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Building Associated Fire Problems-- Report of Meeting CIB. W14, April 1-5, 1974

A. F. Robertson, D. Gross and R. B. Williamson

Center for Fire Research
Institute for Applied Technology
National Bureau of Standards
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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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A. F. Robertson, D. Gross and R. B. Williamson

This report summarizes discussions which took place at the recent meeting of Commission W14 of CIB. About 46 of the more than 100 documents related to fire problems were considered at the meeting. It was agreed that current trends in building construction and furnishing materials present new forms of fire hazard which warrant increased attention. While progress was evident in methods for analyzing fire endurance performance of structural building elements it seems desirable to place greater emphasis on the fire gas hazard as a cause of fire casualties. A symposium is planned on methods for managing gas movement and disposal during building fires. A state-of-the-art paper is also planned to review and document current work on the influence of fire gases on animals and humans. It was noted that the smoke production characteristics of furnishing items may present serious problems and must be considered in any attempt to control smoke during building fires.

Key words: CIB; codes; Commission W14; fire endurance; fire gases; fires; fire tests; growth; models; smoke.

1. INTRODUCTION

The 11th meeting of Commission W14 of Conseil International du Batiment pour la Reserche, L'Etude et la Documentation (CIB) was held at the Braunschweig Technical University. Professor Pierig welcomed the delegates, Annex I, and gave a brief history of the University which now has about 7,300 students. Professors are expected to spend about one-half of their time on research. Professor Kordina was introduced as the host and Chairman of the meeting. Dr. Thomas introduced the agenda, Annex II, and asked for revision of the report of his comment on fire load surveys to make more evident his concern that several countries are collecting information which will not be useful in design of new buildings. This was accepted and no further revisions proposed. A brief review was made of activities proposed in that report for future action. Many of these had been implemented although others had not been accomplished. Some of the latter included:

a. a symposium on concrete spalling, possibly in connection with a meeting of the Federation International Precontrainte (FIP), and

b. meetings to explore the means for coordinating statistical work relating to building fires.

New developments were reported:

a. It was noted that two building material associations (CECM & FIP/CEB) were on the verge of publishing model structural codes. It was proposed that CIB might review these and comment on their merit and general applicability as performance criteria for all materials.

b. Dr. Thomas indicated that there was pressure from the CIB Governing Board for Commission W14 to produce more tangible outputs. There were comments that Commission W14 could improve its overall effectiveness by development of reviews of the literature and recommendations on appropriate fire safety procedures or requirements. The delegates were asked to remember this in preparation of the reports of their groups.

Dr. Thomas then indicated his recommendation for classifying the papers into four groups as indicated in Annex III.

I. Structural (Fire Endurance)
II. General Fire Considerations
III. Smoke and Reaction to Fire
IV. Papers of General Interest

It was proposed that the latter group of papers be presented and discussed in plenary session. This was agreed and the discussions are summarized below.

2. PLENARY MEETING

Dr. Thomas, continued as Chairman of this meeting, to discuss papers of general interest to all delegates. Papers 72/71 and 7/74 were presented by Dr. Berl. These are the Annual reports for 1972 and 1973 of the fire program underway and the Johns Hopkins Applied Physics Laboratory. Four major thrusts were briefly mentioned:

a. fire casualty studies,
b. mechanism of chemical inhibition,
c. means for assisting fire department operations, and
d. fire science training.

Only the first of these was discussed in any detail. Their findings showed that about 80 percent of the fire victims examined in the State of Maryland had carboxyhemaglobin contents high enough to explain the fatality (in the absence of any other cause). Mention was made of the prevalence of prior heart trouble and alcohol as aggravating the problem. In 10 percent of the fatalities, the cause of death could not be determined. In reply to questions, it was reported that oxygen deficiency was not a likely cause for the fatalities so far studied, and that approximately 100 of 120 lives might have been saved if a sensitive CO detector/alarm had been present.

Mr. Maroni presented his paper 12/74[1] on the large-scale burn tests of panels and assemblies of foamed plastic insulation for interior lining of buildings. He emphasized that small-scale bench-top tests were inadequate for prediction of the foam behavior under severe fire exposure. Even fire retardant treated foams showing low tunnel ratings may be unsafe unless additional fire safety measures such as sprinklers are arranged to protect the occupancy. The film showing fire tests of large corner wall assemblies was shown. Considerable interest was evident in the study.

Mr. Nice reviewed paper 27/74. This involves a report of the first phase of a three-year study of furniture fire problems.

This work is discussed in detail in the report of Group III. The interest feature of this work was the comprehensive aspect of the ignition source and materials being investigated. They, like we, find that smoldering ignition of foams can be enhanced when a cotton fabric is placed between the foam and the ignition source.

Mr. Keough presented his paper 31/74. This is similar to 27/74 and involved use of 16 textile and plastic coated upholstery covering materials alone and with 6 different cushion backing materials. The tests used included: Austrailian Standard AS1530 part 2-1973, a vertical flammability test using a match-like ignition flame source; AS-30 part III-1970, the Early Fire Hazard Test which assesses ignition, spread of flame, heat evolved and smoke developed; a radiant ignition test involving a hot wire to pilot ignition, irradiance levels of 20, 32 and 50 KW/m^2 were used. Duration of flaming and smoldering following ignition were observed as well as depth of burning penetration. It was concluded that:

a. Penetration of cover and cushion backing material by small ignition sources was affected by type of cover material. Wool fabrics showed best performance.

b. With small ignition sources PVC coated fabrics showed resistance to penetration. This was not observed for polyurethane coated fabrics.

c. With high radiant exposures the properties of the backing material override those of the cover. The cushion materials may be listed in the following order of increasing hazard:

   1. mineral wool,
   2. compact wool waste and hair felt,
   3. cotton floc and polyurethane foam, and
   4. sponge rubber.

[1]The number indicates CIB/W14 paper No. 12 of the year 1974 (see complete title in Annex III at end of paper).

Professor Williamson reviewed his paper 24/74 "Impact of Contents of Building Fires." The presentation was primarily through use of movies and slide projection photographs of corner, 3/4 room and baby crib fire tests. The main thrust was that the planned introduction of a wide variety of plastic furniture building finish and other occupancy items present a serious new hazard to the public. It was stated that many of these items can be ignited and propagate fire from a match or other small ignition source. It was further suggested that since the ratio of heat of combustion to heat of vaporization, or "B" number, of plastics was higher by a factor of about 2.5 than that of wood, the former may represent a more flammable type of fuel. Since paper 24/74 is not complete, Williamson requested comments from any who had suggestions. It was evident that many delegates were concerned about problems related with plastic home furnishings items.

Dr. Stolp of Netherlands emphasized the need for an analytical model to relate ignition and other reaction to fire properties to the fire behavior of various products.

Dr. Thomas introduced document 40/74 "The early stages of fire growth in a compartment." This describes the cooperative study of fire growth and development in a model compartment. He reported that the document could be considered as the draft manuscript of a second paper to be published soon on compartment fires. Any comments would be appreciated. The work reported indicates that the time for flame spread to involve all the fuel within the compartment is:

1. not significantly affected by compartment shape and only slightly by fuel continuity and compartment ventilation, and

2. does depend on position of ignition, fuel height, stick spacing, and compartment lining.

Professor Pettersson reviewed document 47/74 "Principles of Fire Engineering Design" authored by Wittereen and Twilt of TNO. He reported that this was the first of five documents that would be required to cover the subject and forms one chapter of a building design text or proposed code for the Commite European du Construction Metallique (CECM).

This discussion completed the first days work. The three groups were assigned rooms for their work during the next day and a half. The reports of these three groups are included in Annex IV. We elaborate on these further only to the extent that supplementary material was discussed which has not been either adequately reported in Annex IV or is not available in a document circulated.

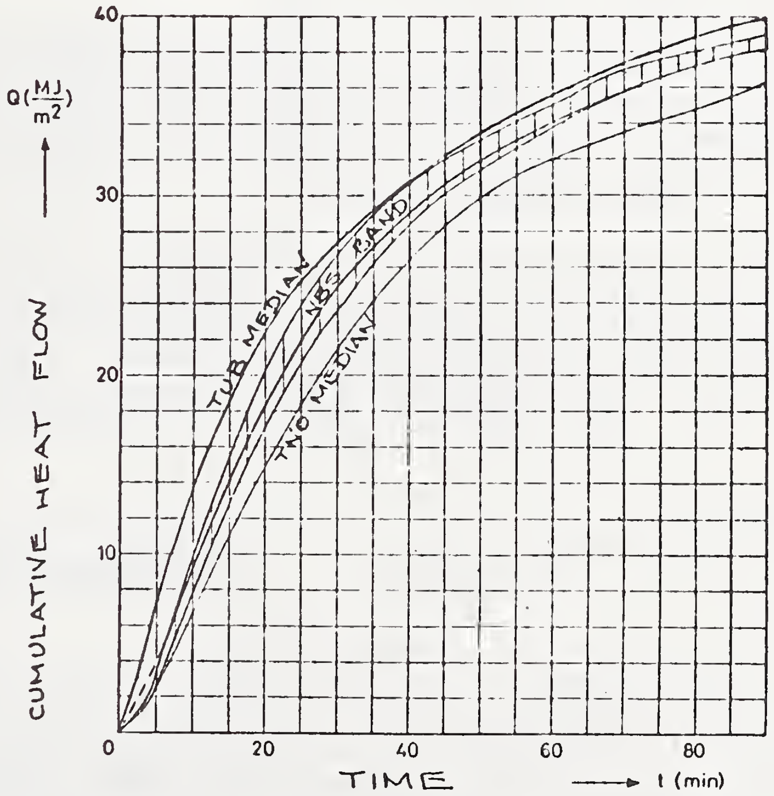
3. GROUP MEETINGS

This section of the report presents information on discussions which took place during the three simultaneous group meetings above and beyond that included in Annex IV.

A. Group I (Mr. Malhotra, Chairman)

The main discussion items were: 1) correlation of furnaces, 2) design of structures (concrete, steel), 3) properties of materials, 4) model tests and large-scale tests, and 5) structural codes and philosophy of structural fire protection.

1. Correlation of Furnaces - An analysis was made by Dr. Van Keulen and Dr. Stolp in Document 41/74(NL) of the interlaboratory data on the heat flux to a wall during the standard time-temperature exposure in a fire endurance test. Due to damage or evaporation of the gold layer on the heat flux meter, distinctions between radiative and convective heat transfer could not be made. The largest differences occurred in the first 15 minutes. By 60 minutes the differences between furnaces were of the same order as the variation in a given furnace. The results from the NBS furnace fell within the main band of results from all other laboratories (3 labs in Germany, 1 each in the Netherlands, Australia and U.K.).



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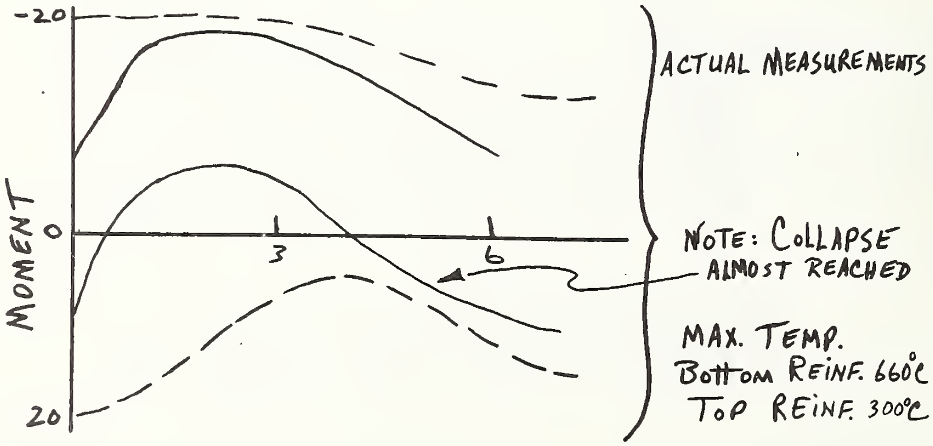
There was considerable discussion on (a) the importance of radiation (from hot gases versus walls) particularly between oil versus gas-fired furnaces (however, the test results did not show startling differences); and on (b) the influence of the thermal conductivity of the furnace bricks. For the NBS furnace, it was reported that the heat input was nearly equally divided among (a) the convective heat transfer to the walls, (b) the radiative heat transfer to the walls, and (c) the heat carried out by the exhaust gases. The preparation of a guide report on a method for evaluating heat balance in a furnace was assigned as a task for Mr. Gross (NBS). Mr. Keough (Australia) was assigned the task of recommending a procedure for achieving greater uniformity in the radiation characteristics of furnaces.

2. Design of Structures - Dr. Jarosz of the Polish Institute of Building Technology, Warsaw, described fire tests on loaded prestressed concrete L-beam girders 18 metres long and prestressed concrete roof panels 12 metres long. These tests were conducted to verify the conventional method of calculating fire resistance based on the "minimum cover" method. Since there were no gas or oil furnace facilities available, the tests were performed by burning wood in a "provisional fire chamber." The standard time-temperature curve was approached but not reached. A structural load was applied using additional concrete slabs.

Explosive spalling of concrete caused early collapse of the roof panels (21 to 28 minutes) presumably due to the limited curing (approximately 3 to 6 months). Explosive spalling in the web (8 cm thick) of the girders also occurred. Considerable background information on this effect is available in reports by Meyer-Ottens.

Additional discussions were held on calculation of the fire performance of concrete structural elements. Mr. Anderberg of Sweden described calculations and tests on concrete slabs restrained against end rotation but permitted to move longitudinally (Document 22/73S). He illustrated how collapse of a structure could occur during the cooling phase, sometimes several hours after the end of heating. A more complete paper will be published on these predictive techniques.



On the subject of steel structures, the Rudolphi and Knublauch (BAM) model for predicting heat transfer through an insulated layer over steel was briefly described (Document 17/73D). Comparisons were made between small and large-scale furnace test results using a scaling factor involving the profile factor ratio F/U where F is the steel cross-sectional area and U is the perimeter surface of the assembly. Additional attention was given to the influence of creep, the significance of critical temperature, and the use of deflection criteria in the discussions of papers by Lie and Stanzak and by Wakamatsu.

Mr. Thor (Document 43/74S) showed that rate of loading had a large effect on stress particularly at high temperatures; this is a measure of creep strain. A mid-span deflection failure criterion based on Ryan-Robertson (1/800 L^2/D) was stated to be more appropriate than deflection rate, but this was questioned by Malhotra and by Meyer-Ottens (based on approximately 60 tests at Braunschweig).

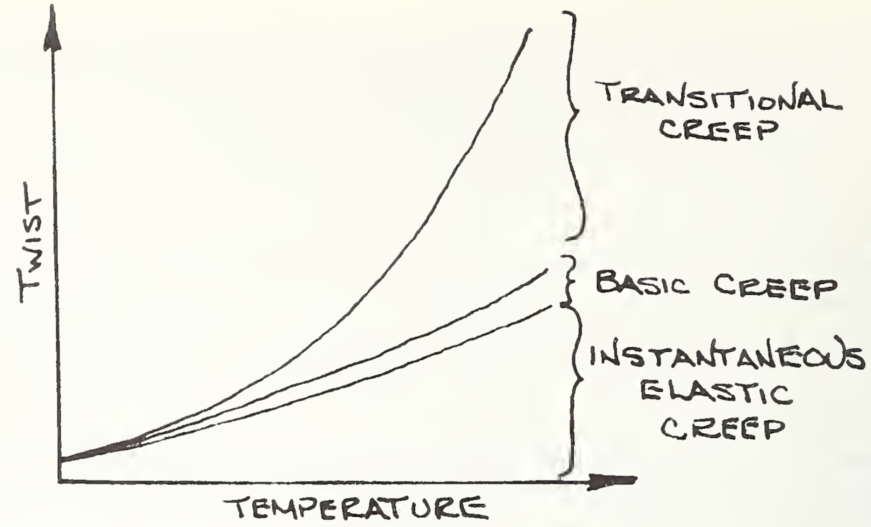
The behavior of a multi-story steel framed structure exposed to fire was the subject of a paper by Saito (Document 38/74J), briefly discussed by Professor Kawagoe). It was estimated that instability due to thermally induced deformation could result when steel temperatures exceeded 150°C.

3. Properties of Materials - Mr. Malhotra summarized briefly discussions which had taken place on the subject of concrete spalling among experts from Germany (Meyer-Ottens), Netherlands, and the U.K. (Malhotra, Dougall, Sullivan). Dr. Meyer-Ottens' thesis paper is completed and a short summary will be circulated to members. Both parts, i.e., (a) Theory and Results of 120 Tests, and (b) Thesis, will be published by the German Association for Concrete Structures this year.

Mr. Kalos from Greece (Document 26/74G) discussed the effect of carbonization which might lead to severe spalling in aged concrete. Since subsurface cracking and porosity increase with age, the loss of water vapor will tend to limit pore clogging and subsequent spalling (no spalling if total moisture content is less than 2-1/2%).

The question of planning a conference on concrete spalling was discussed and it was decided to leave the decision up to the CIB Plenary Group with the thought that expansion of the topic and collaboration with other societies (RILEM/FIP, CEB) could be considered.

Anderberg and Thelandersson (Document 23/73S) have done considerable work on measuring and analyzing the stress and deformation characteristics of concrete at high temperatures. Using concrete specimens in torsion at high temperatures, twist angle data were obtained under constant and transient temperature-creep conditions. Creep was classified into instantaneous elastic (and plastic) creep, basic creep, and transitional creep.



Dr. Schneider has performed similar experiments at Braunschweig in which he varied one component, kept one component constant, and measured the third component (stress, temperature, strain). This work will be presented at the May 1974 FIP meeting in New York.

4. Model Tests and Large-Scale Tests - Mr. Twilt described several studies involving reduced scale tests on columns and on braced and unbraced frames. The objective in the first study (Document 48/74NL) was to determine the effect of the rate of heating on the creep and load bearing capacity of steel columns. The heating rates, which ranged from 5 to 50°C per minute, had very little effect for the model beams and columns, and it was felt that the history of heating may not affect prior performance greatly.

In the study of frames (Document 49/74NL), the principal conclusions were that (a) thermal expansion (i.e., comparing insulated versus uninsulated beams) had no significant effect on the critical temperature for the frame, and (b) the critical frame temperature is higher than the critical temperature for single columns. It was stated that full-scale verification was needed. A question was raised as to the applicable slenderness ratio to use and the interpretation of the relatively better performance of the uninsulated frame.

At the present time, Mr. Magnusson is monitoring a series of full-scale tests on the load bearing capacity of axially restrained steel columns at Metz. This work is sponsored jointly by CECM and the Swedish Building Research Council. Excellent agreement was noted between the measured and predicted collapse temperatures and failure loads.

In an extensive paper (Document 34/74D), Dr. Knublauch showed how to model the fire-induced temperature field created on the outside of a building with a model structure in which the story height was one-half metre. Using wood cribs scaled to give a burning rate proportional to the 5/2 power of the linear dimensions (for ventilation-controlled fires), experiments were carried out with steel columns placed in several positions in front of the window. It was concluded that steel column protection was only needed on one side and that normal unprotected steel columns could be overloaded.

5. Structural Codes - Various international committees are preparing sturctural codes for concrete and steel based on different approaches. It was felt that the CIB Commission could help to ensure a harmony of codes by studying code proposals, advising committees of the latest information, and pointing out areas of needed research. Professor Kordina raised several basic technical questions, but insufficient time was available for discussions:

a. Should building codes require residual strength for structural elements?

b. How can codes be altered to define the fire performance of the complete structure where codes currently consider only individual members?

c. Should codes continue to be based on standard fires and standard fire loads, or should they address the individual situation, i.e., fire loads, geometry, thermal properties, ventilation, time-temperature curve, and finally fire performance?

Harmathy suggested that we should consider "designing the fire" instead of designing fire protection for a hypothetical fire. He argued that fire spread through doors and building openings by radiation and convection was more realistic than heat conduction through a structure leading to ultimate collapse.

B. Group II (Professor R. B. Williamson, Chairman)

The group divided the discussion into three broad categories: 1) the analysis of fully developed compartment fires, 2) the optimum design and specification of fire safe buildings, and 3) recommendations to commission W14 concerning possible actions in Group II's sphere of interest.

1. The analysis of fully developed compartment fires - Document 16/73(C) "A New Look at Compartment Fires, Part I and Part II" by T. Z. Harmathy. The author began by noting that he would include some points made in two recent publications which had not yet been circulated to this commission. These documents are entitled "Design Approach to Fire Safety in Buildings," recently published in Progressive Architecture and "Designers' Option: Fire Resistance or Ventilation," to be presented at the 6th Congress of CIB in Budapest during October 1974. In the Document 16/73(C) the author started with sections on the basic burning characteristics of cellulosic materials. He follows this with a theoretical model which is used as the basis for two equations that describe the rate of burning in the two regimes of compartment fires, namely: fuel-surface-controlled and the ventilation-controlled regimes. By examining these relations, the author drew a number of conclusions. First, the worst conditions with respect to high temperature occurs at or just before the "critical point" where the rate of burning is already maximum and the rate of the flow of fresh air into the room is still relatively low. He pointed out in his theory, however, that a substantial portion of the fuel load

burns outside the room of origin. This means that the ventilation controlled fires are hotter and longer than the corresponding fuel-surface-controlled fires where excess air is available to dilute the fire gases and carry larger portions of these out of the compartment prior to their complete combustion.

The design recommendations contained in the two new papers are based on the concept that larger ventilation openings can be provided with a high degree of reliability to be open in a fire situation. This design approach moves away from the classic concept that the destructive potential of a fire is solely dependent on the amount of combustible material in the fire compartment. Dr. Harmathy indicates that from his analysis the transition from ventilation control to fuel surface control takes place when the air flow rate into the compartment is 1.8 kg/s per m^2 of the surface area of fuel. He recommends that the designer can choose opening dimensions which are larger than necessary to supply this critical air flow and thus control the expected fire to burn out within the original fire compartment in 30 minutes or less. He discussed some of the possible drawbacks such as unexpectedly high fire loads, passage of fire through doors or other openings in the walls, ceiling or the exterior of the building and finally the late involvement of the fire designer in the planning stage of the building.

Document 42/74(S) "A Discussion of Compartment Fires" by Sven Erik Magnusson and Sven Thelanderson. The authors highlighted the similarities and the differences between their approach and that presented in the previous document. They note that their approach also shows a less severe fire at higher ventilation and they indicate the increased performance of steel structures at high ventilation using the Swedish building regulations. They point out that perhaps the greatest differences in the two approaches is that they calculate their results on the basis that all of the fuel burns inside the fire compartment while Harmathy's analysis under certain conditions of fuel load and ventilation shows a relatively large portion of the fuel burning outside the original compartment.

They noted that the evolution of heat during the most intense phase of the fire is in close agreement with that predicted by Harmathy. The differences lie in the energy release during the decay period while Harmathy believes it has burned outside of the fire compartment in these specific cases. The common occurrence of flames outside the window of fire compartments supports Harmathy's contention, while the continued evolution of heat during the decay period supports Magnusson and Thelanderson. It also seems likely that endothermic characteristics of cellulosic fuel are probably ended at about the time the decay period starts, and thus, the relative contribution may be greater.

Document 39/74(UK) "The Effect of Crib Porosity and Recent CIB Experiments" by P. H. Thomas. The author indicated that the most important aspect of the paper was the identification of three types of conditions in crib experiments; one, where fuel porosity is controlled, a second, where surface of the fuel was dominant, and finally, a third area where ventilation in the compartment was most important. Dr. Thomas believed that the fuel porosity controlled situations are probably not very important for most actual fire conditions.

In more general terms, he noted that the most important aspect of a fully developed compartment fire is the quantity of air flowing into the compartment. The previous papers both take account of this factor, but it was Dr. Thomas' opinion that it could be used as a more central parameter in the structure of the analysis. He noted that the heat evolution curves were extremely sensitive to other factors such as feedback of energy to fuel bed which cannot be scaled easily. He presented briefly the concept of the mass transfer, sometimes known as the B-number (the ratio of heat generated by a unit mass of fuel to the energy necessary to drive it into the vapor phase) and indicated that a detailed knowledge of these factors is necessary to understand the rate of heat evolution inside and outside the compartment. The use of air flow is potentially a much easier concept since it is required for all of the combustion within the compartment.

Document 21/74(USA) "Modeling of Vented Enclosure Fires" by Paul A. Croce, Factory Mutual Research Corporation, was briefly described by Mr. Williamson. This work is in progress and it was noted that it was in general agreement with that presented by Dr. Thomas. The group encouraged the program and hopes to see a more complete paper at its next meeting Dr. Thomas discussed this paper further on Wednesday morning and it is hoped that we will hear more of the work before the next meeting.

L. Nilsson discussed the papers introduced. He stated that a recent report by P. H. Thomas and Nilsson points out that another regime, that is the crib porosity regime, ought to be involved. To study the different regimes about 350 tests have been performed and about 100 of these tests theoretically analyzed. Different combinations of the following parameters have been studied:

1. the fire load a; $17.5 \leq q \leq 87.5$ MJ/m^2 enclosing surface area of the fire cell,
2. the opening factor $A\sqrt{H}/A_t$, $0.020 \leq A\sqrt{H}/A_t \leq 0.114$ $m^{1/2}$,
3. the piling density of the fire load expressed by the porosity factor ϕ $cm^{1.1}$ defined by Gross. $0.1 \leq \phi \leq 1.1$ $cm^{1.1}$,
4. the stick thickness b of the fuel $10 \leq b \leq 50$ mm, and
5. the thermal properties of the enclosing construction of the fire cell.

In the tests the temperature-time curve, burning rate, radiation, and smoke density have been measured.

The computer program proposed by Sven Thelandersson and Sven-Erik Magnusson has been used with the experimentally measured temperature-time curve to yield the energy-time curve released during the burning.

The results indicate that instead of two different fires, that is fuel-bed and ventilation-controlled fires you have to talk about six regimes, that is for easy burning cribs:

1. fuel-bed controlled fires,
2. ventilation-controlled fires,
3. a transition zone between them (and for fires also, depending on the crib),
4. combination of fuel bed - and crib-controlled fire,
5. combination of ventilation and crib-controlled fire, and
6. combination of fuel bed - ventilation crib-controlled fire.

The report gives equations to determine six important points on the energy-time curve which makes it possible to sketch this curve with sufficient accuracy in practical design. The equations take into account the parameters described above.

In the report an effort is also made to find a crib carefully defined which gives an equivalent fire as for real furniture in a compartment.

2. Optimum Design and Specification of Fire Safe Buildings - Document 25/73 (UK) "Passive and Active Fire Protection - The optimum Combination" by R. Baldwin and P. H. Thomas. Dr. Thomas presented a short description of the paper and noted that there were some situations where it was clearly best to use either an active or a passive protection system because the alternate was too expensive. There are also situations where either approach is too expensive, but the most interesting situation lies in the region where the two approaches are competitive. This introduces the concept of "trade-offs" and he discussed this philosophy at some length. This combination runs through all of the design concepts discussed below.

Document 24/73 (S) "Principles of Fire Engineering Design and Fire Safety of Tall Buildings" by Professor Pettersson. The author notes that this was a review paper presented at the International Conference on Tall Buildings held in August of 1972. In this paper he reviewed the available framework for a functional design approach to tall buildings. He describes the General Services Administration's (USA) "Decision tree" approach. Professor Pettersson commented that this system was good in that it made engineers think in an overall fire safety way. In addition, it gives a framework for understanding where we should put our research effort.

Mr. Harmathy commented that in the "Decision tree" approach, the designer must rely on the state-of-the-art at the time he or she makes the final design choices. The continuing research effort will refine our understanding and the code of practice must be geared to a changing set of choices at specific locations in the decision tree.

Document 44/74 (S) "The Connection Between a Real Fire Exposure and the Heating Conditions According to Standard Fire Resistance Tests, With Special Reference to Steel Structures" by O. Petterson. The author described the whole document of which this contribution is the second chapter.

He than went on to describe the contents of the paper. The most significant point was the clear reliance on an equivalent time based on actual steel temperature rather than the more traditional area-under-the-curve concept (discussed in Document 23/74).

Document 47/74 "Principles of Fire Engineering Design" by J. Witterveen and L. Twilt. This paper was discussed in the complete Commission W14 meeting on Monday and may be discussed again on Thursday.

Document 22/74 (USA) "Fire Safety Criteria and Tests for Dwellings - Pre-flashover" by R. B. Williamson describes a restatement of existing fire safety requirements and some criteria and tests in a new form. The author noted that it was an early draft and he welcomed any suggestions or comments. Dr. Thomas indicated that the inclusion of feedback and research into the traditional scheme of control requirements and criteria assumed a dynamic system.

Document 23/74 (USA) "Fire Safety Criteria and Tests for Dwellings - Post-flashover." A special report by Mr. Vytenis Babrauskas on the general topic of compartment fires was submitted in place of the above named document. The report discussed the bases of our understanding of fully developed fires in compartments.

Document 24/74 (USA) "Impact of Centents on Building Fires" by P. S. Klitgaard and R. B. Williamson. This paper describes some of the new hazards represented by the large growth of plastics in buildings for furniture and other large content items. Mr. Williamson noted that the criteria for fire propagation in 22/74 could be used to control these hazards to some extent. The role of plastics in the fully developed fire was discussed earlier.

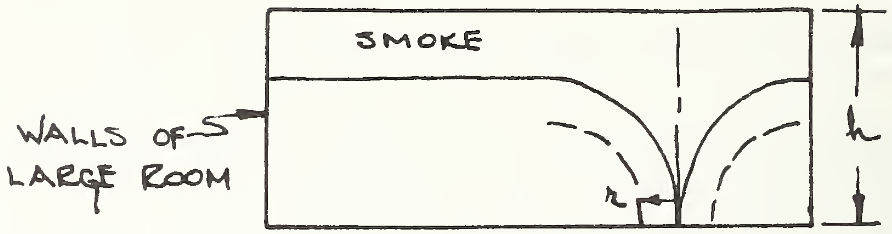
3. Recommendations to Commission W14 concerning possible actions in Group II's sphere of interest - The Group II discussion centered on the design and control of buildings in a changing society. It was noted that there are a number of organizations engaged in trade-off schemes and it was decided to make the recommendation to the entire Commission W14 that a draft document be circulated prior to our next meeting which identified the general principles of fire safety. This might include a methodology of approached trade-off as well as other topics.

C. Group III (Dr. Robertson, Chairman)

The papers in this group were classified under the following subjects: 1) fire behavior of plastics and textiles, 2) measuring the fire hazard, 3) fire gas movement in buildings, and 4) growth and spread of fires.

It is suggested that the reader review Annex IV for the main report of discussion of these subjects. Some points of further interest developed at the meeting are reported here.

Dr. Kawagoe in discussing the time available for escape when fires develop described recent Japanese thinking on this subject which had been developed on the basis of plume theory. If one has

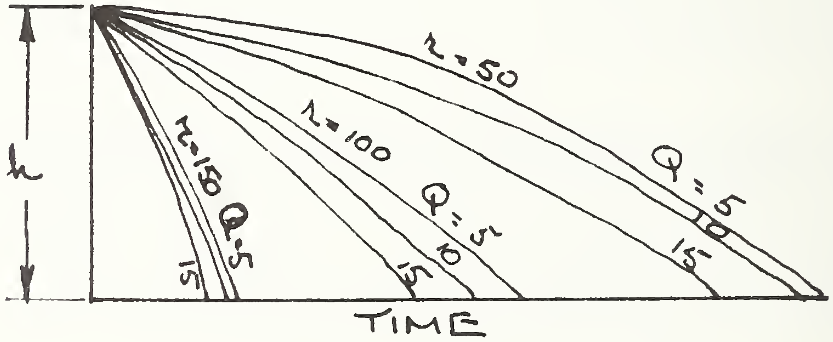


a large room in which a smokey fire develops, the time at which various stages of smoke development occur in the room may be described by:

$$t \approx 1/Q^{1/3} \quad \text{or} \approx 1/Q^{1/3} r^{5/3}$$

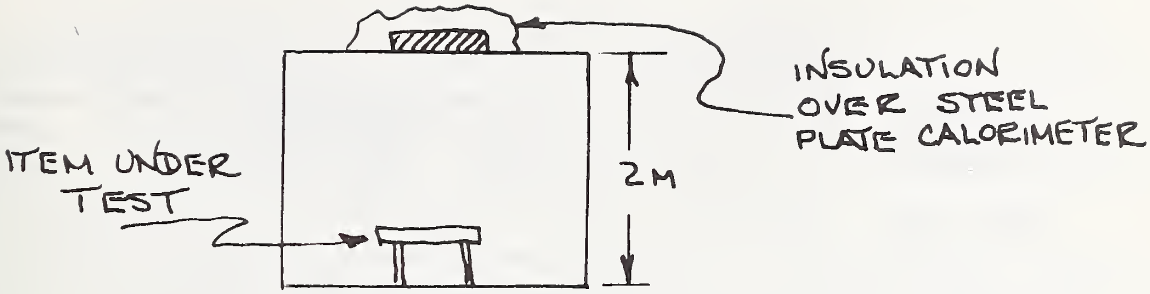
for the cases of point source and area fire, respectively.

t is the time to various levels of smoke accumulation,
Q is the smoke production rate assumed equal to the burning rate, and
r is the radius of the fire



Thus, the time required for smoke to fill various fractions of the room height can be illustrated by the diagram above. The curved lines represent the conditions for a fire that grows rapidly in size while smoke fills the room. This, of course, is only illustrative, but does seem to provide a means for visualizing smoke movement and spread.

Later during discussion of papers 13/74 and 14/74 on combustion rate calorimetry studies in USA, a description was provided of a burn out room for a similar purpose. The room has been built in Dortmund and comprises a roughly cubical compartment of about 2 metres dimension.



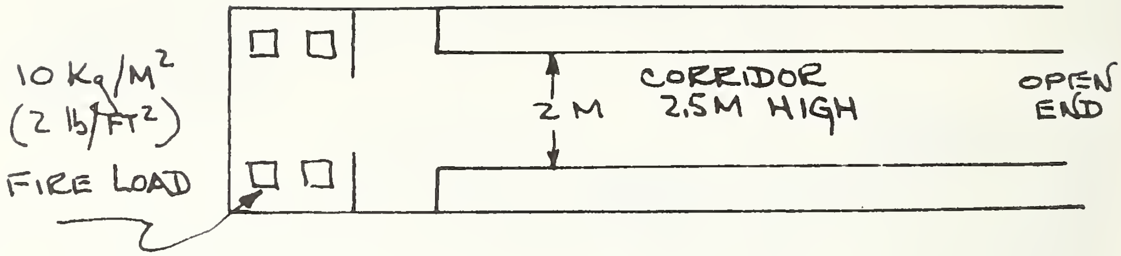
The steel plate is used to measure the thermal impact of the enclosure walls when items are burned in the room. This is compared with the equivalent time for the standard time-temperature curve, as defined in ISO R 834, required to match the heat input to the steel plate. An "m" factor, which is defined in the proposed German Standard DIN 18230 for industrial buildings, appears to denote the time ratios for the two tests. This factor is proposed as a way of defining the contribution of the building contents in terms of its composition and form. A paper on this development was presented by W. Halpaap in Switzerland last fall. There was considerable discussion about this work. The point was made that m would not be a material property but would be a function of surface to volume ratio of the item burned. The basic idea of course is to measure the relative thermal impact of a burning item on the enclosure walls and ceiling and, thus, define the fire endurance performance which should be designed into the structure.

In discussion of the review paper 6/74 on toxic species in combustion gases, Dr. Berl emphasized the importance of CO as the main fire gas hazard observed to date. He indicated that he personally considered it very unlikely that phosgene could be present as a serious hazard. This position was taken both because of its instability at high temperatures and the very low equilibrium concentrations at low temperatures.

In connection with this point Dr. Robertson suggested an experiment with animals or humans in the sleeping mode to determine whether they would be awakened by an irritating gas. If they were awakened this might provide a means for alerting occupants of a building when fire occurs.

During discussions of smoke movement in buildings Dr. Kawagoe described an air-inflated portable barrier through which a man can climb, but which closes automatically and maintains a smoke seal in any passageway in which it is installed.

In connection with discussion of paper 15/74 on the NBS corridor fire tests, Dr. Stolp of Netherlands described a series of tests they had conducted on ten or more floor covering materials. The geometrical and air flow conditions differed appreciably from the NBS arrangement.



Their tests were run by igniting one of several cribs in the burn room at the end of a corridor. It usually required about 20 min to involve all the cribs. The floor coverings included wood, linoleum and a wide variety of carpeting materials. Various combinations of these were used on burn room, cross corridor, and main corridor length. In most instances fire spread along the floor only 3 to 4 metres. As a result they have concluded that when there is no need for concern with more severe burn exposure.

Dr. Stolp also described a series of crib fire extinguishment tests. For these tests the crib was placed in a compartment under various ventilation conditions and water applied uniformly over the top of the crib. Observations were made of crib weight loss, water application rate as a function of time. They also plan similar experiments with N_2 as an inerting agent. We plan to correspond with Stolp and get more information on this study.

4. VISIT TO FIRE LABORATORY

At the Institute for Building Materials and Reinforced Concrete in Braunschweig, the following activities were observed:

a. A fire endurance test of a suspended ceiling hung from a steel beam and concrete floor (loaded to 1,600 Kg/M^2) over a large undivided area. Furnace pressure was maintained at 1.0 to 1.2 mm wg. A subsequent test will involve the addition of a 60-min rated dividing partition in the furnace with fire exposure on one side only. The test to be run until thermal failure of the partition occurs and then fire exposure will be applied to the full specimen length.

b. Explosive spalling of a loaded concrete section representing the 8 cm thick web of a concrete beam. The concrete had 3% moisture by weight, the load was 140 $kilotons/cm^2$ and fire exposure was applied to both sides. As previously predicted by Meyer-Ottens, explosive spalling occurred at 17 to 18 minutes.

c. Fire tests on safes, including drop tests.

d. Measurements of the high temperature properties of concrete carried out by Dr. Schneider. In a very comprehensive volume entitled "On the Dynamic Loss of Strength Reactions in Standard Concrete at High Temperatures," published at Braunschweig in December 1973, Dr. Schneider summarized analytical and experimental studies on thermal and mechanical properties, as well as X-ray analysis of concretes involved in fire.

e. Construction was underway on a new $1 million building to house a large L-shaped furnace capable of fire endurance testing of columns, girders, beams, floors, and combination column/beams and wall/floors.

This new furnace will be 8.80 metres long. Maximum distributed floor load is planned for 90 tons plus a concentrated column load of 400 tons. By closing off the horizontal section, a column up to 5.5 metres may be tested. Lateral loads and moments may be applied to beams and floors and braced (restraint) or unbraced conditions can be simulated. Column deflections will be measured optically. Professor Kordina stated that no attempt was made to supersede or compete with the fire furnace at Metz. A preliminary prediction calculation has already been made by Mr. Haksever on the fire performance of a rigid L-frame of reinforced concrete with hinged supports and no displacement at ends.

5. REPORT SESSION AND CONCLUSIONS

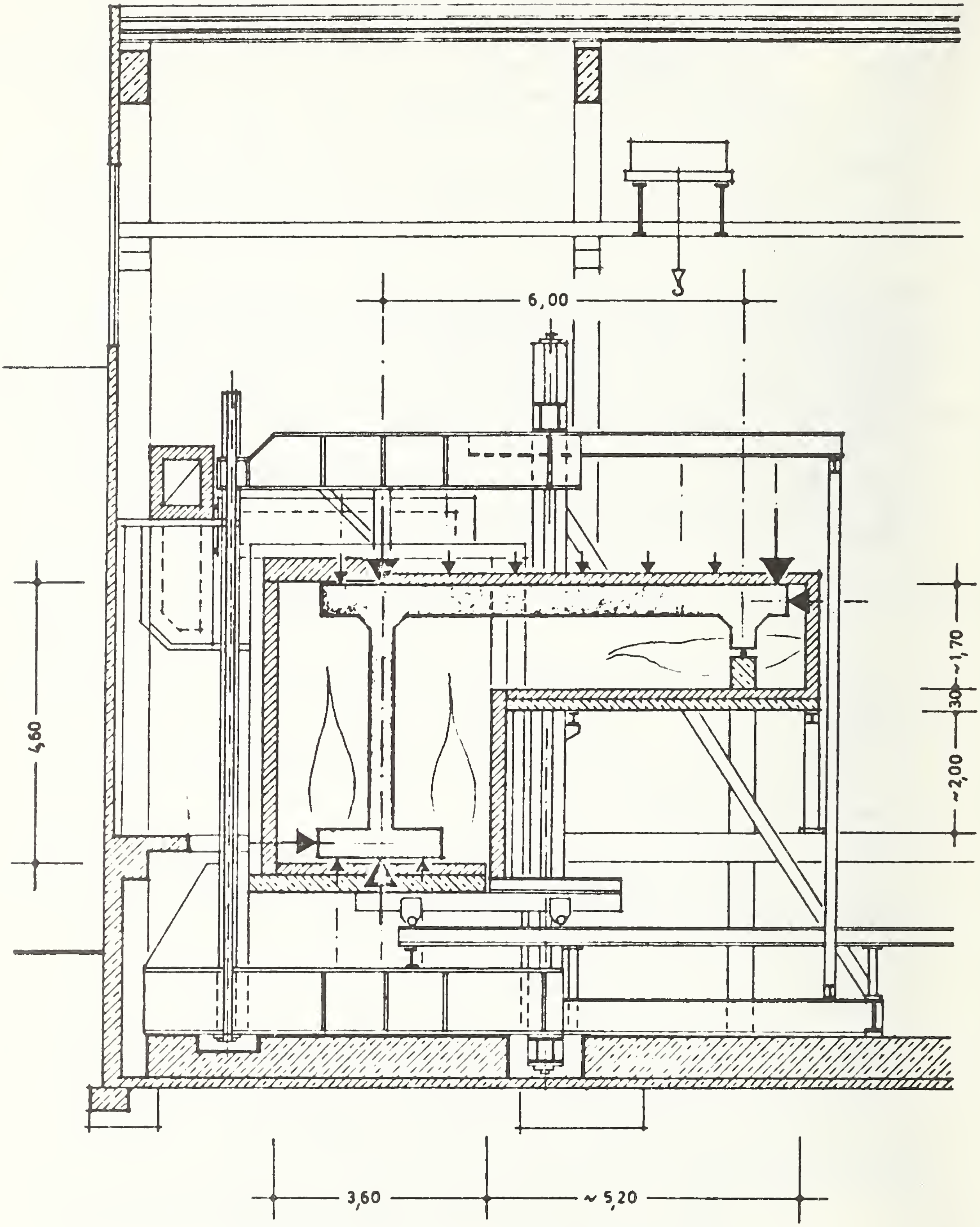
A report session was held at the end of the meeting, during which each of the three groups summarized their discussions. Since these are covered in the draft reports included in Annex IV there is no need to repeat them here.

A brief resume of the conclusions reached at the meeting may be summarized as follows:

1. It was proposed that CIB would serve a most useful purpose by reviewing and commenting on the merit and applicability of model codes being currently developed by two different building material associations CECM and FIP/CEB.

2. Task Groups were identified to:

    a. develop a procedure for characterizing the heat balance and radiation characteristics of fire endurance furnaces,
    b. develop new methods for design of concrete and steel frame structures,
    c. participate in a proposed FIP symposium on fire damage including spalling and repairability of concrete structures, and
    d. prepare a state-of-the-art paper including future research needs on physical and thermal properties of materials at high temperature.



Elevation of Furnace under Construction

3. The expected introduction of polymeric materials as substitutes for more conventional building and furnishing materials requires a review of their behavior during fires and consideration of the validity of existing test methods for evaluating fire safety.

4. A paper is planned to discuss the basic fire research objectives as they apply to building problems (structural and occupant safety).

5. Increased recognition should be given to the importance of fire gases as a threat to building occupant safety.

6. Commission W14 should encourage a symposium on the subject "Building Design Techniques to Control Gas and Smoke Movements during Fires."

7. A survey paper should be prepared to review and document current work on the influence of fire gases and smoke on animals and humans.

8. There is need for increased emphasis on study of:

   a. early warning of occupants when a fire occurs,
   b. study of human behavior when alerted to a fire,
   c. characteristic times of fire phenomena as a determinant of fire safety, and
   d. improved reaction to fire test methods.

9. It was generally agreed that because of the quantity of smoke and gases resulting from burning even small quantities of building finish or furnishing items, a great need exists for the development and utilization of special means for the control of fire gases and smoke during building fires.

Appendix

ANNEX I

o. PROF. DR.-ING. KARL KORDINA · TECHNISCHE UNIVERSITÄT BRAUNSCHWEIG
Lehrstuhl für Stahlbeton- und Massivbau · Institut für Baustoffkunde und Stahlbetonbau

Liste der angemeldeten Teilnehmer zur Tagung der CIB-Kommission WG 14 in Braunschweig, 1.-5.4.1974

Australien	Mr. Keough	Experimental Building Station Chatswood
Belgien	Mr. Minne	Laboratorium voor Annwending der Brandstoffen, Gent
Kanada	Mr. Harmathy	National Research Council of Canada, Ottawa
Dänemark	Mr. Aegidius	National Institute of Materials Testing, Kopenhagen
England	Mr. Malhotra	Fire Research Station, Borehamwood
	Mr. Nice	dito
	Mr. Thomas	dito
Finnland	Mr. Oksanen	Technical Research Centre of Finland, Otaniemi
Frankreich	M. Adam	S.N.B.A.T.I., Paris
	M. Arnault	Centre Technique Industriel de la Construction, Puteaux
	M. Bellisso n	Centre Scientifique et Technique du Bâtiment, Paris
	M. Cabret	dito
Griechenland	Mr. Kalos	The Technical Chamber of Greece Athen
Japan	Mr. Kawagoe	Building Research Institute, Tokio
Niederlande	Mr. Stolp	Institute TNO for Building Materials and Building Structures Rijswijk
	Mr. Twilt	dito
	Mr. Witteveen	dito
Neuseeland	Mr. Kenna	Building Research Association of New Zealand, Wellington
Norwegen	Mr. Bakke	Fire Research Laboratory, Universität Trondheim
	Mr. Landrø	dito
Polen	Mr. Jarosz	Instytut Techniki Budowlanej, Warschau

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bitte Nr. 391 2781

Besuchszeiten:
Montag bis Freitag 8-17 Uhr

Schweden	Mr. Anderberg	Division of Structural Mechanics and Concrete Construction, Lund
	Mr. Bengtsson	Swedish Fire Protection Ass., Stockholm
	Mr. Hägglund	The Research Institute of the Swedish National Defence, Stockholm
	Mr. Magnusson	Division of Structural Mechanics and Concrete Construction, Lund
	M.r Nilsson	Dito
	Mr. Pettersson	dito
	Mr. Sjölin	The Research Institute of the Swedish National Defence, Stockholm
	Mr. Thelandersson	Division of Structural Mechanics and Concrete Construction, Lund
	Mr. Thor	Swedish Institute of Steel Construction, Stockholm
	Mr. Tolstoy	National Swedish Institute for Materials Testing, Stockholm
	Mr. Ödeen	Division of Building Materials, Stockholm
Ungarn	Mr. Kovacs	Institute for Quality Control of Building, Budapest
USA	Mr. Berl	Johns Hopkins University
	Mr. Gross	National Bur of Stds, Wash., D.C.
	Mr. Hacker	Battelle
	Mr. Maroni	Factory Mutual
	Mr. Radnofsky	NASA
	Mr. Robertson	National Bureau of Standards, Washington
	Mr. Williamson	University of California, Berkeley
Deutschland	die Herren	
	Bechtold	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Becker	BASF Ludwigshafen
	Fischer	Staatl. Materialprüfungsamt Dortmund
	Glüsing	Bundesanstalt für Materialprüfung Berlin

Deutschland	Haksever	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Klingelhöfer	Staatl. Materialprüfungsamt Dortmund
	Klingsch	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Knublauch	Bundesanstalt für Materialprüfung Berlin
	Kordina	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Frau Krampf	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Meyer-Ottens	dito
	Rudolphi	Bundesanstalt für Materialprüfung Berlin
	Schneider	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Stanke	Bundesanstalt für Materialprüfung Berlin
	Teichen	Otto Graf-Institut, Stuttgart
	Teichgräber	Institut für Holzforschung, München
	Wesche	Institut für Baustoffkunde und Stahlbetonbau, Braunschweig
	Westhoff	Staatl. Materialprüfungsamt Dortmund

ANNEX II

CIB COMMISSION W14

Programme for 11th Meeting

Sunday, 31 March 1930 -	Arrive in Braunschweig. Drinks and snacks for participants and ladies at the Hotel Deutches-Haus
Monday, 1 April	At University Rooms -
0900	(a) Opening of Meeting in Room 32 in basement of the wing Schleinitzstrasse entrance in Pockelsstrasse
1200	(b) Acceptance of record of 10th Meeting
Lunch 13.30	
	(c) Election of officers for meeting
17.00	
	Report presented by Co-ordinator of developments within CIB, its relations with other bodies and consequences for W14. Discussion of tasks and methods of working. Divide into groups.
Tuesday	
0900	At University Rooms
1200	
Lunch	
13.30	Group discussions
17.00	
Wednesday	
0900	At University Rooms
1200	Group discussion and preparation of group reports
Afternoon	Visit to fire section of Technische Universität (Details to be announced)
Evening	Commission dinner (Details to be announced)
Thursday	
0900	Presentation of reports from groups and full W14 discussion. At University Rooms
1200	
Lunch	
13.30	
17.00	
Friday	
0900	Final discussion
1200	Future activities of W14. Arrangements for next meeting. Other business.

<u>Friday afternoon and evening</u>	Excursion for participants and ladies (Details to be announced later) (A small charge may need to be made if expenses prove to be too high) Lunch (Monday to Friday) is available at the "Mensa" about 5 minutes' walk from the meeting. During morning and afternoon Session coffee will be served.

CIB/1000/17/23F

ANNEX III

CIB COMMISSION W14

COMPLETE LIST OF PAPERS CIRCULATED TO DELEGATES SINCE THE MAY 1972 MEETING IN STOCKHOLM

CIB CTF/72/51(C)	Remote measurement of large deflections in fire tests.
I II * CIB CTF/72/52(S)	Some essential material properties connected to a differentiated fire engineering design.
I9 IV * CIB CTF/72/53(UK)	Report of the Tenth Meeting of CIB Commission. Sweden 15-19 May 1972
CIB CTF/72/54(C)	A numerical procedure to calculate the temperature of protected steel columns exposed to fire. 1972
CIB CTF/72/55(C)	Bibliography of Fire Research Problems in Japan. (1961-1971) 1972
III * CIB CTF/72/56(J)	Visibility through smoke. (Part 2. Visibility of monochromatic signs through smoke). Japan 1971
CIB CTF/72/57(J)	Study on injurious properties of combustion products of building materials at initial stages of fires. Japan 1971
CIB CTF/72/58(J)	Propagation of Combustion in Solid Materials, Part III. Temperature distribution in a smouldering rod. Japan 1968
CIB CTF/72/59(J)	Some statistical features on extinction of small diffusion flame of burning liquid with sprays of several salt solutions. Japan 1968
CIB CTF/72/60(J)	Experimental study on behaviour of smoke flow and smoke-proofing of escape routes. Japan 1969
CIB CTF/72/61(J)	Visibility through fire smoke. Japan 1970
CIB CTF/72/62(J)	Characterisation of smoke-motion in the building fire (1) On the flow pattern of smoke through the corridors and staircases. Japan 1970
CIB CTF/72/63(J)	Model experiments on a smoke tower Part III. Japan 1971
CIB CTF/72/64(J)	Characterisation on factor in estimating fire-hazard by furnace-test based on the patterns in the modelling of fire for the classification of organic interior building materials. Part I Japan 1971
CIB CTF/72/65(J)	The characterisation on the mode of combustion and smoke evolution of organic materials in fire Part II. Japan 1972

CIB CTF/72/66(UK)	Fully-developed fires in Single Compartments - A co-operative research programme of the Conseil International du Batiment. United Kingdom 1972
CIB CTF/72/67(UK)	Extreme Value Theory and fire resistance. United Kingdom 1972
CIB CTF/72/68(D)	Uber Ausfuhrung and Aussagefahigkeit des Normbrandversuches nach DIN 4102 B.A.M. Germany 1972
CIB CTF/72/69(B)	La resistance au feu des portes - "The Fire resistance of doors". Belgium 1972
III * CIB CTF/72/70(CA)	Venting fires through roofs. Experimental fires in an aircraft hanger. Australia 1972
III IV * CIB CTF/72/71(USA)	Fire problems Program Annual. Summary Report July 1971 - June 1973. USA 1972
I * CIB/W14/1/73(C)	Calculation of the fire resistance of reinforced concrete columns. August 1972
CIB/W14/2/73(F)	Etudes de Vieillissement Accelere de Produits Ignifuges du Commerce Francais. France 1972
CIB/W14/3/73(UK)	The behaviour of people in fires. United Kingdom 1972
CIB/W14/4/73(C)	Contribution of insulation in cavity walls to propagation of fire. Canada October 1972
CIB/W14/5/73(D)	Baulicher Brandschutz .
CIB/W14/6/73(C)	Fire and The Civil Engineer. Ottawa 1972
CIB/W14/7/73(UK)	Fire problems of pedestrian malls. Part 2. Large scale experiments with a shaft vent. United Kingdom 1972
CIB/W14/8/73(C)	Thermal degradation of cellulose and levoglucosan- The effect of inorganic salt. Ottawa 1972
CIB/W14/9/73(D)	Brandverhalten von raumabschliessenden Bauteilen. 1972
CIB/W14/10/73(UK)	Behaviour of building structures. Extract from "A complete guide to fire and buildings"
I IV * CIB/W14/11/73(UK)	Report of the meeting at Institute TNO for building materials and building structures. Delft, The Netherlands on January 29 - 30 1973.
CIB/W14/12/73(C)	Combustion products of polymeric materials containing nitrogen in their chemical structure.

	CIB/W14/13/73(C)	Identification of CIS-4, 5-Epoxy-2-Pentenal from Pyrolysis of H_3PO_4 treated cellulose. February 1973
	CIB/W14/14/73(C)	Thermal properties of selected masonry unit concretes. February 1973
	CIB/W14/15/73(D)	Brandrisike elektrisher Leitungen and Installationen in Wanden. Berlin April 1973
II *	CIB/W14/16/73(C)	A new look at compartment fires. Parts I and II. Ottawa 1972
I *	CIB/W14/17/73(D)	Untersuchlingen fur ein Prufverfahren zur Bemessung der Brandschutzbekleidung von Stalzlstutzen.
III *	CIB/W14/18/73(UK)	The problems of pedestrian precincts - Part 3. The smoke production of sprinklered fires (low water pressure). United Kingdom June 1973
	CIB/W14/19/73(C)	An improved hydraulic heat flow simulator.
	CIB/W14/20/73(S)	Effect of high temperatures on tensile strength of concrete. Sweden 1972
II	CIB/W14/21/73(S)	Fire Research and Building. Sweden 1971
I *	CIB/W14/22/73(S)	Fire-exposed hyperstatic concrete structures. Sweden 1973
I *	CIB/W14/23/73(S)	Stress and deformation characteristics of concrete at high temperatures. 1. General discussion and a critical review of literature. Sweden 1973
II *	CIB/W14/24/73(S)	Principles of fire engineering design and fire safety of tall buildings. Sweden 1973
II *	CIB/W14/25/73(UK)	Passive and active fire protection - The optimum combination. United Kingdom 1973
	CIB/W14/26/73(UK)	A method of evaluating life for economic purposes. United Kingdom 1972
	CIB/W14/27/73(UK)	Fire tests on air-supported structure. United Kingdom 1972
	CIB/W14/28/73(UK)	The economics of accident prevention - Explosions. United Kingdom 1973
	CIB/W14/29/73(UK)	Collected summaries of Fire Research Notes. United Kingdom 1972

	CIB/W14/1/74(C)	Design of concrete masonry walls for fire endurance. 1973
I *	CIB/W14/2/74(C)	Fire resistance of protected steel columns.
	CIB/W14/3/74(C)	Prediction of fire endurance of concrete slabs. 1973
	CIB/W14/4/74(CA)	Control of smoke from fire in an air conditioned building Australia.
III *	CIB/W14/5/74(USA)	The accumulation of gases on an upper floor during fire buildup.
III *	CIB/W14/6/74(USA)	Survey of toxic species evolved in the pyrolysis and combustion of polymers.
	CIB/W14/7/74(USA	Annual summary report 1972-3
	CIB/W14/8/74(USA)	Topical report survey and evaluation of U.S. National fire death statistics.
	CIB/W14/9/74(USA)	Topical report sample survey of Maryland fire fatality data.
	CIB/W14/10/74(USA)	Loss prevention data insulated steel deck.
	CIB/W14/11/74(USA)	Loss prevention data high rise buildings.
I III IV *	CIB/W14/12/74(USA)	Large scale fire tests of rigid cellular plastic wall and roof insulations.
III *	CIB/W14/13/74(USA)	Development of a heat release rate calorimeter.
III *	CIB/W14/14/74(USA)	An experimental method for evaluating fire hazard.
III *	CIB/W14/15/74(USA)	NBS corridor fire tests: Energy and radiation models
III *	CIB/W14/16/74(USA)	Evaluation of a pressurized stairwell smoke control system for a 12 story apartment building.
III *	CIB/W14/17/74(USA)	Report of fire tests on flexible connections in HVAC systems.
III *	CIB/W14/18/74(USA)	Radiative energy transfer from Gaseous diffusion flames.
III *	CIB/W14/19/74(USA)	Extinguishment of radiation augmented plastic fires by water sprays.
	CIB/W14/20/74(USA)	Calculation of response time of ceiling mounted fire detectors.

II *	CIB/W14/21/74(USA)	Modeling of vented enclosure fires.
II *	CIB/W14/22/74(USA)	Fire safety criteria and tests for dwellings preflashover.
II *	CIB/W14/[illegible]/74(USA)	Fire safety criteria and tests for dwellings postflashover.
IV *	CIB/W14/24/74(USA)	Impact of contents on building fires.
IV *	CIB/W14/25/74(USA)	A full-scale fire program to evaluate new furnishings and textile materials developed by NASA.
	CIB/W14/26/74(G)	Influence of the carbonisation of the concrete on the explosive spalling under fire conditions. Athens 1973
IV *	CIB/W14/27/74(UK)	Fire hazards of plastics in furniture and furnishings: ignition studies. United Kingdom 1974
	CIB/W14/28/74(CA)	Fire behaviour of pipe instalation. Australia 1973
	CIB/W14/29/74(C)	Prediction of fire endurance of concrete masonry walls.
I *	CIB/W14/30/74(B)	La resistance au feu des portes.
III IV *	CIB/W14/31/74(CA)	Fire properties of some commonly used upholstry materials. TR 44/153/412 Australia
I *	CIB/W14/32/74(C)	Commensurability problems in fire endurance testing. Ottawa 1973
	CIB/W14/33/74(D)	Das Brandverhalten von Hotzstutzen unter Druckbeanspruchung.
I *	CIB/W14/34/74(D)	Uber das Brandgeschehen von der fassade lines brennenden Gebaudes unter besonderer Berucksichtigung der feuerbean-spruchung von aussenstutzen.
	CIB/W14/35/74(D)	Verhalten von Baustoffen im feur.
	CIB/W14/36/74(D)	Untersuchungen zum brandverhaten.
I *	CIB/W14/37/74(J)	Design of fire cover on steel structures.
I *	CIB/W14/38/74(J)	Fire resistance design for steel structures.
II *	CIB/W14/39/74(UK)	The effect of crib porosity and recent CIB experiments. (Available at meeting)
III IV *	CIB/W14/40/74(UK)	The early stages of fire growth in a compartment. A co-operative research programme of the CIB. (Available at meeting)

I	* CIB/W14/41/74(N)	Comparison of heat transfer in several wall furnaces.
II IV	* CIB/W14/42/74(S)	A discussion of compartment fires.
I	* CIB/W14/43/74(S)	Deformations and critical loads of steel beams under fire exposure conditions.
II	* CIB/W14/44/74(S)	The connection between a real fire and the heating conditions according to standard fire resistance tests, with special application to steel structures.
	CIB/W14/45/74(S)	Probalistic analysis of structural fire safety.
I	CIB/W14/46/74(B)	La Rasistance an fen de poulous an beton arine.
II IV	CIB/W14/47/74(NED)	Principles of fire engineering design.
I	CIB/W14/48/74(NED)	On the behavior of steel columns at elevated temperatures.
I	CIB/W14/49/74(NED)	Oriented small scale model tests on the stability of braced and unbraced frames at elevated temperatures.
	CIB/W14/50/74(N)	Analysis of combustion products from polystyrene polyurethane, polyurethane and polyvinyl chloride and also combustion gases from pine-wood and spruce.

ANNEX IV

CIB-WG 14 - Meeting, April 1974, Braunschweig

Report of Group I - Structural Protection

The following delegates participated in the discussion:

Messrs. Malhotra (Chairman)
Klingsch (Secretary)

Participants:

Messrs.	Stolp	Netherlands
	Gross	USA
	Jarosz	Poland
	Kalos	Greece
	Schneider	Germany
	Kordina	Germany
	Twilt	Netherlands
	Magnusson	Sweden
	Thelandersson	Sweden
	Arnault	France
	Bellisson	France
	Pettersson	Sweden
	Anderberg	Sweden
	Thor	Sweden
	Fischer	Germany
	Stanke	Germany
	Knublauch	Germany
	Bierbauer	Germany
	Haksever	Germany
	Keough	Australia
	Kenna	New Zealand
	Bakke	Norway
	Harmathy	Canada
	Kawagoe	Japan

The group divided its discussion into the following items:

1. Correlation of furnaces (32/74, 41/74)
2. Design of structures
   a) concrete (1/73, 64/74, 22/73, note by Mr. Jarosz)
   b) steel (17/73, 2/74, 37/74, 43/74)
   c) others
3. Properties of materials (23/73, 26/74, note on spalling by the chairman)
4. Model tests and large scale tests (48/74, 49/74, 34/74)
5. Structural codes, philosophy of structural fire protection (11/73)
6. Proposals for tasks, output etc.

1. Correlation of furnaces

Mr. Stolp presented his document containing the final report on the laboratory exercise on the correlation of vertical furnaces in ten different laboratories using the TNO developed heat-fluxmeter. The date when examined showed that in many cases the gold facing had been damaged and hence it was not always possible to make a distinction between the radiative and the convective heat transfer, It was nevertheless obvious that the biggest differences occur in the first 30 minutes but when the walls of the furnace are sufficially lost the differences are considerably reduced. By 60 minutes the differences between furnaces were of the same order as the variation in a given furnace.

Mr. Harmathy in his paper outlined an analytical method of evaluating the heat-balance of a furnace from a knowledge of the total heat input, heat absorbed by the furnace walls and heat lost by the fluegases. Mr. Gross had used this technique and found that in his furnace the surface temperature of the SIPOREX-wall and the refractory blocks was about the same and assuming that convective heat transfer was proportional to the gas temperature and the radiative heat transfer to the gas temperature to the 4^{th} power, the heat loss to furnace walls,the specimen and the exhaust gases was equal and 1/3 of the total heat input.

Mr. Keough pointed out that the major part of differences were caused by building furnaces with refractory materials having widely differing thermal characteristics. One solution would be to line all furnaces with a low density and low conductivity material (such as B & W 28 or M.I. 28 blocks). From his experience this will enable the furnace walls to acquire gas temperatures after 15 minutes or so become radiative; it will further more decrease some of the effects due to different fuels and make the environment in the furnace similar to that in a fire even for short duration tests.

It was agreed that the group will produce a guide to this topic (see item 5).

2. Design of Structures -(a) concrete-

Mr. Jarosz gave details of tests on prestressed concrete I-section beams and concrete-slabs in a building using wood as fuel. The web of the beam suffered severe damage by spalling causing it to fail prematurally. Difficulties were also expected with the adhesion of plaster to the smooth concrete surface. Mr. Harmathy spoke on Mr. Lie's paper which describes a numerical approach to establishing the fire resistance of reinforced concrete columns by establishing heat transfer into concrete, reduction in strength of concrete and steel and increase in the slenderness ratio.

Mr. Pettersson had experienced some difficulties in correlating some test data to a numerical technique without taking full account of short time creep and physical damage which concrete may suffer.

Mr. Anderberg described tests on slabs restrained against rotational movement at both ends but without any longitudinal restraint. Moments at the supports and in midspan varied not only during the heat-period but often suffered the maximum alteration in the cooling-down phase, sometimes a few hours after the end of heating. This indicates the possiblity of collapse of a concrete structure after the main severity of the fire had been passed.

The discussion showed progress that was being made in finding numerical solutions to predict the behaviour of simple structural elements.

(b) - steel

Mr. STanke described a model developed in BAM to predict heat transfer through and isulating coating to a steel plate representing a column. Comparisons were made with full scale tests and relationships derived between steel temperature and the duration of exposure taking into account, steel thickness, properties of the encasement and the factor F/U (F is steel cross section and U the perimeter surface of the section).

A paper by Dr. Lie dealt with deriving empirical relationships to predict the temperature of steel section when different encasements were provided. Mr. Pettersson informed the group that a document was under preparation in Sweden which will deal with the design of protected and unprotected steel structures on the basis of theoretical fire exposure conditions which take into account the characteristics of compartments and the heating and the cooling phase of the fire. It was however felt that the present information on thermal properties of elements was inadequate which prevented accurate solutions to be provided.

Mr. Wakamatsu's paper dealt with the same topic and gave a computer programme which has been developed. Mr. Twilt found that the buckling curves used were different from those in Mr. Lie's paper.

Mr. Thor gave a detailed account of experiments to establish stress/strain curves for mild steel at different temperatures and under different rates of loading. As the shape of the curves altered at high temperatures he doubted the wisdom of using 0,2% proofstress as a basis for estimating the stability. Tests on steel beams showed that midspan deflection was a useful criterion of failure and a limiting deflection of 1/800 of span^2 divided by the depth of the section was appropriate. On the other hand some tests carried out at Braunschweig for the ECSS had shown that the rate of deflection was a better measure of stability.

Mr. Kawagoe described Mr. Saito's paper which analysed the likely behaviour of a multi-storey steel framed structure. It appeared that if steel temperatures were to exceed 150°C the deformation caused by thermal expansion may cause instability.

(c) - Others

Note was made of the interesting series of tests undertaken in Belgium on a number of doors.

3. Properties of materials

Mr. Malhotra in a brief note gave account of discussions which had taken place in the spalling of concrete since the last meeting. A few experts from Germany, Netherlands and UK met to discuss their findings and future activities relative to this problem.

Mr. Meyer-Ottens' paper was to be presented by the German Association of concrete structures and will be circulated to members.

Mr. Kalos presented an account of his views based on information on the charges that take place in carbonaceous concrete with age. He felt that clogging of the pores 10 to 20 mm below surface could lead to more severe spalling in old concrete. Mr. Meyer-Ottens' experience led him to believe that sub-surface cracking will help relieve the pressure and no serious effect may occur in practice.

The panel considered the question of holding a conference, seminar or symposium on the topic of spalling. There was agreement that this topic should be dealt with as a part of a general discussion on predicting fire damage to concrete and its repairability. Mr. Gross asks the plenary session to seek collaboration with other organisations such as FIP, CEB, RILEM etc. for holding such a conference preferably at the time of some other international meeting.

Mr. Thelandersson presented the results of his work on the stress and deformation characteristics of concrete at high temperatures and highlighted the differences that occurred under constant and transient temperature-creep conditions. Data had been obtained on concrete specimens tested under torsion at high temperatures. More recently stress/strain relationships with compression tests had also been examined and a report was under preparation.

Mr. Schneider describes some experiments of a simular type undertaken at Braunschweig and he found many similarities between his results and those obtained at Lund.

Mr. Schneider supported by Mr. Pettersson suggested that need for obtaining data on properties of materials at high temperatures was such that its absence would seriously hinder the prediction of behaviour of structures of sizes and complexity which cannot be tested with our present equipment. Document 72/52 had provided a list of needs and these should be carefully examined to plan future work..

4. Model tests and large scale scale tests (48/74, 49/74, 34/74).

Mr. Twilt described a series of model scale tests on columns and braced and unbraced frames. Effect of rate of heating on structural properties of steel, particularly creep, was examined. Mid-span deformation of pin-jointed columns was measured at different temperatures. In tests on frames vertical deformation of beams was not significantly affected by the rates of heating used. Although creep is an important factor it was felt that in practical cases the history of heating may not have a significant effect on performance.

In the frame tests there was no significant effect of the thermal expansion of beam on the critical temperature. Critical temperatures for columns were the same or higher as determined by tests on a single unit.

Mr. Harmathy pointed out the variations in rates of heating and stress levels which occur in real fires, hence there would be need for full scale verification. Mr. Kordina felt that for slenderness ratio of 72 uninsulated beams and columns gave better performance than insulated ones, which needed to be explained in any future report .

Mr. Magnusson gave some advance information on a study he had undertaken on the loadbearing capacity of fire exposed steel columns with axial restraint. The analytical approach used, with step by step computation of flexural rigidity, has been confirmed in full scale tests on 18 columns carried out at Metz (Project sponsored jointly by CCCM and Swedish Building Association). The mathematical model had reproduced with great accuracy the experimental set up at Metz. The range of failure temperatures was between 250 and 680°C. A report will be available shortly.

Mr. Knublauch had been able to model the temperature field created on the outside of a building on a 1/2 m storey height structure. This was achieved by controlling the burning rate of gases such that the rates of burning were related by a power law of 5/2. This was found to be the case for ventilation controlled fires only. Experiments were carried out on steel columns placed in various positions in front of the window and it was found that generally one face was exposed to more severe conditions than others and normal unprotected steel columns could be overloaded.

Mr. Harmathy felt that the height of the compartment could be factor in establishing the shape and height of flames outside the window.

5. Structural Codes

The chairman described activity in various international committees and associations which will shortly lead to the issue of structural codes on concrete and steel based on quite different concepts. It was important to ensure there was harmony in different codes and the CIB Commission could play an important role in this connection. Both Mr. Pettersson and Mr. Kordina were wholeheartedly in favour of ensuring unanimity of approach even though the contribution maybe only modest at this stage. The plenary session was asked to take necessary action to cover the following aspects either singly or together as appropriate.

1. Scrutinizing of codes before publication
2. Advising code committees on latest knowledge
3. Adopting a long term role of producing data on structural fire protection including philosophy.

6. Tasks

The discussion had led to the identification of areas where an output was possible which would be of help to various international and national organizations and those engaged in the fire safety field. All of the tasks were not equal in importance and on some only a state of the art type of statement could be made.

1. Correlation of furnaces

   (a) A method of evaluating the heat balance of a furnace (Mr. Gross - abt 6 months)

   (b) Unifying radiative characteristics of furnaces (Mr. Keough - abt 6 months)

2. Design of structures

   (a) Stimulating the behaviour of concrete beams and solumns

   (b) ditto for protected and unprotected steel beams and columns (Mr. Magnusson and a colleague from Braunschweig, 6 to 12 months)

   (c) Evaluating the behaviour of frames (Mr. Witteveen(?), Mr. Sullivan(?) - a state of the-art-paper in 6 to 12 months).

3. Properties of materials

   (a) Spalling of concrete and arrangement of a symposium on 'the prediction of fire damage to concrete and its repairability' (Mr. Malhotra through Mr. Thomas)

   (b) The state of art on the effect of high temperatures on properties of structural materials

   (c) Future needs
   (b,c: Mr. Pettersson and Mr. Harmathy - 12 to 24 months)

4. Guide lines to indicate relationship between micro and macro fire tests (should be discussed at the next meeting).

5. Structural codes, advice, scrutiny and longtime needs (philosophy)
   (Messrs. Pettersson, Kordina, Witteveen and Malhotra).

REPORT OF GROUP 2 - GENERAL FIRE CONSIDERATIONS

The following delegates participated in the discussions:

Prof. R.B. Williamson (Chairman and secretary)
Mr. T.Z. Harmathy
Mr. F. Hoffmann
Mr. H.G. Klingelhöfer
Mr. S.E. Magnusson
Mr. L. Nilsson
Prof. O. Pettersson
Mr. S. Thelanderson
Dr. P.H. Thomas
Mr. R. Bechtold

This was the first meeting of this group and the first order of business was to look over the papers assigned for its review. The group divided the discussion into three broad categories of the analysis of fully developed compartment fires, the optimum design and specification of fire safety in buildings and finally to make recommendations to the whole Commission W14 concerning possible actions in group 2's sphere of interest.

1. The analysis of fully developed compartment fires

The group began its discussion by hearing a short presentation of each document by its author or someone from the same country. The meeting was quite informal and there was continuous discussion within the group.

Document 16/73(C) "A New Look at Compartment Fires, Part I and Part II" by T.Z. Harmathy starts with a discussion of the empirical burning characteristics of cellulosic materials in general and wood cribs in particular. The paper then presents an analysis which contains one equation to describe the rate of burning in the fuel-surface-controlled regime and another equation in the ventilation controlled regime. Several conclusions were reached concerning choices of parameters. M. Harmathy then discussed how this analysis suggested design proceeduresthat might reduce the import of fully developed fires on buildings.

Document 42/74(S) "A Discussion of Compartment Fires" by S.E. Magnusson and S. Thelandersson. The Authors presented the discussion by highlighting the similarities and differences between their approach and that presented in the previous document 16/73(C). The discussion was very extensive and many members of the group entered into issues.

Document 39/74 (UK) "The Effect of Crib Porosity and Recent C.I.B. Experiments" by P.H. Thomas and Document 21/74 (USA) "Modeling of Vented Enclosure Fires" by P.A.Croce were discussed together and found to present consistant information.

In the discussion on fully developed compartment fires the differing approaches of Mssr.Harmathy, Magnusson and Thelanderson were discussed in some detail after presentations by the authors. The group points out all theories so far available rely somewhere on experimental data uncorrelated by theory and almost exclusively based on wood fuels. The conventional heat balance equations are approximations in that they adopt empirically the "best" values for calorific value or net rate of heat release. This does not detract from the value of these theories so long as they only apply to wood. If the role of feed back to the fuel (to provide its effective "latent heat" to go from the solid to gas phase) is important one might expect it to be responsible for considerable differences between pastics and wood. Because when heat release in the room is controlled by the air flow in ventilation controlled fires the primary difference in fully developed fires would be manifest in the extremal flame outside the compartment and in the transition between ventilation and fuel controlled fires, probably raising the value of the ventilation parameter at which it occurs. This makes it less likely that a plastic fire is fuel controlled.

Mr. Nilsson and Mr. Thomas pointed out that their recent work, based on considerations similiar to those of Heskestad and Croce (CIB W14 21/74 USA), can be used to identify areas where the porosity of the fuel bed itself (as opposed to the surface area) led to departures from the well established ventilation and fuel surface controlled regimes. This could account for some of the scatter to which Harmathy had drawn attention in one earlier discussion in the group.

2. Optimum Design and Specification of Fire Safety in Buildings

Document 25/73 (UK) "Passive and Active Fire Protection - The optimum Combination" by R. Baldwin and P.H. Thomas. Dr. Thomas presented a short description of the paper and noted that there were some situations where it was clearly best to use either an active or a passive protection system because the alternate was too expensive. There are also situations where either approach is too expensive, but the most interesting situation lies in the region where the two approaches are competitive. This introduces the concept of "trade-offs" and he discussed this philosophy at some length. This combination runs through all of the design concepts discussed below.

Document 24/73 (S) "Principles of Fire Engineering Design and Fire Safety of Tall Buildings" by Prof. Pettersson. The author noted that this was a review paper presented at the International conference on Tall Buildings held in August of 1972. In this paper he reviewed the available framework for a functional design approach to tall buildings. He describes the General Services Administration's (USA) "Decision tree" approach.
Prof. Pettersson commented that this system was good in that it made engineers think in an overall fire safety way.
In addition it gives a framework for understanding where we should put our research effort.

Mr. Harmathy commented that in the descission tree approach the designer must rely on the state-of-the-art at the time he or she makes the final design choices. The continuing research effort will refine our understanding and the code of practice must be geared to a changing set of choices at specific locations in the descission tree.

Document 44/74 (S) "The Connection between a Real Fire Exposure and the Heating Conditions According to Standard Fire Resistance Tests, With Special Ref. to Steel Structures" by O. Pettersson. The author described the whole document of which this contribution is the second chapter. He then described the content of the paper and there was considerable discussion on the topic.

Document 47/74 "Principles of Fire Engineering Design" was discussed in the complete Commission W14 meeting on Monday and may be discussed again on Thursday.

Documents 22/74 (USA) "Fire Safety Criteria and Tests for Dwellings-Preflashover" by R.B. Williamson describes a restatement of existing fire safety requirements and some criteria and tests in a new form. The author noted that it was an early draft and he welcomed an suggestions or comments. Mr. Thomas indicated that the inclusion of feedback and research into the traditional scheme of control requirements and criteria assumed a dynamic system.

Document 23/74 (USA) "Fire Safety Criteria and Tests for Dwellings - Post Flashover". A special report by Mr. Vytenis Babranskas on the general topic of compartment fires was submitted in the place of the above named document. This report discusses the bases of our understanding of fully developed fires in compartments.

Document 24/74 (USA) " Impact of Contacts on Building Fires by P.S.Klitgaard and R.B. Williamson. This paper describes some of the new hazards represented by the large growth of plastics in buildings for furniture and other large content items. Mr.Williamson noted that the criteria for fire propagation in 22/74 could be used to control these hazards to some extent. The role of plastics in the fully developed fire were discussed earlier.

3. C.I.B. Contribution on Principles of Fire Safety

The group 2 discussion centered on the design and control of building fires in a changing society. It was noted that there are a number of organizations engaged in trade-off schemes and it was decided to make the recommendation to the entire Commission W14 that a draft document be prepared prior to our next meeting which identifies the general concepts of fire safety. This might include a methodology of approaching trade-off as well as other topics.

Report of Group III CIB WG 14, 1974

Chairman : Mr. Robertson

Participants:

Mr. Maroni	USA
Mr. Bengtson	Sweden
Mr. Tolstov	Sweden
Mr. Oksanen	Finland
Mr. Sjölin	Sweden
Mr. Kawagoe	Japan
Mr. Kovacs	Hungary
M. Cabret	France
Mr. Westhoff	Germany
Mr. Becker	Germany
Mr. Glüsing	Germany
Mr. Nice	U. K
Mr. Aegidius	Denmark
Mr. Berl	USA
Mr. Stolp	Netherlands
Mr. Klingelhöfer	Germany
Mr. Gross	USA
Mr. Keough	Australia

This group was concerned with problems of smoke and reaction to fire phenomena. Mr. Westhoff opened the session and proposed that Mr. Robertson serve as chairman. This was unanimously agreed to. The members of this group are listed above.

Mr. Robertson proposed a subdivision of the papers into four groups:

1. Fire Behaviour of Plastics and Textiles. 27/74 31/74 12/74 and 12/14
2. Measuring the Fire Hazard. 72/56 13/74 14/74 and 6/74
3. Movement of fire gases and smoke in buildings. 5/74 17/74 72/70 18/73 16/74
4. Growth and Spread of Fires. 15/74 18/74 19/74

A. Fire Behaviour of Plastics and Textiles

Mr. Nice discussed paper 27/74 Fire Hazards of Plastics in Furniture and Furnishings: Ignition Studies
This report of the first years work on a three year study describes a systematic study of ignition and burning of textiles and foamed polymers used in furniture. The study involves application of the following standard and special tests:

1. BS 4735:71 horizontal burning
2. ASTM D 2843-70 Smoke production
3. Several ad hoc ignition tests
   a. Cigarettes
   b. Matches
   c. Hot wire
   d. Candle
   e. Radiant heating

The results showed that uncovered foamed polymers give varying fire propagation with ignition more likely for larger sources and lower density foams. With a cellulosic cover between a cigarette and the foam, smouldering of the foam was usually observed. The cushioning on a chair could ignite and burn out up to 70 minutes after a burning cigerette had been placed on it.

Mr. Berl briefly reviewed the complementary Australian paper 31/74 Fire Properties of some Commonly used Upholstery Materials.This paper reports studies of the ignition of the materials with radiant energy of various levels. Again the covering material, when of cellulosic nature, seemed to encourage the ignition and smouldering propagation of foamed materials.

In England and most other countries there is little if any control over furnishings of residential occupancies. UK considers this an important fire hazard problem and is investing about ten percent of the time of the Fire Research Station on it.

In the USA the Consumer Product Safety Commission is charged through the Flammable Fabrics Act with insuring public safety from such fire problems. It nas already set some standards for carpets and mattresses.

Mr. Nice reported that studies in UK had shown that the toxic effect of CO in the presence of HCl or HCN is greatly enhanced. A report on this work will be available shortly.

Mr. Robertson suggested the possibility of animal experiments in the sleeping mode to determine if an alarm mechanism could be provided by an irritating gas. Mr. Nice mentioned work currently in progress on toxic hazards of gases and said that they too had considered work of the type suggested by Robertson.

Mr. Kawagoe reported studies which had been made in Japan of the time required for smoke to complete various stages of filling a compartment. He reported modification of the relationship for point sources $t \propto 1/Q^{1/3}$ proposed by Mr. Thomas. Dr. Yokoi proposed the relationship $t \propto 1/Q^{1/3} r^{5/3}$ which recognizes the effect of fire radius in modifying the behaviour.

t is time,
Q is burning rate and
r is the fire radius.

Mr. Maroni's paper was 12/74 Large Scale Fire Tests of Rigid Cellular Plastic Wall and Roof Insulations , but this was not discussed further. It was generally recognized that the behaviour of the materials presented an important problem. There was some discussion on the relative hazard of the different polymer foams.

In Summary

The group agreed that

1. Fires involving building furnishing items present a serious hazard problem.
2. Legislative action in several countries places increasing emphasis on this subject.
3. Further studies on various methods for alerting people during early stages of a fire are needed.

4. Although CO has been shown to be one of the most important of the toxic fire gases a lot remains to be learned on the toxic hazard of other combustion products (HCN, HCl etc.) Attention should be directed to the importance of time as a measure of fire safety.

5. The group recommended that Commission W14 give continued consideration to a rapid resolution of the fire gas hazard, to help in the coordination of the effort and assist in rapid interchange of information on this subject.

B. Measuring the Fire Hazard

Mr. Kawagoe discussed paper 72/56 Visibility through Fire Smoke. A previous paper by the same author, Dr. Jin, had discussed visibility through smokes from cellulosic materials. The present paper is primarily concerned with smokes from polymeric materials. It includes statistical information on the particle size distribution as well as range of visibility of both front and back lighted signs both in the presence and absence of scattered light. It was concluded that

1. The product of the attenuation coefficient and the visual range is proportional to the brightness of the sign divided by the intensity of the illumination causing scattered light.
2. The visibility of signs through smoke is reduced when the smoke particulate is black and illumination favours light scatter.
3. In these experiments the effect of eye irritants was not investigated although it was stated that such effects would greatly reduce visual range.
4. It was also stated that the color of the sign was unimportant compared to its brightness.

Mr. Nice suggested that emphasis should be placed on elimination of smoke production as far as possible and on controlling smoke movement.

Col. Cabret suggested the importance of contrast measurements. Mr. Berl suggested the need for floor level indication of the direction for movement to exits or refuge centers.

Mr. Robertson summarized the papers 13/74 and 14/74 Development of a Heat Release Rate Calorimeter and An Experimental Method for Evaluating Fire Hazard. These both involve heat release rate measurement methods. They both depend on the radiant exposure of a specimen in a flowing air stream and provide for a measurement of the resulting heat release of the specimen as a function of time. There are significant differences in the mass and complexity of the experimental apparatus. One apparatus, NBS, measures heat release only whereas the Smith calorimeter furnace is claimed to provide information on flammability, time related heat and smoke release, and flame spread behavior at various irradiance levels. Provision is made for testing the specimen in both vertical and horizontal positions.

Mr. Becker described a full scale Dortmund room calorimeter device designed to measure the heat flux to room walls. The purpose is to compare this heat flux from a variety of materials with the heat flux measured during development of ISO R/834 fire temperature time curve in the same room. The results are reported as the M factor of the specimen. This factor is found to be dependent on geometry and subdivision of the specimen and product under study.

Col. Cabret questioned the merit of the method since the measurements are influenced by the surface to volume ratio of the specimen. He emphasized the large number of measurements which would have to be made for a given material for all possible products.

Several participants emphasized the need to make heat release rate measurements under a range of irradiance levels including the maximum values to be expected under full scale fire conditions (Maroni, Stolp and Berl).

Mr. Berl introduced paper 6/74 Survey of Toxic Species Evolved in the Pyrolysis and Combustion of Polymers. This was very briefly reviewed. Mr. Berl seriously questioned the possibility that phosgene could be present as a hazardous product of the combustion of any chlorinated polymers because of its instability at high temperatures and unfavourable equilibrium concentration at low temperatures. However he drew attention to the possibility of metal oxides appearing in smokes. He encouraged further study of them.

In Summary:

The group agreed that:

1. The Japanese work on visual range of signs was of great value although the importance of securing information on the reduction of visual range resulting from eye irritation should not be overlooked.

2. The group recognized the fallacy of the belief that smoke production during building fires could be significantly reduced by control of smoke production of building materials in the absence of similar controls on the occupancy fire load.

3. The importance of heat release measurements was recognized and the group offered encouragements to ISO/TC 92 towards their planned development of a heat release calorimeter. Such a device should provide flexibility in the heat flux levels during specimen test.

4. Metal oxides appear to warrant further study as a possible hazard in fire. This may pose a special occupational hazard for fire fighters.

C. Fire Gas Movement in Buildings

Mr. Berl presented paper 5/74 The Accumulation of Gases on an Upper Floor During Fire Buildup. This paper describes experiments in which fires were started in a first floor room of a building and measurements were made of temperatures in the fire room and oxygen depletion, CO and CO_2 accumulation in an upstairs room. These measurements were made at three different heights above the floor level roughly 15 cm, 60 cm and 160 cm. Both a large wooden crib and a chair were burned individually. The development of toxic concentrations occurred very rapidly with little difference in the time of their occurance at different levels above the floor. In the case of the crib burn very little smoke was produced but the CO concentration rose to lethal levels in less than eight minutes. The burning chair on the other hand produced large quantities of smoke. It was concluded that the danger from CO was dominant over oxygen depletion and CO_2 generation.

Mr. Stolp suggested that it might be possible to incorporate an olfactory material in the furniture or building finish item which in the event of fire could serve as an alarm mechanism to alert building occupants.

Mr. Robertson very briefly discussed paper 17/74 Report on Fire Tests Flexible Connectors on HVAC (Heating Ventilating and Air Conditioning) Systems. Briefly this paper is concerned with design of duct systems which will limit the movement of gas between floors during a building fire. It also recommends precautions for limiting smoke production from materials used in duct connections.

This paper stimulated discussion by Mr. Klingelhöfer of work under way at Dortmund on fire performance of ventilating systems and the testing of dampers.

Mr. Keough presented paper 72/70 Venting Fires Through Roofs (Fires in an aircraft hangar). The objecture was to study the roof venting conditions required to permit disposal of fire gases. The following variables were considered:

1. Fire burn area

2. Roof vent area

3. Wall inlet area

4. Depth of roof curtain

He emphasized the importance of recognizing the gas discharge coefficient of various types of roof vents. It was concluded that an effective roof vent area of about 3,5 percent of the floor area covered. For large hangers air leakage of the building was adequate to replace the gas outflow, However for smaller buildings special provision should be made for such openings. During the study fire whirls were sometimes observed and it was suggested that building design might be arranged to dispose of gases where they could burn outside the building.

Mr. Becker asked about the possibility that PVC might be used as a vent closure. Mr. Keough did not consider that this would be feasible. The UV degradation is a serious problem at the Australian latitudes.

Mr. Nice presented paper 18/73 Problems of Pedestrian Precincts Part B Smoke Production of Sprinkelerd Fires. This is a part of an extending study of smoke behaviour and control in a shopping arcade during a fire. Four points were emphasized:

1. Automatic sprinklers must be properly located to cool the products of combustion
2. Reservoirs should be provided as part of the building design to collect the smoke
3. Venting devices must be available to exhaust the smoke to the outside
4. Adequate air inlets must be present

The sprinkler tests indicated that gas temperatures were substantially lowered even in circumstances where direct impingement on the burning materials did not occur. The smoke density was not affected by the sprinkler action.

Mr. Stolp reported on similar experiences in Holland where venting devices proved adequate to remove accumulated smoke. Mr. Nice responded that English building regulations do not as yet permit the use of venting devices that rely on the building electric power supply.

Kawagoe outlined Japanese practice regarding means to establish pressure fields that could inhibit the flow of smokes through corridors. Cabret agreed with Kawagoe that air curtains did not provide an effective means to modify smoke flow patterns.

Mr. Gross presented paper 16/74 Evaluation of a pressurized stairwell smoke control system for a 12 storey apartment building. As part of the US Department of Housing and Urban Development Project Break-through an apartment building was designed with a stairwell having an independent air supply and exhaust in conformity with Canadian building design. The tests were run under climatic conditions where the temperature difference between inside and outside were 10-18^{o}F. Sulfur hexafluoride was used as a tracer substance.

The "ignition source" was located either on the second or ninth floor.

It was found that the fan capacity was adequate to prevent intrusion of the tracer gas into the stairwell with as many as five doors open to the building.

Kawagoe described Japanese Fire Service techniques by which escape corridors could be sealed off from the building by the use of inflatable barriers equipped with escape hatches for occupants.

In Summary

The group emphasized that:

1. The speed of movement and the concentration of smoke and toxic gases observed during experimental fires place emphasis on the associated life hazard.

2. The quantity of smoke which can result from the burning of even small amounts of building finish or furnishing items is so large that it seem unlikely that control of these items on a national basis will be effecting in eliminating the hazard. Because of this great importance is attached to the need far incorporation of special gas transport systems in buildings for movement and removal of gases when fire occurs.

3. There continues to be a need for development of improved engineering design methodology for proper control of smoke to insure life safety of building occupants.

4. Consideration should be given to the desireablity of a symposium which might be sponsored by Commission W 14 of CIB on the subject building design methods to assure smoke and gas movement during building fires.

5. A need exists for studies of methods suitable to encourage desireable and life saving human response during building fires.

Mr. Gross described recent fire studies reported in document 15/74 NBS Corridor Fire Tests: Energy and Radiation Models. A corridor test facility has been used to study the importance of floor covering material in influencing fire spread along the corridor length. He reported fire loads in the associated burn room were on the order of 13-14 kc/m^2. This comprised 4 wooden cribs which were ignited simultaneously. During these studies all floor covering were found to ignite with the result of rapid flame travel down the corridor length after 5-15 minutes of crib burning time. This behaviour has been attributed to heating of the floor covering through radiation from hot gases and the ceiling of the corridor.
Mr. Gross described plans for development of a test method to measure fire properties of floor covering materials. This device involves use of a radiant panel heat source with a horizontally oriented specimen irradiated with a flux level varying from 1-2 /cm^2 at one end to about 0,1-0,2 /cm^2 at the other end.

Mr. Stolp described recent studies of a similar nature in Delft. A variety of floor covering material including wood and linoleum as well as carpeting had been tested in a corridor of roughly 2 m width and 2,5 m height. The walls and ceiling were lined with light weight concrete block walls. All the combustion air entered the corridor from the end opposite to that at which the exposing fire was located. This fire as in the NBS tests was developed in a separate but connecting room. It made use of four wooden cribs representing a fire load of about 10 kg/m^2. Only one of these cribs was ignited and it took about 20 minutes before all were completely involved.

Mr. Stolp indicated that none of their ten or more tests exhibited complete involvement of the floor covering. Fire spread on the carpet extended but about one fourth of the corridor length and they have concluded that floor covering materials which do not spread fires from a small ignition source do not present a prominent fire hazard.

Paper 19/74 on Extinguishment of Radiation Augmented Plastic Fires by Water Spray by R.S. Wagee and R .D. Reitz deals with the turbulent burning of several plastics (Plexiglass, polystyrene, polyethylene and Delrin 500) with and without added radiation enhancement and determining the effect of varying amounts of water spray on burning rates and complete extinction of combustion. Water was applied by a single spray nuzzle.

Results have been obtained for a variety of energy fluxes superimposed on the "normal" burning of plastic sheets, mounted both vertically or horizontally. All data indicated a linear dependence of burning rate on external radiant flux. Water spray produced a lower burning rate, still linearly dependent on external radiant flux. At a critical radiant flux level and water flow rate, combustion stopped.

From the results it should be possible to obtain a clearer understanding of minimum water requirements for sprinklers or other water suppression methods.

Col. Cabret emphasized the observed difficulties under realistic conditions to extinguish rubber fires with water.

Complementary experiments on water extinguishment of wood cribs were described by Mr. Stolp. Water was applied to the top of a rotating burning fuel crib. The weight loss of the crib was obtained as a function of time and as a function of water flow rate.

By enclosing the rotating crib in housings in which the ventilation and combustion gas exhaust flow can be varied the experimental technique lends itself to a variety of investigations.

The paper by G. Markstein 14/18 on Radiative energy transfer from gaseous diffusion flames deals with a study of radiation from laminar gaseous diffusion flames of nine saturated and unsaturated hydrocarbons burning in air. The objective is to investigate the contribution of emitted radiation from the flame soot and from the heated gaseous products of combustion. Since considerable temperature gradients exist absorption of parts of the radiant energy in the cooler parts of the flame is likely, thereby reducing the radient heat output.

From the experimental results, in which the integrated radiation from up to ten parallel flames was observed it was concluded that their radiant output could be described as being due to 6 combinations of radiation coming from the soot at the hottest part of the flame and from the variating product gases, CO_2 and H_2O at a lower effective temperature.

At a future date measurements in turbulent diffusion flames will be undertaken under conditions that will be similar to those met in actual fires.

In Summary

The group decided that:

1. The apparent conflicting findings of two reported studies on the behaviour of floor covering materials emphasizes our lack of understanding of the phenomena involved. They encourage further studies of the reason for the differences observed in the two investigations with the objective of clarifying the relationship between the test method results to those observed in actual building fires.

2. Basic combustion studies of the type reported in two of the papers considered are likely to provide a portion of the basic technical information required for future engineering system design for fire safety.

General Summary and Recommendations

The definition of occupancy safety during building fires requires a more intensive effort than has been given to it heretofore. The emphasis on building structural safety needs to be accompanied by a parallel effort on life safety and fire prevention.

1. The group noted increasing evidence of the importance of fire gas properties and behaviour as serious life hazard.
2. The group agreed that smoke and toxic gas production from the occupancy fire load presents a grave hazard and must be recognized in any attempts to minimize smoke and fire gas production.
3. Several countries have already established minimum performance standards for building furnishings and clothing items to minimize fire casualties.
4. There is need for increased emphasis on:
   a) Early detection and warning of occupants to permit effective evasive action.
   b) Study of human behaviour during presence of fires.
   c) Characteristic times of fire phenomena as a determinant of fire safety.
   d) Investigation of the relative hazards associated with toxic gases and smokes from both construction and building occupancy materials.
5. Because of the quantities of smoke and toxic gases resulting from the burning of even small quantities of building finish or furnishing items a great need exists for the development and utilization of special means for the control of and removal of smoke and toxic gases during building fires.
6. The importance of reaction to fire measurements including heat release, gas and smoke evolution and flammability under a wide range of thermal exposure conditions call for the rapid development of suitable testing methods.
7. It is recommended that Commission W 14 of CIB sponsor a symposium on the subject of building design methods to control gas and smoke movement during building fires.
8. It has been brought to the attention of the group that a substantial number of investigations are planned and are being carried out on the influence of fire gases and smokes on animals and humans. An effort should be made to survey and document this work in time for a report at the next meeting of W 14.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report summarizes discussions which took place at the recent meeting of Commission W14 of CIB. About 46 of the more than 100 documents related to fire problems were considered at the meeting. It was agreed that current trends in building construction and furnishing materials present new forms of fire hazard which warrant increased attention. While progress was evident in methods for analyzing fire endurance performance of structural building elements it seems desirable to place greater emphasis on the fire gas hazard as a cause of fire casualties. A symposium is planned on methods for managing gas movement and disposal during building fires. A state-of-the-art paper is also planned to review and document current work on the influence of fire gases on animals and humans. It was noted that the smoke production characteristics of furnishing items may present serious problems and must be considered in any attempt to control smoke during building fires.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* CIB; codes; Commission W14; fire endurance; fire gases; fires; fire tests; growth; models; smoke.

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