SUPPRESSION OF HIGH VIOLENCE DUST EXPLOSIONS USING NON-PRESSURISED SYSTEMS

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Explosion suppression is an accepted form of explosion protection against gas and dust explosions. Typically, systems have employed high pressure storage canisters, actuated using explosives as the means by which to inject chemical extinguishing agents. These systems can be costly to purchase and often require considerable maintenance. A new system has been developed that requires little maintenance and does not use pressurised canisters or high explosives. The system is actuated by a gas generator that is activated on explosion detection, propelling the chemical into the vessel to be protected. The technique and system development will be discussed. The test and research data compiled during ST1 and ST2 dust explosion testing will be presented and compared with pressurised systems. Future system developments, particularly with respect to ATEX compliance, will be addressed.

KEYWORDS: EXPLOSION, SUPPRESSION, HIGH VIOLENCE, NON PRESSURISED, GAS GENERATOR

INTRODUCTION

In the past, one of the most widely-used safety techniques to prevent the consequences of industrial gas and dust explosions was 'explosion venting'. However, the associated side effects are increasingly perceived as a problem in the modern processing industry. The (fire) damage, the refurbishing and start-up costs and reduction of productivity, associated with this method, can be considerable.

Furthermore, there is increasing resistance, on environmental and safety grounds, to the emission of large jets of flame, as well as burnt and unburnt product. Even if this only occurs occasionally.

One very good alternative to explosion venting is offered by the technique known as 'explosion suppression'. This method detects an explosion in its 'infancy' and extinguishes the flame in milliseconds. On detection of ignition, an extinguishing agent is released into the fireball, where the combustion process is interrupted by interaction between the flame and the extinguishant.

The main obstacle to the widespread acceptance of modern suppression technology is often the initial investment and the intensive maintenance is imposed on process productivity and efficiency.

OPERATING PRINCIPLE

If a cloud of gas or fine flammable powder, mixed in the right ratio with air, is ignited, a very rapid combustion occurs. The speed at which the flame spreads through the fuel cloud is dependent on a number of factors including the type of fuel, the geometry of the cloud and the initial conditions (pressure, temperature, turbulence).

The deflagration flame speed can range from less than 10 m/s to over 100 m/s. Compared with high-explosives, where the flame speed is measured in km/s, this is relatively slow. This offers the possibility of extinguishing the explosion before it assumes catastrophic proportions, provided that it is detected at an early stage and the extinguishing agent is injected quickly.

If the explosion is confined, say within a steel process vessel, the explosion can develop rapidly. Providing there is enough oxygen and fuel, the explosion can generate a maximum explosion pressure of <10 barg, in tens of milliseconds (figure 1). This pressure load would, normally, be well beyond the strength of vessels such as filters and silos. By using effective explosion suppression techniques the maximum explosion pressure can be reduced to a fraction of its expected intensity.

Although, of course, there are differences between one manufacturer of explosion suppression systems and another, until recently, the basic principles of virtually all such systems were identical.

All systems use a detector (usually pressure or optical), some suppression device and a control unit to perform power control and process interface functions.

Stuvex embarked on a project known as FLASH to improve on conventional techniques and to find less expensive ways of achieving installed protection and ongoing maintenance. The project was to look at all aspects of explosion suppression and to find some form of technical and commercial improvement.

DETECTION

The first area to be assessed was detection. Frequent calibration of detectors can often be the cause of high maintenance costs. It was decided that the detector must have fixed calibration that need not be checked frequently. Looking into the market place showed that conventional venting panels and vessel bursting discs have extremely good calibration properties but lacked the response time required to operate the system. With the help of one of the worlds leading burst disc manufacturers, Stuvex were able to design a fixed pressure sensor with close tolerances and good temperature characteristics (figure 2). The detector is able to withstand high negative pressures and is not affected by high mechanical shock or vibration.

The most important aspect however, is that once the detector is installed there is no need (or way for that matter) to check the calibration level. Maintenance is limited to checking for excessive powder accumulation or hard deposits on the PTFE lined sensing face.

On activation, the detector sensing membrane is permanently deformed and destroyed, providing conclusive evidence of over-pressure. The "spent" detector is then removed and replaced with a new, calibrated unit and the detection system is ready for further operation.

SUPPRESSORS

For the suppressors the improvements would need to be substantial. The FLASH project aim was to design a system eliminating pressurised vessels and high explosives.

The technique that was to be investigated uses techniques similar to those used in the inflation of vehicle air bags. The bags are inflated using rapid acting gas generators activated from a signal received from a central control unit. This technique is very similar to the way suppression systems are activated.

Again, specialist help was sought to design a gas generator that could produce clean, high pressure, gas - very quickly. A company at the leading edge of rocket motor development and gas generators for aerospace applications, produced the prototype gas generators. The initial discharge tests proved that the suppressant could be discharged from a non-pressurised canister, further and faster than conventional pressurised systems. The main problems were that the generators were incredibly expensive to produce and operated too quickly for the mechanics of the rest of the system.

The design was refined and the gas generator re-tested. Further discharge tests were very encouraging and the production costs reduced dramatically. The gas generator was sent for third party testing for classification as a pyrotechnic actuator, and was approved without the need for further design. Following this exercise Stuvex owned a range of gas generators with known properties (<5ms to pressurise the canisters) that can be stored and transported in a simple cardboard box without the need for special licenses.

With the suppressor canisters and gas generator designs finalised (figure 3) the discharge system was configured to accept sealed cartridges filled with powder suppressant (figure 4). The cartridges are produced in humidity controlled conditions thus ensuring that the contents are free from moisture. This had the added benefit that the suppressors can be easily refilled on site, possibly by the User, following an activation (figure 5) and that the cartridge can be checked for leakages and even checked weighed if necessary.

The discharge system would also need a dispersion nozzle. Many tests were conducted to achieve a discharge profile that would provide the correct concentration within the powder cloud, combined with forward throw. Many different configurations were tested. Telescopic systems provided the most hygienic option. Stuvex designed a two piece system comprising a stub pipe, which is welded to the vessel, and a nozzle which is retained in a retracted position until the system is activated (figure 6). The stub pipe aperture is sealed using a red silicone cap which is also securely retained.

The results were, that Stuvex now had a range of nozzles that could disperse suppressants in different ways and concentrations, that would enable the system to tackle odd shaped vessels and ducts.

TESTING

Test vessels of 4.0 m^3 and 9.4m^3 were used and were configured in accordance with ISO standard 6184 for determination of efficacy of explosion protection systems. The test vessel configuration is shown in figure 7. In the case of the 9.4m^3 vessel, three pressure transducers located at the top, middle and bottom of the vessel were used to record test data. Four dust discharge canisters, filled with a specified quantity of combustible dust, were equally distributed around the vessel and pressurised to 20 bar. The canisters, on activation by the sequence control unit, simultaneously discharge the pressurised dust into the vessel, generating a near homogeneous dust cloud within the test vessel. Ignition was by two 5kJ igniters at the geometric centre of the test vessel. The test vessel system was calibrated to the desired K_{st} by adjusting the ignition delay time (t_v), between activation of dust canisters to the point of ignition.

Investigation showed that a large percentage of the suppressant was left inside the suppressor despite the large gas generators installed. New discharge tests were conducted which conclusively showed that, in some instances, smaller gas generators proved more efficient in dispersing the suppressant than large units.

Modifications were made to the discharge system and the tests recommenced. The unsuppressed explosions provided a new insight into the characteristics of the system which could be confirmed and developed in suppression trials.

Test	Gas Generator	Suppressor Type	Detection Pressure P_a (mbarg)	Measured Suppressed Explosion Pressure (barg)
1	600 600 600	14 14 14	50	0.27
2	600 600 600	14 14 14	100	1.2
3	600 325 600	14 7 14	50	0.25
4	600 325 325	14 7 7	100	0.27

Table 1 - Suppressed explosion results

A summary of the many trials is shown in table 1. Here the system is tested against a standard test configuration with the same number and size of suppressors. The detector setting (P_a), the suppressant quantity and the gas generator type are altered to compare performance.

In test 1 with P_a=50 mbarg, a reduced explosion pressure of 0.38 barg was measured. This was achieved using a system with large gas generators on each suppressor. Test 2 proved that doubling the detection pressure (P_a=100 mbarg) caused the system to fail (1.23 barg achieved). On test 3 the P_a was set to 50 mbarg but the central suppressor was reduced in both suppressant capacity and gas generator size. Here an improvement of reduced explosion pressure was measured at 0.21 barg. This was corroborated by test 4 when two of the three suppressors were reduced in both size and gas generator volume, and the P_a set to 100 mbarg. A reduced explosion pressure of 0.28 barg was measured.

In addition, the contribution of propelling gas to the overall reduced explosion pressure was seen to be lower than pressurised systems, owing to the small volume of gas produced by the gas generator.

Having established the most efficient gas generator/suppressant fill combinations, tests were conducted using materials with a higher K_{st} to establish the limits of applicability. At low detection pressures the system suppressed easily. But as shown in the table above the efficiency decreased as the detection pressure increased to the point where a threshold value was achieved. For instance with a detection pressure of 70 mbarg a K_{st}130 yielded a P_{red}<0.27 barg. A pressure time graph for this test is shown in figure 8. The identical system however, struggled to suppress once the detection pressure reached 100mbarg. These tests are vital in determining the limits of applicability.

Having achieved successful results at K_{st}100 and 130 the same system combination with the same detection pressure was tested against K_{st}200 resulting in P_{red}<1.0 barg. A pressure - time trace in figure 9 clearly shows (in comparison with the trace in figure 8) an oscillating pattern to the suppression. This is a clear sign that the suppressors are struggling to deal with the higher violence explosion. There were two important considerations. Firstly the detection pressure of 70 mbarg is probably too high for K_{st}200 with this system configuration. Secondly the dispersion characteristics were not correct.

The tests were repeated using detection pressures of 50 mbarg and four suppressors instead of three with a different gas generator combination. The tests were then successful but, more importantly, another set of limits had been defined relating to the maximum detection pressure, the minimum required suppressant concentration and propellant configuration.

CONTROL UNIT

In this electronic age, the improvements in control offered many possibilities. Apart from the normal coupling of detection and activation circuits, the new control unit (figure 9) features a 'black box recorder'. This is a real time memory that records faults and activations that can be analysed at a later date, even on power loss. The main control panel has a display showing information on alarms and faults, and a keypad to choose from a menu of different analytical operations.

The interrogation of the memory and the analysis of other data is password protected. The unit also provides data transmission via an RS 232 interface, or via fibre optics. The control system is DEN approved, and meets all the relevant European standards, including 'fail-safety', and 'EMC' (STS 032) approval.

OTHER FEATURES

Accessibility and ease of replacement by semi unskilled personnel have been uppermost in the minds of the designers. MIL-SPEC electrical plug and socket connectors allow the rapid changing of the detectors and gas generators. Systems can be easily tested using simulation units for both detectors and suppressors. Hinges on the suppressor stub pipe (figure 10) and beneath the gas generator (figure 5) allow easy access to both the nozzle and the powder cartridge without having to strip down and remove the complete suppressor assembly.

The success of the gas generating system spawned another product aptly titled MULTI-FLASH. In this case a central gas generating system is directly coupled to powder canisters via high pressure hoses (figure 11). On activation, the gas generator rapidly pressurises all of the canisters attached to the main housing and discharges the powder cartridges into the vessel at the same time. The major benefit is that the number and size of activation devices are reduced dramatically. This system has now been installed on a number of grain elevators.

Suppressors were also developed and tested for application on single pipes and ducts both as chemical barriers and advance inerting suppressors.

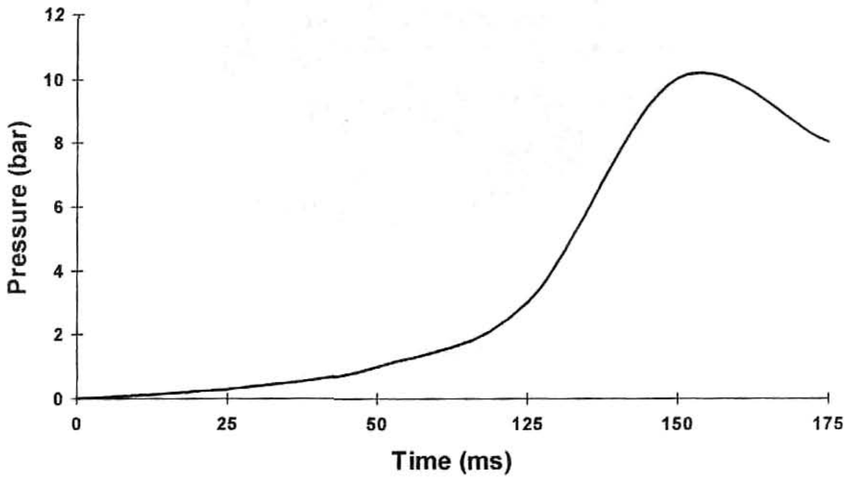
CONCLUSION

The FLASH project has utilised new and emerging technologies and brought the concept of suppression up to date. Many of the inherent problems such as high initial cost, expensive maintenance and false activations, have been addressed and in many cases solved.

Testing and refinement of the system will be an ongoing project for years to come with benefits to industry each time a new development is achieved. The system has been successfully tested against high violence explosions up to $K_{st}200$ and the latest work in progress seeks to take the system into the ST2 range of applicability.

The whole FLASH project has been focused on allowing the User to take more control and ownership of, what have often been considered to be, complex systems.

Fig 1 Explosion Pressure vs Time



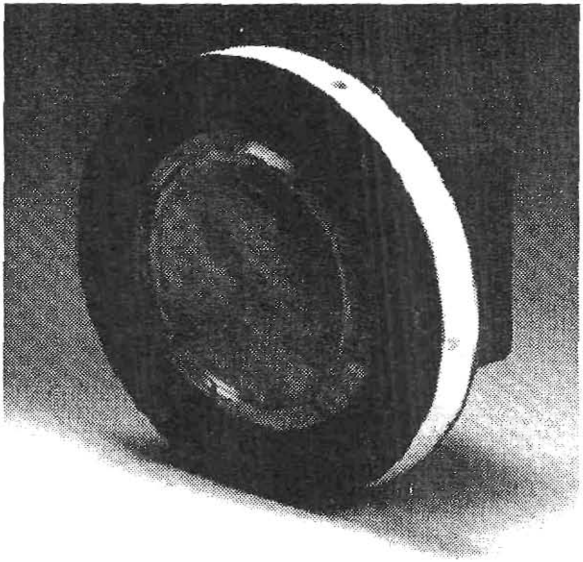


Fig 2 Static Pressure Detector

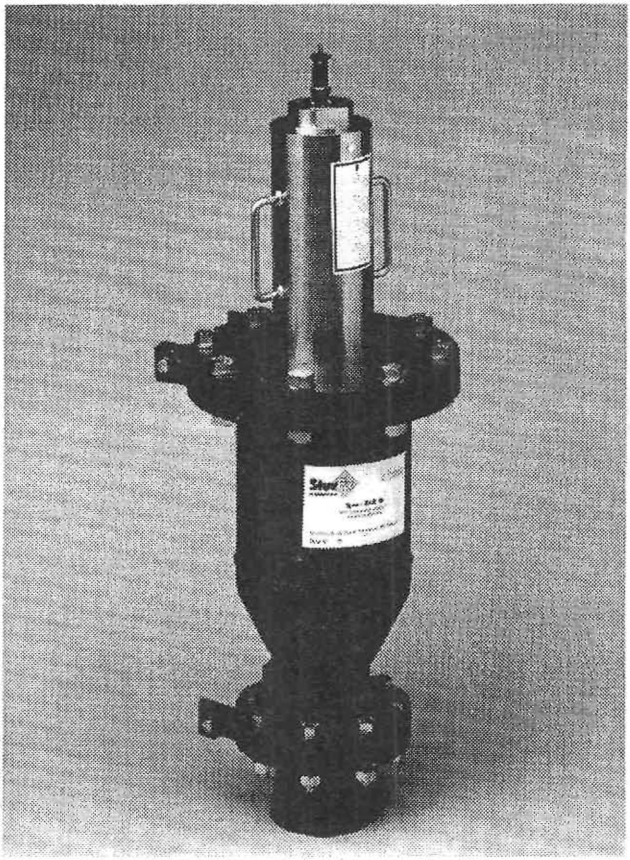


Fig 3 Explosion Suppressor

Fig 4 Powder Cartridges

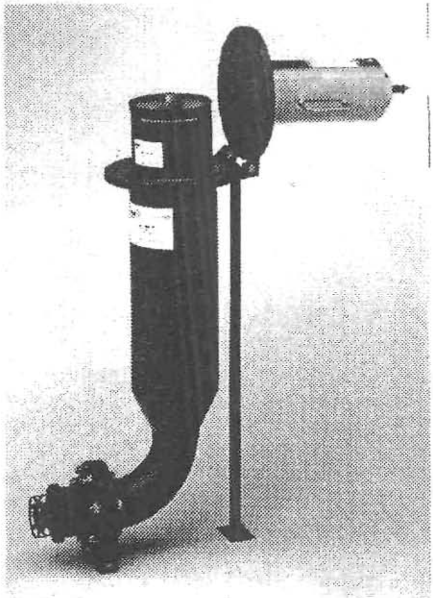


Fig 5 Access to gas generator and powder cartridge

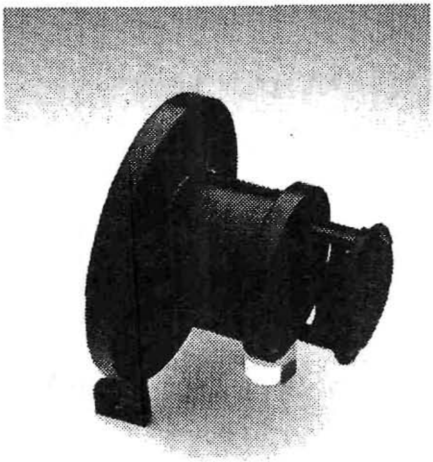
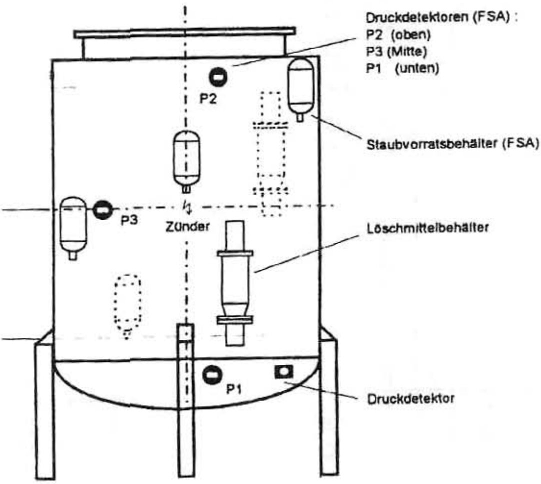


Fig 6 Dispersion Nozzle

Fig 7 Test vessel arrangement



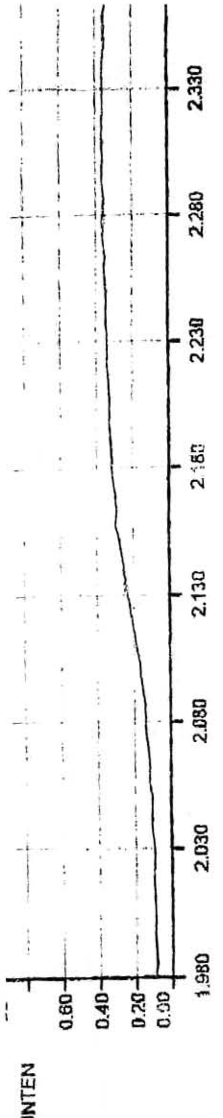


Fig 8 Test with Kst130

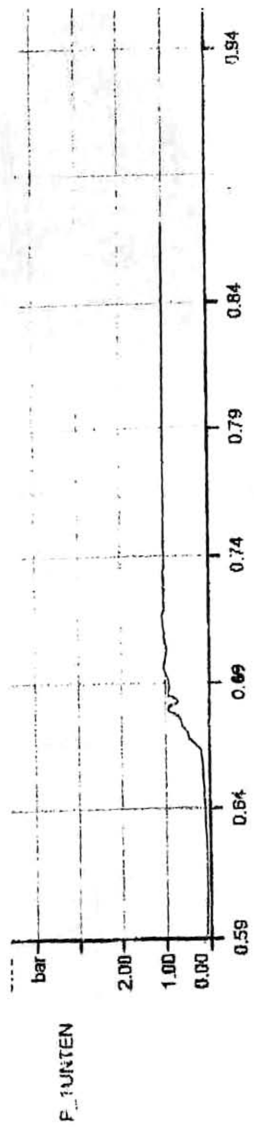


Fig 9 Test with Kst200

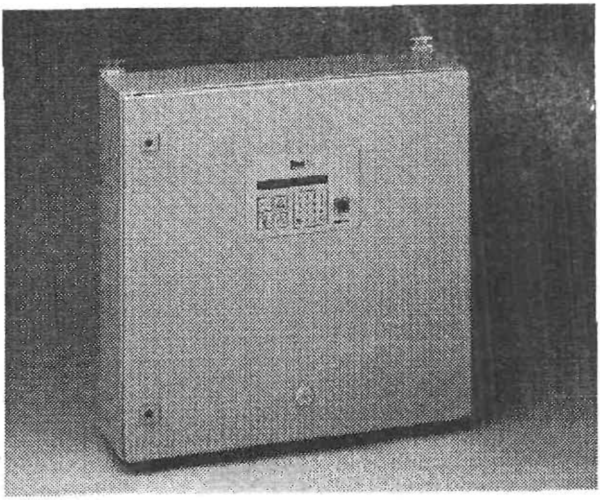
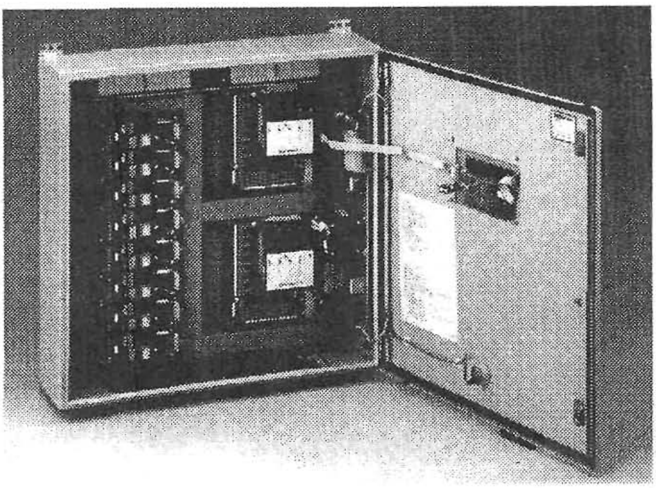


Fig 9 Control Unit



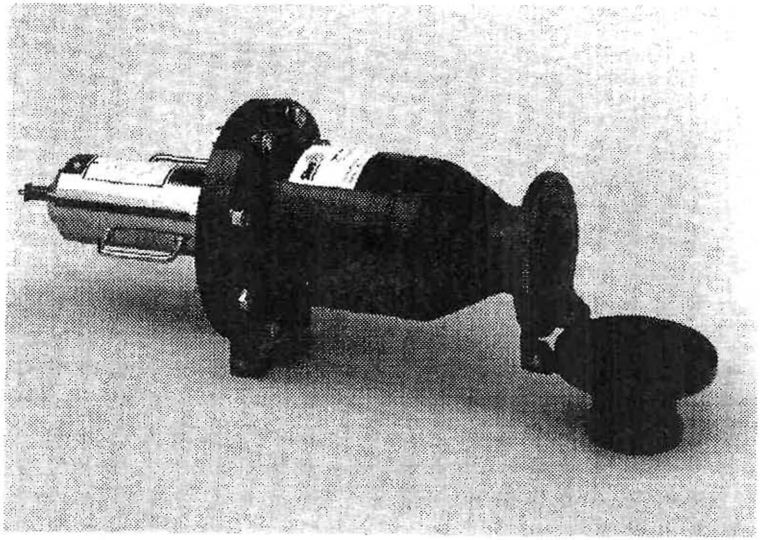


Fig 10 Hinged flanges

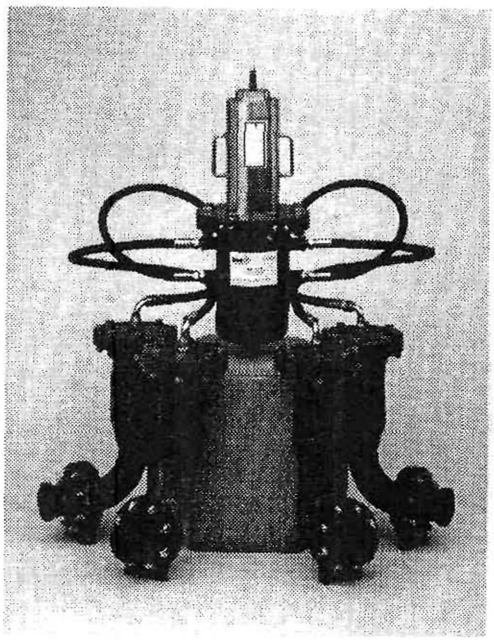


Fig 11 Multi-port discharge suppressor