

# Early history of shunt diode safety barriers

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## Synopsis

The history of the development of shunt diode safety barriers in the United Kingdom from 1961-1971 is used to illustrate the time taken and the many factors affecting the development of light current equipment for use in hazardous areas.

## Introduction

This document attempts to record the early development of shunt diode safety barriers within the United Kingdom.[1961-1971], with a brief reference to the subsequent expansion. It demonstrates that to succeed it was necessary for many people from different sections of the process instrument industry, to recognise the need for barriers and to become involved in the development and acceptance process. The significant contribution of many of these people is generally not recognised.

During this period the author was employed at Kent Instruments Ltd in the Research Department, which at that time allowed individuals the freedom to explore their particular individual interests. Support for the barrier project was limited to a few individuals and it was opposed by an even smaller [but influential] number. The majority of the people who might have been expected to have an interest in the technique because of the possible effect on process instrumentation were totally indifferent.

Inevitably some people who made significant contributions will have been omitted from this account or possibly had their names miss-spelled and profuse apologies are offered in anticipation of this error. Any account of the past is always influenced by the author's recollections and prejudices. If these are too evident in this particular case a further apology is offered.

Developments in the field of intrinsic safety always take a long time. The development of the initial concept and the need to consult others who are involved in certification or the application of instruments and can bring a different viewpoint are factors which contribute to the time taken. The tortuous path through the certification labyrinth, which usually includes the creation of new standards or the modification of existing standards and the creation of an acceptable Code of Practice also contribute to the elapsed time. All these factors are illustrated by this document. This long time scale and the indeterminate costs involved serve as a deterrent to the majority of financially controlled manufacturers entering this field but the long term rewards can be significant. Shunt diode safety barriers are still manufactured in significant numbers and several million have been manufactured and installed since the concept was introduced.

The following history is based on some recollections but reinforced by the information listed in the appendix which is supported by existing documentation. This document only discusses the development within the UK. Parallel development in other countries did take place towards the end of this period particularly in Germany but detailed accurate information of this development is not readily available to the author and hence is not included.

## History

### The concept years 1961-1963

It is recognised that the 1960's were very different from the current situation. Then BS 1259 was the current standard for intrinsic safety, and CENELEC and IEC standards did not exist. The current equivalent of BS 1259 [18 A5 pages] is a combination of the general requirements BS EN 60079-0 [88pages], apparatus standard BS EN 60079-11[141pages] and the system standard BS EN 60079-25 [74 pages]. The grand total of 303 A4 pages as compared with 18 A5 pages represents the advance in technology or the submerging in bureaucracy depending on your viewpoint. Probably it is a little of both.

At this time, certification of intrinsically safe equipment for surface industries in the UK was the responsibility of the Factory Inspectorate, based on testing by the Safety-in-Mines Research Establishment [SMRE] in Sheffield. In 1961 intrinsic safety as a technique for instrumentation in surface industry in the UK was beginning to be an acceptable technique in the petrochemical and pharmaceutical industries but was not widely accepted in refineries. Germany was further advanced in accepting the technique and the USA was firmly wedded to the plumbing of the explosion proof technique. For new developments in this field the current situation on first appraisal appears to be very different but the circumstances

are fundamentally similar and new developments still take a similar time as illustrated by the FISCO [Fieldbus] and Power 'i' developments.

The first use of zener diodes for the limitation of voltage in intrinsically safe circuits in the UK was probably in the output isolator stage of a very early [1959] electronic controller manufactured by Evershed and Vignoles. The possible use of a fuse/zener diode/resistor network as a barrier was first publicly discussed by Bob Redding at a symposium [organised by Ludwig Finklestein] at Northampton College of Advanced Technology [now City University]

in 1961. Bob Redding at the time worked for Evershed and Vignoles, but later became a very independent consultant. Bob had an incredible inventive flair combined with an irrepressible temperament. He made a very significant contribution to the development of barriers, other aspects of intrinsic safety and process instrumentation generally.

The proposed design was beautifully simple and is illustrated in Figure 1 and this initiated a very long and searching discussion. At this time Kent Instruments was trying to get its Transdata range [an early transistorised measurement and control system] certified as 'associated apparatus' [not a defined term at that time] for use in IS systems and not having a great deal of success. A prototype model of the Redding barrier using a terminal block component holder was created as a possible way forward. Figure 2 shows part of the drawing of this device. [As an aside it is interesting to note that the drawing was created by John Notley who later became a significant player in the ABB organisation but was a youthful draughtsman within Kent Instruments at the time].

A fairly intensive discussion period followed and the need to duplicate or triplicate the diodes emerged. At this time the question of the permitted fault count, which components were considered infallible and the possibility of 'ia' and 'ib' levels of intrinsic safety were all at very early stages of discussion. The permitted use of only two specially tested diodes in what is essentially an 'ia' apparatus was influenced to some extent by the necessity to continue the use of bridge rectifiers to suppress inductive loads such as solenoid valves. There was limited knowledge on the surge rating of zener diodes and the relationship with the rupturing characteristics of fuses was endlessly debated. Fortunately much of the necessary experimental work was done by a combination of Bert Riddlestone and Adrian Bartel at the Electrical Research Association [ERA] and consequently was readily accepted. The majority of the tests were done using stud mounted diodes from International Rectifiers who cooperated well throughout. On one occasion there was a meeting at ERA with Dr Gehm the then head of the German certifying authority Physikalisch-Technische

Figure 1 Initial Redding proposal

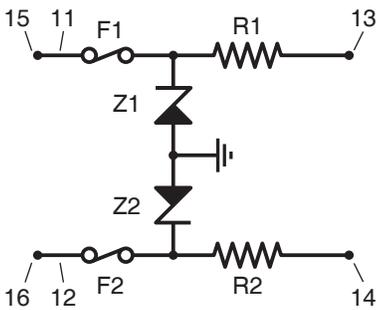
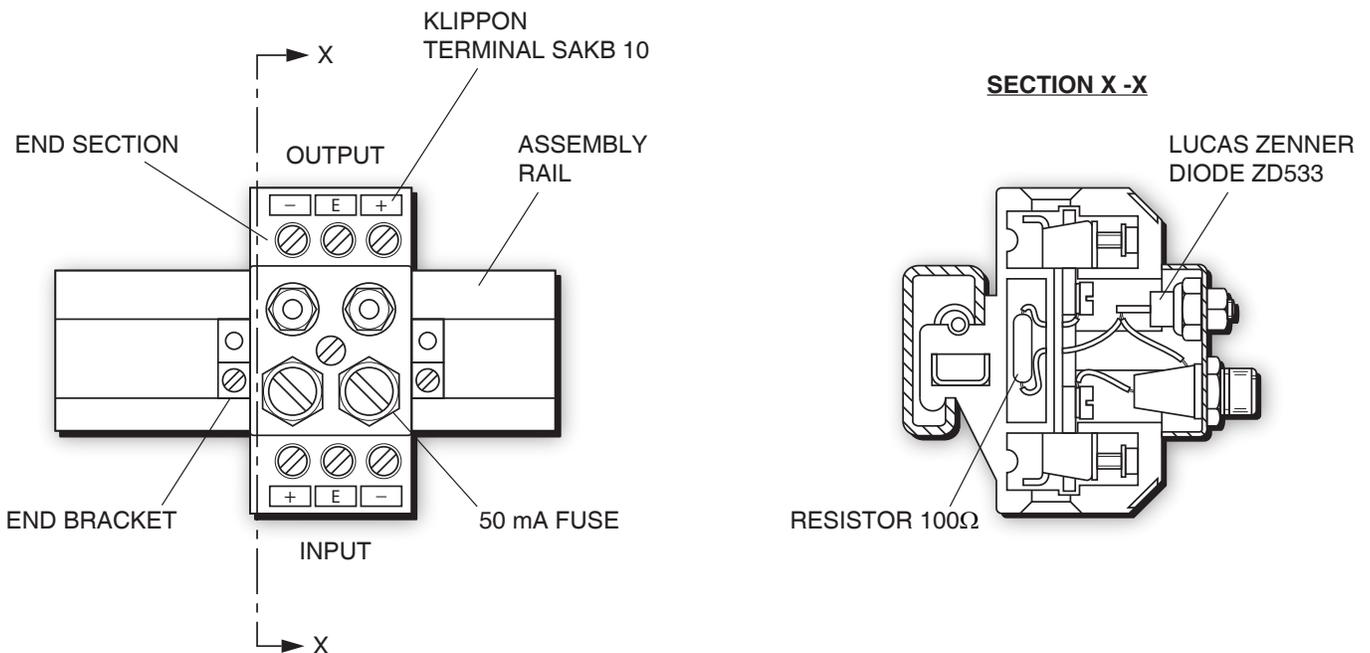


Figure 2 Early barrier prototype



Bundesanstalt [PTB] who was not in favour of barriers and had recorded the statement that 'barriers would never be permitted in Germany'. This reflected a Germanic preference for isolation which is still present and was possibly influenced by their skills with magnetic amplifiers. [Hartman Braun used them very successfully in the 1960's] This was a considerable setback at the time because even then the European market was significant from both economic and technical acceptance reasons. Later this attitude softened slightly and a PTB document in 1969 discussed the application of barriers but only allowed their application in Zone 1 with well-defined earthing requirements.

### Early prototypes and further evaluation 1963-1964

During this period large prototype open construction barriers as illustrated in Figure 3 were used to promote discussion and generate interest.

Despite this construction not being suitable for large installations, one was installed in a carbon black plant in

Scotland and was in use until the mid-1990's. A number of people evaluated units. Tom Cook and Jop Beeftink of ICI were deeply involved and made numerous suggestions which were subsequently discussed with Noel Elliott who was head of the electrical section of the Factory Inspectorate. The outcome was that it was considered necessary to encapsulate the barrier so as to avoid problems caused by pollution and the possibility of unauthorised replacement of components. Encapsulation also improved the thermal dissipation. Discussions were held with Gresham Transformers Ltd, who had experience in the use of epoxy resin encapsulation of small transformers, which was a rare skill at the time. A practical design was produced by Doug Adams with Trevor Bolton acting as driving force. A significant event was the signing of a 'letter of no objection' by Noel Elliott on December 24th 1964 based on an ERA report. How far this was influenced by the Christmas spirit of goodwill and the fact that Noel was retiring on that day is open to speculation.

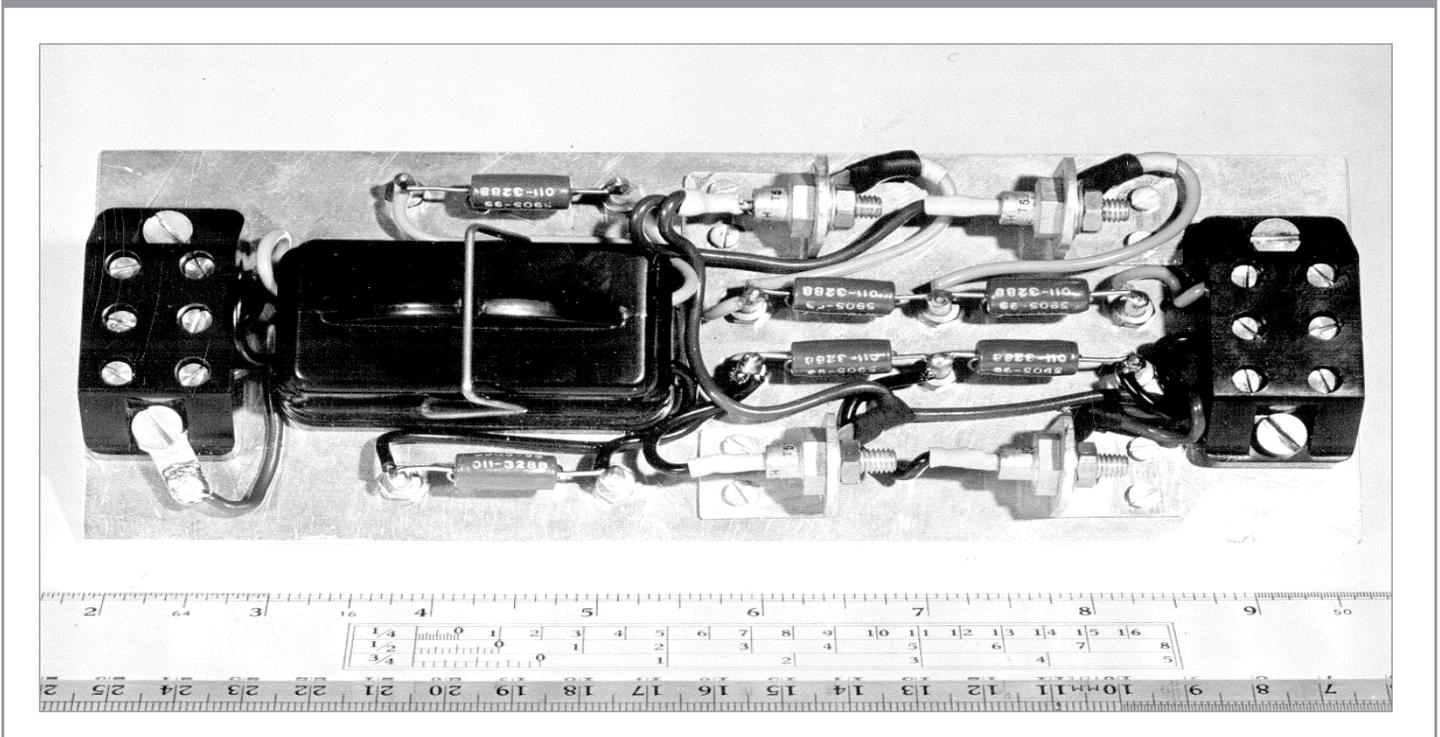
Freddie Arnaud a Senior Electrical Factory Inspector actively progressed

the barrier project. His expertise on earthing and intense suspicion of auto-transformers had a major influence on the developing codes of practice. It was his concern to avoid the possible deluge of apparatus and system certificates which led to his proposal of the 'simple apparatus' concept. This was intended to avoid the need for certifying switches, thermocouples, resistance thermometers and other simple devices. The concept of 'simple apparatus' remains a significant factor in the design of intrinsically safe systems and this is almost entirely due to this early initiative.

### Certification and wider acceptance

In order to justify the amount of effort being put in by the Factory Inspectorate it had to be made clear that the barrier concept should become 'public property' and not limited to one organisation. Fortunately at that time BIMCAM [later became part of GAMBICA] had an active Flammable Atmospheres Group [FLAG] with representation from all the major UK instrument companies under the chairmanship of Ken Brown of Foxboro.

Figure 3 An early open-construction barrier





Ministry of Labour  
H.M. FACTORY INSPECTORATE  
19 St. James's Square, LONDON S.W.1  
Entrance by 35 King Street  
Telephone: WHITEhall 6200, ext. 657

Your reference:

Our reference:

21st. December 1964

Messrs. George Kent Limited,  
Biscot Road,  
LUTON, Beds.

For the attention of Mr. L.C. Towle  
Research & Development

Dear Sirs,

Barrier Device Type 1

We have considered the report entitled "Report on Barrier Device Type 1" dated 13th. December 1964 which lists the design principles, method of construction and experiments carried out on the barrier.

Having due regard for the fact that this report has been checked and found satisfactory by the Electrical Research Association, we confirm that the device manufactured in accordance with drawing No. 1 of that report and applied according to the principles laid out in detail in that report, in our opinion affords the degree of protection implied in the terms of Regulation 27 of the Electricity Regulations, and is suitable for use in connection with Division 1 Areas, the output circuits being safe from incendive sparking where there may be a risk of gases or vapours of the Hydrogen/Ethylene/Pentane Classes.

Yours faithfully,

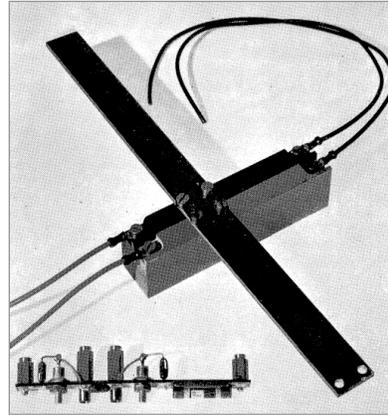
A handwritten signature in dark ink, appearing to read 'H. Elliott'.

H. Elliott  
H.M. Electrical Inspector of Factories

NOTE: BIMCAM was The British Industrial Measuring & Control Apparatus Manufacturers' Association. The initials GAMBICA do not translate into a name which adequately covers the combination of instrumentation orientated organisations which form its membership; hence these letters are just a name.

At that time Foxboro, Taylor, Honeywell, Kent and General Electric were all members of FLAG and lunch at the St Ermin's hotel, Westminster was a considerable attraction. FLAG plus Bob Redding became the core of the co-operative action on barriers. Possibly the group's most useful action was the publication of the BIMCAM code of practice on barriers which served industry well for a number of years before being replaced by the BASEEFA code of practice SFA 3004. The publication of this document was due to the persistence of Ken Brown who overcame the initial resistance of the BIMCAM council. The relationship between the various participants was stretched at times but problems were usually resolved because in general the problems did not involve what was perceived as high commercial stakes and the participants were engineers. A typical problem was that barriers had to carry a manufacturer's name because of the certification requirements. The 28V 240Ω barrier was developed by a combination of Kent and Taylor activity. Ron Sunderland and Olec Binski of Taylor Instruments Ltd were deeply involved and the question of whose name should be used inevitably arose. The problem disappeared when a senior director at Kents refused to pay the certification fee [a few hundred pounds] and Taylor with a better sense for future potential willingly stepped in. In the late 1960's the co-

Figure 5 Encapsulated barrier



operation weakened, and Foxboro, Honeywell and Taylor all introduced variants on the theme, but the major usage remained with the Kent/Taylor versions. At about this time other UK manufacturers, notably Robertson and Davy United developed barriers for specific applications.

During the period from 1964 to 1967, the early discussions were mostly with 'Widge' Widginton [testing being done by 'Bish' Bishop] with inputs from other members of SMRE and ERA and all other relevant and some irrelevant organisations. Topics included were, whether to use the UK cadmium curves or the PTB version, the characteristics of fuses compared to the surge rating of diodes and the reliability of earth connections. The use of cable parameters and other aspects of system design were all under discussion at this time and contributed to the general confusion. The possibility of applying and certifying barriers initiated many of the questions relating to intrinsically safe system design and this made a major contribution to the subsequent development of the 'entity concept' and system standard.

The British Approvals Service for Electrical Equipment [BASEEFA]

was created in 1967. Many of the SMRE staff transferred to BASEEFA and continued to deal with barrier certification and consequently the changeover had little effect on the progress of certification. However BASEEFA was, and in its modified form still is, a major influence in the development of barriers and intrinsic safety as a whole.

The Factory Inspectorate certificates emerged in 1967-8. A comprehensive test report on the 10V 47Ω barrier was compiled in March 1967 [signed by J.Cartwright]. The certificate followed in August and stipulated the use of the instructions card illustrated in Figure 6.

The first significant use of the encapsulated barriers was at an ICI Rosenberg [Amsterdam] site in 1965. At that time UK certification was pending and only partially acceptable in the Netherlands and hence approval by the appropriate authority KEMA in Arnhem was sought. There were fears that the plant start-up would be delayed for lack of acceptable approval. Vivid memories of a long fast drive across Holland on the last day to avoid a delay in start-up, bearing the KEMA documentation in the company of Jop Beeftink and Gordon Kingham [two ICI plastics stalwarts] remain as part of the barrier history. From that time the use of barriers began to increase and gained momentum as the three types of barrier [3V 10Ω, 10V 47Ω and 28V 300Ω] were fully certified by the end of 1968. Usage was given a boost as the use of computer control became the norm. One of the early large installations was at a Glaxo plant in Northumberland which used an early Kent K70 computer and led to a clarification of many of the perceived problems on earthing for operational and safety reasons.



# 10V 47Ω Zener Barrier

INS 625-1

## A. CERTIFICATION CONDITIONS

### 1. Installation

(a) The barrier must be mounted in a safe area and protected by an adequate enclosure. The temperature within the enclosure must not exceed 45°C.

(b) Terminals 2 and 4 must be so connected to earth that the total earth loop impedance does not exceed 1 ohm as measured in accordance with Appendix 6, paragraph 2 of the Institution of Electrical Engineers Regulations for the Electrical Equipment of Buildings, 14th Edition.

### 2. Connection to terminals 1 and 2

(a) Apparatus connected to terminals 1 and 2 must not be supplied from, or contain, a source of potential exceeding 360 volts peak (250 volts R.M.S.) with respect to earth.

(b) Mains powered apparatus connected to terminals 1 and 2 must be isolated from the mains supply by a double wound transformer. The primary winding of the transformer must be protected by appropriately rated H.B.C. or re-wirable fuses.

### 3. Connection to terminals 3 and 4

Nothing may be connected to terminals 3 and 4 except:—

- (i) Apparatus and circuits exactly as specified in a schedule of certificate No. IS6020 or
- (ii) Apparatus and circuits exactly as separately certified for use with this barrier.

**N.B.** These schedules and certificates specify cable restrictions and may restrict the location of equipment and/or the class of atmosphere in which use is permitted.

A list of the schedules and certificates issued in respect of apparatus and circuits for use with this barrier is available from: **H.M. Senior Electrical Inspector of Factories, Baynards House, 1-13 Chesham Place, Westbourne Grove, London, W.2.**

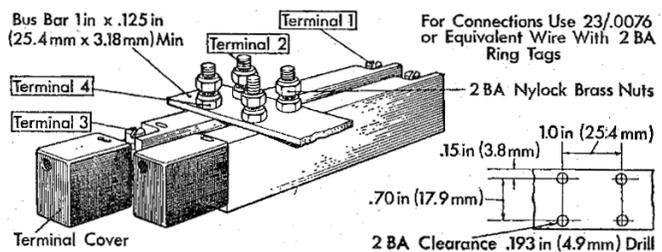
## B. RECOMMENDED ROUTINE TESTS

To test Zener operation apply 200 mA through terminals 1 and 2. The voltage between terminals 3 and 4 should be 7.5 to 9.6 volts, the voltage between terminals 1 and 3 should be less than 6.5 volts, and the voltage between terminals 1 and 2 should be greater than 12.0 volts.

Before either the above test or the earth loop impedance test (certification condition 1 [b]) are carried out, terminals 3 and 4 must be disconnected from the circuit entering the danger area.

Type	Body Colour	Mfg. Drawing
+ve	Red	ELA 3996
-ve	Black	ELA 3997

## C. INSTALLATION DIAGRAM



## The following years

After 1971 barriers became an accepted technology and the original BIMCAM agreements fell into disuse. Within the UK a number of manufacturers emerged. Included in these were Safety Technology Ltd who emerged from Gresham Transformers Ltd and Measurement Technology Ltd [MTL] who were created by a redundancy purge at Kent Instruments Ltd. BASEEFA became the certifying authority and CENELEC standards began to be created and applicable. In Europe several manufacturers, notably Stahl and GeorGIN, were very active. This increased activity led to standards and codes of practice being developed and the usual interaction between users, manufacturers and certifying authorities created a lively market. Later ATEX and IEC Ex became major factors in the market development.

Galvanic isolators with switch inputs and relay outputs were available earlier than 1961. However the introduction of isolators for analogue signals in the early 1970's increased their acceptability and they became the preferred solution for some applications.

If the relevant information covering the period from 1971 onwards from all the possible sources could be collated this would be an interesting account of the further development of a particular product in this field. Perhaps the most useful account would be of the projects which failed or just fizzled out, since these probably contain the most significant lessons. The commercial interests involved make it difficult to gain access to accurate information and therefore probably this part of the history will not be written.

## Conclusion

This document records the first ten years of the development of shunt diode safety barriers in the UK. This was only the beginning; the following years were equally interesting as the design and applications developed. This history illustrates the lengthy timescales for any new concept in the field of safety in explosive atmospheres to develop and become acceptable. Inevitably the surrounding circumstances change, but the time for development of any slightly different approach taken today will meet different but similar obstacles and the time to overcome them will be similar if not longer.

## Acknowledgements

The author wishes to acknowledge the valuable contributions of Robin Garside [Hexagon Technology] and Robin Hingley [BEKA associates] to this document.

## A verifiable record of the early days of shunt diode safety barriers

	1956	U.S. National Electrical Code published by the National Fire Protection Association [NFPA] recognised intrinsic safety by defining it.
	1958	BS 1259 entitled 'Intrinsically safe electrical equipment and circuits for use in explosive atmospheres' published
February	1959	Redding patent 918534 using Zener diodes as rectifier bridge following transformer
July	1960	Kent Transdata isolator used Zener diodes as output rectifier.
June	1961	Northampton College of Advanced Technology, Summer School. Redding discussed safety barriers using zener diodes
March	1962	Patent application for Redding barrier filed. No 977,913
April	1962	Redding IEE paper describing barrier and other applications of Zener diode limitation
June	1962	Drawing of Redding type barrier in terminal block created
January	1963	ERA note listing Dr Gehm's [PTB] objections to barriers. 'barriers will not be permitted in Germany'
November	1963	Kent report no 83 Open construction barrier with duplicated diodes discussed. Report was widely circulated
February	1964	Evershed 0-10 mA isolator drawings created
	1964	Cook and Beeftink of I.C.I. involved in testing early barrier design. Need for encapsulation evolved.
September	1964	Meeting with Elliott Electrical Factory Inspector produced further design requirements. James of G.E. heavily involved at this stage.
September	1964	Two channel 10V and three channel diode barrier [large design] drawings created
October	1964	Early meetings at Gresham Transformers Ltd on barrier manufacture. James of G.E. involved. Adams subsequently was largely responsible for the encapsulated design, Bolton was the driving force.
	1964	Meeting of IEC in Warsaw discussed intrinsic safety
July	1964	Evershed Series 300 granted PTB certificate (Ex) s G5
	1964	Riddlestone ERA report on 10V 47Ω barrier
December	1964	Kent report on Type 1 [10v 47Ω]
December	1964	Letter of 'no objection' from H.M Electrical Inspector of Factories
May	1965	Kent sales literature on 10V 47Ω barrier published
April	1965	Early document on U.L. approach to IS certification
August	1965	KEMA [Arnhem] report which allowed installation at ICI Rosenberg
October	1965	Article in Kent technical magazine [circulated to customers] The Instrument Engineer on 10v 47Ω barrier.
March	1966	Evershed Factory Inspectorate certificate for ER 300 Series issued
May	1966	ERA Report on Type2 5V 10Ω barrier issued
June	1966	ERA report on Foxboro barrier using a reed switch
July	1966	Kent internal memo discusses Evershed certificate IS 3302 covering output stage as galvanic isolator for 0-10 mA
	1966	T.J.Cook [I.C.I.] paper on intrinsic safety suggests that barriers 'would overcome most of the disadvantages of the present system
	1966	Kent report [not dated] on Type2 5V 10Ω barrier published
July	1966	South African Bureau of Standards approved Type 1 and Type 2 barriers
December	1966	Redding + Towle IEE paper discusses 10V 47Ω and 5V 10Ω barriers
December	1966	Early 28V barrier design drawings
May	1967	NFPA tentative standard on intrinsic safety
March	1967	Comprehensive SMRE test report on 10V 47Ω barrier
August	1967	1966 Report of Factory Inspectorate contained details of barriers and some galvanic isolators
	1967	BASEEFA formed, Changeover smooth and slow
August	1967	Factory Inspectorate certificate IS 6020 for 10V 47Ω barrier issued
September	1967	Redding paper on barriers and intrinsic safety in Instrument Practice
January	1968	First draft of BIMCAM publication on barriers
February	1968	Taylor note on application of 28V 300Ω Type3 barrier
April	1968	Type 3 Taylor barrier Approved by Factory Inspectorate IS 3344 28V 240Ω
December	1968	4V 10Ω barrier approved. Certificate No IS 6026
July	1969	Redding filed patent on improvements to barriers. No 1 310 354
	1969	PTB Mitteilungen 2/69 on safety barriers published
July	1969	Kent publication on use of barriers with RTDs
May	1970	Taylor filed master barrier patent with active current and voltage limits