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Edwin H. Young
Associate Professor of Chemical and Metallurgical Engineering

James R. Wall
Marvin L. Katz
Research Assistants

Project 1592

CALUMET AND HECLA, INCORPORATED
WOLVERINE TUBE DIVISION
DETROIT, MICHIGAN

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ABSTRACT

This report contains a summary of the operations of the research group and work completed during the year 1955. The status of the work of the project is reviewed and discussed. Recommendations as to the future research program are presented.

INTRODUCTION

The Wolverine Tube heat transfer project at the Engineering Research Institute is entering its seventeenth year of operation. The activities of the research project were considerably expanded during the past year.

At the start of the year six men were employed on the project on a part time basis. As the activities of the research project were expanded during the year additional men were added to the project group so that at the close of the year ten men were employed on a part time basis.

The research group has always had more prospective investigations than could be handled simultaneously. The investigations which were carried out during the year were those which were given priority status as a result of conferences held with the Technical Manager of Wolverine Tube.

PROJECT STATUS AS OF JANUARY, 1956

In January the research group was working on the following investigations, with priority in the order presented:

1. An investigation of the fouling of 19-fin-per-inch admiralty tubes in three heat transfer units located at the Aurora Gasoline Company Refinery, Detroit, Michigan.
2. An investigation of the fouling of an 11-fin-per-inch coil in an internal tankless water heater.
3. An evaluation of the Hudson Engineering Company air-test bond-resistance test apparatus.
4. A numerical analysis investigation of the temperature distribution in the root wall of two high-fin all aluminum tubes.
5. An investigation of the relative performance of nine coaxial freon condensing coils.
6. The development of an improved bimetal bond resistance measurement apparatus.

Also included in the priority list was an investigation of the effect of cyclic operation on bond resistance. This investigation was contingent upon item no. 6 above, i.e., the development of a sensitive bond resistance measuring device.

A number of prospective investigations in addition to the above were carried over from the previous year. Although these items had no assigned priority they were considered to be of fundamental importance. Some of the important ones were:

1. Heat transfer and pressure drop characteristics of internal finned tubes.
2. Further investigations of the boiling characteristics of external finned tubes.
3. Extension of the investigation of natural convection heat transfer co-

efficients of finned tubes.

4. Studies of the performance of finned tubes in hot water storage heaters.

5. Studies of the effect of finned tube and tube bank geometries on the heat transfer and pressure drop characteristics of air cooling units.

At the beginning of the year the following men were employed on the project on a part time basis as research assistants:

Dennis J. Ward (Group Leader)
James R. Wall (Graduate Student)
Jack Alcalay (Graduate Student)
Luis O. Gonzalez (Graduate Student)
Marvin L. Katz (Senior)
William F. Conroy (Junior)

CHANGE OF STATUS DURING THE YEAR

Changes in Priority:

During the first half of the year four technical reports were issued (these reports are itemized in a later section of this report). Since the work on some of the priority items was completed, the priority list was revised on July 16 to the following:

1. The influence of cyclic operation on the bond resistance of bi-metal tubes.
2. The development of an improved bimetal bond resistance test apparatus.
3. The rating of nine coaxial coils with condensing Freon-12.
4. The revision of the Williams-Katz report (to bring it up to date).

A short time after the above list was established, the newly developed corrugated tube, now identified as the "Corro-Tube", appeared to be a useful tube for certain industrial applications. Consequently, an investigation of the heat transfer and pressure drop characteristics of this new tube warrented inclusion in the priority program. This item became no. 4 on the list and the revision of the Williams-Katz report became item no. 5.

The Finned Tube Committee on August 10, 1956, recommended that priorities be established as follows:

Current Projects

1. Influence of cycling operation on bond resistance.
2. Development of an improved bimetal tester.
3. Rating of co-axial coils.
4. Type C/T Tube, the Corro-Tube referred to above.

The Finned Tube Committee recommended certain projects for future investigation as follows:

Proposed Projects for Study

1. Revision of Katz-Williams report.
2. Boiling studies with finned tube to determine maximum flux.
3. Performance of internal finned tubes.
4. Natural convection correlation.

In August the project supervisor, Prof. E. H. Young, a Lieutenant Commander in the United States Naval Reserve, served a two-week tour of duty in the Materials Development Branch of the Research and Development Division of the Bureau of Ships. During this tour of duty heat transfer problems of the Navy were reviewed and conferences were held with various heat transfer sections. One of the major heat transfer problems of concern to the Navy is the development of special tubes for naval steam condensing applications. Several research reports on the work done in this field by the United States Engineering Experiment Station at Annapolis, Maryland, were carefully reviewed. An inspection trip to the Engineering Experiment Station was arranged and the research work was discussed with the supervisor of the steam condensing investigation. Following this tour of duty a conference was held with the Technical Manager and the Product Development Manager of Wolverine Tube on September 10, 1956. The advisability of expanding the research program to include an investigation in the development of special tubes for steam condensing applications was discussed. As a result of this conference an investigation in this field was added to the project's research program.

The steam condensing investigation was well under way by the end of the year along with the influence of cycling operation on bond resistance, the development of an improved bimetal bond resistance testing device, and studies of the heat transfer characteristics of the Corro-Tube. The laboratory data for the rating of the nine co-axial coils had been obtained and the report was being prepared.

The possibility of using a vibrational testing device for measuring bond resistance was partially investigated. Arrangements were made for Prof. Julian Frederick of the University of Michigan Physics Department to make an exploratory investigation of the feasibility of using the vibrational damping response of vibrating bimetal finned tubes as a measurement of the bond resistance. The preliminary investigation indicates that the method has considerable merit. The method will require calibration and will be further investigated during 1957.

Technical Conferences:

A number of technical conferences concerning the research program were held with representatives of Wolverine Tube on various occasions during the year (March 1, April 12, August 6, August 22, September 10, October 24, and November 29).

During the first quarter of the year several conferences were held at the Aurora Gasoline Company Refinery in Detroit, Michigan, with the Plant Manager and representatives of Wolverine Tube. The progress of the field test investigation of three finned tube heat transfer units in the Refinery was discussed.

In September Prof. Young attended the American Society of Mechanical Engineers "Petroleum-Mechanical Engineering Conference" at Dallas, Texas, with Mr. C. H. Kuthe and Mr. H. F. Powell of Wolverine Tube to hear two technical papers concerning (a) problems encountered in the selection and use of air cooled heat transfer equipment and (b) problems encountered in the manufacture and rating of air cooled equipment.

On December 3rd a conference was held at the Wolverine Tube plant with Mr. Mueller and Mr. Mathews of E. I. Du Pont de Nemours and Company. The Du Pont organization is concerned with the conservation and use of process cooling water in a number of their plants and are seriously considering the use of air cooling heat transfer units. The subject was discussed in detail by Prof. Young.

Wolverine Trufin Fellowship:

Mr. Dennis Ward, the project group leader, submitted a thesis proposal to the Doctoral Standards Committee of the Department of Chemical and Metallurgical Engineering of the University of Michigan on February 2, 1956. He proposed to study the "effect of finned tube geometry on the heat transfer and pressure drop of air in forced convection across finned tube banks". The scope of his proposed work was to study the effect of fin height, fin spacing, and fin diameter on the air side heat transfer coefficient and pressure drop of integral finned tubes in staggered tube banks with air in forced convection. For comparison purposes some plain tube data are to be obtained. Steam is to be condensed inside vertical tubes with air being drawn through the tube banks by use of a wind tunnel.

A copy of his proposal was submitted to Wolverine Tube in March, 1956, with a letter requesting that the Wolverine Trufin Fellowship be reopened. Pursuant to this request, the fellowship was granted by Wolverine Tube to the University of Michigan for the amount of $4,000. The University appointed Mr. Ward "Wolverine Trufin Fellow" effective September 20, 1956.

The Director of the Engineering Research Institute made available to the research project a wind tunnel for the study of air cooling units. The project made this wind tunnel available to Mr. Ward for his doctoral thesis investigation.

Use of Digital Computer Facilities:

A large amount of experimental data is being obtained in many of the investigations currently in progress. Considerable time would be required by the project personnel in analyzing the data. In order to best utilize the time of the project personnel, some of the analysis are being programmed for the digital computers available on the University of Michigan campus. The use of digital computers should increase the project efficiency and enable the group to better correlate the results of various investigations.

Changes in Personnel:

Mr. Ward accepted the Wolverine Trufin Fellowship and terminated his employment on the project in October. Mr. James R. Wall took over Mr. Ward's

duties as group leader. Mr. Luis Gonzalez left the University in February and transferred back to the University of Louisville.

During the year six new men were added to the project group. At the end of the year the following men were employed on the project on a part time basis as research assistants:

James R. Wall (Group Leader)
Marvin L. Katz (Graduate Student)
Jack Alcalay (Graduate Student)
James R. Fleming (Graduate Student)
Byron S. Gottfried (Graduate Student)
Harry Hsiung (Graduate Student)
Robert H. Cherry (Graduate Student)
William F. Conroy (Senior)
Walter R. Gutchess (Senior)
Larry D. Wheaton (Senior)

A part time typist, Miss Jean Storms, was added to the group in September.

SUMMARY OF TECHNICAL REPORTS AND LETTER REPORTS SUBMITTED TO WOLVERINE TUBE IN 1956

A. Technical Reports

1. Report No. 40, "Annual Report for 1955," issued January 31, 1956.

2. Report No. 41, "Numerical Analysis of the Temperature Distribution in the Root of Two High-Fin All-Aluminum Tubes," issued March 19, 1956.

3. Report No. 42, "Fouling of an 11-Fins-Per-Inch Coil in an Internal Tankless Water Heater," issued July 12, 1956.

4. Report No. 43, "Evaluation of the Hudson Engineering Company Air-Test Bond-Resistance Apparatus," issued June 1, 1956.

5. Report No. 44, "An Investigation of the Fouling of 19-Fins-Per-Inch Admiralty Tubes in Three Heat Transfer Units Located at the Aurora Gasoline Company Refinery," issued October, 1956.

B. Letter Reports

1. Letter report on the air-test program and the proposed "U-factor", January 27, 1956.

2. Letter report on the fouling of internal tankless water heater coils, January 30, 1956.

3. Letter report on a comparison of fouled 3/16 inch and 1/8 inch fin height tubes in a tankless water heater, February 23, 1956.

4. Letter report on a discussion of the Happy Company reply to our Report No. 38, March 30, 1956.

5. Letter report giving the bond resistance curves obtained in the air-test investigation, April 19, 1956.

6. Letter report on the results of testing a wrap-on finned tube and a 5/8" fin height tube in the air-test apparatus, April 19, 1956.

7. Letter report on hydrogen damage in metals, May 1, 1956.

8. Letter report on the Vibrational Testing of Bond Resistance, May 2, 1956.

9. Letter report on the effect of water on gasoline condensing rates on type S/T tubing, May 21, 1956.

10. Letter report containing translation of the Mannesmann Company brochure, June 29, 1956.

11. Letter report on an improvement of Beatty's equation for condensing coefficients on finned tubes, July 6, 1956.

12. Letter report on the fin resistance method of Dusinberre, July 18, 1956.

13. Letter report on steam condensing coefficients on finned tubes, August 16, 1956.

14. Letter report on the effect of water vapor on hydrocarbon condensing coefficients for finned tubes, August 16, 1956.

15. Letter report on the relative performance of Wolverine tubes 197049-01 and 60-116038-01 when used to condense Freon-114, August 28, 1956.

16. Letter report on the analysis of the U. S. Navy, Bureau of Ships steam condensing report No. 030038, September 17, 1956.

17. Letter report reviewing a proposed test program for storage water heaters, November 19, 1956.

18. Letter report on recommendations for a study of large diameter 19 fin per inch and Corro-Tubes in concentric pipe heat exchangers, November 27, 1956.

19. Letter report presenting test data on steam condensing on a 5 fin per inch, a 7 fin per inch, and a Corro-Tube, December 1, 1956.

PREPARATION OF MANUSCRIPT ON HEAT TRANSFER THROUGH FINNED TUBES

Professor E. H. Young, project supervisor, and Professor Donald L. Katz, chairman of the Department of Chemical and Metallurgical Engineering are co-authoring a book entitled Heat Transfer Through Finned Tubes. The book will be published by John Wiley and Sons of New York. The authors wish to acknowledge the grant received by the University of Michigan from Wolverine Tube to support the preparation of the manuscript.

RECOMMENDATIONS

A. OPERATIONS

In order to insure that definite progress is continually being made on the fundamental items of major importance to the sponsors of the project it is recommended that a proper balance be made between research and non-research-type activities such that Wolverine Tube will most greatly benefit from the group's operations. It is recommended that Wolverine Tube proceed with the establishment of testing facilities so as to relieve the research group of this type of work.

B. FUTURE RESEARCH PROGRAM

An examination of many of the items that have not as yet been investigated indicates that there exist a number of fundamental investigations that should be undertaken. The proposed projects list given on Page 3 of this report should be extended to include the following:

1. Shell and Tube Investigations.—

a. Liquid-Liquid. An investigation of the relative performance of 19 fin-per-inch tubes (Type S/T), laid out on a square pitch arrangement rotated 45°, to plain tubes of the same arrangement should be undertaken. Also, data should be obtained on the equilateral triangular pitch arrangement without the shell-circle arrangement.

b. Gas Cooler. The use of Type S/T low-finned tubes in shell and tube gas coolers represents an ideal application for this tube. Relative pressure-drop and heat transfer data for finned and plain tubes in identical shell arrangements with gas flow are needed.

c. Partial Condensers. Low-finned tubes of Type S/T can be used to definite advantage in partial condenser applications. A laboratory investigation for measuring experimental coefficients with plain and finned tubes in identical shell arrangements should be undertaken.

2. Storage Water Heaters.—The mixed natural and forced convection heat transfer that exists in storage water heaters presents an ideal application for low-finned tubes.

3. Internal-External Finned Tubes.—Finned tubes of this type developed by Wolverine Tube can be used to advantage in gas-to-gas heat exchangers. The performance of these tubes should be investigated.

4. Unbaffled Shell and Tube Heat Exchangers.—Interest is developing in the possibility of using unbaffled finned tube shell and tube units for liquid-to-liquid and liquid-to-gas heat transfer applications. No studies of the shell side performance of such units has as yet been undertaken.

5. Tube-Baffle Leakage.—The helical fin of the low fin tube permits fluid to leak around the tube through the baffle hole. The influence of this leakage on the tube-baffle orifice coefficient is unknown. Some preliminary studies have been made but further investigation is needed.

6. Concentric Pipe Heat Transfer.—Large diameter (2 inch O.D.) low-finned tubes and the Corro-Tube can be used in concentric pipe heat transfer applications. The performance of these tubes should be determined for such applications.

7. Fouling of Corro-Tubes.—The performance of the Corro-Tube in fouling heat transfer applications is unknown.

8. Fouling of Finned Tubes in Shell and Tube Units.—Two of the heat exchangers used in the Katz-Williams investigations could be used for a pilot-plant study of shell-side fouling in one or more refinery applications. The two units of identical tube layout, but with finned tubes in one unit and plain tubes in the other unit, could be tied into an existing process stream paralled with an existing commercial heat exchanger. Fouling-rate studies of the two types of tubes could be obtained and compared. It is recommended that this type of investigation be undertaken.

9. Steam in Hydrocarbon Condensation.—Recent developments indicates that more information is needed concerning the influence of water vapor on the condensation of hydrocarbons on finned tubes.

10. Influence of Internal Roughness of Tubes on Heat Transfer and Pressure Drop.—The development of the Corro-Tube is generating new interest in the influence of the internal grooves of corrugated tubes on heat transfer and pressure drop. It will soon be essential that an earlier investigation (Report No. 35, February, 1955) be extended to include the new tube.

11. High-Fin Forced-Air Units.—As indicated earlier, Mr. D. J. Ward is studying the performance of monometal finned tubes in triangular arrangements using a wind tunnel as a doctoral dissertation. The investigation needs to be extended to cover more tube sizes and arrangements than his dissertation program calls for. His research work will indicate what tubes and arrangements should be studied in the future. The information is essential in order to determine optimum fin heights and fin spacing.