MAGNETROL®

UNDERSTANDING SAFETY INTEGRITY LEVEL

SPECIAL APPLICATION SERIES

Buncefield
Petrol Depot Explosion

On the morning of 12/11/05, the largest detonation since the end of WWII rocked the Buncefield Petrol Depot north of London. 72 million gallons of fuel ignited causing a shock that registered 2.4 on the Richter scale. Catastrophic events like Buncefield, Texas City and Bhopal are what the information in this brochure is meant to prevent.

The New Standards in Safety

Protecting People, Profitability, Productivity, and the Environment

Industrial safety in pre-digital eras centered mainly around safe work practices, hazardous materials control, and the protective "armoring" of personnel and equipment. Today, safety penetrates far deeper into more complex manufacturing infrastructures, extending its protective influence all the way to a company's bottom line. Contemporary safety systems reduce risk with operational advancements that frequently improve reliability, productivity and profitability as well.

Nothing is more important than safety to the process control industries. High temperature and pressure, flammable and toxic materials are just some of the issues faced on a daily basis. Reliability is a key component of safety; the more reliable the device, the safer the critical process. After years of work by the **ISA SP84** committee, **IEC 61508** and **IEC 61511** have recently come together to yield a safety standard that the world is embracing. **IEC 61511** is particularly important as it is written specifically for the Process Industries. This standard quantifies safety issues as never before. Although the safety issues addressed are critical to users with installations like Emergency Shutdown Systems (ESD), the reliability defined in this specification is being used by all users to separate great products from good ones. SIL (Safety Integrity Level) and SFF (Safe Failure Fraction) are two of the key values that customers can use as an objective comparison of instrument reliability from various suppliers.

Reliability. Although this brochure targets safety applications and installations like Emergency Shutdown Systems, more than 90% of al applications are not safety-related. Those people are now using the SIL data as an indicator for reliability, i.e., the better the numbers, the more reliable the instrument.

MILESTONE

TUV (Bavaria) *Microcomputers in Safety-Related Systems* (1984)

Health & Safety Executive (UK): *Programmable Electronic Systems in Safety Related Applications* (1987)

OSHA (29 CFR 1910.119) (1992): *Process Safety Management of Highly Hazardous Chemicals*

Instrument Society of America ANSI/ISA 84 (2004): *Safety Instrumented Systems for the Process Industries*

International Electrotechnical Commission (1998-2003)
IEC 61508 (2000): A general approach to Functional Safety Systems
IEC 61511 (2003): Process sector implementation of IEC 61508

Understanding Risk. All safety standards exist to reduce risk, which is inherent wherever manufacturing or processing occurs. The goal of eliminating risk and bringing about a state of absolute safety is not attainable. More realistically, risk can be categorized as being either negligible, tolerable or unacceptable. The foundation for any modern safety system, then, is to reduce risk to an acceptable or tolerable level. In this context, safety can be defined as "freedom from unacceptable risk."

The formula for risk is:

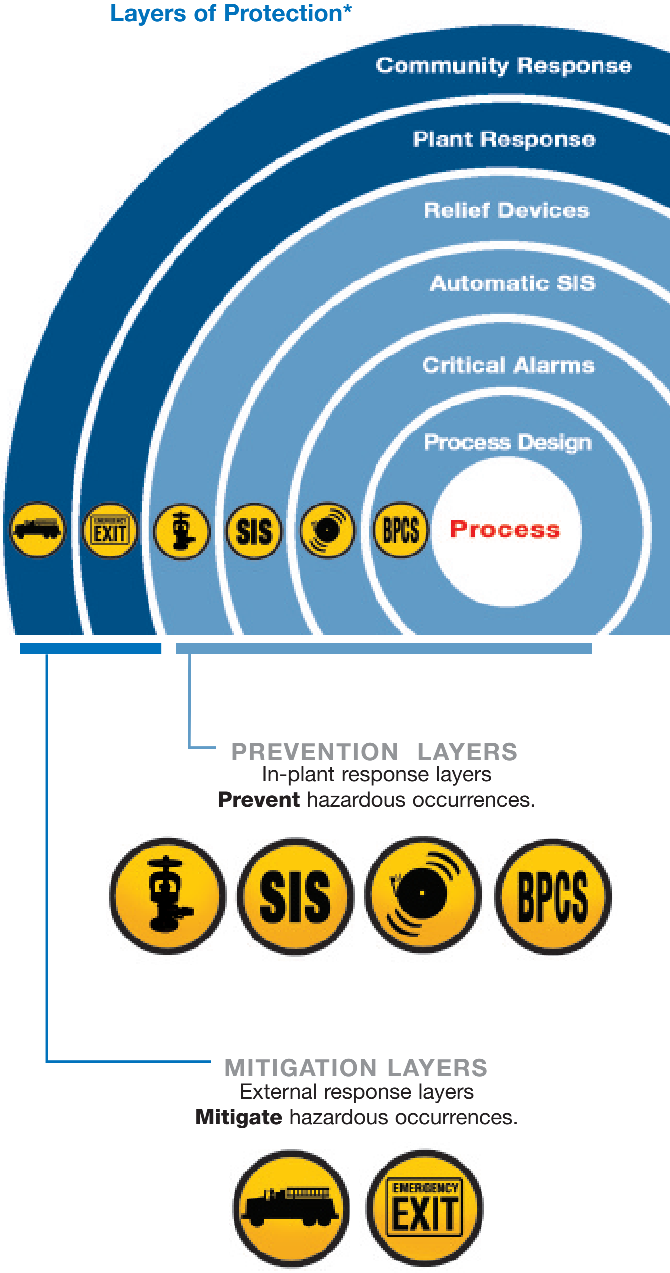
RISK = HAZARD FREQUENCY x HAZARD CONSEQUENCE

Risk can be minimized initially by inherently safe process design, by the **Basic Process Control System** (**BPCS**), and finally by a safety shutdown system.

Layered Protection. Much evaluation work, including a hazard and risk assessment, has to be performed by the customer to identify the overall risk reduction requirements and to allocate these to independent protection layers (IPL). No single safety measure can eliminate risk and protect a plant and its personnel against harm or mitigate the spread of harm if a hazardous incident occurs. For this reason, safety exists in protective layers: a sequence of mechanical devices, process controls, shutdown systems and external response measures which prevent or mitigate a hazardous event. If one protection layer fails, successive layers will be available to take the process to a safe state. If one of the protection layers is a safety instrumented function (SIF), the risk reduction allocated to it determines its safety integrity level (SIL). As the number of protection layers and their reliabilities increase, the safety of the process increases. Figure A shows the succession of safety layers in order of their activation.

Hazards Analysis. The levels of protective layers required is determined by conducting an analysis of a process's hazards and risks known as a **Process Hazards Analysis** (**PHA**). Depending upon the complexity of the process operations and the severity of its inherent risks, such an analysis may range from a simplified screening to a rigorous **Hazard and Operability** (**HAZOP**) engineering study, including reviewing process, electrical, mechanical, safety, instrumental and managerial factors. Once risks and hazards have been assessed, it can be determined whether they are below acceptable levels. If the study concludes that existing protection is insufficient, a **Safety Instrumented System** (**SIS**) will be required.

Figure A
Layers of Protection*



*The above chart is based upon a Layers Of Protection Analysis (**LOPA**) as described in IEC 61511 part 3 Annex F.

Safety Instrumented Systems (SIS)

The **Safety Instrumented System (SIS)** plays a vital role in providing a protective layer around industrial process systems. Whether called an SIS, emergency or safety shutdown system, or a safety interlock, its purpose is to take process to a "safe state" when pre-determined set points have been exceeded or when safe operating conditions have been transgressed. A SIS is comprised of safety functions (see SIF below) with sensors, logic solvers and actuators. Figure B shows its basic components:

- Sensors for signal input and power
- Input signal interfacing and processing
- Logic solver with power and communications
- Output signal processing, interfacing and power
- Actuators (valves, switching devices) for final control function

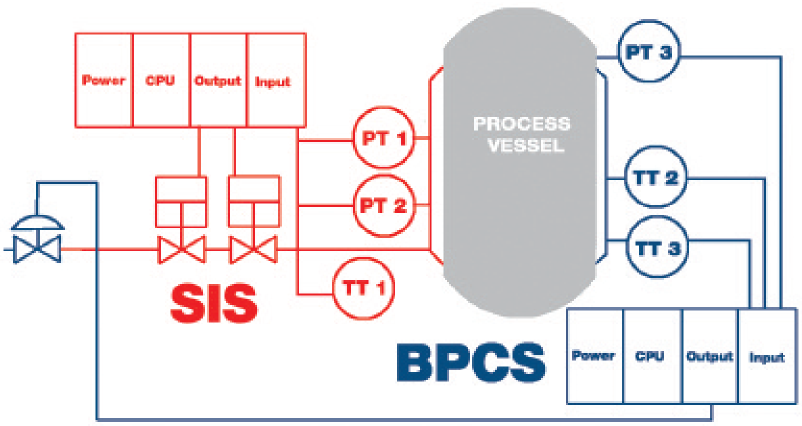


Figure B
Process schematic showing functional separation of SIS (red) and BPCS (blue).

SIF: Safety Instrumented Functions. A **Safety Instrumented Function (SIF)** is a safety function with a specified Safety Integrity Level which is implemented by a SIS in order to achieve or maintain a safe state. A SIF's sensors, logic solver, and final elements act in concert to detect a hazard and bring the process to a safe state. Here's an example of a SIF: A process vessel sustains a buildup of pressure which opens a vent valve. The specific safety hazard is overpressure of the vessel. When pressure rises above the normal set points a pressure-sensing instrument detects the increase. Logic (PLC, relay, hard-wired, etc.) then opens a vent valve to return the system to a safe state. In fact, the increased availability and use of this reliability data has allowed the traditional example above to be improved using HIPPS (High Integrity Process Pressure System) to eliminate even the risk of venting to the environment. When HIPPS is implemented, the system controls are so thorough and reliable that there is no need to vent, or use a relief valve.

Like the safety features on an automobile, a SIF may operate continuously like a car's steering, or intermittently like a car's air bag. A safety function operating in the demand mode is only performed when required in order to transfer the **Equipment Under Control (EUC)** into a specified state. A safety function operating in continuous mode operates to retain the EUC within its safe state. Figure C shows the relationship between SIS, the Safety Instrumented Functions it implements, and the Safety Integrity Level that's assigned to each Safety Instrumented Function.

SIS • SIF • SIL RELATIONSHIP

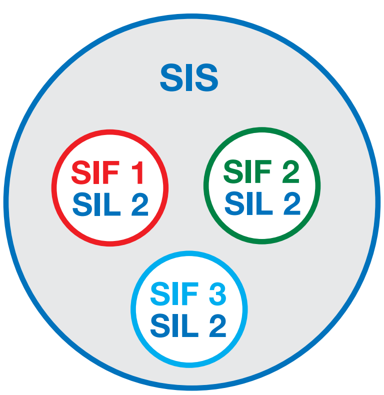


Figure C
Every SIS has one or more safety functions (SIFs) and each affords a measure of risk reduction indicated by its safety integrity level (SIL). **The SIS and the equipment do NOT have an assigned SIL. Process controls are "suitable for use" within a given SIL environment.**

Safety Life Cycle. Earlier we mentioned how a Hazard and Risk Assessment study will determine the need for an SIS. This assessment is one part of a safety life cycle which all major safety standards have specified. The safety life cycle shows a systematic approach for the development of a SIS. A simplified version is shown in Figure D.

Figure D
The Safety Life Cycle is a sequential approach to developing a Safety Instrumented System (SIS). References to a Safety Life Cycle can be found in ANSI/ISA 84.00.01 Parts 1–3; IEC 61508 Part 1; and IEC 61511 Parts 1–3.

Safety Integrity Level (SIL)

To what extent can a process be expected to perform safely? And, in the event of a failure, to what extent can the process be expected to fail safely? These questions are answered through the assignment of a target **Safety Integrity Level** (**SIL**). SILs are measures of the safety risk of a given process.

IMPORTANT: It is incorrect to call a particular device "SIL 1" or "SIL 2." For example, it is common to call the Eclipse® 705 (51A) a "SIL 2 device." This is inaccurate because the entire control loop must be taken into account. Technically, it is accurate to say a device is "suitable for use within a given SIL environment." For example, "the Eclipse® 705 (51A) is now certified as suitable for use in a SIL 3 environment."

Four Levels of Integrity. Historically, safety thinking categorized a process as being either safe or unsafe. For the new standards, however, safety isn't considered a binary attribute; rather, it is stratified into four discrete *levels* of safety. Each level represents an order of magnitude of risk reduction. The higher the SIL level, the greater the impact of a failure and the lower the failure rate that is acceptable.

Safety Integrity Level is a way to indicate the tolerable failure rate of a particular safety function. Standards require the assignment of a target SIL for any new or retrofitted SIF within the SIS. The assignment of the target SIL is a decision requiring the extension of the Hazards Analysis. The SIL assignment is based on the amount of risk reduction that is necessary to maintain the risk at an acceptable level. All of the SIS design, operation and maintenance choices must then be verified against the target SIL. This ensures that the SIS can mitigate the assigned process risk.

Hardware Fault Tolerance. IEC61508-4 defines "fault tolerance" as the "ability of a functional unit to continue to perform a required function in the presence of faults or errors." Therefore, hardware fault tolerance is the ability of the hardware (complete hardware and software of the transmitter) to continue to perform a required function in the presence of faults or errors. A hardware fault tolerance of 0 means that if there is one fault, the transmitter will not be able to perform its function (for example, measure level). A hardware fault tolerance of N means that N+1 faults could cause a loss of the safety function. When an FMEDA is performed on a device, the resultant SFF has an associated hardware fault tolerance of 0.

Type B
(complex devices)
Table 3 from IEC-61508

Safe Failure Fraction	Hardware Fault Tolerance		
	0	1	2
<60%	Not	SIL 1	SIL 2
60% to <90%	SIL 1	SIL 2	SIL 3
90% to <99%	SIL 2	SIL 3	SIL 4
≥99%	SIL 3	SIL 4	SIL 4

Figure E SIL and Related Measures*

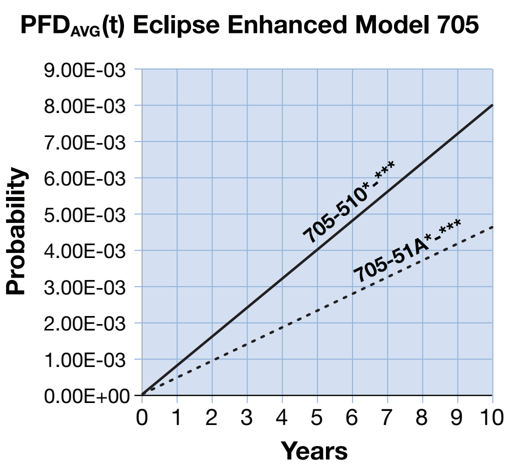
SIL	Availability	PFDavg	Risk Reduction	Qualitative Consequence
4	>99.99%	10^{-5} to $<10^{-4}$	100,000 to 10,000	Potential for fatalities in the community
3	99.9%	10^{-4} to $<10^{-3}$	10,000 to 1,000	Potential for multiple on-site fatalities
2	99 to 99.9%	10^{-3} to $<10^{-2}$	1,000 to 100	Potential for major on-site injuries or a fatality
1	90 to 99%	10^{-2} to $<10^{-1}$	100 to 10	Potential for minor on-site injuries

SIL: Safety Integrity Level.

AVAILABILITY: The probability that equipment will perform its task.

PFDavg: The average PFD used in calculating safety system reliability. (**PFD: Probability of Failure on Demand** is the probability of a system failing to respond to a demand for action arising from a potentially hazardous condition.)

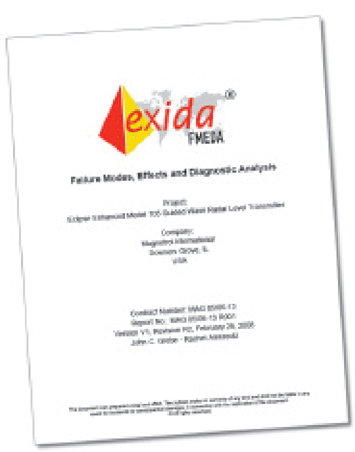
* Both IEC and ANSI/ISA standards utilize similar tables covering the same range of PFD values. ANSI/ISA, however, does not show a SIL 4. No standard process controls have yet been defined and tested for SIL 4.



Determining SIL Levels – Process

When a **Process Hazards Analysis** (**PHA**) determines that a SIS is required, the level of risk reduction afforded by the SIS and the target SIL have to be assigned. The effectiveness of a SIS is described in terms of "the probability it will fail to perform its required function when it is called upon to do so." This is its **Probability of Failure on Demand** (**PFD**). The average PFD (PFDavg) is used for SIL evaluation. Figure E shows the relationship between PFDavg, availability of the safety system, risk reduction and the SIL level values.

Various methodologies are used for assignment of target SILs. The determination must involve people with the relevant expertise and experience. Methodologies used for determining SILs include—but are not limited to—Simplified Calculations, Fault Tree Analysis, Layer of Protection Analysis (**LOPA**) and Markov Analysis.



Determining SIL Levels – Instrumentation

SIL levels for field instruments are established by one of two methods:

- **FMEDA** (Failures Modes, Effects and Diagnostic Analysis) is best when reviewed or certified by a third party like exida or TUV although self-declarations can be done by the manufacturer. A systematic analysis technique is necessary to determine failure rates, failure modes and the diagnostic capability as defined by IEC 61508/651511.
- **Proven In Use** (also called Prior Use) is typically used by a customer with a mature instrument in known processes. This approach requires sufficient product operational hours, revision history, fault reporting systems and field failure data to determine if there is evidence of systematic design faults in a product. IEC 61508 provides levels of operational history required for each SIL. It is generally considered of more value when done by users in their facility when comparing like data. It is considered less reliable when done by a device manufacturer whose data may be less relevant to the end user's application.

> If you are using Manufacturer's prior use data because a selected product does not reach the required level under FMEDA analysis, be aware that there are significant requirements on the end user. A mature product must generally be used to have the required field experience, and the design and assembly must be "frozen in time" in such a way that no upgrades, modifications or even configuration changes may be allowed that may render the "Proven In Use" data useless.

A key result of the analyses is establishing a Safe Failure Fraction (SFF) for a product. Figure F below shows the relationship of SFF values, SIL ratings and the effects of redundancy.

Figure F

Safe Failure Fraction (SFF) *(for Type B, microprocessor-based devices)*	No Redundancy	Single Redundancy	Double Redundancy
<60%	Not Allowed	SIL 1	SIL 2
60%<90% *(typical competitor)*	SIL 1	SIL 2	SIL 3
90%<99% *(ECLIPSE, JUPITER, E3)*	SIL 2	SIL 3	SIL 4
>99%	SIL 3	SIL 4	SIL 4

While two SIL 1 devices can be used together to achieve SIL 2 and two SIL 2 devices may be used to achieve SIL 3 (as suggested by the chart above), it is not automatic. Using redundancy to attain a higher SIL rating has additional requirements beyond hardware. It has an additional requirement of systematic safety which includes software integrity.

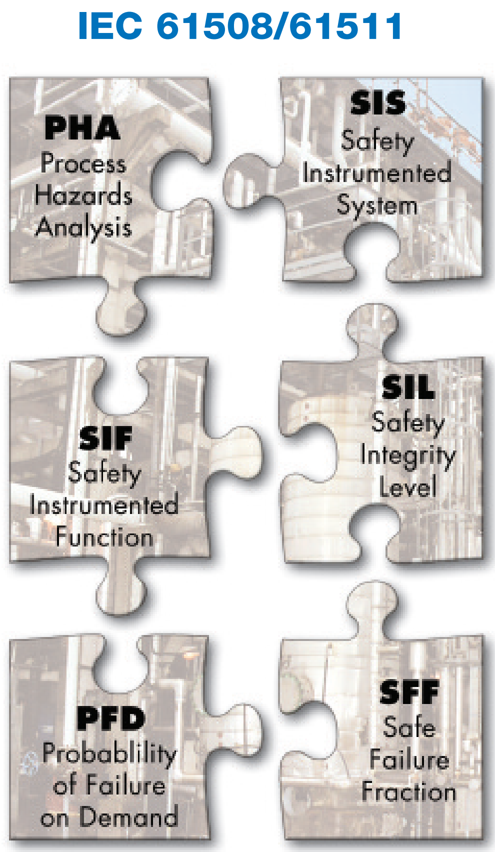
It is important to note that the most conservative approach to redundancy is to use dissimilar technologies. This reduces failures due to application issues.

Within the SFF determination is an understanding of types of failures and the ability of the instrument to diagnose them. Figure G shows the basic relationship.

Figure G Failure Designation

	Detected	Undetected
Safe	Nuisance	Nuisance
Dangerous	Important but accepted since they are detected	DANGER

It should be obvious that the most critical category of failures is called Dangerous Undetected (DU). For example, the certified ECLIPSE 705 (51A) has a high trip SFF of 91.9% with 130 Dangerous Undetected failures; this means that 91.9% of all failures are detected or safe (nuisance). Conversely, 130 represents the remaining 8.1% that are dangerous and undetected (see Pages 10 & 11). The lower the number of Dangerous undetected failures the better. This number is key in reliability evaluation, even for non safety-related applications.



Tying It All Together

Understanding how safety is quantified in IEC 61508/61511 can be difficult for anyone new to the concept. It is a daunting task to immediately grasp how all the various aspects of analysis fit together. Following is one perspective which yields a sound, basic understanding of the key terms that have been discussed throughout this brochure. It is meant to be a quick-reference for the safety "novice."

PHA (Process Hazards Analysis): This is where it starts. It is an analysis of the process that may range from a simplified screening to a rigorous Hazard and Operability (HAZOP) engineering study. PHA will determine the need for a SIS.

SIS (Safety Instrumented System): Its purpose is to take process to a "safe state" when pre-determined set points have been exceeded or when safe operating conditions have been transgressed. It does so by utilizing SIFs.

SIF (Safety Instrumented Function): One loop within the SIS which is designed to achieve or maintain a safe state. A SIF's sensors, logic solver, and final control elements act in concert to detect a hazard and bring the process to a safe state. What devices are used in the SIF are based on their required SIL.

SIL (Safety Integrity Level): A way to indicate the tolerable failure rate of a particular safety function. It is defined as four discrete levels of safety (1-4). Each level represents an order of magnitude of risk reduction. The higher the SIL level, the greater the impact of a failure and the lower the failure rate that is acceptable. SIL values are related to PFD and SFF. The claimed SIL is limited by the calculated PFD and SFF.

PFD (Probability of Failure on Demand): the probability a device will fail to perform its required function when it is called upon to do so. The average PFD (PFDavg- failure rate of all elements within a Safety Instrumented Function) is used for SIL evaluation.

SFF (Safe Failure Fraction): A number that shows the percentage of possible failures that are self-identified by the device or are safe and have no effect. The key number in this calculation is Dangerous Undetected failures—those that are not identified and do have an effect.

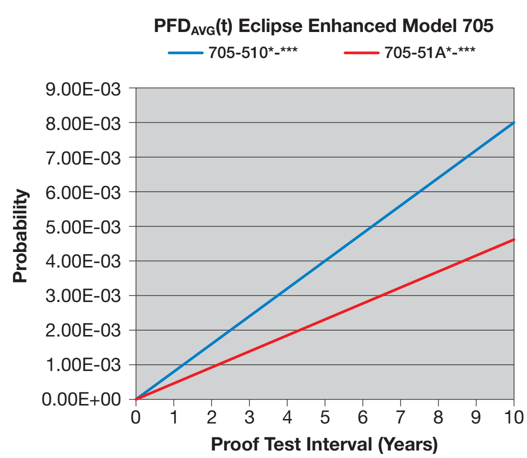
FMEDA Device Data

Assessing SIL-Suitable Controls A **Failure Modes, Effects and Diagnostic Analysis (FMEDA)** is a detailed performance evaluation that estimates the failure rates, failure modes, and diagnostic capability of a device. The following pages show data for specific devices.

The following explanations of key FMEDA data for SIL-suitable Magnetrol® controls can be used as reference:

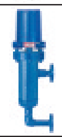
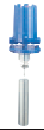
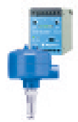
- **FAIL DANGEROUS DETECTED (λ_{dd})** Dangerous failures detected by internal diagnostics or a connected logic solver.
- **FAIL DANGEROUS UNDETECTED (λ_{du})** Dangerous failures that are not detected by the device.
- **FAIL SAFE (λ_{sd} & λ_{su})** Safe Failures (detected & undetected) that cause system to enter the fail-safe state without a demand from the process.
- **FITs Failures in Time (FITs)** where 1 FIT = 1×10^{-9} failures per hour. A second failure rate column has been added showing Annual data as it is also a commonly used value.
- **INSTRUMENT TYPE** Type "A" units are devices without a complex micro- processor on board, and all possible failures on each component can be defined. Type "B" units have a microprocessor on board and the failure mode of a component is not well defined.
- **MTBF Mean Time Between Failure** is calculated from FMEDA FITs data using the formula: $\dfrac{1}{(\lambda_{dd} + \lambda_{du} + \lambda_{sd} + \lambda_{su}) * (1E\text{-}9) * 8760}$
- **SERIES** The brand and model designation of the control (e.g., ECLIPSE Model 706).
- **SFF Safe Failure Fraction** is a percentage of Safe failures as compared to all failures: $SFF = 1 - \lambda_{du} / \lambda_{total}$

  A SFF of 93% for the ECLIPSE 706-511, for example, means that 93% of the possible failures are self-identified by the device or are safe and have no effect.
- **SIL** A device's Safety Integrity Level per IEC 61511. The safety integrity level corresponds to the range of safety integrity values (SIL 1, 2, 3 or 4), measured in terms of average probability of failure to perform a safety function on demand and in terms of the safe failure fraction. Redundant sensors can increase the SIL, it is often stated as "1 as 1oo1 /2 as 1oo2," meaning: SIL 1 if the device is one-out-of-one device used; SIL 2 if it is one-out-of-two devices used.
- **PFDavg** Average probability of failure on demand. It represents the probability a safety-related function will fail to respond when a demand occurs (in occurrence of a potential dangerous situation, the safety-related function is supposed to detect). It corresponds to a measure of its inability to perform the intended function in a safe time frame.
- **PROOF TEST INTERVAL** The frequency of manual testing to detect any failures not detected by automatic, on-line diagnostics.



SIL-Suitable Magnetrol Controls

- The SIL indicated below is per IEC 61508/61511.
- Failure rates expressed in FITS and Annual.
- PFDavg is calculated according to a proof test interval of one year, though other proof test intervals can be applied. (Refer to FMEDA report for additional information.)
- Transmitter failure rates assume the logic solver can detect both over-scale and under-scale currents.
- Contact MAGNETROL for complete FMEDA reports.

		Series and Description
TRANSMITTERS		**Eclipse® Model 706 Guided Wave Radar Level Transmitter** The Model 706 is a 24 VDC loop-powered transmitter that utilizes a variety of Coaxial, Twin, and Single rod probes. The performance of the Model 706 is not process dependent, and it is capable of measuring low dielectric liquids or solids.
TRANSMITTERS		**Eclipse® Model 705 Guided Wave Radar Level Transmitter (*Certified SIL 3 Capable)** The Model 705 is a 24 VDC loop-powered transmitter that utilizes a variety of Coaxial, Twin, and Single rod probes. The performance of the Model 705 is not process dependent, and it is capable of measuring low dielectric liquids or solids.
TRANSMITTERS		**Pulsar® Thru-Air Radar Level Transmitter** Pulsar® Models R86 and R96 are the latest loop-powered, 24 VDC, thru-air radar transmitters. They offer faster response time, easy operation and are not process dependent. 26 GHz and 6 GHz models offer superior performance in applications of turbulence, vapor, buildup and some foam.
TRANSMITTERS		**Modulevel® Displacer Level Transmitter** E3 takes displacer transmitters to the next level. Set up in as few as two steps without level movement. Microprocessor-based, HART, AMS and PACT*ware*™ compatible, E3 offers stable, reliable 4-20 mA output in most applications, including interface.
TRANSMITTERS		**Aurora® Magnetic Level Indicator** Aurora® is a patented, redundant, Magnetic level Indicator combined with an Eclipse® Guided Wave Radar Transmitter. In the event of float failure, the Eclipse® radar transmitter will continue to provide an accurate 4-20 mA output signal.
TRANSMITTERS		**Jupiter® Model JM4 Magnetostrictive Level Transmitter** A loop-powered level transmitter with HART communications, PACT*ware*™ DTM interface, LCD display and push buttons for simple configuration. It may be externally mounted to a MLI or directly into a vessel.
TRANSMITTERS		**TA2 Thermal Mass Flow Meter** TA2 thermal mass flow meter provides reliable flow measurement of air and gases. Provides excellent low flow sensitivity, high turndown and low pressure drop. Pre-calibrated and configured for the user's application. Integral or remote electronics.
SWITCHES		**Echotel® Single Point Ultrasonic Level Switches** Echotel® Model 961 switches feature advanced self-testing that continuously monitors the electronics, transducer and piezoelectric crystals. An adjustable time delay is provided for reliable measurement in turbulent processes.
SWITCHES		**Echotel® Dual Point Ultrasonic Level Switches** Echotel® Model 962 switches are designed for dual point level measurement or pump control. A tip sensitive lower gap allows measurement to within ¼" of the vessel bottom. The flow-through upper gap allows up to a 125" (318 cm) separation between switch points.
SWITCHES		**Single-stage External Cage Float Level Switches** These field-proven switches are self-contained units designed for external mounting on the side of a vessel, tank or bridle. Over 30 models of mechanical switches have proven their reliability and repeatability for decades in numerous applications.
SWITCHES		**Single-stage Displacer Level Switches** Models A10, A15 and External Caged Displacer Switches offer reliable and repeatable operation in sumps, storage and process vessels. Displacer switches offer flexibility in application and are not affected by dirty liquids, coating, foam, turbulence or agitation.
SWITCHES		**Thermatel® TD Series Flow, Level Interface Switches** With continuous self diagnostics these switches provide reliable operation for flow, level, or interface detection. Temperature compensation provides repeatable switch operation with varying process temperature. Gas or liquid flow applications.
SWITCHES		**Thermatel® TG Series Flow, Level Interface Switches** Providing a two-wire intrinsically safe circuit between the probe and remote DIN rail enclosure these switches are suitable for liquid or gas flow, level, or interface detection. 24 VDC input power, relay plus mA signal for flow trending/indication.

Model	SIL (1oo1)	Instrument Type	SFF	Fail Dangerous Undetected	Fail Dangerous Detected
				FITs	FITs
*706 (511) *Certified	2	B	93.1%	61	748
*705 (51A) *Certified	2	B	92.7%	51	861
705 (510)	1	B	84.5%	183	567
R86	2	B	93.2%	75	953
R96	2	B	92.7%	81	972
*E3 (HART) *Certified	2	B	90.6%	61	579
705 (510)	1	B	84.5%	183	567
705 (51A)	2	B	91.0%	106	650
JM4	2	B	93.1%	92	1113
TA2 (HART)	1	B	88.0%	218	865
961-5 Wet Safe / Dry Safe	2 / 2	B / B	90.4% / 96.5%	27 / 10	234 / 234
961-2/7 Relay	2	B	92.0%	40	351
962-5 Wet Safe / Dry Safe	2 / 2	B / B	90.6% / 98.0%	47 / 10	426 / 426
962-2/7 Relay	2	B	91.5%	52	427
Low Level, NO (SPDT)	2	A	61.0%	278	0
Low Level, NO (DPDT)	2	A	72.0%	197	0
Low Level (DPDT)	2	A	68.2%	40	71
High Level (DPDT)	2	A	77.7%	28	98
TD1	1	B	69.3%	140	252
TD2	1	B	73.0%	161	390
TG1/TG2	1	B	79.4%	115	188

Visit magnetrol.com for more information on SIL-suitable MAGNETROL controls including complete FMEDA reports. For further information regarding SIS, SIL and general process safety we recommend these online resources:

Subject:	www:
IEC standards & bookstore	iec.ch/home
ISA standards & bookstore	isa.org
exida engineering guides	exida.com
TUV functional safety services	tuv-global.com
UK Health & Safety Executive	hse.gov.uk
Institution of Chemical Engineers	icheme.org
IHS/Global engineering documents	global.ihs.com
Factory Mutual process safety	fm global.com
OSHA process safety standards	osha.gov
Center for Chemical Process Safety	aiche.org

MAGNETROL®

CORPORATE HEADQUARTERS
705 Enterprise Street • Aurora, Illinois 60504-8149 USA • Phone: 630-969-4000
magnetrol.com • info@magnetrol.com

EUROPEAN HEADQUARTERS
Heikensstraat 6 • 9240 Zele, Belgium • Phone: 052 45.11.11

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