3.3.1 The Application and Mounting of Air Cannons

3.3.2 Synopsis

Air cannons are a widely used device in the bulk solids handling industry. They influence the flow of materials by injecting a volume of compressed gas, by means of a quick acting large diameter valve and storage reservoir, into the bulk solid to be affected. Application knowledge is largely the accumulation of experience, but more and more engineering information is being developed relating to this simple, reliable and economical flow aid device.

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APPLICATION AND MOUNTING OF AIR CANNONS

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1.0 Summary

The purpose of this paper is to discuss the application of the air cannon, including the methods in which it works and the sizing and location of air cannons. Air cannons are used to solve the typical problems of funneling, ratholing, arching, bridging and build-up of material in bulk solids handling systems. The application of air cannons is still very much an art which depends on the accumulated knowledge of the application engineer. There are many basic engineering specifications that are of use to the engineer responsible for determining if air cannons can be applied to a structure and the likelihood of success.

2.0 Introduction

The use of low pressure (less than 10 bar, 150 psi) compressed air as a flow aid device in bulk material handling only dates back to the early 1970's. Prior to that time, aeration through surface pads or nozzles at low flow rates, or use of very high pressure (700 bar, 10,000 psi) injectors or expansive gases, such as CO-2 cartridges, or even dynamite, were common. Since the development of the air cannon and its application by Martin Engineering Company, it has become one of the most widely used flow aid devices ever.

We estimate that there are over 75,000 air cannons in use worldwide. The success of this device is due to the development of the application knowledge and the simplicity of the design.

An air cannon consists of a pressure reservoir, coupled with a quick acting large diameter valve. It is mounted by means of ordinary piping, usually of 100mm (4 in.) or 50mm (2 in.) size. The common pressure vessel sizes range from 10 liters to 300 liters. Quite often specialized nozzles are used to direct the flow of air.

3.0 Discussion

The forces created by the use of air cannons are of two types - static and dynamic. The static loads depend on the mounting of the air cannon as well as the type of air cannon. There are several valve arrangements commonly available, but in general there are two types of air cannon discharge styles - in line with the long axis of the air reservoir and at an angle (usually 90 degrees) to the long axis of the air cannon.

The valve arrangement is important since it determines the speed at which the cannon operates and correspondingly limits the rate at which the tank empties and the maximum force output. Unless the tank is of unusual design, the shape of the tank does not limit the flow of the air.

3.1 Static Forces

Figure one (1) shows the static forces on an air cannon with the discharge in line with the center line of the long axis of the tank. Figure two (2) shows the static forces on an air cannon where the discharge is at 90 degrees to the center line of the long axis of the tank. Typical values for the moment on the mount plate are on the order of magnitude of 830 kg-meters (500 ft-lbs) and shear values of 100 kg (220 lbs).

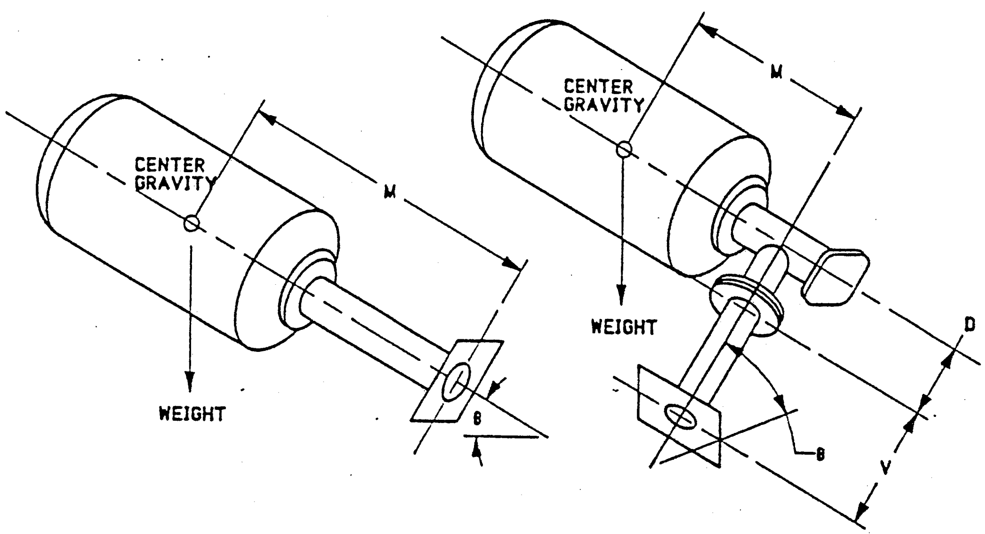


Figure 1 Figure 2

Shear = wt of unit
Vertical moment = (v + d)(wt)(cos θ)
Torsional moment = (m)(wt)(cos θ *)

* Figure 1

The weights of the air cannons will vary somewhat from manufacturer to manufacturer, and governmental pressure vessel codes are far from uniform. However, the static forces are rather low and usually can be added to structures without redesign. The dead weight of the air cannon is often offset by the installation of a cable which can also serve as a safety cable. Each case should be evaluated by an engineer familiar with the structure on which the cannons are to be mounted.

3.2 Dynamic Forces

There are many reactions that occur when the cannon is operated. The piston accelerates and stops suddenly. The pressure tank expands and contracts, and the air rushes out at near sonic velocity. Tests have shown that by far the most important dynamic force to be concerned about in operation is the force created by the escaping air. Tests on all major brands of air cannons show a considerable difference in the duration of the pressure force and the peak value of this force. The faster the valve operates the shorter the duration of the pulse and the higher the force peak. Tests show that a close approximation to the peak force can be estimated by simply taking the pressure times the area of the discharge pipe. So an air cannon operating at 8 bar (120 psi) with a 100 mm (4 in.) pipe discharge valve would have a peak force of approximately 150 newtons (1500 lbf).

Tests show that calculations of the opening speed of the valve are not reliable, and that actual test data is required if the length of the pulse is required. Air cannons on the market have discharge times ranging from .5 to 2 seconds. A typical pressure vs. time and force curve is shown in Figure Three (3). (Ref. #2)

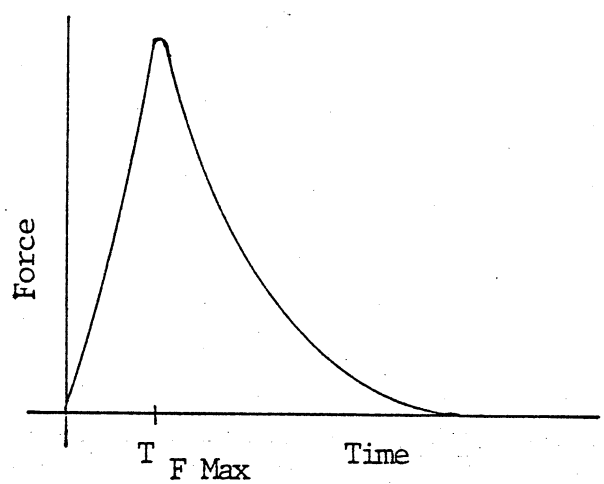


Figure 3

3.3 Other Forces and Mounting Considerations

A sophisticated anaylsis of the bulk solid is often not warranted. However, there are always unusual circumstances that require the judgment of an experienced engineer. The condition of the structure the air cannons are to be mounted on is important. We recommend at least a 5 mm (.25 in.) thick mild steel wall or 150 mm (6 in.) reinforced concrete wall. (Ref. #1) Air cannons can be mounted on wood, plastic and concrete stave silos with proper mounting details.

Thermal expansion and contraction, as well as ambient temperatures, must be considered. Air cannons are regularly used in climates where the air temperatures are -40 degrees centigrade and on process applications such where the product temperatures reach +1000 degrees centigrade. Air cannons can be charged with inert gas in cases where fire or explosion is a concern.

Vibration from process equipment can cause loads on the air cannon and its mounts that may result in fatigue failure. Failure of this type is very rare, and the result is usually a small crack that develops, preventing the air cannon from accepting a charge of compressed air. On truck dump hoppers or areas of high amplitude vibration, an isolation style mounting should be used.

3.5 Selection

The selection of the proper size air cannon, the correct operating pressure and cycle time is largely one of reliance on accumulated experience. It is possible to test the bulk solid flow properties and relate the required force for flow in the operation of the cannon. Only in extreme cases can this expense be justified. In most cases it is better to slightly over-design the number of air cannons, since the equipment cost is usually one-third or less of the total installed cost, and installation cost is affected more by working conditions than by the number of air cannons.

Tests have shown that air cannons have a range of effectiveness that depends on the valve design and how fast it operates, as well as on the properties of the bulk solid material to be affected. Porosity, density and cohesiveness are key properties that influence the effectiveness of an air cannon. This range of effectiveness can be described as a hemispherical volume generated radially from the discharge, provided there are no special directional nozzles or diffusers used. Figure four (4) shows typical ranges for a granular bulk solid with a bulk density of 1000 kg/M-3 (62.4 lbs/ft-3).

Volume Liters	Discharge Size (mm)	Effective Radius (M)
50	50	1.0
150	100	3.0
300	100	5.0
600	150	7.0

Figure 4

The size of air cannon to be used depends upon the material characteristics, as well as the area to be affected. The most difficult materials to move using air cannons are those with a high porosity and high interlocking tendency like wood chips, agricultural refuse, garbage and frozen materials. Figure Five (5) is based upon experience. In general, the higher the density and/or cohesiveness and/or porosity of the material, the larger the volume of air cannon used as compared to Figure four (4).

Material Density kg/M-3	Volume Liters	Discharge Size (mm)
0 - 400	10	50
400 - 600	50	100
600 - 1000	150	100
1000 - 1400	300	100
1400+	600	150

Figure 5

3.6 Quantity

The quantity for complete evacuation of the hopper or silo can be determined by ensuring that the effective area of operation of each cannon overlaps, and all areas of the silo slope section are covered. However, in practice there are usually only a few flow trouble spots within a silo or hopper. These are often well-known by the crews that have manually cleaned them in the past. If not, an inspection should be performed and air cannons placed where they will be most effective. In general, the discharge should be pointed downward toward the direction you want the material to flow. Special nozzles can be fabricated to direct the flow for special situations. Such nozzles are commonly used to prevent build-up due to condensation or impact, or on kilns or dryer walls. As a general rule, air cannons should be placed in hopper valley angles, and a smaller unit installed near the outlet at about the height bridging may occur.

3.7 Operating Sequence

Air cannons give the best results when they are used before they are needed. If you wait to fire them on a no-flow situation chances are that the blockage may be too severe for a single firing sequence to loosen material,and you risk the possibility of collapsing a very large blockage resulting in hopper damage. Air cannons should be fired on a timed sequence, starting at the discharge and spiraling upward. One of the reasons that air cannons are so valuable as a flow aid is that unlike mass flow designs or low friction liners they can be controlled. In some cases, special firing sequences can be determined by trial and error. On initial start-up, if the hopper has not been cleaned, firing each cannon every five minutes will often initiate flow. The sequence can often be reduced so that each individual cannon is fired only once during each operating shift. Manual overides and emergency stop controls are recommended.

3.7 Special Considerations

One common objection to the use of air cannons is: they will tend to aid combustion in materials such as coal. This is very correct; the addition of air will indeed help the fire to continue. However, most bunker fires originate in non-flow areas where spontaneous combustion can occur. Experience confirms that the use of air cannons reduces, not increases, the probability of hopper fires. This question has been reviewed in detail by a major insurance underwriter.

Some processes require clean air or inert gas. Air cannons work best on filtered, lubricated air. Special design considerations are required when other gases are used. Often such systems are closed systems, and the container is designed to operate at a slight negative or positive pressure. Adequate pressure relief valves and controls are required in these cases to prevent rupturing or collapse of the container.

Cyclic loading of air cannons is a popular topic in pressure vessel code writing committees. In all but extreme cases, where firing cycles require operating every few seconds, this should be a consideration. Design for cyclic loading considerably increases the cost of the pressure vessel with very little added benefit over a properly constructed vessel based on non-cyclic loading. It may well be better to put a lifetime limit, in terms of years or firings, on the standard vessels than incur the extra cost and weight penalties for cyclic loading.

4.0 Conclusion and examples

Air cannon application and mounting is a combination of engineering and experience. The use of air cannons on thousands of hoppers, silos and process equipment provides a record virtually free of damage to the structure to which they are attached. They are an economical means of promoting flow for a very wide range of bulk solid materials.

Safety is another good reason for installing air cannons, but it does not eliminate all hazards. Many lives have been lost in cleaning out silos or hoppers when a bridge or arch collapses. Air cannons can greatly reduce the need for manual cleaning. However, they should be treated with caution because they can propel the bulk solid at high velocities. Inspection or service of the air cannon can only be done following a proper shutdown sequence where no chance of air cannon discharge exists.

4.1 Applications

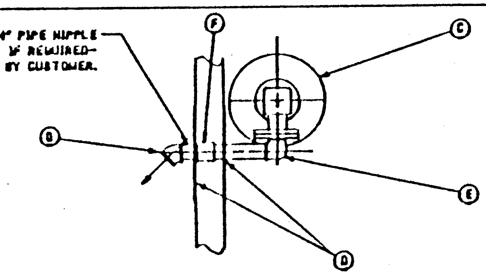
Example #1 shows the applications on a wood chip hopper. The system was designed to provide complete emptying of the hopper, which arching and ratholing throughout the slope section had prevented. Thirteen 150 liter and nine 300 liter air cannons were used.

Example #2 is an application on gypsum rock designed to maintain flow with the lower three cannons and provide for nearly complete emptying by using the third level. Six 150 liter cannons and one 50 liter air cannon were used.

Example #3 is an application on a dry process cement kiln. A large number of blasters, covering virtually the entire inner surface with their effective area of coverage, reduces build-up and maintains the system's effectiveness. Sixty-six 150 liter high temperature air cannons were used.

These three examples are actual case histories of successful applications of air cannons to solve bulk material handling problems.

Example #1



DETAIL #1

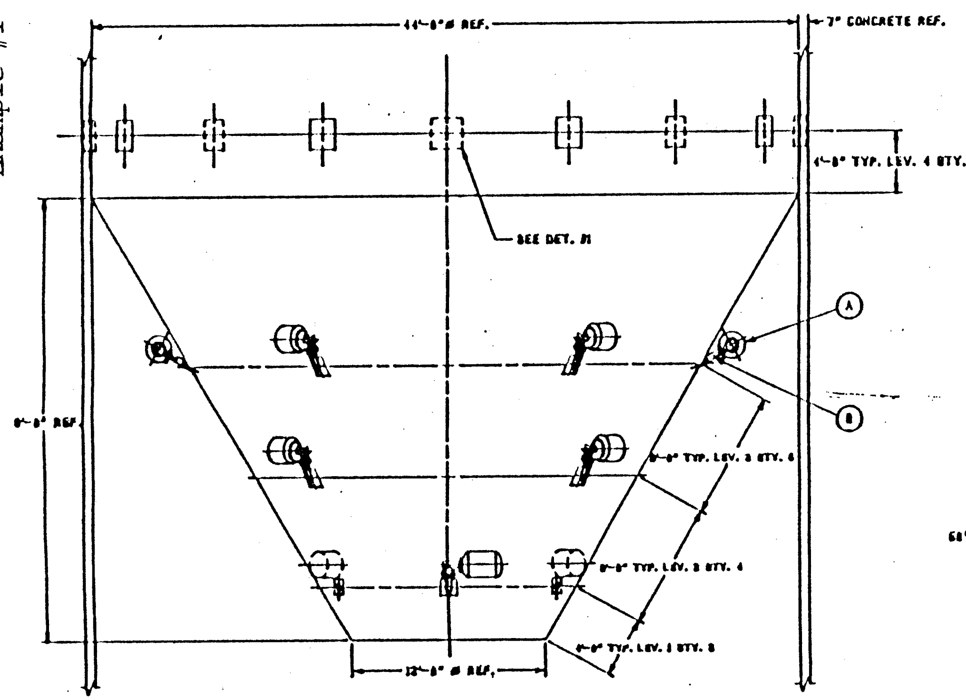
1) ENCIRCLED NOS. INDICATE FIRING SEQUENCE
2) REF. DIMS. PER CUSTOMER DRW'G
3) DUE TO POSSIBLE STRUCTURAL INTERFERENCE, DIMS. & LOCATIONS MAY VARY.
4) THIS DRW'G FOR PROPOSAL PURPOSES ONLY.
5) ACCESSORY PACK CONSISTS OF THE FOLLOWING: SOLENOID VALVES, FILTER, BALL VALVE, CHECK VALVE
6) BB4 SHIP PACK CONSISTS OF THE FOLLOWING: Q.E. VALVE, HOSE WHIP, MT. FLGS., GASKET & FASTENERS
7) REFER TO MARTIN OWNERS/OPERATORS MANUAL FOR PROPER INSTALLATION, OPERATION, & MAINTENANCE.
8) REFER TO DRW'G. D-93030 FRO CONCRETE SILO MOUNTING KIT INSTALLATION DETAILS.

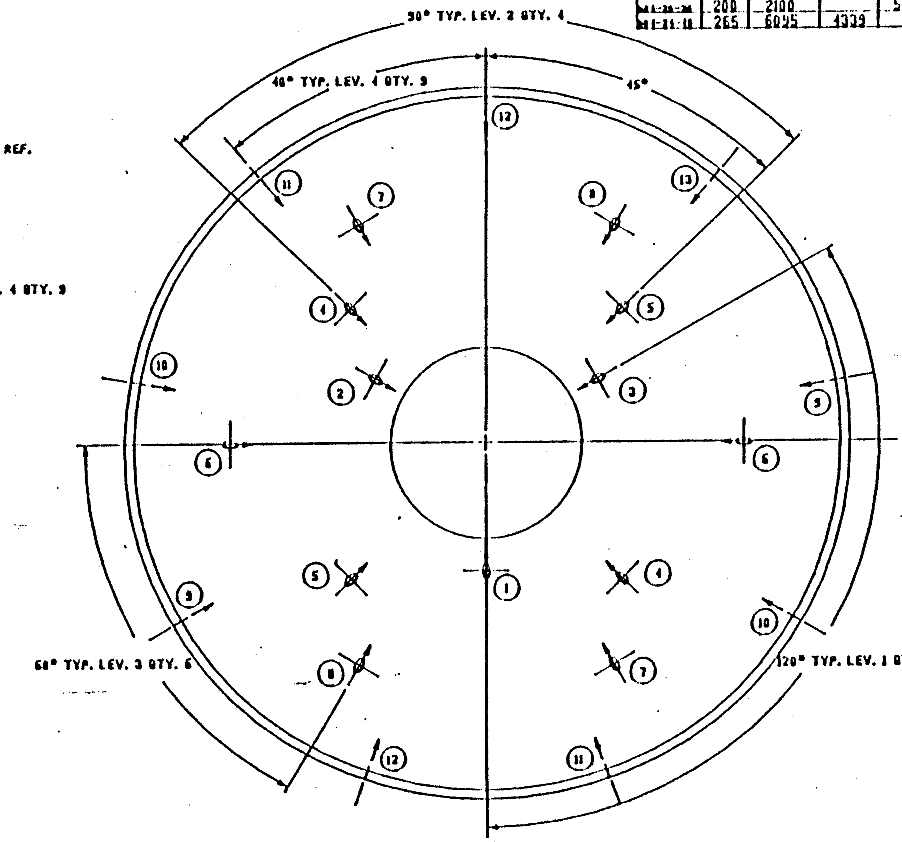
	ITEM	QTY	DESCRIPTION	PART NO.
	A	13	BB4-20-30	D-22101
	B	13	4" 30° MOUNT PLATE	C-23024
	C	9	BB4-24-48	D-22107
	D	9	MOUNTING KIT FOR CONCRETE SILO	A-29828
	E	9	4" 90° STREET ELBOW	A-23401
	F	9	4" PIPE COUPLING	A-20331
	G	9	4" 45° ELBOW	A-20583
N.S.	H	22	BB4 ACCESSORY PACK	A-24673
N.S.	I	22	BB4 SHIP PACK	A-26105
N.S.	J	1	WBT-1 TIMER (13 CIRC.)	D-28107-13

LOAD DATA

STATIC LOADING ON BIN

MODEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BB4-20-30	200	2100		5000		7.07
BB4-24-48	265	6095	4339			7.07





TOP VIEW

MATERIAL HANDLED WOOD CHIPS
MOISTURE CONTENT NA %
BULK DENSITY NA LBS. CU. FT.
AIR SUPPLY REQD. 56.1 C.F.M. AT 80 P.S.I. BASED ON A 15 MIN. TOTAL FIRING SEQUENCE. AFTER INITIAL START UP TIME MAY BE LENGTHENED OR SHORTENED TO OBTAIN REQUIRED FLOW, WHICH WILL INCREASE OR DECREASE CFM REQUIREMENTS.

NO.	DESCRIPTION	DATE	BY

REVISIONS

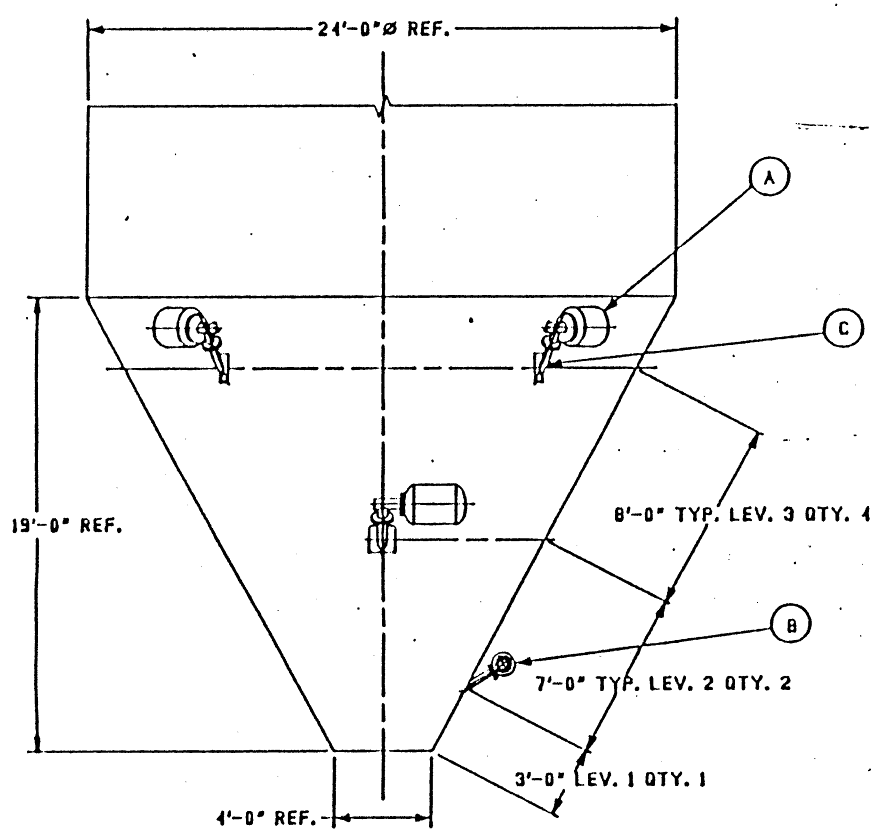
MARTIN ENGINEERING COMPANY
NEPONSET, ILLINOIS USA

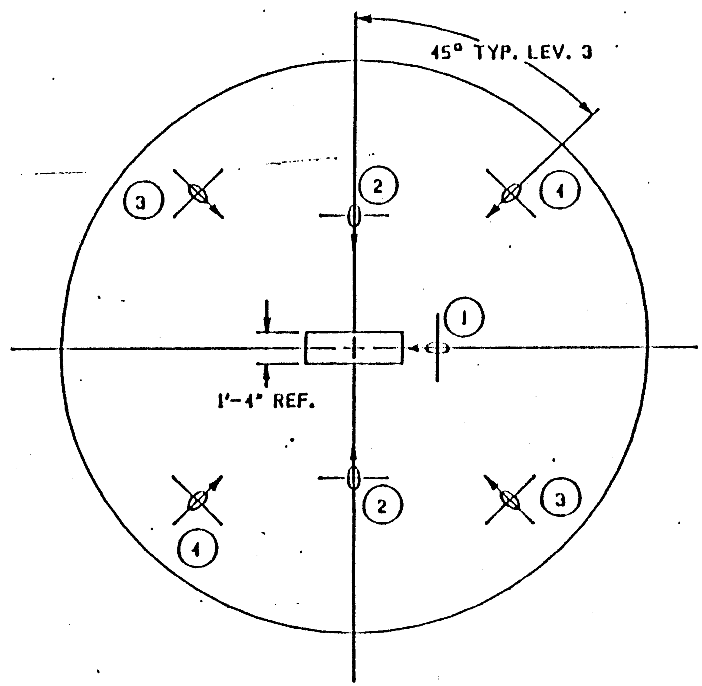
TITLE BLASTER® PROPOSAL
CUSTOMER
DRAWING NO.

DRAWN
DATE
CHECKED
DATE
APPROVED
DATE
SCALE
REVISION

1) ENCIRCLED NOS. INDICATE FIRING SEQUENCE
2) REF. DIMS. PER CUSTOMER DRW'G
3) DUE TO POSSIBLE STRUCTURAL INTERFERENCE, DIMS. & LOCATIONS MAY VARY.
4) THIS DRW'G FOR PROPOSAL PURPOSES ONLY.
5) ACCESSORY PACK CONSISTS OF THE FOLLOWING: SOLENOID VALVES, FILTER, BALL VALVE, CHECK VALVE
6) BB4 SHIP PACK CONSISTS OF THE FOLLOWING: Q.E. VALVE, HOSE WHIP, MT. FLGS., GASKET & FASTENERS
7) REFER TO MARTIN OWNERS/OPERATORS MANUAL FOR PROPER INSTALLATION, OPERATION, & MAINTENANCE.

	ITEM	QTY	DESCRIPTION	PART NO.
	A	6	BB4-20-30	D-22101
	B	1	BB4-12-28	D-22077
	C	7	4" 30° MOUNT PLATE	C-23024
N.S	D	7	BB4 ACCESSORY PACK	A-24679
N.S	E	7	BB4 SHIP PACK	A-26405
N.S	F	1	MBT-1 TIMER (4 CIRC.)	D-28107-04





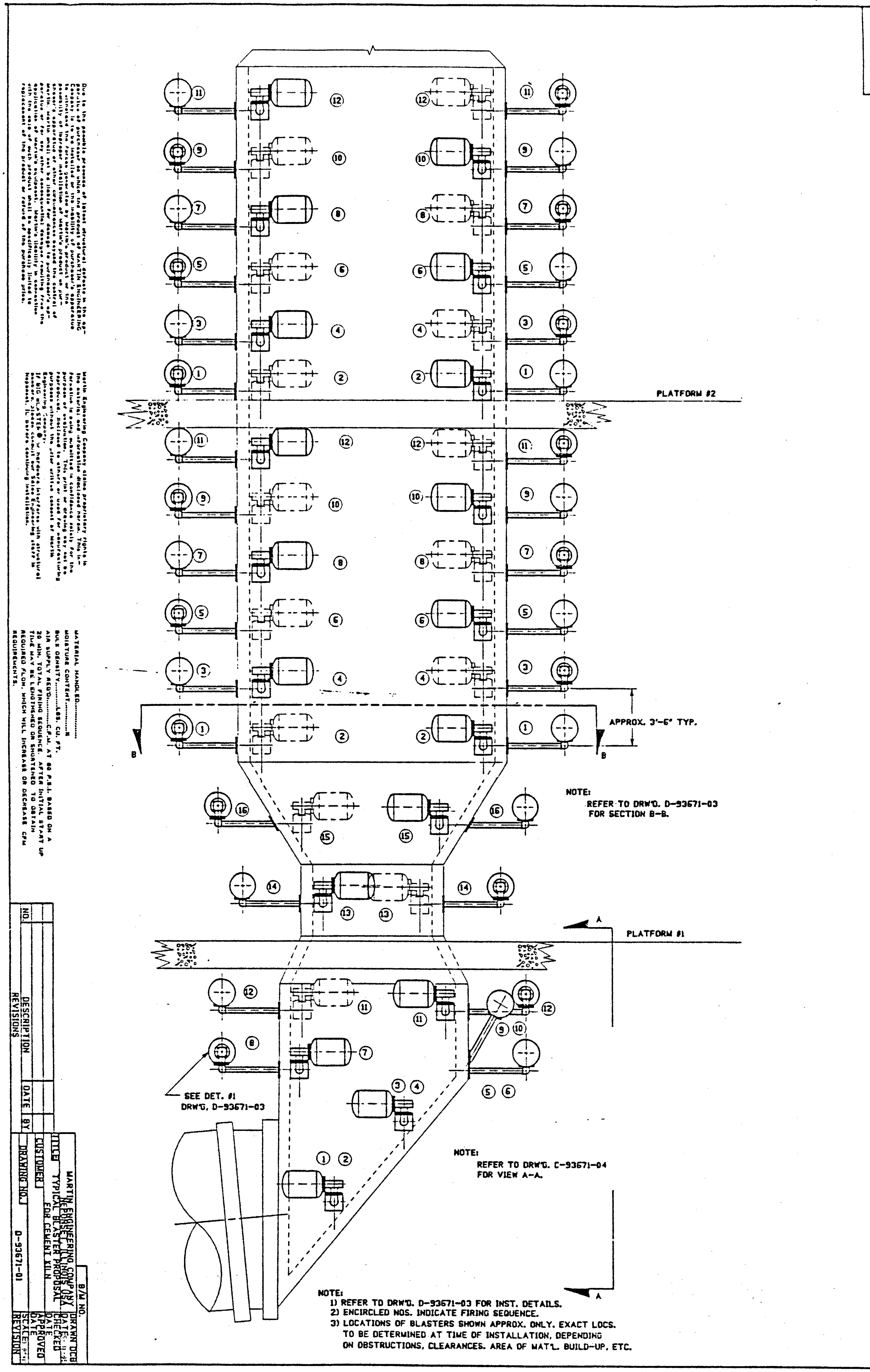
TOP VIEW

MATERIAL HANDLED..GYPSUM ROCK
MOISTURE CONTENT...3%.....
BULK DENSITY...80...LBS. CU. FT.
AIR SUPPLY REQ'D...33..C.F.M. AT 80 P.S.I. BASED ON A 5 MIN. TOTAL FIRING SEQUENCE. AFTER INITIAL START UP, TIME MAY BE LENGTHENED OR SHORTENED TO OBTAIN REQ'D FLOW, WHICH WILL INCREASE OR DECREASE C.F.M. REQUIREMENTS

NO.	DESCRIPTION	DATE	BY
	REVISIONS		

	B/M NO.
MARTIN ENGINEERING COMPANY NEPONSET, ILLINOIS USA	DRAWN
	DATE
TITLE BLASTER PROPOSAL	CHECKED
	DATE
CUSTOMER	APPROVED
	DATE
DRAWING NO.	SCALE

Example #3


PLATFORM #2
APPROX. 3'-6" TYP.
NOTE:
REFER TO DRW'G. D-93671-03
FOR SECTION B-B.
PLATFORM #1
SEE DET. #1
DRW'G. D-93671-03
NOTE:
REFER TO DRW'G. C-93671-04
FOR VIEW A-A.
NOTE:
1) REFER TO DRW'G. D-93671-03 FOR INST. DETAILS.
2) ENCIRCLED NOS. INDICATE FIRING SEQUENCE.
3) LOCATIONS OF BLASTERS SHOWN APPROX. ONLY. EXACT LOCS.
TO BE DETERMINED AT TIME OF INSTALLATION, DEPENDING
ON OBSTRUCTIONS, CLEARANCES, AREA OF MAT'L. BUILD-UP, ETC.
REVISIONS
NO.
DESCRIPTION
DATE
BY
TYPICAL BLASTER PROPOSAL
FOR CEMENT KILN
CUSTOMER
DRAWING NO.
D-93671-01

REFERENCES

(2) Johanson, Jerry R. Two-phase-flow effects in solds processing and handling. Chemical Engineering, January 1979.

(3) Rappen, Albert. Air-blasting silo blockages. Bulk Systems International, October 1981. Vol. 3, No. 6.

(1) Wright, Dr. Harold, Weare, F. E., and Swinderman, R. Todd. A Preliminary Investigation Into The Effects Of Air Cannon Discharge On Steel And Concrete Structures. Neponset, IL: Martin Engineering Company.