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NATIONALLY STANDARDIZED FIRE TEST PROCE-  
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NEED FOR AND SOME REMARKS ON INTERNATIONALLY STANDARDIZED FIRE TEST PROCEDURES<sup>1)</sup>

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NEED FOR AND SOME REMARKS ON INTERNATIONALLY  
STANDARDIZED FIRE TEST PROCEDURES

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ABSTRACT

Introductory, the characteristics are given for on one side the conventional, highly schematic fire engineering design, connected to classification systems, and on the other side a differentiated fire engineering design procedure, directly based on performance criteria and functionally well-defined requirements. The two different approaches are compared for an application to load-bearing structures. From this background, the consequential need for standardized fire test procedures is analysed and some general conclusions are drawn. Parallely, fundamental requirements on internationally standardized fire test procedures - for classification or more general purposes - are presented and summarily discussed, as regards applications to existing ISO recommendations and to a differentiated fire engineering design. Finally, the concept equivalent time of fire duration is mentioned and fragmentarily exemplified as a mean of translation from a real fire exposure to the standard heating conditions in fire resistance tests.

TRENDS OF DEVELOPMENT OF FIRE ENGINEERING DESIGN METHODS

The different ISO recommendations concerning fire test procedures and the corresponding national standards have been developed mainly on the basis of classification requirements, stipulated in building codes and regulations. The recommendations and standards then have been drawn up with the fundamental aim that the test results are to be used as data for a fire engineering design, taking into account real conditions in practice as well as possible.

In the light of these facts, it seems natural to begin a discussion of the need for an international standardization of fire test procedures by a general survey of the present state and the trends of development of fire

engineering codes, regulations and design methods.

For a long time back, a fire engineering design of buildings and elements of building construction ordinarily is characterized by a highly schematic procedure, based on undifferentiated classification systems with respect to combustibility and ignitability of materials, spread of flame and smoke production of surface layers, and fire resistance of structural elements. For a classification, each property then is determined in a standardized fire test with fixed heating conditions. In a fire engineering design, the results of such standard classification tests directly are to be compared with the corresponding requirements, specified in the codes and regulations.

Applied to a load-bearing structural element, the internationally conventional system of fire engineering design can be illustrated according to Figure 1 [1]. The building codes and regulations are giving a required time of fire duration, which depends on the occupation, the height and the volume of the building, and the importance of the structural element. The fire engineering design comprises a proof that the proposed structural element has a fire resistance time, determined in a standard fire resistance test, which exceeds the fire duration required.

At present, a clear trend can be seen of a development of the building codes and regulations in many countries towards functionally more well-defined requirements. As a consequence, the need continuously increases of methods for a differentiated fire engineering design. As concerns load-bearing structures or structural elements, several such design methods also have been published during the last ten years.

Mainly, these methods can be referred to one of two different groups with respect to the use of the basic data of the process of fire development. Characteristic for the methods of the first group is a design procedure with the varying properties of a real fire development taken into

account over an equivalent time of fire duration, connected to the heating according to the standard time-temperature curve. The methods of the second group are characterized by a design procedure, directly based on gastemperature-time curves of the complete process of a real fire development, specified in detail with regard to the influence of the fire load and the geometrical, thermal and ventilation properties of the fire compartment.

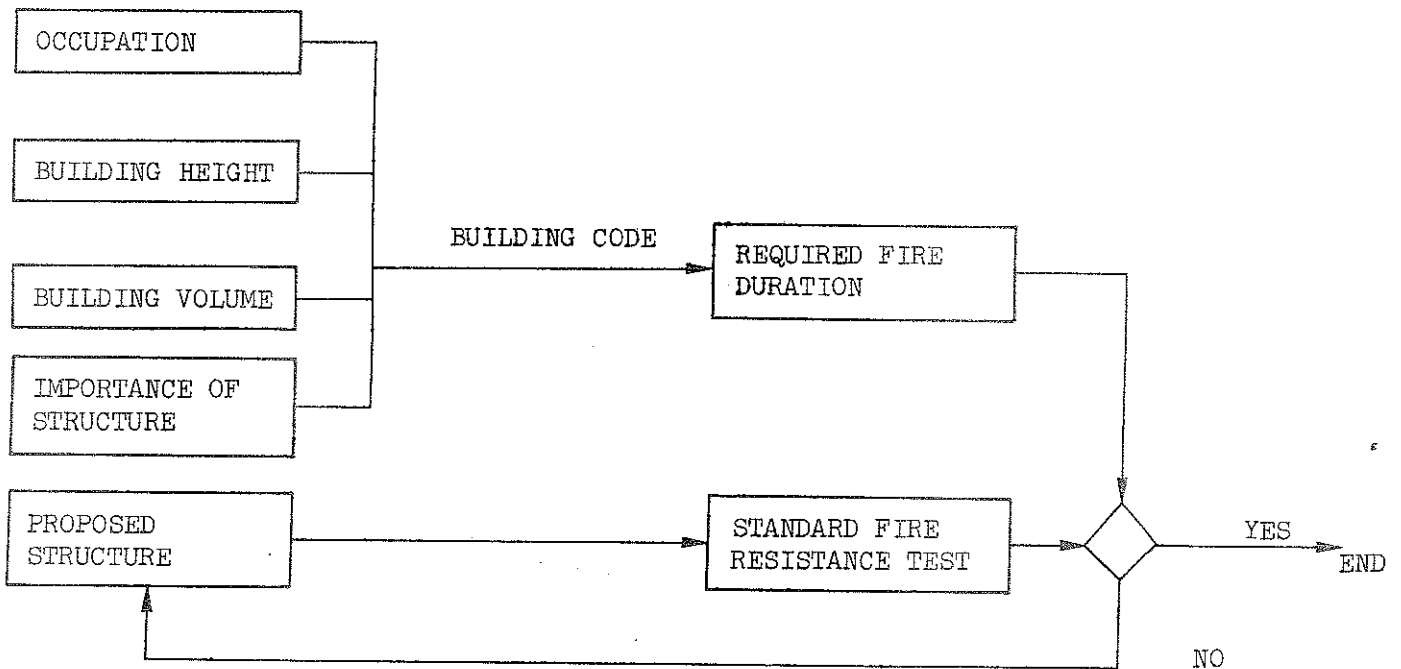


Figure 1. Conventional fire engineering design of load-bearing structural elements [1]

Such a design according to the second group methods comprises the following main components [2] to [5]:

- (a) The choice, in each particular case, of representative combustion characteristics of the fire load.
- (b) The determination for these combustion characteristics of the gastemperature-time curve and the convection and radiation properties of the complete process of fire development, taking into account the geometry of

compartment, the size and shape of window and door openings and the thermal characteristics of the structures, enclosing the compartment.

(c) The determination of the corresponding temperature-time fields in the structure or the structural element, exposed to fire.

(d) The determination - on the basis of data according to (c) and data on the strength and deformation properties of the structural materials in temperature range, associated with fires - of the point of time for collapse at prescribed loading or, alternatively, of the minimum load-bearing capacity of the structure or the structural element for the process of fire development valid.

(e) The application of the results according to (d) in a structural design, based on functional requirements and specifications on load and fire load levels, given in building codes and regulations.

The design procedure is shown more in detail in Figure 2.

The differentiated design system according to Figure 2 is to be seen primarily as a pure, theoretical procedure. The system can be applied in this way at present to, for instance, steel structures and isostatic, reinforced concrete beams and slabs. For these types of structures, now also design diagrams exist which considerably can facilitate a practical application. Fragmentary examples of such diagrams are given in Figure 3 and 4.

In Figure 3 [5], [6], then some design curves are presented, giving directly for a complete process of fire development the corresponding maximum steel temperature  $\vartheta_{s_{max}}^{\circ}$  for an insulated steel structure at varying fire load  $q_t$ , and structural quotients  $U/F$  and  $d/\lambda_i$ . The curves are related to an opening factor of the compartment  $A_v \sqrt{h}/A_t = 0,04 \text{ m}^{1/2}$ .  $A_v$  is the opening area,  $h$  the opening height, and  $A_t$  the total interior surrounding surface of the compartment.  $U$  is the interior surface of the insulation per unit length,  $F$  the volume of the steel structure per unit length,  $d$  the thickness of the insulation, and  $\lambda_i$  the thermal

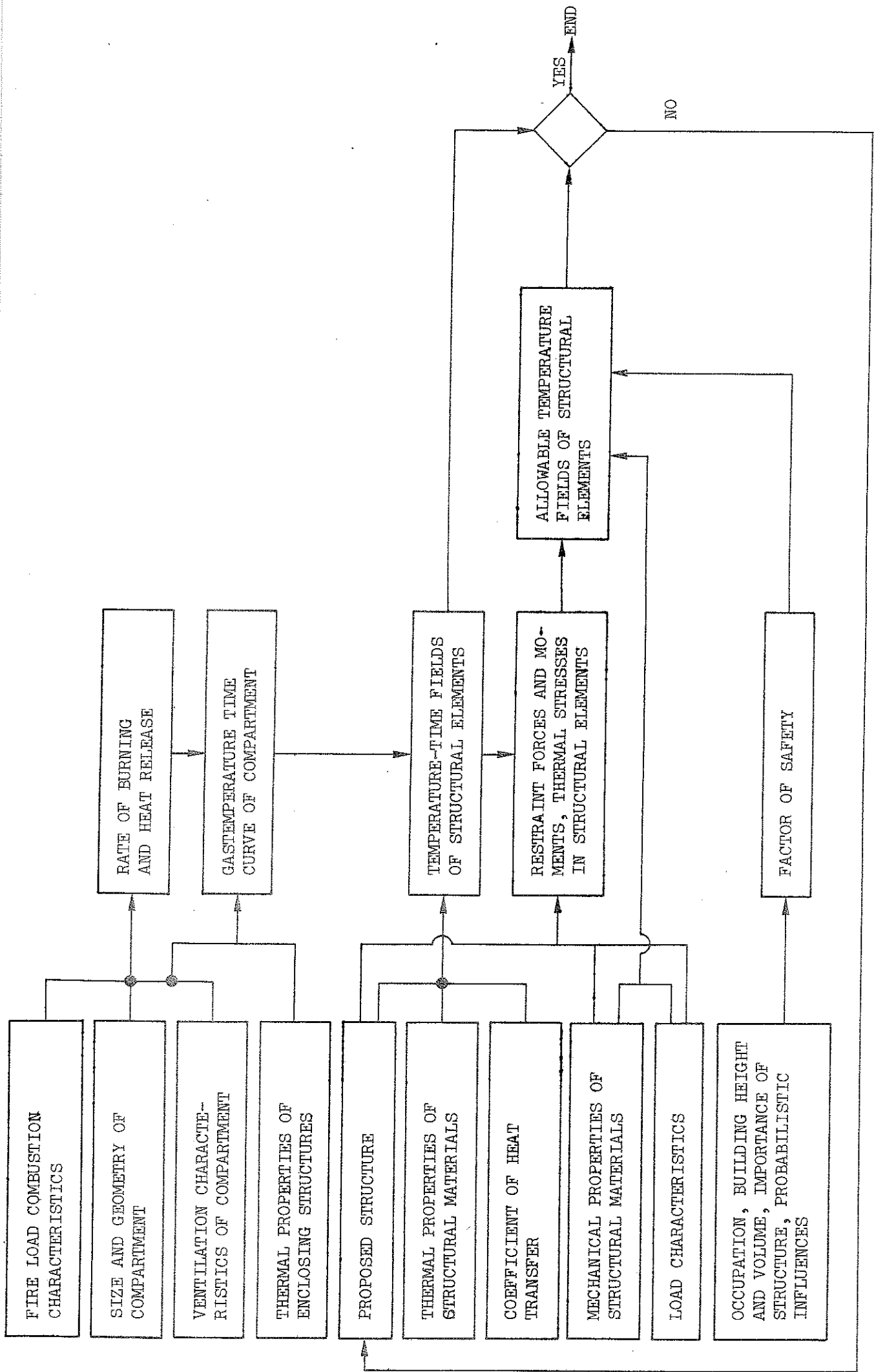


Figure 2. Differentiated fire engineering design of load-bearing structural elements [1] to [5]



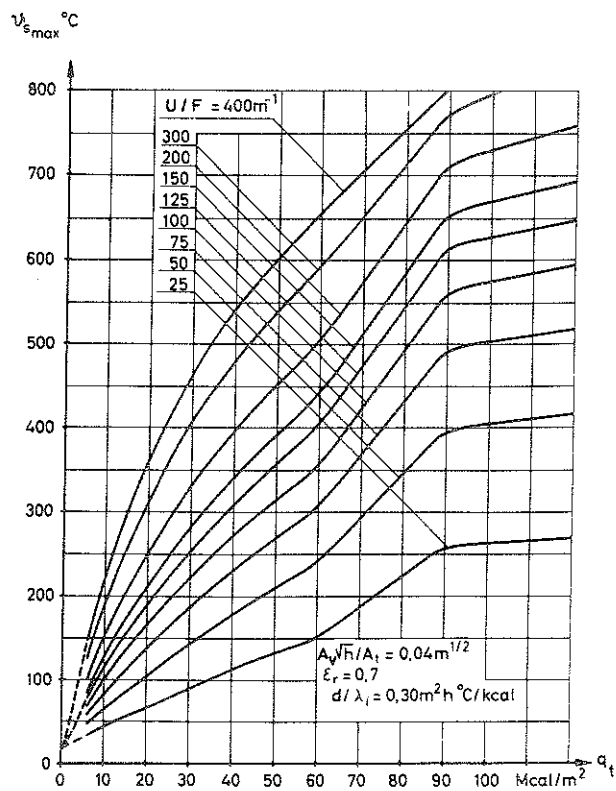
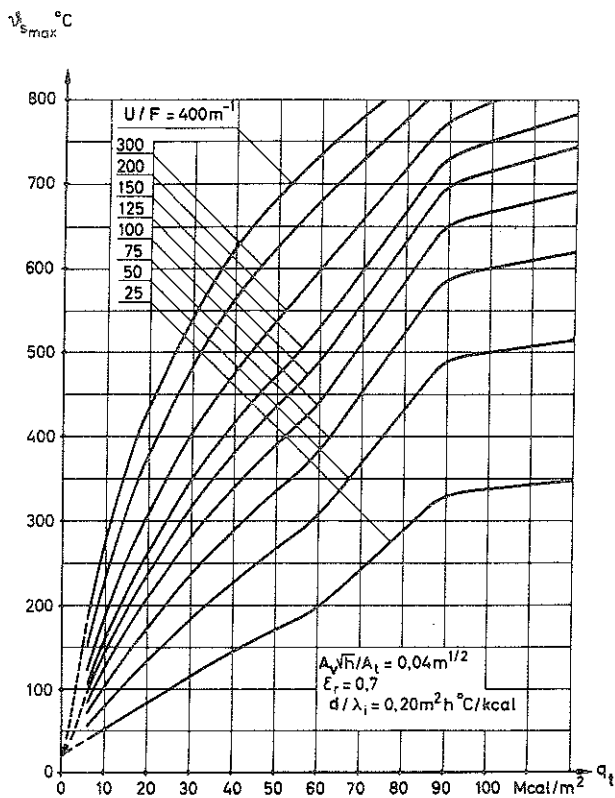
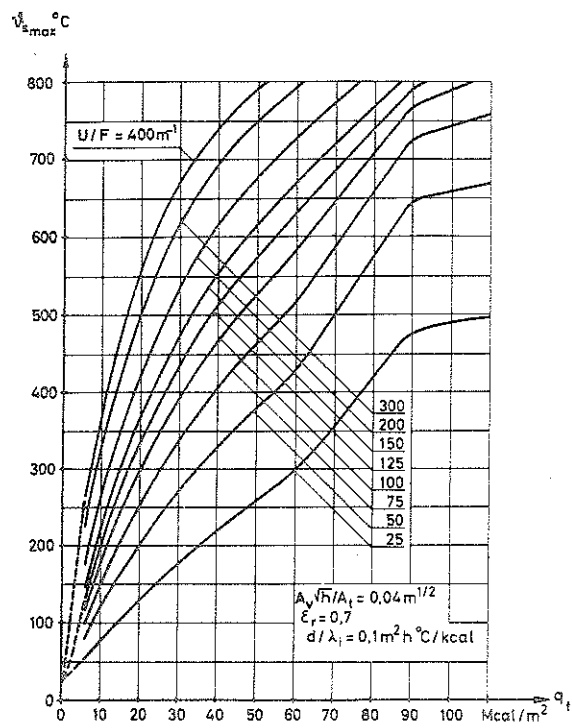
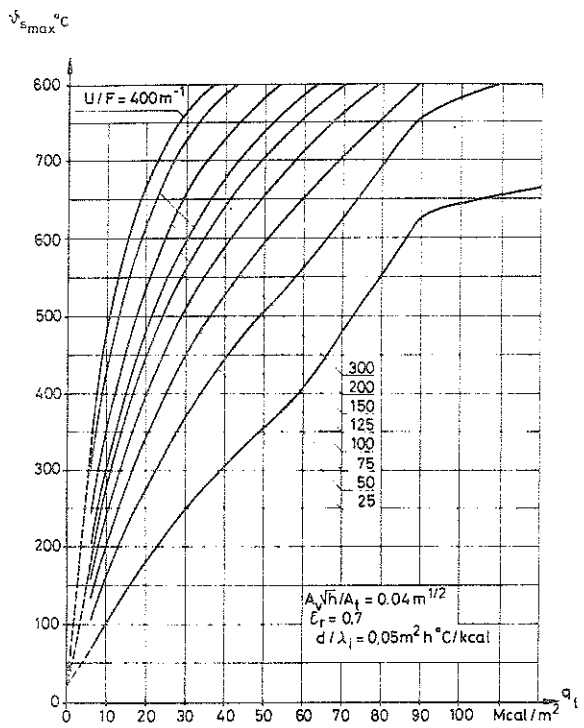


Figure 3. Maximum steel temperature  $\theta_{s,max}^h$  for a fire exposed, insulated steel structure at varying fire load  $q_t$  and structural characteristics. Opening factor  $A_v\sqrt{h}/A_t = 0.04 \text{ m}^{1/2}$  [5], [6]

conductivity of the insulation material. The fire load  $q_t$  is defined as the corresponding heat value per unit area of the surrounding surface  $A_t$ .

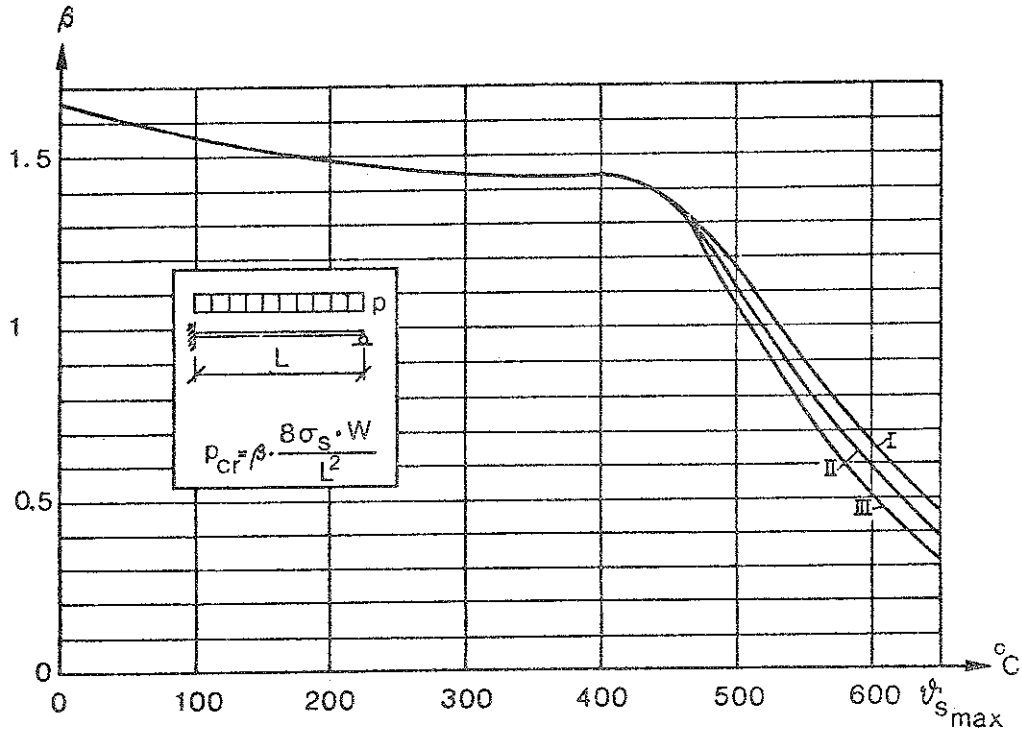


Figure 4. The critical load  $p_{cr}$  for a fire exposed steel beam with an I cross section, simply supported at one end and built-in at the other. Uniformly distributed load  $p$  [7]

Figure 4 [7] exemplifies another type of design diagrams, enabling a direct translation of the maximum steel temperature  $\psi_{s_{max}}$  for a fire exposed steel structure to an adherent load-bearing capacity or critical load. The exemplified diagram applies to a steel beam with an I cross section, simply supported at one end and built-in at the other, acted upon by a uniformly distributed load  $p$ . In the formula for the critical load  $p_{cr}$ ,  $\sigma_s$  denotes the yield point stress of the material at ordinary room temperature, and  $W$  the elastic modulus of resistance of the cross section. The curves I, II and III are connected to a rate of heating of 100, 20 and  $4^\circ\text{C}$ , respectively, and a rate of subsequent cooling, which is one third of the rate of heating.

CONSEQUENTIAL NEED OF STANDARDIZED FIRE TEST PROCEDURES.

GENERAL REQUIREMENTS AND REMARKS

In a conventional fire engineering design, based on classification systems, standardized fire test procedures are of primary importance. It is reasonable to assume, that this will be the case also in the future for a considerable time. By reason of that, the need of an international standardization of the test procedures is obvious. The need is further emphasized by the fact that the test procedures are comparatively expensive in many practical applications.

In pointing this out, it is essential to realize the development in progress towards a more differentiated approach to a fire engineering design, which will lead to a successively decreased importance of classification fire tests. Moreover, improved knowledge continuously will increase the possibilities to replace in a classification procedure parts of a fire test or a whole fire test by theoretical calculations. Such possibilities already exist for certain types of structures, for instance uninsulated or insulated steel beams, frames and columns.

In developing internationally standardized fire test procedures - for classification or more general purposes - certain fundamental requirements must be fulfilled. The most important requirements then are:

- (a) A test method shall comprise a determination of either one single, well-defined physical, chemical or mechanical property or a more global, integrated effect, based on a number of relevant, well-defined properties.
- (b) A test method shall give relevant and useful results. That means, that the exposure conditions in the test must simulate important and typical parameters of a real fire and, for instance, for the loading and restraint conditions, the decisive parameters of the fire behaviour of a real structure.
- (c) A test method must give reliable and quantitative results with an acceptable degree of reproducibility among laboratories and repeatability

within a laboratory.

(d) A test method must comprise a recording and reporting of data of measurements in such an extent, that different practical applications of the test results can be facilitated. That means, for instance, that the results of a fire test, made in one country, should be directly applicable as a basis for classification in different countries with varying classification requirements. This gives as a consequence, that a test method ordinarily ought to provide continuous scales of measure and that a test method should include a full description of the procedure of the test together with general test criteria, while detailed classification requirements are to be excluded [8]. It can be useful to supplement international fire test procedures with commentaries to serve as a guidance for planning, performance and reporting of a fire test and for an application of the test results to various situations in practice.

As concerns the existing ISO-recommendations for fire test procedures, it can be stated, that the test method for a determination of the calorific potential of building materials - ISO / R 1716 [9] - is giving values of the amount of heat released by a complete combustion, which now are generally applied in calculating the fire load of a compartment. Against the test method can be said, that the combustion conditions in the calorific potential test are more severe than in real fires. The importance of this difference can be illustrated fragmentarily by referring some test results, reported in [10], giving for a compact fire load component of paper a comparison of the calorific potential  $H$  according to ISO / R 1716 with the heat release  $H_f$  during a fire exposure, characterized in relation to the temperature-time curve of a standard fire resistance test. The results, summarized in the following table, are giving evidence of the great influence of the fire exposure conditions on the heat release for this type

Fire exposure	$H_f/H$
100 % ISO curve	0.73
67 % ISO curve	0.55
50 % ISO curve	0.27

of fire load. Further developments of laboratory test methods, recently published [11], [12], for a small scale determination of the rate of heat release of materials and linings at accurately specified heating conditions, relevant to real fires, could be a future way of solving this problem.

The non-combustibility test according to ISO Recommendation R 1182 [13] for a determination of whether a building material is non-combustible or combustible, is now frequently used for a classification in building code specifications. In spite of this fact, the test method does not fulfill the fundamental requirement (a) of giving precise information on one or several well-defined physical or chemical, material properties. A development, leading to a future replacement of the present non-combustibility test by either a number of single tests or an integrated test, connected to functionally based, distinct and well-defined material properties, therefore has a high degree of priority. About the same principal characterization is valid for that family of different national fire tests which is concerned with the contribution of materials, usually combustible linings on walls, to the initiation and spread of a fire.

The international research work in progress concerning the behaviour of building materials in connection with fire, has initiated a thinking in terms of "reaction to fire of materials" [14], [15]. In [14] then an integrated test method is presented, comprising the following relevant

properties:

- (a) the rate of heat release C,
- (b) the inflammability I, which describes the ease with which an exothermic reaction occurs in the solid material ( $I_1$ ) and in the gases set free by the material in the form of flaming ( $I_2$ ),
- (c) the flame propagation at the surface of the material P,
- (d) the smoke opacity O, divided into the opacity when the material is in smouldering condition ( $O_s$ ) and the opacity when the material is in flaming condition ( $O_f$ ).

The different material properties are integrated into a reaction to fire index

$$I_{rf} = \frac{k_1 C + k_2 I_1 + k_3 I_2 + k_4 P + k_5 O_s + k_6 O_f}{k_1 + k_2 + k_3 + k_4 + k_5 + k_6}$$

where  $k_1$  to  $k_6$  are dimensionless coefficients of relative importance of the relevant properties.

In a long-term perspective, it is urgent to direct the research work towards a deduction of theoretical models which can describe, with acceptable degree of accuracy, different well-defined components of reaction to fire of building materials and/or the integrated concept as a whole. Such theoretical models then must take into account not only the relevant material properties but also the influence of varying environmental conditions, as concerns geometrical, thermal and ventilation characteristics.

The ISO Recommendation R 834 concerning fire resistance tests of elements of building construction fulfils the above requirement (a) in comprising a determination of the functionally based properties load-bearing capacity and fire separating capacity with respect to insulation and initial and ultimate integrity failure [16], [17]. As regards the requirements (b) and (c), the ISO recommendation comprises insufficiently

accurate specifications in several respects, for instance concerning the heating and restraint characteristics, the environment of the furnace and the thermocouples for measuring the furnace temperature [17], [18]. From a basic functional point of view, it would be a fundamental improvement of the existing fire test procedure to replace the stipulation concerning a fixed temperature-time curve by a requirement, which specifies fixed realistic time curves representing the combustion energy supplied per unit time to the fire testing furnace [2], [3], [19], [20].

Going over from a conventional fire engineering design, based on classification systems, to a differentiated fire engineering design, the following summary statement can be made, as concerns a design of fire exposed, load-bearing structures or structural elements, cf. Figure 2.

A structural fire engineering design, directly based on differentiated gastemperature-time curves is characterized mainly by a theoretical design procedure. The applicability in practice of this procedure, essentially can be facilitated by design diagrams, calculated for different types of structures or structural elements by means of computers. The design procedure is not connected to any need of classifications and gives a low priority to the present standard fire resistance test of elements of building construction. In the design procedure, the results of such standard tests can be used either for a confirmation, point by point, of the theoretical treatment or for getting basic information, necessary for the calculations. In those cases, when the basic information depends on the detail characteristics of the process of fire development - for instance, basic data concerning the disintegration of structural materials, enlarged short-time effect of creep and shrinkage, effect of crack formation and spalling, behaviour and strength of fastening devices for different types of insulation, rate of increase in the depth of the charred layer at timber structures - the design procedure can

necessitate experimental investigations at gastemperature-time curves diverging from the standard time-temperature curve. In most cases, the data required then can be determined by essentially less extensive experiments than the standard fire resistance test. The importance of internationally coordinated efforts for a development of such tests for essential material and component properties, connected to a differentiated fire engineering design, has been stressed at the "Colloque sur les Principes de la Sécurité au Feu des Structures", held in Paris 1971, and also within CIB Commission W14 [21].

#### THE CONCEPT EQUIVALENT TIME OF FIRE DURATION

As emphasized above, a fundamental aim of a fire test is, that the test results can be used as data for a fire engineering design taking into account real conditions in practice. This very essential requirement of a fire test method will be discussed a little more in detail in the following, as concerns the possibilities of a translation for a load-bearing structure from a real fire exposure to the standardized heating conditions in fire resistance tests. Today, such a translation can be done over the concept equivalent time of fire duration.

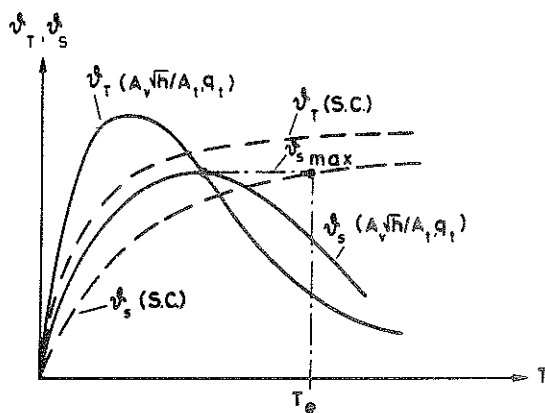


Figure 5. The concept equivalent time of fire duration  $T_e$



In principle, the equivalent time of fire duration  $T_e$  can be defined according to Figure 5, giving an exemplification for a fire exposed uninsulated steel structure [3], [5], [18], [22]. The figure shows by the full-line curves the time-variation of the gastemperature  $\dot{v}_T^h$  and the steel temperature  $\dot{v}_s^h$  corresponding to a real fire action, determined by the fire load  $q_t$ , the opening factor  $A_v\sqrt{h}/A_t$ , and the thermal properties of the structures bounding the compartment. The dash-line curves give the standard time-temperature variation  $\dot{v}_T^h$  (S.C.) and the apparent time-curve of the temperature  $\dot{v}_s^h$  (S.C.) of the steel structure. A transfer of the maximum steel temperature  $\dot{v}_{s\max}^h$  for the real fire action to the curve  $\dot{v}_s^h$  (S.C.), belonging to the standard time-temperature curve, determines the equivalent time of fire duration  $T_e$ .

Defined in this way, the equivalent time of fire duration  $T_e$  will be a function of the basic influences on the process of fire development as well as structural parameters. This is fragmentary illustrated by Figure 6 [23], giving the equivalent time of fire duration  $T_e$  for insulated steel structures as a function of the fire load  $q_t$  and the structural parameter  $U\lambda_i/dF$ . The curves presuppose a fire compartment with an opening factor  $A_v\sqrt{h}/A_t = 0.04 \text{ m}^{1/2}$  and with surrounding structures of a certain type. The dash-line curves of the figure are giving directly the level of the maximum steel temperature  $\dot{v}_{s\max}^h$ .

A modified way of defining the equivalent time of fire duration  $T_e$  has been presented by Law [24], [25] with limited application to fire exposed insulated steel structures. Among elements of construction with varying thermal characteristics with respect to fire exposure that element is chosen, which for a given gastemperature-time curve of a real fire development gets a maximum steel temperature of a fixed value.  $T_e$  is then determined over the standard time-temperature curve for the same element and the same steel temperature. By repeating this procedure for different

characteristics of real fires, a diagram can be constructed, applicable to a rough determination of the equivalent time of fire duration  $T_e$  for an insulated steel structure, irrespective of the detail properties of the structure.

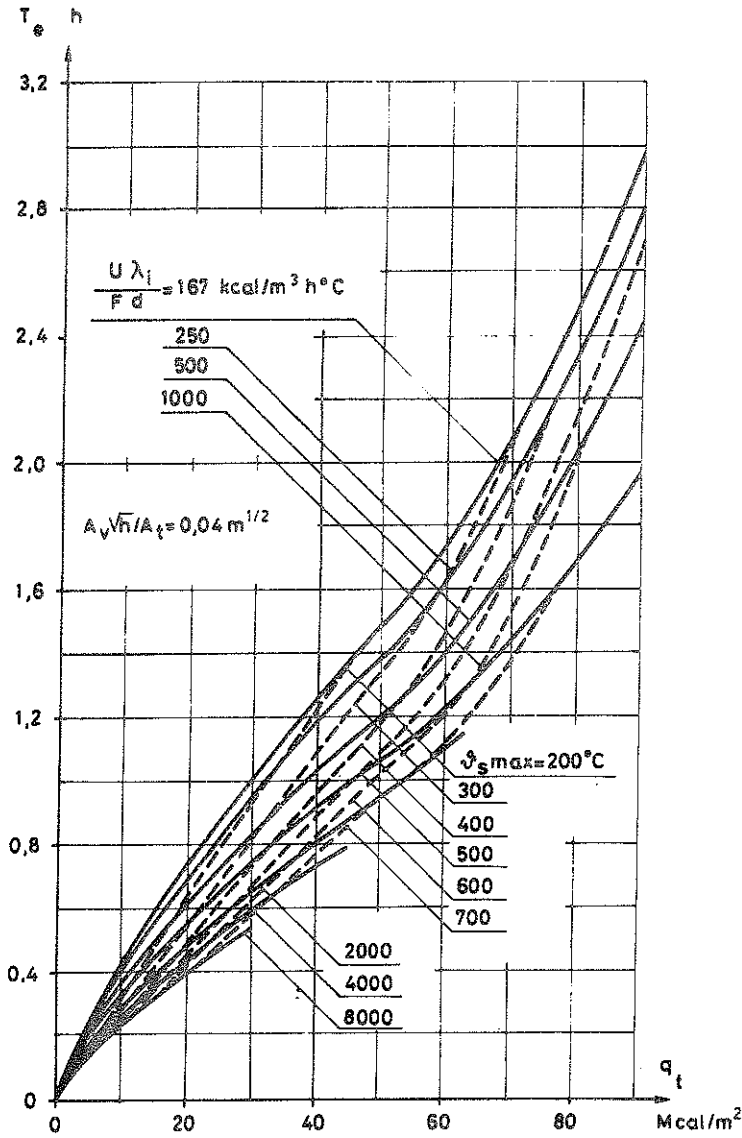


Figure 6. Equivalent time of fire duration  $T_e$ , defined according to Figure 5, for a fire exposed, insulated steel structure at varying fire load  $q_t$  and structural characteristics. Opening factor  $A_v \sqrt{h} / A_t = 0.04 \text{ m}^{1/2}$ . Dash-line curves give the corresponding maximum steel temperature  $\theta_{s \max}$  [23]

A rough design diagram constructed in this way is exemplified in Figure 7 [23], giving a relation between the equivalent time of fire duration  $T_e$  and the parameter  $B/\sqrt{A_v A_t \sqrt{h}}$ .  $B$  then is the total fire load in Mcal of the compartment. The different curves of the figure refer to different values of the fire load  $q_t$ . The approximating straight line corresponds to the formula

$$T_e = 0.28 \frac{B}{\sqrt{A_v A_t \sqrt{h}}} \quad (\text{min})$$

assuming  $A_v$  and  $A_t$  in  $m^2$  and  $h$  in  $m$ .

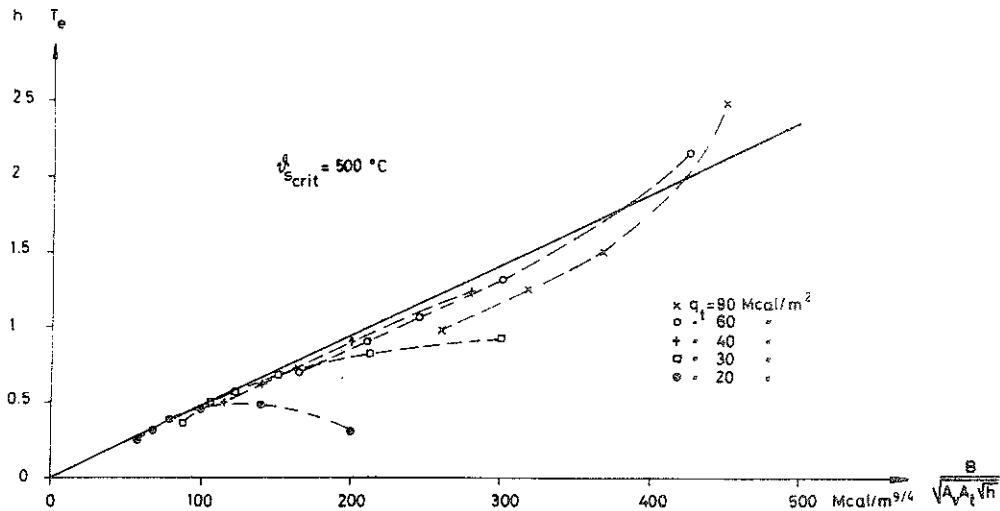


Figure 7. Equivalent time of fire duration for insulated steel structures  $T_e$ , determined in a more approximate way, as a function of the parameter  $B/\sqrt{A_v A_t \sqrt{h}}$  [23]

The chosen fragmentary examples primarily serve in this connection to draw the attention to the possibilities of making test results, received at fixed standard conditions, generally applicable in a differentiated fire engineering design. A deduction of such means, connecting real fire conditions and exposure conditions in standardized fire tests, always ought to be an evident rule in relation to future developments of new and improved fire test procedures.

REFERENCES

- [1] KAWAGOE, K., System Design for Fire Safety. ASCE-IABSE International Conference on Planning and Design of Tall Buildings, Lehigh University, Bethlehem, Pennsylvania, August 21 - 26, 1972. Conference Preprints: Reports Vol. 1b-8, p. 111.
- [2] PETTERSSON, O., Structural Fire Engineering Research Today and Tomorrow. Acta Polytechnica Scandinavica, Civil Engineering and Building Construction Series, No 33, Stockholm 1965.
- [3] PETTERSSON, O., The Possibilities of Predicting the Fire Behaviour of Structures on the Basis of Data from Standard Fire Resistance Tests. A Critical Analysis with Respect to Varying Characteristics of the Fire Load and the Fire Compartment. Provocative Paper, Centre Scientifique et Technique du Batiment, Colloque sur les Principes de la Sécurité au Feu des Structures à Paris les 2 - 3 et 4 Juin 1971. Bulletin No. 20, Division of Structural Mechanics and Concrete Construction, Lund Institute of Technology, Lund, 1971.
- [4] PETTERSSON, O., Some Characteristics of Modern Swedish Structural Fire Engineering Design (written discussion), ASTM Special Technical Publication 502, 1972, p. 152.
- [5] PETTERSSON, O., Fire Engineering Design of Tall Buildings. ASCE-IABSE International Conference on Planning and Design of Tall Buildings, Lehigh University, Bethlehem, Pennsylvania, August 21-26, 1972. Conference Preprints: Vol DS, p. 350.
- [6] MAGNUSSON, S.E. - PETTERSSON, O., Brandteknisk dimensionering av stålkonstruktioner (Fire Engineering Design of Steel Structures). Handbook, issued by Norrbottens Järnverk AB, Luleå, 1972.
- [7] THOR, J., Beräkning av brandpåverkade statiskt bestämda och statiskt obestämda stålbalkars deformation och kritiska belastning (Calculation of Deformation and Critical Load of Statically Determinate and

- Indeterminate Steel Beams Exposed to Fire). Swedish Institute of Steel Construction, Report No. 22:9, Stockholm 1972.
- [8] ISO/TC92/WG7 (Secretariat-16)35, Report of Meeting of Working Group 7 Held in Munich on 8 March 1972.
- [9] ISO Recommendation R 1716, Building Materials - Determination of Calorific Potential. October 1971.
- [10] HERPOL, G.A. - MINNE, R. - VANDEVELDE, P., Charge d'Incendie Effective Représentée par le Papier. CECM, Commission 3, Février 1973.
- [11] SMITH, E.E., Heat Release Rate of Building Materials. ASTM Special Technical Publication 502, 1972, p. 119.
- [12] PARKER, W.J. - LONG, M.E., Development of a Heat Release Rate Calorimeter at NBS. ASTM Special Technical Publication 502, 1972, p. 135.
- [13] ISO Recommendation R 1182, Non-Combustibility Test for Building Materials. January 1970.
- [14] MINNE, R., The Belgian Point of View on Testing Reaction to Fire of Building Materials. ASTM Special Technical Publication 502, 1972, p.35.
- [15] ISO/TC92 (Secretariat-177)362, The Development of Tests for Measuring "Reaction to Fire" of Building Materials. Draft Technical Report by Working Group 4, June 1973.
- [16] ISO/TC92, Revised Draft Proposal for ISO/R834 - Fire Resistance Tests of Elements of Building Construction. ISO/TC92/WG11 (Secretariat-2)2, February 1972.
- [17] ISO/TC92, Commentary on ISO/R834 - Fire Resistance Tests of Elements of Building Construction. ISO/TC92/WG11 (Sweden-2)5, April 1972.
- [18] KNUBLAUCH, E., Über Ausführung und Aussagefähigkeit des Normbrandversuches nach DIN 4102, Blatt 2 im Hinblick auf die Nachbildung natürlicher Schadensfeuer. BAM-Berichte Nr. 16, Berlin, August 1972.

- [19] ÖDEEN, K., Theoretical Study of Fire Characteristics in Enclosed Spaces. Division of Building Construction, Royal Institute of Technology, Bulletin No. 10, Stockholm 1963.
- [20] HARMATHY, T.Z. - LIE, T.T., Fire Test Standard in the Light of Fire Research. National Research Council of Canada, Technical Paper No. 312 of the Division of Building Research, Ottawa, 1970.
- [21] PETTERSSON, O. - ÖDEEN, K., Some Essential Material Properties Connected to a Differentiated Fire Engineering Design. CIB/CTF 72/52 (S).
- [22] EHM, H., Tendenzen im baulichen Brandschutz. Bauen heisst experimentieren, Stahlbau-Verlags GmbH, Köln, 1970.
- [23] PETTERSSON, O., The Connection Between a Real Fire Exposure and the Heating Conditions According to Standard Fire Resistance Tests - With Special Application to Steel Structures, CECM, Committee 3, September 1973.
- [24] LAW, M., A Relationship Between Fire Grading and Building Design and Contents. Joint Fire Research Organization, Fire Research Note 877, Borehamwood, Herts., 1971.
- [25] LAW, M. - ARNAULT, P., Fire Loads, Natural Fires and Standard Fires. ASCE-IABSE International Conference on Planning and Design of Tall Buildings, Lehigh University, Bethlehem, Pennsylvania, August 21 - 26, 1972. Conference Preprints: Reports Vol. 1b-8, p. 13.