AN INVESTIGATION INTO COMBINE HARVESTER FIRES

A REPORT by Dr GRAEME R QUICK
Revised & Enlarged November 10, 2010

An investigation funded by the Grains Research and Development Corporation. This report was prepared by Dr Graeme R Quick.

HARVESTER FIRES

EXECUTIVE SUMMARY

Australian broadacre harvest conditions are arguably the most hazardous in the world for fires. Each year there are hundreds of harvester fire incidents and approximately a dozen half-million dollar-plus machines burnt to the ground at harvest. In some instances there are associated crop losses as well. Altogether the costs of harvester fires are substantial. Insurers are stepping up their insurance premiums on harvest machinery, in a land that has extreme fire hazards with the mix of combustible material, heat, often low humidity and wind at the harvest season. A spate of harvester fires on Yorke Peninsula in South Australia in the'09/'10 harvest season triggered farmer, Police, and Country Fire Authority reactions. That included calls for harvester designers to do something to minimise harvester fire hazards. GRDC instigated an investigation of the issues around harvester fires. This report and an Ag Bureau meeting followed.

It is estimated that three-quarters of harvester fires emanate from the engine bay. Others are initiated by problems with failed bearings, or brakes, electricals, rock strikes etc. *The key to avoiding harvester fires is diligence in cleandown and inspection - and, in the highest fire risk periods, to postpone paddock work.*

Static electricity builds up on operators and machinery in low-humidity atmospherics and is frequently blamed as a cause of harvester fires. Drag chains may reduce static charge, but the evidence however does *not* support static electricity as a prime cause of harvester fires. Certainly the adoption of plastic panels on modern harvesters has not aggravated the fire issue, despite vociferation to the contrary. Manufacturers and after-market suppliers provide the means to minimize the risk of harvester fires, as detailed here. The greatest need is vigilance and equipment operator diligence in a fire-prone environment.

This report addresses the issues and details hazard-recognition, procedures and equipment to avoid harvester fires.

GRAINS RESEARCH AND DEVELOPMENT CORPORATION

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1. Project Preamble: There was a spate of harvester fires in the immediate past harvest season on the Yorke Peninsula in South Australia. Concerns about those fires triggered farmer, Police, and Country Fire Authority reactions. That included demands for harvester designers to do something to minimise harvester fire hazards. There were a number of fires in previous seasons, but the 2009 season had two exceptionally hot and low humidity weeks that resulted in a breakout of eight harvester fires in that period (Munzer, CFS, Personal Communication). There are perceptions that the number of fire incidents is increasing. Machines of all brands are implicated. Some operators have formed the opinion that static electricity (SE) on low humidity days is the prime cause.

The CFS in SA is following that line as well. There are reasons to believe that Static Electricity is *not* a prime cause.
Whatever the cause, the costs of harvester fires in terms of crop loss and of machinery are extensive. It is possible that there are around one in one hundred harvester fires that have totalled harvesters, requiring replacement of machines, probably at the rate of a dozen a year. On the other hand, many harvester fires go unreported, for example in the instance of spot fires quickly extinguished by the operators.
So far no lives have been lost due to *combine harvester* fires, fortunately.
More than sixty people were visited or interviewed in the pursuit of this project.
A number of causes were identified and some remedial measures are listed, along with illustrations of steps taken by manufacturers to reduce harvester fire risks. Many operators are concerned about increases in Insurance coverage for harvester fires.

2. Project Objectives:

1. To canvass professional advice and industry opinions about combine fires and about static electricity in particular, as that may relate to combine harvester fires.
2. Contact the five makers of harvesters that are sold in Australia for their opinions : namely Deere, Case, New Holland, Claas and Agco.
3. To conduct a limited investigation of harvester fires in two regions, Southern Queensland/NNSW and on the Yorke Peninsular of S Australia.
4. Maintain independence from any one company in reporting.
5. Endeavour to get some statistics about harvester fires.
6. Prepare a report and a set of recommendations for reducing the impact and consequences of combine harvester fires.

3. What causes harvester fires ?

The following three conditions are needed for a fire to take hold:

• Some material is heated to its ignition temperature and minimum ignition level of energy (MIE).
• There is an adequate supply of oxygen (air).
• There is a propagation path for the fire. Fire is possible under many initiating conditions, but conditions are often unsuitable to *propagate* a fire.

While the greater majority of fire incidents encountered in this survey were due to mechanical factors, particularly exhaust area initiations and bearing failures, there are four essential field factors:

H.A.W.C. The four primary field conditions that set up for a harvester fire are:

- **Relative Humidity**
- **Ambient Air Temperature***
- **Wind Speed**
- **Crop Type and Condition.**

** Note incidentally that combine fires are known to occur at freezing temperatures. Recently, a harvester and crop was burnt starting from a combine at sub-zero temperatures when harvesting sunflowers in South Dakota. The relative humidity at the time was extremely low. Dry corn in the US midwest is also susceptible to harvester-initiated fires at freezing temperatures.*

Potential sources of ignition:

- Hot engine and especially exhaust components, overheated bearings and brakes etc

- Friction from crop wrapping or packing
- Mechanical failures (bearing, A/C compressor, etc…)
- Electrical short circuits
- Striking field stones or rocks - outside or up inside the machine
- Ingestion of foreign objects into machine processing systems
- Careless use by personnel of smoking materials, and
- Possible Spontaneous Combustion of crop material over time.

Change in farming practices that contribute to higher fire risks:

- *Desiccating crops.* 'Spraying out' practically eliminates green crop materials and green weeds from going through machine; this is beneficial for uniform crop maturity at harvest, but that green material might otherwise have dampened fire risks
- *Changes in cropping patterns* – particularly in South Australia, with the expansion of more combustible varieties such as lupins and pulses, although chick pea growing has declined. These leguminous crops generate fibrous dust that clings to other dust particles and machine components to cause accumulation of debris around the machine. When debris forms or clumps on hot exhaust components, embers can form and are blown off by the engine cooling fan blast to random areas on the machine. One customer reported that he could form a "snowball" of chick pea dust that would bind together – something he could not do with wheat dust.

The latest model harvesters are bigger and more productive machines that can handle higher volumes of crop. This means more horsepower (600 HP headers are on the market). Added to that, Tier 3 and 4 emission controls result in more heat rejection.

Figs 1, 2. Combine Harvester fires afflict all brands. Right: The heat from this fire in an 8020 harvesting chick peas was so intense that both axles sagged and bent out of shape.

Fig 3. This Claas Lexion was destroyed when a failed bearing at the front set fire to the machine with such intensity and speed that the operator barely had time to jump clear. On Paul White's property at Edgeroi, NSW.

Fig 4. Brian Lanzen, Manager, Product Safety, Deere & Co., visited from the Corporate headquarters of Deere in Moline and brought invaluable expertise to the study. Here he talks to Ron Clancy (left) in Clancy's Parts yard in Toowoomba.

4. General Observations from the Visits, Machine Inspections and Interviews.

1. Harvesters work in a high fire risk environment. But some crops are more susceptible than others to promoting fires ; *chick peas*, sunflowers and *lentils* top the list on the mainland. *Pyrethrum,* grown in Tasmania, was said to be the worst for fires, but this crop was not sighted.
2. The costs of any harvester fire incident are high, since combines are the single most highly-capitalised item on a farm, aside from land. One of the latest model machines is retailing at close to *one million dollars*, that includes the draper gathering front and header trailer.
3. Record-keeping and Statistics on Harvester Fires are inadequate, the numbers that are bandied around may not be accurate and could be misleading or cause problems for the farm community and harvester contractors if in the wrong hands. South Australia's CFS / SAFF is involved with a project to try and better quantify the facts behind harvester fires.
4. Some organisations and farmer/operators blame Static Electricity as a prime cause of harvester fires; this project found no evidence to support Static Charge as a prime cause.
5. There is no doubt that Static Electricity builds up on parts of combines under some conditions, but it is concluded that it is *highly improbable as a primary cause* of fires.
6. Citing Static Electricity as source of harvester fires has a number of ramifications, and has a bearing on combine design. It is certainly of relevance to insurance claims. Blaming Static Electricity could distract attention from other causes.
7. The number of ideas about how to minimize combine fires is legend. Just exactly how to eliminate Static Electricity is more complex than the psychological prop of hanging one or more earth straps or chains from the machine. A number of operators deploying chains and conductor straps still reported getting a shock from the harvester body. Note that an operator also builds up a charge on himself in low humid conditions.
8. The total number of combine harvester events involved in fires each season is significant – more than half of the operators interviewed reported fire incidents, but the number actually burnt out is a fractionally small proportion of the fleet out there.
9. It appears likely that there may be half a dozen harvesters burned out or totaled for insurance purposes each year from the new machines sold in Australia. Then ther are around another half dozen older machines that are totaled. If so, that would be almost 1 in 100 burnt out. Based on a very limited sampling, the number burnt out from *the total* combine fleet on farms is also estimated to be about one in a hundred (Author's estimates). The total number of fire incidents however, is higher. Most of the operators that I have interviewed have been involved in harvester fire *incidents* during their career, most incidents go unreported.

10. The relative proportion of fire incidents on combines may be rising somewhat, but that could simply be due to the increasing capacity (Workload in Tonnes/hour X Separator hours) of modern machines with their bigger engines and greater heat load. In South Australia's Yorke Peninsula district, the increase in fire incidents is also attributed to the large expansion in lentil production in recent years. This crop barely reaches 300 mm in height, so it requires harvesting low to the ground to gather the pods. Lentil harvest generates liberal amounts of sticky dust. Flinty rocks increase the chances of fires at the front.

11. Several operators complained that there had been an almost overnight escalation of the insurance excess on their harvester premiums - for example a jump from $2000 to $8000 - and that without warning. There are also some misleading survey requirements imposed on owners in their insurance renewals. This situation merits investigation and perhaps education of both operators *and* Insurance people.

12. Harvesting low enough to gather such a low-growing crop as lentils inevitably results in stone strikes. Some stones can cause sparks when struck by metallic harvester front components, such as the skid plates or even the sickle bar. Sparks from this cause have caused fires. One farmer named near Roseworthy was reported to be regularly having fires from this cause. Drag chains were also named as a potential *cause* of such fires – they can initiate sparks when used in stoney fields or if dragged on roadways.

5. Dessication. Many such crops are dessicated -"sprayed out" - with a chemicals such as Roundup etc; boomsprayed with the intent of speeding maturity, but more to ensure even ripening of the crop for imminent harvest. It was reported that the effect of this was to cause more dust and sticky material that is even more inclined to settle on surfaces than if the crop was not sprayed out. This tacky dust material was said to be more combustible in lentils**.** Dessication reduces risks of plugging the harvester, while also practically eliminating harvesting green crop and weed material that might otherwise have dampened fire risk.

6. ***Critical importance of hygiene.*** Chick peas and lentils were stated to be so fire-prone that some operators said it was necessary to blow down the machine even as often as 'half a round', or else have a fire fighting unit following the combine in case of fire.

Figs 5 A,B,C. Photos courtesy Kym Flint, Larwoods, Case Kadina, showing extent of dust when harvesting lentils. That's a trailed chaff cart on back.

7. Why has Electrostatic Charge loomed large in the thinking of a number of operators ?

A. Because there's no question that harvester or header components can carry a charge, especially in the often low-humidity atmospheric conditions in South Australia. And when a ladder for example is first touched, the operator often experiences a shock.

B. There is a perception that Electrostatic Discharge is more common nowadays. This can be nailed down to the predominance of rotary combines (more friction than walkers) and particularly to the greater amount of crop flowing through and the greater workload of these machines. That can be added to the increased acreage of dust-prone crops like lentils that tend to adhere more readily to the machines so readily and more visibly. Thus it is understandable - even if inaccurate - to nail ESD as the prime cause of harvester fires. There are more plastic panels on the latest generation of rotaries and this increases the *perception* that ESD is a cause. People need to be reminded however that these " plastics" are in fact not readily ignited and in the absence of a continuous source of fire they self-extinguish. They are also insulators electrically.

8. A RATIONAL CONSIDERATION OF ELECTROSTATIC DISCHARGE IN RELATION TO HARVESTERS:

1. Controlled environment tests by Chilworth Global in New Jersey have been carried out on finely-ground crop residues (<75µm fineness). It was found that the Minimum Ignition Energy required was 500 milliJoules in a <u>continuous arc</u>. See Appendix #1, #4.
2. The energy in an electrostatic spark from a harvester may not exceed around 150 milliJoules. Even at 500 mJ, a <u>spark</u> (unlike a continuous arc) did *not* ignite crop dust in air in the controlled experiments.
3. Unless there are volatile gasoline vapours present, it is highly improbable that there is sufficient discharge energy from an ESD source to ignite crop materials on a combine.
4. *Therefore there have to be other sources of ignition found that cause spot fires on combines.*

9. The most common cause of harvester fires is material collecting on hot engine components such as the manifold, exhaust and turbocharger. *Crop materials collecting or clumping on those components can ignite, then embers can drop down or are blown around the machine and into crop to cause spot fires or smouldering.* The temperatures out of a diesel engine exhaust pipe can be between 540 – 650 degrees C. Surface temperatures on these components can approach 500 degrees C. Crop residues can ignite at temperatures above 200 degrees C. Insulating muffs can bring the surface temperature on the exhaust down to 250 degrees C or somewhat less.

Caution: There is a possibility that such a wrapping muffs could lead to overheating of a Turbocharger's bearings. Yet to be endorsed by Combine makers. *See section 13 below.*

Fig 6. An aftermarket insulating shield or muff on a Case AFX header that encloses the exhaust pipe and turbocharger, similar to units used in marine applications. (Product Source: COLPRO, Pendle Hill ,NSW. www.colpro.com.au)

Shutske'e work on Combine Fires in N America*.* John Shutske in Minnesota has examined records of some 9000 combine fires over a period of fifteen years. He found that 77% of those fires emanated from the engine and engine bay. *My work, although nowhere near as extensive, endorses those findings.* Shutske emphasizes the need for preparation and prevention activity to minimize fire hazards.

10. The Grain Harvesting Voluntary Code of Practice in South Australia.

This was designed by the South Australian Country Fire Service (CFS) and SA Farmers Federation (SAFF) with the State Emergency Service (SES), as a basis for a *voluntary* District Harvesting Code of Practice. It applies to the harvesting of any flammable crop. It requires that grain harvesting practices be suspended whenever the local actual Grassland Fire Danger Index (GFDI) exceeds 35. It requires a knowledge of the local weather conditions: namely Temperature, Relative Humidity and Wind speed.

THE GRASSLAND FIRE DANGER INDEX (GFDI):

Grain Harvesting Code of Practice

Grain Harvesting Operations table

The table below calculates the average wind speed¹ (kilometres per hour) for different temperature (degrees Celsius) and relative humidity (RH) combinations that equate to a GFDI of 35.

GRAIN HARVESTING OPERATIONS MUST CEASE FOR PERIODS WHEN THE AVERAGE WIND SPEED¹ FOR A PARTICULAR COMBINATION IS EXCEEDED.

Is the wind speed too high for me to harvest right now?

TEMP °C	5	10	15	20	25	30	40	50	60	65	RH%*
15	31	35	38	40	43	45	49	53	56	58	AVERAGE WIND SPEED (KPH)
20	29	33	36	38	40	43	46	50	53	55	
25	27	30	33	36	38	40	44	47	50	52	
30	25	28	31	33	35	37	41	44	47	49	
35	23	26	28	31	33	35	38	41	44	46	
40	21	24	26	28	30	32	35	39	41	43	
45	19	22	24	26	28	30	33	36	39	40	
TEMP °C	5	10	15	20	25	30	40	50	60	65	RH%*

Combination example

Refer to the highlighted areas on the adjacent table.

1. TEMP = 35°
2. RELATIVE HUMIDITY (RH) = 14% (Round down to 10%)
3. For this combination of TEMP and RH, grain harvesting operations must cease when the average wind speed¹ is greater than 26kph.

*RH% (Relative Humidity rounded down)
¹Wind speed averaged over 10 minutes

Government of South Australia

CFS

SOUTH AUSTRALIAN FARMERS FEDERATION

Fig 7. GFDI 35 Calculator. Source: Reproduced from CFS-SAFF Grain Harvesting Code of Practice, 2010.

Footnote: Despite the register on the index some operators were inclined to press on with harvesting in lentils, believing that the low yields and therefore lower fuel load in that crop would reduce the risks, whereas they would have stopped harvesting under the same conditions in a cereal crop. In reality the risks in lentils are higher under certain weather events.

11. Emphasis on Static Electricity Rings Warning Bells

The following legislative requirement is noted in this SA Code of Practice: *"Operators being aware of the construction materials on harvesting machines and taking reasonable steps to reduce any potential buildup of static electricity through harvesting operations." (*Underlining emphasis added).

There is concern over the two paragraphs that talk about static Electricity in the document. It is suggested that this emphasis is misplaced for the following reasons:

1. There is no universally effective way of dissipating static electricity from a working vehicle. Motorists are aware of this. Suspending and dragging conductive chains or straps is not necessarily effective on low humidity days and on dry soils. Many operators have reported that drag chains or straps have not eliminated static charge on their machines. Some components may not be earthed to the combine chassis and in dry soil there may be no effective charge dissipation.
2. An operator may be lulled into a false sense of security when using a drag chain or conductor straps.
3. In the event of a fire, an operator may use the idea that static electricity has caused a fire as a cover for poor sanitation practices or other carelessness such as overlooking a failing bearing or weeping oil line near an engine.
4. There is no proof that static electricity *per se* is a prime cause of a fire. On the other hand, there are many perceptions or beliefs that static electricity is a cause. The fact that the CFS document states such in the second table in their otherwise excellent document only reinforces that myth.

Excerpt from Table two, where Fire Causes are tabulated: example for the 04/05 season: Static Electricity is listed in this document as the *cause* of 9 out of 59 (of the five lines listed of causes of fires), ie 15% stated as static electricity.

12. How the myth about Static Electricity as a prime cause of harvester fires might be despatched:

1. The older machines (say older than a decade or more) never had any plastic panels, yet were just as prone to fires as some of the very latest machines surrounded by "plastic" panels, if all else was equal (eg same amount of crop going through). Some late models such as New Holland's CR don't have plastic panels, yet spot fires have been reported on them.
2. The older machines *sans plastic* were also as fully capable of building up a static charge that could give an operator a shock. There is no evidence that modern machines carry more charge than older steel machines – except to the extent that they have more crop movement in them. The rotaries have more friction rubbing in the processor than walker-type machines and that *could* lead to a higher charge, but still not having enough minimum ignition energy in a spark to ignite bone-dry crop residues. The minimum energy to initiate combustion in powdered dry crop residues is around 500 mJ whereas the ES spark energy may be 20 mJ; that could only start a fire if the material was soaked in gaseous petrol vapours.

3. If SE was the primary cause of harvester fires, how come there is distinct bias of fire initiation on the left hand side of the harvester and, in particular, on machines that the operator admitted hadn't been cleaned down as regularly as others ??
4. This question needs to be considered: a person can build up a charge under some circumstances (even up to 20kV, see appendix 1) – is it possible that the operator is the source of the spark when reaching for the combine ladder ?
5. There are hundreds of thousands of motor cars on the roads with plastic panels or even the entire body is made of plastic, yet one never hears about vehicle fires caused by static electricity due to the panels. On the other hand, painful car-door sparks are a commonplace.
6. As for drag chains to supposedly dissipate charge, there is a great divergence of opinions about their efficacy. Some operators swear by them, while others say they have had as many as six chains, yet still get a shock (go back to item 2).

13. RECENT COMBINE FACTORY-INSTALLED MODIFICATIONS and FEEDBACK FROM THE US

I am re-assured from firsthand contacts that harvester manufacturers are extremely conscious of the need to do whatever is reasonably possible to reduce combine fire incidents. *In the first place they want to minimize litigation.* To that end, the two major manufacturers with the biggest share in the global market, Deere and CNH, have *full time* staff addressing the fire and safety aspects of their designs. They also have a system in place to systematically record any issues reported to them by their area representatives. As a good example of action taken, Deere's latest 70 series combines have been remodeled so that the air entering the radiator screen has to come from the *top* instead of from the side where it had been for decades. One operator in SA who had a number of fire incidents in lupins said those incidents had dropped to zero after he traded in a 60 series for a 70 series machine. Both these companies have given detailed attention to reconfigure the battery and fuel tank areas. Airflow around the engine bay has been changed to better ensure material is blown off the manifold, turbo and exhaust areas by the 100+ km/h wind from the radiator fan.
That consciousness has been sharpened by the mandated shift in diesel engine emission controls – Tier 3 & 4 engines run hotter, so there is more potential for fires around the engine. Still, a practically unavoidable problem emerges if there is a stiff tail wind *behind* a machine with chaff spreaders. The spreaders cause swirls of dust to rise high and enter the radiator area from where those particles are circulated over the hot exhaust zones. Manufacturers have installed deflector shields to reduce buildup and focus airflow in vulnerable areas. Operators need to be reminded that

- harvest time is a hazardous time for fires
- engines under load are very hot
- crop dust is flammable, some moreso than others, and
- modern combine harvester throughputs these days elevate the risks.

Fig 8. On the latest 70 series STS models, Deere have relocated the inlet to the rad fan. This forces cooling air to come in from atop the machine instead of where it used to be on the RHS.

Operators say this modification, distinguished on those models by the bulge on the top right side, has made a large difference to the cleanliness in the engine bay and has reduced spot fires.

LOCAL ATTACHMENTS TO REDUCE FIRE RISK

Fig 9. Engine bay modifications. This is a farmer-installed extra fan (ex-Auto) and insulation wrapping around the exhaust system on an STS by Custom Contractor Harry Roper in Goondiwindi. The non-standard shield wrapped around the exhaust system has not caused any turbo problems so far but it is not a Company authorized fitment.

There are several Fire Suppression systems available on the market - see Appendix 2. However I have not heard of any farmers installing an on-board system. There is also a fire retardant paint available but this is only good for one shot and it's efficacy can be diminished with blow downs by the air lance etc.
Several farmer/operators have installed misting systems so that the rad fan picks up the injected mist pumped from a 200 litre tank and swirls that around the engine bay.
Case has after-market electrically-conductive brushes on radiator and cleaning fans purportedly to dissipate electric charge onto the chassis. Others have installed wire conductors attached to the panels back to an earth - however, there is a serious question whether this is any better than a psychological prop. The subject plastic panels are essentially non-conductive and besides, there are only certain conditions that would induce a charge in the panels. Even if the panel was charged, there is no assurance that the electric charge would conduct out of the area remote from the earth conductor.

Figs 10,11. Conductive brushes can be fitted near to rotating components to reduce static buildup. Left shows such a brush next to the rad fan on a Case combine, as installed by Larwoods of Kadina; who also installed the Colpro-brand exhaust system insulating shielding (right) on an AFX combine.
Case-IH recommends the whiskers on fans on their combines in more fire-prone harvests, but does not as yet warrant the addition of exhaust system muffs. Company policy on this seems to be to treat any given situation on its merits, but in all events to urge serious and systematic sanitation activity at harvest.

14. A Checklist for Reducing Fire Hazards on Combine Harvesters :

1. Recognise the big four factors that contribute to fires, namely: ***Relative Humidity, Ambient temperature, Wind - and Crop type and conditions***. ***"HAWC".*** Not only recognize and measure the factors, but act accordingly ! Stop harvest when the danger is extreme.
2. Double your efforts on service, maintenance and machine hygiene at harvest on the days more hazardous for fire. Follow systematic Preparation and Prevention procedures.
3. Use every means possible to avoid the accumulation of flammable material on the manifold, turbocharger or the exhaust system. Even less-dry material is a possible fire hazard from possible spontaneous combustion over time if it gets packed into moving components.
4. Be on the lookout for places where *chafing* of fuel lines, battery cables, hot wires, tyres, drive belts etc, can occur.
5. Avoid overloading electrical circuits.
6. Periodically check bearings around the front and the machine body. Use a hand-held *digital heat-measuring gun* for temperature diagnostics on bearings, brakes etc.
7. Drag chains, or better still drag cables or grounding conductors, help dissipate electrical charge *but are patently not universally successful* in all conditions.
8. Use the battery isolation switch when the harvester is parked. And, recognizing their taste for electrical wiring, use *vermin deterrents* in the cab and elsewhere. Vermin have a taste for some kinds of electrical insulation.
9. Observe the GFDI protocol on high fire risk days. Don't jump to a conclusion that Static Electricity is a cause of fires; the evidence doesn't support that as a prime cause on harvesters. While it is true that SE builds up on moving machinery, the charge is most probably insufficient to ignite dry crop materials. Given appropriate conditions, an operator can generate higher charge from sliding across the seat of the ute.
10. Maintain two-way contact with base and others. And keep an eye out for hazards on yours as well as other's machines during the season.

15. LIST OF PEOPLE VISITED OR CONTACTED ON THIS PROJECT:

(58, in approximate order of association or contact; and there have been more since the Mallala meeting with the AG Bureau on Oct 27, 2010)
White, Ben. *Kondinin Group Northern Regional Manager, Toowoomba . 07 46 39 6180.*
Warwick, Chris. *Kondinin Group Research Engineer, Toowoomba . 07 46 39 6180.*
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Edwards, Marney. *Neil's of Gawler, Main North Rd., Gawler. 1800 246 994.*
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Jensen, Troy. *National Centre for Eng in Agr. USQ, West St Toowoomba. 07 46 31 1873.*
East, Matthew. *G&J East (Claas, MF dealership) Kadina, 08 8821 1188.*
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Pratt, Andrew. *Case IH. SA Area Manager, Case IH Adelaide. 0408 503 364.*
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Wolf, Brent. *Harvester Mgr., Chesterfields Australia, Louden Rd., Dalby. 0428 790 901.*
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Roper, Harry. *Harvest Contractor, (Deere Mcs) Goondiwindi, Qld. 0427 132 716.*
Tink, Rob. *Contract Harvester (Case), C/- Clancy's Toowoomba 4350. 07 46 30 4066.*
Verner, Richard. *Farmer, Mallala, 0419 774 225.*
Schuster, Gavin. *Farmer, Freeling, 0428 811 407.*
Tiller, Derek. *Farmer, Mallala, 0438 272 100.*
Price, Greg. *Farmer/Harvest Contractor, Paskeville. 0428 619 426.*
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Sargent, Malcolm. *Farmer,(Case combines 8120 now), Gladstone, SA. 0407 395 075.*
White, Paul. *Farmer (Lexion 480 totalled), Edgeroi NSW. 02 67 93 8341.*
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Hayward, Bryan. *Farmer/Harvest Contractor (Deere), Toowoomba. 0429 988 962.*
Smith, Bradley. *Farmer/Harvest Contractor (Case) W Moree, NSW. 0427 755 259.*
Harris, Phil. *Farmer/Contractor. (Case) Mungindi. 0427 961 451.*

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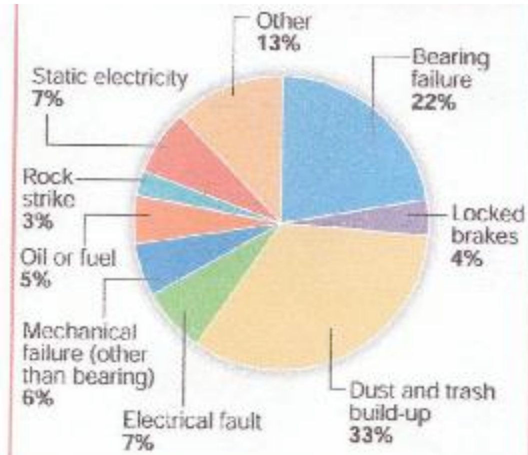
McDougall, Allan. *State Emergency Management Training Officer, Disaster Management Services, SES, 60 Waymouth St., Adelaide. 0419 829 915.*
Munzer, Fred. *CFS, SA. Kadina. 0418 859 373.*
Hassam, Terry. *CFS, SA. Mt Barker. (08) 8391 6077 .*

16. Kondinin's survey of 1170 farmers *(Farming Ahead #169 Feb 2006:8-13)*

Kondinin's report was based on a 2005 survey of 1170 farmers, a quarter of whom had experienced a harvester fire. Of those, 30 machines, or 11% were totalled. Just how far back the data came from was not stated. The report stated that the cost of harvester fires was almost 29 million in machinery repairs and 16 million in crop damage. The respondents listed fire incident *causes* as follows: 42% summed up as mechanical faults (bearings, brakes, mechanical failures); 'dust and trash buildup' (whatever that is supposed to mean) at 33%; rock strikes 3%, and 7% stated as due to Static Electricity.
Pie Cart as Figure 13 .



Causes of harvester fires experienced by farmers according to Kondinin Group's 2005 National Agricultural Survey.
Source: Kondinin Group's 2005 NAS.

17. Summary of causes of harvester fires that were stated by the interviewees so far on this 2010 project:

Fires emanating from the engine bay (35 out of 77 = 45%). *This are likely to be much higher when other factors are considered. I suggest three-quarters of combine fires start from the engine bay.*
Friction causing smouldering materials to exit from rear of a rotor (2)
Fire initiated by hot exhaust gas igniting residue on Case unloading auger (1)
Fuel system faults (3)
Sparks down at front from metals clashing with rocks etc (5)
Failed bearings (17)
Electrical faults (3)
Static Electricity specifically blamed (7 = 9%)
*Spontaneous combustion** of residues on the spreader skirt and in rear of rotor on STS (1)
Unknown (4)
"Financial Combustion" ie *let it burn out to collect insurance*. Also labeled a "Friction Fire" ie friction between owner and his bank ! - A possibility, but exact number will never be known.
Seventy-seven harvester fire incidents have been recorded in this survey, of which 20 machines were burnt out – that's 26% of the total in this sample (this is over the past two decades).
Fires initiating in the engine bay resulted in embers being fanned throughout the machine. This is definitely the cause of spot fires in strange places such as pockets in the side panels and on the cleaning shoe. This scenario of swirling embers has been videod by two operators and seen to be aggravated by machines operating with chaff spreaders. The swirling vortices created by spreaders cause debris to enter the radiator fan inlet and land

on or attach to engine components. – A vicious circle ! Two contractor operators installed a videocam on back and were able to observe exactly this situation developing while harvesting legumes at night. Other operators have clearly seen sparks or embers flowing from the exhaust outlet. It is not uncommon for the exhaust system and manifold to be glowing a dull red at full load. That is a potential incendiary area. It was notable that many of the spot fires occurred on the left hand side - the side where the exhaust discharges. On some earlier machines the exhaust is over the top of the tank and/or battery area. Operators explained that having a tail wind was especially nasty on high-risk days and that it was worthwhile to change directions to avoid that where possible.
Two operators who harvested chick peas at night observed a soft blue glow on parts of the harvester. They attributed this to static electricity, but were prepared to concede that it was possibly smouldering crop dust – chick pea or lentil dust does not burn fast and resembles burning metho when smouldering.
The dealer individual who blamed spontaneous combustion* as a cause of fire was adamant about that, although an area rep discounted this as a cause.
Whatever the situation, the fire risks are exacerbated by the bigger heat load from Tier 3 & 4 engines on combines.

18. CONCLUSIONS

It is estimated that three-quarters of harvester fires emanate from the engine bay. Others are initiated by problems with failed bearings, or brakes, electricals, rock strikes etc. *The key to avoiding harvester fires is diligence in cleandown and inspection - and, in the highest fire risk periods, to postpone paddock work.*
Static electricity builds up on *operators* and machinery in low-humidity atmospherics and is frequently blamed as a cause of harvester fires. Drag chains may reduce static charge, but the evidence however does *not* support static electricity as a prime cause of harvester fires. Certainly the adoption of plastic panels on modern harvesters has not aggravated the fire issue, despite noises to the contrary. Manufacturers and after-market suppliers provide the means to minimize the risk of harvester fires. The greatest need is suitable equipment and operator diligence in a fire-prone environment. This calls for systematic Preparation and Prevention procedures. All operators should equip their machines with at least two fire extinguishers and mount on board or have at hand a high capacity air compressor with air lances. Blowdowns may be needed as frequently as every half hour in the worst conditions.

19. Follow up recommendations. Potential Researchable Areas.

- Develop a data base on harvester fire incidents
- Investigate Retrofittable options for combines to reduce fires.
- Do exhaust component insulating shields shorten Turbo bearing life ?
- Develop more Debris Management strategies for harvesting equipment.
- Conduct actual measurements of static electricity on combines in the field. Although experts do not expect potentials to exceed 20kV, this needs to be verified by numerous field measurements in a variety of atmospheric conditions.
- Investigate the possibility/theory that static electricity may be charging the machine opposite to that on the crop dust, so that the dust may be attracted to the machine, including the hot exhaust components.

- Determine whether the plastic styling panels have any effect on the accumulation or dissipation of static electricity on combines
- Settle the question (on which opinions vary): is SE a *significant* factor in exacerbating harvester fires ?
- Apply videocams on machines to observe sparks etc and harvester fire behaviour
- Investigate the effectivity of lower-cost misting systems for combines.
- Consider avenues with Insurance companies for addressing the issue of escalating insurance excess charges.

Prepare a suitably-illustrated bulletin for all involved with harvesting; as a follow-up on this report. Use the 'ute guide' or pocket-book style for ready reference.

The Mallala AG Bureau meeting on Oct 27, 2010. This was attended by around 100 people including dealer and press personnel. The lively Q&A session after the Powerpoint presentation lasted for 1 ½ hours ! A subsequent ABC radio interview followed as well and this was reportedly played on several ABC programs. There has also been some press coverage. Some unusual insurance requirements voiced at the Mallala meeting needs addressing; this and other matters were raised in a meeting with CFS/SES people in Adelaide on October 288, 2010..

20. Acknowledgements.
Credit must go to the Grains Research and Development Corporation (GRDC) for funding this project through the office of Paul Meibusch. The cooperation of each of the the people mentioned on this list – especially Richard Konzag - is gratefully acknowledged. Ben White of the Kondinin Group has been very supportive. The advice of Brian Lanzen of Deere & Co., Moline, was especially noteworthy.

21. References, Further Reading

National Fire Protection Association, NFPA 10, *Standard for Portable Fire Extinguishers.*
Pratt, T. H. 2000. *Electrostatic Ignitions of Fires and Explosions* . Center for Chemical Process Safety/AIChE
Britton, LG. 1999. *Avoiding Static Ignition Hazards in Chemical Operations.* CCPS.
Delta T. *The Red Alert System for Acceptable Conditions for Spraying.* http://www.bom.gov.au/lam/deltat.shtml
Kondinin, 2006. *High Fire Danger Sparks Call for Safer Machines.* Owner Survey: Harvester Fires. Farming Ahead #169. Feb 2006.
AlphaLab, Inc. (*Surface Charge Meters etc.)* 3005 South 300 West Salt Lake City, Utah 84115 USA.

APPENDIX 1. What Causes Static Electricity ? An Excerpt.

Static electric discharges can be irritating and their cause sometimes seems mysterious. Most people have encountered household shocks and painful car-door sparks, as well as those wintertime sparks from doorknobs and large metal objects. Children often play the trick of scuffing their shoes across a carpet to build up charge on their bodies, then finding a victim to "zap" with their electric fingers. Sparks from rug-

scuffing are familiar. But why do our bodies sometimes become charged from simply walking around?
Electrifying Causes. Actually, friction or rug-scuffing is not mandatory in order to electrically charge your body. "STATIC ELECTRICITY" is not unmoving, it actually means "HIGH VOLTAGE ELECTRICITY." The tiniest spark requires about 500 volts. Discharges are hard to notice until the voltage on your body is above 1KV. Friction will increase the charge-separation process, but friction isn't the cause. The real cause is *electrical imbalance.* Whenever two different insulating surfaces touch together, opposite charges found within the two surfaces become separated. Simply walking across certain rugs or plastic flooring will cause your shoe soles to touch the dissimilar material of the rug. This is enough to separate the negatives from the positives and create imbalanced electric charges on the bottoms of your shoes.

"Static" electricity (more correctly called "net electric charge") appears whenever the normal quantities of positive and negative electricity in a substance are not perfectly equal. Everything is made of atoms, and atoms in turn are made of positive and negative electric charges. Our bodies are a collection of positive and negative electrical particles. Normally the positives cancel out the negatives, and everything behaves electrically "neutral." No mysterious sparking. But whenever there is more negative than positive, or more positive than negative, then there is a charge-imbalance on your body. You will get zapped the next time you touch a large metal object.

Exactly how can this imbalance occur? Whenever we walk, the soles of our shoes steal some negative charge from the floor. We leave behind electrified positive footprints, and our bodies aquire an overall imbalance of negatives. (Or sometimes vice versa with the negative and positive, since polarity is determined by the type of shoe soles and the type of rug.) After many footsteps, our bodies attain a high level of electric charge and a high voltage.

Body-voltage can easily rise to several thousand volts, and the next time you touch someone else... ZAP!, the imbalanced charge gets shared between you and the other person. The spark is painful because it's extremely hot. It drills into your skin like a white-hot needle, creating a microscopic burned area.

It is possible for a person wearing nylon clothing and in the right circumstances to build up to 20KV. *Ouch*. (Q added) *This is on the order of magnitude of the potential across a spark plug in an engine*.

Cures. The simplest cure: before touching a doorknob, a car door, etc., first touch it with a metal car key. The fiercely hot spark will jump to the tip of the metal key rather than your sensitive fingertip, and it will painlessly discharge your body's charge. (Grip your keys firmly so no spark appears between the keys and your skin.) Once you've been discharged, you can safely grab the doorknob. However, if you walk around some more, or if you sit upon a plastic car seat, you'll again need to use the keys discharge yourself.

To prevent sparks entirely, we must somehow stop the charge separation process. This can be done by:

Changing your shoe soles to another type (try leather or ESD Shoes)
Using a humidifier to raise the humidity in the room
Spraying carpets, floors, chairs etc with an antistatic coating
Wearing metal-coated shoe soles (try alum. foil, but it's slippery)
Wearing a grounded wire connected to a wrist strap
Install a conductive carpet, and wear a conductive ankle-cuff connected to a metal shoe plate
As with the car keys, the problem can also be prevented by discharging your excess body-charge in some way that doesn't cause pain. This can be done by:
Grabbing the metal car door as you climb out of the car.
Holding your car keys, a coin, or a metal pen, touch it to grounded metal objects.
Knocking your knuckles against doorknobs (fewer nerve endings, less pain.)

The sparking problem is usually found in low-humidity locations, such as in air-conditioned office buildings. *High humidity prevents the charge-separation which causes sparks.* Raising the humidity in the environment stops the sparking. High humidity makes the surfaces of shoes and rugs slightly conductive, so the separated charges can instantly flow back together.

Usually all of the "static electricity" will vanish when the RH is above 60%. If you live in a single house or apartment, use a room humidifier. Or just boil away a few quarts of water on your kitchen stove.

Source: http://www.electrostatics.net/articles/static_shocks.htm. Emphasis added.

Appendix 2 A. On Board Fire Suppression Example. *Citation:*

Firetrace Systems provide Cost-Effective, Stand-Alone, Automatic Fire Suppression Systems for your Critical

Equipment, Electrical/Technical Systems and various types of enclosures. The effectiveness of a genuine **Firetrace System,** happens by utilizing the proprietary **Firetrace Detection Tubing** (a Linear Pneumatic Heat Sensor), which detects a fire due to precise temperature sensitivity, allowing our systems to react quickly and effectively. This unique detection can be run through the smallest or most complex enclosures to ensure detection is always close at hand.

A Firetrace System can be utilized anywhere that a fire poses a risk, and it is flexible enough for virtually any Industrial Equipment, Traditional as well as Emergency Vehicles, Storage Compartments, Control Cabinets or various types of Remote Installations. From CNC Machines and Fume Hoods, to Bus Fire Suppression, a **Firetrace System** is the leader in reliable Automatic Fire Suppression for your critical equipment care. **Firetrace Systems** quickly detect and suppress fire, directly at the source, efficiently and automatically.To learn more about how **Firetrace Systems** work, please see our current Product listings.

Wormalds are agents in Australia.

Cost *quoted for a simple direct Firetrace system with 5 Kg cylinder ~ $2300. This would serve to detect and suppress a small fire in the engine bay, however it would not detect a fire elsewhere on the machine. A more complex system for a combine could cost up to $15,000. No farmer or contractor is known (from this survey at least) to have acquired one of these systems. Price is obviously a factor.*

Appendix 2B: "No Fire" - a fire retarding paint.

.

NoFire® does everything that ordinary paint does...

Except Burn!

Source: http://www.nofiretechnologiesinc.com/

APPENDIX 2C. FireXIT systems. Refer www.firexit.com.au. For the Fire Knockout bottles that when appropriately located, burst when exposed to elevated temperatures and extinguish a fire in seconds. Costs are in the $ low hundreds. Details: Represented in South Australia at Keswick.

APPENDIX 3. ATTENTION TO FIRE EXTINGUISHERS THAT ARE MANDATORY ON COMBINES.

Source: Cleaning and Inspection Guide for Deere Combines.

Inspection:

At least once per month, inspect your fire extinguishers and ensure the following:
(a) Fire extinguisher shall be positioned in its designated place on the cab ladder landing and at the rear of the machine.
(b) There should be no obstruction to access or visibility.
(c) Operating instructions on nameplate legible and facing outward.
(d) Safety seal not broken or missing.
(e) Fullness determined by weighing or "hefting".
(f) Examination for obvious physical damage, corrosion, leakage, or clogged nozzle.
When inspection of a fire extinguisher reveals a deficiency the extinguisher should be serviced or replaced.
Reference: National Fire Protection Association, NFPA 10, *Standard for Portable Fire Extinguishers.*

APPENDIX 4. CHILWORTH LABORATORY TESTING ON CROP DUSTS ETC

Chilworth Global of New Jersey, USA, is a professional process safety firm. Testing is conducted according to ASTM and other recognized standards. Using ASTM Test standard E2019 they determined the MIE of finely powdered soybean residues dried to 1.5% moisture content (WB).
MIE needed exceeded 500 milliJoules with a *continuous* arc.
In summary they found that a continuous arc of that energy could ignite the powdered residue whereas a 500 mJ spark could not, over a range of residue thicknesses.
It has been postulated that a combine could *theoretically and in the extreme* generate sufficient spark energy possibly up to 150 mJ with 20kV potential. This level of energy approximates that of a weak flashlight bulb at 0.15 watt.seconds - still insufficient to ignite powdered dry crop residue.
Source: http://www.chilworth.com/Dust-Explosion-Testing.cfm

POST SCRIPT

KADINA South Australia, rainfall 11-15 inches.