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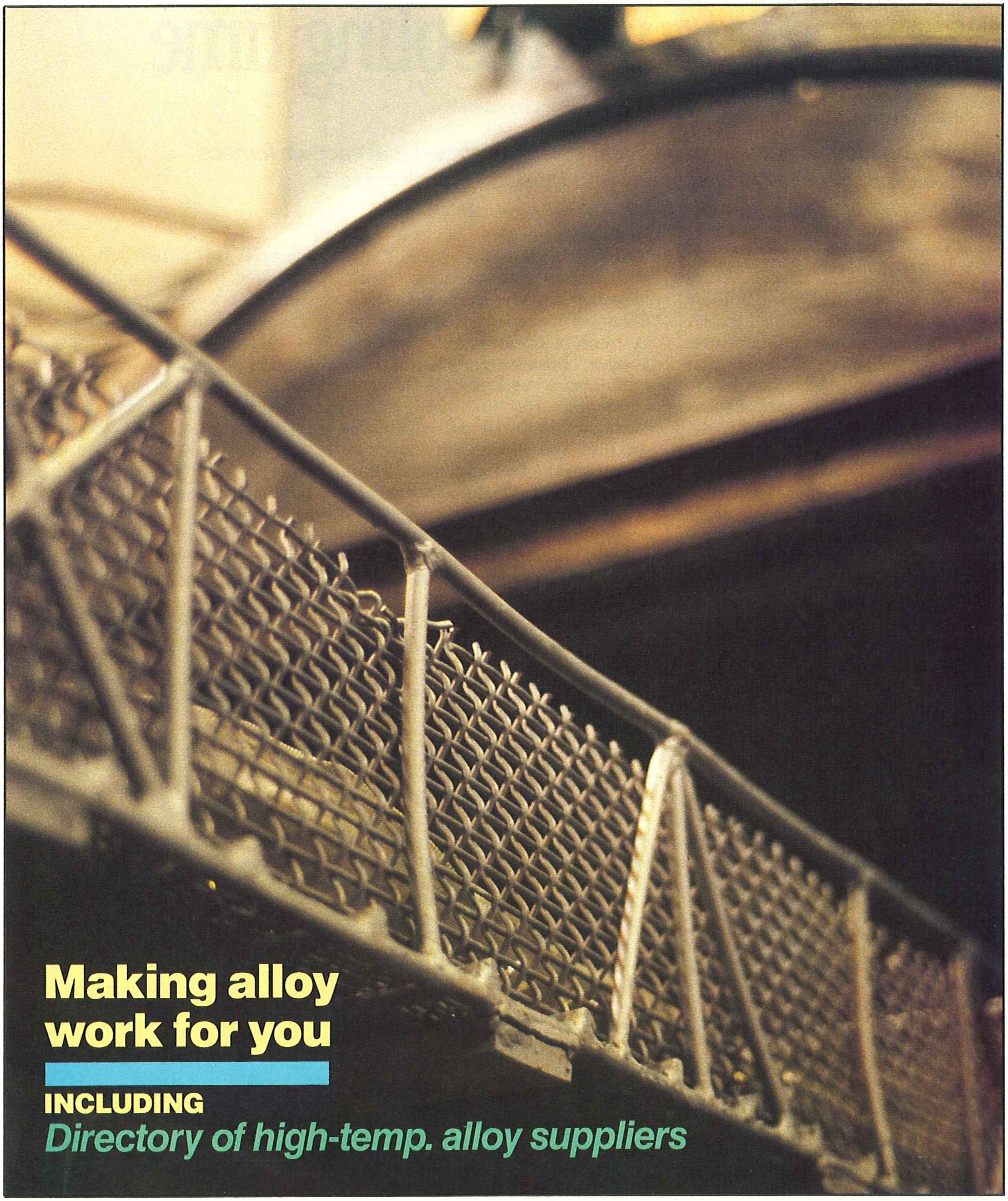

High alloy, thin-section baskets reduce vacuum cooling time

A year-long test at a commercial heat treater has shown that vacuum furnace fixtures with thinner cross-sections and reduced overall mass cut cooling times for vacuum loads by an average of 20%.

BY Robert J. Myers

A recent joint evaluation by a commercial heat treater and an alloy manufacturer has demonstrated that quench times can be reduced substantially by proper selection of furnace hardware materials. Benedict-Miller, Inc., Lyndhurst, N.J., and Haynes International, Inc., Kokomo, Ind., collaborated on a direct comparison of alloy baskets used for a year for the vacuum heat treating of specialty steel aircraft and aircraft engine parts.

Benedict-Miller, a 50-year-old firm, operates a service center for specialty alloy steels and tool steels in conjunction with a full-service heat treating facility and laboratory. The heat treating department includes three Atmosphere Furnace Co. batch-type gas carburizing and hardening furnaces, three Ipsen vacuum furnaces, two Gleason gear press-quenching systems, a Gleason roller-quench system, subzero freezing equipment and a modern metallurgical laboratory.

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Haynes International, a 78-year-old firm, specializes in the development, production and distribution of nickel- and cobalt-base wrought alloys. The first-generation alloys were marketed primarily to aircraft engine builders; now a concerted effort is being made to extend the use of the newer alloys to the industrial heating field.

While state-of-the-art heat treat equipment offers quench rate improvement, it also entails significant additional capital expenditure. Benedict-Miller and Haynes set out to achieve a more rapid quench by simply reducing the mass of fixture used in the furnace during the heat treating cycle. Using a more robust material of construction, they designed fixturing with the same strength but reduced cross-sections and, hence, less overall mass. Obviously, less extraneous mass in a furnace during heat up and cooling not only saves energy but helps speed the thermal cycle.

Distortion of high-temperature heat treat baskets is a common occurrence. The source of the distortion can normally be traced either to overloading or to the imposition of severe thermal stresses during heating and/or cooling. In the first case, the use of thicker component section size, a higher strength material, or even reduction of the load on the component are all effective means for addressing the problem.

In the latter case, the issue is a bit more complex. Thermal stresses arise when different parts of a component expand or contract at different rates during heating or cooling. Presuming only one material of

Basket in 601 alloy, standard design

Quantity	Dia./ Thick	Width	Length	Weight
1	0.625		155.375	13.87
7	0.625		59.750	37.35
14	0.500		33.00	26.38
8	0.500		7.00	3.20
2	0.500		6.625	0.76
4	0.500		8.938	2.04
8	0.500		4.250	1.94
2	0.500		15.750	1.80
2	0.500	2.500	32.750	23.83
			TOTAL	111.17

Basket in 230 alloy, redesigned to lower mass

Quantity	Dia./ Thick	Width	Length	Weight	% Reduction weight
1	0.437		155.375	7.43	46.5
7	0.437		59.750	19.99	46.5
14	0.375		33.00	16.26	38.4
8	0.375		7.00	1.97	38.4
2	0.375		6.625	0.47	38.4
4	0.375		8.938	1.26	38.4
8	0.375		4.250	1.20	38.4
2	0.375		15.750	1.11	38.4
2	0.250	2.500	32.750	13.06	45.2
			TOTAL	62.74	43.6

Table I: Standard vs high alloy basket

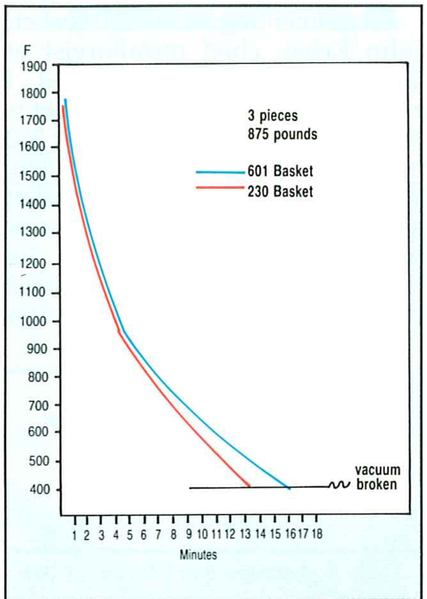


Fig. 1: Range of cooling—trial 3

construction is involved (this is always desirable), the source of such differential expansion or contraction can be either a variation in component section thickness or a variation in actual heating or cooling rate. Uniformity in component section thickness is virtually always a good design principle. Uniformity in component heating and cooling is something certainly to be sought after, but very difficult to achieve in actual practice. Regardless of whether the issue is distortion from overloading or from thermal stresses, the material solution to the problem calls for higher strength.

The comparison test

Haynes alloy 230, a solid-solutioned-strengthened alloy (Ni-22Cr-2Mo-14W), was selected to be tested with reduced cross-sections. Alloy 601, also a solid-solutioned-strengthened alloy (Ni-23Cr-14Fe-1.4Al-0.5Mn), which has been traditionally used by Benedict-Miller, was tested keeping its standard design. The bill of materials for each basket is exhbitied in **Table I**.

Two baskets were constructed to the 33-x46.5-x 8-inch design. One basket was constructed from 230 alloy plate and round bar with cross-section ranging from 0.250 to 0.437 inch. The 601 alloy basket ranged from 0.500 to 0.625 inch. When constructed, the 230 alloy basket weighed 63 pounds, compared with 111 pounds for 601—a weight reduction of 44%. (See photo.)

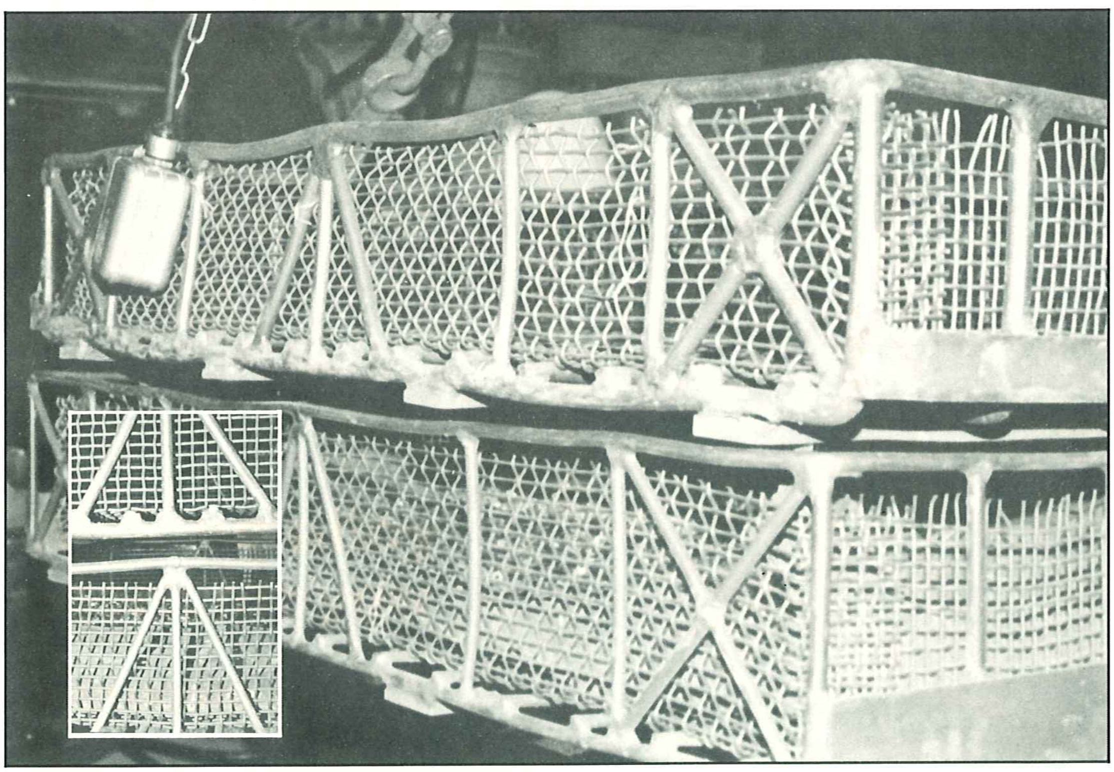
In service, the function of a heat treat basket is to support the load of parts being treated, so resisting deformation is of key importance. For baskets subject to quenching after thermal exposure, the resistance to distortion and cracking from the severe thermal stresses generated puts a premium on high yield strength, fine grain size, and low expansion characteristics. In vacuum furnace forced-gas quenching, the mass of fixturing can have a significant influence upon quench time for the parts. This puts a premium upon creep and stress-rupture strength, if fixturing mass is to be minimized. Based upon the comparative stress-to-rupture data shown in **Table II**, the reduced cross-sectional design of the 230 basket appeared feasible.

°F	230 alloy	Alloy 601
1200	42.5	28.0
1400	20.0	9.8
1600	8.9	4.4
1800	3.0	2.2
2000	1.0	1.0

Table II: Stress to rupture (Ksi) in 1,000 hrs.

Another factor relevant to dealing with distortion arising from thermal stresses is a material's thermal expansion characteristics. The lower these are, the less potential there is for the generation of thermal stresses due to differential expansion or contraction during heating and cooling. Typical expansion characteristics for both heat-resistant alloys are shown in **Table III.** The lower expansion behavior is exhibited by 230 alloy as a consequence of its nickel base and high tungsten content.

A large variety of parts is heat treated at Bene-



High alloy basket, bottom, has thinner cross-section supports than conventional basket, top. Inset shows detail of both baskets.

°F	230 alloy	Alloy 601
400	7.2	8.0
800	7.6	8.3
1200	8.1	8.9
1400	8.3	9.2
1600	8.6	9.5
1800	8.9	9.8

Table III: Mean coefficient of thermal expansion micro-in./in.°F (RT to temp.)

dict-Miller, and most are either tool steel or stainless steel. Cooling rates are more critical in the tool steels, which require a highly efficient quench to get by the knee of the "S" curve for a fully martensitic structure in hardening operations. The trials were conducted in one of the Ipsen vacuum furnaces starting last June. The heat treat operation is fairly simple. After the furnace is heated to the required temperature, the parts are held between 1600°-1900°F; quenching is carried out by backfilling with nitrogen. When parts are cooled to 400°F, the furnace vacuum seal is broken and parts are allowed to cool further under ambient conditions.

Results

A direct comparison of the performance of the two baskets is made in **Table IV**. Trials were made using four different loads, and quench times were measured for both baskets. Overall, quench rates were 15-25% faster in the 230 basket, with an average improvement of 20%. Comparative quench rates are given in **Table V**. A typical cooling curve is shown in **Fig. 1**.

Trial (min.)	Load (lbs.)	230 basket quench time (min.)	601 basket quench time (min.)	% improvement in quench time
1	1,140	12	16	25
2	120	8	10	20
3	875	13	16	19
4	156	11	13	15
			Average improvement	20

Table IV: Measured quench times of two baskets

In commenting on the 230 basket, John Kelso, chief metallurgist at Benedict-Miller, said: "What I really like about this alloy basket is the way it is holding up. After 250 cycles, it looks like it has hardly been used at all." The 230 basket still shows no significant signs of warpage, thanks largely to its higher strength capabilities and its lower thermal expansion coefficient.

	°F/min	
Trial	230 basket	601 basket
1	100.0	90.0
2	192.5	154.0
3	111.9	96.0
4	135.5	114.6

Table V: Average quench rate of two baskets

The test continues, and we expect the final results will show an even greater advantage for the specially-designed high alloy baskets when the final life cycle is achieved. HT