CAN WE LEARN FROM PAST INCIDENTS

Paul Markham

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WHO AM I

- Paul Markham, B.Eng, C.Eng, MIMechE, TechIOSH
  - Risk Management Engineer, Technical Services
  - Responsible for “Risk Engineering” for Power Generation (Operations and Construction) for London Office,
  - Risk Survey/Inspection, Pre-Underwriting risk review, technical support,
  - 11 (9 yrs with LSM) years in Insurance,
  - 8 years working for Siemens Power Generation (service and plant management),
  - 8 years Royal Navy (Marine Engineer).
  - Apprentice British Steel

OVERVIEW OF LIBERTY SPECIALTY MARKETS (LSM)

- Established in 2013, bringing together Liberty's company (LMIE), Syndicate (Liberty Managing Agency Limited) and Reinsurance operations (LMRe)
- Offers specialty and commercial insurance and reinsurance products across key UK, Continental European, US and other international locations
- Over 900 employees in 25 offices
- GWP $3,676m (based on 2014 business plan):
  - $1,249m Specialty
  - $1,067m Commercial
  - $1,360m Reinsurance
- Part of Liberty Mutual Insurance Group, a Boston-based US Fortune 100 company

” There is a wealth of data available and valuable lessons to be learnt from not only insurance claims but from events which fall below deductible levels. How do we achieve this?”

Introduction

- Should we learn lessons? Do we learn? How should we achieve this?

- Review incidents and data – are there any trends

- Identify hazards and discussion about learning from incidents

- Can the insured and the insurer (OEM) improve this?

- Starts with survey reporting competency and knowledge

Introduction

Risk can be divided into the following areas:

-- **technical risk**

-- economical risk

-- judicial risk (laws, contracts)

-- management, financial and trading risks

-- ecological and environmental risk

-- other risks

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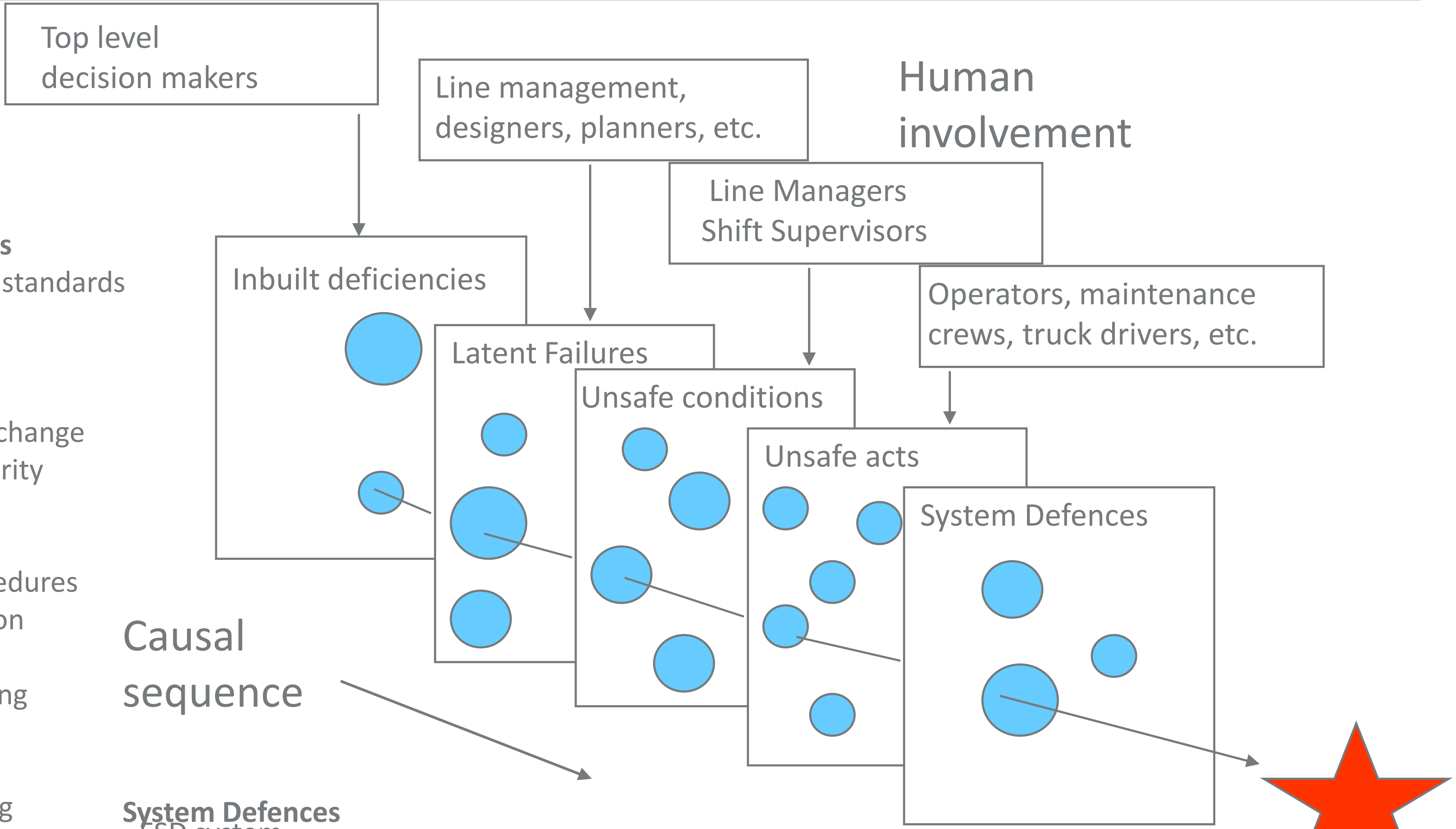
LAYERS OF PROTECTION

Inbuilt deficiencies
- Lack of company standards

Latent failures
- Design
- Management of change
- Mechanical Integrity

Unsafe conditions
- Inadequate procedures
- Lack of supervision
- Poor Training
- Ineffective auditing

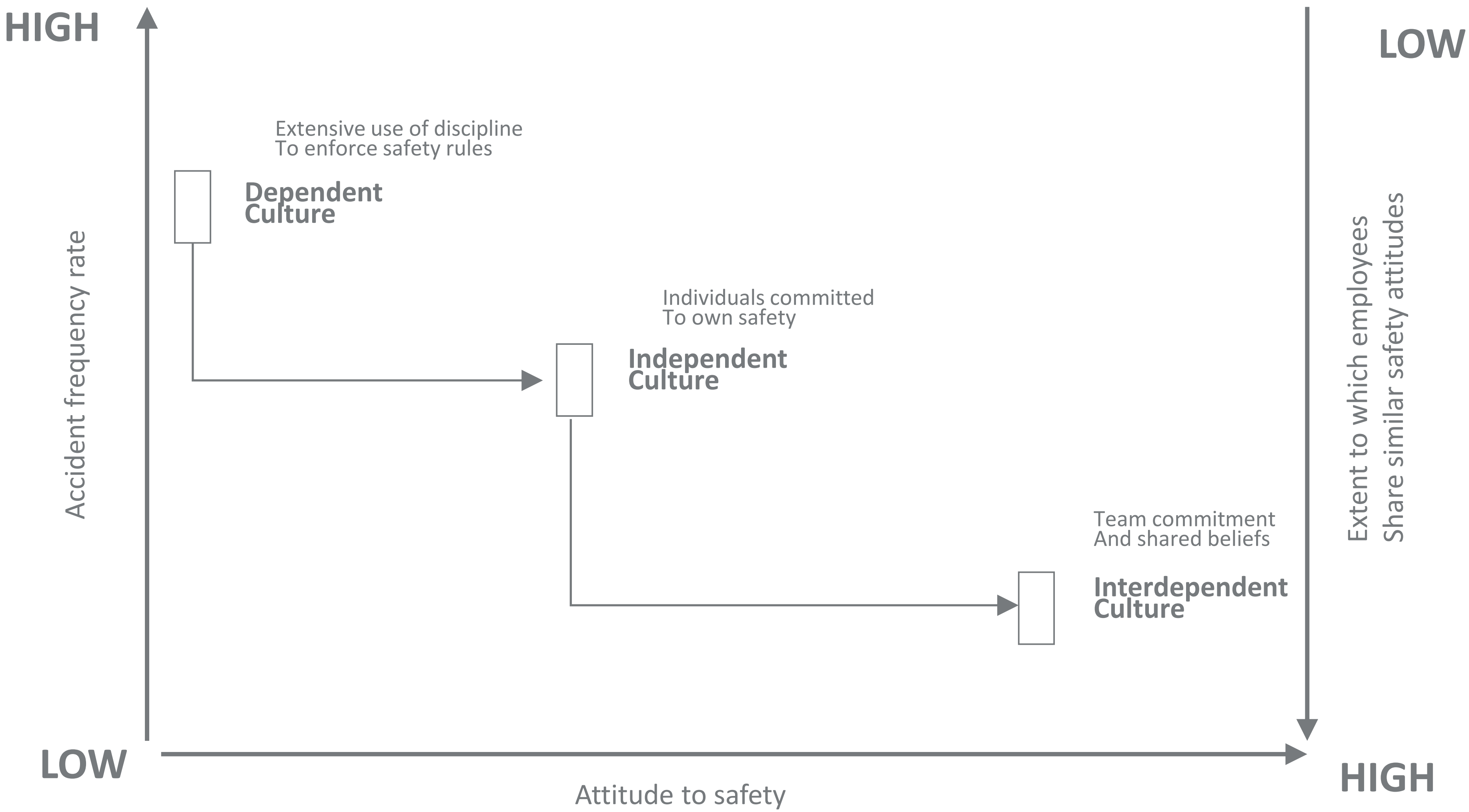
Unsafe acts
- Misunderstanding
- Non-compliance



System Defences
- ESD system
- Blinds
- Emergency procedures
- Safety culture
- Task checking

Limited window for accidents

SAFETY CULTURE



- All incidents are preventable
- Improve safety culture
- Management visibility
- Managers and front-line supervisors must audit
- Checking critical activities and process deviations
- Zero tolerance – non-compliance not tolerated
- Safety should be a condition of employment
- REVIEW OTHERS MISTAKES

Human Factors

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CONTRIBUTING RISK ISSUES

- **GT technology issues –** compressor, turbine, workmanship/QA, not abating
- **Transformer** – aging, sulphur, losses increasing
- **New equipment** – less robust, so not as forgiving
- **Manpower** – reduced technical power knowledge, a lot of know how lost and succession planning too late
- **Aging fleets –** apathy, never happens to us, obsolescence
- **Hydro civils** – fixed price contracts/QA/frequency
- **Single large losses** – increasing
- but cooling tower, air intakes, **standby emergency systems** have all taken their toll

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HISTORIC DATA 2013

Sum of Total_Gross	
Equipment_Type_Detail	Total
Air Intake	18,000,000
Cable room	4,415,000
Coal Conveyor	100,000,000
Control room	329,000,000
DC Supply	112,508,000
Dredger	6,300,000
Flood	71,000,000
Gas_Turbine	356,640,000
Generator	404,380,000
ICE	28,700,000
Maintenance	52,600,000
Power Supply (owned)	49,105,000
Solar Trough	1,350,000
Steam_Turbine	103,500,000
Transformer_GSU	141,750,000
Turbine	138,032,000
Water treatment	10,000,000
Wind_Turbine	300,000,000
(blank)	58,500,000
Warehouse	120,000,000
Shell & Tube Exchanger	13,500,000
Cooling Tower	32,000,000
Grand Total	2,451,280,000

Count of Equipment_Type_Detail	
Equipment_Type_Detail	Total
Control room	2
Cooling Tower	1
Dredger	1
Flood	2
Gas_Turbine	24
Generator	11
ICE	4
Power Supply (owned)	4
Steam_Turbine	5
Transformer_GSU	12
Warehouse	1
Wind_Turbine	1
(blank)	
Cable room	1
Turbine	5
Air Intake	1
Coal Conveyor	1
Solar Trough	1
Maintenance	1
DC Supply	5
Water treatment	1
Shell & Tube Exchanger	1
Grand Totall	85

	Data	
Facility_Type	Count of Facility_Type	Sum of Total_Gross
CCGT	38	686,570,000
Cogen	1	17,105,000
Geothermal	3	34,000,000
Hydroelectric	6	221,015,000
ICE	4	28,700,000
Mixed Portfolio	1	56,000,000
Nuclear	1	22,000,000
OCGT	2	19,000,000
Solar	3	51,582,000
Sub station	5	56,000,000
Thermal Coal	10	279,808,000
Thermal Mixed	1	95,000,000
Thermal Oil	1	66,000,000
Wind	1	300,000,000
WTE	1	120,000,000
(blank)		48,000,000
EAR	3	300,500,000
Thermal Gas	1	50,000,000
Grand Total	85	2,451,280,000

HISTORIC DATA 2014

Count of Equipment_Type_Detail	
Equipment_Type_Detail	Total
Boiler	1
Cooling tower	1
Flood	1
Gas_Turbine	17
Generator	8
ICE	1
Power Supply (owned)	2
Steam_Turbine	6
Transformer_GSU	9
Wind_Turbine	3
Power Supply (3rd party)	4
Coal Stockyard	1
Turbine	2
DC Supply	2
Shell & Tube Exchanger	1
FGD	1
Cables	1
Grand Total	61

Sum of Total_Gross	
Equipment_Type_Detail	Total
DC Supply	175,000,000
Flood	20,000,000
Gas_Turbine	302,010,000
Generator	221,500,000
ICE	20,000,000
Power Supply (owned)	25,000,000
Steam_Turbine	231,500,000
Transformer_GSU	103,000,000
Turbine	133,000,000
Wind_Turbine	8,490,000
(blank)	
Power Supply (3rd party)	12,000,000
Cooling tower	4,000,000
Coal Stockyard	22,000,000
Shell & Tube Exchanger	16,000,000
Boiler	260,000,000
FGD	40,000,000
Cables	20,000,000
Grand Total	1,613,500,000

	Data	
Facility_Type	Count of Facility_Type	Sum of Total_Gross
(blank)		16,000,000
Hydroelectric	5	206,500,000
CCGT	23	557,600,000
Sub station	4	30,500,000
Wind	4	8,990,000
Cogen	4	10,910,000
Thermal Coal	12	692,500,000
Solar	1	16,000,000
OCGT	3	14,500,000
Geothermal	1	20,000,000
CAR	1	20,000,000
ICE	1	20,000,000
Grand Total	61	1,613,500,000

HISTORIC INCIDENT DATA 2009-2012

Year	Number of Incidents	Gross Value US$m
2009	129	2,160
2010	154	2,163
2011	113	2,184
2012	121	2,684

Transformers

Claims Overview - Transformers

56 transformer losses between 2011 and 2013

2011 - 18 losses, gross loss USD 202 million

2012 - 16 losses, gross loss USD 195 million

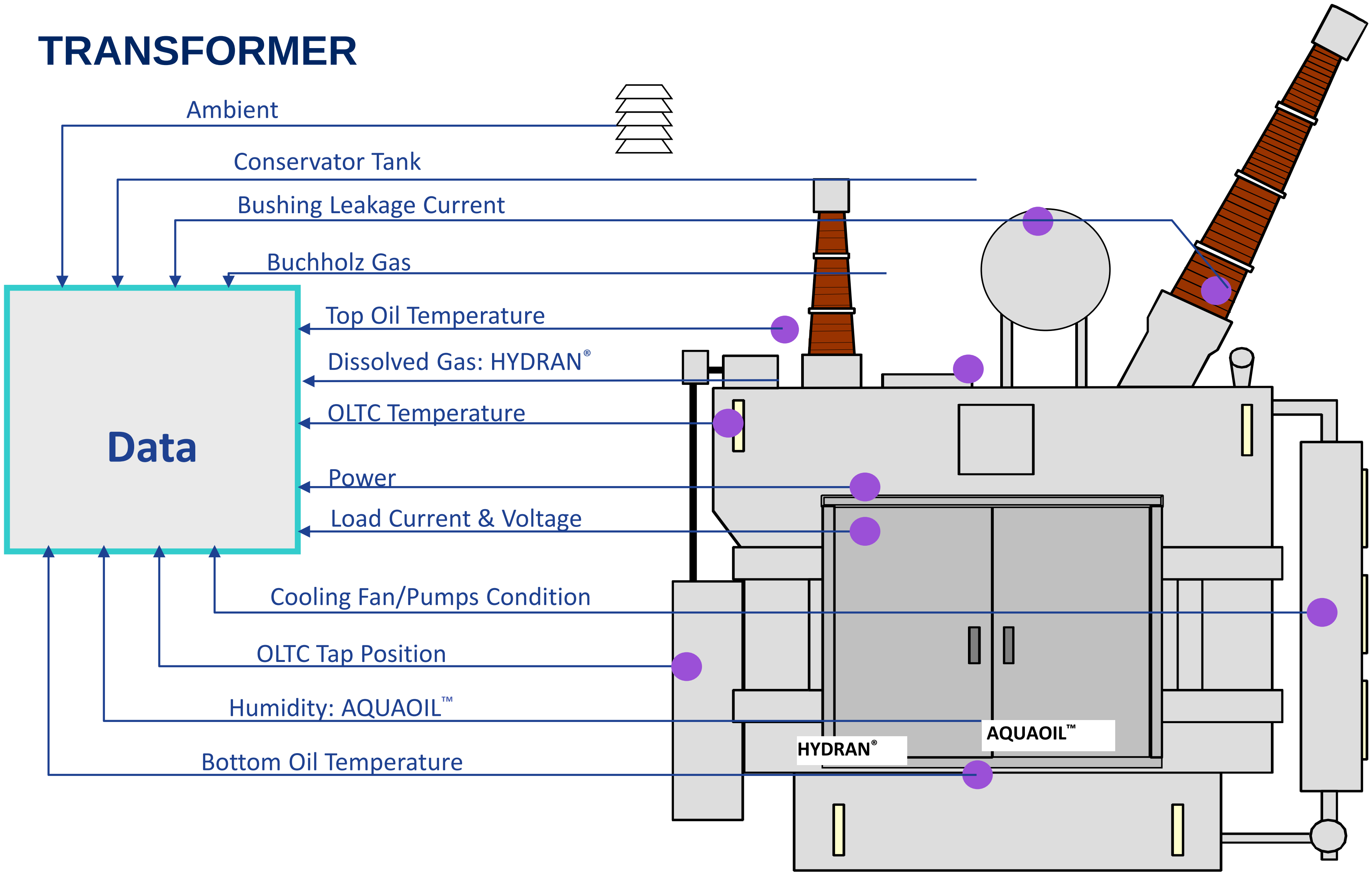
2013 – 12 losses, gross loss USD 169 million

2014 - 10 losses, gross loss USD 57 million

Claims Overview - Transformers

- About 2/3 of losses involving GSU transformers, typically more highly loaded and cyclic operation – industry statistics indicate 2% failure rate
- Majority of claims involve PD only as BI not covered, typical in USA
- Oldest transformer 1964 and youngest 2010, variety of manufacturers – no particular trend on age or manufacturer
- Main cause of loss from internal fault, often have latent defect which is exposed in future years when system fault condition occurs
- Evidence of poor plant behaviour - running transformer to destruction with no fleet replacement strategy
- Some clients use insurers as ‘spare parts supplier’
- Root cause often not identified, once policy coverage established

TRANSFORMER



CAN WE IMPROVE?

TRANSFORMER – WORST CASE

OIL FILLED BUSHING FAILURE

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Specialty Markets

WHERE CAN WE IMPROVE?

WHERE CAN WE IMPROVE?

WHERE CAN WE IMPROVE?

Standby Emergency Systems (SES)

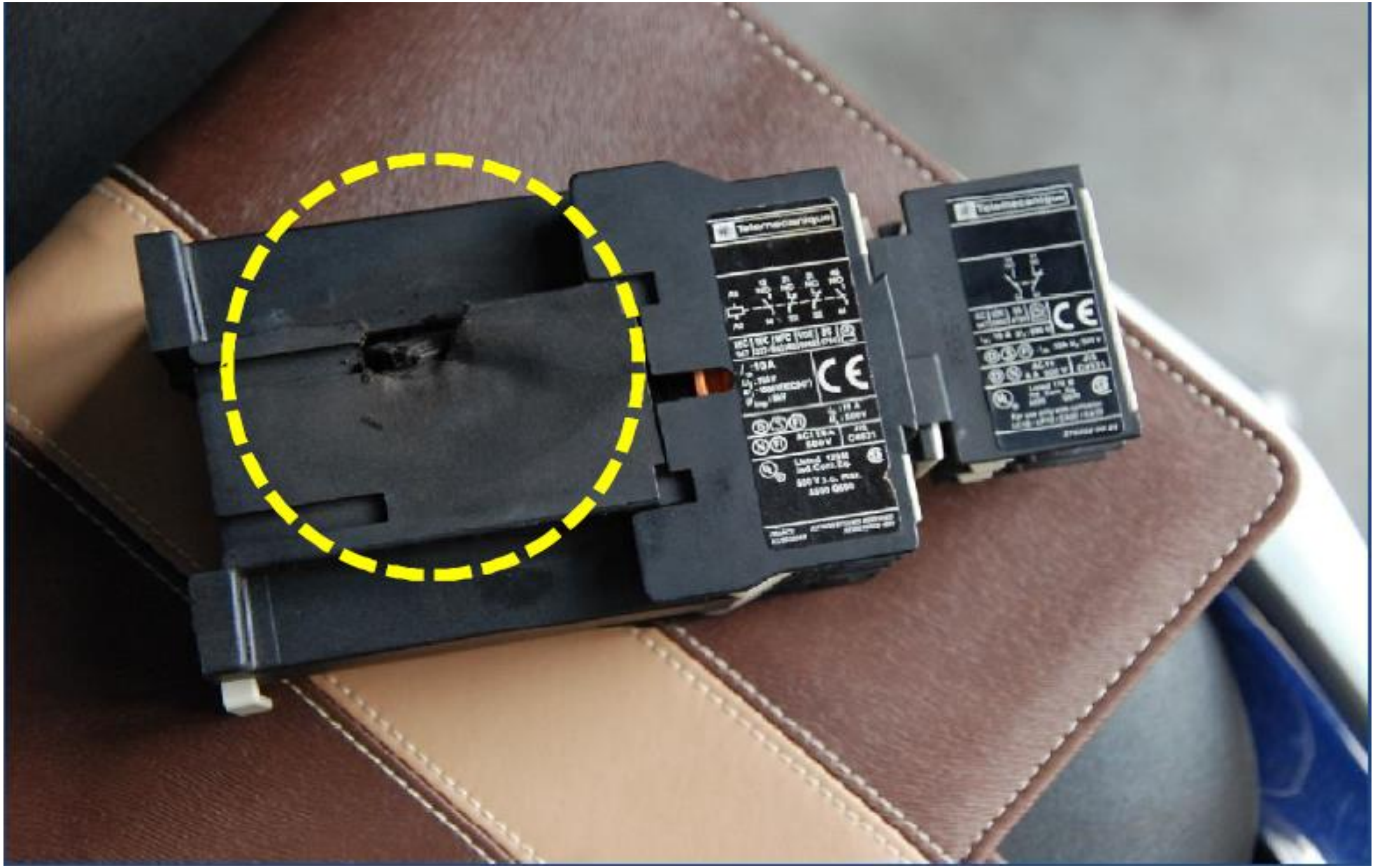
What makes up a SES?

- AC supply (redundancy)
- Emergency diesel generator set
- UPS
- DC supplies
- Essential services board
- Essential services
- Back up logistics (portable lights, tannoy, door locks, radios, electric gates, grid operator comms, mobile phones, telephone system, etc)

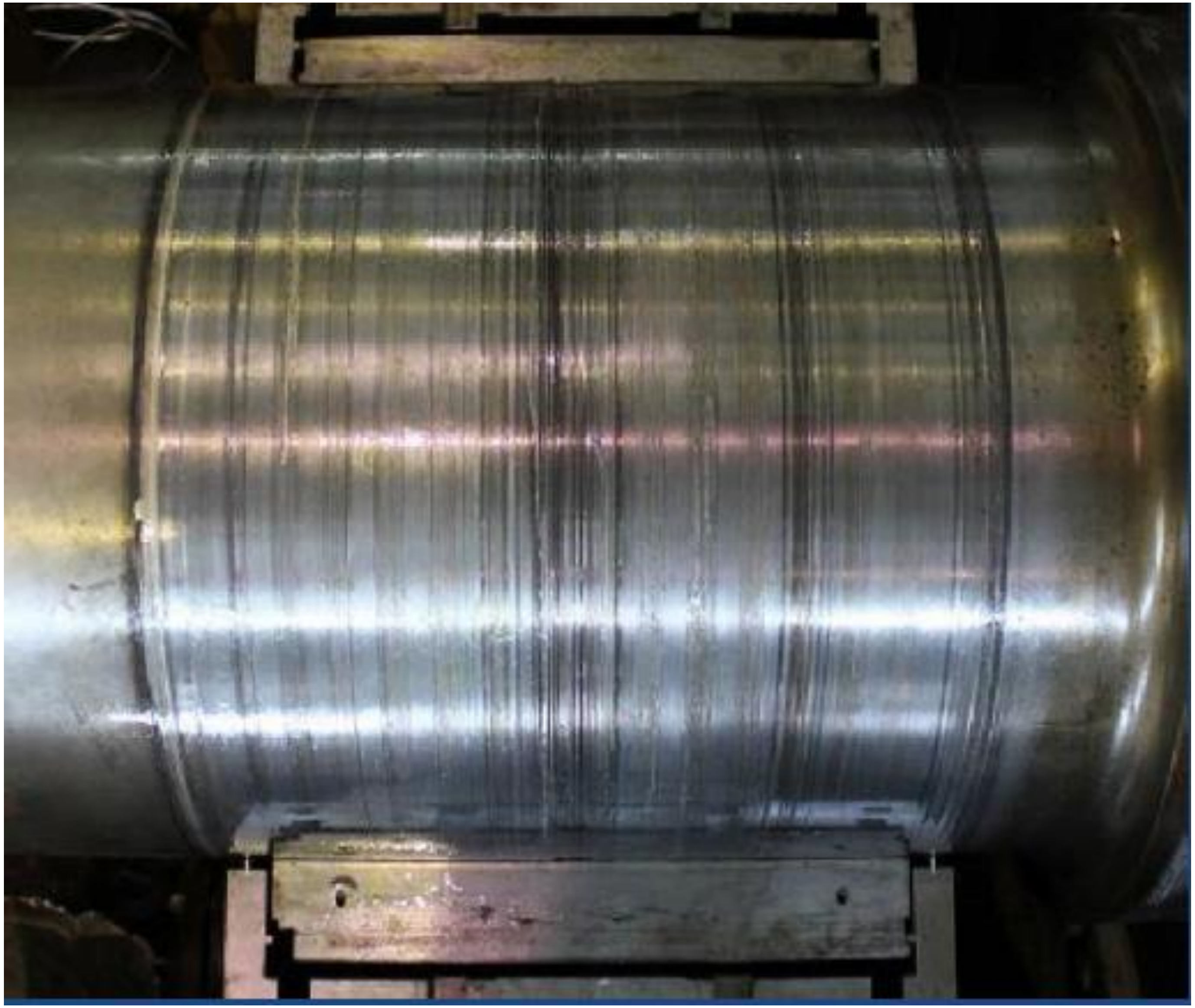
TYPICAL AFFECTS

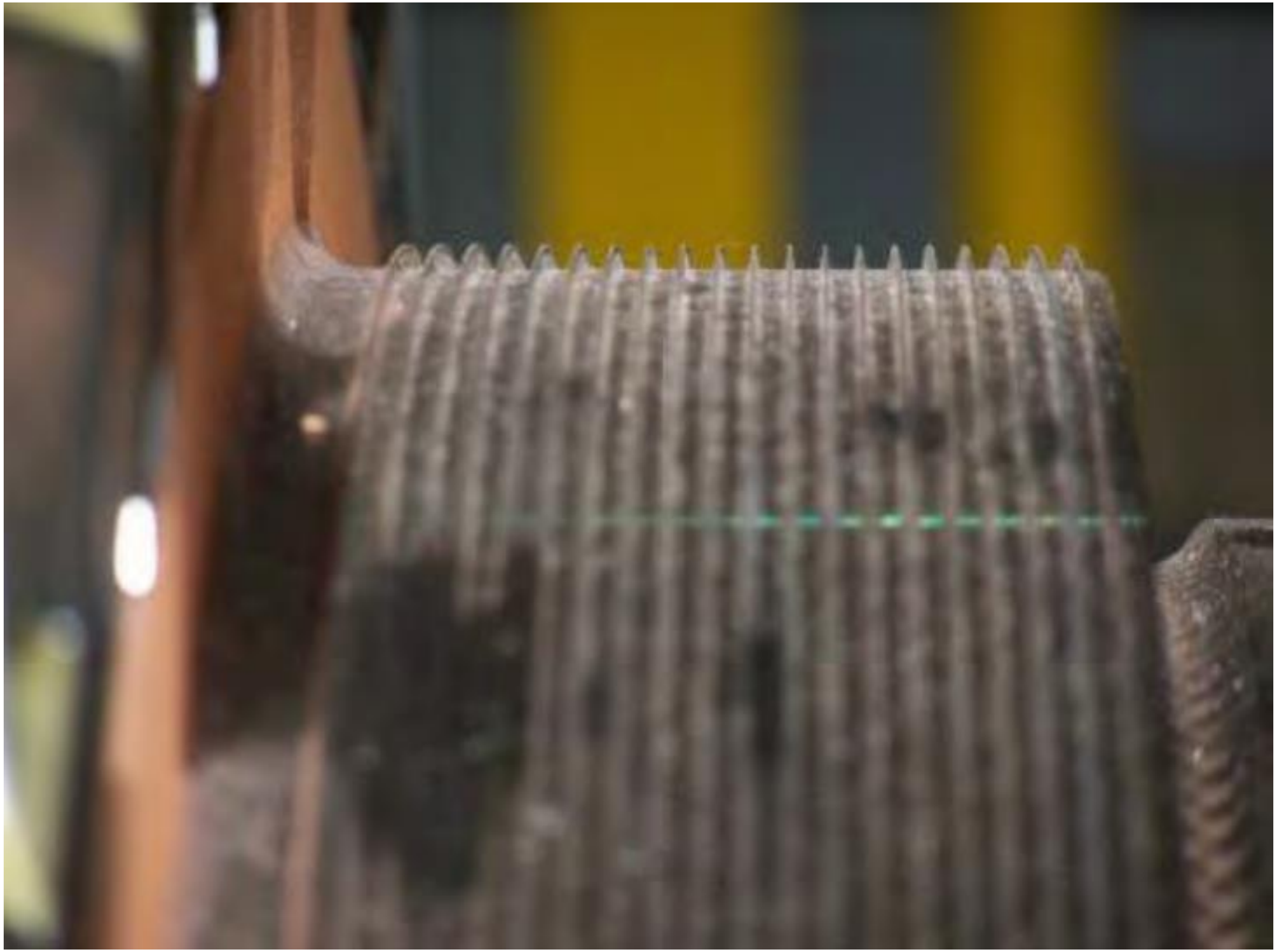
- Plant trip resulting in loss of AC Power Supplies
- Emergency DC Oil Pump Fails to Operate
- Turbine runs down without Lubricating oil / Seal oil
- Damage to bearings due to overheating
- Damage to generator hydrogen seals
- Potential lubricating oil fire and / or generator hydrogen explosion
- Damage to turbine stationary parts seals and diaphragms, and to rotating blades due to contact
- Overheating damage to turbine rotor
- Seizure of shaft and potential for shaft bowing
- Potential contamination of generator from metallic debris

220V DC RELAY



TYPICAL ROTOR DAMAGE





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STANDBY EMERGENCY SYSTEMS INCIDENTS

- **Kuwait Jan 2014**
  - Still under investigation – maintenance work on DC system, AC and DC supply interrupted, lubricating oil and seal oil to turbine generator lost
  - Fire started at exciter end of generator followed by hydrogen explosion
  - AC power supply was restored causing a lubricating oil fire
  - Steam turbine and generator complete loss and consequential damage
  - Estimated loss USD 100 million

Australia Mar 2013

- Plant tripped due to earth fault; heavy rainfall which entered 22 kV IPB
- Standby lube oil pump failed to start – breaker not racked in
- Emergency lube oil pump failed to start – fuses removed
- Total USD 15 million

Holland July 2013 Waste to Energy Plant

- Operator opened wrong breaker, loss of oil to turbine and plant trip
- DC system did not function
- Generator breaker did not open so the machine motored without oil
- One hour later AC power restored and lube oil was sent to the hot bearings and ignited resulting in a major fire loss. EUR 57 million, 14 months to repair

USA Jan 2013

- Plant was being returned to service following Hurricane Sandy Loss
- DC systems were not fully commissioned, electrical fault caused an overload in the DCS which shutdown the plant – UPS not available
- Loss of lubricating oil to two steam turbine generators
- Damage to 2 steam turbines and associated generators
- Total loss USD 11 million, 4 months to repair

Argentina November 2012

- Plant trip following lightning strike causing grid failure
- Emergency Generator started but tripped due to loss of DC supplies
- Steam turbine ran down without oil
- Total loss USD 45 million – 7 month outage to repair rotor in Switzerland

Argentina Feb 2011

- Maintenance being carried out on one part of the dual redundant DC supply system. Operator opened the wrong breaker.
- All breakers tripped from loss of minimum DC supply protection (common fail safe protection on substations; not on power plants)
- Steam turbine ran down without oil
- Total loss USD 44 million – 8 months to repair, rotor journals machined on site

Argentina Oct 2013

- Maintenance being carried out on batteries. Operator opened the wrong breaker.
- Steam turbine ran down without oil
- Total loss USD 40 million – 244 days to repair, due mainly from territory issues.
- Lack of awareness of system.
- Over 30 recommendations from insurers

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Bangladesh 2014

- 450 MW Ansaldo GTG and Fuji Steam turbine.
- DC supply system from Hyundai.
- UPS failure caused interruption to DC supplies, the generator breaker opened but steam turbine valves did not close resulting in catastrophic overspeed after about 53 seconds.
- This plant previously had problems with the UPS system.
- Probably the cooling fans failed which caused UPS to overheat and fail. UPS caused DCS to fail. ***USD 130 million***.

Malaysia Nov 2013

Relay failure, no back up.

Steam turbine ran down without oil

Total loss USD 75 million – 153 days to repair, due mainly from territory issues.

Lack of awareness of system.

Typical Essential Supplies

- Emergency Turbine Lubricating Oil Pump
- Emergency Generator Seal Oil Pump
- Turbine Turning Gear Drive
- Control Power for Switchgear
- Emergency Lightning
- Boiler Air-heater Emergency Drive Motor

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- **Purpose**
  - To supply clean, cool oil, to turbine generator bearings
  - Turbine shaft runs with a film of oil between the rotating parts and bearings – no metal to metal contact
  - A critical supply so will have built in redundancy
  - Includes oil treatment, filtration and purification (removal of water)
  - Lubricating oil quality is important – routine analysis required

What does it support in power plant applications

- Tie Feeders
- Switchgear incoming feeder
- DC bus (drives AC switchgear)
- Natural gas/fuel oil valve signalling
- Compressor blow of valve signalling
- Emergency lighting
- 400V s/w gear control
- Generator protection supply
- DC/DC conversion
- Lube oil and H2 seal oil pumps

Typical Arrangement

- 2 x AC 100% lubricating oil pumps – Duty / Standby
- 1 x DC 100% emergency lubricating oil pump – Battery Powered
- Similar arrangement for generator seal oil system
- The last line of protection is the emergency lubricating oil pump this is supplied with DC power from the essential supply system.

Essential Supply System Comprises:

- Redundant AC supplies fed from different switchboards
- Two sets of AC/DC inverters and battery chargers
- Battery bank designed to supply power for sufficient time to allow safe plant shutdown – conventional lead acid batteries preferred
- Essential Services Distribution Board
- Normally backed up by emergency generator

- For new installation the essential supply system should be subject to a design review by competent third party
- Emergency oil supply systems should be subject to rigorous function testing during plant commissioning and after outages
- There should be no thermal overload trip protection on DC oil pumps; should give alarm but no trip
- Routine testing (weekly) of emergency lubricating and seal oil pumps – should test full system from low pressure switch
- Routine Load testing of DC battery banks – depends on age and type of battery bank
- Routine testing of emergency generators
- Only essential maintenance on these systems when in service
- Maintenance personnel training

- Robust maintenance procedures
- Good plant labelling to ensure correct breaker operation
- Re-commissioning and testing following any work on the system
- Emergency plans should cover turbine oil fire events

- Operations and Maintenance
  - Breakers clearly labelled.
  - Any converter alarms should be duplicated to DCS
  - DC earth fault should alarm converter
  - Never work on system when plant is running (unless duplicated/redundancy and knowledge)
  - Reconfiguring breaker sequence can be tempremental (do they understand)
  - FMEA before build (and after if not)
  - Commissioning procedures (what and how was it all tested)
  - System Integration in a non turnkey plant

- Alternative supplies to main and auxiliary motors
- Cable routing separated
- Check capacity of both pumps
- Test using pressure switch, not just daily starts routine
- Where is filter? Supply or return

STEAM TURBINE LUBE OIL PIPEWORK RUPTURE

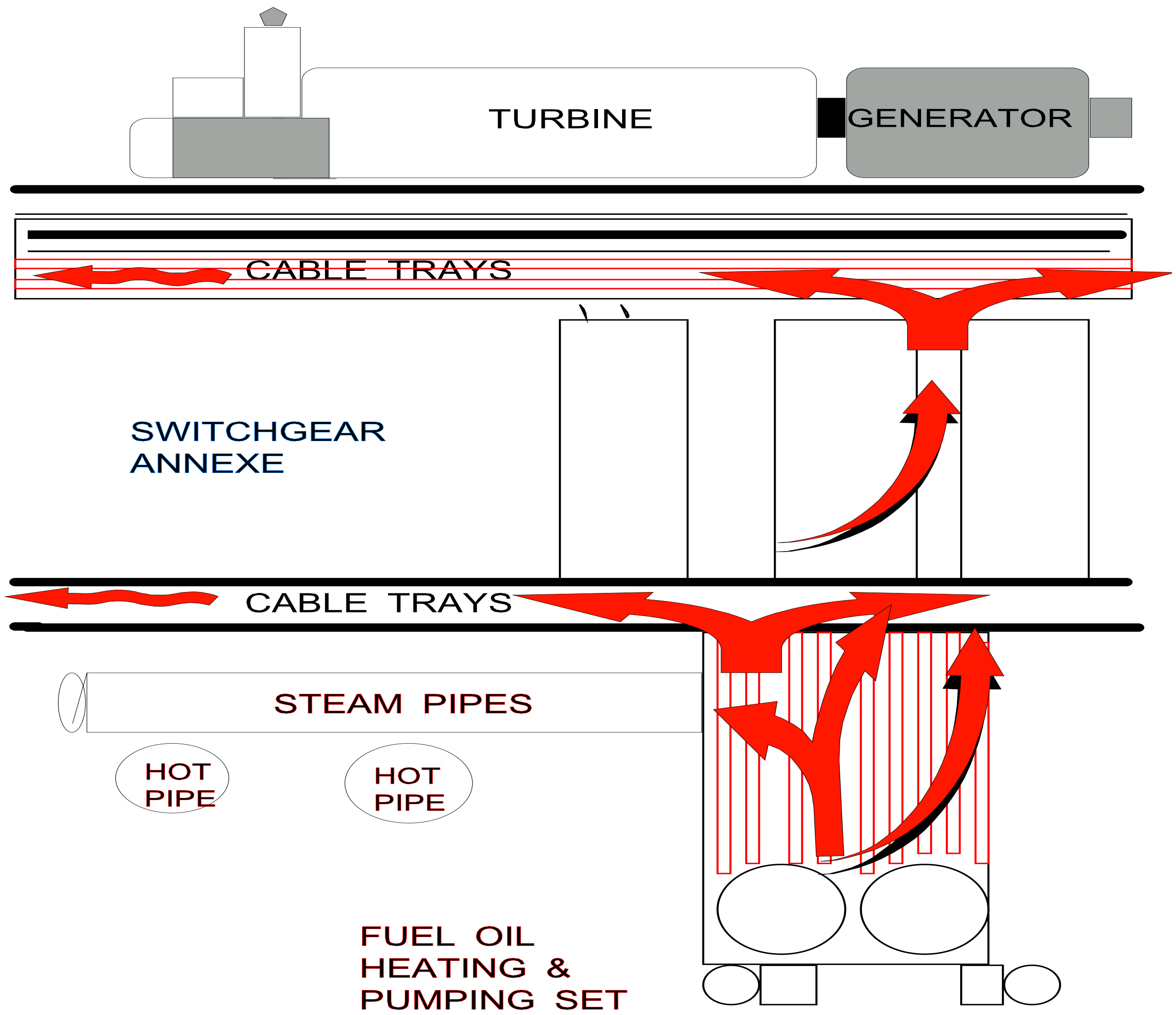
- Venice Plant Fire report Update.mpg

STEAM TURBINE LUBE OIL PIPEWORK RUPTURE – US$80M

FIRE PROTECTION/PASSIVE PROTECTION/EMERGENCY RESPONSE/MAINTENANCE & INSPECTION

- Turbine house of a thermal power station
- 5 steam 70MW turbine-generator units, axially in line
- Enclosed turbine hall 315m long x 41m wide
- Each t-g unit has own aux plant within the footprint of the unit.
- Layout - ground floor
- Steam pipes cross the ground floor area, and penetrated the boiler-turbine house division wall near to the fuel oil heating and pumping sets
- Incandescent lamps light the area above the fuel oil pump set
- A small, pinhole sized leak in the hot oil discharge pipe of the heavy fuel oil heating and pumping set for unit number 4 occurred.
- Due to corrosion or poorly fitted pipe jointing material
- Fuel oil in this pipe is at 19 barg and 90C
- These conditions create an **oil mist** which is ignited by –
  - Hot unprotected steam pipes or
  - Unprotected incandescent lamps
- Resultant fire resembles a jet fire, ignites nearby vertical cable trays.

LUBE OIL FIRE SPREAD



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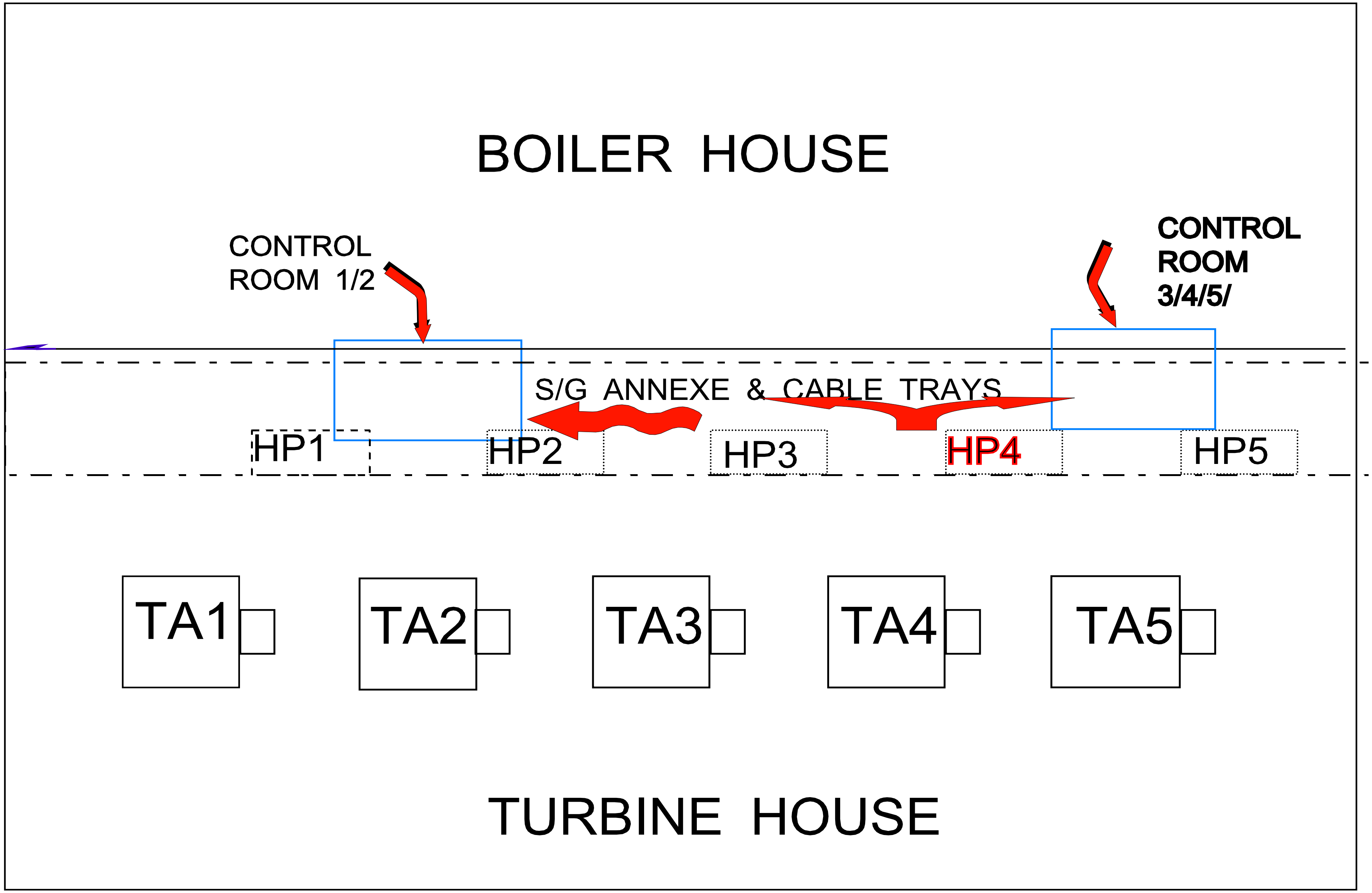

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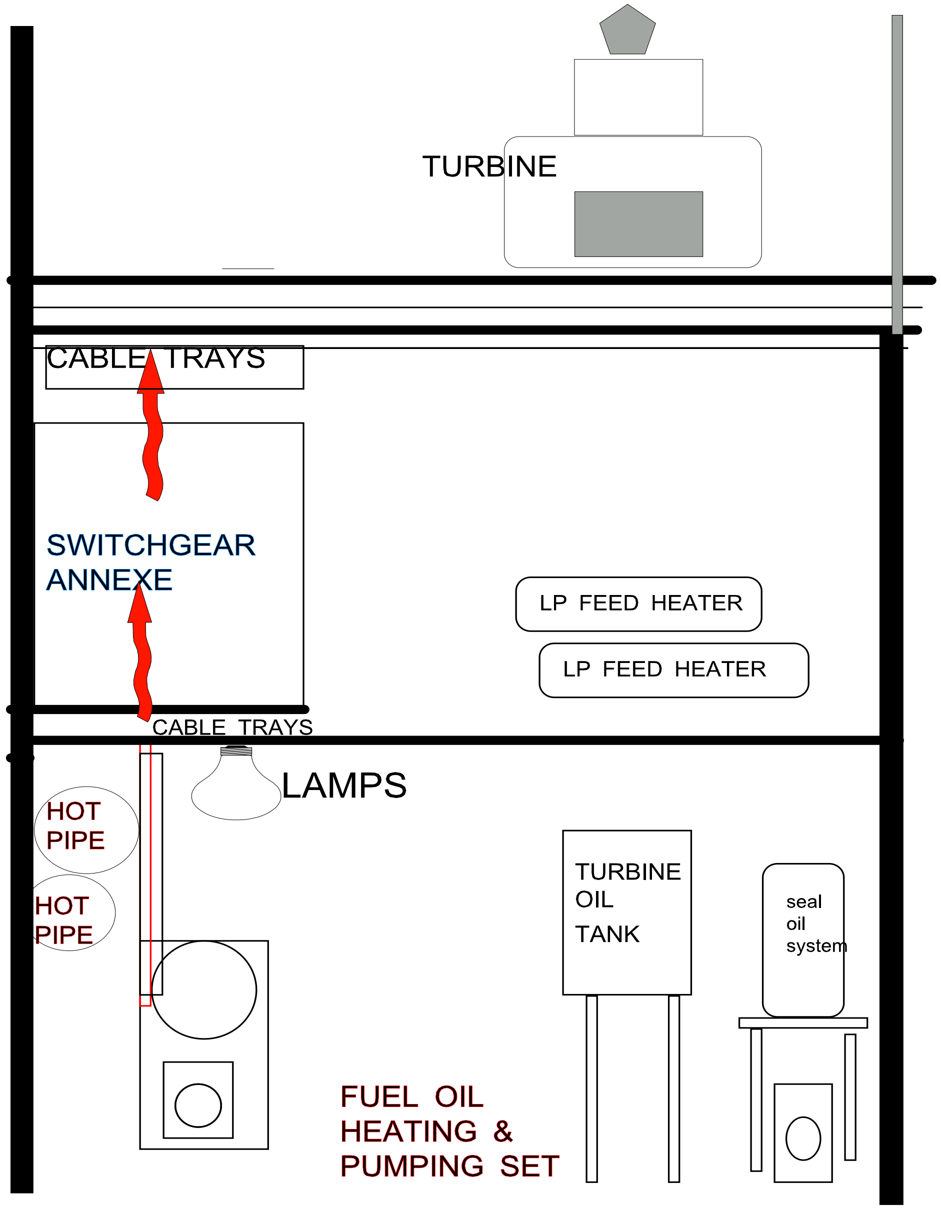

LUBE OIL FIRE SPREAD

- Negative Loss Control Features

  - Location/Layout
  - Poor location of fuel oil heating and pumping unit - within the turbine house directly below cable runs close to hot steam pipes
  - No segregation provided between units in switchgear/cable annexe
  - Design/Construction
  - Cables do not have a fire retarding or intumescent coating
  - Poor choice of lamps in a potentially hazardous area - should be explosion proof rated
  - None of the cable trays fire blocked at penetrations through walls, floors and ceilings
  - Design/Construction
  - Control cables not run in conduit or duplicated
  - No diversification of control cable routes - all units' control cables run on same cable tray
  - No pipe penetrations were sealed
  - Management Systems
  - Inadequate surveillance of areas without fire detectors
  - Station fire team inadequate to fight fierce, well developed fire
  - Regular fire drills for different areas not practised

LUBE OIL FIRE SPREAD

- Fire Detection/Protection

  - Smoke detectors were **not** installed in ground floor area, neither
  - In vicinity of heating and pumping unit nor
  - Lubricating oil and generator seal oil and hydrogen systems
  - No smoke detectors in control room panels/cabinets
  - Fixed fire extinguishing water deluge systems above the fuel oil heating & pumping sets were not automatic
  - No fixed fire extinguishing system(s) in switchgear annexe
  - No fixed fire extinguishing system over cable trays

OBVIOUS, BUT……

- Cleanliness

- *$8 million roll of paper towels ...*
- *This is being sent to reinforce the need to final inspect inlets after cleaning to assure nothing is left behind.*
- *Texas power generation station that had catastrophic compressor damage due to a roll of paper towels. The site's maintenance workers entered the inlet housing to clean the inlet guide vanes. After the work was complete, the towels were left near the top in the inlet bellmouth. When the unit was run, the towels were sucked up to the IGVs and stuck there still rolled up. Since the area where the towels were caused a low pressure area, the blades entered an area that allowed the blades to become unloaded for a fraction of a second during each revolution.*
- *After 23 hours of operation, one of the first stage blades liberated from the rotor. In the first picture you will see an IGV embedded in the side of the inlet housing and the remains of the paper towels laying on the floor to the right of the man's leg. Other compressor parts were found laying in and embedded in the "trash screen" located approximately 25 feet up inside the inlet housing. Since this unit has only one rotating mass, the entire rotor was removed and sent for overhaul. The upper and lower compressor casing had to be replaced due to significant damage*

Thank You

paul.markham@libertyiu.com

+44 20 7860 6660