NATIONAL BUREAU OF STANDARDS REPORT

7373

VISIT TO EUROPEAN
FIRE RESEARCH LABORATORIES

1961

by

A. F. Robertson

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT **NBS REPORT**

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ABSTRACT

Notes and comments are presented on observations made during a visit to some laboratories in England, Germany and Italy.

Introduction

During the last meeting of the Working Party on Fire of the Conseil International du Batiment (CIB/CTF), it was decided, at the suggestion of General Piermarini, that the next meeting be held in 1962 in Rome. However, the planned retirement of General Piermarini made it seem desirable that the schedule for the meeting be advanced to October 1961. This report presents the results of the observations made during visits prior to this meeting as well as some comments relative to the meeting itself.

Imperial College

I visited Dr. Spalding at Imperial College, London, and there was introduced to Dr. D. Vortmeyer who took me around the laboratory. Several different analog devices were shown to me. These were, in general, intended to solve combustion and heat transfer problems.

Dr. Spalding's steady flow combustion analog[1/] was intended to permit studies of flame geometry where aerodynamic phenomena were largely important in defining this factor. An air flow model was used and the chemical reaction simulated by an array of heaters located downstream from the flame holder. Associated

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1/ D. B. Spalding "Analogue for High-Intensity Steady Flow Combustion Phenomena" Proc. Inst. Mech. Eng. V.171 No. 10, 1957, pp. 383-412.

with each heater element is a thermocouple for measurement of local air temperature. On the assumption that reactivity or existence of the flame would be temperature dependent, the heater elements were all manually switched on, and then those providing temperature rise below a fixed level were turned off; the flame shape was simulated in this manner. The temperature level assumed would be a function of fuel reactivity. The air flow rate was modeled and thus considerable flexibility in use of the device existed. The assumptions made in its use preclude simulation of gas viscosity changes, heat losses, carbon formation and latent heat of atomization phenomena.

Dr. M. D. Samain was then visited. He has been working for about four years on development of an electrical analog device which operates on the same principal as those used by Leibman[2/]. His analog is, however automated. This type of analog involves the use of discrete time as well as space intervals. The electrical network involved is simply a resistive one and, by appropriate techniques, it can be used to solve problems expressible by the following equations:

1. $$\frac{\delta^2 T}{\delta X^2} + \frac{\delta^2 T}{\delta y^2} + \frac{\delta^2 Z}{\delta Z^2} = \nabla^2 T = 0$$

   The steady state form of Fourier's equation.

2. $$\frac{\delta^2 T}{\delta X^2} \quad \frac{\delta^2 T}{\delta y^2} \quad \frac{\delta^2 Z}{\delta Z^2} = \nabla^2 T = f(T)$$

   A form important for solution of numerous combustion problems.

3. $$\frac{\delta^2 T}{\delta X^2} + \frac{\delta^2 T}{\delta y^2} + \frac{\delta^2 Z}{\delta Z^2} = \nabla^2 T = f\left(\frac{\delta T}{\delta t}\right)$$

   The Fourier equation important in transient heat and mass flow.

2/ G. Liebmann, "A New Electrical Analog Method for the Solution of Transient Heat Conduction Problems" ASME Trans. V.78, Apr 1956 pp. 655.

While this analog device has not been described in the technical literature certain features of it have been mentioned[3]. Other publications related to spherical flames are also available[4], [5].

I was impressed with the utility of this analog device and feel that they have made a real step forward in devising so versatile an instrument.

Fire Research Station

My first visit to the Fire Research Station was on Thursday, 28 September. I visited with Mr. Pickard who had recently done work on the influence of winds on burning behavior of crib fires. Their work, which is currently being put in shape for publication, seems to be well along in yielding some information on the behavior of such fires. He indicated that they had found a correlation between $\frac{L}{D} \left(\frac{U^2}{gD}\right)^{.11}$ and $\frac{m^2}{\rho^2 gD}$

where:

m = weight rate of burning per unit base area

D = length of burning zone

g = gravitational constant

L = flame length

U = wind speed

ρ = cold gaseous fuel density

$$\rho = 62 \times 10^{-3} \text{ lb/ft}^3$$

He reported that the burning behavior of cribs similar to that of Mr. Fons of 12-inch width could be significantly modified by the addition of sides of asbestos wood of 3/8-inch thickness.

3/ D. B. Spalding, V. K. Jain, and M. D. Samain, "The Theory of Steady State Laminar Flame Propagation: Analog Solution" Combustion and Flame, V. 5, Mar 1961, pp. 19-25.

4/ D. B. Spalding, "The Theory of Steady Laminar Spherical Flame Propagation: Equations and Numerical Solutions" Combustion and Flame, V. 4, Mar 1960, pp. 51-58.

5/ D. B. Spalding and V. K. Jain, "The Theory of Steady Laminar Spherical Flame Propagation: Analytical Solutions" Combustion and Flame, V. 5, Mar 1961, pp. 11-18

Mr. Pickard has recently been transferred to work previously done by Mr. Nash on study of dry chemical inhibiting agents.

I visited Mr. Hazleton who is working with Dr. Thomas on enclosure fires. They have set up a cubical box of perhaps 3/4-inch size and with a window of perhaps about 35 percent of one side although this can be varied. Near the inside bottom of the box is a tray filled with vermiculite used as a gas burner. A water-cooled calorimeter with guarded receiving area of about 1-3/8 inch in diameter is arranged just above the burner to view flames and box walls. The results of the first tests with the system have been reported[6/]. They apparently have not made detailed measurements on the neutral zone position during burn experiments. He was interested in our photographic technique for obtaining this type of data.

They also have been doing some experiments on the charring of wood and studying the influence, on the rate of char formation, of variations in the surrounding atmosphere. Their work, to date, shows little difference in bahavior of wood in atmospheres of oxygen and nitrogen.

I visited Dr. Thomas on his return after illness. He gave me copies of three new papers he had prepared.

We discussed the models study for some time but made no decisions. As usual, he was enthusiastic about their work and the extent to which flame height data was understood. He is critical of Blinov and Khudiakov data[7/] on flame height and Dr. Hottel's analysis of it because the approach to a constant height flame resulted from a single observation on a very large size fire, the experiment on which was not performed at the same station as the others.

6/ P. H. Thomas "Fundamental Studies on Compartment Fires" Fire Research Station Internal Note No. 99. CIB/CTF 61/39(UK) Aug 1961.

7/ P. H. Thomas, C. T. Webster, and M. M. Raftery "Some Experiments on Buoyant Diffusion Flames" FR Note No. 449 Dec 1960.

Dr. Thomas also described some work he had recently done, on analysis of the work of Wright and Hayward[8] on charring of wood. The results of this analysis have been prepared in report form[9] and suggest:

1. That the rate of charring of wood exposed to high temperatures is almost constant with time.

2. The currently assumed conductivity values for charcoal may be too low by one order of magnitude.

This work would be of considerable interest to those concerned with heat balance calculations in respect to fire development. A further study he has made[10] was not discussed, but is of interest in this same connection. In this he suggests that if it is assumed that the decomposition of wood is exothermic and independent of oxygen supply, then it seems possible that a uniform rate of decomposition might result.

Dr. Thomas also has formulated his thoughts with respect to spread of fire[11] and compared a theoretical model he has developed with one proposed by Fons in 1946.

I talked briefly with Dr. Scott and asked about work she had been planning on extinguishment experiments in model enclosure fires. She indicated that little progress had been made on this, but some work had been done on stopping fires by sealing the box after various preburn times. They apparently had been able to actually extinguish the fire with this technique with only minor weight loss after sealing the box.

8/ R. H. Wright and A. M. Hayward "Kinetics of the Thermal Decomposition of Wood" Can. J. of Techn. 29 Dec 1951. p. 503.

9/ P. H. Thomas "A Comment on the Thermal Decomposition of Wood at High Temperatures" FR Note No. 471, Aug 1961.

10/ P. H. Thomas "On the Rate of Burning of Wood" FR Note No. 446, Sept 1960.

11/ P. H. Thomas "A Theoretical Model of the Rate of Spread of Fire in a Continuous Bed of Fuel" FR Note No. 459, Apr 1961

I visited Mr. Bowes and discussed work he had under way on study of unstable compounds. He currently is concentrating on study of benzoyl peroxide. He reported that they had observed what appeared to be high order detonations after prolonged storage at 80°C. The sample size was 25 gm and the time about 16 hours. It is believed the explosion took place from the liquid phase in spite of the fact that the melting point for the initial material is 105°C. Bowes had an elaborate experiment under way in which a large number of small specimens of this material were being exposed to constant temperatures of 80° and 90°C. Samples were removed after various periods of heating and iodine index number determinations were being made to measure the degree of degradation. He showed me a specially constructed cylindrical furnace with walls about 1/2-inch thick which was being used in their Chemical Laboratory for study of larger specimens of this chemical. The furnace had automatic temperature control and was designed to vent in the vertical direction in case of explosion. Color photographs of this equipment are available.

I asked Mr. Bowes what work had been done on smoldering. He indicated that no really quantitative method had been developed for measuring this property of materials. He referred to FR Note No. 415 as indicative of the best analysis to date. He does not know of any work planned on this subject apart from the empirical hot plate studies previously reported.

I witnessed a test on an aluminum frame wall facing panel of four stories height on their outdoor test building. The construction used differed from conventional construction in that the spandrel wall below the window was of lightweight insulated sheet metal rather than of masonry construction. The test was considered successful since complete burnout of the first floor unit was accomplished without ignition of material in the room above.

This test impressed on me the necessity for simulation of a wider front for tests of this type since much of the flaming rose away to one side of the upper units. It was also evident that building fronts of this type must be self supporting at intervals along the height of the building since the complete framwork was melted out of the speciment at the level of the fire.

On Wednesday morning, 4 October, Mr. Shorter and I were invited to participate in a discussion with the senior staff on the question of the value of international cooperative experiments and studies. This proved interesting and resulted in rather general agreement that such work was highly desirable. In addition to the opportunity to share the work of large experiments, such cooperation provided an excellent means of comparison of measureing methods.

I talked with Messrs. Ashton and Malhotra on the subject of fire test methods. I was interested to learn that they had been concerned with aircraft fires in which foamed polyurethane had been the source of trouble. They indicated that there was some evidence that combinations of different plastics were worse than either plastic alone. So far, they had not much experimental data to discuss.

We discussed again their previously reported finding that the thermal properties of the interior finish of a room has considerable influence on the rate of fire growth in the furnishings. They indicated that a number of additional tests have been conducted[12/] and they hope, before too long, to be able to make a report on this subject.

The program of column tests which was just starting during the last visit was nearing completion. This was intended to provide an indication of the feasibility of permitting the concrete cover of columns to carry a portion of the designed load. Mr. Malhotra indicated that the results had shown good performance of columns[13/]. Somewhat shorter fire endurance periods were observed, but that was to be expected.

I visited the various portions of the new laboratories and offices of the Fire Research Station. They had certainly built a useful facility and I was again impressed with the usefulness of the high bay buildings. In each of these, they had installed a three ton-capacity overhead rail hoist. Numerous comments were made on the usefulness of this device for setting up and arranging equipment.

12/ "Fire Research 1960" DSIR and FOC HM Stationery Office. pp. 24-25. Also see "Factors Influencing the Growth of Fire" CIB/CTF 61/34 (UK).

13/ "Protection of Steel in Buildings" CIB/CTF 61/32 (UK).

Visit to Dr. Magnus at Mannheim and Karlsruhe

During the last visit to Europe, Dr. Magnus had shown disappointment with my inability to visit his laboratory. Therefore, both Mr. Creitz and I visited him this time. In Mannheim, we visited the fire station he has charge of. We were interested in the degree to which the fire chief assists in planning for fire safety in this industrial city. Dr. Magnus indicated that great confidence was placed in his advice and he was usually furnished proprietary processing information necessary for specification of the fire precaution measures which would be necessary to insure safety. He apparently assumes the responsibility normally assigned to fire protection officials of private companies with respect to advising on safety measures required by companies operating in Mannheim.

He showed us his fire station which appeared efficient. Various aspects or special features of the engine units were pointed out. They use lined polyester fiber hose, rubber-lined airplane-type tanks for carrying water, and plastic hose nozzles. Other inovations were mentioned, but nothing was as impressive as the statement that the city of 136,000 population, had only about 200 fire calls per year. This compares with 12,000 calls on the Washington Fire Department in a city of about 1,000,000 population.

We were taken to Karlsruhe on the following day. His group doing fire research work at the Technischen Hochschule Karlsruhe, consists apparently of about three technical men and a secretary. We were shown work they have under way on:

1. Compatible dry chemical extinguishing agents.

2. Tests for storage stability and caking behavior of dry powders.

3. Dispensing devices for controlled application of powders to flames.

4. Abrasion test equipment for fire hoses.

5. Test for measuring hose deterioration under high radiation exposure conditions.

6. Studies of fire nozzle design and development.

7. Research investigations on various dry chemical powders.

Mr. Creitz, Dr. Friedrich, Dr. Magnus and I spent about three hours talking about the possibility that ionic processes might assume some importance in determining the process of combustion reactions. There seemed to be some enthusiasm for the research Mr. Creitz is doing in this field.

CIB/CTF Meeting - Rome

This meeting was held at the Scuole Centrali Antincendi, Capannelle, Rome, Italy. The facilities for conducting the meeting were elaborate and impressive. The program of the meeting is included as Appendix I.

The first day was given over to discussions on the use of models for study of enclosure fires. There was a suggestion that the work be continued at the various laboratories as proposed in CIB/CTF 61/49 (UK). It was suggested that the work might be completed in a period of 1-1/2 years. I objected to undue haste in finishing the work. I emphasized the need to better standardization of experimental techniques and encouraged that some exploratory work was first necessary in defining test methods. There was partial acceptance of this suggestion. It was decided to allow Dr. Lie, in TNO Netherlands, time to run some initial experiments in a large enclosure they have constructed. Based on his experience, the various participating laboratories would be informed of methods which might be useful for standardizing enclosures and fires in them.

The second day was given to discussions on fire resistance. There was first, a discussion of possible criteria of load failure. Few of the countries involved have tested structures which have been restrained by fixing or tying the ends against withdrawal from the supports. As a result, there has been little appreciation for the need for both deflection and rate of deflection criteria for load failure. It was, however, stated that the new German Standard would specify the point of load failure as $\ell^2/800d/$

There was discussion of the influence of confinement restraint on the behavior of floor constructions. It was indicated that a group of cooperative experiments were being planned to permit intra-laboratory studies of this behavior.

There was a discussion of the protection of steel in buildings. The Italians have developed a new standard or code[14,15] which deals with this subject. Dr. Seekamp drew our attention to a one-dimentional method he had developed for estimating the protective cover required for steel columns[16].

Further discussions were held on plastics, flammability problems, and fire door. Nothing of special interest was noted here.

The last meeting was given over to further miscellaneous topics. Paints, smoke in buildings, and fire statistics.

Before closing the meeting, it was suggested and agreed that three subcommittees or working groups be organized. These were to be concerned with:

1. Endlosure Fires
2. Fire Resistance
3. Size of Buildings

I agreed that we would share with the British and Netherlands, the responsibilities of guiding the work on enclosure fires. This is the only group we were to be directly concerned with, although I did agree to do what we could in cooperative study of fire endurance test methods.

14/ "Norme di Sicurezza per la Protezzione Contro if Fuoco dei Fabbricati a Struttura in Acciaio Destinati ad Uso Civile" (Security Standards for Fire Protection of Steel Buildings for Civilian Use). Ministero Dell'Interno, Direzione Generale Dei Servizi Antincendi, Roma, 1961.

15/ O. Piermarini. "Fire Protection in Steel Framed Buildings" CIB/CTF 61/61 (I), Oct 1961 (In English)

16/ Dr. Ing. Baue "Der Feurschutz im Stahlhochbau" Heft 21, Deutschen Stahlbau-Verband, Köln, Ebert Platz 1.

Laboratories of the Scuole Centrali Antincendi

One morning was used in touring the laboratories of this organization. In Italy, problems of fire and structural stability, as it influences the safety of the public, are centralized in the Government in the Ministry of the Interior. The school they have established serves, not only as a special postgraduate training center for officers of the Italian fire departments, but also accepts volunteers for fire fighting from the men drafted for military service. In 1961, there are over 700 such men who are being trained for service in the fire fighting stations throughout the country. The total enrollment of this school in 1961 is over 1100 men. In addition to its service as a training center for officers and firemen, it also serves as the central fire research laboratory for the country.

The school is located on a ten-acre site at Capannelle some distance south of Rome. The facilities are valued at $15,000,000. The administration building and entrance way are impressive, the buildings being trimmed with marble and serpentine. These, however, are common building materials in Rome. On the tour we were shown:

1. Two fine hydraulic laboratories. One for work at low and the other at high fluid pressures.
2. A large motor transmission, and pump test and instruction laboratory.
3. A fire endurance test laboratory with a single multipurpose furnace capable of taking floor, column, and wall panels. This furnace was unusual in its provision for flexibility of burner position.
4. The structural test laboratory was modestly large, but very well equipped for tests of walls, slabs and columns. We witnessed a test of a slab about 2 x 3 meters size.
5. The dynamic test laboratory was very well equipped for instruction and studies of metal behavior under alternating stress cycles.
6. Creep test facilities were impressive. All test equipment appeared to be of the latest type usually of U. S. construction,

7. A laboratory for use of radioactive materials.

8. Several laboratories for electronic investigations including studies of radio communication equipment, high voltage generators, power and frequency measurements.

9. Several chemical laboratories including some specialized for calorimetric measurements, gas analysis, etc.

After looking at the facilities, I couldn't help wondering how well they were used. There was little evidence of their use for research purposes, however, it is evident that they were also intended for instructional needs.

The poor translation performance at the CIB meeting impressed on us all the importance of personnel competent in this work for success of such meetings.

APPENDIX I

DETAILED AGENDA AND PAPERS REQUIRED FOR
C.I.B./C.T.F. MEETING

9TH TO 11TH OCTOBER, 1961.

SESSION I
RESEARCH WITH MODELS OTHER THAN THAT CARRIED
OUT AS PART OF THE CO-OPERATIVE PROGRAMME
9TH OCTOBER 10.00 - 12.30

Papers submitted for discussion

1. Mechanism of burning in buildings

CIB/CTF 61/38(UK) - Fundamental Studies on Compartment Fires

CIB/CTF 61/42(J) - Effect of Internal Linings on Spread of Fire at its Early Stage - General Results on Model Study

CIB/CTF 61/46(N) - Comparison Flashover Time in Lined Models with the Flame-Forming Intensity

CIB/CTF 61/48(USA) - Preliminary Results of Experimental Fires in Enclosures

2. Size of flames

CIB/CTF 61/39(UK) - The Size of Flame

3. Roof venting

CIB/CTF 61/37(UK) - Roof venting

SESSION II
CO-OPERATIVE RESEARCH USING MODELS
9TH OCTOBER 14.00 - 16.30

Papers submitted for discussion

4. Report on Progress

CIB/CTF 61/36(UK) - Comparative tests by three laboratories on a fire in a small scale compartment

CIB/CTF 61/40(UK) - International Modelling Programme on the Growth of Fire Analysis of Ceiling Temperatures and Radiation from the Opening

5. Next Stage in Programme

CIB/CTF 61/49(UK) - Proposals for Next Stage of C.I.B. Programme on Fires in Compartments

Other relevant papers

CIB/CTF 60/50(USA), CIB/CTF 60/54(UK), CIB/CTF 61/8(UK), CIB/CTF 61/15(UK).

SESSION III
FIRE RESISTANCE
10TH OCTOBER 10.00 - 12.30

Papers submitted for discussion

6. Deflection criteria of failure

CIB/CTF 61/28(D) - Legende für die Zusammenstellung von Bauteilen für DIN 4102, Blatt 2

CIB/CTF 61/50(D) - Deflection criteria of failure

7. Correlation of floor tests and effect of restraint on fire resistance of floors

CIB/CTF 61/31(UK) - Correlation of floor tests and effect of restraint on fire resistance of floors

CIB/CTF 61/45(USA) - The New Beam Furnace at PCA and Some Experience gained from its Use

8. Protection of steel in buildings

CIB/CTF 61/25(F) - C.S.T.B. Essais de résistance au feu concernant la protection des ossatures métalliques effectués a la station du feu du C.S.T.B. ~~Point 9 de l'Ordre du Jour~~

CIB/CTF 61/32(UK) - Protection of steel in buildings - some present trends

CIB/CTF 61/43(J) - Full Scale Fire Test on a Steel Frame Construction

Other relevant papers

CIB/CTF 60/45(F), CIB/CTF 60/53(F), CIB/CTF 61/1(F), CIB/CTF 61/4(UK), CIB/CTF 61/6(F), CIB/CTF 61/9(C), CIB/CTF 61/16(F), CIB/CTF 61/18(I), CIB/CTF 61/19(I), CIB/CTF 61/20(I), CIB/CTF 61/41(C).

SESSION IV
FIRE RESISTANCE
10TH OCTOBER 14.00 - 16.30

Papers submitted for discussion

9. Fire hazard of plastics

CIB/CTF 61/33(UK) - Fire hazard of plastics

CIB/CTF 61/47(USA) - Surface Flammability of Cellular Plastic Foams

10. Factors influencing the growth of fire

CIB/CTF 61/23(J) - Study on the Prevention of Fire-Spread Caused by Hot Upward Current

CIB/CTF 61/34(UK) - Factors influencing the growth of fire

11. Requirements for doors, shutters and windows for the protection of openings in buildings

CIB/CTF 61/26(F) - C.S.T.B. Comportement au feu de portes diverses, y compris les rideaux. Point 11 de l'Ordre du Jour

CIB/CTF 61/35(UK) - Requirements for doors, shutters and windows for the protection of openings in buildings

Other relevant papers

CIB/CTF 60/48(UK), CIB/CTF 60/55(UK), CIB/CTF 61/2(C), CIB/CTF 61/7(F), CIB/CTF 61/21(F).

SESSION V
TOUR LABORATORIES OF THE
SCUOLE CENTRALI ANTINCENDI
11TH OCTOBER 10.00 - 12.30

SESSION VI
OTHER BUSINESS
11TH OCTOBER 14.00 - 16.30

Papers submitted for discussion

12. General matters connected with fire protection of buildings

CIB/CTF 61/11(N) - Fire-Protection of Buildings

CIB/CTF 61/24(F) - C.S.T.B. No. 50, Cahier 397. Essais de résistance au feu d'elements de construction

13. Fire-retardant treatments and paints

CIB/CTF 61/29(USA) - Surface Flammability of Fire-Retardant and Conventional Paint Assemblies

14. Fire statistics

CIB/CTF 61/44(Dk) - How Can Fire Statistics be improved to comply with wishes from the building research

Other relevant papers

CIB/CTF 60/46(C), CIB/CTF 60/47(C), CIB/CTF 60/49(UK), CIB/CTF 60/52(C), CIB/CTF 60/56(C), CIB/CTF 60/57(F), CIB/CTF 60/58(C), CIB/CTF 61/10(UK), CIB/CTF 61/13(C), CIB/CTF 61/17(C).

15. Report on International Standards Organization meeting in London

16. Date and Place of Next Meeting

APPENDIX II

Furnace for Testing Fire Resistance of Building Materials

Very valuable contributions from the various laboratories (Chemical, Thermal and Construction Science) have been studied and incorporated in the recently completed large furnace for testing the fire endurance behavior of structural and marine materials.

This important facility, now complete and operating, represents, in itself, a valuable testing instrument.

This furnace, installed in a large building constructed of concrete and glass, has internal dimensions of 6.50 x 3.00 x 4.00 meters, and within it, it is possible to reach, depending on the desired test requirements, a temperature of 1,200°C (in some cases during experimentation, it has been raised to as high as 1,250°C).

The frontal opening has dimensions of 1.20 x 1.80 meters with a double, hinged door mounted on metal columns and, in addition, it is provided with a sliding, water-cooled wall closure. On the four walls, 53 positions are provided for the naphta burners or for thermocouples.

The burners, (12 in number) may be moved to various positions, even under the furnace floor for indirect heating. These are regulated automatically by appropriate, thermocouple controlled mechanisms.

The upper furnace opening which would normally receive a floor construction intended for test is closed when not in use by movable, refractory beams which can be easily dismounted.

There are also available, 4 hydraulic jacks, each capable of applying a load of 50 tons. These, together with restraining beams allow placing the test speciemns under the various load conditions. A bridge-type hoist with electric controls, and a capacity of 50 tons, permits easy movement of the test specimen. The use of thermocouples and electrical deflection sensors allows the detailed recording of data with regard to temperatures as well as movements which the test specimen has been subjected to.

From the above, the many uses this furnace can be put to are easily seen.

*Translated from "Le Scuole Antincendi" Ministry of the Interior. Rome, by J. M. Fernandez.

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS