DOE/CS40041-1

MASTER

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

FINAL REPORT NO HI-CS 40041

SLOT FORGE FURNACE DEMONSTRATION

Contract No. DE-AC02-77CS 40041 Mod. A007

Formerly EC-77-C-02-4236

Prepared by:

Hague International
3 Adams Street
South Portland, Maine 04106

For the Department of Energy

February, 1981

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EEB

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

I. SUMMARY:

A Hague International Slot Forge Furnace was tested at the Tube Turns Division of Chemetron Corporation in Louisville, Kentucky, from December, 1979 through April 11, 1980. The furnace was installed at Tube Turns under the subject contract to demonstrate a high performance energy conserving slot forge furnace in an industrial environment.

This furnace was used to heat 2 1/2" round x 31 1/8" long bars in preparation for an upsetting operation. Each piece was heated twice, in separate operations, and upset on both ends. The Hague International Model IV Slot Forge Furnace used in the program was designed with a nominal throughput capacity of 3,000 lbs/hr. Due to production requirements the demonstration furnace was operated in the range of 3,800 lbs/hr. A base case furnace adjacent to the Hague furnace operated simultaneously. Fuel consumption and steel throughput data for both furnaces were collected and analyzed. Test data were collected on March 12 by Hague personnel in conjunction with data generated by Tube Turns personnel. A heating rate of 746 Btu/lb for the Hague furnace and 1620 Btu/lb for the base case furnace was demonstrated. These figures demonstrated the Hague furnace's ability to save 54% of the fuel consumed by the base case furnace.

II. BACKGROUND:

The U.S. Department of Energy (DOE), realizing the potential of technologies developed at Hague International (HI), contracted with HI in 1976 to demonstrate a fuel efficient slot forge furnace in Hague's South Portland facility (DOE Contract No. EC-77-C-02-4236). This Contract was extended to include demonstrations of coal/oil mixture firing of a slot forge furnace, slot forge furnace demonstrations to the forging industry and

a unique high pressure ceramic heat exchanger operation. The final demonstration under this contract was of a fuel efficient slot forge furnace in an industrial environment. The subject of this report is the work performed under the contract modifications directed towards the demonstration of a fuel efficient slot forge furnace in an industrial environment.

The Hague International fuel efficient slot furnace incorporates a high temperature ceramic tube recuperator, high temperature recirculating burners, and an automatic fuel/air ratio trim control. Other design improvements incorporated in the furnace include cold frame construction, low thermal mass insulation, and flexible ceramic slot closures.

Tube Turns Division of Chemetron Corporation was eventually selected as a suitable test site for this demonstration. In August of 1979 the second furnace built for commercial use by Hague International was shipped to Tube Turns. Between September and December additional test instrumentation was purchased, assembled and shipped to the demonstration site.

III. PROGRAM DESCRIPTION:

It was the objective of this program to demonstrate that the Hague International high efficiency slot forge furnace is suitable for an industrial environment and can achieve the energy savings potential made possible by the utilization of high technology and improved engineering design. To accomplish this, the demonstration furnace was placed in a production forge facility and utilized as a standard production furnace. In the Tube Turns facility it was possible to operate the demonstration furnace and a base case furnace simultaneously in close proximity. Both furnaces heated the same material for the upsetter. A rough representation of the test area layout is included in Figure 1. The HI slot forge furnace was instrumented to record temperatures and pressures in predetermined

operating conditions pertinent to an engineering evaluation of the design. Additionally, both furnaces were monitored for fuel consumption. This program also provided funds to maintain the furnace in an operating condition to ensure that a suitable demonstration could be conducted.

The base case furnace was typical of existing, fuel inefficient slot forge furnaces. Such furnaces typically use fire brick insulation, steel skeletal structure and air inspiring burners at either end of the furnace chamber. The base case furnace was capable of heating 21 pieces of steel 2 1/4" dia x 31 1/8" long at a time. Tube Turns personnel noted that in their opinion, the base case furnace "was one of the most efficient furnaces" in their plant prior to the arrival of the HI furnace.

Figure 1

Furnace performance data were collected throughout the demonstration period to provide a solid basis for evaluation. A daily log which included basic data such as fuel consumption and steel throughput was kept by Tube Turns personnel. A sample of this log is included in Figure 2. Periodically throughout the demonstration period Hague personnel conducted detailed evaluations of the furnace operations. During these evaluations the following data were collected:

	<u>HI FURNACE</u>	<u>BASE CASE FURNACE</u>
Furnace Temp. ($^{\circ}\text{C}$)	X	X
Time (hrs)	X	X
Fuel Consumption (Btu)	X	X
Steel Processed (lb)	X	X

Data were collected by Hague International on three (3) separate occasions. The data collected have been reduced to show the fuel consumed vs lbs of steel heated. This information is represented graphically in Figure 3, 4, & 5. On 3/21/80 the Hague furnace showed the ability to heat steel to forging temperature at an average rate of 746 Btu/lb compared to the base case furnace's rate of 1620 Btu/lb. This represents a fuel consumption reduction of 54%.

Partially reduced data from HI's visit of 3/12/80 have been included in Appendix A.

The Hague International furnace was removed by Tube Turns from the production line on April 11. The facility was undergoing substantial changes on a management level and was being severely affected by auto industry slowdowns which required a cutback in the manufacture of transmission gears which were being produced at the test workstation. A summary of the key dates of this program has been included in this report as Table 1.

FIGURE 2

Daily Log

Date _____, Barometer _____, Ambient Temperature - Start _____
 End 1 _____
 2 _____
 3 _____

Fuel/Btu Content

Billet Material

Character-- Dimensions/Weight

istics: Forging Temperature

Billet Placement - in furnace, extending beyond door

Cumulative fuel meter reading Start up _____
 Start of production _____
 End of shift 1 _____
 2 _____
 3 _____

Throughput - each shift 1 _____ lbs.
 2 _____
 3 _____

Production items - each shift 1 _____ lbs.
 2 _____
 3 _____

Figure 3

Hague International Slot Forge Furnace Demonstration at
Tube Turns

Fuel Consumption vs Steel Throughput

12/11 - 12/15/79

Billet: 2 1/4" Dia. x 31 1/8" Long
SAE 4029

Avg. Furnace Temp. 2450°F

46 1512

10 X 10 TO THE CENTIMETER
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 4
Hague International Slot Forge Furnace Demonstration
at Tube Turns
HI Furnace vs Base Case
3/12/80

Figure 5

Hague International Slot Forge Furnace Demonstration
at Tube Turns

HI Furnace vs Base Case
3/12/80

TABLE 1

Key Date Summary

<u>DATE</u>	<u>REMARKS</u>
7/23/79	P.O. placed for furnace by Tube Turns (T.T.).
8/8/79	Slot furnace shipped
11/18 - 12/8/79	Instrumentation installed
12/4 - 12/10/79	Unit start up - Flow meter problems - T.T. had too small supply regulator - Cure in
12/14/79	Slot furnace lit off
12/15/79	Unit in production
1/15/80	Control adjustments, burner adjustments
1/17/80	Emergency shutdown - Front wall coolant circuit blew pressure caps (cleaned heat exchanger)
1/22 - 1/25/80	HI visited site to help T.T. acquire data/D.O.E. in attendance
1/31/80	Roof failure (inspect)
2/2-2/4/80	Burner maintenance, recuperator maintenance and roof repair
2/17/80	Blower filter problems
3/11-3/13/80	Full test day
3/24/80	Lost a lintel block
4/3/80	Two more blocks failed
4/8/80	Lost all lintel blocks, failures due to continued operation without replacement of failed blocks.
4/11/80	Out of service

IV. DISCUSSION:

The analysis indicates that the HI furnace had the ability to conserve as much as 54% of the fuel consumed by the base case furnace at Tube Turns. Considering that the furnace which was replaced by the HI furnace during this demonstration was viewed by all to be substantially more wasteful than the base case furnace, it can be concluded that the HI furnace has the ability to conserve in excess of 54% of the energy consumed by many of the forging industry's slot furnaces as they exist today. The levels of fuel conservation proven by this demonstration correlate well with the theoretical values calculated for the HI furnace on the basis of recuperator efficiencies, reduced excess air levels, and improved design (Reference 1).

Some field service problems occurred during the demonstration period and were adequately serviced by Hague personnel. These field service problems were representative of an initial demonstration of a large piece of industrial capital equipment.

Certain design features of the Hague furnace have received favorable comments:

- Energy conservation
- Variable slot height
- Slot closure doors
- Front wall cooling without continuous water flow
- Worker comfort
- Quiet operation
- Clean stack emissions

The results of this demonstration have made it possible to further penetrate the industrial sector and to define quantitatively the fuel savings potential of Hague International high efficiency slot forge furnaces. Technologies employed in this high performance slot forge furnace have now been utilized in the development of a full standardized line of slot, box and pusher furnaces for the steel forging industry.

Reference:

1. J. W. Bjerklie and P.G. LaHaye, Demonstration and Testing of High Performance Slot Furnace, National Technical Information Service, U.S. Department of Commerce, C00-4236-2, 1978.

APPENDIX A

Hague International Slot Forge Furnace

3/12/80

<u>Time</u>	<u>Metered Fuel (ft3)</u>	<u>Corrected Fuel (ft3)</u>	<u>Lbs Steel Processed Cumulative</u>
08:00	0	0	0
09:00	2158	2182	3780
10:00	5335	5394	7560
11:00	----	----	11340
12:00	10741	10859	15120
13:00	13750	13901	18900
14:00	16659	16842	22680
15:00	19163	19374	26460

Fuel heat value = 1020 Btu/ft3

Steel - 2 1/4" Dia. x 31 1/8" long (35 lb ea)

36 pcs/heat @ 20 minute intervals

Avg. steel rate - $26460 \text{ lb} \div 7 \text{ hrs.} = 3780 \text{ lb/hr}$

Avg. fuel rate = $19374 \text{ ft}^3 \times 1020 \text{ btu/ft}^3 \div 7 \text{ hr} = 2.823 \times 10^6 \text{ Btu/hr}$

Avg. heating rate - 746 Btu/lb

APPENDIX A

BASE CASE FURNACE

3/12/80

<u>Time</u>	<u>Metered Fuel (ft3)</u>	<u>Corrected Fuel (ft3)</u>	<u>lbs. Steel Processed Cumulative</u>
08:00	0	0	0
09:00	2183	3320	2205
10:00	4777	7266	4410
11:00	6858	10431	6615
12:00	9018	13716	8820
13:00	11475	17453	11025
14:00	13810	21005	13230
15:00	16164	24585	15435

Fuel heating value = 1020 Btu/ft3

Steel 2 1/4" Dia x 31 1/8" long (35 lb ea)

21 pcs/heat 2 20 minute intervals

Avg. steel rate = $15435 \text{ lb} \div 7 \text{ hr} = 2205 \text{ lb/hr}$

Avg. fuel rate = $24585 \text{ ft}^3 \times 1020 \text{ Btu/ft}^3 \div 7 \text{ hr} = 3.582 \times 10^6 \text{ Btu/hr}$

Avg. heating rate = 1,620 Btu/lb

U.S. DEPARTMENT OF ENERGY

DOE AND MAJOR CONTRACTOR RECOMMENDATIONS FOR
DISPOSITION OF SCIENTIFIC AND TECHNICAL DOCUMENT

See Instructions on Reverse Side

1. DOE Report No. DOE/ DT/CS-40041 -1	2. Contract No. DE-AC02-77CS-40041 Mod. A00	3. Subject Category No. TID-4500
---	---	--

4. Title
Slot Forge Furnace Demonstration **FINAL REPORT**

5. Type of Document ("x" one)
☒ a. Scientific and technical report
☐ b. Conference paper: Title of conference _____
Date of conference _____
Exact location of conference _____ Sponsoring organization _____
☐ c. Other (Specify Thesis, Translations, etc.) _____

6. Copies Transmitted ("x" one or more)
☐ a. Copies being transmitted for standard distribution by DOE-TIC.
☒ b. Copies being transmitted for special distribution per attached complete address list.
☐ c. Two completely legible, reproducible copies being transmitted to DOE-TIC.
☐ d. Twenty-seven copies being transmitted to DOE-TIC for TIC processing and NTIS sales.

7. Recommended Distribution ("x" one)
☒ a. Normal handling (after patent clearance): no restraints on distribution except as may be required by the security classification.
Make available only ☐ b. to U.S. Government agencies and their contractors. ☐ c. within DOE and to DOE contractors.
☐ d. within DOE. ☐ e. to those listed in item 13 below.
☐ f. Other (Specify) _____

8. Recommended Announcement ("x" one)
☒ a. Normal procedure may be followed. ☐ b. Recommend the following announcement limitations:

9. Reason for Restrictions Recommended in 7 or 8 above.
☐ a. Preliminary information. ☐ b. Prepared primarily for internal use. ☐ c. Other (Explain) _____

10. Patent Clearance
Does this information product disclose any new equipment, process or material? ☐ Yes ☒ No
Has an invention disclosure been submitted to DOE covering any aspect of this information product? If so, identify the DOE (or other) disclosure number and to whom the disclosure was submitted. ☐ Yes ☒ No
Are there any patent related objections to the release of this information product? If so, state these objections.

("x" one) ☐ a. DOE patent clearance has been granted by responsible DOE patent group.
☐ b. Document has been sent to responsible DOE patent group for clearance.

11. National Security Information (For classified document only; "x" one)
Document ☐ a. does ☒ b. does not contain national security information other than restricted data.

12. Copy Reproduction and Distribution
Total number of copies reproduced 5 Number of copies distributed outside originating organization 3

13. Additional Information or Remarks (Continue on separate sheet, if necessary)

14. Submitted by (Name and Position) (Please print or type)
John W. Bjerklie, Vice President of R&D
Organization
Hague International
Signature **John W Bjerklie** Date **3/6/81**

To: U. S. Department of Energy
Technical Information Center
Oak Ridge, TN 37830

Date: 3/9/81

FINAL TECHNICAL REPORT:

Contract Number: DE-AC02-77CS40041

Contractor: Hague International

Contractor Location: 3 Adams Street
So. Portland, ME

On the basis of our records we believe that the scientific and technical information products required have been made available to the Technical Information Center except as noted below (if no exceptions, indicate "None"):

Jerry L. Zimmer, Supervisor
Acquisition and Assistance Unit

Patricia Russo
Contract Specialist

Phone: (312) 972- 2088

(Date)

The contract from a technical information standpoint:

_____ May be closed out

_____ Should not be closed out nor should final payment be made until the items listed under exceptions are received by the Technical Information Center.

Date: _____

TIC Representative

To: U. S. Department of Energy
Technical Information Center
Oak Ridge, TN 37830

Date: 3/9/81

FINAL TECHNICAL REPORT:

Contract Number: DE-AC02-77CS40041

Contractor: Hague International

Contractor Location: 3 Adams Street
So. Portland, ME

On the basis of our records we believe that the scientific and technical information products required have been made available to the Technical Information Center except as noted below (if no exceptions, indicate "None"):

Jerry L. Zimmer, Supervisor
Acquisition and Assistance Unit

Patricia Russo
Contract Specialist

Phone: (312) 972- 2088

(Date)

The contract from a technical information standpoint:

 May be closed out

 Should not be closed out nor should final payment be made until the items listed under exceptions are received by the Technical Information Center.

Date: _____

TIC Representative