Scandiflash

Flash x-ray system Model 300

Scandiflash AB

The leading supplier of flash x-ray equipment worldwide

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LIST OF CONTENTS

1. GENERAL

This is a description of the Scandiflash Model 300kV Flash X-ray System with supporting items and accessories. The system is designed for recording typical high speed events found in ballistics, detonics and hyper velocity impact. The short exposure time and small focal spot size make this system ideal for a variety of applications in these fields.

The system is manufactured to meet relevant European Safety legislation. The system complies with directive 2004/108/EC and is CE marked. The supplied equipment complies with the European Directives on the restriction of the use of hazardous substances in electrical and electronics equipment (RoHS) and on Waste of Electrical and Electronic Equipment.

2. SYSTEM

A system includes one or several channels. Each channel gives one, or with dual tubes, two simultaneous exposures at a preset time.

The first channel, called a Basic Channel, includes all parts needed to make one image at a preset time.

Several Add-on Channels can be connected to the basic channel to form a multi channel system giving a series of images. To save costs and simplify operation all channels are connected to the same control system.

2.1 Basic channel

A basic channel system includes the following parts:

Control console cabinet, Flash x-ray channel control unit, Trigger initiation pendant, Power distribution unit with high voltage power supply, Crowbar switch, Laptop with software for system operation and control, 10m cabinet to Laptop Ethernet cable, 10m control console to pulser cable assembly, Trigger amplifier, Pulse generator with stand, Resistive load, Straight line x-ray tube, 5m pulser to x-ray tube high voltage cable, Instruction manual

2.2 Add-on channel

An add-on channel includes the following parts:

Flash x-ray channel control unit, 10m control console to pulser cable assembly, Trigger amplifier, Pulse generator with stand, Resistive load, Straight line x-ray tube, 5m pulser to x-ray tube high voltage cable

3. CONTROL SYSTEM

A computerised control system is used for the Scandiflash systems. The electronic units are micro processor controlled and connected to a Laptop via an Ethernet switch. All operating parameters can be set and read from the Laptop.

For short distances the control console is connected to the Laptop via an Ethernet cable. Where safety reasons, or facility layout, call for remote control, the system can be operated from a long distance via fibre optic cabling.

3.1 Basic channel control system

A basic channel control system includes the following parts:

1 (one) Control cabinet 34HU
1 (one) Power distribution unit Model PDU 4
1 (one) Flash x-ray channel control unit Model FXRC 4
1 (one) Ethernet switch unit Model SU 8
1 (one) Crowbar Model CB 50
1 (one) Laptop computer with software for local/remote operation of the system
1 (one) 10m Control cabinet to Laptop Ethernet cable
1 (one) Set of control cables 10 m
1 (one) Trigger amplifier Model TA 500

The control electronics, except for the trigger amplifier, is installed in a standard 19" cabinet. The trigger amplifier is mounted on the pulser stand to minimize system delay time. It also includes a signal conditioning unit for transducers used for the pulser and x-ray tube.

Fig. 1 Four channel control system

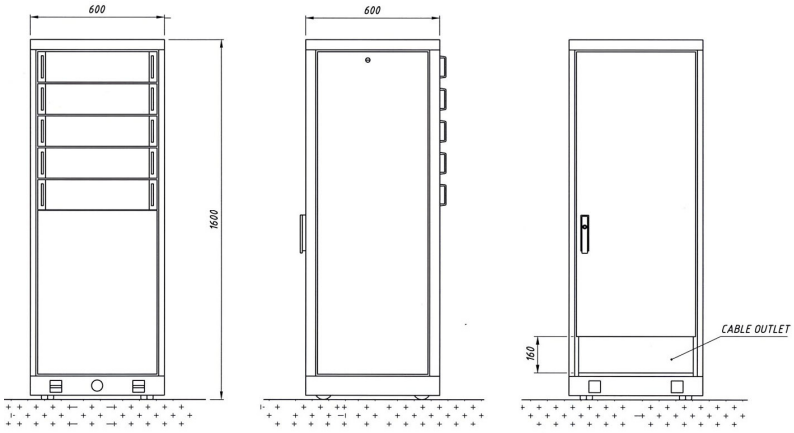

Fig. 2 Control cabinet dimensions

3.2 Add-on channel control system

Each add-on channel includes the following control system parts:

1 (one) Flash x-ray channel control unit Model FXRC 4
1 (one) Trigger amplifier Model TA 500
1 (one) Set of control cables 10 m

3.3 Power Distribution Unit Model PDU 4

A switch mode high voltage power supply is used to charge pulser capacitors. The power supply is located inside the PDU 4. The power supply is controlled by one of the FXRC 4.

The output of the power supply is connected to a crowbar switch with several outputs. PDU 4 also supplies the control signal for the crowbar.

Fig. 3 Model PDU 4 power distribution unit

The safety functions External Interlock and Warning are controlled from this unit.

The PDU 4 supplies +24 VDC for an external safety switch. The switch must be closed before the high voltage can be switched on. If the external interlock is opened, pulsers will be discharged to ground preventing firing of the system.

The PDU 4 has a connector for an external warning device. AC power is supplied to this connector when the high voltage is switched on.

The unit has a key switch which, when not activated, will prevent charging up of the system. A quick stop push button is mounted on the front panel. When activated, the pulsers will be discharged to ground and all gas valves closed.

3.4 Flash x-ray channel control unit Model FXRC 4

Each of the system channels has a Flash x-ray channel control unit including the following functions:

- Delay generator
- Time interval meter
- Dry air pressure control
- Dielectric gas pressure control
- Ion pump power supply with protection circuit (1)
- System monitoring unit

(1) Two ion pump power supplies are used for systems with dual tubes.

Fig. 4 Model FXRC 4 flash x-ray channel control unit

3.4.1 Delay generator

The range of the delay generator is 0 – 999.999 ms in increments of 1 µs. The delay generator has two triggering modes:

- Triggering by a contact closure
- Triggering by a pulse

In the contact closure mode the FXRC 4 will supply -12 V to the trigger device. When this voltage is shorted, the delay generator will start.

In the pulse mode the amplitude of the trigger pulse should be minimum 5 V and maximum 50 V. The polarity of the pulse may be positive or negative. The input offset can be set from -9 to +9 V. For safe triggering the rise time should be less than 0.5 µs

3.4.2 Time interval meter

The time interval meter measures the time between trigger input and the pulser output with a time resolution of 0.05 µs. The measured time is shown on the Laptop after firing.

3.4.3 Dry air pressure control

Dry air is used to insulate the pulser high voltage modules. The pressure can be varied to give optimum operating conditions at different pulser charging voltages.

The dry air pressure is automatically set by the system software using electrically controlled valves. An electrical transducer is used to measure the pressure. The pressure can be read at the front panel of the Flash x-ray channel control unit also when the Laptop is not connected.

3.4.4 Dielectric gas pressure control

A high quality dielectric gas such as sulphur hexafluoride (SF_6) is used to insulate the ends of the pulser to x-ray tube high voltage cable.

The dielectric gas pressure automatically set by the system software using electrically controlled valves. An electrical transducer is used to measure the pressure. The pressure can be read at the front panel of the Flash x-ray channel control unit also when the Laptop is not connected.

3.4.5 Ion pump power supply

The ion pump power supply generates the voltage for the x-ray tube ion pump. The power supply has a built in ion pump protection function to prevent over heating of the ion pump.

The ion pump current can be read at the front panel of the flash x-ray channel control unit also when the Laptop is not connected. An additional ion pump power supply is installed in the FXRC 4 for channels with dual tubes.

3.4.6 System monitoring unit

The system monitoring unit, built into each channel, follows the pulse going through the system. Signals are picked up from up to six check points.

1. Trigger input to delay generator
2. Delay generator output
3. Trigger amplifier output
4. Pulser output
5. Pulser to tube cable output (1)
6. X-ray tube output (optional) (2)

(1) and (2): two signals for channels with dual tubes

The information is available immediately after the system has been fired, revealing possible malfunctions.

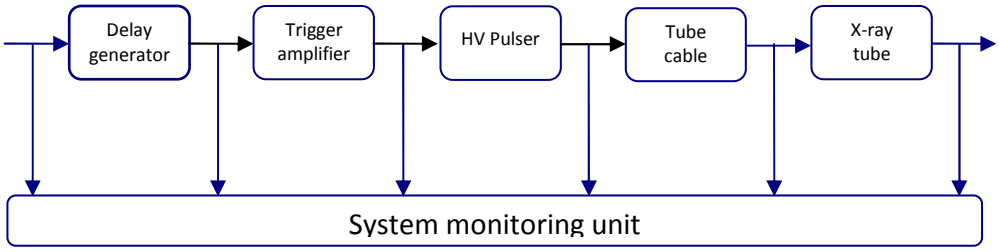

Fig 5 System monitoring unit

3.5 Switch Unit Model SU 8

The Model SU 8 is an 8-channel Ethernet switch unit handling the communication between the Laptop and the FXRC 4 units.

An Ethernet to fibre optics modem is built into the SU 8 when fibre optic cabling is used.

Fig. 6 Model SU 8 switch unit

3.6 Laptop

The system is operated from a Laptop or PC connected to the control cabinet. Connections between the computer and the control electronics is via an Ethernet cable. For distances longer than 50 m fibre optic cabling is recommended.

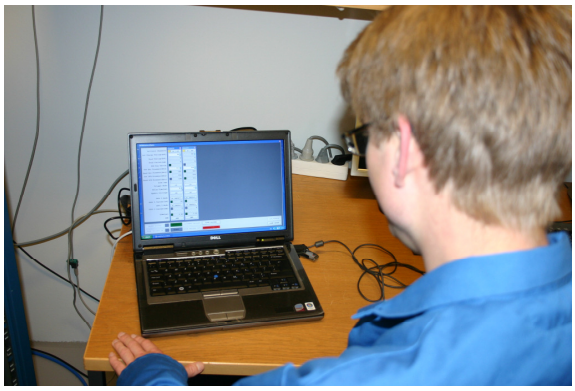

Fig. 7 The system is operated from a Laptop

3.7 Trigger amplifier Model TA 500

The model TA500 trigger amplifier serves two purposes. The main purpose is to amplify the trigger output signal from the FXRC 4 to suitable amplitude to trigger the pulser.

The second purpose is to receive and process the information from the pressure transducers for dry air and dielectric gas and transfer it to the FXRC 4.

TA 500 is also used for the pulser to x-ray tube cable current viewing resistors, and the optional x-ray detectors at the output of the x-ray tubes. The trigger amplifier is mounted on the pulser stand to minimize system delay time.

Fig. 8 Model TA 500 trigger amplifier

3.8 Cables

The length of the system cables can be matched to the layout of the experimental site. The standard length of the control cabinet to pulser cables is 10 m. For control cables longer than 100 m, please consult factory.

The pulser to x-ray tube high voltage cable is normally 5 m. It is recommended that the length of this cable does not exceed 30 m.

3.9 Software

ScandiControl is a software program developed for operation and control of flash x-ray systems. The software gives full remote control of all settings of the system's operational parameters. The software can, in its basic version, handle up to eight channels.

The software is the property of Scandiflash AB. No third party license is required.

The ScandiControl software has four user modes:

ScandiControl config: This mode is used to configure the system hardware. The configuration is done at the factory before shipment. The configuration mode allows the user to extend the system, add or remove system units.

ScandiControl user: This mode is the standard mode for taking radiographs.

Test mode user: This mode is used to operate the system with resistive loads.

Scandiflash: This user mode allows Scandiflash personnel to log into the computer and run the ScandiControl software for diagnostic purposes.

3.9.1 Operation

The software interface for a four channel system is shown Fig. 10.

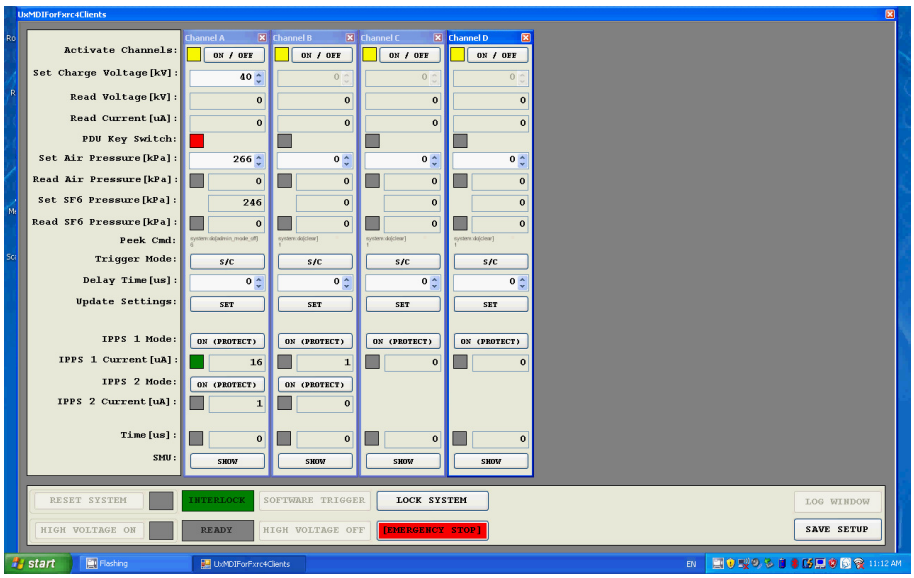

Fig. 9 X-ray system control panel

Windows are used for typing in the selected operating parameters. The lower part of the window shows the current value.

Normally the system charging voltage is first chosen and typed in. For systems with a single high voltage power supply, the charging voltage of the first channel is automatically copied to other channels.

The software can handle systems with more than one high voltage power supply, allowing different output voltages of the channels in the same system.

The software will find and recommend the optimum spark gap and dielectric gas pressures. These pressures can be manually adjusted within certain limits.

The next step is to select the trigger mode, i.e. pulse or contact closure, and to set the delay times. If triggering by contact closure is chosen, the FXRC 4 will supply -12 VDC to the trigger transducer.

When all parameters have been chosen, the SET button is pressed. The high voltage power supply will be set, but not switched ON. The delay times and gas pressures will be set. An indicator for each channel will show when the settings are ready.

When all settings of the channels have been done, the RESET SYSTEM button is pressed. The software will make final check of all settings.

The system is then ready for use. The high voltage can be switched ON. The charging high voltage is ramped up to the set value. When all pulsers are charged, the READY light will come ON, and the system can be triggered.

The pulser output indicators will show if the channel fired or not. These indicators will also show if one of the channels prefires. If a channel fails to trigger, the window will show if a trigger signal was received or not.

A time interval meter is used to measure the time between the trigger input and the pulser output. The measured time will be shown after the firing.

By pressing the RESET SYSTEM button, the system can be operated again with the same settings. A software manual trigger is included to allow manual testing of one or several channels.

4. PULSER

The pulser used in the system is the Model PG 300. PG 300 is an 12-stage Marx-generator with an output voltage that can be varied between 100 and 300kV.

The pulser is supplied mounted vertically on a wheeled stand, allowing it to be moved around without specialised equipment.

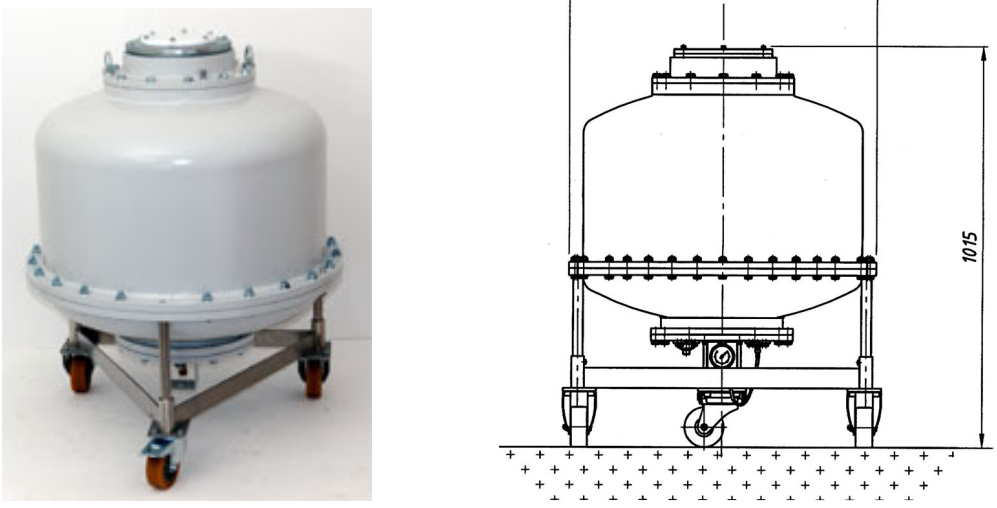

Fig. 10 Model PG 300 high voltage pulser

5. X-RAY TUBE

Self contained, demountable x-ray tubes are used. The robust design and a small focal spot size make these tubes ideal for ballistics and detonics work.

The x-ray tubes are self contained, i.e. a separate tube head is not needed for remote operation of the x-ray tube. The tube is directly connected to the pulser by a flexible high voltage coaxial cable.

The tube is demountable with all parts individually replaceable to keep operating costs low. The anode can be replaced after a number of exposures at a fractional cost of a new tube.

The same tube can be used for single or dual tube operation.

The focal spot size determines to a large extent the quality of the radiographs. The smaller the focal spot size, the sharper the radiographs will be. The tubes may be used with a 1 mm spot size giving sharp radiographs even at short source to object distances.

5.1 Straight line or right angle

Model XT 300A is a straight line tube with the x-ray beam being emitted along the tube axis. The optional Model 3000R is the right angle version, i.e. the x-ray beam is emitted at 90 degrees to the tube axis.

5.2 Soft x-rays

All x-ray tubes emit a continuous spectrum of x-ray energies where the maximum energy is determined by the voltage applied to the tube. The lowest energy radiation, or soft X-rays, is easily absorbed and part of it is stopped by the tube window.

For applications where the low energy radiation is essential, e.g. to improve the contrast, an optional soft x-ray adapter may be used. Using this adapter a thin plastic window is fitted to the tube. This window will transmit radiation with energies down to a few keV.

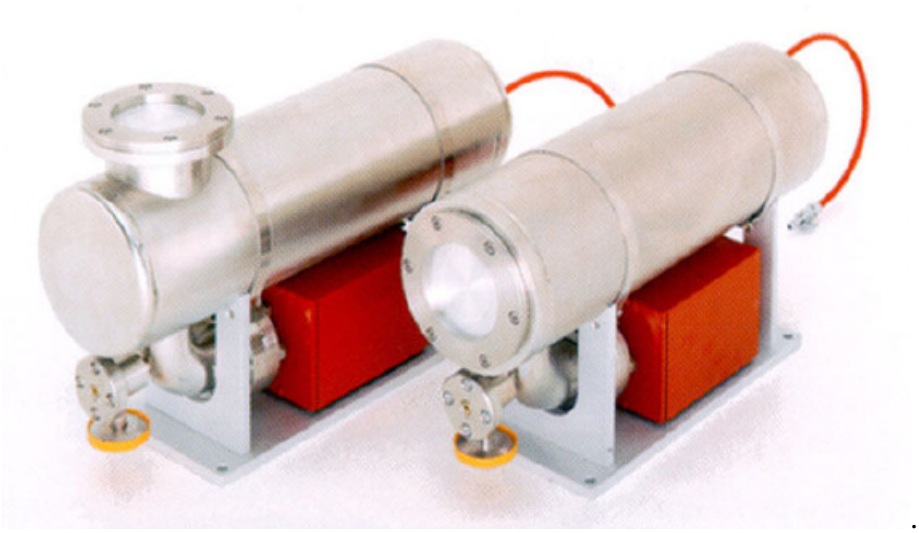

Fig. 11 Model XT 300A and XT 300R straight line and right angle tubes

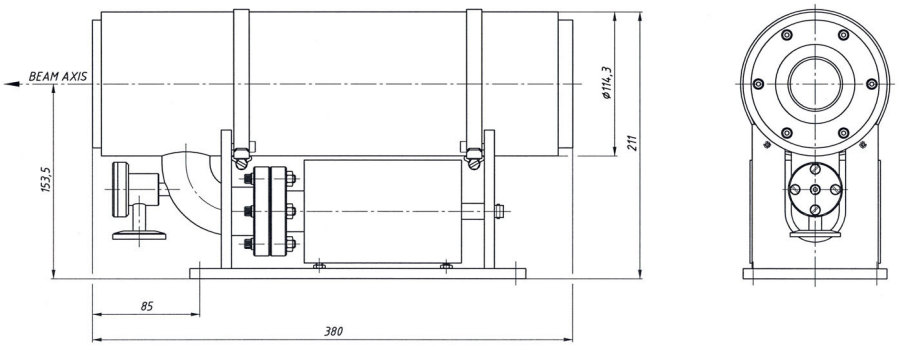

Fig. 12 Model XT 300A straight line x-ray tube

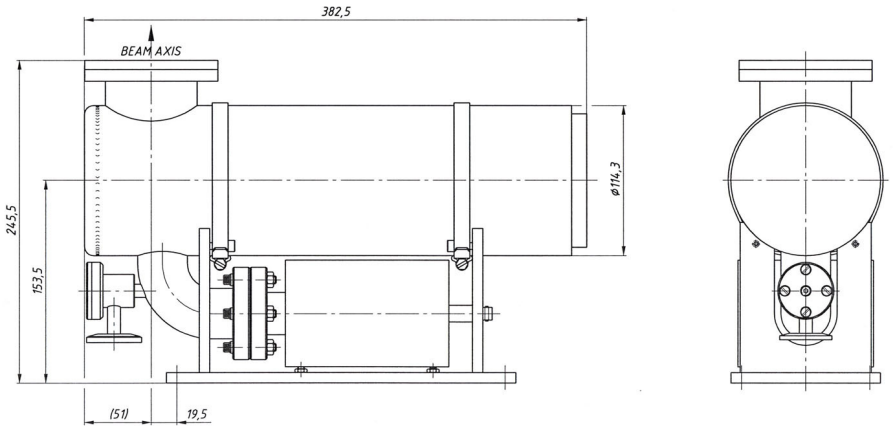

Fig. 13 Model XT 300R right angle x-ray tube

5.3 Dual tubes

The Model DTA 300 Dual Tube Adapter provides the possibility to connect two remote tubes to the same pulse generator for simultaneous orthogonal views of an event.

The same tubes and pulser to tube cables are used in both single and dual tube modes. A channel may have either two XT 300A straight line tubes or two XT 300R right angle tubes or one of each. The DTA 300 is designed to permit operation in either single or dual tube mode.

6. MULTI ANODE TUBE

Development work is often quite expensive. Therefore, it is desirable to get as much information as possible from each test. For applications where flash x-ray systems are used, it means that a sequence of images is needed. To achieve this several x-ray sources must be used. If the object is moving several x-ray tubes can be positioned along the trajectory of the object. Maximum framing rate is then only limited by the speed of the object.

If the object does not move linearly, but rather expands or collapses, the tubes can be arranged to observe the object from different angles. For these cases there is no upper limit to the framing rate. This arrangement works fine for objects with symmetry of revolution. If that is not the case, the interpretation of the images becomes very complex.

To overcome some of these problems we have developed so called multi anode x-ray tubes. The general idea of these tubes is to put several anodes within the same vacuum enclosure, with the anodes as close together as possible. This way the parallax is reduced, and all radiographs are taken from almost the same point in space. One pulser is used for each anode.

The pulsers are fired in a sequence, and the times between the exposures are set with the system's time delay generators.

A fluorescent screen is used behind the radiographed object to convert the x-ray pulses into visible light. The images are recorded with an intensified CCD camera.

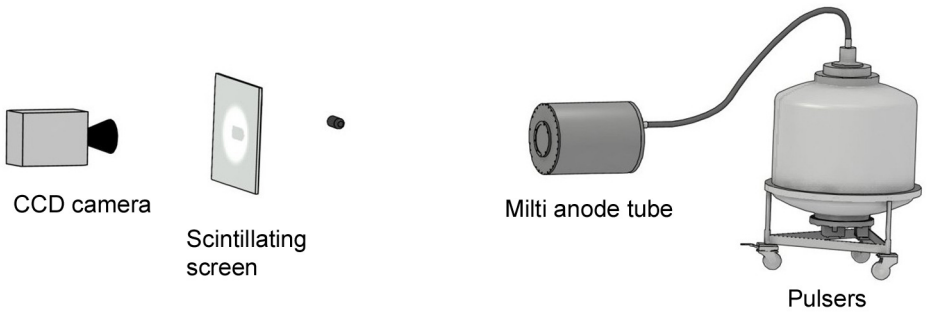

Fig. 14 An intensified CCD camera can be used to record the images from a multi anode tube

The anodes are normally positioned on a circle. Tubes with up to eight anodes have been built. Fig. 16 shows a four channel 450 kV tube. The anodes are positioned on a circle with a diameter of 55 mm.

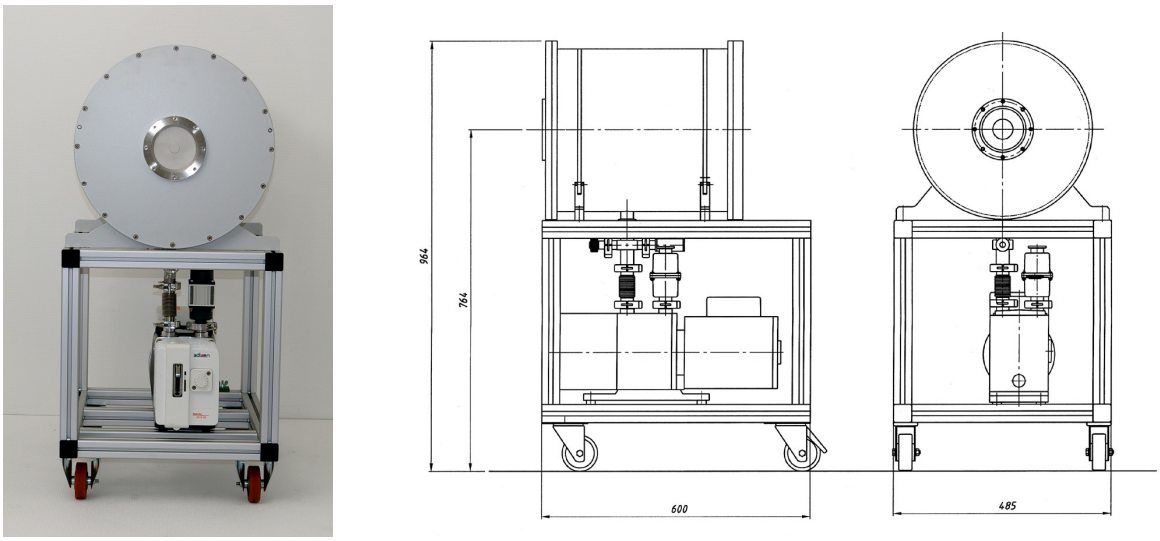

Fig. 15 Model XT 300-4C multi anode tube

Time between the pulses, and hence the framing rate, is set with delay generators in the x-ray system. The time between pulses may be the same or different. There is no lower limit for this time. The exposure time for each individual image is determined by the x-ray system pulser, and is normally 20 ns.

Maximum framing rate is no longer limited by the x-ray system but rather by the decay time if the visible image on the scintillating screens.

An example of the use of an eight channel multi anode tube is shown in Fig. 17.

The radiation from the tube is directed onto the fluorescent screen placed behind the object. The screen converts the radiation into visible light and produces visible images on its back side. These images are intensified, captured and stored by an array of up to 4 individual cameras, each camera capable of recording up to two individual images.

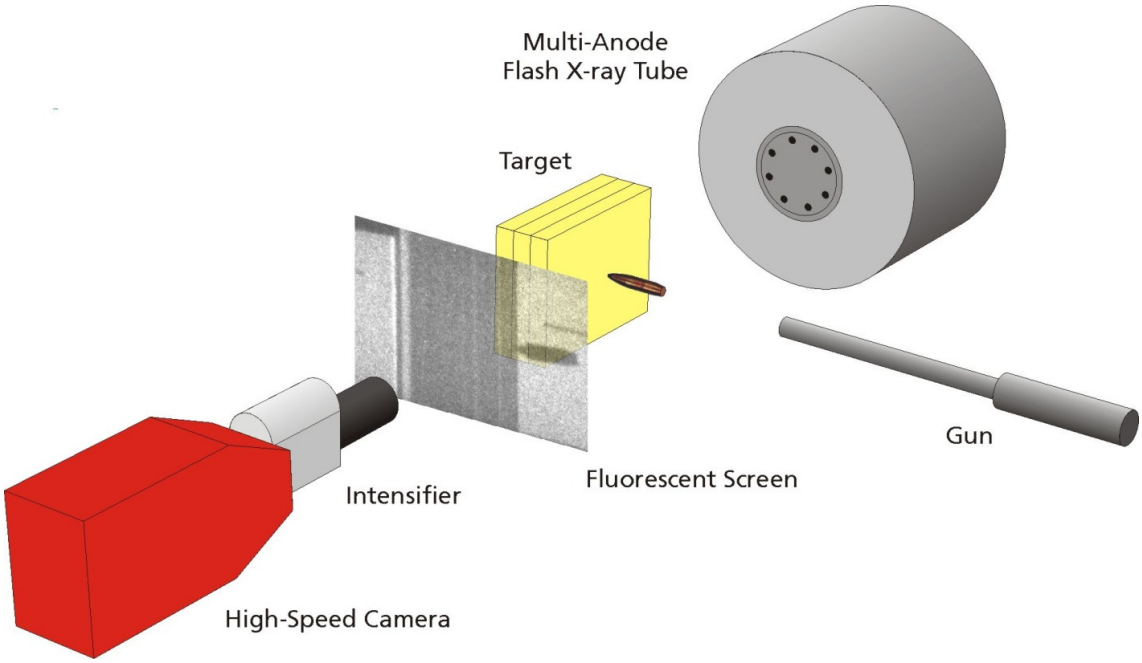

Fig. 16 Target penetration studies with multi anode tube (courtesy Fraunhofer EMI 2010)

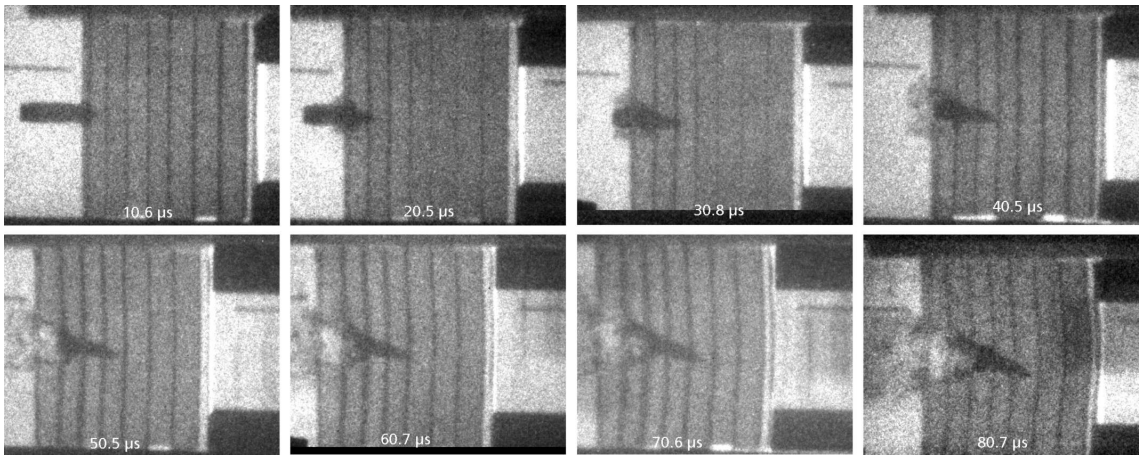

Fig. 17 Transparent Armor: Projectile: 7.62 mm x 51 AP steel core @ 850 m/s
conventional transparent armor without Ceramic Front -> No Erosion and Deformation of Steel Core
courtesy Fraunhofer EMI 2010)

7. SUPPORT EQUIPMENT

7.1 Tools

The system is supplied with a set of tools for x-ray tube maintenance and service.

7.2 Roughing pump system

The Scandiflash x-ray tubes can be serviced on site. Each x-ray tube is supplied with a small integrated ion pump. After service a roughing pump system is used to evacuate the x-ray tube to the starting pressure of the ion pump. The same roughing pump system can be used to service many tubes.

The system uses a turbo molecular pump and is available in two versions. Model RPS 30M is designed for pump of one x-ray tube. Model RPS 30M-4 is used to pump up to four x-ray tubes simultaneously.

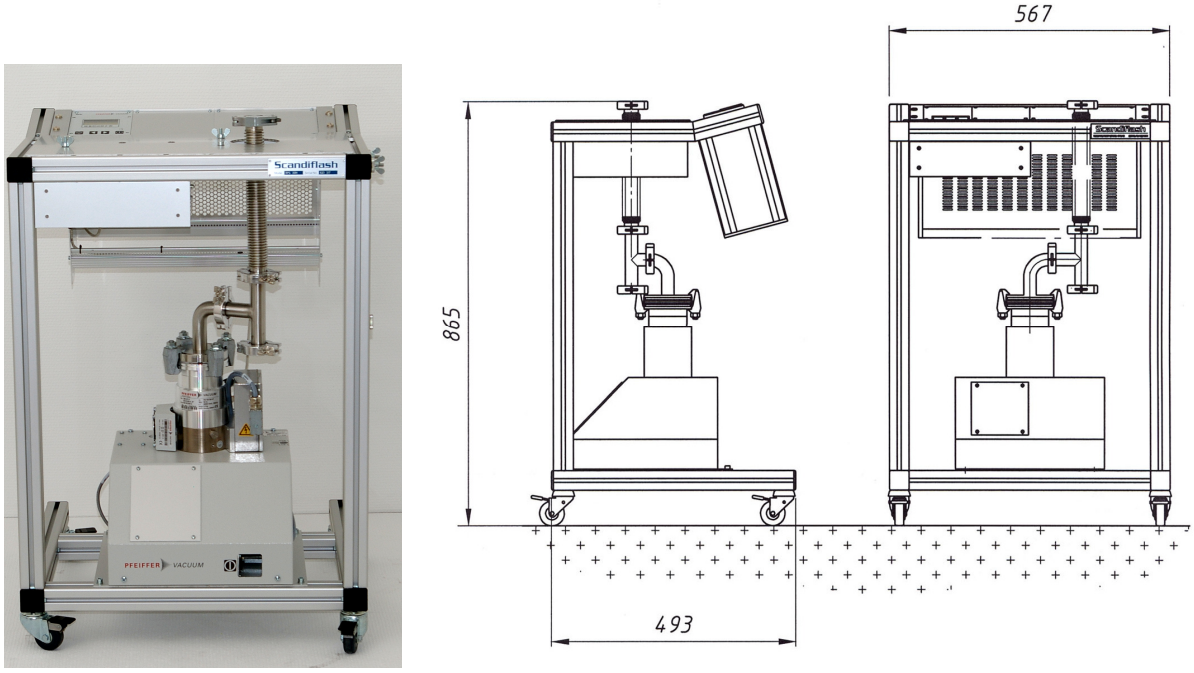

Fig. 18 Roughing pump system Model RPS 30M

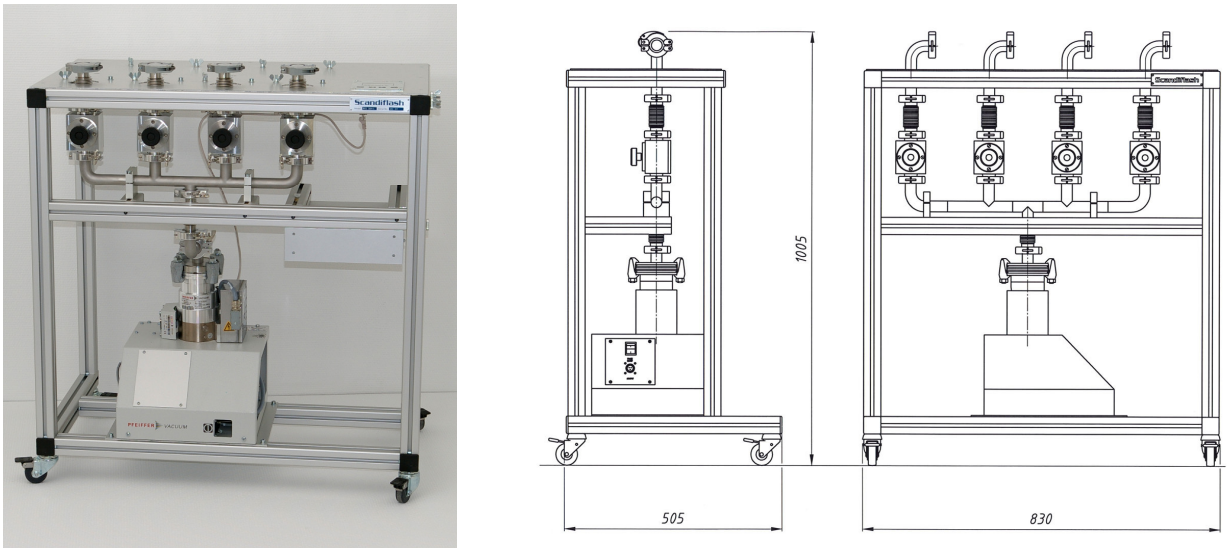

Fig. 19 Roughing pump system Model RPS 30M-4

8. CONTAINERISED FLASH X-RAY SYSTEMS

8.1 General

Full scale ballistic testing is for safety reasons often done at remote sites. Arranging and protecting the measuring equipment can be quite costly and time consuming. The Scandiflash containerised flash x-ray systems can be transported and quickly set at different test sites. The container may be protected on site by e.g. concrete blocks and no special building is needed.

Fig. 20 Containerised flash x-ray system

Fig. 21 Second pulser position

8.2 Pulser configuration

Fig. 21 shows a four channel, 450 kV containerised flash x-ray system. The system is built into a modified 20 foot ISO container. The container is reinforced, insulated and heated. Everything needed for the system is factory installed in the container. X-ray tubes and tube cables are stored in the container during transport or storage.

The pulsers can be positioned along one of the long walls (Fig. 21) or two plus two at the inner short end (Fig. 22). The pulsers are firmly fixed to the reinforced side walls.

The electronics hardware needed for system is installed in a 19” cabinet. The cabinet is reinforced and the electronics left fully assembled during transport.

Gas bottles used for insulation of the high voltage parts are fixed to the container wall. A four channel roughing pump system is used. Up to four tubes can be pump down at the same time.

8.3 Cable ports

The container shown in Fig. 21 and 22 has eight x-ray tube cable ports; four along one of the long sides and four at one of the short sides. One or two cables can be used. Two cables are used for systems with dual x-ray tubes. The cables are firmly fixed from the inside. The ports are sealed from the outside. Ports not being used are closed with steel covers.

All signal cables going into or out of the container are connected to a patch panel. The panel is protected on the outside. The system is connected to a single phase AC power source is fused at 10 A.

8.4 Operation

The system is operated from a Laptop. The Laptop can be positioned inside the container and connected to the control electronics via an Ethernet cable. For tests where the personnel

cannot be close to the test area fibre optic cabling is used. The fibre optic cable is connected to the patch panel.

Fig. 22 Operation can be from inside the container

Fig. 23 Operation can be via fibre optics cable

8.5 Transportation

The container system can be transported either by truck or tractor. The ISO design allows the use of standard lifting devices. At the test site the container is protected with concrete blocks.

Fig. 24 Container transport

Fig. 25 The container is protected with concrete blocks

9. CONSUMABLE PARTS

The following parts of the x-ray tube are consumables and must be changed regularly for optimum system performance:

Part No.	Description
340-005	Anode F1
340-009	Cathode
340-013	Window
340-012	O-ring for window

Typical number of pulses that can be applied to the F1 anode at full voltage is 50. The cathode, window and o-ring should be changed for every fifth anode.

10. DOCUMENTATION

All documentation is written in English and is supplied with the system as soft and hard copies.

11. ACCESSORIES

We supply a full line of accessories normally used with flash x-ray systems e.g.:

- X-ray film, intensifying screens and cassettes
- X-ray film processing equipment
- X-ray film scanners

- Computed radiography systems
- Image storage screens

- X-ray dose measuring equipment

- Dry air processing equipment

For more information, please inquire.

12. Technical characteristics Scandiflash Model 300

Output voltage (kV)	100 - 300
Output peak current (kA)	10
Pulse width (ns)	20
Dose per pulse at 1 m from the tube window (mR)	9
Typical focal spot size (mm)	2.5 (1)
Penetration of steel at 2.5 m film to source distance (mm)	10 (2)
Input power	115/230VAC, 10A, 50/60Hz, single phase (3)
Insulation gas	dry air (10 ppm)
Pressure range	0 - 400 kPa

Dimensions (mm)

Pulser (diameter x length)	780 x 830
Control console (height x width x depth)	1,850 x 550 x 620

Weights (kg)

Pulser	240
Control console	150

1) The focal spot size can be changed.

(2) Scandiflash Fast 600 intensifying screens and Kodak Hyper Speed film. 5m pulser to x-ray tube high voltage cable.

(3) Input voltage and frequency to be specified at order.

Specifications are subject to change without notice.