further work on tubes with wire corrugations is of little use now that the methods of making welded-up corrugated pipes have been developed.

V. M. Antufev, in connection with Kremnev and Zozulyn's paper, observed how necessary it was to allow for power loss in mitigating resistance when evaluating surfaces. He maintained that the question of using a mesh type surface for gas turbine regenerators, as described in Latenko's paper, needs further confirmation.

S. N. Turin, answering Philipov, pointed out that seamless rolled tubes with corrugations have not been fully developed and still have some drawbacks.

L. I. Volper (Kirov Factory) pointed out that despite the great amount of work being carried out on regenerative air heaters for gas turbines, it is still difficult for designers to decide objectively on the best surface. This is probably due to bad co-ordination of the work. In addition to this he recommended large scale testing for the effect of fouling and cleaning.

In a winding-up talk it was remarked that insufficient attention had been paid up to the present to theoretical methods of calculation and to the analysis of the experimental results.

Abstracts contributed by B. M. Borishanskii.

CONFERENCE ON THE CONDENSATION OF SUPERHEATED STEAM MARCH, 1961

(*Received* 17 *July* 1961)

THE process of heat transfer by condensing steam is of great importance to a wide range of industry, and has been studied by many workers since the days of Nüsselt. There are, nevertheless, aspects of the subject in which a sound basis for design is still lacking. The effect of superheat is a case in point. The National Engineering Laboratory (Great Britain) started, a few years ago, a programme of work on the thermal design of the kind of feedwater heater used in modern power stations, in which highly superheated steam bled from the turbines is used to heat the boiler feedwater. This work led to a realization that the whole subject of the effect of superheat was imperfectly understood, and indeed revealed that a long-standing controversy was still alive: in the apparently straightforward use of steam for "process" heating, some workers were convinced that superheated steam was inferior to saturated steam, in the simple and direct sense that the rate of heat transfer in a given piece of plant would be less if the supply steam were superheated than if it were saturated at the same pressure. Others, however, confidently contended that superheat slightly increased the rate of heat transfer.

In view of this unsatisfactory situation, the National Engineering Laboratory recently organized an informal two-day conference with the object of bringing together the wide variety of people concerned with the subject, and enabling them to exchange ideas, opinions and the results of experience. Over 100 delegates attended, chiefly from industry, but also from universities and other centres of research. There were only a few papers, and the greater part of the time was occupied by free discussion.

Proceedings began with the presentation of a paper by D. Chisholm of NEL, surveying the state of knowledge as it existed in published literature. This revealed very clearly the unsatisfactory position already touched upon, and some of the complications which make convincing experimental work so difficult. Chisholm laid stress on a paper by Balekjian and Katz [1] which, he suggested, was the most substantial of the comparatively few which reported attempts to investigate the effects of superheat experimentally in a satisfactory, scientific manner. This paper reported that a significant reduction in heat transfer by condensing steam was obtained when the degree of superheat was raised. The tentative explanation given was that the surface temperature of the condensate layer was reduced, presumably as a result of a change in the value of the molecular condensation coefficient. Chisholm's survey also drew attention to the lack of published data on the condensation of superheated steam when non-condensable gases were present, and when the steam had a significant velocity past the condensing surface.

The second paper, by R. S. Silver and H. C. Simpson of G. & J. Weir Ltd., Glasgow, was exclusively concerned with the basic physical process of condensation. It considered the significance of the molecular condensation coefficient in some detail and described experiments for estimating its magnitude. In presenting the paper, Silver concentrated on the implications of the Knudsen condensation equation, as modified by Schrage, and deduced from this equation that the rate of condensation would be reduced, other things being equal, if the temperature of the vapour near the condensing surface were raised; indeed, for a sufficiently great rise in temperature condensation would cease. This effect, he suggested, might provide an explanation for a reduction in condensation rate with increase in superheat. The paper also drew attention to the very serious difficulties which would

have to be overcome in any attempt to investigate the matter experimentally.

The attention of the Conference was then turned to a completely different aspect of the subject by a paper by J. L. Gray and L. H. Levene of the Central Electricity Generating Board, London, which was concerned with the experience of their organization with feedwater heaters using superheated steam. After discussing the reasons for using such feedheaters and the extent to which this is now accepted practice, they considered the problems arising in their design, and the results of tests on a number of feedheaters in actual use. The precision of the tests was naturally not very high, but the results as a whole gave the impression that the degree of superheat made comparatively little difference to the performance of these feedheaters. This was supported by experiments in which the degree of superheat was varied by injecting water into the steam.

G. G. Watson of NEL gave a detailed account of the experimental rig which is being developed at NEL for work on the feedheater problem. The intention is to set up a fully instrumented feedheater operating with steam-side conditions of 750 lb/in², 750°F, and water-side conditions of 2200 lb/in². In most respects the feedheater will be designed in accordance with current practice, but a number of special features permitting flexibility of operation and detailed study of condensing conditions will be incorporated.

I. C. Finlay presented a paper by himself, D. Chisholm and Miss M. R. Foote, all of NEL, on the use of an automatic digital computer for carrying out the thermal design of a feedheater using superheated steam. This deals with both the de-superheating and the condensing sections, which are designed on entirely different lines; it estimates the required surface areas for given steam-side, feed-outlet, and flow rate conditions, and provides, if required, the steam, feed and tube-wall temperature distributions within the heater.

An entirely different aspect of the subject was introduced by Miss E. J. Macnair, of the Admiralty, who described some experiments on heat transfer between bubbles of superheated steam and saturated water through which they are passing. A theoretical attack on the problem is made difficult by the complicated nature of the process: the bubbles initially formed are unstable, and tend to coalesce into larger bubbles or break up into smaller ones; they are far from spherical; the surface area is unknown and continually changing; turbulence is intense; bubbles bursting at the surface throw up drops of water and bring about spray de-superheating.

The remainder of the time was occupied by discussion. The subjects considered included not only all those raised in the formal papers but others of a more general nature, such as the need for more research work directed specifically at problems arising in the process industries, the inter-relation between thermodynamic efficiency and economic efficiency, and the advantages and disadvantages of carrying out research work using apparatus deliberately designed to simulate normal industrial equipment as closely as possible.

The fundamental process of condensation was discussed by a number of speakers who, stimulated by Chisholm's remarks on the work of Balekjian and Katz and by Silver and Simpson's speculations on the conditions near to the condensing surface, advanced a variety of hypotheses and mathematical arguments. This discussion may be said to have epitomized the general state of the subject; some of the ideas put forward seemed more plausible than others, but in the absence of reliable experimental work no conclusions could be reached. It is unfortunately an exceedingly difficult subject for investigation and even the straightforward question of the value of the condensation coefficient for saturated steam does not seem to have been finally settled. The possibility that it may be greatly affected by surface contamination is perhaps a very important one.

The contributions from speakers with practical experience, particularly with process steam, were also somewhat inconclusive. Instances where superheat had apparently reduced output were quoted, but so were instances where it had not. Some speakers pointed out the dangers of accepting evidence of this sort too readily because unexpected factors may influence performance in practical cases and so give misleading results. As an example, it was suggested that, in an internally heated, rotating drum drier, the condensate carried around by the drum might de-superheat the incoming steam. Several speakers argued that the rate of heat transfer in process plant is by no means the only consideration: temperature control by pressure control, and reduction in the stresses introduced in pipework were examples of factors pointing to the desirability of avoiding too much superheat.

The feedheater problem aroused a good deal of attention. The interesting feature here is the use of the superheat to heat the feedwater a degree or so above the saturation temperature of the steam. If this is to be achieved, part of the tube surface in the feedheater must be above saturation temperature, so that condensation will not take place in this region, which should, therefore, be designed on the basis of ordinary, dry gas, forced convection conditions, with baffles to increase the steam velocity over the tubes. Another important consideration, however, is that pressure drop in this region reduces the saturation temperature of the steam in the rest of the feedheater, so that a proper balance must be struck between this effect and the increased heat transfer in the non-condensing region.

The complex design problems that are raised are admirably suited to analysis by means of a digital computer, and considerable interest was expressed in the paper on this subject, and also in the description of the experimental work in progress. Several speakers claimed that, largely by intelligent guess-work, they had designed feedheaters which had the hoped-for characteristics of "negative terminal temperature difference".

Miss Macnair's paper gave rise to a very interesting and varied series of comments. The intractably complicated geometry of the process led to a consideration of statistical methods of approach. Practical considerations were also discussed, and speakers remarked on the similarity

of the process to the operation of the Loeffler boiler and the steam deaerator.

No attempt was made to arrive at any formal conclusions; it would have been almost impossible to do so in any other than very general terms. It may, however, be accepted that the vigour of the discussion and the interest shown demonstrated that the subject, in its various aspects, is still of great interest and importance to a wide range of workers, from the classical physicist to the most matter-of-fact industrial engineer.

The Proceedings of the Conference, including the discussion, will be published in full.

National Engineering Laboratory A. J. EDE
East Kilbride
Glasgow

REFERENCE

1. G. BALEKJIAN and D. L. KATZ, *J. Amer. Inst. Chem. Engrs*, **4** (1), 43–48 (1958).

JOURNEES INTERNATIONALES DE LA TRANSMISSION DE LA CHALEUR

(*Paris* 19–24 *Juin* 1961)

ORGANISÉES par l'*Institut Français des Combustibles et de l'Energie*, sous la présidence du Professeur Veron, avec le concours de la Société Française des Thermiciens, ces Journées ont rencontré un très grand succès.

Elles ont réuni en effet plus de 500 inscriptions, dont un grand nombre de participants étrangers (14 pays étaient représentés: outre la France, Allemagne, Angleterre, Argentine, Afrique du Sud, Belgique, Brésil, Hollande, Hollande, Italie, Suisse, Tchécoslovaquie, Yougoslavie, U.S.A., Vénézuela): il s'agissait de savants, chercheurs, ingénieurs, tous spécialistes des problèmes de Transmission de la Chaleur.

Parmi ceux-ci, on notait les plus grands noms en ce domaine, notamment les Professeurs Boehm (Caracas), Broglio (Rome), Burnay (Liège), Glaser (Göttingen), Gregorig (Bello-Horiçonte), Hartnett (Minneapolis), Hausen (Hannover), Linke (Aachen), Malic (Belgrade), Schack (Aachen), Schultz-Grunow (Aachen), Spalding (Londres), Treves (New York), Velickovic (Belgrade), MM. Brauer, Elenbaas (Eindhoven), Kühne (Hannover) et parmi les auteurs français, les Professeurs Bory, Edmond Brun, Edouard Calvet, Cordier, Gosse, Kling, Liebaut, Lucas, Mathieu, Thureau, Valensi, Weil, les Ingénieurs généraux Marchal et Vernotte, le Révérend Père Camia, MM. Anglesio, Beurtheret, Pierre Calvet, Dennery, de l'Estoile, Devienne, Dupuy, Foex, Le Foll, Goenaga, Kaiser, Loeb, Tavernier.

Le caractère scientifique et industriel tout à la fois de cette manifestation avait justifié son patronage conjoint par les Ministres de l'Education Nationale, de l'Industrie, des Travaux Publics et des Transports, de la Construction et le Ministre délégué auprès du premier Ministre pour l'Energie Atomique et la Recherche Scientifique.

90 communications par 107 Auteurs ont porté sur l'ensemble des domaines de transfert de la chaleur, par conduction, convection, rayonnement, sur les méthodes d'analyse des champs thermiques (notamment par les méthodes analogiques), sur des méthodes de mesure particulières récentes, enfin sur la mise en oeuvre des modes de transfert dans les échangeurs thermiques et sur la réalisation de ceux-ci. Un tel programme faisant état des travaux les plus récents et pour certains inédits, a montré la collaboration très fructeuse ainsi acquise entre l'Enseignement supérieur, la Recherche Scientifique, la Recherche technique et les applications industrielles. Aussi bien auteurs que participants, (parmi lesquels l'on remarquait notamment M. le Prof. Chato du Massachusetts Institute of Technology, M. Darrieus, de l'Institut, M. le Prof. Dzung de Suisse, Le Dr. MacFarlane, Président de l'Institute of Fuel, M. Grass d'Euratom, le Président Marcq de l'Association belge des Ingénieurs de chauffage) faisaient en effet partie: de l'Université, du CNRS, des laboratoires de Facultés, des Centres d'Etudes et de Recherches (Commissariat à l'Energie Atomique, Office National d'Etudes et Recherches Aéronautiques, Institut de Recherches de la Sidérurgie) et de nombreuses sociétés industrielles.

Pendant 57 heures de séances en six jours, les exposés et débats n'ont cessé d'interesser une assistance toujours nombreuse et attentive, participant activement aux discussions, suivies aussi aisément par tous, grâce à une interprétation simultanée, exacte et sans défaillance, et grâce à la remise préalable de l'intégralité des textes.

A certains exposés les auteurs avaient ajouté, pour les compléter, la projection de courts métrages, films extrêmement précis et utiles; ainsi furent présentés:

—par M. Hartnett, une prise de vues figuratives de l'ablation des missiles à leur rentrée dans l'atmosphère, pour divers matériaux, à des températures de 11 000°C,

—par la S.N.E.C.M.A., un film sur l'amélioration de la convection par jets,

—un film sur les travaux de la SOGREAH concernant la turbulence dans des faisceaux d'échange,

—un film sur les contraintes thermiques dans les voilures d'avion (ONERA),