C/ORNL 95-0396

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CRADA Final Report for CRADA Number ORNL 95-0396

NON-HEAT TREATABLE ALLOY SHEET PRODUCTS

CRADA with the Research Consortium on Non-Heat Treatable Aluminum Auto Body Sheet, ALCAR™

H. Wayne Hayden
Oak Ridge National Laboratory

Gregory W. Barthold
American Society of Mechanical Engineers
Center for Research and Technology Development

Subodh K. Das
ARCO Aluminum, Inc.

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6285
managed by
Lockheed Martin Energy Research Corporation
for the
U.S. Department of Energy
under contract DE-AC05-96OR22464

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ORNL-27 (3-96)

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CRADA WITH THE RESEARCH CONSORTIUM ON NON-HEAT TREATABLE ALUMINUM AUTO BODY SHEET, ALCAR™[1]

H. Wayne Hayden
Oak Ridge National Laboratory

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American Society of Mechanical Engineers
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Subodh K. Das
ARCO Aluminum, Incorporated

ABSTRACT

ALCAR™ is an innovative approach for conducting multi-company, pre-competitive research and development programs. ALCAR™ has been formed to create a partnership of aluminum producers, the American Society of Mechanical Engineers Center for Research and Technology Development (ASME/CRTD), the United States Department of Energy (USDOE), three USDOE National Laboratories, and a Technical Advisory Committee for conducting cooperative, pre-competitive research on the development of lower-cost, non-heat treated (NHT) aluminum alloys for automotive sheet applications with strength, formability and surface appearance similar to current heat treated (HT) aluminum alloys under consideration. The effort has been supported by the USDOE, Office of Transportation Technology (OTT) through a three-year program with 50/50 cost share at a total program cost of $3 million. The program has led to the development of new and modified 5000 series aluminum alloy compositions. Pilot production-size ingots have been melted, cast, hot rolled and cold rolled. Stamping trials on samples of rolled product for demonstrating production of typical automotive components have been successful.

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[1]Research sponsored by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Transportation Technologies, Lightweight Materials Program, under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corporation.

STATEMENT OF THE OBJECTIVES

The objective of the program has been to develop non-heat treatable alloy(s) for automotive applications combining resistance to stress corrosion cracking combined with strength formability, weldability/bondability, and surface appearance similar to current compositions requiring heat treatment for full development of properties such as AA 6111.

CRADA BENEFIT TO DOE

The successful use of non-heat treatable aluminum alloys in automotive applications directly benefits DOE's Partnership for the Next Generation Vehicle (PNGV) by reducing the weight of the vehicle and improving energy efficiency. The development of new energy efficient aluminum alloy products also benefits DOE's Vision Industry program for the Aluminum Industry.

TECHNICAL DISCUSSION

1. Background

A coordinated, multi-pronged effort was carried-out to seek broad-base involvement in efforts for the development of non-heat treated aluminum alloy sheet for automotive applications. These efforts were encouraged through the endorsement of Dr. Sidney Diamond, Program Manager, Lightweight Materials, DOE, Office of Transportation Technology (OTT). Research and Development (R&D) groups from Oak Ridge National Laboratory (ORNL), the Idaho National Environmental and Engineering Laboratory (INEEL) and the Pacific Northwest National Laboratory (PNNL) indicated high interest for participation in the proposed program. Recognizing that ultimate success requires close coordination in meeting customer needs, liaison with the members of the U.S. automotive industry was established and has been maintained throughout the program.

With close cooperation of the Aluminum Association, ASME-CRTD made a broad solicitation of interest of the members of the US aluminum industry for participation in a consortium for pre-competitive research on non-heat treated sheet alloys. Although several companies indicated no interest, several companies indicated positive interest. Through a series of detailed discussions, continuing interests were expressed by three aluminum companies: ARCO Aluminum, Commonwealth Aluminum, and Ravenswood Aluminum (now Century Aluminum). These companies share common characteristics:

- All are high-volume producers of aluminum sheet alloys.
- Significant portions of their product output are to the highly competitive aluminum beverage container market requiring the attainment of demanding quality levels.
- All would like to establish increasing positions as suppliers to the automotive industry and/or parts suppliers to that industry.

- All are of the view that the combined capital and operating costs requirements for continuous heat treatment equipment make the 6xxx automotive sheet alloy market unsuitable for them.
- All lack dedicated R&D laboratory facilities and staff resources for conducting a program of the magnitude anticipated for the development of a non-heat treated automotive sheet alloy.

After posting notice of the intent to form a consortium, the three companies entered in a formal agreement for the formation of a consortium on August 23, 1995. The ALCAR™ Consortium (Aluminum from Commonwealth, ARCO, and Ravenswood) was formed with the intent to cooperate in efforts with the DOE and DOE National Laboratories for carrying out pre-competitive research and development in the area of non-heat treatable aluminum alloys for automotive applications. Table I. presents a chart of roles and responsibilities for each of the participants in the ALCAR™ Consortium and the Non-Heat Treated Alloy Development Program.

Table I. ALCAR™ Roles and Responsibilities

Participant	Roles and Responsibilities
• DOE-OTT, Lightweight Materials Program	Sponsor
• ASME-CRTD	Administration
• Aluminum Industry Partners Support	1. Technical Staff Interaction & Support 2. Raw Materials & Baseline Products 3. Materials Characterization 4. Scale-Up Study Mill Processing
• National Laboratories	
- ORNL	Physical & Process Metallurgy
- INEEL	Welding Engineering
- PNNL	Corrosion Science
• Consortium Sponsored Efforts	
- Technical Advisory Group	Consultation
- Energetics	Road-mapping and Team Building
- Prof. Frank Field, MIT	NHT vs. HT Sheet Cost Model
- Reynolds Metals	Scale-Up Ingot Melting and Casting
- Stampers	Forming Demonstration Studies
• Automotive Industry	Ultimate Customer

The consortium has been administered by the ASME-CRTD and chaired on a rotating basis by technical management personnel from each of the companies. Through providing public notice to cooperate in a consortium, the companies absolved themselves from possible treble damages in the event of any future litigation. The consortium would hold all intellectual property developed through the proposed program. Each of the companies agreed to pay an annual fee to the ASME-CRTD for participation in the consortium. These fees were intended to provide financial support for items including: ASME-CRTD administrative expense, the formation of a high-level university/industry advisory committee, expenses of the members of the advisory committee for technical services and attendance at regular quarterly progress meetings, purchase of outside services, legal services, etc.

With the assurance of funding support for efforts at the DOE laboratories through the DOE-OTT Lightweight Materials Program, execution of a Cooperative Research and Development Agreement (CRADA) between the ALCAR™ Consortium and each of the three participating DOE National Laboratories was essential prior to the initiation of R&D activities. All CRADA agreements were in place on February 25, 1996.

Efforts for forming the proposed advisory committee of experts from both academia and industry were conducted concurrent with the CRADA agreement activities. These efforts were successfully completed and contracts for participation in the committee were executed with each of the members. The membership and affiliations of the advisory committee chaired by Prof. Amit Ghosh of the University of Michigan is shown in Table II. In addition to providing expert advice and guidance to the program, the members of the committee were asked to assist the consortium in establishing broad-based contacts with the automotive industry and its suppliers.

Table II. ALCAR™ Technical Advisory Group

Name	Affiliation
University	
Prof. Amit Ghosh, Chairman	University of Michigan
Prof. Charlie Brooks	University of Tennessee
Prof. Henry R. Piehler	Carnegie Mellon University
Prof. Robert H. Wagoner	Ohio State University
Industrial	
Dr. Norman A. Gjostein	Consultant (Retired Ford Motor Co.)
Dr. Inge Hansson	Consultant (Retired ALCAN)
John L. Mihelich	Consultant (Retired Commonwealth Aluminum)

2. Experimental Studies

With the completion all of the above formalities, R&D activities were initiated in a kick-off meeting at ORNL on March 1, 1996. Efforts for the development of a non-heat treatable sheet alloy for automotive applications were driven by several factors:

- Automotive down-weighting will require increased usage of aluminum sheet products.
- The heat treatable 6xxx alloys, which are now preferred for automotive sheet applications based on their strength, formability, dent resistance, and surface appearance, require continuous heat treating process capabilities.
- Only the larger aluminum companies have process facilities for supplying heat treatable 6xxx aluminum alloy sheet products.
- Non-heat treatable 5xxx alloys should be lower cost.
- Use of non-heat treatable aluminum alloys could expand the automotive supply base.

Before initiating experimental efforts, a detailed review of patents and publications in the area of 5xxx alloys was carried out. The findings of the review were utilized to define promising areas of alloy composition and processing that could meet the needs for automotive application. Simultaneously, interactions with each of the major U.S. automotive manufacturers were initiated to establish a range of target properties for 5xxx alloys that would be competitive with 6xxx alloys for applications including: structural components, interior body panels, and exterior body panels. For each of these individual applications there were sets of targets for strength, formability, surface appearance, weldability, and corrosion resistance.

A matrix of candidate experimental alloy compositions and processing parameters, as well as baseline commercial ingot, coil, and sheet materials for comparative studies, was developed through detailed discussions between the consortium industry partners, the participating DOE National Laboratory investigators, and the Technical Advisory Committee. Attention was given to assuring that all compositions and processing conditions being proposed could be manufactured using existing facilities at each of the industry partner plants. The development of experimental plans and procedures was enhanced through a road-mapping and team building program facilitated by Energetics. Initial investigations of experimental compositions were based on "book mold" castings that were processed using experimental facilities at ORNL. The use of baseline commercial materials provided a method for calibrating differences between experimental and commercial practices. A schedule for characterization studies of all experimental and baseline materials was established. This included microstructural evaluations, mechanical testing, surface appearance, weldability, and stress corrosion.

A key question from the projected automotive industry customers has been magnitude of cost savings that could be projected for an NHT versus HT alloy. To address this question, the consortium funded a cost modeling study by Prof. Frank Field of Massachussetts Institute of

Technology (MIT). The study considered both variable and fixed operating costs and investment-related financial costs. The results indicated a potential for at least 10 percent lower costs for the NHT alloy.

On the basis of the results on the experimental materials, two experimental alloy compositions, a commercial baseline alloy, and a range of processing procedures were developed.

3. Scale-Up Studies

All scale-up studies were supported through direct-funding contributions made by the commercial consortium partners. The following efforts have been completed:

- Two experimental alloy compositions and a baseline alloy have been selected for scale-up studies.
- Consortium-funded melting and casting of commercial-size DC cast ingots have been completed under contract with the Reynolds Metals R&D foundry.
- All ingots have been successfully hot rolled to 0.118" coil. Samples of the hot rolled coils were used for stamping studies for automotive structural applications.
- Parts of the hot rolled coil from all ingots have been cold rolled to 0.047" and 0.039" for inner and outer panel stamping tests.
- Roller leveling and side trimming of all gages has been completed.
- Samples of all coil products have been cut to lengths requested by the commercial stampers interested in evaluating the material.
- Cut-to-length samples have been finish annealed and shipped for stamping trials and stamped component evaluations.
- Laboratory assessments of strength, ductility, formability, weldability, and corrosion resistance of all finished gages are completed.
- Stamping trials demonstrating the production of typical automotive parts (seat bracket, fender) have been completed successfully.

Figure 1 presents photographs of the commercial equipment for the processing the cast ingots to hot and cold rolled products. Figure 2 presents a photograph of the trial stamped components produced from the 5xxx experimental alloy.

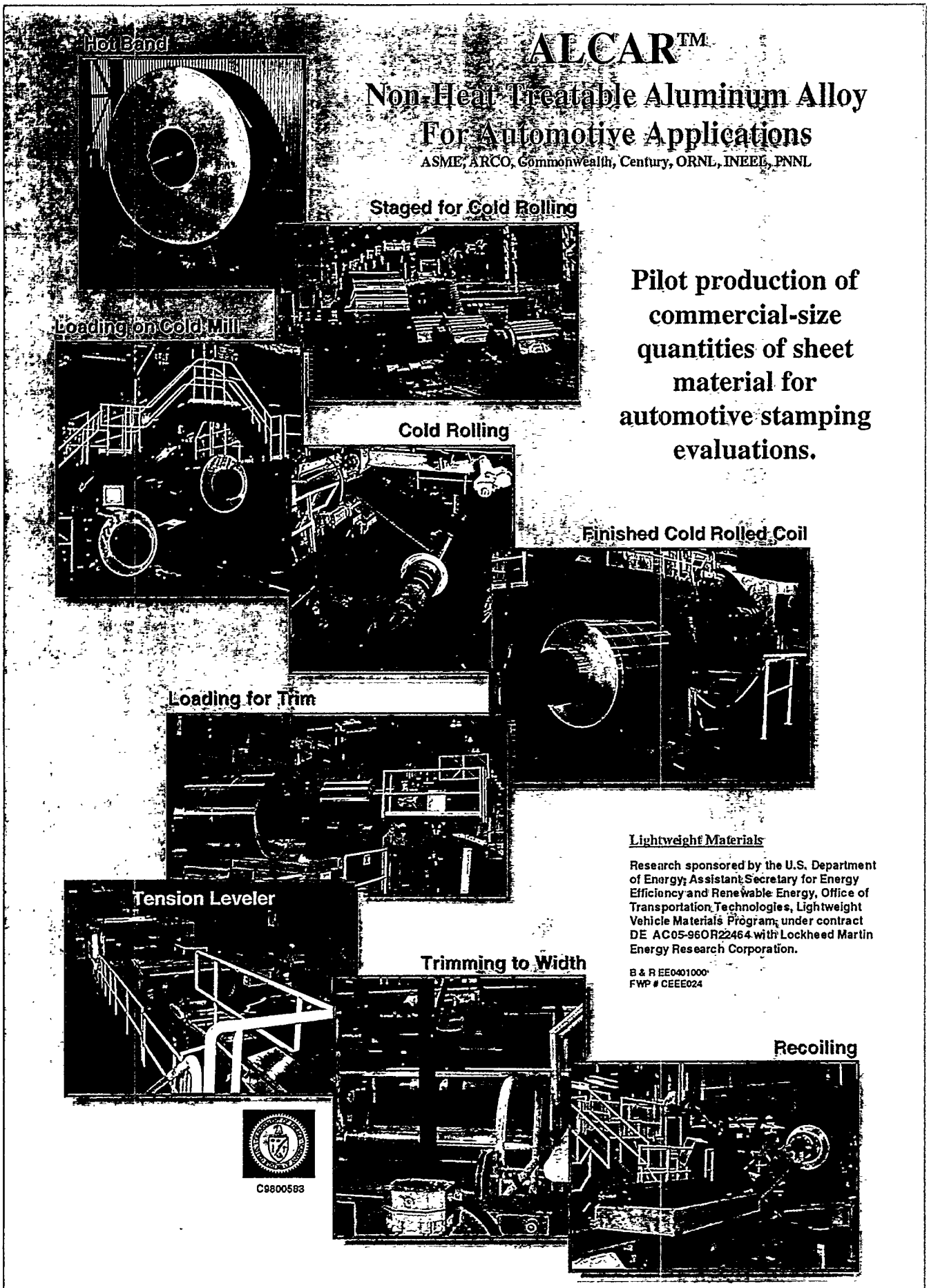

Figure 1. Processing operations for production of cold rolled aluminum alloy sheet product.

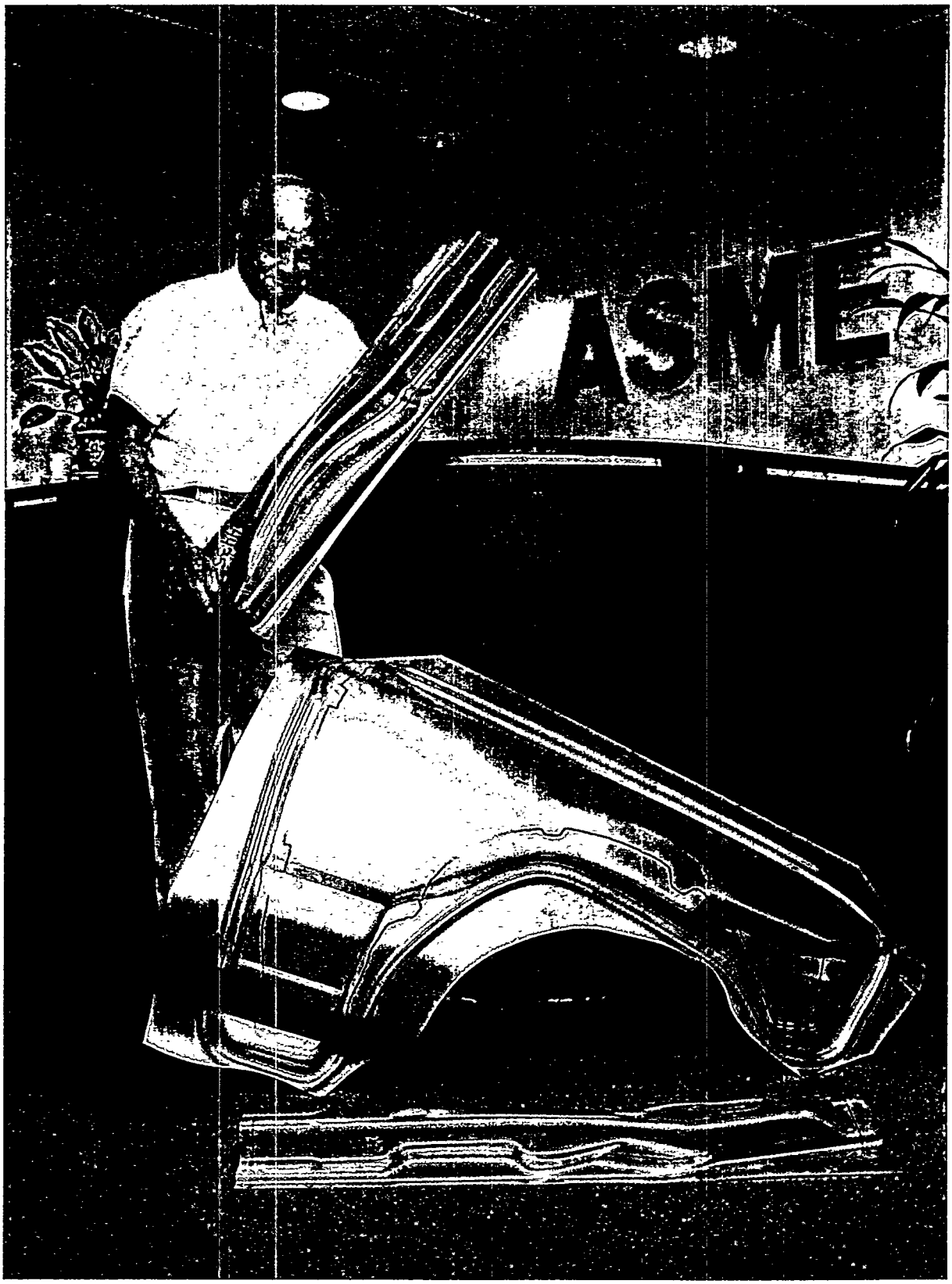

Figure 2. Prototype stamped automotive components produced from ALCAR developed 5xxx alloy steet.

COMMERCIALIZATION POSSIBILITIES

On the basis of the successful production scale-up studies and recent stamping demonstrations, it appears that the materials developed through the program can meet several needs for the automotive industry. Future efforts for commercialization will require competitive production operations, and marketing efforts that will be carried-out individually by each of the ALCAR™ aluminum companies

PLANS FOR FUTURE COLLABORATION

Future efforts related to the materials developed under this CRADA will be of a competitive and not pre-competitive nature. Hence, such efforts could not be done through the existing multi-company/national laboratory collaboration. Potential collaborative programs between one (or more) of the aluminum industry members of ALCAR™ and national laboratory partners in other areas of aluminum technology are likely.

INVENTIONS (MADE OR REPORTED)

Three invention disclosures describing proprietary alloy compositions and processing procedures have been submitted. Patent applications are being prepared through Consortium funding.

CONCLUSIONS

1. The potential for automotive use of the non-heat treatable 5xxx series alloys has been demonstrated through an integrated program of alloy development, production scale-up demonstration studies, and automotive component stamping trials.

2. Commercialization of the alloys developed by the program will rest with the individual efforts of each of the commercial consortium members.

3. All ALCAR™ partners share the view that the Consortium has been a successful method for the accomplishment of the specific program objectives.

4. In the broader sense, it is believed that the ALCAR™ approach is a general model for competing companies to cooperate in carrying out pre-competitive R&D program.

DISTRIBUTION

1. D. J. Alexander, MST Center for Materials Science, MS K765, Los Alamos National Laboratory, P. O. Box 1663, Los Alamos, NM 87545
2. G. B. Barthold, Assistant Director, Center for Research and Technology Development, American Society of Mechanical Engineers, 1828 L Street, N.W., Suite 906, Washington, DC 20036-5104
3. C. R. Brooks, Department of Materials Science, University of Tennessee, 434 Dougherty Engineering Building, Knoxville, TN 37996
4. J. A. Carpenter, U.S. Department of Energy, 1000 Independence Avenue, SW, MS EE-32, Washington, DC 20585-0121
5. S. K. Das, ARCO Aluminum, Inc., P. O. Box 32860, 2900 First National Tower, Louisville, KY 40232
6. J. B. Deschapelles, Technical Manager, Ravenswood Aluminum Company, P. O. Box 98, Ravenswood, WV 26164
7. S. Diamond, Metallurgist, Office of Heavy Vehicle Technologies, EE-33, Building FORS, Mail Stop 6A-116, Washington, DC 20585
8. A. K. Ghosh, Professor, Materials Science & Engineering, The University of Michigan, 2300 Haywood Street, 2102 Dow Building, Ann Arbor, MI 48109-2136
9. N. Gjostein, 544 Claremont, Dearborn, MI 48224
10. S. Goodrich, Technical Department, Ravenswood Aluminum, P. O. Box 98, Ravenswood, WV 26164
11. I. Hansson, Hanson Technology Management, 399 Naomi Crescent, Mississauga, ONTARIO L5B 3S4, CANADA
12. W. Hartung, Commonwealth Aluminum, 1372 State Road, P. O. Box 480, Lewisport, KY 42351
13. S. McGuire, Commonwealth Aluminum, 1372 State Road 1957, P. O. Box 480, Lewisport, KY 42351-0480
14. J. L. Mihelich, Metallurgical Engineer, Metal Experts International, 7440 Mason Falls Drive, Winston, GA 30187
15. J. O'Donnell, Commonwealth Aluminum Technologies, 1200 Meidinger Tower, Louisville, KY 40202
16. H. Piehler, Materials Science Engineering, Carnegie Mellon University, 2323 Lean Hall, Pittsburgh, PA 15213-3890
17. C. Seidler, ARCO Aluminum, 2900 National City Tower, Louisville, KY 40202
18. H. Smartt, Lockheed Martin Idaho Technologies, P. O. Box 1625, Idaho Falls, ID 83415-2210
19. M. Smith, Battelle Pacific Northwest Laboratory, P. O. Box 999, Battelle Boulevard, Richland, WA 99352
20. M. Sorensen, Manager, Materials Processing, Idaho National Engineering Laboratory, P. O. Box 1625, Idaho Falls, ID 83415-2210
21. J. Vetrano, Pacific Northwest Laboratory, P. O. Box 999, MSIN, P8-16, Richland, WA 99352
22. R. Wagoner, Department of Materials Science & Engineering, Ohio State University, 2041 College Road, Columbus, OH 43210-1179

23. A. Watkins, Lockheed Martin Idaho Technologies, P. O. Box 1625, Idaho Falls, ID 83415-2210
24. Work for Others Office, DOE-ORO, ER-113, MS G209, P. O. Box 2001, Oak Ridge, TN 37831
25. R. A. Bradley
26. D. F. Craig
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30. P. S. Sklad
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32-33. Laboratory Records (for transmittal to OSTI)