steel in the same section, in place of aluminum, our estimate was $3.85.

Both aluminum and stainless steel were approved by the Corrosion Committee as acceptable as an outside finish in this area. The committee recommended 3S Alclad aluminum alloy in order to obtain the maximum protection against possible corrosion rather than the 3S alloy normally supplied by fabricators. Because of proper detailing and fabrication and use of good erection methods we anticipate the panel walls will have a long life free from maintenance.

Based upon these studies and estimates, drawings were prepared, specifications were written, and requests for bids submitted to several fabricators of this type of panel construction. The bids were thoroughly analyzed, and after consideration of all factors, aluminum was selected as an outside finish. This selection was consistent with the Corrosion Committee's recommendation, was the least costly, and offered good prospects for the need of a minimum of maintenance.

Figure 1.3 shows a perspective of the proposed River Rouge power project, on which our studies were based. One of the wall sections that were developed before working drawings were made is shown in Figure 1.4. A wall section through the office building is shown in Figure 1.5. You will note that masonry is used as a base course and glazed pile as a back-up to the metal panel wall on the second floor. Figure 1.6 shows a section of a part of a panel in the power plant. This shows some of the sections that were developed and how we propose to handle the various flashing and plaster wall details. The power plant actually under construction is shown in Figure 1.7. The office building, with the aluminum panels completed, is shown in the foreground. In the lighter section at the top of the power plant the aluminum is completed. They are now in process of erecting the aluminum in that section of the plant where the scaffolding is in place. Figure 1.8 shows how simple and easy it is for workmen to handle the type of panel used on this job. This panel is 12 inches in width.

It is estimated that a saving of over $600,000 on the first two units of this power plant project will be realized, based on the cost of a 12" masonry curtain wall construction used on a previous power plant project. On the completed project the ultimate savings will amount to $1,800,000. This represents a first cost saving of a little more than a dollar per kilowatt of plant capacity. And because of the difference in weight of the two wall sections, a saving of 1,000 tons of steel is expected on the first two units and ultimately 3,000 tons on the 6-unit plant design.

This project is underway. The panels are being fabricated within a few miles of the site and immediately erected on arrival by truck. The interior galvanized panels are fabricated first and placed vertically and welded to the structural steel girts. The outstanding interlocking ribs are then die-clinched at intervals to insure uniform strength. This operation has many continuing advantages, one of which is permanent weather protection for mechanical, electrical, and building tradesmen erecting boiler, generating equipment, and interior building finishes. This is a very important consideration in meeting accelerated construction schedules.

The next operation, required to complete the field fabrication, is the welding of 1/4" x 1" coated steel bars to the outstanding ribs in horizontal runs spaced about four feet apart. The 1-1/2" fiberglass insulating bats are then inserted into the 1-1/2" deep pans provided by the interior utility panels. The final operation is the application of the fluted aluminum panel. This is accomplished by welding to the horizontal bars coated steel clips that secure the aluminum panel to the inside sheet. Successive interlocking ribs, which have been filled with caulking compound, are again die-clinched at about two-foot intervals, including each point where a welding clip occurs. And by installing flashings, sills, and copings, the outside walls are complete. These walls when fully assembled are 3-1/4" in total thickness, free of bolts and screws in the continuous metal face and thus forming a beautiful fluted aluminum surface.

In areas where heavy construction operations are in progress and aluminum panels may be subject to damage, the aluminum is not installed until such operations are complete. This is one feature that favors the field fabricated panel over the shop fabricated design. It may be interesting to note that aluminum panels in lengths up to 60' have been fabricated, shipped by truck, and erected on this project. No difficulty has been encountered in handling and erecting such length.

Many exciting designs of all types of buildings are being produced today by architects all over the country, using the type of panel construction just described. Its acceptance by the architectural profession, building owners, and the construction industry is an indication that a good product, using aluminum and stainless steel in various finishes and fluted sections, is being produced at a reasonable cost. Because of this acceptance we can expect many improvements in use, fabrication, and erection methods. Also the use of other types of insulating materials will be explored and used to meet the various code requirements for outside walls of buildings.

Building owners are interested in well designed, maintenance-free buildings, constructed at a reasonable cost. We in The Detroit Edison Company who are responsible for the costs of structures realize our responsibilities and will continue to explore all materials and construction methods that offer possibilities of reducing building costs. We are convinced that metal curtain walls, as described here, have found a useful place in the building construction field. We will continue to be interested in improvements which I am sure will be made as experience is gained in their use by the construction industry and the architectural profession.

PART II

ARCHITECTURAL DESIGN

By Max Abramovitz
Partner
Harrison & Abramovitz

Mr. TUTTLE (Chairman): Your Moderator for this session on architectural design is Mr. Douglas W. Orr, architect of the Office of Douglas Orr, Architect, New Haven, Connecticut. Mr. Orr is a graduate of Yale University, with degrees of B.F.A. and M.F.A. He is a Fellow and Past President of the American Institute of Architects; Honorary Associate of the National Academy of Design. Mr. Orr is Consulting Architect at Princeton University.

Mr. ORR (The Moderator): Mr. Chairman, Members of the Conference: There are so many considerations in the use of curtain walls. We have had some of them indicated this morning. Some are economic, some are technical, and many have to do with architectural characteristics. The purpose of this particular panel is to consider some of the aesthetic aspects of these methods of construction and their impact on the design of architecture today.

Following the presentations there will be a question-and-answer period. We would request that you address the particular speaker who you would like to have answer your question, and please keep these questions on matters of design, as that is all this panel is concerned with.

It is my privilege to present the first of two very distinguished architects we have as our panel members, Mr. Max Abramovitz.

Mr. Max Abramovitz is a partner in the firm of Harrison and Abramovitz. He is a Fellow of the American Institute of Architects, a member of the New York Chapter, and of the Architectural League of New York and of the American Society of Civil Engineers. During his very busy career, he finds time also to be Vice President and Governor of the New York Building Congress, a Trustee of Mt. Sinai Hospital, a member of the Advisory Council of the School of Architecture at Princeton, and a member of the Board of Consultants of the School of Architecture, Columbia University.

Mr. ABRAMOVITZ: Before we get deeply into what the architect or perhaps the building industry and the public may, or should, hope for in curtain wall construction, I would like to establish the proper perspective.

The curtain wall is not essentially a new idea. It is a development of the non-bearing wall which has been a tool of the building industry since the first development of skeleton construction. If you will, wood clapboards and shingles, brick and stone veneers, since they are non-bearing walls, can easily be considered a type of curtain wall construction. And should they be fitted into large panels and assembled in factories and brought to the job they could even qualify as panel construction. I mention this because I think that although we are concentrating on metal today, we have many aspects of this picture that spread across all the facets of the building industry. The iron clads of the 19th century ships, the corrugated sheets of factory buildings of the 1880 and 1890's, the metal panels in shop fronts of the last few decades, the wood and metal panels in prefabricated houses of World Wars I and II, and the precast concrete panels of today are all in the same category.

I admit that today's technology and industry has pushed this thinking into the world of newer metals, plastics, and glass and were not considered much at home in the building world until recently. And with the research developed by the pressure of war technology and the aviation world we are now in the process of pushing it further.

The architect has been an ally in this research because he cannot shut his eyes to the world around him. We all are different. We do the kinds of things we do because we enjoy them. Some of us like to build, some like to do new things, and some of us like to express our own personalities. I think the architect in this picture is probably just another egoists who wants to express himself in some satisfying way. Somehow he has found his roots in the building industry and he is going to try to be the person that is expressing his method to society. The musician has his own method and the sculptor still another. The architect is challenged, in his attempt to express his world today, by the genius displayed in the aviation, automotive, and mechanical world, as well as by that part of yesterday which is a part of us today. He is interested also in new ideas to build quicker and more permanently and with fewer of the headaches control of the elements present. If he can find walls which can produce attractive finishes, have properties to satisfy human requirements, and impose no limitations on his creativeness; need he ask for more?

Accepting the fact that intangible creative directions will vary with each individual, there are many factors of a technical nature which are appealing to the architect and will effect his creations aesthetically and practically. The main factors are:

1. The dry wall. This is to supplant the wet wall to enable us to work in cold and wet weather and give us more actual and usable building time.

2. Light weight. This is to permit ease of erecting and thereby requiring less construction manpower and less load to support.

3. Larger units. Larger units mean fewer field joints, improve speed of erection, and mean fewer trouble spots. Movement of buildings caused by winds and temperature changes give the architect his biggest headache - the uncontrolled joint. I am sure that every architect has had more clients come back to him with complaints about leaks of one kind or another than probably any other complaint.

4. Non-corrosive and fire-resistant materials. These produce safe, fireproof buildings. Generally these materials have been hard to tool, but today the tooling advances of the metal age have overcome this difficulty to an unusual degree.

5. Prefabrication. This may mean entire buildings or building parts built under controlled conditions and with a possibility of continuous production and better construction. We will get more construction for our money.

Some of this may be contrary to what you may have heard and what you may hear. I am merely pointing out my own personal reactions. I think there is a great deal of good in panel construction but I have found it very hard to get a cheap panel that does all the things I think it ought to do. I feel sincerely that such a panel can be made, but there are a great number of panels coming on the market, trying to meet competition, that are overlooking those elements and thus doing harm to your potential industry.

Now, during this conference and in the discussions of papers you will absorb a great deal of technical information on the curtain wall. I have read some of the pre-conference material and there is much of interest. I note that surveys have been made of the views of architects, builders, and owners. There is great interest and, as is to be expected, a greater agreement on the potential use of this newer development in commercial, educational, and industrial buildings. There are reports on the reactions - economical, aesthetic, and technical - brought out in an interesting fashion by the A.I.A. Survey of Architects and the BRAB Survey of Owners and Contractors.

One comment was of special interest to me: "The panel available today which meets the aesthetic and the technical requirements does not meet economic requirements." And I may add that those which may be economical will not necessarily meet the aesthetic and/or the technical requirements. This may or may not be true of all systems developed to date or in process of development, but this statement leads me to carry this discussion to what I consider its most vital aspect. It is this: we must always remember that the sum of the parts do not make the whole in architecture, nor is the whole the sum of all its physical parts. There are the intangibles of the aesthetic, the emotional, and the physical reactions which combine to make a satisfying building. Technicians must never develop systems that will limit their search for their qualities by the creative architect. He is and always will be the leader in his field. He must remain flexible and free to adjust to the aspirations of our society, a society that respects the freedom of expression of the individual, a society that will resist, I feel certain, imposition of an inflexible expression on our architecture; that is, one unable to adjust to the constant and healthy change for better living and better building.

A few of my colleagues believe that we are now in the golden age of architectural expression, that all the answers lie therein, and that now we should perfect the details. I don't agree. I don't believe that we have developed an architecture that permits man's moods, man's complex life, and man's individuality to reach his full scope and potential and, therefore, we must continue to be open minded for any advance. Some are so positive that the answer lies in this pattern of architecture that they are now ready to warp the individual to this pattern. I do not see how that attitude can survive for long because it runs counter to the basic philosophy of this country and is for this reason doomed to failure.

Do not let panel or curtain wall construction fall into this trap of over-self-confidence. I am worried when I see so many organizations getting on the band wagon and attempting to sell panel construction to architects and potential clients like so much wall paper and regard it as the cure-all. You can kill the good that is in it.

And what is the good in it? Well, if you constantly improve its technically weak points, if you can so tool up for production that it can be adjusted to the imagination of the creative people of the construction world, if you can make it economically possible for small as well as large buildings to benefit by it, and if you can give it as much variation as wood construction has permitted in the past, and still does, it will be good and I feel it will survive. From my own experience I find that the panel fabricators and the people who make materials seem to be developing more flexibility in the use of the material and using more imagination than the technicians who are behind the rollers, the dies, and the molds. They are still using ancient, antiquated methods and have not found a way to give us flexibility to fit new ideas. Often we have had people come to us and say you can't do a particular thing because of this or because of that, or because of something, but mostly because the die costs so many thousand dollars. And when we ask a few questions, we find that there is room for research and there is opportunity to take advantage of new methods in industry to overcome the rigidity of this tool. This means that methods of tooling, be they dies, rollers, or molds, must be devised so cheaply that they do not hamper new ideas nor result in excessive or unreasonable standardization. If we do not solve this problem we will force curtain wall construction into a high price bracket. The benefits of mass production, dry wall construction, speed, freedom from weather problems coincident with wet construction, and simplified techniques can then be passed on to the small building as well as the large building.

The curtain wall which is made of a homogeneous material or is wedded to other materials to solve technical requirements and is prepared to be bolted, welded, or fused on the job may be, made of metals, glass, compositions, or plastics. This wall panel can also become a structural element with fillers of metals, glass, masonry compositions, and plastics. We have examples of all of these either in use or in a stage of development. There are endless possibilities. The wall panel should not be limited to exterior wall construction. Do not overlook the possibilities for their use in interior walls and partitions and in floor and ceiling construction, with their general requirements of flexibility, demountability, sound isolation, and appearance.

My plea is: don't jell! If you do jell temporarily, be certain that your research is carrying you on the next step. I feel that there are two or three companies in the United States that have maintained something of a corner on the interior wall and that they are now not flexible enough and are not keeping up with exterior metal wall developments and advances. There is much room for improvement in this respect. I think there is opportunity here for someone to give those companies a shaking up so that we can get more than we have today. We architects will always be looking for something better and more attractive with which to do our work.

What else do we want? We want color. Color cannot be neglected in the aesthetic consideration of the direction the curtain wall may go. True, each of the metals have their own quality or tone, and this is satisfactory to some people. Yet many people may desire colors other than the natural color of the material. One cannot tell which direction will dominate, but if the past is a guide philosophies will develop to justify either. In metals this may mean coatings of one kind or another; in glass, whether of the normal strength or of the tempered or semi-tempered kind, it can mean color applied or color maintained within the glass; and in the plastics it may mean a combination of methods that will produce materials that are either opaque or translucent.

Since color in one form or another has appeared as part of our aesthetics in the past, appears in the present, and will appear in the future, we must be prepared to provide it. If you have been a student of art, you know that our philosophies about art are very fickle. They change very, very often to satisfy the popular thing we are doing, so we can't tell what to expect in the future. Of course, building construction will have rigid requirements: it will demand colors that are unaffected by the weather and the sun; and if the color is an enamel or an applique, it will demand that it must not chip or break in erection and must not permit any corrosive action from within or without.

And we want texture of a variety in size and appearance. Texture, pattern, and relief are also to be considered seriously. This is a designer's tool as well as a technician's tool, and for some materials it is a technical necessity. The breaking of surfaces is done for artistic relief - for variation. It also is done as a method of allow for movement, increase the strength of metals in a controlled form, and absorb imperfections in an acceptable visible pattern. When Mr. Scheick said that only about 18 percent questioned the aesthetics of the metal wall, I felt that perhaps the reason for that was that some of the architects were not setting their sights high enough. I feel that there are great aesthetic potentials in the panel wall. I think also that we have too few attractive solutions and that we have a long way to go.

There are arguments as to the use of the plain unbroken surface as opposed to the textured and patterned surface. Here again I am certain that in time the philosophies of art will justify both. I believe that the technical limitations of most materials will force the use of texture and pattern, unless very small units are used. But small units are contrary to our trend to larger units and fewer joints.

My personal experience has convinced me that if metals are used patterns must be developed to work with, and adjust to, the qualities and limitations of the metals. Aesthetically it can be pleasing, provide accents and contrast, and also give our structure a life of light and shade and relief that the movement of the sun is ever ready to provide.

Since the breaking up of surfaces will of necessity play an important part in the technology and design of the curtain wall, I feel that it is incumbent on manufacturers and researchers to learn more about their materials and to disseminate to architects and fabricators the proper technical information about movement and flow of materials and any specific limitations of their materials, and thus enable proper design to be developed. I hope you will hear more about that before this conference is over. In the last 4 or 5 years, I have had several fabricators and material producers admit to me that they didn't know enough about their materials; that they hadn't asked enough questions; that they hadn't had problems imposed on them; and that they had much to discover. This knowledge should be developed against the background of building construction requirements of climate and rough handling in field installations. We see solutions coming out of certain laboratories that do not recognize that there is a certain way to fill in, that there is a certain roughness, and that there is a certain way of handling that everyone must be aware of.

Finally, we want materials and systems we can use for the different climatic requirements of the tropical, temperate, and cold zones. In the United States we have a great variation in climate. We have people coming to us with a solution for the South and trying to tell us that it is also the solution for the North. They don't even attempt to think past the fact that we must solve our problems in relation to our specific climatic situations. Since it is so easy to distribute material in this country, there is a tendency to think that distribution overcomes temperature. We would like to see walls which can deflect heat, heat itself by thermostatic and electronic control, as well as keep heat in.

We (and I include building owners) want freedom for space disposition within buildings, for we are annoyed by the complications which we must put up with now, such as the present method of climate conditioning within buildings, which forces us to use a complicated network of ducts and piping and wastes space. We want space we can use and space we can live in. We spend too much time worrying about all the methods of creating this climate, and I feel the methods are too complicated. Sometimes it seems the researchers must say, "Let's see how complicated we can make the solution" instead of "How simple can we make the solution?"

Do you realize that much of the problem is created by the fact that our walls are not doing a full job for us? They are letting in much of what we must then, in our present complicated way, get rid of or change to our needs. It seems all wrong. Perhaps our walls should do for us what biotics are beginning to do today in the science of preventive medicine.

It is ridiculous to accept without complaint that today it takes 9 months to a year to create a substantial building, with its hundreds of drawings for plans and details. The span of 2 to 2-1/2 years from conception to execution is too much of one's life to devote to one building. If we can discover how to shorten that substantially it will give us all an opportunity to do more exciting things and provide more shelter for all. Perhaps then some of us could more easily solve the greater problems of our country and build or rebuild more rapidly to make life in our cities, towns, suburbs and rural areas more comfortable and joyful.

Mr. ORR (The Moderator): Thank you very much, Mr. Abramovitz. The next speaker is also well-known to you, Mr. Robert W. McLaughlin.

ARCHITECTURAL DESIGN

By Robert W. McLaughlin
Director
School of Architecture
Princeton University

Mr. ORR (The Moderator): Mr. McLaughlin was educated at Princeton University, is a Fellow of the American Institute of Architects, a former partner in the firm of Hogan, McLaughlin & Associates, and is now the Director of the School of Architecture of Princeton University.

I am glad that this part of the program has been devoted to architectural design in the broadest sense, since I believe it to be the fundamental core of the curtain wall problem. It is too easy for us to become overly involved in the technical details of the problem, what we might term the nuts and bolts phase of architecture and building. The details are important, but not in themselves. The important objective that all of us in the building industry sense is designing, fabricating, and constructing the finest possible buildings in order to satisfy human needs and aspirations.

When the Stainless Steel Producers Committee of the American Iron and Steel Institute asked us, some two years ago, to study curtain walls with special regard for the uses of stainless steel, we were happy to do so on the very broad premises which they outlined. Two years ago we felt we had to answer the question as to whether this concept of building, which involves the hanging of light, rigid curtains from a skeletal structural frame, was a stylistic fancy of the moment, or whether it was a fundamental method quite basic in the architecture of our times. Our earliest explorations at that time - here, in Europe, and in Latin America - convinced us of the truth of the latter. Incidentally, we have a feeling that it is possible to prognosticate architectural trends on the basis of what the economists would call leading indexes. At any rate, it is interesting to note that what was a question only two years ago is an accepted fact today - an indication of the accelerating tempo of architectural developments. Where we used to date architectural developments in terms of centuries, a decade now is none too brief a period for measuring architectural changes. So much for the broader aspects of the curtain wall problem.

Within the broad area, we accepted the particular challenge of investigating and developing the capacities of a specific material, in this case, stainless steel. Architecture is much more than technology, but if we had to try to state one particular characteristic that distinguishes the building of our own times from others, I think we could agree that it is the impact of technology on the art of architecture. The inherent technical possibilities of a material can lead to striking developments in architecture; witness, for example, reinforced concrete. Stainless steel, as you know, was discovered in the laboratories of Sheffield during the first World War, and its properties as a building material were first exploited in this country in the late twenties. It is, of course, one of three materials most widely used in curtain wall construction, along with aluminum and carbon steel, which is often enameled. The exploration and exploitation of the particular characteristics of stainless steel, as with any material, gives us our cue as to its architectural expression. John Hancock Callender will talk this afternoon about some of the more detailed work that we did at Princeton. I merely want to point out now a basic premise on which we worked.

Stainless steel is a high quality material, uniquely strong and durable. It is also, as building materials go, expensive. The relative poundage cost of fabricated building materials is a fascinating study, going from concrete blocks at half a cent a pound on up. Obviously, if poundage cost were the sole determining factor we would not be meeting here. A combination of high quality along with comparatively high cost per pound leads to a whole new design approach. The strength and durability of stainless steel are such that alone among building materials it can be used throughout permanent, complete, exterior wall systems in thicknesses measurable in several hundredths of an inch. Quality and price set the technical stage.

Our problem then becomes a little like that of the airplane manufacturers, who, working with aluminum alloys, under great pressure to reduce weight, find that their chief problem is how to design airplanes using as small a poundage of aluminum as is possible, and still get the greatest ultimate strength. The use of stainless steel in buildings is a rather similar situation and equally stimulating design possibilities develop.

Here is an analysis of what we believe are the requirements of the curtain wall.

The traditional ways (Figures 2.1 and 2.2) of looking at walls no longer hold, in the sense that walls have ceased to be fundamentally elements to carry roofs and secondarily to keep out weather.

Figure 2.3 shows the concept of a wall as a filter, which is what it really is. Certain factors, such as rain, dirt, insects, vermin, and burglars need to be kept out completely. There are other factors, which we filter either in or out of the building, depending on how favorable or unfavorable they are. We naturally want light to come in, but not to an undue extent. We want air to come in, but not so as to create drafts; and so it is with heat, cold, wind, vision, and sound. We are not trying to sound-proof buildings so that they are dead, but we want objectionable sound levels reduced by the filtering process.

We approached the subject fundamentally as architects, not only because we are architects, but because this is a problem in architecture, and everything that anyone of us does in this area is part of the solution of an architectural problem. One of the first things we did was to conduct a visual analysis of the various design alternatives involved. Figure 2.4 has to do with basic curtain wall units. The analysis of the basic types possible and the design considerations is, generally speaking, broken up into two areas. First, walls that essentially are on a single plane and, secondarily, walls that have visual depth. Figure 2.5 is an analysis of the design alternatives involved in certain types of curtain walls basically consisting of a single plane. Now that is the type of most of the curtain-wall buildings in this country, and it is our own belief that over the coming years we will see a marked departure from this fetish for flatness. This will happen not only on aesthetic grounds, because there is certainly a dreariness in flatness when repeated without relief, but also on human grounds, since the flat walls do not accomplish as filters the best results in filtering in and out desirable and undesirable environmental factors.

Figures 2.6, 2.7 and 2.8 facades with depth which tie in with work with climate in architecture. The work in that area of Professors Victor and Aladar Olgyay at Princeton is well-known. There are basically three types. The first type is expressed by the Melrose Building in Houston (Figure 2.6) where we have horizontal sun shades. These are generally applicable to the south side of a building where we want to keep the sun off the walls, and off the glass in particular, during hot weather and to let sunlight in during cool weather.

The Pan-American Life Insurance Building, New Orleans, La. is shown in Figure 2.7. The vertical louvre is generally applicable to east and west facades, where the sun is low.

Figure 2.8 shows the Georgia Baptist Hospital, Atlanta, Ga. An egg-crate device is generally used where the sun's path changes rapidly in its altitude and its azimuth, working best toward the south-west and in hot climates also toward the south-east.

The economic factors are strong. The Olgyays have demonstrated that on economic grounds an expenditure of from $4.00 to $9.00 per square foot for shading devices will pay its way through savings in air-conditioning costs alone. It is our conviction that we will be building many more buildings having facades with depth than we did in the past, with of course a great effect on curtain-wall design and fabrication.

I want to mention here the importance of color. In our early efforts in designing curtain walls, we have been so enamored of the technical problems involved in joints and materials that we have tended to neglect color. This cannot last. Mr. Callender will discuss tomorrow Princeton's developments in the application of color to stainless steel. As first this seemed like something of a lily-gilding operation, but permanent color has been applied without destroying the inherent characteristics of stainless steel.

Contemporary architecture is inextricably woven with modern technology. Modern architecture has breadth and variety, but it sorely needs the depth that comes from the understanding of the processes behind it. What starts as technology becomes architecture, good, bad or indifferent, when frozen into physical environment. For this reason we believe that architects must dig deeply into the technical areas and possibilities of their time, understand them, and then through the design process mold them in the light of values other than technical or material.

CURTAIN WALL REQUIREMENTS

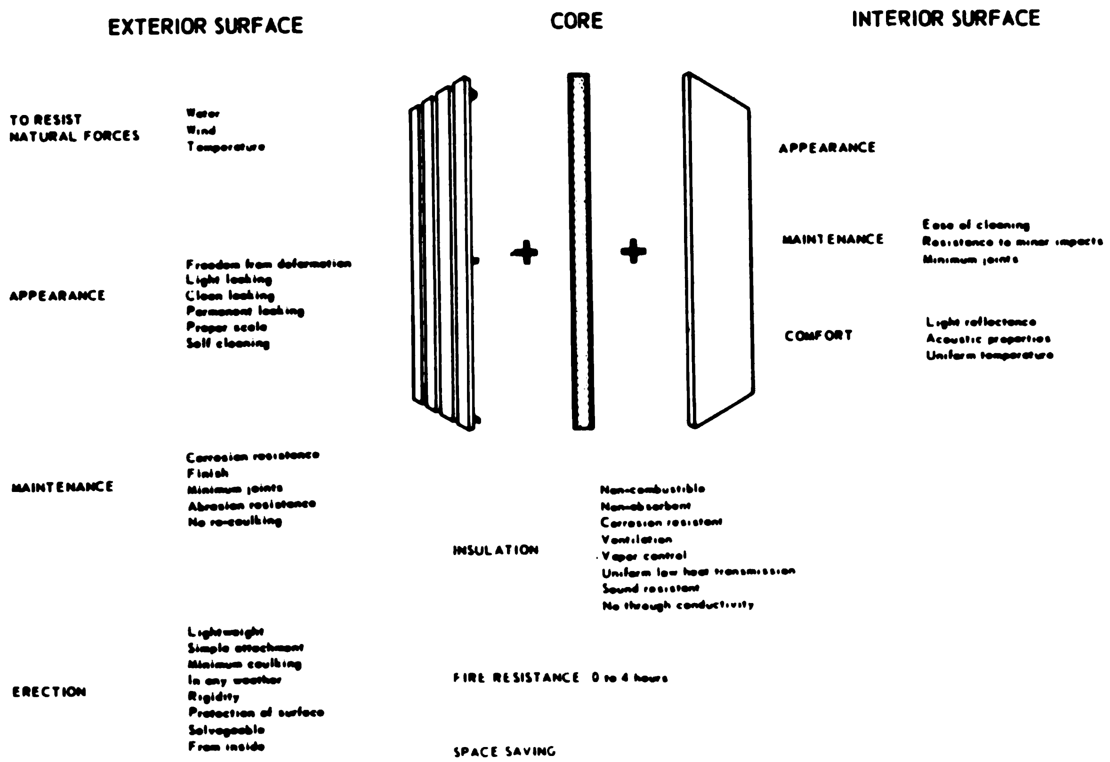

Figure 2.1

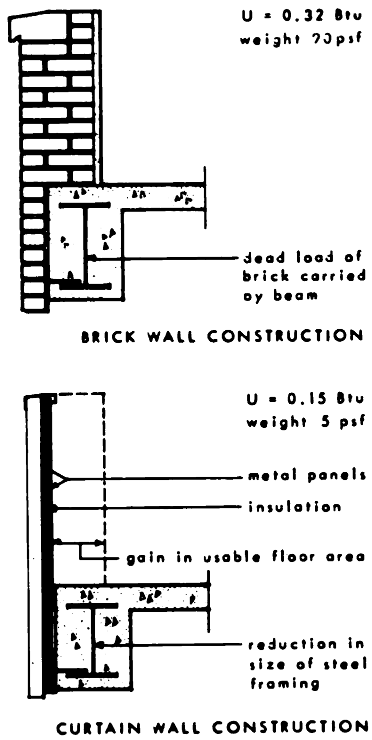

Figure 2.2

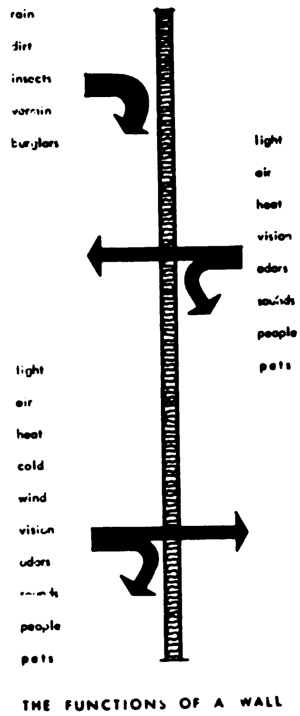

Figure 2.3

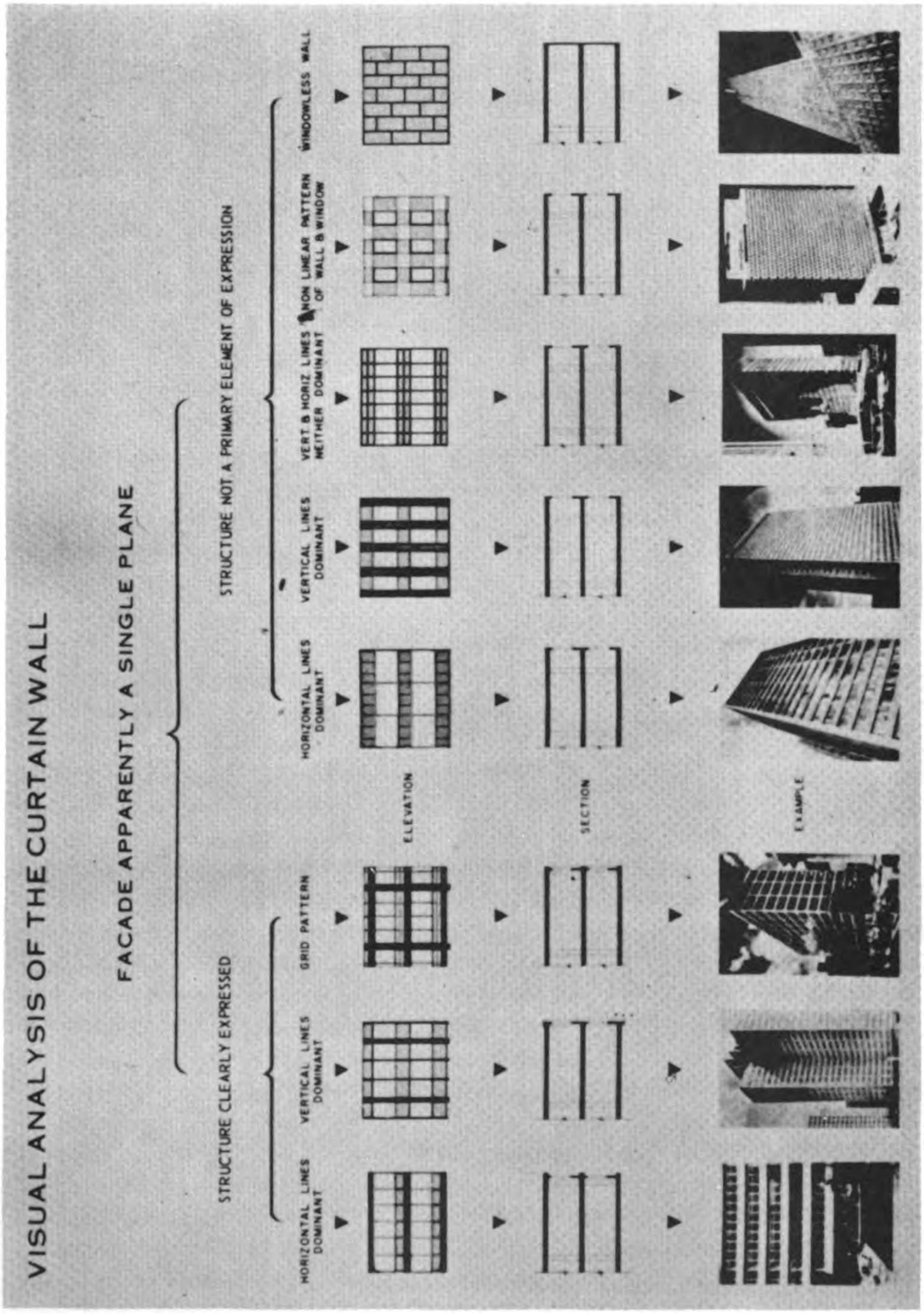
VISUAL ANALYSIS OF THE CURTAIN WALL
FACADE APPARENTLY A SINGLE PLANE
STRUCTURE CLEARLY EXPRESSED
STRUCTURE NOT A PRIMARY ELEMENT OF EXPRESSION
HORIZONTAL LINES DOMINANT
VERTICAL LINES DOMINANT
GRID PATTERN
ELEVATION
SECTION
EXAMPLE
HORIZONTAL LINES DOMINANT
VERTICAL LINES DOMINANT
VERT & HORIZ. LINES NEITHER DOMINANT
NON LINEAR PATTERN OF WALL & WINDOW
WINDOWLESS WALL

Figure 2.4

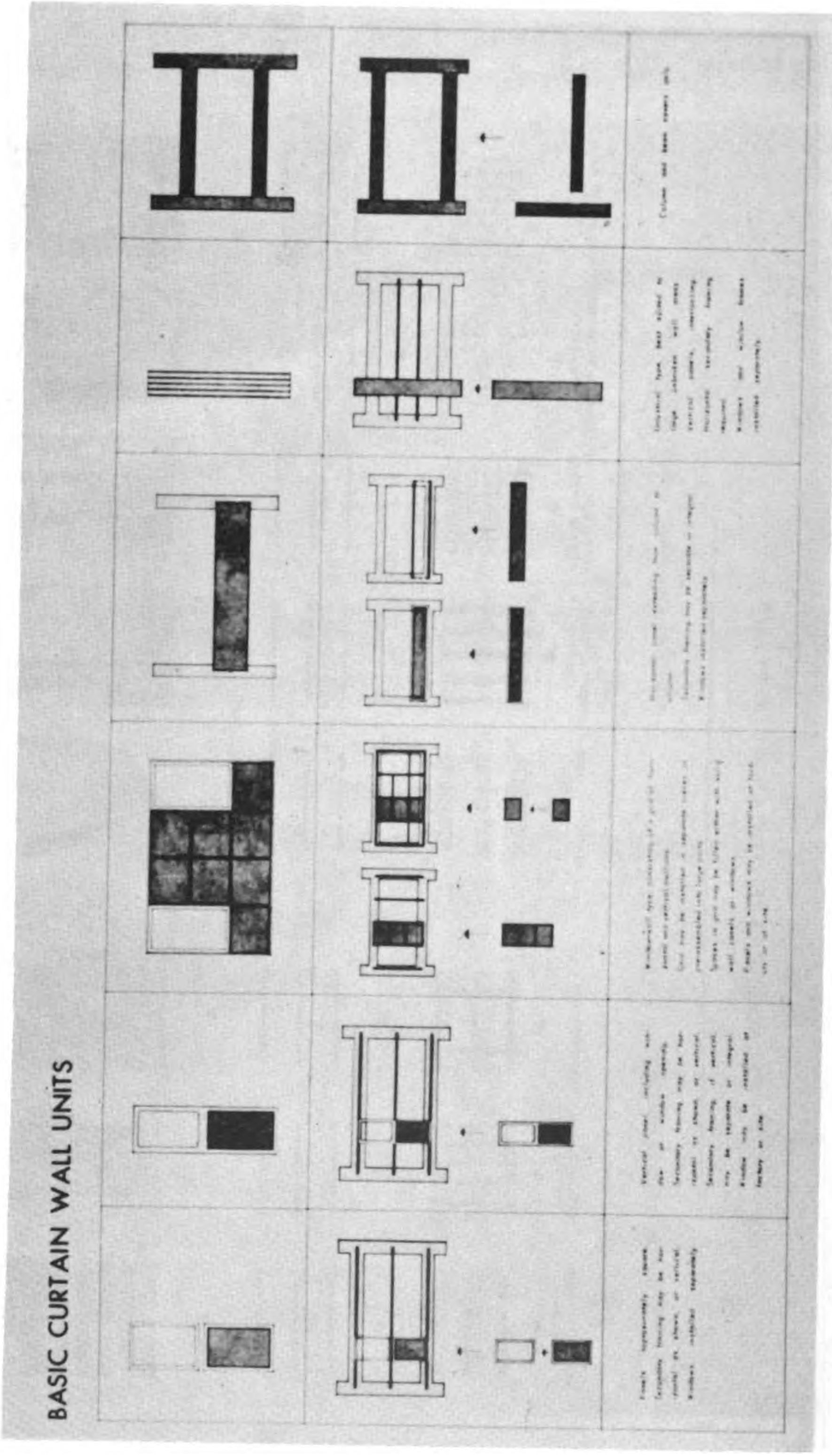

Figure 2.5

Figure 2.6

Figure 2.7

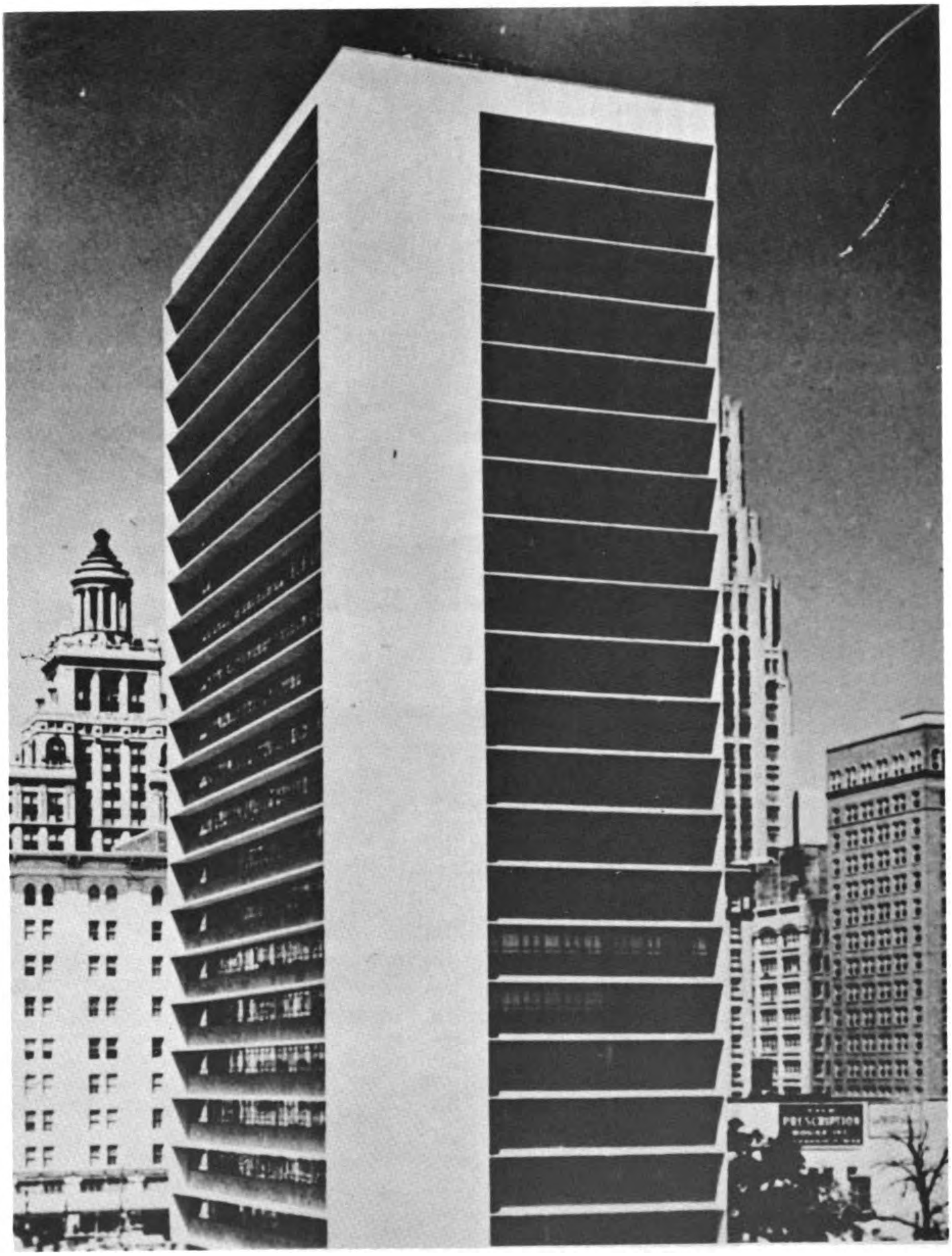

Figure 2.8

DISCUSSION

DOUGLAS W. ORR (Moderator): If the panel will move over to the table now, we will have a question-and-answer period. I am sure there are going to be a great many questions now from the stimulating papers that were presented by Mr. Abramovitz and Mr. McLaughlin. Mr. Scheick has asked that you write out your questions, as there are no floor microphones. Please direct your question to whomever you would like to have answer it, either Mr. Abramovitz or Mr. McLaughlin.

QUESTION: As an architect, what do you consider to be the greatest problems or disadvantages in using curtain wall construction?

MR. ABRAMOVITZ: This is a little difficult to answer in a simple way. I believe we spent a little time this morning talking about advantages and disadvantages. I can't think of any serious disadvantage in using curtain wall construction. I am mentioning this on a theoretical basis. Of course, when we take a specific problem about budget or availability or individual plant problems we may run into some disadvantages, but I would say, in theory, that there aren't any that cannot be solved from the point of view of the information available.

One problem that has worried me a little bit more than the other—I think I mentioned it before—is that I have some pretty strong convictions about what a curtain wall should do, both as to joint and texture and in meeting the technical problems, but quite often I find that the price I have to pay for it is too high. This is a problem for some of the people in this room or for the organizations they represent. Their problem is largely a matter of finding an economic approach to the competitive materials they must deal with.

There are competitive panel walls--not all of them, but some of them—that I sincerely believe are not doing the job properly. Some of the manufacturers have approached the economic problem by omitting the solution to some of the problems. I must say that, in theory, there are no disadvantages. I believe that there are greater advantages to the panel wall construction than almost any other kind.

QUESTION: What tooling did you find inadequate in panel design?

MR. ABRAMOVITZ: On this question I can talk much more easily. When you want to design a molding in a very hard material, you will find that the metals used to make roller dies are now so expensive that you may have to fall back on what somebody else has developed somewhere.

I am not an expert in this field but I have heard innuendoes, in talking to people about plastics and other materials, that some people are working on the problem in the back room, and that they can make some of the guides much more quickly and cheaper. I have tried to run some of them down but I haven't had any success.

You also run into difficulties when you want to use stamping in a panel. Generally you can't afford to wait for someone to make a steel die. I sometimes wonder why it can't be done almost as easily as one makes a mold out of plastic. I wonder why there aren't methods for speeding this up, perhaps by having workmen take a shape and get some quick strength in an improvised guide to stamp some form out, rather than waiting two, three, or four months while it goes through some complicated machining process. The long processing time itself knocks it out of consideration. I believe that if you don't solve this question of stamping, rolling and molding, you are going to slow up the whole process and stop some people from exploring and exploiting your materials.

QUESTION: Your examples, of the use of metal curtain walls in Mexican architecture, Mr. McLaughlin, seem to be predominantly government work. Do you care to comment upon the contrasting attitude in the United States?

MR. McLAUGHLIN: Well, certainly we have in this country what almost no other country has, this terrific strength and vitality in industry, as witnessed by the presence of all of us here. Out of it should come developments in the curtain wall area that will exceed anything done anywhere else. I used those examples merely to show that a little, poor country, that has feeling, can do. We ought to do infinitely better things here.

QUESTION: You mentioned larger panels and less joints, Mr. Abramovitz. Does this present other technical problems due to expansion and contraction, distortion, etc., and possibly leakage?

MR. ABRAMOVITZ: These problems that exist are problems of expansion, contraction, etc., but my whole point with respect to the large panels is that all of these problems exist all the time and they can be solved in the shop. In other words, I am inclined to feel that we should make panels as large as the workmen in the field can handle, as large as can easily be shipped without any problems of trans-shipment.

If you have material that may have to be broken up in pieces, put it together in the shop under controlled conditions, whether it is welding, fusing, or any other method that has to be used, and then under controlled conditions, protect and solder your joints. In this way you will have the fewest number of joints subject to the rough handling in the field.

QUESTION: When you say you want color in panels, do you mean that standard colors would be usable? By "standard" I mean, for instance, the colors that might be offered by a manufacturer of enamel.

MR. McLAUGHLIN: My impression is that the enamel manufacturers quite adequately are able to provide any range of color that the designer has in mind, broadly speaking. Would you say that was so, Max?

MR. ABRAMOVITZ: Yes, I think so.

MR. McLAUGHLIN: Great flexibility is possible there.

QUESTION: What is your opinion of the merits of porcelain enamel versus colored aluminum as a decorative and practical outside surface?

MR. ABRAMOVITZ: This question may get me into trouble. Number one, if the end result in color is the same, I would say, from appearance, the merits are the same.

VOICE FROM THE FLOOR: Get off the fence!

MR. ABRAMOVITZ: Number two, if the porcelain enamel people can solve their problem--and it is their problem, which sometimes they have solved and sometimes they haven't--then I see little difference. It is a handling problem in the field, and, sincerely, it is one that disturbs me. I have seen cases where porcelain enamel is chipped in transit or on the job, or it is chipped and broken by the workman jimmying something into place in a tight position.

As soon as you break the surface, you have a material subject to corrosion. If the same thing happens to aluminum, unless you have a material that is affected by corrosion (there are one or two, we know, and if you are designing for aluminum, you certainly don't use those materials) you break the color but you still have a non-corrosive or relatively non-corrosive material, and that is really about where it stands as far as I am concerned.

I know that the porcelain enamel people are able to produce a product in color presently much cheaper than the aluminum. Now if they can find a way of being assuring that the panel gets in place without damage, and cannot be damaged, they will overcome in the minds of many of us any reluctance to use porcelain enamel, unless there is a budget problem.

QUESTION: Did your study point up the specific technical shortcomings of panels, like joints (leaks, calking, gaskets), condensation, sound transmission, corrosion, and so forth?

MR. McLAUGHLIN: The answer is yes.

QUESTION: Where can the report be obtained?

MR. McLAUGHLIN: Mr. Richard Paret, American Iron and Steel Institute, Empire State Building, New York.

QUESTION: How does curtain wall construction compare with other types of construction in withstanding atomic blast?

MR. ABRAMOVITZ: That's a technical question I can't answer and I won't attempt to hazard a guess. I would say that a question like that ought to be addressed to the governmental agencies that have done research in the various atomic testing areas and get an answer from them. I haven't any information of that kind.

MR. ORR (The Moderator): I would like to say we are not going to consider questions which are too technical in nature, so I am setting those aside. These have particularly to do with design.

QUESTION: A Congressman from Massachusetts, in discussing the Air Force Academy Building, stated that glass and metal and curtain walls are un-American materials. Any comments? [Laughter]

MR. McLAUGHLIN: I think you have commented.

QUESTION: Is it your opinion that metal or other curtain walls are just another component which should be developed, or do you believe that they will take over the field as a superior component?

MR. ABRAMOVITZ: I think that time will answer that. It is just another development now, but I am sincerely reluctant to accept the idea that it will take over, because I think we have to be satisfied aesthetically by many things. Some of us for some reason feel happier with wood, feel happier with earth materials in certain areas, with stone, with marble, or with metals. I believe that as long as we have human beings with these diverse feelings, no one material, whether it is metal or something else, will take over the entire field. There is room for all of them.

I do feel that the odds for advanced development right now are in the metal field because we are really in a Metal Age and there has been a great deal of development in the masonry materials. Maybe this development in the Metal Age will stimulate the people in the masonry field to concern themselves more with how to tune up their materials to take advantage of some of the things that are being developed and used in the metal world, and work the two together. I can't say that one is going to be superior to the other, but I think time will answer that one.

QUESTION: Coming back to the question about color and your answer regarding the fact that manufacturers would provide any desired color, wouldn't this prevent complete factory production and stocking of standardized units, and, consequently, affect economics?

MR. McLAUGHLIN: I can't believe that anybody is going to stock panels for major buildings in this country.

QUESTION: If a unit of metal pan-insulation and other-than-metal facing were to be prefabricated at plant for simple installation, would this not aid flexibility in design?

MR. ABRAMOVITZ: I would say yes. I feel that there are two things coming out of this metal curtain wall development. One is the entire package (you have seen some indications of this today) where the entire panel has its own joint and is brought to the job either with an interior facing or insulation to be applied or is brought to the job with everything as a unit.

But with it there also has developed another method, which is seen in some buildings, a method using a prefabricated framework that is capable of being set on the job and glass placed in the frame. I can visualize that you can place glass in it and I can visualize that you can place plastic, metal, masonry, and wood panels in it. Apparently there is going to come out of this the possibility of having a framework put up on the site very quickly, taking advantage of prefabricated and pre-set methods, to push building in some directions we haven't fully developed yet.

QUESTION: Has your project explored the interaction of some dimensional standardization or coordination system, latitude for development of character, and design development?

MR. McLAUGHLIN: Of course, the use of a module is fundamental in any kind of factory-fabricated work and it is my conviction—and I think most people working in this area will agree with me—that the acceptance of this module doesn't inhibit freedom of design, basically.

QUESTION: You speak of the need for complete flexibility. Will you be content to use standard designs which can be arranged with flexibility and, therefore, allow for cost improvement due to standardized production, or will panels always be best produced on a job-shop basis?

MR. ABRAMOVITZ: Well, I wouldn't be content to be limited to standard designs. I feel there is room for both. There will be a great number, I am sure, of standard designs developed that can be arranged with flexibility, with a great deal of creative energy, and that also will allow for cost improvement. There will be certain areas where you will have work done on a job basis. I am sure many of the architects here have done large buildings where they could walk into almost any factory and have special windows and special elements designed. The slight charge for retooling or setting up jigs is so small compared to the entire cost that it is infinitesimal.

I believe that costs and economies, although they are quite a governing factor in this economic world we live in, are not always the prime considerations behind building a building. As long as we have human beings and egos and personalities, and as long as a great number of buildings are built as monuments to people, we will have people in our society—and I hope they continue to exist--who want something done personally and creatively and completely new. We have had them all through society and they are still being born. I think you will still have them.

QUESTION: In the use of metal walls, have we progressed very far beyond the tin ceiling in grandfather's saloon? [Laughter]

MR. McLAUGHLIN: Well, I think the answer is that we have not progressed as far as we will progress. Certainly I think this, again, leads to what I referred to as the fetish for flatness. I think we became very much enamored with the fact that where we used to build a wall 16 inches thick, it can now be as little as 2 or 3 inches. Although flat surfaces are certainly important in places, I think that as we develop facade and depth and sculptor and get back to structural quality, we will go still farther beyond grandfather's saloon.

MR. ABRAMOVITZ: I think we are getting some of these questions that reach past this Conference, but they are interesting. Here is one that I think is very interesting:

QUESTION: Realizing that many of the people responsible for production of the elements used by the architect have little or no background in art or design, do you have any thoughts on the means of communication toward the ultimate goal of better understanding by management and the desire of the architect?

MR. ABRAMOVITZ: The reason I think it is interesting is that it has something to do with our whole educational system. I think that the best way our society can produce the finest buildings is to have the production people recognize and feel what the (if you will permit me to use the word) artist of the period is attempting to do, and the other way around. Let's not live in a vacuum. The people with creative talents, the artists, should be able to know what the production people can do, what the technical world can and may be able to do. I think that in our educational processes we have been kept separate. I find all this interesting because there is a school, one of our colleges, right now considering the construction of a building where they want, in the program of design, to have all their students be subjected to normal living conditions and activities, to the arts, and to all of the elements (that the school may be teaching) that make up society, even though particular students might be interested in only certain phases of the work.

I think that is a very interesting and vital step, and I believe that if this is done in more schools, and if we start down at an elementary level, we will probably find that we are working together in more closely knit teams and producing finer results in our society. It is just a question of education. I believe that anyone who is seriously interested has to improvise methods for closing that gap today, but I hope the gap will be closed. I have heard this subject come up in one way or another at various school conferences, and some people are beginning to get concerned about it. I think it is a very vital problem.

QUESTION: Do you think that the variety of expression in many of the foreign curtain wall constructions, as in Mexico, is largely due to low labor costs permitting more hand-made installations? If this is true, will not the possible variety in America necessarily be of a different nature?

MR. McLAUGHLIN: I think that is a very good question. I feel we want to avoid, in designing curtain wall units, the natural tendency to think in terms of great mass production. We love mass production in this country and we know what it can do, particularly in consumer goods, but I just can't believe that we as a people are going to be satisfied with putting ourselves in a rigid frame--which we do when we go into substantial tooling up and die cost for wall construction. I believe that our efforts ought to be devoted to trying to find ingenious ways of using the materials that we have without thinking in terms, essentially, of Detroit and the automotive industry and rolling and substantial die costs. I believe it can be done and is being done.

QUESTION: If your architectural desires are geared to the technologies of the times, would not that bring economies?

MR. ABRAMOVITZ: I would say, in principle, yes; but, specifically, not necessarily yes because sometimes a new idea, the first time, is very expensive. Although technically and theoretically proper, it may not be the cheapest thing for a long time, but if production methods and other methods are developed, it could be. So, fundamentally, there are going to be economic solutions, but sometimes it won't be possible to get the practical solution.

QUESTION: Wall surfaces recessed far back under slabs (as in "egg-crate") may have distinct weathering advantages. How does the architect feel toward its future in our market? Is this weathering advantage fancied or real?

MR. McLAUGHLIN: This question really gives the answer and I think it is a good one. I think we are going to find some solutions to some of our weathering problems when we get a little depth.

QUESTION: Will you comment upon the use of joints and curtain walls in decorative or expressive features?

MR. ABRAMOVITZ: I feel that the joint can and will and should, in many cases, become very decorative. I don't see why it isn't as much an element of decoration and expression as the deformation of a panel. It can do many things that we, ourselves, have made it do purposely. We have exaggerated the joint, played with it to catch light and shadow. It can give you horizontal, vertical, or variable patterns. It should not be ignored as a possible element for improving or enhancing the appearance of a building. It has many, many possibilities.

MR. ORR (The Moderator): I think our time is up, gentlemen. There are quite a number of unanswered questions. Most of them are of a technical nature that do not have, particularly, to do with design. We will turn the meeting back to our Chairman, Mr. Tuttle.

MR. TUTTLE (Chairman): Thank you very much, Mr. Orr, Mr. Abramovitz, and Mr. McLaughlin.

PART III

PERFORMANCE REQUIREMENTS IN PANEL DESIGN

By Tyler S. Rogers
Technical Consultant
Owens-Corning Fiberglas Corporation

MR. TUTTLE (Chairman): Mr. Rogers is Technical Consultant for the Owens-Corning Fiberglas Corp., Toledo, Ohio. He is a graduate of the University of Massachusetts and of Harvard University Graduate School of Design. He was manager of the design department and acting general manager for The House Co., Boston; general manager and manager of The Ballinger Co., New York District office; and is vice president, treasurer, and a director of Taylor, Rogers and Bliss, Inc. He is a director of Wells and Rogers. He has been managing editor and technical editor of American Architect and Architecture and is the author of two books: "Plan Your House to Suit Yourself" and "Design of Insulated Buildings for Various Climates." He is a member of the American Society of Refrigerating Engineers; a member and past president of the Producers' Council, Inc., and a past member of the Building Research Advisory Board.

MR. ROGERS: Building walls of any type are constructed to perform specific functions. The chief functions are to shield the comfortably controlled building interior from wind, rain, hail, snow, sleet, dust, fire, heat, and cold. Sometimes, but not always, the walls are structural supports for other parts of the building.

The metal curtain and spandrel walls we are concerned with here have no structural job to do, beyond supporting themselves and perhaps some window components that are made a part of the panel assembly. We are dealing with walls that can literally be hung, like a curtain, upon the structural frame and are usually made in panel form.

Such panels may be mere sheets of metal, flat, fluted, corrugated or otherwise preformed; or they may be sandwiches of two metal sheets with an insulating material or a stiffening material between them; or they may be ornamental panels with pressed, cast, or molded metal surfaces (often colored) of infinite variety, sometimes self-insulated and sometimes backed up by purely functional materials that supplement the partial protection afforded by the ornamental skin.

In order to design such panels, or to select from those commercially available the type best suited to a specific building, we must have some yardstick or criteria for measuring their performance. The essential properties may be considered under seven topics:

Temperature Factors
Thermal Transmission
Vapor Transmission or Condensation Control
Weather Stresses
Sound Transmission and Absorption
Appearance Requirements
Erection Requirements

In addition, it would be reasonable to consider the fire resistance of various types of panels but this subject was exhaustively treated at a prior conference* and need not be developed here.

<u>Temperature Factors</u>

Building interiors are normally maintained at a temperature of approximately 72° to 80° F., summer and winter. It should be noted that the heating and air conditioning industry is attempting to agree on standard inside comfort conditions of 72° ± 2° F. and 20 to 60% relative humidity, both summer and winter. The exterior surfaces of building walls are subject to climatic changes in air temperature ranging from perhaps -30° F. in the colder areas to +120° F. in hot areas (Figure 3.1). In addition, sun heat may raise wall surface temperatures to 150° F. or more, sometimes when the air temperature is comparatively low.

These temperature differences, ranging from 70° F. above to perhaps 100° F. below normal interior temperatures, affect the two opposite faces of relatively thin metal wall panels. Since metals have a considerable coefficient of thermal expansion, the assemblies are bound to be subject to temperature stresses. Panel exterior surfaces will, unless bound at corners and edges, become larger than the interior member under hot conditions and smaller when cold (Figure 3.2). If bound so that such expansion and contraction can not take place fully, the warm panel will tend to develop a warped outer face and the cold panel to contract on the outer face causing distortion of the inner member.

The movements shown in these illustrations are, of course, exaggerated to make the point clear. Small panels have imperceptible movement. But large panels may warp visibly. The total metal movement across a steel building front 100 feet long or perhaps 10 stories high may exceed one inch from a cold midnight to a sunny mid-day (Figure 3.3). This movement, unless divided by slip joints, tends to distort panels designed to remain flat.

One significant point should be made in passing. Curtain walls hung over the exterior of metal or concrete frames have a distinct functional advantage over those supported by floors extending to the outside: they tend to keep all parts of the structural frame nearly the same temperature.(Figure 3.4). With modern heating and cooling adding to high operating costs, plus the tremendous fly-wheel effect of the building mass, there appears to be a major advantage in locating the insulating element entirely outside of the structural frame.

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*Building Research Advisory Board Conference on "Fire Resistance of Non-load-bearing Exterior Walls," November 21, 1950.

Another temperature factor to be considered by the panel designer is the effect of temperature changes on hermetically sealed panels. Air entrapped within a metal case is subject to expansion and contraction with temperature (Figure 3.5). Dry air, confined in a 2-inch sealed space and heated through a rise of 100° F., will create a pressure of about 490 pounds per square foot. If the entrapped air contains moisture, the pressure may be more than twice as great. Bulging and "oil canning" is likely to prove troublesome, especially when the designer is seeking to create with metal the perfectly plane surfaces associated with glass or polished stones.

Designers should consider fire temperatures in their design as well as the normal temperature variations stemming from climatic sources. Without respect to the hourly rating of a panel, it is essential that the design be such that the panel facing will not fall away from the structure in the event of fire and create a hazard to fire fighters.

Thermal Transmission Properties

The economic value of a wall assembly is dependent upon its initial cost in place and its effect on operating and maintenance costs. These are dependent upon its thermal properties, cleanability, and durability.

Heat transmission through a wall represents loss of heat in winter and gain of heat, at the cost of discomfort or excessive power for cooling, in summer.

Metals are exceptionally good conductors of heat. Simplifying the facts slightly, we can call the rate of heat transmission of dry wood as 1 or unity. Materials which are properly classed as insulating materials transmit less than 1 heat unit (Btu) per square foot of surface per inch of thickness in one hour when there is a temperature difference of 1 degree Fahrenheit between the air on the opposite sides (Figure 3.6). Compared to wood as transmitting 1 Btu, masonry transmits about 12 Btu, steel 314 Btu, and aluminum 1,400 Btu. To offset this high rate of heat transmission, metal wall panels are normally insulated.

The effectiveness of the insulation employed in the panel depends not only upon its inherent resistance to heat flow (its "conductivity" or "k" factor) but upon its thickness and the offsetting effect of metal-to-metal contacts from one face of the panel to another.

Suppose we consider a metal panel one-foot square with insulation between two metal faces. If there is no metal connecting the two faces, and the insulation has a "k" value (thermal conductivity) of 0.27 Btu, the over-all rate of heat transmission of the panel (its "U" value) will be 0.22 Btu for one inch of thickness; 0.12 Btu for two inches, and 0.084 Btu for three inches. Now assume a 1/4-inch diameter rivet or bolt is used in the center of this panel to connect the two metal faces. If the connector is made of steel it transmits slightly over one-tenth of a Btu (0.11) for one inch of length. If made of aluminum, the transmission is more than four times greater, or almost one-half of a Btu (0.48). Longer connectors transmit less heat.

The result of introducing this very slender connector is shown in Figure 3.7. With steel, a one-inch panel increases in transmission rate from 0.22 Btu to 0.33, an increase of 50%. With an aluminum connection, the rate rises to 0.70, an increase of 218%. Increasing the insulation thickness reduces the impact of the metal. A steel rivet in a 3-inch panel raises the "U" value from 0.084 Btu to 0.12 Btu, a rise of 43%, while an aluminum rivet, under the same conditions, increase the heat movement to 0.24 Btu, a rise of 186%. Obviously, panel designers must seek to minimize metal-to-metal heat conduction as well as employ an adequate amount of insulation.

These changes in heat transmission rates are too often neglected. They are difficult to calculate. Equally difficult is the estimation, by mathematical means, of heat transfer by radiation from the edge of one metal stiffener to a nearby metal surface, such as may exist within certain types of panels. Therefore, all metal panel wall sections, including typical joints and erection connectors, should be tested in order to give the heating and cooling systems engineer a correct picture of the heat transmission rates. The tests require large "hot box" apparatus or a room unit like the Penn State Climatometer. Only a few laboratories are equipped to test whole wall panels and their joints in this manner.

Condensation Control and Vapor Transmission

The thermal properties of a panel have a considerable effect upon the accumulation of condensed moisture on its surfaces, or within the panel itself, when any part of the panel is at a temperature below the dew point temperature of the ambient air. Surface condensation will occur on the room face of a panel when that face drops in temperature below the dew point temperature of the indoor air. Theoretically, a metal connector transmitting heat at from 1,000 to 5,000 times the transmission rate of the insulation, should create a cold spot on the inner panel when the outdoor temperature drops a few degrees below the dew point temperature of the indoor air (Figure 3.8). But here the high conductivity of the metal in the panel facing comes into play in a beneficial manner. Heat flows transversely through the metal facing to or from the metal connector so that the cold spot tends to spread out to become simply a cool area. Thus spot condensation is much less of a problem than would theoretically appear probable.

Vapor pressures within heated buildings are invariably higher than concurrent vapor pressures outdoors. This is so because cold air brought into the building, though possibly near saturation at the time of its entrance, becomes capable of holding much more water vapor after its temperature has been raised. Moisture is generated indoors by most types of occupancy. The corresponding rise in indoor vapor pressure causes the vapor to seek its way out through any openings or porous building materials.

The absolute impermeability of sheet metals used in metal wall panels constitutes a perfect vapor barrier, except at joints between panels or where perforations are deliberately introduced. If the inner face of the panel is an absolute vapor barrier and its temperature remains above the dew point temperature of the indoor air, no condensation can take place on or in the panel (Figure 3.9). However, if the inner member is not a solid sheet of vapor-impervious material, water vapor will penetrate it and enter any porous insulation or the joints between blocks of impervious materials. Then, if the outer face of the panel is a solid metal vapor barrier, condensation will inevitably occur on the inner face of the outside metal whenever its temperature drops below the dew point of the air-vapor mixture within the panel.

It is easy to relieve this situation by designing the panel so that the inner face is a perfect vapor barrier, or if not, the outer face is perforated or otherwise made several times more permeable to vapor than the inner face (Figure 3.10). Such perforations, or vents, may be in the edge of the panel or at the joint line, and if properly located they will serve as weep holes to drain out any condensate that might form. They also will relieve air pressures that would otherwise be generated by sun heat. Joints between panels should follow the same principle. Joints at the inner face should be vapor tight; those at the outer face should be weather-protected, but be vapor porous.

A vapor barrier somewhere in the wall is highly desirable in air conditioned buildings because it tends to prevent the entrance of water vapor from outdoors during peak summer cooling loads. Such vapor increases the latent heat load on the air conditioning equipment.

The question always arises as to whether or not it is necessary to place the vapor barrier on the outer, or warm-in-summer, side of the air conditioned structure. Where air cooling is for human comfort purposes, the difference between the outside and inside dry bulb temperatures only occasionally exceeds the normal difference between dry and wet bulb temperatures; and therefore no condensation occurs. However, in extremely humid climates, as along the Gulf Coast, exterior vapor pressures may exceed indoor vapor pressures during cooling cycles, and thus the flow of vapor is transiently inward. Furthermore, the inner vapor barrier normally specified may be cooler than the dew point temperature of the outdoor air. Condensation may appear on the outer face of this barrier. An example of such conditions is: inside conditions of 75° F. dry bulb and 50% relative humidity combined with outside conditions of 100° F. dry bulb and 50% relative humidity (78° F. dew point).

The proper answer is found when climatic conditions are related to indoor conditions and to time. It will be found that where only comfort cooling (not refrigerated storage) is involved, the number of hours during the year when condensation might occur on a vapor barrier placed near the interior of the wall is substantially less than the number of hours when vapor flow will be outward. This statement applies to every city in the United States so far studied by the author, including Galveston, Texas. Hence it is not necessary, nor even good practice, to provide two vapor barriers in a wall. The proper position for the single barrier in comfort-conditioned buildings is invariably near the warm-in-winter surface of the wall.

Weather Stresses

Any curtain wall must be designed to resist wind pressures of the greatest magnitude likely to occur. The same requirement applies to the supporting elements. Hurricane-force winds are rarely destructive to metal-frame or reinforced concrete buildings. Metal curtain walls should be designed to withstand these winds equally as well. Tornadoes are vastly more destructive, but they rarely destroy fireproofed steel or reinforced concrete structures. The question of requisite strength is moot because no one knows what forces must be resisted.

Wind force is important with respect to air infiltration, presumably through the joints between panels. Leakage could seriously upset heating and cooling load calculations. Every panel assembly wall section should be tested for infiltration and the values published. Wind force combined with rain may drive water into, or through, joints that normally will shed water. Ice forming in such joints containing water may be a destructive force.

Winds that cause the vibration of thin metal edges can sometimes produce objectional noise ranging from a hum to a howl or a screech. The "Aeolian-harp" effect is one the designer should consciously avoid, although its appearance has been rare in practice.

Sound Transmission and Absorption

This suggests further consideration of the sound-control properties of curtain walls. Walls of solid masonry meet the "weight law" governing sound transmission and are likely to produce a high attenuation of sound. The lighter mass of metal curtain walls calls for design study, especially where external noises are troublesome. A recent case in point was the client's demand on an architect that his airport office building, adjacent to the starting stand of a jet airplane runway, be designed to seal out the noise of such aircraft!

Hail and wind-driven rain may produce excessive noise on metal-clad buildings where the skin is only a single sheet. Usually an insulated panel subdues this noise to the point of no complaint, but it should be kept in mind in the design of panels.

The use of metal wall panels for indoor sound absorption is always a temptation, because the thermal insulation employed often has excellent noise absorption properties. However, such an effort almost invariably introduces moisture condensation problems because the inner face, for sound absorption purposes, is made porous to vapor in exact contradiction of good design practice.

Appearance Requirements

Designers of metal curtain wall panels, have, in most cases, recognized the physical characteristics of metals and have accepted them as a part of their design problem. Thus fluted, corrugated, ribbed, dimpled, and otherwise deformed surfaced have taken up temperature stresses without change in appearance and so have proved appropriate for metal.

When metal is used to resemble polished stone, plate glass, or other building materials offering perfectly flat or plane surfaces, metal panels must be designed with stiffened or supported faces and an effort made to transfer temperature stresses to the joints.

Color and color fastness are considerations quite new to metal building design and are of major interest to the architect. Apparently the desired properties are now being found in porcelain enamels and in some of the anodizing and metal-coloring processes.

Other appearance factors to be considered in panel design and selection are cleanability, freedom from staining (as at weep-holes), and texture. It is not enough to consider the original appearance; thought should also be given to the effect of airborne dusts, gases, smog, and weather over the years.

Erection Requirements

Curtain walls of metal can be site fabricated or factory fabricated. In the former case the cost of the finished wall is materially affected by the simplicity of assembly either on the wall or on the ground prior to erection. In the latter case the finished product must not only be easy to put in place but it must be designed to withstand handling and shipping as a finished, high value product. Panels also must be constructed to close tolerances and each section identified as to its installed position.

Erection requirements for all types of panels include these factors: light weight, for economical shipment and handling; strength, to assure installation without breakage or injury; stiffness, to prevent warping or taking a permanent set as a result of handling strains; and surface protection or toughness, to prevent denting, scratching, or discoloration.

Equally important is the design of the joints between panels so that they will nest or interlock readily, provide for expansion, and at the same time contribute to the perfectly uniform alignment of the panels. Both ultimate appearance and economy of erection are influenced by the design of the joints.

Summary

These design criteria, or performance requirements, for metal wall panels are no more exacting than those that apply to wall materials of other types; nor are they more tolerant of carelessness or error. Emphasis changes with design, quality of appearance and protection, relative cost, and method of erection or assembly, but fundamentally all walls must perform in essentially the same way, except in their functioning as supporting members of the structure.

MR. TUTTLE (Chairman): Thank you, Tye. The discussion of this paper will follow immediately.

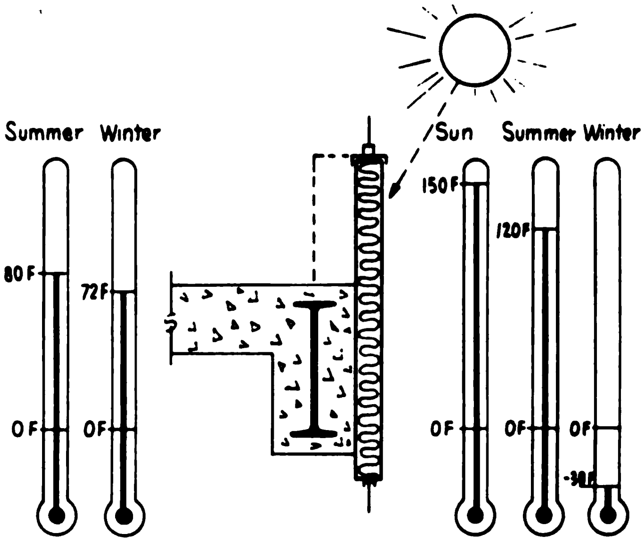


Figure 3.1 - Temperature conditions experienced on both sides of typical building wall.

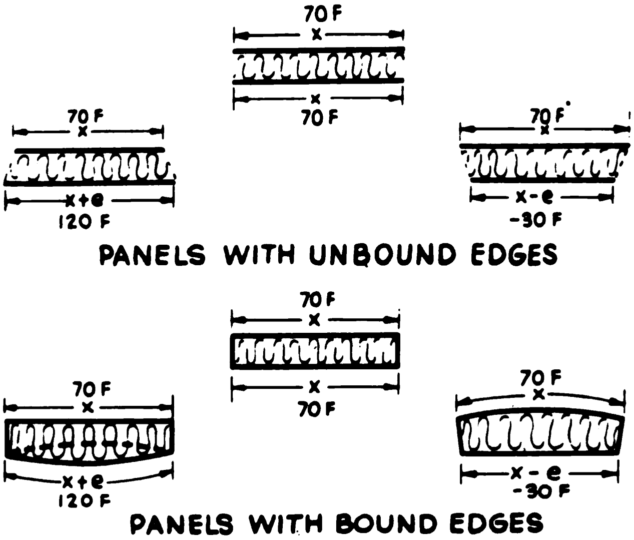


Figure 3.2 - Warping effect of temperature differences on panels with unbound and bound edges. "e" represents thermal expansion of panel at temperature indicated.

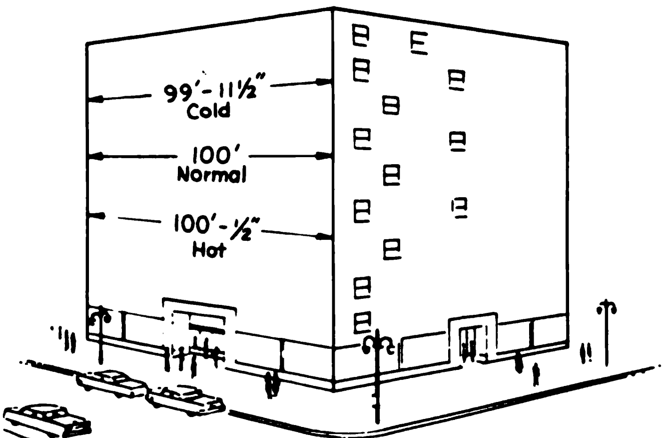


Figure 3.3 - Theoretical dimensional changes in a 100 foot wide building due to effects of temperature differences on metal facings.

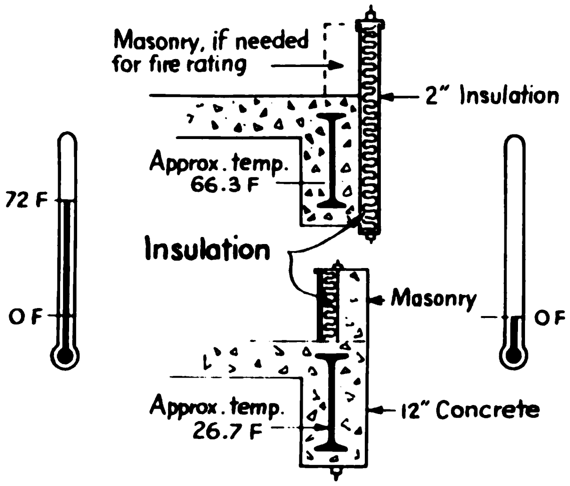


Figure 3.4 - Externally placed insulation, as in metal faced curtain or spandrel walls, tends to maintain stable temperatures on structural frame and floors.

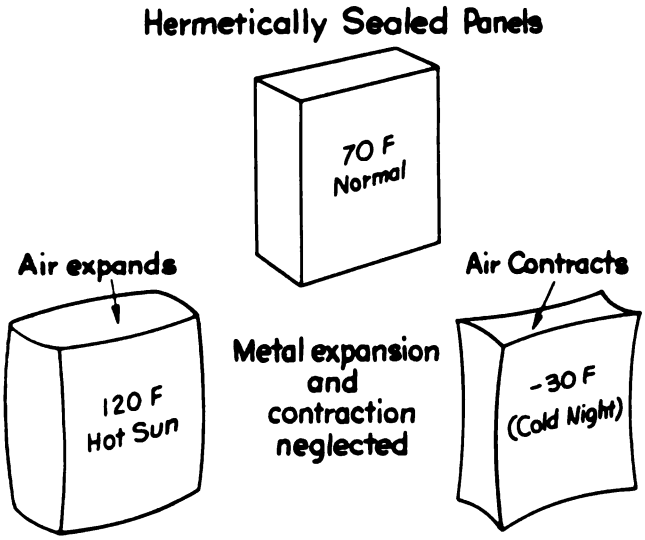


Figure 3.5 - Hermetically sealed panels are subject to deformation due to effect of temperature changes on entrapped air.

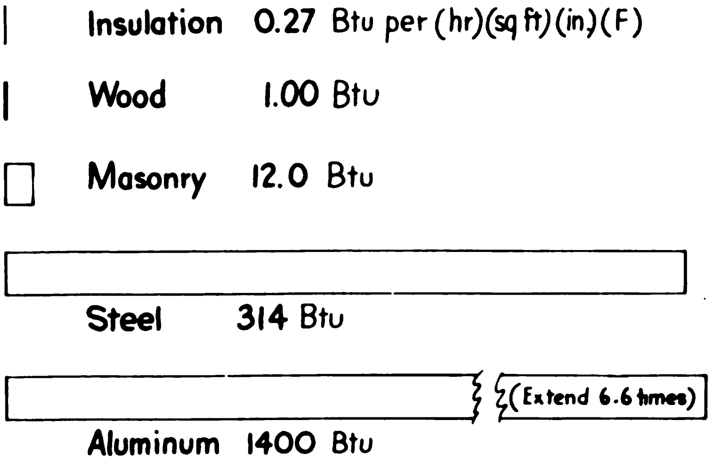
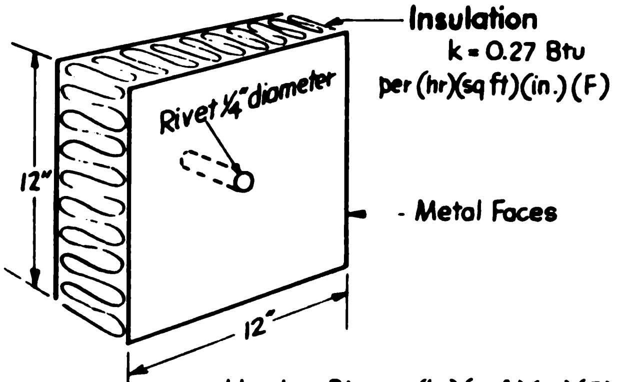


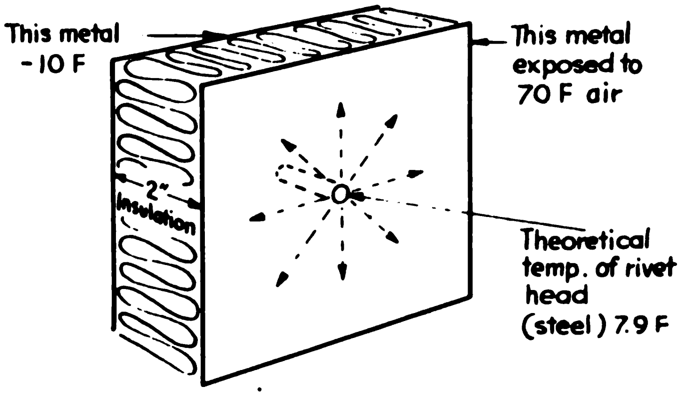
Figure 3.6 - Comparative amount of heat that will be transmitted through one inch thickness of various types of building materials.



U value, Btu per (hr)(sq ft)(in.)(F)

Insulation Thickness	1"	2"	3"
No rivet	0.223	0.122	0.084
Steel rivet	0.330	0.176	0.120
Aluminum rivet	0.701	0.361	0.243

Figure 3.7 - Influence on heat transmission of a metal connection extending between metal faces.



Actual average panel temperature
No rivet = 64.1 F
¼" steel rivet = 61.5 F

Figure 3.8 - The high conduction of metal faces spreads the temperature effect of through-metal connections.

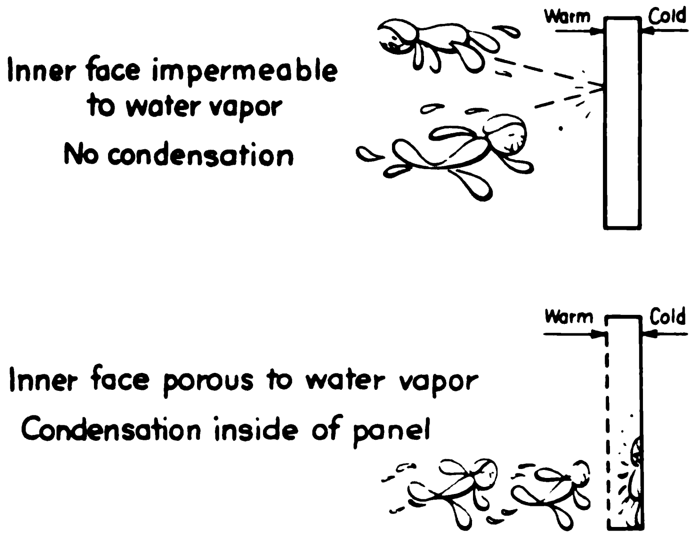


Figure 3.9 - The possibility that condensation will form within a panel depends first upon the impermeability of the indoor surface.

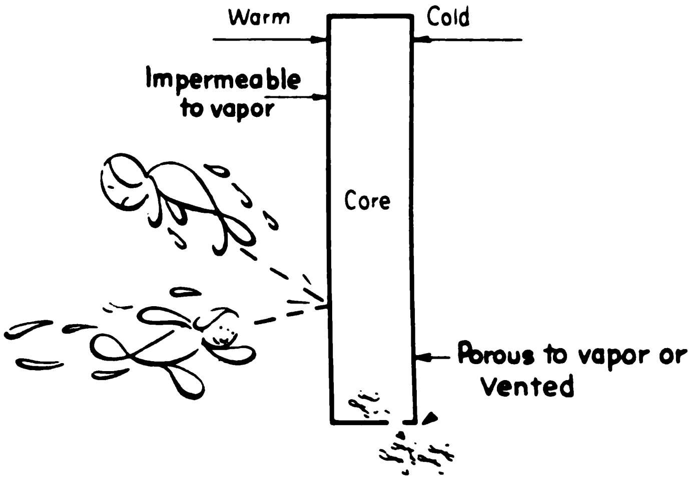


Figure 3.10 - Condensation can be controlled by an imperme- able vapor barrier on inner face, a porous exterior face or suitable venting of the interior to the outer air.

DISCUSSION

MR. TUTTLE (Chairman): We are going to have another short question-and-answer period. This time we will accept questions from the floor and Mr. Rogers will try to answer them. Does anyone have a question he would like to ask Mr. Rogers?

MR. R. F. BELOW (Republic Steel Corporation): What is the effect of having an air space on the outer space of a panel on its conductivity? Does the air tend to change the conductivity of the insulation?

MR. ROGERS: The answer, as I understand it, is no, it does not have any material effect whatever. We frequently use air spaces in conjunction with air spaces for the purpose of increasing the total effectiveness of the wall as a total barrier.

Furthermore, I have had the question raised in this form: Will perforations on the exterior, used for venting or otherwise, allow a lot of cold air to get in and go into the insulation? The best answer I can give is that it is like trying to blow cigarette smoke into a jug: it is practically impossible. These vent holes that do it, take in a blast of air which merely presses the air aside. There is no effect on the insulation, in my opinion.

MR. GEORGE W. MORGAN (Textile, Inc.): In behalf of a dark-colored surface, such as a dark porcelain on aluminum or dark aluminum, in which you have an air space directly behind and in your insulation, is it possible that the temperature of this air space can be increased because of the radiant energy from the darkness, and thus increase your temperature difference between the surfaces of the insulation and be more detrimental than beneficial?

MR. ROGERS: The problem there is the color of the exterior finish of the metal panel, and then an air space before you come to the insulation--would the color of the metal, dark or light, have an effect upon the temperature of the air and, therefore, on the total induction of the panel? Am I correct in my summary?

There is no question but that the temperature of the panel surface is affected by its color, the lighter colors having more reflectivity (I believe that is the right way to say it) than the darker colors which have more absorption. Therefore, if it was a light panel, the inside of that panel would be cooler than it would be if it was a dark panel. Therefore, the air would be warmer if it was a dark panel and cooler if it was a dark panel. In other words, just to go all the way through, if the panel is light it will not transmit as much sun heat through the wall as it would if it was dark, and that is the air space for the insulation. It doesn't make much difference there.

MR. MORGAN: Following that thought, if you have a dark panel, is there a point at which you would be better off without the air space--like the hot attic in the past?

MR. ROGERS: There is evidently some question that we still have to resolve on that. I don't think we know all the answers there. The air space value is primarily a matter of lowering the pressures within a panel, or of allowing condensation to occur and drain off with the insulation. It may not be so if the insulation is porous, but you are posing some very interesting design problems that I think time and experience will solve.

Also, Professor Queer, who is going to speak tomorrow on insulation problems, may be willing to answer those questions. I think we should leave some of these questions of a very technical nature for the experts who are to follow.

MR. TUTTLE (Chairman): Thank you, Tye.

PART IV

STRUCTURAL DESIGN TECHNIQUES

THE DESIGN OF METAL CURTAIN WALLS

By John Hancock Callender
Research Associate
Princeton University

MR. TUTTLE (Chairman): Your Moderator for this panel on Structural Design Techniques is Mr. William B. Tabler, architect from New York City. He is a graduate of Harvard College, with a B.S. degree and a graduate of the Harvard Graduate School of Design, with degrees of Bachelor of Architecture and Master of Architecture. He is a member of the American Institute of Architects.

MR. TABLER (The Moderator): Gentlemen, I accepted this moderator assignment because I am getting a little hard of hearing and I wanted to be assured of a good seat down front where I could hear the speeches. Actually, I came here to hear the fine speeches that have been prepared by our panel of three speakers, Mr. Callender, Mr. Posey, and Mr. Roehm. So, let's get along with the program. At the end of the last speech, we will have a question-and-answer period, and I suggest that each one write out your questions and address them to specific panel members. At the end of the three panel speeches, we will have them collected and brought up here to the panel members. They will take turns so that each one can answer as many questions as possible. Our first speaker is Mr. Callender. Mr. Callender is a well-known architect in New York City and a Research Associate at Princeton University. He has done an outstanding job in publishing a report on a study of the use of stainless steel in curtain walls. He is a member of the American Institute of Architects.

MR. CALLENDER: At this morning's session, Mr. McLaughlin described some of the work done at Princeton on the subject of curtain walls, with particular attention to aesthetics and problems of architectural expression. It is my intention to give further details of this study, with emphasis on the technical aspects.

The study was undertaken by the School of Architecture of Princeton University, at the request of the Committee of Stainless Steel Producers of the American Iron and Steel Institute. The general subject of the study was the use of stainless steel for curtain walls. Our attack was in three steps: 1. A study of curtain walls in general; 2. A study of the properties and characteristics of stainless steel; 3. The application of these properties in the design of curtain wall panels of stainless steel.

The Ideal Curtain Wall

As a first step, a list of the desirable characteristics of a curtain wall was drawn up. This gave us goals to strive for and also furnished a useful check-list for the evaluation of specific designs, whether our own or those of others. A performance specification for the ideal curtain wall would include the following items (values less than ideal, which would be acceptable in most cases, are given in parentheses):

Durability	life 100 years (minimum 40)
Thickness	2" (maximum 5")
Weight	5 psf (maximum 15)
Insulation	U = 0.05 Btu (maximum 0.15)
Fire resistance	2 hours (minimum incombustible)
Strength	resist 150 MPH wind (minimum 100 MPH)
Weatherproof	on outer face
Vapor proof	on inner face
Ventilated & Drained	for control of internal moisture, whether from condensation or from wind-driven rain
Ventilated	for summer cooling
Flexible	provide for expansion and contraction and building movement
Removable	panels easily removable for repair or replacement
Sound Transmission	reduction 50 db (minimum 25)
Sound-deadened	against impact of rain and wind
Size	large units, 25 to 100 sq ft (minimum 10 sq ft)
Adaptable	to all types of building framing - steel or reinforced concrete, simple or cantilevered
Erection	installed from inside the building - no outside scaffolding required
Attachment	to building simple and positive - adjustable in 3 dimensions
Handling	easy, preferably by manpower only
Shipping	easy, by standard transportation

Fabrication	simple - can be done in any reasonably well equipped fabricating shop
Appearance	attractive - no waviness, not too reflective, wide variety of textures and colors, weathers uniformly, self-cleaning
Maintenance	none required - no painting, caulking or refinishing, cleaning not required for durability or appearance, cleaning easy if desired
Cost	moderate - competitive with conventional construction (maximum $5 per square foot in place)

STAINLESS STEEL AS A FACING MATERIAL

Types and Structural Properties

Stainless steel is the generic name for a large family of alloys which are remarkably resistant to corrosion. The chromium-nickel alloys (300 series) are the best known and the most corrosion-resistant. They are characterized by very high strengths and retain a remarkable amount of strength at high temperatures. Type 302 (17-19% chrome, 8-10% nickel) is the general-purpose stainless steel and the one most often used, especially for outdoor applications on buildings. The chromium alloys (400 series) also have high strength. Although somewhat less corrosion-resistant than the nickel-bearing steels, they have proven satisfactory for building use, except along the seacoast. They are generally lower in price than the nickel-bearing alloys. Type 430 (14-18% chromium) is the one most used in building work.

Stainless steel is available from the mill in coil stock and in cut sheets. Maximum widths available vary with the gauge: the thinner the gauge, the narrower the sheet. Since sheet width is often a critical factor in curtain wall design, note should be taken of the following table of maximum width for each gauge:

Gauge	Thickness	Max. Width
20	(.038")	72"
22	(.031")	66"
24	(.025")	60"
26	(.019")	49"
28	(.016")	48"
30	(.013")	38"
32	(.010")	36"

Stainless steel sheet can be roll-formed, pressed, bent, sheared, welded, and soldered. Tooling costs for rolls and dies are considerable, and these processes are economical only for mass-production. For a single building, or a group of buildings, brake-forming is usually the most economical fabricating method.

Finishes

The standard finishes of stainless steel sheet are:

No. 2D - Dull cold rolled
No. 2B - Bright cold rolled
No. 4 - Polished
No. 6 - Polished and tampico brushed

The cold rolled finishes are attractive in appearance and suitable for curtain wall use. They are furnished at no extra charge. The polished finishes are used where fine appearance is of paramount importance. They cost, depending upon gauge, from 15 to 60% more than the rolled finishes. For the facade of an entire building, these luxurious finishes are unnecessary and in the case of the No. 4 finish undesirable because of high reflectivity.

Besides specular reflection, No. 4 finish exhibits a remarkable property of reflecting any light source, regardless of its shape, as a brilliant straight line. The line is always perpendicular to the direction of the polishing, regardless of the position of the sheet or the angle of incidence. It may appear on a building as a horizontal or vertical line, depending upon which way the sheet is installed.

No. 2B finish shows a similar reflective effect, but to a much lesser degree. In this case the light source is reflected as a bright round spot with a thin straight line running through it. The duller finishes, No. 2D and No. 6, do not exhibit this property.

So far as is known, dirt accumulation is a property of the smoothness of the surface. Generally speaking, on a smooth vertical surface little dirt can collect and what does is easily washed off by the rain. For minimum dirt collection, smooth flat panels with flush joints and no projecting horizontal members are desirable. It should be remembered, however, that smooth flat panels may collect less dirt but show it more. Any streaking or other irregular form of dirt-staining can be very disfiguring to a plain flat panel. Textured sheets will naturally tend to collect dirt, but the dirt accumulations generally accentuate the pattern and are thus less likely to be objectionable in appearance.

Texture

A wide range of textures is available to the designer of stainless steel curtain walls. Textured sheets are rolled with patterns ranging in depth from .005" to 1-1/2" and in pattern width from 1/8" to 8". Patterns are of two general types -- all-over and one-directional. The shallower patterns are usually called "embosed" and the somewhat deeper patterns are often referred to as "rigidized," although it should be noted that this is a trade name. "Textured" will be used here to designate both types. The deeper over-all patterns present something of a problem at the joints, particularly the vertical ones, which are difficult to make tight. One solution is to have the pattern stop short of the edges of the sheet, which remain flat and can be formed as desired. Or the edges of the textured sheet can be re-flattened and then formed. The one-directional patterns are generally referred to as "ribbed" or "fluted." Sections through the ribs may be rectangular, v-shaped, or curved. These patterns are very widely used, almost always in a vertical position. When so used they present few joint problems.

Textured sheets furnish rigidity, diffuse reflections, and conceal unevenness and other minor defects. They also play an important part in the final appearance of the building. By his selection of texture the architect not only gives visual interest and character to the wall, but more important, he gives scale to the building as a whole. Textures of still larger scale can be obtained by the use of alternating panels of different depth or pattern. For a particularly important building, the architect may prefer to design a special pattern to be die-stamped in the sheet. This may be an expensive process, but it does give the architect complete control of the texture and scale of the building wall.

Color

On first thought, the application of color to stainless steel would seem to be a lily-gilding operation. The material has an attractive color of its own, which is subject to varying tonal effects through polishing and brushing. But on color, no matter how beautiful, there is a limitation to a designer. There are naturally many times when a change of pace in color is high desirable. This premise was strikingly confirmed by the results of the survey of architects conducted by the American Institute of Architects, as reported at this conference by Walter Taylor. More than 95% of the architects stated that if a full range of colors were available, they would use color, even at extra cost.

The ideal method of achieving permanently colored stainless steel would be by the addition of color during the alloying process, but this appears to be impossible. Superficial colors have been obtained by treating the metal in hot vaporous solutions, but the durability of the result is questionable. A dull black surface, which is apparently durable, can be obtained by an oxide process. A good interplay of values can be achieved with this black finish by varying the amount of surface covered, resulting in various shades of gray, as seen from normal viewing distances.

Permanent colors of unlimited range can be obtained by the use of porcelain enamel on stainless steel. Since the enamel is used for color only and not for protection from corrosion, only a single coat is required and it need not be continuous. Color can be applied in a spatter or other discontinuous pattern, thus permitting the natural luster of the stainless steel to show through. The same effect can be obtained on textured sheets by leaving the high points uncoated. These uncoated areas must be cleaned after firing, since heat discolors the surface of the metal. Using the low-temperature frits originally developed by du Pont for use on glass and now used also on aluminum, thin stainless steel sheets coated on only one side showed no evidence of warpage after firing. If these preliminary results are confirmed, it will mean that a wall panel of stainless steel can be fabricated and then color can be applied only where it is desired, leaving the remainder of the panel in its natural state. This is not possible with any other metal.

Economy in the Use of Stainless Steel

The most obvious way to use stainless steel economically is to use it in as thin a gauge as possible. The high strength of the material makes this feasible, if the proper techniques are employed, such as texturing and continuous backing.

For preliminary estimating purposes, the architect needs to know the price of stainless steel per square foot. Steel is priced by the pound and conversion to square feet is not simple because the price increases as the thickness decreases. For the guidance of the curtain wall designer the project staff had the following table of relative costs per square foot prepared by one of the major producers of stainless steel:

INDEX OF RELATIVE COSTS PER SQUARE FOOT OF STAINLESS STEEL SHEETS (1)

Gauge No.	Thickness Inches	Weight psf	Width 36"	Width 48"	Width 60"
14	.078	3.281	1.00	1.02	1.10
16	.063	2.625	.82	.84	.90
18	.050	2.100	.66	.68	.74
20	.038	1.575	.51	.53	.58
22	.031	1.313	.44	.46	
24	.025	1.050	.36	.39	
26	.019	.788	.29	.32	
28	.016	.656	.25	.29	
30	.013	.525	.24		
32	.010	.426	.22		

(1) Based on a unit of Type 302 No. 2D or 2B finish sheets in lengths of 60 to 120 inches, paper wrapped, in quantities of 10,000 pounds and over, as determined by one producer as of July 6, 1955. Factor of 1.00 arbitrarily assigned.

For greatest economy, serious consideration should be given to the use of Type 430 stainless steel, which costs 15-20% less than Type 302. The Korean War caused the withdrawal of the nickel-bearing alloys from the building market and resulted in the use of chromium alloys on several large buildings. Although not as highly corrosion-resistant as Type 302, and therefore not previously recommended for outdoor use, Type 430 has proven satisfactory in use in Pittsburgh, Cleveland, and other inland locations.

Economy in Fabrication is of course just as important as in the selection of the type and gauge of metal. Obviously, the simpler the fabrication, the lower the cost. Roll-forming and press-forming are the most practical fabrication methods for curtain wall panels in small quantities.

PREVENTING WAVINESS

The Definition of Visual Flatness

A problem common to all sheet metals is the tendency of the sheets to become wavy when used in large flat panels. Although it is the nature of the material to behave in this manner, nevertheless waviness in metal curtain walls is generally considered to be objectionable in appearance. Since there is no generally recognized standard for acceptable flatness, it was necessary to establish one. Accordingly an instrument (Figure 4.1) was developed which could be used to obtain accurate profiles of building walls. This instrument was used to measure the flatness of a number of metal wall panels, some conspicuously wavy, others acceptably flat in appearance. It soon became apparent that the significant factor in the definition of visual flatness is not the height nor the number of waves, but the steepness of the slope (Figure 4.2).

The readings were plotted in graph form with the scale of the deformations greatly exaggerated. Slopes in percent were calculated for all critical points and marked on the curves (Figure 4.3). After many tests a tentative conclusion was drawn that for smooth metals in the common finishes the threshold of acceptability seems to be a slope of about 1-1/2%, slightly lower for the more reflective finishes, 2B and 4, and slightly higher for the duller finishes, 2D and 6. There is some evidence that greater slopes can be tolerated in the immediate proximity to a joint. The architect who wishes to insure visual flatness in curtain walls of stainless steel should specify maximum slopes of panel faces, as installed in the building, not to exceed the following:

No. 2B and No. 4 finishes	1.00%
No. 2D and No. 6 finishes	1.25%
Heavily textured finishes	2.00%

What Causes Waviness?

The basic cause of waviness is structural instability of flat diaphragms. The specific reasons are not so well known. Possible causes of waviness, proven or suspected, are as follows:

1. Minor production variations.

2. Sheets not flat when shipped from the mill.

3. Unequal stresses resulting from fabrication.

4. Stresses resulting from erection (racking, warping, squeezing).

5. Expansion due to temperature rise.

6. Shrinkage of the backing can have the same effect as expansion of the face.

7. Movement of the building frame can rack or warp panels which were originally set plumb and level.

Of these possible causes of waviness, thermal expansion is most often cited, and this subject therefore was explored in some detail. Unbacked strips of stainless steel of various lengths and gauges, with ends restrained, were subjected to the maximum temperature rise likely to be encountered in practice, and the resulting buckling was measured (Figures 4.4, 4.5 and 4.6). As a result of these tests, it was concluded that, in order to avoid objectionable buckling due to temperature rise in the design of flat unbacked sheets of Type 302 stainless steel, the distances between supports or stiffening ribs should not exceed the following:

Thickness Gauge	Thickness Inch	No. 2B and No. 4 finish	No. 2D and No. 6 finish
20	.038	5.6"	7.5"
22	.031	4.7"	6.2"
24	.025	3.7"	4.9"
26	.019	2.9"	3.8"
28	.016	2.4"	3.2"
30	.013	1.6"	2.5"
32	.010	1.5"	2.0"

How to Prevent Waviness

The prevention of waviness cannot be guaranteed, but a number of measures can be taken that will greatly reduce the likelihood of distortion. For the best results, use as many of these measures as may be applicable:

1. Avoid the use of large flat surfaces.

2. Avoid the use of reflective finishes.

3. Specify stretcher-leveled sheets.

4. Use textured sheets.

5. Specify a system of attachment to the building that puts no strain on the panel and allows for some movement.

6. Specify that the face of the panel, as installed in the building, shall be flat within the limits described above.

7. Use continuous backing behind the metal skin, either by laminating it to a flat board-like material or by pouring a cementitious material directly behind the metal face.

8. If a flat metal face is not backed continuously, then the distance between stiffening members should not exceed those recommended above.

Lamination of Stainless Steel to Incombustible Rigid Boards

The lamination of stainless steel (.010" to .025" thick) and other metals to plywood has been done successfully for many years. There appears to be no reason why the same principle cannot be used, employing an incombustible board instead of plywood. After conducting a number of experiments in this field, it was concluded that the lamination of thin stainless steel sheets to asbestos-cement board, gypsum board, and calcium silicate board appears to be feasible, using adhesives of either the synthetic rubber or the epoxy resin type. Further study is needed before the method can be recommended for general use.

Sandwich Panels

Instead of laminating stainless steel to a board whose sole function is to keep the metal flat, it would be more efficient to laminate it directly to the insulation. For this purpose, a rigid insulation is required, such as precast insulating concrete, calcium silicate board, or cement-excelsior board. Where combustible materials are permitted, foamed plastic, paper honeycomb, or fiber board faced with asbestos cement board, can be used. When the metal facing is laminated directly to the insulation, it is usually advisable to adhere the interior facing to the other side of the insulation, in order to obtain the benefits of sandwich panel construction.

Stainless Steel Backed with Poured Cementitious Materials

If insulating concrete is to be used as a core material, the possibility arises that it could be poured directly into the preformed metal facing, thereby saving the cost of the separate laminating operation. As a first step in the investigation of this subject, the strength of the natural bond between stainless steel and various cementitious backings was tested in relation to the forces of thermal expansion and shrinkage of the backing. These tests disclosed that the natural bond between stainless steel and stone concrete was surprisingly good. The bond to light aggregate concrete was poor and could not resist the stresses caused by the shrinkage of the concrete in curing or the thermal expansion of the facing. An adhesive of the epoxy resin type, applied to the stainless steel before the concrete was poured, resulted in a satisfactory bond.

Various methods can be used to supply a mechanical tie between facing and backup. Studs can be welded to the inner face of the steel panel and wired to reinforcing mesh in the concrete. In the case of textured panels, wire mesh can be welded directly to inward projecting ribs. Generally these are discontinuous methods and care must be exercised that the bonding method does not cause, rather than prevent, distortion.

OTHER CONSIDERATIONS IN THE DESIGN OF CURTAIN WALL PANELS

I have dealt at some length with only one part of the subject—the exterior facing material. There are, of course, many other problems in the design of curtain walls. Some of these are: strength, joints, insulation, through-conductivity, condensation, vapor barrier, interior finish, fire resistance, and attachment to the building structure. I do not propose to discuss here all of these subjects in detail. But I do wish to comment briefly on two or three points.

You will be interested in the list we drew up of what we believe are the characteristics of the ideal insulating material for use in curtain wall panels. Here it is:

1. Low heat transmission (k = 0.25 Btu maximum)
2. Light weight (10 lbs. per cu. ft., or less)
3. Large size (30 sq. ft. or more)
4. Rigid - for use as core material in sandwich panels

5. Fire resistant - capable of at least 1-hour rating for 2" thickness
6. Waterproof
7. Vapor proof
8. Non-deteriorating
9. Inexpensive (in range of 10¢ per sq. ft. 1" thick)

Needless to say, this ideal material does not exist.

Joints have always been a problem in building. This age-old problem is greatly accentuated in the case of metal walls because of their high coefficients of thermal expansion and the large sizes of the units. It cannot be said that this problem has been solved in current practice when we learn from surveys of building owners that more than 1/3 of the owners reported noticeable air infiltration through their curtain walls.

A joint should offer sufficient tolerance to allow for minor variations in the fabrication and erection of the panels and should permit some movement of the panels, whether caused by thermal expansion or by movement of the building structure. It must do all these things and remain weatherproof at all times. A joint should be designed to be as weathertight as it is humanly possible to make it. It should be assumed that the joint nevertheless will leak; therefore a second line of defense should be provided, along with positive means for conducting moisture out of the wall.

Joints can be made weathertight by the use of resilient gaskets, by interlocking or spring action in the joint itself, or by the periodic application of caulking mastic. The constant expansion and contraction of metal panels causes caulking to fail in a relatively short time, necessitating frequent recaulking. Resilient gaskets of rubber, plastic, and felt have been used successfully, but their durability over a long period has not yet been proved. Interlocking and spring-type metal weatherstrip has been successfully used for many years, and this principle would seem to be feasible for use in panel joints. A survey of current practice discloses a wide variety in the types of joints. Among the types in common use are the batten, spline, tongue and groove, interlocking, and glazing bar. Examples of these are illustrated in Figures 4.7, 4.8 and 4.9.

Attachment to the Building

This important subject has received less attention than it deserves. The metal curtain wall is produced by modern industrial methods and is characterized by a fairly high degree of dimensional precision. Since building frames, whether of steel or reinforced concrete, do not provide this degree of precision, it is necessary that an intermediate element be introduced between the wall panel and the structural frame to provide the required adjustment. Attachment devices should meet the following requirements:

1. Strength sufficient to support the wall panels independently and prevent "stacking," which can cause buckling.

2. Permanence - attachment must not loosen as a result of building movement or thermal expansion of the wall panels.

3. Adjustability in 3 dimensions to permit correct alignment of wall panels.

4. Corrosion resistance equal to the life of the building.

5. Fire resistance sufficient to insure that the wall panels will stay in place in the event of fire.

6. Erection from interior - important especially for multi-story buildings.

The method of panel fastening used should be kept as simple as possible which will lead to economy in fabrication and erection. Split responsibility in the erection of curtain walls should be avoided whenever possible. It is recommended that the panel fabricator erect the wall units whenever he is qualified to do so. The speed and efficiency with which the panels are placed will depend, to a great extent, upon the close coordination of those responsible for the design, fabrication, and erection of the wall units. As in the case of joints, a wide variety of attachment devices are in current use. A number of examples are shown in Figures 4.10 through 4.13.

EXPERIMENTAL CURTAIN WALL DESIGNS[1]

Stainless steel has inherent characteristics obtainable in no other material. The architect's problem is to exploit these characteristics through designs particularly adaptable to the material used, rather than to attempt to substitute stainless steel in systems basically designed for other metals. In order to compensate for necessary dies, an economical curtain wall system requires volume production usually beyond that inherent in a single building. Volume requires standardization. There is need for the development of methods that standardize the elements not fundamental to the visual aspects of design.

General Purpose System

There exists a vast category of structures from one to three stories high which includes such buildings as schools, hospitals, small office buildings, laboratories, motels, and shopping centers. They are usually built without elevators and often need not be of highly fire-resistant construction. A practical structural system involves the use of steel studs approximately four feet on center, with panels and windows inserted as desired. A batten device, preferably flush, is the most practical method for holding the windows and panels in place. This basic system can also be used in multi-story buildings, the studs then becoming secondary framing for the attachment of wall panels and windows.

Multi-Story System

This area of building includes the most dramatic examples of curtain wall construction, although the greater volume lies in buildings of lesser height.

[1]These experimental designs are the property of Princeton University; patent rights are reserved.

The design in Figure 4.9 emphasizes the capacity that stainless steel has for the weatherstripping of joints. It is used for that purpose in many windows made of other materials. In panels of stainless steel it is possible to so form the edges of the panels as to provide for interlocking joints of excellent weather-proofness without resort to additional devices. There is considerable advantage in making a curtain wall system entirely of one material, without using plastic gaskets or caulking. This appears to be possible with stainless steel. The illustration shows merely a basic method. In practice, allowance must be made for expansion, and the panel surface would be better textured than flat.

Industrial System

Large areas of many industrial buildings need to be enclosed with a simple, economical, durable curtain wall. In general, systems now in common use were originally designed for metals other than stainless steel. The objective here is to capitalize on the inherent qualities of stainless steel. Its durability in lighter gauges is coupled with resilience which comes from its high yield strength. Panels of 16 or 18 gauge carbon steel form the interior surface; in small buildings they may also act as bearing walls. Stainless steel sheets, 26 gauge (28 gauge, if textured) fit into the openings formed by the interior panels. After exterior panels are inserted, 26 gauge stainless steel keys are down, fixing the panels in place and causing them to arrive at a predetermined curvature. The curved section is of itself pleasing and serves to obscure any waviness or defects. Insulation may be applied as shown or may be adhered to the inside of the exterior panels. The latter method also adds stiffening and sound-deadening qualities to the panel.

SHADING DEVICES

Before closing, I wish to call attention to a subject that is not generally thought of as being part of the curtain wall problem. Shading devices are permanent projections from the building wall, designed to protect the wall from the rays of the sun during the hours of the day and the seasons of the year when the sun's heat is not wanted. In an air conditioned building, sunshades are an economic necessity. The Olgyays have calculated that properly designed shading devices can save in air conditioning cost from $3.60 to $4.00 per square foot on a south elevation, and from $8.00 to $9.00 per square foot on an east or west elevation. The cost of the usual fixed shading device runs around $3.50 per square foot of wall. Stevens and Wilkinson, architects for the Georgia Baptist Hospital, which is protected by an eggcrate type of sunshade, concluded that "this system saved in air conditioning equipment considerably more than its cost and will effect a 15% saving in the cost of operations." It can be safely predicted that the use of shading devices will increase as the use of air conditioning increases.

Sunshades can be vertical, horizontal, or a combination of the two, often called eggcrate. They may be fixed or operable. A single building may have several types, perhaps fixed horizontal devices on the south elevation and operable vertical units on the east and west elevations. These new elements, with their strong patterns of light and shade, easily dominate any facade, indeed in many cases they become the facade. The design of the wall behind these screen facades is obviously a very different problem from the one we have been discussing here today.

MR. TABLER (The Moderator): Thank you very much, John.

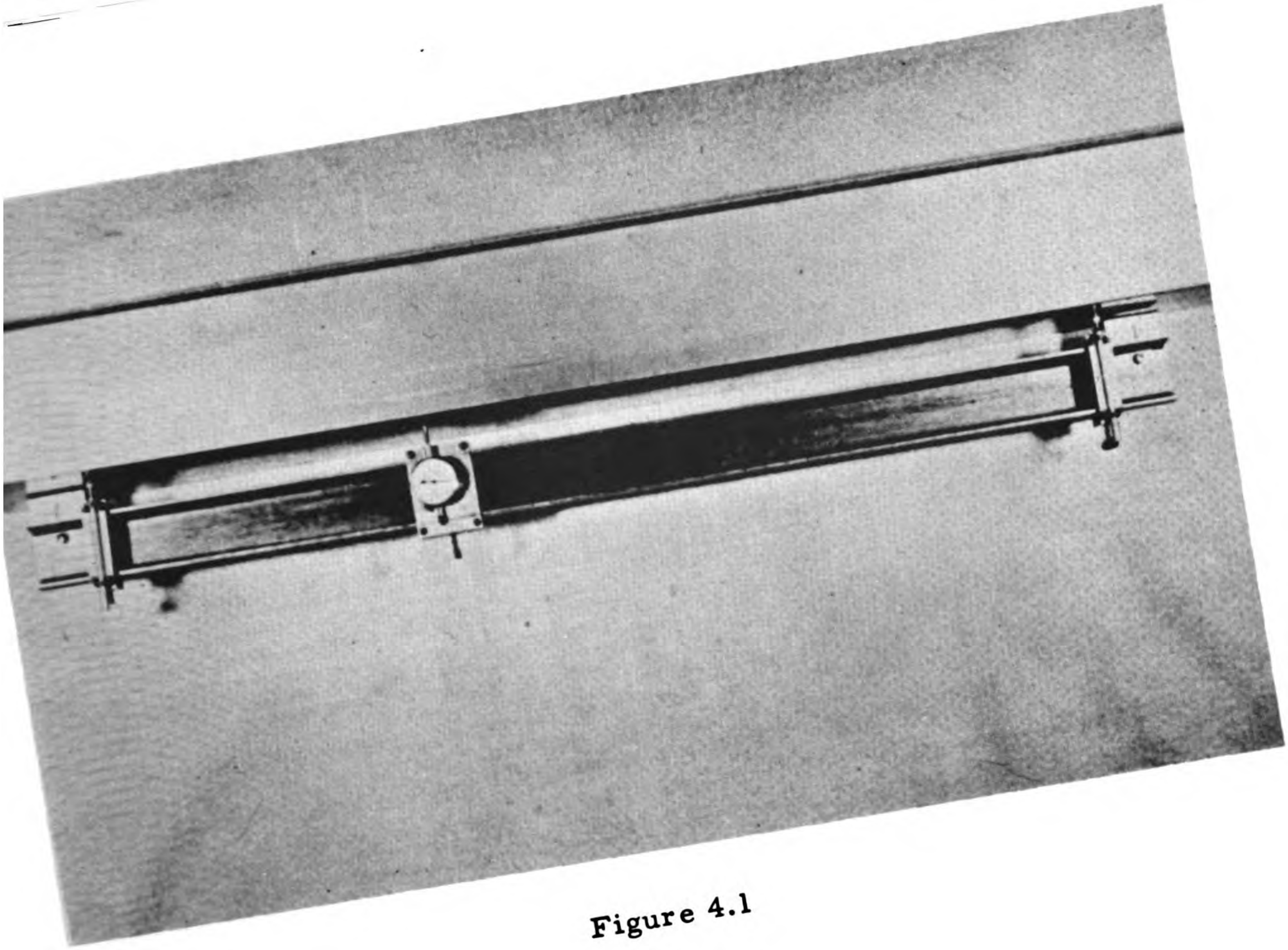


Figure 4.1

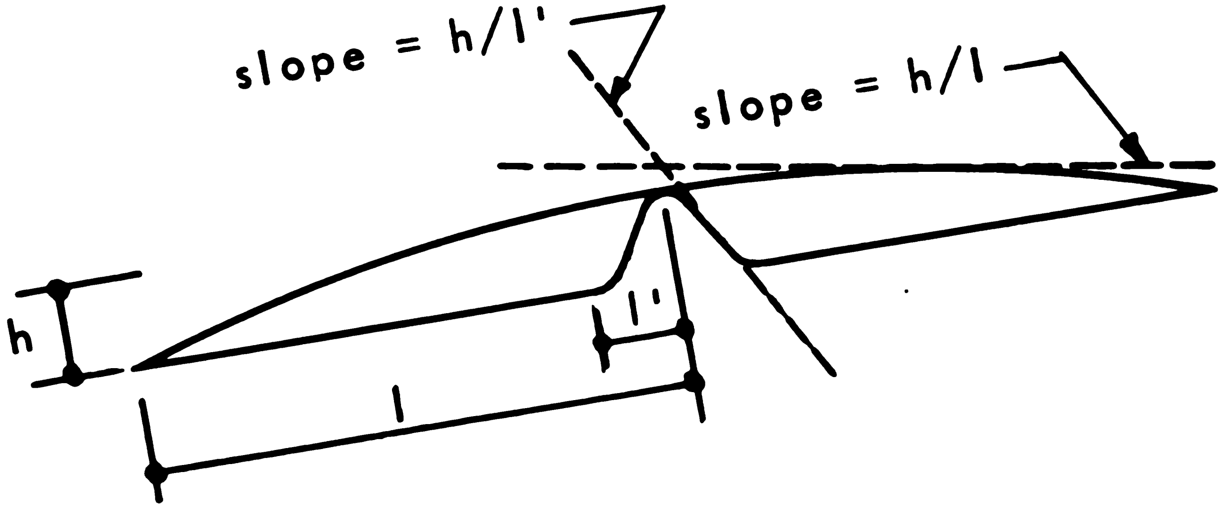


Figure 4.2

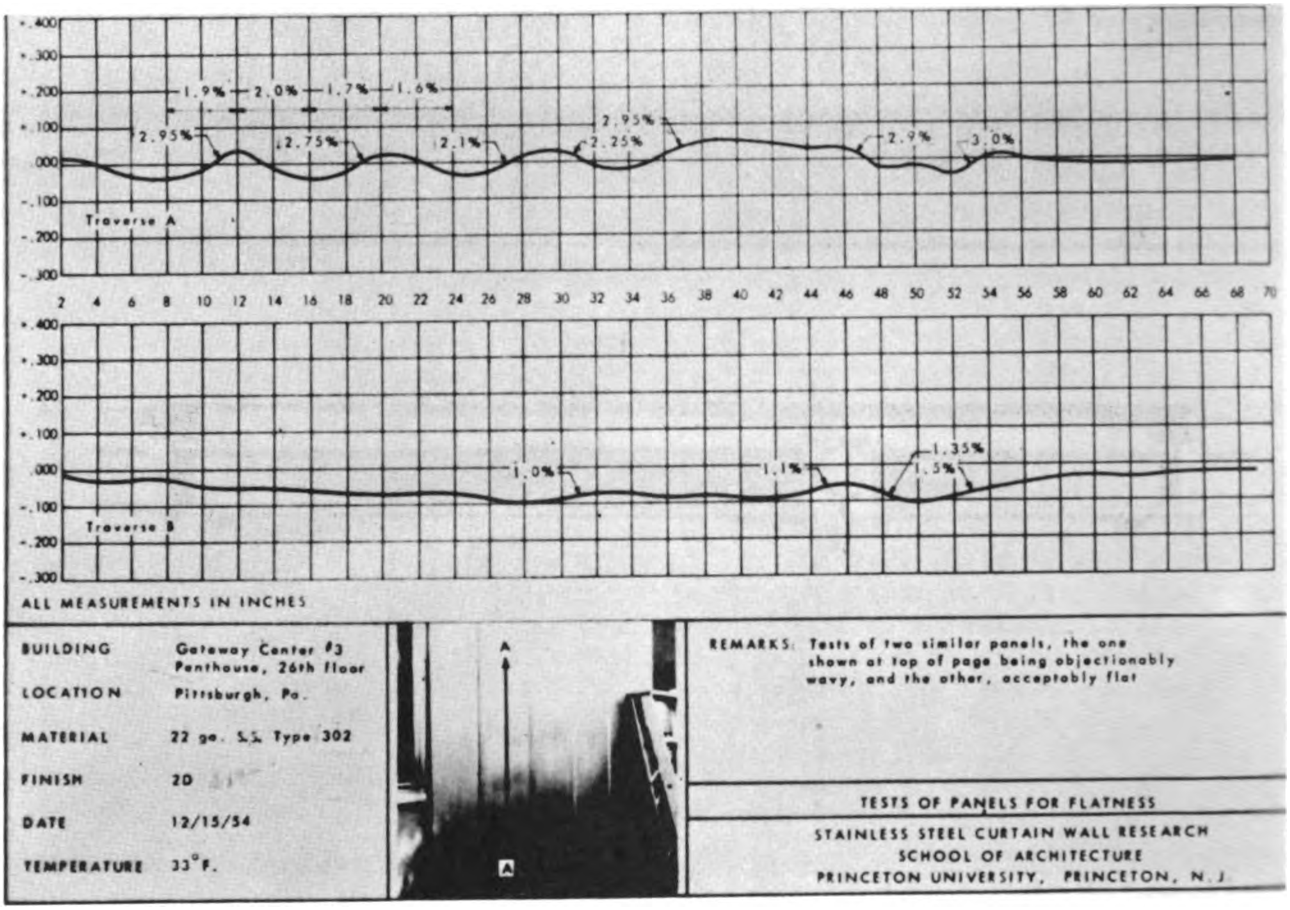


Figure 4.3

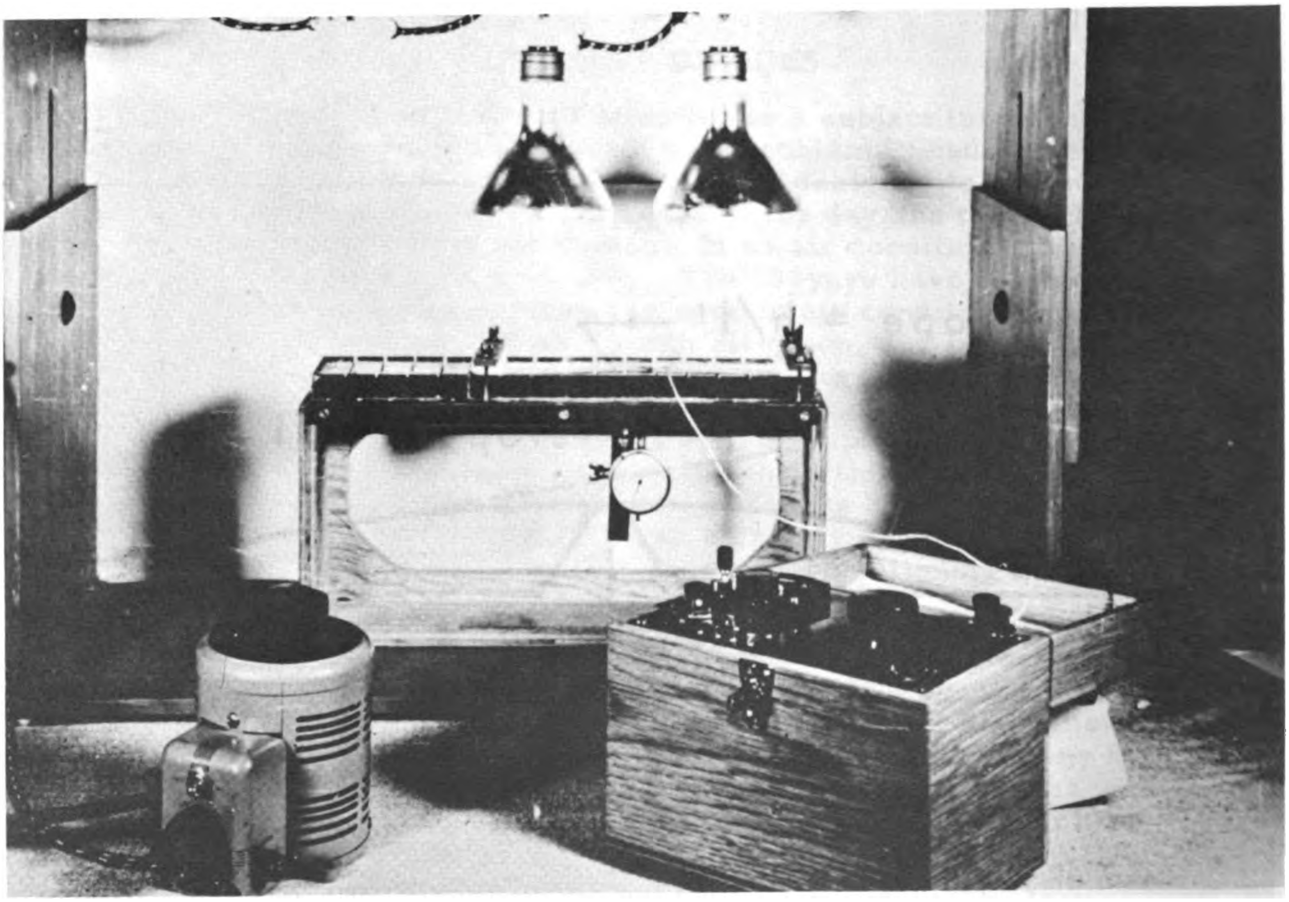


Figure 4.4

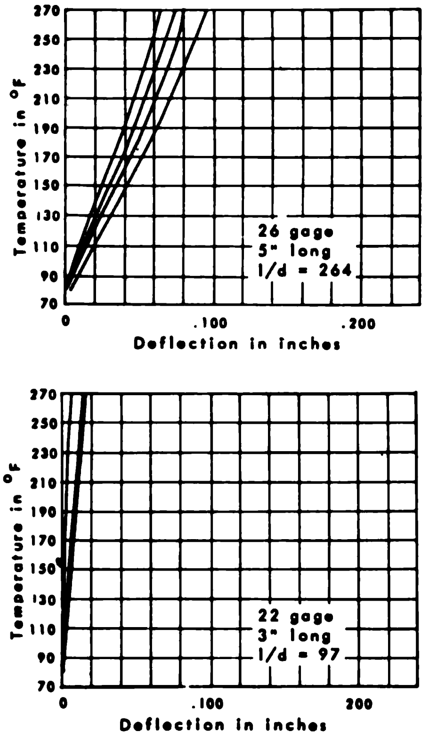


Figure 4.5

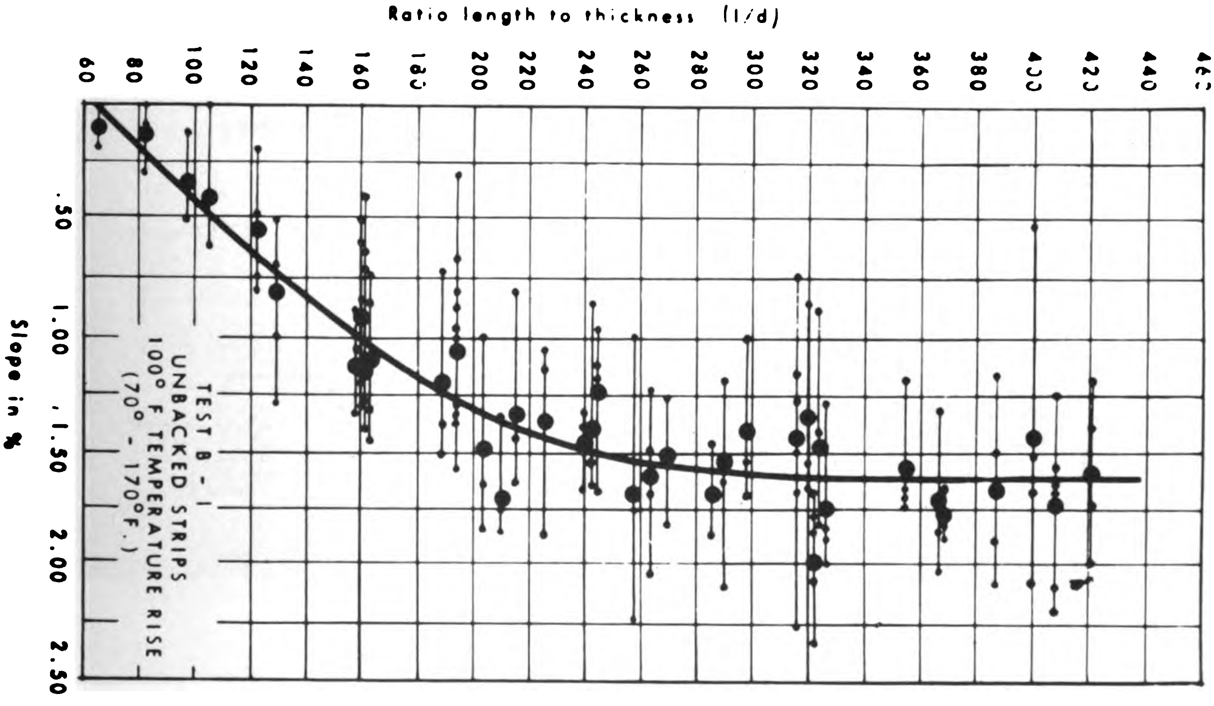


Figure 4.6

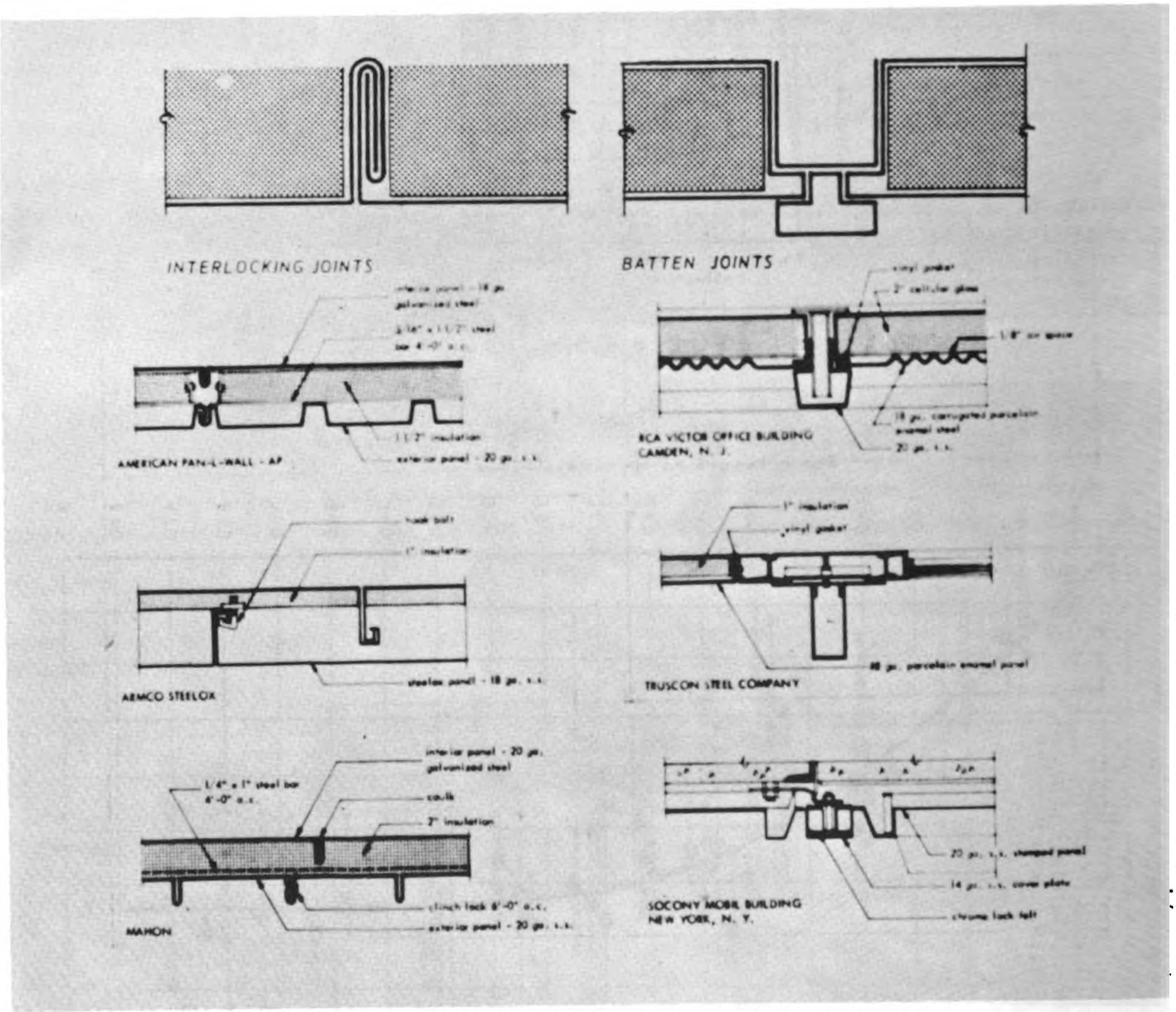

INTERLOCKING JOINTS
BATTEN JOINTS
AMERICAN PAN-L-WALL - AP
ARMCO STEELOX
MAHON
RCA VICTOR OFFICE BUILDING
CAMDEN, N. J.
TRUSCON STEEL COMPANY
SOCONY MOBIL BUILDING
NEW YORK, N. Y.

Figure 4.7

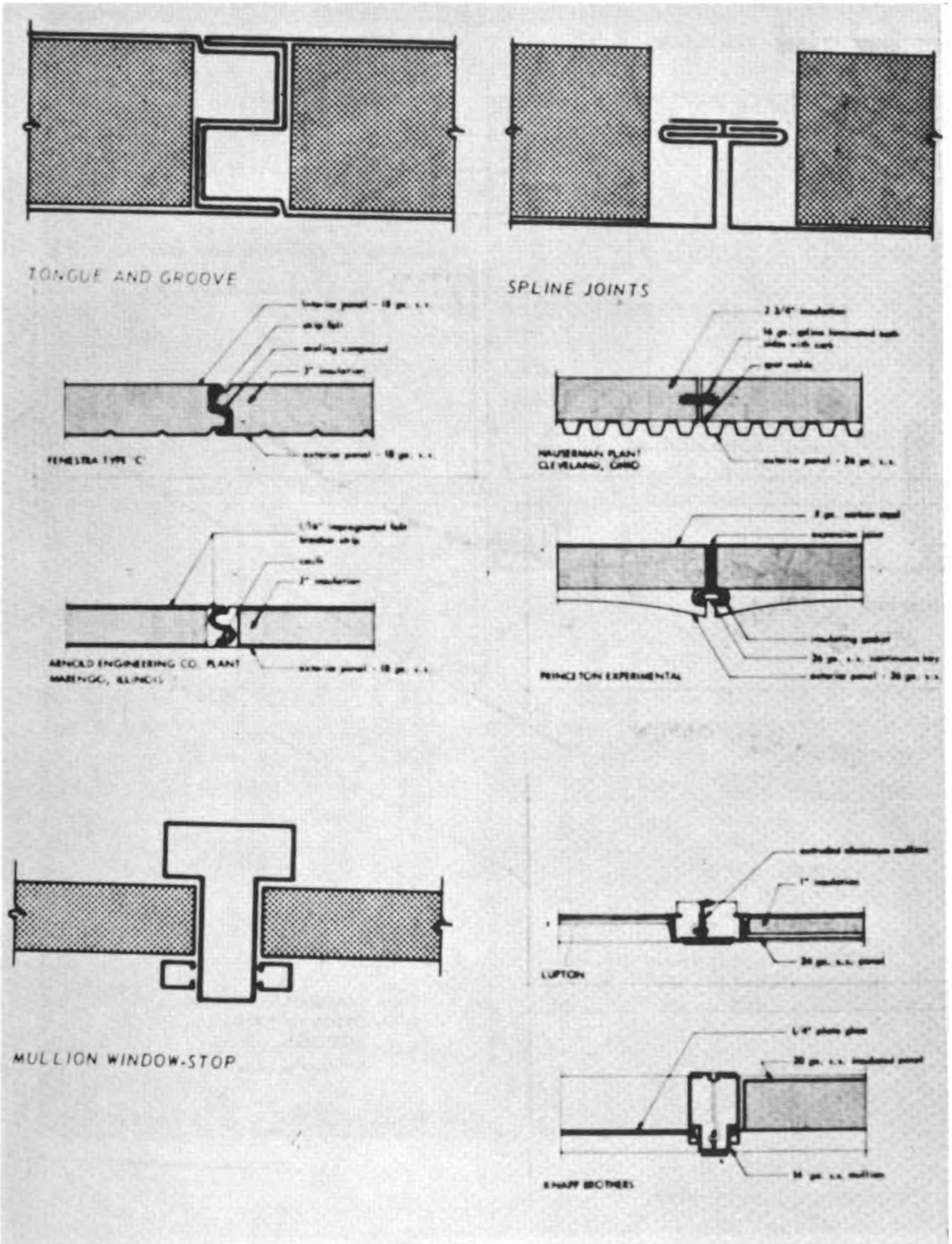

TONGUE AND GROOVE
SPLINE JOINTS
FENESTRA TYPE "C"
HAUSERMAN PLANT
CLEVELAND, OHIO
ARNOLD ENGINEERING CO. PLANT
MARENGO, ILLINOIS
PRINCETON EXPERIMENTAL
MULLION WINDOW-STOP
LUPTON
KNAPP BROTHERS

Figure 4.8

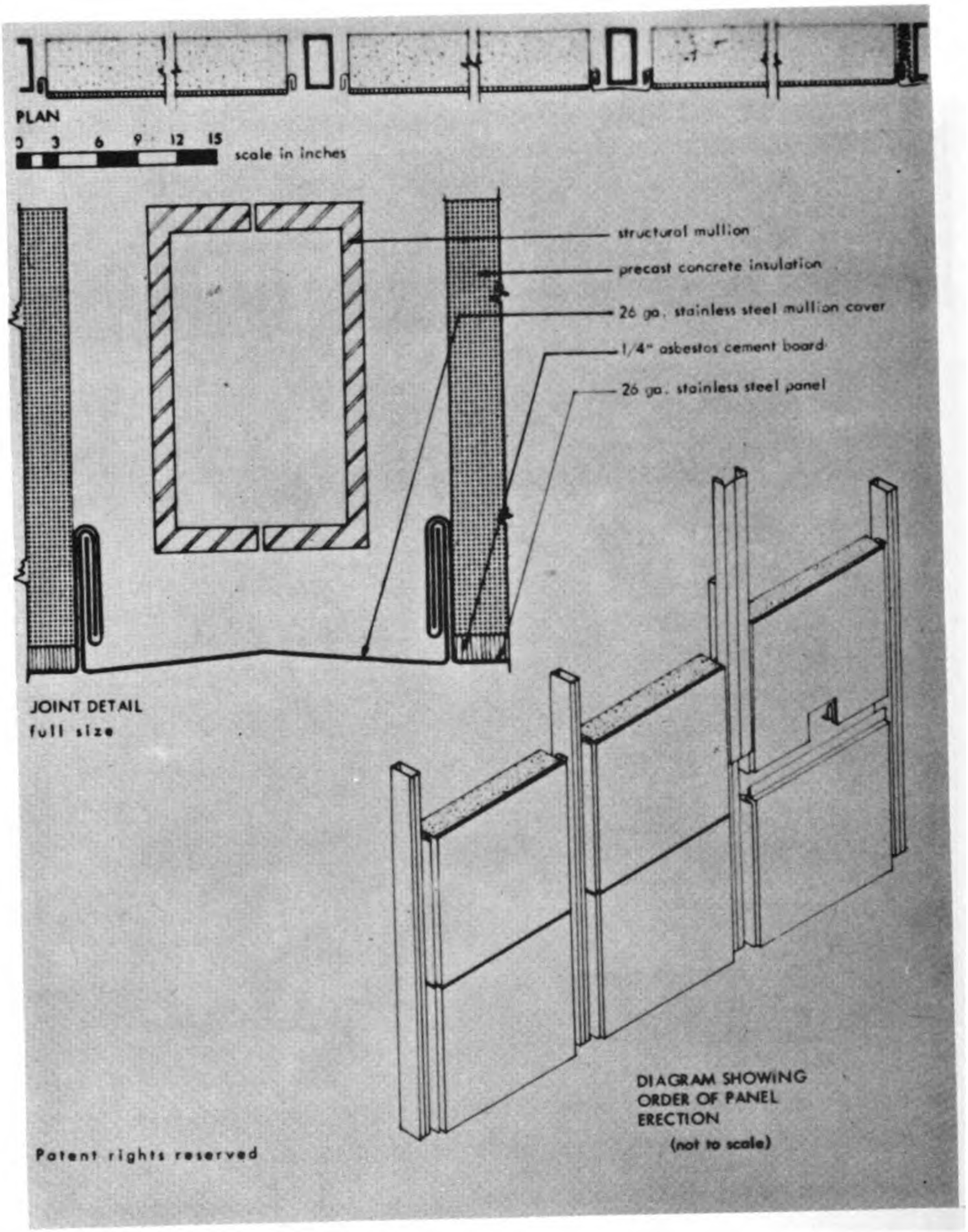

PLAN
0 3 6 9 12 15
scale in inches
structural mullion
precast concrete insulation
26 ga. stainless steel mullion cover
1/4" asbestos cement board
26 ga. stainless steel panel
JOINT DETAIL
full size
DIAGRAM SHOWING
ORDER OF PANEL
ERECTION
(not to scale)
Patent rights reserved

Figure 4.9

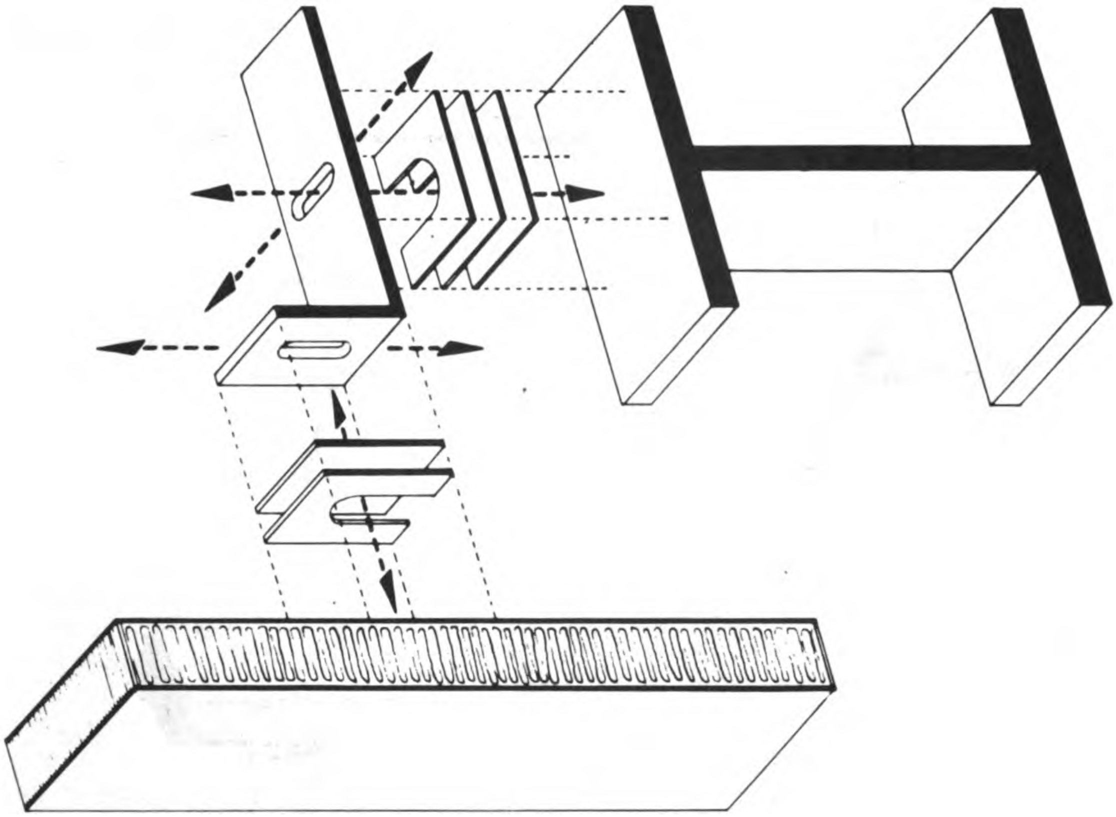


Figure 4.10

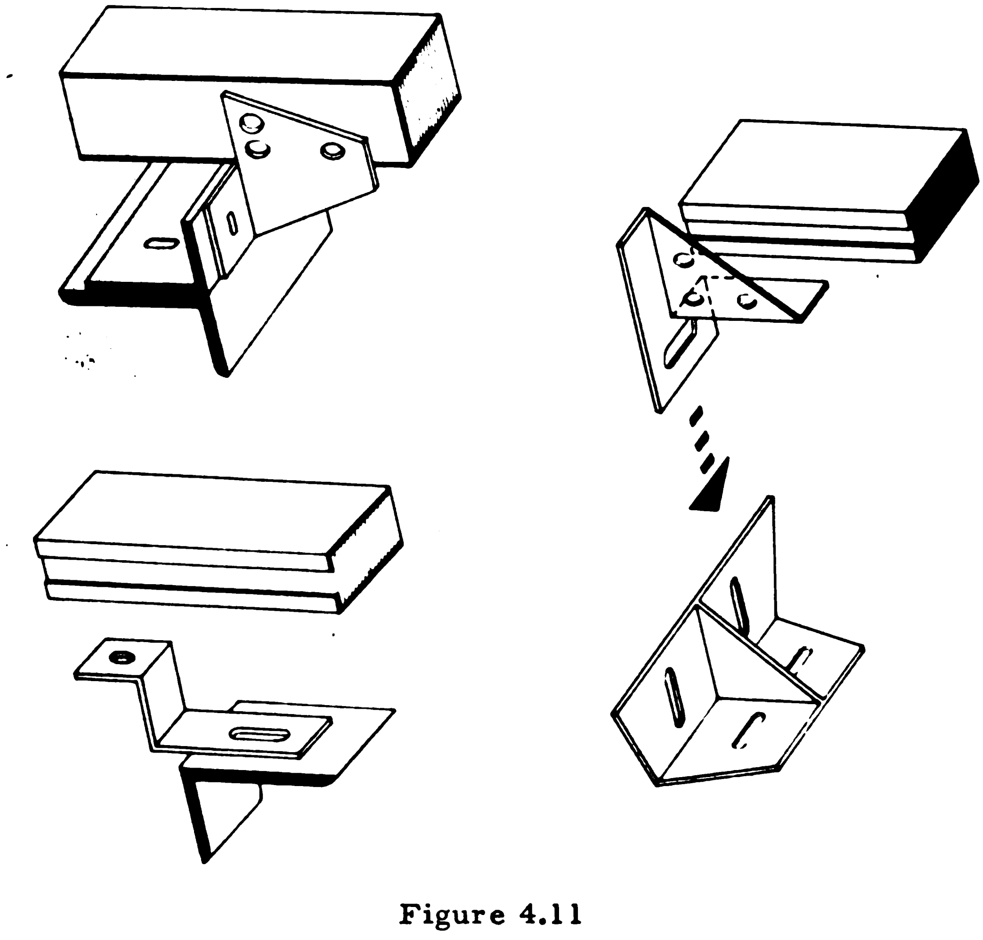


Figure 4.11

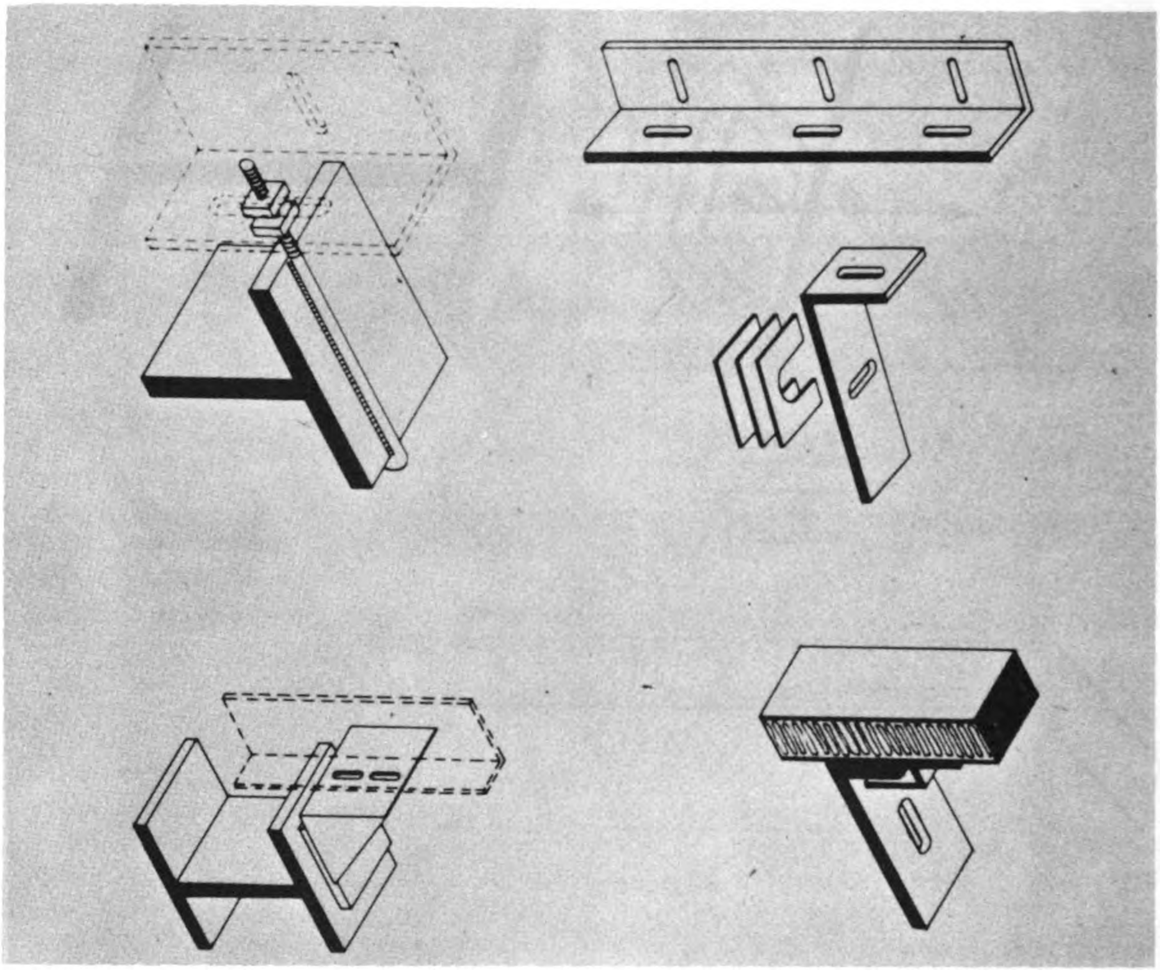


Figure 4.12

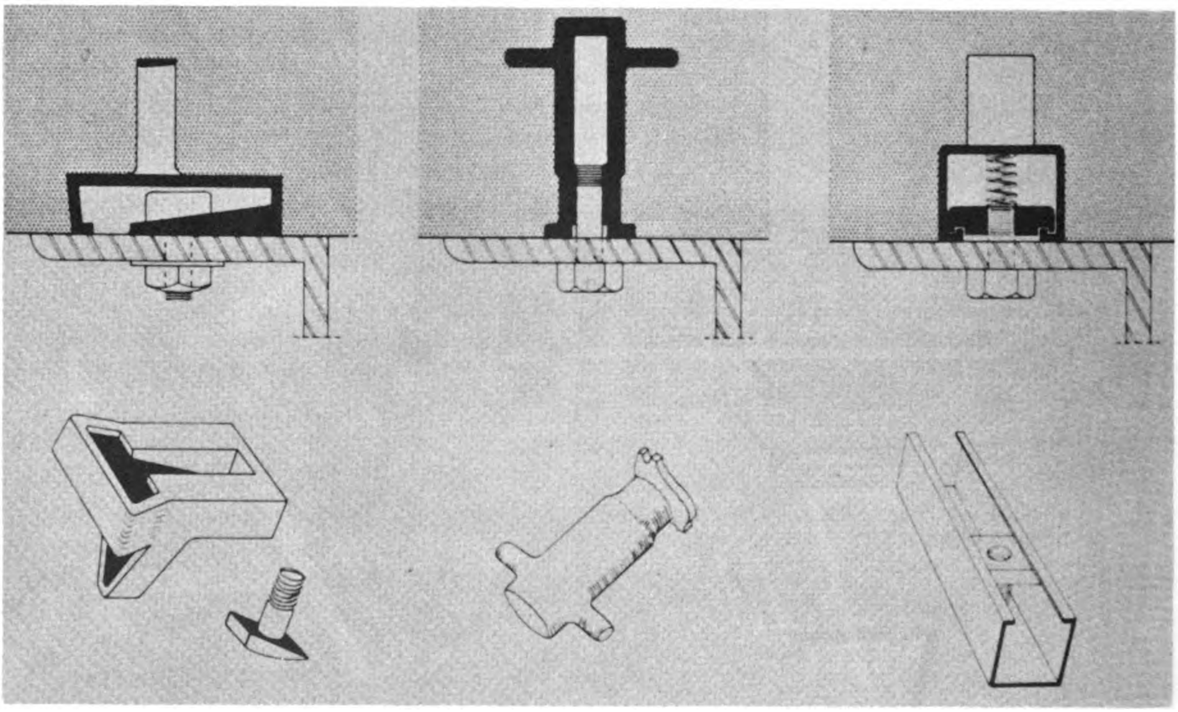


Figure 4.13

METAL CURTAIN WALL STRUCTURAL DESIGN TECHNIQUES

By Robert K. Posey
Associate Partner
Skidmore, Owings & Merrill

MR. TABLER (The Moderator): Mr. Posey is an Associate Partner of the firm of Skidmore, Owings & Merrill in New York City. He is a graduate of Alabama Polytechnic Institute, with a B.S. degree in architecture and has a degree of B.S. in Architectural Engineering from Beaux-Arts Institute of Design. Mr. Posey is a member of the American Institute of Architects.

MR. POSEY: Mr. Tabler, Fellow Members of the Conference: I have the enviable position of having been told that I can talk about our experiences, so if I seem not to be factual from your viewpoint, you understand they are our experiences.

The Structural Steel Grid Frame

The predominate structural system today is a three-dimensional grid frame of reinforced concrete or steel posts and beams, as is exemplified by the Ford Motor Co. office building in Dearborn, Michigan, shown in Figure 4.14. Masonry bearing walls have been pushed aside in the press for economy and for a shorter work day for building tradesmen. Their places have been taken by "skins" or curtain walls of various materials.

A natural expression of this grid structural frame is an exterior curtain wall of panels held by means of a metal framework or web. Deletion of operable sash, made possible by today's advances in air conditioning and artificial lighting, permits use of small, lightweight framework sections. This gives the webbing a narrow line appearance which contrasts happily with the heavier structural frame of the building.

The Architectural Metal Webbing Recalls the Structural Grid

In its simplest form, the floor-to-floor, post-to-post, skin web is an architectural metal section capable of withstanding wind but not a vertical load. It becomes the inside finish material but stops short of the outside cover assembly in order to break thermal conductivity. It is shop-fabricated and assembled into operationally convenient frames.

When these frames arrive at the site, they are hoisted into position and fastened. In Figure 4.15 (another view of the Ford building), the center vertical rail is fastened at each end to the structural steel frame. The remaining verticals are not held rigidly but are hung at the top and mounted upon bronze slip-pads to afford horizontal movement when the frame expands or contracts. An expansion joint is provided at each side of each column.

A Pane of Glass Goes Into Place

After the skin frame is secured, the glaziers install the glass panels (Figure 4.16, which shows such installation on the Wyeth Laboratories office building at Radnor, Pa.), and sheet metal mechanics install a porcelain-covered metal panel in a very similar procedure.

A Metal Panel is Installed

In this case (Figure 4.17) the panel in the Wyeth Laboratories building is being set into a glazing compound suitable for use where its retention of plasticity does not depend upon occasional painting. Small fibre blocks are used to insure retention of proper alignment, in the same manner that one sets a piece of glass. A continuous neoprene gasket is a highly recommended alternate method of setting the panel into the glazing rebate. In this technique, a pressure type bead is used to tighten onto the gasket in order to insure a positive water seal around the periphery of the panel.

An Outside Cover Mould is Applied

Upon completion of a full bay with both glass and metal panels, the architectural metal workers return to the scaffold and apply the finishing cover moulds over the glazing beads (Figure 4.18). All three trades have worked from a common exterior hanging scaffold.

The spacing of these covers is carefully designed to form an organized, pleasing pattern over the entire exterior surface of the building. The covers not only add sheen and lustre, but perform the utilitarian function of shading the glazing compound or gaskets from intense solar radiation. This excess heat, if not blocked, accelerates the drying of the exposed edge of the compound, making necessary an extensive pointing operation within a few years.

An additional very great appearance benefit is attained by projecting these surfacing members an inch or so from the face of panels. This depth of enframement affords an interesting play of light and shadow and prevents a sharply oblique view of the panel surface. Such a view is a cruel one even where exacting flatness tolerances have been maintained.

The Exterior Curtain Near Completion

During the course of construction, a number of the scaffolds are hung simultaneously from the roof and parallel crews speed the building to the completely enclosed stage (Figure 4.19). No time is lost because of cumbersome procedures, such usually prevail in elevating heavy materials in small units. It is not necessary to allow time out for mortar to set; nor is it necessary to protect from freezing the metal and glass, the gaskets and putty.

The construction of the metal panel itself is of prime interest at the moment. The panels under discussion are porcelain-covered ones. Waviness, or lack of flatness, had been in the past the greatest hindrance to the architectural acceptance of porcelain-coated metal sheets as surfacing materials. A steel sheet deforms under the intense heat necessary for the fusion of the porcelain surfacing. Unless it is held rigidly flat it will regain the deformed shape even after being assembled into a panel. Lamination with a suitable core successfully maintains flatness.

The sheet to be porcelainized must be at least No. 16 gauge stretcher-leveled steel, for a final panel of about 3 feet by 5 feet, and both sides must receive the fused porcelain coating. It then must be made to adhere to a core, which in turn is backed with a sheet of steel to maintain even stress. The core itself can take varied forms. An eggcrate or honeycomb of treated paper or aluminum is presently giving best results. For a 3' x 5' panel the aluminum honeycomb needs to be only 1/4-in. thick.

If the panel manufacturer chooses a treated paper instead of an aluminum honeycomb core, the construction becomes somewhat different. The core itself then must be not less than 2 inches thick. Thus, the over-all panel depth increases to 4 inches, if the core and insulation are separate and there are three layers of metal. One alternative is to fill the paper honeycomb with an insulating material to eliminate one sheet of steel, making a 2 inch thick panel. This is satisfactory insofar as flatness is concerned. These materials, however, being poorly ventilated, could become saturated with condensation moisture. If such a condition were to occur, the paper core and the laminating glue would be subject to continual wetness, and the inner disintegration hazard would be magnified.

Solid core panels of asbestos board or rigid insulation have been used where lower cost was of prime importance. Neither material has produced a flatness equal to the honeycomb core, and delamination is more probable. Unless a panel is flat and free from warpage it is not recommendable for architectural use. Excessive stressing of low cost on a new building is foolish if the desired appearance, though attained initially, cannot be maintained.

Aside from shedding water a panel must keep out the heat or cold and must not load to excess reasonably engineered heating and air conditioning systems. Today there are thermal insulations, such as mineral or glass wool, compressed fibres, reflecting surfaces, and expanded substances, that equal in 2-inch thickness the insulating value of a 12 inch thick masonry wall. Since these materials are also light in weight it is entirely feasible to attach a 2-inch insulation blanket to the back of an aluminum honeycomb cored panel and still have a maximum thickness of only 2-1/2 inches.

With these criteria we have built our most successful metal curtain walls. A bright future for the metal curtain wall in architectural use is anticipated, and developments are being followed with the keenest interest. Earlier discussions have opened avenues of approach for improvements upon the textured surface school of design. Walls of composite glass and smooth surface panels are equally promising of a bright future.

Panel manufacturers deserve the praise of the owners and architects for the recent rapid development of the metal curtain wall panel. With a sympathetic attitude toward architectural thinking, the industry will play a strong part in the evolution of our architectural form. Lightness and color will inspire and challenge the designer of the future, and a gayer aesthetic mood will prevail in the buildings of tomorrow.

MR. TABLER (The Moderator): Thank you, Bob.

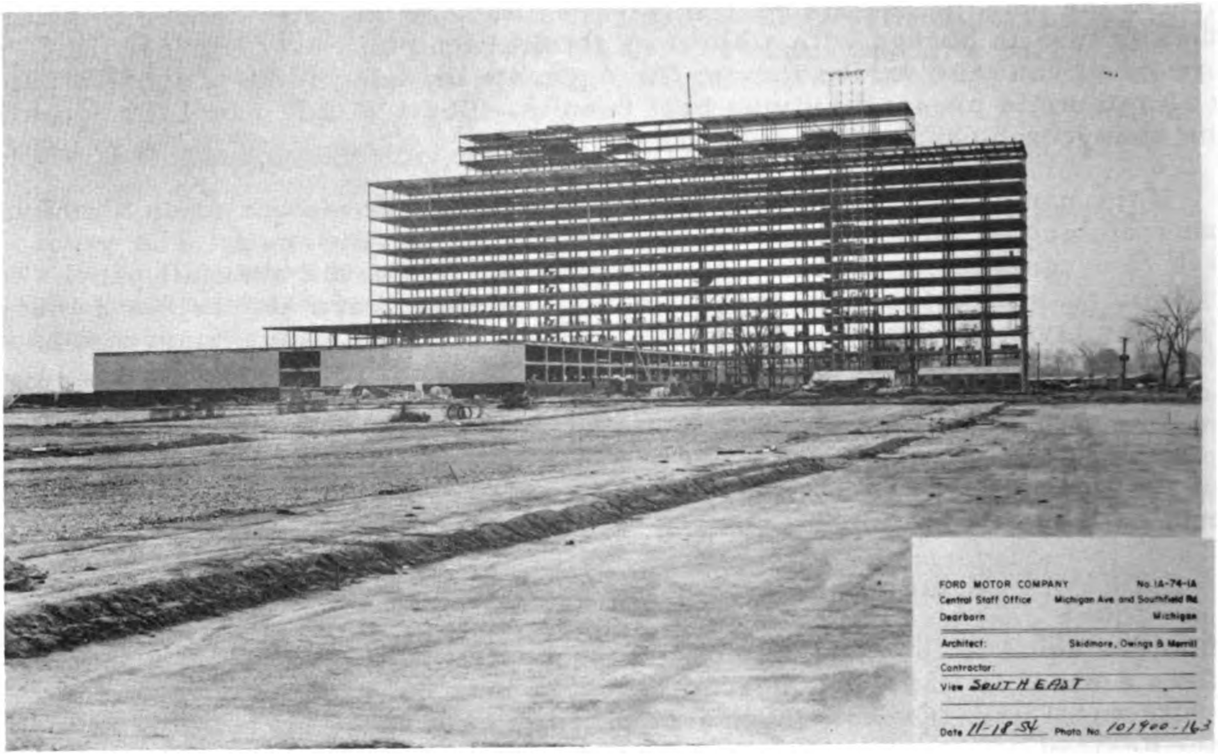


Figure 4.14

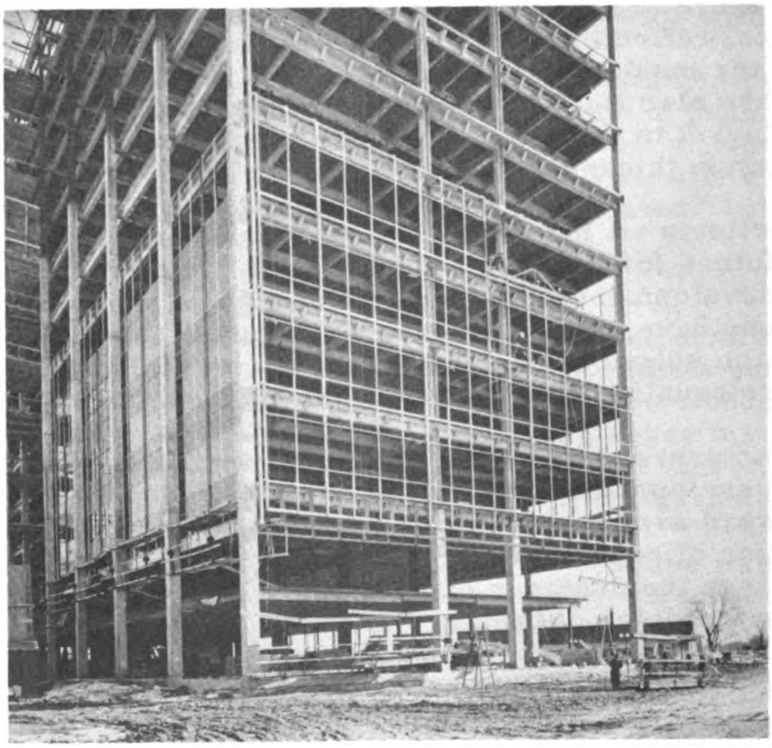


Figure 4.15

Figure 4.16

Figure 4.17

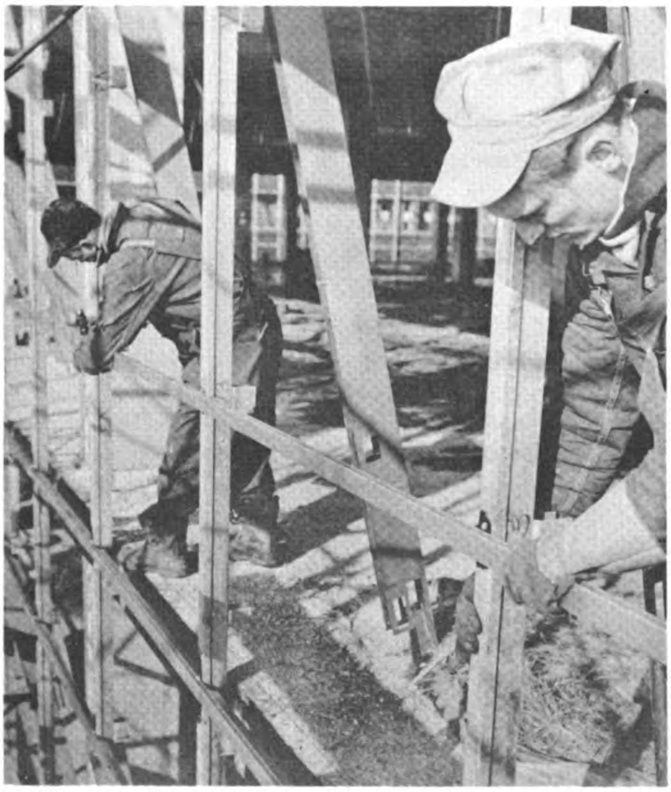


Figure 4.18

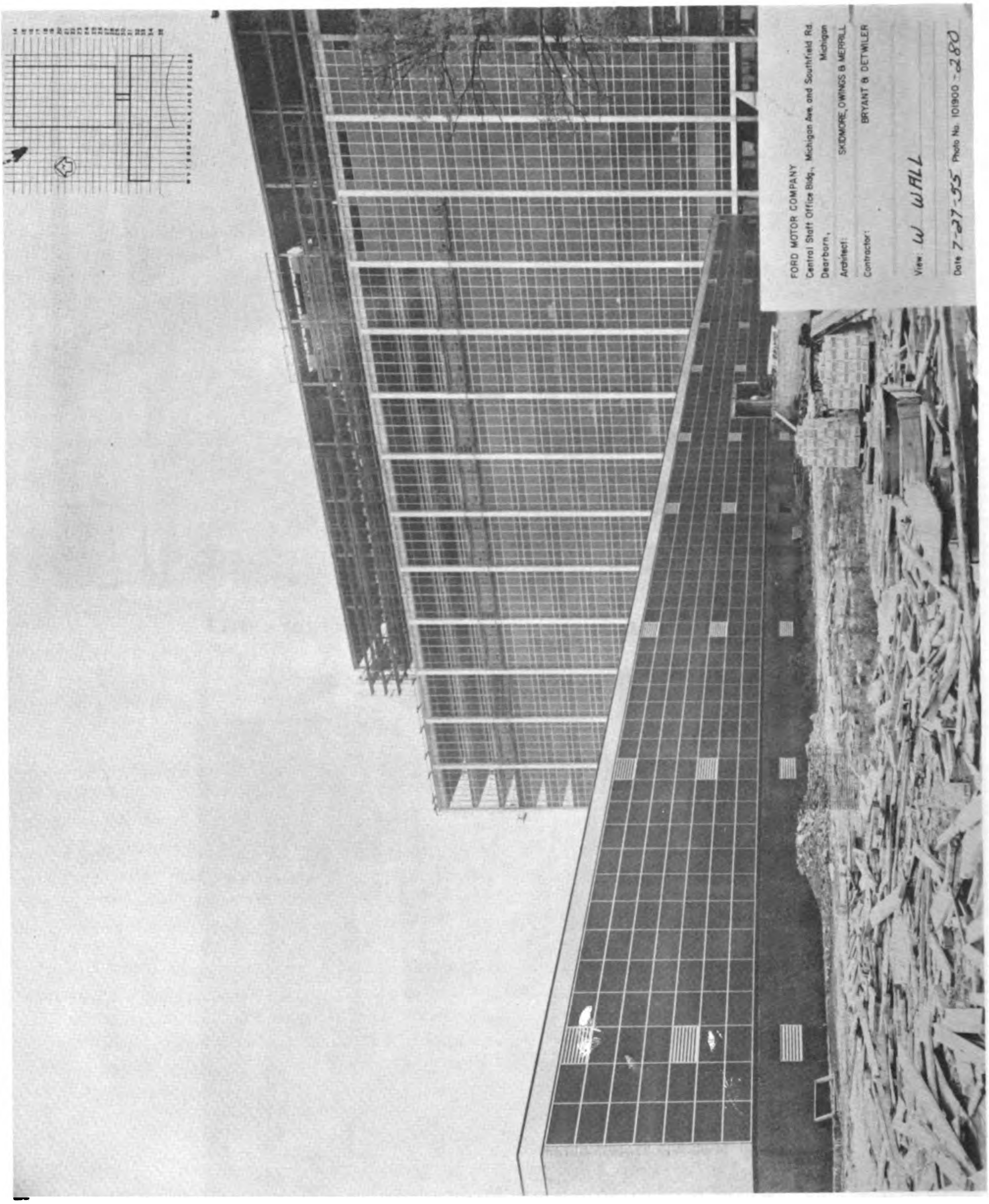

FORD MOTOR COMPANY
Central Staff Office Bldg., Michigan Ave. and Southfield Rd.
Dearborn, Michigan
Architect: SKIDMORE, OWINGS & MERRILL
Contractor: BRYANT & DETWILER
View: W WALL
Date 7-27-55 Photo No. 101900-280

Figure 4.19

CORE MATERIALS AND ADHESIVES FOR SANDWICH PANEL CONSTRUCTION

By Jack M. Roehm
Director of Research and Development
The Kawneer Company

MR. TABLER (The Moderator): Mr. Roehm is Director of Research and Development, The Kawneer Company, Niles, Mich. He is a graduate of Tulane University, with a B.E. degree in Mechanical and Electrical Engineering and obtained a M.S. degree in Electrical Engineering from the California Institute of Technology. Mr. Roehm is a member of the American Institute of Electrical Engineers, American Society of Mechanical Engineers, and the Institute of Aeronautical Sciences.

MR. ROEHM: I guess I am one of these researchers that Mr. Abramovitz referred to this morning, one of the fellows who makes life so complicated for the architects and builders. That came as quite a jolt to me, because I always thought it was the architects who made life difficult for us. [Laughter] I don't know if there is any moral to that, but I do think we should get together a little more often and thrash out our problems.

GENERAL DESIGN CRITERIA

Introduction

This subject is extremely broad and we can only cover the highlights here. The types of building panels currently being produced are so numerous that to catalog them would be a major task in itself. However, as a general statement, it may be said that there are two types: monolithic panels, i.e., precast concrete, marble slabs, cemesto boards, etc.; and sandwich panels, which are made up of a core material literally sandwiched between two skins. The skins are usually a different material than the core.

The sandwich panel itself, for the purposes of our discussion, may be divided into two basic types. One type is constructed by mechanically fastening the skins. The core in this case is used simply as a filler. In the other basic type of panel the skins are adhesively bonded to the core material, the core thus becoming an integral part of the structure. Skins may be made of quite a variety of materials but panels of lightest weight, highest strength are obtained with metal skins.

This discussion will deal with panels constructed by adhesively bonding metal skins to a core material. We have chosen this type of panel in preference to the others because this type of construction gives us the greatest opportunity to make the most of the desirable properties of panel construction at reasonable cost and using practical production methods.

Functions of Panel

Before going further into panel details let's examine some of the functions performed by a curtain wall, particularly the panel, which in itself provides for both the exterior and interior wall. Here are the principal functions:

1. Appearance - must be architecturally excellent.

2. Structure - must withstand the loads to which it is subjected throughout the life of the building.

3. Temperature - must provide adequate insulation between the interior and exterior. And in some installations it must resist fire.

4. Moisture - must prevent entrance of moisture into interior of the building and must not be adversely affected by moisture.

5. Costs - must economically justify its use.

The foregoing five items are the principal factors establishing criteria for the design of panels. There are others, to be sure, but from these we can set forth fundamental technical considerations.

Appearance

The first item requires that the panel have an architecturally excellent appearance. Selection of the exterior metal skin, plus its finish, begins at this point. Generally we will have the following to choose from:

Steel - porcelain enamel
Stainless Steel - plain or textured surface, special finishes
Aluminum - plain or textured surface, plain or color anodized, porcelain enamel

Excellent appearance demands that the exterior surface of a panel be free from flaws, waviness, and excessive bowing. Porcelain enamel finish both on steel and on aluminum causes distortions, which makes it necessary to use particular bonding techniques to obtain a flat surface. The distortions induced in the sheets are a result of the high temperatures at which the porcelain enamel frit is fused to the metal. In the subsequent cooling operation, the difference in the coefficient of expansion of glass and metal causes residual stresses which distort the sheet. The problem is more difficult with aluminum than with steel. This problem, of course, is not encountered in the use of stainless steel or in the use of plain or anodized aluminum.

In our panel work we prefer to enamel only one side of the sheet which has a tendency to further aggravate the problem of distortion. This permits us to bond directly to metal rather than porcelain. Although our laboratory is testing certain adhesives which show promise for bonding directly to porcelain, we have not yet reached a point where we are willing to use this type of bonding in production. I believe other companies are doing this in the case of porcelain on steel, and it is my understanding that good results have been achieved.

Going back to the distortions which exist in the sheet, these distortions are overcome when the sheet is bonded into the final panel assembly. It is basic, however, that when distortions are overcome residual stresses are introduced. These stresses constantly try to pull the skin away from the core. Adhesives must therefore be selected which will withstand these stresses throughout the life of the panel.

In the case of porcelain enamel on steel, both aluminum honeycomb and paper honeycomb have been satisfactorily used as core materials. Their use results in an acceptably flat panel. In the case of our own experience with porcelain enamel on aluminum, we have also successfully used both aluminum honeycomb and paper honeycomb as core materials. However, in our estimation aluminum honeycomb is too expensive for most commercial applications. The Kawneer panels are generally a composite construction in which the exterior skin is bonded to a reinforcing sub-skin, such as hardboard or asbestos-cement board, which in turn is bonded to a paper honeycomb core, the honeycomb being bonded to the interior metal skin. By interior metal skin we mean that surface which faces the building interior. Sometimes there will be a sub-skin behind the interior metal skin also, particularly if the interior metal skin forms the interior wall of the building. Reinforcing sub-skins are used to prevent damage from denting. Interior skins can be either aluminum or steel. In the case of steel it will be galvanized or aluminized.

One of the most important things, in our opinion, relative to appearance is the use of a textured surface. We highly recommend the porcelain enamel aluminum panel in which the exterior skin is textured. This textured skin can hide a multitude of minor skins which make no difference in the quality or life expectancy of a panel. Minor surface imperfections and minor variations in porcelain enamel generally cannot be detected readily if a textured sheet is used. We would like to be perfect but we recognize that perfection is not quite attainable and therefore we should take steps to compensate. So much for appearance.

Structure

The next function listed for a panel is structural - or the ability of a panel to withstand the loads to which it is subjected throughout the life of the building. By our definition, curtain wall sandwich panels are non-load bearing, so far as carrying any of the vertical load of the building is concerned. Of course the panels must support their own weight and must meet the structural requirements imposed primarily by wind loads, temperature changes, and residual stresses.

The adhesively bonded sandwich panel is probably the best type for withstanding loads normal to the plane of the panel. Since we are generally concerned with wind loads which are specified at a maximum of 20 pounds per square foot, we find that most any type of soft core -- paper honeycomb, plastic foams, etc. -- provides strength far beyond anything required by the imposed loads. The critical points for the loads are generally encountered outside the panel itself in the vertical and horizontal members supporting the panel. In my opinion the loads which are perhaps the most critical are those induced by temperature. The expansion and contraction of the skins, which is going on all the time, day in and day out, year in and year out, requires that the adhesive be of such a nature that it can expand and contract along with the skin without developing any failures. The same is true of residual stresses, always present in the skins, which add to or subtract from the temperature stresses and also the wind loads. The panel must withstand the total effect of all these loads acting simultaneously. These are complicated loads beyond our ability to analyze accurately, even in the laboratory. Our only recourse is to subject the panels in the laboratory to the most rugged effects of temperature that we can devise and observe the results.

We do not have 50 years of experience to call upon in the case of adhesives, but from comparative laboratory data available to us we feel that in the long run adhesively bonded panels should be superior to mechanically fastened panels. Mechanical fastenings such as nuts, bolts, and screws are always subject to working loose. Also, unless welds are adequately protected, there is always the danger of fatigue failures and corrosion. It must be remembered that with respect to adhesive panels the loads are distributed over the entire surface. In the case of mechanically fastened panels loads must be taken off at points. Hence the effect of stresses is generally greater in the latter case. It is recognized, of course, that well designed panels mechanically bonded will perform satisfactorily.

Temperature

Although we have talked about temperature in connection with the structure of the panel and the loads imposed on the panel, temperature itself is one of the largest factors which the curtain wall panel is designed to control. Literally, we put a panel in a wall primarily to insulate the inside of the structure from the outside. In any building it is desired to maintain the interior of the building at a temperature which will provide maximum comfort for the occupants. This means that almost always there will be a temperature difference between the inside and the outside of the building and that panels must provide a barrier to heat transmission one way or the other.

Depending on the economics of the situation and on structural and other requirements, we select our core material so as to provide the maximum insulation value. In our opinion, the appropriate compromise between cost and function turns out to be a paper honeycomb core filled with Perlite or a foamed plastic. At somewhat greater expense, and with more problems relative to achieving a satisfactory bond, we can use foamglas, which provides excellent insulation. One of the objections to using foamglas is the difficulty experienced in taking care of the expansion and contraction which occurs between the skin and the core. Failure to have proper elasticity at this bonding point will cause fracture of the surface cells of the foamglas and thereby cause a panel failure. In our own opinion foamglas, as well as fiberglas, is most satisfactorily used as a filler contained in a pan fixed behind the surface panel.

Difference in temperature between the inside and outside of the panel causes bowing of the panel. This is a fundamental physical phenomenon which occurs in any bi-metallic structure. Bowing cannot be eliminated entirely but it can be minimized through proper design.

Another effect of temperature is to cause a build-up of pressure within the panel core. This pressure is never great enough to cause delamination but it is great enough at times to force out caulking compounds around the periphery of the panel.

The temperature which a panel must withstand sometimes becomes very high, such as the temperature generated by a fire in the building. Building codes require that panels under certain circumstances withstand fire for a period of an hour or more without failure. There are several materials on the market which make satisfactory cores for withstanding fires. To name a few, we have mineral fiberboard, asbestos-cement board and gypsum board. Again, the use of these relatively hard cores recalls the need for proper selection of adhesives for bonding the core to the skin.

Moisture

The subject of moisture and its infiltration and condensation within the panel, is covered in some detail in other papers. Therefore I shall not dwell on the subject except to say that construction of a hermetically sealed panel utilizing present manufacturing techniques is so impractical as to be virtually impossible. For this reason it is our opinion that the selection of core materials and adhesives should always be based on the assumption that somehow moisture will get inside a panel. The presence of this moisture must in no way deteriorate the panel. Also, provision must be made to ventilate and drain a panel so that any moisture that gets in can get out readily. Panels should be so mounted as to avoid wicking action.

Cost

The fifth item set up as a criterion for determining panel design is cost. Perhaps instead of making this the fifth item, it should have been made the first to emphasize its importance. If cost were not a factor it would be much easier for us to meet all of the other criteria. Cost has forced us to consider various means of designing panels incorporating low cost materials as much as possible and utilizing expensive materials only where absolutely essential.

In order to reduce the cost and thus enable builders to afford the advantages of porcelain on aluminum, we have used aluminum in thicknesses ranging from 0.015" to 0.040", depending on whether or not a texture is incorporated and a soft core is used. We can use successfully such thin sheets by backing them with a reinforced sub-skin, such as hardboard or asbestos-cement board. This in turn can then be bonded to a paper honeycomb core.

Of all the materials we have investigated, 18% phenolic impregnated paper honeycomb provides most of the desirable characteristics at the least cost. A panel using aluminum skins, hardboard sub-skins, and a paper honeycomb core gives excellent performance and is very economical to produce. Added properties, such as higher insulation and fire resistance qualities, are achieved only by using more expensive materials.

CORE MATERIALS

No core material is available which satisfies all requirements for sandwich panel construction. In our investigation of core materials for panel construction we found that structural types are preferred where the core contributes to the strength of the sandwich, rather than the filler types added for insulation in a rigid pan.

Paper Honeycomb

Paper honeycomb impregnated with 18% to 20% phenolic resin has been thoroughly investigated and, as indicated, is considered highly satisfactory. It is available in 7/16" cell (TIP 2 grade) and 1" cell (TIP 23 grade). Lower resin impregnation is not approved. Paper honeycomb has high structural strength and stability. In a sandwich it will resist warpage and is resistant to moisture, heat, rot, and fungus. Though it is porous and will soak up water it retains good strength wet and is not deteriorated. Compression strengths of 75 to 110 psi make possible strong, light sandwiches, with fair thermal insulation.

Paper Honeycomb Filled with Perlite

When filled with perlite the thermal insulation qualities of a honeycomb panel are increased greatly. The grade of perlite must be selected for the lowest K-value and the easiest handling. K-values of perlite vary from 0.25 to 0.39. Very fine grades are difficult to handle because of dust. The larger-cell honeycomb is easier to fill and the fill in the honeycomb is more effective in lowering conduction. Perlite is preferred to vermiculite because of its lower water absorption.

Paper Honeycomb Filled with Polystyrene Foam

Kawneer has developed a unique process for foaming polystyrene in place in the cells of a honeycomb to increase the thermal insulation of a sandwich. This very light density foam (about 1 lb./cu.ft.) is impervious to water. The structure is stable at temperatures up to 200°F. because its strength depends on the impregnated honeycomb, not the thermoplastic polystyrene foam. The improvement in U-value depends on the amount of fill, the thickness and cell size of the honeycomb, and the reflectivity of the surfaces of the panel. We have produced panels of this type 1" thick, having a U-value of 0.27.

Styrofoam

Styrofoam, produced by Dow Chemical Company, has about the best thermal insulation of any core material that we have investigated but it has some structural limitations. It is unaffected by moisture or decay and the cells are closed so that the material absorbs no water. Styrofoam is flammable but a self-extinguishing grade is available. It is recommended where thermal insulation and waterproofness are of great importance and where temperatures do not exceed 150°F. It is not recommended where panel flatness and stability under hot sun temperatures are important. Also, it should not be used where warped facing sheets must be flattened out, leaving residual stresses which may cause warpage under heat.

Rubatex

Rubatex is the trade name of a rigid, closed-cell, foamed rubber. We have considered it for architectural sandwiches, since it has excellent thermal insulating properties, good structural strength, and stability with respect to moisture and moderate heat. However, its price is high, it becomes brittle at low temperatures, it is limited in thicknesses available, and adequate data on its aging properties are not available.

Foamglas

Foamglas, produced by Pittsburgh-Corning Corporation, has a sealed glass-cell structure which is impervious to water, maintains a constant insulating value, is non-inflammable, and has high compression strength. It has a density of 8 to 10 lbs./cu.ft. and a K-value of about 0.39 BTU/hr./sq. ft./°F./inch. Though non-inflammable, it has only fair fire resistance because it shatters and melts in a flame. The principal limitations of foamglas are its brittleness and limited sizes. Panels with foamglas cores must be fabricated with a rigid sub-skin under the facing sheet. This is necessary because foamglas thickness tolerances are not accurate and because the panels have a number of joints due to the small block size of 18" x 12". The adhesive materials must be resilient, such as neoprene-base cements. We have had no production experience with adhesively bonded foamglas sandwich panels.

Temlok and Other Wood-Fiber Boards

Temlok is a wood-fiber board which is available in a waterproof grade impregnated with asphalt. It is very cheap, and our laboratory tests have indicated that it has adequate strength and moisture resistance for many architectural sandwich cores. Temlok is manufactured by Armstrong Cork Company. Similar materials are available from other manufacturers. For panel use the waterproofness of the factory lamination requires improvement. In thicknesses over about 0.7 inch it is built up by laminating several thicknesses in the factory. It can be used in place of plywood for moderately thin panels and it may be used to replace honeycomb for thicker panels.

Minitone - Mineral Fiber Board

Minitone, manufactured by Armstrong Cork Company, is glass fiber board with binders that are partly inorganic. This material has been adopted by us for a flush fire door. It has possibilities for use in fire-rated wall panels. The material has poor dent resistance and can be delaminated easily, but in a properly designed sandwich, with bound edges and sub-skin reinforcement, it would appear to be a satisfactory fireproof core.

Fiberglas

Fiberglas is a glass fiber material manufactured by the Owens-Corning Fiberglas Corporation. It has excellent thermal properties and ideal resistance to weather. It is not ideal in an adhesively bonded sandwich, however, because of its poor resistance to compression and its tendency to delaminate. These difficulties can be overcome, to a large extent, by mounting the fibers normal to the plane of the panel. Unfortunately, doing this results in a great loss of thermal resistance.

Asbestos-Cement Board

Asbestos-cement board is recommended as a core material for thin panels or as a reinforcing sub-skin in thick composite panels. Asbestos cement is superior to other materials for these uses because of its good resistance to fire, heat, moisture, and rot, and its very hard, strong structure.

Hardboard

Standard hardboard is made of wood fibers bonded under heat and pressure, with their own natural resins as the principal binder. Tempered hardboard is the same material impregnated with oil and/or resin. Hardboard is recommended for use as a reinforcing sub-skin and as a thin core. It gives high dent resistance to the facing. Either standard or tempered hardboard are approved for these uses. Tempered board will not warp or expand as much as the standard board under severe moisture conditions, but the standard board is cheaper and with some adhesives gives a better bond. Some adhesives have been found which greatly reduce the effect of moisture by effectively sealing the surface of the hardboard. The greatest weakness of hardboard is its tendency to delaminate internally and to swell with moisture, but it will pass the Forest Products Laboratory accelerated aging test (detailed specifications are included at the end of this paper) with but little loss of strength.

Plywood Cores

Exterior grade plywood is a satisfactory material for the cores of thin panels. In the field it is easier to cut than asbestos-cement board cores, and thus would be desirable where large panels are to be laminated in the plant and cut to size on the job. It is stronger than hardboard, especially in its resistance to pulling apart and delaminating within the core. It has stood up well in the accelerated aging test.

ADHESIVES

Introduction

Adhesives are a vital part of structural architectural sandwiches. If the individual components should separate or delaminate because of adhesive failure, the whole structure would be useless. Even though the panels may not be load bearing, the bond must be strong enough to withstand the internal and external stresses that tend to tear it apart. These stresses may be caused by handling, wind loads, uneven expansion and contraction, and warpage or irregularities of the original components straightened out during lamination. This bonding strength must be maintained under extreme service conditions of heat, cold, and moisture, and the bonding adhesive must resist aging and chemical attack. Some of the factors to be considered in the selection of adhesives are their durability under the conditions of use, the chemical and physical nature of the components to be bonded, the processing methods which can be used in applying and curing, and the cost of the adhesive as applied.

Adhesive Bond Strength

The adhesive must bond to the metal surfaces of the sandwich facings. Most of those which will be discussed here have good adhesion directly to metal, provided the surface is clean and properly prepared. A few, like the resorcinol-phenolics, have poor adhesion to metals and require that the metal be primed with another type of adhesive. In some cases special treatments have been developed to give better bonds which are more resistant to moisture. With some adhesives the advantages of such treatments are difficult to prove. These treatments may be acid chromate dips, as usually specified for aircraft aluminum bonding, or they may be proprietary conversion coatings, such as those used for improving adhesion of paint coatings. Some special treatments have been developed also for aluminum, porcelain, and stainless steel.

Cohesive Bond Strength

It is necessary to accept a compromise in the properties of the adhesive, according to the specific use. A hard adhesive may have high shear or static load strength but may be too brittle and fail under impact or peel tests. A soft, flexible adhesive, on the other hand, may have better resistance to impact and peel but may creep or flow under stress.

Durability of Adhesives

If a panel is to last the life of a building, all parts of it, including the adhesive, must resist moisture, heat, and chemical deterioration. Since many of the materials are new, the selection of durable adhesives must be deduced from their performance under conditions more severe than those in actual service, using accelerated aging tests.[1] The results of such tests are not positive, and may be unfair to some materials, but they are the best we have. Properties of some of the base materials can be predicted from known performance in other uses. Selection of adhesives for chemical resistance should take into consideration not only such environmental factors as resistance to oxidation and moisture, but also the possible reactions between the adhesive and other sandwich components. For example, some plastic core materials may be attacked by solvents used in the adhesive, and some materials, like asbestos-cement board, are alkaline and will deteriorate certain adhesives.

Processing

Most of the adhesives used in structural sandwiches are thermo-setting to varying degrees, and the time required to obtain the optimum cures is a factor in selection. In architectural work it is desirable to keep processing time to a minimum, if costs are to be competitive. Some adhesives require hot platen presses, but others may be pre-heated and bonded in squeeze rolls or cold presses.

Physical Characteristics of the Components to be Bonded

The porosity or permeability of the sandwich component are an important factor in the selection of adhesives. If the bond is between two non-permeable materials, such as metal, foamglas, or styrofoam, there must be no trapped solvents or gases in the adhesive. Some adhesives, like epoxys, cure to 100% solids, with no evolution of gases. These are ideal for bonding impermeable materials. Some adhesives can be dried of all solvents and heat reactivated, and thus used with impermeable materials. Porous materials are much simpler to bond.

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[1] Forest Products accelerated aging test: Tech. Paper No. 7, Housing & Home Finance Agency, Washington: or A.S.T.M. Spec. D1037-52T, A.S.T.M. Standards 1952, Vol. 4, P. 845

Neoprene Type Adhesives

The most versatile of the adhesives now being used for architectural sandwiches are those based on neoprene synthetic rubber. Neoprene has an established reputation for excellent resistance to aging, weathering, and heat. These desirable qualities have been reflected in many of the neoprene adhesives. These adhesives have stood up well in accelerated aging tests and have excellent adhesion to metals and most other materials. Their peel strength is the highest of any adhesives we have tested, and their shear and creep strengths are quite adequate.

There are a number of brands and grades of neoprene type adhesives on the market. They are usually blended with other resins so that they vary in heat resistance, curing conditions, etc. Most of them are of the solvent types and their cost is moderate. A few are available as emulsions or latices, which are very easily applied. Neoprene type adhesives are adaptable to several different techniques of hot and cold bonding, depending on the specific case. Hot laminating generally gives stronger and more resistant bonds, as the adhesives cure or vulcanize. Some of the adhesives formulated from neoprene can be dried and heat activated after application, so that they give "instantaneous" bond on contact. This bond has enough initial strength to permit immediate release of pressure, thus facilitating handling and fabricating. This also makes possible high speed continuous laminating, using "squeeze rolls" instead of platen presses.

Modified Phenolic Adhesives

Ordinary phenolic adhesives do not adhere well directly to metals and are brittle, but they can be modified with various other resins and rubbers to give excellent properties. The aircraft industry is using large amounts of phenolics modified with polyvinyl acetates, butyrals, and other resins. These "vinyl-phenolics" have demonstrated excellent strength and durability. They would be of more use in structural architectural work if they did not require such long-time curing at high temperatures.

Phenolics modified with acrylonitrile rubber ("Hycar," "Buna-N" or "GRA") have excellent potentialities in architectural sandwiches. Though they do not have flexural or shear strength as high as the vinyl-phenolics or epoxys, some of them are more convenient to process, more flexible, and cheaper. Our tests indicate that their durability and strength are satisfactory for architectural sandwiches. These modified phenolics are available as solutions and also as dried films. The dried films can be laid in place during assembly and then bonded with heat and pressure, eliminating much of the time and equipment required to apply and dry the solution-type of adhesives.

Resorcinol-Phenolic Adhesives

Resorcinol-phenolic adhesives are thermo-setting resin adhesives. They are well-known for their use in waterproof bonding of woods. They do not adhere well directly to metals. However, by applying a primer, such as casien-neoprene latex, to the metal and then using the resorcinol-phenolics, a very durable, strong but brittle bond is obtained. These adhesives are mixtures of resorcinol-formaldehyde and phenol-formaldehyde resins, usually in alcohol solutions. The resorcinol gives them the property of thermo-setting in short times at relatively low temperatures, compared to most phenolics. They are not tacky when applied and thus are an advantage in complicated assemblies where parts must be fitted and moved. There are some special cases where the properties of these adhesives have been found very desirable. Their general use is limited, however, by their brittleness and low peel strength and by processing difficulties, such as the necessity of two components mixing, short pot-life, and irritating formaldehyde fumes.

Epoxy Adhesives

The most recent resins to be employed as basic materials in adhesive formulations are the epoxy, or ethoxyline, resins[1] made from derivatives of ethylene oxide reacted with polyfunctional alcohols or phenols. They have great potentialities in structural sandwiches because of their excellent adhesive strength and durability. Their adhesion to metals and most other materials is very good, and they are very inert to moisture, most chemicals, and aging. They can be cured, with catalysts, over a wide range of temperatures from room temperature up, which makes them versatile under conditions where heating is difficult. Epoxys can be formulated without solvents or other volatiles so that they can be placed between two impervious materials, e.g., metal-to-metal, and they will cure into 100% solid with no trapped gases. On the other hand, they are still too expensive for many architectural applications. Moreover, they have processing difficulties because they must be mixed with the catalyst just before use; they have limited pot-life; they are somewhat toxic; and they require relatively long curing times.

The epoxy resins are often blended with other resins and rubbers, such as polyamides, phenolics, or Thiokol, to improve their properties for specific uses. The principal uses of epoxy adhesives have been in aircraft sandwiches and metal bonding. However, they have properties that make them uniquely suited for solving special problems in architectural panels and structures. For example, the Wolverine Porcelain Company found that epoxy adhesives were the best solution to the bonding problems in the panels used in the General Motors Technical Center.

Miscellaneous Adhesives

We have experimented with and tested a number of other types of adhesives, but so far they have not proven satisfactory. Emulsions have interested us because of economy and ease of application, but none has stood up in the accelerated aging tests when used alone. Some have been satisfactory as primers, however. There are other resins, such as polyurethanes, polyesters, etc., which have many desirable qualities and may be important in architectural laminates in the future. We do not expect adhesive manufacturers to come up with an ideal, universal adhesive, for it appears that there must always be a compromise on properties, processing, and prices.

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[1] "Epon" is Shell tradename.

FOREST PRODUCTS LABORATORY ACCELERATED AGING TEST

Test specimens, 3 in. by 12 in., in varying thicknesses are subjected to the aging test as follows:

1. Immersed in water at 122° F. for 1 hour.

2. Sprayed with wet steam at 194° to 200° F. for 3 hours.

3. Stored at 10° F. for 20 hours.

4. Heated in dry air at 212° F. for 3 hours.

5. Sprayed with wet steam at 194° to 200° F. for 3 hours.

6. Heated in dry air at 212° F. for 18 hours.

The above sequence of exposures constitutes one cycle. Test specimens are continued through six cycles after which they are examined visually with any changes being noted. Tests are made to determine any change in strength properties. The test results are compared with the results of tests made on control specimens not subjected to the aging test.

MR. TABLER (The Moderator): Thank you, Jack.

DISCUSSION

MR. TABLER (The Moderator): We will ask the three panel members, Mr. Callender, Mr. Posey, and Mr. Roehm to come up here. They will answer the questions you have written and addressed to them.

QUESTION: What pre-treatment was given the stainless steel prior to enameling?

MR. CALLENDER: The answer is none. It was simply cleaned, using a form of common cleaning compound.

MR. SIMMONS: Which, if any, of the stainless steel alloys gave the best results?

MR. CALLENDER: I suppose the question refers to the experiments on coloring. I can't answer that question. We tried it on both type 302 and type 430, with no perceptible difference in the results, although we did not subject the colored samples to exhaustive tests of every description. We were primarily interested in the appearance.

QUESTION: In all of the present methods of curtain wall construction there remains only one wet operation, the hand placement of glazing or calking compound. Could you discuss its elimination and also the trap operation by means of factory-installed neoprene or vinyl continuous gaskets or extrusions? Is it possible to detail a joint which will remain weather-tight when all its calking has deteriorated or is without calking or gaskets?

MR. POSEY: There are two questions here that are quite parallel: they have to do with glazing compounds, primarily, or the sealing of the joint. I think that a brief description of glazing compounds, as such, might be in order here. Originally, calking compounds depended upon occasional repainting to retain their oil and their plasticity. When we started using aluminum windows, or windows that were not painted, the compound manufacturers changed their formulation so as to develop a compound that would retain its elasticity over a longer period of time without repainting.

Quite frankly, I believe that the life of present unpainted glazing compounds is altogether too short. We have had problems, as Mr. Tabler mentioned, with the glazing compound giving away on the surface, and we have had to go back (as in the case of the Lever House, which is now in its fifth year) and go over the periphery of the glass with a thin pointing of synthetic rubber. I am afraid that is what we are going to be faced with again and again if the glazing compound people can't meet the challenge by coming up with a practical material that can be used as a glazing compound that will still stand up over a period of years.

The synthetic rubber that we have used comes in a cartridge, which is inserted into a calking gun. Sure, it is a very simple operation, but you can't use that messy stuff for the entire glazing bed, for it is a pointing compound, purely and simply. In several instances we have used neoprene and other types of pre-molded gaskets. In some instances, we have included these in the original specifications and also protected those sealing materials with this synthetic-rubber pointing compound.

In the first place, I think there is no final answer to any construction problem. If there were, the architect might not be as useful as he is. Architecture has been defined as the most useful of the fine arts. I should like to keep it useful, and I think that the architect has to contribute to the solution of these problems. I believe that our lives would be rather dull if we didn't have some of these glazing problems.

QUESTION: If a non-metallic laminate has an inherent tendency to curve, why not use a tri-laminate?

MR. ROEHM: The bimetallic laminate has a tendency to curve, to bow, primarily because of the temperature difference on each side of the panel. If we have perfectly flat aluminum on each side of the panel and we have the same temperature on both sides, the panel will remain flat. If the outside temperature is increased greatly, the outside skin would expand more than the inside skin, curving in an outward bow. If the temperature should drop, just the opposite would occur. The tri-laminate would not solve the problem at all. It is a matter of metallic expansion and contraction as the result of temperature changes. You can attain some compensation if you know the conditions of climate by using, let's say, aluminum on one side and perhaps steel, aluminum, or steel on the other.

QUESTION: Considering the stainless steel slab pre-cast concrete wall panel, do you believe that a thin layer of non-hardening adhesives between the steel and the concrete would assist in overcoming a waviness tendency in the stainless steel due to expansion and contraction?

MR. CALLENDER: If the question means what I think it does, the answer is yes. We found that in pouring a light-weight concrete into a stainless steel pan type of facing, there was not sufficient natural bond between the light-weight insulated concrete and the stainless steel to resist even the shrinkage of the backing, much less resist the stresses set up by the expansion and contraction of the face. However, by the introduction of an adhesive before the concrete was poured, we found that a sufficient bond could be developed to overcome the stresses that would arise and, from our experiments, that the combination seemed to be quite promising.

QUESTION: What is your opinion regarding inside glazing as compared to outside glazing against rabbit stop?

MR. POSEY: There is a very simple answer. Glaziers are human beings, and unless there is someone on the outside watching when they push the glass in, they are very much inclined to push it into the rabbit so far that the exterior bed of glazing is made so thin that it is going to dry out very quickly. If that same thing happens on the outside, it is not so serious. Best of all, try to get your glaziers to exercise the utmost care in centering the glass in the seating bed, and also use one of the various methods of assuring the centering of the glass or the metal panel in the bed.

MR. ROEHM: I have here a number of questions addressed to me (I was afraid I was going to get this) on moisture migration, ventilation, and taking water out of any construction using a paper honeycomb sandwich. I don't want to avoid the specific issues that are posed but I can answer them best by discussing some principles. First of all, in our construction we try to keep all moisture out by suitable edge construction of the panel. We have metal both inside and outside forming a vapor barrier, which Mr. Rogers mentioned as being so important.

There will always be a tendency for vapor, moisture, and light to come in around joints or any flaw. We put some panels out for a couple of winters and, literally, put a steam chest on one side while we had freezing weather on the other side. Moisture will condense in the honeycomb, but even with its phenolic impregnation it is porous, and the moisture will tend to go to the bottom. If it can get to the bottom, it will get into the frame and fray out, and no damage will be done.

It can also evaporate. Vapor can go up through the top of a suitable vent. Someone might ask, what happens if the moisture stays trapped in there? That is what we don't want to happen. If moisture should stay trapped (let's assume it is filled up solid with water), the strength of panel will not be weakened as nearly as we can tell. There will be no bad effects unless you get a quick freeze. If you get a quick freeze the panel will fail, so you have to be sure to design the structure properly; that is, the whole system--panel, supporting system, and the like.

QUESTION: You mentioned porcelain enamel on one side of thin stainless steel, Mr. Callender. Did not this result in curvature?

MR. CALLENDER: No, it didn't. Frankly, that surprised us as much as it surprised you, I suppose. Why it didn't, I wouldn't undertake to say, but it didn't in the samples that we tested.

QUESTION: You mentioned that larger panels of paper honeycomb construction had to be made from 2 to 4 inches thick. Would it interest you to know many large panels are now made 3/4" to 1" thick, in sizes from 3'-6" to 9'-6"? The extra thickness is usually recommended for extra insulation.

MR. POSEY: Yes, I am interested, but I still wouldn't use it.

QUESTION: With respect to fastening to building frame, how do you take care of expansion and contraction?

MR. ROEHM: We like to factory-assemble the panel between split bonding framing elements and vertical elements. We recommend that a final gasket be used around that panel, between the panel and its aluminum frame. We take care of our expansion and contraction, actually, between the modern elements themselves which are interlocked and allow for motion of a certain type. We can take care of a small amount of this motion and also the motion between various elements, because of this final gasket that we use.

MR. TABLER (The Moderator): Gentlemen, so that we don't detain all of you, I know we have run a little over our time schedule here and I probably should call the panel discussion to a close. Before we adjourn, I will turn the meeting back to Mr. Tuttle. I think we should have a round of applause for our panel members here. [Applause]

MR. TUTTLE (Chairman): Thank you very much, Mr. Tabler, Mr. Roehm, Mr. Posey, and Mr. Callender. You have been a very attentive audience today. I think that speaks very well for the excellent speakers.

INTRODUCTION TO PARTS V, VI, AND VII

By Harry B. Tour
Head Architect
Tennessee Valley Authority

MR. TUTTLE (Chairman): Your Moderator for the presentation and discussion of the next three papers is Mr. Harry B. Tour. Mr. Tour is Head Architect of the Tennessee Valley Authority. He is a graduate of the University of Illinois, with a degree of B.S. in Architectural Engineering. He is a member of the American Society of Civil Engineers and also the American Institute of Architects in which he served as Director of its Knoxville Chapter.

MR. TOUR (The Moderator): Thank you, Mr. Tuttle. Ladies and Gentlemen: As Mr. Tuttle told you, we in the TVA have been using metal panels quite extensively for the past 6 or 7 years and we have liked them very much. But whatever induced the planners of this program to assume that the use of metal panels qualified the user to serve as moderator of a session of this kind, I haven't any idea. Anyway, here I am, and I consider it a privilege and pleasure to be invited to participate in this panel discussion.

Our speakers yesterday spoke considerably about the architectural design and some of the construction details and gave us a very interesting preview of the wonderful possibilities of metal curtain wall construction. With few exceptions, they expressed the feeling that this type of construction would provide almost unlimited architectural possibilities, would reduce building costs, and would provide better building if--and this is an important if--we understand properly the limitations of this material and are aware of the problems and how to deal with them.

The three speakers this morning are prepared to discuss some of the special problems encountered in the design and erection of metal curtain walls and to tell us how to avoid trouble in order to get the most out of this kind of construction.

The planners of this program had intended that there would be a question period after each of our speakers this morning. But, considering that we do not have floor microphones, and that it takes a little time to get questions up to the panelists from the audience, and also because of the possibility of some interrelationship of the subject matter covered by the speakers, it seemed desirable to the planners to have all three speakers present their papers first and then allow a question-answer period after that.

Judging from the AIA and the BRAB surveys and the questions that came from the floor yesterday, one of the most important considerations, apparently, in the minds of you people, and others who are concerned with this subject, is the matter of thermal insulation and the control or the elimination of condensation. Here to discuss this subject is Professor Elmer R. Queer.

PART V

PANEL INSULATION AND CONDENSATION CONTROL

THERMAL INSULATION AND CONDENSATION CONTROL IN METAL CURTAIN WALLS

By Elmer R. Queer
Director and Professor of Engineering Research
The Pennsylvania State University

MR. TOUR (The Moderator): Mr. Queer is Director and Professor of Engineering Research at the Pennsylvania State University. Professor Queer graduated from Penn State in 1926 and received his Master's Degree in Electrical Engineering from the same school in 1928. Thus, he has been associated with the research end of the Engineering Experiment Station at Penn State, except for a 6-year stretch in the Navy, in which he helped Uncle Sam develop technical procedures for preserving ships and military material by dehumidification. He is a member of the American Society of Heating and Ventilating Engineers, A.S.M.E., the Chairman of Committee C-16 of the American Society of Testing Materials.

Now, if that isn't enough to convince you that our speaker is well qualified to discuss this subject, I would like to quote a sentence from a letter which was received by the Building Research Institute from the president of the Erie Enameling Company, commenting upon the subject of condensation of vapor water, in which he says, "No one actually knows what goes on inside the wall, and Professor Queer knows much more than anyone else."

MR. QUEER: A great deal of attention is being given to the thermal properties of materials and combinations of materials in modern construction practice. This is made necessary for economic reasons as well as comfort considerations. Mounting fuel costs and the desire for a greater degree of comfort for the occupants are the principal motivating factors that make it necessary that buildings be made tighter and better insulated. Other economic factors, as well as aesthetic appeal, have made the metal curtain wall a practical means for enclosing new buildings. As an outgrowth of these developments there are thermal and moisture problems that become exceedingly complex when the chief components of the spandrel wall sections are metal. If the problems are well recognized and careful consideration is given to the factors involved there is little likelihood that any trouble will develop during the life of the building. In this discussion windows will also be considered a part of the curtain walls.

Among the thermal factors that must be considered are: first, a high resistance to heat flow in a thin panel; second, the thermal by-pass in the structural members of the wall, the joints between panels, and the points at which panels are fastened onto the structure of the building; third, the heat capacity of the panel, which has a bearing upon the thermal lag of the structure; fourth, the expansion and contraction of the wall caused by temperature changes; and fifth, the color and shading effects of the outer skin of the panel on the heat transfer characteristics of the walls.

The second major consideration that will be discussed deals with water, in its vapor, liquid, and solid forms and its effects upon the walls. Consideration must be given to water because of the insidious problems that it creates. The most important item is condensation, and proper provisions must be made to avoid it. Second, the weather joints must be tight to prevent the entrance of weather water. Third, the inner faces of the wall must be warm enough to prevent the formation of condensation and incidentally warm enough for the comfort of the occupants. Fourth, panel deformation caused by repeated freezing and thawing of water can be a problem. Fifth, corrosion, which is aided and abetted by moisture, must be guarded against.

Certain laboratory procedures have been developed to observe and measure these thermal and moisture conditions in the panel under exposures that simulate actual practice so as to avoid difficulties in future installations. These procedures have not yet been standardized. On the other hand, the heat transfer measurement procedures are well standardized and the results therefrom are quite indicative of those to be expected on installation.

Thermal Factors

Owing to the high strength factors of the materials at hand for fabrication of metal curtain walls, it is possible with a thin outer shell to gain an advantage of additional space in the building. In order to provide the desired thermal resistance in a panel, heat insulation in some form is incorporated in the construction. There are several desirable properties of insulation that will encourage the selection of those materials which possess them. A reasonably low thermal conductivity, or "k" value, is useful in order to give a high thermal resistance to the wall. Since good handleability and low transportation costs of the curtain wall are desired properties, low density insulation has a fair degree of importance. The insulation should not be so fragile that it can be damaged easily in handling. These two factors are important in preassembled panels. When the insulation has good structural strength it can be laminated into the wall with adhesives which may reduce the metal structural ties between the two faces, consequently the over-all heat resistance of this type of panel will be favorable.

Another property of the curtain wall that plays an important role in air conditioning is the heat capacity of the composite assembly. When a wall section has considerable weight and mass, as in masonry construction, it is slow to respond to temperature changes. As a result of this slow response, the thermal-lag develops a longer-time transient heat flow condition that can make the peak and valley heat waves be delayed as much as 8 to 12 hours in air conditioning heat loads. For a light-weight, low-mass panel the response wave may be one hour or less. For example, the summer sun heat load on a west wall in the afternoon in the northern latitude will have to be accounted for at about full value a very short time after it is projected onto the wall. In both air conditioning and heating these factors must be recognized, otherwise the system will not meet the requirements set forth, particularly in certain zones of the building. In other words, large mass and high heat-capacity have permitted the mechanical equipment designers certain liberties that they cannot afford in these curtain wall constructions. It is not meant to infer that the low-density, light-weight wall has an undesirable property of low heat-capacity, with its reflection on the mechanical equipment requirements, but the effect of this property must be recognized in the design. Low heat capacity, and the resultant quick response, is one of the reasons why metal walls do not perform at the same standards required for masonry walls. The high thermal conductivity of the metal and its loss of strength at elevated temperatures are other reasons for a shorter durability of the metal curtain wall when being fire-tested.

The effect of the relatively high coefficients of expansion of metals must be evaluated for the walls under consideration. Since the primary requirement of a wall is to provide a tight closure for the envelope of the building, unplanned openings resulting from the movement of the structure can cause trouble. Water and air leakage into the building, resulting from contraction of openings, cannot be tolerated. On the other hand, uncontrolled expansion from heat will cause buckling of the walls. Improper attention to the thermal expansion and contraction characteristics may be a source of complaints if the metal walls make "creaking" and "cracking" noises from movement.

Another factor that is very difficult to resolve in the insulation of the metal curtain wall is thermal by-pass caused by the necessity of heavy metal structural clip members in the wall to obtain the desired strength. In most cases the insulation itself does not possess sufficient strength to make the wall structurally adequate without these members. The metal members, although of small cross-section area, have a relatively high thermal conductivity (insulation "k" values 0.30 to 0.40 -- metal "k" values 100 to 1400) and form parallel heat by-passes through the insulation. This is particularly true at the edges of the panel and where the panel is fastened to the building structure proper. Much good thermal insulation can be nullified by these small structural members and attachment points on the main building structure.

As a result of numerous tests and observations made in the Thermal Research Laboratory at The Pennsylvania State University, it has been found that tortuous metal paths at the edge of panels add little to the thermal resistance. The best procedure at the edges is to keep the metal as thin as possible consistent with the structural requirements of the panel. If it is practical to provide a break in the metal-to-metal faces on the edges of the panel, the break will serve as a good means to raise the heat resistance at one of the most troublesome and thermally weak points. Plastics which have a relatively low "k" value compared to metal should be considered for the structural ties between the two faces. Quilting bolts of the proper size, judiciously spaced, do not detract materially from the thermal resistance of the insulation. This is a rather unusual thing. You calculate the heat load through those thermal tortuous paths and it looks as though they can damage the insulation very easily. We found in ship structures that we could use these metal studs quite effectively without hurting the thermal transmission value very seriously. To cite an example, we got about a 5 percent rise in the heat transfer coefficient over what one would normally expect if the insulation were put on the base of the material. This arrangement is important because it can form the basis for securing a strong structure that is well insulated thermally. The same method can be used to fasten the panel to the main building structure. The primary considerations are to place some insulation in series with the path of heat flow and to avoid by-passes as much as possible. In the case of quilting bolts this is desirable but not essential.

The last two factors that will be discussed under the thermal heading are the effects of color of the exterior surfaces and the shading effect of the outer skin on the thermal properties of the panel. White and the light colors will reflect a large portion of the energy contained in solar radiation. On the other hand, black and the dark colors will absorb much of this energy and convert it to heat. All clean, bright, metals will reflect the sun's short wave infra-red rays quite well, but they also absorb a portion of the energy in the white-light band. Their solar absorption characteristics lie between white and black. Part of this heat is radiated and convected to the outside atmosphere and the remainder is available to be transmitted into the building. The magnitude of the heat load from this source can be large or small, depending on the surface color and the design arrangement within the panel. For instance, if an adequate air wash system is provided behind the outer skin in the panel then the color effect is largely nullified. Most of the heat absorbed by the surface is carried off by natural convection on both sides of the skin. Obviously, the outer skin in this case serves to "shade" the building, and shading is one of the most effective natural means of controlling solar heat gains. Buildings with dark exteriors and an air wash system have practically no solar heat gain problems. This factor can be an important consideration in tropical installations as well as any place that summer air conditioning is to be used in the buildings erected.

In passing from this subject, a comment should be made about windows which do form a part of the wall. At best, a window has a high heat-transfer coefficient compared to the rest of the wall ("U" value of 1.13 for single panes and 0.45 for double panes as compared to "U" values of 0.20 to 0.10 for the walls). Solar energy received through the glass can be substantial when the sun shines on the window. Solar-retardant glasses have been developed and are used extensively in an attempt to limit this source of heat. An understanding of heat generation and transfer in glass should be known to properly handle the situation that develops in this element of the wall. When the sun's rays strike a single pane of solar-retardant glass a substantial portion of the energy is converted into low temperature heat which raises the glass temperature. The glass becomes a radiator to both the weather and the inside of the building, since its emissivity at these low temperatures is close to that of a black body. It is also opaque to low temperature, long wave length radiation as well as a portion of the short-wave solar energy. Therefore, in order to prevent the single pane solar-retardant glass from becoming a serious panel heat radiator in the summer at higher latitudes and at all times in the tropics, a clear pane of glass should be used on the inside to serve as a radiation screen. Otherwise, venetian blinds or some other screening arrangement must be used to maintain the comfort of the occupants. To take advantage of the solar energy in both the summer and winter the ideal situation would be to have a reversible double window arrangement. In the summer, the retardant glass would be on the outside with the clear glass on the inside; in the winter, the clear glass on the outside with the retardant glass on the inside. Care must be observed in the design of the metal window mounting of the glass and the frame so as to avoid excessive heat transfer at these points. Otherwise, troublesome condensation will result in the winter.

Water Factors and Condensation

In general, condensation and water in metal curtain walls has rarely been a problem, principally because careful attention has been given to the design, utilizing the results obtained from testing and experimental programs. Perhaps I should qualify that statement by saying that where they have not been carefully tested with a change in the arrangement, there have been times when this condensation problem has been serious in certain metal wall constructions. Of immediate concern is the deposition of water in walls, which may cause staining of the exterior, buckling from repeated freezing and thawing, corrosion, and ultimate deterioration from the insidious effects of water. In order for condensation to occur in a wall there must be a source of moisture and the temperature of the wall in the presence of the moisture must be below the dew point of the air within the wall. Moisture is always present in the atmosphere, and this can be a source of condensation in the exterior ventilated wall. However, this is not considered a serious condition because the weather air ventilation will ultimately clear it out of the wall. This condition occurs only when relatively mild weather conditions prevail following an extreme cold spell. The quantity of water deposited during this time is usually small because the condition disappears as soon as the weather turns colder or the building structure becomes warmer.

The more serious source of moisture is that coming from the occupied spaces in cold weather. This moisture may be purposely injected in the building air to provide comfort of the occupants, it may be the result of industrial processes, or it may come from ordinary living activities such as cooking, bathing, and laundering. In the winter the moisture content of the weather air is low, and owing to the vapor pressure differential between the inside air and that of the weather a large outward pressure gradient is created. This causes moisture to flow outward if unimpeded. Because of the large temperature differential between the inside and the outside existing at that time of the year, the temperature of the outer portion of the wall may be well below the dew point temperature, with plenty of opportunity for condensation. Under prolonged conditions of cold weather, substantial ice build-up has been known to occur in walls. In the summertime the vapor pressure differential is in the opposite direction, or inward, in an air conditioned building and the moisture lead, if the moisture flow is unimpeded, can add to the latent load of the cooling system. However, the condensation problem in this case is virtually non-existent because of the relatively small temperature differential between the weather air and the interior of the building.

The egress or ingress of moisture in a building can be controlled with an adequate, continuous vapor barrier. In order to prevent trouble, the barrier must be located as near the winter warm-side of the building wall as possible. So far as the summer condition is concerned, this arrangement will be satisfactory in the great majority of the cases. It is conceivable that some situations may arise when industrial processes requiring exceptionally low dew points and intermediately low temperatures in the summer would require a dual vapor barrier system. These cases will be exceptions. If the building is plastered on the inside, a good paint system consisting of two coats of high gloss or aluminum paint, with a decor finish over them, will provide an adequate barrier. In the event that plaster cracks occur, the paint barrier system will be discontinuous at these points. Continuous metal sheets and foils, properly sealed and installed, can serve as excellent vapor barriers. Asphalt duplex papers under a plaster base serve as good vapor barriers. In many cases it is found expedient to combine the excellent heat insulating aluminum foil with gypsum lath (applied to its back) for the purpose of creating a vapor barrier. The importance of good workmanship in the application of vapor barriers cannot be over-emphasized. If the design is adequate, careful inspection should be provided to assure that the desired results are attained.

Since air conditioning has become an important factor in modern buildings, it is necessary that a vapor-tight structure be provided in office and apartment, as well as industrial, types of buildings. Not much attention has been paid to this requirement in the past, but now to properly control the latent load on the cooling system it is essential to have a good degree of tightness as well as a low water-vapor transmission factor. Tightness is also important to prevent wind-blown rain from entering the walls of the building. Water from this source has been the cause of many condensation problems. Streaking on a building usually comes from the weather water entering the walls, since the quantity of water is much greater from other sources. Joints and wall flashing must be effectively tight and properly installed to prevent water from leaking directly into the building and damaging the interior finishes.

Since water and ice may accumulate in walls, repeated freezing and thawing can be quite damaging to the appearance of the building. In some cases where there is no air space between the metal skin and the mass material backing the skin, it is likely that freezing occurs, and waviness of the exterior surface could be caused by this action. Such conditions will be more severe on the north side of the building in the colder climates. Generally, freezing and thawing to any major extent is a rather remote possibility. The greatest likelihood of its occurrence is in industrial type buildings where processes require or produce high humidities in the winter months.

The presence of moisture in a metal wall is always a potential catalyst for corrosion. Although protective coatings are specified and used in ample quantities, they are not at all times applied to a completely dry surface. Hence, moisture is trapped under the coating, and corrosion can occur to disrupt the coating and open it to further corrosion. Another potential source of corrosion in metal walls is the use of dissimilar metals that are not properly insulated electrically. Water, which serves as an electrolyte at the points of contact, can materially hasten corrosion. Therefore it is desirable to keep the wall as free of water and moisture as is possible.

In the previous discussion the emphasis has been on preventing the water from entering the wall. Now with all these precautions carefully observed it will be found that in actual practice it is difficult to keep a wall completely dry. Therefore, a weather air wash or ventilation system is being used effectively to keep a wall safely dried out. For the system to be completely effective, sufficient air must be taken from the weather and passed under the outer skin and then released to the weather. Care must be observed to insure that the thermal insulation system provided is not penetrated or by-passed by the ventilation air. If the insulation is adequate and properly installed, the flow of weather air will not reduce the heat resistance of the wall very much. It is the practice to recommend as much ventilation area in the wall as is possible to secure, consistent with the maintenance of the general weather integrity of the wall. For this purpose, air tubes or channels can be provided in cast or formed low-density concretes. The spacing and size of these vent systems have not been resolved completely. It is essential that the ventilation system provided be protected on the weather side from wind-blown rain, insects, and birds. If small holes are used one should be cautioned that frost has been known to form crystals in them and clog the vent system. A 3/4-inch diameter tube is large enough to avoid this condition. If wire screening is provided, attention is directed to the fact that 16-mesh screen reduces the effective area by about 50%.

Testing Procedures

It is believed that one of the most important things to be done for walls at the present time is to develop testing procedures that are realistic and can be standardized. These are essential to assure the designers, the construction industry, and the financing or underwriting agencies that the building will have the full life for which it is designed, without excessive maintenance. The chief difficulty in devising a testing procedure is the necessity for making the requirements of the test realistic. Time does not permit that a test be continued for a log period. In general, results must be forthcoming in not more than 12 to 15 weeks in the case of condensation tests. Sometimes longer periods are required. In order to obtain satisfactory data results in this short period of time a certain degree of acceleration must be applied.

It has been customary to build a replica of a wall section 8' high and 2' to 4' wide, depending on the wall model being used. This is inserted into a building in the Climatometer, composed of as many as thirteen wall sections. After each section is sealed in place the building is conditioned for a week at 70° F. on the inside without adding moisture to the air to raise the humidity. The resulting inside humidity is 13% RH. The air outside the building is maintained at a temperature of 0° F. and humidity of about 75% RH. During this period adjustments are made to the instrumentation and recording equipment. Following the conditioning period, the humidity of the air is controlled at predetermined values up to 40% RH. In some tests a cyclic temperature condition has been imposed on the exterior of the building, according to the following schedule:

a. 7 hours at 50° F. with a 2-hour warm-up period
b. 12 hours at 0° F. or -10° F. with a 3-hour cooling period

Through removable, sealed ports in the walls, observations are made weekly to determine when condensation occurs. Temperatures throughout the walls are measured periodically with thermo-couples. In the event that unusual changes occur in these readings, an investigation is made to determine if condensation is taking place or ice is building up in the walls. Simultaneous heat flow measurements have been attempted but the measurements have not been satisfactory. New methods of measurement are under consideration which should resolve the difficulties encountered. At the end of ten to twelve weeks the tests are terminated and the panels completely disassembled to find what has occurred. Photographs, sketches, and notes are made to record the conditions encountered. All findings are reported along with comments and recommendations. Usually, any faults found in the wall can be resolved and corrected after the information obtained is analyzed and evaluated. Sometimes it is necessary to retest a modified version of the original wall but this rarely happens.

I should like to say that if you use good engineering judgment with the factors and tools that have been given you, I am quite certain that you can resolve most of the problems that may arise in this type of wall.

Speaking of good engineering judgment, I am reminded of a situation that arose in one of the aircraft companies some years back when it received an order from the Government to construct a supersonic aircraft. The first model was flown and the wings tore off, and the pilot had to bail out. The Engineering Department got the best heads together and they concentrated a great deal of engineering effort on a new design. The second model repeated the same failure that occurred in the first model. Well, they were really having a hard time of it, so they called on everybody in the plant to make suggestions, and among the suggestions was one awfully far-fetched one, which everyone with any brains labeled as a screwy idea. The man recommended that they bore holes through the wings at regularly spaced intervals. Desperation knows no bounds and so the plane was constructed and it was flown and it passed through the sonic barrier without any difficulty. They were amazed. They called this man in and wanted to know where he had been hiding, how long he had been with the company, and how this engineering genius had come about. Well, he meekly said, "I have been a janitor for 10 years in the Production Department, and I observed that toilet paper never tears along the perforations."

MR. TOUR: In listening to Professor Queer, I am sure that many of you foresaw the possibility of a fortunate relationship between thermal-insulation and sound-insulation. In other words, a porous material which successfully acts as a barrier to the transmission of heat and cold might also act as a sound barrier and capture a few decibels in the process. Although sound absorption or noise control in the average building may be of somewhat less importance than thermal insulation, or the retention or transmission of heat and cold, nevertheless, there may be installations in which this is of vital importance, and it seemed desirable to have the subject covered this morning. Because of his wide experience in this field, Mr. Robert B. Newman was invited to appear on this program this morning to present his views on sound transmission in metal curtain walls.

PART VI

SOUND TRANSMISSION

By Robert B. Newman
Vice President
Bolt, Beranek & Newman, Inc.

MR. TOUR (The Moderator): Mr. Newman is Vice President of Bolt, Beranek & Newman, Inc., a firm of acoustical consultants of Cambridge, Massachusetts. Mr. Newman has a B.A. and an M.A. in Physics from the University of Texas, a Master's in Architecture at M.I.T. He is an Assistant Professor of Architecture at M.I.T. and his previous experience being in the Audio Division of the Naval Air Experiment Station at Philadelphia, Special Research Associate at Harvard, and Engineer on Acoustics with RCA. He is a Fellow of the Acoustical Society of America and Chairman of its Committee on Architectural Acoustics.

MR. NEWMAN: I want to cover a vary basic subject here this morning and perhaps disillusion some of you about some of your misconceptions on what makes for good sound insulation in any kind of panel.

We are going to talk first in general about the properties of any sort of panel which gives you good sound insulation; then we are going to talk about what makes it a good sound absorber, which is a very different thing; and then we are going to talk about the equally important question of how these panels are installed, the connections with the other elements of the building, and how these influence the sound transmission. I think that too often we talk about the panels and forget how we are going to put them in. I think maybe in this Conference we have all realized the great importance of the how.

Now, the transmission of sound through any kind of barrier is determined almost entirely by the weight of the barrier. It is a proposition of inertia. It is not a proposition of fuzz or thermal insulation. We have got to think about sound waves in air as molecular motion, as the wiggling back and forth of molecules. There is no draught between you and me. There is a movement, however, of a wave in the air and this is a back-and-forth kind of motion.

When we think about any sort of barrier to the transmission of sound, we think of it standing up and resisting to some extent the motion of air molecules. The molecules try to move the wall back and forth, and as the wall gets heavier, it gets harder to move back and forth. The more inertia the wall has, the better it resists the motion in the air.

The sound, itself, doesn't actually flow through a wall, whether it is outside or inside. It simply moves the wall and, in moving it, forces the wall to reradiate sound on the other side, giving more of the compressions and rarefactions.

Also, we can consider the effect of the frequency of sound. The hi-frequency sounds find it much harder to move a given barrier than low frequency sounds. If I have a brick here and I move it back and forth, I can move it slowly, but if I try to move it fast it resists the motion much more readily. In other words, the inertia is higher if it goes faster—in still other words, Mr. Newton's Law, F equals MA, a basic, simple fact.

There are no magic tricks in this business. We cannot get a whole lot more transmission loss or noise reduction, whatever we want to call it—insulation--into a wall than its weight will give us. Now, there are some tricks, and we will talk about how we go about solving the problem where we can't always have a foot of concrete, and certainly we are not talking about 1-foot concrete walls today, for there are other ways of getting that insulation.

The mechanism of sound absorption, on the other hand, is one of the motion of the particles in and out of a porous material, with a texture something like shredded wheat or rock wool or any of the various materials that you are familiar with, and the energy is simply dissipated in heat in these materials. There is no danger of heating up the material very much. Someone has done a calculation which shows that if 80,000 people at a football game shout at the top of their lungs for one hour, they will generate just enough acoustic energy to fry one egg. It is not a fire hazard. It is a very small wattage that we are talking about.

The very mechanism which gives us sound absorption, which gives up this molecular motion in and out of a porous material, also enables the sound to go right through, if we have porouus material. It must, or we wouldn't get this kind of dissipation. So if between me and you we put up a blanket or a heavy velour curtain or any other sort of efficient sound absorber, the sound will, it is true, be absorbed to some extent. There will be very little reflection back but you will continue to hear me. We may muffle the high frequencies a little bit, but we don't do very much in the way of stopping sound with fuzzy heat-insulating materials. We can use heat-insulating materials inside of a construction and make some gains. We will talk about that in a minute, but I want to deal with just these fundamental facts first.

The other point about this mass, this inertia, is that the barrier, the wall, the panel, must be completely impervious to air flow. Let's see what a leak of some sort will do to us. Suppose we have a wall which gives us a transmission loss of 40 decibels. This is a reasonably good sort of thing. It is what we would expect to get out of most of our reasonably heavy steel panels that we are using today, or out of a double-glazed window unit, or something--a fairly reasonable sort of transmission loss. This wall has a transmission coefficient to sound energy of .0001; that is, .0001 of the energy striking one side is reradiated on the other side. The wall stands there and resists all but .0001 of the sound energy, and that little .0001 leaks on through by reradiation from the back side of the panel.

If we take a 10' x 10' wall sample having a .0001 transmission coefficient, we have 100 square feet of wall. Now, let us punch a hole in that wall. A hole has a transmission coefficient, not of .0001 but of 1.0. And by diffraction it may even have a transmission coefficient of 1.5, simply by sort of a suction action, a flowing of energy into this small hole.

If we take a 1/100-sq.-ft. hole, which is about a square inch, in this 100-sq.-ft. panel, we will find that with a unity transmission coefficient we get just as much energy through the square-inch hole as we get through the rest of the wall and, very quickly after that as we increase the size of that hole, it takes over the show and it just doesn't matter much what the wall is made of. It can be paper or concrete; it just doesn't matter. Leaks and holes and cracks are the downfall of any curtain wall or any other kind of wall we want to talk about. We have to have air tightness. We have got to have no porosity through the material and we have got to have the material be able to stand there and resist by its own inertia this molecular motion. That is perhaps enough of that harangue at the moment. I think you get the picture, in general, of the great importance, then, of weight.

Now, as I said, we cannot always beat the game with weight. If we have exceptionally high noise-isolation requirements (we will talk about some of them in a minute), then we have to resort to the trick of using two elements in the construction. We separate them so that when the molecules in the air wiggle one side of this space, the other space doesn't follow it exactly by rigid ties through. We separate them so that we have a spring of air in there, and one element maybe takes off 1/100 of the energy and then we go through air and then the other element takes over another 1/100 of the energy, rather than putting them together and letting them take over about 1/200 or so. We can gain a great deal very quickly by using double constructions.

The air space, in order to be effective in separating two elements in double construction, has to be reasonably big. A half inch isn't enough. We find in this double-glazed unit, where the increase in transmission loss in 1/2-inch air space is very little more than we would expect from the increased weight of two pieces of glass, that we have to go up to two or three inches and, in critical cases, to more than a foot between the two elements of double construction if we are going to realize the real advantage of the separation of this spring action of the air in the middle.

We find on making measurements on certain types of panels that we get some of this separation action if we have our studs (let's call them studs for a moment)--whatever our connectors are between the inner and outer space--centered no closer than two feet. When we get closer than two feet in the center with these braces between the faces, then the faces are effectively mechanically coupled, but at greater spaces than about two feet we begin to get some separate panel flexor action, some separate motion of these two faces. This is, of course, quite good and picks up quite a lot more than we would get simply out of the solid weight of the panel.

Now, what effect does sound-absorbing, heat-insulating material, have on the panels? Let us assume, first, that we are talking about a completely sealed unit, a panel with faces that are not perforated for sound absorption. This is another problem. Let's just have two panels, say, two sheets of 18 gauge steel and a 3-inch space in there and two studs on two centers; what sort of effect can we expect from the sound-absorbing, heat-insulating material, we put in there? Our measurements show--and this is borne out time and time again--that we gain about 3 decibels in the transmission loss of panels in this weight range, where we are talking 18 gauge steel--roughly that sort of range of weight. If we were looking for a 3-decibel increase in the transmission loss of a wall, there are cheaper ways of doing this than putting in the sound-absorbing material in the core. We need the heat insulation and the sound absorption for other reasons in exterior curtain walls, and, therefore, we have the material there and we might as well take advantage of that extra three decibels or so that we get.

This assumes that the spaces are tied together with studs of some sort. If we have a separated construction with the two faces structurally separated and not tied together, then the sound absorbing material in the interior can sometimes give us as much as 6 decibels improvement over the unfilled partition. The action of sound absorbing material on the interior of a panel of this sort is simply one of dampening the resonances of the space with the faces and, instead of getting a very jagged, peaked curve of response of transmission loss against frequency, where we have high resonant peaks and low dips, and so on, at various frequencies, we get a smoother function and an over-all slightly better performance.

But if we have, as I said, the problem simply of increasing the transmission loss, the insertion of sound absorption material is probably not the most economical way of doing it.

There is another very important point. In this weight consideration, we have got to consider damping. The panels must be damped if we are going to realize the full action of the weight. Of course, insulating materials quite often provide this dampening. Sometimes we actually have to spray on the inside of panels, materials such as are used for undercoating automobiles, the gunky dum dum, and so forth, the gooey, sticky materials that give us a dead, massive sort of surface, and we often beef up the surface weight of the panels by using a fairly heavy spray of one of these gummy materials.

In most assemblies, panels, or buildings, involving the use of glass--and this is quite often the case--the glass sets the limit. Ordinary 1/4-inch plate glass gives a transmission loss, an average transmission loss over the whole frequency range, of about 30 decibels. For most ordinary purposes in buildings, in cities, and so on, this is good enough. We are not usually troubled by the transmission of traffic noise, and so on, through windows with 30 decibels of transmission loss. A sealed, double-glazed unit with 1/2-inch plate on both sides or 1/2-inch plate gives us 35 to 36 decibels of transmission loss.

The average steel panel--I say, average, a typical steel panel--with 18 gauge steel faces, 3 inches apart, filled with a heat insulating material (a glass-fibre type material), has a transmission loss of about 35 decibels. This is good enough for most ordinary situations, as I say. We talk about, well, "the good old days" when we had a foot of brick on the outside of a building, and think how much better that was. That gave us 55 decibels of transmission loss, but if at the same time we had a window in the wall, we were not getting anything like that kind of transmission loss, because the window sets the limit. The weakest element in any sound barrier sets very quickly the limit on the achievable isolation of that barrier.

Mr. Rogers referred to the noise-isolation request for an office building right at the airport. This crazy sort of requirement very often is made. It may be that curtain walls aren't the answer. If you have just got to use them, if there are reasons for light-weight panels, panels that are demountable, and so on, then we have to resort to double construction. Sometime ago we designed a demountable jet engine test facility. This was something which could be set up for awhile and moved--quite a big building. Actually the solution that we came up with, to duplicate the transmission loss of about a foot of concrete, or somewhere around 60 decibels average transmission loss, was to construct two buildings, one inside the other, with separate framing, a truss system to carry the roof panels. The columns came on down on the outside to separate footings. We had two sets of foundation walls or two sets of footings, and the space between the two panels was 18 inches. The inside faces of the panels were separated by 18 inches, with separate framing members carrying the inner box from that carrying the outer box, and then using two 3-inch panels, one on the outside and one on the inside, each with 18 gauge steel faces and filled with sound-absorbing, heat-insulating material.

That kind of construction will give a 60-decibel transmission loss, almost twice the value of one panel. It can happen only if both of these are completely air-tight and if the structural separation is carried right on through the whole business. This gets very tricky at points where you must come in and out with doors, and jet engine test cells have great stacks on them for bringing in great quantities of air. These all have to be handled very specially and it is a very tricky business, but it can be done.

Here in Washington they are about to build a motel near the airport and in this case the requirement for noise isolation is being met with windows, two pieces of glass set about 6 inches apart. They are actually using masonry backups in some cases. The air for the individual rooms, I believe, is being handled with individual units in each room. A labyrinth is built in the curtain wall bringing the air up and down around a tortuous labyrinth path, which is lined with sound-absorbing material, to bring the air in without airplane noise along with it. It is a very carefully detailed situation and everything is air-tight, with rubber gasketing, and so on. We have to keep this air-tight business in mind.

So, we can take care of the very high noise-isolation requirement situations, but they are not easy and we cannot beat them with single constructions unless we are willing to go to something like a foot of concrete. You just have to resort to the double kind of business.

I mentioned at the outset the terrific importance of proper detailing. Not so long ago I was in the office of a rather medium executive in one of our large corporations occupying a brand new building. This building used curtain walls on the outside and the slab went over and terminated in some sort of steel channel up against this curtain wall. There was a dry connection. Nobody worried much about it. The weather was kept out on the outside and who cares about a little of air leaking up on the inside?

This fellow said that the floor was defective under his office and he could hear the man downstairs very distinctly. The floor was a 3- or 4-inch slab on steel framing, a perfectly respectable sort of slab construction that you would expect to do a good job of sound isolation, but he swore up and down that the floor was defective. I went in there with him and we sat and listened for a minute. Some man downstairs was talking about a very interesting funeral he had been to. We got all the details. It was really quite interesting.

Now, where was this sound coming up? It was coming up through the little crack at the edge of the slab where the slab joined the curtain wall. That edge had not been calked, it had not been sealed absolutely air-tight, and there was a little crack. You couldn't see right through the little crack, but all of the sound was coming up through there. You could pinpoint it; that man with the funeral story was over by the outside wall. He wasn't underneath where he ought to be; he was over by the wall and talking to us up this little crack.

Also, the connections between the mullions or any other portion of the curtain wall construction and the partitions inside are very important. These have to be air-tight, so we have calking problems not only outside for all this moisture business but also against air flow within the space, and we have to detail things so that we get air-tightness at every juncture of the curtain wall of the building, if we expect to have high sound-insulation.

The other question has to do with the sound-absorption use of curtain walls. Sound absorptive treatment has become quite general in buildings. We usually place it on the ceilings or incorporate it somehow into the ceiling systems. Often there is the temptation to use the walls as sound-absorbing elements. I don't think it makes much sense in the ordinary office building situations. The areas simply aren't great enough to be significant and the great problems we have already heard about of condensation in the sound-absorbing, thermal-insulating material, make it just not worth the trouble. In industrial situations, if the aspect ratio of the building is one in which we have, say, 100 feet of space and a 10-ft. ceiling, then it doesn't make any difference if we use the wall as sound-absorbing material. That sound-absorbing material isn't going to have any effect at all on the noise in the general space. If we have a big space of fairly high ceiling and not too wide across, there is a temptation to use this thermal material double as a sound absorber and as a heat insulator, and of course, we have to face up to this moisture barrier question right away.

The perforations on the face, to be effective in admitting sound to the sound-absorbing core inside, should not be greater than 3/4 inch apart, preferably 1/2 inch. The perforations simply admit sound, and they don't do anything about absorbing it themselves; they let it leak into the fuzzy stuff, the fuzzy heart of the thing which does the absorbing. They should comprise not more than 10 percent of the surface area. This, then, makes that surface of no use whatever as a sound barrier. We say we perforate it to let sound through and it is finished as a sound barrier. It simply adds to the total weight of the panel, and we get no benefit from it as a separate barrier in which we might get a little bit of flexure, as I said, between the studs.

The sound-absorbing material inside, the heat-insulating material, which is exposed to the room, anyhow, should be at least an inch thick, and in many industrial cases should be considerably thicker if there is a low-frequency noise problem. The sound-absorbing characteristics of materials vary with frequency. We need much thicker materials for absorbing the lower frequencies, but this matter of the vapor barrier keeps coming up, how we are going to get it in there, and so on, which I think is a problem that has not been adequately solved. We certainly have to solve it if we are going to use these materials as sound absorbers.

The curtain wall as a sound absorber is no different from an acoustical tile or any other kind of acoustic treatment. It makes good sense if it can be used, if we can use the material to double as a thermal insulation, but it isn't a matter nearly as important as the detailing of the installation of the barriers.

MR. TOUR (The Moderator): We have now learned from the experts many desirable features of metal curtain wall construction. Esthetically, they give architects a great deal of flexibility for exercising their ingenuity in creating design. Financially, they provide better buildings at lower cost. In the realm of livability, they provide better control of the sound, thermal concentrations and, in general, give us a better place in which to live and work. But these benefits can be achieved successfully only if the panels are designed and fabricated so that they go together easily and quickly. Erectors are not magicians. They can't stretch, bend, warp, or shrink the panels. No matter how attractive the details look on paper, if these panels can't be erected simply and economically, the results are going to be something less than perfect.

To give us the final word of wisdom on how to get the most out of our curtain walls, we have a man who has had a great deal of experience in installing metal panels. He is our next speaker, Mr. Norman S. Collyer.

PART VII

ERECTION OF METAL CURTAIN WALLS

By Norman S. Collyer
President
F. H. Sparks Company, Inc.

MR. TOUR (The Moderator): Mr. Collyer is President of the well-known contracting firm of F. H. Sparks Company of New York. He graduated in Civil Engineering at Cornell in 1934 and has been associated with Turner Construction Company and with the Elwyn E. Seely & Company of New York.

MR. COLLYER: Most people think of erection as starting when material arrives at the job-site, ready to be put in place, and as being completed when this material is in place on the building. Unfortunately, this is when consideration of erection problems on a job often starts. Actually, the erector's problems commence with the original design or preliminary planning of the job and are not complete until the job is finally accepted by the owner. In this discussion of the erection of metal curtain walls, therefore, it is our intention to begin with the designer who is planning the project and follow it through, step by step, to the final completion of the building.

Since the term "curtain wall" covers such a wide range of materials and variety of buildings, it is impossible in this discussion to be specific about most problems. So much harm has been done by giving specific answers to general questions that we want to avoid this mistake here and seek, rather, to indicate the problems of erection and enlist some help in avoiding or solving them.

Perhaps it may seem peculiar to some to talk about the design of a building in relation to the erection problems. Actually, however, many of the erector's problems originate with the design, and often these are problems which could be avoided without detriment to the architectural effect. Frequently, some requirement of the architectural design will necessitate attaching members or pieces from the outside, using a scaffold, whereas otherwise all of the work could be done from the interior at a considerable saving in cost. Frequently the architect will insist on requirements which later lead to trouble and require modifications in the work after it has been completed. An example of this is a case where the architect would not permit expansion mullions in his design, because he insisted on a narrow sight-line. After the work was done in accordance with the architectural design, which ignored the advice of the general contractor, the window manufacturer and the window erector, trouble resulted as was prophesied, and it was necessary to go back and put in the expansion mullions which the architect had originally refused to include in his design. It was, of course, the window manufacturer and the erector who were stuck with the cost, but this cost has to be absorbed somewhere in the over-all picture.

The architect's insistence on certain features in his design may increase the erection cost considerably. It is not unusual to see two jobs which are essentially similar, but with the erection cost of one is more than double that of the other. Since we may be talking here about a differential of at least $1.00 or $1.50 per square foot, this is a very important problem, as owners will attest. The designer should also give special thought to avoiding designs that impose difficult erection conditions which, in turn, may lead to bad construction and in the long run harm not only the job involved, but reflect on curtain wall construction in general. If the designer always keeps in mind the question of how the job is to be erected and consults those who are familiar with curtain wall erection, he will avoid most of the serious pitfalls.

In connection with design we should also think about the quality of the erection job required as related to the over-all quality of the job itself. It is impossible to erect any material within closer tolerance than that which is observed in the manufacture of the product and in the manufacture and installation of the materials to which the product is attached in the field. Frequently, I have seen materials, which were intended for a rather rough application where tolerances can be large, specified and used where a finished architectural effect was desired. The materials specified simply could not be made within the tolerances which the erector was asked to observe. This is poor design. On the other hand, when the designer requires that his material be manufactured to close tolerances and pays a high price for that precision, he is very foolish not to insist on the same quality in the erection. As in the manufacture, a higher price must be paid for precision erection. The designer has a grave responsibility to the owner and to the industry generally in the requirements of his design. He will do well in assuming this responsibility if he gives serious consideration to the installation of the design.

Probably the most critical stage in the development of a curtain wall job is the preparation of fabrication and erection details. This stage is critical not only for the over-all good of the job, but for the ease of fabrication and the possibility of doing a good erection job. If the job is poorly detailed, it will be difficult for the fabricator to do a good job, and this will add to the woes of the erector. I have seen many erection details on approved erection drawings which were physically impossible of fulfillment. There are details shown which, although possible of fulfillment, are so difficult as to make it impossible for the mechanic in the field to consistently do a good job. On the other hand, some of the potentially difficult jobs which we have performed have turned out to be very simple and without problems in the field--primarily because proper consideration was given to the details and because the erector and the fabricator were consulted when the drawings were prepared. Consideration must be given both to the assembly of the various elements, one to another, and to the attachment of the curtain wall to the structural frame. Since labor costs are less, working conditions better, and supervision more complete in the shop than on the job, it is a good beginning point in detailing to assume that anything that can be done in the shop should not be left to be done in the field. The ultimate of this would, of course, be a completely shop-fabricated building, which is out of the question for the situation we are discussing. We must, therefore, arrive at some limitation on the size of units as related to the size and weight that can be easily shipped and handled at the job-site and that will provide for water-tight and air-tight joints and still provide proper expansion and contraction.

Obviously, there are also shop problems involved, but in this discussion we must consider the erector's problems rather than those of the fabricator. As related to size and weight, the controlling factor at the job is apt to be that of hoisting. I do not think that there is any magic number for either size or weight of materials, since the type of job and the local working conditions can vary so much. Probably a good guide for most jobs is to have no item heavier or larger than can be taken up conveniently on a job hod hoist or which cannot be handled easily by four men. There will, of course, be exceptions to this in cases where material can be handled easily with a crane and where the job will not be penalized by employment of a crane. It should be remembered, however, that crane rentals are expensive and require a large number of men and that the job may not be ready just as expected.

In the case of standard insulated panels -- either shop or field assembled -- such as are manufactured by Detroit Steel Products, Mahon, Robertson, and others, the controlling conditions are apt to be different. These panels are narrow and can be handled in long lengths. Jobs have been satisfactorily completed with panel lengths over sixty feet. Transportation and handling problems would normally make such lengths impractical. Wind conditions and scaffolding problems make long lengths objectionable in other locations. Our own experience indicates that lengths much in excess of twenty feet or spanning more than three girt spaces are uneconomical for erection. These objections, of course, must be balanced against manufacturing costs and the disadvantages of additional field joints.

The size and weight of pieces which can properly be handled is obviously going to affect the manner in which the detailer must break down the units of his job. A consideration here would be whether to combine windows and spandrels or make them separately, whether to make up the mullion as a separate unit or combine it with the panel, and whether to make the spandrel panel part of the frame or have the spandrel field-installed into the frame. I was surprised to note in the report of the Building Research Advisory Board that the contractors reported the size and weight of the panels as almost 100% satisfactory on completed jobs. It seems likely that these were considered satisfactory because the job was completed rather than with regard to whether they were the best sizes or weights for the erector.

The degree of water-tightness and air-tightness of a building is going to be affected by the number and type of joints created by the detailing. Again, there is no magic solution, but the fewer joints that are left to be sealed in the field, the better chance there is of having a tight building. Likewise, the easier it is to seal the joint, the less possibility there is of the mechanic making a mistake and not providing a complete seal.

In this connection, of course, the materials to be used in the joints, whether they be caulking compounds, metal flashings, or gaskets of some type, are obviously a factor. It would appear that in the past the joints had been the most troublesome point in curtain wall construction. This undoubtedly was partly due to faulty materials and faulty workmanship as well as to bad design. It must be kept in mind here that if the design is poor or the material difficult to apply, the chances of having faulty workmanship are increased. The best material is not good if it is difficult for the mechanic to use. It seems to me that some of the new rubber-base caulking compounds come in this classification where satisfactory installation is apt to be difficult and very costly. An ideal compound would be one which would combine the durability of the two-part Thiokol compounds and the ease of application of standard caulking or glazing compounds. We expect materials of this type to be available in the near future. When these materials are available, one of our biggest problems will be solved provided the owner will be willing to pay a little bit more for longer life in his structure.

It appears to be a tendency in design to want to let the water get past the metal curtain wall construction and then pick it up and weep it out to the outside again. It seems to me that this is a fallacy and that the right approach is to keep the water out completely and then provide some weeping action to dispose of condensation and the water which will somehow sneak in at some place in the structure. The maintenance of weep holes during the course of construction to prevent them from being clogged with mortar, plaster, and other dirt is a continual headache for the erector. Somehow a clogged-up weep hole will weep into the building much better than it will weep out.

In the design of joints, one of the most crucial requirements for the erector is to have proper tolerance to take care of field variations. Hand in hand with this problem goes expansion and contraction, which, aside from the question of good design, affects the erector in that he is never sure whether he will be erecting at a hot temperature or a cold temperature. Thus, the variation which is allowed may be increased or decreased with the temperature. Obviously, the larger the panel, the greater the tolerance which must be provided in each joint. Probably the most common joint, and from the erector's standpoint one of the easiest joints to work with, is the standard sheet metal standing seam joint. This is particularly satisfactory on long narrow panels, where a sizeable amount of variation throughout the length of the panel is normal. This type of joint has the advantage of being somewhat self-aligning during erection and of not opening up with expansion or contraction. A tongue and groove joint is difficult to align, particularly if there are fabrication variations in the metal. The tongue and groove joint tends to open up with contraction and push out any joint sealer when expanding. If tolerance is to be allowed to take up field variations, then obviously something must be used to fill up the voids left by these variations. While there are times one would like to do away with mastic caulking of all types, this still seems to be the most satisfactory way of filling these joints in a watertight manner. The emphasis should be placed on improving the quality of these materials rather than on their elimination.

Another important factor in the design of the joint is the question of job procedure, especially in regard to whether the erector can start at one point and work consecutively around or up and down the building and whether he will be required to leave out panels in certain locations and fill them in later. With the standard sidewall panel, such as is commonly used in factory construction and low buildings, it is usually possible to commence in one location and work consecutively around the building. On multi-story construction this is not usually practical because of job hoists, dirt chutes and other obstructions, which require the leaving out of panels. On multi-story work, therefore, the greatest amount of flexibility in procedure should be provided. Obviously, the erector on multi-story buildings will proceed much more rapidly if he can work continuously around each floor progressively up the building.

Building code requirements often restrict the type of wall construction which can be used and contain special fireproofing requirements. These code requirements are usually such as to affect primarily the materials to be used and are not directly erection problems. They do, of course, affect the erector in the sense that erection procedures and schedules are affected by the requirements of coordination with other trades. When special back-up walls or other fireproofing requirements must be met, there are coordination problems which add to the cost of the curtain wall erector. On the other hand, the addition of back-up walls or other coverings inside of the curtain wall eliminate the need for the curtain wall erector to leave a finished surface on the inside. There are some restrictions, such as requirements for certified welders and welding inspection which are required in New York City and some other cities, that are definitely the erector's problem. It is the obligation of the erection contractor to furnish certified welders where required, and since there is normally a shortage of such mechanics, this presents an additional labor problem to the erector. When welding inspection is required, the inspector normally has to be on the job whenever any welding is being done. This cost, therefore, becomes a factor of the life of the job, and if a job is delayed or slow moving, the cost of the welding inspection can be increased considerably. Responsible erectors and the industry generally should favor such regulations, if properly administered, since they result in a higher standard of workmanship, insure against a serious failure, and remove some responsibility from the contractor. Occasionally, there are fire safety requirements which may contribute to the cost of the erection. Such regulations usually concern welding and burning of metal.

While the type of material used on a job is not basically an erection problem, it can become rather an important factor for the erector. If the erector is working with material which has a rough finish and which is going to receive its final finish, such as painting, after the erection is complete, the erector does not have to be as careful in the handling of the material, and he will therefore reduce his erection cost. If, however, the material is such that it has to be carefully protected against staining, scratching, or abrasion or if the finish surface is such that it is easily marred, then the erector must take special precautions at all times, and his cost of handling the material will be increased and his speed in completing the job will be decreased.

A question which often arises with certain types of curtain wall construction is whether or not insulation should be shop-installed or field-installed. This is particularly a factor in the case of panels made up with an inside backing sheet, an outside finish sheet, and insulation in between. There is something to be said for the field-assembled panel. The back-up sheet, not being a finished surface, can sometimes be erected under conditions which would not be satisfactory for installation of the outside finish sheet. Also, it is somewhat easier to store this type of panel, since the insulation itself can be more easily protected, and only the finish sheet (and not the back-up sheet) needs special protection prior to erection. There is also perhaps some advantage with this type of panel in being able to stagger the joints between the face sheet and the back-up sheet. It has been our experience, however, that the installation of the field-assembled panel is considerably more expensive than the installation of a shop-assembled panel where the back-up sheet, the face sheet, and the insulation are shop-assembled in one unit. We have had jobs where, I am sure, it cost more to install one element of the field-assembled panel than it would have cost to install the complete shop-assembled unit. In other words, the erection cost of the field-assembled panel was more than double that of a shop-assembled panel. Weather conditions, especially wind, are a very important factor in this decision, it being much better to have a shop-assembled panel where windy conditions are apt to prevail. In selecting the type of material to be used for panels on any job, consideration should be given to susceptibility of the materials to damage from wind, water, mortar, and plaster and the possibility of staining by paper, cardboard, insulation materials or other materials which might possibly be on the particular job. Addative ingredients, such as materials used in light-weight concretes, and anti-freeze ingredients used with masonry materials are two such special materials which must be watched for their possible effect on the curtain wall finish.

Since we are talking about curtain wall construction in general rather than about any specific type of curtain wall construction, it is impossible to put a definite price tag on erection. We have completed jobs for 40¢ a square foot, and we have figured jobs which ran as high as $10.00 a square foot for erection. Frequently, we are aksed to quote an erection price for a job based on certain quantities of a certain type panel. Any erector who quotes in this manner will either lose the job or lose his money. In this respect, also, I should like to caution against too careless use of budget erection figures. It seems to me that most budgets are set up on the basis of a square foot price which somebody guesses or pulls out of a hat, without any real understanding of the problems involved. This inevitably produces an unrealistic budget price, which accounts for a great many of the over-the-budget contract bids and results in chopping the price and the quality at a later date. Proper consideration of the erection problems at the planning state would produce realistic budget erection prices and avoid a great deal of trouble for everyone.

I cannot pass over the topic of prices without some reference to the results on construction of the practice of bid shopping. As long as builders and general contractors resort to the practice of playing one price against the other and buying strictly on the basis of the cheap price, we will continue to have problems with all types of construction and especially metal curtain walls.

One of the most critical problems for the erector on any job is the method of packing, crating, and shipping. The proper method of packing or crating is primarily determined by the product itself. Some items can be bundled together or shipped loose without any protective coverings because they are going to be painted on the job after erection. Even with such products, we find that the architects and owners complain regularly about the scratches which occur in shipping and handling. It is high time that architects, when writing their specifications, realize that such products will be scratched and marred in shipping and handling, and make allowances for this in their painting specification, depending on the type of finish which is desired. It is not reasonable to expect the erector of this type of product to avoid scratching or marring the surface, though it is reasonable to hold him responsible for carelessness or outright abuse in handling.

When a product having a finished surface is involved, it must ordinarily be crated or enclosed in cardboard containers. We have found that with some products less damage results when portions are simply wrapped in cardboard rather than being placed in over-all containers. In any event, with any product which is shipped in a container of any sort, there will regularly be concealed damage which cannot be determined until the material is removed from the container. Since the material should be left in the container until it is ready to be put in place on the building, this can be a source of considerable irritation for everybody concerned. It is not always true that an external blow which will damage the material in the container will leave a mark which is discernible on the container itself.

Disposing of the cartons and crates and other packaging is a serious problem for the erector and adds considerably to his cost. It can also create a fire hazard if left scattered around the building and is a hazard even before the material is removed from the containers. It is especially important in such cases that the general contractor or owner carry extended fire coverage insurance.

The best method of shipping, whether by truck or rail, depends on the particular job and the accessibility of the railroad or trucking facilities in relation to the job location. From the erector's standpoint, it is normally an advantage to have material delivered direct to the job by truck. This has the disadvantage, however, of not being able to know exactly when the trucks will arrive at the job. We have had some success in having the trucking companies keep us advised on deliveries, but generally speaking we have found them uncooperative. This is a problem which the trucking companies should look into very seriously. We have had excellent results recently with material delivered by railroad Piggy-Back Service. This has combined the advantages of truck delivery with the railroad's advantage of control over delivery.

It is, of course, important to the erector that material arrive on the job when the job is ready for the material to be erected. Most general contractors demand that material be shipped to the job as fast as they can force it out of the manufacturer's plant. This causes the erector considerable grief in storing and re-handling material and increases the possibilities of damage or staining and can only increase the possibilities of an inferior job. On the other hand, it is hard to blame the contractor, since the manufacturers so often disregard their promised schedules, which, of course, results in costly delays to the contractor. More honesty on everyone's part in scheduling material as to when it is actually needed will help the erector, will not hurt the contractor, and will produce a better job.

In shipping material to multi-story buildings, it is essential from the erector's standpoint that all material be boxed, marked, and shipped separately for each individual floor. The manufacturer may think that this imposes an additional cost burden on him, but he will find that he will not only save on the erection cost of his material but will also save a considerable amount in having less shortages and wrong material at the job site. I feel quite sure that the saving in lost material through proper marking and packing will more than offset the expense involved.

Tied in with the problem of proper packing and shipping is hoisting at the job site. Obviously, if the material is packed or bundled in sizes or weights which are unwieldy to handle at the job, the erector and the material are going to suffer through improper handling. Again, there is no magic formula that covers every situation. If we have a job where material can be easily hoisted by a crane, it is advantageous to bundle or crate the material so as to make the best possible use of the available crane. On a multi-story building, sizes and weights are usually restricted by the size and capacity of the hod hoist. It is normally slow and costly when it is necessary to erect a special boom on the upper floors to hoist material to the floors. The cheapest and quickest method of hoisting is usually by means of a hod hoist. In curtain wall construction with larger panels it may be necessary to provide a hoist with extra clearance. Of course, the hoist tower and runways must also be designed to allow this extra clearance. We have always found our hoisting to be more efficient when smaller units which can be handled easily by one or two men, both as to size and weight, were provided.

In any type of curtain wall construction, it is important that the work be installed according to accurate lines and grades. If this is not done, a wavy, irregular appearance will result, which will detract from the final appearance. It should be and is the responsibility of the general contractor on the job to establish proper marks for both line and level at sufficient points on each floor level to give the mechanics installing the work accurate points to work from. This obligation rightfully belongs to the general contractor, since most, if not all, of the other trades on the job will work from the same marks. These marks must be placed sufficiently ahead of the erection crews so as not to delay them and also so that errors in lines or grades, which will inevitably occur on a job, may be discovered before the mistake becomes critical. We find that most general contractors do not have sufficient engineers on the job to provide proper engineering marks and, as a result, their job suffers through delaying the erector and also through errors which slow the job. These errors would not occur if the mechanics had proper marks to work from.

Having established the proper line and grades for the erection of a curtain wall, we are apt to find that we are conflicting with some other part of the structure at some point because of the variations in the component parts of the building. These variations may be in the form of steel erected out of line or concrete not just where it should be because of buckled or bowed forms, or it simply may be variations produced by temperature changes. This is one point at which the skill and common sense of the detailer in providing proper clearances and tolerances both for his own work and for joining up with the structure will show. In some types of panel construction, the panel is set directly against the steel frame. In these cases the panel erector can be only as accurate as the steel itself. If there are variations in the steel beyond that which is to be permissible for the panel erector, these variations should be determined and corrected before the panel erection is started. Better supervision on the work done by all trades and by the general contractor would eliminate a great deal of the difficulties which are so common on jobs today and are so costly to the erector. The cost to the erector is not so much in making some change in the field as it is in the lost time for his entire crew while some condition is being adjusted. The designers and detailers should be more aware of the tolerance which all trades must have in their work and provide for this tolerance in their details.

Part of the problem of field variations is created by expansion and contraction caused by temperature changes. This is particularly true on large buildings, whether they are large in horizontal or vertical extent. The roof on a large flat building will expand and contract so as to push exterior walls out of plumb one way or the other. This, of course, makes it difficult for the erector to set his work in proper relation to both the roof and the first floor level. In multi-story construction, the same thing occurs, and as the sun moves around the building from morning to night, the building will go with it to a great enough extent to throw out the erector's working lines.

Expansion and contraction also create many of the difficulties encountered in making and keeping joints between panels tight. Obviously, this is one problem which cannot be eliminated, but it is one which I think better engineering can make easier for the erector and permit him to do a better job.

The best method of connecting the curtain wall construction to the structure will vary with the type of curtain wall and also with the type of structure. In the case of sandwich type panels, either shop- or field-assembled, where the back-up sheet is normally directly against the structural steel framing, the most common and usually the easiest method of attachment is by arc welding. Methods involving direct bolting or screwing or the use of molly bolt fastenings are equally satisfactory. In fact these methods are preferable, provided they do not involve punching or drilling the structural steel framing in the field. This is particularly true where long sheets are involved and the welder must move from one horizontal girt to another in order to make his connections. With further complications being forced on the erector by both the engineers' and electricians' unions, where welding is involved, the advantages of other types of fastenings in certain areas are becoming greater.

In the case of multi-story construction involving a concrete frame, some form of insert, preferably one designed to receive a bolt, or built-in anchor bolts, seem to be the best method of attaching to the structure. In the case of structural steel frames, it is usually easier to weld to the structural steel spandrel beams after the concrete arches are in place. This requires the concrete arch contractor to leave cutouts in the concrete to permit access to the steel. This is somewhat of an aggravation to everybody concerned, but we have found it satisfactory to instal brackets prior to the concreting operation on multi-story buildings. Clips or brackets shop-installed on the structural steel would be useful if properly planned and located. In any of these connections, it is important that adjustment in all directions be provided in the connection to make up the variations which will occur in the structure.

The erector's biggest problem in the field is securing, training, and supervising satisfactory labor, mechanics who are willing and able to perform the work to be done. It is a safe assumption that all of the work will be performed with union mechanics of one trade or another. It is therefore important that the trade which will actually perform the work be kept in mind by everybody concerned in designing and detailing the job. There have been, and probably will continue to be, questions of jurisdiction involving different trades performing different items of work. Frequently, a major jurisdictional problem between different trades will arise and cause considerable delay and extra cost on a job because of some simple little detail or even because of a word used on a drawing. The same item of work may be controlled by different trades simply because it is called by a different name. If the erector is consulted in advance on these matters, he should be familiar enough with his local trade conditions to avoid most of these "booby traps."

There is today a definite shortage of mechanics who are skilled in performing the work which is required of them on curtain wall construction. It is the usual practice of employers simply to blame this problem on the unions and to contend that the unions have not been willing or able to supply men to do work which they are supposedly capable of doing. While there is plenty of justification for this criticism, we must realize that we have suddenly asked the mechanics involved to jump from one type of work, which was not particularly exacting in requirements of skill, into another type of work which is extremely involved and which at times would task the ingenuity of the finest engineer or layout man.

Since the key to any erection job is the foreman, it is particularly important that good, trained foremen be available for the erection of curtain wall construction. By and large, the differential in pay between a mechanic and a foreman is not sufficient to offer proper incentive to take on the additional responsibility and worry which goes with the foreman's job. The proper solution to the problem of shortage of skilled mechanics and foremen would be to provide training in some sort of special school. Since it is probably impossible to provide training in this manner for mechanics, the actual solution is to train mechanics on each job at the beginning of the job until they have learned how to proceed. The contractor's only solution to the problem is to carry trained mechanics from one job to another. As regards the foreman, the same solution applies, but in addition some sort of training program by the employers is definitely in order. Within our own company, we have adopted this policy and hold periodic foremen's meetings to better prepare our foremen to do their job properly. We have found both the men and the unions cooperative. Carrying men from one job to another and running training programs is expensive, but in the long run it produces a much better job and builds up a reserve of trained men. Recently, the unions have recognized the need for skilled mechanics to perform this type of work and have increased their apprentice training programs to provide trained mechanics. This is a slow process, but meanwhile we have found the unions receptive to the idea of giving special consideration to curtain wall jobs.

The survey of building contractors opinions conducted by the Building Research Advisory Board indicates that in only 20% of the jobs reported was there any jurisdictional question raised. From our own experience, I would say that the percentage was undoubtedly much higher than this, but that in the majority of cases the jurisdictional question had been solved by the erection contractor and the unions, without recourse to any jurisdictional board. We usually find that where possible the trades involved would rather settle their problems locally with the erection contractor and not create an issue which would reflect to the disadvantage of curtain wall construction. It is our opinion that both the unions and the workmen will cooperate if the proper initiative is taken by the erection contractor.

The need for properly trained skilled mechanics and better supervision is indicated by the frequent reference on the part of owners commenting to the Building Research Advisory Board about "poor workmanship" on their jobs. The building trade unions concerned and the erection contractors will do well to heed these warnings, lest metal curtain walls be replaced by masonry construction.

It is our opinion that erection time can be saved on most buildings by the use of curtain wall construction. This will not be true, however, if the job is not properly laid out and scheduled and the schedules adhered to by everybody concerned. On every job there is a considerable delay in getting a crew organized to work efficiently. This is particularly true on multi-story curtain wall construction where each job is started off fresh with inexperienced men. The first two or three weeks on a large job are apt to show very little progress. After that, if everybody is cooperating and the job is properly organized, progress can be very rapid. It has been our experience that most contractors want to start the metal wall installation too soon in relation to the other trades on the job. This is a carry-over from masonry construction and partially due to their desire to have the building closed-in for the other trades. The curtain wall erector can catch up with the steel and concrete work after he is organized if he is given a chance. If the curtain wall erector is too close behind the concrete arch man, his mechanics will be working among piles of stripped forms and amid falling concrete and debris from the concreting operations, all of which will only slow down his work, mess up the finish, and cause other damage to the material. It is far wiser to give the concrete man a good lead with a minimum of six or eight floors. As the concrete man tapers off with his finishing operations at the top of the building, the curtain wall erectors should catch up. It is probable that the metal curtain wall construction could proceed efficiently at an earlier date on a job using metal floor panels.

The general contractor is responsible for coordinating the work of the various trades on the job. How well he does this job is particularly important to the curtain wall erector. On an industrial panel job, the main problem is to have the steel erected and properly aligned sufficiently far in advance. Other problems of coordination, such as having the concrete floors and the roof slab in place before erection of the panels, painting of the steel, and completion of any adjoining masonry, can also be important factors in the erector's speed and economy. In multi-story construction, such as an office building, there are many other items, such as flashings, back-up masonry, air conditioning units, convectors, interior trim, plastering, under-floor ducts, and finish floors and the various to be considered and trades coordinated in such a way that one will not interfere with the other. Since many of these items fit directly to some portion of the curtain wall construction, and frequently fit with almost zero tolerance for variations, it is essential that the items be coordinated throughout the design and shop drawing stage, as well as at the job-site. There is both a time and location coordination required on these jobs. If the various items have been planned well in advance and the architect has coordinated the fitting together of the items, the curtain wall erector should be able to proceed with his work with very little difficulty.

The combination of skilled mechanics, close supervision, and a conscientious erection contractor is the key to a fast and satisfactory job. Since the curtain wall erector comes ahead of all of the other finish trades, the burden is on him to have his work right. There is a tendency for other trades to abuse the work of the curtain wall erector by using it to support scaffolds, banging into it with planks and other heavy articles, spilling concrete and other materials on it, and in other ways damaging the material. The general contractor supervising the job must keep constant vigil to see that such damage is not caused and to fix the responsibility in the event of damage.

Related to job progress and erection time is the weather. Therein lies one of the big advantages of metal curtain wall construction as compared with masonry construction. It is true that on some forms of metal wall construction, such as are normally used in industrial buildings, the erector may be stopped by snow or rain, or sometimes by wind. On multi-story buildings which we have erected, we have found that while the weather may slow down operations we have rarely lost any time by our erection crews. As a matter of fact, we have as yet to lose any time whatsoever on the Socony Mobil Building we are now finishing in New York City. Weather can be a very important factor in the completion of a building, and it is another reason why the structural steel and concrete arch men should be given a good start ahead of the metal curtain wall erector. If this is done there will be less loss of time in the erection of the metal wall and less possibility of receiving an inferior job because of the weather.

The glass in curtain wall construction is often a very large part of the finish wall surface on the outside. The glass and the compounds that are used in setting the glass are frequently one of the biggest sources of difficulty on this type of job. It seems peculiar, therefore, that the glass is so seldom made a part of the curtain wall contract, although the architects and contractors will usually insist on including in the curtain wall contract a lot of other items which could just as well be placed separately. It would certainly be more logical to place the entire curtain wall area, including the glass and glazing, under the responsibility of one contractor. With the advent of large glass areas in building walls and the use of new materials and larger glass dimensions, there has been almost a complete failure of the putties and compounds used in the setting of the glass. It would appear that so far very little has been done about this. New glazing compounds that can withstand the severe conditions imposed on them by these new conditions are sorely needed, and a new attitude towards the work is required on the part of the glass contractors. We have seen some of the new glazing compounds that are in process of development, and believe that some of them hold promise of solving this serious problem. They will be of no avail, however, if they are put in irresponsible hands.

Most curtain walls, particularly in office building construction, contain windows which sometimes are fixed and sometimes are ventilated. The adjusting of ventilators in operable sash has always been somewhat of a problem for both the manufacturer and the erector. With the new types of windows, such as awning windows and vertically pivoted windows especially, special adjusting problems are created. It is normally the responsibility of the manufacturer to adjust the ventilators in his sash upon completion of the erection, although the erector may do this work by special arrangement with the manufacturer. In curtain wall jobs the erector, in effect, creates the opening in which the window ventilator must operate. He, therefore, must assume a greater responsibility for the operation of the ventilators than he otherwise would. If he does not take special precautions in erecting the metal wall, considerable difficulty may be experienced in making the ventilators operate and weather properly. This is a special problem for each manufacturer and for each type of window. Most window ventilators are particularly susceptible to damage caused by improper glazing. If the glazier blocks his glass incorrectly or operates the ventilator improperly during the course of glazing, the ventilators will be thrown out of adjustment, sometimes to the extent that they will never operate properly or weather well.

This is another reason for including the glass and glazing in the metal wall contract.

As we approach the completion of a metal curtain wall job, the question of cleaning the finish surfaces invariably arises. Sometimes the question of protection and cleaning is completely ignored in the specifications, but more often it is placed in the hands of the curtain wall supplier. The worst thing that the architect can do in his effort to preserve the quality of the finished appearance of the metal wall is to place the responsibility on the curtain wall erector. The responsibility should be placed completely in the hands of the general contractor who is running the job. The general contractor is the only one who has control over all of the trades on the job. He is in a position to make demands on the various sub-contractors; to police them and give them instructions; and to withhold their payments if they do not cooperate. He has the same authority over the curtain wall erector. The curtain wall erector is just another sub-contractor on the job, having no control whatsoever over the other sub-contractors. If the curtain wall erector is responsible for protection and cleaning of the wall surfaces, the other trades will abuse the curtain wall, and at the completion of the job the owner will have to settle for the best that can be done under the circumstances. If the general contractor is responsible, he can police the job and see to it that no damage is done. There are some metal finishes that are particularly susceptible to damage and once these surfaces are damaged there is nothing that can be done to correct the situation.

Many specifications are unrealistic about protective coatings and their removal at the completion of the job. Some of the protective coatings that have been used are almost impossible to remove at a reasonable cost. Other protective coatings, if properly applied, can be left on and will actually provide additional protection for the metal for some time. It seems to me that more thought should be given to the proper use of protective coatings and to leaving them in place at the end of the job.

In the report of the Building Research Advisory Board covering opinions and experience of building owners and building contractors relative to metal curtain wall construction, there are frequent references which indicate a lack of coordination and poor workmanship. Certainly better coordination on the part of the designer, the detailer, and the manufacturer are needed if the erector is to do his job properly. Better coordination will eliminate some of the poor workmanship, but primarily the problem of poor workmanship is one for the erector to solve. The erectors will solve this problem only if high standards are insisted upon by everybody concerned, from the architect and owner down through the manufacturer, the general contractor, the erection sub-contractor, and the mechanics in the field. Many architects, engineers, contractors, and erectors are doing an excellent job. Speaking as an erector, I say that we must produce a consistently better job or we will lose the opportunity to produce any job.

DISCUSSION

MR. TOUR (The Moderator): I am sure these three speakers have given you some ideas for questions, so I am going to ask our three panelists to come to the platform. We will start by asking Professor Queer to take the first question.

QUESTION: Will you please elaborate on weather air wash and the use of tubes to gain this effect.

PROFESSOR QUEER: Air wash is a system that is used under the outer skin of the panel for the purpose, of course, of carrying away the moisture. If the tubes are imbedded in the back-up material, which can be perlite concrete or something like that, we generally advise installing paper tubes. Thus when the paper, which has a very high permeability or rate of water vapor transmission, is installed back of the metal panel, and the perlite concrete is spread around it, the tube merely serves to form a channel. Water vapor will migrate to that opening and be dissipated to the weather air.

QUESTION: Is the sound transmission of a metal panel reduced by rigidizing the panel with ribs or embossing or other reinforcing members?

MR. NEWMAN: The answer is no, it is not reduced or increased. There is a slight increase in stiffness given to the panel by such embossing or other reinforcing, which has very slight effect at the higher frequencies, but it is definitely a second-order proposition.

QUESTION: Would you favor the frame erector or sash manufacturer assuming full responsibility for installation of metal panels and glazing?

MR. COLLYER: The answer is simply, yes, I would.

PROFESSOR QUEER: I have several questions addressed to me dealing with an inconsistency that appeared in Mr. Rogers' paper and in mine this morning, where I pointed out that the quilting bolts or the studs that go through the wall do not have too much effect on the heat transfer coefficient. If you recall, I qualified that statement by saying that if they are used judicially spaced, that is true. Our statement is based on test results. Mr. Rogers, in his article, used a lighter stud than is normally used and his statement is based on a theoretical calculation. I suspect that the calculated value tends to be higher than the experimental value. We are not always so fortunate that the experimental values come in the favorable direction, as they do in this case.

MR. NEWMAN: There are a couple of questions here dealing with the value of having discontinuities in the medium, the use of several types of material, and this one in particular: "Is it true that much improved attenuation in light-weight double constructions, for example, metal curtain wall panels, results when one face has about twice the mass of the other?" Let me answer the mass question first and then the discontinuity.

There is a little advantage in varying the mass of the two faces in that the resonant frequencies of the two faces will be different, and we will have less likelihood of transmission of sound efficiently at the resonant frequencies. If the panels are thoroughly damped, however, there is little advantage in different mass for the two elements. This, again, is a refined point of view on the thing.

As to discontinuities, in the airplane problem we have an interesting use of discontinuities of impervious septa set into the sound-absorbing material between the skin of the airplane, where weight is a very critical limitation. By introducing impervious septa, not just changes in density of glass fibre or something like that, but actually putting in an impervious septa of steel or aluminum or sheet (something along the line of inside sound-absorbing material in the inner space between the two faces), one can increase the transmission loss of the panel over that given simply by the increase in weight of the septum.

MR. COLLYER: I have three questions here, all of which refer generally to standard prefabricated panels, so I will take the liberty of answering the three of them together. The first one refers to my statement that I thought around 20 feet was the maximum convenient size for length for these panels. The question is, "Panels higher than 20 feet become more expensive. For clarification, would you mind giving a cost differential if, say, 30 feet, 40 feet or 50 feet high panels are used?"

I don't believe that we can give a differential based on the length applying to any job in general. Perhaps we could if that were limited to some specific installation. It is entirely possible that on a particular job the 30-ft. or 40-ft. panels might work out satisfactorily, and even without any extra field cost, but, generally speaking, the longer panels do present problems in handling, and they are subject to more damage.

QUESTION: You stated that field-assembled panels were much more costly to erect than pre-fab units. Wouldn't you say that this differential is equalized by the cost of the materials only?

MR. COLLYER: Well, frankly, I doubt it. It depends on how much the manufacturer charges for the material and what differential he allows between shipping it marked down and shipping it factory-assembled. I can't estimate that differential, and I have no control over it. There certainly is some offsetting factor in price, but I don't know whether it offsets the extra field cost.

QUESTION: Is it practical to plan the erection of curtain panel walls so that during future expansion of the building the panels may be remounted and erected again elsewhere in the building?

MR. COLLYER: The answer is yes, because there have been a number of jobs where that has been done. Of course, in such an installation, field welding should be avoided and some sort of bolt or screw that can be removed more easily should be used. There will be some damage to the sheets, and the job won't be quite 100% perfect after the reinstallation. Tied in with that is this other question about the preferred method of fastening panel, in asking for cost considerations of different types of fasteners. That is a pretty complicated question to go into here. The choice will depend entirely on the individual job and the problems involved in that particular locality. I don't think I can give a specific answer to that here.

MR. TOUR (The Moderator): Professor Queer, have you consolidated some of your questions?

PROFESSOR QUEER: I have one or two questions here that have a similarity between them.

QUESTION: What has been done to develop a simple design procedure for the vapor transmission qualities of composite walls? Has enough study been made on building materials to have enough data available for such a procedure?

PROFESSOR QUEER: The ASTM Committees, E-5 and E-6, are doing a very fine job in trying to correlate test procedures for the composite wall. To date, the standardization has not progressed as far as we would like, but there will be, I can assure you, good standards developed in the next year or so. Committee E-6 is under the chairmanship of Mr. Leggett of the Building Research Division of the Canadian National Research Council, and he is quite active in that particular field.

QUESTION: Based on experience to date, would you say that hermetically sealed panels for curtain walls are impractical and would lead to moisture problems?

PROFESSOR QUEER: The hermetically sealed panel is a very fine panel if you can keep it hermetically sealed but, as pointed out yesterday by Mr. Rogers, the expansion and contraction exerts tremendous stresses on the panel, which has a tendency to make the panel breathe, and I have great doubts that you can keep a panel permanently hermetically sealed.

MR. NEWMAN: There are a number of questions here about what sort of core materials would do the best job of producing good sound isolation. I would say sand is the best thing, because it is heavy. Specifically, the question comes up, what about materials such as gypsum, Kalo, any of these things? They act just exactly according to their weight. Almost any solid filling of that sort is likely to be heavier than one of the fuzzy fillings, and will do a little bit better job in achieving a high transmission loss.

QUESTION: What about using reinforced polyester panels to replace glass in glazing of a building?

MR. NEWMAN: These materials have about 5 decibels less transmission loss than the equivalent thickness of glass--that is, most of these plastic materials. So, if you had a 30-decibel situation with 1/4-inch plate glass, you would expect about 25 decibels to be the limit with one of these acrylic materials.

MR. COLLYER: I have two questions directed to me that seem to tie into the same problem of coordination of shipments to the job.

QUESTION: As a solution to the problem of coordination, do you feel that this could be achieved by the manufacturer supplying a supervisor from the plant during the course of erection?

MR. COLLYER: I do think that can do a lot of good. Basically, the problem of coordination is one for the general contractor's control, and unless the general contractor cooperates, the supervisor from the manufacturer isn't going to accomplish any more than the supervisor from the erector. I do think, however, that it is a very desirable thing to have. We erectors would like to have manufacturer representation on the job.

QUESTION: Can you suggest a method whereby manufacturers can better coordinate shipments of materials with erectors' requirements? After a supplier is told a job is ready, he manufactures the material as quickly as he can, and then is told to hold shipment.

MR. COLLYER: I can think of several cases where that is true. That, of course, is a costly matter for the manufacturer and it is a costly matter for the erector. As to how it can be better coordinated, I think, really, the only answer is: a little more honesty on everybody's part. If a manufacturer's representative were assigned to that job in some very early stage, let's say right after the manufacturer received his order, and if he followed the job closely and had the authority to work with the general contractor, I think that he could accomplish very much. We erectors try to do that ourselves but, unfortunately, we are so far down the ladder that we don't have much authority.

QUESTION: Yesterday we were told the metal curtain wall in Dallas or Hartford used less tons of air conditioning capacity than the conventional wall in Beverly Hills. Today we are told that the heat transfer of metal walls is greater and air conditioning capacity increased accordingly. How do you reconcile these statements?

PROFESSOR QUEER: It is very difficult to tie in statements taken from two quite different papers. The heat transfer coefficient may not necessarily determine the magnitude of the air conditioning load. There are other factors. The latent load in the metal building may be materially lower than what it is in a conventional building because the building can be sealed up more tightly than it can be otherwise. Also, the design conditions in different places vary a great deal.

QUESTION: If black surface plus air wash is good, why would not high-reflectance surface plus air wash be better?

PROFESSOR QUEER: There is relatively little difference. A good air wash can clean up the radiant load, regardless of the color. In other words, this permits the architect to use virtually any color to get the proper decor in the building.

The question was raised whether the grids in the panel can be used for the air wash system. They can be, and can be used very effectively. You have to be careful in that the grids go all the way through the wall structure. In other words, you may over-cool the wall by virtue of the fact that you have your heavier air wash adjacent to the metal structure and go on through and cause difficulties in the winter by having condensation on the inner face of the wall.

QUESTION: What is the relative effectiveness of the following two systems: (1) curtain panel filled with sound-absorbing material, one face perforated; (2) curtain panel filled with sound-absorbing material, neither face perforated? In other words, panels the same except one is perforated on one face?

MR. NEWMAN: Actually, assuming that the two faces of the panel are the same weight, you would probably lose about 5 or 6 decibels in the transmission loss due to perforating one side.

QUESTION: Mention was made of a 35-decibel sound reduction for metal skin curtain walls. Is this a calculated or test value?

MR. NEWMAN: It is a test value. Tests have been made at the Bureau of Standards in Washington, at the River Bank Lab at Armour Institute, and we have made quite a few in the field for a number of specific jobs. There isn't a single report on this that is available, but data are available from these testing agencies.

MR. TOUR (The Moderator): Mr. Collyer, can you consolidate the questions you have and summarize in one final answer?

MR. COLLYER: They are very scattered questions but I shall try to cover them very briefly. Two of these refer to the question of these new Thiokal feelers.

QUESTION: What requirements would you suggest for a Thiokal feeler?

MR. COLLYER: I am not a Thiokal manufacturer and I am not a chemist. The requirements that I would want, however, are a feeler which would have a long life and would be easy for the mechanic to apply in the field. There are various Thiokal materials on the market. One of these questions here refers to some of these Thiokals and asks where they may be obtained. I would suggest that anybody interested in these look up the various manufacturers of Thiokal materials.

QUESTION: How much tolerance should be provided between the building frame and the wall panels?

MR. COLLYER: Again, that depends on the particular job and the particular type of panel. Usually on multi-story construction (I am talking about high buildings), you need a variation of around 2 inches. I think 2 inches would be desirable on almost any job.

QUESTION: Regarding standard shop fabricated units, should the corner closures be shipped with the original shipment or should they be sealed measured and made up specially later on?

MR. COLLYER: We have had a lot of trouble both ways. From the erector's standpoint, we would much rather have them shipped with the panels. But even that may at times lead into difficulties.

MR. TOUR (The Moderator): I wish we had more time to continue for awhile. There are, I am sure, some interesting questions that haven't been considered and answered.

I would like to conclude this panel session by thanking each of our panelists, Professor Queer, Mr. Newman, and Mr. Collyer, for having delivered very stimulating, informative talks this morning, and they have done a very fine job in answering questions.

I will now turn the meeting back to our Chairman, Mr. Tuttle, for concluding this part of the session.

MR. TUTTLE (Chairman): Thank you, Gentlemen. Before proceeding with the summaries of what has been, I am sure to all of you, a very interesting meeting, I would like to express our sincere thanks to the United States Chamber of Commerce for the use of their auditorium.

These meetings have become noted in scientific circles for being unusual in that they are run almost always within a few minutes of schedule, and we can all thank just one person for that, Bill Scheick. Bill is one of the best organizers and conductors of meetings of this kind that I have ever seen. He also is very energetic and highly successful in gathering material and setting up the meeting, and for 99 percent of the success of this meeting we can thank Bill Scheick.

He has a couple of things he would like to say before we conclude the meeting.

MR. SCHEICK: I am not going to take all of that credit. I had a real good Program Committee of the Institute members, and they are the men who picked the speakers and got the program organized. With that kind of a start we just make the thing go like clockwork.

Let me say to the people who asked questions and didn't get answers, if you don't know with whom to get in touch, write us and we will help you get in touch with the right person. If you know the person, tell him you heard him or saw him here and talked about it at the Institute. That is one of the main ideas behind the Institute--getting people from the many different lines of the building industry together to talk about problems of common interest.

MR. TUTTLE (The Chairman): The Program Committee felt that it would be wise to arrange for a summary of this conference from two points of view, that of the manufacturer and that of the designer, that is, the architect. The industry point of view will be presented to you by a man whom I have known and grown to like over a period of several years, Mr. Frederick J. Close.

PART VIII

SUMMARY AND FUTURE OUTLOOK

By Frederick J. Close
Manager of Market Development
Aluminum Company of America

MR. TUTTLE (Chairman): The Institute supplied me with very complete information regarding the background, experience and academic history of all the speakers whom I have had the pleasure of introducing to you, but up to this minute they have not been able to give me any information about Mr. Close. By making inquiries of several individuals who do not care to be quoted, I find really very little known about his early history, other than that he left several of the seaports of South America where some of the tougher Latins, through his efforts, gained new respect for American sailor men.

He apparently at one period left his mark in the Texas oil fields. Penn State awarded him a Bachelor's Degree, but not before several periods of reconsideration. Their reluctance was not due to his brilliant academic record, however.

He has been connected with Alcoa and its marketing activities for a long time, and is now Manager of Market Development for the Aluminum Company of America. I am pleased to present Mr. Frederick J. Close.

MR. CLOSE: I would say that is a heck of an introduction, but this is the last of the show, so I think we are probably all right.

If there is any doubt in the minds of any of you people as to the interest in this curtain wall business, I believe all you have to do is to look around at the great assemblage that is here.

As I look around, I see many people with whom I have been associated in the building business for the past 27 years. To me, that is one of the wonderful things about the industry; it's the type of business that brings people close together. It's also the type of business that makes good, long-lasting friends and, I'm sorry to say, once in a while a good, long-lasting enemy. I can assure you that I have not escaped the latter.

If it hadn't been for the imaginations of the group here represented, and their unselfish devotion to doing things better and more economically, I feel certain that the metal curtain wall would not be nearly as far advanced as it is today. You have heard some of the experts in the field discuss their particular subjects. These people know whereof they speak. Most important, they are dedicated to their work. I was asked to try to summarize their papers, and to give some look into the future for metal curtain walls.

To summarize briefly, we have ample evidence that many, many good buildings using metal curtain walls are now occupied by happy and satisfied owners. They are functioning properly and, depending upon your taste, they have added a new type of art to the panorama of America. It is apparent from what has been discussed, that there is much work yet to be done before we in this industry can come anywhere near being satisfied, even using the proven materials and techniques now at hand.

The future will undoubtedly furnish us with new and better materials and better techniques. Collectively, we have the brains and the equipment; somehow we'll get the money to solve the existing problems and the problems that will arise as a result of these new techniques. And if we constantly keep at this job, it seems to me that our future is assured--provided we continue to exhibit the same high degree of imagination, put into the problems the same energy as in the past, and continue to assure our many bosses that this effort is worthwhile so that they will continue to provide financial support.

Our forces have been rather meager. We need much help from allied industries. We need the cooperation of the architectural profession, the architectural metal workers, the construction industry, and those industries which make nonmetallic components which are so essential to our continued success.

I believe that the aesthetics of metal-clad buildings must be left to the architect and I have every confidence that he will solve this problem if we furnish the tools. These tools must come from good, sound engineering. They must come from a thorough knowledge of what a curtain wall is supposed to be. They must come from the research laboratories and the development divisions of the many companies who are to participate in the progressiveness of this industry. The stakes are high. The problems confronting us today, and those of tomorrow, will be solved. But, before we can attempt to solve them I feel that everyone interested in this field should understand what these problems are.

We at Alcoa have been at this thing for many, many years and while we do not profess to be right all of the time, I should like to give you some idea of how we approached the problem. I hope you will forgive me for using Alcoa as an example, but obviously this is the one company, the one product, and the one set of bosses I know best.

Before we had even announced to the world that we were going to build an all-aluminum building as our headquarters in Pittsburgh, we sought the services of a good firm of architects. We paid for and got advice from many consulting engineering firms. We ran several fire tests at the Underwriter's Laboratories, and we ran innumerable structural tests. Then, without fanfare or publicity, we built a small four-story administration building for our Davenport Works.

While this work was going on, we tried to determine what our problems were and what we would ultimately have to solve. We knew that we had to have a product with a permanent weathering surface. We hoped we could get this product in all colors. We felt that it had to be available in all of the many forms known to the metal working industry -- sheet, plate, extrusions, wire, bar, foil, tubing, castings, etc. We wanted a product that could be welded, punched, formed, textured, drilled and tapped. We felt it absolutely necessary to have a product that would stay put in a true plane. We felt that our product would have to be used with materials other than metal — materials which would perform functions that aluminum, as such, was inherently incapable of performing. And, we knew that a technique had to be developed for combining these dissimilar materials.

We knew that we had to have a product that could be engineered to make a water-tight joint, at the same time allowing for expansion and contraction; or, we had to develop a technique that would allow the water to penetrate the joints and then be removed without damaging the curtain wall as a unit. We felt it most desirable to develop a curtain wall that did not require the use of sealing materials that would need constant replacing or patching.

We wanted a panel that could be erected economically from the inside of the building -- without considerable special rigging, and with a minimum number of component parts. We wanted a panel that would allow for considerable flexibility on the part of the architect. We were most anxious to find a more practical solution to what we might call the odds and ends, or that 15% of the job that kills you. We knew that we had to have a better understanding with the architectural profession as to what can and cannot be accomplished on this 15%.

We were certain that if we were to meet success our panels had to be shop-fabricated--with windows, louvers and what-have-you installed—and we determined that our size should be either from floor-to-floor or column-to-column. We were concerned about how to protect the panels during shipping, while stored on the job, and during the course of erection, and how to clean up the job after erection. Most important of all, we wanted to accomplish all of these things more economically than the traditional type of construction.

Let me say here and now--for the benefit of those who may have heard to the contrary--we have had no trouble with the curtain wall of the Alcoa Building. We have no leaks. There is not one pound of caulking between wall panels of the building, and we have actually solved most of the problems which we set out to solve. However, our method of solution on the Alcoa Building was not as economical nor probably as practical as is now available. But then, neither are today's methods and techniques as nearly as practical and economical as tomorrow's will be if we continue our efforts.

Now it goes without saying that if, through our combined efforts, we were able to assure an owner that metal curtain walls are the most economical means of construction and that they will reduce his maintenance to an absolute minimum, and if we could convince Mr. Architect that he has absolutely complete freedom of design including color, then we would really be IN. I suppose if we ever reach that point we'll be fighting like wildcats among one another on aluminum versus stainless steel -- porcelain enamel versus aluminum -- or some plastic bombarded with neutrons versus porcelain enamel. However, for my money that would be a happy day!

If we in the metal curtain wall business really mean it, and speaking for Alcoa I'll say here and now that <u>we do</u> mean it, then we will want to cooperate with one another for the good of the industry and the good of ourselves. We will want the owners to get value received. We will want to put added effort on research and development on a much accelerated scale. We will want to sell our materials on a profitable basis. We will want to cooperate with the subcontractors and the architectural metal fabricators, so that their techniques can be developed to permit them to do a good job and also make a profit. We will want to conduct our affairs in a manner that will enable us to sell metal curtain walls on the merits of our materials and not on the demerits of other materials used for the same purpose. And, we will want all jobs to be the good jobs of which we, as a group, can be proud.

We all recognize that we have problems. We've got to approach the solutions in a manner that will be conclusive; one which would include a testing program that would assure the architectural profession that the solution has been found. There is no short-cut to success in this field. It's research -- it's developing -- it's cooperation -- it's a tremendous lot of work, with a liberal dose of frustration.

Much, much progress has been made. For the most part we have Code approval. Aluminum, porcelain enamel on aluminum, and porcelain enamel on steel are offered in a wide variety of colors. We have products that will stay put in a true plane—if properly handled. We have several very good proven core materials and back-up materials.

Actually, I believe that the three major factors that require considerable more work are, (1) the development and testing of more economical dry joints with less component parts; (2) we must better familiarize the architectural profession with our product so they can help us avoid that killing 15%, or at least learn how to handle it economically; and (3) of prime importance, while metal-clad buildings are today economical in comparison to many other types of construction, our constant aim should be to improve this economy.

Many of us have spent considerable time and money in arriving at this point. I would be remiss if I didn't pay tribute to the architectural metal fabricators and to the manufacturers of sandwich panels, as well as a number of progressive architects, all of whom have worked closely with our industry and many of whom contributed generously of their time and money. We at Alcoa are proud that we can include ourselves among those who have contributed to the growth of this new and exciting industry. Over the past 20 years it has developed from a rather puny child to a strong young man and it's time someone had a talk with him. He is inclined to be impetuous. He is inclined not to think as honestly as he should. He is a little inclined to barrel ahead without too much regard for the consequences and very often he is inclined to have bad manners.

Some of us in the promotion of metal-clad buildings have had just such a talk among ourselves and we have reached the conclusion that in the best interests of the curtain wall industry we should continue our research and development. We should have outside testing laboratories and universities evaluate our results before recommending their use. We should then thoroughly acquaint the architectural profession with our proven results.

We should be on the alert constantly to develop better alloys, better and more exciting finishes, more economical means of fabrication, and expand our advertising and promotional efforts to achieve wider acceptance for this type of structure, particularly among the decision-making people who may have spent too many years in the gas light era.

You people familiar with Alcoa's advertising and technical bulletins--Achievements Series, Care of Aluminum During Construction, Cleaning and Maintenance of Aluminum--and the all-important work of our architectural service inspectors, the fundamental work of our vast force at the Research Laboratories, the Process Development Laboratories and the Development Division, know that we are sincerely attempting to follow a program that would insure an ever-increasing volume of our favorite metal for curtain wall construction. You may or may not agree with the brief outline of what we are doing but it is my sincere belief that many of the industries represented here, and undoubtedly some that are not represented, should build up a program of development, research, advertising and promotion to assure the complete acceptance of this type of construction for the future.

It's a strange thing but it appears to be a fact that the monumental-institutional type of building is the easiest place to break in a new idea. From there, these ideas seem to filter down to the commercial and public kind of building. I predict, if we all do a good job, that eventually metal walls and roofing, requiring practically no maintenance, will be used rather extensively in the residential field.

Now, while we collectively lay out this ambitious program for the future, and while we dream of the day when we have metalized the world insofar as construction is concerned, it would be folly for us not to realize that competitive materials are not going to stand by and watch us steal their market. Actually, they are accomplishing considerable right now and I think we must be alert and capitalize on every advantage we have--of which there are many. If we are sincere, honest, aggressive, smart, and imaginative--a word of caution: you've got to be on good terms with your banker, as this sort of thing takes money--our children's children are very likely going to look upon a far different type of America insofar as buildings are concerned, an America that will be a much more exciting place in which to live.

In closing, I would like to make a few observations, the gist of which I am sure will not be overlooked. Stainless steel is an excellent material. My meat and potatoes is aluminum. I think aluminum is a better material. Porcelain enamel on steel is an excellent product. I think porcelain enamel on aluminum is a better product. I believe I could defend this on the merits of aluminum. I am sure the stainless steel people and the porcelain enamel on steel people feel they can defend their products on their merits. In my considered opinion the manner in which we conduct ourselves with one another will determine our chances of either winning or losing this ball game. We in the metal curtain wall business have a small percentage of the total available to us. Let's develop the market and we will all profit--of that I am sure. And let's stop quarrelling with our kin, or even our real competitors, and build that better mouse trap.

MR. TUTTLE (Chairman): Thank you, Frity. That is what I wanted to hear.

It seems particularly appropriate to me that the summary of this Conference from the architect's point of view should be given by one who has had a rich background in the architectural field, both in practice and in education. Our final speaker in this series of erudite, stimulating speakers is Mr. D. Kenneth Sargent.

SUMMARY AND FUTURE OUTLOOK

By D. Kenneth Sargent
Partner
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MR. TUTTLE (Chairman): Mr. Sargent is a partner of Sargent-Webster-Crenshaw & Folley of Syracuse, New York. He has given much study and thought to metal curtain wall design and has evolved some very interesting concepts on the subject. He received his architectural degree from Syracuse University, where he is now a Professor of Architecture. He is a fellow of the American Institute of Architects. I am pleased to present to you Mr. D. Kenneth Sargent.

MR. SARGENT: The post of last man on the totem pole is a difficult one, especially when you have been cautioned not to repeat. That would leave little to say.

It would seem rather fitting that I review the proceedings from the position of the average architect in the ordinary U. S. city, especially so since much of the discussion has been pertaining to large projects from the viewpoint of the large office.

In a few words, it would seem that the real basic aim of this Conference and all that are sponsored by the Institute is, as has been said before, better buildings for less money. To partially attain this aim with respect to panel construction, this fine exchange of ideas between producers and designer has been most beneficial.

It has made possible for me, an average architect, to learn many details concerning this construction that I know will assist me in the design of future work. Certainly there has been much indication of great possibilities for improvement in what we now have, especially in the matter of the dry joint that has been so often mentioned. Any improvement and progress in attaining a more waterproof assembly will result in greater acceptance of this construction.

I recall a situation in which a practicing architect came to us with a design for a fairly important county building. He had been struggling to perfect it and desired assistance. In aiding him, the designers suggested a very fine appearing structure, composed largely of panel wall construction.

The architect was delighted and after some study and investigation, produced the contract drawings and it was constructed. He was very proud of it. When I had opportunity to see the building, I too found it very satisfying except for just one little trouble: It leaked. I know he isn't discouraged because it is apparently a minor difficulty. This trouble will soon be remedied. The important fact remains that notwithstanding his difficulties, he would repeat this type of construction.

One other very interesting thing became evident in that one of his competitors soon after designed another building for the same political body, employing a panel wall construction. In other words, even his competitors were not deterred by the fact that he had some difficulties. They, too, were eager to benefit by his innovations.

We certainly must improve this part of the system, namely jointing methods, if we are to hope for general acceptance of this method of construction. The architect must have some real assurance that these walls may be made tight.

Ideas have been expressed indicating desire for color. As an average architect, I too, am always desirous of color. In fact, in many cases, I would insist upon it. However, again I must have assurance of permanency if I invest my clients funds wisely. Not only am I interested in color of the panel; I may desire color on the structural members as well when design so dictates.

The idea of combining other facing materials with metals in the construction of panels has intriguing possibilities. Some current research indicates that such combinations are both logical and economical. I think we should all go away from this Conference feeling that we will not stop at this point, but that we will completely explore other possibilities.

Naturally, the reduction of dead load by panel construction has long been recognized. It has been mentioned on this program. To me, an average architect, doing the ordinary problem, this is not much of an argument to influence its employment. The average job is 2 or 3 stories and the reduction of dead load, even though materially lessened, will not make any great difference in cost of construction. I mention this because I know that many of you are interested in the average or ordinary building, which, in most instances, is the large market.

Certainly there could be certain things said about saving in space, and I come away from this Conference feeling that I should take a more positive approach in comparison of masonry and curtain wall construction. I should begin with the thin panel wall plus a given floor space and when comparing it with masonry, recognize that I add costly area to the building rather than that reversed opinion that starts in with masonry and says, "There may be a saving." I believe the architect must now take a more positive approach in this comparison. Obviously, at this stage of development, there must be comparison.

The subject as assigned me also included, "What are the Future Implications"? I discern a trend in the building industry that has long existed in the clothing industry. When a well-known designer, Dior, Cassini, comes out with a garment, it is soon published in the exclusive journals of fashion. It is immediately copied, or at least greatly influences other designers who, in turn, market it in the above-average shops at above-average prices. Eventually the influences--yes, even the exact design--is found on the racks of the chain-store markets for the benefit of the masses.

A new pattern has been established in building design and it has already influenced many of the recognized designers. It has now spread to a greater segment of the industry but general acceptance is a little bit more difficult than the usual design in the clothing industry. It is retarded too often by lack of knowledge and experience on the part of a designer or consumer. As acceptance increases, experience increases and the system is improved. As research continues to perfect and improve the pattern, we remove past difficulties and thus encourage greater use.

I certainly hope for a continuation of research, especially as Mr. Close has just mentioned. Such information must be distributed to all architects to ensure more general and intelligent use of these fabricated materials. This future research, as well as the data as discussed at this Conference, must be widely distributed. Only by possession of such information can we intelligently design and provide walls which will be satisfactory to the consumer.

That information must be realistic and factual. It must be authoritative. I am a bit tired of laboratory figures that are flashed before me about what this will do and that will do which too often are misleading. I am inclined to think that a laboratory can certify to almost anything under certain conditions of control. The results can be most misleading. We need tests which are realistic, upon which we can depend.

We must improve the panel joints. We need information concerning gaskets, and what is their life expectancy. We should know the resulting figures of tests on sound transmission of the typical completed assembly, not just a part of a system.

We should be informed how these particular assemblies will function with respect to variations in interior and exterior temperature, weather and humidity. I use the word "assemblies" because the trial of erected building structures and the practical experiment so often differs from a controlled laboratory experiment. It would appear that future increase in the use of panel wall construction is certainly dependent upon dissemination of such information.

Acceptance of panel construction has too often been limited by cost of installations. Like other building materials, cost of such systems vary considerably according to the opinion of the estimator. Certainly the thing that is new to a particular estimator will be approached rather cautiously and will quite likely result in excessive pricing. Continued effort to inform contractors of installation methods and erection costs would seem essential to increase use and therefore production.

We recognize that cost of development and research must be written off in these sales prices, but it would appear that greater production in the future and added simplification can reduce in some degree the cost of the completed system. Certain, sure, increased future use will be dependent upon competitive pricing with other comparable systems on the ordinary construction job.

To illustrate my point a bit more forcibly, I would say that no architect uses concrete blocks for exterior walls because they are either beautiful or weatherproof. Incidentally, I suggest that you survey requirements for low budget construction methods and develop some methods of panel construction which will be competitive with that kind of material. We need it.

Why should present building codes that were predicated on combustible and ordinary construction which have been common in past years still exist to prevent progress and the introduction of new methods of construction in many structures? I will accept the fact that in many instances the architect can fight this battle to alter the codes to allow more modern construction methods, but not so with the small average commission.

I hope that some concerted effort by the producers to assist in changing out-dated codes which limit unfairly the use of such wall assemblies will result from this Conference. We know that acceptance of this type of construction in many instances is inhibited by this reason alone.

At this Conference, you have heard many times the word "flexibility." I concur wholeheartedly with that plea for variation, for we must have materials which will fit changing needs, functions, patterns and finishes in buildings. I say that because the one thing that I am sure of in this world, is "change." Producers must not jell or settle on any one system. Completely survey this field and develop new types and allow fabrication of many. Too often I note someone developing excellent material or a good product, whereupon other manufacturers immediately imitate. I believe there is greater opportunity for good production if a manufacturer will develop materials of similar function yet something different in appearance, pricing, installation or method and thus give the architect a wide range of products from which he may select. The selection is limited today to a few types.

Certainly it has been pointed out at this Conference that panels must combine more than one function. Perhaps it is a little bit in the future but we certainly should look to the inclusion of heating elements in panels and, naturally, the essential combination of sound transmission and weather resistance.

I dislike very much to keep mentioning the problem of weather resistance but I often think we are too prone to forget the importance of further perfecting this basic detail. We should cast an eye at masonry procedure to learn many truths that have been evolved over the years. We know that masonry is not perfect. Masonry details have been notably imperfect, as was mentioned yesterday in the discussion of hotels. But I also notice some defective masonry details that the panel industry is copying. I can recall some years ago a building being constructed in masonry without drips or washes. I remember the fact that that building was very soon streaked with dirt and became an eyesore. It was noted soon after construction that many thousands of dollars were spent in waterproofing the critical joints because they were not protected by any drips or offsets. Yet a few weeks ago, I examined a panel assembly with similar flush joint construction. I wonder how such an assembly of panels will appear after a few years of exposure to normal atmospheric dirt. I wonder how much some owner will expend to weatherproof unprotected and exposed joints. Perhaps something can be learned from mistakes of others in the past.

Yesterday, it was suggested that a building is much more pleasant to look upon if it is not a flush-flat surface. Thus, there are other reasons, including the esthetics, to indicate that we must cast an eye upon the past and learn some of the lessons that have evolved over the years.

Daily we are finding it necessaty to develop and design new construction methods to reduce high costs of labor at the site, and thus the cost of buildings to our clients. Certainly metal curtain walls can be and will be developed to provide a solution to this problem for even the low-cost structure. Eventually, I believe that the arch conservative designer will also be forced to accept this approach to reduce cost and provide better building. To this end, we should continue to develop more simplified methods of panel construction that will result in building costs competitive with older construction methods.

It would appear that the average architect is willing, waiting and ready to utilize metal curtain wall construction when he has authoritative information that will indicate a degree of perfection in manufacturing and assembly of these products, if they are at competitive prices, as the American economic system dictates.

The future depends on continuation of research, progress and development. If we continue that research and progress, acceptance and production will be the natural result.

MR. TUTTLE (Chairman): Thank you, Mr. Sargent.

We extend our thanks to all the speakers, and thank you, the audience, for your kind attention. The meeting is adjourned.

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