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REPORTS

CONFERENCE ON CONVECTIVE HEAT TRANSFER

15–20 JUNE 1959, LENINGRAD

(Abridged Report)

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THE Conference was organized by the Academy of Sciences Thermal Commission, by the Committee on Heat Transfer and Combustion of the Turbine Sub-Section of the N.E.S. of the Lensovnarkhoz, the Central Boiler and Turbine Institute, and the Power Institute of the Academy of Sciences.

The late N. V. Ilyukhin opened the session. There were three sections: Heat Transfer in single and two-phase flows, cooling of parts of steam and gas turbines, and auxiliary equipment. Seventy papers were read.

PLENARY SESSION

Several members of ENIN (Academy of Sciences) M. A. Styrikovich *et al.*, described fundamental results on the effect of hydrodynamic conditions and distribution of heat flux on nuclear boiling (crisis) with forced flow of water and steam water mixture. Tests were done at 26–220 atm and 100–3000 kg/m^2 s and on pipe diameters from 3–18 mm. Tests revealed a relatively weak effect of the length of the heated portion in the boiling of under heated liquid (not fully heated) and its significant effect in the range of positive steam content, especially at low pressures and medium mass flows. The important effect of throttling at the entry of the heating portion was revealed, even when the throttle was a good way away. Tests on 8 mm pipes over the whole range of parameters up to 100 kg/m^2 s did not reveal much effect of direction of flow on the quantity q_{crit1}.

Several workers from the VTI described results of tests to reveal the effect of surface finish, entry condition, endurance of heating surface, geometry of pipe dimensions and wall thickness on q_{crit}. The tests were done with condensate flowing in a cylindrical pipe heated electrically. Comparative tests revealed that the duration of the operation had no effect on the critical thermal load. It was also shown that factors like the wall thickness of the piping, the surface roughness, throttling at entry, etc. hardly affected q_{crit}.

I. I. Novikov stated that full similarity in heat transfer for various fluids can be established from thermodynamical similarity considerations.

G. N. Abramovich gave an application of the fundamental law of outward flow of a turbulent stream to the general case of a variable density stream, in particular, a diffusing stream. A method was described for determining curves of velocity distribution, of mixture concentration and other parameters in the transverse sections and along the axis of two-phase streams.

Guchman (TsKTI) gave fresh data on transonic flows. The upper limit of application of the linear law of entropy variation (region of constant dissipation coefficient) is lower than 1·65. With all the nozzles tested (diverging conical channels with small vertex angles and smooth surfaces) the dissipation coefficient lies between 1 and 2×10^{-2}.

V. V. Dydakin and V. L. Lelchuk described studies of local heat transfer and hydraulic resistance in a turbulent gas flow in pipes with large temperature differences. Tests were done in 17·8 mm bore tubes 2620 mm long. Formulae were obtained to estimate local and mean heat transfer and resistance coefficients.

Kosterin and Koshmarov (ENIN) put forward a formula to estimate the important temperatures when working out convective heat transfer and friction for gases with $Pr = 1$.

Berman and Fuks (VTI) described the main results of work in designing and manufacturing cooling surfaces of condensers. The work followed the following lines:

(1) Improving basic data on the relation between the nominal mean heat transfer coefficient and various factors and the possibility of improvements in method of calculation.
(2) Obtaining data and evolving method of heat transfer calculation, taking into account the basic process parameters and intensity, thermal and mass exchange resulting from the motion of a steam–air mixture in a tube pack.

V. A. Rachko (TsKTI) gave a talk on heat transfer and mass exchange in tube batches in moving steam–air mixture in vacuum and gave results of a study of condensation carried out on a bundle of copper nickel pipes 16 mm diameter and 1600 mm long. It is observed that in a moving air–steam mixture an air content of up to 1·5 per cent by weight does not affect heat transfer.

L. M. Zysina-Molozhen (TsKTI) gave the method of calculating mean heat transfer in profile cascades in a compressible gas flow. The method was based on solving equations of heat balance set up for the volume bounded by sections parallel to the cascade axis and located in the region of the undisturbed stream far in advance of and a good way beyond the cascade.

S. S. Kutateladze and E. P. Karpeev (TsKTI) gave experimental results of condensing steam at high pressure in a horizontal tube. Theoretical analysis of the condensate film carried out for high Reynolds numbers assuming predominating influences of friction of the steam against the film gave agreement with experiment.

Zh. Miropolskii (ENIN) gave results of heat transfer on cooling water and condensation at high pressure in a vertical copper tube 8 mm diameter. Pressures varied between 7 and 220 atm; water temperature from 150° up to saturation temperature, steam content of stream 0–1·0, mass velocity 400–1300 kg/m^2 s, specific thermal flux 150–5000 $\times$ 10^3 kcal/m^2. The effect of steam content on heat transfer was revealed. Experimental data was worked out as a functional relationship between non-dimensional criteria.

Mironov gave a short review of the main results on heat transfer from the Nevsky Machine Factory (Lenin.); Heat transfer in a horizontal combustion chamber with a secondary swirl, comparative heat transfer and hydraulic resistance investigations on five different corrugated surfaces under the same conditions. Heat transfer of a gas stream flow into a slot and a study of screen or baffle cooling of gas turbines.

Discussion of papers given at the Plenary Session

G. M. Kruzhilin pointed out that he agreed with Kutateladze and Miropolski's views that the heat transfer coefficient during condensation at high steam flows is determined by turbulent transfer in the liquid phase. According to him, however, one might obtain slightly different expression to that of Kruzhilin.

L. D. Berman said that the concepts of condensation heat transfer in tubes expressed at the meeting required some modification. There is a difference between the flow conditions of condensate down a vertical surface when exceeding the critical Reynolds number and the flow conditions in a horizontal pipe when turbulence in the film is caused by the action of the high velocity steam. Moreover, at the high velocity of dense steam at high pressure, the liquid can separate from the wall and move along partly in the form of drops distributed over the tube section. Berman also pointed out that the determination of partial steam pressure at the division between phases in terms of wall temperature yields a lowering of coefficient of mass transfer and some deviation in its relations with the parameters which represent the condensation regime; he did not agree with Rachko's thesis on the absence of effect of small amounts of air on the heat transfer during condensation.

V. S. Zhukovski emphasizing his great interest in the concepts advanced by Novikov pointed out that in the work published previously by Brishanski, where this idea was put forward in a slightly different form, there was sufficient experimental data to generalize the heat transfer coefficients and this confirmed Novikov's views.

Gukhman said that Novikov's ideas struck him as very original and interesting. The interpretation of the physical properties as functions of dimensionless parameters (pressure, volume, temperature) arouses no trepidation for the quantities are those used in thermodynamics. Extension of this idea, however, to quantities which represent molecular transfer requires further confirmation.

B. S. Petukhov also underlined the originality of Novikov's paper. He expressed the opinion that it will be essential to study the effect of fluctuations, of pipe diameter and to concentrate attention on extending and applying results already obtained by various organizations.

V. M. Borishanski said that the difficulties which arise in describing the transfer parameters by thermodynamic methods can be mitigated to a large extent by considering dimensionless characteristics (viscosity, conductivity) in terms of dimensionless thermodynamic parameters (pressure, temperature).

SESSION ON CONVECTIVE HEAT TRANSFER IN HOMOGENEOUS MEDIA

B. S. Petukhov *et al.* (M.E.I.) read a paper "Studies of Heat Transfer and Temperature Recovery at the Walls with Turbulent Gas Flow in Tubes at Values of M up to 4". As a result of extending experimentally the data obtained from a single dimensional model an interpolation formula has been obtained for local heat transfer with highly turbulent gas flow in a circular tube over the range $M = 0{\cdot}65$–$4{\cdot}0$ and $Re = 3 \times 10^4$–9×10^5.

In the talk given by V. P. Motulevich (ENIN) a method was given for working out heat transfer close to the nose of a plane axially symmetrical body in a supersonic gas stream.

Another member from ENIN in a paper called "Heat Transfer Investigation, Cooling Water and Steam in the near Critical Region" described a method of working out turbulent streaming flow of compressible gas, based on an assumption of similarity between the density fields, the momentum flow, excess total heat, etc.

S. I. Kosterin *et al.* (ENIN) gave an approximate semi-empirical method of calculating the turbulent boundary layer, making allowance for the effect of pressure fluctuation in the gas stream on the heat transfer resistance coefficient.

I. G. Kulakov (ENIN) in a paper called "Application of Heating by Electronic Bombardment to Heat Transfer Studies", pointed out the possibility of obtaining thermal fluxes of several tens of millions of kcal/m^{2}h.

B. S. Petukhov (MEI) in a paper "Heat Transfer due to Flow of Liquid in Pipes at low Re" gave a theoretical solution of the problem with laminar flow, taking into consideration conductivity along the stream. Experiments with mercury with laminar flow confirmed the solution.

Kh. A. Barlybaev and S. V. Buchman (Institute of Energetics, Kazakhstan Academy of Sciences) described the experimental work carried out on convective heat transfer at high thermal fluxes.

M. S. Pirogov and V. L. Lelchuk communicated some fundamental results of heat transfer tests on sodium in a circular pipe at Re ranging from 20–4000. The results did not reveal loss in heat transfer at low *Re* with turbulent flow.

E. M. Khabakhpasheva gave results of heat transfer in eutectic sodium potassium alloy flowing in annular clearance with heat flux from one side and $Re > 500$, experimental points agreeing with the calculated recommendations obtained on the assumption that the coefficient of "non-similarity" of heat transfer and the momentum = unity. With symmetrical heat flux the heat transfer coefficients were increased by a factor of 1·7.

L. A. Vulis and V. P. Ustimenko (University and Power Institute, Kazakhstan Academy of Sciences) in a paper entitled "Calculation of Convective Heat Transfer at low Prandtl numbers (Internal Problem)" put forward the proposition of the analogous effect of stream turbulence on the total resistance and on heat transfer when the turbulent Prandtl number = unity.

V. I. Petrovichev gave a talk on the heat transfer into mercury with variable thermal load along the length of a channel. Experimental determination of the heat transfer with sinusoidal thermal loading along the channel was done for two circular smooth pipes with different L/d ratios (67 and 45) and for annular clearances with $d_2/d1 = 1{\cdot}34$ and 1·68.

L. G. Loitsyanskii (LPI) remarked that in theoretical heat transfer and diffusion calculations it is more correct to start from a three layer (Kármán, Shvab) and not from a two layer dynamic flow pattern (Prandtl); he described a method of approximating the velocity field by a single hyperbolic function in the intermediate zone and in the turbulating nucleus.

P. A. Kirillov: "The Effect of Oxides on the Heat Transfer of NaK and Cleansing of the Alloys from Oxide". The author pointed out that the experimental results of heat transfer carried out under conditions of continuous cleansing of the metal agreed with calculations using the Martinelli Lyon formula.

B. I. Petrovichev gave results of heat transfer investigations on flow of mercury in annular clearances and these agreed with the results given by E. M. Khabakhpasheva.

E. V. Kudryavtsev and N. V. Shumakov (ENIN) gave a paper "Relation between Transient Heat Transfer and Dimensions and Physical Parameters of Solids" and observed that experiments and analysis of the literature enabled them to construct an equation giving the relation between the heat flux entering solids, the duration of the process and the solid parameters.

I. E. Virozub (Thermal Institute, Ukraine Academy of Sciences) gave an approximate solution of the laminar boundary layer equation with a flow gradient and with heat transfer.

Yu. P. Shlykov and A. I. Evstafevi described experiments on heat transfer to water in plain slot channels at high heat fluxes. It was remarked that in choosing a characteristic dimension for the equivalent hydraulic diameter, the best agreement was obtained using Mikheev's formula.

I. I. Shvets, E. P. Dyban *et al.* (Thermal Institute, Ukraine Academy of Sciences) gave a talk entitled "Effect of Initial Turbulence on Heat Transfer and Hydraulic Resistance in Air Motion through Tubes" and described the experimental method and derived several experimental relations.

Yakovlev in "Local and Mean Heat Transfer in Turbulent Flow of Water in Pipes at fluxes up to $3{\cdot}5 \times 10^6$ kcal/m^{2}h remarked that the test results are described by Mikheev's formula to an accuracy of ±10 per cent, and using Petukhov's formula, ±5 per cent.

P. A. Ushakov gave a paper on heat transfer and hydraulic resistance in longitudinal flow of mercury and water through batches of tubes.

I. P. Sviridenko gave experimental results of hydraulic resistance and heat transfer in flow of mercury in narrow annular channels.

A. A. Sholokhov gave a method of correcting temperatures for various methods of fixing thermocouples.

N. I. Buleev gave a theoretical method of choosing the determining linear measurement for heat transfer in longitudinal flow of liquid through channels of complicated cross section.

CONVECTIVE HEAT TRANSFER IN TWO-PHASE MEDIA

V. M. Borishanskii gave a paper entitled "The Laws of Heat Transfer in Film Boiling" and gave data on the relation between heat transfer coefficient and the physical properties of a liquid, the thermal loading and saturation pressure. It was shown that when working out heat transfer for vertical surfaces it is useful, as a linear dimension, to introduce into theoretical formula the quantity—$\delta = (\sigma/y - y'')^{1/2}$.

A. P. Ornatski (KPI): "The Effect of Length of Diameter of Pipe on the Critical Density of Thermal Flux". Results were given of tests on water in tubes at pressures up to 25 kg/cm^2 and "under-heating" to 60°C.

A. P. Ornatski and M. A. Kichigin: "Critical Heat Transfer at Low Under-heating". At small under-heats the magnitude of the mass flow and under-heating hardly affects the magnitude of the critical density of the heat flux.

V. N. Filatkin (LIKhP): "Boiling Heat Transfer of Water Ammonium Solutions". The heat transfer coefficient, in addition to the heat flux and the pressure, depends on the concentration of the solution.

V. I. Nevstrueva: "Distribution of Steam Content Determined by Irradiation under Conditions of Surface Boiling of Water below Saturation Temperature".

V. E. Doroshchuk said that there was a special interest in heat transfer studies in film boiling at high pressures, where this type of boiling does not cause direct disruption of the heating surfaces. The work, he said, should be pursued in the direction of explaining the regime of wall temperature fluctuation in film boiling. In connection with Ornatski's paper he remarked that there was no point in studying critical fluxes on very short tubes, because there are great difficulties in the method involved in allowing for side flow (leakage) which can affect the results. He observed that Nevstruev's work was very original and the results should be compared with those of G. G. Treshchev.

G. G. Treshchev drew attention to the great importance of work studying boiling by means of irradiation.

M. A. Styrikovich drew attention to the importance of doing work on forced fluid motion in the study of film boiling. At present work on this subject has already given rise to a modified outlook on the process.

In V. I. Tolubinski's paper (KPI) "Velocity of Growth of Steam Bubbles", it is pointed out that the quantity uD_0 for Freon 12 was three times smaller than for water. This, he claimed, confirmed the correctness of the earlier assumption in the formulae for heat transfer.

D. D. Treshchev (VTI): "High Speed Cinephotography of Surface Boiling Water up to 50 atm" points out that the distribution of bubble diameter and frequency of propagation with increase in pressure does not vary from the values at low pressure.

V. G. Morozov gave a talk on new experimental data on critical boiling thermal load and heat transfer. The data on critical thermal loading with bubble boiling was compared with calculations based on Kruzhlin's, Kutateladze's, Sterman's and Borishanski's formulae. The boiling heat transfer in tubes was measured at pressures from 31–41 kg/cm^2. The results agree with Sterman, Morozov and Kovalev for boiling in tubes at 2–85 kg/cm^2 pressure, and they agree with Borishanski's, Bovich and Minchenko for boiling in large volumes between 1 and 200 kg/cm^2 and with VTI experiments (Tarasov, Armand and Konkov) for boiling in tubes at 170 kg/cm^2.

I. S. Sagan (KTIPP) gave a paper entitled "Boiling Heat Transfer in Highly Concentrated Sugar Rheostats".

N. V. Tarasova (VTI) in a talk "Hydraulic Resistance during Surface Boiling of Water in Tubes" gave results of tests carried out at pressures between 50 and 200 atm. The mean hydraulic resistance coefficient from the instant of surface boiling is higher than without boiling and is increased with decrease in degree of "under-heating" of the water.

A. P. Ornatskii and A. M. Kichigin (KPI) in "Hydraulic Resistance of Small Diameter Tubes with High Thermal Fluxes" gave results of tests at 10–75 atm and up to 200° "under-heating". In the region of surface boiling hydraulic resistance increases with increase in thermal flux.

I. I. Semenov and S. I. Kosterin (ENIN) in "Relative Velocities and Hydraulic Resistances to Flow in a Two Phase Mixture in a Vertical Pipe" gave experimental results of frictional resistance and real steam contents in steam–water mixtures in an unheated vertical pipe at pressures of 40, 69 and 119 atm.

S. I. Mochan (TsKTI) in a talk on the local resistance of a two phase mixture flow described the head losses in collectors and bends. Tests with steam and air–water mixtures established the nature of the pressure losses and local resistances.

K. P. Shumskii (NII khimmash) in "The Nature of Condensation Heat Transfer in the Solid State", described experimental results of condensation on internal surfaces of cylindrical tubes and checked them with the loss obtained from condensation on a plane surface.

N. A. Buckho (LIKhP) gave a paper "Convective Heat Transfer during Freezing of Water". The results agreed with Tkachev's experiments and confirm qualitatively his theory.

S. S. Kutateladze and B. A. Burakova in "Heat Transfer from Boiling Dowtherm" described experiments to determine q_{crit} for boiling Dowtherm in vertical and horizontal pipes at pressures between 1 and 10 atm "under-heating to 120°C", and gave further information about the heat transfer coefficient.

N. V. Zozul and V. I. Tolubinskii (ITE AN USSR): in "Condensation Heat Transfer with Dowtherm" revealed that the condensation is film-wise and the heat transfer follows laws which apply to film condensation with other media.

I. P. Vishnev and N. K. Elukhin gave a paper entitled "Boiling Heat Transfer of Liquefied Gases in Tubes".

B. F. Glikman read "Some Peculiarities in the Process of Streamwise Condensers". The kinetic pressure distribution, temperature and mean density were found, using radioactive means. In a second paper B. F. Glikman described a study of a two-phase boundary layer with stream-wise steam condensation. The condensation tests of steam in a volume of liquid and the condensation of steam on a stream of liquid revealed that in all cases at the boundary of interacting phases there is an unstable boundary layer, so that the dimensionless kinetic pressure distribution and temperature distribution are approximately similar.

S. A. Gorodinskaya (KPI) read a paper "Condensation of Binary Mixtures". Tests were done with mixtures of ethyl and methyl alcohols and water (10 to 60 per cent pure alcohol). Results revealed good agreement with Nüsselt's formula.

E. I. Suckharev (TsKTI): "Effect of Structure of Steam–Water Mixtures on the Hydraulic Characteristics of Resistance" gave several instances and concepts of the effect of physical and chemical factors on the hydraulic resistance in steam–water flows through tubes.

D. F. Peterson (TsKTI) remarked that the pressure in circulating pipes can be very much affected by the appearance of foam.

B. A. Pereverzev (TsKTI) described studies of heat transfer in cooling steam–water mixtures.

SECTION ON HEAT TRANSFER IN STEAM AND GAS TURBINE ELEMENTS AND AUXILIARY EQUIPMENT

I. T. Shvets and E. P. Dyban (ITE AN UkSSR), in "Several Results of Tests on Air Cooling Gas Turbine Rotors" gave a simplified method of solving the heat conductivity equation for calculation of more general conditions of gas turbine rotor cooling.

E. I. Molchanov and E. P. Plotkin (VTI) wrote a paper entitled "Temperature Distribution in Gas and Steam Turbine Elements". Calculations were done using a hydraulic integrator for temperature distribution in a welded-up drum rotor, in disk rotors and in gas turbine blades. For steam turbines, electro- and hydro-integrators were used to determine temperature distributions of a disk under steady turbine working conditions, and also for various conditions of cooling air "sweep", and the temperatures in the disk were determined resulting from air flow.

E. I. Shanin (TsKTI) in a paper "Experimental Determination of Heat Transfer Coefficients through the ends of Gas Turbine Rotors during Rotation" gave the heat transfer coefficients through a smooth shaft. In the gland labyrinth part of the shaft the heat transfer coefficient is much higher than on a smooth part and hardly varies with speed of rotation.

B. V. Podsevalov (TsKTI) in "Experiments on Cooling a Gas Turbine Rotor by Blowing air through Clearances in the Blade Roots" remarked that heat transfer coefficients and hydraulic resistances could be constructed for the clearances of working blade roots from results obtained from a good sized model.

O. A. Kremnev and A. L. Satanovskii (ITE AN UkSSR) in "A Study of Sweat Cooling of Turbines and Other Equipment" related that sweat cooling leads to increase in heat transfer coefficient by a factor up to 250 per cent as compared with air cooling.

V. G. Tyryshkin (TsKTI) remarked that it followed from the papers given by ITE and TsKTI that the problem of cooling the blade roots requires further work, because considerable temperature gradients are evident. He pointed out the usefulness of mixing moisture with cooling air for auxiliary units. To cool the body, water spraying is recommended. It appears that at the TsKTI work will be done mainly on rotating models and on machines built by the "Economiser", Kirov and LMZ Factories.

E. P. Dyban pointed out that all the published work lacked equality in the actual and model parameters. In this connexion it is insufficient to represent the tests in terms of temperature distributions and similar primary relationships. It is essential to express the tests in terms of criteria. Coefficients should be developed which allow results to be transformed from stationary models to rotating test pieces, and it should be possible to indicate the limits to application of the results. He pointed out how essential it was to co-ordinate the work.

V. P. Mironov also supported the plea for co-ordination.

V. S. Zhukovskii also joined forces. He also recommended the introduction of an experimental chair which would embrace work of both physicists and engineers. The situation too where there are only a few experimental turbines must be altered.

V. K. Migai (TsKTI) in a paper "Heat Transfer with Laminar Gas Flow in Small Hydraulic Temperature Channels" gave a theoretical solution of the heat conductivity equation for triangular and rectangular section ducts which are used in assembly of surfaces of several heat exchangers (regenerative air heaters for gas turbines, radiators, etc.).

V. S. Miller (ITE AN UkSSR) in a paper entitled "Contribution to the Problem of Contact Heat Transfer in Gas and Steam Turbine Parts" gave results of the determinations of the thermal resistance between metal surfaces and sintered alloys.

E. A. Ganin and Yu. P. Shlykov in "A Study of Contact Heat Transfer" gave experimental results of thermal contact resistance to rough and theoretically smooth surfaces.

N. P. Klitin and V. A. Lokshin (VTI) gave a paper "Heat Transfer in Laminated-corrugated Heating Surfaces".

S. N. Tulin (VTI) gave "Heat Transfer in Tube Bundles with Wire Corrugation".

V. G. Fastovskii and Yu. V. Petrovskii (VEI) in "Heat Transfer and Resistance of Staggered Tubes with a Continuous Spiral Corrugation" investigated six-row staggered batches with various corrugation coefficients. They revealed the effectiveness of the continuous spiral corrugation, as compared with batches of tubes with wire corrugation.

O. A. Kremnev and N. V. Zozulyn (ITE AN UkSSR) contributed "Convective Heat Transfer to Small Flat and Cylindrical Surfaces and to Corrugated Surfaces of Regnerators and Oil Heaters". They studied continuous, divided and perforated laminated corrugations and also wire and looped wire corrugated tubes with longitudinal air flow and lateral flow through the corrugations.

S. N. Fainzilber and A. I. Butuzov (KPI) in "Liquid and Evaporative Cooling Large Turbo-generators from Models" recommended Freon and Water.

V. I. Tolubinskii and V. M. Elgkii (KPI) in "Heat Transfer and Resistance of Contact Batches of Finned Tube and Batches of Circular Tubes" gave results of 62 transverse flow tube batches of which 47 had fins of rectangular and trapezoidal profile at various pitch relationships.

B. V. Latenko (KPI) gave a communication on "Heat Transfer and Aerodynamic Resistance of Regenerative Water Heaters of a Network Type".

V. N. Antufev (NZL and LTI) read "Intensification of Heat Transfer Using the Roughness Effect with Longitundinal and Transverse Flow".

B. A. Zysin (LPI) in "Several Heat Transfer Problems in Power Installations with Steam–Gas Mixtures" gave test results on heat transfer cooling of turbulent steam–air stream in a circular horizontal tube. Test results are given of heat transfer through wet steam and humidified air to a single cylinder in transverse flow.

S. I. Mochan and O. G. Revzina (TsKTI) gave a talk on the work of extending experimental results to aerodynamic resistance of transverse flow smooth tube batches. New formulae are given for calculating resistance. The method is improved and corrected for stream acceleration due to its isothermal condition.

V. G. Chakryin described the investigation of a small new type water economizer and indicated the possible use of corrugated economizers for large boilers.

During a discussion L. G. Gelfenbein pointed out that Kremnev and Zozulyn's paper did not deal with the metal heat capacity. Perforation of a corrugation is only effective at its beginning. They gave a good evaluation of Migai's paper, and pointed out that in evaluating a surface it is necessary to take account of heat extraction per unit surface area for a given amount of energy expended on resistance to gas motion.

N. I. Filippov (Electrosila Factory) pointed out that 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

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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