VG335
Intrumented sphere assessment of onion grading and harvesting equipment

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Know-how for Horticulture™

VG335

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SUMMARY

Damage to onions caused during harvest and postharvest handling can lead to serious quality losses. The identification of sites contributing to cuts, bruises etc. has been made more objective by new technology. The Instrumented Sphere model 100 is an electronic impact recording device which quantifies the drops and collisions that fruit and vegetables experience during handling.

This investigation of Vecon's handling equipment in Tasmania is the first in Australia to use the sphere for identification of physical causes of onion damage. The sphere's characteristics proved to be well suited to handling studies of this particular crop. It accurately represented onion movement through mechanical equipment and its size, which approximates a large onion, enabled assessment of all handling line processes. In addition, the impact acceleration range which can be accurately registered by the sphere was the appropriate range for impacts occurring during onion harvesting, sizing, grading and packing .

The sphere enabled a relative comparison of potentially damaging impact sites. The highest impact acceleration recorded by the sphere was 328G during a fall onto a vertical lifting device. Twenty-four sites were associated with impact accelerations which averaged in excess of 100G. The impacts recorded during storage, sorting, grading and packing in the factory were generally more numerous and had greater magnitude than those occurring on the field equipment. Recommendations have been made for the lowering of G levels at the eight worst sites.

Future studies should aim to correlate the instrumented sphere's impact readings with drop heights and extent of damage on different onion varieties.

INTRODUCTION

During mechanical harvesting and handling, onions are subject to impact forces which may cause damage such as cuts and bruises. The loss in quality associated with this damage can have a detrimental effect on domestic prices and decrease the export value of the produce.

Onion damage can consist either of internal bruising or surface incisions. When an impact causes internal bruising, the concentric rings of an onion slide over one another, and the seal between the rings is broken. A space is provided for fluids to accumulate and this location provides an excellent environment for pathogenic organisms to develop (Maw *et al.*, 1989).

Peterson *et al.* (1984) determined the effect of onion damage on storage rot, and found that mechanical handling followed by a period of storage increased rot development. Wounds which penetrated the surface were observed to result in almost total loss of onions but surface bruising that only crushed cells tended to dry out and heal. The amount of bruising which results in tissue discoloration, decay and reduction in shelf life is not fully established.

The instrumented sphere has been used in Australian horticulture since 1990 but until now research has not been undertaken on onions. The sphere (or IS) enables a quantitative and accurate assessment of handling procedures so that drops and collisions which are potentially damaging to horticultural produce can be identified.

Vecon Pty. Ltd. are the southern hemisphere's largest exporter of onions, and annually approximately 30,000 tonnes pass through their mechanical handling equipment. Vecon have sought to improve the effectiveness of this equipment by using an instrumented sphere to locate sites causing large impacts that could potentially lead to onion quality loss.

THE INSTRUMENTED SPHERE 100

The IS100 was developed at Michigan State University in conjunction with the U.S. Department of Agriculture. It consists of a battery powered computer and a piezo-electric accelerometer enclosed in a spherical beeswax shell of 90mm diameter (Fig. 1A). The accelerometer senses impacts along three axes (Fig. 1B).

Impact signals registered by the accelerometer are sent to a processor chip where they are logged, timed and finally passed to a memory chip. After the IS is operated the accumulated data are loaded into a computer for analysis (Fig. 1C). IS based software controls sampling rates, checks and stores data, and sends the data to the computer. Computer based software provides data analysis and graphical display.

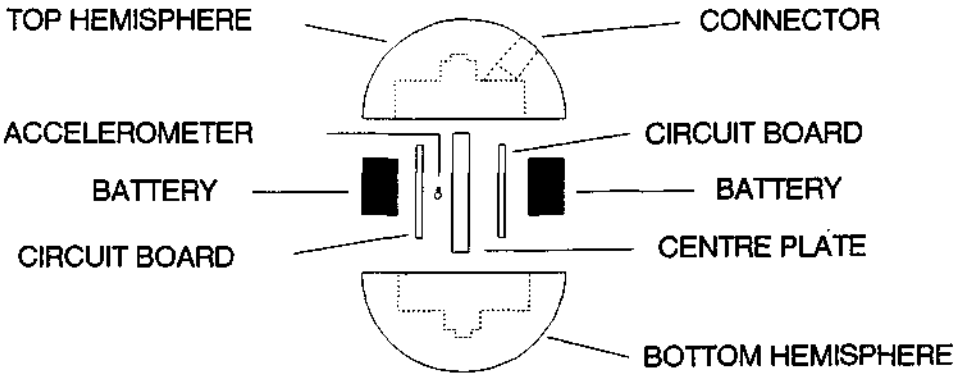
ONION BRUISE THRESHOLDS

For a specific surface, there is an impact level at which an onion will begin to bruise, the probability of bruising increasing with drop height and increasing 'G' levels. The damage potential of an impact is measured in terms of it's impact acceleration (G).

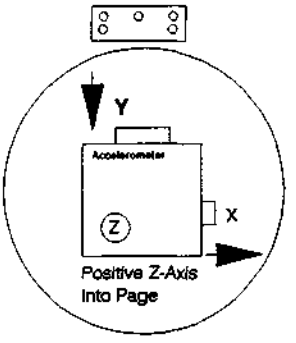
Timm *et al.* (1991) attempted to define the damage thresholds for onions by performing laboratory drop tests using fresh and cured (dried) 'Spartan Banner 80' variety onions. Test procedure involved dropping onions from different heights onto steel and urethane microcell sponge to simulate the impact conditions that cause bruising. Bruising was initiated at a drop height of 10mm onto steel for freshly harvested onions compared to 6mm for the cured onions. The IS recorded 85 and 56 G for these respective drops. In comparison, bruising on a 6.4mm thick sponge surface was initiated at 450mm (203G) for fresh and 400mm (179G) for cured onions.

To date the only published trials which have attempted to correlate IS impact readings to onion bruising are those described by Timm *et al.* (1991). Their findings can only be used as a rough guide in the interpretation of impact data recorded by an IS on Vecon's machinery. For a given drop height or impact acceleration, the expression of bruising will depend on variety, temperature, curing time, etc.. Instrumented sphere data presented in this report should be viewed as a relative measure of the damage potential of different sites.

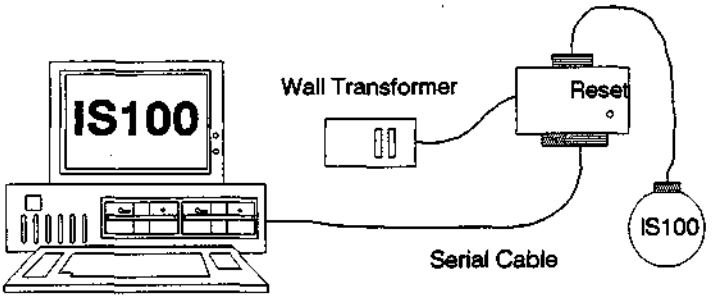
FIGURE 1:INSTRUMENTED SPHERE 100 HARDWARE



A. IS100 Components



B. Accelerometer Orientation Within IS100



C. IS100 Configuration

RELEVANT LITERATURE

Brook, R. & T. Dudek (1992) Impact Evaluation on Onion Packing Lines in Michigan. Onion World, January.

Brown, G.K., N.L. Schulte-Pason & E.J. Timm (1990) Impact Classification Using the Instrumented Sphere. ASAE Paper No. 90-6001.

Maw, B.W., Y.C. Hung, E.W. Tollner & D.A. Smittle (1989) Some Physical Properties of Sweet Spanish Onions. ASAE Paper No. 89-6007.

Peterson, C.L., G.J. Shropshire, J.C. Thompson & M.K. Thornton (1991) Using the Instrumented Sphere for Evaluating Handling of Sweet Spanish Onions. ASAE Paper No. 91-6594.

Peterson, C.L., K.B. Emerson, C.J. Crothers & M.C.Hall (1984) Packing Yellow Sweet Spanish Onions. ASAE Paper No. 84-6540.

Timm, E.J., G.K. Brown, R.C. Brook, N.L. Schulte & C.L. Burton (1991) Impact Bruise Estimates For Onion Packing Lines. Applied Engineering in Agriculture, 7(5):571-576.

ASSESSMENT

Assessment involved repetitively passing the IS together with onions (varieties 'Vecon Regular' & 'Vecon Early') through the normal handling equipment, and video-filming its progress. By co-ordinating the intrinsic timing mechanism in the IS with the camera's stopwatch it was usually possible, on replay of the footage, to determine at what site a particular impact had occurred.

The IS was programmed with a 40G threshold during data accumulation which means that small impacts with accelerations less than 40G were not recorded, or included in the findings. Impacts of less than 40G are unlikely to cause damage to onions under normal handling circumstances.

Average impact acceleration figures presented in the results are based on all replicated runs (usually 5-10) through a particular site. In contrast, the 'maximum impact acceleration' is the largest G reading recorded from any run at the site. Most sites are defined by a single principal impact but for others (e.g. site 23) an impact number greater than one is specified.

The frequency figure (see results tables) is based on total runs through a site, and serves to describe the consistency of impact at that site. Where frequency is less than 100% it can be assumed that factors like onion loading, onion positioning and minor variations in route combined to ensure that impact didn't occur on every run.

RESULTS and DISCUSSION

FIELD EQUIPMENT

The machinery used for lifting (extraction from the soil) and turning (during field drying) incorporated only one impact site (Fig. 2). No impacts larger than 40G (the threshold) were recorded at the blade/soil interface but the drop off the primary web to the ground was of slight concern. During lifting, the impacts registered at this drop were small (59G average, 80-100% frequency) because fresh onion stalks probably acted as a cushion. However, impacts registered by the IS during turning were slightly higher (69G, 89%), the partially desiccated stalks being less able to buffer the fall. A secondary impact (71G, 44%) recorded off the primary web may have been caused by onions dropping onto the sphere (Fig. 2).

During assessment of harvest, the IS was placed on the soil surface amongst onions and carried along the harvester webs and into a bunker (Fig. 3&4). High impact levels were found at two transfer points, the drop off the primary web onto the cross-over belt (Site 6, 134G, 85%), and off the draper onto the primary web (Site 4, 93G, 91%). Other impacts (Tables 1&2) recorded on the Wuhlmaus harvester ranged on average between approximately 60 and 80G with the frequency of occurrence depending on loading. Loading is a reference to the quantity (or density) of a crop on handling equipment.

FIGURE 2: SUMMARY OF IMPACTS ASSOCIATED WITH FIELD LIFTING AND TURNING PROCESSES

LIFTING (Fresh Crop)

Impact Frequency:	80-100%
Average Impact Size:	59 G
Maximum Impact Size:	82 G

TURNING (Dried Crop)

Primary Impact

Impact Frequency:	89%
Average Impact Size:	69 G
Maximum Impact Size:	94 G

Secondary Impact (Subsequent to primary impact)

Impact Frequency:	44%
Average Impact Size:	71 G
Maximum Impact Size:	99 G

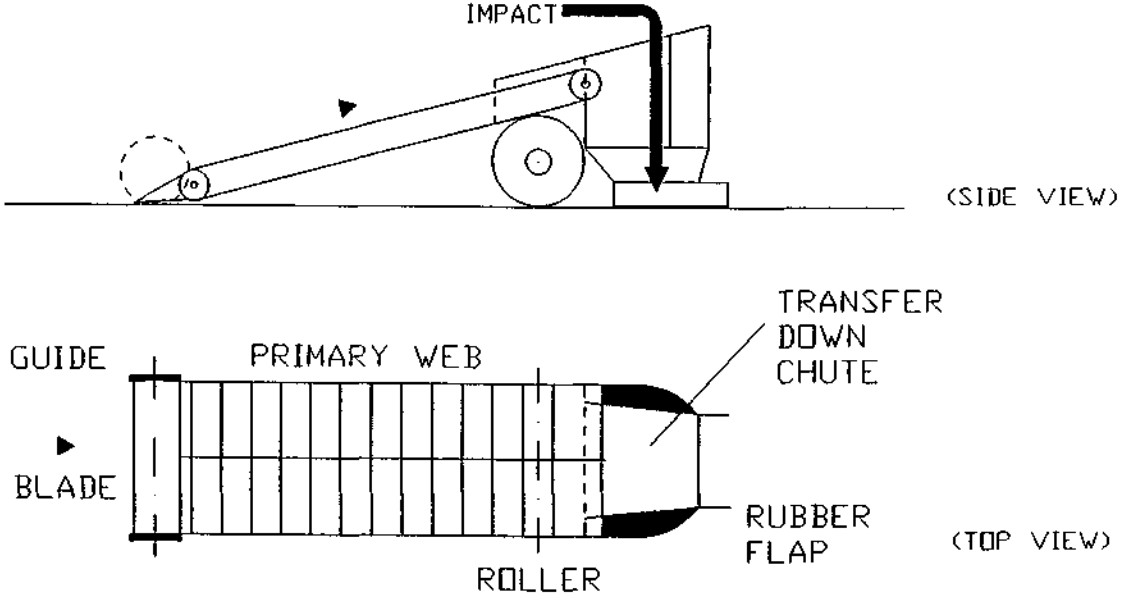
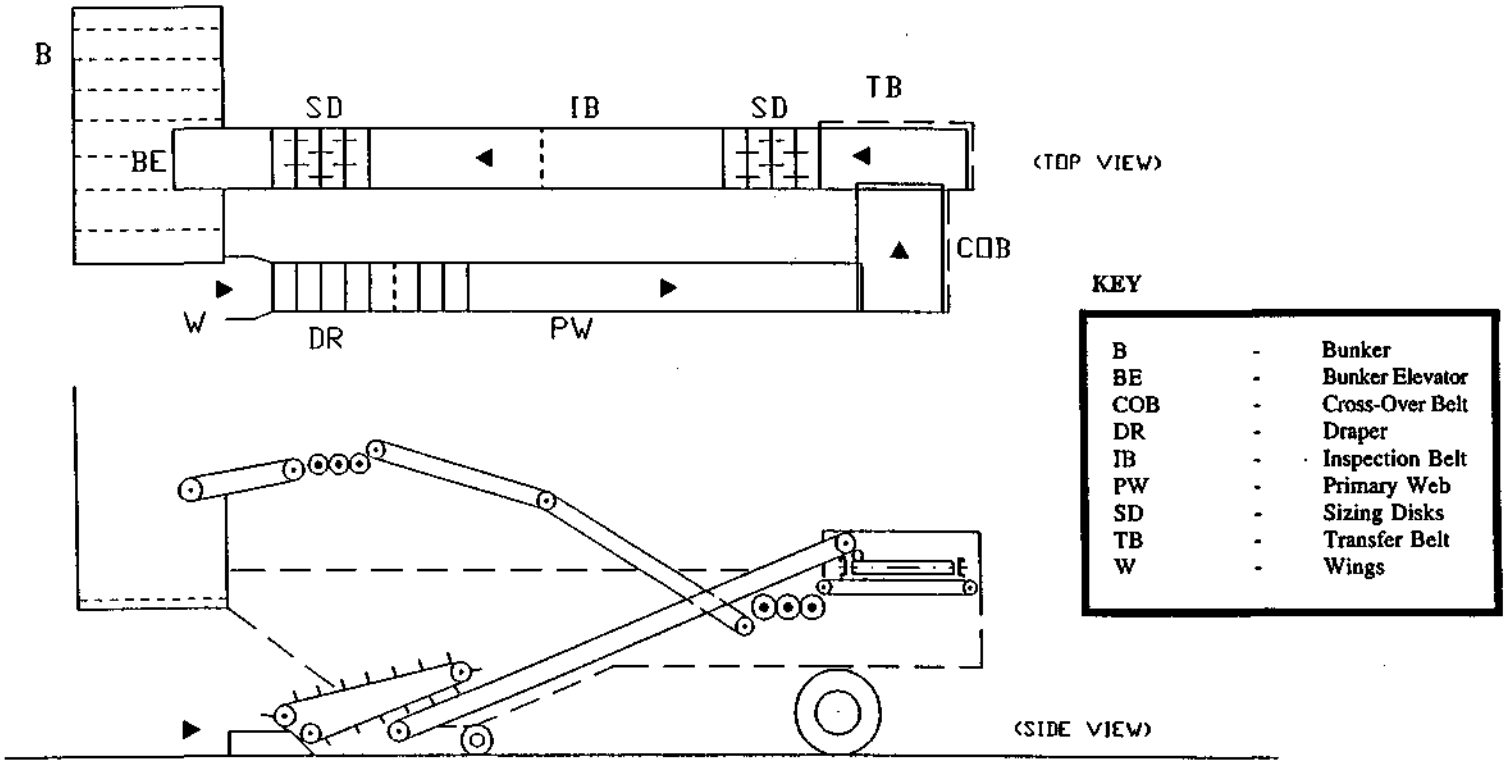


FIGURE 3: MECHANICAL COMPONENTS OF THE ONION HARVESTER



WUHLMAUS 1733P HARVESTER

FIGURE 4: IMPACT SITES ON THE ONION HARVESTER

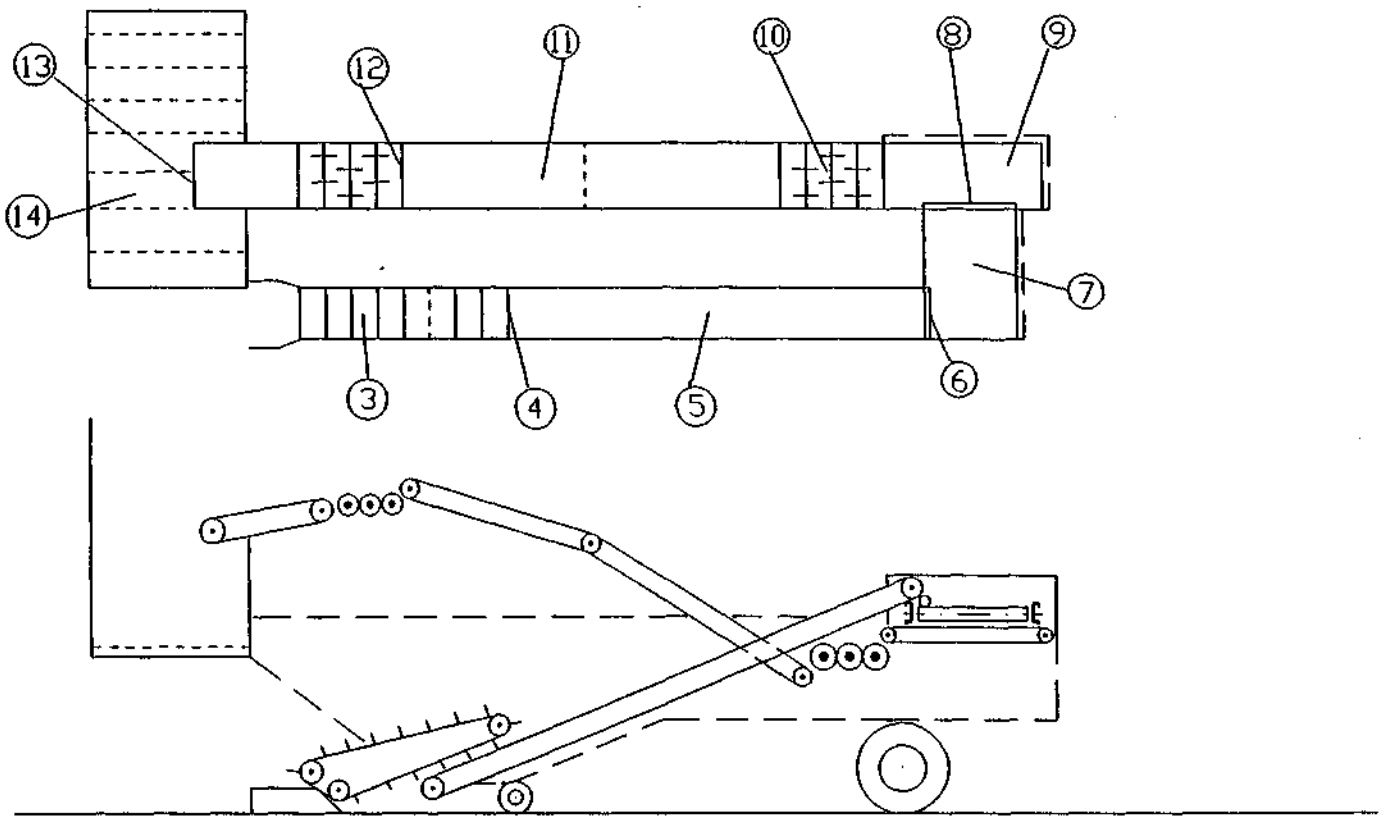


TABLE 1: DESCRIPTION OF IMPACT SITES ON FIELD EQUIPMENT

SITE	IMPACT SITE DESCRIPTION	COMMENTS
1	Off Lifter Primary Web onto ground - Lifting	
2(a)	Off Lifter Primary Web onto ground - Turning	Primary impact
2(b)	Off Lifter Primary Web onto ground - Turning	Secondary impact
3	Along Draper on Harvester	
4	Off Draper onto Primary web	
5	Along Primary Web	
6	Off Primary Web onto Cross-over Belt	
7	Along Cross-over Belt	
8	Off Cross-over Belt onto Transfer Belt	
9	Along Transfer Belt	
10	Along Sizing Disks	
11	Along Inspection Belt	
12	Off Inspection Belt onto Sizing Disks	
13	Initial drop off Bunker Elevator into Bunker	
14	Settling drop inside Bunker	Range of Bunker depths

TABLE 2: SUMMARY OF IMPACT DATA RECORDED BY AN INSTRUMENTE SPHERE ON ONION FIELD HANDLING EQUIPMENT

SITE	AVERAGE IMPACT ACCELERATION (G)	FREQUENCY OF OCCURRENCE (%)	MAXIMUM IMPACT ACCELERATION (G)	IMPACT NUMBER (>1)
1	59	80-100	82	
2(a)	69	89	94	
2(b)	71	44	99	
3	60	82	78	1.9
4	93	91	140	
5	84	70	136	4.1
6	134	85	192	
7	71	54	106	1.3
8	76	77	106	
9	59	31	70	
10	63	46	82	
11	64	23	76	
12	63	54	78	
13	74	69	106	
14	79	54	113	

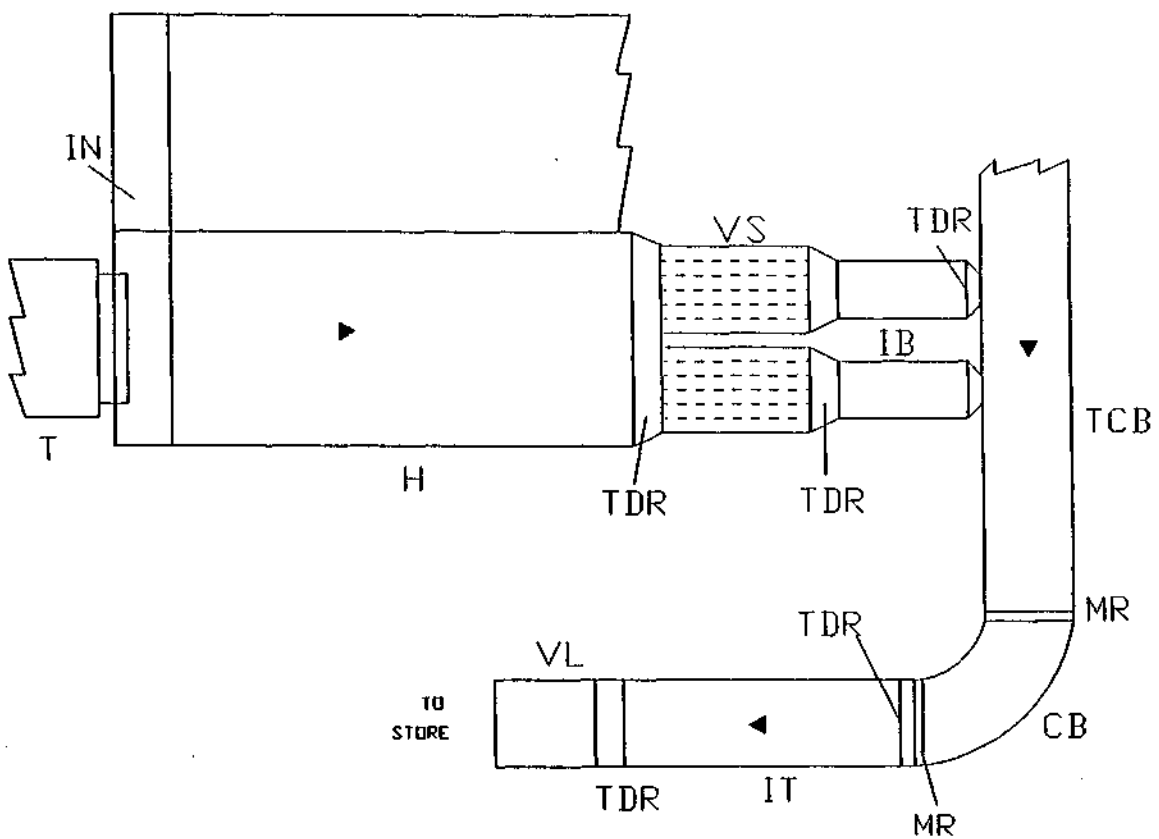
BULK INTAKE TO STORE

Harvested onions were bulk transported by truck to the Vecon factory and tipped *en masse* into a hopper at the intake line entrance (Figs. 5&6). The IS was placed on top of, or just below, the surface of the onion load in an attempt to maximise drop height. Resulting impacts (Site 15, 63G, 100%) suggest that padding material placed on the hopper floor, and high onion loading, combine to minimize impact size and potential onion damage.

Impact levels on this section of the line again demonstrated the importance of high loading in reducing damage potential (Tables 3&4). Drops off the inspection belts onto the transfer down ramp (Site 19, 114G, 42%) and then onto the transfer conveyor belt (Site 20, 125G, 33%) caused the highest impact readings. The impact frequencies reflect variation in loading; on some runs cushioning created by high loading prevented impact. The 275G maximum impact off the hopper onto the vibrating screen was a direct consequence of low loading.

Onions are transferred to the store via a vertical lifter at the end of the intake line. Very large impacts occurred at the lifter's entrance (Site 23, 168G, 100%, 3.4 impacts/run), and on one run with low loading, the IS registered 328G. This transfer point is potentially very damaging because onions are subject to a large drop into moving steel buckets.

FIGURE 5: COMPONENTS OF INTAKE TO STORE



(SEE KEY TO ABBREVIATIONS ON FINAL PAGE)

FIGURE 6: IMPACT SITES FOR INTAKE TO STORE

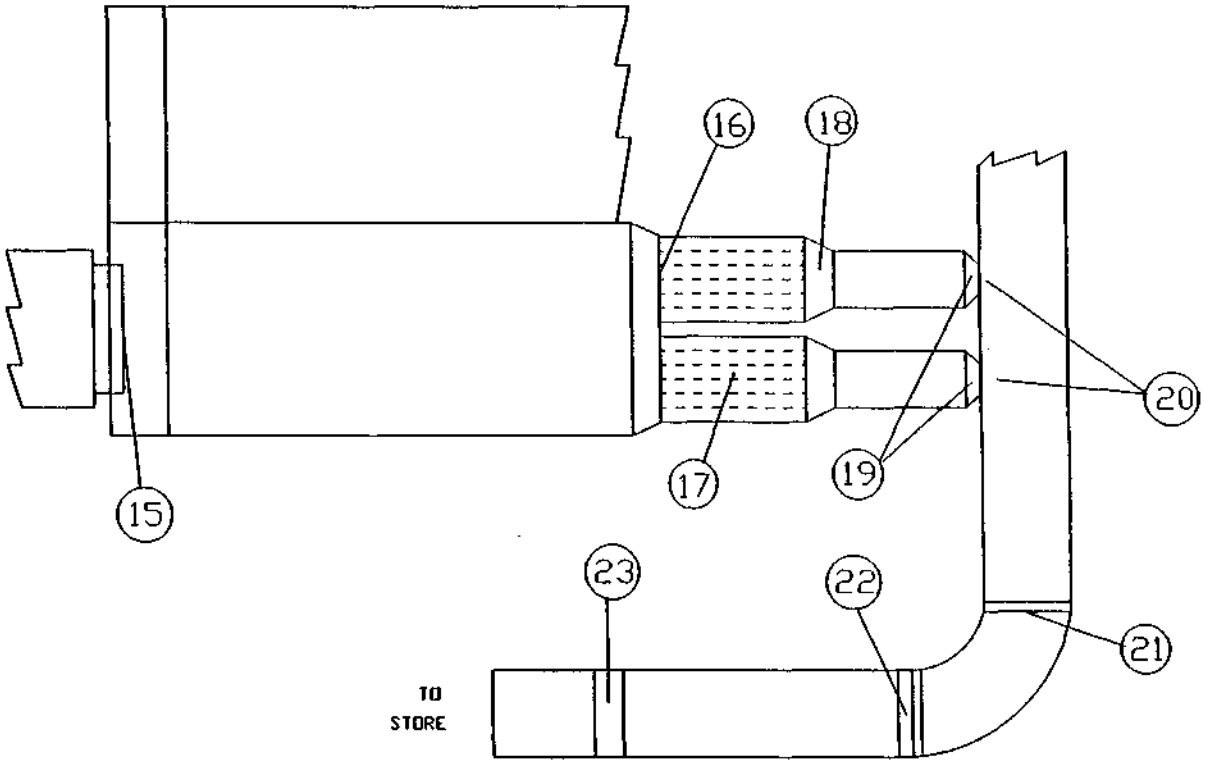


TABLE 3: DESCRIPTION OF IMPACT SITES - BULK INTAKE

SITE	IMPACT SITE DESCRIPTION	COMMENTS
15	Off Truck into Hopper	
16	Off Hopper onto Vibrating Screen	Various onion loadings
17	Along Vibrating Screen	
18	Off Vibrating Screen onto Transfer-Down Ramp	
19	Off Inspection Belt onto Transfer-Down Ramp	
20	Off Transfer-Down Ramp onto Transfer Conveyor Belt	
21	Off Transfer Conveyor Belt onto Conveyor Belt	Over Metal Roller
22	Off Conveyor Belt onto Transfer-Down Ramp	Before Inspection Table
23	Off Inspection Table onto Vertical Lifter	

TABLE 4: SUMMARY OF IMPACT DATA RECORDED BY AN INSTRUMENTEI SPHERE IN THE BULK INTAKE

SITE	AVERAGE IMPACT ACCELERATION (G)	FREQUENCY OF OCCURRENCE (%)	MAXIMUM IMPACT ACCELERATION (G)	IMPACT NUMBER (>1)
15	63	100	82	
16	123	100	275	
17	53	67	57	
18	60	50	88	
19	114	42	151	
20	125	33	183	
21	61	17	62	
22	60	17	69	
23	168	100	328	3.4

DISTRIBUTION WITHIN STORE

During onion transfer from the vertical lifter through to the floor of the store (Figs. 7 & 8), large sections of the line were inaccessible and could not be video-filmed. However, time matching and the replicated sequence of readings indicate that the large impacts occurred when the IS passed onto the conveyor belt running above the store (Site 26, 115G, 71%), and when it exited this conveyor down a chute onto the 'Donk' (Site 27, 175G, 100%, 3.1 impacts/run).

Using a 'Scoopie' apparatus, stored onions were accumulated and deposited onto an underfloor store conveyor which runs to the factory. Large impacts were recorded within the scoopie at site 30 (95G 100%), and off the scoopie onto the store conveyor (Site 31, 94G, 100%).

Impact sites and data are described fully in Tables 5 and 6.

TABLE 5: DESCRIPTION OF IMPACT SITES WITHIN STORE

SITE	IMPACT SITE DESCRIPTION	COMMENTS
24	Off Vertical Lifter onto Conveyor Belt	
25	Off Conveyor Belt onto Transfer Conveyor	
26	Off Transfer Conveyor onto Conveyor Belt	Conveyor running above store
27	Off Conveyor Belt into Transfer-Down Chute	Onto "Donk"
28	Off "Donk" into Store	Drop onto onions
29	Off Store floor onto "Scoopie" Blade	
30	Off "Scoopie" onto Conveyor Belt	
31	Off Conveyor Belt onto Store Conveyor Belt	Running below store

TABLE 6: SUMMARY OF IMPACT DATA RECORDED BY AN INSTRUMENTED SPHERE ON HANDLING EQUIPMENT IN THE STORE

SITE	AVERAGE IMPACT ACCELERATION (G)	FREQUENCY OF OCCURRENCE (%)	MAXIMUM IMPACT ACCELERATION (G)	IMPACT NUMBER (>1)
24	72	14	72	
25	72	29	72	
26	115	71	164	
27	175	100	292	3.1
28	75	100	109	3.0
29	49	40	53	
30	95	100	174	
31	94	100	205	

FIGURE 7: COMPONENTS FOR CROP TRANSFER AND DISTRIBUTION WITHIN STORE

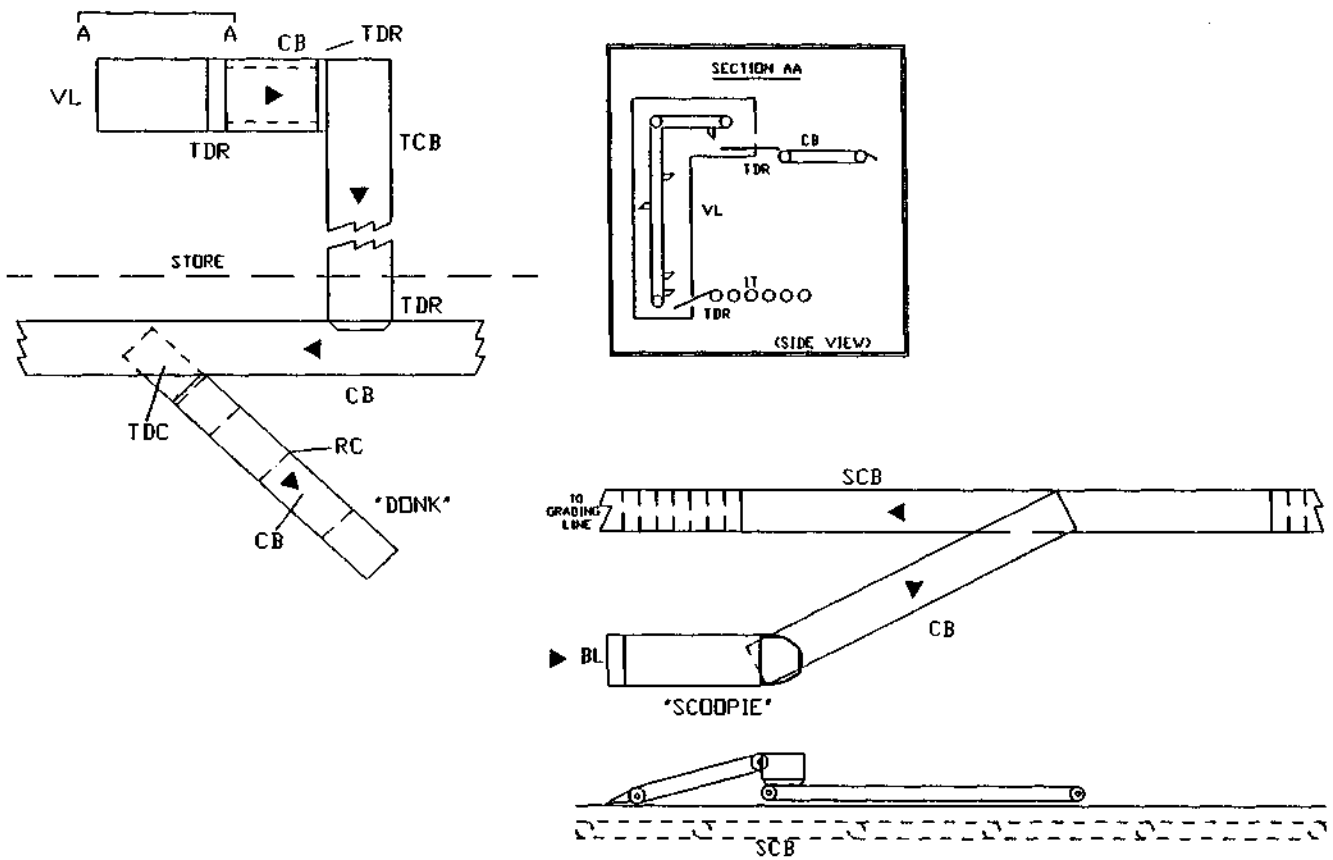
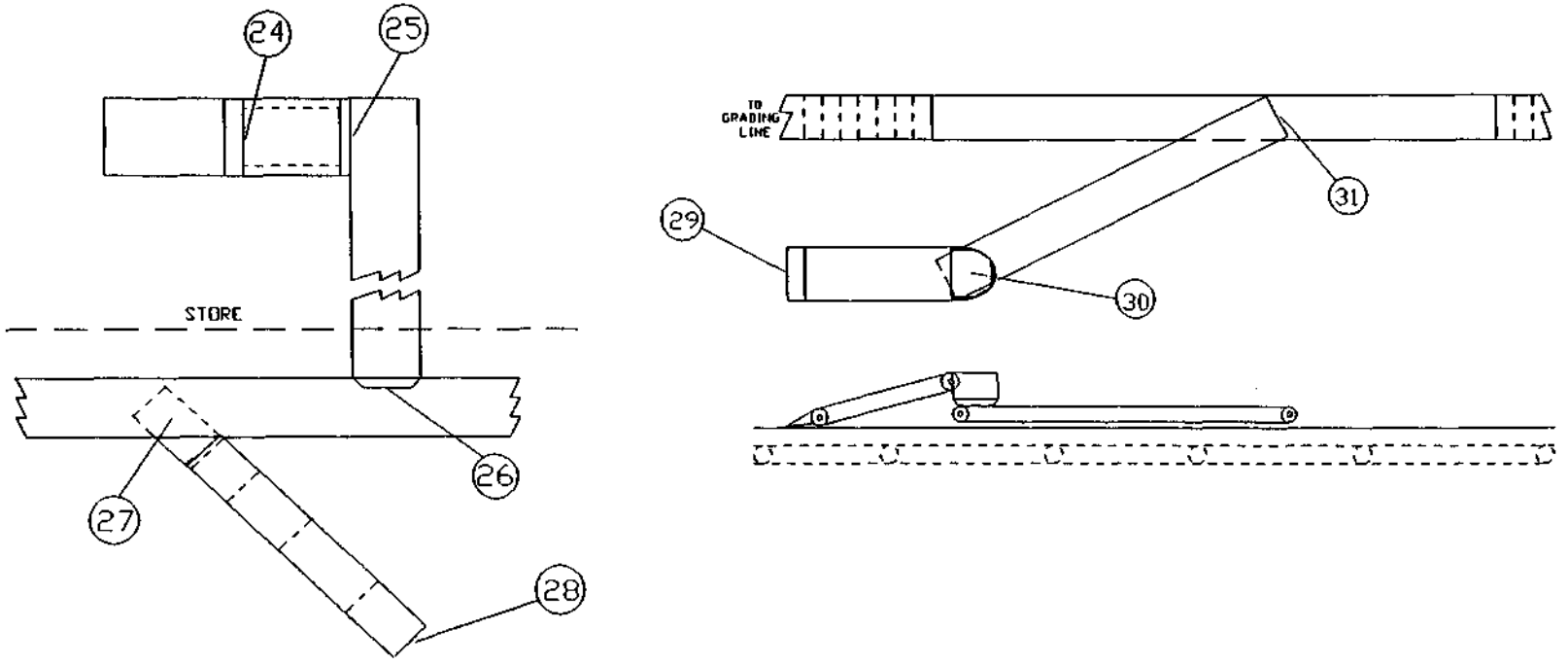


FIGURE 8: IMPACT SITES DURING TRANSFER AND DISTRIBUTION WITHIN STORE



FACTORY ENTRANCE, TOPPING, SIZING AND GRADING

This section of the factory line (Figs.9&10) incorporated several sites (centred on the topper and inspection table) which caused high G readings. The largest impact was at the entrance to the topper vibrating screen (site 35, 144G, 100%). Within the topper other large impacts averaging more than 100G occurred on the transfers (sites 36-38) between the vibrating screens (Tables 7&8). On the topper's vibrating screen sections, the IS recorded an average of 70 impacts per run with a mean acceleration of 55G.

Transfer ramps (sites 49 & 51 respectively) leading onto and off the inspection table were also associated with impacts averaging in excess of 100G (Table 8).

Like the topper vibrating screen, the sizing screens also caused large numbers (50 per run) of low level impacts averaging 62G. It has not been established whether a multitude of cumulative smaller impacts could have a damaging effect equivalent to fewer larger impacts. Figures 11 and 12 outline in more specific detail the impact data associated with the different sizer components. The 234G impact recorded on B reflects the ineffectiveness of thin rubber sheeting positioned over hard surfaces. Impacts onto the ends of the wooden director boards (C) could be simply and effectively reduced by the installation of thick padding foam at these points. Similarly at site 45, the final sizer component, padding would effectively reduce G levels.

The instrumented sphere's size necessitates that it passes through the sizing and packing elements with the largest onions. Large onions travel further than smaller ones on this line, and are therefore subject to more accumulated impact.

FIGURE 9: TOPPING, SIZING AND GRADING SECTIONS OF FACTORY HANDLING LINE

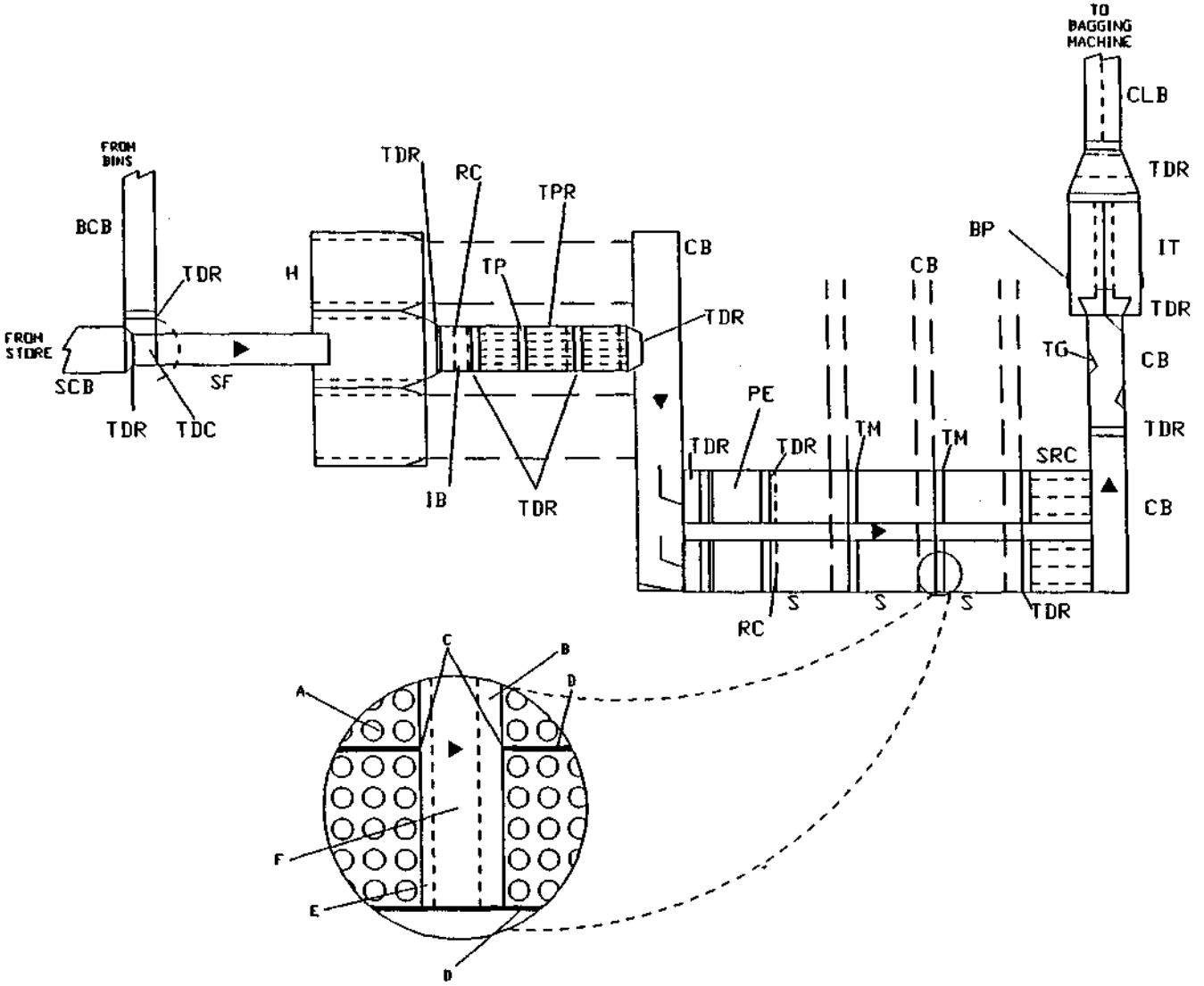


FIGURE 10: IMPACT SITES ON TOPPING, SIZING AND GRADING SECTIONS

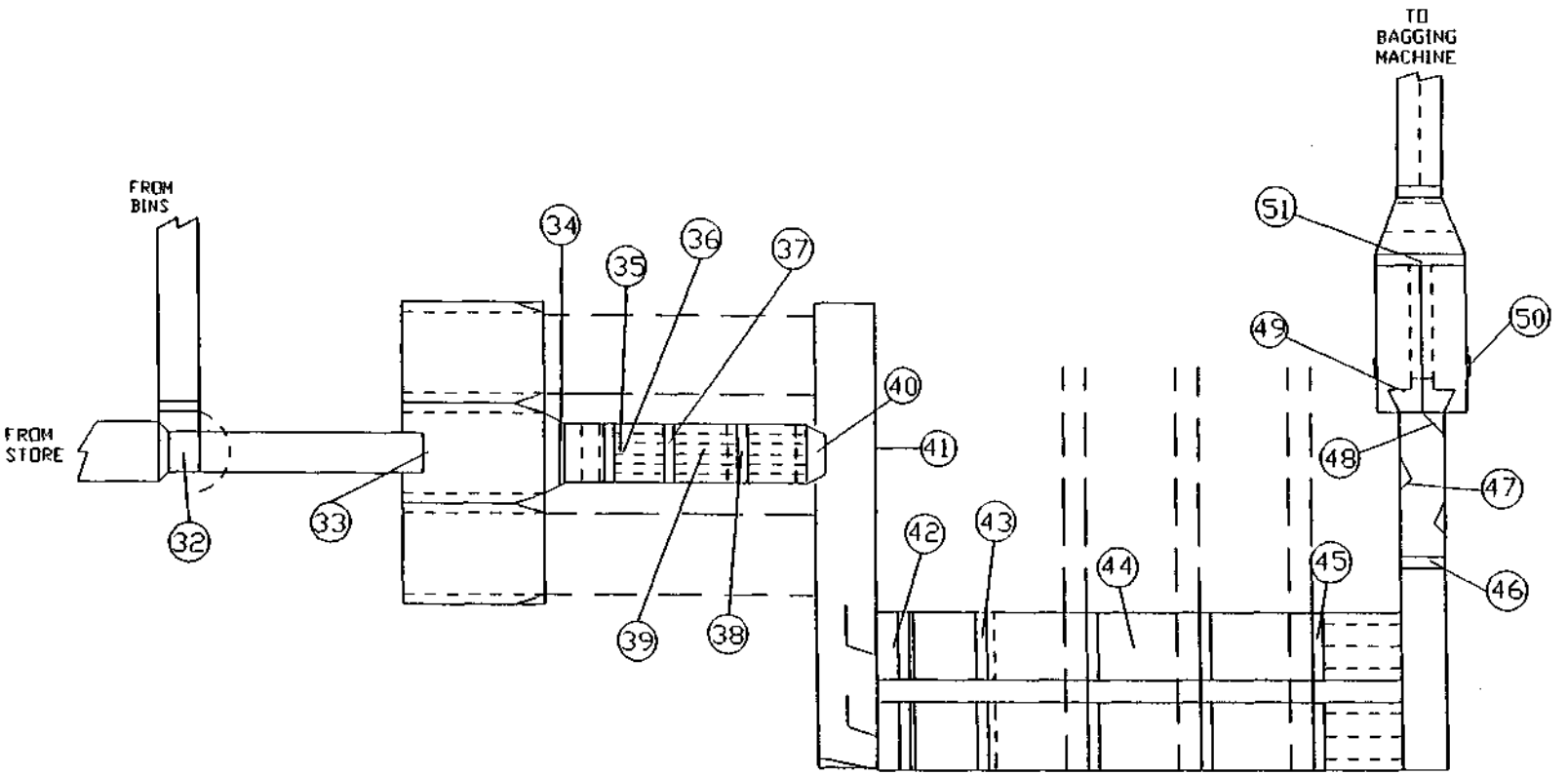


TABLE 7: DESCRIPTION OF IMPACT SITES - TOPPING, SIZING AND GRADING SECTIONS OF FACTORY LINE

SITE	IMPACT SITE DESCRIPTION	COMMENTS
32	Off Store Conveyor Belt into Transfer-Down Chute	Onto Space-Finder
33	Off Space-Finder into Hopper	
34	Off Hopper onto Transfer-Down Ramp	
35	Off Transfer-Down Ramp onto Topper	
36	Rebound onto Topper	
37	Over Transfer Plate inside Topper	
38	Over Transfer-Down Ramp inside Topper	
39	Along Topper	Vibrating screen section
40	Out of Topper onto Transfer-Down Ramp	
41	Rebound off wall opposite Topper	
42	Off Conveyor Belt onto Transfer-Down Ramp	Before Paddle Elevator
43	Off Paddle Elevator onto Transfer-Down Ramp	Before Sizer
44(a)	Along Sizer - Onto Sizer holes	
44(b)	Along Transfer Mat - Thinly padded edge board	
44(c)	Off Transfer Mat - Onto end of wooden director	
44(d)	Along Sizer - Onto wooden side boards	
44(e)	Along Transfer Mat - Solid edge at end of each Sizer section	
44(f)	Along Transfer Mat - Middle of rubber mat	
45	Off Sizer onto Transfer-Down Ramp	Before Suspended Rubber Chutes
46	Off Conveyor Belt onto Transfer-Down Ramp	After Suspended Rubber Chutes
47	Off Transfer-Down Ramp onto Triangular Guide	
48	Onto Metal Guide on Conveyor Belt	Before Inspection Table
49	Off Conveyor Belt onto Transfer-Down Ramp	On Inspection Table
50	Rebound onto Baffle Plates along Inspection Table	
51	Off Inspection Table onto Transfer-Down Ramp	Initial Ramp

TABLE 8: SUMMARY OF IMPACT DATA RECORDED BY AN INSTRUMENTED SPHERE ON THE TOPPING, SIZING AND GRADING SECTIONS OF THI FACTORY LINE

SITE	AVERAGE IMPACT ACCELERATION (G)	FREQUENCY OF OCCURRENCE (%)	MAXIMUM IMPACT ACCELERATION (G)	IMPACT NUMBER (>1)
32	63	86	100	
33	66	78	79	
34	105	100	194	
35	144	100	193	
36	111	50	141	
37	109	75	139	
38	113	63	183	
39	55	100	59	70.0
40	114	100	152	
41	115	25	116	
42	73	88	102	
43	46	50	55	
44(a)	62	100	132	49.5
44(b)	71	100	234	26.5
44(c)	82		132	1.5
44(d)	73		97	1.8
44(e)	65		115	7.8
44(f)	66		93	7.3
45	113	60	128	
46	117	100	144	
47	106	43	133	
48	53	14	53	
49	109	100	153	
50	94	57	133	
51	104	100	135	

FIGURE 11: PERCENTAGE OCCURRENCE OF IMPACTS ON DIFFERENT PARTS OF THE SIZER (SITE 44)

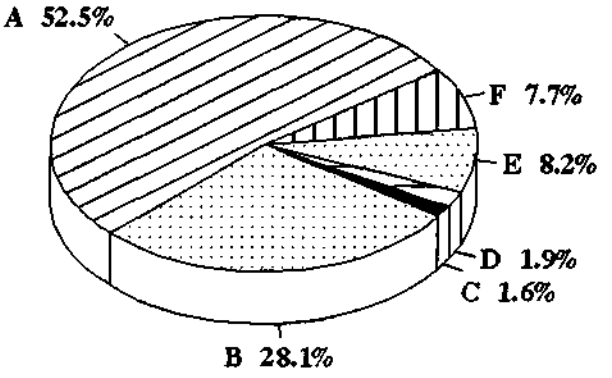
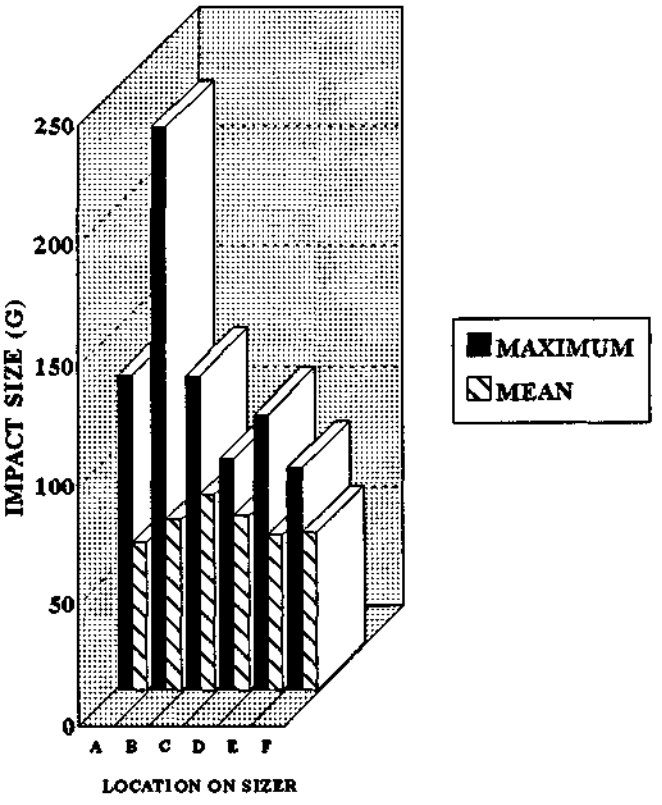


FIGURE 12: MAXIMUM AND MEAN IMPACT SIZES ON DIFFERENT PARTS OF THE SIZER (SITE 44)



PACKING, BULK LOADING, CONTAINERISATION

Sized and graded onions were either filled into 20 kg bags or loaded loose into bulk containers (Figs. 13&14). At the start of the bagging line (site 52) drops down the TDR to the base of the cleated belt averaged over 100G (Tables 9&10). Impacts against the baffle plate at the entrance to the bagging machine (site 53, 104G, 100%), and falls into the bag (site 54, 152G, 100%) were problems. Bags used in the tested runs were filled to various degrees so that a range of drop heights was examined. Impacts associated with the handling and positioning of sealed bags into bulk bins were not excessive (Tables 9&10).

On the container filling line the primary problem was the drop down the chute onto the conveyor (site 60, 119G, 100%) leading down the line towards the hopper. The hopper was full during most runs and as a result drop heights off the paddle elevator were small, however, occasionally the IS rolled back onto the hopper's steel wall (site 63, 119G, 33%). Drops off the telescopic conveyor into the container (site 66, 77G, 67%) produced low level impacts because the conveyor could be lowered to minimise drop height onto the onions.

FIGURE 13: PACKING COMPONENTS OF HANDLING LINE

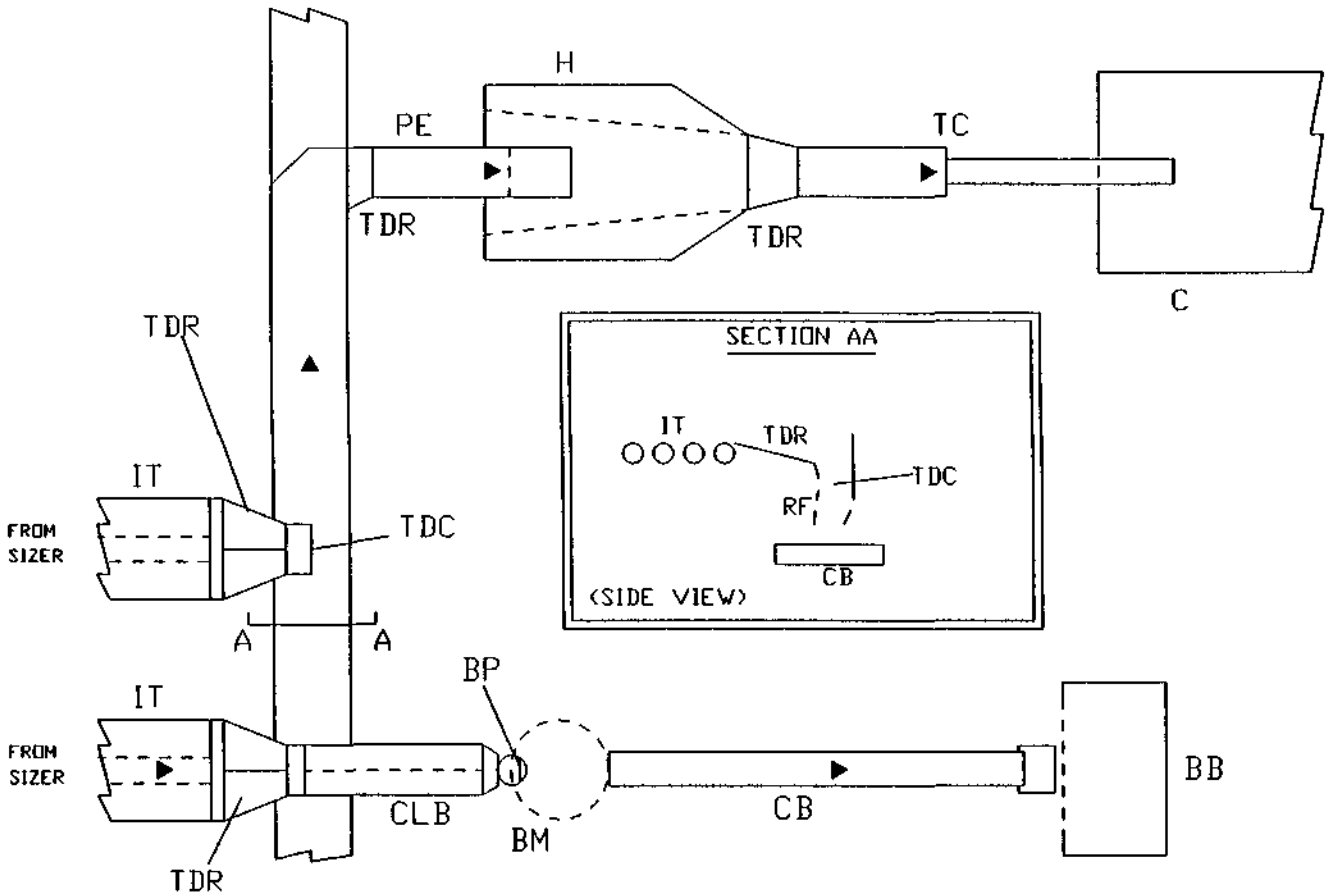


FIGURE 14: IMPACT SITES ON PACKING COMPONENTS OF HANDLING LINE

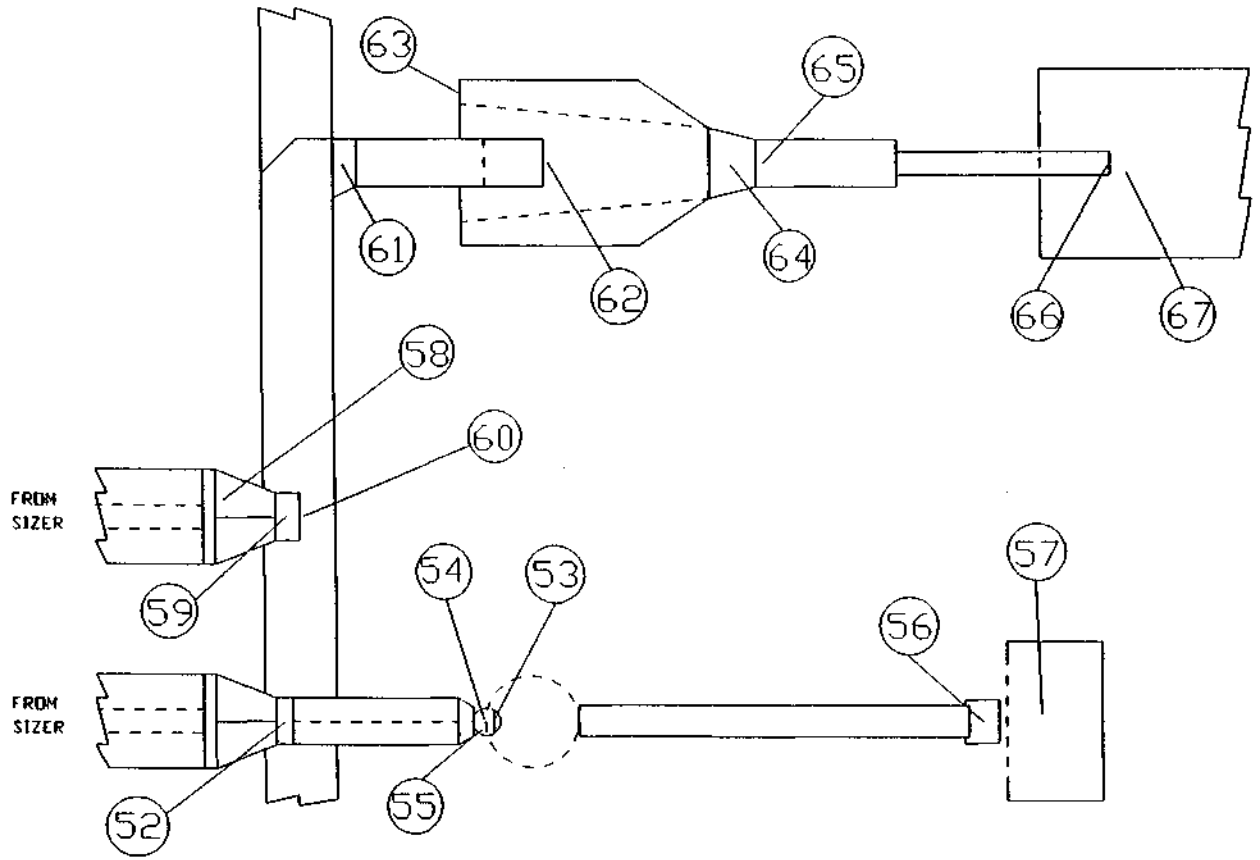


TABLE 9: DESCRIPTION OF IMPACT SITES ON PACKING AND BULK LOADING COMPONENTS OF HANDLING LINE

SITE	IMPACT SITE DESCRIPTION	COMMENTS
52	Off Transfer-Down Ramp to base of Cleated Belt	
53	Off Cleated Belt onto Baffle Plate	Entrance into Bagging Machine
54	Drop into Bag	Inside Bagging Machine
55	Onion drops into Bag	Subsequent impacts
56	Flattening of Onion Bag contents	At end of Conveyor Belt
57	Bag placed into Bulk Bin	End of Packing
58	Off initial Transfer-Down Ramp and rebound off large Ramp	After Inspection Table
59	Off large Ramp into Transfer-Down Chute	Impact at top of chute
60	Down Chute onto Conveyor Belt	
61	Off Conveyor Belt onto Transfer-Down Ramp	Container line, before Paddle Elevator
62	Off Paddle Elevator into Hopper	
63	Roll down to back of Hopper	Hopper empty
64	Off Hopper onto Transfer-Down Ramp	
65	Off Transfer-Down Ramp onto Telescopic Conveyor	
66	Off Telescopic Conveyor into Container	Initial impact
67	Settling impact inside Container	

TABLE 10: SUMMARY OF IMPACT DATA RECORDED BY AN INSTRUMENTED SPHERE ON THE PACKING AND BULK LOADING COMPONENTS OF THE HANDLING LINE

SITE	AVERAGE IMPACT ACCELERATION (G)	FREQUENCY OF OCCURRENCE (%)	MAXIMUM IMPACT ACCELERATION (G)
52	121	86	242
53	104	100	173
54	152	100	217
55	84	67	100
56	90	50	151
57	67	50	79
58	59	50	78
59	60	25	60
60	119	100	156
61	53	100	64
62	56	100	75
63	119	33	177
64	56	67	60
65	49	33	49
66	77	67	89
67	57	67	61

TABLE 11: SUMMARY OF MAJOR IMPACT SITES RECORDED BY AN INSTRUMENTED SPHERE DURING VECON ONION HANDLING PROCESSES

IMPACT SITE	DESCRIPTION	AVERAGE IMPACT ACCELERATION (G)	FREQUENCY OF OCCURRENCE (%)	MAXIMUM IMPACT ACCELERATION (G)	IMPACT NUMBER (>1)
HIGH IMPACT ACCELERATION/HIGH FREQUENCY					
27	Off CB into TDC (onto Donk)	175	100	292	3.1
23	Off IT onto Vertical Lifter	168	100	328	3.4
54	Drop into Bag	152	100	217	
35	Off IB onto TDC (Onto Topper)	144	100	193	
16	Off Hopper onto Vibrating Screen	123	100	275	
60	Down TDC onto CB (Cont. line)	119	100	156	
46	Off CB onto TDR (End of Sizer)	117	100	144	
40	Out of Topper onto TDR	114	100	152	
49	Off CB onto TDR (Inspec. table)	109	100	153	
34	Off Hopper onto TDR	105	100	194	
51	Off Inspec. table onto TDR	104	100	135	
53	Off PE onto BP (Bagging)	104	100	173	
30	Off Scoopie onto CB	95	100	174	
31	Off CB onto Store conveyor	94	100	205	
HIGH IMPACT ACCELERATION/MEDIUM FREQUENCY					
6	Off Primary Web onto Cross-over Belt (Harvester)	134	85	192	
52	Down TDR to base of Cleated Belt	121	86	242	
26	Off TCB onto CB above Store	115	71	164	
38	Over TDR inside Topper	113	63	183	
45	Off end of Sizer onto TDR	113	60	128	
36	Off TDR into Topper	111	50	141	
37	Over Transfer plate inside Topper	109	75	139	
4	Off Draper onto Primary Web	93	91	140	
HIGH IMPACT ACCELERATION/LOW FREQUENCY					
20	Off TDR onto CB (Intake)	125	33	183	
63	Roll back inside Hopper	119	33	177	
41	Rebound opposite Topper	115	25	116	
19	Off IT onto TDR (Intake)	114	42	151	
47	Off TDR onto Triang. guide	106	43	133	
HIGH IMPACT NUMBER					
39	Along Topper	55	100	59	70.0
44(a)	Along Sizer - Onto sizer holes	62	100	132	49.5
44(b)	Transfer Mat - Edge board	71	100	234	26.5

RECOMMENDATIONS

Potentially damaging sites have been summarised and ordered, with respect to severity, in Table 1
Impact sites requiring prioritised attention are listed in Table 12 with recommended modifications.

TABLE 12: DAMAGE REDUCTION RECOMMENDATIONS FOR MAJOR IMPACT SITES

IMPACT SITE	RECOMMENDATIONS
27	* Note: given that the site was not accessible for viewing, specific recommendations are not considered possible
23	* Cover internal surfaces of lifter buckets with cushioning material * Maintain high onion loading
54	* Reduce drop height * Install padding on baffle plate to reduce rebound velocity * Reduce onion 'throw' off cleated belt i.e. slower belt speed
35	* Reduce TDR slope before Topper * Install padding on initial vibrating screen rods below TDR * Modify retarding curtain associated with TDR
6	* Ensure that appropriate chain speed-to-ground speed keeps onion loading high on primary web * Cover individual steel web bars on cross-over belt with air cushion type rubber moulded sleeves
16	* High onion loading must be maintained * Consider installing heavy rubber curtain
52	* Install padding material at base of TDR * Reduce slope of TDR * Use heavier retarding curtain
60	* Remove metal support under conveyor belt at impact point below chute * Line upper chute surfaces with padding material * Reduce gap between rubber flaps at bottom of chute to restrict fall of onions

KEY TO ONION HANDLING LINE DIAGRAMS

BB	-	Bulk Bin
BCB	-	Bin Conveyor Belt
BL	-	Blade
BM	-	Bagging Machine
BP	-	Baffle Plate
C	-	Container
CB	-	Conveyor Belt
CLB	-	Cleated Belt
H	-	Hopper
IN	-	Intake
IB	-	Inspection Belt
IT	-	Inspection Table
MR	-	Metal Rollers
PE	-	Paddle Elevator
RC	-	Retarding Curtain
RF	-	Rubber Flap
S	-	Sizer
SCB	-	Store Conveyor Belt
SF	-	Space Finder
SRC	-	Suspended Rubber Chutes
T	-	Truck
TC	-	Telescopic Conveyor
TCB	-	Transfer Conveyor Belt
TDC	-	Transfer-Down Chute
TDR	-	Transfer-Down Ramp
TG	-	Triangular Guide
TM	-	Transfer Mat
TP	-	Transfer Plate
TPR	-	Topper
VL	-	Vertical Lifter
VS	-	Vibrating Screen
▶	-	Direction of onion flow