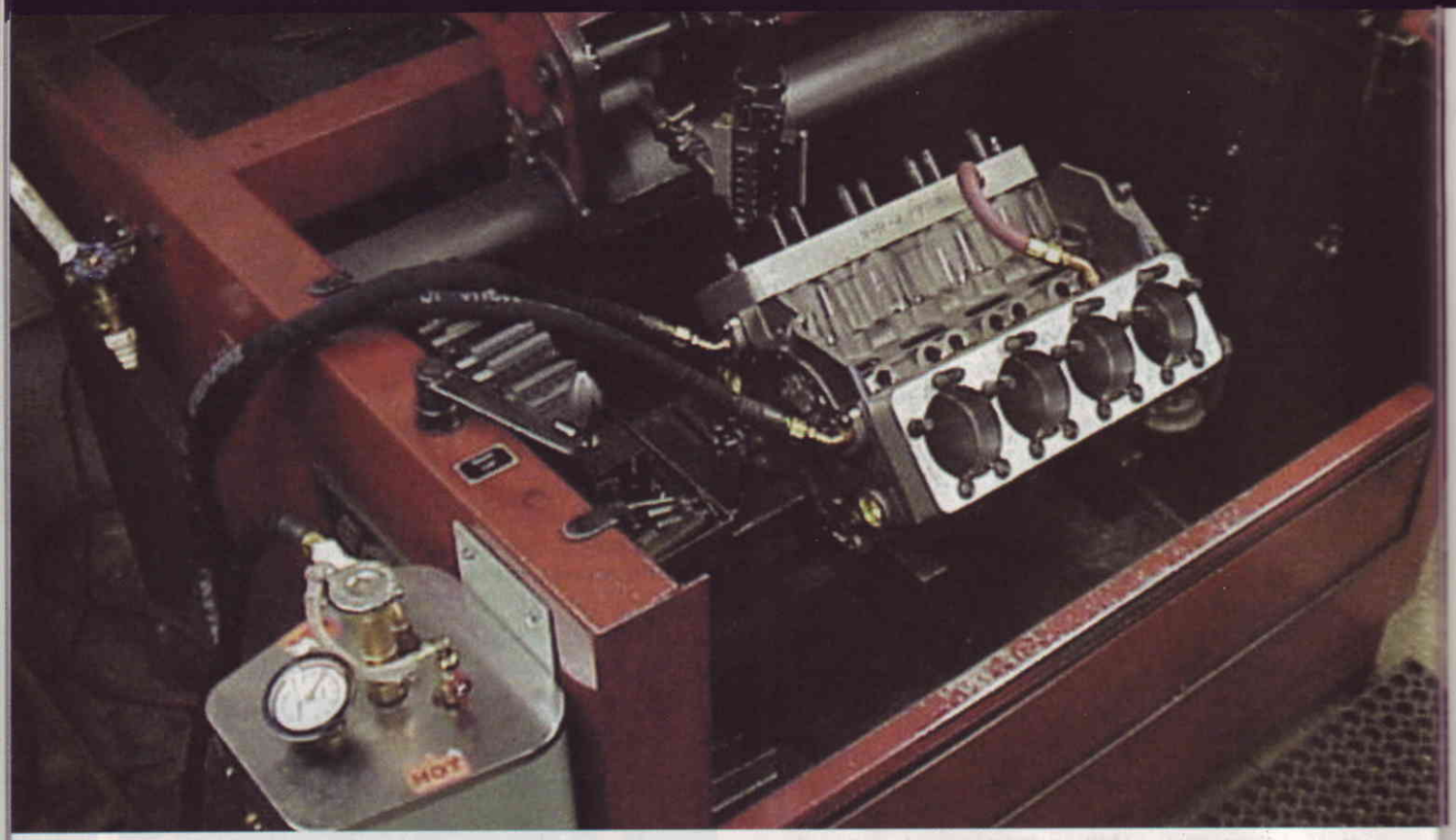

HONED TO PERFECTION

HERE'S THE RESULT WHEN SOLID ENGINEERING AND PRACTICAL EXPERIENCE COLLIDE IN THE STUDY OF MAKING CYLINDER BLOCK BORES CONCENTRIC AT OPERATING TEMPERATURE

TEXT BY JIM MCFARLAND
PHOTOGRAPHY BY DENNIS WELLS

It is widely recognized that cast, machined metal parts tend to have "memory" created from internal stresses. In the presence of temperature changes, these stresses often cause dimensional and structural shifts. Racing engine builders know about this condition that can have a direct bearing on cylinder bore concentricity. In fact, we often spend extra time and funds to produce round cylinders in an attempt to produce bore dimensions equal to those that exist after an engine reaches operating temperature and cylinder pressures.

More specifically, cast and machined bores in a cylinder block are subjected to thermal and load distribution that add complexity to the goal of maintaining concentric bores in a running and highly stressed engine. Like it or not, there's some "Kentucky windage" built into the task of producing dimensionally correct cylinder bores that model those subjected to in-use heat.

We know the distribution of operating temperatures and combustion pressure is anything but uniform in the metal structure surrounding cylinders; three-dimensional growth of block material occurring in this proximity is unavoidable. So we've contrived ways to preload blocks with honing plates by heating the material or by using of other methods intended to anticipate how a given block will experience

350 010									
	COLD READINGS		HOT READINGS			COLD READINGS		HOT READINGS	
CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths	CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths
1	5	- 5	38	40	2	24	- 18	58	10
	10	- 15	43	17		31	- 25	66	7
	13	- 10	40	20		28	- 5	60	20
3	5	7	35	42	4	5	14	30	48
	19	- 30	47	5		15	- 5	48	32
	15	- 15	47	15		17	0	48	43
5	5	0	35	32	6	10	- 20	40	28
	13	- 30	42	10		22	- 30	57	5
	12	- 3	48	20		30	- 10	62	15
7	10	0	40	25	8	10	- 5	40	35
	15	- 20	43	27		15	- 13	43	18
	10	- 5	38	25		15	- 5	40	20

Bowtie									
	COLD READINGS		HOT READINGS			COLD READINGS		HOT READINGS	
CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths	CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths
1	6	15	41	55	2	2	2 ?		
	9	12	45	50		9	1 ?		
	5	10	40	45		9	1		
3	25	- 2	60	45	4	25	2		
	25	3	60	40		25	1		
	18	6	54	38		19	1		
5	5	5	40	60	6	8	1		
	2	2	38	45		8	5		
	0	0	38	40		2	3		
7	2	2	60	40	8	2	1 ?		
	2	2	60	40		22	1		
	12 ?	3	58	40		22	1		

Dart 060									
	COLD READINGS		HOT READINGS			COLD READINGS		HOT READINGS	
CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths	CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths
1	- 5	- 4	32	37	2	- 5	- 5	25	32
	- 4	- 4	32	35		- 5	- 5	30	32
	0	- 3	35	33		- 5	0	30	33
3	- 10	- 3	25	42	4	- 7	- 3	25	40
	- 6	- 3	28	35		- 5	- 2	27	38
	- 3	- 2	23	32		- 5	0	33	38
5	- 5	- 5	25	40	6	- 5	- 2	25	40
	- 5	- 3	28	38		- 5	- 2	25	35
	- 2	0	32	35		- 3	- 2	30	35
7	- 5	- 2	32	33	8	- 4	- 5	30	30
	- 5	- 3	32	32		- 5	- 3	28	30
	- 3	- 4	33	30		- 5	- 3	30	30

bore distortion once it is assembled and running . . . sometimes on the assumption that all bores will distort the same, which they do not.

None of this is to suggest such methods are not effective, because they have been and are. Rather, these comments go directly to the problem of devising improved ways to compensate for the "effective" distortion that is inescapable under the influence of operating conditions.

Enter Stephen Kuzara of Sheridan, Wyoming-based Millennium Products Corporation. He has engineering training as an engine builder/machinist and is running his own machine shop. That's not an unworthy combination.

In prior conversations he'd had with Smokey Yunick (who had tried the process of "hot honing" during the '50s), Kuzara explored ways to circulate heated liquid through the cooling jacket of a cylinder block during finishing honing operations.

"Curiosity and frustration arose from chasing the final few tenths in the honing process," Kuzara says. "During

Dart Little M Lightened / cold readings @ 65 Deg / hot readings @ 200 deg TQ Plate temp 195 Deg									
	COLD	COLD TO HOT		HOT		COLD	COLD TO HOT		HOT
CYL No.	Out of round	Change Thrust Tenths	Change Long Tenths	Out of round	CYL No.	Out of round	Change Thrust Tenths	Change Long Tenths	Out of round
1	17	32	40	25	2	15	35	35	15
	15	32	38	21		15	32	35	18
	15	32	35	18		17	34	32	15
3	0	28	44	16	4	**0**	**24**	**44**	**20**
	2	30	35	7		**2**	**27**	**38**	**13**
	2	30	30	2		**7**	**35**	**31**	**3**
5	0	30	42	12	6	2	30	42	10
	2	30	38	10		2	27	40	15
	0	30	32	2		5	34	30	1
7	12	32	33	13	8	8	33	38	13
	10	32	33	11		12	32	33	13
	0	27	30	3		6	33	35	8

FROM DENNIS WELLS' PERSPECTIVE

Wells is a no-nonsense builder who changes his techniques only when the benefits are worthwhile. Following are his observations on the process, after having used it on each of the cylinder blocks presented in the accompanying data charts.

Why would you substitute this honing process for any you've previously used?

"Simple. In order to have straight and round bores when the engine is operating at running temperature."

In your experience thus far, what dimensional advantages have you discovered this process provides compared to methods you are currently using?

"Most cylinders grow an average of 0.0035 inch when a block is heated to 200 degrees F from 65 degrees F, but they don't grow in a concentric manner, and this is an important factor. Therefore, the bores are basically different sizes from top to bottom."

Until being introduced to hot honing, what steps did you follow in cylinder-bore preparation?

"Previously, we installed a torque plate and did a four-step honing process."

From what you've seen, what improvement in power can you estimate compared to your previous practices?

"There should be between a 1 and 2 percent power increase, and you should need to change rings less frequently to obtain proper ring seal."

What problems or other benefits do you anticipate engine builders will experience while adapting to this process?

"Well, here's what I've learned so far: An exhaust fan will be needed to remove the smoke from the heated honing oil. Water and a drain hose will be needed at the machine. The water is very easy to remove from the block without getting into the honing machine. All you need to do is remove the quick-connect coupling from the fill side, connect the drain hose at the bottom of the tank, and blow air into the fill hose.

You need to measure cylinders when they are cold, heat the block to operating temperature, and re-check the bores. Subtract cold numbers from hot numbers; this is the amount you add to the dial bore gauge for the finished size. If this method isn't used, the pistons will stick in the bores when cold. It's advantageous to heat the block, thereby identifying any leaks. I've found leaking freeze plugs just by heating the block.

After you wash the block, there'll be less black residue to wipe away, as there is with cold-honed blocks. If you find a cylinder that grows an unusual amount, I would not use the block. This can save money from problems that appear later.

Finally, I discovered that painting a black spot on the side of the block helped radiate heat and trigger my infrared heat gun, making it easier to know the block and cylinder temperature during the honing process."

Dart Little M Lightened / cold readings @ 65 Deg / hot readings @ 200 deg TQ Plate temp 195 Deg									
	COLD READINGS		HOT READINGS			COLD READINGS		HOT READINGS	
CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths	CYL No.	Thrust Tenths	Long Tenths	Thrust Tenths	Long Tenths
1	- 2	15	30	55	2	0	15	35	50
	0	15	32	53		0	15	32	50
	0	15	32	50		- 2	15	32	47
3	8	8	36	52	4	**8**	**8**	**32**	**52**
	8	10	38	45		**8**	**10**	**35**	**48**
	8	10	38	40		**5**	**12**	**40**	**43**
5	10	10	40	52	6	10	8	40	50
	8	10	38	48		8	10	35	50
	10	10	40	42		8	13	42	43
7	5	17	37	50	8	2	10	35	48
	5	15	37	48		3	15	35	48
	10	10	37	40		4	10	37	45

Dart Little M Lightened								
Step by Step Honing of Cyl No. 4 @ 200 Deg						60 Deg/70Deg/TQ plate off		
HOT READINGS			HOT READINGS			COLD READINGS		
No. of hone pass	Thrust Tenths	Long Tenths	No. of stone pass	Thrust Tenths	Long Tenths	CYL No.	Thrust Tenths	Long Tenths
1st	48	60	5th	71	73	4@60	54	37
	55	58		74	75		54	42
	53	57		75	74		50	48
2nd	58	65	6th	77	78	4@70	57	40
	67	65		80	78		58	48
	65	67		79	78		55	53
3rd	63	67				4@70	58	43
	69	68				plate	57	48
	68	68				off	54	53
4th	68	70						
	73	70						
	72	72						

Dart Little M Cyl No. 4							
Cold to Hot Tenths			Change Tenths	Hot to Cold Tenths			Change Tenths
8	to	32	24	77	to	54	23
8	to	35	27	80	to	54	26
5	to	40	35	79	to	50	29
8	to	52	44	78	to	37	41
10	to	48	38	78	to	42	36
12	to	43	31	78	to	48	30

the early '70s, I worked with a machinist friend who owned a CK-10. I began wondering how important those last few tenths were in the overall effort of achieving precision-machined blocks. I'd already observed how the stones would heat the bore surfaces and create dimensional changes, so it seemed logical some major changes would probably occur at engine operating temperatures."

In fact, Smokey had abandoned the process (although in the '70s he'd shared with this author the benefits he'd projected would occur), considering the way he'd tried the method was cumbersome, "messy," and "took too long."

Kuzara appears to have been more persistent. "My first setup was hooked up to our water heater, with one hose running water into the block and another running out to the drain," he says. "The outlet hose had a pressure gauge and a valve to help monitor the pressure and control the flow. Water temperature during the first test I ran was at 180 degrees F. The distortion measured was significant enough that I quickly concluded the last few tenths I had been chasing 'cold' were lost in the greater distortion I was seeing 'hot,' which was several times that produced by torque plates."

Interpretation? While torque plates do preload and create bore distortion, thereby providing data that enables improved honing precision, the process of hot honing (using torque plates) appears to create and allow material movement that closely relates to cylinder dimensions of a running engine at temperature.

TYPICAL BORE DIMENSIONAL VARIATIONS

For purposes of this story, four small-block Chevrolet cylinder blocks were selected from inventory at Wells Racing Engines in Duncanville, Texas: a stock 350, a stock Bow Tie, a 0.060-overbored Dart, and a Dart Little M (lightened). Elsewhere in this story, there are charts of data provided, each of which presents cylinder bore dimensions obtained "cold" (65 degrees F) with a torque plate and "hot" (200 degrees F jacket temperature and 195 degrees F torque plate coolant temperature). Cylinder bore measurements were taken as "long" (parallel to crankshaft axis) and "thrust" (perpendicular to the crankshaft axis). Also, three measurements per cylinder were taken: top, middle, and bottom.

Spend a little time examining the accompanying charts. From them you can determine the dimensional differences and accuracy measured between the two methods used: torque plates and hot honing versus neither. Particularly interesting is the data that shows the number of honing passes required to bring a cylinder into concentricity as depicted in the chart entitled "Dart Little M Lightened" (note cylinder No. 4). This same chart also shows a comparison (same cylinder) of cold readings at 60 and 70 degrees F and one at 70 degrees with the torque plate removed. Here, the two readings make a direct comparison between readings with and without the plate. Remember, all readings are shown in tenths of a thousandth of an inch.

SOME CONCLUDING THOUGHTS

Is hot honing worthwhile? Some observations may be made from information gathered in this story. For example, with the use of torque plates, stresses and bore distortion created by the installation of cylinder heads can be imposed. Therefore, it's possible to finish-hone cylinders to compensate for such deformities. However, the body of

information gathered from hot honing indicates greater bore distortion is created by circulation of hot water through a block's cooling jacket than by cylinder head clamping forces.

It was also apparent that cylinders in blocks that have been "lightened" will notably benefit from the hot-hone process and should be finish-honed after all material is removed.

Finally, as noted by Wells, bore-gauging cylinders that have been hot-honed and allowed to cool will produce measurements that appear quite skewed. Once they are brought up to temperature, these same cylinders will assume the desired concentricity and, according to the data, be more concentric than if the hot-hone process had not been employed.

Where simulations or approximations are used to approach in-use conditions (in a variety of engine or parts applications), the nearer a process comes to duplicating those conditions the more beneficial it becomes. In terms of cylinder bore concentricity and preparation, it appears the hot-hone process closely approximates the dimensional environment of a running engine's cylinders. Smokey would likely have approved. **EM**

FROM STEPHEN KUZARA'S PERSPECTIVE

Given the improvement in bore concentricity and consistency the hot-hone process enables, what sort of power (or parts durability) can be expected from using the method?

"I'd say less ring land wear, possibly ring wear itself, and ring tension mutation. I believe bore surfaces to be somewhat smoother, resulting in less friction (friction horsepower). In terms of power, there are no magic numbers. During development of the process, I didn't have access to a dyno facility to verify differences, but the engines just seemed freer to me. One ring company stated that you could expect up to 5 hp in a 600hp engine.

A prominent NASCAR team told Kwik-Way they were seeing about 5 more horsepower after 50 laps than when they were coming off the dyno. At that level of horsepower, the cost was around $100,000 per horsepower. Formula One engines have been hot-honed for years, and several other people using the process swear by it. To date, I've not seen any really good data. Logically, it makes sense. We just know it works."

On the assumption an engine builder feels current methods of finish-honing a block are adequate, what reasons can you provide that might change his mind?

"Experience with hot-honing has taught me several things. First, it's the almost one in every eight bores that you find that distorts more than the average in an unpredictable way that makes you feel so good about finding it. The average distortion is several times that found when using torque plates. In addition, I have found many cracks and leaks even after a block has been closely inspected.

"Hot-honing also reveals a lot about each block and the inconsistencies of the manufacturing and machining process. For example, when you lighten a block, it had better be done before the honing is done. (The data charts show that it required almost 0.008 inch to straighten bores in the Dart Little M block that had previously been lightened.)

"Finally, I believe rings are being launched off the bore surface irregularities, and when they land they begin to bounce, creating destructive harmonics, increased wear, and reduced cylinder pressure. These harmonics may be why some piston ring lands wear out so quickly and, I expect, contribute to decreased ring seal and related possibilities. Imagine the speed of a ring approaching a 0.0007 'hill' on the surface of a bore at 8,000 rpm and the resulting deformation of the remainder of the ring as it tries to accommodate this vandalistic attack."

How cost-effective is this process?

"Besides offering an opportunity to shorten the time required to finish-hone a block, it also doubles as a hot pressure test. It is also a good method to check out different types of gasket materials and sealants. When I was machining blocks, I charged an extra $150 (1980 dollars) and had no complaints at this price. Except for torque plates, not many pieces of shop equipment will pay for themselves in a dozen uses."

What are common mistakes that should be avoided when using the hot-hone method?

1. Not measuring a bore while it's cold. You lose your frame of reference.
2. Forgetting to make sure all plugs and connections are watertight.
3. Build a water trap in the hone to help keep the water from going through the pump and being mixed with the oil. You will have an accident or two.
4. Venting the oil smoke in some manner.
5. Continually checking and adjusting the gauge. It will pick up heat and expand.
6. Not writing down honing figures. I use the torque plate as a slate.
7. Turning on the heater without any water in the tank. These are very dense heating elements and will burn out in about 10 seconds if fired dry.
8. Remember, the system is as hot as an engine fresh off the track.

Are there types of engine blocks that would benefit more than others from the hot-hone process?

"I'd say the following is a pretty comprehensive list: siamese bores, factory blocks, blocks extensively lightened or have other metal removed, welded blocks, sleeved blocks, and block/head combinations with dissimilar metals . . . cast-iron blocks with aluminum cylinder heads obviously need aluminum torque plates."

What is the hot-hone question (and answer) you have found to be the most often asked by an engine builder?

"Without a doubt: 'How do you know what size to hone the bore to?' The answer to this is pretty lengthy, and I'd like to refer readers to the operator's manual that's available from Kwik-Way. (www.kwik-way.com)."