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Group 4c

Evaluation Report 531

Case IH Self-Propelled Combine

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

CASE IH 1660 SELF-PROPELLED COMBINE

MANUFACTURER:
J. I. Case Company
700 State Street
Racine, Wisconsin 53404
U.S.A.

DISTRIBUTOR:
J.I. Case Co.
P.O. Box 5051
240 Henderson Drive
Regina, Saskatchewan
S4P 3M3
PHONE: (306) 924-1600

Retail Price:
$135,126.00 (May, 1987, f.o.b. Humboldt, with a 13 ft (4.0 m) headers, 13 ft (4.0 m) pickup, feeder reverser, rock trap, grain scan monitor, grain pan sidehill dividers and rasp bar tolerance attachment.

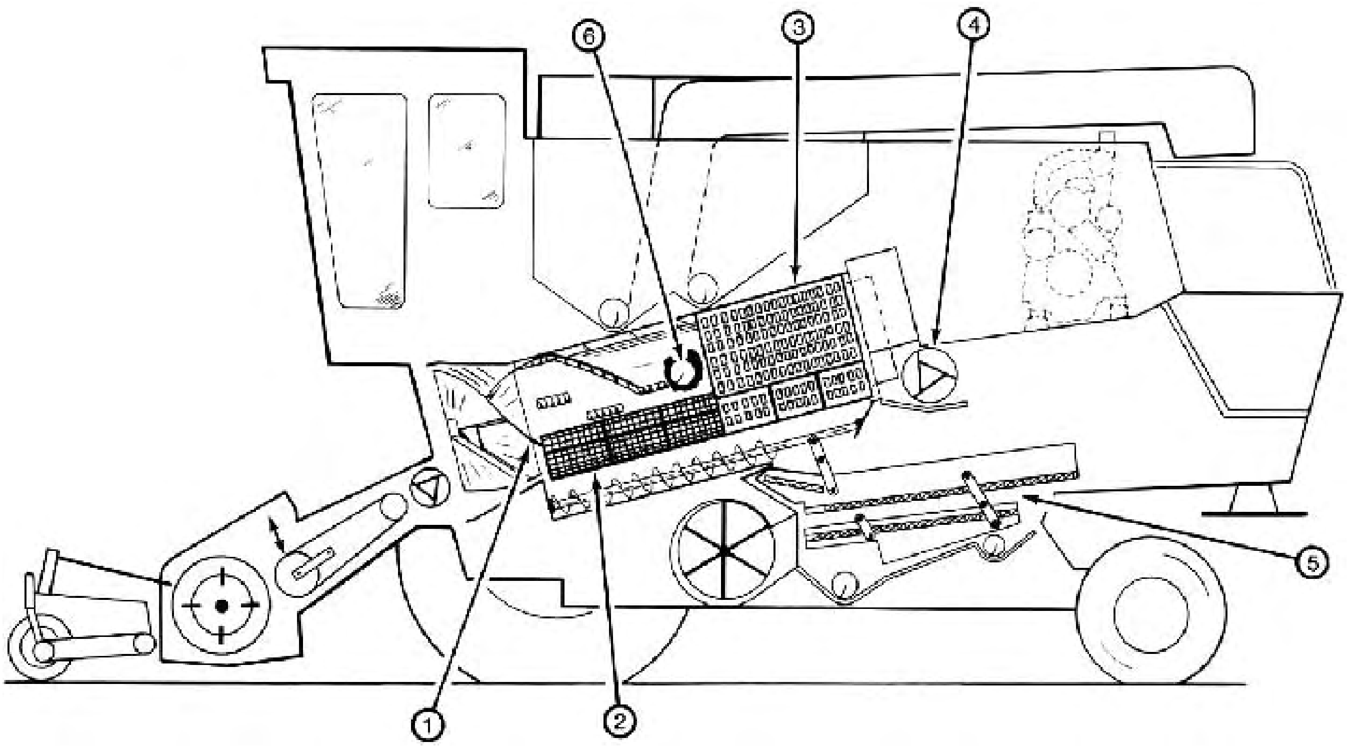


FIGURE 1. Case IH 1660 (1) Rotor, (2) Threshing Concaves, (3) Separating Concaves, (4) Back Beater, (5) Shoe, (6) Tailings Return.

SUMMARY AND CONCLUSIONS

Capacity: In the capacity tests, the MOG feedrate* at 3% total grain loss in Harrington barley was 585 lb/min (16.0 t/h). In wheat crops, combine capacity ranged from 800 lb/min (21.8 t/h) at power limit in Columbus wheat to 825 lb/min (22.5t/h) in Katepwa wheat at 3% total grain loss.

In barley, the Case IH 1660 had approximately 1.40 times the capacity of the PAMI Reference II combine at 3% total grain loss. In wheat, at 3% total grain loss, the capacity of the Case IH 1660 was 1.20 to 1.30 times the capacity of the Reference II combine.

Quality of Work: Pickup performance was good. In most crops it picked cleanly and fed the crop smoothly under the table auger. In some conditions, the crop was not stripped from the pickup teeth. Feeding was good in most crops and conditions.

The powered stone beater provided good protection. Most roots and stones were trapped in the pocket below the beater. Some small stones, which entered the rotor housing, caused minor concave damage.

Threshing was very good. The Case IH 1660 threshed smoothly and aggressively in all crops. Unthreshed losses and grain damage were low. Straw break-up was severe in dry conditions. In tough conditions, combine throughput was reduced slightly.

Separation of grain from straw was very good. Rotor loss was low over the entire operating range and did not limit combine capacity.

*MOG feedrate (Material-Other-than-Grain Feedrate) is the mass of straw and chaff passing through the combine per unit of time

Cleaning shoe performance was good. Shoe loss was low in wheat crops but limited capacity in some barley and oilseed crops. The grain tank sample was clean in all crops.

Grain handling was very good. The 175 Imperial bu (6.4 m^3) grain tank filled evenly in all crops, although the corners did not fill completely. The auger was convenient to position. Unloading was fast, taking about 110 seconds to unload a full tank.

Straw spreading was poor. The straw spread was even but only up to 15 ft (4.6 m) wide.

Ease of Operation and Adjustment: Operator comfort in the Case IH 1660 was very good. The cab was very quiet and relatively dust free. The heater and air conditioner provided comfortable cab temperatures. The seat and steering column could be adjusted to suit most operators. Visibility forward and to the sides was very good. Rear view mirrors provided good visibility to the rear. View of the incoming swath was partially blocked by the steering column.

Instrumentation was good. The instruments monitored all important functions and had built-in warning systems. The instruments to the right of the operator were easy to observe day or night. However, those in the upper right corner of the cab were inconvenient to observe while harvesting. Controls were good. Most of the controls were conveniently located, responsive and easy to use.

Loss monitor performance was very good. Both shoe loss and rotor loss could be monitored. The reading was meaningful only if compared to actual losses.

Lighting for night time harvesting was very good.

Handling was very good. Steering was smooth and responsive. The combine was easy to maneuver and stable in the field and while transporting.

Ease of adjusting combine components was good. Most components except the cleaning sieve were convenient to adjust. Ease of setting the components to suit crop conditions was very good.

Ease of unplugging was good. The feeder reverser worked well and was easy to use for unplugging the table auger and feeder. A plugged rotor could usually be cleared by lowering the concave and powering the slug through. Ease of cleaning the combine exterior was good, however, cleaning the inside was time consuming and laborious.

Ease of lubrication was very good. Daily lubrication was quick and easy. Gaining access to perform general maintenance and repair was very good.

Engine and Fuel Consumption: The engine started easily and ran well. In most conditions the engine was run at or near power limit. Average fuel consumption for the year was 5.9 gal/h (27L/h). Oil consumption was insignificant.

Operator Safety: The operator's manual emphasized operator safety. All moving parts were well shielded. The Case IH 1660 was safe to operate if normal safety precautions were taken and warnings heeded.

Operator's Manual: The operator's manual was well written and contained much useful information on safety, servicing, lubrication, trouble-shooting, setting and specifications.

Mechanical History: A few mechanical problems occurred during the test.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Investigating the cause of the cleaning sieves accidental closing and making modifications to either prevent the sieve from closing by itself or to prevent the cleaning sieve from plugging.
2. Supplying full bin sensors.
3. Modifications to improve straw spreading.
4. Modifications to make the shaft speed monitor more convenient to view.
5. Modifications to the propulsion control lever to reduce the side-to-side free play and to give it smooth positive positioning.
6. Modifications to provide convenient, positive cleaning sieve adjustment.
7. Modifications to allow safe convenient sampling of the return tailings while harvesting.

Senior Engineer: G.E. Frehlich
Project Manager: L.G. Hill
Project Technologist: W.A. Beckett

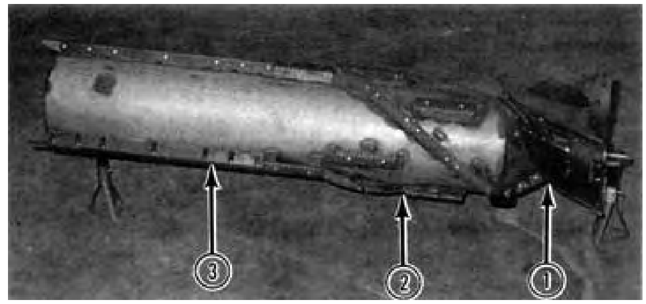
THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. Modifications to the cleaning sieve adjusting mechanism will be evaluated.
2. A full grain tank warning indicator will be evaluated for the future.
3. Modifications to improve straw spreading are being evaluated.
4. Modifications will be considered for the future.
5. This will be considered for the future.
6. This will be investigated for future models.
7. Methods for sampling or measuring return tailings will be investigated for future models.

GENERAL DESCRIPTION

The Case IH 1660 is a self-propelled combine. It has a single longitudinally mounted rotor, threshing and separating concaves, discharge beater, and cleaning shoe. The rotor is a closed tube design with infeed fins, a combination of parallel and spiral rasp bars, and separating fins (FIGURE 2). The threshing concaves are bar, and wire design. The separating grate is slotted, formed metal (FIGURE 3). The discharge beater is a wing type beater. The cleaning fan is a single paddle fan. The chaffer sieve and cleaning sieve are adjustable lip design and move in opposed motion.



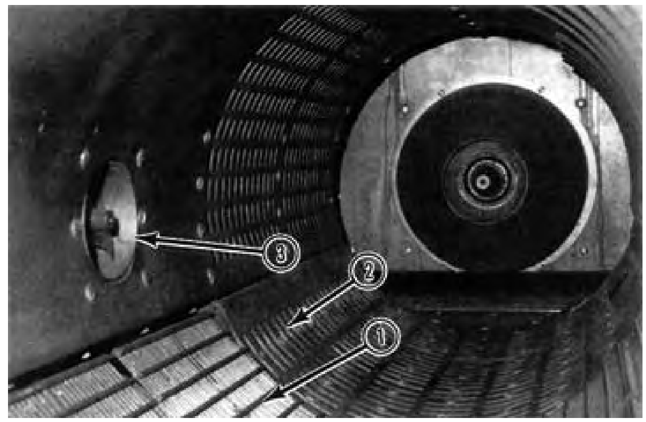


FIGURE 2. Rotor: (1) Intake Section, (2) Threshing Section, (3) Separating Section.
FIGURE 3. (1) Threshing Concaves, (2) Separating Concaves, (3) Tailings Return.

Crop is fed to the rotor intake fins, which spiral the material into the rotor. Threshing begins upon first contact with the rotor and continues throughout the length of the threshing concaves. The angled rasp bar ribs and adjustable fins on the top of the rotor housing move the crop rearward. Separation starts at the threshing concaves and continues as the crop spirals over the separating grates. The winged discharge beater strips the processed crop away from the rotor and discharges it out the back of the combine. The material separated from the threshing and separating concaves is fed to the cleaning shoe by augers. Tailings are returned to the rotor above the third threshing concave (FIGURE 3).

The test combine was equipped with a 180 hp (134 kW) turbo-charged 6 cylinder diesel engine, a 13 ft (4.0 m) pickup header, 13 ft (4.0 m) 2 roller belt pickup, powered rock beater, and optional accessories as listed on page 2.

The Case IH 1660 has a pressurized operators cab, power steering, hydraulic wheel brakes and a three speed transmission with hydrostatic ground drive.

Separator and header drives are electrically controlled through hydraulically actuated belt tighteners. Header height and unloading auger swing are hydraulically controlled. Rotor speed, pickup speed and cleaning fan speed are controlled from the cab while concave clearance and shoe settings are made on the machine. There is no provision to safely sample return tailings while operating. Important component speeds and harvest functions are displayed on electronic monitors.

Detailed specifications are given in APPENDIX I.

SCOPE OF TEST

The Case IH 1660 was operated for 130 hours while harvesting about 1183 ac (479 ha) of various crops. The crops and conditions are shown in TABLES 1 and 2. During the harvest, it was evaluated for rate of work, quality of work, ease of operation and adjustment, operator safety, and suitability of the operator's manual. Extended durability testing was not conducted. Mechanical failures were recorded.

TABLE 1. Operating Conditions

Crop	Variety	Average Yield		Width of Cut		Hours	Field Area	
		bu/ac	t/ha	ft	m		ac	ha
Barley	Bonanza Herrington Johnstone	60 65 45	3.3 3.5 2.4	25 30, 60, 25	7.6 9.1, 18.3 7.6	10 8 8	73 65 69	30 26 28
Canola	Tobin Westar	25 25	1.4 1.4	25, 30 18, 25	7.6, 9.1 6.5, 7.6	10 10	55 116	22 47
Rye	Muskateer	30	1.9	20, 21, 24	6.1, 6.4, 7.3	39	346	140
Flax	Dufferin	35	2.1	21	6.4	6	35	14
Wheat	Columbus Katepwa Neepawa	30 35 30	2.0 2.4 2.0	25, 28, 42 30, 60 24	7.6, 8.5, 12.8 9.1, 18.3 7.3	14 22 3	168 222 34	68 90 14

TABLE 2. Operation in Stony Conditions

Field Conditions	Hours	Field Area	
		ac	ha
Stone Free	12	106	43
Occasional Stones	81	734	297
Moderately Stony	37	343	139
Total	130	1183	479

RESULTS AND DISCUSSION

TERMINOLOGY

MOG, MOG Feedrate, Grain Feedrate and MOG/G Ratio: A combine's performance is affected mainly by the amount of straw and chaff it is processing, and the amount of grain or seed it is processing. The straw, chaff, and plant material other than the grain or seed is called MOG which is an abbreviation for "Material-Other-than-Grain". The quantity of MOG being processed per unit of time is called the "MOG Feedrate". Similarly, the amount of grain being processed per unit of time is called the "Grain Feedrate".

The MOG/G ratio, which is the MOG Feedrate divided by the Grain Feedrate, indicates how difficult a crop is to separate. For example, MOG/G ratios for prairie wheat crops may vary from 0.5 to 1.5. In a crop with a 0.5 MOG/G ratio, the combine has to handle 50 lb. (22.7 kg) of straw for every 100 lb (45.4 kg) of grain harvested. However, in a crop with a 1.5 MOG/G ratio, for a similar 100 lb (45.4 kg) of grain harvested, the combine now has to handle 150 lb (68.2 kg) of straw – 3 times as much. Therefore, the higher the MOG/G ratio, the more difficult it is to separate the grain.

Grain Loss, Grain Damage, and Dockage: Grain loss from a combine can be of two main types: Unthreshed Loss, consisting of grain left in the head and discharged with the straw and chaff, or Separator Loss which is free (threshed) grain discharged with the straw and chaff. Separator loss can be further defined as Shoe Loss and Walker (or Rotor) Loss depending on where it came from. Loss is expressed as a percentage of the total amount of grain being processed.

Damaged or cracked grain is also a form of grain loss. In this report, cracked grain is determined by comparing the weight of the actual damaged kernels to the entire weight of the sample taken from the grain tank.

Dockage is determined by standard Grain Commission methods. It consists of large foreign particles and of smaller particles that pass through a screen specified for that crop. It is expressed as a percentage of the total sample taken.

Capacity: Combine capacity is the maximum rate at which a combine, adjusted for optimum performance, can process crop material at a certain total loss level. PAMI expresses capacity in terms of MOG Feedrate at 3% total loss. Although MOG Feedrate is not as easily visualized as Grain Feedrate, it provides a much more consistent basis for comparison. A combine's ability to process MOG is relatively consistent even if MOG/G ratios vary widely. Three percent total loss is widely accepted in North America as an average loss rate that provides an optimum trade-off between work accomplished and grain loss. This may not be true for all combines nor does it mean that they cannot be compared at other loss levels.

Reference Combine: It is well recognized that a combine's capacity may vary greatly due to differences in crop and weather conditions. These differences make it impossible to directly compare combines not tested in the same conditions. For this reason PAMI uses a reference combine. The reference combine is simply one combine that is tested along with each combine being evaluated. Since the test conditions are similar, each test combine can be compared directly to the reference combine to determine relative capacity or "capacity ratio". This capacity ratio can be used to indirectly compare combines tested in different years and under different conditions. As well, the reference combine is useful for' showing how crop conditions affect capacity. For example, if the reference combine's capacity is higher than usual, then the capacity of the combine being evaluated will also be higher than what might be normally expected.

For 10 years PAMI has used the same reference combine. However, capacity differences between the reference combine and some of the combines tested have become so great that it has become difficult to test the reference combine in the conditions suitable for the evaluation combines. PAMI has changed its reference combine to better handle these conditions. The new reference combine is a larger conventional combine that was tested in 1984 (see PAMI report #426). To distinguish between the reference combines the new reference will be referred to as Reference II and the old reference as Reference I.

RATE OF WORK

Capacity Test Results: The capacity results for the Case IH 1660 are summarized in TABLE 3.

The performance curves for the capacity tests are presented in FIGURES 4 to 6. The curves in each figure indicate the effect of increased feedrate on rotor loss, shoe loss, unthreshed loss, and total loss. From the graphs, combine capacity can also be determined for loss levels other than 3%.

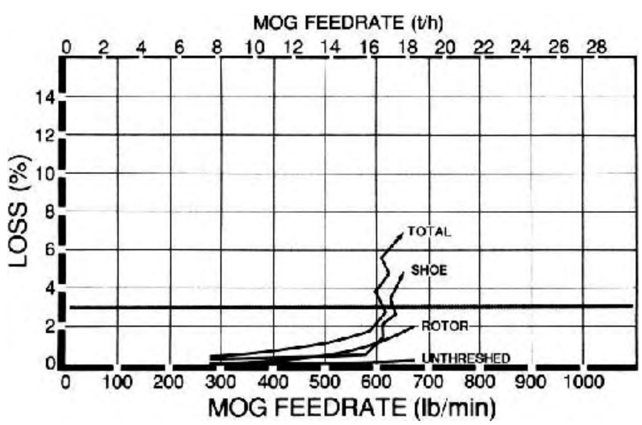


FIGURE 4. Grain Loss in Harrington Barley.

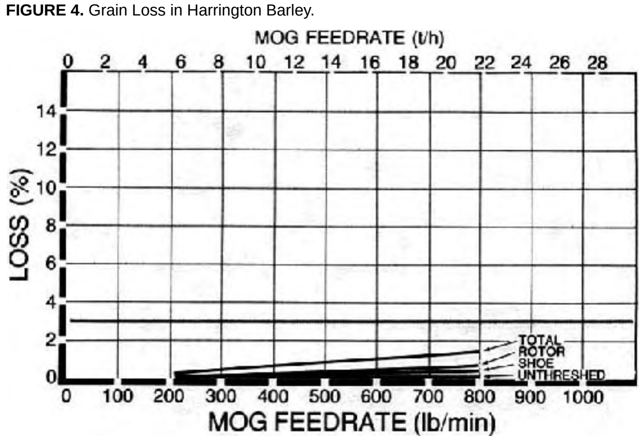


FIGURE 5. Grain Loss in Columbus Wheat.

The Harrington barley crop used for the test was from a uniform stand and was laid in well formed side-by-side double windrows. The crop was mature and both the grain and straw were very dry. The grain threshed easily and the awns broke off readily. Straw break-up was quite high. The grain yield was slightly below average but the straw was short which resulted in a low MOG/G ratio. The low MOG/G ratio meant that high grain feedrates accompanied relatively low MOG feedrates.

TABLE 3. Capacity of the Case IH 1660 a Total loss of 3% of Yield

Crop Conditions									Results							
		Width of Cut		Crop Yield		Moisture Content			MOG Feedrate		Grain Feedrate		Grain Cracks %	Dockage %	Foreign Material	Loss Curve
Crop	Variety	ft	m	bu/ac	t/ha	Straw %	Grain %	MOG/G	lb/min	t/h	bu/h	t/h				
Barley	Harrington	56	17.1	54	2.9	10.2	10.8	0.64	585	16.0	1140	24.9	0.5	0.5	0.5	2
Wheat	Columbus*	29	8.9	43	2.9	8.5	16.4	1.21	800	21.8	660	18.0	0.9	2.9	2.9	3
Wheat	Katepwa*	29	8.9	46	3.2	8.4	14.3	1.40	825	22.5	590	16.1	1.1	0.8	0.8	4

*Loss at maximum attainable feedrate was 2% of yield.

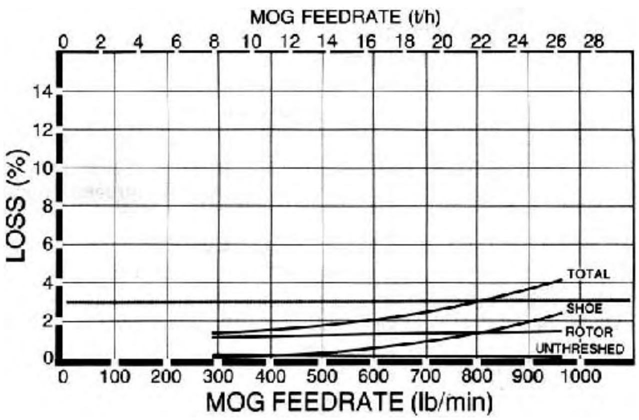


FIGURE 6. Grain Loss in Katepwa Wheat.

In this barley crop, the maximum practical feedrate was about 585 lb/min (16.0 t/h) MOG. Total loss at this feedrate was about 2%; beyond this feedrate total loss increased sharply due to erratic shoe loss. Operating at higher feedrates would be impractical. It is possible that in barley crops with a higher MOG/G ratio, the shoe loading wouldn't be as severe and slightly higher MOG feed-rates would be attained.

Both wheat crops were from uniform stands. Both crops were laid in well formed single windrows. The crops were mature and the straw was dry. The grain was dry for the Katepwa wheat and tough for the Columbus wheat. In both crops, the grain threshed easier than Neepawa wheat. The straw was long and did not break up readily. Although the grain yield was above average, the very long straw resulted in high MOG/G ratios for both crops. The high MOG/G ratios meant that relatively low grain feedrates accompanied the MOG feedrates.

In wheat the capacity ranged from about 800 lb/min (21.8 t/h) at power limit and 2% total loss in Columbus to 825 lb/min (22.5 t/h) at 3% loss in Katepwa. More available power would have increased capacity in Columbus wheat.

In both wheat and barley, the low loss over most of the operating range enabled large variations in feedrate with only small changes in loss.

Average Workrates: TABLE 4 indicates the average workrates obtained in each crop over the entire test season. These values are considerably lower than the capacity test results in TABLE 3. This is because the results in TABLE 3 represent instantaneous rates while average workrates take into account operation at lower loss levels, variable crop and field conditions, availability of grain handling equipment, and differences in operating habits. Most operators could expect to obtain average rates in this range, while some daily rates may approach the capacity test values. The average workrates should not be used to compare combines. The factors, which affect workrates are too variable and cannot be duplicated for all combine tests.

Comparing Combine Capacities: The capacity of combines tested in different years or in different crop conditions should be compared only by using the PAMI reference combines. Capacity ratios comparing the test combine to the reference combine are given in the following section. For older reports where the ratio is not given, a ratio can be calculated by dividing the MOG feedrate listed in the capacity table by the corresponding MOG feedrate of the reference combine listed in APPENDIX II for that particular crop.

Once capacity ratios for different evaluation combines have been determined for comparable crops, they can be used to approximate capacity differences. For example, if one combine has a capacity ratio of 1.2 times the reference combine and another combine has a capacity ratio of 2.0 times the reference combine, then the second combine is about 67% larger (2.0 - 1.2) / 1.2 x 100 = 67%).

TABLE 4. Average Workrates

		Average Yield		Average Workrates			
Crop	Variety	bu/ac	t/ha	ac/h	ha/h	bu/ac	t/h
Barley	Bonanza	60	3.3	7.3	3.0	440	9.6
	Herrington	65	3.5	8.1	3.3	630	11.6
	Johnston	45	2.4	8.6	3.5	390	8.5
Canola	Tobin	25	1.4	5.5	2.2	140	3.2
	Westar	25	1.4	11.6	4.7	170	3.9
Rye	Musketeer	30	1.9	8.9	3.6	170	4.3
Flax	Dufferin	35	2.2	5.8	2.4	200	5.1
Wheat	Columbus	30	2.0	12.0	4.9	360	9.8
Wheat	Katepwa	35	2.4	10.1	4.1	350	9.6
Wheat	Neepawa	30	2.0	11.3	4.6	340	9.3

A test combine can also be compared to the reference combine at losses other than 3%. The total loss curves for the test combine and reference combine are shown in the graphs in the following section. The shaded bands around the curves represent 95% confidence belts. Where the bands overlap very little difference in capacity exists; where the bands do not overlap a significant difference can be noticed.

PAMI recognizes that the change to the new Reference II combine may make it difficult to compare test machines which were compared only to the older Reference I. To overcome this, a capacity ratio comparing the test combine to Reference I is also given in the Summary Chart on the last page of the report. This ratio is based on two years of tests, which indicate that Reference II has about 1.50 to 1.60 times the capacity of Reference I in wheat and about 1.40 to 1.50 times Reference I's capacity in barley.

Capacity Compared to Reference Combine: Capacity of the Case IH 1660 was greater than that of the PAMI Reference II combine in both barley and wheat. The Case IH 1660 had about 1.40 times the capacity of the Reference II combine at 3% loss in Harrington barley, about 1.20 times its capacity at power limit in Columbus wheat and about 1.30 times its capacity at 3% loss in Katepwa wheat. FIGURES 7 to 9 compare the total losses of both combines in wheat and barley.

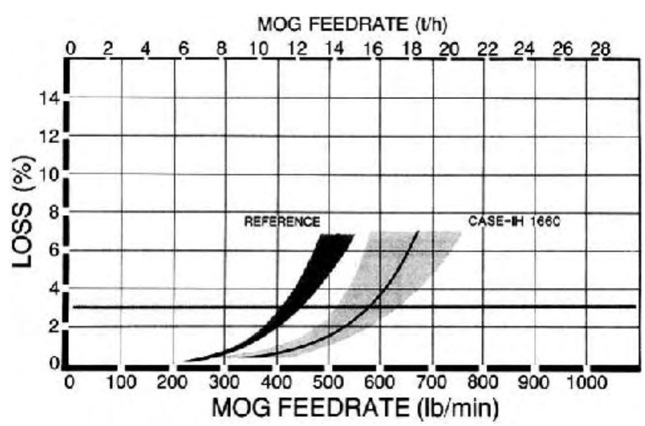


FIGURE 7. Total Grain Loss in Harrington Barley.

QUALITY OF WORK

Picking: Pickup performance was good. The pickup was normally operated at about a 30 degree angle with the ground. The picking speed was set just slightly faster than ground speed with the teeth just touching the ground. With these settings, crops in well supported windrows were picked cleanly at speeds up to 5 mph (8 km/h). In poorly supported windrows, the picking angle was reduced and pickup speed increased. In hard-to-pick conditions, pickup loss often increased noticeably at speeds over 3.5 mph (5.6 km/h).

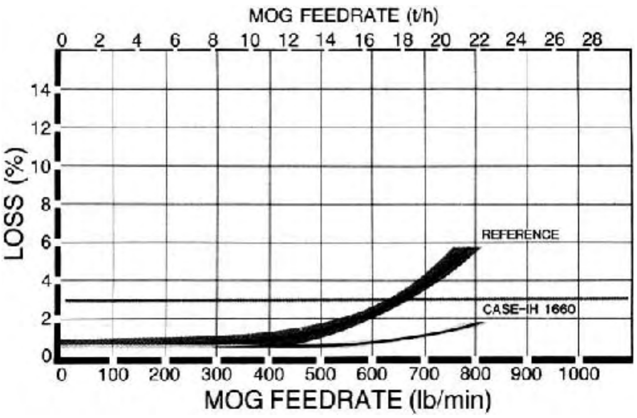


FIGURE 8. Total Grain Loss in Columbus Wheat.

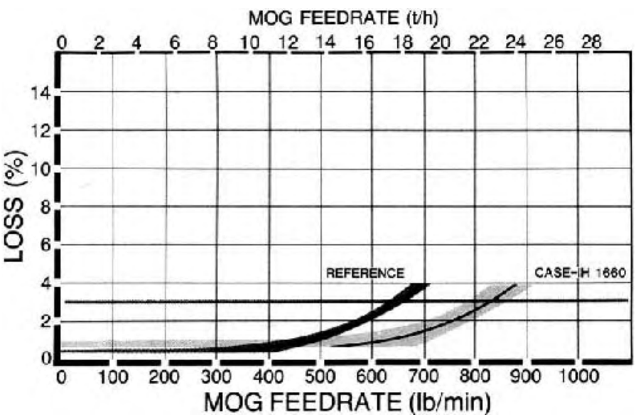


FIGURE 9. Total Grain Loss in Katepwa Wheat.

The pickup picked small stones when operating in hard-to-pick conditions.

Feeding: Feeding was good.

Feeding the windrow off centre with the feeder did not affect combine performance.

The table auger, which is larger than previous models, provided smooth flow of crop under the auger and to the feeder conveyor. The auger seldom plugged but did wrap in tough flax straw. Changing the auger finger timing did not stop the wrapping.

The feeder conveyor was aggressive and conveyed most crops without plugging. Although the conveyor handled dry canola well, it plugged frequently between the top conveyor shaft and rock beater in tough canola crops. This made harvesting tough canola nearly impossible.

Backfeeding down the top side of the feeder conveyor occurred occasionally in tough conditions, but seldom plugged the conveyor.

Stone Protection: Stone protection was good.

The stone trap was most effective if emptied regularly to prevent grain and dirt from hardening in the “trap”. The stone trap collected many stones and roots, which were driven into the pocket when contacted by the rock beater. Objects up to 4 in (102 mm) in diameter were often emptied from the trap. A full stone trap often caused backfeeding. Some roots and stones did go through the combine, but caused only minor damage to the concaves (FIGURE 10).

Threshing: Threshing was very good.

In most crops, rotor speeds used were similar or slightly higher than the cylinder speeds used for equivalent size cylinders in a conventional combine. Fairly close concave clearance was also used. With these settings, in dry conditions, crop flowed smoothly into and around the rotor. In tough or damp conditions, the crop throughput was decreased slightly due to the increased power required.

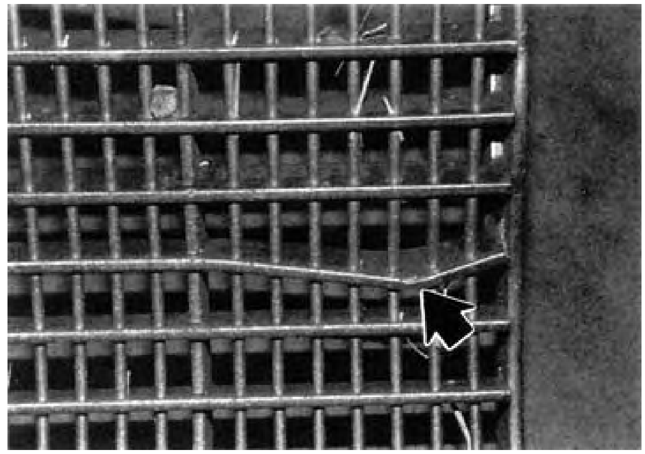


FIGURE 10. Concave Damage.

In all crops, the multiple pass threshing action maintained very low unthreshed loss over the entire operating range. Even in tough conditions, unthreshed loss was only a small part of the total loss. Reducing rotor speed and increasing concave opening increased unthreshed loss noticeably.

Even with the aggressive threshing, grain damage measured in the clean grain sample was low for all crops. Generally, changing rotor speed had little effect on grain damage, while changing concave opening had no effect.

TABLE 5 shows the settings PAMI found to be suitable for different crops.

TABLE 5. Crop Settings

Crop Settings										
Crop	Rotor Speed	Concave Setting Position	Chaffer Sieve Setting		Chaffer Extension Setting		Cleaning Sieve Setting		Fan Speed
	rpm		in	mm	in	mm	in	mm	rpm
Barley	800-900	3ww	7/8	22	5/8	16	1/2	13	700-850
Canola	700-800	4nw	1/2	13	5/8	16	1/16-1/8	2-3	600-700
Flax	900-1000	0nw	3/8	10	1/2	13	1/8	3	500
Rye	800-900	2nw	5/8	16	5/8	16	1/4	6	600-700
Wheat	1000-1100	0nw	5/8	16	3/4	19	1/4		800-860

nw -- narrow wire
ww -- wide wire

Separating: Separating was very good. In all crops, the crop flowed smoothly through the separating section. Plugging and bridging did not occur.

In barley, two wide wire threshing concaves were used. The transport vanes and separating grate channels were left in the factory set position. Rotor loss increased gradually with feedrate and was low at feedrates up to when shoe loss limited capacity. However, had shoe loss remained low then rotor loss would have limited capacity at higher feedrates.

In wheat, all three narrow wire threshing concaves were used. Rotor loss was very low over the entire operating range and did not limit capacity even in long straw wheat crops.

In canola and flax, the narrow wire threshing concaves were used. In canola there was always some rotor loss, although it did not limit capacity.

The settings used to achieve optimum separation in the different crops encountered are listed in TABLE 5.

Cleaning: Cleaning shoe performance was good.

In all crops, the material was delivered uniformly to the shoe. However, the cleaning sieve plugged several times, usually in wheat. After unplugging, the cleaning sieve was found to be almost closed. It was not determined if the adjustment had worked closed and caused the plugging or if the shoe had plugged first and forced the sieve closed. It is possible that material destined for the return was stopped by the “air dam” or more likely the rubber flap hanging from the chaffer (FIGURES 11 and 12). It is recommended that the manufacturer consider investigating the cause of the cleaning sieve's accidental closing and make modifications to either prevent the sieve from closing by itself or to prevent the cleaning sieve from plugging.

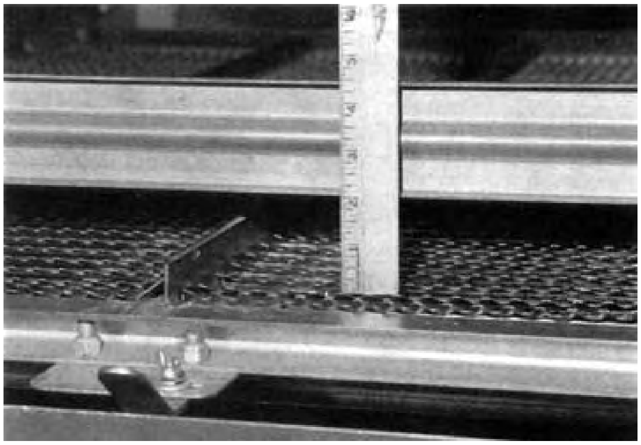


FIGURE 11. Air Dam Between Chaffer and Cleaning Sieves.

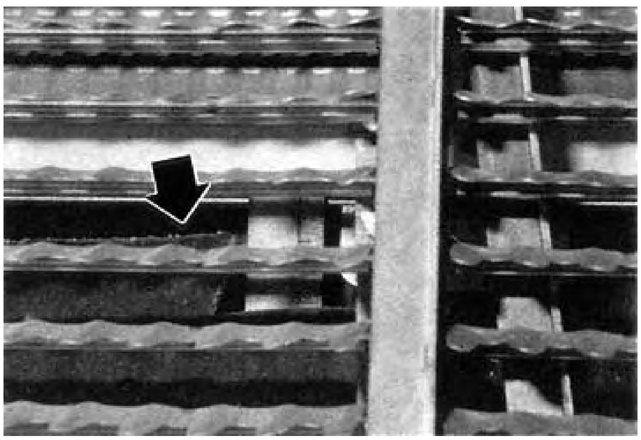


FIGURE 12. Rubber Flap From the Chaffer Sieve.

In barley, shoe loss was low over most of the operating range but became erratic at about 580 lb/min (15.8 t/h) of MOG. This sudden increase in shoe loss limited combine capacity. Although the MOG feedrate was not extremely high, the accompanying grain feedrate was well over 1000 bu/h (21.8 t/h), which is a high shoe load for most combines.

In wheat, shoe loss was low over most of the operating range. In Columbus, shoe loss was very low even at power limit. In Katepwa, shoe loss increased at the high feedrates so that at capacity it was about half of the total loss.

In flax and canola crops, shoe loss limited capacity. The shoe could be set to obtain low loss (less than 1%) in most of these crops.

In all crops, the Case IH 1660 had a clean grain sample when the shoe was set for minimal loss. The settings PAMI found suitable for the crops encountered are listed in TABLE 5.

Clean Grain Handling: Grain handling was very good.

The open grain tank filled evenly in all crops, although the top corners usually did not fill completely. A full tank of dry wheat held about 175 bu (6.4 m^3). No full bin sensors were provided and if overfilled, grain spilled over the front of the tank. It is recommended that the manufacturer consider supplying "full bin" warning sensors. The unloading auger was hydraulically positioned for unloading to the left. The hydraulic swing was useful for topping loads and unloading on-the-go. The unloading auger had ample reach and clearance for unloading into all trucks and trailers encountered (FIGURE 13). The auger discharged the grain in a compact stream and unloaded a full tank of dry wheat in about 110 seconds.

Straw Spreading: Straw spreading was poor.

In most conditions the straw from the rotor of the Case IH 1660 was severely broken and additional chopping was not required, The bat-type spreaders spread most of the straw evenly over about 12 to 15 ft (3.7 to 4.6 m) directly behind the combine (FIGURE 14). This was a narrow spread for the windrow width needed for this combine. It is recommended that the manufacturer consider modifications to improve straw spreading.

Chaff was not spread and the windrow formed when dropping the straw was generally not suitable for baling.

FIGURE 13. Unloading.

FIGURE 14. Straw Spreading.

EASE OF OPERATION AND ADJUSTMENT

Operator Comfort: Operator comfort was very good. The Case IH 1660 was equipped with an operator's cab positioned ahead of the grain tank and slightly left of center. The cab was easily accessible and quiet. However, the noise from the feeder chain was annoying. Incoming air was effectively filtered while fans pressurized the cab to reduce dust leaks. The heater and air conditioner provided comfortable cab temperatures. The seat and steering column were adjustable and provided a comfortable operating combination for most operators. Forward and side visibility was very good. The large convex rear view mirrors provided good rear visibility. View of the incoming windrow was partially blocked by the steering column (FIGURE 15). The view was improved if the operator leaned forward and to the right. This was still a comfortable operating position. Grain level visibility was restricted by the grain tank screen. Visibility while unloading was good.

Instruments: Instrumentation was good.

The instruments were located to the right of the operator and in the upper right corner of the cab (FIGURES 16 and 17). The instrument panel to the operator's right contained gauges for engine oil pressure, coolant temperature, battery voltage, fuel level and engine hours. It also contained an audio alarm and warning lamps for low engine oil pressure, excessive coolant temperature, and shoe and elevator drive speed reductions. A digital readout selectively displayed engine rpm, fan rpm, rotor rpm and ground speed. A separate continuous readout for engine rpm would have been useful.

The instrument panel in the upper right corner, had warning lamps and audio alarm for reduced speed of the clean grain elevator, tailing elevator, cleaning fan, feeder, rear beater, spreaders, shoe shake, and rotary air screen. The alarm set point for the rotor and fan was adjustable. The warning lamps for shaft speed reductions worked well but were inconvenient to observe while harvesting. This was annoying when momentary slowdowns in shaft speeds occurred. Although the alarm sounded, the warning lamps did not stay illuminated long enough for the operator to see which alarm had triggered. It is recommended that the manufacturer consider modifications to make the shaft speed monitor more convenient to view.

FIGURE 15. Operator's View of Incoming Windrow.

FIGURE 16. Instrument Panel to Right of Operator.

Controls: The Case IH 1660 controls were good.

Most of the controls were located to the right of the operator (FIGURE 16), a few to the left, and the rest on the steering column. Most of the controls were conveniently placed and easy to use.

The separator and header drives were engaged by toggle switches. These switches were protected from accidental engagement by detents. The switches had to be lifted to turn the drive on. The feeder reverser control switch worked in conjunction with the feeder drive switch. The header height control switch was located on the propulsion control lever. Although it was convenient to operate, the lift rate was slow. The propulsion control lever had annoying side-to-side free play, which gave a poor feel of control. Also, the tension adjustment could not be easily set for smooth fore-and-aft control. If the control lever was set to keep it from creeping back to neutral then its operation was stiff and jerky. It is recommended that the manufacturer consider modifications to reduce the side-to-side free play and to provide smooth positive operation of the propulsion control lever.

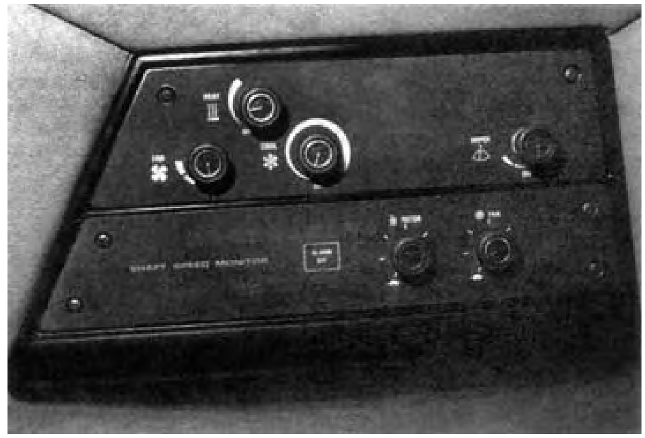


FIGURE 17. Shaft Speed Monitor in Upper Right Corner of the Cab.

The pickup speed could be either adjusted manually, or set to automatically maintain the same pickup to ground speed ratio. The automatic control worked well and was very convenient. Rotor speed and fan speed were adjusted by rocker switches. The unloading auger swing control on the steering column was convenient. The unloading drive lever was located to the left of the operator and was easy to use.

Loss Monitor: The loss monitor was very good.

Two grain loss sensor pads were located at the rear of the rotor and two at the rear of the chaffer sieve. The meter display was located to the right of the operator on the cab corner post and was convenient to observe (FIGURE 18). The grain loss monitor contained four sensor lights above the meter that signalled which sensor(s) were being activated. These lights did not indicate the amount of loss. However, a meter was also provided to indicate a relative loss from the shoe, rotor or both. Grain loss readings were meaningful only if compared to actual losses observed behind the combine.

Lighting: Lighting was very good.

Lighting for nighttime harvesting was provided by six field lights, a grain tank light, and an unloading auger light. The field lights provided long, medium, and short range forward lighting. The unloading auger light provided rear lighting when in the transport position. It also illuminated the auger and side of the truck and grain stream while unloading, regardless of auger position. The grain tank light effectiveness was reduced by the small holes in the grain tank screen. The instruments were well lit and a dimmer was provided to adjust the backlighting to personal preference. The road lights were adequate. The two tail lights and four warning lights aided in safe road transporting.

Handling: Handling was very good.

The Case IH 1660 was easy to drive and very maneuverable. Steering was smooth and responsive. The wheel brakes aided in cornering but were not required for picking around most windrow corners. The "foot-n-inch pedal" was helpful when combining bunchy windrows and also aided in shifting the transmission, which otherwise was often difficult to shift. The hydrostatic ground drive was very convenient for matching ground speed to crop conditions. It also made backing up on hard to pick corners quick and easy.

The combine was very stable in the field even with a full grain tank. Normal caution was needed when operating on hillsides and when travelling at transport speeds. The combine travelled well at speeds up to its maximum of 16.6 mph (26.7 km/h). However, while combining in some soil conditions, the combine vibrated noticeably. No cause or cure was found.

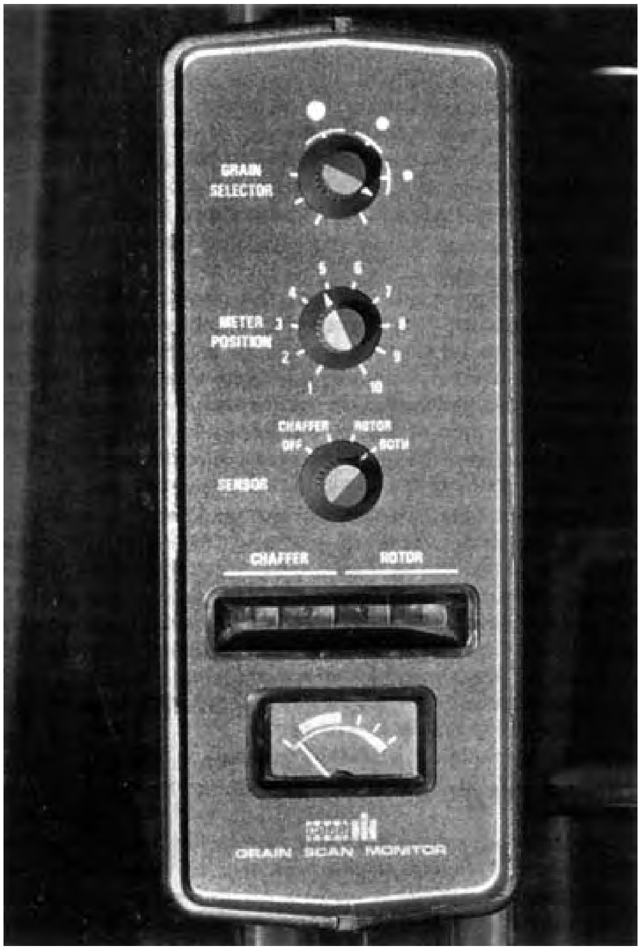


FIGURE 18. Grain Loss Monitor.

Adjustment: Ease of adjusting the combine components was good.

Pickup speed, rotor speed, and fan speed could be adjusted from within the cab while operating. Concave clearance, and shoe settings were located on the machine.

Auger finger timing, auger clearance and auger stripper bar adjustments were easily made to suit crop conditions and once set, did not have to be readjusted.

Adjusting concave clearance was easy. Changing threshing concaves for combining different crops was not difficult but was inconvenient. Changing the rear two concaves took about 20 minutes while changing all three took from 40 minutes to one hour.

The cleaning sieve was easy to adjust. However, the wing nut on the adjustment lever had to be tightened with a wrench to keep the lever from moving. This was inconvenient. It is recommended that the manufacturer consider modifications to provide convenient, positive cleaning sieve adjustment.

Field Setting: Ease of setting the Case IH 1660 to suit crop conditions was very good. Once initial adjustments had been made, usually little fine tuning was required.

Threshing was easy to set for in all crops. Since the combine was not equipped with a straw chopper, unthreshed losses could be easily checked. Separation was also easy to set for, especially when the spreaders were removed. The settings that provided optimum threshing were usually the same settings that provided optimum separating.

Setting the shoe for optimum performance was fairly easy. Shoe loss was easy to sample and the manufacturer's suggested settings were close. The operator had to be careful not to overload the shoe by over-threshing the crop as this made setting more difficult. No provisions were made for sampling the return. It is recommended that the manufacturer consider modifications to permit safe, convenient sampling of the return tailings while harvesting.

Unplugging: Ease of unplugging was good.

The power feeder reverser backed out most slugs from the table auger and feeder. However, a severe plug in the feeder often caused the feeder clutch to slip before the slug was backed out. When a severe plug occurred between the feeder chain top shaft and the rock beater, it was often easier to open the stone trap and to eject the slug by running the feeder forward.

Operating the reverser put heavy demands on the electrical system. This was most noticeable at night. As the reverser was engaged the lights dimmed substantially.

The rotor seldom plugged. If a plug did occur, it could usually be cleared by lowering the concave, putting the rotor drive into low gear and powering the slug through. If the slug could not be powered through, the concaves had to be partially removed and the slug cleared by hand. The slug wrench provided to rock the rotor did not help because the variable speed belt slipped.

Machine Cleaning: Cleaning the Case IH 1660 for harvesting seed grain was good.

Cleaning the grain tank was easy, but, cleaning the grain tank sump was difficult. The sieves were fairly easy to remove and provided access for cleaning the tailings and clean grain auger troughs. The shoe delivery auger troughs were accessible from the sides and could be cleaned using a vacuum. Chaff and dust that built up on top of the rotor cage and in front of the rotor housing was difficult to remove, unless a portable blower was used. The outside of the combine was easily cleaned.

Lubrication: Ease of lubrication was very good.

Daily lubrication was quick and easy. There were only a few lubrication points and most were easily accessible. The combine had 54 pressure grease fittings. Five required greasing at 10 hours, twenty-two at 50 hours, an additional sixteen at 200 hours and eleven more on an annual basis. Engine, gearboxes and hydraulic oil levels required regular checking.

The fuel inlet was 7.5 ft (2.3 m) above the ground and was difficult to fill from some gravity fuel tanks. Changing engine oil and filters was easy. **Maintenance:** Ease of performing routine maintenance was very good.

Most chains and belts were easily accessible for checking and adjusting tension. The engine was also easily accessible for inspection and service.

Although the rotary screen greatly reduced radiator plugging, the radiator had to be cleaned periodically. Gaining access to the radiator was difficult. The engine air filter restriction indicator indicated when the primary filter needed servicing.

Slip clutches protected the table auger, feeder, clean grain and tailings return drives.

ENGINE AND FUEL COMSUMPTION

The Navistar DT-466 diesel engine started easily and ran well. The engine operated at or near power limit in most crops. It provided adequate power to maintain its capacity in most conditions.

Average fuel consumption was about 5.9 gal/h (27 L/h). Oil consumption was insignificant.

OPERATOR SAFETY

The operator's manual emphasized operator safety. The Case IH 1660 had warning decals to indicate dangerous areas. All moving parts were well shielded and most shields were easily removed for easy access.

A header cylinder safety stop was provided. The stop should be used when working near the header or when the combine is left unattended.

If the operator is required to work in the header or other potentially dangerous areas, it is important that all clutches be disengaged and the engine shut off.

The combine was equipped with a slow moving vehicle sign, warning lights, signal lights, tail lights, road lights and rear view mirrors to aid safe road transport.

A fire extinguisher, class ABC should be carried on the combine at all times.

OPERATOR'S MANUAL

The operator's manual was very good. It was clearly written and well organized. It provided useful information on safety, controls, adjustments, crop settings, servicing, trouble-shooting, and machine specifications.

MECHANICAL HISTORY

The intent of the test was evaluation of functional performance. Extended durability testing was not conducted. However, TABLE 6 outlines the mechanical history of the Case IH 1660 for the 130 hours of field operation during which about 1183 ac (479 ha) of crop was harvested.

TABLE 6. Mechanical History

Item	Operating Hours	Field Area ac	(ha)
-An O-ring on a plug in the hydrostatic motor failed and was replaced at	10	83	(34)
-The oil seal between the engine and transmission started leaking at	29	260	(105)
-The header reverser chain broke and was replaced at	106	991	(401)
-The drive chain for the clean grain elevator came off and was replaced at	122	1122	(454)
-Several concave wires were damaged by small stones	During Test Season		

Oil Seal: The main seal between the engine and transmission started leaking slightly. The problem was not serious enough to have to be repaired during the test season.

APPENDIX I
SPECIFICATIONS

MAKE:	Case IH Self-Propelled Combine
MODEL:	1660
SERIAL NUMBER:	Header-001197 Body-016065 Engine-467TF2V1951501
MANUFACTURER:	J. I. Case Company 700 State Street Racine, Wisconsin 53404 U.S.A.
WINDROW PICKUP:	
-- make	Case IH
-- type	belt
-- pickup width	13 ft (4.0 m)
-- number of belts	7
-- type of teeth	plastic
-- number of rollers	2
-- height control	castor wheels
-- speed control	hydrostatic
-- speed range	0 to 534 ft/min (0 to 2.71 m/s)
HEADER:	
-- type	centre feed
-- width	
- table	13 ft (4.0 m)
- feeder house	34.5 in (880 mm)
-- auger diameter	23.25 in (590 mm)
-- feed conveyor	2 roller chains, undershot slatted conveyor
-- conveyor speed	8.2 ft/s (2.5 m/s)
-- range of picking height	-39.5 in to 41 in (-1000 mm to 1040 mm)
-- number of lift cylinders	2
-- raising time	6s
-- lowering time	adjustable
-- options	rigid header, flex header, corn heads, auto header height control, accumulator, auto feeder shutoff
STONE PROTECTION:	
-- type	travel limited front feeder drum and a power driven three winged beater
-- ejection	manually open and close trap door
ROTOR:	
-- number of rotors	1
-- type	longitudinally mounted, closed tube with parallel and spiral rasp bars at front portion and 3 parallel smooth bars at rear portion
-- diameter	
- tube	19.5 in (492 mm)
- feeding	34 in (860 mm)
- threshing	24.5 in (622 mm)
- separating	22 in (562 mm)
-- length	
- feeding	20.25 in (515 mm)
- threshing	43 in (1095 mm)
- separating	46 in (1165 mm)
- total	109 in (2770 mm)
-- drive	electrically controlled variable pitch belt through 2 speed gearbox
-- speeds	
- low	250 to 611 rpm
- high	470 to 1190 rpm
-- options	specialty rotor
CONCAVE (THRESHING):	
-- number	3
-- type	bar and wire
-- number of bars	23 each
-- configuration	
- narrow space	22 intervals with 0.19 in (4.8 mm) wires and 0.23 in (6 mm) spaces
- wide space	22 intervals with 0.25 in (6.4 mm) wires and 0.55 in (14 mm) spaces

-- area	WIDE	NARROW
- concave total	1339 in² (0.86 m²)	1339 in² (0.86 m²)
- concave open	749 in² (0.48 m²)	605 in² (0.39 m²)
- open area	55%	45%

-- wrap	140 degrees
-- grain delivery to shoe	4 auger conveyors
-- options	filler bars
CONCAVE (SEPARATING):	
-- number	3, plus perforated upper cage
-- type	perforated formed metal
-- area total	2434 in² (1.57 m²)
-- area open	691 in² (0.45 m²)
-- open area	30%
-- wrap	280 degrees
-- grain delivery to shoe	4 auger conveyors
-- options	square bar grates
THRESHING AND SEPARATING CHAMBER:	
-- number of spirals	12
-- pitch of spirals	22 degrees
DISCHARGE BEATER:	
-- type	3 wing triangle
-- speed	800 rpm
SHOE:	
-- type	opposed action
-- speed	260 rpm
-- chaffer sieve and tailing sieve	adjustable lip, 2635 in² (1.70 m²) with 2.25 in (57 mm) throw
-- tailings sieve	adjustable lip, 465 in² (0.30 m²)
-- clean grain sieve	adjustable lip, 2330 in² (1.50 m²) with 1.25 in (32 mm) throw
-- options	straw chopper chaffer sieves - 1-1/8 in (29 mm) regular tooth - 1-5/8 in (41 mm) deep tooth - 1-1/8 in (29 mm) Petersen - 1-5/8 in (41 mm) Close slat round hole sieves - 1/10 in (3 mm), 7/32 in (6mm) - 3/8 in (10 mm), 1/2 in (13 mm) Alfalfa Package, Side Hill Grain Pan Dividers
CLEANING FAN:	
-- type	6 blade undershot
-- diameter	23 in (585 mm)
-- width	33.7 in (855 mm)
-- drive	electrically controlled variable pitch belt
-- speed range	440 to 1400 rpm
-- options	slow speed kit, inlet shields
ELEVATORS:	
-- type	roller chain with rubber flights
-- clean grain (top drive)	6 x 12 in (152 x 305 mm)
-- tailings (top drive)	6 x 8 in (152 x 203 mm)
-- options	steel flights, perforated screens
GRAIN TANK:	
-- capacity	174 bu (6.3 m³)
-- unloading time	109 s
-- unloading auger diameter	11.25 in (285 mm)
-- unloading auger length	195 in (4950 mm)
-- options	perforated unloader tube, longer tube
STRAW SPREADER:	
-- number of spreaders	2
-- type	steel hub with 6 rubber bats
-- speed	240 rpm
-- options	straw chopper
ENGINE:	
-- make	Navistar
-- model	DT-466B
-- type	4 stroke, turbo-charge, after cooled
-- number of cylinders	6
-- displacement	466 in³ (7.6 L)
-- governed speed (full throttle)	2690 to 2770 rpm
-- manufacturers rating	180 hp (134 kW)
-- fuel tank capacity	75 gal (340 L)
CLUTCHES:	
-- header	electro-hydraulic
-- separator	electro-hydraulic
-- unloading auger	over center belt tightener
-- traction drive	hydraulic valve (foot-n-inch pedal)

NUMBER OF CHAIN DRIVES:	8
NUMBER OF BELT DRIVES:	12
NUMBER OF GEARBOXES:	4
LUBRICATION POINTS:	
-- 10 hr	5
-- 50 hr	22
-- 100 hr	16
-- annually	11
TIRES:	
-- front	23.1 x 26 R1
-- rear	11 x 16F2
TRACTION DRIVE:	
-- type	hydrostatic
-- speed ranges	
- 1st gear	0 to 3.4 mph (0 to 5.5 km/h)
- 2nd gear	0 to 6.3 mph (0 to 10.1 km/h)
- 3rd gear	0 to 16.6 mph (0 to 26.7 km/h)
-- options	adjustable axles, wheel spacers, drive tracks, weights, axle extensions, platform ladder extensions, powered rear axle
OVERALL DIMENSIONS:	
-- wheel tread (front)	9.0 ft (2.7 m)
-- wheel tread (rear)	6.5 ft (2.0 m)
-- wheel base	11.5 ft (3.5 m)
-- transport height	13.0 ft (3.9 m)
-- transport length	31.8 ft (9.7 m)
-- transport width	18.9 ft (5.8 m)
-- field height	13.0 ft (3.9 m)
-- field length	31.4 ft (9.6 m)
-- field width	18.9 ft (5.8 m)
-- unloader discharge height	12.8 ft (3.9 m)
-- unloader reach	6.7 ft (2.0 m)
-- unloader clearance	13.1 ft (4.0 m)
-- turning radius	
- left	20.3 ft (6.2 m)
- right	21.0 ft (6.4 m)
WEIGHT (EMPTY GRAIN TANK):	
- right front wheel	7862 lb (3566 kg)
- left front wheel	8633 lb (3916 kg)
- right rear wheel	2775 lb (1259 kg)
- left rear wheel	2775 lb (1259 kg)
TOTAL	22045 lb (10000 kg)

PAMI REFERENCE COMBINE CAPACITY RESULTS

APPENDIX II

PAMI REFERENCE COMBINE CAPACITY RESULTS

TABLE 7 and FIGURES 19 and 20 present the capacity results from the PAMI reference combines in barley and wheat crops harvested in 1984 to 1986.

FIGURE 19 shows capacity differences in barley crops for 1984 and 1986. The 1986 Harrington barley crop shown in TABLE 7 had lower than average straw yield and slightly lower than average grain yield. It also had slightly below average straw and grain moisture.

FIGURE 20 shows capacity differences in wheat crops for the two years. In 1986 the Katepwa wheat crop had higher than average straw yield, and average grain yield. It also had average grain moisture and slightly below average straw moisture content.

Results show that the reference combine is important in determining the effect of crop variables and in comparing capacity results of combines evaluated in different years.

TABLE 7. Capacity of the PAMI Reference Combines at a Total Grain Loss of 3% Yield

	Crop Conditions									Capacity Results							
			Width of Cut		Crop Yield		Moisture Content		MOG/G	MOG Feedrate		Grain Feedrate		Grain Cracks	Dockage	Foreign Material	Loss
	Crop	Variety	ft	m	bu/ac	t/ha	Straw %	Grain %	Ratio	lb/min	t/h	bu/h	t/h	%	%	%	Curve
REF II	Barley	Harrington[1]	56	17.0	62	3.3	10.5	10.8	0.64	424	11.6	828	18.1	0.4	0.3	0.2	19
	Wheat	Columbus[1]	56	17.0	51	3.4	8.8	16.7	1.14	647	17.7	568	15.5	1.5	4.6	3.5	
	Wheat	Katepwa	29	8.9	49	3.3	6.5	14.0	1.32	644	17.6	488	13.3	1.8	1.7	1.0	20
	Barley	Bonanza[1]	42	12.8	52	2.8	15.0	11.2	0.70	363	9.9	648	14.1	0.5	1.0		19
	Barley	Bonanza	24	7.3	77	4.1	11.3	11.6	0.66	352	9.6	687	14.6	0.5	1.0		
	Wheat	Neepawa[1]	44	13.4	36	2.4	6.3	10.9	1.32	539	14.7	408	11.1	1.1	5.5		20
	Wheat	Neepawa	22	12.8	44	3.0	8.7	10.2	1.18	601	16.4	509	13.9	4.5	7.0		
REF I	Barley	Harrington	28	8.5	59	3.7	10.5	9.2	0.56	294	8.0	656	14.3	0.8	0.5	0.2	
	Wheat	Columbus[1]	42	12.8	32	2.2	11.8	14.7	1.09	438	12.0	402	11.0	1.2	4.9	3.0	
	Wheat	Katepwa	29	8.9	50	3.4	7.5	14.1	1.33	420	11.5	316	8.6	1.3	1.5	0.7	
	Barley	Argyle[1]	60	18.0	75	4.0	25.5	11.4	0.94	293	8.0	390	8.5	2.0	1.0	0.4	
	Barley	Bonanza[1]	55	16.8	83	4.5	21.0	15.0	0.76	285	7.7	469	10.2	1.0	1.7	1.2	
	Wheat	Neepawa[1]	42	12.8	42	2.8	23.7	18.0	1.43	391	10.7	273	7.5	4.9	2.3	0.2	
	Wheat	Katepwa[1]	41	12.5	82	4.2	24.8	18.5	0.95	435	11.9	458	12.5	2.5	1.3	0.2	
	Barley	Bonanza[1]	42	12.8	68	3.7	18.5	12.9	0.74	275	7.5	464	10.1				
	Barley	Bonanza	24	7.3	85	4.8	12.0	12.1	0.62	213	5.8	429	9.4				
	Wheat	Neepawa[1]	44	13.4	42	2.8	6.7	11.8	1.47	308	8.4	209	5.7				
	Wheat	Neepawa[1]	42	12.8	41	2.8	8.5	10.3	1.17	356	9.7	304	8.3				
	Wheat	Neepawa[1]	42	12.8	23	1.8	7.2	12.5	0.99	345	9.4	348	9.5				

[1]Side by side double windrows

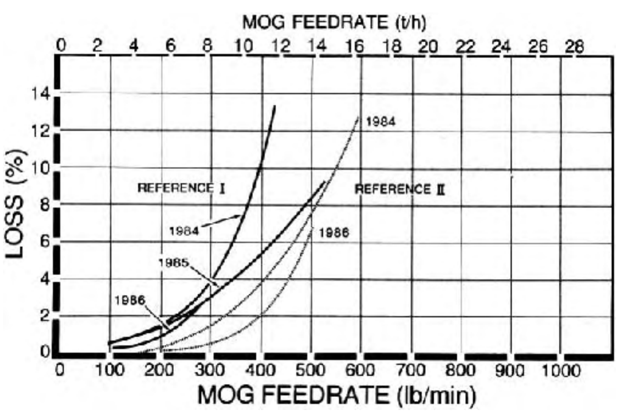


FIGURE 19. Total Grain Loss for the PAMI Reference Combines in Barley.

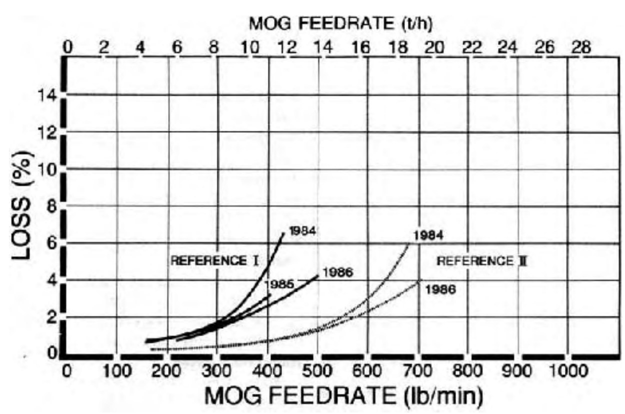


FIGURE 20. Total Grain Loss for the PAMI Reference Combines in Wheat.

APPENDIX III
REGRESSION EQUATIONS FOR CAPACITY RESULTS

Regression equations for the capacity results shown in FIGURES 4 to 6 are presented in TABLE 8. In the regressions, U = unthreshed loss in percent of yield, S = shoe loss in percent of yield, R = rotor loss in percent of yield, F = the MOG feedrate in lb/min, while $\ln$ is the natural logarithm. Sample size refers to the number of loss collections, Limits of the regressions may be obtained from FIGURES 4 to 6 while crop conditions are presented in TABLE 3.

TABLE 8. Regression Equations

Crop - Variety	Figure Number	Regression Equations	Simple Correlation Coefficient	Variance Ratio	Sample Size
Barley - Harrington	2	$\ln U = -5.66 + 6.73 \times 10^{-3} F$ $S = -0.11 + 3.401 \times 10^{-14} F^5$ $\ln R = -4.44 + 7.74 \times 10^{-3} F$	0.86 0.72 0.96	38.15[2] 15.56[2] 236.70[2]	8
Wheat - Columbus	3	$U = 0.17 + 5.89 \times 10^{-5} F$ $S = -0.06 + 7.45 \times 10^{-4} F$ $R = -0.19 + 1.21 \times 10^{-3} F$	0.08 0.63 0.80	0.54 10.18[1] 24.38[2]	8
Wheat - Katepwa	4	$U = 0.02 + 4.51 \times 10^{-4} F$ $S = -0.004 + 2.67 \times 10^{-9} F^3$ $\ln R = -2.74 + 3.30 \times 10^{-3} F$	0.77 0.70 0.88	17.17[2] 00.89[2] 36.45[2]	7

[1]Significant at $P \leq 0.05$
[2]Significant at $P \leq 0.01$

APPENDIX IV
MACHINE RATINGS

The following rating scale is used in PAMI Reports:

excellent	fair
very good	poor
good	unsatisfactory

SUMMARY CHART

CASE IH 1660 SELF-PROPELLED COMBINE

RETAIL PRICE	$135,126.00 (May, 1987, f.o.b. Humboldt, Sask.)
CAPACITY	
Compared to Reference	
Combine - barley	1.40 x Reference II, 2.0 x Reference I
- wheat	1.20 to 1.30 x Reference II, 1.85 to 2.00 x Reference I
MOG Feedrates	
- barley - Harrington	585 lb/min (16.0 t/h) at 3% total loss, FIGURE 2
- wheat - Columbus	800 lb/min (21.8 t/h) at 3% total loss, FIGURE 3
- Katepwa	825 lb/min (22.5 t/h) at 2% total loss, FIGURE 4
QUALITY OF WORK	
Picking	**Good;** picked cleanly, fed crop smoothly under table auger
Feeding	**Good;** handled dry crops but plugged in tough canola straw
Stone Protection	**Good;** small stones caused minor concave damage
Threshing	**Very Good;** aggressive, low unthreshed losses
Separating	**Very Good;** changing concaves was inconvenient
Cleaning	**Good;** losses unstable at high feedrates in barley
Grain Handling	**Very Good;** unloading system was fast and convenient
Straw Spreading	**Poor;** spread up to 15 ft (4.6 m)
EASE OF OPERATION AND ADJUSTMENT	
Comfort	**Very Good;** quiet cab, adequate seat and steering adjustment
Instruments	**Good;** upper console difficult to observe
Controls	**Good;** propulsion control lever hard to adjust for operation
Loss Monitor	**Very Good;** useful if reading compared to actual loss observed
Lighting	**Very Good;** good long range visibility
Handling	**Very Good;** easy to maneuver
Adjustment	**Good;** lower sieve adjustment inconvenient
Setting	**Very Good;** little fine tuning required
Unplugging	**Good;** feeder reverser worked well
Cleaning	**Good;** cleaning internal components was difficult
Lubrication	**Very Good;** few daily lubrication points
Maintenance	**Very Good;** easily accessible
ENGINE AND FUEL CONSUMPTION	
Engine	**Very Good;** ran well, adequate power
Fuel Consumption	5.9 gal/h (27 L/h)
OPERATOR SAFETY OPERATOR'S	All moving parts well shielded
MANUAL MECHANICAL HISTORY	**Very Good;** contained much useful information A few mechanical problems

ALBERTA FARM MACHINERY RESEARCH CENTRE
3000 College Drive South
Lethbridge, Alberta, Canada T1K 1L6
Telephone: (403) 329-1212
FAX: (403) 329-5562
http://www.agric.gov.ab.ca/navigation/engineering/afmrc/index.html

Prairie Agricultural Machinery Institute
Head Office: P.O. Box 1900, Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-2555

Test Stations:
P.O. Box 1060
Portage la Prairie, Manitoba, Canada R1N 3C5
Telephone: (204) 239-5445
Fax: (204) 239-7124

P.O. Box 1150
Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-5033
Fax: (306) 682-5080